Ekinox INS

Inertial Navigation System

User Manual

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SBG SYSTEMS

Revision history

Rev.	Date	Author	Information
1.2	Mar 6, 2014	Alexis Guinamard	Fixed RTCM input diagram in connection topologies section Added ShipMotionHP description and specifications Added support for new input protocols (Septentrio SBF) Added support for new output protocols (VBW, GST)
1.1	Nov 8, 2013	Alexis Guinamard	Update for Firmware 1.1 – Added Ekinox D information. Added DVL integration details. Added augmented states description Updated alignment procedures
1	May 16, 13	Alexis Guinamard	First public version
Pre1	Jan 21, 2013	Alexis Guinamard	First version of this document

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Terminology

ADC: Analog to Digital Converter
AHRS: Attitude and Heading Reference System
CAN (Bus): Controller Area Network
DHCP: Dynamic Host Configuration Protocol
DVL: Doppler Velocity Log
EKF: Extended Kalman Filter
EEPROM: Electrically-Erasable Programmable Read-Only Memory
FIR: Finite Impulse Response (filter)
FTP: File Transfer Protocol
FS: Full Scale
FOG: Fiber Optic Gyroscope
GNSS: Global Navigation Satellite System
GPS: Global Positioning System
IIR: Infinite Impulse Response (filter)
IMU: Inertial Measurement Unit
INS: Inertial Navigation System
IP: Internet Protocol
LBL: Long Baseline
MAC (address): Media Access Control
MEMS: Micro Electro-Mechanical Systems
NED: North East Down (coordinate frame)
NA: Not applicable
NMEA (NMEA 0183): National Marine Electronics Association (standardized communication protocol)
PPS: Pulse Per Second (signal)
RAM: Random Access Memory
RMA: Return Merchandize Authorization
RMS: Root Mean Square
RTCM: Radio Technical Commission for Maritime Services (Protocol)
RTK: Real Time Kinematics
SI: International System of Units
TBD: To Be Defined
TCP: Transmission Control Protocol
UDP: User Datagram Protocol
UTC: Coordinated Universal Time
USBL: Ultra Short Base Line
VRE: Vibration Rectification Error
WGS84: World Geodetic System 1984
WMM: World Magnetic Model

1. Introduction

Ekinox INS is a MEMS based Inertial Navigation System which achieves tactical grade accuracy in a compact and affordable package, filling the gap between Industrial grade MEMS sensors and FOG technology. It includes an Inertial Measurement Unit (IMU) and runs an on-board enhanced Extended Kalman Filter (EKF). In addition, Ekinox N and D models embed a single or dual antenna high-end L1/L2 GNSS receiver. Created to achieve the best accuracy for every application, Ekinox INS integrates data from various aiding equipments such as GPS, Odometer, DVL, etc.

Figure 1.1: The Ekinox INS (N model)

To achieve the best performance in every project, specific error models have been implemented to meet applications requirements. An embedded web interface enables easy configuration and a wide connectivity as well as standard protocols output provide direct integration into existing applications.

1.1. Ekinox INS Overview

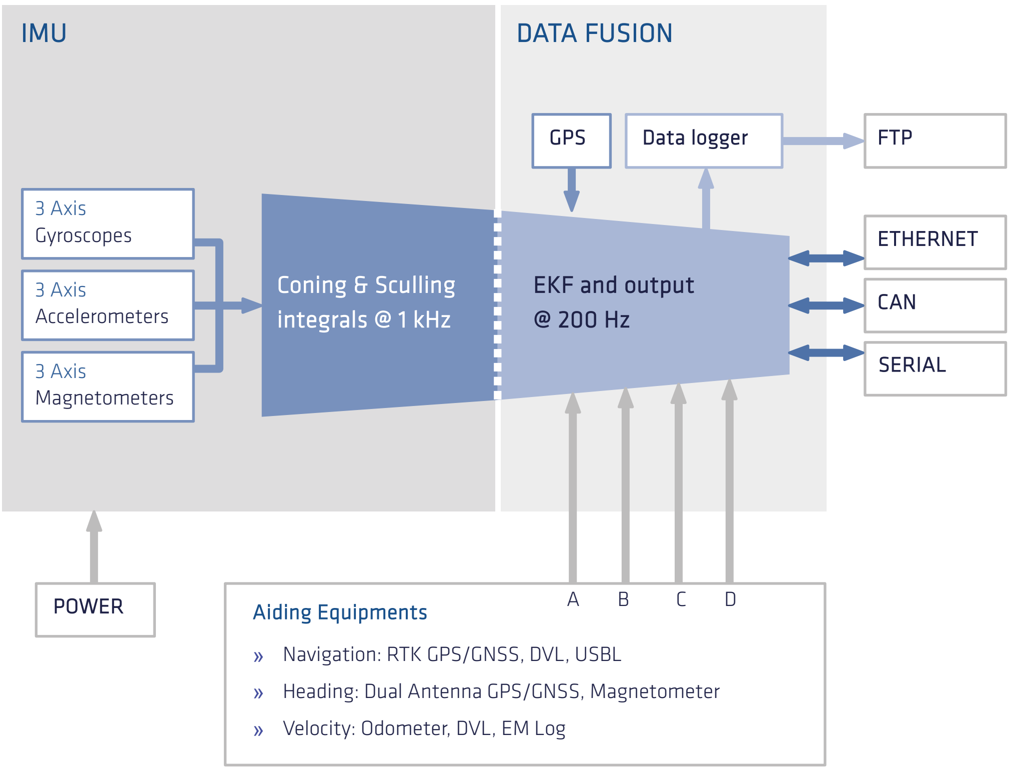


Figure 1.2: Ekinox INS simplified block diagram

1.2. Inertial Measurement Unit

As an IMU is the main component of an inertial navigation system, the Ekinox IMU has been carefully designed to take full advantage and performance of the MEMS technology.

1.2.1. Sensors

1.2.1.1. MEMS technology

High end MEMS components have been selected for this IMU. This MEMS technology provides many advantages over competing technologies such as mechanical or FOG gyroscopes, servo accelerometers:

- A miniature design provides smaller, lighter products, enabling new applications to be covered.
- This technology is very robust and provides much higher shock resistance as well as maintenance free operation.
- MEMS designs provide cost effective solutions compared to other technologies such as FOG or RLG.

> **Note:** Although the same MEMS technology is used for consumer applications such as smart-phones and tablets, there is a very large performance gap between low cost MEMS and tactical grade MEMS sensors. SBG Systems has selected for this product tactical grade sensors only.

1.2.1.2. Accelerometers

The Ekinox IMU embeds a set of 3 tactical grade MEMS capacitive accelerometers. An efficient set of hardware and software filters ensures that vibrating environments will not affect accelerometer more than the sensor intrinsic performance:

Accelerometer signal is first filtered by a third order analog filter and sampled at 5 KHz by a 24-bit ADC. Once sampled, an advanced FIR filter design ensures no aliasing will degrade accelerometer performance. The overall filter provides more than 70 dB attenuation to provide alias free output.

1.2.1.3. Gyroscopes

The set of 3 tactical grade digital MEMS gyroscopes is sampled at 1 KHz. An efficient FIR filter design ensures best performance in vibrating environments. The overall filter provides more than 50 dB attenuation in the stop band.

1.2.1.4. Magnetometers

A set of three Anisotropic Magnetoresistive magnetometers is embedded within the Ekinox IMU. This technology provides a very high sensitivity compared to coil based technologies.

Magnetometers signals are first filtered by a second order analog low pass filter that rejects out high frequency noise above sampled at 1 KHz and then filtered by a FIR filter to prevent any aliasing in the 200 Hz output. The overall filter provides more than 60 dB attenuation in the stop band.

Warning: Note that magnetometer sampling design makes it impossible to reject 1kHz harmonics. Especially frequencies between 935 Hz and 1065 Hz, and between 1935 Hz and 2065 Hz. Harmonics above 4 kHz are filtered out by the analog filter to at least 22 dB and should not cause troubles.

1.2.2. Factory Calibration and test

In order to provide best quality sensors, SBG Systems has developed unique calibration and test procedures for the Ekinox. When dealing with sensors error parameters, we consider that a good calibration is always better and more reliable than on-line sensor estimation.

We calibrate and test each product in our factory in order to provide efficient and defect free units. A calibration report is shipped with each product.

This calibration procedure allows taking the maximum precision of each sensor over the full temperature range (-40 to 75°C).

The calibration and test procedure provide:

- Functional and accuracy test of all sensors, and subsystems over full temperature range.
- Gain and bias compensation over full temperature range for accelerometers and gyroscopes,
- Non linearity compensation for gyroscopes and accelerometers over full measurement range,
- Gain compensation over full temperature range for magnetometers,
- Cross-axis and misalignment effects compensation for accelerometers, gyroscopes and magnetometers,
- Gyro-G effect compensation for gyroscopes.

Note: For best accuracy, each gyroscope and accelerometer channel is calibrated with its own internal temperature sensor. Magnetometers use a dedicated external temperature sensor for calibration.

Note: There is no bias compensation for magnetometers because bias is maintained stable over temperature by hardware design.

1.2.3. Vibration handling

The Ekinox IMU has been designed for harsh environments. Specific developments led to efficient vibration handling.

When exposed to vibrations, an accelerometer or gyroscope will have some increased bias. This vibration effect on accelerometer is called VRE. So a good starting point is to choose sensors that have low VRE in order to sustain higher levels of vibrations.

The second point is to design efficient hardware and software low pass filters that will reject out noise and unwanted signals to deliver only reliable and anti-aliased motion information.

Finally, a major performance improvement in vibrating environment is achieved by our efficient sensor calibration. Accelerometer linearity compensation significantly reduces the accelerometer VRE in low to medium frequencies, thus providing bias free acceleration measurements even in harsh conditions.

1.2.4. Coning and sculling integration

In nowadays "strapdown" inertial systems, angular rates from gyroscopes and accelerations from accelerometers must be integrated over time to maintain an orientation and navigation solution.

As this orientation and velocity integration is highly non linear, it may become necessary to use very small integration steps when motion becomes highly dynamic in order to maintain consistent accuracy.

Coning and sculling algorithms provide computation efficient ways to integrate accelerometers and gyroscopes signals at high frequency such as 1 kHz.

The Ekinox IMU computes a 1 KHz coning sculling integration for best accuracy in dynamic environments.

Delta angle filters and delta velocity filters have been designed to provide an equivalent output delay.

1.2.5. Specifications

1 σ specifications over -40°C to +75°C (-40 to 167°F) unless otherwise stated.
Sensors specifications are obtained after factory calibration procedure.

Sensor bandwidth is provided as a "Minimum bandwidth", based on sensor manufacturer tests and Ekinox IMU filters.

Resolution is provided as a minimum resolution achievable. Higher resolution can be obtained in some situations without warranty.

1.2.5.1. Accelerometer

	A1	A2	A3	A4	Remarks
Full scale (g)	2	5	10	30	
One year bias stability (μg)	300	750	1500	4500	
In run bias instability (μg)	10	25	40	TBD	Allan variance – @ 25°C
Velocity Random Walk ($\mu g/\sqrt{hz}$)	18	45	100	TBD	Allan variance – @ 25°C
Gain (ppm)	300	300	300	300	
Linearity (% of FS)	0.05	0.05	0.05	0.05	
Noise (μg)	90	225	450	1350	Over 1 to 25 Hz band
Bandwidth (Hz)	100	100	100	100	Attenuation < 3 dB
Resolution (mg)	0.1	0.25	0.6	1.7	
Sampling rate (kHz)	5	5	5	5	
Orthogonality (°)	0.03	0.03	0.03	0.03	

1.2.5.2. Gyroscopes

	G4	Remarks
Full scale (°/s)	400	Specified performance, saturates at 450°/s
One year bias stability (°/hr)	< 300	Total composite bias
In run bias instability (°/hr)	< 3	Allan variance – @ 25°C
Angular Random Walk ($°/hr/\sqrt{hz}$)	< 30	Allan variance – @ 25°C
Gain (ppm)	300	
Linearity (% of FS)	0.05	
Noise (°/s)	0.3	Over 1 to 25 Hz band
Bandwidth (Hz)	100	Attenuation < 3 dB
Resolution (°/s)	0.03125	
Sampling rate (kHz)	1	
Orthogonality (°)	0.03	

1.2.5.3. Magnetometers

	Specifications	Remarks
Full scale (Gauss)	6	
Gain (ppm)	1000	
Linearity (% of FS)	0.1	
Noise (μGauss)	50	Over 1 to 25 Hz band
Bandwidth (Hz)	50	Attenuation < 3 dB
Resolution (μGauss)	120	
Sampling rate (kHz)	1	
Orthogonality (°)	0.1	After user magnetic calibration

1.3. Extended Kalman Filter

1.3.1. Overview

Thanks to a powerful DSP architecture, the Ekinox runs a real time loosely coupled Extended Kalman Filter (EKF). The loose coupling between GPS/GNSS and the Kalman Filter allows GPS data to improve inertial sensor performance, and on the other hand inertial data improve overall navigation performance.

More than just a direct EKF implementation, the Ekinox software include advanced error models and wrong measurement rejection algorithms to ensure that best navigation performance is provided at any time.

A modular design allows a wide range of aiding sensors to be connected to the Ekinox INS. GNSS, Odometer, DVL, USBL and other aiding sensors can be connected to further enhance navigation performance.

In addition, the Ekinox Kalman filter is able to estimate some user entered parameters to further improve accuracy, such as GPS lever arm, aiding sensors alignments, odometer's gain, and others.

Specialized motion profiles and error models provide optimal options and tuning for each application, and each aiding equipments.

1.3.2. Theory of operation

Inertial sensors (accelerometers and gyroscopes) provide very accurate short term motion measurements but suffer from drift when integration time becomes long. Some other systems such as GNSS receivers or magnetometers provide low frequency measurements that can be fooled by jamming, or magnetic interferences in a short term, but these sensors provide good performance over long term.

The basic idea behind the Kalman filter is to take the best of each sensor, without drawbacks. A high frequency prediction (also called propagation) step uses inertial sensors to precisely measure motion and navigation data. When aiding data (GPS position, Odometer data or Magnetometer reading for example) becomes available, the Kalman filter will use it to correct the current state and prevent drift.

As aiding measurements are made at a lower frequency than the prediction step, a small jump can be observed after a correction is applied. This jump should be really small in normal operating conditions.

A covariance matrix maintains up to date each estimated parameter error. When there is no measurement available, estimation error tends to increase; when a new measurement is received, this error will decrease. This covariance matrix is also used to handle the “link” between each estimated parameters.

Besides the EKF, a sensor manager is implemented to check aiding measurements and reject bad ones.

To summarize the Ekinox Extended Kalman Filter operation, the following diagram shows how IMU and external sensors are used inside the EKF to provide navigation and orientation data.

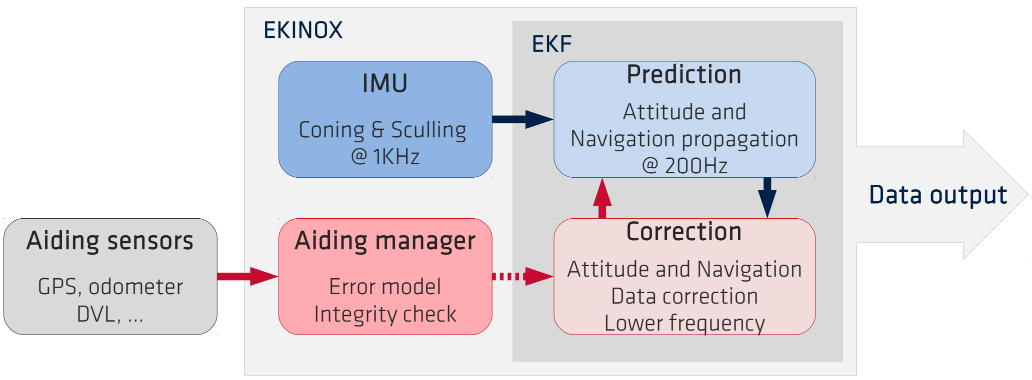


Figure 1.3: EKF simplified block diagram

1.3.2.1. Modes of operation

The Kalman filter inside the Ekinox INS will run into several computation modes depending on situations:

Initialization

This mode is observed at startup only and corresponds to the first attitude initialization using the internal accelerometer as vertical reference. It assumes low accelerations so best accuracy is achieved when the Ekinox is powered up stationary or at constant speed. If the INS is powered up during motion, the full accuracy will be reached within a few minutes after startup.

Vertical Gyro operation

Once roll and pitch angles are initialized, the Kalman filter is running in a limited mode, where only attitude (roll and pitch angles) is valid. This mode uses a vertical reference and internal gyroscopes to estimate orientation. Therefore, heading angle is freely drifting, as well as position and velocity. Ship motion data is provided accurately in this mode but is not velocity aided.

Heading alignment procedures

When operated in "vertical gyro" mode, the Ekinox will try to align heading angle using different procedures. These procedures have some constraints and the following table explains how they are used and in which situations:

Method	Availability	Constraints – Remarks
GPS Course Heading alignment	In automotive, aircraft and marine motion profiles. Or, when GPS Course is used as aiding input.	This method is the default for most dynamic applications. It uses GPS course as an input for heading, considering that preferred direction of travel is forward. The device must drive/fly in forward direction, at least at 3.0 m/s.
GPS True Heading alignment	When GPS True Heading is activated as an aiding input	This method uses input GPS true heading provided by dual antenna GPS. Open sky condition is preferred for initialization due to the dual antenna system sensitivity to multi-path effects. Device must be in static or constant heading condition.
GPS+accelerations	In Helicopter and airplane motion profiles	This method uses GPS and accelerations to define a heading. This allow any motion, in any direction. Due to higher sensitivity to GPS signal reflection, the sensor should be initialized in good GPS conditions. The device must be accelerated at more than $2.5 m/s^2$ during at least 2 seconds.
Magnetic Heading	Available when Magnetic heading aiding is enabled.	If magnetometers are enabled, this signal is available at startup. A good magnetic field must be available for proper operation.

AHRS mode

In this mode, a full orientation set is accurately estimated using a vertical reference and a heading input (magnetometer or other sensor input). Roll, Pitch and Yaw angles are accurate. Position and velocity are freely drifting and cannot be considered as valid.

Navigation modes

- Navigation Velocity mode; In this mode a velocity input (GPS, or Odometer + vehicle constraints, or DVL) is provided to maintain accurate orientation and velocity data. Position output is unreferenced but should not drift as much as in AHRS mode.
- Full Navigation mode; In this mode, the Ekinox provides the full output set accurately: Orientation, absolute position and velocity are fully estimated.

The Kalman filter will always try to use the best or highest computation mode. In some situations such as long GPS drop outs, the computation mode may be downgraded from Full Navigation to Navigation Velocity or AHRS mode depending on outage duration. This makes it possible to maintain reliable orientation even during long GPS outages, with an accuracy similar to AHRS systems.

1.3.2.2. Heading observability with single antenna GPS

Depending on the device configuration, the Ekinox EKF will make use of all available measurements to estimate orientation and navigation parameters. GPS or odometers will be able to stabilize navigation data but also orientation data. Roll and pitch are always accurately estimated when GPS is available.

When the sensor is subject to acceleration, the EKF is also able to stabilize heading angle.

In some applications where the dynamics are too low for good heading observability, it may be necessary to find an alternative heading measurement, coming either from a magnetometer, a dual antenna GNSS system (providing true heading) or the GPS Course (available when the device is in motion).

1.3.2.3. Heading observability with dual antenna GPS

Thanks to its internal dual antenna GNSS receiver, the Ekinox D provides reliable heading, even in static condition. Using an external dual antenna GNSS system, the Ekinox E also provides this functionality.

Compared to a stand-alone GNSS dual antenna system, the Ekinox will smooth GNSS heading measurements and reject wrong heading measurements in order to provide best output accuracy. The internal gyro will also provide reliable heading information during temporary GNSS drop outs.

1.3.2.4. Operation during long aiding outages

When there is no aiding measurement available (no GPS fix or between measurements), the propagation step maintains navigation and orientation data up to date, but navigation error will increase. This condition is also referred as "dead reckoning". After a long dead reckoning period, the first correction applied can generate large jumps depending on actual error.

After a long dead reckoning period (> 3 min), navigation data will still be computed but may contain a large error. Orientation behavior will become similar to AHRS version.

1.3.2.5. Augmented state estimation (lever arms, alignments)

In most application, measuring lever arms or misalignment angles can be very difficult tasks. That's why the Ekinox Extended Kalman filter is able to estimate several additional states that will ensure maximum accuracy:

- Lever arms (GPS, Odometer, DVL) estimation makes it possible to improve user measurements. It is still required to enter those lever arms, but with a reasonable accuracy of 5 cm, the Kalman filter will finish the adjustments with less than 1 cm accuracy.
- Alignments (Vehicle alignment, GPS True Heading or DVL alignments) can also be estimated. User entered alignments angles can be performed with only 3° accuracy to ensure good operation using these algorithms.
- DVL / Odometer Gains are also constantly estimated to minimize dead reckoning errors when using those sensors.
- DVL Water layer current is finally estimated to allow short term navigation using only the DVL water layer information (can be useful when bottom tracking data is not available for some time).

> Note that all these "augmented states" are only enabled when relevant with an application. In addition, most of these states require some dynamic motion, so for example GPS True heading alignment can only be used in airborne or land applications.

1.3.3. Motion profiles and aiding sensors error models

Each application has specific requirements and constraints such as angular rate dynamics, vibrations, presence of long term accelerations, magnetic disturbances and others. Instead of having different products for each environment, SBG Systems has developed a cutting edge technology able to adapt the sensor to each situation.

The Motion Profile technology is tightly integrated with the embedded Kalman Filter and inertial sensors. It provides with a simple application selection a deep and fine Ekinox configuration. Different motion profiles have been designed to fit most typical applications and should provide optimal performance.

A similar technology is used to specialize error models for each aiding device. A single click allows the user to choose an aiding sensor model and everything will just work properly.

> Note: Most applications should find a suitable motion profile and error models to obtain optimal performance. However, if a specific application requires fine tuning, it is still possible to design a specific motion profile for that application. Feel free to contact our SBG Systems support team that will assist you during this operation.

1.3.4. Ship motion computation (Heave, Surge, Sway)

Mainly used in marine applications, we refer here to ship motion computation. Vertical motion is called heave, Surge and Sway are the two horizontal components of the ship motion.

Two different heave computations algorithms are proposed depending on application requirements:

- Real Time Ship Motion that provides instantaneous heave information for real time applications.
- ShipMotionHP that provides fixed 450s delayed heave information for greatly enhanced precision.

> **Note:** As these outputs are relative to local position, Ship motion data cannot be used as navigation data.

1.3.4.1. Real time Ship Motion

Aside from the EKF, the Ekinox computes at 50Hz ship motion data from accelerometers double integration. As this double integration generates drift due to orientation error or sensor bias, the best way to get a stable output is to use a high pass filter design that will remove any constant component in the motion.

SBG Systems has developed an advanced filter design that ensures no phase and gain errors are generated. In addition, an automatic filter tuning ensures proper behavior is obtained with swell periods up to 25 seconds.

Due to high pass filter design, the heave, surge and sway data will always return to zero in static conditions. If a step is performed, the heave output will show the step and then will smoothly come back to zero. It may take a few minutes for the output to be stabilized after a step.

The Ekinox ship motion computation is more accurate in the vertical direction than in horizontal ones. This is why surge and sway can only measure motion periods up to 2.5 s.

For best accuracy, the Ekinox uses GNSS receiver data to compensate accelerations that could disturb ship motion computations during turns or acceleration phases.

ShipMotionHP (delayed Heave)

The new shipMotionHP algorithm makes use of past measurements to greatly enhance the heave performance. Common phase issues related to real time Heave operation are seamlessly corrected and the filter will provide even better performance under long swell period conditions.

The shipMotionHP algorithm has a fixed delay of 450s. The output messages have the same format as real time ship Motion mode and a time-stamp can be used to correctly date the ship Motion data.

This algorithm is ideal for applications that does not require strict real time operation such as seabed mapping.

The real time Heave operation remains available to get a first heave estimate before the delayed heave data becomes available.

Note 1: Because ShipMotionHP is a delayed algorithm, the unit must remain turned ON in normal operating conditions at least 10 minutes before, and 10 minutes after the actual survey path is performed.

Note 2: Only vertical ship motion (heave) is available in ShipMotionHP mode. Surge and Sway are not provided in this mode of operation.

1.3.4.2. Deported heave operation

As shown in the following figure, heave value may differ depending on the Ekinox location. In order to provide accurate heave measurements, the Ekinox should be placed as close as possible to the monitoring point.

When this mechanical installation is not possible, or when several monitoring points should be tracked, 3 secondary heave monitoring points can be configured (in addition to the main heave monitoring point).

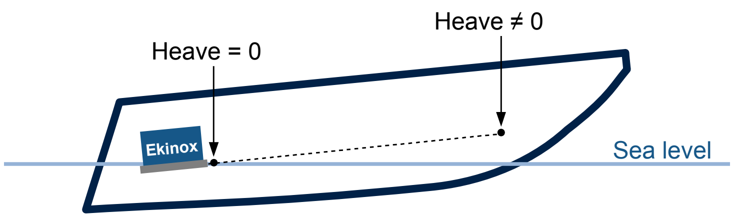


Figure 1.4: Effect of pitch angle on heave output

Note: When the boat is stationary, pitch angle, should be precisely set to 0 by mechanical installation or by software configuration in order to provide consistent heave values on secondary points.

1.4. Aiding sensors

Many different aiding sensors can be used to aid the Ekinox INS.

1.4.1.1. Ekinox N and D internal GNSS receiver

The Ekinox N embeds a high performance GNSS receiver (L1/L2 GPS + GLONASS), capable of centimeter accuracy using RTK solution. With a refresh rate of up to 20Hz, this receiver provides reliable and accurate position measurements even in challenging GPS environments. The Ekinox D version embeds the same type of GNSS receiver, with additional true heading output.

	Specification		Remark
Channels	120		
Signal tracking	GPS: L1, L2, L2C GLONASS: L1, L2 Galileo: E1 Compass, SBAS, QZSS		
Horizontal position accuracy	Single point L1 + Glonass	1.5 m	
	Single point L1/L2	1.2 m	
	SBAS	0.6 m	
	DGPS	0.4 m	
	RTK	1 cm	
Velocity accuracy	0.03 m/s RMS		
True Heading Accuracy	0.2° 0.1° 0.05°	1m baseline 2m baseline 3m baseline	Ekinox D only. Baseline should not exceed 3m
Velocity limit	515 m/s		Due to export licenses
Time to First Fix	Cold start	< 50 s	
	Hot start	< 35s	
Signal reacquisition	L1	< 0.5 s	
	L2	< 1.0 s	
Output frequency	20 Hz		
Options	RAIM, RTK, L1/L2		

1.4.1.2. Third party GNSS receiver

The Ekinox N and D models already include one GNSS receiver. A second receiver can also be connected if required. The Ekinox-E model does not include a GNSS receiver, but can be connected to up to two GNSS modules.

All GNSS receivers will provide velocity and position aiding. In some applications such as automotive ones, the GPS course can also be used as heading reference input.

Dual antenna systems can also provide a True Heading aiding. RTK GPS receivers can be used to improve positioning accuracy.

Note: When two GNSS modules are in use simultaneously, the Ekinox will integrate both incoming data to further improve navigation accuracy.

1.4.1.3. Odometer

In addition to the GNSS aiding, the Ekinox includes an odometer input which can greatly improve performance in challenging environments such as urban canyons. The odometer provides a reliable velocity information even during GPS outages. This increases significantly the dead reckoning accuracy.

The Ekinox handles quadrature output or compatible odometers in order to support forward and backward directions.

> **Note:** Odometer integration is made really simple as the Kalman filter will finely adjust odometer's gain and will correct residual errors in the odometer alignment and lever arm.

1.4.1.4. Internal magnetometer

Although part of the Ekinox internal IMU, the magnetometer is in fact considered as an "aiding sensor" and is not mandatory for proper operation.

Nevertheless, in many applications such as airborne or several marine application, this magnetometer is still a reliable and efficient way to observe heading.

> **Note:** Magnetometer use requires a specific in place calibration in order to compensate surrounding ferromagnetic materials and magnets. Please refer to the Ekinox Iron Calibration Tools documentation for more information about this.

1.4.1.5. Doppler Velocity Log (Teledyne – PD0 protocol)

In many marine or underwater applications, the DVL is a good choice to improve navigation when GPS is not available. DVL has been fully coupled with the Ekinox Kalman filter to provide full navigation performance in both bottom tracking and water layer conditions.

No calibration is required as the Ekinox Kalman filter will automatically adjust alignments and gain parameters.

The fusion of DVL data with the Ekinox can provide very accurate and reliable underwater position data in real conditions. A carefully chosen mission pattern such as a lawn mower one can also dramatically limit the position error growth.

In addition to the Kalman filter integration with DVL, the Ekinox can store and output back the DVL messages (PD0) for water profiling applications.

1.4.1.6. Other aiding sensor

The Ekinox INS has been designed to be highly modular and can be connected to a variety of other aiding equipments such as:

- USBL
- LBL
- EM Log
- Depth sensor
- Third party magnetometer

> **Note:** Please contact SBG Systems support for more information about those sensors.

1.5. System Performance

All specifications are rated to 1 σ, over -40°C to +75°C (-40 to 167°F) unless otherwise stated.

These specifications have been measured based on typical mission scenarios with simulated GPS outages and compared to post processed RTK data of a high end FOG based INS.

For each application, we present the measured accuracies for different positioning modes. You can find below a short description of each positioning mode:

- SP refers to Single Point mode and is the default L1 GPS fix quality
- RTK stands for Real Time Kinematics with a typical 1 cm accuracy position
- PP is for Post Processed data using Inertial Explorer with at least Precise Point Positioning data

1.5.1.1. Common specifications

	Performance	Remarks
Measurement range	360° in all axes, no mounting limitation	Solid state sensors
Orientation noise	< 0.03° RMS	Static

1.5.1.2. Land applications

Outage Duration	Positioning Mode	Position Accuracy		Velocity Accuracy		Attitude Accuracy (°)		
		Horizontal	Vertical	Horizontal	Vertical	Roll	Pitch	Heading
0s	SP	1.20 m	1.2 m	0.02 m/s	0.02 m/s	0.05°	0.05°	0.1°
	RTK	0.01 m	0.02 m	0.02 m/s	0.02 m/s	0.05°	0.05°	0.1°
	PP	0.01 m	0.02 m			0.02°	0.02°	0.04°
10 s	SP	1.5 m	1.4 m	0.03 m/s	0.03 m/s	0.1°	0.1°	0.15°
	RTK	0.2 m	0.2 m	0.03 m/s	0.03 m/s	0.1°	0.1°	0.15°
	PP	0.03 m	0.03 m			0.02°	0.02°	0.05°
	Odometer aiding	0.1% of DT	0.5% of DT			0.1°	0.1°	0.15°
60 s	SP	5 m	6 m	0.05 m/s	0.05 m/s	0.2°	0.2°	0.2°
	RTK	4 m	2 m	0.05 m/s	0.05 m/s	0.2°	0.2°	0.2°
	PP	0.6 m	0.08 m			0.04°	0.04°	0.07°
	Odometer aiding	0.1% of DT	0.5% of DT			0.2°	0.2°	0.2°

1.5.1.3. Marine & Subsea applications

Orientation and navigation performance

Outage Duration	Positioning Mode	Position Accuracy		Velocity Accuracy		Attitude Accuracy (°)		
		Horizontal	Vertical	Horizontal	Vertical	Roll	Pitch	Heading
0s	SP	1.20 m	2.0m	0.02 m/s	0.02 m/s	0.05°	0.05°	0.1°
	RTK	0.01 m	0.02m	0.02 m/s	0.02 m/s	0.05°	0.05°	0.1°
	PP	0.01 m	0.02 m			0.02°	0.02°	0.04°
10 s	SP	2.0 m	3.0m	0.03 m/s	0.03 m/s	0.1°	0.1°	0.15°
	RTK	0.2 m	0.2m	0.03 m/s	0.03 m/s	0.1°	0.1°	0.15°
	PP	0.03 m	0.03 m			0.02°	0.02°	0.05°
	DVL aided	0.4% of DT	0.4% of DT	0.03 m/s	0.03 m/s	0.05°	0.05°	0.15°
60 s	SP	8 m	10m	0.05 m/s	0.05 m/s	0.2°	0.2°	0.2°
	RTK	5 m	5m	0.05 m/s	0.05 m/s	0.2°	0.2°	0.2°
	PP	0.6 m	0.08 m			0.04°	0.04°	0.07°
	DVL aided	0.4% of DT	0.4% of DT	0.05 m/s	0.05 m/s	0.05°	0.05°	0.2°

Heave performance

	Real Time Heave	ShipMotionHP	Remark
Range	50 meters	50 meters	
Period	0 to 25 s	0 to 50 s	
Accuracy	5 cm or 5%	2.5 cm or 2.5 %	Whichever is greater; Velocity aided heave
Mode	Real time, auto tuning	Fixed 450s delay	
Monitoring points	1 main + 3 deported	1 main + 3 deported	Designed for echo sounder integration

1.5.1.4. Airborne applications

Outage Duration	Positioning Mode	Position Accuracy		Velocity Accuracy		Attitude Accuracy (°)		
		Horizontal	Vertical	Horizontal	Vertical	Roll	Pitch	Heading
0s	SP	1.20 m	2.0m	0.02 m/s	0.02 m/s	0.05°	0.05°	0.1°
	RTK	0.01 m	0.02m	0.02 m/s	0.02 m/s	0.05°	0.05°	0.1°
	PP	0.01 m	0.02 m			0.02°	0.02°	0.04°
10 s	SP	2.0 m	3.0m	0.03 m/s	0.03 m/s	0.1°	0.1°	0.15°
	RTK	0.2 m	0.2m	0.03 m/s	0.03 m/s	0.1°	0.1°	0.15°
	PP	0.03 m	0.03 m			0.02°	0.02°	0.05°
60 s	SP	8 m	10m	0.05 m/s	0.05 m/s	0.2°	0.2°	0.2°
	RTK	5 m	5m	0.05 m/s	0.05 m/s	0.2°	0.2°	0.2°
	PP	0.6 m	0.08 m			0.04°	0.04°	0.07°

1.6. Time and synchronization

When dealing with external devices, latency and synchronization can be important points to consider because of different calculation delays within each device and transmission times.

1.6.1. Output Latency

A specific design has been implemented to provide minimum latency for most important outputs. For good understanding, we must consider here the various sets of Logs (messages) provided by the Ekinox:

- Inertial sensor Logs coming from the Ekinox IMU are the most important Logs and they can be provided less than 1 ms after the actual sensor sample.
- EKF output Logs require some processing. These are sent once computed, 2 ms after sample time.
- Other output Logs have lower priority and can be sent afterward.

Note: CAN Logs are all sent with lower priority messages as the CAN protocol cannot guarantee in any case the output delay.

Note: A full description of output Logs is provided in the Ekinox Firmware Reference Manual.

The following graph explains how data is processed and delivered.

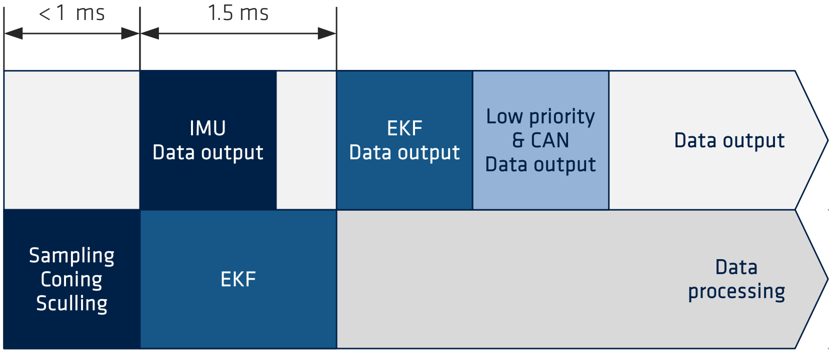


Figure 1.5: Timing and processing diagram

1.6.2. Event inputs

The Ekinox INS includes 6 synchronization inputs that can be used for different purposes:

- Event input: All pulses received generate events that can generate specific Logs output. Any output log can be triggered by an event pulse.
- Event Marker: An event marker log can be sent each time a pulse is received in order to time mark each event.
- PPS input: When the Ekinox E is connected to a GNSS system, the PPS signal is used to realign and synchronize internal clock to GPS clock.
- Aiding input time-stamping: If a specific aiding sensor generates pulses that time stamp the following output, the corresponding event input can be used for data synchronization.

1.6.2.1. Event triggered logs

The following example shows how event triggered logs are generated. In this example, three processing loops are shown, from N to N+3. Event received during loop N generates an output after N+1 computation. Event received during N+1 loop generates an output after N+2 computation.

The Ekinox handles up to 200Hz input. In case of higher frequency events, only the last received event will be taken into account.

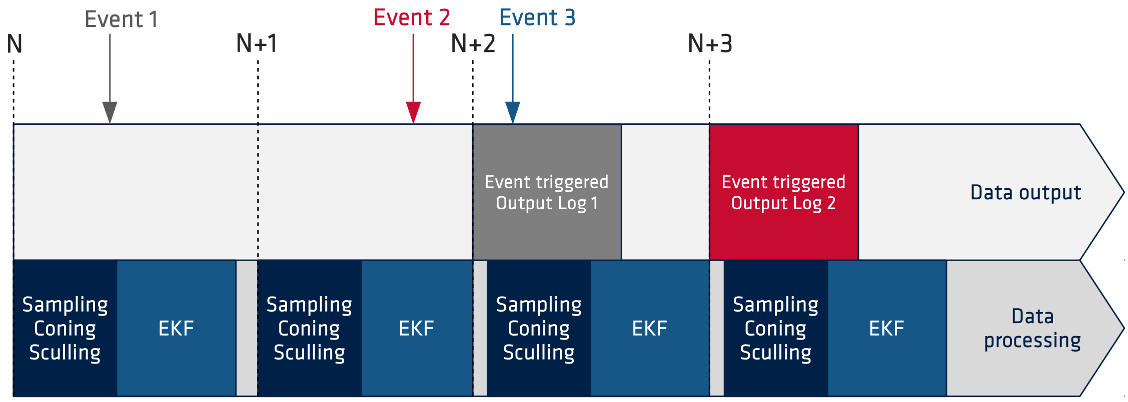


Figure 1.6: Event triggered log example

1.6.2.2. Event markers handling

Event marker handling is very similar to the event triggered logs. Events received are stacked in the system and an event marker message can be sent at each computation loop. This log will include all events details during previous loop.

The Ekinox handles up to 1kHz event Markers input. Sending more than 1KHz events may overload the internal CPU.

The following diagram explains this behavior:

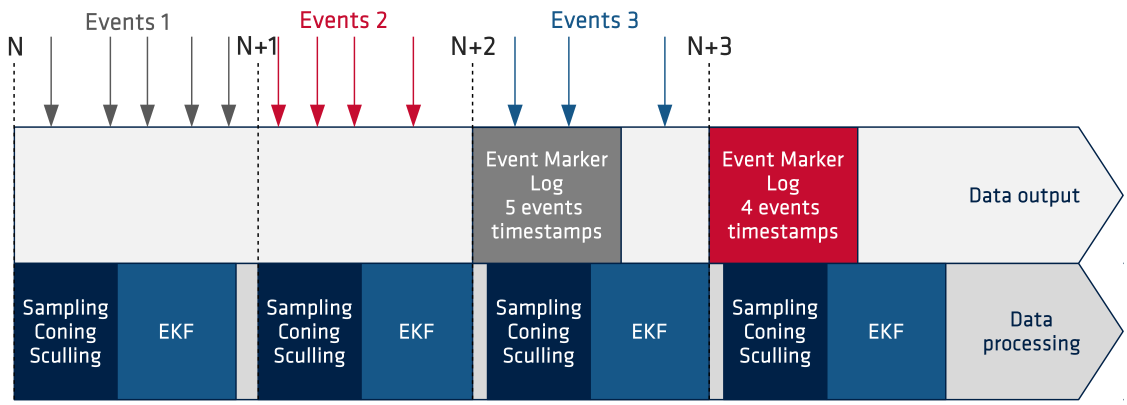


Figure 1.7: Event markers

1.6.3. Event Output

A synchronization output pin allows pulses generation in following conditions:

- Main loop divider: This event is activated at the sensor sample time, but its frequency is divided by the output divider. If the divider is set to 4, pulse output frequency will be 200Hz / 4 = 50Hz.
- PPS: This output will also be synchronized with the sample time, but it will be provided at 1Hz only when clock is correctly estimated. So this output is provided at each top of a second in UTC time.
- Virtual odometer: This outputs provide a sync pulse, each time the sensor travels the specified distance.

1.6.4. Clock bias and gain estimation with GPS

The Ekinox internal crystal has an accuracy of 40ppm over full temperature range. In order to reduce this crystal error over time, the Ekinox E should be connected to the GNSS PPS signal.

This PPS signal also allows GPS data synchronization, required for good navigation accuracy, as well as internal clock bias and gain estimation.

It is generally sent at each top of a UTC time second.

The Ekinox N automatically performs this estimation when GPS is available.

Clock estimation is made in two steps:

- The first step is to realign the main loop to the PPS: each pulse received on the PPS must correspond to a new sample data.
- The second step is to finely adjust the clock gain by comparing the actual PPS time with internal clock time.

1.6.5. Internal time and UTC time

The Ekinox internal clock reference is always started at 0 when the sensor is powered on. During clock bias estimation, the internal time may slide up to +/- 2.5 ms in order to align internal time with UTC time. Once synchronized, the internal time keeps counting from power up without being affected by UTC.

When internal clock has been synchronized to PPS and UTC time is available from the GNSS system, the Ekinox will also provide a UTC time reference, with corresponding internal time. Thanks to the internal time and UTC offset, it is possible to recalculate a UTC time for each received log.

Note: Before GPS is available, the UTC time starts at the date configured in settings. When the GPS becomes available, a first value of UTC (based on GPS time) is provided but it can be a few seconds away from the actual UTC time. When “leap seconds” information becomes available, a jump can be observed to realign output on actual UTC time. A specific flag informs the user about the UTC time validity.

Fore more information, please search “GPS Leap Seconds” on the Internet to find some more details about this notion.

2. Conventions

2.1. Reference coordinate frames

Although this matter requires some mathematics skills, it may be important to take some time to fully understand how navigation and orientation are represented.

We remind that an inertial frame is a frame in which Newton's laws of motion apply. An inertial frame is therefore not accelerating, but can be in uniform linear motion.

All Inertial sensors (accelerometers, gyroscopes) produce measurements relative to an inertial frame.

2.1.1. Earth Centered Earth Fixed (ECEF) Coordinate frame

This coordinate frame has its origin placed at the center of Earth. The frame is rotating with Earth so that constant coordinates will point to a single point on Earth. The frame rotation rate ω_{ie} is 360° per day plus 360° per year.
Due to this frame rotation, the ECEF frame is not an inertial frame.

Note: The Ekinox algorithms take into account this frame rotation rate in order to ensure best navigation accuracy.

There are two main coordinate systems used to represent positions within this ECEF frame.

2.1.1.1. ECEF Cartesian coordinate system

The first is the Cartesian where the origin is placed at the Earth Center of mass; *X* axis is pointing to the equator and prime meridian intersection. *Z* axis is pointing to the North pole and *Y* axis complete the right hand rule.

This system is widely used inside GPS systems because of its easy and precise computations, but is not easily understood by human beings.

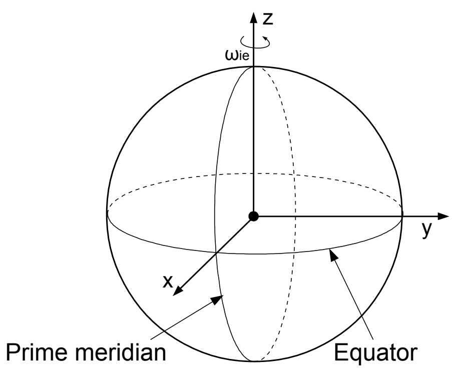


Figure 2.1: ECEF Coordinate system

2.1.1.2. Geodetic coordinate system (WGS84)

The second coordinate system is the most commonly used to represent positions relative to Earth. It uses an ellipsoid to represent the overall Earth shape.

Several geodetic models exist, but nowadays, the WGS84 ellipsoid is probably the most common one due to its use as the GPS standard. When talking about Geodetic coordinates, we will always refer to WGS84 referenced coordinates.

A geodetic coordinate is a set of three parameters: Latitude (Φ), Longitude (λ) and Altitude (h).

The Latitude is the angle in the meridian plane from the equatorial plane to the ellipsoid normal. Note that in most situations, the ellipsoid normal will not intersect the center of the Earth.

The Longitude is the angle in the equatorial plane from the prime meridian to the projection of the point of interest onto the equatorial plane.

The Altitude is the length, along the ellipsoid normal, from the ellipsoid surface to the point of interest.

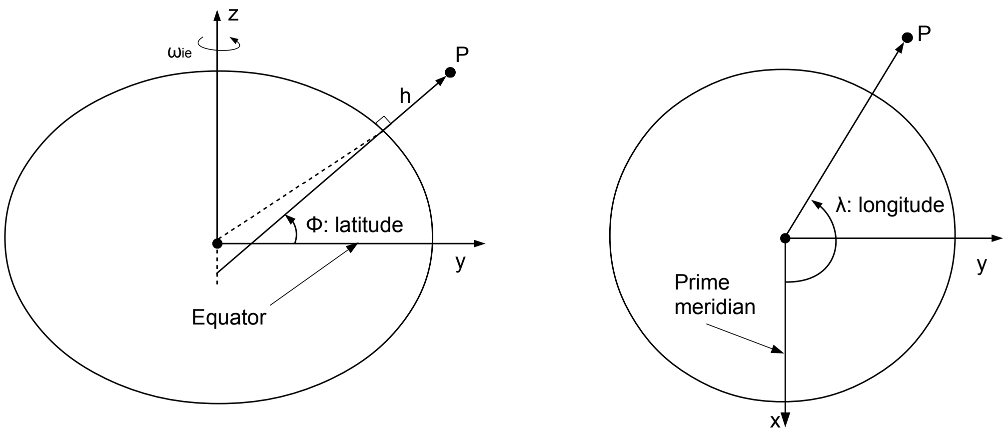


Figure 2.2: Latitude, Longitude, and Altitude definition

Altitude reference

As mentioned above, the WGS84 altitude reference is the ellipsoid surface. Unfortunately, this surface does not exactly match the actual Earth surface.

A geoid shape which is based on complex gravity models is often used to give a better Earth shape approximation than typical spherical or ellipsoidal models. The total variation between the WGS84 ellipsoid shape and a geoid is less than 200m.

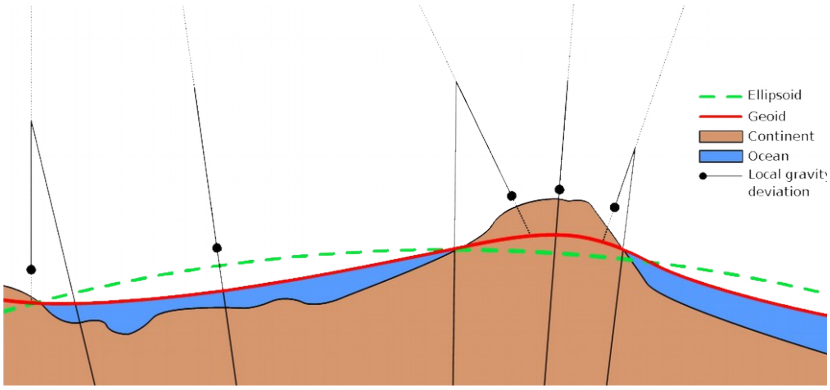


Figure 2.3: Geoid representation with ellipsoid and actual Earth shape

When an altitude is provided with respect to the geoid model, it becomes consistent with the Mean Sea Level (MSL). Geoid based altitude will then be called altitude above MSL.

The Ekinox INS allows providing altitude referenced to the Ellipsoid or to the Mean Sea Level.

2.1.2. Local Geodetic frame

The local Geodetic frame refers to the North, East, Down rectangular frame (NED).

This frame is obtained by fitting the local ellipsoid shape by a tangent plane at the current position. This coordinate frame is attached to a fixed point relatively to the Earth surface.

X axis is turned toward North, *Z* axis turned down, along the local ellipsoid normal, and *Y* axis completes the right hand rule, pointing East.

As it's impossible to perfectly fit the ellipsoidal shape by a plane, this frame is only suitable for local measurements.

Note: The Ekinox INS internally accounts for this frame rotation when the vehicle moves at high speed in order to ensure best navigation performance.

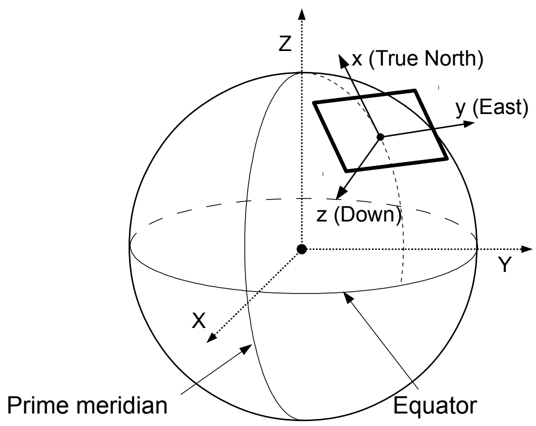


Figure 2.4: Local Geodetic coordinate frame representation

2.1.3. Vehicle coordinate frame

Depending on application, a vehicle coordinate frame is defined as follows: *X* axis is turned in Forward direction, *Z* axis is turned Down, and *Y* axis, thanks to right hand rule is turned to the right of vehicle.

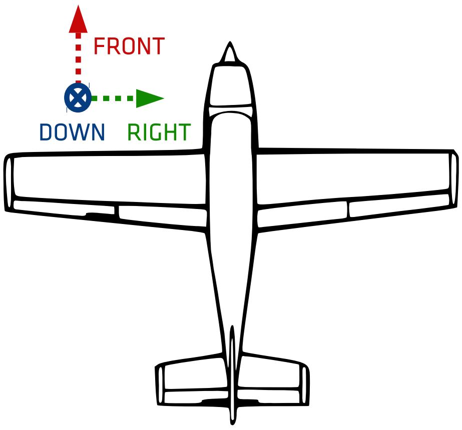


Figure 2.5: Vehicle coordinate frame

2.1.3.1. Ship motion conventions

According to the vehicle coordinate frame defined above, the ship motion conventions are the following:

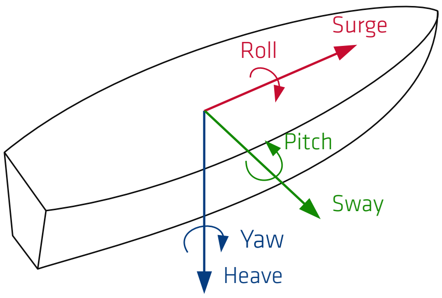


Figure 2.6: Ship motion conventions

2.1.4. Sensor (body) coordinate frame

This frame is attached to the Ekinox.

The following diagram shows the body coordinate frame as configured by default. In most situations, the body coordinate frame must be aligned with vehicle coordinate frame. Some user configuration allow rotating this frame as explained in further paragraphs.

Figure 2.7: Default body coordinate frame

2.1.4.1. Origin of measurements

We have defined the Ekinox axes directions, but we also need to know where is the Origin of this coordinate frame. This coordinate frame origin is the intersection of the three accelerometers and corresponds to the center of velocity and position measurements.

This origin must be considered when measuring lever arms.

A symbol in the mechanical specifications defines and locates this Origin of measurements.

2.2. Rotations between two coordinate frames

2.2.1. Positive rotation direction

According to the "Right Hand Rule", the positive direction for rotations is clockwise in the axis direction:

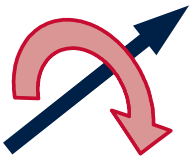


Figure 2.8: Positive rotation direction

2.2.2. Rotations representation

There are several ways to represent the orientation of the device that are provided by the Ekinox. Some are easy to understand, others are very efficient such as quaternion form.

2.2.2.1. Euler Angles

Euler angles are a commonly used representation of spatial orientation. Euler angles are in fact a composition of rotation from the Local Geodetic Coordinates System. This orientation is defined by the sequence of the three rotations around the Local Frame *X*, *Y* and *Z* axes.

Euler angles are widely used because they are easy to understand. The three parameters: Roll, Pitch and Yaw define rotations around the fixed frame's axes:

- Roll *(φ)*: Rotation around *X* axis. $\varphi \in [-\pi ; \pi]$
- Pitch *(θ)*: Rotation around *Y* axis. $\theta \in \left[-\frac{\pi}{2} ; \frac{\pi}{2}\right]$
- Yaw *(Ψ)*: Rotation around *Z* axis. $\psi \in [-\pi ; \pi]$

> **Note:** As Euler angles suffer from a singularity called "Gimbal lock", when Pitch approaches ± π/2, we do not advise to use Euler angles if the device has to be used in a wide range of orientations. Quaternion and Rotation matrix do not suffer from this problem.

2.2.2.2. Rotation matrix (Direction Cosine Matrix)

The Direction Cosine Matrix (DCM) is a rotation matrix that transforms one coordinate reference frame to another. Rotation matrices are a complete representation of a 3D orientation, thus there is no singularity in that model.

A DCM locates three unit vectors that define a coordinate frame. Here the DCM transforms the body coordinate frame to the Local NED coordinates. The DCM is the combination of the three rotation matrices RM_φ , RM_θ and RM_ψ respectively around Local Geodetic (NED) X, Y and Z axes.

Here is defined a DCM in terms of Euler Angles:

$$DCM = RM_\psi RM_\theta RM_\phi$$

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

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

As for any rotation matrix, the inverse rotation equals to the transposed matrix:

$$DCM^{-1} = DCM^T$$

In order to transform a vector expressed in the Body coordinate system into the NED frame, user will use the DCM as expressed below:

$$V_{NED} = DCM \cdot V_{body}$$

Reciprocally:

$$V_{body} = DCM^T \cdot V_{NED}$$

2.2.2.3. Quaternions

Quaternions are an extension of complex numbers as defined here:

$Q = q_0 + i \cdot q_1 + j \cdot q_2 + k \cdot q_3$ Where i, j and k are imaginary numbers.

Particular quaternions such as $\|Q\| = 1$ can represent, as DCMs, a complete definition of the 3D orientation without any singularity.

Quaternion algebra do not require a lot of computational resources, they are therefore very efficient for orientation representation.

The inverse rotation of Q is defined by the complex conjugate of Q , denoted $\overline{Q}$:

$$\overline{Q} = q_0 - i \cdot q_1 - j \cdot q_2 - k \cdot q_3$$

Quaternion can be defined as a function of DCM coefficients:

$$q_0 = \frac{1}{2}\sqrt{1 + DCM_{11} + DCM_{22} + DCM_{33}}$$

$$q_1 = \frac{1}{4q_0}\left(DCM_{32} - DCM_{23}\right)$$

$$q_2 = \frac{1}{4q_0}\left(DCM_{13} - DCM_{31}\right)$$

$$q_3 = \frac{1}{4q_0}\left(DCM_{21} - DCM_{12}\right)$$

Or as a function of Euler Angles:

$$q_0 = \frac{1}{2}\sqrt{1 + \cos\theta\sin\psi + \sin\phi\sin\theta\sin\psi + \cos\phi\cos\psi + \cos\phi\cos\theta}$$

$$q_1 = \frac{1}{4q_0}\left(\sin\phi\cos\theta - \cos\phi\sin\theta\sin\psi + \sin\phi\cos\psi\right)$$

$$q_2 = \frac{1}{4q_0}\left(\cos\phi\sin\theta\cos\psi + \sin\phi\sin\psi + \sin\theta\right)$$

$$q_3 = \frac{1}{4q_0}\left(\cos\theta\sin\psi - \sin\phi\sin\theta\cos\psi + \cos\phi\sin\psi\right)$$

2.2.2.4. Other useful conversion formulas

Some other conversion formulas can be useful for many users, and are listed below:

Quaternion to DCM

It may be useful to compute a DCM based on the quaternion parameters:

$$DCM = \begin{pmatrix} 2q_0^2+2q_1^2-1 & 2q_1q_2-2q_0q_3 & 2q_0q_2+2q_1q_3 \\ 2q_1q_2+2q_0q_3 & 2q_0^2+2q_2^2-1 & 2q_2q_3-2q_0q_1 \\ 2q_1q_3-2q_0q_2 & 2q_2q_3+2q_0q_1 & 2q_0^2+2q_3^2-1 \end{pmatrix}$$

Quaternion to Euler

Here is quaternion translated into Euler angles.

$$\phi = \tan^{-1}\left(\frac{2q_2q_3+2q_0q_1}{2q_0^2+2q_3^2-1}\right)$$

$$\theta = -\sin^{-1}\left(2q_1q_3-2q_0q_2\right)$$

$$\psi = \tan^{-1}\left(\frac{2q_1q_2+2q_0q_3}{2q_0^2+2q_1^2-1}\right)$$

DCM To Euler

Finally, DCM matrix is converted into Euler Angles.

$$\phi = \tan^{-1}\left(\frac{DCM_{32}}{DCM_{33}}\right)$$

$$\theta = -\sin^{-1}\left(DCM_{31}\right)$$

$$\psi = -\tan^{-1}\left(\frac{DCM_{21}}{DCM_{11}}\right)$$

2.3. Accounting for Misalignment

The Ekinox alignment procedure involves two steps: an axis alignment, and a fine alignment. Some aiding sensors must also take into account misalignment, that will be measured like it has been done for the IMU, comparing the external sensor with vehicle coordinate frame.

2.3.1. Axis misalignment

The following example shows how to measure IMU axis misalignment. The Ekinox axes must be compared to the Vehicle axes as follows:

IMU Axis	Vehicle direction
X	LEFT
Y	FRONT
Z	DOWN

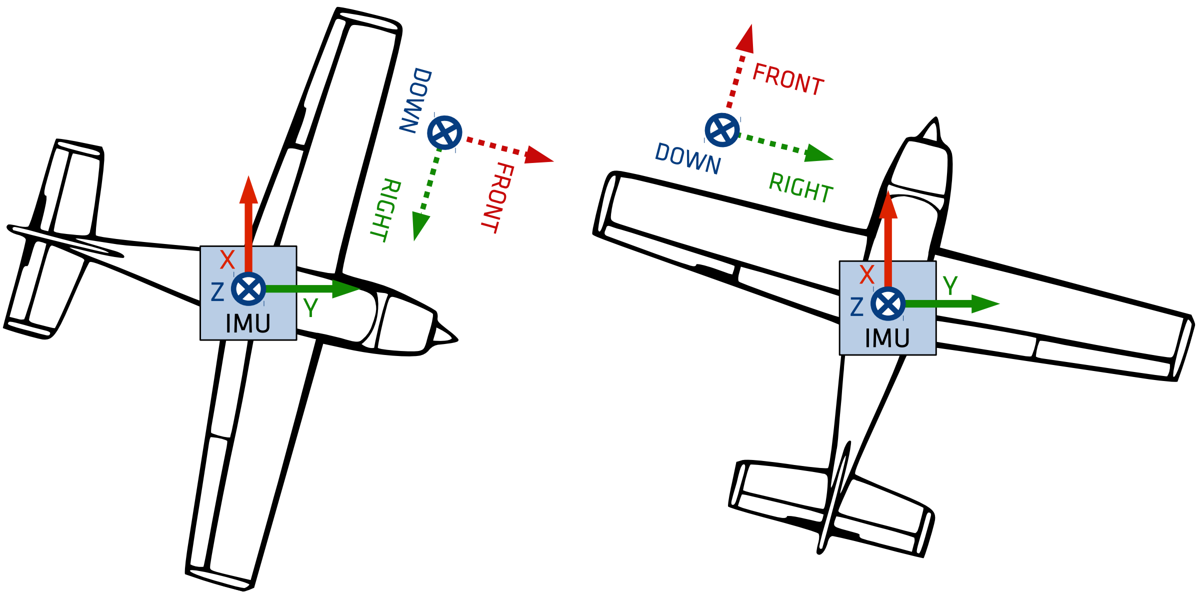


Figure 2.9: Axis alignment example.
Left: Initial mechanical installation. Right: Ekinox coordinate frame after axis alignment.

2.3.2. Fine misalignment

Once axes axis alignment is performed, the small residual angles must then be measured as follow. Misalignment angles correspond to the residual rotation required to pass from the IMU coordinate frame to the vehicle coordinate frame. In our example, alpha corresponds to the misheading and its sign is negative.

Most applications will only have low angles on roll and pitch misalignment. If large angles on roll and pitch are expected (> 5°), user must consider the rotation composition order: roll, then pitch, then yaw.

Mis Angles	Value
misroll	Not shown
mispitch	Not shown
misheading	- α (negative)

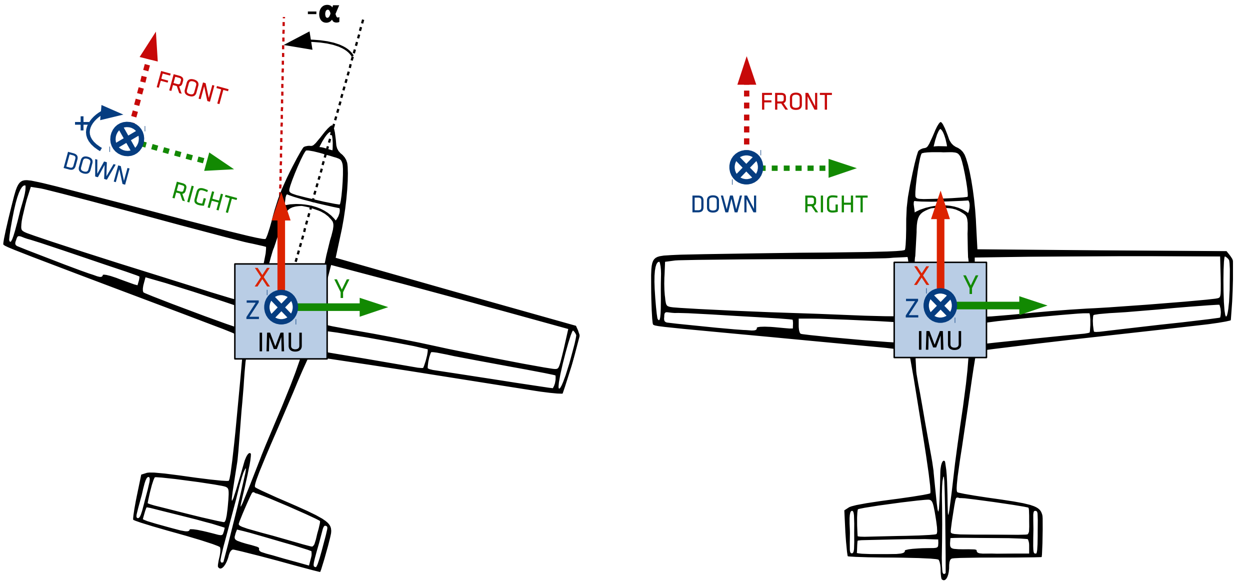


Figure 2.10: Misalignment residuals measurement
Left: Residual measurement. Right: Ekinox coordinate frame after fine alignment.

Once the fine misalignment angles are measured and entered into Ekinox configuration, the Ekinox coordinate frame is assumed to be aligned with the vehicle coordinate frame.

2.3.3. Instruments misalignment

Most instruments (aiding sensors) alignments will only consider a limited rotation:

- GPS true Heading alignment requires only two angles: pitch and yaw.
- DVLs require roll, pitch and yaw alignment angles.

The following diagram shows that instruments alignments with the Ekinox are measured in a similar way to the "fine misalignment" with the vehicle coordinate frame. We consider in this example a GPS true heading system that provides the direction from antenna 1 to antenna 2. The misalignment between the Ekinox and the antenna system is shown as the angle "mis yaw". It is negative in this case.

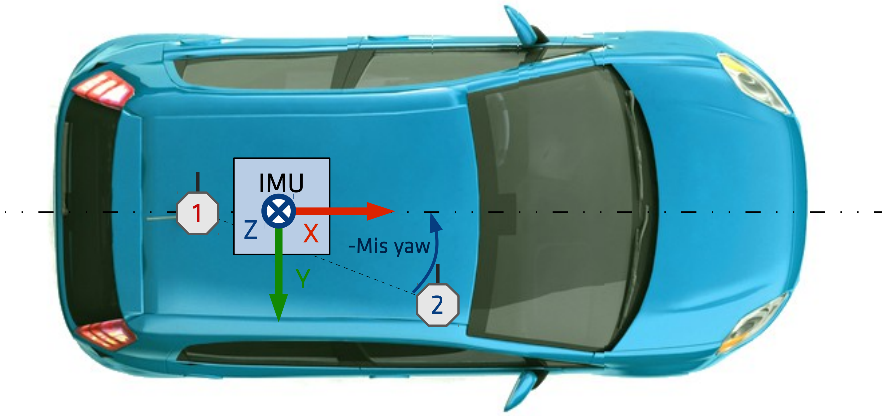


Figure 2.11: GPS Dual antenna misalignment measurement

2.4. Accounting for Lever arms

All lever arms are considered in the vehicle (body) coordinate frame, and are measured FROM the Ekinox, TO the point of interest.

Below is an example showing a GPS antenna lever arm measurement:

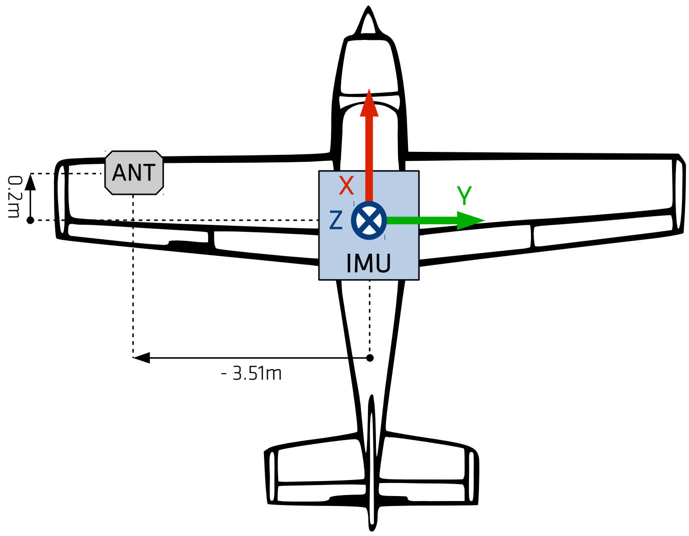


Figure 2.12: GPS antenna Lever Arm example

3. Mechanical and Electrical specifications

3.1. Mechanical specifications

All dimensions are expressed in millimeters using the International System of Units (SI) conventions.

3.1.1. Overview

The Ekinox enclosure is composed of two anodized aluminum parts, one for the cover and one for the base plate. The device uses high quality alloys and connectors to offer a full IP68 enclosure and a good resistance to harsh environments.

The cover part is made of 5083 aluminum alloy for its resistance to both seawater and industrial chemical environments. In addition, this material offers a nice visual aspect.

The base plate is made of 7075 aluminum alloy to ensure best durability and accuracy. Indeed, this alloy offers an incredible mechanical strength to guarantee the base plate integrity and accuracy during device installation.

The cover and base plates are sealed together by four M3 stainless steel A4 screws (3016L). The Ekinox should be installed to the host interface using four M4 stainless steel A4 screws.

The Ekinox connectors are high quality Fischer connectors that offers IP68 protection even unconnected. The Ekinox-N version also includes a TNC connector (manufactured by Telegärtner) to connect the GPS antenna. When used with a waterproof GPS antenna cable, this connector offers an IP68 protection.

Note: If you are planing to use Ekinox internal magnetometers, please make sure that you don't use ferromagnetic materials to mount the device.

Warning: The TNC connector offers an IP68 protection only when a waterproof GPS cable is connected. If you don't want to connect a GPS cable, please use the provided dust cap.

3.1.2. Specifications

The table below summarizes all mechanical and environmental specifications.

Mechanical Specifications

	E	N	D
Height	5.8 cm (2,28")	6.4 cm (2.52")	7.5 cm (2.9")
Width	10 cm (3,94")	10 cm (3,94")	10 cm (3,94")
Depth	8.6 cm (3,39")	8.6 cm (3,39")	8.6 cm (3,39")
Weight	435 grams (1.0 lb)	520 grams (1.1 lb)	630 grams (1.4 lb)
Shocks	$< 1\,000g$		
Operating Vibrations	8g RMS – 20Hz to 2 kHz as per MIL-STD-810G		
Non-Operating Vibrations	20 000g		

Environmental Specifications	
Enclosure	Anodized Aluminum
IP rating	IP-68 (24 hours at 2 meters)
Operating (Ekinox E / N)	-40 to 75°C (-40 to 167°F)
Operating (Ekinox D)	-40 to 71°C (-40 to 160°F)
Storage	-40 to 85°C (-40 to 185°F)
Humidity	Sealed, no limit
MTBF (computed)	50.000 hours
Calibration interval	None required, maintenance free

3.1.3. Device mechanical alignment

For best measurement accuracy, a good mechanical alignment is required. During manufacturing, the Ekinox measurement frame has been carefully aligned to 0.02° with the base plate for roll, pitch and yaw angles.

To ease the yaw alignment (X axis), the base plate features two alignment holes Ø 4 mm H7 that guarantees with two taper pins Ø 4 mm G6 a yaw alignment better than ±0.04°.

Note: The base plate is the same for the Ekinox A, D, E and N models.

3.1.4. Origin of measurements

The center of measurement for acceleration, velocity and position is represented on the mechanical outlines by the symbol. It is referenced to the base plate fine alignment hole.

3.1.5. Device label

SBG Systems manufacturing process is based on EN-9100 system with individual and full traceability of every component and operation. Each Ekinox is identified by a unique serial number that can be used to trace all operations during the product lifetime such as manufacturing, calibration, tests and repairs.

In addition to a unique serial number, a product code is used to define exactly the device type and options. Finally, the Ekinox features an Ethernet interface and a unique MAC address is required to identify the device on a network.

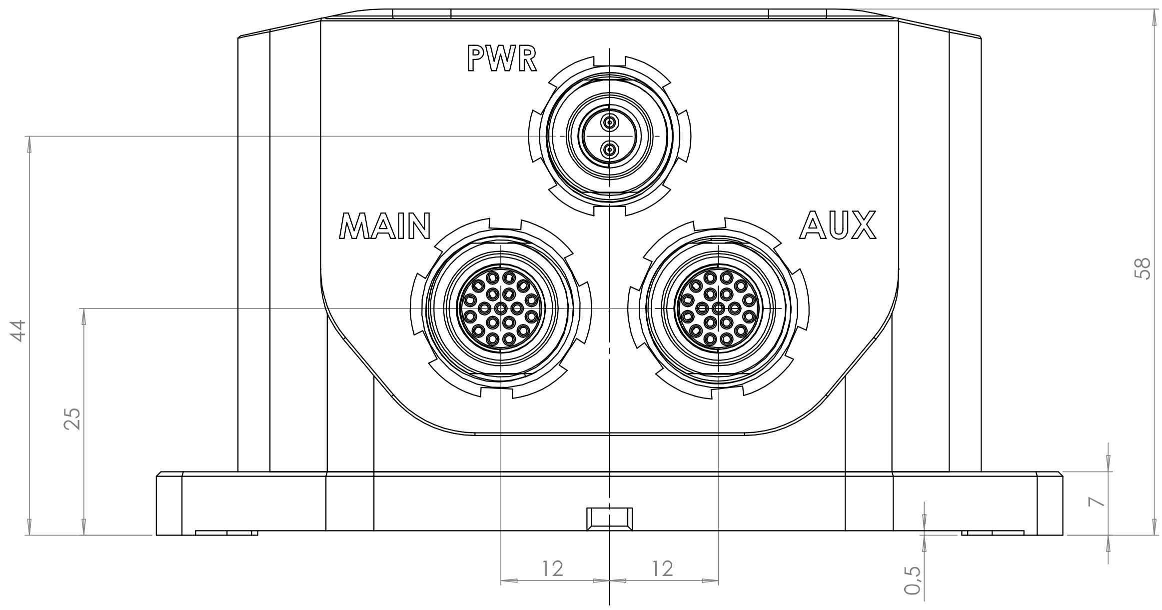
You can find on the right side of the Ekinox a laser printed label that hold all these identification information. This label also includes a data-matrix code that encodes the device unique serial number.

Figure 3.1: Ekinox device label sample

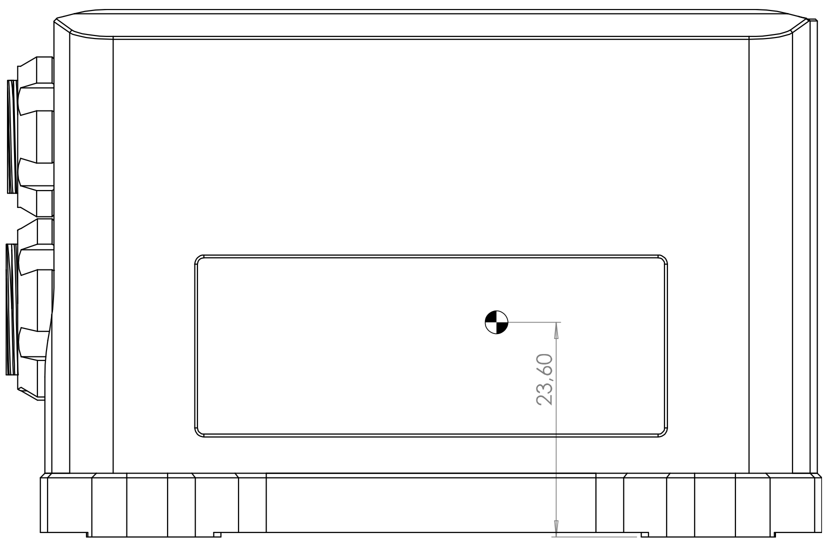
3.1.6. EKINOX-E mechanical outline

All dimensions are in mm.

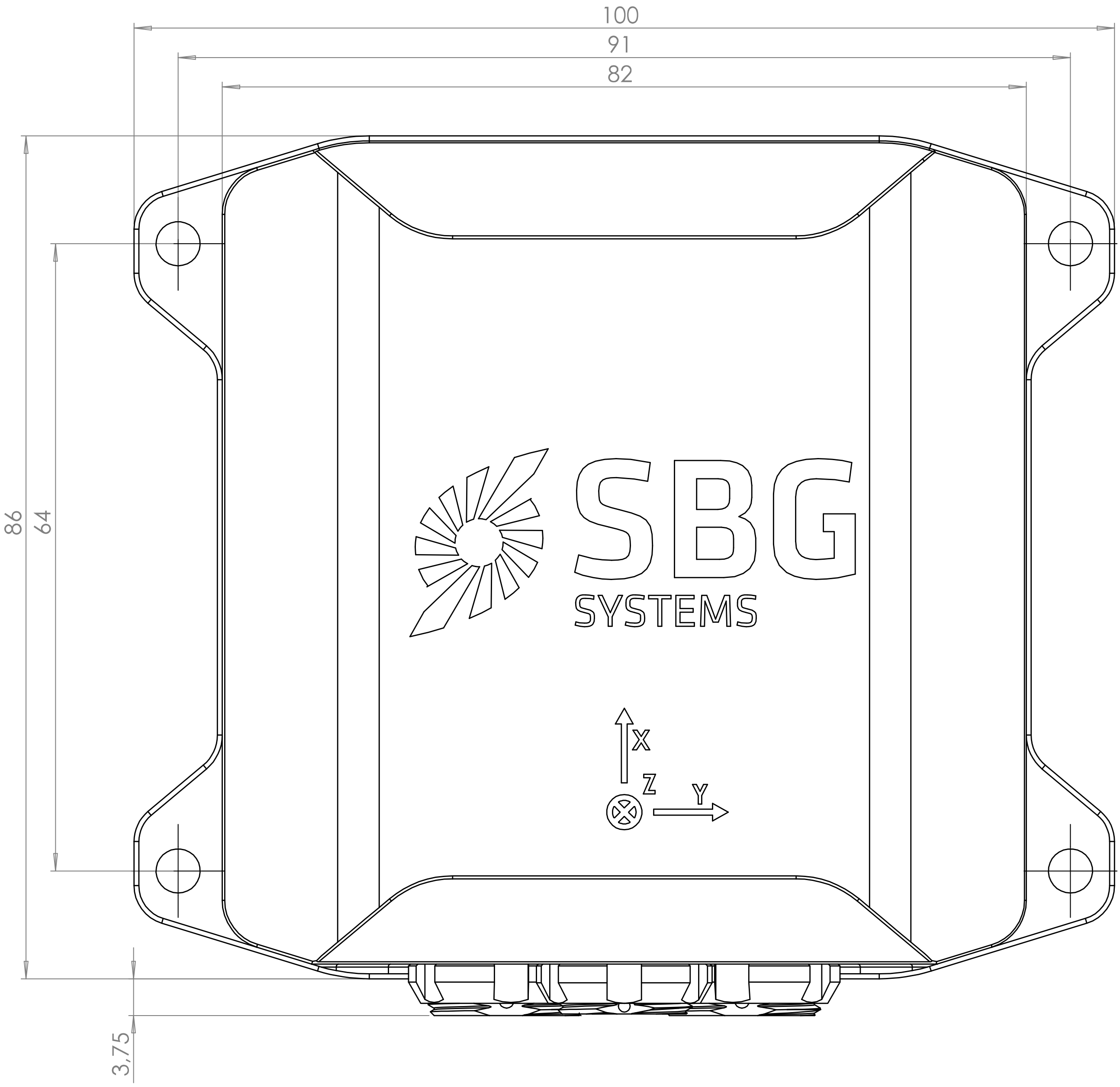
3.1.6.1. Front view



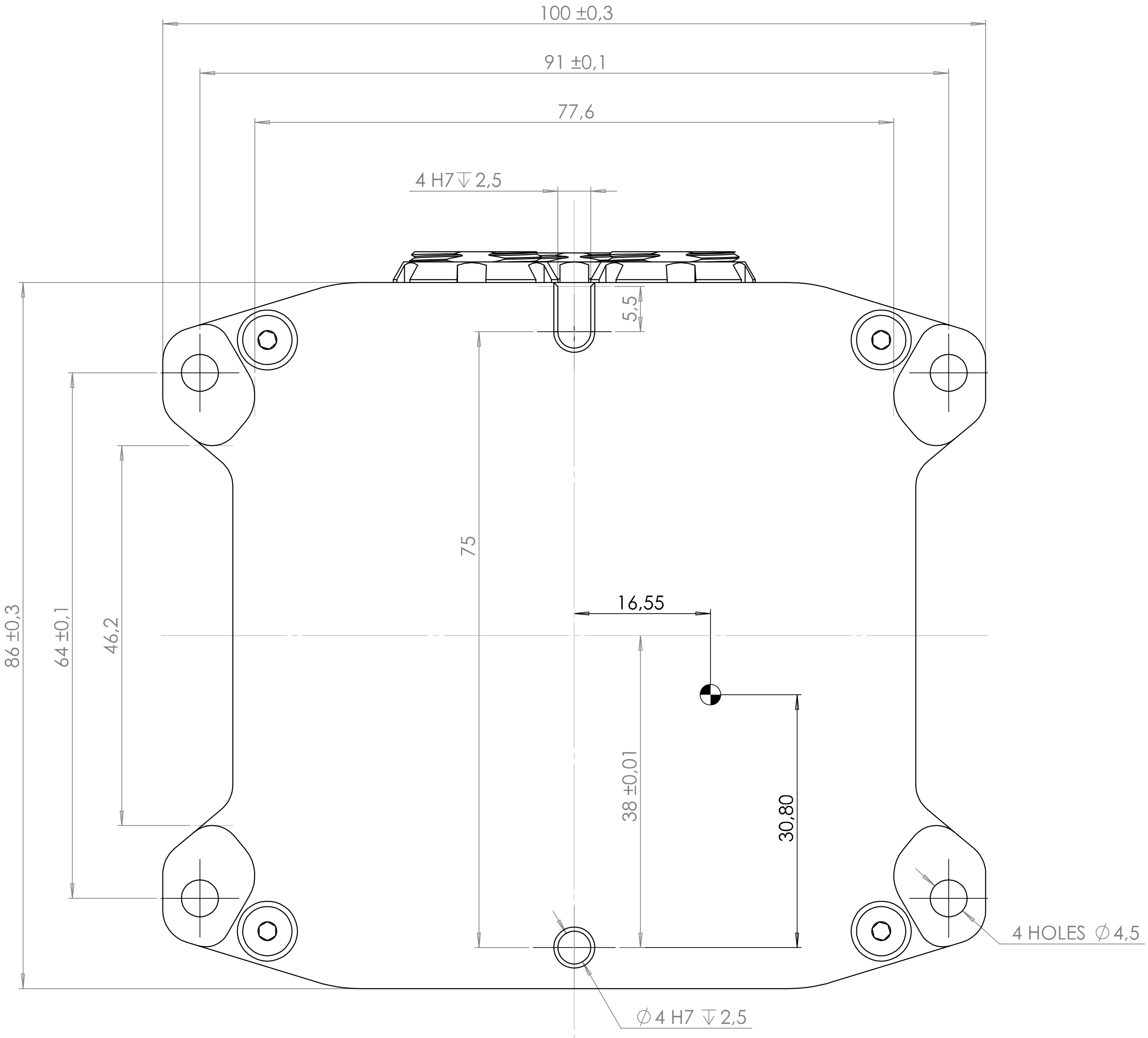
3.1.6.2. Right view



3.1.6.3. Top view



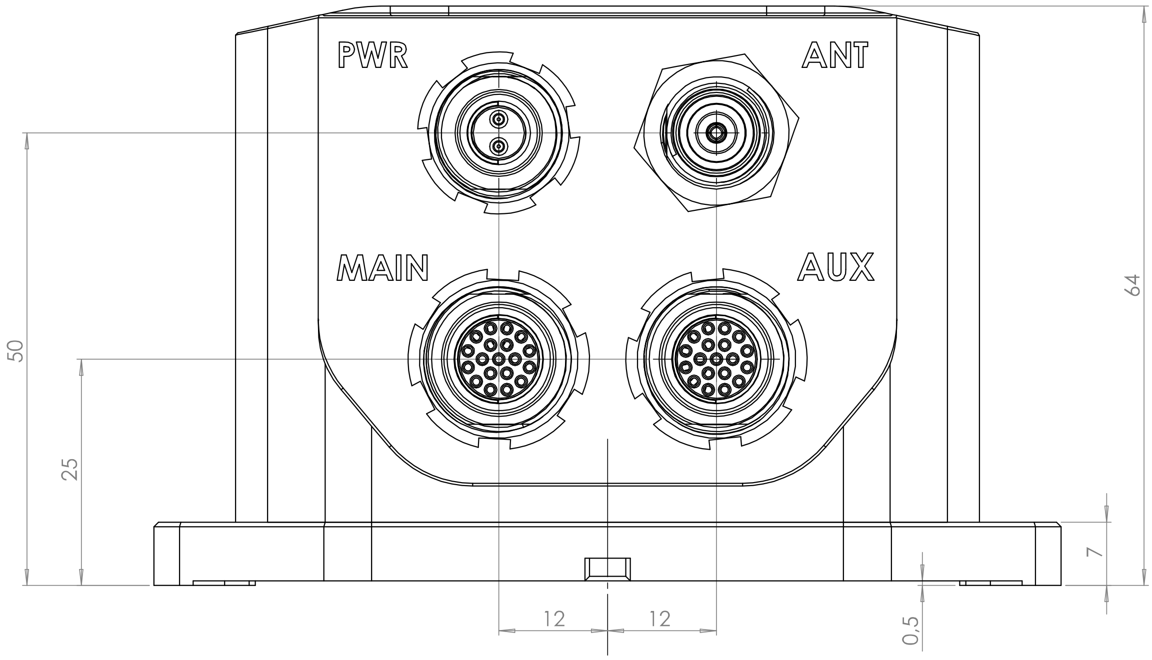
3.1.6.4. Bottom view



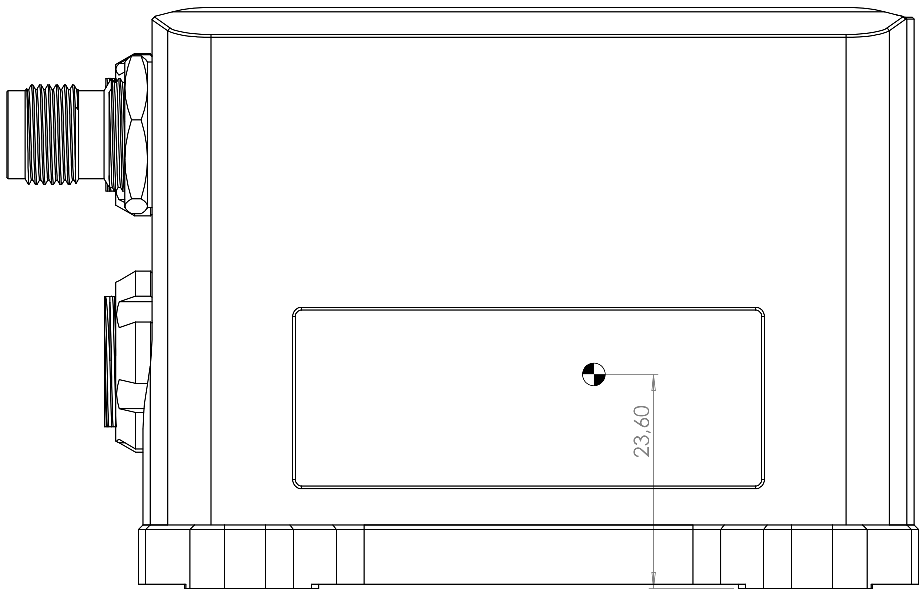
3.1.7. EKINOX-N mechanical outline

All dimensions are in mm.

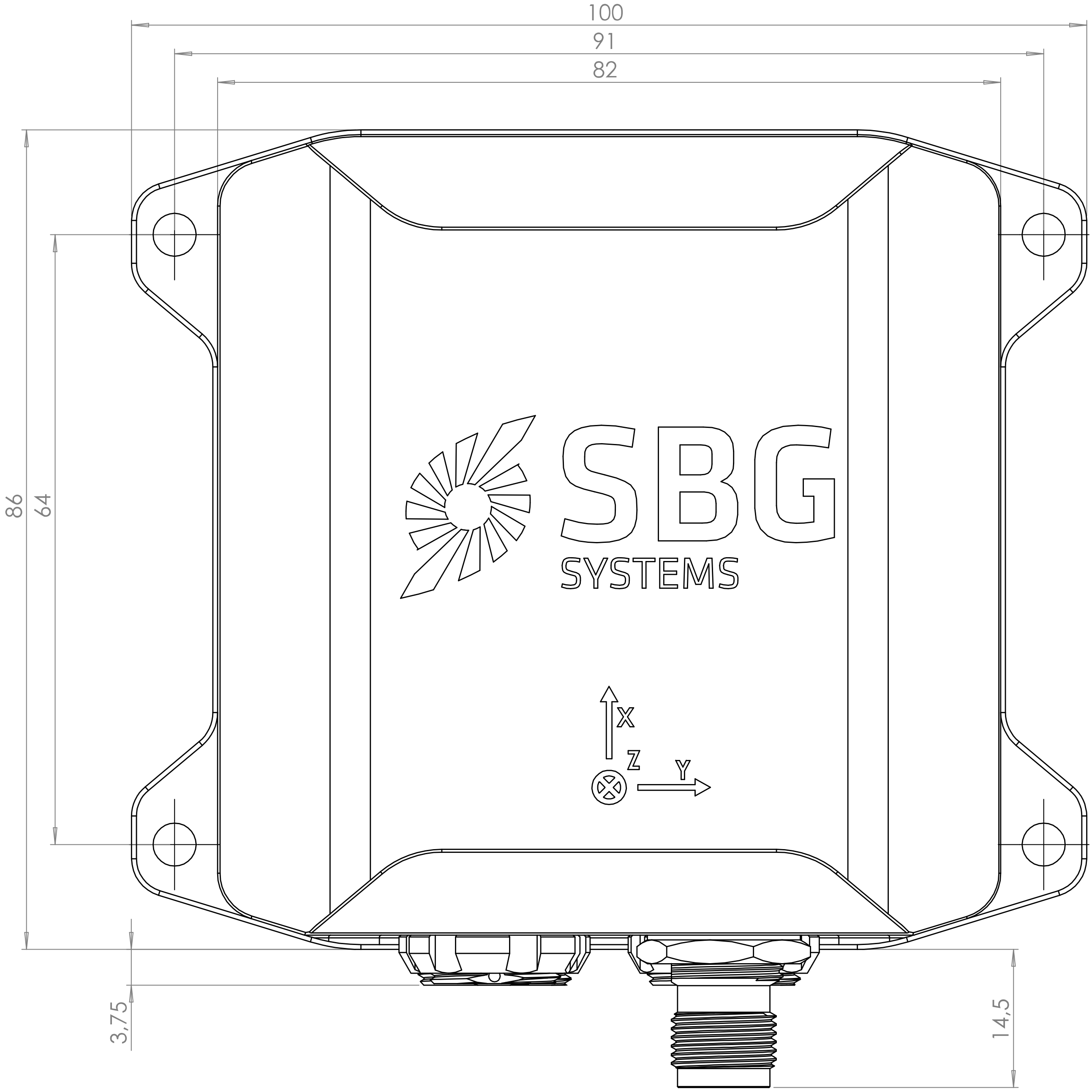
3.1.7.1. Front view



3.1.7.2. Right view



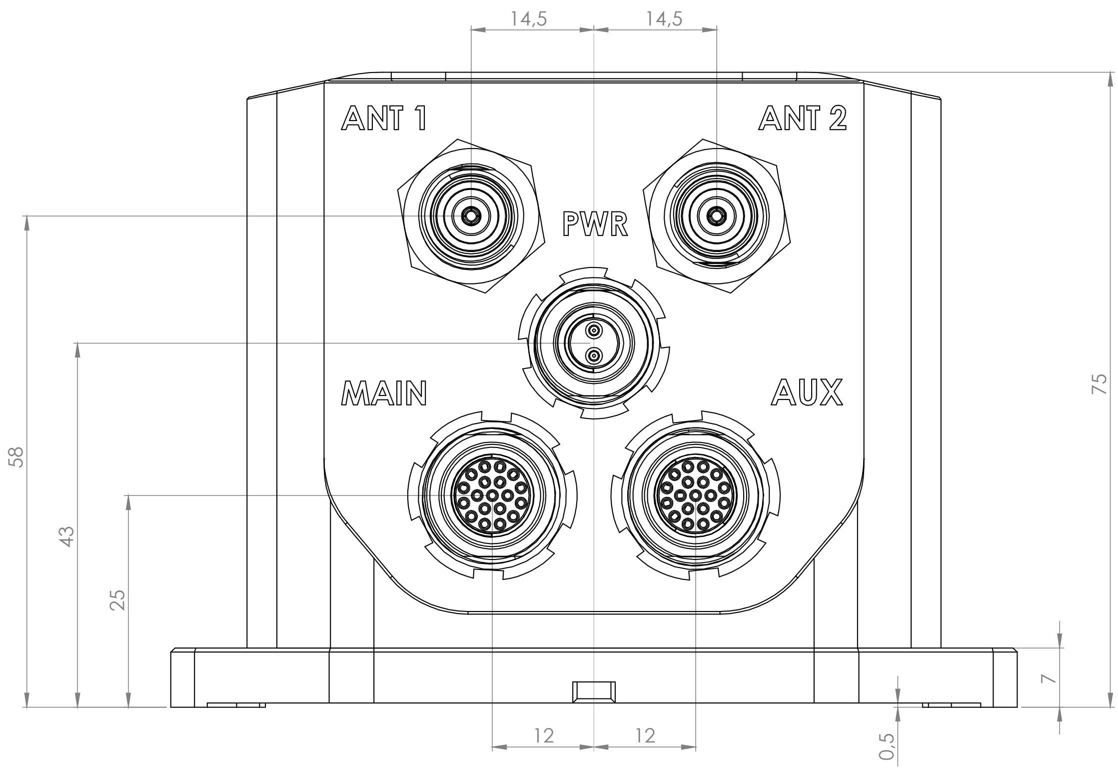
3.1.7.3. Top view



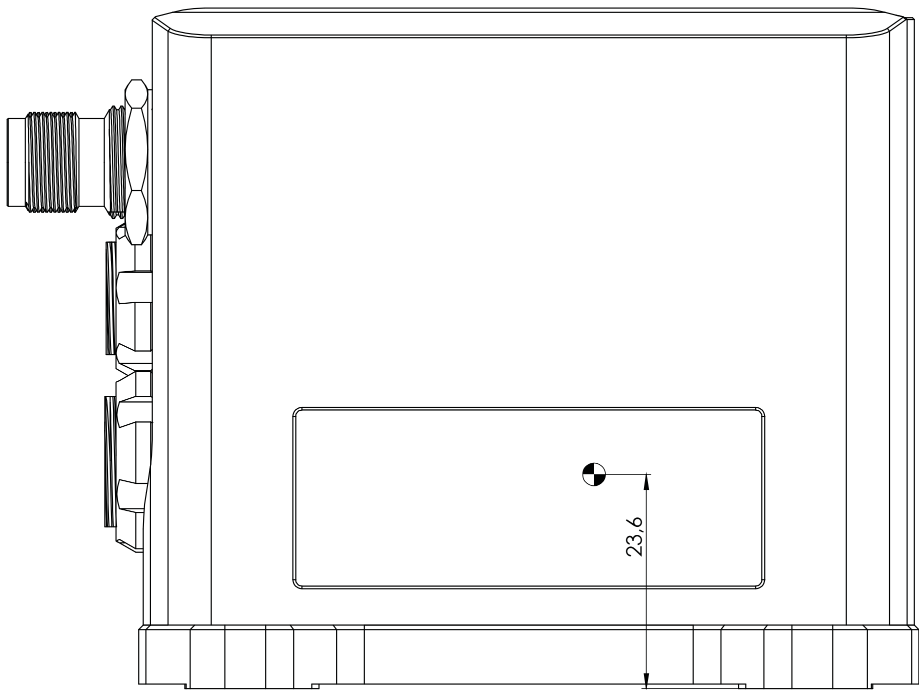
3.1.8. EKINOX-D mechanical outline

All dimensions are in mm.

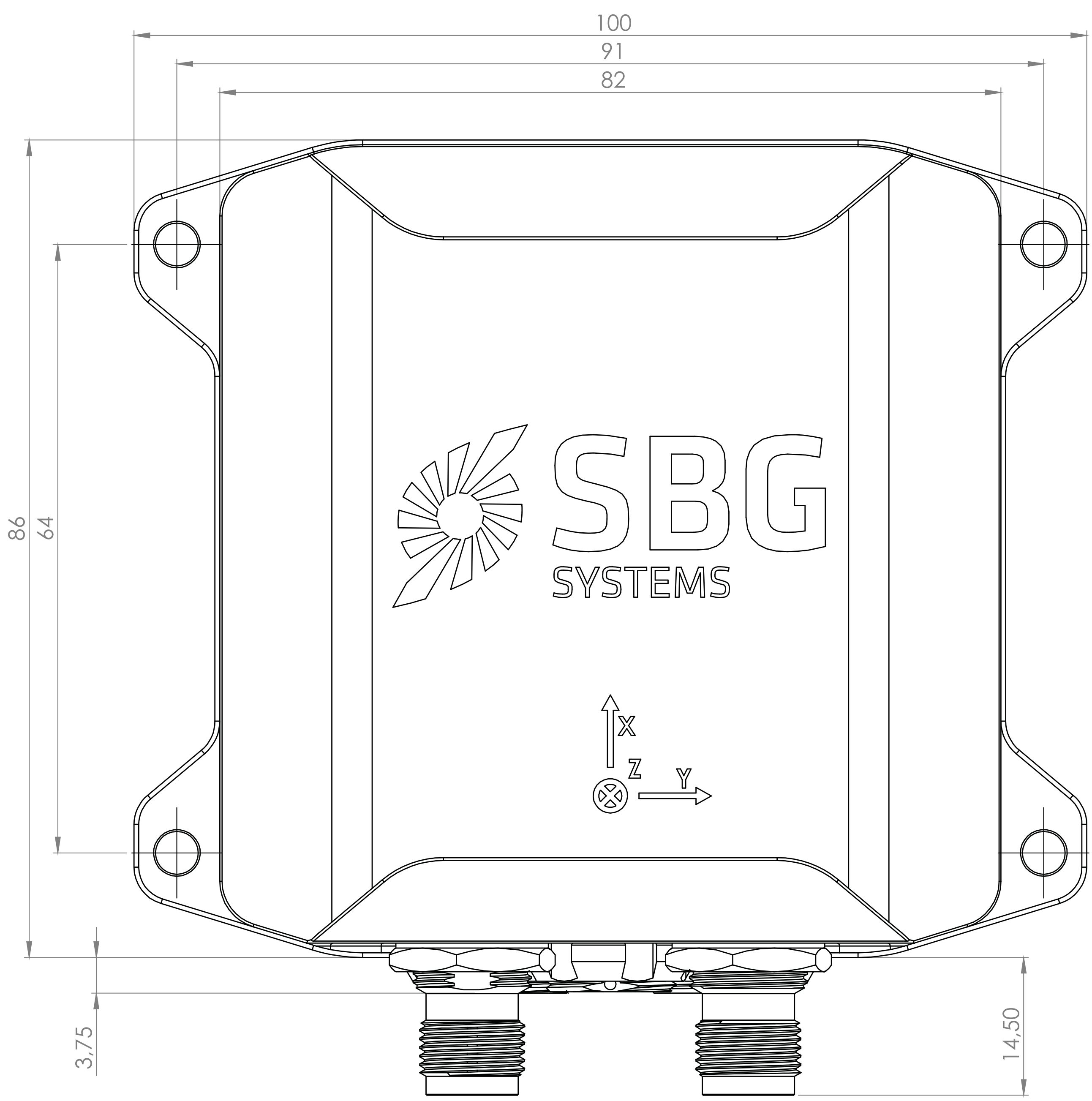
3.1.8.1. Front view



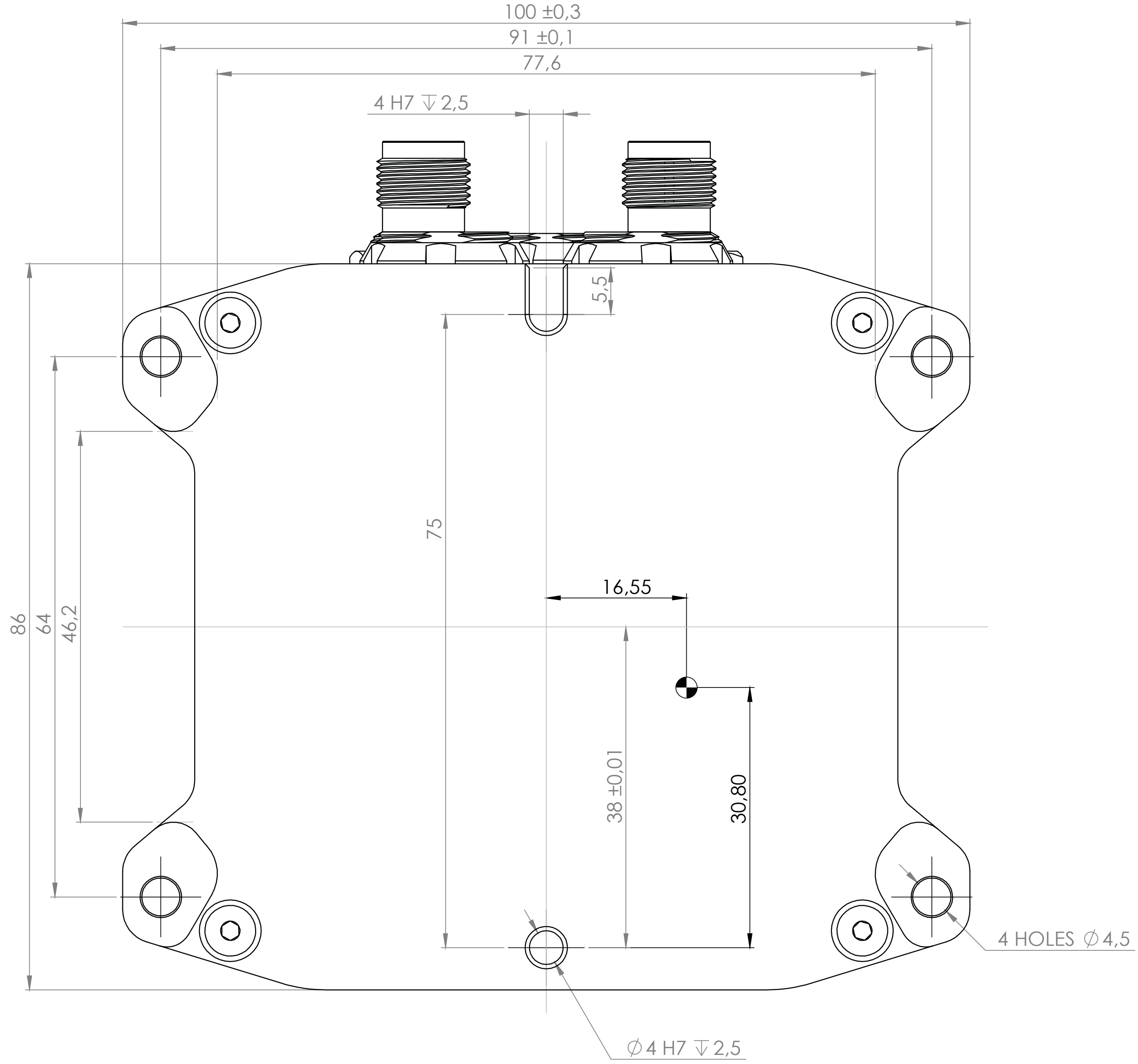
3.1.8.2. Right view



3.1.8.3. Top view



3.1.8.4. Bottom view



3.2. Electrical specifications

The Ekinox connectors are all placed on the front panel. The connectors are referenced and identified by laser marking on the enclosure. Each connector is different and fool proofed using a specific keying to avoid any misconnection.

SBG Systems has selected high quality connectors designed for harsh environments. They offer an IP-68 protection when the plug is properly mounted.

Note: The Ekinox development kit cables are not designed to offer an IP68 protection. Contact SBG Systems to get further support about IP-68 protection.

3.2.1. Ekinox-E with external aiding only

Figure 3.2: Ekinox INS without GPS (E version)

3.2.2. Ekinox-N with embedded GNSS

Figure 3.3: Ekinox INS with GNSS receiver (N version)

3.2.3. Ekinox-D with dual antenna GNSS

Figure 3.4: Ekinox INS with dual antenna GNSS receiver (D version)

3.2.4. Power supply connector

The Ekinox can be powered by a DC voltage from 9 to 36 Volts. For best robustness and to reduce power consumption, the internal power module is a high efficiency isolated DC/DC converter.

Apply a constant power supply to VIN+ and VIN- pins. The shield is directly connected to the device mechanical enclosure. It should not be used as the ground return signal.

3.2.4.1. Connector specifications

The power supply uses a 2 ways male AluLite Fischer connector which is compatible with the Fischer Core Series. The exact receptacle reference is: AL1731-DBPU-103-Z051PB11-12G13

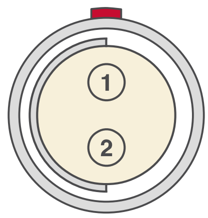


Figure 3.5: Power receptacle front view

This size 103 connector mates with both AluLite or Core Series female plugs. AluLite plugs offer a lightweight solution but Core Series connectors are easier to procure. In addition, you can save some space by using a right-angle plugs instead of a straight one.

There is not only one plug reference that can be used for the power supply. Please find below two references, one for an AluLite plug and an other one for a Core Series connector. Don't forget that these two references don't include the cable clamp sets.

- AL1731-S-103-Z051SR11-11 (AluLite version)
- S-103-Z051-130 (Core Series version)

Figure 3.6: Power plug top view

Note: Although Fischer connectors are IP68 and specified to operate from -40°C to +75°C, the plug should be connected at temperatures above -20°C and in a dry environment.

Warning: The power receptacle uses male connectors for obvious security reasons. Please make sure that you order the correct plug reference.

3.2.4.2. Connector pin out

Pin #	Name	Description
Shield	Shield	Connected to mechanical ground
1	VIN+	Connected to the power supply
2	VIN-	Connected to the electrical ground

3.2.4.3. Electrical specifications

Recommended electrical specifications from -40°C to 75°C.

Parameter	Min.	Typ.	Max.	Units	Conditions
Operating voltage	9	12	36	VDC	
Power consumption		3	TBD	W	Ekinox-E version
		4	TBD	W	Ekinox-N version with L1 + Glonass
		5	TBD	W	Ekinox-N version with L1/L2 + Glonass
		7	TBD	W	Ekinox-D version
In-Rush Current		TBD		A	
Allowable Input Voltage Ripple			400	mV p-p	
Under voltage lock out		8,5		V	Turn on threshold
		7,5		V	Turn off threshold
Reflected ripple current		12		mA p-p	
Switching frequency		180		kHz	
Galvanic Isolation			200	VDC	VIN+ to Mechanical Ground VIN- to Mechanical Ground

3.2.5. Main connector

The main connector is mainly used to configure the device and read data from it. It features the following connections:

- One serial connection that supports full-duplex operations at up to 921 600 bps. It can be configured to operate as an RS-232 or RS-422 interface by pulling down the pin 2.
- One CAN 2.0A/B connection that supports up to 1 Mbit/s data rate used to output data.
- One Ethernet 100BASE-T connection for device configuration, FTP access and virtual UDP or TCP/IP serial ports.
- One synchronization input / event marker signal for clock synchronization or to output data on a signal event.
- Two Synchronization output signals for time stamping and to trigger some equipments.

3.2.5.1. Connector specifications

The main connector uses a 19 ways female AluLite Fischer connector which is compatible with the Fischer Core Series. To avoid misconnection the main connector uses the keying code 11. The exact receptacle reference is: AL1731-DBPU-104-A092PB11-12G13

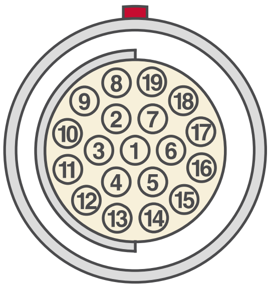


Figure 3.7: Main receptacle front view

This 104 size connector mates with both AluLite or Core Series male plugs. AluLite plugs offer a lightweight solution but Core Series connectors are easier to procure. In addition, you can save some space by using a right-angle plugs instead of a straight one.

There is not only one plug reference that can be used for the main connector. Please find below two references, one for an AluLite plug and another one for a Core Series connector. Don't forget that these two references don't include the cable clamp sets.

- AL1731-S-104-A092SR11-11 (AluLite version)
- S-104-A092-130 (Core Series version)

Figure 3.8: Main plug top view

Note: The main connector uses the standard keying code 11 and can thus be easily procured on electronic components distributors such as Digikey, Mouser, Farnell, ...

3.2.5.2. Connector pin out

Connector's pin out is sorted by function rather than pin numbering.

Pin #	Name	Description
Shield	Shield	Connected to the mechanical ground
1	GND	Connected to the main connector electrical ground
5	GND	Connected to the main connector electrical ground
7	GND	Connected to the main connector electrical ground
2	RS-232/RS-422	Pull to GND to select RS-422 mode
3	Sync Out A	Synchronization output signal A
4	Sync Out B	Synchronization output signal B
6	Sync In A	Synchronization input signal A
8	Port A – RS-422 - Rx+	Port A serial input data / configuration RS-422
9	Port A – RS-422 - Rx-	Port A serial input data / configuration RS-422
10	Port A – RS-422 - Tx-	Port A serial output data / configuration RS-422
11	Port A – RS-422 - Tx+	Port A serial output data / configuration RS-422
12	Port A – RS-232 - Rx	Port A serial input data / configuration RS-232
13	Port A - RS-232 - Tx	Port A serial output data / configuration RS-232
14	CAN H	CAN bus 2.0 high line
15	CAN L	CAN bus 2.0 low line
16	Ethernet Tx+	White/Green RJ45 pin#1
17	Ethernet Tx-	Green RJ45 pin#2
18	Ethernet Rx-	Orange RJ45 pin# 6
19	Ethernet Rx+	White/Orange RJ45 pin# 3

Note: By default, if you leave the RS-232/$\overline{\text{RS-422}}$ signal unconnected, the Port A will operate in RS-232 mode.

3.2.5.3. Electrical specifications

Recommended electrical specifications from -40°C to 75°C.

All signals are referenced to GND_MAIN. Pins #3, #4 and #7 are internally connected.

Parameter	Conditions	Min.	Typ.	Max.	Units
RS-232/RS-422					
Input Voltage Range		-25		+25	V
Input Threshold	Threshold Low	0,8	1,5		V
	Threshold High		1,8	2,7	V
Input Hysteresis			300		mV
Input Resistance		3	5	7	kΩ
Internal Pull-Up Resistor	Pull Voltage = +5VDC		1		kΩ
ESD Protection	Human Body Model	±15			kV
Sync Out A, Sync Out B					
Output Type		Open-Drain			-
High-level Input Voltage				25	V
Low-level Output Voltage			0,25	0,4	V
Low-level Output Current				40	mA
ESD Protection	Human Body Model	±15			kV
Sync In A					
Input Voltage Range		-25		+25	V
Input Threshold	Threshold Low	0,8	1,5		V
	Threshold High		1,8	2,7	V
Input Hysteresis			300		mV
Input Resistance		3	5	7	kΩ
Maximum Sync Pulse Rate		1			kHz
Pulse High-level Duration		TBD			ns
Pulse Low-level Duration		TBD			ns
ESD Protection	Human Body Model	±15			kV
Port A – RS-422 – Receiver					
Receiver Data Rate		4800		921600	bps
Input Resistance	-7V < Common Mode Voltage < +12V	96			kΩ
Input Current	Common Mode Voltage = -7V			-0,075	mA
	Common Mode Voltage = +12V			0,125	mA
Input Differential Threshold	-7V < Common Mode Voltage < +12V	-200		-50	mV
Input Hysteresis			30		mV
ESD Protection	Human Body Model	±15			kV
Port A – RS-422 – Transmitter					
Transmitter Data Rate	SLEW_RATE = SLOW	4800		230400	bps
	SLEW_RATE = FAST	4800		921600	bps
Transmitter Rise & Fall Time	SLEW_RATE = SLOW	200	400	800	ns

Parameter	Conditions	Min.	Typ.	Max.	Units
	SLEW_RATE = FAST		10	25	ns
Differential Output Voltage		2			V
Change in Magnitude of Differential Output Voltage for Complementary Output States				0,2	V
Common-Mode Output Voltage				3	V
Change in Magnitude of Common-Mode Output Voltage for Complementary Output States				0,2	V
Output Short-circuit Current	-7V < TX+ or Tx- < +12V			±250	mA
Output Leakage Current	-7V < TX+ or Tx- < +12V, RS-232/RS-422 = HIGH			±25	mA
ESD Protection	Human Body Model	±15			kV
Port A – RS-232 – Receiver					
Receiver Data Rate		4800		921600	bps
Input Voltage Range		-25		+25	V
Input Threshold	Threshold Low	0,8			V
	Threshold High			2,4	V
Input Hysteresis			500		mV
Input Resistance		3	5	7	kΩ
ESD Protection	Human Body Model	±15			kV
Port A – RS-232 – Transmitter					
Transmitter Data Rate	SLEW_RATE = SLOW	4800		230400	bps
	SLEW_RATE = FAST	4800		921600	bps
Transition-Region Slew Rate	SLEW_RATE = SLOW	4		30	V/µs
	SLEW_RATE = FAST	24		150	V/µs
Output Voltage Swing	Tx loaded with 3kΩ to GND_MAIN	±5	±5,4		V
Output Short-Circuit Current	Tx = GND_MAIN		±30	±60	mA
Output Leakage Current	RS-232/RS-422 = LOW			±25	µA
ESD Protection	Human Body Model	±15			kV
CAN					
Data Rate		10		1024	kbps
Recessive Bus Voltage		2		3	V
Recessive Output Current	CAN H, CAN L = ±76V		±3		mA
	-32V ≤ CAN H ; CAN L ≤ +32V	-2,5		+2,5	mA
CAN H Output Voltage	Dominant	3,0		4,25	V
CAN L Output Voltage	Dominant	0,5		1,75	V
Matching Between CAN H & CAN L Output Voltage	Dominant	-100		+150	mV
Differential Output (CAN H – CAN L)	Dominant	1,5		3,0	V
	Recessive	-50		+50	mV
CAN H Short-circuit Current		-100	-70	-45	mA
CAN L Short-circuit Current		40	60	90	mA

Parameter	Conditions	Min.	Typ.	Max.	Units
Differential Input Voltage	-12V ≤ Common Mode Voltage ≤ +12V	0,5	0,7	0,9	V
Differential Input Hysteresis	-12V ≤ Common Mode Voltage ≤ +12V		70		mV

3.2.6. External aiding connector

The external aiding connector is mainly used to connect aiding equipments to the Ekinox. It features the following connections:

- Up to two serial connections that support full-duplex operations at up to 921 600 bps. Each serial port can be configured to use RS-232 or RS-422 signals.
- Two Rx only serial ports that can operate at up to 921 600 bps. Each serial port can be configured to use RS-232 or RS-422 signals.
- Four synchronization input signals used for internal clock synchronization, data time stamping and/or event markers

3.2.6.1. Connector specifications

The external connector uses a 19 ways female AluLite Fischer connector which is compatible with the Fischer Core Series. To avoid misconnection the external connector uses the keying code 12. The exact receptacle reference is: AL1731-DBPU-104-A092PB12-12G13

Figure 3.9: External receptacle front view

This 104 size connector mates with both AluLite or Core Series male plugs. AluLite plugs offer a lightweight solution but Core Series connectors are easier to procure. In addition, you can save some space by using a right-angle plugs instead of a straight one.

There is not only one plug reference that can be used for the extended connector. Please find below two references, one for an AluLite plug and another one for a Core Series connector. Don't forget that these two references don't include the cable clamp sets.

- AL1731-S-104-A092SR12-11 (AluLite version)
- S-104-A092-230 (Core Series version)

Figure 3.10: External plug top view

Note: The external connector is using a special keying code 12 to avoid misconnection with the main connector.

3.2.6.2. Connector pin out

Connector's pin out is sorted by function rather than pin numbering.

Pin #	Name	Description
Shield	Shield	Connected to the mechanical ground
1	GND	Connected to the external connector electrical ground
5	GND	Connected to the external connector electrical ground
7	GND	Connected to the external connector electrical ground
4	Sync In B	Port B input synchronization
12	Port B – RS-232/RS-422 – Rx+	Port B serial input RS-232/RS-422
13	Port B – RS-422 – Rx-	Port B serial input RS-422
14	Port B – RS-422 – Tx+	Port B serial output RS-422
15	Port B – RS-232/RS-422 – Tx-	Port B serial output RS-232/RS-422
6	Sync In C	Port C input synchronization
16	Port C – RS-232/RS-422 – Rx+	Port C serial input RS-232/RS-422
17	Port C – RS-422 – Rx-	Port C serial input RS-422
18	Port C – RS-232/RS-422 – Tx-	Port C serial output RS-232/RS-422
19	Port C – RS-422 – Tx+	Port C serial output RS-422
2	Sync In D	Port D input synchronization
8	Port D – RS-232/RS-422 – Rx+	Port D serial input RS-232/RS-422
9	Port D – RS-422 – Rx-	Port D serial input RS-422
3	Sync In E	Port E input synchronization / Odometer B
10	Port E – RS-422 – Rx-	Port E serial input RS-422
11	Port E – RS-232/RS-422 – Rx+	Port E serial input RS-232/RS-422 / Odometer A

For Ekinox-N and D, if the internal GNSS receiver is enabled, the PORT B will not be available as it is used internally by the GNSS receiver. However, the Sync In B signal will still be available.

3.2.6.3. Electrical specifications

Recommended electrical specifications from -40°C to 75°C.

Parameter	Conditions	Min.	Typ.	Max.	Units
Port B, C, D, E Sync In					
Input Voltage Range		-25		+25	V
Input Threshold	Threshold Low	0,6	1,2		V
	Threshold High		1,5	2,4	V
Input Hysteresis			300		mV
Input Resistance		3	5	7	kΩ
Maximum Sync Pulse Rate		1			kHz
Pulse High-level Duration		TBD			ns
Pulse Low-level Duration		TBD			ns
ESD Protection	Human Body Model	±15			kV
Port B, C, D, E – RS-422 – Receiver					

Parameter	Conditions	Min.	Typ.	Max.	Units
Receiver Data Rate		4800		921600	bps
Input Resistance	-7V < Common Mode Voltage < +12V	48			kΩ
Input Current	Common Mode Voltage = -7V			-0,15	mA
	Common Mode Voltage = +12V			0,25	mA
Input Differential Threshold	-7V < Common Mode Voltage < +12V	-200		-50	mV
Input Hysteresis			30		mV
ESD Protection	Human Body Model	±15			kV
Port B, C, D, E – RS-422 – Transmitter					
Transmitter Data Rate	SLEW_RATE = SLOW	4800		230400	bps
	SLEW_RATE = FAST	4800		921600	bps
Transmitter Rise & Fall Time	SLEW_RATE = SLOW	200	400	800	ns
	SLEW_RATE = FAST		10	25	ns
Differential Output Voltage		2			V
Change in Magnitude of Differential Output Voltage for Complementary Output States				0,2	V
Common-Mode Output Voltage				3	V
Change in Magnitude of Common-Mode Output Voltage for Complementary Output States				0,2	V
Output Short-circuit Current	-7V < TX+ or Tx- < +12V			±250	mA
ESD Protection	Human Body Model	±15			kV
Port B, C, D, E – RS-232 – Receiver					
Receiver Data Rate		4800		921600	bps
Input Voltage Range		-25		+25	V
Input Threshold	Threshold Low	0,8			V
	Threshold High			2,0	V
Input Hysteresis			500		mV
Input Resistance		3	5	7	kΩ
ESD Protection	Human Body Model	±15			kV
Port B, C, D, E – RS-232 – Transmitter					
Transmitter Data Rate	SLEW_RATE = SLOW	4800		230400	bps
	SLEW_RATE = FAST	4800		921600	bps
Transition-Region Slew Rate	SLEW_RATE = SLOW	4		30	V/µs
	SLEW_RATE = FAST	13		150	V/µs
Output Voltage Swing	Tx loaded with 3kΩ to GND_AUX	±5	±5,4		V
Output Short-Circuit Current	Tx = GND_AUX		±30	±60	mA
ESD Protection	Human Body Model	±15			KV

3.2.7. GPS antenna connectors

To connect external GPS antennas, the Ekinox N and D versions feature one or two IP-68 TNC connectors. Each Ekinox is provided with dust caps to seal the TNC connector offering an IP-68 protection. The internal GNSS receiver only supports active GPS antennas.

3.2.7.1. Connector specifications

The female TNC connector, manufactured by Telegärtner (reference J01011B0030), is made of nickel-plated brass. The female TNC dust cap is also manufactured by Telegärtner (reference H00050A0000).

Figure 3.11: GPS antenna connector

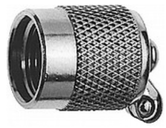


Figure 3.12: TNC dust cap

Any standard GPS cable with a TNC male connector can be used with the Ekinox. However, the Ekinox TNC connector provides only an IP-68 protection when plugged with either the TNC dust cap or an IP-68 antenna cable. SBG Systems can provide IP68 compliant GPS cables.

Figure 3.13: Typical TNC antenna cable

Please be advise that the Ekinox doesn't implement any lightning protection. The GPS antenna and cable are very sensitive to strikes and a proper installation with lightning protection devices may be required.

> **Note:** For best performance, the antenna(s) should be connected before the power is applied. The Ekinox GPS estimates the noise floor of the antenna during the startup sequence.

> **Warning:** The TNC connector offers an IP68 protection only when a waterproof GPS cable is connected. There is no IP rating when the TNC connector is not connected to an IP-68 dust cap or cable. If you don't want to connect a GPS cable while maintaining the IP rating, please use the provided dust cap.

3.2.7.2. Electrical specifications

Recommended electrical specifications from -40°C to 75°C.

Parameter	Specifications	Remark, conditions
Antenna connector	TNC female	IP-68 when connected
Input impedance	50 Ω	
LNA supply voltage	5 VDC	±5%
LNA supply current	< 70 mA	
RF input frequencies	**GPS L1:** 1575.42 MHz **GPS L2:** 1227.60 MHz **GLONASS L1:** 1596 – 1610 MHz **GLONASS L2:** 1237 – 1253 MHz **Galileo E1:** 1575.42 MHz	
RF input level signal	L1: -122 to -87 dBm L2: -126 to -93 dBm	
RF input level noise	L1: -161 to -141 dBm/Hz L2: -161 to -141 dBm/Hz	

3.2.7.3. GPS antenna advices

The Ekinox N and D embed a high performance GNSS receiver that supports L1/L2 and GLONASS signals. For best performances and robustness, please use low noise and high gain active GPS antennas that support the frequencies band you are planning to use.

In addition, the Ekinox D requires L1/L2 GPS + GLONASS antennas for optimal True Heading performance.

Don't forget to also check the GPS antenna LNA power requirements such as input voltage (must accepts 5 VDC) and input current (must be below 70 mA).

SBG Systems has selected some high quality GPS antennas for different applications. Please refer to the section 9.3.7 GPS Antennas to get more details on available antennas.

> **Note:** As a rule of thumb, true heading and/or RTK measurements require higher quality GPS antennas to achieve the stated accuracies.

3.3. Typical wiring

In this section, we briefly describe a few recommended wiring diagrams.

3.3.1. Power supply connection

Concerning power supply, we recommend shielded cable, with at least AWG 24 wires.

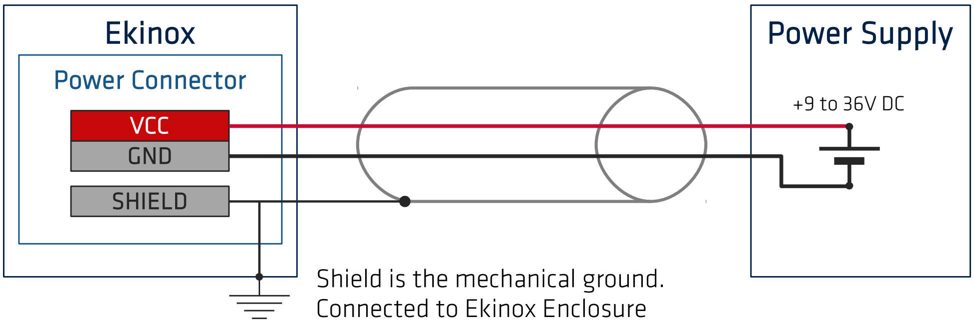


Figure 3.14: Power supply wiring connections

3.3.2. Main interface connection on RS-232

Below is shown the main interface (Port A) connection, using a full duplex RS-232 connection. The recommended cable is a shielded AWG26 cable.

A protocol selector pin is left open in RS-232 mode.

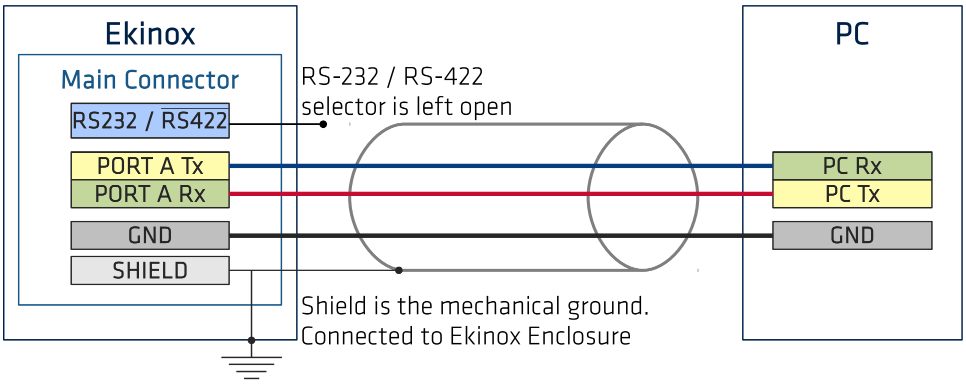


Figure 3.15: Main serial interface full duplex connection in RS-232

3.3.3. Main interface connection on RS-422

Below is shown the main interface (Port A) connection, using a full duplex RS-422 connection. The recommended cable is a shielded twisted pairs AWG26 cable.

Note the termination resistors (Usually 120 ohms) that can optionally be placed on receiver side to avoid communication errors in long distance communications. These resistors can be omitted in short distance communications in order to reduce power consumption.

A protocol selector pin is connected to GND in RS-422 mode.

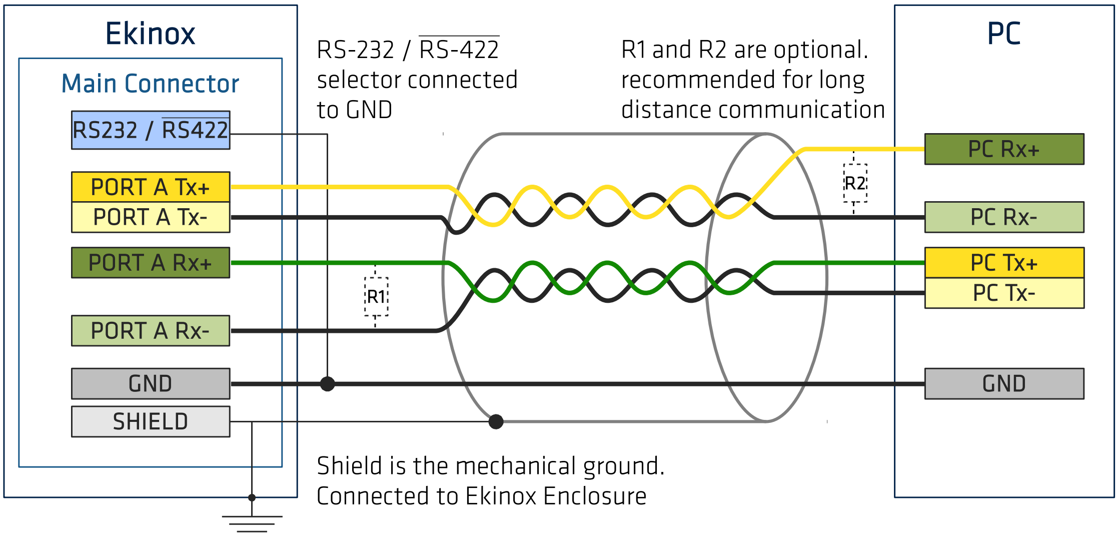


Figure 3.16: Main serial interface full duplex connection in RS-422 mode

3.3.4. CAN Bus typical wiring

CAN bus is designed to operate with low cost twisted pairs cables. The bus may be terminated by a single 60 ohm resistor, or multiple resistors on each bus ends (as long as the equivalent parallel impedance is 60 ohm). This resistor is not present in the Ekinox.

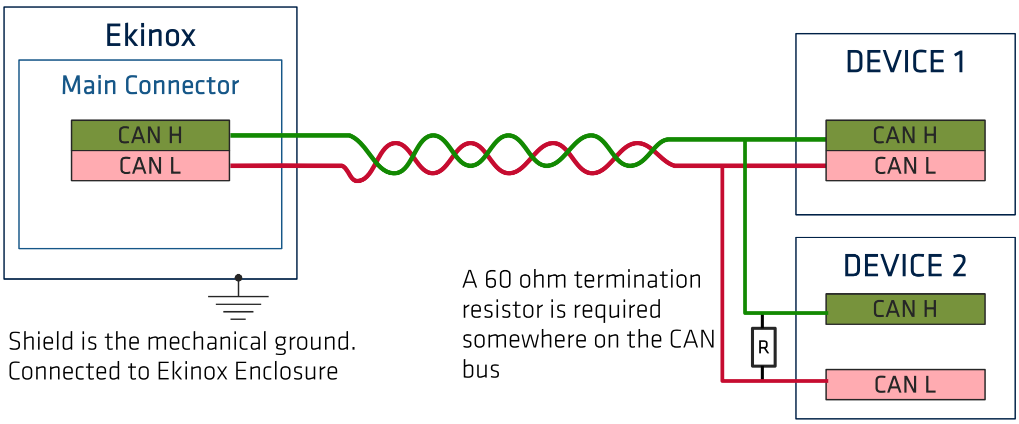


Figure 3.17: Basic CAN bus wiring

3.3.5. GNSS connection in RS-232 mode

For this typical connection, a shielded AWG 26 cable should be used. Depending on PPS signal strength, we do not recommend this cable to measure more than a few meters. For long distance, PPS signal and GPS NMEA signals should be separated in two cables for better noise immunity.

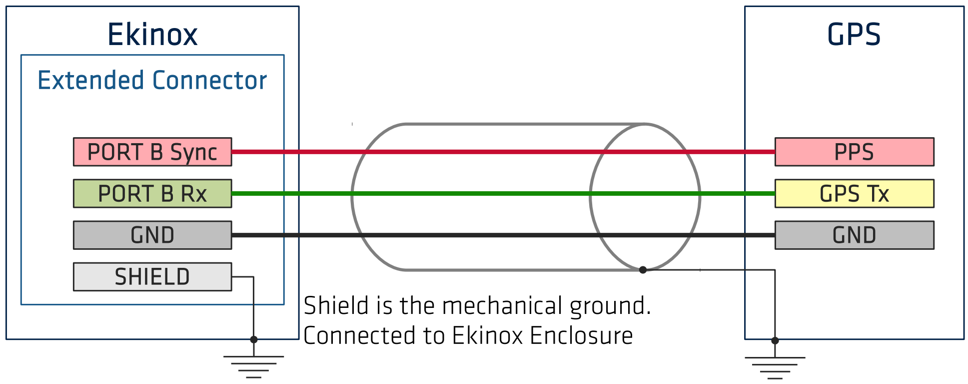


Figure 3.18: Typical wiring diagram for Ekinox E with external GNSS receiver

3.3.6. Third party aiding equipment connected in RS-422

For this connection, we recommend shielded twisted pairs AWG26 cable. As for main communication interface, a termination resistor may be required depending on the communication distance.

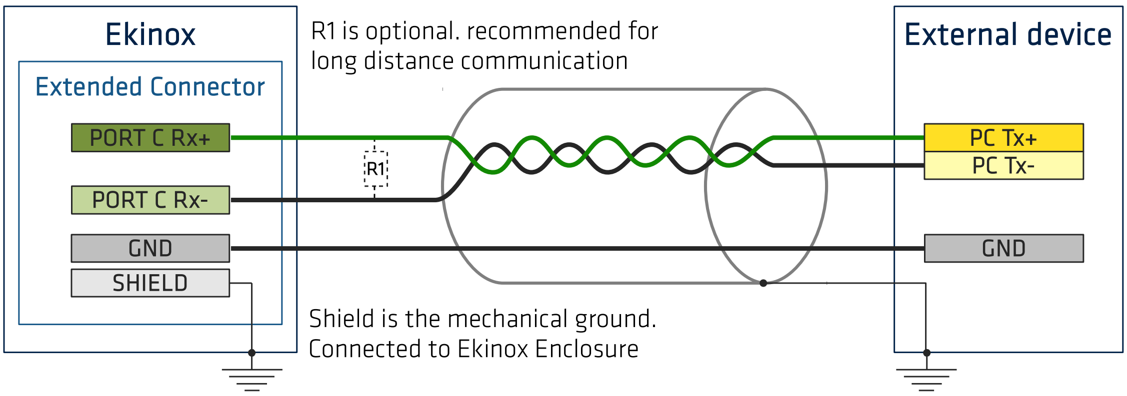


Figure 3.19: Third party aiding equipment with RS-422 interface

3.3.7. Triggering external devices with the sync Out

Consider a camera that must take a picture when an event is provided on Event Out pin. Event Out and Sync Out are “open drain” outputs, which means a pull up resistor must be used on receiver side, as shown on the diagram.

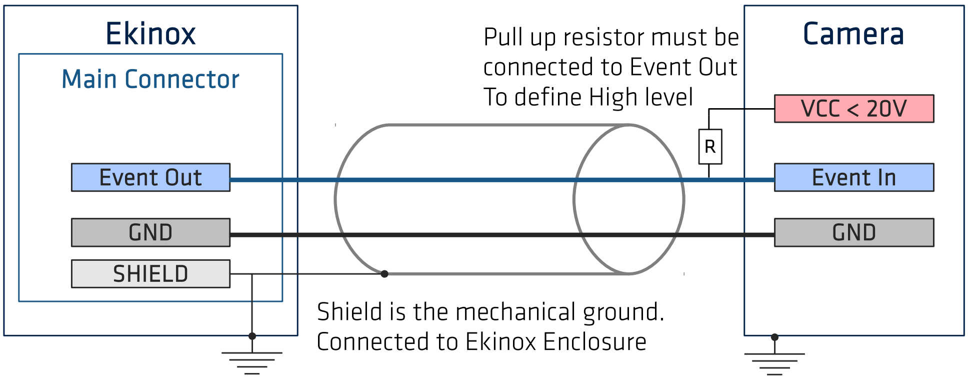


Figure 3.20: Sync Out connection with pull up resistor

4. Interfaces specifications

4.1. Interfaces Overview

The Ekinox implements a powerful interface mechanism to allow maximum flexibility while reducing as much as possible the configuration complexity. An interface is a pipe that can be used to output log messages and/or communicate with an aiding equipment.

The Ekinox features the following interfaces:

- Physical RS-232/RS-422 serial ports (Port A to Port E)
- Virtual serial ports over Ethernet (Eth 0 to Eth 5)
- Internal data logger

Interfaces are handled in a generic way so sending data over a physical serial port is handled as sending these data to the internal data logger. The same philosophy is used for aiding equipments connections and configuration. An external GPS can either be connected to the Port B serial port or to the Eth 3 virtual serial port over Ethernet.

For a specific interface, input and output pipes are handled separately so you can for example feed aiding data on Port B and output log messages on the same Port B.

In addition, the Ekinox supports CAN 2.0A/B connectivity to output log messages. Due to the CAN implementation and limitations (payload limited to 8 bytes), the CAN interface is not handled like the other interfaces.

Finally, Synchronization input and output signals may be associated with an interface to provide, for example, a 1 PPS signal if a GPS receiver is used.

4.2. Ethernet specifications

The Ekinox main port features an Ethernet 100BASE-T interface. This interface is used for the device installation and configuration through an embedded web page.

The Ekinox Development Kit contains an Ethernet cable to allow quick setup, configuration and tests on any system that features a modern web browser.

This Ethernet interface is a key feature of the Ekinox device as it provides the following services:

- A Bonjour service used to easily discover any connected Ekinox and get its IP address
- An embedded web interface used to configure the device and visualize output data
- An FTP access to download logs recorded in the internal Flash memory
- Five virtual serial ports Eth0 to Eth4 that support either UDP or TCP/IP protocols

4.2.1. Zero Configuration Networking (Bonjour)

In order to facilitate the device configuration, the device acquires automatically a private IP as soon as the Ekinox is connected to a network. This private IP allows the device to broadcast its name and ip address automatically using the Bonjour protocol. Thanks to this system, there is always an easy way to access the device configuration and in particular to change its TCP/IP configuration.

Note: The ZeroConf technology, uses multicast addresses and an UDP connection on the port 5353. Please make sure that your network allows these connections.

4.2.2. TCP/IP configuration

As for any device connected to a network, the Ekinox TCP/IP configuration should be set according to the network topology.

The Ekinox only supports IPv4 addresses and offers the following TCP/IP configurations:

- Automatic DHCP address attribution (default setting)
- Static address, mask and router definition

You can easily read the current Ekinox MAC address and IP address in the information tab of the embedded web interface.

Note: Even if the Ekinox is configured with an invalid TCP/IP configuration, the device will still be accessible thanks to the ZeroConf technology.

4.2.3. Embedded web interface

The Ekinox embeds a very advanced and powerful web 2.0 interface. Based on the latest web technologies, this interface combines a native experience and the advantages of a web interface.

The web interface has been designed to provide both an easy and efficient way to configure the Ekinox and a quick solution to display real time data and check the device status.

Thanks to the ZeroConf technology, you can easily access the web page using the Ekinox serial number. Indeed, the Ekinox broadcast a web service so you can connect to the configuration web page using the following address:

http://ekinox_020000001.local.

Where 02000001 is the device serial number. It can be found on a label located on the enclosure's right side.

If your web browser supports DNS Service Discovery such as Safari or Firefox through "DNSSD for Firefox" extension, you should directly see a link to all Ekinox devices available on the network.

Note 1: Please, don't forget to append the last "." character to get a valid URL address.

Note 2: On the first load or if the device firmware has been updated, the Ekinox will cache the entire embedded website to optimize the responsiveness. This preload operation may take up to two minutes according to your system configuration.

4.3. Supported protocols

The Ekinox has been designed to be connected to a large range of aiding equipments and materials. In addition to the native Ekinox binary protocol, other third party or standard protocols are also supported such as NMEA, RTCM, TSS1, Novatel Binary protocol and others.

4.3.1. Ekinox binary protocol

The Ekinox binary protocol is the main and native protocol used to output log messages, to input user aiding data and to configure the device.

4.3.1.1. Log messages

All Ekinox binary output log messages are listed in the section 4.4-Log outputs overview below.

4.3.1.2. User aiding

The Ekinox binary protocol support the following user aiding messages:

- User heading
- User velocity in NED frame
- User velocity in body frame (X, Y, Z)
- User position in Latitude, Longitude, Altitude frame

4.3.1.3. Commands

With this protocol, it's possible to change the device configuration using a configuration file. A configuration file can either be exported from a device using the embedded web interface or using the SBG_ECOM_CMD_EXPORT_SETTINGS. This configuration file can then be uploaded to an Ekinox thanks to the command SBG_ECOM_CMD_IMPORT_SETTINGS or trough the web interface. The device will automatically reboot to use the new settings.

In addition to the configuration file, some commands can be sent to the device to change, in real time, some settings such as aiding rejection filters.

Note: For a complete description of the Ekinox binary protocol, please refer to the Ekinox Firmware Reference Manual.

4.3.2. Novatel binary protocol

The Ekinox supports the Novatel binary protocol to parse GPS input data such as position, velocity and UTC time data. The following Novatel messages are handled:

- BESTPOS – Provides the best available position solution
- PSRXYZ – Provides velocity from Doppler measurements and associated accuracy. Preferred solution.
- PSRVEL – Provides Doppler velocity but no accuracy data.
- TIME – Provides UTC time data

4.3.3. Septentrio SBF binary protocol

The Ekinox implements Septentrio SBF binary protocol for GPS data aiding input. The following messages are used for Septentrio → Ekinox integration:

- PVTGeodetic: For position and velocity input
- PosCovGeodetic: For position advanced error management
- VelCovGeodetic: For velocity advanced error management
- AttEuler: Orientation for dual antenna systems
- AttCovEuler: Orientation accuracy
- ReceiverTime: Timing data
- xPPSOffset: Timing data

4.3.4. NMEA protocol

The Ekinox implements NMEA 0183 standard protocol for both log outputs and aiding equipments input. A detailed list of NMEA output logs can be found in the section 4.4-Log outputs overview below.

The following NMEA messages are handled by the Ekinox to input aiding data:

- GGA for position and altitude
- RMC for horizontal velocity and course
- HDT for true heading
- ZDA for UTC time data

4.3.5. Ekinox N and D internal GPS aiding protocols

The Ekinox N and D versions embed a high performance Novatel dual band GNSS receiver that supports both one centimeter RTK accuracy as well as true heading computation.

4.3.5.1. Differential GPS and RTK corrections

In order to compute a RTK or DGPS position, you must input correction data to the Ekinox. This can only be done through the using a serial Port D. The device supports most differential data formats as you can see in the following list:

- RTCA
- RTCAOBS2
- RTCM V2.3 (with or without GLONASS)
- RTCM V3 (with or without GLONASS)
- CMR+
- CMR

The computed RTK solution uses L1/L2 + GLONASS signals to provide a robust 1 cm accuracy even in difficult environments.

Note: To enable RTK positioning, you must have an Ekinox with a valid RTK license. However, you don't need any additional license to input differential corrections and get a DGPS accuracy.

Warning: Only the Port D can be used to input differential GPS corrections.

4.4. Log outputs overview

The Ekinox can output log messages using different protocols on each interface that implements an output channel.

The CAN interface handles log outputs in a different manner than serial, virtual port or datalogger interfaces. For more details, please refer to the section 4.6-CAN 2.0 A/B interface below.

4.4.1. Logs configuration

For a particular interface, the user can configure how each log message should be outputted using the following options:

- Disabled, this log message is never generated
- Continuous, this log message is outputted according to the configured output frequency
- New data, this log message is sent each time a new data is available
- Event #, this log message is sent each time a signal is received on the Event # pin

4.4.1.1. Continuous mode

The continuous mode is recommended to output log data on a regular basis. It is usually used to output inertial data, computed attitude, velocity and position. When this mode is selected, a divider can be set for each log message to reduce the output rate from 200 Hz down to 0.1 Hz.

When the device is correctly fed with UTC data and a PPS signal, the device time is UTC aligned. In this case, configuring a log message in continuous mode to 1 Hz means that each time an UTC second elapses, the log message is sent.

This feature is very useful to ease data synchronization between multiple equipments.

4.4.1.2. New data

The new data mode is very useful to output aiding equipments data such as GPS position or odometer velocity.

With this mode, you are always sure to get the most recent data without logging duplicates.

4.4.1.3. Event input signals

The Ekinox can be configured to output log messages when an event input signal is detected. An input signal can be generated on a rising edge, falling edge or both rising and falling edges.

When an event signal is detected, a log message can be outputted using two methods according to the log message type:

- If the log message can't be interpolated such as a GPS position, the last received data is sent
- If the log message can be interpolated, a log message is interpolated to the exact event reception time

4.4.2. NMEA Talker Id

A NMEA talker id can be defined for each output interface. The NMEA talker id is appended at the beginning of the NMEA frame to form a complete NMEA identifier.

For example if the Ekinox has to output the log message GGA and the NMEA talker id is set to GP, the resulting NMEA message name will be GPGGA.

This feature is useful to increase the NMEA log messages compatibility with external equipments.

4.4.3. Heave monitoring point

The Ekinox can compute and output heave data at four different monitoring points. For each output interface, it is possible to define which heave monitoring should be used to generate log messages.

This setting will not affect Ekinox binary logs output because four different heave logs are implemented (SBG_ECOM_LOG_SHIP_MOTION_0 to SBG_ECOM_LOG_SHIP_MOTION_3). It will rather be used for NMEA or third party log generation such as the TSS1 frame.

4.4.4. Log messages list

The Ekinox output logs architecture is very versatile and powerful. For example, the device can output sbgECom binary logs and NMEA messages on the same output port.

As explained previously, each message can be triggered based on different conditions. For some logs, it makes sense to output them on a time basis such as 50 Hz. However, for other logs, it's much better to output them as soon as a new data is available (for example a GPS position).

In addition, some logs data will be interpolated if they are triggered on an external synchronization event to ensure that the outputted data exactly reflect the synchronization signal instant.

For each available log, you can use the following color code to know if a log will be interpolated when outputted on a “Sync In” signal and if it's recommended to output a log on a “New Data” event.

Color Code	Description
●	This log will be interpolated if outputted using a “Sync In” signal
●	It's strongly recommended to output this log on a “New Data” trigger

4.4.4.1. Ekinox Binary Log messages

The Ekinox binary protocol offers the best security, latency and options to output log messages. You can find in the table below a summary of all available binary log messages that can be outputted by the Ekinox.

For a complete description of each log message, please refer to the Ekinox Firmware Reference Manual.

Output		Description
SBG_ECOM_LOG_STATUS	●	Output the system, solution, clock, aiding status
SBG_ECOM_LOG_IMU_DATA		Output accelerometers, gyroscopes, delta angle and delta velocity
SBG_ECOM_LOG_EKF_EULER	●	Output computed Euler angles attitude
SBG_ECOM_LOG_EKF_QUAT	●	Output computed quaternion attitude
SBG_ECOM_LOG_EKF_NAV	●	Output computed velocity and position
SBG_ECOM_LOG_SHIP_MOTION_0		Real time heave output at the main monitoring point
SBG_ECOM_LOG_SHIP_MOTION_1		Real time heave output at the second monitoring point #1
SBG_ECOM_LOG_SHIP_MOTION_2		Real time heave output at the second monitoring point #2
SBG_ECOM_LOG_SHIP_MOTION_3		Real time heave output at the second monitoring point #3
SBG_ECOM_LOG_SHIP_MOTION_HP_0		Delayed heave output at the main monitoring point
SBG_ECOM_LOG_SHIP_MOTION_HP_1		Delayed heave output at the second monitoring point #1
SBG_ECOM_LOG_SHIP_MOTION_HP_2		Delayed heave output at the second monitoring point #2
SBG_ECOM_LOG_SHIP_MOTION_HP_3		Delayed heave output at the second monitoring point #3
SBG_ECOM_LOG_UTC_TIME	●●	Output the synchronized UTC date and time
SBG_ECOM_LOG_MAG	●	Output magnetometers and related accelerometers aiding data
SBG_ECOM_LOG_MAG_CALIB	●	Magnetometer calibration data (raw buffer)
SBG_ECOM_LOG_GPS1_VEL	●	Output GPS 1 velocity aiding data
SBG_ECOM_LOG_GPS1_POS	●	Output GPS 1 position aiding data
SBG_ECOM_LOG_GPS1_HDT	●	Output GPS 1 true heading aiding data
SBG_ECOM_LOG_GPS1_RAW	●	GPS 1 raw data for post processing.

Output		Description
SBG_ECOM_LOG_GPS2_VEL	●	Output GPS 2 velocity aiding data
SBG_ECOM_LOG_GPS2_POS	●	Output GPS 2 position aiding data
SBG_ECOM_LOG_GPS2_HDT	●	Output GPS 2 true heading aiding data
SBG_ECOM_LOG_ODO_VEL	●	Output odometer velocity aiding data
SBG_ECOM_LOG_EVENT_A/B/C/D/E	●	Output the list of received event markers on Sync A/B/C/D/E pin
SBG_ECOM_LOG_DVL_BOTTOM_TRACK	●	Doppler Velocity Log for bottom tracking data
SBG_ECOM_LOG_DVL_WATER_TRACK	●	Doppler Velocity log for water tracking data

4.4.4.2. NMEA log messages

The Ekinox supports some standard NMEA 0183 messages to ensure GPS drop in replacement and protocol compatibility with other hardware.

However, the NMEA standard offers only a very limited set of messages and generating, transmitting and parsing NMEA sentences requires a lot of computational resources and transmission bandwidth.

If you don't really need NMEA messages, please use binary logs instead to reduce data latency and reveal the full potential of the Ekinox device.

Output		Description
$##GGA	●	Output the computed position
$##RMC	●	Output the computed position, velocity and course
$##ZDA	●	Output the synchronized UTC date and time
$##HDT	●	Output true heading angle
$##GST	●	Output GNSS Pseudorange Error Statistics
$##VBW	●	Output Dual Ground/Water Speed

4.4.4.3. ASCII and Third Party Log messages

In this part, you will find all log messages that can be generated by the Ekinox to support third party materials such as echo sounders. In addition, the Ekinox can output some proprietary ASCII log messages for debug and ease of use.

Output		Description
TSS1	●	Output computed roll, pitch, heave and accelerations data
PD0		Output last received PD0 frame from Teledyne DVL
PRDID	●	RDI Proprietary Heading, Pitch, Roll
SIMRAD EM1000/3000	●	Kongsberg proprietary messages for heading, pitch, roll, heave

> **Note:** The Ekinox supports most common third party protocols and materials. However, If your equipment is not supported by the Ekinox, please feel free to contact SBG Systems at support@sbg-systems.com.

4.5. Serial interfaces

The Ekinox features 5 physical RS-232/RS-422 serial connections (Port A, B, C, D and E) and virtual serial ports (Eth 0, 1, 2, 3, 4) through Ethernet UPD or TCP/IP connections.

Some physical serial ports provide both an input and output signal, some just have an input signal. All virtual serial interfaces have both input and output lines. For best flexibility, the input and the output of a given port is handled separately.

For example, the Port C input can accept NMEA data from a GPS and the Port C output can, at the same time, send TSS1 frame with deported heave to an echo sounder.

4.5.1. Physical serial interfaces

Physical serial interfaces are designated as Port A, B, C, D and E. Each port can be configured to operate in RS-232 or RS-422 mode at a baud rate from 4 800 to 921 600 bps.

Some ports offer special functionalities. For example, the Port A is the only port that accepts Ekinox Binary Protocol commands and the Port E is used for odometer connections.

> **Note:** The Ekinox automatically limits the serial signals slew-rate to minimize EMI and reduce communication error when the baud rate is below 230 400 bps.

4.5.1.1. Main port A

The Port A is located on the main connector and has been designed to be the main serial connection between the device and a host system. The RS-232/RS-422 mode is hardware selected using the pin 2 located on the main connector.

The Port A is the only physical port that accepts Ekinox Binary Protocol commands. It can be used, for example, to input user aiding heading, velocity, position and to send device configurations.

The factory default configuration for the Port A is:

Parameter	Value
Baudrate	115200
Data Bits	8
Parity	None
Stop Bits	1
Flow Control	Disabled

4.5.1.2. Aiding ports B, C, D and E

The Port B, C, D and E are located on the external connector. These ports are intended to connect aiding external equipments. The RS-232/RS-422 mode is selected trough the Web Interface.

For the Ekinox N and D versions, the Port B is not available if the internal GNSS receiver is enabled and the Port D is used to provide RTCM data to the embedded GPS receiver. These ports can also be used as general purpose inputs/outputs ports.

The Port E can be used to connect an external odometer input pulse using the Rx signal. If your odometer also provides a direction signal, it can be connected to the Sync In E pin.

By default, Port B, C, D and E are all disabled for both data input and output.

> **Note:** Please refer to the connection mapping table below to understand exact connections availability.

4.5.2. Virtual serial interfaces

Virtual serial interfaces are a very simple and powerful way to increase the number of inputs/outputs without adding too much cables and connectors. Some equipments directly support virtual serial interfaces and other, that only have standard RS-232/RS-422 connections, can still use virtual serial interfaces trough an Ethernet to serial converter.

A virtual serial interface is just a TCP/IP or UDP connection that can send and receive raw data. The Ekinox implements the following modes to create a virtual serial interface:

- Raw UDP to reduce latencies and allow high throughput
- TCP/IP client or server to guarantee message delivery and ordering

As for the physical serial interface Port A, the Eth 0 virtual serial port can be used to send commands trough the Ekinox Binary Protocol. Virtual serial port Eth 1 to 4 can be used indifferently to input aiding data and to output log messages.

> **Note:** Virtual serial interfaces are handled internally exactly the same way as physical interfaces. For example, you can either connect an external GNSS to Port C or to Eth 1.

4.5.2.1. Raw UDP connection

UDP connection is the preferred way to implement a virtual serial port because of its simplicity and to ability to provide minimum latency. However, there is no guaranty of delivery, ordering or duplicate protection but UDP provides checksums for data integrity.

To configure an UDP virtual serial port, the following settings have to be defined:

- Output ip address and port, the Ekinox will send UDP datagram to this ip address and port
- Input port, the Ekinox will listen for incoming UDP datagram from any ip address on this port

The Ekinox also supports UDP broadcast to output log messages to everyone on the network by using an appropriate destination ip address.

4.5.2.2. Raw TCP/IP connection

TCP/IP connection is a connected protocol with a server and a client. The main advantage of this type of connection is to guarantee message delivery thanks to an acknowledgment system. The drawback is a network, processing overhead and higher latency.

Unlike UDP mode, a TCP/IP connection has to be established before any data can be sent or received. To establish a TCP/IP connection, a TCP/IP client has to connect to a listening TCP/IP server. The created TCP/IP connection can then be used to both send and receive data in a secured manner.

The Ekinox supports both TCP/IP client and TCP/IP server modes to allow maximum compatibility and flexibility with third party materials.

The TCP/IP virtual serial port configuration depends on the selected mode:

- If the Ekinox is configured to be the TCP/IP server, you just have to enter a listening port. The device will then wait until a TCP/IP client establish a valid connection.
- If the Ekinox is configured to be the TCP/IP client, you have to enter the server ip address and port to connect to. The device will try to establish the connection at startup and every second if needed.

Note: If the connection is lost and the Ekinox is configured in TCP/IP client mode, the device will try to reconnect to the server every second.

4.5.2.3. Ethernet to serial converter

Some third party equipments directly have an Ethernet connectivity with virtual serial ports support. If you would like to use Ethernet virtual serial ports with a material that only have RS-232 or RS-422 connectivity, you can easily do it using an Ethernet to serial converter.

Figure 4.1: Ethernet to serial converter

SBG Systems has tested with the Ekinox the IOLAN DS1 serial to Ethernet converter manufactured by Perle Systems. It features a standard DB9 plug for RS-232/RS-422 and an RJ-45 connector for the Ethernet part. Both raw UDP and raw TCP/IP connections are handled.

4.5.3. Connections Mapping

You will find below the available connections configuration for aiding inputs. The Ekinox E, the Ekinox N and the Ekinox D share roughly the same mapping but there are some specificities due to the embedded GNSS receiver present in the Ekinox N and Ekinox D.

4.5.3.1. Ekinox E version

	Port A	Port B	Port C	Port D	Port E	Eth 0	Eth 1-4
Binary commands	●					●	
User heading input	●					●	
User velocity input	●					●	
User position input	●					●	
GPS 1 input	●	●	●	●			●
GPS 2 input	●	●	●	●	●		●
Odometer input					●		
DVL input	●	●	●	●	●		●

4.5.3.2. Ekinox N / D versions

The Ekinox N and D embed a high performance GNSS receiver that supports RTK and true heading for the Ekinox D version only. To enable RTK positioning, differential corrections have to be sent to the embedded GNSS receiver through the Port D.

	Port A	Port C	Port D	Port E	Eth 0	Eth 1-4
Binary commands	●				●	
User heading input	●				●	
User velocity input	●				●	
User position input	●				●	
GPS 2 input	●	●	●	●		●
Odometer input				●		
RTCM input			●			
DVL input	●	●	●	●		●

Note 1: Please remember that the Port B is not available for the Ekinox N/D versions when the internal GNSS is enabled.

Note 2: If Port A input is not used to connect any external aiding sensor, it will be dedicated to sbgECom binary protocol.

4.6. CAN 2.0 A/B interface

The main port contains a CAN 2.0 A/B interface that supports transfer rate at up to 1 Mbits/s. This CAN interface is mainly used to output log messages. By default, the CAN interface is disabled.

The CAN bus implementation and especially timing settings complies with the CAN in Automation (CiA) DS-102 standard.

The Ekinox supports the following standard CAN bus bitrates:

- 1 000 kBit/s
- 500 kBit/s
- 250 kBit/s
- 125 kBit/s
- 100 kBit/s
- 50 kBit/s
- 20 kBit/s
- 10 kBit/s

4.6.1. Configuration

For each log message the user can define the CAN message identifier, the output mode (continuous, new data, event) and the output frequency. CAN log messages offer the same configurations options as log messages outputted on standard serial interfaces.

4.6.2. CAN messages logs

For each available log, you can use the following color code to know if a log will be interpolated when outputted on a "Sync In" signal and if it's recommended to output a log on a "New Data" event.

Color Code	Description
●	This log will be interpolated if outputted using a "Sync In" signal
●	It's strongly recommended to output this log on a "New Data" trigger

Output		Description
SBG_ECAN_LOG_IMU_INFO		Time stamp and IMU status
SBG_ECAN_LOG_IMU_GYRO		3d rate or turn
SBG_ECAN_LOG_DELTA_ANGLES		Delta angle (coning output)
SBG_ECAN_LOG_IMU_ACCEL		3D Acceleration
SBG_ECAN_LOG_IMU_DELTA_VEL		Delta velocity (Sculling output)
SBG_ECAN_LOG_IMU_TEMP		IMU internal temperature
SBG_ECAN_LOG_EKF_INFO	●	Extended Kalman filter time and status
SBG_ECAN_LOG_EKF_QUAT	●	Quaternion output
SBG_ECAN_LOG_EKF_EULER	●	Euler Angles output
SBG_ECAN_LOG_EKF_ORIENTATION_ACC	●	Orientation standard deviation
SBG_ECAN_LOG_EKF_POS_1	●	Latitude and Longitude data
SBG_ECAN_LOG_EKF_POS_2	●	Altitude and Horizontal + vertical standard deviations

Output		Description
SBG_ECAN_LOG_EKF_VEL_1	●	North and East Velocities
SBG_ECAN_LOG_EKF_VEL_2	●	Down velocity and velocity standard deviation
SBG_ECAN_LOG_SHIP_MOTION_INFO		General information about ship motion status
SBG_ECAN_LOG_SHIP_MOTION_[0-3]_0		Real time surge, sway & heave at defined monitoring point
SBG_ECAN_LOG_SHIP_MOTION_[0-3]_1		Real time ship accelerations at defined monitoring point
SBG_ECAN_LOG_SHIP_MOTION_[0-3]_2		Real time ship velocity at defined monitoring point
SBG_ECAN_LOG_SHIP_MOTION_HP_INFO		General information about delayed ship motion status
SBG_ECAN_LOG_SHIP_MOTION_HP_[0-3]_0		Delayed surge, sway & heave at defined monitoring point
SBG_ECAN_LOG_SHIP_MOTION_HP_[0-3]_1		Delayed ship accelerations at defined monitoring point
SBG_ECAN_LOG_SHIP_MOTION_HP_[0-3]_2		Delayed ship velocity at defined monitoring point
SBG_ECAN_LOG_MAG_1	●	Magnetometer status and time stamp
SBG_ECAN_LOG_MAG_2	●	3D Magnetometer data
SBG_ECAN_LOG_GPS_1_VEL_1	●	Time of velocity and velocity status
SBG_ECAN_LOG_GPS_1_VEL_2	●	Velocity North and Velocity East
SBG_ECAN_LOG_GPS_1_VEL_3	●	Velocity Down
SBG_ECAN_LOG_GPS_1_VEL_4	●	Velocity accuracy North, East Down
SBG_ECAN_LOG_GPS_1_POS_1	●	GPS position status and internal time stamp
SBG_ECAN_LOG_GPS_1_POS_2	●	Altitude and GPS time of week
SBG_ECAN_LOG_GPS_1_POS_3	●	GPS Latitude, Longitude
SBG_ECAN_LOG_GPS_1_POS_4	●	GPS position accuracy
SBG_ECAN_LOG_GPS_1_TRUE_HEAD_1	●	Time stamp and GPS true Heading status
SBG_ECAN_LOG_GPS_1_TRUE_HEAD_2	●	GPS True heading and true heading accuracy
SBG_ECAN_LOG_UTC_TIME_1	●●	Time since reset, UTC time status, Year and Month
SBG_ECAN_LOG_UTC_TIME_2	●●	Day, Hour, Minutes, Seconds, Nanoseconds
SBG_ECAN_LOG_ODOMETER_VELOCITY_0	●	Time stamp, Odometer status
SBG_ECAN_LOG_ODOMETER_VELOCITY_1	●	Odometer velocity
SBG_ECAN_LOG_EVENT_INFO_A/B/C/D/E	●	Output the list of received event markers on Sync A/B/C/D/E pin
SBG_ECAN_LOG_EVENT_TIME_A/B/C/D/E	●	Output the list of received event markers on Sync A/B/C/D/E pin

4.7. Internal Datalogger

The Ekinox includes an internal datalogger capable of storing all data at 200Hz for 48 hours. The internal datalogger is composed of a high speed memory buffer and an 8 GB flash storage. To allow high bandwidth and to reduce power consumption, the memory buffer is saved to the flash storage ten times per second.

4.7.1. Overview

Each time the Ekinox is powered on, a new session directory is created. This session directory will store all log data until the device is powered off / on again. Based on the Ekinox UTC time, each day, a directory is created to store a log file every hour. This directory is named using the following date format: *YYYY_MM_DD*

You can see in the screenshot below a typical datalogger files organization.

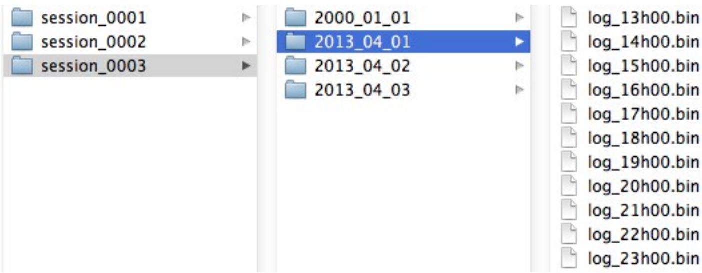


Figure 4.2: Datalogger files organization

The Ekinox doesn't maintain an absolute UTC time when the device is powered off. However, an initial UTC time can be configured to be used at device power on. Until the Ekinox gets a valid UTC time, the datalogger uses the initial UTC time as a reference.

As you can see on the screenshot above, there is a directory named *2000_01_01.* This directory has been created at the device startup and log files are being stored in it until a valid UTC time is received. As soon as the Ekinox jump to a valid UTC time, the directory *2013_04_01* is created to store upcoming log files.

Note: The internal datalogger only stores raw bytes so an Ekinox binary log or an NMEA sentence can be spread between two consecutive files.

4.7.2. Configuring output logs

The datalogger interface is handled exactly the same way as a physical or virtual serial interface. The sbgECom Binary, NMEA or third party output logs can be configured to be stored in the internal datalogger.

SBG Systems has designed the output log system to be very powerful and versatile. All aiding equipments data can be stored in the internal datalogger to allow data post processing. You can even mix binary and NMEA messages in log files but the parsing may be more difficult.

4.7.3. FTP access

Data stored in the internal datalogger can be downloaded from the Ekinox using the embedded FTP server. You can find FTP access details in the information tab of the embedded web page.

The following settings are used to access the datalogger:

Parameter	Value
address	ftp://xxx.xxx.xxx.xxx
port	21
login	sbg
password	pass

Note 1: The Ekinox never deletes files automatically so please make sure to release some space to store new logging sessions.

Note 2: If the Ekinox cannot store new log files because the internal flash storage is full, a status flag will be updated to warn the user.

5. Installation

5.1. Ekinox installation

5.1.1. General rules

In nominal use, the Ekinox INS does not require to be placed at a special location for proper operation. However, for best reliability in harsh environments where the Ekinox cannot rely on GNSS for extended periods, best performance will be obtained in the vehicle center of rotations.

5.1.2. Airborne applications

The Ekinox INS should be placed in the aircraft coordinate frame, which is defined as follows: Ekinox *X* axis should be turned in aircraft Front direction, *Y* axis should be turned in aircraft Right direction, and *Z* axis should be turned to the aircraft bottom direction.

When this mechanical alignment is not possible, the Ekinox misalignment with respect to the vehicle coordinate frame must be measured, as described in section 2.3–Accounting for Misalignment.

Hence it is not required, the Ekinox should be placed at the center of rotations for best performance.

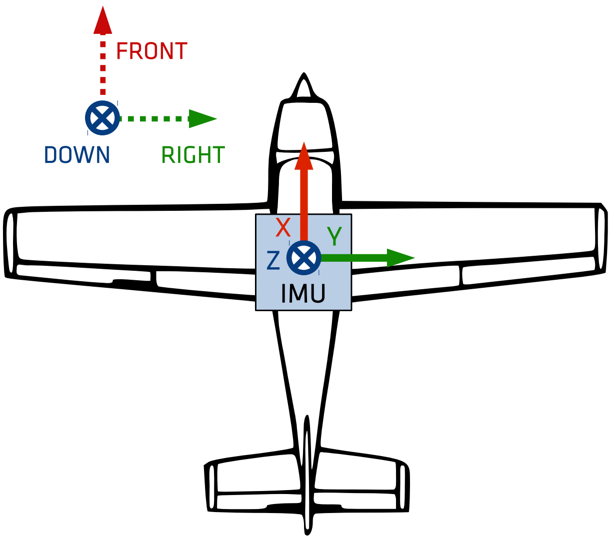


Figure 5.1: Ekinox placement in airborne applications

Note: Please consider the installation restrictions that may apply: Highly vibrating applications should consider vibration isolation as explained in section 5.1.5.1-Vibration considerations.

In addition, magnetometer use will also generate some placement restrictions, explained in section 5.1.5.2-Magnetic field influence.

5.1.2.1. Primary lever arm

In some applications, mechanical constraints make it difficult to place the Ekinox exactly where we want to get navigation data. For most applications, this monitoring point would be the actual vehicle center of rotations.

The "primary lever arm" has to be measured from the Ekinox to the desired monitoring point.

Note: The primary lever arm will affect navigation data. IMU data will be provided at the actual IMU location.

5.1.3. Marine applications

The Ekinox INS should be placed in the vessel coordinate frame, which is defined as follows: Ekinox *X* axis should be turned in vessel Front direction, *Y* axis should be turned in vessel Right direction, and *Z* axis should be turned to the vessel bottom direction.

When this mechanical alignment is not possible, the Ekinox misalignment with respect to the vehicle coordinate frame must be measured, as described in section 2.3–Accounting for Misalignment.

Hence it is not required, the Ekinox should be placed at the center of rotations for best performance.

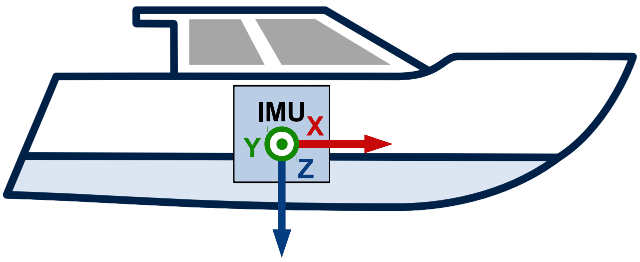


Figure 5.2: Ekinox Placement in a marine application

Note: Please consider the installation restrictions that may apply: Highly vibrating applications should consider vibration isolation as explained in section 5.1.5.1-Vibration considerations.

In addition, magnetometer use will also generate some placement restrictions, explained in section 5.1.5.2-Magnetic field influence.

5.1.3.1. Primary lever arm

In some applications, mechanical constraints make it difficult to place the Ekinox exactly where we want to get navigation data. For most applications, this monitoring point would be the actual vehicle center of rotations but it can be another point of interest.

The “primary lever arm” has to be measured from the Ekinox to the desired monitoring point.

Note: The primary lever arm will affect navigation data. IMU data will be provided at the actual IMU location.

5.1.3.2. Secondary Heave monitoring points

When required, each secondary Heave monitoring point should be measured from the Ekinox to the actual point of interest.

5.1.4. Land applications

The Ekinox INS should be placed in the vehicle coordinate frame, which is defined as follows: Ekinox *X* axis should be turned in vehicle Front direction, *Y* axis should be turned in vehicle Right direction, and *Z* axis should be turned to the vehicle bottom direction.

When this mechanical alignment is not possible, the Ekinox misalignment with respect to the vehicle coordinate frame must be measured, as described in section 2.3–Accounting for Misalignment.

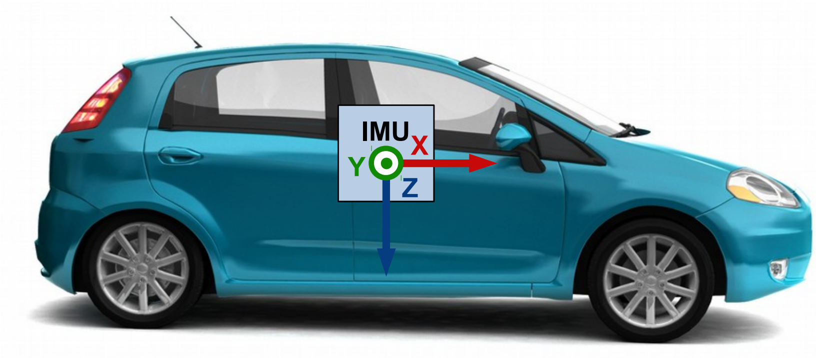


Figure 5.3: Ekinox axes in land vehicle application

Note: Please consider the installation restrictions that may apply: Highly vibrating applications should consider vibration isolation as explained in section 5.1.5.1-Vibration considerations.

5.1.4.1. Primary lever arm (Non steering Axle)

When a non steering axle is present in the vehicle, the distance from the Ekinox to the Non-steering axle center should be measured as the Primary lever arm.

This axle center corresponds to the vehicle's center of rotation and must be correctly measured in the vehicle coordinate frame, from the Ekinox to the Axle center, within at least 5 cm accuracy.

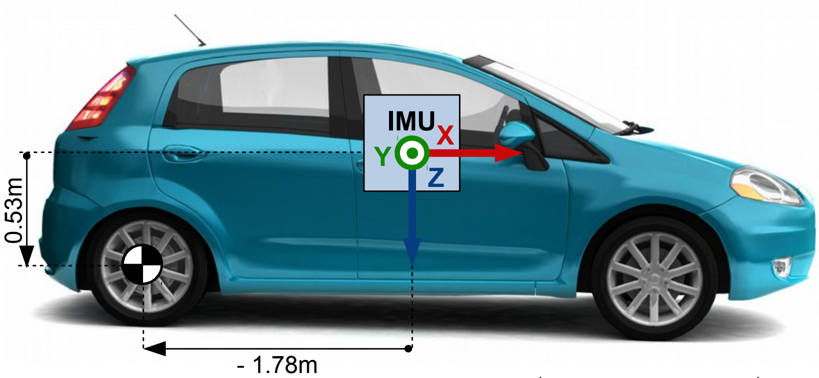


Figure 5.4: Non steering axle lever arm (Primary lever Arm)

5.1.5. Restrictions

5.1.5.1. Vibration considerations

SBG Systems has designed the Ekinox with a high quality MEMS sensors combined with high sampling frequency as well as efficient anti aliasing FIR filters to limit vibration issues as much as possible. Nevertheless, a good mechanical isolation will ensure getting the full sensor performance:

High amplitude vibrations can cause a bias in accelerometer reading. Thanks to a superior factory calibration, this effect is limited. Nevertheless it cannot be fully avoided. This effect is called the VRE (Vibration Rectification Error) and comes from the internal accelerometer non-linearity.

Ultimately, very high amplitude vibrations cause the sensor to saturate. The bias observed will be drastically increased, leading to a huge error on orientation.

> **Note:** If proper mechanical isolation cannot fully prevent high amplitude vibrations, consider using a 10 g accelerometers unit, which has a lower VRE than the standard 5 g accelerometers.

5.1.5.2. Magnetic field influence

When the internal magnetometer is used as heading reference, care should be taken with ferromagnetic environment.

Ferromagnetic materials or magnets that are placed in the vicinity of the device can generate error in the magnetometers readings by distorting the magnetic field. High current power supplies or the associated wires may also generate magnetic fields.

The Ekinox INS should be placed as far as possible from ferromagnetic materials, particularly those who can be moved independently with respect to the Ekinox INS. In practice placing the device more than 2 meter away from disturbing materials is enough to avoid generating error.

In most cases, a calibration procedure can be performed to map the magnetic distortions and therefore get the full performance of the unit. The Ekinox INS can compensate both Hard and Soft iron interferences.

Note 1: See Ekinox Iron Calibration Tools documentation for more information about the magnetometers calibration procedure.

Note 2: Some disturbances of the magnetic field cannot be predicted: a magnet passing suddenly near the device or a cell phone communication for example.

The internal Kalman filter is able to cope with short term magnetic disturbances. Ultimately if magnetic field direction changed for a long period, the Ekinox INS will realign itself to the new magnetic field direction.

Note 3: When the internal magnetometers are not in use, the magnetic influence on performance is weak but very strong magnetic fields can affect gyroscopes performance and such high amplitude magnetic fields should be avoided.

5.2. Aiding sensors installation

5.2.1. GNSS antenna placement

5.2.1.1. Single GNSS antenna

The GNSS antenna placement requirements are not always compatible with the Ekinox placement. Therefore, user can set a 3D offset defining where is placed the GPS antenna. Offset is expressed in meters, in the vehicle coordinate frame. Accurate lever arm measurement ensures optimal output accuracy.

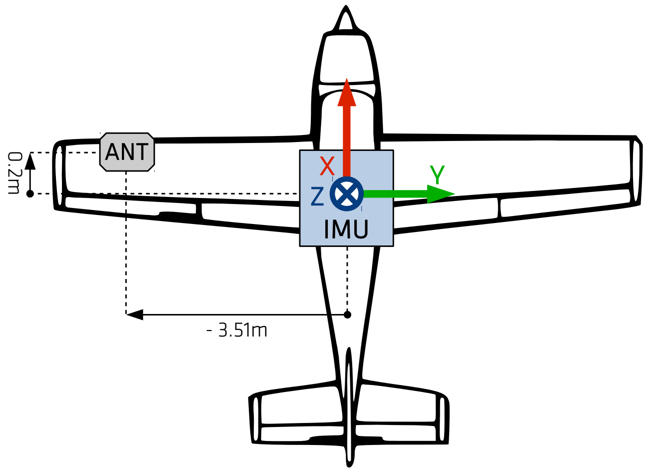


Figure 5.5: GNSS antenna lever arm measurement

5.2.1.2. Dual GNSS antenna

For optimal performance, dual antenna systems require some extra considerations during installation. We consider in the following example an Ekinox D installation. When dealing with a third party GNSS receiver, these recommendations should also apply, but please refer to manufacturer recommendations for other specific requirements.

- The primary antenna is the one used for position computation. Therefore, the GPS Lever arm should be measured from this antenna to the Ekinox. The GPS lever arm is the signed distance, expressed in the vehicle coordinate frame, from the GPS antenna to the Ekinox.
- The secondary antenna (also called sometimes the rover) should be placed in front of the primary antenna. This antenna is only used for True Heading measurements. If a specific alignment is made between the two antennas, a misalignment angle between antennas and vehicle coordinate frame must be measured.
- The (unsigned) distance between the two antennas should be measured.
- The same type of antenna must be used for primary and secondary antennas. In addition, these antennas must be placed in the same orientation, as shown in the figure below. Finally, the cables used for both antennas must have the same type and same length.
- Both antennas must be placed on a ground plane, and more than 20cm away from the ground plane edges.

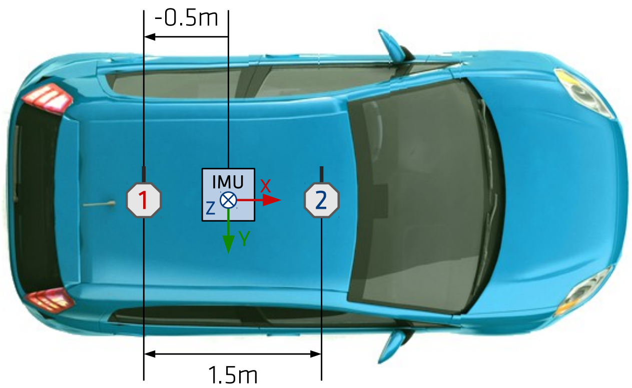


Figure 5.6: Dual GNSS antennas installation in the vehicle

5.2.2. External GNSS receiver electrical installation

When using an external GNSS receiver, the following electrical connections must be performed:

- RS-232 or RS-422 GPS data output has to be connected on a dedicated Ekinox port.
- GPS PPS signal must be connected to a Sync In X pin on the Ekinox.

> **Note:** When connecting a secondary GNSS receiver, there is no need to connect an additional PPS signal.

5.2.3. Odometer

5.2.3.1. Mechanical installation

As for the GPS or external navigation sensor, the odometer requires a lever arm (signed distance between the Ekinox and the odometer) to be set for optimal use.

You can find below an example of how to setup the odometer lever Arm.

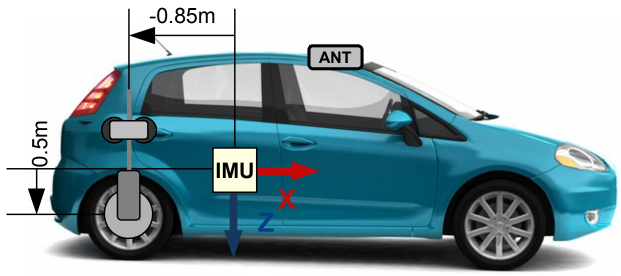


Figure 5.7: Odometer lever arm measurement

5.2.3.2. Electrical installation

The Ekinox supports pulse output odometers, and for direction finding, quadrature and direction output odometers. The following pictures show the connections for each type of odometer;

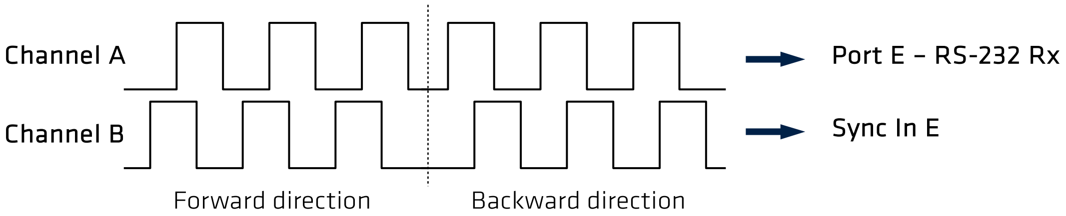


Figure 5.8: Quadrature output connection example

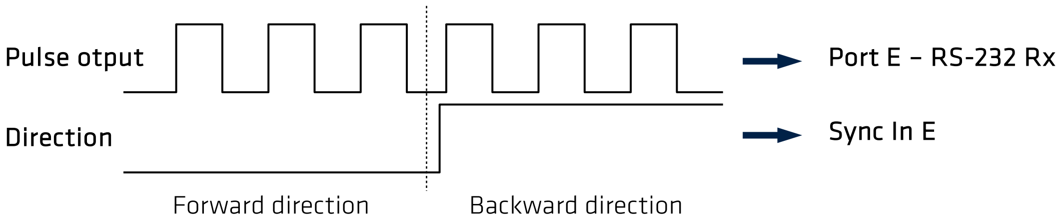


Figure 5.9: Direction output connection example

> **Note:** In case of single channel odometer, then tie the Sync In E pin to GND to force the system in normal direction.

5.2.4. External DVL installation

5.2.4.1. Mechanical installation

DVL must be rigidly fixed to the vessel structure. The lever arm from the Ekinox to the DVL must be measured accurately. It is recommended to set the alignment between the Ekinox and the DVL according to the diagram below, using a 45° angle offset between DVL instrument coordinate frame and vessel coordinate frame. In the following example, the mis-yaw angle is set to +45°.

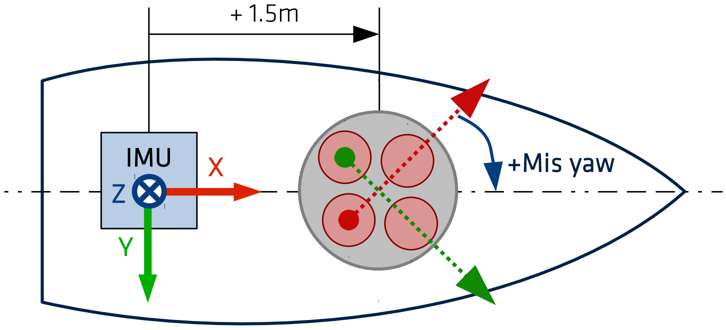


Figure 5.10: Typical DVL installation: alignment with Ekinox is set to +45°

5.2.4.2. Electrical installation

When using an external DVL sensor, the following electrical connections must be performed:

- RS-232 or RS-422 DVL data output has to be connected on a dedicated Ekinox "Rx" port.
- DVL synchronization with Ekinox must be performed either:
  - Internally, by triggering the DVL pings by an Ekinox Sync Out pin (A or B).
  - Externally, by connecting the external trigger signal to an Ekinox Sync In pin, and to the DVL synchronization input.

5.2.5. User (third party) sensors installation

5.2.5.1. Lever arm

When used, third party sensor lever arm must be measured precisely, using the same procedure as for GPS antenna or Odometer lever arms.

5.2.5.2. Sensor alignment

When third party sensor provides velocity data in the vehicle (or body) coordinate frame, or when it provides heading data, an external sensor alignment measurement is required for good operation, as done for the Ekinox alignment in vehicle frame:

1. The third party sensors axes must be compared to vehicle frame
2. Small residual angles must be measured, as explained in 2.3–Accounting for Misalignment section.

5.3. Typical connection topologies

The following use cases are presented to quickly show how to connect the Ekinox to various external materials in different applications.

5.3.1. Ekinox-D in advanced automotive application

Here we present an advanced use case where the Ekinox-D sensor is used in a land survey application. The Ekinox configuration is the following:

- On the aiding/input side:
  - Two GNSS antennas are connected for GNSS true heading measurement
  - RTCM data coming from a RTK base station is connected to PORT C to provide RTK accuracy to internal GPS.
  - An odometer is connected to PORT E to provide velocity aiding in harsh GPS environments.
  - Finally an event input is triggered by user at several instants. For example, this helps locating physical objects within the recorded data.
- On the output side:
  - Sync Out pulse is configured as “Virtual Odometer” to trig a camera each 5 meter traveled.
  - Data output is stored on a PC through ETH 0 interface. A new log is sent for each captured picture.

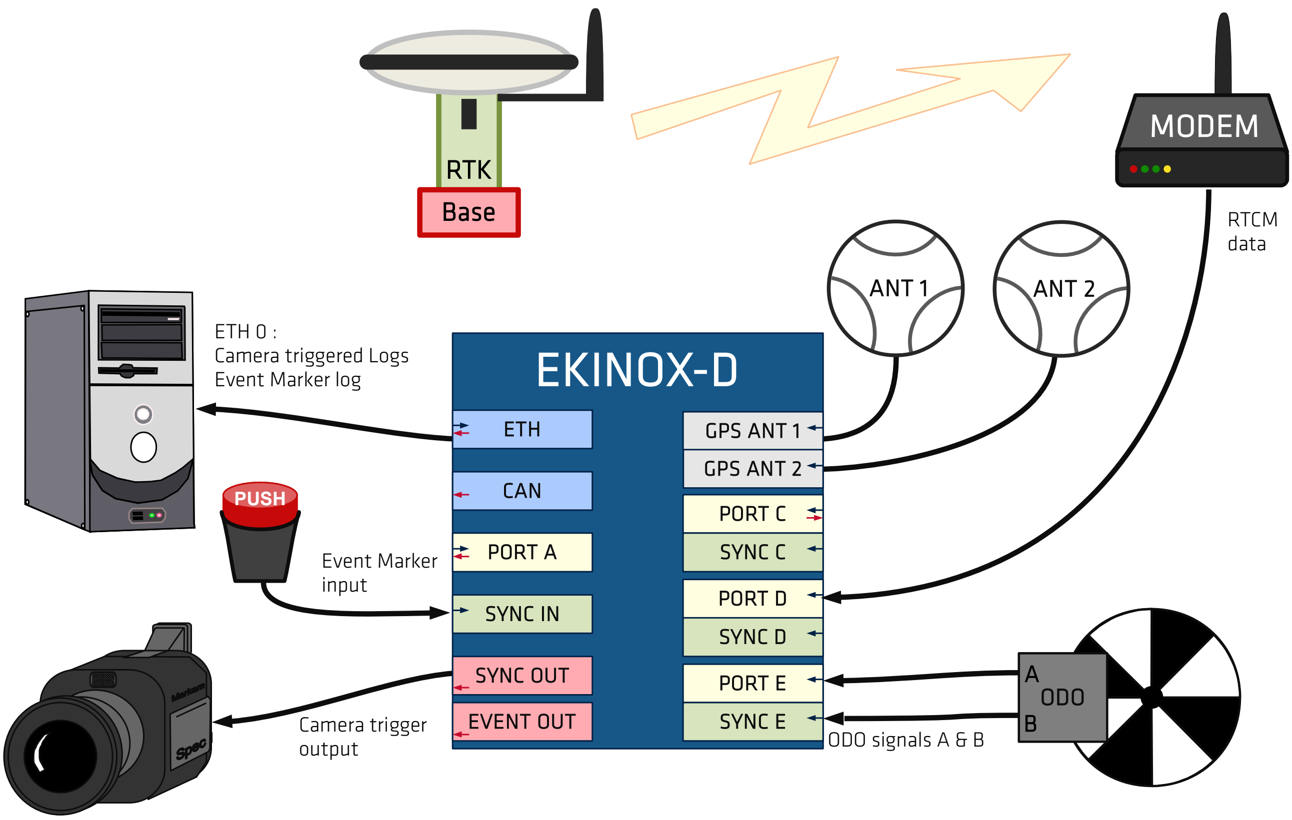


Figure 5.11: Ekinox D connection in an advanced automotive application

5.3.2. Ekinox-E in marine application

In the next application example, the Ekinox is used for both vessel display and monitoring, as well as ship motion sensor for several third party equipments.

Connections are made easy using Ethernet interface when available with external devices.

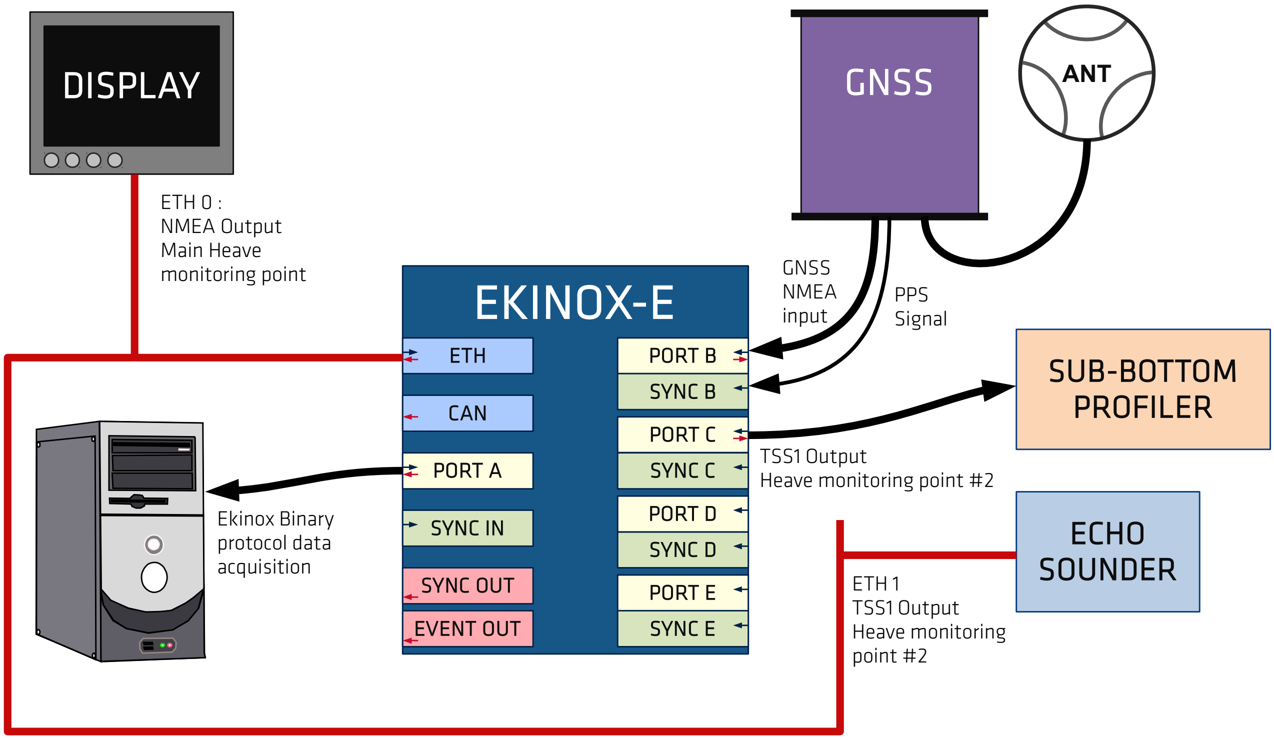


Figure 5.12: Ekinox-E use in advanced Marine application

6. Configuration

The easiest and fastest way to get an Ekinox configured is to use the Web interface. This web interface is described in details in the following sections.

In some specific or volume application, it may be desirable to configure automatically a sensor. A web interface is not the perfect way for that purpose, that's why all the configuration is accessible through the Ekinox Binary Protocol, using an exported settings buffer. Some settings can also be modified in real time through the serial interfaces.

6.1. Web interface overview

The Ekinox is intended to be used in a wide range of applications including underwater, marine, ground and aerial vehicles. To offer the best experience to our customer, SBG Systems has developed a specific layout for each main application.

For example, on the home web page, the user can choose between a marine layout which displays heave data, a ground one that focuses on position information or even a debug view very useful to make sure that the device is working correctly.

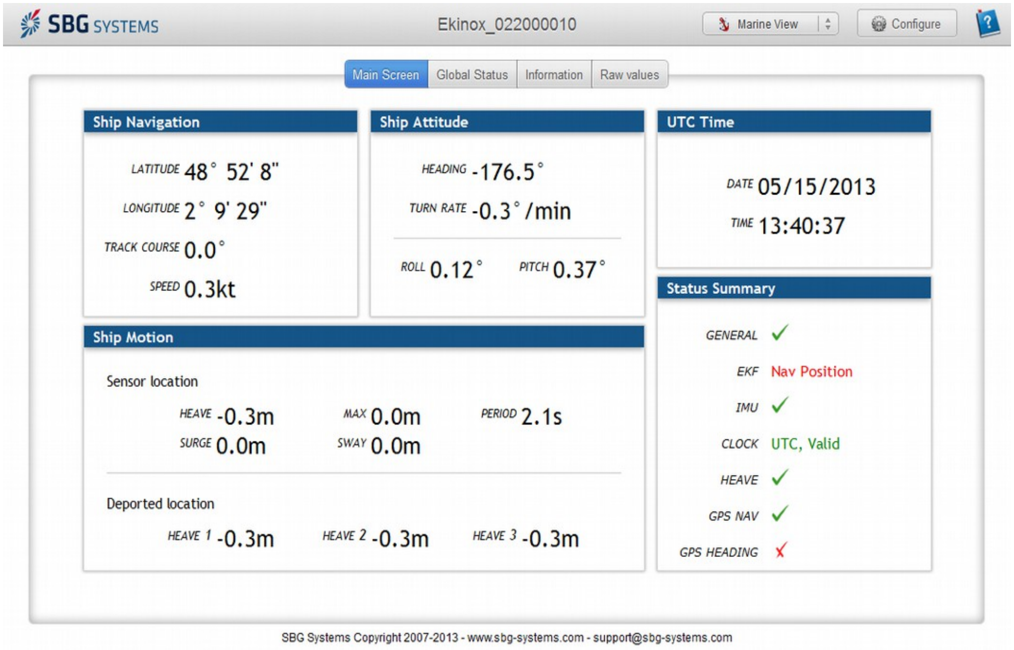


Figure 6.1: Main dashboard window – Marine layout

Note: At the first access or if the device firmware has been updated, the Ekinox will cache the entire embedded website to optimize the responsiveness. This preload operation may take up to two minutes depending on your system configuration.

6.1.1. Global status display

The global status display provides exhaustive status information about all internal and external components.

Most status items are displayed as a check box that should be set to ✓ in case of normal operation. Some other are written in a text form such as GPS fix information.

Note that ✗ sign does not necessary mean “failure”. It can also signify that a COM port is not opened or that the corresponding data is not received.

This panel is very helpful when connecting an external device, to check that aiding data is correctly received and used in Kalman filter solution.

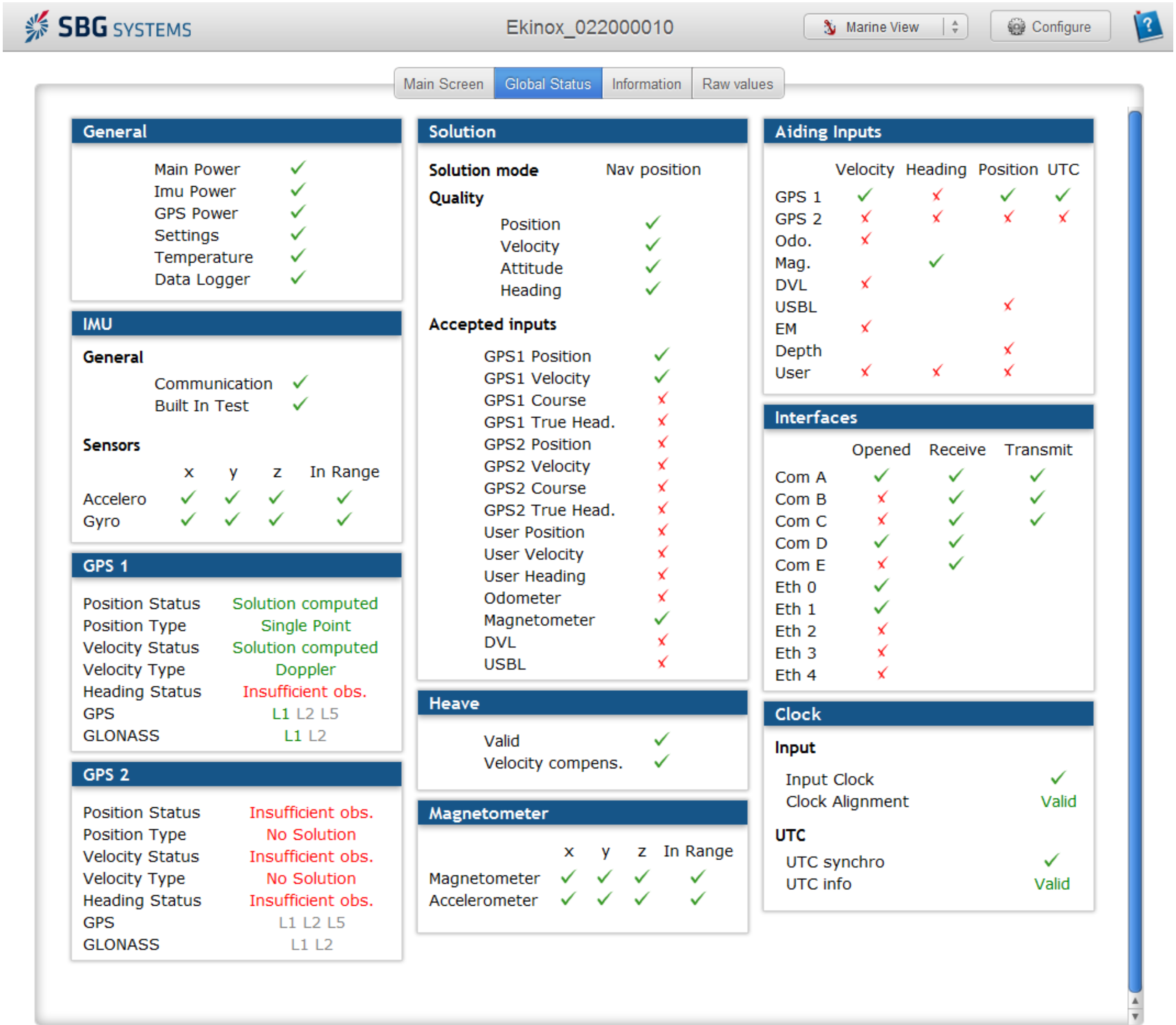


Figure 6.2: Global status panel

6.1.2. Information panel

This panel provides general information about the sensor, internal IMU, calibration date as well as available space in the internal data-logger and installed firmware licenses.

On this page, you can also upgrade the firmware in case of new available version, or upload a new license file.

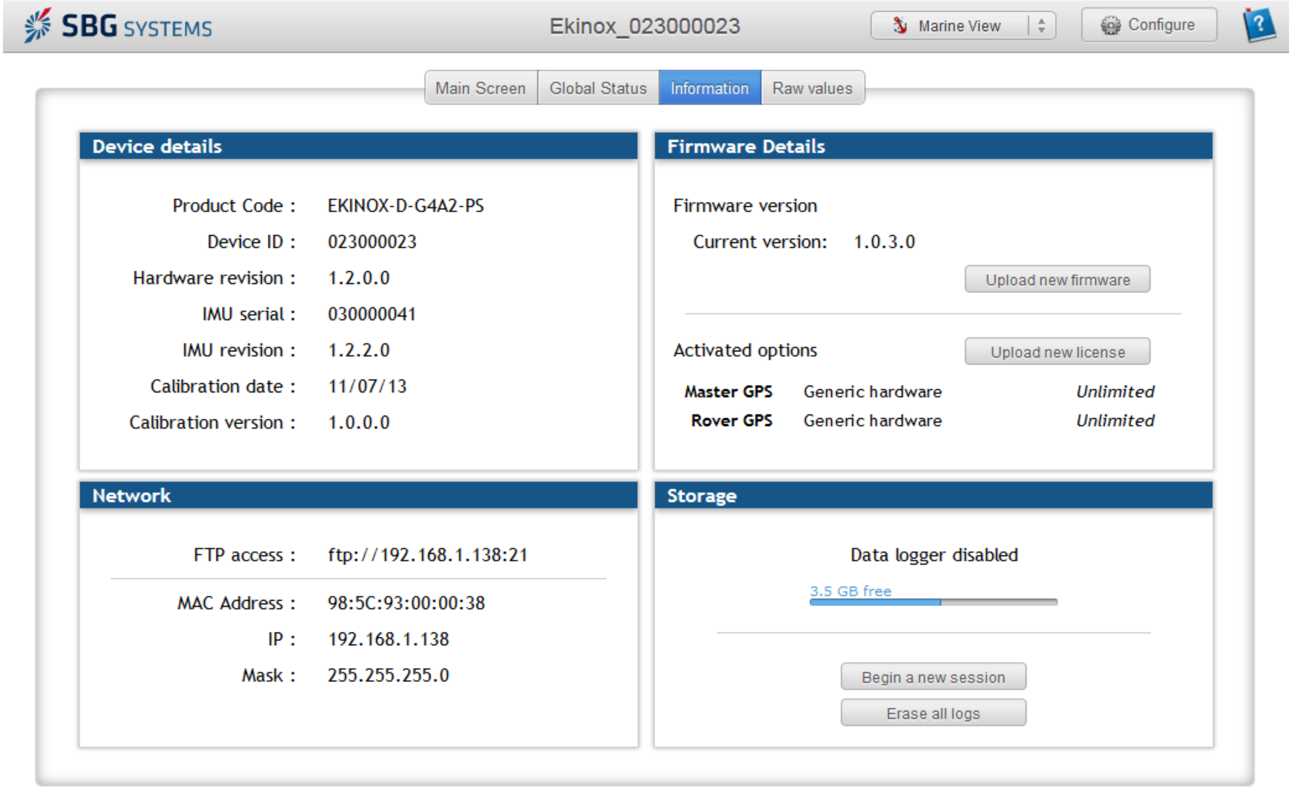


Figure 6.3: Information panel

6.1.3. Configuration panel

The recommended way to configure the Ekinox is to use the embedded web page. To open the configuration panel, just click on the configure button located on the top right corner of the home page.

On the left part of the configuration panel, you will find configurations sorted in chronological order:

- First, define the main device configuration
- Then, setup interfaces such as serial port baud rate
- Define aiding equipments assignments
- Configure each connected aiding equipments
- Define which logs messages you would like to output

On the bottom part of the configuration panel, you have three buttons:

- Default: load factory default settings and store them into Flash memory
- Save: store current configuration into Flash memory
- Cancel: close the panel without applying the new configuration

The new settings are only applied when the save button is pressed. The device will then perform a software reboot before the new settings are effective.

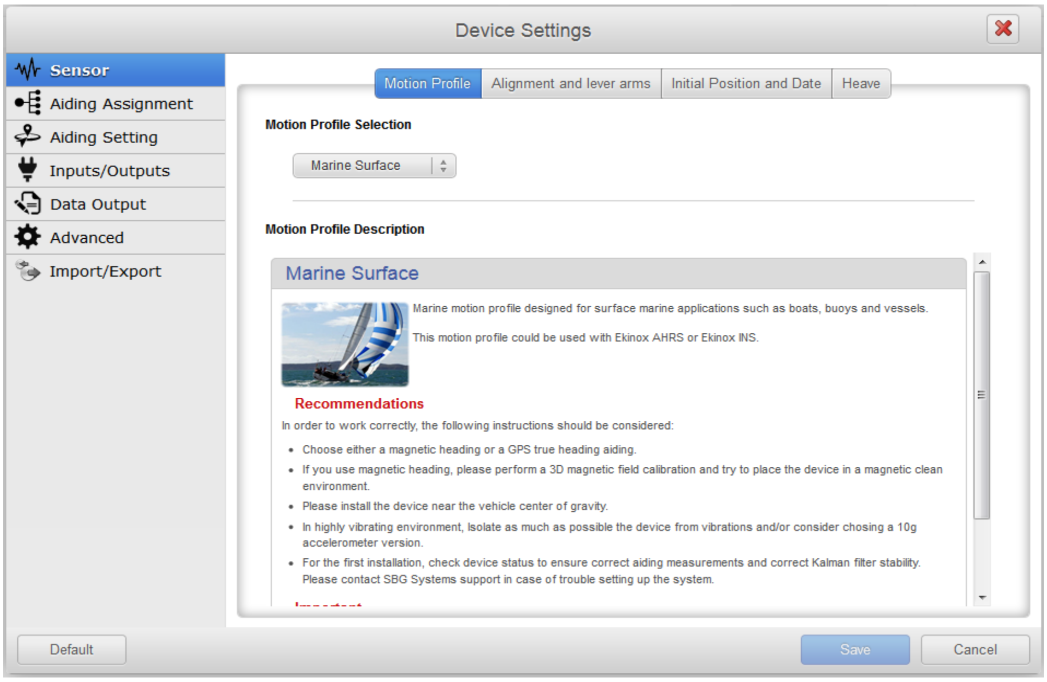


Figure 6.4: Motion profile selection window

Locking mechanism

The Ekinox web page can be accessed by more than one user at the same time. To prevent configuration conflicts, a locking mechanism has been implemented. If the configuration panel is accessed from a web browser, the access is locked to other users. This lock is released when the configuration panel is closed either by applying new settings or canceling changes.

If the configuration panel isn't closed properly or if the connection with the device is lost, the configuration panel access can stay locked. If it is the case, you can still force the access or wait for the lock time out.

6.2. Sensor configuration

This web interface has been designed to make Ekinox configuration flow easily understood. The main idea is to follow each configuration tab in the provided order to get an Ekinox ready to function.

6.2.1. Motion profile selection

The first item to configure is to set a motion profile. This motion profile includes Kalman filter parameters and other tuning settings that enable operation in your specific environment.

When selecting a new profile, a brief description is shown to have a better overview of each profile.

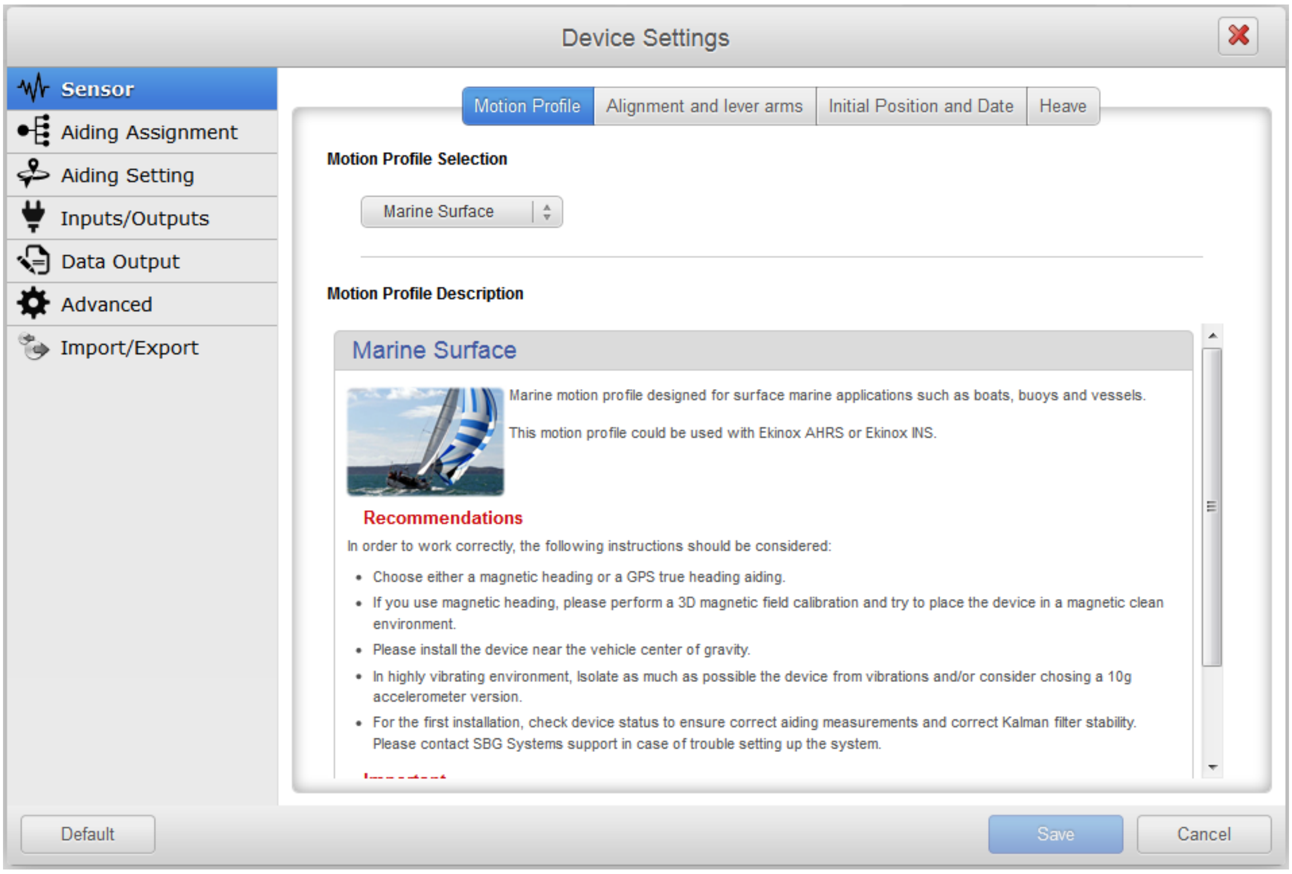


Figure 6.5: Motion profile selection window

6.2.2. Alignment and Main lever Arm

Using the Ekinox alignment parameters (refer to section 2.3-Accounting for Misalignment section) measured during mechanical installation, the web interface provides a quick access to modify these settings:

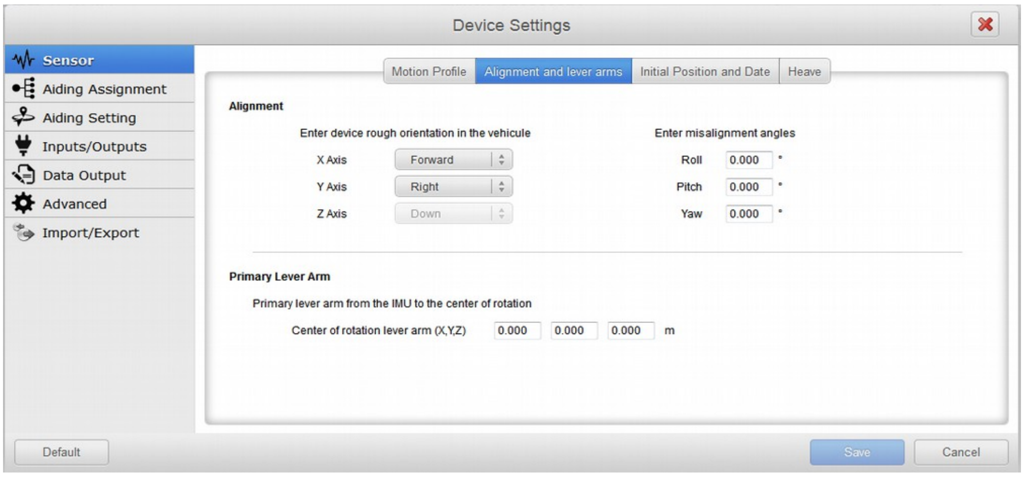


Figure 6.6: Ekinox alignment in vehicle frame, and Primary lever arm configuration

6.2.3. Initial position and date

In order to obtain best performance quickly after power up, it can be useful to set an initial date and time before the GNSS or other aiding equipment is available. This information does not require to be very accurate, but it will provide average local gravity values as well as local magnetic field parameters.

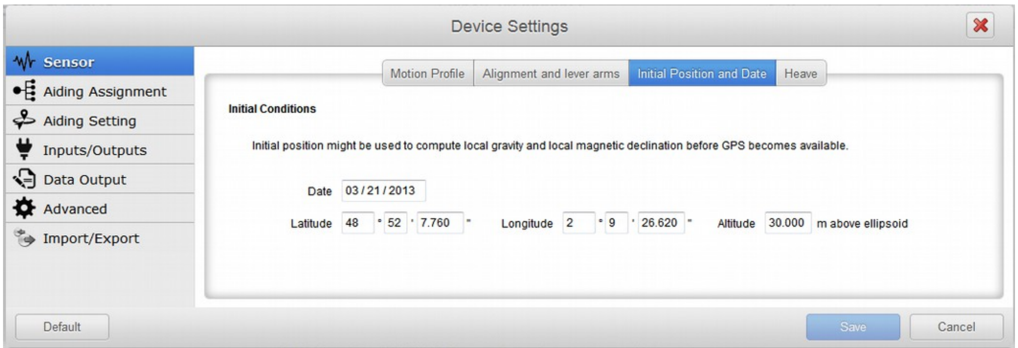


Figure 6.7: Initial date and time configuration

6.2.4. Heave configuration

For marine applications, Heave configuration allows different secondary monitoring points to be entered.

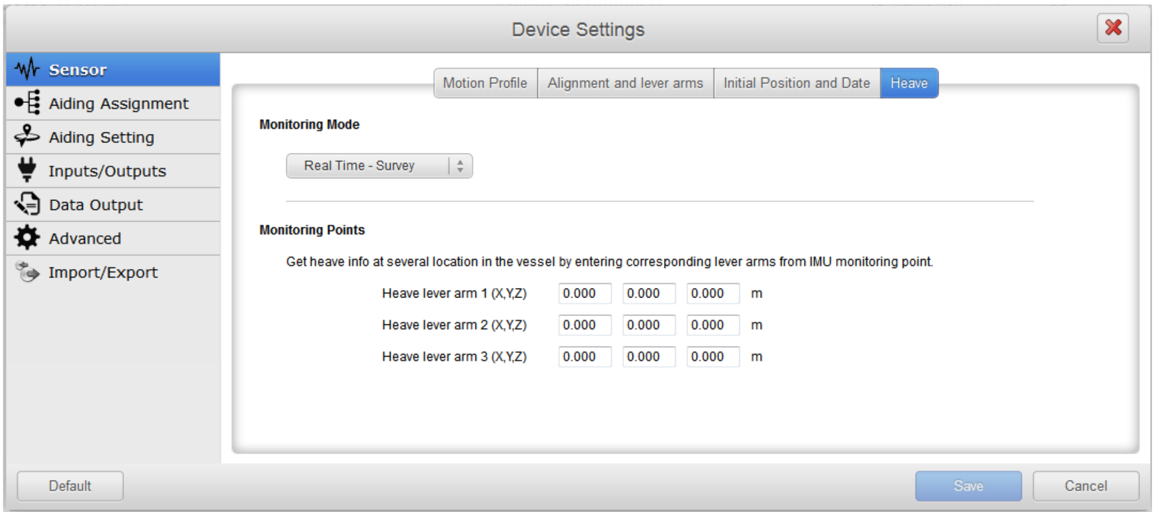


Figure 6.8: Heave configuration window

6.3. Aiding sensor assignments

The first step when configuring aiding sensors is to assign aiding modules (GPS 1, Odometer, ...) to physical or virtual ports. An assignment for corresponding synchronization pins is also possible depending on module.

Aiding modules configuration that have been assigned to a port become available for configuration.

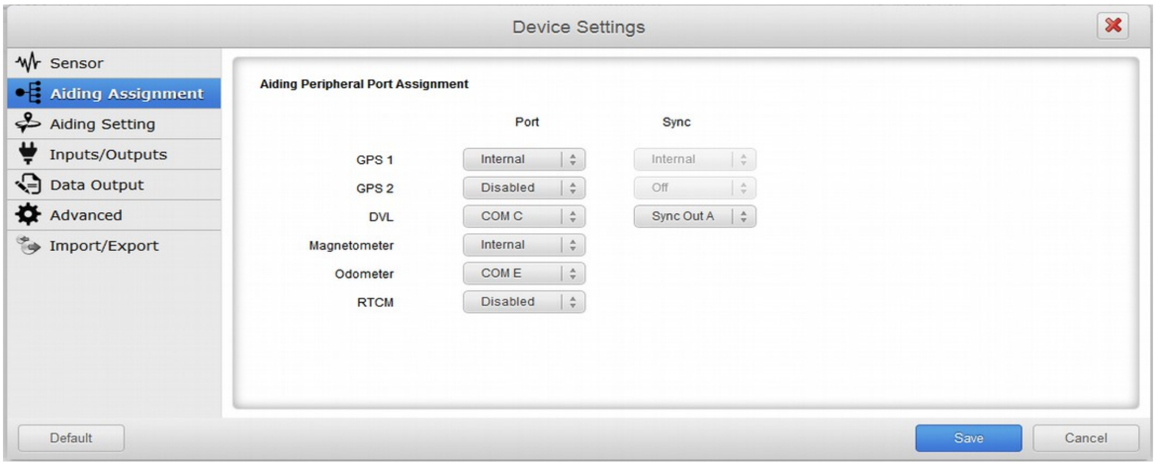


Figure 6.9: Aiding sensors assignment

6.4. Aiding sensor configuration

6.4.1. Common considerations

6.4.1.1. Aiding sensor use and Rejection

It is possible to configure the way the Ekinox will use each aiding data provided by the different aiding systems:

- "Always accept" mode should be used carefully as the Kalman filter will always make use of the corresponding measurement, even if it's not consistent with current state.
- "Auto rejection" parameter means that the Kalman filter will automatically check if the measurements are consistent with current estimate, and will reject inconsistent measurements. In case of long term inconsistency, it will accept again measurement after a time-out.
- "Never accept" can be used when the corresponding measurement is known to be wrong (e.g. GPS course is not a reliable source of heading in marine applications).

Note: Never accept can also be used in some applications where a specific measurement is known to be wrong for some time. For example, in a AUV application, magnetometers are known to be wrong for some time during the operation, and become available again after mission.

It's then possible to change these parameters in real time.

6.4.2. GPS 1 & GPS 2 configuration

The GPS configuration provides different parameters. The GPS model provides actual GNSS module in use selection. Different models are available by default:

- Internal (Ekinox N and D)
- Novatel – OEM 6xx
- Generic NMEA

As measured during Ekinox installation, the GPS antenna lever arm must be properly entered for good operation.

In case of dual antenna GNSS system, It is necessary to enter the GNSS alignment offset with respect to the Ekinox. The distance between the two antennas must also be entered. In case of single antenna systems, there is no need to enter alignment parameter.

Finally, concerning the aiding use and rejection mode: Position, Velocity, and True Heading are set to “Auto rejection”, and course set to “Never accept”. Course is not a reliable heading measurement for many application, that's why it is not enabled by default.

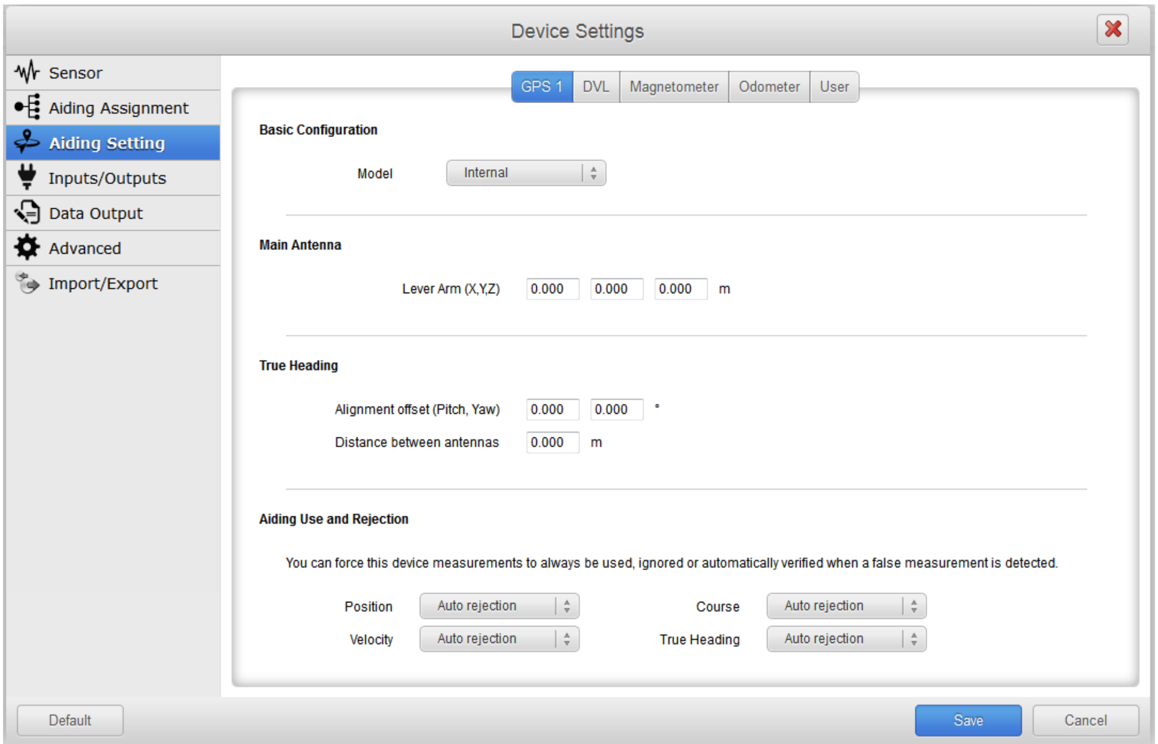


Figure 6.10: GPS modules configuration window

6.4.3. Odometer configuration

The first parameter to set is Odometer error model. There is no specific protocol here but we might consider different odometer behaviors such as low or high slipping.

The odometer's gain must also be entered in terms of pulses per meter. The Kalman filter automatically tunes this odometer gain in order to improve dead reckoning performance, and this first parameter is considered as an initialization gain.

The Odometer is considered to be aligned precisely to the vehicle coordinate frame so there is no alignment configuration.

The Odometer lever arm must be entered as measured during system installation.

Finally, the aiding use and rejection mode (Auto rejection by default) can be changed if required.

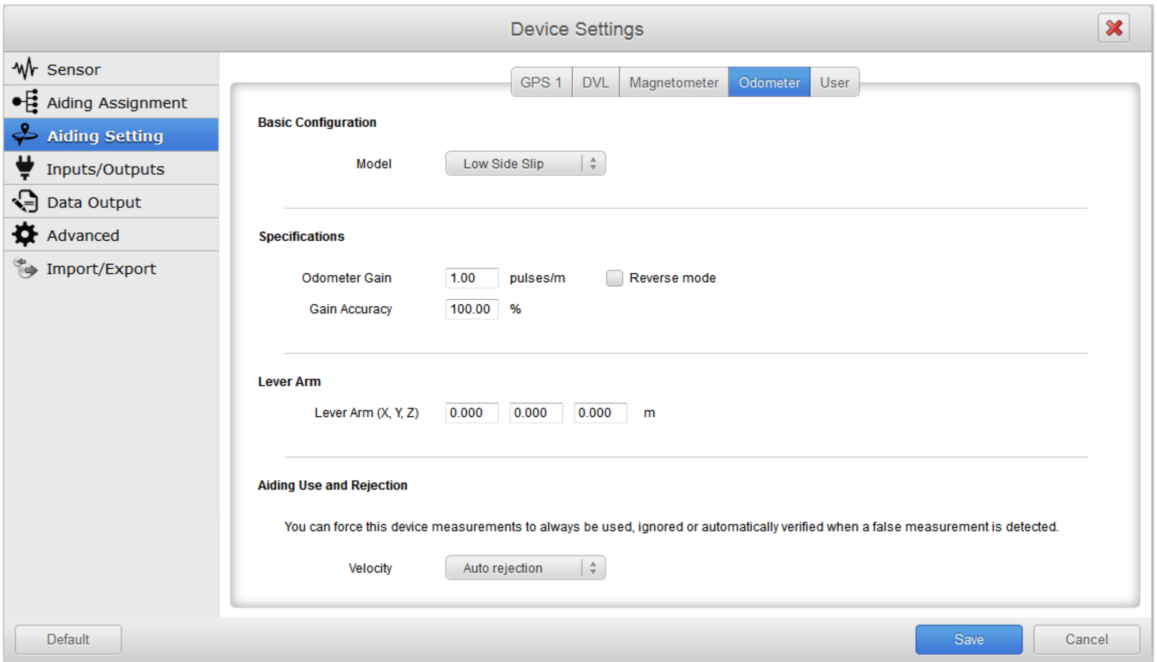


Figure 6.11: Odometer configuration

6.4.4. Magnetometer configuration

The magnetometer error model provides different magnetic environment parameters depending on application.

In case of magnetometer use, it's necessary to run the magnetic calibration procedure using either the sbgCenter or a calibration library.

The magnetometer alignment parameters should be left to 0 in case of internal magnetometer.

Finally, the aiding use and rejection parameter may be configured according to application:

- Never accept (default) for most applications
- Auto rejection for applications that can rely on magnetometer measurements
- Always accept should be used carefully.

> **Note:** Please read the Ekinox Magnetic calibration Manual for more information about the calibration procedure.

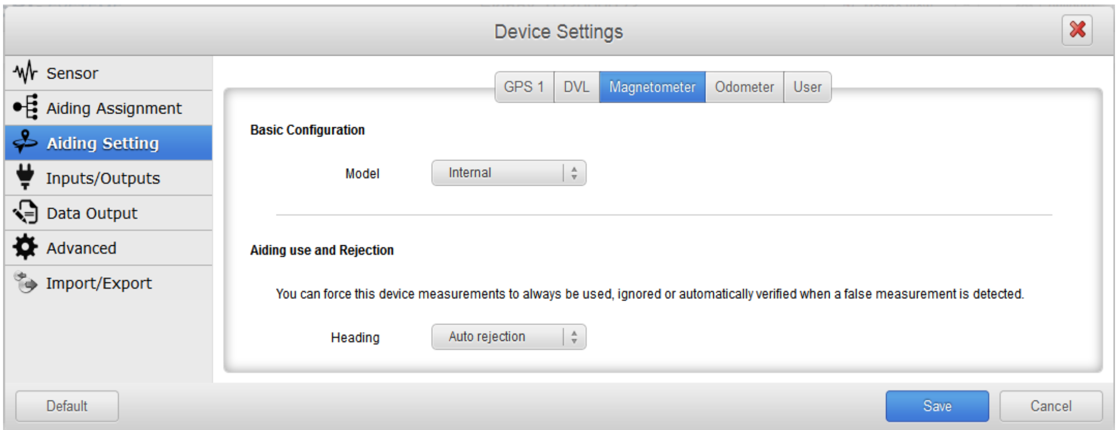


Figure 6.12: Magnetometer configuration

6.4.5. DVL aiding configuration

The first parameter is the DVL model. Up to now, only a Teledyne DVL or compatible is supported.

Then, the DVL alignment must be entered in terms or roll, pitch and yaw angles as well as DVL's lever arm, measured during system installation.

Finally, the aiding use and rejection mode (Auto rejection by default) can be changed to allow or reject bottom tracking and/or water layer velocity. Most users will let both aiding data to “auto rejection”.

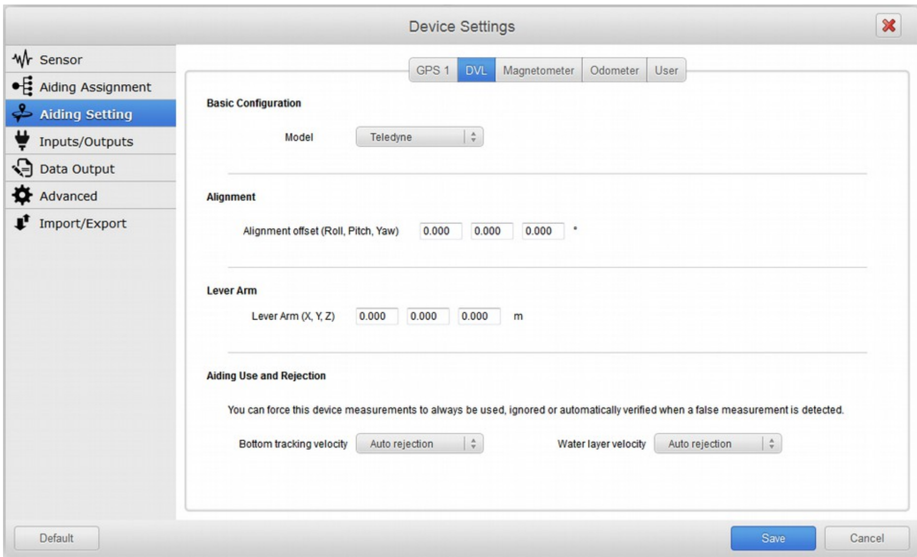


Figure 6.13: DVL configuration panel

6.4.6. User aiding configuration

User aiding consists of dedicated aiding messages in the Ekinox binary protocol. It can be used either on PORT A or ETH 0 ports. The main configuration concerning user aiding is the sensor lever arm. In addition, the alignment parameter can be used when user Heading or user Body Velocity is provided. It then is possible to enable or disable each measurement in the aiding rejection mode.

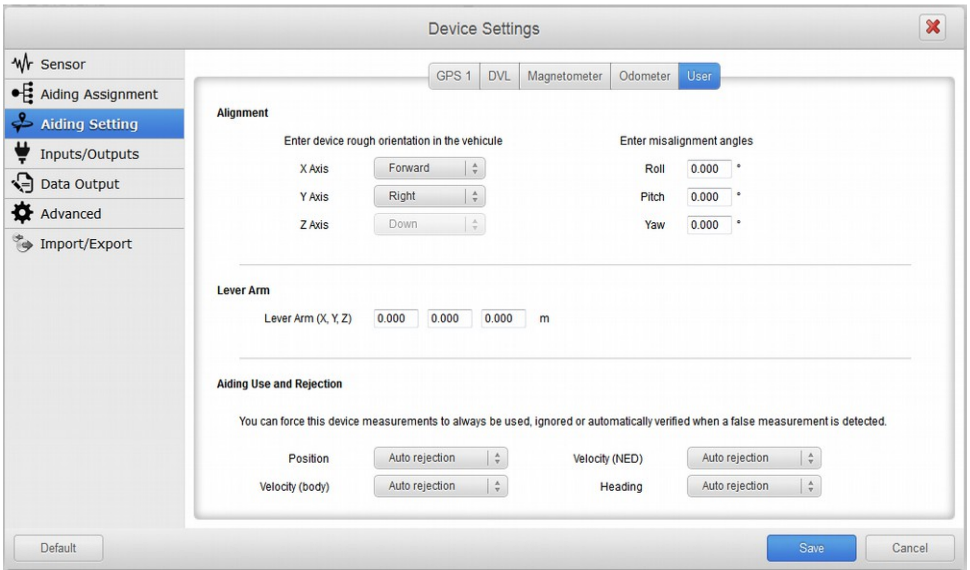


Figure 6.14: User aiding configuration window

6.5. Interfaces and logic input/output configuration

6.5.1. Serial ports

Physical serial ports need to have a defined baud-rate and a protocol mode.

Baud-rate can be set from 9600 to 921 600bps for each port. Protocol mode can be either disabled (port closed), RS-232, or RS-422.

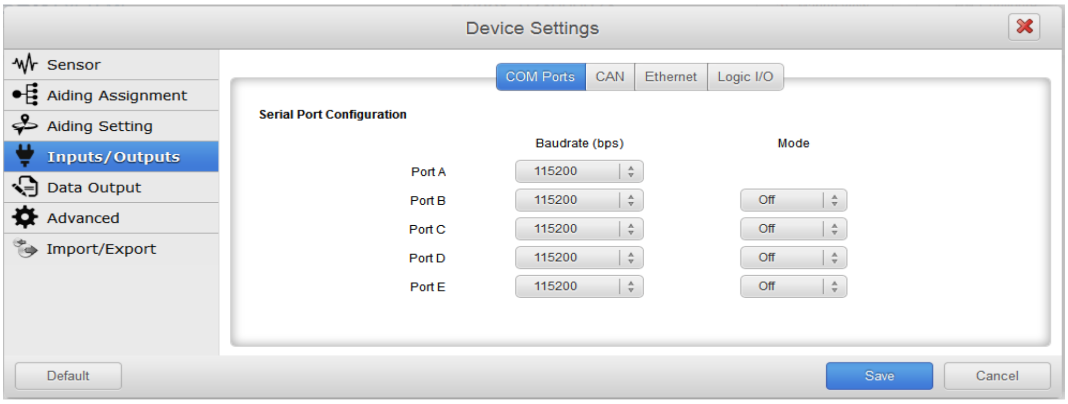


Figure 6.15: Physical serial ports configuration

6.5.2. Logic inputs/output

Sync In pins sensitivity can be configured to Falling Edge, Rising Edge, Level Change or Disabled. In addition, a software delay can be implemented to offset the actual event time.

Logic outputs also feature a polarity setting (rising, falling edges or toggle mode). In case of rising or falling edge, pulse width settings have to be tuned. These outputs can be triggered on different events: PPS signal, Main loop divider, etc. A specific divider can also be configured to reduce the pulse output rate.

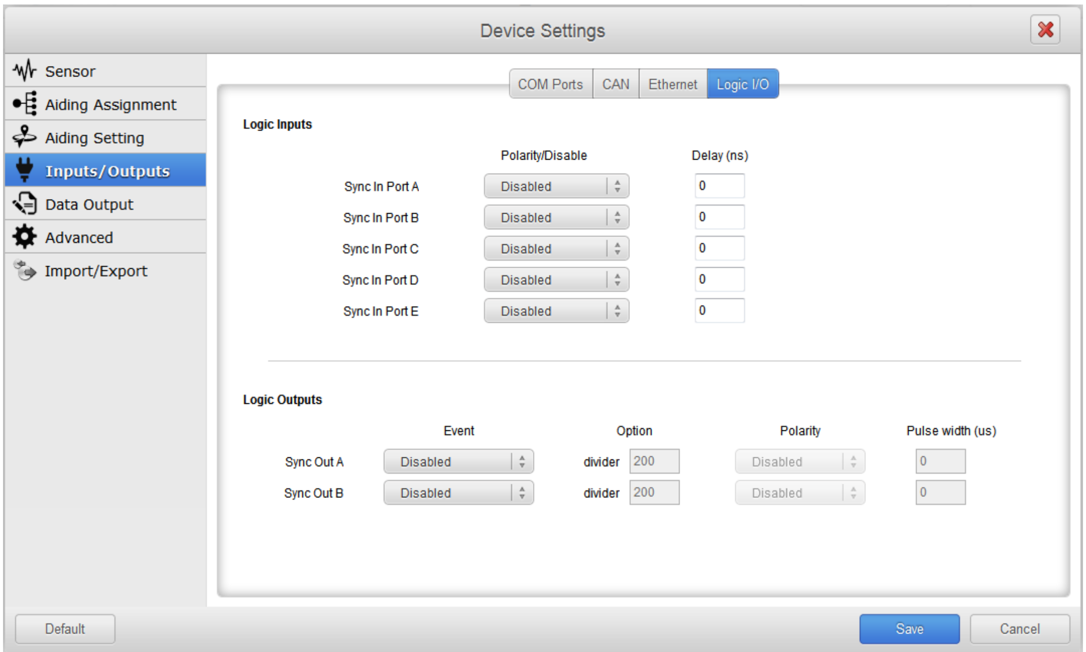


Figure 6.16: Logic inputs & outputs configuration

6.5.3. Ethernet configuration

The Ethernet interface configuration window provides access to two main points:

- The global configuration allows changing the connection in the network. IP configuration is done here: automatic IP addressing using DHCP or static configuration.
- In a second time, each virtual serial ports can be configured.

These ports can be either TCP or UDP protocol, using specified port numbers and output destination address.

Figure 6.17: Ethernet interface configuration window

6.5.4. CAN bus

CAN interface allows configuring major CAN parameters:

- CAN bus Bitrate.
- CAN log messages IDs: All Logs sent from the Ekinox to the CAN bus can be redefined with specific IDs to meet different CAN bus implementations. It is possible to set either Standard or Extended IDs.

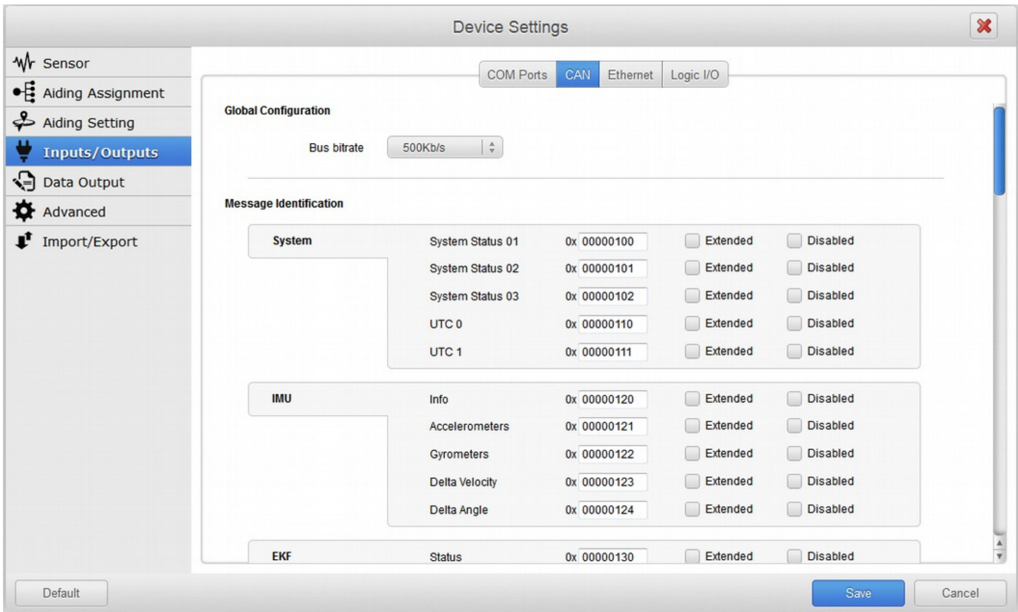


Figure 6.18: CAN bus configuration window

6.6. Data output configuration

6.6.1. Serial ports and Data-logger interface

All physical and virtual serial ports, and internal data-logger share a similar output configuration.

The first parameter is the heave monitoring point. As it can be useful to have for different ports, the same message (e.g. TSS1) transmitting a specific heave monitoring point, each port can be assigned to a dedicated heave monitoring point.

> **Note:** This parameter only affects NMEA and other third party logs. Ekinox Binary Protocol Logs are not affected by this configuration

Another setting allows changing the NMEA talker ID for each port. This allows one port sending NMEA logs using GP for GPS ID, and the other one with HE for Heading sensor ID.

Finally, the available logs can be configured for automatic output:

- Continuous mode generates output on a regular basis, as configured in the continuous output frequency.
- New data generates the corresponding output when newly computed or received data is available
- Sync A, Sync B, C, D or E generates output when triggered by the synchronization pulse.

Logs are split into proprietary sbgECom binary logs, NMEA logs, and third party logs for easier navigation.

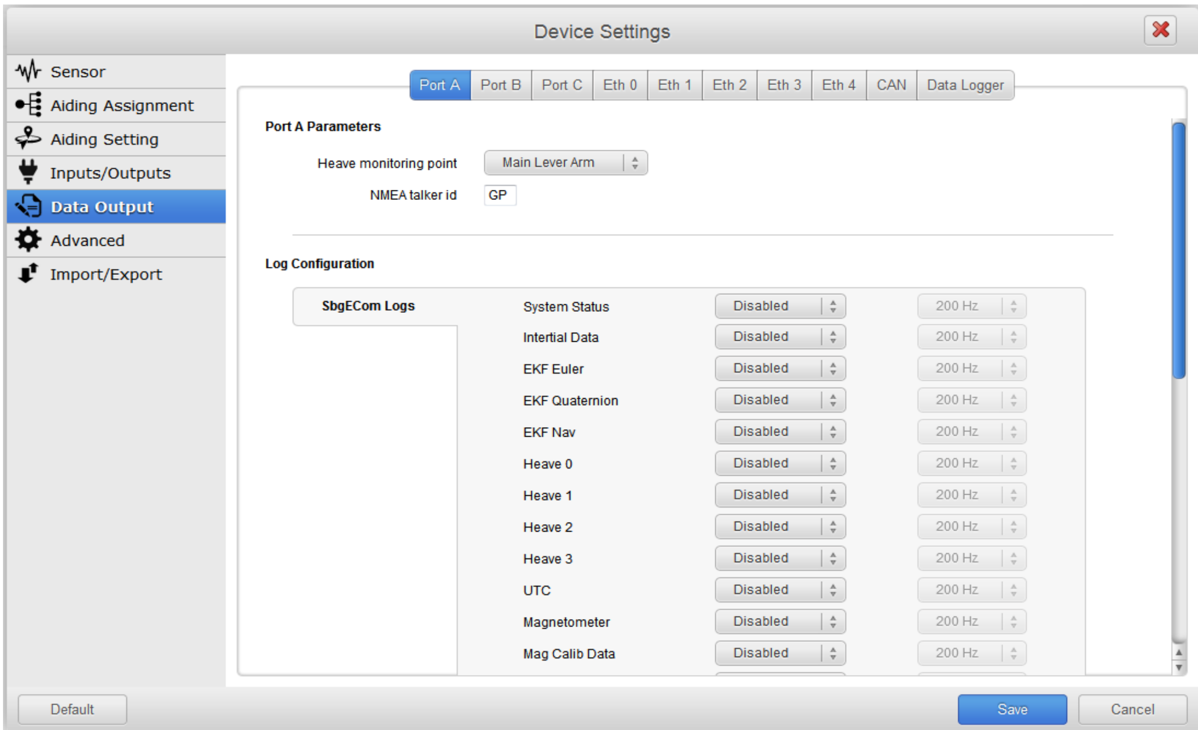


Figure 6.19: Output logs configuration

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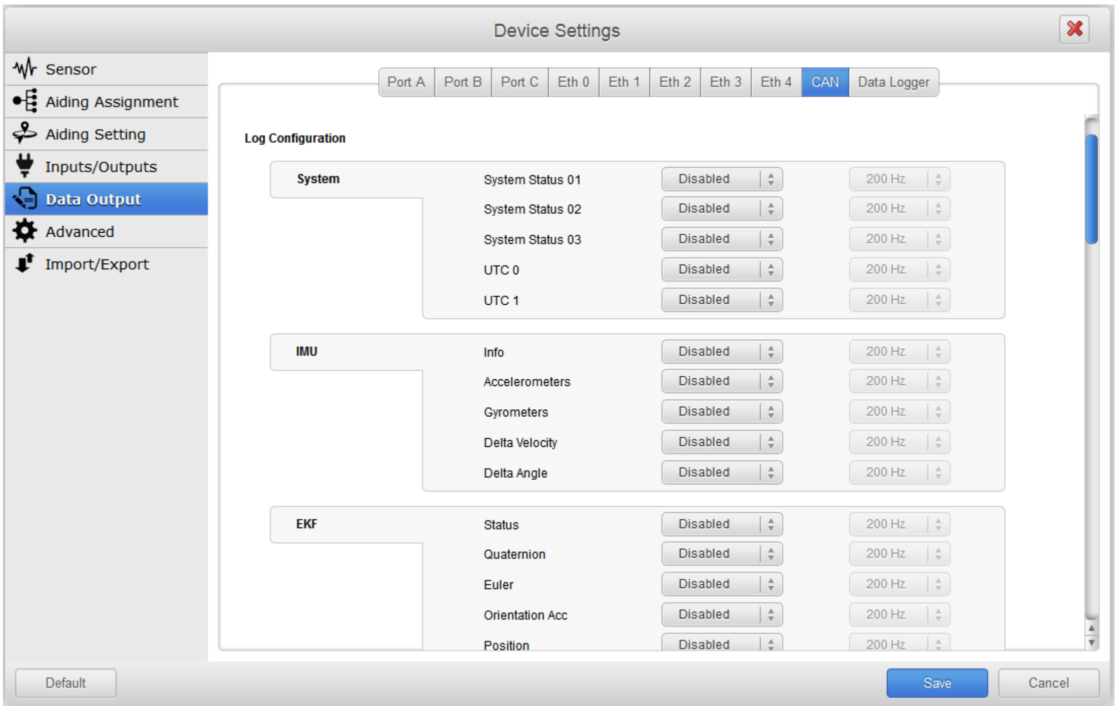
6.6.2. CAN bus output

CAN output logs can be configured in a similar way to the serial logs. Due to CAN bus limitations, different logs are provided. These logs can be sent on the following conditions:

- Continuous mode generates output on a regular basis, as configured in the continuous output frequency.
- New data generates the corresponding output when newly computed or received data is available
- Sync A, Sync B, C, D or E generates output when triggered by the synchronization pulse.

Logs are split into comprehensive blocks for easier navigation.



6.7. Advanced settings

An advanced settings panel provides clock alignment input configuration. This will be most of the time set to GPS 1 module or to an external sync In pin.

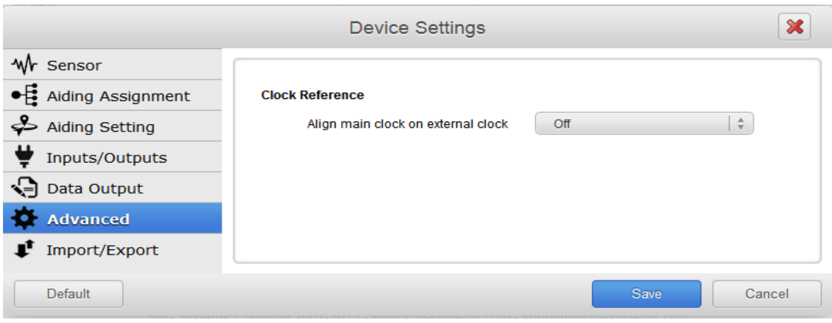


Figure 6.20: Advanced Options window

6.8. Import Export settings

The last panel available in the settings provides an efficient way to store/import all the Ekinox configuration from/into a file.

Figure 6.21: Ekinox settings import / export panel

7. Operation

This section describes the basic operation scenario and provides some performance checking information. We consider previous User Manual sections were followed: The Ekinox INS is correctly installed and configured.

7.1. Initialization

When powered ON, the Ekinox will first initialize to an approximated attitude (roll / pitch angles), based on accelerometers used as a vertical reference. Initial heading and velocity are set to 0, and initial position is defined as set in configuration. During this time, the Kalman filter runs in a "vertical gyro" mode.

Once reasonable roll/pitch angles are estimated, heading alignment procedures are tried until a first heading guess is found. As soon as an alignment procedure has been successful, the Kalman filter will start full AHRS computations.

As navigation aiding data becomes available (Odometer, GNSS, ...) the Ekinox will make use of it to initialize velocity, position, and to improve orientation accuracy.

All outputs are provided but may not be valid until all parameters are initialized.

Once all estimated parameters (attitude, heading, velocity, position) are initialized, the navigation phase start, but with sub-optimal accuracy. The system is estimating sensors error parameters continuously to improve performance. It may take 15 minutes to improve performance.

It is possible to use the navigation and orientation data before those 15 minutes are elapsed.

7.2. Navigation

After the first 15 minutes of operation, outputs provided are considered as nominal performance. The Ekinox can be used as required.

Data provided by the Ekinox is either sent in real time through the different interfaces (serial, Ethernet, CAN), or recorded in the internal data-logger.

It is also possible to have an overview of navigation data on the web interface.

7.3. Performance monitoring

During initialization and navigation phases, it may be necessary to check that provided data are consistent. The Ekinox provides deep status information that allows a good interpretation.

7.3.1. Checking External devices data reception

In order to check proper operation with external sensors, the first thing to check is whether consistent data are retrieved from those external devices or not.

For each aiding data, a status flag indicates if data were received in the last seconds or not. Data may be valid or invalid, but the main thing here is that we want to know if the device is well connected to the Ekinox.

7.3.2. Checking aiding data use in Kalman filter

Once External devices connection has been checked, it's then possible to check if the Kalman filter is able to use incoming data. Each aiding data has a dedicated status flag indicating:

“OK” when the corresponding aiding data could be used by the Kalman filter in the last seconds

“NO” when the Kalman filter was not able to use the aiding data. Possible reasons can be:

- Invalid data is provided (e.g. no GNSS fix is available)
- Kalman filter rejected the data (data is currently not consistent with current estimated state)

7.3.3. Checking sensor status

Internal sensor provides useful status information, and it is important to keep an eye on this information in order to check output accuracy.

Gyroscopes include a built in test that continuously checks if each gyro channel is performing in a correct way. A gyro over-range error status informs about the orientation integrity: In case of over-range, orientation accuracy is degraded in an unlimited way until normal gyro operation is recovered.

Accelerometers include an over-range status that informs about navigation integrity. In case of high acceleration or strong vibrations, this status may be in error, informing about what's wrong.

Magnetometers include a start-up self test that makes it possible to check the sensor behavior at each power up. A magnetic field range checking is also provided for measurement integrity check.

7.3.4. Checking orientation and navigation accuracy

Once aiding data were checked to be good, it is still possible to have another accuracy indication. In each EKF Log message, an accuracy parameter provides the 1σ estimated accuracy for the corresponding output.

7.4. Ending operation

Once a log session is finished, simply disconnect the power supply to turn off the sensor.

7.5. Data-logger access

Once a log session has been recorded in the internal data-logger, an FTP interface is provided for easy data access.

8. Important notices

8.1. Absolute maximum ratings

Stresses above those listed under the Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Parameter	Rating
VDD – GND	+/- 36 V
Galvanic isolation: Power supply connector to chassis ground Main connector GND to chassis ground Extended connector to chassis ground	+/- 200V
Rx+, Rx-, Logic inputs pins input voltage to signal GND	±25V
Sync Out voltage	-0,3V to +25V
Logic output Max current	150 mA
CANH, CANL	±80 V
Shock	500 g for 0.3ms
Operating temperature range	-40 to 75°C (-40 to 167°F)
Storage temperature range	-40 to 85°C (-40 to 185°F)

Table 1: Absolute maximum ratings

8.2. Maintenance

The Ekinox will not require any specific maintenance when properly used. In the case you observe sub-optimal performance, please contact SBG Systems support.

Nevertheless, if you would like to maintain your sensor performance to the highest level, SBG Systems can provide a maintenance service with regularly planned checkups and calibrations.

8.2.1. Cleaning

Disconnect the Ekinox from the power supply as well as other connections. Use damp cloth to clean the enclosure. Do not use any solvent or abrasive materials for cleaning.

8.3. Support

Our goal is to provide the best experience to our customers. If you have any question, comment or problem with the use of your Ekinox, we would be glad to help you, so please feel free to contact us. Please do not forget to mention your Ekinox Device ID (written on your Ekinox' label).

You can contact us by:

- Email: support@sbg-systems.com
- Phone: +33 1 80 88 45 00

8.4. Warranty, liability and return procedure

SBG Systems provides a warranty covering this product against any defect in materials or manufacture for a period of two (2) years from the date of shipment. In the event that such a defect becomes obvious during the stipulated warranty period, SBG Systems will undertake, at its sole discretion, either to repair the defective product, bearing the cost of all parts and labor, or to replace it with an identical product.

In order to avail itself of this warranty, Customer must notify SBG Systems of the defect before expiry of the warranty period and take all steps necessary to enable SBG Systems to proceed. Upon reception of required information (Sensor serial number, defect description), SBG Systems will issue an RMA and will provide return instructions. Customer shall be responsible for the packaging and the shipment of the defective product to the repair center notified by SBG Systems, the cost of such shipment being borne by Customer.

This warranty shall not be construed as covering defects, malfunctions or damages caused by improper use or inadequate maintenance of the product. Under no circumstances shall SBG Systems be due to provide repair or replacement under this warranty in order a) to repair damage caused by work done by any person not representing SBG Systems for the installation, repair or maintenance of the product; b) to repair damage caused by improper use or connection to incompatible equipment, and specifically, the opening of the housing of the equipment under warranty shall cause the warranty to be automatically canceled.

This warranty covers the product hereunder and is provided by SBG Systems in place of all and any other warranty whether expressed or implied. SBG Systems does not guarantee the suitability of the product under warranty for sale or any specific use.

SBG Systems' liability is limited to the repair or replacement of defective products, this being the sole remedy open to Customer in the event the warranty becomes applicable. SBG Systems cannot be held liable for indirect, special, subsequent or consequential damage, irrespective of whether SBG Systems has or has not received prior notification of the risk of occurrence of such damage.

9. Appendix A: Accessories

Following accessories can be provided with the Ekinox INS.

9.1. Development Tools & Software accessories

9.1.1. DK-EKI-01

The Development Kit is an essential accessories that should be used along with the Ekinox series. The Development kit provides the following items;

- Small sized transport case
- 3 meters Ethernet Cable with RJ-45 connector
- 3 meters International AC/DC power supply
- sbgCenter analysis software suite
- Magnetic calibration tools and C library
- sbgECom C library and C code examples
- Unlimited software upgrades
- Unlimited phone and email support.

Figure 9.1 : DK-EKI-01

9.1.2. DK-EKI-02

This Development Kit is similar to the DK-EKI-01, but provides a larger transport case. It contains the following items:

- Large sized transport case
- 3 meters Ethernet Cable with RJ-45 connector
- 3 meters International AC/DC power supply
- sbgCenter analysis software suite
- Magnetic calibration tools and C library
- sbgECom C library and C code examples
- Unlimited software upgrades
- Unlimited phone and email support.

Figure 9.2 : DK-EKI-02

9.1.3. Split Box: SB-EKI-STD

The Split Box standard version is the easiest way to connect your Ekinox to various equipments without special developments. It provides standard SUB-D9 or SMA connectors for each available port, and a 3 meters long cable.

Check the Split Box User Manual for more information about this product.

Figure 9.3 : The Ekinox Split Box

9.1.4. Split Box: SB-EKI-LND

Figure 9.4 : The Ekinox Split Box

The Split Box Land version is the easiest way to connect your Ekinox to various equipments without special developments. It provides standard SUB-D9 or SMA connectors for each available port, and a 3 meters long cable.

This version is well suited for odometer use and UHF radio RTCM input.

Check the Split Box User Manual for more information about this product.

9.1.5. SW-PP-IE (Post-processing suite)

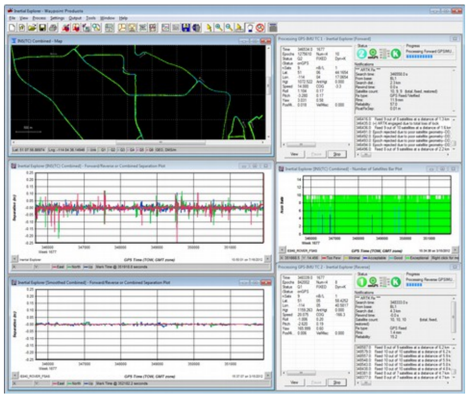


Figure 9.5 : Inertial Explorer

The post-processing software suite is based on Novatel Inertial Explorer. It provides:

- Easy Ekinox integration into Post-processing software suite
- Much higher accuracy than real time processing
- Loosely and tightly coupled GNSS/INS processing
- Precise Point Positioning (PPP) processing, for accurate positioning, even without RTK station.
- 1 Year support and updates

9.2. Transport cases

9.2.1. CASE-EKI-01


Figure 9.6 : 9.2.1. CASE-EKI-01

This small transport case can be used to securely ship or stock:

- An Ekinox A, E or N
- A GPS antenna ref CA-GPS-ANT-AC-G3 or CA-GPS-ANT-AC-G5
- One or two cables for power supply and Ethernet connection.
- The Inertial Software Development Kit USB Key.

9.2.2. CASE-EKI-02


Figure 9.7 : 9.2.2. CASE-EKI-02

This larger transport case can be used to securely ship or stock:

- An Ekinox A, E or N or D
- Up to two GPS antennas ref CA-GPS-ANT-AC-G3 or CA-GPS-ANT-AC-G5
- Many cables or third party devices in the 28 x 28 x 11 cm dedicated emplacement.
- The Inertial Software Development Kit USB Key.

9.3. Cables

9.3.1. CA-EKI-PWR-SUP

This cable is an international AC/DC adapter to power up the Ekinox.

- 110 / 250 V input with UK, US and EU plugs.
- 12V output
- 1.8m long cable
- No IP rating

Figure 9.8 : AC / DC power adapter

9.3.2. CA-EKI-PWR-ALT

This cable mates with the POWER connector to power up the Ekinox from external power supply.

- 1 x Fischer Core Series S-103-Z051-130 connector
- IP-68 rating
- 3m long AWG 18 cable
- 1 x open end

Figure 9.9 : Alternative Power cable

Cable wiring is:

Pin	Signal	Color
SHIELD	NC	SHIELD
1	V+	Red
2	V-	Black

9.3.3. CA-EKI-ETH

This cable provides easy Ethernet access to the Ekinox.

- 1 x Fischer Core Series S-104-A092-130.
- 2.5 m cable (CAT5 type)
- 1 x RJ-45 connector for Ethernet connection.
- No IP rating.

Figure 9.10 : Ethernet cable

Cable wiring is:

Pin on Fisher connector	Signal	Color
SHIELD	SHIELD	SHIELD
16	ETHERNET_TXD+	Green / White
17	ETHERNET_TXD-	Green
18	ETHERNET_RXD-	Orange
19	ETHERNET_RXD+	Orange/ White

Unspecified pins or colors are not connected internally.

9.3.4. CA-EKI-MAIN-RS232

This cable is designed to mate with the MAIN connector and provides RS-232 communication with PORT A as well as other MAIN connector pins access.

- 1 x Fischer Core Series S-104-A092-130
- 3 m AWG26 shielded cable with twisted pairs
- 1 open end
- IP-68 rating

Figure 9.11 : Main RS-232 cable

Cable wiring is:

Pin on Fisher connector	Signal	Color
SHIELD	SHIELD	SHIELD
1	GND	Grey
2	RS$\overline{422}$/232 PORT A	
3	SYNC OUT A	Pink
4	SYNC OUT B	Purple
5	GND	Black
6	SYNC IN A	Light blue
7	GND	Light green
8	PORTA_422_RX+	
9	PORTA_422_RX-	
10	PORTA_422_TX-	
11	PORTA_422_TX+	
12	PORTA_232_RX	Grey / White
13	PORTA_232_TX	Grey / Red
14	CAN_H	Brown / White
15	CAN_L	Brown
16	ETHERNET_TXD+	Dark green / White
17	ETHERNET_TXD-	Dark green
18	ETHERNET_RXD-	Orange
19	ETHERNET_RXD+	Orange / White

Unspecified pins or colors are not connected internally.

9.3.5. CA-EKI-MAIN-RS422

This cable is designed to mate with the MAIN connector and provides RS-422 communication with PORT A as well as other MAIN connector pins access.

- 1 x Fischer Core Series S-104-A092-130
- 3 m AWG26 shielded cable with twisted pairs
- 1 open end
- IP-68 rating

Figure 9.12 : Main RS-422 cable

Cable wiring is:

Pin on Fisher connector	Signal	Color
SHIELD	SHIELD	SHIELD
1	GND	Grey
2	$\overline{\text{RS422}}$/232 PORT A	- Internally connected to pin 1 -
3	SYNC OUT A	Pink
4	SYNC OUT B	Purple
5	GND	Black
6	SYNC IN A	Light blue
7	GND	Light green
8	PORTA_422_RX+	White
9	PORTA_422_RX-	Red
10	PORTA_422_TX-	Dark blue
11	PORTA_422_TX+	Dark blue / White
12	PORTA_232_RX	
13	PORTA_232_TX	
14	CAN_H	Brown / White
15	CAN_L	Brown
16	ETHERNET_TXD+	Dark green / White
17	ETHERNET_TXD-	Dark green
18	ETHERNET_RXD-	Orange
19	ETHERNET_RXD+	Orange / White

Unspecified pins or colors are not connected internally.

9.3.6. CA-EKI-AUX

This cable is designed to mate with the AUX connector and provides access to all AUX connector pins.

- 1 x Fischer Core Series S-104-A092-230
- 3 m AWG26 shielded cable with twisted pairs
- 1 open end
- IP-68 rating

Figure 9.13 : Auxiliary cable

Cable wiring is:

Pin	Signal	Color
SHIELD	SHIELD	SHIELD
1	GND	Grey
2	Sync In D	Yellow
3	Sync In E	Pink
4	Sync In B	Purple
5	GND	Grey / Red
6	Sync In C	Light blue
7	GND	Grey / White
8	Port D – RS-232/RS-422 – Rx+	White
9	Port D – RS-422 – Rx-	Red
10	Port E – RS-422 – Rx-	Dark blue
11	Port E – RS-232/RS-422 – Rx+	Dark blue / White
12	Port B – RS-232/RS-422 – Rx+	Light green
13	Port B – RS-422 – Rx-	Black
14	Port B – RS-422 – Tx+	Brown / White
15	Port B – RS-232/RS-422 – Tx-	Brown
16	Port C – RS-232/RS-422 – Rx+	Dark green / White
17	Port C – RS-422 – Rx-	Dark green
18	Port C – RS-232/RS-422 – Tx-	Orange
19	Port C – RS-422 – Tx+	Orange / White

Unspecified pins or colors are not connected internally.

9.3.7. GPS Antennas

The following GPS antennas are recommended for Ekinox-N operation:

Product code	Manufacturer / Mfg Product code	Description	Photo
CA-GPS-ANT-AC-G3	Antcom / G3Ant-2AMNT1	L1 GPS + GLONASS Magnetic Mount – TNC Connector	
CA-GPS-ANT-AC-G5	Antcom / G5Ant-3AMT1	L1/L2 GPS + GLONASS Magnetic Mount – TNC Connector	
CA-GPS-ANT-NOV-702GG	Novatel / GPS702GG	Survey grade antenna L1 / L2 GPS + GLONASS Excellent multipath rejection	

9.3.8. TNC Cables

Finally, to connect the GPS antennas to an Ekinox, TNC cables can be provided. All TNC cables are sealed. The following lengths:

Product code	Length – Remarks
CA-GPS-TNC-3M	3 m
CA-GPS-TNC-5M	5 m
CA-GPS-TNC-15M	15 m
CA-GPS-TNC-30M	30 meters – low-loss cable

Figure 9.14 : TNC cable