IG-500A
Sub-miniature AHRS
User Manual

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1. Introduction

1.1. IG-500A Overview


Figure 1: IG-500A overview

The IG-500A is an innovative gyro-enhanced Attitude and Heading Reference System (AHRS). Based on the latest MEMS technology, it uses a set of 3 gyroscopes, 3 accelerometers, 3 magnetometers and temperature sensors to detect motion and compute precisely 3D orientation data. Several dynamic range options allow precise measurements for a wide range of applications. A 1000Hz coning integration enables highest orientation tracking accuracy during highly dynamic motion. The IG-500A provides to user all needed information, very easily, such as calibrated sensors information and 3D orientation.

The IG-500A therefore perfectly matches with control, stabilization, motion analysis of robots, machines, as well as human body segments.

An OEM version of the IG-500A is proposed to make it very easy to integrate our product in weight and size sensitive applications.

The IG-500A merges all sensor information through a specially designed Extended Kalman Filter. This makes it possible to estimate a drift-less and very accurate 3D orientation by taking full advantage of each sensor.

Thanks to the exclusive Motion Profile technology, the IG-500A Kalman Filter can easily and finely adapted to all application dynamics and constraint.

Outputs provided by the IG-500A are:

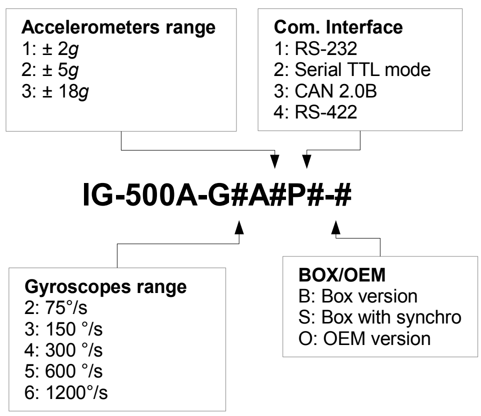
- 3D Orientation (Euler Angles, Matrix or Quaternion form),
- Heave,
- Calibrated Sensors data (3D Acceleration, 3D Angular rate, 3D Magnetic field, Temperatures),
- Delta Angles
- Time in ms since the last reset of the device
- Raw sensor data.

1.2. Product codes and options

Standard version is the box version, with ± 300°/s gyroscopes, ± 5*g* accelerometers, RS-232 communication.

The standard product code is:

IG-500A-G4A2P1-B



1.3. Provided development kit

The IG-500 Development Kit is an essential tool that has been designed to provide easy and efficient IG-500A integration. Provided software and libraries will give the opportunity to rapidly develop powerful applications. In addition, it is made very easy to connect the IG-500A to a PC with the provided USB interface.

1.3.1. Content of the development kit

Each DK is provided with the following elements:

- An UsbToUart converter with a 3m cable, or USB Can interface with associated 3M cable and power supply
- A set of compatible screws for easy mounting
- A quick start manual
- A CD-Rom containing :
  - Usb interface driver
  - sbgCenter analysis software
  - sbgUpdater software to maintain your software up to date
  - sbgFirmwareUpdater software for firmware upgrades
  - sbgCom C library
  - sbgCan C library
  - sbgMatlab plug-in for Matlab for serial devices
  - sbgLabView plug-in for LabView for serial devices
  - Example projects with source code
  - Full documentation :
    - IG-500A User Manual
    - IG-Devices Serial Protocol Specifications
    - IG-Devices CAN Protocol Specifications
    - OEM Integration manual
    - sbgCom Library Reference Manual
    - sbgCan Library Reference Manual
    - Magnetometers Calibration Tools
    - sbgCenter User Manual
    - Various application notes

Figure 2: Development Kit

2. IG-500A Presentation

2.1. Block diagram

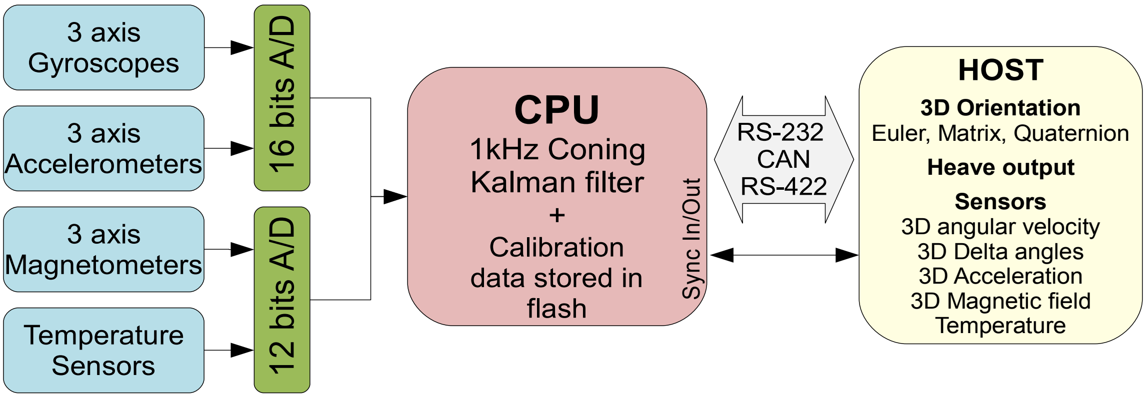


Figure 3: IG-500A simplified block diagram

2.2. Extended Kalman filter

2.2.1. Purpose

The IG-500A includes a real time Extended Kalman Filter. It delivers to the IG-500A precise tracking of the device's orientation, as well as sensor information such as gyroscopes bias. This Kalman filter performs data fusion between the three main sensors: Gyroscopes, Accelerometers and Magnetometers, to take full advantage of all collected information:

- Gyroscopes integration allows calculating orientation very precisely in a short term. As integration sums rotational speed as well as a small amount of error, the orientation accuracy, which is very good at startup, constantly decreases over time.
- By detecting magnetic north and local gravity, accelerometers and magnetometers can measure a very accurate orientation, but only in static conditions. Movements make the accelerometers precision decrease, and magnetometers can be disturbed by irons, and magnets. These sensors can give good information of orientation, but with a low bandwidth.

The Kalman filter estimates in real time how much it can trust gyroscopes, magnetometers and accelerometers in order to deliver the best attitude estimate.

Moreover, and external heading capability allows the device operating in severe magnetic conditions, as long as user can provide heading information regularly to the device.

In addition, the Kalman filter computes orientation data at up to 100 Hz. If lower output rates are required, it is possible to divide the output frequency while keeping the efficiency of a high internal rate, and a low data rate.

2.3. Motion profiles

Each application has particular 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 in 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 IG-500 configuration.

Different motion profiles have been designed to fit with most typical applications and should provide optimal performance, but it's still possible to finely tune a specific motion profile for a particular requirement.

Each motion profile includes parameters relative to magnetic field and other heading observation methods. It's then possible to select different heading sources within a motion profile configuration.

The following motion profiles are available by default on the IG-500A. Their characteristics and assumptions are described and special recommendations are also provided if required.

2.3.1. General Purpose

Assumptions	Comments
Description	This motion profile is well suited for many applications that have medium vibrations and accelerations, such as land robots, camera stabilization It should be used if other motion profiles do not well describe the user application. 
Update rate	100Hz
Vibrations	Low to medium vibrations are tolerated.
Accelerations	Low long term accelerations
Magnetic field	Good confidence in magnetic field measurement.
Recommended heading sources	Magnetometers (3D, 2D or 2D Horizontal mode) None (vertical gyro mode)
Specific assumptions	No specific assumption is made.
Placement requirements	-

2.3.2. Airplane

Assumptions	Comments
Description	This motion profile is well suited for general aircraft applications that have low to medium dynamics. This motion profile can be used only for fixed wings vehicles of any size. 
Update rate	100Hz
Vibrations	High vibrations are tolerated.
Accelerations	Presence of long term accelerations assumed.
Magnetic field	Good confidence in magnetic field measurement.
Recommended heading sources	Magnetometers (3D, 2D or 2D Horizontal mode) None (vertical gyro mode)
Specific assumptions	A significant velocity is assumed.
Placement requirements	Sensor coordinate frame must be aligned within less than 1° to the airplane coordinate frame: IG-500 X axis must be turned toward the airplane nose direction, and Z axis should be turned downward.

2.3.3. Airplane – High dynamics

Assumptions	Comments
Description	This motion profile provides a similar configuration as the airplane one but is finely tuned for highly dynamic flights. 
Update rate	100Hz
Vibrations	High vibrations are tolerated.
Accelerations	Presence of long term accelerations assumed.
Magnetic field	Good confidence in magnetic field measurement.
Recommended heading sources	Magnetometers (3D)
Specific assumptions	High speed is assumed.
Placement requirements	Sensor coordinate frame must be aligned within less than 1° to the airplane coordinate frame: IG-500 X axis must be turned toward the airplane nose direction, and Z axis should be turned downward.

2.3.4. Helicopter

Assumptions	Comments
Description	This motion profile is well suited for helicopter applications, as well as many land robots with significant vibration level. 
Update rate	100Hz
Vibrations	High vibrations are tolerated.
Accelerations	Presence of long term accelerations assumed.
Magnetic field	Good confidence in magnetic field measurement.
Recommended heading sources	Magnetometers (3D, 2D or 2D Horizontal mode) None (vertical gyro mode)
Specific assumptions	No significant velocity is assumed (stationary flight)
Placement requirements	Sensor coordinate frame must be aligned within less than 1° to the airplane coordinate frame: IG-500 X axis must be turned toward the airplane nose direction, and Z axis should be turned downward.

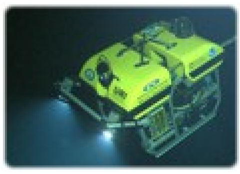
2.3.5. Automotive

Assumptions	Comments
Description	This motion profile is well suited for automotive applications as well as land robots that do not perform side slip. 
Update rate	100Hz
Vibrations	Medium vibrations are tolerated.
Accelerations	Presence of medium/long term accelerations assumed.
Magnetic field	Magnetic field not recommended.
Recommended heading sources	None (vertical gyro mode)
Specific assumptions	Medium velocity is assumed.
Placement requirements	Sensor coordinate frame must be aligned within less than 1° to the vehicle coordinate frame. X axis must be turned toward vehicle direction of travel, and X axis must be turned down.

2.3.6. Marine

Assumptions	Comments
Description	This motion profile is dedicated to general marine applications. 
Update rate	100Hz
Vibrations	Medium vibrations are tolerated.
Accelerations	Low long term accelerations.
Magnetic field	Medium confidence in magnetic field measurement.
Recommended heading sources	Magnetometers (3D, 2D or 2D Horizontal mode)
Specific assumptions	No significant velocity is assumed
Placement requirements	-

2.3.7. Underwater

Assumptions	Comments
Description	This motion profile is designed for underwater and quasi static applications. 
Update rate	100Hz
Vibrations	Medium vibrations are tolerated.
Accelerations	Very Low long term accelerations.
Magnetic field	Aggressive magnetic field disturbances filtering.
Recommended heading sources	Magnetometers (3D)
Specific assumptions	No significant velocity is assumed
Placement requirements	-

2.3.8. Human motion

Assumptions	Comments
Description	This motion profile is specially designed for high speed rotations seen in human motion applications. It requires the High Performance mode to be enabled 
Update rate	200Hz
Vibrations	Non vibrating environment is assumed
Accelerations	Low long term accelerations
Magnetic field	Aggressive magnetic field disturbances filtering.
Recommended heading sources	Magnetometers (3D, 2D or 2D Horizontal mode) User heading
Specific assumptions	No specific assumption is made.
Placement requirements	-

2.3.9. IMU 500

Assumptions	Comments
Description	This special motion profile disables the internal Kalman filter and provides reduced output latency as well as 500Hz output rate. 
Update rate	500Hz
Vibrations	-
Accelerations	-
Magnetic field	-
Recommended heading sources	-
Specific assumptions	-
Placement requirements	-

2.4. Heave computation

Mainly used in marine applications, we refer here to ship motion computation. Vertical motion is called heave.

Aside from the EKF, the IG-500 computes at 100Hz 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 as long as correct average heave period is provided by user.

As there is a high pass filter, the heave 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 to stabilize the output after a step.

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

2.5. Internal Sensors

2.5.1. Inertial and magnetic sensors sampling and filtering

The IG-500A includes advanced sampling and filtering techniques that avoid as much as possible common aliasing effects. This allows a very high vibration immunity, as well as optimal noise reduction. The following block diagram explains the overall sensor sampling structure:

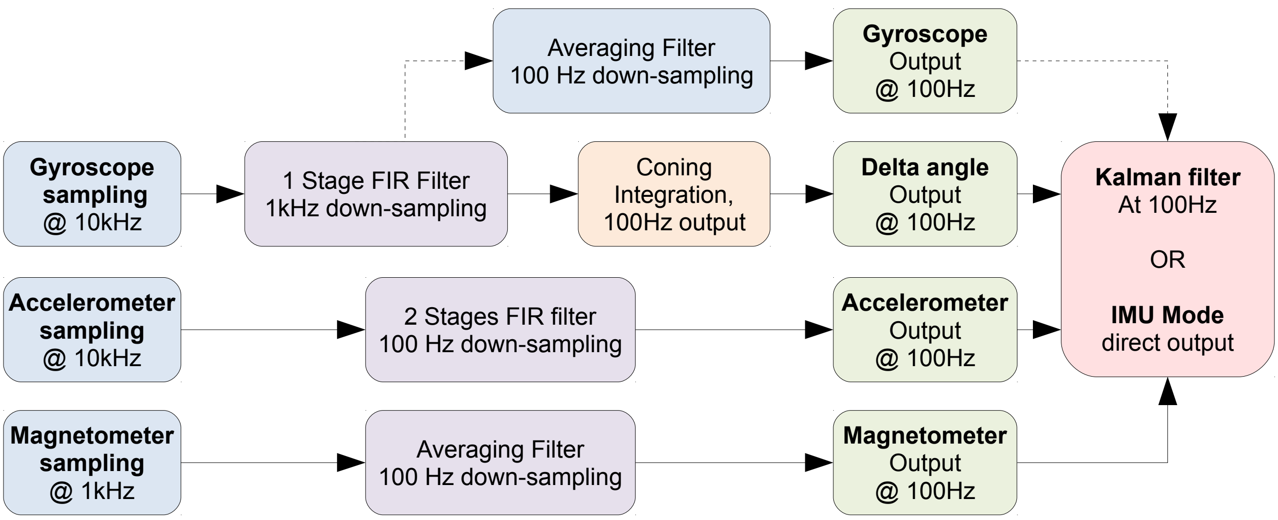


Figure 4: Advanced and high efficiency sampling and filtering design

2.5.1.1. Accelerometers

Accelerometers outputs are first fed into a hardware one pole low pass filter. This filter ensures anti aliased sampling. Once sampled by a 16 bit SAR (Successive Approximation Register) Analog to Digital Converter, measurements are fed into a 2 stages high efficiency FIR filter. This filter provides the best vibration isolation.

The filter cascade generates a small delay between a stimulus and output response. Overall accelerometer delay is: 31.9 ms.

2.5.1.2. Gyroscopes

Gyroscopes are first filtered by a 2 poles hardware low pass filter that provides high frequency rejection before sampling. The 10kHz samples are then fed into a high efficiency FIR filter that provides a 1kHz down-sampling. After that, Coning integration at 1kHz provides high performance orientation tracking. At the same time, the gyroscopes output is filtered down by an averaging filter to provide the 100Hz output.

The filter cascade generates a small delay between stimulus and output response. Overall delay are the following:

Delta Angle delay: 1.8ms

Gyroscope output delay: 6.4ms

2.5.1.3. Magnetic sensors

Magnetometers are first filtered by a 1 pole hardware low pass filter that reduces high frequency noise coming from RF interferences for example. (F > 2 kHz). The 3 channels are then over-sampled at 1 kHz by a 12 bit SAR ADC. These samples are fed into an averaging filter that remove all the noise comprised between the Kalman filter frequency and 500 Hz.

The filter cascade generates a small delay between stimulus and output response. Overall delay for magnetometers is 4.5 ms.

Note: *Due to hardware requirement of magnetic sensors, the magnetic noise comprised between 500 Hz to 2 kHz cannot be well filtered, and must be avoided for proper operation.*

2.5.1.4. Factory calibration procedure

Our products are provided with fully calibrated inertial sensors and magnetometers. We calibrate and test each product in our factory. A calibration report is also shipped with each product.

This calibration procedure allows taking the maximum precision of each sensor. This procedure contains:

- Temperature compensation of gain and bias for accelerometers and gyroscopes,
- Temperature compensation of gain for magnetometers,
- Cross-axis and misalignment effects compensation for accelerometers, gyroscopes and magnetometers,
- Non linearity correction for gyroscopes over temperature.
- Gyro-G effect compensation for gyroscopes.

Note 1: *For best accuracy, each gyroscope channel is calibrated with its own internal temperature sensor. Accelerometers and magnetometers use a dedicated external temperature sensor for calibration.*

Note 2: *There is no temperature compensation of bias for magnetometers because it is stable over temperature by hardware design.*

2.5.1.5. Magnetometers in place calibration

Magnetometers are fully calibrated in factory. However, they are very sensitive to their close environment and mainly the object on which they are strapped. Some ferromagnetic materials can produce magnetic field distortions causing errors in heading estimation. These distortions are often called Hard and Soft Iron effects and must be addressed for good attitude results.

The IG-500A includes a powerful algorithm especially designed to easily compensate both **Hard AND Soft** iron effects. We advise user to call this procedure when:

- A loss of precision is observed in heading estimation,
- The device is mounted on an object that may contain ferromagnetic materials or magnets,
- The device is removed from an object containing ferromagnetic materials or magnets.

Note: *Please refer to the Magnetometers Calibration Tools documentation for a complete description of the magnetometers calibration procedure.*

2.5.1.6. Gyroscopes bias

Bias is a common concern with gyroscopes, and in particular MEMS gyros.

The IG-500A includes an industrial grade gyroscope which is very stable. Nevertheless, bias variations can still be observed due to:

- Temperature variations (this effect is mostly compensated by the factory calibration),
- Noisy power supply,
- Random walk effect, which change slowly bias over time.

It's also important to know that fast temperature changes cannot be modeled by the temperature compensation algorithms, and therefore induce bias. Optimal performance is obtained with a stable ambient temperature.

Note: *The Kalman filter inside the IG-500A is designed to estimate in real time gyro bias evolutions, but a static gyro bias reset sequence can be made to provide faster bias estimation, and faster Kalman filter stabilization. In addition, the gyro bias can be saved into nonvolatile memory in order to get faster filter convergence.*

2.6. IG-500A timing and synchronization with other devices

When dealing with external devices, time synchronization can be a very important point to consider because of different calculation delays within each device associated with transmission times.

The IG-500A includes a synchronization input and a synchronization output in order to keep optimal timing accuracy in system.

2.6.1.1. Synchronization Input

The IG-500A accepts a logic input (Sync In) signal to synchronize the IG-500A with an external device, or host clock. Events can be generated on rising, falling edge, or on level change.

In addition, a software delay can be added after the actual trigger time.

The following events are supported on the input:

1. Event input: Here the IG-500A computes freely its orientation with its internal clock. When a new event is received, the IG-500A will send the last computed data. So this event accuracy is not as good as previous one. A jitter as long as the computation period can be observed.

Note: *The Sync In pin is not available on the IG-500A RS-422 version.*

2.6.2. Synchronization Output

The Synchronization output pin allows the user application to synchronize itself on the internal IG-500E clock, and also on the UTC time reference. It is possible to set different output types depending on user needs. A high/low pulse can be sent, or the output level can be changed on the following event conditions:

1. Main loop start: It corresponds to the exact time when all inertial sensors are sampled. Once the sensors are sampled, the Kalman filter will estimate orientation, and navigation data. At the end of the loop, if some data has to be sent, it will correspond to this synchronization output pulse time.

2. Main loop divider: This event is also activated at the main loop start time, but its frequency is divided by the output divider. So a continuous/triggered output is set with a frequency divider, the pulse will only be set when an output will be sent at the end of the loop.

Note: *The synchronization output is an open drain output. Please connect a pull-up resistor for proper operation.*

2.6.3. Computation and transmission delays

The following diagram shows what happens when user sets the output divider to 2 (one data frame is send each two loops), and a synchronization output is enabled. This example covers serial devices, but similar considerations can be used on CAN bus devices.

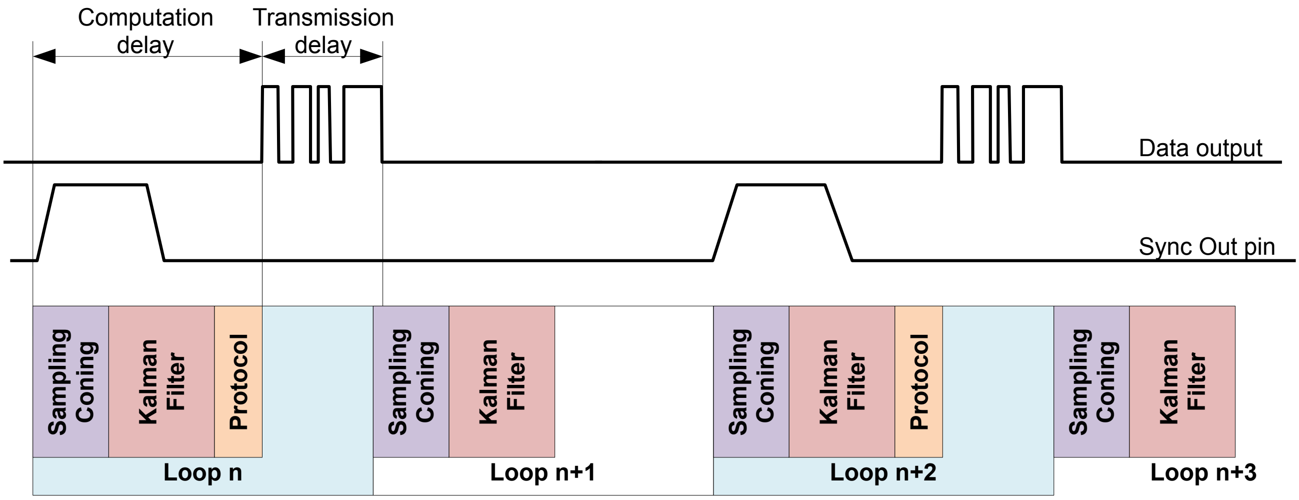


Figure 5: Timing diagram with synchronization output and output divider set to 2

2.6.3.1. Strategies to reduce overall latency

As shown with Figure 5, final delay is divided into two main parts: Computational delay that includes sensor sampling, Kalman filtering and Protocol management, and transmission delay, directly linked to the amount of data to transfer and bus speed. It's possible to optimize both delays and minimize them taking into account the following considerations:

- Computational latency
  1. Avoid Heave and Euler angles computation if not required
  2. Avoid using simultaneously binary and ASCII protocols
  3. Avoid sending the data into “Fixed Point” format. Standard IEEE floating point format is preferred.
  4. If ultra low latency is required, consider using the High performance power mode.
- Transmission latency
  1. Increasing the baudrate limits the transmission time
  2. Reducing the data throughput limits the transmission time.

The following table shows the different computational times required:

Output Options	Computational latency (normal power mode)	Computational latency (High performance power mode)
Output mask: *Time since reset, device status, Euler Angles, Accelerometers, Gyroscopes, Magnetometers* **Output format**: Fixed point	4,2 ms	1.7 ms
Output mask: Time since reset, device status, *Euler Angles*, Accelerometers, Gyroscopes, Magnetometers **Output format**: *Floating point*	4.15 ms	1.69 ms
Output mask: Time since reset, device status, *Quaternion*, Accelerometers, Gyroscopes, Magnetometers **Output format**: *Floating point*	3.9ms	1.59 ms
Output mask: *Time since reset, device status, Quaternion, Accelerometers, Gyroscopes, Magnetometers, Heave* **Output format**: *Floating point*	N/A	2.45ms

Table 1: Computational latency depending on output options and power mode

Now the next table shows transmission latency with different output sets and baudrates:

Output mask	Transmission delay
Output mask: *Time since reset, device status, Euler Angles, Gyroscopes, Magnetometers* **Baudrate**: *115 200bps*	5.55 ms
Output mask: *Time since reset, device status, Euler Angles, Gyroscopes* ***Baudrate***: *921 600bps*	0.694 ms

Table 2: Transmission delays with several output configurations

Note: *Output format is not available in CAN devices so this consideration cannot be taken into account. But the CAN bus speed has an effect on transmission delay, as well as CAN Bus usage. If the CAN bus is used by many different devices, a higher transmission delay can be expected.*

2.6.3.2. Synchronization Examples

Here we describe basically how to use the IG-500A synchronization input and output. In this example, we consider a camera that requires an accurate timing, position and orientation of each filmed frame.

On the first example, the IG-500A computes orientation with its internal clock, and each time a new computation loop is started, it sends a sync Out pulse. User application can then synchronize itself on the IG-500A by knowing exactly when is measured each sample.

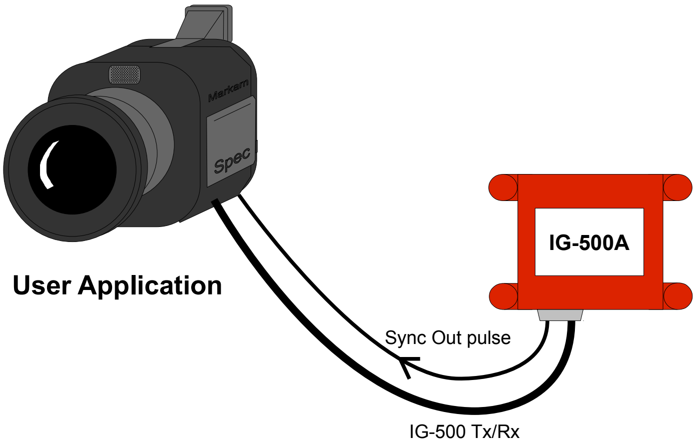


Figure 6: Basic synchronization example with sync pulse Output

In a second example, he IG-500A is synchronized itself on user application. The event input trigger is here used, so the camera needs to send pulses corresponding to each IG-500A data sample.

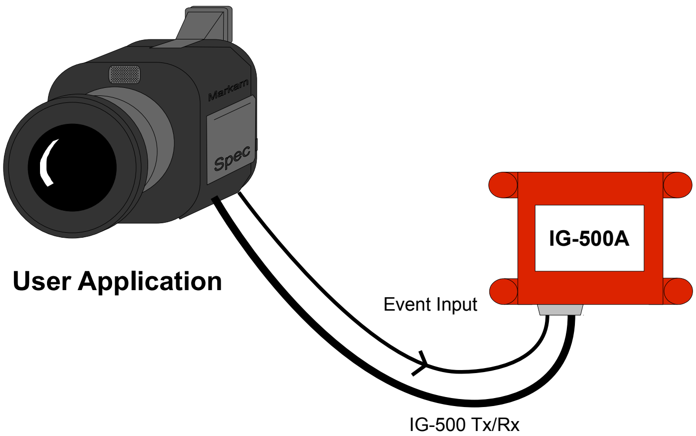


Figure 7: Basic synchronization example with sync. Input

2.7. Specifications

All specifications are valid in the full temperature range -40°C to 85°C unless otherwise specified.

2.7.1. Performance

Parameter	Specification	Remarks - Conditions
Sensing range	360° in all axes, no mounting limitation	Solid state sensors
Orientation Accuracy *Underwater applications*	± 0.35° RMS (Pitch, Roll) ± 0.8° RMS (Heading)	2*g* accelerometer – 150°/s gyroscope Homogeneous magnetic environment
Orientation Accuracy *Marine applications*	± 0.45° RMS (Pitch, Roll) ± 1° RMS (Heading)	2*g* accelerometer – 150°/s gyroscope Reliable heading observation
Orientation Accuracy *Automotive applications*	± 2.0° RMS (Pitch, Roll) N/A (Heading)	5*g* accelerometer – 300°/s gyroscope Good gravity observability Vertical Gyro mode
Orientation Accuracy *Airborne applications*	± 2.0° RMS (Pitch, Roll) ± 2.0° RMS (Heading)	5*g* accelerometer – 300°/s gyroscope Good gravity observability, and clean magnetic environment.
Repeatability	0.2°	
Resolution	< 0.05°	
Integration method	1 000Hz Coning integration	For accurate fast motion tracking
Heave	10 cm or 10%	Whichever is greater

Table 3: Orientation performance specifications

2.7.2. Internal sensors specifications

Accelerometers	**A1**	**A2**	**A3**	**Remarks - Conditions**
Measurement range	± 2*g*	± 5*g*	± 18*g*	
Non-linearity	< 0.2%	< 0.2%	< 0.2%	% of full scale
Bias at startup	± 2 m*g*	± 5 m*g*	± 10 m*g*	Over full temperature range
Bias in-run stability	± 0.04 m*g*	± 0.06 m*g*	± 0.08 m*g*	Allan variance – constant temperature
Orientation residual	0.1°	0.3°	0.6°	Static orientation error due to initial bias
Scale factor stability	< 0.1%	< 0.1%	< 0.1%	Over full temperature range
Noise density	0.22 mg/√Hz	0.25 mg/√Hz	0.32 mg/√Hz	
Alignment error	< 0.05°	< 0.05°	< 0.05°	
Bandwidth	250 Hz	250 Hz	250 Hz	
Sampling rate	10 000 Hz	10 000 Hz	10 000 Hz	Advanced anti-aliasing FIR filter

Table 4: Accelerometers specifications

Gyroscopes	**G2**	**G3**	**G4**	**G5**	**G6**	**Remarks - Conditions**
Measurement range	± 75°/s	± 150°/s	± 300°/s	± 600°/s	± 1200°/s	
Non-linearity	< 0.1%	< 0.1%	< 0.05%	< 0.05%	< 0.05%	% of full scale
Bias at startup	± 0.5°/s	± 0.5°/s	± 0.5 °/s	± 0.5°/s	± 1°/s	Over full temperature range
Bias in-run stability	20 °/h	20 °/h	20 °/h	30 °/h	30 °/h	Allan variance – constant temperature
Scale factor stability	< 0.05 %	< 0.05 %	< 0.05%	< 0.05 %	< 0.05 %	
Noise density	0.04 °/s/√Hz	0.04 °/s/√Hz	0.05 °/s/√Hz	0.05 °/s/√Hz	0.05 °/s/√Hz	
Alignment error	< 0.05°	< 0.05°	< 0.05°	< 0.05°	< 0.05°	
Bandwidth	240 Hz	240 Hz	240 Hz	240 Hz	240 Hz	
Sampling rate	10 000 Hz	10 000 Hz	10 000 Hz	10 000 Hz	10 000 Hz	Advanced anti-aliasing FIR filter

Table 5: Gyroscopes specifications

Magnetometers	**Specification**	**Remarks - Conditions**
Measurement range	± 1.2 Gauss	Check optional sensors specifications
Non-linearity	< 0.2%	% of full scale
Bias stability	± 0.5 mGauss	Over full temperature range
Scale factor stability	< 0.5%	Over full temperature range
Noise density	0.01 mGauss/√Hz	
Alignment error	< 0.1°	
Bandwidth	500 Hz	
Sampling rate	1 000 Hz	

Table 6: Magnetometers specifications

2.7.3. Communication Interfaces

Main communication interface : Serial		Remarks – Conditions
Interface type	RS-232 RS-422, TTL 3.3V, USB	Product codes P1; P2; P4
Protocols	IG-Devices Serial Protocol (Binary) NMEA and proprietary ASCII protocol	ASCII protocol only for data output
Outputs (binary)	Euler angles, quaternion, rotation matrix, heave, calibrated sensor data, delta angles, device status...	Each output can be enabled or disabled
Outputs (ASCII)	HEHDT, HEHDM, PSXN23, SBG01 (Euler angles)	Each output can be enabled or disabled
Baudrate	9 600 to 921 600 bps ; Fast or Slow Slew Rate	User selectable
Output rate	500 Hz 100 Hz	IMU mode (sensors data only) INS mode (orientation & navigation data)

Table 7: Serial interface specifications

Main communication interface : CAN		Remarks – Conditions
Interface type	CAN 2.0 A / B, USB	Product code P3
Protocol	IG-Devices CAN Protocol	Each frame can be configured, enabled or disabled
Outputs	Euler angles, quaternion, rotation matrix, heave, calibrated sensor data, delta angles, device status...	Each output can be enabled or disabled
Bit-rate	10 to 1 000 kbps	User selectable
Bus termination	Not included	Contact SBG Systems if bus termination is required

Table 8: CAN interface specifications

2.7.4. Electrical specifications

Parameter	Specification		Remarks – Conditions
Operating voltage	3.3 to 30V		
Power consumption	400 mW @ 5.0V		Normal performance mode
Logic Inputs	0 Level: < 0.8 V 1 Level: > 2.0V	Input Range : ± 20V Input Delay: <150 ns	
Logic Output	*Type* *Pull-up Voltage:* *Switching OFF delay:*	Open drain [-0.3;25V] <100 ns	Use a pull up resistor for proper operation.
Start-up time	< 2s		First valid data
Fully stabilized time	< 10 min		For optimal attitude measurement

Table 9: Electrical specifications

2.7.5. Physical specifications

Parameter	Specification	Remarks – Conditions
Dimensions	36x49x22 mm / 36x49x25 mm	B package / S package
Weight	40 grams / 44 grams	B package / S package
Operating temperature	-40° to 85°C	Non condensing environment
Storage temperature	-40° to 85°C	
Operating vibrations	3g RMS (20Hz to 2 kHz per MIL-STD 810G)	Valid for 18g accelerometers
Shock limit	1 000 *g* (Powered), 2 000 *g* (unpowered)	Check absolute maximum ratings

Table 10: Physical specifications

3. Optimal installation guidelines and limitations

3.1. Optimal placement

3.1.1. Application specific considerations

As explained in section Motion profiles, some sensor alignment requirements have to be observed for proper operation.

This alignment is not always possible mechanically. Therefore a software alignment procedure (pre-reset) can be used to realign sensor coordinate frame with the system or vehicle coordinate frame.

3.1.2. Heading considerations

Depending on the heading observation method used, particular placement considerations have to be followed.

In addition to the motion profile alignment constraints, heading source alignment constraints may be added or not.

3.1.2.1. Magnetometers use

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 IG-500A should be placed as far as possible from ferromagnetic materials, particularly those who can be moved independently with respect to the IG-500A. In practice placing the device more than 1 meter away from moving ferromagnetic 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 IG-500A can compensate both Hard and Soft iron interferences.

Note 1: *See 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 IG-500 will realign itself to te new magnetic field direction.*

Note 3: *As any magnetometer or compass based system, the heading provided by the device will not be valid near north and south poles (magnetic field inclination higher than 80°).*

Magnetometers 2D Horizontal calibration requirements

If you perform a 2D horizontal magnetometers calibration, you have to respect carefully the following placement requirements.

The IG-500 coordinate frame must be consistent with the vehicle coordinate frame. The X axis must be turned toward the front of the vehicle, whereas the Z axis has to be turned downward. If mechanical alignment is not possible, a pre-rotation reset can be used to re-align by software the sensor coordinate frame.

Note: This placement requirement is also seen in several motion profiles.

3.1.2.2. User heading

When using the User heading source, the IG-500A assumes that the heading provided is consistent with the IG-500A X axis direction. It belongs to user to realign heading value if required.

3.1.3. Accelerations

3.1.3.1. Transient acceleration

During transient accelerations, the device is not able to differentiate gravity and other accelerations. Care should be taken to place the device where you expect to get the least transient accelerations. Generally, the center of mass is the best choice for placing the IG-500A. In that place, rotation of the object would not generate centripetal accelerations.

3.1.3.2. Low gravitational fields

The device needs the gravity to estimate the local vertical. It will not work properly in low gravitational fields, such as during spaceflights.

3.1.4. Vibrations

As a rule of thumb, the IG-500A must be **mechanically isolated as much as possible** from any vibrations to get the best performance. Vibrations generate accelerations that are measured by accelerometers. SBG Systems has designed the IG-500A with a high sampling frequency (10 kHz) as well as high efficiency anti aliasing FIR filters to limit vibration issues. Nevertheless, a good mechanical isolation will ensure getting the full sensor performance:

High amplitude vibrations generate a bias in accelerometer reading. This cannot be compensated during factory calibration as this effect depends on vibration frequency and amplitude. 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.

If proper mechanical isolation cannot fully prevent high amplitude vibrations, consider using an 18*g* accelerometers unit, which has a lower VRE than the standard 5g accelerometers.

> ***Note:*** *High frequency vibrations (> 9 kHz) could generate aliasing in accelerometers measurements. In most applications, this should not be a problem because vibrations above 1 kHz can be easily filtered using simple mechanical dampers.*

3.2. Environmental considerations

The normal condition to operate the IG-500A is within the industrial range: -40 to +85°C, in a dry and non condensing environment. If the device is operated beyond absolute maximum ratings, expressed in 16, the device may be damaged.

Temperature variations cannot be modeled in the sensor calibration. This is why for optimal results the temperature during measurements should be as stable as possible. Moreover, a 10 minutes warm-up should be allowed to the IG-500A in order to get optimal results.

The IG-500A should be protected from humidity and dust, as it can damage the internal hardware.

The IG-500A should be protected from drops onto hard surfaces and violent handling, as it can cause shocks higher than those specified in the absolute maximum ratings.

3.3. Power supply

The power supply of the IG-500A has been designed to isolate as much as possible sensors from power supply noise. However keep in mind that a noisy power supply can decrease sensors performance. For best performance, power supply should be isolated from high frequency by inductors or ferrite beads and from low frequency by a regulator.

4. Quick and efficient device operation

4.1. Driver and software installation

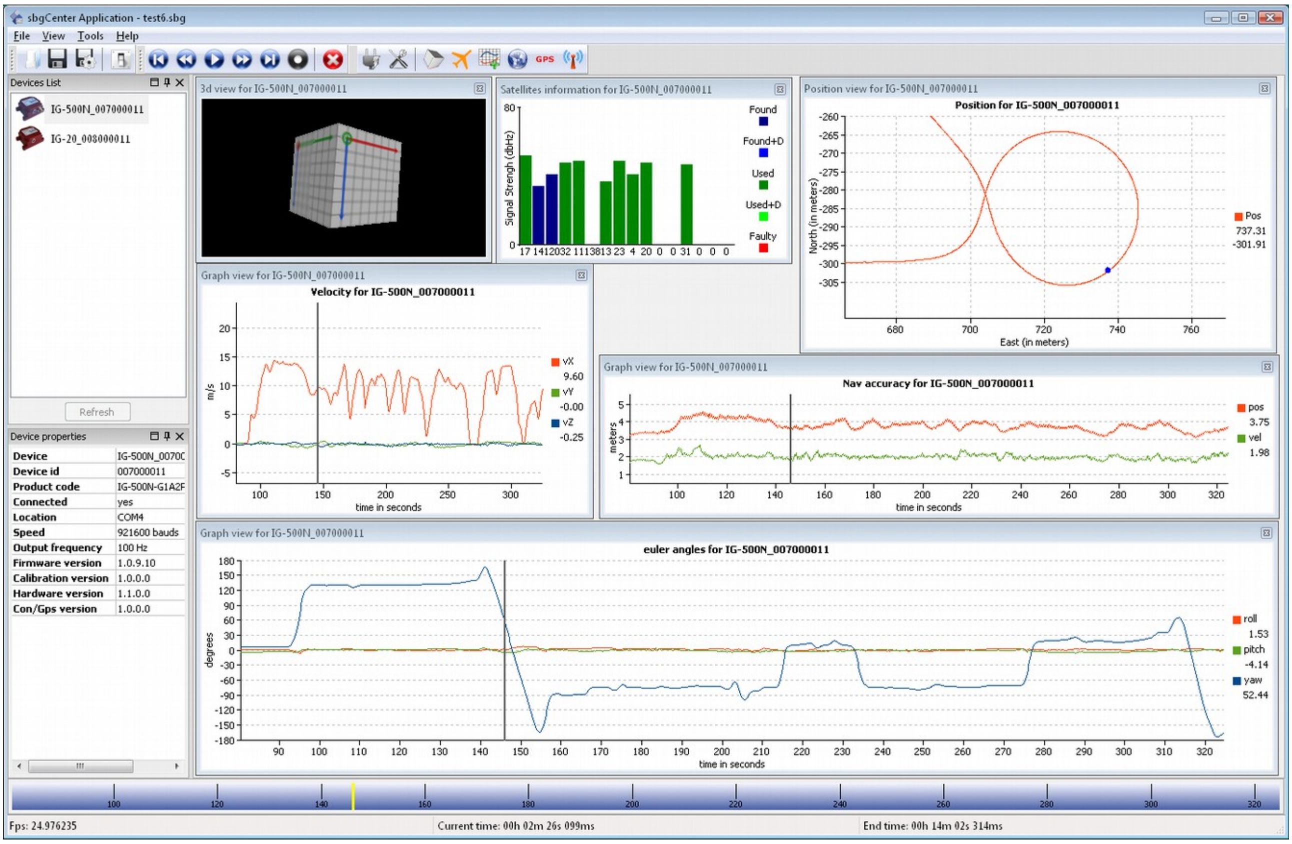
This easy installation is described in the “IG-500 Quick start Guide”.

4.2. Provided software and libraries

4.2.1. The sbgCenter

The sbgCenter is a very powerful program suit. It allows deeply analyzing outputs of the IG-500A, by displaying, recording, and exporting a set of data. Graphs can be displayed, as well as a 3D representation of orientation.

A powerful time management allows deep exploration of any recording, with the ability to display in a single frame 50 ms of recording, or the whole record.



Note: *Please refer to the sbgCenter User Manual for more information*

4.2.2. Communication with the device

SBG Systems provides multiple ways to interface the IG-500A with another system. An easy solution is to use the C library sbgCom or sbgCan included in the DK. You can also refer to the IG-Devices Serial Protocol Specifications and IG-Devices CAN Protocol Specifications to directly communicate with the device.

For even easier integration into existing systems, the IG-500A is able to output an ASCII output.

4.2.2.1. The C libraries sbgCom / sbgCan

The IG-500A DK provides an easy access to the device with the libraries sbgCom and sbgCan. These libraries allow access to all functions of the IG-500A, including continuous mode of communication.

These libraries are developed for most popular OS: Ms Windows, Linux, and Mac OS X. They should also be easily compiled on all UNIX platforms.

sbgCom/sbgCan were designed to simplify the work needed to port the libraries to a specific platform, by separating the low level communication functions such as serial com port from the high level one.

> ***Note:*** *Please refer to the sbgCom and sbgCan Reference Manual to have a complete description of these two libraries.*

Provided example programs

- **Minimal example:** This small C example is simply the smallest program you can write to use the IG-500A. Only 6 lines of code are needed to initialize the device, start communications and display in real time results. This example illustrates the simplicity of use of sbgCom.
- **3D Cube:** This 3D Cube is a small C example, which source is available in the SDK. To use it, you just have to define the right com port and serial communication baud rate in the file “main.c” and compile the project. If everything goes well, you should obtain the two windows below:

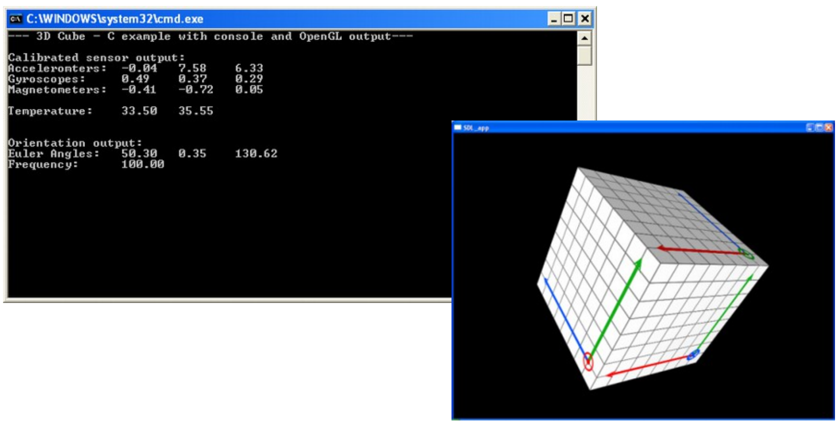


Figure 9: Overview of the 3D Cube example

4.2.3. Low level communication with the IG-500A

When it is not possible to use sbgCom or sbgCan libraries, you can still communicate directly with the device, by implementing its low level communication protocol based on the provided documentation.

Note: *Please refer to the IG-Devices Serial Protocol Specifications or IG-Devices CAN Protocol Specifications to have a complete documentation of the protocol format, the commands and their parameters.*

4.2.4. Matlab and Labview integration

4.2.4.1. Matlab

The sbgMatlab plug-in developed by SBG Systems allows a direct access in real time to your IG-500A. All functions of the sbgCom have been implemented in a Matlab class CSbgMatlab, providing an easy interface for users.

The plug-in is based on a DLL for Windows platform. A UNIX version of this dynamic library is being finalized and will be available in a next release.

A few example codes may help you in your developments. Also note that continuous mode has to be enabled in order to retrieve outputs from the IG-500A.

4.2.4.2. Labview integration

The sbgLabView library provides a full support of the IG-500A on Labview 8.2. An example using this library is provided for a better understanding of the library. Also note that continuous mode has to be enabled in order to retrieve outputs from the IG-500A.

4.3. Getting optimal results

The IG-500A is a measuring device, and in order to reach optimal performance, some checks and considerations have to be carefully done. If it is not the case, performance of the device can be rapidly affected.

We consider here the Optimal installation guidelines and limitations have been followed.

Before starting a measurement:

1. Configure properly your device
   a. Select required outputs and baudrate. A Higher baudrate allows more data to be transmitted. Check in the device status that the “protocol” flag is set to Yes; If it's not, increase baudrate or reduce data throughput.
   b. Set appropriate Kalman filter options: Motion profile should be chosen accordingly to your application dynamics, as well as heading source.
   c. If the heading source is set to “Magnetometers”, a hard and soft iron calibration has to be performed in the place where the sensor is used. (Check the Iron Calibration Tools documentation for more information). By default, the local magnetic declination will be automatically computed.
   d. If the sensor can be considered as static at startup, then initialization time can be greatly reduced by enabling “initial static condition until motion is detected” option. It would ensure fast gyro bias acquisition and faster Kalman filter convergence. This is particularly useful when heading source is set to “none” for vertical gyro operation.

When you start a measurement:

1. Let some time for the device’s electronics to warm up. It can take up to 10-15 min. If the device is not fully warmed up, the sensors might have a degraded performance or bias. In the same time, you also let the Kalman filter stabilize. Filter Stabilization requires several minutes before reaching best performance. Before that time, it's possible to use the sensor but accuracy will improve over time until reaching optimal accuracy after about 10-15 min.

During operation

1. Gyro bias can be fully estimated only if:
   a. heading and gravity are both regularly observable (this will be mostly the case when magnetometers are used and proper motion profile is set).
   b. In case of no heading is observable at all (vertical gyroscope operation), the device should be regularly rotated in significantly different orientations for full gyro bias observation. This is also why setting an static initial condition in this mode will greatly improve performance.

5. IG-500A Outputs

The following section describes all IG-500A outputs. Please refer to the IG-Devices Serial Protocol Specifications and IG Devices CAN Protocol Specifications for more information about all outputs such as units.

5.1. Calibrated sensors output

The IG-500A includes 14 calibrated sensors: 3 accelerometers, 3 gyroscopes, 3 magnetometers and 5 temperature sensors. These 14 calibrated sensors values can be outputted by the device. By calibrated value, we mean compensated for any sensor errors (temperature effects, linearity errors, sensor misalignment, gyro-G effect…).

Gyroscopes values

Gyroscopes calibrated values are the three rotational speeds around the device's axes *X*, *Y* and *Z*.

Delta Angles values

1 kHz coning integration output. These angles should be used in the same way as gyroscopes values, but provide better integration accuracy with high dynamic applications. These can be considered as rotational speed around the device's axes *X*, *Y* and *Z*.

Accelerometers values

Accelerometers calibrated values are the three accelerations measured on device coordinate frame.

Magnetometers values

Magnetometers calibrated values reflect the local magnetic field in the device coordinate system. These values are temperature compensated and corrected for soft and hard iron effects (as evaluated in the last calibration procedure).

Magnetometers values are expressed in an arbitrary unit and in homogeneous magnetic field, the norm of the magnetic field vector should be the same in all orientations and ideally equal to 1.0.

Temperature values

The temperature calibrated output is the temperature measured by the external magnetometers and accelerometers temperature sensor, and the internal ADC temperature sensor

Gyroscopes Temperature values

The gyroscopes temperature output is the temperature measured by the three temperature sensors included in the gyroscopes.

> ***Note:*** *The temperature sensors inside the IG-500A have a very good repeatability, required for sensor calibration, but only a poor absolute accuracy, especially the gyroscopes internal temperature sensors.*
>
> *If absolute measurement is needed, the accelerometers/magnetometers temperature sensor should give best results, with an absolute accuracy of [-2/+4] °C over the full -40 to 85 °C range.*
>
> *This accuracy can be enhanced to 0.5°C by performing a bias calibration at +25°C.*

5.2. Orientation and navigation outputs

Euler angles

Euler angles provide Roll, Pitch and Yaw values. (If the device can be rotated in all directions, you would prefer rotation matrix or quaternion forms as they do not suffer from singularities when pitch approaches $\pm\frac{\pi}{2}$.

Rotation Matrix

This form provides the nine coefficients of the rotation matrix representing the IG-500A orientation.

> ***Note:*** *Rotation matrix output is only available with serial output devices (P1, P2 and P4 options)*

Quaternion

The quaternion is the smallest form that provides a full coverage of 3D orientations.

> ***Note:*** *Please refer to chapter 4. to have more information about how orientation can be represented and the coordinate frames of the IG-500A.*

Heave Output

High pass filtered altitude output for wave height measurement. This output is expressed in meters above mean altitude.

5.3. Other outputs

Accuracy indicators

These three indicators represent the attitude accuracy, the velocity accuracy and position accuracy estimates. They can provide good real time information about the robustness of the filter.

Raw sensors output

Accelerometers, magnetometers, gyroscopes and temperatures can be output by the IG-500A in raw form. The raw sensor output is the reading of the Analog to Digital Converter, then filtered by the averaging filter and eventually the low pass filter. These values are not exploitable directly but may sometimes be useful as they reflect the real values of the physical sensors.

Time since last reset

This output provides in ms the time elapsed since the last reset of the IG-500A. This time is measured at the beginning of the sampling and calculation loop of the device.

Device Status

The IG-500A performs at start-up a sensor Self-Test, as well as some internal initialization checks. This self test inform the user of potential device failure. Some other outputs are updated in real time and inform about the health of the Kalman filter.

***Note:** that the sensor self test is only reliable if the device is not moving during start-up.*

Bit	Name	Description
0	SBG_CALIB_INIT_STATUS_MASK	Set to 1 if the calibration structure is well initialized
1	SBG_SETTINGS_INIT_STATUS_MASK	Set to 1 if the settings structure is well initialized
[2 – 4]	SBG_ACCEL_X_SELF_TEST_STATUS_MASK	Set to 1 if the X accelerometer has passed self test
5	SBG_ACCEL_RANGE_STATUS_MASK	Set to 1 if the readings of accelerometers do not exceed operating range.
[6 – 8]	SBG_GYRO_X_SELF_TEST_STATUS_MASK	Set to 1 if the X gyroscope has passed self test
9	SBG_GYRO_RANGE_STATUS_MASK	Set to 1 if the readings of gyroscope do not exceed operating range.
10	SBG_MAG_CALIBRATION_STATUS_MASK	Set to 1 if the magnetic field calibration looks OK
11	SBG_ALTI_INIT_STATUS_BIT_MASK	Set to 1 if altimeter could initialize
12	SBG_GPS_INIT_STATUS_BIT_MASK	Set to 1 if GPS receive could initialize properly
13	SBG_G_MEASUREMENT_VALID_MASK	Set to 1 if gravity is observable sufficiently for proper Kalman filter operation
14	SBG_HEADING_MEASUREMENT_VALID_MASK	Set to 1 if heading is observable sufficiently for proper Kalman filter operation
15	SBG_VEL_MEASUREMENT_VALID_MASK	Set to 1 if velocity is observable sufficiently for proper Kalman filter operation
16	SBG_POS_MEASUREMENT_VALID_MASK	Set to 1 if position is observable sufficiently for proper Kalman filter operation
17	SBG_UTC_VALID_MASK	Bit mask for GPS UTC Validation: Leap Seconds already known
18	SBG_UTC_ROUGH_ACCURACY_MASK	Bit mask for UTC time validation with rough accuracy
19	SBG_FINE_ACURACY_MASK	Bit mask for UTC time synchronization
20	SBG_PROTOCOL_OUTPUT_STATUS_MASK	Set to 1 in protocol normal operational Set to 0 in case of output buffer saturation
[21 – 31]	-	Reserved – Set to 0

Table 11: Device status bit-field

Magnetic field Calibration Data

This buffer contains data used for the SBG Systems Magnetic Calibration tools.

Check the Magnetic calibration tools documentation for more information about this output.

6. Orientation representation

6.1. Coordinate systems

User has to distinguish two coordinate frames when working with an inertial measurement unit, such as the IG-500A. The first coordinate frame is the inertial (or device) coordinate frame, in which values are expressed in this local coordinate frame. This coordinate frame follows the movements of the device. The fixed coordinate frame represents the environment of the device.

In other words, the device frame is moving and rotating in the fixed frame. When the two frames are aligned (*X*, *Y*, *Z* axes of the two frames are aligned), the device should output no rotation (*yaw = pitch = roll = 0*).

In all case, all coordinate systems are "Right handed" and the positive direction for rotations is clockwise in the direction of the axis:

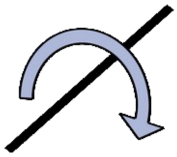


Figure 10: Positive Rotations

6.1.1. Device coordinate system

Below is defined the inertial coordinate frame.

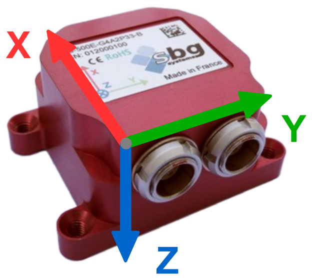


Figure 11: Inertial coordinate frame

6.1.1.1. Origin of the device coordinate system

If highest precision are needed for velocity and position measurements, it may be useful to know the real center of accelerations as measured by the device. The diagram below describes the position of the 3D accelerometer. Note that this information is in general negligible if only accurate orientation is needed.

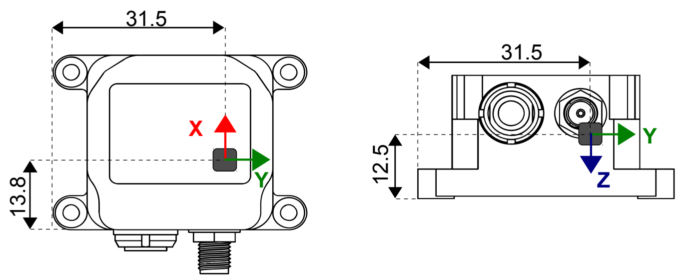


Figure 12: 3D Accelerometer physical location in box version.

Dimension are in mm.

6.1.2. Fixed coordinate system (North – East - Down)

The fixed coordinate frame is defined by these three vectors:

- *X* vector is aligned with the local magnetic north,
- *Z* vector is aligned with the local gravity, turned down,
- *Y* vector is chosen such as the coordinate frame is “right-handed”. Therefore, *Y* is turned toward East.

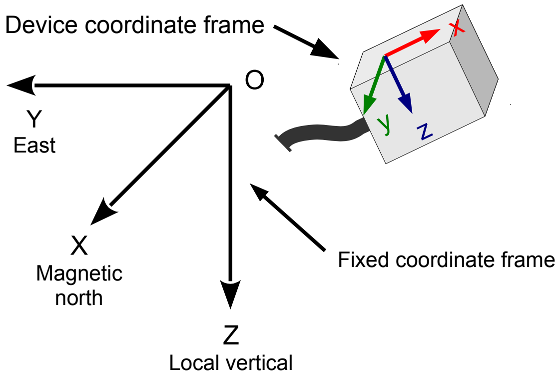


Figure 13: Sensor and fixed coordinate frames

6.1.2.1. Magnetic North vs. true North

By default, the IG-500A is aligned on the local magnetic North. It is important to note that this magnetic North is not aligned with the true North. The difference between the real north direction and the magnetic north direction is called declination.

The magnitude of declination may vary significantly: About 0.5° near Paris, it may grow to 20° in Canada and even more in other locations. The declination depends on the location on Earth, as well as the current date, as the declination may vary over time.

It is possible to set the local magnetic declination in order to align the device orientation with True North.

6.2. Orientation representation

There are several ways to represent the orientation of the device that are provided by the IG-500A. Some are easy to understand, others are very efficient such as quaternion form:

6.2.1. Euler Angles

Euler angles are a commonly used representation of spatial orientation. Euler angles are in fact a composition of rotation from the reference (Earth fixed) frame. This spatial orientation is defined by the sequence of the three rotations around X, Y and Z axis of the fixed frame.

Euler angles are widely used because of their ease of interpretation. 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 sensors has to be used in a wide range of orientations. Quaternion and Rotation matrix do not suffer from this problem.*

6.2.2. 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 sensor coordinate frame to the earth fixed coordinates. The DCM is the combination of the three rotation matrices RM_φ , RM_θ and RM_ψ respectively around Earth *X*, *Y* and *Z* axes.

Here is defined a DCM in terms of Euler Angles:

$$DCM = RM_\psi RM_\theta RM_\varphi$$

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

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

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 sensor coordinate system into the Earth fixed frame, user will use the DCM as expressed below:

$$V_{Earth} = DCM \cdot V_{Sensor}$$

Reciprocally:

$$V_{Sensor} = DCM^{T} \cdot V_{Earth}$$

6.2.3. 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 in terms of the 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 in terms of Euler Angles:

$$q_0 = \frac{1}{2}\sqrt{1 + \cos\theta\sin\psi + \sin\varphi\sin\theta\sin\psi + \cos\varphi\cos\psi + \cos\varphi\cos\theta}$$
$$q_1 = \frac{1}{4q_0}\left(\sin\varphi\cos\theta - \cos\varphi\sin\theta\sin\psi + \sin\varphi\cos\psi\right)$$
$$q_2 = \frac{1}{4q_0}\left(\cos\varphi\sin\theta\cos\psi + \sin\varphi\sin\psi + \sin\theta\right)$$
$$q_3 = \frac{1}{4q_0}\left(\cos\theta\sin\psi - \sin\varphi\sin\theta\cos\psi + \cos\varphi\sin\psi\right)$$

6.2.4. Other useful conversion formulas

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

6.2.4.1. Quaternion to DCM

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

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

6.2.4.2. Quaternion to Euler

Here is the quaternion translated into Euler angles.

$$\varphi=\tan^{-1}\left(\frac{2q_2q_3+2q_0q_1}{2q_0^2+2q_3^2-1}\right)$$
$$\theta=-\sin^{-1}(2q_1q_3-2q_0q_2)$$
$$\psi=\tan^{-1}\left(\frac{2q_1q_2+2q_0q_3}{2q_0^2+2q_1^2-1}\right)$$

6.2.4.3. DCM To Euler

Finally the DCM matrix is converted into Euler Angles.

$$\varphi=\tan^{-1}\left(\frac{DCM_{32}}{DCM_{33}}\right)$$
$$\theta=-\sin^{-1}(DCM_{31})$$
$$\psi=-\tan^{-1}\left(\frac{DCM_{21}}{DCM_{11}}\right)$$

7. Configure your IG-500A

The IG-500A is a widely configurable device. Everything has been done to improve user experience: most of the default configuration should be suitable to all users, but advanced users who desire to tune the IG-500A can do this very deeply. All configurable settings can be saved in the non-volatile memory or not. Thanks to this mechanism, the user can configure his device permanently or temporary depending on his needs.

Indeed, all settings stored in volatile memory will be erased when the device is turned off.

7.1. Protocol configuration

7.1.1. Serial communication versions

7.1.1.1. Baudrate

The following baudrates can be configured on the IG-500A.

`[9 600; 19 200; 38 400; 57 600; 115 200; 230 400 460 800; 921 600]`

Default configuration is 115200 bps.

7.1.1.2. Output mode (serial communication)

On serial communication devices, the output mode contains two configurations that may be combined. This configuration is only provided on the serial communication version.

Endianness		Decimal formats	
Little-endian	**Big-endian**	**Float – double**	**Fixed point 32 – 64 bits**
Words are transmitted with the LSB first	Words are transmitted with the MSB first	Decimal numbers are provided in the standard IEEE 754 format, in single or double precision. All numbers are in float format, except the position data which requires the double precision.	Decimal numbers are provided in fixed point format. **32 bit format** is in [12:20] (1 sign bit, 11 integer bits, 20 fractional bits) **64 bit format** is in [32:32] (1 sign bit, 31 integer bits, 32 fractional bits) All numbers are in 32 bits, except the position data which require 64 bits precision.

Table 12: Serial communications Output format

The default configuration for output mode is big-endian, and float.

> ***Note:*** *The fixed point format requires additional computation time. Therefore, we only advise this output mode in case the host system cannot handle floating point numbers.*

7.1.1.3. Default output mask

The IG-500A protocol allows polling all the output information (sensors data, orientation for example) in one frame. The default output mask is used to configure which information is included in the default output frame.

By default, the default output mask contains a standard set of data:

- Orientation: quaternion, Euler angles
- Gyroscopes, accelerometers and magnetometers calibrated data, and temperature,
- Time since last reset.

7.1.1.4. Normal, Continuous and Triggered modes

Normal mode

The normal mode is a classical Question / Answer mode. Each question of the user is acknowledged or answered by the device. This also means that user has to spend some time to ask his questions.

Continuous mode

The continuous mode allows the unit to send automatically a fixed set of data at a constant rate. This kind of output is very simple and is very efficient as it requires no user action.

Note 1: *The normal mode is still functional while continuous mode is enabled.*

Note 2: *When continuous mode is enabled, some continuous frames can be skipped if the user is asking some other questions and the device's answer is too big for the serial buffer. Normal mode has always priority over the continuous mode. Once the serial buffer is not saturated anymore, the continuous frames will be sent again.*

Triggered mode

In addition to the basic continuous mode, the IG-500A supports a triggered output mode which offers the possibility to send only newly computed data. It is really suitable with data that are not continuously updated such as GPS fix or barometer data. Some triggers inform about newly received/sampled data and can generate the output.

User can activate 4 different triggers conditions (see section 7.1.3.2 for triggers definitions), corresponding to a specific output buffer. All trigger conditions are then combined to generate a unique output frame that contains a trigger mask that informs what triggers are active, an output mask to inform of what data is transmitted and the actual output buffer.

Note : *For some users, it could be interesting to only use a trigger frame on the main filter loop rather than using the traditional continuous mode. Indeed, each trigger frame indicates which data has been updated and the used output mask. This approach can reduce data transmitted on the serial port and perfectly fit for data logging applications.*

7.1.1.5. NMEA and ASCII outputs

The IG-500A is able to provide an ASCII output sentence. Configuration has to be made through the main IG-Devices Serial protocol.

The following message is supported:

Message	Content
$SBG01	Euler angles and orientation accuracy in degrees.

Table 13: Supported ASCII sentences

Each sentence can be enabled with the same mechanism as triggered output; in addition, each sentence can use a specific main loop divider.

Note 1: *Please consult the IG-Devices Serial Protocol Specifications for more details about NMEA and ASCII outputs.*

Note 2: *ASCII protocol requires very high CPU usage. In normal performance mode, you can't output all NMEA messages at 100 Hz. In addition, don't use simultaneously ASCII and binary protocols to avoid CPU overflow.*

If you would like to output all NMEA frames at 100 Hz and/or output both ASCII and binary data, please consider using the High Performance mode.

7.1.2. CAN Bus Version

7.1.2.1. Bitrate and propagation segment

The IG-500A CAN version 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`

Default Configuration is 1 000 kBit/s.

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

7.1.2.2. Frames Identifiers (CAN bus)

CAN devices have to be able to adapt to a user CAN bus. It is possible to configure the device to use standard or extended CAN messages ids. In addition, for each CAN message, handled by the device, it's possible to define it's id or even disable it.

> ***Note:*** *Please check the IG-Devices CAN Protocol Specifications in order to see the best way to configure CAN identifiers*

7.1.2.3. Output modes

On CAN devices, each data has been separated into dedicated frames. Each frame can be configured to be sent automatically or on demand. The following output frames are enabled by default:

- Time since last reset and trigger mask
- 3D orientation using quaternions
- 3D orientation using Euler angles
- 3D position and velocity
- Gyroscopes, accelerometers and magnetometers calibrated data
- Device temperature

Normal mode

The normal mode is a classical Question / Answer mode. Each question of the user is acknowledged or answered by the device. This also means that user has to spend some time to ask his questions.

Continuous/Triggered mode

With the CAN protocol, each output frame can be configured independently to be sent automatically with several conditions. It can be transmitted each time the continuous divider is updated, or at different trigger conditions.

The most important advantage of this communication mode is that once the device is configured, the data is transmitted automatically, at the best update rate.

7.1.3. Common protocol settings

7.1.3.1. Main loop divider

The continuous / triggered outputs can be configured with a main loop frequency divider. The output frequency is then defined as follows:

$$F_{DataOutput} = \frac{F_{Filter}}{divider}$$

When this divider is set to a value larger than one, the IG-500A will send a new output frame each N loops in order to limit output bandwidth.

7.1.3.2. Available Triggers

The following triggers sources can generate outputs. Multiple triggers can be active in the same time so that an output is generated by multiple triggers,

- Main Loop frequency divider trigger (equivalent to the basic continuous mode)
- New magnetometers data available
- New User event input

Note : Please referrer to the IG-Devices Serial Protocol Specifications and IG-Devices CAN Protocol Specifications for more details about triggers configuration and frame definition.

7.2. General purpose configuration

7.2.1. User ID

Each device can be configured with a user ID. This ID can help user to identify sensors if many sensors are connected to the same computer. Default configuration is 0.

7.2.2. User Buffer

As a User ID complement , the IG-500A includes a 64 bytes buffer reserved for user needs. This buffer can be written, read, and saved to non volatile memory.

7.2.3. Synchronization

The IG-500A embeds a synchronization input (hard wired to internal GPS time synchronization pin) and one synchronization output, which can be configured depending on user requirements.

7.2.3.1. Synchronization Inputs

The synchronization input can be configured to fit each application. Here are the different options provided:

- Event type: Disabled, Event input
- Input Sensitivity : Rising Edge, Falling edge, or level change can be set
- Input delay: A custom delay can be added before the event is actually processed.

Note: *The synchronization input is not available on RS-422 versions*

7.2.3.2. Synchronization Output

This single synchronization output allows the user to synchronize its system with the IG-500A. The following options are provided:

- Output type: Main loop start, or Continuous divider trigger
- Output polarity: Rising edge pulse, Falling edge pulse, Level change. When the Rising/falling edge is set, a pulse duration is also configured.

7.3. Kalman filter configuration

The IG-500A Kalman filter can be configured by a set of independent parameters. Theses options provide an easy access to deep sensor behavior configuration.

7.3.1. Motion profiles

The IG-500A Kalman filter is configured through the motion profile. Please check section 2.3 Motion profiles for more information about motion profiles.

The following motion profiles can be implemented into the IG-500A.

- General Purpose
- Airplane
- Airplane – High Dynamics
- Helicopter
- Automotive
- Marine
- Underwater
- Human motion
- IMU 500Hz.

7.3.2. Select heading source

In conjunction with the motion profile, a good heading source has to be configured for proper operation.

Heading Source	Constraints for optimal use	Example application
None	• Static startup assumption may improve initialization performance. • the device needs to be moved in significantly different orientations for bias estimation to be performed properly.	• Vertical gyroscope use (only roll/pitch data used) • Temporary ignore magnetometers
Internal Magnetometers (Default)	• Needs a not disturbed magnetic fled environment • Needs to use the local magnetic declination for optimal results (Done automatically by the sbgCenter)	• Unmanned vehicles • Marine • Aircraft
User heading	• User must feed the device with regular heading information, coming from an external heading sensor. One data per second is a minimum for optimal operation. • User heading information must be aligned with true north.	• Applications where magnetometers cannot be used.

Table 14: Heading sources

7.3.3. Setting the local magnetic declination

When magnetometers are used, it is possible to set the local magnetic declination. The sbgCenter can set the magnetic declination automatically; taking into account the current time and a GPS position. It is also possible to set manually the current declination.

This declination does not affect magnetometers calibrated values, but only the orientation output.

By default the declination is set to 0°.

7.3.4. Setting the local gravity constant

It's possible to configure the local gravity and store it into non volatile memory. This is a good idea to set this information as gravity value can change significantly over the world.

Default value for gravity constant is $g=9.809\,m\cdot s^{-2}$.

7.3.5. Heave computation

If this output is required, User has first to enable the IMU “High performance” mode, and then enable Heave computation. This computation will increase output latency by approximately 2ms.

7.4. Coordinate frames transformation

7.4.1. Pre-Rotations

Sometimes, it is hard to align the device local axes with the object on which it is installed. IG-500A devices have an easy way to manage these kinds of problems. Those three functions allow user to realign the local coordinate frame with the object axes.

We call that kind of transformations "pre-rotations" as it is applied on sensors input. Once this transformation is set, all sensors calibrated data and orientation output will be expressed with respect of the new coordinate frame.

> ***Note:*** *Calibrated sensors are affected by pre-rotations, as well as orientation output.*
>
> *Raw sensor outputs will remain unchanged.*

7.4.1.1. Z Reset

This procedure can be called when the device's *X* axis is not aligned to the object *X* axis.

To perform this calibration procedure, align the object in direction of the magnetic north and call the function. Once performed, the device will express its values in the object coordinate frame.

7.4.1.2. XY Reset

In that kind of reset, we assume that the device is strapped on the object pointing to the same heading (*X* axis of the device is in the *XZ* plane of the object). The object must be set horizontal while calling this function. After reset, the device's sensors data will be realigned in the object coordinate system.

7.4.1.3. XYZ Reset

This function can be used if the device is strapped in a fully arbitrary orientation on the object. The object must be first precisely aligned with the magnetic north and set horizontal for this procedure to be well executed.

> ***Note:*** *Results of Z and XYZ resets in pre-rotations are only valid when magnetometers source of heading is selected.*

7.4.1.4. Manual transformation

Reset functions are easy to execute, but have some limits: It is not always possible to level properly the object, or align it with the magnetic north.

With the manual procedure, user can set a rotation matrix to perform the transformation. This is the best method to keep the full precision of the device.

7.4.2. Post Rotations

So called “post rotations” are transformations that are applied on the orientation output. These transformations allow user to rotate the output coordinate frame.

These post rotations only affect orientation output. Sensors data will stay in the device local coordinate frame.

7.4.2.1. Z Reset

It may be useful that the *Z* axis stays along vertical, while the *X* axis points to a specific direction (for example *X* axis pointing to the screen of a computer). A *Z* reset in post rotation is designed for that purpose. This reset function will set the device's heading to 0.

7.4.2.2. XY Reset

It could be useful to realign the output coordinate to a local horizontal which is different from the real horizontal, while keeping the real north information. If your desk is not perfectly horizontal for example, you can use the post reset *XY* function to realign the output horizontal with your desk.

7.4.2.3. XYZ Reset

When this function is called, orientation is reset to a zero in all angles: roll pitch and yaw, whatever is your orientation. If the screen on which you want to display the IG-500A orientation is not vertical but is fixed on the ceiling or the ground for example, you can simply point the device to the screen, and its orientation will be referenced with respect to the screen.

7.4.2.4. Manual transformation

As for “pre” rotations, a manual transformation of the output is possible, by setting the rotation matrix that may be applied on output.

> ***Note:*** *When the magnetometers source of heading is not selected, a Z reset will act as a reset of the IG-500A, and the XYZ and XY resets will have the same results.*

7.5. Calibration procedures

7.5.1. Magnetometers calibration

As explained in the Magnetic sensors section, a calibration procedure have to be performed when the IG-500A is placed near ferromagnetic objects.

Once the calibration is performed, user can save the results to the non-volatile flash memory.

Note 1: *When using magnetometers for heading, you have to calibrate the magnetometers carefully after installing the IG-500A into your application. If the magnetometers calibration is incorrect, all measurements including roll and pitch could be greatly impacted.*

Note 2: *The whole procedure is described in the Magnetometers Calibration Tools documentation.*

7.5.2. Gyro bias calibration

The onboard Kalman filter performs a live gyro bias estimation. An accurate gyro bias tracking requires some time. In addition, a good heading observability, or significant rotations are required to get accurate and 3D gyro bias tracking.

Some application cannot provide a 3D gyro bias tracking at startup (when the device is stationnary without heading data). In order to get faster Kalman filter convergence, it's possible to use a “no motion” assumption, either automatically at startup or on demand, during sensor operation.

Using such assumption makes it possible to estimate quickly the gyro bias in all three axes.

It's then possible to save a well estimated gyro bias in non volatile memory.

7.6. Advanced options

7.6.1. Power modes

7.6.1.1. IMU power mode

The IG-500A now supports two power modes:

- **Normal mode**, which is the default one and is convenient with most applications.
- **High Performance mode** which allows Heave computation and provides ultra low computational latency. This mode also increase power consumption and higher heat dissipation should be considered if the device has to be operated at high temperature.

7.6.2. Miscellaneous

Finally some various options can be enabled or disabled to fit user needs:

Option	Comments
Use coning integrals for attitude computation	Most of the time it's better to use coning integrals. But in high vibration environments, it can be a better idea to use direct filtered gyroscopes measurements.
Capture gyroscopes bias at device startup for 10s	Allows faster Kalman filter convergence. If a motion is detected during startup, this initialization is ignored.
Capture gyroscopes bias at device startup until a motion is detected	Same as previous option. Gyro estimation is performed until a small movement is detected on gyroscopes. Best for long term stationary runs.
Output unbiased gyroscopes and delta angles	When checked, gyroscopes and delta angles are Kalman filter enhanced; Otherwize, only the factory calibrated sensor data will be provided.
Force the use of an horizontal magnetometer calibration	May be useful in airplane applications when magnetometers cannot get a real in-flight 3D calibration.

7.7. Device default settings

Here are summarized the default parameters for the IG-500A:

Parameter	Default value
Serial protocol	
Protocol mode	115 200 bauds
Output mode	big-endian, float
CAN protocol	
Bit rate	1 000 Kbit/s
Propagation segment	1
Message ids format	Standard identifiers (11 bits)
Common settings	
User ID	0
Default output mask	Quaternion, Euler angles, Gyroscopes, accelerometers, magnetometers calibrated data Device internal temperature, device status, Time since last reset(with triggers for CAN devices)
Output divider	2 (100 Hz / 2 -> 50Hz output)
Motion profile	General Purpose. 100Hz operation
Local Magnetic declination	0°
Heading Source	Internal Magnetometers
Heave computation	Disabled
Local gravity constant	9.809 m.s-2
Power modes	IMU: Normal mode
Sensor pre-rotation	No rotation
Sync Out Pin	Disabled
Sync In Pin	Disabled
Advanced options	Use Coning integrals Output unbiased gyroscopes, delta angles

Table 15: IG-500A Default settings

8. Electrical and mechanical specifications

8.1. Absolute maximum ratings

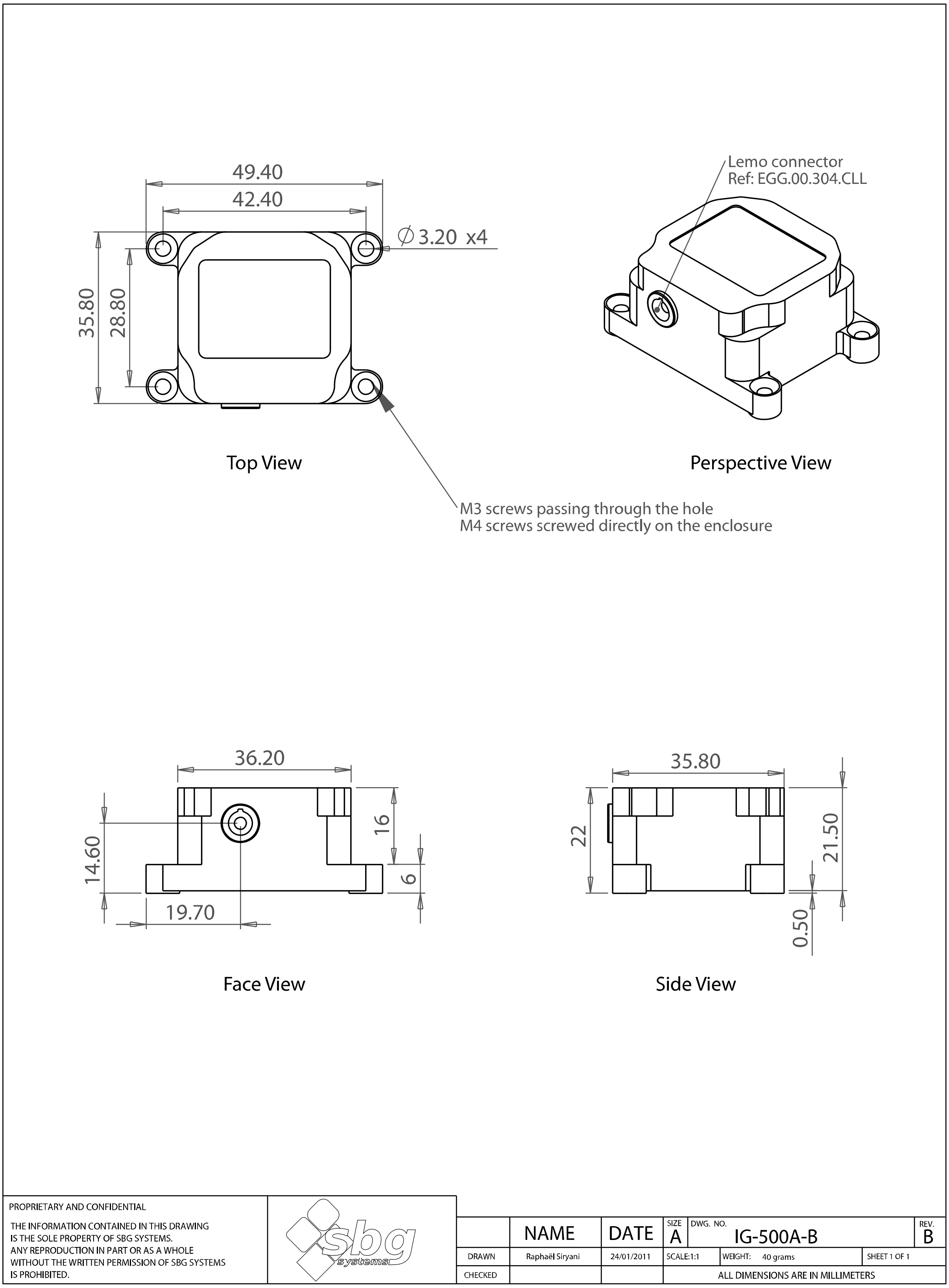
Stresses above those listed under the Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to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

Parameter	Rating
VDD - GND	-0.3 V to 30V
Acceleration (powered)	+ 1 000 g for 0.3ms
Acceleration (unpowered)	+ 2 000 g for 0.3ms
I_{Vreg} (OEM)	10 mA
Rx pin input voltage (OEM)	-0.3V to 4.0V
Rx pin input voltage (Box)	±25V
Logic output voltage	-0,3V - +25V
Logic output Max current	180mA
CANH, CANL (Box)	±80V
Operating temperature range	-40 to 85°C
Storage temperature range	-40 to 85°C

Table 16: Absolute maximum ratings

8.2. Box -B version

8.2.1. Mechanical outline



8.2.2. Device connectors

All signal lines are expressed from IG-500A side. For example, Tx line is IG-500A Tx so it's an output.

8.2.2.1. Main connector

The main connector is a Lemo receptacle which mates with a four wire Lemo connector, ref `FGG.00.304.CLAD35`. Other suppliers such as ODU provide compatible connectors (ref `S1L0C-P04MCC0-3500`).

Figure 14: The FGG.00 Lemo plug

Pins numbering is the following:

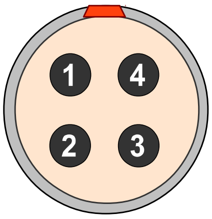


Figure 15: FGG 4 way Lemo connectors pin-out (Solder Face)

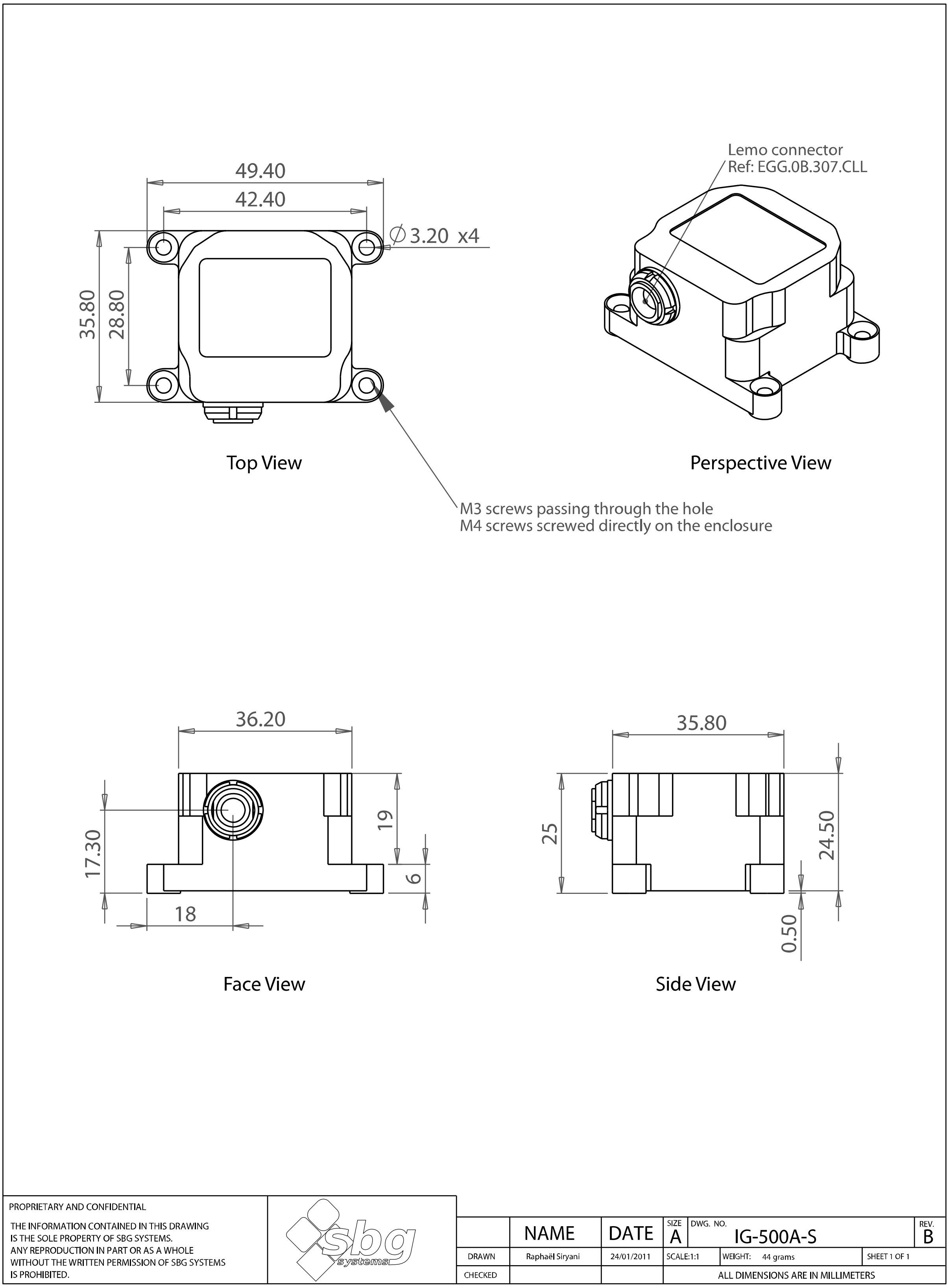
The main connector contains the power supply and all necessary signals to communicate directly with the IG-500A.

Pin	Name	Description	Type
1	RX	Serial input	INPUT
2	TX	Serial output	OUTPUT
3	GND	Ground	SUPPLY
4	VDD	Supply voltage	SUPPLY

Table 17: Main connector pin-out

8.3. Box -S version

8.3.1. Mechanical outline



8.3.2. Box device connector

All signal lines are expressed from IG-500A side. For example, Tx line is IG-500A Tx so it's an output.

8.3.2.1. Main connector

The Main connectors is a Lemo receptacle which mates with a seven way Lemo connector, ref FGG.0B.307.CLAD35. Other suppliers such as ODU provide compatible connectors.

Figure 16: The FGG.0B Lemo plug

Pins numbering is the following for both connectors:

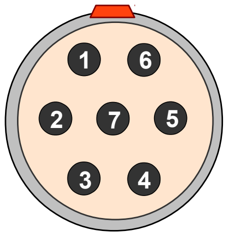


Figure 17: FGG 7 way Lemo connectors pin-out (Solder Face)

Main connector

The main connector contains the power supply and all necessary signals to communicate directly with the IG-500A. Depending on the protocol used, the pins connections are the following:

Pin	Signals version P1/P2, RS-232	Signals Version P3 : CAN 2.0	Signals Version P4: Rs 422
1	VCC	VCC	VCC
2	GND	GND	GND
3	-	Sync In	Tx+
4	Tx	-	Tx-
5	Rx	CANH	Rx+
6	Sync In	CANL	Rx-
7	Sync_Out	Sync_Out	Sync_Out

Table 18: Main connector pin-out

9. Warranty and Support

Support information

Our goal is to provide the best experience to our customers. If you have any question, comment or problem with the use of your IG-500A, we would be glad to help you, so please feel free to contact us. Please do not forget to mention your IG-500A Device ID (written on your IG-500A's label).

You can contact us by:

- Email : support@sbg-systems.com
- Phone : +33 (0)1 80 88 45 00

Warranty

All products shipped by SBG Systems are provided with a 1 (ONE) year warranty, from date of shipment.

Return procedure

Before returning any product, please contact the support team. SBG Systems will not accept any return without a valid RMA (Return Merchandize Authorization) provided by SBG Systems.

SBG Systems provide the detailed return procedure on demand by email or phone.

Postal Address

Use the following address for all product returns.

SBG Systems
S.A.V.
3bis, chemin de la Jonchère
92500 Rueil Malmaison
FRANCE

10. Appendix: Accessories

10.1. UsbToUart interface

For RS-232 and RS-422 products, the development kit provides the UsbToUart interface. It features the following characteristics:

- 64x42x20 mm box
- 3 meters long cable
- USB 1.1 or higher compatible
- Communication speed allowed up to 921 600 bps
- IG-500 device is directly powered by the USB port.
- Operating temperature range: 0 – 70°C

Figure 18: UsbToUart interface

The following ordering codes are available:

Ordering code	Description
USB2UART-P1-B	Interface used with the RS-232 output, with a 4 way cable (no synchronization devices)
USB2UART-P1-S	Interface used with the RS-232 output, with a 7 way cable (synchronization enabled devices)
USB2UART-P2-O	Interface used with TTL serial versions, in OEM (the IMU is fixed on the usb2uart board). Interface used for RS-422 devices.
USB2UART-P4-S	Interface used for RS-422 devices.

Table 19: USB2UART Ordering codes

10.2. CAN specific cables

10.2.1. UsbToCAN interface

CAN devices development kit is shipped with the UsbToCan interface. It has the following characteristics:

- Transfer rates up to 1 Mbit/s
- Compliant with CAN 2.0A and 2.0B
- CAN bus connection via D-Sub, 9-pin (to CiA® 102)
- NXP SJA1000 CAN controller
- 82C251 CAN transceiver
- Operating temperature: -40 – 85°C

Ordering code: **USB2CAN**

Figure 19: USB2CAN interface

10.2.2. CAN to USB2CAN cable

The CAN development kit also includes a cable required to connect the IG-500A to the USB2CAN interface. It has the following features:

- 3 meters long shielded cable with twisted pairs for data transmission.
- Connector A: Lemo FGG.0B.307.CLAD35
- Connector B: Standard Sub D9
- Connector C: 2,1mm Jack connector for power supply
- 60Ω resistor included for CAN bus termination.

Ordering code: **CA-3M-7-CAN**

Figure 20: CA-3M-7-CAN cable

10.2.3. Power Adapter

The power adapter included in the CAN devices Development Kit provides the IG-500A power supply. It has the following features:

- 1.8m cable length
- US, UK and Europe standards, support
- 12 V output @ 500mA
- Operating temperature range: 0 – 40°C

Ordering code: **CA-POWER**

Figure 21: Power adapter

10.3. Other cables

Those cables provide rapid access to the IG-500A without having to manage the Lemo plug soldering. They consist on a 3m cable, connected on one side to the IG-500A Lemo plug, and on the other side to a 1.25mm Molex connector.

Figure 22: Straight cables

10.3.1. 4 ways cable

This cable fits with the -B devices (RS-232, without synchronization features).

- Connector A: Lemo FGG.00.304.CLAD35
- Connector B: Molex 51021-0400

The connections on the MOLEX connector are described in the table below:

Pin	Connection	Color (Old cable)	Color (New cable)
1	GND	**Black**	**Black**
2	IG-500 Tx	**Green**	**Yellow**
3	IG-500 Rx	**Blue**	**Red**
4	VCC	**Red**	**Pink**

Table 20: 4 ways 3 meters cable pin-out

Ordering code: **CA-3M-4-UART**

10.3.2. 7 ways cable

This cable fits with the -S devices (RS-232, RS-422 or CAN devices, with synchronization features).

- Connector A: Lemo FGG.0B.307.CLAD35
- Connector B: Molex 51021-0700

The connections on the MOLEX connector are described in the table below:

Pin	Color	Signal with P1 version (RS-232)	Signals with P4 versions (RS-422)	Signals with P3 version (CAN 2.0)
1	**Red**	VCC	VCC	VCC
2	**Black**	GND	GND	GND
3	**Yellow**	-	Tx+	Sync In
4	**Green**	Tx	Tx-	-
5	**Blue**	Rx	Rx+	CANH
6	**Brown**	Sync In	Rx-	CANL
7	**White**	Sync_Out	Sync_Out	Sync_Out

Table 21: 7 ways 3meters cable pin-out

Ordering code: **CA-3M-7-UART**