

**ADVANCED
NAVIGATION**

Motus Reference Manual



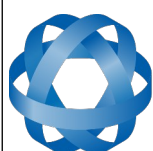


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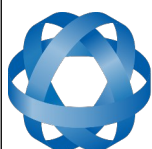
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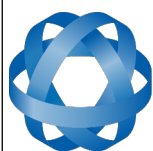
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1 Revision History

Version	Date	Changes
2.6	14 November 2023	Updated Software changelog, section 12.1 Updated automatic magnetometer calibration explanation to reflect Firmware changes, section 11.5.3 Updated Disclaimer
2.5	20 February 2023	Updated Software changelog, section 12.1 Updated software installation information to include Java 11 requirement, section 12.3 Added instructions to run Manager on MacOS, section 12.3
2.4	12 October 2022	Updated Software changelog, section 12.1 Updated product part numbers, section 8 Added Device ID table, section 16.8.4.1 Updated Log Converter information to include log path configuration, section 12.9.3 Added breakout cables to list of accessories, section 8.4 Updated connector pinout to include RS422, section 9.10 Added RS422 breakout cable information, section 9.12.2 Added ODU connector pin location diagram, section 9.10 Clarified geoid, ellipsoid and orthometric heights, section 5.7 Updated External Time Packet to show it is Read only, section 16.7 Added note that Motus Manager only works on systems with x64 architecture, sections 7.2 and 10.1
2.3	25 October 2021	Updated firmware changelog section 2 Updated hardware changelog section 3
2.2	12 July 2021	Updated firmware changelog section 2 Improved power supply specifics section 13.4 & 14.5
2.1	22 January 2021	Updated firmware changelog section 2 Updated hardware changelog section 3 Updated OEM images section 13, 14 & 14.4
2.0	28 October 2020	Update for v2 Hardware, sections 9, v1 hardware now obsolete Update Manager section 12 Updated OEM drawings and detail, sections 13 and 14
1.1	29 November 2019	Updated firmware changelog 2 Updated hardware changelog 3 Updated dynamic pin functions table 15.4 Updated GPIO configuration packet 16.10.7 Added pressure depth transducer deprecated input function 15.4.16 Added Nortek DVL input function 15.4.24 Added Teledyne DVL input function 15.4.20 Added Tritech USBL input function 15.4.21 Added Linkquest DVL input function 15.4.22 Added Linkquest USBL input functionality 15.4.23 Added reverse alignment input functions 15.4.41 Added zero angular velocity input function 15.4.43



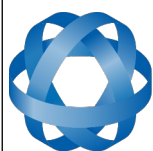
Version	Date	Changes
		Clarified port baud rates in sections 9.4 , 15.1 , 15.3 and 16.10.3 Updated read status for external air data packet 16.7 Updated read status for external odometer packet 16.9.40 Modified quaternion element labels 16.9.8 and 16.9.21 Clarified geoid height packet description 16.9.35 Removed external pitot pressure packet 16.9.36 Updated external body velocity packet size and definition 16.9.28 Added wheel speed sensor specifications 15.4.28 Corrected Raw GNSS packet velocity units 16.9.10 Updated GPIO output configuration packet 16.10.14 Clarified negative acknowledgement packets 16.8.1 Clarified 1PPS output voltages 15.4.1 Updated specifications 9 Clarified navigation specifications 9.2 Corrected power supply drop out voltage 10.4 Added odometer information to Installation chapter 10.5 Added magnetics information to Installation chapter 10.6 Updated operating temperature information 11.12.1 Corrected IP rating of rugged enclosure 9.6 and 11.12.2 Clarified raw GNSS data output packets 16.9.10 , 16.9.11 , 16.9.12 Corrected system status and filter status flags 16.9.1.1 , 16.9.1.2 Corrected raw sensors packet fields 16.9.9
1.0	17 March 2016	Initial Release

Table 1: Revision history

2 Firmware Changelog

Version	Date	Changes
2.3	6 September 2021	Update to support hardware v2.3 Fix Magnetometer Axis Swap for hardware v2.0
2.2	29 June 2021	Fix Magnetometer axis swap for hardware v2.1 and v2.2
2.1	14 December 2021	Bug fix for calibration issue (magnetometer scaling) Minor fixes to magnetic initialisation
1.8	2 March 2020	Support for v2 hardware
1.6	28 November 2019	Improvements to raw sensor calibration algorithm Prevents fast temperature variations from introducing digital noise into accelerometer values which was regression from firmware version 1.4
1.5	03 October 2019	Improvements to raw sensor calibration algorithm More accurate temperature compensation of sensors leads to overall performance improvement Improvements to heading integrity monitoring algorithm to better reject erroneous measurements
1.4	05 September 2019	Improvements to raw sensor calibration algorithm Better sensor performance through rapid temperature changes leads to performance improvement in cases of fast temperature ramps
1.3	31 May 2019	Improvements to integrity monitoring allows better rejection of erroneous position and velocity data
1.1	17 July 2018	New zero angular velocity functionality Better hot start performance
1.0	01 March 2016	Initial release

Table 2: Firmware changelog



3 Hardware Changelog

Version	Date	Changes
2.3	6 September 2021	Pressure sensor update
2.2	29 September 2020	Internal manufacturing improvements
2.0	04 September 2020	Minor changes to the baseplate thickness. No increase to overall height, length or width Added alignment markings to baseplate Improved sensor performance Removal of 0.2 mm material from the inner area of the base of the housing to make mounting onto uneven surfaces easier
1.4	16 July 2018	Internal manufacturing improvements No noticeable changes for customers
1.3	07 September 2017	Improvements to ADC synchronisation results in slightly improved performance under high dynamics
1.2	05 October 2016	Internal manufacturing improvements
1.0	14 September 2015	Initial release

Table 3: Hardware changelog



4 Introduction

Motus is a miniature ultra high accuracy MEMS IMU/AHRS. It features some of the highest accuracy MEMS accelerometers and gyroscopes currently available, combined with magnetometers. Motus is extensively calibrated for all sensor errors over a wide temperature range.

It can be software upgraded to offer GNSS/INS functionality, through the use of an external GNSS receiver.

It is available in both OEM and enclosed (rugged) packages.

Motus will provide outstanding results when mounted, configured and operated correctly. Please read through this manual carefully to ensure a successful outcome for your application.

If you have any questions please contact support@advancednavigation.com.



5 Foundation Knowledge

This chapter is a learning reference that briefly covers knowledge essential to understanding Motus and the following chapters. It explains the concepts in simple terms so that people unfamiliar with the technology may understand it.

5.1 GNSS

GNSS stands for global navigation satellite system. A GNSS consists of a number of satellites in space that broadcast navigation signals. These navigation signals can be picked up by a GNSS receiver on the earth to determine that receiver's position and velocity. For a long time the only operational GNSS was the United States GPS. However, the Russian GLONASS, the Chinese BeiDou GNSS, and the European Union's Galileo GNSS are fully operational.

GNSS is excellent for navigational purposes and provides fairly accurate position (2.5 metres) and velocity (0.05 metres/second). The main drawback of GNSS is that the receiver must have a clear signal from at least 4 satellites to function. GNSS satellite signals are very weak and struggle to penetrate through buildings and other objects obstructing view of the sky. GNSS can also occasionally drop out due to disturbances in the upper atmosphere.

5.2 INS

INS stands for inertial navigation system. An inertial navigation system can provide position and velocity similar to GNSS but with some big differences. The principle of inertial navigation is the measurement of acceleration. This acceleration is then integrated into velocity. The velocity is then integrated into position. Due to noise in the measurement and the compounding of that noise through the integration, inertial navigation has an error that increases exponentially over time. Inertial navigation systems have a very low relative error over short time periods but over long time periods the error can increase dramatically.

5.3 GNSS/INS

By combining GNSS and INS together in a mathematical algorithm, it is possible to take advantage of the benefits of GNSS long-term accuracy and INS short-term accuracy. This provides an overall enhanced position and velocity solution that can withstand short GNSS drop outs.

5.4 AHRS

AHRS stands for attitude and heading reference system. An AHRS uses accelerometers, gyroscopes and magnetometers combined in a mathematical algorithm to provide orientation. Orientation consists of the three body angles roll, pitch and heading.

5.5 The Sensor Co-ordinate Frame

Inertial sensors have 3 different axes: X, Y and Z and these determine the directions around which angles and accelerations are measured. It is very important to align the axes correctly in installation otherwise the system won't work correctly. These axes are marked on the top of the device as shown in Illustration 1 below with the X axis pointing in the direction of the connector, the Z axis pointing down through the base of the unit and the Y axis pointing out of the starboard side.

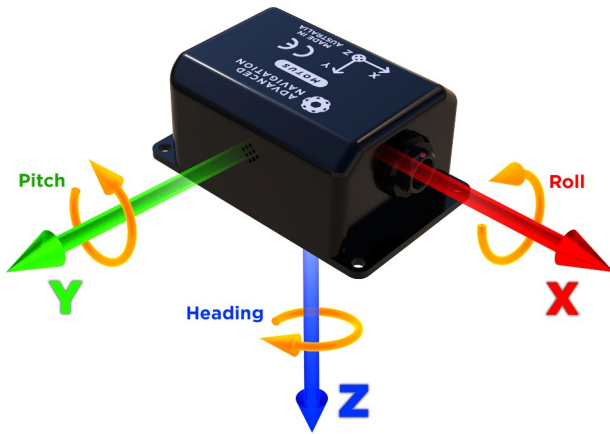


Illustration 1: Motus axes

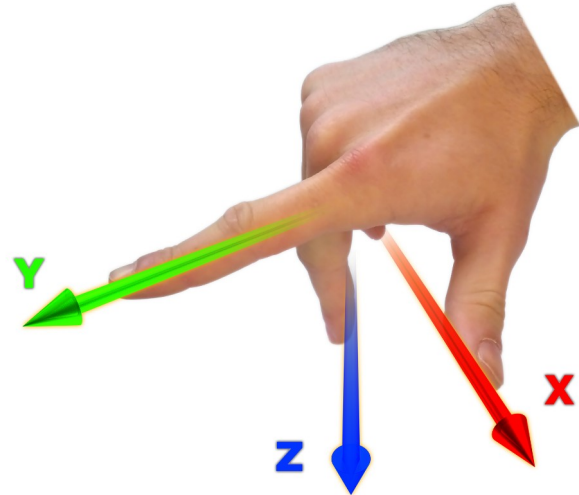


Illustration 2: First right hand rule

When installed in an application the X axis should be aligned such that it points forwards and the Z axis aligned so that it points down when level. A good way to remember the sensor axes is the right hand rule, which is visualised in Illustration 2. You take your right hand and extend your thumb, index and middle. Your thumb then denotes the X axis, your index denotes the Y axis and your middle denotes the Z axis.

5.6 Roll, Pitch and Heading

Orientation can be described by the three angles roll, pitch and heading, these are known as the Euler angles. The rotation axes of roll, pitch and heading are shown visually in Illustration 1. The arrow indicates the positive rotation direction.

Roll is the angle around the X axis and is zero when the unit is level. Pitch is the angle around the Y axis and is zero when the unit is level. Heading is the angle around the Z axis and is zero when the positive X axis is pointing to true north.

5.6.1 Second Right Hand Rule

The two right hand rules are often the best way to memorise the sensor axes and directions of positive rotation. The first right hand rule gives the positive axis directions and is described in section 5.5. The second right hand rule shown in Illustration 3 provides the direction of positive rotation. To use it, point your thumb in the positive direction of that axis, then the direction that your fingers curl over is the positive rotation on that axis.

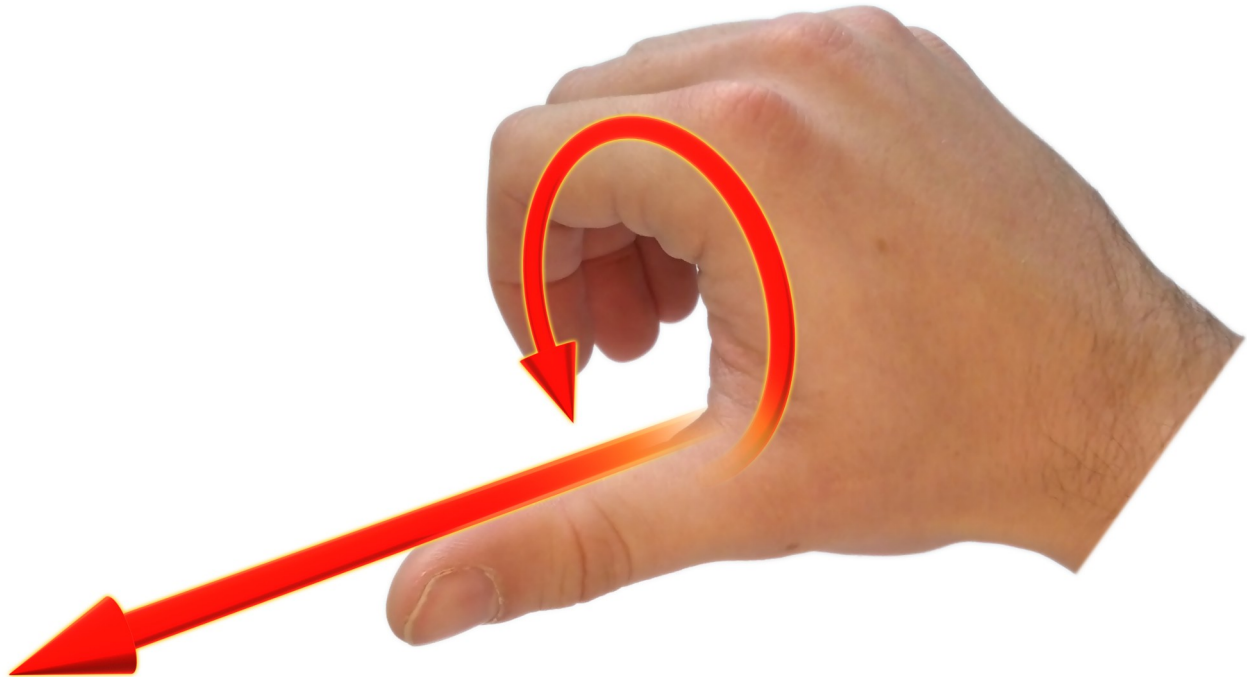


Illustration 3: Second right hand rule

5.6.2 Rotation Order

When multiple axes are rotated, to imagine the final orientation the three rotations must be performed in the order heading first, then pitch and then roll. To deduce the final orientation the unit should first be considered level with the X axis pointing north and the Z axis pointing down. Heading is applied first, then pitch is applied and finally roll is applied to give the final orientation. This can be hard for some people to grasp at first and is often best learned experimentally by rotating Motus with your hand whilst watching the orientation plot in real time on the computer.

5.7 Geodetic Co-ordinate System

The geodetic co-ordinate system is the most popular way of describing an absolute position on the Earth. It is made up of the angles latitude and longitude combined with a height relative to the ellipsoid.

5.7.1 Longitude and Latitude

Latitude is the angle that specifies the north to south position of a point on the Earth's surface, reported as $\pm 90^\circ$. Longitude is the angle that specifies the east to west position of a point on the Earth's surface, reported as $\pm 180^\circ$. The line of zero latitude is the equator and the line of zero longitude is the prime meridian. Illustration 4 shows how latitude and longitude angles are used to describe a position on the surface of the Earth.

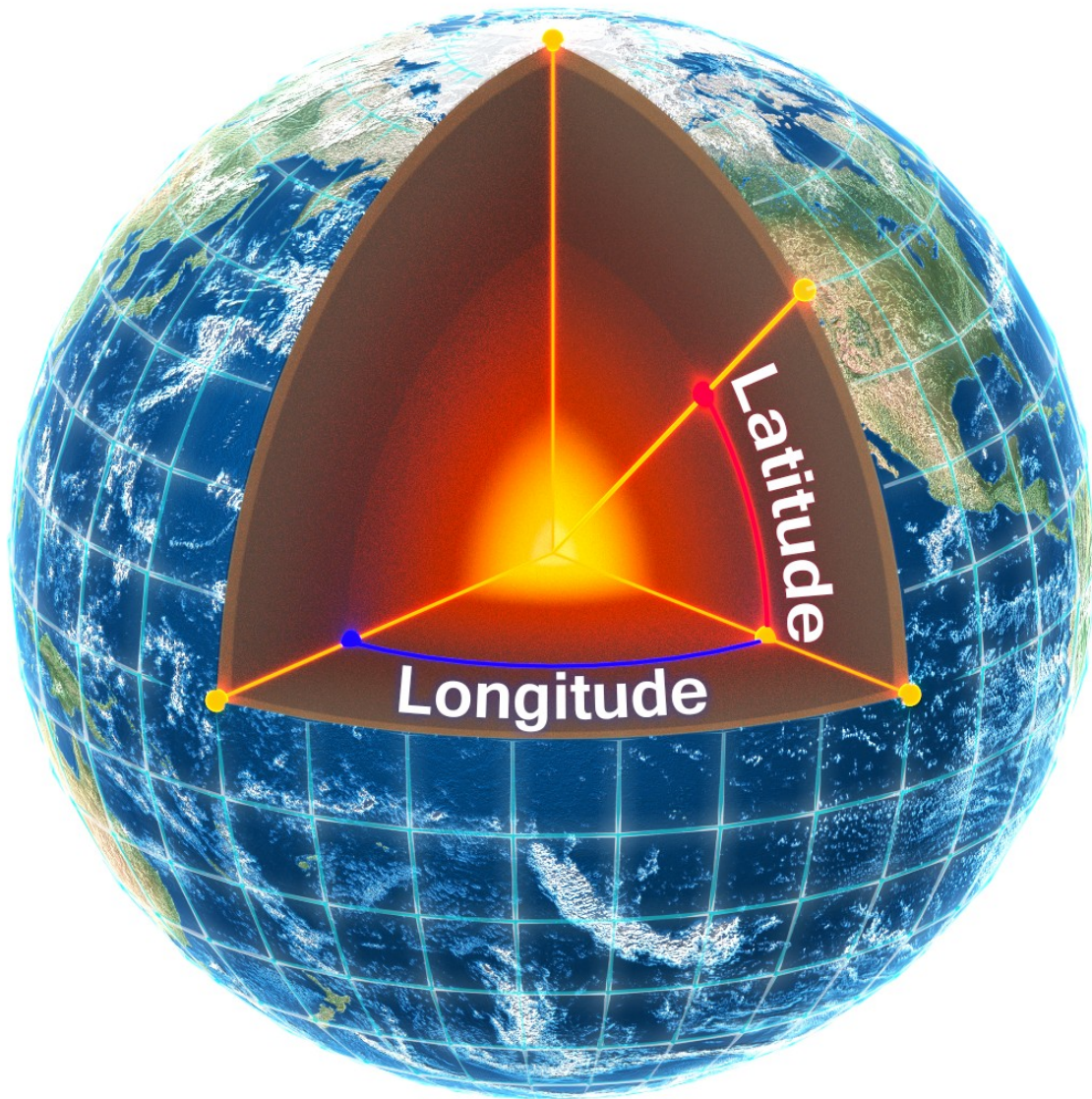


Illustration 4: Latitude and longitude represented visually to describe a position

Illustration 5 shows latitude and longitude on a map of the world, represented with a standard Mercator projection.

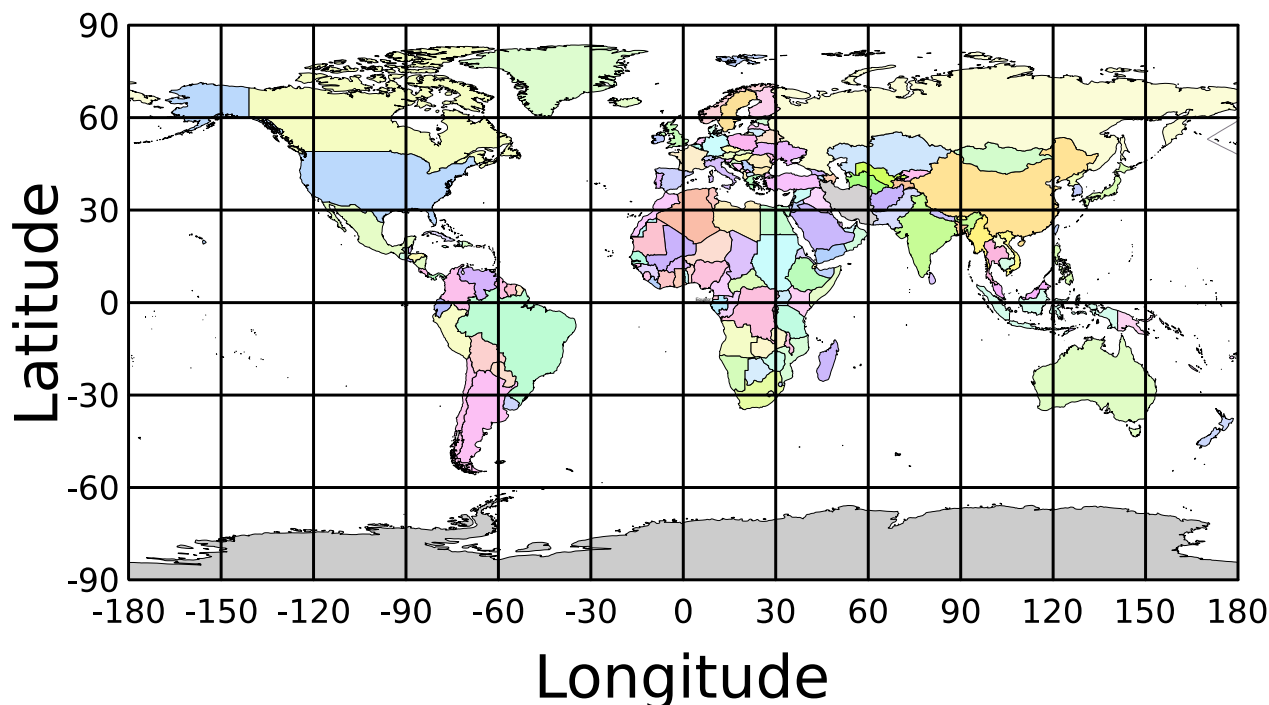


Illustration 5: World map showing latitudes and longitudes

Latitude and longitude give the 2D point on the surface of the Earth. These are combined with height to give the 3D position on the Earth.

5.7.2 Height

Any height data output by Advanced Navigation devices is the height referenced the WGS84 reference ellipsoid. The WGS84 reference ellipsoid is a smooth mathematical model that approximates the form of the surface of the earth. The ellipsoid height (as used by GNSS) is not referenced to mean sea level; the height from the EGM96 geoid (orthometric height) approximates the height above mean sea level (MSL).

See Illustration 6 below for a visual representation of geoid height, ellipsoid height and orthometric height (height above mean sea level).

Note:

- Ellipsoid height refers to the height of a point of interest referenced to the WGS84 reference ellipsoid
- Geoid height refers to the height of the EGM96 geoid referenced to the WGS84 reference ellipsoid at a point of interest
- Orthometric height is the height at a point of interest referenced to the EGM96 geoid.

All heights can be either positive or negative dependant upon direction from the reference surface.



$$H = h - N$$



Illustration 6: Orthometric, ellipsoid and geoid height diagram

The value required to convert the WGS84 ellipsoid height to orthometric height can be found in the geoid height packet, see section 16.9.35 .

5.8 NED Co-ordinate Frame

The NED (North East Down) co-ordinate frame is used to express velocities and relative positions. The origin of the co-ordinate frame can be considered the current position. From that origin, the north axis points true north and parallel to the line of longitude at that point. The east axis points perpendicular to the north axis and parallel to the line of latitude at that point. The down axis points directly down towards the centre of the Earth. See Illustration 7 for a graphical representation of the NED co-ordinate frame at a position on the Earth.

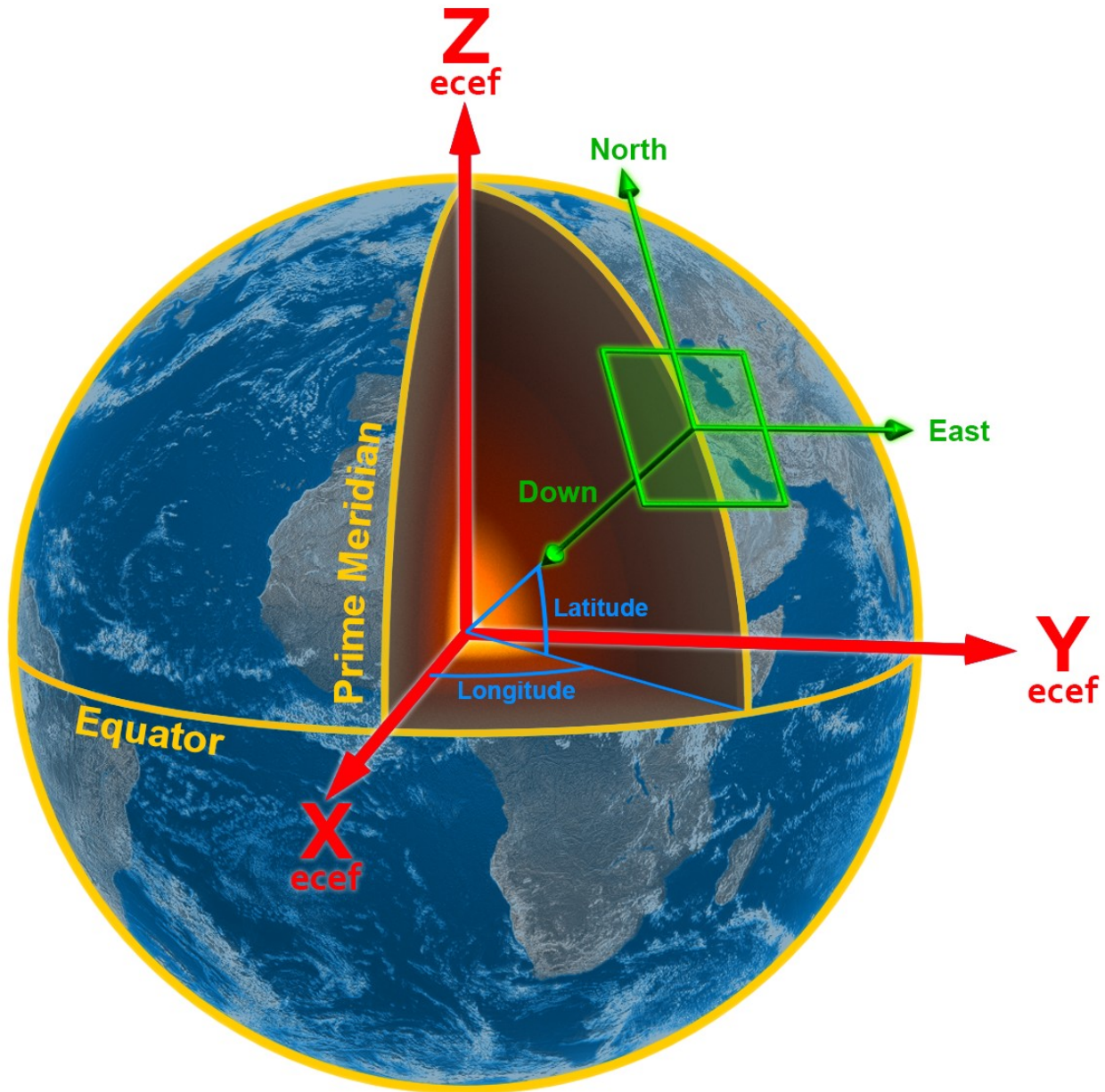


Illustration 7: Graphic showing geodetic, NED and ECEF co-ordinates

5.9 ECEF Co-ordinate Frame

The ECEF (Earth-centred earth-fixed) co-ordinate frame is a Cartesian co-ordinate frame used to represent absolute positions on the Earth. It's origin is at the centre of the Earth. ECEF is an alternative to the geodetic co-ordinate frame. It is represented by the three axes X, Y and Z which are presented graphically in Illustration 7. ECEF positions can be retrieved from Advanced Navigation products however the geodetic system is used as the default.

6 Rugged Evaluation Kit

Motus is supplied in an evaluation kit that contains everything required to get started operating the system right away. The evaluation kit is supplied in a plastic carry case to protect the equipment during shipping.



Illustration 8: Motus Evaluation Kit case



Illustration 9: Motus Evaluation Kit contents

6.1 Kit Contents

1. Motus Rugged unit
2. 2 metre USB to RS232 cable, part number A503-SDC20796, see section 9.11

6.2 Quick Start

1. Plug the interface cable into Motus.
2. Plug the USB end of the interface cable into your computer.
3. Download the Motus Manager software from the Motus page of the Advanced Navigation website.

Java 11 is required to run Motus Manager. Adoptium JRE 11 is the recommended Java installer to be used on all platforms. Install the latest version of Java 11 from [Adoptium](https://adoptium.net/), selecting the correct operating system and architecture for your computer.

Note: Spatial FOG Manager is only available for systems with x64 and ARM architectures.

4. Click the connect button in Motus Manager.
5. The various windows in Motus Manager can be used to view the real time data.
6. To view the data logs, click disconnect in Motus Manager. In the Tools menu, select Log Converter and press Convert. The *.anpp binary log file will be converted to CSV files that can be opened with popular data processing programs such as Matlab or Microsoft Excel. The log files can be found in the same folder as the Motus Manager software.

7 OEM Evaluation Kit

Motus OEM is supplied in an evaluation kit that contains everything required to get started operating the system right away. The evaluation kit is supplied in a plastic carry case to protect the equipment during shipping.



Illustration 10: Motus OEM Evaluation Kit case



Illustration 11: Motus OEM Evaluation Kit contents

7.1 Kit Contents

1. Motus OEM unit
2. Motus OEM development board
3. Mini USB cable

7.2 Quick Start

1. Mount the Motus OEM unit onto the Motus OEM development board and screw it down.
2. Plug one end of the USB cable into the Motus development board and the other end into your computer.
3. Download the Motus Manager software from the Motus page of the Advanced Navigation website. Java is required to run the software. Java is available from <http://www.java.com> if not already installed.

Note: Motus Manager is only available for systems with x64 and ARM architectures.

4. Click the connect button in Motus Manager.
5. The various windows in Motus Manager can be used to view the real time data.
6. To view the data logs, click disconnect in Motus Manager. In the Tools menu, select Log Converter and press Convert. The *.anpp binary log file will be converted to CSV files that can be opened with popular data processing programs such as Matlab or Microsoft Excel. The log files can be found in the same folder as the Motus Manager software.

8 Part Numbers and Ordering Options

8.1 Evaluation Kit

Part Number	Description	Notes
MOTUS2-RUG-EK	Motus Rugged Evaluation Kit (RS232)	Motus rugged evaluation kit Includes items listed in section 6.1 IMU/AHRS functionality only INS upgrade license can be purchased separately, see section 8.3
MOTUS2-OEM-EK	Motus OEM Evaluation Kit (RS232)	Motus OEM evaluation kit Includes items listed in section 7.1 IMU/AHRS functionality only INS upgrade license can be purchased separately, see section 8.3

Table 4: Evaluation kit part numbers

8.2 Standalone Unit

Part Number	Description	Notes
MOTUS2-RUG	Motus Rugged Unit (RS232)	Motus rugged unit No cables included IMU/AHRS functionality only INS upgrade license can be purchased separately, see section 8.3
MOTUS2-RUG-422	Motus Rugged Unit (RS422)	As above With optional RS422 interface instead of standard RS232 interface
MOTUS2-OEM	Motus OEM Unit (RS232)	Motus OEM unit No cables included IMU/AHRS functionality only INS upgrade license can be purchased separately, see section 8.3

Table 5: Standalone unit part numbers

8.3 Software License Upgrades

The license upgrade can be purchased when ordering the unit or purchased later

Part Number	Description	Notes
MOTUS2-LIC-INS	INS license upgrade for Motus	Software license upgrade for Motus INS functionality.

Table 6: Software license upgrade part numbers

8.4 Accessories

Part Number	Description	Notes
A503-SDC20796	ODU plug to FTDI USB cable	Motus rugged ODU plug with 2 metres of cable to FTDI USB plug, see section 9.11
A503-SDC20740-2M	ODU plug with 2m cable (unterminated)	Motus rugged ODU plug with 2 metres of unterminated cable, see section 9.10
A503-SDC20740-5M	ODU plug with 5m cable (unterminated)	Motus rugged ODU plug with 5 metres of unterminated cable, see section 9.10
A503-SDC20740-10M	ODU plug with 10m cable (unterminated)	Motus rugged ODU plug with 10 metres of unterminated cable, see section 9.10
A503-SDC20740-20M	ODU plug with 20m cable (unterminated)	Motus rugged ODU plug with 20 metres of unterminated cable, see section 9.10
A503-SDC20753	ODU to D9 connectors and DC socket (RS232)	Motus rugged ODU plug with 2m of cable to industry standard D9 connectors and DC socket, see section 9.12.1
A503-SDC20755	ODU to D9 connectors and DC socket (RS422)	Motus rugged ODU plug with 2m of cable to industry standard D9 connectors and DC socket, see section 9.12.2

Table 7: Accessories part numbers



9 Specifications

9.1 Mechanical Drawings

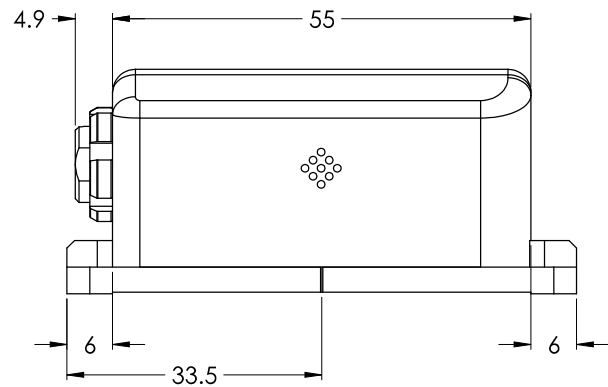
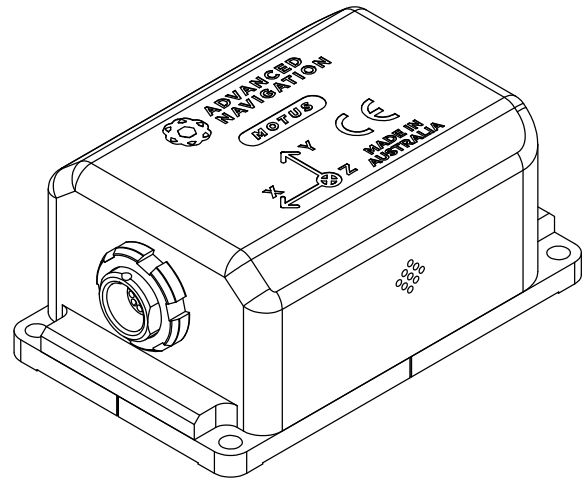
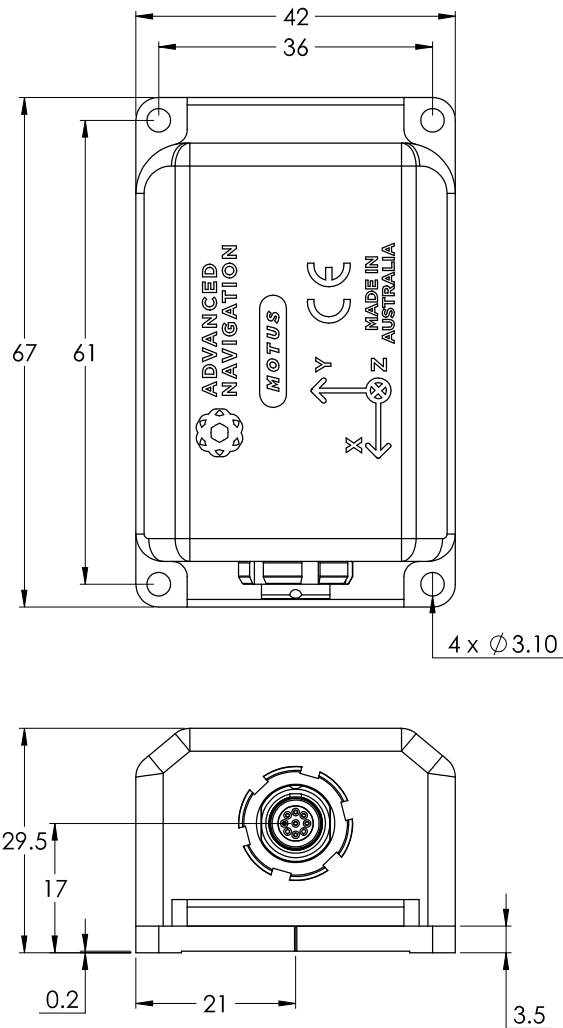


Illustration 12: Motus rugged mechanical drawings

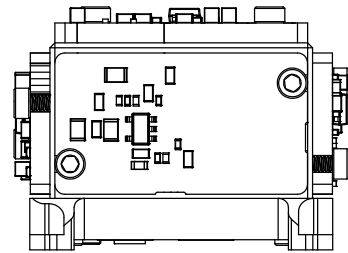
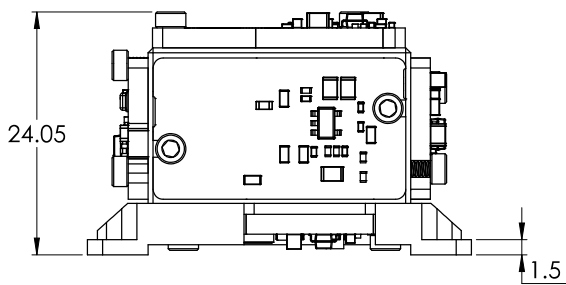
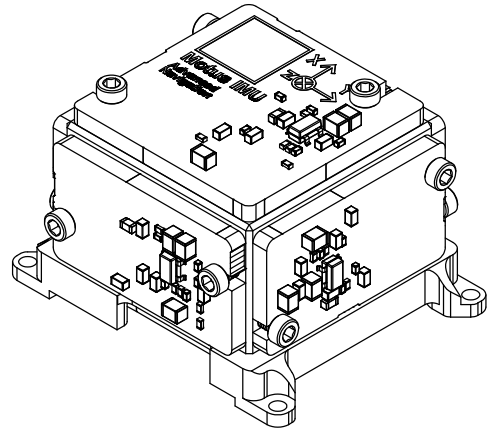
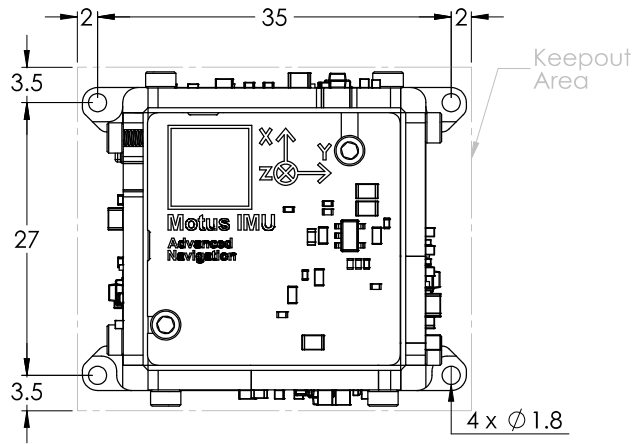


Illustration 13: Motus OEM mechanical drawings

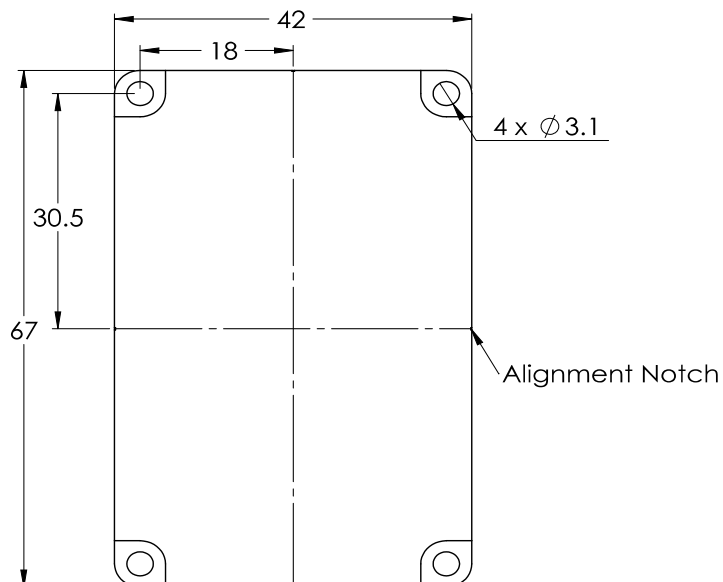


Illustration 14: Motus mounting plate

9.2 Navigation Specifications

Motus as a standalone IMU/AHRS can achieve the following performance:

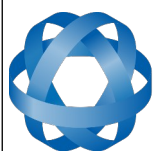
Parameter	Value
Roll & Pitch Accuracy	0.05 °
Heading Accuracy (magnetic)	0.8 °
Orientation Range	Unlimited
Hot Start Time	500 ms
Internal Filter Rate	1000 Hz
Output Data Rate	Up to 1000 Hz

Table 8: Orientation specifications

Motus software license upgrade required for use of INS capability. As an INS it can be interfaced to any of the leading brands of GNSS receivers to create an OEM GNSS/INS solution. When using a Trimble MBTwo receiver, for example, the following specifications are achievable:

Parameter	Value
Horizontal Position Accuracy	0.8 m
Vertical Position Accuracy	1.5 m
Horizontal Position Accuracy (RTK)	0.008 m
Vertical Position Accuracy (RTK)	0.015 m
Velocity Accuracy	0.007 m/s
Roll & Pitch Accuracy (GNSS aided)	0.03 °
Heading Accuracy (GNSS aided)	0.1 °
Heading Accuracy (dual antenna GNSS)	0.05 °

Table 9: Navigation specifications (with external GNSS)



9.3 Sensor Specifications

Parameter	Accelerometers	Gyroscopes	Magnetometers
Range	± 10 g	± 475 °/s	± 8 G
Bias Instability	8 ug	0.2 °/hr	-
Initial Bias	< 0.45 mg	< 3 °/hr	-
Initial Scaling Error	< 0.03 %	< 0.02 %	< 0.07 %
Scale Factor Stability	< 0.04 %	< 0.03 %	< 0.09 %
Non-linearity	< 0.05 %	< 0.03 %	< 0.08 %
Cross-axis Alignment Error	< 0.05 °	< 0.05 °	< 0.05 °
Noise Density	2 ug/ $\sqrt{\text{Hz}}$	6 °/hr/ $\sqrt{\text{Hz}}$	210 uG/ $\sqrt{\text{Hz}}$
Bandwidth	250 Hz	200 Hz	110 Hz

Table 10: Sensor specifications

9.4 Rugged Communication Specifications

Parameter	Value
Interface	RS232 (RS422 optional)
Primary and Auxiliary Port Speed	2400 to 2 M baud
GPIO Port Speed	2400 to 250 K baud
Protocol	AN Packet Protocol NMEA TSS1 Simrad
Peripheral Interface	2x GPIO and 1x Auxiliary RS232
GPIO Level	5 V or RS232

Table 11: Rugged communication specifications

9.5 OEM Communication Specifications

Parameter	Value
Interface	3.3V TTL serial port (5V tolerant input)
Speed	2400 to 10M baud
Protocol	AN Packet Protocol
Peripheral Interface	2x GPIO and 1x Auxiliary serial port (3.3V TTL)
GPIO Level	3.3V TTL (5V tolerant input)

Table 12: OEM communication specifications

9.6 Rugged Hardware Specifications

Parameter	Value
Operating Voltage	5 to 36 V
Input Protection	± 60 V
Power Consumption (typical)	1.4 W
Power Consumption (maximum)	1.8 W
Inrush Current	0.5 A
Hot Start Battery Capacity	> 48 hrs
Hot Start Battery Charge Time	30 mins
Hot Start Battery Endurance	> 10 years
Operating Temperature	-40 °C to 85 °C
Environmental Sealing	IP67 MIL-STD-810G
Shock Limit	150 g, 6 ms, half sine
Vibration Limit	8 g RMS
Dimensions	42 x 67 x 30 mm
Weight	98 grams

Table 13: Rugged hardware specifications

9.7 OEM Hardware Specifications

Parameter	Value
Operating Voltage	4.5 to 5.5 V
Input Protection	None
Power Consumption (typical)	1.4 W
Power Consumption (maximum)	1.8 W
Inrush Current	0.5 A
Hot Start Battery Capacity	> 48 hrs
Hot Start Battery Charge Time	30 mins
Hot Start Battery Endurance	> 10 years
Operating Temperature	-40 °C to 85 °C
Environmental Sealing	None
Shock Limit	150 g, 6 ms, half sine
Vibration Limit	8 g RMS
Dimensions	34 x 39 x 24 mm
Weight	26 grams

Table 14: OEM hardware specifications

9.8 Rugged Electrical Specifications

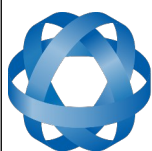
Parameter	Minimum	Typical	Maximum
Power Supply			
Input Supply Voltage	5 V		36 V
Input Protection Range	-60 V		60 V
RS232			
Tx Voltage Low		-5.7 V	-5 V
Tx Voltage High	5 V	6.2 V	
Tx Short Circuit Current			±70 mA
Rx Threshold Low	0.8 V	1.3 V	
Rx Threshold High		1.7 V	2.5 V
GPIO			
Output Voltage Low	0 V		0.3 V
Output Voltage High	4.8 V		5 V
Output Current			5 mA
Input Voltage	-20 V		20 V
Input Threshold Low			1.5 V
Input Threshold High	3.5 V		

Table 15: Rugged electrical specifications

9.9 OEM Electrical Specifications

Parameter	Minimum	Typical	Maximum
Power Supply			
Input Supply Voltage	4.5 V		5.5 V
Input Protection Range	None		None
Serial and GPIO Signal Levels			
Output Voltage Low	0 V		0.4 V
Output Voltage High	2.4 V		3.3 V
Output Current			10 mA
Input Voltage	0 V		5.5 V
Input Threshold Low			0.8 V
Input Threshold High	2 V		

Table 16: OEM electrical specifications



9.10 Rugged Connector Pin-out

Power supply and signal connections are made through a ODU Mini-Snap Series B 9 pin connector (part number S30B0S-P09MCC0-5000). The connector provides a reliable and rugged connection to the Motus under demanding conditions and is rated to IP68 in the mated condition. Advanced Navigation stocks 2 metre unterminated ODU cables that are shielded and have external TPE insulation, see section 8.4 for ordering. Each individual wire is colour coded, FEP coated 28AWG wire, labelled with the ODU pin number on the unterminated end. Custom cable lengths can be ordered by request.



Illustration 15: ODU B series mating plug for Motus

See Illustration 16 for ODU connector pin locations and Table 17 for each pin function. Illustration 17 shows the perspective used for the pin location diagram.

PIN SIDE VIEW

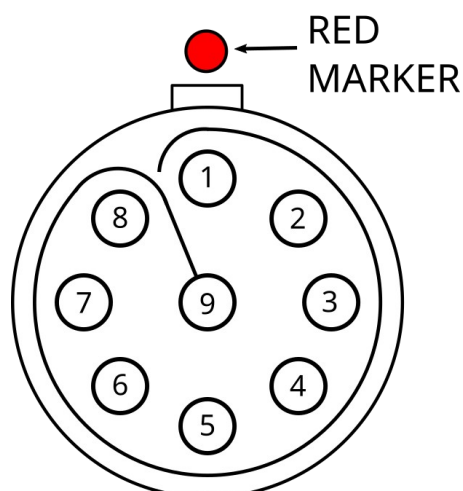


Illustration 16: ODU B series pin locations



Illustration 17: Pin-out view perspective

Pin	Colour	Function (RS232 version)	Function (RS422 version)
1	Black	Ground	Ground
2	Brown	Power Supply	Power Supply
3	White	GPIO 1	GPIO 1
4	Green	GPIO 2	GPIO 2
5	Red	Primary RS232 Transmit	RS422 Transmit +
6	Orange	Primary RS232 Receive	RS422 Receive +
7	Yellow	Auxiliary RS232 Transmit	RS422 Transmit –
8	Blue	Auxiliary RS232 Receive	RS422 Receive –
9	Pink	Ground	Ground

Table 17: Pin allocation table

9.11 Rugged Evaluation Kit USB Cable

The evaluation kit is supplied with a 2 metre cable with a Motus ODU plug on one end and an overmoulded RS232 to USB converter on the other end, please see Illustration 18. The cable is the same 9 wire cable supplied with unterminated ODU cables and all 9 wires are connected on the ODU end. If required, it is possible to cut off the overmoulded RS232 converter to get access to all the individual wires. The chip used in the overmoulded RS232 converter is an FTDI FT232R and supports baud rates of up to 2,000,000 baud.

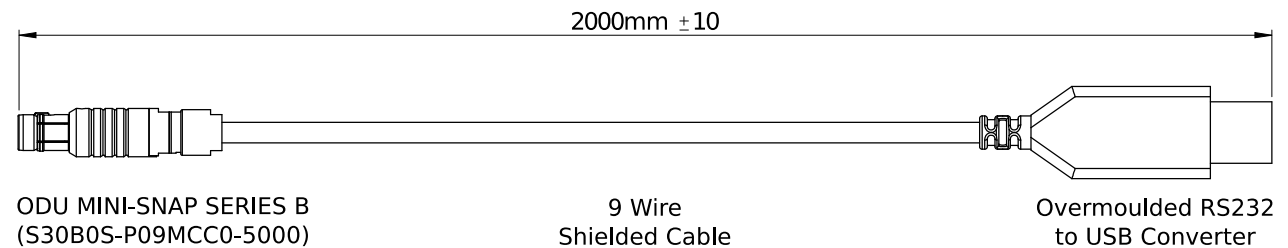


Illustration 18: Evaluation kit USB cable

Pin	Function	RS232 Converter Connection
1	Ground	USB Ground
2	Power	USB 5 volt supply
3	GPIO 1	
4	GPIO 2	
5	Primary RS232 Tx	FTDI RS232 Rx
6	Primary RS232 Rx	FTDI RS232 Tx
7	Auxiliary RS232 Tx	
8	Auxiliary RS232 Rx	
9	Ground	

Table 18: Evaluation kit USB cable pin-out

9.12 Optional Rugged Breakout Cables

Advanced Navigation offers pre-terminated breakout cables for access to all of Motus' pins. There are two breakout cables – one for RS232 communication and one for RS422 communication. All external signal and power connections are provided with 2m of cable. The breakout cables are an optional extra and are not supplied as standard with the evaluation kit.

9.12.1 RS232 Breakout Cable (A503-SDC20753)

The RS232 interface cable is provided with industry standard 9 pin DSUB connectors for each of the two RS232 communication channels and GPIO pins.

Please note that this cable is only applicable to the RS232 version of Motus (part number MOTUS-RUG or MOTUS-OEM)

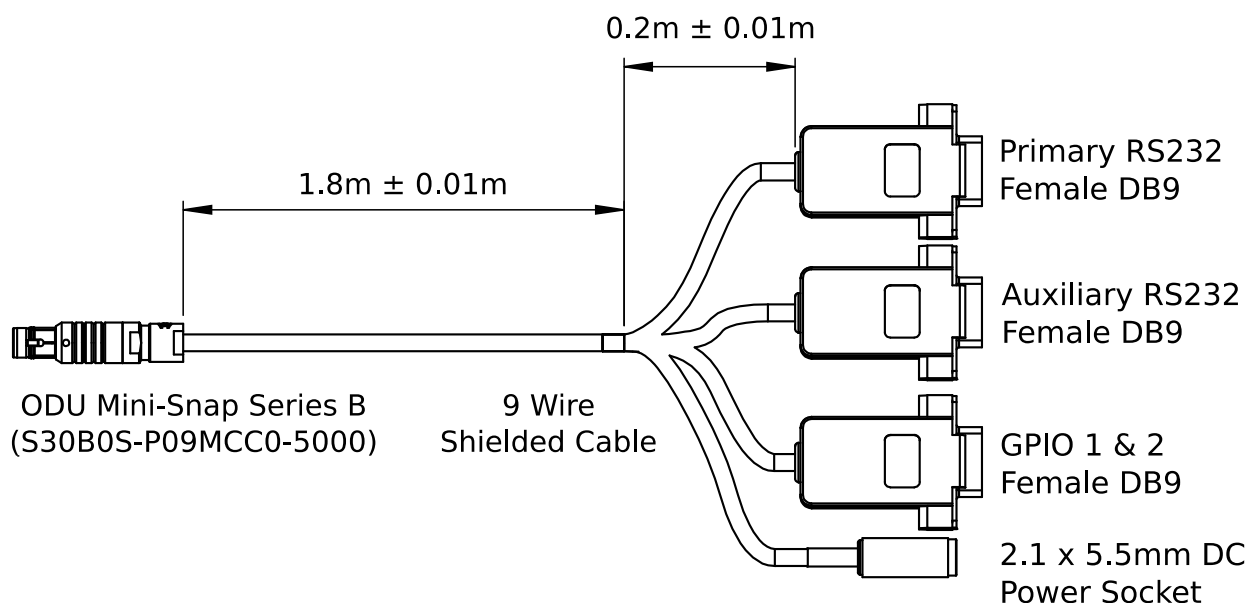


Illustration 19: Optional RS232 breakout cable diagram



Pin	Function	Primary	Auxiliary	GPIO	Power
1	Ground	5	5	5	
2	Power				Tip
3	GPIO 1			2	
4	GPIO 2			3	
5	Primary RS232 Tx	2			
6	Primary RS232 Rx	3			
7	Auxiliary RS232 Tx		2		
8	Auxiliary RS232 Rx		3		
9	Ground				Ring

Table 19: Optional RS232 breakout cable connector pin-out

9.12.2 RS422 Breakout Cable (A503-SDC20755)

The RS422 interface cable is provided with an industry standard 9 pin DSUB connector for the RS422 communication channel and GPIO pins.

Please note that this cable is only applicable to the RS422 version of Motus (part number MOTUS-RUG-422)

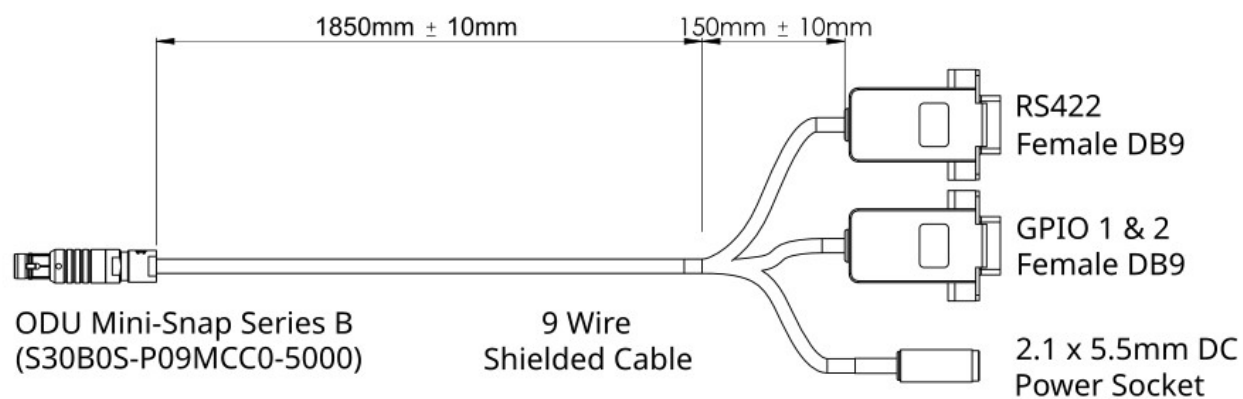


Illustration 20: Optional RS422 breakout cable diagram

Pin	Function	RS422	GPIO	Power
1	Ground	5	5	
2	Power			Tip
3	GPIO 1		2	
4	GPIO 2		3	
5	RS422 Tx +	2		
6	RS422 Rx +	3		
7	RS422 Tx –	8		
8	RS422 Rx –	7		
9	Ground			Ring

Table 20: Optional RS422 breakout cable connector pin-out

9.13 Sensor Calibration

Motus's sensors are calibrated for bias, sensitivity, misalignment, cross-axis sensitivity, non-linearity and gyroscope linear acceleration sensitivity across the full operating temperature range.

9.14 Serial Number

The serial number can be inspected by using the Device Information dialogue in the Motus Manager software, see section 12.7.1. The primary serial number label is located inside the enclosure and is accessible only by Advanced Navigation technicians. The secondary serial number label is located on the outside rear of the enclosure with the serial number encoded in a 2D data matrix bar code to assist customers in tracking their units, see Illustration 21. The external label also contains the hardware version and build date. Applications are available for most smartphones that can scan the 2D data matrix bar code to display the serial number.



Illustration 21: Motus external serial number label



10 Installation

10.1 Installation Checklist

1. Securely mount the unit to the vehicle following the guidelines in section 10.2.
2. Connect the connector cable to Motus and then connect the USB end to a computer.
3. Open the Motus Manager software and click connect.

Note: Motus Manager is only available for systems with x64 and ARM architectures.

4. If the unit is mounted in an alignment other than the standard alignment of X pointing forward and Z pointing down, this alignment offset will need to be entered into the Alignment Configuration dialogue in Motus Manager. Please see section 10.3 for more details.
5. The system is now ready for use.

10.2 Mounting Position

When installing Motus into a vehicle, correct positioning and alignment are essential to achieve good performance. There are a number of goals in selecting a mounting site in your application, these are:

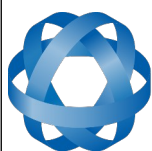
1. Motus should be mounted in an area that is not going to exceed its temperature range and mounted in a manner that will properly dissipate heat; please contact support@advancednavigation.com for advice specific to your application.
2. Motus should be mounted away from vibration where possible.
3. Motus should be mounted close to the centre of gravity of the vehicle where possible.
4. If the magnetic sensors or magnetic heading are going to be used the Motus unit should be mounted away from sources of changing magnetic interference such as high current wiring, motors, moving steel masses and rotating or reciprocating machinery.

Motus's mounting plate and hole guide is shown below in Illustration 14. The holes are designed for M3 bolts.

10.3 Mounting Alignment

The easiest way to align Motus is by installing it with the sensor axes aligned with the vehicle axes. This means that the X axis points forward towards the front of the vehicle and the Z axis points down towards the ground. There are notches marked on the X and Y axis as shown in Illustration 14 to assist with alignment and positioning.

If aligning Motus with the vehicle axes is not possible or not optimal, it may be mounted in a different alignment and the alignment offset should be configured using the Alignment configuration dialogue in Motus Manager, see section 12.8.4. For easy alignment, the set zero orientation button in the Motus Manager Alignment configuration dialogue can be used to set the current orientation as the zero orientation alignment, see section 12.8.4. Please note that this will only correct for roll and pitch offsets. Any heading offset will need to be entered manually and saved before using this function.



10.4 Power Supply

A high level of power supply filtering has been built into Motus to allow for reliable operation in demanding environments. Motus contains a fully isolated power supply and has separate grounds for power and signal to ensure that power supply noise does not corrupt communications or cause ground loops with other equipment. When wiring the system, the signal ground should be routed with the primary RS232, auxiliary RS232, GNSS RS232 and GPIO pins. The power ground should be routed with the power supply to the power source.

A power supply should be selected that can provide at least the maximum current calculated from section 9.8 or 9.9

Motus contains an active protection circuit on the power supply input that protects the unit from under-voltage, over-voltage and reverse polarity events. The protection circuit shuts off power and automatically recovers the unit to full operation once the fault is removed. Take care when running the unit close to its under-voltage lockout of 4.2 V because small voltage drops can engage the under-voltage shutdown and potentially oscillate between the on and off state. It is recommended that the unit is always run at 5 V or more to avoid issues associated with this.

10.5 Odometer

On ground vehicles, the use of an odometer input can greatly improve Motus's navigation and orientation solution during GNSS dropouts. With a high resolution wheel encoder Motus can be used to navigate indoors with GNSS disabled altogether.

There are several different options for odometer installation which are listed below.

10.5.1 Factory VSS Signal

Most road cars since 1980 contain a VSS (vehicle speed sensor) signal that can be wired directly into one of Motus's GPIO pins. The vehicle should be taken to an automotive electrician to perform the work.

To setup the odometer, the appropriate GPIO pin should be set to odometer input using Motus Manager, see section 12.8.6. The odometer pulse length must then be set either manually or automatically, please see section 11.8 for more information.

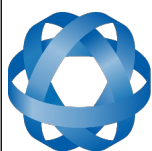
For more information on the GPIO signals and their requirements please see section 15.4.3.

10.5.2 OBDII Odometer Interface

For applications where it is undesirable to modify the vehicle or the system needs to be used with multiple vehicles, the OBDII odometer interface may be a better solution. OBDII is a vehicle diagnostic port standard and most vehicles from the mid 1990s onwards contain an OBDII port in the drivers side foot well. Advanced Navigation produces an OBDII odometer interface that plugs into this OBDII port and feeds Motus with odometer data over the Auxiliary RS232 port, please see Illustration 22. These units are priced at approximately AUD 500. Please contact Advanced Navigation sales for more information.



Illustration 22: Advanced Navigation OBDII Odometer



10.5.3 Aftermarket Wheel Speed Sensor

Applications requiring very high performance are recommended to use a high precision aftermarket wheel speed sensor. Advanced Navigation recommends aftermarket wheel speed sensors from Pegasem or GMH Engineering.



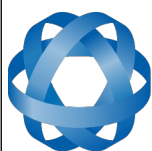
*Illustration 23:
Aftermarket wheel speed
sensor*

10.5.4 Radar Speed Sensor

For applications requiring high performance in harsh conditions where aftermarket wheel speed sensors are not feasible, a radar speed sensor is recommended. Advanced Navigation recommends radar speed sensors from Stalker or GMH Engineering.



*Illustration 24: Radar speed
sensor*



10.6 Magnetics

Motus contains magnetometers which it uses to measure the Earth's magnetic field in order to determine its heading. The principle is the same as that of a compass. When operating Motus with magnetic heading enabled, sources of magnetic interference can degrade Motus's solution if not compensated for. There are two types of magnetic interference, these are static and dynamic.

Static magnetic interference is caused by steel and other magnetic materials mounted in the vehicle. Static disturbances are easily compensated for by running a magnetic calibration, see section 11.5. A magnetic calibration should always be run after installation into a vehicle.

Dynamic magnetic interference is generally a much bigger issue. Sources of dynamic magnetic interference include high current wiring, electric motors, servos, solenoids and large masses of steel that don't move with Motus. Motus should be mounted as far as possible from these interference sources.

Motus contains a special algorithm to remove the effects of dynamic magnetic interference. This is able to compensate for most typical interference sources encountered, however certain types of prolonged dynamic interference cannot be compensated for. The best way to check for dynamic magnetic interference is to use the raw sensors view in Motus Manager and watch the magnetometer outputs whilst the vehicle is operating but stationary, see section 12.7.4. The values should be constant, if the values are fluctuating there is dynamic magnetic interference present.

If dynamic magnetic interference is causing performance problems and there is no way to mount Motus away from the interference source, the magnetometers should be disabled, see section 11.5.4.

10.7 Vibration

Motus is able to tolerate a high level of vibration compared to other inertial systems. There is however a limit to the amount of vibration that Motus can tolerate and large levels of vibration will cause Motus's accuracy to degrade.

When mounting Motus to a platform with vibration there are several options. It is recommended to first try mounting Motus and see whether it can tolerate the vibrations. The raw sensor view in the Motus Manager software can give you a good idea of how bad the vibrations are. If the vibrations are causing the sensors to go over range you will need to take preventative steps against the vibration.

If Motus is unable to tolerate the vibrations there are several options:

1. Try to find a mounting point with less vibration.
2. Motus can be mounted on top of a small flat piece of rubber. Please note that this may cause small changing orientation errors due to flexing of the rubber.
3. Motus can be mounted to a plate which is then mounted to the platform through vibration isolation mounts.



11 INS and AHRS Operation

11.1 Initialisation

There are four different levels of initialisation on Motus. These are orientation, navigation, heading and time. The initialisation can be monitored by inspecting the status view in Motus Manager, see section 12.7.2.

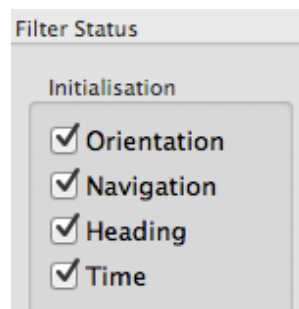


Illustration 25: The four initialisation levels

After all four levels of initialisation, Motus's filter takes several minutes to achieve its full accuracy. It is recommended to wait two minutes after initialisation for applications requiring high accuracy.

11.1.1 Orientation Initialisation

Orientation initialisation occurs automatically upon power on and typically completes within several seconds. Once orientation initialisation is complete, the roll, pitch and angular velocity values will be valid.

When Motus starts up, it assumes that it can be in any orientation. To determine its orientation it uses the accelerometers to detect the gravity vector. Whilst this is occurring, if there are random accelerations present, these can cause an incorrect orientation to be detected. To prevent this, Motus monitors the accelerometers and gyroscopes and restarts the orientation detection if there are sudden movements. It is however still possible under some circumstances for it to miss minor movements and start with a small orientation error. In this scenario Motus will progressively correct the orientation error over a period of several seconds.

11.1.2 Navigation Initialisation

Please note that Navigation is only relevant for Motus INS features. A license upgrade is required for Motus INS capability.

Navigation initialisation completes once the system has determined a starting position. The most common method of navigation initialisation is for the system to get a 3D GNSS fix from a connected GNSS receiver. If the system is hot starting it will remember its position from when it was switched off and use this as the starting position. The other possibility for navigation initialisation is an external position source, see section 15.2 for more information. In a situation where a GNSS fix is not available to initialise navigation, it can be initialised manually by entering a position into the Manual Initialisation dialogue in Motus Manager, see section 12.8.11.



Once navigation initialisation is complete, the position, velocity and acceleration values will be valid.

11.1.3 Heading Initialisation

Heading initialisation completes once the system has determined a heading. The conditions required to determine a heading depend upon the heading source being used, see section 11.4. If magnetic heading is enabled as a heading source the heading initialisation should complete within 2 seconds after power on. If magnetic heading is disabled and velocity heading is used as the only heading source, the heading will initialise once the system travels at a speed of over 1.15 metres/second for over 5 seconds with a 3D GNSS fix or other source of velocity information. If the system is hot starting it will remember its heading from when it was switched off and use this as the starting heading until another source becomes available.

Until the heading has been initialised, the system will not be able to navigate without a GNSS fix or other position source and the roll and pitch values will not be able to reach full accuracy.

11.1.4 Time Initialisation

Time initialisation completes once the system has determined time accurately. For this to occur the system must receive rough time as well as a 1PPS signal on one of the GPIO pins. The rough time is typically received from a GNSS receiver when it achieves a fix. It is also possible to provide an external source of time, see section 15.2 for more information on external time sources.

Until the time has initialised the values of Unix time and formatted time that Motus outputs will not be valid and may change.

11.2 Hot Start

Motus is the first GNSS/INS on the market with hot start functionality. This allows Motus to start inertial navigation within 2 seconds. Motus's hot start is always on and fully automatic.

A next generation backup battery system within Motus provides the hot start ability for more than 48 hours without power. When Motus hot starts it assumes that it is in the same state it was when it lost power and begins navigating from that position. When the GNSS achieves its first fix, if this position deviates from the hot start position, Motus will jump to the new position without causing any side effects to the filter.

Whilst Motus is without power it keeps track of the time accurately to within 1 second so that the time is immediately valid on a hot start.

Motus's hot start is of particular benefit to vehicle tracking and robotics applications. The primary benefits are immunity and fast recovery from power failure as well as fast startup time.

11.3 Time

Motus was designed to provide a highly accurate time reference. When a GNSS fix is available Motus's time is accurate to within 50 nanoseconds. When a GNSS fix is lost, Motus's time accuracy typically remains within 10 microseconds over extended time periods. When Motus hot starts the time accuracy is typically within 1 second immediately on startup and corrected to within 50 nanoseconds as soon as a GNSS fix is achieved and 1PPS received. To synchronise with Motus's high accuracy time, both the packet protocol and a 1PPS line must be used.



11.4 Heading Source

There are three different heading sources available for Motus. By default Motus uses both magnetic heading and velocity heading. It is possible to use multiple heading sources and this will often provide performance benefits.

11.4.1 Magnetic Heading

This is the default heading source and works well in the majority of cases. When using magnetic heading, calibration is required every time Motus's installation changes. The downside of magnetic heading is that prolonged dynamic magnetic interference sources can cause heading errors.

11.4.2 Velocity Heading

Velocity heading works by deriving heading from the direction of velocity and acceleration. Velocity heading works well with cars, boats, fixed wing aircraft and other vehicles that don't move sideways. Velocity heading does not work with helicopters and other 3D vehicles. The downside of velocity heading is that heading can not be measured until the vehicle moves at a horizontal speed of over 1.15 metres/second with a GNSS fix. The benefits of velocity heading are that it is immune to magnetic interference and no calibration is required when Motus's installation changes.

11.4.3 External Heading

External heading can be used if there is some other way to derive heading that is external to Motus. Examples include dual antenna GNSS systems, gyro-compasses, reference markers and SLAM systems. The heading must be fed into Motus using the External Heading Packet or through NMEA into a GPIO pin.

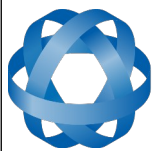
11.5 Magnetics

Static magnetic interference is defined as anything that provides a fixed vector of magnetic interference to Motus, an example would be the steel body of a car that Motus is mounted on. Dynamic magnetic interference is defined as anything that provides varying magnetic interference, an example would be when Motus is mounted on an engine and the pistons within are moving relative to Motus and providing a changing magnetic field.

Static magnetic interference is resolved through magnetic calibration and dynamic magnetic interference is compensated by a filter algorithm but should be minimised where possible through installation location. To compensate for static magnetic interference, magnetic calibration should be performed any time Motus's installation changes.

Motus contains a dynamic magnetic compensation filter that is able to mitigate the effects of short term magnetic interference sources while in operation. For example if Motus is installed in a car and the car drives over a large piece of magnetised steel, this will be compensated for. Another example is driving through a tunnel which is built from heavily reinforced concrete. It is important to note that for Motus's dynamic magnetic compensation filter to operate correctly, Motus needs to get a GNSS fix at least once every time it is moved more than 50km. Each time Motus moves more than 50km the new position is stored permanently and allows Motus to update it's world magnetic model values.

There are three types of magnetic calibration available, these are 2D calibration, 3D calibration and automatic calibration. 2D calibration involves one level rotation about the Z axis and is designed for vehicles that cannot easily or safely be turned upside down, such as full size cars, planes and



boats. 3D calibration involves rotating through all orientations and is designed for vehicles that can easily and safely be rotated upside down, such as model size vehicles. 3D calibration offers slightly better performance and is recommended where possible. Automatic magnetic calibration continuously and automatically calibrates for static magnetic interference while the unit is in operation. It is not as accurate as the 2D or 3D calibration, however it is very convenient for applications where Motus needs to just work without user intervention.

Please note that if Motus is going to be used in a vehicle, the calibration should be performed while Motus is mounted in and fixed to that vehicle. This means that the whole vehicle must be moved to perform the calibration. The calibration needs to be performed in an area away from sources of magnetic interference. For example if Motus is installed in a car, the calibration should not involve driving over steel drains or reinforced concrete etc. If Motus is being calibrated to operate standalone, the calibration should not be done on a desk with a steel frame.

11.5.1 2D Magnetic Calibration

The following procedure should be used to perform a 2D magnetic calibration.

11.5.1.1 Using the Motus Manager Software

1. The unit should be powered on while the vehicle is in a level orientation and kept stationary.
2. After power on wait 5 minutes for the temperature and filter to stabilise.
3. Open Motus Manager and connect to the device. Ensure that the device has either a GNSS fix or the position has been manually entered in the Manual Initialisation window before proceeding.
4. In the Tools menu, open Magnetic Calibration. Click the 2D Calibration button. See section 12.9.1.
5. Whilst keeping as level as possible, rotate the vehicle in either direction through one and a quarter full rotations. In a car this can be achieved by driving in one and a quarter circles.
6. Check the status in the Magnetic Calibration window to ensure that the calibration completed successfully. If not successful click Cancel, wait 2 minutes and repeat from step 4. Do not press the save button in the lower half of the dialogue, this will over write the new calibration values. The calibration values are automatically saved internally.

11.5.1.2 Using the Packet Protocol

1. The unit should be powered on while the vehicle is in a level orientation and kept stationary.
2. After power on wait 5 minutes for the temperature and filter to stabilise.
3. Ensure that the device has a position fix, either from an external GNSS receiver, or using the External Position and Velocity packet #44 or the External Position packet #45, before proceeding.
4. Send the Magnetic Calibration Configuration Packet with the action Start 2D Magnetic Calibration.
5. Whilst keeping as level as possible, rotate the vehicle in either direction through one and a quarter full rotations. In a car this can be achieved by driving in one and a quarter circles.
6. Read the Magnetic Calibration Status Packet to ensure that the calibration completed



successfully. If not successful, send the Magnetic Calibration Configuration Packet with the action Cancel, wait 2 minutes and repeat from step 4.

11.5.2 3D Magnetic Calibration

The following procedure should be used to perform a 3D magnetic calibration.

11.5.2.1 Using the Motus Manager Software

1. The unit should be powered on and the vehicle kept stationary.
2. After power on wait 5 minutes for the temperature and filter to stabilise.
3. Open Motus Manager and connect to the device. Ensure that the device has either a GNSS fix or the position has been manually entered in the Manual Initialisation window before proceeding.
4. In the Tools menu, open Magnetic Calibration. Click the 3D Calibration button. See section 12.9.1. The following steps 5, 6 and 7 can be performed in any order.
5. Slowly rotate the vehicle twice around the X axis (roll).
6. Slowly rotate the vehicle twice around the Y axis (pitch).
7. Slowly rotate the vehicle twice around the Z axis (heading).
8. Check the status in the Magnetic Calibration window to ensure that the calibration completed successfully. If not successful click Cancel, wait 2 minutes and repeat from step 4. Do not press the save button in the lower half of the dialogue, this will over write the new calibration values. The calibration values are automatically saved internally.

11.5.2.2 Using the Packet Protocol

1. The unit should be powered on and the vehicle kept stationary.
2. After power on wait 5 minutes for the temperature and filter to stabilise.
3. Ensure that the device has a position fix, either from an external GNSS receiver, or using the External Position and Velocity packet #44 or the External Position packet #45, before proceeding.
4. Send the Magnetic Calibration Configuration Packet with the action Start 3D Magnetic Calibration. The following steps 5, 6 and 7 can be performed in any order.
5. Slowly rotate the vehicle twice around the X axis (roll).
6. Slowly rotate the vehicle twice around the Y axis (pitch).
7. Slowly rotate the vehicle twice around the Z axis (heading)
8. Read the Magnetic Calibration Status Packet to ensure that the calibration completed successfully. If not successful, send the Magnetic Calibration Configuration Packet with the action Cancel, wait 2 minutes and repeat from step 4.

11.5.3 Automatic Magnetic Calibration

Automatic magnetic calibration is an algorithm that continuously and automatically calibrates for static magnetic interference. Automatic magnetic calibration is enabled by default and it is



recommended to keep it enabled for all vehicle types. When used on top of a 2D or 3D calibration it can give the best results from magnetic heading. Automatic magnetic calibration can be turned off using the Filter Options dialogue in the Web UI or Motus Manager, see section 12.8.2.

11.5.3.1 2D Vehicle Profiles

2D vehicles are those which cannot easily or safely be turned upside down, and typically include vehicles such as cars and bicycles.

Each time Motus is powered on in a cold start (48 hours without power) the automatic calibration is reset. The automatic magnetic calibration starts operating when Motus is travelling at a speed over 5 m/s with a GNSS fix and either dual antenna is the heading source or velocity heading is turned on.

Automatic magnetic calibration is not as accurate as 2D or 3D calibration, however, it is sufficient for most vehicles and allows Motus to be installed into vehicles and operated without user intervention.

11.5.3.2 3D Vehicle Profiles

3D vehicles are those which can easily or safely be turned upside down, and typically include vehicles such as humans, underwater vehicles and fixed wing planes.

Each time Motus is powered on in a cold start (48 hours without power) the automatic calibration is reset, and a new calibration will begin if a significant change in calibration values is detected. The automatic calibration for 3D vehicle profiles requires no prior calibration or minimum velocity to begin.

The calibration time is dependent upon the rotation about each axis; approximately, 1 degree of uniform motion in each axis will take up to an hour to converge, motion as low as 0.2-0.5 degrees will take upwards of 12 hours to converge, and 10 degrees of motion will take around 40 seconds to converge. These time estimates are dependent on the environment and nature of the motion.

11.5.4 Disabling Magnetometers

In situations where there is very strong dynamic magnetic disturbances present, it is recommended to disable the magnetometers. When the magnetometers are disabled a secondary heading source is required otherwise may become inaccurate. Velocity heading is the recommended source. Please see section 11.4 for information on heading sources. The magnetometers can be disabled using the Filter Options dialogue in Motus Manager, see section 12.8.2.

11.6 Data Anti Aliasing

Internally Motus's filters update at 1000 Hz. When Motus outputs data, most applications require the data at a much lower rate (typically < 100 Hz). This causes a problem for time based data such as velocities and accelerations where aliasing will occur at the lower rate. To prevent this problem, if the output rate is lower than 1000 Hz, Motus will low pass filter the values of the time dependent data between packets to prevent aliasing. This is only the case when a packet is set up to output at a certain rate. If the packet is simply requested no anti aliasing will occur. Additionally there is no anti aliasing for non time dependent fields such as position.



11.7 Vehicle Profiles

Motus supports a number of different vehicle profiles. These vehicle profiles impose constraints upon the filter that can increase performance. If your application matches one of the available vehicle profiles, it is recommended to select it for use in the Filter Options dialogue in Motus Manager, see section 12.8.2. For a list of the different vehicle profiles please see section 16.10.5.1. Please note that if the wrong vehicle profile is selected it can cause a significant decrease in performance.

11.8 Odometer Pulse Length

For Motus to use a wheel speed sensor or odometer input, it must know the pulse length of the signal. The pulse length is the distance in metres between low to high transitions of the signal. The odometer pulse length can either be entered manually or automatically calibrated by Motus. To enter the pulse length manually, please use the Odometer configuration dialogue in Motus Manager, see section 12.8.7. To automatically calibrate the odometer pulse length please use the procedure listed below in section 11.8.1. By default the odometer will automatically calibrate itself.

11.8.1 Odometer Automatic Pulse Length Calibration Procedure

1. Ensure that the signal is connected correctly and that the GPIO pin is configured as an odometer input using the GPIO configuration dialogue in Motus Manager, see section 12.8.6.
2. Open Motus Manager, connect to Motus and open the Odometer configuration dialogue. In the Odometer configuration dialogue tick the automatic pulse length calibration check box and press the write button, see section 12.8.7.
3. Wait until Motus has a continuous GNSS fix and then drive 1000 metres over flat terrain with as little turning as possible.
4. If Motus loses a GNSS fix for any extended period of time during the calibration, the distance travelled will be reset. The distance travelled can be checked in the Odometer configuration dialogue to ensure that it has passed 1000 metres.
5. Once 1000 metres has been driven, press the read button and check that the automatic pulse length check box becomes un-ticked and the pulse length value is read.

11.9 Reversing Detection

Reversing detection is an algorithm that can detect when the vehicle is travelling in reverse. Knowledge of reverse motion is important when using velocity heading or odometer input to provide correct results. If Motus is fitted to a vehicle that does not reverse or doesn't use velocity heading or odometer, this function should be disabled. Reversing detection is enabled by default and it can be disabled using the Filter Options dialogue in Motus Manager, see section 12.8.2.

11.10 Motion Analysis

Motion analysis is an artificial intelligence algorithm that associates patterns in high frequency inertial data with the speed of the vehicle. After power on it takes some time to match patterns with speed before it will become active. Motion analysis only activates when dead reckoning and is most effective when the vehicle is near stationary. Motion analysis does not work in all situations and it's primary benefit is in ground vehicles. When active it can be recognised by 2Hz steps in



velocity data. Motion analysis is disabled by default and can be enabled using the Filter Options dialogue in Motus Manager, see section 12.8.2.

11.11 Heave

Motus can provide vertical heave position at four different points on a ship. Motus's heave filter is always on and fully automatic. After power on, Motus requires approximately 5 minutes for its heave filter to converge upon an accurate solution. Heave works without a GNSS fix, however best heave performance is achieved when Motus has a GNSS fix.

By default Motus provides heave from the point at which the Motus unit is mounted, however it can provide heave at four different offset points on the ship. To set the heave offsets, use the Reference Position Offsets dialogue in Motus Manager, see section 12.8.9.

11.12 Environmental Exposure

Whilst Motus Rugged is environmentally protected, there are clearly defined limits to this protection that must be adhered to for reliable operation.

Motus Rugged is only protected when its connector is mated. When any of these connections are not made the unit offers no environmental protection.

Spanners or tools should never be used to tighten the connectors. They should only ever be finger tight.

11.12.1 Temperature

Motus should not be subjected to temperature's outside of its operating range. Subjecting Motus to temperature's outside of the storage range can cause failure of the system and or effect the factory sensor calibration which will cause a permanent performance degradation.

If the temperature rises above 90 degrees Celsius, Motus will automatically shut off power to its sensors in an attempt to prevent damage, this will also send the filters into reset.

11.12.2 Water

Motus Rugged is water-proof to the IP67 standard which means that it can be submersed in water to a depth of up to 1 metre only. Submersion to depths beyond 1 metre can cause water entry and destruction of the internal electronics.

11.12.3 Salt

Motus Rugged is made from marine grade aluminium which gives it reasonably good salt water corrosion resistance. However Motus Rugged cannot tolerate extended periods of time in salt water environments. After any contact with salt water environments, Motus Rugged should be thoroughly rinsed with fresh water.

11.12.4 Dirt and Dust

Motus Rugged is completely sealed against dirt and dust entry. It is important to note that this is only the case when the connectors are mated. When un-mating the connectors if the Motus Rugged unit is dirty or dusty, the dirt should be rinsed off with fresh water first and then dried off. This is to prevent dirt or dust entering the connectors which can cause them to fail.



11.12.5 PH Level

Environments with a high or low PH level can cause the Motus Rugged enclosure to corrode. If Motus Rugged comes into contact with these environments it should be rinsed in fresh water as soon as possible. It is not recommended to operate Motus Rugged in non neutral PH environments.

11.12.6 Shocks

Motus can tolerate shocks to 2000g, however continuous shocks of this severity are likely to cause premature failure. Shocks above 2000g can effect the factory sensor calibration and degrade performance. Normally shocks to Motus when mounted in a vehicle are fine. Even a high speed car crash is likely to reach a peak of only 50g. Shocks directly to Motus Rugged's enclosure can more easily go over the limit however so care should be taken when handling the unit prior to mounting.



12 Motus Manager

Motus Manager is a software tool provided by Advanced Navigation for logging, testing, display and configuration of Motus. It is designed to be simple and easy to use.

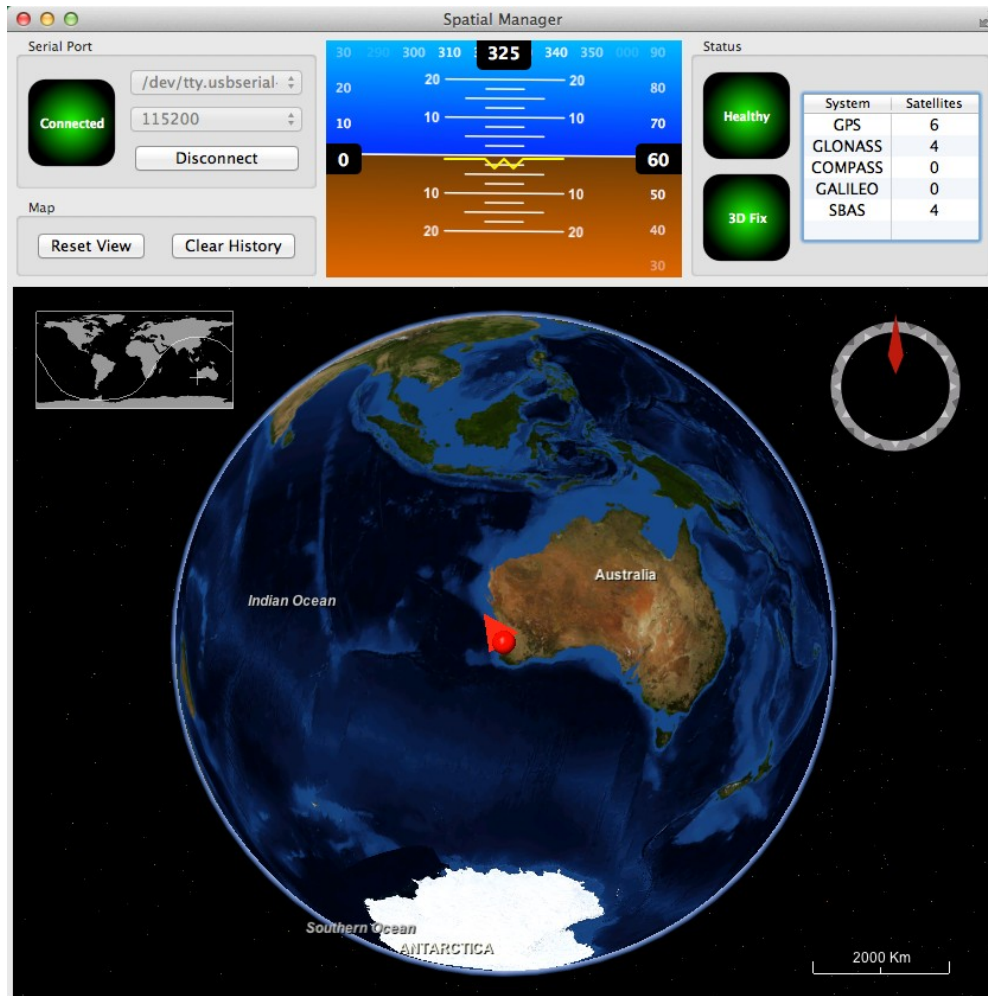
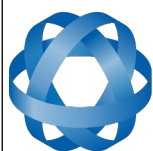


Illustration 26: Screenshot of Motus Manager



12.1 Software Changelog

Version	Date	Changes
7.2	10/11/2023	Clear map history on reconnection Fix incorrect timezone text displayed in terminal.csv Updated leap-seconds list URL Add automatically log configuration at the start of a new log Added elevation to the gimbal state packet Fixed indicators behaviour on disconnect Updated support for Mac silicon with latest macOS Removed GNSS status indicator Renamed External GNSS Enabled to Internal GNSS Enabled
7.0	13/02/2023	Updated from JDK8 to JDK11. JRE11/JDK11 required to run this release Refresh Port Mode information on reconnection Refresh Packet Rates information on reconnection Improved reliability of firmware update When the NTRIP sourcetable says authentication type is any of ", 'B', 'N', then use Basic Authentication. This is to workaround NTRIP servers that incorrectly populate the authentication field. Overwrite/clear existing packet rates on import of configuration Added support for ARM (aarch64) processors with 64-bit OS Added support for Apple M1 processors and improved MacOS support
6.2	10/10/2022	Renamed position error to position standard deviation in position page of view menu Allowed copying version numbers etc from Device Information and GNSS Receiver Information dialog boxes. Clicking on the field will copy it to the clipboard Supported NTRIP Casters that request Username & Password to retrieve Source Table. Renamed Log Conversion menu item Added Settings menu item
6.1	18/02/2022	Device information updated automatically after a firmware update Fixed configuration export Add ability to control log file location Included software version number in title Improved NTRIP server reconnection Improve export configuration reliability Added external GNSS Filter option Improved Log files saved by default in the directory from where the application is launched Improved NTRIP mountpoint selection. Added handling of non-standard NTRIP server responses Force the device to exit bootloader mode if a firmware update is not in progress
5.6	09/09/2020	Updated raw sensors dialogue to include all temperatures

		More information on the GNSS Receiver Information page Fixed bug with communications statistics dialogue cutting off numbers Added zero angular velocity update GPIO function Added Mavlink output GPIO function
4.6	18/09/2017	Added new GPIO functions to GPIO configuration Added new NMEA messages to GPIO output configuration Update to 3D mapping fixes issues with map data not loading
4.5	17/03/2017	Fix for incorrect leap second in RINEX files since 01/01/2017 More signals output in RINEX files
4.4	12/04/2016	Extended NTRIP support for older versions Log converter now outputs a KML file for Google Earth with detailed information as well as the GPX file Added serial port passthrough tool Secondary antenna raw satellite data is now converted to RINEX as well as the primary antenna
4.3	08/03/2016	Initial Release

12.2 System Requirements

Motus Manager is only available for systems with a 64-bit architecture.

The software includes a 3D mapping display which requires a modern 3D graphics card and up to date drivers to run. If your machine does not meet the graphics requirements the mapping view will only show space without a globe.

When Motus is running at very high output rates e.g. 1000 Hz, Motus Manager can consume significant system resources handling the large quantity of data.

12.3 Installation

The latest version of Motus Manager can be downloaded from the Motus [product page](#) of the Advanced Navigation website. Installation notes are as follows:

- Java 11 is required to run Motus Manager. Adoptium JRE 11 is the recommended Java installer to be used on all platforms. Install the latest version of Java 11 from [Adoptium](#), selecting the correct operating system and architecture for your computer.
- Motus Manager does not need to be installed and on a Windows system it can be run from any directory by simply double clicking on it. To open the program on some systems it may be necessary to right click and select open with → Java Runtime Environment.
- On MacOS systems it may be necessary to run the application from a terminal window:

```
java -jar -XstartOnFirstThread MotusManager-7.x.jar
```
- On Linux systems it may be necessary to run the application from a terminal window:

```
java -jar MotusManager-7.x.jar
```

The Motus evaluation kit makes use of an FTDI USB to RS232 device. The drivers are normally installed automatically, if not they are available from <http://www.ftdichip.com/Drivers/VCP.htm>.



12.4 Troubleshooting

Please contact support@advancednavigation.com if you are having issues.

12.4.1 All Platforms

If the globe does not appear in the 3D map area, this indicates that either your graphics card is not powerful enough or your graphics card driver is out of date.

12.4.2 Windows

There is a well known problem with USB serial devices under Windows known as “crazy mouse”. The problem occurs when the system mistakenly installs the USB serial device as a mouse. Unfortunately Microsoft has not fixed this problem in over 15 years, so it probably won't be fixed. If you experience this problem, often a restart will resolve it. Otherwise there is a tool available at <http://www.stentec.com/anonftp/pub/wingps/pnpblockersetup.exe> that can fix the issue.

If the serial port does not show up when you plug in your Motus USB device, you may need to install the drivers from <http://www.ftdichip.com/Drivers/VCP.htm>.

If you experience a blue screen of death whilst using Motus Manager, this is typically a problem associated with older FTDI drivers. To resolve the problem, install the latest drivers from <http://www.ftdichip.com/Drivers/VCP.htm>.

When operating Motus at a very high data rate, data can be lost due to the latency of the FTDI driver. To resolve this problem the latency of the driver should be reduced by going to control panel → system → device manager → ports and right click on the USB serial port, then click properties. In the properties window click the port settings tab and then the advanced button. You then need to change the latency timer setting to 1ms. Please see the screenshot in Illustration 27.

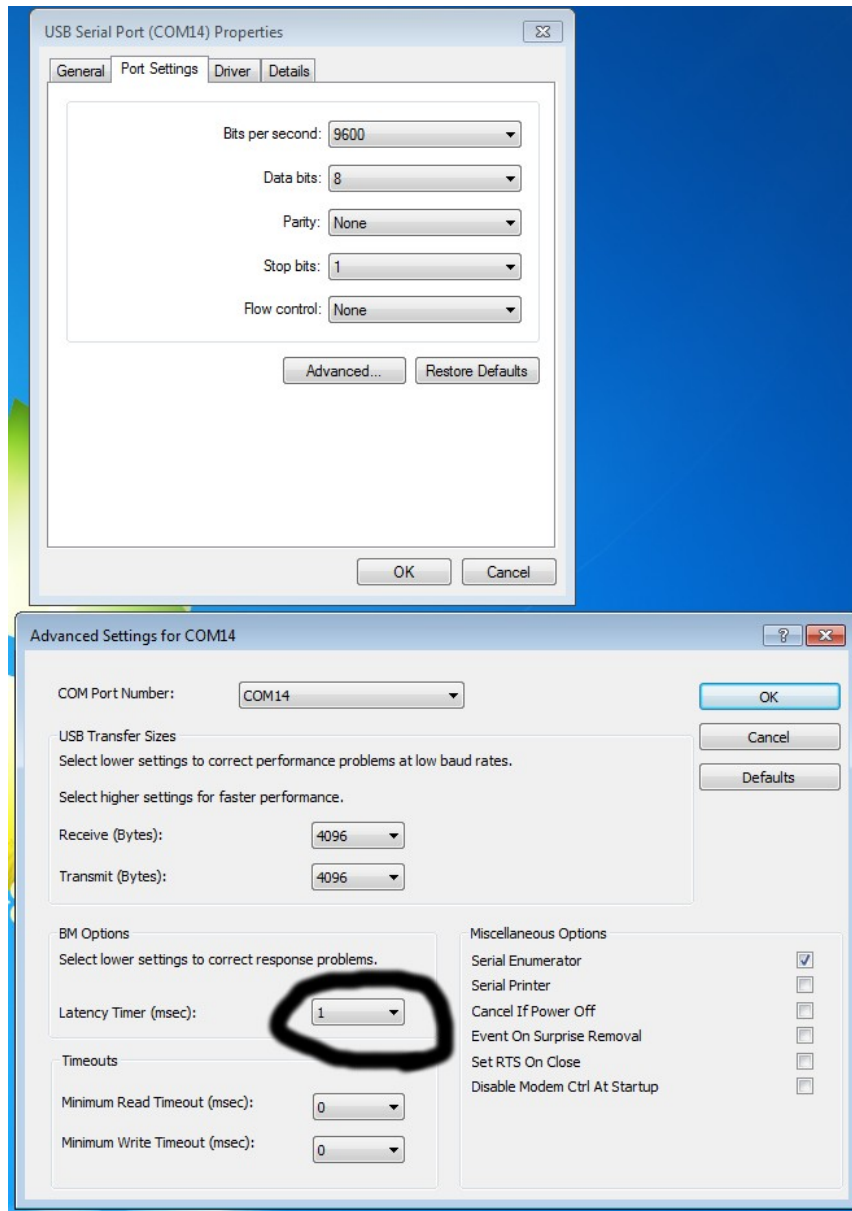


Illustration 27: Screenshot of latency timer setting

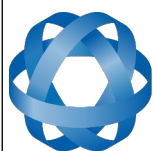
12.4.3 Linux

If serial ports do not show up, the typical cause is permissions. The user should add themselves to the dialout group with the command `sudo adduser username dialout`.

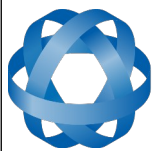
Compiz causes issues with the 3D mapping. If you are experiencing problems it is recommended to turn off compiz.

Modemmanager can also sometimes cause problems on Linux installations. If you are not using a modem, it is recommended to remove modemmanager with the command `sudo apt-get remove modemmanager`.

Motus Manager is able to run on the OpenJDK JRE but it uses significantly more system resources



than when it is running on the Oracle JRE.



12.5 Main View

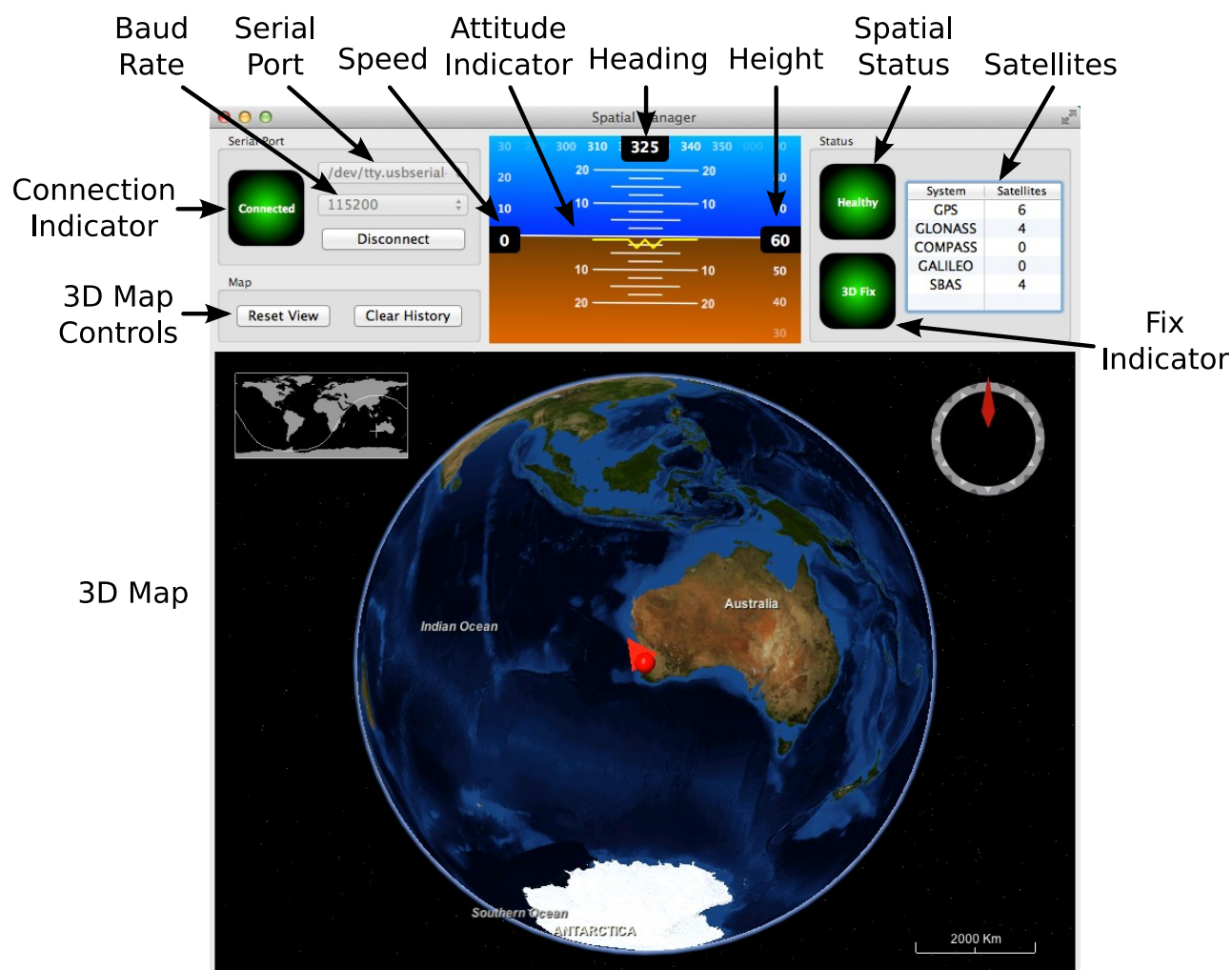


Illustration 28: Screenshot of Motus Manager main view

12.5.1 Serial Port

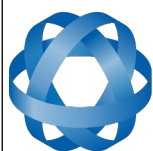
The Serial Port list is used to connect to Motus. You should select a serial port and baud rate and click connect. The default baud rate of Motus is 115200. The Connection Indicator displays whether there is communication with a Motus unit.

12.5.2 Attitude Indicator

The aircraft style Attitude Indicator shows roll and pitch through a virtual horizon. Around the sides heading, speed and height are shown. All units are SI (metric) and degrees.

12.5.3 Status Indicator

The Status indicator section contains a Motus status indicator, a fix indicator and a satellites table.



12.5.3.1 Motus Status Indicator

This indicator shows any problems with Motus. Before a GNSS fix is achieved it will show the status "Filter not initialised". Once the filter has initialised it should show "Healthy". Clicking on the indicator will show the detailed status flags.

12.5.3.2 Fix Indicator

This shows the status of the GNSS fix. Under normal operating conditions it should show either "3D Fix" or "SBAS Fix". When satellite visibility is poor it may show either "2D Fix" or "No Fix".

12.5.3.3 Satellites Table

The Satellites table shows the number of active satellites being used in the current GNSS solution. More detailed information can be found in the satellites view.

12.5.4 3D Map

The 3D map shows Motus's position on the Earth as well as a red trail of position history. When the filter initialises the map will automatically reset the view to Motus's location. To move the camera click and drag on the map. To zoom in and out use the scroll wheel. To change the camera view right click and drag or shift click and drag.

12.5.5 3D Map Controls

12.5.5.1 Reset View

This resets the map view to Motus's current position.

12.5.5.2 Clear History

This clears the current position history, this is the red trail shown on the map.

12.6 Logging

Motus Manager features a fully automatic logging system. Every time the serial port connect button is clicked Motus Manager starts a new log file in either the current directory or the user's home directory. The log file is given the file name `MotusLog_date_time.anpp` and contains all of the raw data received from Motus in the AN packet protocol. The log files are closed when the serial port is disconnected.

Logging can be disabled via command line `-n,--logdisable`, and log file location can be set via command line `-l,--logpath <Path of output logfile>`.

To convert these log files into easily accessible formats, the Log Converter dialogue in the Tools menu can be used, see section 12.9.3. The Log Converter dialogue creates a folder and generates files in the CSV (comma separated values) format that can be easily opened with Microsoft Excel, Matlab, LibreOffice, Google Sheets and most other data analysis programs. It also creates a GPX file of position that is designed to be opened with Google Earth.

▼	📁 SpatialLog_13-02-11_11-30-52	Today 1:02 PM	--	Folder
	📄 EulerOrientation.csv	Today 1:02 PM	40 KB	comm...values
	📄 EulerStandardDeviation.csv	Today 1:02 PM	39 KB	comm...values
	📄 GoogleEarth.kml	Today 1:02 PM	78 KB	Googl...ument
	📄 RawSensors.csv	Today 1:02 PM	101 KB	comm...values
	📄 Satellites.csv	Today 1:02 PM	8 KB	comm...values
	📄 State.csv	Today 1:02 PM	753 KB	comm...values
	📄 Status.csv	Today 1:02 PM	57 KB	comm...values
	📄 SpatialLog_13-02-11_11-30-52.anpp	Today 11:32 AM	264 KB	Document

Illustration 29: Screenshot showing log file and log conversion folder

12.7 View

The View menu contains a number of different options for viewing data from Motus.

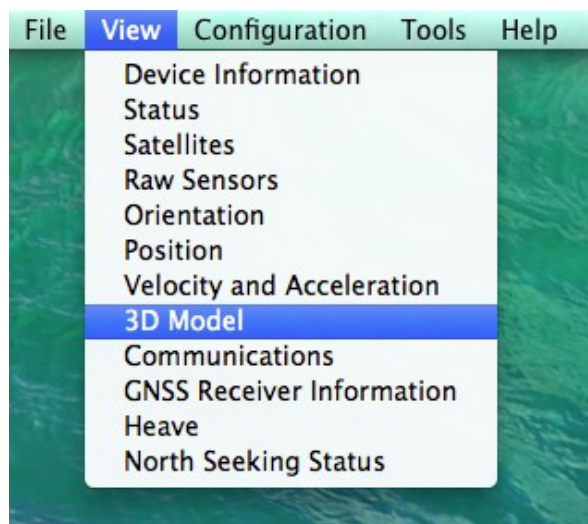


Illustration 30: Screenshot of Motus Manager View menu

12.7.1 Device Information

Device information is useful during technical support and for tracking your serial number, firmware and hardware version.

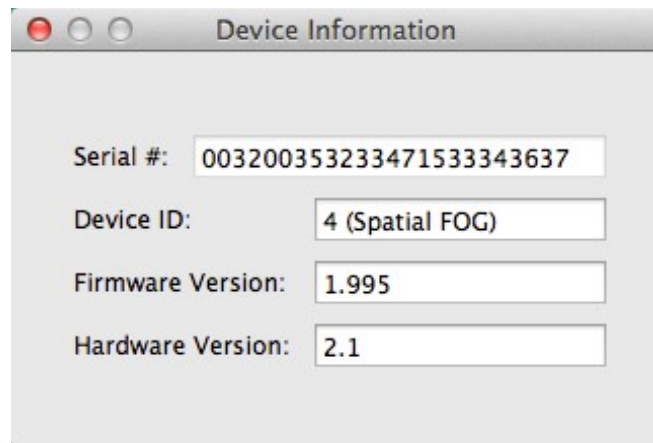


Illustration 31: Screenshot of Motus Manager Device Information dialogue

12.7.2 Status

Status shows Motus's complete status as contained in the system state packet detailed in section 16.9.1.1.

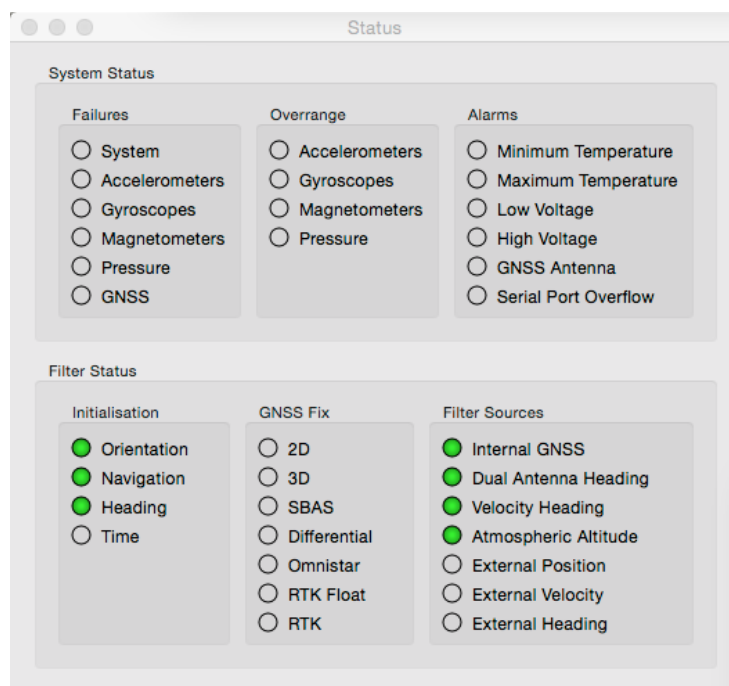
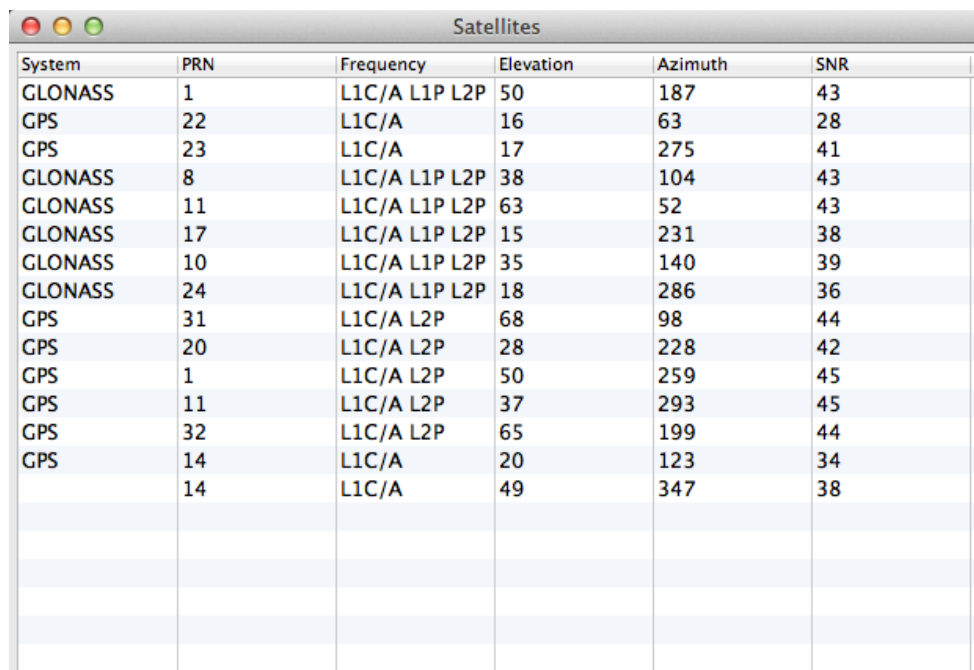


Illustration 32: Screenshot of Motus Manager Status dialogue



12.7.3 Satellites

Satellites shows detailed information on the satellites that Motus's GNSS receiver is tracking. Elevation and azimuth are in units of degrees.



System	PRN	Frequency	Elevation	Azimuth	SNR
GLONASS	1	L1C/A L1P L2P	50	187	43
GPS	22	L1C/A	16	63	28
GPS	23	L1C/A	17	275	41
GLONASS	8	L1C/A L1P L2P	38	104	43
GLONASS	11	L1C/A L1P L2P	63	52	43
GLONASS	17	L1C/A L1P L2P	15	231	38
GLONASS	10	L1C/A L1P L2P	35	140	39
GLONASS	24	L1C/A L1P L2P	18	286	36
GPS	31	L1C/A L2P	68	98	44
GPS	20	L1C/A L2P	28	228	42
GPS	1	L1C/A L2P	50	259	45
GPS	11	L1C/A L2P	37	293	45
GPS	32	L1C/A L2P	65	199	44
GPS	14	L1C/A	20	123	34
	14	L1C/A	49	347	38

Illustration 33: Screenshot of Motus Manager Satellites dialogue



12.7.4 Raw Sensors

Raw sensors shows the temperature calibrated raw sensor values.

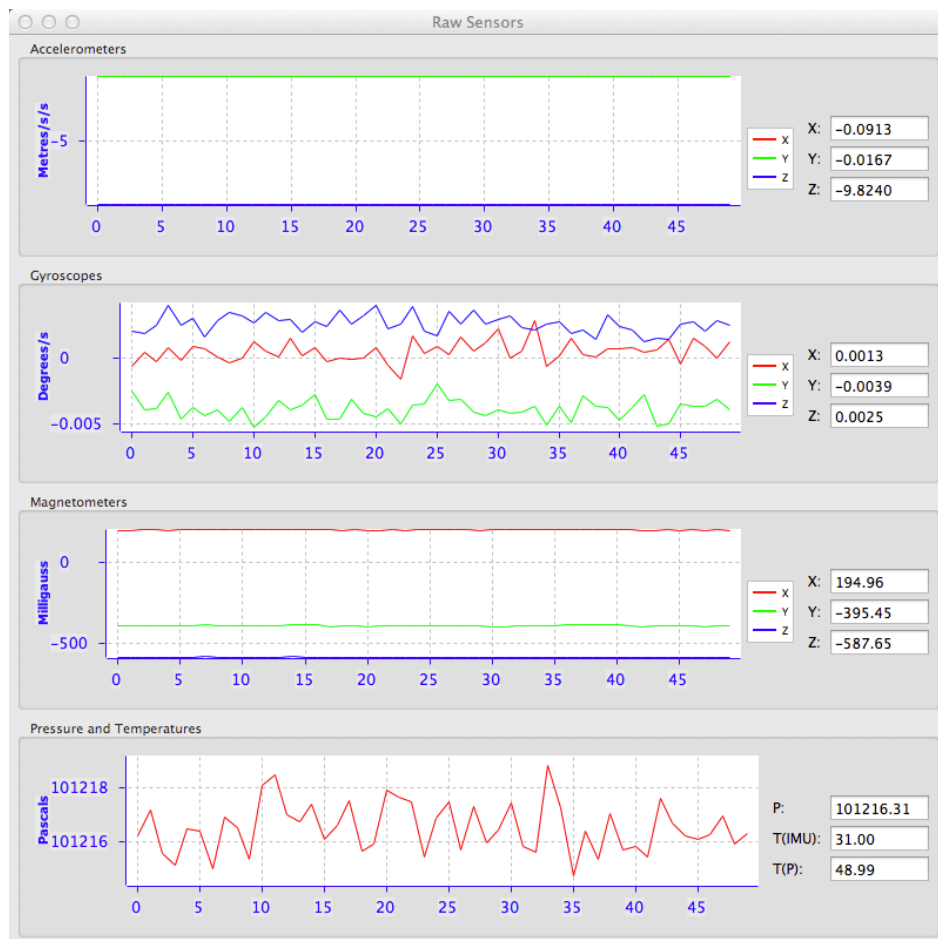


Illustration 34: Screenshot of Motus Manager Raw Sensors dialogue



12.7.5 Orientation

Orientation shows Motus's orientation, angular velocity and orientation error.

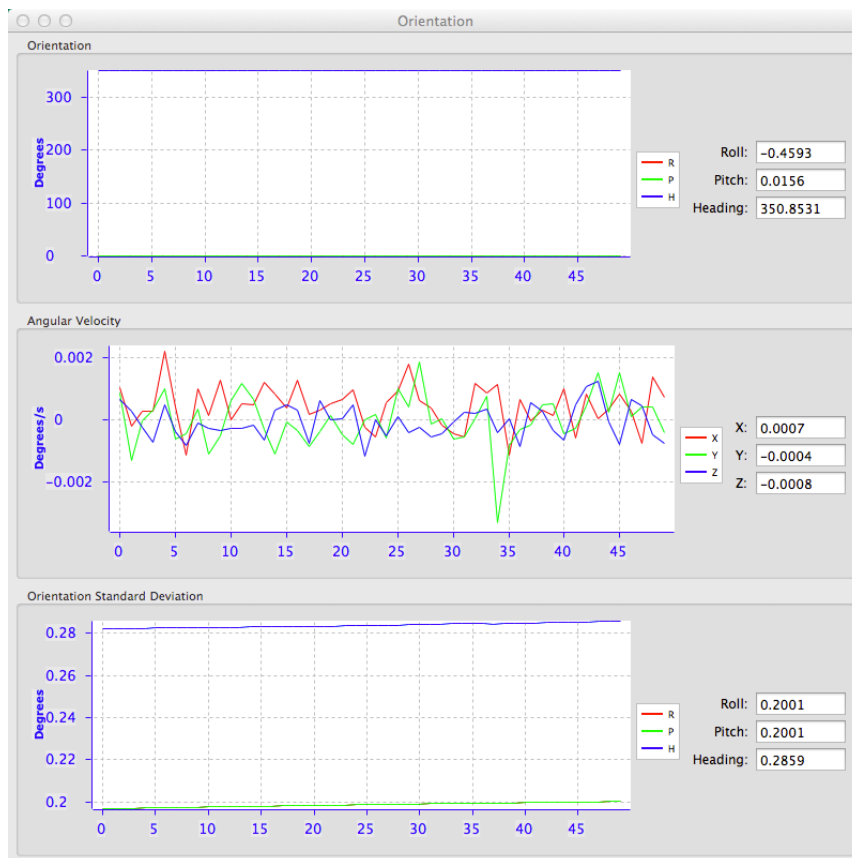


Illustration 35: Screenshot of Motus Manager Orientation dialogue



12.7.6 Position

Position shows Motus's position and position error. Latitude and longitude are converted to North and East metres from a reference point that can be reset.

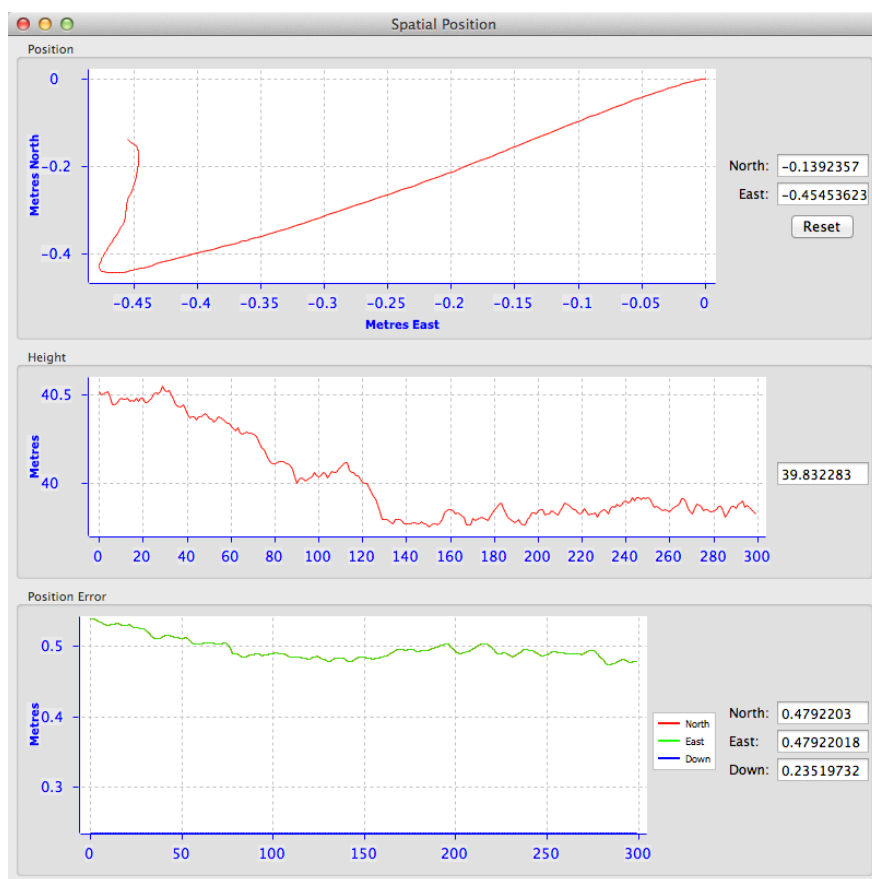


Illustration 36: Screenshot of Motus Manager Position dialogue



12.7.7 Velocity and Acceleration

Velocity and Acceleration shows Motus's velocity, acceleration and g-force.



Illustration 37: Screenshot of Motus Manager Velocity and Acceleration dialogue



12.7.8 Communications Statistics

This dialogue shows statistics on the data packets received from Motus and can be useful in diagnosing signal integrity problems.

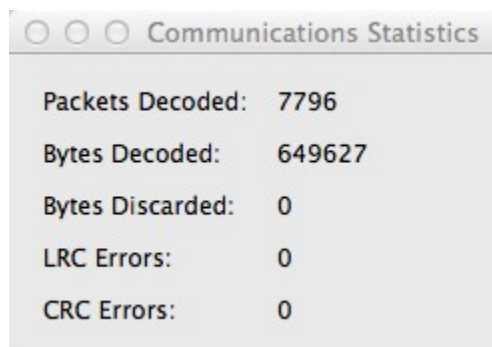


Illustration 38: Screenshot of Motus Manager Communications Statistics dialogue

12.7.9 Heave

For the Heave dialogue to function the heave packet (ID 58) must be set to output periodically using the Packet Rates dialogue.

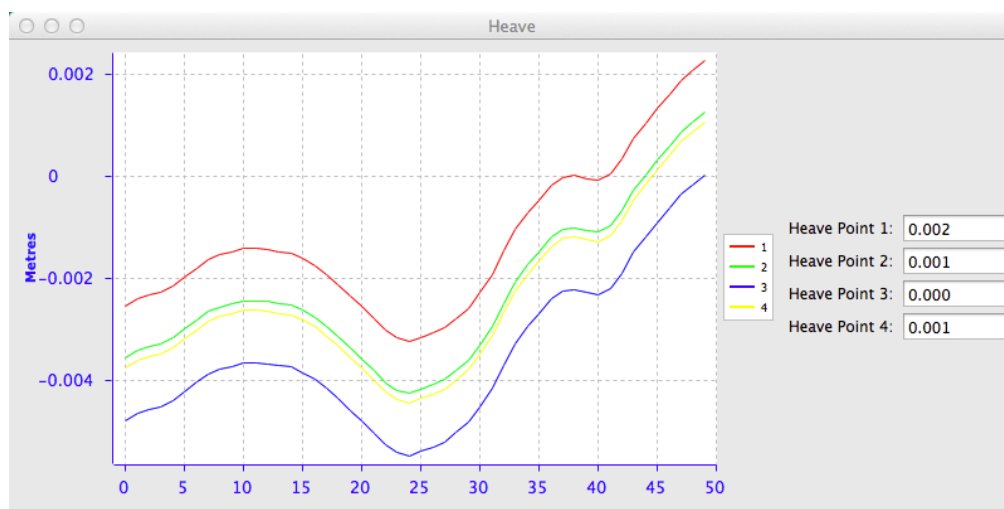


Illustration 39: Screenshot of Motus Manager Heave dialogue



12.8 Configuration

The Configuration menu contains a number of dialogues for the configuration of Motus.

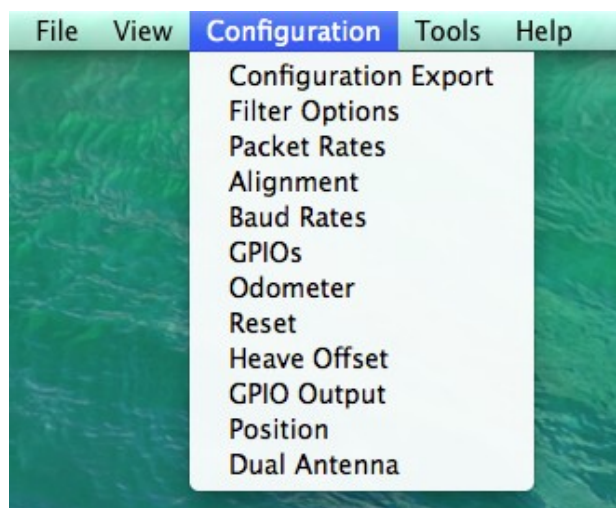


Illustration 40: Screenshot of Motus Manager Configuration menu

12.8.1 Configuration Export

The Configuration Export dialogue can be used to export all Motus settings to a file. This file can be imported at a later date or on other units. This is useful to restore a unit to preset configuration at a later date or for batch configuration of multiple units.

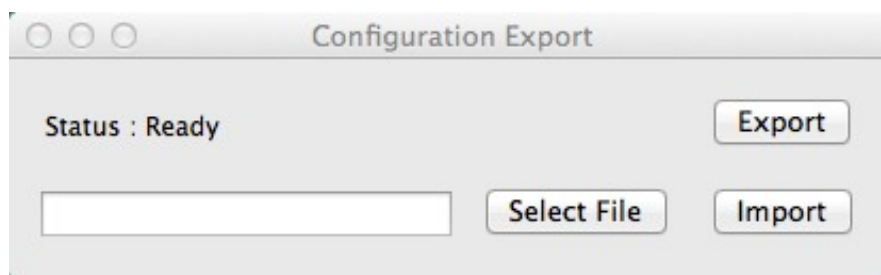


Illustration 41: Screenshot of Motus Manager Configuration Export dialogue



12.8.2 Filter Options

For most applications the default filter options should be used and only the vehicle profile set. If in doubt please contact support@advancednavigation.com.

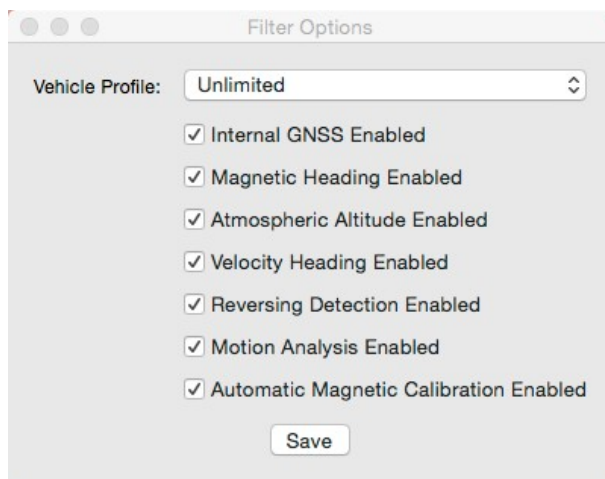
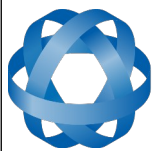


Illustration 42: Screenshot of Motus Manager Filter Options dialogue

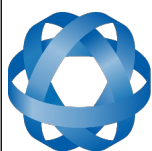


12.8.3 Packet Rates

The Packet Rates dialogue allows the user to specify which packets output on a periodic basis and at what rate. The default packets enabled are the System State Packet (ID 20) and the Raw Sensors Packet (ID 28) at 20Hz and these typically provide all the data that a user will require. These two packets need to be enabled for the data graphs to update in Motus Manager. Other state packets can be enabled as required. Please see the Packet Summary table in section 16.7 for a list of all packets.

Packet ID	Period	Output Rate
20	50	20.0 Hz
28	200	5.0 Hz

Illustration 43: Screenshot of Motus Manager Packet Rates dialogue



12.8.4 Alignment Configuration

The Alignment configuration dialogue is used to set the alignment offsets of the system installation. It is important to set the values in this dialogue correctly for accurate results. For most applications only the GNSS antenna offset values need to be entered and the rest of the values can be left at their factory defaults of zero.

Section	Parameter	Value	Unit
Alignment Offset	Roll Offset	0.000	Degrees
	Pitch Offset	-0.000	Degrees
	Heading Offset	0.000	Degrees
	Zero Current Orientation (button)		
Odometer Offset	X Offset	0.000	Metres
	Y Offset	0.000	Metres
	Z Offset	0.000	Metres
GNSS Antenna Offset	X Offset	1.800	Metres
	Y Offset	0.000	Metres
	Z Offset	-0.800	Metres
External Data Offset	X Offset	0.000	Metres
	Y Offset	0.000	Metres
	Z Offset	0.000	Metres
Save (button)			

Illustration 44: Screenshot of Motus Manager Alignment configuration dialogue

12.8.4.1 Alignment Offset

If Motus is installed into the vehicle with the X axis pointing forwards and the Z axis pointing down, then no alignment offset is required and the roll, pitch and heading offset values can remain at the factory defaults of zero.

If the unit is installed in a different orientation then the roll, pitch and heading offset must be entered. For example if the unit is installed on its side with the X axis pointing up and the Z axis pointing forwards and no change to the Y axis, then this would result in a pitch offset of +90 degrees with roll and heading remaining zero.

If there is a small misalignment due to mechanical mounting error this can be compensated for by setting the vehicle stationary on a level surface and pressing the zero current orientation button. Please note that this will only correct for roll and pitch offsets, the heading offset must be entered manually and saved before using this function.

All the other offsets will be measured in the realigned body co-ordinate frame (X positive forward, Z positive down) after being corrected for any alignment offset entered.

12.8.4.2 GNSS Antenna Offset

The GNSS antenna offset is measured from the centre of the Motus unit to the centre of the antenna in the body co-ordinate frame (X positive forward, Z positive down).



12.8.4.3 Odometer Offset

The odometer offset is measured from the centre of the Motus unit to the point at which the vehicle's tyre makes contact with the road in the body co-ordinate frame (X positive forward, Z positive down).

12.8.4.4 External Data Offset

These values are only required for speciality applications operating with external sources of data. Please contact support@advancednavigation.com for assistance with these values.

12.8.5 Baud Rates

When changing baud rates, some Microsoft Windows machines are unable to function at the higher baud rates. It is recommended to test the baud rate first with the Permanent box unticked. This way, if it is not possible to communicate at the higher baud rate, a power cycle can be used to revert to the previous baud rate.

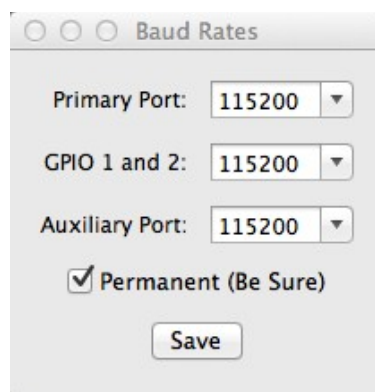


Illustration 45: Screenshot of Motus Manager Baud Rates dialogue



12.8.6 GPIO Configuration

This dialogue allows the user to select the function of the GPIO pins and Auxiliary RS232. These functions change dynamically and are effective immediately upon pressing save. Please note that GPIO pins function at RS232 levels for data functions and 0 to 5 volt levels for all other functions. The internal hardware automatically reconfigures based upon the selected function.

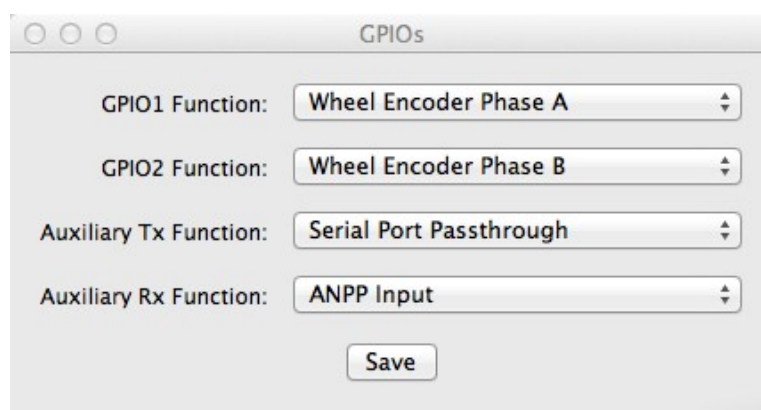


Illustration 46: Screenshot of Motus Manager GPIO configuration dialogue

12.8.7 Odometer

The Odometer dialogue allows the user to configure the odometer pulse length and view the real time odometer data to verify correct operation.

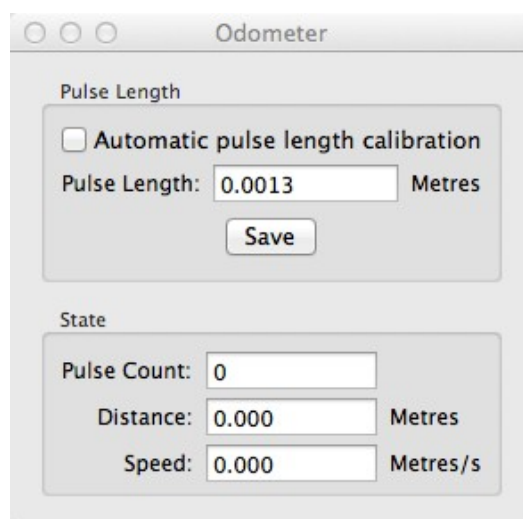
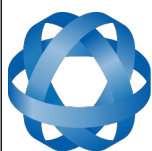


Illustration 47: Screenshot of Motus Manager Odometer configuration dialogue



12.8.8 Reset

The reset button causes the system to perform a power cycle as if the unit had the power removed and reapplied. The factory restore button causes the system to erase all settings and restore factory defaults. It also erases the hot start data so that the system is forced to perform a cold start.

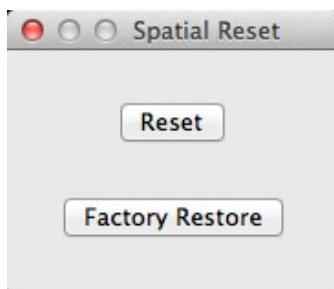


Illustration 48: Screenshot of Motus Manager Reset dialogue

12.8.9 Reference Position Offsets

The Reference Position Offsets dialogue allows the user to move the heave measurement points to different positions on the vessel. When the values are zero the measurement point is the centre of the Motus unit. This can be offset to a different position on the ship by entering the offset value from the centre of the Motus unit to the desired position in the body co-ordinate frame (X positive forwards, Z positive down). Please note that these values only apply to the Heave Packet. NMEA, TSS and Simrad heave is not affected by the values in this dialogue which are always measured at the centre of the Motus unit.

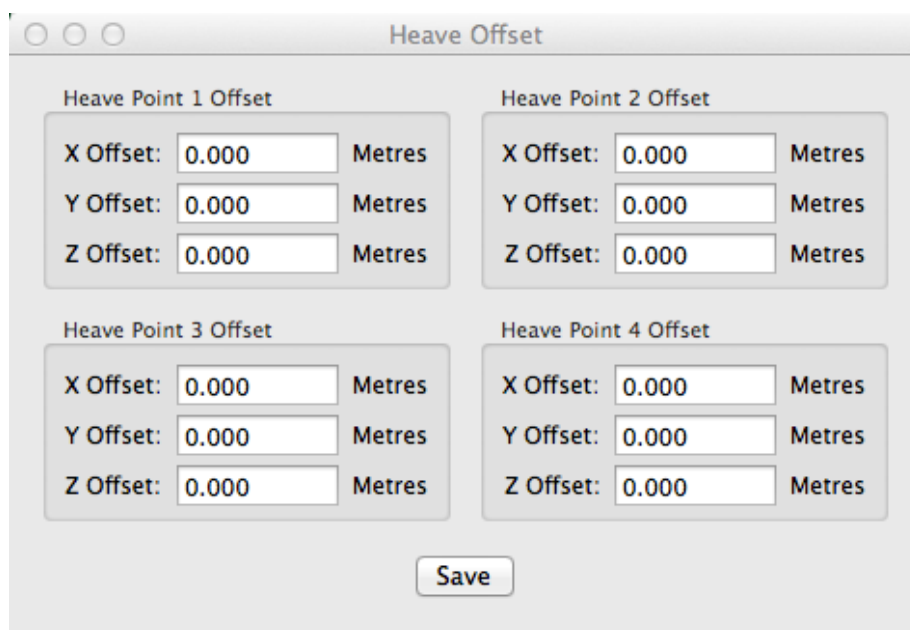


Illustration 49: Screenshot of Motus Manager Reference Position Offsets dialogue



12.8.10 GPIO Output

The GPIO Output configuration dialogue allows the user to configure the output rates for the GPIO and Auxiliary RS232 data functions NMEA, TSS and PASHR.

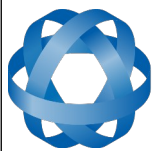
NMEA		
Fix Mode:	Normal	
	GPIO1 Rate	Auxiliary Tx Rate
GPZDA Rate:	Disabled	Disabled
GPGGA Rate:	Disabled	Disabled
GPVTG Rate:	Disabled	Disabled
GPRMC Rate:	1 Hz	1 Hz
GPHDT Rate:	Disabled	Disabled
GPGLL Rate:	Disabled	Disabled
PASHR Rate:	Disabled	Disabled

TSS		
	GPIO1 Rate	Auxiliary Tx Rate
	1 Hz	1 Hz

Simrad		
	GPIO1 Rate	Auxiliary Tx Rate
	1 Hz	1 Hz

Save

Illustration 50: Screenshot of Motus Manager GPIO Output configuration dialogue



12.8.11 Manual Initialisation

This dialogue can be used to manually initialise Motus when a GNSS fix is not available. Setting the position will initialise the navigation filter. Setting the heading will initialise the heading.

Illustration 51: Screenshot of Motus Manager Manual Initialisation dialogue

12.9 Tools

The Tools menu contains tools for performing procedures with Motus.

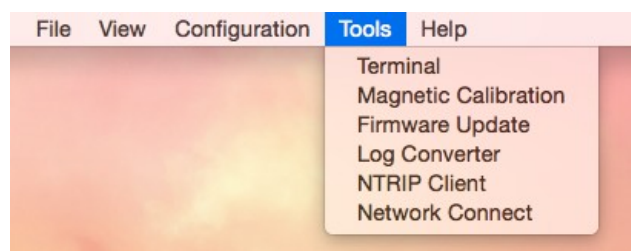


Illustration 52: Screenshot of Motus Manager Tools menu

12.9.1 Magnetic Calibration

The Magnetic Calibration dialogue allows the user to perform magnetic calibration as well as view and modify the magnetic calibration values. The actual magnetic calibration is performed inside the Motus unit. This dialogue does not have any smarts, it is just a control and display interface.

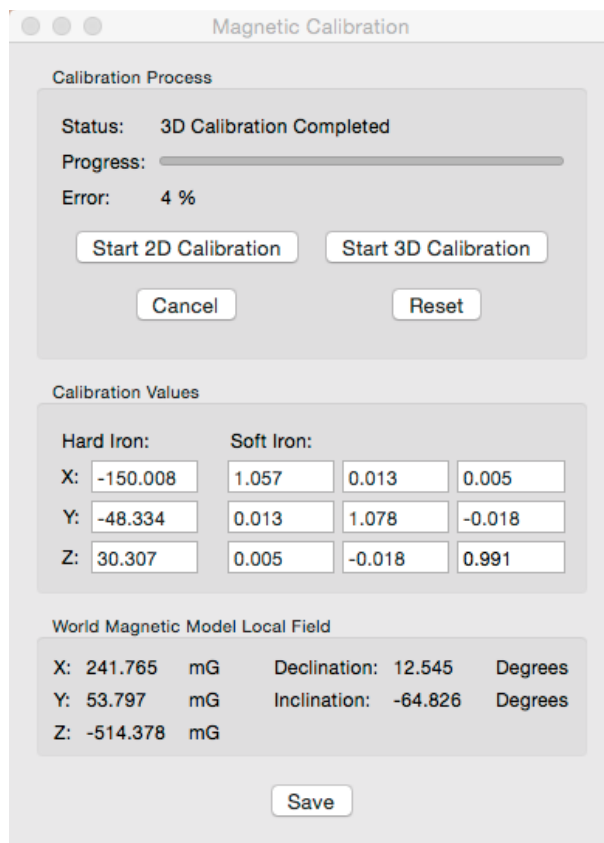


Illustration 53: Screenshot of Motus Manager Magnetic Calibration dialogue

12.9.2 Firmware Update

The Firmware Update dialogue is used to update Motus's firmware. Advanced Navigation firmware files have the extension .anfw. The dialogue shows the version number of the firmware file along with the date and time it was generated by engineering.

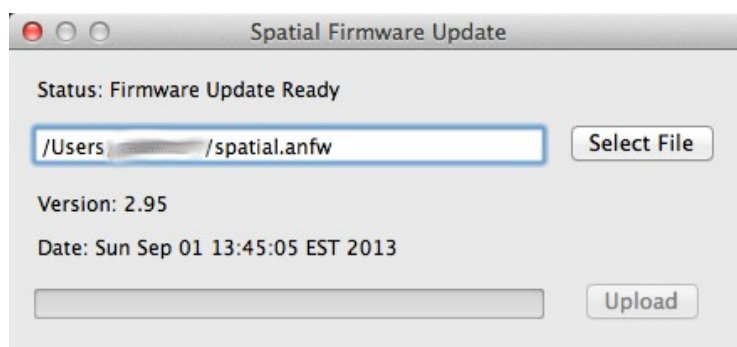


Illustration 54: Screenshot of Motus Manager Firmware Update dialogue



12.9.3 Log Converter

This tool allows the user to convert Motus log files into various standard formats that are readable by many programs. The position offset values can be used to project the exported position to a point other than the centre of the Motus unit. For most users these values should be left at zero.

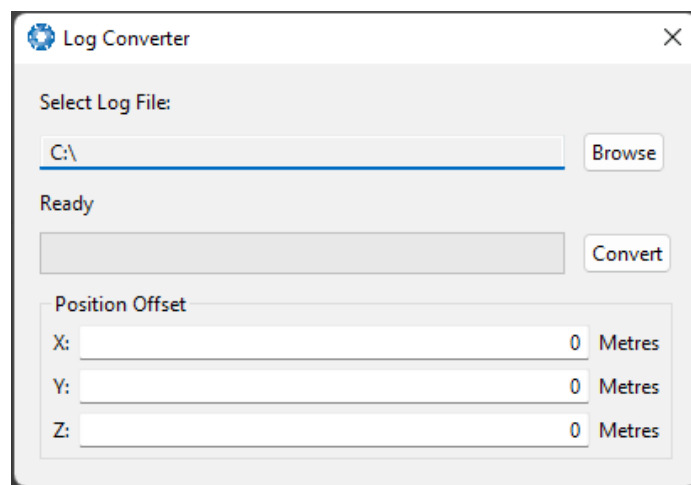


Illustration 55: Screenshot of Motus Manager Log Converter dialogue

To configure the Log path, navigate to *Settings* under the File menu

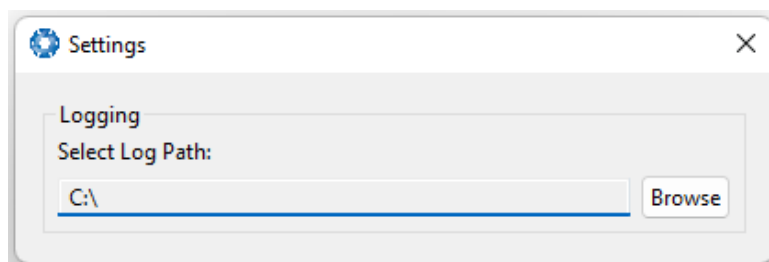


Illustration 56: Settings menu for configuring log path



12.9.4 Network Connect

The Network Connect dialogue allows Motus Manager to make a connection to Motus over a TCP/IP network rather than the default serial port connection. This allows Motus to be used with ethernet to serial converters. Advanced Navigation recommends Lantronix ethernet to serial converters.

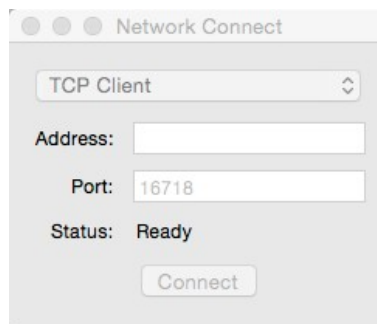


Illustration 57: Screenshot of Motus Manager Network Connect dialogue



13 OEM Integration

13.1 OEM PCB Mechanical Mounting

Motus OEM mounts to its target PCB through the use of four mounting holes on the aluminium frame. The aluminium frame is designed to achieve effective mating height for the board to board connector without any additional components. Once the Motus OEM is connected to target PCB, four M1.6 screws and washers and nuts on the back side of the target PCB are used to hold the Motus OEM in place, please see Illustration 58. The length of the M1.6 screws will be depended on the thickness of the target PCB. M1.6x6mm screws are recommended for 1.6mm thickness target PCBs.

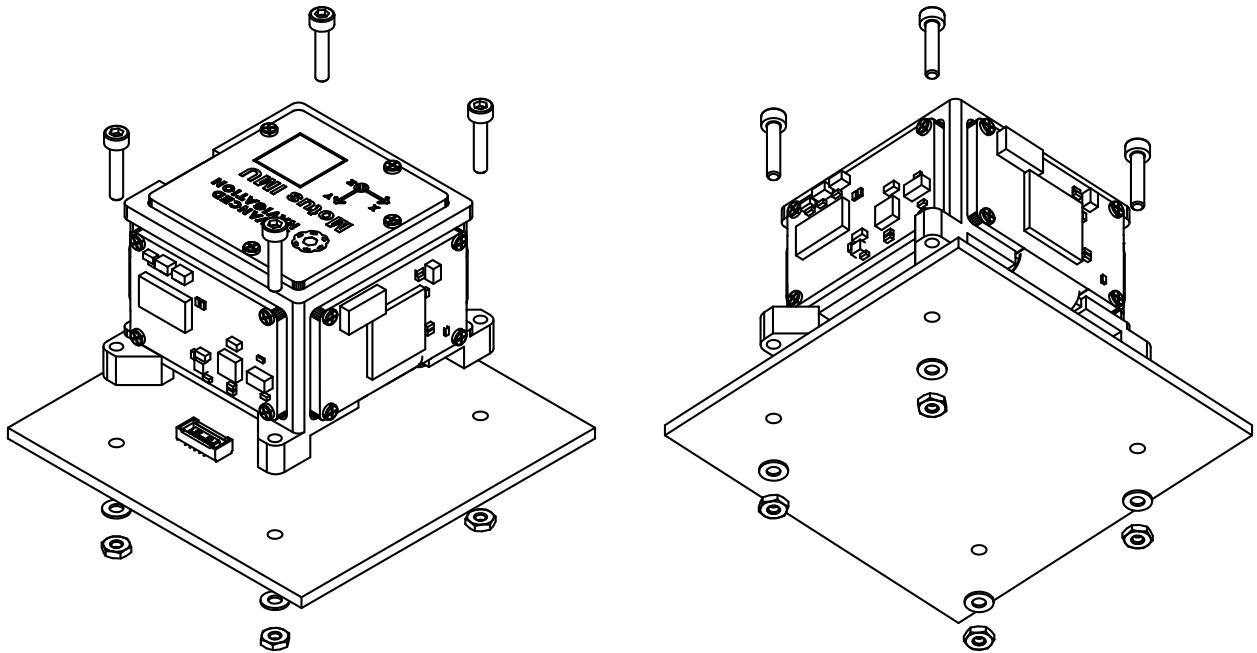


Illustration 58: Motus OEM exploded mounting view

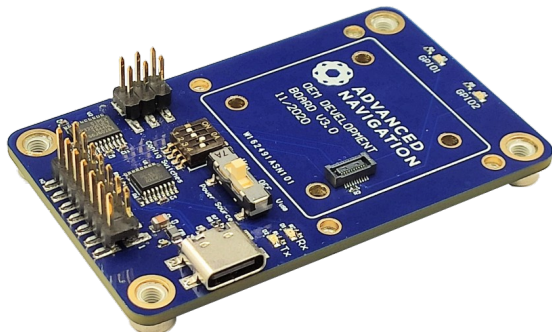


Illustration 59: Motus OEM development board

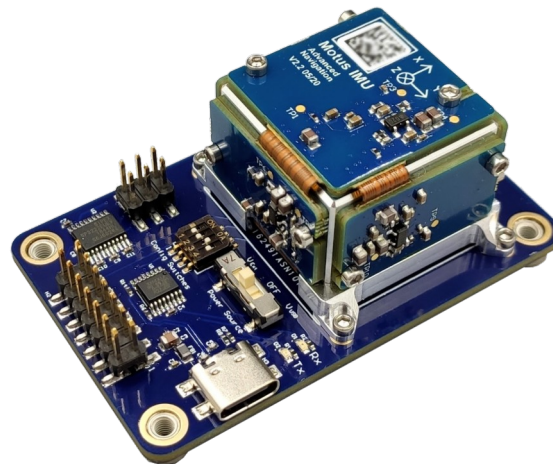


Illustration 60: Motus OEM mounted on development board

13.2 OEM Electrical Connector

The electrical connection to the Motus OEM PCB is through a Hirose DF40 series 20 pin micro pitch board to board connector. These connectors have shock absorbing features, a large self-alignment distance and high contact reliability. A positive click should be felt when successful mating occurs between Motus OEM and the target board. It should be noted that this connector is not designed for the Motus OEM to be plugged in whilst power is applied to the user's PCB and connector mating cycles should not exceed 50 cycles to ensure connector reliability.

The manufacturers part number for the required PCB connector is
Hirose Part #: DF40C(2.0)-20DS-0.4V(51)

The connector can be ordered from the following distributors using the following numbers:

Digikey Part #: H11905CT-ND

Mouser Part #: 798-DF40C20DS0.4V51

Please see Illustration 61 below for the connector pin numbering.

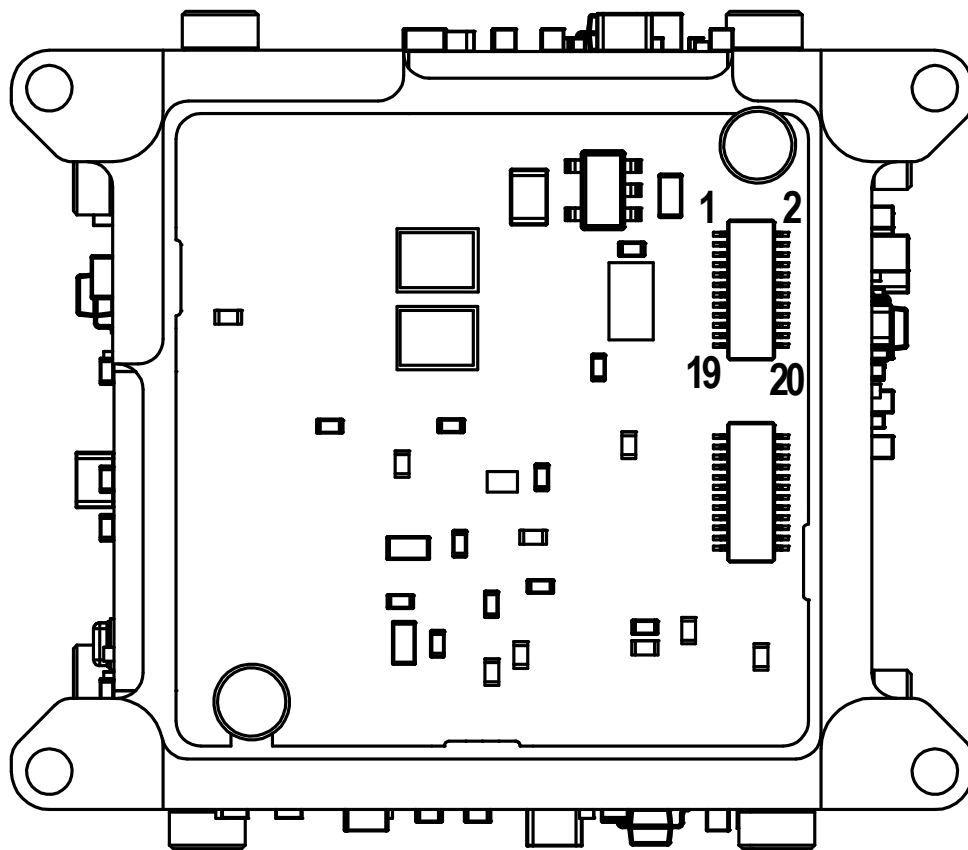
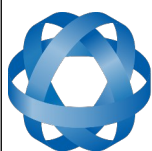


Illustration 61: Motus OEM connector pin numbering

Pin	Function
1	Supply Voltage
2	Ground
3	Supply Voltage
4	Ground
5	Supply Voltage
6	Ground
7	3.3V translator supply, see section 13.2.1
8	Ground
9	Primary UART receive
10	Reset line, see section 13.2.2
11	Primary UART transmit
12	GPIO1
13	No connection
14	GPIO2

15	No connection
16	Auxiliary UART transmit
17	No connection
18	Auxiliary UART receive
19	No connection
20	No connection

Table 21: Pin allocation table

13.2.1 Interoperability with Different Voltage Systems

All signals are 3.3 volt level, however inputs are tolerant to 5 volt signals from the target interface. If you require a different voltage level to be compatible with your target system it is recommended that you install a voltage level translator between the signals of each device. To power the translator 3.3V is provided on pin 7 of the Motus OEM connector. This supply is only capable of driving up to 25mA and should be appropriately decoupled when powering a circuit.

13.2.2 Reset Line

The reset line is internally pulled high on Motus OEM. This pin must be left floating for normal operation. If a user wishes to reset Motus OEM the pin can be pulled low externally to force a reset. It is important that this signal is not driven high under any circumstances as it will prevent the Motus OEM from functioning correctly. Please keep the reset line track length to a minimum to avoid noise.

13.2.3 Basic Connection

Please see Illustration 62 for the basic electrical connections required by Motus OEM.

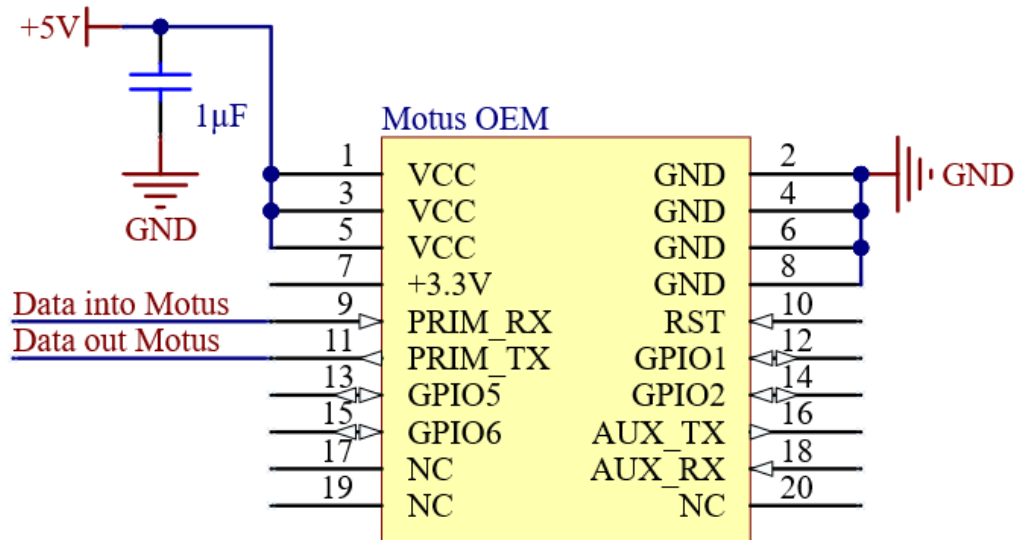


Illustration 62: Motus OEM basic electrical connections

13.3 Recommended Footprint

The footprint for Motus OEM incorporates four through-hole for M1.6 screws to pass through and 20 SMD pads for the board to board connector. The board to board connector should be the only component within the “keep out” area as shown in Illustration 63 and Illustration 64.

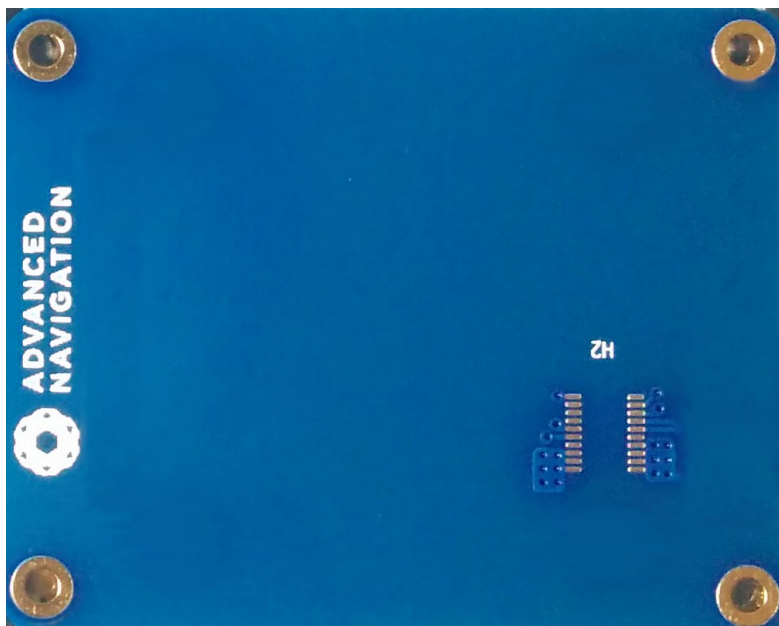


Illustration 63: Photo of Motus OEM mounting PCB footprint

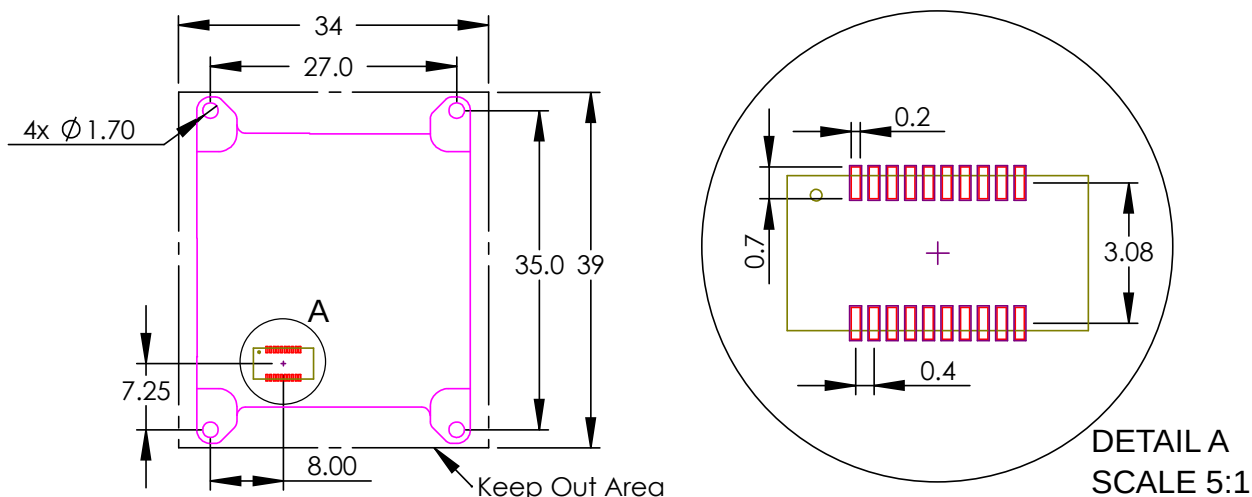
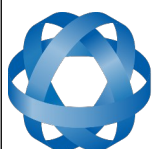


Illustration 64: Recommended footprint for Motus OEM

PCB footprint files are provided in the documentation section of the website. Please contact Advanced Navigation support if you have any issues or to verify your footprint is correct.

13.4 OEM Power Supply

The power supply is a nominal 5V DC. A high level of power supply filtering has been built into Motus OEM, however it is still recommended that the power supply be low noise (< 20mV peak-to-peak). The unit is only rated for inputs from 4.5 V to 5.5 V, exceeding 6 V can cause permanent damage to the unit.

On start-up of the Motus OEM the device will initially draw an increased impulse current (~400mA for 2 microseconds) whilst it charges on board capacitors. It is important that the user's circuit is tolerant to these small impulses on start-up to avoid unsuccessful power up. It is recommended that a supply is selected that can provide a maximum current of 0.5A. Switch-mode supplies are suitable as Motus OEM has on-board filters to remove any supply noise and ripple.

13.5 OEM Pin Protection

Users should ensure that any signals that are connected externally from the PCB, including GPIO and UART pins, are adequately protected. The use of a 5V zener diode and 1k resistor should provide enough protection for the majority of use cases, see Illustration 65.

External interface pins on Motus have on board pull-up/pull-down resistors enabled to avoid signals oscillating when not connected. The user shouldn't need to place any pull-up or pull-down resistors on their PCB.

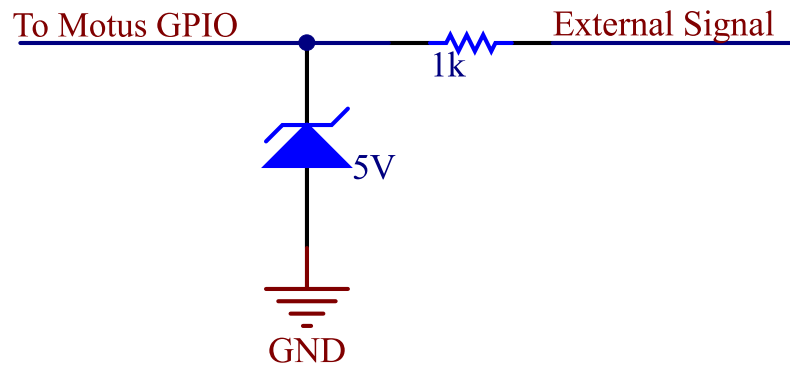


Illustration 65: Motus OEM external signal protection example



14 OEM Development Board

The OEM development board is a configurable PCB that provides developers with easy access to all of the features of the Motus OEM unit through a number of different interfaces. Illustration 66 shows an image of the OEM development board.

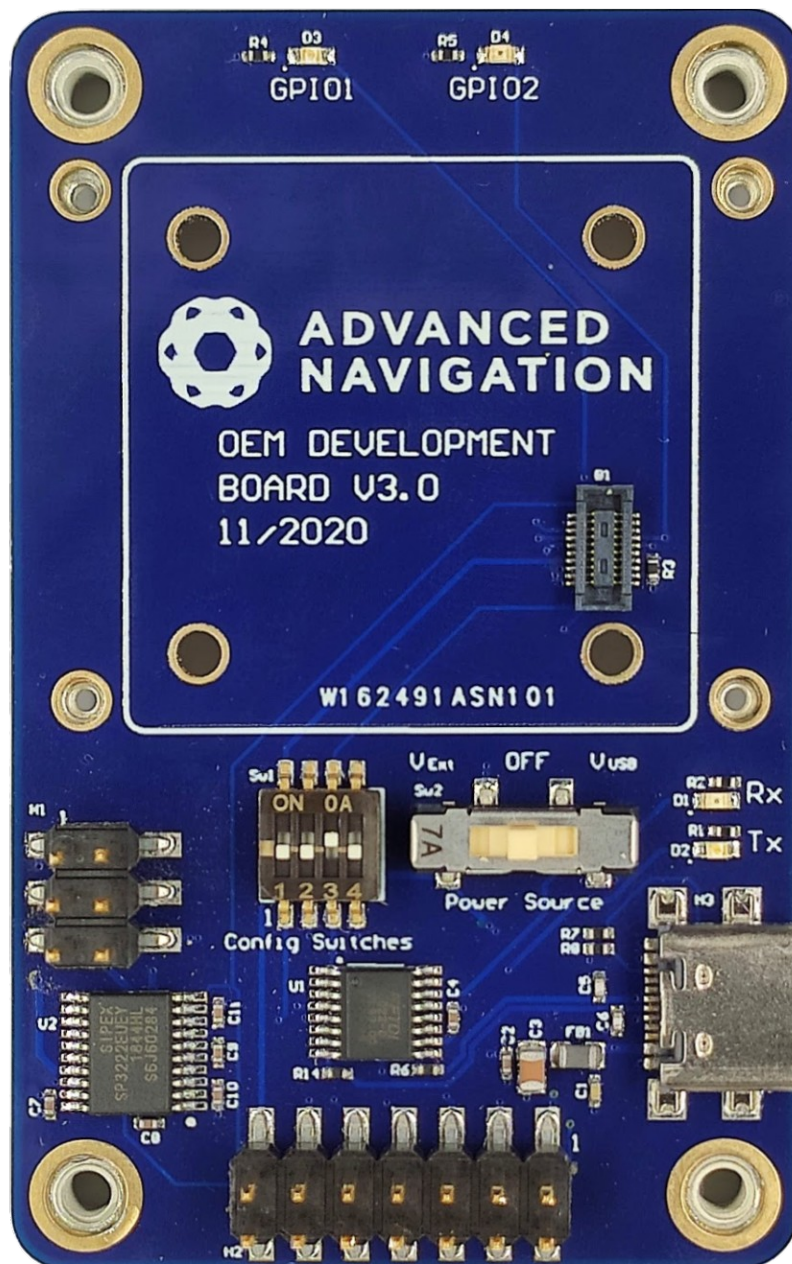


Illustration 66: Motus OEM development board



14.1 Serial UART to USB Converter

An FTDI FT232R USB to serial UART converter chip is included on board to allow the Motus OEM to interface directly to a computer through USB. Two status LEDs indicate the flow of data to and from the USB port.

USB drivers for all operating systems can be downloaded directly from FTDI's website at <http://www.ftdichip.com/Products/ICs/FT232R.htm>.

All development boards are shipped with this interface enabled as standard.

14.2 Dual RS232 Transceiver

An Exar Corporation SP3222EU dual channel serial UART to RS232 transceiver is included on the development board to allow developers to communicate with the Motus OEM unit via RS232. The SP3222EU allows baud rates of up to 1000000 baud.

Channel 1 of the SP3222EU is for use with the primary serial port on the Motus OEM unit and Channel 2 of the SP3222EU is for use with GPIO 3 (RS232 TX 2) and GPIO 4 (RS232 RX 2).

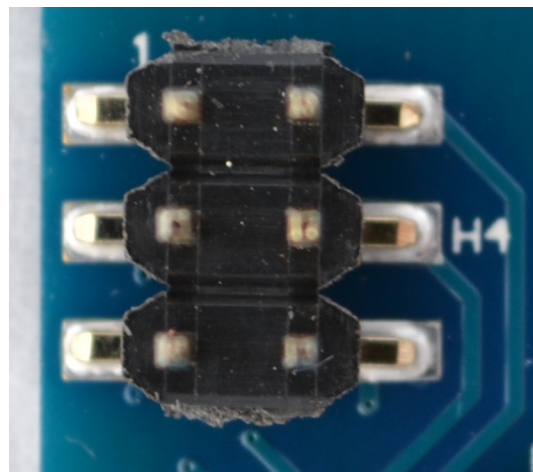
Connection to the RS232 level signals is through a 3x2 2.54mm header, see Illustration 67. This header is on the left of the board and allows developers to attach wires or headers as needed.

Please note that by default the SP3222EU is disabled. Switch 1 turns it on, please see section 14.4.

RS232 TX 1

RS232 TX 2

GND



RS232 RX 1

RS232 RX 2

VEXT

Illustration 67: RS232 header with functions labelled

14.3 GPIO Header and Status LEDs

Users have access to 4 multi-purpose GPIO pins from Motus OEM. These are available on the 7x2 2.54mm header, see Illustration 68. Two of these pins (GPIO 1 & 2) are also connected to LEDs on the development board. When using a GPIO in certain input functions, the LED can cause interference with the signal. In this situation, the LED's resistor should be removed. When using the GPIO lines for off board functions it is important to note that these signals are not protected against static charges, over-voltage or over-current events. Failure to protect the signals may result in damage to Motus OEM. Other pins on the GPIO header include a regulated 3.3V supply from Motus that can supply up to 50mA, Motus' reset line and the external voltage input (VEXT).

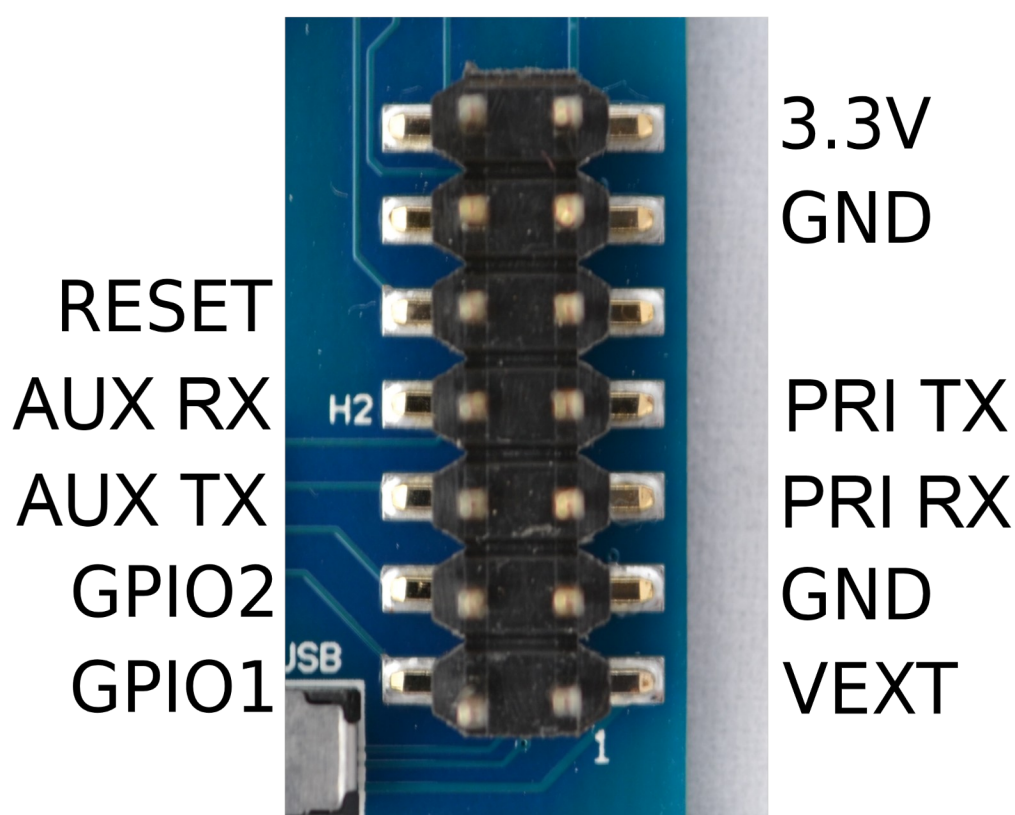


Illustration 68: GPIO header with functions labelled

14.4 Configuration Switches

The OEM development board contains a DIP switch array that allows the user to route signals between the USB to serial converter, RS232 converter and GPIO header. The configuration switches are shown below in Illustration 69 in their default positions. The default position routes the Motus primary serial port to the USB to serial converter and has GPIO 3 and GPIO 4 connected only to the GPIO header. Please see Table 22 for the configuration switch functions.

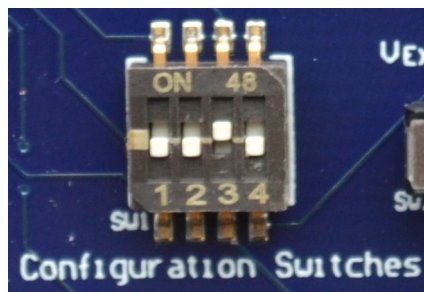
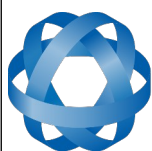


Illustration 69: Configuration switches in their default position

Switch	Default	Function
1	Off	Power on RS232 transceiver. When the RS232 transceiver is powered on GPIO 3 and 4 will be connected to RS232 TX 2 and RS232 RX2 respectively. It will no longer be possible to use GPIO 4 in a TTL level mode. The primary serial port TX will also be connected to RS232 TX 1 but the primary serial port RX will only be connected to RS232 RX 1 if switch 2 is turned on.
2	Off	Connect primary serial port RX to RS232 transceiver (RS232 RX 1). Please note that only one of the switches 2,3 or 4 should be turned on at once to prevent short circuit.
3	On	Connect primary serial port RX to USB serial converter. Please note that only one of the switches 2,3 or 4 should be turned on at once to prevent short circuit.
4	Off	Connect primary serial port RX to GPIO header (UART RX). Please note that only one of the switches 2,3 or 4 should be turned on at once to prevent short circuit.

Table 22: Configuration switch functions

14.4.1 Primary Serial Port to USB

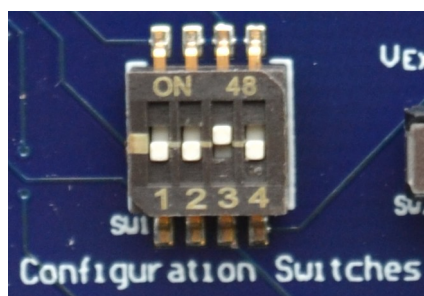


Illustration 70: Switch positions for primary serial port to USB (default)

14.4.2 Primary Serial Port to RS232 1 and GPIO 3 & 4 to RS232 2

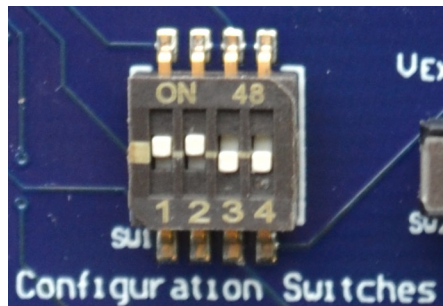


Illustration 71: Switch positions for primary serial port to RS232 1 and GPIO 3 & 4 to RS232 2

14.4.3 Primary Serial Port and GPIO 3 & 4 to GPIO Header at TTL levels

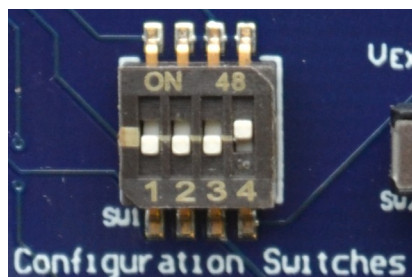


Illustration 72: Switch positions for primary serial port and GPIO 3 & 4 to GPIO header at TTL levels

14.5 Power source

The development board has two power source options; USB power (5V nominal) or an external power source. By default, the development board is configured to use USB power.

The external power source can be fed into the board through V_{Ext} on either the GPIO header or of RS232 header. The external power is a 5 V input. See section 13.4 for further details.

The power source is selected by a three way switch, please see Illustration 73 and Illustration 74.

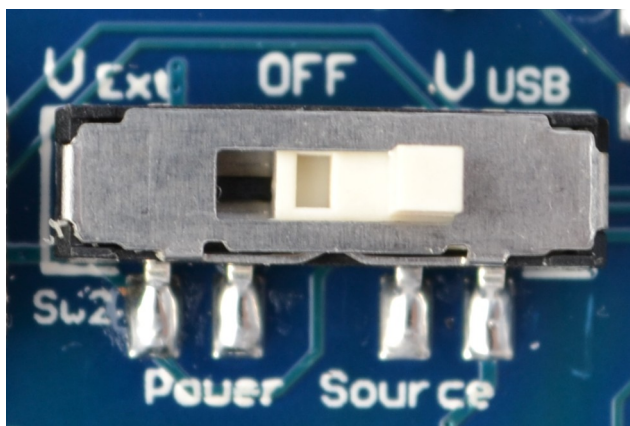


Illustration 73: Power switch position for USB power (default)

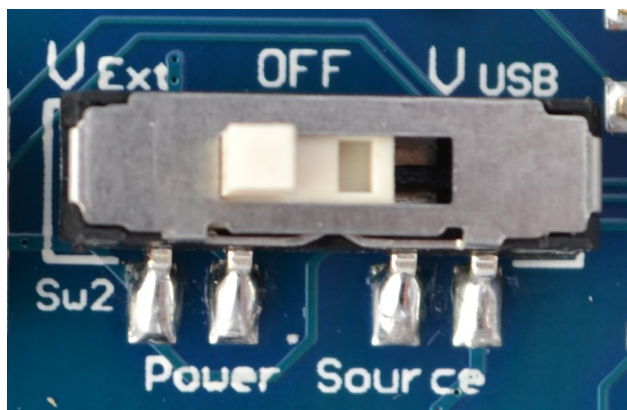
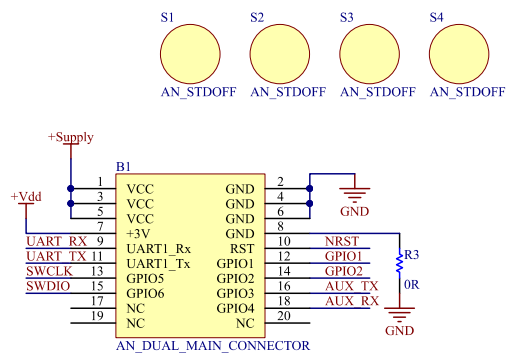
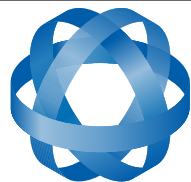


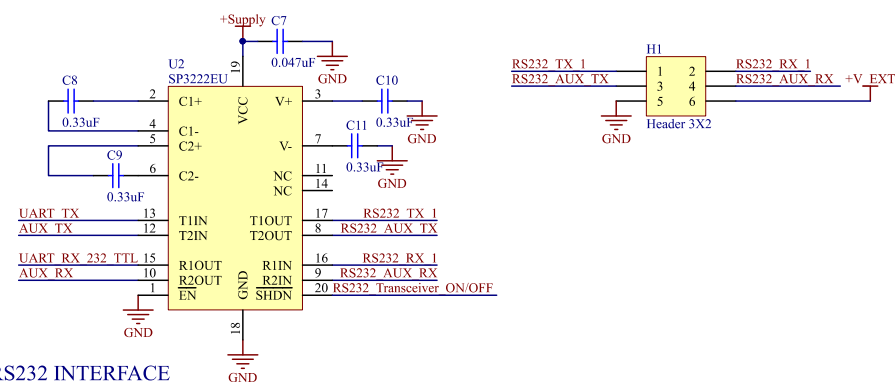
Illustration 74: Power switch position for external power

14.6 Schematics

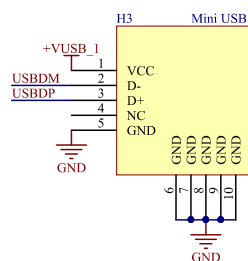
See the following pages for the development board schematics.



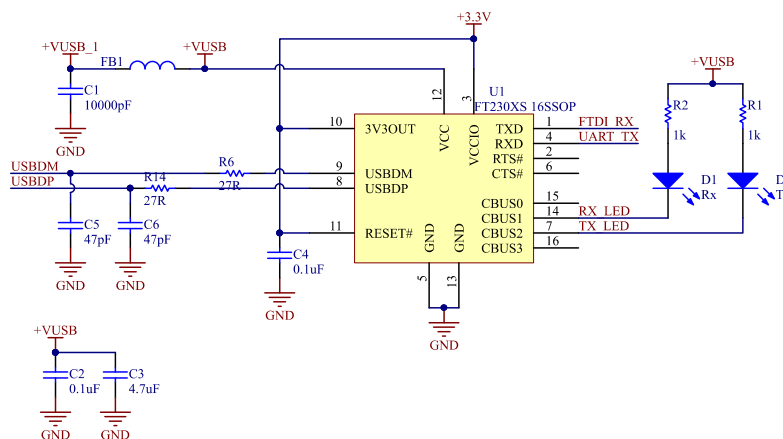
BOARD TO BOARD CONNECTOR

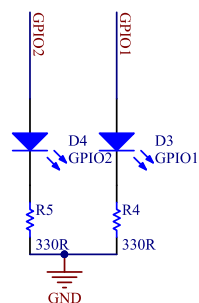
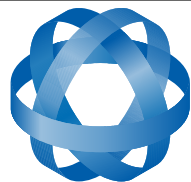


RS232 INTERFACE

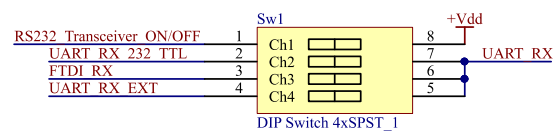


FTDI USB TO UART

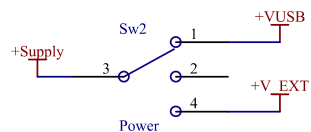




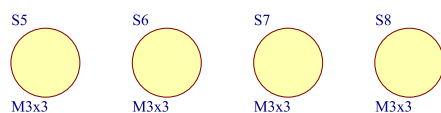
GPIO STATUS LEDS



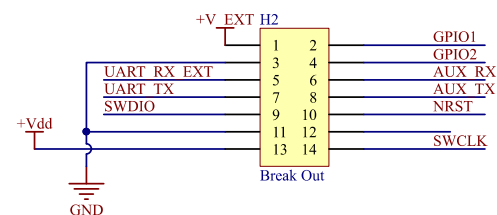
CONFIGURATION SWITCHES



POWER SWITCH



M3 STANDOFFS



IO INTERFACE

15 Interfacing

15.1 Communication

Communication with Motus is over the primary RS422 or RS232 interface in the Advanced Navigation Packet Protocol (ANPP). The RS422 or RS232 format is fixed at 1 start bit, 8 data bits, 1 stop bit and no parity. See section 16 for details on the protocol.

Model	Primary Port	Auxiliary Port	GPIO Port
Motus Rugged RS232	Yes	Yes	Yes
Motus Rugged RS422	Yes	No	Yes

Table 23: I/O ports available

The primary port is used to communicate with Motus Rugged using the ANPP format. Any required data in ANPP packet format can be configured to output on request or at predetermined rates.

15.1.1 Baud Rate

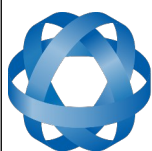
The default baud rate for all the ports of Motus Rugged is 115200 bps. The primary port baud rate can be set anywhere from 2400 to 2000000 baud and can be modified using the Motus Manager software (see section 12.8.5) or the Baud Rates packet, see section 16.10.3. It is important to select a baud rate that is capable of carrying the amount of data that Motus is configured to output. See Packet Rates in section 16.5 for more details on the data output calculation. The data rate in bytes per second can be calculated by dividing the baud rate by 10. For example, if the baud rate is 115200, then the data rate is 11520 bytes per second.

15.2 External Data

External sources of position, velocity and/or heading can be integrated into Motus's filter solution. The data can be sent to Motus in the ANPP format over the primary port or through one of the GPIO pins in a number of different formats. If using the ANPP, please use Table 24 below to find the relevant section. If using the GPIOs, please see section 15.3.

Packet	Section
External Position and Velocity	16.9.25
External Position	16.9.26
External Velocity	16.9.27
External Body Velocity	16.9.28
External Heading	16.9.29
External Time	16.9.33
External Depth	16.9.34
External Odometer	16.9.40
External Air Data	16.9.41

Table 24: ANPP external data reference



15.3 GPIO Pins and Auxiliary RS232

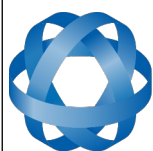
The RS232 model of Motus contains two general purpose input output (GPIO) pins and an auxiliary RS232 port on the main connector. The RS422 model of Motus does not have the auxiliary port. These pins and ports are multi function and can be used to extend Motus with additional peripherals, sensors and data formats. The GPIO pins have digital input, digital output, frequency input and frequency output functionality.

For both models, GPIO1 can also function as an RS232 serial transmit line and GPIO2 can function as an RS232 serial receive line. The GPIO serial baud rate can be configured anywhere from 2400 to 250 K baud. The auxiliary serial baud rate can be configured anywhere from 2400 to 2 M baud. Changes to these baud rates can be made by using the Baud Rates dialog box in Motus Manager (see section 12.8.5) or the Baud Rates Packet (see section 16.10.3).

The available GPIO pin functions and auxiliary RS232 functions are listed below in section 15.4. The function of a GPIO pin or the auxiliary RS232 can be changed at any time using the GPIO configuration dialog box in Motus Manager (see section 12.8.6) or the GPIO Configuration Packet (see section 16.10.7). GPIO 1 and GPIO 2 function at 0 – 5 volt levels for digital input, digital output, frequency input and frequency output, but when a serial data function is selected that GPIO pin automatically switches to RS232 level.

15.4 Dynamic Pin Functions

Function	Type	GPIOs	Auxiliary RS232
Inactive	Tristate	All	All
1PPS Output	Digital Output	All	Transmit
GNSS Fix Output	Digital Output	All	Transmit
Odometer Input	Frequency Input	All	Receive
Zero Velocity Input	Digital Input	All	Receive
Pitot Tube Input	Frequency Input	All	Receive
NMEA Input	Serial Receive	2	Receive
NMEA Output	Serial Transmit	1	Transmit
Novatel GNSS Input	Serial Receive	2	Receive
Topcon GNSS Input	Serial Receive	2	Receive
ANPP Input	Serial Receive	2	Receive
ANPP Output	Serial Transmit	1	Transmit
Disable Magnetometers	Digital Input	All	Receive
Set Zero Orientation Alignment	Digital Input	All	Receive
System State Packet Trigger	Digital Input	All	Receive
Raw Sensors Packet Trigger	Digital Input	All	Receive
Pressure Depth Transducer	Frequency Input	All	Receive
Trimble GNSS Input	Serial Receive	2	Receive



Function	Type	GPIOs	Auxiliary RS232
u-blox GNSS Input	Serial Receive	2	Receive
Hemisphere GNSS Input	Serial Receive	2	Receive
Teledyne DVL Input	Serial Receive	2	Receive
Tritech USBL Input	Serial Receive	2	Receive
Linkquest DVL Input	Serial Receive	2	Receive
Linkquest USBL Input	Serial Receive	2	Receive
Nortek DVL Input	Serial Receive	2	Receive
Left Wheel Speed Sensor	Frequency Input	All	Receive
Right Wheel Speed Sensor	Frequency Input	All	Receive
1PPS Input	Digital Input	All	Receive
Wheel Speed Sensor	Frequency Input	All	Receive
Wheel Encoder Phase A	Frequency Input	All	
Wheel Encoder Phase B	Frequency Input	All	
Event 1 Input	Digital Input	All	Receive
Event 2 Input	Digital Input	All	Receive
TSS1 Output	Serial Transmit	1	Transmit
Simrad 1000 Output	Serial Transmit	1	Transmit
Simrad 3000 Output	Serial Transmit	1	Transmit
Serial Port Passthrough	Serial	All	All
Gimbal Encoder Phase A	Frequency Input	All	
Gimbal Encoder Phase B	Frequency Input	All	
Odometer Direction, Forward Low	Digital Input	All	Receive
Odometer Direction, Forward High	Digital Input	All	Receive
Reverse Alignment, Forward Low	Digital Input	All	Receive
Reverse Alignment, Forward High	Digital Input	All	Receive
Zero Angular Velocity Input	Digital Input	All	Receive

Table 25: GPIO pin functions

15.4.1 1PPS Output

In this function, the pin pulses for 50 milliseconds to signal the precise second. The 1PPS line starts pulsing approximately 100 milliseconds after power up and always fires irrespective of whether Motus has accurate time or not. It is important to note that when Motus acquires time corrections from a GNSS receiver, the 1PPS signal may fire at an interval of less than 1 second. This typically only occurs the first time the GNSS receiver obtains a fix after startup. The time initialised status flag can be used to determine whether the time and 1PPS line is accurate or not.

1PPS Source	Voltage Level	Trigger
Auxiliary	-5 V to 5 V	Falling Edge
GPIO	0 to 5 V	Rising Edge

Table 26: 1PPS Specifications

15.4.2 GNSS Fix Output

In this function, the pin is low when there is no GNSS fix or a 2D fix and high when there is a 3D, SBAS, Differential or RTK GNSS fix.

15.4.3 Odometer Input

This function is designed for low resolution vehicle speed sensors and odometers. It expects a normally low input with a high state for the trigger. If the pulse length is more than 0.1 metres this odometer input function should be used, if it is less than 0.1 metres the wheel speed sensor function should be used. Please contact Advanced Navigation support for help integrating with your speed sensor.

Parameter	Value
Trigger	Low → High
Maximum Frequency	600Khz
Maximum Pulse Rate	4294967 pulses/metre

Table 27: Odometer Specifications

15.4.4 Zero Velocity Input

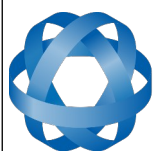
When using this function, a high state indicates to Motus that it is stationary. The low state indicates that the vehicle is not stationary. Use of this function can significantly improve drift performance when a GNSS signal is not available.

15.4.5 Pitot Tube Input

This function is designed for fixed wing aircraft to enhance navigation through the use of a pitot tube to measure airspeed. It requires a differential pressure sensor that has a frequency output such as the Kavlico P992 (frequency output option) or the Paroscientific series 5300. Please contact Advanced Navigation support for help integrating with a pitot tube.

15.4.6 NMEA Input

This function accepts external data in the NMEA format. Advanced Navigation recommends against using NMEA where possible due to the inefficiency, inaccuracy and poor error checking of the format. All NMEA messages received must have a valid checksum. Supported messages are listed below. The recommended combination of messages are GPGGA, GPVTG and GPZDA with optional messages GPGSV and GPGSA.



Message ID	Description
GPGBA GNGBA	3D position
GPGLL GNLL	2D position
GPRMC GNRMC	2D position, 2D velocity and coarse time
GPVTG GNVTG	2D velocity
GPHDT GNHDT HEHDT	Heading
GPGSV NGSV	Satellites
GPGBA GNGBA	Dilution of Position
GPZDA GNZDA	Time

Table 28: Supported NMEA messages

15.4.7 NMEA Output

This function outputs a configurable combination of NMEA messages at up to 50 Hz. The messages output and the output rate can be configured using the GPIO Output configuration dialogue in Motus Manager. A complete list of available messages can be found in section 16.10.14 .

Advanced Navigation recommends against using NMEA where possible due to the inefficiency, inaccuracy and poor error checking of the format.

\$GPZDA,031644.460,07,05,2013,00,00*52

\$GPGBA,031644.460,3352.3501851,S,15112.2355488,E,6,00,1.4,150.0,M,0.0,M,,*7E

\$GPVTG,089.19,T,089.19,M,000.00,N,000.00,K,E*27

\$GPRMC,031644.460,A,3352.3501851,S,15112.2355488,E,0.0,89.2,070513,12.5,W,E*02

\$GPHDT,89.2,T*06

\$PASHR,031644.460,089.19,T,-00.01,-00.47,-00.00,,,,,0,0*2E

15.4.8 Novatel GNSS Input

This function is designed for interfacing Motus with a Novatel GNSS receiver. It accepts data in the Novatel binary format and requires messages BESTPOSB and BESTVELB at rates higher than 1 Hz (20Hz recommended). The message BESTSATSB is optional to display detailed satellite information. The message HEADING is also supported for ALIGN capable receivers.



15.4.9 Topcon GNSS Input

This function is designed for interfacing Motus with a Topcon GNSS receiver. It accepts data in the GRIL TPS binary format and expects messages PG and VG at rates higher than 1 Hz.

15.4.10 ANPP Input

This function accepts data in the ANPP format as specified in section 16.

15.4.11 ANPP Output

This function outputs data in the ANPP format as specified in section 16. For packets to be sent out they must be requested through another GPIO functioning as ANPP input.

15.4.12 Disable Magnetometers

This function accepts a digital input with a low state enabling the magnetometers and a high state disabling the magnetometers.

15.4.13 Set Zero Orientation Alignment

This function accepts a digital input. The input is normally low and a transition from low to high causes Motus to set its alignment so that the current orientation is zero. Due to the risk of exhausting the flash cycles, the change is not permanent and will disappear on reset. To make it permanent the Installation Alignment Packet must be read and then sent back to Motus with the permanent flag set. This function requires de-bouncing if attached to a switch.

15.4.14 System State Packet Trigger

This function accepts a digital input. The input is normally low and a transition from low to high causes Motus to send the system state packet. This function requires de-bouncing if attached to a switch.

15.4.15 Raw Sensors Packet Trigger

This function accepts a digital input. The input is normally low and a transition from low to high causes Motus to send the raw sensors packet. This function requires de-bouncing if attached to a switch.

15.4.16 Pressure Depth Transducer

This function is designed for interfacing with a legacy pressure depth transducer. These are no longer available and the function is now deprecated.

15.4.17 Trimble GNSS Input

This function is designed for interfacing Motus with an external Trimble GNSS receiver. It accepts data in the Trimble binary format GSOF and expects packet 0x40 with records 1, 2, 8, and 12 at rates higher than 1Hz (20Hz recommended) and optional records 9 and 34 at 1 to 2Hz.



15.4.18 u-blox GNSS Input

This function is designed for interfacing Motus with a u-blox GNSS receiver. It accepts data in the u-blox binary format and expects message NAV-PVT at rates higher than 1Hz.

15.4.19 Hemisphere GNSS Input

This function is designed for interfacing Motus with a Hemisphere GNSS receiver. It accepts data in the Hemisphere binary format and expects message Bin1 at rates higher than 1Hz. For Hemisphere receivers that provide heading using two antennas, NMEA should be used instead as the binary format does not allow for transmission of heading information.

15.4.20 Teledyne DVL Input

This function accepts DVL data from a Teledyne DVL. For assistance with configuration please contact support@advancednavigation.com.

15.4.21 Tritech USBL Input

This function accepts USBL data from a Tritech USBL. For assistance with configuration please contact support@advancednavigation.com.

15.4.22 Linkquest DVL Input

This function accepts DVL data from a Linkquest DVL. For assistance with configuration please contact support@advancednavigation.com.

15.4.23 Linkquest USBL Input

This function accepts USBL data from a Linkquest USBL. For assistance with configuration please contact support@advancednavigation.com.

15.4.24 Nortek DVL Input

This function accepts DVL data in the Nortek DVL binary format. It accepts the packets 0x1B (DVL Bottom Track) and 0x1D (DVL Water Track). The recommended update rate is 8Hz.

15.4.25 Left Wheel Speed Sensor

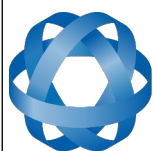
This function is designed for the left wheel of a vehicle with dual wheel speed sensors.

15.4.26 Right Wheel Speed Sensor

This function is designed for the right wheel of a vehicle with dual wheel speed sensors.

15.4.27 1PPS Input

This function is designed to allow external GNSS receivers to synchronise time with Motus. It triggers on a transition from low to high.



15.4.28 Wheel Speed Sensor

This function is designed for high resolution vehicle speed sensors and wheel speed sensors. It expects a normally low input with a high state for the trigger. If the pulse length is more than 0.1 metres the odometer input function should be used, if it is less than 0.1 metres this wheel speed sensor function should be used. Please contact Advanced Navigation support for help integrating with your speed sensor.

Parameter	Value
Trigger	Low → High
Maximum Frequency	40 MHz
Maximum Pulse Rate	4,294,967,295 pulses/metre

Table 29: Wheel Speed Sensor Specifications

15.4.29 Wheel Encoder Phase A

This function is designed for rotary incremental quadrature encoders. It should be used in combination with Wheel Encoder Phase B.

15.4.30 Wheel Encoder Phase B

This function is designed for rotary incremental quadrature encoders. It should be used in combination with Wheel Encoder Phase A.

15.4.31 Event 1 Input

This function is designed to allow external events to be recorded inside Motus's output. The event is recorded in the filter status, see section 16.9.1.2, and resets after the next packet is output. The event triggers on a transition from low to high.

15.4.32 Event 2 Input

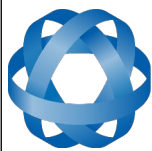
This function is designed to allow external events to be recorded inside Motus's output. The event is recorded in the filter status, see section 16.9.1.2, and resets after the next packet is output. The event triggers on a transition from low to high.

15.4.33 TSS1 Output

This function outputs the TSS1 format at a user configurable rate up to 50 Hz. The output rate can be configured using the GPIO Output configuration dialogue in Motus Manager, see section 12.8.10.

15.4.34 Simrad 1000 Output

This function outputs the Simrad 1000 format at a user configurable rate up to 50 Hz. The output rate can be configured using the GPIO Output configuration dialogue in Motus Manager, see section 12.8.10.



15.4.35 Simrad 3000 Output

This function outputs the Simrad 3000 format at a user configurable rate up to 50 Hz. The output rate can be configured using the GPIO Output configuration dialogue in Motus Manager, see section 12.8.10.

15.4.36 Serial Port Passthrough

This function allows passthrough communication through either GPIO 1 and 2 or the Auxiliary RS232. To transmit data use the Serial Port Pass-through Packet. When data is received it will be sent back using the same Serial Port Pass-through Packet.

15.4.37 Gimbal Encoder Phase A

This function is designed for interfacing with a rotary incremental quadrature encoder to measure the azimuth angle of a gimbal that Motus is installed in. It should be used in combination with Gimbal Encoder Phase B.

15.4.38 Gimbal Encoder Phase B

This function is designed for interfacing with a rotary incremental quadrature encoder to measure the azimuth angle of a gimbal that Motus is installed in. It should be used in combination with Gimbal Encoder Phase A.

15.4.39 Odometer Direction, Forward Low

This function is designed to take a reversing indication input for direction with an odometer or wheel encoder. It should be used in combination with Odometer Input or Wheel Speed Sensor.

15.4.40 Odometer Direction, Forward High

This function is designed to take a reversing indication input for direction with an odometer or wheel encoder. It should be used in combination with Odometer Input or Wheel Speed Sensor.

15.4.41 Reverse Alignment, Forward Low

This function is designed to reverse the alignment settings for vehicles that can have two vehicle forward directions, such as locomotives.

15.4.42 Reverse Alignment, Forward High

This function is designed to reverse the alignment settings for vehicles that can have two vehicle forward directions, such as locomotives.

15.4.43 Zero Angular Velocity Input

In this function, a high state indicates to Motus that the vehicle is not rotating. The low state indicates that the vehicle could be rotating. Use of this function can significantly improve heading drift performance as well as improve bias estimates when a GNSS signal is not available.

It should be asserted whenever the vehicle has been stationary about the heading axis for at least 0.1 seconds.

16 Advanced Navigation Packet Protocol

The Advanced Navigation Packet Protocol (ANPP) is a binary protocol designed with high error checking, high efficiency and safe design practices. It has a well defined specification and is very flexible. It is used across all existing and future Advanced Navigation products.

16.1 Data Types

The following data types are used in the packet protocol. All data types in the protocol are little endian byte ordering.

Abbreviation	Bytes	Also known as
u8	1	unsigned char, unsigned byte, uint8_t
s8	1	char, byte, int8_t
u16	2	unsigned short, uint16_t
s16	2	short, int16_t
u32	4	unsigned int, unsigned long, uint32_t
s32	4	int, long, int32_t
u64	8	unsigned long long, uint64_t
s64	8	long long, int64_t
fp32	4	float
fp64	8	double

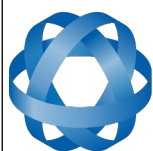
Table 30: Data type abbreviations used in the ANPP

16.2 Packet Structure

The ANPP packet structure is shown in Table 31 and the header format is shown in Table 32. Example code can be downloaded from the software section.

Header				
Header LRC	Packet ID	Packet Length	CRC16	Packet Data

Table 31: ANPP Packet Structure

**ANPP Header Format**

Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Header LRC, see section 16.2.1
2	1	u8	1	Packet ID, see section 16.2.2
3	2	u8	1	Packet Length, see section 16.2.3
4	3	u16	2	CRC16, see section 16.2.4

Table 32: ANPP header format

16.2.1 Header LRC

The header LRC (Longitudinal Redundancy Check) provides error checking on the packet header. It also allows the decoder to find the start of a packet by scanning for a valid LRC. The LRC can be found using the following:

$$\text{LRC} = ((\text{packet_id} + \text{packet_length} + \text{crc}[0] + \text{crc}[1]) \wedge 0xFF) + 1$$

16.2.2 Packet ID

The packet ID is used to distinguish the contents of the packet. Packet IDs range from 0 to 255.

Within this range there are three different sub-ranges, these are system packets, state packets and configuration packets.

System packets have packet IDs in the range 0 to 19. These packets are implemented the same by every device using ANPP.

State packets are packets that contain data that changes with time, i.e. temperature. State packets can be set to output at a certain rate. State packets are packet IDs in the range 20 to 179.

Configuration packets are used for reading and writing device configuration. Configuration packets are packet IDs in the range 180 to 255.

16.2.3 Packet Length

The packet length denotes the length of the packet data, i.e. from byte index 5 onwards inclusive. Packet length has a range of 0 – 255.

16.2.4 CRC

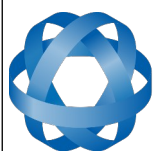
The CRC is a CRC16-CCITT. The starting value is 0xFFFF. The CRC covers only the packet data.

16.3 Packet Requests

Any packet can be requested at any time using the request packet. See section 16.8.2.

16.4 Packet Acknowledgement

When configuration packets are sent to Motus, it will reply with an acknowledgement packet that



indicates whether the configuration change was successful or not. For details on the acknowledgement packet, see section 16.8.1.

External data packets will also generate negative acknowledgement packets if there is a problem with the packet. Positive acknowledgements will not be sent.

16.5 Packet Rates

The packet rates can be configured either using Motus Manager or through the Packets Period Packet. By default Motus is configured to output the System State Packet at 50Hz. When configuring packet rates it is essential to ensure the baud rate is capable of handling the data throughput. This can be calculated using the rate and packet size. The packet size is the packet length add five to account for the packet overhead. For example to output the system state packet at 50Hz the calculation would be:

Data throughput = (100 (packet length) + 5 (fixed packet overhead)) * 50 (rate)

Data throughput = 5250 bytes per second

Minimum baud rate = data throughput x 11 = 57750 Baud

Closest standard baud rate = 115200 Baud

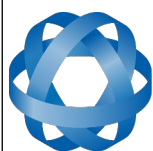
When multiple packets are set to output at the same rate, the order the packets output is from lowest ID to highest ID.

16.6 Packet Timing

Packets are output in order of packet ID from lowest ID to highest ID and all packets that are output in one sequence have their data matched to the same time of validity. The time of validity can be found in either the System State Packet, the Unix Time Packet or the Formatted Time Packet. For example if the Unix Time Packet, Status Packet and NED Velocity Packet packet were all set to output at 10 Hz, at each 0.1 second period the three packets would output consecutively by order of packet ID with all data synchronised between them and the Unix Time Packet providing the time of validity for the other two packets.

16.7 Packet Summary

Packet ID	Length	R/W	Name
System Packets			
0	4	R	Acknowledge Packet
1	Varies	W	Request Packet
2	1	R/W	Boot Mode Packet
3	24	R	Device Information Packet
4	4	W	Restore Factory Settings Packet
5	4	W	Reset Packet
10	Varies	R/W	Serial Port Pass-through Packet
State Packets			



Packet ID	Length	R/W	Name
20	100	R	System State Packet
21	8	R	Unix Time Packet
22	14	R	Formatted Time Packet
23	4	R	Status Packet
24	12	R	Position Standard Deviation Packet
25	12	R	Velocity Standard Deviation Packet
26	12	R	Euler Orientation Standard Deviation Packet
27	16	R	Quaternion Orientation Standard Deviation Packet
28	48	R	Raw Sensors Packet
29	74	R	Raw GNSS Packet
30	13	R	Satellites Packet
31	Varies	R	Detailed Satellites Packet
32	24	R	Geodetic Position Packet
33	24	R	ECEF Position Packet
34	25	R	UTM Position Packet
35	12	R	NED Velocity Packet
36	12	R	Body Velocity Packet
37	12	R	Acceleration Packet
38	16	R	Body Acceleration Packet
39	12	R	Euler Orientation Packet
40	16	R	Quaternion Orientation Packet
41	36	R	DCM Orientation Packet
42	12	R	Angular Velocity Packet
43	12	R	Angular Acceleration Packet
44	60	R/W	External Position & Velocity Packet
45	36	R/W	External Position Packet
46	24	R/W	External Velocity Packet
47	16 or 24	R/W	External Body Velocity Packet
48	8	R/W	External Heading Packet
49	8	R	Running Time Packet
50	12	R	Local Magnetic Field Packet
51	20	R	Odometer State Packet
52	8	R	External Time Packet
53	8	R/W	External Depth Packet



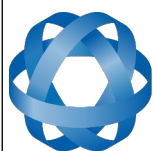
Packet ID	Length	R/W	Name
54	4	R	Geoid Height Packet
56	-	-	External Pitot Pressure Packet
57	12	R/W	Wind Packet
58	16	R	Heave Packet
59	-	-	Post Processing Packet
67	13	W	External Odometer Packet
68	25	R/W	External Air Data Packet
72	8	R/W	Gimbal State Packet
73	24	R	Automotive Packet
83	8	W	Zero Angular Velocity Packet
Configuration Packets			
180	4	R/W	Packet Timer Period Packet
181	Varies	R/W	Packets Period Packet
182	17	R/W	Baud Rates Packet
185	73	R/W	Installation Alignment Packet
186	17	R/W	Filter Options Packet
187	-	-	Advanced Filter Parameters Packet
188	13	R/W	GPIO Configuration Packet
189	49	R/W	Magnetic Calibration Values Packet
190	1	W	Magnetic Calibration Configuration Packet
191	3	R	Magnetic Calibration Status Packet
192	8	R/W	Odometer Configuration Packet
193	5	W	Set Zero Orientation Alignment Packet
194	49	R/W	Reference Point Offsets Packet
195	33	R/W	GPIO Output Configuration Packet
198	64	R/W	User Data Packet
199	65	R/W	GPIO Input Configuration Packet

Table 33: Packet summary

16.8 System Packets

16.8.1 Acknowledge Packet

Acknowledgement Packet	
Packet ID	0



Length				4
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Packet ID being acknowledged
2	1	u16	2	CRC of packet being acknowledged
3	3	u8	1	Acknowledge Result, see section 16.8.1.1

Table 34: Acknowledge packet

16.8.1.1 Acknowledge Result

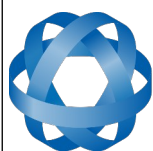
Value	Description
0	Acknowledge success
1	Acknowledge failure, CRC error
2	Acknowledge failure, packet size incorrect
3	Acknowledge failure, values outside of valid ranges
4	Acknowledge failure, system flash memory failure
5	Acknowledge failure, system not ready
6	Acknowledge failure, unknown packet

Table 35: Acknowledge result

16.8.2 Request Packet

Request Packet				
Packet ID			1	
Length			1 x number of packets requested	
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Packet ID requested
+				Field 1 repeats for additional packet requests

Table 36: Request packet



16.8.3 Boot Mode Packet

Boot Mode Packet				
Packet ID				2
Length				1
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Boot mode, see section 16.8.3.1

Table 37: Boot mode packet

16.8.3.1 Boot Mode Types

Value	Description
0	Bootloader
1	Main Program

Table 38: Boot mode types

16.8.4 Device Information Packet

Device Information Packet				
Packet ID				3
Length				24
Field #	Bytes Offset	Data Type	Size	Description
1	0	u32	4	Software version
2	4	u32	4	Device ID, see 16.8.4.1
3	8	u32	4	Hardware revision
4	12	u32	4	Serial number part 1
5	16	u32	4	Serial number part 2
6	20	u32	4	Serial number part 3

Table 39: Device information packet

16.8.4.1 Device ID

Bit	Description
1	Spatial
4	Spatial FOG
5	Spatial Dual
11	Orientus >v3
13	Air Data Unit
14	Subsonus
16	Spatial FOG Dual
17	Motus
19	GNSS Compass
21	Subsonus Tag
22	Poseidon
26	Certus
27	Aries
28	Boreas D90

Table 40: Device ID

16.8.5 Restore Factory Settings Packet

Restore Factory Settings Packet				
Packet ID			4	
Length			4	
Field #	Bytes Offset	Data Type	Size	Description
1	0	u32	4	Verification Sequence (set to 0x85429E1C)

Table 41: Restore factory settings packet

16.8.6 Reset Packet

Reset Packet				
Packet ID			5	
Length			4	
Field #	Bytes Offset	Data Type	Size	Description
1	0	u32	4	Verification sequence, see section 16.8.6.1

Table 42: Reset packet

16.8.6.1 Verification Sequence Values

Value	Description
0x21057A7E	Standard hot start reset
0x9A5D38B7	Cold start reset

Table 43: Verification sequence values

16.8.7 Serial Port Pass-through Packet

Serial Port Pass-through Packet				
Packet ID			10	
Length			Variable, up to 255 bytes	
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Pass-through route, see section 16.8.7.1
2	1			Pass-through data

Table 44: Serial port pass-through packet

16.8.7.1 Pass-through Routes

Value	Description
1	GPIO 1 and 2
2	Auxiliary RS232

Table 45: Pass-through routes

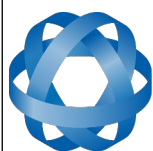
16.9 State Packets

Motus supports a large number of packets providing extensive functionality. However for the majority of users the easiest approach is to configure Motus using the Motus Manager software and then support only the single system state packet shown below in section 16.9.1. Advanced functionality can be added as required through the other packets.

16.9.1 System State Packet

System State Packet				
Packet ID				20
Length				100
Field #	Bytes Offset	Data Type	Size	Description
1	0	u16	2	System status, see section 16.9.1.1
2	2	u16	2	Filter status, see section 16.9.1.2
3	4	u32	4	Unix time seconds, see section 16.9.1.4
4	8	u32	4	Microseconds, see section 16.9.1.5
5	12	fp64	8	Latitude (rad)
6	20	fp64	8	Longitude (rad)
7	28	fp64	8	Height (m)
8	36	fp32	4	Velocity north (m/s)
9	40	fp32	4	Velocity east (m/s)
10	44	fp32	4	Velocity down (m/s)
11	48	fp32	4	Body acceleration X (m/s/s)
12	52	fp32	4	Body acceleration Y (m/s/s)
13	56	fp32	4	Body acceleration Z (m/s/s)
14	60	fp32	4	G force (g)
15	64	fp32	4	Roll (radians)
16	68	fp32	4	Pitch (radians)
17	72	fp32	4	Heading (radians)
18	76	fp32	4	Angular velocity X (rad/s)
19	80	fp32	4	Angular velocity Y (rad/s)
20	84	fp32	4	Angular velocity Z (rad/s)
21	88	fp32	4	Latitude standard deviation (m)
22	92	fp32	4	Longitude standard deviation (m)
23	96	fp32	4	Height standard deviation (m)

Table 46: System state packet

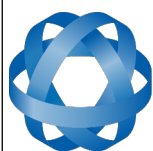


16.9.1.1 System Status

This field contains 16 bits that indicate problems with the system. These are boolean fields with a zero indicating false and one indicating true.

Bit	Description
0	System Failure
1	Accelerometer Sensor Failure
2	Gyroscope Sensor Failure
3	Magnetometer Sensor Failure
4	Reserved (set to zero)
5	Reserved (set to zero)
6	Accelerometer Over Range
7	Gyroscope Over Range
8	Magnetometer Over Range
9	Reserved (set to zero)
10	Minimum Temperature Alarm
11	Maximum Temperature Alarm
12	Low Voltage Alarm
13	High Voltage Alarm
14	Reserved (set to zero)
15	Data Output Overflow Alarm

Table 47: System status



16.9.1.2 Filter Status

This field contains 16 bits that indicate the status of the filters. These are boolean fields with a zero indicating false and one indicating true.

Bit	Description
0	Orientation Filter Initialised
1	Navigation Filter Initialised
2	Heading Initialised
3	UTC Time Initialised
4	GNSS Fix Status, see section 16.9.1.3
5	
6	
7	Event 1 Occurred
8	Event 2 Occurred
9	Reserved (set to zero)
10	Magnetic Heading Active
11	Velocity Heading Enabled
12	Reserved (set to zero)
13	External Position Active
14	External Velocity Active
15	External Heading Active

Table 48: Filter status

16.9.1.3 GNSS Fix Status

Value	Bit 6	Bit 5	Bit 4	Description
0	0	0	0	No GNSS fix
1	0	0	1	2D GNSS fix
2	0	1	0	3D GNSS fix
3	0	1	1	SBAS GNSS fix
4	1	0	0	Differential GNSS fix
5	1	0	1	Omnistar/Starfire GNSS fix
6	1	1	0	RTK Float GNSS fix
7	1	1	1	RTK Fixed GNSS fix

Table 49: GNSS fix status

16.9.1.4 Unix Time Seconds

This field provides UTC time in seconds since January 1, 1970 including leap seconds.

16.9.1.5 Microseconds

This field provides the sub-second component of time. It is represented as microseconds since the last second. Minimum value is 0 and maximum value is 999999.

16.9.2 Unix Time Packet

Unix Time Packet				
Packet ID			21	
Length			8	
Field #	Bytes Offset	Data Type	Size	Description
1	0	u32	4	Unix time seconds, see section 16.9.1.4
2	4	u32	4	Microseconds, see section 16.9.1.5

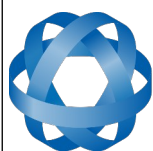
Table 50: Unix time packet

16.9.3 Formatted Time Packet

Formatted Time Packet				
Packet ID			22	
Length			14	
Field #	Bytes Offset	Data Type	Size	Description
1	0	u32	4	Microseconds
2	4	u16	2	Year
3	6	u16	2	Year day, 0 - 365
4	8	u8	1	Month, 0 - 11
5	9	u8	1	Month Day, 1 - 31
6	10	u8	1	Week Day, 0 - 6
7	11	u8	1	Hour, 0 - 23
8	12	u8	1	Minute, 0 - 59
9	13	u8	1	Second, 0 - 59

Table 51: Formatted time packet

16.9.4 Status Packet



Status Packet				
Packet ID			23	
Length			4	
Field #	Bytes Offset	Data Type	Size	Description
1	0	u16	2	System status, see section 16.9.1.1
2	2	u16	2	Filter status, see section 16.9.1.2

Table 52: Status packet

16.9.5 Position Standard Deviation Packet

Position Standard Deviation Packet				
Packet ID			24	
Length			12	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Latitude standard deviation (m)
2	4	fp32	4	Longitude standard deviation (m)
3	8	fp32	4	Height standard deviation (m)

Table 53: Position standard deviation packet

16.9.6 Velocity Standard Deviation Packet

Velocity Standard Deviation Packet				
Packet ID			25	
Length			12	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Velocity north standard deviation (m/s)
2	4	fp32	4	Velocity east standard deviation (m/s)
3	8	fp32	4	Velocity down standard deviation (m/s)

Table 54: Velocity standard deviation packet

16.9.7 Euler Orientation Standard Deviation Packet

Euler Orientation Standard Deviation Packet				
Packet ID			26	
Length			12	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Roll standard deviation (rad)
2	4	fp32	4	Pitch standard deviation(rad)
3	8	fp32	4	Heading standard deviation(rad)

Table 55: Euler orientation standard deviation packet

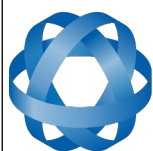
16.9.8 Quaternion Orientation Standard Deviation Packet

Quaternion Orientation Standard Deviation Packet				
Packet ID			27	
Length			16	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Qs standard deviation
2	4	fp32	4	Qx standard deviation
3	8	fp32	4	Qy standard deviation
4	12	fp32	4	Qz standard deviation

Table 56: Quaternion orientation standard deviation packet

16.9.9 Raw Sensors Packet

Raw Sensors Packet				
Packet ID			28	
Length			48	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Accelerometer X (m/s/s)
2	4	fp32	4	Accelerometer Y (m/s/s)
3	8	fp32	4	Accelerometer Z (m/s/s)
4	12	fp32	4	Gyroscope X (rad/s)
5	16	fp32	4	Gyroscope Y (rad/s)
6	20	fp32	4	Gyroscope Z (rad/s)
7	24	fp32	4	Magnetometer X (mG)



8	28	fp32	4	Magnetometer Y (mG)
9	32	fp32	4	Magnetometer Z (mG)
10	36	fp32	4	IMU Temperature (deg C)
11	40	fp32	4	Reserved (set to zero)
12	44	fp32	4	Reserved (set to zero)

Table 57: Raw sensors packet

16.9.10 Raw GNSS Packet

This packet represents the raw data as it is received from the GNSS receiver. The position is not corrected for antenna position offset and the velocity is not compensated for the antenna lever arm offset. The INS position and velocity that are in the other packets are corrected for antenna position offset and lever arm.

If the information for a specific field is not received from the external GNSS receiver, the field will be output as zero.

Raw GNSS Packet				
Packet ID				29
Length				74
Field #	Bytes Offset	Data Type	Size	Description
1	0	u32	4	Unix time stamp (seconds)
2	4	u32	4	Microseconds
3	8	fp64	8	Latitude (rad)
4	16	fp64	8	Longitude (rad)
5	24	fp64	8	Height (m)
6	32	fp32	4	Velocity north (m/s)
7	36	fp32	4	Velocity east (m/s)
8	40	fp32	4	Velocity down (m/s)
9	44	fp32	4	Latitude standard deviation (m)
10	48	fp32	4	Longitude standard deviation (m)
11	52	fp32	4	Height standard deviation (m)
12	56	fp32	4	Tilt (rad)
13	60	fp32	4	Heading (rad)
14	64	fp32	4	Tilt standard deviation (rad)
15	68	fp32	4	Heading standard deviation (rad)
16	72	u16	2	Status, see section 16.9.10.1

Table 58: Raw GNSS packet

16.9.10.1 Raw GNSS Status

Bit	Description
0	GNSS Fix Status, see section 16.9.1.3
1	
2	
3	Doppler velocity valid
4	Time valid
5	External GNSS
6	Tilt valid
7	Heading valid
8	Floating ambiguity heading
9-15	Reserved (set to zero)

Table 59: Raw GNSS status

16.9.11 Satellites Packet

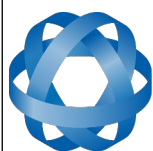
If the information for a specific field is not received from the external GNSS receiver, the field will be output as zero.

Satellites Packet				
Packet ID			30	
Length			13	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	HDOP
2	4	fp32	4	VDOP
3	8	u8	1	GPS satellites
4	9	u8	1	GLONASS satellites
5	10	u8	1	BeiDou satellites
6	11	u8	1	GALILEO satellites
7	12	u8	1	SBAS satellites

Table 60: Satellites packet

16.9.12 Detailed Satellites Packet

If the information for a specific field is not received from the external GNSS receiver, the field will be output as zero.



Detailed Satellites Packet				
Packet ID				31
Length				7 x number of satellites
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Satellite system, see section 16.9.12.1
2	1	u8	1	Satellite number (PRN)
3	2	s8	1	Satellite frequencies, see section 16.9.12.2
4	3	u8	1	Elevation (deg)
5	4	u16	2	Azimuth (deg)
6	6	u8	1	SNR
+				Fields 1-6 repeat for additional satellites

Table 61: Detailed satellites packet

16.9.12.1 Satellite Systems

Value	System
0	Unknown
1	GPS
2	GLONASS
3	BeiDou
4	GALILEO
5	SBAS
6	QZSS
7	Starfire
8	Omnistar

Table 62: Satellite systems

16.9.12.2 Satellite Frequencies

Bit	Description
0	L1 C/A
1	L1 C
2	L1 P
3	L1 M
4	L2 C
5	L2 P

6	L2 M
7	L5

Table 63: Satellite frequencies

16.9.13 Geodetic Position Packet

Geodetic Position Packet				
Packet ID		32		
Length		24		
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp64	8	Latitude (rad)
2	8	fp64	8	Longitude (rad)
3	16	fp64	8	Height (m)

Table 64: Geodetic position packet

16.9.14 ECEF Position Packet

ECEF Position Packet				
Packet ID		33		
Length		24		
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp64	8	ECEF X (m)
2	8	fp64	8	ECEF Y (m)
3	16	fp64	8	ECEF Z (m)

Table 65: ECEF position packet

16.9.15 UTM Position Packet

UTM Position Packet				
Packet ID		34		
Length		26		
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp64	8	Northing (m)
2	8	fp64	8	Easting (m)
3	16	fp64	8	Height (m)
4	24	u8	1	Zone number

5	25	s8	1	Zone character
---	----	----	---	----------------

Table 66: UTM position packet

16.9.16 NED Velocity Packet

NED Velocity Packet				
Packet ID			35	
Length			12	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Velocity north (m/s)
2	4	fp32	4	Velocity east (m/s)
3	8	fp32	4	Velocity down (m/s)

Table 67: NED velocity packet

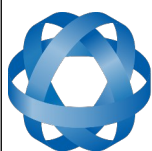
16.9.17 Body Velocity Packet

Body Velocity Packet				
Packet ID			36	
Length			12	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Velocity X (m/s)
2	4	fp32	4	Velocity Y (m/s)
3	8	fp32	4	Velocity Z (m/s)

Table 68: Body velocity packet

16.9.18 Acceleration Packet

This packet includes the acceleration due to gravity.



Acceleration Packet				
Packet ID			37	
Length			12	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Acceleration X (m/s/s)
2	4	fp32	4	Acceleration Y (m/s/s)
3	8	fp32	4	Acceleration Z (m/s/s)

Table 69: Acceleration packet

16.9.19 Body Acceleration Packet

This packet does not include the acceleration due to gravity.

Body Acceleration Packet				
Packet ID			38	
Length			16	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Body acceleration X (m/s/s)
2	4	fp32	4	Body acceleration Y (m/s/s)
3	8	fp32	4	Body acceleration Z (m/s/s)
4	12	fp32	4	G force (g)

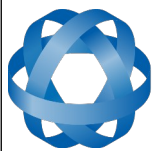
Table 70: Body acceleration packet

16.9.20 Euler Orientation Packet

Euler Orientation Packet				
Packet ID			39	
Length			12	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Roll (rad)
2	4	fp32	4	Pitch (rad)
3	8	fp32	4	Heading (rad)

Table 71: Euler orientation packet

16.9.21 Quaternion Orientation Packet



Quaternion Orientation Packet				
Packet ID			40	
Length			16	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Qs
2	4	fp32	4	Qx
3	8	fp32	4	Qy
4	12	fp32	4	Qz

Table 72: Quaternion orientation packet

16.9.22 DCM Orientation Packet

DCM Orientation Packet				
Packet ID			41	
Length			36	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	DCM[0][0]
2	4	fp32	4	DCM[0][1]
3	8	fp32	4	DCM[0][2]
4	12	fp32	4	DCM[1][0]
5	16	fp32	4	DCM[1][1]
6	20	fp32	4	DCM[1][2]
7	24	fp32	4	DCM[2][0]
8	28	fp32	4	DCM[2][1]
9	32	fp32	4	DCM[2][2]

Table 73: DCM orientation packet

16.9.23 Angular Velocity Packet

Angular Velocity Packet				
Packet ID			42	
Length			12	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Angular velocity X (rad/s)
2	4	fp32	4	Angular velocity Y (rad/s)

3	8	fp32	4	Angular velocity Z (rad/s)
---	---	------	---	----------------------------

Table 74: Angular velocity packet

16.9.24 Angular Acceleration Packet

Angular Acceleration Packet				
Packet ID			43	
Length			12	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Angular acceleration X (rad/s/s)
2	4	fp32	4	Angular acceleration Y (rad/s/s)
3	8	fp32	4	Angular acceleration Z (rad/s/s)

Table 75: Angular acceleration packet

16.9.25 External Position & Velocity Packet

External Position & Velocity Packet				
Packet ID			44	
Length			60	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp64	8	Latitude (rad)
2	8	fp64	8	Longitude (rad)
3	16	fp64	8	Height (m)
4	24	fp32	4	Velocity north (m/s)
5	28	fp32	4	Velocity east (m/s)
6	32	fp32	4	Velocity down (m/s)
7	36	fp32	4	Latitude standard deviation (m)
8	40	fp32	4	Longitude standard deviation (m)
9	44	fp32	4	Height standard deviation (m)
10	48	fp32	4	Velocity north standard deviation (m/s)
11	52	fp32	4	Velocity east standard deviation (m/s)
12	56	fp32	4	Velocity down standard deviation (m/s)

Table 76: External position & velocity packet

16.9.26 External Position Packet



External Position Packet				
Packet ID			45	
Length			36	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp64	8	Latitude (rad)
2	8	fp64	8	Longitude (rad)
3	16	fp64	8	Height (m)
4	24	fp32	4	Latitude standard deviation (m)
5	28	fp32	4	Longitude standard deviation (m)
6	32	fp32	4	Height standard deviation (m)

Table 77: External position packet

16.9.27 External Velocity Packet

External Velocity Packet				
Packet ID			46	
Length			24	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Velocity north (m/s)
2	4	fp32	4	Velocity east (m/s)
3	8	fp32	4	Velocity down (m/s)
4	12	fp32	4	Velocity north standard deviation (m/s)
5	16	fp32	4	Velocity east standard deviation (m/s)
6	20	fp32	4	Velocity down standard deviation (m/s)

Table 78: External velocity packet

16.9.28 External Body Velocity Packet

This packet has been defined to support a single velocity standard deviation for all three axes, or, different values for all three axes. Please ensure you modify the packet length in the packet header accordingly, depending on which format you are using.

External Body Velocity Packet				
Packet ID			47	
Length			16 or 24	
Field #	Bytes Offset	Data Type	Size	Description

1	0	fp32	4	Velocity X (m/s)
2	4	fp32	4	Velocity Y (m/s)
3	8	fp32	4	Velocity Z (m/s)
4	12	fp32	4	Velocity standard deviation all axes or X only (m/s)
5	12	fp32	4	OPTIONAL: Velocity standard deviation Y (m/s)
6	12	fp32	4	OPTIONAL: Velocity standard deviation Z (m/s)

Table 79: External body velocity packet

16.9.29 External Heading Packet

External Heading Packet				
Packet ID			48	
Length			8	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Heading (rad)
2	4	fp32	4	Heading standard deviation (rad)

Table 80: External heading packet

16.9.30 Running Time Packet

Running Time Packet				
Packet ID			49	
Length			8	
Field #	Bytes Offset	Data Type	Size	Description
1	0	u32	4	Running time (seconds)
2	4	u32	4	Microseconds

Table 81: Running time packet

16.9.31 Local Magnetic Field Packet

Local Magnetic Field Packet				
Packet ID			50	
Length			12	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Local magnetic field X (mG)
2	4	fp32	4	Local magnetic field Y (mG)

3	8	fp32	4	Local magnetic field Z (mG)
---	---	------	---	-----------------------------

Table 82: Local magnetic field packet

16.9.32 Odometer State Packet

Odometer State Packet				
Packet ID		51		
Length		20		
Field #	Bytes Offset	Data Type	Size	Description
1	0	s32	4	Odometer pulse count
2	4	fp32	4	Odometer distance (m)
3	8	fp32	4	Odometer speed (m/s)
4	12	fp32	4	Odometer slip (m)
5	16	u8	1	Odometer active
6	17		3	Reserved

Table 83: Odometer state packet

16.9.33 External Time Packet

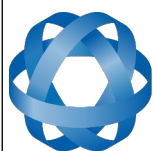
External Time Packet				
Packet ID		52		
Length		8		
Field #	Bytes Offset	Data Type	Size	Description
1	0	u32	4	Unix time (seconds), see section 16.9.1.4
2	4	u32	4	Microseconds, see section 16.9.1.5

Table 84: External time packet

16.9.34 External Depth Packet

External Depth Packet				
Packet ID		53		
Length		8		
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Depth (m)
2	4	fp32	4	Depth standard deviation (m)

Table 85: External depth packet



16.9.35 Geoid Height Packet

This packet provides the offset at the current location between the WGS84 ellipsoid and the EGM96 geoid model. This can be used to determine the current height above mean sea level and also depth through the following equations:

Height Above Mean Sea Level = WGS84 Height – Geoid Height

Depth = Geoid Height – WGS84 Height

WGS84 Height is the height at the current location in the System State packet.

Geoid Height Packet				
Packet ID			54	
Length			4	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Geoid Height (m)

Table 86: Geoid height packet

16.9.36 External Pitot Pressure Packet

This packet is no longer supported. The External Air Data packet #68 should be used.

16.9.37 Wind Packet

This packet provides Motus's current 2D wind velocity. These values are only valid when external air data is provided to Motus. This can be either through the External Pitot Pressure Packet, the External Air Data Packet or when a pitot tube is interfaced to one of the GPIO pins. When this packet is written to the device, it disables the wind estimation filter and the wind values provided are used statically.

Wind Packet				
Packet ID			57	
Length			12	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Wind velocity north (m/s)
2	4	fp32	4	Wind velocity east (m/s)
3	8	fp32	4	Wind velocity standard deviation (m/s)

Table 87: Wind packet

16.9.38 Heave Packet

Heave Packet				
Packet ID			58	
Length			16	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Heave point 1 (m)
2	4	fp32	4	Heave point 2 (m)
3	8	fp32	4	Heave point 3 (m)
4	12	fp32	4	Heave point 4 (m)

Table 88: Heave packet

16.9.39 Post Processing Packet

This packet is no longer supported. If you need an IMR file please contact Advanced Navigation support for required settings.

16.9.40 External Odometer Packet

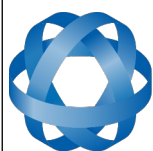
External Odometer Packet				
Packet ID			67	
Length			13	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Estimated delay (s)
2	4	fp32	4	Speed (m/s)
3	8	fp32	4	Reserved (set to zero)
4	12	u8	1	Odometer flags, see section 16.9.40.1

Table 89: External odometer packet

16.9.40.1 Odometer flags

Bit	Description
0	Reversing detection supported
1-7	Reserved (set to zero)

Table 90: Odometer flags



16.9.41 External Air Data Packet

External Air Data Packet				
Packet ID			68	
Length			25	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Barometric altitude delay (s)
2	4	fp32	4	Airspeed delay (s)
2	8	fp32	4	Barometric altitude (m)
3	12	fp32	4	Airspeed (m/s)
4	16	fp32	4	Barometric altitude standard deviation (m)
5	20	fp32	4	Airspeed standard deviation (m/s)
6	24	u8	1	Flags, see section 16.9.41.1

Table 91: External air data packet

16.9.41.1 External Air Data Flags

Bit	Description
0	Barometric altitude set and valid
1	Airspeed set and valid
2	Barometric altitude reference reset

Table 92: External air data flags

16.9.41.2 Notes

Barometric altitude does not need to be referenced to any co-ordinate frame or QNH. If the barometric altitude reference is changed during operation, the barometric altitude reference reset flag should be set for the next packet.

16.9.42 Gimbal State Packet

Gimbal State Packet				
Packet ID		72		
Length		8		
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Current angle (rad)
2	4		4	Reserved (set to zero)

Table 93: Gimbal state packet

16.9.43 Automotive Packet

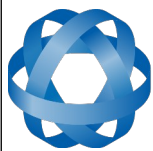
Automotive Packet				
Packet ID		73		
Length		24		
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Virtual odometer distance (m)
2	4	fp32	4	Slip Angle (rad)
3	8	fp32	4	Velocity X (m/s)
4	12	fp32	4	Velocity Y (m/s)
5	16	fp32	4	Distance standard deviation (m)
6	20		4	Reserved (set to zero)

Table 94: Automotive packet

16.9.44 Zero Angular Velocity Packet

Zero Angular Velocity Packet				
Packet ID		83		
Length		8		
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Duration, see section 16.9.44.1
2	4		4	Reserved (set to zero)

Table 95: Zero angular velocity packet



16.9.44.1 Duration

Duration is the duration that the unit has been stationary for about the heading axis. The minimum value is 0.1 seconds and the maximum value is 2 seconds.

16.10 Configuration Packets

Configuration packets can be both read from and written to the device. On many of the configuration packets the first byte is a permanent flag. A zero in this field indicates that the settings will be lost on reset, a one indicates that they will be permanent.

16.10.1 Packet Timer Period Packet

Packet Timer Period Packet				
Packet ID			180	
Length			4	
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	u8	1	UTC synchronisation, see section 16.10.1.1
3	2	u16	2	Packet timer period, see section 16.10.1.2

Table 96: Packet timer period packet

16.10.1.1 UTC Synchronisation

This is a boolean value that determines whether or not the packet timer is synchronised with UTC time, with zero for disabled and one for enabled. For UTC Synchronisation to be enabled the packet timer period must multiply into 1000000 evenly. For example if the packet timer period is 10000 (10 ms), $1000000/10000 = 100$ which is valid for UTC synchronisation. If the packet timer period is 15000 (15 ms), $1000000/15000 = 66.6666$ which is not valid for UTC synchronisation. To get the rate use the following.

Packet Timer Rate = $1000000/(\text{Packet Timer Period})$ Hz

16.10.1.2 Packet Timer Period

This is a value in microseconds that sets the master packet timer period. The minimum value is 1000 (1 ms) or 1000 Hz and the maximum value is 65535 (65.535 ms) or 15.30 Hz.

16.10.2 Packets Period Packet

Packets Period Packet				
Packet ID			181	
Length			2 + (5 x number of packet periods)	
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	u8	1	Clear existing packet periods, see section 16.10.2.1
3	2	u8	1	Packet ID

4	3	u32	4	Packet period, see section 16.10.2.2
+				Fields 3-4 repeat for additional packet periods

Table 97: Packets period packet

16.10.2.1 Clear Existing Packets

This is a boolean field, when set to one it deletes any existing packet rates. When set to zero existing packet rates remain. Only one packet rate can exist per packet ID, so new packet rates will overwrite existing packet rates for the same packet ID.

16.10.2.2 Packet Period

This indicates the period in units of the packet timer period. The packet rate can be calculated as follows.

Packet Rate = $1000000 / (\text{Packet Period} \times \text{Packet Timer Period})$ Hz

For example if the packet timer period is set to 1000 (1 ms). Setting packet ID 20 with a packet period of 50 will give the following.

Packet 20 Rate = $1000000 / (50 \times 1000)$

Packet 20 Rate = 20 Hz

16.10.3 Baud Rates Packet

Baud Rates Packet				
Packet ID			182	
Length			17	
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	u32	4	Primary RS232 and RS422 baud rate (2400 to 2000000)
3	5	u32	4	GPIO 1 & 2 baud rate (2400 to 250000)
4	9	u32	4	Auxiliary RS232 Baud Rate (2400 to 2000000)
5	13		4	Reserved (set to zero)

Table 98: Baud rates packet

16.10.4 Installation Alignment Packet

Installation Alignment Packet				
Packet ID			185	
Length			73	
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	fp32	4	Alignment DCM[0][0]
3	5	fp32	4	Alignment DCM[0][1]
4	9	fp32	4	Alignment DCM[0][2]
5	13	fp32	4	Alignment DCM[1][0]
6	17	fp32	4	Alignment DCM[1][1]
7	21	fp32	4	Alignment DCM[1][2]
8	25	fp32	4	Alignment DCM[2][0]
9	29	fp32	4	Alignment DCM[2][1]
10	33	fp32	4	Alignment DCM[2][2]
11	37	fp32	4	GNSS antenna offset X (m)
12	41	fp32	4	GNSS antenna offset Y (m)
13	45	fp32	4	GNSS antenna offset Z (m)
14	49	fp32	4	Odometer offset X (m)
15	53	fp32	4	Odometer offset Y (m)
16	57	fp32	4	Odometer offset Z (m)
17	61	fp32	4	External data offset X (m)
18	65	fp32	4	External data offset Y (m)
19	69	fp32	4	External data offset Z (m)

Table 99: Installation alignment packet

16.10.4.1 Alignment DCM

The alignment DCM (direction cosine matrix) is used to represent an alignment offset of Motus from it's standard alignment. A DCM is used rather than euler angles for accuracy reasons. To convert euler angles to DCM please use the formula below with angles in radians.

$$\text{DCM}[0][0] = \cos(\text{heading}) * \cos(\text{pitch})$$

$$\text{DCM}[0][1] = \sin(\text{heading}) * \cos(\text{pitch})$$

$$\text{DCM}[0][2] = -\sin(\text{pitch})$$

$$\text{DCM}[1][0] = -\sin(\text{heading}) * \cos(\text{roll}) + \cos(\text{heading}) * \sin(\text{pitch}) * \sin(\text{roll})$$

$$\text{DCM}[1][1] = \cos(\text{heading}) * \cos(\text{roll}) + \sin(\text{heading}) * \sin(\text{pitch}) * \sin(\text{roll})$$

$$\text{DCM}[1][2] = \cos(\text{pitch}) * \sin(\text{roll})$$

$DCM[2][0] = \sin(\text{heading}) * \sin(\text{roll}) + \cos(\text{heading}) * \sin(\text{pitch}) * \cos(\text{roll})$

$DCM[2][1] = -\cos(\text{heading}) * \sin(\text{roll}) + \sin(\text{heading}) * \sin(\text{pitch}) * \cos(\text{roll})$

$DCM[2][2] = \cos(\text{pitch}) * \cos(\text{roll})$

16.10.5 Filter Options Packet

Filter Options Packet				
Packet ID			186	
Length			17	
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	u8	1	Vehicle type, see section 16.10.5.1
3	2	u8	1	Internal GNSS enabled (boolean)
4	3	u8	1	Magnetometers enabled (boolean)
5	4	u8	1	Reserved (set to zero)
6	5	u8	1	Velocity heading enabled (boolean)
7	6	u8	1	Reversing detection enabled (boolean)
8	7	u8	1	Motion analysis enabled (boolean)
9	8	u8	1	Automatic magnetic calibration enabled (boolean)
10	9		8	Reserved (set to zero)

Table 100: Filter options packet

16.10.5.1 Vehicle Types

Value	Description
0	Unconstrained
1	Bicycle or Motorcycle
2	Car
3	Hovercraft
4	Submarine
5	3D Underwater Vehicle
6	Fixed Wing Plane
7	3D Aircraft
8	Human
9	Boat
10	Large Ship

11	Stationary
12	Stunt Plane
13	Race Car

Table 101: Vehicle types

16.10.6 Advanced Filter Parameters Packet

This packet is no longer supported.

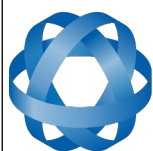
16.10.7 GPIO Configuration Packet

GPIO Configuration Packet				
Packet ID				188
Length				13
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	u8	1	GPIO1 function, see section 16.10.7.1
3	2	u8	1	GPIO2 function, see section 16.10.7.2
4	3	u8	1	Auxiliary RS232 transmit function, section 16.10.7.3
5	4	u8	1	Auxiliary RS232 receive function, section 16.10.7.4
8	5	u8	8	Reserved (set to zero)

Table 102: GPIO configuration packet

16.10.7.1 GPIO1 Functions

Value	Description
0	Inactive
1	1PPS Output
2	GNSS Fix Output
3	Odometer Input
4	Zero Velocity Input
5	Pitot Tube Input
7	NMEA Output
12	ANPP Output
13	Disable Magnetometers
16	Set Zero Orientation Alignment
17	System State Packet Trigger

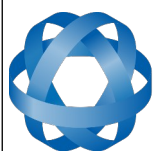


18	Raw Sensors Packet Trigger
26	Pressure Depth Transducer
27	Left Wheel Speed Sensor
28	Right Wheel Speed Sensor
29	1PPS Input
30	Wheel Speed Sensor
31	Wheel Encoder Phase A
32	Wheel Encoder Phase B
33	Event 1 Input
34	Event 2 Input
39	TSS1 Output
40	Simrad 1000 Output
41	Simrad 3000 Output
42	Serial Port Passthrough
43	Gimbal Encoder Phase A
44	Gimbal Encoder Phase B
45	Odometer Direction, Forward Low
46	Odometer Direction, Forward High
53	Reverse Alignment, Forward Low
54	Reverse Alignment, Forward High
55	Zero Angular Velocity Input

Table 103: GPIO1 functions

16.10.7.2 GPIO2 Functions

Value	Description
0	Inactive
1	1PPS Output
2	GNSS Fix Output
3	Odometer Input
4	Zero Velocity Input
5	Pitot Tube Input
6	NMEA Input
8	Novatel GNSS Input
9	Topcon GNSS Input
11	ANPP Input

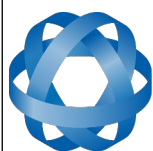


13	Disable Magnetometers
16	Set Zero Orientation Alignment
17	System State Packet Trigger
18	Raw Sensors Packet Trigger
20	Trimble GNSS Input
21	u-blox GNSS Input
22	Hemisphere GNSS Input
23	Teledyne DVL Input
24	Tritech USBL Input
25	Linkquest DVL Input
26	Pressure Depth Transducer
27	Left Wheel Speed Sensor
28	Right Wheel Speed Sensor
29	1PPS Input
30	Wheel Speed Sensor
31	Wheel Encoder Phase A
32	Wheel Encoder Phase B
33	Event 1 Input
34	Event 2 Input
35	Linkquest USBL Input
42	Serial Port Passthrough
43	Gimbal Encoder Phase A
44	Gimbal Encoder Phase B
45	Odometer Direction, Forward Low
46	Odometer Direction, Forward High
51	Nortek DVL Input
53	Reverse Alignment, Forward Low
54	Reverse Alignment, Forward High
55	Zero Angular Velocity Input

Table 104: GPIO2 functions

16.10.7.3 Auxiliary RS232 Transmit Functions

Value	Description
0	Inactive
1	1PPS Output

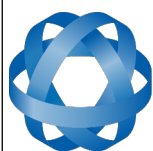


2	GNSS Fix Output
7	NMEA Output
12	ANPP Output
39	TSS1 Output
40	Simrad 1000 Output
41	Simrad 3000 Output
42	Serial Port Passthrough

Table 105: Auxiliary RS232 transmit functions

16.10.7.4 Auxiliary RS232 Receive Functions

Value	Description
0	Inactive
3	Odometer Input
4	Zero Velocity Input
5	Pitot Tube Input
6	NMEA Input
8	Novatel GNSS Input
9	Topcon GNSS Input
11	ANPP Input
13	Disable Magnetometers
16	Set Zero Orientation Alignment
17	System State Packet Trigger
18	Raw Sensors Packet Trigger
20	Trimble GNSS Input
21	u-blox GNSS Input
22	Hemisphere GNSS Input
23	Teledyne DVL Input
24	Tritech USBL Input
25	Linkquest DVL Input
26	Pressure Depth Transducer
27	Left Wheel Speed Sensor
28	Right Wheel Speed Sensor
29	1PPS Input
30	Wheel Speed Sensor
33	Event 1 Input



34	Event 2 Input
35	Linkquest USBL Input
42	Serial Port Passthrough
45	Odometer Direction, Forward Low
46	Odometer Direction, Forward High
51	Nortek DVL Input
53	Reverse Alignment, Forward Low
54	Reverse Alignment, Forward High
55	Zero Angular Velocity Input

Table 106: Auxiliary RS232 receive functions

16.10.8 Magnetic Calibration Values Packet

Magnetic Calibration Values Packet				
Packet ID			189	
Length			49	
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	fp32	4	Hard iron bias X
3	5	fp32	4	Hard iron bias Y
4	9	fp32	4	Hard iron bias Z
5	13	fp32	4	Soft iron transformation XX
6	17	fp32	4	Soft iron transformation XY
7	21	fp32	4	Soft iron transformation XZ
8	25	fp32	4	Soft iron transformation YX
9	29	fp32	4	Soft iron transformation YY
10	33	fp32	4	Soft iron transformation YZ
11	37	fp32	4	Soft iron transformation ZX
12	41	fp32	4	Soft iron transformation ZY
13	45	fp32	4	Soft iron transformation ZZ

Table 107: Magnetic calibration values packet

16.10.9 Magnetic Calibration Configuration Packet

Magnetic Calibration Configuration Packet				
Packet ID			190	
Length			1	
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Magnetic calibration action, see section 16.10.9.1

Table 108: Magnetic calibration configuration packet

16.10.9.1 Magnetic Calibration Actions

Value	Description
0	Cancel magnetic calibration
2	Start 2D magnetic calibration
3	Start 3D magnetic calibration
4	Reset calibration to defaults

Table 109: Magnetic calibration actions

16.10.10 Magnetic Calibration Status Packet

Magnetic Calibration Status Packet				
Packet ID			191	
Length			3	
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Magnetic calibration status, see section 16.10.10.1
2	1	u8	1	Magnetic calibration progress (%)
3	2	u8	1	Local magnetic error (%)

Table 110: Magnetic calibration status packet

16.10.10.1 Magnetic Calibration Status

Value	Description
0	Magnetic calibration not completed
1	2D magnetic calibration completed
2	3D magnetic calibration completed
3	Custom values magnetic calibration completed
5	2D calibration in progress
6	3D calibration in progress

7	2D calibration error: excessive roll
8	2D calibration error: excessive pitch
9	Calibration error: sensor over range event
10	Calibration error: time-out
11	Calibration error: system error
12	Calibration error: interference error

Table 111: Magnetic calibration status

16.10.11 Odometer Configuration Packet

Odometer Configuration Packet				
Packet ID			192	
Length			8	
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	u8	1	Automatic pulse measurement active
3	2	u8	2	Reserved (set to zero)
4	4	fp32	4	Pulse length (m)

Table 112: Odometer configuration packet

16.10.12 Set Zero Orientation Alignment Packet

This packet was modified as of firmware version 1.0 for code safety certification. Previously it was 1 byte long with no verification sequence.

Set Zero Orientation Alignment Packet				
Packet ID			193	
Length			5	
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	u32	4	Verification sequence (set to 0x9A4E8055)

Table 113: Set zero orientation alignment packet

16.10.13 Reference Point Offsets Packet

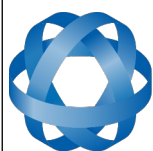
The reference point offsets packet can be used to adjust the measurement point that all data is referenced to. By default all the values of this packet are zero and the measurement point that all data is referenced to is the centre of the Motus unit. The primary reference point offset can be used to adjust the measurement point to a different location on the vehicle. The primary reference point

offset applies to all data output including NMEA etc as well as heave point 1. The other heave point offsets apply only to heave points 2-4 in the Heave Packet.

Reference Points Offset Packet				
Packet ID			194	
Length			49	
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	fp32	4	Primary reference point offset X (m)
3	5	fp32	4	Primary reference point offset Y (m)
4	9	fp32	4	Primary reference point offset Z (m)
5	13	fp32	4	Heave point 2 offset X (m)
6	17	fp32	4	Heave point 2 offset Y (m)
7	21	fp32	4	Heave point 2 offset Z (m)
8	25	fp32	4	Heave point 3 offset X (m)
9	29	fp32	4	Heave point 3 offset Y (m)
10	33	fp32	4	Heave point 3 offset Z (m)
11	37	fp32	4	Heave point 4 offset X (m)
12	41	fp32	4	Heave point 4 offset Y (m)
13	45	fp32	4	Heave point 4 offset Z (m)

Table 114: Reference point offsets packet

16.10.14 GPIO Output Configuration Packet



GPIO Output Configuration Packet				
Packet ID				195
Length				33
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	u8	1	NMEA fix behaviour, see section 16.10.14.1
3	2	u16	2	GPZDA Rates, see section 16.10.14.2
4	4	u16	2	GPGGA Rates, see section 16.10.14.2
5	6	u16	2	GPVTG Rates, see section 16.10.14.2
6	8	u16	2	GPRMC Rates, see section 16.10.14.2
7	10	u16	2	GPHDT Rates, see section 16.10.14.2
8	12	u16	2	GPGLL Rates, see section 16.10.14.2
9	14	u16	2	PASHR Rates, see section 16.10.14.2
10	16	u16	2	TSS1 Rates, see section 16.10.14.2
11	18	u16	2	Simrad Rates, see section 16.10.14.2
12	20	u16	2	GPROT Rates, see section 16.10.14.2
13	22	u16	2	GPHEV Rates, see section 16.10.14.2
14	24	u16	2	GPGSV Rates, see section 16.10.14.2
15	26	u16	2	PFECAtt Rates, see section 16.10.14.2
16	28	u16	2	PFECHve Rates, see section 16.10.14.2
17	30		3	Reserved (set to zero)

Table 115: GPIO output configuration packet

16.10.14.1 NMEA Fix Behaviour

Value	Description
0	Normal
1	Always indicate 3D fix when the navigation filter is initialised

Table 116: NMEA fix behaviour

16.10.14.2 GPIO Output Rates

Bit	Description
0-3	GPIO 1 rate, see 16.10.14.3
4-7	Auxiliary RS232 Tx rate, see 16.10.14.3
8-15	Reserved (set to zero)

Table 117: GPIO output rates

16.10.14.3 GPIO Output Rates Index

Value	Bit 3	Bit 2	Bit 1	Bit 0	Description
0	0	0	0	0	Disabled
1	0	0	0	1	0.1 Hz
2	0	0	1	0	0.2 Hz
3	0	0	1	1	0.5 Hz
4	0	1	0	0	1 Hz
5	0	1	0	1	2 Hz
6	0	1	1	0	5 Hz
7	0	1	1	1	10 Hz
8	1	0	0	0	25 Hz
9	1	0	0	1	50 Hz

Table 118: GPIO output rates index

16.10.15 User Data Packet

This packet is for storage of users data. The data itself is not used by Motus.

User Data Packet				
Packet ID			198	
Length			64	
Field #	Bytes Offset	Data Type	Size	Description
1	0		64	User Data

Table 119: User data packet

**16.10.16 GPIO Input Configuration Packet**

GPIO Input Configuration Packet				
Packet ID			199	
Length			65	
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	fp32	4	Gimbal radians per encoder tick
3	2		60	Reserved (set to zero)

Table 120: GPIO input configuration packet



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