SMC
SHIP MOTION CONTROL

SMC IMU
User Guide

Notice

The information in this User Guide is subject to change without notice.

Not all the features described in this manual are available in all motion sensor models, hardware and firmware versions. Please check with SMC for details of model specific features such as measurement parameters and Protocol support.

SMC Ship Motion Control is not responsible for any errors in this manual or their consequences.

SMC Ship Motion Control Ltd
Email: info@shipmotion.eu
Web: www.shipmotion.eu
Tel: +46 8 644 5010

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1 INTRODUCTION

This user manual provides information about your SMC motion sensor and how to use it.

Motion sensors also known as IMUs or MRUs determine the orientation of an object relative to an inertial frame of reference or another body. The motion sensor uses 3 accelerometers and 3 gyroscopes which are integrated with a DSP, Digital Signal Processor, to produce accurate pitch, roll and heave information in an industry standard format. These measurements are suitable for any maritime operation that requires attitude determination, motion compensation or dynamic positioning. The SMC Motion sensors provide high accuracy motion measurements in all dynamic environments.

The data output from the SMC motion sensor is sent over serial and Ethernet. As an option an analog converter is available for V and mA outputs. The serial data can be read in any terminal software, the SMCems, SMC IMU configuration software and many third-party applications.

The SMC motion sensors are used in a wide range of applications.
Some examples are:

- Hydrographic surveying for heave compensation using multi beam sonars, single beam sonars and sub bottom profilers
- System integration for different type of monitoring systems such as Helideck Monitoring and crane monitoring systems
- Active heave compensation for cranes and winches.
- Dynamic positioning systems

Products Covered in this User Guide

Surface motion sensors

	Roll & Pitch (Dynamic)	Heave	Acceleration
IMU-007	0.25 RMS	N/A	0.05 m/s^2 RMS
IMU-008	0.25 RMS	5cm or 5%	0.05 m/s^2 RMS
IMU-106	N/A	5cm or 5%	N/A
IMU-107	0.03 RMS	N/A	0.01 m/s^2 RMS
IMU-108	0.03 RMS	5cm or 5%	0.01 m/s^2 RMS

Subsea motion sensors, 30 m depth rated

	Roll & Pitch (Dynamic)	Heave	Acceleration
IMU-008-30	0.25 RMS	5cm or 5%	0.05 m/s^2 RMS
IMU-108-30	0.03 RMS	5cm or 5%	0.01 m/s^2 RMS

Custom motion sensors

	Roll & Pitch (Dynamic)	Heave	Acceleration
IMU-007-L	0.25 RMS	N/A	0.05 m/s^2 RMS
IMU-028	0.25 RMS	5cm or 5%	0.05 m/s^2 RMS
IMU-108R-L	0.03 RMS	5cm or 5%	0.01 m/s^2 RMS
IMU-108R-30	0.03 RMS	5cm or 5%	0.01 m/s^2 RMS

As an option, Analog outputs are available and covered by this user guide

1.1 RECEIVING THE MOTION SENSOR

Unpack the equipment and remove all the packaging materials and shipping carton.

The standard motion sensors are delivered in a transit case designed to protect it from high shocks during transit.

When the motion sensor has been received, it must be inspected for damage during shipment. If damage has occurred during transit, all the shipping cartons and packaging materials should be stored for further investigation. If damage is visible, a claim for shipping damage must be filed immediately.

Because of the sensitive nature of the motion sensor the package must not be dropped.

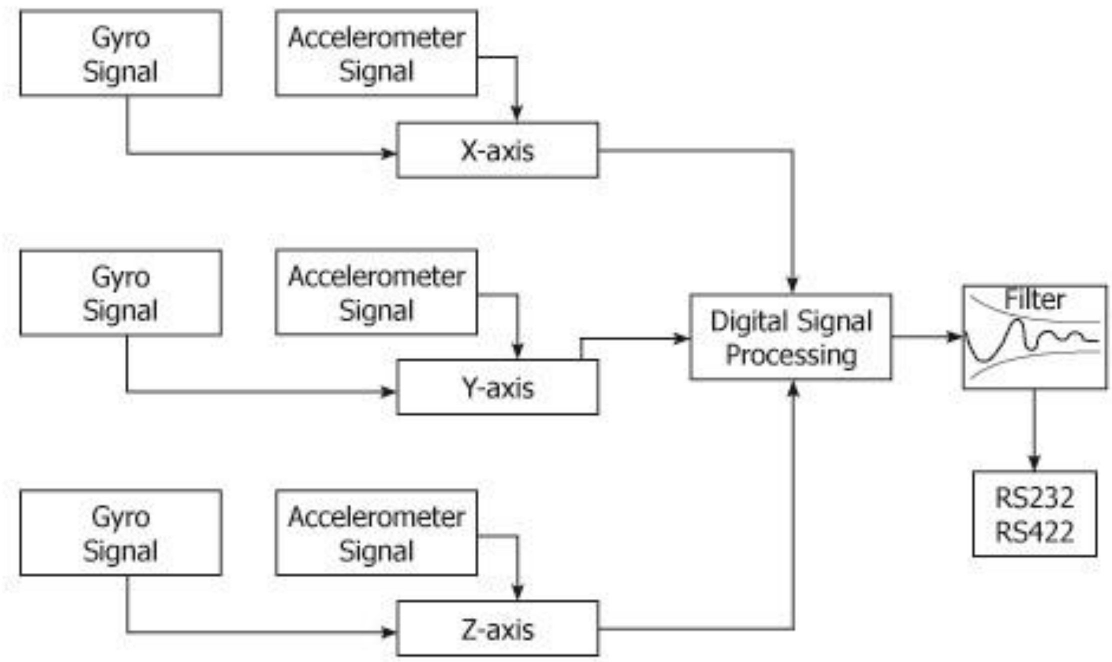
Standard Delivered Items

- Motion Sensor
- Transit Case
- Junction Box fitted with
    - Cable from Motion sensor to JB 10m, 19 core cable
    - Serial Output Data cable 1.5m
    - AC Input Cable 0.9m
- Calibration Certificate
- CD with IMU Configuration Software and IMU User Manual

2 SYSTEM DESCRIPTION

The SMC motion sensors have three separate axial measurement component groups converting signals from actual movements via three accelerometers and three gyroscopes into output data of angles and attitude. The output parameters are presented in a digital output string via RS422 and RS232. On hardware versions 8.5 or higher Ethernet communication is available.

The signal from the gyroscopes are combined with the signal from the accelerometers and are processed in a Kalman filter inside the motion sensor to provide output values for accelerations, attitudes and angles with limited influence from noise and other inaccuracies.



Heave, surge and sway are calculated by integrating the acceleration in the X, Y and Z axis twice. The integrated data is filtered with a high pass filter. The calculations of the distances are optimized for continuous motion and not for static distance measurements, as the high pass filter will filter the position over time to zero. The dynamic motion filtering is designed to measure motions over a period between 1 s and 25 s.

Before delivery all motion sensors are calibrated. The readings from the accelerometers and angular rate gyroscopes are calibrated for alignment, linearity and temperature variations, to ensure they meet the performance specifications.

The calibration is optimized for angles up to +/-30 degrees of angle. The best motion sensor performance is achieved within this angle range. If the motion sensor angle exceeds the calibrated angular range the motion sensor will continue to measure the data, but performance may be decreased.

2.1 SPATIAL MOVEMENT - COORDINATE SYSTEM

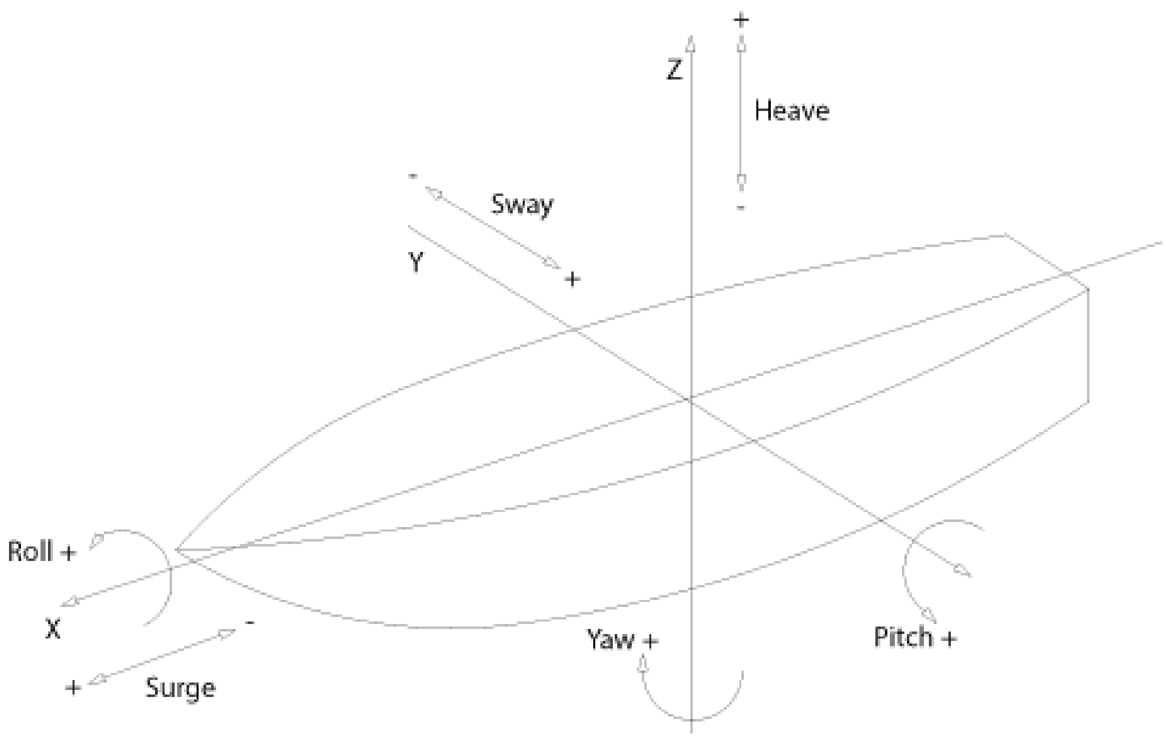
Mounting offsets for the SMC Motion sensor in the roll, pitch and Z axis can be set in the SMC IMU configuration software to compensate for physical alignment errors in the installation. For optimum performance align the motion sensor physically as accurate as possible before setting up offsets electronically.

Note: The Z-axis offset is used to compensate for a physical misalignment in the Z-axis mounting and is not used to set the yaw angle output in the motion sensor.
An improper Z-axis rotation will rotate the coordinate system and will induce roll motion readings in the pitch axis and the vice versa.

The SMC IMU default rotational and acceleration directions are defined in the drawing below. By setting an offset the motion sensor rotates its coordinate system. From the configuration software it is possible to invert the axis rotational directions to suit the receiving application.

Roll is the rotation around the longitudinal axis**, X**, the axis running from the stern to the bow of the vessel.
Pitch is the rotation around the transverse axis, **Y**, the axis running from starboard to port of the vessel.
Yaw is the rotation around the vertical axis, **Z**

Shown in the figure below:



In the SMC motion sensors, the coordinate system can be defined by a setting option in the SMC Configuration software that is included with the motion sensor. The user can choose between the IMU Coordinate system and the Earth Coordinate system. The IMU Coordinate system is the vessel coordinate system when the motion sensor is aligned with the vessel mechanically and/or by offset entries to the motion sensor.

The default setting for the SMC motion sensor is Earth Coordinates without earth G in Acceleration.

The Coordinate system selection does have two selections. One for the Angular Rate and Acceleration coordinate system and the second selection for the linear motion and its velocities.

The coordinate system settings does not change the angular coordinate system, as it is being fixed to the earth coordinate system.

The SMC motion sensor defines its body axis from the Tait-Bryan (z-y-x) angles which have the order yaw, pitch, roll to describe the orientation of a vessel. This is the standard order definition for marine and avionic applications.

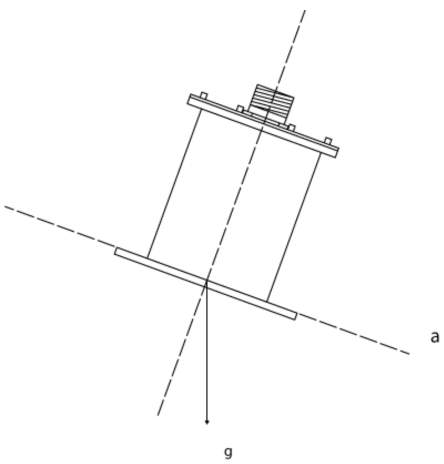
In the Earth Coordinate system positive Z is vertical with reference to the earth horizon. The X-axis in the earth coordinate system has the same direction as the X-axis of the IMU coordinate system projected onto the horizontal plane of the earth. The Y-axis is horizontal and is perpendicular with respect to the earth fixed X-axis and has close to the same direction as the IMU coordinate Y-axis.

To obtain the accelerations in the IMU coordinate system the accelerations measured by the motion sensor are rotated with a three-dimensional calculation with respect to the mounting angles offsets.

To obtain the accelerations in the earth fixed system the accelerations measured in the motion sensor in the IMU coordinate system are rotated with a three-dimensional calculation with respect to the current value of the roll and pitch angles and their offsets.

The accelerations are sent according to the selection for the Angular Rate and Acceleration Coordinate system in the configuration software and is not related to the selection of the Linear Coordinate system selection for Heave, surge and sway output in the motion sensor.

Heave, surge and sway motions are calculated in the earth fixed coordinate systems as default. The calculations of these linear motions are done by using the accelerations in the Earth Coordinate system and integrate them twice to obtain surge, sway and heave positions.



If the IMU coordinates is selected for the Surge, sway and heave, Linear Coordinate system, in the IMU configuration software these values are rotated three-dimensional using the roll and pitch angular data before being output.

The surge, sway and heave velocities are the derivatives of the surge, sway and heave positions and will be output as set in the Linear Coordinate system.

For the Roll, Pitch and Yaw calculations which are always in the Earth Coordinate system, the three-dimensional rotation corresponding to the motion sensor readings is composed (conjugated) with the three-dimensional rotation of the mounting offsets.

The roll, pitch and yaw velocities being output in the earth coordinate system are the derivatives of the corresponding angular values.

The roll, pitch and yaw velocities being output in the IMU coordinate system are the roll, pitch and yaw velocity values measured by the motion sensor and three-dimensional rotated, multiplicatively composed, by the mounting offsets entries.

All compositions of three-dimensional rotations are done by first converting the Tait-Bryan angles to quaternions. Then performing the composition by using quaternion multiplication and finally either obtaining the angles by the citation above or the rotation matrix.

2.2 DEFINITIONS

Alignment
The alignment of the motion sensor is the positioning of the IMU onto the structure of the rig or vessel. The physical alignment must be done as accurately as possible and then it can be fine-tuned in the system configuration software by entering offsets for roll (X), pitch (Y) and the Z-axis.

Yaw in the SMC IMU units
Without an external aiding input the yaw in the SMC motion sensor will drift over time and so it cannot be used as an absolute heading output. Positive yaw is a clockwise rotation. The yaw output from the SMC unit, when it is not aided from an external heading input, is the integration of the yaw gyroscope or the integrated rotation in the Z axis in the earth coordinate system.

Roll
Roll is the rotation about the roll axis (X) of the vessel. SMC defines the port up as a positive roll.

Pitch
Pitch is the rotation about the pitch axis (Y) of the vessel. SMC defines the bow down as a positive pitch.

Heave
Heave is the vertical dynamic motion of the vessel. The heave is calculated by a double integration of the vertical acceleration. The vertical position is filtered with a high pass filter. Heave measures the relative position dynamically and *cannot* be used for a static height position measurement. An upwards motion is defined as a positive heave.

Surge and Sway
Surge and Sway are the horizontal dynamic motion of the vessel. Surge is the linear motion along the roll axis; a positive surge is when the vessel is moving in the bow direction. Sway is the linear motion along the pitch axis where a positive sway is in the port direction. The surge and sway calculation are attained by a double integration of the horizontal acceleration. The horizontal position is filtered with a high pass filter. The dynamic horizontal linear measurement is a relative position and cannot be used for a static horizontal position measurement.

Center of Gravity
Centre of gravity CG is the mass center of a vessel.

X-axis/Roll axis
The X axis is the bow/stern axis in the vessel. Rotation in the X axis will generate a roll motion where a positive rotation is port side up.

Y-axis/Pitch axis
The Y axis is the port/starboard axis in the vessel. Rotation in the Y axis will generate a pitch motion where a positive rotation is bow down.

Z-axis
The Z axis is the vertical axis pointing up and down in the vessel. Rotation in the Z axis will generate a yaw motion, where positive yaw is a clockwise rotation.

RMS
Root mean square (RMS) is a statistical measure of the magnitude of a varying quantity.

3 INSTALLATION

The SMC motion sensor must be installed according to the instructions in this manual.
The motion sensor is designed to be installed in an internal environment.

3.1 LOCATION

The optimal location for the SMC motion sensor is as close as possible to the vessels center of gravity (CG). However, for certain applications, mainly when heave and accelerations are to be measured at a specific location, it is advisable to mount the motion sensor as close as possible to the actual measurement point, for example in Helideck Monitoring Systems and some hydrographic survey systems.

Recommendations for location of the motion sensor to obtain optimal performance:

Roll & Pitch
When mounting the SMC motion sensor, take care to align the motion sensor to the vessels roll, pitch and Z axis. If there is a rotation misalignment in the Z-axis, roll motions will induce errors in pitch measurements and vice versa.

Small alignment errors can be adjusted mathematically inside the motion sensor. The alignment offsets can be set from the SMC IMU configuration software.

Heave/acceleration
If the motion sensor is equipped with Heave/acceleration measurement it is recommended that the motion sensor is placed as close to the point where Heave/acceleration is to be measured. For a helideck installation, it is required to install the motion sensor within 4 meters from the center of the helideck.

Temperature
The SMC motion sensors have been calibrated and designed to work within the stated temperature range as specified in the motion sensor technical specifications. SMC recommend that the motion sensor is mounted in a location without extreme variations in temperature.

Vibrations
Avoid mounting the motion sensor on any hull location that is subject to substantial vibrations. Also, avoid mounting a sensor near to machines with sporadic operation e.g. hydraulic pumps. The use of dampers between the Motion Sensor mounting plate or fixture points may be of benefit in installations where vibrations are present. Care ought to be taken to ensure the dampers are sufficiently firm so as not to introduce a sag and therefore alignment errors. Heavy vibrations will reduce measurement performance mainly on the positioning outputs as for example heave as these are calculated from the accelerations.

Weather protection
The SMC IMU-007, IMU-008, IMU-106, IMU-107 and IMU-108 are as a standard IP66 protection rated. The standard surface motion sensor is designed to be mounted in a sheltered environment, an enclosure is highly recommended to prolong service life and life time expectations.

The SMC IMU-108-30 is IP68 water resistant to 30 meters depth or optionally 1000 meters.

Mounting orientation
The Motion Sensor is calibrated from the factory for either Deck or Sideways orientation. Deck orientation is when the Motion Sensor is mounted on a horizontal surface with the connector pointing upwards. Deck mounting calibration is the default orientation. Sideways orientation is when the motion sensor is calibrated to be mounted on a vertical surface.

Note: A motion sensor that has been calibrated for Deck mounting cannot be used in a sideways mounting and vice versa without recalibration of the motion sensor at the factory.

3.2 MOUNTING INSTRUCTIONS

The Motion sensor base plate has been specifically designed to enable ease of installation and alignment.

The SMC Motion sensor is shipped without mounting screws or bolts. The base plate can be fixed with M6 (max M8) screws or bolts with washers. The dimensions of the motion sensor for the mounting locations can be found in Chapter 3.6

After drilling any holes for mounting, be sure to de-burr the holes and clean the mounting location of any debris that can induce mounting offsets.

Mount and screw the motion sensor in position, make sure to align the motion sensor as accurately as possible with the vessels coordinate system.

A motion sensor calibrated for deck mounting/horizontal surface, must be mounted with the connector pointing upwards. It is *not* designed to be mounted with the connector pointing downwards.

In the SMC IMU Configuration Software, there is a function to fine tune the motion sensor alignment in the X, Y and Z axis. This setting will rotate the coordinate system inside the motion sensor. See chapter 4.1 on IMU Configuration Software for further instructions.

When mounting the motion sensor sideways there are 4 mounting options in the SMC IMU Configuration Software to rotate its coordinate system correctly. For more information, see chapter 3.5 for sideways calibrated setup. If an incorrect mounting selection is chosen, the coordinate system will be inverted. In this case, the roll motion will become the pitch motion or alternatively the positive negative rotation of the angles will be inverted.

When the motion sensor is calibrated for sideways mounting, connector pointing horizontally, and is mounted upside down, with the single notch pointing in the wrong direction, the output signal from the motion sensor will display – 180 degrees wrong angle for roll output. If the Motion Sensor is mounted incorrectly it will not work within its calibrated range and will output inaccurate values.

3.2.1 MOUNTING BRACKET - OPTIONAL

An optional mounting bracket is available, designed to simplify wall mounting installations combined with easy motion sensor alignment. One advantage with the mounting bracket is that the motion sensor can be removed for servicing or recalibration and repositioned in exactly the same position.

The bracket base plate has two pins***** that correspond to two of the notches in the Motion sensor base. Alignment adjustments can then be made by rotating the bracket adapter.

The mounting bracket is delivered with a mounting adapter and screws for fixating the motion sensor to the bracket. The mounting bracket is produced in Stainless steel 316.

The adapter, included with the bracket, allows 45 degrees of rotational adjustment.
See chapter 3.6.5 for details of the mounting bracket dimensions.

***Note** SMC recommend using a 4mm spring pin in the mounting plate.

3.3 ALIGNMENT

To achieve maximum performance of the motion sensor, it is important to perform an accurate alignment of the motion sensor along the vessel longitudinal axis. The physical alignment must be as accurate as possible using the notches on the motion sensor mounting plate for reference.

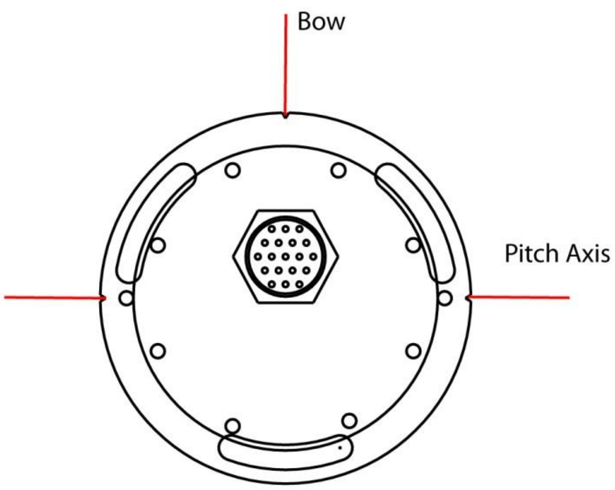
For the deck mounted standard motion sensor, the single notch is to be pointing to the fore direction of the vessel. A misalignment in the Z axis rotation (yaw) will generate a cross axis motion, where pitch will generate a roll reading from the motion sensor and vice versa. From the SMC IMU Configuration Software, it is possible to fine tune the alignment errors from the installation of the motion sensor.

Note: The Z-axis alignment is only to be used to correct the physical misalignment and *not* to change the yaw output reading from the motion sensor.

3.4 DECK MOUNTED - MOUNTED ON HORIZONTAL SURFACE

When the motion sensor is delivered for Deck mounting the motion sensor cannot be used for sideways mounting without a recalibration at the factory.

Mounting of the motion sensor must be carried out with the mounting plate placed horizontally. The notches on the plate mark the orientation points of the motion sensor. The indexes marking the Pitch axis must be aligned to port/starboard, along the vessels center of rotation or on the axis you have defined. The single notch is to be mounted pointing to the fore of the vessel. In the figure below the Motion Sensor viewed from the top.



3.5 SIDEWAYS MOUNTING

When the Motion sensor is delivered for Sideways mounting the motion sensor cannot be used for Deck mounting without a recalibration at the factory.

The mounting of the motion sensor must be carried out with the mounting plate oriented vertically.
The notches on the mounting plate mark the orientation points of the motion sensor.
The single notch must be mounted pointing horizontally to the bow/stern/port/starboard of the vessel.

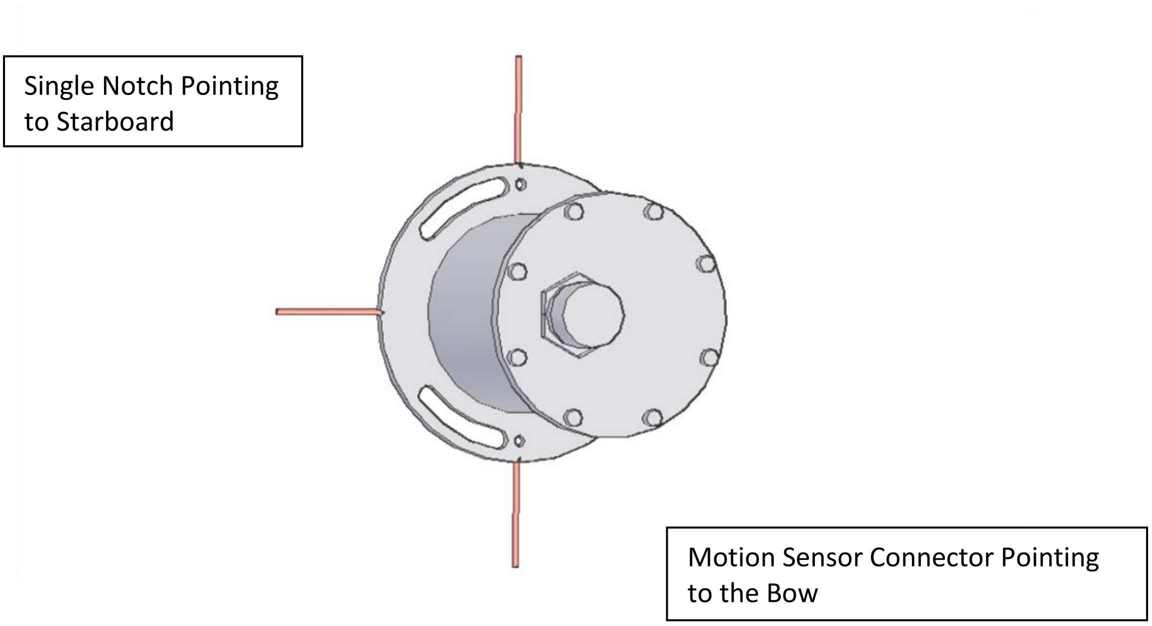
Depending on the mounting orientation the Motion sensor will need its coordinate system to be selected in the SMC IMU configuration software Mounting Orientation options.

Note: The Motion sensor cannot be mounted in the sideways orientation unless it has been specifically calibrated to do so. Contact SMC if clarification is required.

3.5.1 TOP OF THE MOTION SENSOR POINTING TO THE BOW

When the Motion sensor top, where the connector is located, is pointing to the Bow of the vessel the single notch must be pointing horizontally to Starboard.

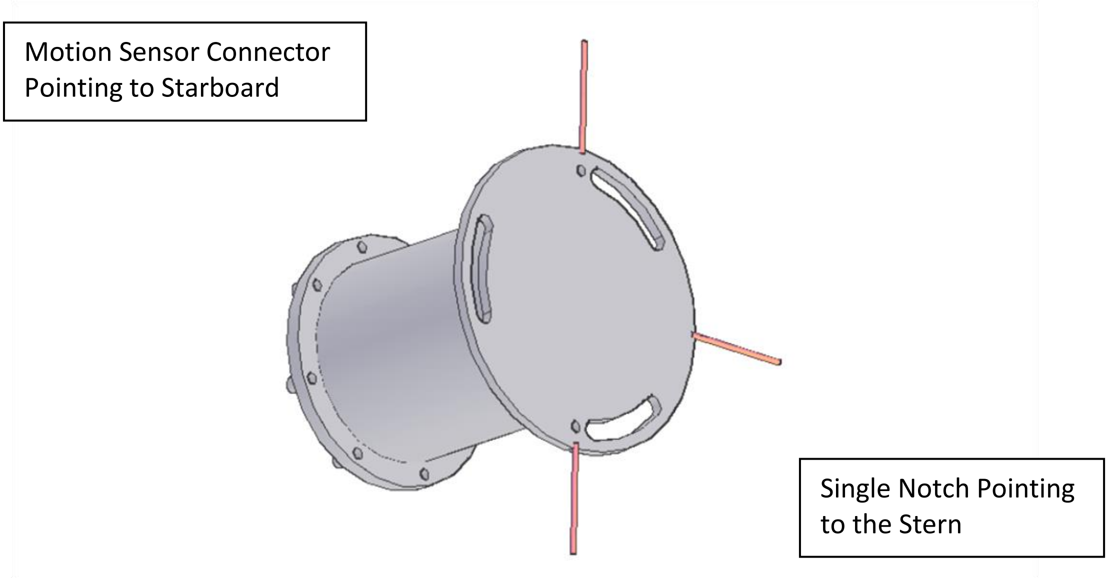
In the SMC IMU Configuration Software **IMU top to the Bow** must be selected.



3.5.2 Top of the motion sensor pointing to the starboard

When the Motion sensor top, where the connector is located, is pointing to the **Starboard** of the vessel the single notch must be pointing horizontally to the **Stern**.

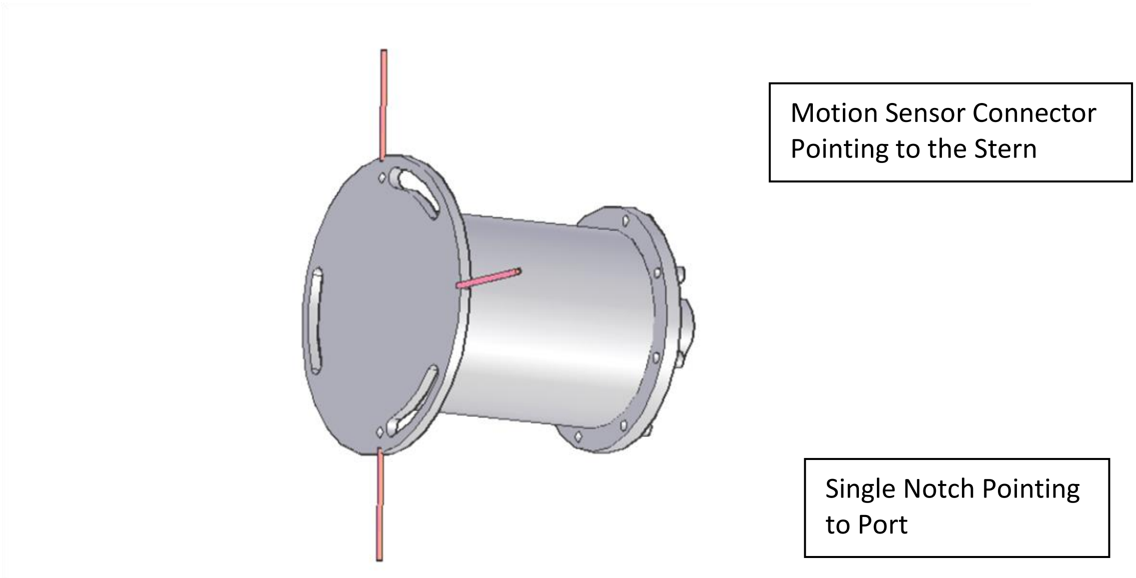
In the SMC IMU Configuration Software **IMU top to the Starboard** must be selected.



3.5.3 TOP OF THE MOTION SENSOR POINTING AT THE STERN

When the Motion sensor top, where the connector is located, is pointing to the **Stern** of the vessel the single notch must be pointing horizontally to **Port**.

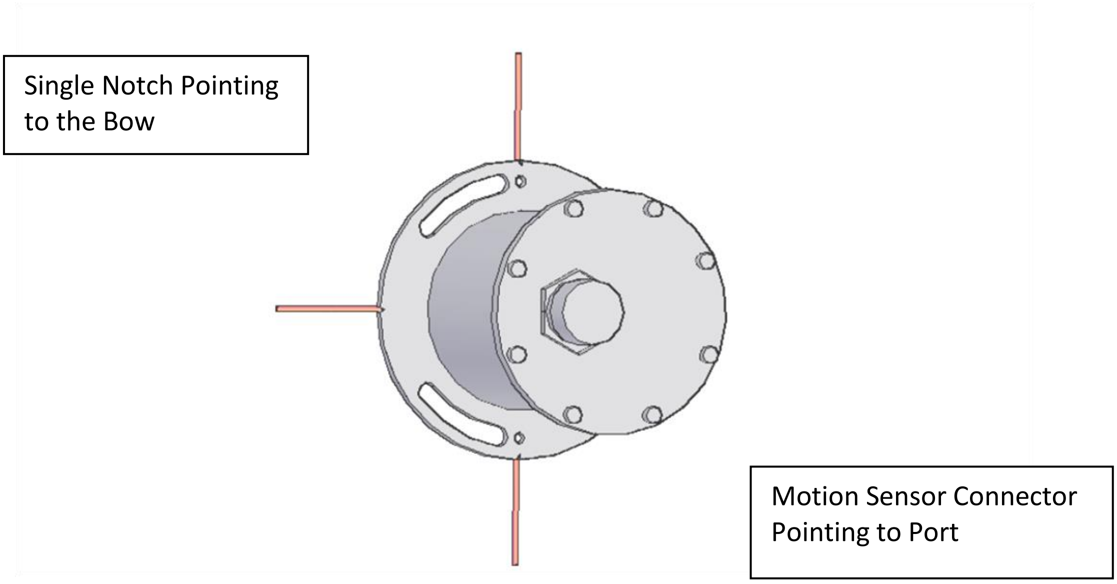
In the SMC IMU Configuration Software **IMU top to the Stern** must be selected.



3.5.4 TOP OF THE MOTION SENSOR POINTING TO THE PORT

When the Motion sensor top, where the connector is located, is pointing to the **Port** of the vessel the single notch must be pointing horizontally to the **Bow**.

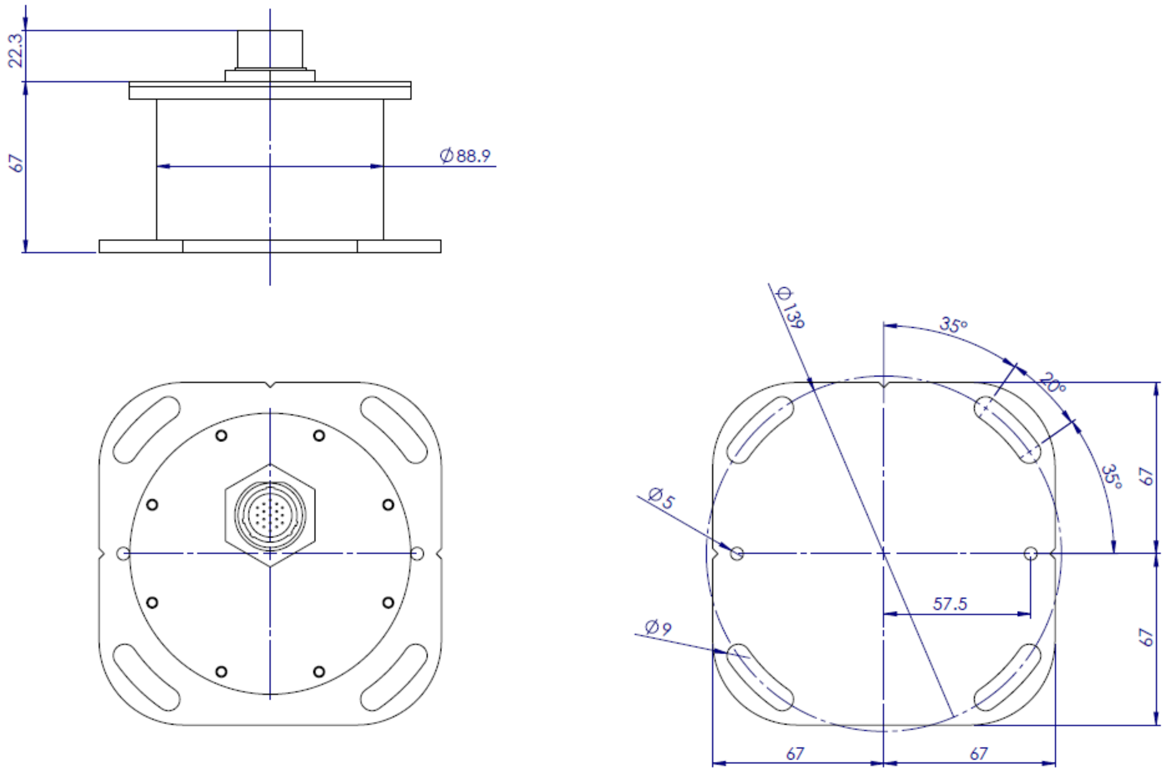
In the SMC IMU Configuration Software **IMU top to the Port** must be selected.



3.6 MOTION SENSOR DIMENSIONS

3.6.1 IMU-00X SURFACE MOTION SENSOR

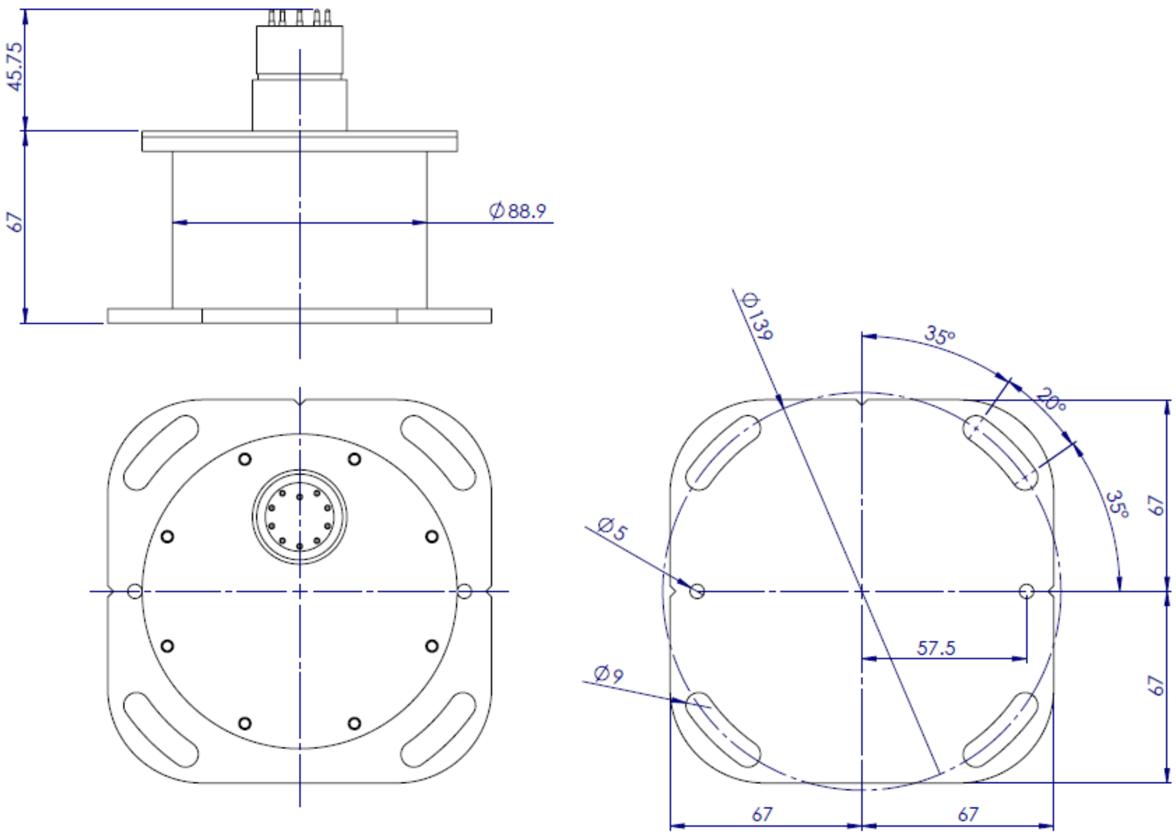
Dimensions in mm



Note the IMU base plate has two 5mm holes for mounting and alignment. SMC recommend using 4mm spring pins. The springs pins are an interference fit in the optional mounting bracket plate but should be a push fit in the IMU base.

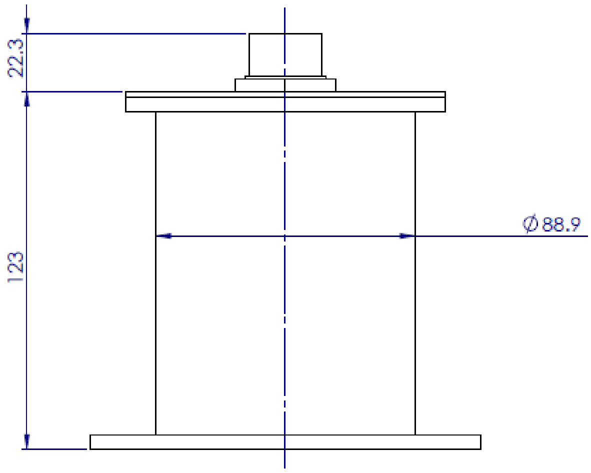
3.6.2 IMU-00X 30M DEPTH RATED MOTION SENSOR

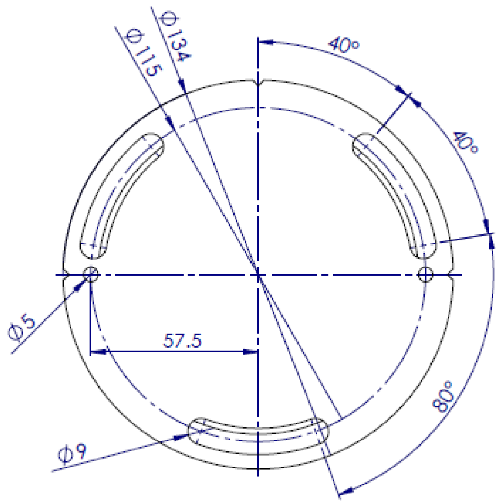
Dimensions in mm

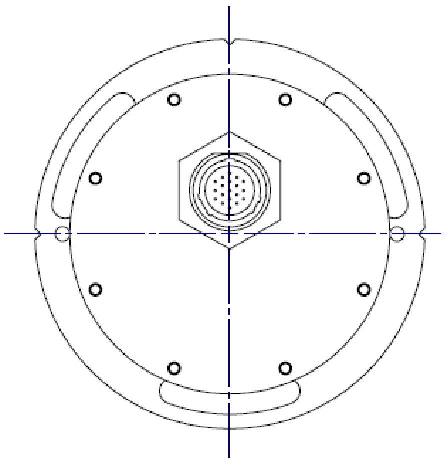


Note the IMU base plate has two 5mm holes for mounting and alignment. SMC recommend using 4mm spring pins. The springs pins are an interference fit in the optional mounting bracket plate but should be a push fit in the IMU base.

Dimensions in mm



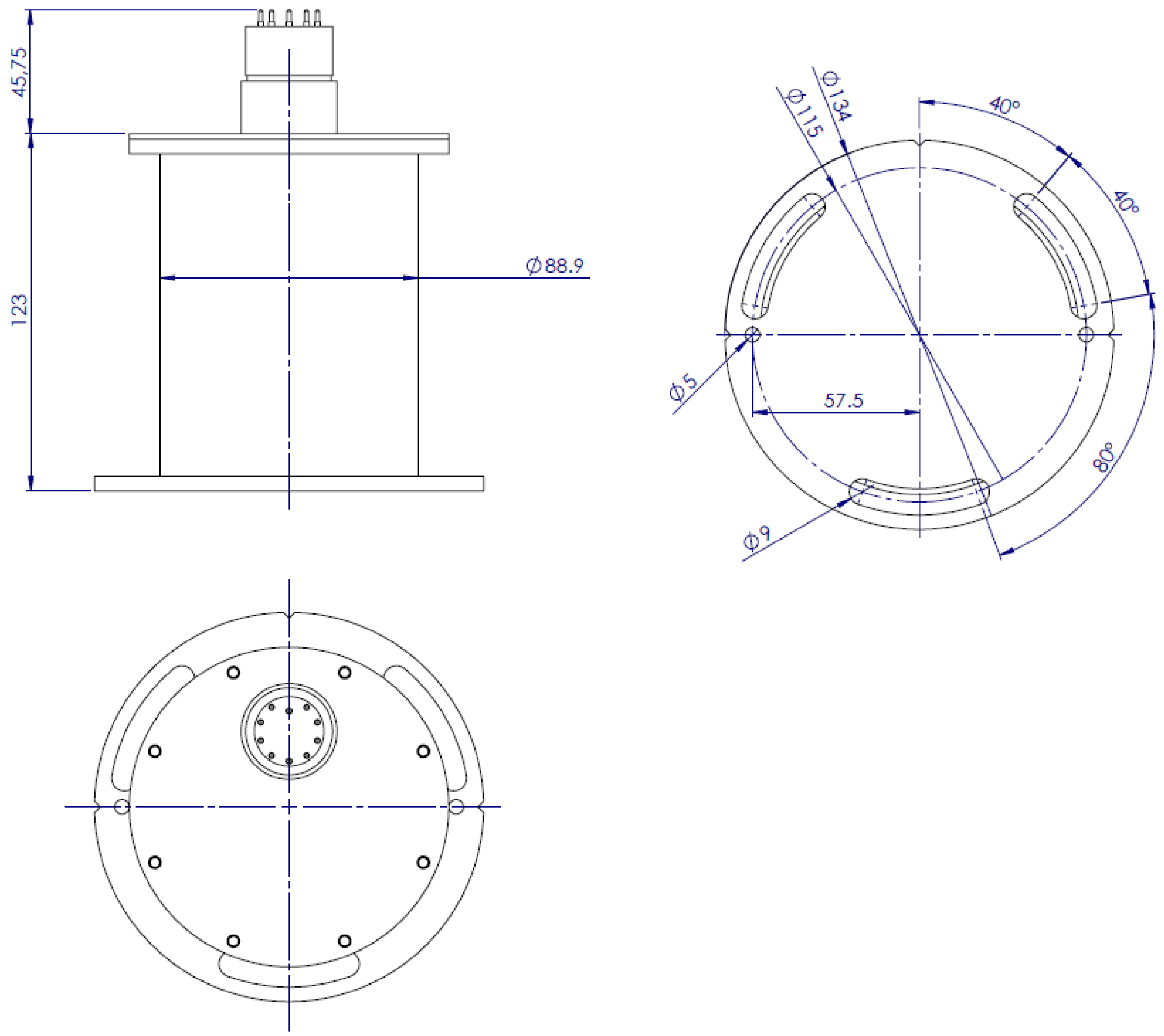




Note the IMU base plate has two 5mm holes for mounting and alignment. SMC recommend using 4mm spring pins. The spring pins are an interference fit in the optional mounting bracket plate but should be a push fit in the IMU base.

3.6.4 IMU-10X 30M DEPTH RATED MOTION SENSOR

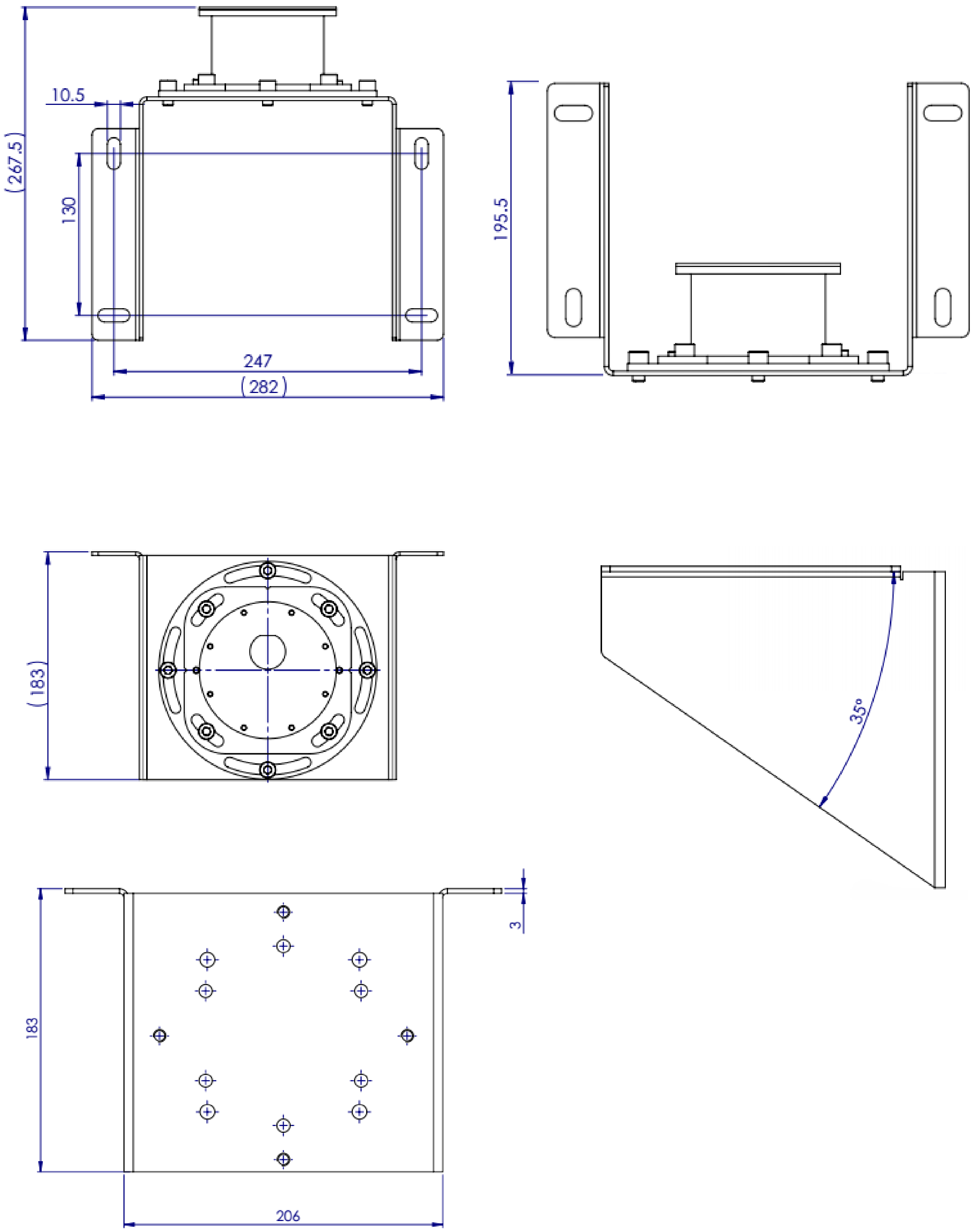
Dimensions in mm



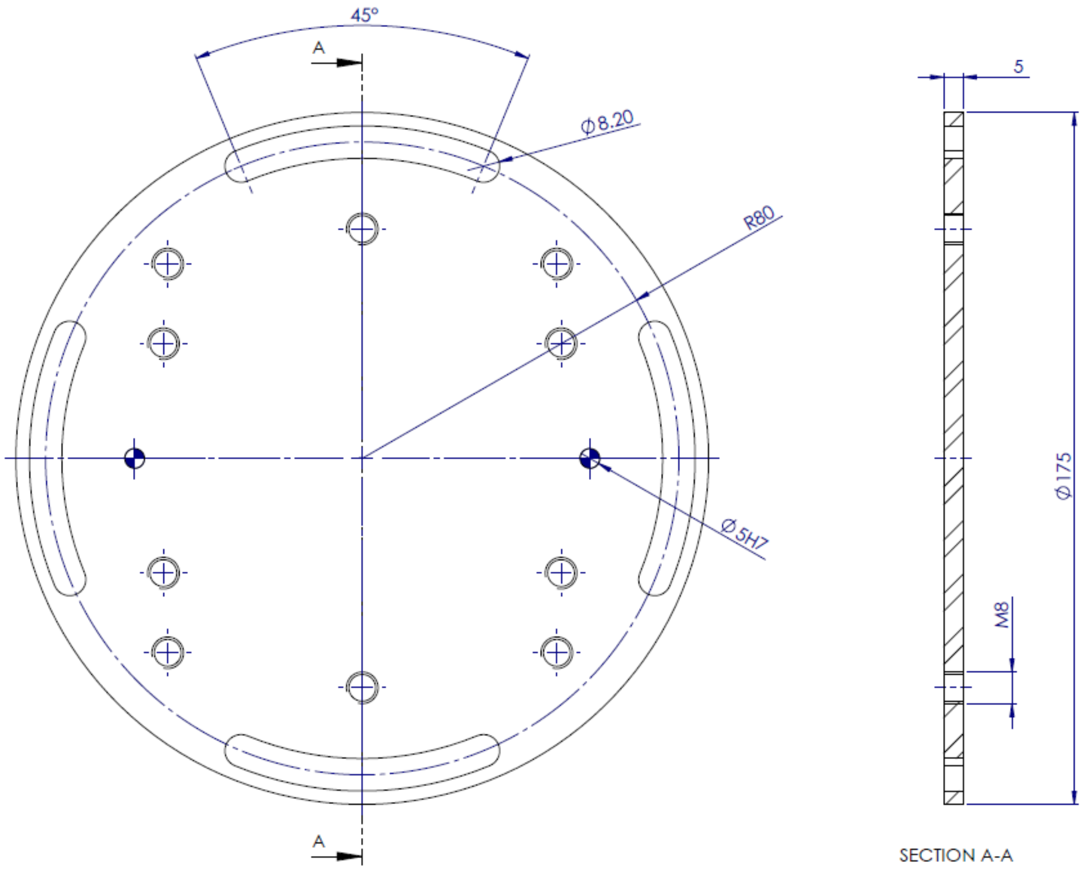
Note the IMU base plate has two 5mm holes for mounting and alignment. SMC recommend using 4mm spring pins. The spring pins are an interference fit in the optional mounting bracket plate but should be a push fit in the IMU base.

3.6.5 IMU MOUNTING BRACKET OPTIONAL

Dimensions in mm



IMU bracket base plate



3.7 ELECTRICAL COMMUNICATION

The SMC Motion sensors are powered with a standard 12 VDC or 24 VDC supply. It is possible however to supply power at any voltage between 10 VDC and 30 VDC. The power consumption during normal conditions is about 2 watts for hardware versions below 8.4 and 3 watts for hardware version 8.5 and higher.

The resistance of power cables must be so that the voltage does not drop below 12 VDC for the motion sensor operation. The thickness of power cables is such that there is no more than a 2V drop with a 50mA current applied over an exceptional length of cable.

The SMC Motion sensors do not have an on/off switch. The motion sensor operates as soon as power is supplied to it. There is an initialization period that prevents the motion sensor from outputting numerical data for the first 1 minute after the motion sensor has been powered up.

The SMC Motion sensors have RS232 and RS422 serial outputs as standard and Ethernet. The motion sensor is simultaneously communicating over both RS232 and RS422 and no configuration is needed inside the motion sensor to activate the communications.

For motion sensor firmware versions from 3.22 and higher one of the serial input ports can be used for outputting data. The settings as baud rate will be the same on all outputs. The string is selectable for the comport 1/2 and comport 3 separately. For firmware versions below 3.22 data cannot be transmitted over serial port 3 of the motion sensor. Com 3 and Com 4 can be used to input serial data for aiding purposes from GPS and Compass. If Com 3 is used to output motion data the receive pin cannot be used for settings for the motion sensor. The Rx pin will continue to listen for serial GPS and Compass inputs in the selected baud rate set for the serial input. The Tx output will use the baud rate set from the main output and can differ from the serial input baud rate.

Motion sensors from hardware version 8.5 are equipped with an Ethernet interface. The SMC Motion Sensor can supply data output on both the serial and Ethernet interfaces at the same time.

In the standard delivery, the motion sensor junction box is equipped with a power cable, a motion sensor cable and a serial DB9 cable for RS232 or RS422 communication. The Junction Box factory pre-configuration for RS232 or RS422 can be changed in the field by modifying the wiring of the serial cable inside the junction box. See the wiring diagram for wiring details.

The RS232 cable consists of single twisted-pair conductors, 2 wires, for full communication and a signal ground wire. RS232 is designed for short distance communication, max 15 meters.

The RS422 cable consists of two twisted-pair conductors, 4 wires, for full communication.
The RS422 communication can achieve data transfer over long distance cables, up to 1000 meters.

The RS232 and RS422 cable normally terminate with a conventional DB9 connector.

The Ethernet cable consists of two twisted-pair conductors, 4 wires, for bi-directional communication, following the RJ45 568B standard. The maximum cable length is approximately 100m.

Two RS232 serial ports are also available for aiding the motion sensor by GPS or Compass input.
IMU-10x with a hardware below 2.72 does not have the serial input communication ports.

Permanent damage to the motion sensor may occur if power is applied to the digital connections. It is important to check the power connections by measuring the voltage at the connector prior to the motion sensor being connected. Damage resulting from incorrect connection is not covered by the warranty.

3.7.1 SURFACE MOTION SENSOR CABLE CONNECTION

IMU Connector	Cable Colour	IMU Function	External device
A	White	COM1 RS232 – RxD main	DB9 pin3 – TxD
B	Red	COM1 RS232 – TxD main	DB9 pin2 – RxD
C	Brown	COM2 RS422 – TxD+ main	DB9 pin3 – RxD+
D	Orange	COM2 RS422 – TxD- main	DB9 pin4 – RxD-
E	Green	COM2 RS422 – RxD- main	DB9 pin1 – TxD-
F	Purple	COM2 RS422 – RxD+ main	DB9 pin2 – TxD+
G	Yellow	COM3 RS232 – TxD Data output	DB9 pin2 – RxD
H	Transparent	COM3 RS232 – RxD serial aiding/input	DB9 pin3 – TxD
J	Black	COM4 RS232 – TxD serial aiding/input	DB9 pin2 – RxD
K	Blue	COM4 RS232 – RxD serial aiding/input	DB9 pin3 – TxD
L	Grey	Supply Voltage -	
M	Pink	Supply Voltage + 12 to 30Vdc	
S	White/Black	Ethernet – TxD+	RJ45 pin1 – RxD+
T	White/Red	Ethernet – TxD-	RJ45 pin2 – RxD-
U	White/Green	Ethernet – RxD+	RJ45 pin3 – TxD+
V	White/Yellow	Ethernet – RxD-	RJ45 pin6 – TxD-

Position A to V is available on motion sensor with hardware 8.5 or higher. On the 12-wire cable position A to M is available only. The 12-wire cable and connector and 19-wire cables are inter-changeable for the serial communication.

3.7.2 DEPTH RATED UNIT

COM1 RS232 Output Connections DB9 Connections

IMU Connector	Cable Colour	IMU Function	DB9 to PC/Converter
1	Black	RS232 – RxD	3
2	White	RS232 – TxD	2
11	Blue/Black	Supply Voltage -	5
12	Black/White	Supply Voltage + 12 to 30Vdc	

COM2 RS422 Output Connections DB9 Connections

IMU Connector	Cable Colour	IMU Function	DB9 to PC/Converter
3	Red	RS422 – TxD+	3
4	Green	RS422 – TxD-	4
5	Orange	RS422 – RxD-	1
6	Blue	RS422 – RxD+	2
11	Blue/Black	Supply Voltage -	5
12	Black/White	Supply Voltage + 12to 30Vdc	

COM3 RS232 Serial Input 1 Connections and Motion data output DB9 Connections

IMU Connector	Cable Colour	IMU Function	DB9 to PC/Converter
7	White/Black	RS232 – TxD	2
8	Red/Black	RS232 – RxD	3
11	Blue/Black	Supply Voltage -	5
12	Black/White	Supply Voltage + 12 to 30Vdc	

RS232 Serial Input 2 Connections DB9 Connections

IMU Connector	Cable Colour	IMU Function	DB9 to PC/Converter
9	Green/Black	RS232 – TxD	2
10	Orange/Black	RS232 – RxD	3
11	Blue/Black	Supply Voltage -	5
12	Black/White	Supply Voltage + 12 to 30Vdc	

3.7.3 SURFACE MOTION SENSOR HARDWARE VERSION HIGHER THAN 8.5

PCB Version 1.2 model

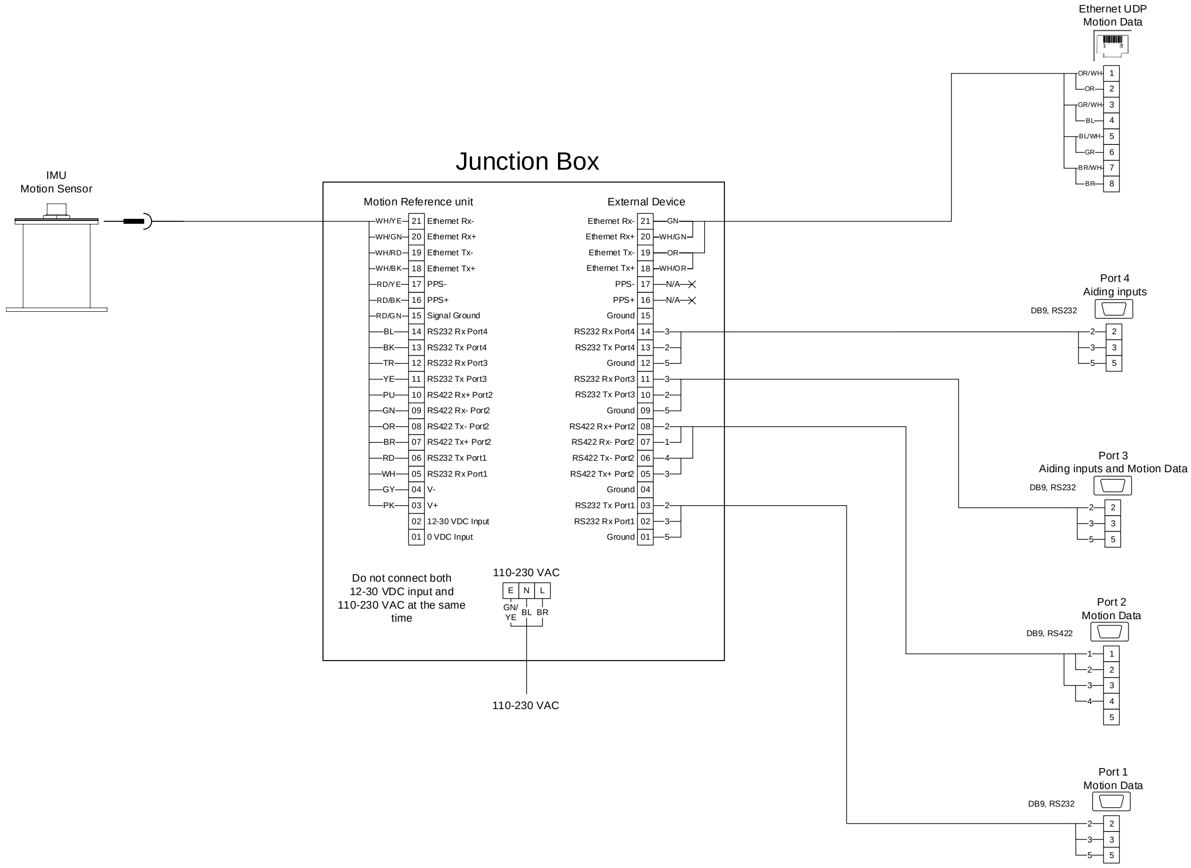
AC input	110 – 230 VAC
Onboard IMU operating power	24 VDC

When AC power to the IMU junction box is not practical or available, the IMU can be powered by 12 to 30 VDC, connected to the terminals labelled **PWR IN**.

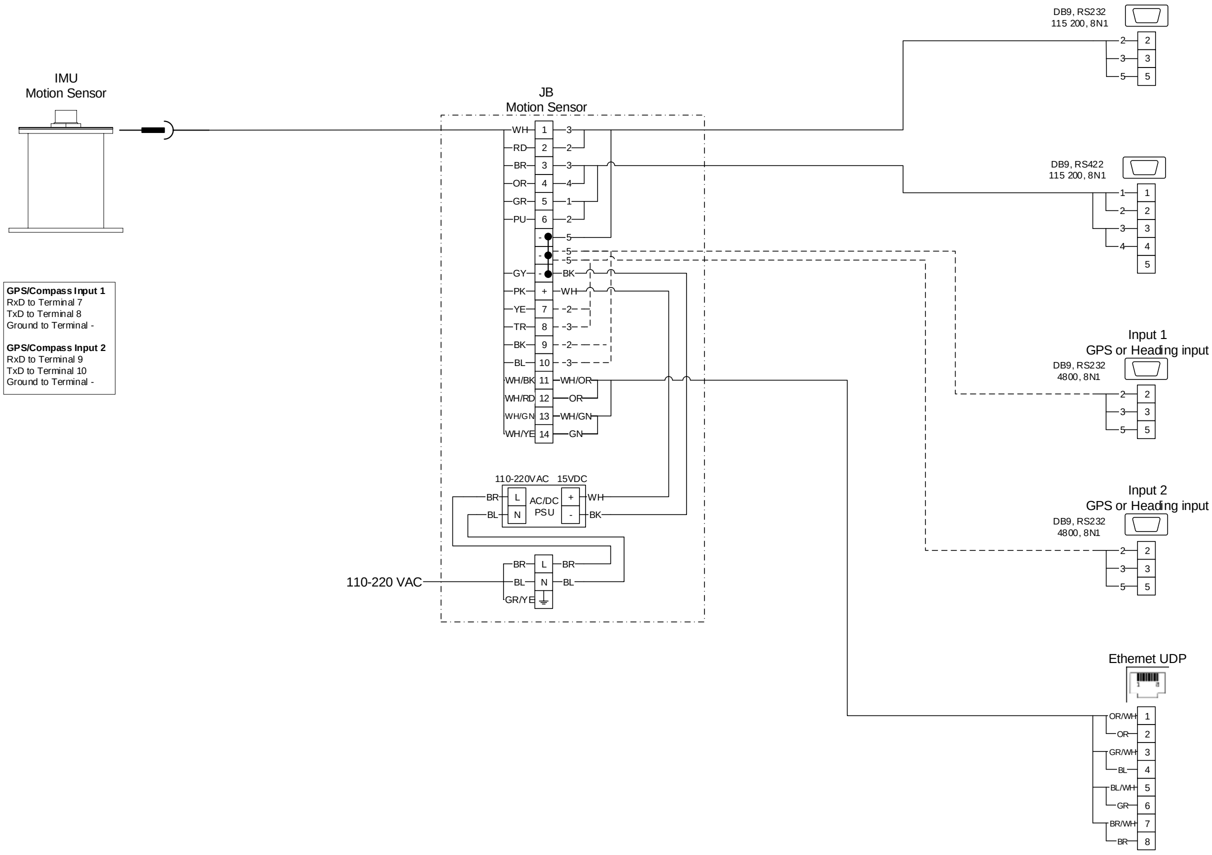
Do not connect DC power and AC power at the same time to the motion sensor

Note: Applying power to the data wires will damage an attached IMU.

Potential electric shock risk.
It is highly recommended to disconnect the AC power to the junction box when connecting data wires.

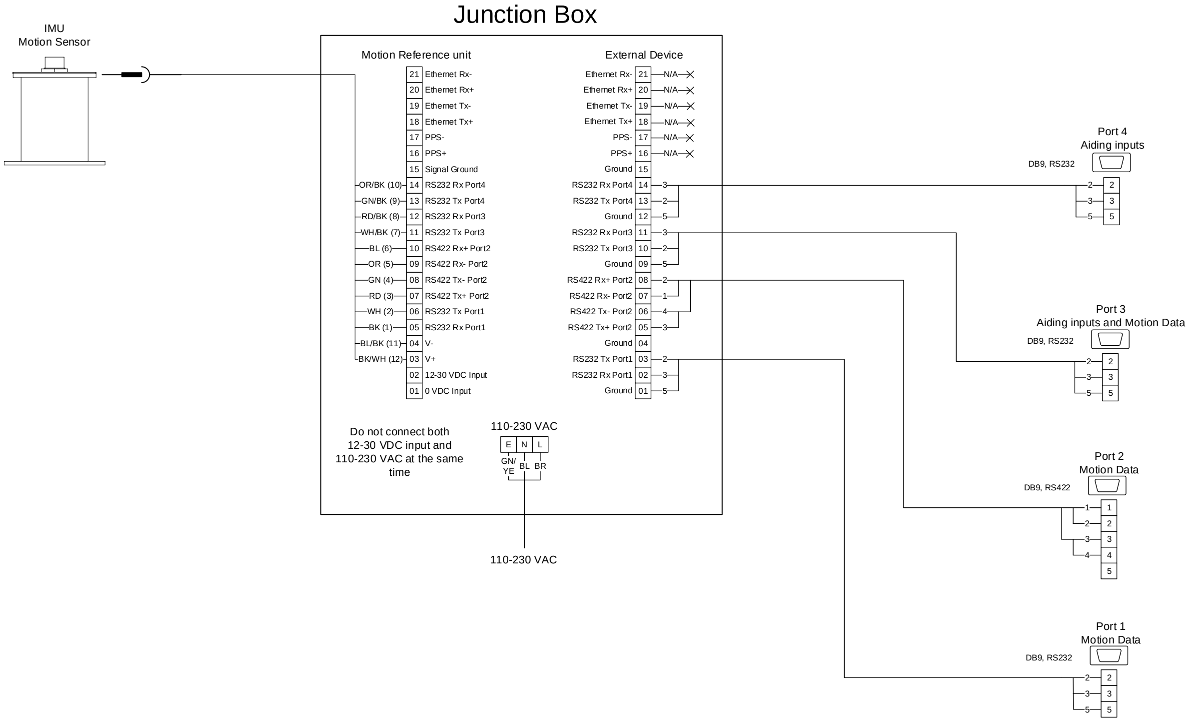


JB Terminal list model

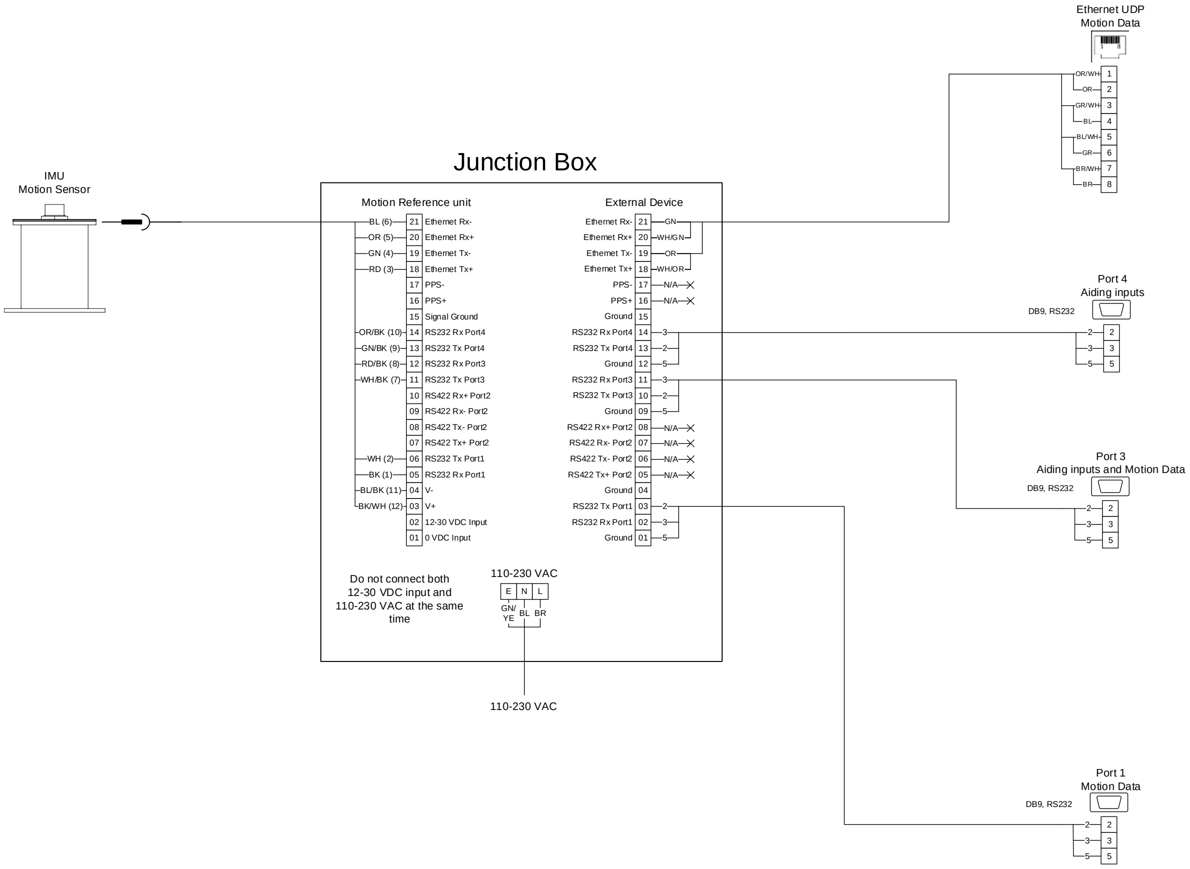


3.7.4 DEPTH RATED MOTION SENSOR

PCB Version 1.2 model without ethernet

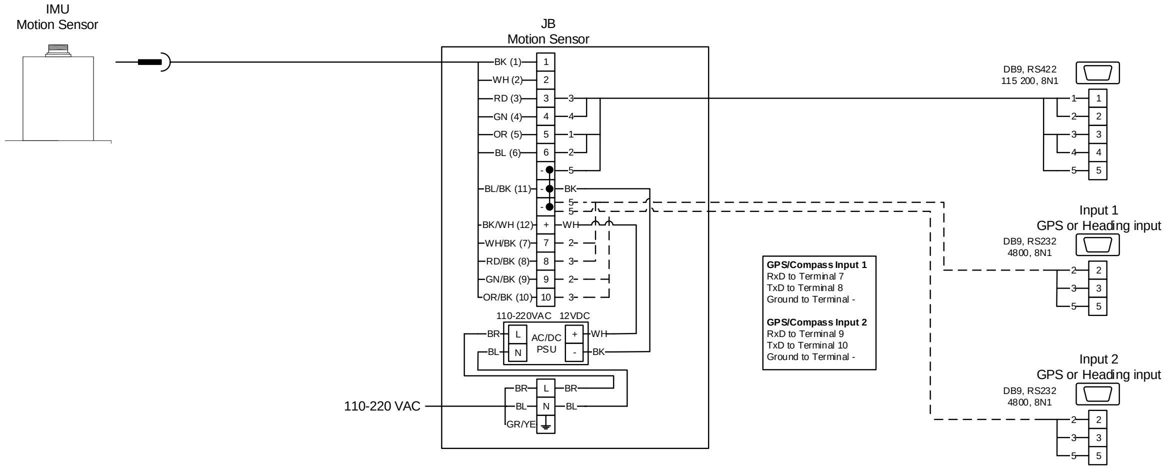


PCB Version 1.2 model with ethernet

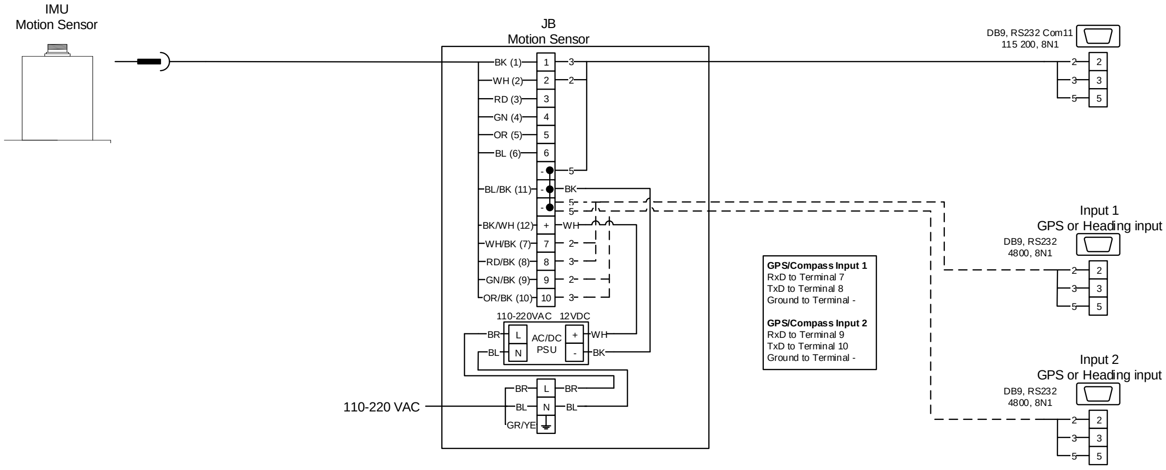


JB Terminal list model

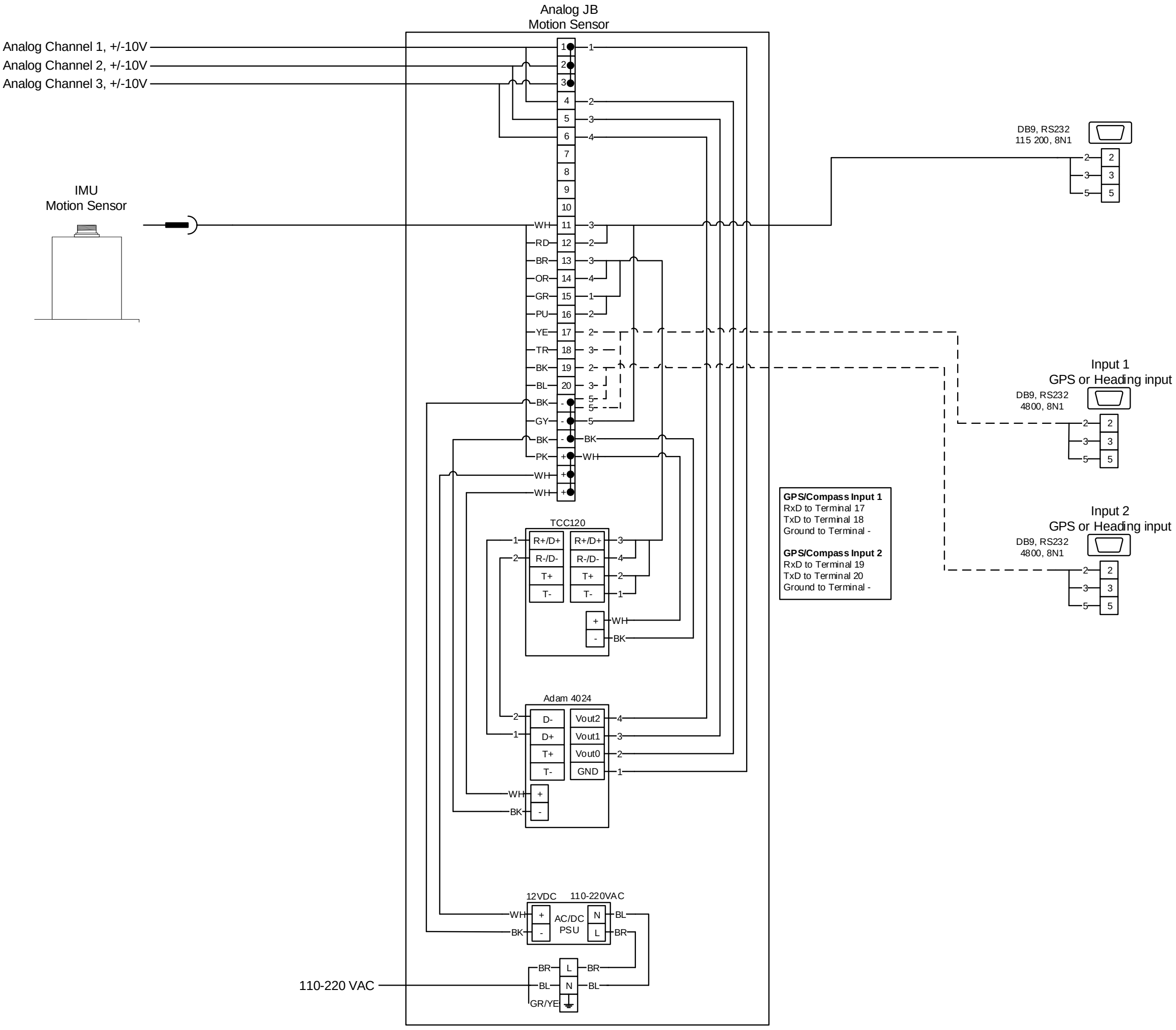
RS422



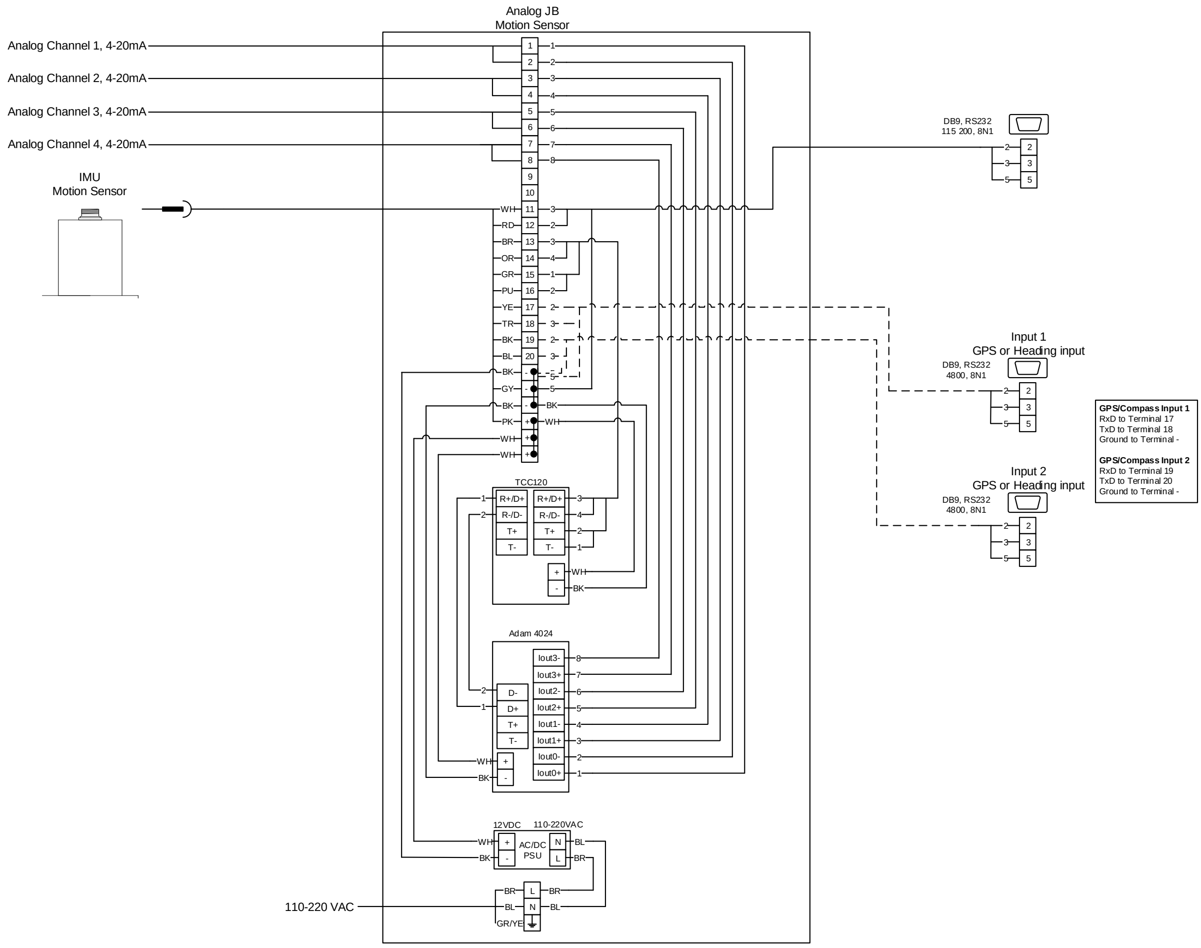
RS232



3.7.5 ANALOG OUTPUTS VOLTAGE +/-10V



3.7.6 ANALOG OUTPUTS CURRENT 4-20MA



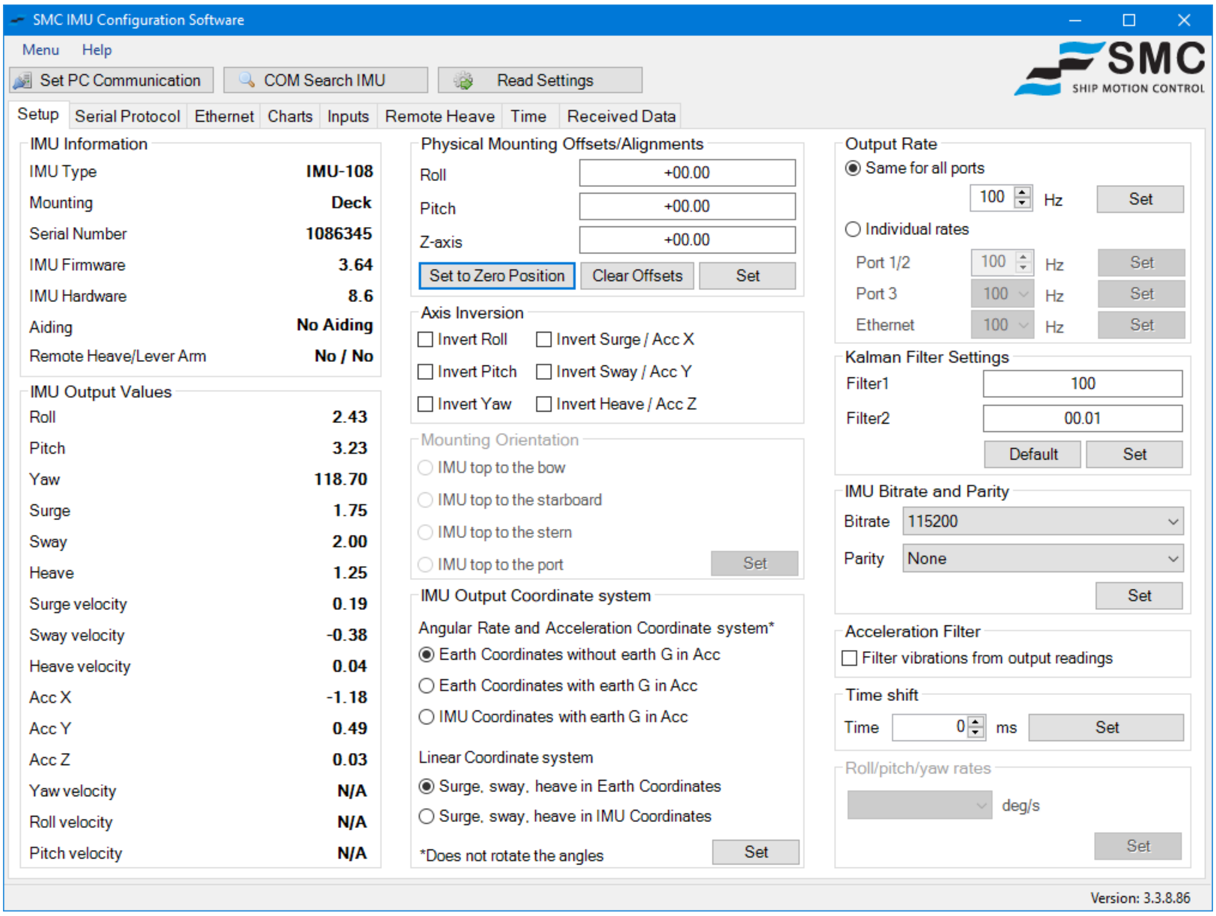
4 MOTION SENSOR CONFIGURATION GUIDE

4.1 IMU CONFIGURATION SOFTWARE

After the motion sensor has been mounted correctly the SMC IMU Configuration Software can be used to set the Motion sensor configuration and communication parameters according to the user requirements.

The configuration software is a PC based tool, communicating with the motion sensor over a serial port alternatively Ethernet if available.

The settings made in the IMU Configuration software are written to the motion sensor. The settings are stored in flash memory inside the motion sensor and are not dependent on power supply or battery power.



4.1.1 DEFAULT SETTINGS AT THE FACTORY

The motion sensor is delivered from SMC with a set of default parameters. The default parameters can be changed from the SMC IMU Configuration Software.

Please refer to 4.1.2 (General Settings).

The factory default settings are as follows.

Settings	Selection	Factory Default
Output Rate	1 – 100Hz	100
Kalman Filter Settings **Note**: It is not advisable to change the settings for the Kalman Filter without consulting with SMC	Filter 1 (0 – 1000) Filter 2 (0 – 1000)	IMU-00x • Filter 1 (25) • Filter 2 (0.01) IMU-10x • Filter 1 (100) • Filter 2 (0.01)
IMU Bit Rate	4800 9600 19200 38400 57600 115200	115200
Parity	None Even Odd	None
IMU Output Coordinate System	Earth Coordinates without earth G in Acceleration Earth Coordinates with earth G in Acceleration IMU Coordinates with earth G in Acceleration	Earth Coordinates without earth G in Acceleration
	Surge, sway, heave in Earth Coordinates Surge, sway, heave in IMU Coordinates	Surge, sway, heave in Earth Coordinates

4.1.2 GENERAL SETTINGS & SETUP TAB

Set PC Communication
Sets the communication settings used by the configuration software to connect and communicate with the motion sensor.

IMU Information
Shows information about motion sensor IMU type, mounting orientation, serial number, IMU firmware, IMU Hardware, Aiding and Remote Heave/Lever Arm.

IMU Output Values
Shows data sent from the motion sensor in real time. Note the motion sensor does not output any numerical data during the first minute after power up.

Physical Mounting Offsets/Alignments
The mounting offsets are used to fine tune the physical alignment differences to the vessel coordinate system and the motion sensor coordinate system. The offsets entered rotate the IMU coordinate system. Try to align the motion sensor as well as possible physically before adjusting the offsets electronically. The axis alignment is very crucial to achieve accurate angle output from the motion sensor, where a misalignment in the Z axis will introduce an error between the roll and pitch readings.

The offsets are set by entering the values in degrees for the roll, pitch and the Z axis. Note that the offsets are related to the attitude of the vessel and not the current reading of the motion sensor. For example, the Z axis offset is to be used to align the bow notch of the motion sensor mounting plate with the vessel fore aft axis and is not to remove an offset in the yaw reading from the motion sensor output.

If the vessel is perfectly aligned with the horizon as for example in a dry dock, pressing the S*et to Zero* Position button in the configuration software will read the current IMU inclination and set the roll and pitch offsets. The Z axis offset needs to be entered manually.

The *Clear Offsets* button will enter 0 offset for the roll, pitch and Z-axis values.

Axis Inversion
Enables the sign inversion of the output signals from the motion sensor. See Section 3 for information about SMC rotational definitions.

Mounting Orientation
Is only available if the Motion sensor has been calibrated for sideways mounting orientation. See chapter 3.2 for more information about the mounting orientation options.

IMU Output Coordinate System
The motion sensor can be set to output its data in the earth coordinate system or in the IMU coordinate system.

Earth Coordinates without earth G in Acc; In this configuration, the motion sensor will use the earth horizon as the coordinate system for the angular and acceleration output. The acceleration will not include the earth gravity as part of the value.

Earth Coordinates with earth G in Acc; In this configuration, the motion sensor will use the earth horizon as the coordinate system for the angular and acceleration output. The acceleration will include the earth gravity force of about 9.8 m/s^2.

IMU Coordinates with earth G in Acc; In this configuration, the calculations will use the motion sensor coordinate system as its reference for the calculations of angular and acceleration output. The motion sensor acceleration will include the earth gravity force of about 9.8 m/s^2.

Surge, Sway and Heave and its velocities can be set to be output in the earth coordinate system or in the IMU coordinate system regardless of the setting selected for the angles output.

Output Rate
Adjusts the number of times the motion sensor outputs a string per second. There is a global setting for all the serial and Ethernet channels and Individual rates* for the serial and Ethernet channels. Select the radio button and choose the required value in the list box.
A high output frequency and low baud rate will reduce the output rate by limitation of data transfer rate over the serial communication line.
Too high an output rate in relation to the data transfer rate will create measurement inconsistency.
*available from Firmware 3.60

Kalman Filter Settings
Filter 1 sets the filter for the accelerometers in the Kalman filter calculations. A higher filter 1 value will reduce the accelerometer sensor reading influence in the Kalman filter angular calculation.

The default settings are
IMU-10x = 100
IMU-00x = 25

Filter 2 sets the filter for the gyroscopes in the Kalman filter calculation. A higher filter 2 value will reduce the gyroscope reading influence in the Kalman filter angular calculation.

The default settings are
IMU-10x = 0.01
IMU-00x = 0.01

It is not advisable to change the settings for the Kalman Filter without consulting with SMC
The default button will reset the filter settings to the factory defaults.

IMU Bitrate and Parity
The bitrate setting adjusts the data transfer rate that the motion sensor uses for transmitting. To be able to connect to the motion sensor a matching communication setting must be set for the receiving device

Available Bit rates: 4800, 9600, 19200, 38400, 57600, 115200

Note: For Long protocols, such as for example PSMCC using a high data output frequency like 100Hz, a high Bitrate, 115200 bps, will be needed, to be able to transfer the data from the motion sensor. See notes beside each protocol.

Read Settings
Clicking on the *Read Settings* button will prompt the IMU Configuration Software to read the current motion sensor settings and display them in the software interface.

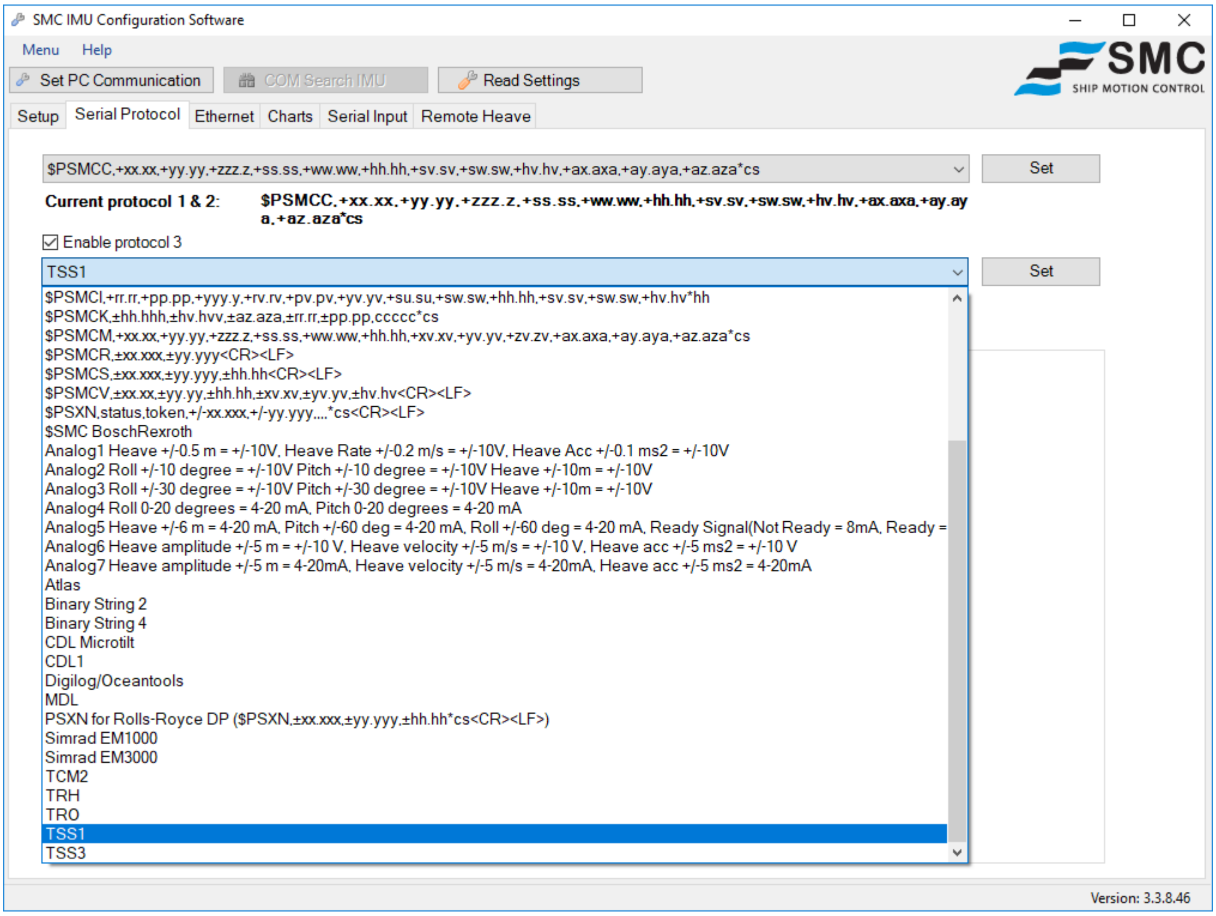
4.2 SERIAL ASCII PROTOCOLS

The SMC IMU Configuration software enables the selection of a number of standard protocols from a drop-down menu. Apply the chosen protocol by clicking on the *Set* button.

The Comport 1 & 2 share the same protocol output
Comport 3 can be set to output motion data by ticking the checkbox in the Serial protocol tab and select a different string output from the Comport 1 & 2 but using the same baud rate and sample rates.
The output on Comport 3 is available from firmware version 3.22

The majority of the protocol outputs are NMEA 0183 formatted string.

Additional protocols can be implemented by SMC on request.



4.2.1 PSMCA

Data Frame
$PSMCA,±xx.xxx,±yy.yyy,±hh.hh,±ss.ss,±ww.ww<CR><LF>

Example
$PSMCA,+00.089,-00.888,-00.04,+00.20,-00.10

Bitrate	Max output Rate
115200	100
57600	100
38400	80
19200	40
9600	20
4800	10

Description	Form
Start Characters	$PSMCA
Roll Angle (xx.xxx)	Degrees Resolution 0.001° (+ve=port up)
Pitch Angle (yy.yyy)	Degrees Resolution 0.001° (+ve=bow down)
Heave (hh.hh)	Meters Resolution 0.01m
Surge (ss.ss)	Meters Resolution 0.01m
Sway (ww.ww)	Meters Resolution 0.01m
Termination Characters	<CR><LF>

4.2.2 PSMCB

Data Frame
$PSMCB,±xx.xx,±yy.yy,±zzz.z,±xv.xv,±yv.yv,±zv.zv,±GG.GGG,±HH.HHH,±II.III,±ss.ss,±ww.ww,±hh.hh,±sv.sv,±sw.sw,±hv.hv,±ax.axa,±ay.aya,±az.aza

Example
$PSMCB,+00.29,+00.55,+349.0,+06.68,+06.86,-01.95,-18.074,-22.016,+12.390,-00.01,-00.00,+00.00,-00.00,-00.00,+00.00,+00.121,-00.048,+00.046

Bitrate	Max output Rate
115200	75
57600	35
38400	25
19200	10
9600	5
4800	2

Description	Form
Start Characters	$PSMCB
Roll Angle (xx.xx)	Degrees Resolution 0.01° (+ve=port up)
Pitch Angle (yy.yy)	Degrees Resolution 0.01° (+ve=bow down)
Yaw (zzz.z)	Degrees Resolution 0.1°
Roll Velocity (xv.xv)	Degrees/second Resolution 0.01°/s
Pitch Velocity (yv.yv)	Degrees/second Resolution 0.01°/s
Yaw Velocity (zv.zv)	Degrees/second Resolution 0.01°/s
Roll Acceleration (GG.GGG)	Degrees/second^2 Resolution 0.001°/s^2
Pitch Acceleration (HH.HHH)	Degrees/second^2 Resolution 0.001°/s^2
Yaw Acceleration (II.III)	Degrees/second^2 Resolution 0.001°/s^2
Surge (ss.ss)	Meters Resolution 0.01m
Sway (ww.ww)	Meters Resolution 0.01m
Heave (hh.hh)	Meters Resolution 0.01m
Surge Velocity (sv.sv)	Meter/second Resolution 0.01m/s
Sway Velocity (sw.sw)	Meter/second Resolution 0.01m/s
Heave Velocity (hv.hv)	Meter/second Resolution 0.01m/s
Acceleration X (ax.axa)	Meter/second^2 Resolution 0.001m/s2
Acceleration Y (ay.aya)	Meter/second^2 Resolution 0.001m/s2
Acceleration Z (az.aza)	Meter/second^2 Resolution 0.001m/s2
Termination Characters	<CR><LF>

4.2.3 PSMCC

Data Frame
$PSMCC,+xx.xx,+yy.yy,+zzz.z,+ss.ss,+ww.ww,+hh.hh,+sv.sv,+sw.sw,+hv.hv,+ax.axa,+ay.aya,+az.aza*cs

Example
$PSMCC,-09.42,-02.85,+144.1,+00.28,-00.05,+00.00,+00.01,-00.00,+00.00,+00.004,-00.000,-00.005*71

Bitrate	Max output Rate
115200	100
57600	50
38400	25
19200	10
9600	5
4800	2

Description	Form
Start Characters	$PSMCC
Roll Angle (xx.xx)	Degrees Resolution 0.01° (+ve=port up)
Pitch Angle (yy.yy)	Degrees Resolution 0.01° (+ve=bow down)
Yaw (zzz.z)	Degrees Resolution 0.1°
Surge (ss.ss)	Meters Resolution 0.01m
Sway (ww.ww)	Meters Resolution 0.01m
Heave (hh.hh)	Meters Resolution 0.01m
Surge Velocity (sv.sv)	Meter/second Resolution 0.01m/s
Sway Velocity (sw.sw)	Meter/second Resolution 0.01m/s
Heave Velocity (hv.hv)	Meter/second Resolution 0.01m/s
Acceleration X (ax.axa)	Meter/second^2 Resolution 0.001m/s2
Acceleration Y (ay.aya)	Meter/second^2 Resolution 0.001m/s2
Acceleration Z (az.aza)	Meter/second^2 Resolution 0.001m/s2
Checksum (cs)	XOR checksum
Termination Characters	<CR><LF>

4.2.4 PSMCD

Data Frame
$PSMCD,±xx.xx,±yy.yy,±xv.xv,±yv,yv,±zv.zv,c*cs<CR><LF>

Example
$PSMCD,+03.11,+08.97,-20.53,-11.11,-04.04,4*7F

Bitrate	Max output Rate
115200	100
57600	100
38400	75
19200	35
9600	10
4800	5

Description	Form
Start Characters	$PSMCD
Roll Angle (xx.xx)	Degrees Resolution 0.01° (+ve=port up)
Pitch Angle (yy.yy)	Degrees Resolution 0.01° (+ve=bow down)
Roll Velocity (xv.xv)	Degrees/second Resolution 0.01°
Pitch Velocity (yv.yv)	Degrees/second Resolution 0.01°
Yaw Velocity (zv.zv)	Degrees/second Resolution 0.01°
Counter (c)	Output message Counter 0-9
Checksum (cs)	XOR checksum
Termination Characters	<CR><LF>

4.2.5 PSMCE

No longer available from firmware 3.88

Data Frame

$PSMCE,±xx.xx,±yy.yy,±zzz.z,±hh.hh,±ss.ss,±sw.sw*cs<CR><LF>

Example

$PSMCE,+03.20,+05.75,+350.7,-00.38,+00.26,+00.42*40

Bitrate	Max output Rate
115200	100
57600	100
38400	60
19200	30
9600	15
4800	5

Description	Form
Start Characters	$PSMCE
Roll Angle (xx.xx)	Degrees Resolution 0.01° (+ve=port up)
Pitch Angle (yy.yy)	Degrees Resolution 0.01° (+ve=bow down)
Yaw (zzz.z)	Degrees Resolution 0.1°
Heave (hh.hh)	Meters Resolution 0.01m
Surge (ss.ss)	Meters Resolution 0.01m
Sway (sw.sw)	Meters Resolution 0.01m
Checksum (cs)	XOR checksum
Termination Characters	<CR><LF>

4.2.6 PSMCF

Data Frame
$PSMCFnnnnnnn,±xx.xxx,±yy.yyy,±hh.hh,±ss.ss,±ww.ww<CR><LF>

Example
$PSMCF1082256,+05.415,+02.928,-00.06,-00.03,-00.01

Bitrate	Max output Rate
115200	100
57600	100
38400	70
19200	35
9600	15
4800	7

Description	Form
Start Characters	$PSMCF
IMU Serial Number (nnnnnnn)	7 digit serial number
Roll Angle (xx.xxx)	Degrees Resolution 0.001° (+ve=port up)
Pitch Angle (yy.yyy)	Degrees Resolution 0.001° (+ve=bow down)
Heave (hh.hh)	Meters Resolution 0.01m
Surge (ss.ss)	Meters Resolution 0.01m
Sway (ww.ww)	Meters Resolution 0.01m
Termination Characters	<CR><LF>

4.2.7 PSMCG

Data Frame
$PSMCG,Date,Time,±xx.xx,±yy.yy,±ww.ww,±ss.ss,±hh.hh,±ax.axa,±ay.aya,±az.aza*cs<CR><LF>

Example
$PSMCG,2016-04-04,15:06:18.81,-00.30,-02.93,-00.31,-00.65,-00.06,-00.002,-00.202,-00.167*5D

Bitrate	Max output Rate
115200	100
57600	59
38400	39
19200	19
9600	9
4800	4

Description	Form
Start Characters	$PSMCG
Date (yyyy-mm-dd)	Date
Time (hh:mm:ss,ss)	Time resolution to hundredths of a second
Roll Angle (xx.xx)	Degrees Resolution 0.001° (+ve=port up)
Pitch Angle (yy.yy)	Degrees Resolution 0.001° (+ve=bow down)
Sway (ww.ww)	Meters Resolution 0.01m
Surge (ss.ss)	Meters Resolution 0.01m
Heave (hh.hh)	Meters Resolution 0.01m
Acceleration X (ax.axa)	Meter/second^2 Resolution 0.001 m/s2
Acceleration Y (ay.aya)	Meter/second^2 Resolution 0.001 m/s2
Acceleration Z (az.aza)	Meter/second^2 Resolution 0.001 m/s2
Checksum (cs)	XOR checksum
Termination Characters	<CR><LF>

4.2.8 PSMCH

Data Frame
$PSMCH,±xx.xxx,±yy.yyy,±hh.hh,±hv.hv<CR><LF>

Example
$PSMCH,-02.000,+05.856,-00.06,-00.01

Bitrate	Max output Rate
115200	100
57600	100
38400	96
19200	48
9600	24
4800	12

Description	Form
Start Characters	$PSMCH
Roll Angle (xx.xxx)	Degrees Resolution 0.001° (+ve=port up)
Pitch Angle (yy.yyy)	Degrees Resolution 0.001° (+ve=bow down)
Heave (hh.hh)	Meters Resolution 0.01m
Heave Velocity (hv.hv)	Meters/second Resolution 0.01m/s
Termination Characters	<CR><LF>

4.2.9 PSMCI

Data Frame
$PSMCI,+rr.rr,+pp.pp,+yyy.y,+xv.xv,+yv.yv,+zv.zv,+ss.ss,+ww.ww,+hh.hh,+sv.sv,+sw.sw,+hv.hv,*cs<CR><LF>

Example
$PSMCI,+03.01,-02.44,+200.6,+00.00,+00.01,-01.71,+00.07,+00.04,-00.03,-00.00,+00.01,-00.00,*6D

Bitrate	Max output Rate
115200	100
57600	57
38400	38
19200	19
9600	9
4800	4

Description	Form
Start Characters	$PSMCI
Roll (rr.rr)	Degrees Resolution 0.01° (+ve=port up)
Pitch (pp.pp)	Degrees Resolution 0.01° (+ve=bow down)
Yaw (yyy.y)	Degrees Resolution 0.1°
Roll velocity (xv.xv)	Degrees/second Resolution 0.01°
Pitch velocity (yv.yv)	Degrees/second Resolution 0.01°
Yaw velocity (zv.zv)	Degrees/second Resolution 0.01°
Surge (ss.ss)	Meters Resolution 0.01m
Sway (ww.ww)	Meters Resolution 0.01m
Heave (hh.hh)	Meters Resolution 0.01m
Surge velocity (sv.sv)	Meters/second Resolution 0.01m/s
Sway velocity (sw.sw)	Meters/second Resolution 0.01m/s
Heave velocity (hv.hv)	Meters/second Resolution 0.01m/s
Checksum (cs)	XOR checksum
Termination Characters	<CR><LF>

4.2.10 PSMCJ

Available from firmware 2.984

Data Frame

$PSMCJ,YYYY/MM/DD,HH:MM:SS.SS,±xx.xx,±yy.yy,±GG.GGG,±HH.HHH,±hh.hh,±ax.axa,±ay.aya,±az.aza<CR><LF>

Example

$PSMCJ,2017/11/01,12:59:19.05,+02.84,-02.27,+00.000,+00.040,-00.01,+00.008,-00.005,+00.000

Bitrate	Max output Rate
115200	100
57600	59
38400	39
19200	19
9600	9
4800	4

Description	Form
Start Characters	$PSMCJ
Date (YYYY/MM/DD)	Date
Time (HH:MM:SS.SS)	Time
Roll Angle (xx.xx)	Degrees Resolution 0.01° (+ve=port up)
Pitch Angle (yy.yy)	Degrees Resolution 0.01° (+ve=bow down)
Roll Acceleration (GG.GGG)	Degrees/second^2 Resolution 0.001°/s^2
Pitch Acceleration (HH.HHH)	Degrees/second^2 Resolution 0.001°/s^2
Heave (hh.hh)	Meters Resolution 0.01m
Acceleration X (ax.axa)	Meters/second^2 Resolution 0.001 m/s^2
Acceleration Y (ay.aya)	Meters/second^2 Resolution 0.001 m/s^2
Acceleration Z (az.aza)	Meters/second^2 Resolution 0.001 m/s^2
Termination Characters	<CR><LF>

4.2.11 PSMCK

Available from firmware 3.16

Data Frame

$PSMCK,±hh.hhh,±hv.hvv,±az.aza,±rr.rr,±pp.pp,ccccc*cs<CR><LF>

Example

$PSMCK,-00.001,-00.000,-00.001,+00.81,+03.84,03834*4F

Bitrate	Max output Rate
115200	100
57600	100
38400	66
19200	33
9600	16
4800	8

Description	Form
Start Characters	$PSMCK
Heave (hh.hhh)	Meters Resolution 0.001m
Heave Velocity (hv.hvv)	Meter/second Resolution 0.001m/s
Acceleration Z (az.aza)	Meter/second^2 Resolution 0.001m/s2
Roll Angle (xx.xx)	Degrees Resolution 0.01° (+ve=port up)
Pitch Angle (yy.yy)	Degrees Resolution 0.01° (+ve=bow down)
Counter (ccccc)	Counter message incremental 0-32767
Checksum (cs)	XOR checksum
Termination Characters	<CR><LF>

4.2.12 PSMCM

Data Frame
$PSMCM,+xx.xx,+yy.yy,+zzz.z,+ss.ss,+ww.ww,+hh.hh,+xv.xv,+yv.yv,+zv.zv,+ax.axa,+ay.aya,+az.aza*cs <CR><LF>

Example
$PSMCM,-14.36,-21.70,+340.0,-00.01,+00.01,+00.07,-64.80,-19.89,-44.16,+00.047,+00.254,-02.008*7C

Bitrate	Max output Rate
115200	100
57600	56
38400	37
19200	18
9600	9
4800	4

Description	Form
Start Characters	$PSMCM
Roll Angle (xx.xx)	Degrees Resolution 0.01° (+ve=port up)
Pitch Angle (yy.yy)	Degrees Resolution 0.01° (+ve=bow down)
Yaw (zz.zz)	Degrees Resolution 0.1°
Surge (ss.ss)	Meters Resolution 0.01m
Sway (ww.ww)	Meters Resolution 0.01m
Heave (hh.hh)	Meters Resolution 0.01m
Roll Velocity (xv.xv)	Degrees/second Resolution 0.01°/s
Pitch Velocity (yv.yv)	Degrees/second Resolution 0.01°/s
Yaw Velocity (zv.zv)	Degrees/second Resolution 0.01°/s
Acceleration X (ax.axa)	Meters/second^2 Resolution 0.001 m/s^2
Acceleration Y (ay.aya)	Meters/second^2 Resolution 0.001 m/s^2
Acceleration Z (az.aza)	Meters/second^2 Resolution 0.001 m/s^2
Checksum (cs)	XOR checksum
Termination Characters	<CR><LF>

4.2.13 PSMCR

Data Frame
$PSMCR,±xx.xxx,±yy.yyy<CR><LF>

Example
$PSMCR,-08.393,-13.671

Bitrate	Max output Rate
115200	100
57600	100
38400	100
19200	76
9600	38
4800	19

Description	Form
Start Characters	$PSMCR
Roll Angle (xx.xxx)	Degrees Resolution 0.001° (+ve=port up)
Pitch Angle (yy.yyy)	Degrees Resolution 0.001° (+ve=bow down)
Termination Characters	<CR><LF>

4.2.14 PSMCS

Data Frame
$PSMCS,±xx.xxx,±yy.yyy,±hh.hh

Example
$PSMCS,+00.089,-00.888,-00.04

Bitrate	Max output Rate
115200	100
57600	100
38400	100
19200	59
9600	29
4800	14

Description	Form
Start Characters	$PSMCS
Roll Angle (xx.xxx)	Degrees Resolution 0.001° (+ve=port up)
Pitch Angle (yy.yyy)	Degrees Resolution 0.001° (+ve=bow down)
Heave (hh.hh)	Meters Resolution 0.01m
Termination Characters	<CR><LF>

4.2.15 PSMCT

Available in hardware versions that includes a Real Time Clock

Data Frame

$PSMCT, YYYY/MM/DD,HH:MM:SS.SS,±xx.xxx,±yy.yyy,±hh.hh<CR><LF>

Example

$PSMCT,2016/04/04,15:27:39.50,-18.630,-14.328,+00.21

Bitrate	Max output Rate
115200	100
57600	100
38400	67
19200	33
9600	16
4800	8

Description	Form
Start Characters	$PSMCT
Date (YYYY/MM/DD)	Date
Time (HH:MM:SS.SS)	Time
Roll Angle (xx.xxx)	Degrees Resolution 0.001° (+ve=port up)
Pitch Angle (yy.yyy)	Degrees Resolution 0.001° (+ve=bow down)
Heave (hh.hh)	Meters Resolution 0.01 m
Termination Characters	<CR><LF>

4.2.16 PSMCU

Available from firmware 3.88

Note: PSMCU is a combined output together with $PSMCB sent only when a GPS input is connected to the motion sensor and sends a time stamp message. The accepted GPS message is xxRMC.

Data Frame
$PSMCU,HHMMSS,DDMMYY, ±LLL.LLLLLL, ±LLL.LLLLLL,xxx.x,s*cs<CR><LF>

If the GPS input is for example 1Hz, the PSMCU string output will be 1Hz regardless of the PSMCB + PSCMCU output frequency being set higher.
However, if the GPS input is for example 10Hz and the combined output is set to 10Hz (or higher), then the PSMCU output will be 10Hz.
Similarly, if the GPS input is 10Hz and the PSMCB + PSCMCU output is 1Hz, then the PSCMU output will be 1Hz.

Example
GPS input to the motion sensor
$GPRMC,225446,A,4916.45,N,12311.12,W,000.5,054.7,191194,020.3,E*68
Motion sensor output
$PSMCU,225446,191194,+49.274167,-123.185333,000.5,A*03

Bitrate	Max output Rate
115200	75
57600	35
38400	25
19200	10
9600	5
4800	2

Description	Form
Start Characters	$PSMCU
Time (HHMMSS)	UTC time
Date (DDMMYY)	Date
Latitude (±lll.llllll)	Decimal GPS
Longitude (±lll.llllll)	Decimal GPS
Speed over ground (xxx.x)	Knots
Status mode (s)	GPS status, A = Ok and V = Warning
Checksum (cs)	XOR checksum
Termination Characters	<CR><LF>

4.2.17 PSMCV

Data Frame
$PSMCV,±xx.xxx,±yy.yyy,±hh.hh,±xv.xv,±yv.yv,±hv.hv<CR><LF>

Example
$PSMCV,+06.780,+03.900,+00.00,-02.80,+12.03,-00.01

Bitrate	Max output Rate
115200	100
57600	100
38400	70
19200	35
9600	17
4800	8

Description	Form
Start Characters	$PSMCV
Roll Angle (xx.xxx)	Degrees Resolution 0.001° (+ve=port up)
Pitch Angle (yy.yyy)	Degrees Resolution 0.001° (+ve=bow down)
Heave (hh.hh)	Meters Resolution 0.01 m
Roll Velocity (xv.xv)	Degrees/second Resolution 0.01°/s
Pitch Velocity (yv.yv)	Degrees/second Resolution 0.01°/s
Heave Velocity (hv.hv)	Meters/second Resolution 0.01m/s
Termination characters	<CR><LF>

4.2.18 DD50

No longer available from firmware 3.88

The DD50 string is intended to be used to connect the Vaisala DD50 LED display.

Example
DDA@1 "IMU / MRU",Units,Roll 02.78 deg,Pitc -02.09 deg,Heav 00.00 m,@2 "Accs   ",Units,AccX -00.00 ms2,AccY 00.00 ms2,AccZ 00.00 ms2

Note: In firmware versions 3.22 and lower this output alternates with the SMCC protocol.
In firmware version 3.22 and lower

Bitrate	Max output Rate
115200	46
57600	23
38400	15
19200	7
9600	3
4800	1

In firmware version 3.24 and higher

Bitrate	Max output Rate
115200	79
57600	39
38400	26
19200	13
9600	6
4800	3

Data displayed on the DD50 is Roll, Pitch and Heave on the first page. Acceleration X, Y and Z on the second page.

4.2.19 TCM2

No longer available from firmware 3.88

Data Frame
$C<ccc.c>P<±p.pp>R<±r.rr>X<x.xx>Y<y.yy>Z<z.zz>T<t.t>E<eee>*cs<CR><LF>

Example
$C51.7P0.1R-0.0X0.00Y0.00Z0.00T0.0E000*3A

Bitrate	Max output Rate
115200	100
57600	100
38400	85
19200	42
9600	21
4800	10

Description	Form
Start Characters	$
Compass identifier	C
Yaw (ccc.c)	Degrees Resolution 0.1°
Pitch identifier	P
Pitch angle (p.pp)	Degrees Resolution 0.1° (+ve=bow down)
Roll identifier	R
Roll Angle (r.rr)	Degrees Resolution 0.1° (+ve=port up)
Magnetic field X axis identifier	X
Magnetic field X axis (x.xx)	µT micro Tesla X axis Resolution 0.00µT
Magnetic field Y axis identifier	Y
Magnetic field Y axis (y.yy)	µT micro Tesla Y axis Resolution 0.00µT
Magnetic field Z axis identifier	Z
Magnetic field Z axis (z.zz)	µT micro Tesla Z axis Resolution 0.00µT
Temperature internal identifier	T
Temperature (t.t)	Degrees Celsius Resolution 0.1°
Magnetic status identifier	E
Magnetic status (eee)	Magnetic Distortion flag 001 if a magnetic anomaly is nearby else 000
Checksum	*cs
Termination characters	<CR><LF>

4.2.20 TRH

No longer available from firmware 3.88

Data Frame
$PHTRH,y.yy,P,x.xx,T,h.hh,O*cs<CR><LF>

Example
$PHTRH,0.12,P,8.51,T,0.09,O*05

Bitrate	Max output Rate
115200	100
57600	100
38400	100
19200	57
9600	28
4800	14

Description	Form
Start Characters	$PHTRH
Pitch angle (y.yy)	Degrees Resolution 0.01°
Sign (P)	P Positive M Negative (+ve=bow down)
Roll (x.xx)	Degrees Resolution 0.01°
Sign (T)	B roll to port, T roll to starboard
Heave	Meters Resolution 0.01m
Sign (O)	O upwards U downwards acceleration
Checksum	*cs
Termination characters	<CR><LF>

4.2.21 TRO
No longer available from firmware 3.88

Data Frame
$PHTRO,y.yy,M,x.xx,B*cs<CR><LF>

Example
$PHTRO,0.03,M,0.15,B*59

Bitrate	Max output Rate
115200	100
57600	100
38400	100
19200	73
9600	36
4800	18

Description	Form
Start Characters	$PHTRO
Pitch angle (y.yy)	Degrees Resolution 0.01°
Sign (M)	P Positive M Negative (+ve=bow down)
Roll angle (x.xx)	Degrees Resolution 0.01°
Sign (B)	B roll to port, T roll to starboard
Checksum	*cs
Termination characters	<CR><LF>

4.2.22 MDL

No longer available from firmware 3.88

Data Frame

Hhhhh.P±pppp.R±pppp.<CR><LF>

Example

H0000.P-0201.R+0268.

Bitrate	Max output Rate
115200	100
57600	100
38400	100
19200	83
9600	41
4800	20

Description	Form
Heading identifier	H
Heading*10 (hhhh)	Degrees Resolution 0.1° (SMC outputs 0000)
Pitch identifier	P
Pitch Angle*100 (pppp)	Degrees Resolution 0.01° (+ve= bow down)
Roll Designator	R
Roll Angle*100 (rrrr)	Degrees Resolution 0.01° (+ve=port up)
Termination Characters	<CR><LF>

4.2.23 OCEAN TOOLS

No longer available from firmware 3.88

Data Frame
Hhhhh.P±pppp.R±pppp.s<CR><LF>

Example
H3499.P+0011.R-0023.E

Bitrate	Max output Rate
115200	100
57600	100
38400	100
19200	79
9600	39
4800	19

Description	Form
Heading identifier	H
Heading*10 (hhhh)	Degrees Resolution 0.1° (SMC outputs 0000)
Pitch identifier	P
Pitch Angle*100 (pppp)	Degrees Resolution 0.01° (+ve= bow down)
Roll Designator	R
Roll Angle*100 (rrrr)	Degrees Resolution 0.01° (+ve=port up)
Status character (s)	valid compass aiding E=yes, S=no
Termination Characters	<CR><LF>

4.2.24 CDL MICROTILT

No longer available from firmware 3.88

Data Frame:
P±yy.yyR±xx.xx
Example
P+03.85R-05.52

Bitrate	Max output Rate
115200	100
57600	100
38400	100
19200	100
9600	57
4800	28

Description	Form
Pitch identifier (P)	P
Pitch Angle (±yy.yy)	Degrees Resolution 0.01° (+ve=bow down)
Roll identifier (R)	R
Roll Angle (±xx.xx)	Degrees Resolution 0.01° (+ve=port up)
Termination Characters	<CR><LF>

4.2.25 CDL1

No longer available from firmware 3.88

Data Frame:
Hzzz.zP±yyy.yyR±xxx.xxTaa.aaDbbbb.bbBcc.cLddFe<CR><LF>

Example
H350.0P-000.04R-000.14T00.0D0000.00B00.0A00W00LN00F0

Bitrate	Max output Rate
115200	100
57600	100
38400	67
19200	33
9600	16
4800	8

Description	Form
Heading identifier (H)	H
Heading (zzz.z)	Yaw Degrees Resolution 0.1°
Pitch identifier (P)	P
Pitch Angle (yy.yy)	Degrees Resolution 0.01° (+ve=bow down)
Roll identifier (R)	R
Roll Angle (xx.xx)	Degrees Resolution 0.01° (+ve=port up)
Identifier (T)	T
Not used	Output 0
Identifier (D)	D
Not used	Output 0
Identifier (B)	B
Not used	Output 0
Identifier (L)	L
Not used	Output 0
Identifier (F)	F
Not used	Output 0
Termination Characters	<CR><LF>

4.2.26 TSS1

Available from firmware 1.92

The default SMC pitch rotation direction definition differs from TSS1 format definition. By this reason the axis inversion checkbox for ***Pitch*** must be ticked to have the correct rotational direction as per the TSS1 string definition, where positive Pitch is bow up. Use the SMC IMU Configuration Software to change the inverted Pitch if required. As default when selecting the TSS1 string the configuration software will tick the checkbox for the pitch axis inversion.

Note: When settling, in addition to having the status flag 'U'; roll, pitch and heave will be 0.

Data Frame
:XXAAAASMHHHHQMRRRRSMPPPP<CR><LF>

Example
:05FEFF 0000H 0102 -0049

Bitrate	Max output Rate
115200	100
57600	100
38400	100
19200	67
9600	33
4800	16

Description	Form
Start Character	:
Horizontal Acceleration (XX)	Hexadecimal value, unit is $3.83 cm/s^2$ in the range $9.81 m/s^2$
Vertical Acceleration (AAAA)	Hexadecimal value, unit $0.0625 cm/s^2$ in the range -20.48 to $+20.48 m/s^2$
Space Character (S)	
Value prefix (M)	M = space if positive, - if negative
Heave (HHHH)	Heave unit cm.
Status Flag (Q)	‘U’ Unaided mode Running ‘u’ Unaided mode Startup ‘G’ GPS Aided mode Running ‘g’ GPS Aided mode Startup ‘H’ Heading Aided mode Running ‘h’ Heading Aided mode Startup ‘F’ Full Aided mode Running ‘f’ Full Aided mode Startup
Value prefix (M)	M = space if positive, - if negative
Roll (RRRR)	Roll ±90° units hundredths of degrees (+ve=port up)
Value prefix (M)	M = space if positive, - if negative
Pitch (PPPP)	Pitch ±90° units hundredths of degrees (+ve=bow up)
Termination Characters	<CR><LF>

4.2.27 TSS3

Available from firmware 2.98

The default SMC pitch rotation direction definition differs from TSS3 format definition. By this reason the axis inversion checkbox for ***Pitch*** must be ticked to have the correct rotational direction as per the TSS3 string definition, where positive Pitch is bow up. Use the SMC IMU Configuration Software to change the inverted Pitch if required. As default when selecting the TSS3 string the configuration software will tick the checkbox for the pitch axis inversion.

Data Frame
:RMhhhhSMHHHHQMRRRRSMPPPP<CR><LF>

Example
:R 0014 0014H 0037 0983

Bitrate	Max output Rate
115200	100
57600	100
38400	100
19200	67
9600	33
4800	16

Description	Form
Start Character (:R)	
Value prefix (M)	M = space if positive, - if negative
Remote Heave (hhhh)	Remote Heave unit cm
Space Character (S)	
Value prefix (M)	M = space if positive, - if negative
Heave (HHHH)	Heave unit cm
Status Flag (Q)	U' Unaided mode Running 'u' Unaided mode Startup 'G' GPS Aided mode Running 'g' GPS Aided mode Startup 'H' Heading Aided mode Running 'h' Heading Aided mode Startup 'F' Full Aided mode Running 'f' Full Aided mode Startup
Value prefix (M)	M = space if positive, - if negative
Roll (RRRR)	Roll unit hundredths of degrees (+ve=port up)
Space Character (S)	
Value prefix (M)	M = space if positive, - if negative
Pitch	Pitch unit hundredths of degrees (+ve=bow up)
Termination Characters	<CR><LF>

4.2.28 PRDID

Available from firmware 1.92

The default SMC pitch rotation direction definition differs from PRDID format definition. By this reason the axis inversion checkbox for ***Pitch*** must be ticked to have the correct rotational direction as per the PRDID string definition, where positive Pitch is bow up. Use the SMC IMU Configuration Software to change the inverted Pitch if required. As default when selecting the PRDID string the configuration software will tick the checkbox for the pitch axis inversion.

Data Frame
$PRDID,±yy.yy,±xx.xx,±hhh.hh<CR><LF>

Example
$PRDID,+05.42,+00.15,347.94

Bitrate	Max output Rate
115200	100
57600	100
38400	100
19200	63
9600	31
4800	15

Description	Form
Start Characters	$PRDID
Pitch Angle (yy.yy)	Degrees Resolution 0.01° (+ve=bow up)
Roll Angle (xx.xx)	Degrees Resolution 0.01° (+ve=port up)
Heading (hhh.hh)	Heading Resolution 0.01°
Termination Characters	<CR><LF>

4.2.29 PRDID WITH CHECKSUM

Available from firmware 2.986 onwards (except 2.989)

The default SMC pitch rotation direction definition differs from PRDID format definition. By this reason the axis inversion checkbox for ***Pitch*** must be ticked to have the correct rotational direction as per the PRDID string definition, where positive Pitch is bow up. Use the SMC IMU Configuration Software to change the inverted Pitch if required. As default when selecting the PRDID string the configuration software will tick the checkbox for the pitch axis inversion.

Data Frame
$PRDID,±yy.yy,±xx.xx,±hhh.hh*cs<CR><LF>

Example
$PRDID,+05.42,+00.15,347.94*73

Bitrate	Max output Rate
115200	100
57600	100
38400	100
19200	57
9600	28
4800	14

Description	Form
Start Characters	$PRDID
Pitch Angle (yy.yy)	Degrees Resolution 0.01° (+ve=bow up)
Roll Angle (xx.xx)	Degrees Resolution 0.01° (+ve=port up)
Heading (hhh.hh)	Heading Resolution 0.01°
Checksum (cs)	*cs
Termination Characters	<CR><LF>

4.2.30 PSXN – ROLL & PITCH

Available from firmware 2.988

NMEA protocol, measurements in Radians.

Note: When settling roll and pitch will be 0.

The default SMC format of the PSXN string is ***Pitch positive when* bow down.** Use the SMC IMU Configuration Software to invert the Pitch if required.

Data Frame
$PSXN,,, ±xx.xxx,±yy.yyy,,,,*cs<CR><LF>

Example
$PSXN,10,014,3.974e-3,-2.365e-3,,,,*44

Bitrate	Max output Rate
115200	100
57600	100
38400	92
19200	46
9600	23
4800	10

Description	Form
Start Characters	$PSXN
Status	10 normal running, 11 starting/settling
Token	14
Roll Angle (±xx.xxx)	Radians. Scientific format with exponent
Pitch Angle (±yy.yyy)	Radians. Scientific format with exponent
Checksum	*cs
Termination Characters	<CR><LF>

4.2.31 PSXN - HEAVE

Available from firmware 3.46

NMEA protocol, measurements in Radians.

Note: When settling all heave values will be 0.

Data Frame
$PSXN,,, ±a.zaz,±h.hhh, ±h.hvh,,,*cs<CR><LF>
$PSXN,status,token,heave acceleration,heave, heave velocity,,,*cs<CR><LF>

Example
$PSXN,10,010,-3.870e-3,-7.914e-3,1.012e-3,,,*75

Bitrate	Max output Rate
115200	100
57600	100
38400	78
19200	39
9600	19
4800	9

Description	Form
Start Characters	$PSXN
Status	10 normal running, 11 starting/settling
Token	10
Heave Acceleration (±a.zaz)	Radians. Scientific format with exponent
Heave (±h.hhh)	Radians. Scientific format with exponent
Heave velocity (±h.vhv)	Radians. Scientific format with exponent
Checksum	*cs
Termination Characters	<CR><LF>

4.2.32 PSXN FOR ROLLS ROYCE DP

Available from firmware 1.92

Rolls-Royce NMEA protocol, measurements in Radians.

Note: When settling roll, pitch and heave will be 0.

The default SMC format of the PSXN string is ***Pitch positive when*** **bow down.** Use the SMC IMU Configuration Software to invert the Pitch if required.

Data Frame
$PSXN,,,±xx.xxx,±yy.yyy,±hh.hhh,,,*cs<CR><LF>

Example
$PSXN,,,1.000e-1,1.908e-1,1.203e+0,,,*44

Bitrate	Max output Rate
115200	100
57600	100
38400	87
19200	43
9600	21
4800	10

Description	Form
Start Characters	$PSXN
Roll Angle (±xx.xxx)	Radians. Scientific format with exponent
Pitch Angle (±yy.yyy)	Radians. Scientific format with exponent
Heave (±hh.hhh)	Meters. Scientific format with exponent
Checksum	*cs
Termination Characters	<CR><LF>

4.3 BINARY PROTOCOLS

4.3.1 ATLAS (HYDROGRAPHIC)

Each field in the Atlas output string is a 16-bit 2's complement number expressed as two binary coded digits. Attitude measurements are supplied in units (360°/65536=0.0054931641°). Heave measurements are in mm. The frame contains 9 bytes in binary format.

Data Frame (bytes)
ERRPPHHSE

Example
00010000 11111111 10100101 00000000 00000111 11111111 11110001 00000100 00010000

Bitrate	Max output Rate
115200	100
57600	100
38400	100
19200	100
9600	83
4800	41

Description	Bytes	Form
DLE (E)	1	0x10
Roll (RR)	2	Unsigned 16 bit, i.e. 0..65535 representing 360° with a resolution of 360°/65536 range 0..360°
Pitch (PP)	2	Unsigned 16 bit, i.e. 0..65535 representing 360° with a resolution of 360°/65536 range 270°..90°
Heave (HH)	2	Signed 16 bit range -32767 mm to + 32766 mm Positive when elevated.
Status (S)	1	1*unsettled+2*velocityaiding+4*heading aiding (where variables are interpreted as 0=false, 1=true)
DLE (E)	1	0x10

4.3.2 SIMRAD EM1000 & EM3000

Data Frame, Contains 10 bytes
SHRRPPHHYY

Example
0000000 10010000 11001010 11111111 00000101 00000000 00000000 00000000 10110111 10001000

Bitrate	Max output Rate
115200	100
57600	100
38400	100
19200	100
9600	76
4800	38

Description	Scaling	Format	Bytes	Value
Status byte (S)			1	0 (EM1000) 0x90 (EM3000)
Header (H)			1	0x90
Roll (RR)	0.01 degrees	Signed hex	2	-17999 - 18000 hundredths of °
Pitch (PP)	0.01 degrees	Signed hex	2	-17999 - 18000 hundredths of °
Heave (HH)	0.01 m	Signed hex	2	-32767 - 32766 cm
Heading (YY)	0.01 degrees	Unsigned hex	2	0 - 35999 hundredths of °

Note: When settling roll, pitch and heave will be 0.

4.3.3 BOSCH REXROTH HEXADECIMAL HEAVE

Data Frame
$SMCHHHHVVVVAAAA<CR><LF>

Example
$SMC00000000FFF6
Heave 1mm is sent as 0x0001
Heave -2mm is sent as 0xFFFE

Bitrate	Max output Rate
115200	100
57600	100
38400	100
19200	91
9600	45
4800	22

Description	Bytes	Form
Header	4	$SMC
Heave (HH)	4	Signed 16 bit range -32767 mm to + 32766 mm Positive when elevated.
Heave velocity (VV)	4	Signed 16 bit range -32767 mm/s to + 32766 mm/s
Heave acceleration(AA)	4	Signed 16 bit range -32767 mm/s^2 to + 32766 mm/s^2
Termination characters	2	<CR><LF> (0x15 0x12)

Note: When the IMU is settling, roll, pitch and heave will be 0.

4.3.4 BINARY STRING 2

Example
00000001 00001101 00000000 00011110 00110111 10001001 00000101 00000000
11010101 01110010 10011100 11111111 00000000 00000000 00000100

Bitrate	Max output Rate
115200	100
57600	100
38400	100
19200	100
9600	53
4800	26

Description	Bytes	Hex	Form
Header (32 bits)	4	0x01	
SOH		0x0D	Start of header Byte
Message length		0x00	Remaining number of Bytes to follow
Message Type			Message code
EOH			End of Header
Data	10		
Pitch Byte 1		LSB	Positive Pitch = Bow up
Pitch Byte 2			
Pitch Byte 3			
Pitch Byte 4		MSB	
Roll Byte 1		LSB	Positive Roll = Port up
Roll Byte 2			
Roll Byte 3			
Roll Byte 4		MSB	
Pitch invalid			Invalidity byte flag 0x00=Valid, 0x01-0xFF=Invalid
Roll invalid			Invalidity byte flag 0x00=Valid, 0x01-0xFF=Invalid
Footer			
EOM	1	0x04	End of Message

Pitch/Roll Value = $360/(2^{32})$
0 (00000000 Hex) = 0 Degrees
1 (00000001 Hex) = +0.0000008382 Degrees
-1 (FFFFFFFF Hex) = -0. 0000008382 Degrees

4.3.5 BINARY OUTPUT MESSAGE 4

Available from firmware 2.986 onwards (except 2.989)

The output data from the motion sensor is represented as a Hexadecimal value and must be converted to float values or decimal readings using Big Endian order for the bytes. The data field sizes are presented in the table below and are in most cases 4 bytes, 32 bits, in size.

The Binary Output Message 4 uses the IEEE Standard 754 representation of the float numbers.

In the output message fields, no scaling for the motion sensor data is used when converting from Hex representation to the float values.

Below is an example of the Motion Sensor, Binary Output Message 4, Hex data output.
The three fields in bold are Roll, Pitch and Yaw angles - Bytes 6 to 17, following the header and counter.

24,42,49,4E,34,0E,**40,A7,2C,E5,3E,C4,95,4D,41,C4,EE,E4**,3D,B3,65,00,BD,92,B2,B0,3D,4A,58,00,BD,FE ,3E,F8,BD,AB,68,88,3D,63,
7D,6E,BC,32,5C,7F,3C,09,80,42,BB,E8,D9,98,38,B1,58,00,39,66,DC,00,3A,19,CB,DF,BB,61,65,8F,BB,2A ,FE,C0,3C,94,48,00,0D,0A,

Float values from Hex data
05.224, 00.384, 024.62, 00.088, -00.072, 00.049, -00.124, -00.084, 00.056, -00.011, 00.008, -00.007, 00.000, 00.000, 00.001, -00.003, -00.003, 00.018,

Roll Angle

Hex (4 Bytes/32 bits)	Float value
40A72CE5	**5.2242303**

Pitch angle

Hex	Float value
3EC4954D	**0.38395157**

Yaw angle

Hex	Float value
41C4EEE4	**24.616646**

Bitrate	Max output Rate
115200	100
57600	66
38400	44
19200	22
9600	11
4800	5

Description	Bytes	Byte offset	Form
Header	5	0 to 4	$BIN4
Counter	1	byte 5	0 – 255
Roll angle	4	6 to 9	-180 to +180 degrees (Maximum values **no** scaling) C3340000 = -180 00000000 = 0 43340000 = +180
Pitch angle	4	10 to 13	-180 to +180 degrees
Yaw angle	4	14 to 17	0 to 360 degrees
Roll velocity	4	18 to 21	-180 to +180 degrees/second
Pitch Velocity	4	22 to 25	-180 to +180 degrees/second
Yaw Velocity	4	26 to 29	-180 to +180 degrees/second
Roll Acceleration	4	30 to 33	-180 to +180 degrees/second^2
Pitch Acceleration	4	34 to 37	-180 to +180 degrees/second^2
Yaw Acceleration	4	38 to 41	-180 to +180 degrees/second^2
Surge	4	42 to 45	Metres
Sway	4	46 to 49	Metres
Heave	4	50 to 53	Metres
Surge Velocity	4	54 to 57	Metres/second
Sway Velocity	4	58 to 61	Metres/second
Heave Velocity	4	62 to 65	Metres/second
Surge Acceleration	4	66 to 69	Metres/second^2
Sway Acceleration	4	70 to 73	Metres/second^2
Heave Acceleration	4	74 to 77	Metres/second^2
Termination characters	2	78 to 79	CR LF

4.4 ANALOG OUTPUTS

The analog outputs are available using the optional analog junction box supplied by SMC.

4.4.1 ANALOG1 ±10V, HEAVE ±0.5M, HEAVE RATE ±0.2M/S, HEAVE ACC 0.1M/S2

Data Frame
#01C0+hh.hhh<CR><LF>
#01C1+vv.vvv<CR><LF>
#01C2+aa.aaa<CR><LF>

Description	Form
Analog Channel 0	Heave ±10V = ±0.5m
Analog Channel 1	Heave Rate ±10V = ±0.2m/s
Analog Channel 2	Heave Acceleration ±10V = ±0.1m/s^2

4.4.2 ANALOG2 ±10V, ROLL ±10°, PITCH ±10°, HEAVE ±10M

Data Frame
#01C0+xx.xxx<CR><LF>
#01C1+yy.yyy<CR><LF>
#01C2+hh.hhh<CR><LF>

Description	Form
Analog Channel 0	Roll ±10V = ±10°
Analog Channel 1	Pitch ±10V = ±10°
Analog Channel 2	Heave ±10V = ±10m

4.4.3 ANALOG3 ±10V, ROLL ±30°, PITCH ±30°, HEAVE ±10M

Data Frame
#01C0+xx.xxx<CR><LF>
#01C1+yy.yyy<CR><LF>
#01C2+hh.hhh<CR><LF>

Description	Form
Analog Channel 0	Roll ±10V = ±30°
Analog Channel 1	Pitch ±10V = ±30°
Analog Channel 2	Heave ±10V = ±10m

4.4.4 ANALOG4, 4~20MA, ROLL 0-20°, PITCH 0-20°

Data Frame
#01C0+xx.xxx<CR><LF>
#01C1+yy.yyy<CR><LF>

Description	Form
Analog Channel 0	Absolute Roll 4-20 mA = 0-20° (10mA = 12°)
Analog Channel 1	Absolute Pitch 4-20 mA = 0-20° (10mA = 12°)

4.4.5 ANALOG5, 4~20MA, HEAVE ±6M, PITCH ±60°, ROLL ±60°, STATUS

Available from firmware 2.94

Data Frame
#01C0+12.004<CR><LF>
#01C1+11.796<CR><LF>
#01C2+11.799<CR><LF>
#01C3+16.000<CR><LF>

Description	Form
Analog Channel 0	Heave 4-20 mA = ±6M, 12mA = 0m, 4mA = -6m
Analog Channel 1	Pitch 4-20 mA = ±60°, 12mA = 0, 4mA = -60°
Analog Channel 2	Roll 4-20 mA = ±60°, 12mA = 0, 4mA = -60°
Analog Channel 3	Status, Not Ready = 8mA and Ready = 16mA

4.4.6 ANALOG6 ±10V, HEAVE ±5M, HEAVE RATE ±5M/S, HEAVE ACC 5M/S2

Available from firmware 2.982

Data Frame
#01C0+00.370<CR><LF>
#01C1+00.171<CR><LF>
#01C2+01.144<CR><LF>

Description	Form
Analog Channel 0	Heave ±10V = ±5m
Analog Channel 1	Heave Rate ±10V = ±5m/s
Analog Channel 2	Heave Acceleration ±10V = ±5m/s^2

4.4.7 ANALOG7 4~20MA, HEAVE ±5M, HEAVE RATE ±5M/S, HEAVE ACC 5M/S2

Available from firmware 2.986 onwards (except 2.989)

Data Frame
#01C0+00.370<CR><LF>
#01C1+00.171<CR><LF>
#01C2+01.144<CR><LF>

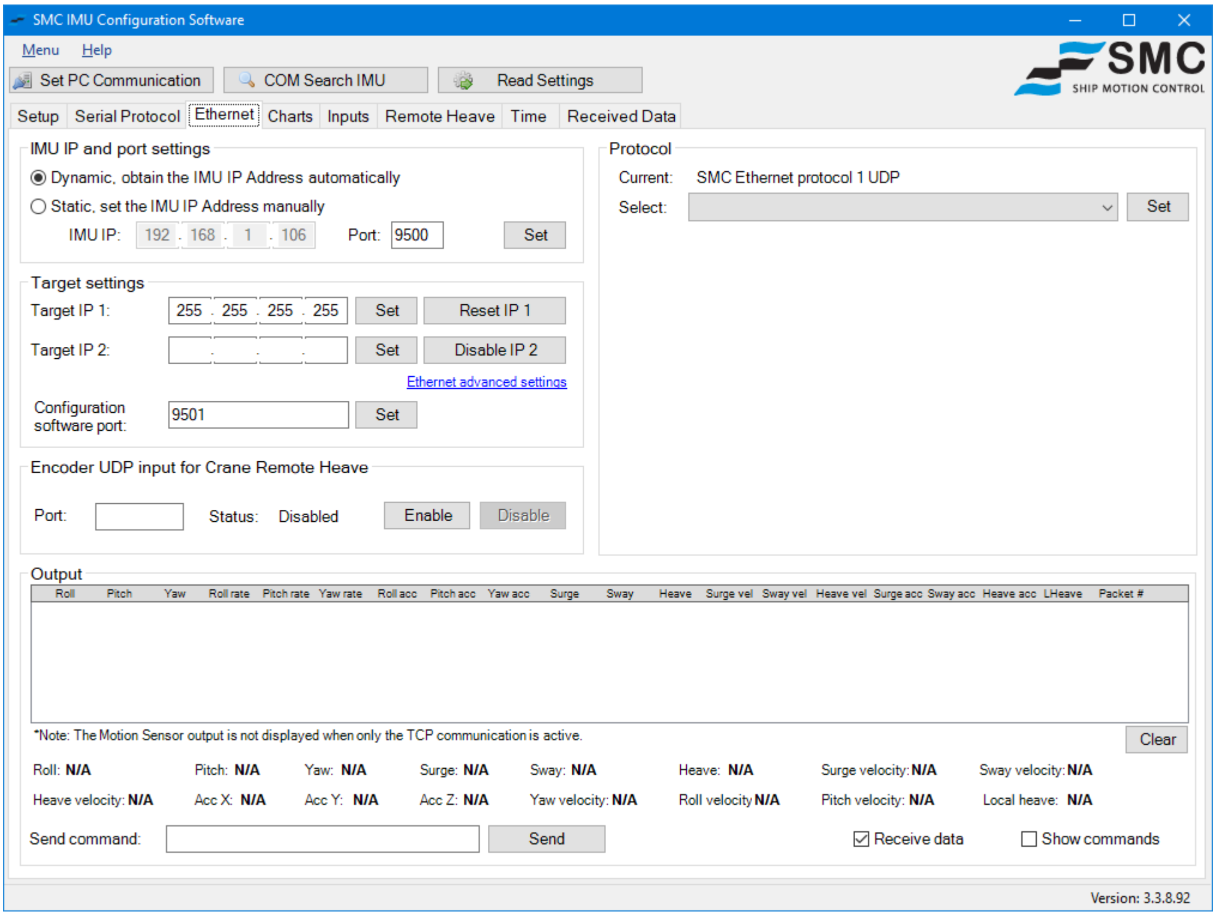
Description	Form
Analog Channel 0	Heave 4~10mA = ±5m
Analog Channel 1	Heave Rate 4~10mA = ±5m/s
Analog Channel 2	Heave Acceleration 4~10mA = ±5m/s^2

4.5 ETHERNET

The SMC motion sensor IMU-00x and IMU-10x with hardware version 8.5 or higher is equipped with a 10/100mbit ethernet communication port. The SMC data output over Ethernet is sent in an 8 bit per byte binary format. The data can be viewed from the SMC IMU configuration software or other third-party software suitable to read the ethernet messages.

The configuration of the motion sensor is done using the SMC IMU Configuration Software. Both serial communication and ethernet communication can be used to do the desired settings.

For a SMC motion sensor outputting data over ethernet the following settings can be made in the SMC IMU configuration software related the communication.



4.5.1 IP SETTINGS

When the SMC motion sensor is connected to the LAN the motion sensor will receive a dynamic IP address from the DHCP in the network if the Dynamic IP radio button is selected in the SMC configuration software.
Note *that the motion sensor is only searching for the DHCP server during the boot up process.*

The motion sensor IP address is user configurable from the SMC Configuration Software. A radio button option to enter a static IP address is available.

If the ethernet connection does not have a DHCP server in the network, as for example when connecting the motion sensor directly with a crossed ethernet cable to a PC the IP addresses will have to be entered manually in the SMC IMU Configuration software. The motion sensor does not require to enter a subnet mask.

If a static IP is set for the motion sensor and the selected IP address is no longer available, the motion sensor will have to be setup using the serial communication to enter a new IP address within the network alternatively set the motion sensor to acquire a new dynamic IP if there is an available DHCP server in the LAN.

The *IMU IP address* displayed in the configuration software when connected to the network is the IP address that the motion sensor is currently using. It can be the last IP address acquired via DHCP or an IP that has been set manually. If the option to use a dynamic IP address is used the motion sensor may get a different IP Address by the DHCP server during the next startup.

Note: Care must be taken when setting a static IP address, that the IP address chosen, does not conflict with another device on the network. The motion sensor will start broadcasting on the selected IP address even if there is another device with the same IP address in the network. The SMC motion sensor will not respond to ARP requests such as a ping.

4.5.2 PORT SETTINGS

The IMU UDP default port is 9500.
The configuration software default port is 9501.
Each port can be changed to a User defined port number if required from the SMC IMU Configuration Software.

4.5.3 TARGET IP ADDRESSES

By entering a specific Target IP address, the motion sensor will transmit, unicast, its message to one single receiver with this IP address. Only this receiver will be able to receive the message from the motion sensor. It is possible to have 2 Target IPs where 2 devices on the network can configure and read data from the motion sensor at the same time. The motion sensor will not communicate with any other devices with different IP addresses than the one being selected in the Target IP fields.

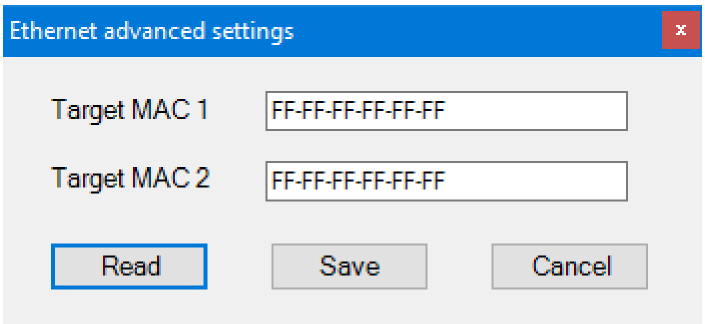
Target IP 1 is set to broadcast the motion sensor data by default. This means that when the motion sensor Ethernet is connected to the network all devices on the network will receive data and communicate with the motion sensor. Set the Target IP 1 to 255.255.255.255 to set the motion sensor to broadcast. As an option entering xxx.xxx.xxx.255 where the x is the local network IP will limit the broadcast from the motion sensor to within the sub network. By entering a single Target IP address instead of the broadcast address, the motion sensor communication will be unicast and will only be sent to the Target IP number.

Target IP 2 will allow a second device on the network to configure and read data from the Motion Sensor. The Target 2 can only be enabled after Target IP 1 is defined with an IP address. Enter an IP address in the Target IP 2 fields to enable unicast or broadcast to a second target device or network.

Select *Disable IP2* to disable the Target IP 2 feature. The Target IP 2 is disabled when the Target IP 2 fields are empty.

If *Reset IP1* is selected for Target IP 1 the IP address will be cleared and the Motion Sensor will revert to the network broadcast default, 255.255.255.255

MAC Address; To read the MAC address of the Target IPs, click on the *Ethernet advanced settings.* When the motion sensor is set to broadcast or if no Target device is found the MAC address will be received as FF-FF-FF-FF-FF-FF. The MAC addresses are commonly used for creating firewall and port forwarding rules.



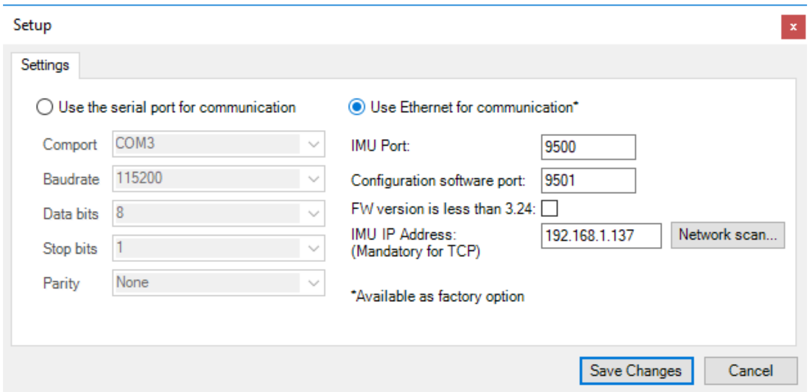
Note: When moving the motion sensor to another device or network with a different IP address or range, ensure *Reset IP1* has been selected to clear the target IP address stored in the motion sensor. Otherwise the motion sensor will continue to unicast to the Target IP address or broadcast to the different range and no other device will be able to connect to the motion sensor via Ethernet.

However, if this step is overlooked, the serial connection can be used to restore communication with the IMU and clear the stored target IP address.

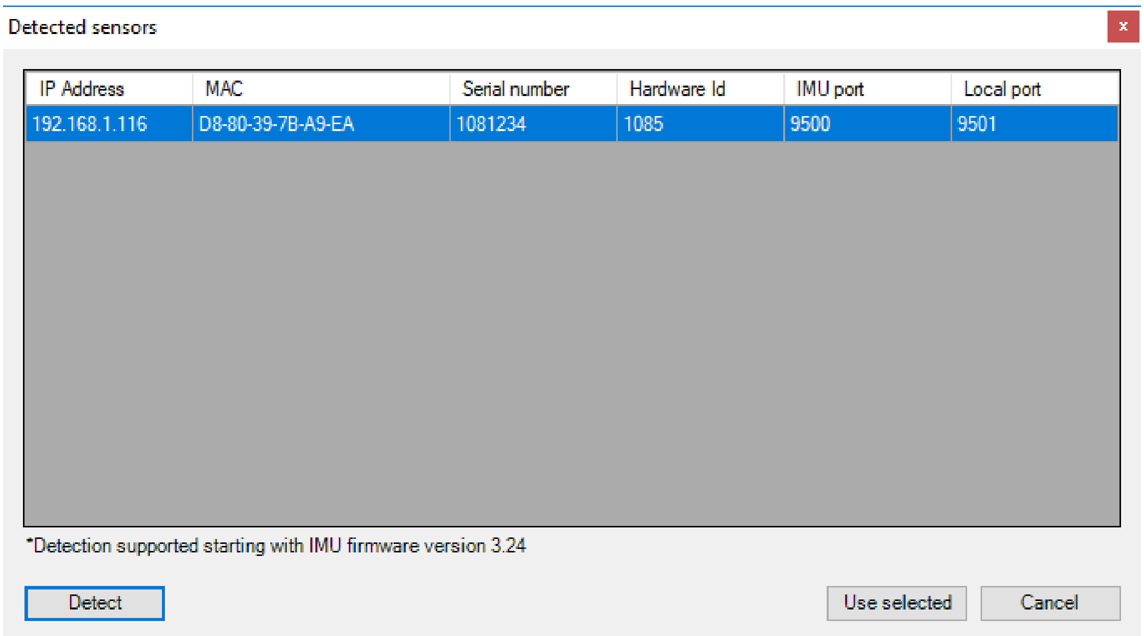
4.5.4 NETWORK SCAN

Available from firmware 3.24

The network scan feature will assist to find SMC ethernet connected Motion Sensors on the network. The feature is found in the Set PC Communication.



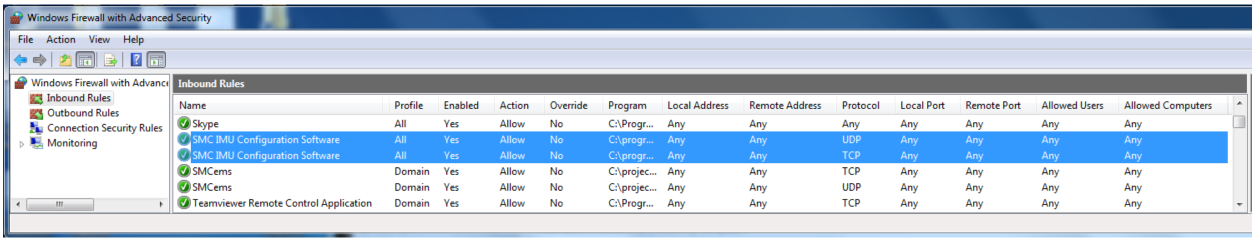
Click on the Network scan button and popup window shown below will open where the found motion sensors on the network are displayed and can be selected. If no data is being received from the motion sensor after it has been selected from the network scan window, ensure that the motion sensor is broadcasting or does unicast to the PC that runs the network scan, otherwise no communication with the motion sensor will be established.



4.5.5 WINDOWS FIREWALL

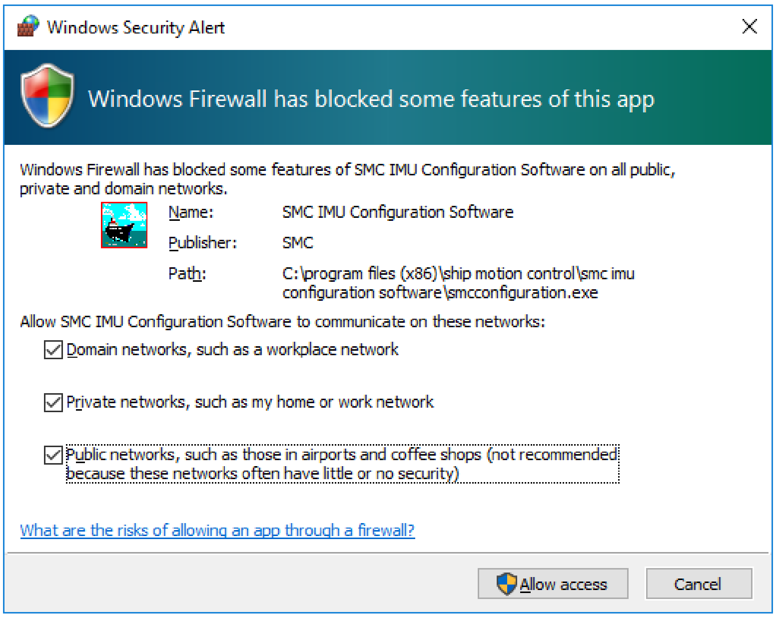
Normally the Windows Firewall rules for the SMC IMU Configuration software are created on first launch of the software.

However, if the configuration software does not display all the values for Target IP etc. in the IP and Port settings section it is usually due to a firewall rule setting.
The host PC and any client PCs should have an **Inbound Rule** for UDP and TCP as shown below



The default path to the SMC IMU configuration software executable is
C:\Program Files (x86)\Ship Motion Control\SMC IMU Configuration Software\SMCconfiguration.exe

If a problem occurs, close the configuration software and delete all SMC IMU Configuration Firewall rules, relaunch the software and accept the automatically created rules.



4.6 ETHERNET PROTOCOLS

4.6.1 CHECKSUM CALCULATION

When checksum is being used in the Ethernet UDP protocols the motion sensor does calculate a checksum using a 16-bit 1's complement checksum using RFC 1071 standard. The checksum is being presented in the SMC header within the payload section.
In the checksum calculation the bytes 16 and 17 are excluded.

4.6.2 SMC ETHERNET PROTOCOL 1 UDP

Available from firmware 3.12 and hardware version 8.5

The UDP datagram follows the standard RFC 768 format, below is the definition of the data fields contained within the UDP datagram payload, each field consists of 4 bytes.

Note the field marked as the SMC header below is the header within the *payload* of the datagram and must not be confused with the header of the UDP datagram itself. The payload is encoded in big-endian.

	Byte	Description
SMC HEADER	0, 1, 2, 3	Sender identifier "SMC"
SMC HEADER	4, 5, 6, 7	Model Type "108"
SMC HEADER	8, 9, 10, 11	Serial number "1082222"
SMC HEADER	12, 13	Device Status 10 or 20
SMC HEADER	14, 15	String identifier "1"
SMC HEADER	16, 17	Checksum 16-bit 1's complement
SMC HEADER	18, 19	Counter 0-255
SMC DATA	20, 21, 22, 23	Roll
SMC DATA	24, 25, 26, 27	Pitch
SMC DATA	28, 29, 30, 31	Yaw
SMC DATA	32, 33, 34, 35	Roll rate
SMC DATA	36, 37, 38, 39	Pitch rate
SMC DATA	40, 41, 42, 43	Yaw rate
SMC DATA	44, 45, 46, 47	Roll Acceleration
SMC DATA	48, 49, 50, 51	Pitch Acceleration
SMC DATA	52, 53, 54, 55	Yaw Acceleration
SMC DATA	56, 57, 58, 59	Surge
SMC DATA	60, 61, 62, 63	Sway
SMC DATA	64, 65, 66, 67	Heave
SMC DATA	68, 69, 70, 71	Surge Velocity
SMC DATA	72, 73, 74, 75	Sway Velocity
SMC DATA	76, 77, 78, 79	Heave Velocity
SMC DATA	80, 81, 82, 83	Surge Acceleration
SMC DATA	84, 85, 86, 87	Sway Acceleration
SMC DATA	88, 89, 90, 91	Heave Acceleration

The UDP 1 protocol uses the IEEE Standard 754 representation of the float numbers. In the output message fields, no scaling for the motion sensor data is used when converting from Hex representation to the float values.
Below is an example of the Motion Sensor, UDP 1 protocol, Hex data output. Payload only

SMC	108	108xxxx	20	1	CRC	Counter	Roll	Pitch	Yaw
53 4d 43 20	30 31 30 38	00 10 7a c0	14 00	00 01	ea 88	00 0e	bf 1c 6c a1	40 93 2d d8	43 ac f8 8f

Roll rate	Pitch rate	Yaw rate	Roll Acc	Pitch Acc	Yaw Acc	Surge	Sway
3c 16 7d 00	bc aa 50 00	bc f8 70 00	3a 8b ce 95	3c 9d ed df	3c 74 3a 69	bc 01 c4 bb	3c a6 ef d1

Heave	Surge Vel	Sway Vel	Heave Vel	Surge Acc	Sway Acc	Heave Acc
39 d6 4a ac	ba ef 80 80	bb b9 7d	f0 b9 5d 21	60 bb bd 1f	6c 3b 79 89	9b 3b 2e 99

First 19-byte breakdown

Sender identifier SMC (ASCII)

Byte 0	S	Hex 53
Byte 1	M	Hex 4d
Byte 2	C	Hex 43
Byte 3	space	Hex 20

Model Type, IMU model (ASCII)

Byte 4	0	Hex 30
Byte 5	1	Hex 31
Byte 6	0	Hex 30
Byte 7	8	Hex 38

Serial number, Ex. 1080000, (Integer)(in this case 108000)

Byte 8		Hex 00
Byte 9		Hex 10
Byte 10		Hex 7a
Byte 11		Hex c0

Device Status,

Byte 12	2	Hex 14
Byte 13	0	Hex 0

String Identifier, 1 for UDP 1 protocol

Byte 14	0	Hex 00
Byte 15	1	Hex 01

Checksum, 16 bits 1's complement 60040

Byte 16		Hex ea
Byte 17		Hex 88

Counter, 0-255, in this example 14

Byte 18		Hex 00
Byte 19		Hex 0e

4.6.3 SMC ETHERNET PROTOCOL 2 UDP

Available from firmware 3.48 and hardware version 8.5
Heave Period available from FW version 3.76

The UDP datagram follows the standard RFC 768 format, below is the definition of the data fields contained within the UDP datagram payload, each field consists of 4 bytes.

Note the field marked as the SMC header below is the header within the *payload* of the datagram and must not be confused with the header of the UDP datagram itself. The payload is encoded in big-endian.

	Byte	Description
SMC HEADER	0, 1, 2, 3	Sender identifier "SMC"
SMC HEADER	4, 5, 6, 7	Model Type "106, 107, 108, 007, 028, 008"
SMC HEADER	8, 9, 10, 11	Serial number "1082222"
SMC HEADER	12, 13	Device Status "0"
SMC HEADER	14, 15	String identifier "2"
SMC HEADER	16, 17	Checksum (CRC16)
SMC HEADER	18, 19	Counter 0-255
SMC DATA	20, 21, 22, 23	Roll
SMC DATA	24, 25, 26, 27	Pitch
SMC DATA	28, 29, 30, 31	Yaw
SMC DATA	32, 33, 34, 35	Roll rate
SMC DATA	36, 37, 38, 39	Pitch rate
SMC DATA	40, 41, 42, 43	Yaw rate
SMC DATA	44, 45, 46, 47	Roll Acceleration
SMC DATA	48, 49, 50, 51	Pitch Acceleration
SMC DATA	52, 53, 54, 55	Yaw Acceleration
SMC DATA	56, 57, 58, 59	Surge
SMC DATA	60, 61, 62, 63	Sway
SMC DATA	64, 65, 66, 67	Heave
SMC DATA	68, 69, 70, 71	Surge Velocity
SMC DATA	72, 73, 74, 75	Sway Velocity
SMC DATA	76, 77, 78, 79	Heave Velocity
SMC DATA	80, 81, 82, 83	Surge Acceleration
SMC DATA	84, 85, 86, 87	Sway Acceleration
SMC DATA	88, 89, 90, 91	Heave Acceleration
SMC DATA	92, 93, 94, 95	Local Heave
SMC DATA	96, 97, 98, 99	Heave Period
SMC DATA	100, 101, 102, 103	For Future Use outputs 9999
SMC DATA	104, 105, 106, 107	For Future Use outputs 9999
SMC DATA	108, 109, 110, 111	For Future Use outputs 9999
SMC DATA	112, 113, 114, 115	For Future Use outputs 9999
SMC DATA	116, 117, 118, 119	For Future Use outputs 9999
SMC DATA	120, 121, 122, 123	For Future Use outputs 9999
SMC DATA	124, 125, 126, 127	For Future Use outputs 9999
SMC DATA	128, 129, 130, 131	For Future Use outputs 9999
SMC DATA	132, 133, 134, 135	For Future Use outputs 9999

The UDP 2 protocol uses the IEEE Standard 754 representation of the float numbers. In the output message fields, no scaling for the motion sensor data is used when converting from Hex representation to the float values.

Below is an example of the Motion Sensor, UDP 2 protocol, Hex data output. Payload only

53 4d 43 20 30 30 32 38 00 04 54 12 14 00 00 02 52 3a 00 24 3f 00 24 3f a1 45 a6 bf b4 28 77 42 d3 52 b1 bd db 6f 00 bd 78 70 00 3b fa 00 00 3d 9a ea ea be 18 70 bc bd 9f 18 a5 00 00 00 00 00 00 00 00 b9 b7 df 96 ba b3 c9 00 bb 8b 94 d0 b9 9b f5 00 ba ec 0f 8c bc 12 61 27 bb 80 81 7d b9 b7 df 96 00 00 27 0f 00 00 27 0f 00 00 27 0f 00 00 27 0f 00 00 27 0f 00 00 27 0f 00 00 27 0f 00 00 27 0f 00 00 27 0f 00 00 27 0f

First 19-byte breakdown

Sender identifier SMC (ASCII)

Byte 0	S	Hex 53
Byte 1	M	Hex 4d
Byte 2	C	Hex 43
Byte 3	space	Hex 20

Model Type, IMU model (ASCII)

Byte 4	0	Hex 30
Byte 5	0	Hex 30
Byte 6	2	Hex 32
Byte 7	8	Hex 38

Serial number, Ex. 1080000, (Integer) (in this case 283666)

Byte 8		Hex 00
Byte 9		Hex 04
Byte 10		Hex 54
Byte 11		Hex 12

Device Status,

Byte 12	2	Hex 14
Byte 13	0	Hex 0

String Identifier, 2 for UDP 2 protocol

Byte 14	0	Hex 00
Byte 15	2	Hex 02

Checksum, 16 bits 1's complement 60040

Byte 16		Hex 52
Byte 17		Hex 3a

Counter, 0-255, in this example 36

Byte 18		Hex 00
Byte 19		Hex 24

4.6.4 SEAPATH 23 AND 26

Seapath 23 *Available from firmware 3.66*
This binary format consists of a fixed-length message using 1, 2 and 4–byte signal and unsigned integers. The signed integers are represented as two-complement numbers. For the multi-byte elements, the most significant byte is transmitted first.
Data Frame contains 44 bytes

Bitrate	Max output Rate
115200	100
57600	100
38400	82
19200	40
9600	20
4800	10

Description	Bytes	Format	Scaling
Header	1	Unsigned	
Header	1	Unsigned	
Time, seconds	4	Integer	seconds
Time, fraction of seconds	2	Unsigned	0.0001 second
Latitude	4	Integer	2^{30}= 90 degrees
Longitude	4	Integer	2^{30} = 90 degrees
Height	4	Integer	centimetres
Heave	2	Integer	centimetres
North Velocity	2	Integer	centimetres/second
East Velocity	2	Integer	centimetres/second
Down Velocity	2	Integer	centimetres/second
Roll	2	Integer	2^{14} = 90 degrees
Pitch	2	Integer	2^{14} = 90 degrees
Heading	2	Unsigned	2^{14} = 90 degrees
Roll rate	2	Integer	2^{14} = 90 degrees/second
Pitch rate	2	Integer	2^{14} = 90 degrees/second
Yaw rate	2	Integer	2^{14} = 90 degrees/second
Status word	2	Bit-fields	
Checksum	2	Unsigned	

Checksum is calculated as a 16-bit Block Cyclic Redundancy Check of all bytes between, but not including the Header and Checksum fields. The CRC algorithm is described in a separate section. Time is divided in an integer seconds part and a fractional second part. The integer seconds part of time is counted from 1970-01-01 UTC time, ignoring leap seconds.
The status word consists of 16 single bit flags numbered from 0 to 15, where 0 is the least significant bit.

Seapath 26 *Available from firmware 3.66*

This binary format consists of a fixed-length message using 1, 2 and 4–byte signal and unsigned integers. The signed integers are represented as two-complement numbers. For the multi-byte elements, the most significant byte is transmitted first.

The Data Frame contains 52 bytes

Bitrate	Max output Rate
115200	100
57600	100
38400	70
19200	35
9600	17
4800	8

Description	Bytes	Format	Scaling
Header	1	Unsigned	
Header	1	Unsigned	
Time, seconds	4	Integer	seconds
Time, fraction of seconds	2	Unsigned	0.0001 second
Latitude	4	Integer	2^{30}= 90 degrees
Longitude	4	Integer	2^{30} = 90 degrees
Height	4	Integer	centimetres
Heave, real time	2	Integer	centimetres
North Velocity	2	Integer	centimetres/second
East Velocity	2	Integer	centimetres/second
Down Velocity	2	Integer	centimetres/second
Roll	2	Integer	2^{14} = 90 degrees
Pitch	2	Integer	2^{14} = 90 degrees
Heading	2	Unsigned	2^{14} = 90 degrees
Roll rate	2	Integer	2^{14} = 90 degrees/second
Pitch rate	2	Integer	2^{14} = 90 degrees/second
Yaw rate	2	Integer	2^{14} = 90 degrees/second
Delayed heave time, seconds	4	Integer	seconds
Delayed heave time, fraction of seconds	2	Unsigned	0.0001 second
Heave, delayed	2	Integer	centimetres
Status word	2	Bit-fields	
Checksum	2	Unsigned	

Checksum is calculated as a 16-bit Block Cyclic Redundancy Check of all bytes between, but not including the Header and Checksum fields. The CRC algorithm is described in a separate section. Time is divided in an integer seconds part and a fractional second part. The integer seconds part of time is counted from 1970-01-01 UTC time, ignoring leap seconds.

Latitude is positive north of the Equator. Longitude is positive east of Greenwich.

Height is above the ellipsoid. Heave is positive down. Roll is positive with port side up. Pitch is positive with bow up. The status word consists of 16 single bit flags numbered from 0 to 15, where 0 is the least significant bit.

4.6.5 KM BINARY

Available from firmware 3.66

Data Frame contains 132 bytes

Bitrate	Max output Rate
115200	85
57600	42
38400	28
19200	14
9600	7
4800	3

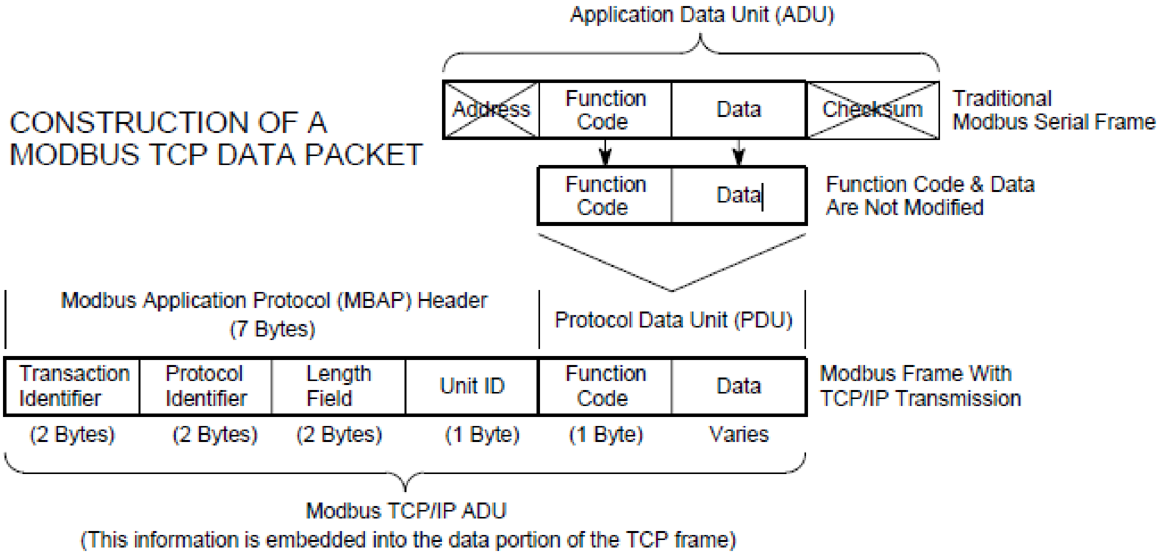
Description	Bytes	Format	Scaling
Start ID	4	Char	
Datagram length	2	Unsigned int 16	
Datagram version	2	Unsigned int 16	
UTC seconds	4	Unsigned int 32	s
UTC nanoseconds	4	Unsigned int 32	ns
Status word	4	Unsigned int 32	
Latitude	8	Double	Degrees
Longitude	8	Double	Degrees
Ellipsoid height	4	Float	Metres
Roll	4	Float	Degrees
Pitch	4	Float	Degrees
Heading	4	Float	Degrees
Heave	4	Float	Metres
Roll rate	4	Float	Degrees/s
Pitch rate	4	Float	Degrees/s
Yaw rate	4	Float	Degrees/s
North velocity	4	Float	m/s
East velocity	4	Float	m/s
Down velocity	4	Float	m/s
Latitude error	4	Float	m
Longitude error	4	Float	m
Height error	4	Float	m
Roll error	4	Float	Degrees
Pitch error	4	Float	Degrees
Heading error	4	Float	Degrees
Heave error	4	Float	m
North acceleration	4	Float	m/s^2
East acceleration	4	Float	m/s^2
Down acceleration	4	Float	m/s^2
Delayed heave	-	-	-
UTC seconds	4	Unsigned int 32	s
UTC nanoseconds	4	Unsigned int 32	ns
Delayed heave	4	Float	m

Status word, one bit per status info, 1= active

4.6.6 SMC MODBUS TCP

Available from firmware 3.xx and hardware version 8.5

The SMC MODBUS protocol is transmitted by the SMC motion sensor via the MODBUS TCP protocol standard. The motion sensor is the Master in the hierarchy.
The encapsulated data is a standard MODBUS Application Protocol packet minus the Frame Address before the data, which is replaced by the Unit Identifier (slave ID) and the checksum after the data. The Checksum is redundant due to the data being encapsulated in a TCP packet which uses a checksum.



The SMC MODBUS TCP Protocol contains the same fields as the SMC Ethernet protocol 2 UDP.

The SMC IMU configuration software cannot be used to read the output data from the TCP Modbus protocol. Settings of parameters and features can be made from the configuration software when the TCP protocol is selected both over the ethernet and using the serial communication.

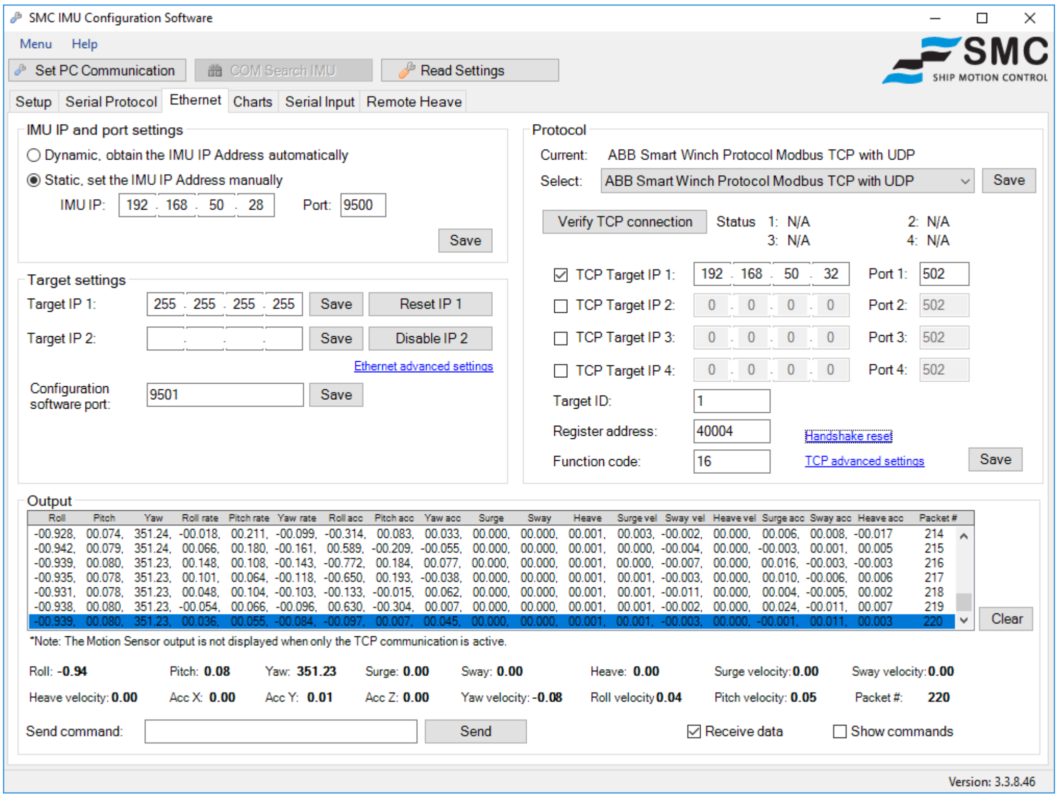
Data from the SMC motion sensor sent via MODBUS TCP can be read on the target devices with the Target IP address set from the SMC IMU Configuration software.

The MODBUS TCP exchange is a standard three-way handshake, as follows
The motion sensor reads the MAC address of the Target IP

- the motion sensor initiates the TCP handshake with a sync request to the target device
- the target device acknowledges the sync request
- the motion sensor acknowledges the target device sync acknowledge

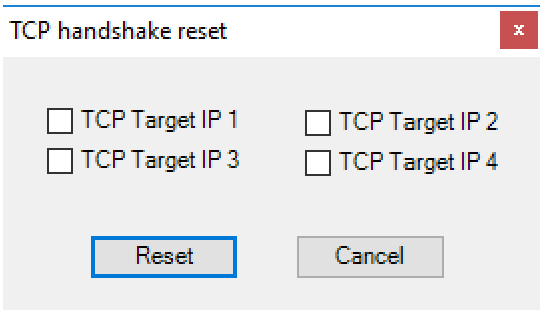
After the handshake is finalized the SMC motion sensor will start sending packets to the selected target devices automatically.

When the session is established between the target device and the motion sensor, the motion sensor will continue to send its messages in the output rate selected and does not wait for the target packet received acknowledgement before sending its next message string.



Handshake reset

In the Handshake reset setting, there is an option to restart the handshake process between the motion sensor and the target IP device. This is useful if the ARP request timeout is enabled (see below) and a Target IP device is connected to the network after the TCP handshake timeout has elapsed.

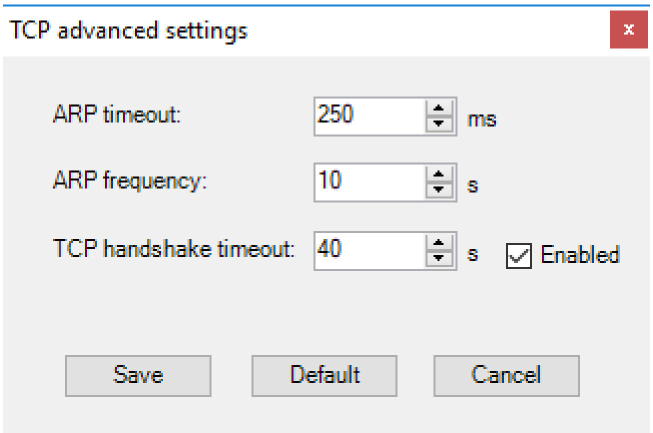


TCP advanced settings
In the TCP advanced settings there are options for the handshake process between the motion sensor and the Target Device.

The ARP timeout settings, sets the time the motion sensor will wait for the ARP request response from the target device, before stopping the ARP request process. Default timeout is 250ms

The ARP frequency is the frequency that the motion sensor will send a new ARP request to the target IP. This will only be repeated when there is no handshake process established. As soon as the handshake process is established with the Target IP device the ARP requests are be stopped. The default ARP frequency is 10s.

The TCP handshake timeout setting is for how long the motion sensor will try to establish the handshake process with the target IP device. After the set time the ARP request process will be stopped and will not be processed again until the motion sensor is restarted or the handshake is being reset from the configuration software. For the timeout feature there is a selection to enable the timeout or to let the motion sensor to do the TCP handshake process continuously at the frequency set and with the ARP timeout settings as specified above. The Default setting is enabled and 40s timeout.



Register table
The start register is settable from the SMC IMU Configuration software. As default the register starts at 3 (40004 for holding registers). This settable from the configuration.

Parameter	MODBUS			
	Register	Data Type	Number of registers	Unit and scaling
Sender identifier	X	TChar	2	ASCII "SMC"
Model Type	X+2	T1	1	Model Type *example 108*
Serial Number	X+3	T6	2	Serial number *example 1085526*
Device Status	X+5	T1	1	20 data invalid. 10 data valid. (decimal)
String Identifier*	X+6	T1	1	String ID 100 (64 hex)
Checksum (CRC16)	X+7	T1	1	Checksum (zeroed)
Counter		T1	1	Counter message incremental 0-65535
Roll		T5	1	Degrees Resolution 0.01° (+ve=port up)
Pitch		T5	1	Degrees Resolution 0.01° (+ve=bow down)
Yaw		T4	1	Degrees Resolution 0.01°, 0-359
Roll rate		T5	1	Degrees/second Resolution 0.01°/s
Pitch rate		T5	1	Degrees/second Resolution 0.01°/s
Yaw rate		T5	1	Degrees/second Resolution 0.01°/s
Roll Acceleration		T7	1	Degrees/second² Resolution 0.001°/s²
Pitch Acceleration		T7	1	Degrees/second² Resolution 0.001°/s²
Yaw Acceleration		T7	1	Degrees/second² Resolution 0.001°/s²
Surge		T7	1	Meters Resolution 0.001
Sway		T7	1	Meters Resolution 0.001
Heave		T7	1	Meters Resolution 0.001
Surge Velocity		T7	1	Meter/second Resolution 0.001m/s
Sway Velocity		T7	1	Meter/second Resolution 0.001m/s
Heave Velocity		T7	1	Meter/second Resolution 0.001m/s
Surge Acceleration		T7	1	Meter/second² Resolution 0.001m/s²
Sway Acceleration		T7	1	Meter/second² Resolution 0.001m/s²
Heave Acceleration		T7	1	Meter/second² Resolution 0.001m/s²
Local Heave		T7	1	Meters Resolution 0.001
For Future Use			1	For Future Use
For Future Use			1	For Future Use
For Future Use			1	For Future Use
For Future Use			1	For Future Use
For Future Use			1	For Future Use
For Future Use			1	For Future Use
For Future Use			1	For Future Use
For Future Use			1	For Future Use
For Future Use			1	For Future Use
For Future Use			1	For Future Use

4.6.7 ABB SMARTWINCH MODBUS TCP

Available from firmware 3.12 and hardware version 8.5

The ABB MODBUS protocol is transmitted by the SMC motion sensor via MODBUS TCP protocol standard. The motion sensor is the Master in the hierarchy.

The SMC IMU configuration software cannot be used to read the output data from the TCP Modbus protocol. Settings of parameters and features can be made from the configuration software when the TCP protocol is selected both over the Ethernet and using the serial communication.

The ABB Smart Winch Protocol can be combined with the SMC Ethernet protocol 1 UDP. In this case the UDP message will be read by the IMU Configuration Software.

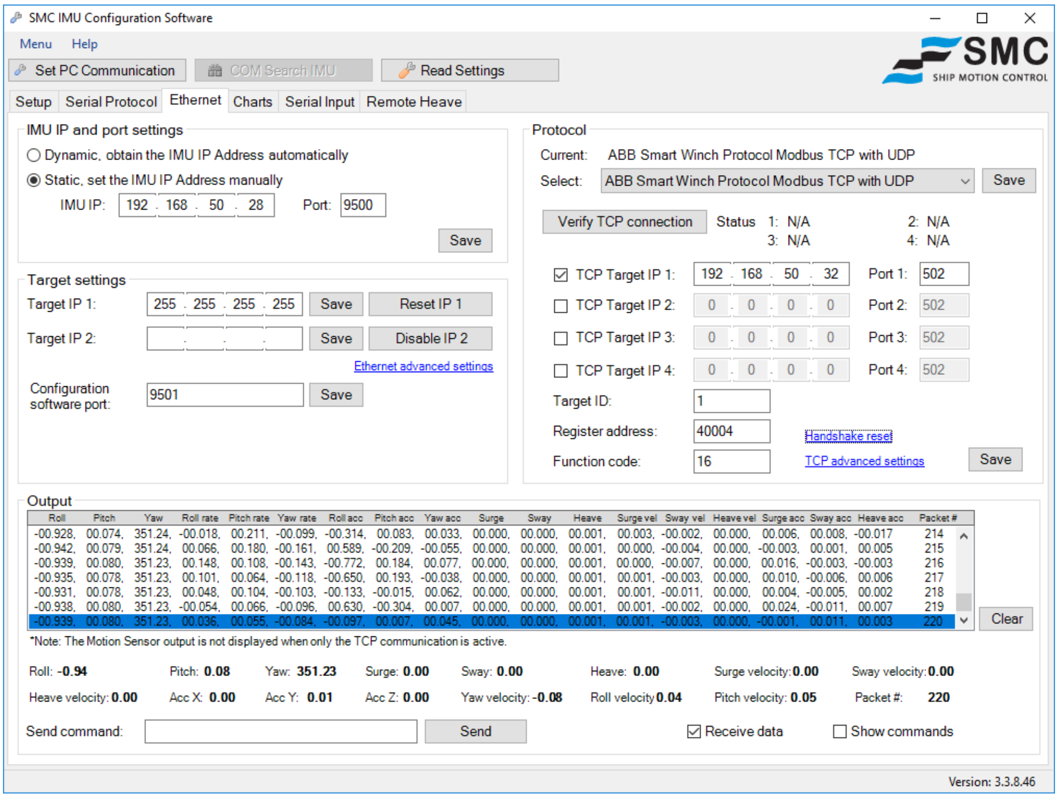
Data from the SMC motion sensor sent via MODBUS TCP can be read on the target devices with the Target IP address set from the SMC IMU Configuration software.

The MODBUS TCP exchange is a standard three-way handshake, as follows
The motion sensor reads the MAC address of the Target IP

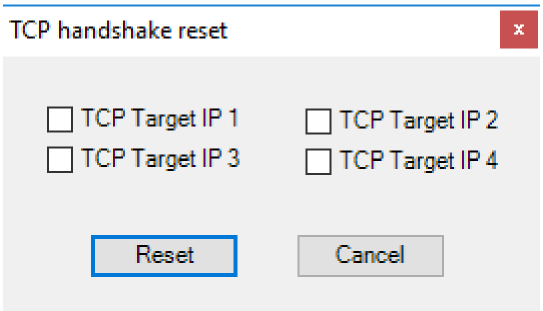
- the motion sensor initiates the TCP handshake with a sync request to the target device
- the target device acknowledges the sync request
- the motion sensor acknowledges the target device sync acknowledge

After the handshake is finalized the SMC motion sensor will start sending packets to the selected target devices automatically.

When the session is established between the target device and the motion sensor, the motion sensor will continue to send its messages in the output rate selected and does not wait for the target packet received acknowledgement before sending its next message string.



Handshake reset
In the Handshake reset setting, there is an option to restart the handshake process between the motion sensor and the target IP device. This is useful if the ARP request timeout is enabled (see below) and a Target IP device is connected to the network after the TCP handshake timeout has elapsed.

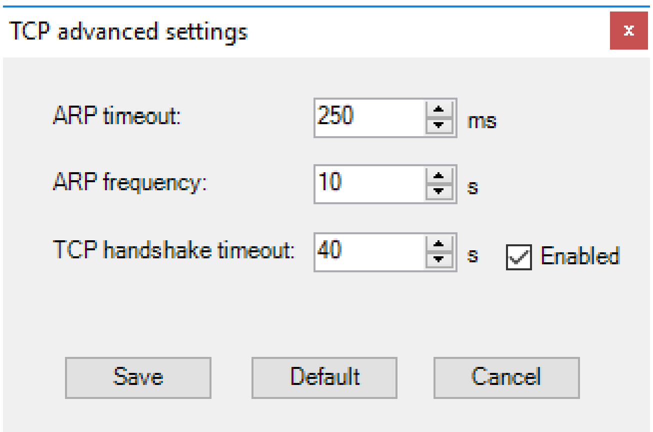


TCP advanced settings
In the TCP advanced settings there are options for the handshake process between the motion sensor and the Target Device.

The ARP timeout settings, sets the time the motion sensor will wait for the ARP request response from the target device, before stopping the ARP request process. Default timeout is 250ms

The ARP frequency is the frequency that the motion sensor will send a new ARP request to the target IP. This will only be repeated when there is no handshake process established. As soon as the handshake process is established with the Target IP device the ARP requests are stopped. The default ARP frequency is 10s.

The TCP handshake timeout setting is for how long the motion sensor will try to establish the handshake process with the target IP device. After the set time the ARP request process will be stopped and will not be processed again until the motion sensor is restarted or the handshake is being reset from the configuration software. For the timeout feature there is a selection to enable the timeout or to let the motion sensor to do the TCP handshake process continuously in the frequency set and with the ARP timeout settings as specified above. The Default setting is enabled and 40s timeout.



Register table

The start register is settable from the SMC IMU Configuration software. As default the register starts at 40004. This settable from the configuration.

Parameter	MODBUS			
	Register	Data Type	Number of registers	Unit and scaling
Heave	40004	T7	1	Meters Resolution 0.001
Heave Velocity	40005	T7	1	Meter/second Resolution 0.001m/s
Acceleration Z	40006	T7	1	Meter/second^2 Resolution 0.001m/s2
Roll Angle	40007	T5	1	Degrees Resolution 0.01° (+ve=port up)
Pitch Angle	40008	T5	1	Degrees Resolution 0.01° (+ve=bow down)
Watchdog Counter	40009	T5	1	Counter message incremental 0-32767

Example

01 31 ff a8 ff ba 00 10 FF C1 00 9f

Where

01 31 is heave 0.305 Meter

ff a8 is heave velocity -0.088 Meter/second

ff ba is Acceleration Z -0.070 Meter/second2

00 10 is roll is 0.16 Degrees

FF C1 is pitch -0.63 Degrees

00 9f is counter 159

4.6.8 ABB SMARTWINCH MODBUS TCP WITH UDP

The ABB Smart Winch Protocol combined with the SMC Ethernet protocol 1 UDP. Use this selection to read the UDP message in the IMU Configuration Software.

4.6.9 ABB SMARTWINCH MODBUS TCP WITH REMOTE HEAVE

The ABB Smart Winch Protocol combined with, if enabled, the Remote Heave placed in Register 10

4.6.10 ABB SMARTWINCH MODBUS TCP WITH UDP R HEAVE

The ABB Smart Winch Protocol combined with the SMC ethernet protocol 1 UDP. In addition, if enabled, the Remote Heave is placed in Register 10

Register table
The start register is settable from the SMC IMU Configuration software. As default the register starts at 40004. This settable from the configuration.

Parameter	MODBUS			
	Register	Data Type	Number of registers	Unit and scaling
Heave Local	40004	T7	1	Meters Resolution 0.001
Heave Velocity	40005	T7	1	Meter/second Resolution 0.001m/s
Acceleration Z	40006	T7	1	Meter/second^2 Resolution 0.001m/s2
Roll Angle	40007	T5	1	Degrees Resolution 0.01° (+ve=port up)
Pitch Angle	40008	T5	1	Degrees Resolution 0.01° (+ve=bow down)
Watchdog Counter	40009	T5	1	Counter message incremental 0-32767
Heave (inc remote)	40010	T7	1	Meters Resolution 0.001

Example
01 31 ff a8 ff ba 00 10 FF C1 00 9f 01 31

Where
01 31 is heave 0.305 Meter
ff a8 is heave velocity -0.088 Meter/second
ff ba is Acceleration Z -0.070 Meter/second2
00 10 is roll is 0.16 Degrees
FF C1 is pitch -0.63 Degrees
00 9f is counter 159
01 31 is heave 0.305 Meter

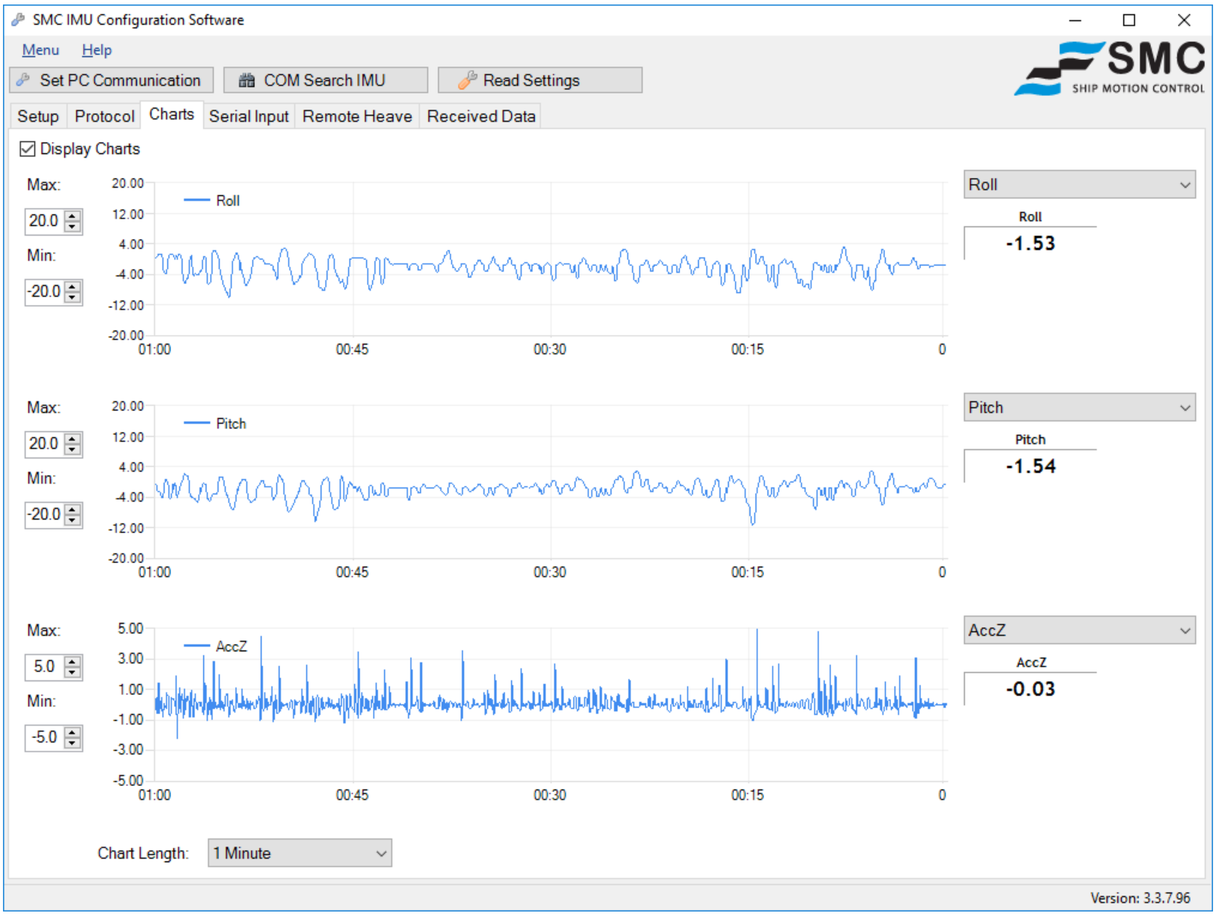
4.6.11 DATA TYPES FOR MODBUS PROTOCOL

Type	Description
T1	Unsigned Value (16 bit) Example: 12345 = 3039(16)
T2	Signed Value (16 bit) Example: -12345 = CFC7(16)
T3	Signed Long Value (32 bit) 6 decimals Example: 12.345678 = 00 BC 61 4E -12.345678 = FF 43 9E B2 T3 occupies 2 registers T3 value = ((reg1 << 16) + reg2) / 1000000
T4	Unsigned Value (16 bit), 2 decimal places Example: 123.45 = 3039(16)
T5	Signed Value (16 bit), 2 decimal places Example: -123.45 = CFC7(16)
T6	Unsigned integer value (32 bit) T6 occupies 2 registers T6 value = (reg1 << 16) + reg2 Example: 1234567890 = 49 96 02 D2
T7	Signed Value (16 bit), 3 decimal places Example: 12.345 = 30 39(16) -12.345 = CF C7(16)
TChar	ASCII character 8 bit
T_Str2	Two ASCII character 16 bit (8 bit each)

4.7 CHARTS

As a visual aid to or as a simple motion monitoring system, SMC have a Chart screen that displays up to 3 parameters in a graphical representation.

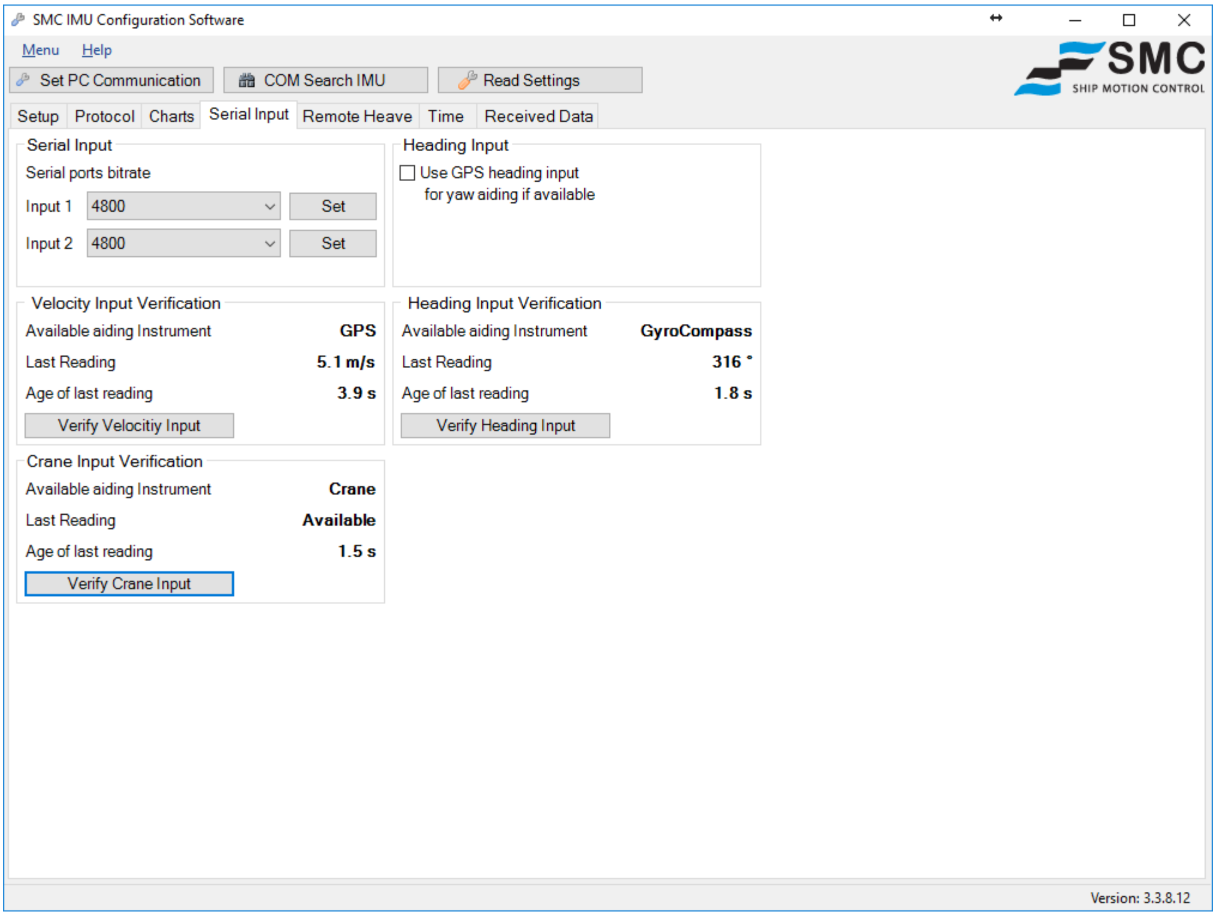
After selecting the Charts tab tick the Display Charts tick box to activate the data display.
Beside each chart is a drop-down menu from where the parameter to be displayed can be selected.
The chart scale is set on the left of the screen with a Maximum and Minimum setting. The chart length is set for all the charts from the drop-down menu at the bottom of the screen.



4.8 SERIAL INPUT

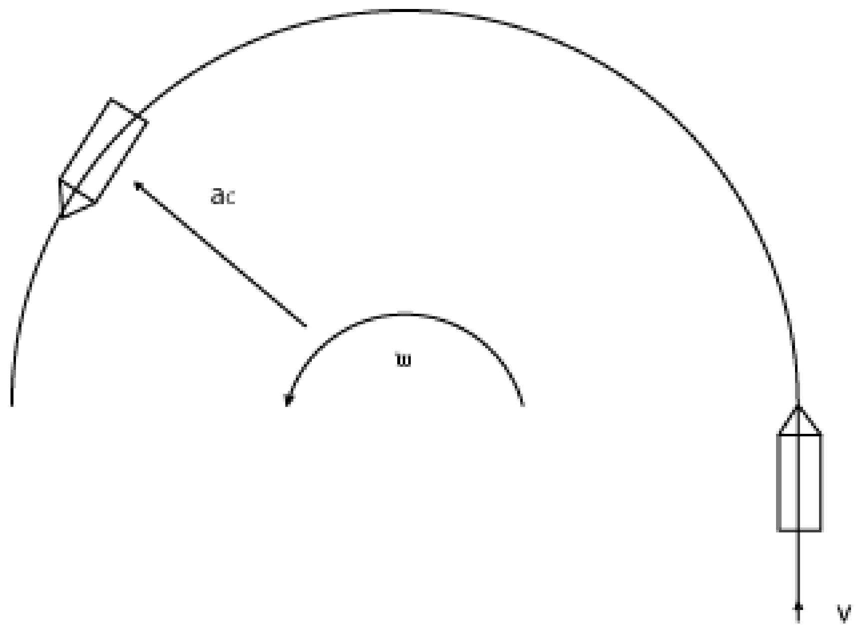
The SMC IMU has two RS232 serial ports for input from external devices.

The ports can be used for
- Aiding in vessel turns; input from GPS, Speed log
- Heading aiding; Gyrocompass or GPS
- Remote heave for AHC (Active Heave Compensation) in crane applications; Encoders via PLC (Programmable Logic Controllers)
- Output motion sensor reading data (available from firmware version 3.22 and later)



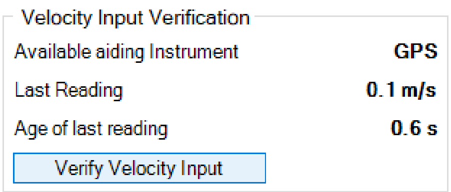
4.8.1 AIDING VIA GPS AND SPEED LOG

During vessel turns with small vessels a centrifugal force is generated from the turn. This force has a negative effect on the accuracy of the angular and heave calculations. By input the vessel velocity to the motion sensor, the centrifugal force can be estimated in the calculations in the motion sensor and the centrifugal effect can be heavily reduced, improving the accuracy of the readings.



The SMC Motion Sensor accepts velocity input from a GPS or a speed log.
The accepted input strings for the velocity input are
$xxRMC
$xxRMA
$xxVTG
$xxVBV
$xxVHW

To confirm that the motion sensor is receiving data from the velocity device, select **Verify Velocity Input** in the serial input tab. The motion sensor replies with information about the time since the last reading and the velocity received. If N/A is displayed when clicking the button, the velocity input is not working.



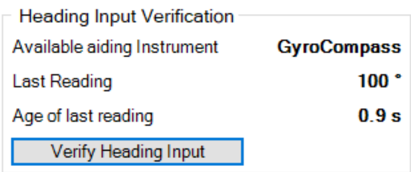
4.8.2 HEADING INPUT

When a heading input is connected, the motion sensor will use the heading for aiding the yaw signal, combining the data from internal gyros in the motion sensor with the input from the external compass. The heading output is available in strings where yaw or heading is available

The accepted strings for heading inputs are $xxHDT and $xxHDG.

Heading can also be retrieved from the GPS string but is not advisable if the vessel is not under constant motion unless a dual head GPS antenna is being used. The $GPHDG string is not accepted as default for the heading input. To use the GPS heading data for yaw aiding tick the *Use GPS heading input for yaw aiding if available* checkbox in the Serial Input tab otherwise the $GPHDG string will be ignored.

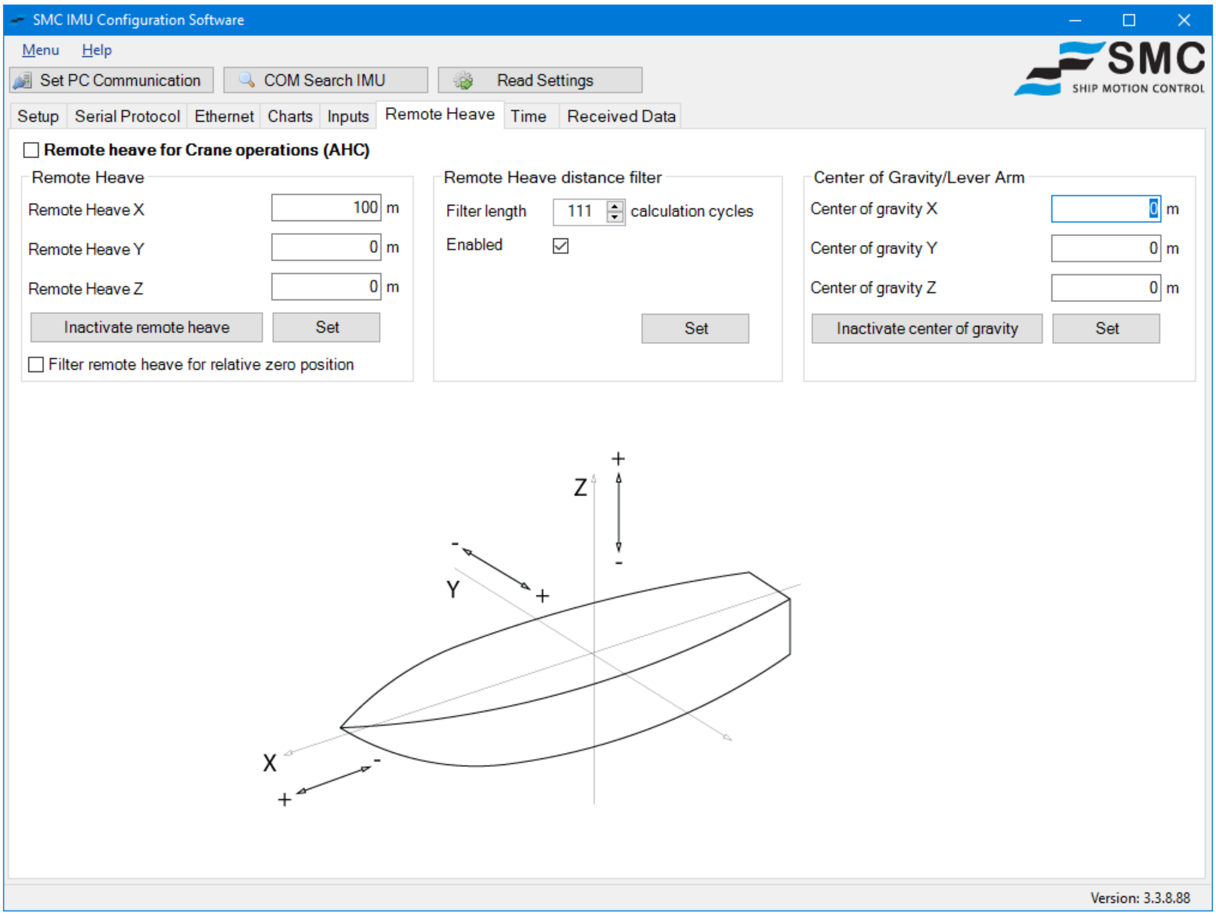
To confirm that the motion sensor is receiving data from the heading device click the **Verify Heading Input** button on the Serial Input tab. The IMU replies with the time since the last reading and the heading received. If N/A is displayed when clicking the button, the heading input is not working.



4.9 REMOTE HEAVE TAB

Remote heave; Heave is measured by the motion sensor in the installation location. In installations where heave is to be measured at a different location than the installed location of the motion sensor remote heave calculation can be used for a virtual mounting location of the motion sensor.

Lever Arm; By entering the mounting location of the motion sensor related the rotational point of the vessel, Center of Gravity, rotational accelerations will be calculated by the motion sensor and removed from the calculations, which gives an increased accuracy. The lever arm should be used in installation where mainly the Z distance between the rotational point and the mounting location of the motion sensor is big and at the same time the rate of rotation is high.



Filter remote heave for relative zero position
When using Remote Heave and Lever Arm distances the Remote Heave calculation will use the distance and angles for the new Heave measurement point. A static vessel/Motion Sensor angle will result in a heave offset, E.g. the heave will not be centered around 0.

SMC has added a filter to remove a fixed angle offset of the vessel from the remote heave output. This is selected from the checkbox **Filter remote heave for relative zero position**. Unless Filter remote heave for relative zero position is checked, setting a Remote Heave or Lever Arm distance on any axis, will result in a heave that is not *centered* at 0 when the vessel is not levelled.

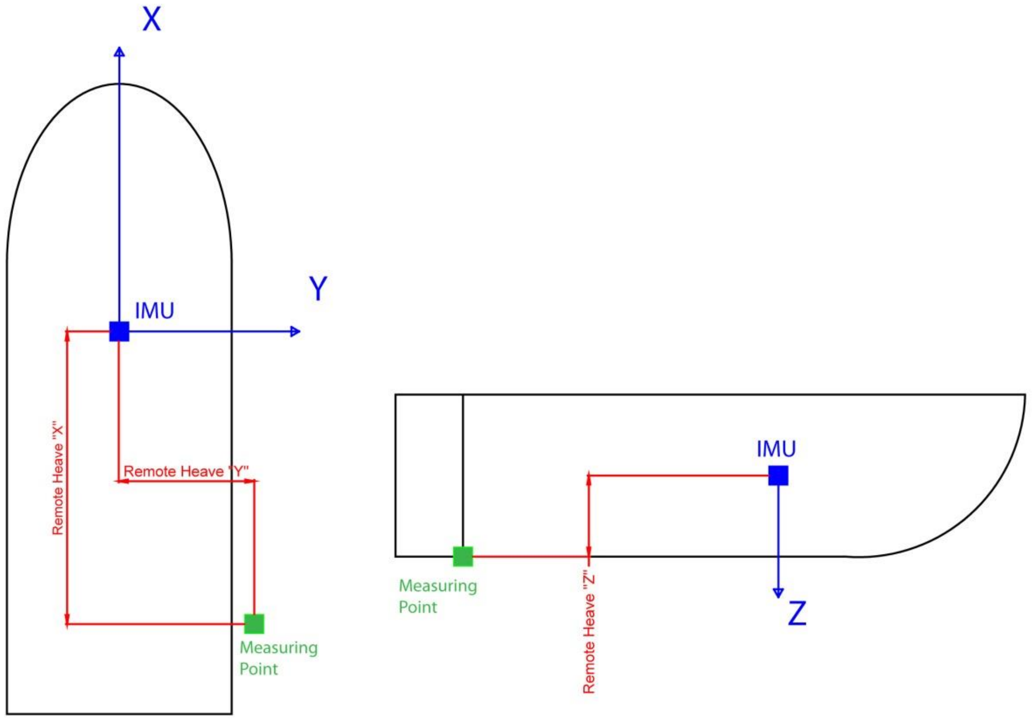
Note: that remote heave calculations will not be as accurate as heave at the physical location of the Motion Sensor as the remote heave is a combined calculation of heave and angle from a remote location. The calculation assumes that the vessel is rigid. If the remote heave distance is far from the physical location of the Motion Sensor, any small angular error, from flexing hulls etc. may generate a significant error in the remote heave output.

Lever Arm and Remote Heave distances must not exceed 50m.

4.9.1 REMOTE HEAVE

The remote heave function calculates the heave and the heave velocity output of the IMU from its physical location to a remote location.

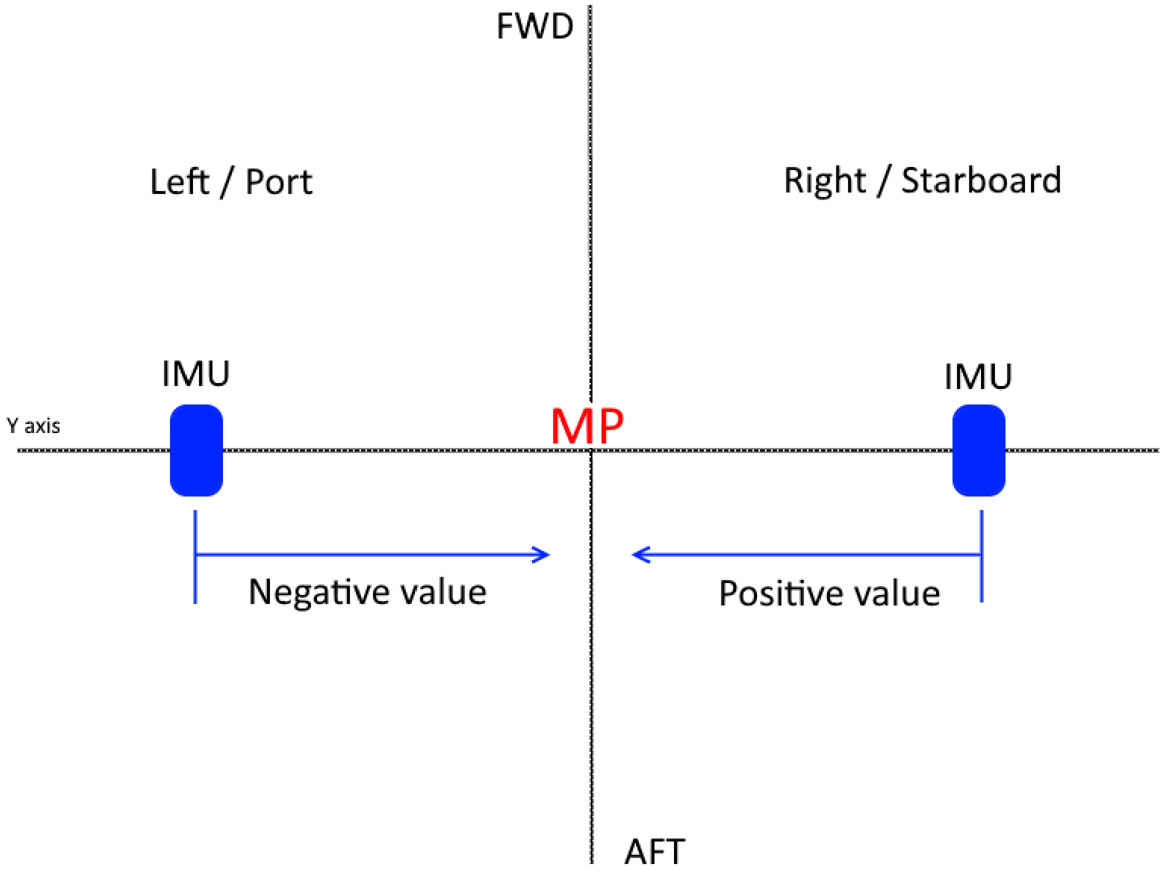
Remote Heave moves the heave and heave velocity calculation position *only* and not the virtual position for all other calculations. To move the calculation point for all measurement values please see the Lever Arm chapter.



Remote heave X is the fore aft distance in meters between the Motion Sensor and the remote heave point. Where a positive distance represents that the remote heave measurement point is located fore of the Motion Sensor physical location.

Remote heave Y is the sideways distance in meters between the Motion Sensor and the remote heave point. Where a positive distance represents that the remote heave measurement point is located to the port of the Motion Sensor physical location.

The drawing below illustrates the principle



Remote heave Z is the vertical distance in meters between the IMU and the remote heave point. Where a positive distance represents that the remote heave measurement point is located above the Motion Sensor physical installation location.

4.9.2 LEVER ARM

The best placement for the motion sensor is at the vessel Center of Gravity (CG) as the vessel has the lowest lateral accelerations in this point.

When the motion sensor is mounted in another location than the Center of Gravity, the accuracy of the output may be degraded from rotational accelerations onboard the vessel. By entering the distance between the motion sensor and the center of gravity, lever arm, in the SMC IMU Configuration software the motion sensor will subtract rotational accelerations and improve the readings. The highest rotational accelerations are generated when there is a large Z distance between the rotational point and the motion sensor.

The Lever arm feature moves the motion sensor mathematically, and all of its calculations, to the entered Lever Arm position.

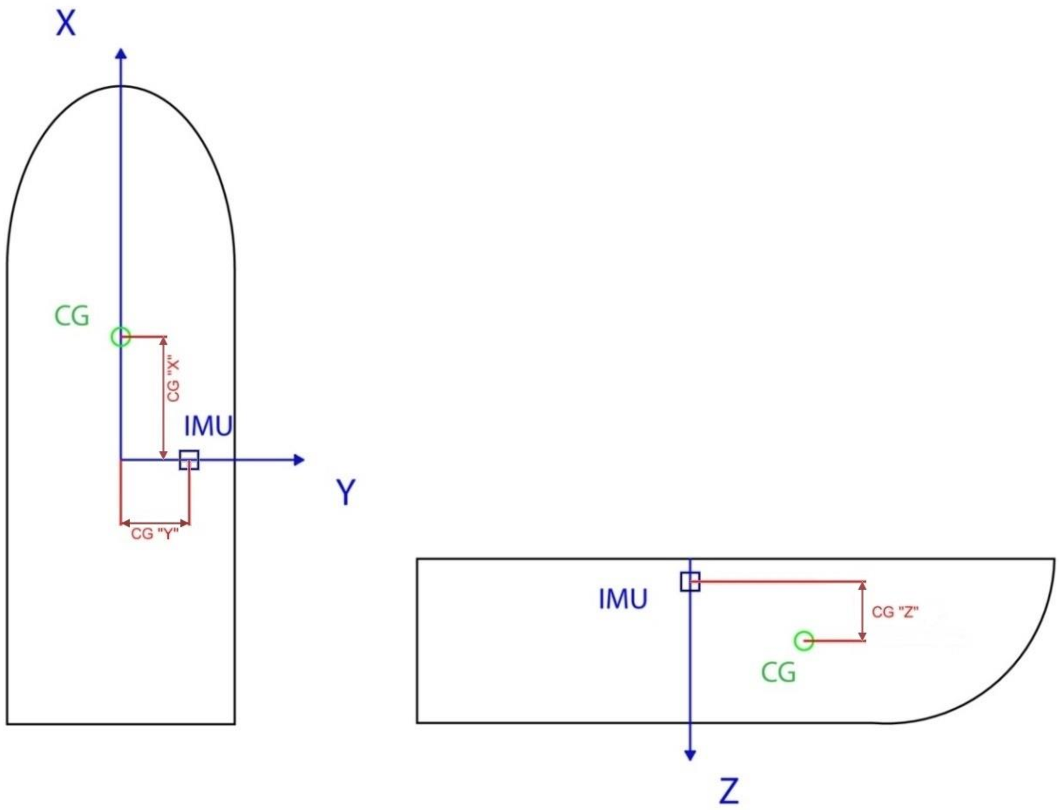
In the case of entering a Lever Arm distance, the heave calculation is moved to the entered Lever Arm location and then returned back automatically with a remote heave calculation to the physical mounting location. This remote heave calculation by the Lever Arm feature is not to be seen in the remote heave fields in the configuration software.

When a lever arm distance is entered, practically the Heave and Heave velocity will remain in the physical location of the motion sensor while accelerations and angular calculations are moved to the Lever Arm location. If Heave and Heave velocity is to be moved to the Lever Arm position a remote heave distance will have to be entered in the configuration software with the same distances as entered for the Lever Arm.

Remote heave locations different from the motion sensor physical installation point will be entered with the motion sensor ***physical location*** as the starting point for the distance measurements.

When a Lever Arm is entered and the calculation is moved to the new calculation point, static offsets in the Heave output will occur from static angles of the motion sensor when automatic remote heave calculation is returning the motion sensor to the physical mounting point. Filter heave to Zero tick box will filter this offset to zero.

The values are entered as follows:



Lever Arm X is the fore aft distance in meters between the Motion Sensor and the Lever Arm position. Where a positive distance represents that the Lever Arm measurement point is located fore of the Motion Sensor physical location.

Lever Arm Y is the sideways distance in meters between the IMU and the CG. Where a positive distance represents that the Lever Arm measurement point is located to the port of the Motion Sensor physical location.

Lever Arm Z is the vertical distance in meters between the IMU and the CG. Where a positive distance represents that the Lever Arm measurement point is located above the Motion Sensor physical installation location.

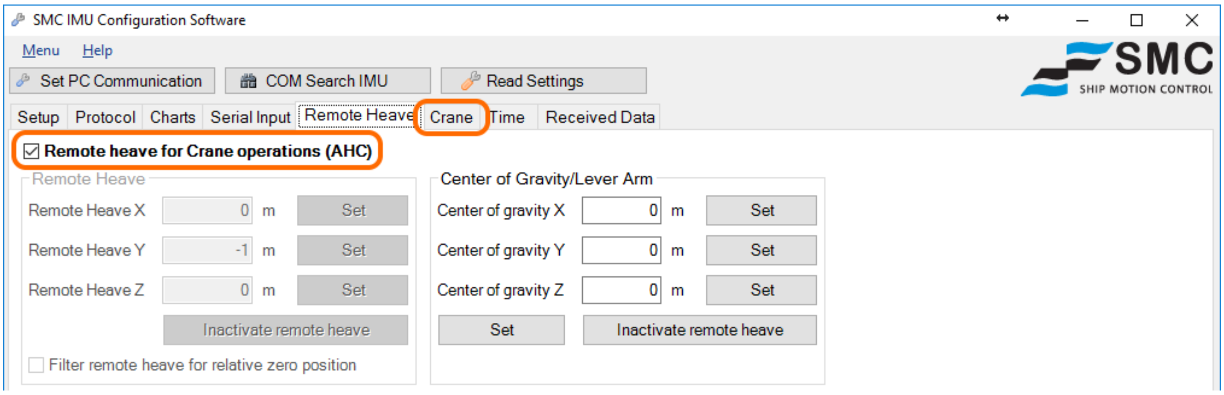
4.9.3 AHC - ACTIVE HEAVE COMPENSATION

SMC has developed a remote heave function that accepts dynamic crane position data for active heave compensation in marine crane applications.

A failsafe handling system must be built into the system so that if there is a failure in the IMU, PLC or the encoder feeding the active heave operation will be cancelled automatically.
Note that SMC will not be responsible for damages that occur related to Active Heave Compensation.

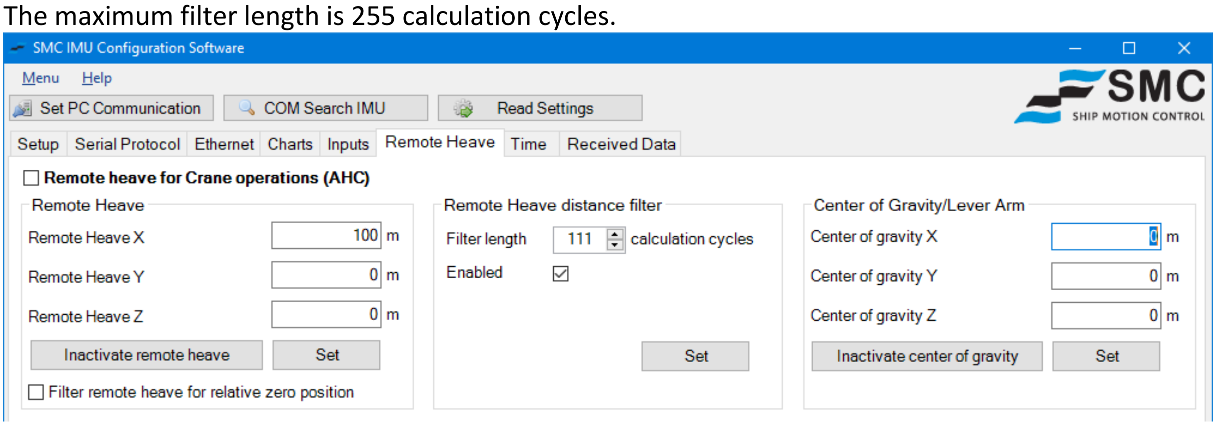
With the remote heave for Crane Operations active, the IMU will continually calculate the remote heave data based on the information that is supplied to the IMU from the crane encoders.
Remote heave and remote heave velocity data is then calculated continuously for any requested single point location along the crane boom which can be used to compensate for the vessel motions during crane operations.

Tick the checkbox **Remote heave for Crane Operations (AHC)** in the remote heave tab and the crane settings will be enabled.



4.9.4 REMOTE HEAVE DISTANCE FILTER

The Remote Heave distance filter, should only be used in specific circumstances, such as in crane operations where large instant heave movements are undesirable.
The filter applies an average to the heave data over the cycle range selected in the *Filter length* drop down. If there is a sudden change in the input, the remote heave will experience a gradual change.
The input is made up of the remote heave point entered in the configuration software and the crane input (when available).
The maximum filter length is 255 calculation cycles.



4.10 CRANE

Specifics for setting up an SMC IMU for crane use, using the configuration software

1. On the *Remote Heave* tab, when the *Remote heave for Crane operations (AHC)* check box is selected, the **Crane** tab is added and the Remote Heave settings are moved to the new tab.
2. Under the *Remote Heave* tab, the Center of Gravity/Lever Arm settings mathematically place the IMU in a "virtual" position from where the Remote Heave calculations will be made. The setting can be used to place the IMU at the vessel CG. From that virtual position at CG, a Remote Heave setting can be entered that will represent the distance from the IMU CG position to the desired heave measurement location, the location of the crane for example.
3. On the *Crane* tab, The Protocol dropdown allows the selection of:
   PENCR for use of hexadecimal values in the crane data strings sent to the sensor
   and **PENCO** for standard text encoder values. These strings are described in 4.10.7
4. On the *Crane* tab, Crane Type, currently only *Rotating* crane type can be chosen.
5. On the *Crane* tab, Angle Unit, choose **Degrees** or **Radians**.
6. For a crane that is actually rotating you need to check *IMU is mounted on crane base* i.e. the IMU rotates with the crane.
7. On the *Crane* tab, enter the remote heave settings in accordance with chapter 4.9.11
8. On the *Crane* tab, if there are offsets in the values that will be sent in the command strings (this is usually the case) these have to be set in accordance with section 4.10.4.

4.10.1 CRANE ZERO POSITIONS AND OFFSETS

The crane rotation reference *zero* position is aligned with the vessel fore-aft line, when the IMU is mounted on the vessel, and towards the crane arm when the IMU is mounted on the crane.

When the crane is pointing, with no offsets entered, to the:
- Fore of the vessel, the encoder should be 0 degrees
- Starboard side, the encoder value should be 90 degrees.
- Port side, the encoder value should be 270 degrees or -90 degrees if the default clockwise rotation is being used.

4.10.2 IMU MOUNTED ON THE CRANE BASE

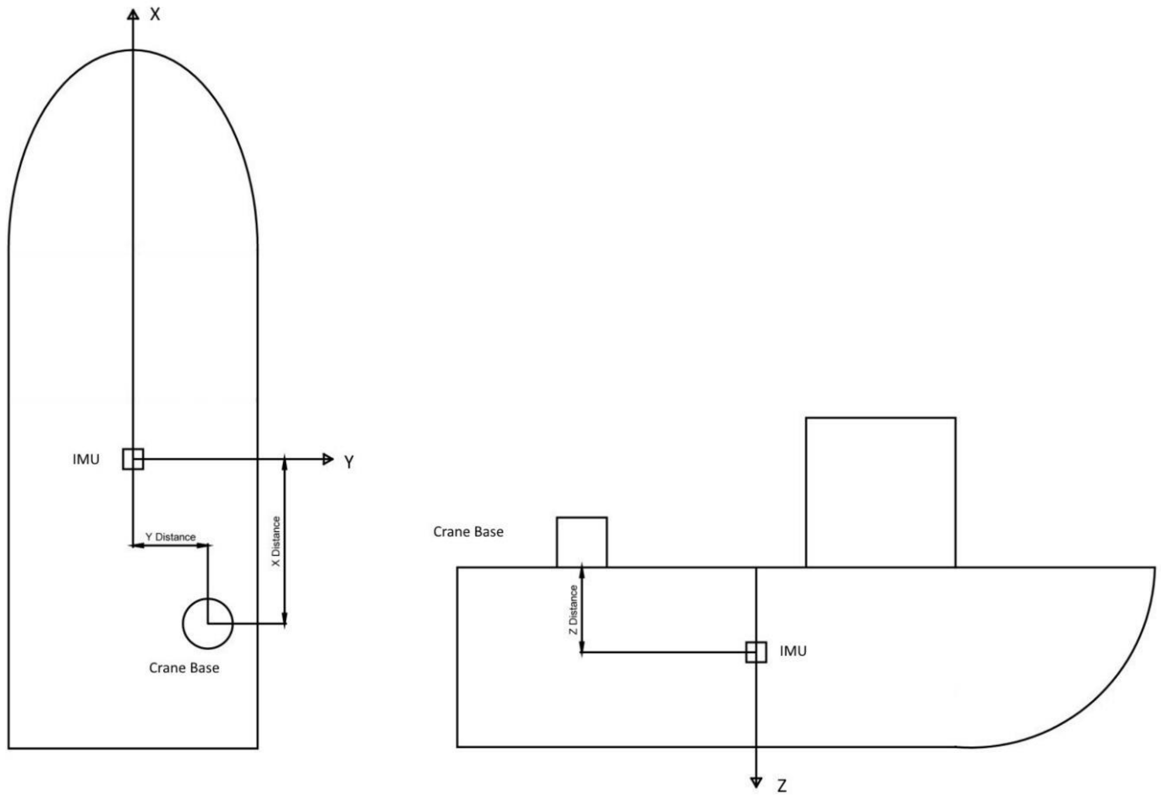
When the IMU is mounted on the rotating base of the crane tick the checkbox that the "IMU is mounted on the crane base" in the configuration software. When this checkbox is ticked the IMU is assumed to be rotating with the yaw rotation of the crane.

When the IMU is mounted on the crane base the single notch must be aligned with the crane arm i.e. the single notch is pointing to the boom tip.

The yaw encoder value which is the first encoder input should be left empty or as a value zero in the input string from the PLC. Example $PENCR,,value2,value3,value4,value5

4.10.3 IMU MOUNTED ON THE VESSEL

If the IMU is mounted elsewhere on the vessel, the single notch of the motion sensor should point towards the bow. The remote distance between the crane base and the IMU should be entered in the configuration software under the crane tab between. These fields are named Remote Heave X, Remote Heave Y and Remote Heave Z. The units are in meters.



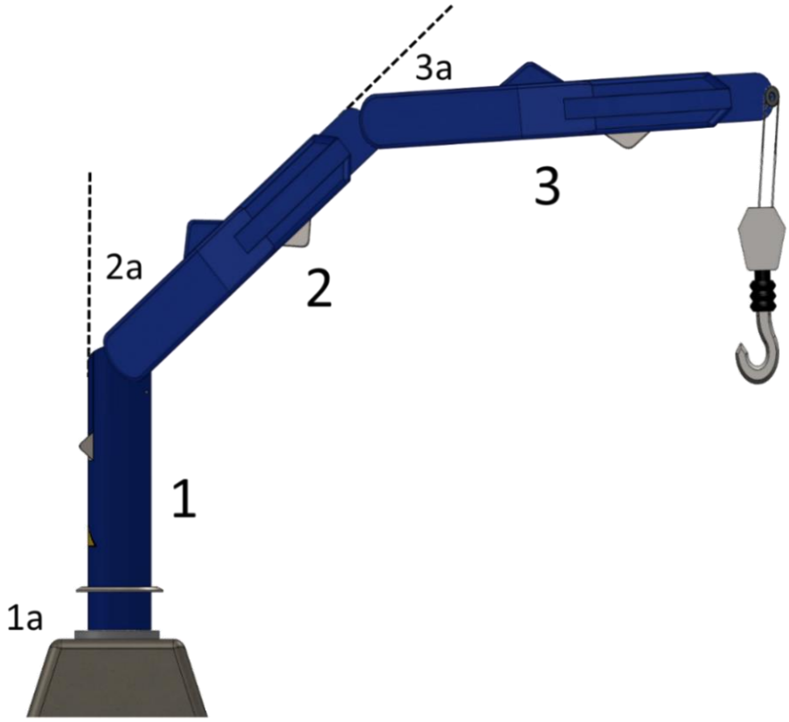
“Remote heave X” is the fore aft distance in meters between the IMU and the crane base. Where a positive distance represents that the motion sensor is located aft of the crane base

“Remote heave Y” is the sideways distance in meters between the IMU and the crane base. Where a positive distance represents that the motion sensor is located to the starboard side of the crane base

“Remote heave Z” is the vertical distance in meters between the IMU and the crane base. Where a positive distance represents that the motion sensor is located below the crane base.

4.10.4 SETTING CRANE DISTANCE & ANGLE OFFSETS

For the encoders an offset can be entered into the motion sensor. The angle offset information is entered in position 1 to 5 in the column Angle offset.



Position 1
The Angle Offset in position 1 sets the angular offset for the yaw encoder marked as 1a in the crane drawing. Seen from above when the crane is pointing to the fore of the vessel the encoder should display 0 degrees. When the crane is pointing starboard the encoder should display 90 degrees angle. When the crane is pointing to the port side the encoder value should be 270 degrees or -90 degrees if the default clockwise rotation is being used. The offsets are to be used to remove the encoder offsets from the motion sensor mounting orientation in the fore aft vessel alignment.

In the distance field for position 1 the height of the first node from the crane base is entered, it is marked as 1 in the below crane image.

Position 2, 3, 4 and 5
For the encoders 2, 3, 4 and 5 the angle is relative to the previous leg of the crane. This means that when there is no angular difference between the crane leg 2 and 3 the encoder 3 has a 0 angle. The encoder angles are illustrated as 2a and 3a in the below crane drawing.

Encoder 2, 3, 4 and 5 rotations are seen from the starboard side of the crane. The clockwise rotation is as default a positive rotation when seeing the crane from this position. Counter clockwise positive is possible to select by ticking the checkbox for the encoder in the configuration software. I.e. as default a positive rotation is when the crane arm is being adjusted downwards towards the water line. If the crane has zero angles from the encoders and no offsets entered this would mean that the crane is pointing straight up.

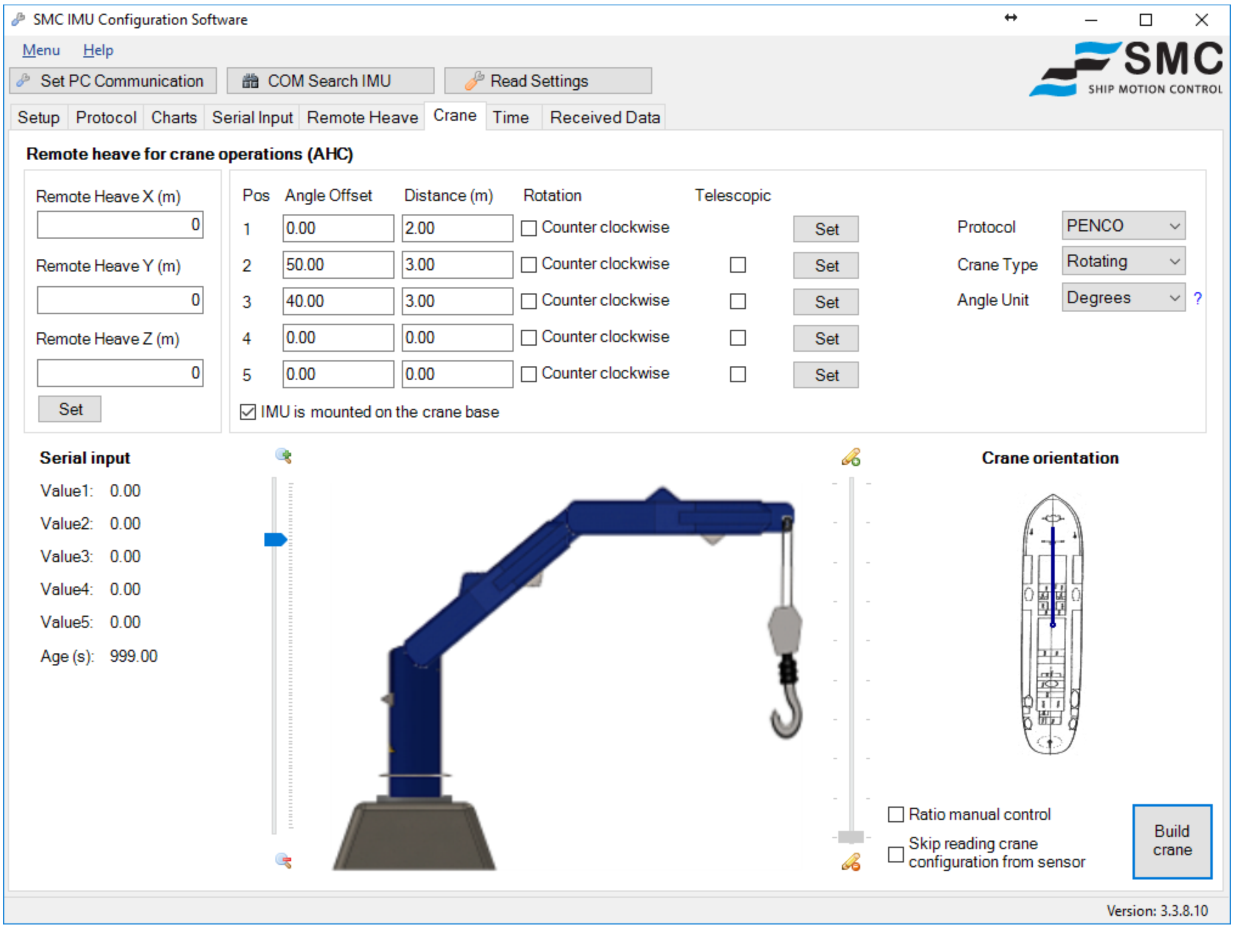
The distance after the encoder to the next encoder is to be entered into the system under column Distance.

Telescopic arm

When a telescopic arm is being used instead of a knuckle the telescopic check button should be ticked in the configuration software for this position. An offset can be entered and if so, it is referring to the distance offset in the telescopic arm. Zero encoder input is when the telescopic arm is fully retracted. The distance column is disabled when the telescopic arm is ticked as the distance to the start of the telescopic arm extension is to be entered in the previous row distance info.

Crane examples

The crane layout below will be used as the basis for all the crane examples in the sections below. The encoder distances and offsets have been entered manually, the angles are in degrees.

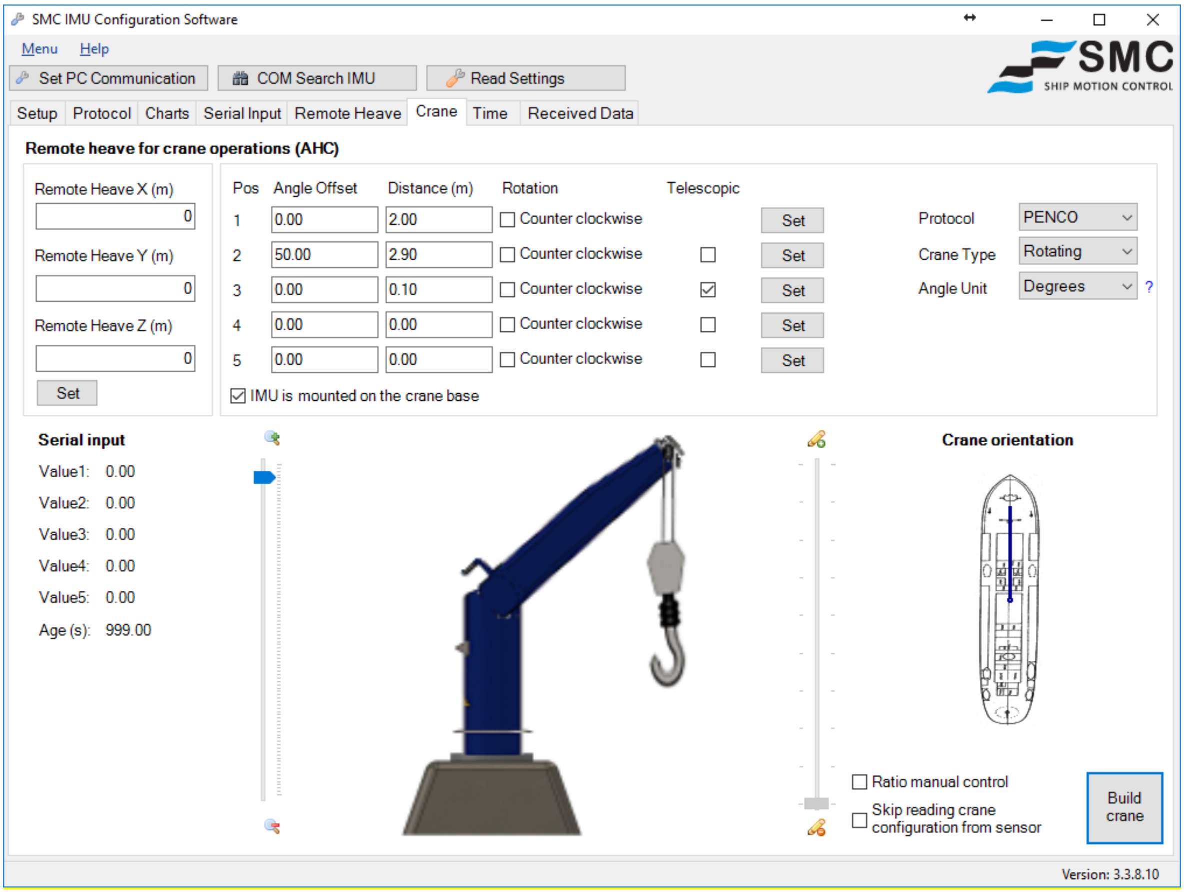


4.10.5 TELESCOPIC ARM INPUT DATA

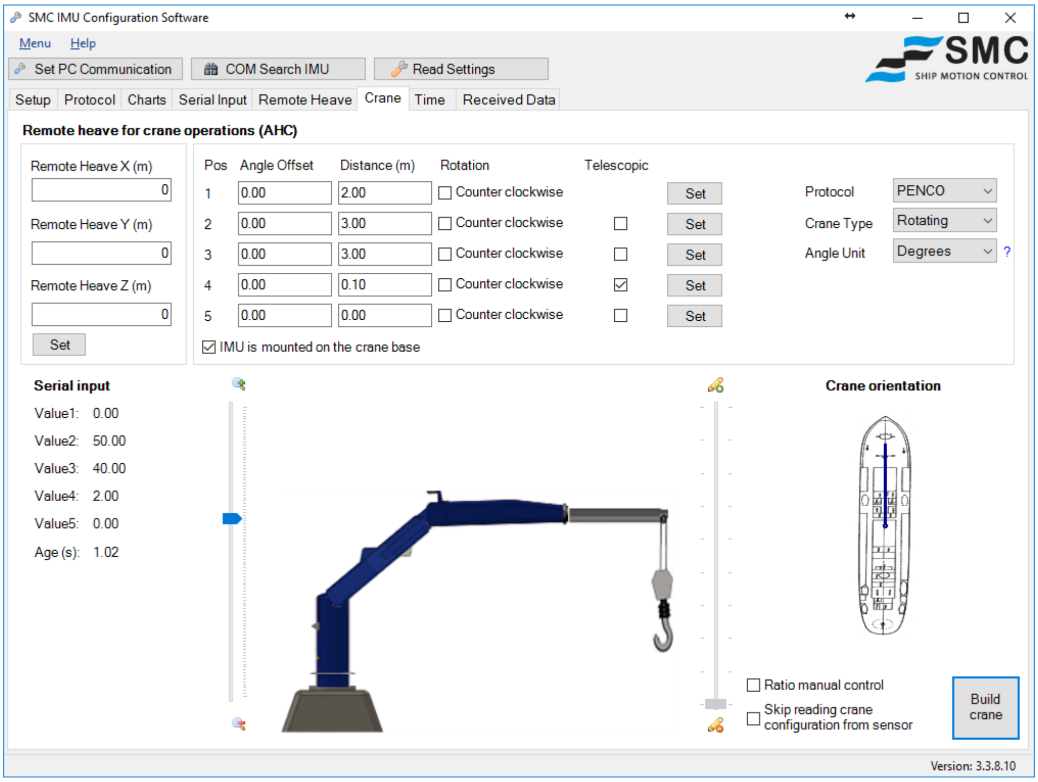
If the crane has a telescopic arm, the **Telescopic** box must be ticked for its position.
No angle offset can be set for the telescopic position.
The encoder input value for the telescopic position is used as the length of the telescopic arm.

For the visualization Enter a nominal distance in the Position - Distance field for the telescopic part of the crane, or the telescopic section will *not* be shown in the crane model.

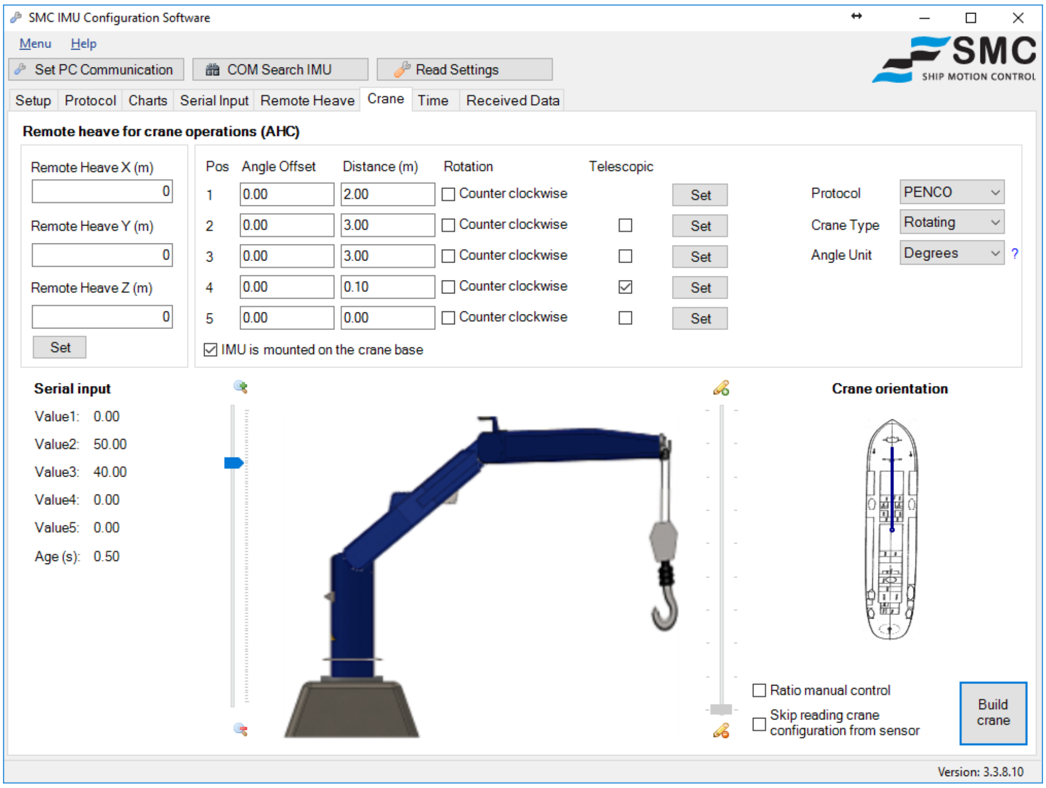
For example, in the below image, Position 3 is a telescopic arm 3m long in total.
The nominal value of 0.1m has been subtracted from Distance 2.



In the example below, **encoder data is used**, with the same position distances as before.
Position 4 is telescopic and Value 4 from the encoder data, is used to draw the distance the arm is extended, in this example 2m.
$PENCO,00.0,50.0,40.0,**2.0**,00.0



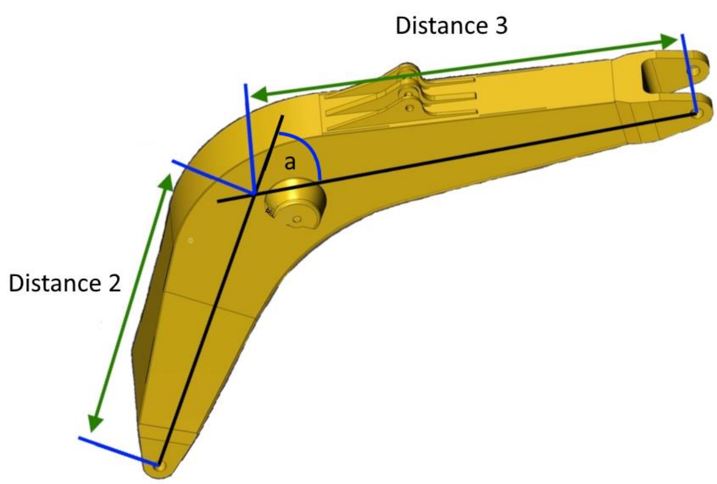
Now the encoder Value 4 is zero and the telescopic arm is fully retracted.
$PENCO,00.0,50.0,40.0,**00.0**,00.0



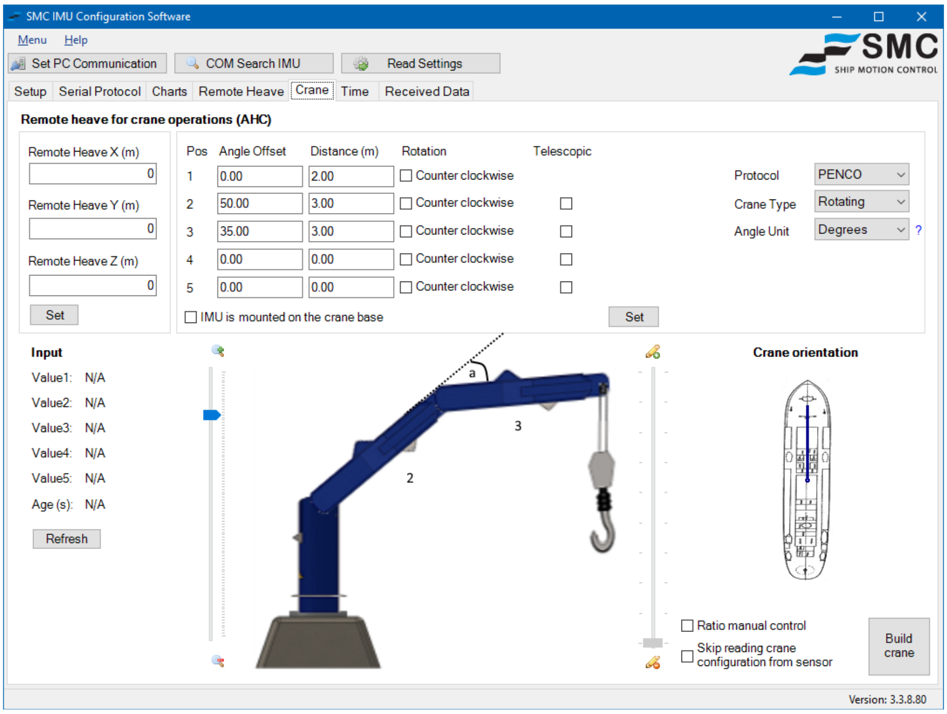
4.10.6 CRANE BOOMS

If the crane has a fixed bend or curved boom, it can be setup in two ways.
Either by sending fixed encoder values from the PLC/encoder device **or** by entering an offset for the bend in the configuration software.

The boom can then be visually represented by dividing the boom into 2 or 3 sections, as appropriate.
In the example below the curved section is divided into two, Distance 2 and Distance 3.
Measured from the knuckle joint to the where the center lines of the arm converge.
The center line intersection also provides angle (**a**) used for the Angle Offset.



For example, if Distance 2 is 3m and Distance 3 is 3m with an offset angle (**a**) of 35 degrees between them, the crane below will be drawn.



The offset is positive in value, if the crane bend is clockwise/downwards.

4.10.7 STRING INPUT

When using crane serial input communication, the data has to be transmitted over an RS232 serial interface.

When the crane position data is being fed into the motion sensor, the output string from the unit will use the current crane position for a remote heave calculation. For the motion sensor to calculate the remote heave on an operating crane installation the crane encoder readings are transferred to the motion sensor for the new crane working position. Below is the description of the predefined data strings to be sent to the motion sensor serial input

Two string options are available for the data input
$PENCR and $PENCO

$PENCR
The $PENCR data string includes up to 5 encoder values:
$PENCR,Value1,Value2,Value3,Value4,Value5<CR><LF>
$PENCR,3FFF,2000,0FA0,0000,0000 = 90˚ rotation, 45˚ first knuckle angle, 22˚ second knuckle angle

Description	Form
Start Characters	$PENCR
Value1	Value1 is the encoder for the Z-axis/yaw/base rotation. I.e. typically the complete crane rotation. Data with the resolution 360°/65536
Value2	Value2 is the encoder for the first knuckle or telescopic arm. When it is being used as a knuckle the data with the resolution 360°/65536 is being entered. If it is a distance being returned from the crane it is in the format 0 – 65535 cm
Value3	Value3 is the encoder for the second knuckle or telescopic arm. When it is being used as a knuckle the data with the resolution 360°/65536 is being entered. If it is a distance being returned from the crane it is in the format 0 – 65535 cm
Value4	Value4 is the encoder for the third knuckle or telescopic arm. When it is being used as a knuckle the data with the resolution 360°/65536 is being entered. If it is a distance being returned from the crane it is in the format 0 – 65535 cm
Value5	Value5 is the encoder for the fourth knuckle or telescopic arm. When it is being used as a knuckle the data with the resolution 360°/65536 is being entered. If it is a distance being returned from the crane it is in the format 0 – 65535 cm

Description of the encoder values:
The encoder readings are sent in an Unsigned 16 bit.
The values are in hexadecimal format 0 to 65535 = 0x0000 …0xFFFF representing 0° - 360°.

If an encoder input is set to be used as Telescopic in the IMU Configuration software, the given encoder value represents a distance value.

The length of a telescopic arm is given in the range of values:
Unsigned 16 bit; values in hexadecimal format 0…65535 = 0x0000 …0xFFFF representing 0 – 65535 cm.

If one rotational point is not being used or is not available input 0 or leave the position blank in the PLC string.

For example, when the motion sensor is mounted on the crane base
$PENCR,0,Value2,encoder3,encoder4,encoder5
Or
$PENCR,encoder2,encoder3,encoder4,encoder5

$PENCO
The $PENCO data string is similar to the $PENCR data string but uses standard notation for the values instead of hexadecimal e.g.:

$PENCO,value1,value2,value3,value4,value5<CR><LF>
$PENCO,32.1,-19.5,0.12,30.4,20.57

If there is no first value (crane rotation) it is excluded or sent as 0 in the same way as the $PENCR string.

Description	Form
Start Characters	$PENCO
Value1	Value1 is the encoder for the Z-axis/yaw/base rotation. I.e. typically the complete crane rotation. Data is in radians or degrees for angles depending of the settings.
Value2	Value2 is the encoder for the first knuckle or telescopic arm. When it is being used as a knuckle the data is entered as degrees or radians. If it is a distance being returned from the crane it is in meters.
Value3	Value3 is the encoder for the second knuckle or telescopic arm. When it is being used as a knuckle the data is entered as degrees or radians. If it is a distance being returned from the crane it is in meters.
Value4	Value4 is the encoder for the third knuckle or telescopic arm. When it is being used as a knuckle the data is entered as degrees or radians. If it is a distance being returned from the crane it is in meters.
Value5	Value5 is the encoder for the fourth knuckle or telescopic arm. When it is being used as a knuckle the data is entered as degrees or radians. If it is a distance being returned from the crane it is in meters.

Description of the encoder values:
The encoder readings are sent in standard encoding e.g.: -17.5, 0.123 and is given as radians or degrees depending on the setting in the configuration program.

If an encoder input is set to be used as Telescopic in the IMU Configuration software, the given encoder value represents a *distance* value.

The length of a telescopic arm is given in meters i.e. 12cm is sent as 0.12

4.10.8 VERIFICATION STRING AND EXAMPLE STRINGS

When the IMU receives a proper $PENCR string with the crane position it will output a verification string with the latest received reading. The verification string is being output on the main com port and not in the serial input port.

The verification string corresponds to the $PENCR string and has the same string format.

If data is being received but is not readable by the motion sensor a fault message will be returned instead of the normal verification string. The Fault message is defined as a string that is not complete or cannot be parsed by the motion sensor.

Example fault message
$PENCT,0000,0000,0000,0000,0000<CR><LF>

When this encoder position below is sent using the $PENCR string:
$PENCR,0000,3FFF,03E8,0000,0000

The motion sensor will return
$PENCT,0000,3FFF,03E8,0000,0000

4.11 TIME

The time feature is available from IMU hardware version 8.2 onwards.

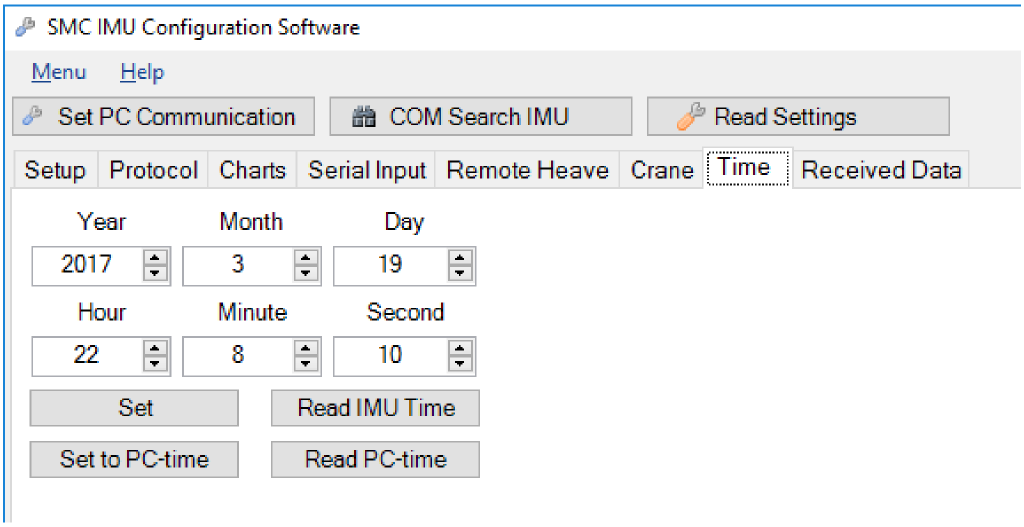
Click on the **Time** tab to display the IMU internal time.

The IMU internal clock time and date can be set manually by adjusting the date and time fields and clicking on the **Set** button.

The IMU time is not displayed continuously but can be refreshed by clicking on the **Read IMU Time** button.

The IMU clock can be set to the PC time by clicking on the **Set to PC-time** button.

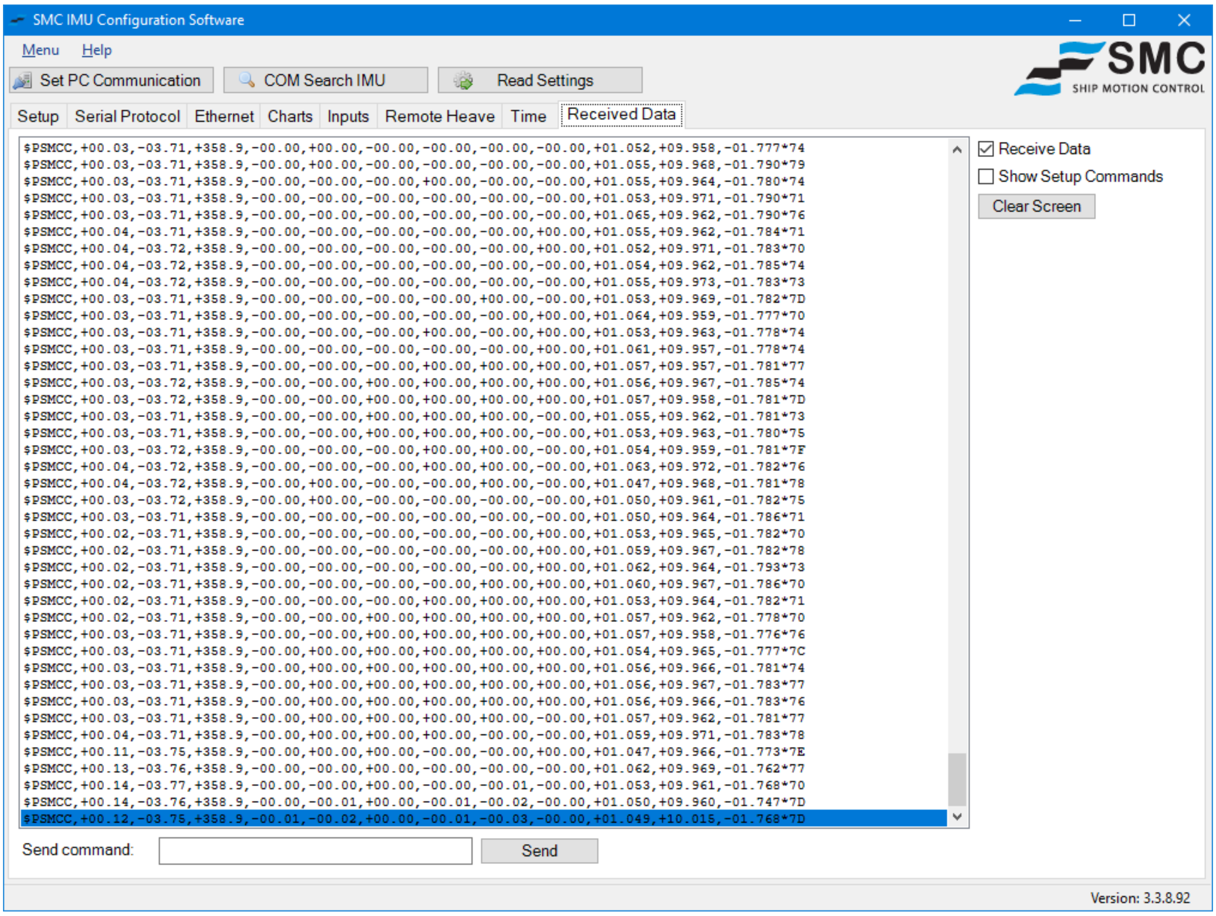
Note: due to read write times the IMU and PC time may not sync exactly.



4.12 RECEIVED DATA

The received data tab shows the raw data string that the sensor sends. Check the Receive checkbox to show the sent data. Press the clear button to clear the window from the sensor strings. Binary strings will not be shown in the received data tab.

When Ethernet communication is used, the Received data tab is hidden and the received data is found in the ethernet tab.



The *Send command* feature can be used to send commands, such as diagnostic queries, to the IMU without the need for terminal software.

This feature must be used with caution and only with the guidance of SMC support personnel.

4.13 OPTIONAL SMC SOFTWARE

There are several optional PC based software packages available from SMC.
They present the vessel motions measured by the motion sensor in a graphical form.
Meteorological instruments are commonly integrated to the SMC software together with the motion sensor. The software displays the integrated instruments in real-time and is also logging the data for future analysis

Examples of SMC software packages are
SMC**mms**: Motion Monitoring System, a general monitoring tool that makes it possible to log and display all ship motions.
SMC**hms:** Helideck Monitoring System, a custom-made system to monitor the motions of a helicopter deck.
SMC**ems:** Environmental Monitoring System
SMC**wms:** Weather Monitoring System

5 MOTION SENSOR OPERATION

5.1 SETTLING TIME

The SMC IMU internal filtering system uses both past and present data to calculate the output. Hence, immediately after being connected to its power source, the sensor will produce less accurate measurements since there are only short sequences of historical data available for processing.

The SMC IMU has a settling time of approximately 1 minute, from the motion sensor startup it will take 1 minute till output data is shown. During this settling time, the sensor output dependent on protocol selected could read for example $PSMCS,+rr.rr,+pp.pp,+hh.hh

5.2 HEAVE OPERATION

SMC IMU-008, IMU-106 and IMU-108 uses a heave measurement and filter system that continually monitors the motions and reviews the previous motions to maintain accurate results whatever the vessel size and sea state. Heave is not available in the IMU-007 and IMU-107 motion sensor.

Heave Zero Point, the zero point is set by the spectral analysis of the sinusoidal waveform along with using filtering techniques that can track the zero point of the heave motions within a maximum of 5 cycles. There is no need to input data of vessel type and sea states expected.

Heave Period; The SMC IMU technology enables the measurement of heave cycles with different periods without any manual setup. The IMU-008, IMU-106 and IMU-108 units adjust their calculations after the current motion and sea state and heave period.

6 SERVICE AND WARRANTY

6.1 TECHNICAL SUPPORT

SMC recommend a recalibration or verification of the motion sensor every second year of usage. This is due to the aging over time of the internal sensors and components in the motion sensor.

If you experience any problem, or you have a question regarding your sensor please contact your local agents or SMC directly.

Refer to website http://www.shipmotion.eu/

Please have the following information available

- Equipment Model Number
- Equipment Serial Number
- Fault Description

Worldwide Service contact
Telephone: +46 8 644 50 10 (CET 8am – 5pm)
E-mail: support@shipmotion.eu

Return Procedure

If this is not possible to solve the problem a Ship Motion Control technician will issue a Return Material Authorization Number (RMA#). Please be ready to provide the following information.

- Name
- Address
- Telephone, Fax, E-mail
- Equipment Model Number
- Equipment Serial Number
- Installation Date

If the Sensor is under warranty, repairs are free. Please see the SMC Ship Motion Control warranty statement.

Pack the sensor in its original packaging, or suitable heavy packaging.

Mark the RMA# on the outside of the package

Return the Sensor, prepaid carrier to SMC

6.2 WARRANTY

All products are inspected prior to shipment and SMC manufactured products are guaranteed against defective material or workmanship for a period of two (2) calendar years after delivery date of purchase. SMC liabilities are limited to repair, replacement, or refund of the factory quoted price (SMC's option). SMC must be notified and provided with sufficient time to remedy any product deficiencies that require factory attention. This time period may include but is not limited to standard production lead times, travel time and raw material lead times. SMC will not be responsible for any charges related to repair, installation, removal, re-installation, or any actual, incidental, liquidated, or consequential damages. All claims by the buyer must be made in writing. All orders returned to SMC must have an issued RMA number supplied by the SMC prior to shipment. Only SMC shall have the authority to issue RMA numbers.

Any products manufactured by others supplied with and/or installed with SMC's products are covered by the original manufacturers' warranty and are excluded from SMC's warranty

SMC manufactured product must be sent to SMC for repair or replacement.

Please read the SMC Ship Motion Control terms and conditions for complete information.

6.2.1 LIMIT OF LIABILITY

SMC shall have no liability under the warranties in respect of any defect in the Products arising from: specifications or materials supplied by the Buyer; fair wear and tear; wilful damage or negligence of the Buyer or its employees or agents; abnormal working conditions at the Buyer's premises; failure to follow SMC's instructions (whether oral or in writing); misuse or alteration or repair of the Products without SMC's approval; or if the total price for the Products has not been paid.

SMC shall in no event be liable for any indirect or consequential, or punitive damages or cost of any kind from any cause arising out of the sale, use or inability to use any product, including without limitation, loss of profits, goodwill or business interruption. In case of failure in the product the company is not liable to compensate the buyer with anything exceeding the cost of the product sold by SMC.

The exclusion of liability in these Terms & Conditions shall not apply in respect of death or personal injury caused by SMC's negligence.

SMC shall not be bound by any representations or statements on the part of its employees or agents, whether oral or in writing, including errors made in catalogues and other promotional materials.

Please read the SMC Ship Motion Control terms and conditions for complete information.

6.2.2 RESTRICTION OF WARRANTY

The warranty does not cover malfunction of the motion sensor generated from

- If the IMU has been exposed to extreme shock and vibrations
- If the IMU case has been opened by the customer in an attempt to carry out repair work
- If the IMU has been fed with an over voltage in the power supply wires or the signal wires

The motion sensor electronics are shielded in a cast of plastic supported inside an outer casing made of Titanium to prevent damage from impact and moisture.

The SMC IMU should not be opened as this could affect the warranty on the unit. All operations inside the sensor must be carried out by SMC personnel.

7 TECHNICAL SPECIFICATIONS

7.1 IMU-00X TECHNICAL SPECIFICATIONS

Model Features

	IMU-007	IMU-008
Roll / Pitch	Yes	Yes
Accelerations	Yes	Yes
Heave	N/A	Yes

Performance

Angle Accuracy static	0.2° RMS	0.2° RMS
Angle Accuracy Dynamic @ ±5° simultaneous roll and pitch	0.25° RMS	0.25° RMS
Angle range Roll/Pitch	± 30°	± 30°
Heave Accuracy	N/A	5cm or 5%
Acceleration accuracy	0.05 m/s^2 RMS	0.05 m/s^2 RMS

Communication

Ethernet 10/100 mbit. UDP and Modbus TCP/IP

Com1: RS232 Bi-Directional

Com2: RS422 Bi-Directional

Com3: RS232 Data Output and Aiding input

Com4: RS232 Aiding input only

Analog output V or mA with remote converter (optional)

Velocity input formats RMC, RMA, VTG, VBV, VHW; Heading input formats HDT, HDG

SMC IMU Configuration software included

User selectable Output Protocols

User selectable Output Rate 1-200hz

Physical

Dimensions (W x D x H) 134 x 134 x 67mm excl connector

Weight ~1 kg

Housing Material Titanium

Environmental

Temperature -20° to +55° Celsius

Storage Temperature -40° to +65° Celsius

MTBF (computed) 50 000 hours

IP66 as standard; IP68 30 meter depth rated optional

Mounting Orientation Horizontal as standard or Vertical as option (factory set)

Electrical

Power requirements 12 - 30 VDC; 3 W, versions without ethernet 2 W

Standard Complies with the IEC 60945

Warranty & Support

2-year Limited Hardware & Software Warranty

Free Technical & Hardware support

7.2 IMU-10X TECHNICAL SPECIFICATIONS

Model Features

	IMU-106	IMU-107	IMU-108
Roll / Pitch	N/A	Yes	Yes
Accelerations	N/A	Yes	Yes
Heave	Yes	N/A	Yes

Performance

	IMU-106	IMU-107	IMU-108
Angle Accuracy static	N/A	0.02° RMS	0.02° RMS
Angle Accuracy Dynamic @ ±5° simultaneous roll and pitch	N/A	0.03° RMS	0.03° RMS
Angle range Roll/Pitch	± 30°	± 30°	± 30°
Heave Accuracy	5cm or 5%	N/A	5cm or 5%
Acceleration accuracy	N/A	0.01 m/s^2 RMS	0.01 m/s^2 RMS

Communication

Ethernet 10/100 mbit. UDP and Modbus TCP/IP
Com1: RS232 Bi-Directional
Com2: RS422 Bi-Directional
Com3: RS232 Data Output and Aiding input
Com4: RS232 Aiding input only

Analog output V or mA with remote converter (optional)
Velocity input formats RMC, RMA, VTG, VBV, VHW; Heading input formats HDT, HDG
SMC IMU Configuration software included
User selectable Output Protocols
User selectable Output Rate 1-200hz

Physical

Dimensions (W x H) Ø134 x 127mm excl connector
Weight ~1.5 kg
Housing Material Titanium

Environmental

Temperature -20° to +65° Celsius, outside 0° to +55° Celsius, 0.1° angle performance
Storage Temperature -40° to +65° Celsius
MTBF (computed) 50 000 hours
IP66 as standard; IP68 30 meter depth rated optional
Mounting Orientation Horizontal as standard or Vertical as option (factory set)

Electrical

Power requirements 12 - 30 VDC; 3 W, versions without ethernet 2 W
Standard Complies with the IEC 60945

Warranty & Support

2-year Limited Hardware & Software Warranty
Free Technical & Hardware support

8 FAQ & SUPPORT

If no communication is seen or bad data is displayed, please refer to the FAQs below which cover the most common configuration problems.

Configuration

Is the unit sending data with RS422 or RS232?

The motion sensor is *always on* and sends data over the RS232 and RS422 channels simultaneously.
The IMU sensor junction boxes are dispatched pre-configured for either RS422 or RS232.
Check the wiring as per the Electrical configuration guide to see which output is being used.

Data is being received but is either seen as bad data or wrong data.

Check which format your sensor has been configured with or contact SMC quoting the units serial number for confirmation.

When applying a setting change in the SMC IMU Configuration Software the output signals can display bad data.
This occurs during the automatic restart of the sensor unit, the values will settle after a few minutes.

Data that is being received is missing data or freezing. First check if the Output Rate is set too high for the configured output string and baud rate. Details are supplied in Section 4.2 for each protocol.

Also check the Serial port, if using a Serial to USB adapter, use a high quality adapter. Contact SMC for advice.

Parameters changed in the Configuration software are not being set in the IMU.

If after pressing the set button the parameters set in the IMU are not changing, check if the IMU serial number and software version is displayed in the configuration software.
If not, press the **Read Settings** button. If the data is still not showing this is typically due to the lack of two way communication to the IMU. The Receive data lines are connected but not the Transmit data lines. Check the wiring through to the IMU.

Are the cables connected correctly?

No Communication with the IMU

Check the cable connection and disconnect and reconnect is necessary.
Is the sensor powered up? Voltage should be 9 to 30 VDC

Check what Baud Rate and Output Rate should be used or has been set up. Use the **Search IMU** button to scan all available ports.

The default baud rate set when the unit is shipped from SMC is 115200 and the standard output rate is set to 100Hz. (note for SMCems software the IMU output rate should be 10Hz).

If there is a chance that the baud rate has been changed and the **Search IMU** button does not find the IMU, systematically check each baud rate option in the SMC IMU Configuration Software until the correct rate is found.
When applying a setting change in the SMC configuration software the output signals can display bad data. This occurs during the automatic restart of the sensor unit, the values will settle after a few minutes.

No GPS or Gyro data is received

Select the relevant **Verify** button in the Serial Input configuration screen.
If no data is received check the baud rate setting of the GPS device. Set the GPS to 4800 baud rate if set higher and verify again.
Check the wiring of the RS232 serial input.

Heading Information from GPS is not shown in the Output Protocol

There is a check button in the SMC configuration software to accept the heading string from the GPS ($GPHDT) Check the box labelled **Use GPS Heading input for Yaw aiding if available**.