# SMC IMU

## User´s Guide

# Notice

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



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SMC Ship Motion Control Ltd
Email: info@shipmotion.eu
Web: www.shipmotion.eu
Tel: +46 8 644 50 10

# TABLE OF CONTENTS

# 1 INTRODUCTION

This user's manual gives information about your IMU - motion sensor and how to use it.

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

- Hydrographic business for heave compensation using multi beam sonars, single beam sonars and sub bottom profilers.

- System integration for different type of monitoring systems as helideck monitoring, crane monitoring systems.

- Active heave compensation for cranes and winches.

- Dynamic positioning systems

Products Covered in this User´s Guide

***Surface units***

| | Roll & Pitch (Dynamic) | Heave | Acceleration |
|---|---|---|---|
| IMU-007 | 0,25 RMS | N/A | 0,01 $m/s^2$ RMS |
| IMU-008 | 0,25 RMS | 5cm or 5% | 0,01 $m/s^2$ 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 units, 30 m depth rated***

| | Roll & Pitch (Dynamic) | Heave | Acceleration |
|---|---|---|---|
| IMU-008-30 | 0,25 RMS | 5cm or 5% | 0,01 $m/s^2$ RMS |
| IMU-108-30 | 0,03 RMS | 5cm or 5% | 0,01 $m/s^2$ RMS |

***Special units***

| | Roll & Pitch (Dynamic) | Heave | Acceleration |
|---|---|---|---|
| IMU-007-L | 0,25 RMS | N/A | 0,01 $m/s^2$ 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´s guide

## 1.1 DEFINITIONS

**Alignment**
The alignment of the motion sensor is the adjusting the IMU into the frame system of the external body/vessel. The alignment should be done physically and can be tuned in the system software by entering offsets for roll, pitch and the Z-axis.

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

**Roll**
Roll is the rotation about the roll axis of the body. SMC defines the port up as a positive roll.

**Pitch**
Pitch is the rotation about the pitch axis of the body. SMC defines the bow down as a positive pitch.

**Heave**
Heave is the vertical dynamic motion of the body. The heave calculation is done 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/Sway**
Surge/Sway is the horizontal dynamic motion of the body. The Surge motion is the linear motion in the roll axis direction where a positive surge is when the body is moving forward in the bow direction. The Sway motion is the linear motion in the pitch axis direction where a positive sway is in the port direction. The surge and sway calculation is done 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 CoG is the mass center of a vessel.

**X-axis/Roll axis**
The X axis is the bow/stern axis in the vessel/body. The 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/body. The rotation in the Y axis will generate a pitch motion where a positive rotation is bow down.

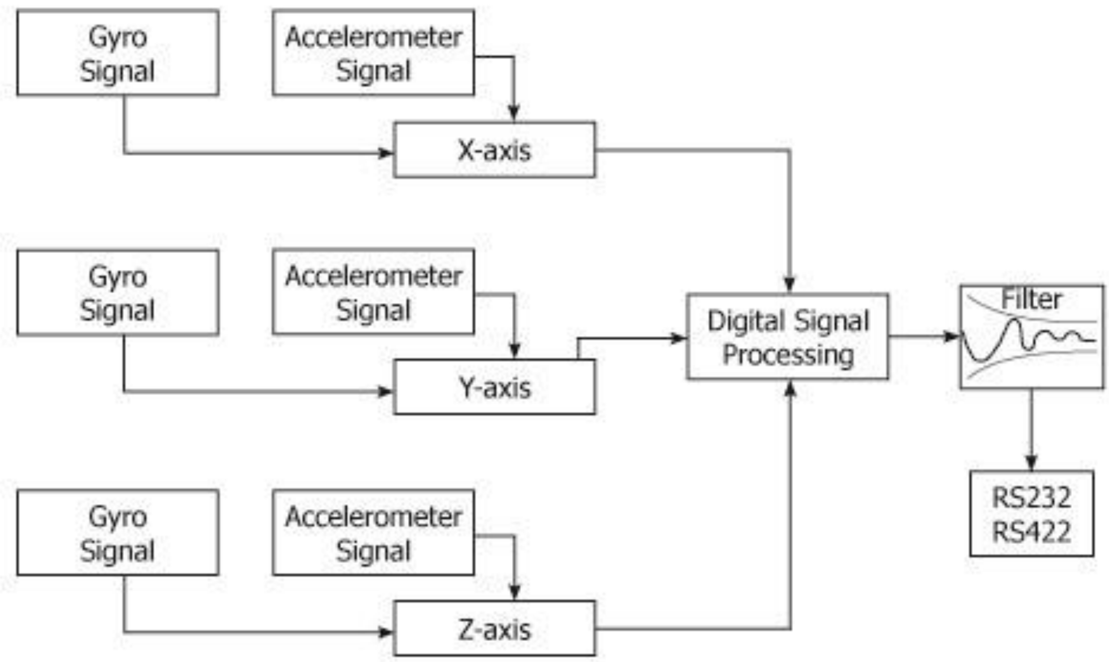
**Z-axis**
The Z axis is the vertical axis pointing up and down in the vessel. The rotation in the Z axis will generate a yaw motion where a positive rotation is a clock wise rotation.

**RMS**
Root mean square (RMS) is the average error of a measurement

# 2 SYSTEM DESCRIPTION

The SMC motion sensors has 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.

The signal from the gyroscopes are combined with the signal from the accelerometers and is processed in a Kalman filter inside the IMU to provide the output of acceleration, attitude and angle values from the motion sensor with limited influence of accelerations.

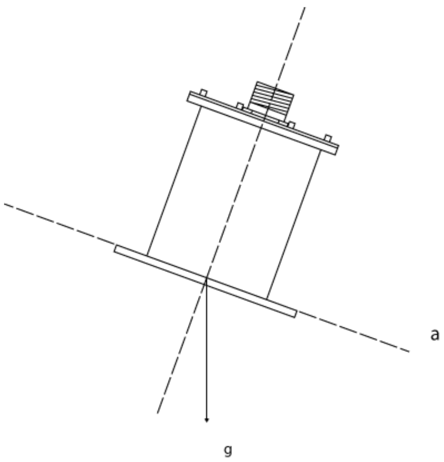



Heave, surge and sway is calculated by integrating the acceleration in the X, Y and Z axis twice. The integration is then filtered with a high pass filter. The calculations of the distances are optimized for continues motion and is not working properly for static distance measurements as the high pass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

Before delivery all motion sensors passes a calibration. In this process which is individual for every motion sensor unit the readings from the accelerometers and angular rate gyroscopes are being calibrated for alignments, linearity and temperature. The motion sensors are verified after the calibration to meet the performance specifications. The calibration is done in angles up to +/-30 degrees angle. The best performance is achieved within this angle range. If the motion sensor angle exceeds the calibrated angular range the calibration data will be extrapolated outside the calibrated range, which may lead to decreased performance in large angles.

## 2.1 SPATIAL MOVEMENT (COORDINATE SYSTEM)

The SMC motion sensor defines its body axis from the Tait-Bryan/Euler angles.



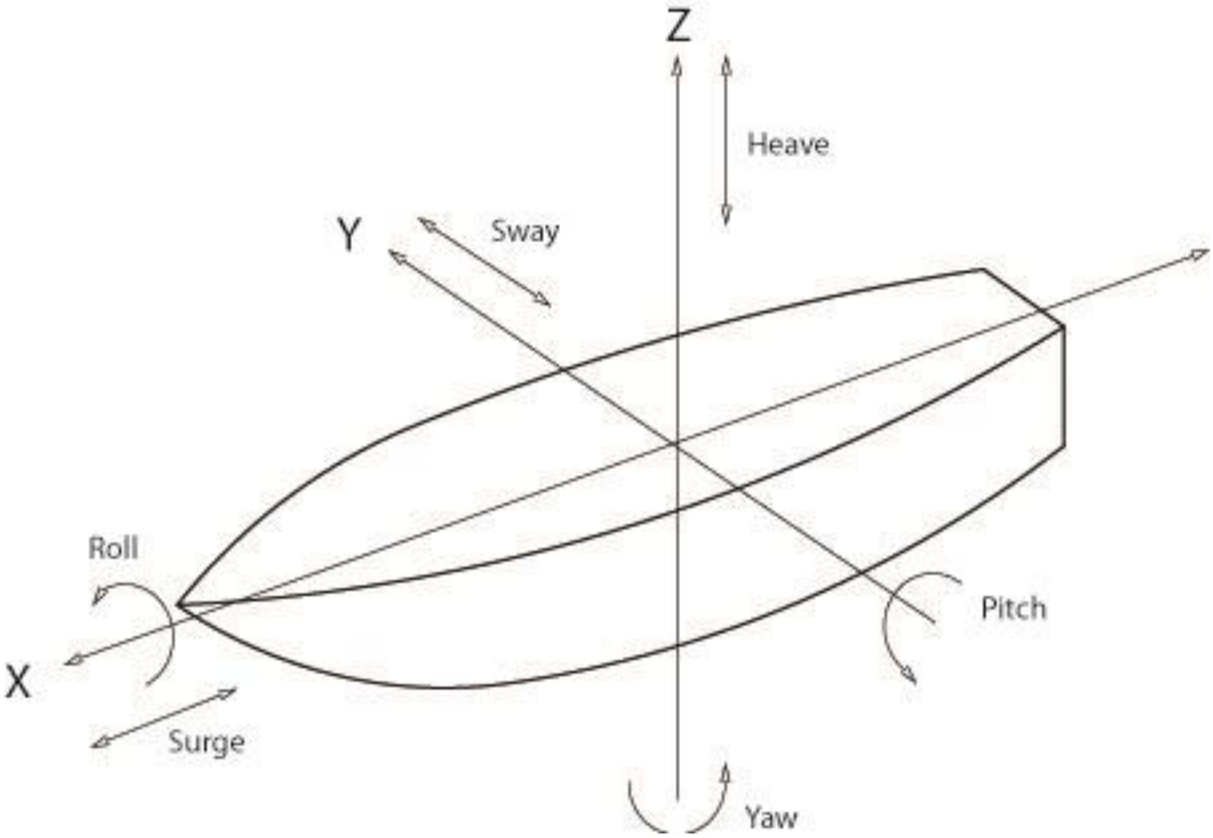

In the SMC motion sensors the coordinate system can be defined by a simple setting option in the PC based SMC configuration software that is included together with the motion sensor. The user can choose between the rigid body coordinate system and the absolute earth coordinate system.
The standard IMU set is for Earth Coordinates without earth G in Acc.

With knowledge of the gravity (g) and the measured acceleration in different directions from the accelerometers and is used to calculate the orientation of the accelerometers in relation to earth.

From the SMC configuration software motion sensor offset in roll, pitch and Z-axis can be set for alignment errors in the physical installations. It is also possible to invert the axis to fit the receiving application. The SMC default rotational and acceleration directions are defined in the drawing below. By setting an offset in the SMC configuration software the motion sensor rotates its coordinate system. For optimum performance align the motion sensor as good as possible before setting up offsets electronically.

**Note that the Z-axis offset is to be used to align the physical misalignment in the Z-axis mounting and is not to set the yaw angle output in the motion sensor. An improper Z-axis rotation will rotate the coordinate system. A misalignment in the Z axis will induce roll motion readings in the pitch axis and the vice versa**.

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


Z
Heave
Y
Sway
Roll
Pitch
X
Surge
Yaw

# 3 STORAGE AND UNPACKING

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

The motion sensor is delivered in a transit case designed to protect it from high shocks during transit.

When the unit has been received it should 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 the damage is visible a claim for shipping damage should be filed immediately.

Because of the sensitive nature of the IMU's the package must not be dropped.

**Standard Delivered Items**

- IMU
- Transit Case
- Junction Box     Fitted with
    - IMU to JB 10m 12 core cable
    - Serial Output Data lead 1.5m
    - AC Input Cable 0.9m
- Calibration Certificate
- CD with IMU Configuration Software plus IMU User Manual

# 4 INSTALLATION

The SMC motion sensor has to be installed according to the instructions of this manual.

## 4.1 LOCATION

The optimal positioning of the sensor is normally as close to the vessels center of gravity as possible. However for certain applications, mainly when heave and accelerations are to be measured at a specific location, it is advised to mount the motion sensor as close as possible to the actual measurement point. These applications are for example in helideck systems and in some hydrographic survey systems. The motion sensor is designed to be installed in an internal environment.

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

**Roll & Pitch;** when mounting the IMU, take care to align the sensor according to the vessels roll and pitch axis. If there is an axis misalignment in the Z-rotation, 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 setup 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 unit 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. At the same time avoid mounting the sensors near to machines with sporadic operation e.g. hydraulic pumps.

**Water;** The SMC IMU-007, IMU-008, IMU-106, IMU-107 and IMU-108 as standard is IP64 protection rated. The standard surface unit is designed to be mounted in an internal environment but is possible to mount outdoor. The SMC IMU-108-30 is IP68 water proof down to 30 meters depth or optional 1000 meters.

**Mounting orientation;** The IMU is calibrated from the factory for Deck or Sideways orientation. Deck orientation is when the IMU is mounted on a horizontal surface. Sideways orientation is when the IMU is calibrated to be mounted on a vertical surface. The Deck mounting calibration is the default orientation. A unit that has been calibrated for Deck mounting cannot be used in a sideways mounting and vice versa without recalibration of the IMU at the factory.

## 4.2 MOUNTING INSTRUCTIONS

The mounting plate has been specifically designed to enable ease of installation by allowing freedom of movement to help align the motion sensor. The motion sensor is not shipped with mounting screws or bolts. The mounting plate can be used with a maximum M8 screw or bolt. Remove the motion sensor while the mounting location is prepared. See motion sensor Dimensions **Figure 4.3**

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

Mount and screw the motion sensor in position, taking care to align the IMU as best possible.

For a deck mounting motion sensor, it is not possible to mount the unit upside down with the connector pointing downwards. The motion sensor has to be mounted with the connector pointing upwards.

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

When mounting the motion sensor sideways the user is given 4 mounting options in the SMC setup software to rotate its coordinate system correct. For more information see the chapter for sideways calibrated setup.

If an incorrect mounting selection is done in the Configuration software the coordinate system will be inverted. In this case the roll motion will become the pitch motion alternatively the positive negative rotation of the angles will be inverted.

When the motion sensor is calibrated for sideways mounting (connector pointing horizontally) and has been 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 unit has been mounted incorrectly the mounting will need to be corrected. If the IMU is mounted incorrectly it will not work within its calibrated range and output inaccurate values.

## 4.3 ALIGNMENT

**To achieve maximum performance it is important to perform an accurate alignment of the motion sensor to the vessel longitudinal axis.**

**The physical alignment should be done as good as possible using the notches on the motion sensor mounting plate. For the deck mounting option the single notch is to be pointing to the fore direction of the vessel. A misalignment in the Z-rotation (yaw) will generate a cross axis motion, where pitch will generate in a roll reading from the motion sensor and vice versa.**

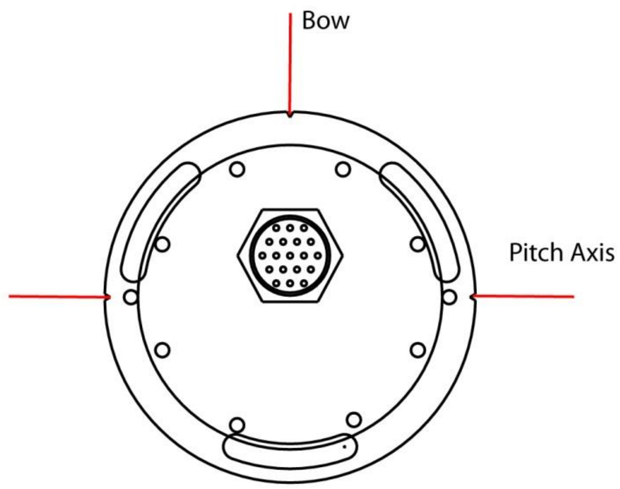
**From the SMC configuration software it is possible to do a mathematical alignment for the fine tuning of the motion sensor. Note that the Z-axis alignment in the IMU configuration software only to be used for the physical misalignment and not to change the yaw output reading from the motion sensor.**

## 4.4 DECK MOUNTED (MOUNTED ON HORIZONTAL SURFACE)

When the IMU is calibrated for Deck mounting the unit cannot be used for Sideway mounting without a recalibration at the factory.

The mounting of the motion sensor should be carried out with the mounting plate lying horizontally. The notches are marking the rotation of the motion sensor. The indexes (see fig) marking the P-axis (Pitch axis) is supposed to be mounted pointing to port/starboard. The single notch is to be mounted pointing to the bow of the vessel.

Place the motion sensor flat on the mounting location that have been selected and align the P-axis mounting indexes along the vessels center of rotation or on the axis you have defined. (The single notch should be pointing to the bow)



## 4.5 SIDEWAYS MOUNTING

When the IMU is calibrated for Sideways mounting the unit cannot be used for Deck mounting without a recalibration at the factory.

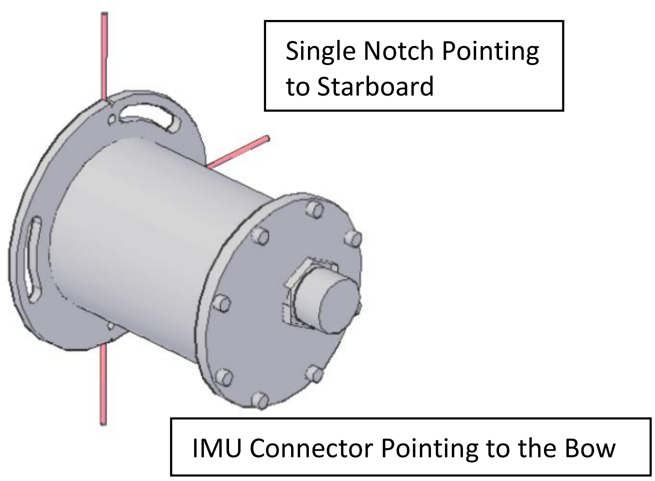
**Note: The IMU cannot be mounted in the sideways orientation unless it has been specifically calibrated to do so. Contact SMC if clarification is required.**

The mounting of the motion sensor should be carried out with the mounting plate lying vertically. The notches mark the rotation of the motion sensor. The indexes marking the P-axis should be mounted pointing to vertical. The single notch should be mounted pointing horizontally to the bow/stern/port/starboard of the vessel. Depending of the mounting direction the unit needs to be setup for its coordinate system. This is done in the SMC configuration software.

### 4.5.1 TOP OF THE IMU POINTING TO THE BOW

When the IMU top (where the connector is located) is pointing to the **Bow** of the vessel the single notch should be pointing horizontally against the **Starboard**.

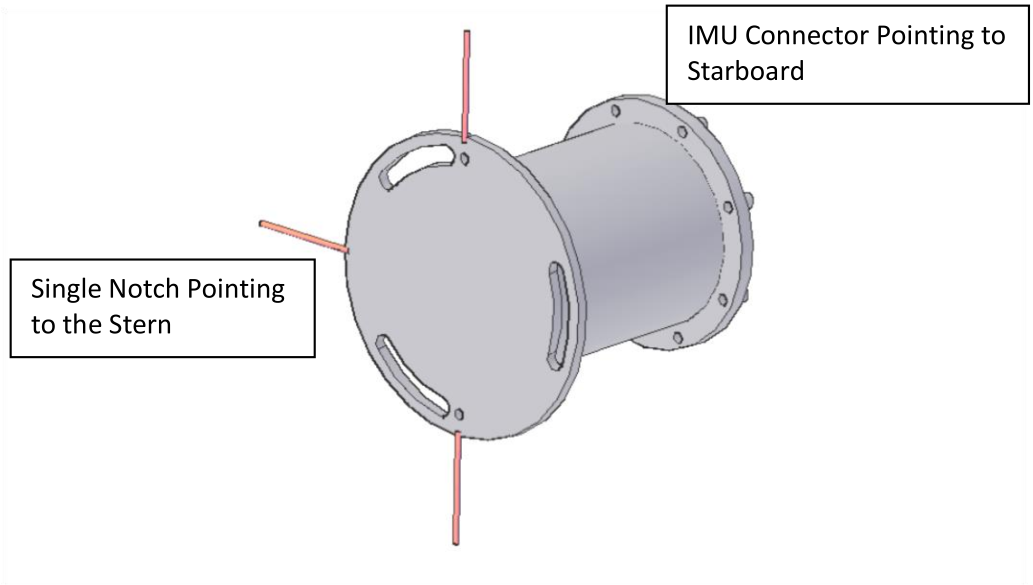
In the SMC setup software "Top of the IMU pointing to the Bow" must be selected.



### 4.5.2 TOP OF THE IMU POINTING TO THE STABOARD

When the IMU top (where the connector is located) is pointing to the **Starboard** of the vessel the single notch should be pointing horizontally against the **Stern**.

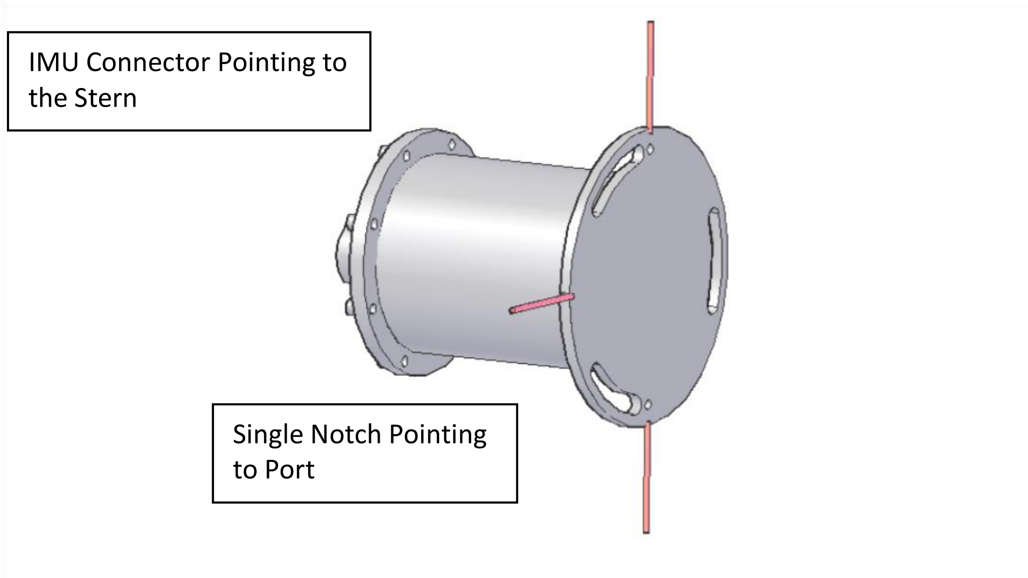
In the SMC setup software "Top of the IMU pointing to the Starboard" must be selected.




### 4.5.3 TOP OF THE IMU POINTING TO THE STERN

When the IMU top (where the connector is located) is pointing to the **Stern** of the vessel the single notch should be pointing horizontally against the **Port**.

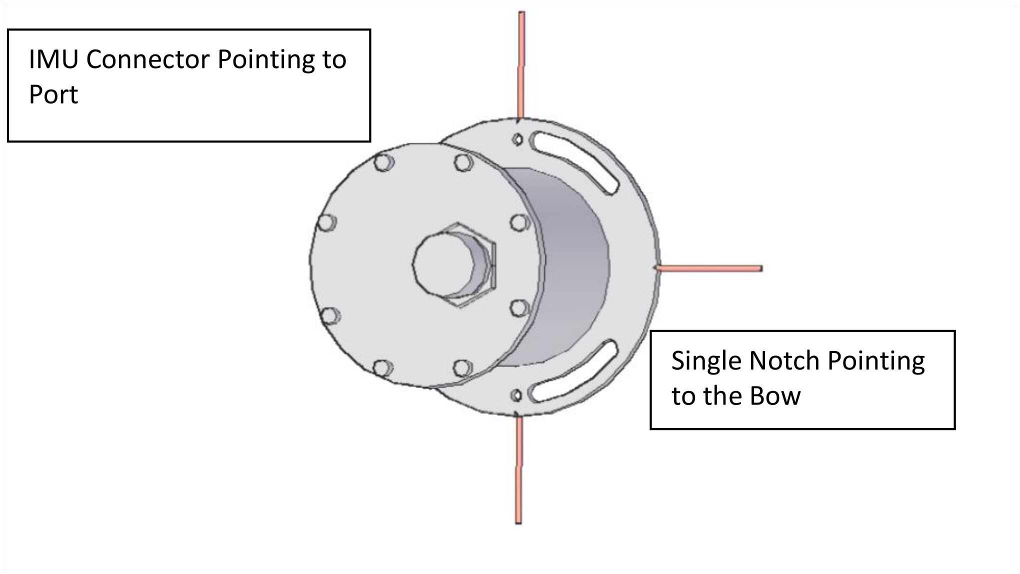
In the SMC setup software "Top of the IMU pointing to the Stern" must be selected.



### 4.5.4 TOP OF THE IMU POINTING TO THE PORT

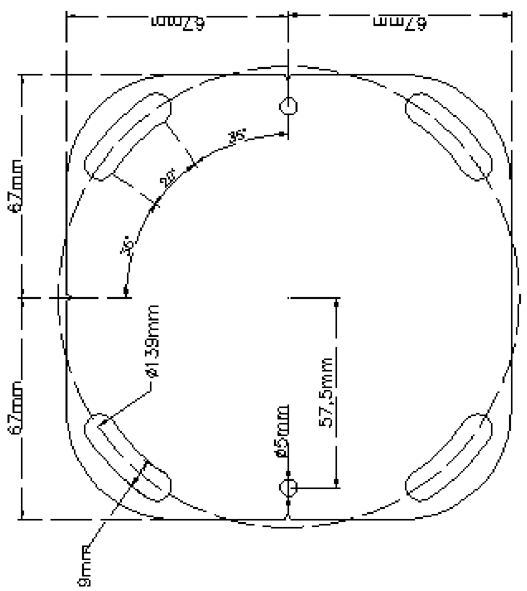
When the IMU top (where the connector is located) is pointing to the **Port** of the vessel the single notch should be pointing horizontally against the **Bow**.

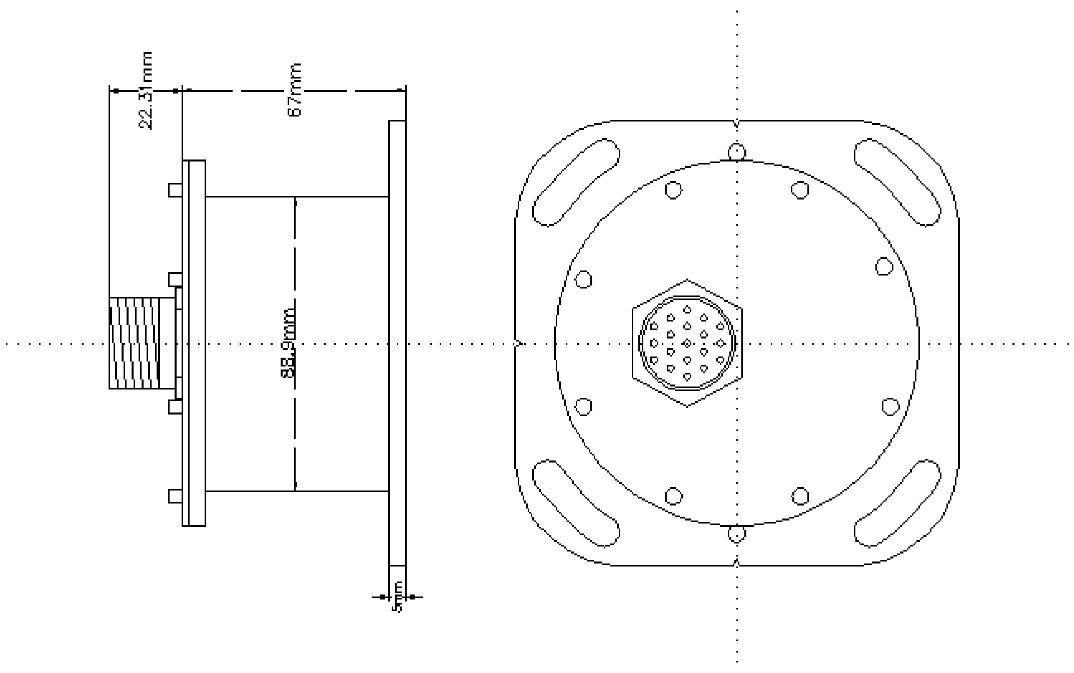
In the SMC setup software "Top of the IMU pointing to the Port" must be selected.



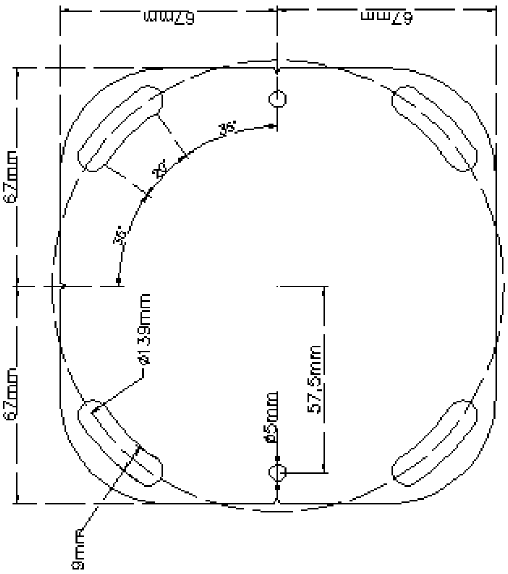
## 4.6 IMU DIMENSIONS

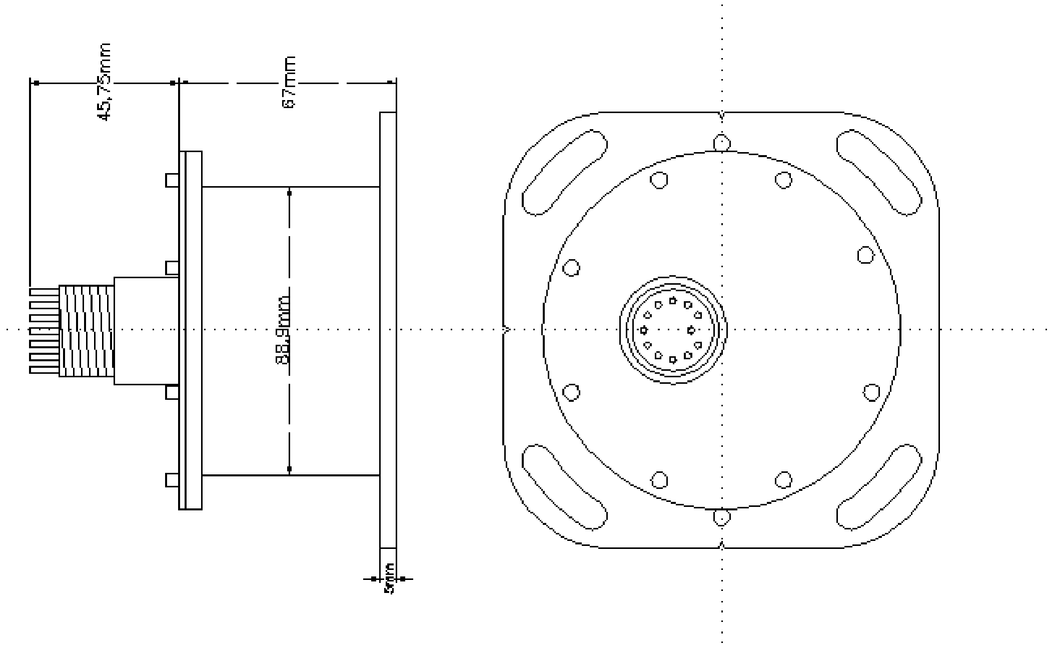
### 4.6.1 IMU-00X SURFACE UNIT



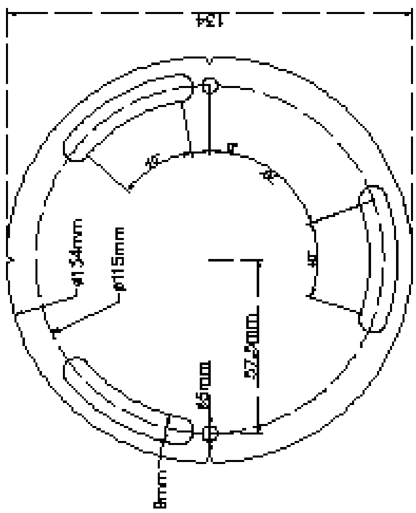



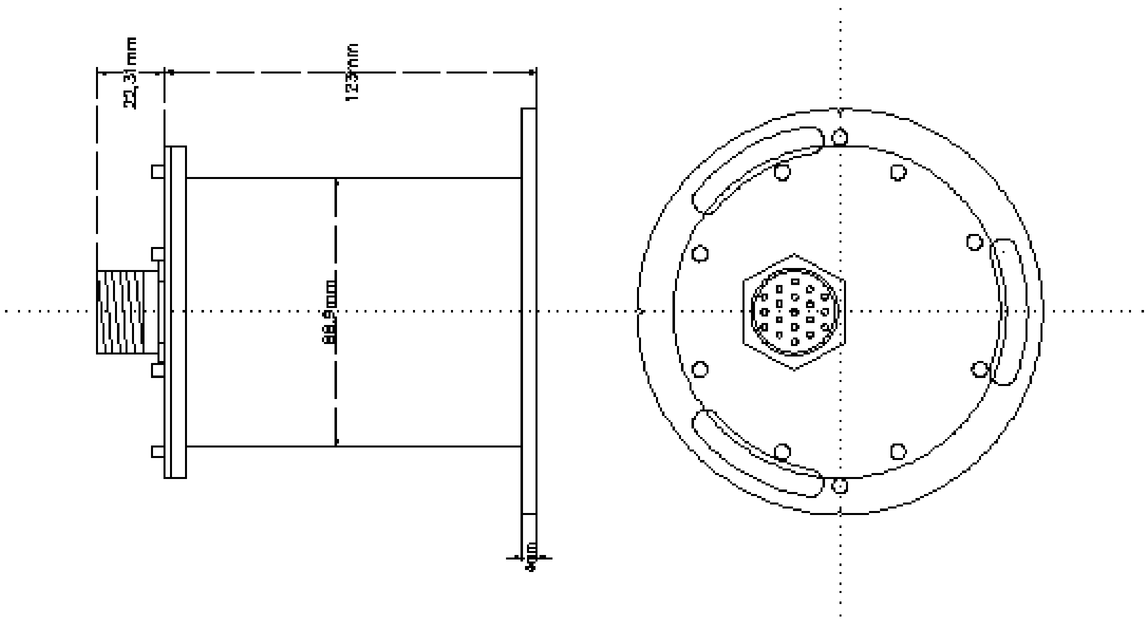
### 4.6.2 IMU-00X 30M DEPTH RATED UNIT



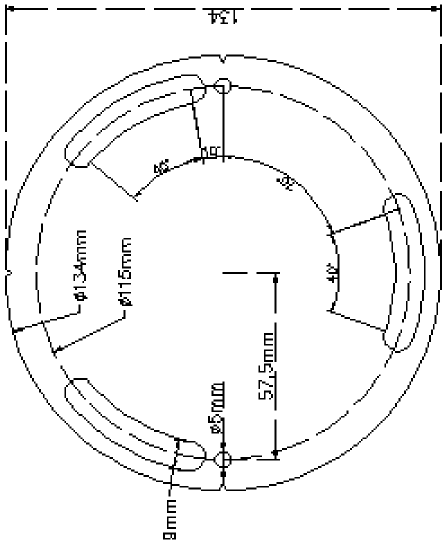



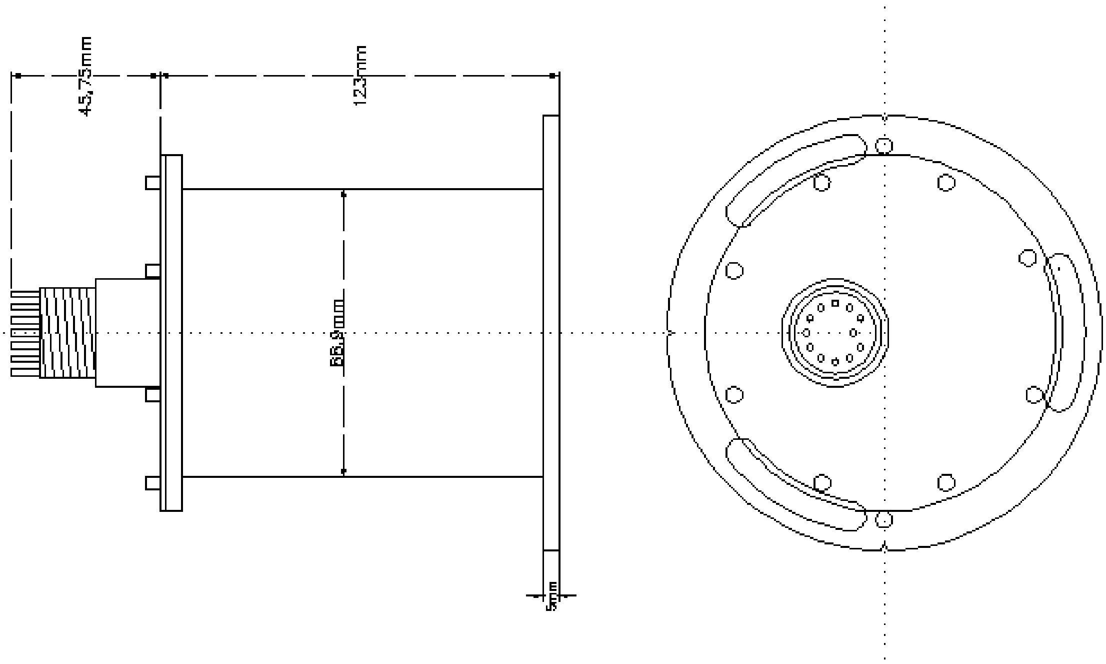
## 4.6.3 IMU-10X SURFACE UNIT





#### 4.6.4 IMU-10X 30M DEPTH RATED UNIT



## 4.7 ELECTRICAL COMMUNICATION

The SMC IMU is operating from 12-30 VDC power supply. The power consumption during normal conditions is between 2 and 2.5 watts.

The SMC IMU's have both RS422 and RS232 serial outputs as standard. The Junction Box shipped with the unit is prefigured in the factory for RS232 or RS422. This can be changed in the field by the user by change the wiring of the serial cable inside the junction box. See the wiring diagram for wiring details.

RS422 communication can achieve data transfer over long distance cables. RS232 is designed for short distance communication, (max 20 meters). The RS422/RS232 cable normally terminates with a conventional DB9 connector.

Two RS232 serial ports are also available for aiding by GPS and/or Compass of the motion sensor.

[redacted]

**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.**

### 4.7.1 SERIAL RS232 AND RS422 INTERFACE CONNECTION GUIDE

The IMU's are equipped with both an RS422 and RS232 interface. In the below tables information is available for the cable communications. The motion sensor is at all times communicating over both RS232 and RS422 and no configuration is needed inside the motion sensor.

The IMU can be used to supply data out on both the RS232 & RS422 outputs at the same time. Only one data string output format and set up can be used for both outputs.

As a default there is one cable interface into the junction box. Below are two tables for RS232 and RS422 connections. The DB9 connector should have the below configuration.

#### 4.7.1.1 IMU SURFACE UNITS OUTPUT CONNECTION CABLING

**RS232 Connections DB9 Connections**

| Sensor Connector | Cable Colour | Sensor Function | DB9 to PC/Converter |
|---|---|---|---|
| 1 | White | RS232 – RxD | 3 |
| 2 | Red | RS232 – TxD | 2 |
| 11 | Grey | Supply Voltage - | 5 |
| 12 | Pink | Supply Voltage 12 – 30 Vdc | |

**RS422 Connections DB9 Connections**

| Sensor Connector | Cable Colour | Sensor Function | DB9 to PC/Converter |
|---|---|---|---|
| 3 | Brown | RS422 – TxD+ | 3 |
| 4 | Orange | RS422 – TxD- | 4 |
| 5 | Green | RS422 – RxD- | 1 |
| 6 | Purple | RS422 – RxD+ | 2 |
| 11 | Grey | Supply Voltage - | 5 |
| 12 | Pink | Supply Voltage 12 – 30 Vdc | |

#### 4.7.1.2 IMU SURFACE UNITS INPUT CONNECTIONS

**RS232 Serial Input 1 Connections DB9 Connections**

| Sensor Connector | Cable Colour | Sensor Function | DB9 to PC/Converter |
|---|---|---|---|
| 7 | Yellow | RS232 – RxD | 3 |
| 8 | Transparent | RS232 – TxD | 2 |
| 11 | Grey | Supply Voltage - | 5 |
| 12 | Pink | Supply Voltage 12 – 30 Vdc | |

**RS232 Serial Input 2 Connections DB9 Connections**

| Sensor Connector | Cable Colour | Sensor Function | DB9 to PC/Converter |
|---|---|---|---|
| 9 | Black | RS232 – RxD | 3 |
| 10 | Blue | RS232 – TxD | 2 |
| 11 | Grey | Supply Voltage - | 5 |
| 12 | Pink | Supply Voltage 12 – 30 Vdc | |

### 4.7.1.3 IMU 30 DEPTH RATED UNIT CONNECTION CABLING

**RS232 Output Connections DB9 Connections**

| Sensor Connector | Cable Colour | Sensor 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 – 30 Vdc | |

**RS422 Output Connections DB9 Connections**

| Sensor Connector | Cable Colour | Sensor 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 12 – 30 Vdc | |

**RS232 Serial Input 1 Connections DB9 Connections**

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

**RS232 Serial Input 1 Connections DB9 Connections**

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

### 4.7.2 RS422 CABLE CONNECTION

The RS422 cable consists of two twisted-pairs conductors (4 wires) for bi-directional communication.

The thickness of power cables is such that there is no more than a 2V drop with a 50 mA current applied over an exceptional length of cable. Cable and conductors are supplied on demand for an additional cost. The maximum cable length allowed is approximately 1 300 m using RS422.

### 4.7.3 RS232 CABLE CONNECTION

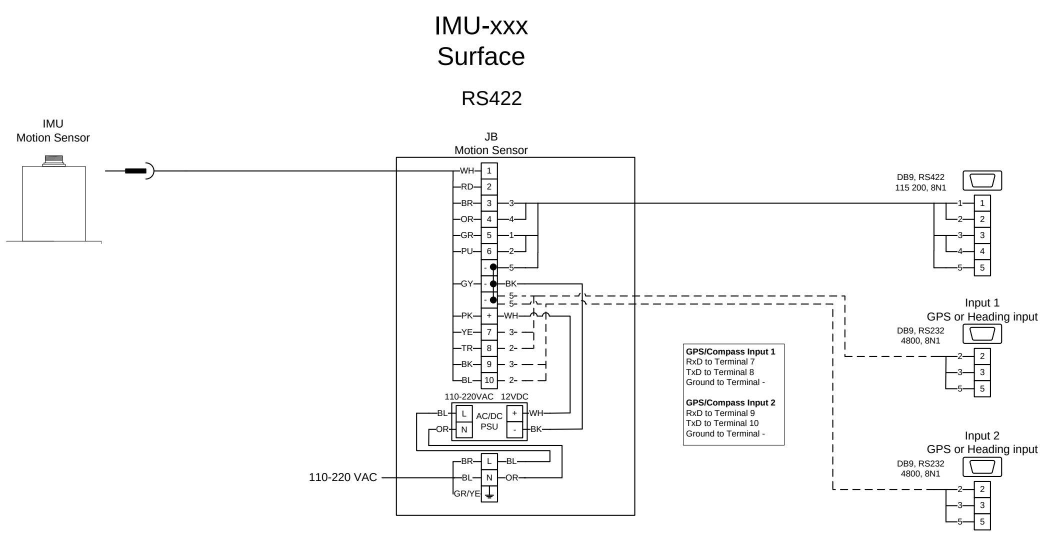
The RS232 cable consists of single twisted-pair conductors (2 wires) for bi-directional communication, plus 2 power supply wires. Total of 4 conductors. The maximum cable length allowed is approximately 20 m using RS232.

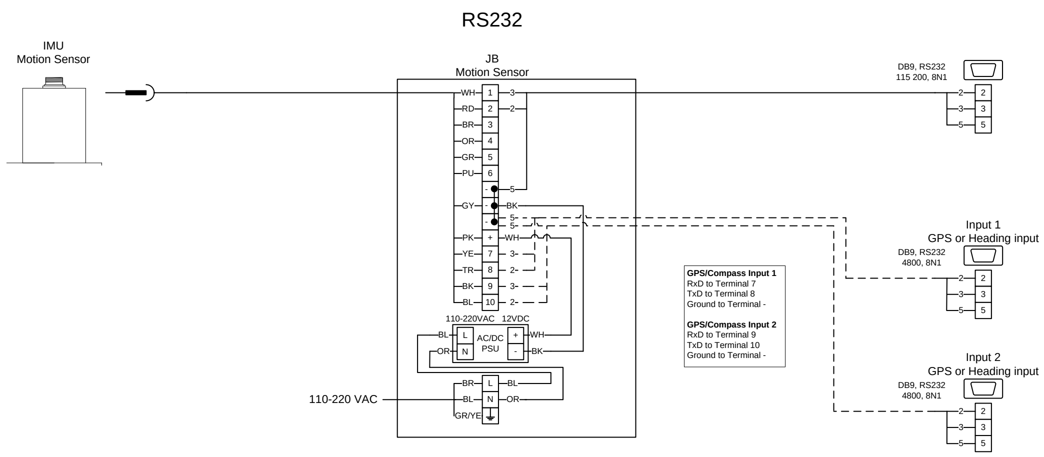
## 4.8 ELECTRICAL INSTALLATION

The SMC IMU's are powered with a standard 12 VDC or 24 VDC supply. It is possible however to supply power at any voltage between 9 VDC and 30 VDC.

The SMC IMU's does not have an on/off switch. The motion sensor operates as soon as power is supplied to it. There is an initialization of the IMU that prevent it from outputting numerical data for the first 4 minutes after the motion sensor has been powered up.

### 4.8.1 IMU-XXX SURFACE UNIT WITH SERIAL INPUTS

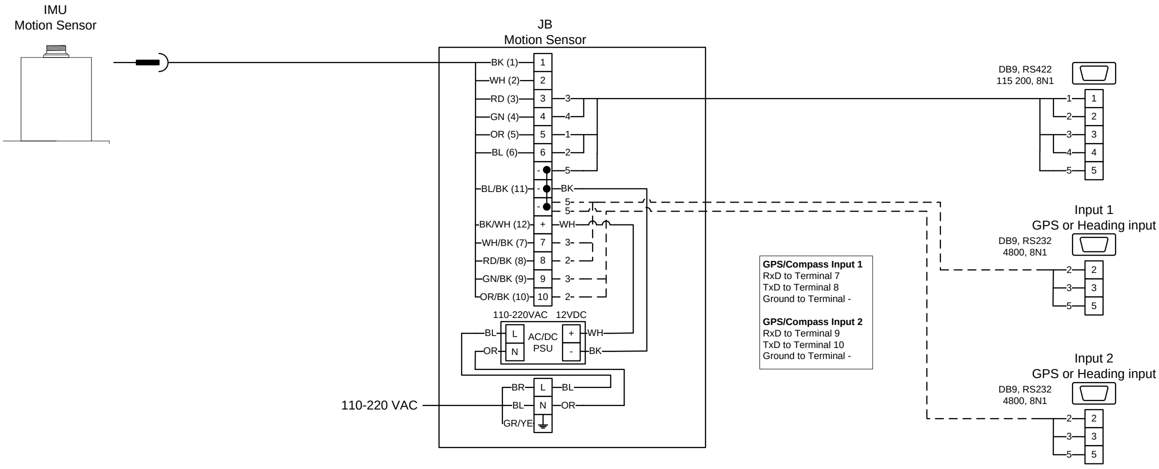


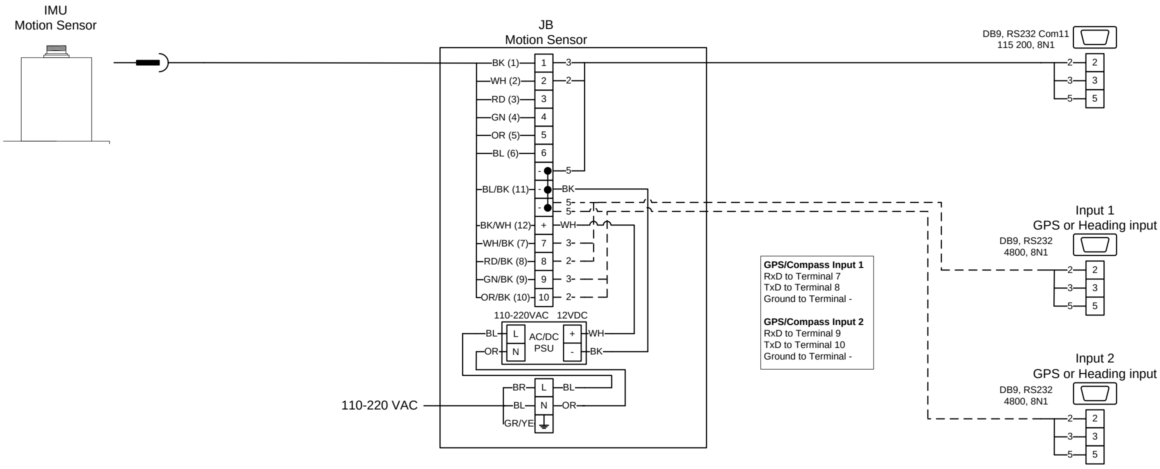
## 4.8.2 IMU-XXX-30 DEPTH RATED UNIT

IMU-xxx-30

RS422

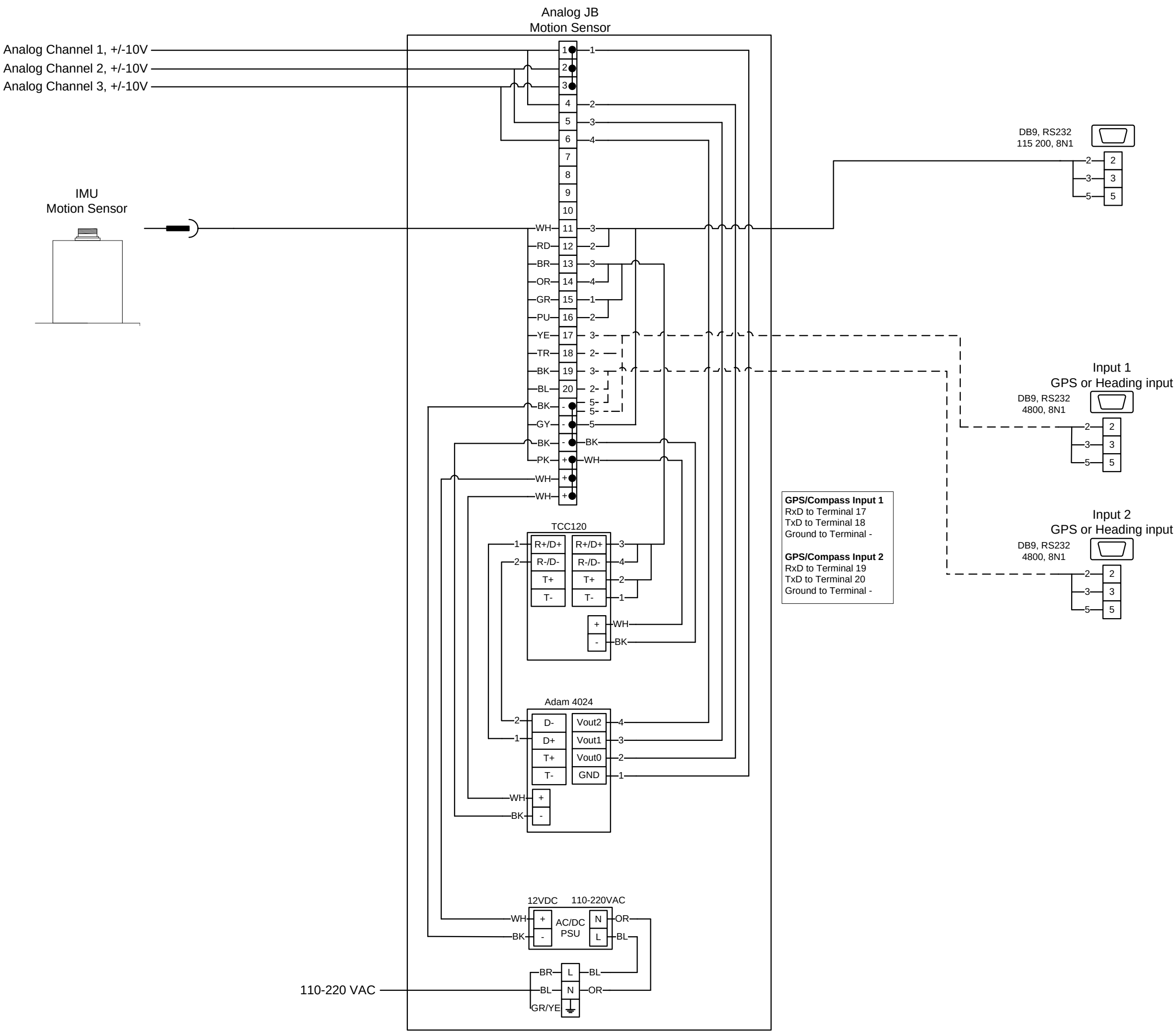



RS232



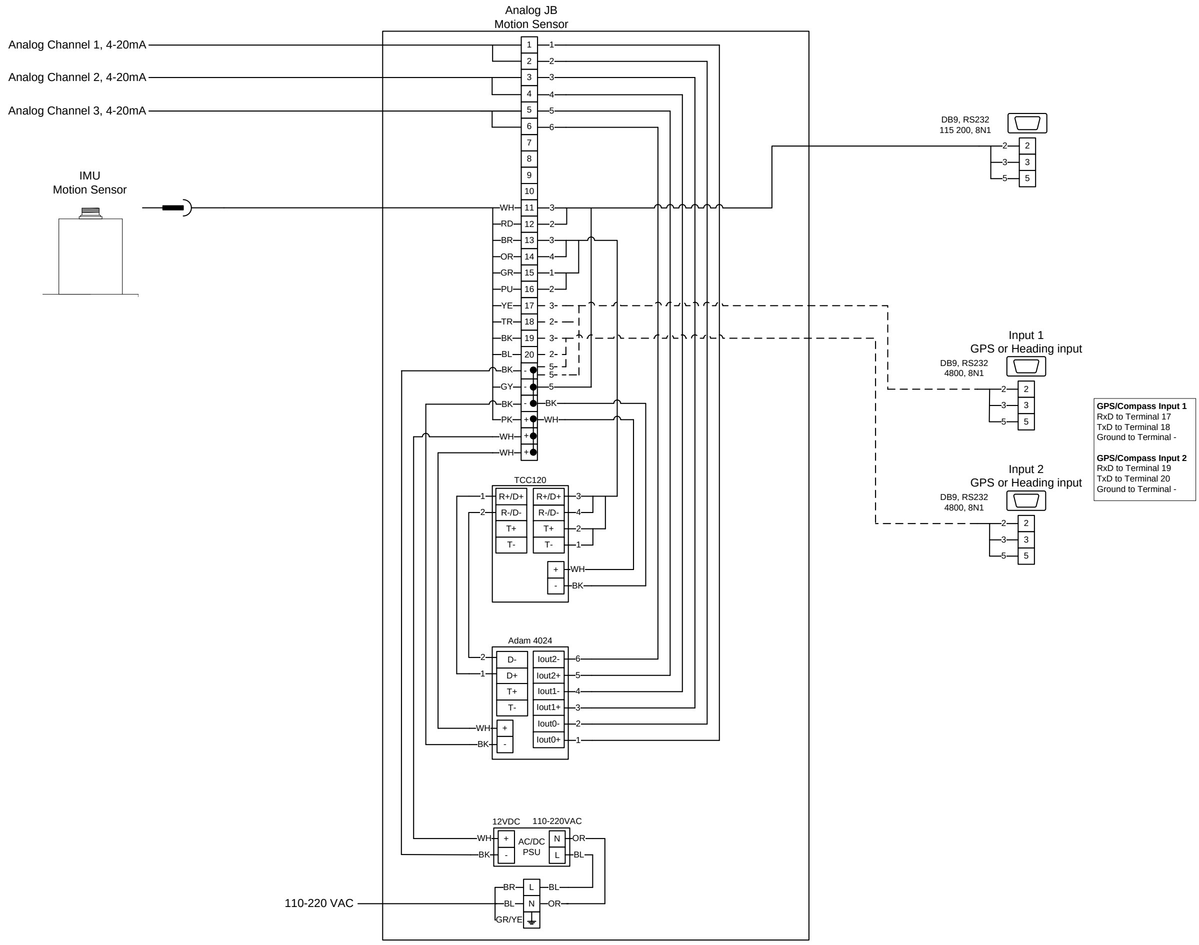
### 4.8.3 IMU-XXX ANALOG VOLTAGE OUTPUTS

**IMU-xxx analog output**



## 4.8.4 IMU-XXX ANALOG CURRENT 4-20MA OUTPUTS

IMU-xxx analog output

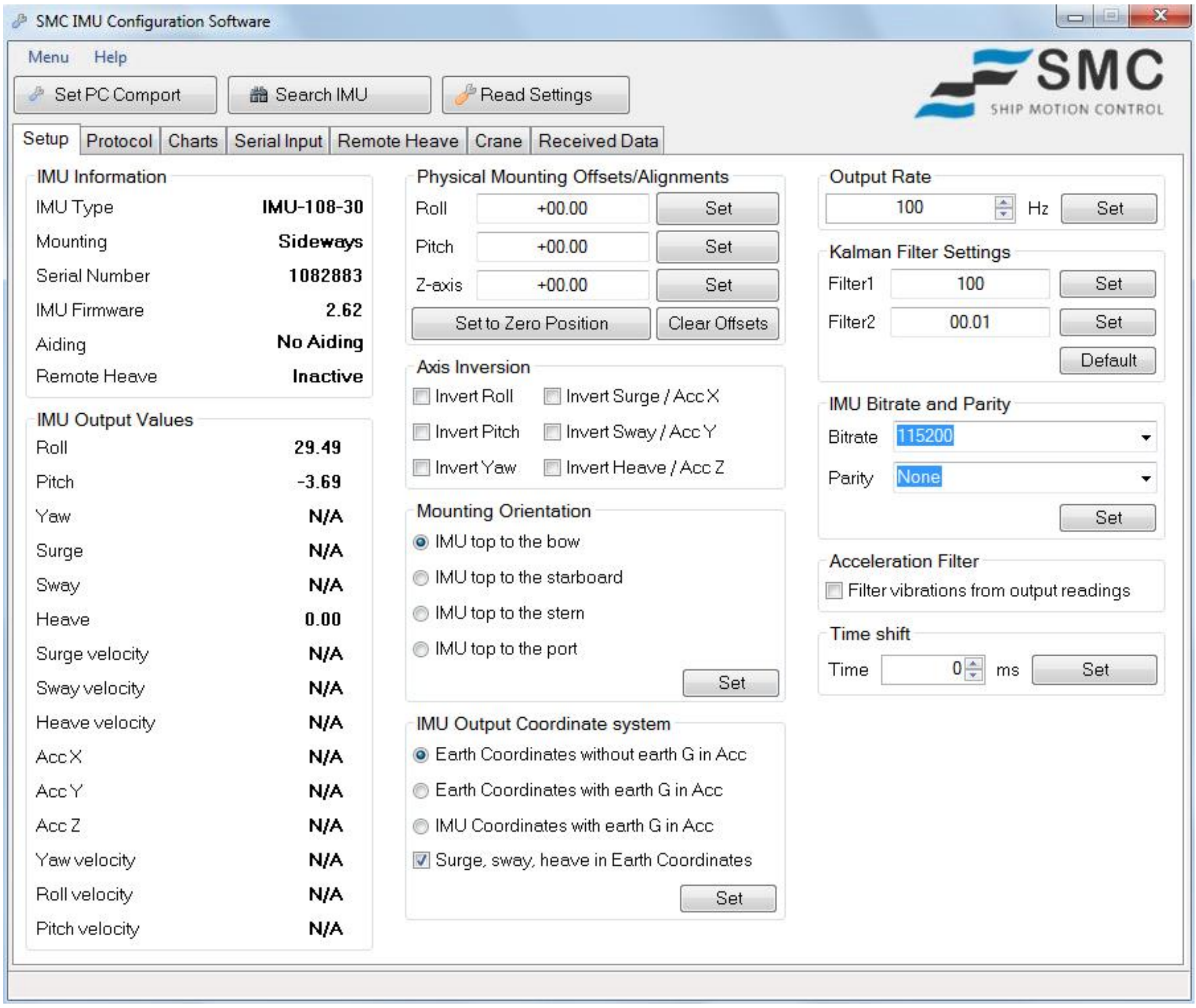


# 5 IMU CONFIGURATION GUIDE

## 5.1 IMU CONFIGURATION SOFTWARE

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

The settings made from the IMU Configuration software is made inside the motion sensor. The settings are stored in a flash memory inside the motion sensor and are not dependent of power supply or battery power.



### 5.1.1 DEFAULT SETTINGS AT FACTORY

There are several Motion Sensor parameters that can be selected from the Configuration software. The factory default settings are as follows.
If you want to change the default settings it is recommended to do it after the installation but before you connect to any systems. Please refer to 5.1.2 (setup).

| Settings | Selection | Factory Default |
|---|---|---|
| Data Update Frequency | 1 – 100Hz | 100 |
| Bit Rate | 9600<br>19200<br>38400<br>57600<br>115200 | 115200 |
| Data Bits | 8 | 8 |
| Stop Bits | 1 | 1 |
| Parity | None<br>Odd<br>Even | None |
| Flow Control | None | None |
| Angular Filter | Filter 1 (0 – 1000)<br>Filter 2 (0 – 1000) | IMU-00x Filter 1 (25)<br>Filter 2 (0.01)<br><br>IMU-10x Filter 1 (100)<br>Filter 2 (0.01) |
| Coordinate System | Earth<br>Motion Sensor | Earth |

### 5.1.2 SETTINGS

**Set COM-port configuration;** The COM-port settings are where and with which parameters the computer is receiving data from the sensor. These should be the same as in the sending sensor. The sensor will always send its data with 8 data bits, 1 stop bit, and no parity and without flow control.

**IMU Information;** Shows information about motion sensor IMU type, mounting orientation, serial number, IMU firmware, date and time. If a signal string selected does not include time the motion sensor time will not be shown in the setup software.

**IMU Output Values;** Shows data sent from the motion sensor in real time. Only values that are being output from the IMU are displayed in this section.

**IMU Zero Position;** By pressing the "Set Zero Position" button the current IMU inclination will be set to be the zero point, i.e. reference point for the angle measurements. "Clear zero" button will enter 0 offset for the roll, pitch and yaw values.

**Mounting Offset Angles;** the offsets can be manually entered into the motion sensor instead of using the IMU Zero Position. *The yaw alignment has to set manually. The offset entered into the IMU rotates its coordinate system.* To achieve accurate angles outputs from the motion sensor the yaw axis alignment is very crucial. Try to mount the motion sensor as good as possible physically before adjusting the offsets electronically.

**Axis Inversion;** Enables the sign inversion of the output signals from the motion sensor. See Chapter 2 for information about SMC rotational definitions.

**Mounting Orientation;** Is available only if the IMU has been calibrated for sideways mounting orientation. See Chapter 4 for more information about the mounting orientation options.

**IMU Output Coordinate System;** The IMU 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 IMU will use the earth (horizon) as the system by which Roll & Pitch & Heave are based around. The acceleration will not include g as part of the value.

Earth Coordinates with earth G in Acc; in this configuration the IMU will use the earth (horizon) as the system by which Roll, Pitch & Heave are based around. The acceleration will include the g value of $9.81 m/s^2$.

IMU Coordinates with earth G in Acc; in this configuration the IMU will use its form or the equipment it is mounted to as a basis around which Roll, Pitch & Heave are calculated around. The acceleration will include the g value of $9.81 m/s^2$.

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

**Output Rate;** adjusts the number of times the IMU outputs its string per second. Choose the wanted value in the list box and press the set button to set the wanted frequency.

**Kalman Filter Settings**
Filter 1 sets the filter for the accelerometers (default 100)
Filter 2 sets the filter for the gyros (default 0.01)

The value entered in the angle filter setting specifies how much each sensor type (accelerometer and gyro) is “applied”. The lower value the more we apply the sensor type.

This means that the higher value that is set on the accelerometer the less influence the acceleration will have. But it will also generate a bigger random walk from the gyros.

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;** Adjusts the bit rate that the sensor uses for transmitting data. Write down the selected Bitrate and Parity. To be able to connect to the IMU a matching communication setting must be set for the receiving device

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

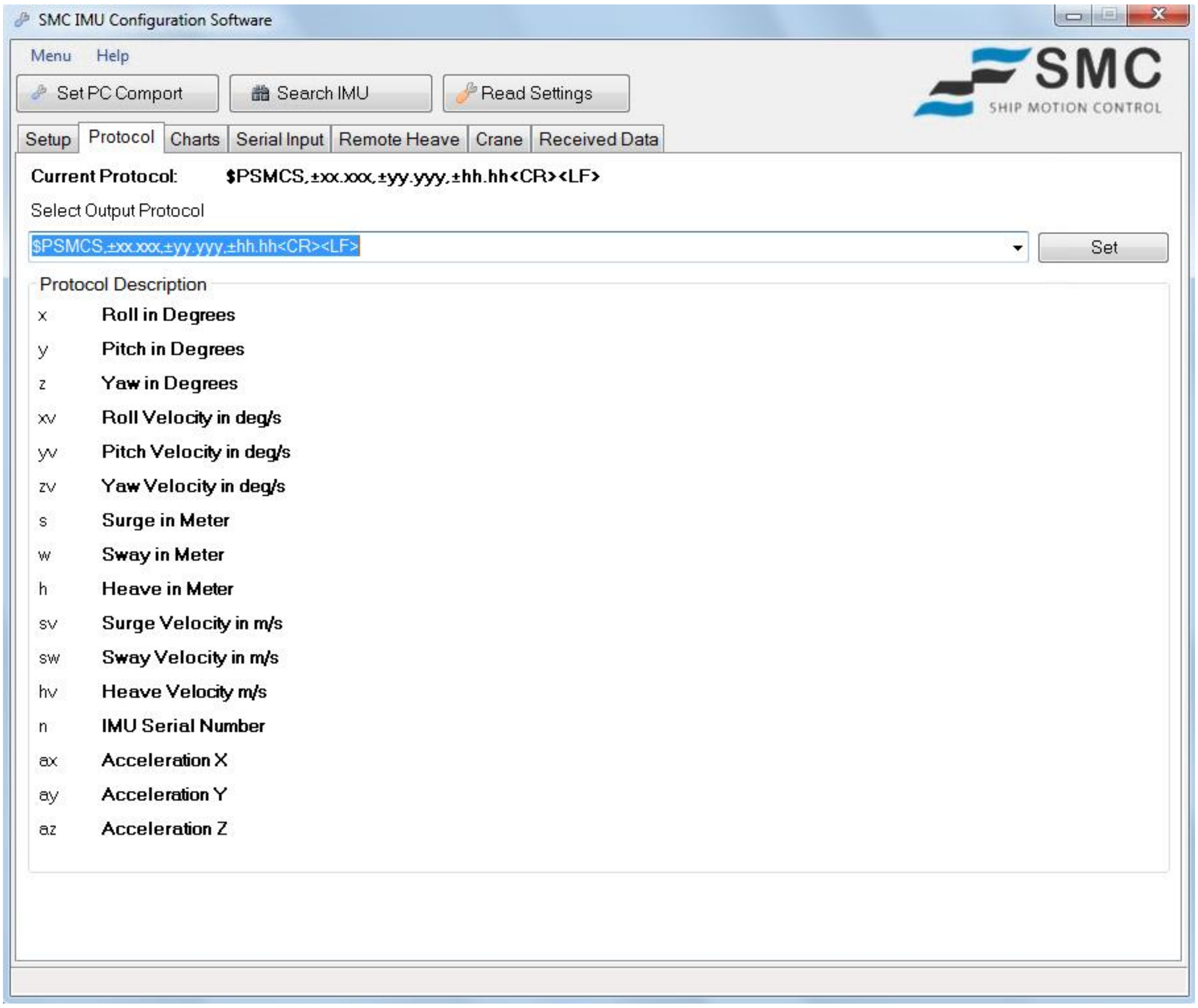
Note: For Long protocols such as SMCT / SMCA & SMCF the Bit Rate will have to be set to high bit rates like 115200 if the Data Update Frequency is 100Hz to be able to transfer the data from the motion sensor. See notes beside each protocol.

**Read IMU Settings;** By pressing the “Read Setting” button the setup software checks the current IMU settings and displays them in the setup software.

## 5.2 PROTOCOL

Choose Protocol
The SMC IMU Configuration software enables the selection of a number of standard protocols by selecting a protocol from the drop down menu and clicking on the set button.

Additional protocols can be set up by SMC to request.



### 5.2.1 SMC STANDARD PROTOCOLS

SMC Standard - This is a NMEA 0183 based compatible string.

#### 5.2.1.1 SMCA

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

Note: For the SMCA protocol to run at a Data Update Frequency of 100Hz the sensor bit rate must be set at a minimum of 38400. To run the sensor at a Bit Rate of 19200 the Data Update Frequency needs to be below 53Hz. Failure to do this may result in problems with the output data.

Note: During startup roll, pitch and heave is output as -123456.

| Description | Form |
|---|---|
| Start Characters | $PSMCA |
| Roll Angle (xx.xxx) | ±100 degrees Resolution 0.001° (+ve=port up) |
| Pitch Angle (yy.yyy) | ±100 degrees Resolution 0.001° (+ve=bow down) |
| Heave (hh.hh) | Heave ±10m Resolution 0.01m |
| Surge (ss.ss) | Surge ±10m Resolution 0.01m |
| Sway (ww.ww) | Sway ±10m Resolution 0.01m |
| Termination Characters | <CR><LF> |

#### 5.2.1.2 SMCB

Complete output of all available internal values.

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

Available from software version 2.59

Note: Very long protocol. Does not work with 100 Hz even at 115200 baud.

| Description | Form |
|---|---|
| Start Characters | $PSMCB |
| Roll Angle (xx.xx) | ±100 degrees Resolution 0.01° (+ve=port up) |
| Pitch Angle (yy.yy) | ±100 degrees Resolution 0.01° (+ve=bow down) |
| Yaw (zzz.z) | Yaw 0 – 359.9° Resolution 0.1° |
| Roll Velocity (xv.xv) | Degrees/second Resolution 0.01°/s |
| Pitch Velocity (yv.yv) | Degrees/second Resolution 0.01°/s |
| Yaw Velocity (zv.zv) | Degrees/second Resolution 0.01°/s |
| Roll Acceleration (GG.GGG) | Degrees/second$^2$ Resolution 0.01°/s$^2$ |

| | |
|---|---|
| Pitch Acceleration (HH.HHH) | Degrees/second$^2$ Resolution 0.01°/s$^2$ |
| Yaw Acceleration (II.III) | Degrees/second$^2$ Resolution 0.01°/s$^2$ |
| Surge (ss.ss) | Surge ±100m Resolution 0.01m |
| Sway (ww.ww) | Sway ±100m Resolution 0.01m |
| Heave (hh.hh) | Heave ±100m Resolution 0.01m |
| Surge Velocity (sv.sv) | Surge velocity ±100m/s Resolution 0.01m/s |
| Sway Velocity (wv.wv) | Sway Velocity ±100m/s Resolution 0.01m/s |
| Heave Velocity (hv.hv) | Heave Velocity ±100m/s Resolution 0.01m/s |
| Acceleration X (ax.axa) | X acceleration ±100 m/s2 Resolution 0.001 m/s2 |
| Acceleration Y (ay.aya) | Y acceleration ±100 m/s2 Resolution 0.001 m/s2 |
| Acceleration Z (az.aza) | Z acceleration ±100 m/s2 Resolution 0.001 m/s2 |
| Termination Characters | <CR><LF> |

#### 5.2.1.3 SMCC

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

Available from software version 1.91

Note: For the SMCC protocol to run at a Data Update Frequency of 100Hz the sensor bit rate must be set at a minimum of 115200. To run the sensor at a Bit Rate of 38400 the Data Update Frequency needs to be below 30 Hz. Failure to do this may result in problems with the output data.

Note: There exists one version of the SMCC protocol where this alternates with analog output for a DD50 display.

| Description | Form |
|---|---|
| Start Characters | $PSMCC |
| Roll Angle (xx.xx) | ±100 degrees Resolution 0.01° (+ve=port up) |
| Pitch Angle (yy.yy) | ±100 degrees Resolution 0.01° (+ve=bow down) |
| Yaw (zzz.z) | Yaw 0 – 359.9° Resolution 0.1° |
| Surge (ss.ss) | Surge ±100m Resolution 0.01m |
| Sway (ww.ww) | Sway ±100m Resolution 0.01m |
| Heave (hh.hh) | Heave ±100m Resolution 0.01m |
| Surge Velocity (sv.sv) | Surge velocity ±100m/s Resolution 0.01m/s |
| Sway Velocity (wv.wv) | Sway Velocity ±100m/s Resolution 0.01m/s |
| Heave Velocity (hv.hv) | Heave Velocity ±100m/s Resolution 0.01m/s |
| Acceleration X (ax.axa) | X acceleration ±100 m/s2 Resolution 0.001 m/s2 |
| Acceleration Y (ay.aya) | Y acceleration ±100 m/s2 Resolution 0.001 m/s2 |
| Acceleration Z (az.aza) | Z acceleration ±100 m/s2 Resolution 0.001 m/s2 |
| Termination Characters | *Cs (Checksum) <CR><LF> |

#### 5.2.1.4 SMCD

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

| Description | Form |
| --- | --- |
| Start Characters | $PSMCD |
| Roll Angle (xx.xx) | ±100 degrees Resolution 0.01° (+ve=port up) |
| Pitch Angle (yy.yy) | ±100 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° |
| Termination Characters | <CR><LF> |

#### 5.2.1.5 SMCE

Data Frame
$PSMCE,±xx.xx,±yy.yy,±zzz.z,±hh.hh,±ss.ss,±sw.sw

| Description | Form |
| --- | --- |
| Start Characters | $PSMCE |
| Roll Angle (xx.xx) | ±100 degrees Resolution 0.01° (+ve=port up) |
| Pitch Angle (yy.yy) | ±100 degrees Resolution 0.01° (+ve=bow down) |
| Yaw (zzz.z) | Yaw 0 – 359.9° Resolution 0.1° |
| Heave (hh.hh) | Heave ±100m Resolution 0.01m |
| Surge (ss.ss) | Surge ±100m Resolution 0.01m |
| Sway (ww.ww) | Sway ±100m Resolution 0.01m |
| Termination Characters | <CR><LF> |

#### 5.2.1.6 SMCF

Data Sent

Data Frame
$PSMCFnnnnnnn,±xx.xxx,±yy.yyy,±hh.hh,±ss.ss,±ww.ww

| Description | Form |
| --- | --- |
| Start Characters | $PSMCF |
| Serial Number (nnnnnnn) | 7 digit serial number |
| Roll Angle (xx.xxx) | ±100 degrees Resolution 0.001° (+ve=port up) |
| Pitch Angle (yy.yyy) | ±100 degrees Resolution 0.001° (+ve=bow down) |
| Heave (hh.hh) | Heave ±100m Resolution 0.01m |
| Surge (ss.ss) | Surge ±100m Resolution 0.01m |
| Sway (ww.ww) | Sway ±100m Resolution 0.01m |
| Termination Characters | <CR><LF> |

#### 5.2.1.7 SMCH

Data Sent

Data Frame
$PSMCH,±xx.xx,±yy.yy,±hh.hh,±hv.hv

| Description | Form |
|---|---|
| Start Characters | $PSMCH |
| Roll Angle (xx.xx) | ±100 degrees Resolution 0.01° (+ve=port up) |
| Pitch Angle (yy.yy) | ±100 degrees Resolution 0.01° (+ve=bow down) |
| Heave (hh.hh) | Heave ±100m Resolution 0.01m |
| Heave Velocity (hv.hv) | Heave Velocity ±100m/s Resolution 0.01m/s |
| Termination Characters | <CR><LF> |

#### 5.2.1.8 SMCM

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

Available from software version 2.26

| Description | Form |
|---|---|
| Start Characters | $PSMCM |
| Roll Angle (xx.xx) | ±100 degrees Resolution 0.01° (+ve=port up) |
| Pitch Angle (yy.yy) | ±100 degrees Resolution 0.01° (+ve=bow down) |
| Yaw (zz.zz) | Yaw 0 – 359.9° Resolution 0.1° |
| Surge (ss.ss) | Surge ±100m Resolution 0.01m |
| Sway (ww.ww) | Sway ±100m Resolution 0.01m |
| Heave (hh.hh) | Heave ±100m Resolution 0.01m |
| Roll Velocity (xv.xv) | Roll velocity ±100°/s Resolution 0.01°/s |
| Pitch Velocity (yv.yv) | Pitch velocity ±100°/s Resolution 0.01°/s |
| Yaw Velocity (zv.zv) | Yaw velocity ±100°/s Resolution 0.01°/s |
| Acceleration X (ax.axa) | X acceleration ±100 m/s2 Resolution 0.001 m/s2 |
| Acceleration Y (ay.aya) | Y acceleration ±100 m/s2 Resolution 0.001 m/s2 |
| Acceleration Z (az.aza) | Z acceleration ±100 m/s2 Resolution 0.001 m/s2 |
| Termination Characters | *Cs (Checksum) <CR><LF> |

#### 5.2.1.9 SMCR

Data Frame
$PSMCR,±xx.xxx,±yy.yyy

| Description | Form |
|---|---|
| Start Characters | $PSMCR |
| Roll Angle (xx.xxx) | ±100 degrees Resolution 0.001° (+ve=port up) |
| Pitch Angle (yy.yyy) | ±100 degrees Resolution 0.001° (+ve=bow down) |
| Termination Characters | <CR><LF> |

#### 5.2.1.10 SMCS

Data Sent Roll
Pitch
Heave

Data Frame
$PSMCS,±xx.xxx,±yy.yyy,±hh.hh
Example
$PSMCS,+00.089,-00.888,-00.04

Note: For the SMCS protocol to run at an Data Update Frequency of 100Hz the sensor bit rate must be set at a minimum of 38400. To run the sensor at a Bit Rate of 19200 the Data Update Frequency needs to be below 53Hz. Failure to do this may result in problems with the output data.

| Description | Form |
|---|---|
| Start Characters | $PSMCS |
| Roll Angle (xx.xxx) | ±100 degrees Resolution 0.001° (+ve=port up) |
| Pitch Angle (yy.yyy) | ±100 degrees Resolution 0.001° (+ve=bow down) |
| Heave (hh.hh) | Heave ±100m Resolution 0.01m |
| Termination Characters | <CR><LF> |

#### 5.2.1.11 SMCU/SMCE

Data Frame
$PSMCU,<datestring><timestring><mode> *cs (only output when time input in last 1.1s)
$PSMCE,+rr.rr,+pp.pp,+yyy.y,+hh.hh,+ss.ss,+ww.ww*cs

Available in this form from software version 2.52

| Description | Form |
|---|---|
| Start Characters | $PSMCU |
| <datestring> (9 characters) | |
| <timestring> (11 characters) | |
| <mode>(2 characters) | |
| Termination Characters | *cs (Checksum) <CR><LF> |
| Start Characters | $PSMCM |
| Roll Angle (rr.rr) | ±100 degrees Resolution 0.01° (+ve=port up) |
| Pitch Angle (pp.pp) | ±100 degrees Resolution 0.01° (+ve=bow down) |
| Yaw (yyy.y) | Yaw 0 – 359.9° Resolution 0.1° |
| Heave (hh.hh) | Heave ±100m Resolution 0.01m |
| Surge (ss.ss) | Surge ±100m Resolution 0.01m |
| Sway (ww.ww) | Sway ±100m Resolution 0.01m |
| Heave (hh.hh) | Heave ±100m Resolution 0.01m |
| Roll Velocity (xv.xv) | Roll velocity ±100°/s Resolution 0.01°/s |
| Termination Characters | *cs (Checksum) <CR><LF> |

### 5.2.1.12 SMCV

Data Frame
$PSMCV,±xx.xx,±yy.yy,±hh.hh,±xv.xv,±yv.yv,±hv.hv

| Description | Form |
|---|---|
| Start Characters | $PSMCV |
| Roll Angle (xx.xx) | ±100 degrees Resolution 0.01° (+ve=port up) |
| Pitch Angle (yy.yy) | ±100 degrees Resolution 0.01° (+ve=bow down) |
| Heave (hh.hh) | Heave ±100m Resolution 0.01 m |
| Roll Velocity (sv.sv) | Degrees/second Resolution 0.01° |
| Pitch Velocity (xv.xv) | Degrees/second Resolution 0.01° |
| Heave Velocity (yv.yv) | Heave Velocity ±100m/s Resolution 0.01m/s |

### 5.2.1.13 SMCT

Data Frame
$PSMCT, YYYY/MM/DD,HH:MM:SS.SS,±xx.xx,±yy.yy,±hh.hh

Note: This protocol will only be available in specially requested code versions.

| Description | Form |
|---|---|
| Start Characters | $PSMCT |
| Year (YYYY) | |
| Month (MM) | 1-12 |
| Day (DD) | 1-31 |
| Hour (HH) | 0-23 |
| Minute (MM) | 0-59 |
| Second (SS.SS) | 0-59.99 |
| Roll Angle (xx.xx) | ±100 degrees Resolution 0.01° (+ve=port up) |
| Pitch Angle (yy.yy) | ±100 degrees Resolution 0.01° (+ve=bow down) |
| Heave (hh.hh) | Heave ±100m Resolution 0.01 m |
| Termination Characters | <CR><LF> |

### 5.2.1.14 DATA

Data Frame
$DATA,+xx.xxx,+yy.yyy,+xv.xvxx,+yv.yvyy,+zv.zzzv,+ax.axaa,+ay.ayaa,+az.azaa

| Description | Form |
|---|---|
| Start Characters | $PSMCM |
| Roll Angle (xx.xxx) | ±100 degrees Resolution 0.001° (+ve=port up) |
| Pitch Angle (yy.yyy) | ±100 degrees Resolution 0.001° (+ve=bow down) |
| Roll Velocity (xv.xvxx) | Roll velocity ±100°/s Resolution 0.0001°/s |
| Pitch Velocity (yv.yvyy) | Pitch velocity ±100°/s Resolution 0.0001°/s |
| Yaw Velocity (zv.zvzz) | Yaw velocity ±100°/s Resolution 0.0001°/s |
| Acceleration X (ax.axaa) | X acc ±100 m/s2 Resolution 0.0001 m/s2 |

| | |
|---|---|
| Acceleration Y (ay.ayaa) | Y acc ±100 m/s2 Resolution 0.0001 m/s2 |
| Acceleration Z (az.azaa) | Z acc ±100 m/s2 Resolution 0.0001 m/s2 |
| Termination Characters | *Cs (Checksum) <CR><LF> |

#### 5.2.1.15 DIGILOG/OCEAN TOOLS

Data Frame
$HhhhhP+ppppR+pppp (Digilog)
$HhhhhP+ppppR+pppps (Ocean Tools)
Example
$H0014P+0030R-0024E (Ocean Tools)

Available from software version 2.36

| Description | Form |
|---|---|
| Heading designator | H |
| Heading*10 (hhhh) | 0-3599°*10 |
| Pitch designator | P |
| Pitchl Angle*100 (pppp) | ±9999°*100 Resolution 0.01° (+ve=port up) |
| Roll Designator | R |
| Pitch Angle (yy.yyy) | ±9999°*100 Resolution 0.01° (+ve=bow down) |
| Status character (s) (only Ocean Tools) | E/S (valid compass yes/no) |
| Termination Characters | <CR><LF> |

### 5.2.2 HYDROGRAPHIC PROTOCOLS

Note: ATLAS protocol is found under binary protocols.

#### 5.2.2.1 CDL MICROTILT

Data Frame:
Pyy.yyRxx.xx

Available from software version 2.36

| Description | Form |
|---|---|
| Pitch designator (P) | P |
| Pitch Angle (yy.yy) | ±100 degrees Resolution 0.01° (+ve=bow down) |
| Roll designator (R) | R |
| Roll Angle (xx.xx) | ±100 degrees Resolution 0.01° (+ve=port up) |
| Termination Characters | <CR><LF> |

#### 5.2.2.2 CDL1

Data Frame:
Hzzz.zPyy.yyRxx.xxs

Available from software version 2.36

| Description | Form |
|---|---|
| Heading designator (H) | H |
| Heading (zzz.z) | Yaw 0 – 359.9° Resolution 0.1° |
| Pitch designator (P) | P |
| Pitch Angle (yy.yy) | ±100 degrees Resolution 0.01° (+ve=bow down) |
| Roll designator (R) | R |
| Roll Angle (xx.xx) | ±100 degrees Resolution 0.01° (+ve=port up) |
| Ending string (s). Gives 0 for not available values. 30 characters. | T00.0D0000.00B00.0A00W00LN00F0 |
| Termination Characters | <CR><LF> |

### 5.2.2.3 TSS1

TSS Proprietary protocol with Heave

**Note:** For the TSS1 protocol to run at a Data Update Frequency of 100Hz the sensor bit rate must be set at a minimum of 38400. To run the sensor at a Bit Rate of 19200 the Data Update Frequency needs to be below 58Hz. Failure to do this may result in problems with the output data.

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

Data Frame
:XXAAAASMHHHHQMRRRRSMPPPP

Correct from software version 1.92

| Description | Form |
|---|---|
| Start Character LSB | : |
| Horizontal Acceleration (XX) | Hexadecimal value |
| Vertical Acceleration (AAAA) | Hexadecimal value |
| Space Character (S) | |
| Heave (MHHHH) | Heave ±100m unit 0.01m.<br>M = space if positive, - if negative |
| Status Flag (Q) | ‘U’ Settled mode (Nominal)<br>‘u’ Settling mode |
| Roll (MRRRR) | Roll ±90° units 0.01°<br>M = space if positive, - If negative |
| Pitch (MPPPP) | Pitch ±90° units 0.01°<br>M = space if positive, - If negative |
| Termination Characters | <CR><LF> |

#### 5.2.2.4 RDID

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

Available from software version 2.16 and in version 2.08

| Description | Form |
|---|---|
| Start Characters | $PRDID |
| Pitch Angle (yy.yy) | ±100 degrees (+ve=bow up) |
| Roll Angle (xx.xx) | ±100 degrees (+ve=port up) |
| Yaw Angle (yyy.yy) | 0 to 359.99 degrees |
| Termination Characters | <CR><LF> |

#### 5.2.2.5 SXN

Rolls-Royce NMEA protocol

Data Frame
$PSXN,,,R.RRReE,P.PPPeE, P.PPPeE,,,*cs<CR><LF>

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

| Description | Form |
|---|---|
| Start Characters | $PSXN |
| Roll Angle (R.RRReE) | Radians. Scientific format with exponent |
| Pitch Angle (P.PPPeE) | Radians. Scientific format with exponent |
| Heave (P.PPPeE) | Meters. Scientific format with exponent |
| Termination Characters | *cs(Checksum) <CR><LF> |

### 5.2.3 ANALOG OUTPUTS

#### 5.2.3.1 BOSCH REXROTH

Data Frame:
#01C0+hh.hhh
#01C1+vv.vvv
#01C2+aa.aaa

Available from software version 2.56

| Description | Form |
|---|---|
| 1st Header | #01C0 |
| Heave*20 (hh.hhh) | Heave ±100m*20 Resolution 0.001m*20 |
| Termination Characters | <CR><LF> |
| 2nd Header | #01C1 |
| Heave velocity*50 (vv.vvv) | Heave ±100m/s*50 Resolution 0.001m/s*50 |
| Termination Characters | <CR><LF> |
| 3d Header | #01C2 |
| Heave velocity*100 (aa.aaa) | Heave ±100m/$s^2$*50 Resolution 0.001m/$s^2$*100 |
| Termination Characters | <CR><LF> |

#### 5.2.3.2 ANALOG 10 DEGREES

Data Frame:
#01C0+xx.xxx
#01C1+yy.yyy
#01C2+hh.hhh

Available from software version 2.28

| Description | Form |
|---|---|
| 1st Header | #01C0 |
| Roll Angle (xx.xxx) | ±100 degrees (+ve=port up) Resolution 0.001° |
| Termination Characters | <CR><LF> |
| 2nd Header | #01C1 |
| Pitch Angle (yy.yyy) | ±100 degrees (+ve=bow up) ) Resolution 0.001° |
| Termination Characters | <CR><LF> |
| 3d Header | #01C2 |
| Heave (hh.hhh) | Heave ±100m Resolution 0.001m |
| Termination Characters | <CR><LF> |

#### 5.2.3.3 ANALOG 30 DEGREES

Data Frame:
#01C0+xx.xxx
#01C1+yy.yyy
#01C2+hh.hhh

Available from software version 2.28

| Description | Form |
|---|---|
| 1st Header | #01C0 |
| Roll Angle/3 (xx.xxx) | ±60 °3 (+ve=port up) Resolution 0.001°*3 |
| Termination Characters | <CR><LF> |
| 2nd Header | #01C1 |
| Pitch Angle/3 (yy.yyy) | ±60 °/3 (+ve=bow up) ) Resolution 0.001°*3 |
| Termination Characters | <CR><LF> |
| 3d Header | #01C2 |
| Heave (hh.hhh) | Heave ±100m Resolution 0.001m |
| Termination Characters | <CR><LF> |

#### 5.2.3.4 DD50

Data Frame: (no line break in actual data)
\x01DDA\x02@1 \"IMU / MRU\",Units,Roll xx.xx deg,Pitc yy.yy deg,Heav hh.hh m,@2 \"Accs \",Units,AccX ax.ax ms2,AccY ay.ay ms2,AccZ az.az ms2\x03<CR><LF>
Available from software version 2.32

Note: This output if used alternates with the SMCC protocol.

| Description | Form |
|---|---|
| Roll Angle (xx.xx) | ±100 degrees Resolution 0.01° (+ve=port up) |
| Pitch Angle (yy.yy) | ±100 degrees Resolution 0.01° (+ve=bow down) |
| Heave (hh.hh) | Heave ±100m Resolution 0.01m |
| Acceleration X (ax.ax) | X acceleration ±100 m/s2 Resolution 0.01 m/s2 |
| Acceleration Y (ay.ay) | Y acceleration ±100 m/s2 Resolution 0.01 m/s2 |
| Acceleration Z (az.az) | Z acceleration ±100 m/s2 Resolution 0.01 m/s2 |

### 5.2.4 BINARY PROTOCOLS

#### 5.2.4.1 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

Status byte corrected in software version 2.72

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

#### 5.2.4.2 SIMRAD EM1000 & EM3000

Data Frame:
SHRRPPHHYY

EM3000 available from software version 2.01, status byte corrected in 2.76

Contains 10 bytes:

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

| Description | Scaling | Format | Bytes | Value |
|---|---|---|---|---|
| Status byte (S) | | | 1 | 0 (EM1000)<br>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 ° |

#### 5.2.4.3 BOSCH REXROTH HEXADECIMAL HEAVE

Data Frame (bytes):
$SMCHHVVAA<CR><LF>

Available from software version 2.56

Contains 12 bytes:

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

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

#### 5.2.4.4 SMC2 TERMA

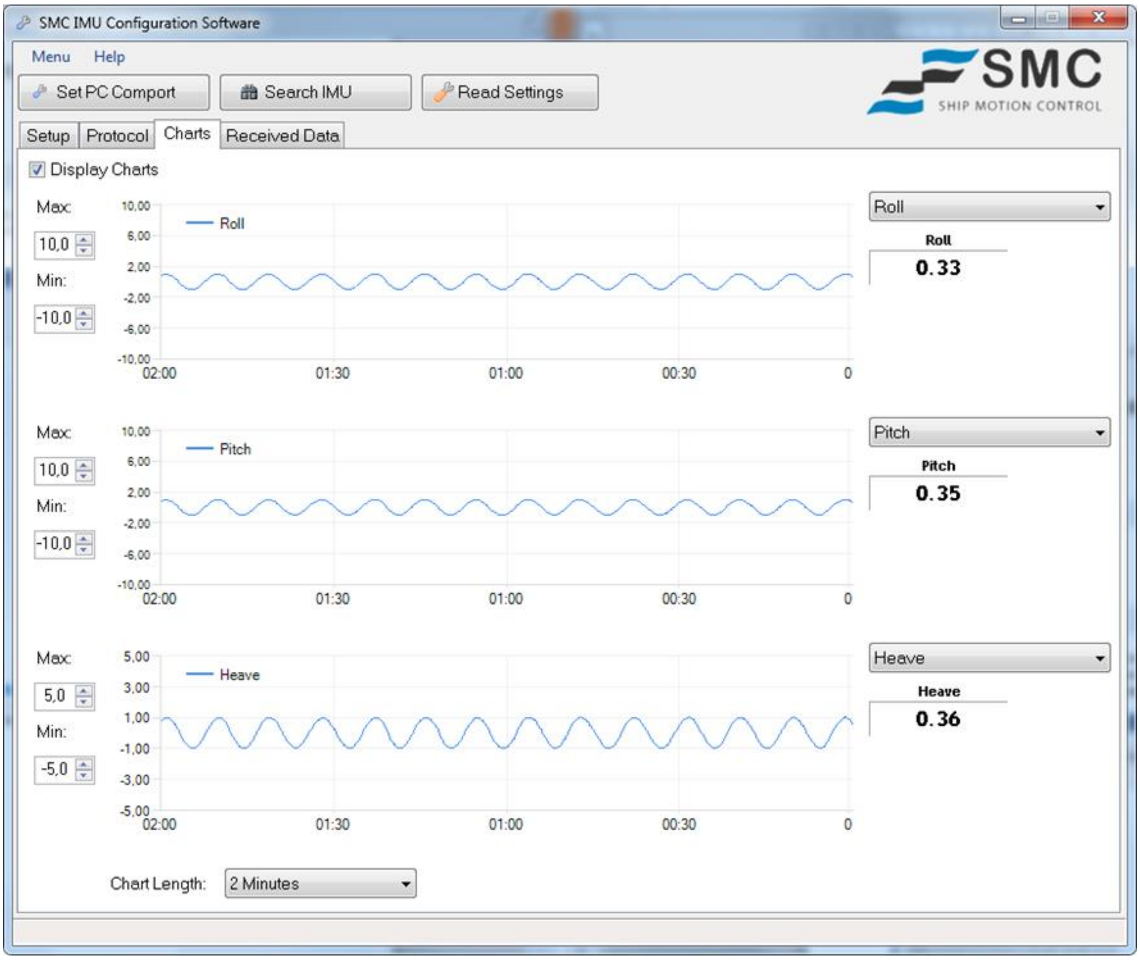
Data Frame (bytes):
\x01\x0D\x00\x1EPPPPRRRR

| Description | Bytes | Form |
|---|---|---|
| Header | 4 | \x01\x0D\x00\x1E (SOH 12 0 EOH) |
| Pitch/180*2$^{31}$ (PPPP) | 4 | Siqned 32 bit, i.e. -2$^{31}$-1 - 2$^{31}$-2 representing -180° - 180° with a resolution of 180°/*2$^{31}$ |
| Roll/180*2$^{31}$ (RRRR) | 4 | Siqned 32 bit, i.e. -2$^{31}$-1 - 2$^{31}$-2 representing -180° - 180° with a resolution of 180°/*2$^{31}$ |

## 5.3 CHARTS

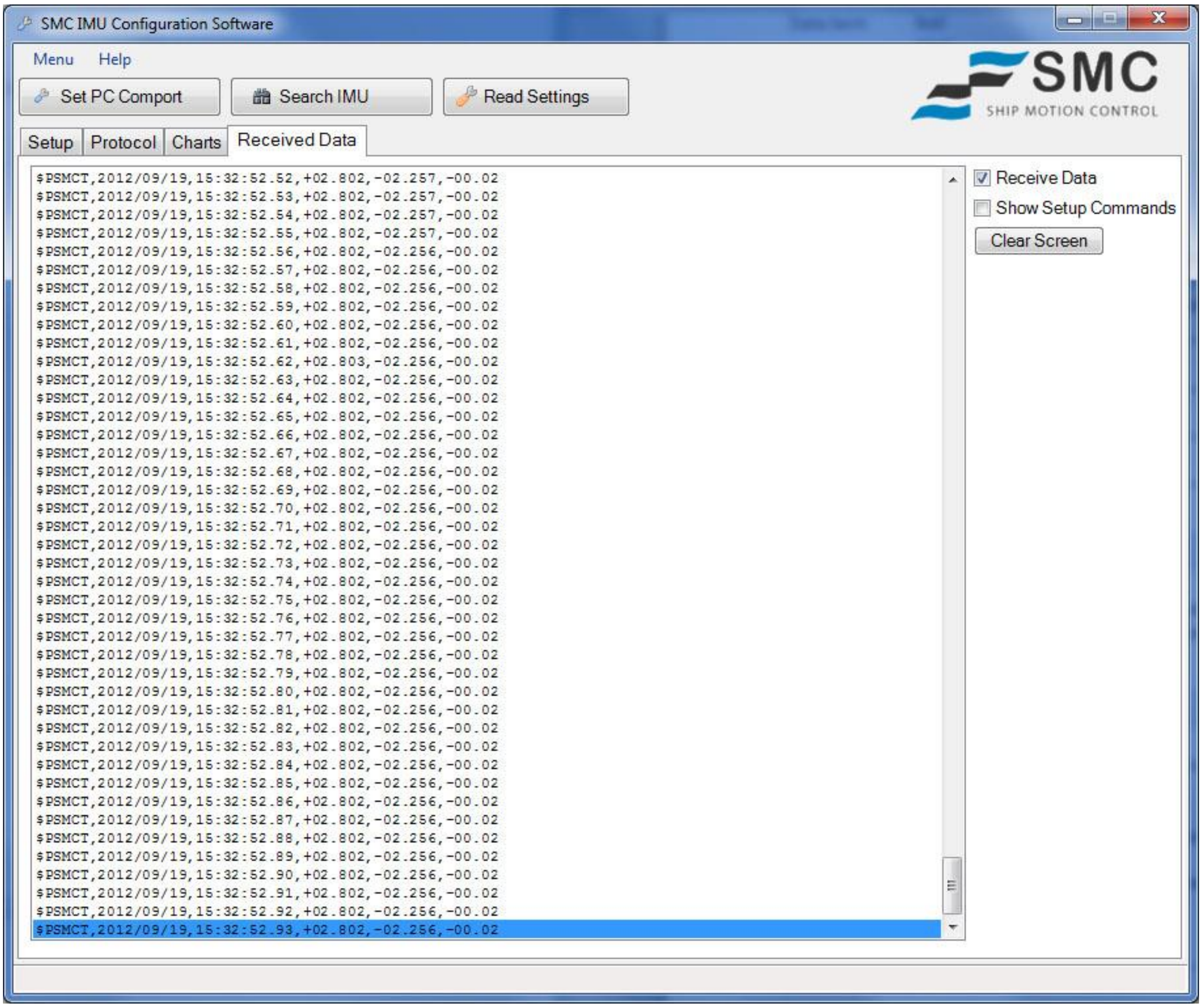
As a visual aid to or as a simple motion monitoring system, SMC have a Chart screen that displays up to 3 parameters in a graphical representation.

After selecting the Charts tab tick the Display Charts tick box which will activate the data display. Beside each chart is a drop down box. Click on this and then select the parameter to be displayed. The chart scale is set on the left of the screen with a Max and Minimum setting. The chart length is set for all the charts from the drop down menu at the bottom of the screen.



## 5.4 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.

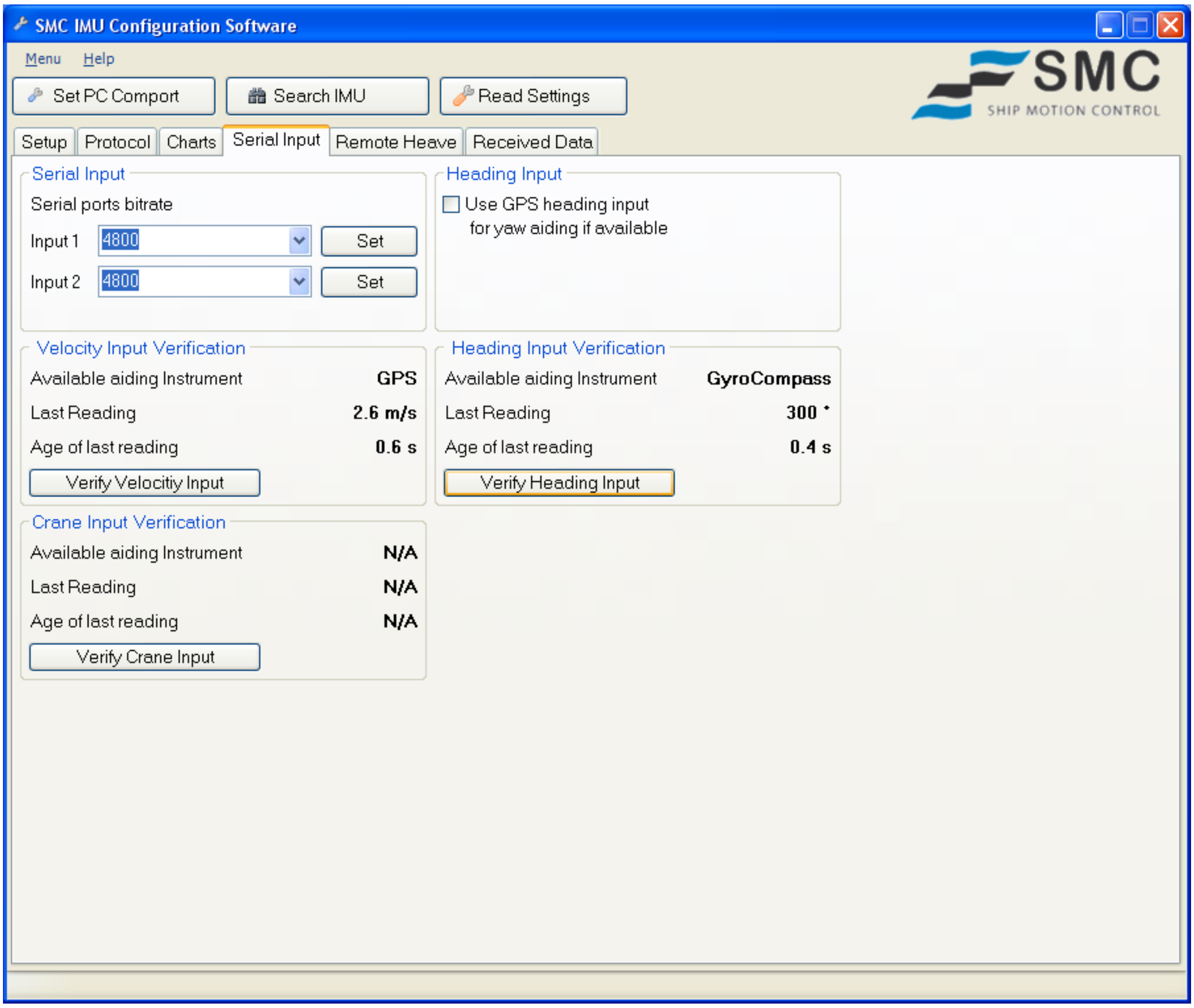


## 5.5 SERIAL INPUT

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

These 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



### 5.5.1 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 angle and heave calculation. By knowing the vessel velocity the centrifugal force can be estimated inside the IMU and the centrifugal effect can be heavily reduced, improving the accuracy of the readings from the IMU.

The SMC IMU 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 IMU is receiving data from the velocity device use the SMC configuration software. Select the "Verify Velocity Input" in the serial input tab in the configuration software. The IMU replies with information about the time since the last reading and the velocity received.


### 5.5.2 HEADING INPUT

When a gyrocompass is connected (or a GPS is selected to be used for heading input), the IMU will use the gyrocompass for aiding of the yaw signal, combining the data from internal gyros in the IMU with the input from the external gyrocompass. The output is available in strings where yaw or heading is available. See the IMU user manual for a list of available data strings.

The accepted strings from the GyroCompass are $xxHDT and $xxHDG.

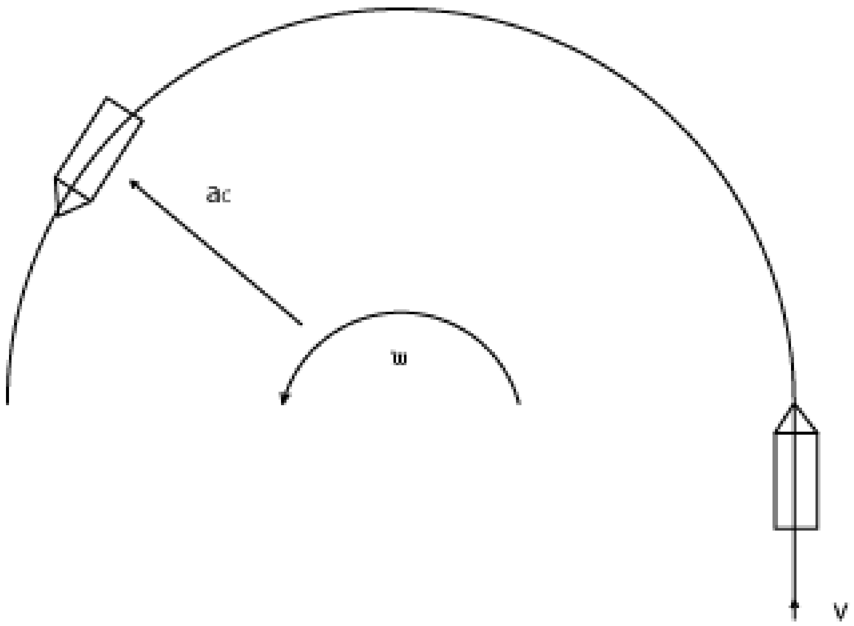
Heading can also be retrieved from the GPS string but is not advisable if the vessel is not under constant motion. The $GPHDG string is not accepted as default for the heading input. To use the GPS heading data for yaw aiding tick the "Use GPS heading input for yaw aiding if available" checkbox in the external input tab in the SMC configuration software otherwise the $GPHDG string will be ignored.

To confirm that the IMU is receiving data from the heading device use the SMC configuration software click the verify input in the serial input tab in the configuration software. The IMU replies with information about the time since last reading and the heading received.

### 5.5.3 VESSEL TURNS

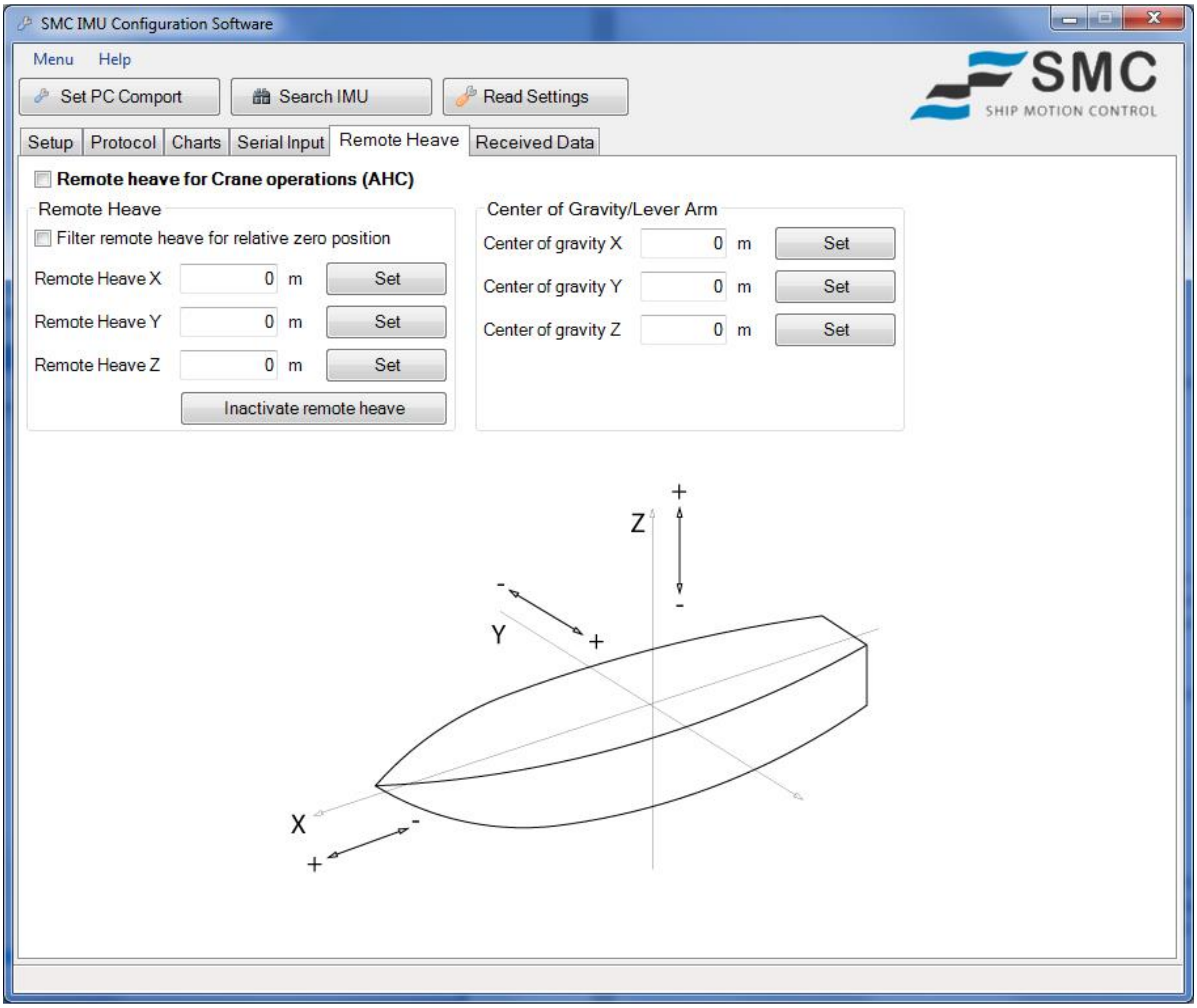
When a vessel makes a turn without the additional information of vessel speed and position change the IMU can see the turn as an acceleration value that will affect the accuracy of the output data.

The IMU takes the vessel speed and rate of turn to calculate the centripetal acceleration and remove this from the measurements during a vessel turn.



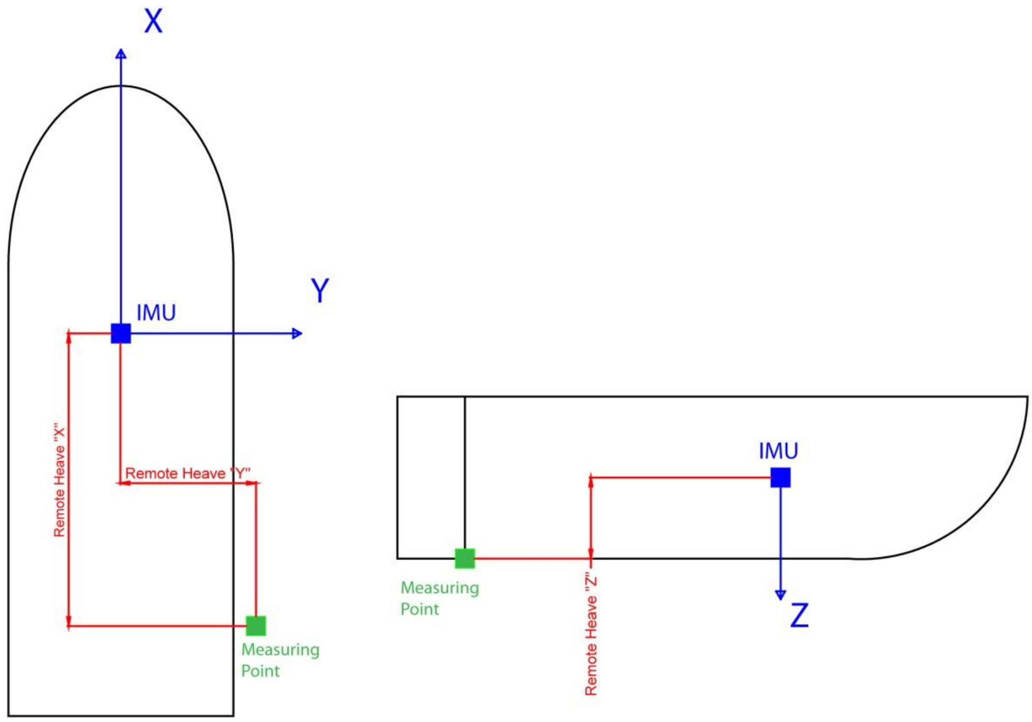
## 5.6 REMOTE HEAVE

The Remote Heave Screen has three control setups, 1. Remote Heave, 2. Center of Gravity/Lever Arm & 3. Remote Heave for Crane operations (AHC).



### 5.6.1 REMOTE HEAVE

The remote heave function calculates the heave and the heave velocity output of the IMU to a remote location from the IMU physical location. The setup of the remote heave is done in the remote heave tab in the SMC configuration software.




"Remote heave X" is the fore aft distance in meters between the IMU and the remote heave point. Where a positive distance represents that the motion sensor is located aft of the desired measurement point.

"Remote heave Y" is the sideways distance in meters between the IMU and the remote heave point. Where a positive distance represents that the motion sensor is located to the starboard side of desired measurement point.

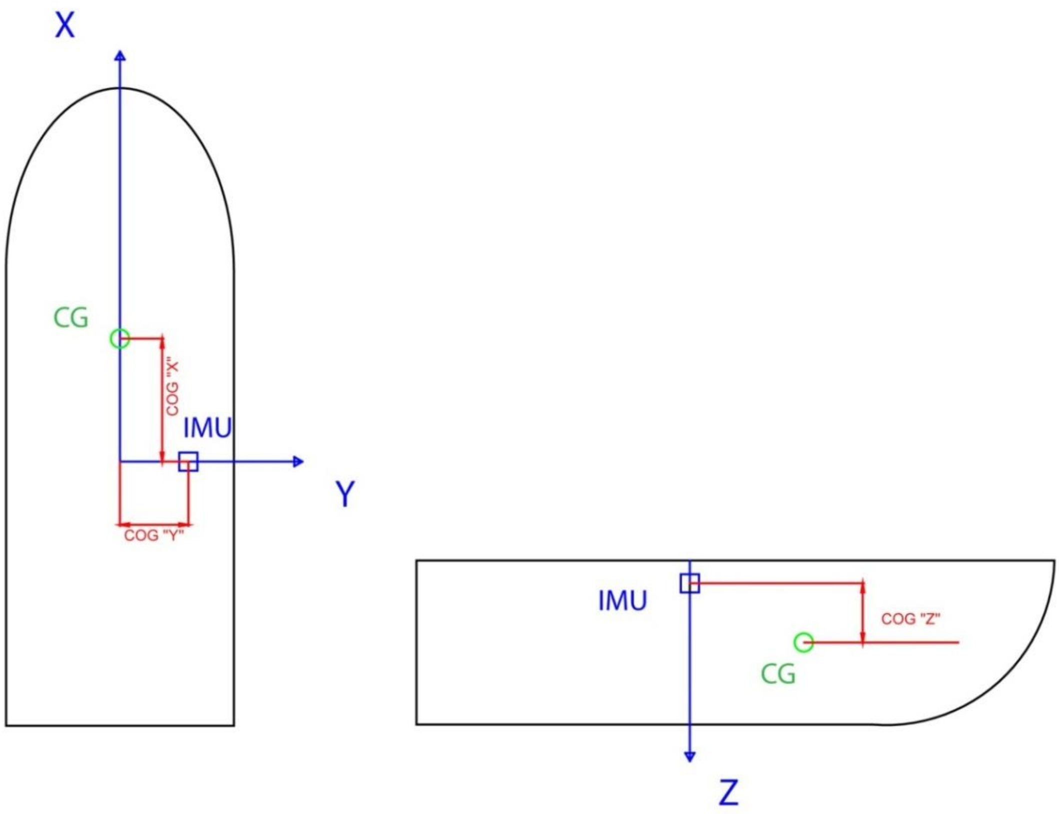
"Remote heave Z" is the vertical distance in meters between the IMU and the remote heave point. Where a positive distance represents that the motion sensor is located below the desired measurement point.

As the remote heave calculation is a combination of distance, angles and heave, a fixed angle will give a constant heave position that is different from zero. As the heave definition is a relative motion and the angle is an absolute angle, SMC has added a filter to remove a fixed trim of the vessel from the remote heave output. This is selectable from the checkbox "Filter remote heave for relative zero position".

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

### 5.6.2 CENTER OF GRAVITY CG LEVER ARM

The best placement for the motion sensor is at the center of gravity (CG). If the sensor is placed in another location the accuracy of the output in general and heave in particular can be improved by giving the location of CG with respect to the sensor in the setup program. It is preferable to have a close approximation of the CG rather than no data. These values are given in the same way as the values for the remote heave location coordinates i.e.:




"COG X" is the fore aft distance in meters between the IMU and the COG. Where a positive distance represents that the motion sensor is located aft of the COG.

"COG Y" is the sideways distance in meters between the IMU and the COG. Where a positive distance represents that the motion sensor is located to the starboard side of the COG.

"COG Z" is the vertical distance in meters between the IMU and the COG. Where a positive distance represents that the motion sensor is located below the COG.

Unless "Filter remote heave for relative zero position" is checked (which you typically not want to have) setting a non-zero distance to COG may result in a heave that is not "centered" at 0 when the vessel is not leveled even when you have zero remote-heave distance (have the IMU as the point for which heave is desired). This means that the IMU is horizontally displaced with respect to the position it would have when the vessel is leveled and is usually what is desired.

### 5.6.3 AHC (ACTIVE HEAVE COMPENSATION

Note that SMC will not be responsible for damages that occur related to Active Heave Compensation. 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 must be cancelled automatically.

SMC has developed a remote heave function that accepts dynamic crane position data for active heave compensation in marine crane applications. 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. The position for the remote heave is continuously calculated from the crane encoder data. Remote heave and remote heave velocity data is then calculated for any requested single point location along the crane boom which can be used to compensate for the vessel motions during crane operations.

By activating the "Remote heave for Crane Operations" by checking the checkbox in the remote heave tab in the IMU configuration software, the crane settings will be enabled.

How to setup remote heave for active heave compensation with encoder feedback to the IMU.

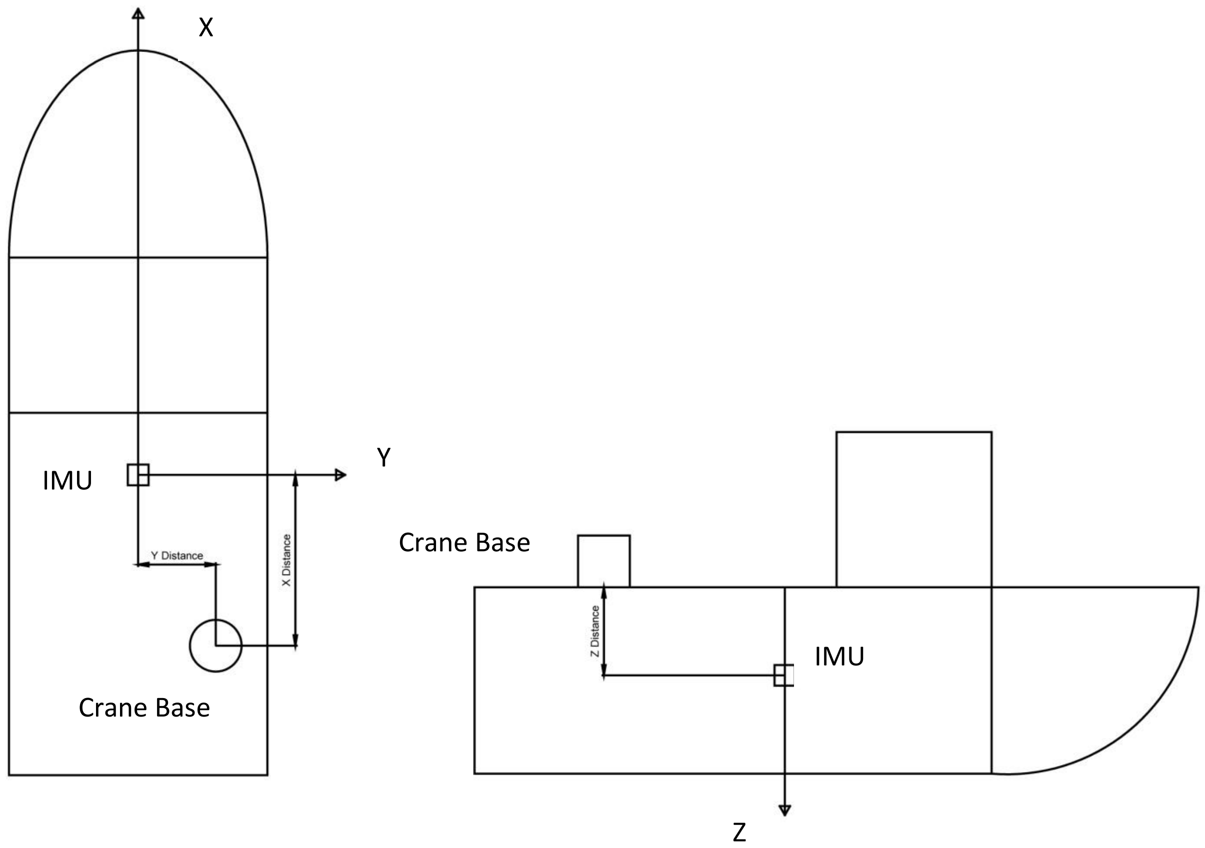
#### 5.6.3.1 SETUP OF CRANE LAYOUT IN THE SMC CONFIGURATION SOFTWARE

The IMU should be aligned with the vessel so that the single notch point on the base of the IMU is pointing to the bow. Mount the IMU as close as possible to the crane base to optimize the remote heave output.

If 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.

If the IMU is mounted on the crane base the single notch is supposed to be aligned with the crane arm (i.e. 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. This is the row position 1 in the configuration software. The Input string should for encoder 1 should be either blank or have a 0 in the first value. Example $PENCR,,value2,value3,value4,value5

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 and are marked with C in the below figure. The unit is meter.




"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.

## SETTING ANGLE OFFSETS

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

For the encoder1, the yaw encoder marked as 1a in the crane drawing, the offset has its reference position aligned with the vessel for fore-aft line. Encoder1 angles are seen from above. This means that when the crane is pointing to the fore of the vessel the encoder should display 0 degrees, when the crane is pointing starboard side 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 offset settings can be done both in the PLC and by entering the offset value in the SMC configuration software. 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.

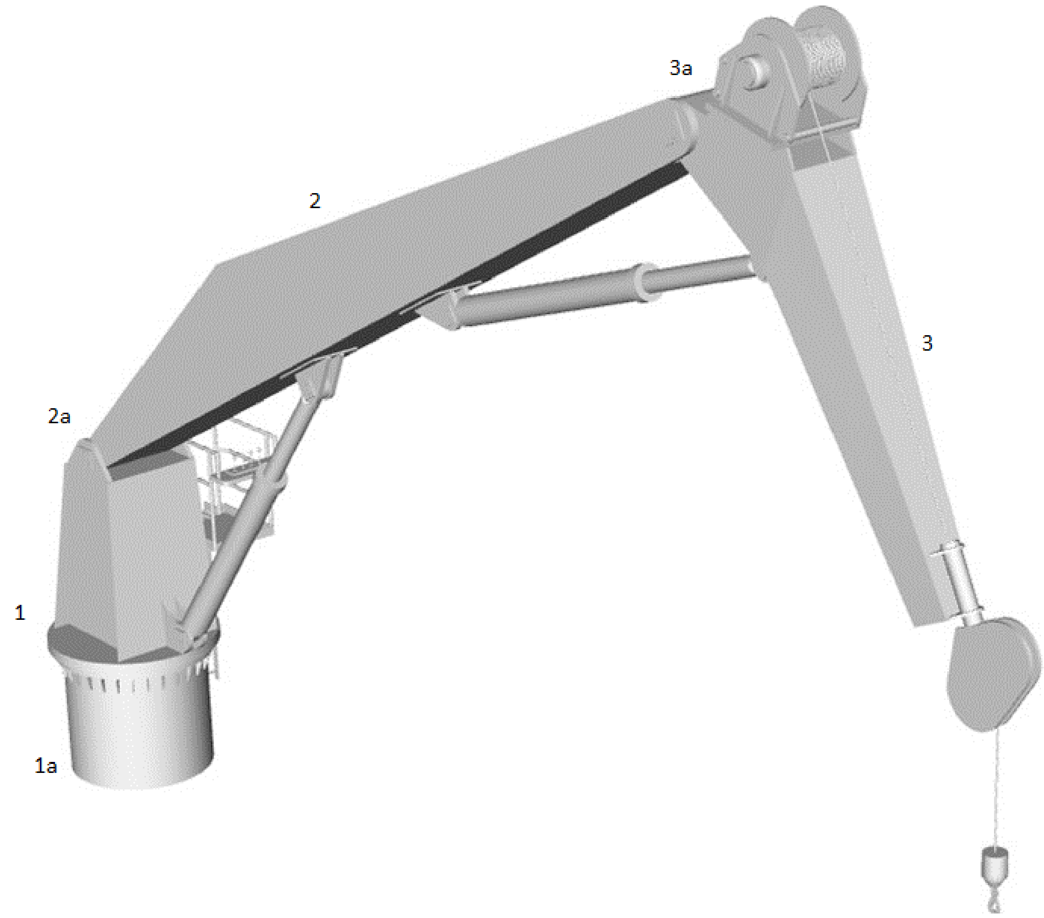
For the encoders 2, 3, 4 and 5 the angle is relative to the previous leg of the crane. This means that when there is no angular difference between the crane leg 2 and 3 the encoder 3 has a 0 angle. The encoder angles are illustrated as 2a and 3a in the below crane drawing.

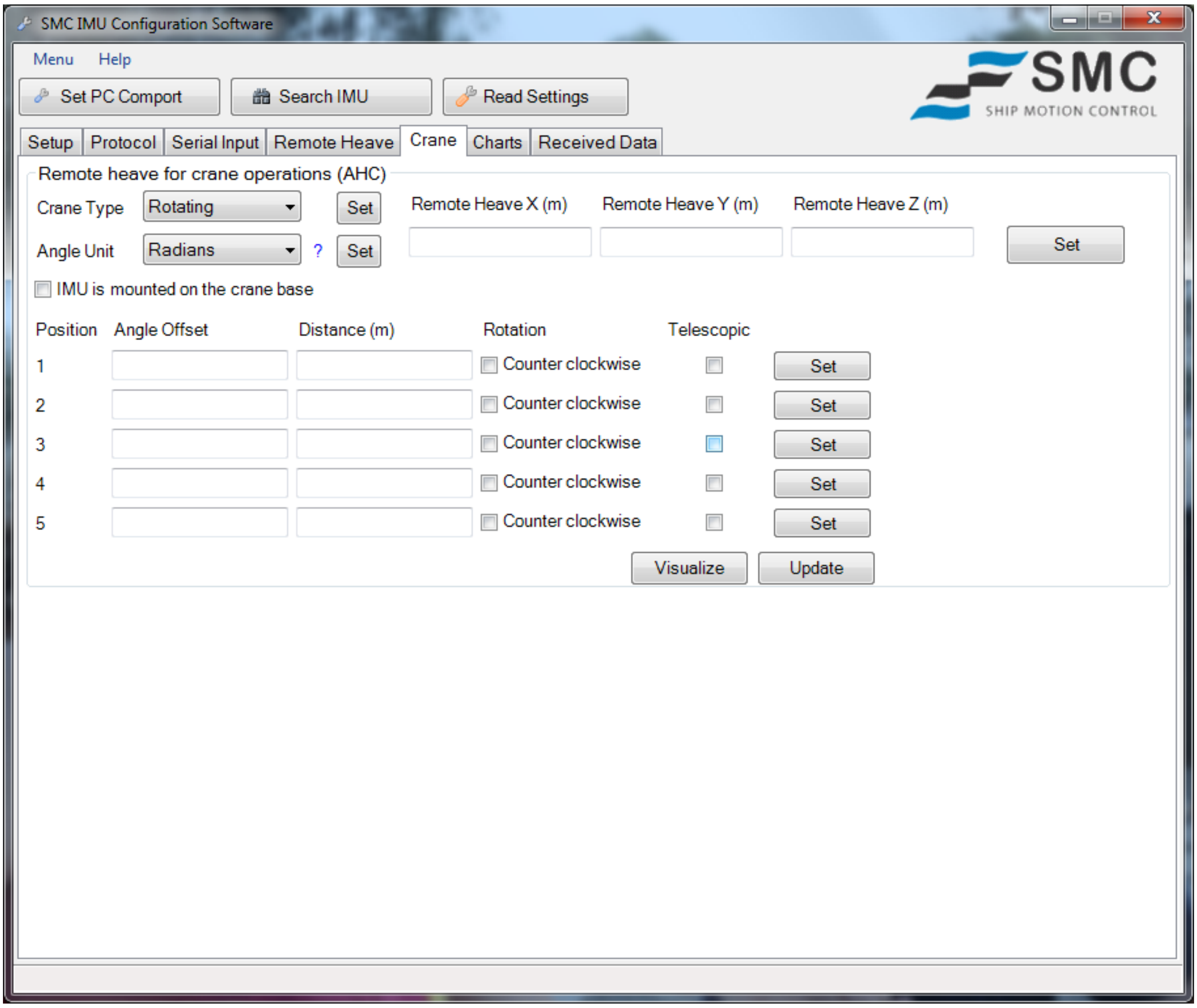
Encoder 2, 3, 4 and 5 rotations are seen from the starboard side of the crane. The clockwise rotation is as default a positive rotation when seeing the crane from this position. Counter clockwise positive is possible to select by ticking the checkbox for the encoder in the configuration software. I.e. 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. If the next encoder position is a telescopic arm the distance to be entered is the length of the telescopic arm fully retracted.

The distances are marked as 1, 2, 3 in the below crane drawing.

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 is to be entered in the previous row distance info.






### 5.6.3.2 STRING INPUT

When using the crane serial input communication the data has to be transmitted over 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. To have the motion sensor to calculate the remote heave on an operating crane installation the crane encoder readings are being 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 including up to 5 encoder values is:
$PENCR,Value1,Value2,Value3,Value4,Value5<CR><LF>

Where:

| 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 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 |
| Value5 | Value5 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 |

Description of the encoder values:

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

If an encoder input is set to be used as a "Telescopic" in the IMU Configuration software ", the given encoder value represents a length value = distance.
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, 0000 or leave the position blank in the PLC string.

For example when Z-axis rotation is not available
$PENCR,0,Value2,encoder3,encoder4,encoder5
or
$PENCR,,encoder2,encoder3,encoder4,encoder5

$PENCR

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

**$PENCO**
$PENCO,value1,value2,value3,value4,value5<CR><LF>

Example of a $PENCO string:
$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.

Where

| 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 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. |
| Value5 | Value5 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. |

Description of the encoder values:

The encoder readings are being sent in standard encoding ie: -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 a “Telescopic” in the IMU Configuration software “, the given encoder value represents a length value = distance.
The length of a telescopic arm is given in meters ie 12cm is sent as 0.12

#### 5.6.3.3 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.

Fault message
$PENCT,0000,0000,0000,0000,0000<CR><LF>

String examples
In the below example the knuckle at node 2 at 90 degrees so that the second leg of the crane is directed horizontally. From the second leg there is a telescopic arm extended 10 meters.

With this encoder positions we would send the below using the $PENCR string:
$PENCR,0000,3FFF,03E8,0000,0000
The motion sensor would return
$PENCT,0000,3FFF,03E8,0000,0000

By using $PENCO string:
$PENCO,0,90,10,0,0
It is possible to also add decimals to the $PENCO string:
$PENCO,0,90.0,10.00,0.0,0.0

#### 5.6.3.4 TELESCOPIC ARM INPUT DATA

If the crane has a telescopic arm, data can be entered at the next position from the previous encoder angle and the distance data entered into the configuration software. In the example below this telescopic arm would have been entered into position 4 in the configuration software and the checkbox for the telescopic information should be ticked for the specific row. The string with encoder values will then need the distance information in meters instead of the angle value for the rotation encoder. The example below displays a crane with a yaw rotation, and two rotational encoders followed by a telescopic arm.

For example
$PENCO,encoder1,encoder2,encoder3,distance4,0

If the crane has a fixes bend it is taken care of by either entering a fixed encoder value from the PLC/sending device. It is also possible to enter an offset from the configuration software for this bend. This is done by entering an offset that is negative value. I.e. if the crane bend is clockwise positive/downwards the entered angular offset should be negative.

## 5.7 OPTIONAL PC BASED SOFTWARE

There are several optional PC based software packages available from SMC. These 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 SMCmms (Motion Monitoring System, SMChms (Helideck Monitoring System), SMCems (Environmental Monitoring System) and SMCwms (weather Monitoring System). SMCmms is a general monitoring tool that makes it possible to log and display all ship motions. SMChms is a tool custom made to monitor the motions of a helicopter take-off and landing deck.

# 6 MOTION SENSOR OPERATION

## 6.1 SETTLING TIME

The SMC IMU's 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. This means that 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".

## 6.2 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 on 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 a 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.

# 7 SERVICE AND WARRANTY

## 7.1 TECHNICAL SUPPORT

**SMC do recommend a recalibration or verification of the motion sensor every second year of usage. This is due of 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 our local agents or Ship Motion Control directly.

Refer to website www.shipmotion.se/contact.html

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. If not there is a repair charge. Please see Ship Motion Controls 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 the address below.

SMC Ship Motion Control
3 Georgious Katsounotou
Kitallides Building, Office 1A
3036 Limasol
Cyprus

## 7.2 WARRANTY

All products are inspected prior to shipment and guaranteed against defective material or workmanship for a period of two (2) calendar years after date of purchase. 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. The Company 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 the company must have an issued RMA number supplied by the Company prior to shipment. Only the Company shall have the authority to issue RMA numbers.

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

The product must be sent to the Company for repair or replacement.

### 7.2.1 LIMIT OF LIABILITY

The Company 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; willful damage or negligence of the Buyer or its employees or agents; abnormal working conditions at the Buyer's premises; failure to follow the Company's instructions (whether oral or in writing); misuse or alteration or repair of the Products without the Company's approval; or if the total price for the Products has not been paid.

The company 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 Ship Motion Control.

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

The Company 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.

### 7.2.2 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's 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 should be carried out by SMC personnel

# 8 TECHNICAL SPECIFICATIONS

## 8.1 IMU-00X TECHNICAL SPECIFICATIONS

| Technical Specification | IMU-007 | IMU-008 |
|---|---|---|
| **Roll / Pitch** | Yes | Yes |
| **Accelerations X,Y,Z** | Yes | Yes |
| **Heave** | N/A | |

| Performance | | |
|---|---|---|
| **Angle Accuracy Static** | 0.2° RMS | 0.2° RMS |
| **Angle Accuracy Dynamic @ ±5º simultaneous roll and pitch** | 0.25° RMS | 0.25° RMS |
| **Resolution Angle** | 0.001° | 0.001° |
| **Resolution Heave** | N/A | 0.01m |
| **Angle Range Roll / Pitch** | ±30° | ±30° |
| **Heave Range** | N/A | ±10m |
| **Heave Accuracy** | N/A | 5cm or 5% |
| **Acceleration Accuracy** | 0.05 m/s² RMS | 0.05 m/s² RMS |

| Communications | |
|---|---|
| **IMU Configuration Software** | The IMU is shipped with SMC configuration windows software allowing on site setup |
| **Output Signal Protocol** | Multiple, user selectable Output Protocols ASCII NMEA and binary |
| **Communications Interface** | Output RS422 and RS232, Analog and remote converter (optional)<br>2 x RS232 External inputs, (not available on all models)<br>Velocity input formats RMC, RMA, VTG, BBV, VHW; Heading input formats HDT, HDG |

| Physical | |
|---|---|
| **Dimensions for IMU-00x (WxH)** | Tube Ø89 mm, mounting plate 134 mm, flange Ø110mm x 67 mm excl. connector |
| **Weight** | ~0.5 kg |
| **Housing Material** | Titanium |

| Environmental | |
|---|---|
| **Temperature (absolute max)** | 0° to +55° Celsius (-10° to 65°); Storage Temperature -40° to + 65° Celsius |
| **Mounting Orientation** | Vertical or Horizontal mounting (factory set) |
| **Power Requirements** | 12 – 30 VDC; 2 W |
| **MTBF (computed)** | 50 000 hours |
| **Depth Rating** | IP64 (standard); IP68 30 meter depth rated (optional) |
| **Standards** | IEC 60945/EN60945 standards on electromagnetic compatibility (immunity and radiation) |

| Warranty & Support | |
|---|---|
| **Warranty** | 2-year Limited Hardware & Software Warranty |
| **Support** | Free Technical & Hardware Support |

| Bundled Delivery | |
|---|---|
| **Junction Box** | Multiple input & output connection case, including 10m cable (Longer Options available). |

## 8.2 IMU-10X TECHNICAL SPECIFICATIONS

| Technical Specifications | IMU-106 | IMU-107 | IMU-108 |
|---|---|---|---|
| **Roll / Pitch** | N/A | Yes | Yes |
| **Accelerations X,Y,Z** | N/A | Yes | Yes |
| **Heave** | Yes | N/A | Yes |

| Performance | | | |
|---|---|---|---|
| **Angle Accuracy Static** | N/A | 0.02° RMS | 0.02° RMS |
| **Angle Accuracy Dynamic @ ±5º simultaneous roll and pitch** | N/A | 0.03° RMS | 0.03° RMS |
| **Resolution Angle** | N/A | 0.001° | 0.001° |
| **Resolution Heave** | 0.01m | N/A | 0.01m |
| **Angle Range Roll / Heave** | ±30° | ±30° | ±30° |
| **Heave Range** | ±10m | N/A | ±10m |
| **Heave Accuracy** | 5cm or 5% | N/A | 5cm or 5% |
| **Acceleration Accuracy** | N/A | 0.01 m/s² RMS | 0.01 m/s² RMS |

| Communications | |
|---|---|
| **IMU Configuration Software** | The IMU is shipped with SMC configuration windows software allowing on site setup |
| **Output Signal Protocol** | Multiple, user selectable Output Protocols ASCII NMEA and binary |
| **Communications Interface** | Output RS422 and RS232, Analog and remote converter (optional)<br>2 x RS232 External inputs, (not available on all models)<br>Velocity input formats RMC, RMA, VTG, BBV, VHW; Heading input formats HDT, HDG |

| Physical | |
|---|---|
| **Dimensions for IMU-10 (W x H)** | Tube Ø89 mm, mounting plate 134 mm, flange Ø110mm x 127 mm excl. connector |
| **Weight** | ~2 kg |
| **Housing Material** | Titanium |

| Environmental | |
|---|---|
| **Temperature (absolute max)** | 0° to +55° Celsius (-10° to 65°); Storage Temperature -40° to + 65° Celsius |
| **Mounting Orientation** | Vertical or Horizontal mounting (factory set) |
| **Power Requirements** | 12 – 30 VDC; 2 W |
| **MTBF (computed)** | 50 000 hours |
| **Depth Rating** | IP64 (standard); IP68 30 meter depth rated (optional) |
| **Standards** | IEC 60945/EN60945 standards on electromagnetic compatibility (immunity and radiation) |

| Warranty & Support | |
|---|---|
| **Warranty** | 2-year Limited Hardware & Software Warranty |
| **Support** | Free Technical & Hardware Support |

| Bundled Delivery | |
|---|---|
| **Junction Box** | Multiple input & output connection case, including 10m cable (Longer Options available). |

# 9 FAQ & SUPPORT

This is a small guide to help with configuration problems when connecting to the SMC S-108 sensor. If no communication is seen or bad data is displayed refer to the FAQ's below.

**Configuration**

**Is the unit sending data with RS422 or RS232?**

The IMU-xxx sensors are dispatched pre-configured for either RS422 or RS232. The junction box supplied is wired for either RS232 or RS422. Check the wiring as per the Electrical configuration guide.

**Data is being received and 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 doing a setting change in the SMCsetup software the output signals can display "bad data". This occurs because of an 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 update rate is set to high for the configured Output string and baud rate. Details are supplied in section 5.2 for each protocol.

Also check the Serial port, if using a Serial to USB adapter check, 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 being shown in the configuration. If not, press the check setting 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? See manual Chapter 4 Sections 4.7 and 4.8

**No Communication with the IMU**

Power, is the sensor powered up? Voltage should be 9 to 30 Volt see section 4.7 and 4.8

Baud rate and update rate? Check what Baud Rate and Update rate should be used or has been set up. Use the "Search IMU" button on the IMU configuration software to scan all available ports.

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

If there is a chance that the baudrate has been changed and the IMU “search IMU” check does not find the IMU, systematically check each selectable baud rate option in the SMCsetup software till the correct rate is found.

When doing a setting change in the SMCsetup software the output signals can display “bad data”. This occurs because of an automatic restart of the sensor unit, the values will settle after a few minutes.

**No GPS or Gyro data is being received**

Select the relevant “Verify” button in the Serial input IMU 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 see section 4.7 & 4.8.

**Heading Information from GPS is not being shown in the Output Protocol**

There is a check button in the SMC configuration software to accept the heading string from the GPS ($GPHDT) See section 5.5. Check the box labeled “Use GPS Heading input for Yaw aiding if available”.