CAUTIONARY NOTICES

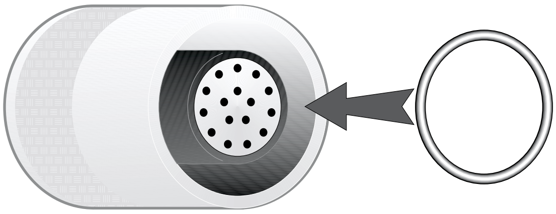
Your attention is drawn to the following cautionary notices that apply throughout this Product Manual.

CAUTION

You will void the warranty if you open the Sensor housing without prior authorisation from the Customer Service Department at TSS (UK) Limited. Do not open the Sensor for any reason until you have contacted TSS (UK) Limited by telephone. The title page of this Manual lists the contact details for TSS (UK) Limited.

CAUTION

To seal the Sensor port against water ingress you must fit one of the supplied O-rings to the connector on the Sensor cable. To prevent their loss during transit, the connectors do not have these O-rings fitted.



CAUTION

To avoid the possibility of forming a ground loop, you must isolate the Sensor housing from any local ground connection. Use the insulating mounting plates supplied with the System to install the Sensor.

Failure to take this precaution could result in Sensor malfunction and possible corrosion of the housing.

CAUTION

If the Sensor communication cable is longer than 15 metres, you may lose communication with the Sensor when you command a change from RS422 to RS232.

Do not change from RS422 to RS232 communication unless you are entirely certain the communication link, with or without a remote repeater, will continue to operate correctly.

CONTENTS

AMENDMENTS

Old issue	New issue	Date	Details
–	1.0 1.0A 1.0B 1.0C 1.0D 1.0E 1.0F	2.09.1998 23.11.1998 4.12.1998 8.01.1999 9.03.1999 27.04.1999 9.06.1999	New issue Add DMS 2-25 variant. Clarify description of action under horizontal acceleration. Clarify alignment details for horizontal mounting. Add ROV mounting details and UTC field option to user configurable packet. Add instructions to fit connector O-ring. Add polled data format. Amend Table 2–18 for details of RS232/RS422 connections
1.0F	1.1 1.1A 1.1B	31.08.1999 01.02.2000 23.02.2000	Add Repeater DAC calibration instructions and Windows software description. Alter compass output reading. Clarification of measurement datum.
1.1B	1.2	29.08.2000	Move drawing list and training details.

1 INTRODUCTION

The TSS DMS 2-xx Dynamic Motion Sensor is a small portable system for measuring the vertical displacement and attitude of a vessel when no stationary reference is available. Typical applications for the Sensor include motion compensation of a multibeam sounder.

Among the useful features available from the Sensor are:

- A small, depth rated housing.
- Low power consumption.
- Connection through a single cable.
- Choice of horizontal or vertical mounting orientation.
- Choice of digital output formats, including a user-configurable format.
- Communication remotely settable for RS232 or RS422.

Optional features available for use with the Sensor include:

- Implementation of aiding from user-supplied GPS and gyrocompass systems to enhance Sensor performance during vessel turns.
- Remote repeater unit for use when the Sensor is too far from the receiving equipment to use RS232 communications. The repeater supports cable lengths up to 1000 metres between the Sensor and the receiving equipment.
- Analogue outputs to represent heave, roll and pitch measurements. To use these outputs, you **must** use the Remote Repeater.

All heave-capable Sensors in the DMS 2-xx range have the same specification for heave measurement accuracy. However, not all applications will require the highest attitude measurement accuracy and so there are alternative types of DMS 2-xx offering different performance in this area. It is therefore possible to select a Sensor whose performance matches closely the specific needs of an application. To distinguish between Sensors of differing specification, the suffix '-xx' in the product identification includes two digits to indicate the attitude measurement accuracy of the unit. These are:

- Sensor type DMS 2-05 with an attitude measurement accuracy ±0.05°.
- Sensor type DMS 2-10 with an attitude measurement accuracy ±0.10°.

Refer to Section 5 for full Sensor specifications. The instructions in this Manual apply equally to both Sensors in the DMS 2 range, unless the text identifies a particular unit specifically.

This Manual is an important part of the System. It describes the DMS 2 and contains full installation and operating instructions. You should retain the Manual with the Sensor for use by personnel who will install and operate the System.

Installation and operation of the Sensor are not complex tasks. However, you should spend time to familiarise yourself with the contents of this Manual before you start to install or use the Sensor. Time spent in identifying the task sequence now will ensure your Sensor is operational in the minimum of time.

WARNINGS and CAUTIONS

Where appropriate, this Manual includes important safety information highlighted as WARNING and CAUTION instructions. You must obey these instructions:

- **WARNING instructions alert you to a potential risk of death or injury to users of the System.**
- **CAUTION instructions alert you to the potential risk of damage to the System.**

For your convenience, the Table of Contents section includes copies of all the WARNING and CAUTION instructions included in this Manual.

Throughout this Manual, unless stated otherwise all measurements conform to the SI standard of units.

For your convenience, this Manual includes several sections, each of which describes specific features of the Sensor:

You should read sections 1 and 2 before you attempt to install the Sensor:

Section 1 contains introductory notes and describes those items supplied with the standard Sensor.

Section 2 describes how to select a suitable location for the Sensor. This section includes full instructions to install the Sensor and connect it to external receiving equipment.

You should read sections 3 to 5 before you use the Sensor:

Section 3 describes how to change the operator-selectable variables, and includes details of the output data formats.

Section 4 contains more information on operational details.

Section 5 lists the full Sensor specification.

You should read section 6 if you suspect that any part of the System has developed a fault condition:

Section 6 describes the diagnostic functions and suggests some basic problem-solving procedures.

CAUTION

You will void the warranty if you open the Sensor housing without prior authorisation from the Customer Service Department at TSS (UK) Limited. Do not open the Sensor for any reason until you have contacted TSS (UK) Limited by telephone. The title page of this Manual lists the contact details for TSS (UK) Limited.

For reference, this Manual also contains Appendices that provide additional information about the Sensor:

Appendix A describes the Sensor operating theory.

Appendix B explains the special features of the operating software supplied with the Sensor.

Appendix C describes the options that are available with the Sensor.

Appendix D describes the commissioning trials that you should perform to confirm correct Sensor operation.

1.1 System Description

1.1.1 Sensor Package

Figure 1–1: Sensor electronics package

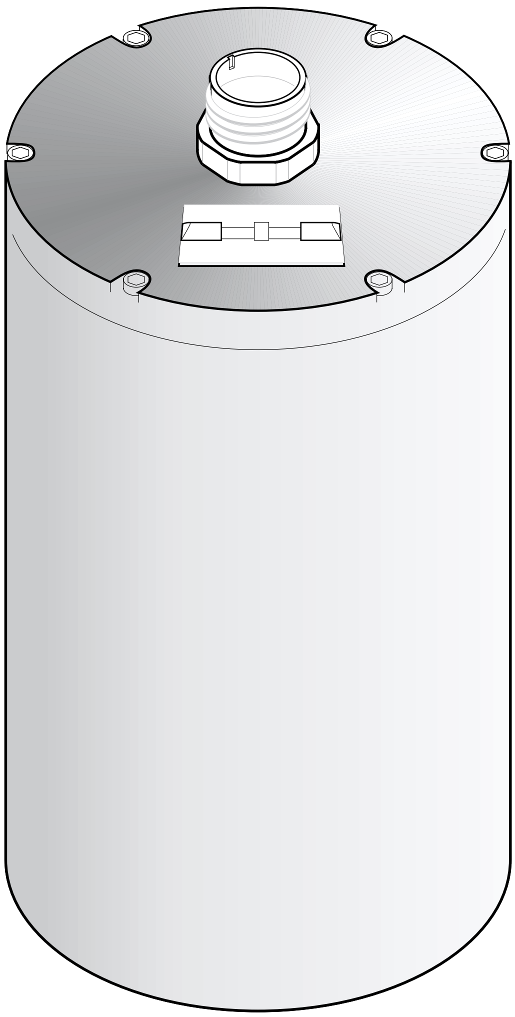


Figure 1–1 shows the depth rated Sensor electronics package. This housing contains the solid-state accelerometers and rate sensors that resolve the magnitude and direction of forces acting upon the Sensor so that it can supply measurements of motion.

A high-speed DSP converts signals from the accelerometers and rate sensors into measurements of attitude and motion. The Sensor communicates these via RS232 or RS422 to your receiving equipment. Optionally, you may use a TSS Remote Repeater unit to generate analogue output signals and to connect the Sensor to external equipment. Refer to Appendix C for a description of the repeater.

It is a relatively simple operation to install the Sensor and you should be able to accomplish this task quickly without the need for specialised personnel or equipment. Because the Sensor is small, you may mount it close to the point for which you require measurements.

The alignment procedure during installation is not exacting, although you should select a location for the Sensor with care. Refer to Section 2 for full instructions to install, connect and align the Sensor.

1.1.2 Software

You may connect a PC to the Sensor to configure and control the System and to log its digital measurements. See Section 3 for full operating instructions and for a description of the Sensor control software. The System includes PC software that you may use to carry out this procedure. Refer to Appendix B for instructions to install and use the supplied software.

1.1.3 Auxiliary Inputs

The Sensor can accept signals from auxiliary equipment such as a gyrocompass and either a Global Positioning System (GPS) or a Doppler log. The System uses these 'aiding' inputs to maintain the accuracy and stability of measurements throughout vessel turns and other manoeuvres. Refer to Section 4 and Appendices A and C for more information.

1.2 Principle of Operation

The Sensor includes an array of solid-state sensing elements that measures the instantaneous linear accelerations and angular rates that affect it. These measurements allow the Sensor to determine its attitude relative to the true vertical.

Additionally, the Sensor can use velocity and heading information supplied by appropriate aiding sources to maintain its measurement accuracy throughout vessel turns.

Changes in the signals supplied by the sensing elements allow the Sensor to measure its vertical displacement (heave). For installations where you cannot install the Sensor at its ideal location (described in Section 2), you may configure the Sensor to supply measurements of remote heave.

See Appendix A for a full description of the operating theory.

The Sensor transmits new measurements to external equipment (optionally through the TSS Remote Repeater unit) at the fastest update rate compatible with the selected communication protocol. You may configure the Sensor and the repeater to use either RS232 or RS422 serial communications at speeds up to 38400 baud.

When you use the optional Remote Repeater unit, the Sensor can also supply scalable analogue outputs for heave, roll and pitch. These outputs are available *only* from the optional Remote Repeater unit.

1.3 Warranty

TSS (UK) Limited warrants the Sensor to be free of defects in materials or workmanship for twelve months beginning on the date when the equipment was shipped from the TSS factory or from an authorised distributor.

To ship the units between installation sites or to return them to TSS (UK) Limited or an authorised distributor for repair, package them with care. You should retain the original transit packing case for this purpose.

The use of improper packing for shipping any part of this equipment will void the warranty.

For information concerning the proper return location and procedure, contact TSS (UK) Limited or an authorised distributor. The title page of this Manual lists the contact details for TSS (UK) Limited.

The responsibility of TSS (UK) Limited in respect of this warranty is limited solely to product replacement or product repair at an authorised location only. Determination of replacement or repair will be made by TSS (UK) Limited personnel or by personnel expressly authorised by TSS (UK) Limited for this purpose.

This warranty will not extend to damage or failure resulting from misuse, neglect, accident, alteration, abuse, improper installation, non-approved cables or accessories, or operation in an environment other than that intended.

In no event will TSS (UK) Limited be liable for any indirect, incidental, special or consequential damages whether through tort, contract or otherwise. This warranty is expressly in lieu of all other warranties, expressed or implied, including without limitation the implied warranties of merchantability or fitness for a particular purpose. The foregoing states the entire liability of TSS (UK) Limited with respect to the products described herein.

Contact TSS (UK) Limited for information if you require further cover beyond the warranty period.

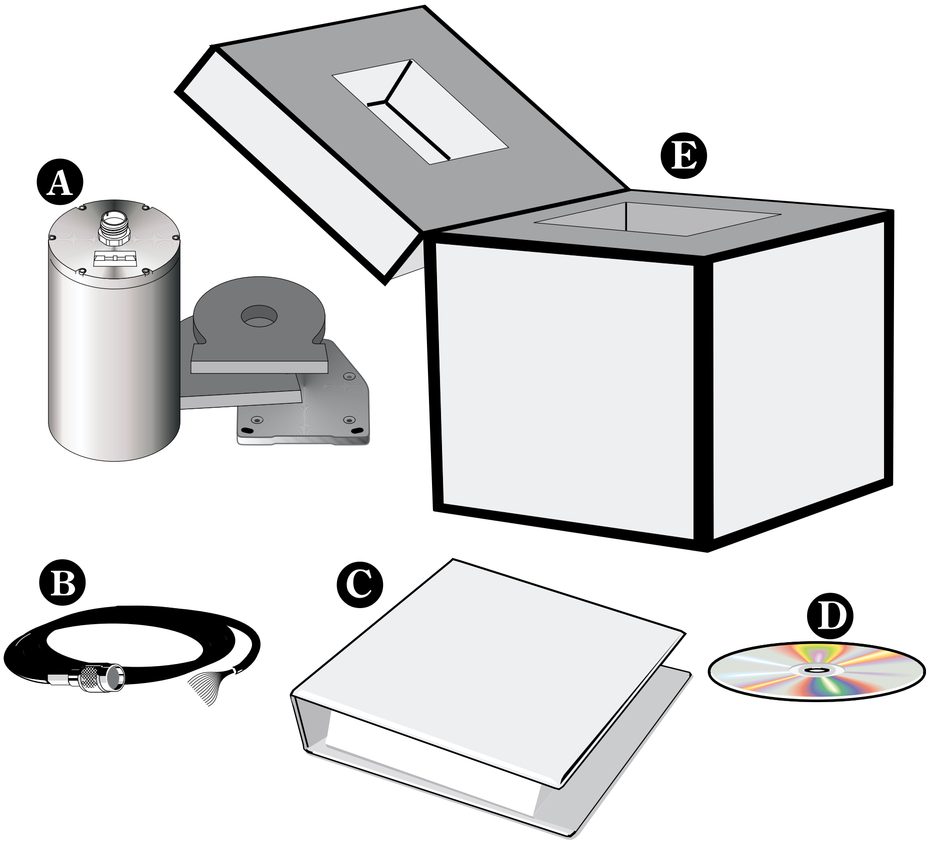
2 INSTALLATION

To gain the best performance from the Sensor you must take care when you install and connect it. This section includes all the information and instructions you will need to select an appropriate location to install the Sensor and to connect it to receiving equipment.

You should read this section carefully and understand the important instructions that it contains before you begin to install the equipment.

2.1 Scope of Delivery

Figure 2–1: Components of the standard System



The standard DMS 2 System includes the following parts:

- **A** Sensor electronics package with calibration certificate and mounting plates
- **B** Sensor cable
- **C** System Manual
- **D** CD with graphical display and logging software
- **E** Transit case

Appendix C describes the optional items that you may use with the System. These include:

- Auxiliary GPS receiver (user supplied)
- Auxiliary gyrocompass system (user supplied)
- Remote Repeater unit
- Field support kit
- Training support

2.2 Unpacking and Inspection

The Sensor receives a full series of electrical and mechanical tests during manufacture and before dispatch. The packing case uses a special design to protect the equipment against shock during transit so that it should arrive without damage or defect.

Retain the original transit cases so that you may use them to transport the Sensor when necessary. You will void the warranty if you use improper packing during transportation.

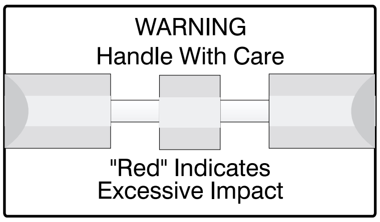


Figure 2–2: Shockwatch impact sensitive label

As soon as possible after you have received the Sensor, check all items against the shipping documents. Inspect all sub-assemblies carefully to check for any damage that might have occurred during transportation. Note especially the 'Shockwatch' impact-sensitive label fitted to the top of the Sensor package.

If you see any damage, or if the 'Shockwatch' indicator has been triggered so that any part of the central vial appears red, file a claim with the carrier and immediately notify TSS (UK) Limited.

Rough handling may damage the delicate accelerometer and rate sensor components inside the Sensor. If the 'Shockwatch' label has been triggered this may indicate a possible fault in one or more components of the accelerometer array. Refer to sub-section 6.1.2 for a simple procedure to check these components.

To avoid loss or damage to any components of the System, store all sub-assemblies safely in the transit case until you need to install them. Obey the storage temperature and humidity limits listed in Section 5.

Notify TSS (UK) Limited immediately if there are any components missing from the shipment.

The title page of this Manual lists the contact details for TSS (UK) Limited. TSS also operates a 24-hour emergency telephone support line managed by trained and experienced TSS engineers.

2.3 Physical Installation

2.3.1 Selecting a location for the Sensor

There are certain guidelines that you should follow to install the Sensor successfully:

- The Sensor can measure the heave motion of the vessel. For these measurements to be accurate, you should mount the Sensor close to the point for which they are required. A Remote Repeater unit is available that you may use when you have installed the Sensor at a distance from the receiving equipment. See Appendix C for a description of the Remote Repeater.

  If you cannot locate the Sensor close to the point for which you require heave measurements, you may use the remote heave measurement facility. Refer to sub-section 2.3.4 and sub-section 3.2.1.3 for a description of this feature.

- Mounting the Sensor either very high or very low in the vessel could introduce severe horizontal acceleration as the vessel rolls. You should avoid this mounting arrangement because it can introduce measurement errors.

  Ideally therefore you should locate the Sensor vertically in line with the position for which you require heave measurements and, if possible, on a horizontal plane with the vessel rotation point. If you do not know precisely where the vessel rotation point is, a position close to the waterline will usually be acceptable. See sub-section 2.3.1.1 for guidance that you should follow if you cannot avoid a high or a low mounting position.

- A software routine, described in sub-section 3.2.1.1, allows the Sensor to measure its static mounting angles relative to a level plane. Therefore you do not need to select a mounting location that is precisely level. Note however that any major departure from a level mounting could limit the range of attitude that the Sensor can measure.

- The Sensor package is depth rated to the limit stated in sub-section 5.3. **Never go beyond this depth rating with the Sensor.**

- Do not install or operate the Sensor where the ambient temperature could fall below 0°C or rise above +40°C. Do not install the Sensor where rapid changes of temperature can occur.

- Do not install the Sensor close to strong mechanical or electrical noise sources, or in a location susceptible to vibration or shock.

- Select a location that allows convenient access to install, connect and service the Sensor. You should also make certain the location protects the Sensor from accidental damage by personnel or equipment.

- Ground the Sensor at a single point only through the green tail (screen) of its connection cable. Insulate the Sensor housing from ground by using the mounting plates supplied. This precaution prevents the formation of a ground loop that could degrade performance.

2.3.1.1 Off-axis Mounting

There may be circumstances where Sensor installation is possible *only* at a point that is displaced vertically away from the vessel rotation point. These non-ideal installation conditions will give rise to attitude measurement errors whose magnitude will depend upon three factors:

1. Vertical displacement between the Sensor and the vessel rotation point.

Any vertical displacement between the Sensor and the centre of vessel rotation will cause a linear degradation in attitude measurement accuracy: If the vertical displacement doubles then the measurement error will also double.

Errors also arise through any lateral offsets that may exist between the Sensor and the centre of vessel rotation, i.e. when the Sensor is to port/starboard or fore/aft of the centre of rotation. However, these errors are usually very small and you do not need to consider them under normal circumstances.

2. The attitude experienced by the vessel.

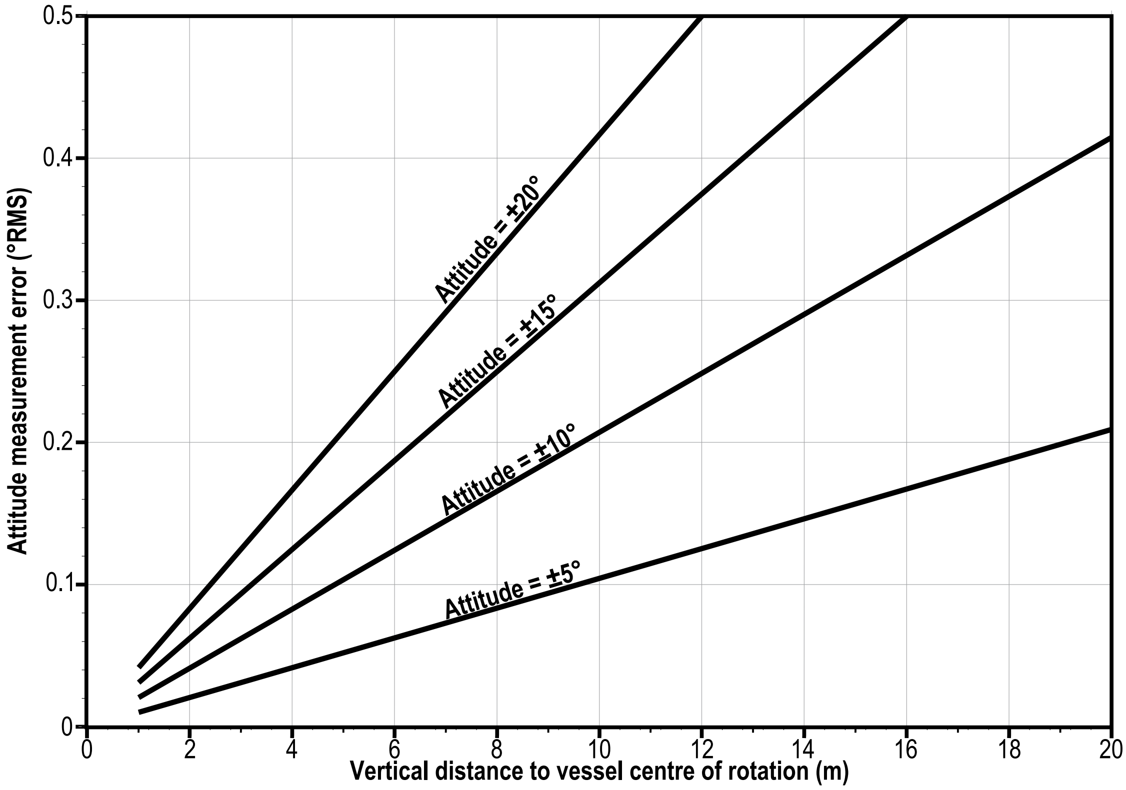
When you install the Sensor at some vertical displacement away from the centre of vessel rotation, attitude measurement errors are also related linearly to the amplitude of roll and pitch experienced by the vessel. For example, doubling the amplitude of roll will double the magnitude of errors in the attitude measurements.

3. The period of vessel motion.

Due to the filtering action of the Sensor, errors in the measurement of attitude are also slightly dependent upon the period of motion. These errors remain almost constant at the levels shown in Figure 2–3 up to a motion period of 20 seconds. At a motion period of 25 seconds, errors reach a peak that is approximately 20% greater than shown, after which they reduce. Errors due to the vertical displacement of the Sensor become negligible at a motion period of approximately 50 seconds.

The graph in Figure 2–3 shows the theoretical degradation in attitude measurement accuracy (in degrees RMS) for a Sensor installed with a vertical displacement up to 20 metres above or below the horizontal plane of the vessel rotation point. The graph includes information for peak attitude changes of ±5°, ±10°, ±15° and ±20°.

Figure 2–3: Off-axis accuracy degradation



The following formula allows you to estimate the theoretical attitude measurement errors for conditions that the graph does *not* describe specifically:

$$\text{Error (degrees RMS)} = \frac{D \times A}{480}$$

Where: D = Vertical offset (metres) between the Sensor and the vessel centre of rotation

A = The instantaneous attitude of the vessel in degrees (the combined angles of roll and pitch).

To measure heave to the specified accuracy the Sensor must have an attitude measurement accuracy of approximately 0.5° RMS, or better. If the accuracy of attitude measurement does not meet this requirement then drift may appear in the heave measurements.

2.3.2 Sensor Orientation

2.3.2.1 Vertical or Horizontal Orientation

For convenience, you may install the Sensor either vertically or horizontally. There is no difference in the performance between a vertically mounted and a horizontally mounted Sensor.

Select a convenient horizontal or a vertical orientation for the Sensor and make certain the location allows easy access to install, connect and service the equipment.

Follow the instructions in sub-section 2.3.2.2 to install the Sensor.

After you have installed the Sensor, you must configure the software so that it knows whether you have selected a vertical or a horizontal orientation. Refer to sub-section 3.2.1.1 for instructions to do this.

2.3.2.2 Installation and Alignment

You must align the sensitive axes of the Sensor with the vessel so that there is no breakthrough of roll movements onto the pitch measurement axis and *vice versa*. To maintain a roll and pitch measurement accuracy of 0.05° with 10° of roll or pitch present, you must align the Sensor to within ±0.3°.

The Sensor has a bow marker arrow on its main label. Depending on the orientation you choose, align the Sensor as follows:

- For vertical mounting orientations, the main label must be on the side of the Sensor closest to the bow of the vessel. The alignment notch and bow alignment arrow on the circular top plate must point towards the bow.

- For horizontal mounting orientations, align the arrow on the main label to point towards the bow of the vessel, with the alignment notch and the bow alignment arrow on the circular top plate pointing upwards.

Whichever alignment orientation you choose, you must align the Sensor carefully for your particular application.

Vertical mounting arrangements

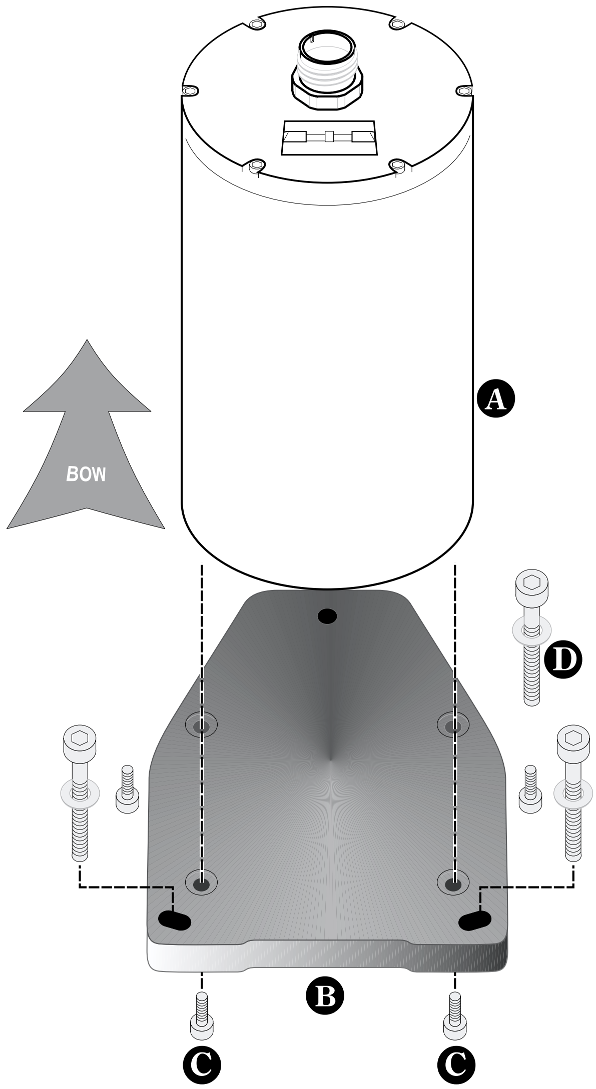


Figure 2–4: Sensor mounting arrangements – Vertical orientation

1. To mount the Sensor **A** vertically you must use the mounting plate **B** designed specially for this orientation. In the vertical orientation, the main label of the Sensor must be on the side closest to the bow, with the arrow on the circular top plate pointing towards the bow. Align the Sensor and the mounting plate to meet this requirement.

2. Insert the four M5 × 16mm socket screws **C** through the mounting plate and engage them in the threaded holes at the bottom of the Sensor. Use a 4mm hexagonal key to tighten the screws evenly. **Do not over tighten these screws.**

3. Place the Sensor and mounting plate on the deck at the location you have chosen and align them to the fore-aft line of the vessel. Note that the mounting plate has a circular hole and two slots that allow some freedom of movement to help you align the Sensor accurately after installation. Mark the position of the three mounting holes carefully on the deck. Store the assembled Sensor and mounting plate safely while you prepare the mounting location.

4. Drill and tap three holes to take the screws or bolts **D** that you will use to fix the mounting plate and Sensor in position. The Sensor shipment does not include these screws or bolts. Remove any burrs or swarf from the mounting location.

5. Re-locate the Sensor and then insert the three securing screws or bolts through the holes in the mounting plate. Do not tighten the securing screws or bolts fully until *after* you have aligned the Sensor accurately with the vessel.

6. Complete the electrical installation of the Sensor by following the instructions in sub-section 2.4.

7. Follow the procedure in Appendix D to align the Sensor accurately to the vessel. Tighten the securing screws or bolts fully.

8. After you have installed the Sensor, perform the routine described in sub-section 3.2.1.1 to measure and save the static Roll/Pitch Mount Angles.

Note however that, for applications where you will use the Remote Heave feature, you may have to make special arrangements to determine the Sensor mounting angles. See sub-section 2.3.4 below.

Horizontal mounting arrangements:

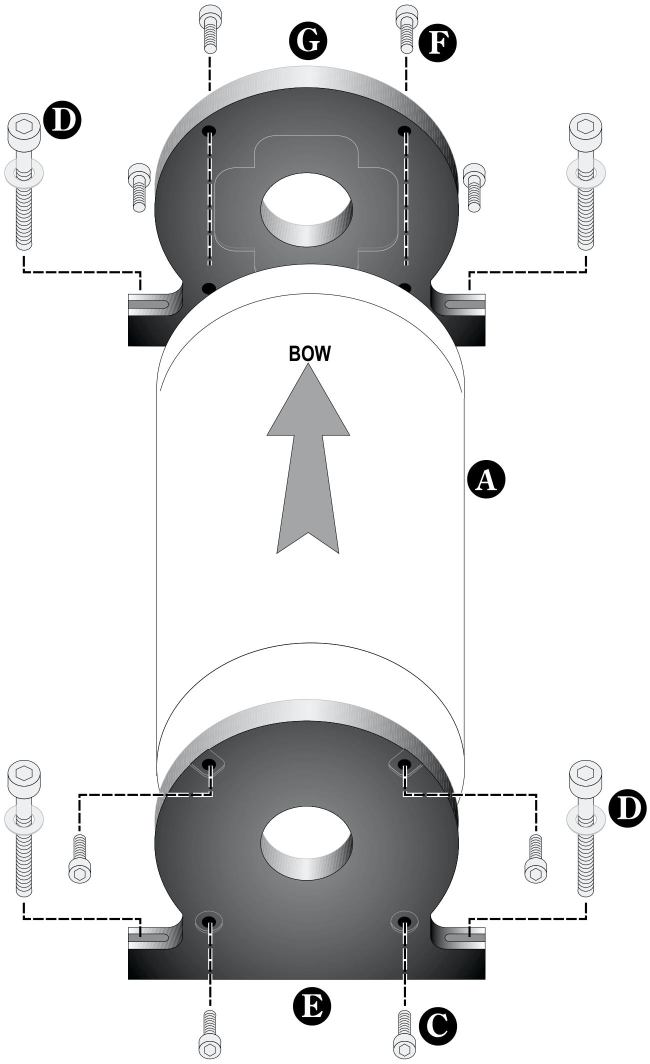


Figure 2–5: Sensor mounting arrangement – Horizontal orientation

9. To mount the Sensor Ⓐ horizontally you must use the two mounting plates designed specially for this orientation.

10. In the horizontal orientation, the main label of the Sensor must be uppermost with the arrow pointing towards the bow. Align the Sensor carefully to meet this requirement.

11. Insert the four M5 × 16mm socket screws Ⓒ through the base mounting plate Ⓔ and engage them in the threaded holes at the bottom of the Sensor. Use a 4mm hexagonal key to tighten the screws evenly. **Do not over tighten these screws.**

12. Insert the four M5 × 20mm socket cap head screws Ⓕ through the top mounting plate Ⓖ and engage them in the threaded holes in the Sensor top plate. Use a 4mm hexagonal key to tighten the screws evenly. **Do not over tighten these screws.**

13. Place the Sensor assembly on the deck at the location you have chosen and align it closely to the fore-aft line of the vessel. Note that the mounting plates have slots to accept the screws or bolts Ⓓ that you will use to secure the assembly to the deck. The Sensor shipment does not include these screws or bolts. The slots allow some freedom of movement to help you align the Sensor accurately to the vessel after installation. Carefully mark the position of the four mounting holes on the deck. Store the assembled Sensor and mounting plates safely while you prepare the mounting location.

14. Drill and tap four holes to take the screws or bolts that you will use to fix the Sensor assembly in position. Remove any burrs or swarf from the mounting location.

15. Re-locate the Sensor and insert the four securing screws or bolts through the slots in the mounting plates. Do not tighten the securing screws or bolts fully until after you have aligned the Sensor accurately with the vessel.

16. Complete the electrical installation of the Sensor by following the instructions in sub-section 2.4.

17. Follow the procedure in Appendix D to align the Sensor accurately to the vessel. Tighten the securing screws or bolts fully.

18. After you have installed the Sensor, perform the routine described in sub-section 3.2.1.1 to measure and save the static Roll/Pitch Mount Angles.

Note however that, for applications where you will use the Remote Heave feature, you may have to make special arrangements to determine the Sensor mounting angles. See sub-section 2.3.4 below.

2.3.3 ROV Mounting

The standard Sensor is depth rated so that you may install it on an ROV. Refer to sub-section 5.3 for details of the approved depth rating for the Sensor.

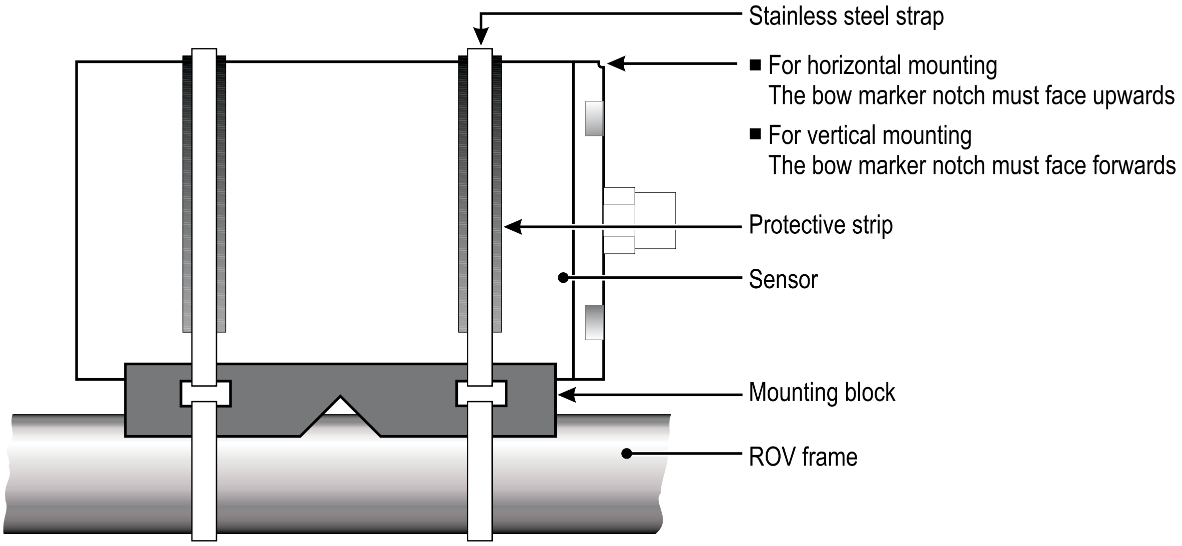
If you intend to mount the Sensor against one of the frame members on the ROV, you must use the special mounting block designed for this purpose. This mounting block helps to prevent damage to the surface coating of the Sensor and therefore protects it against the onset of corrosion. Contact TSS (UK) Limited if you require the optional mounting block.

Do not attempt to mount the Sensor directly against any frame member on the ROV without using the correct mounting block.

If you use this mounting method, shown in Figure 2–6, you must make certain the bow arrow and the bow notch have the correct orientation:

- For a vertical mounting orientation, the bow marker notch and arrow must both point forward.
- For a horizontal mounting orientation, the bow marker notch and arrow must point upwards.

Figure 2–6: Sensor mounting to an ROV frame member



2.3.4 Remote Heave

Sub-section 2.3.1 defines the ideal location for the Sensor as being vertically in line with the point for which you require heave measurements, and on the same horizontal plane as the vessel rotation point.

There may be circumstances where this ideal location is not available. In these circumstances, you must install the Sensor at a location remote from the point for which you require heave measurements.

The Sensor can allow for such an offset by measuring the angles of roll and pitch and then applying trigonometry to the offset distance.

Figure 2–7: Calculation of remote heave

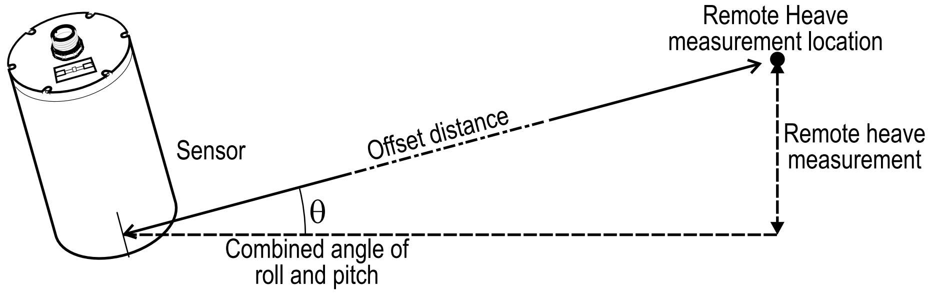


Figure 2–7 shows a simplified example where remote heave measurements are required for a position that is offset horizontally from the Sensor. The remote heave can be calculated:

remote heave = *offset distance* × sin θ

Where θ is the combined angle of roll and pitch

The *offset distance* is the distance measured from the datum point of the Sensor to the remote heave measurement location. The datum point at is the centre of the Sensor end plate opposite the connector, as indicated in Figure 2–7.

Note the following:

1. The calculation assumes that the vessel is rigid.

Any vibration or twisting of the vessel that affects the remote location and the Sensor differently will cause noise and errors to appear in the remote heave measurements.

For an offset distance in the horizontal plane of 10 metres, a vibration that causes 0.1° of attitude change at the Sensor will cause a 2cm component of noise in the remote heave output.

2. Errors in remote heave increase with offset distance

Any errors in the measurement of θ will give rise to errors in the measurement of remote heave:

Remote heave measurement error = *Horizontal offset distance* × sin(*error in measuring* θ)

For a Sensor that has a basic attitude measurement accuracy of 0.05° then the error in remote heave could exceed 5cm when the horizontal offset distance is greater than 57 metres.

2.3.4.1 Offset distances

For the Sensor to deliver measurements of remote heave you must configure it with the *x*, *y* and *z* offset distances shown in Figure 2–8. To do this you must use the *vessel* frame of reference for these offset distances:

Vessel frame of reference:	The surveyed fore/aft and port/starboard horizontal axes and the vertical axis of the vessel.
Sensor frame of reference:	The horizontal and vertical Sensor axes that align with the orthogonal array of linear accelerometers and rate sensors.

IMPORTANT
You must configure the Sensor with offset distances that use the vessel frame of reference. This frame of reference does not allow for the Sensor mounting angle.

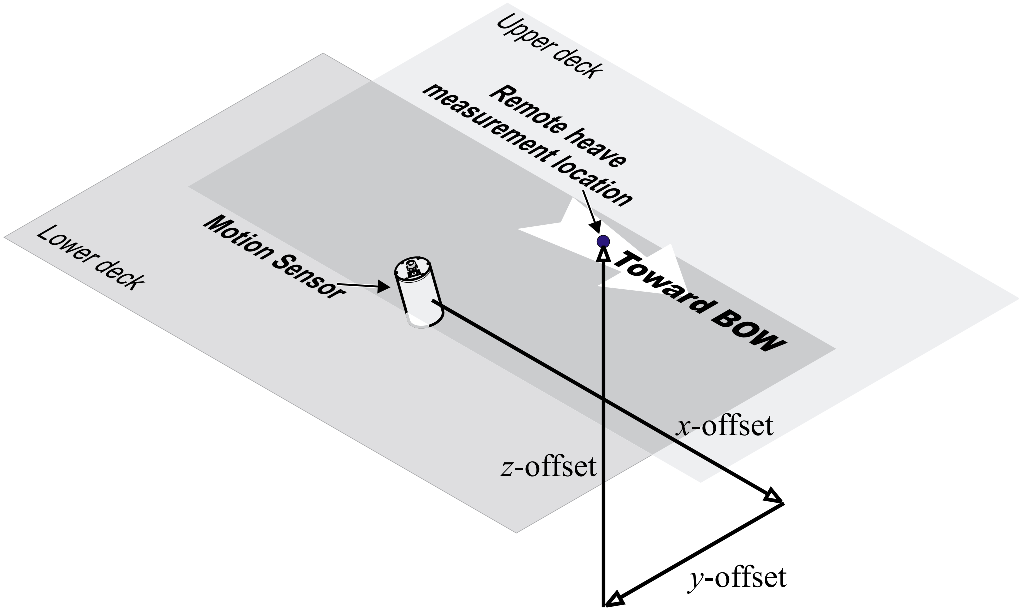
Before the Sensor can determine remote heave accurately, you must configure the System with the roll and pitch angles between the Sensor and the vessel frames of reference. Enter these details using the Roll/Pitch Mount Angle measurement routine described in sub-section 3.2.1.1.

The example in Figure 2–8 shows the Sensor mounted with a positive pitch angle between the Sensor and the vessel frames of reference. After installation, you may use the Roll/Pitch Mount Angle measurement routine to measure this angle *only* if the vessel is on a perfectly even keel. Otherwise, you must refer to the vessel plans to determine the angle of the mounting position with respect to the vessel frame of reference.

The offset distances can be positive or negative:

x offset	The offset along the fore-aft line of the vessel between the Sensor and the remote heave measurement location. **A positive x offset indicates a remote heave measurement location forward of the Sensor.**
y offset	The offset along the port-starboard line of the vessel between the Sensor and the remote heave measurement location. **A positive y offset indicates a remote heave measurement location to port of the Sensor.**
z offset	The offset along the vertical axis of the vessel between the Sensor and the remote heave measurement location. **A positive z offset indicates a remote heave measurement location above the Sensor.**

Figure 2–8: Remote Heave offset distances



Make careful measurements of the Sensor mounting angles and of the *x*, *y* and *z* offset distances. Any errors in measuring these will introduce errors in the determination of remote heave.

After you have installed the System, measure the mounting angles and the remote heave offset distances (or 'lever arms') and then follow the instructions in sub-sections 3.2.1.1 and 3.2.1.3 to configure the Sensor correctly.

2.4 Electrical Installation

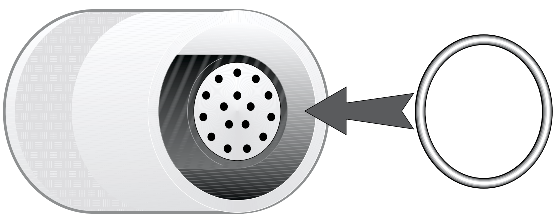
Complete the physical installation of the Sensor package as described in sub-section 2.3 above.

There are two methods available to connect and configure the Sensor:

- Directly to external equipment
- Through the optional remote repeater

CAUTION

To seal the Sensor port against water ingress you must fit one of the supplied O-rings to the connector on the Sensor cable. To prevent their loss during transit, the connectors do not have these O-rings fitted.



1. Check that the O-ring is in good condition. Apply a very thin coating of silicone oil approved by the manufacturer for use in deep water seals.

2. Place the O-ring so that it surrounds the central pillar of the connector.

3. Use a thin probe with a rounded end to gently press the O-ring into position inside the connector. Do not snag or damage the O-ring during fitting.

Complete the electrical connections as instructed throughout this section.

Figure 2–9: Direct connection to external equipment

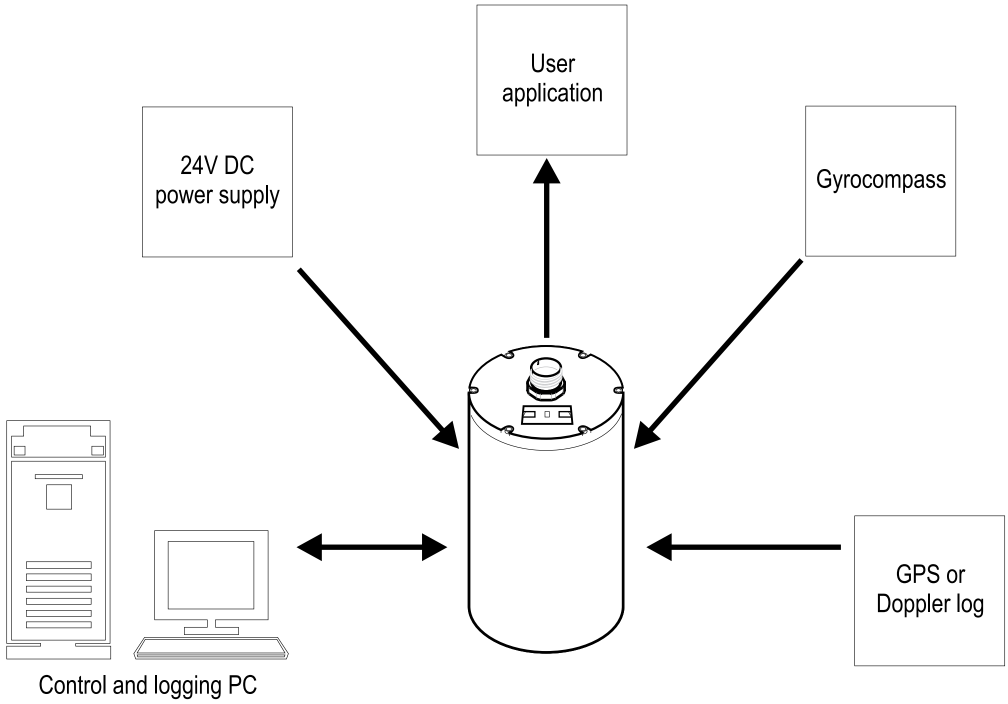


Figure 2–9 shows a direct connection to external equipment. The arrangement allows for digital connections only and includes the following provisions:

Mandatory connections:

- Nominal 24V DC power supply.
- Primary communications to a control and logging PC. *Note: If you do not require the data logging facility, you may disconnect the PC after you have configured the Sensor.*
- Data connection to the external application.

Optional connections:

- Heading aiding communications from a gyrocompass system. *This is an input to the Sensor only.*
- Velocity aiding communications from a GPS receiver or a Doppler log. *This is an input to the Sensor only.*

Figure 2–10: Connection through the optional Remote Repeater

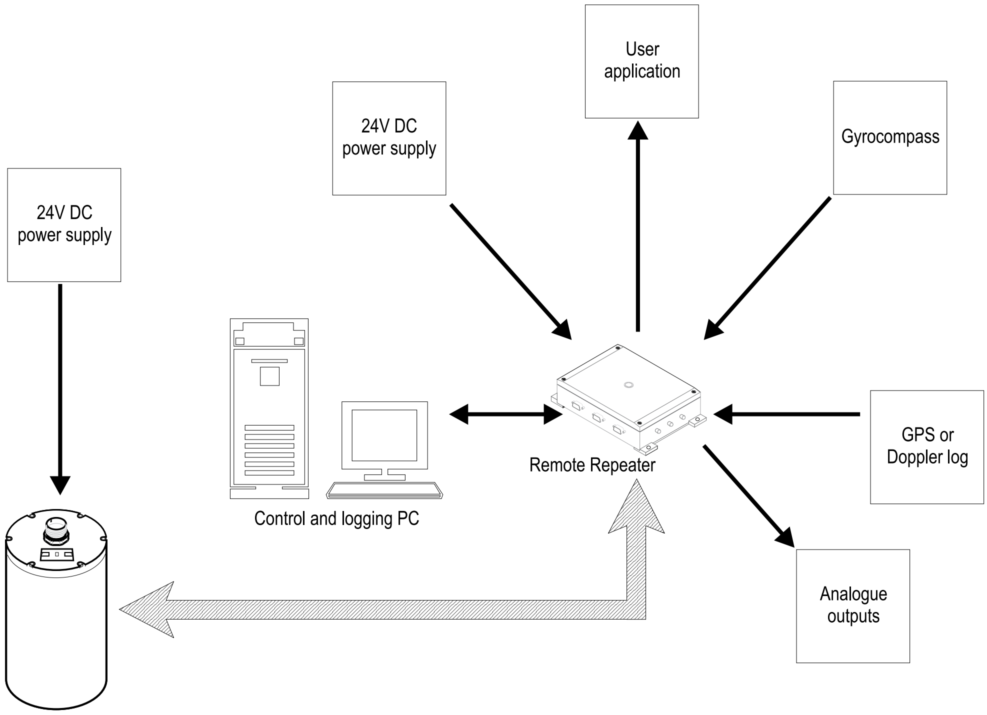


Figure 2–10 shows an installation that uses the optional Remote Repeater unit to make connections between the Sensor and external equipment. The arrangement allows communication through digital and analogue channels and includes the following provisions:

Mandatory connections:

- Nominal 24V DC power supply to the Sensor *and* to the repeater unit.
- High speed digital link to pass bi-directional communications between the Sensor and the repeater unit.
- Primary communications to a control and logging PC. *Note: If you do not require the data logging facility, you may disconnect the PC after you have configured the Sensor. If necessary, you may make this connection locally to the Sensor instead.*
- Data connection from the repeater to the external application.

Optional connections:

- Gyrocompass aiding communications to the repeater unit.
- Velocity aiding communications from a GPS receiver or a Doppler log to the repeater unit. This can be a bi-directional communication link that allows the Sensor to configure the GPS receiver to provide the correct output sentences.
- Analogue outputs of heave, roll and pitch in the range ±10V. You may configure the scale factors, polarity and offset of the analogue outputs.

Refer to Appendix C for details of the Remote Repeater unit and of the aiding connections.

All connections to the Sensor are through a single 5-metre length of 16-way cable. Refer to Table 2–1 below and drawing 600732 in sub-section 6.4 for cable details.

Table 2–1: Sensor cable connection details

Connection description	Core colour	Pair	Function RS422	Function RS232	Pin number
Power + Power –	BL BK	+ –	Power 24V DC + Power –	Power 24V DC + Power –	1 2
Primary comms to PC Primary comms to PC	BL WH	A A	Ch B TxA primary Comms Ch B TxB primary Comms	Tx Primary Comms N/A	3 4
Primary comms from PC Primary comms from PC	RD WH	B B	Ch B RxA primary Comms Ch B RxB primary Comms	Rx Primary Comms Common Primary Comms	5 6
Remote Repeater link Remote Repeater link	YL WH	C C	Ch A TxA Remote Comms Ch A TxB Remote Comms	N/A N/A	7 8
Remote Repeater link Remote Repeater link	GN WH	D D	Ch A RxA Remote Comms Ch A RxB Remote Comms	N/A N/A	9 10
Gyrocompass	BK WH	E E	Ch C RxA Gyro Comms Ch C RxB Gyro Comms	Rx Gyro Comms Common Gyro Comms	11 12
GPS or Doppler log	OR WH	F F	Ch C RxA GPS Comms Ch C RxB GPS Comms	Rx GPS Comms Common GPS Comms	13 14
Ground	GN	S	No connection Cable screen	No connection Cable screen	15 16

Colour key: BK = Black BL = Blue GN = Green OR = Orange RD = Red WH = White YL = Yellow

Route the Sensor cable carefully from the Sensor to the external equipment. Avoid any sharp bends or points of mechanical stress, and use suitable cable clips to support the cable at intervals.

In order for the Sensor to comply with the requirements of the EMC Directive 89/336/EEC (to standards EN 50081-1: 1997, EN 50082-1: 1992 and EN 60954: 1997 Sections 9 & 10) it must be used only with the supplied Sensor cable (P/N 600732). The user of the Sensor is responsible for ensuring that any modified or substituted cables will continue to allow the System to conform to those standards.

TSS (UK) Limited cannot be held responsible for any unauthorised alterations to cable specifications.

Follow the instructions on page 13 and check that there is an O-ring fitted to the cable connector. Connect the cable to the Sensor and tighten the locking collar by hand.

Make all connections from the Sensor to external equipment as appropriate for your installation. If necessary, refer to the technical manuals supplied with the external equipment for relevant connection details.

Use the controlling PC to configure the Sensor. Refer to Section 3 and Appendix B for instructions to do this.

Electrical connection summary:

1. The Sensor accepts DC electrical power in the range 12 to 36V DC. Be careful to connect the supply using the correct polarity:

- The +24V supply must connect to the + (blue) core on pin1.
- The negative return must connect to the – (black) core on pin 2.

If your System includes the optional Remote Repeater, you must also provide a DC electrical supply in the range 18V to 36V DC to operate the repeater. It is possible to connect the 24V DC supply to the Remote Repeater and then pass an electrical supply to operate the Sensor through the umbilical cable. However, the voltage drop may be too great if the umbilical cable is longer than approximately 200 metres. The instructions throughout this Manual assume you will operate the Sensor and the Remote Repeater from separate 24V DC supplies.

2. Connect all cable screens to a single ground point. Do not allow the Sensor housing to connect to ground through a separate electrical path.

3. If you deploy the Sensor underwater, make certain you use a ground point that is at the same electrical potential as the ROV. This precaution is to avoid galvanic corrosion of the Sensor housing.

CAUTION

To avoid the possibility of forming a ground loop, you must isolate the Sensor housing from any local ground connection. Use the insulating mounting plates supplied with the System to install the Sensor.

Failure to take this precaution could result in Sensor malfunction and possible corrosion of the housing.

4. If necessary, for example when you use the Sensor underwater, you may remove the dust cap from around the Sensor port. To do this, unscrew the retaining washer. Store the dust cap in the transit case for future use.

3 OPERATING INSTRUCTIONS

Firmware resident in the Sensor allows you to configure and control the System. To use this firmware you must connect a control and logging PC to the Sensor through a serial RS232 port. The System includes the DMSView graphical display software that you may use for this purpose.

After you have installed and configured the Sensor correctly, you may leave it to operate independently with no further need for a controlling PC. In this mode, the Sensor supplies digital measurements continuously through its output port. If you use the Sensor with the optional TSS Remote Repeater unit, you may also demand analogue output signals from the BNC ports on the repeater.

This section explains how to power-on and configure the Sensor after you have installed it. It also lists and describes the digital data formats available from the Sensor.

Explains how to power-on the Sensor after installation and describes the initialisation sequence.

Describes the features of the menu system that you use to configure and control the Sensor. This sub-section explains the various operating parameters of the Sensor and lists their default values.

You may use a PC running communication software, such as the program supplied with the System, to interrogate the Sensor menu structure. Refer to Appendix B for instructions to install and use the supplied software.

Describes the various digital data formats available from the Sensor.

The Sensor can accept auxiliary digital inputs from GPS or gyrocompass systems. Refer to Appendix C for details of the data formats that these systems must supply for the GPS and heading aiding facilities to work.

Throughout this section, the keys that you must press to call the described function appear in square brackets. For example, [SHIFT]+[F4] means to press the shift key and the function key F4 simultaneously.

3.1 Initial Power-on

The Sensor always uses RS232 communication and operates at 9600 baud during the power-on self-test and initialisation sequence. If you have configured your Sensor and its controlling PC to operate at a communication speed other than 9600 baud, the screen will show unintelligible strings of characters until the Sensor establishes its correct operating speed after the initialisation sequence.

If you have configured your System to use RS422, this short period of RS232 operation will cause no damage because the Sensor will maintain both transmit lines at the same potential relative to each other during the initialisation sequence.

If necessary, press the [R] key on the receiving equipment during the initialisation sequence to restore the Digital I/O communications parameters to their default values listed in sub-section 3.2.4. *Note that this feature works only when using an RS232 connection to the Sensor.*

Immediately upon application of power, the Sensor performs a power-on self-test to check its memory. This procedure always runs at 9600 baud. After successful completion of the power-on self-test the Sensor loads a series of operating parameters from its internal non-volatile memory and then starts to supply digital data packets.

The operating parameters used when you power-on the Sensor are those that were active when you powered-off the Sensor previously. A new Sensor will use the factory default settings.

The Sensor will supply digital output data that conforms to the format you have selected – see sub-section 3.2.2.1. Use the DMSView display software supplied with the System to see measurements from the Sensor presented on a PC connected to the Sensor. You may view the measurements as vertically scrolling columns of numbers or as horizontally scrolling graphical charts. The DMSView graphical display software allows you to view the measurements in both forms simultaneously. Appendix B includes instructions to connect the Sensor to a PC and to install and use the supplied software.

During the first three minutes after power-on, the Sensor operates in a 'settling' condition. In this condition, the outputs will not be within the specified limits of accuracy and you should not use them for critical measurements. Some of the digital output formats include a status flag that indicates when the Sensor is in a settling condition. Refer to sub-section 3.3 for descriptions of the available digital output formats and for details of those formats that include the status flag. Refer to sub-section 5.1 to see the accuracy specifications for the Sensor.

3.2 Menu Structure

You may configure and control the Sensor by issuing commands and selecting options through the Sensor menu structure. To do this you must connect a PC running appropriate software to the Sensor. The 32-bit Windows™-based DMSView software supplied with the Sensor allows you to control and configure the Sensor, and to read, display and log its measurements.

Follow the instructions in Appendix B to connect your PC to the Sensor, and to install and start the supplied software.

With the PC displaying data strings on the scrolling text screen, press the [ESC] key to display the Main Menu shown in Figure 3–1.

The Sensor does not supply digital output packets while the menus are on display.

Figure 3–1: Main menu screen of the Sensor

```
----------------------------------
DMS 2-05 Version x.x Terminal Mode
----------------------------------
Main Menu
1    Configure Calculation Options
2    Configure I/O
3    Display Raw Data
4    Load Default Configuration
ESC  Exit
Select Option >
```

See sub-section:

3.2.1

3.2.2

3.2.3

3.2.4

Press keys [1] to [4] to select the relevant option. Refer to the appropriate listed sub-section to see a description of each option.

Press the [ESC] key to exit the Main Menu and return to the scrolling text screen. The Sensor accepts and responds only to valid key entries.

IMPORTANT
Any new configuration for the Sensor will become active immediately after you complete entries within each sub-menu.

3.2.1 Configure Calculation Options

Press key [1] from the Main Menu to access the Configure Calculation Options menu.

Figure 3–2: Configure calculation options menu

```
---------------------------------
DMS 2-05 Version x.x Terminal Mode
---------------------------------
Configure Calculation Options Menu
1    Roll/Pitch Mount Angles
2    Heave Bandwidth
3    Remote Heave Offsets
ESC  Return to Main Menu
Select Option >
```

See sub-section:

3.2.1.1

3.2.1.2

3.2.1.3

Press key [1] to [3] to select the relevant function. Refer to the appropriate listed sub-section to see a description of each function.

Press [ESC] to return to the Main Menu.

The Sensor accepts and responds only to valid key entries.

3.2.1.1 Roll/Pitch Mount Angles

If you need to use the Remote Heave measurement facility, you must first configure the Sensor with the differences between the Roll/Pitch Mount Angles of the Sensor and the vessel frames of reference. See sub-section 2.3.4 for relevant information.

With the vessel stationary and level, the roll and pitch angles should display a zero reading.

To avoid the need for making minuscule and tedious mechanical adjustments at the mounting location during the installation procedure, the Sensor has a special ‘calibration routine’. This routine measures the average roll and pitch angles over a long period and then uses these mounting angles as the datum against which to measure all future angles of roll and pitch.

After you have installed, connected and powered-on the Sensor, use the Roll/Pitch Mount Angles facility to measure and store the static mounting angles.

If the vessel is not on an even keel when you perform this measurement, the Sensor will measure and store the residual angles of roll and pitch and these will appear as a constant error offsets in the attitude output.

It is important to measure the roll and pitch mounting angles with the vessel on an even keel or when it has the trim conditions expected throughout the survey.

Figure 3–3: Mount angle measurement screen

```
---------------------------------
DMS 2-05 Version x.x Terminal Mode
---------------------------------
Roll/Pitch Mount Angles

Orientation:          Vertical
Roll Mount Angle      [ 0.000 deg] :
Pitch Mount Angle     [ 0.000 deg] :

Measure Roll/Pitch Mount Angles? Y or N :

Measurement Time [ 1 min ] :

1 mins. To completion – <ESC> to end – r:–0134 p: 0033

Measure Mount Angles:
Roll    : –1.343 deg
Pitch   : 0.332 deg

Save New Mount Angles? Y or N :
```

You may perform the following operations from this screen:

Field	Operation
Orientation	Press the spacebar to toggle between 'Vertical' or 'Horizontal'. Press [ENTER] to accept the displayed value.
[Roll, Pitch] Mount Angle	Enter floating-point values for the roll and pitch mount angles. This option assumes you have measured these angles previously using the Sensor or some other method. If you must mobilise a single Sensor between a number of different mounting locations, this facility allows for a shortened re-initialisation cycle. To take advantage of this feature you must maintain a *written* record of the roll and pitch mount angles at each location. The factory default for both values is 0.000 degrees.
Measure Roll/Pitch Mount Angles?	Press [Y] to select the measuring routine for the static mount angles. Press [N] to return to the Main Menu. Any new values entered will be stored.
Measurement Time	Enter a figure in whole minutes for the time over which the Sensor will measure and determine an average for the static mount angles. Press [ENTER] to accept the displayed value. You should measure the mounting angles in calm conditions when there is minimal roll and pitch movement. However, if you select this option while the vessel is at sea, set the time to its maximum fifteen minutes to make an accurate measurement of the angles.
[*n*] mins. to completion	This field displays the time remaining in whole minutes until completion of the mount angle measurement. The field displays instantaneous measurements of roll and pitch in hundredths of a degree alongside the remaining time. Press [ESC] to abort the Mount Angle Measurement routine.
Save New Mount Angles?	Press [Y] to save the measured static mount angles. Press [N] to ignore the measured mount angles and to display the Configure Calculation Options Menu. Note that the Sensor will retain and use the values stored previously for static mount angles.

3.2.1.2 Heave Bandwidth

Figure 3–4: Heave bandwidth screen

```
----------------------------------
DMS 2-05 Version x.x Terminal Mode
----------------------------------
Heave Bandwidth

Select Heave Bandwidth :
```

To measure heave, the Sensor performs a double integration on the vertical acceleration output from its inertial sensors. This process includes a heave filter whose characteristics are a compromise:

- The filter needs a long time constant to extend the range of dynamic conditions through which the Sensor can respond so that it includes very slow heave movements. Such movements can occur over a very long period if the vessel is travelling in the same direction as the swell.

- The filter needs a short time constant to remove the effects of short-term noise impulses, which would otherwise integrate to a constantly changing vertical displacement. It is also necessary to prevent the Sensor from responding unnecessarily to steady state changes in vertical displacement caused by tidal variations.

Furthermore, because the dynamic characteristics of vessels depend on factors such as their size and displacement, loading condition and hull shape, and the prevailing weather conditions, the heave filter must also allow for these variations.

Due to the mathematical restraints of calculating the heave of the vessel, the motion algorithm requires a heave bandwidth value to operate optimally. The following examples provide a starting point to help you decide on an optimal setting for heave bandwidth. The bandwidth value applies only to heave measurements.

Table 3–1: Suggested heave bandwidth settings

Vessel type	Suggested bandwidth setting
Vessel of 8 to 15 metres overall length to be used for shore and harbour surveys	**Short** (heave period = 8s)
Vessel of 15 to 20 metres overall length to be used for shallow water or coastal surveys	**Medium** (heave period = 12s)
Vessel of 20 to 25 metres overall length to be used for coastal surveys	**Medium** (heave period = 12s) or **Long** (heave period = 16s)
Vessel of 25 metres or longer overall length to be used for deep surveys	**Long** (heave period = 16s) or **Extended** (heave period = 20s)
Floating platforms, FPUs, or FPSOs	**Extended** (heave period = 20s)

Press the spacebar to cycle through the options SHORT, MEDIUM, LONG or EXTENDED. Press [ENTER] to accept the selected value and return to the Configure Calculation Options Menu. Press [ESC] to ignore any changes and return to the Configure Calculation Options Menu.

Heave measurements require three minutes to settle after you power-on the Sensor and after you have changed the heave bandwidth setting.

3.2.1.3 Remote Heave Lever Arm

Figure 3–5: Remote Heave Lever Arm screen

```
---------------------------------
DMS 2-05 Version x.x Terminal Mode
---------------------------------
Remote Heave Lever Arm

Remote Heave Coupling : AC
X-axis lever arm [ 0.000 m] :
Y-axis lever arm [ 0.000 m] :
Z-axis lever arm [ 0.000 m] :
```

The remote heave measurement facility allows the Sensor to deliver measurements of heave for a remote location. Before it can perform this function you must configure the Sensor with the x, y and z lever arm distances between the two locations.

Figure 3–5 shows the Remote Heave Lever Arm screen.

Press the spacebar to toggle between AC or DC coupling for remote heave:

AC COUPLING: ***The default condition uses AC coupling.***

When you select AC coupling the Sensor uses an additional filter to remove any steady-state offset in remote heave caused by a list of the vessel. With AC coupling active, the remote heave will settle eventually to zero regardless of any list.

The filters for remote heave and local heave have different characteristics. This causes an unavoidable transient error when either the remote heave measurement location or the Sensor experience a steady-state shift in vertical displacement.

DC COUPLING:

The Sensor calculates remote heave by using the roll and pitch angles to determine the difference in height to the remote heave measurement location. When the vessel experiences a list, there may be a steady-state difference in vertical displacement between the remote heave measurement location and the Sensor.

When you select DC coupling the remote heave value does not decay to zero with any steady-state list of the vessel. The remote heave calculation includes compensation for any local heave measured by the Sensor at its installed location.

3.2.2 Configure I/O

Press key [2] from the Main Menu to select the 'Configure I/O' menu.

Figure 3–6: Configure I/O menu

```
----------------------------------
DMS 2-05 Version x.x Terminal Mode
----------------------------------
Configure I/O Menu
1    Digital Output
2    Repeater Link
3    GPS Input
4    Gyro Compass Input
5    Test Digital Output
6    Test Repeater Analogue Outputs
7    Calibrate Repeater DACs
ESC  Return to Main Menu
Select Option >
```

See sub-section:
3.2.2.1
3.2.2.2
3.2.2.3
3.2.2.4
3.2.2.5
3.2.2.6
3.2.2.7

Press key [1] to [7] to select the relevant option. Refer to the appropriate listed sub-section to see a description of each option.

Press the [ESC] key to return to the Main Menu. The Sensor accepts and responds only to valid key entries.

3.2.2.1 Configure Digital Output

Use the Configure Digital Output screen to select the format of the digital output from the Sensor. You may change the digital output parameters from this screen.

Figure 3–7: Configure Digital Output screen

```
----------------------------------
DMS 2-05 Version x.x Terminal Mode
----------------------------------
Configure Digital Output

Digital Output Format: TSS1
Baud Rate            : 9600
Data Bits            : 8
Stop Bits            : 2
Parity               : None
Interface            : RS422
```


You may perform the following operations from this screen:

Field	Operation
Digital Output Format	Press the spacebar to cycle through the available options. Press [ENTER] to accept the displayed option. Refer to sub-section 3.3 for a description of the available digital output formats. The System will set appropriate communications parameters for the chosen output format. You may then modify these if necessary.
Baud Rate	Press the spacebar to cycle through the options 1200, 2400, 4800, 9600, 19200 and 38400 baud. Press [ENTER] to accept the displayed value.
Data Bits	Press the spacebar to toggle between 7 or 8 data bits. Press [ENTER] to accept the displayed value.
Stop Bits	Press the spacebar to toggle between 1 or 2 stop bits. Press [ENTER] to accept the displayed value.
Parity	Press the spacebar to cycle through the options None, Even or Odd. Press [ENTER] to accept the displayed value.
Interface	Press the spacebar to toggle between RS422 and RS232. Press [ENTER] to accept the displayed option and return to the Configure I/O menu. To alert you to a possible communication loss when you change from RS422 to RS232 communication, the Sensor displays a warning message if you command this change: **Warning: Changing this channel to RS232 when connected to a Remote Repeater will result in unrecoverable communication loss! Do you still want to use RS232? [Y/N]** The only way to recover from this condition is to connect directly to the Sensor using RS232 from a local PC.

CAUTION

If the Sensor communication cable is longer than 15 metres, you may lose communication with the Sensor when you command a change from RS422 to RS232.

Do not change from RS422 to RS232 communication unless you are entirely certain the communication link, with or without a remote repeater, will continue to operate correctly.

IMPORTANT

The new digital output configuration will become active on return to the Configure I/O Menu. The Sensor will display a message that advises you to check the communications settings on the receiving device:

"WARNING: Ensure your terminal settings are now correct."

3.2.2.2 Configure Repeater Link

Press key [2] from the Configure I/O menu to display the ‘Configure Repeater Link’ screen (illustrated in Figure 3–8).

Figure 3–8: Configure Repeater Link screen

```
---------------------------------
DMS 2-05 Version x.x Terminal Mode
---------------------------------
Configure Repeater Link

Baud Rate       : 38400

Heave [local/remote] : Local Heave
Heave Scaling        [ 1.000 V/m] :
Heave Offset         [ 0.000 m] :

Roll lin/sin         : LIN
Roll Scaling         [ 0.200 V/deg] :
Roll Offset          [ 0.000 deg] :

Pitch lin/sin        : LIN
Pitch Scaling        [ 0.200 V/deg] :
Pitch Offset         [ 0.000 deg] :
```

You may perform the following operations from this screen:

Field	Operation
Baud Rate	Press the spacebar to cycle through the options 1200, 2400, 4800, 9600, 19200 and 38400 baud to set the communication rate between the repeater and the Sensor. **You will reduce the update rate for the analogue outputs if you set this value lower than the default 38400 baud. You might also impair the ability of the Sensor to handle GPS and heading aiding information supplied through the repeater if you set a lower baud rate. You cannot change other communication parameters for the repeater link, for example the number of data, start and stop bits.**
Heave source	The analogue heave output channel can supply either the local heave experienced by the Sensor (the default condition) or the remote heave. Press the spacebar to toggle between local and remote heave. Note that you may have to change the settings for heave scaling and offset when you use the analogue remote heave. You must determine this for each installation. If you have selected analogue remote heave, the analogue heave output from the repeater will supply the remote heave regardless of the selected digital output format.
Scaling	Enter a floating-point number that will scale the selected output to a voltage in the range –10 to +10 volts. You may change the polarity of an analogue output by setting a negative scaling factor.
Offset	Enter a floating-point value that should set the affected analogue output channel to zero volts.
lin/sin	Choose whether the roll and pitch analogue outputs vary linearly with the angle of attitude, or with the sine of the angle of attitude ($V_{out} = \textit{scaling} \times \sin(\textit{angle} + \textit{offset})$).

After you have configured the repeater link, press [ENTER] to accept the selection. The Sensor will then perform two tasks:

1. Using the previous communication baud rate, it will send a message that instructs the repeater to set the new baud rate.

2. The Sensor will then change to the new baud rate and will send a message at the new rate to the repeater requesting a response.

   Following this action there will be one of two possible messages displayed on the screen:

   - If the change in communication baud rate has been successful at both ends and the Sensor receives a valid response from the repeater, then the message will be displayed:

     Repeater Baud Rate Updated

     Following this message, the Sensor restores the Configure I/O Menu.

   - If the Sensor does not receive a valid response from the repeater then the message will be displayed:

     Repeater Not Found. Use New Baud Rate? (Y/N)

     From this message press [N] to quit to the Configure I/O Menu without setting the new baud rate, or press [Y] to set the new baud rate.

3.2.2.3 Configure GPS Input

Use the Configure GPS Input screen to set the data format for the velocity aiding from a Global Positioning System or a Doppler log. Refer to Appendix C for instructions to connect a GPS aiding source.

Figure 3–9: Configure GPS Input screen

```
----------------------------------
DMS 2-05 Version x.x Terminal Mode
----------------------------------
Configure GPS Input

GPS Input Format      : TSIP
GPS Input Source      : Local
Baud Rate             : 9600
Data Bits             : 8
Stop Bits             : 1
Parity                : Odd
Interface             : RS232
```

You may perform the following operations from this screen:

Field	Operation
GPS Input Format	Press the spacebar to select from: **None** – No GPS input is required. **TSIP** – Selects the Trimble Standard Interface Protocol* format. **NMEA** – Selects the National Marine Electronics Association 0183 format. **Doppler 1** – Selects a velocity input from a Doppler log. **Ulvertech DATS** – Selects a velocity input from an Ulvertech Doppler Acoustic Tracking System**. Refer to Appendix C for a description of these data formats. Press [ENTER] to accept the selection. The Sensor will set appropriate communications parameters for the chosen input format. You may then modify these if necessary.
GPS Input Source	If the System includes the optional Remote Repeater unit you may connect a GPS aiding receiver directly to the Sensor or to the 'GPS Comms' port on the repeater. Press the spacebar to toggle between 'Local' (the default condition) or 'Repeater'. **Note: You must give appropriate settings to the following communication parameters even when you have set the GPS Input Source to 'Repeater'.**
Baud Rate	The Sensor will default to either 4800 or 9600 baud automatically. If necessary, press the spacebar to cycle through the options 1200, 2400, 4800 and 9600 baud. Press [ENTER] to accept the displayed value.
Data Bits	The Sensor will default to eight data bits automatically. If necessary, press the spacebar to toggle between 7 or 8 data bits. Press [ENTER] to accept the displayed value.
Stop Bits	The Sensor will default to one stop bit automatically. If necessary, press the spacebar to toggle between 1 or 2 stop bits. Press [ENTER] to accept the displayed value.
Parity	The Sensor will select either None or Odd parity automatically. If necessary, press the spacebar to cycle through the options None, Even or Odd. Press [ENTER] to accept the displayed value.
Interface	Press the spacebar to toggle between RS232 and RS422. Press [ENTER] to accept the displayed value and return to the Configure I/O screen. **Note**: If you configure the System to use the repeater, you cannot use this screen to select the communications interface. Instead, you must set a switch inside the repeater unit. Refer to Appendix C for instructions to do this.

* The TSIP format is proprietary to Trimble Navigation.
** The Ulvertech DATS format is proprietary to Hyspec Systems Limited.

3.2.2.4 Configure Gyro Compass Input

The Sensor can accept heading information from a magnetic compass that has a data output capability. However, there are errors inherent in measurements made by instruments of this type during vessel turns and under the influence of acceleration transients. Therefore, you should prefer to use a gyrocompass that has negligible servo lag for this purpose.

Use the Configure Gyro Compass Input screen to select the data format for the Auxiliary I/O connection from a gyrocompass. Refer to Appendix C for instructions to connect an aiding gyrocompass.

Figure 3–10: Configure Gyro Compass Input screen

```
----------------------------------
DMS 2-05 Version x.x Terminal Mode
----------------------------------
Configure Gyro Compass Input

Gyro Compass Input Format  : SGB
Gyro Compass Input Source  : Local
Baud Rate                  : 4800
Data Bits                  : 8
Stop Bits                  : 2
Parity                     : None
Interface                  : RS232
```

You may perform the following operations from this screen:

Field	Operation
Gyrocompass Input Format	Press the spacebar to select from: None – No gyrocompass input is required. SGB* – Selects SGB ASCII format. Robertson's** – Selects the Robertson's gyrocompass format. NMEA – Selects the National Marine Electronics Association 0183 format. LR40/60*** – Selects the format for use with the Sperry LR40 and LR60 gyrocompasses. Refer to Appendix C for an explanation of these data formats. Press [ENTER] to accept the selection. The Sensor sets appropriate communications parameters for the chosen input format. You may then modify these if necessary.
Gyrocompass Input Source	If the System includes the optional Remote Repeater unit, you may connect the gyrocompass directly to the Sensor or to the 'Heading Comms' port on the repeater. Press the spacebar to toggle between 'Local' (the default condition) or 'Repeater' **Note: You must give appropriate settings to the following communication parameters even when you have set the Gyrocompass Input Source to 'Repeater'.**
Baud Rate	The Sensor will default to either 4800 or 9600 automatically. If necessary, press the spacebar to cycle through the options 1200, 2400, 4800 and 9600 baud. Press [ENTER] to accept the displayed value.
Data Bits	The Sensor will default to either 7 or 8 data bits automatically. If necessary, press the spacebar to toggle between the available options. Press [ENTER] to accept the displayed value.
Stop Bits	The Sensor will default to either 1 or 2 stop bits automatically. If necessary, press the spacebar to toggle between the available options. Press [ENTER] to accept the displayed value.

Field	Operation
Parity	The Sensor will select None, Even or Odd parity automatically. If necessary, press the spacebar to cycle through the available options. Press [ENTER] to accept the displayed value.
Interface	Press the spacebar to toggle between RS232 and RS422. Press [ENTER] to accept the displayed value and return to the Configure I/O screen. **Note**: If you configure the System to use the repeater, you cannot use this screen to select the communications interface. Instead, you must set a switch inside the repeater unit. Refer to Appendix C for instructions to do this.

* The SGB format is proprietary to SG Brown.
** The Robertson's format is proprietary to Robertsons.
*** The LR40/60 format is proprietary to Sperry.

3.2.2.5 Test Digital Output

Use the Test Digital Output screen to test the digital output from the Sensor. The data strings in the digital test output will conform to your chosen digital output format and will contain the parameter values that you set using this screen.

Figure 3–11: Test Digital Outputs screen for TSS1 format

```
----------------------------------
DMS 2-05 Version x.x Terminal Mode
----------------------------------
Test Digital Output

Enter X acceleration [ 0.000 m/s/s] :
Enter Y acceleration [ 0.000 m/s/s] :
Enter Z acceleration [ 0.000 m/s/s] :

Select Mode     : u
Enter Heave     [ 0.000 m] :
Enter Roll      [ 0.000 deg] :
Enter Pitch     [ 0.000 deg] :

{Scrolling columns of data in the selected packet format}
Press [ESC] to stop

Test stopped
```

Figure 3–11 shows the Test Digital Outputs screen that you will see with the TSS1 output format selected. If you have set another format then you will see data fields appropriate to the selected output format. Enter values for each data field.

After you have made the final data entry, the screen will show scrolling columns of data using the current data format. Each of the fields will contain a fixed value defined in the Test Digital Outputs screen. Press [ESC] to stop the test and return to the Configure I/O Menu.

Binary outputs will appear as unintelligible strings of characters on the screen.

3.2.2.6 Test Repeater Analogue Outputs

This screen has no purpose unless your Sensor uses the optional TSS Remote Repeater unit.

You may use the Test Repeater Analogue Outputs screen to test the output of analogue signals from the repeater unit. You should run this test after you have installed the Sensor and after you have configured the analogue repeater outputs (see sub-section 3.2.2.2 above). The test helps you to match the selected analogue output channels to items of external equipment.

Figure 3–12: Test Analogue Outputs screen

```
----------------------------------
DMS 2-05 Version x.x Terminal Mode
----------------------------------
Repeater Analogue Output Test

Enter Heave          [ 0.000 m] :
Enter Roll           [ 0.000 deg] :
Enter Pitch          [ 0.000 deg] :

Press Any Key to Start Test
Testing...

Press ESC to stop the test
```

You may perform the following operations from this screen:

Field	Operation
Enter [Heave, Roll, Pitch]	Enter the physical value whose voltage you wish to output on the selected channel. If you do not enter a value then the Sensor will use the previous value, shown in square brackets. If you have selected remote analogue heave (see sub-section 3.2.2.2 above) then this test facility will output the remote heave value on the heave channel.
'Press ESC to stop'	The repeater will output analogue test voltages on the selected channels until you press the [ESC] key. The Sensor will then display the Configure I/O menu.

3.2.2.7 Calibrate Repeater DACs

This screen has no purpose unless your Sensor uses the optional TSS Remote Repeater unit. Do not perform this calibration procedure unless you are certain the DAC calibration is incorrect and that you have the correct facilities to perform the operation properly.

The repeater receives digital information from the Sensor at very high speed and uses this information to generate the analogue outputs of heave, roll and pitch.

With the relevant calibration details stored in the repeater memory during manufacture, you may attach the repeater to any Sensor with no further calibration necessary.

Incorrect calibration settings will cause the analogue output voltages from the repeater unit to be wrong. Follow the instructions below carefully to calibrate the repeater DACs.

To calibrate the repeater DACs you will need a calibrated digital voltmeter capable of displaying DC voltages greater than ±10V to an accuracy of at least three decimal places.

IMPORTANT
You must include any voltage drop that occurs in the analogue output cables when you calibrate the repeater DACs. To ensure this you must connect the digital voltmeter in turn to the ends of the analogue cables at their connection to the receiving equipment.

IMPORTANT
Do not use the remote heave setting for analogue output when you calibrate the repeater DACs. Follow the instructions in sub-section 3.2.2.2 to set the analogue heave output to Local.

Figure 3–13: Calibrate Repeater DACs screen

```
----------------------------------
DMS 2-05 Version x.x Terminal Mode
----------------------------------
Calibrate Repeater DACs

Do you really want to change the DAC calibration? Y or N:

Heave Maximum Positive Voltage    [ 10.000 V] :
Heave Maximum Negative Voltage    [-10.000 V] :

Roll Maximum Positive Voltage     [ 10.000 V] :
Roll Maximum Negative Voltage     [-10.000 V] :

Pitch Maximum Positive Voltage    [ 10.000 V] :
Pitch Maximum Negative Voltage    [-10.000 V] :
```

1. From the Configure I/O menu press [7] to select the Calibrate Repeater DACs option.

   If the Sensor cannot communicate with the repeater for any reason the screen will show an error message:

   No Response from Repeater. Press Any Key.

   If this error message appears, press any key to return to the Configure I/O menu.

2. If there is successful communication with the repeater the screen will prompt you to continue or abort the calibration. Press [Y] to continue the calibration or press [N] to abort it. **Note that you cannot abort the routine from this point onwards**.

3. Connect the digital voltmeter to the end of the heave analogue cable.

4. Measure the maximum positive voltage from the cable.

5. Type this value and press [ENTER]. The value will appear in the square brackets of the appropriate line on the screen.

6. Press [ENTER] again to accept the value, or re-type the value if it is incorrect.

7. Measure the maximum negative voltage from the cable.

8. Type this value and press [ENTER]. The value will appear in the square brackets of the appropriate line on the screen.

9. Press [ENTER] again to accept the value, or re-type the value if it is incorrect.

10. Connect the digital voltmeter to the end of the roll analogue cable, and repeat paragraphs 4 to 9.

11. Finally, connect the digital voltmeter to the end of the pitch analogue cable, and repeat paragraphs 4 to 9.

12. When you have calibrated all three analogue output channels for their maximum positive and negative voltages, the repeater stores their values automatically and the System returns to the Configure I/O menu.

3.2.3 Display Raw Data

Press key [3] from the Main Menu to select the Raw Data Display menu. You may use this menu to display raw data received from the accelerometers and rate sensors; the GPS; and the gyrocompass system (if appropriate).

Figure 3–14: Raw Data Display Screen

```
----------------------------------
DMS 2-05 Version x.x Terminal Mode
----------------------------------
Configure I/O Menu
1    Raw
2    Calibrated
3    GPS Raw Input
4    GPS Calculated Input
5    Gyro Compass Raw Input
6    Gyro Compass Calculated Input
ESC  Return to Main Menu
Select Option >
```

See sub-section:

3.2.3.1

3.2.3.2

3.2.3.3

3.2.3.4

3.2.3.5

3.2.3.6

Press key [1] to [6] to select the relevant option. Refer to the appropriate listed sub-section to see a description of each option.

Press the [ESC} key to return to the Main Menu. The Sensor accepts and responds only to valid key entries.

You may view outputs from the array of sensing elements in either raw or calibrated formats. The information contained in these two displays will help you to identify a suspected fault condition.

3.2.3.1 Raw

With the raw format selected, the Sensor displays signals from the sensing elements without applying calibration constants, offsets or scaling. The line of data includes ten fields with a continually updating set of values displayed in units of millivolts.

See sub-section 6.2 for instructions on how to use the raw data display for diagnostic purposes.

3.2.3.2 Calibrated

With the calibrated format selected the Sensor displays signals from the sensing elements with all calibration and scaling applied. The measurements are in units appropriate to the relevant physical parameter.

Table 3–2 shows the format of the calibrated data output. The typical values shown for each field assume that the ambient temperature is approximately 20°C and that the Sensor is stationary and vertical.

Table 3–2: Calibrated 'Raw' data with the Sensor vertical

TMPx	TMPy	TMPz	LINx	LINy	LINz	ARx	ARy	ARz	SPEED
Celsius			cm/s/s			(100×deg/s)			cm/s
0030	0030	0029	0005*	0002	0980	–0081	0002	0217	0000

Mnemonic	Meaning
TMPx,y,z	Temperature signals from the three linear accelerometers.
LINx,y,z	Linear acceleration signals from the three linear accelerometers. See the information panel below for an explanation of the behaviour of the **LINx** and **LINz** accelerometers.
ARx,y,z	Signals from the three angular rate sensors.
SPEED	The most recent velocity aiding information supplied by an aiding source. If you have configured the Sensor for use without velocity aiding information this field will contain '----'.This field will always contain '----'.

***When you select a vertical installation configuration for the Sensor, the z-axis of the orthogonal array aligns with the vertical direction. The LINz accelerometer should therefore show approximately 0980 with the Sensor vertical and the LINx accelerometer should show approximately zero. This is the condition illustrated in Table 3–2.**

If you select a horizontal installation configuration for the Sensor, the z-axis of the orthogonal array aligns with the horizontal direction. In this configuration, the LINx accelerometer should show approximately 0980 with the Sensor horizontal, and the LINz accelerometer should show approximately zero.

3.2.3.3 GPS Raw Input

You may view information received from a GPS receiver in either raw or calculated format. However, before you can view this information you must set two conditions:

1. You must have a working velocity aiding source such as a GPS receiver or a Doppler log connected to the Sensor. Refer to Appendix C for instructions to connect a velocity aiding source to the Sensor.

2. You must configure the Sensor properly to receive information from the velocity aiding source. Refer to sub-section 3.2.2.3 for instructions to configure the Sensor to receive velocity aiding.

When you use the default TSIP input format, the GPS Raw Input screen will show a scrolling series of unintelligible characters. Although you cannot interpret these characters easily, they prove that the Sensor is receiving information through the GPS input channel.

When you use the NMEA format, the display will show ASCII data packets that you can interpret easily.

Refer to Appendix C for details of the acceptable velocity aiding formats.

3.2.3.4 GPS Calculated Input

The GPS Calculated Input screen shows data supplied by the velocity aiding source after the Sensor has decoded it. The displayed information includes five data fields:

Vel E	East/West velocity: {space character} = eastward, – = westward
Vel N	North/South velocity: {space character} = northward, – = southward
Vel U	Up/Down velocity: {space character} = upward, – = downward (Should always be zero in this version of software.)
Lat	Latitude in degrees and tenths: {space character} = north, – = south If you use Ulvertech DATS velocity aiding, remember that you must supply the operating latitude of the Sensor to one-degree accuracy.
Time	GPS time in hours minutes and seconds. *Note*: There is a variable integral number of seconds time difference between GPS time and UTC. If you use Doppler 1 or Ulvertech DATS aiding there will be no time information available and this field will contain --:--:--.

3.2.3.5 Gyro Compass Raw Input

You may view information received from a gyrocompass using either raw or calculated format. However, before you can view this information you must set two conditions:

1. You must have a working gyrocompass connected to the Sensor. Refer to Appendix C for instructions to connect a gyrocompass to the Sensor.

2. You must configure the Sensor properly to receive information from the gyrocompass. Refer to sub-section 3.2.2.4 for instructions to configure the Sensor to receive gyrocompass input.

When you select either the SGB or the NMEA format, data supplied by the gyrocompass will appear as scrolling columns on the display screen.

When you select either the Robertson's or the LR40/60 format, the binary data supplied by the gyrocompass will appear as unintelligible character streams.

Refer to Appendix C for details of these heading aiding input formats.

3.2.3.6 Gyro Compass Calculated Input

The Gyro Compass Calculated Input screen shows data supplied by the gyrocompass after the Sensor has decoded it. The displayed information includes only one data field:

Heading	0.0 to 359.9 degrees from north using standard compass convention.

3.2.4 Load Default Configuration

Figure 3–15: Load Default Configuration screen

```
----------------------------------
DMS 2-05 Version x.x Terminal Mode
----------------------------------
Load Default Configuration

Load All User Default Values? Y or N :
```

You may restore default values for the operating parameters used by the Sensor. When you select this option, the Sensor updates only those values that you may change through the menu structure (that is, those parameters described throughout this section).

Note that, when you load the default configuration, the Sensor will not change the interface standard (RS232 or RS422) that you have established for the digital channels.

The Sensor will retain all other parameters, for example the accelerometer calibration details loaded at the time of manufacture.

At the screen prompt:

- Press [Y] to set all configurable parameters to their default values.
- Press [N] to return to the Main Menu without loading the default values.

Table 3–3: Default settings

Parameter	Default setting
Heave bandwidth	Medium (12 seconds)
Roll/pitch mount angles	Orientation Vertical Roll angle 0.00° degrees Pitch angle 0.00 degrees Measurement time 1 minute
Configure Digital I/O	Format: TSS1 at 9600 baud, 8 data, 2 stop bits, no parity GPS input: TSIP at 9600 baud, 8 data, 1 stop bits, odd parity Gyro input: None

3.3 Digital Data Format

The Sensor can supply information using any of the available digital data formats.

If you connect the optional TSS Remote Repeater unit to the Sensor, you may also obtain the heave, roll and pitch measurements in analogue form. When connected in this way, the System can supply analogue and digital measurements simultaneously. Refer to Appendix C for instructions to connect and use the repeater.

If you select the default digital configuration, the Sensor will use the TSS1 data format and RS232 protocol to communicate with external receiving equipment. The default communication parameters are 9600 baud using 8 data bits, 2 stop bits and no parity.

Each digital output string contains a series of data fields. The content of each data field depends upon the selected digital output format. The available formats are:

- Format TSS1 – Refer to sub-section 3.3.1
- Format TSS1 supplying remote heave – Refer to sub-section 3.3.2
- Format TSS3 supplying remote heave – Refer to sub-section 3.3.3
- Two Simrad formats supplying local heave for use with the Simrad EM1000 and EM3000 multibeam sounders – Refer to sub-sections 3.3.4 and 3.3.6
- Two Simrad formats supplying remote heave for use with the Simrad EM1000 and EM3000 multibeam sounders – Refer to sub-sections 3.3.5 and 3.3.7
- NMEA 0183 $PRDID format – Refer to sub-section 3.3.8
- BMT1 format – Refer to sub-section 3.3.9
- Polled data format – Refer to sub-section 3.3.10
- A user-configurable output format – Refer to sub-section 3.3.11

Refer to sub-section 3.2.2.1 for instructions to select and change the digital output format and the communication parameters.

3.3.1 Format TSS1

- The TSS1 data string contains 27 characters in five data fields.
- The acceleration fields contain ASCII-coded hexadecimal values. Horizontal acceleration uses units of 3.83cm/s² in the range –20.48 to +20.48m/s². Vertical acceleration uses units of 0.0625cm/s² in the range zero to 9.81m/s².
- The motion measurements contained in the data string will be in real time, valid for the instant when the Sensor begins to transmit the string.
- Motion measurements include ASCII-coded decimal values.
- Heave measurements are in cm in the range –99 to +99 metres. Positive heave is above datum.
- Roll and pitch measurements are in degrees in the range –90° to +90°. Positive roll is port-side up, starboard down. Positive pitch is bow up, stern down.

Table 3–4: Format TSS1

```
:XXAAAASMHHHHQMRRRRSMPPPP[CRLF]
```

:	Start character
XX	Horizontal acceleration
AAAA	Vertical acceleration
S	Space character
M	Space if positive, minus if negative
HHHH	Heave
Q	Status flag
M	Space if positive, minus if negative
RRRR	Roll
S	Space character
M	Space if positive, minus if negative
PPPP	Pitch
[CRLF]	Carriage return Line-feed characters

Table 3–5: Status flag definitions for TSS formats

Status flag	Description
U	**UNAIDED MODE – SETTLED CONDITION** The Sensor is operating normally in its settled conditionwithout any input from a gyrocompass, a GPS receiver or a Doppler log.
u	**UNAIDED MODE – SETTLING** The Sensor is operating as above but is still awaiting the end of the 3 minutes settling period after power-on or a change of mode or heave bandwidth.
G	**GPS AIDED MODE – SETTLED CONDITION** The Sensor is receiving and using velocity aiding signals from a GPS receiver or a Doppler log.
g	**GPS AIDED MODE – SETTLING** The Sensor is receiving velocity aiding signals from a GPS receiver or a Doppler log, but is still awaiting the end of the 3 minutes settling period after power-on or a change of mode or heave bandwidth.
H	**HEADING AIDED MODE – SETTLED CONDITION** The Sensor is receiving and using heading aiding signals from a gyrocompass.

Table 3–5: Status flag definitions for TSS formats (Continued)

Status flag	Description
h	**HEADING AIDED MODE – SETTLING** The Sensor is receiving heading aiding signals from a gyrocompass but is still awaiting the end of the 3 minutes settling period after power-on or a change of mode or heave bandwidth. The gyrocompass may take several hours to settle after it has been powered-on. During this time, gyrocompass aiding of the Sensor will not be perfect. The status flag does NOT indicate this condition.
F	**FULL AIDED MODE – SETTLED CONDITION** The Sensor is receiving and using aiding signals from a gyrocompass and from a GPS receiver or a Doppler log.
f	**FULL AIDED MODE – SETTLING** The Sensor is receiving aiding signals from a gyrocompass and a GPS receiver or a Doppler log, but is still awaiting the end of the 3 minutes settling period after power-on or a change of mode or heave bandwidth.

The output data rate will depend upon the baud rate that you have selected for the serial data communications, for example:

BAUD RATE	APPROXIMATE UPDATE RATE
9600	30 updates per second
19200	60 updates per second

3.3.2 Format TSS1 with Remote Heave

This format is identical to format TSS1 described in sub-section 3.3.1 above, except the heave field contains the remote heave measurement in units of 1cm.

This format does not supply local heave information.

3.3.3 Format TSS3

- The TSS3 data string contains 27 characters in five data fields.
- After the start character (a colon, ASCII 3Ah) the TSS3 data string includes an upper case ‘R’ to identify the string as using TSS3 remote heave format.
- The motion measurements contained in the data string will be in real time, valid for the instant when the Sensor begins to transmit the string.
- Motion measurements include ASCII-coded decimal values.
- Local and remote heave measurements are in cm in the range –99 to +99 metres. Positive heave is above datum.
- Roll and pitch measurements are in degrees in the range –90° to +90°. Positive roll is port-side up, starboard down. Positive pitch is bow up, stern down.

Table 3–6: Format TSS3

```
:RMhhhhSMHHHHQMRRRRSMPPPP[CRLF]
```

- Start character and format identifier
- Space if positive, minus if negative
- Remote heave
- Space character
- Space if positive, minus if negative
- Heave
- Status flag
- Space if positive, minus if negative
- Roll
- Space character
- Space if positive, minus if negative
- Pitch
- Carriage return Line-feed characters

The output data rate will depend upon the baud rate that you have selected for the serial data communications, for example:

BAUD RATE	APPROXIMATE UPDATE RATE
9600	30 updates per second
19200	60 updates per second

3.3.4 Simrad EM1000 Format

- This format is suitable for use with Simrad EM1000 multibeam sounders.
- The data string is a 10-byte message of 16-bit 2's complement numbers, each expressed as two binary-coded digits.
- Positive heave is above datum. Positive roll is port-side up, starboard down. Positive pitch is bow up, stern down.
- The motion measurements contained in the data string will be in real time, valid for the instant when the Sensor begins to transmit the string.
- The data string does not include a status flag. The Sensor will take three minutes to settle after power-on or a change of mode or heave bandwidth.
- The Sensor updates the heading field in the data string only when it receives new heading information from the gyrocompass. Depending on the transmission rate of the gyrocompass there may therefore be a difference between the instantaneous heading and the value included in the data output string.
- Gyro heading information is available only if you have enabled the appropriate heading input channel – see sub-section 3.2.2.4. The gyro heading is NOT a 2's complement number.

Table 3–7: Format Simrad EM1000

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8	Byte 9
MSB	LSB	MSB	LSB	MSB	LSB	MSB	LSB	MSB	LSB
Header MSB = 00h	Header LSB = 90h	**Roll** Range ±20° Units 0.01°		**Pitch** Range ±20° Units 0.01°		**Heave** Range ±20m Units 1cm		**Heading** Range 0 to 359.99° Units 0.01°	

MSB = Most significant byte. LSB = Least significant byte.

The output data rate will depend upon the baud rate that you have selected for the serial data communications, for example:

Baud Rate	Approximate Update Rate
9600	83 updates per second
19200	167 updates per second

3.3.5 Simrad EM1000 format with Remote Heave

This format is identical to the Simrad EM1000 format described in sub-section 3.3.4 above, except the heave field contains the remote heave measurement in units of 1cm.

This format does not supply local heave information.

3.3.6 Simrad EM3000 format

- This format is suitable for use with Simrad EM3000 multibeam sounders.
- The data string is a 10-byte message of 16-bit 2's complement numbers, each expressed as two binary-coded digits.
- Positive heave is above datum. Positive roll is port-side up, starboard down. Positive pitch is bow up, stern down.
- The motion measurements contained in the data string will be in real time, valid for the instant when the Sensor begins to transmit the string.
- The Status byte = 91h for an unsettled unit or 90h for a settled unit. The Sensor will take three minutes to settle after power-on or a change of mode or heave bandwidth.
- The Sensor updates the heading field in the data string only when it receives new heading information from the gyrocompass. Depending on the transmission rate of the gyrocompass there may therefore be a difference between the instantaneous heading and the value included in the data output string.
- Gyro heading information is available only if you have enabled the appropriate heading input channel – see sub-section 3.2.2.4. The gyro heading is NOT a 2's complement number.

Table 3–8: Format Simrad EM3000

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8	Byte 9
		MSB	LSB	MSB	LSB	MSB	LSB	MSB	LSB
Status byte	Header LSB = 90h	**Roll** Range ±20° Units 0.01°		**Pitch** Range ±20° Units 0.01°		**Heave** Range ±20m Units 1cm		**Heading** Range 0 to 359.99° Units 0.01°	

MSB = Most significant byte. LSB = Least significant byte.

The output data rate will depend upon the baud rate that you have selected for the serial data communications, for example:

BAUD RATE	APPROXIMATE UPDATE RATE
9600	83 updates per second
19200	167 updates per second

3.3.7 Simrad EM3000 format with Remote Heave

This format is identical to the Simrad EM3000 format described in sub-section 3.3.6 above, except the heave field contains the remote heave measurement in units of 1cm.

This format does not supply local heave information.

3.3.8 NMEA PRDID Format

- This is a standard NMEA 0183 format.
- The data string has variable length with leading zeros and minus signs added where necessary.
- Positive roll is port-side up, starboard down. Positive pitch is bow up, stern down.
- The attitude measurements contained in the data string will be in real time, valid for the instant when the Sensor begins to transmit the string.
- There is no status indicator in the data string. The Sensor will take three minutes to settle after power-on or a change of mode.
- This data string does not include the optional checksum allowed within the NMEA 0183 standard.
- The data string will include gyro heading information only if it is available. If there is no heading information available, the heading field will be null.

Table 3–9: NMEA PRDID format

```
$PRDID,PPP.PP,RRR.RR,hhh.hh[CRLF]
```

Field	Description
$	Start character
PRDID	Mnemonic for attitude data
,	Comma separator
PPP.PP	Pitch (–30.00° to +30.00°)
,	Comma separator
RRR.RR	Roll (–30.00° to +30.00°)
,	Comma separator
hhh.hh	Heading (0 to 359.99°)
[CRLF]	Carriage return Line-feed characters

3.3.9 BMT1 Format

The BMT1 data format provides attitude and acceleration measurements in six axes to an external data processor. The external data processor can use the supplied information to compute the linear accelerations for a large number of points on the vessel. A suitable application for this format may be, for example, to calculate the loads on the securing straps for the various deck-mounted containers on a container vessel.

Inevitably, errors will exist in the calculations made by the external processor caused primarily by flexing of the vessel. Typically, such errors will result from high frequency vibrations that affect the Sensor directly, but not the vessel.

To reduce the effect of such vibrations, you will need to filter the outputs from the Sensor. The Sensor does not apply such filtration because the specific characteristics of the vessel, its loading condition, and the installation location of the Sensor will have a significant influence on the filter design parameters. Therefore, you must exercise control over the filtering function through the software of the external data processor.

- By default the Sensor uses 19200 baud to transmit this string. You will reduce the update rate if you set a lower baud rate. Using the default communication settings, the update rate will be fifty data strings per second.
- The heave and attitude measurements contained in the data string will be in real time, valid for the instant when the Sensor begins to transmit the SOP byte.
- The six fields for angular rate and linear acceleration contain values averaged over the update period. They refer to the mid-point between one update cycle and the next. Refer to sub-section 3.3.9.1 for a suggested method to extract the acceleration data from these fields.
- Angular rates and linear accelerations are all in the vessel body reference frame.
- Positive heave is above datum. Positive roll is port-side up, starboard down. Positive pitch is bow up, stern down.
- Roll and pitch measurements use units 60÷65536 degrees.
- Heave measurements use units 100÷65536 metres.

- Angular rate measurements use units 200÷65536 degrees/s.
- Linear acceleration measurements use units 40÷65536 metres/s².
- There is no status indicator in the data string. The Sensor will take three minutes to settle after power-on or a change of mode.
- The MSB and LSB form 16-bit 2's complement signed values in the range –32767 to +32768 to represent the relevant measurement.
- You may recover the floating point value for each word by using $\text{Value} = (\text{<Value MSB>} \times 256 \text{ OR } \text{<Value LSB>}) \times 60 \div 65536$. In this expression, the OR function is an arithmetic OR performed in integer arithmetic.
- The Sensor computes the checksum value by summing all the bytes, excluding the SOP and EOP fields and itself: $\text{CKSUM} = \sum_{i=1}^{18} byte(i)$ where SOP = $byte(0)$

Table 3–10: BMT1 format

Byte	Field	Meaning
Byte 0	SOP	Start of packet
Byte 1	LSB	Roll
Byte 2	MSB	Roll
Byte 3	LSB	Pitch
Byte 4	MSB	Pitch
Byte 5	LSB	Heave
Byte 6	MSB	Heave
Byte 7	LSB	Angular rate X
Byte 8	MSB	Angular rate X
Byte 9	LSB	Angular rate Y
Byte 10	MSB	Angular rate Y
Byte 11	LSB	Angular rate Z
Byte 12	MSB	Angular rate Z
Byte 13	LSB	Linear acceleration X
Byte 14	MSB	Linear acceleration X
Byte 15	LSB	Linear acceleration Y
Byte 16	MSB	Linear acceleration Y
Byte 17	LSB	Linear acceleration Z
Byte 18	MSB	Linear acceleration Z
Byte 19	SUM	Checksum
Byte 20	EOP	End of packet

MSB = Most significant byte. LSB = Least significant byte.

3.3.9.1 Filtering

The following suggestion helps you to compute the average of each measurement during the previous Sensor calculation cycle. This will reduce the problems caused by vibration, but not eliminate them. Note that the averaged value will be valid for an instant in time half way between the start and the end of the averaged period.

You will also need to compute the angular accelerations. To do this, divide the measurements in half (time-wise) and compute the average of each half. Take the difference between the two and then divide this by half the time interval. This is the process of differentiation.

For example, on a set of 50 samples (lasting one second) you should compute the angular accelerations from the angular rates by using the following method:

$ArX_{am} = \text{mean}(ArX[1]..ArX[25])$

$ArX_{pm} = \text{mean}(ArX[26]..ArX[50])$

$AaX = (ArX_{pm} - ArX_{am}) \div 0.5$

AaX is the angular acceleration in the X-axis.

0.5 is the time interval (half a second).

3.3.10 Polled Output Format

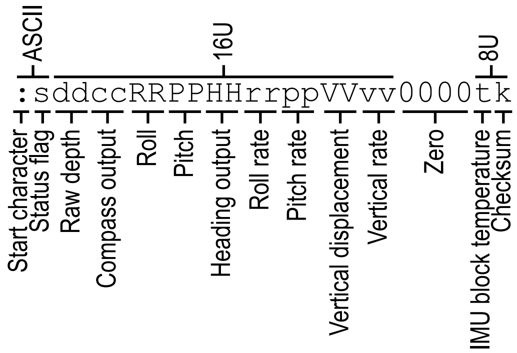
IMPORTANT
When using the polled output format, press [ESC] four times to select the terminal mode. This sequence is not a valid packet and therefore should never occur during normal operations.

- The conventions used to define some of the coordinates in this output format differ from the conventions used in other formats. Note the details throughout this sub-section carefully if you intend to use the polled output format.
- Measurements contained in the data string will be in real time, valid for the instant when the Sensor begins to transmit the start character.
- The data string includes data encoded using three methods:

  1. **ASCII** – 7-bit characters in an 8-bit field. The eighth bit is always set to zero.
  2. **16U** – Unsigned 16-bit numerical values.
  3. **8U** – Unsigned 8-bit numerical values.

- The heave output is in the range –50.00 to +100.00m in units of 1050÷65536 metres.
- The roll and pitch outputs are in the range $-\pi$ to $+\pi$ rad in units $\pi \div 32768$ rad.
- Roll is the Euler roll angle ϕ with respect to the locally level reference frame.
- Pitch is the Euler pitch angle θ with respect to the locally level reference frame.
- The heave rate measurement is in the range –50.0 to +50.0m/s in units of 50÷32768m/s. The Sensor registers a positive heave rate when the vessel moves downwards.
- Roll and pitch rate measurements are in the range –5 to +5 rad/s in units 5÷65536 rad/s.
- Angular rates are all in the vessel body frame. The Sensor registers a positive roll rate when the starboard side of the vessel moves downwards. The Sensor registers a positive pitch rate when the bow of the vessel moves upwards.
- The compass output (if applicable) is in the range 0.0° to 360.0° in units 360÷65536 degrees. It will always be zero unless the Sensor includes the optional compass module.
- The heading output (if applicable) is in the range 0.0° to 360.0° in units 360÷65536 degrees.
- The status indicator in the data string follows the convention explained in Table 3–5.
- The IMU block temperature measurement is an average of the three measurements reported by the linear accelerometers and is in the range –100.0 to +100.0°C using units of 100÷128°C.
- The format always assumes raw depth is zero.

Table 3–11: Polled format



IMPORTANT
MEASUREMENT DEFINITIONS
The conventions used to define some of the co-ordinates in the polled output format differ from the co-ordinate conventions used in other output formats because it defines the *z*-axis as down and the *y*-axis as starboard. The *x*-axis is the same as that used in other formats. Note the following details carefully.

The body co-ordinate system:

***x*-axis**	Positive is towards the bow of the vessel along the centre line.
***y*-axis**	This is the port-starboard axis, perpendicular to the x-axis, where starboard is positive.
***z*-axis**	This is the axis perpendicular to both the x-axis and the y-axis where positive is towards the vessel keel.

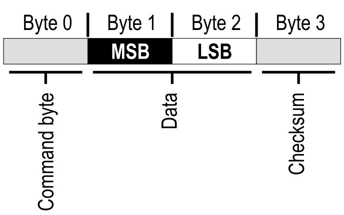
The locally level reference:

***x*-axis**	This is a locally horizontal axis where positive is towards the vessel bow.
***y*-axis**	This is a locally horizontal axis where positive is towards the starboard side of the vessel.
***z*-axis**	This is the axis perpendicular to both the x-axis and the y-axis where positive is along the direction of gravity.

The polled format defines rotations as positive when they are clockwise looking along the axis away from the centre of rotation.

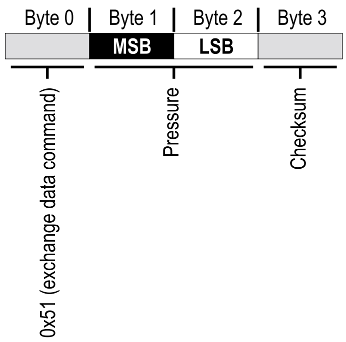
3.3.10.1 Exchange Data Command

When supplying data using the polled output format, the Sensor accepts one input command on the communications channel. The command, called ‘Exchange Data’, is four bytes long and has the following format:



Due to the nature of the command format, it may not be possible to synchronise correctly on the message. The Sensor will attempt to synchronise by testing the last four characters received to see if they form a valid Exchange Data Command message. When it receives a valid message the Sensor will interpret it and then invalidate the last four characters to prevent their use in another message.

The Exchange Data Command sends a pressure reading to the Sensor, which responds by sending the output packet. The format of the pressure reading command appears below:



Note that the Sensor does not interpret the pressure reading.

The Sensor verifies the checksum by:

$$\text{if}\left(\text{byte}(4) = \left(0\text{xFF}\ \&\ \sum_{i=1}^{3} byte(i)\right)\right) \text{ then the packet is good.}$$

Checksum

The Sensor calculates the checksum using:

$$k = 0\text{xFF}\ \&\ \sum_{i=1}^{25} byte(i)$$

16U encoding and decoding

The Sensor encodes values into 16U format by:

$$c = floor\left(65536.0 \times \frac{\text{value} - \text{min}}{\text{range}} + 0.5\right)$$

Where: value = the value to be presented
min = the minimum value from the table
range = the range of available measurements in the field
floor() = a function that determines the nearest integer less than or equal to the parameter.

You may decode the 16U representation to its original value by:

$$\text{value} = \frac{c \times \text{range}}{65536.0} + \text{min}$$

8U encoding and decoding

The Sensor encodes values into 8U format by:

$$c = floor\left(256.0 \times \frac{\text{value} - \min}{\text{range}} + 0.5\right)$$

Where: value = the value to be presented
min = the minimum value from the table
range = the range of available measurements in the field
floor() = a function that determines the nearest integer less than or equal to the parameter.

You may decode the 16U representation to its original value by:

$$\text{value} = \frac{c \times \text{range}}{256.0} + \min$$

In the 16U and 8U representations described it is not possible to represent the maximum values.

3.3.10.2 Accuracy

The following table lists the accuracy of those data fields in the polled output format excluded from the main Sensor specification.

Raw depth	The Sensor does not calculate raw depth.
Compass output	Determined by the compass unit in use. The compass unit requires careful positioning and calibration to perform correctly.
Heading	The Sensor can quieten a noisy compass output and improve its response. It cannot maintain heading accuracy during transients and cannot improve the accuracy of steady-state errors in the compass output.
Vertical rate	The accuracy of vertical rate measurements is better than 5cm/s RMS, excluding the filter timing response.
IMU block temperature	Sensing element temperature transducer is within ±2°C.

3.3.11 User Configurable Format

The Sensor allows you to configure a special output packet to meet the particular needs of your application. The user configurable packet can have any length and can include the available data fields in any convenient order. If necessary, you may set the format to repeat data fields within any single string (although both occurrences will always include the same values).

To set and configure the User Configurable format, follow the instructions in sub-section 3.2.2.1. Complete the fields of the Configure Digital Output screen as shown in Figure 3–16 below.

Figure 3–16: Setting the User Configurable output

```
----------------------------------
DMS 2-05 Version x.x Terminal Mode
----------------------------------
Configure Digital Output

Digital Output Format : User Configurable
Baud rate       : 9600
Data Bits       : 8
Stop Bits       : 2
Parity          : None
Interface       : RS422
User Field 1    : Roll
User Field 2    : Pitch
User Field 3    : Heave
User Field 4    : ...
```

User fields 1 to 3 inclusive will be set to roll, pitch and heave already when you select this output format. You may change these if necessary.

To establish your special output format:

1. Select the User Configurable format from the Configure Digital Output screen.

2. Establish appropriate settings for the baud rate, data bits, stop bits and parity. Set RS232 or RS422 communications as required.

3. Set the content of User Field 1. When you first select this data format, User Field 1 will contain Roll. Press the space bar to cycle through the available options listed in Table 3–12. Press [ENTER] to set the displayed User Field and progress to the next.

4. Continue setting the contents of the User Fields as required. You may change the contents of those fields that already contain a default.

5. To complete your selection, choose the User Field called ‘None’ and then press [ENTER]. The Sensor will then restore the Configure I/O menu.

Table 3–12: User configurable data fields

User field name	Contents	Range and (units)
Roll	Angle of roll	–90° to +90° (0.01°)
Pitch	Angle of pitch	–90° to +90° (0.01°)
Heave	Heave displacement	–99 to +99m (1cm)
Remote Heave	Remote heave displacement	–99 to +99m (1cm)
Angular Rate X	Angular rate of rotation in the X direction using the body frame of reference of the Sensor.	–9999 to +9999 (0.01°/s)
Angular Rate Y	Angular rate of rotation in the Y direction using the body frame of reference of the Sensor.	–9999 to +9999 (0.01°/s)
Angular Rate Z	Angular rate of rotation in the Z direction using the body frame of reference of the Sensor.	–9999 to +9999 (0.01°/s)
Acceleration X	Linear acceleration in the X direction using the body frame of reference of the Sensor	–20000 to +20000 mm/s^2
Acceleration Y	Linear acceleration in the Y direction using the body frame of reference of the Sensor	–20000 to +20000 mm/s^2
Acceleration Z	Linear acceleration in the Z direction using the body frame of reference of the Sensor	–20000 to +20000 mm/s^2
Status	Status flag as defined in Table 3–5.	N/A
IMU Temperature	Average temperature measured by three linear accelerometers	Temperature °C (0.01°C)
External Speed	N/A	Always zero
Heading	Heading delivered by the internal compass module (if fitted)	0 to 359.99° (0.01°)
UTC time	N/A	000000.00
None	Indicator during configuration that no further data fields are to be included	N/A

4 OPERATIONAL CONSIDERATIONS

This section explains how the Sensor maintains a high standard of performance during vessel manoeuvres and throughout the wide range of dynamic conditions that are common in a marine survey environment.

If you connect the optional TSS Remote Repeater to the Sensor, a three-colour LED on the repeater front panel indicates the System status.

4.1 Influence of a Dynamic Environment

Refer to Appendix A for a description of the Sensor operating theory.

In a static environment you may measure the attitude of a platform by using an inclinometer made from a simple weighted line. At rest, the line will provide a vertical reference against which it is possible to make attitude measurements.

The Sensor is a solid-state device whose inclinometer comprises an array of linear accelerometers. Appendix A describes how this array provides a static vertical reference.

Problems arise when using this form of attitude measurement for maritime applications because the marine environment is not static: The vessel, and therefore the Sensor, will be subjected to a continuously varying pattern of forces caused by the action of waves and swell. These will give rise to errors in the measurements made by an inclinometer.

In a marine environment, the principal source of measurement error in attitude sensors is horizontal acceleration. This occurs in two forms:

- Short-term horizontal acceleration transients caused by the action of waves and swell.
- Long-term horizontal acceleration as the vessel undergoes a prolonged turn.

4.2 Horizontal Acceleration Transients

In highly dynamic sea conditions, the vessel will experience acceleration transients called surge and sway. These can be particularly severe if the vessel is crashing into waves: For example, a small vessel can undergo a reduction in speed of 2 knots in less than a second.

Experience aboard a range of vessels of varying size and characteristics has shown that, except in the most severe conditions, peak levels of horizontal acceleration will remain below 200mg (where 1000mg = 9.81m/s^2). Background horizontal acceleration levels usually are below 80mg RMS.

Rolling and pitching motions will also introduce horizontal acceleration at points above or below the centre of vessel rotation. As advised in sub-section 2.3.1, you should avoid installing the Sensor in a location that is significantly above or below the centre of vessel rotation.

Horizontal acceleration introduces errors into the attitude measurements made by the array of linear accelerometers. The Sensor reduces these errors by using an array of angular rate sensors to measure attitude (refer to Appendix A for details).

4.3 Vessel Turns

During vessel turns, the linear accelerometer array perceives the attendant centripetal acceleration as a prolonged application of horizontal acceleration. Without additional information, the Sensor cannot filter out this steady-state condition so that, eventually, it will cause errors to appear in the output.

It is possible to calculate the amplitude of centripetal acceleration experienced as a vessel makes a turn:

$$a_c = \omega v$$

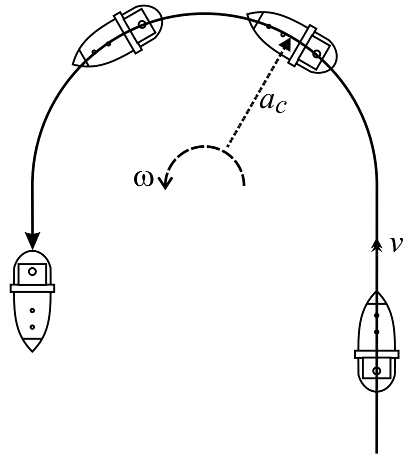
Where: a_c = centripetal acceleration m/s^2

ω = rate of turn (rad/s)

v = vessel speed (m/s)

In the ideal case illustrated in Figure 4–1 the centripetal acceleration acts in a direction that coincides exactly with the port-starboard axis of the vessel (the pitch axis). The linear accelerometer that aligns with the pitch axis will measure this acceleration and will therefore introduce errors into the measurement of attitude and vertical displacement (heave).

Figure 4–1: Ideal vessel turn conditions



If the Sensor receives sufficient information about the speed of the vessel and the rate of turn, it can calculate the amplitude of centripetal acceleration a_c. Once the Sensor has made this calculation, it can then compensate measurements delivered by the pitch axis accelerometer to remove the effects of centripetal acceleration. Measurements will then remain substantially error-free throughout turns.

This is the function of the aiding input facility of the Sensor.

4.3.1 Velocity Input Only

As stated above, to calculate the centripetal acceleration the Sensor needs to know the rate of turn ω and the velocity v of the vessel.

- The Sensor accepts rate of turn information from the rate sensor that aligns with the vertical axis of the accelerometer array (this is the yaw rate sensor).
- You may use a suitable speed measurement system such as a Doppler log to supply velocity information.

Problems might arise when you use only velocity aiding to provide measurement stability during vessel turns. These arise from two sources:

1. The velocity v measured by a speed log may not be accurate because it does not allow for the effect of currents upon the vessel speed.
2. As discussed in Appendix A, the angular rate sensors suffer from drift and the long-term accumulation of errors. The linear accelerometer array cannot provide a reference for the yaw rate sensor and so the measurements supplied by this device may drift significantly throughout a prolonged vessel turn. Such drift will cause errors to appear in the measurement of ω and therefore in the calculation of centripetal acceleration.

4.3.2 GPS Input

GPS receivers can supply information concerning the true speed and track of the vessel, irrespective of currents and other effects.

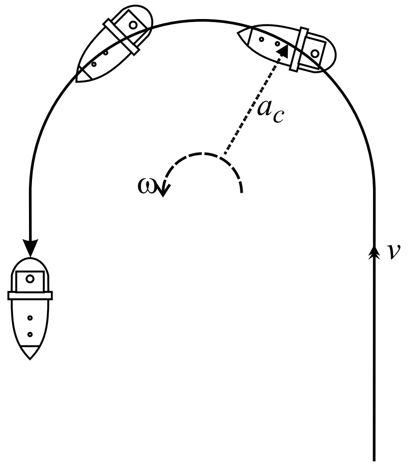
- The Sensor uses **Speed** information v supplied by the GPS receiver in its calculation to determine the magnitude of centripetal acceleration.
- The Sensor uses the **vessel track** information from the GPS receiver to provide a reference for the yaw rate sensor. This additional information allows the Sensor to compensate for any drift exhibited by the yaw rate sensor during the turn and improves the accuracy of the ω measurement. This will result in a more accurate assessment of centripetal acceleration.

Under the ideal conditions illustrated in Figure 4–1, the aiding information supplied by a GPS receiver will be sufficient to provide full stability of measurements throughout vessel turns.

In practice the information supplied by a GPS receiver is not sufficient by itself to provide full correction. This is because:

- Measurements of velocity and track from a GPS receiver become unreliable and inaccurate below a speed of approximately 1m/s (2 knots).
- Actual vessel turns are not ideal and will exhibit differences between the instantaneous heading and the track of the vessel throughout the turn. Figure 4–2 illustrates an example of this situation.

Figure 4–2: Vessel turn showing differences between heading and track

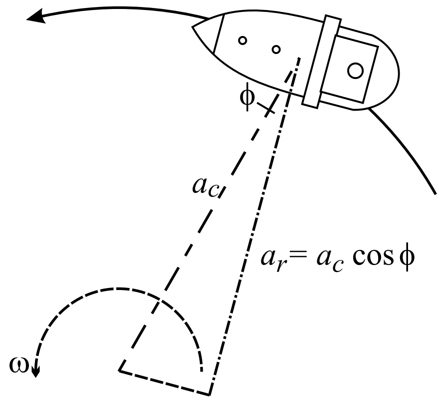


During a turn, there will be some difference between the actual heading and the instantaneous track of the vessel. Figure 4–3 illustrates this condition:

- The heading of the vessel measured by a gyrocompass coincides with the surveyed fore-aft line.
- The instantaneous track of the vessel coincides with the tangent of the arc of travel throughout the turn.

In the example shown this difference is 15°, with the vessel heading to port of the vessel track. The magnitude of this difference will depend on a number of factors and arises from the lateral force exerted by the rudder, the special manoeuvring capabilities of a DP vessel, or the effects of wind and current. It would not be a simple task to predict its magnitude under all conditions throughout a turn.

Figure 4–3: Roll-axis accelerometer misaligned with centripetal acceleration



In the example shown in Figure 4–3 the linear accelerometer in the Sensor pitch axis will not measure the full centripetal acceleration a_c. Instead, it will measure some proportion of this acceleration, a_r, whose magnitude will also depend on the angle between the instantaneous heading and the track of the vessel:

$$a_r = a_c \cos\phi$$

Where a_r = centripetal acceleration measured by the pitch axis accelerometer (m/s^2)

a_c = actual centripetal acceleration affecting the vessel (m/s^2)

ϕ = instantaneous angle between the heading and the track of the vessel

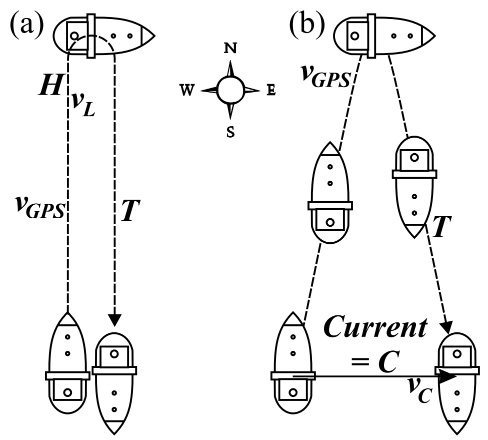
For the example shown, the pitch axis accelerometer would measure less than 97% of the actual centripetal acceleration affecting the vessel.

However, the velocity and rate of turn information supplied by the GPS receiver and the vertical rate sensor (v and ω) would be unaffected by this difference: They would allow the Sensor to calculate the true magnitude of centripetal acceleration. Because of the difference between the calculated and the actual magnitude of centripetal acceleration, accurate compensation for its effects would not be possible.

The Sensor can apply full compensation for the effects of centripetal acceleration throughout a turn only if it also receives information to indicate the difference between the heading and the track of the vessel.

Vessels operating in areas where there are cross-currents will experience considerable errors between the track and the heading of the vessel. The example shown in Figure 4–4 illustrates this condition.

Figure 4–4: Survey operations in cross-currents



In the example shown in Figure 4–4(a) there is no current affecting the vessel. In these circumstances the track of the vessel T (measured by GPS) is the same as the heading of the vessel H (measured by a gyrocompass) throughout the survey pattern.

In the example shown in Figure 4–4(b) the vessel attempts to perform the same survey pattern as before but in the presence of a cross-current. For this example the following conditions apply:

Vessel speed indicated by speed log throughout the manoeuvre v_L	5 knots
True vessel heading indicated by a gyrocompass at the start of the survey pattern	000°
True vessel heading indicated by a gyrocompass at the end of the survey pattern	180°
True speed of current v_C	2 knots
True direction of current C	090°

At the start of the survey line:

H = 000° $v_L = 5$ knots

C = 090° $v_C = 2$ knots

The speed measured by a GPS system $v_{GPS} = \sqrt{v_L^2 + v_C^2} = 5.38$ kts.

The track measured by a GPS system $T = \operatorname{atan}\left(\frac{v_C}{v_L}\right) = 021.8°$.

At the end of the survey line:

H = 180° $v_L = 5$ knots

C = 090° $v_C = 2$ knots

The speed measured by a GPS system $v_{GPS} = \sqrt{v_L^2 + v_C^2} = 5.38$ kts.

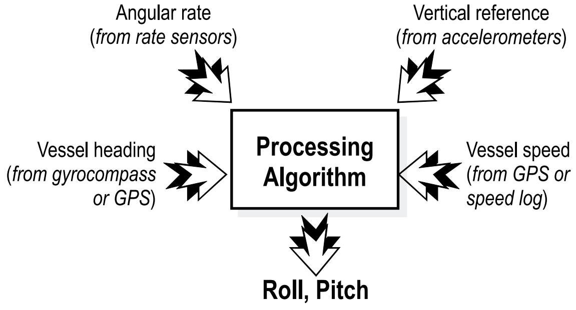
The track measured by a GPS system $T = 90 + \operatorname{atan}\left(\frac{v_C}{v_L}\right) = 158.2°$.

The effect of the current in this example is to introduce an easterly drift of the vessel throughout the operation. There is a difference between the true heading indicated by a gyrocompass and the actual track of the vessel throughout the survey pattern. When the indicated heading changes by 180° the track of the vessel changes by only 136.4° and, in a Sensor with GPS aiding only, this will cause errors in the heading reference used by the yaw rate sensor.

4.3.3 GPS and Compass inputs

For full aiding to be possible at all speeds during a survey, the Sensor must receive velocity information from a GPS receiver *and* heading information from a compass system to provide:

- True vessel speed information (*from the GPS system*);
- True vessel heading (*from the gyrocompass system*).



If these sources of 'aiding' information are not available, errors will be present in attitude and heave measurements made by the Sensor during turns and for a short period immediately afterwards.

4.4 Status Flag

Sub-section 3.3 describes the various data formats available from the primary communication channel. Several of the data strings described include a 'status' flag that indicates the instantaneous Sensor operating condition. Table 3–5 lists those status flags and describes their meanings.

- Lower case letters in the status flag indicate an unsettled condition. This will always be the status for three minutes after power-on or a change of operating mode or heave bandwidth. While it operates in an unsettled condition you should avoid using data supplied by the Sensor for critical functions.
- Upper case letters in the status flag indicate a settled condition.

For installations that use the optional Remote Repeater, the three-colour status LED on the repeater front panel also indicates the System status.

The status flag is included in the digital output string for logging.

Measurements made during the settling time do not possess the specified accuracy of the Sensor. You should not use them for critical purposes.

5 SPECIFICATIONS

Where given, UK imperial conversions of weights and dimensions are to two decimal places only.

5.1 PERFORMANCE

HEAVE:

Range	±100 metres
Resolution	1cm
Bandwidth	0.05 to >10Hz
Accuracy	The greater of 5cm or 5%
Measurement datum	All measurements are with respect to the centre of the bottom surface of a vertically mounted Sensor.
Acceleration range (vertical)	2g
Noise (at cut-off frequency 0.05 Hz)	<1cm RMS

Roll, Pitch:

Range		±30°
Resolution	Digital	0.01°
Bandwidth		0 to >10Hz
Accuracy	(Dynamic / Static) DMS 2-05 (Dynamic / Static) DMS 2-10	±0.05° / ±0.05° RMS ±0.10° / ±0.10° RMS
Angular rate change		100°/second
Noise		<0.05° RMS
Cross axis coupling		<1%

5.2 ELECTRICAL

Power requirement	12V to 36V DC 12W at 24V
Digital Interface	RS232C, RS422 user selectable
Digital output data rate	Dependent upon output format and baud rate. The Sensor will supply data packets at the highest possible transfer rate. Using the default settings (format TSS1 at 9600 baud), the digital output rate will be 32 packets per second.

5.3 Environmental

Temperature range	(operating)	0 to +40°C {*32°F to 104°F*}
	(storage)	–20 to +70°C {*–4°F to 158°F*}
Shock (survival)		30g peak 40ms half-sine
Vibration (operating)		Meets Lloyd's Register ENV2 (1996) specification for vibration.
		Meets ABS Table 4/11.1 (1996) No. 12 IEC Publication 68-2-6 (1995) Test F.
Transverse acceleration		500mg peak 0.1s sine
Enclosure ingress protection		3000m {*9840 feet*} depth rated
Tilt	Operating	±30° any plane
	Transit / storage	No limit
Yaw immunity		10° per second with 30° roll and pitch

5.4 Physical

Sensor

Size	Ø115mm × 217.5mm {*Ø4.53 × 8.56 inches*} + connector
Weight	3.6kg {*7.94 pounds*}(4.8kg {*10.58 pounds* with 5m length of Sensor cable)
Finish	Black anodised aluminium

Mounting Plate

For Vertical mounting (one supplied):	
Size	137mm × 116mm {*5.39 × 4.57 inches*}
Weight	0.3kg {*0.66 pounds*}
Finish	Black Delrin
For Horizontal mounting (two supplied):	
Size	120.5mm × 139mm {*4.74 × 5.47 inches*}
Weight	0.3kg {*0.66 pounds*} each
Finish	Black Delrin

6 MAINTENANCE

CAUTION

You will void the warranty if you open the Sensor housing without prior authorisation from the Customer Services Department at TSS (UK) Limited. Do not open the Sensor for any reason until you have contacted TSS (UK) Limited by telephone. The title page of this Manual lists the contact details for TSS (UK) Limited.

The Sensor uses high-speed digital circuitry and surface mount techniques. Many components are susceptible to electrostatic damage and you may destroy them if you handle the internal circuitry improperly. Component level fault finding is not possible. Do not open the Sensor housing for any reason until you have contacted TSS (UK) Limited by telephone.

This section includes a series of flow charts to help you identify, locate and clear a suspected fault condition.

If your Sensor develops a fault that you cannot identify or clear by following the advice contained in this section, request technical assistance. The title page of this Manual lists the contact details for TSS (UK) Limited. TSS (UK) Limited also operates a 24-hour emergency support line managed by trained and experienced service engineers. You should follow the instructions included in this section *before* you request technical assistance.

This simple test procedure allows you to test the basic functions of the Sensor after you have installed the System.

Use the raw data display to help identify a fault condition.

A series of flow charts helps you to identify a simple fault condition. If necessary, contact TSS (UK) Limited for technical support after you have followed the advice included in the charts.

The drawing for the supplied Sensor connection cable.

6.1 Functional Test Procedure

6.1.1 Power-on test

1. Connect the Sensor to a PC and run the graphical display software supplied with the System. Refer to Appendix B for instructions to do this.

2. Set the software to show charts for heave, roll, pitch and horizontal acceleration. Set another window to show the terminal mode.

3. If your System includes the optional Remote Repeater unit, power-on the repeater.

4. Power-on the Sensor. If necessary press [R] on the PC to restore the default communication parameters of the Sensor.

5. At the PC check that the terminal window shows a short banner message and then, after a short delay, scrolling columns of data appear as the Sensor delivers measurements.

6. If your System includes the optional Remote Repeater unit, check that the Status LED on the repeater behaves correctly as defined in Table C–13.

7. If you use a data format that includes the status flag, check that the flag behaves correctly. Refer to Table 3–5 for a description of the status flag.

6.1.2 Inertial block test

You may use the changes that occur to the raw data display as the Sensor moves to identify a fault condition in the linear accelerometers or rate sensors:

Before you release the Sensor from its installed location, make reference marks on its base plate and on the deck. You may then use these marks to help you restore accurate alignment when you re-install the Sensor.

To prevent corrosion, do not scratch the Sensor housing.

1. With the Sensor powered-on, remove the bolts or screws that secure it to the deck.

2. Follow the instructions in sub-section 3.2.1.1 and set the Sensor orientation to ‘Vertical’. From the Main Menu, press key [3] and then press key [1] to select the display of raw data. Position the controlling PC where you may see it while you move the Sensor by hand.

3. On a flat and level surface, position the Sensor by hand into each of the attitudes listed in Table 6–1. On the raw data display, check that each of the ‘Linear’ outputs is within ±250mV of the values indicated.

Table 6–1: Linear accelerometer tests

Sensor attitude	LINx	LINy	LINz
On its base plate (Normal vertical attitude)	0000	0000	2250
On its port side	0000	2250	0000
On its starboard side	0000	–2250	0000
On its bow side	–2250	0000	0000
On its stern side	2250	0000	0000
On its lid (upside down)	0000	0000	–2250

4. On a flat and level surface apply angular motion to the Sensor by hand about each of the axes listed in Table 6–2. Check that the appropriate output is the one that you see change predominantly. Note that the signals are proportional to the rate of turn – other channels will show small values too.

Table 6–2: Rate sensor tests

Axis of Rotation	ARx	ARy	ARz
Roll to port	Negative	0000	0000
Roll to starboard	Positive	0000	0000
Pitch bow up	0000	Negative	0000
Pitch bow down	0000	Positive	0000
Yaw – Bow moving to starboard	0000	0000	Negative
Yaw – Bow moving to port	0000	0000	Positive

6.1.3 Functional test

With the Sensor removed from its mounting position complete the following tests to confirm that the digital output behaves normally:

1. On the PC, set the display to show ±2m heave, ±10° roll and ±10° pitch. Set the acceleration trace to show 0.1g.

2. Place the Sensor on a surface approximately 1m above the deck and allow it to settle.

3. Lower the Sensor carefully to the deck, taking approximately two seconds to complete the movement. Check that the PC indicates a heave measurement of –1m.

4. Allow the Sensor to settle in its new position and then carefully lift the Sensor back onto the raised surface, taking approximately two seconds to complete the movement. Check that the trace indicates a heave measurement of +1m.

This completes the test.

6.2 Raw Data Display

Section 3 describes the software menu structure of the Sensor. Within the menu structure there is a feature called 'Raw Data Display'. You may use the information contained in this display to help identify a suspected fault.

Select the Raw Data Display sub-menu by pressing key [3] from the Main Menu. Refer to sub-section 3.2.3 for a description of the Raw Data Display menu. Refer to Table 3–2, which lists and describes the calibrated raw data display, and perform the tests described in sub-section 6.1.2 for a procedure to test the components in the inertial block.

If you detect a fault in any components of the inertial block, you *must* return the Sensor to TSS (UK) Limited for service and repair. You cannot conduct field repairs on the inertial block.

6.3 Flow Charts

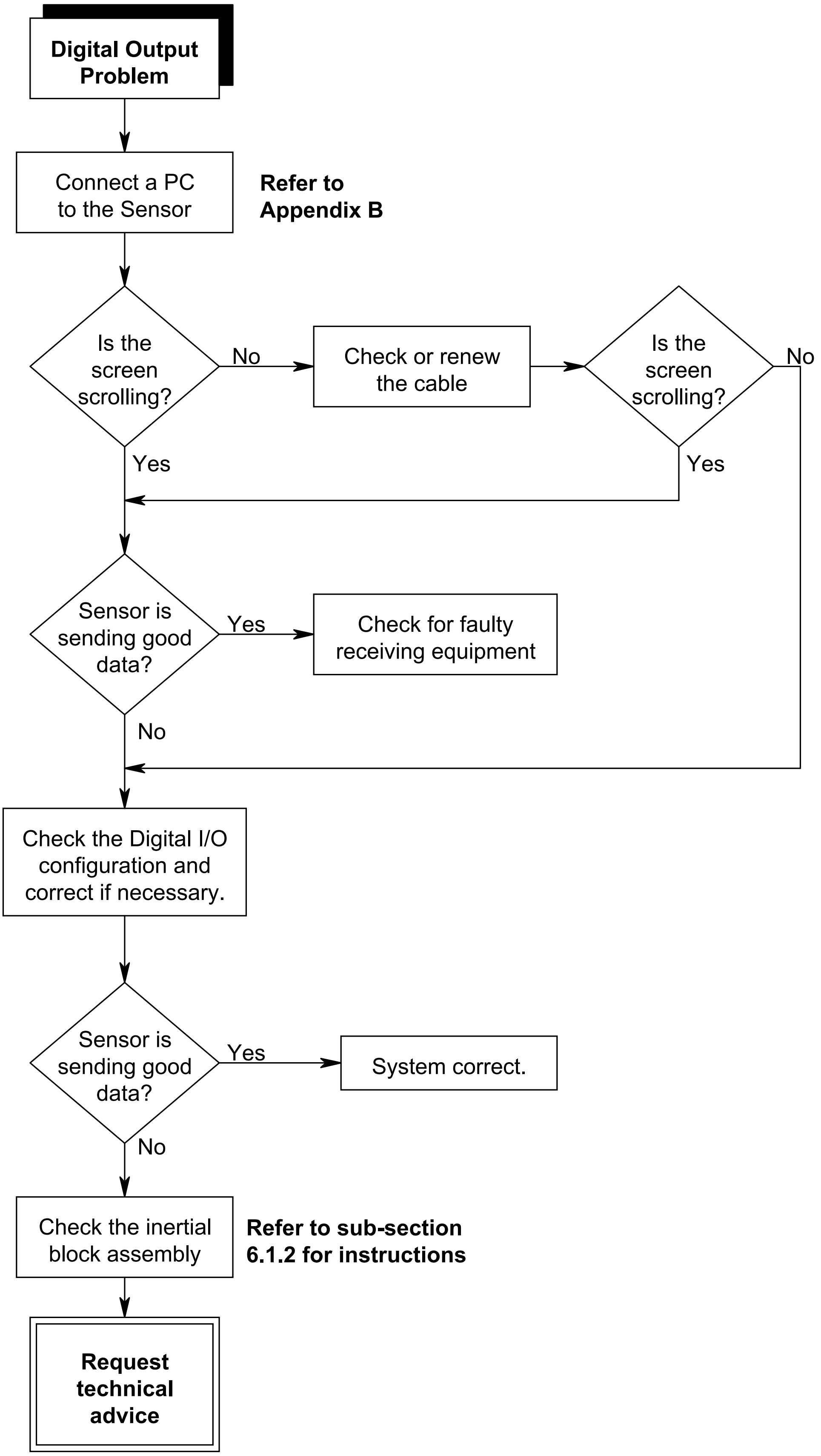
The flow charts that follow are to help you identify whether the Sensor has developed a fault. Because the Sensor uses high-speed digital circuitry and surface-mount components, field servicing is not possible.

If you suspect that your Sensor has developed a fault condition, conduct the tests described in the flow charts and, if necessary, contact TSS (UK) Limited for technical help.

There are no user serviceable parts inside the Sensor. You will invalidate the warranty if you attempt to open it without first contacting TSS (UK) Limited.

6.3.1 Standard Sensor

Figure 6–1: Check sequence 1 – Digital output



6.3.2 Sensor with Remote Repeater

Figure 6–2: Check sequence 2.1 – LED shows red

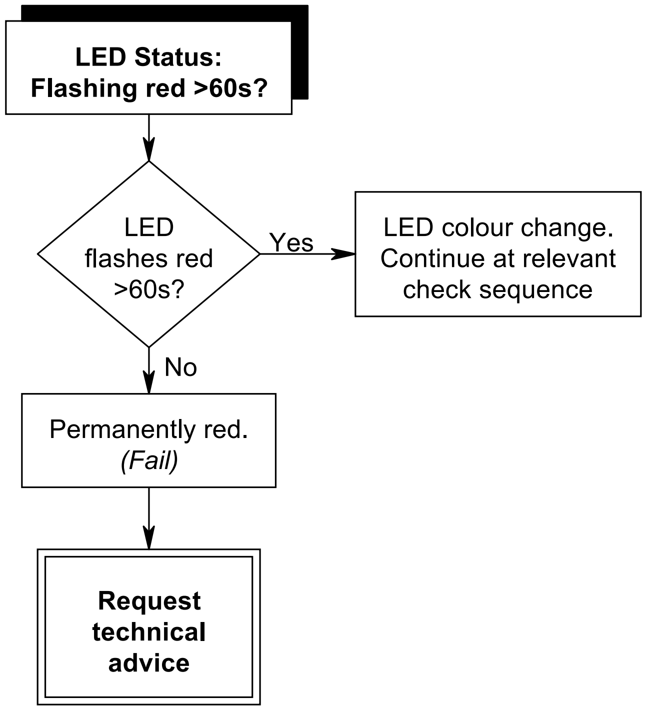


Figure 6–3: Check sequence 2.2 – LED shows flashing green

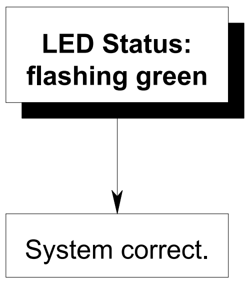


Figure 6–4: Check sequence 2.3 – LED shows permanently red

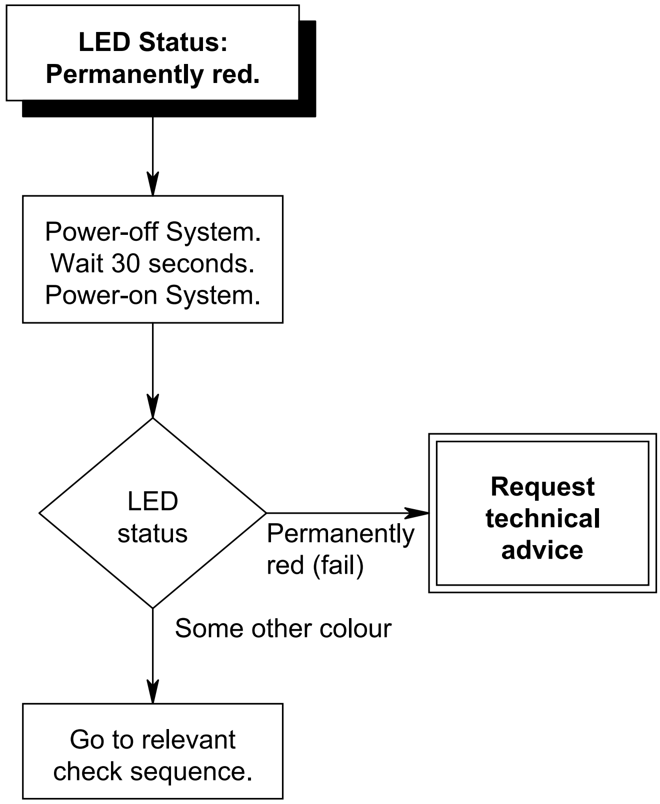


Figure 6–5: Check sequence 2.3 – LED shows permanently green, orange or off

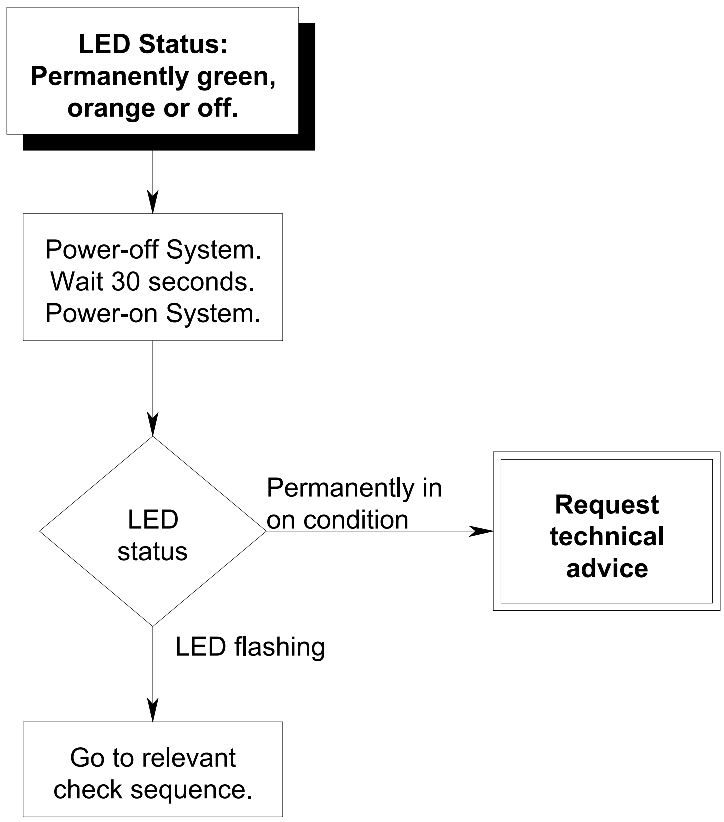
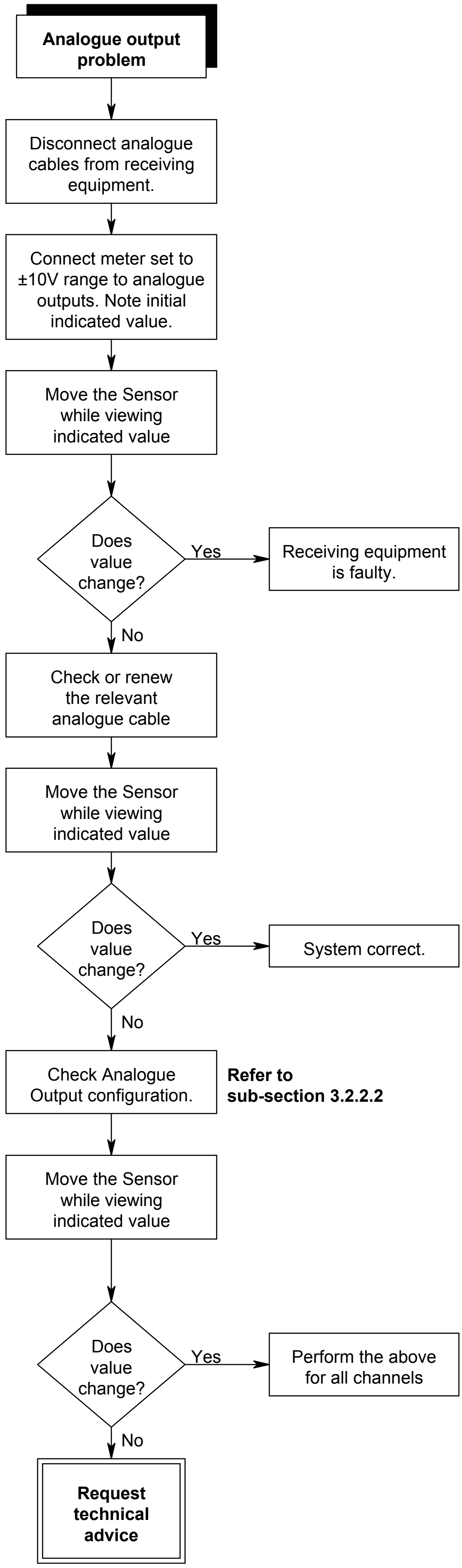


Figure 6–6: Check sequence 3 – Analogue outputs



6.4 DRAWINGS

Table 6–3: Technical drawings list

Drawing Number	Description
600732	Sensor cable 5-metres

A OPERATING THEORY

The Sensor includes an array of sensitive accelerometers and rate sensors. These devices measure the forces of gravity and acceleration that act on the Sensor. The Sensor converts the signals from these devices into measurements of motion and attitude.

This appendix describes the theory of motion measurement used by the Sensor.

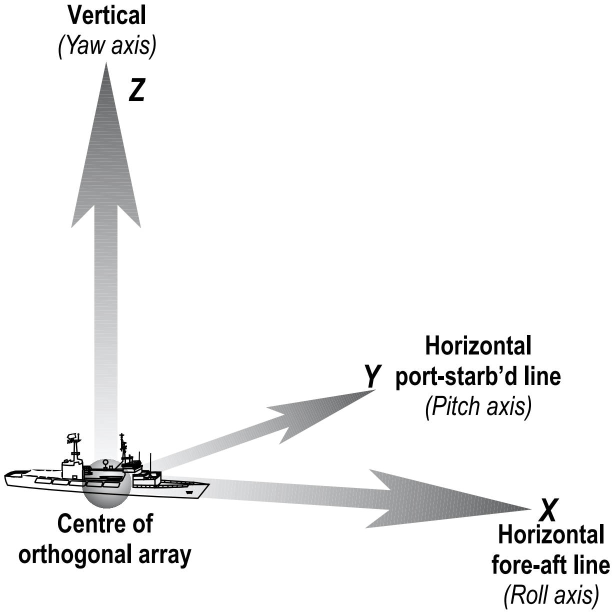
A.1 Sensing Elements

The Sensor uses two types of sensing element:

- Linear accelerometers.
- Angular rate sensors.

These components are in an orthogonal three-axis array as shown in Figure A–1 so that each arm of the array includes one linear accelerometer and one rate sensor.

Figure A–1: Axes of the orthogonal array



A.1.1 Linear Accelerometers

The sensitive axis of each linear accelerometer aligns with one of the three orthogonal arms of the array. These devices respond to accelerations along their direction of sensitivity but are *insensitive* to rotation in any plane.

Linear accelerometers used in the Sensor comprise two major elements:

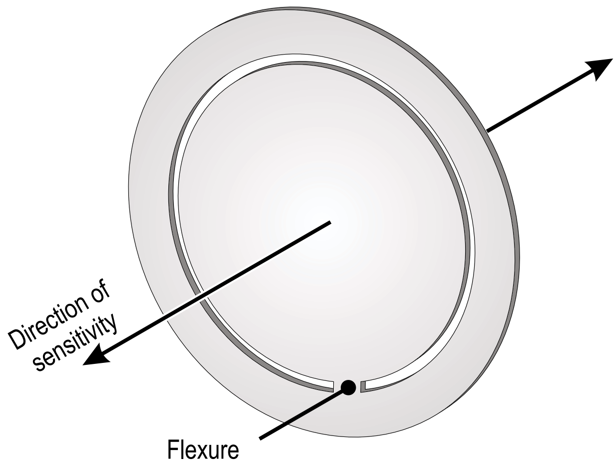
- Proof mass
- Detection and feedback network

Proof Mass

The sensitive part of the accelerometer consists of a thin circular slice of amorphous silicon approximately 10mm in diameter. This material has the property of being elastic in one direction and rigid in all others.

By a process of chemical etching during manufacture, an inner circle of silicon becomes partially detached from the outer ring so that it remains supported only by a narrow flexure as shown in Figure A–2.

Figure A–2: Accelerometer proof mass



When mounted in the accelerometer, the outer ring of the silicon disk attaches to the body of the device. The central part has only the narrow flexure to provide support so that it is free to deflect along the direction of sensitivity, but not in any other direction.

When the device experiences acceleration along the direction of sensitivity, the central disk lags behind and therefore deflects in a relative direction opposite to that of the applied acceleration.

Figure A–3: Proof mass deflecting under acceleration

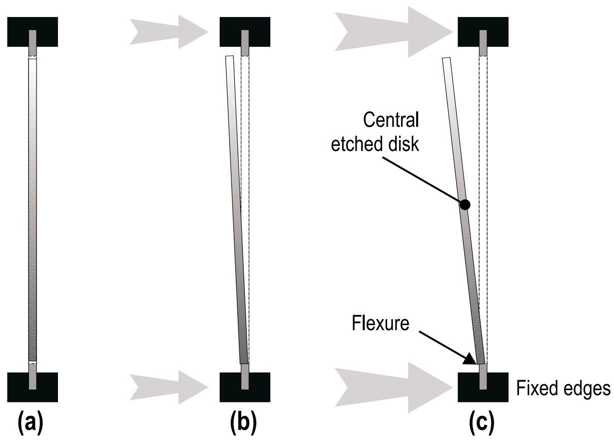


Figure A–3 illustrates a side view of the silicon disk under three conditions:

(a) The accelerometer is experiencing no component of acceleration in the direction of sensitivity. The proof mass aligns with the outer edge of the disk.

(b) The accelerometer is experiencing a low level of acceleration towards the right. The proof mass 'lags' behind the movement and appears to deflect towards the left relative to the outer edge of the disk.

(c) The accelerometer is experiencing stronger acceleration towards the right. The deflection angle of the proof mass is therefore greater.

Detection and feedback network

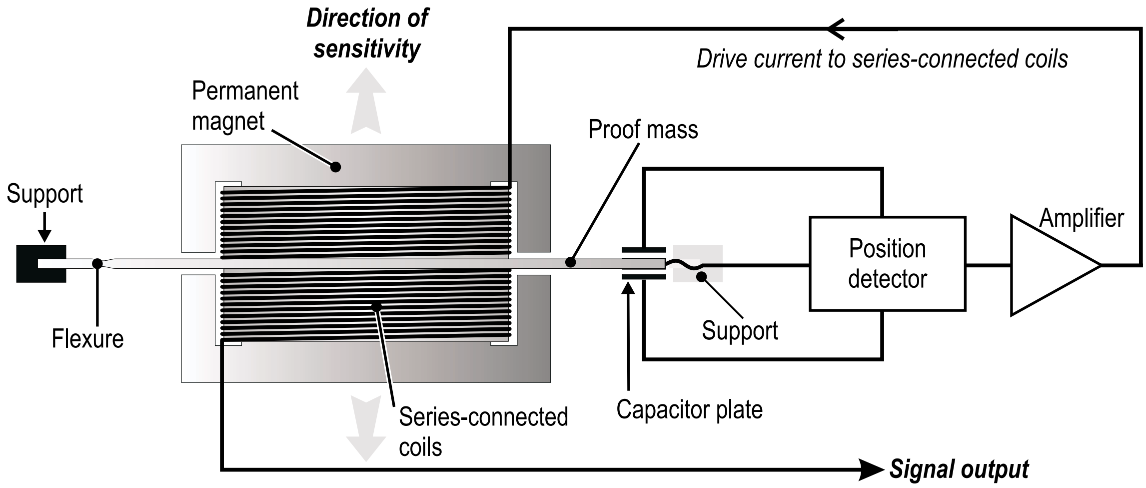
From Figure A–3, it is clear that stronger levels of acceleration give rise to greater angles of deflection. In theory, it should be possible to determine the magnitude of applied acceleration by measuring the angle of deflection. However, this method would not be practicable because:

- The relationship between applied acceleration and the deflection angle is not linear.
- The point of flexure is fragile and would break after a short period of operation under moderate levels of acceleration.

For these reasons the accelerometer uses a detection network to measure any deflection experienced by the proof mass, with feedback applied to hold the proof mass at its central position.

Figure A–4 shows a simplified drawing of the detection and feedback network.

Figure A–4: Detection and feedback network



Attached firmly to each side of the proof mass there is a light electrical coil. These are connected electrically in series with each other. A fixed permanent magnet surrounds each of the coils in an arrangement similar to the driver of a loudspeaker. Movements of the proof mass therefore allow the coils to move relative to the magnets.

At the edge of the proof mass farthest from the point of flexure there is a thin conductive coating that connects through a flexible link to one input of a position detection circuit.

Two conductive surfaces on each side of the proof mass form the two outer plates of a differential capacitor with the centre plate formed by the conductive coating on the edge of the proof mass.

- **Under steady-state conditions**:

  Under steady-state conditions when there are no resultant forces acting upon the assembly, the proof mass will rest in a central position between the two magnets. The differential capacitor and the position detector will balance and there will be no output from the amplifier.

- **With applied acceleration**

  Whenever the assembly experiences forces of acceleration along the sensitive direction, the proof mass will deflect away from its central position between the magnets.

  Because of this deflection, the differential capacitor will become unbalanced and the position detector will send a signal to the amplifier. The amplifier will produce an output current that passes through the two series-connected coils.

  The polarity and magnitude of the output current from the amplifier will drive the coils towards the centre of the magnet assembly, moving the proof mass simultaneously.

  The magnitude of drive current necessary to keep the proof mass centralised relates closely to the strength of the applied acceleration. The Sensor applies linearity, scale factor and zero offset corrections before using the accelerometer measurements in its calculations.

A.1.2 Angular Rate Sensors

The rate sensor array is sensitive to any rotation about its three orthogonal arms. The array measures angular velocity and is *insensitive* to linear movements in any direction.

To understand how rate sensors work it is helpful first to consider some of the properties of a simple pendulum:

Figure A–5: Fixed oscillation plane of a pendulum

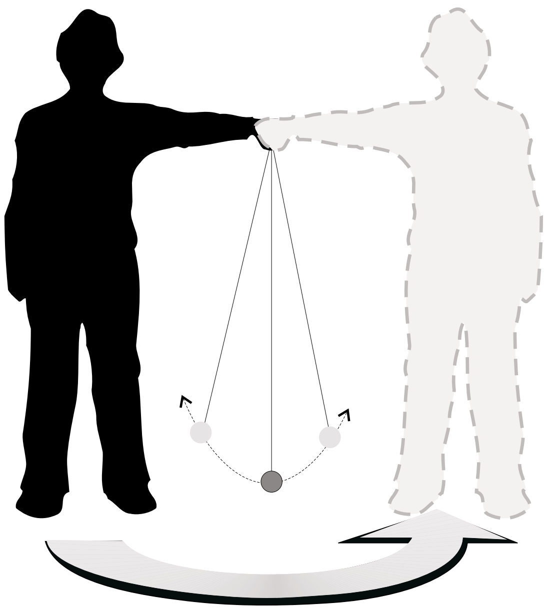


Figure A–5 shows a pendulum suspended so that it can swing freely in a single plane of oscillation. One property of the pendulum is that, once it has been set in motion, it will resist any attempts to change its plane of oscillation. If the point of suspension turns, as illustrated in Figure A–5, the plane of oscillation does not rotate at the same time.

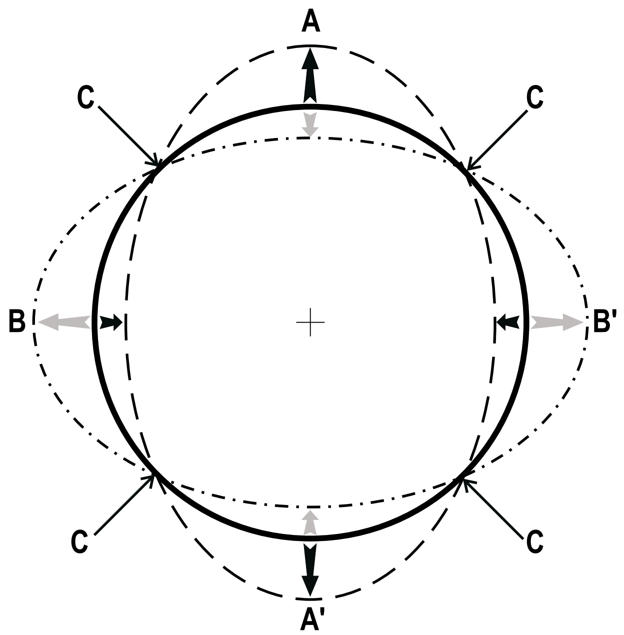
Figure A–6 shows, in exaggerated scale, how a vibrating mass exhibits properties similar to those of the pendulum already described. In this case, external forces cause the mass to vibrate so that the antinodal points A and A’ move simultaneously inwards towards the centre of the mass, and then move simultaneously outwards again on the next half-cycle of oscillation. Simultaneously, the antinodal points B and B’ also move outwards and inwards as indicated by the broken lines.

Between these antinodes there are four nodal points, C, that remain stationary throughout all stages of the oscillating cycle.

With the oscillating mass in a fixed orientation, the resonant vibration pattern described will stay fixed in space until it eventually decays to zero in the absence of a sustaining input. The nodal points, C, would never experience any of the resonant vibration.

If the vibrating mass were to rotate about its centre while the oscillation continued, the pattern of vibration would NOT rotate with it. With the rotation, those parts of the physical mass previously located at the nodal points, C, would move towards one of the antinodes and would begin to vibrate.

Figure A–6: Resonant vibration pattern of a circular mass

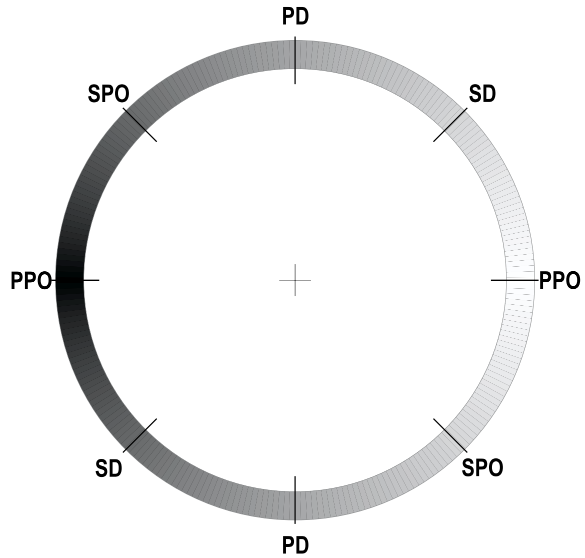


Rate sensors use this principle to measure rates of rotation. The vibrating mass they rely on may be a small cup-shaped piezo-electric crystal, a small ring of silicon, or some other shape or material defined by the device manufacturer.

To measure the rotation rate, the rate sensor must establish a stable pattern of vibration in the mass and must then detect any relative movement between the pattern and the mass. Figure A–7 shows the eight connections around the edge of the vibrating mass that allow the rate sensor to deliver an output. These connections are:

- PD Primary drive × 2
- SD Secondary drive × 2
- PPO Primary pick-off × 2
- SPO Secondary pick-off × 2

Figure A–7: Paired connections to the vibrating mass

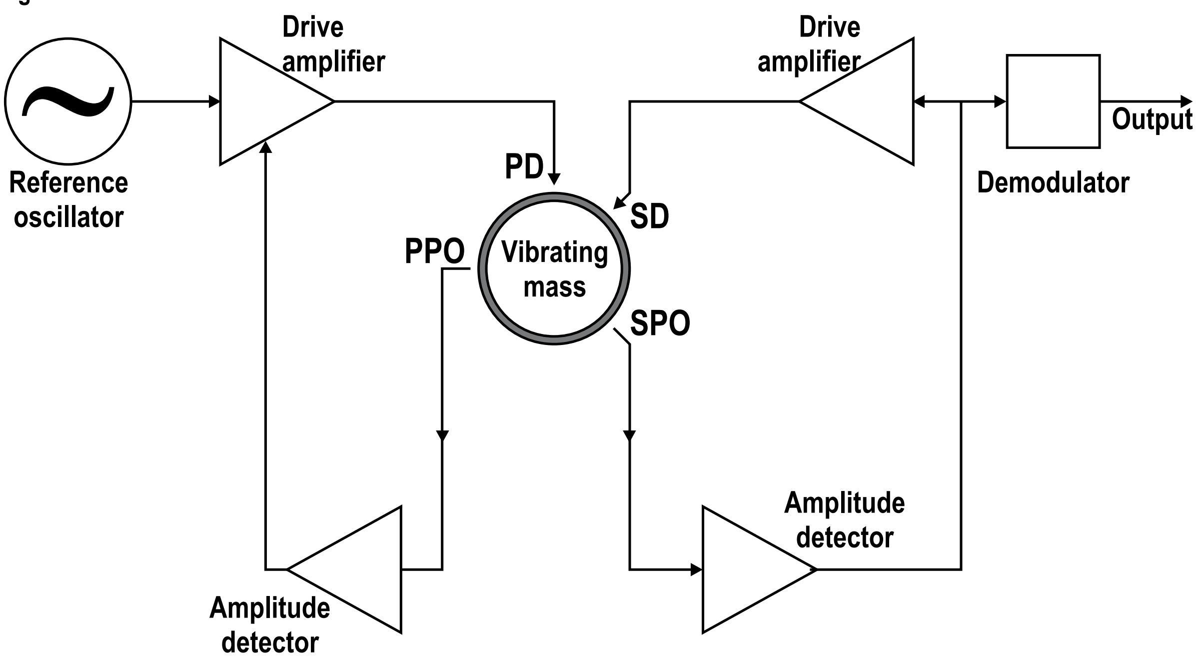


One property of the material used to create the vibrating mass causes it to distort very slightly under an applied voltage. The rate sensor uses this property to establish the oscillation pattern by applying an electrical signal at the resonant frequency between the Primary Drive (PD) connections.

A complementary characteristic of the material also causes it to *generate* a small signal when physically distorted. This property means that a small voltage at the oscillating frequency appears on the Primary Pick-off (PPO) connections.

The rate sensor amplifies signals from the PPO connections and uses them as feedback to the primary drive circuitry to stabilise the oscillation frequency. A crystal reference oscillator helps to establish the correct operating frequency and ensures stability of operation. The left-hand side of Figure A–8 shows this primary feedback loop.

Figure A–8: Rate sensor block schematic



With a stable pattern of vibration established in the mass and with no rotation applied to the device, there will be no output from the Secondary Pick-off (SPO) connections. This is because the SPO connections coincide with the nodal points, C, shown in Figure A–6.

When the rate sensor begins to rotate, the SPO connections begin to supply an output as they move away from the nodal points on the pattern of vibration. The phase of the SPO signals will depend on the direction of rotation.

The rate sensor conditions and amplifies the SPO signals and applies them to the Secondary Drive (SD) connections. By setting the magnitude and phase of the signal applied to the SD connections so that it *directly opposes* any vibration at the SD connection, the rate sensor forces the pattern of vibration to rotate with the mass.

To maintain a stable 'locked' condition between the pattern of vibration and the mass demands a stronger signal at the SD connections for faster rates of rotation. This is similar to the case of a spinning-mass gyroscope that resists any attempts to realign its spin axis and requires a strong torque to overcome that resistance.

The right-hand side of Figure A–8 shows the secondary feedback loop and the output demodulator. The rate sensor output derives from the amplitude of drive to the SD connection and therefore represents the rate of turn.

The Sensor applies linearity, scale factor, bias and zero offset corrections before using the rate sensor measurements in its calculations.

A.2 Properties of the Orthogonal Array

The Sensor includes three linear accelerometers and three rate sensors arranged in an orthogonal array. When mounted correctly, the three arms of the orthogonal array align with the roll, pitch and yaw axes of the vessel as shown in Figure A–1.

In summary, the characteristics of the two types of sensing element are as follows:

Linear accelerometer Sensitive axis is along one of the three orthogonal arms of the array. It is insensitive to rotation in any plane.

Rate sensor Measures angular velocity. It is insensitive to linear movements in any direction.

A.2.1 Static Conditions

Under static conditions, the only acceleration acting upon the orthogonal array is the $9.81 m/s^2$ (1g) due to gravity. By performing a vector addition on the accelerometer outputs, the Sensor measures the acceleration due to gravity and its relative direction.

If you rotate the Sensor into any other static position, the measurements made by the three linear accelerometers will change relative to each other. However, their vector sum will still indicate the magnitude and direction of gravity.

In this way the array of linear accelerometers functions as a solid-state inclinometer and allows the Sensor to measure its attitude under static conditions.

A.2.2 Dynamic Conditions

Linear accelerometer array

Sub-section 4.2 explained that measurements performed by the array of linear accelerometers could contain errors in the presence of horizontal acceleration. This is because the array performs a vector addition of all the forces of acceleration acting on the Sensor at any time:

Figure A–9: Vector addition of gravity and horizontal acceleration

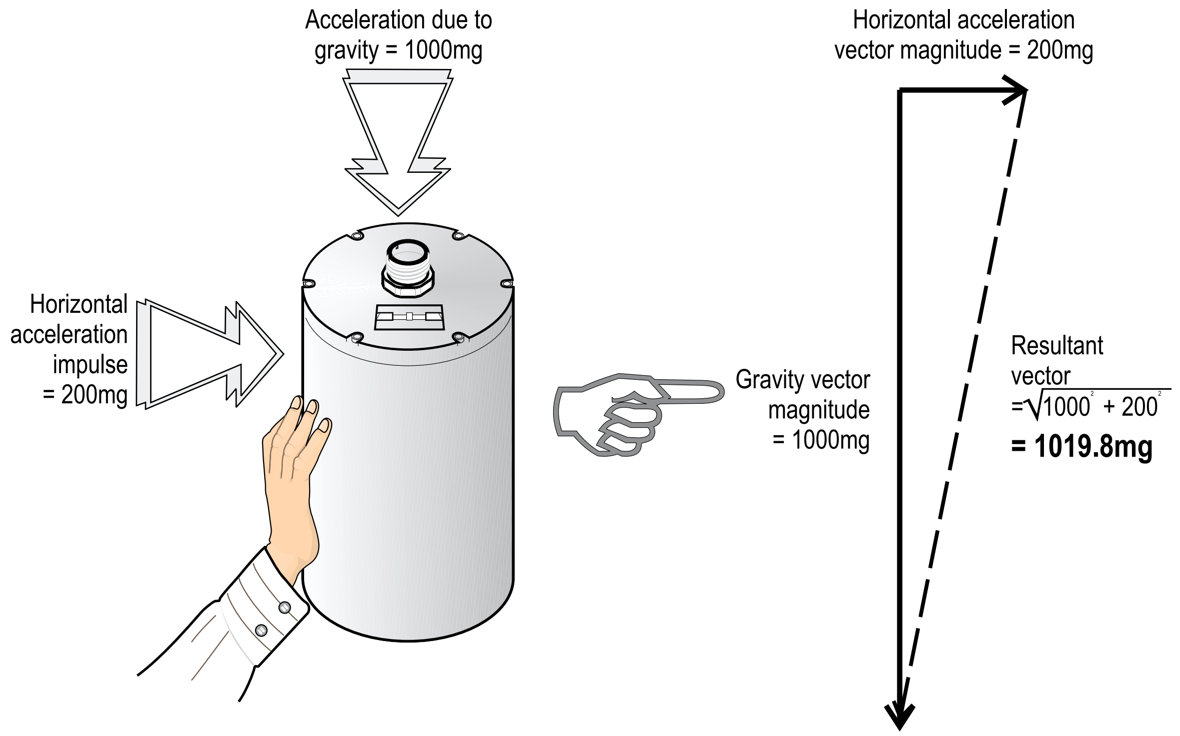


Figure A–9 shows an example where a Sensor experiences a horizontal acceleration impulse with no accompanying vertical displacement or change of attitude.

The array of linear accelerometers performs a vector addition of the horizontal acceleration impulse and the constant gravitational acceleration. The output from the array shows a net acceleration at some angle away from the vertical and with a magnitude more than 1g. The Sensor interprets this as a *positive* (upward) heave displacement with some change in attitude.

Errors of this type are the reason why you cannot use a simple solid-state inclinometer for accurate motion measurement in a marine environment.

Rate sensor array

Because rate sensors are immune to the effects of horizontal acceleration, an array of these devices could be used to provide error-free attitude measurements in a dynamic environment. In practice, this is not possible for two important reasons:

1. They are incapable of measuring absolute angles with reference to a fixed direction – they can track only *changes* in angle.

2. They suffer from an effect called drift, or bias, which causes them to generate some output even when they are not rotating. Errors in the outputs from rate sensors accumulate over time.

Combined array

To overcome the limitations that are inherent in either one of the above methods of measuring attitude, the Sensor uses the benefits of each method to eliminate the disadvantages of the other.

Although the transient influences of surge and sway affect the array of linear accelerometers, over time these effects average to zero. Provided this condition remains true the Sensor can filter the array output to reduce transient effects so that the vertical reference remains valid.

The application of filtering in this way allows the outputs from the linear accelerometers to provide attitude information only when changes in attitude occur very slowly. Normal motion in a marine environment would occur too rapidly for these measurements to be of any real use during a survey.

To measure the more rapid changes of attitude that are normal within a marine environment, the Sensor uses the outputs from the array of rate sensors. These are unaffected by surge and sway and can continue to respond throughout very high rates of roll. Unfortunately they have no static component and can only respond to changes in attitude – they have no way of determining a *true* vertical reference.

Instead, the Sensor obtains this static component from the filtered output of the linear accelerometer array.

The output from the Sensor therefore consists of high frequency measurements performed by the rate sensors, and static and low frequency measurements performed by the linear accelerometers. These measurements are almost entirely free from errors caused by transient horizontal acceleration and have a true vertical reference.

The filtering process described above cannot remove the extended horizontal acceleration that exists during a prolonged vessel turn. Under these conditions, errors will begin to appear in the Sensor measurements and these will persist throughout the turn and for a short period after. You may significantly reduce errors of this type by supplying the Sensor with aiding information from a gyrocompass and either a GPS receiver or Doppler log system.

The following sub-section includes a simplified block schematic and an explanation of the network used by the Sensor to combine the outputs from the linear accelerometers, the rate sensors and the aiding sources.

A.3 Sensor Block Schematic

Figure A–11 shows how the Sensor combines signals from the linear accelerometers and the rate sensors:

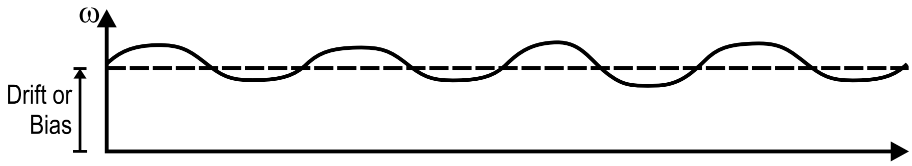
The accelerometer signals *ax*, *ay* and *az* arrive at A for conversion to roll and pitch information at B. At the same time, information from the array of rate sensors *ωx*, *ωy* and *ωz* arrives at C for application to the input of the integrator D. The integrator processes the rate of turn information and derives the angle of turn in each plane of rotation. For example:

Input to integrator		**Output from integrator**
3° per second	*Applied for 10 seconds* ➨	30°

The integrator therefore supplies the angles of roll, pitch and yaw through which the array rotates.

The output from a rate sensor appears similar to the example shown in Figure A–10. In addition to the short-term variations caused by changes of attitude as the vessel manoeuvres, there is also some very small level of drift or bias. This means the output does not vary symmetrically about zero.

Figure A–10: Rate sensor output showing offset



If left uncorrected, the Sensor would integrate this bias so that the resulting measurements would contain errors of increasing magnitude.

To eliminate this effect, the Sensor compares the output from the integrator with attitude measurements made by the array of linear accelerometers (which do not suffer from this effect). This comparison occurs at E. The Sensor uses the difference between these two independent measurements, at F, to estimate the magnitude of bias for each of the rate sensors.

The negative feedback loop formed by modules D, E, F and G removes the effect of rate sensor bias and delivers accurate measurements of attitude at M.

Velocity aiding signals *v* arrive at H from the GPS receiver. The Sensor uses these at I, together with rate-of-turn information supplied by the rate sensors, to derive the magnitude of centripetal acceleration:

$$a_c = v \times \omega$$

The result of this calculation, at I, significantly reduces errors caused by centripetal acceleration during prolonged vessel turns.

Heading aiding information arrives at K. The Sensor uses this information to provide the yaw-axis reference for the rate sensor array.

The bias described above in the outputs from the rate sensors consists of two elements:

1. A bias value that is intrinsic to the sensing component and which varies from one device to the next.

2. A value of 0.25°/minute caused by the rotation of the earth. If left uncorrected this could cause a maximum error in attitude measurement of 0.1°.

This earth rotation value changes according to two factors:

- The vessel heading.

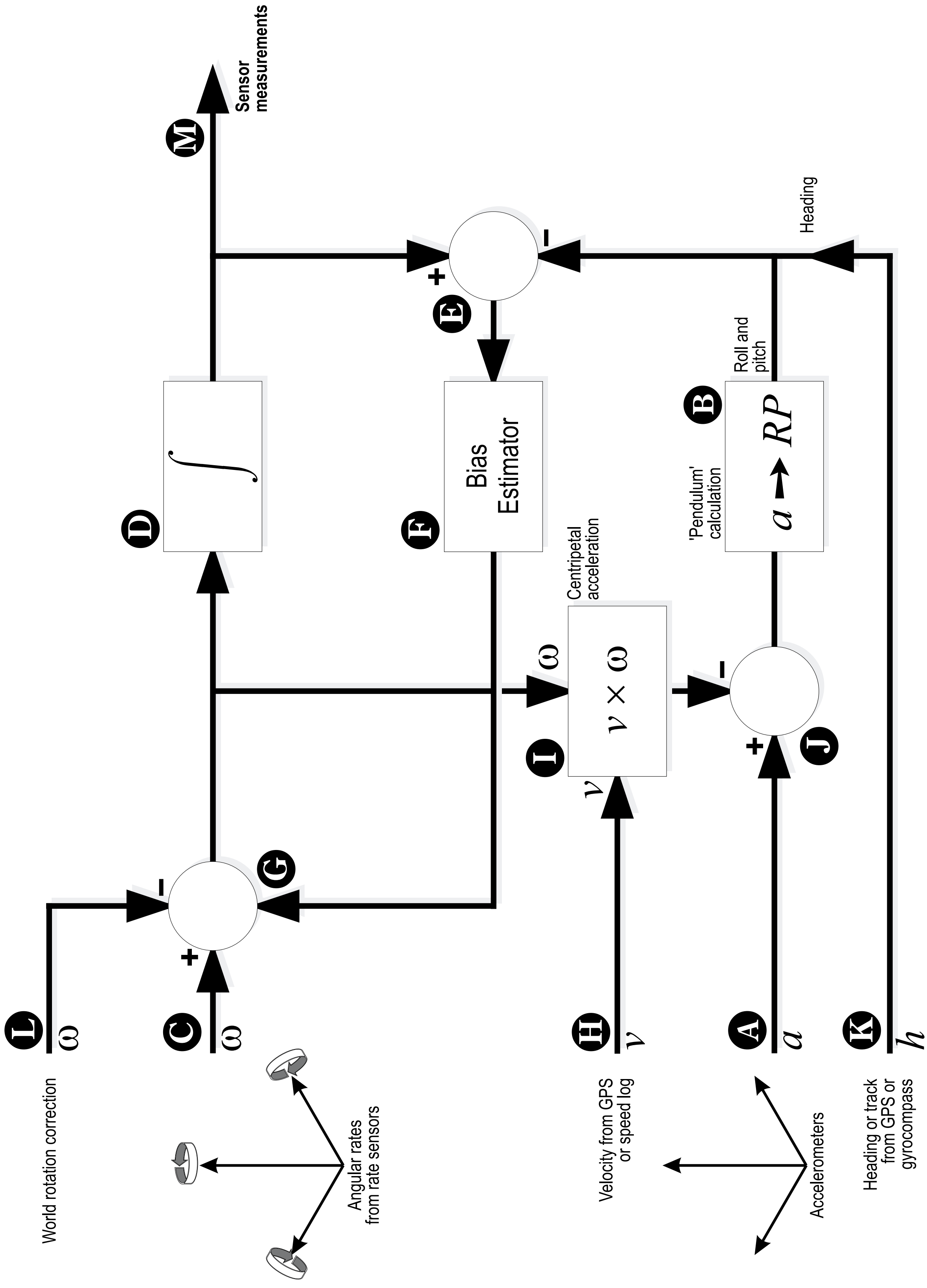
- The operating latitude of the vessel.

Correction for earth rotation effects takes place at Ⓛ using information supplied by the GPS and the gyrocompass systems.

The Sensor uses the feedback loop described above to remove any remaining errors caused by rate sensor bias.

The output from the sensing array at Ⓜ therefore has all corrections applied and maintains the specified attitude measurement accuracy throughout the survey.

Figure A–11: Sensor block schematic diagram



A.4 AC Coupled Heave

The Sensor measures heave by performing a double integration on the vertical acceleration output from the inertial sensors. After each integration, a filtering action takes place to limit the low frequency response of the Sensor and to allow recovery from the effects of random noise and horizontal acceleration. Without it, the smallest element of noise in the acceleration data would integrate to a constant velocity. Eventually, such an uncorrected output would show an ever increasing or decreasing displacement.

Under some circumstances the motion experienced by the Sensor may have a very long period. For example, a vessel travelling in the same direction and at approximately the same speed as the waves will 'surf-board' in a wave trough for some minutes at a time.

There is therefore a conflict between the need to reduce the bandwidth away from a steady state to minimise the effects of errors, and the need for an extended bandwidth to maximise the operational ability of the instrument.

Because of practical limitations, a period of 20 seconds is the longest the Sensor can measure to within the stated limits of accuracy. However, in many situations (choppy seas and short period swells), the motion of the vessel will be much faster than 20 seconds.

The Sensor therefore allows you to select among bandwidths of 8, 12, 16 and 20 seconds to provide accurate measurements with improved error performance through a range of dynamic conditions. Refer to sub-section 3.2.1.2 for instructions to configure the heave bandwidth.

The most important aspect of these filters is that they should introduce no phase distortion. What actually happens in any bandwidth-limited system is that as the 'edge' of the pass band approaches, the system can no longer keep track of an input signal. While still being able to measure amplitudes correctly, it can no longer supply an output in the correct time slot: a 'phase difference' occurs between input and output.

The real-time response of the Sensor depends on this effect, and the accuracy specification quoted for the Sensor reflects the *total* phase and amplitude performance of the filter. In practice, the operating bandwidths are well within the cut-off frequencies of the filters, phase being the limiting factor governing the range over which the Sensor can measure heave accurately and in real-time. The Sensor uses special filter algorithms specifically to maintain zero phase distortion in the operating bands and alleviate this potential problem.

B DISPLAY SOFTWARE

You may control and configure the Sensor using a PC running the display software supplied with the System. This software also allows you to display measurements from the Sensor using a clear graphical style.

You must install the software onto your controlling PC – you cannot run the software from the CD supplied with the System.

The PC performs the control and logging operations in response to commands issued through the RS232 serial port COM1 or COM2. Connection between the Sensor and a controlling PC is through a single cable.

Install the display software from the CD ROM. The software features and controls follow a pattern that should be familiar to experienced users of the Windows™ 95, 98, 2000 or NT environments.

TSS (UK) Limited supplies the display software subject to a licence agreement.

B.1 Connection

Refer to Section 2 for instructions to connect the Sensor to external receiving and aiding equipment using the supplied cable (P/N 600732). Sub-section 6.4 includes a drawing of this cable, and Table 2–1 lists the connections you will need to make to it.

Normally, you would use the ‘COM1’ serial port of the controlling PC to connect to the Sensor. However, you may use the ‘COM2’ port if you prefer. Refer to the technical manual of your PC for instructions to connect to its serial communication ports.

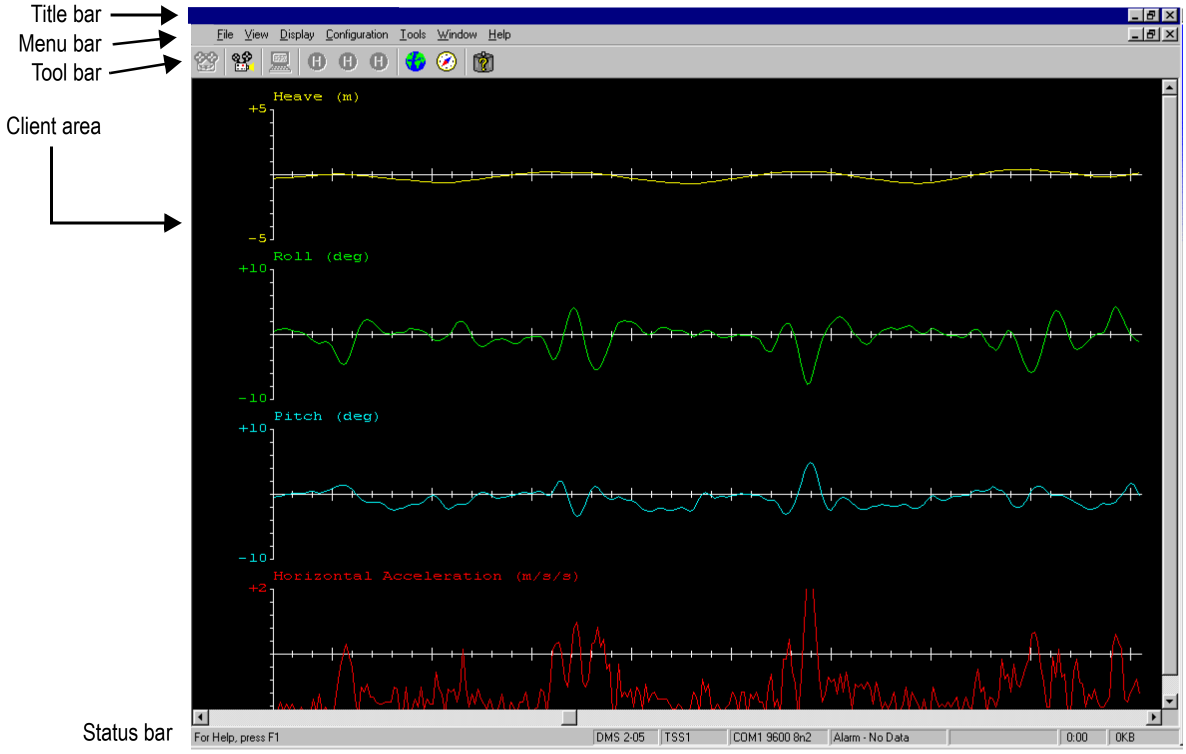
B.2 Software Description

To run the Windows™ display software effectively, your PC should meet or exceed the following specification:

- Processor type – P166 or better
- At least 16MB of RAM
- CD-ROM drive
- Mouse
- Microsoft Windows™ 95, 98, 2000 or NT 32-bit environments. *You cannot use this program in DOS or in Windows™ 3.11.*
- Colour display configured for 256 colours (or more) at a resolution of at least 800 × 600 pixels
- At least one free serial port available for communication with the Sensor. Ideally, the PC should have three serial ports available so that you may use the GPS and gyrocompass simulators if necessary.

The display software allows you to communicate with the Sensor so that you may configure and control it. You may also use the software to log measurements from the Sensor and to display them in real time. If you log data from the Sensor using this software, then you may also use the same software to replay that data and analyse the recordings using its on-screen features.

Figure B–1: Windows™ display software



B.2.1 Installation and Operation

To install the display software, insert the supplied CD into the CD-ROM drive of your PC. Select Start➥Run➥D:\SETUP.EXE (where D: is the drive letter for your CD-ROM) and then follow the instructions on screen to install the program. **You cannot run the software from the CD.**

Contact TSS (UK) Limited for assistance if you need to install the software from 3½-inch diskettes.

The installation wizard will suggest a default directory that it will create for the display software and its support files. You may choose or create an alternative directory if you prefer. The instructions that follow in this appendix assume that you have installed the program in the default directory.

After you have completed the installation, select Start➥Programs➥TSS➥DMSView32 from the Windows™ Desktop to start the display software. The Sensor connection wizard will prompt you to select a connection mode. Follow the on-screen prompts to connect to a Sensor using your preferred method as described below.

B.2.1.1 Auto Sensor detection

Auto Sensor detection allows you to connect to a Sensor whose configuration you do not know. Although this process requires the program to poll the Sensor several times, it occurs automatically and does not take long to complete.

To make certain the Sensor is not operating with its menu structure active, cycle power to the Sensor off and then on again. You do not need to do this if you are entirely confident that the Sensor is supplying measurements using one of its digital output formats.

The software will alert you to any problems that it encounters while trying to connect to the Sensor. Unsuccessful attempts at connection will cause the software to adopt the replay mode.

After a successful connection, the wizard allows you to decide whether to run the connection wizard automatically when you next start the software. You may deselect this option safely because you may start the wizard from within the software when necessary.

On completion of a successful connection, the software also allows you to run a Sensor data check that displays raw data from the accelerometer array and allows you to test that it falls within appropriate ranges. The Sensor must be stationary to perform a successful data check. Failed test measurements will appear in red.

B.2.1.2 Manual Sensor configuration

Make certain you know the detailed configuration of the Sensor before you select this connection method. In particular, you will need to know the full RS232 or RS422 communication parameters and the selected data format. If you do not know these, select 'Auto Sensor detection' instead.

Cycle power to the Sensor off and then on again after you choose to continue with a manual Sensor configuration.

The manual configuration method allows you to set the software parameters to match the connected Sensor.

B.2.1.3 Replay mode

Replay mode allows you to use the software with no Sensor connected. Use this mode if you need to replay logged data.

Data logged by the display software uses a special format developed specifically for this purpose. You should use an external data logging system to record all data included in the digital data stream transmitted by the Sensor.

B.2.2 Main Window

Figure B–1 shows the resizable main window of the display software with an example of the logging replay window open. The main window includes the following important main features:

Title bar

This is at the very top of the main window and includes the application name. You may click on the title bar with the mouse and drag the window to a new location on the PC screen.

Menu bar

The menu bar is immediately below the title bar. You may access the commands on the menu bar through keyboard strokes or by clicking with a mouse. Refer to sub-section B.2.2.1 for a detailed description of the commands available through the menu bar.

Tool bar

The tool bar is immediately below the menu bar and includes the buttons that allow access to some of the software features. You must use mouse clicks to use these buttons. If your PC has no mouse connected, you may access all the tools through the menu bar instead. Refer to sub-section B.2.2.2 for a detailed description of the facilities available through the tool bar.

Client area

The client area is the main region of the window. When you launch the program, the opening splash remains on screen for a short period and then disappears to leave a blank client area. Figure B–1 shows the main window with the client area occupied entirely by the logging replay window.

When you first open a new window within the program, it will always appear inside the client area. However, you may then move the new window outside the client area by clicking on its title bar and dragging it to a new location on the screen. You may then use the standard windows facilities to resize, maximise, minimise or close it as necessary.

You may have more than one window open and 'live' on the screen at any time. Using this method, for example, you may open two separate windows to examine logged and real time information simultaneously. Note however that you will deplete your system resources seriously if you have several windows active and you should therefore close windows that you no longer need.

Refer to sub-section B.2.3 for a full description of the various windows available for display in the client area.

Status bar

The status bar at the bottom of the main window shows the Sensor type in use, the digital data format, the communication parameters and the alarm status.

The alarm status can show several conditions:

- 'Alarm – Disk Full' will appear if there is insufficient space on the disk to log data. To avoid potential system crashes the software will stop logging automatically when there is only 100k of disk space remaining.
- 'Alarm – No Data' will appear if the software loses communications from the Sensor.
- 'Alarm – Invalid Data' will appear if the software does not recognise the data format from the Sensor.

B.2.2.1 Menu bar

There are three alternative methods that you may use to access the drop-down commands on the menu bar. You may also access some of the commands by clicking buttons on the tool bar – refer to sub-section B.2.2.2 for details.

1. If the PC has a mouse, click on the menu item.

2. Press [ALT] and then use the [TAB] or [SHIFT]+[TAB] keys to select an option on the menu bar. Then use the [UP] or [DOWN] cursor keys to move the focus through the sub-menu entries. Press [ENTER] to select the highlighted sub-menu item.

3. Press [ALT] and then press the underlined shortcut key for the relevant function. For example, in the menu bar **Display** appears with 'D' underlined. This means 'D' is the short-cut key for the Display sub-menus.

File

New Log File	Create a new file to log data from the Sensor. By default, the dialogue box gives the new file a name consisting of the date and time of opening using the format 'DD-MM-YY-HH:MM.DAT'. You may change this filename if necessary. The directory path for the logged file is the same as that used previously. For a new software installation, the program creates a directory called 'LOGS' under the directory that holds the executable.
Close Log File	Stop logging information from the Sensor and close the logging file. The software will prompt you to confirm the command before it closes the logging file.
Open Replay File	Opens an existing logged file for replay.
Close Replay File	Closes the replay file in the current display window.
Print Configuration	Print the Sensor configuration file. This file holds information concerning the Sensor type, data format and communication parameters. It allows the software to connect quickly to the Sensor after you launch the application.
Recent File	Display a list of the logging files created most recently. You may select one of these to replay.
Exit	Exit the display software and return to the Windows desktop. If you are logging information, the software will prompt you to confirm the exit command before it closes.

View

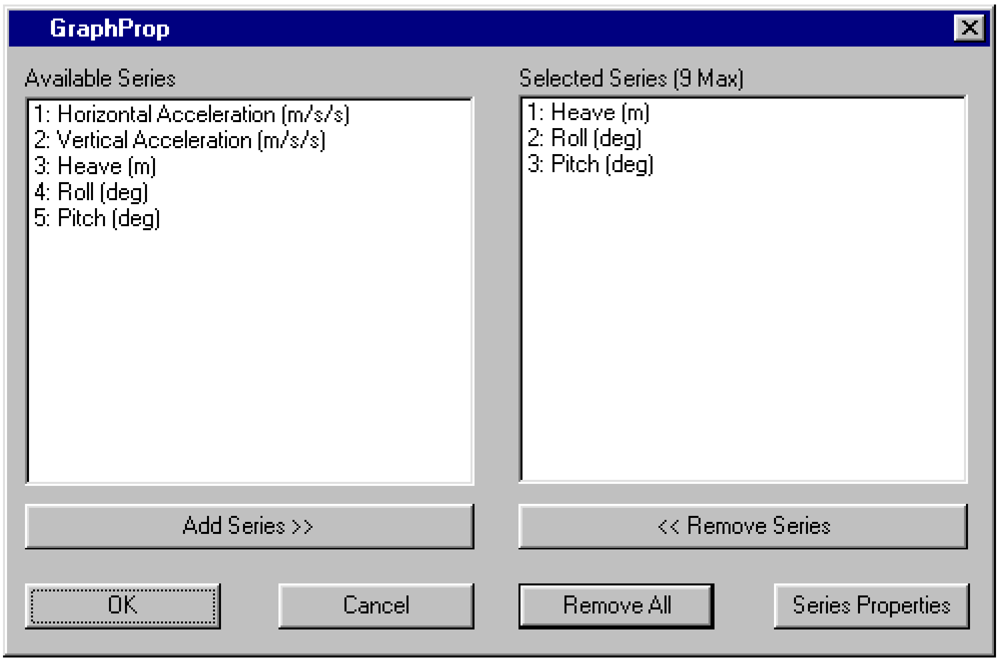
Logging Window	Select this menu item to see the logging window during operation.
Terminal Window	Select this menu item to see the terminal window during operation.

Display

Pause	If selected, the display window receives no further updates in real time. Logging will continue, if enabled. To resume the real time updates of the display, deselect this menu item.
Annotate	Select this item to see the annotation bar. You may use the annotation bar to add text messages to the logged record.
Measure ▸	Refer to sub-section B.2.3 for a description of the point and difference measurement facilities.
▸ Point	Select this item to use the point measurement facility.
▸ Difference	Select this item to use the difference measurement facility.
Go To Time…	Select this item to go to a specific time while replaying a logged file.

Properties	Select this item to open the display properties window (shown in Figure B–2). You may use this window to select the data series whose charts you wish to see. Select all required items from the 'Available Series' and then click on 'Add Series'. You may also use this item to set specific chart colours and to set the displayed scale ranges for any data series. To do this, select an item in the 'Selected Series' pane and then click on the Series Properties button.

Figure B–2: Display Properties window



Configuration

Sensor Digital I/O	Select this item to configure the software to match the digital output characteristics of the connected Sensor.
Sensor Connection Wizard	Select this item to start the Sensor connection wizard. This same wizard appears when you first use the software. Refer to sub-section B.2.1 above for a description of this feature.

Tools

DMM ▸	This selection and its sub-menus are for use with the TSS Deck Motion Monitor. Refer to sub-section B.2.3.3 for details.
GPS/Doppler Log Message Simulator	Select this item to use the GPS and Doppler log message simulator. It allows you to generate artificial velocity aiding messages that you may supply to the Sensor. It is a useful tool to help you integrate the Sensor into a suite of survey equipment.
Gyrocompass Message Simulator	Select this item to use the gyrocompass message simulator.
	To use the GPS and Gyrocompass message simulators, your PC must have two spare COM ports (in addition to the one you use for primary communications with the Sensor). **In this configuration, GPS simulation messages pass through one COM port to the Sensor and gyrocompass simulation messages pass through the other.**
Sensor Data Check	Select this item to perform a Sensor data check. This option confirms correct operation by showing raw data from the accelerometer array in the Sensor.

Window

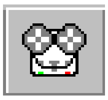
Cascade	Displays all open windows in the display area.
Tile Horizontally	Tiles all open windows horizontally in the display area.
Tile Vertically	Tiles all open windows vertically in the display area.
Active window list	The active window list allows you to select among all open windows.

Help

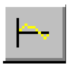
DMSView	Displays functional help information for the screens and features of the software.
Sensor Installation Guide	Displays information to help you install a TSS Sensor.
Sensor Manual	Allows you to read the electronic manuals recorded on the installation CD.
About DMSView	Shows the version number of the display software.

B.2.2.2 Tools

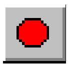
The tool bar on the main window includes the following buttons:



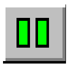
Open/Close Real Time Logging Window
Select this button to make the logging window visible. Deselect it to hide the logging window.



Display properties
Select this button to set the range, colour and other details of the displayed data charts.

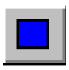


Open Log File Window
Select this button to create and open a new file for logged data. You may open a maximum of eight logging files at the same time.

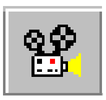


Logging pause
Select this button to temporarily suspend data written to the logged file. The acquisition of real time data continues and is unaffected by this control. Deselect the button to continue logging data.

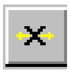
Logging annotate
Select this button to add a short text message to the logged record.



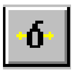
Logging stop
Select this button to stop logging data and close the file.



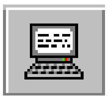
Logging replay
Select this button to replay and examine a file logged previously.



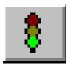
Measure point
Select this button to use the point measurement feature. This will show the instantaneous amplitude of any point you select on the displayed charts. Set the position of the point by clicking and dragging the 'thumb' in the horizontal scroll bar.



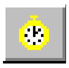
Measure difference
Use the 'measure point' feature first to set a single point and then select the Measure Difference button to set a second point on the displayed charts. The display will show the time difference between the two points, and the amplitude difference between the two points for each of the displayed charts.



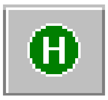
Close/Open Terminal Window
Select this button to make the terminal window visible. Deselect it to hide the terminal window.



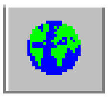
Terminal Polling
Click on this button to send a polling character to request data from the Sensor. You need use this facility only when you have configured the Sensor to supply a polled digital data format.



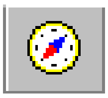
Go to time
Click on this button to specify a particular time in the logged or real time data and to display that data on the charts. Alternatively, you may click and drag the 'thumb' in the horizontal scroll bar to set the display to show a particular time.



DMM CAP 437
These three coloured buttons are for use with the TSS Deck Motion Monitor. Refer to sub-section B.2.3.3 for details.



GPS/Doppler Log Simulator
Use this button to select the GPS/Doppler Log Simulator feature described in sub-section B.2.2.1 above.



Gyrocompass Simulator
Use this button to select the Gyrocompass Simulator feature described in sub-section B.2.2.1 above.

Sensor Manuals
This button launches Adobe™ Acrobat Reader and allows you to read and print the Sensor manuals stored on the installation CD.

If you point to a button with the mouse you will see a 'tool tip' that reminds you of the button function.

B.2.3 Client Area

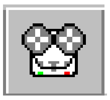
The client area is where the software originally shows the various data displays that you select. You may move the data displays outside the client area and resize them so that they fit on your PC screen more easily. Figure B–1 shows the software with the client area occupied entirely by a replaying logged file.

The client area shows the available window types:

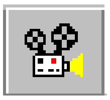
- Logging window
- Replay window
- Terminal window
- CAP 437 display for the TSS Deck Motion Monitor (DMM)

B.2.3.1 Logging and Replay windows

The logging and the replay windows are similar in appearance.



Select the logging button to display the logging window. Deselect the logging button to close the logging window.



Select the replay button to display the replay window. Deselect the replay button to close the replay window.

The display area includes up to nine horizontally scrolling charts to show measurements. These can include real time data from the Sensor (in the logging window), or recorded data read from a logged file (in the replay window). You may have a logging and a replay window open simultaneously.

Each chart has white axes with horizontal scale gradations at fixed one-second intervals. All charts in the display are synchronised in time.

The display area includes a vertical scroll bar if the number of charts selected exceeds the number that the screen can display simultaneously. The display area also includes a horizontal scroll bar that you may use to move to specific times in the displayed data. You may use this feature in the logging window and in the replay window:

- The logging window usually shows real time data updating the chart as it arrives from the Sensor. The chart scrolls towards the left as the software receives further data, with new data appearing at the right-hand end. You may use the horizontal scroll bar to move backwards through the chart to view data recorded earlier. Real time data will continue to append the chart while you examine earlier chart details.
- You may use the horizontal scroll bar to move backwards and forwards through the replay file. You may also use the ‘Go To Time…’ command available through the Display menu and as a tool bar button to display a specific time of the logged record.

The replay logged file facility displays static ‘snap shots’ of the logged record only. This always starts from the beginning of the logged file when you open the file.

You may specify the start time for each snap shot, but you cannot set the replay facility to show an animated sequence from the logged file.

Annotations

To annotate the logged file with a short text message, select **Display➥Annotate** or click on the Logging Annotate button.

Annotations appear on the charts during replay as broken grey vertical lines. The associated text appears in the annotation bar whenever an annotation marker appears on the chart.

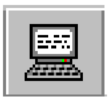
Measurements

The software provides two measurement modes that help you to analyse data from the Sensor. You may access either option by selecting **Display➥Measure** and then selecting the ‘Point’ or ‘Difference’ measurement modes. You may also select these measurement modes by clicking on their appropriate button in the tool bar.

- **Point** measurements allow you to measure the specific time and amplitude for a single point on the charts. Click and drag the button in the horizontal scroll bar to set the measurement point, which appears as a red vertical line on the display. There is only one vertical marker, although each chart on display has its own horizontal marker.

- **Difference** measurements allow you to measure the difference in time and amplitude between two points on the chart. To do this, you must first use the Point measurement facility to set the reference point in the chart. Then select Difference measurement mode and use the button in the horizontal scroll bar to move the green difference marker to the left or right. Read the differential measurements from the display.

B.2.3.2 Terminal window



Select **View➥Terminal Window** or click on the terminal window button to use the terminal mode. Use this window to access the internal menu structure of the Sensor to configure the System after installation. Refer to Section 3 for instructions to configure the System.

You may also use the terminal window to view scrolling columns of data supplied by the Sensor.

B.2.3.3 CAP 437 Display

To use the special CAP 437 display features you must fit a hardware key or ‘dongle’ to the controlling PC. The software feature will not work without it. You may obtain this hardware key, at additional cost, from TSS (UK) Limited.

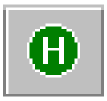
The CAP 437 display mode is specifically for use during controlled helicopter flight operations on a moving platform. The display features are special and specific to the needs of this application. It operates only with a Sensor capable of measuring heave, roll and pitch.

There are three display variants. Each display variant includes maximum measurements recorded during the previous ten minutes of operation. If the System has been operating for less than ten minutes, the top line of the display will indicate the measurement period.

The displays also indicate the real time measurements of heave, roll and pitch against scales under the TSS logo on the right-hand side.

The bottom line of the display shows messages for use by the helicopter control official, together with a two-state indicator to confirm whether data received from the Sensor is good or bad.

Refer to the separate manual for the TSS Deck Motion Measurement System for a full description.



Select **Tools➡DMM** or click on one of the three DMM buttons to use the CAP 437 display mode.

- Figure B–3 shows the standard display that you may access using the green DMM button. It shows the maximum measured values for heave, roll and pitch experienced by the Sensor during the operational period defined at the top of the screen.

- Figure B–4 shows the same information as the standard display but with an additional line to indicate the maximum heave velocity measured during the operational period defined at the top of the screen. You may access this display mode by clicking on the blue DMM button.

- Figure B–5 shows the CAP 437 display with maximum heave displacement and rate during the operational period defined at the top of the screen, and a motion severity index (MSI). The software derives this index from a specially developed algorithm that analyses the dynamic movements of the platform. You may access this display mode by clicking on the red DMM button.

Figure B–3: CAP 437 standard display

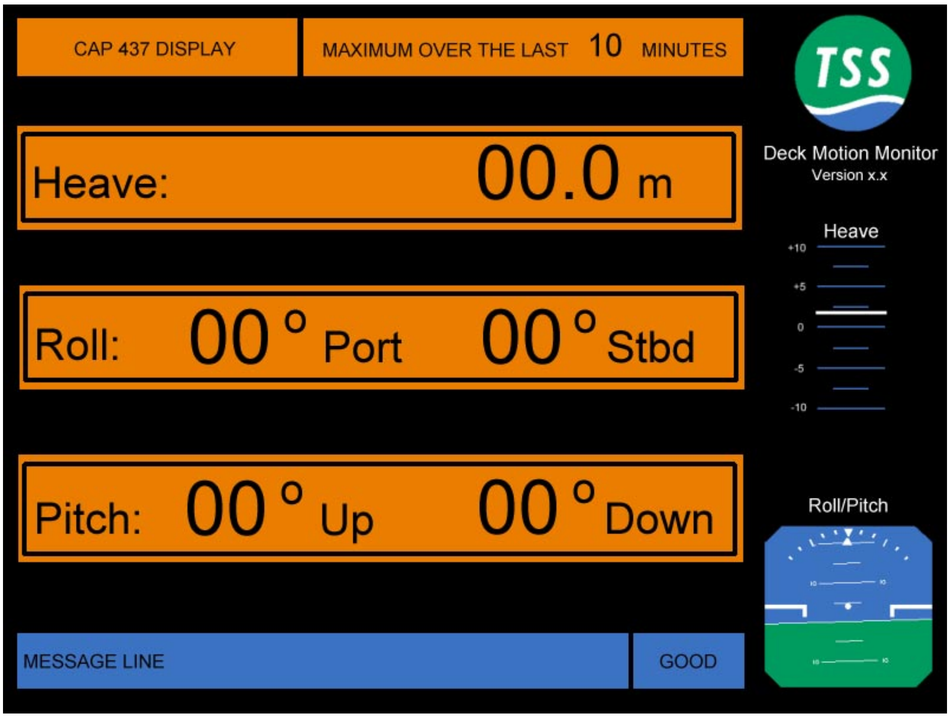


Figure B–4: CAP 437 display with heave rate

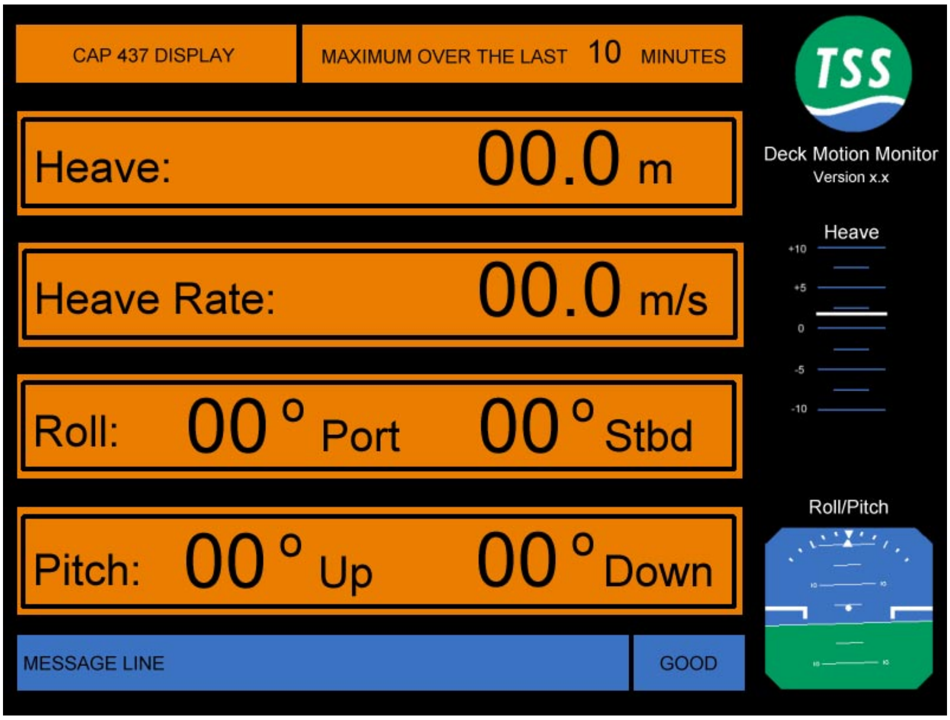


Figure B–5: CAP 437 display with Motion Severity Index (MSI)

B.3 SOFTWARE LICENCE AGREEMENT

IMPORTANT NOTICE: Please read the terms of the following Licence Agreement carefully. Your use of the product signifies your acceptance of the terms of the Agreement.

This product contains copyrighted computer programs ("software") which are the inalienable intellectual property of TSS (UK) Limited and which are protected by law, including United States copyright laws and international treaties. This software is both integrated within the product and also contained on the hard disk of the computer supplied or on a data carrier supplied with the product. The purchase of this product does not include the software and the associated rights of usage from TSS (UK) Limited. TSS (UK) Limited grants the end user the right to use the software solely in accordance with the conditions of this software licence agreement. By purchasing this product you agree to the terms of this licence.

1. TSS (UK) Limited grants the customer a personal, non-exclusive license to use the software product on a single machine.

2. This license may be transferred to another party only in connection with this product and only if that party agrees to accept the terms of this Agreement and you do not retain any copies of the software in any form.

3. The customer may not license, lease or loan the software to a third party, nor allow a third party to access the software in any other way.

4. The customer may not without prior written authorisation from TSS (UK) Limited copy, modify, transmit or edit the software, apart from the actions of copying necessary to create a single backup copy in support of a single machine.

5. The customer may not modify, translate, disassemble or decompile the software, or any copy, in whole or part.

C ANCILLARY FEATURES

Throughout the main part of this Manual, the descriptions and instructions refer to the standard Sensor.

This appendix describes the additional and optional features that you may use or specify for use with the Sensor.

Aiding information from a GPS receiver can enhance the measurement performance of the Sensor during vessel turns. You may connect your GPS receiver directly to the Sensor, or through the Remote Repeater option.

You will gain further enhancements in Sensor performance if you supply it with aiding information from a GPS receiver *and* from a gyrocompass.

The Sensor can accept aiding information from a magnetic compass that has a data output capability. However, these instruments tend to introduce errors during vessel turns and under the influence of acceleration transients. For this reason, magnetic compasses may not be the best source of aiding data.

If possible, use a gyrocompass that has negligible servo lag to supply heading aiding data to the Sensor.

This sub-section explains how to connect a gyrocompass, and lists the data formats that the Sensor can use.

You should use the Remote Repeater unit if you must install the Sensor at some distance from the receiving equipment, or if you require analogue outputs from the System.

The optional field support kit includes several important components that will help to restore full operation of the Sensor after field disassembly.

TSS provides a supporting range of training courses for all its products.

C.1 GPS System

The Sensor can use velocity aiding information to enhance the accuracy and stability of its measurements throughout turns and other vessel manoeuvres. Refer to Section 4 and Appendix A for an explanation of this process.

Usually, the Sensor accepts velocity aiding signals from a GPS receiver. However, for some applications you may use a Doppler speed log to supply this information instead. Throughout this Manual, 'GPS aiding' applies to any source of velocity aiding information unless the text identifies a method specifically.

This sub-section explains how to use GPS aiding information with the Sensor. Refer to the technical manuals of your GPS receiver or Doppler log to help establish a successful connection with the Sensor.

C.1.1 Installation

Follow the instructions supplied by the manufacturer of your GPS receiver to install the GPS receiver and antenna. Take note of the general installation guidelines listed below:

- The Sensor does NOT supply electrical power to operate the GPS receiver installation. You must make separate arrangements to supply power to operate your GPS receiver.
- If necessary, provide a battery backup supply for your GPS receiver memory to retain important navigation details during the times when your receiver is inactive. This precaution allows the receiver to acquire satellites more quickly after power-on by performing a 'warm start'. **Refer to the technical manual of your GPS receiver for specific instructions.**
- Signals from the GPS satellites are extremely weak. Choose a position for the antenna that allows it an unobstructed view of the sky in all directions.
- Avoid mounting the antenna in areas where it will receive multipath satellite signals caused by reflections off nearby structures.
- Avoid mounting the antenna where salt deposits might accumulate and degrade the received signals. Remove salt deposits by washing the antenna with fresh water.
- Make certain that there is a clearance of at least 0.5 metres between the GPS antenna and nearby radar, satellite communications or other transmitting antennas.
- Follow the installation instructions supplied by the manufacturer of your GPS receiver to choose a suitable location for the receiver.
- Refer to sub-section 2.4 and Table 2–1 for details of the Sensor cable that you may use to connect your GPS receiver or Doppler log directly to the Sensor.
- Refer to sub-section C.3 if you intend to use the optional Remote Repeater to connect your GPS receiver or Doppler log to the Sensor installation.
- Refer to sub-section C.1.2 below for instructions to configure the Sensor to accept a GPS aiding input.

C.1.2 Operation

Use the Sensor menu structure to configure the System correctly for a GPS aiding input. Refer to sub-section 3.2.2 for instructions to select the ‘Configure I/O’ menu.

From the ‘Configure I/O’ menu select ‘Configure GPS Input’.

Follow the instructions in sub-section 3.2.2.3 to select the appropriate input format. Refer to the technical manuals of your GPS receiver for instructions to configure your receiver output correctly.

Set the RS232 parameters according to the requirements of your GPS receiver.

Return the Sensor to normal operation.

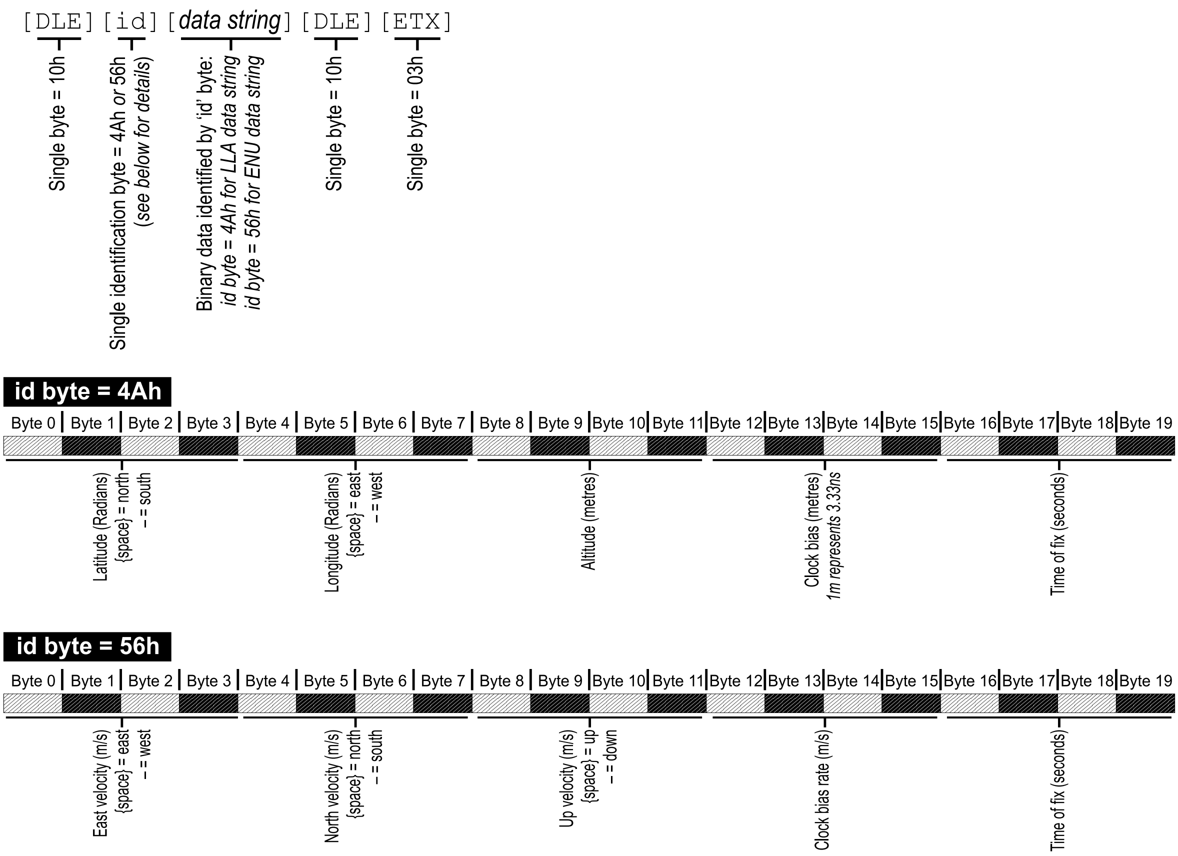
C.1.3 Data Formats

The Sensor can accept GPS aiding data using any of the formats described in the following sub-sections.

C.1.3.1 TSIP

For flexibility, the TSIP output string can include different types of information to meet the needs of specific applications.

Table C–1: TSIP data format



For operation with the Sensor, the GPS receiver must supply the report packets identified by the ‘id’ bytes 4Ah and 56h as defined below and in Table C–1. You *must* configure your GPS receiver to supply these report packets to the Sensor.

If your GPS receiver accepts commands from the Sensor, the Sensor can configure the receiver automatically to supply the necessary TSIP report packets.

This facility works only if you connect a suitable GPS receiver to the optional Remote Repeater using a bi-directional serial data link. You cannot use this facility if you connect your GPS receiver directly to the Sensor.

Report Packet 4Ah – Single precision LLA

This packet supplies the current position of the GPS antenna in LLA (latitude, longitude and altitude) co-ordinates. The receiver issues an LLA packet each time it calculates a position fix. Clock bias, included as bytes 12 to 15, is the offset between the internal real-time clock and GPS time, expressed in metres where 1m represents 3.33×10^{-9}s.

Report Packet 56h – Velocity fix, East-North-Up (ENU)

The GPS receiver issues an ENU packet each time it calculates a position fix.

C.1.3.2 NMEA 0183

The NMEA 0183 format includes a variety of ‘sentences’, each of which features a different combination of data fields.

For GPS aiding to work using the NMEA 0183 format, the Sensor must receive a particular set of data fields from the GPS receiver. These data fields are included in three NMEA 0183 sentences, and the Sensor must receive *two* of these:

- NMEA 0183 VTG – Course over ground and ground speed

and *either*

- NMEA 0183 GLL – Geographic position – Latitude/longitude

or

- NMEA 0183 GGA – Global positioning fix data

For GPS aiding to function with the NMEA 0183 format, the System *must* receive the NMEA 0183 VTG sentence plus *either* the NMEA 0183 GLL *or* the GGA sentence.

Configure your GPS receiver to supply these sentences. If the Sensor does not receive the correct sentences, then GPS aiding will not function.

The Sensor will ignore all NMEA 0183 sentences that are not relevant to the aiding function. It will also ignore data fields in the sentence that are not relevant to the aiding function. The following tables include descriptions of all data fields for completeness.

Table C–2: NMEA 0183 VTG sentence format

```
$GPVTG,ttt.t,T,mmm.m,M,nn.n,N,kk.k,K*xx[CRLF]
```

- Start character
- Talker identifier
- VTG sentence identifier
- Comma separator
- Track made good (degrees)
- Comma separator
- True heading mnemonic
- Comma separator
- Magnetic track made good (degrees)
- Comma separator
- Magnetic heading mnemonic
- Comma separator
- Speed (knots)
- Comma separator
- Mnemonic for knots
- Comma separator
- Speed (km/h)
- Comma separator
- Mnemonic for km/h
- Checksum (*optional*)
- Carriage return line-feed characters

Table C–3: NMEA 0183 GLL sentence format

```
$GPGLL,LLLL.LL,N,YYYYY.YY,E,hhmmss.ss,Q*xx[CRLF]
```

- Start character
- Talker identifier
- GLL sentence identifier
- Comma separator
- Latitude (ddmm.mm)
- Comma separator
- Latitude indicator 'N' or 'S'
- Comma separator
- Longitude (dddmm.mm)
- Comma separator
- Longitude indicator 'E' or 'W'
- Comma separator
- Time of fix
- Comma separator
- GPS status flag
- Checksum (*optional*)
- Carriage return line-feed characters

Table C–4: NMEA 0183 GGA sentence format

```
$GPGGA,hhmmss.ss,LLLL.LL,N,YYYYY.YY,E,Q,nn,a.a,b.b,M,c.c,M,d.d,ffff*xx[CRLF]
```

- Start character
- Talker identifier
- GLL sentence identifier
- Comma separator
- Time of fix
- Latitude (dddmm.mm)
- Comma separator
- Latitude indicator 'N' or 'S'
- Comma separator
- Longitude (dddmmss.ss)
- Comma separator
- Longitude indicator 'E' or 'W'
- Comma separator
- GPS status flag
- Comma separator
- Number of satellites in use
- Comma separator
- Horizontal dilution of precision
- Comma separator
- Antenna altitude
- Comma separator
- Units (metres)
- Comma separator
- Geoidal separation distance
- Comma separator
- Units (metres)
- Comma separator
- Age of differential GPS data
- Comma separator
- Differential reference station identity
- Checksum (*optional*)
- Carriage return line-feed characters

C.1.3.3 Doppler 1

The Doppler 1 format supplies velocity measurements to the Sensor through the GPS aiding channel. It is particularly useful where you have installed the Sensor on a submersible vehicle. The aiding data must include the fore-aft and the lateral velocities, and the latitude of the vehicle.

The default communication parameters for this format are 9600 baud, 8 data bits, 2 stop bits and no parity.

Table C–5: Doppler 1 format

```
SXX.XX_SYY.YY_SLL[CRLF]
```

- S: Space or + if positive, minus if negative
- XX.XX: Forward velocity (m/s)
- _: Space character
- S: Space or + if positive, minus if negative
- YY.YY: Starboard velocity (m/s)
- _: Space character
- S: Space or + if positive, minus if negative
- LL: Latitude (degrees), north is positive
- [CRLF]: Carriage return Line-feed characters

All the fields are variable in length. The Sensor decodes the string by searching for the space characters and then converts the numbers in the subsequent data fields. To gain optimal performance from aiding using the Doppler 1 format, the fields should include floating point numbers with a precision of at least one decimal place. If greater precision is available, the Sensor will use it to provide a solution. The Sensor also accepts scientific notation.

The Sensor will reject the packet unless it includes exactly three data fields. It will also reject the packet if there are non-numeric characters in the fields.

The Sensor will not output any string to request the aiding packet and will instead expect Doppler 1 aiding packets to arrive periodically from the Doppler log system. Ideally, the Doppler log should supply data packets at intervals of 100ms. However, if this is not possible, the packets should arrive at intervals no greater than 1 second. The Sensor will change its aiding mode if the Doppler 1 data packet fail to arrive for 10 seconds or longer, following which there will be a three-minute settling period.

To maintain optimal aiding performance, the Doppler 1 packets should include a delay of less than 500ms. The packet delay is the time difference between the instant of data validity to the last character in the string (including the carriage return line-feed characters).

Note that the Sensor and the Doppler log systems have different co-ordinate conventions: The Sensor defines the *x*-axis towards the bow, the *y*-axis to port and the *z*-axis up. The Doppler 1 format has its y-axis to starboard and its *z*-axis down. The Sensor allows for this difference in conventions automatically.

C.1.3.4 Ulvertech DATS

The Ulvertech Doppler Acoustic Tracking System (DATS) uses continuous-wave acoustic transmissions from a dual-axis ‘Janus’ transducer array to measure the speed of the vessel in the fore-aft and port-starboard directions.

When you configure the Sensor to use the Ulvertech DATS format, you must also set the operating latitude of the Sensor manually through the Configure GPS Input screen. Set this value to the nearest degree, with a positive value for northerly latitudes and a negative value for southerly latitudes. The Sensor uses this additional information in its aiding calculations.

Figure C–1: Configure GPS Input to use Ulvertech DATS

```
----------------------------------
DMS 2-05 Version x.x Terminal Mode
----------------------------------
Configure GPS Input

GPS Input Format      : Ulvertech DATS
Enter Latitude [ 0.000 degree] :
GPS Input Source      : Local
Baud Rate             : 9600
Data Bits             : 9
Stop Bits             : 1
Parity                : None
Interface             : RS232
```

Table C–6: Ulvertech DATS format

```
_xxxxx,yyyyy,zzzzz_XXXXX,YYYYY,ZZZZZ_TTT_CCC[LFCR]
```

Field	Description
_	Space character
xxxxx	Fore-aft distance moved *(positive is forward movement)*
,	Comma separator
yyyyy	Port-starboard distance moved *(positive is starboard movement)*
,	Comma separator
zzzzz	Up-down distance moved *(positive is upward movement)*
_	Space character
XXXXX	Fore-aft velocity *(positive is forward movement)*
,	Comma separator
YYYYY	Port-starboard velocity *(positive is starboard movement)*
,	Comma separator
ZZZZZ	Up-down velocity *(positive is upward movement)*
_	Space character
TTT	50ms clock in decimal format
_	Space character
CCC	Decimal checksum
[LFCR]	Line-feed Carriage return characters *(note unconventional sequence)*

Note the following:

- **Distance values**: The values included in the data packet are in decimal format with a resolution of 1mm. The field will include a maximum range of 65.535 metres before it clocks over to zero.
- Velocity values: The values in the data packet use decimal format and include an offset so that:

  A value of 00000 represent –5m/s actual velocity

  A value of 05000 represents zero actual velocity

  A value of 10000 represents +5m/s actual velocity
- The format ends with the line-feed carriage return characters in this unconventional sequence.

C.2 Gyrocompass

After you power-on your gyrocompass, it may take several hours to stabilise and settle. Refer to the gyrocompass manual for specific details.

During the settling period, aiding signals supplied by the gyrocompass to the Sensor may contain errors that can affect the accuracy of heave and attitude measurements. The Sensor does NOT alert you to this potential error source.

The Sensor can accept input from a gyrocompass. Such information to describe the actual vessel heading will further enhance the Sensor performance during prolonged vessel turns. See Section 4 and Appendix A for an explanation of this feature.

C.2.1 Connection

If you decide to use heading aiding, you should arrange to supply RS232 or RS422 serial data using one of the available formats described in sub-section C.2.3.

Refer to sub-section 2.4 and Table 2–1 for instructions to connect the aiding gyrocompass to the Sensor. The same cable allows you to connect an aiding GPS receiver or possibly a Doppler log to the Sensor.

Refer to sub-section 3.2.2.4 for instructions to configure the Sensor for the heading aiding input.

C.2.2 Operation

Use the Sensor menu structure to configure the System correctly for input from a gyrocompass:

- From the ‘Configure I/O’ menu select ‘Configure Gyro Compass Input’.
- Follow the instructions in sub-section 3.2.2.4 to select an appropriate input format.
- Set the RS232 or RS422 parameters to match the requirements of your gyrocompass.
- Return the Sensor to normal operation.

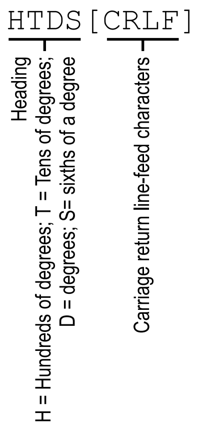
C.2.3 Data format

The Sensor can accept aiding data from a gyrocompass using any of the formats described in the following sub-sections.

C.2.3.1 SG Brown format

The SGB format includes heading information as a six-character ASCII string terminated with the carriage-return line-feed sequence.

Table C–7: SG Brown format

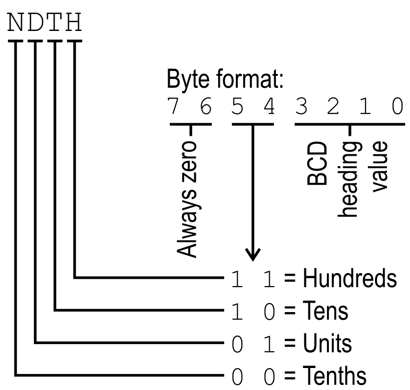


The default RS232 communication parameters set for this format are 4800 baud, 8 data and 2 stop bits with no parity. The transmission interval for the SG Brown 1000S gyrocompass is 100ms.

C.2.3.2 Robertson's format

The Robertson's format includes heading information as a BCD-encoded four-byte ASCII string.

Table C–8: Robertson's format



Within each of the four bytes in the string:

- Bits 7 and 6 are always zero
- Bits 5 and 4 identify the order of magnitude for the included heading information
- Bits 3 to 0 include the heading information

The default RS232 communication parameters set for this format are 9600 baud, 8 data and 2 stop bits with odd parity. The Sensor expects continuous transmissions from the gyrocompass.

IMPORTANT
The SKR-80 and SKR-82 gyrocompasses send data continuously with each string unlatched between bytes. This means for example that, when the 'tens' value is sent it may not refer to the same heading reading as when the 'units' value is sent. It is therefore possible for the gyrocompass to send the following heading values when the heading is increasing steadily:

299.8 299.9 200.0 300.1 ...

The Sensor resolves this potential problem by ignoring heading values that vary by more than 0.5° from the value received previously. Since the SKR-80 and SKR-82 gyrocompasses transmit data at intervals of 5 ms, this means that the maximum allowable turn rate is 100°/s before the Sensor begins to drop excessive packets.

The SG Brown 100S gyrocompass transmits packets at intervals of 20ms and this reduces the maximum allowable turn rate to 25°/s – a value that is still sufficiently high to allow for normal vessel dynamics.

The performance of the Sensor will remain unaffected if it drops a few heading packets.

C.2.3.3 NMEA 0183 format

Among the various NMEA 0183 data formats accepted by the Sensor there are options to include true heading, magnetic heading and speed. The data strings can also include a checksum if you require this facility.

The Sensor accepts three NMEA 0183 transmission formats described in Tables C–9 to C–11 below:

Table C–9: NMEA 0183 HDT sentence format

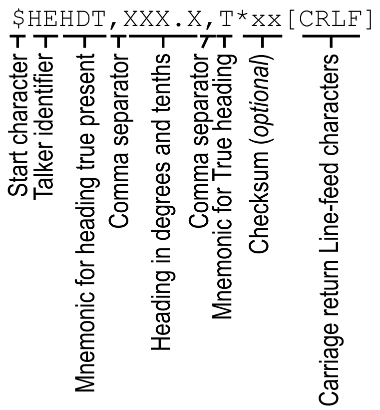


Table C–10: NMEA 0183 HDM sentence format

```
$HEHDM,XXX.X,M*xx[CRLF]
```

- Start character
- Talker identifier
- Mnemonic for heading true present
- Comma separator
- Heading in degrees and tenths
- Comma separator
- Mnemonic for Magnetic heading
- Checksum (*optional*)
- Carriage return Line-feed characters

This format is identical to the NMEA 0183 HDT format but includes heading information supplied by a suitable magnetic compass. Note that some magnetic compasses experience lag when subjected to high rates of vessel turn. If this occurs, heading aiding will not be perfect.

Table C–11: NMEA 0183 VHW sentence format

```
$HEVHW,XXX.X,T,,M,XX.X,N,XX.X,K*xx[CRLF]
```

- Start character
- Talker identifier
- VHW identifier
- Comma separator
- Heading in degrees and tenths
- Comma separator
- Mnemonic for True heading
- Null field between separators
- Mnemonic for Magnetic heading
- Comma separator
- Speed in knots
- Comma separator
- Mnemonic for knots
- Comma separator
- Speed in km/h
- Comma separator
- Mnemonic for km/h
- Checksum (*optional*)
- Carriage return Line-feed characters

The Sensor recognises which of these formats is used and will interpret the data accordingly. The Sensor does not require or use the checksum and will ignore it if present.

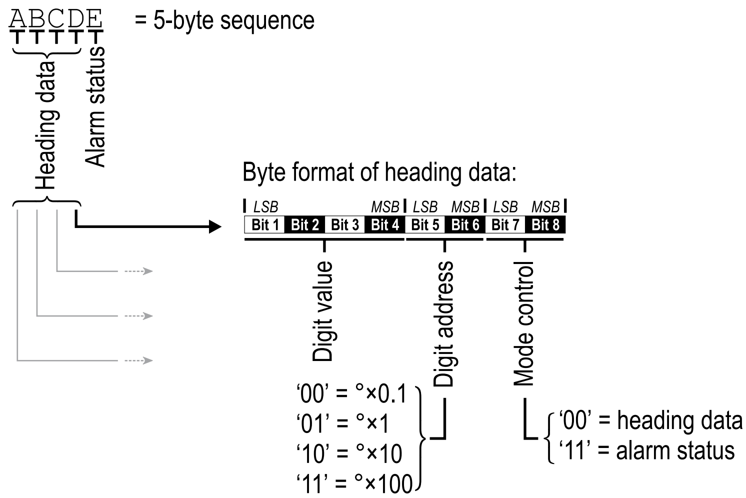
You should never supply the Sensor with both the true *and* the magnetic heading. If you do, the Sensor will attempt to use both and will provide poor aiding performance. Do not connect an aiding source that supplies the NMEA 0183 HDT and HDM strings in a recurring sequence.

Magnetic variation causes a nominal difference between the magnetic and true headings. This does not affect aiding performance.

C.2.3.4 Sperry LR40/60 Format

The LR40/60 format includes heading information as a five-byte binary-coded decimal (BCD) string.

Table C–12: LR40/60 format



Heading information arrives as a binary data string sent at 9600 baud with eight data bits and one stop bit.

- Bytes can occur in any order in the LR40/60 string. The Sensor identifies each byte by its digit address and arranges them in their correct sequence.
- The alarm status terminates the string and signifies that the previous four bytes constitute a valid data string.

C.3 Remote Repeater

The standard Sensor cable is 5-metres long and requires the Sensor to be close to the receiving equipment.

For installations where you will install the Sensor at a distance from the receiving equipment, you must use the TSS Remote Repeater unit. You must also use the repeater if you require analogue outputs from the Sensor installation.

The Remote Repeater is a small, compact unit that uses a high-speed bi-directional digital link to communicate with the Sensor. The repeater provides the same digital input and output features available from the Sensor so that you may install it at any convenient dry location near to the aiding and receiving equipment.

Depending on the quality of the cable that joins the Sensor and the repeater, the two units can be up to 1000 metres apart. To install the Sensor at a distance from the receiving equipment you must provide two junction boxes and a good data-quality umbilical cable that you will use to interconnect the junction boxes. The Sensor does not include these items.

Throughout this description, the following naming conventions apply to the junction boxes:

- Connect the Sensor to the **local junction box**.
- Connect the Remote Repeater to the **repeater junction box**.

C.3.1 Scope of Delivery

Figure C–2: Remote Repeater and cables

The repeater unit includes a cable 15 metres long that connects it to the repeater junction box, and a power cable that is 5-metres long. The power cable has two power cores and a screen. Both cables are hard-wired into the repeater through EMC cable glands and both have open tails for connection to your repeater junction box.

Use the supplied Sensor cable to connect the Sensor to your local junction box. Figure C–2 shows this cable in front of the repeater. This cable has a 16-way moulded plug for mating to the Sensor and open tails for connecting into your local junction box.

There are two methods that you may use to connect a controlling PC to the Sensor:

- By a direct connection from the PC to the Sensor. This method can use either RS232 or RS422. Refer to sub-section 2.4 and Table 2–1 for connection details.

- By connecting the Sensor to the umbilical cable and then connecting your PC to the Remote Repeater. The Sensor uses RS422 communications to communicate with the Remote Repeater. You may set the repeater to communicate with the PC using either RS232 or RS422.

You must supply a suitable umbilical cable to interconnect the local and the repeater junction boxes. Follow the instructions in sub-section C.3.3 to connect the Sensor and the Remote Repeater.

C.3.2 Physical Installation

1. Select a suitable and convenient mounting position for the Remote Repeater according to the following guidelines:

- The mounting position should be within 15 metres of the repeater junction box.

- Allow sufficient clearance around the Remote Repeater to allow easy connection of the D-type and the BNC connectors.

- The Remote Repeater meets IP60 ingress protection rating only. Do not install the repeater where it might become exposed to water.

- During operation, you should not subject the Remote Repeater to temperatures below 0°C or above 55°C. You should also avoid exposing the unit to rapid changes in temperature.

- The mounting surface should be reasonably smooth and of sufficient strength to support the Remote Repeater without flexing.

- Avoid mounting the Remote Repeater where it might experience heavy vibration or be influenced by strong electrical noise sources.

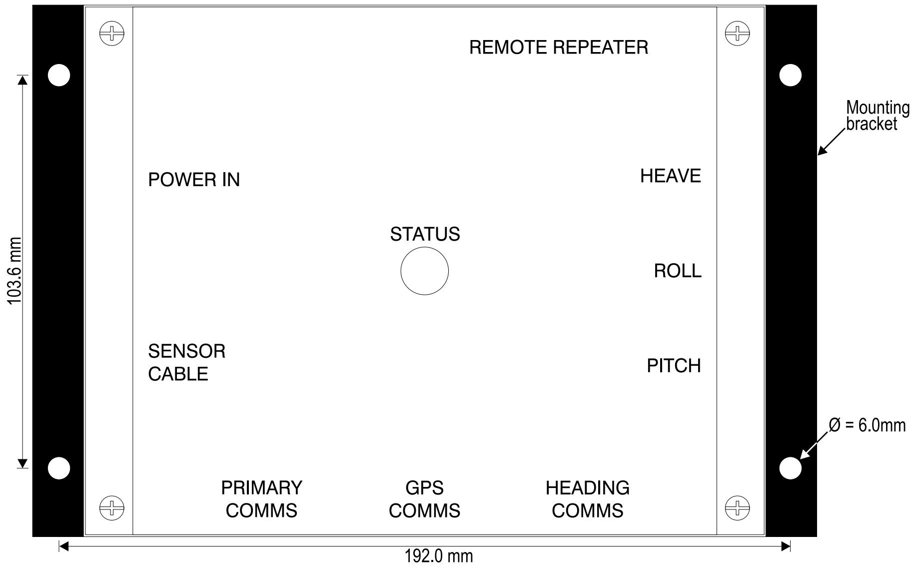
- You may mount the Remote Repeater in any orientation.

2. Refer to the dimensions in Figure C–3 and drill four mounting holes.

3. Use suitable bolts or screws to secure the repeater mounting brackets to the mounting surface. If necessary, fit flat and shake proof washers to prevent vibration loosening the screws. Tighten the screws fully. The System does not include the mounting screws and washers.

4. Route the cables from the Remote Repeater unit to the repeater junction box and to the receiving equipment as appropriate. Avoid exposing the cables to any sharp bends or other mechanical stresses along their length and secure them at intervals using suitable clips.

Figure C–3: Remote Repeater mounting arrangement



C.3.3 Electrical Connection

IMPORTANT
During operation, the Sensor requires approximately 12W power at a nominal voltage of 24V DC. Depending on the length and quality of the umbilical cable, you could supply power for Sensor operation from the Remote Repeater through the umbilical.

For umbilical cables that are longer than approximately 200 metres, the voltage drop along the cable would be too great. In these circumstances, you *must* supply power to the Sensor directly from the local junction box.

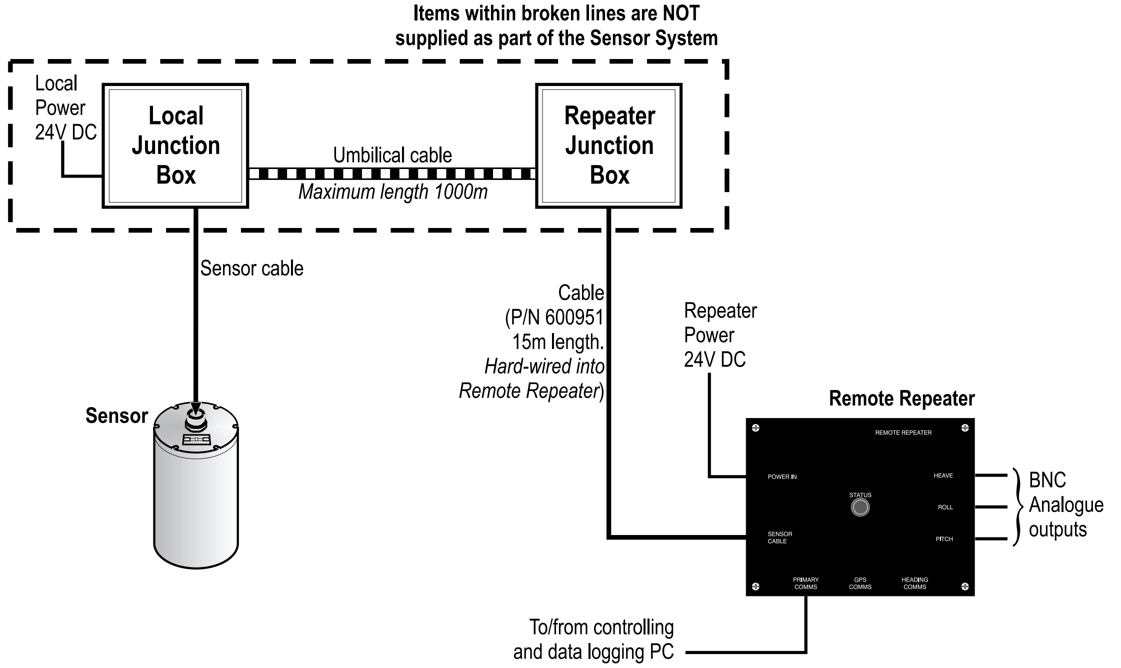
The following instructions assume you will supply power to the Sensor from the local junction box.

It is possible for the Remote Repeater and the receiving equipment to be located together at a distance up to 1000 metres from the Sensor. To maintain reliable operation and to provide all the facilities available from the System, connection between the Sensor and the repeater should be as described below. You should supply and fit junction boxes and an interconnecting umbilical cable of good quality and capable of supporting communication speeds up to 38400 baud.

The umbilical should have the following conductors available:

- Two power conductors (if you wish to supply power for Sensor operation from the Remote Repeater unit)
- Main cable screen
- Eight twisted pairs

Figure C–4: Connection between the Sensor and the Remote Repeater



C.3.3.1 Sensor connection

When you use the Sensor with the Remote Repeater unit, you must make two connections:

1. Remote Repeater link – this is necessary for Sensor operation.

2. Primary Communications – this is necessary to support Primary Communications for Sensor configuration and data logging.

Remote Repeater link from Sensor:

IMPORTANT
Communication between the Sensor and the repeater occurs at a default speed of 38400 baud. The umbilical must include screened twisted pairs of sufficient quality to allow this fast communication rate.

See sub-section3.2.2.2 for instructions to change the repeater configuration and baud rate setting.

The repeater link carries high-speed digital data from the Sensor that the repeater interprets and uses for two functions:

- For the repeater LED to provide the Sensor status indication

- To generate the analogue outputs from its BNC ports

Connection from the Sensor to the local junction box is through the Sensor cable supplied. Figure C–5 on page 18 shows the connection details.

1. Connect the Sensor cable to the Sensor and tighten the locking collar by hand. Run the cable from the Sensor to the local junction box. Avoid applying any sharp bends or exposing the cable to mechanical stresses. Secure the cable at intervals using suitable cable clips.

2. At the local junction box, connect pins 1 and 2 of the Sensor cable respectively to the +24V and 0V DC supply.

3. Connect the cores of the Sensor cable to cores of the umbilical. Make a written record so that you may make the correct connections at the repeater. Figure C–5 identifies the cores of the Sensor cable.

Primary Communications from the Sensor

Section 3 describes how to configure the Sensor after installation. To perform this function you must attach a controlling PC to the Sensor.

When you use the Sensor with a Remote Repeater, there are two alternative methods for configuring and controlling the Sensor.

Either:

1. At the Sensor location, connect a controlling PC directly to the port on the top plate. Refer to Appendix B for instructions to connect your PC to the Sensor. *This is the method of controlling the Sensor described throughout the main part of this Manual.*

   If you control the Sensor locally in this way, you may use either RS232 or RS422 communications.

or:

2. At the Remote Repeater, connect a PC to the 9-pin D-type 'Primary Comms' port. If you use this method, you must set the communications output from the Sensor to RS422 by following the instructions in sub-section 3.2.2.1.

You may set the 'Primary Comms' output from the repeater to either RS232 or RS422 by following the instructions in sub-section C.3.6.1. See Figure C–5 for connection details using the supplied Sensor cable.

To provide 'Primary Comms' through the umbilical:

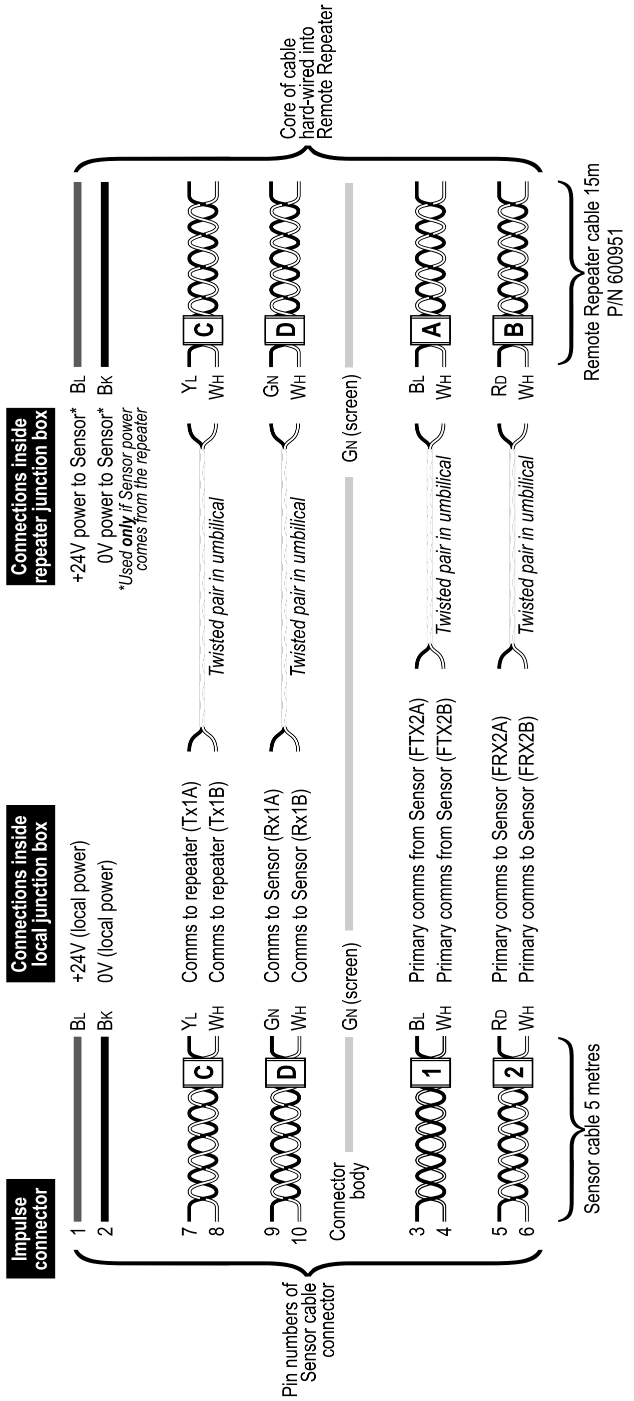
1. Connect the Sensor cable to the Sensor and tighten the locking collar by hand. Run the cable from the Sensor to the local junction box. Avoid applying any sharp bends or exposing the cable to mechanical stresses. Secure the cable at intervals using suitable cable clips.

2. Connect the cores of the Sensor cable to cores of the umbilical. Make a written record so that you may match the connections from the Sensor to the Remote Repeater correctly. Figure C–5 identifies the cores of the Sensor cable for use with RS422 communications.

C.3.3.2 Repeater connection

IMPORTANT
Ensure that you match the cores in the repeater cable to the cores of the Sensor correctly.

Figure C–5: Sensor and Repeater interconnection details



Colour key codes:

BK = Black	BL = Blue	BN = Brown	GN = Green	RD = Red
WH = White	YL = Yellow			

The 14-way repeater cable is hard-wired into the Remote Repeater through an EMC gland. The cable also carries twisted pairs [E] (black/white) and [F] (orange/white) but these are not used. Figure C–5 shows the wiring details that allow a communications connection to a controlling PC at the repeater, and power for Sensor operation supplied at the local junction box.

Connect the repeater link to its junction box:

1. Run the 15m Remote Repeater cable from the repeater to the repeater junction box. Avoid applying any sharp bends or exposing the cable to mechanical stresses. Secure the cable at intervals using suitable cable clips.

2. Connect the cores of the Remote Repeater cable to the correct cores of the umbilical. Refer to the written record that you made when you connected the Sensor to the local junction box. Make certain you match the connections from the Sensor to the repeater correctly. See Figure C–5 for details.

Connect power to the Remote Repeater:

Power for Remote Repeater operation arrives through a 5-metre length of cable hard-wired into the repeater.

1. Run the repeater power cable from the Remote Repeater to the +24V DC power supply. Avoid applying any sharp bends or exposing the cable to mechanical stresses. Secure the cable at intervals using suitable cable clips.

2. Connect the cores of the repeater power cable to the DC supply.

Core identification	Description	Tail colour
+	+24V DC (acceptable range +18 to +36V DC)	Red
–	0V	Black
Screen	System ground	Green

Data cable connection:

Data connection to the repeater is through 9-way D-type ports. Refer to the table below for electrical details of the D-type ports. Refer to the technical manual of your PC to make data connections to the appropriate PC communications port.

Pin number	Description
1	Not connected.
2	RS232 – Receive* data.
3	RS232 – Transmit data.
4	RS422 – Transmit A (TxA) data.
5	RS232 – Signal ground.
6	Not connected.
7	RS422 – RS422 Transmit B (TxB) data.
8	RS422 – Receive A (RxA) data.
9	RS422 – Receive B (RxB) data.

*The convention in this table determines that Receive data passes into the Remote Repeater and Transmit data passes out of the Remote Repeater through the port.

C.3.4 Operation

Sub-section 3.1 describes the Sensor power-on procedure.

The repeater LED indicates the status of the Sensor and confirms the current baud rate setting of the Remote Repeater link – see below.

Power-on procedure:

The Sensor begins to operate when it receives power from a 24V DC electrical supply. This can come directly from the local junction box or, for umbilical cables that are less than approximately 200 metres long, from the Remote Repeater unit.

For installations where the Sensor and the Remote Repeater receive separate power supplies, it does not matter whether you power-on the Sensor or the Remote Repeater first.

Initialisation sequence:

After power-on, the Sensor performs a self-test routine and then starts to operate in a settling condition. It remains in the settling condition for a period of three minutes and then changes to a settled condition.

The repeater LED confirms the status of the Sensor by a sequence of coloured flashes. Refer to Table C–13 for the complete list of valid indications available from the repeater LED.

Table C–13: Status indication by Repeater LED

Colour 1	Colour 2	Sensor status
Red	Off	Power-on self-test running
Green	Off	Normal operation
Orange	Off	You have selected to use input from a GPS or gyrocompass, but it is not functioning.
Green	Orange	All signals are normal but the Sensor is settling. The accuracy of measurements will not be within specified limits.

If you see any unlisted sequence of colours from the repeater Status LED, this indicates a fault condition. If such a condition occurs, power-off the Sensor and wait 30 seconds before you power-on the Sensor again. If the fault condition persists or re-appears, contact TSS (UK) Limited for assistance.

The repeater Status LED also indicates the current communication rate setting for the repeater link. It does this by emitting a number of red flashes after you power-on the repeater:

Table C–14: Indication of repeater communication rate

Number of red flashes	Remote Repeater link baud rate
1	1200
2	2400
3	4800
4	9600
5	19200
6	**38400 (default condition)**
Any other number	Fault condition

A single green flash will follow the final red flash and then the LED will behave according to Table C–13 to show the Sensor status.

If you power-on the repeater before you power-on the Sensor, the repeater LED will show its sequence of red flashes and will then switch off until you power-on the Sensor. You may change the repeater communication rate by following the instructions in sub-section 3.2.2.2.

The 38400 baud default allows the repeater to update all three analogue channels at 500Hz while leaving some additional capacity to control the LED.

Reducing the transmission rate to 19200 baud or lower will reduce the analogue update rates to 250 Hz or lower.

C.3.5 Repeater Specification

C.3.5.1 Electrical

Power requirement	Repeater only	18 to 36 V DC 2W at 24 V

Note: If the Sensor receives its power supply from the repeater then you must allow for this additional power demand.

Digital interface	RS232C, RS422
Digital output data rate:	The same as the Sensor.
Analogue outputs	Available through standard BNC ports from the Remote Repeater only. Scale, linear/sine response, offset and polarity are all configurable.
Analogue range	±10 V
Analogue resolution	12-bit
Analogue minimum load	10 kΩ//1500pF
Analogue output rate:	Dependent upon the rate set for the repeater link. At the default setting of 38400 baud, the analogue outputs will update at 500Hz.

C.3.5.2 Environmental

Temperature range	(operating) (storage)	0 to +40°C {*32°F to 104°F*} –20 to +70°C {*–4°F to 158°F*}
Shock (survival)		30g peak 40ms half-sine
Vibration (operating)		$30mm/s^2$ or 0.2 mm, 7 to 300 Hz
Enclosure protection		Designed to be IP60

C.3.5.3 Physical

Size	228mm × 139mm × 94mm {*8.98 × 5.47 × 3.70 inches*}
Weight	1kg {*2.20 pounds*} excluding cables

C.3.6 Disassembly and Reassembly

There are no user serviceable parts inside the repeater. You do not need to open this unit unless you must change between RS232 and RS422 communications from the 9-way D-type ports.

To disassemble the Remote Repeater unit:

1. Power-off the Sensor and the repeater. It does not matter which part of the installation you power-off first.

2. If necessary, disconnect the D-type and the BNC connectors and remove the repeater from its mounting location.

3. Release the four screws that secure the repeater front panel.

4. Lift off the front panel and reach inside the box to disconnect the repeater LED.

5. Reassemble the repeater by following the above instructions in the reverse order. Check the condition of the EMC gasket that seals the front panel and renew it if necessary.

C.3.6.1 Communication Protocol

You may select either RS232 or RS422 communications through the 9-way D-type repeater ports. These ports are for primary communications between the repeater and a controlling PC; and aiding connections to a GPS receiver and gyrocompass. The aiding ports are not applicable for the type of Sensor described in this Manual.

You cannot change the communication method used between the Sensor and the Remote Repeater.

Selection between RS232 and RS422 communication is by three switches on the Remote Repeater PCB. Figure C–6 shows these switches, SW1 to SW3, in their default RS232 positions.

Figure C–6 also shows the connector details for the repeater power and for the Remote Repeater cables. Note the following:

- Connector TB1 has two 0V and two +24V terminals. The repeater power supply arrives on either of the +24V and the 0V terminals. The additional pair of terminals allows you the option to connect the 24V DC supply to the Sensor if necessary.

- Make connections to the Remote Repeater cable at TB2. Under normal conditions, you will never need to disconnect the cores of this cable from TB2.

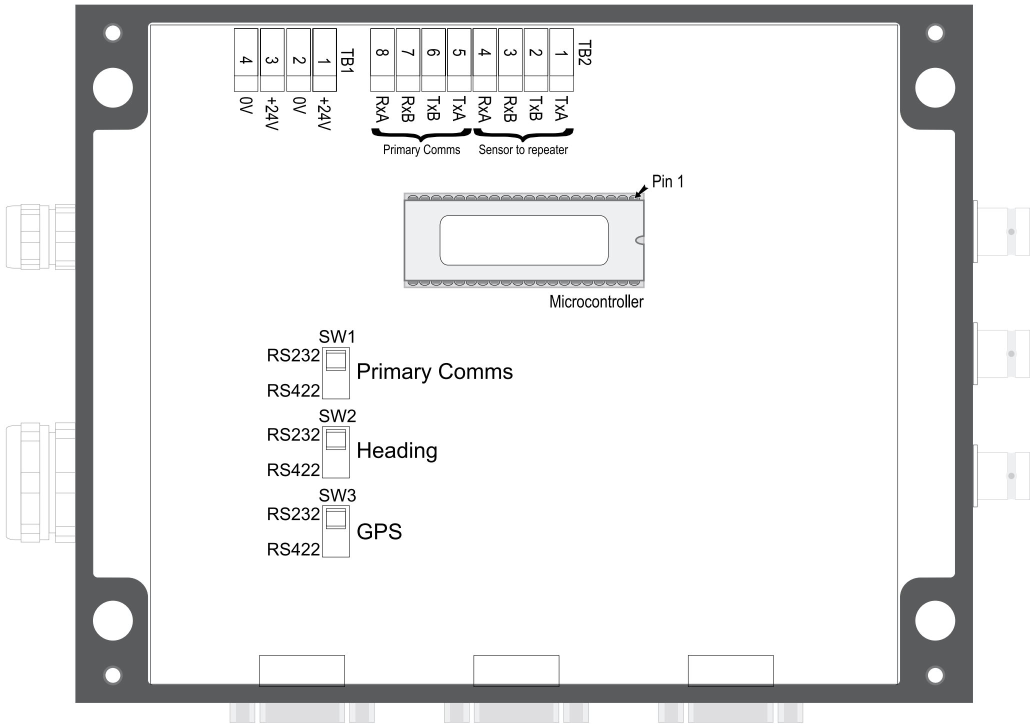
To change a channel communication method:

1. Identify the appropriate switch or switches:

- **SW1** =Primary communications between the repeater and a controlling PC.
- **SW2** =Aiding communications from a compass system.
- **SW3** =Bi-directional aiding communications between the repeater and a GPS receiver.

2. Slide the switch or switches to select either RS232 or RS422 communications.

Figure C–6: Internal layout of the Remote Repeater



C.4 Field Support Kit

The optional Field Support Kit contains the parts listed in Table C–15 that you will need to open the Sensor housing.

CAUTION

You will void the warranty if you open the Sensor housing without prior authorisation from the Customer Service Department at TSS (UK) Limited. Do not open the Sensor for any reason until you have contacted TSS (UK) Limited by telephone. The title page of this Manual lists the contact details for TSS (UK) Limited.

Table C–15: Contents of the Field Support Kit

Item	P/N	Description	Quantity
1	303073	Delrin sealing cap – Black	1
2	304311	M2.5 × 10 socket cap head screws	4
3	304327	M4 × 8 socket cap head screws	4
4	304353	M5 × 16 socket cap head screws	10
5	305112	Nylon spacer 6mm × 6mm	4
6	305116	Nylon spacer 2mm long, 6mm OD, 3.5mm ID	4
7	307521	O-ring 2mm section × 87mm	2
8	307522	O-ring 2mm section × 82mm	4
9	307523	O-ring Nitrile size 2-016	2
10	310305	2.5mm hexagonal key	1
11	310306	4mm hexagonal key	1
12	310307	2mm hexagonal key	1
13	312013	Loctite 242 threadlock	1
14	318163	I/O and power wiring loom	1
15	318165	Accelerometer wiring loom	3
16	318167	Earth lead set	1
17	401129	PSU PCB assembly	1
18	401135	CPU–PSU bridge PCB assembly	1
19	402176	FSK Instruction Note	1

C.5 Training

TSS Motion Sensors are precision ‘front line’ survey tools. To exploit their full potential, all personnel who will install, operate or maintain the System should possess a sound understanding of its theory of operation, its performance and its field of application.

TSS has therefore developed a comprehensive training programme to support this recommendation. For efficiency, the maximum number of participants for each course is limited to four.

The training programme is for all personnel who are involved with TSS Motion Sensors. All participants will receive a comprehensive set of course notes. The course duration is 4 hours and covers the following:

- System overview
- Principles of operation
- Initial installation
- Software overview and interfacing with other equipment
- Operational considerations and limitations
- System Hardware
- System Testing
- System Maintenance
- Fault Finding
- Practical demonstration

To gain full benefit from each part of the course outlined above, participants should have a basic understanding of electronics. On successful completion of the course, participants will have gained an overall appreciation of the operational considerations of TSS Motion Sensors.

D COMMISSIONING TRIALS

The Sensor receives a full test and calibration before shipment and has a one-year product warranty.

This appendix explains how to perform a series of commissioning trials after you have installed and configured the Sensor. These trials confirm the correct operation of the Sensor, and help you to integrate it into your survey system.

To perform the commissioning trials described in this appendix, you will need a PC running the display software supplied with the Sensor. Refer to Appendix B for full instructions to install and use this software.

Connect the serial COM1 port of the PC either:

- Directly to the Sensor by following the instructions in Appendix B *or*,
- To the 'Primary Comms' port of the Remote Repeater if you are using this optional unit.

Refer to Section 3 of this Manual for instructions to use the Sensor menu structure.

IMPORTANT
Perform these commissioning trials only after you have read and understood the Sensor operating instructions throughout this Manual.

D.1 Sensor Alignment **Page 2**

You must align the Sensor before you can use its attitude measurements effectively.

D.2 Functional Tests **Page 2**

Measure and store the mounting angles of the Sensor. Make certain the Sensor remains unaffected by other items of equipment on board the vessel.

D.3 System Integration **Page 5**

Use the digital and analogue test features to confirm correct operation with your application.

D.4 Sea Trials **Page 6**

Performance checks on the Sensor will confirm proper operation during surveys and throughout turns.

D.1 Sensor Alignment

It is important to align the Sensor closely with the vessel or application that requires motion measurements. If you do not do so, then there will be some level of breakthrough where rolling movements will appear in the pitch output channel and *vice versa*. Errors of this type will increase in magnitude with larger angles of Sensor misalignment.

To deliver attitude measurements accurate to ±0.05° with 10° of roll and pitch applied simultaneously, you will need to align the Sensor and the vessel or application to within 0.3°.

To achieve this degree of alignment accuracy you can use any combination of the following:

- Align the Sensor to the longitudinal line of the vessel using a known reference line, such as a surveyed bulkhead.
- Use the services of a Marine Surveyor to align the Sensor.
- If the facility exists, connect the Sensor temporarily to a multibeam sounder and perform a patch test.

You can remove any misalignment either by making minuscule adjustments to the Sensor (by slackening the securing bolts temporarily) or by using the software of the receiving equipment to apply compensation.

The roll axis of the vessel will change with varying loading conditions. You should therefore be aware that the Sensor alignment might also change.

D.2 Functional Tests

D.2.1 Pre-trial Inspection

1. Visually inspect the Sensor for signs of physical damage.

2. Check that the Shockwatch label on top of the Sensor shows white. If any part of the central vial shows red, this indicates that the Sensor has experienced a shock that may have damaged one or more of the sensing elements. Refer to sub-section 6.1.2 for a simple procedure to test the sensing elements. Contact TSS (UK) Limited for advice if the Shockwatch label on your Sensor shows red.

3. Confirm that you have installed and connected the Sensor correctly according to the instructions in Section 2.

4. Connect your controlling PC to the Sensor and run the display software supplied with the System. *Refer to Appendix B for instructions to use this software.*

5. Power-on the Sensor and use the software terminal mode to monitor the initialisation sequence. Depending on which data format the Sensor uses you should see scrolling columns of data. If you have the Remote Repeater option fitted, monitor the correct operation of its Status LED.

D.2.2 Functional Check

For these checks, you should have the vessel secured alongside in a sheltered berth. The trim of the vessel should be as close as possible to that used during surveys – there should be no list or roll present. If possible the propulsion and other major mechanical equipment should not be operating.

The tests described below are to confirm correct Sensor operation. Due to the extreme difficulty in providing by hand the physical motion required without introducing unwanted acceleration transients, do not use this procedure as a means of calibration.

1. With the System powered-off, carefully mark the exact mounting position of the Sensor and release it from the deck. Place the Sensor on the deck, connect all cables and restore power.

2. Start the graphical display software on the PC and set it to show heave, roll, pitch, and horizontal acceleration. Wait until all the traces settle to essentially straight lines close to the axes.

3. *Skip this step if you wish to retain the previous Sensor Configuration.*
   For new installations in particular, you should set the Sensor default configuration by following the instructions in sub-section 3.2.4.

4. Wait for three minutes until the graphic display shows that the Sensor has settled. *GENTLY* lift the Sensor by hand through approximately one metre, and then lower it back to the deck. Check the sign and magnitude of the displayed heave. Note that the acceleration transients introduced when you move the Sensor by hand may introduce errors.

5. Gently incline the top of the Sensor approximately 15° astern (+15° pitch). Increase to approximately 30° and then return to zero. Check that at each stage the displayed pitch shows the correct sign and amplitude. Attitude measurements are much less susceptible to acceleration transients than heave measurements.

Repeat the attitude test, tilting the Sensor to bow, to starboard, and finally to port, again checking both sign and amplitude:

6. Top inclined towards the bow (negative pitch).

7. Top inclined towards starboard (positive roll).

8. Top inclined towards port (negative roll).

9. Re-install the Sensor at its correct mounting position and restore its correct alignment.

D.2.3 Mount Angle Measurement.

Before you begin to use the Sensor for the first time, you must measure and save its static mounting angles. To make certain you have measured these angles accurately, you should run the procedure for fifteen minutes.

For the purposes of these trials, you can run a shortened measurement procedure lasting five minutes. Remember to run the full fifteen-minute measurement procedure and save the mounting angles *before* you use the Sensor in your application.

Refer to sub-section 3.2.1.1 for a complete description of the screen that you will use to measure the static mounting angles.

1. Follow the instructions in sub-section 3.2.1.1 to measure the static mounting angles. Set the measurement time to five minutes on this occasion.

2. The on-screen display of remaining time will decrement by intervals of one minute as the test progresses. The screen shows the measured static mounting angles when the countdown ends. Press [Y] to accept and save them. Set the software to show the graphics screen and data charts.

3. Depending upon the actual motion of the vessel, the three traces for heave, roll and pitch should now be close to zero.

D.2.4 Mutual Interference Check

With the Sensor properly installed and the mount angles measured as described above, perform the following check. This is to confirm that the Sensor experiences or causes no mutual interference with other equipment on the vessel. Ideally, the propulsion plant, air conditioning, electrical distribution and survey equipment on board the vessel should all be running for this test, although the vessel should not be moving.

1. Follow the instructions in sub-section 3.2.1.2 to set the heave bandwidth to ‘Short’. Select the graphical display of Sensor measurements. Observe the horizontally scrolling charts for five minutes and check that all the lines remain within 10cm or 1° of zero.

   This test assumes that the vessel is essentially at rest – you must make due allowance if sea conditions are rough.

2. Repeat the above test using the ‘Medium’, ‘Long’ and ‘Extended’ wave periods.

3. Return the Sensor to the heave bandwidth setting that you expect to use during the survey. If you do not know the proper setting, select ‘Medium’ wave period. Sub-section 3.2.1.2 includes some useful advice to help you determine the correct setting for heave bandwidth for your particular vessel and weather conditions.

D.3 System Integration

The Sensor provides digital and analogue test features that you can use to help integrate the System with your application.

Test Digital Outputs

1. Refer to sub-section 3.2.2.5 for a description of the Test Digital Outputs screen.
2. Set values for the measured parameters appropriate to the selected digital output format.
3. Make certain that your application receives and interprets the values from the Sensor correctly. Make any software adjustments necessary to correct any errors.
4. Change the values transmitted by the Sensor and make certain your application interprets these correctly also.
5. Restore the Sensor to its normal operating condition.

Test Analogue Outputs

This test applies only if your System includes the optional Remote Repeater.

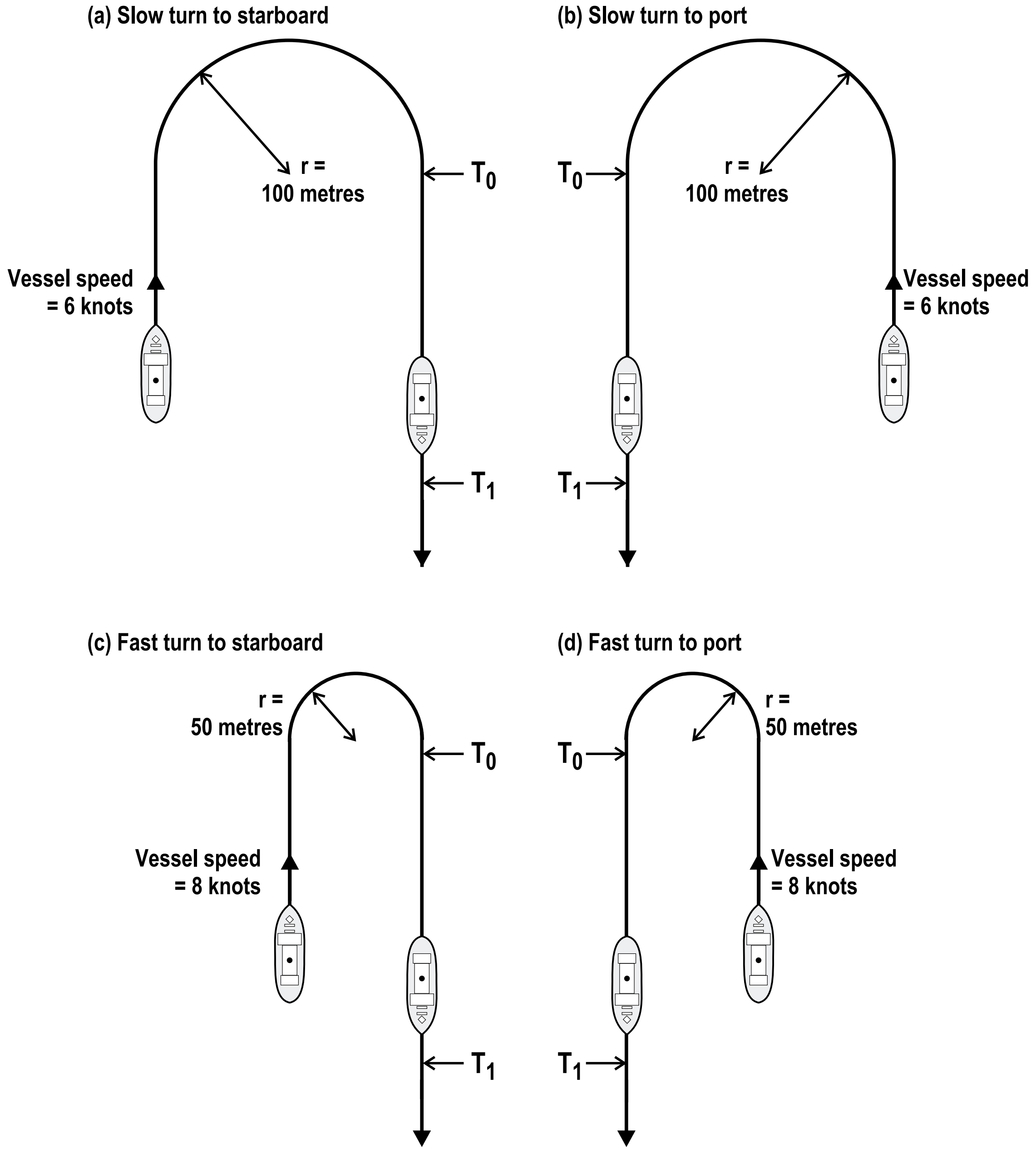
6. Refer to sub-section 3.2.2.6 for a description of the Test Repeater Analogue Outputs screen.
7. Set values for the measured analogue parameters.
8. Make certain that your application receives and interprets the values from the Sensor correctly. Make any software adjustments necessary to correct any errors of magnitude, sense or offset.
9. Change the values transmitted by the Sensor and make certain your application interprets these correctly also.
10. Restore the Sensor to its normal operating condition.

D.4 Sea Trials

In quiet sea conditions up to sea state 3, it is straightforward to evaluate the performance of the Sensor as the vessel undergoes various turns while maintaining a steady speed.

The trials described below evaluate the performance of the Sensor during vessel turns.

Figure D–1: Fair weather sea trials – Settling time after turns



1. Follow the instructions in sub-section 3.2.1.2 to set the heave bandwidth to ‘Medium’. Select the graphical display of Sensor measurements. Observe the horizontally scrolling charts for five minutes and check that all the lines remain within 10cm or 1° of zero.

2. Achieve a vessel speed of 6 knots, preferably running either into or with the sea, on a steady course.

3. Using a turn radius of 100 metres perform a slow 180° starboard-turn to a reciprocal heading – see Figure D–1(a). During the turn check that the measured heave remains within ±50cm.the following limits:

- Aided Sensor ±10cm.
- Unaided Sensor ±50cm.

4. Complete the 180° turn and steady the vessel on the reciprocal course. Measure the time taken from reaching the new course [T_0 in Figure D–1(a)] to the time that all traces have resumed a steady state [T_1 in Figure D–1(a)]. This should be 60 seconds or less.

5. Using a turn radius of 100 metres perform a slow 180° port-turn to a reciprocal heading – see Figure D–1(b). During the turn check that the measured heave remains within ±50cm.the following limits:

- Aided Sensor ±10cm.
- Unaided Sensor ±50cm.

6. Complete the 180° turn and steady the vessel on the reciprocal course. Measure the time taken from reaching the new course [T_0 in Figure D–1(b)] to the time that all traces have resumed a steady state [T_1 in Figure D–1(b)]. This should be 60 seconds or less.

7. Achieve a vessel speed of 8 knots, preferably running either into or down-sea, on a steady course.

8. Using a turn radius of 50 metres perform a fast 180° starboard-turn to a reciprocal heading – see Figure D–1(c). During the turn check that the measured heave remains within ±100cm.the following limits:

- Aided Sensor ±10cm.
- Unaided Sensor ±100cm.

9. Complete the 180° turn and steady the vessel on the reciprocal course. Measure the time taken from reaching the new course [T_0 in Figure D–1(c)] to the time that all traces have resumed a steady state [T_1 in Figure D–1(c)]. This should be 90 seconds or less.

10. Using a turn radius of 50 metres perform a fast 180° port-turn to a reciprocal heading – see Figure D–1(d). During the turn check that the measured heave remains within ±100cm.the following limits:

- Aided Sensor ±10cm.
- Unaided Sensor ±100cm.

11. Complete the 180° turn and steady the vessel on the reciprocal course. Measure the time taken from reaching the new course [T_0 in Figure D–1(d)] to the time that all traces have resumed a steady state [T_1 in Figure D–1(d)]. This should be 90 seconds or less.

IMPORTANT
At each stage, ensure the vessel is steady on the new course for three minutes before commencing the next turn.

