Super SeaKing 700 V7 Bathymetric Sensor
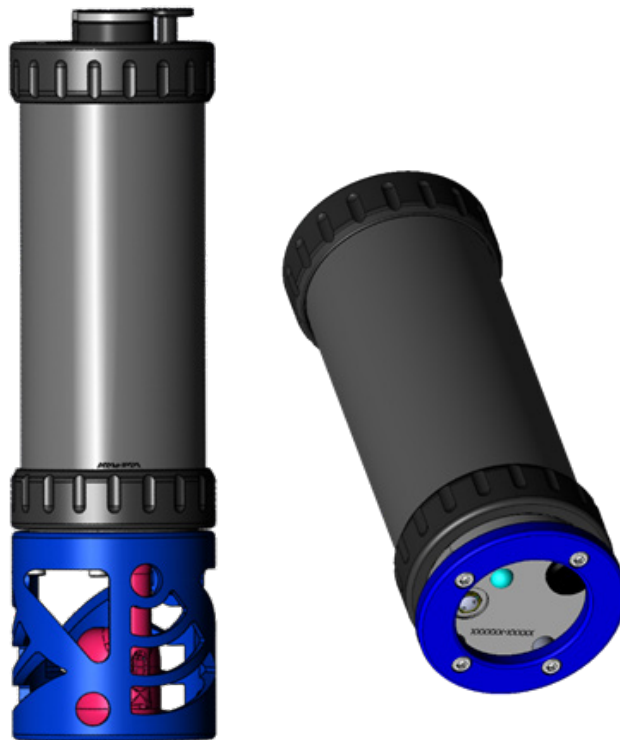
Product Manual

Tritech

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First please read this manual thoroughly (particularly the Troubleshooting section, if present). If a warranty is applicable, further details can be found in the Warranty Statement, 0080-STF-00139, available upon request.

Tritech International Ltd can be contacted as follows:

Address	Tritech International Ltd Peregrine Road Westhill Business Park Westhill, Aberdeenshire AB32 6JL, UK
Telephone	+44(0)1224 744 111
Email	support@tritech.co.uk
Website	www.tritech.co.uk

Prior to contacting Tritech International Ltd please ensure that the following information is available:

1. The Serial Number of the product and any Tritech International Ltd equipment connected directly or indirectly to it

2. Software or firmware revision numbers

3. A clear fault description

4. Details of any remedial action implemented

⚠ Contamination

If the product has been used in a contaminated or hazardous environment you must de-contaminate the product and report any hazards prior to returning the unit for repair. Under no circumstances should a product be returned that is contaminated with radioactive material.

The name of the organisation which purchased the system is held on record at Tritech International Ltd and information of new software or hardware packages will be announced at regular intervals. This manual may not detail every aspect of operation and for the latest revision of the manual please refer to **www.tritech.co.uk**

Tritech International Ltd can only undertake to provide software support of systems loaded with the software in accordance with the instructions given in this manual. It is the customer's responsibility to ensure the compatibility of any other package they choose to use.

Warning Symbols

Throughout this manual the following symbols may be used where applicable to denote any particular hazards or areas which should be given special attention:

Note

This symbol highlights anything which would be of particular interest to the reader or provides extra information outside of the current topic.

Important

When this is shown there is potential to cause harm to the device due to static discharge. The components should not be handled without appropriate protection to prevent such a discharge occurring.

Caution

This highlights areas where extra care is needed to ensure that certain delicate components are not damaged.

Warning

DANGER OF INJURY TO SELF OR OTHERS. Where this symbol is present there is a serious risk of injury or loss of life. Care should be taken to follow the instructions correctly.

Table of Contents

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1.1   Overview

The Super Seaking V7 series is built on a new platform, introducing an improved front end design, Ethernet connectivity and software power isolation for AUX port output.

We have incorporated state of the art sensors to gather precision Sound Velocity and Density profiles for accurate depth and height data. Pairing a V7 Seaking 700 with an altimeter and sonar from Tritech's Seaking or Gemini range gives a fully integrated oceanographic system which can be controlled from a single user interface and easily integrated into any existing survey suit.

The V7 is a direct replacement for a V3 Bathy with the exception of customers requiring Ethernet capability. This will require either a proprietary Tritech 'V7 Connector' or a compatible connector and cable harness. Arcnet and Serial comms protocols are still supported on the non Ethernet units.

Depth Accuracy	*Temperature Accuracy*	*Conductivity Accuracy*
0.015%	±0.005°C	±0.3mS/m
		of full scale depth

Features

- State-of-the-art sensor integration.

- New generation of algorithms.

- Software switchable Ethernet, ARCNET and Serial Comms Protocols.

- Free running & interrogate modes.

- Simple integration to survey suites.

- Improved power efficiency.

Applications

- ROV

- OCEANOGRAPHIC OPERATIONS

- METROLOGY

Benefits

- Higher accuracy real-time output for:

    - Depth
    - Temperature
    - Conductivity
    - Density
    - Sound Velocity and
    - Altitude
- Ease-of-use and integration.

- Robust performance for high-speed   data acquisition.

Related Products

PA500/6 Altimeter

Super Seaking V7 Sonar

Seaking Side Scan

Gemini Multibeam Sonars

1.2   Technical Specifications

Super Seaking 701

303

Super Seaking 704

ø110

ø99

261

278

392

160

72

41

ø43

ø47
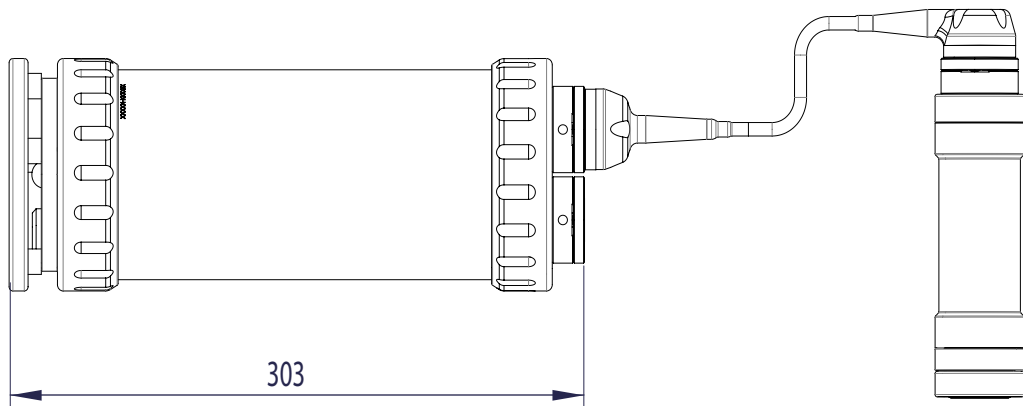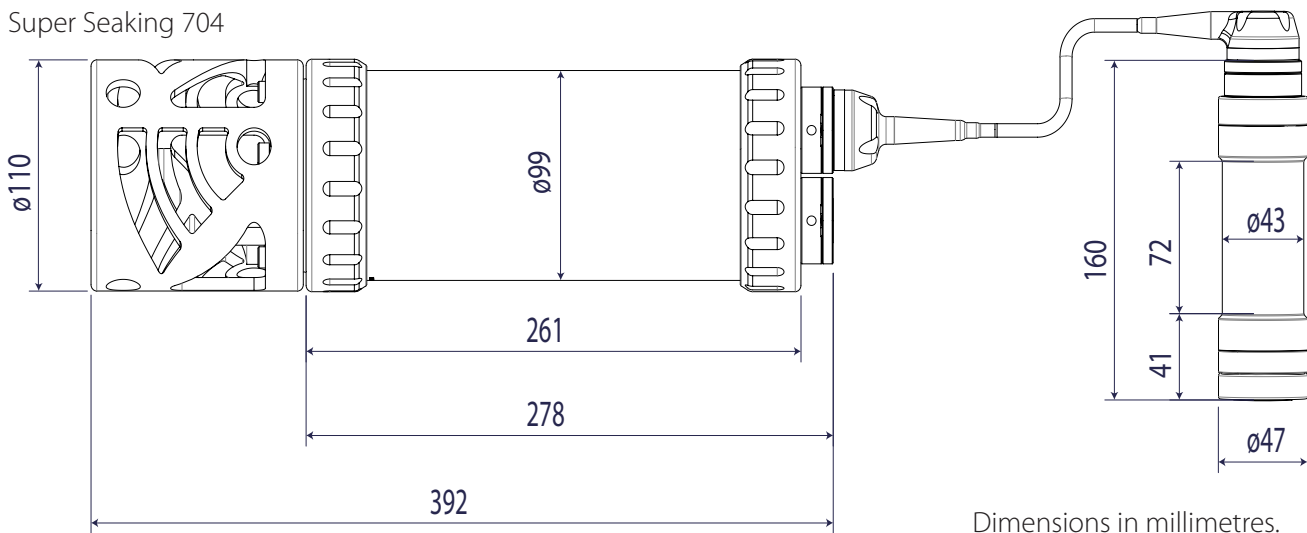
Dimensions in millimetres.

System Physicals	Super Seaking 701 Series	SSK704 Series
Weight in air (kg)	3.74	4.19
Weight in Water (kg)	1.44	1.69
Housing Material	Anodised Aluminium Alloy	
Depth Ratings	700m, 1400m, 2000m, 4000m	

Electrical and Communication

Power Requirement	Main		20-70VDC @ 8w
	Aux		Voltage set to 24VDC
Communications	SXXXXX nn ETH	Main	Ethernet & Serial RS232/RS485
		Aux	Serial RS232/RS485
	SXXXXX nn ARC	Main	ARCNET & Serial RS232/RS485
		Aux	

Depth Sensor

Repeatability	0.01% FSD (Full Scale Depth)
Hysteresis	0.015% FSD
Drift	0.015% FSD

Temperature Sensor

	Survey Grade	Scientific Grade
Range	-5˚C to 35˚C	-5˚C to 35˚C
Accuracy	±0.01˚C	±0.005˚C
Drift	±0.002˚C per year	±0.005˚C per year

Conductivity Sensor

	Survey Grade	Scientific Grade
Range	0 to 8.5 S/m	0 to 8.5 S/m
Accuracy	±1.0mS/m	±0.3mS/m
Drift	±0.1mS/m per month	±0.1mS/m per month

Software Requirements	Version	Build
SeaNet Pro	2.25	588
Genesis (*Limited Functionality)	1.7.0	

Altimeter Specifications

Type	PA500
Weight in air	1150g
Weight in Water	800g
Frequency	500kHz
Beam width	6˚ conical
Range	0.3m to 50m
Resolution	1mm
Material	Stainless Steel (Titanium 6AI4V optional)

2. Installations

2.1   Hardware Installation

Mount the Seaking 700 using 3mm insulating rubber, and jubilee clamps to firmly secure to the vehicle.

For accurate pressure measurement, the Seaking 700 Bathymetric sensor can be orientated in a port up or port down configuration with calibrated offsets provided by the factory.

It's recommended, during installation, that the bathy and altimeter be positioned so they receive good water flow while avoiding prop-wash from thrusters.

It's advisable that the conductivity sensor head should have a free radius of at least 10cm. Objects within this must be electrically stable (either a fixed dielectric or conductor) and have a fixed position relative to the sensor. Locate the sensor head away from items such as motors, sense coils and cameras to ensure accurate readings.

Ensure the Seaking 700 is protected from the possibility of impact damage.

During Installation, be sure to safeguard against damage to the protective anodised coating on the main housing. Any chips or scratches may lead to corrosion of the housing which may impact the performance of the system.

Mate connectors/blanks ensuring the washers are in places and have been greased and the securing screws have been tightened.

> **DO NOT OVER-TIGHTEN RETENTION SCREWS.**
>
> If using a Seacon connector, you are reminded that the retention ring should be finger tight. Applying too much pressure risks damaging the connector.

Check that the cables and connectors are not subjected to excessive strain and are not kinked or bent excessively. The safe bend radius of the V7 cables is 100mm.

> **Caution**
>
> Non-metallic clamps are preferred when securing the Bathy, however, if metallic clamps are to be used they must be electrically insulated to protect the housing.
>
> **Avoid any clamping material that may contain brass or bronze.**

XXXXXX-XXXXX
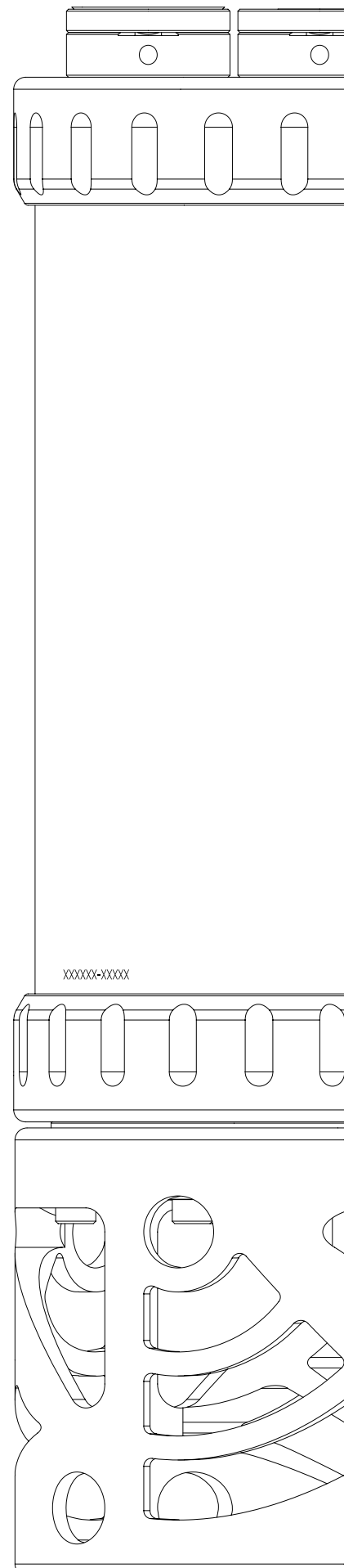
The SeaKing 700 Series units are designed to work from a smoothed DC power supply.

If using a rectified transformer PSU, the output of the PSU must have a filter capacitor of not less than 470μF, for each unit being powered.

If an unregulated PSU is used, the voltage value measured during power on/off and running conditions at the unit should be within the voltage range specified for the system.

If powering the unit(s) down a long lead or umbilical, the maximum recommended resistance of the power line must not exceed 10Ω for one unit, 5Ω for two units and 3Ω for three units.

2.3   Electrical Connections

The SeaKing 700 is typically supplied with a 1meter polyurethane jacketed cable whip, fitted with a Tritech connector. Depending on the specification of the system, the cable will either need to be terminated to a suitable connector or may be supplied already terminated.

The standard Tritech connector may be disconnected from the unit by unscrewing the four retaining screws and removing the connector from the water block that is fitted to the end-cap. Do not remove the water block.

While the cable is removed the exposed connectors should be fitted with appropriate blanking caps to prevent the ingress of dirt or moisture.

For devices fitted with non-Tritech connectors this procedure will vary. For information on Tritech Standard wiring, connectors and pin-outs please refer to the relevant sections of this manual.
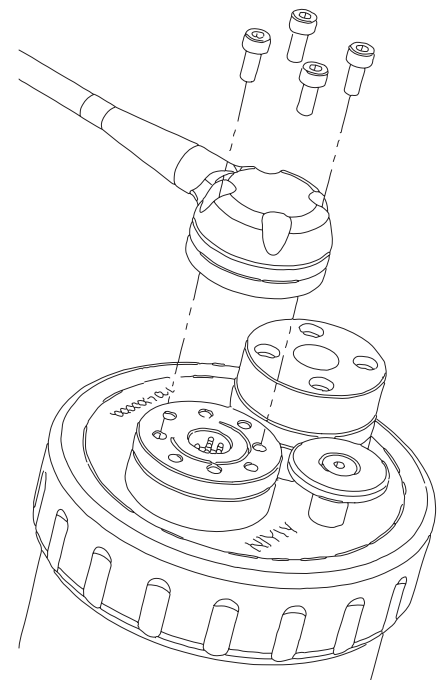
2.4   Connecting an Altimeter

The Bathy is designed to directly interface with a Tritech PA500/06 altimeter. Connection is made to the Bathy Aux Port using a standard Tritech double ended S01226 (R/A to Str) interconnect cable.
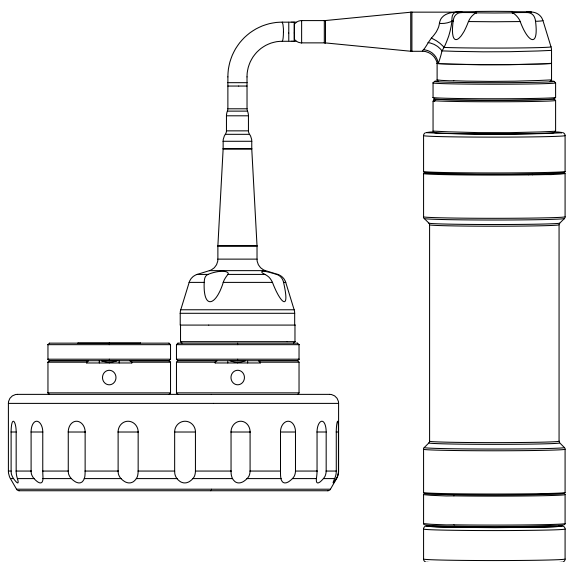
2.5   Communications Configurations

The V7 is a direct replacement for a V3 Bathy with the exception of customers requiring Ethernet capability. This will require either a proprietary Tritech 'V7 connector' or a compatible connector and cable harness. Arcnet and Serial comms protocols are supported..

Seaking 700 Bathymetric sensors are supplied as Ethernet with Serial RS232/485 or as ARCNET with Serial RS232/485 communication protocols. There is no ARCNET and Ethernet option.

See section on software setup for guidance on configuring your network.
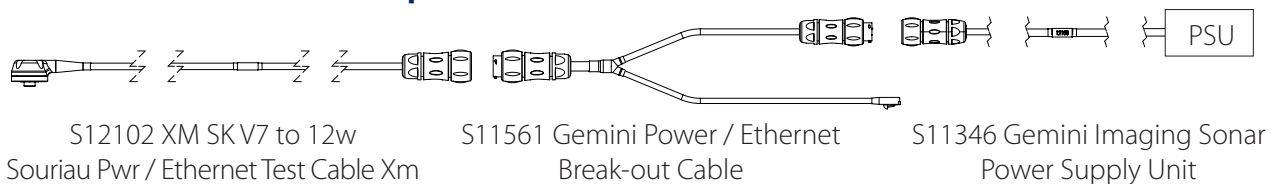
Ethernet & Serial (RS232/RS485)

When connecting via Ethernet, the Bathy can communicate at 100Mbps while returning environmental data.

If the Bathy shares it's Ethernet link with other high bandwidth devices, such as video cameras, it is recommended that a gigabit (or faster) network interface be used to the surface to reduce possible network congestion.

Basic Ethernet Cable Setup

| S12102 XM SK V7 to 12w Souriau Pwr / Ethernet Test Cable Xm | S11561 Gemini Power / Ethernet Break-out Cable | S11346 Gemini Imaging Sonar Power Supply Unit |

ARCNET & Serial (RS232/RS485)

The SeaKing 700 series can be set to form part of an ARCNET multidrop network of sensors that are normally interfaced to a Surface Control Unit (SCU) through an internal DA-15 ARCNET interface (AIF) port or through the DA-15 AIF port on a SeaHub.

Normal communication with the Bathy head is via a customised version of the ARCNET network system and requires a good quality balanced twisted pair. There is also the option to run a single head from an RS232/RS485 connection.

> **Note**
> The ARCNET system requires termination resistors to be fitted at each end of the umbilical. Please refer to Appendix A, ARCNET Termination for more details of the termination requirements.

2.6   Ground fault Monitoring

The power supply within SeaKing subsea devices contain an electrically isolated DC-DC converter. There is a small capacitive connection to the Bathymetric Sensor chassis which should not noticeably affect any impressed current ground fault indicator (GFI) equipment.

The below wiring diagrams refer to the standard Tritech connector, other connector options are available upon request. Please contact our sales team for full details.

> **WARNING**
> Application of reverse supply voltage to the unit or supply voltage across any of the communication connections may lead to equipment damage not covered under the warranty conditions.

> **Note**
> Ethernet communications require the use of V7 cables. Other communications modes are compatible with both V7 and Standard Tritech cables.

Ethernet Wiring.
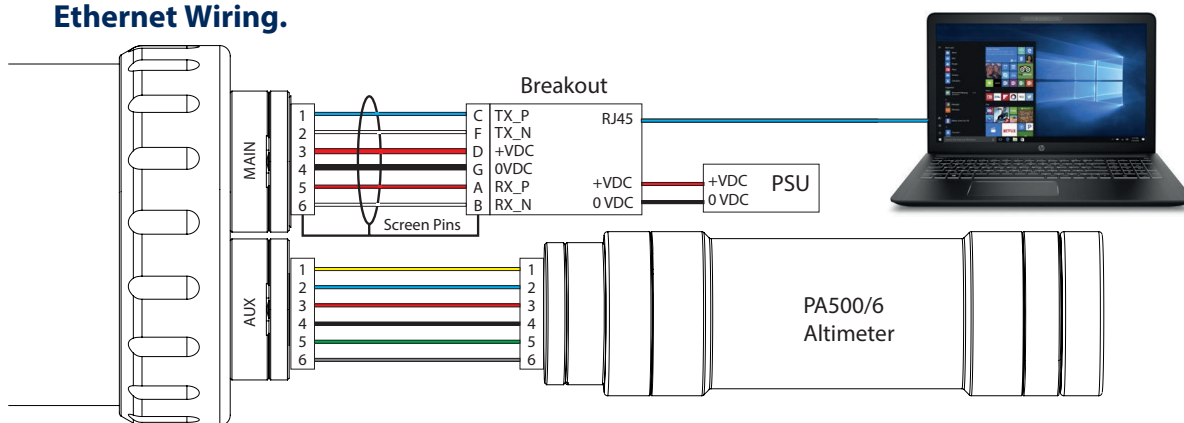
ARCNET Wiring.

Serial RS232/485 wiring.
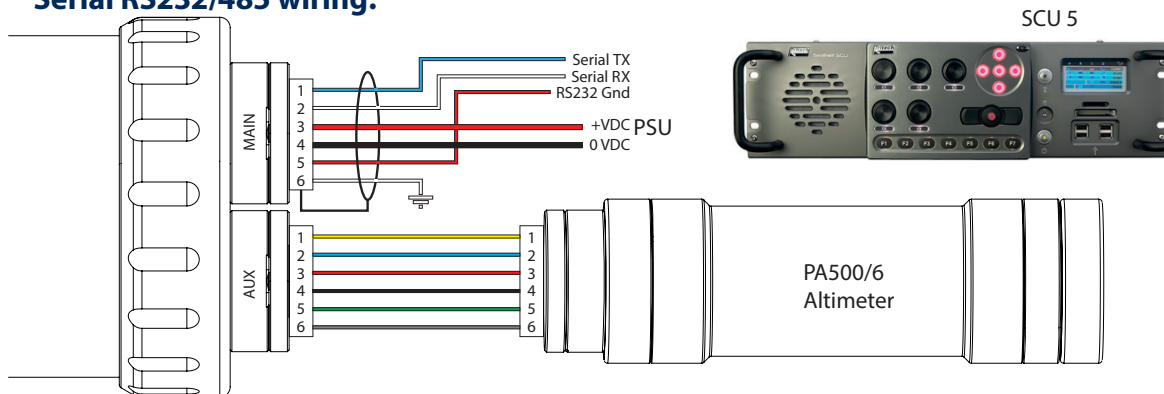
2.8 Wiring Pin-outs

V7 Cable Pin-Out

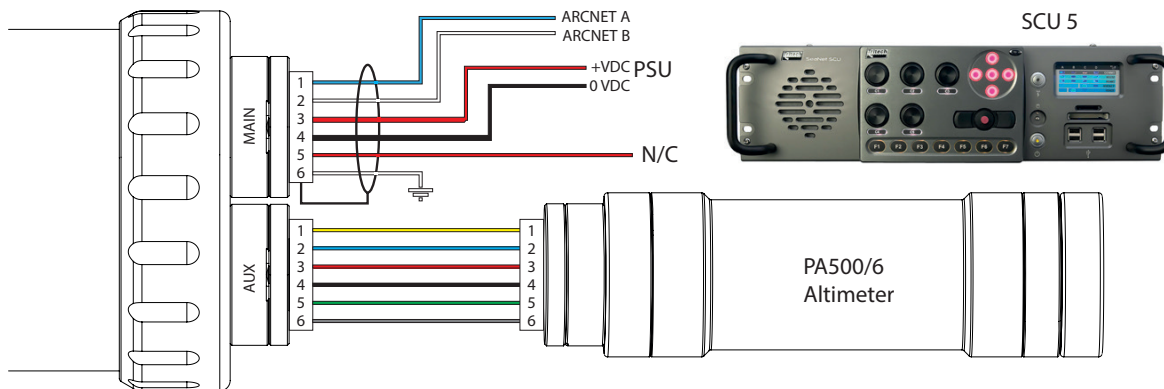| Contact	Pin-Out				Cable		
	ARCNET	RS232	RS485	V7 Conn. Ethernet	Conductor Colour V6	Conductor Colour V7	Conductor ID
1	A	TX	A	TX_P	Yellow	Blue	UTP #1: $0.22mm^2$ / ~24 AWG
2	B	RX	B	TX_N	Blue	White	UTP #1: $0.22mm^2$ / ~24 AWG
3	+VDC				Red	Red	$0.5mm^2$ / ~20 AWG
4	-VDC				Black	Black	$0.5mm^2$ / ~20 AWG
5	N/C	RS232 GND	N/C	RX_P	Green	Red	UTP #1: $0.22mm^2$ / ~24 AWG
6	Earth			RX_N	Screen	White	UTP #1: $0.22mm^2$ / ~24 AWG
Chassis Earth Connection					Screen / Drain Wire	Foil Screen with Drain wire $0.022mm^2$	

2.9 Tritech V7 Connector

The V7 cable connector has the addition of the screen pin in the outer ring of the connector. This makes contact with the chassis ground of the system which is required when using Ethernet Comms.

When using ARCNET and Serial Communications systems, standard cables are compatible.

Cable Connector Pin View
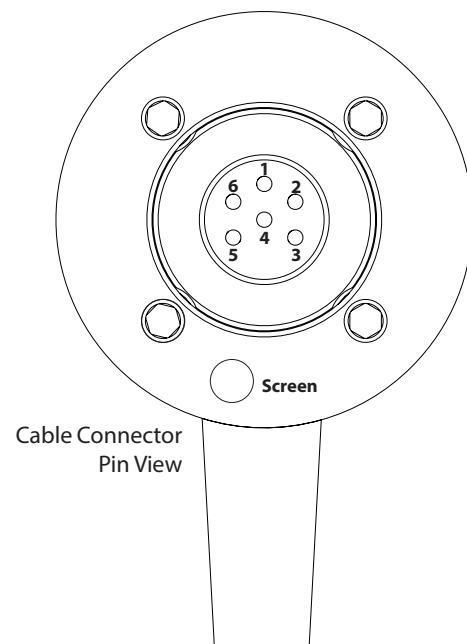
3. SeaNet Pro

SeaNet Pro is Tritech's proprietary software which enables control and communication to our full range of products. SeaNet Pro is capable of displaying and outputting multiple sensors simultaneously. This means Sonar, Bathy and PA Altimeter data can all be displayed on the same screen.

3.1 Software Overview

SeaNet Pro is Tritech's survey data acquisition and logging software package. Seanet Pro can simultaneously run and display several combinations of Imaging Sonar, Profiling Sonar, USBL Positioning, Bathymetric and Sidescan sensors. Seanet Setup is used to display status of all connected nodes and to download new software and firmware upgrades into the subsea devices.

3.2 System Requirements

In order to install and run SeaNet Pro to its full potential, the operating system should meet the following system requirements:

	Minimum	Recommended
Processor	2GHz	2GHz dual core
RAM	1GB	2GB
Graphics	3D hardware accelerated graphics card	
OpenGL	Version 2.0 or greater	
Display	1280x1024 (32bit colour)	1600x1200 (32bit colour)
Disk space		
Serial	Hardware based, or USB converters for RS232 or RS485 communications	
Networking	100MB/s (fast Ethernet)	1000MB/s (Gigabit Ethernet)

3.3 SeaNet Pro Software Installation.

Tritech Software is provided with each purchase of our equipment either on CD-ROM or a USB memory stick.

Updates and latest versions of software can also be downloaded from the Tritech website www.tritech.co.uk

Once installed, you can launch the application from the desktop icon or from the Start menu in windows.

> **Updates**
>
> Download the latest software versions from www.tritech.co.uk
>
> Tritech International Ltd continually develop our software so it is recommended to check the website for updates regularly.

3.4   Windows Setup

Ethernet Protocol Settings

The Ethernet adapter needs to be setup on the host PC to be in the same IP address range as the sensor being attached. Using network comms allows multiple sensors to be integrated using standard networking equipment.

A minimum 100BASE–TX link is recommended. The Ethernet enabled Tritech Systems Require 100Mbps in order to function correctly and may not work on lower 10BASE–T lines. It's not recommended to connect Tritech units through a network hub, a network switch is recommended to be used instead.

> **Note**
>
> If Ethernet devices don't appear when connected and powered on, check the computer's TCP/IPv4 settings in Windows Network Centre and ensure the IP address and Subnet masks use the correct range of 192.168.2.XXX with Subnet Mask 255.255.255.0
> Do not set the host computer IP address the any of the sonar devices or reserved addresses xxx.2.17, xxx.2.200, xxx.2.201
> Also, do not use the "Obtain an IP address automatically" option.

> **Warning**
>
> By default our Ethernet enabled systems have their subnet set to '2'. and main IP address set to 192.168.2.17. Make sure that the host computer's IP address does not conflict with this IP address.

Windows Firewall Settings

Check your anti-virus settings. Firewalls will see the data from the network and may stop the broadcast message. Occasionally a firewall will allow the broadcast message but will stop the high data rate from the sensor believing it to be a denial of service attack. If this is the case, navigate to "Allowed Apps" in windows and add permissions to the firewall settings for Seanet Software.

Serial Comms Setup

COM port allocations vary depending on the computer you use. They can be found by opening Windows Device Manager where there is a list of COM ports called Ports (COM & LPT).
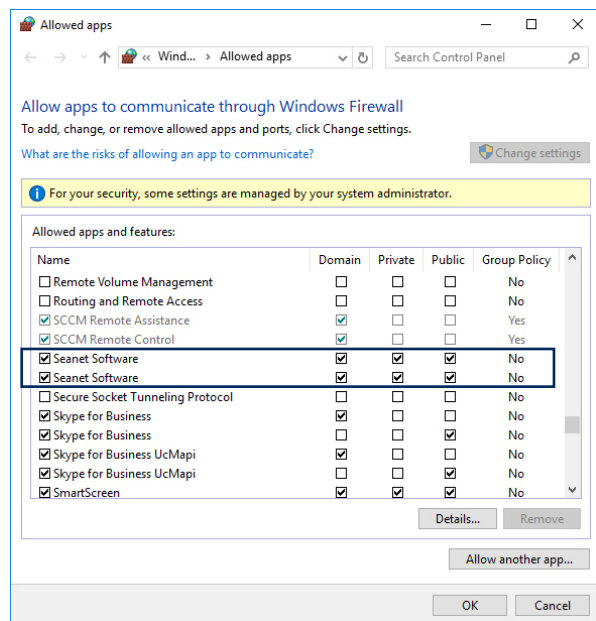
> **NOTE**
>
> When using ARCNET It is worth noting that a SeaHub or Tritech SCU is required to interface with the sensor. This is because Tritech use our own proprietary version of the ARCNET protocol.
>
> Wiring diagrams and pin-outs can be found in sections 2.7 and 2.8 of this manual.
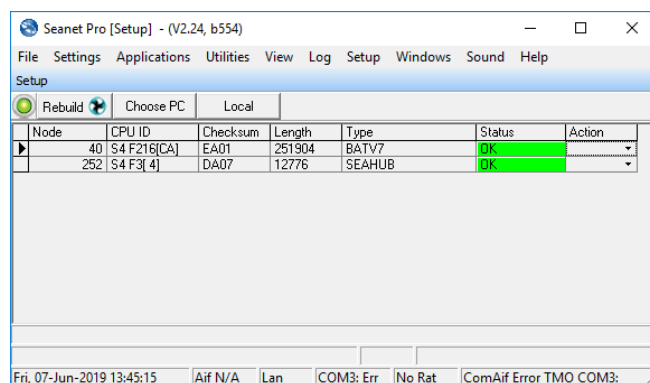
Setup window

Having installed the hardware it is now time to setup communications within SeaNet Pro.

To do this go to the Applications in menu at the top of the screen and select Setup.

This brings up the Node list where the sensors will appear.

If using Ethernet the sensor will be detected automatically and will appear in the Node list.

Serial Comms Setup

Make sure the com ports are activated by clicking the *Utilities* menu and select *Com Setup*.

In the Channel Setup dialogue (right) that appears, find the entry called "*Aif*" (by default, it is the top entry). if not, it can be added by selecting *New* then *Aif*.

Check the com port number is correct and corresponds to the port of your device and that the Enabled check box is ticked.

When SeaNet Pro's comms Interface has been properly configured, the device/s will appear in the Node List where they can be fully configured.

Changing the Comms Protocol of the Device

The comms protocol on V7 systems is software selectable. This means changing between Ethernet/Arcnet and serial comms can be done from the node list in Seanet Pro setup. Click on the drop-down under the Actions column in the node list to bring up the Device Setup Window. Full details can be found in section 4.

If the comms mode or baud rate of a system has been changed to an unknown state, there is a quick solution to reset the communications protocol to a known state.
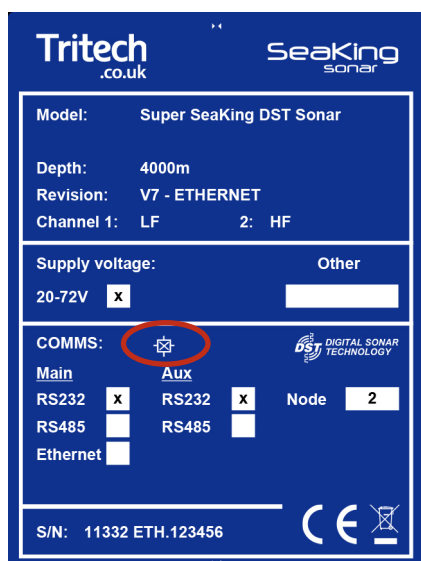
The following steps will reset the unit to RS232 comms protocol.

Connect the unit under test to an available RS-232 interface.

Do not apply power just yet.

Return to 'Seanet Setup'.

Ensure the Com Port of the device is setup and enabled

Place a S11247 magnet on the Reset symbol on the label (Circled in red).

Hold the magnet in position and power up the instrument.

When the node appears in Seanet Setup, remove the magnet.

If after 15 seconds, the device does not appear in the Seanet Node list, ensure magnet is aligned correctly and cycle the power.

4. Device Configuration Window

The device Configuration window is accessed from the node list by clicking on the drop-down (under the action column) and selecting setup. Below is an overview of the Configuration window.

1. **Head Info/Coeffs Tab-** Information relating to the instrument build. The Run Time field will show the total time the instrument has been logging for (between calibration dates). LAN Mode will either be ARCNET or ETHERNET dependant on system configuration.

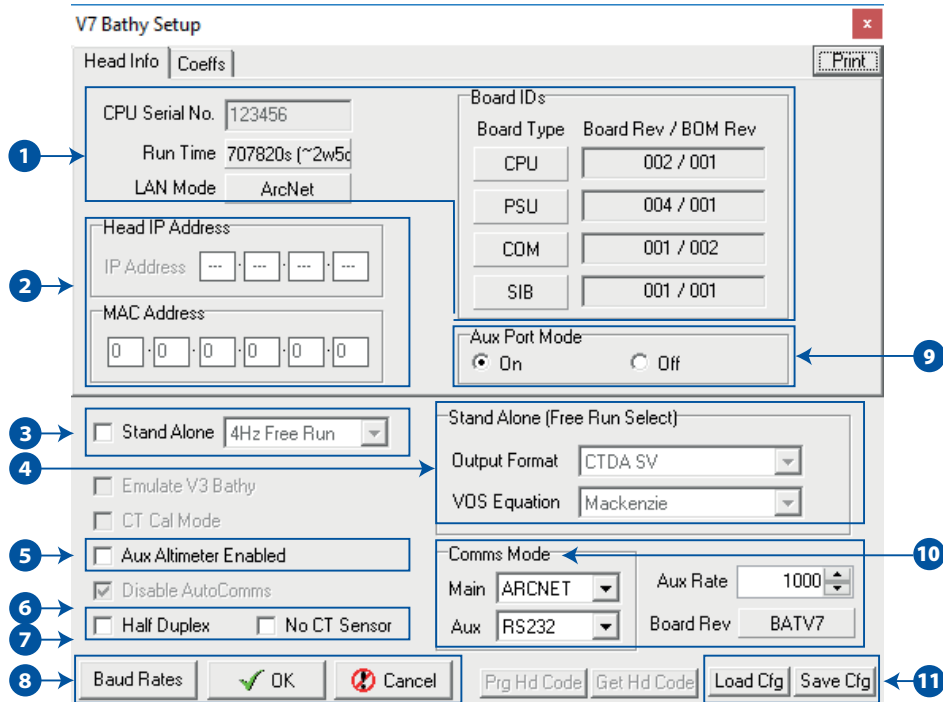2. **Head IP Address-** This section is only relevant to 'ETH' instrument variants. The IP Address field is modifiable to allow reprogramming of the static IP set by the factory. The MAC Address is a read only control that displays the allocated MAC for the instrument, and will be populated at the factory during build.

3. **Standalone Mode-** This enables the alternate 'stand-alone' communications mode. In this mode, the instrument will output ASCII text in a range of CSV formats. Output rates range from 1-4Hz (free-running), as well as the option to interrogate for data. For further details about 'stand-alone' mode, see Appendix C.

4. **Output Format-** These settings are in respect to 'stand-alone' operational mode. The output format drop-down offers a range of string formats. For output formats including 'SV' (Sound Velocity), the VOS equation drop-down offers a range of industry standard VOS calculations. Please note these VOS calculations are only in respect to 'stand-alone' mode, and will not affect the value derived in Seanet (when running in normal operational mode).

5. **Aux Altimeter Enabled-** This setting notifies the instrument to reserve the AUX port for a Tritech PA (altimeter). By default, this option will be checked.

6. **Half Duplex-** This option is auto-selected when operating over RS-485. It may also be required when operating over RS-232 via a serial MUX.

7. **No CT Sensor-** This is a factory-only option, and is specific to the SK701 instruments.

8. **Baud Rates-** This control will open the Baud Rate setup dialog. This window allows the operator to make changes to the Main/Aux port communications speeds.

9. **Aux Port Mode-** This control allows the operator to turn off power to the AUX port on the instrument. Please note that even if the AUX Port Mode is set to off, a blanking cap must still be fitted to the AUX port before immersion of the instrument.

10. **COMMS Mode-** These controls allow changing of the communication modes for both MAIN and AUX.

11. **Load/Save Cfg-** This allows the operator to save the current settings/coefficients to a 'UserBBCfg' file. It also offers the option of loading a previous 'UserBBCfg' file back into the instrument. These can be provided by the factory if accidental changes are made to the instrument settings.

The Following section covers basic operation within SeaNet Pro. The SeaKing 700 series can be operated alongside other devices in a multi-window application. For this example we will focus on the Single Bathy Application.

In the Applications menu at the top of the window, select "Single Bathy" to bring up the main Bathy interface screen. Below is brief overview of the Bathy Application window.
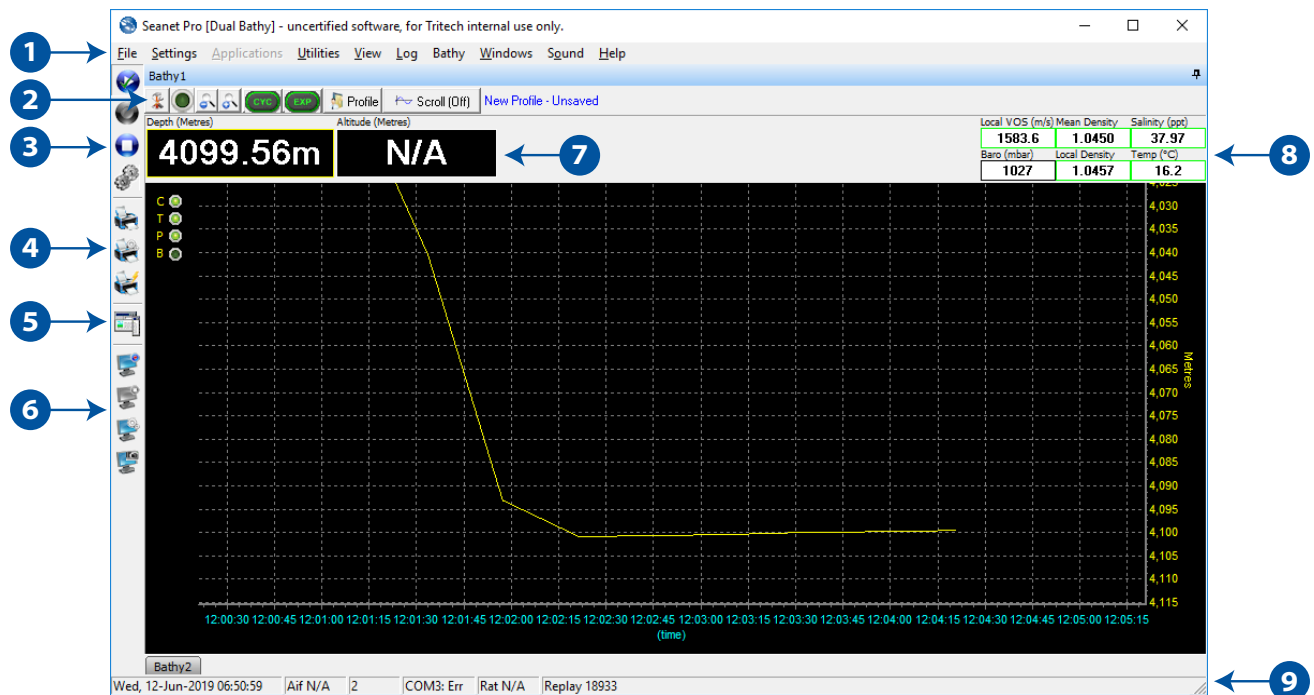
The Bathy Application generates a rolling display showing depth against time. The two main toolbars used consist of the data display bar (running horizontally across the top of the bathy application), and the Seanet controls short-cut bar (running vertically down the LHS of the display). There are two main toolbars, one long the top of the screen and one vertically on the left of the depth profile.

1. **Main Seanet Menu**- This accesses the global functions of Seanet Pro. Here you will also find environmental offsets and configuration for devices as well as the ability to load and playback stored log files.

2. **Bathymetric Settings Bar**- Quick access to some of the basic functions of the bathy. To the left is the Application tools button which accesses the bathy setup and configuration. See section 4.3 for full details on the Application Tools Menu. Next is the start/stop sensor button.

3. **Logging Short**- Cuts- Logging controls to load existing log files, Start and stop a new log. The gears icon accesses the log settings panel to select file destinations

4. **Print Bar**- Print, Quick Print and Print setup options for printing the screen data.

5. **Side Bar Short**-cut- Opens a side bar which can be used as an events logger or to store project specific information to the log.

6. **Screen Capture**- Seanet Pro has it's own screen capture built in. Basic start/stop and setup can be found here.

7. **Depth and Altitude** - Text boxes that display live depth and altitude reading . Note that "NA" is displayed when no Altimeter is connected.

8. **Bathymetric Data**- The system displays sensor measurements for VoS, Density, Salinity, pressure and temperature.

9. **System information bar**- Seanet   system information including local time and com status are displayed.

Bathy Application Menu

The Bathy application menu can be accessed either by clicking the menu icon in the top left of the top toolbar or by right clicking the mouse in the Bathy application window.

Here you can access all settings and information screens for the bathy.
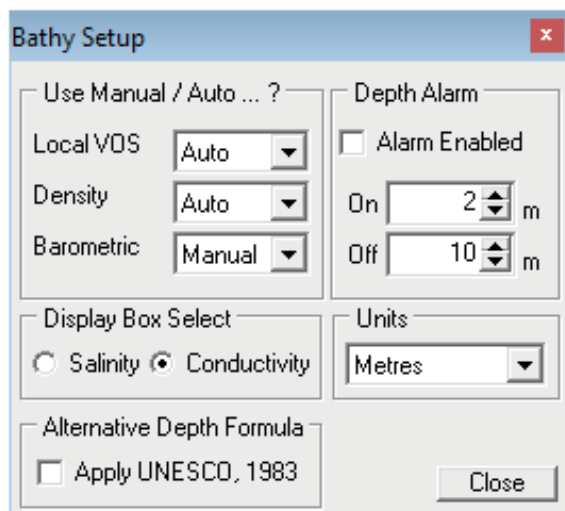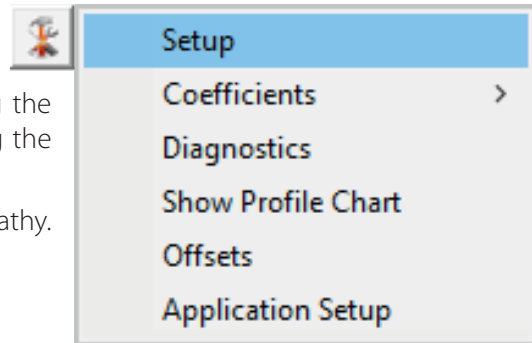
Setup

Set Auto or Manual values for Local VOS, Density, and Barometric. If Auto, the application calculates the correct based on Bathymetric data available. Otherwise manually entered values must be applied in the environmental settings.

Display Box Select - Toggles the display between Salinity or Conductivity in the top right of the main Bathy Screen.

Alternative Depth Formula - Uses the UNESCO standard depth calculation described in Appendix B .

Depth Alarm - Set the depth range for alert. When activated, the Bathymetric Display will flash.

Units - Selects units of measurement Meters, Feet, Fathom or Yards.

Coefficients / View DQ Coefficients

Opens a pop-up window displaying all coefficient data relating to the Digiquarts. These values are calculated during the calibration process of the Bathy.

This data is for information only and cannot be modified. If Coefficient values need to be updated please refer to the Coeffs Tab in the Device Configuration window as outlined in section 4.0

Coefficients / View CT Coefficients

This is a legacy option from the V3 Bathy and is not relevant to V7 systems. Only the CT probe serial number is available to view.

Bathy Diagnostics

Time - Time (in ms), synchronized to the PC clock.

DQSN - Serial number of the Digiquartz unit

DQ N and DQ F - not relevant to the V7 systems.

CALC - Internally calculated DQ temperature (°C) and pressure (psi

Calculated Sensor Values-

Depth - The calculated depth value.

Echo - Measured value from Altimeter if connected.

Density - Calculated water density based on sensor data.

Atmos P - Barometric pressure value.

Loc.VOS- Calculated sound velocity based on bathy data.

> **Note**
> Much of the information in the Bathy Diagnostics dialogue refers to the V3 Bathy and is no longer relevant to the V7 system.

Profile Chart

This displays the window where the profile data is displayed.

Click the drop down to select which data type to plot against PSI. Options are Depth, Temperature, Salinity, V.o.S., Local Density and Mean Density

The profile chart displays selectable Bathy data over the range of the current loaded or updating profile.
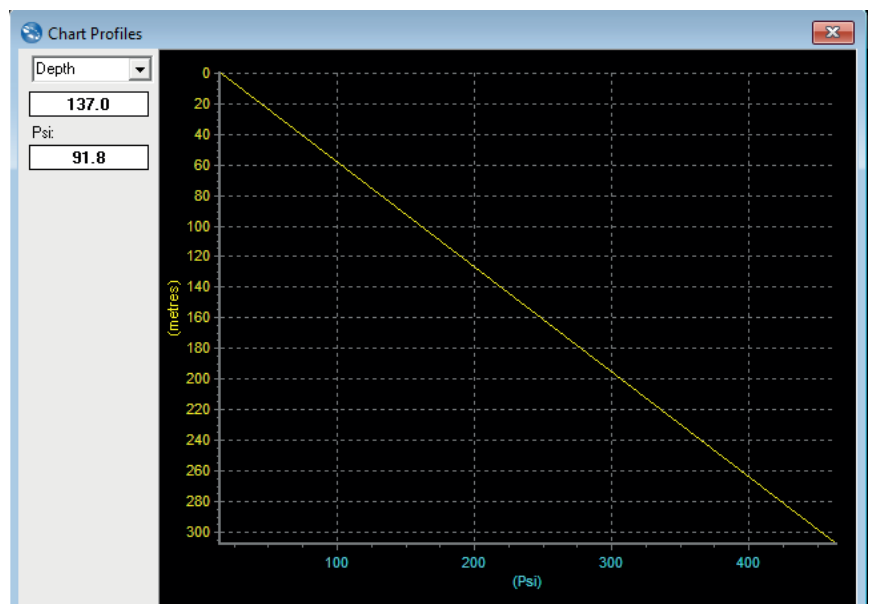
Bathy Offsets

After mounting the Bathy on the vehicle, Zero the instrument by entering a vertical offset. This should include the port up/down offset dependent on the mounting orientation, see Section 4.4

Bathy App Config

Hints - Show the pop-up hints when cursor moves over certain control.

Update Manual VOS - Updates the Global Manual VOS throughout Seanet with a Vos derived from the Bathy.

Update Manual Density- Update the Manual Density with the current Mean Density calculation taken from CT readings.

Altimeter is Global - Apply Altimeter data across connected devices.

DQDepth is Global - Apply DQ data across connected devices.

4.4   System Configuration.

Offsets

The sensor head vertical offset (DQ Offset) and altimeter vertical offset (Alt Offset) will be required if a datum reference point is to be used on the vehicle above or below the SeaKing 700 series sensor head and/or the altimeter.

If the survey datum is above the pressure port then apply a positive DQ Offset. If the datum is below the altimeter transducer then apply a negative Alt Offset. These offsets need to be input into the Offsets dialogue box outlined in section 4.3

Datum's and Zeroes

Survey Datum

DQ Offset

Alt Offset

Negative DQ Offset
Positive Alt Offset

Alt Offset

DQ Offset

Positive DQ Offset
Negative Alt Offset
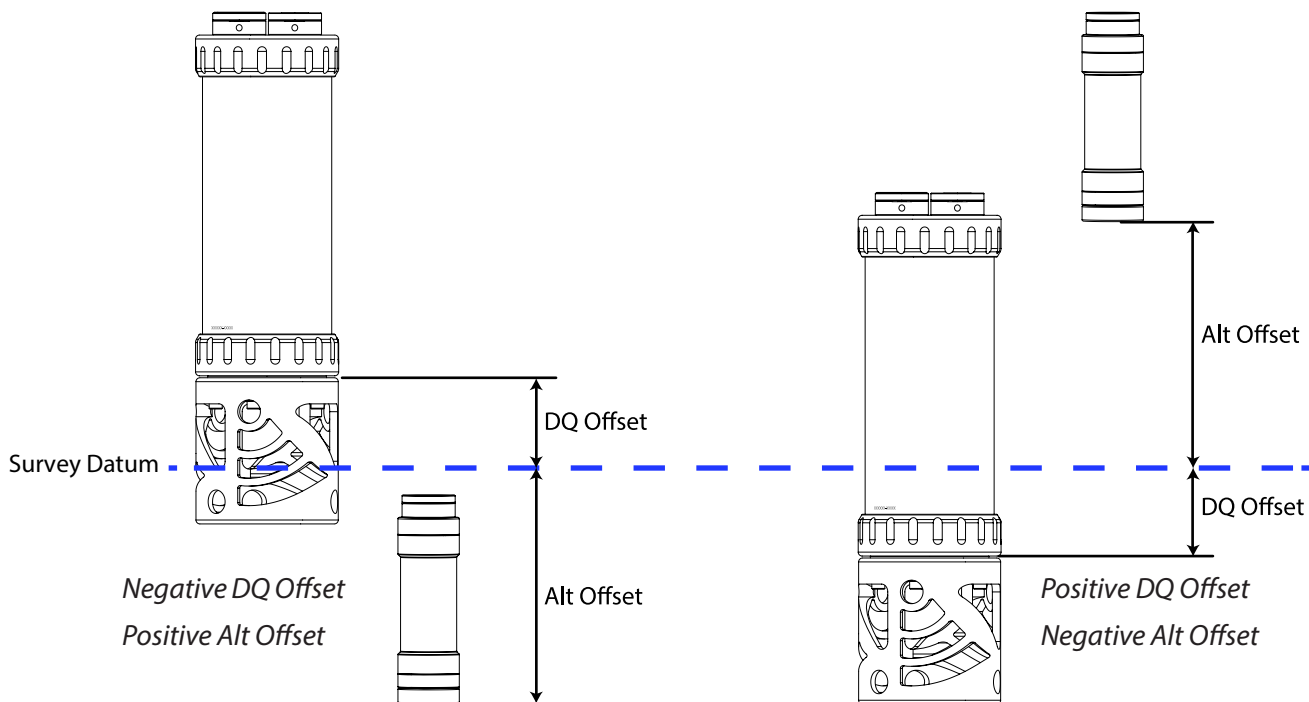
Usually a datum is established on the vehicle as a survey datum. This is generally not where the SeaKing 700 series head is actually mounted.

Seanet Pro allows for a position offset to be entered which corrects the displayed data for any physical offset between the survey datum and the location of the SeaKing 700 series head and Altimeter.

The SeaKing 700 series heads should be checked for serviceability on the bench prior to undertaking any testing underwater. Before applying power to the unit ensure that it is in good physical condition with no damage to the sensors or housing.

The unit should be wired up and installed in exactly the same manner as it is intended to be used (i.e. on an ROV/AUV) and connected to the surface computer. Power should then be applied.

> **Note**
> The device will dissipate a small amount of heat but this will not cause any overheating problems if left running continuously in air or water.

5.2   Pre-dive Setup

Before deploying the sensors, start Seanet Pro and ensure that the system has been configured as follows:

- Enter or check the Latitude
- Enter or check Density ("Mean Relative Density", default: 1.029g cm-3)
- Enter or check V.O.S. ("Velocity of Sound", default: 1475.0m s-1)
- Enter Barometer ("Barometric Pressure", default: 1000mbar)
- Set all offsets (see Section 4.3, "Bathy Offsets")

Options 1 to 4 are found in the Environment setup page (select Settings menu and then Environment). Option 5 is found by right-clicking on the main Bathymetric display and selecting Offsets.

> **Note**
> For the above options to be available it may be necessary to open the Bathymetric screen by selecting Single Bathy (or similar) from the Applications menu.

5.3   Recommended Pre-Dive checklist

The following is a suggestion list of items to be checked during a Pre-Dive procedure when using SeaKing 700 units.

- The communications protocol for the Bathy is known and the topside control unit has been setup appropriately
- All cabling has been correctly fitted with o-rings and is secure
- The head has been securely fastened to the ROV
- All offsets (Altimeter and Digiquartz) have been measured and entered into Seanet Pro
- Latitude information has been correctly entered into Seanet Pro
- Barometric pressure has been correctly entered into Seanet Pro
- Third party outputs (to Survey packages) are setup in REMV4
- If requiring absolute measurements:

    a. The Port Up/Port Down offset has been entered into the DQ Zero section of Seanet Pro

    b. The ROV is deployed and held at the surface so that the sensors can stabilise

- If requiring relative measurements:

    a. A value is entered into DQ Zero that gives a reading of 0.000m on screen.

    b. This would conclude the minimum recommended pre-dive checks required for the Bathy.

> **Note**
> All other pre-dive checks would need to be carried out as per your own guidelines and procedures.

Water Density

A bathymetric sensor measures seawater pressure. In order to calculate depth it must know the density throughout the water column from the surface to the operating depth.

This value will change as the sensor moves through the water column, because varying temperatures and salinity will affect the overall density.

Atmospheric Pressure

The pressure measured includes the atmospheric pressure imposed on the surface of the water. A bathymetric system must know this pressure and subtract it from the total pressure measured (1mbar change is equal to 1cm in the depth measurement). For sudden changes of barometric pressure, for instance when a weather front moves across, there may be a significant lag (up to 1 hour) in the transmittal of the effect to the pressure measurements.

The height of barometric measurement above sea level may need to be accounted for if this is significant (10m air height is equivalent to 1cm difference in depth reading).

> **Note**
>
> Tritech International Ltd can supply barometric sensors as an option. These are accurate to 1mbar. If the option is not used then the barometric pressure must be entered into the system manually.

Tidal Movement

Tidal movement does not directly affect the depth measurement from the surface, but is needed to establish the datum for a survey. Surveyors will need to correct the depth measurements to mean seawater levels.

Local Gravity

Gravity varies with position on the Earth's surface. To a good approximation it varies as a function of latitude and can be calculated using known geodetic formulae.

Instrument Accuracy and Stability

The different sensors housed within the SeaKing 700 series units have different levels of accuracy. All the sensors are fully calibrated when the unit is shipped and fit within the following parameters:

Pressure

Specified as having a repeatability of 0.01% and hysteresis of 0.015% of full range, these figures represent one standard deviation and are cumulative such that the statistical variability of the calibrated pressure sensor will result in a depth value uncertainty of 0.015%.

Density

Applicable to SeaKing 704 units only, the conductivity and temperature sensor are used to calculate density local to the instrument using standard oceanographic equations. The values calculated are valid only at the time of descent and if water condition change (e.g. varying temperature or salinity) the value becomes historic and may induce errors. If desired the calculated value can be overwritten with a manually entered value. Generally for calculated values it is expected that density variations could double the uncertainty of a depth measurement to 0.03% of full scale.

Relative Measurements

For relative measurements there is no requirement to zero the unit on deck because any error at the surface will represent a constant offset (gravity effects are also negligible).

The important parameters are variations in atmospheric pressure, water column mean density and tidal corrections for the duration of the measurements. See the "Pre-dive Setup" section of this manual.

SeaKing 700 units may be mounted in any orientation and with the correct atmospheric pressure entered an approximate zero offset can be entered such that the output depth reading is zero while on deck. It is recommended that no further alteration is made to the zero settings for the duration of the job. See Section 4.3, "Bathy Offsets".

Absolute Pressure

All of the factors affecting measurement as detailed in the above sections will apply and any zero offset applied will also need to be known.

The pressure sensor fitted to the Super SeaKing 700 series heads is temperature compensated, however, it can take up to 2 hours for the sensor to stabilise (if the external temperature is varying considerably this time will be longer). To get a reading the unit needs to be powered up and allowed to stabilise completely. If removing from the seawater to a deck that is a very different temperature then the readings can have a significant error.

There are two alternative approaches to setting the zero offset:

1. Ensure the unit is mounted either port up or port down and use the zero offset figure published on the build and calibration sheet for the instrument. This figure should not be altered unless a full check is completed (i.e. follow step 2 below) even if errors are showing while on deck. The results at depth will be consistent and accurate.

2. Perform a thorough deck zero check as follows:

   - Keep the unit at a temperature close to seawater (i.e. use a bucket and ice/hot water as appropriate).
   - Power the unit for a minimum of 2 hours to allow stabilisation to occur.
   - Obtain correct values for atmospheric pressure and latitude and enter them into the system.
   - Set the position offset currently in the system to zero.
   - Remove the SeaKing 700 series head from the vehicle and lower to a known depth.
   - Adjust the zero offset so that the depth reading matches the known depth.

> **Note**
>
> If setting the zero offset using method 2 it will be necessary to do so with the SeaKing 700 head vertical with the sensor cage at the bottom (i.e. port down) and subsequently the unit should always be used in this orientation.

6. Care and Maintenance

> **⚠ Warning**
> Opening of the unit will void the warranty. This unit is not designed to be field serviceable. Calibration and pressure certification will also become invalid should the unit be opened.

6.1 After using the Super Seaking 700

We recommend that the unit be rinsed down with fresh water after each dive, especially if the unit is not intended to be used for an extended period. The anodised housing and plastic components are resistant to corrosion, using fresh water is a simple way ensuring the longevity of the system.

The temperature / conductivity sensor should be cleaned to remove any build-up of dirt, oil, mud or sediment. Any build up may reduce sensitivity and affect accuracy of measurements. This can be done with a with a plastic bottle brush or similar.

Wherever possible try to avoid prolonged exposure to extreme climatic and weathering conditions so as to reduce the wear and aging of components and connectors.

6.2 Seaking Basic Maintenance

It is recommended the o-rings and connector o-rings be inspected regularly to ensure they are in good condition. Worn or damaged o-rings should be replaced and greased. The Bathy should be visually inspected and cleaned regularly.

6.3 Field Service

The Super SeaKing is not designed to be field serviceable, unauthorised opening of the housing will void the warranty, pressure and calibration.

6.4 Storage

Make sure the Super SeaKing 700 is completely dry (if necessary leave to dry in air before stowing). Pack into storage container along with several pouches of silica gel.

6.5 Calibration

Super SeaKing 700 Bathymetric devices are shipped fully calibrated and should not require further calibration prior to use. Tritech recommend that the unit be serviced and recalibrated every 12 months although this may be reduced if the unit has suffered mechanical shock or exceeded the pressure rating by 10% or more. Please contact Tritech International for details of calibration and service options.

Appendix A

A.1. ARCNET Termination

Depending on the cable length the ARCNET communication link requires a termination resistor to be installed at each end of the umbilical cable. Normally this is supplied fitted within the ARCNET cable DA-15 or within the SCU/SeaHub at the surface and is left for the user to fit at the sub-sea end in a convenient junction box or by use of a special waterblock.

The purpose of these terminations is to attenuate any electrical interference or "reflections" which may occur due to an impedance miss-match and the overall aim is to improve signal quality and negate any effects which might otherwise be felt by other sources of impedance such as from the cable itself.

The diagram below shows best practice to use when installing termination resistors on an ARCNET network of Tritech International Ltd sonar products.

> **Note**
> A special yellow waterblock is available from Tritech International Ltd which contains an in-line impedance of 39Ω which will enable quick and easy installation of the subsea termination resistor.

Waterblock Connectors	
1	ARCNET A
2	ARCNET B
3	+V DC
4	-V DC
5	RS232 GND
6	Earth/Screen
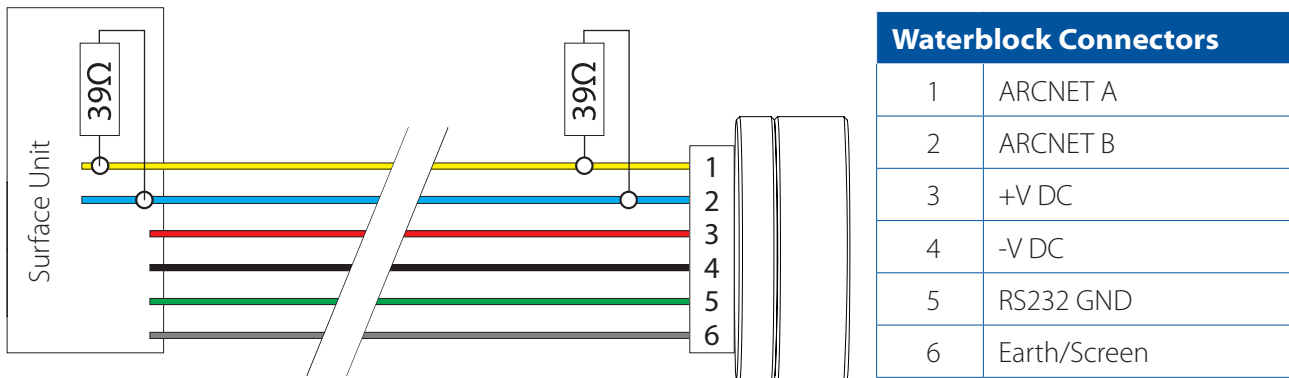
Cable length	Termination	Baud rate setting
Less than 100m	Single 39Ω subsea resistor	Normal baud rate
100-1200m	270Ω at surface and 39Ω subsea	Normal baud rate
1200-2500m	270Ω at surface and 39Ω subsea	Half baud rate

> **Note**
> If there is more than one sensor connected then the sub-sea resistor should befitted at the junction box or splice of the cable.

B.1. Depth Derivation

The Bathy V7 uses its ARM processor to carry out the various calculations required to derive depth, salinity, density, VOS, and altitude. This allows the V7 system to operate in a completely standalone mode, as opposed to the V3 system that requires the use of Seanet/Desktop PC to derive the above outputs.

The V7 system offers operators to select from a list of industry standard algorithms for deriving both Depth and Velocity of Sound.

This following section lists the formulae (used internally) to derive those output values.

B.2. Default Depth Equation

$$Depth\ (m) = \frac{g^n}{g}\left(\frac{0.70307(p - 0.01450377a)}{\rho}\right)$$

$p = absolute\ pressure\ in\ PSI$
$a = surface\ atmospheric\ pressure\ in\ mbar$
$\rho = mean\ density\ from\ CT\ probe\ (SK704)\ or\ fixed\ system\ density\ (SK701)$
$0.01450377 = mbar\ to\ PSI\ conversion\ factor$
$0.70307 = standard\ gravity\ of\ 9.80665m\ s^{-2}$
$g = local, latitude\ dependent\ gravity$

B.3. Gravity Formula

$$g = 9.7803184\ (1 + 0.0053024\ sin^2\theta - 0.0000059\ sin^4\theta)$$

$given\ \theta = local\ latitude\ in\ degrees$

(International Association of Geodesy, Sp.Pub.Bull Geodesy 1970)

B.4. Alternative Depth Equation

$$Z_s(P, \theta) = \frac{9.72659 * 10^2 P - 2.512 * 10^{-1} P^2 + 2.279 * 10^{-4} P^3 - 1.82\ * 10^{-7} P^4}{g(\theta) + 1.092 * 10^{-4} P}$$

Where g(θ), the international formula for gravity, is given by:

$$g(\theta) = 9.780318\ (1 + 5.2788 * 10^{-3}\ sin^2\theta + 2.36 * 10^{-5}\ sin^4\theta$$

$Z = Depth\ in\ meters$
$P = Pressure\ in\ mPa$
$\theta = latitude$

B.5. Salinity Equation

$$Salinity\ (ppt) =\ S + S_D$$

$$S =\ 0.008 - 0.1692 R_t^{\frac{1}{2}} + 25.3851 R_t + 14.0941 R_t^{\frac{2}{3}} - 7.0262 R_t^2 + 2.7081 R_t^{\frac{5}{2}}$$

$$S_D =\ \left(0.0005 - 0.0056 R_t^{\frac{1}{2}} - 0.0066 R_t - 0.0375 R_t^{\frac{2}{3}} + 0.0636 R_t^2 - 0.0144 R_t^{\frac{5}{2}}\right) F_t$$

$$F_t =\ \frac{T - 15}{1 + 0.0162(T - 15)}$$

$$R_t =\ \frac{R}{R_p * \tau_t}$$

$$R_p =\ \frac{1 + P(2.06 \times 10^{-5} - 6.37 \times 10^{-10} + 3.989 \times 10^{-15} P^2}{1 + 0.3426T + 4.464 \times 10^{-4} + (0.4215 - 0.003107TR)}$$

$$\tau_t = 0.6766097 + 0.200564T + (1.104259T) \times 10^{-42} - 6.9698 \times 10^{-7}\,T^3 + 1.0031 \times 10^{-9}\,T^4$$

$$R =\ \frac{C}{42.914}\ (note: 42.914\ is\ conductivity\ at\ S = 35, T = 15\ ^oC, P = 0$$

$$P =\ \frac{abs.\,pressure\,measured\,by\,sensor - barometric\,pressure}{10}$$

$C = Measured\ Conductivity\ in\ mS/cm$

$T = Measured\ Temperature\ in\ degrees\ Celsius$

(UNESCO, 1981)

B.6. Density Equation

$$Density(kg/m^3) =\ \frac{\rho_0}{1000\left(1 - \frac{P}{k}\right)}$$

$k =\ gs^{1.5} + fs + e + P(js^{1.5} + is + h) + P^2(ns + m)$

$\rho_0 =\ ds^2 + cs^{1.5} + bs + a$

$n =\ 9.1697 \times 10^{-10}\,T^2 + 2.0816 \times 10^{-8}\,T - 9.9348 \times 10^{-7}$

$m =\ 5.2787 \times 10^{-8}\,T^2 - 6.12293 \times 10^{-6}\,T + 8.50935 \times 10^{-5}$

$j =\ 1.91075 \times 10^{-4}$

$i =\ -1.6078 \times 10^{-6}\,T^2 - 1.0981 \times 10^{-5} + 2.2838 \times 10^{-3}$

$h =\ -5.77905 \times 10^{-7}\,T^3 + 1.16092 \times 10^{-4}\,T^2 + 1.43713 \times 10^{-3}\,T + 3.239908$

$f =\ -6.67 \times 10^{-5}\,T^3 + 1.09987 \times 10^{-2}\,T^2 + 0.603459T + 54.6746$

$e =\ -5.155288 \times 10^{-5}\,T^4 + 1.360477 \times 10^{-2}\,T^3 - 2.327105\,T^2 + 148.4206T + 19652.21$

$d =\ 4.8314 \times 10^{-4}$

$c =\ -1.6546 \times 10^{-6}\,T^2 + 1.0227 \times 10^{-4}\,T - 5.72466 \times 10^{-3}$

$b =\ 5.3875 \times 10^{-9}\,T^4 - 8.2467 \times 10^{-7}\,T^3 + 7.6438 \times 10^{-5}\,T^2 - 4.0899 \times 10^{-3}\,T + 0.824493$

$a =\ 6.536332 \times 10^{-9}\,T^5 - 1.120083 \times 10^{-6}\,T^4 + 1.001685 \times 10^{-4}\,T^3 - 9.09529 \times 10^{-3}\,T^2$
$\qquad + 6.793952 \times 10^{-2}\,T + 999.842594$

$s =\ Calculated\ Salinity\ in\ parts\ per\ thousand$

$P =\ measured\ absolute\ pressure - barometric\ pressure\ (in\ bar)$

$T =\ measured\ temperature\ in\ degrees\ Celsius$

(Journal of Geographical Research, 1985)

Free Running mode can be customised to use the following formulae to calculate sound velocity based on Bathymetric Data.

C.1.   Chen & Millero Equation

Velocity of Sound (VoS) Algorithms Chen and Millero
Source: NPL Technical Guides – Speed of Sound in Sea-water
Validity: T = 0 to 40oC, S = 0 to 40psu, P = 0 to 100 bar (Wong and Zhu, 1995)

Table of Coefficients

Coefficients	Numerical values	Coefficients	Numerical values
C_{00}	1402.388	A_{02}	7.166E-5
C_{01}	5.03830	A_{03}	2.008E-6
C_{02}	-5.81090E-2	A_{04}	-3.21E-8
C_{03}	3.3432E-4	A_{10}	9.4742E-5
C_{04}	-1.47797E-6	A_{11}	-1.2583E-5
C_{05}	3.1419E-9	A_{12}	-6.4928E-8
C_{10}	0.153563	A_{13}	1.0515E-8
C_{11}	6.8999E-4	A_{14}	-2.0142E-10
C_{12}	-8.1829E-6	A_{20}	-3.9064E-7
C_{13}	1.3632E-7	A_{21}	9.1061E-9
C_{14}	-6.1260E-10	A_{22}	-1.6009E-10
C_{20}	3.1260E-5	A_{23}	7.994E-12
C_{21}	-1.7111E-6	A_{30}	1.100E-10
C_{22}	2.5986E-8	A_{31}	6.651E-12
C_{23}	-2.5353E-10	A_{32}	-3.391E-13
C_{24}	1.0415E-12	B_{00}	-1.922E-2
C_{30}	-9.7729E-9	B_{01}	-4.42E-5
C_{31}	3.8513E-10	B_{10}	7.3637E-5
C_{32}	-2.3654E-12	B_{11}	1.7950E-7
A_{00}	1.389	D_{00}	1.727E-3
A_{01}	-1.262E-2	D_{10}	-7.9836E-6

$$(S,T,P) = Cw(T,P) + A(T,P)S + B(T,P)S^{3/2} + D(T,P)S^2$$

$$Cw(T,P) = (C_{00} + C_{01}T + C_{02}T^2 + C_{03}T^3 + C_{04}T^4 + C_{05}T^5) +$$
$$(C_{10} + C_{11}T + C_{12}T^2 + C_{13}T^3 + C_{14}T^4)P +$$
$$(C_{20} + C_{21}T + C_{22}T^2 + C_{23}T^3 + C_{24}T^4)P^2 +$$
$$(C_{30} + C_{31}T + C_{32}T^2)P^3$$

$$A(T,P) = (A_{00} + A_{01}T + A_{02}T^2 + A_{03}T^3 + A_{04}T^4) +$$
$$(A_{10} + A_{11}T + A_{12}T^2 + A_{13}T^3 + A_{14}T^4)P +$$
$$(A_{20} + A_{21}T + A_{22}T^2 + A_{23}T^3)P^2 +$$
$$(A_{30} + A_{31}T + A_{32}T^2)P^3$$

$$B(T,P) = B_{00} + B_{01}T + (B_{10} + B_{11}T)P$$

$$D(T,P) = D_{00} + D_{10}P$$

T = temperature in degrees Celsius
S = salinity in Practical Salinity Units (parts per thousand)
P = pressure in bar

C.2. DelGrosso Equation

Source: NPL Technical Guides – Speed of Sound in Sea-water
Validity: T = 0 to 30oC, S = 30 to 40ppt, P = 0 to 1000 kg/cm2 (Wong and Zhu, 1995)

Table of Coefficients

$$c(S,T,P) = C_{000} + \Delta C_T + \Delta C_S + \Delta C_P + \Delta C_{STP}$$

$$\Delta C_T(T) \quad C_{T1}T + C_{T2}T^2 + C_{T3}T^3$$

$$\Delta C_S(S) = C_{S1}S + C_{S2}S^2$$

$$\Delta C_P(P) = C_{P1}P + C_{P2}P^2 + C_{P3}P^3$$

$$\Delta C_{STP}(S,T,P) = C_{TP}TP + C_{T3P}T^3P + C_{TP2}TP^2 + C_{T2P2}T^2P^2 + C_{TP3}TP^3 + C_{ST}ST + C_{ST2}ST^2 + C_{STP}STP + C_{S2TP}S^2TP + C_{S2P2}S^2P^2$$

T = temperature in degrees Celsius
S = salinity in Practical Salinity Units
P = pressure in kg/cm² (where 100 kPa = 1.019716 kg/cm²)

Coefficients	Numerical values
C_{000}	1402.392
C_{T1}	0.5012285E1
C_{T2}	-0.551184E-1
C_{T3}	0.221649E-3
C_{S1}	0.1329530E1
C_{S2}	0.1288598E-3
C_{P1}	0.1560592
C_{P2}	0.2449993E-4
C_{P3}	-0.8833959E-8
C_{ST}	-0.1275936E-1
C_{TP}	0.6353509E-2
C_{T2P2}	0.2656174E-7
C_{TP2}	-0.1593895E-5
C_{TP3}	0.5222483E-9
C_{T3P}	-0.4383615E-6
C_{S2P2}	-0.1616745E-8
C_{ST2}	0.9688441E-4
C_{S2TP}	0.4857614E-5
C_{STP}	-0.3406824E-3

C.3. Wood Equation

Source: The Hydrographic Society Special Publication No. 34
Validity: Unknown.

$$C(D,S,T) = 1410 + (4.21 * T) - (0.037 * T^2) + (1.14 * S) + (0.018 * D)$$

T = Temperature in degrees Celsius
S = Salinity in parts per thousand
D = Depth in meters

C.4. Mackenzie Equation

Source: NPL Technical Guides – Speed of Sound in Sea-water
Validity: T = 2 to 30oC, S = 25 to 40psu, D = 0 to 8000 meters (K.V. Mackenzie, 1981)

$$C(D,S,T) = 1448.96 + 4.591T - 5.304 * 10^{-2}T^2 + 2.374 * 10^{-4}T^3 + 1.340(S - 35)$$
$$+ 1.630 * 10^{-2}D + 1.675 * 10^{-7}D^2 - 1.025 * 10^{-2}T(S - 35) - 7.139$$
$$* 10^{-13}TD^3$$

T = Temperature in degrees Celsius
S = Salinity in parts per thousand
D = Depth in meters

Source: The Hydrographic Society Special Publication No. 34
Validity: T = -4 to 30oC, S = 25 to 37ppt, P = 0 to 1000 kg/cm2 (Wilson W D., 1960)

$$V = \mathbf{1449.14} + V_T + V_P + V_S + V_{STP}$$

$$V_T = 4.5721 * T - 4.4532E^{-2}\, T^2 - 2.6045E^{-4}\, T^3 + 7.9851E^{-6}\, T^4$$

$$V_P = 1.60272E^{-1} * P_k + 1.0268E^{-5}\, P_k{}^2 + 3.5216E^{-9}\, P_k{}^3 - 3.3603E^{-12}\, P_k{}^4$$

$$V_S = 1.39799 * (S - 35) + 1.69202E^{-3} * (S - 35)^2$$

$$V_{STP} = (S - 35)(V_{STP0} + V_{STP1} + V_{STP2} + V_{STP3})$$

$$V_{STP0} = -1.1244E^{-2}\, T + 7.7711E^{-7}\, T^2 + 7.7016E^{-5}\, P_k - 1.2943E^{-7}\, P_k{}^2$$
$$+ 3.1580E^{-8}\, P_k\, T + 1.5790E^{-9}\, P_k\, T^2$$

$$V_{STP1} = P_k\, (-1.8607E^{-4}\, T + 7.4812E^{-6}\, T^2 + 4.5283E^{-8}\, T^3)$$

$$V_{STP2} = P_k{}^2\, (-2.5294E^{-7}\, T + 1.8563E^{-9}\, T^2)$$

$$V_{STP3} = P_k{}^2\, (-1.9646E^{-10}\, T)$$

T = Temperature in degrees Celsius
S = Salinity in parts per thousand
P_k = Pressure in kg/cm^2 (where $1\ kg/cm^2$ is 0.980665 bar)

Source: NPL Technical Guides – Speed of Sound in Sea-water
Validity: T = 0 to 35oC, S = 0 to 45ppt, D = 0 to 4000 meters (A.B. Coppens, 1981)

$$C(D,S,t) = C(0,S,t) + (16.23 + 0.253t)D + (0.213\text{-}0.1t)D^2 + [0.016 + 0.0002(S35)](S - 35)tD$$

$$C(0,S,t) = 1449.05 + 45.7t - 5.21t^2 + 0.23t^3 + (1.333 - 0.126t + 0.009t^2)(S - 35)$$

$$t = \frac{T}{10}\ (where\ T = Temperature\ in\ degrees\ Celsius)$$

S = Salinity in parts per thousand
D = Depth in meters

C.7.   Medwin Equation

Source: NPL Technical Guides – Speed of Sound in Sea-water
Validity: T = 0 to 35oC, S = 0 to 45ppt, D = 0 to 1000 meters (Medwin H., 1975)

$$VoS \; = \; 1449.2 + 4.6T - 0.055T^2 + 0.00029T^3 + (1.34 - 0.010T)(S - 35) + 0.016D$$

$T = Temperature\ in\ degrees\ Celsius$
$S = Salinity\ in\ parts\ per\ thousand$
$D = Depth\ in\ meters$

C.8.   Leroy Equation

Source: The Acoustic Society Vol. 124, No. 5, Nov 2018
Validity: S = 0 to 42ppt

$$
\begin{aligned}
c \; = \; & 1402.5 + 5T - 5.44 * 10^{-2}T^2 + 2.1 * 10^{-4}T^3 + 1.33S - 1.23 * 10^{-2}ST + 8.7 \\
& * 10^{-5}ST^2 + 1.56 * 10^{-2}Z + 2.55 * 10^{-7}Z^2 - 7.3 * 10^{-12}Z^3 + 1.2 \\
& * 10^{-6}Z(\theta - 45) - 9.5 * 10^{-13}TZ^3 + 3 * 10^{-7}T^2Z + 1.43 * 10^{-5}SZ
\end{aligned}
$$

$Z = Depth\ in\ meters$
$S = Salinity\ in\ parts\ per\ thousand$
$T = Temperature\ in\ degrees\ Celsius$
$\theta = Latitude$

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