

# **MODUS SVS Sound Velocity Sensor**

## **Section 2 - Software Operation**

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# 1 INTRODUCTION

DataLog 400 is the user interface program supplied with all 400 Series systems from Valeport Ltd, including the MODUS SVS Sound Velocity Sensor. The program is written in Delphi, and will run on all PCs operating Windows 95 or above. As is the nature of all software, the faster the computer, the better the software will perform. As an absolute minimum, we recommend the following PC specification:

- Pentium 100MHz (or equivalent)
- 32Mbyte RAM
- CDROM Drive
- 1 spare comm port
- 100Mbyte Disk Space

Note that installation of DataLog 400 itself requires only 5.4Mbyte of disk space. However, Windows will utilise a large amount of disk space as “virtual memory” (upwards of 20Mbyte), which must be taken into account.

This manual will guide the operator through all the functions that DataLog 400 and the MODUS SVS have to offer, including the wide variety of sampling regimes and data viewing. Please note that although DataLog 400 offers a variety of data display modes, users may wish to utilise a standard spreadsheet package such as Microsoft Excel for data manipulation.

The MODUS SVS has no capability for internal data storage, or “logging”, only for real time data output. Any references in this manual to internal data logging or data upload do not relate to this product, but to other Valeport instruments that also operate with the DataLog 400 software. The capability to record real time data output on the operating PC is retained.

## 1.1 INSTALLATION

As with all installation programs, we recommend that all other applications be closed before commencing installation.

DataLog 400 is supplied on a single CDROM. It does not feature an Auto-run facility, so users will be required to insert the CDROM into their CD drive, and run the Setup.exe program manually. This can be done either by selecting Run from the Start menu, and browsing for the Setup.exe file under the CD drive (typically drive D or E), or by clicking on the Setup.exe program under the CD drive in Windows Explorer.

The Setup.exe program will launch a wizard that will guide the user through the remainder of the installation process. By default, the installation program will create a new directory in which to install DataLog 400, although you may change this if you wish:

C:\Program Files\DataLog 400

On completion of installation, a window will appear with a shortcut icon to the program. This may be dragged onto the desktop if required:

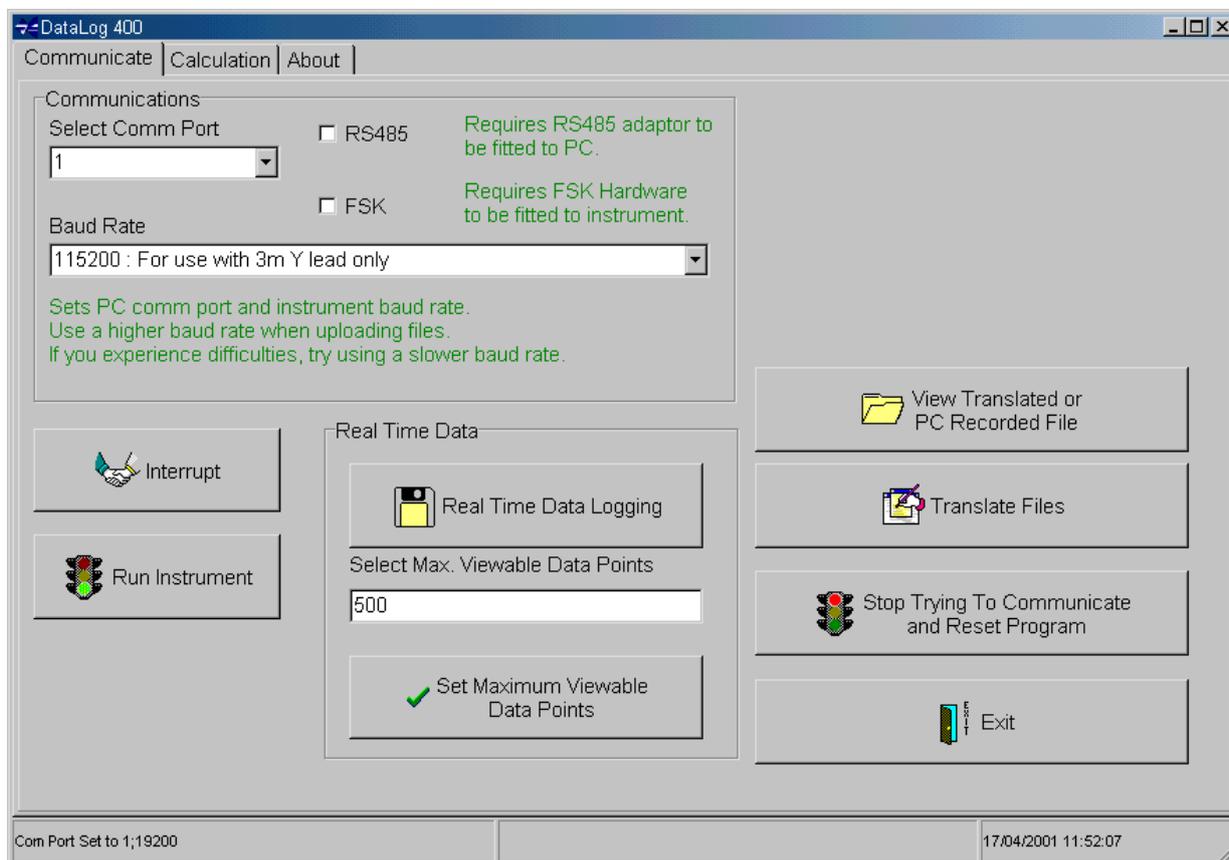


Note that DataLog 400 software is distributed free with the equipment – therefore no password or software key is required for installation.

To Run the software, simply double click the Desktop icon. The following pages describe the operation of the software.

## 2 OPENING DATALOG 400

Double clicking the desktop icon (  ), or running the DataLog 400.exe program through Windows Explorer, will reveal the following screen, which allows access to all major DataLog 400 functions. Note that all features are accessed through a selection of tabs at the top of the page – there is no menu bar. Also note that at any point in the software, only tabs which are relevant will be visible. The Calculation and About tabs, which are less important in terms of instrument operation and data viewing, are covered in later Chapters.



If the user wishes to close down DataLog 400 at any time, simply click on the Exit button:



If for any reason communications are lost, the “Stop Trying” button may be used. Clicking on this button will return the user to this point in the software:



The major functions that DataLog 400 will allow at this point are as follows. Each function is described fully at subsequent chapters in this manual. Note also the section of the screen titled “Real Time Data”. Please refer to Chapter 5 for details of this section.



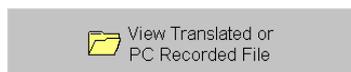
Interrupt

Establishes communications with the instrument, and causes the unit to wait for further instructions. See Chapter 3.



Run Instrument

Puts the instrument into Run mode. This button should only be used if the user is confident of the current instrument settings. See Chapter 5.



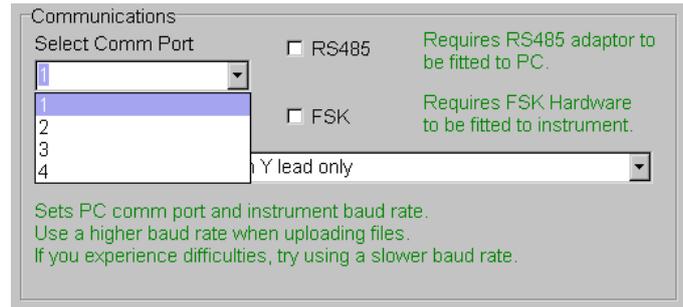
View Translated or PC Recorded File

View an existing data file, either previously uploaded and translated, or saved from the real time output. See Chapter 7.

### 3 ESTABLISHING COMMUNICATIONS

After connecting the instrument to the PC using the 500mm Y lead as described in Section 1 of this manual, the first step in establishing communications with the instrument is to select the correct communications (comm) port. A drop down menu allows the user to select from up to 4 available comm ports.

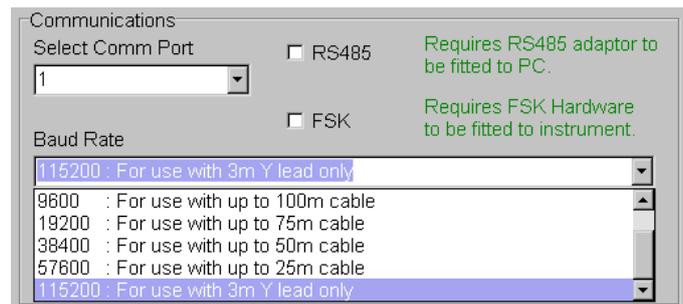
*Selecting the incorrect comm port is the most likely reason for any failure to communicate.*



Note that all Valeport 400 Series instruments (i.e. instruments designed to work with DataLog 400) are fitted with three standard digital data outputs – RS232, RS485 and RS422. The larger “MIDAS” instruments also have one optional output, FSK modem. This option is not available on the smaller “Monitor” & “MODUS” instruments. RS232 format can be read directly by a PC comm port. If using any of the other methods, the PC will need to be fitted with a suitable interface, which will either be a special adaptor unit supplied by Valeport, or in the form of an additional circuit board added to the PC. If using RS485 or FSK communications, please check the box next to the comm port selection box. This will slightly alter the protocol that DataLog 400 uses to communicate with the instrument (note that FSK comms defaults to 19200 baud rate). It is important that the boxes are left unchecked if just standard RS232 communications or RS422 communications are being used.

The next step in establishing communications is to select the required baud rate. **Note : The MODUS SVS will only work at up to 38400 baud.**

The instrument will automatically detect which baud rate is being used, but note that the longer the cable being used, the slower the rate that will be required. A guide to suitable baud rates is given in the drop down menu. Note also that even some new PCs may be fitted with low quality comm ports – users may find that a lower baud rate is necessary.



Next, ensure that the power supply is turned on.

All Valeport 400 Series instruments (i.e. instruments designed to work with DataLog 400) can be interrupted at any point during their operation, whether they are actually in the process of sampling or in a sleep mode between bursts.

Finally, click on the Interrupt button:



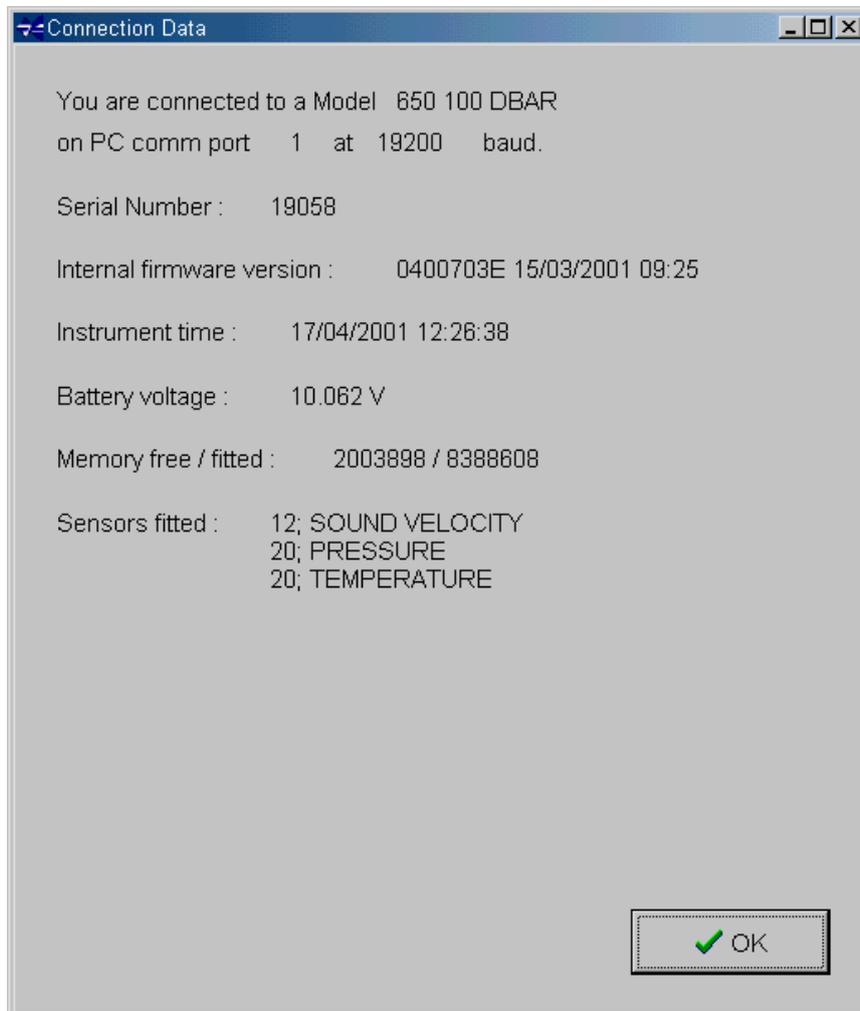
During operation, DataLog 400 will show the current status of the software at the bottom of the screen:



The left hand section shows the software status, the centre section shows the last response from the instrument, and the right hand section shows the PC date and time.

The Autobauding procedure by which the instrument detects which baud rate is being used may take up to 15 seconds to complete – please be patient while the software shows “Attempting to Communicate”. After the baud rate has been established, the instrument will send various pieces of information to the software, including Serial Number, type and number of sensors fitted, current sampling setup and so on. Again, this may take some seconds to complete, so please be patient!

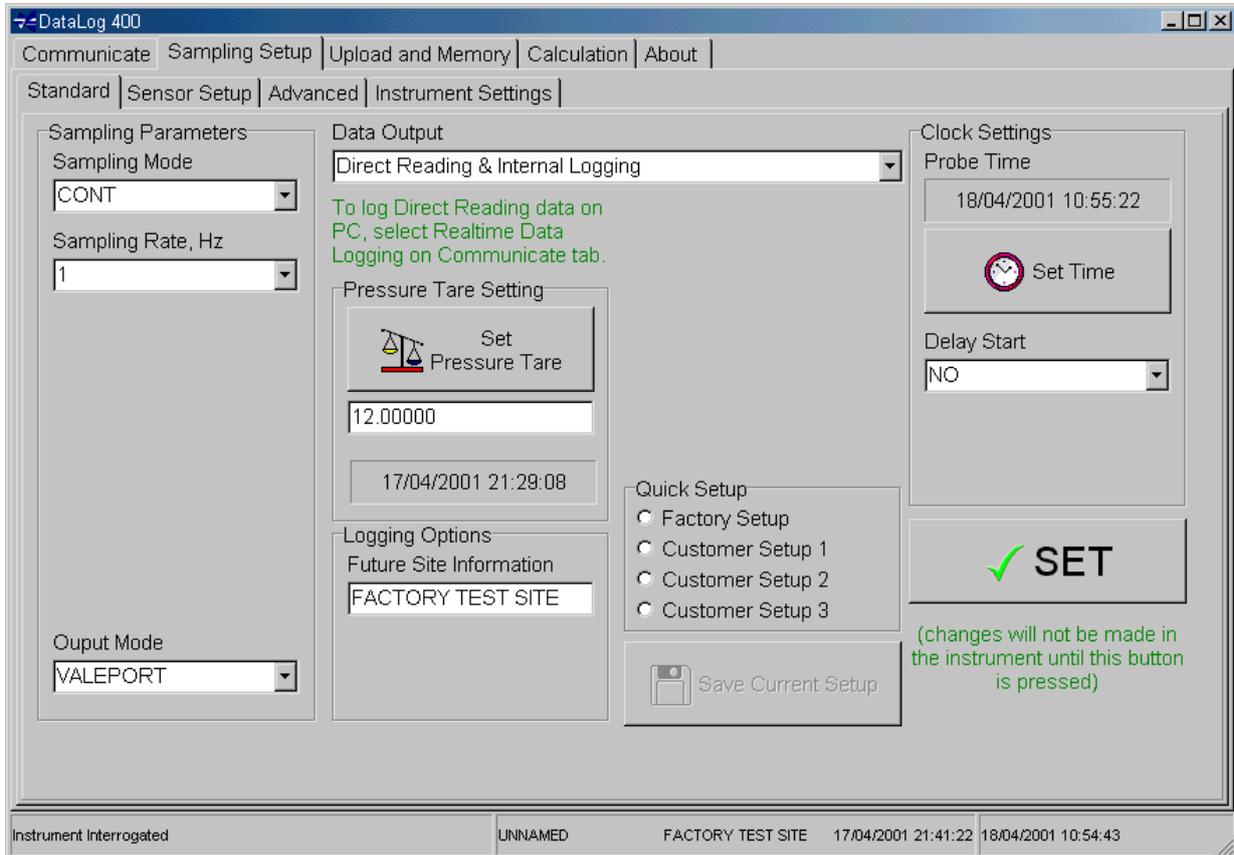
Once DataLog 400 has communicated with the instrument, an information screen appears detailing connection information, and basic sensor information such as serial number, code and name of all fitted sensors, and software version. To clear this screen, simply click on OK.



## 4 INSTRUMENT SETUP

Once the Connection Data screen has been cleared, the Sampling Setup page will appear.

The Sampling Setup tab allows the user to set the instrument's sampling regime. The MODUS SVS will allow six different sampling modes. There are four sub-menus, labelled Standard, Sensor Setup, Advanced and Instrument Settings.



### 4.1 STANDARD

This page gives access to all the basic setup functions required to control the instrument operation – The more advanced setup features are accessed through the Sensor Setup and Advanced tabs.

DataLog 400 will only allow the user to set sampling parameters relevant to the selected mode – for example, in continuous sampling mode (CONT, above), the user is not required to select an interval for BURST sampling, so that section is not displayed. Later pages explain the different sampling patterns available, and show the parameters which the user will need to set for each mode. However, there are some functions which apply to all sampling modes, and these are discussed first:

#### 4.1.1 SET BUTTON

Any parameters which are changed in this screen will not be sent to the instrument unless the SET button is pressed, with the exception of Pressure Tare Setting and Set Time.



If the user leaves this screen without confirming any changes with the SET button then the following warning will be displayed:



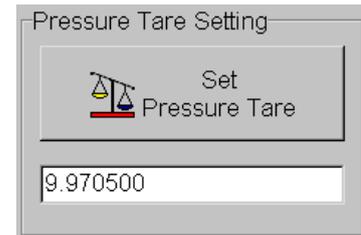
## 4.1.2 PRESSURE TARE SETTING

The user may wish to set a Pressure Tare value. In underwater instruments, pressure sensors are usually of the absolute type – that is to say, they measure the total pressure exerted on the transducer face, including atmospheric pressure.

It is often the case that the user wishes to disregard the atmospheric pressure, particularly in short term deployments where it is unlikely to change significantly over the deployment period. If this is the case, then a Tare value can be set. This is done by positioning the instrument at sea level, and taking a pressure reading. This reading is recorded in the instrument as being the atmospheric pressure at time of deployment, and may be subtracted from all subsequent pressure readings.

Press the Set Pressure Tare button to take a Pressure Tare reading. The current Pressure Tare value is indicated in the text box below the button.

Alternatively, the user may enter their own desired value for the Pressure Tare by simply typing in the text box and then clicking the Set Pressure Tare button. This is particularly useful for resetting the Tare value to zero.



Having taken a Pressure Tare reading, the user still has the choice of whether or not to actually subtract this value from the subsequent pressure readings, or just keep it as a record of the atmospheric pressure at time of deployment. Please refer to the Sensor Setup tab to confirm whether the Tare value should actually be used or not (Chapter 4.2.2)

### 4.1.3 QUICK SETUP

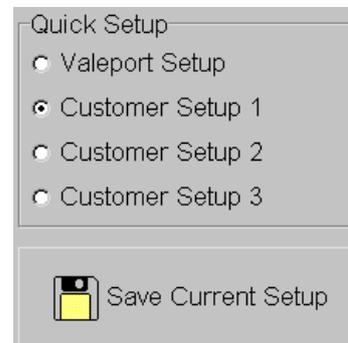
Many work schedules require that standard customer specified sampling regimes are used. To allow for this, DataLog 400 will store up to three such regimes, as well as Valeport's own factory default setup.

#### 4.1.3.1 SAVING A QUICK SETUP REGIME

Select one of the Customer Setup buttons as shown. Then setup the required sampling regime – note that all setup parameters are recorded, with the exception of the Pressure Tare value. When the screen shows the required sampling regime, click on the Save Current Setup button. The displayed setup will be recorded under whichever Customer Setup button is currently highlighted.

NB: Save Current Setup BEFORE using the SET button.

Note that the user cannot alter the Valeport Setup configuration.



#### 4.1.3.2 SELECTING A QUICK SETUP REGIME.

Simply select any of the four Quick Setup buttons. The screen will automatically display the saved Setup. Then simply click on the SET button to confirm.

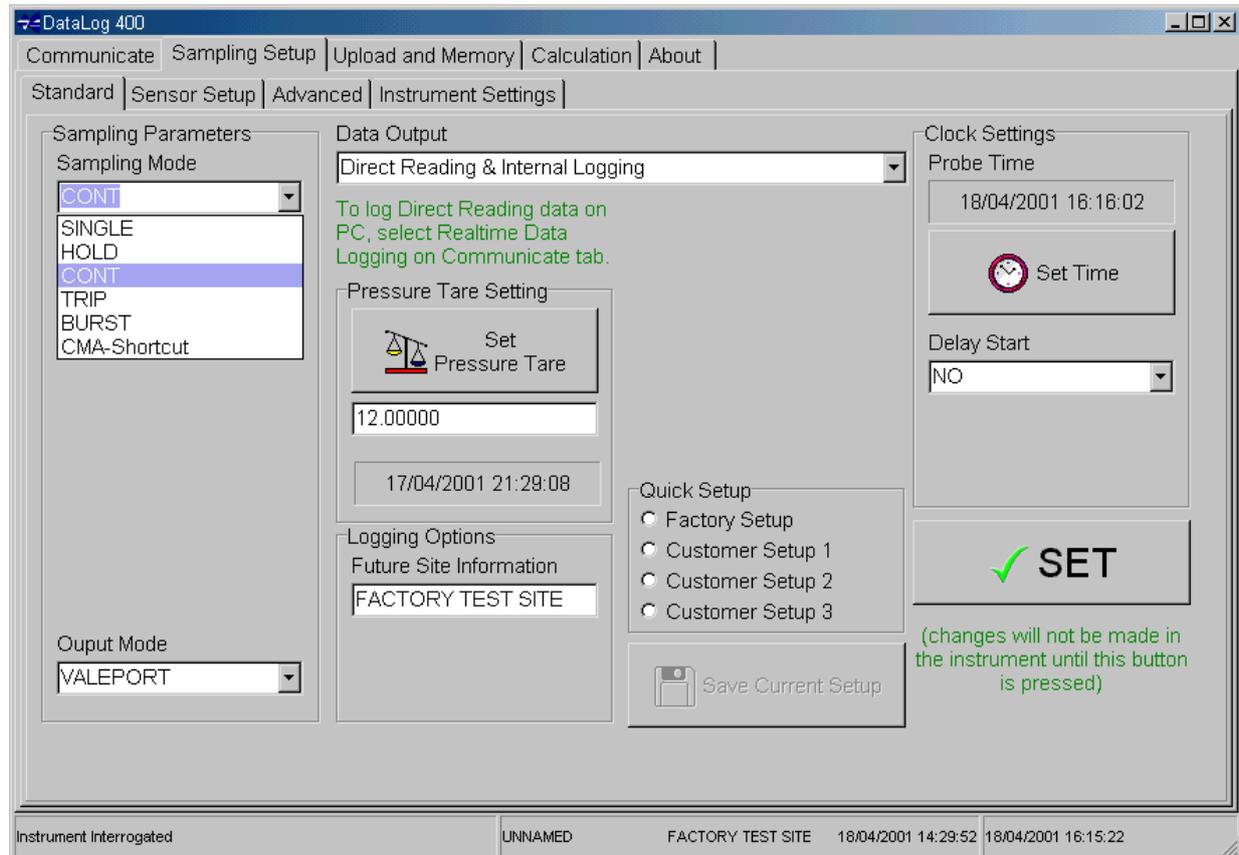
### 4.1.4 SAMPLING MODES & PATTERNS

The MODUS SVS has 6 different basic sampling modes. These are explained in detail over the next few pages.

One of the key features of the MODUS SVS (and indeed all other Valeport 400 Series instruments) is the synchronised sampling pattern. Most other similar products on the market (including older Valeport products) sample the fitted sensors in sequence – that is to say, the microprocessor samples data from Sensor 1, then Sensor 2, then Sensor 3 etc., before repeating the sequence. As technology advances, these sampling sequences are becoming more and more rapid, but they still result in non-synchronised data.

The Valeport system works differently. It sends a single command to all fitted sensors at exactly the same time, meaning that each sensor samples at exactly the same time. The microprocessor then collects data from the sensors to produce the full data record. This pattern is repeated up to 8 times per second, and the result is absolutely synchronised data. This synchronised sampling pattern is a feature of all the sampling modes available.

To select a sampling mode, simply highlight the required mode in the drop down menu under Sampling Parameters, as shown:



#### 4.1.4.1 SINGLE MODE

The Single sampling mode means that when the unit is set to Run, it takes a single measurement of all parameters fitted, and outputs the single data string in real time. This operation will happen every time the Run command is sent to the instrument (Run command is described in Chapter 5.1.3)

When using the Single mode, no other functions under the Sampling Parameters section are required, and are therefore not visible.

#### 4.1.4.2 HOLD MODE

Hold mode is similar to Single in that it will take a single set of measurements each time the Run command is used. However, the data is held in instrument RAM until requested by a separate command (Get Held Data command is described in Chapter 5.1.3.2).

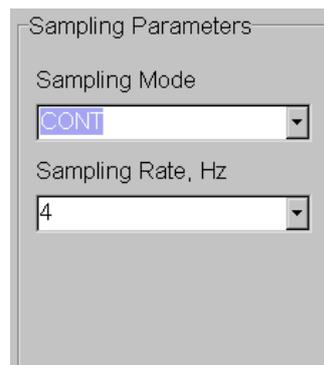
Again, no other functions need be set under Sampling Parameters.

In Hold mode, data is only available in real time. Data may, however, be recorded on PC as described in Chapter 5.2.1.

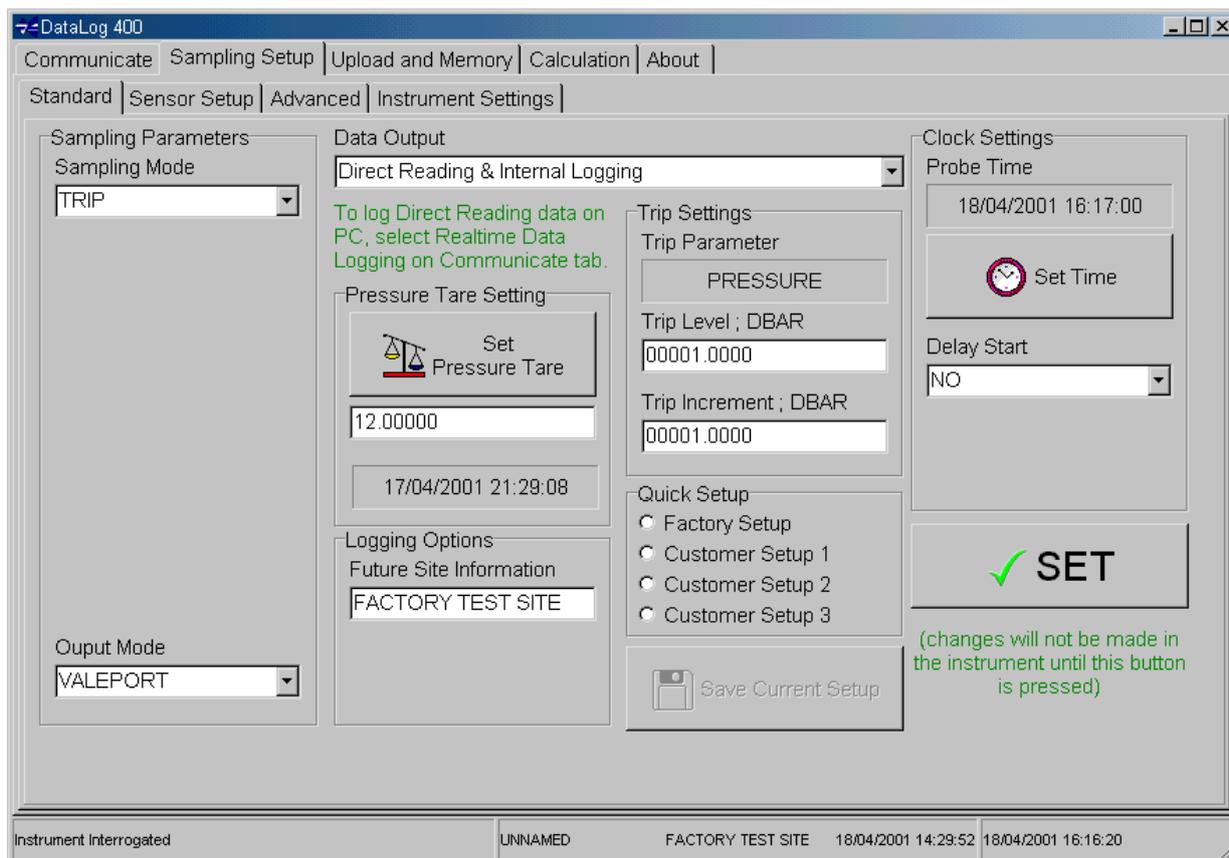
#### 4.1.4.3 CONTINUOUS MODE

Continuous Mode (CONT) causes the instrument to sample data at a fixed rate until it is interrupted, or power is removed. As can be seen, the user is also required to select the sampling rate.

All data is available in Real Time.



#### 4.1.4.4 TRIP MODE



Trip mode is an event triggered mode, typically used during profiling. In this mode, data will be sampled only once a trigger value on a chosen sensor has been reached, and then again at regular incremental changes of that parameter. A good example is using a Pressure Trip on a profile. The instrument may be set to monitor the Pressure sensor, and when the output reaches the Trip Level (i.e. the instrument reaches a certain depth), sampling will begin. Subsequent samples will then be taken every time the pressure changes (i.e. instrument descends or ascends) by the Trip Increment (maximum sampling rate is 8Hz).

When Trip mode is selected, a separate section of the screen will become visible, showing the Trip Parameter (Pressure in this case), Trip Level, and Trip Increment. In the above screen, the Trip Level is 12 dBar (approx 12m), and the Trip Increment is 0.25dBar (approx 0.25m). Note that the Trip Level takes account of any pressure tare that has been set.

The user should simply type the desired Trip Level and Trip Increment values in the text boxes.

Note that use of the Trip mode is not restricted to the Pressure Sensor, even though it is the most commonly used. Any sensor fitted to the instrument may be used as the Trip Parameter; the desired sensor may be selected in the Sensor Setup screen (Chapter 4.2).

#### 4.1.4.5 BURST MODE

Burst Mode offers the user the greatest flexibility in sampling setup. Generally speaking, the sampling programme causes the instrument to take a set number of samples at a chosen rate, then go into sleep mode for a defined period of time before waking up and repeating the sequence. The user may set the desired sampling rate, the number of samples in the burst, and the interval between bursts. In this way, the deployment time of the instrument may be greatly extended. Burst mode is particularly suitable for long term studies, where specific parameters do not change rapidly and overall trends are more significant.

Parameters that the user must set are therefore:

- Sample Rate** Select 1, 2, 4 or 8Hz from the drop down menu
- Period** This is the number of samples in the Burst (minimum 1). In this example, 20 samples at 4 Hz will take 5 seconds.
- Interval** This is how often a burst will occur, in seconds. Note that the instrument requires a minimum of 20 seconds between the end of one burst and the start of the next – DataLog 400 will not allow an interval less than this to be set. If the user tries to set a shorter interval than this, the minimum interval possible with the present Sampling Rate and Period will be entered automatically.
- Average Type** Finally, the user has a choice of three data averaging modes, which require further explanation:

When using Burst mode, the MODUS SVS is capable of calculating the mean value of data during a measurement burst, for each parameter fitted. The user has the following options:

- NONE** No data averaging is performed over the burst. The instrument will log and output every measurement made during the burst.
- FIXED** The instrument will wait until the end of the burst, and will then calculate the mean value of each parameter over the burst. If the burst is cut short by the user attempting to communicate with the instrument, then the average of that burst will be calculated as the mean of all measurements that were made.
- MOVING** The user can also create a Moving Average window. A new text box will appear asking the user to choose the moving average length required, which may be any number up to the number of samples in the burst. The instrument will log and output the mean value of the previous 'x' measurements made in the burst, where 'x' is the Moving Average length. The output will be updated with every sample until the end of the burst. For example, in the above screen, if a Moving Average length of 5 samples were set, the output would be as follows:

Sample No.	Output	Sample No.	Output
1	Mean of Sample 1	5	Mean of Samples 1,2,3,4,5
2	Mean of Samples 1,2	6	Mean of Samples 2,3,4,5,6
3	Mean of Samples 1,2,3	19	Mean of Samples 15,16,17,18,19
4	Mean of Samples 1,2,3,4	20	Mean of Samples 16,17,18,19,20

Finally, if either the Fixed or Moving Average option is selected, the instrument will also calculate the Standard Deviation of the data. This value will always be output in real time, but the user may decide that in order to conserve memory, it does not need to be logged.

#### 4.1.4.6 CMA (CONTINUOUS MOVING AVERAGE)

This mode is a specific configuration of the Burst mode, where data is output continuously. Users may wish to use this output instead of the standard Continuous mode if data averaging or Standard Deviation data is required.

The user is simply required to enter the Sample Rate (1,2,4 or 8Hz), and the length of the Moving Average window in samples.

In this mode, the instrument will run indefinitely, always outputting the mean of the last 'x' samples, where 'x' is the number of samples in the Moving Average window.

Note that a continuous moving average regime can be setup manually by the user using the Burst mode. This mode is simply a shortcut to such a setup.

Sampling Parameters

Sampling Mode  
CMA-Shortcut

Sampling Rate, Hz  
4

Moving Average, Samples  
5

Sampling Parameters

Sampling Mode  
BURST

Sampling Rate, Hz  
4

Period, No. of Samples  
4

Interval, Seconds  
1

Average Type  
MOVING

Moving Average, Samples  
5

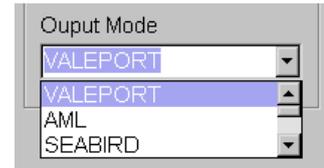
Note also that the instrument interprets CMA mode as a Burst mode. If an instrument is setup in CMA mode, the sampling regime will be recorded in the instrument as a Burst mode. This means that when the instrument is subsequently interrogated, the screen will show that the instrument is set in Burst mode, as shown left.

Note that the screen shows the key points for setting a Continuous Moving Average manually:

1. The sampling period must be the same as the sampling rate, giving a duration of 1 second.
2. The Sampling Interval must be set to 1 second.

## 4.1.5 OUTPUT MODE

A feature of the MODUS SVS is its ability to emulate data output formats of other manufacturer's sensors. This feature is included to allow the MODUS SVS to be easily swapped for existing sensors, and to give compatibility with third party loggers and instrumentation.



DataLog 400 is only capable of displaying data which is generated in Valeport's own output mode, but it may be used to setup the sensor in these other modes.

Available output modes, together with descriptions are below. Note that the MODUS SVS also has a separate mode for total emulation of an Applied Microsystems Ltd Smart Sensor, in which the instrument will respond to AML type commands as well as output data in that format. This mode is settable through a Terminal program such as Hyperterminal (section 5.2.3), and is distinct from the AML Output mode as set in this section, which only causes data to be output in AML mode, with all commands remaining as standard Valeport commands.

### 4.1.5.1 VALEPORT

This is the factory set Valeport output mode. Data output in this mode may be viewed by DataLog 400.

```
1484.401<space>M/SEC
1484.402<space>M/SEC
1484.401<space>M/SEC
```

Or, if pressure sensor fitted:

```
1484.401<space>M/SEC<space>0001.00<space>DBAR
1484.402<space>M/SEC<space>0001.10<space>DBAR
1484.401<space>M/SEC<space>0001.20<space>DBAR
```

If the unit is running in Burst sample mode, the output string will include the standard deviation after each parameter, as follows:

```
1484.401<space>M/SEC<space>0.001
1484.402<space>M/SEC<space>0.001
1484.401<space>M/SEC<space>0.002
```

Or, if pressure sensor fitted:

```
1484.401<space>M/SEC<space>0.001<space>0001.00<space>DBAR<space>0.050
1484.402<space>M/SEC<space>0.001<space>0001.10<space>DBAR<space>0.061
1484.401<space>M/SEC<space>0.002<space>0001.20<space>DBAR<space>0.042
```

#### 4.1.5.2 AML

The data is output in the format of the Applied Microsystems Ltd “Smart Sensor”, as a six-digit number. Sound velocity is in metres / second expressed as the following format: XXXX.XX followed by a carriage return and line feed:

```
1503.21
1503.25
1503.26
```

#### 4.1.5.3 CSV

CSV output (Comma Separated Variable) is:

```
mm/dd/yy, hh:mm:ss, VVVV.V,D.D,TT.T
```

VVVV.V is the sound velocity data, D.D is the measurement depth for each record, and TT.T is the unit temperature. Since this format is a simulation of a standard output, temperature must be included in the string. However, the Modus SVS contains no temperature sensor, so this value is fixed at 00.0.

A typical output would therefore look like:

```
04/20/00, 15:36:20, 1506.2,2.0,00.0
04/20/00, 15:36:20, 1506.3,2.5,00.0
04/20/00, 15:36:21, 1506.2,3.0,00.0
04/20/00, 15:36:21, 1506.1,3.5,00.0
```

#### 4.1.5.4 SVP16

This configuration outputs the data in the same format as the Applied Microsystems Ltd SVP16 Sound Velocity Profiler.

```
“CALC, DBxxxx, 09/16/99, 1, Meters”
OHSI Sound Velocity Profiler S/N DBxxxx
Date: 99259 Time: 1133
Depth Offset (M): 0
Depth (M) Velocity (M/S) Temp (C)
1.5 1503.0 8.5
2.0 1504.2 9.0
2.5 1504.4 9.0
```

xxxx signifies the serial number of the instrument. In the first line of the header, the date format is mm/dd/yy, and in the third line of the header it is yyddd, where ddd is the Julian day.

The header is included at the start of the output to allow the data to be compatible with certain third party devices.

#### 4.1.5.5 NMEA

This output string complies with the sentence structure of the NMEA standard for manufacturers proprietary strings.

```
$PSSV, 1503.0, 1.5,M*54 (for Units = Meters)
$PSSV, 4860.0, 4.0,F*52 (for Units = feet)
```

The "\$" character denotes start of sentence.

"P" Proprietary sentence ID

"SSV" Manufacturer's mnemonic code

"," The comma delimiter character starts each field except address and checksum

<ccc> Velocity, Depth, Measurement units data fields

"\*" Checksum delimiter

<Checksum field> The absolute value calculated by exclusive-OR'ing the 8 data bits of each character in the sentence between, but not including the "\$" and "\*".

<CR><LF> End of sentence

#### 4.1.5.6 WESTGEO

This sentence complies with the requirements of the current WG-1100 velocimeter output string.

```
634 01503
635 01503
636 01504
```

The string is composed of a 3-digit sequential event number, followed by a space, and then 5 characters of velocity data. Each record is delimited by a <CR><LF>.

#### 4.1.5.7 HYPACK

Selection of the Hypack SV Format causes the sensor to output a header: FTP New followed by the cast data in two columns (depth velocity). All readings are in meters.

```
FTP New
002.5 1500.0
003.0 1503.1
003.5 1503.2
```

#### 4.1.5.8 SEABIRD

The MODUS SVS can also output data in the format of a Seabird CTD probe. The data has no header information.

```
<LF><tab>TTT.TTTT,CC.CCCCC,PPPP.PPP,SSSS.SSSS,VVVVV.VVV<CR>
```

where,

TTT.TTTT = Temperature in Celsius

CC.CCCCC = Conductivity Siemens per meter

PPPP.PPP = Pressure in Decibars

SSSS.SSSS = Salinity in Parts per Thousand

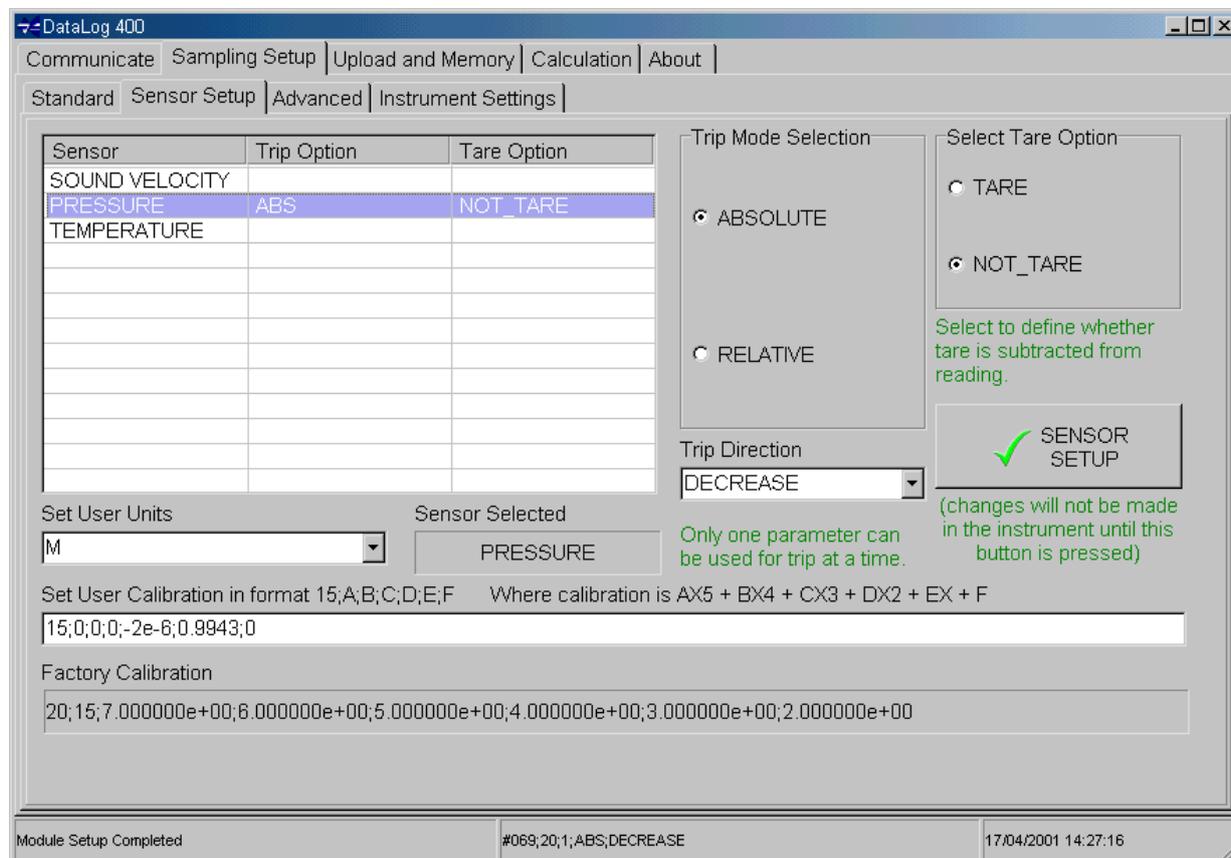
VVVVV.VVV = Sound Velocity in Meter per second

Parameters which are not measured by the SoundBar are output as zeros.

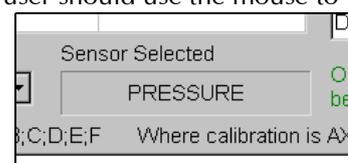
**Note that DataLog 400 is not able to display data in formats other than Valeport format.**

## 4.2 SENSOR SETUP

The Sensor Setup screen gives the user access to certain controls that are applicable to individual sensors rather than the instrument as a whole. For example, the user may add their own calibration and units to any particular sensor, and control whether the pressure sensor is to be subjected to the Pressure Tare value (See Chapter 4.1.2)



The screen shows a table listing all the sensors fitted to the instrument. The user should use the mouse to highlight the sensor of interest – the chosen sensor will be displayed in the text box in the centre of the screen. Once selected, the user may alter the setup of that particular sensor, as detailed on the following page:



If the user makes any changes to an individual sensor setup, these changes must be confirmed by clicking on the Sensor Setup button. This button must be pressed for each sensor – if a second sensor is selected before this button is pressed, then the changes to the first sensor will not be sent to the instrument. A warning message will confirm this.



## 4.2.1 TRIP MODE

As described in Chapter 4.1.4.4, the MODUS SVS can be programmed to operate in a TRIP mode, where regular changes in output from a particular parameter will cause data to be sampled. There are two types of trip mode, Absolute and Relative:

**Absolute** This should be used where the selected parameter will be changing from zero (or another known value), for example, a pressure based profile through the water column. The pressure sensor will be reading zero at sea level, and the output will increase as the instrument is lowered through the water column. Also, the user is able to select whether the Trip Level will be reached as data Increases or Decreases. Select the required direction using the drop down menu. For standard pressure profile, the Direction should be set to INCREASE.

**Relative** This should be used where the initial value of the Trip parameter is unknown. For example, the user may wish to take a reading whenever the temperature of the water changes by 0.1°C. However, the temperature of the water will not be known until the instrument begins sampling. The relative trip function will therefore use the first measurement as its baseline, and refer the trip increment to this initial reading. Neither Trip Direction nor Trip Level (standard setup screen) are required if RELATIVE trip mode is set, and are therefore not visible.

The screenshot shows a control panel titled 'Trip Mode Selection'. It contains two radio buttons: 'ABSOLUTE' (which is selected) and 'RELATIVE'. Below these is a dropdown menu labeled 'Trip Direction' with 'INCREASE' selected.

Note that only one parameter may be selected for use as a Trip sensor – as soon as another sensor has a Trip mode assigned to it, the currently selected Trip Sensor will cease to be so.

## 4.2.2 TARE OPTION

As mentioned previously the user has the option to decide whether or not the pressure sensor is subjected to the Pressure Tare value. The pressure sensor will show either TARE or NOT\_TARE in the right hand column. To change this, simply highlight the sensor, and select either TARE or NOT\_TARE in the section at the right hand side of the screen. Note that this section of the screen is only visibly when the Pressure sensor is selected.

The screenshot shows a control panel titled 'Select Tare Option'. It contains two radio buttons: 'TARE' and 'NOT\_TARE' (which is selected). Below these is a green text instruction: 'Select to define whether tare is subtracted from reading.'

### 4.2.3 USER CALIBRATION

Data from all sensors on the MODUS SVS is output in calibrated format – however, the calibrations are factory set. If the user wishes to input their own calibration data, or even change the units in which the data is presented, this can be done by means of a secondary calibration (or USER calibration).

To enter the new required units, simply type into the Set User Units text box (all characters will be stored in CAPITALS).

The new calibration string must be entered in a specific format. First of all, the user must determine the equation that will convert the standard output format into the desired units. A good example is converting pressure data in deciBar (DBAR) into data in metres. This can be performed to a good level of approximation by a quadratic equation:

$$y = 2 * 10^{-6} x^2 + 0.9943x$$

The instrument will accept up to a fifth order polynomial equation as a secondary calibration:

$$y = ax^5 + bx^4 + cx^3 + dx^2 + ex + f$$

The calibration string must be entered in the format

15;a;b;c;d;e;f

The format of the secondary calibration string for converting deciBars to metres is therefore:

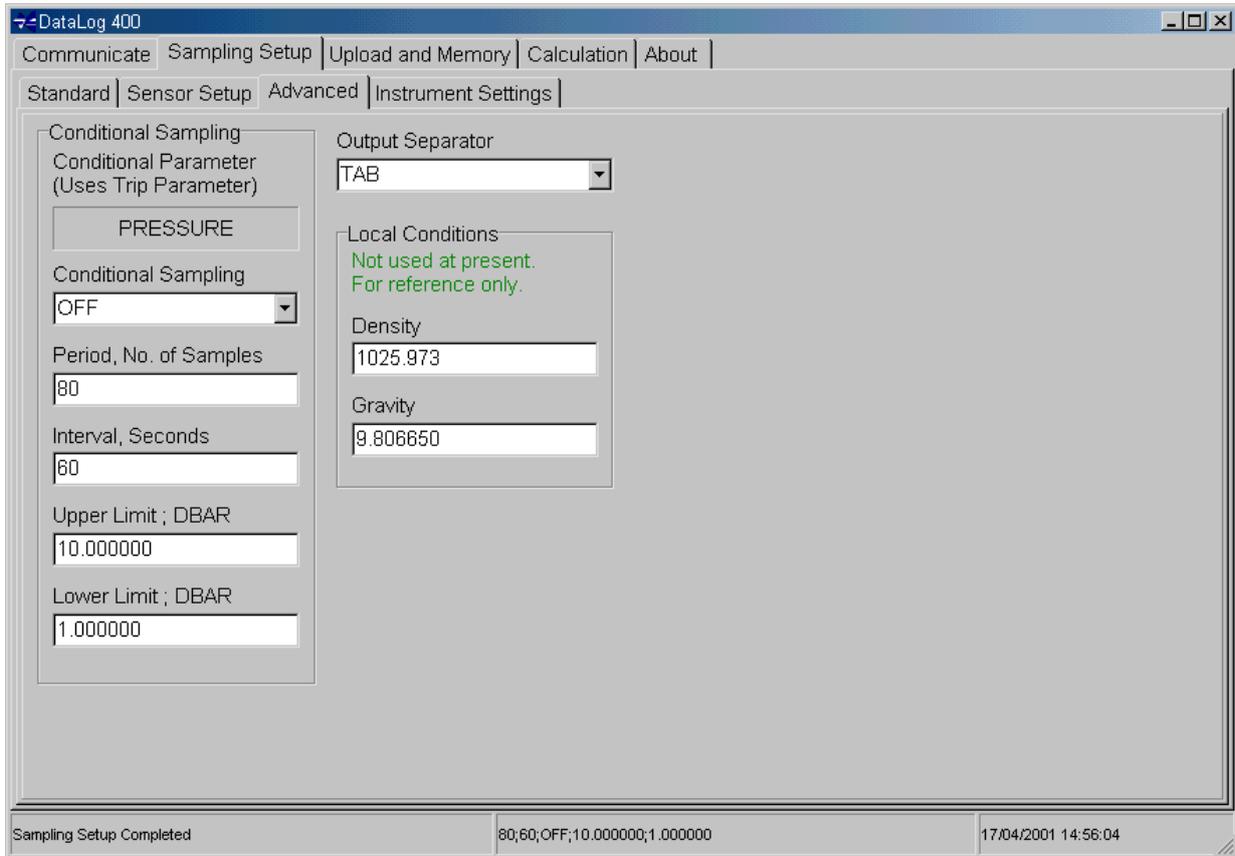
15;0;0;0;2e-6;0.9943;0

**NB:** The initial figure 15 indicates to the instrument that the following information is a calibration string. It must be included in the string. Note that the separators are all semi-colons (;). The instrument assumes that all equations are fifth order polynomials – blank values must therefore be padded out with zeros.

Since data from Pressure sensors is often required in metres or feet, these secondary calibrations are included as options in a pull down menu (visible only when selected sensor is a Pressure sensor).

## 4.3 ADVANCED

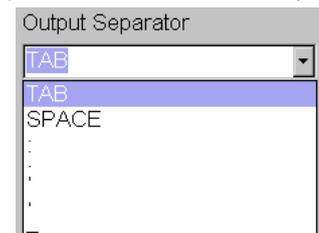
The Advanced page of the Sampling Setup tab is laid out as shown. **Note that any changes made in this page must be confirmed by using the Set button in the Standard page:**



### 4.3.1 OUTPUT SEPARATOR

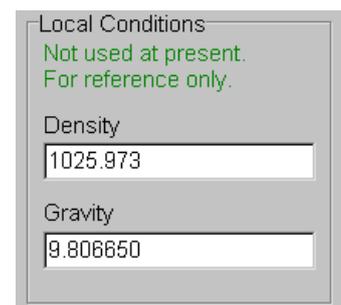
The standard data strings from the MODUS SVS are output in the format of tab separated data, that is to say each data value is separated from the next by a TAB. However, the user may wish to use an alternative separator so that data is compatible with other systems. A choice of separators is available, selectable from the drop down menu. Choose between:

- TAB
- SPACE
- : (colon)
- ; (semi-colon)
- , (comma)
- \_ (underbar)



### 4.3.2 LOCAL CONDITIONS

These values are included for reference only, and are not included in any onboard calculations. The Gravity value shown is the local Gravity at Valeport's premises in m/s<sup>2</sup>. The Density value is the Density of Standard Seawater at 35 Salinity and 15°C. The user may alter these values if required by simply typing in the text boxes.



## 5 RUNNING THE INSTRUMENT

Once the user has set the instrument up as required, the instrument may be set into Run mode. There are two methods of doing this:

### 5.1 SOFTWARE SWITCH ON

#### 5.1.1 METHOD 1

If the user is confident of the current instrument settings, and wishes to Run the instrument whilst it is connected to PC, then the Run button may be pressed as soon as DataLog 400 is opened. The software will communicate with the instrument automatically, in order to determine which sensors are fitted, and in which mode the instrument is set up.

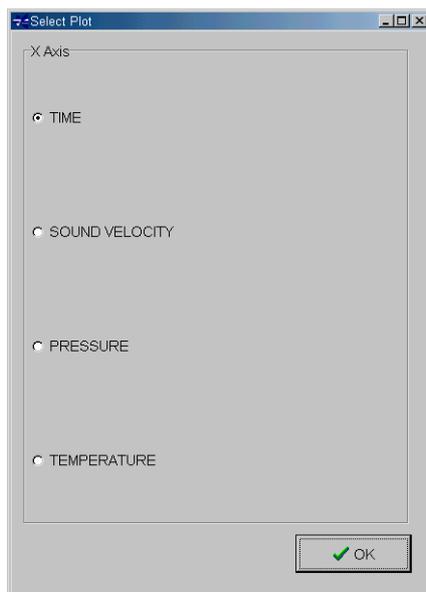
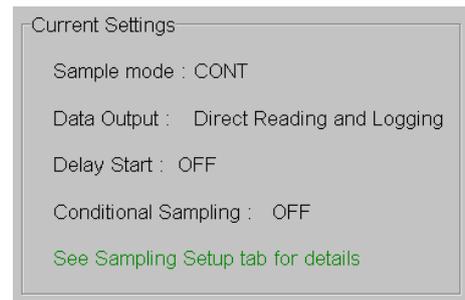


#### 5.1.2 METHOD 2

If the user has used the Interrupt button to communicate with the instrument, and subsequently viewed and/or Set the sampling regime, then the Communicate tab should be selected to allow access to the Run button.

#### 5.1.3 RUN

Note that once DataLog 400 has established communications with the instrument, a separate section will become visible in the Communicate screen, indicating some brief details about the current setup. Users will only notice this once they press the Run button, or when they return to the Communicate screen after Setup.



As soon as the instrument is set into Run mode, DataLog 400 will display this screen. The graphical display facility within the software can plot any of the parameters against any of the other parameters on the x axis, or against time. The user is required to select which parameter should be used as the x axis before any data viewing is possible. Then click on OK to proceed.

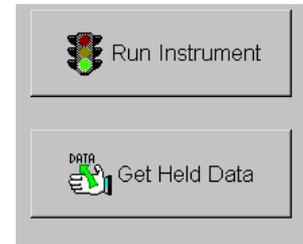
What happens next depends on the sampling mode that has been selected:

### Single Mode

Display screens will be updated every time the Run button is pressed.

### Hold Mode

If the instrument is set in Hold mode, a new button will be shown on the Communicate screen, just under the Run button. As with Single mode, data is available for display in all screens, but update will occur every time the Get Held Data button is pressed. The sequence of operation should therefore be Run button, Get Held Data button, Run button, Get Held Data button, etc.



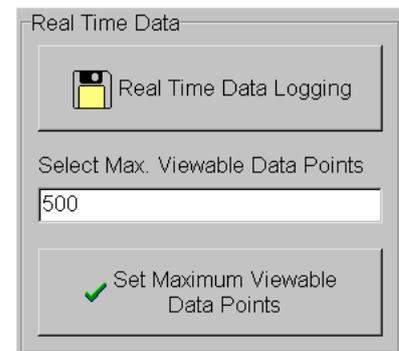
### All Other Modes

Display screens will be updated automatically as data is received

All display screens will be available under separate tabs – to view data, simply click on the desired tab. Refer to Chapter 7 for a description of each screen.

## 5.2 REAL TIME DATA

From the opening screen of DataLog 400, the user will have been aware of a section titled “Real Time Data”. This section has two functions – allowing the recording of real time data to disk as it is received, and limiting the amount of data that will be displayed at any one time.



### 5.2.1 REAL TIME DATA LOGGING

All data is received in real time in ASCII text format. This data may be logged as a text file for subsequent viewing within DataLog 400, or for importing into another software package.

To record real time data as it is received, simply click on the Real time Data Logging button:

A standard Windows type dialogue box will be shown, asking the user to enter a file name under which to save the data. The default extension is \*.txt. Once the user clicks on OK, all data received will be added to this file, until the instrument is stopped.

Note that the software will allow existing files to be overwritten. However, the immediately previous contents of any overwritten file will be stored as another text file titled \*.bak.

### 5.2.2 SELECT MAX VIEWABLE DATA POINTS

This feature has been included to prevent the potentially large amounts of incoming data from adversely affecting PC performance. As each line of data is received through the PC comm port, it is held in PC RAM, and also added to the Scroll and Plot display pages (each of which also uses PC RAM). On the Plot page particularly, some older, slower PC's may struggle to cope with plotting these large amounts of data.

The Real Time Data feature therefore allows the user to set the maximum number of data lines that will be viewable in the graphical display of DataLog 400. Once this limit is reached, the oldest data will be removed, so that only the most recent data points are visible. To choose the required number of visible data points, simply type into the text box, and click the Set button.

---

Note that the number of lines of data in the Scroll screen is automatically set to 16360. Again, once full, the oldest data will be removed.

### 5.2.3 AML EMULATION MODE

The MODUS SVS has an alternative operating mode, where it exactly emulates an Applied Microsystems Ltd Smart Sensor. In this mode, the Modus SVS will only respond to AML type commands, which are listed in Appendix 1.

To operate in this mode, enter the command #012;AML<cr>

Note: the instrument will now only respond to the AML codes listed on page 49.

To return to Valeport operating mode, the Modus SVS will respond to the command VALE<cr>

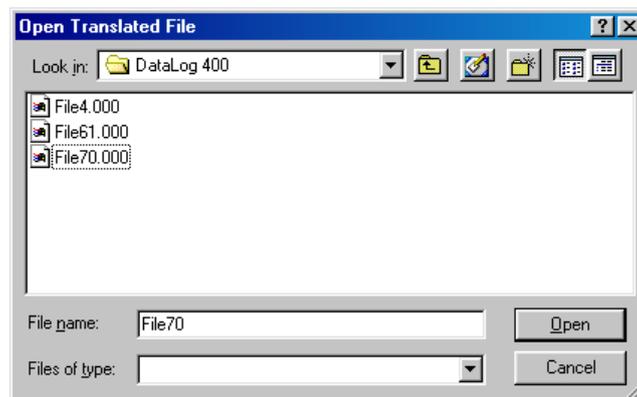
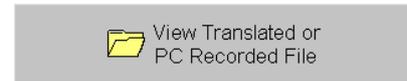
Note: the instrument will now only respond to the Valeport codes listed on page 48 & 49

## 6 DATA VIEWING

DataLog 400 offers three different display modes. All are available for both real time data and for files that have been saved.

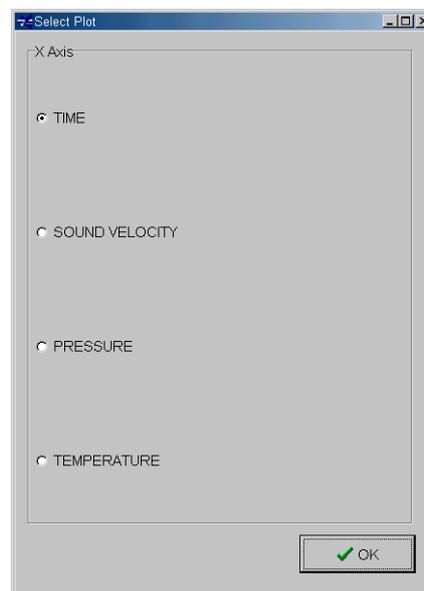
### 6.1 OPENING STORED DATA FILES

Stored data files may be opened by clicking on this button in the Communicate screen. The following dialogue box will appear, asking the user to select which file to open. Note that only one file may be opened at a time.



Files containing data that have been stored from a real time input will have the extension .txt, as described in Chapter 5.2.1.

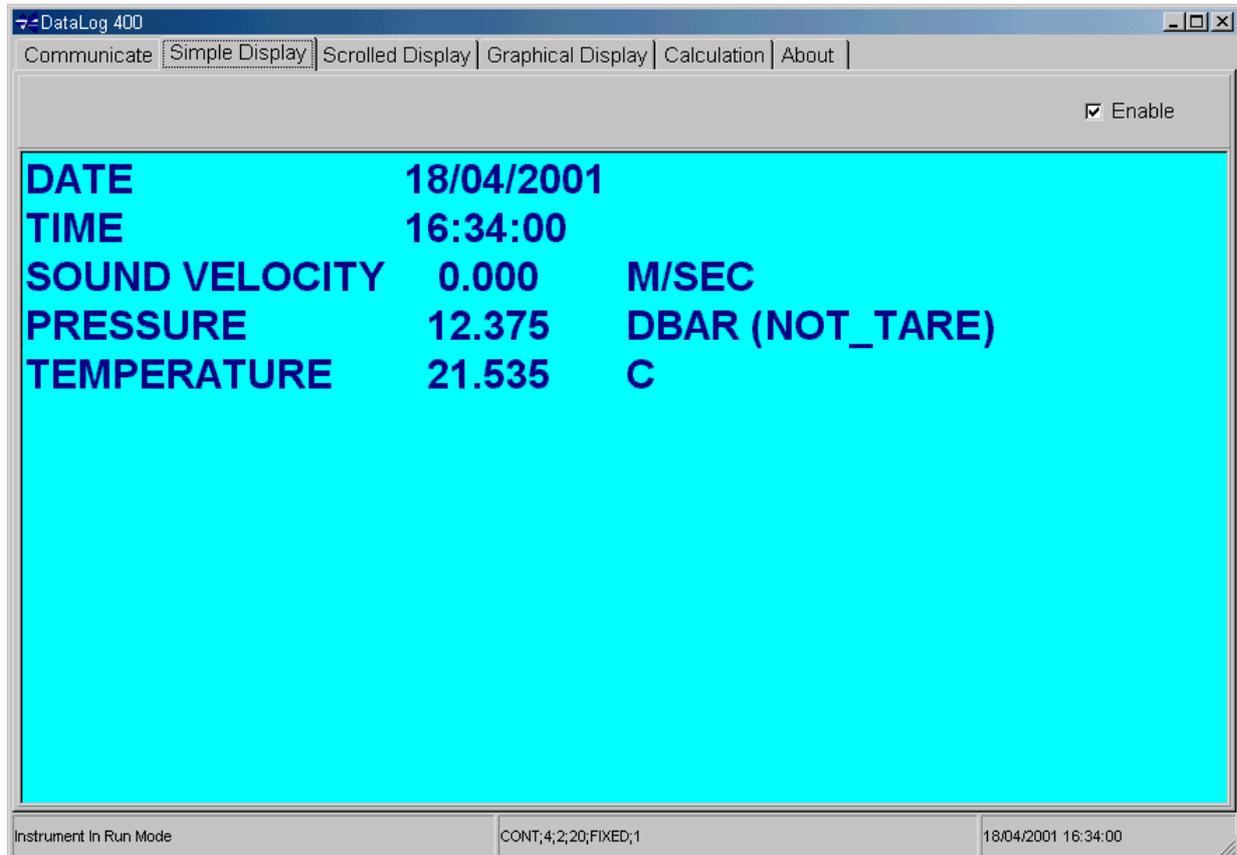
Once the desired file has been selected, click on the Open button. As with viewing data in real time, the user will be asked which parameter to use as the x axis in graphical displays. Select the required parameter, and click on OK.



## 6.2 SIMPLE DISPLAY

The simple display is designed primarily for real time use. It is available for use with uploaded data files, but will simply display each data point in turn as it is read from memory, and then fix on the final data recorded in the file.

The function of the simple display is to provide the user with a readout of the last set of data received by the PC.



The display gives the date and time of the last data point, and then the last output of each fitted parameter. In Burst modes, the standard deviation of the data is also given.

Note the check box at the top right corner of the screen – while this is checked, the screen will continue to be updated. Some older PCs may struggle to update all displays at fast data rates, so disabling unwanted displays may help. To disable the display, simply uncheck the box. To re-enable, re-check the box – the next data point received will be displayed as normal.

## 6.3 SCROLL DISPLAY

The scroll display provides the user with a record of all data received by the software (subject to the maximum number of lines, 16360).

The screen shows the date and time at the left-hand side, followed by data from each fitted parameter. Again, if in Burst mode, standard deviation data will be included.

DATE	TIME	SOUND VELOCITY; M/SEC	PRESSURE; DBAR (NOT_TARE)	TEMPERATURE; C
18/04/2001	16:38:09	0.000	12.375	21.498
18/04/2001	16:38:08	0.000	12.375	21.498
18/04/2001	16:38:08	0.000	12.375	21.499
18/04/2001	16:38:08	0.000	12.375	21.498
18/04/2001	16:38:08	0.000	12.250	21.498
18/04/2001	16:38:07	0.000	12.375	21.499
18/04/2001	16:38:07	0.000	12.375	21.499
18/04/2001	16:38:07	0.000	12.375	21.498
18/04/2001	16:38:07	0.000	12.375	21.499
18/04/2001	16:38:06	0.000	12.375	21.499
18/04/2001	16:38:06	0.000	12.250	21.499
18/04/2001	16:38:06	0.000	12.375	21.500
18/04/2001	16:38:06	0.000	12.250	21.500
18/04/2001	16:38:05	0.000	12.250	21.499
18/04/2001	16:38:05	0.000	12.250	21.499
18/04/2001	16:38:05	0.000	12.250	21.500
18/04/2001	16:38:04	0.000	12.250	21.500
18/04/2001	16:38:04	0.000	12.250	21.500
18/04/2001	16:38:04	0.000	12.250	21.500
18/04/2001	16:38:04	0.000	12.250	21.500
18/04/2001	16:38:04	0.000	12.375	21.500

Note that the columns of data are sizeable, after the first two lines of data have been received. Simply position the mouse over the edge of a column title, and use the left mouse button to drag the column to a suitable size.

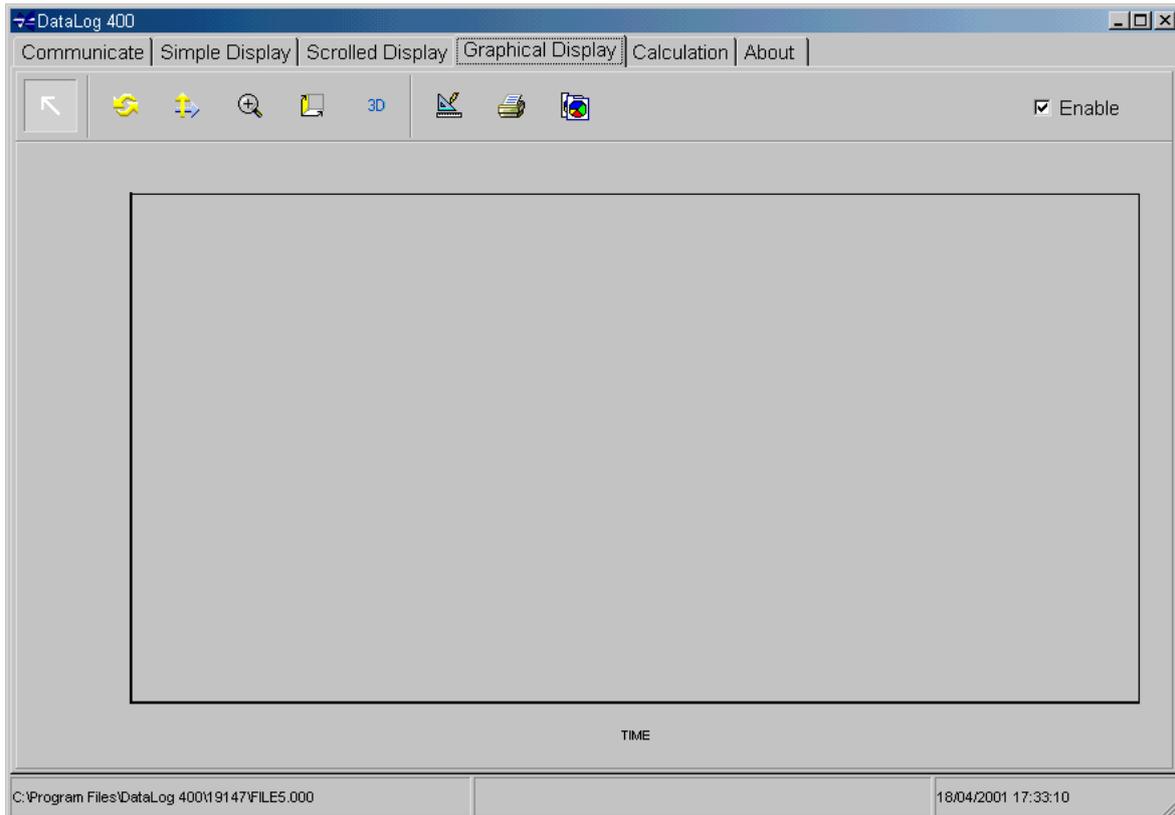
As with the Simple display, this screen can be disabled by unchecking the Enable check box at the top right corner. Re-checking the box re-enables the display, and data will continue to be added when the next data line is received.

## 6.4 GRAPHICAL DISPLAY

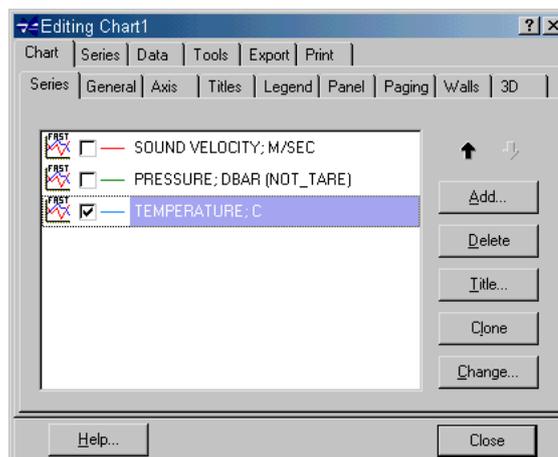
The graphical display facility in DataLog 400 is an integral feature of the Delphi programming language in which DataLog 400 is written. Consequently, there are many features of this display type that are beyond what is absolutely necessary for functional data display. Such features include adding a picture to the background of the graph, and changing the size of the border around the image.

This manual does not cover the majority of these features, but instead concentrates on those features that are necessary to enable standard data displays. Users familiar with standard Windows functions and common programmes such as Microsoft Excel will be able to customise their graphical displays as they wish, simply by exploring the many features available.

When the user first views the graphical display, they will be presented with a blank page:



All graph functions are controlled with the various buttons at the top of the screen. The first button to use is the Graph Edit button – this allows the user to decide which parameters are to be graphed, and in which format. Clicking on this button reveals the following screen:



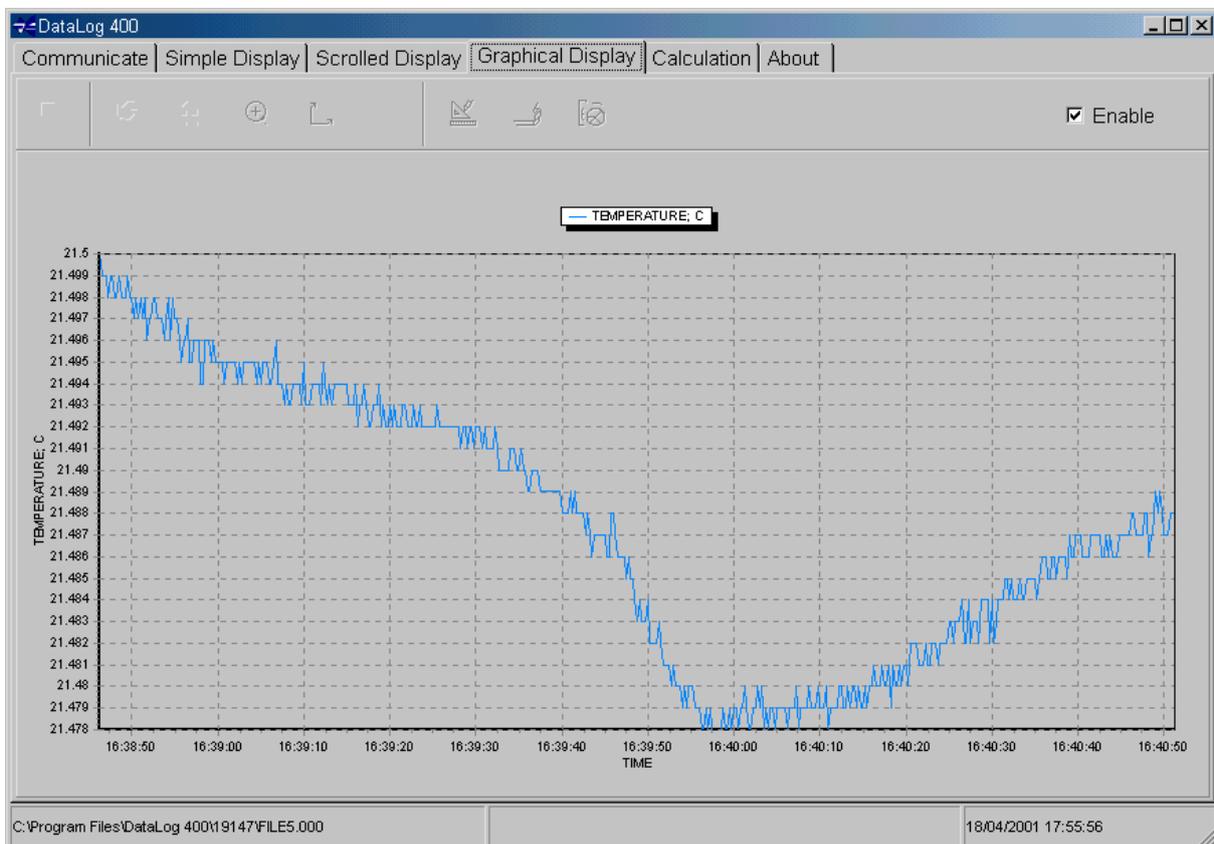
All the fitted parameters are shown as being available for graphing against time. Simply click on the check box against each parameter to indicate whether it is to be graphed or not.

To alter the colour of any parameter, simply double click on the coloured line adjacent to each parameter, and select from the variety of available colours. Further modifications to line style can be made by selecting the upper Series tab, followed by Format, and the Border button.

Finally, users may double click on the icon to the left of each parameter to alter the graph type. DataLog 400 is best able to display data at rapid rates using the “Fast Line” style, which is the default. However, users may wish to select other styles to suit their own preference.

As can be seen from the screen on the previous page, there are several other tabs available to alter the appearance of the graph. This manual does not cover all these options, but be assured that DataLog 400 will revert to its default style if closed down and reopened.

The example screen below shows only a single parameter checked for display, simply for reasons of clarity. Note that secondary y axes will appear for each parameter checked, and each will autoscale to show the full range of data. The scale may be manually set under the Chart, Axis, Scale tab. The x axis will also autoscale as new data is received, and will then slide as the maximum number of viewable data points is reached (Chapter 5.2.2).



Note that once the graph has been set up, the function buttons are inactivated and greyed out. This inactivation is simply to conserve PC RAM for data display, and the buttons may be reactivated simply by clicking on the toolbar.

The functions of the other buttons are as follows:



Clicking on this button will allow the user to print the graph. A preview page is shown, allowing the user to alter page size, margin size and printer. Simply press Print when the page is shown as required.



This button copies the graph as currently displayed to the PC clipboard, for import into other programs as a bitmap.

The remainder of the icons on the graphical display page allow the user to control certain features of the graph using the mouse.

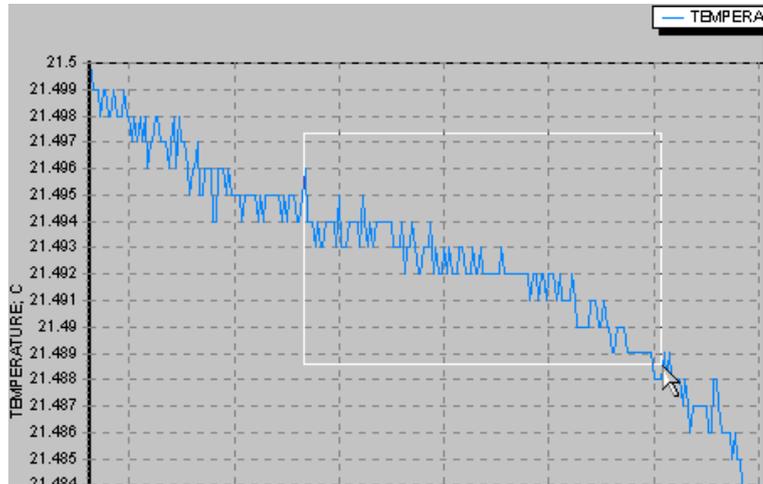


### 6.4.1 SCROLL & FOCUS

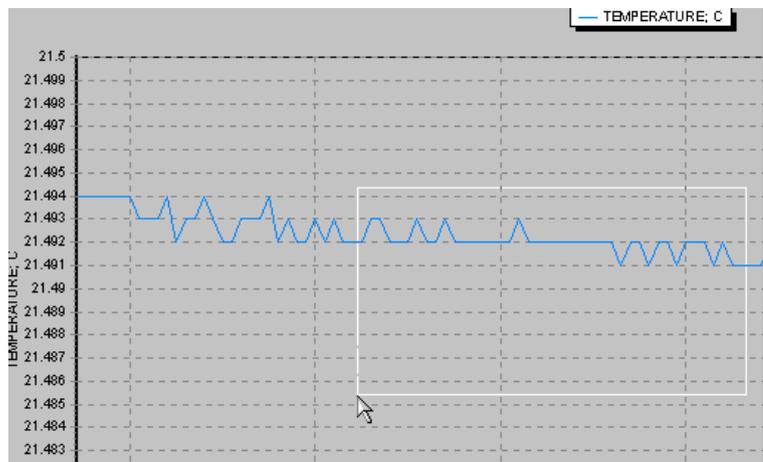


The first icon (default icon when the screen opens) gives the mouse two functions. By holding down the right mouse button, it is possible to scroll both axes of the graph, simply by dragging the mouse in the appropriate direction.

By holding down the left button, the user may focus onto a particular section of the graph. Simply drag and draw a box over the required section of data, starting at the top left corner.



To focus out again, drag and draw a box on the graph starting at any other corner.



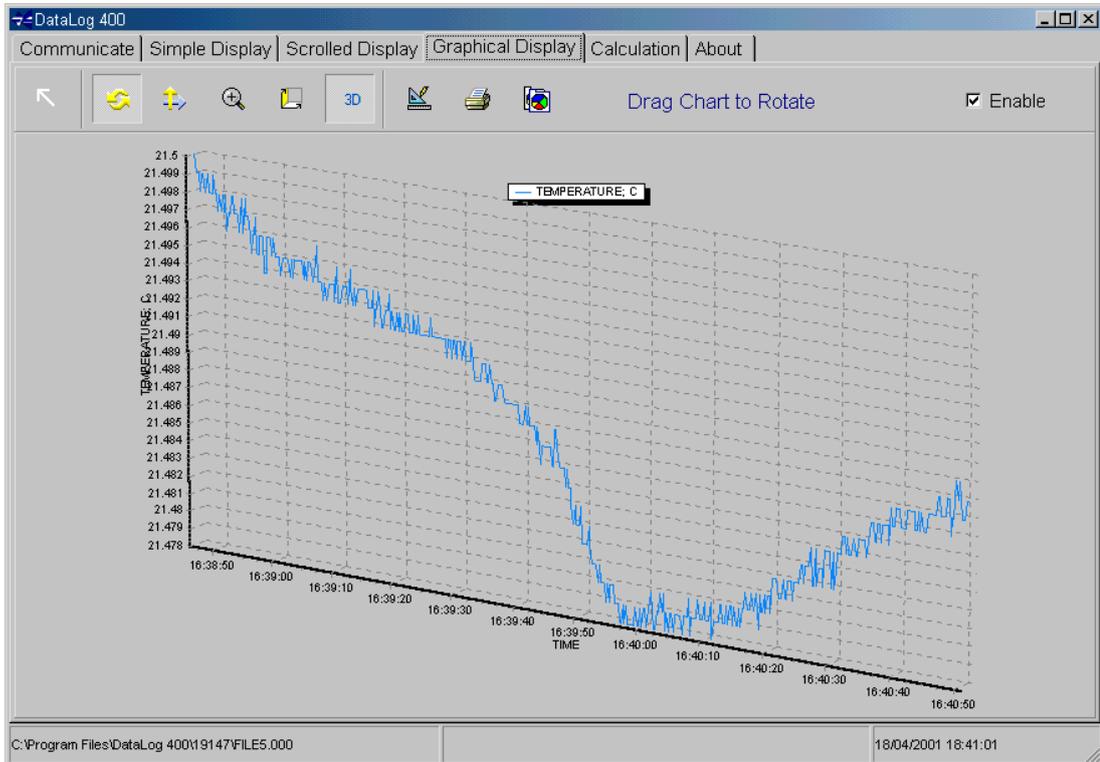
The remaining icons alter the 3 dimensional properties of the graphical display. If any are selected, the graph will automatically switch into 3D mode, but at any time, 3D mode can be toggled on and off by using the 3D button.



## 6.4.2 ROTATE



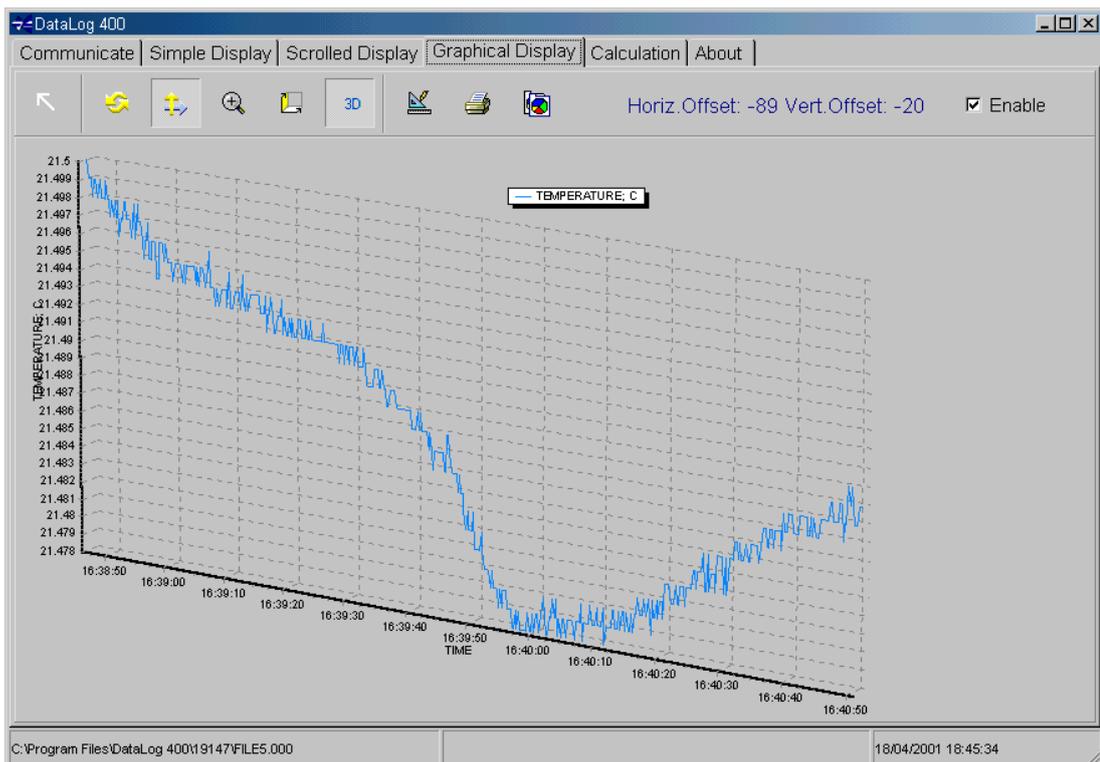
This icon allows the user to rotate the graph so that it may be viewed from any position either above or to the right of the current perspective. Simply use the left mouse button to drag the graph to the desired orientation.



## 6.4.3 MOVE



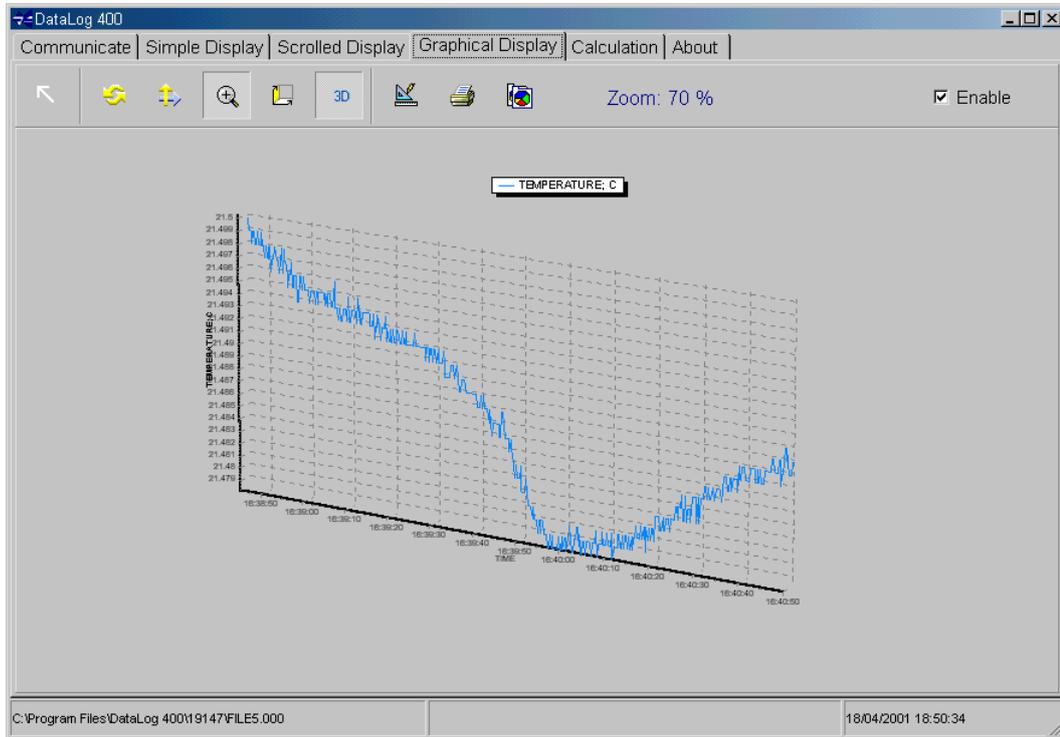
This icon allows the user to alter the position of the graph on the page. Use the left mouse button to drag the graph around the page to the desired position. This picture shows the graph moved to the left hand side of the screen.



### 6.4.4 ZOOM



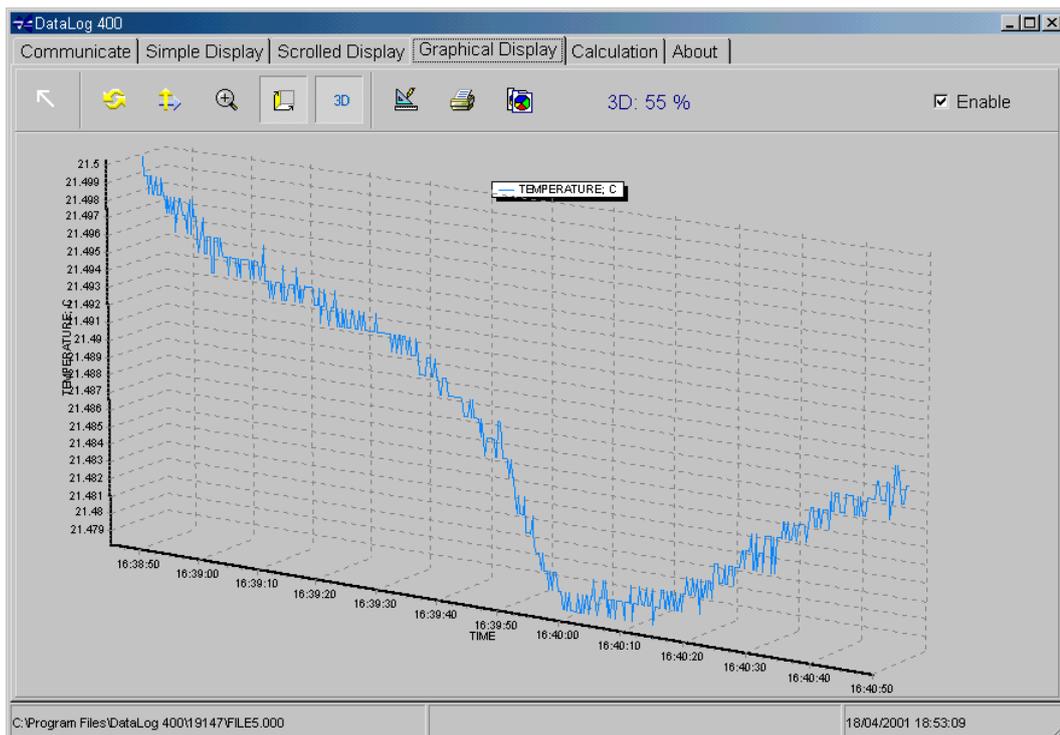
As can be guessed from the icon, this button allows the graph to be zoomed in or out. Holding down the left mouse button, drag the mouse upwards to zoom in, or downwards to zoom out. This picture shows the graph zoomed out:



### 6.4.5 DEPTH



This button controls the three dimensional depth of the graph. It is best seen in graphs that have been rotated to view from a different perspective.



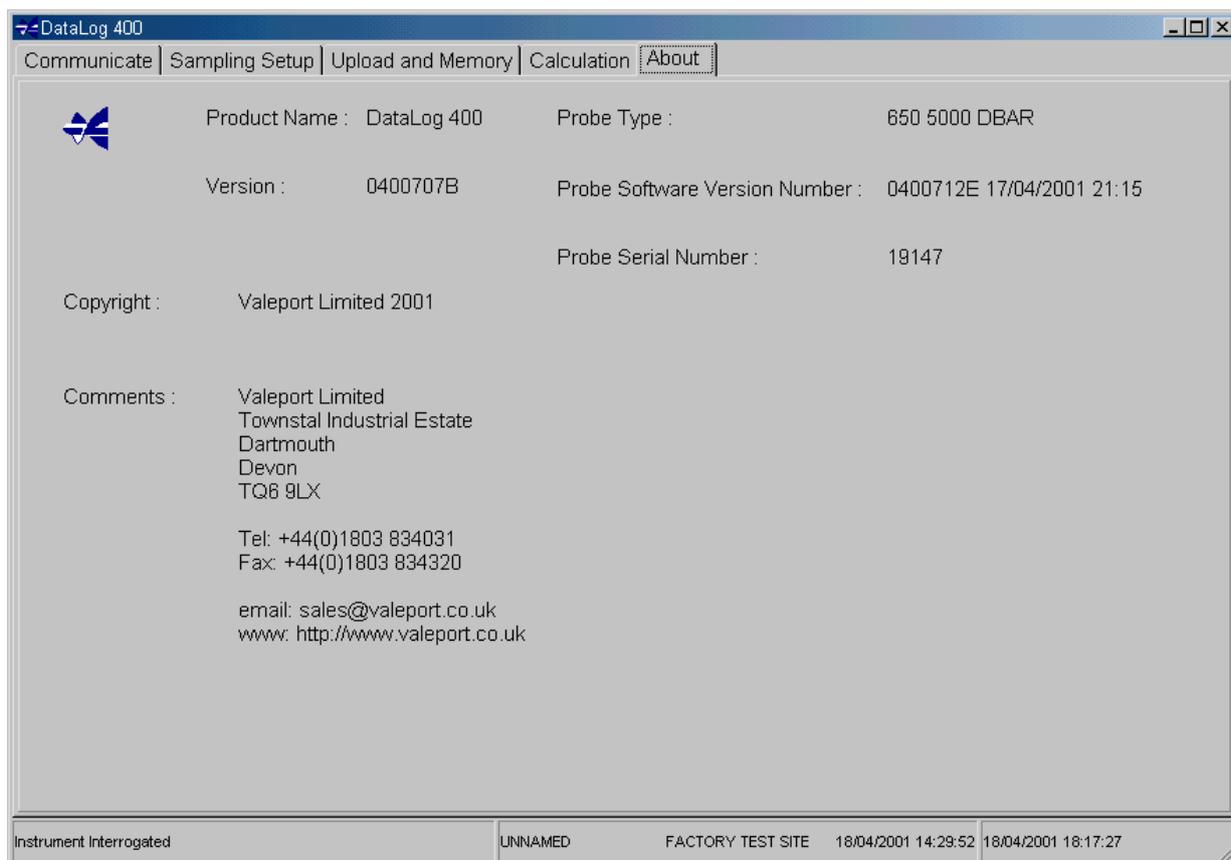
## 7 CALCULATION

The Calculation function is provided as a tool for the user to carry out standard oceanographic calculations.

Simply input Conductivity/Salinity, Pressure Temperature (in IPT68 or IPT 90 scales) and Latitude (if known), and click on the Calculate button. The program will calculate and display the following parameters:

- Density Anomaly Gamma (difference between calculated Density and Density of Pure Water)
- Conductivity or Salinity (whichever the user did not enter).
- Sound Speed calculated using the chosen Speed of Sound Formula.
- Depth in metres calculated using the UNESCO standard formula. This is an approximation, and does not account for variations in density distribution throughout the water column. Its accuracy has been estimated at better than 0.1m.

All formulae, including the various Speed of Sound formulae are given in full in Chapter 10

8 ABOUT

The About tab, available for selection at all times, shows Valeport's contact details and software version. If the About tab is selected after the user has interrupted the unit operation, then the instrument serial number and internal firmware version will also be shown.

## 9 CALCULATION FORMULAE

The following extracts are taken and adapted from "Processing of Oceanographic Station Data", published by UNESCO in 1991.

### 9.1 SALINITY

The Practical Salinity Scale (PSS-78)

The fundamental step in constructing the practical salinity scale PSS-78 consisted of defining a single reference point ( $S=35$ ) on the scale as having the same electrical conductivity as a reference potassium chloride (KCl) solution at 15°C and atmospheric pressure. The transition from the previous scale was made by selecting a single batch (P79) of Standard Seawater and equating the new scale to the old through the chlorinity relationship  $S = 1.80655 C$  for that particular batch. As the salinity on the practical scale is defined to be conservative with respect to addition and removal of water, the entire salinity range is accessible through precise weight dilution or evaporation without additional definitions. However, the practical scale is defined in terms of conductivity ratio and not by its conservative properties. Thus the second part of the definition was constructed by measuring the conductivity ratio to the KCl standard or an equivalent secondary standard over the entire range of salinities (1 to 42) of samples prepared by evaporation or dilution of batch P79 SSW and computing an empirical formula  $S = S(R_{15})$ , where  $R_{15}$  is the conductivity ratio 15°C and atmospheric pressure to the KCl standard. Thus salinities on the PSS-78 scale are defined by conductivity ratios alone. Salinities determined by any other method would not necessarily coincide with the PSS-78 scale and would have to be identified separately. Lewis and Perkin (1981) and Mamayev (1986) discuss differences between PSS-78 and previous scales and provide algorithms and tables to convert existing data to the new scale.

The algorithm for converting conductivity ratio to salinity is constructed in terms of the conductivity ratio  $R$  defined as:

$$R = C(S, t, p)/C(35, 15, 0) \quad (1)$$

where  $C(S, t, p)$  is the electrical conductivity as a function of salinity  $S$ , temperature  $t$  and pressure  $p$ . The ratio is factored into the functions:

$$R = r_t(t) \cdot R_t(S, t) \cdot R_p(R, t, p) \quad (2)$$

where

$$\begin{aligned} r_t(t) &= C(35, t, 0)/C(35, 15, 0) \\ R_t(S, t) &= C(S, t, 0)/C(35, t, 0) \\ R_p(R, t, p) &= C(S, t, p)/C(S, t, 0) \end{aligned}$$

Salinity is given by the function

$$S = \prod_{n=0}^5 \left[ a_n + \frac{\Delta t}{1+k\Delta t} b_n \right] \cdot R_t^{n/2} \quad (3)$$

with coefficients

$a_0 =$	+0.0080	$b_0 =$	+0.0005	$k =$	+0.0162
$a_1 =$	-0.1692	$b_1 =$	-0.0056	$\Delta t =$	$t - 15$
$a_2 =$	+25.3851	$b_2 =$	-0.0066		
$a_3 =$	+14.0941	$b_3 =$	-0.0375		
$a_4 =$	-7.0261	$b_4 =$	+0.0636		
$a_5 =$	+2.7081	$b_5 =$	-0.0144		

At  $t = 15^\circ\text{C}$  (3) reduces to the formula defining the practical salinity scale (Perkin and Lewis 1980).

The factors  $r_t$  and  $R_p$  are given by

$$r_t = \sum_0^4 C_n t^n \quad (4)$$

where

$$\begin{aligned} C_0 &= +0.6766097 & C_3 &= -6.9698E-7 \\ C_1 &= +2.00564E-2 & C_4 &= +1.0031E-9 \\ C_2 &= +1.104259E-4 & & \end{aligned}$$

and

$$\begin{aligned} R_p &= 1 + \frac{e_1 p + e_2 p^2 + e_3 p^3}{1 + d_1 t + d_2 t^2 + (d_3 + d_4 t) \cdot R} \\ &= 1 + \frac{C}{B + AR} \end{aligned} \quad (5)$$

with

$$\begin{aligned} e_1 &= +2.070E-5 & d_1 &= +3.426E-2 \\ e_2 &= -6.370E-10 & d_2 &= +4.464E-4 \\ e_3 &= +3.989E-15 & d_3 &= +4.215E-1 \\ & & d_4 &= -3.107E-3 \end{aligned}$$

for temperature in °C and pressure in dBar.

Given a measurement of  $R$ ,  $t$  and  $p$ , salinity is computed by solving (2) for  $R_t$ ;  $R_t = R/(r_t R_p)$  and evaluating  $S$  from (3). If conductivity ratio  $R$  is required given  $S$ ,  $t$  and  $p$ , the ratio  $R_t$  can be found by numerical inversion of (2), and  $R$  can be found by solving the quadratic equation

$$R = r_t \cdot R_t \cdot R_p = r_t \cdot R_t \cdot \left[ 1 + \frac{C}{AR + B} \right]$$

or

$$R = \frac{[(Ar_t R_t - B)^2 + 4r_t R_t A(B + C)]^{1/2} + [Ar_t R_t - B]}{2A} \quad (6)$$

This description of PSS-78 has been adapted from Fofonoff (1985)

## 9.2 DENSITY ANOMALY GAMMA

Equation of State of Seawater (EOS-80)

The equation of state of seawater is the mathematical expression to calculate density from measurements of temperature, pressure and salinity. Virtually all the computations of density of seawater made since the beginning of the century have been based on the direct measurements of density, chlorinity and salinity made by Knudsen, Forch and Sørensen (1902), and of compression of seawater made by Ekman (1908). This equation was obtained from measurements of density of natural seawater in which the proportions of the various ions are not exactly constant. To be consistent with the new definition of the Practical Salinity, 1978, the new equation of state is based on measurements of density of standard seawater solutions obtained by weight dilution with distilled water and by evaporation. As the absolute density of pure water is not known with enough accuracy, the density of distilled water used for these measurements was determined from the equation of the SMOW (Standard Mean Ocean Water) whose isotopic composition is well defined.

The new equation of state (EOS-80) which was adopted by JPOTS in 1981 (UNESCO, 1981c) is:

$$\left. \begin{aligned} v(S, t, p) &= v(S, t, 0)[1 - p / K(S, t, p)] \\ \rho(S, t, 0) &= 1 / v(S, t, 0) = A + BS + CS^{3/2} + DS^2 \\ K(S, t, p) &= E + FS + GS^{3/2} + (H + IS + JS^{3/2})p + (M + NS)p^2 \end{aligned} \right\} (7)$$

where the coefficients  $A, B, \dots, N$  are polynomials in temperature  $t$ . Units: salinity, PSS-78; temperature, °C; pressure ( $p$ ), bar; density ( $\rho$ ), kg/m<sup>3</sup>; specific volume ( $v$ ), m<sup>3</sup>/kg. These coefficients are given below.

	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>
$t^0$	+999.842594	+8.24493E-1	-5.72466E-3	+4.8314E-4
$t^1$	+6.793952E-2	-4.0899E-3	+1.0227E-4	
$t^2$	-9.095290E-2	+7.6438E-5	-1.6546E-6	
$t^3$	+1.001685E-4	-8.2467E-7		
$t^4$	-1.120083E-6	+5.3875E-9		
$t^5$	+6.536332E-9			
	<b>E</b>	<b>F</b>	<b>G</b>	
$t^0$	19652.21	+54.6746	+7.944E-2	
$t^1$	+148.4206	-0.603459	+1.6483E-2	
$t^2$	-2.327105	+1.09987E-2	-5.3009E-4	
$t^3$	+1.360477E-2	-6.1670E-5		
$t^4$	-5.155288E-5			
	<b>H</b>	<b>I</b>	<b>J</b>	
$t^0$	+3.239908	+2.2838E-3	+1.91075E-4	
$t^1$	+1.43713E-3	-1.0981E-5		
$t^2$	+1.16092E-4	-1.6078E-6		
$t^3$	-5.77905E-7			
	<b>M</b>	<b>N</b>		
$t^0$	+8.50935E-5	-9.9348E-7		
$t^1$	-6.12293E-6	+2.0816E-7		
$t^2$	+5.2787E-8	+9.1697E-10		

Density Anomaly  $\gamma$  is defined as the Density of the water minus 1000 kg/m<sup>3</sup>.

### 9.3 SPEED OF SOUND

The following information, discussion and conclusions are taken from Special Publication No.34 of the Hydrographic Society, prepared by JM Pike and FL Beiboer of METOCEAN plc. The report is entitled "A Comparison Between Algorithms for the Speed of Sound in Seawater".

The following abbreviations and units are used:

V	Computed speed of sound in seawater (m/s)
T	Temperature (°C)
S	Salinity
$\phi$	Latitude in degrees
$g(\phi)$	Gravitational acceleration at the given latitude ( $m/s^2$ )
$P_b$	Hydrostatic pressure (bar) ( $1\text{bar} = 10^5\text{Pa} = 10/g(\phi)$ ( $kg/cm^2$ ))
$P_k$	Hydrostatic pressure ( $kg/cm^2$ )
D	Depth (m)

### 9.3.1 STANDARD FORMULAE

#### 9.3.1.1 PRESSURE/DEPTH RELATIONSHIP

Several relationships are identified by Robertson(l), ranging from the approximate ("1 km of seawater generates a pressure of 101 bar"), to the precise (use of the MacKenzie or UNESCO algorithms).

The accurate relationships require computation of the gravitational field at the latitude in question using an appropriate formula for the gravitational field.

The UNESCO pressure/depth relationship has not been the subject of significant academic debate since its introduction, and is stated as follows:

$$D = \frac{(C_1 * (P_b * 10) + C_2 * (P_b * 10)^2 + C_3 * (P_b * 10)^3 + C_4 * (P_b * 10)^4)}{(g(\phi) + \frac{1}{2} g' * P_b)} + \Delta d / 9.8$$

where:

$$g(\phi) = 9.780318 * (1.0 + 5.2788E-3 * \sin^2\phi + 2.36E-5 * \sin^4\phi)$$

$$G' = +2.184E-5 \text{ m.s}^{-2} \cdot \text{bar}^{-1}$$

$$C_1 = +9.72659$$

$$C_2 = -2.2512E-5$$

$$C_3 = +2.279E-10$$

$$C_4 = -1.82E-15, \text{ and}$$

$P_b$  is the hydrostatic pressure (bar)

$\Delta d$  is the geopotential anomaly, expressed in J/kg. This term is zero for standard seawater ( $S = 35$ ,  $T = 0^\circ\text{C}$ ).

The geopotential anomaly term ( $\Delta d$ ) contains the correction for the actual density distribution within the water column, and can be evaluated for precise computation (or where there are extremes of temperature or salinity) by integrating the specific volume anomaly over the required pressure range. The procedures for this are also included in UNESCO Technical Paper #44.

The DataLog 400 program, however, does not feature the ability to input  $\Delta d$  (which is therefore assumed to be 0).

This assumption is recognised as being legitimate, with the resultant pressure depth algorithm called 'Simple UNESCO Depth':

$$D = \frac{(C_1 * (P_b * 10) + C_2 * (P_b * 10)^2 + C_3 * (P_b * 10)^3 + C_4 * (P_b * 10)^4)}{(g(\phi) + \frac{1}{2} g' * P_b)}$$

This value of D is used in all formulae within DataLog 400.

#### 9.3.1.2 WOOD (1949)

$$V = 1410 + 4.21 * T - 0.037 * T^2 + 1.14 * S + 0.018 * D$$

This formula was recognised before 1960 as being inadequate, and was replaced (at least in US Navy Hydrographic Office operations) in 1962 by the Wilson formula. It is thus not used in DataLog 400.

### 9.3.1.3 WILSON (OCTOBER 1960)

#### Full Version

The full version of this formula is:

$V = 1449.14 + V_T + V_P + V_S + V_{STP}$  , where

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

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

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

$$V_{STP} = (S - 35) * (-1.1244E - 2 * T + 7.7711E - 7 * T^2 + 7.7016E - 5 * P_k - 1.2943E - 7 * P_k^2 + 3.1580E - 8 * P_k * T + 1.5790E - 9 * P_k * T^2) \\ + P_k * (-1.8607E - 4 * T + 7.4812E - 6 * T^2 + 4.5283E - 8 * T^3) \\ + P_k^2 * (-2.529E - 7 * T + 1.8563E - 9 * T^2) \\ + P_k^3 * (-1.9646E - 10 * T)$$

Wilson states that the formula is valid to within  $\pm 0.3$  m/s in the ranges:

$$-4^\circ\text{C} < T < 30^\circ\text{C}; 0 < S < 37.1 \text{ kg/cm}^2; < P_k < 1000 \text{ kg/cm}^2.$$

where  $P_k = P_b \cdot \frac{10}{g(\phi)}$

#### Simplified Version

A simplified version of this formula, which is believed to have been used for a number of offshore surveys, is:

$$V = 1.449.14 + 4.5721 * T - 4.4532E - 2 * T^2 - 2.6045E - 4 * T^3 + (1.39799 - [1.1244E - 2 * T]) * (S - 35) + 1.643E - 2 * D$$

The range of validity is likely to be comparable to the full version, with simplification (and inaccuracy) introduced by replacing the pressure terms with a depth term (of unknown provenance), and ignoring 4th order temperature terms (*inter alia*).

### 9.3.1.4 MEDWIN (1975)

This simple formula was based on the Del Grosso equation and is:

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

Medwin states the formula is valid "for realistic combinations of  $T$ ,  $S$ ,  $P$ " in the ranges  $0 < T < 35^{\circ}\text{C}$ ,  $0 < S < 45$ ,  $0 < D < 1000$  m. The fact that the equation was based on the Del Grosso equation, however, leads to the conclusion that the range of validity cannot be superior to the Del Grosso formula itself, which is deemed to be valid only in a limited temperature and salinity range.

The more likely validity of the Medwin formula is indicated in the matrix below, in which the maximum valid pressure (in bar) is indicated for each temperature and salinity:

$S$	$T (^{\circ}\text{C})$			
	$0$	$5$	$10$	$15$
33	100	100	100	69
34	100	100	100	100
35	100	100	100	100
36	100	100	100	69
38	69	69	100	100

## 9.3.1.5 CHEN AND MILLERO (1977)

This formula was adopted by UNESCO in 1983 and is as follows:

$$V = C_w(t, p) + A(t, p) \cdot S + B(t, p) \cdot S^{3/2} + D(t, p) \cdot S^2$$

where,

$$\begin{aligned} C_w(t, p) = & C_{00} + C_{01} \cdot T + C_{02} \cdot T^2 + C_{03} \cdot T^3 + C_{04} \cdot T^4 + C_{05} \cdot T^5 + \\ & (C_{10} + C_{11} \cdot T + C_{12} \cdot T^2 + C_{13} \cdot T^3 + C_{14} \cdot T^4) \cdot P_b + \\ & (C_{20} + C_{21} \cdot T + C_{22} \cdot T^2 + C_{23} \cdot T^3 + C_{24} \cdot T^4) \cdot P_b^2 + \\ & (C_{30} + C_{31} \cdot T + C_{32} \cdot T^2) \cdot P_b^3 \end{aligned}$$

$$\begin{aligned} A(t, p) = & A_{00} + A_{01} \cdot T + A_{02} \cdot T^2 + A_{03} \cdot T^3 + A_{04} \cdot T^4 + \\ & (A_{10} + A_{11} \cdot T + A_{12} \cdot T^2 + A_{13} \cdot T^3 + A_{14} \cdot T^4) \cdot P_b + \\ & (A_{20} + A_{21} \cdot T + A_{22} \cdot T^2 + A_{23} \cdot T^3) \cdot P_b^2 + \\ & (A_{30} + A_{31} \cdot T + A_{32} \cdot T^2) \cdot P_b^3 \end{aligned}$$

$$B(t, p) = B_{00} + B_{01} \cdot T + (B_{10} + B_{11} \cdot T) \cdot P_b$$

$$D(t, p) = D_{00} + D_{10} \cdot P_b$$

with the coefficients defined in the following matrix:

<i>Subscript</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>
00	+1.389	-1.922E-2	+1402.388	+1.727E-3
01	-1.262E-2	-4.42E-5	+5.03711	
02	+7.164E-5		-5.80852E-2	
03	+2.006E-6		+3.3420E-4	
04	-3.21E-8		-1.47800E-6	
05			+3.1464E-9	
10	+9.4742E-5	+7.3637E-5	+0.153563	-7.9836E-6
11	-1.2580E-5	+1.7945E-7	+6.8982E-4	
12	-6.4885E-8		-8.1788E-6	
13	+1.0507E-8		+1.3621E-7	
14	-2.0122E-10		-6.1185E-10	
20	-3.9064E-7		+3.1260E-5	
21	+9.1041E-9		-1.7107E-6	
22	-1.6002E-10		+2.5974E-8	
23	+7.988E-12		-2.5335E-10	
24			+1.0405E-12	
30	+1.100E-10		-9.7729E-9	
31	+6.649E-12		+3.8504E-10	
32	-3.389E-13		-2.3643E-12	

The Chen & Millero expression is based upon comprehensive observations on seawaters in the ranges  $0 < T < 40^\circ$ ,  $0 < S < 40$ ,  $0 < P_b < 1000$ . Some concern has been expressed, however, at the accuracy of the formula at pressures exceeding 100 bar.

## 9.3.1.6 DEL GROSSO (1974)

$V = C_{000} + DC_T + DC_S + DC_P + DC_{STP}$ , where

$$C_{000} = 1402.392$$

$$DC_T = 0.501109398873E+1 * T - 0.550946843172E-1 * T^2 + 0.221535969240E-3 * T^3$$

$$DC_S = 0.132952290781E+1 * S + 0.128955756844E-3 * S^2$$

$$DC_P = 0.156059257041 * P_k + 0.244998688441E-4 * P_k^2 - 0.883392332513E-8 * P_k^3$$

$$DC_{STP} = -0.127562783426E-1 * T * S + 0.635191613389E-2 * T * P_k$$

$$+ 0.265484716608E-7 * T^2 * P_k^2 - 0.159349479045E-5 * T * P_k^2$$

$$+ 0.522116437235E-9 * T * P_k^3 - 0.438031096213E-6 * T^3 * P_k$$

$$- 0.161674495909E-8 * S^2 * P_k^2 + 0.968403156410E-4 * T^2 * S$$

$$+ 0.485639620015E-5 * T * S^2 * P_k - 0.340597039004E-3 * T * S * P_k$$

The formula is deemed to be valid only in the temperature and salinity ranges, and up to the pressures (bar), indicated in the matrix below:

<i>S</i>	<i>T (°C)</i>			
	<i>0</i>	<i>5</i>	<i>10</i>	<i>15</i>
33	1034	1034	275	69
34	1034	1034	207	207
35	1034	1034	414	207
36	1034	1034	275	69
38	69	69	414	414

### 9.3.1.7 MACKENZIE (1981)

Based upon widespread oceanographic measurements, the MacKenzie formula is:

$$\begin{aligned}
 V = & 1448.96 + 4.591 * T - 5.304E - 2 * T^2 + 2.374E - 4 * T^3 \\
 & + 1.340 * (S - 35) + 1.630E - 2 * D + 1.675E - 7 * D^2 \\
 & - 1.025E - 2 * T * (S - 35) - 7.139E - 13 * T * D^3
 \end{aligned}$$

and is stated to be valid for naturally occurring seawaters in the intervals indicated in the matrix below:

$P_k$	$T (^{\circ}C)$	$S$
0	0-30	30-40
50	0-20	32-40
100	0-14	32-34
	0-16	35-38
	10-16	39-40
200	0-12	32-36
	0-16	37
	8-16	38-39
500	0-5	33-36
	12-14	38-39
800	0-5	34-35

## 9.3.2 DISCUSSION

### 9.3.2.1 DEVELOPMENT OF FORMULAE

A useful overview of the history of seawater speed of sound measurements and formulae is provided by Dulshaw *et al.*

All formulae given above (and the majority of others referred to in the course of this study) were empirically derived from measurements of acoustic velocity of seawater samples whose temperature, salinity and pressure were measured in the oceans and/or varied in the laboratory. The Robertson equation is one of the few attempts to base the equations for the speed of sound on theoretical considerations alone.

The Wood formula, while in use even now, was considered as early as 1960 to be unreliable for the advancing technology and requirements of that era, and was superseded by the Wilson formula in 1961.

The recognition of defects in the experimental methods of Wilson, together with the adoption of the practical salinity scale and the international equation of state for seawater (EOS-80) resulted in the Wilson formula being superseded for oceanographic purposes by the Chen & Millero formula, which still represents the formal standard for oceanographic purposes.

The limitations of the Chen & Millero formula in turn were revealed by precise in situ observations of acoustic velocity with depth, and by the advent of tomographic methods to determine seawater physical properties along very large path-lengths (across oceans) and to great depths.

These observations have led in recent years to the realisation that the Chen & Millero formula has distinct limitations at high pressures, and that the Del Grosso equation may be more realistic for such specialist purposes. The wide validity range for salinity and temperature of the Chen & Millero formula is of value for measurements on the continental shelf, however. The quality of fit of the Del Grosso equation to the modern high-pressure data sets (and the corrections that should consequently be applied to the Del Grosso equation) is currently the subject of some debate.

### 9.3.2.2 COMPARISON OF FORMULAE

The Wood and Wilson formulae do not fit modern experimental and observational data well, and should no longer be used for precise computations. This probably is the result of improvements in observational and analytical techniques over the years, together with changes in computational methods of salinity and depth.

The remaining algorithms show fairly close agreement with one another, diverging as pressure increases.

The Chen & Millero formula is commonly accepted for oceanographic use, and was derived from measurements over a wide salinity, temperature and pressure range.

At high pressures (>100 bar), however, recent research suggests that the Del Grosso equation is more accurate, although this formula is valid only for a limited range of oceanic waters.

The Del Grosso formula has been used as a benchmark to appraise the accuracy of the other algorithms.

The following order of preference is suggested:

- i) Chen & Millero (only for water depths less than 1000m)
- ii) Del Grosso (only for water depths greater than 1000m)
- iii) MacKenzie (for rapid computations in oceanic waters to 8000m water depth)
- iv) Medwin (for rapid computations in oceanic waters to 1000m water depth)

The Medwin and Wilson (simplified) formulae diverge considerably from the remaining algorithms at temperatures greater than 20°C. This is expected from two simple formulae lacking higher order temperature terms.

There may be some advantages in using the MacKenzie and Medwin formulae where depth is known, and where the computation of pressure for inclusion in the Chen & Millero or Del Grosso formulae would become unnecessarily onerous. The user should be made aware, however, of the limited range of conditions of temperature, salinity and pressure over which these formulae are valid.

### 9.3.2.3 THE PRESSURE/DEPTH ALGORITHM

An accurate expression for computing pressure from depth (and *vice versa*) may be desirable:

- a) for its own sake, to enable precise pressure and depth computations to be made for a variety of purposes; and
- b) to enable precise speed of sound computations to be made.

When using speed of sound algorithms with a pressure term (Chen & Millero, Del Grosso), the water pressure can be measured directly, estimated from a known depth and inversion of the UNESCO pressure/depth algorithm (possibly based on a carefully calibrated conductivity/temperature/depth cast), or calculated from standard tables. According to Saunders and Fofonoff, who were the originators of the basic method adopted in the UNESCO formula, these estimates should be carried out at 5 bar pressure intervals near the surface and at 200 bar intervals for greater depths.

When using speed of sound formulae with a depth term (MacKenzie or Medwin), the depth may be estimated or measured by some independent means; or computed from a pressure measurement and a conductivity/temperature depth cast. It is more likely, however, that these methods would not be used for precise purposes; they are in any case valid only for oceanic waters in which the errors in the estimation of depth, introduced through ignoring the geopotential anomaly, would not be excessive.

### 9.3.3 CONCLUSIONS

1. It is recommended that use of the Wood and Wilson formulae be discontinued for precise purposes, as they do not provide good agreement with modern data sets and computational methods of salinity and depth.
2. It is of crucial importance to ensure that the formulae (of whatever origin) are used only for observations made within the ranges of temperature, salinity and pressure for which each expression is deemed valid.
3. It is recommended that the Chen and Millero formula be used for seawaters on the continental shelf. This incorporates a pressure term which should be measured directly; evaluated from a known depth using the full UNESCO formula and data obtained either from oceanographic tables or from a conductivity/temperature/depth cast; or the error in using the simplified UNESCO formula deliberately accepted.
4. In deep ocean waters, the Del Grosso formula is currently favoured, especially for long path-lengths. This also uses a pressure term.
5. Where rapid computations are necessary, or where the depth is known (but not pressure), the simple MacKenzie (9 terms) and Medwin (5 terms) formulations may prove of value. These expressions are strictly valid only for normal oceanic waters. Where depth is computed from pressure, the simplified UNESCO equation for the pressure/depth relationship could be used without introducing significant error.
6. Incorporation of the full UNESCO pressure/depth algorithm (incorporating the geopotential anomaly) would be a useful addition to any software package, although there may be little discernible benefit to the accuracy of the speed of sound computations. The complete formula would, however, enable a full suite of precise applications to be available for use worldwide.

10 **APPENDIX 1 CONFIGURATION CODES****General control codes #000 - #099**

<b>Code</b>	<b>Followed By</b>	<b>Operation</b>	<b>Access</b>
#000	Do Not Use	Used as an error code	
#001	;modus_address<CR>	Sets the modus address	
#002	<CR>	Sends the modus address	
#003	;mode;rate;period;interval;average; moving_ave_length<CR>	Sets the sampling regime	
#004	<CR>	Sends the sampling regime	
#005	;ON<CR> or ;OFF<CR>	Turns ON or OFF address mode	
#006	<CR>	Sends ON or OFF for address mode	
#007	;RAW<CR> or ;CAL<CR>	Sets the output to be raw or calibrated values	
#008	<CR>	Sends the output values raw or cal	
#009	;TARE<CR>	Sets the tare value in systems with pressure fitted (If no value entered a measured value is used)	Only if pressure fitted
#010	<CR>	Sends the tare value	Only if pressure fitted
#011	<CR>	Scans the I2C bus to see what devices are fitted	
#012	;AML<CR>	Sets the unit to AML mode accepting only AML commands	
#013	;OUTPUT_MODE<CR>	Sets the output format used :- AML,VALEPORT,CSV,SVP16,NMEA, WESTGEO,SOUNDER,HYPACK,SEABIRD	
#014	<CR>	Sends output format to be used	
#015	<CR>	Sends last reading	
#016	;ON<CR> or ;OFF<CR>	Turns on or off ident option	
#017	<CR>	Sends ident option on or off	
#018	;module_address;units;units<CR>	Sets valeport calibrated units label	Not available on SVP
#019	<CR>	Sends valeport calibrated units label	
#020	;module_address;units;units<CR>	Sets user calibrated units label ( Space means no user cal to be used @ means user cal to be used but no units)	

#021	<CR>	Sends user calibrated units label	
#022	; module_address;parameter_no(1or2);fit(15);coef5; coef4; coef3; coef2; coef1; offset<CR>	Sets USER calibration in module module_address parameter parameter_no to a fifth order polynomial defined by the coefficients.	
#023	;module_address;parameter_no <CR>	Sends USER calibration in module module_address parameter parameter_no	
#024	; module_address;parameter_no(1or2);fit(15);coef5; coef4; coef3; coef2; coef1; offset<CR>	Sets VALEPORT calibration in module module_address parameter parameter_no to a fifth order polynomial defined by the coefficients.	
#025	;module_address;parameter_no <CR>	Sends VALEPORT calibration in module module_address parameter parameter_no	
#026	;valeport_separator<CR>	Sets the valeport output string separator	
#027	<CR>	Sends the valeport output string separator	
#028	<CR>	Puts unit into run	
#029	;pressure_trip;pressure_increment <CR>	Sets the depth sampling parameters	Only if Pressure fitted
#030	<CR>	Sends the depth sampling parameters	Only if pressure fitted
#031	;unit_address;RAW<CR> or ;unit_address;CAL<CR>	Continuously sends calibrated or raw data from specific module as set by unit_address.	
#032	<CR>	Sends the software version number.	
#033	;SERIAL_NUMBER<CR>	Sets the units serial number	
#034	<CR>	Sends the units serial number	
#035	;unit_address; parameter_no(1or2) ;gain;offset<CR>	Sets the gain and offset values for module unit_address parameter parameter_no.	
#036	;unit_address; parameter_no(1or2)<CR>	Sends the gain and offset values for module unit_address parameter parameter_no.	
#037	;unit_address<CR>	Sends the module software version.	
#038	;unit_address;AUTOorRESET<CR>	Performs SVP characterisation	SVP Only
#039	;unit_address; parameter_no(1or2);gsr1;gsr2;tfr1 <CR>	Sets the gsr registers and tfr1 register in the module selected for the parameter selected	
#040	;unit_address; parameter_no(1or2)<CR>	Sends the gsr registers and tfr1 register in the module selected for the parameter selected	

## AML COMMANDS

Code	Operation	Access
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R<CR>	Sets unit to operate in RAW data units	
RE<CR>	Sets unit to operate in real or cal units	
S<CR.	Performs single measurement	
M<CR>	Performs multiple measurements forever (only cycling the power will restart the device)	
VALE<CR>	Set to valeport command mode (AML commands are no longer accepted)	