Online communication with the DST CTD

Table of Contents

1 The physics

DST CTD online is a submersible sensor measuring conductivity/salinity, temperature and pressure/depth. It is designed for streaming the measurements into user's own embedded system for real-time viewing or for later time data retrieval. The sensor is fitted with a connector and is supplied with a subsea cable that comes with a matching connector for threading on the sensor's connector. Cable length is customer defined. The subsea cable and connector are submersible for pressure up to a few km but the limiting factor on the pressure tolerance is the membrane on the sensor end, which can be equipped with a max. 2400 m depth/pressure sensor. Both the pressure and the conductivity calibration ranges are customer defined.

Figure 1: DST CTD online with subsea connector and subsea cable

The conductivity, temperature and pressure/depth (optional) sensors are located on the opposite end of the connector end as can be seen in figure 2. The two electrodes conductivity cells are visible inside the wall of the small cup at the end of the housing. Temperature and pressure sensors are located at the membrane. It is important that seawater freely flows to the area where the sensors are located.

Figure 2: DST CTD online top view of the connector and sensor end

The connector end has four pins connection as depicted in figure 3. When part of a system such as an AUV the sensor sticks out to the seawater whilst the connector end is placed inside the device.

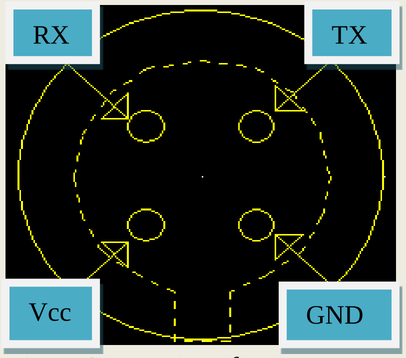


Figure 3: Drawing of connector seen from the soldering pins

The connector diagram is seen from the soldering side of the cable connector or as if looking on top of connector end of the CTD online.

The four communication pins

- Vcc = 4-5V DC supply from user's system.
  The CTD online has two batteries inside, only necessary for off-line calibration, and can thus operate without the external Vcc supply; this will though quickly drain the batteries. Thus if there is no voltage on the Vcc line, Rx voltage may not exceed the Vbat=3,0V
- GND = Signal Ground and -Vcc
- TX: = DST CTD online Transmit line (= user's Rx line)
  The voltage on the Tx is Vcc-0,6V, with a weak pull-up (1MΩ)
  Note:
  - External voltages on the Tx line, higher than the Vcc may damage the DST CTD.
  - Also short circuiting the Tx line may damage the DST CTD.
- RX: = DST CTD Receive line (= user's Tx line)
  The Rx has a 22kΩ pull-down.
  Note: The Rx must not be subjected to higher voltages than Vcc-0,6V.

Common ground

The signal ground of the computer/embedded system and the conducting media must not share a common ground. Tests have shown that common ground will result in shifted measurements. The user must make sure that common ground is avoided.

Communication cable

The subsea cable is delivered with a special connector on its end, which a supplied PC communication cable (called StarCom) can be connected to. The purpose of this connector is for connection and testing with online measurements using Star-Oddi's *SeaStar* software or user's own software. This connector end is not waterproof but is often switched out with user's connector fitting to the embedded system connection. The supplied PC cable converts standard RS232 signal ±12V DC / ±5 signals, on the PC side, to 0-4V on the recorder side, and vice versa. A USB serial converter is supplied with the StarCom cable for PC connection.

Figure 4: Starcom communication cable and USB serial converter

Embedded system hardware connection

There are (at least) two ways of wire connection to the CTD.

1. Direct to a microprocessor, 4-5V Vcc, where the RC232 port operates at 0-Vcc, and the resting voltage is high (=Vcc).
2. If the embedded system comes with a USART, i.e. a RS232 port with -Vp to +Vp, a transceiver chip is needed for voltage level adjustment and signals inversion.

The Vp can range from 5 to 12V.
Below is a schematic (from the Starcom cable) where such an RS232 transceiver chip is used.

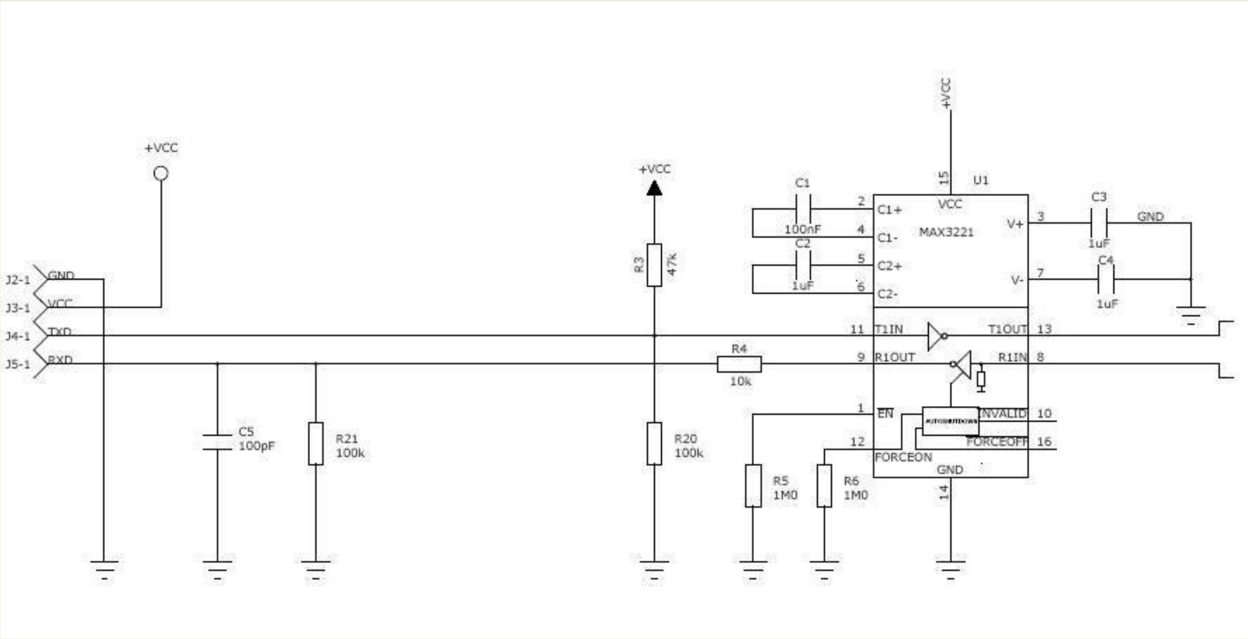


Figure 5: StarCom cable connection

2 Communication

DST CTD operation modes

The DST CTD has two modes of operation:

- Measurement-mode (using the SeaStar software only)
  The CTD operates as an offline data logger, logging measurements in the memory.
- PC-mode (using SeaStar or user's own software)
  In this mode the DST CTD will communicate via the RS232, and can act as an online measuring device.

As a part of the start-up routine streaming data online, the DST CTD should always be placed in PC-mode as described in this chapter.

Communication is via a RS232 port/asynchronous

Baud rate:	4800
Data bits:	8
Parity:	None
Stop bits:	1
Flow control:	None

Awakening the DST CTD

The user must make sure that the embedded system's Rx line/Tx line is normally high.
As the DST CTD has batteries it will lay dormant (sleeping) until it is interrupted, i.e. when a voltage is applied to the Rx wire. When interrupted the DST CTD is ready to communicate, and awaits instruction from the PC/Embedded system.
As long as the Rx is high, the DST CTD awaits to be polled for data.
If the Rx goes low, the DST CTD will wait 2 sec. to see if communication is permanently disengaged and then goes to sleep.

Star Oddi protocol

The DST CTD only reacts to commands from the user's embedded system.
Commands are numbered 0, 1 etc, and the DST CTD echoes commands back.
ACK is defined as 85 decimal = 55h (hex)

Test the connection

To see if the DST CTD is awake, issue the Test-Com command:

The embedded system sends out: 0
The DST CTD replies with: 0 and (a delayed) 55h:

Set the DST CTD in PC-mode

Just in case the DST CTD is not in PC-mode, issue the PC-mode command.
NB: This is only necessary to execute once, after awakening the DST CTD

The embedded system sends out: Ch
The DST CTD replies with: Ch and (a delayed) 2
The DST CTD is now in PC-mode.

Polling the DST CTD for data

This is the actual measurement procedure, which needs to be repeated at a constant rate.

The embedded system sends out: 1
The DST CTD replies with: 1
The user's embedded system sends out: 55h
The DST CTD replies with 6 byte: Tl,Th,Pl,Ph,Cl,Ch (the measurement raw data)

Each measurement is low and high byte, temperature (Tl,Th), pressure (Pl,Ph) and conductivity (Cl,Ch). These are raw decimal value data.

Working with the online-data

The user can choose to work with the data in the embedded system, see chapter "Converting online measurements" or transfer the raw data to another system for processing.
Also the raw data can be stored for comparison purposes or testing to be converted later, for example in Star-Oddi's SeaStar software.

Transferring stored data to a file

The embedded system can transfers the data, some point to a "land based" PC, to be stored in a file. As the user defines the measurement frequency, information about start time and measurement frequency should be stored with the file.

At some point a copy of the file can be taken, and converted to SeaStar DAD-file format, so the data can be converted to unit values and viewed graphically in SeaStar.

Converting online measurements to SeaStar DAD format

The SeaStar DAD format is defined as 9 byte for two consecutive CTD measurements:
For two measurement transferred as 2 x 6byte from the DST CTD, described above as T1l,T1l,P1l,P1h,C1l,C1h and T2l,T2l,P2l,P2h,C2l,C2h.
The values compacted in the following way.

B1= T1l
B2= P1l
B3= P1h (high nibble)+T1h (low nibble)
B4= T2l
B5= P2l
B6= P2h (high nibble)+T2h (low nibble)
B7= C1l
B8= C2l
B9= C2h (high nibble)+C1h (low nibble)

For example if the values received are:
120, 10, 77, 4, 100, 2 and 130, 10, 90, 4, 110, 2
They should be compacted and stored in a text file, one decimal value per line, as:

120
77
74
130
90
74
100
110
34

The name of the DAD text file should be xxSyyyy.DAD, for example: 1S5000.DAD

xx: Last sequence number in DST CTD, usually 1
yyyy: Recorder number, fx 5000

Place the file in an appropriate DST CTD folder under SeaStar.
For example: C:\SeaStar\DST CTD\S5000\

3 Working with SeaStar

Installing SeaStar

To view online measurements from DST CTD in SeaStar install the latest version of SeaStar. If SeaStar has been previously installed make sure the latest version is being used. It's possible to check for updates under the Help menu in SeaStar.

Converting the online measurement *.DAD file to unit values in SeaStar

As described previously in "Transferring the data to a file" the raw data should reside in a DAD file. Converting the DAD file to unit requires the measurement sequence (measurement frequency) and the calibration constants, which are kept in the MID file.

Conversion: DAD + MID → DAT

Star-Oddi will supply the user with RID and MID files, in folders, one for each recorder, that can be copied to the SeaStar\DST CTD\ folder. For example, for serial no. S5000 the following files would be included:

S5000\	S5000.RID	Recorder Information Data file
	0S5000.MID	Sequence 0 Measurement Information file Used for SeaStar online measurement conversion
	1S5000.MID	Sequence 1 Measurement Information file Used for user's online measurement conversion Meas. Freq. defined as 1 sec.

Normally all the information about the measurement sequence is in the MID file, but as the user defines the start time and measurement frequency, this must be punched in when reconverting the data. For detailed information on converting the data to unit values, please refer to the SeaStar User Manual, Chapter 10.

The data conversion procedure is as follows: (example for S5000)

1) Place a 0S5000.DAD data file in C:\SeaStar\DST CTD\S5000\
2) In SeaStar select the S5000 recorder.
3) Select the 0 data sequence via <File\Select measurement>
   Select the 0S5000.MID measurement file.
4) Using a single interval definition, in <Edit\New Measurement Def.>
   Define the measurement interval.
5) In <Edit\Reconvert Definitions>
   Set the start time.
   In the "In reconversion use measurement intervals from" select
   "Current new measurement sequence definition"
6) Convert the DAD to DAT via <File\Reconvert data>

Online measurements in SeaStar

In order to check the recorders online measurement capabilities and to see how data are stored in SeaStar, a new Online measurement option has been introduced in SeaStar.
The measurement frequency is fixed to every second. A 0Sxxxx.DAD file is created that can be used with the 0Sxxxx.MID for converting the data to a DAT file, that can be viewed graphically.

To make online measurements in SeaStar perform the following steps:

- Connect the StarCom cable to the PC and the DST CTD cable
- Make sure the right port is selected.
- Define that a StarCom cable is used, under <Settings\Connection>

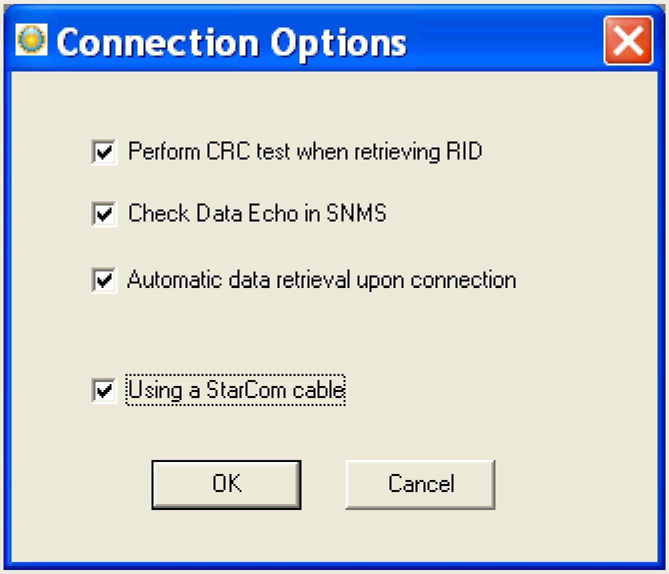


Figure 6: Using a StarCom cable as a connection with DST

These above steps are important as otherwise no connection will be established.
Then do the following:

- Connect to the DST CTD via <Recorder\Connect>
- Perform online measurements via <Recorder\Online measurements>
- When finished use the Exit button to exit the Online measurement.
- Finally disconnect the recorder via <Recorder\Disconnect>

The online measurement produces a 0Sxxxx.DAD data file, that is available for conversion, thus the user can practise DAD->DAT conversion as described in 1)-6).

When the online measurement is quitted the online measurements come on screen.
The ySxxxx.ONL file is available for viewing later via <View\Online measurements>

Note: Reconversion is only available when the recorder is disconnected.

4 Converting online measurements

In case the user wants to work with the measurements in the embedded system, the following conversion methods can be used.

Converting to decimal values: Tl,Th ->T, Pl,Ph -> P and Cl,Ch -> C

When data is received online from the DST CTD, the values are transmitted as 6 byte

Tl = Temp Low byte
Th = Temp High byte

Pl = Pressure Low byte
Ph = Pressure High byte

Cl = Conductivity Low byte
Ch = Conductivity High byte

The “raw” decimal values are calculated from these low and high bytes as:

Temperature:
(1): T = Tl + (Th*256)

Pressure:
(2): P = Pl + (Ph*256)

Conductivity:
(3): C = Cl + (Ch*256)

The decimal value range, for T, P and C is [0-4095]

For example if the online values are:

Tl = 120
Th = 10
Pl = 77
Ph = 4
Cl = 100
Ch = 2

Then the decimal values are calculated as:

T = 120 + (10*256) = 2680
P = 77 + (4*256) = 1101
C = 100 +(2*256) = 612

When working with SeaStar the raw decimal values T, P and C are listed in the *.DAB file.

Converting decimal values to unit values

To convert the decimal values to unit values the calibration polynomials are used.
All these constants, and ranges are listed in the *.RCI file. These same polynomial constants are listed in the *.CAT file as floating point values. The CAT is easier to read directly and thus recommended to use when converting decimal values to unit values outside SeaStar.

Temperature

The temperature polynomial constants are:

T.C0, T.C1, T.C3, T.C4 and T.C5

The native calibration unit is (°C)

Defining:

T = Temperature measured raw decimal value
Tv = Temperature unit value (°C)
Tf = Temperature unit value (°F)

The temperature (in °C) is calculated as:

(4): Tv = T.C0 + (T.C1*T) + (T.C2*T^2) + (T.C3*T^3) + (T.C4*T^4) + (T.C5*T^5)

Temperature in Fahrenheit:

To convert °C to °F use:

(5): Tf := 32+Tv*(9/5)

Pressure

The pressure polynomial constants are:

P.C0, P.C1, P.C3, P.C4 and P.C5

The native calibration unit is (Bar)

The pressure decimal value need to be temperature corrected
The pressure temperature correction polynomial constants are:

Ptc.C1, Ptc.C3, Ptc.C4 and Ptc.C5

Defining

P = Pressure measured raw decimal value
Pc = temperature corrected pressure decimal value
Pv = Pressure in unit value (Bar)
Tpr = Reference temperature (°C) found in CAT file
Tv = measured temperature (°C) (calculated from T)

(6): Pc = P + (Ptc.C1*Tpr) + (Ptc.C2*Tpr^2) + (Ptc.C3*Tpr^3) + (Ptc.C4*Tpr^4) + (Ptc.C5*Tpr^5) - ((Ptc.C1*Tv) + (Ptc.C2*Tv^2) + (Ptc.C3*Tv^3) + (Ptc.C4*Tv^4) + (Ptc.C5*Tv^5))

The pressure (in BAR) is then calculated as:
(7): Pv = P.C0 + (P.C1*Pc) + (P.C2*Pc^2) + (P.C3*Pc^3) + (P.C4*Pc^4) + (P.C5*Pc^5)

Depth:
If depth is the desired parameter, then the pressure (Bar) can be converted to meters (m) as follows:
D = Depth in unit value (m)
g = standard acceleration of gravity = 9.80665 (m/s^2)
Sd = Seawater density = 1.026
gc = gravity conversion constant = 100/g = 10.19716

If measurements are performed in seawater then
(8): D = Pv*gc/Sd
Else:
(9): D = Pv*gc

Conductivity
The polynomia that defines the conductivity can varie from 5° to 11° in the DST CTD.
In the DST CTD-online it´s restricted to a 7° polynomia, a degree that seems to give the best result.
The conductivity calibration constants are.
Cond.C0, Cond.C1, Cond.C2, Cond.C3, Cond.C4, Cond.C5, Cond.C6 and Cond.C7.
The conductivity measurement circuitry temperature correction constants in each end oft the load range are:
Low end: Ctc.C1, Ctc.C2, Ctc.C3, Ctc.C4 and Ctc.C5
High end: Ctc1.C1, Ctc1.C2, Ctc1.C3, Ctc1.C4 and Ctc1.C5

As with pressure, the decimal values are correct with the difference between the actual temperature and the conductivity calibration reference temperature.
Basically this is done by calculating a temperature corrected decimal value for both low and high load correction polynomials. Then a linear equation is created from both the calculated values and the inner range points of the two equations.
This equation is then used to find the corrected decimal value, which agin can be used in the Conduc-polynomial to find the conductivity value.
Defining:
C: Conductivity measured raw decimal value
Cc0: Conductivity tempemperature corrected decimal value from Ctc-polynomial
Cc1: Conductivity tempemperature corrected decimal value from Ctc1-polynomial
Cc: Conductivity temp corrected decimal value
Cv: Conductivity in unit value (mS/cm)
Tv: Temperature (°C)
Tcr: Temperature ref. value (°C) shown in the RCI file (often 24°C)
L: Conductivity Low load inner range value
H: Conductivity High load inner range value
A: lin. equation constant
B: lin. equation constant

Correction for low load:
(10): Cc0 = C+(Ctc.C1*Tcr) + (Ctc.C2*Tcr^2) + (Ctc.C3*Tcr^3) + (Ctc.C4*Tcr^4) + (Ctc.C5*Tcr^5) - ((Ctc.C1*Tv) + (Ctc.C2*Tv^2) + (Ctc.C3*Tv^3) + (Ctc.C4*Tv^4) + (Ctc.C5*Tv^5))

Correction for high load:
(11): Cc1 = C+(Ctc1.C1*Tcr) + (Ctc1.C2*Tcr^2) + (Ctc1.C3*Tcr^3) + (Ctc1.C4*Tcr^4) + (Ctc1.C5*Tcr^5) - ((Ctc1.C1*Tv) + (Ctc1.C2*Tv^2) + (Ctc1.C3*Tv^3) + (Ctc1.C4*Tv^4) + (Ctc1.C5*Tv^5))

Combining high and low correction ina linear equation:
(12): A = (Cc1-Cc0)/(H-L)
(13): B = Cc0-A*L
(14): Cc= B+A*C

The conductivity unit value (mS/cm):
(15): Cv = Cond.C0 + (Cond.C1*Cc) + (Cond.C2*Cc^2) + (Cond.C3*Cc^3) + (Cond.C4*Cc^4) + (Cond.C5*Cc^5) + (Cond.C6*Cc^6) + (Cond.C7*Cc^7)

Salinity

Conductivity is based on

- The amount of salt/minerals (ions) in the water
- Water temperature
- Depth.

To calculate salinity, conductivity, temperature and depth need to be known.
Depth plays a minor role, it´s only when down to several hundred meaters it starts to have effect.

In SeaStar salinity is calculated in PSU according to Unesco formulas. (Practical Salinity Scale 1978 (PSS-78))
To calculate salinity please use the formulas stipulated in that paper.

Included in appendix there is a copy of the “core” part of the PSS-78 that defines these calculations.
For reference purposes the equations have been prefixed with an equation number (PSSeq-x), were x= 1 to 6

The RCI file

SeaStar creates a Recorder Calibration Information file (*.RCI), each time you connect to a recorder and each time you select a recorder.
Below is a copy of a RCI file.

```
Filename: E:\DST CTD ONLINE\8213_02\ST\S8422.RCI
       SeaStar 7.24
       File creation Date & Time: 24.3.2016 13:35:33
       Recorder type              : DST CTD
       Recorder number            : S8422
       Production number          : 82138422
       Production date [dd:mm:yy] : 16:03:16
       Calibration number         : 1
       Calibration date[dd:mm:yy] : 16:03:16

       Temperature Calibration constants:
       ------------------------------------------------------
       Temp.C0: 122,622785746828
       Temp.C1: -0,138854530877331
       Temp.C2: 0,000108169890868935
       Temp.C3: -5,58470579894668E-8
       Temp.C4: 1,53702000127998E-11
       Temp.C5: -1,81435671827578E-15

       Temperature Calibration range:
                    Decimal Temp.(°C)/(°F)
              Min:   2586       -1 /   30
              Max:   1286       40 /  104
              Ave.resol.: 31(m°C) / 88(m°F)

       Temperature sensor: Thermistor

       Pressure Calibration constants:
       ------------------------------------------------------
       Pres.C0: -1,61597635237222
       Pres.C1: 0,00565052106231862
       Pres.C2: -9,09681400791005E-8
       Pres.C3: 4,90908801913798E-11
       Pres.C4: -8,71492645777175E-15
       Pres.C5: -4,81753801054678E-19

       Pressure Temperature Regulation constants
       -------------------------
       TPR.C1: 7,02439662414173
       TPR.C2: -0,21053250673308
       TPR.C3: 0,00980786039230989
       TPR.C4: -0,000240862172070564
       TPR.C5: 2,17405487656103E-6

       Ambient pressure (mBar): 1003
       Pressure Calibration Temperature reference (°C): 22,44

       Pressure Sensor Type: 1
       Max pressure tolerance(Bar):0 - 30

       Pressure Calibration range:
                    Decimal   (Bar) / (m)
              Min:    290        0.02       0.2
              Max:   2105        10.1       103
              Ave.resol.: 6(mbar)  61(mm)
```

```
Conduct Calibration constants:
------------------------------------------------------
Conduc.C0: 98,0544546827358
Conduc.C1: -0,263561387205901
Conduc.C2: 0,000376092808984272
Conduc.C3: -3,09143413610036E-7
Conduc.C4: 1,50598310444937E-10
Conduc.C5: -4,27928881371478E-14
Conduc.C6: 6,5323443704887E-18
Conduc.C7: -4,12913234939624E-22

Conductivity Calibration Temperature reference (°C): 23,88
Conductivity Cell Type: 1
Conductivity Cell Range (mS/cm): 3 - 37

Conductivity Calibration range:
             Decimal Conduc.(mS/cm)
      Min:   3867        2
      Max:    365       39
      Ave.resol.(uS/cm): 10

Conductivity Temperature Regulation constants
-------------------------
TCR.C1: -0,398142680468083
TCR.C2: -0,00259321862905614
TCR.C3: -0,000684962594896168
TCR.C4: 2,30924943510067E-5
TCR.C5: -1,76713340491716E-7

TCR1.C1: -0,276279974677843
TCR1.C2: -0,0925221052164181
TCR1.C3: 0,00180276949585506
TCR1.C4: -1,54831091575708E-5
TCR1.C5: 2,09671367968997E-7

TCR  Decimal Value Range :  526 -  549
TCR1 Decimal Value Range : 3146 - 3208
```

The CAT file.

SeaStar creates a *.CAT text file, each time you connect to a recorder <u>and</u> each time you select a recorder. The CAT files can be viewed in SeaStar via <View\Text files>
The CAT file contains the calibration constants as floating point values, previously only for temperature and pressure but to accommodate the user's conversion of on-line data, calibration constants for conductivity have been added to the DST CTD xxSyyyy.CAT files.

The *.CAT is a text file, where floating point numbers are listed one number pr. line.
Below is a list from a CAT file. <u>Note # marked lines are normally NOT included.</u>

```
# Temperature: T.C0 - T.C5
122,622785746828
-0,138854530877331
0,000108169890868935
-5,58470579894668E-8
1,53702000127998E-11
-1,81435671827578E-15
#
# Pressure: P.C0 –P.C5
-1,61597635237222
0,00565052106231862
-9,09681400791005E-8
4,90908801913798E-11
-8,71492645777175E-15
-4,81753801054678E-19
#
# Pressure Temp. Corr.: Ptc.C1 – Ptc.C5
7,02439662414173
-0,21053250673308
0,00980786039230989
-0,000240862172070564
2,17405487656103E-6
#
# Pressure temperature calibration reference: Tpr
22,4427798102788
#
# Conductivity: Cond.C0 – Cond.C7
98,0544546827358
-0,263561387205901
0,000376092808984272
-3,09143413610036E-7
1,50598310444937E-10
-4,27928881371478E-14
6,5323443704887E-18
-4,12913234939624E-22
```

```
#
# Conductivity Temperature Correction low: Ctc.C1-Ctc.C5
-0,398142680468083
-0,00259321862905614
-0,000684962594896168
2,30924943510067E-5
-1,76713340491716E-7
#
# Conductivity Temperature Correction high: Ctc1.C1-Ctc1.C5
-0,276279974677843
-0,0925221052164181
0,00180276949585506
-1,54831091575708E-5
2,09671367968997E-7
#
# Conductivity temperature calibration reference: Tcr
23,88
#
# Conductivity Low load range inner value: L
549
#
# Conductivity High load range inner value: H
3146
```

As can be seen here, the numbers are written European style with a decimal separator = ",". This is because the CAT file is written according to regional settings.

Calculation example

All Star-Oddi recorders are post tested after having passed calibration.
This example is based on actual DST CTD calibration post-tests, using the calibration constants in the CAT file (and RCI file) listed in this document.
Reference to equations is by "(x)" were x is the equation number.
Graphical presentations are from SeaStar.

Pressure test

The recorder is placed in a pressure chamber monitored with an accurate reference pressure meter.

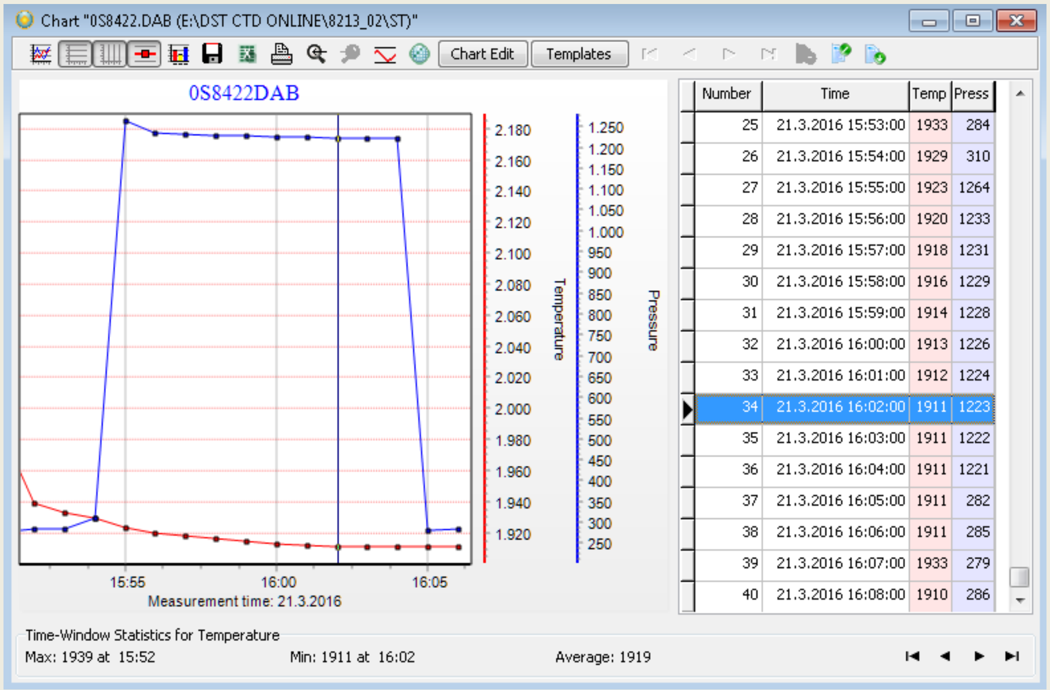


Figure 7: Pressure test. Recorder raw pressure and temperature data

In the pressure post-test point 34 was used.

Converting to raw values from "high/low" values

(1) T = 1911
(2) P = 1223

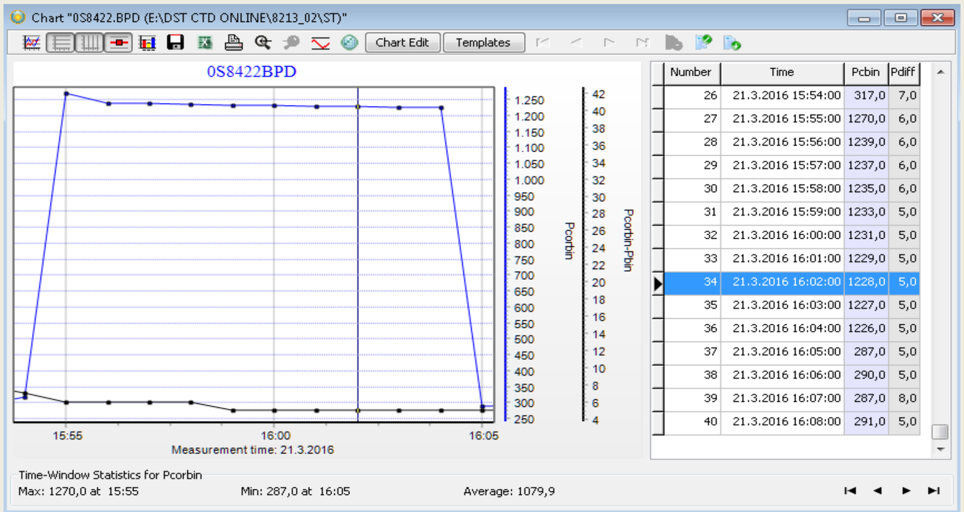
Temperature:

(4) Tv = 21,297 (°C)

Pressure temperature correction:

The pressure reference temperature Tpr = 22,44 (°C)

(6) Pc = 1228



Number	Time	Pcbin	Pdiff
26	21.3.2016 15:54:00	317,0	7,0
27	21.3.2016 15:55:00	1270,0	6,0
28	21.3.2016 15:56:00	1239,0	6,0
29	21.3.2016 15:57:00	1237,0	6,0
30	21.3.2016 15:58:00	1235,0	6,0
31	21.3.2016 15:59:00	1233,0	5,0
32	21.3.2016 16:00:00	1231,0	5,0
33	21.3.2016 16:01:00	1229,0	5,0
34	21.3.2016 16:02:00	1228,0	5,0
35	21.3.2016 16:03:00	1227,0	5,0
36	21.3.2016 16:04:00	1226,0	5,0
37	21.3.2016 16:05:00	287,0	5,0
38	21.3.2016 16:06:00	290,0	5,0
39	21.3.2016 16:07:00	287,0	8,0
40	21.3.2016 16:08:00	291,0	5,0

Figure 8: Pressure temperature correction

The raw pressure data has been increased by 5, as can be seen in the BPD file.

Pressure:

(7) Pv = 5,255 (Bar)

The reference value from the pressure chamber meter was 5,249 (Bar)

The difference is 6 (mBar) = 0,058% FS (Full Scale)

The accuracy for this pressure sensor is 0,6% FS = 0,06 (Bar)

Depth

Calculating depth (in meters) in the ocean one should use:

(8) D = 52,23 (m)

Temperature and salinity test

Temperature and salinity were tested at the same time in a salinity bath.
Both salinity and temperature were accurately monitored.

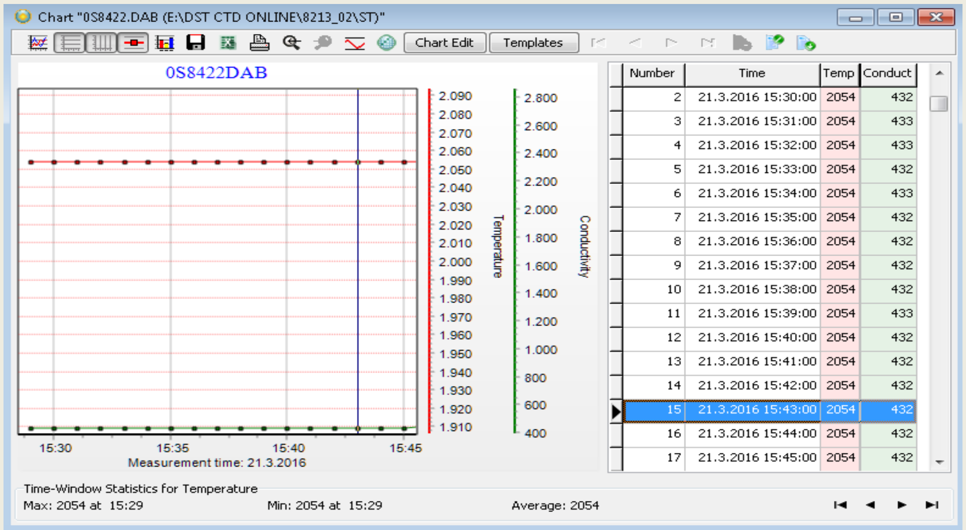


Figure 9: Recorder raw temperature and salinity data.

In the temperature and salinity post-test point 15 was used.

Converting to raw values from "high/low" values

(1) T = 2054
(3) C = 432

Temperature

(4) Tv = 17,070 (°C)
The salinity bath temperature reference value was 17,103 (°C)
The difference is 0,033(°C) or 33(m°C)
The specified accuracy for the temperature sensor is +/-0,1(°C) or +/-100(m°C)

Pressure

Pressure is calculated as in the previous example using (6), (7) and then depth via
(7) Pv = -0,00233 (BAR)
In this example there is no pressure exerted on sensor and thus outside calibration range, first pressure calibration point was 0,02 (BAR) (see RCI file).

Conductivity temperature correction

The conductivity temperature reference value is Tcr = 23,88 (°C)

The conductivity low load range inner value is L = 549

The conductivity high load range inner value is H = 3149

(10) Cc0 = 427,074

(11) Cc1 = 417,494

(12) A = -0,0036890564167

(13) B = 429,0993313

(14) Cc = 428

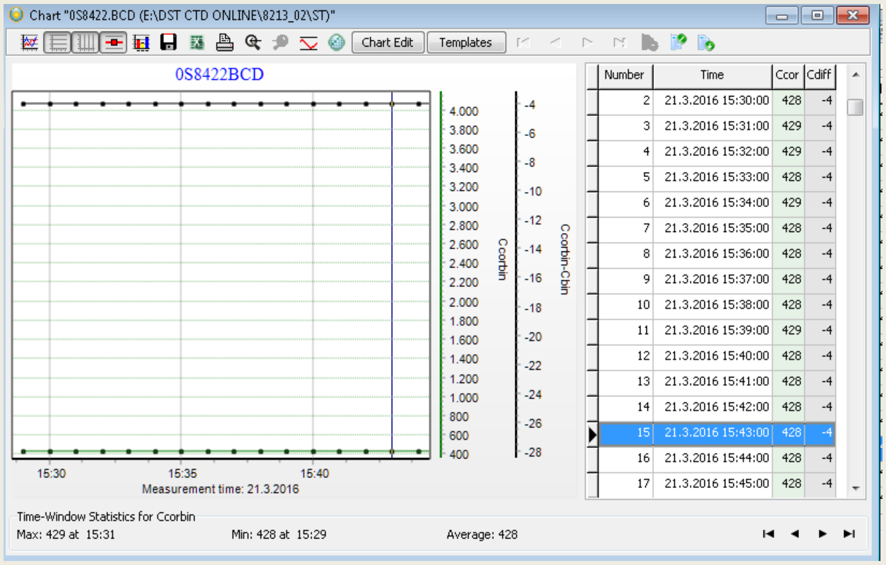


Figure 10: Conductivity temperature correction

The raw conductivity data has been decreased by 4, as can be seen in the BCD file.

Conductivity

(15) Cv = 34,4198 (mS/cm)

The reference value from the salinity bath meter was 34,4013 (mS/cm)

The difference is 18.5(uS/cm) = 0,05% FS (Full Scale)

The accuracy for this conductivity sensor type is specified +/-4% FS = +/-1,4 (mS/cm)

Salinity

Salinity is found by using/inserting Cv, Tv and Pvda in the UNESCO formulas, see the Appendix.
Pvda is the absolute value of Pv in (desi meters)
Pvda = ABS(Pv*10) = 0,0233 (dBAR)

The following insertion is used:

- Cv -> C
- Pvda -> p
- Tv -> T

Calculation should be carried out in the following order.

- (PSSeq-3) R = 0,80260375311
- (PSSeq-5) R_p = 1,0000000824
- (PSSeq-6) r_T = 1,0477628031
- (PSSeq-4) R_T = 0,76550108289

Thus the salinity is found to be in (PSU):
(PSSeq-2) S = 25,9938 (PSU)

The reference value from the salinity bath meter was 25,957 (PSU)
The difference is 37 (mPSU) = 0,13% FS (Full Scale)
The specified accuracy for salinity at this temperature is +/-4% FS = 1,1 (PSU).

5. Start-up suggestions

The following are some suggestions on how to start using your DST CTD online

Setup the SeaStar application program

Setup SeaStar and familiarise yourself with various options available, by reading the user's manual accessible under the Help menu. Especially about data file options.
When analysing DST CTD data there are several graphically viewable files, for example:

- DAB
  Raw data
- BPD
  Raw pressure data temperature corrected
- BCD
  Raw conductivity data temperature corrected
- DAT
  Unit value data

Connect via SeaStar to the DST CTD online

Connect the DST CTD online using the StarCom cable.
This way the RCI file and especially the CAT file are available.

Make online test measurements via SeaStar

You can test your DST CTD by making online measurements.
It´s difficult to test pressure, but placing the DST CTD in a known salinity solution is fairly easy.
Still some things you must consider:

- Do not place the connector in the liquid solution, it is not waterproof.
- Make sure not to touch the conductivity cells.
- Use a cotton swab to insure there are no air bubbles on the conductivity cells.
- Salinity calculations are highly temperature dependent, so make sure the temperature is stable, thus presenting the temperature of the solution.

Note: The ONL file can be viewed any time after the online session is ended.

Make a cable for your embedded system

Follow the description in chapter 1 in this document to make the cable connection.

Connect to the DST CTD with your embedded system

Follow the guidelines in chapter 2 in this document.

Make online test measurements with your embedded system

Make the same measurements as you made with SeaStar and compare the results by:
-Make a raw data DAD file to convert in SeaStar to unit values
-Convert raw data directly in the embedded system and compare to SeaStar

Appendix

The Practical Salinity Scale 1978 (PSS-78)

The Practical Salinity Scale 1978 (PSS-78) has been considered by the Joint Panel on Oceanographic Tables and Standards and recommended by all oceanographic organizations as the scale in which to report future salinity data.

Definition of the practical salinity

Practical salinity, symbol S, of a sample of seawater, is defined in terms of the ratio K_{15} of the electrical conductivity of the seawater sample at the temperature of 15°C and the pressure of one standard atmosphere, to that of a potassium chloride (KCl) solution, in which the mass fraction of KCl is 32.4356E-3, at the same temperature and pressure.
The K_{15} value exactly equal to 1 corresponds, by definition, to a practical salinity exactly equal to 35.
The practical salinity is defined in terms of ratio K_{15} by the following equation:

(PSSeq-1) $$S = a_0 + a_1 K_{15}^{1/2} + a_2 K_{15} + a_3 K_T^{3/2} + a_4 K_{15}^2 + a_5 K_{15}^{5/2}$$

Formulated and adopted by the UNESCO/ICES/SCOR/IAPSO Joint Panel on Oceanographic tables and Standards, Sidney, BC, Canada, 1-5 September 1980. PSS-78 is based on an equation relating salinity to the ratio of the electrical conductivity of seawater at 15°C to that of a standard potassium chloride solution (KCl). It has already been pointed out that a "conductivity ratio" defined salinity scale is better than a "chlorinity" scale for density determination; and added to this is the study of Farland showing that in the hands of average observers, titration is a less precise than is conductivity measurement.
In order to eliminate the ambiguity exhibited by (1) and (2) under conditions of ionic ratio variation, the Practical Salinity Scale 1978 breaks the existing chlorinity-salinity tie in favor of a definite salinity-conductivity ratio relationship; all waters of the same conductivity ratio then have the same salinity.

A standard seawater of 35 has by definition a conductivity ratio of unity at 15°C with a KCl solution containing a mass of 32.4356 g KCl in a mass of 1 kg of solution.

In practice Merk "Suprapur" KCl has been found to be of adequate purity being consistent within a bath and between batches. It is worth nothing that the major impurity is NaCl, and at the level of interest the molal conductivities of the two salts are sufficiently near to minimize the effect of the impurity. From measurements on weight diluted (with pure water) or weight evaporated North Atlantic surface water, the following relationship was established:

(PSSeq-2) $$S = a_0 + a_1 R_T^{1/2} + a_2 R_T + a_3 R_T^{3/2} + a_4 R_T^2 + a_5 R_T^{5/2} + \frac{(T-15)}{1+k(T-15)}\left\{b_0 + b_1 R_T^{1/2} + b_2 R_T + b_3 R_T^{3/2} + b_4 R_T^2 + b_5 R_T^{5/2}\right\}$$

where:
a_0 = 0.008
a_1 =-0.1692
a_2 = 25.3851
a_3 = 14.0941
a_4 = -7.0261
a_5 = 2.7081
b_0 = 0.0005
b_1 = -0.0056
b_2 = -0.0066
b_3 = -0.0375
b_4 = 0.0636
b_5 = -0.0144
k = 0.0162 -2°C < T < 35°C

In all cases temperatures are measured according to the International Practical Temperature Scale (1968).
The values of coefficients in PSS-78 are based on experiments carried out on existing standard seawaters that were diluted and evaporated by weight. This ensures the conservatism of a salinity so defined and its local reproducibility. The standard deviation was 0.0013 in salinity. This equation is used for calculation of the practical salinity measured only by laboratory salinometers, where R_t is a measured value.

A supplementary equation was also established for converting conductivity ratios measured at pressure greater then one atmosphere (i.e. for CTD-measurements).
Given *in situ* measurements of conductivity ratio:

(PSSeq-3) $$R = \frac{C(S, T_{68}, P)}{C(35, 15_{68}, 0)}$$

where:

$C(35,15_{68},0)$ = 42.914 mS/cm = 4.2914 S/m
$T_{68} = 1.00024 \times T_{90}$
T_{68} - temperature IPTS-68, C
T_{90} - temperature ITS-90,ºC

(PSSeq-4) $$R_T = \frac{R}{r_T R_P}$$

where:

(PSSeq-5) $$Rp = 1 + \frac{A_1 p + A_2 p^2 + A_3 p^3}{1 + B_1 T + B_2 T^2 + B_3 R + B_4 TR}$$

where
$A_1 = 2.070\times10^{-5}$
$A_2 = -6.370\times10^{-10}$
$A_3 = 3.989\times10^{-15}$
$B_4 = -3.107\times10^{-3}$
$B_1 = 3.426\times10^{-2}$
$B_2 = 4.464\times10^{-4}$
$B_3 = 4.215\times10^{-1}$

The standard deviation was 1.3 ppm in salinity. Given R, T, and p, a may be computed and the factor rt, the temperature coefficient of standard seawater, may be obtained from the polynomial equation:

(PSSeq-6) $$r_T = c_0 + c_1 T + c_2 T^2 + c_3 T^3 + c_4 T^4$$
where:

$c_0 = 6.766097 \text{ X } 10^{-1}$

$c_1 = 2.00564 \text{ X } 10^{-2}$

$c_2 = 1.104259 \text{ X } 10^{-4}$

$c_3 = -6.9698 \text{ X } 10^{-7}$

$c_4 = 1.0031 \text{ X } 10^{-9}$

These equations enable the practical salinity S in a range 2 to 42 to be calculated from conductivity C (mS/cm or S/m) measured at temperature T (ºC) and hydrostatic pressure p(dBar) and is valid in the temperature range -2°C to +35°C and hydrostatic pressure 0-10000 dBar.

Practical salinity should be expressed by dimensionless number only and should be written as, *e.g. S = 35.034.*