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SBE 41plus: OEM Reference Manual (Rev. H)

Introduction

This manual outlines the features and characteristics of the SBE 41plus. The SBE 41plus is factory-configured to any of the following variants:

- Spot sampling standard or 'Standard'
- Continuous sampling standard or 'CP Standard'
- Continuous sampling UW or 'CP UW'
- Continuous sampling MetOcean or 'CP MetOcean'

Note that some of the features and performance characteristics are variant dependent. These are noted throughout this manual with a (+)

Electrical Interface[†]

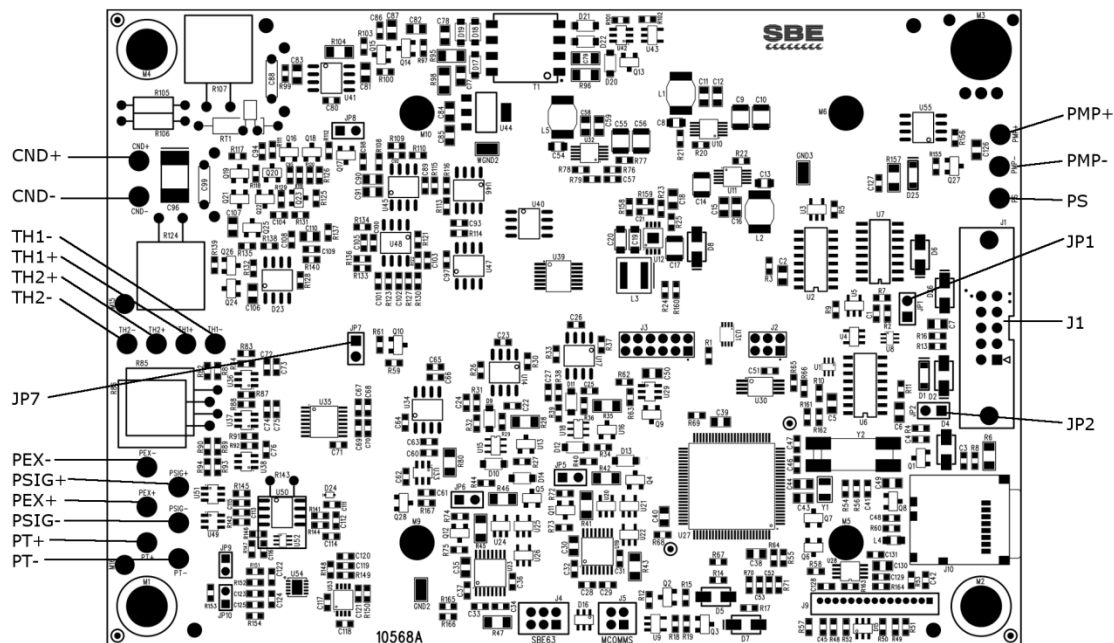


Figure 1 - SBE 41plus Standard Board

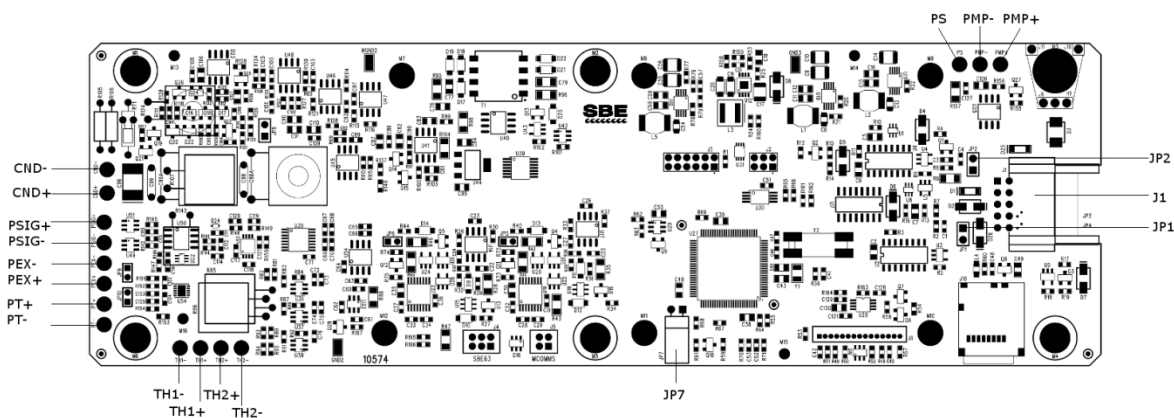


Figure 2 - SBE 41plus Slim Board

SOLDER TURRET	DESCRIPTION
CND+	Conductivity sensor center electrode
CND-	Conductivity sensor outer electrodes
TH1+	Temperature sensor
TH1-	Temperature sensor
TH2+	NOT USED
TH2-	NOT USED
PT+	Pressure sensor temperature compensation diode anode
PT-	Pressure sensor temperature compensation diode cathode
PEX+	Pressure sensor positive excitation
PEX-	Pressure sensor negative excitation
PSIG+	Pressure sensor positive input
PSIG-	Pressure sensor negative input
PMP+	Pump positive power
PMP-	Pump negative power
PS	Pump speed control (CP variants only)

Table 1- Board Electrical Connections

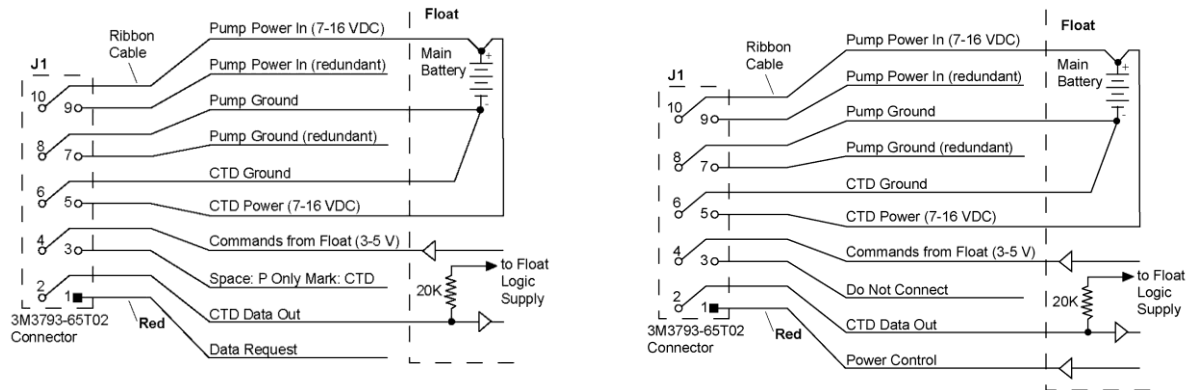


Figure 3 - J1 Detail. Left: Standard and UW Variant. Right: CP Standard and MetOcean Variant.

CONNECTOR DESIGNATOR	FUNCTION														
J1	Power and data connector with the following pin-out: <table border="0"> <tr> <td>1. Data Request /</td><td>6. GND</td></tr> <tr> <td>Power Control</td><td>7. Pump GND</td></tr> <tr> <td>2. SBE 41plus TX (open</td><td>8. Pump GND</td></tr> <tr> <td>collector)</td><td>9. Pump +</td></tr> <tr> <td>3. Sample Type</td><td>10. Pump +</td></tr> <tr> <td>4. SBE 41plus RX</td><td></td></tr> <tr> <td>5. Vin (7-16V)</td><td></td></tr> </table>	1. Data Request /	6. GND	Power Control	7. Pump GND	2. SBE 41plus TX (open	8. Pump GND	collector)	9. Pump +	3. Sample Type	10. Pump +	4. SBE 41plus RX		5. Vin (7-16V)	
1. Data Request /	6. GND														
Power Control	7. Pump GND														
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collector)	9. Pump +														
3. Sample Type	10. Pump +														
4. SBE 41plus RX															
5. Vin (7-16V)															
JP1 (0.1" jumper)	Continuous power-enable: Default: Not installed <i>This is a hardware override that powers the instrument regardless of activity timeout or command to sleep. This can result in odd, although not destructive, behavior in those instances. Rebooting by physical power cycle will fix this behavior.</i>														
JP2 (0.1" jumper)	Hardware interface disable: Default: Not installed <i>If fitted the instrument will wake to command mode on serial activity and will not respond to the hardware interface.</i>														
JP7 (0.1" jumper)	Firmware update mode enable: Default: Not installed <i>If fitted the instrument will boot in firmware update mode.</i>														

Table 2 - Electrical Interface

Logic Level Signals

HIGH: 3.0 – 5.0V

LOW: 0 – 0.3V

Serial Communications Parameters:

9600 baud

8 data bits

1 stop bit

No parity

Hardware Sampling Interface[†]

This interface provides an independent mechanism to trigger various types of samples with and without sampling parameters depending on the hardware interface mode. To use the hardware interface the instrument must be asleep and JP2 not installed.

The SBE41plus features two different interface modes when enabled: 'Standard' and 'MetOcean'. The hardware interface mode is factory-set and must not be changed.

Standard Hardware Interface

In this mode, the interface is read, once, approximately 260mS after the DATA_REQ rising edge. The SBE 41plus uses the states of the I/O lines to make decisions about what sample to take and what data to return.

Command	Pin 4 (RX)	Pin 3 (Sample Type)	Pin 1 pulse (Data Request)
Enter command mode	HIGH	HIGH	Long
Take pressure-temperature-salinity sample	HIGH	HIGH	Short
Take fast pressure and temperature	HIGH	LOW	Short
Take fast pressure	LOW / HiZ	LOW	Short

Table 3- Standard Hardware Interface

Timing Characteristics

Table 4 specifies the timing requirements for the DATA_REQ pulses.

Pulse type	Min duration	Max duration
Long	400 ms	-
Short	1 ms	100 ms

Table 4 - Pulse Timing Requirements

Transitions on the RX line will wake up the controller and can result in spurious sampling or resumption of the commanded mode. For this reason RX must be set after the DATA_REQ rising edge. Additionally, 100ms after the DATA_REQ rising edge the RX and SMPL_TYPE lines must be stable and remain stable until at least 400ms after the DATA_REQ rising edge. Figure 4 summarizes these requirements.

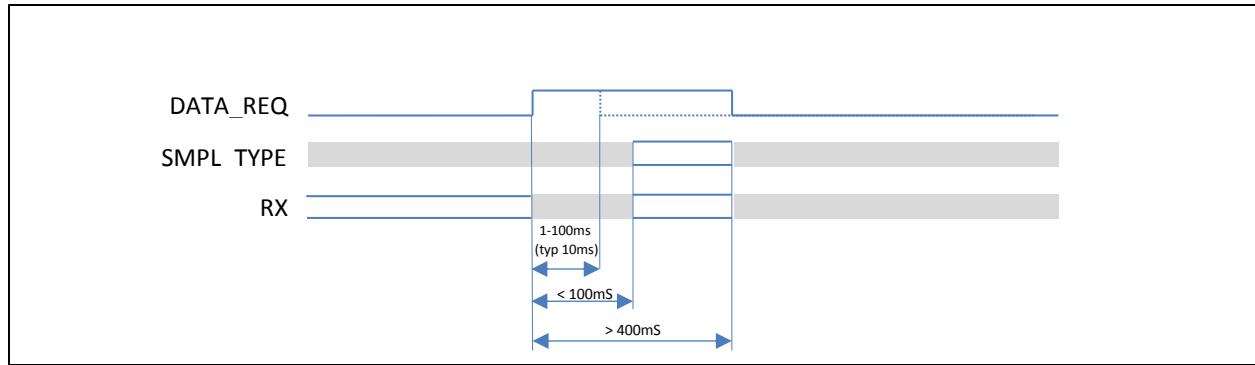


Figure 4 - Standard HW Interface Timing

MetOcean Hardware Interface

In the 'MetOcean' variant the 'Sample Type' line is ignored. The RX line wakes up the controller and can put it in commanded mode.

In this mode, when the 'Power Control' line is asserted (voltage > 3V) the CTD will power up and begin sampling data. A sample is stored and transmitted every 1 or 2 seconds (depending on 'samplerate='). When the 'Power Control' line is de-asserted (voltage < 0.5V) the CTD will stop sampling and enter a quiescent power state.'

The following table summarizes the interface behavior:

Power Control	RX	Result
Hi (> 3V)	Don't care	CTD samples every 1 or 2 seconds (profiling mode)
Lo (< 0.5V)	No change	CTD enters quiescent power state
Lo (< 0.5V)	Falling edge	Wake up and enter commanded mode

Table 5 - MetOcean Hardware Interface

Command Reference

Operational Commands

Command	Description
fp	Take and display a pressure measurement (in dbar) and power down the instrument.
fpt	Take a pressure and a temperature measurement. Display the results (in dbar, and C), and power down the instrument.
pts	Power on, pump for 'tswait' seconds (see 'tswait='), take and display (in dbar, C, and psu) a pressure/temperature/salinity sample and power down the instrument.
lts	Send last sample (acquired with: hardware fpt, hardware pts, 'fpt', 'pts', 'lts', or 'ltss') and take a new pressure, temperature, and salinity sample without pumping.
ltss	Execute 'lts' and power-off.
startprofile	Set sample counter to 0, start profile, store t, c, p at 1Hz or 0.5Hz according to 'samplerate=' setting.
startprofileN	Set sample counter to 0, wait 'N' seconds with pump running, start profile, store t, c, p at 1Hz or 0.5Hz according to 'samplerate=' setting.
resumeprofile	Resume profiling mode, store t, c, p at 1Hz or 0.5Hz according to 'samplerate='.
resumeprofileN	Wait 'N' seconds with pump running, resume profiling mode, store t, c, p at 1Hz or 0.5Hz according to 'samplerate=' setting.
slp	Send last pressure acquired during profiling. (works only during profiling)
slt	Send last temperature acquired during profiling. (works only during profiling)
slpt	Send last pressure and temperature acquired during profiling. Real-time output must be disabled (see 'outputrt='). This command works only during profiling.
stopprofile [†]	Stop profiling mode. If the number of 'stopprofile' received since the last 'startprofile' is > 1 calculates dt/dp. Profile is halted automatically when acquired pressure is less than the cutoff (see 'pcutoff=') ¹ . Profile is halted automatically after acquiring 30.000 samples.
dtdp	Send last calculated value for dt/dp.
resetoffset	Sample pressure for 1-minute. Store pressure as new pressure offset. The maximum allowed offset is 2% of the full range as listed by the 'dc' command.
binaverage	Average stored data into bins.
qs	Power off digital and analog electronics, enter low power quiescent state. Quiescent state is entered automatically when not profiling and a command has not been received for 2 minutes.
qsr	Same as 'qs' but with a response.

Note 1: MetOcean firmware variant only stops the pump when pressure is below 'pcutoff'. In this variant the CTD will continue to profile while the DATA_REQ line is asserted.

Table 6 - Operational Commands

Status Commands

Command	Description
ds	Display CTD settings.
dc	Display CTD calibration coefficients.
ddn	Display number of stored samples.
nbin	Display number of bins created when averaging as: 'number of bins = NNN<CR><LF>' .
dan	Display number of bins created as: 'NNN<CR><LF>' .
getcc	Display calibration in XML format.
getcd	Display settings in XML format.
getsd	Display status in XML format.
gethd	Display CTD hardware data in XML format.
getec	Display event counters in XML format.

Table 7 - Status Commands

Data Upload Commands

Command	Description
dd	Dump all non-averaged data in engineering units.
ddS,F	Dump non-averaged data in engineering units from scan 'S' (≥ 1) to scan 'F' ($\geq S$).
ddh	Dump all non-averaged data in hexadecimal format.
ddhS,F	Dump non-averaged data in hexadecimal format from scan 'S' (≥ 1) to scan 'F' ($\geq S$).
da	Dump all bin-averaged data in engineering units.
daS,F	Dump bin-averaged data in engineering units from bin 'S' (≥ 1) to bin 'F' ($\geq S$).
dah	Dump all bin-averaged data in hexadecimal format.
dahS,F	Dump bin-averaged data in hexadecimal format from bin 'S' (≥ 1) to bin 'F' ($\geq S$).

Table 8 - Data Upload Commands

Configuration Parameters[†]

Parameter	Description	Default	Allowed values
tswait=	Set delay before pressure/temperature/salinity sample in seconds. Applies for both command line and hardware interface 'pts'.	0	0-255
pcutoff= [†]	Profiling cutoff pressure in dBar. ¹	2	(-10)-10,000
samplerate=	Profiling sampling rate: fast (1Hz), slow (0.5Hz)	See Note 3	'fast', 'slow'
pumpfastpt=	Set run/not run pump for 250ms before taking fast PT sample. Applies for both command line and hardware interface.	y (1)	n(0), y(1)
outputpressure= [†]	Output pressure when profiling. ²	y (1)	n(0), y(1)
outputpts= [†]	Output pressure, temperature, and salinity when profiling. ^{2,3}	See Note 3	n(0), y(1)
outputs=	Output sample number when profiling. ²	n (0)	n(0), y(1)
outputdensity=	Output density on 'pts' command and hardware 'pts'.	n (0)	n(0), y(1)
outputrt=	Enable/disable real-time output while profiling. ²	y (1)	n(0), y(1)
autobinavg=	Automatically average stored data when profile is automatically stopped due to p < pcutoff	n (0)	n(0), y(1)
includenbin=	Output number of scans in bin average (for 'da' commands) or the scan number (for 'dd' commands).	n (0)	n(0), y(1)
echocmd=	Enable/disable command echo.	y (1)	n(0), y(1)
dsreplyformat=	Configure ds reply format to standard (s) or Webb (w).	s	s - Standard w - Webb
outputdensity=	Append density to real-time output (on PTS frames only).	n (0)	n(0), y(1)
addtimingdelays=	Add delays after sampling and before sending data for backward compatibility.	n (0)	n(0), y(1)

Note 1: Profiling and pump stop if pressure is below cut-off, except for 'MetOcean' variant in which only the pump is stopped.

Note 2: UW variant also requires the SMPL_TYPE line to be low to enable real-time output.

Note 3: 'outputpts=' and 'samplerate=' defaults depend on the variant. 'outputpts=' default is 'n (0)' for all variants except MetOcean. The 'samplerate=' default is 'fast' for all variants except MetOcean.

Table 9 - Configuration Parameters

Display Status (DS) Format for Non-Profiling Variant (SBE41plus-Standard)

In the non-CP variant of the SBE41plus, the 'ds' reply format can be controlled by means of the 'dsreplyformat=' setting. Other variants ignore this setting.

Standard format ('dsreplyformat=s')

```
SBE 41 V 6.1.0 SERIAL NO. 10008
variant: Standard
pump 0.25 sec before fastpt measurement
firmware compilation date: May 12 2015 09:23:48
add timing delays = no
outputdensity = no
```

Webb format ('dsreplyformat=w')

```
SBE 41 V 6.1.0 SERIAL NO. 10008 XX
variant: Standard
firmware compilation date: May 12 2015 09:23:48
add timing delays = no
outputdensity = no
```

Where XX=01 means 'pump will run before fast PT sample', and XX=02 means 'pump will not run before fast PT sample'

Bin Averaging Parameters

Parameter	Description	Default
top_bin_interval=	Top bin interval (dbar).	10
top_bin_size=	Top bin size (dbar).	10
top_bin_max=	Top pressure section maximum depth (dbar).	100
middle_bin_interval=	Middle bin interval (dbar).	50
middle_bin_size=	Middle bin size (dbar).	50
middle_bin_max=	Middle pressure section maximum depth (dbar).	1000
bottom_bin_interval=	Bottom bin interval (dbar).	100
bottom_bin_size=	Bottom bin size (dbar).	100
includetransitionbin=	Add two transition bins (n(0) / y(1)).	n (0)

Table 10 - Bin Averaging Parameters

Bin Averaging Notes

Bin average is divided into three sections: top, middle, and bottom.

- **Interval:** Spacing between bins. Example: if interval is 10 decibars in top section, then bin centers will be at 0, 10, 20 decibars.
- **Size:** Scans from bin center $\pm$ size/2 will be included in average. Size must be $\leq$ interval.
- **Max:** Maximum pressure for section; bottom section has no maximum pressure.

SBE 41plus performs bin averaging **without** interpolation.

The two transition bins are:

Bin	From	To
#TB1	$top_bin_max + \frac{top_bin_interval}{2}$	$top_bin_max + \frac{middle_bin_interval}{2}$
#TB2	$middle_bin_max + \frac{middle_bin_interval}{2}$	$middle_bin_max + \frac{bottom_bin_interval}{2}$

Table 11 - Transition Bins Limits

Output Formats for Data Upload

Engineering Units Data Format

ppppp.pp,ttt.tttt,sss.ssss, n<CR><LF>

p = pressure in decibars

ttt.tttt = temperature in ITS-90 (Deg C)

sss.ssss = salinity

n = number of scans in this bin average / scan number (if enabled by 'includenbin=')

Hexadecimal Encoded Formats[†]

The hexadecimal encoding format is factory-set and must not be changed after shipping.

Standard Encoding Format

PPPPPTTTTSSSSNN<CR><LF>

- **PPPPP** = 5 HEX characters representing pressure. $P(\text{dbar}) = \text{Hex2Dec}(\text{PPPPP})/100 - 10$.
If pressure < -10dbar then PPPPP = 0x00000. If pressure is > 3000dbar then PPPPP = 0xFFFFF.
- **TTTTT** = 5 HEX characters representing temperature. $T(\text{C}) = \text{Hex2Dec}(\text{TTTTT})/10,000 - 5$.
If temperature < -5C then TTTTT = 0x00000. If temperature is > 35C then TTTTT = 0xFFFFF.
- **SSSSS** = 5 HEX characters representing salinity. $S = \text{Hex2Dec}(\text{SSSSS})/10,000 - 1$.
If S < -1 then SSSSS = 0x00000. If salinity is > 45 then SSSSS = 0xFFFFF.
- **NN** = 2 HEX characters number of scans in this bin average / scan number (if enabled by 'includenbin=')

UW Encoding Format (See 'encode.c' v1.3 by Dana Swift for more details)

PPPTTTTSSSSNN<CR><LF>

- **PPPP** = 4 HEX characters representing pressure
- **TTTT** = 4 HEX characters representing temperature
- **SSSS** = 4 HEX characters representing salinity

- **NN** = 2 HEX characters number of scans in this bin average / scan number (if enabled by 'includenbin=')

Output Formats for Profiling Real-Time Output[†]

The profiling output format is factory-set and must not be changed after shipping.

Standard Output Format

n,ppppp.pp,ttt.tttt,sss.ssss,dddd.ddd<CR><LF>

- **n** = Scan number (if enabled by 'outputsn=')
- **ppppp.pp** = Pressure in decibars (if enabled by 'outputpressure=' or 'outputpts=')
- **ttt.tttt** = Temperature in ITS-90 (Deg C) (if enabled by 'outputpts=')
- **sss.ssss** = Salinity (if enabled by 'outputpts=')
- **dddd.ddd** = Density (sigma-theta in kg/m³) (if enabled by 'outputdensity=')

MetOcean Variant Output Format

n,sss.ssss,ttt.tttt,ppppp.pppp<CR><LF>

- **n** = Scan number (if enabled by 'outputsn=')
- **sss.ssss** = Salinity + 20.0 psu (if enabled by 'outputpts=')
- **ttt.tttt** = Temperature in ITS-90 (Deg C) (if enabled by 'outputpts=')
- **ppppp.pppp** = Pressure in decibars (if enabled by 'outputpressure=' or 'outputpts=')

Hardware Sampling Timing Characteristics

PTS ¹

Event	Elapsed time (‘addtimingdelays=n’, default)	Elapsed time (‘addtimingdelays=y’)
‘Data Request’ rising edge	0.00s	0.0s
Pump start	0.28s	0.28s
Pump stop	1.46s	1.46s
Sample transmission begins	3.12s	3.67s
Power off	3.22s	3.73s

¹ ‘tswait = 0’ (default)

Fast PT ²

Event	Elapsed time (‘addtimingdelays=n’, default)	Elapsed time (‘addtimingdelays=y’)
‘Data Request’ rising edge	0.00s	0.0s
Pump start	0.28s	0.28s
Pump stop	0.53s	0.53s
Sample transmission begins	1.90s	2.11s
Power off	1.95s	2.16s

² ‘pumpfastpt = y’ (default)

Fast P

Event	Elapsed time (‘addtimingdelays=n’, default)	Elapsed time (‘addtimingdelays=y’) ³
‘Data Request’ rising edge	0.00s	0.00s
Sample transmission begins	0.61s	0.61s
Power off	0.65s	0.65s

³ No effect on ‘Fast P’

NOTE: Timing figures can vary +/- 100ms due to hardware reset timing variations.

Power Consumption[†]

NOTE: All ratings are typical at 12V battery voltage and 25°C unless otherwise noted.

Operating condition / Variant	Average current / Estimated energy	
	CP	NON-CP
Quiescent	15 uA	15 uA
Idling (waiting for serial interface command)	3.3 mA	3.3 mA
Profiling (1Hz)	21 mA	-
Computing bin average ¹	6 mA	6 mA
HW requested fast pressure	52 mJ	52 mJ
HW requested fast pressure and temperature	118 mJ (pumpfastpt=n) / 160 mJ (pumpfastpt=y)	118 mJ (pumpfastpt=n) / 760 mJ (pumpfastpt=y)
HW requested pressure, temperature, and salinity	486 mJ	3350 mJ

¹Measured for a 10,000 scans test profile @ 160 scans/second

Testing Commands

NOTE: These commands are meant for factory use only and are subject to change.

memorytest	Test file system and EEPROM. EEPROM contents are not modified
loadprofile	Load 10050 scan dummy profile
loadprofile=N	Load N scan dummy profile
loaddownprofile	Load 10050 scan dummy profile of a downcast
loaddownprofile=N	Load N scan dummy profile of a downcast
analogon	Power analog electronics.
analogoff	Power off analog electronics.
pumpfast	Run pump at fast speed.
pumpslow	Run pump at slow speed.
pumpson	Run pump at fast speed for 2.5 seconds, then run pump at slow speed.
pumpoff	Turn off pump.
ts	Power analog, take sample, send sample in engineering units, power off.
tsr	Power analog electronics, take sample, send sample in raw form, power off.
tse	Power analog electronics, take sample, send sample in engineering units.
tc	Power analog, take 100 C samples, power off analog, output is S/m.
tcr	Power analog electronics, take 1 temperature measurement, take 100 conductivity measurements, power off analog electronics. Output is degree C and raw frequency.
tp	Power analog electronics, take 100 P and P temperature samples, analog off, output is decibars and degrees C.
tsp	Power analog electronics, pressure measurement, power off analog electronics, output is decibars.
tpr	Power analog electronics, take 100 pressure measurements, power off analog electronics, output is raw A/D counts from pressure and pressure temperature.
tt	Power analog electronics, take 100 temperature samples, power off analog, output is degrees C
ttr	Power analog electronics, take 100 temperature measurements, power off analog electronics. Output is scaled temperature ratio.
freerun	Sample and transmit data continuously until receive <esc>
fastc	Transmit converted conductivity until receive <esc>
fastt	Transmit converted temperature until receive <esc>
fastp	Transmit converted pressure until receive <esc>

Table 12 - Factory Testing Commands

CAUTIONARY NOTES

1. Follow normal procedures to avoid static discharges that could damage CMOS and other electronic parts used on the SBE 41plus CTD boardset.
2. Consult Sea-Bird before disassembling any of the CTD electrical or mechanical components.
3. To ensure that the cell flushes properly, the SBE 41plus must mount to the top of the float. CTD acquisition must occur on the upward profile only.
4. The conductivity cell is shipped dry. A red cap over the TC duct inlet and two translucent rubber plugs in the exhaust posts prevent entry of airborne contaminants that could coat the cell resulting in calibration error. Remove these covers just prior to deployment. Float manufacturers who perform ballasting or other operations requiring immersion of the CTD in water should contact Sea-Bird for guidance. These operations can alter the calibration unless performed correctly.
5. After deployment, it is important that the cell never be pumped dry: the "U" shaped sensor geometry must remain water-filled to ensure that surface oils float away when the float re-submerges. To prevent pumping the cell dry when the float breaks the surface, the SBE 41CP automatically stops profiling when the pressure is less than the value set using the 'pcutoff=' command. A value of 5 dbar (approximately 5 meters depth) is recommended.
6. The pressure sensor will tend to drift toward higher readings over time. This has a relatively small effect on salinity accuracy (a 2 dbar pressure error causes a 1 ppm error in calculation of salinity). More importantly, a pressure error can result in the float breaking the surface even though the pump cutoff threshold has not been reached. Accordingly, when the float is at the surface the float controller should send the resetoffset command (refer to the Command Summary for further information). This will correct (re-zero) any pressure offset, thus preventing salinity error and, assuming the cautions described in (5) have been followed, inadvertent surface operation of the pump.
7. FOR CONTINUOUS PROFILING VARIANTS ONLY: The SBE 41plus is designed with the expectation that a profile will be started (command 'startprofile') at the float parking depth and stopped when the 'pcutoff' threshold is reached. To reduce CTD power consumption, users may wish to consider intermittent operation of the CTD during the deep part of the profile; however, this should only be attempted after consultation with Sea-Bird. Unless carefully planned, discontinuous operation of the CTD will prevent thermal equilibration of the conductivity cell, resulting in salinity error.
8. Operation of the CTD during the float parking interval expels the water otherwise trapped in the cell, possibly leading to long-term drift in salinity. Consult with Sea-Bird if sampling during float parking is required in your application.

Revision History

Rev.	Date	Description	Editor
A	2015-05-05	Initial draft for internal alpha testing.	DAS
B	2015-05-12	Noting autobinavg setting for MO variant. Added 'dsreplyformat=' and 'outputdensity='. Corrected typo in 'outputrt='. Corrected 'tcr' description. Moved advanced factory configuration settings to factory section. Added 'addtimingdelays=' and 'legacy41delays='. Added hardware interface timing characteristics. Moved factory configuration reference to a separate document.	DAS
C	2015-05-12	Revised slp,slt,slpt. Edited Header and footer.	DAS
D	2015-06-23	Corrected reference to S11 (changed to S12) Revised voltage range Revised figures for beta board Revised slp,slt,slpt. Revised timing figures Revised 'ds' reply for spot sampling variant.	DAS
E	2015-08-21	Adapted to released product manual	DAS
F	2015-08-28	Removed 'Confidential' watermark and footer	DAS
G	2015-09-15	Revised HW PT timing. Corrected typo in timing table. Updated power consumption section.	DAS
H	2016-04-19	Corrected 'pcutoff' typo in cautionary notes	DAS