

CAST MODE

The CAST mode is the 'normal' operating mode of TAPS. This is the primary use for which TAPS was designed, although other modes are possible. Operation of CAST mode should probably be thoroughly mastered before attempting to use the SOUNDER modes.

In CAST mode, TAPS always takes acoustical samples from a small, finite volume at a fixed range from the transducers. A fixed-duration ping is generated (on each channel sequentially) and the returning echo amplitudes are sampled at 5 intervals centered on a range of 1.5 m. Each sample is spaced one-half pulse length (12.5 cm) from the next so that each echo sample arises from a completely separate set of scatterers.

Thus, the number of separate pings required to obtain a statistically-useful number of independent echo samples can be rather small, speeding up data collection. A more complete description of the acoustical sampling may be found in **Appendix 2: Basic Acoustics**.

CAST mode relies on the depth sensor to control power to the acoustic transceivers, turning them on and off as TAPS is lowered and raised in the water. Thus, installing the shorting plug will not automatically begin data collection.

A TYPICAL CAST

A typical cast might go as follows: The TAPS is physically secured to a CTD cage or to the hydrowire with the transducer end free of any obstruction and pointing horizontally. When the cast is ready to commence, the 2-pin shorting plug is installed and the locking sleeve secured over it. All connectors are checked to ensure a dummy plug or interconnect cable is attached to each jack and the locking sleeves are installed.

Installing the shorting plug applies power to the TAPS CPU board. The first function performed by the CPU is to initialize the TAPS system. This includes



reading stored operating parameters from an EEPROM inside the CPU chip. Since CAST MODE has been selected, the CPU also measures the output of the depth sensor and saves this value as a zero-depth offset. This offset is used to correct depth values once TAPS is put into the water.

After this initialization, the CPU begins sampling the depth sensor continuously. As TAPS is lowered into the water, the depth reading begins to change until it reaches the pre-programmed TURN-ON DEPTH. When this depth is reached, the CPU switches on the transceivers and starts an approximately 3-second delay to let the circuits stabilize. If external sensors are connected to TAPS, they are also powered at this time. During the delay, TAPS writes a data header to non-volatile data RAM containing certain information about the TAPS setup.

When the delay is complete, TAPS begins taking data. TAPS reads and stores the value of the internal real-time-clock (RTC). If external sensors are enabled, these are sampled and the results stored. Then TAPS begins a loop: Each acoustic channel is pulsed once in sequence and the echoes sampled and accumulated into memory. The depth and temperature sensors are sampled and the results added to accumulators. Then the cycle begins again with acoustic channel

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#1. When the pre-programmed number of pings have been completed, the various accumulators are moved from working memory to the non-volatile RAM used for data storage. Then sampling begins again with another read of the RTC.

Why sample depth and temperature on each ping cycle? This way, the data sets (acoustic and physical) have the same depth resolution. They are averages over the same vertical extent.

As TAPS approaches the surface, it will pass above the TURN-OFF DEPTH (which must be less than the TURN-ON DEPTH). Power to the transceivers is removed and an end-of-file mark is written into data memory to mark the end of a cast.

During the downcast, it may happen that the depth exceeds a user-specified threshold called the MAX DEPTH. If this occurs, sampling ceases and power to the transceivers is switched off. TAPS continues to monitor depth but no data are stored. This will mark the end of the first 'cast'.

On the way back up, when TAPS rises above the MAX DEPTH, power is restored to the transceivers and sampling starts again. This will constitute a new cast, with a new cast header being stored in data RAM along with the pertinent setup information.

On deck, the TAPS operator can elect to dump the data just collected (with any internally-recording instrument, it is advisable to dump the data whenever the opportunity presents itself). The dummy plug covering the 8-pin IO connector is removed and either the data cable or one of the charging cables attached.

The operator must then start a terminal program running on the data-logging computer. Note that any sort of computer may be connected to TAPS so long as the serial port is RS-232C compatible. The serial port should be set for 9600 baud, no parity, 8 data bits, and

1 stop bit (9600-N-8-1) unless TAPS has been programmed for another baud rate.

Typing an "S" or an "s" will produce a STATUS screen like that shown in Fig. 1. This screen describes the current TAPS setup and shows the current date, time, depth, temperature and battery voltage. It reports on the number of casts stored in memory and how much memory (expressed as a percentage of total memory) has been filled with data. The acoustic frequencies and the associated calibration constants are displayed. Finally, any external sensors connected to TAPS are listed.

The data may be dumped to the data logging computer by typing a "D" or a "d". In CAST mode, the data are transferred as ASCII text lines. The operator is first reminded to open a data capture file; after pressing the RETURN or ENTER key, a formatted data dump commences. A typical data dump is shown in Fig. 2.

Each cast begins with a data header containing information about the TAPS setup. These data are sometimes quite important in interpreting the results or in deciding what further processing should be done to certain data. For example, there is a user-entered scale factor for the depth sensor. If it were found from comparison with a CTD that the TAPS depth sensor read 5% high, an appropriate scale factor could be entered into TAPS for use on subsequent casts. Knowing which casts were obtained with which scale factor, however, allows post-cast correction of depth values so that all cast data are scaled similarly.

The actual data consists of lines of numbers, beginning with the date (yymmdd), the time (hhmmss), the depth (m) and the temperature (C). Two values for the external sensors follow. The last six numbers are volume scattering strengths at the six TAPS frequencies from lowest to highest. Each line ends with a <CR> <LF>.

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TAPS-6 ACOUSTIC PROFILING SYSTEM
S/N 11
S/W VERSION 7.25

```
CAST MODE : INTERNAL RECORDING
NUMBER OF CASTS STORED      = 0
TURN-ON DEPTH               = 2.50 M
TURN-OFF DEPTH              = 1.50 M
MAXIMUM OPERATING DEPTH     = 190.00 M
MAXIMUM SAFE DEPTH          = 194.10 M
MEAN SAMPLE RANGE           = 125 CM
CURRENT BATTERY VOLTAGE     = 27.76 VDC
CURRENT TIME & DATE         = 07:52:30 03/12/02
CURRENT DEPTH                = 0.00 M
CURRENT TEMPERATURE         = 22.89 C
PINGS PER DATA SET         = 6
PERCENTAGE OF MEMORY USED   = 0.0 %
FREQUENCIES: 265 420 700 1100 1850 3000 KHZ
CALs = -68.3 -62.9 -60.0 -52.3 -37.1 -20.3 dB
SENSOR #1: SBE-4
SENSOR #2: -
```

Figure 1. Example of a STATUS screen from TAPS.

If several casts are stored in memory, each new cast will begin with a new cast header. This is usually redundant but does allow for the possibility that TAPS was reprogrammed between casts without data being dumped and erased.

When all cast data have been transferred to the logging computer, the data capture file should be closed. At this point, the data in TAPS memory can be erased to make room for new data if desired. Typing an “E” or an “e” starts the erase procedure. An “are you sure” dialog lets you change your mind and provides an escape from errant typing. Erasure occurs essentially instantaneously since only a single byte value is changed. You can follow an “E” with an “S” to

display the STATUS screen again and verify that data RAM has been erased.

But what if this is all a big mistake? What if you discover that you forgot to open a capture file or that the data

somehow never made it to disk? All is not lost...quite. If the mistake is discovered before TAPS collects new data, it is possible to recover the stored data by typing <CTRL>-D (holding down the control key and pressing “D” or “d”). This UNERASE command searches memory for certain tell-tale signs of valid data and recovers the end of data pointer. Following this command with “D” or “d” will dump the data—just like before, headers and all. But, if TAPS collects even the smallest smidgen of new data...the old data are gone forever!

But of course *you* will never make this mistake and so TAPS is now ready for another cast or set of casts. The data cable should be removed and the dummy plug installed along with its locking sleeve. If the next cast is to begin fairly soon, the shorting plug may be left in place. If the next cast is some time away (say, more than 30 minutes), some battery capacity will be saved by

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```
TAPS-6: S/N 11 S/W V. 7.25
CAST # 1
PULSELEN = 336 , NPINGS = 6 , NSAMPS = 5 <R> = 1.25 M
BATTERY = 22.62, DEPTH SF = 1.000 , TEMP OFFSET = 0.00
FREQUENCIES: 265 420 700 1100 1850 3000 KHZ
CALC = 0.0 0.0 0.0 0.0 0.0 0.0 dB
SENSOR #1: SBE-4
SENSOR #2: -

010331 074317 39.53 19.57 0.0 0.0 -43.0 -40.2 -40.0 -37.6 -40.0 -38.1
010331 074320 38.35 19.56 0.0 0.0 -41.2 -41.3 -38.6 -38.8 -38.8 -39.1
010331 074324 37.16 19.57 0.0 0.0 -45.6 -44.8 -43.4 -42.8 -42.9 -42.4
010331 074327 36.02 19.57 0.0 0.0 -44.9 -44.6 -43.3 -42.9 -42.9 -42.8
010331 074330 4.74 19.56 0.0 0.0 -45.1 -44.8 -44.0 -42.5 -43.5 -42.0
010331 074333 2.42 19.56 0.0 0.0 -45.5 -44.6 -43.2 -43.5 -42.5 -42.4
```

Figure 2. Example of a data dump from TAPS. In this case, no internal calcs were stored in TAPS and must be applied to the data in subsequent processing. Don't you do this.

removing the shorting plug until just before the next cast. Not a lot, however (see the next section).

Speaking of the battery, it will eventually run down and you will have to stop to recharge it. This is the reason the battery voltage is displayed on the status screen. In addition, you can always get the current battery voltage by typing a "V". This will result in the battery voltage being displayed (no text, just a number).

One (and perhaps the main) advantage of NiCad batteries is that the battery voltage is a useful indicator of remaining capacity. The battery is approximately at half capacity when the voltage is 21.6 V. Total discharge occurs at a battery voltage of approximately 19.8 V. You should never operate TAPS if the battery voltage is below 21 V, which represents approximately 20% capacity remaining.

Golden rule: Charge TAPS whenever the battery voltage drops to about 21 V.

Finally, you will want to process and display the data. Information on data formats, editing tips, and plotting and

inversion programs are provided in **Appendix 3: Data Analysis.**

CHARGING THE BATTERY

Charging the battery begins with connecting TAPS to the Charger/IO box. Two cables are provided for this purpose: one is approximately 4.5m long, the other 38m. Both have an 8-pin underwater connector on one end that plugs into a mating jack on TAPS and a round, military-style Amphenol connector on the other end that plugs into a mating jack on the Charger/IO box. The short cable is provided for use when TAPS can be brought to the charger—which is NOT waterproof and must be kept away from water. The long cable is provided for use when it is inconvenient to bring TAPS inside to charge.

The Charger/IO box connects to the AC mains with a standard AC cord plugged into the rear of the charger unit. (Chargers and cords are available for most common AC power sources.)

Two small jacks on the front panel are connected to the internal power supply. You may measure the Charger/IO

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power supply voltage directly with a voltmeter from these jacks. The actual TAPS battery voltage is not accessible from outside the TAPS; it is shown on the STATUS screen or can be displayed when you type a 'V' whenever TAPS is on.

With TAPS connected to the charger and the charger connected to AC mains power, turn the POWER switch to ON. The power light will illuminate immediately. If TAPS is not turned on (the shorting plug installed), the charge indicator will come on in a few seconds and burn steadily. This indicates high rate charging in progress.

When the battery approaches full charge, the charge indicator will begin to blink. The blink rate is slow initially but increases as full charge is reached. A very-rapidly blinking light indicates a fully-charged battery. A slowly blinking light indicates a nearly fully-charged battery. Sometimes this is good enough.

While no battery manufacturer would recommend it, we occasionally charge the battery briefly between stations just to extend the useful operational life. On 24+ hour stations, this practice may be mandatory to enable TAPS to continue operating. Just don't make it a habit, please.

There is a DB-9 serial jack on the front face of the Charger/IO box. This jack provides serial communications with the TAPS, should you wish to dump data, reprogram, or otherwise communicate with TAPS while it is connected to the charger. Operations and battery charging are basically separate activities; only one may be done at a time. Battery charging merely requires the cable be connected between the Charger/IO box and TAPS. Operations require that the shorting plug be installed on TAPS to power-up the internal computer and enable communications. Doing so causes charging to stop.

The shorting plug can (and must) be removed if charging is the only activity.

When the shorting plug is installed but TAPS is not operating (pinging), the current draw is about 60 mA. The battery capacity (when new) is nominally 5.7 A-hrs. Thus, TAPS can 'idle' for about 95 hours before the battery is dead. Operating, the current drain is about 300-350 mA. Thus, TAPS can operate for about 16-19 hours before the battery is dead. The actual usable time between charges will depend upon the relative amount of time spent waiting and the time spent operating and on the health of the battery. There is an Excel spreadsheet supplied on the CD that lets you estimate battery life (as well as memory capacity). It was created for SOUNDER mode applications but will give you some insights into CAST mode operational lifetimes as well.

It is not recommended that you run the battery completely down on a regular basis. This is deleterious to battery life. And the battery does have a finite lifetime which depends heavily on how it has been treated. In addition, NiCad batteries self-discharge over time. For maximum service life from your TAPS battery, you should recharge the battery about every 2-3 months when not in use.

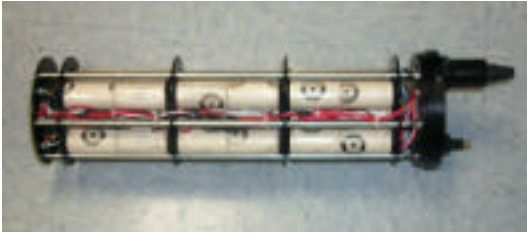
EXTERNAL POWER

TAPS can be provided with external power to increase it's operational life. Several options exist: we provide a long cable with TAPS that can be used with the charger/io box to power TAPS remotely for months on end. Underwater batteries can be used to power TAPS for periods of weeks (see SOUNDER MODE chapter for examples).

We offer an external battery as an option for TAPS that can be useful in extending the operational life of TAPS in CAST MODE. The external battery pack consists of three TAPS batteries wired in

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parallel in a pressure case (shown below without the pressure case). This external battery is



connected to TAPS with a short cable to the Data/IO connector on TAPS. Since this effectively covers up the serial I/O pins, an additional jack has been provided on the external battery pack to connect the TAPS/BATTERY combo to a computer.



The photo above shows the external battery unit with the interconnect cables attached.

TAPS operational lifetime is roughly quadrupled with the external battery pack. The case is rated to the same depths as TAPS itself and is of similar design for mounting. Additional information on the battery pack is supplied with the units.

DATA ANALYSIS

An entire section on this topic is included in this manual. Matlab programs are provided to read, bin, and plot the acoustic data (these may be modified to include data from your external sensors as well) and then to invert the acoustic data to estimate size-abundance spectra of the zooplankton scatterers.

PHYSICAL MOUNTING

It seems rather silly to emphasize this, but in cast mode you are attempting to measure the vertical structure of acoustical scattering – in particular, how acoustical backscattering changes with depth. So, TAPS really ought to be oriented **HORIZONTALLY!** Take another look at the first photo in this chapter.

The acoustic beams of the transducers are aligned parallel to the long axis of the pressure case and the sample volume is located about 1.5 m away from the transducer faces. If you orient TAPS with the transducers pointing at some angle to the horizontal, the acoustic data will not correspond to the temperature data, nor to the depth sensor value, since they are not measured at the same depths.

Also, keep in mind that an echo is an echo. TAPS has no way of knowing if the echoes it measures come from zooplankters or a loop of cable dangling from the rosette cage. It is up to *you* to ensure that TAPS has a clear field of view for the transducers. This is sometimes a bit tricky for the following reason: The directivity patterns of the transducers direct most of the sound energy along the geometric axis of the TAPS but there is some sound energy at all angles. Zooplankton are very weak scatterers, so the source levels and the receiver gains of each transducer are as high as is practical to maximize the on-axis levels. Metal struts, cables, and similar objects are very strong scatterers, however. Such an object located at an angle to the TAPS axis might easily produce an echo as strong or stronger than that from the zooplankton on axis, even though the effective source level and receiving sensitivity off-axis is very small.

So the rule is, keep potential scatterers away from the transducer end of TAPS. Whenever possible, orient TAPS so that any potential reflectors are behind the plane of the transducers.

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TAPS is provided with tabs to simplify the task of mounting it on platforms like CTD cages and net spreaders. It is strongly suggested that you do not use the tabs as a primary means of support, although the CTD frame below is an example of mounting TAPS by the ears.



It is almost always preferable to mount TAPS to the platform with clamps (hoseclamps are suitable) around the pressure case and to use the tabs to limit fore-and-aft motion and as mounts for safety lines.

If you use hoseclamps to mount TAPS, two precautions are in order. First, a layer of neoprene rubber gasket material or heavy tape around TAPS under the hoseclamps will protect the anodizing and prevent the onset of corrosion. Second, use only enough clamping force to lightly compress the neoprene/tape layer. Excess force could (possibly) distort the case enough to affect the o-ring seals, especially for casts close to the depth limit.

PROGRAMMING

Various operating parameters for TAPS can be selected by the user to suit

particular circumstances. Pressing <CTRL>-P starts an interactive programming process (refer to Fig. 3).

After an informational header, TAPS asks you to select an operating mode. Since we are selecting CAST mode operating parameters, enter 0. If the mode is already CAST, you can just press the ENTER key (<CR>). If the mode was different, you will then be asked if it is ok to erase memory. Answer "Y" or "y". Note that you don't have to press ENTER.

Your first parameter selection is the number of pings per average. The larger this number is, the more statistical degrees of freedom attach to each value of volume scattering strength. Up to a point, this is good. On the other hand, it takes time to accomplish each ping cycle and TAPS is moving down the water column while this goes on. So the smaller this number is, the better vertical resolution you obtain. Drat, choices!

A reasonable number of pings for general use is around 6. This gives a new data set every 2.6 seconds and, since each ping averages 5 independent samples, 30 degrees of freedom per average. Doubling the number of pings to 12 doubles the number of degrees of freedom (but does not halve the statistical uncertainty) of each average and doubles the time between data sets.

For higher vertical resolution, we often use 4 pings per average. Together with the binning that occurs in the analysis program, **plot6**, this usually results in sufficient degrees of freedom to obtain useful acoustic averages. The time interval between data samples is about 2 seconds.

You should also keep in mind that TAPS has a finite data memory. Smaller numbers of pings will cause memory to fill faster and vice versa. There is room for about 30,000 cast-mode samples. At 6 pings per average, this would be room for over 20 hours of sampling. At 4 pings

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per average, this would reduce to perhaps 10 hours.

Next, you are asked to enter the turn-on depth for TAPS. As described

above, this is the depth at which TAPS energizes the transceivers and begins taking data. Any value greater than 0.5m will be accepted.

```
REPROGRAM OPERATING PARAMETERS:
ENTER NEW DATA OR <CR> TO ACCEPT CURRENT VALUE

OPERATING MODES INCLUDE:
  0 = CAST MODE
  1 = SOUNDER MODE, EXTERNAL RECORDING
  2 = SOUNDER MODE, INTERNAL RECORDING
  3 = INSTRUMENT MODE, EXTERNAL RECORDING

CURRENT MODE = 2      =>  INTERNALLY-RECORDING-SOUNDER-MODE
ENTER NEW MODE (0-2) =  0
CHANGING OPERATING MODES REQUIRES DATA MEMORY BE CLEARED
IS THIS OK (Y/N)? Y
  DATA RAM HAS BEEN CLEARED
# PINGS/AVERAGE =  24   6
TURN-ON DEPTH [ >=.5M] = 2.00
TURN-OFF DEPTH [ >=.2M] = 1.00
MAXIMUM SAFE DEPTH = 300.00 M
MAX OPERATING DEPTH = 200.00

CHANGE BAUD RATE (Y/N)?

SELECT EXTERNAL SENSOR CODES FROM THE FOLLOWING LIST
  0 = NO SENSOR INSTALLED
  1 = SBE-4 CONDUCTIVITY SENSOR
  2 = WETSTAR FLUOROMETER
  3 = SEATECH FLUOROMETER
  4 = OTHER

EXTERNAL SENSOR # 1 CODE = 0   2
EXTERNAL SENSOR # 2 CODE = 0   1

MAKE THESE CHANGES PERMANENT (Y/N)? Y
```

Figure 3. Example of REPROGRAM screen. This is an interactive screen, thus only portions are visible when first entered.

The turn-off depth is the depth at which TAPS stops collecting data on the way back up. Clearly, this depth must be less than the turn-on depth. It could be just a bit less than the turn-on depth—but this is not usually a good choice. The depth is measured with a pressure sensor. The diaphragm for this sensor is a strain gauge mounted on a thin stainless steel sheet which bends in response to the ambient pressure. The force that deflects

this diaphragm is the ambient pressure; the restoring force to ‘un-deflect’ the diaphragm is the tangential stress in the diaphragm. Large deflections cause a large restoring force, small deflections yield a smaller restoring force.

The diaphragm responds to small negative pressure changes rather slowly because the restoring force is quite low. Thus, if you select a turn-on depth of,

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say, 0.5 m and a turn-off depth of, say, 0.2 m, it might take quite a while for the diaphragm to relax enough on the upcast for the pressure sensor value to catch up to the real pressure. Possibly several minutes. And TAPS will be taking data all this time. So select these depths with some regard for this phenomenon.

Next the MAXIMUM SAFE DEPTH (MSD) is displayed. This is the maximum depth for the depth sensor installed in your TAPS. On the next line, you are shown the current value of MAXIMUM OPERATING DEPTH. The maximum operating depth can be set to any desired value (up to 1000 m). If you set this parameter to a depth greater than the MSD, TAPS will probably never shut off. Unless you have some intricate data collection scheme in mind, this parameter can be set to 1000m and forgotten. Since this depth is used to stop data collection while TAPS is below this depth, it can be used to collect data from some shallow depth interval while the package TAPS is riding goes deeper (but not below the maximum depth for TAPS please).

You should not exceed the maximum working depth of the depth sensor in your TAPS. It is prudent to never take TAPS below the Maximum Safe Depth.

NOTE: the type of pressure sensor installed in your TAPS is noted on the specifications page in **Appendix 1: Calibrations**. While these sensors are rated to withstand 4 or 5 times the rated pressure without failure (bursting), they are only rated to 2 times the rated pressure without damage.^{*} A likely result from overpressure is a change in the output characteristics of the pressure sensor, giving false depth readings thereafter. A maximum working depth for your TAPS is given in the specifications.

^{*} In older TAPS, as the depth exceeds the MSD the voltage output of the depth circuits continues to increase. This will cause an offset in the ADC that is reflected in the acoustic data as well as incorrect depth readings.

This depth may differ from the maximum depth rating for the TAPS pressure case and transducers.

TAPS can operate at several baud rates. Typically one choses the highest rate (9600 baud) and never changes it. The BAUD RATE option was provided for times when TAPS has to operate over long cables and a lower baud rate is required. For cast mode, you would normally stick with 9600 baud and answer “N” or just press ENTER. If the last use was a remote mode, however, answer “Y” or “y”. You will be asked to enter a number corresponding to the new baud rate. After entering this number, TAPS asks you to change the baud rate on your computer to match and then press ENTER. If you do all of this correctly, you will see the programming menu continue with selection of external instruments.

The purpose of entering code numbers for the external sensors is, first, to flag the TAPS code to ensure that the selected sensor channels are measured and, second, to put a flag in the output data to remind you what you had hooked up on this cast. Enter the appropriate number for sensor #1 and sensor #2. Remember that external sensors take a little extra time per data frame so you shouldn’t leave codes here unless there actually is a sensor connected and you want that data.

The last choice is whether or not to make these changes permanent. If you think you entered everything correctly, answer “Y” or “y”. If you know you made a mistake, press ENTER (and then start again).

If you elected to save these changes, TAPS will save these parameters to an EEPROM and then display the status screen for your inspection. If you changed modes, there will be the disclaimer MODE CHANGED - CYCLE POWER TO ENABLE NEW MODE displayed. You will have to remove and replace the shorting plug to

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let TAPS initialize properly. This is almost always what is about to happen anyway.

SETTING THE CLOCK

There is a clock-calendar chip inside TAPS that is used to time-tag data. At the factory, we generally set this clock to Pacific time—standard or daylight, depending upon the season. You may wish to set the clock to your local time or possibly to Universal Coordinated Time (UTC). This is a simple process.

You can display the current date and time by pressing ‘T’ or ‘t’. The clock-calendar chip is read and the current values of time and date displayed, viz,

17:15:23 06/23/00

The order is time (HH:MM:SS) and date (MM/DD/YY).

To set the clock, press CTRL-T (or CTRL-t). TAPS will display a message,

ENTER DATE AS YY MM DD

You should enter the last two digits of the year, a space, the month (one or two digits), a space, and the day (one or two digits). Press ENTER.

TAPS will then ask for the time with the message,

ENTER TIME AS HH MM SS

You should enter the hour (one or two digits in 24-hour format), a space, the minutes, a space, and the seconds. Enter a time several seconds ahead of current time. Then press ENTER.

TAPS will now ask you to press ENTER (or RETURN or <CR>) at the exact time you want to set the clock. Hence the caution to enter a time slightly in the future. When your time reference agrees with the time you entered, press ENTER and the clock will be set.

You can check that the time and date are correct by pressing ‘T’ or ‘t’ again and comparing the displayed values with the current time and date.

If you make a mistake, just repeat the setting procedure until the date and time match your reference.

CAL CONSTANTS

TAPS is designed to measure acoustical volume backscattering (Sv) in absolute units. Of course, what it actually measures are echo voltages from each transceiver channel. Converting these to actual Sv values requires calibration—which is generally a factory job—and application of these calibrations to the measured data.

The calibration sheet supplied with TAPS (or returned with TAPS after re-calibration) contains a line of numbers entitled *CAST mode cal constants*. These numbers are the values that must be added to the measured echo intensity values to convert them to Sv. (Another set of numbers is provided for SOUNDER mode data conversions; these numbers are used in the data analysis software only.)

One handy place to store these numbers is inside TAPS itself. In fact, if you do, the data will be output as Sv values directly. Isn't that clever?

The CAST mode cal constants are installed in your TAPS at the factory (originally and again whenever TAPS is re-calibrated). Normally, you should never have to worry about installing the cal constants. But, stuff happens. TAPS have been known to get struck by lightning, for example, which can do bad things to data stored in EEPROMs.

The cal constants are displayed whenever the STATUS screen is displayed. From time to time, you might want to compare these values to the ones on the calibration sheet. These values are also sent as part of the header information

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whenever data are dumped from TAPS. Should it be necessary, a trail exists for changing the cal constants of even historical data. You are saving the data dumps as archive files, aren't you?

But, suppose your TAPS is the next one to be struck by lightning and the cal constants are lost. Can you re-install them? Sure. It is a simple procedure.

Type "CTRL-Z" or "CTRL-z". You will see an "are you sure" line; answer Y or y to proceed. Then you will be prompted to enter (or accept) six values for the six channels. Enter the numbers carefully as there is minimal error checking in the code. A typical entry might look like

-47.8

Don't forget the minus sign. If the value displayed is correct, you can accept this value by pressing ENTER.

The same screen that lets you re-enter the cal constants also lets you enter the depth sensor rating (in psia) and two 'fudge factors.' The standard depth sensor for TAPS is a 300 psia pressure sensor. If you requested another sensor, this value will be listed in the SPECIFICATIONS section.

The first scale factor is a multiplier for the depth channel, the other is an additive constant for temperature. The depth scale factor lets you adjust the TAPS depth readings to conform to, say, a CTD on the same package. Similarly, you can add a constant offset to adjust the TAPS temperature data to match if needed.

EXTERNAL SENSORS

Provision has been made for connection of up to two external sensors to TAPS. Typical choices might include a conductivity sensor to estimate salinity and a fluorometer to estimate chlorophyll-A. We have used an SBE-4 conductivity sensor, both WetLabs and SeaTech fluorometers, a PAR sensor, a

transmissometer and an optical backscatter sensor with our TAPS at various times. If you have requested a particular setup when ordering your TAPS, the instrument interface PCB has been set up for your choices of sensors and the PCB installed in TAPS. If you did not specify the sensor suite, the instrument interface PCB was left partially un-populated and the card was NOT installed in TAPS. If you need to install this card or change the sensor setups, refer to the EXTERNAL SENSORS section in this manual.

External sensors should be mounted with due regard to orientation and location. That is, the conductivity cell (or fluorescence chamber, etc.) should be mounted so that water will flow through as the package is lowered. The sensor should also be located approximately at the same depth as the transducers and the depth and temperature sensors on TAPS so that all data comes from the same depth.

There is no particular reason that an external pump couldn't be added as well. A special cable would be required and a low-current version pump should be used. You could wire the pump in parallel with the power leads of your external sensor or simply use the second sensor channel to provide power to the pump.

The use of external sensors adds potentially valuable data to the TAPS data stream but there is a slight cost associated with this. Each instrument added to TAPS costs approximately one-tenth second per data frame per instrument. Either a smaller number of pings per average must be selected or TAPS must be lowered more slowly to obtain the same vertical resolution when using external sensors. Also, the external sensors use battery power. This will reduce the operating life of TAPS.

CAST MODE

INSTRUMENT MODE

A variant of the CAST mode has been added for software releases 7.18 and higher. This mode, called INSTRUMENT MODE, is identical to CAST mode except that (1) the depth sensor is not used to start/stop TAPS and (2) data are output continuously on the serial port in ASCII-hex format. This mode was created to permit the use of TAPS with an external datalogger on a vertical profiling package. External power should be provided if long-term operation is desired.

INSTRUMENT MODE is selected as choice 3 in the programming menu. If this choice is selected, you will have the opportunity to select the number of pings as usual but no depth inputs are requested since these values are not used in this mode. Baud rate and external instruments are selected in the standard way.

When power is applied to TAPS in this mode, data begin automatically appearing at the serial output after a delay of a few seconds. Data continue to be displayed until power is turned off.

The data format is fixed; every line is exactly 89 characters long. A special

Matlab® script has been provided to read and convert these files, **rdtapsinst.m**. This subroutine requires some modification before use--you must edit the code to insert the calibration constants for your TAPS and the pressure sensor rating.

For those who wish to write their own code to decode INSTRUMENT MODE data, a table showing the character allocations and decoding is provided below. The data consist of ASCII-hex characters that must be converted first to decimal numbers and then to engineering units.

The initial step in translation is to convert the ASCII-hex characters into decimal numbers. In the case of time and date, the conversion is complete. For the remaining data, however, some computation is required.

The Depth number is a sum of the ADC raw values (less the offset measured in CAST mode on deck) over NP pings. The raw number can be converted to depth in meters by multiplying by DPB, the depth per bit, and dividing by NP. The depth per bit is found from the

Starting character number	Number of characters	Value	Conversion method	Example	Converted value
1	1	Month	HEX->DEC	B	11 or Nov
2	2	Day	HEX->DEC	7	7th
4	2	Hour	HEX->DEC	0E	14
6	2	Minute	HEX->DEC	15	15
8	2	Second	HEX->DEC	08	8
10	8	Depth	HEX->DEC + Equation 1		
18	8	Temp	HEX->DEC + Equation 2		
26	8	Freq1	HEX->DEC + Equation 3		
34	8	Freq2	HEX->DEC + Equation 4		
42	8	Sv1	HEX->DEC + Equation 5		
50	8	Sv2	HEX->DEC + Equation 5		
58	8	Sv3	HEX->DEC + Equation 5		
66	8	Sv4	HEX->DEC + Equation 5		
74	8	Sv5	HEX->DEC + Equation 5		
82	8	Sv6	HEX->DEC + Equation 5		

Table I. Format of data from TAPS in INSTRUMENT MODE and conversion methods. See text for equations.

CAST MODE

following equation

$$d_{pb} = (P_{max} - 14.7) / (14.7 * 4095)$$

where P_{max} is the maximum pressure rating for the depth sensor in psia, 14.7 is the pressure equivalent of 1 atmosphere, and 4095 is the number of steps in the A-D converter.

Temperature is similarly a sum of raw ADC readings but in this case there is a sign bit to account for. The value is first converted to a decimal number, N_t . If N_t is greater than 65536 (signifying negative values), it is replaced by

$$N_t = -(2^{32} - N_t).$$

Then N_t is divided by NP.

Next, N_t is converted to sensor resistance using the following equations:

$$\begin{aligned} Z &= N / 65536 \\ X &= (0.5 + Z) / (0.5 - Z) \\ R &= R_{25} * X \end{aligned}$$

where $R_{25} = 30.0E3$ ohms is the resistance of the thermistor sensor at 25C and R is the measured resistance of the sensor.

Finally, the sensor resistance is converted to temperature using the Steinhart and Hart equations:

$$\begin{aligned} LR &= \ln(R) \\ TI &= a + b * LR + c * LR^3 \\ T &= 1 / TI - 273.115 \end{aligned}$$

where $\ln(R)$ is the natural log of R and T is the temperature in C. The constants are

$$\begin{aligned} a &= 9.354E-4 \\ b &= 2.211E-4 \\ c &= 1.257E-7. \end{aligned}$$

The next two values are the frequencies from external sensors 1 and 2 (if installed; zeroes otherwise). These characters must be converted to decimal frequency. Further processing depends

upon the external sensor(s) and will not be discussed here. See the section on External Sensors for further information.

The last six numbers are the outputs of the echo intensity accumulators. They must be converted to decimal values and divided by 5 times the number of pings, NP. The reason for the extra 5 is that TAPS sums 5 consecutive echo intensity samples on each ping.

The intensities may be converted to volts-squared by dividing by 1E6 (this is because the ADC conversion is one bit per millivolt, or an output of 1000 for a 1 volt input). Then each value of volts-squared can be converted to S_v using

$$S_v(i) = 10 * \log_{10}(V^2) + CAL(i)$$

Where V^2 is the scaled intensity, $S_v(i)$ is the i th value of volume scattering strength and $CAL(i)$ is the associated conversion constant from the TAPS calibration sheet (see Appendix I).

TIME SERIES DATA

It is sometimes interesting to suspend TAPS at a depth and take data for a period of time, say for comparison with some other sensor or to investigate the variability of zooplankton concentrations with time or position. This is often done with TAPS in CAST mode. Afterwards, however, the user is faced with the problem of analyzing such data.

Plot6.m assumes the data are in the form of a vertical profile and bins the data accordingly. This is not satisfactory for data collected over time at a single depth as all the variability has been averaged out.

Plottime.m is a variant of Plot6.m that processes data taken as time series. It operates much like Plot6.m but does not bin data in depth. You do have the option to bin adjacent data sets to increase the degrees of freedom (reduce the variance). Data are plotted versus time of day rather than versus depth. A slightly different set

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of data is saved to disk. A variant of `inv6.m` is thus also required; `Invtime.m` inverts the data from `Plottime.m` and plots the data versus time of day. The operation of `Invtime.m` is identical to `inv6.m`.