ORCAWALE 1996 McArthur CTD PROCESSING

ORCAWALE 1996 CTD data files were collected using a Sea-Bird 911*plus* profiling instrument aboard the NOAA Ship McArthur (MAC). The 911*plus* consists of the 9*plus* underwater CTD and 11*plus* V2 Deck Unit, which has high resolution sampling (24Hz) and pump-controlled conductivity and temperature flow-through sensors. Data were collected using Sea-Bird's SeaSave Win32 v. 4.217 and have been processed using Sea-Bird's SBE Data Processing SEASOFT-Win32 v. 7.20f. More information regarding the SBE software and recommended data processing procedures can be found online at www.seabird.com.

Each CTD directory on the data server contains two folders named Raw and Data. CTD set-up information, pressure test results, and data collected at sea are stored in the Raw folder. All information and files used in processing are saved in the Data folder, including documentation, configuration files, calibration sheets, intermediate processing steps and final data.

No changes in conductivity, temperature or pressure sensor use on the DSJ CTD during VAQT 1997 were necessary. The table below lists the sensors used. The owners of the sensors were responsible for their maintenance.

	Casts	Temp	Cond	Pressure
Legs 1-3	001-051	*T2126*	*C1697*	*P0414*

MAC-owned

Casts 004-081 had WETStar fluorometer, absorbance and transmittance sensors attached; these data were processed with no calibration adjustment.

ORCAWALE 1996 MAC CTD SENSOR CALIBRATION

SWFSC MMTD uses Sea-Bird Electronics conductivity, temperature and pressure sensors. Sea-Bird Electronics conductivity sensors drift with usage and time, while temperature and pressure sensors drift primarily over time. Annual calibrations of the conductivity and temperature sensors are necessary to estimate and correct for this drift during data processing. Pre and post-cruise calibration certificates for the DSJ sensors used during ORCAWALE 1996 are in the \CON_Files\Calibrations folder.

Conductivity, temperature, and pressure are computed as polynomial functions of the sensor frequencies stored in the raw data file. We follow Sea-Bird recommended procedures for adjusting calibration coefficients for drift between calibrations (Sea-Bird App. Note # 31). Details can be found in the internal document "CTD Calibration Adjustments MMTD.pdf".

The Excel spreadsheet, CTDcalibrations ORCAWALE 1996 DSJ.xlsx, in the \Documentation folder contains the pre and post-cruise calibration information for the conductivity, temperature and pressure sensors. It then derives slope or offset values used to correct the calibration coefficients used in the Data Conversion and Derive modules of Sea-Bird's SBE Data Processing software. The adjusted configuration files used to process the ORCAWALE 1996 MAC data are in the \CON Files folder.

Conductivity Sensor Correction:

The SBE 4C series conductivity sensor has a measurement range of 0.0 to 7.0 Siemens/meter (S/m), which spans the conductivity range of SWFSC MMTD's study areas. The SBE 4C sensor is rated to have an initial accuracy of 0.0003 S/m; with a resolution (at 24Hz) of 0.00004 S/m.

The conductivity sensor, C1697, was calibrated on 2 April 1996 and 17 January 1997. The difference between the iSlope values at the start and end of the cruise was less than 0.0003, but the end iSlope was close to 1.00015; consequently, the average iSlope was used for calibration adjustment of the conductivity sensor (slope = 1.00009).

Temperature Sensor Correction:

The SBE 3*plus* series temperature sensor has a measurement range of -5.0 to 35 °C, which spans the range of temperatures in SWFSC MMTD's study areas. The SBE 3*plus* sensor is rated to have an initial accuracy of ± 0.001 °C and a resolution (at 24 samples per second) of 0.0003 °C.

The temperature sensor, T1448, was calibrated on 25 June 1996 and 17 June 1997. The iOffset at the end of the cruise was less than 2mdeg C; consequently, no calibration adjustment was necessary for the temperature sensor (offset = 0).

Pressure Sensor Correction:

The SBE Paroscientific Digiquartz pressure sensor is rated to have an initial accuracy of 1.02m (i.e., 0.015% of the full scale range, which is 0 – 6800m). We do not exceed a maximum vertical depth of 1100m. Initial resolution (at 24Hz) is 0.068m (i.e., 0.001% of the full scale range).

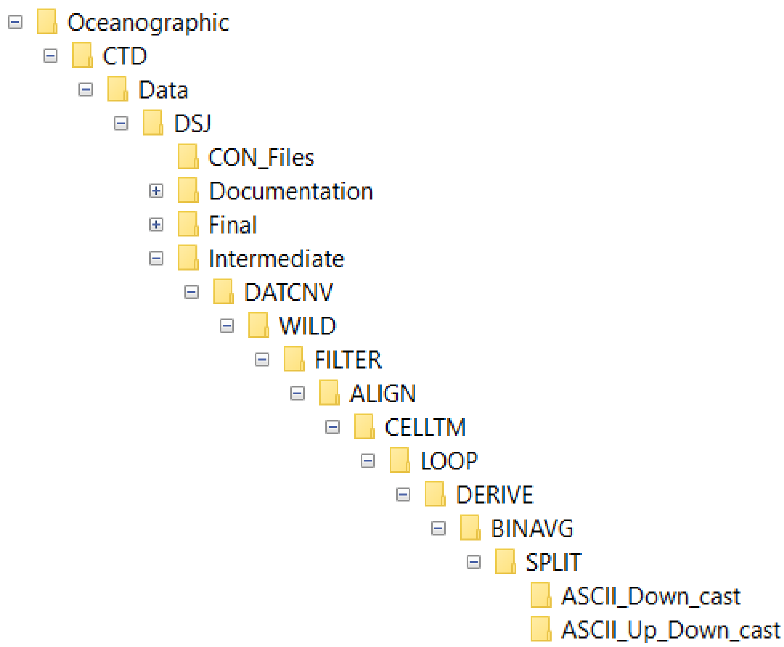
The digiquartz pressure sensor, P0414, was calibrated on 27 April 1995 and 15 January 1998; the average iOffset was 0.651 db. No deck tests were conducted on the MAC during ORCAWALE 1996. Therefore, the average iOffset was used.

We use pre-cruise calibration coefficients for each sensor when available. Before running the processing modules, it is essential to ensure that the correct sensor configuration coefficients and corrections are loaded into the *.con files used by the SBE Data Processing program. Offset and slope adjustments are obtained from CTDcalibrations ORCAWALE 1996 MAC.xlsx in the \Documentation folder. Configuration files for the sensors used on the McArthur during ORCAWALE 1996 are listed in Appendix 1.

ORCAWALE 1996 CTD SBE MODULE PROCESSING

The SBE Data processing modules that were applied to the raw data are listed below. Each SBE module creates a program setup file, named *.psa. The *.psa files are located in the folder preceding their output, i.e. the ‘Derive.psa’ file is found in the ‘LOOP’ folder. Output .cnv files are kept in binary format to speed processing and reduce file sizes. The final module – ASCII Out – converts the binary data to ASCII format; if examination of the data is needed during earlier processing steps, the Translate module can be used to convert to the binary data to ASCII.

Modules are run in the following order: Data Conversion, Wild Edit, Filter, Align CTD (as needed), Cell Thermal Mass, Loop Edit, Derive, Bin Average, Split, ASCII Out. The processed data in various stages are in the \Intermediate folder:



1. **Data Conversion Module:**

Data Conversion converts raw SBE 911plus data, which are typically stored as frequencies and voltages in the *.dat file, to engineering units and stores the converted data in a *.cnv file.

The options selected for processing in Data Conversion were as follows:

name 0 = prDM: Pressure, Digiquartz [db]
name 1 = c0S/m: Conductivity [S/m]
name 2 = t090C: Temperature [ITS-90, deg C]
name 3 = flag: 0.000e+00
file_type = ascii

Two casts were each recorded in two files; these files were joined to complete full down and up profiles: AR1011.cnv and AR1012.cnv.

Fortran program SCRDATA (programmer: Paul Fiedler) was used to exclude pressure values <-5.0 or >1200, temperature values <-1.0 or >33, and conductivity values <2.5 or >7.0. The program first checks the range or span of values from the primary and secondary sensors in the header file. If any span exceeds the above limits, the program writes a new file in which each bad value, and the values in the two scans preceding and the two scans succeeding the bad value are replaced with a missing value of -9.990e-29. The original file is renamed with an "x" prefix. For each edited file, the total number of scans, and for each sensor, the number of values that exceeded the limits and the number of entries replaced with a missing value are summarized in the *ScrData.dat* files in the \\Intermediate\DATCNV folder. Of 51 CTD files, 38 had no outliers, 13 had C0 outliers, 1 had T0 outliers, and 1 had PR outliers.

2. Wild Edit Module:

Wild Edit flags outliers in temperature and conductivity data so that they are not used in further processing. Wild Edit's algorithm requires two passes through the data in blocks of *npoint* scans. The first pass computes the mean and standard deviation and temporarily flags values that differ from the mean by more than *pass1_nstd* standard deviations. The second pass recalculates the mean and standard deviation, excluding values flagged in the first pass. Scans that differ from the mean by more than *pass2_nstd* standard deviations are replaced with a bad data flag. The criteria established by *pass2_nstd* can be overridden using *pass2_mindelta*; specifically, if data are within *pass2_mindelta* of the mean, they are not flagged.

The options selected for processing in Wild Edit were as follows for all casts:

    # wildedit_pass1_nstd = 2.0
    # wildedit_pass2_nstd = 15.0
    # wildedit_pass2_mindelta = 0.000e+000
    # wildedit_npoint = 100
    # wildedit_vars = prDM c0S/m t090C

These options are Sea-Bird defaults, except that *pass2_nstd* was changed from 20.0 to 15.0 to identify more outliers.

3. Filter Module:

The Filter module is run to reduce high-frequency noise in the pressure data, which is caused by counting jitter or other unknown sources. It is important to remove this noise before running the Loop Edit module. Loop Edit flags data that exhibit a change in the CTD velocity. Velocity is calculated using only three successive scans; consequently, noisy pressure data can result in erroneously flagged scans. Filter runs a low-pass filter on the data, which smoothes high frequency (rapidly changing) data. To produce zero phase (i.e., no time shift), the filter is first run forward through the data and then run backward through the data. Pressure data is typically filtered with a time constant equal to four times the CTD scan rate. We run a low-pass filter on the pressure data with time constant = 0.15 seconds, as recommended by Sea-Bird Electronics Inc.

The options selected for processing in Filter were as follows for all CTD casts:

filter_low_pass_tc_A = 0.030
filter_low_pass_tc_B = 0.150
filter_low_pass_A_vars =
filter_low_pass_B_vars = prDM

4. Align CTD Module:

It is essential that all variables derived from the data, such as salinity, density, and sound speed, use measurements of temperature and conductivity from same parcel of water. It is practically impossible to instantaneously measure the same parcel of water with all sensors due to the physical location of the sensors on the unit and the different time delays of the sensors. The typical time delay of conductivity relative to temperature, 0.073 seconds, is automatically corrected by the SBE 11plus Deck Unit during data collection. If spikes are observed in the processed salinity profiles, further alignment of conductivity may be necessary. The Align CTD module can be used to align the conductivity data relative to pressure.

Fortran program TRIALIGN.EXE (programmer: Paul Fiedler) was run to find the optimum alignment value for conductivity (i.e., the number of scans by which to shift conductivity relative to temperature). TRIALIGN finds the maximum temperature gradient within a 240-scan window using linear regression; TRIALIGN tests for the gradient using only the first 10,000 scans to ensure data are from the downcast and imposes the criteria that depth must change by at least 5m in the 240-scan window. Conductivity alignments are tested within the region of maximum temperature gradient because misalignment of temperature and conductivity often results in excessive salinity spikes when temperature is changing rapidly. Within the window, conductivity is shifted by -24 to +24 scans. For each shift, salinity is derived from the temperature and conductivity data in each scan and a linear regression is fit to the salinity values. The shift that results in the minimum standard deviation of the regression residuals is selected as the optimal value for that cast. Optimal values for all casts are averaged to obtain a single alignment value for the cruise (one scan is 0.042 seconds).

Inspection of the MACII 1996 CTD profiles suggested that alignment might improve salinity profiles for some casts. TRIALIGN gave a mean optimum advances of -0.020 sec (SE=0.0043) for conductivity sensor, C1697, (see Trialign.dat in \FILTER, which has the following columns: CTD file name, pressure (db) at the maximum temperature gradient, maximum temperature gradient (deg C/db), optimal advance (scans), and relative standard deviation of residuals). Figure 1 illustrates that salinity spiking at extreme temperature gradients was reduced by alignment.

The options selected for processing in Align CTD were as follows:

alignctd_adv = c0S/m -0.020

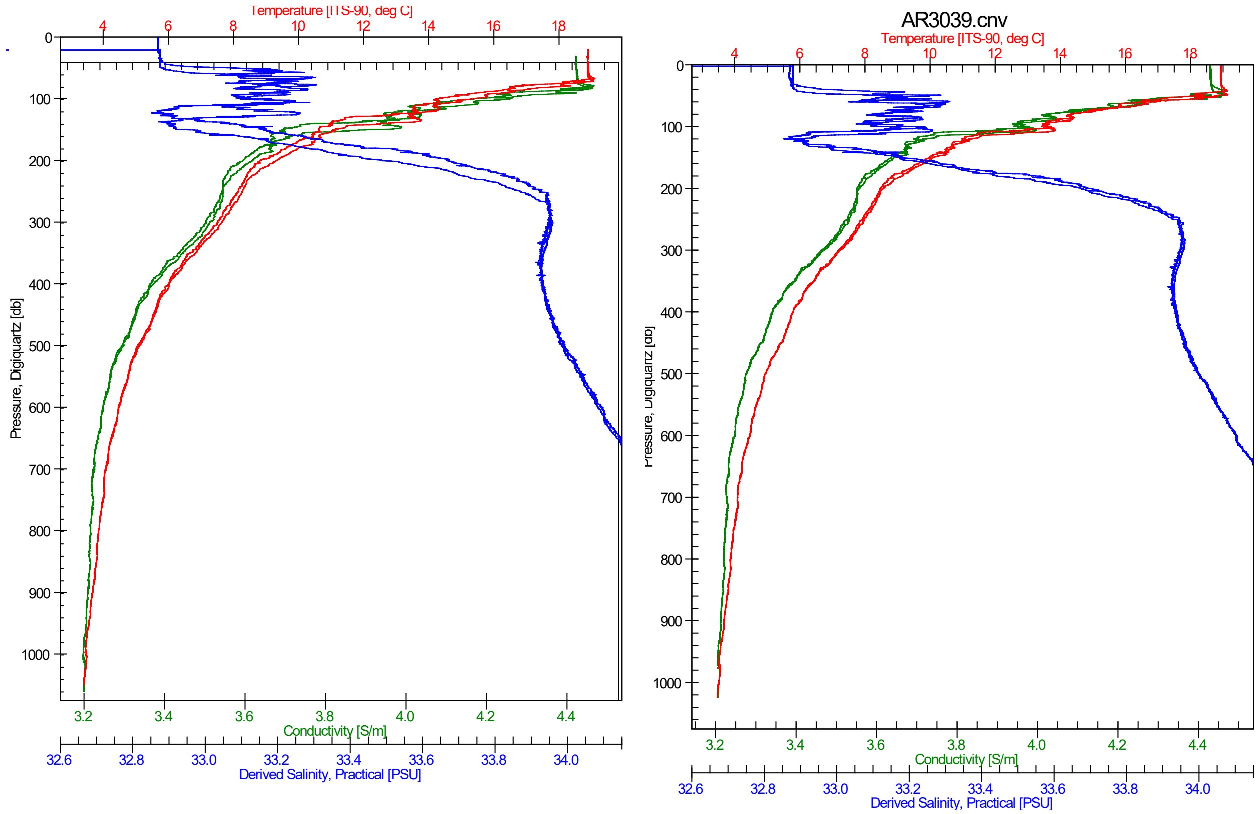


Figure 1. Surface section of CTD cast 039 before (left) and after (right) alignment. Alignment reduces salinity spikes in the thermocline.

5. Cell Thermal Mass Module:

Cell Thermal Mass uses a recursive filter to remove conductivity cell thermal mass effects from the measured conductivity. In areas with large temperature gradients, the thermal mass correction is on the order of 0.005 psu. In areas with small temperature gradients, the correction is negligible.

The following Sea-Bird Electronics Inc. recommendations for Cell Thermal Mass when processing SBE 9plus data, with TC duct, were used:

celltm_alpha = 0.0300, 0.0300
celltm_tau = 7.0000, 7.0000
celltm_temp_sensor_use_for_cond = primary, secondary

6. Loop Edit Module:

Loop Edit flags data that exhibit a change in the mean CTD ascent or descent rate (e.g., pressure reversals or slowdowns). Such changes in ascent or descent rates are usually created by ship heave as the CTD unit is lowered or raised, and indicate unreliable data. Data that have been flagged are documented in the *.cnv header. In this module, we remove any scans that were flagged as bad during data collection.

The options selected for processing in Loop Edit follow the recommendations of Sea-Bird Electronics Inc. for all casts:

loopedit_minVelocity = 0.250
loopedit_surfaceSoak: do not remove
loopedit_excl_bad_scans = yes

7. Derive Module:

Derive uses pressure, temperature, and conductivity from the input *.cnv file to compute the following oceanographic variables, which are routinely used in the assessment of protected species:

- Salinity
- Density (density, sigma-theta, sigma-t, sigma-1, sigma-2, sigma-4)
- Depth (salt water, fresh water)
- Sound velocity (which can be calculated using the Chen-Millero, DelGrosso or Wilson equation)
- Average sound velocity (the harmonic mean from the surface to the current CTD depth, which is calculated on the downcast only)

The following processing options were selected in this module for all CTD casts:

name 3 = depSM: Depth [salt water, m], lat = 35.822
name 4 = sal00: Salinity, Practical [PSU]
name 5 = density00: Density [density, Kg/m^3]
name 6 = svCM: Sound Velocity [Chen-Millero, m/s]
name 7 = avgsvCM: Average Sound Velocity [Chen-Millero, m/s], minP = 2, minS = 20

To calculate average sound velocity, the following values were used:

# minimum pressure = 2 db	[average depth of the acoustic array]
# minimum salinity = 20 psu	[recommended Sea-Bird Electronics Inc.]
# Latitude = 38 °N	[this value is used only if NMEA latitude is not available in the header]

The profiles output by the Derive module were inspected by the Senior Oceanographer for bad data caused by sensor failure, temperature inversions, low surface salinity measurements (likely the result of rain), and spikes in salinity. Comments about each cast are in ORCAWALE1996_castinfo.txt in the \Documentation folder. Comment codes are:

A – acceptable
~A – acceptable for assessments of protected species
R – reject cast

8. Bin Average Module:

The Bin Average module averages temperature, conductivity, pressure, and oceanographic variables in user-selected intervals; the intervals may be defined using pressure, depth, scan number, or time range. SWFSC MMTD uses 1m bins, with no surface bin. In this module, we exclude scans that were flagged as bad during the loop edit module.

The following processing options were selected in this module for all casts:

binavg_bintype = Depth
binavg_binsize = 1
binavg_excl_bad_scans = yes
binavg_skipover = 0
include surface bin = yes
binavg_surface_bin = no, min = 0.000, max = 5.000, value = 0.000

9. Split Module:

Split separates the data from an input *.cnv file into upcast (pressure decreasing) and downcast (pressure increasing) *.cnv files. Downcast only files are output because they do not contain the data collected when the bottles are fired (e.g., repetitive sampling at the same pressure). Consequently, they are used to derive variables such as thermocline depth and strength.

The following options were selected in this module for all casts:

split_excl_bad_scans = no
output the downcast only (into the \Split folder). This command adds a ‘d’ at the beginning of the filenames.

10. ASCII Out Module:

ASCII Out outputs the header and/or the data from a binary data file (*.cnv). Data are written to an ASCII file (*.asc), while the header information, which lists each processing module and the variables applied, is written to a separate ASCII file (*.hdr).

This module was run twice. First, to convert the complete cast; second, to convert the downcast-only files created with the SPLIT module.

The following options were selected in this module for all casts:

Output Header and Data files
Label Column at top of the file
Column separator = space

FINAL PRODUCT

ASCII Out outputs the header and/or the data from a binary data file (*.cnv). Data are written to an ASCII file (*.asc), while the header information, which lists each processing module and the variables applied, is written to a separate ASCII file (*.hdr).

This module was run twice. First, to convert the complete cast; second, to convert the downcast-only files created with the SPLIT module.

The file headers have been saved separately from the final ASCII data files in both directories. The header files contain time in two separate fields: "System UpLoad Time" and "NMEA UTC (Time)". The time in the "System UpLoad Time" field is taken from the PC used to the collect the data and may not be accurate (e.g., this field may be recorded in local time, rather than Coordinated Universal Time, and may not have been adjusted for local time zone changes). The Coordinated Universal Time in the "NMEA UTC (Time)" field is taken from the GPS unit and is accurate as long as the GPS functioned properly.

The downcast profile is used to derive variables commonly used in protected species assessments, such as thermocline depth and strength. Plots of complete casts show hysteresis, or depth offsets, of 5-8 m. The error in the depth, as indicated by the offsets, are expected to occur primarily in the upcasts due to "package wake" (i.e., the "shadowing" of the sensors by the rosette and frame as the CTD is pulled up through the water column). Additionally, the upcasts include repetitive sampling of the same depth when bottles are fired to collect water samples.

In total, 51 CTD casts were conducted during ORCAWALE 1996 on the MAC. The format of the downcast output files is shown below.

```
 PrDM    T090C      C0S/m  DepSM    Sal00  Density00     SvCM  AvgsvCM        Flag
1.008  16.5629  4.030219  1.000  31.3563  1022.8231  1507.37     0.00 0.0000e+00
2.016  16.5725  4.090178  2.000  31.8739  1023.2239  1507.98   862.76 0.0000e+00
3.023  16.5359  4.085739  3.000  31.8640  1023.2292  1507.88  1516.65 0.0000e+00
```

The columns are:
PrDM = Digiquartz pressure in decibars (db)
T090C = Temperature, in degrees Celsius (ºC), calculated using the ITS-90 standard
C0S/m = Conductivity in Siemens per meter (S/m)
DepSM = Salt water depth in meters (m)
Sal00 = Salinity, in practical salinity units (psu), derived from the primary temperature and conductivity sensors
Density00 = Density [sigma-theta], in kilograms per cubic meter (kg/m^3), calculated from the temperature sensor and derived salinity
SvCM = Chen-Millero's sound velocity in meters per second (m/s) calculated from the temperature sensor and derived salinity
AvgsvCM = Chen-Millero's average sound velocity in meters per second (m/s) calculated from the temperature sensor and derived salinity
Flag = error flag

Perl program CTDPositionCheck (programmer: Dan Prosperi) was used to check the CTD cast date/times and positions recorded in the header files against the edited TSG file for the survey. All 51 files had matching TSG records; no corrections were necessary.

Paul Fiedler, 25 June 2021

Appendix 1. ORCAWALE 1996 MAC SBE CTD configuration files used for data processing.

MAC 1996.xmlcon

```
Configuration report for SBE 911plus/917plus
       CTD
--------------------------------------------

Frequency channels suppressed : 0
Voltage words suppressed      : 0
Computer interface            : IEEE-488
(GPIB)
Scans to average              : 1
NMEA position data added      : Yes
NMEA depth data added         : No
NMEA time added               : No
NMEA device connected to      : deck unit
Surface PAR voltage added     : No
Scan time added               : No


1) Frequency 0, Temperature

   Serial number : 2126
   Calibrated on : 26-Mar-96
   G             : 4.07360942e-003
   H             : 6.21125375e-004
   I             : 1.99486531e-005
   J             : 2.17823124e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0000

2) Frequency 1, Conductivity

   Serial number : 1697
   Calibrated on : 02-Apr-96
   G             : -4.13603901e+000
   H             : 4.77425443e-001
   I             : -6.03516967e-004
   J             : 5.53145273e-005
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00009000
   Offset        : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

   Serial number : 60961
   Calibrated on : 09-Apr-96
   C1            : -4.285245e+004
   C2            : -1.357147e-001
   C3            : 1.419860e-002
   D1            : 3.730900e-002
   D2            : 0.000000e+000
   T1            : 3.047956e+001
   T2            : -3.872276e-004
   T3            : 4.571210e-006
   T4            : 2.126270e-009
   T5            : 0.000000e+000
   Slope         : 1.00000000
   Offset        : -0.65100
   AD590M        : 1.130000e-002
   AD590B        : -8.801900e+000

4) Frequency 3, Free

5) Frequency 4, Free

6) A/D voltage 0, Free

7) A/D voltage 1, Free

8) A/D voltage 2, Free

9) A/D voltage 3, Free

10) A/D voltage 4, Free

11) A/D voltage 5, Free

12) A/D voltage 6, Free

13) A/D voltage 7, Free

Scan length                   : 37
```