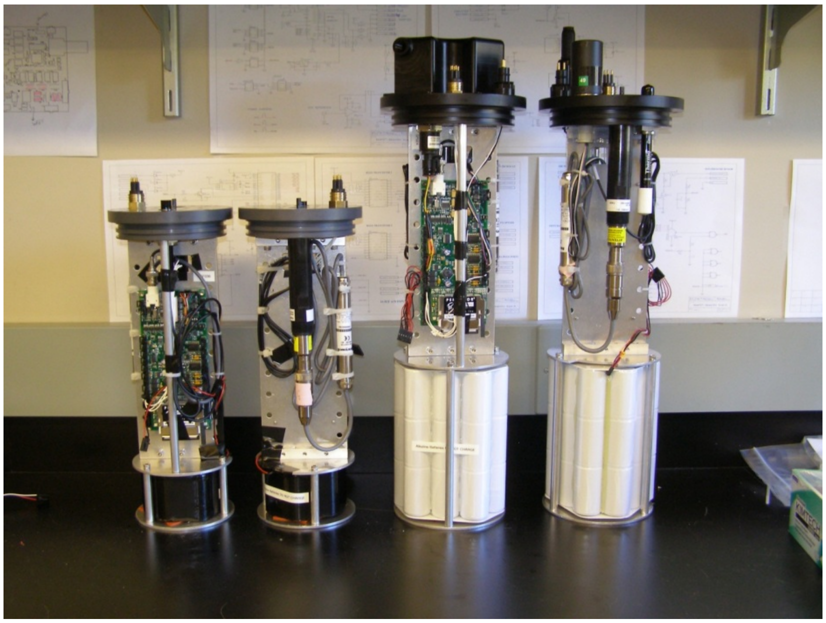
SeaFET & SeapHOx
User Manual



Manual Version 2.1
For use with firmware: SeaFET/SeapHOx V2.1

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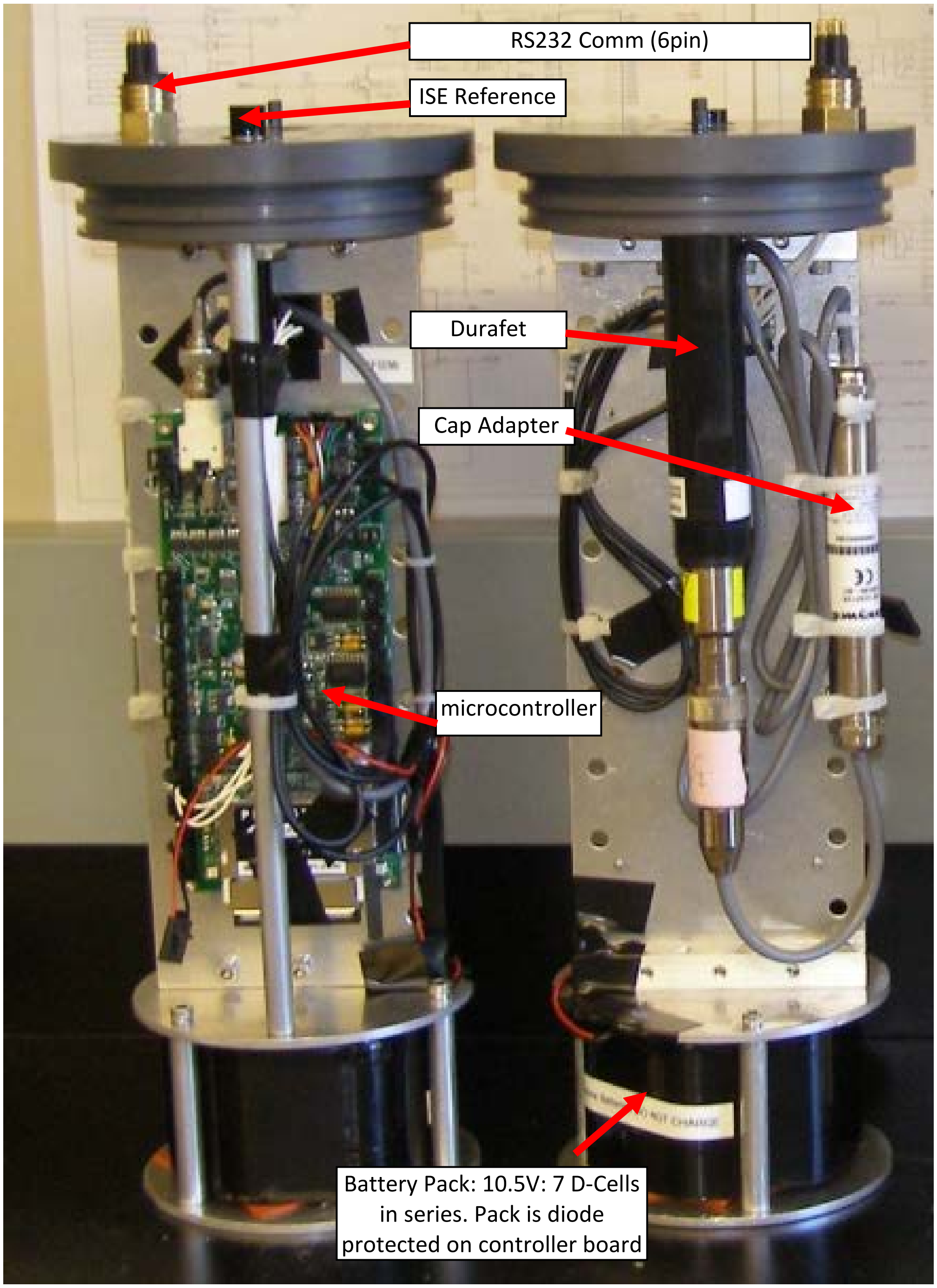
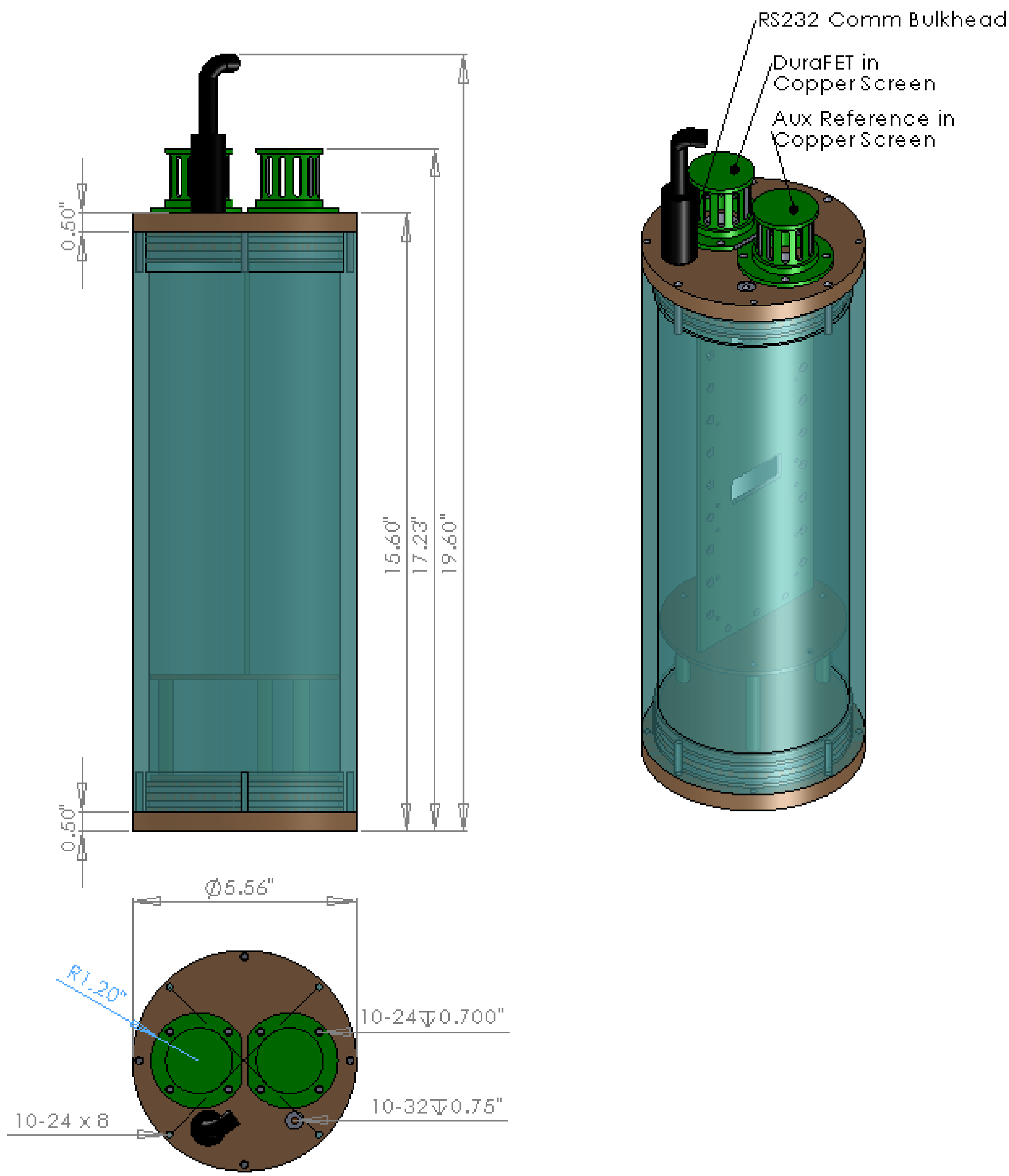


1.2. SeaFET Dimensions

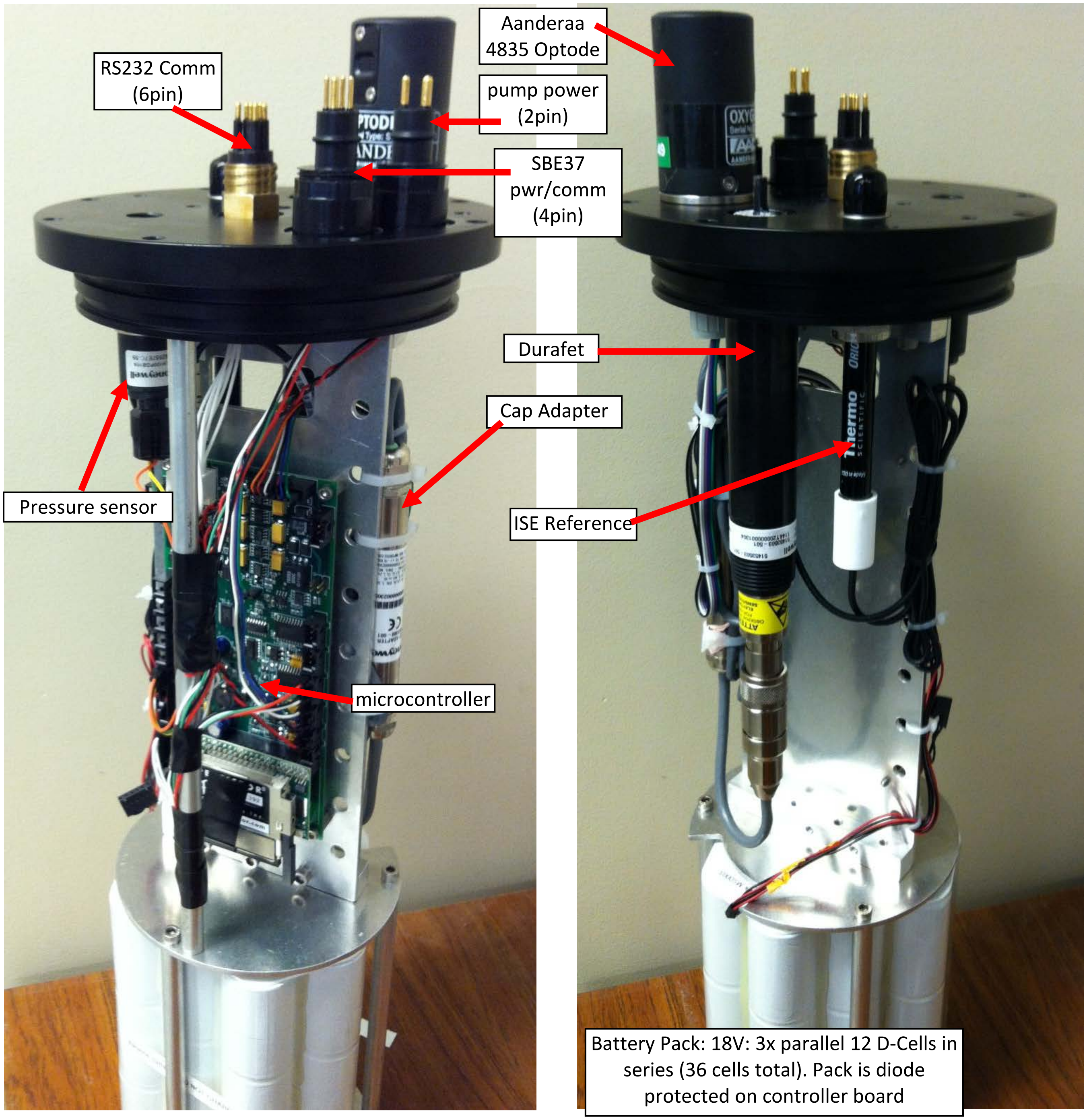


SeaFET Dry Weight: 5.9 kg (13 lbs) SeaFET Immersed Weight: - 1.0 kg (-2.2 lbs)

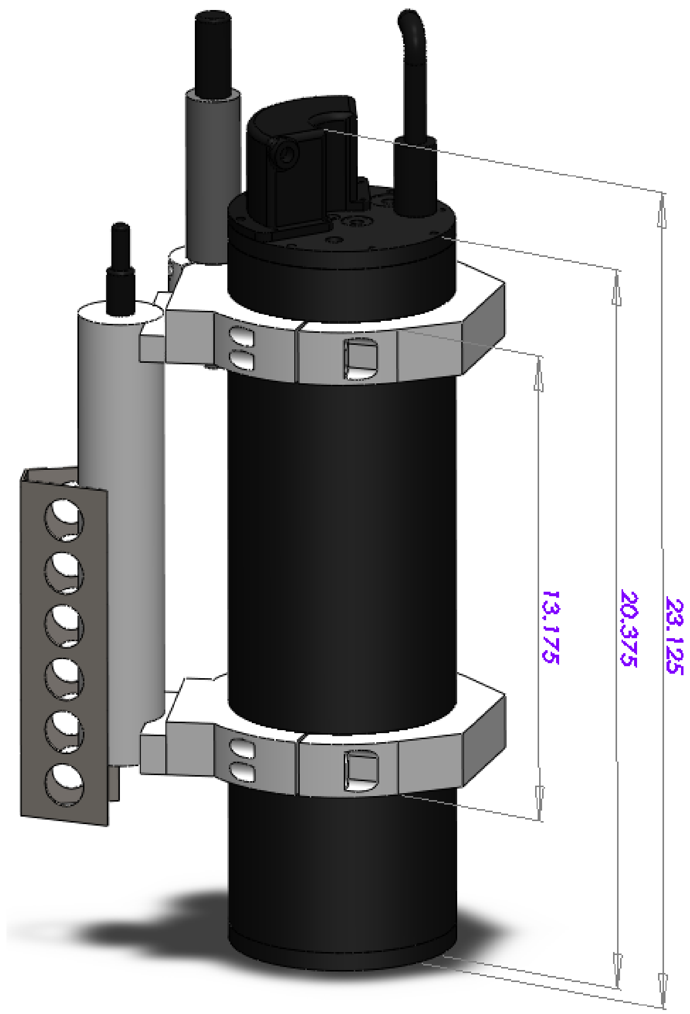
1.3. *SeaFET Fasteners*

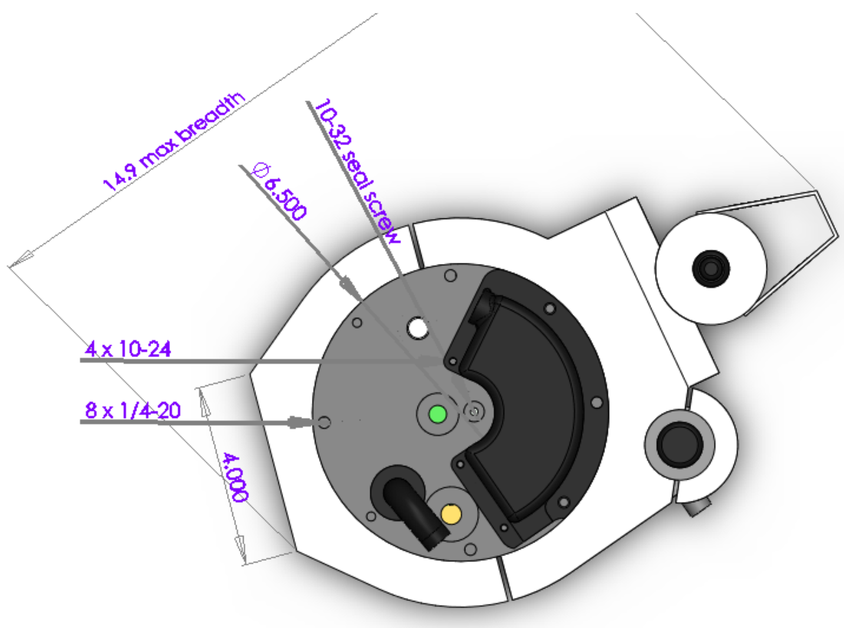
Part Name	Location	qty	Vendor & P/N
316 SS SHCS 10-24 × ½"	Chassis, Endcaps	22	McMaster.com 92185A242
316 SS SHCS 10-24 × 1"	Top endcap, Top chassis mount	12	McMaster.com 92185A247
316 SS Flat Head Slotted Machine Screw 10-24 × ½"	Support rod, Batt. plates	8	McMaster.com 91858A242
18-8 Stainless Steel Fully Threaded Stud 10-24 × ¾"	Top endcap	1	McMaster.com 95412A885
Stainless Steel M/F threaded Hex standoff ¼" Hex, length, 6-32 x 3/8"	Chassis	4	McMaster.com 91075A441
18-8 Stainless Steel Socket Head Cap Screw, 6-32 × 3/16 "	Chassis PCB	4	McMaster.com 92196A143
316 SS General Purpose Flat Washer No. 10 Screw Size, 7/16" OD, .02"-.04" Thick	Endcaps	8	McMaster.com 90107A011
10-32 × ½" Sealing Screw	Top endcap	1	Sealingscrews.com
SS Swagelok Tube Fitting, Male Connector, 12 mm Tube OD x 3/4-16 Male SAE/MS Straight Thread	Top endcap	1	Swagelok.com SS-12M0-1-8ST
Buna-N O-Ring AS568A Dash Number 247	Endcaps	4	McMaster.com 9452K197

1.4. SeapHOx Component Descriptions



1.5. *SeapHOx Dimensions*



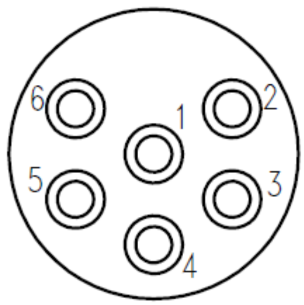
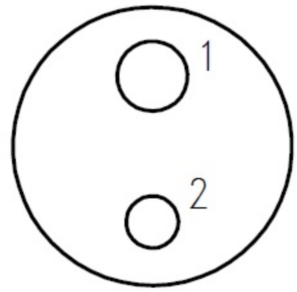
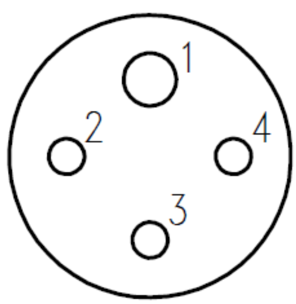


SeapHOx Dry Weight: 18.1 kg (40.0 lbs)
SeapHOx Immersed Weight: 2.9 kg (6.4 lbs)

1.6. *SeapHOx Fasteners*

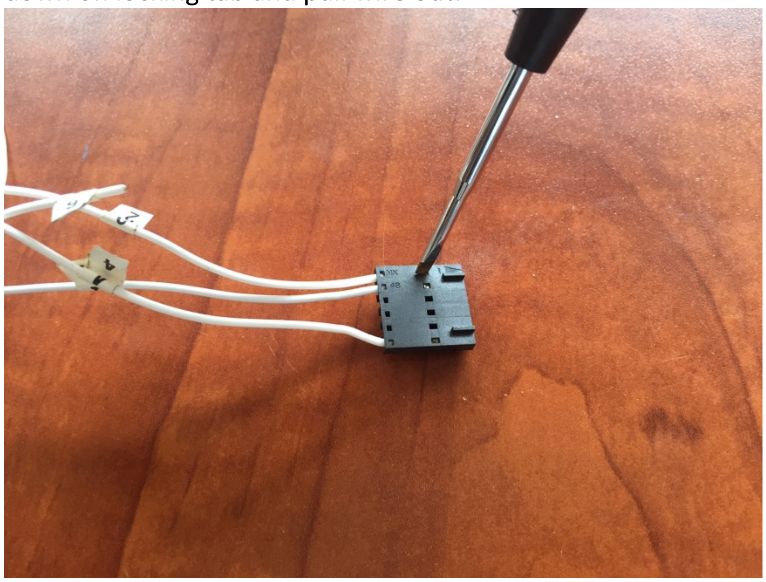
Part Name	Location	qty	Vendor & P/N
316 SS SHCS 10-24 × ½"	Top endcap	12	McMaster.com 92185A242
316 SS SHCS 10-24 × 1"	Top chassis mount	4	McMaster.com 92185A247
316 SS Flat Head Slotted Machine Screw 10-24 × ½"	Support Rod, Battery plates	8	McMaster.com 91858A242
18-8 SS Fully Threaded Stud 10-24 × ¾"	Top endcap	1	McMaster.com 95412A885
Stainless Steel Male-Female Threaded Hex Standoff ¼" Hex, Length, 6-32 × ⅜"	Chassis PCB	4	McMaster.com 91075A441
18-8 SS SHCS, 6-32 × $^3/_{16}$ "	Chassis, PCB	4	McMaster.com 92196A143
316 SS SHCS, ¼"-20 Thread, 1-¼" Length	Endcaps, ext. mounts	13	McMaster.com 92185A544
316 SS Large-Diameter Flat Washer ¼" Screw Size, ½" OD, .04"-.06" Thick	Endcaps	8	McMaster.com 91525A117
10-32 × ½" Sealing Screw	Top endcap	1	Sealingscrews.com
7/16-20 × ½" Sealing Screw	Top endcap	0-2	Sealingscrews.com
1/2-20 × ½" Sealing Screw	Top endcap	0-2	Sealingscrews.com
SS Swagelok Tube Fitting, Male Connector, 12 mm Tube OD x 3/4-16 Male SAE/MS Straight Thread	Top endcap	1	Swagelok.com SS-12M0-1-8ST
MIL Spec Buna N O-Ring Durometer A70, AS568A Dash Number 251	Endcaps	4	McMaster.com 4679T288
MIL Spec Buna N O-Ring Durometer A70, AS568A Dash Number 154	Flow manifold	1	McMaster.com 4679T223
UV-Resistant Black Tygon (R-3400) PVC Tubing 3/8”ID x ½”OD	CTD to pump tubing	1	McMaster.com 5255K23
UV-Resistant Black Tygon (R-3400) PVC Tubing ½”ID x ¾” OD	CTD/pump/Flow cell tubing	1	Mcmaster.com 5255K26

1.7. Bulkhead Pinouts

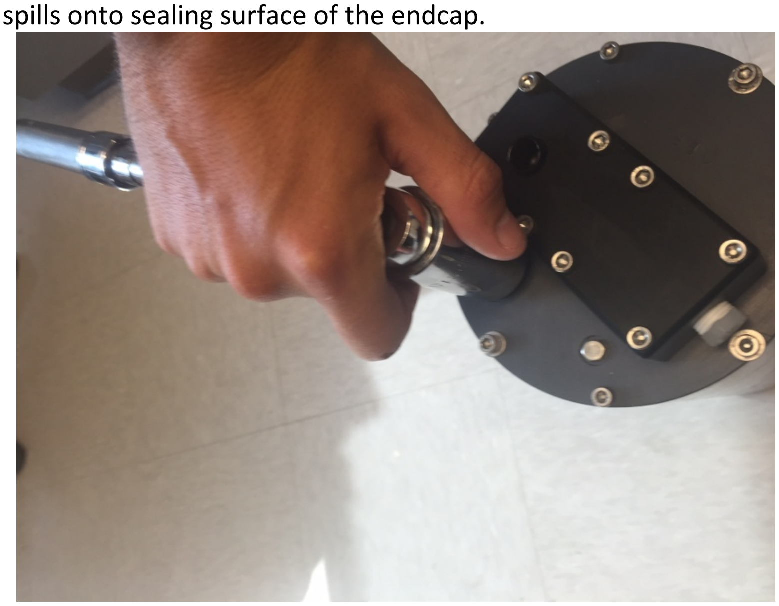
COMM Bulkhead (6pin)	Pump Bulkhead (2pin)
 Teledyne-Impulse bulkhead: MCBH-6-MP dummy plug: MCDC-6-FS plug/cable: MCIL-6-FS locking sleeve: MCDLS/F Bulkhead and Connection to Board PIN-1 (black on serial cable): Transmit PIN-2 (white): Receive PIN-4 (green): RS232 ground Max. mounting torque: 100 in/lbs.	 Teledyne-Impulse bulkhead: XSG-2-BCL HP SS dummy plug: RMG-2-FSD LP locking sleeve: RMG-2-FSD LS double-ended cable: RMG-2-FS to RMG-2-FS Bulkhead PIN-1 (thick pin): ground PIN-2: V batt Max. mounting torque: 18 in/lbs.
SBE37 Bulkhead (4pin)  Teledyne-Impulse bulkhead: XSG-4-BCL HP SS dummy plug: RMG-4-FSD LP locking sleeve: RMG-4-FSD LS double-ended cable: RMG-4-FS to RMG-4-FS Bulkhead and Connection to Board PIN-1 (white cable to board): ground PIN-2 (black): transmit PIN-3 (green): receive PIN-4 (red): V batt Max. mounting torque: 18 in/lbs.	

1.8. *Bulkhead Swap*

1. Open up sensor and remove bulkhead connector from circuit board (COMM port).
2. Remove 3 pins (wire #s 1,2,4) from black connector using tweezers or small screwdriver to press down on locking tab and pull wire out.

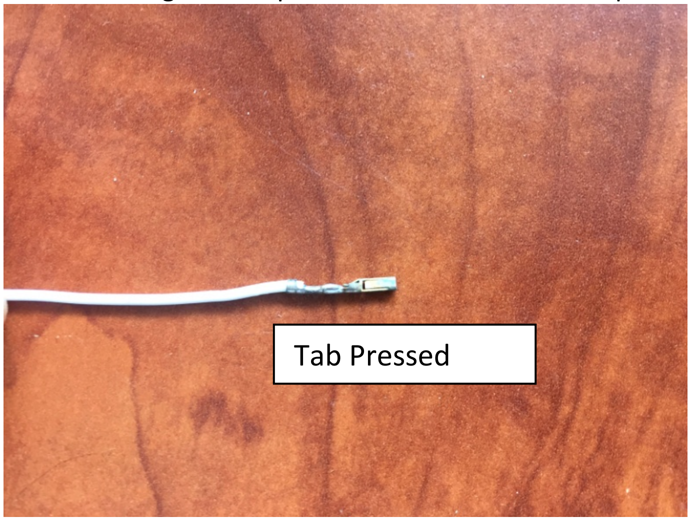


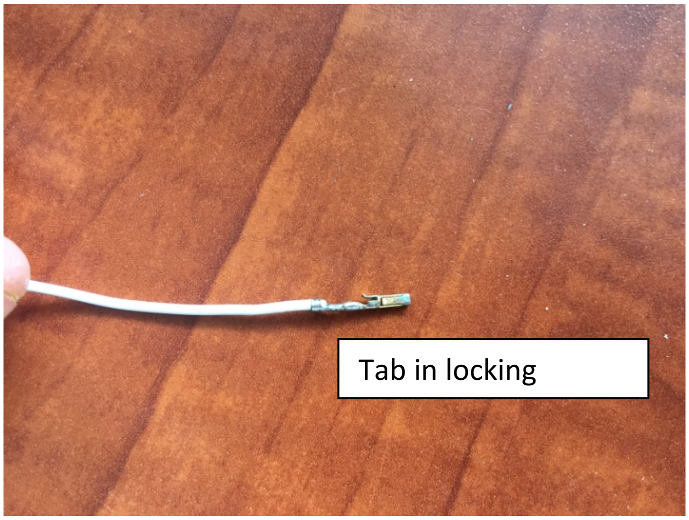
3. Use a ¾" deep socket to unscrew bulkhead, DO NOT USE A WRENCH.
4. Grease (silicone) up new o-ring and place onto sealing surface of new bulkhead.
5. Set wires through bulkhead hole on endcap and set the bulkhead on top of the endcap.
6. Apply about 1-2 threads worth of Loctite on lower threads of bulkhead.
7. Holding the socket wrench near the socket, screw bulkhead down making sure no Loctite spills onto sealing surface of the endcap.



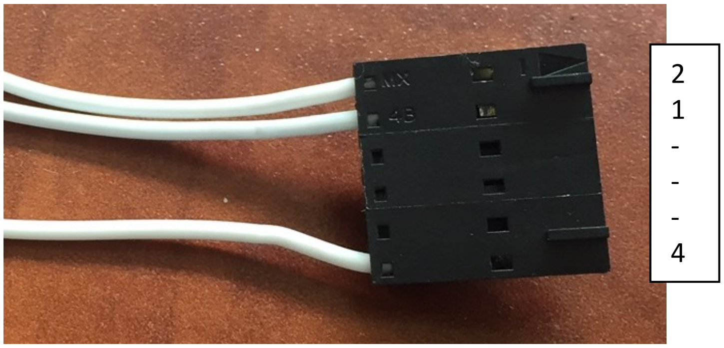
   a. If this does occur, use a Kim wipe to clean up Loctite.
8. Bulkhead should loosely tighten until an abrupt stop.
   a. Holding the socket wrench at the socket, give it a few more taps to tighten (back the socket wrench off and then rotate to tighten until the abrupt stop).

9. Install 3 pins into the black plastic connector and plug into the controller board.
   a. Make sure locking tabs on pins are able to hold wire in place.





10. Place wires in same order as before:



11. Plug connector into communications port on circuit board.

2. User Interface & Communications

2.1. Software

2.1.1. *Hyperterminal or equivalent terminal program*

Hyperterminal is generally used for all user interfacing with the SeaFET and SeapHOx via the command line. Typical tasks include setting the instrument's operating parameters such as sampling interval and clock, downloading/erasing data files. Tera-Term and Motocross are free equivalent terminal programs, but Motocross cannot be used to download data files.
http://ttssh2.sourceforge.jp/index.html.en
http://persistor-picodev-tools.software.informer.com/

For mac users, ZTerm is an equivalent terminal program:
http://www.dalverson.com/zterm/

2.2. RS-232 Settings

2.2.1. *Hardware Requirements*

2.2.1.1. *An RS-232 comm cable to adapt the waterproof bulkhead to DB9*

2.2.1.2. *PC with an RS-232 serial port (or USB-Serial converter)*

2.2.2. *Communication Settings*

Confirm the number of the serial comm port to be used. To identify the active/available comm port addresses on your computer use: Control Panel > System > Device Manager > and expand Ports. Open HyperTerminal, MotoCross or Tera-Term and set port to the appropriate number. Other settings are as follows:

baud rate	115200
Parity	none
Data Bits	8
Stop Bits	1
flow control	none

2.3. Verify Communication& Wake-Up

After setting up an operational RS-232 connection (Section **Error! Reference source not found.**), follow instructions below to establish communication with the instrument.

The instrument should arrive in *Sleep mode*. Use a terminal program (Section 2.1.) to communicate with the instrument. To wake up an instrument in sleep mode, strike any key and it will prompt the user to press ENTER. If you do not press ENTER, the instrument will go into deployment mode. A successful wake-up will look like this:

```
*****Press enter to bring up main menu*****


Main Menu--SeaFET/SeapHOx v2.1 – Will deploy in 30 seconds
1 -- Configure
2 -- Deploy
3 -- Test
4 -- Sleep
5 -- Files
Enter Selection:
```

NOTE: IF USER DOES NOT MAKE A SELECTION WITHIN **30 SECONDS**, THE SENSOR WILL GO INTO DEPLOYMENT MODE.

If the instrument is not connected to power (the battery is unplugged), apply power by plugging in the battery. The main menu will appear once power is applied.

2.4. *Sensor Firmware & Main Menu*

```
Main Menu--SeaFET/SeapHOx v2.1 – Will deploy in 30 seconds
1 -- Configure
2 -- Deploy
3 -- Test
4 -- Sleep
5 -- Files
Enter Selection:
```

2.4.1. Menu Map

The following section shows the Menu map of the SeaFET & SeapHOx controller software. Navigate the program by typing the desired number followed by the enter key (↵). When changing parameters, type in the new value, followed by ↵. The values in [ ] indicate the most recently stored values, and striking ↵ without entering a new number will retain the current value.

1. Configure
    1. Set Clock
        Is it GMT? (Y/N) ?
        Enter time [dd/mm/yy hh:mm:ss]:
    2. Change File Name
        Enter data file name (no spaces, 8 characters before .txt or .xls) [ ]:
        Enter user initials [ ]:
    3. Set Deployment Parameters

Sample aligned to hour? (Y/N) ?
Enter sample period [ ] sec:
Enter pH sample average [ ] samples:
Enter pump on time [ ] sec:
Enter low battery voltage:
Output mode menu
1 -- Normal (Data only)
2 -- Verbose (Data with prompts)

4. Enter pH Sensor Calibration Coefficients
   Enter E0_int @ 25 C [ ]:
   Enter E0_ext @ 25 C [ ]:
   Enter default salinity (PSU) [ ]:
   Enter TCOffset [ ]:
5. Calculate pH Sensor Calibration Coefficients
   Enter pH Calibration point [ ]:
   Perform automatic Durafet calibration (Y/N) ?
   Enter Vint [ ]:
   Enter Vext [ ]:
   Enter bath temperature [ ]:
   Enter bath salinity [ ]:
   Accept and stor calibration values (Y/N) ?
9. Exit to Main Menu

2. Deploy
   Enters deployment mode immediately
3. Test
   1. Display Battery, Internal Temp, Pressure
   2. Display pH Sensor Data
   3. Communicate with Instrument
      MicroCAT
      Optode
      AUX 1
      AUX 2
      Exit
   4. Pump ON/OFF
   5. AUX1 ON/OFF
   6. AUX2 ON/OFF
   9. Exit to Main Menu
4. Sleep
9. Files

2.4.2. Configure

From the main menu type 1↲. Parameters and recommended values that are adjustable through the Configure Menu are shown below:

Set Clock

- *Is it GMT?:* Key in Yes (Y) or No (Y) to specify.
- *Enter Time:* The time can be manually entered in the format MM/DD/YY HH:MM:SS. Alternatively, if using Motocross, the time can be entered from Edit->Paste date and time and choose the second option (this will sync the clock to the computer clock).

Deployment Parameters

- *Sample aligned to hour:* Yes will set the sensor to align when to sample against the hour.
- *Enter sampling period (sec):* Number of seconds in between samples. Consult the power budget (Section 4.5) to determine appropriate interval, depending on deployment length.
- *Number of pH samples to average:* Number of values averaged per logged data point (only refers to V_{therm}, $V_{FET|INT}$, $V_{FET|EXT}$, and V_{iso}).
- *Enter pump on time:* Determines how long the SBE5P (pump) is turned on to flush the cell prior to sampling. For the standard SeapHOx with the SBE37 attached, 25 to 30 seconds is recommended. This will deliver 2-3 volumes of the internal manifold/tubing. The power budget (Section 4.5) is based on a 25 second pump time. For SeaFET, always set pump time to 0 seconds.
- *Enter low battery voltage* - when the main battery pack reaches this voltage the instrument remains in low power mode continuously and takes no more samples. This prevents the sensors from totally draining the battery pack, which may corrupt the data file. For SeapHOx and SeaFET, recommended voltages are 10.5V and 5.5V, respectively.
- *Output Mode:* Choose 1 or 2. Mode 2 will display prompts during deployment mode. Mode 2 is preferred.

Configuration Example: change sample period from 1hr to ½ hr; change averages per logged data point from 30 to 10; change pump time from 10 to 25; output mode from 2 to 1.

```
Configuration Menu--SeaFET,SeapHOx v2.1
1 -- Set Clock
2 -- Change File Name
3 -- Set Deployment Parameters
4 -- Enter pH Sensor Calibration Coefficients
5 -- Calculate pH Sensor Calibration Coefficients
9 -- Exit to Main Menu
Enter choice [9]? 2

Sample aligned to hour? (Y/N) [Y]? Y
Enter sampling period [3600] (sec): 1800
Enter pH sample average [30] samples: 10
Enter pump on time [10] sec: 25
Enter low battery voltage (10.5 V for SeapHOx, 5.5 V for SeaFET) 10.5]:
Output mode menu
1 -- Normal (Data only)
2 -- Verbose (Data with prompts)
Enter Selection [2]: 1
```

2.4.3. Deploy

Upon selecting 2↲ (Deploy) under the Main Menu, the instrument enters an autonomous sampling deployment mode. In this mode, the instrument wakes up on a user-defined interval (sampling period), carries out a sample, stores the data, prints the data out to the RS-232 port, and goes into a low power sleep mode until the next sample. At the time the instrument enters Deployment mode, all configuration parameters are printed out to the screen and saved as a header to the new data file.

A new file name SHOULD be set prior to each deployment, but the program will append data to the same file if a new name is not specified. To set a file name navigate through the configuration menu to change file name. File name must be no longer than **8 characters** and end with .txt or .xls.
The user can also set up a custom start time. This is useful when the user needs to deploy before putting the sensor in the water. All deployments should start with the pump unplugged.

Refer to Section 2.6 for description of the data string printed to the screen and stored by the controller.

SeapHOx Deployment Example

```
Main Menu--SeaFET/SeapHOx v2.1
1 -- Configure
2 -- Deploy
3 -- Test
4 -- Sleep
5 -- Files
Enter Selection: 2

****************** Deployment Settings **********************
Sampling Period:  1800 seconds
Samples hour aligned:   Yes
pH sample average:      10 samples
Pump on time:     25 seconds
Low battery voltage:    10.5 V
Output mode:      Verbose
E0_int @ 25 C =   -0.399639 V
E0_ext @ 25 C =   -1.395824 V
File name:  test.txt
Current time: 05/07/15 07:57:11
************************************************************

SBE pump will run and must be immersed at start time!

Starting deployment. . .

Sleeping until 05/07/15 08:10:10

#0    2013/11/19 08:10:10     18.94 1.148109    0.074718    -0.893044
4.32  22.95 20.077        5.37118    8.2613      6.0892      0.0000
      0.2559      3835  1437  283.69      99.99 19.98 30.75 31.08 0.00
      229.80      194.00      0.00  107.60   20.7024    0.00002
0.0103       19 Nov 2013            15:22:40
```

```
Sleeping until 05/07/15 08:30:00
```

*Note that the data from the Optode and SBE37 will not be displayed for a SeaFET. They will be displayed as NANs.

Exiting the Deployment loop:
While the controller is asleep (i.e. not taking a sample), strike any key and the following prompt will appear:

```
Enter command (ts, gdata, stop):
```

If the prompt does not appear, it is most likely because the controller is in the middle of a sample loop. Wait until the data is transmitted, and try again. If normal (data only) mode is chosen, the prompt will not come up but it will recognize the commands if typed out. If that does not work, check communication settings and power.

Once the prompt appears, the controller accepts three commands:

ts: takes a sample, and continues its deployment loop
stop: exits deployment loop and returns to main menu. The sensor will not redploy or sleep automatically.
gdata: transmits the last 20,000 characters worth of data. Once data is transmitted through this command, it will not be transmitted again.

Type one of the above three commands and **strike enter↵**. The prompt will not come up if you are in normal output mode. If a typo is made, the controller will go back to sleep. The user must press enter after command is sent to bring up the main menu.

SeapHOx Deployment Example (stop command)

```
Sleeping until 05/07/15 08:10:10

#0    2013/11/19 08:10:10     18.94 1.148109    0.074718    -0.893044
4.32  22.95 20.077        5.37118    8.2613      6.0892      0.0000
      0.2559      3835  1437  283.69      99.99 19.98 30.75 31.08 0.00
      229.80      194.00      0.00  107.60    20.7024    0.00002
0.0103       19 Nov 2013            15:22:40


Sleeping until 05/07/15 08:30:00
Enter command (ts, gdata, stop): stop

*****Press enter to bring up main menu*****

Main Menu--SeaFET/SeapHOx v2.1
1 -- Configure
2 -- Deploy
3 -- Test
4 -- Sleep
5 -- Files
```

```
Enter Selection:
```

2.4.4. Test

The Test Menu allows retrieval of the voltages from the pH sensor and communication with peripheral instruments including the SBE-37, SBE Pump, and the Aanderaa 3835 Optode.

Note: For a description of nominal test voltages refer to Section 2.6

1. Display Battery Voltage, Internal Temperature, Pressure

This option displays the Battery pack voltage (~19V and ~10.5V for a new SeapHOx and SeaFET, respectively), the temperature from a thermistor chip located on the board, the pressure in dBar and raw voltage. The program will keep displaying the data every 3 seconds until a key is pressed.

```
Test Menu SeapHOx_V2.1
1 -- Display Battery, Internal Temp, Pressure
2 -- Display pH Sensor Data
3 -- Communicate with Instrument
4 -- Pump ON/OFF
5 -- AUX1 ON/OFF
6 -- AUX2 ON/OFF
9 -- Exit to Main Menu
Enter selection: 1
Exit on any key

Main Battery = 18.939 V

Controller Temp = 23.760 C

Pressure = -0.221 dBar
Raw Voltage = 0.152 V
```

2. Display pH Sensor Data

This option displays voltages for the 4 channels from the isolated 24-bit A/D located on the pH peripheral board. The Ik and Ib voltages are displayed for troubleshooting issues.

```
Test Menu SeapHOx_V2.1
1 -- Display Battery, Internal Temp, Pressure
2 -- Display pH Sensor Data
3 -- Communicate with Instrument
4 -- Pump ON/OFF
5 -- AUX1 ON/OFF
6 -- AUX2 ON/OFF
9 -- Exit to Main Menu
Enter selection: 2
Exit on any key

Vtherm = 1.118509
```

```
TC = 20.949219

Vint = 0.074574
pH_int = 8.258817

Vext = -0.893174
pH_ext = 6.086968

Isolated Battery Voltage = 4.373043

Voltage b/w Ik+ Ik= = 0.000006 V

Ib+ = 0.149140 V
```

3. Communicate with Instrument (SeapHOx)

When one of the peripheral instruments is selected, the controller applies power, polls the instrument, and displays the data returned by the instrument. Refer to Section 2.5for manual commands that can be entered while in this mode. It is a good idea to communicate with the instruments before deployment through this menu in order to ensure the instruments are functioning properly.

1. MicroCAT

A typical test for the microcat may look like this:

```
Microcat and Optode Peripheral Communication Menu
1 -- MicroCAT
2 -- Optode
3 -- AUX 1
4 -- AUX 2
9 -- Exit

Enter peripheral device selection[9]: 1

*Press CTRL-X to stop communication with the MircroCAT.*

SBE 37-SI

<Executed/>
ts
  20.7031,  0.00003,   0.0103, 19 Nov 2013, 15:30:23
<Executed/>
```

2. Optode

To type a command, press any key first so the exclamation point comes up.

```
Microcat and Optode Peripheral Communication Menu
1 -- MicroCAT
2 -- Optode
3 -- AUX 1
4 -- AUX 2
9 -- Exit

Enter peripheral device selection[9]: 2
```

```
*Press CTRL-X to stop communication with the MircroCAT.*

ÿ<%< !do sample
!!<4835     462    263.034     97.149      22.424      28.749
      28.269      37.823      9.554
#
```

4. Pump ON/OFF
   ONLY RUN THE PUMP IF IT IS SUBMERGED IN WATER. You can test the pump by checking the pump cable with a voltmeter while applying power. Just be sure not to touch the leads as it will short the board and cause permanent damage.

5. AUX1 ON/OFF
   Supplies power to AUX 1 port on board.

6. AUX 2 ON/OFF
   Supplies power to AUX 2 port on board.

2.4.5. Sleep

In the Main Menu, select '4' to send the instrument into a low power state. This command is critical if you wish to keep the battery plugged in and do not want to take any samples (e.g. during shipping). If you press a key the instrument will wake up and start a deployment loop immediately if enter is not pressed.

```
Main Menu--SeaFET/SeapHOx v2.1
1 -- Configure
2 -- Deploy
3 -- Test
4 -- Sleep
5 -- Files
Enter Selection: 4

Sleeping...hit any key to wake

*****Press enter to bring up main menu*****

Main Menu--SeaFET/SeapHOx v2.1 – Will deploy in 30 seconds
1 -- Configure
2 -- Deploy
3 -- Test
4 -- Sleep
5 -- Files
Enter Selection:
```

NOTE: Anytime you are finished testing, send the sensor into Sleep mode, or Deploy mode. If not, the controller will remain on and drain the battery within a couple days.

2.4.6. Files

Entering 5↲ in the main menu exits the program and brings up the PicoDOS prompt C:\>. From the PicoDOS prompt, the data file can be downloaded and erased, as described below in Section 3 or a new program can be loaded. Typing ‘help’ will bring up a menu of all the commands in the PicoDOS promt. Restart the program by typing 'exit', C:\>exit↲.

NOTE: Exiting the operating program (e.g. when downloading data) should be done with caution because when the board is at the PicoDOS prompt the batteries are supplying full power to the controller. After downloading data, always restart the program by typing ‘exit’. If the instrument is to remain dormant for a long period, use the Sleep function (Section 2.4.5) or unplug the battery.

2.5. *Communicating with SBE-37 and AADI 3835*

Refer to the SBE-37 and Aanderaa 3835 User Manuals for complete documentation on communications with these peripheral instruments.

In Deployment Mode (Section 0) and Test Mode (Section 2.5.4), the SeapHOx delivers power to and opens a communication channel with the peripheral instrument.

In the *Test Menu*, commands can be entered manually. Some useful commands are: (for a full documentation, refer to the respective manuals)

SBE-37
“TS” (Take Sample): This will take a sample, but will not save it.
“TSS” (Take Sample and Store): This will take a sample and store the data in the internal memory of the SBE-37.
“datetime=MMDDYYYYHHMMSS”: The SBE-37 date and time is set independently of the sensor date and time (accessed through the configuration menu). Check that the SBE-37 is set to the desired date and time prior to deployment.

Aanderaa 4835 Optode

The optode is set to polled mode and disabled text. This is normally done before installing the optode in the SeapHOx by sending the following commands using hyperterminal (See the optode manual).

```
Set passkey(1)
Set mode(smart sensor terminal)
Set enable polled mode(yes)
Save
Do sample
Set passkey(1)
Set enable text(no)
Save
Do sample
```

2.6. Description of Sensor Output

Table 1. Nominal values of the output data string
***SeaFET will display the first eleven values only.**

Data array location*	variable	Chan	Nominal Value	Notes
1	Sample Number			
2	Board Time			Mm/dd/yyyy hh:mm:ss
3	Main Batt Volt	AD16_1	19 V, 10.5 V	New SP, SF battery
4	V Therm	AD24_3	1.1V	At room temp
5	V(FET|INT)	AD24_2	0.02 to .09 V	In seawater
6	V(FET|EXT)	AD24_4	-0.9 to -1.1	In seawater
7	Isolated Power Voltage	AD24_1	5.7 V	Using DC-DC
8	Controller Temp	AD16_2	22 C	At room temp
9	Durafet Temp		20 C	Calculated TC from V Therm
10	V Pressure	AD16_3	500-4500mV	0-300 psig
11	pH_{INT}			Accuracy depends on user entered calib. coefficients
12	pH_{EXT}			
13	Counter Leak		0	Used for troubleshooting
14	Substrate Leak		-.100	Used for troubleshooting
15	Optode Model	Optode	4835	
16	Optode S/N	Optode	NA	
17	$[O_2]$	Optode	250	in Saturated Seawater [μM] Is temperature dependent
18	O_2 Saturation	Optode	~100	In Saturated Seawater (%)
19	Optode Temp	Optode	20 C	At Room Temp
20	Dphase	Optode	28	
21	Bphase	Optode	29	
22	Rphase	Optode	37	

23	Bamp	Optode	8.6	
24	Bpot	Optode	0	
25	Ramp	Optode	0	
26	Raw Temp	Optode	220	
27	SBE37 Temp	SBE37	-2-35 C	
28	SBE37 Cond	SBE37	3-6 S cm^{-1}	@S=35 (0-35C)
29	SBE37 Salinity	SBE37	35	In seawater
30	SBE37 Date	SBE37	NA	DD MMM YYYY
31	SBE37 Time	SBE37	NA	hh:mm:ss

3. Download/Erase Datafile

3.1. Use Hyperterminal or Tera-Term. A data file cannot be downloaded using Motocross.

3.2. Vista does not have Hyperterminal, so it may be necessary to download hypertrm.exe from a separate source or use another terminal program such as Tera Term.

- When you open Hyperterm.exe for the first time, cancel through several screens asking for area code information until you get to the screen called “connect description”.
- Give the Connection Description a name, press OK. Cancel prompts for area code info again if necessary.
- In the “Connect To” window select the correct COM port in the Connect Using drop down menu, press OK.
- Hyperterminal will then ask for COM properties. Make sure that baud rate (Bits per second) = 115200; Parity = none; Data Bits = 8; Stop Bits = 1; flow control = none. Press enter and name your new connection.
- Once the terminal window opens, press enter, and the prompt C:\> should appear. If it does not, check power connections.
- Note: MotoCross and Hyperterminal cannot be open at the same time and assigned to the same COM port.

In Hyperterminal, check files stored on the ARM by typing ‘ls’ at the command prompt

```
C:\>ls
```

The data file stored on the ARM is called ‘SEAPHOXD.txt’. If the instrument is open in the lab, the simplest way to download or erase a data file is to remove the Micro SD Card and read it on a Micro SD card reader. Alternatively, files can be erased in Motocross or Hyperterminal using the ‘rm' command

Download files using the Ymodem ‘ys’ command in Hyperterminal. At the prompt, type the send command

```
C:\> ys filename.txt
```

Erase files using the 'rm' command. At the prompt, type the send command

```
C:\>rm filename.txt
```

Immediately use Hyperterminal to receive the file being sent by the ARM. Click on Transfer > Receive File >. In the dropdown menu for the receive protocol, select Ymodem. Click OK and follow instructions.

If you are using Tera Term, go to File>Change directory… to choose the file that the data file will be saved. Then use the same 'ys' command to send the file. Immediately go to File>Transfer>YMODEM>Receive, and the file will be sent to the specified location.

3.3. Alternate Method:

You can print stored data to the screen using the 'cat' command

```
C:\>cat filename.txt
```

the 'cat' command can be used along with screen capture in your terminal program (motocross or HyperTerminal) to download the data file.

4. Sensor Calculations

4.1. pH, O_2, Salinity

Matlab functions for processing sensor data following Bresnahan et al (2014)[1] are currently available at https://github.com/SUPScientist/pH-with-the-Honeywell-Durafet. The salinity and temperature dependence for the pH sensor are described by Martz et al (2010)[2]. Salinity and temperature corrections for the Oxygen sensor are described in the Aanderaa Optode User Manual and are incorporated into the same matlab functions.

Processing SeaFET data requires a salinity value corresponding to every pH measurement. Under stable salinity conditions where changes are less than 0.1 Salinity, it is usually acceptable to process the pH and Oxygen data using a constant salinity value.

pH sensor calibration
Option 1: post processing. The samplecalc.xls spreadsheet describes a procedure that uses a single-point calibration. The electrode standard potential is calculated based on the pH of a discrete sample, taken during a sensor deployment.

Option 2: on-board processing. Alternatively, the same spreadsheet calculation can be used to obtain the electrode standard potential when the sensor is immersed in a solution of known pH, and this standard potential value can be entered using the menu commands, the present version of the firmware accurately calculates pH for the FET|INT only.

4.2. Battery voltage

When new, the alkaline battery pack is 10.5V (7D-Cells in series) for the SeaFET and ~19V (12 D-Cells in series, 3x parallel, 36-cell pack) for the SeapHOx. At ½ this voltage, the pack is fully discharged. Battery voltage is monitored on each sensor using a simple voltage divider (R13 (100kΩ), R14(1MΩ); Section 6). The isolated power voltage is monitored using the voltage divider (RXX and RXX).The equation used to translate the measured analog output to the battery voltage is shown below. Note that the recorded battery and isolated power voltages have already been converted to its actual voltages.

$$V_{batterypack} = V_{batt} \times \frac{R13 + R14}{R13} = V_{batt} \times \frac{100k + 1M}{100k} = V_{batt} \times 11$$

[1] Bresnahan et al. (2014), https://doi.org/10.1016/j.mio.2014.08.003
[2] Martz et al (2010), https://doi.org/10.4319/lom.2010.8.172

Note: The controller records two operating voltages: The main battery and the isolated power voltage that is either sourced by a DC-DC converter located on the pH peripheral board (when set to isolated mode, typical of the SeapHOx) or jumpered directly to main battery (non-isolated mode, typical of the SeaFET).

4.3. Durafet thermistor

Thermistor resistance is calculated from the V_{therm} value by:

$$R_{thermistor} = \frac{R3}{\frac{V_{supply}}{V_{therm}} - 1} = \frac{20k}{\frac{3.3}{V_{therm}} - 1}$$

Temperature is calculated from $R_{thermistor}$ using:

$$T = 340.982 - 9.1026\times10^{-5} - 95.0881 \times \log(R_{thermistor}) + 0.96537 \times (\log(R_{thermistor}))^3$$

4.4. Pressure Sensor

SeapHOxes with S/N greater than SP022 will have a Honeywell pressure sensor installed. The pressure sensors have an analog output between 0.5-4.5V that is directly proportional to its operational range. Depending on the SP version, the range of the pressure sensors are 0-300, 0-100, and 0-50 PSIG; all SeapHOxes with S/N greater than SP031 will have the 0-50PSIG version installed. The pressure is calculated from $V_{pressure}$ by (0-50PSIG sensor):

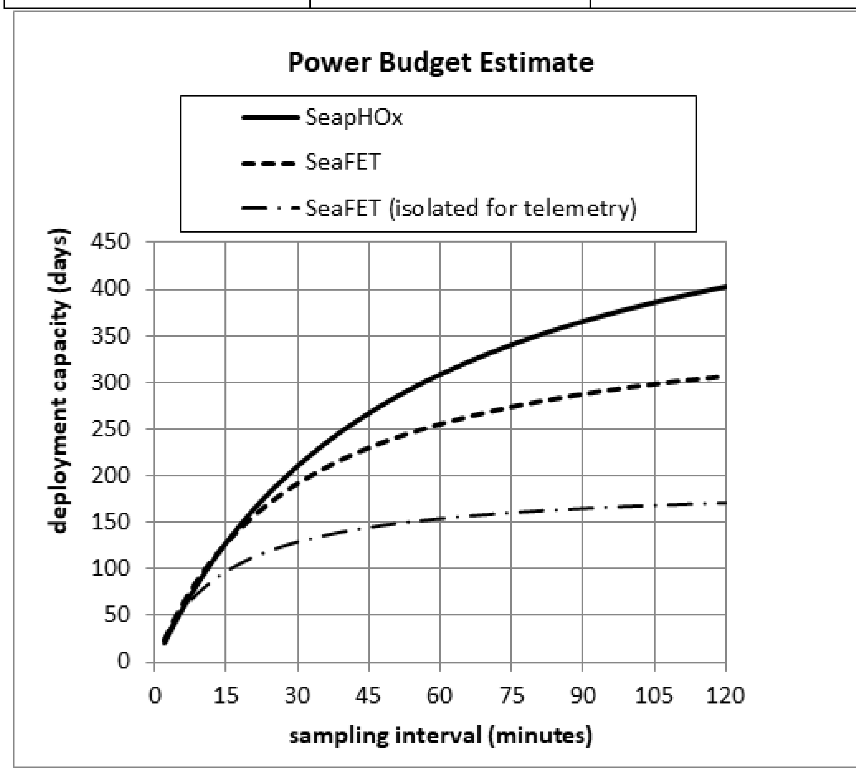
$$\text{Pressure (PSIG)} = 12.5 \times V_{pressure} - 6.25$$

4.5. Power Budget

In general, the most important factors controlling battery drainage rates are ambient temperature and current load. In addition, because there is a significant continuous power draw (due to continuously powering the pH sensor), capacity of the stand-alone battery pack does not translate directly into deployment capacity of the sensor package in terms of a number or measurements or deployment length until additional deployment parameters are specified. The deployment capacity of the SeaFET and SeapHOx are estimated here based on the values given in *Section 2.6: Description of Sensor Output*. As shown in the figure below, deployment capacity is a sensitive function of the sampling frequency. As the sampling interval decreases, less time is spent in sleep mode so more battery power is utilized during sampling mode resulting in more samples. Note that in these calculations the alkaline D-cell was de-rated to 12A*hr. Deployments carried out near 0C, may require further de-rating for accurate estimates of deployment capacity.

Table 2. Power budget estimates

	SeapHOx	SeaFET
D-Cell rating	12000 mA*hr	12000 mA*hr
D-Cell voltage	1.5 V	1.5 V
n cells	12	7
series package volts	18 V	10.5
in parallel	3	1
package capacity	36000 mA*hr	12000 mA*hr
pH ave time	40 sec	40 sec
pump time	25 sec	
Peripheral & com time	10 sec	
controller sleep	2.6 mA	1.3 mA
controller samp	60 mA	60 mA
Optode samp	250 mA	
SBE 37 samp	20 mA	
SBE 5M ON	100 mA	



Estimated deployment length for the SeaFET and SeapHOx based on parameters from Table 2. Note that these estimates are for room temperature, and must be adjusted for colder temperatures.

5. Deployment

5.1. SeaFET/SeapHOx Quick Launch Guide

1. Connect to the SeaFET/pHOx using a terminal program (e.g. Hyper Terminal, Tera Term) using the settings below:

COM Port Settings	
Baud Rate	115200
Parity	None
Data Bits	8
Stop Bits	1
Flow Control	None

2. The sensor should arrive in a sleep state. Press any key to wake the sensor. Then press ENTER within 30 seconds to enter the Main Menu. If ENTER is not pressed, it will start a deployment. It should look like this:

3. Remove cable from the bulkhead on the pump (SBE5M) to prevent the pump from air lock.

```
*****Press enter to bring up main menu*****

Main Menu—SeaFET/SeapHOx v2.1 -- Will deploy in 30 seconds
1 -- Configure
2 -- Deploy
3 -- Test
4 -- Sleep
5 -- Files

Enter Selection:
```

4. Configure the SeaFET/pHOx for Deployment. Follow these steps from the Main Menu. Settings will be shown in RED below.
   a) PRESS 1, ENTER – Set Clock (GMT or local)
   b) PRESS 2, ENTER – Change File Name
   c) PRESS 3, ENTER – Set Deployment Parameters (parameters in brackets are from previous deployment. You can press enter to continue to use these parameters without re-typing).
      I. Sample aligned to hour? (Y/N) [Y]? **Y**
      II. Enter sample period [10] sec: **3600**
      III. Enter pH samples to average: **10**
      IV. Enter pump on time [0]: **25 for SeapHOx, 0 for SeaFET**
      V. Enter low battery voltage (10.5 V for SeapHOx, 5.5 V for SeaFET [10.5]: **10.5 for SeapHOx, 5.5 for SEAFET**
      VI. Output mode menu
      1-- Normal (Data only)

2 -- Verbose (Data with prompts)
Enter Selection [2]: **2**

d) PRESS 9, ENTER – Exit to Main Menu. Press ENTER again to get back to main menu or wait 30 seconds to start deployment.

5. PRESS 2, ENTER – Deploy (will start immediately)
   a) Wait until first sample is taken and confirmed on terminal program

A successful SeapHOx launch sequence should look like this:

```
*****Press enter to bring up main menu*****

Main Menu—SeaFET/SeapHOx v2.1 -- Will deploy in 30 seconds
1 -- Configure
2 -- Deploy
3 -- Test
4 -- Sleep
5 -- Files

Enter Selection: 2

****************Deployment Settings************
Sampling period:       10 seconds
Sample hour aligned:   Yes
pH sample average:     5 samples
Pump on time:  0 seconds
Low battery voltage:   10.5 V
Output mode: Verbose
Eo_int @ 25 C =        -0.400000 V
Eo_ext @ 25 C =        -1.400000V
File name:      test.txt
Current time: 05/23/17 10:02:00
***********************************************

Starting deployment…

Sleeping until 05/23/17 10:02:02
#0      2017/05/23 10:02:00   17.35  1.111147       0.038005       -0.961554       4.22   24.28
        21.169  447.516604835  8.336246       8.123457       0.0000  0.1538  4835    495     190.413
        68.651  21.178  32.567  33.460  42.636  9.176   659.2   668.8   152.1 20.9532    6.0021
33.5215  23 May 2017    10:02:00

Sleeping until 05/23/17 10:02:10
```

6. Plug pump cable back into bulkhead on pump (SBE5M) directly before putting the SeapHOx into water. Make sure pins are properly aligned.

7. To stop a deployment, press any key to bring up command prompt (may have to press a key multiple times):
   Enter command (ts, gdata, stop):
   a. ts, ENTER: takes sample
   b. gdata, ENTER: transmits the last 20,000 characters worth of data (only works once until more samples have been taken)
   c. stop, ENTER: stops the deployment. Prompts user to press ENTER to bring up main menu, otherwise will continue deployment.

5.2. *Misc. Deployment Prep Info*

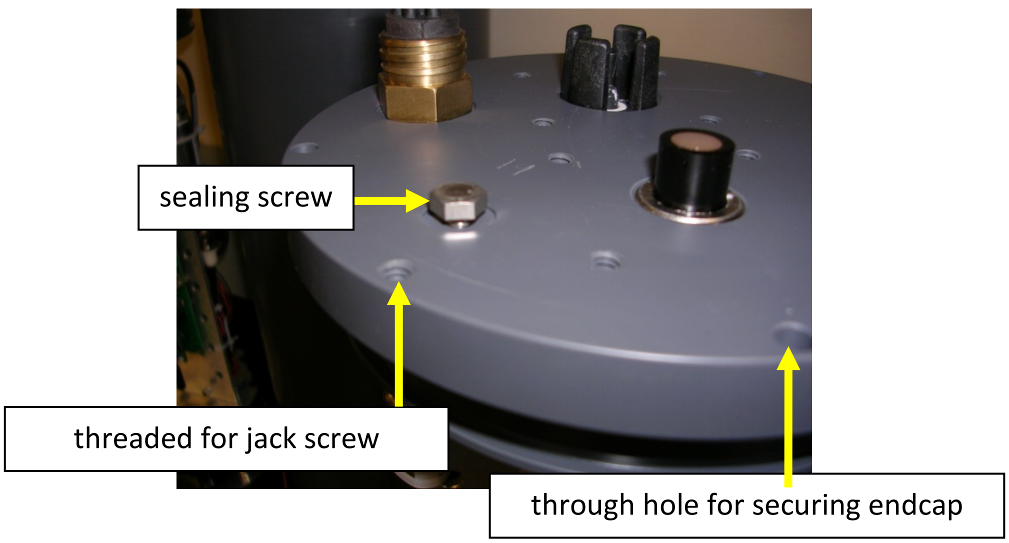
We place a desiccant pack inside of the housing. If the housing is left open or vented for a significant period, the desiccant will saturate and need to be replaced or regenerated;

they can be regenerated by baking them in an oven at the specified temperature (Note that directions are provided on desiccant pack and temperature may be given in degrees Fahrenheit).

For long term deployments, painting the housing with antifouling paint to combat biofouling is recommended. First wrap the sensor housing in polyethylene tape then paint with EP-SN1 Antifouling Bottom Paint.

Screws secure both endcaps. To open the housing remove the four screws around the edge of the endcap and put one or two of them into the threaded holes also around the edge of the endcap and use them to press up the endcap. When opening the housing, loosen the seal screw to vent to the atmosphere. When closing the housing – tighten the seal screw only after securing the sensor past both o-rings and tightening the four ¼-20 screws around the edge. The seal screw only needs to be tightened enough to compress the o-ring. DO NOT OVERTIGHTEN or you will damage the spot face used to seal the o-ring.

For additional information on fasteners and o-rings, refer to the parts lists in Section 1.



6. Controller Electronics

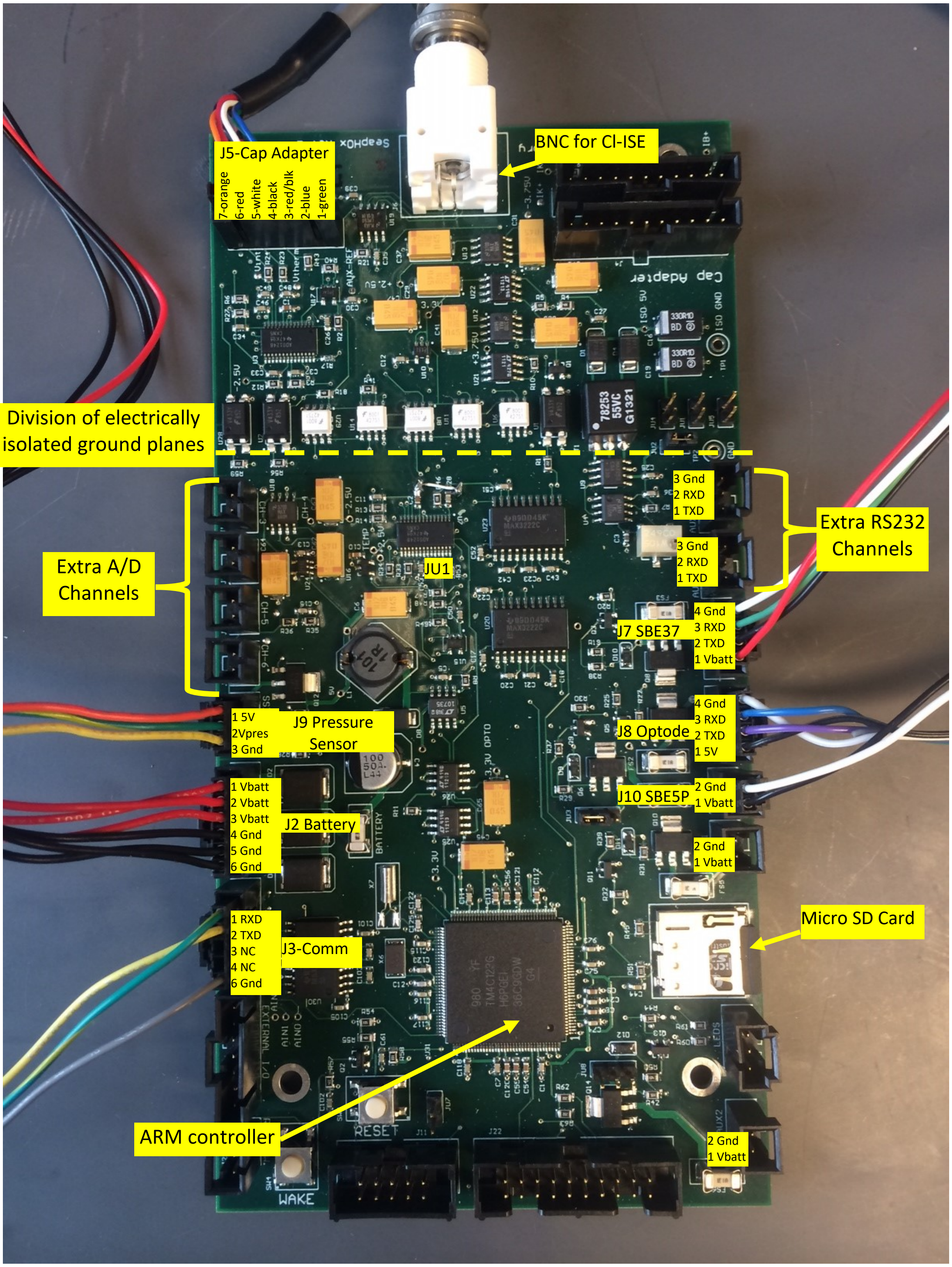
SeaFET & SeapHOx both utilize the Persistor C2 as the primary controller integrated into a custom board. For detailed information and schematics of the CF2, refer to the manuals available on the web.

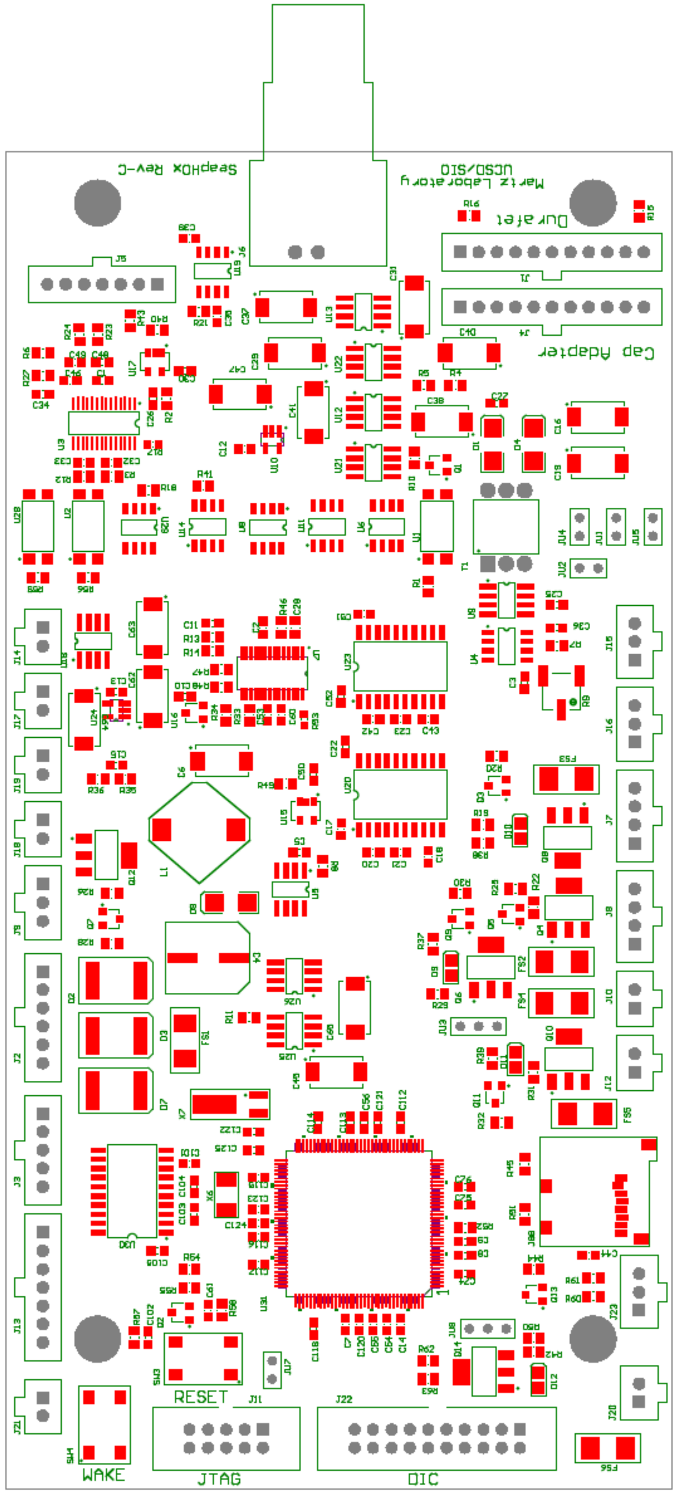
6.1. *Controller schematic and connections*

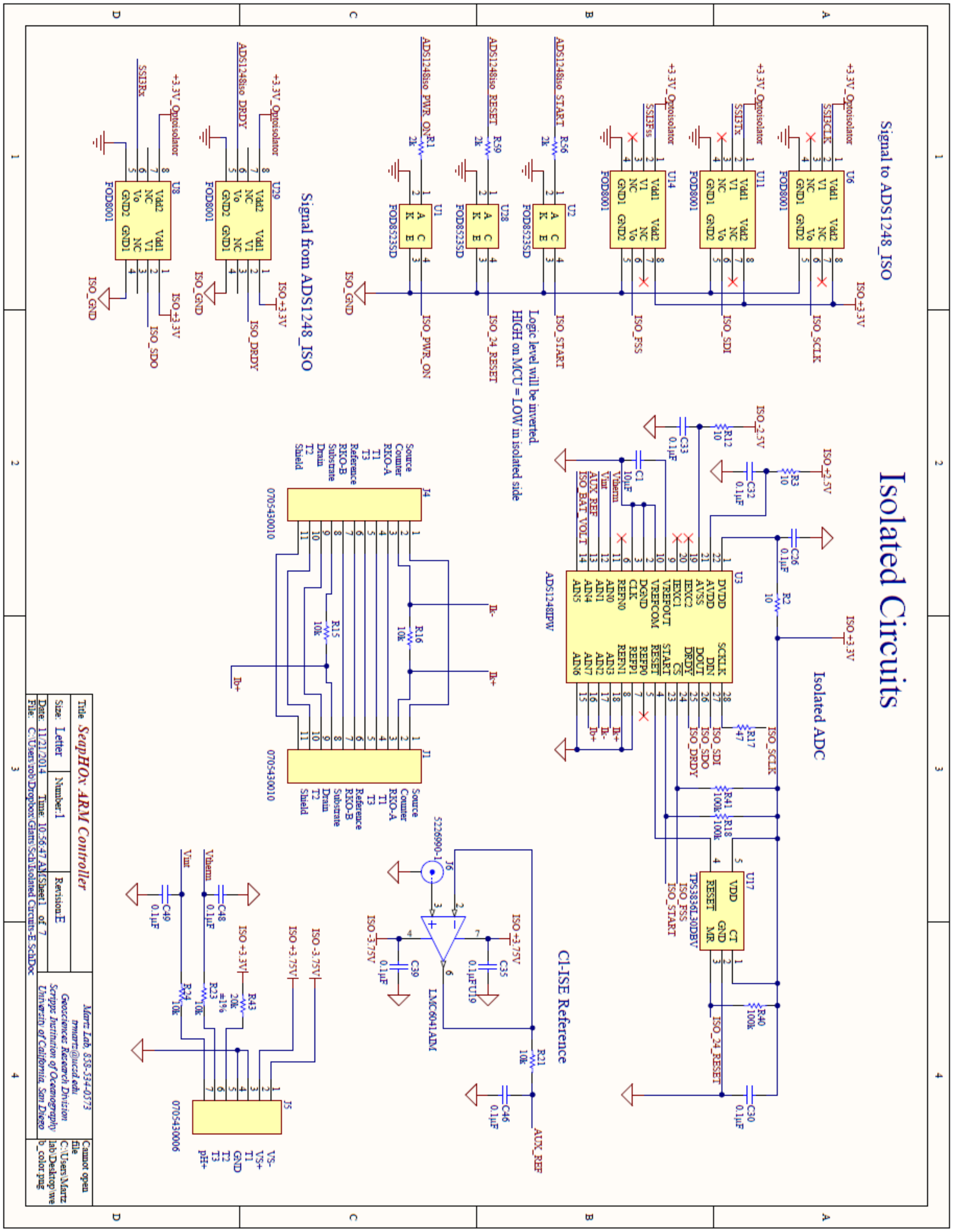
As seen below, the SeapHOx controller consists of a controller board and 5V isolated board on a single plane. The two sections of the board are connected by jumpers (explained below in Section 6.1.1) and the SeaFET and SeapHOx have different jumper configurations.

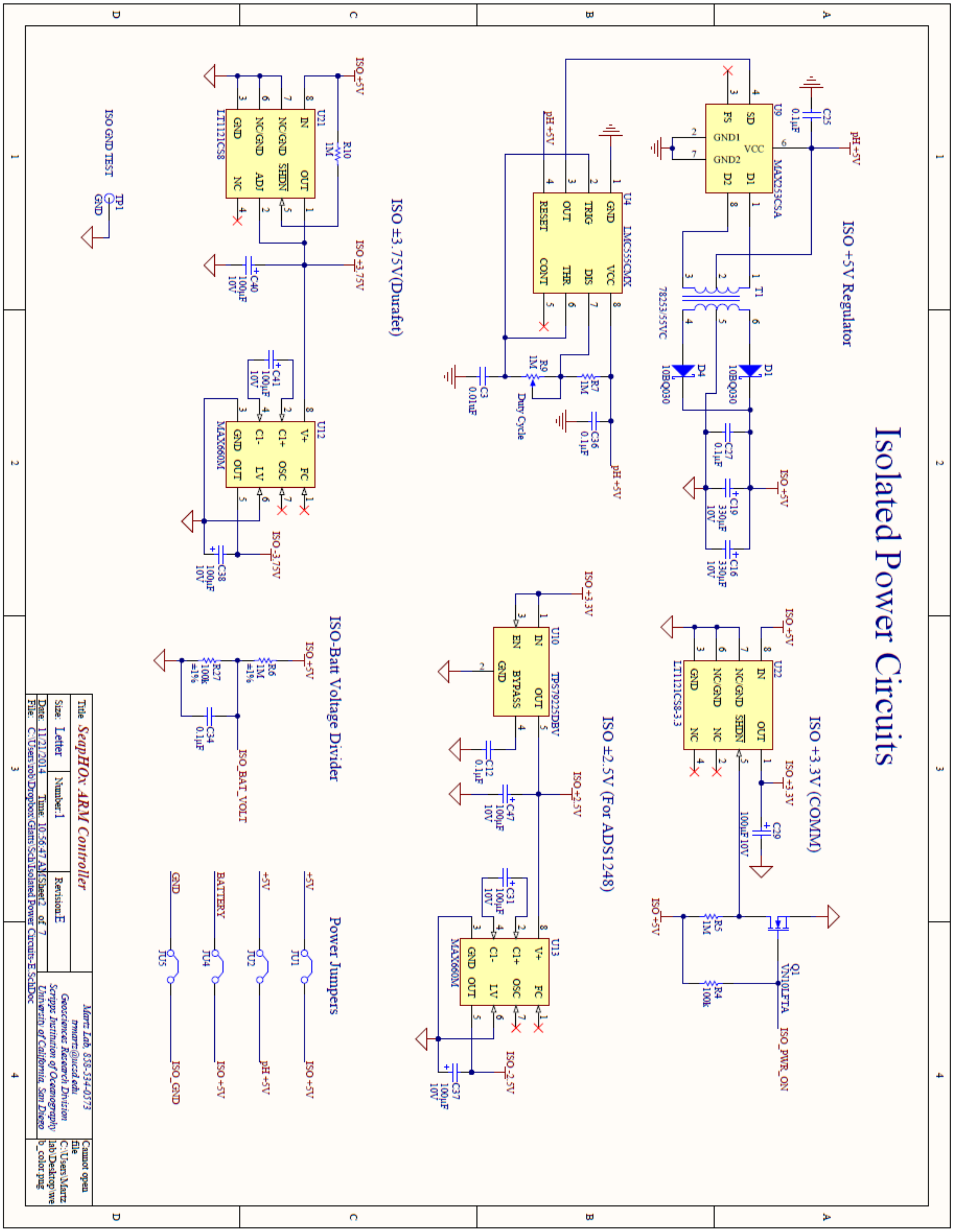
6.1.1. Jumpers

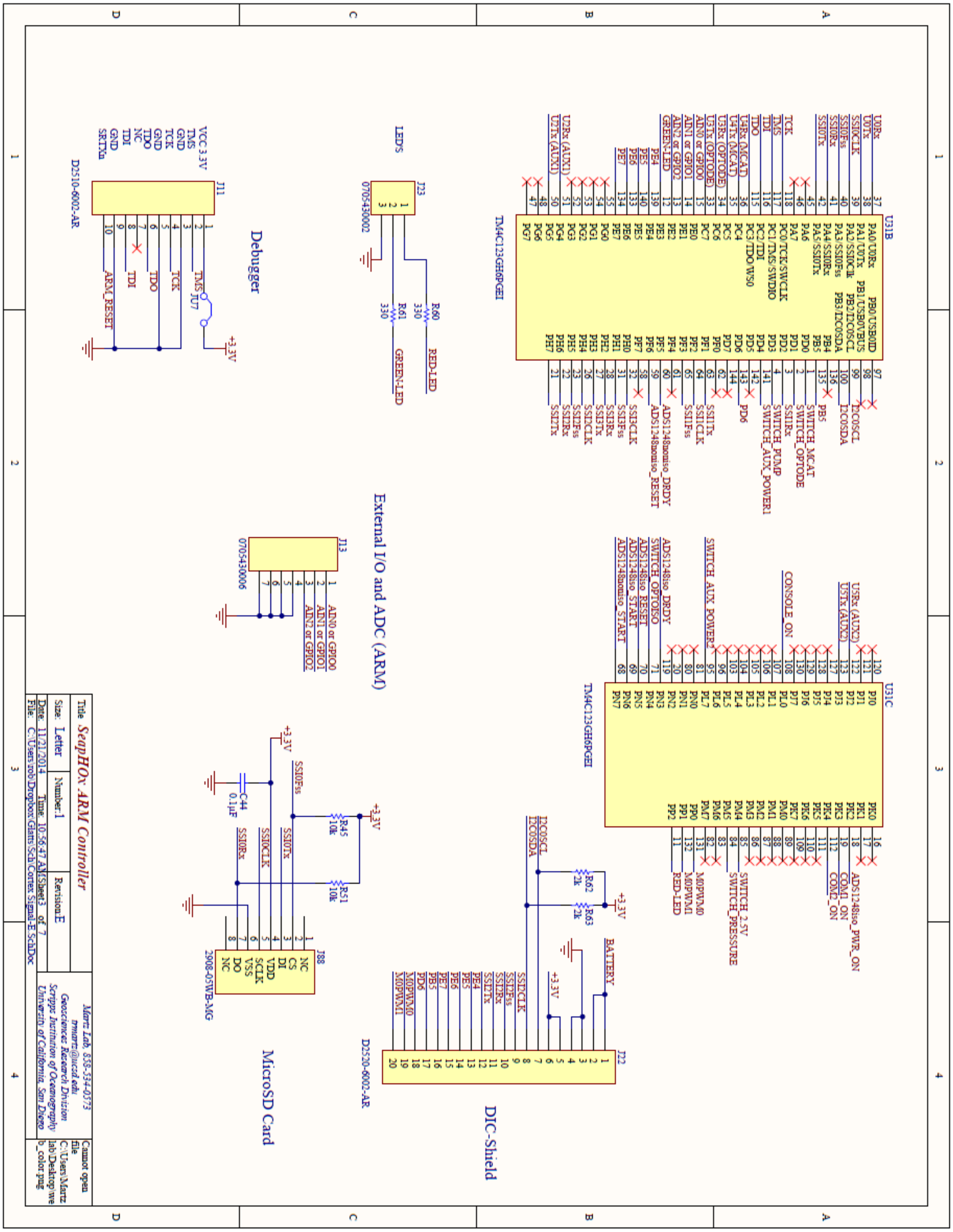
component	Function
JU2 (2pin)	Used to choose the voltage follower circuit for the ISE reference signal. Jump pin 1-2 to use the circuit on the board. Necessary for a properly working board.
JU3 (3pin)	Used to choose the output voltage delivered at AUX1 (J12). Connect pin 1-2 to deliver 5V, and 2-3 for the battery voltage.
JU8 (3pin)	Used to choose the output voltage delivered at AUX2 (J20). Connect pin 1-2 to deliver 5V, and 2-3 for the battery voltage.

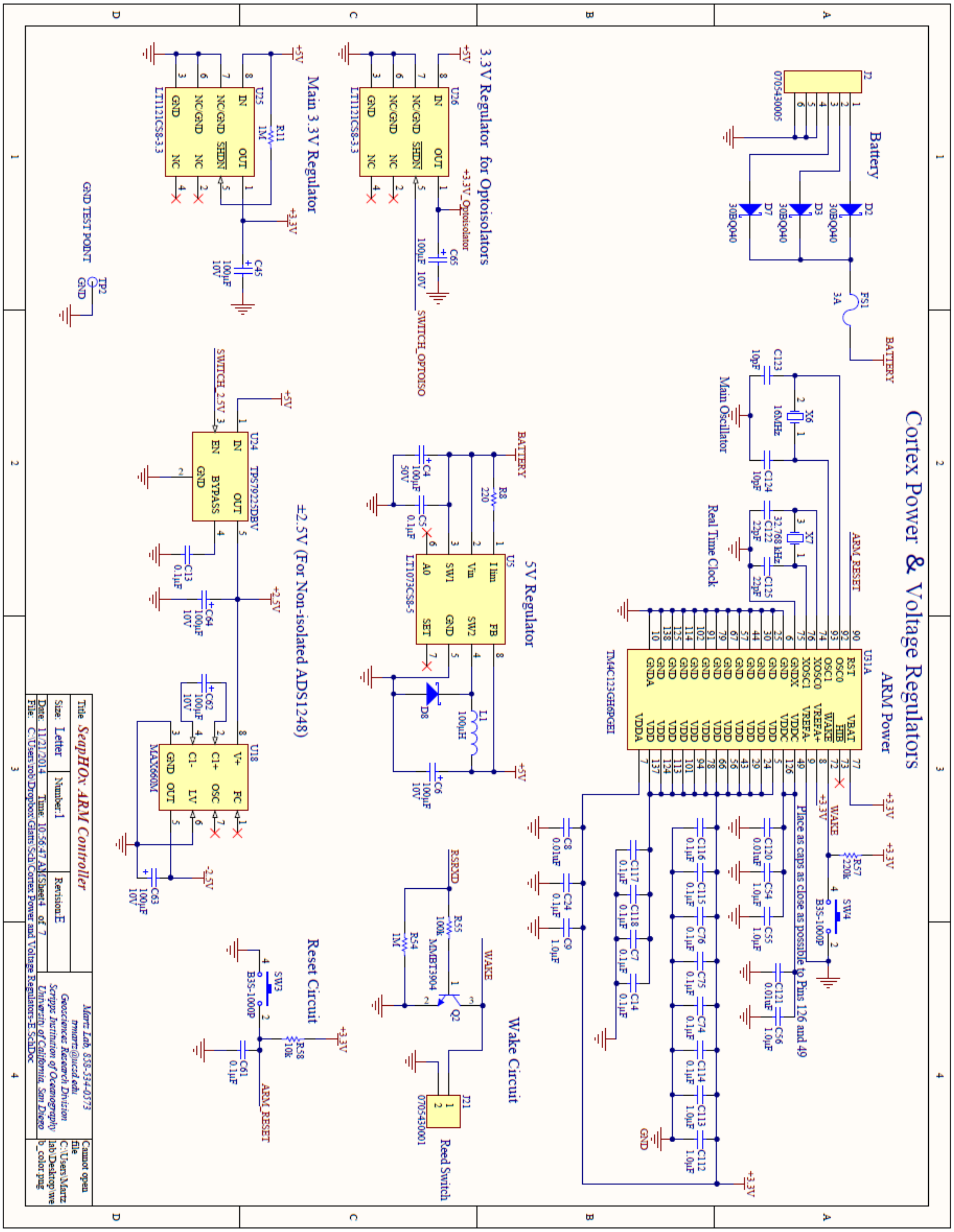

J5-Cap Adapter
7-orange
6-red
5-white
4-black
3-red/blk
2-blue
1-green
BNC for Cl-ISE
Division of electrically isolated ground planes
Extra A/D Channels
3 Gnd
2 RXD
1 TXD
3 Gnd
2 RXD
1 TXD
Extra RS232 Channels
JU1
J7 SBE37
4 Gnd
3 RXD
2 TXD
1 Vbatt
1 5V
2Vpres
3 Gnd
J9 Pressure Sensor
J8 Optode
4 Gnd
3 RXD
2 TXD
1 5V
J10 SBE5P
2 Gnd
1 Vbatt
1 Vbatt
2 Vbatt
3 Vbatt
4 Gnd
5 Gnd
6 Gnd
J2 Battery
2 Gnd
1 Vbatt
Micro SD Card
1 RXD
2 TXD
3 NC
4 NC
6 Gnd
J3-Comm
ARM controller
2 Gnd
1 Vbatt

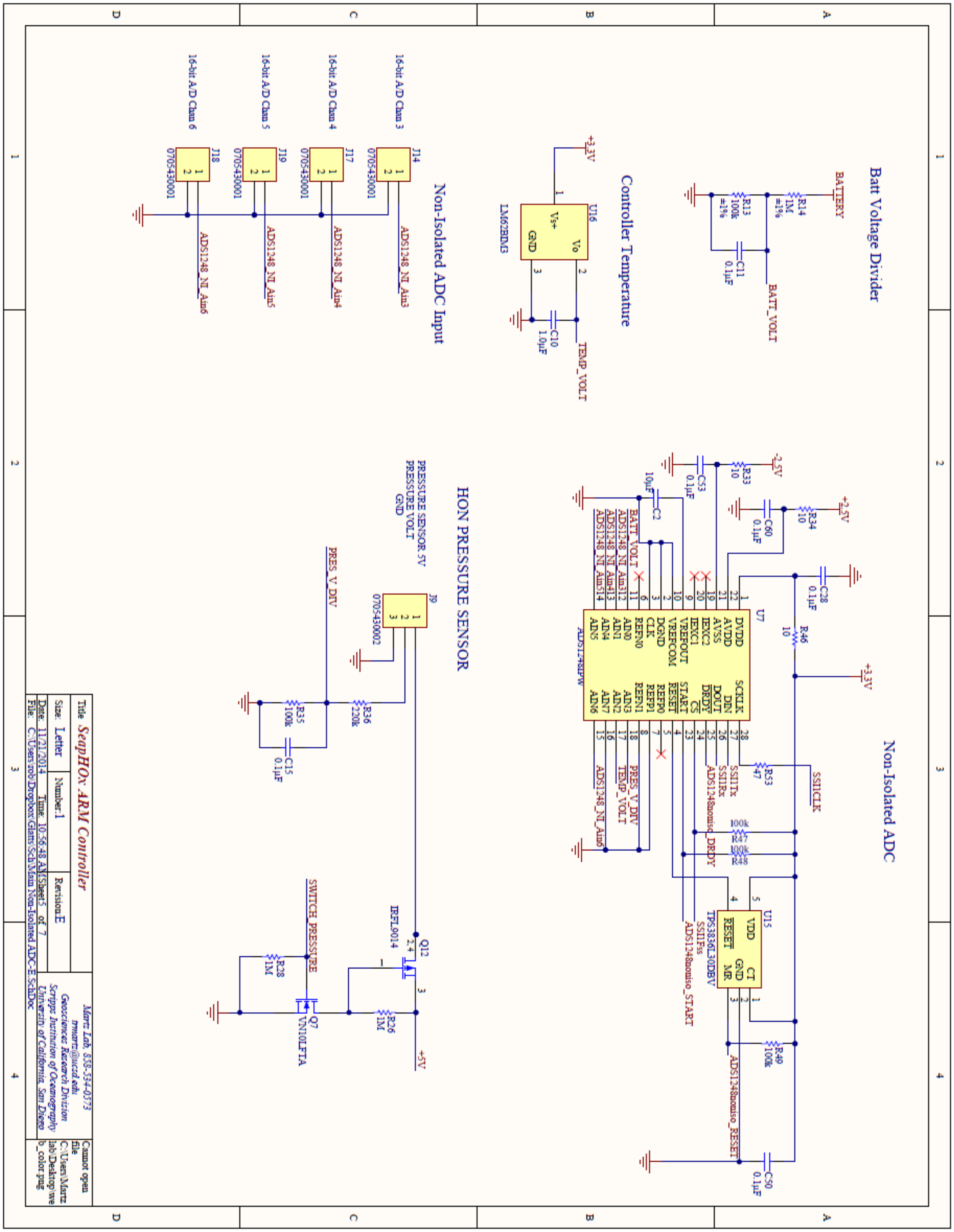

RESET
WAKE
JTAG
DIC

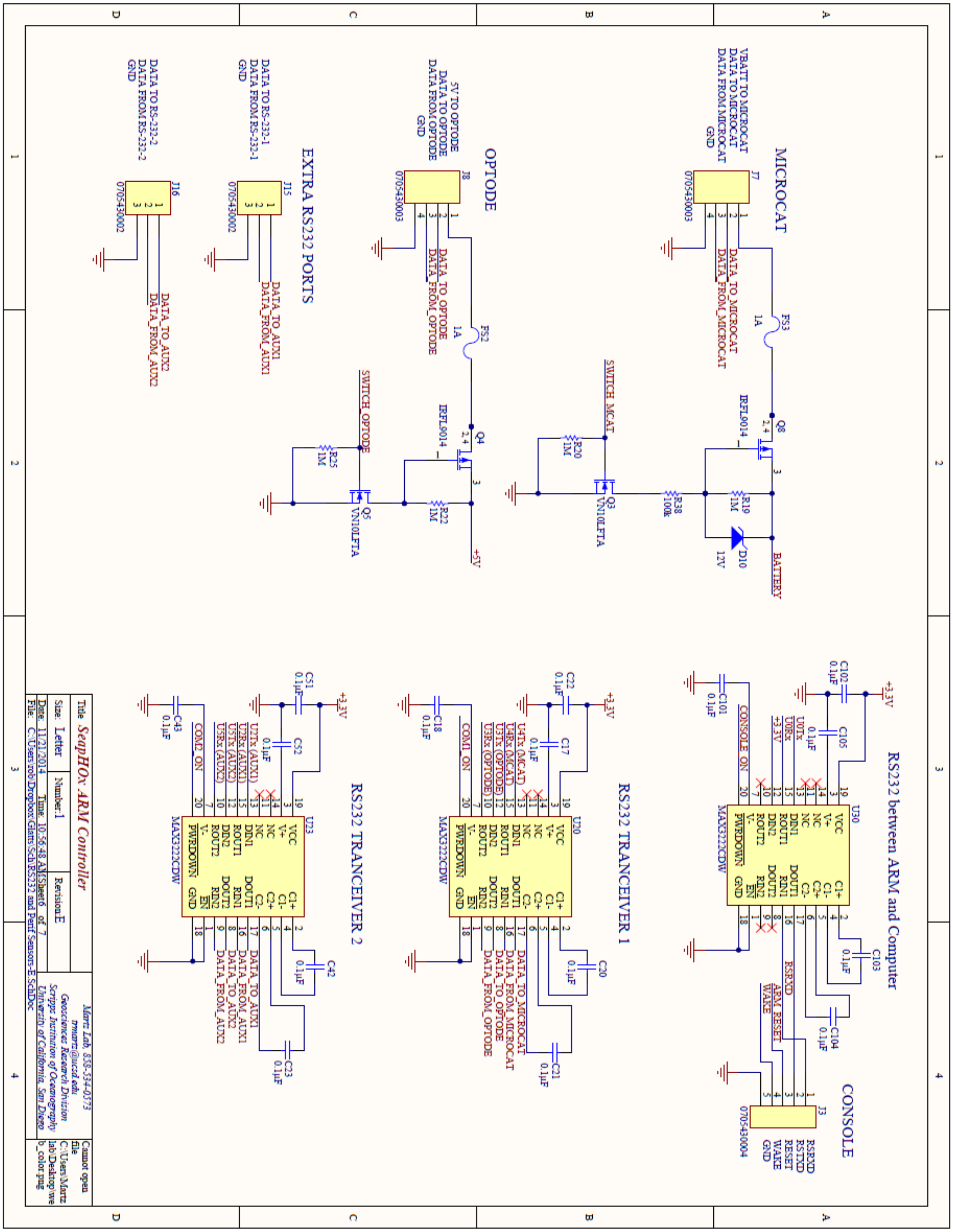

Isolated Circuits
Signal to ADS1248_ISO
Signal from ADS1248_ISO
Isolated ADC
CI-ISE Reference
Logic level will be inverted.
HIGH on MCU = LOW in isolated side
ADS1248IPW
TPS3836L30DBV
LMC6041AIM
FOD8001
FOD852SD
Title SeapHOx ARM Controller
Size: Letter
Number:1
Revision:E
Date: 11/21/2014
Time: 10:56:47 AM
Sheet1 of 7
Martz Lab, 858-534-0573
Geosciences Research Division
Scripps Institution of Oceanography
Univesity of California, San Diego

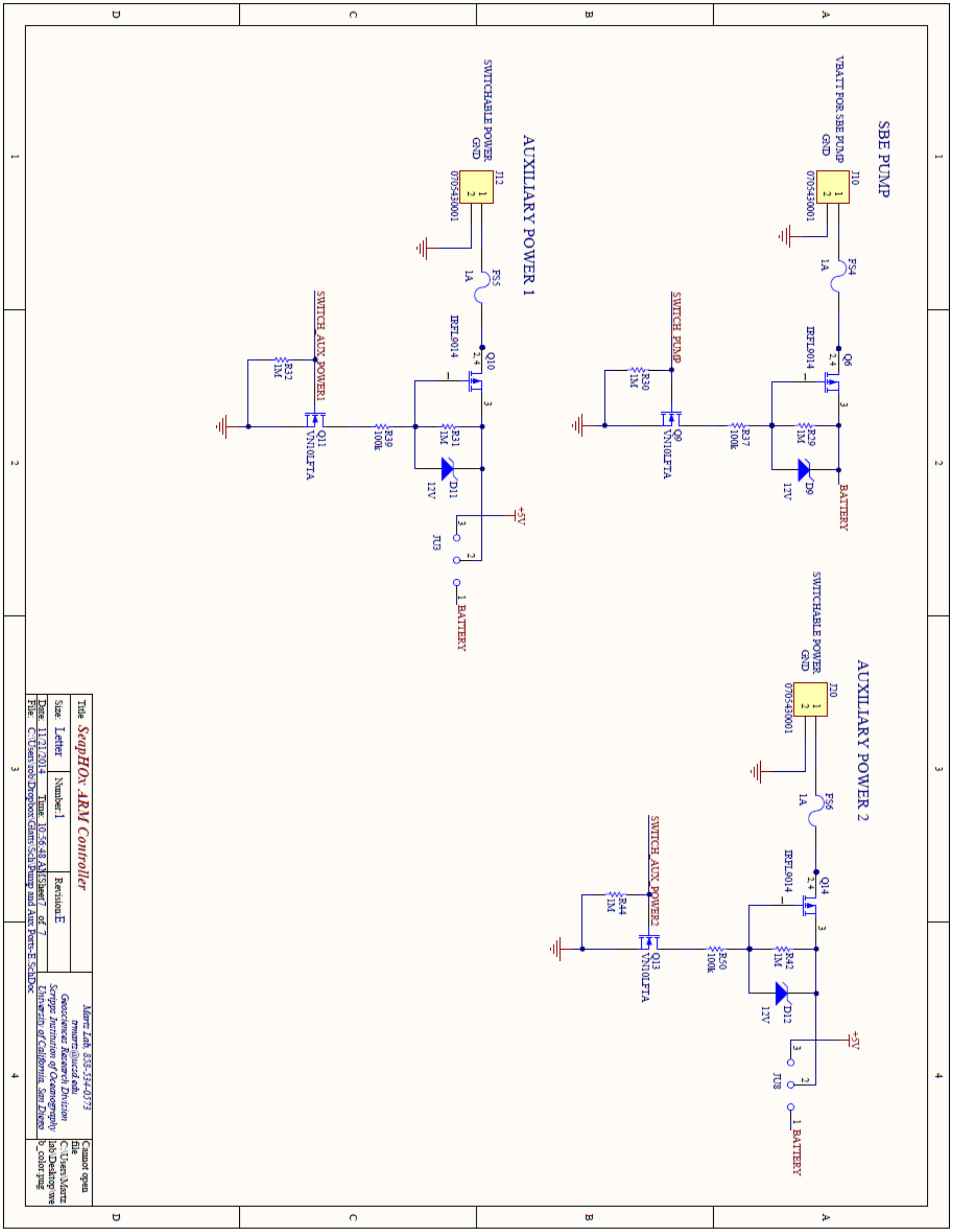

Isolated Power Circuits
ISO +5V Regulator
ISO +3.3V (COMM)
ISO ±3.75V(Durafet)
ISO ±2.5V (For ADS1248)
ISO-Batt Voltage Divider
Power Jumpers
ISO GND TEST
SeapHOx ARM Controller


U31B
TM4C123GH6PGEI
U31C
TM4C123GH6PGEI
LEDS
J23
Debugger
J11
D2510-6002-AR
External I/O and ADC (ARM)
J13
DIC-Shield
J22
D2520-6002-AR
MicroSD Card
J88
Title SeapHOx ARM Controller
Size: Letter
Number:1
Revision:E
Date: 11/21/2014
Time: 10:56:47 AM
Sheet3 of 7
Martz Lab, 858-534-0573
Geosciences Research Division
Scripps Institution of Oceanography
University of California, San Diego


Cortex Power & Voltage Regulators
ARM Power
Battery
Main Oscillator
Real Time Clock
5V Regulator
3.3V Regulator for Optoisolators
Main 3.3V Regulator
±2.5V (For Non-isolated ADS1248)
Wake Circuit
Reset Circuit
Reed Switch
GND TEST POINT
Place as caps as close as possible to Pins 126 and 49
SeapHOx ARM Controller


Batt Voltage Divider
BATTERY
BAT_VOLT
Controller Temperature
LM62BIM3
TEMP_VOLT
Non-Isolated ADC Input
16-bit A/D Chan 3
16-bit A/D Chan 4
16-bit A/D Chan 5
16-bit A/D Chan 6
ADS1248_NI_Ain3
ADS1248_NI_Ain4
ADS1248_NI_Ain5
ADS1248_NI_Ain6
Non-Isolated ADC
ADS1248IPW
TPS3836L30DBV
SSI1CLK
HON PRESSURE SENSOR
PRESSURE SENSOR 5V
PRESSURE VOLT
GND
PRES_V_DIV
SWITCH_PRESSURE
IRFL9014
VN10LFTA
SeapHOx ARM Controller
Size: Letter
Number: 1
Revision: E
Date: 11/21/2014
Sheet 5 of 7
Martz Lab, 858-534-0573
Scripps Institution of Oceanography
University of California, San Diego


MICROCAT
OPTODE
EXTRA RS232 PORTS
RS232 between ARM and Computer
CONSOLE
RS232 TRANCEIVER 1
RS232 TRANCEIVER 2
SeapHOx ARM Controller


SBE PUMP
VBATT FOR SBE PUMP
GND
J10
0705430001
FS4
1A
Q6
IRFL9014
D9
12V
BATTERY
R29
1M
R37
100k
Q9
VN10LFTA
R30
1M
SWITCH_PUMP
AUXILIARY POWER 1
SWITCHABLE POWER
GND
J12
0705430001
FS5
1A
Q10
IRFL9014
R31
1M
D11
12V
+5V
JU3
1 BATTERY
R39
100k
Q11
VN10LFTA
R32
1M
SWITCH_AUX_POWER1
AUXILIARY POWER 2
SWITCHABLE POWER
GND
J20
0705430001
FS6
1A
Q14
IRFL9014
R42
1M
D12
12V
+5V
JU8
1 BATTERY
R50
100k
Q13
VN10LFTA
R44
1M
SWITCH_AUX_POWER2
Title SeapHOx ARM Controller
Size: Letter
Number:1
Revision:E
Date: 11/21/2014
Time: 10:56:48 AM
Sheet7 of 7
File: C:\Users\rob\Dropbox\Giants\Sch\Pump and Aux Ports-E.SchDoc
Martz Lab, 858-534-0573
tmartz@ucsd.edu
Geosciences Research Division
Scripps Institution of Oceanography
University of California, San Diego
Cannot open file C:\Users\Martz lab\Desktop\wel_b_color.png

7. Appendix 1 – Processing Scripts

7.1. Calculate pH sensor calibration coefficients

```
function calib = pHCalib(calEint,calEext,calpH,calT,calsal)
% Univ gas constant, Faraday constant,
R = 8.3145; F = 96487;
% Temperature dependence of standard potentials, Martz et al. 2010
dE0int = -0.00125; dE0ext = -0.001048;
% See Martz et al. 2010 for greater detail
tempK = calT+273.15; % Convert temp from C to K
S_T = (R*tempK)/F*log(10); % Nernst temp dependence
E0int = calEint-S_T*calpH; % Calc E0int from Nernst & pH @ calibration
point
E0int25 = E0int+dE0int*(25-calT);
Z = 19.924.*calsal./(1000-1.005.*calsal); % Ionic strength, Dickson et
al. 2007
SO4_tot = (0.14/96.062)*(calsal./1.80655);  % Total conservative
sulfate
cCl = 0.99889/35.453.*calsal/1.80655; % Conservative chloride
mCl = cCl*1000/(1000-calsal.*35.165/35); % mol/kg-H2O
K_HSO4 = exp(-4276.1/tempK+141.328-23.093*log(tempK)...
          +(-13856/tempK+324.57-47.986*log(tempK))*Z^0.5...
          +(35474/tempK-771.54+114.723*log(tempK))*Z-
2698/tempK*Z^1.5...
          +1776/tempK*Z^2+log(1-0.001005.*calsal)); % Bisulfate
equilibrium const., Dickson et al. 2007
pHint_free = calpH+log10(1+SO4_tot/K_HSO4);
cHfree = 10^(-pHint_free); % mol/kg-sw
pHint_free = pHint_free+log10((1000-calsal.*35.165/35)/1000); % mol/kg-
H2O
mHfree = 10^(-pHint_free); % mol/kg-H2O
DHconst = 0.00000343*calT^2+0.00067524*calT+0.49172143; % Debye-Huckel,
Khoo et al. 1977
log10gamma_HCl = 2*(-DHconst*sqrt(Z)/(1+1.394*sqrt(Z))+(0.08885-
0.000111*calT)*Z);
aHfree_aCl = mHfree*mCl*10^(log10gamma_HCl);
E0ext = calEext+S_T*log10(aHfree_aCl);
E0ext25 = E0ext+dE0ext*(25-calT);

calib = [E0int25 E0ext25];
```

7.2. Calculate pH from sensor voltage

```
function calc =  pHCalc(Eint,Eext,E0int25,E0ext25,tempC,salt)
% Univ gas constant, Faraday constant,
R = 8.3145; F = 96487;
% Temperature dependence of standard potentials, Martz et al. 2010
dE0Int = -0.00125; dE0Ext = -0.001048;
% See Martz et al. 2010 for greater detail
tempK = tempC+273.15; % Convert temp from C to K
S_T = (R*tempK)/F*log(10); % Nernst temp dependence
pHint_tot = (Eint-(E0int25+dE0Int*(tempC-25)))./S_T; % Calc pHint from
Nernst
Z = 19.924.*salt./(1000-1.005.*salt); % Ionic strength, Dickson et al.
2007
SO4_tot = (0.14/96.062).*(salt./1.80655); % Total conservative sulfate
cCl = 0.99889./35.453.*salt./1.80655; % Conservative chloride
mCl = cCl.*1000./(1000-salt.*35.165/35); % mol/kg-H2O
K_HSO4 = exp(-4276.1./tempK+141.328-23.093.*log(tempK)...
          +(-13856./tempK+324.57-47.986.*log(tempK)).*Z.^0.5...
          +(35474./tempK-771.54+114.723.*log(tempK)).*Z-
2698./tempK.*Z.^1.5...
          +1776./tempK.*Z.^2+log(1-0.001005.*salt)); % Bisulfate
equilibrium const., Dickson et al. 2007
pHint_free = pHint_tot+log10(1+SO4_tot./K_HSO4); % free scale mol/kg-sw
DHconst = 0.00000343.*tempC.^2+0.00067524.*tempC+0.49172143; % Debye-
Huckel, Khoo et al. 1977
log10gamma_HCl = 2*(-DHconst.*sqrt(Z)./(1+1.394*sqrt(Z))+(0.08885-
0.000111*tempC).*Z);
pHext_free = -(((E0ext25+dE0Ext*(tempC-25))-Eext)-
S_T.*(log10(mCl)+log10gamma_HCl))./S_T; % mol/kg-H2O
pHext_free = pHext_free-log10((1000-salt.*35.165/35)/1000); % mol/kg-sw
pHext_tot = pHext_free-log10(1+SO4_tot./K_HSO4);

calc = [pHint_tot pHext_tot];
```

7.3. Process oxygen sensor data

```
%% Correct O2 vs Salinity (from Aanderaa)
B0 = -0.00624097; B1 = -0.00693498; B2 = -0.00690358; B3 = -0.00429155;
C0 = -0.00000031168;
Pcorr = 0.032;
Ts = log((298.15-temp)./(273.15+temp));
Sfctr = exp((salt-0).*(B0+B1*Ts+B2*Ts.^2+B3*Ts.^3))+C0*(salt.^2-0);
Pfctr = 1+abs(depth)/1000*Pcorr;
O2_con = O2_con.*Sfctr.*Pfctr;
```

7.4. Process durafet thermistor

```
function tempC = getDurafetTemp(VTherm,TCOffset)
% Convert Durafet thermistor voltage to temperature (C) using following
polynomial
c0 = 340.9819863; c1 = -9.10257E-05; c2 = -95.08806667; c3 =
0.965370274;
RTherm = 20000./(3.3./VTherm-1);
tempC = c0+c1*RTherm+c2*log10(RTherm)+c3*(log10(RTherm)).^3;
tempC = tempC+TCOffset;
```

7.5. Example calibration sheet

Text and figures below are an example of the results and figures generated automatically by the matlab script: *pH_User_Run.m*

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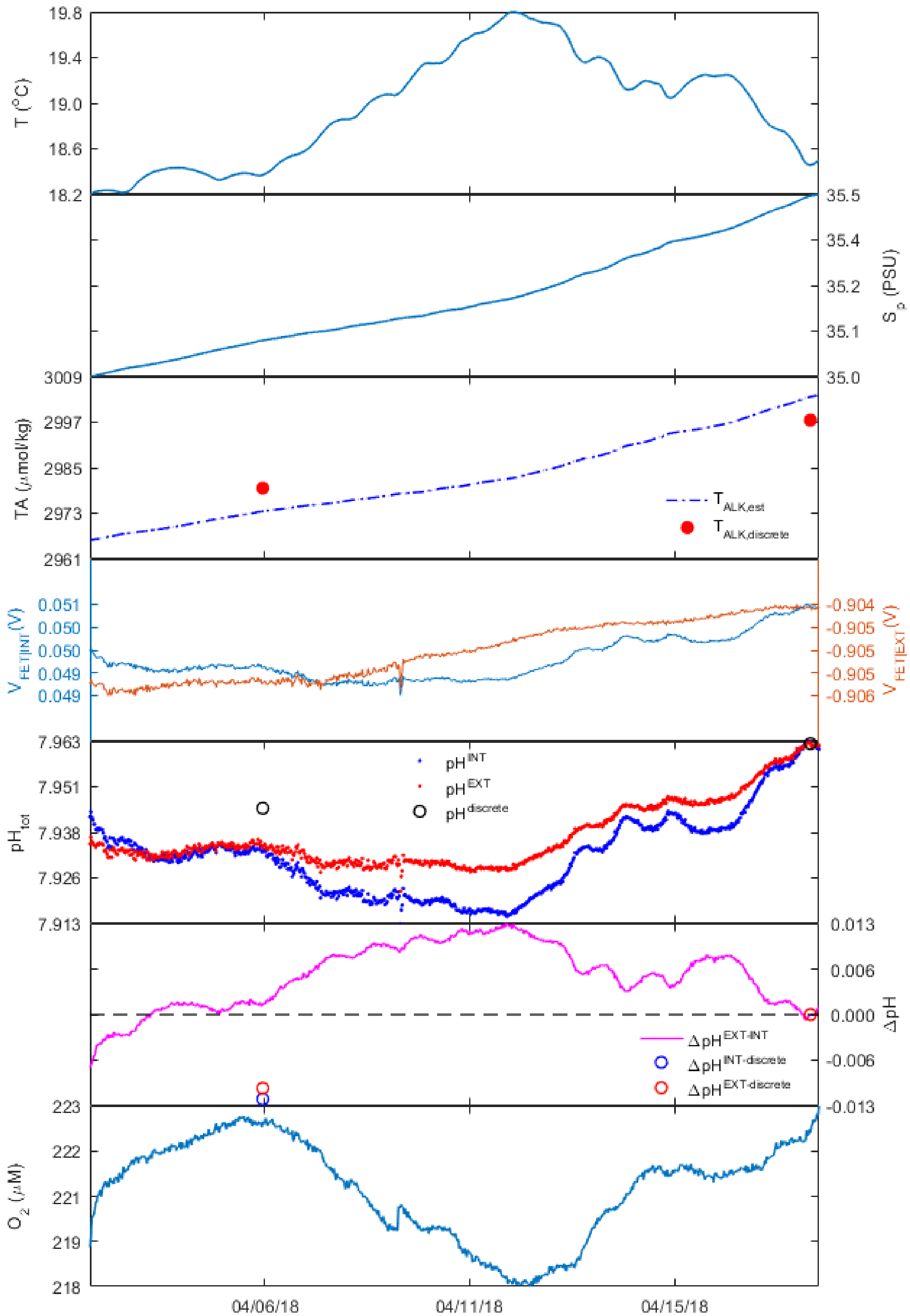
SeaFET/SeapHOx pH Calculation, (Matlab)

Create S/N and output file names based on input file name

```
Operator: TW
Date of processing: 18-Apr-2018 16:37:39
Processing routine: pH_User_Run.m
Sensor package S/N: SP008

User notes:

Deployment start date: 02-Apr-2018 16:00:00
Deployment end date: 18-Apr-2018 16:00:00

Calibration sample taken on: 18-Apr-2018 11:30:00
In situ temperature @ calibration time = 18.4526oC
Salinity @ calibration time = 35.4644PSU
V(FET|INT) @ calibration time = 0.0511V
V(FET|EXT) @ calibration time = -0.904V
dE0/dT(INT) = -0.001101V/oC
dE0/dT(EXT) = -0.001048V/oC

Calibration spectrophotometric pH measured @ 25oC = 7.866
Calibration total alkalinity = 2997.5476umol/kg

E0int(@T=25oC) = -0.41684230V
E0ext(@T=25oC) = -1.40529960V

Calibration pH(@in situ T, total scale): 7.96278
```



19.8
19.4
19.0
18.6
18.2
T (°C)
35.5
35.4
35.2
35.1
35.0
S_p (PSU)
3009
2997
2985
2973
2961
TA (μmol/kg)
$T_{ALK,est}$
$T_{ALK,discrete}$
0.051
0.050
0.050
0.049
0.049
$V_{FET|INT}$ (V)
-0.904
-0.905
-0.905
-0.905
-0.906
$V_{FET|EXT}$ (V)
7.963
7.951
7.938
7.926
7.913
pH_{tot}
pH^{INT}
pH^{EXT}
$pH^{discrete}$
0.013
0.006
0.000
-0.006
-0.013
ΔpH
$\Delta pH^{EXT-INT}$
$\Delta pH^{INT-discrete}$
$\Delta pH^{EXT-discrete}$
223
222
221
219
218
O_2 (μM)
04/06/18
04/11/18
04/15/18