2.2 Illustrated Parts List

3D-printed parts

Magnetic Switch Assembly

Sensor Baseplate for Sparkfun/DIY Pressure Sensor

Electronics Chassis for Protoboard Option

Sensor Baseplate for OpenROV IMU

Protective Cap

Sensor protector

Housing

Schedule 40 PVC Pipe

Oatey Plumber's Test Cap

46 to 70mm Hose Clamp

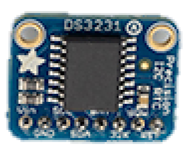
Short Length of Polypro Rope

OpenCTD Rev6 Custom Carrier Board

Custom Carrier Board

Adafruit Adalogger M0

SD Card

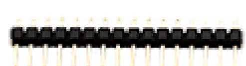


Real-time Clock Module

CR1220 Coin Cell Battery

Atlas EZO Conductivity Circuit

Female Headers



Male Headers

7-pin JST Header

MicroUSB Cable

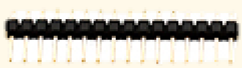
10 kOhm resistor

4.7 kOhm Resistor

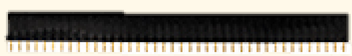
Adafruit Adalogger M0 and Real-time Clock Featherwing

Adafruit Adalogger M0

Adafruit Real-time Clock Featherwing



Male Headers



Female Headers

Extra Long Headers

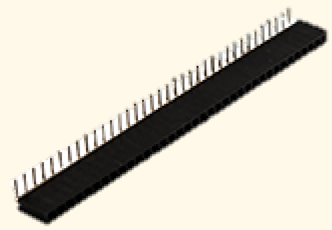
MicroUSB Cable

3V CR 1220 Coin Cell Battery

SD Card

Protoboard Control Unit

Atlas EZO Conductivity Circuit



Right angle headers

Solid core wire

10 kOhm resistor

4.7 kOhm Resistor

Sensors

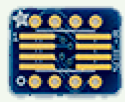
Temperature Sensor

Conductivity Probe

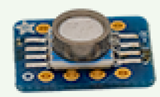
Sparkfun 14-Bar Pressure Sensor Breakout Board

JST Female Connector

Alternative Pressure Sensors



DIP to SOIC Adapter

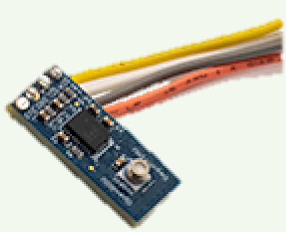


Pressure Chip on DOIC to SOIC Adapter

10 kOhm Resistor

0.1 uF Capacitor

OpenROV



OpenROV 30bar IMU

Baseplate for 30 bar IMU

Power and Ballast

Battery

Board-mounted Switch

10 mm Magnet for External Switch

Assorted weights for ballasting CTD

String of weights to ballast the OpenCTD

10mm double-sided stickers for external switch

Accessories

Solderless Breadboard

Screw Terminals

Alligator Clip

Jumper wire

SD Card Reader

Please reference the full Bill of Materials in Appendix 1 for further details and sourcing.

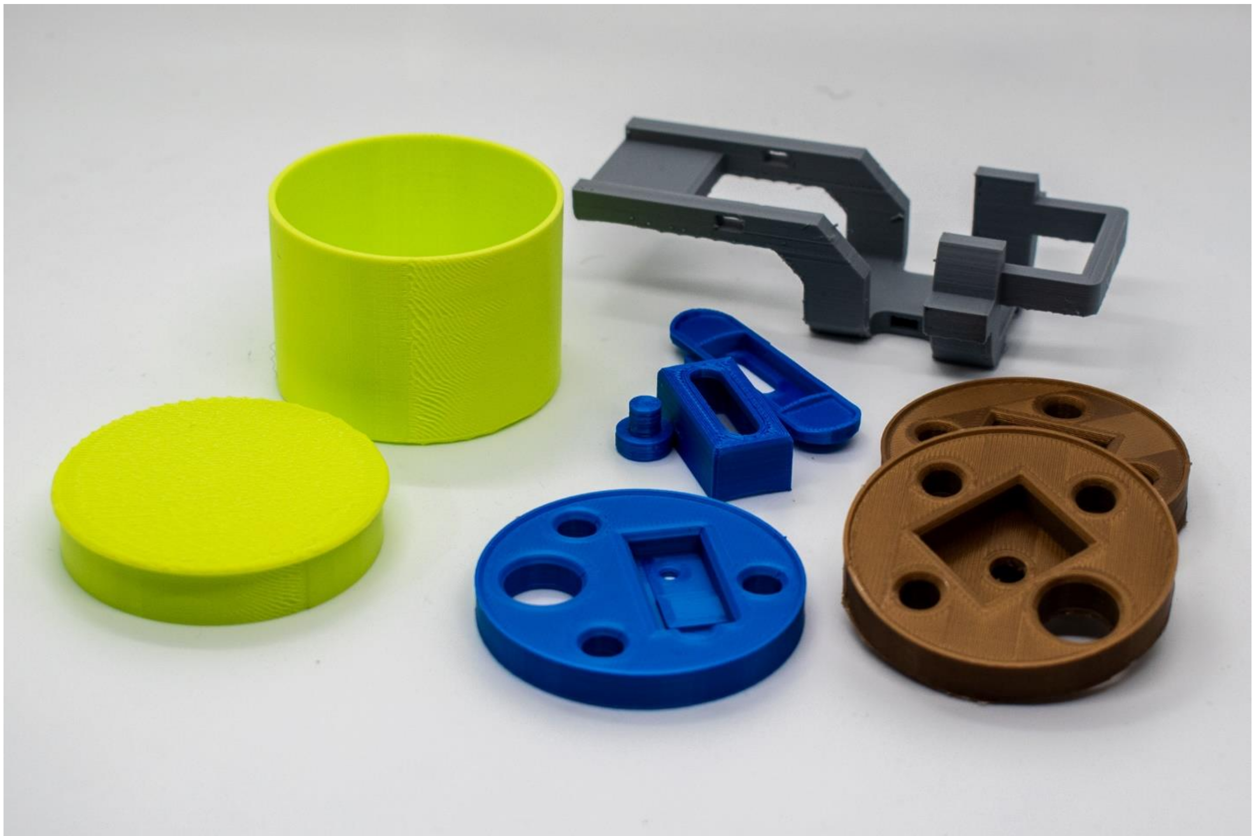


Figure 2: 3D-Printed parts for OpenCTD.

OpenCTD 3D Printed Structural Components:

- OpenCTD Baseplate
  - **Sparkfun Breakout Board:** OpenCTD_M0_Baseplate_SparkfunBreakout.3mf
  - **DIY Pressure Sensor:** OpenCTD_M0_Baseplate.3mf
  - **OpenROV IMU:** OpenCTD_M0_Baseplate_OpenROV_IMU.3mf

- External Magnetic Switch Assembly for all CTDs
  - **Magnetic Switch (external):** OpenCTD_MagneticSwitch_External_M0.stl
  - **Magnetic Switch (internal):** OpenCTD_MagneticSwitch_Internal_M0.stl
  - **Magnetic Switch Pin:** OpenCTD_MagneticSwitch_Pin_M0.stl

- OpenCTD with Protoboard
  - **Electronics Chassis:** OpenCTD_ElectronicsChassis_M0_Reinforced_Switch.stl
  - **Wiring Harness Connector:** OpenCTD_Connector_M0.stl

Once the sensor baseplate is complete, use a deburring tool to round of all the edges on both top and bottom as well as inside each hole. Sensors, especially the pressure sensor, should fit snuggly inside their respective hole and the entire baseplate should fit tightly into a 2” PVC pipe.

4 Preparing the Housing

The OpenCTD housing is comprised of a single piece of schedule-40 2” PVC pipe. Notches or holes cut in the bottom allow water to flow over the sensors while protecting them from impacts and entanglement. This end will be sealed with high strength epoxy, allowing the sensors to pass through the housing while preventing water from entering and damaging the electronics. The open end is sealed with an off-the-shelf pressure test cap designed for plumbers. When cutting and preparing the PVC, take care not to damage the inner surface where the test cap O-ring will seat against the PVC wall. **(Note: while we generally provide measurements in Metric, because US-based plumbing supplies are generally measured in Imperial units, where off-the-shelf parts are used, we will use the measurement standard provided by the manufacturer.)**

1. Cut a 12” section of PVC pipe. Deburr the edges around each cut with a knife, sandpaper, or deburring tool.

2. If you have access to a router table, cut 4 1-inch-deep notches into one end of the PVC using a ½-inch router bit. If you have access to a drill and bit, cut 3 1-inch holes centered ¾-inch from the bottom.

3. Lightly sand the inside bottom of the tube, just above where you cut the slots or holes. This will provide a good surface for the epoxy to adhere to.

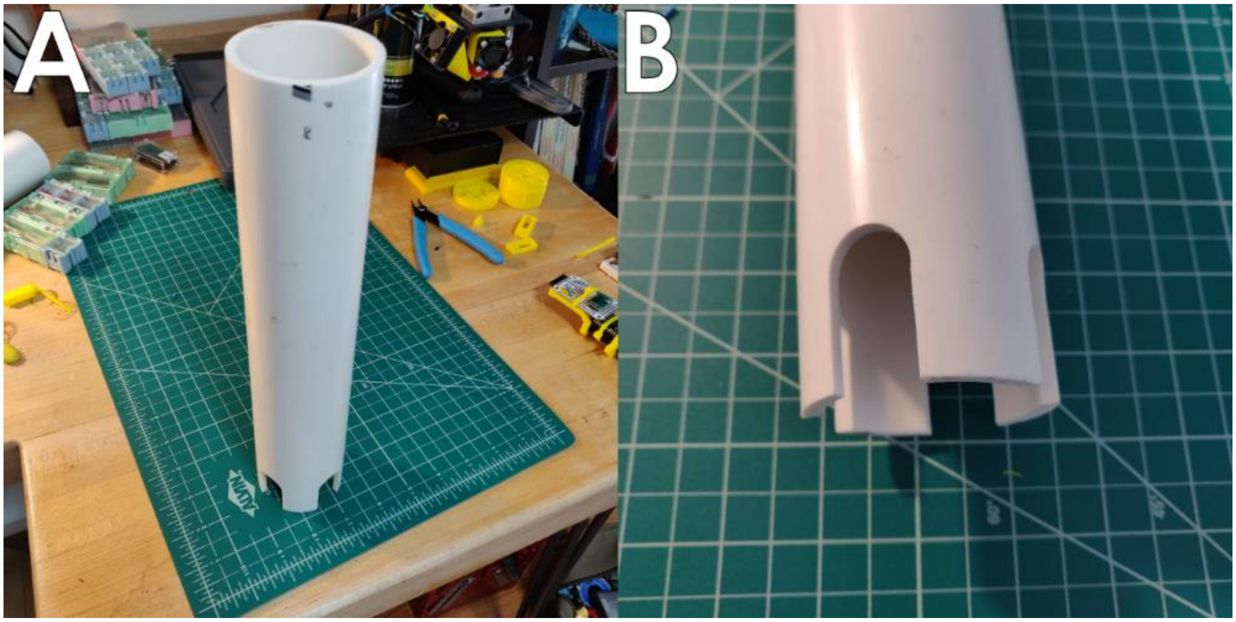


Figure 3. 12" PVC pipe (A) with notches cut at the base (B).

Though seemingly simple, this set-up has several advantages. Underwater housings are notoriously expensive. Using a PVC pipe instead of a conventional housing with sealed

5.1 (Carrier Board) Preparing the M0 Adalogger, Real-Time Clock, and carrier board

The custom carrier board allows for rapid and accurate assembly of the OpenCTD control unit.

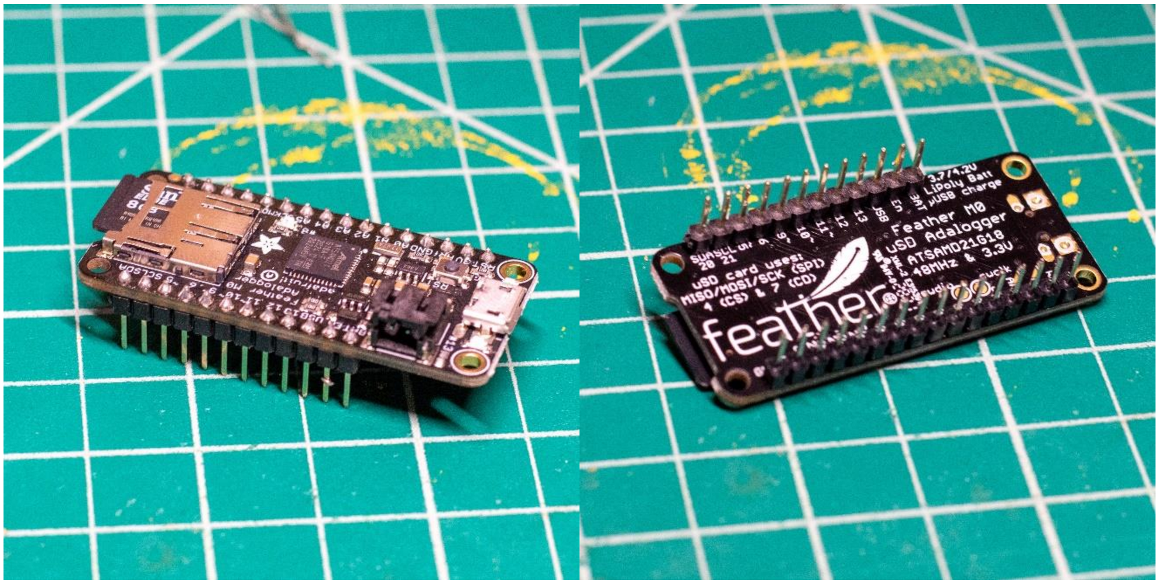


Figure 4. Adalogger M0 with male headers soldered to the pins. Top (left) and bottom (right)

1. Slot the male headers into the through-holes on the underside of the Adalogger M0, ensuring that the number of headers matches the number of available pins. The long header pins should point down. If you are using generic stacking headers, cut them to length with flush cutters so that the number of posts matches the number of pins on each side.

2. Ensure that the headers are square and perpendicular to the face of the Adalogger. On the top of the Adalogger, solder the four corner pins, double check that the headers are straight, and then solder the remaining pins.

3. Slot the standard female headers on the top of the carrier board in the pins for the Adalogger M0. You may need to trim the strip of female headers down to size using flush cutters so that the number of posts match the number of pins in the carrier board.

4. Solder the female headers to the custom carrier board.

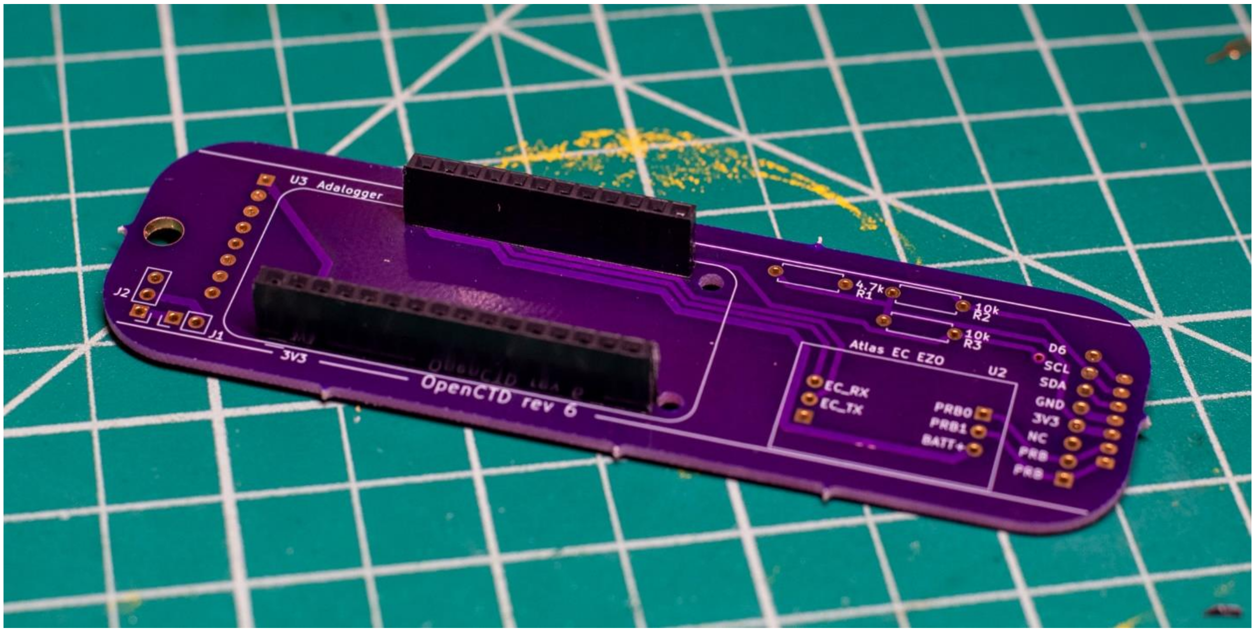


Figure 5. Female headers soldered to the custom carrier board.

5. Slot the male header pins into the RTC module such that the battery is facing up the header pins extend from the opposite side of the module.

6. Solder the RTC to the underside of the custom carrier board by first soldering the short end of the pins to the RTC and then soldering the long end of the pins through the control board. **(Optional: if you would like to keep the modules removable, you can solder female headers to the carrier board and then stack the RTC onto the female headers.)**

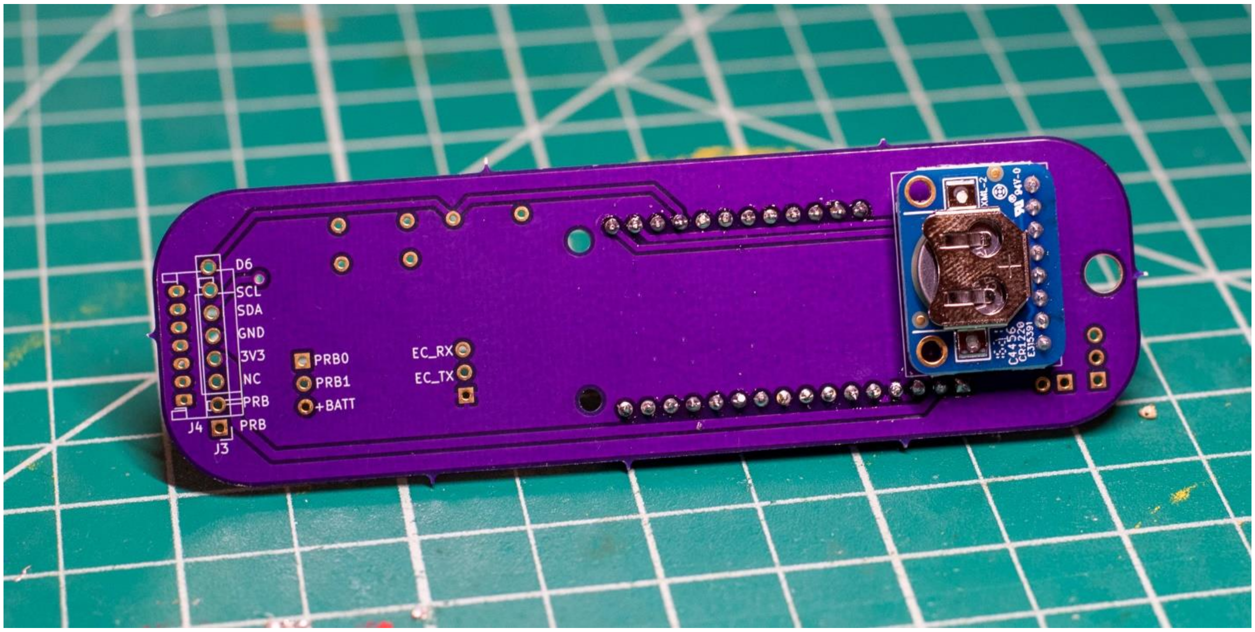


Figure 6.Custom carrier board with RTC module soldered to the underside.

7. Insert the Atlas EZO conductivity circuit into the EZO slots on the topside of the custom carrier board. Ensure that the pin labels on the board correspond to the pin labels on the module.

8. Solder the Atlas EZO conductivity circuit to the topside of the custom carrier board. **(Optional: if you would like to keep the modules removable, you can solder female headers to the carrier board and then stack the EZO circuit onto the female headers.)**

9. Solder the 10kOhm and 4.7 kOhm resistors to their corresponding slots on the topside of the custom carrier board.

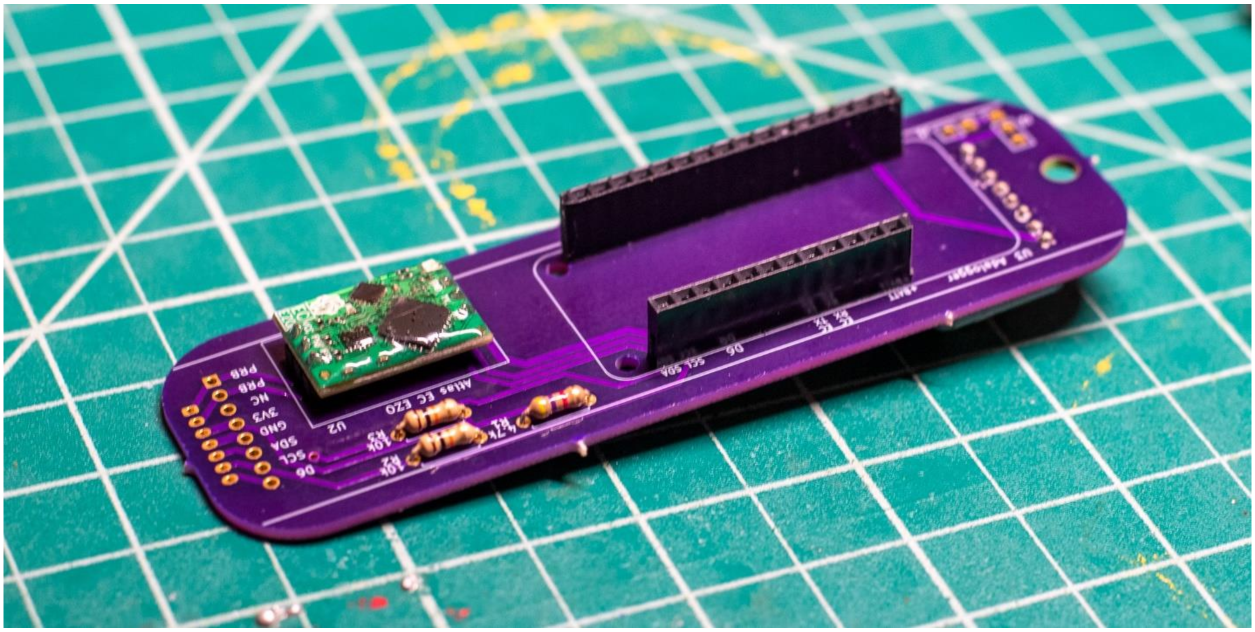


Figure 7. Custom carrier board with Atlas EZO circuit and resistors soldered to the topside.

10. Insert the JST 7-pin connector to the underside of the custom carrier board, ensure that the slot in the plastic connector housing is facing away from the board.

11. Solder the JST connector to the underside of the custom carrier board.

    - **ALTERNATIVE:** if you were unable to source a JST connector, you can solder straight- or right-angle female headers to the 8-pin strip directly adjacent to the JST connector pins. This will allow you to build a simpler, but less reliable connection between the sensors and the control board.

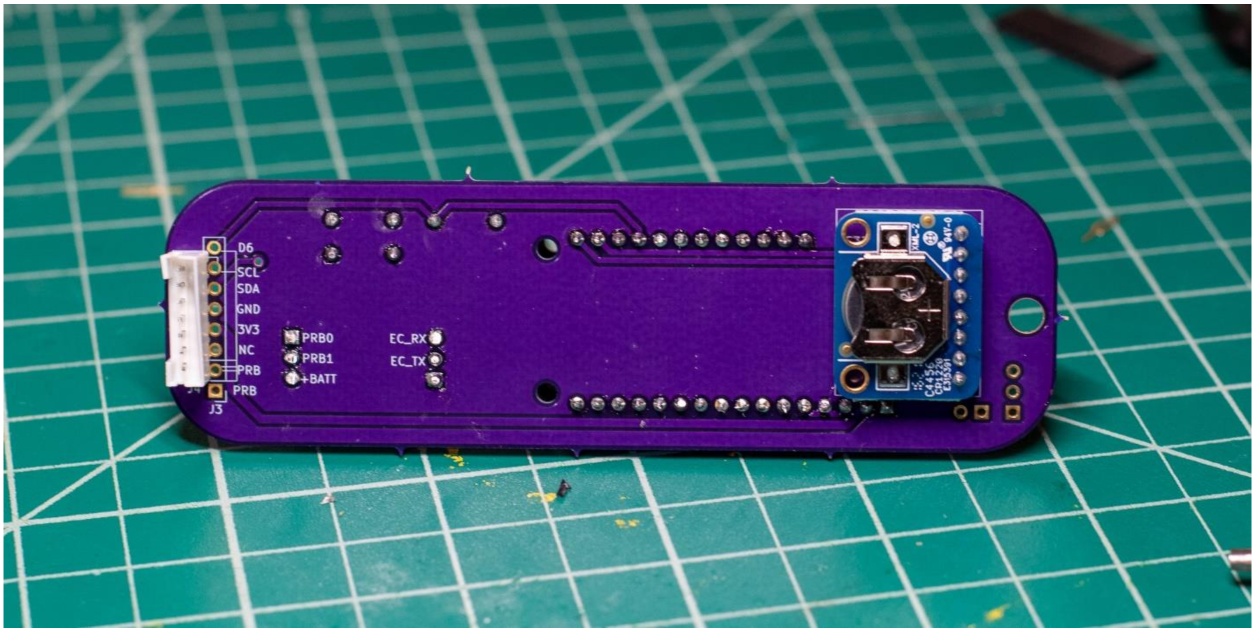


Figure 8. Custom carrier board with JST connector soldered to the underside.

12. Stack the Adalogger M0 on top of the custom carrier board by lining up the male, downward-facing header pins on the Adalogger with the female, upward facing header pins on the carrier board.

13. Insert the CR1220 battery into the RTC.

5.2 (Protoboard) Preparing the Adalogger and Featherwing RTC

The Adalogger will receive stacking headers—headers that contain both male and female ends so that the Adalogger can be connected to a breadboard while a second device (in this case the RTC) can be mounted on top. The RTC will receive male headers facing down so that they can be connected to the Adalogger.

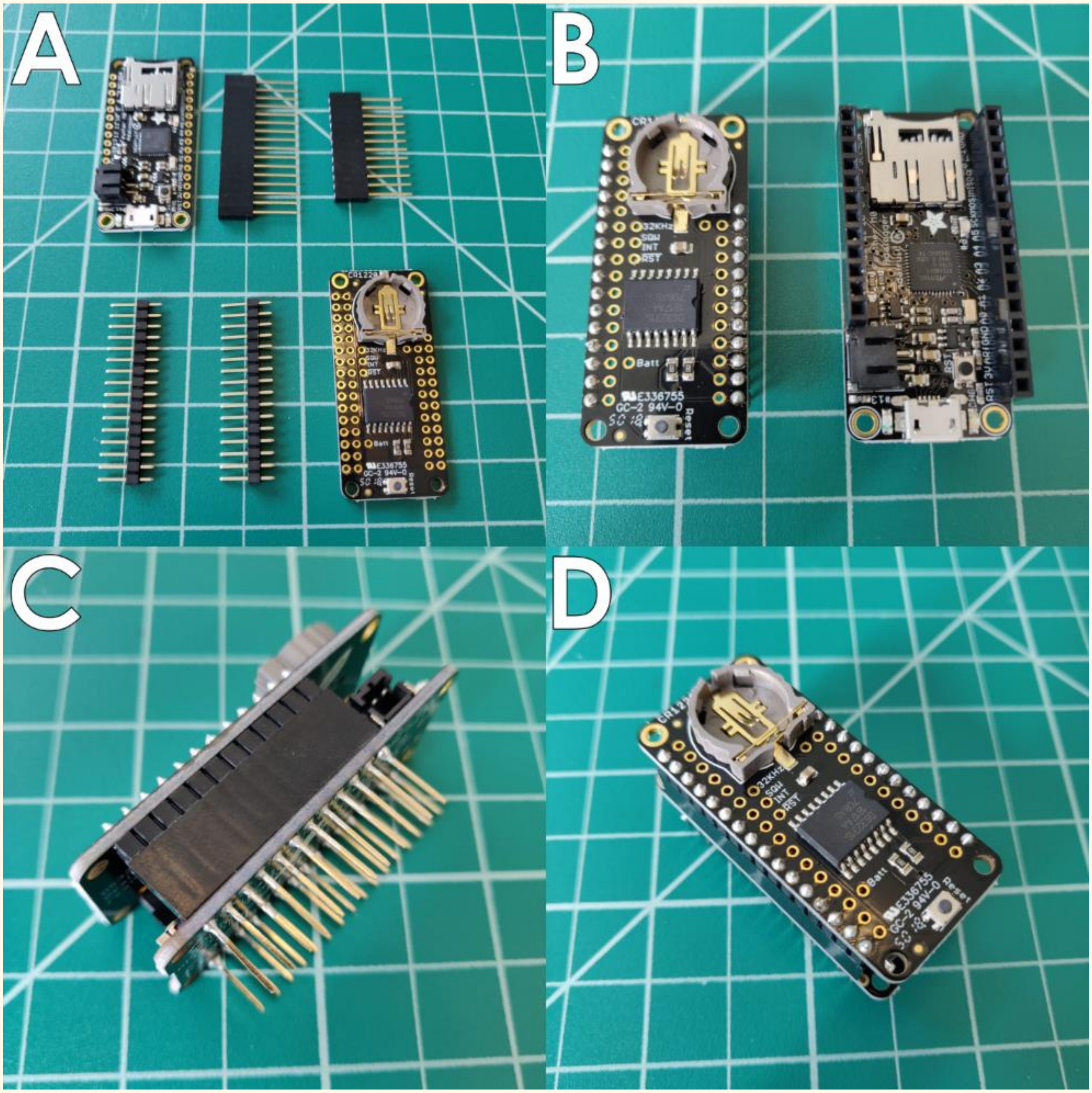


Figure 9. Adalogger and Real-time Clock with associated headers (A); after soldering (B); connected in profile (C); connected from above (D).

6. Under *Tools* > *Port*, select the COM port that reads “Adafruit Feather M0” (if should autodetect, but doesn’t always).

7. Click Upload (either the right pointing arrow on the main interface or under *Sketch* > *Upload*). The code will compile and them upload to the Adalogger. Note: the RTC sets its time based on the time displayed on the computer when the code is compiled. Should the RTC ever lose time, you can reset it by pulling the battery, power cycling the device, then reinserting the battery and recompiling the OpenCTD source code onto the Adalogger.

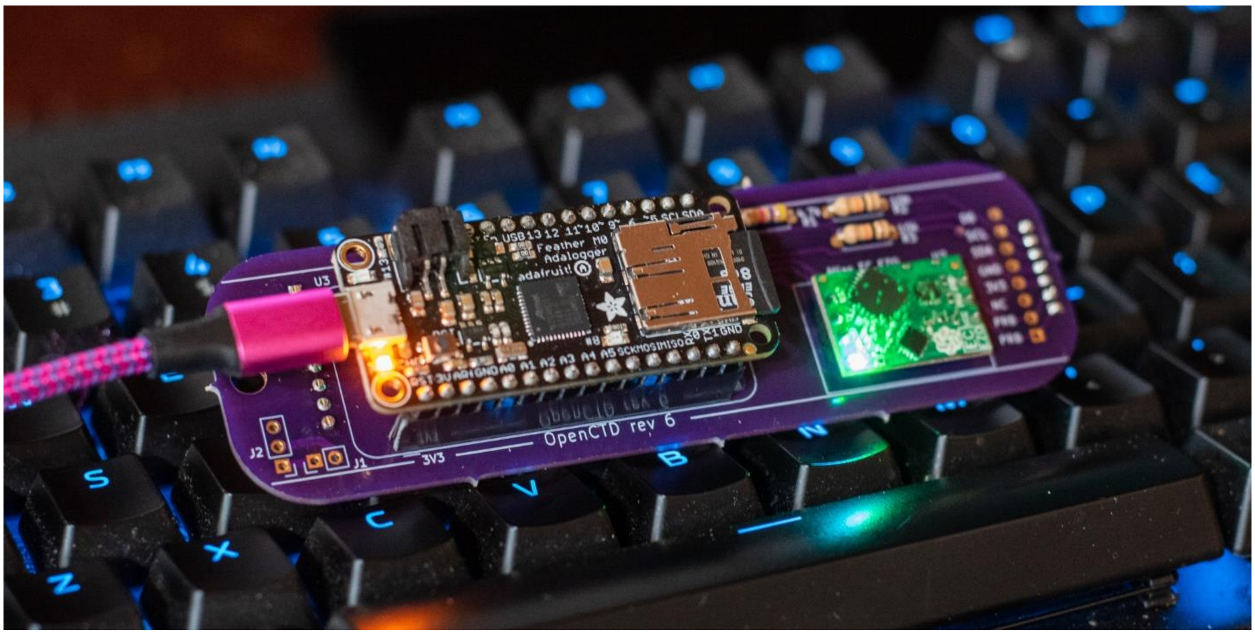


Figure 10. Control unit connected to PC for software validation.

6 Sensor Assembly and Breadboard Testing

The OpenCTD uses three separate types of sensor to measure the marine environment accurately and precisely. The pressure sensor is a MS5803-14BA built by Measurement Specialties and is accurate to 1cm when properly calibrated. The pressure sensor also includes an on-chip thermistor; however, the onboard thermistor is very slow and is unused. For custom builds with extremely limited space that don't need the device to reach equilibrium quickly, users can opt to read temperature directly from the pressure sensor. The standard OpenCTD uses a battery of three DS18B20 thermistors sealed in a stainless-steel housing to take a temperature average of the ambient environment. Finally, the OpenCTD uses a commercially available Atlas EZO conductivity system consisting of a probe and conductivity circuit to determine salinity.

6.1 Sparkfun Pressure Sensor

If you're using the Sparkfun Pressure Sensor Breakout Board, strip ½ cm off the end of 4 8-cm lengths of 22-gauge stranded wire and solder those wires to the GND, 3.3v (or VCC), SDA, and SCL pins on the back of the board. Keep track of which wire goes to which pin by color-coding each pin (we recommend red for VCC; black for GND; yellow for SCL; and white for SDA). Note that the wires project from the side opposite the pressure sensor.

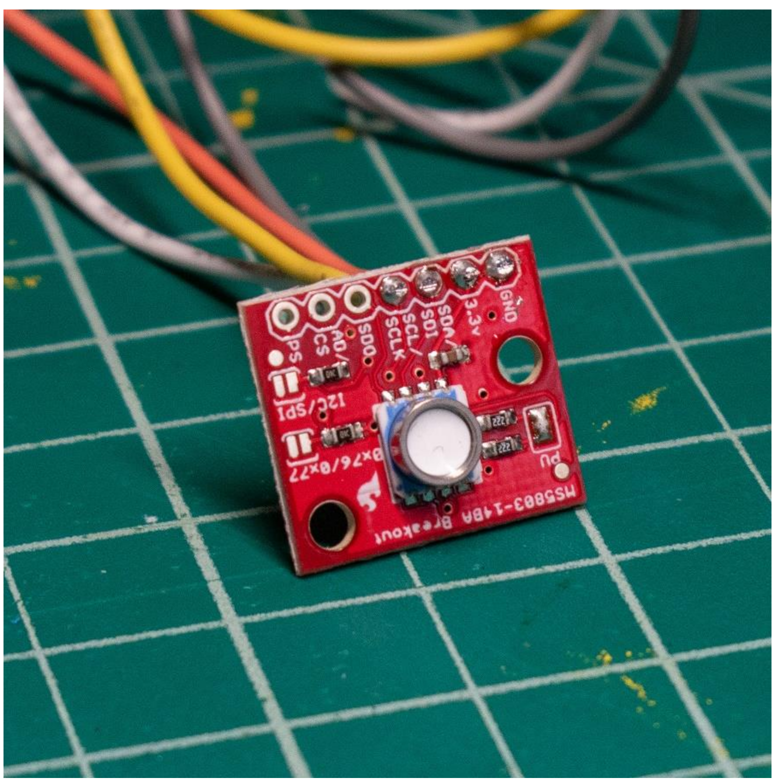


Figure 11. Sparkfun Pressure Sensor Breakout with soldered pins.

6.2 DIY Pressure Sensor

To build the pressure sensor, you will need to surface mount the pressure sensor chip onto an SOIC8-to-DIP adapter. This is the most challenging soldering step in the entire build and requires a steady hand. The pressure chip is able to withstand high heat for a short amount of time, as long as there is no direct contact. Be extremely careful not to touch the gel covering the pressure sensor.

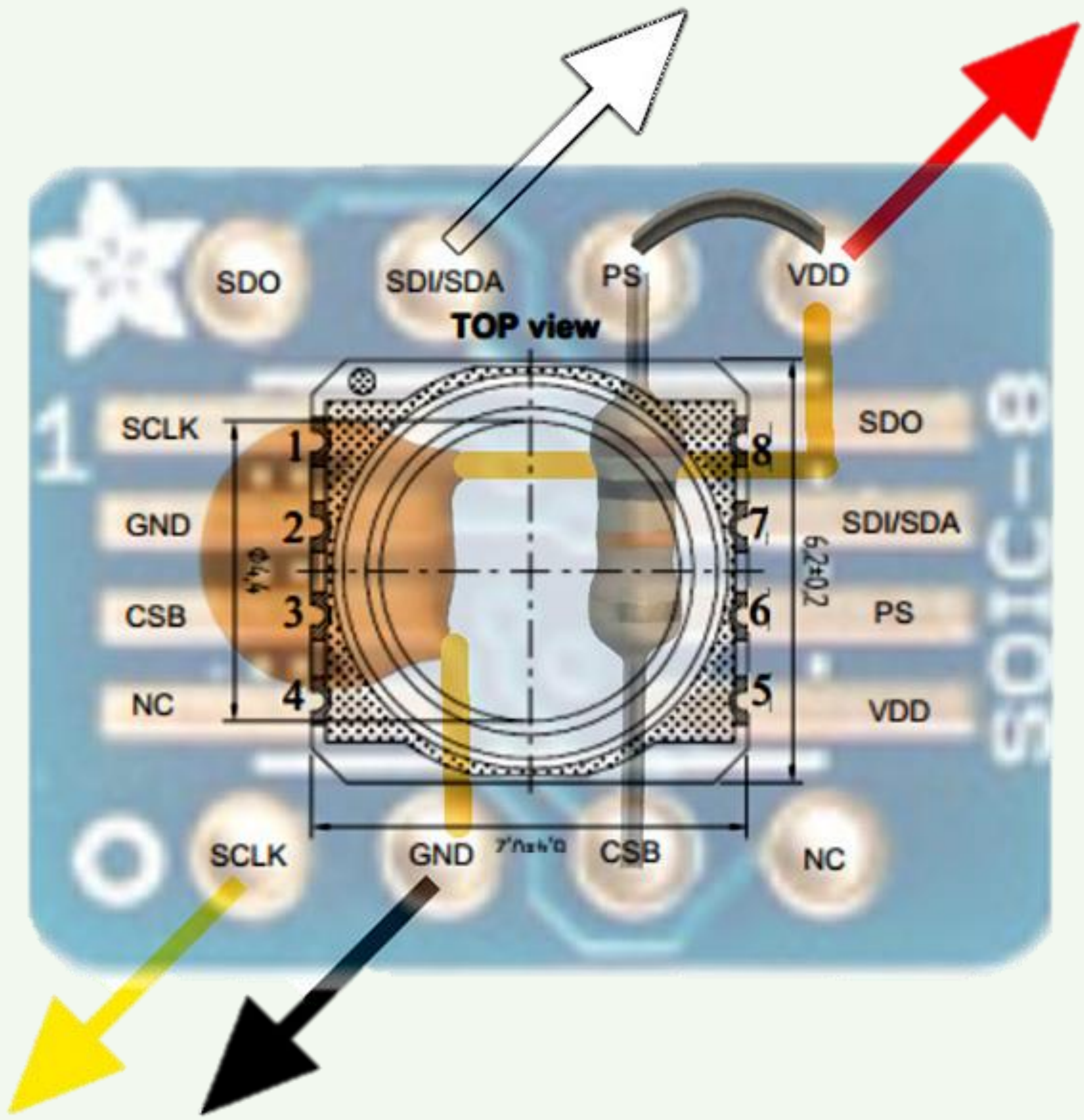


Figure 12. Diagram of pressure sensor chip and component alignment on SOIC-8 to DIP adapter. Note alignment of pin 1 on the chip to the alignment indicator (in this case, the Adafruit star, but on most boards simply a dot). Image courtesy of the Cave Pearl Project, who have an excellent guide to using and soldering these little chips here: https://thecavepearlproject.org/2014/03/27/adding-a-ms5803-02-high-resolution-pressure-sensor/).

1. Make sure that side of the SOIC8-to-DIP adapter with the larger pads is facing up. Add a small amount of solder to each pad. If you have solder rosin, add a dab of rosin to each pad to help the solder flow.

2. Ensure that the dot and notch on the pressure sensor line up with the dot on the SOIC-to-DIP adapter. Solder the sensor in place by applying a small amount of solder to the vertical grooves and drawing it down onto the solder pads. Be careful not to short any connections.

3. Bridge the pads for pin 5 (VDD/VCC) and pin 6 (PS) by drawing a small drop of solder between them.

4. Flip over the adapter and solder a 10kOhm pull-up resistor between pin 3 and 6.

5. Insert the 100nF (104) capacitor between pins 2 and 5 but don't solder yet. Bend the capacitor's legs to hold it in place.

6. Solder a 6 cm length of solid core wire to pin 1 (SCL) and pin 7 (SDA). Keep track of which wire goes to which pin by color-coding each pin (we recommend red for VCC; black for ground; yellow for SCL; and blue for SDA).

7. Solder a 6 cm length of solid core wire to pin 2 (GND) and pin 5 (VDD/VCC) such that the legs of the capacitor are captured in the solder join. You may have to twist the wire a bit to get both the wire and the capacitor leg to fit in a single pin hole. Keep track of which wire goes to which pin by color-coding each pin (we recommend red for VCC; black for ground; yellow for SCL; and blue for SDA).

8. Strip ½ cm of insulation from the exposed ends of each wire.

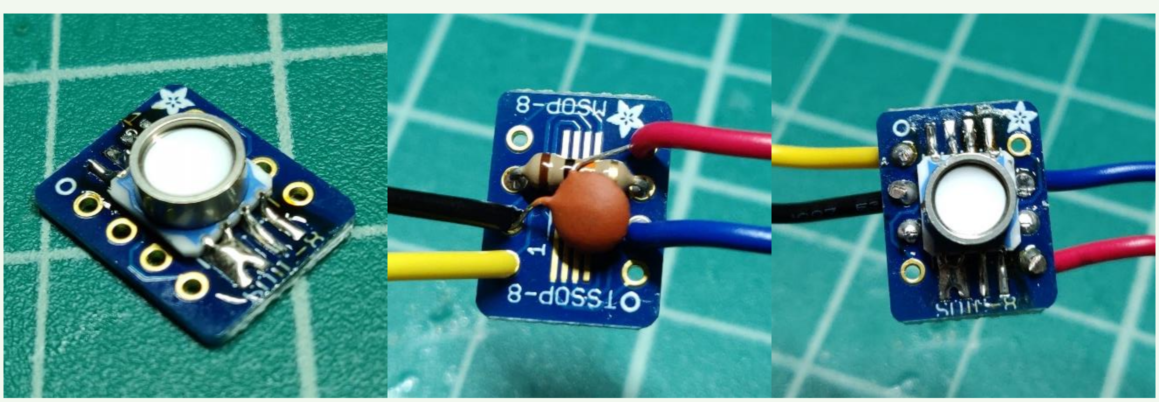


Figure 13. Building the Pressure Sensor unit. A: Components of the sensor. B: Surface mounting the sensor. C: Wiring up the components.

OpenROV IMU If you've received an OpenROV IMU with 30Bar pressure chip, you can use that as an alternative for a deeper operating CTD. Solder a 5 cm length of solid core wire to SCL, GND, VCC, and SDA. Keep track of which wire goes to which pin by color-coding each pin (we recommend red for VCC; black for GND; yellow for SCL; and blue for SDA).

You will also need to 3D print the corresponding baseplate in order to pot the sensor.

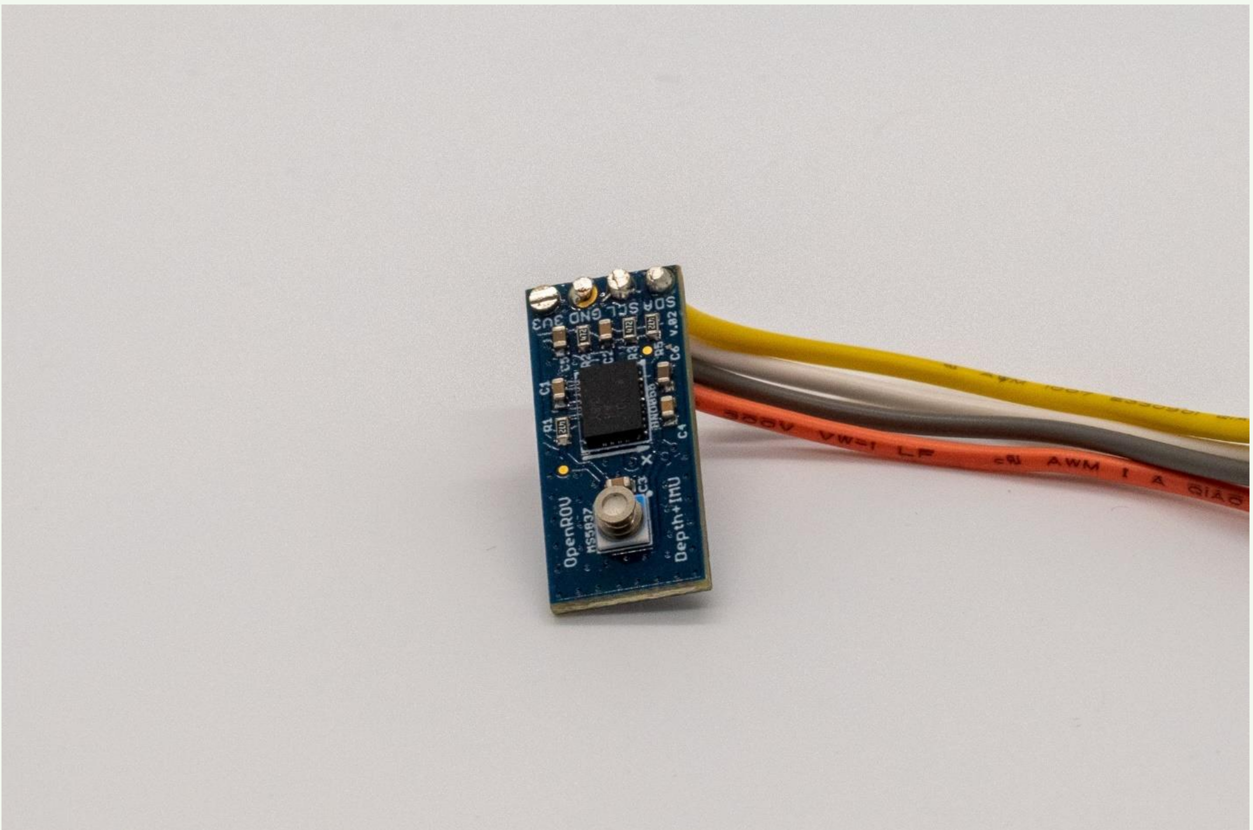


Figure 14. OpenROV IMU with 30-bar pressure sensor.

6.3 Temperature Sensors

The OneWire protocol allows multiple digital sensors to communicate through a single signal, so we can connect all the thermistors to a shared data pin in the Adalogger. In preparing these sensors, our objective is to join the three units together with as little excess wire as possible but with enough slack that moving and positioning the probes do not put any extra stress on the solder joins. Note, that while there may be variation in the color of the data wire, black will always be ground and red will always be VCC

1. Cut the wire on each temperature probe approximately 5 cm from the probe-end terminus.

2. Strip 2 cm of outer insulation, taking care not to break the inner wires.

3. Strip a centimeter of insulation from each inner wire, exposing the metal strands.

4. Twist all three black wire strands together and "tin" the wires by adding solder to the entire length. This will provide a base for more wire to be soldered to the temperature sensor packet. Do the same for the red and yellow wires, respectively (the colors may vary based on manufacturer, but the important thing is to ensure that matching colors are bundled in sets of three).

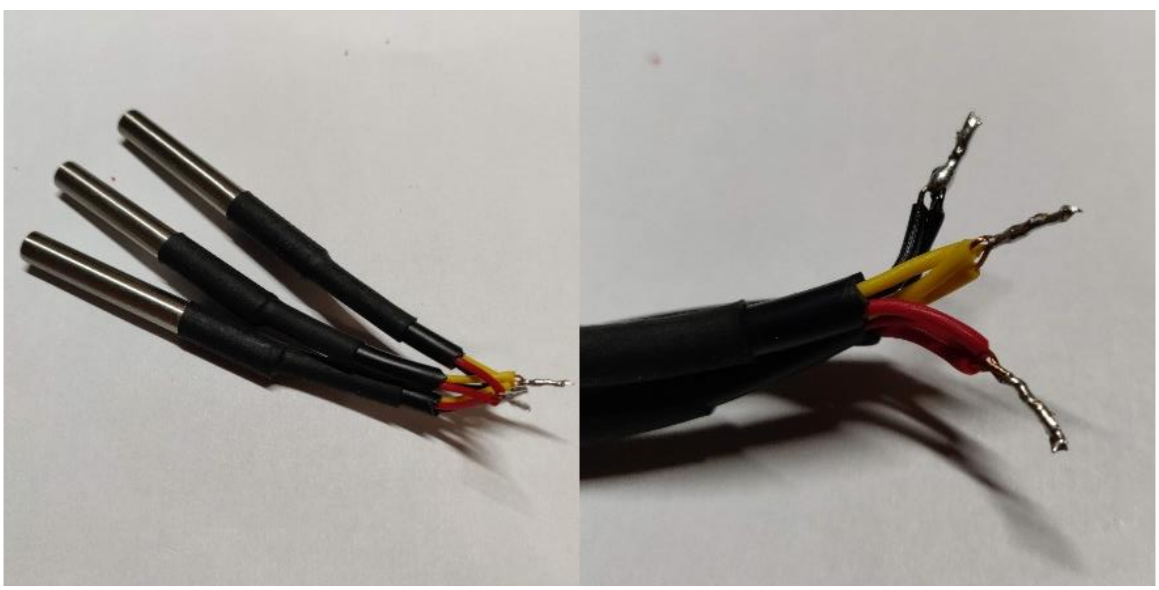


Figure 15. Three potted temperature sensors joined together with a close-up on the tinned tips.

6.4 Conductivity Sensor

The Atlas Scientific conductivity probe comes in both long and short varieties, with either paired leads that terminate at a large BNC connector or shrouded leads that terminate at a smaller SMA connector. Either version is acceptable for the OpenCTD and the connector will be removed during construction.

1. Cut the probe wire such that the full length of the probe and wire extends a little more than 2/3rds of the way up the PVC pipe.

2. Use a utility knife to strip and expose 2 cm of wire.

    a. The wires may be co-axial (one wire is wrapped around the insulated core of the other) in which case you will have to separate the shroud from the central core and expose both. The shrouded wire will need to be twisted together once extracted from the insulation. Ensure that the insulation in the internal wire extends far enough that that wire will not make contact with the exposed external wire.

    b. The wires may be embedded in extruded insulation rather than simply wrapped and will require a bit of care to extract without damaging the internal insulation.

Figure 16. Conductivity probe leads with coaxial wires stripped and soldered.

3. Strip half a centimeter of insulation from each inner wire.

4. Tin the exposed wire stands with a small amount of solder.

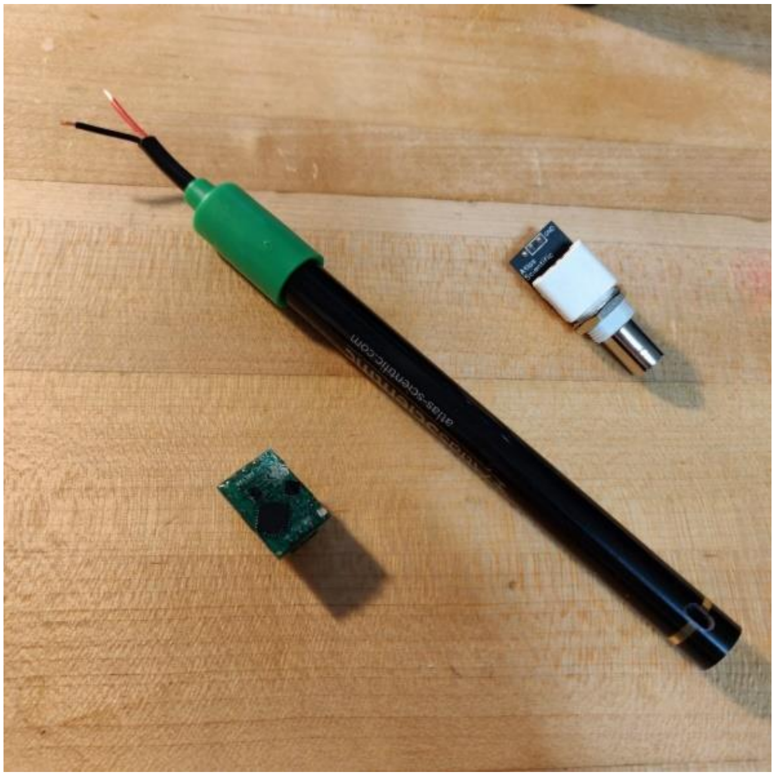


Figure 17. Long conductivity probe with stripped lead wires, Atlas EZO conductivity circuit, and BNC connector for simplified testing.

6.5 Benchmark: Breadboarding the Circuit (Protoboard)

A breadboard is a tool that allows you to prototype an electronic circuit without permanently affixing components. A breadboard is an electronic pegboard with three major regions. The two strips on either side of the board are the ground and positive rail. They are connected vertically. The rails in between are for affixing components. They are connected horizontally and usually clustered in groups of 5. In the center of the breadboard is a dividing groove. Horizontal rails are not connected across the groove. This allows you to mount large components with pins on either side of the central groove, like, for example, an Adalogger. By breadboarding the circuit first, you can ensure that the system is working properly before continuing.

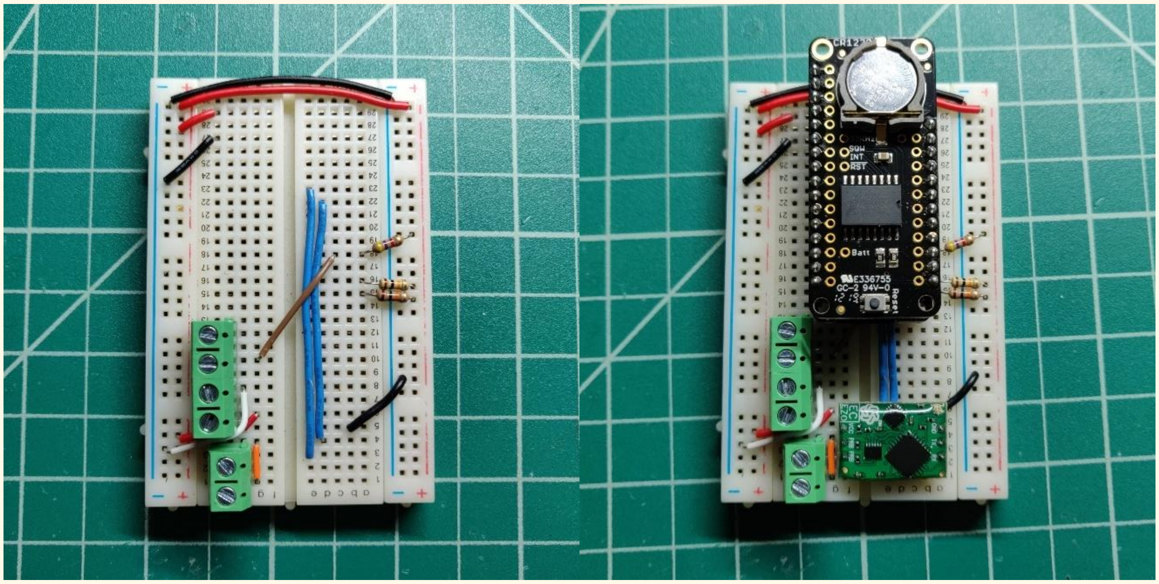


Figure 18. Breadboard with just jumper wires, screw terminals, and resistors attached and with Adalogger/RTC and EZO conductivity circuit.

1. Reference Figure 9 and the photo and pinout guide below. Place Atlas EZO circuit and connect jumper wires in accordance.

2. Connect a 4.7 kΩ resistor between pin D6 and the positive voltage rail.

3. Connect a 10 kΩ resistor between the SDA pin and the positive voltage rail and connect another 10 kΩ resistor between SCL pins and the positive voltage rail.

4. Connect the temperature sensors to digital pin 6, positive, and ground using the screw terminal blocks.

5. Connect the pressure sensor to SCL, SDA, 3.3V, and GND. The solid core wire on the pressure sensor can be loosely slotted directly into the pin holes on the RTC.

6. Connect the temperature probe to the two probe pins on the Atlas EZO using the screw terminal blocks or BNC connector. It does not matter which wire goes to which probe pin. Make sure the conductivity probe itself is submerged or it will read zero.

7. Connect the Adalogger to your PC using a micro-USB cable and open the serial monitor in Arduino IDE.

8. Power the Adalogger down, remove the SD card, and read the data file.

Breadboard Diagram

Note: this diagram does not show the screw terminals. Refer to Figure 13 to see the position of the screw terminals.

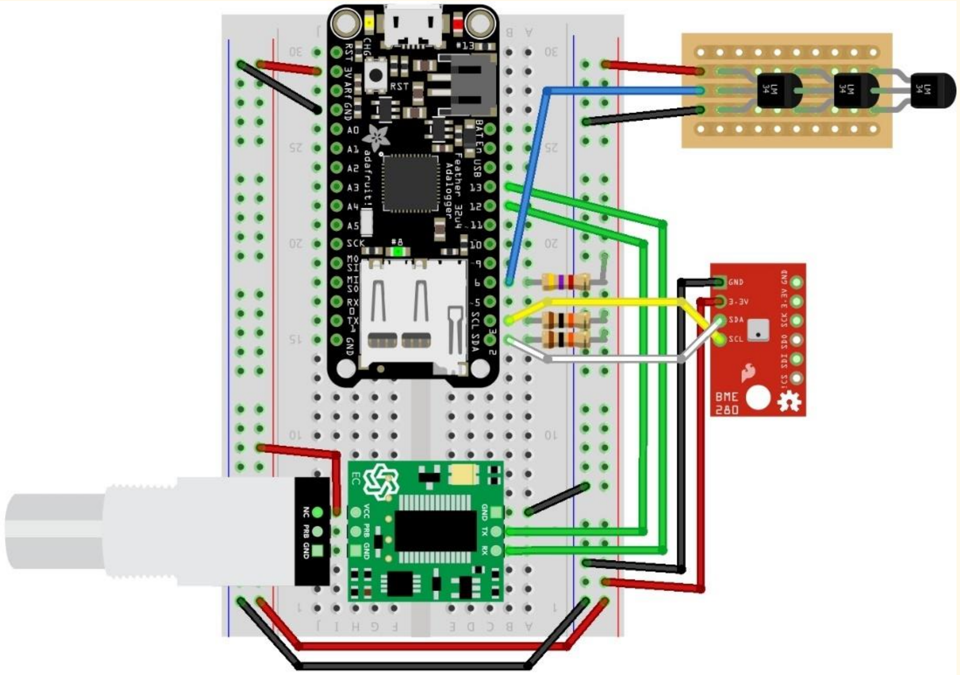


Figure 19. Diagram of breadboard assembly to test completed sensors. Note the presence of BNC connector for the conductivity probe and the use of a barometric pressure sensor to stand in for the OpenCTD pressure sensor.

Checklist

- Atlas EZO circuit is blinking with alternating between green and blue lights.
- Temperature probes are reading ambient temperature and are within 0.5ºC of each other.
- Pressure sensor is reading atmospheric pressure (it should be around 1012 mbar if you’re near sea level).
- Conductivity sensor is reading the conductivity of whatever fluid it is in.
- Data had been logged to SD Card.

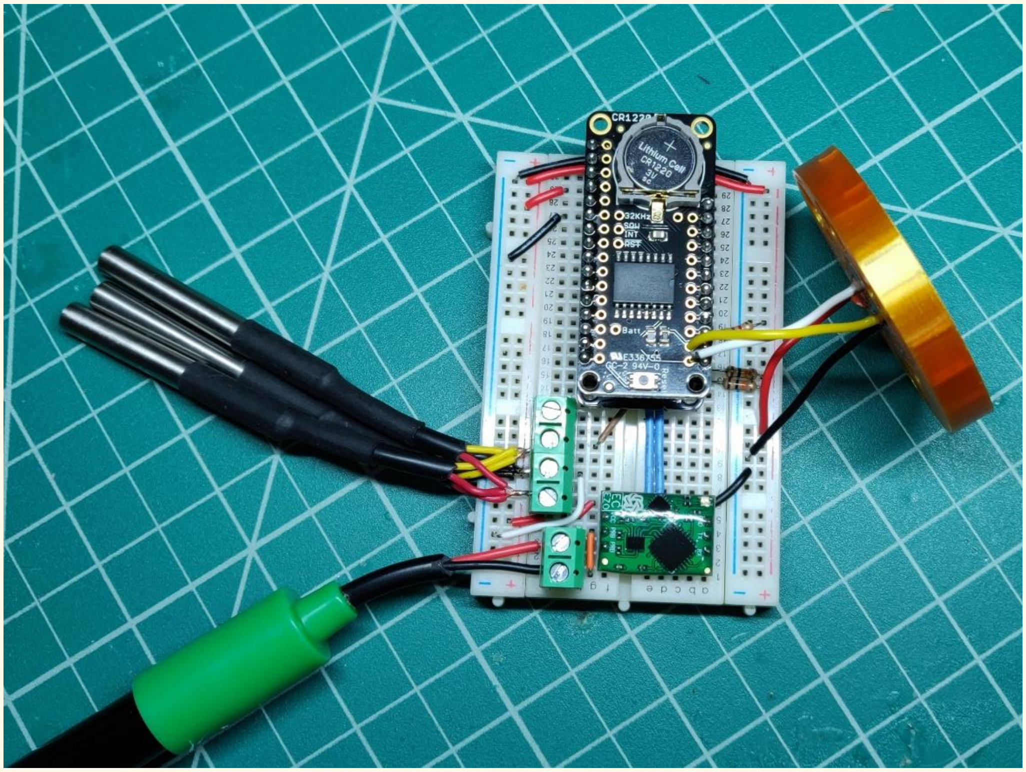


Figure 20. Completed breadboard set-up with all sensors ready for testing.

TESTBENCH

7 (Protoboard) Assembling the Protoboard Control Unit

The protoboard control unit replicates the traces embedded in the custom carrier board. It handles all the processing and signal routing between the sensors and the Adalogger. The protoboard control uses a mint-tin sized permanent breadboard, which is arranged similar to a standard breadboard, but with positive and negative rails in the center of the board and free, unattached pins at either end. This Perma-Protoboard allows you to make permanent electronic connections while mimicking the look and set-up of a breadboard.

7.1 Preparation

First, we will build the connector that interfaces with the sensors in the OpenCTD housing by attaching an 8-pin, right angle female connector to the end of the Perma-proto board and bridging it to the positive and negative rail with solder.

1. Once the Adalogger has been tested, it no longer needs the long pins that connected it to the breadboard. Snip these pins off at the base of the Adalogger. The Adalogger should now sit flush inside the Electronics Chassis.

2. Cut an 8-pin length from a right-angle female header strip.

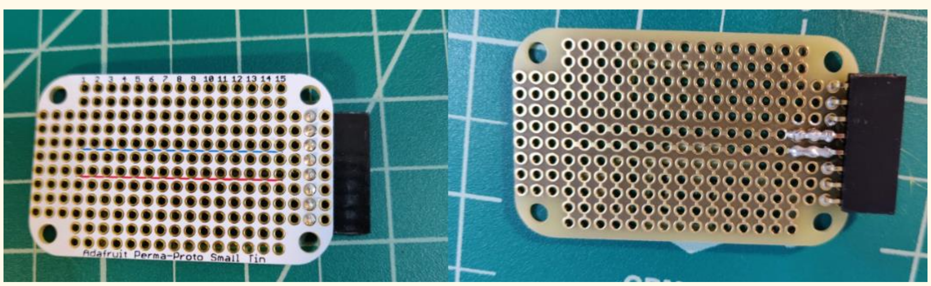


Figure 21. Perma-Protoboard with 8-pin connector top (A) and bottom, with solder bridges (B).

3. Solder the 8-pin connector to the second to last set of through-holes on the right side of the Perma-Protoboard, on the underside such that the pins emerge through the middle column of unconnected through-holes.

4. On the underside of the board, build a solder bridge between the positive and negative strips and their respective, adjacent connector pins. This works best with a soldering iron heated to 750°C. Hotter irons will cause the surrounding solder to melt.

7.2 Powering the Protoboard

Solid core wire will be connected to pass-through holes on the RTC and soldered underneath so that the wires pass between the RTC and the Adalogger and then contact the appropriate pins on the perma-proto board. It is easiest to start with long lengths of wire and cut down to appropriate sizes as you proceed.

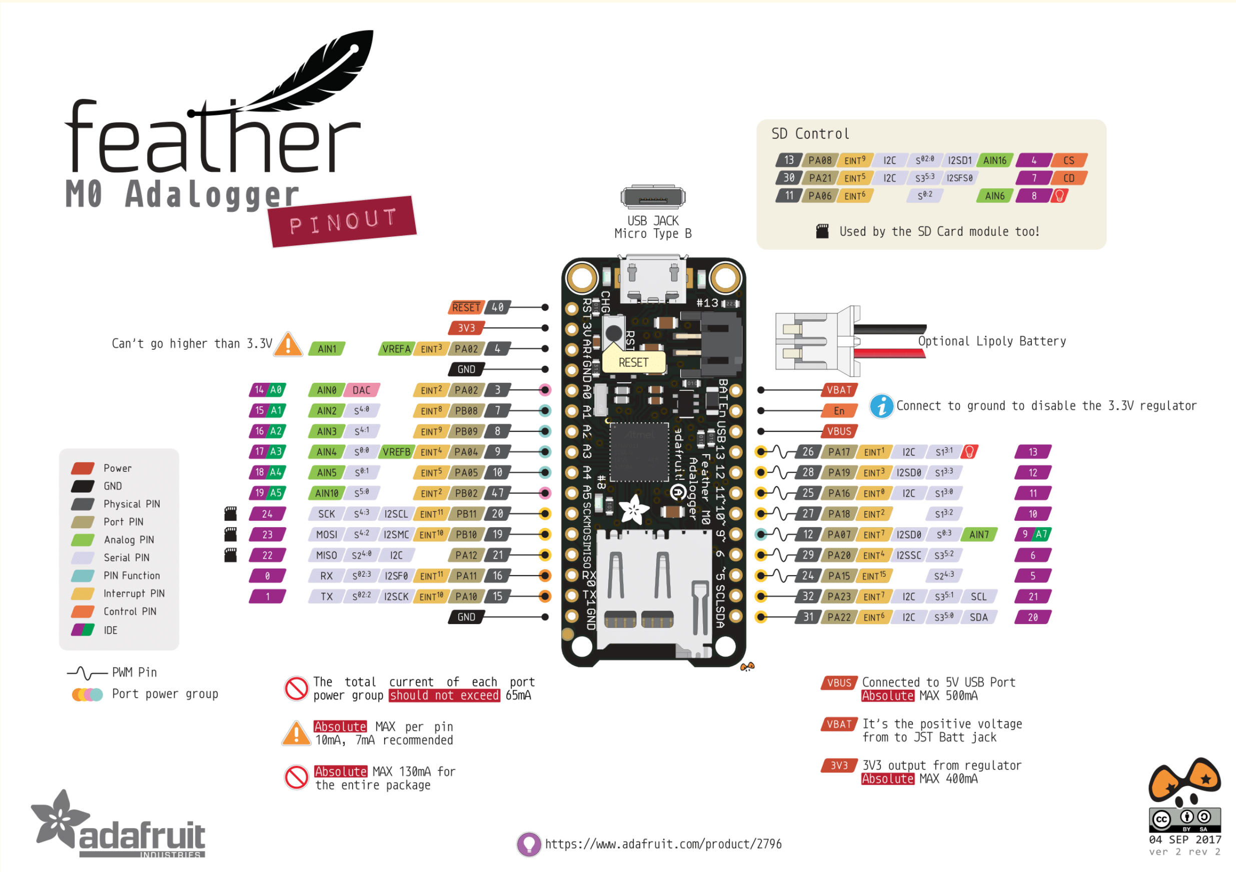


Figure 22. Pinouts for the Adalogger Feather M0. Note, these pinouts also correspond to those of the RTC.

1. Connect red and black solid core wire to the 3.3V and GND pins on the left side of the RTC.

2. Place the complete Adalogger/RTC assembly into the Electronics Chassis and stretch these two wires until the meet the end of the Chassis.

3. Cut the wires near the far end of the zip-tie hole in the e-chassis and strip off half a centimeter of insulation from the leads.

4. Solder these wires to the positive (3.3V) and negative (GND) rails of the Perma-Protoboard along columns 5 or 6.

5. Check the fit by placing the entire unit in the Electronics Chassis. The Adalogger and the Perma-Protoboard should sit flush against their respective support structures.

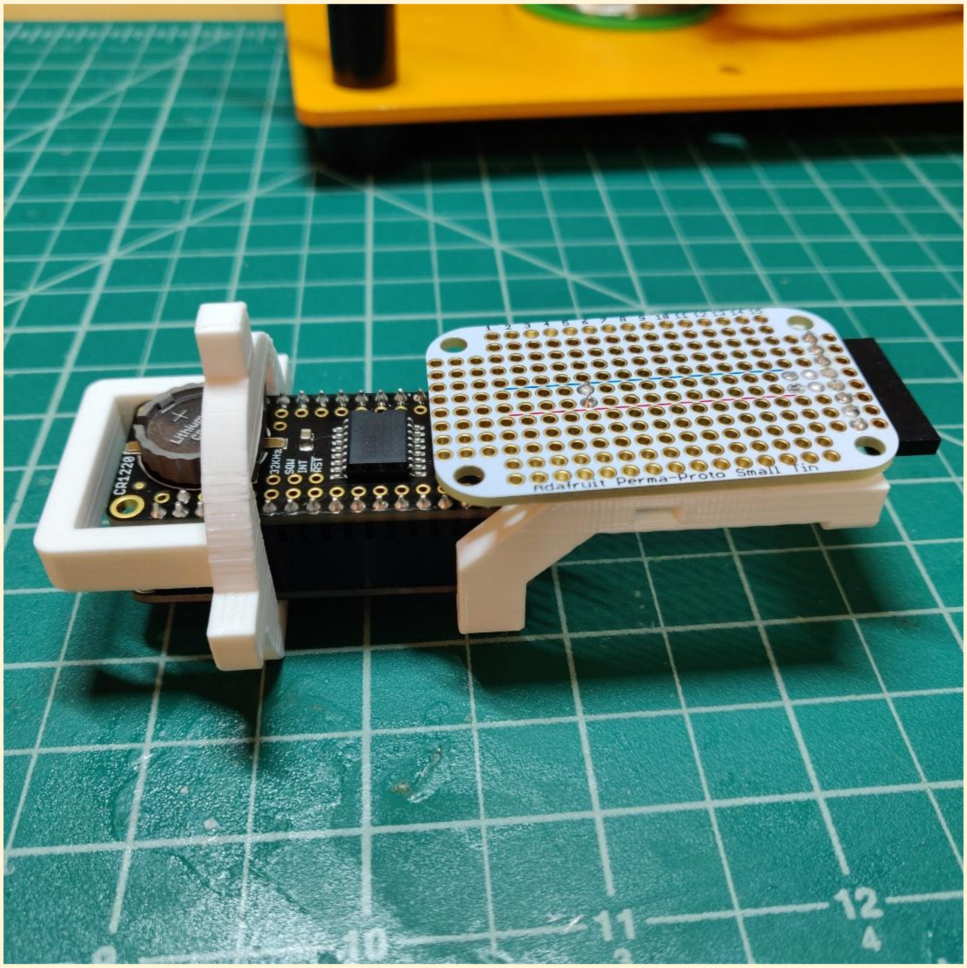


Figure 23. The Adalogger/RTC fit into the electronic chassis.

7.3 Populating the Perma-Protoboard

Skills: Soldering
Consumables: Solder, solid-core wire
Parts: Adalogger/RTC connected to Adafruit Perma-proto board, Atlas EZO circuit, 10 kOhm pull-up resistor (x2), 4.7 kOhm pull-up resistor

These steps will fully populate the protoboard control unit with all necessary components for the OpenCTD. We advise laying out all components first and double checking their placement before soldering. Reference Figures 23 and 24 frequently during assembly.

16. Starting from the inside pins closest to the positive and negative rails, bridge the 8-pin right-angle header pins to the respective adjacent solid core wires on the perma-proto board with solder.

17. Clip off the one unused pin from the male end of the sensor connector and slot it into the unused female header on the protoboard control unit. This will prevent the connector from being inserted into the protoboard control unit backwards, causing a short.

18. Using zip ties, attach the Adalogger/RTC and Perma-proto board to the 3D-printed electronics chassis.

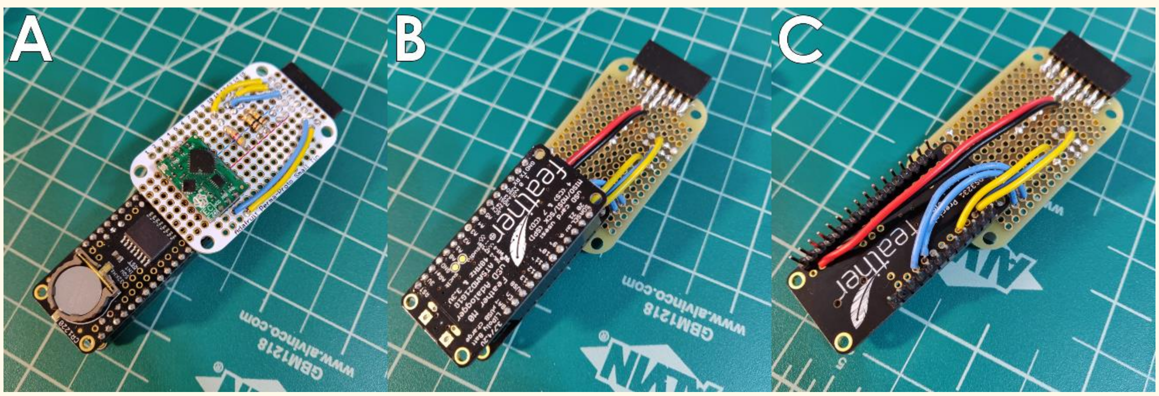


Figure 24. Fully connected CONTROL UNIT shown from the top (A), bottom (B), and bottom but without Adalogger attached (C).

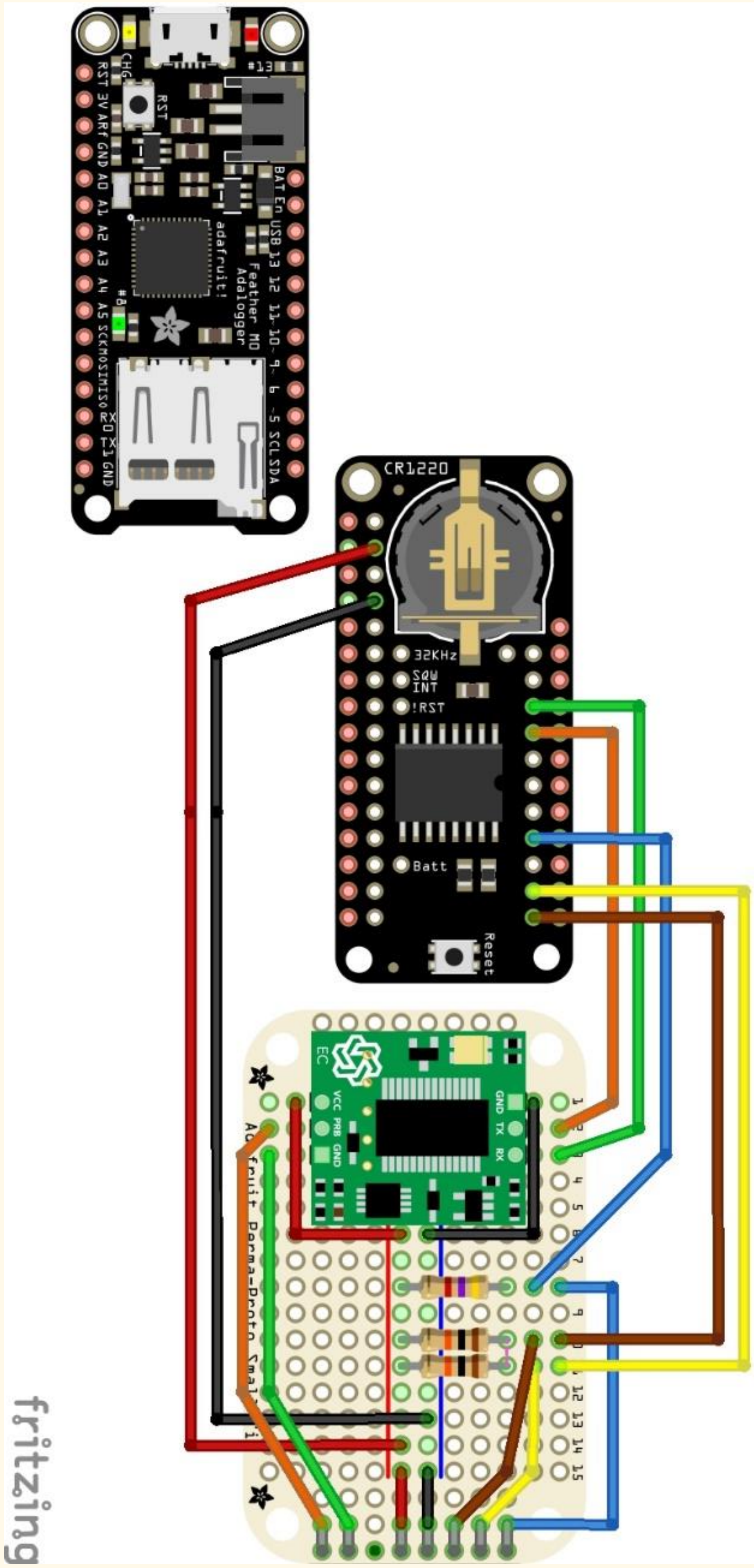


Figure 25. Layout of connections on the Perma-Protoboard.

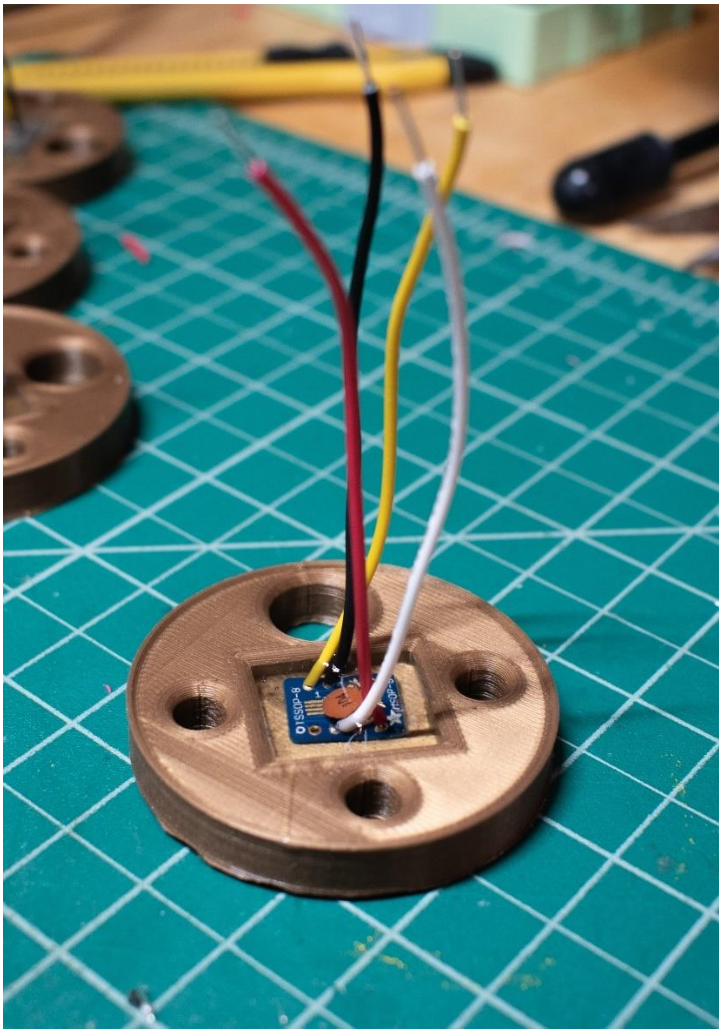


Figure 26. Pressure sensor seated and potted in baseplate.

5. Once the epoxy has set, insert each temperature probe into the three holes such that 1.5 to 2 cm extends out of the bottom of the baseplate.

6. The Pressure and temperature sensors share power. Solder the 3V3 (or VCC) wire from the pressure sensor to the positive (red) wire cluster of the temperature sensor assembly.

7. Solder the GND wire from the pressure sensor to the negative (black) wire cluster of the temperature sensor assembly.

8. Solder additional wire on to extend the GND, 3V3, DATA (the third wire on the temperature sensor cluster), SCL, and SCK wires to align with the wires on the conductivity probe. Seal each joint with heat shrink tubing.

9. Insert the conductivity probe into the large hole such that 1.5 to 2 cm extends out of the bottom of the baseplate. If the probe will not seat into the baseplate,

5. Solder the SDA, SCL, and D6 wires to the leads for SDA and SCL on the pressure sensor and DATA on the temperature sensors. Seal the solder joint with heat shrink.

6. Using a large piece of heat shrink, seal the entire area around the solder joints for added protection.

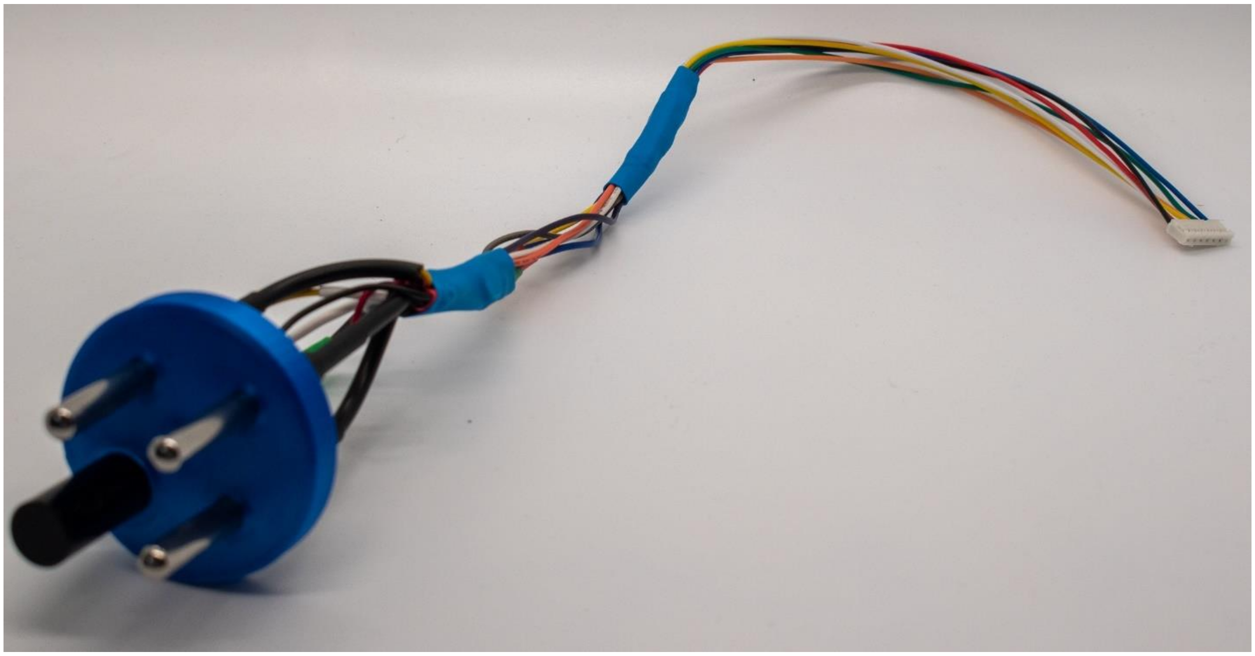


Figure 27. Completed sensor package.

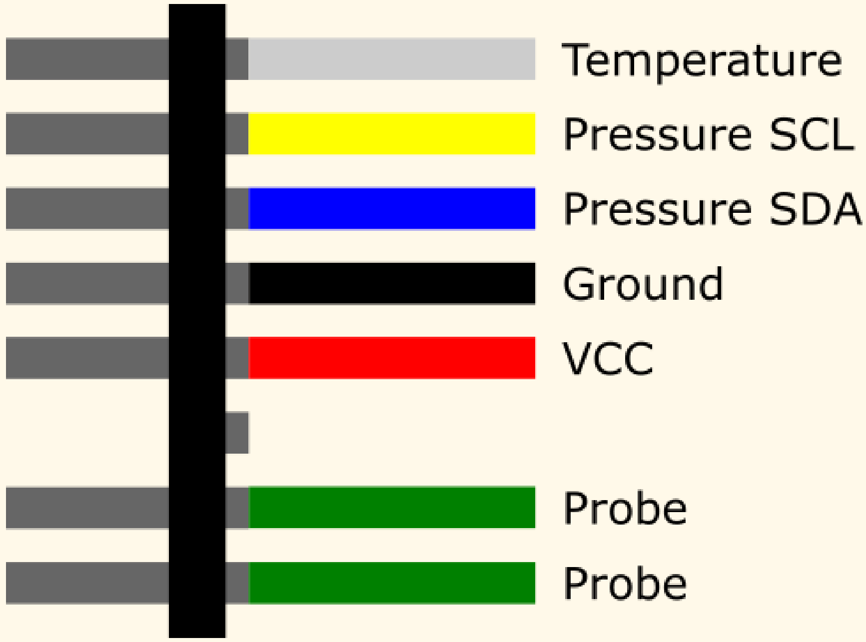


Figure 28. Illustration of connector with wires coming up from the housing. Wires leading to sensors on right, vertical black bar represents 8-pin headers. Pins leading to CONTROL UNIT are on the left.

10. Test the connector by plugging it into the breadboard and reading the sensors. You will have to rearrange the breadboard in order to connect to all seven leads. You can also test each sensor independently using jumper wires.

11. Slide the 3D-printed connector cover over the 8-pin connector.

12. Fill the entire void within the connector with 5-minute epoxy. This prevents strain on the header and solder joints as well as prevent moisture from entering the connector and prevents short circuits. Allow the glue to cure for 30 minutes.

13. Once cured, test the connection again by plugging it into the breadboard and reading the sensors. You will have to rearrange the breadboard in order to connect to all seven leads. You can also test each sensor independently using jumper wires.

Figure 29. A clear OpenCTD showing the thick epoxy potting layer.

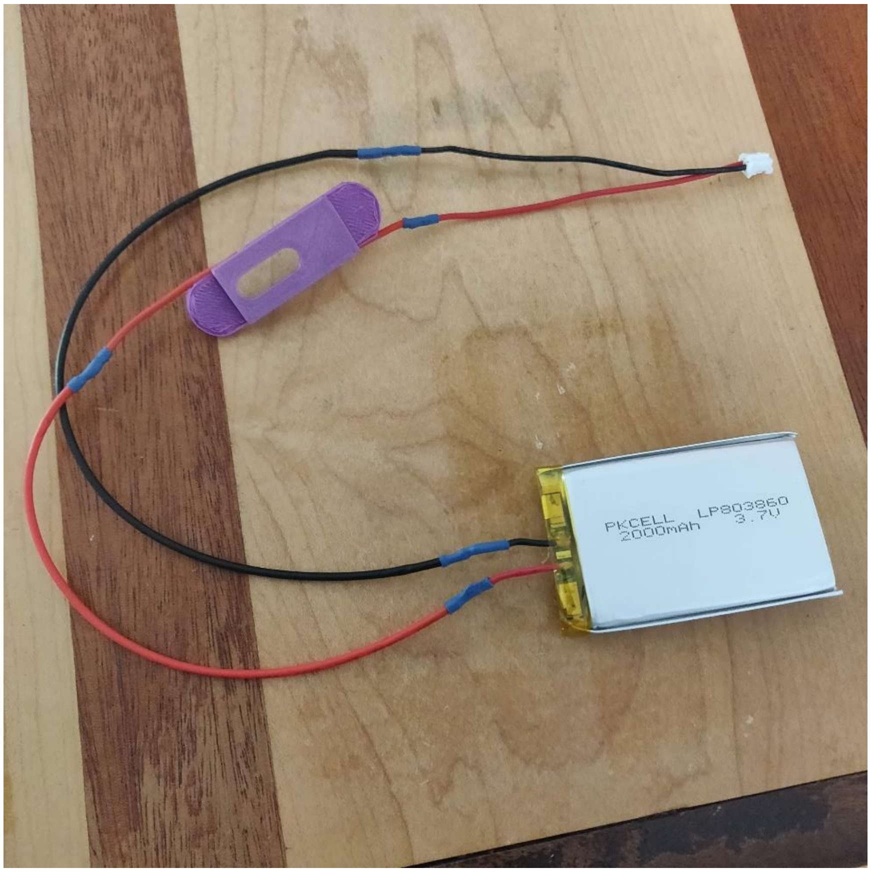


Figure 30. Inner battery switch assembly before battery is taped.

6. Place a 10 mm round magnet inside the housing (you can hold it in place by putting a magnet on the outside, too).

7. Using 10mm adhesive pads, adhere the internal switch component to the wall of the housing. Ensure that the internal magnet moves freely and contacts the two expose wires and that the switch assembly is seated low enough that it does not interfere with the test cap.

8. Stick the switch pin to another magnet using the 10mm double-sided pads.

9. Superglue the external switch assembly to the outside of the PVC pipe such that it traps the pin, is even and parallel with the internal assembly, and the pin can move freely. Line the switch up carefully and tape in place with electrical tape. Take extra caution not to allow the glue to leak into the inner walls of the external switch assembly or it could interfere with movement of the magnet.

10. Connect the control unit to the battery and ensure that the switch works consistently.

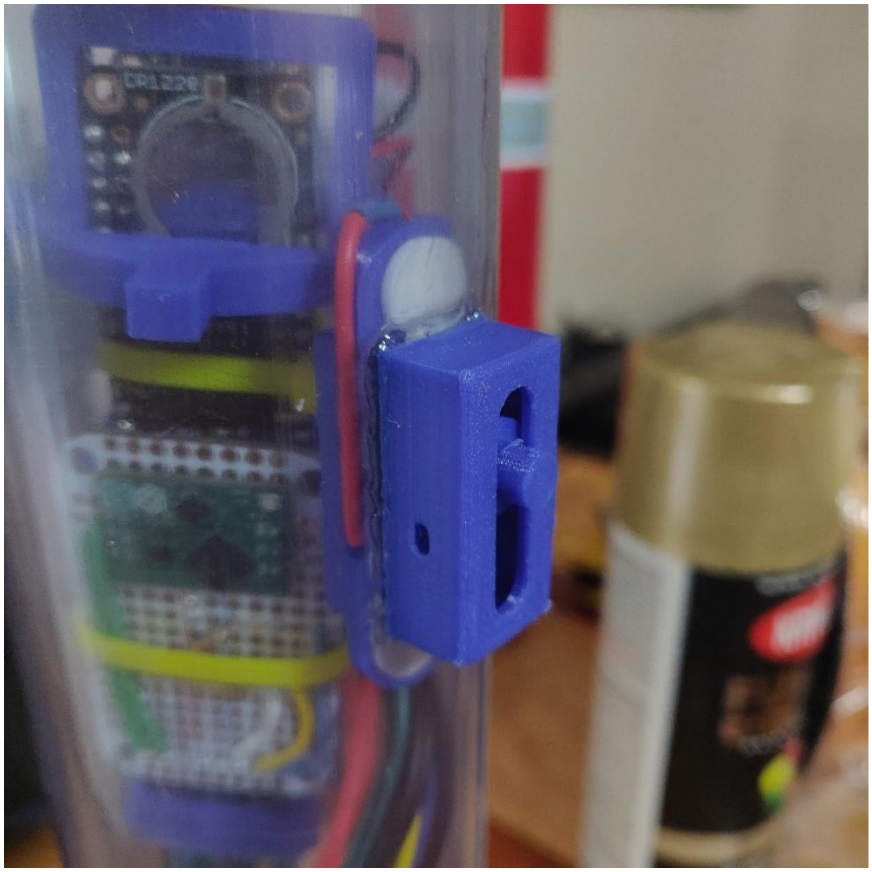


Figure 31. The complete switch assembly in a clear OpenCTD.

10 Casting and Ballast

Precisely how much weight a CTD needs for ballast and how it should be mounted to an instrument of line is entirely dependent on your specific needs. A CTD deployed in a brackish estuary to a relatively shallow depth can sink with no additional weights on something as simple as a handline. A CTD deployed to ocean depths in high current may need to be attached to a weighted anchor line with heavy-duty hose clamps.

Below, we provide a few possible mounting options for the OpenCTD. We recommend for most cases, using the casting loop and a medium-duty Polypro line.

10.1 Casting Loop

This isa basic, durable loop for clipping to a handline that can be constructed using a short length of Polypro rope and a 2” hose clamp, as picture below. For extra security and to avoid snags, we recommend that you also wrap the hose clamp in electrical tape.

Figure 32. Finished OpenCTD with optional casting loop.

The potted and sealed OpenCTD is positively buoyant. In order to make the CTD sink, you will need to ballast it with weights. 2 to 3-ounce lead fishing weights work well and can be carefully inserted into the CTD housing, taking care not to crush any wires or contacts. For coastal areas, we have found that 4 to 6-ounces is sufficient to make the OpenCTD slightly negatively buoyant, but the total amount of weight necessary will vary depending on salinity and water conditions.

10.2 Weighted Casting Line

For deeper deployments, of operations in high current, a weighted anchor line, with the anchor or weight held several feet below the CTD, with provide substantial negative buoyancy while keeping the unit horizontal. We recommend at least two hose clamps to ensure that the unit stay in position.

Figure 33. Example of OpenCTD attached to weighted anchor line using hose clamps.

10.3 Internal Ballast

The OpenCTD is positively buoyant in salt water. As a baseline, we recommend six ounces of standard fishing weights stored inside the housing. This will make the unit slightly negatively buoyant and able to sink in calm waters.

To avoid damaging the electronics, it is best practice to remove the weights between deployments so that they don't shake around during transportation. Wrapping them in rubber or electrical tape will also minimize movement.

Figure 34. Clear OpenCTD with fishing weights inside.

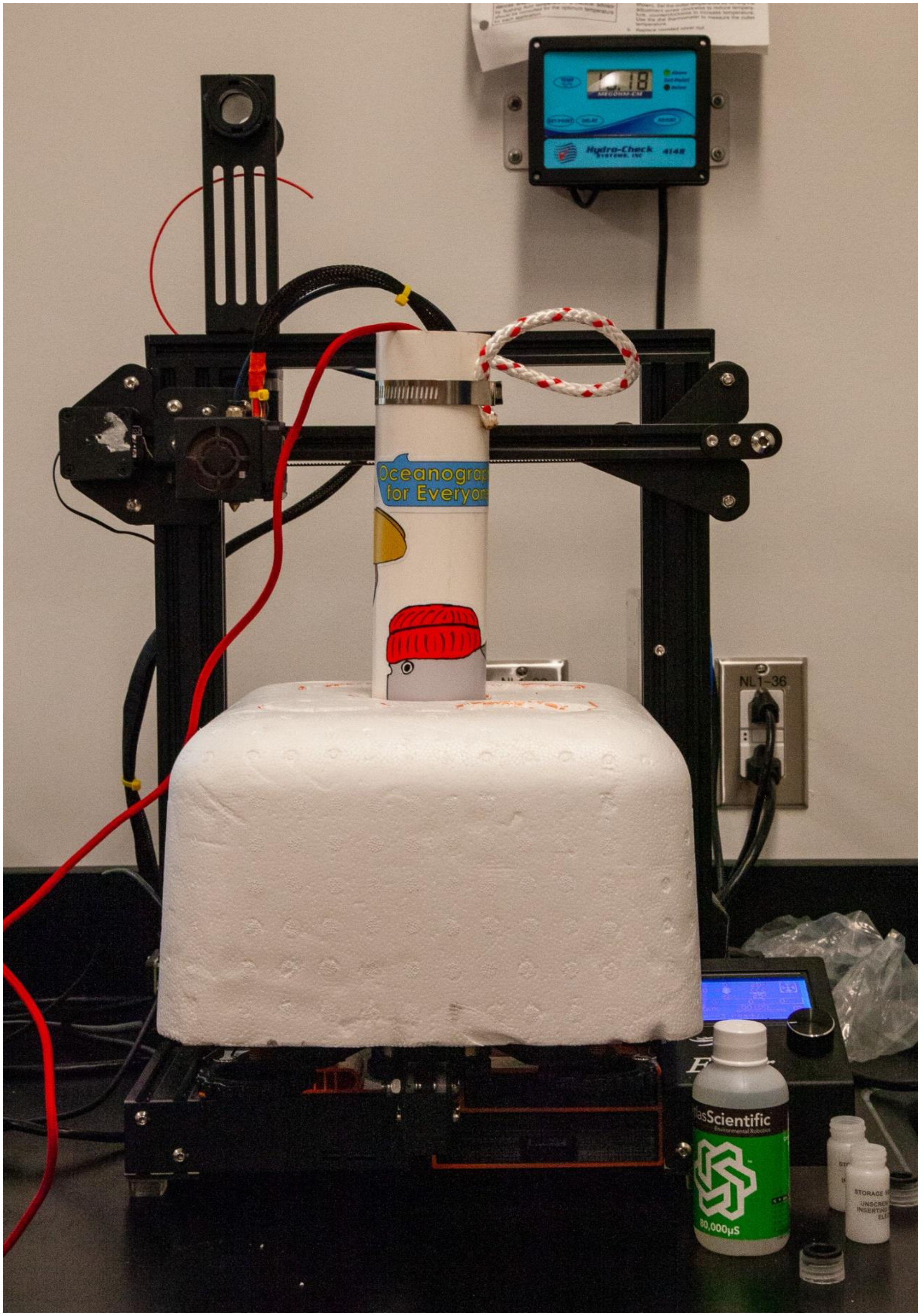


Figure 38. OpenCTD mounted inside a Styrofoam cooler on top of a 3D printer heat bed in order to maintain an ambient 25°C temperature. Photo by Allie Wilkinson.

been calibrated. If there is an error transmitting the command, the serial monitor will report *ER and you should send the command again.

6. With the probe dry (be sure there is absolutely no water on the electrodes) enter **cal,dry** in the command line and hit enter. This will dry calibrate the probe. If there is an error transmitting the command, the serial monitor will report *ER and you should send the command again.

7. Enable continuous monitoring by entering **c,1**. You will begin to see a steady stream of readings from the conductivity probe updating once per second. If the dry calibration was successful, those values should read 0.00.

8. Clean the probe with distilled or RO water and dry with a clean paper towel. Make sure there is no water trapped in the small hole between electrodes. Clean and dry the probe storage bottle with distilled or RO water and dry with a clean paper towel.

9. Fill the probe storage bottle with the less conductive of the two conductivity solutions (12,880 µS if you're using the Atlas standard solutions). Slide the cap ring of the probe storage bottle onto the conductivity probe so that it sits well above the small hole between electrodes. Slide the probe storage bottle onto the probe and screw it into the cap so that it seals tightly, and the calibration standard completely covers the small hole between electrodes. Tap the probe gently to shake out any bubbles.

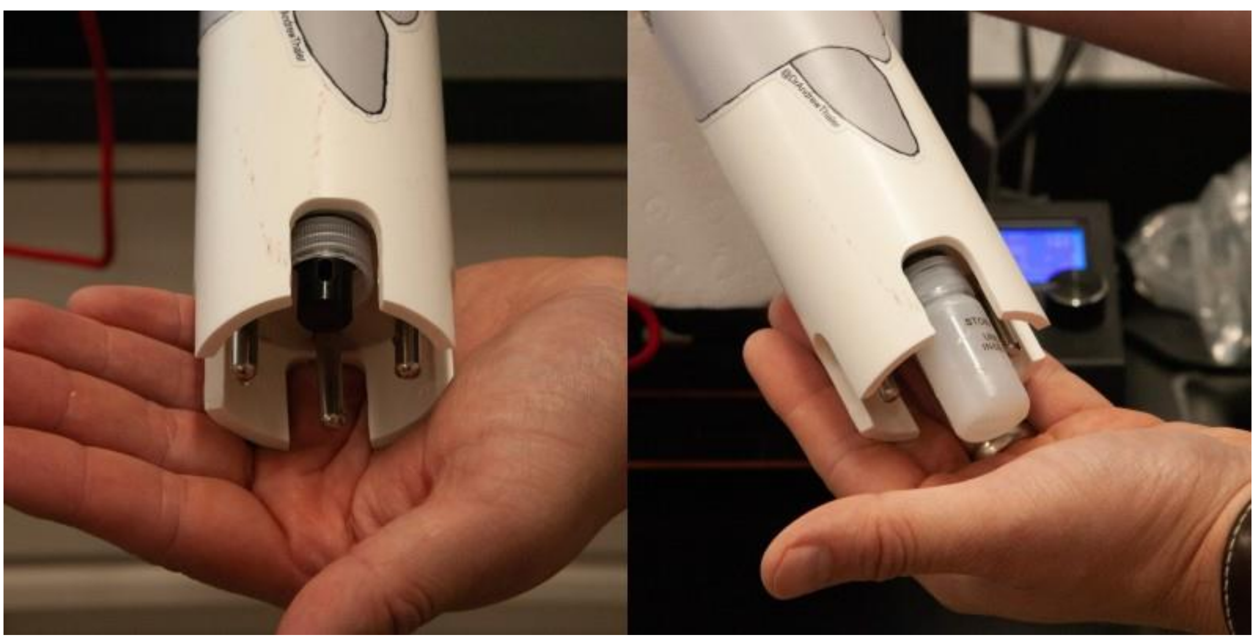


Figure 39. OpenCTD conductivity sensor with the cap ring of the probe storage bottle placed above the electrode opening (left) and with the conductivity probe completely submerged in the probe storage bottle. Photos by Allie Wilkinson.

value of the standard) in the command line and hit enter. Only do this if you do not have two calibration standards.

16. After calibration is complete, upload the OpenCTD software to the Adalogger M0.

If you do not have access to a system that allows you to maintain a temperature at a stable 25°C, there are two alternatives for calibration. You can use the temperature compensation feature of the Atlas EZO-EC conductivity circuit to set a different stable temperature for calibration, provided that the environment around the probe is stable at that temperature. You can derive the compensation temperature from the OpenCTDs temperature probes, rounded up to the nearest tenth of a °C. Set the compensation temperature on the EZO-EC by sending the command **t,x** through the serial monitor, where **x** is the compensation temperature rounded to the nearest tenth of a °C. Once temperature compensation is entered, continue through the above two-point calibration protocol. Temperature compensation will reset to 25°C whenever the unit is powered down.

Review the Atlas EZO-EC Datasheet (https://atlas-scientific.com/files/EC_EZO_Datasheet.pdf) for more thorough instructions.

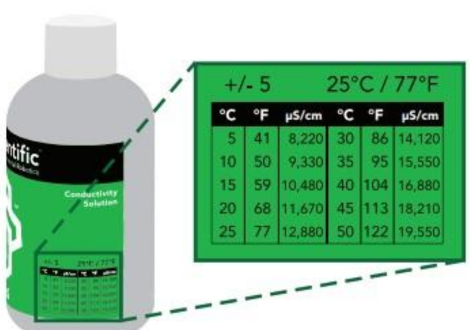


Figure 40. Location of conductivity temperature offsets. Image from Atlas Scientific.

If you cannot maintain a consistent thermal environment, there is one potential alternative that will result in a rough calibration of the probe acceptable for education or for applications where precise salinity measurements are not essential. On the side of bottles of salinity standards provided by Atlas Scientific and others, there is usually a table of compensation values in intervals of 5°C. You can calibrate to the value closest to ambient temperature. This method should only be used if no other alternatives are available.

Conductivity should not need to be calibrated again once the calibration protocol is complete, however it is practice to check calibration at least once per year or whenever components are changed. For more detailed explanation of the calibration process and for an explanation of temperature compensation, refer to the Atlas EZO-EC Datasheet (https://atlas-scientific.com/files/EC_EZO_Datasheet.pdf).

Each control unit is calibrated to a specific sensor package. Control units are not interchangeable between OpenCTDs without recalibration.