SeaGlide Build Instructions

A Small-Scale Autonomous Underwater Vehcile

Version 2.1

This manual is adapted from the one that can be found at www.seaglide.net

Contents

General Notes, Tips, and Tricks:

- Steps 1, 2, and 3 of the Bottle Prep and Ballasting section should be completed first. This is to ensure the silicone sealant has enough time to cure.

-The 3D printed parts are brittle and are prone to cracking or splitting. Threading screws into them requires patience and finesse. Since the parts don't have threads for the screws we are mounting, we are essentially tapping our own threads. While securing screws for the first time it's often best to tighten a couple turns, loosen a turn, and repeat.

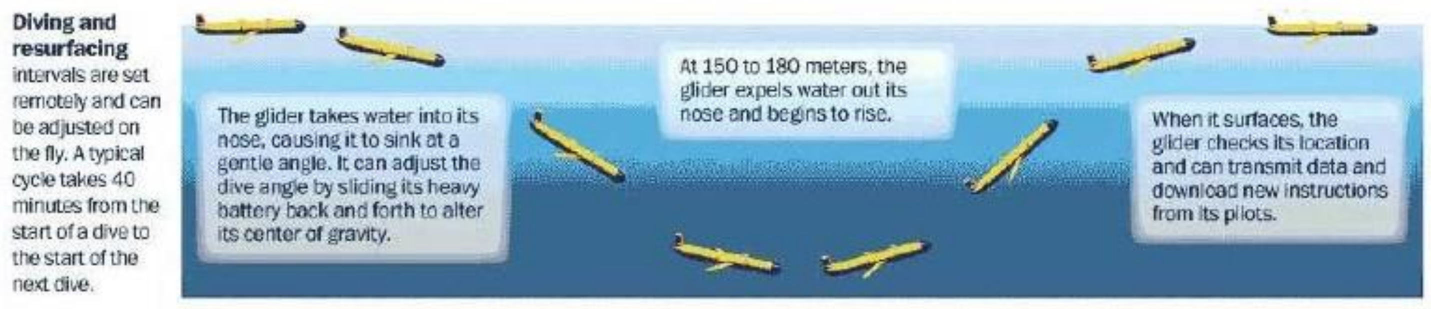
- Solder sometimes has a tendency to jump when it is heated, please wear safety glasses to protect your eyes.

- Before releasing your glider in the water, it is crucial to baptize the vehicle for proper ballasting. To do so, hole the glider by the rudder vertically underwater with the electronics turned on. Let the glider cycle its buoyancy engine twice to expel all air. From this point you can let it free and watch its dive pattern in order to access if it needs more/less lead weight strips or if the steel bars need to be shifted forward or backward.

- SeaGlide files and links to program downloads can be access at the following github page: https://github.com/Finnovators/SeaGlide

Introduction

An underwater glider is a non-tethered, autonomous robot that has no propeller and uses very little energy. It moves by changing its buoyancy, often by taking in or expelling water. This change in buoyancy causes the glider to rise and sink in the water. As the glider travels up and down, its wings generate lift, which propels the glider forward.



SOURCE: Rutgers University Coastal Ocean Observation Laboratory | Bonnie Berkowitz, Patterson Clark and Laris Karklis/The Washington Post - December 15, 2009

Underwater gliders can run for months at a time and cover great distances on very little power. Gliders carry sensors that can help scientists better understand and model the ocean. In 2009, Rutgers University's Scarlet Knight (RU 27) became the first AUV to cross the Atlantic Ocean. It made 11,000 dives and 11,000 ascents to the surface during its 221-=day voyage that covered approximately 7,400 km.

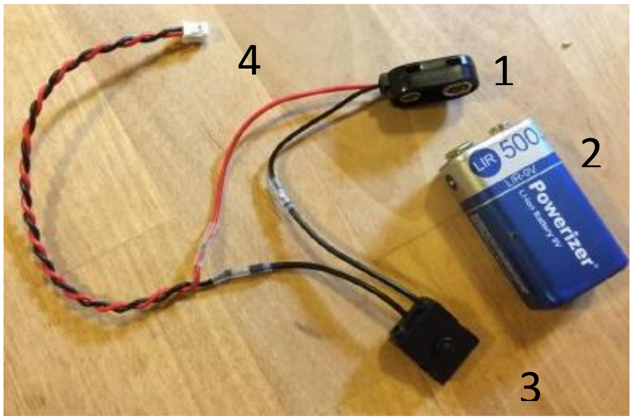
Carderock's small-scale underwater glider, SeaGlide, operates on the same basic principles as the Scarlet Knight. It has a buoyancy engine, pitch control, wings, and a rudder as well as sensors. With lift provided by its wings, it glides forward both as it dives and as it rises. A pressure sensor collects data to determine depth and position over time. This information can be correlated with data from a temperature sensor.

Arduino Pro Mini

SeaGlide kit builders first learn about basic electronics and then progress to circuit board soldering and programming with Arduino Pro Mini microcontrollers. They build servo driven buoyancy engines, each with a large 100cc syringe and a moveable mass, to manage buoyancy and pitch. A critical final step is to ballast gliders for proper underwater flight.

Power Supply

The power supply includes a snap connector (1), a 9 volt rechargeable Lithium-Ion battery (2), and a pushbutton switch which is the ON/OFF control for the glider (3). The power supply also includes a plug (4) that connects to the buoyancy engine controller by sliding into the power supply jack on the controller's circuit board.



The function of the main components are as follows:

1. BATTERY SNAP CONNECTOR –
   Connects battery to power supply circuit.
2. LITHIUM-ION BATTERY –
   Provides rechargeable power to the glider
3. PUSHBUTTON SWITCH –
   The ON/OFF control for the circuit.
4. POWER SUPPLY PLUG –
   Provides power to the buoyancy engine controller by plugging into the power supply jack.

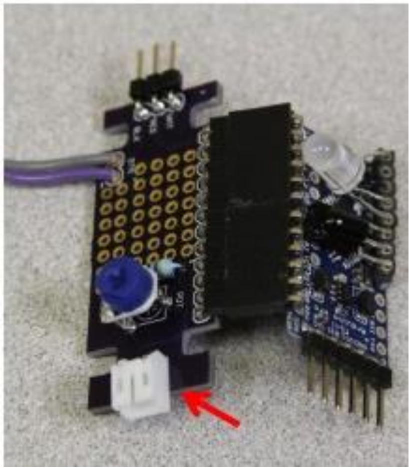
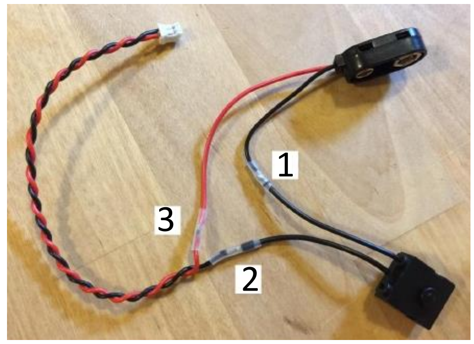


Figure 1: The red arrow points to where the power supply plug will connect

To build the power supply, do the following:

Tools needed:

Solder, soldering iron, safety glasses, wire strippers, shrink tubing, scissors, heat gun, needle nose pliers, clamps or a buddy to help you solder



The three solder joints that you will be connecting are:

1. Black wire of snap connector to black wire of pushbutton.
2. Black wire of pushbutton to black wire of braided plug.
3. Red wire of braided plug to red wire of snap connector.

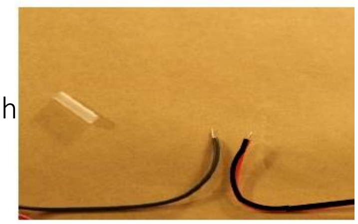
Step 1:

Strip approximately ¼" of plastic insulation from the wires to expose metal strands.
Hint: 20 gauge hole works well.

Step 2:

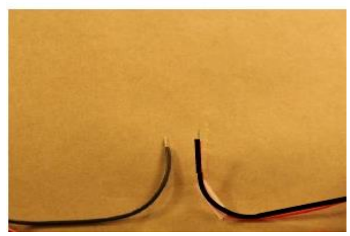
Expose metal strands.

Step 3:



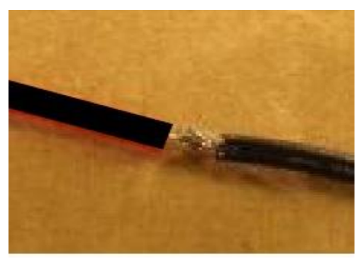
Cut a small piece of heat shrink tubing. 3/32" diameter works well with this gauge of wire.

Step 4:



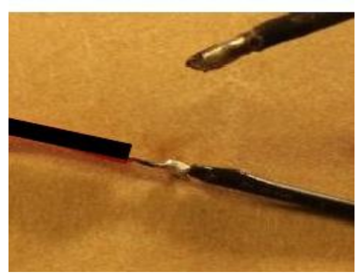
Place heat shrink tubing over one of the wires.

Step 5:



Twist the wires together.
Hint: Be careful, because the wires can poke holes in fingers very easily. Sometimes needle nose pliers are helpful for twisting them together.

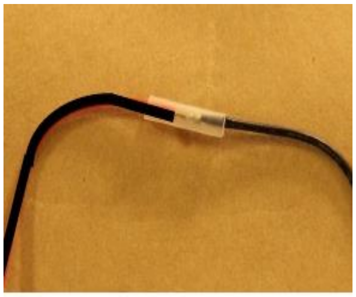
Step 6:



Solder the joint. Safety glasses are recommended.
Hint: Solder is very hot and the wires will heat up. Be careful not to hold the wires too close to the soldering joint or your fingers will be burned. Having a buddy help or using clamps is recommended. Allow the solder about 15 seconds to cool before directly touching it.

Step 7:

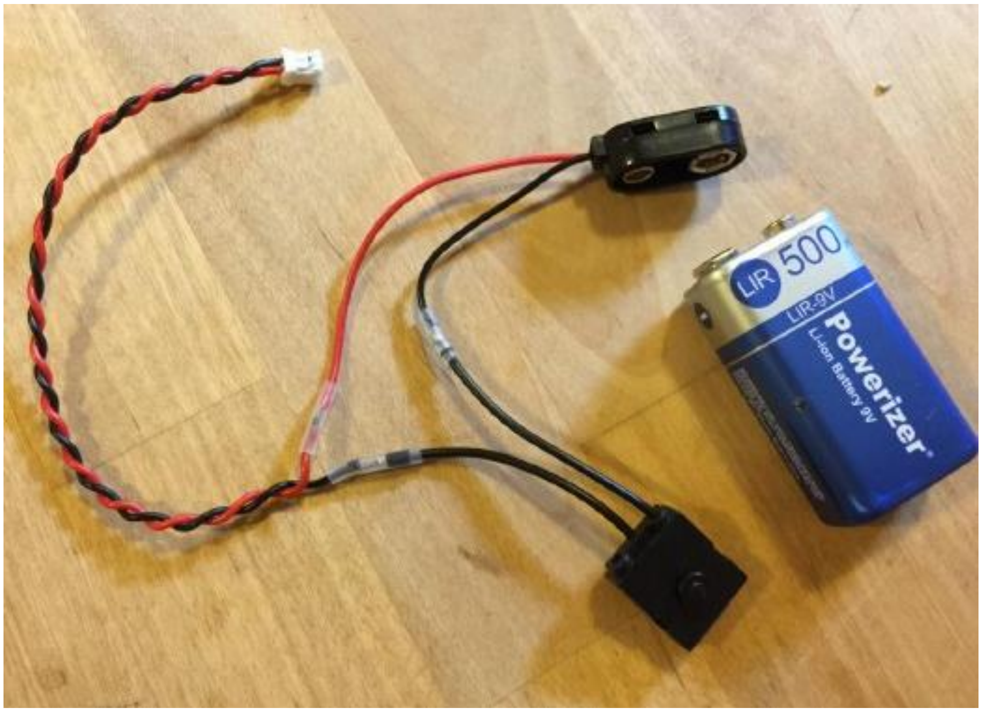
Slide heat shrink tubing over soldered joint.



Step 8:

Use a heat gun to shrink the tubing over the soldered joint.

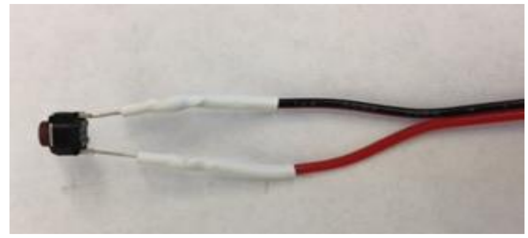
Repeat steps 1-8 until all three joints are soldered.



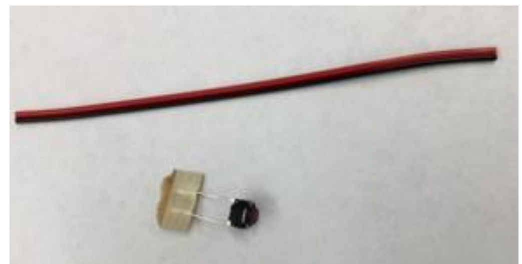
Congratulations! Your finished product should look similar to this. You can recharge the battery with the approved Lithium-Ion wall charger included in your kit. Read and follow the Operating and Safety Instructions provided with the charger.

Set the power supply aside for later use.

Pushbutton Switch



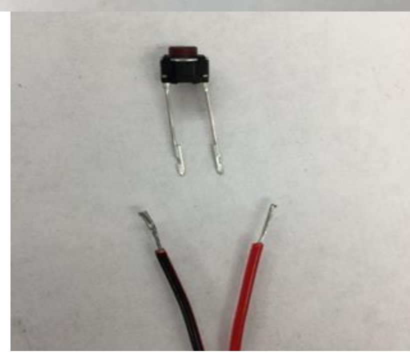
The pushbutton switch will act as a “limit” switch in the buoyancy engine to prevent the moving cylinder plunger from crashing into and stalling the servo. It provides a reliable position at which the mass/plunger will reverse direction… You’ll see.



Tools and Materials:

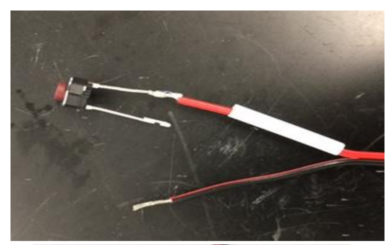
Black and red power wire, pushbutton switch, wire strippers, shrink tubing, solder, soldering iron, heat gun, safety glasses

Step 1:



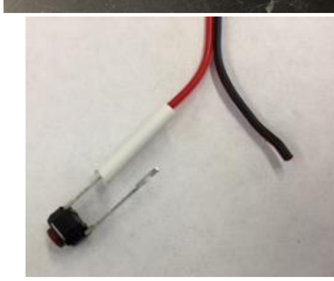
If there is tape on the end of your push button, remove it. Split the wires about 1” down the middle and strip the ends.

Step 2:



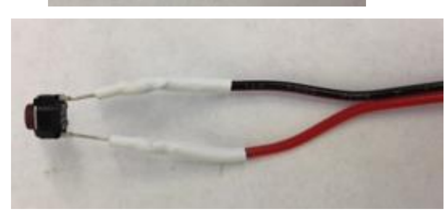
Cut two small pieces of heat shrink tubing. Place one of these on the end of one of the wires. Wrap that wire around one pin of the button.

Step 3:



Solder this joint. Safety glasses are recommended. Slide the heat shrink over the soldered joint and use the heat gun to melt the heat shrink over the soldered joint.
Careful: Again, beware of hot wires and solder!

Step 4:



Repeat step 2 and 3 with the other wire. Put the other piece of shrink tubing on the unsoldered wire. Wrap that wire around the other unsoldered pin of the button. Solder this joint and melt the heat shrink with the heat gun.

Nicely done! Your pushbutton switch is finished. Go ahead and set this aside for later use.

Buoyancy Engine

The main components of the buoyancy engine are:

1. SERVO MOTOR – Drives the lead screw backwards and forwards.
2. LEAD SCREW – Provides mechanical advantage to push and pull the plunger.
3. CYLINDER PLUNGER – Contains ballast for pitch control.
4. 100ml SYRINGE – Provides the casing for the buoyancy engine.

The buoyancy engine is the most important part of any glider, in our case we use a servo powered syringe as the engine. The syringe takes in water from outside the glider body to increase its density. The movement of our cylinder plunger, moving the glider's center of mass forward, causes the glider to pitch down and sink. When the syringe expels water, the glider becomes less dense and rises in the water. The plunger also moves toward the back of the vehicle causing yet another change in center of mass, also referred to as pitching up. The change in both buoyancy and pitch enable the wings on the glider to generate lift and thus forward motion as the glider dives or rises in water. (See illustration in the introduction for a typical dive cycle of a commercial underwater glider.)

Buoyancy Engine Kit

1. 100 ml/cc Syringe with original plunger.
2. 3D printed Plunger Cylinder with hex-head bolt, fender washer (3/8"ID 1"OD), brass nut, and three small screws (#2x3/8").
3. Two-Piece Shaft Coupling with three small screws (#2x3/8") and small washer (#4).
4. Servo Mount with four thread-cutting screws (#6x1/2"), eight small washers (#4), and four small screws (#2x3/8").
5. Continuous Rotation Servo with the tiny servo horn screw and four rubber grommets.
6. BBs for ballast.

Tools needed: Philips #1 or #2 screw driver, scissors, a Sharpie, a pushpin, hot glue gun, hot glue

Step 1:

Place the brass nut into the 3D printed cylinder. Your 3D printed part may be a different color than the one pictured.

Step 2:

Place the large washer on top of the bolt. Insert the three screws halfway into the holes to center the washer.

Step 3:

Tighten screws until flush, but make sure not to make too tight!

Step 4:

Flip this whole unit upside down. Fill the entire cylinder with BBs. They may be different colors than the ones pictured.
Hint: You can use a piece of paper or the plastic bag that your syringe came in as a funnel. It helps reduce the mess of escaping BBs. You can also shake the cylinder to help the BBs settle-you want as many in there as possible.

Step 5:

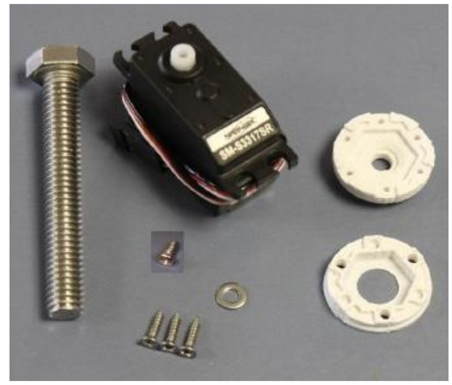
Grab your syringe and remove the plunger. Use a screwdriver to pry off the black end of the plunger. Using a bag as a glove (you can use the bag that your syringe was in), remove the black end and place it on the end of the 3D printed cylinder. This makes a cap so the BBs won't fall out. Be careful not to touch the black end with your hands because it has a special oil on it.

Step 6:

Push the cylinder in the syringe until it is past the opening.

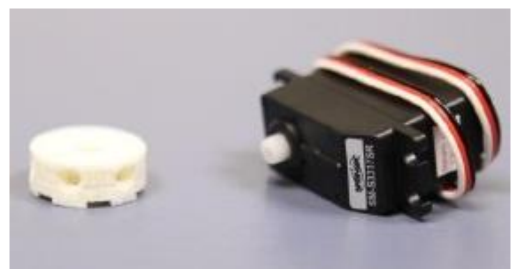
Step 7:

Grab the Lead Screw, Servo, Two-Piece Shaft Coupling. Three small #2 machine screws, a #2 washer, and small servo horn screw (picture added at right). The horn screw can be found in the servo bag.



Step 8:

Press the servo output gear into the small center hole in the coupling. Make sure the coupling is smooth side up.
Hint: It's not just you-it is very difficult to get it in. Feel free to press down against the table, but make sure to put it in as straight as you can.

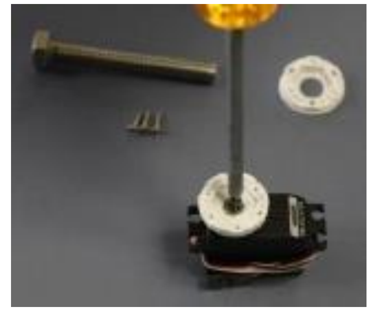


Step 9:

Turn over the servo. Place the washer into the center hole.

Step 10:

Screw the small servo horn screw into the servo output gear. This screw should be nice and tight.



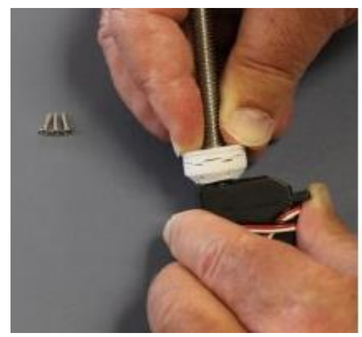
Step 11:

Push the bold through the indented side of the large hole coupling.

Step 12:

Match up the indentations on the couplings and push them together.

Hint: The Lead Screw will be loose and wiggly between the two.



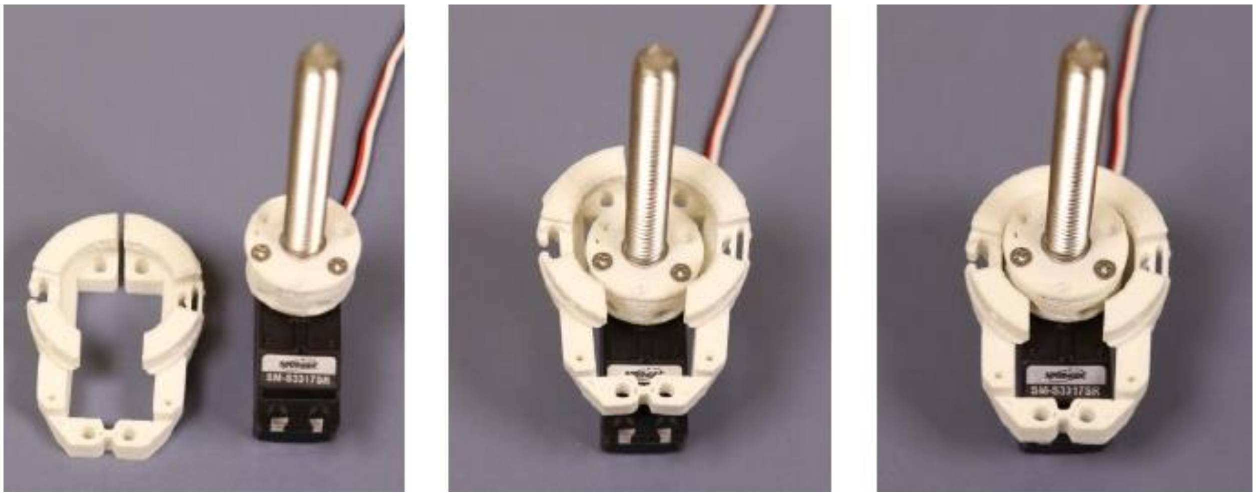
Step 13:

Place three small #2 screws in the open holes and screw each in halfway before completely tightening them flush. Remember, the screw will be loose, but it is okay! This is designed like that in case the servo unit isn't perfectly aligned-the screw is loose enough to have some wiggle room and it won't break the couplings.

This is what you'll need next, the 3D Printed servo mount, rubber grommets, and four #6 thread-cutting screws.

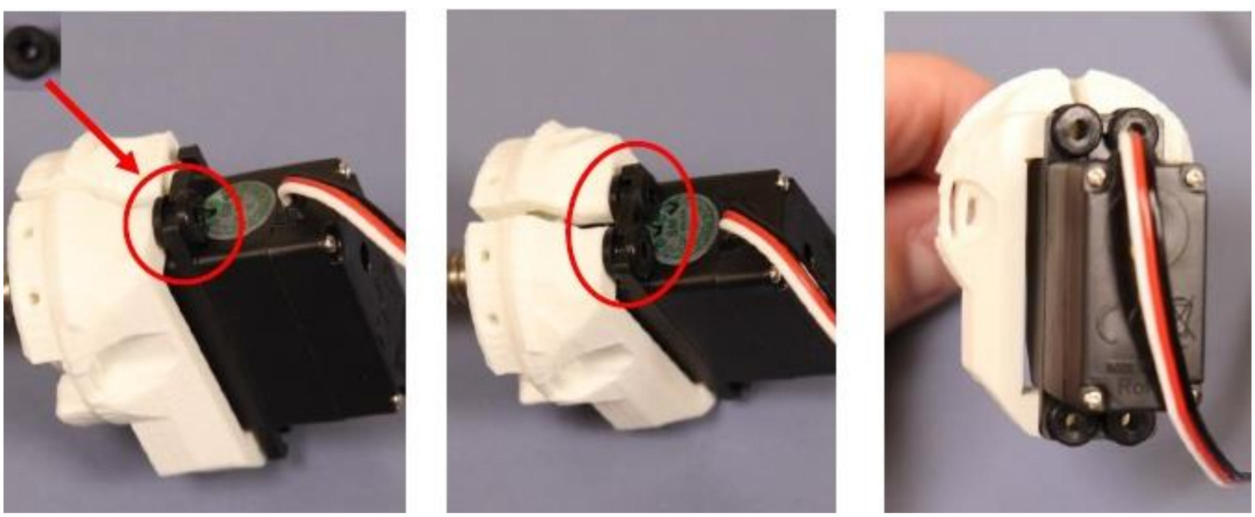
Step 15:

Fit the servo mount over the servo assembly as shown. You will need to pull apart the servo mount a little bit to fit it over.



Step 16:

Fit the rubber grommets into the four screw-holes in the servo.

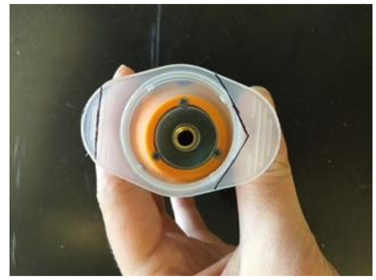


Step 17:

Use four #6 screws to secure the servo to servo mount.

Set this unit aside for now.

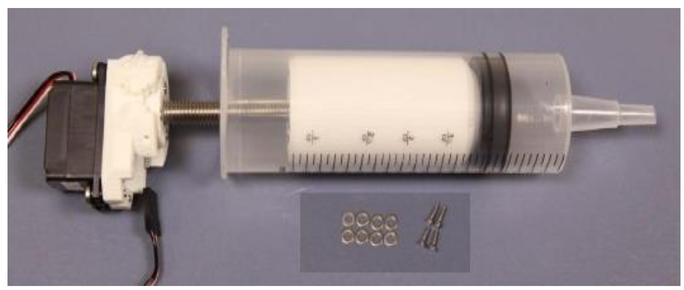
Step 18:



Now you need to cut the flanges on the syringe body so they can fit inside of the glider bottle. Mark one side with a straight line following the second ridge from the outside.

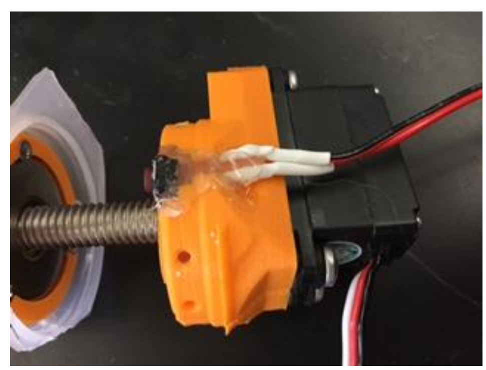
Step 19:

Cut along your dotted lines with scissors. ***<u>Hint:</u>*** The syringe is made of brittle plastic, it's prone to cracking. Cut carefully.



Almost there! It's time to put this whole component together. You will need the servo assembly, syringe assembly, the pushbutton switch, 8 small #4 washers, and 4 small #2 screws.

Step 20:



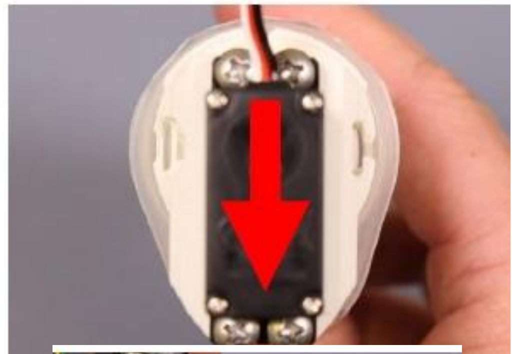
Attach the pushbutton switch to the servo assembly by sliding into the open slot on the side of the servo assembly. Make sure that the button is slightly protruding above the servo mount so that it can be triggered. Hot glue it into place near the heat shrink. Ensure that the glue does not bulge out beyond the servo mount. (Apologies that the 3D printed part in this image is a different color than the rest of the images).

Step 21:

Screw the servo assembly into the syringe component until the plunger about ¼" from the base of the syringe and the servo is flush with the top of the syringe.

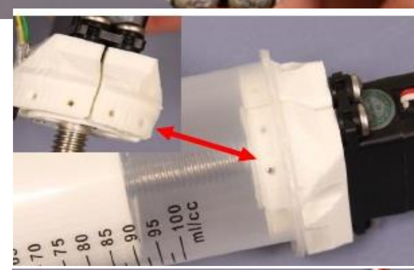
Step 22:

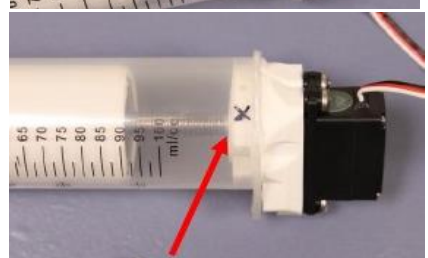
Align the end of the servo with the extended end of the syringe flange that was cut flat in step 19.



Step 23:

On the back (the non-elongated side) there are four holes. With a marker, mark on the syringe plastic where the two outer holes are.



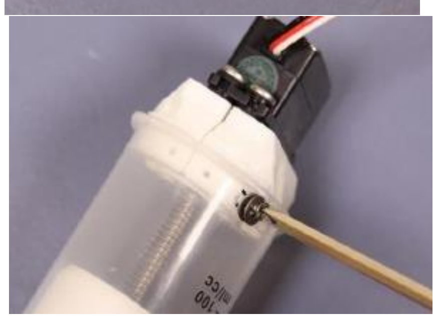


Step 24:

Slightly unscrew the servo unit. Use a pushpin to make a pilot hole where you have marked.

Step 25:

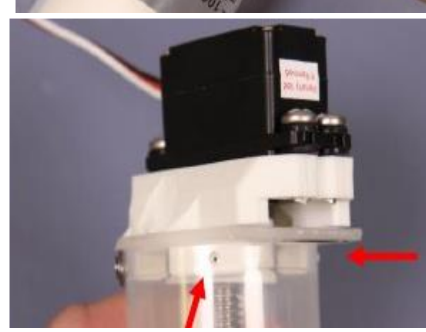
Screw a screw into both pilot holes. Remove it, return the servo to its original position, and put a screw with two washers into the pilot holes until flush. Avoid over tightening. This should now be holding the servo unit in place.



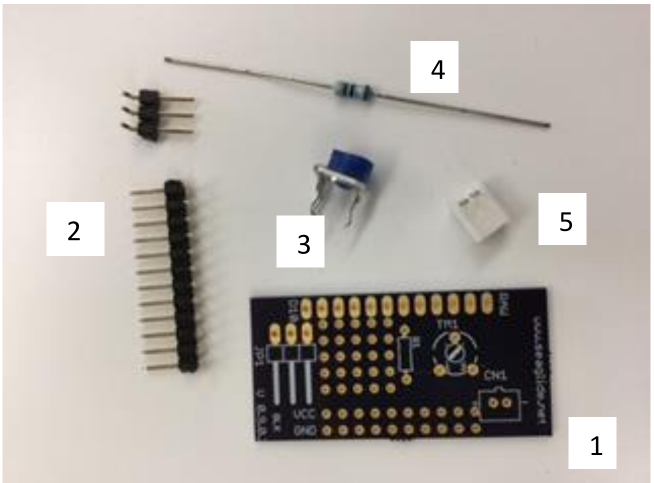
Step 26:

Locate the two holes under the elongated end the syringe flange. Repeat steps 22-24.

VOILÀ! Your buoyancy engine is completed.



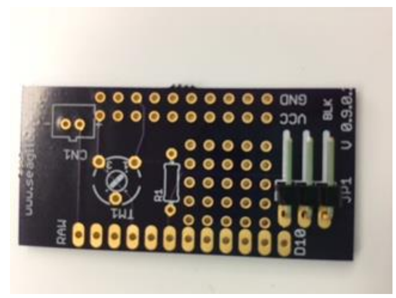
Buoyancy Engine Controller



Materials and Tools needed: Purple Printed Circuit Board (1), 2 right angle headers (2), Potentiometer (3), resistor (4), white power connector (5), soldering iron, solder, safety glasses, wire cutters, electrical tape, a third-hand tool or buddy for soldering

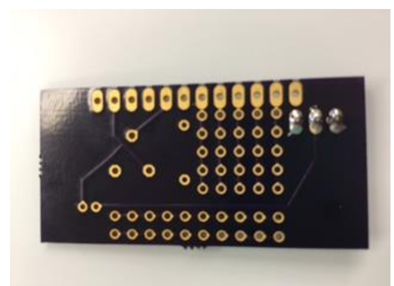
Step 1:

Place 3-pin header in the circuit board as shown.



Step 2:

Flip the circuit board over and solder the pins in place. Using wire cutters, remove the extra pin parts sticking out on the back. It is okay if you cut off some of the solder as well because you want the back of the circuit board to be as flat as possible. Remember the solder will be hot! Also, while you are trimming: the clippings go flying, so it is a good idea to wear safety glasses while trimming off excess material.

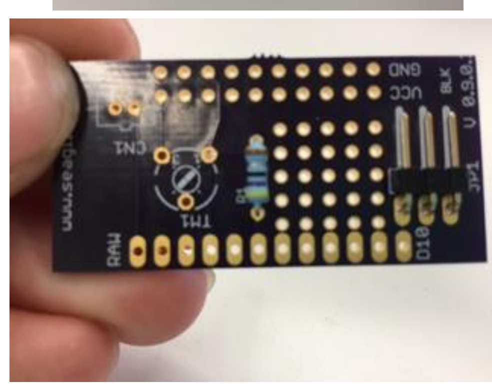


Step 3:

Bend your resistor wires as shown.

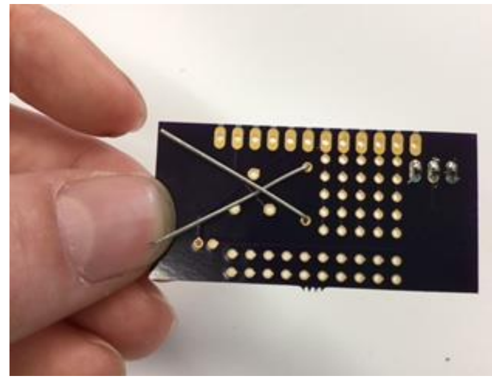
Step 4:

Fit it into the outline labeled “R1”. It can be installed in either direction.



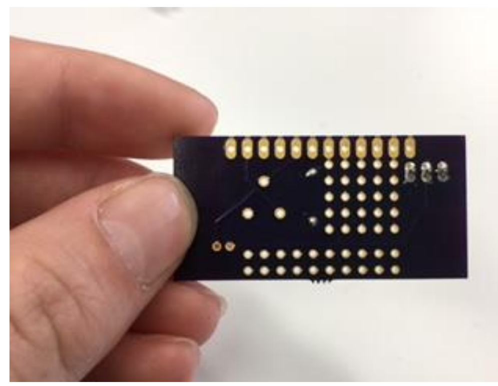
Step 5:

Flip the circuit board over and bend the resistor wires to hold the resister in a low profile position.



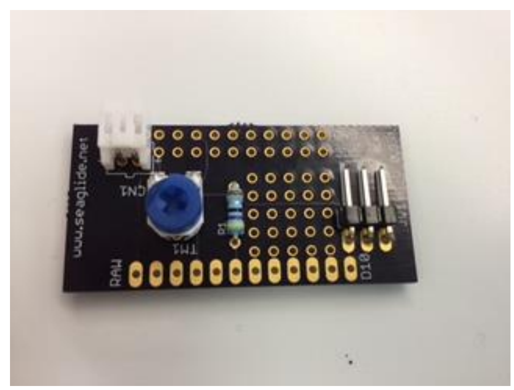
Step 6:

Solder the resistor into place and use wire cutters to trim off excess wire.



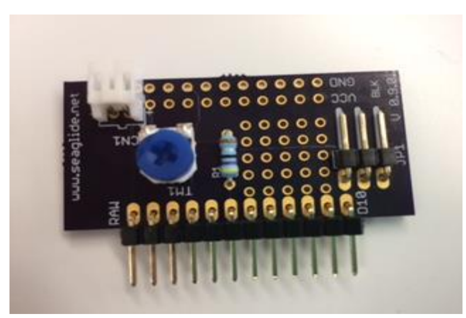
Step 7:

Fit the 10k Ohm potentiometer (POT) and 2-pin JST power jack (PWR) into their outlined positions as shown. Flip the circuit board over and solder the POT and the PWR into position. Trim excess bits off of the back.

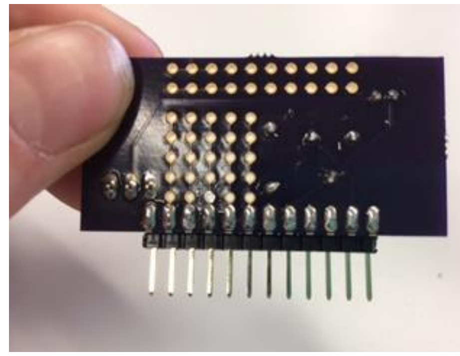


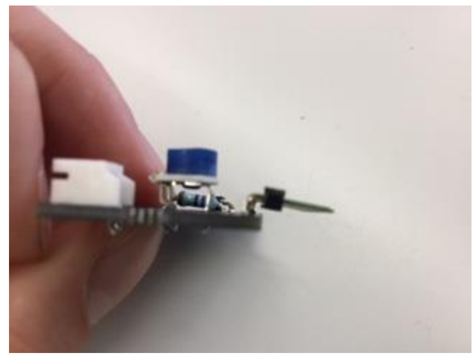
Step 8:

Fit the 12-pin section of header pins into the circuit board as shown.



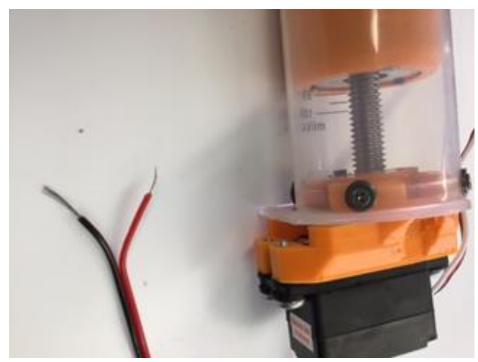
Step 9:





Flip the board over. This is very important: tape the pins into position with electrical tape, use clamps, or have a buddy help you solder this joint. <u>You must have the pins angled downwards so it can later fit into the bottle for your glide.</u> You can also tape over the center of the board to secure the pins while soldering the outer joints, and then remove it to finish soldering. Remove excess pin and solder on the back of the board.

Step 10:



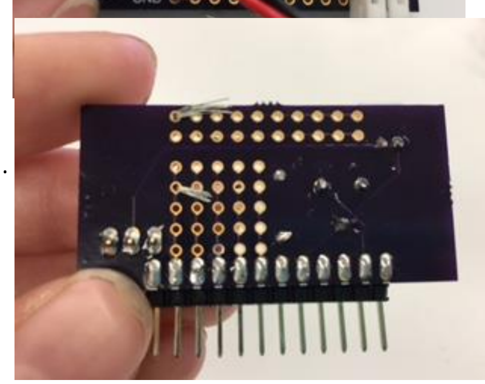
Locate the pushbutton switch that is attached to the buoyancy engine. Split the wires part way down the middle and strip about 1/4 "of the plastic insulation from the ends of the two wires.

Step 11:

Fit the two wires (in any order) into the GND (ground)

hole on the far left and the third whole above that.

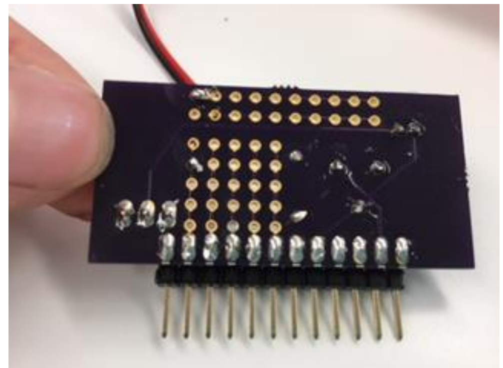
Step 12:



Flip the board over and bend the wires over to secure them.

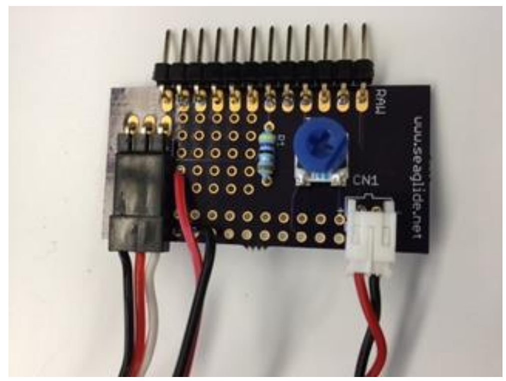
Step 13:

Solder them in place, removing excess wires.

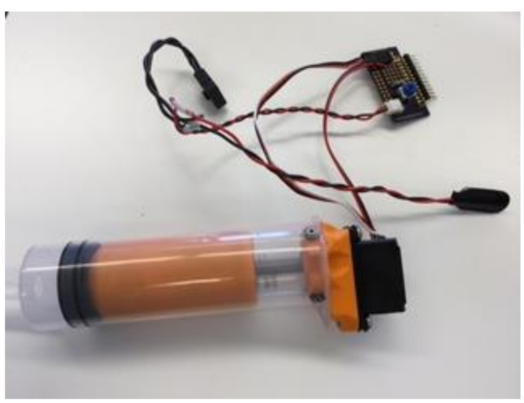


Step 14:

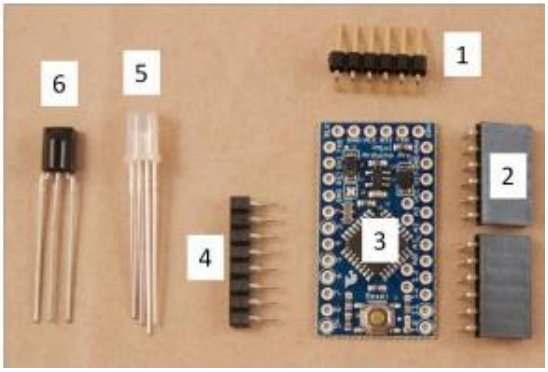
Flip the circuit board over and attach the buoyancy engine servo harness to the circuit board. The ORDER of the color coded wires is IMPORTANT. Attach the harness so that the black wire is with the BLK pin. Also plug in the white prong from the power supply into the white power jack.



Yay! Your Buoyancy Engine is now attached to your circuit board and power supply



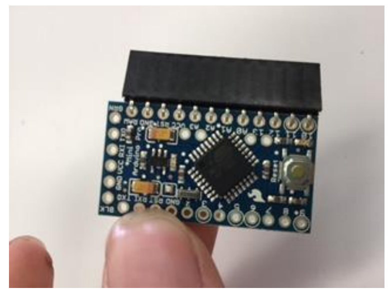
Arduino Pro Mini Build



The Arduino build kit includes one set of male right angle header pins (1), two sets of female right angle header pins (2), an Arduino Pro Mini Board (3), a set of socket pins (4), an RGB (tri-color) LED (5), and an IR Receiver (6).

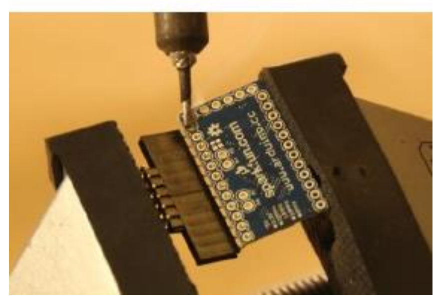
Tools needed: Soldering iron, solder, wire cutters, electrical tape, marker, clamps/buddy for soldering

Step 1:



Attach a female right angle header 12 pin to the Arduino. If you have two 6 pins, that works the same. Solder them side by side as shown.

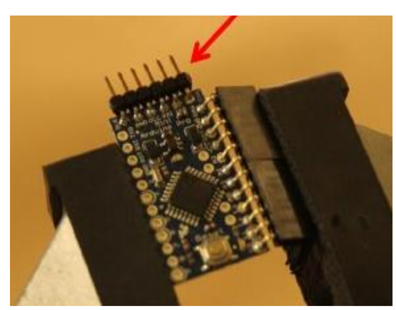
Step 2:



Flip the Arduino over. Be sure that the female header pins are at an angle in relationship to the plane of the Pro Mini. <u>It is very important that they are at an angle.</u> This helps it conform to the shape of the buoyancy engine. Solder the joints. This is a good time to use clamps or a buddy to hold the pins in place. If you solder the ends and two middle pins first, the pins will be secured in place and it will not move as you finish soldering.

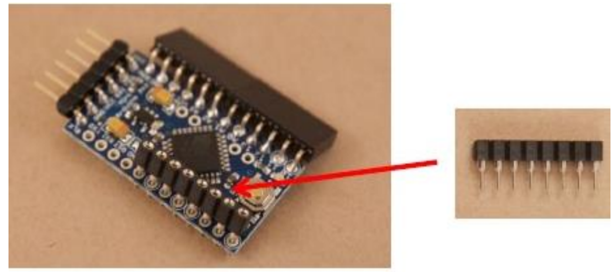
Step 3:

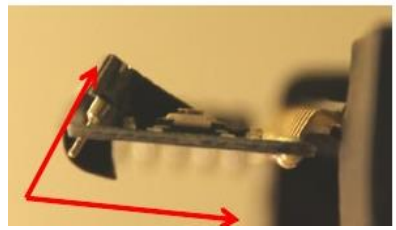
Solder the male header 6 pin on to the end of the Arduino. The six longer pins should stick straight out from the board.



Step 4:

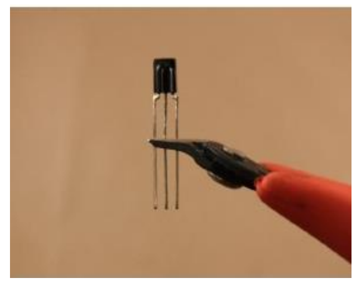
Position the socket pin onto the Arduino as shown. Make sure that the socket pins are at an inward angle in relationship to the Arduino. Use clamps or a buddy to hold them in place while you solder the joints on the back of the board. Trim excess.





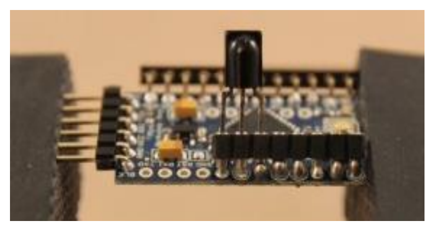
Step 5:

Prepare the IR receiver for attachment by cutting the leads in half.



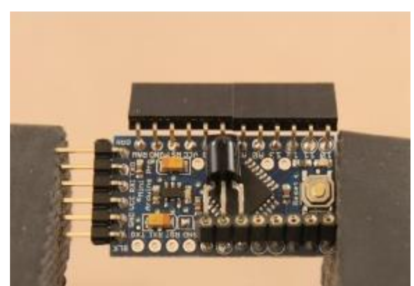
Step 6:

Orient the IR receiver with the photo detector “bump” outward and the leads aligned with the first three sockets in the socket pin row as shown. Press the receiver firmly in place.



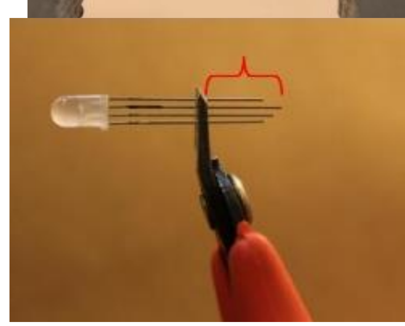
Step 7:

Bend the receiver nearly flat against the Arduino.

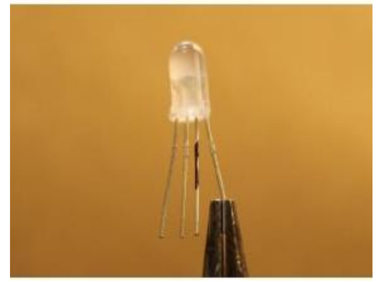


Step 8:

Locate the RGB LED and identify the longest lead. This is the common ground lead. <u>Use a marker and color the top of it so you know which lead is black</u>. Clip all of the leads in half.



Step 9:

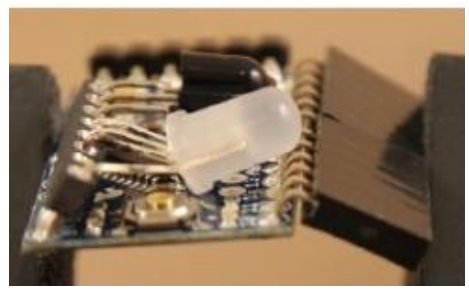


Separate the leads and use needle nose pliers to bend the outer most wire (adjacent to the marked lead) as shown. The tips of the leads should be roughly parallel to one another.

Step 10:

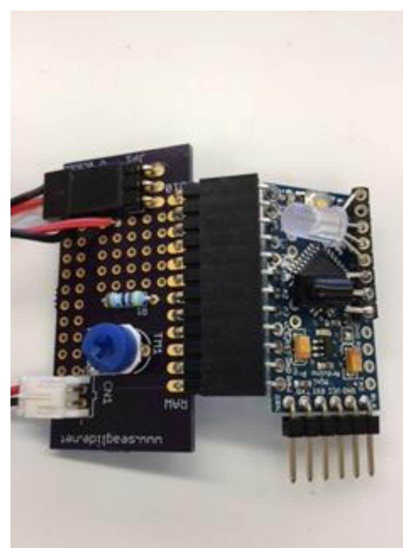
Fit the LED into the open socket pins next to the receiver. Notice that the socket that is second from the right is unoccupied. The ground pin should be at socket #7 (labeled on the Arduino). Press firmly into place. Note the black sharpie marker in the photo.

Step 11:



Bend the LED so that the bulb nearly touches the Arduino as shown.

Step 12:



Now, just plug the circuit board into the Arduino!

All done with that! Congratulations, you're almost there!

Bottle Prep and Ballasting

Parts needed: 700ml Nathan Tritan Flip-straw water bottle, 3D printed wing-yoke and rudder mount, brass ballast weights, sheet of polystyrene, 5 #6 thread-cutting screws

Tools needed: Silicone sealant, electrical tape, box cutter, zip ties, needle nose pliers, marker

Step 1:

Remove the nozzle from the cap and unscrew the cap.

Step 2:

Remove the air hole (the hole closer to the center of the cap) plug from cap (use needle nose pliers to get it out easier).

Step 3:

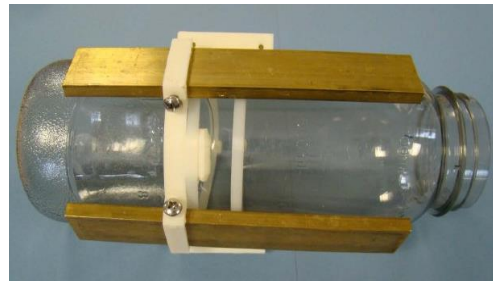
Place the rudder mount on the cap. Flip the cap over, and screw the rudder mount in place with a #6 thread-cutting screw. Seal the screw hole with silicone sealant. This will require some drying time. *Make sure it will watertight.* This is essential.

Step 4:

Position wing yoke on bottle and secure with two large black zip ties.

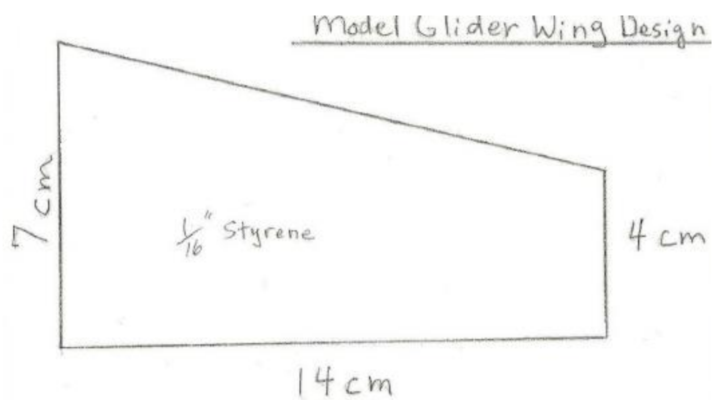
Step 5:

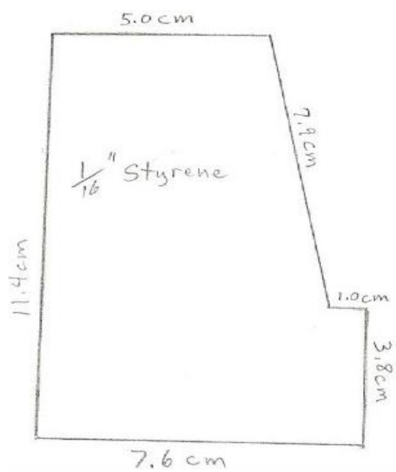
Slide two 6” steel ballast weight through the slots in the wing yoke. Secure with the screws provided. Find the weights with the sticky backs. Start with 4, and add more weights as needed. Peel off the protective backing and stick the weights on the underside of the bottle.



Step 6:

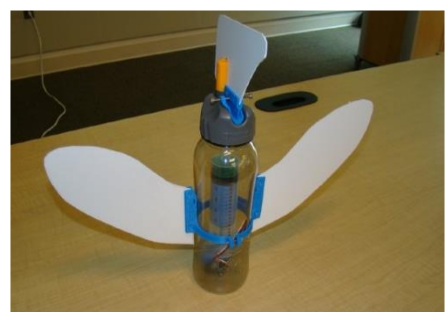
Cut two wings and a rudder from the polystyrene sheet. The images show basic designs. Feel free to be somewhat creative with your pieces.





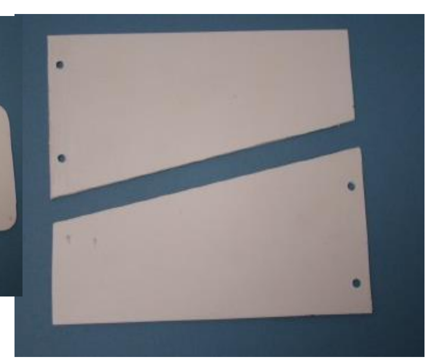
Step 7:

Fit the wings into the wing yoke and the rudder into the rudder mount. Mark the drill holes and remove for drilling.



Step 8:

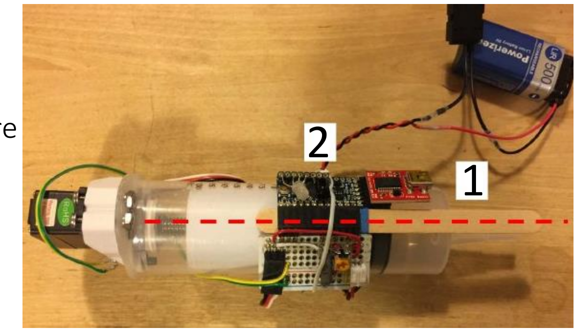
Drill 9/64” holes in marked positions through the wings and rudder. Refit the wings and rudder into the wing yoke and rudder mount. Secure with screws provided.



Buoyancy Engine Final Preparations

Parts needed: Popsicle stick, small white zip ties (1 long one, 1 short), completed Buoyancy Engine, Power Supply

Step 1:

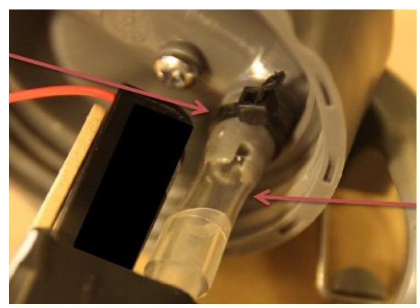


Use tape to attach a popsicle stick in line with the extended (tall) flange end of the syringe. ***Hint:*** Make sure the popsicle stick doesn't extend beyond the tip of the syringe.

Step 2:

Use a thin, long white zip tie to attach the controller on top of the popsicle stick in the middle of the syringe. Secure the push-button switch with electrical tap to the top of the popsicle stick.

Step 3:



Use clear tubing to connect the syringe tip to the cap's interior nozzle. Secure the connection with the small white zip tie provided. ***Note:*** the position of the black zip tie in the picture to the right. ***Hint:*** The clear tubing might need to be cut shorter. If left too long, the tube will bind when the bottle lid is screwed on.

Step 4:

Attach the battery to the power supply unit. Tape the push-button onto the popsicle stick.

Step 5:

Fit the entire unit into the water bottle. Screw the lid on tightly. *Hint:* the electronics can be tough to fit into the bottle. Sometimes putting the battery in first helps.

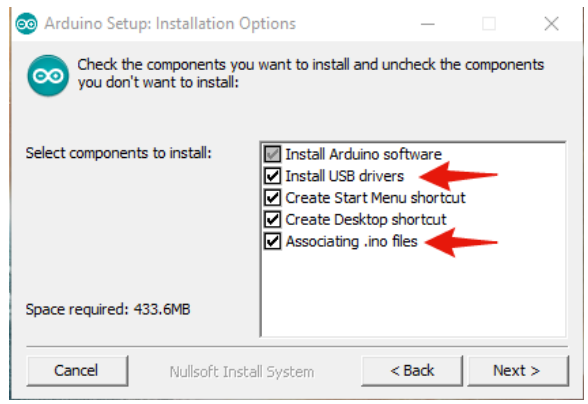
Arduino PC Installation

Step 1:

Go to http://www.arduino.org/downloads and download the appropriate installation file for your operating system.

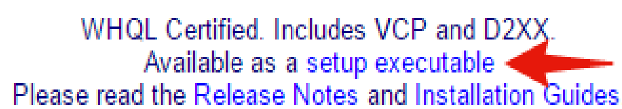
Step 2:

Open the installer and follow the steps to install the Arduino IDE. During installation, make sure to check the boxes that say Install USB Drivers, and Associate .ino Files.



Step 3:

Now that the Arduino IDE has been installed, go to http://www.ftdichip.com/Drivers/VCP.htm and click on the link that is appropriate for your operating system. If you are on Windows, click on the link on the right-hand side of the screen that says "setup executable".



Step 4:

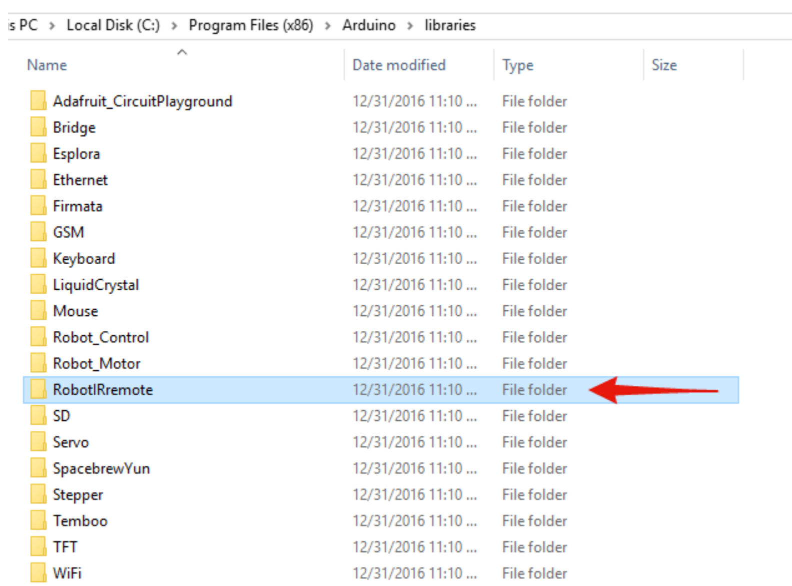
Once the file has downloaded, right click and extract the file. After extracting the file run the setup to install the FTDI drivers needed for communicating with the SeaGlide.

Step 5:

Navigate to the installation directory of your Arduino IDE. On Windows, this is located at:

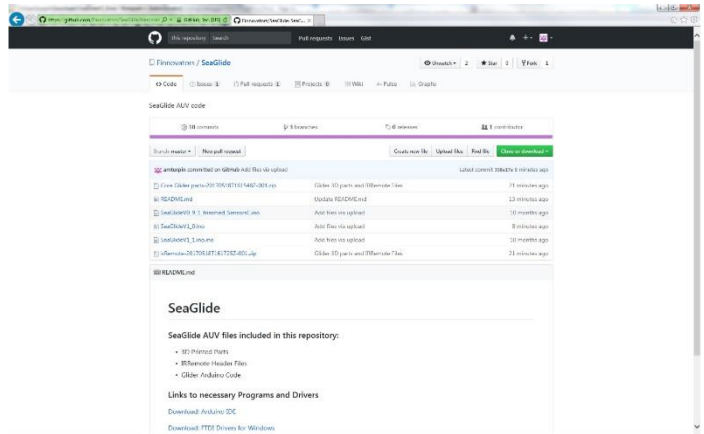
C:\Program Files (x86)\Arduino\libraries.

Find the file named "RobotIRremote" and <u>DELETE</u> this file. Our SeaGlide code uses a different library for controlling the IR receiver.



Step 6:

Go to https://github.com/Finnovators/SeaGlide And download the zip folder named IRremote. Make sure to download the entire folder. Once the file has downloaded, you will once again need to extract it by right clicking and selecting extract.



Step 7:

Move the IRremote folder into the same Arduino libraries directory that was mentioned in Step 5. This IRremote library is replacing the one that comes with the Arduino IDE.

Step 8:

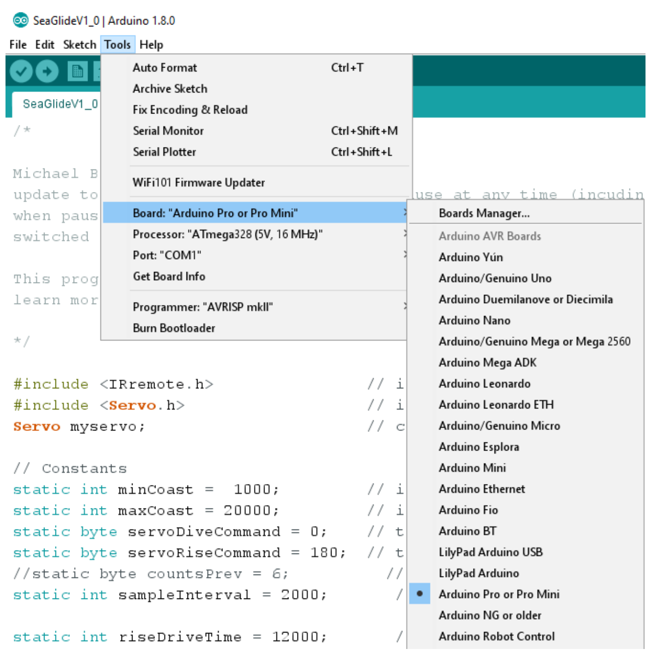
Now you are ready to download the code needed for the SeaGlide. Once again go to https://github.com/Finnovators/SeaGlide and download the file named "*SeaGlideV1_0.ino*." This is the Arduino code for the glider.

Step 9:

Double clicking on this Arduino code should open up displaying all of the code. If the Arduino IDE asks for the file to be put in its own folder, go ahead and click OK.

Step 10:

Click on ***Tools*** menu, go down to the ***Board*** selection, and choose ***Arduino Pro or Pro Mini***. If a different Arduino board is selected the code will have errors and will not run correctly.



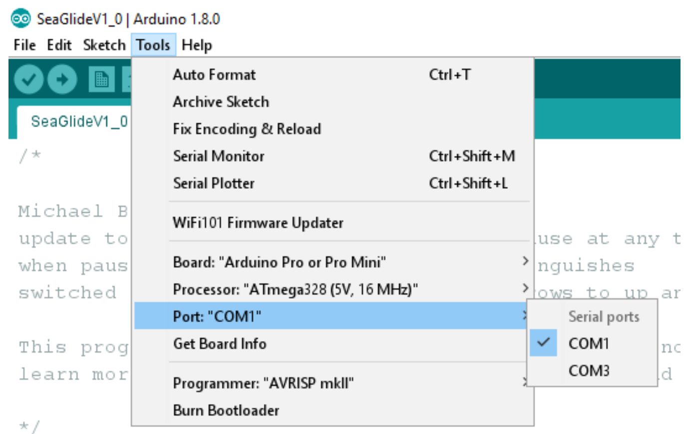
Loading the Arduino Code

Step 1:

Now that the Arduino IDE has been installed and configured, you are ready to load the code onto the glider. Click on the checkmark seen in this picture to compile the Arduino code.

Step 2:

Make sure that the red FTDI board is connected to the Arduino on the SeaGlide. This will allow communication from the USB cable to the Arduino board. Plug USB cable into the small port on the FTDI board, and plug the other end into your computer.



Step 4:

Once again, click on the Tools menu in the Arduino IDE and go down to the Port option. This should bring up a list of the available Arduino communication ports. Select the COM port that is available. If there are multiple options, you will need to test each one until the code successfully loads onto the Arduino.

Step 5:

Click on the Arrow button next to the checkmark in the Arduino IDE. This will upload the code to the Arduino on the SeaGlide. Toward the bottom of the screen you will first see it “Compiling” and then it will say “Uploading,” once the IDE says “Done Uploading,” the SeaGlide is ready for use.

YOU HAVE COMPLETED A SEAGLIDE! CONGRATULATIONS! *