SeaMATE PufferFish ROV Kit Assembly Instructions

1. Assembling the Frame

Time Required: *1 to 5 hours depending upon the complexity of the frame.*

Tools Required: *PVC cutter, ruler, pencil, sketch pad, or engineering notebook.*

Tools recommended: *Drill and drill bits if you decide to use sheet metal screws.*

Parts Required: *½" PVC pipe (10-20 feet depending on ROV size), PVC connectors (20-30 depending on complexity) such as Tee's, Elbows, and Crosses etc.*

The frame can be fairly simple or involve a bit of experimenting. We recommend taking your time to come up with a design you are happy with. Sketch out ideas, build a model! If you want to get fancy, you can run your wires inside the PVC pipe for a nice clean look. You can even purchase colored PVC at *http://www.simplifiedbuilding.com/blog/color-furniture-grade-pvc- fittings-now-available/* (this is a special order and a bit more expensive than white PVC – see Photo 1).


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3

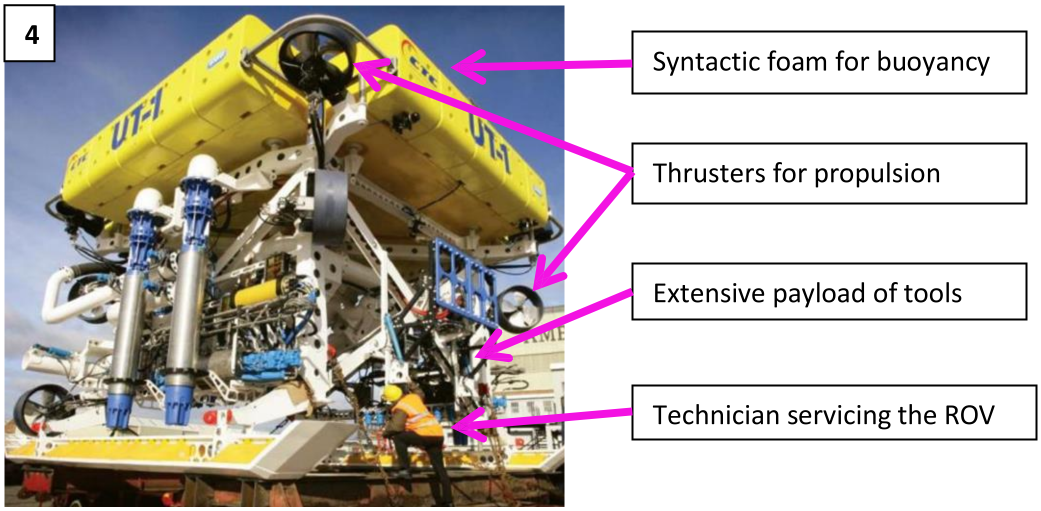
The PufferFish comes with three PVC motor mounts, which are 1¼ x 1¼ x ½ inch reducing T's with the ends cut off (Photo 2). The Johnson bilge pump motor will fit nice and snug into the motor mount once the sticker is removed. This motor mount makes it very easy to attach the motors to a PVC frame. If you would like to run the wires inside the frame, drill a ¼" hole on the base of the mount and run the wires through the hole.

Here are a few guiding principles to help steer the frame design process:

I. Bigger is not necessarily better. Think about the tasks that the ROV needs to accomplish and build with that in mind. Most ROVs are built for a mission or series of missions; see the MATE ROV competition guidelines for examples. Some questions you may want to ask – What type of tools and/or sensors will you want to add to your ROV? Will your ROV need to fit in tight or dark spaces? Will you want to pick up any objects off the bottom?

II. Water will need to flow freely in and out of your frame. Using PVC T's as corner pieces can make this easy (Photo 3); otherwise you might need to drill a lot of holes in your frame to accomplish the same thing.

III. Think about stability. Some designs will be very stable (not likely to roll belly up like a dead fish) and others may act like Spinner Dolphins. Look at photos of commercial ROVs and discuss their designs and how they relate to stability in the water (Photo 4).



IV. Neutral buoyancy is optimal (i.e. your ROV doesn't float, doesn't sink). If you are working with foam (Photo 5) or material that can compress under pressure (can you squeeze it in your hand?) and you want to fly your ROV to the bottom of a deep pool or use it in the ocean or a lake, you could end up with a mini anchor if you are not careful (i.e. your ROV may be too heavy to come up under its own power). Experimenting with foam is great and easy. Once you have a design you are happy with, think about using closed containers or PVC pipe sealed off with end caps to create rigid, non-compressible buoyancy (Photo 6).

V. Think about the placement of your buoyancy. Would you ever jump in the ocean with a life jacket around your feet? Motors are heavy in the water and foam is light. Think of how you might want to position these materials on your ROV for maximum stability.

VI. PVC joints can be secured by using PVC cement but this is generally not necessary, a few modest taps with a rubber mallet is generally enough to hold the frame together. PVC cement also makes the joints brittle and more likely to crack. Another way to secure PVC joints is to use stainless steel sheet metal screws[1], which allows you to take the frame apart and reassemble it (Photo 7). Sheet metal screws require pre-drilling at the joints before adding the screws. Screws are especially needed for colored PVC which is more slippery, but generally not required for white PVC.

[1] 18-8 stainless steel, Phillips, No. 6 Size, 1/4" Length

2. Assembling the control box

Time Required: *1 hour*

Tools Required: *Soldering iron, solder (we recommend 60/40 Rosin Core Solder in .032" (0.08mm) diameter), wire snips, wire cutters, wire strippers, utility knife, Philips screwdriver, ruler with metric scale. If you are unsure of which tools is which, reference Photo 40 at the end of the instructions.*

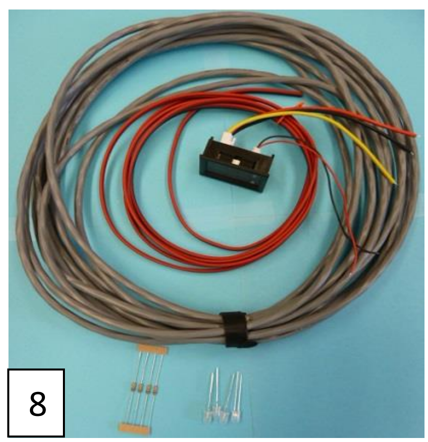
Tools recommended: *Solder sucker to remove hot solder if you make a mistake.*

Parts Required: *Pre-drilled Pufferfish project box, Printed Circuit Board (PCB), components, and wires which are listed below.*

[Notes on solder: Leaded solder is easier to use because of its lower melting point so the soldering iron does not have to be as hot or held to the board as long. Lead-free solder has more flux (acid) in it, which can irritate the eyes if hands are not washed after soldering. Wash hands before and after soldering.]

The following PufferFish components need to be soldered to the PCB (Photo 8):

a. Resistors (4)
b. LEDs (4)
d. Red/Black power wire: 2 solder joints
e. Motor wire: 6 solder joints
f. Amp & volt meter wires: 5 solder joints.



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If you are unfamiliar with soldering, watch some videos on how to solder and how to tin your soldering iron. One of the problems that can occur with cheap soldering irons is that they may not get hot enough or they may get too hot. Soldering should be fairly straight forward if you have a good soldering iron. Read the reviews on soldering irons before you buy. MATE also sells practice mini-printed circuit boards. If you are doing this activity with a number of people who have not soldered before, we recommended soldering the practice board first. Here is a good video on soldering components to circuit boards.
http://www.youtube.com/watch?v=I_NU2ruzyc4&feature=youtu.be

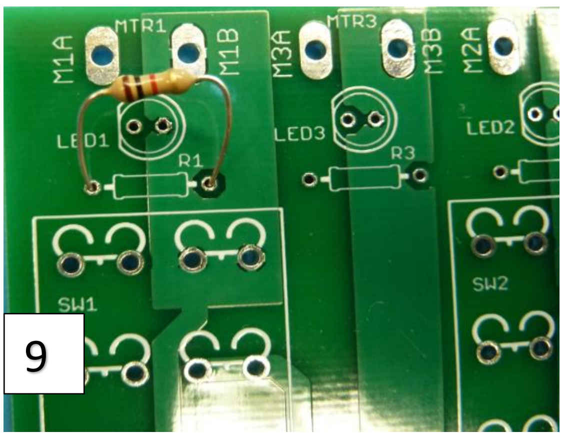
When soldering all of the components, it is important that they do not move while you are soldering. Use electrical tape to hold the components in place if they are not secure.

Note: The front of the circuit board (PCB) has printed words; the back of the board does not.

You insert the components on the front of the board and solder on the back. **However** the wires for power to/from the battery, to/from the motors, and to/from the volt/amp meter are fed through the back of the board and soldered on the front.

Solder the components and wires in the following order:

A. **Resistors** (4): – **Orientation DOES NOT matter.** Bend resistor leads (metal on either side of resistor) and insert the two ends into any of the R1-4 holes (Photo 9). Splay the leads as they come through the back of the board to hold the resistor in place (Photo 10). Solder the leads to the back of the board; the solder joints should look like mini, shiny, silver Hersey's Kisses. Solder all 4 resistors into place. Clip the ends of the leads off with snips.



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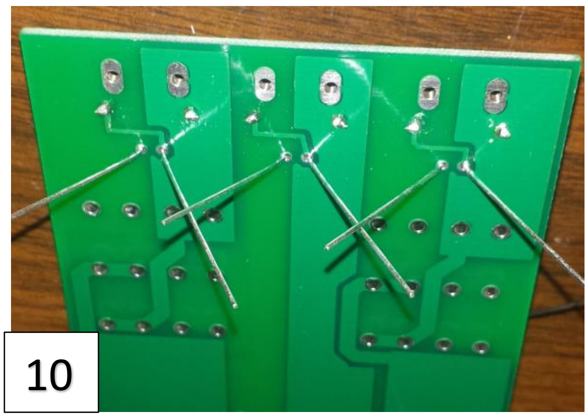
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Learning to read the resistor code is helpful. *Do you know why we need to use resistors for the LEDs? How many Ohm's of resistance do these resistors provide?*

B. **LEDs** (4): **Orientation DOES matter.**

Look carefully at the LED; it is almost circular, but if you look closely, one side is flat and has a shorter lead. Look at the LED symbol on the PCB board; one side is flat. Insert the LED so the flat side matches the PCB board and then solder the leads. These are special bi-polar LEDS. The color will change with polarity change.

Flat side of LED aligns with flat side of LED symbol on the board.

11

C. **Stress relief connectors:** There are four stress relief connectors in the kit; you will use the smaller diameter connectors (3/8") for this step. Each of the 3/8" connectors has 3 parts (Photo 12). The nut will be on the inside of the box and the other two pieces will be on the outside of the box. To avoid a cable cross-over later, put the shorter relief on the side closer to the edge of the box and the longer relief closer to the center of the box. (Photo 13). Screw the nut to the connector so that they are fastened to the box (Photo 13). Feed the red/black power wire through the shorter connector. Secure the cables with ~30 cm of cable through the bottom of the box by twisting the dome and holding the middle piece that is outside of the box in place. By tightening these two pieces, the cable will be squeezed which will help ease the pull on the cables later on. Do not make it too tight at this time; the cables should feed through with slight resistance.


1

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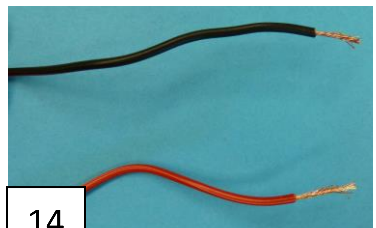
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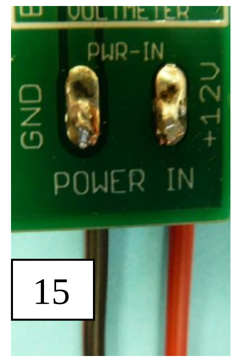

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D. **Power cable**: Your red/black power cable should be fed through the dome-shaped stress relief connector into the control box. Separate the red and black wires 6 mm from the end and strip 4 mm of insulation off the end of each wire (Photo 14). Look for the PWR_IN on the PCB. The red (positive) wire is soldered to the +12V hole and the black (negative) wire is soldered to the GND (or Ground) (Photo 15) Twist the copper ends and feed the wire through the proper hole (12+ or GND) from the *back of the board to the front*, fold over and solder to the front of the board. Do the same for the other wire. It is important that your wires and solder DO NOT exceed the footprint of the silver metal pads (Photo 15). Sloppy soldering can short out the system. After soldering, cut any extra wire off with the snips like you did with the component leads.

E. **Motor cable**: The 18/6 gray motor cable should be fed through the long stress relief connector into the control box at this point (Photo 16). Carefully use a utility knife to cut open part of the gray sheath and tear it away; be careful not to nick or cut any of the wires inside the sheath. You should see 6 stranded copper wires surrounded by 6 different colored sheathes. You may also see a feathery string. The feathery string may help split open the gray sheath as you pull down on it. Remove about 5 cm of gray sheath. Trim off the gray sheath and the string. Strip 4 mm of insulation off the end of each of the colored wires (Photo 17a).

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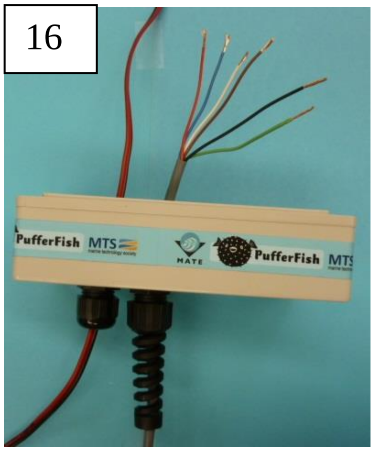
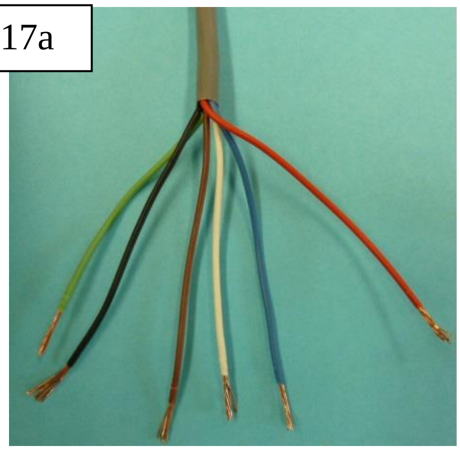


17a



17b

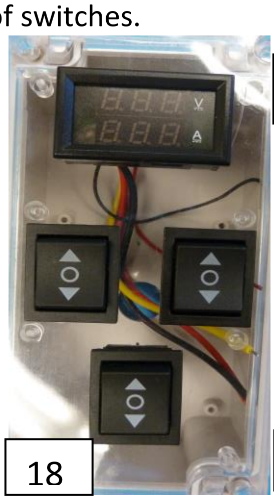
It is important to make sure the control box wiring matches the motor wiring. For example:

Motor / Switch	MTR1 Left Switch	MTR3 Center Switch	MTR2 Right Switch
Wire / Pad Pairing	Green(+) = Pad A White (-) = Pad B	Brown (+) = Pad A Black (-) = Pad B	Red (+) = Pad A Blue (-) = Pad B

Solder the wires to the board following the key above or make up your own. The pattern does not matter; just make sure you have a pattern that you remember! The front of the board should look like Photo 17b.

F. **Ammeter and Switches** (3): The ammeter provides a reading of the voltage and the current going through the PufferFish. The switches are double-pole, double-throw (DPDT) rocker switches. DPDT switches allow the motors to run in forward and reverse by switching the direction of electricity flowing through the DC motors (and thereby reversing the rotation of the motor.) All three switches and the meter come pre-installed on the *bottom* end of the lid (Photo 18)

See **https://learn.sparkfun.com/tutorials/switch-basics/poles-and-throws-open-and-closed** for an overview of switches.



Top of lid

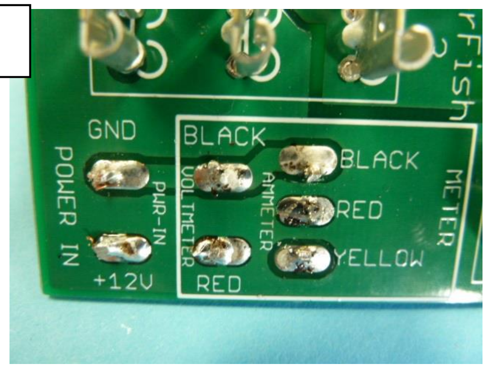
Bottom of lid

18

G. **Amp/Volt Meter Cables**

The cables with the white connectors on the ends connect to the amp/volt meter. Feed the pre-stripped cables through the *BOTTOM* of the circuit board and bend carefully as before to keep the wires in place. The colors of the wires need to match the colors written on the front of the circuit board. (Photo 19) Solder the wires on the front side of the PCB board.

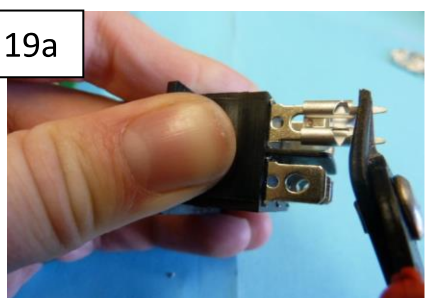
19



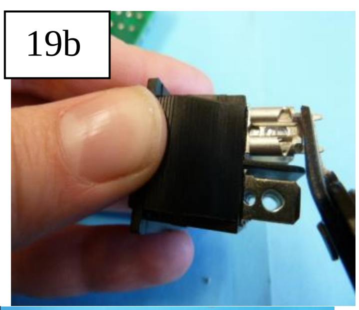
H. **Switch Connectors** (18)

We will use connectors to provide a method to fasten the switches to the circuit board; this allows the switch to be removed at a later date without de-soldering. The connectors have a flat side and a curved side. With the switches popped in the lid, the curved side should be installed toward the top of the box (reference Photo 18 for "top"). The curved ends should also line up with the curved drawing on the PCB board (Photo 20a/b). The connectors will snap into place when secured. You may need a tool, such as snips or needle nose pliers, to snap into place without bending the pins (Photo 19a/b).

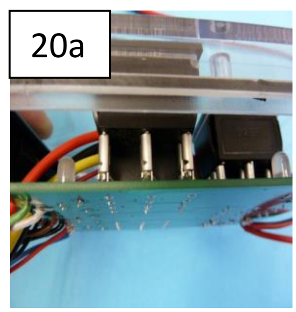
19a



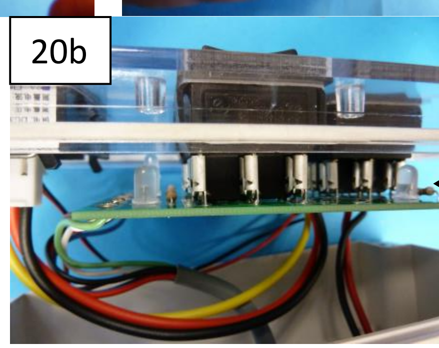
19b



20a



20b

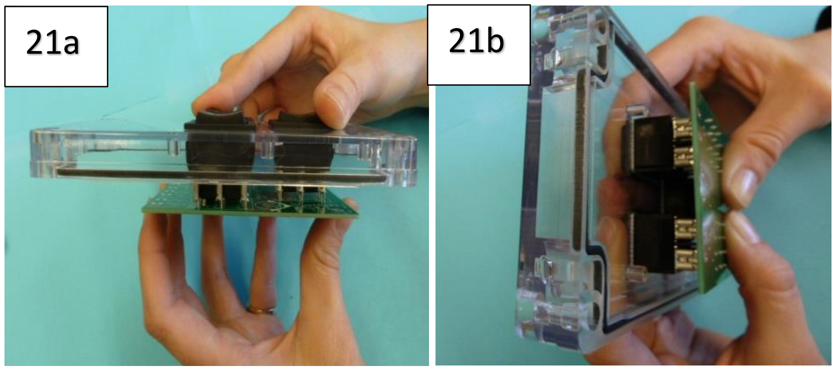


Curved ends point towards the top half, towards the ammeter

I. **Soldering Switch Connector terminal pins to the Circuit Board**

With the terminal pin connectors now attached to the switches in the lid, patiently line up the 18 connector terminal pins with the holes in the circuit board (Photo 21a/b).

Once aligned, push the board down onto the pins so that they stick out slightly on the back side of the PCB. On the back of the circuit board, solder all 18 pins, taking time to apply enough heat to properly melt the solder and allow it to flow around the pins.



J. **Check that all LEDs and switches work**
Separate 6 cm of the other end of the red/black power cable and strip off 25mm of insulation so that there is only copper left. Connect the open ends (the copper parts) to a power source. We recommend a 6 volt lantern battery or a four pack of AA batteries (6 volts) for testing the boards. Alligator leads are helpful for attaching the batteries to the copper wires.

Does the power LED turn on? Is it green? If it is red something is backwards. Do your switches work? As you press the switch towards the top of the board the LED should turn green (forward); as you push the switch towards the bottom of the board the LED should turn red (reverse). Test all the switches and LEDs. If the colors are reversed, something is backwards. If a light does not come on, check your soldering connection. *The switches are assembled with grease inside; you may need to rock the switch a number of times for a contact to be made the first time the switches are used.*

K. **Attach the Amp/Volt Meter Wires to the Amp/Volt Meter**
Using the white, plastic connectors on the cables of the Amp/Volt meter, attach the cables to the back of the meter which should be already snapped into the lid of the control box.

L. **Close up the control box.**
Mount the lid by aligning the four corner holes and securing them with screws. Then adjust the motor and power cables by pulling on them from outside of the box so you have just a little cable in the box. ***Tighten*** the stress relief connectors that are on the outside of the box so the cable does not slide. Use tools such as pliers or small channel locks to tighten the connectors until they are flush with each other. As you tighten these reliefs, they should squeeze on the cables so that there is no stress when the box and the cables are being pulled on.

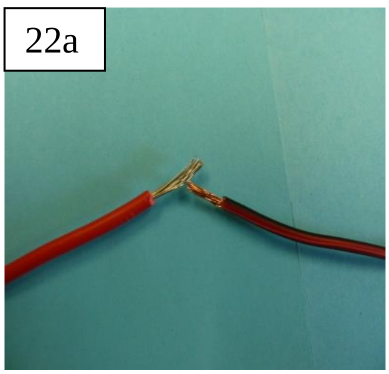
3. Adding the Fuse holder to the power wire and adding the Banana Plugs

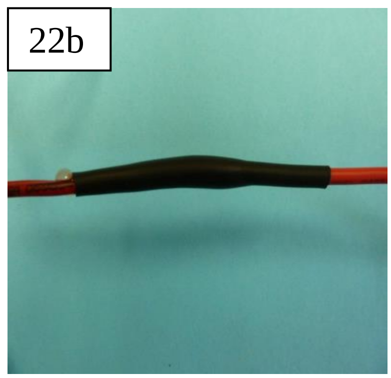
Steps 3 and 4 will require you to splice and seal wires.

Time required: *30 minutes*
Tools required: *Wire cutters, wire strippers, soldering iron, solder, hot glue gun, heat gun*
Parts required: *Power wire, blade fuse holder, 10 or 15 amp fuse, heat shrink, hot glue, banana plugs*

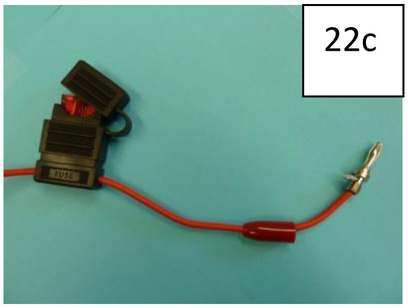
Give your glue gun and soldering iron enough time to heat in advance. Your red/black power wires should be soldered to your control board and run through the stress relief connector out through the bottom of the box.

A. At the unattached end of the power wire, separate the red and black wire for about 28 cm (You originally separated it only 6cm)
B. Cut the red wire power wire so it is 25 cm shorter than the black wire.
C. Strip 25 mm of insulation off of each end of the blade fuse holder and the red and black wires.
D. Slip 50 mm of black heat shrink tubing over the red wire then twist the red power wire and one end of the blade fuse wire together and inspect. (Photo 22a/b)





E. Cover one side of the joint with hot melt glue, let cool, then cover the other side with hot melt glue and let cool.
F. Slide the heat shrink tubing over the solder joint. (If the heat shrink cannot fit over the glued area, snip off just a little bit of glue around the joint until the heat shrink fits over it. Completely heat the joint with your heat gun. As the tubing shrinks, the glue will re-melt and may come out the sides. The result should be completely smooth and water tight (Photo 22b).
G. Check to see that the red and black wires are even in length. If not, trim evenly.
H. Match the red banana plug with the red wire. Unscrew the plug and slide the colored, plastic half onto the red wire with the narrower end facing towards the fuse holder. Insert the stripped end of the wire through the threaded, metal part of the banana plug and push the copper through the hole and upwards leaving the hole visible (Photo 22c).


22c

I. Solder the copper wire at the hole, clip off excess wire, and screw the banana plug back together. Make sure the wire is secure.
J. Repeat these steps for the black wire.
K. Insert a 10 or 15 amp fuse into the fuse blade holder.

4. Adding the propeller to the motors

Time required: *30 minutes*
Tools required: *Loctite or some other thread adhesive, small hex wrench (included), Phillips head screwdriver*
Parts required: *Motors (3), propellers (3), screws (3), nuts (3) and propeller adapters with small hex set screw (3)*

The motors should be mounted in the motor mounts at this time (See Step 1).

A. Thread the large screw through the propeller so the indented end of the propeller is opposite the screw head (Photo 22).
B. Slide your nut onto the screw until it meets the notched side of the propeller. Add a drop of Loctite to the end of the screw Insert the screw into the back of the propeller adapter (the side further away from the small hex set screw). Use a screwdriver to tighten the screw into the propeller adapter (Photo 22).
C. Remove the impeller from the motor by popping it off with something flat such as a screw driver or snips. (Photo23).
D. Loosen the small set screw in the side of the propeller adapter with the hex wrench. Slide the propeller adapter onto the motor shaft. Align the propeller adapter so the small set screw is oriented against the flat side of the motor shaft (the set screw should tighten down against the flat side of the motor shaft). Apply a drop of Loctite near the tip of the set screw and screw back into the propeller adapter.
E. Make sure the propeller assembly is snug (Photo 24).

22


23


24

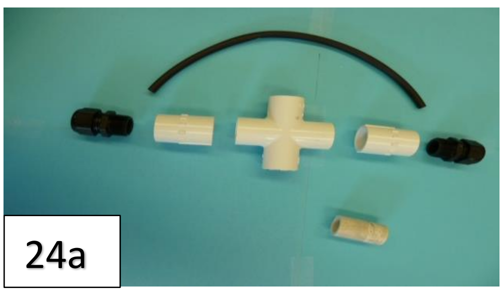
5. Making the Tether Management Cross

Time required: *1.5 hours*
Tools required: *Wire snips, PVC cutters, wire strippers, soldering iron, hot glue gun, heat gun, scissors, pliers (2 pair)*
Parts required:

- *For the Housing: Heat shrink, half-inch dome connectors (2), half inch PVC threaded/slip fitting (2), PVC cross, scrap ½"PVC pieces*
- *For the wiring: 18/6 grey motor cable, motors, heat shrink, hot glue*

The "Cross" is your tether security. It will help to relieve stress on the wire connections. The different parts of the cross are broken down in Photo 24a.

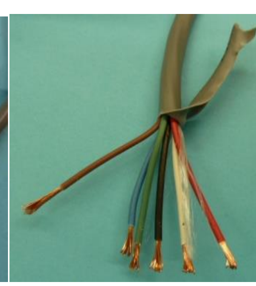
Screw the black, ½'' dome into the ½'' PVC slip. Tighten with pliers until the bottom, black bolt *(not the dome bolt)* and the PVC are flush. Since your frame is built, you should have some scrap PVC left over. With PVC cutters, slice 2 PVC pieces that are four cm long from the scrap. Insert one side of the 4cm slice into the open end of the slip with the dome screwed into the other side. Next, slide any end of the cross around the other end of the sliced PVC. It should look like (Photo 25).

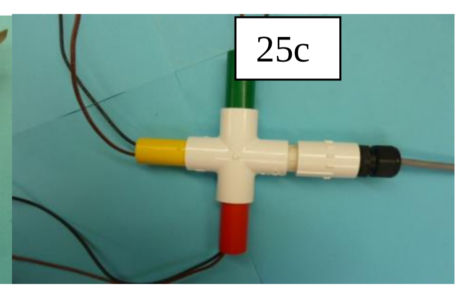

24a


25

A. Feed the 18/6 cable through the black dome piece attached to the "cross" (Photo 25a) you have assembled so far and pull a couple feet through. Strip off 5 cm of the outer sheath from the grey motor cable. Inside, you will see 6 colored wires. Be careful not to nick them when you cut away the grey sheath. You will also see a feathery string, you can pull this to help remove the sheath. Trim away the string and the grey plastic sheath. Strip 25mm off the ends of the six colored wires (Photo 25b). **[Note: If you run the motor wires through the frame, you will not need the second PVC slip or dome shaped stress relief connector (Photo 25c)]. This photo is showing you how the wires would come together is you ran them through the frame. Obviously the majority of the frame has been removed for the photo.**

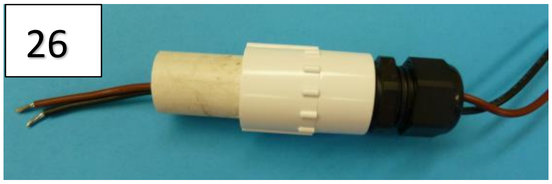
25a


25b


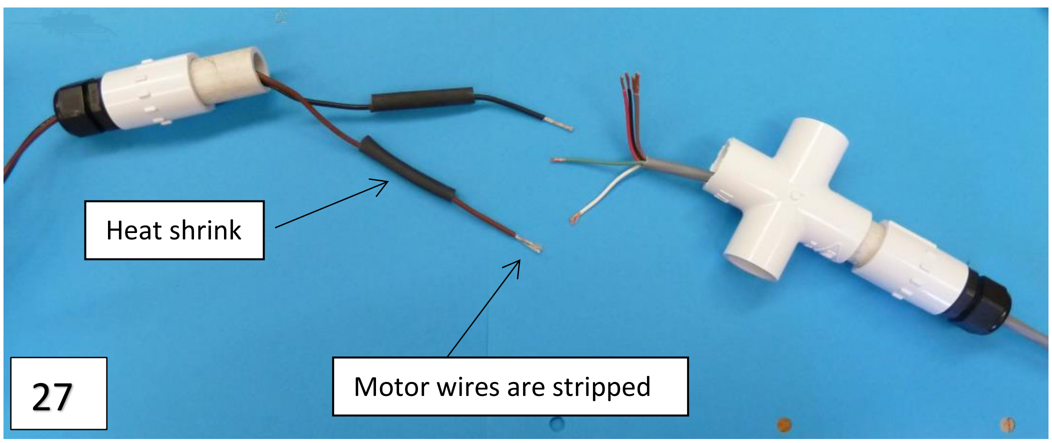

25c

B. Soldering the Motor Wires

Separately, connect the second ½'' dome, the other ½'' PVC threaded/slip fitting, and another piece of cut PVC as you did earlier (photo 25a). Unwrap your black and brown motor wires and feed one pair through the entire piece starting at the dome. The motors should be closest to the dome. Cut the silver, fused tips off the motor wires, and again strip so 25mm of copper is showing.



C. Do these connections one at a time – you should have only one set of motor cables through the dome piece (Photo 26). Here is an idea of your tether management set up (Photo 27).



D. Slide 2'' of heat shrink onto each motor wire, the black and the brown. The black wire of the motor represent positive/power, the brown wire represents negative/ground. Make sure to connect the black motor wires with the correctly colored wires. If you used the table on page 7, the colors should match as follows:

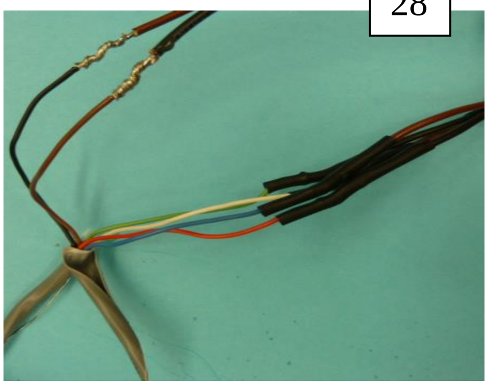
MTR 1: Green to Black 1, White to Brown 1
MTR 2: Red to Black 2, Blue to Brown 2
MTR 3: Brown to Black 3, Black to Brown 3

E. To connect these cables, twist the two copper ends together to make a mechanical connection just like you did with the power (Red and Black) cord earlier.

a. OPTIONAL: At this point, you may want to check the thrust direction of your motors. To check the thrust direction, use your 4 AA batteries and alligator leads or another power source. Connect the black wire to positive and brown wire to negative. Will the motor give you a forward thrust for the right and left motor? And an upward thrust for the up/down motor? Use a little strip of paper taped to a stick to observe "wind" direction created by the motor. Make sure a positive to positive wire connection creates the direction of motion that you need for your

ROV design. You can always reverse the wires if your ROV design requires it.

F. Solder this connection together.
G. To waterproof the connection, use a hot glue gun and cover the connection with glue.
H. Once the joint is dry, pull the heat shrink over the connection and shrink the heat shrink with a heat gun. [Note: if there is too much glue in the way to pull the heat shrink over the connection, cut off small pieces of the glue with snips so that the heat shrink will fit over. The glue will re-melt when the heat gun shrinks the plastic.]
I. Once you have soldered one motor completely, insert the second through the slip the same way, solder, heat shrink and seal, and repeat for the third motor (Photo 28).



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J. Once all wires are soldered, pull the gray 18/6 wire further through the cross until all of the heat shrink wrapped joints are located at the center of the cross. The open end of the PVC scrap will connect to the bottom of the cross and hide all of the joined wires inside (Photo 29)

6. Adding tools and sensors to the ROV

If you are not adding tools or sensors at this time proceed to step 7.
Time required: *30 minutes to 2 hours depending upon the complexity*
Tools required: *pool or testing tank*
Parts required: *assembled ROV, tools or sensors*

The tools and sensors you add will depend upon the tasks you would like your ROV to perform. Common household items can become useful underwater tools. Cameras, especially waterproof backup cameras for cars, are quite good and inexpensive. Make sure you read the notes on the MATE website about building camera filters before you add a camera since you can potentially destroy it with voltage spike as you switch your motors on and off. See. See ***Adding a Video System*** ***for details. (Under Curriculum/Pufferfish on the website.)***


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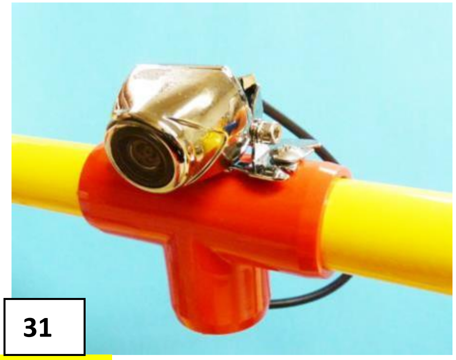
31

Above left is a spray painted kitty litter scoop (Photo 30). Above right is a wide angle, waterproof backup camera that sells for about $13 on *Amazon* (Photo 31).

7. Adjusting the buoyancy on the ROV

Time required: *30 minutes to 2 hours depending upon the complexity*
Tools required: *Pool or testing tank*
Parts required: *Assembled ROV, flotation material.*

If you are adding tools or sensors, you should do that before you adjust your buoyancy. Again, neutral buoyancy is optimal (your ROV doesn't float, doesn't sink). If you are working with foam or material that can compress under pressure (i.e. you can you squeeze it in your hand) and you want to fly your ROV to the bottom of a deep pool or use it in the ocean or a lake, you could end up with a mini anchor (i.e. your ROV may be too heavy to come up under its own power). Experimenting with insulation foam or water noodles is easy. Once you have a design you are happy with, think about using closed containers or PVC pipe sealed off with end caps to create rigid, non-compressible buoyancy (see step 1.)

8. Powering your ROV

Time required: *Lots of time*
Tools required: *Pool or testing tank*
Parts required: *Assembled ROV that is neutrally buoyant, power source.*

There are many different 12 volt DC power sources that you can use: a car battery, a compact rechargeable 12 volt battery, or a car power pack for jump starting a car. We like car power packs because they are inexpensive (about $50 *Harbor Freight*), they have a nice handle for carrying, and they are easy to recharge (plus if you have a dead car battery...) (Photo 32). The power packs have cigarette ports for power. Depending on the power source that you use, you may need an adapter (Photo 33). Radio Shack has a variety of power adapters.

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HAPPY ROVING!

If you plan to compete with your ROV, build props and practice, practice, practice! This will give you a tremendous amount of insight into to how you may want to modify your ROV now or for future competitions.

To learn more about the learning objectives associate with building the PufferFish and participating in the ROV competition please see: the PufferFish Curriculum on the MATE website.

To order PufferFish Kits please go to http://www.marinetech.org/pufferfish/

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