Assembling your AngelFish ROV Kit

Parts overview, tool list, and step by step photo instructions

3 February 2016

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Parts included in the AngelFish ROV Kit

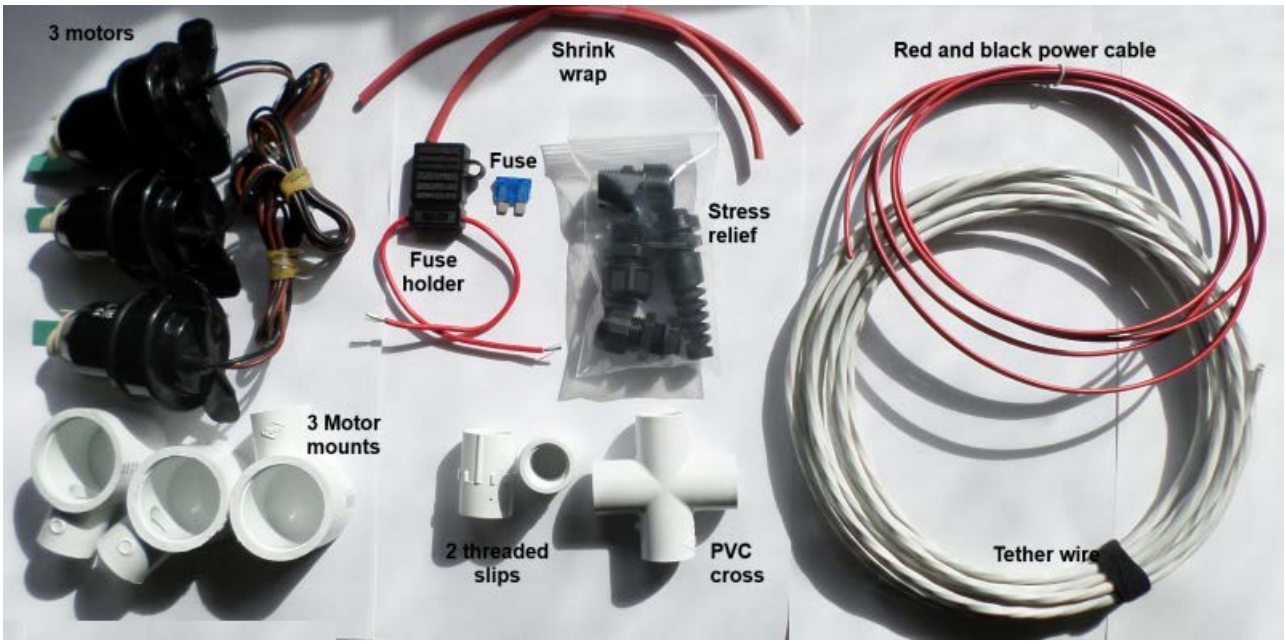


Photo above: Three bilge pump motors, three PVC motor mounts, two lengths of shrink wrap, one fuse holder with fuse, stress relief bag with 3/8-inch dome long, 3/8-inch dome short, and two ½-inch dome short stress reliefs, two threaded PVC slips, one PVC cross, 8 feet of red and black power cable, 25 feet of 18 gauge, six strand tether wire.

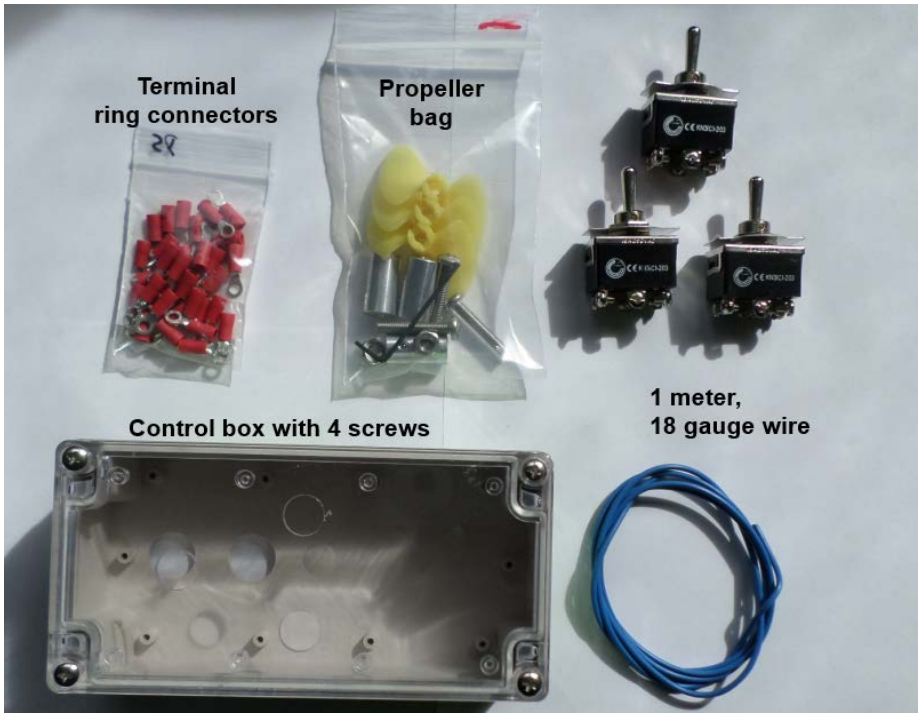


Photo above: Control box with four screws, 32 terminal ring connectors, propeller bag with three propellers, three adapters, three bolts, three nuts, three hex nuts (inside adapter) and one hex wrench, three DPDT switches, and 1 meter of 18-gauge wire (color may vary).

Tools and consumables required for assembly

1. Safety glasses
2. Soldering iron
3. Solder (60/40 Rosin core solder in 0.032”/0.08mm recommended)
4. PVC Cutters
5. Wire cutters
6. Wire strippers or wire cutter/stripper combo tool
7. Ratcheted crimping tool
8. Phillips head and flat head screwdriver
9. Heat gun
10. Hot glue gun & hot glue
11. Multi-meter (highly recommended)
12. Ruler and pencil

List of common quality tools and supplies as a reference

Tool	Manufacturer	Part #	Vendor	Price
Multimeter	Mastech	MS8268	Amazon	24.99
Soldering Station-Medium tip	Weller	WLC100	Amazon	38.85
Conical fine-tip for soldering iron 0.03" X0.79 mm ST Series Conical Tip	Weller	ST7	Amazon	8.09
Heat shrink Kit	9 piece	96024	Harbor Freight	1.99
Mini glue gun	Surebond	GM-160	Amazon	5.49
Heat gun	Drill Master	96289	Habor Freight	14.99
Flush cut wire cutter	Hakko	CHP-170	Amazon	4.85
Wire strippers-auto & classic	Irwin	2078300	Amazon	31
Ratcheting Terminal Crimper	S&G Tool Aid	18900	Amazon	20.46
Solder Sucker	-	-	Amazon	5.41
PVC cutters			Home Depot	12
Electrical Tape			Harbor Freight	1
Screw driver flat #1 & 2, Phillips 1 & 2	"		Harbor Freight	5.41
Heavy duty diagnal cutters	Stanley	84-105	Amazon	5.97
Needlenose Pliers	Stanley	84-096	Amazon	5.16

Consumables				
Rosin Core Solder 60/40 .031	Kester	44	Amazon	28.99
Loctite			Amazon	5

Assembling the frame

Time required:	1 to 5 hours
Tools required:	PVC cutters, ruler, pencil, sketch pad or engineering notebook
Tools recommended:	Drill, drill bits, sheet metal screws if using colored PVC pipe
Parts required:	1/2-inch PVC pipe (10 to 20 feet), PVC connectors (elbows, tees, sideouts) 20 to 30 total connectors

Frame Design

The frame can be fairly simple or involve experimentation. MATE recommends taking time to sketch a design and build a model of the frame. Consider where the motors will be mounted, if tools or cameras are going to be attached, and what the ROV is designed to do. The AngelFish kit comes with three PVC motor mounts that will attach to ½-inch PVC pipe. These motor mounts make it very easy to attach the motors to the frame.

Other things to consider are whether you wish to purchase and use colored PVC or run the wires through the frame. Colored PVC can be purchased at: www.simplifiedbuilding.com/blog/color-furniture-grade-pvc-fittings-now-available/ Colored PVC is more expensive, and will need to be screwed together to secure the frame. For a nice clean look, the wires from each motor can be run through the inside of the PVC pipe of the frame and emerge at the single, strain relief attachment point. To run wires through the frame, drill a 3/16-inch hole through the ½-inch portion of the motor mount. Push the wires through this hole, through the framework of the ROV, and out through the strain relief.

When building your frame, there are a few things to consider:

1) Bigger is not always better. With the motors providing a given amount of thrust, a bigger frame will be slower; a smaller frame will be quicker. Depending on the task the ROV is to perform, a slow and steady ROV may be desirable, or a quick ROV may be desirable.

2) You will want water to flow into and out of the frame. Do not use the air inside the pipe as flotation, as any leak will cause your ROV to sink. You can drill holes in the top and bottom corners of your ROV, or you can use tees at the corners to accomplish this.

3) Think about locations to mount flotation, tools and other devices. To create a stable ROV, all the flotation should go on top of the ROV (if you put flotation on the bottom, the ROV will roll over in the water and be upside-down). Most commercial ROVs have their flotation at the very top of the frame, and all heavy objects near the bottom.

4) ROVs should be neutrally buoyant in the water. When placed in the water, the ROV should not sink, nor should the ROV float to the surface. Soft foam, air filled water bottles and other compressible items will lose their flotation as pressure increases with depth. A good rule is that if you can crush your flotation with your hands, it will not work well as you go deeper in the water. Consider using buoyancy cylinders (1 ½-inch, 2-inch or 3-inch PVC pipe with end caps glued on each end).

5) Colored PVC pipe and connectors will need a screw to secure each joint. White PVC pipe and connectors should not need glue or screws to secure them unless the ROV is very large or is not symmetrical. With standard white PVC, pushing the pipe into the connector by hand is usually enough to secure the pipe in place. PVC glue makes connections very brittle and likely to snap. If a connection point continues to break apart, use a small screw to hold the connection point secure.

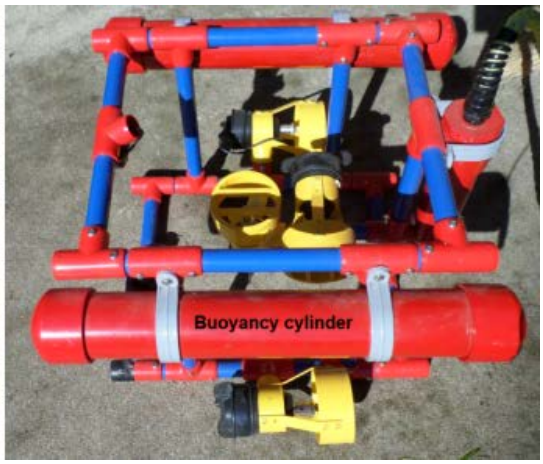


Photo above (left): Soft foam flotation in various sizes, all will compress under pressure.
The ROV on the right uses hard buoyancy cylinders made out of 2-inch PVC pipe with end caps.

Colored PVC frame screwed together. Also note the PVC tee used to allow water to flow in and out the frame of the vehicle.

Assembling the AngelFish controller

Time required:	1 to 2 hours
Tools required:	Wire cutters, wire strippers, crimping tool, phillips head screwdriver, flat head screwdriver, utility knife, pliers
Tools recommended:	Multi-meter
Parts required:	Pre-drilled AngelFish project box, AngelFish kit components, stress relief connectors (one long, one short)

Double pole, double throw switches

The AngelFish control box uses three double pole, double throw (DPDT) switches to control three motors. Properly wired, a DPDT switches allow the motors to run in both forward and reverse direction. The MATE Center recommends that you familiarize yourself with how a DPDT switch operates before wiring the control box.

Installing the switches

The first step is to insert the three switches into the pre-drilled holes on the control box.
To insert the switches:

Disassembled components on the switch

Metal plate- note the small tooth.

1. Unscrew the two nuts and remove the ON/OFF/ON metal plate from the switches. Insert the three switches through the clear plastic faceplate. The black box of the switch should be inside the control box, the toggle switch should stick up through the holes in the clear plastic faceplate.

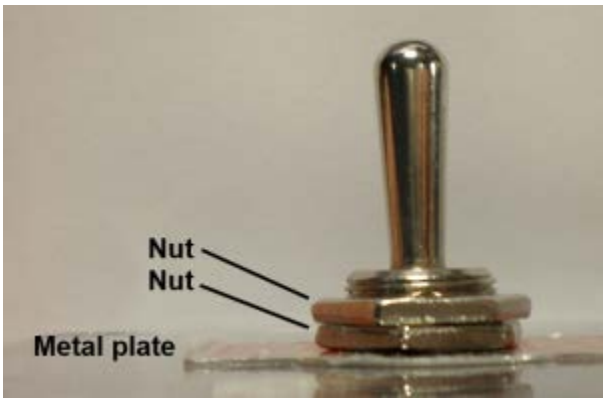
2. Install the metal plate over the switch. Note the small groove on one side of the switch and

notice the small tooth on the inner circle of the metal face plate. Match up the tooth so it fits into the groove.

3. Screw one nut on to loosely hold the switch in place. Before tightening the first nut, twist the switch within hole so the metal plate reads ON/OFF/ON, not NO/OFF/NO. Consider how the controller is going to be held when twisting the switch to the proper orientation.

4. Once the orientation of the switch is correct, use pliers to tighten the nut and hold the switch securely in place. BE CAREFUL not to screw the nut on too tightly, as it can crack the clear plastic. The nut should be just tight enough so the switch does not twist on its own. Once the switch is secure, tighten the second nut down on top of the first.

   Design note: The two bolts, and the ON/OFF/ON metal plate, are re-attached in a different order from what they are taken off the switch. The switch comes with a nut closest to the switch, then the metal plate, then another nut. When the switch is inserted through the clear faceplate, the metal plate goes on first, then the two nuts are screwed in on top of the metal plate to lock it down.



5. Repeat this procedure for the other two switches.

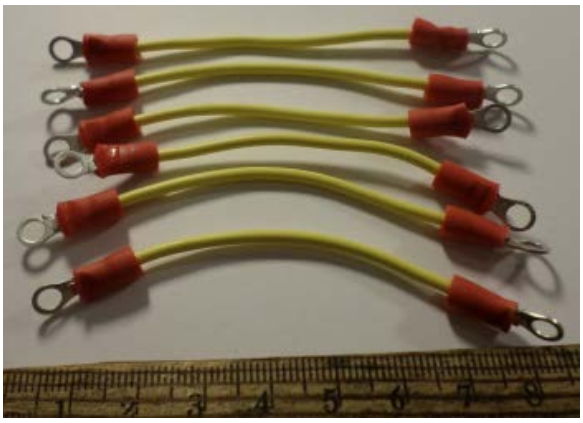
Wire Preparation 1

The next step is to wire the back of the switches. Two wires will make the "X" on the back of each switch that allows the motor to run in two directions. Another set of wires allows power to be jumped from one switch to the other two switches.

To make the AngelFish ROV kit re-usable, ring connectors will be crimped on the ends of each wire. The ring connectors will be screwed onto the back of the switch to make a solid connection. To construct the wires:

1. Cut six 7.5 cm lengths of 18-gauge wire. Strip 1 cm of wire of each end of the six wires. Note that the color of wire for wiring the back of the switch does not matter.

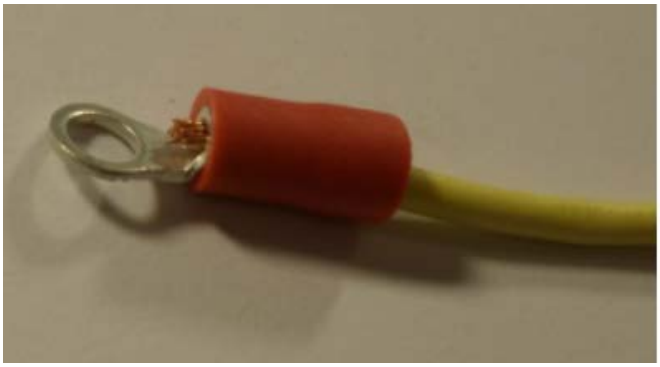
2. Crimp a #6 red ring terminal over each end of the six wires (see below for additional crimping instructions).



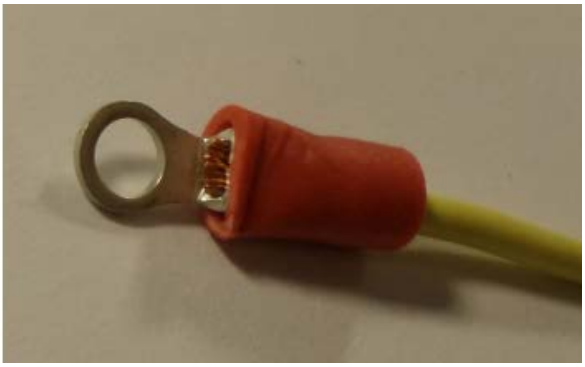
When crimping the ring terminals onto the end of the wire, it is important to get a secure, metal to metal connection. If the ring terminal is not secured properly to the bare metal wire, electricity may not flow through the connection and your controller will not work. To make a secure crimp connection:

1. Twist the 1 cm of stripped wires. Insert them through the hole in the red ring terminal until they emerge 1 mm to 2 mm out of the metal ring.

2. Use a crimping tool to crush the metal ring of the ring terminal over the stripped copper wire. The connection should be metal to metal so electricity can flow freely. The connection should also be physically secure so the wire cannot be pulled out ring terminal.



Copper wire emerging 2 mm beyond the metal ring.



Metal ring securely crimped over copper wire.

A few other hints for good crimping:

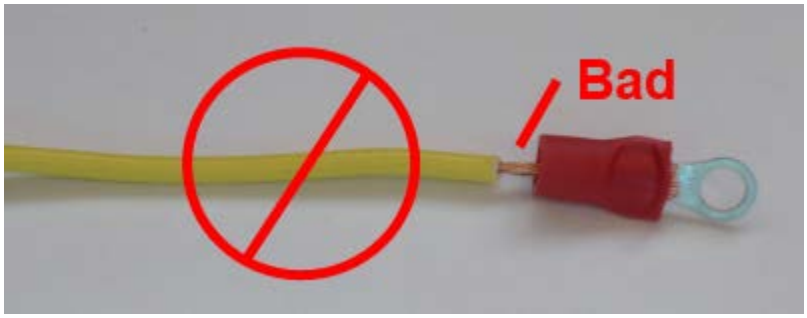
Always use the red dot section of the crimper. The crimp tool may have red, yellow and blue dots/lettering. The color of dot corresponds to the color of sheathing on the terminal ring. The AngelFish uses red ring terminals over 18 gauge wire, so use the red dot/numbering section of the crimper to ensure a good crimp.

Use ratcheting crimpers. A ratcheting crimper will not release until a secure connection has been made. Note that it may need strong hands to squeeze the crimper so it releases.

Give the wire/crimp connection a tug when the crimping is complete to ensure a secure connection. If the wire comes out when you tug on it, the connection was not good. Use a new red ring terminal (throw out the old one) and try again. A few extra terminals are included in AngelFish kit, as is some extra 18-gauge wire, to use when crimping problems occur.

Design note: **VERY IMPORTANT**. The most common cause of failure in the AngelFish control box is a wire that is not properly crimped. If the metal ring was not securely crimped over the copper wire, electricity may not flow through the connection. Also, the wire may also fall out of the ring terminal if not securely crimped, again stopping the flow of electricity through the circuit. MAKE SURE ALL YOUR CRIMPS ARE SECURE. If a switch is not operating, the first troubleshooting technique should be to re-examine all the connections to make sure they are properly crimped.

No wire should be exposed outside the red terminal ring. Exposed wiring may connect with other metal and create a ***short circuit***. This can lead to vehicle malfunctions and sparks/fire/melting components. If wire is exposed outside the red plastic covering on the terminal, shorten the amount of wire being stripped and re-crimp the terminal.



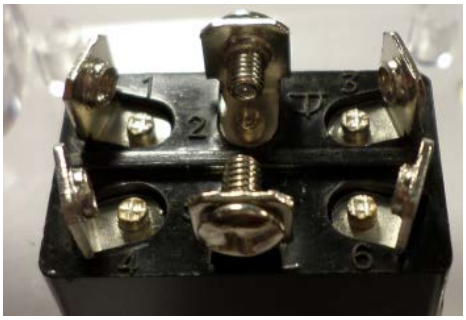
Very bad connection. The exposed wire outside the plastic covering can cause a short circuit.

Making the "X" on the back of each switch

The backside of each switch has 6 poles or posts. These posts are numbered 1 through 6. The six wires with ring terminals will make an "X" on the back of each post, which allows the motors to run in both directions. To make the "X":

1. On one switch, carefully remove screws from post 1, 3, 4 and 6. Be very careful not to lose these screws, set them aside in a safe location where they will not be lost.

Back of switch showing 6 posts.

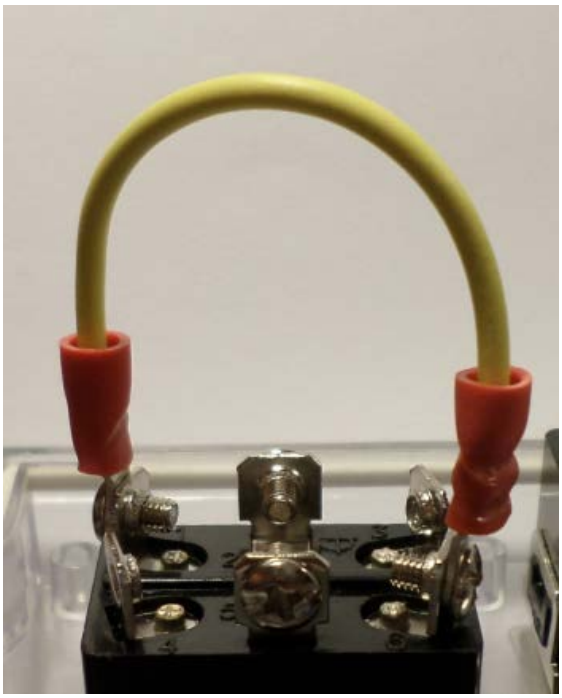


Screws on post 1, 3, 4 and 6 removed.

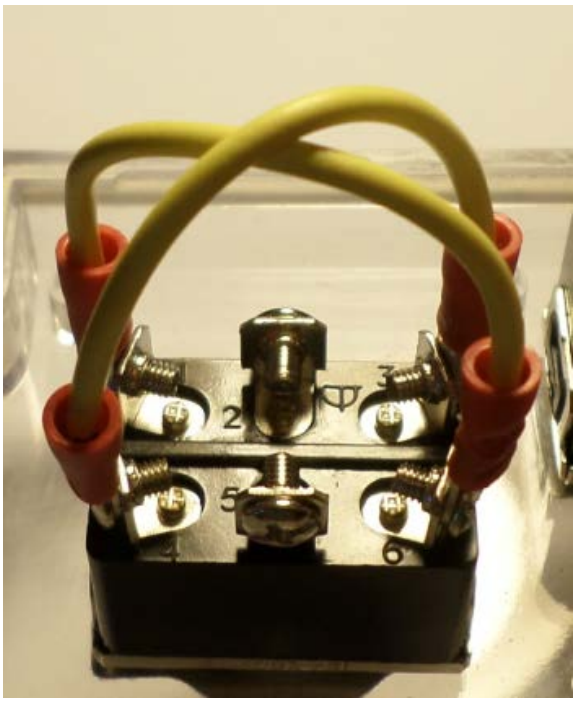
2. Take 1 screw and wire with crimps on both sides. Push the screw through the red ring terminal and screw it into the post #1. The ring terminal should be between the head of the screw and the post.

3. Take another screw and push it through the ring terminal on the other end of the wire. Screw it into post #6. At this point, the wire should connect post #1 to post #6.

4. Using a second wire with crimps at both ends, screw one end into post #3 and the other end into post #4.



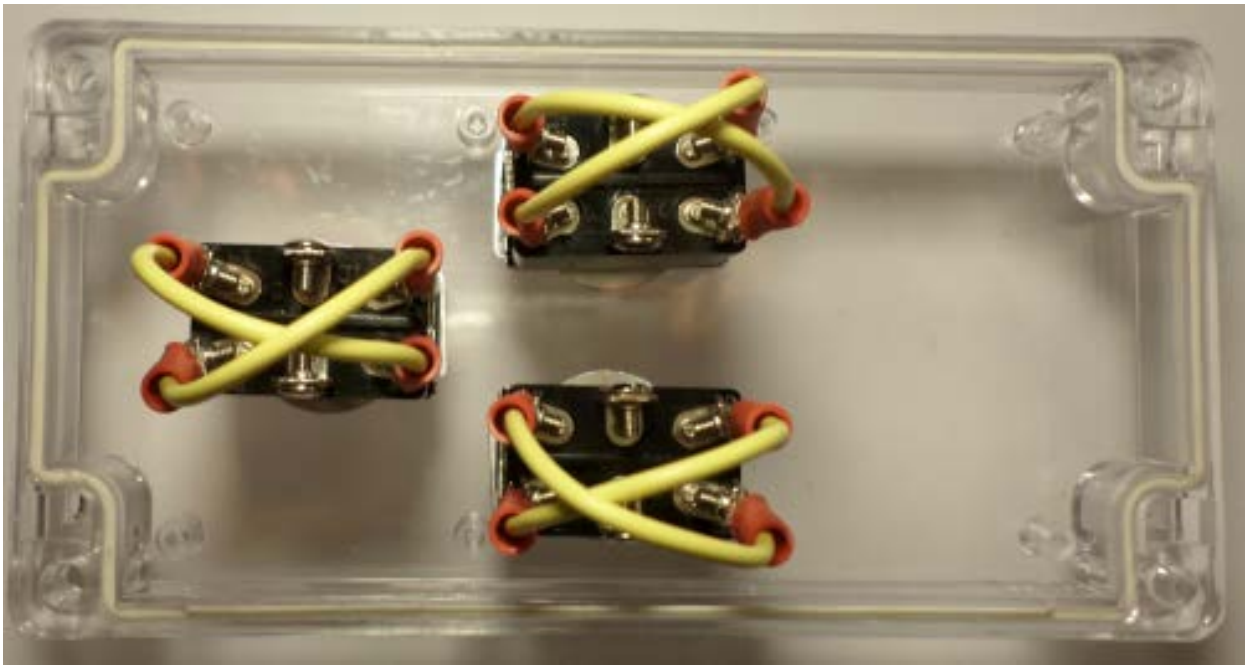
Wire connecting post #1 to post #6



Wires connecting post #1 to #6, post #3 to #4.

5. Repeat this process on the other two switches.

Hint: It may help to rotate the switch a small amount in the hole through the clear plastic faceplate when using a screwdriver to install the screws.



The three switches with "X" wires on the back of each.

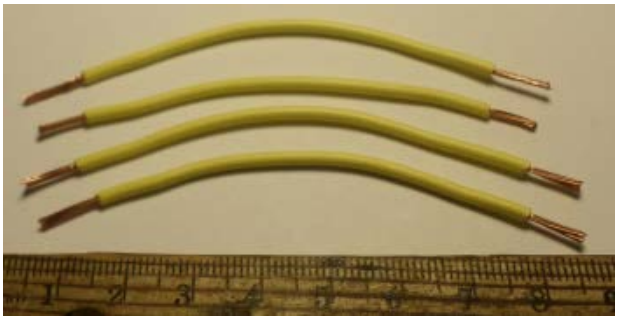
Wire preparation 2

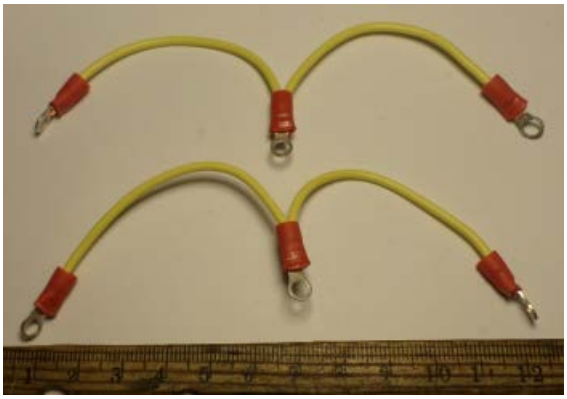
The next step is to wire power jumpers between the three switches. The middle posts, posts #2 and #5 are the posts for bringing power in (red positive, black ground). Jumpers between the switches will allow power brought into one switch and transferred to the other two switches. To construct the jumpers:

1. Cut four 9 cm lengths of 18-gauge wire. Strip 1 cm of wire of each end of the four wires.

2. Take two of the 9 cm lengths of wire, set them side by side, and twist one pair of stripped ends together. Crimp a red ring terminal of the joined ends. Take the other two 9 cm lengths of wire, set them side by side, and twist one pair of stripped ends together. Crimp a red ring terminal over the joint ends. Make sure this is a secure crimp connection!

3. Crimp a red ring terminal over the four remaining single ends of the wires.





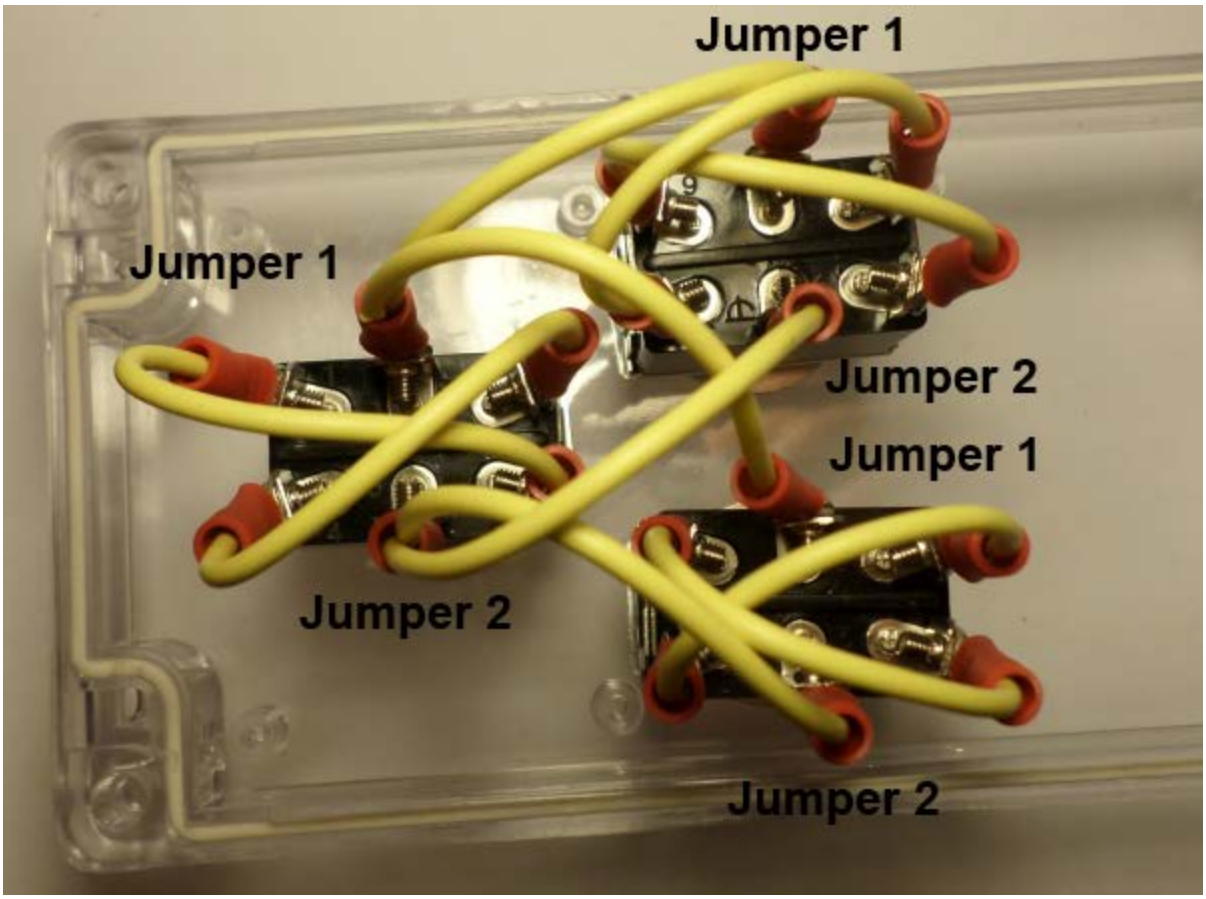
Attaching the power jumpers

The power jumper wires attach to the middle posts of the three switches. A red/black power wire will bring in electricity from a power supply to one switch. The jumpers will transfer the power to the other two switches. To connect the jumper wires:

1. Remove the screws from post #2 and post #5 on each of the three switches. Be very careful not to lose these screws, set them aside in a safe location where they will not be lost.

2. Using one jumper wire, attach the three ring terminals to the center post on the left side of each switch (note that this may be post #2 or #5).

3. Using the other jumper wire, attach the three ring terminals to the center post on the right side of each switch.



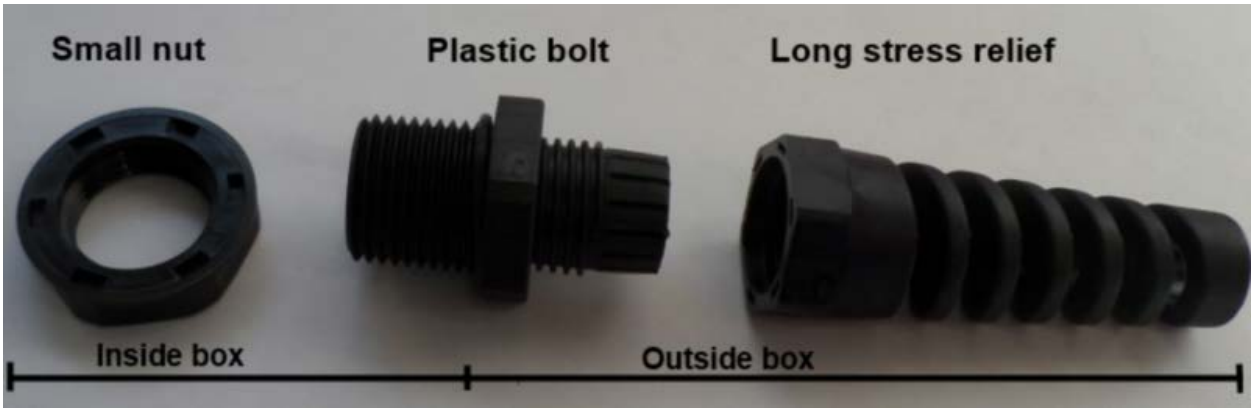
Attaching stress relief

Two holes are drilled in the plastic box. The ROV tether will pass through one hole; the power wires will pass through the other hole. Both wires will pass through stress relievers. The tether wire will pass through the 3/8-inch long stress relief. The power wire will pass through the 3/8-inch long short stress relief. To install the stress reliefs:

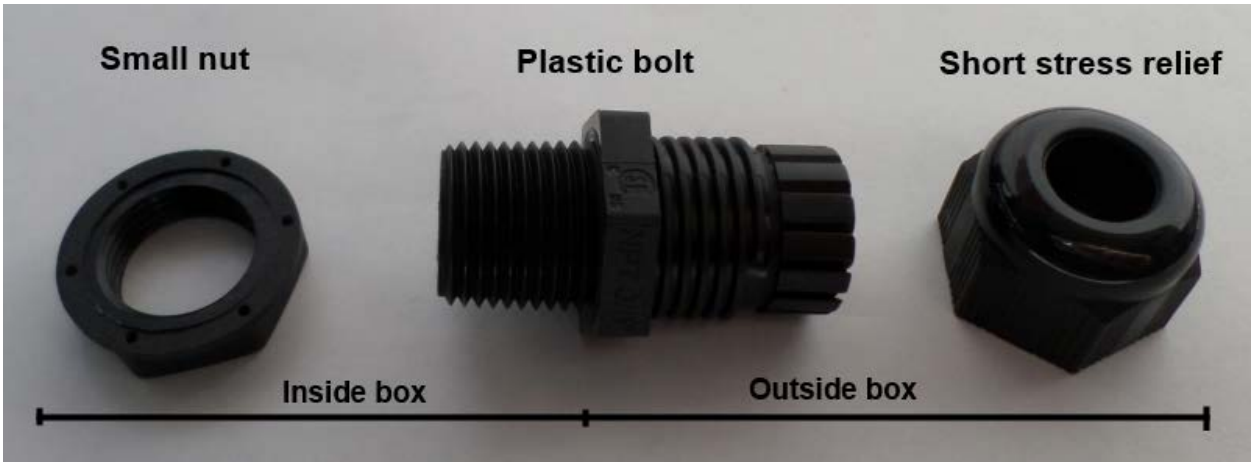
1. Unscrew the long stress relief into the three components. Push the plastic bolt through the hole closest from the center of the controller. The hexagonal part of the bolt should be flush against the outside of the control box, with the small threads protruding through the hole in the control box.

2. Screw the small nut onto the small threads until the bolt is tightly secured to the control box.

3. Loosely screw the stress relief (long) onto the larger threads.



Disassembled long stress relief.



Disassembled short stress relief.

4. Unscrew the short stress relief into the three components. Push the plastic bolt through the hole closest from the center of the controller. The hexagonal part of the bolt should be flush against the outside of the control box, with the small threads protruding through the hole in the control box.

5. Screw the small nut onto the small threads until the bolt is tightly secured to the control box.

6. Loosely screw the stress relief (short) onto the larger threads.

Side view of control box with both stress reliefs installed.

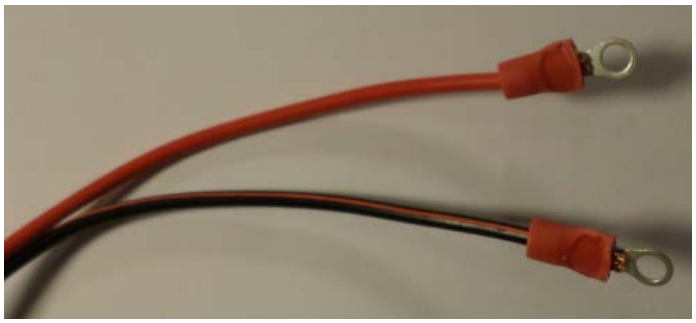
Attaching power wires

The red and black power wire will bring electrical power from the battery/power supply into the controller. The power jumpers (previously installed) will bring electrical power to each switch.
To install the power wires:

1. Push approximately 30 cm of the red and black wire through the short stress relief. The wire should be pushed through from the outside to the inside of the control box.

2. On the 30 cm of wire inside the control box, pull apart 8 cm of the red wire and black wire (separate the two joined colored wires). Strip 1 cm from the end of each wire.

3. Crimp a red ring terminal over the end of both the red wire and black wire.

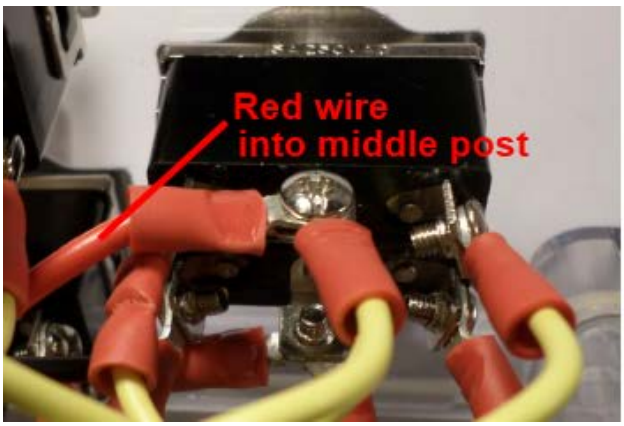


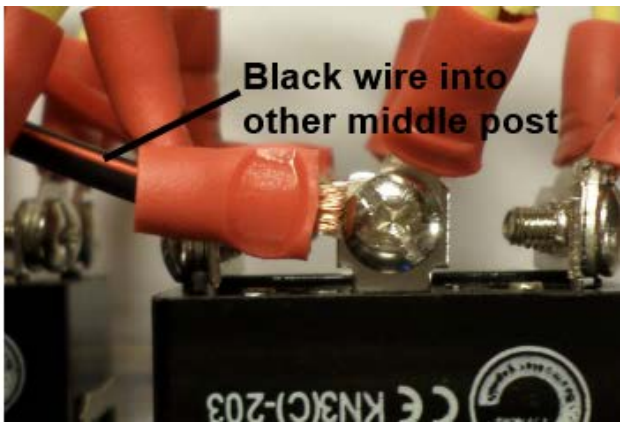
4. Set your clear plastic faceplate upside down to access the bottom of the switches. Carefully unscrew the center, right post (post #2 or post #5, on the right side of the switch as you are looking down at it) screw on ONE switch only. This post should already have a jumper wire attached.

5. Attach both the jumper wire and the red power wire to this post. Use the screw to secure both ring terminals and both sets of wires to the post.

6. Carefully unscrew the center, left post on the same switch. This post should have the other power jumper wire attached.

7. Attach both the jumper wire and the black power wire to this post. Use the screw to secure both ring terminals and both sets of wires to the post.





Once both the red and black wire are secured to a switch, pull the any excess power wire back out through the small stress relief. Tighten the small stress relief nut over the threads to secure the power wire in place.

Design note: The side of the switch that the red and black wires attach into controls polarity; which way the motor runs when you push your switch forward. If all three of your motors run in the opposite direction as desired, you can switch the sides of the red and black wires, and the polarity will change.

Attaching the tether wires

The tether cable connects your controller (on the surface) to your ROV (underwater). There are six, 18-gauge wires in the AngelFish tether. Each motor requires two wires to complete the circuit. The six wires are colored black, white, red, green, brown and blue. There may also be a foil wrapping, cotton thread and bare twisted wire inside the plastic sheath holding all the wires. The foil wrapping, cotton thread and bare twisted wire are not used.

Any two wire colors can be paired for each motor, but be sure to write down what wire color combinations are used. The color combinations topside must match the color combinations

bottomside. The MATE Center uses red/green for the left motor, black/white for the right motor, and blue/brown for the vertical motor. Remember: Blue and brown goes up and down, black and white is on the right (right motor), green and red are left over (left motor).

10 cm of the plastic sheathing around the tether must be removed to expose the 5 wires. To prepare the tether:

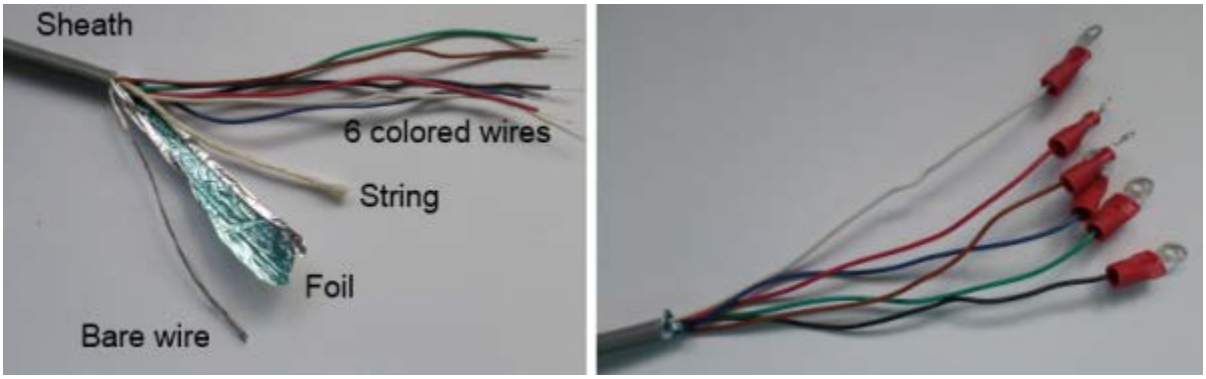
1. Push approximately 30 cm of the tether wire through the long stress relief. The tether should be pushed through from the outside to the inside of the control box.

2. Using a utility knife, **VERY CAREFULLY** cut a small slice in the plastic sheathing around the cable 10 cm from one end. Cut carefully as you do not want to knick any of the colored wires inside the sheath. If any of the six colored wires are knicked by the cutting blade, the tether will not work. Cut the ruined 10 cm off your tether (remember, your tether gets 10 cm shorter every time you make this mistake) and start again.

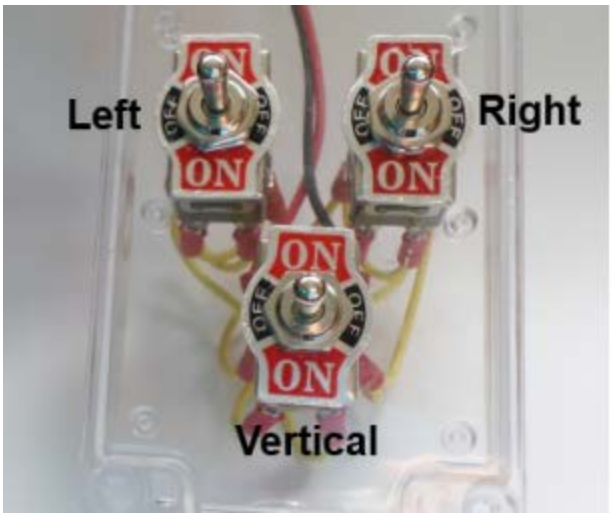
3. Separate out the six colored wires and strip 1 cm from the end of each.

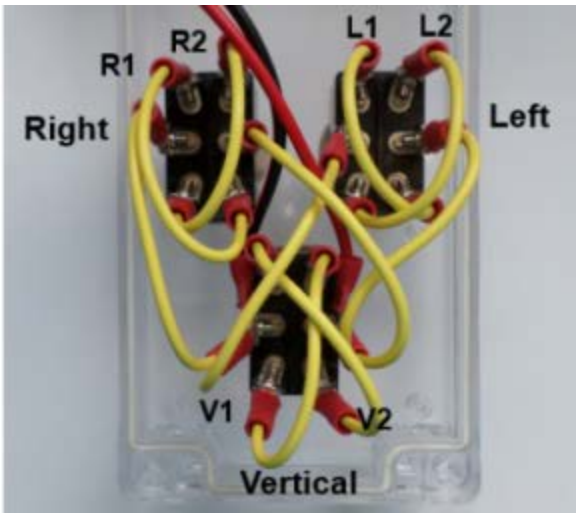
4. Crimp a red ring terminal over the end of all six wires.

Design note: Since the wires in the tether are smaller gauge (thinner), the thickness of the wire can be doubled-up for crimping. Strip 1.5 cm to 2 cm off the end of each wire, and bend the exposed wires back on themselves to make a 1 cm length of bare wire that is twice the diameter. The red terminal rings should make a better connection when crimped to the doubled wire.



Turn the clear plastic faceplate of the control box over to look the top of the switch (the ON/OFF/ON metal plate). Identify which switch is the left switch, right switch and vertical switch.





5. Carefully unscrew R1 on the right switch (Note that this may NOT be post #1). This post should have part of the "X" on it. The right switch is black and white tether wires, unless a different color configuration is used. Attach the black tether wire and the removed "X" wire to this post. Tighten the screw to secure both ring terminals to the post.

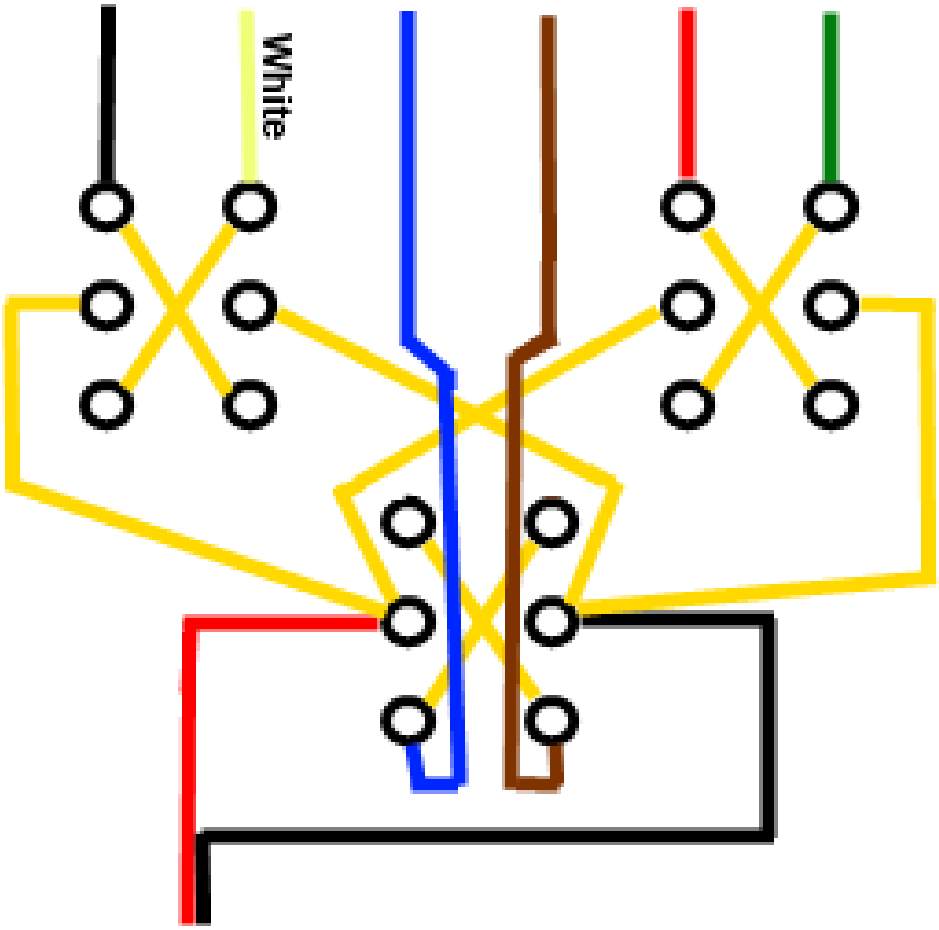
6. Carefully unscrew R2 on the right switch (Note that this may NOT be post #2). This post should have part of the "X" on it. Attach the white tether wire and the removed "X" wire to this post. Tighten the screw to secure both ring terminals to the post.

7. Carefully unscrew L1 on the left switch (Note that this may NOT be post #1). This post should have part of the "X" on it. The left switch is red and green tether wires, unless a different color configuration is used. Attach the red tether wire and the removed "X" wire to this post. Tighten the screw to secure both ring terminals to the post.

8. Carefully unscrew L2 on the left switch (Note that this may NOT be post #2). This post should have part of the "X" on it. Attach the green tether wire and the removed "X" wire to this post. Tighten the screw to secure both ring terminals to the post.

9. Carefully unscrew V1 on the vertical switch (Note that this may NOT be post #1). This post should have part of the "X" on it. The vertical switch is blue and brown tether wires, unless a different color configuration is used. Attach the blue tether wire and the removed "X" wire to this post. Tighten the screw to secure both ring terminals to the post.

10. Carefully unscrew V2 on the vertical switch (Note that this may NOT be post #2). This post should have part of the "X" on it. Attach the brown tether wire and the removed "X" wire to this post. Tighten the screw to secure both ring terminals to the post.



Wiring diagram of the AngelFish control box.

The AngelFish control box completely wired.

Once all six tether wires are secured to the switches, pull the any excess tether back out through the small stress relief. Tighten the long stress relief nut over the threads to secure the power wire in place.

Design note: The pole that the colored tether wires attach into controls polarity; which way the motor runs when you push your switch forward. If one of your motors runs in the opposite direction as desired, you can switch the poles of the two colored tether wires, and the polarity will change. It may be easier to change polarity in the control box after the motor wires have been soldered.

Before closing up the control box, check to make sure all your crimp connections and screw connections are secure. Give each wire a light tug. If the wire comes out of the ring terminal, it will need to be re-crimped. If the entire ring terminal moves on the post, the screw will need to be tightened.

Closing up the control box

When closing up the control box, the switches should go on the opposite side of the controller from the stress relief. Close up the control box. Make sure that all the wires are inside of the control box. Note that the wires that make the "X" and the power jumper wires are long enough (stick up high enough) to touch the inside bottom of the control box. That is okay. Just push the clear plastic faceplate flush against the control box and the wires will flatten out.

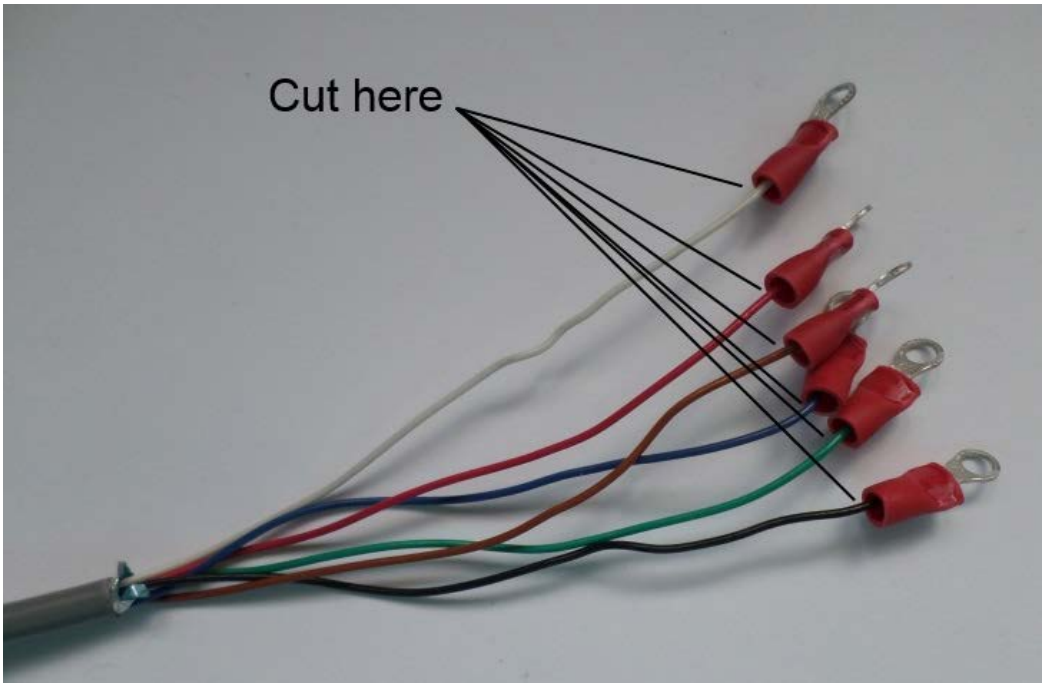
Screw in the four corner bolts to hold the clear plastic face plate against the control box.

Re-using the AngelFish kit

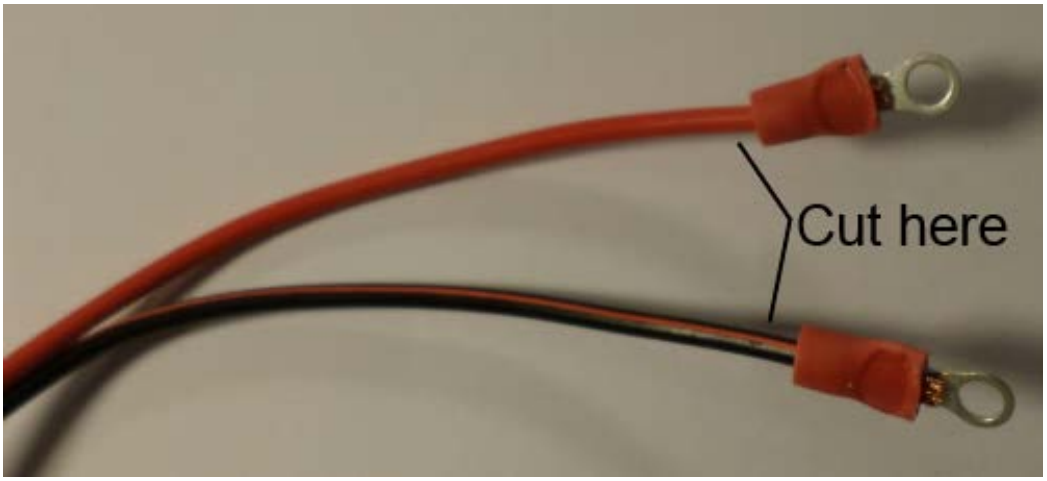
The AngelFish kit was designed to be a reusable learning tool year after year. The control box is easy to disassemble to its basic components. Only a few components have to be discarded, the wires and terminal ring connectors on the back of the switches and tether. An AngelFish replacement kit replaces the discarded wire and terminal ring connectors, allowing the majority of the kit to be re-used in subsequent semesters or years.

To disassemble the AngelFish control box:

1. Remove the six screws from the back of each of the three switches (18 screws total). Be very careful not to lose any of these small screws, as they are important.
2. Remove all the wires from the back of each switch. MATE recommends saving a few of the wires that make the X on the back of the switch and a few of power jumper wires. If too many mistakes are made in crimping the wires, these pre-made X's and jumpers can serve as back up.
3. Cut the six terminal ring connectors from the end of the tether. Cut as closely to the terminal ring connector as possible to preserve the length of the tether. Note that with careful, close cutting, only 1 cm to 2 cm of tether will be lost with each re-use. Discard the cut terminal ends.



4. Cut the two terminal ring connectors from the end of the power wires. Again, cut as closely to the terminal ring connector as possible to minimize loss of wire.



The AngelFish control box replacement kit includes new 18-gauge wire to construct the X's power jumpers on the back of each switch, and new terminal ring connectors to crimp on the end of the wires.

Optional:
Other steps of the ROV construction process can be disassembled by cutting. This will allow other ROV construction processes to be completed in the future.

The fuse holder can be cut out of the power red/black power wire to be reassembled at a later time. Note however, that fuse holder does not have a large lengths of wire and cutting it down may cause problems after a few re-uses.

The power connectors can be removed from the wire to be reused at a later time. Again, if they need to be cut out, this may cause problems after a few re-uses.

The three motors may be detached at the bottom end of the tether by cutting the wires. Cut the entire soldered length of wire, underneath the waterproofing, out. Note that cutting the motors means a loss of 2 cm or 3 cm from both the tether wire and the motor wires.

Please see the PufferFish ROV Instructions for the following topics. The rest of the materials and instructions are identical to the PufferFish Kit.

Adding a fuse holder and power connector

Adding propellers to the motors

Constructing the tether management cross

Adding tools and sensors to the ROV

Adjusting buoyancy

Testing the ROV