Soldering the PufferFish Circuit Board
Rev 6

The MATE Center was established in 1997 with funding from the National Science Foundation. Headquartered at Monterey Peninsula College (MPC) in Monterey, California, the Center is a national partnership of community colleges, secondary schools, universities, informal educational organizations, research institutions, marine industries, professional societies, and working professionals. MATE's mission is to use marine technology to inspire and challenge students to learn and creatively apply science, technology, engineering, and math (STEM) to solving real-world problems in a way that reinforces critical thinking, collaboration, entrepreneurialism, and innovation. A hallmark of all MATE's programs, products and services is that they are aligned with ocean workforce research and trends.
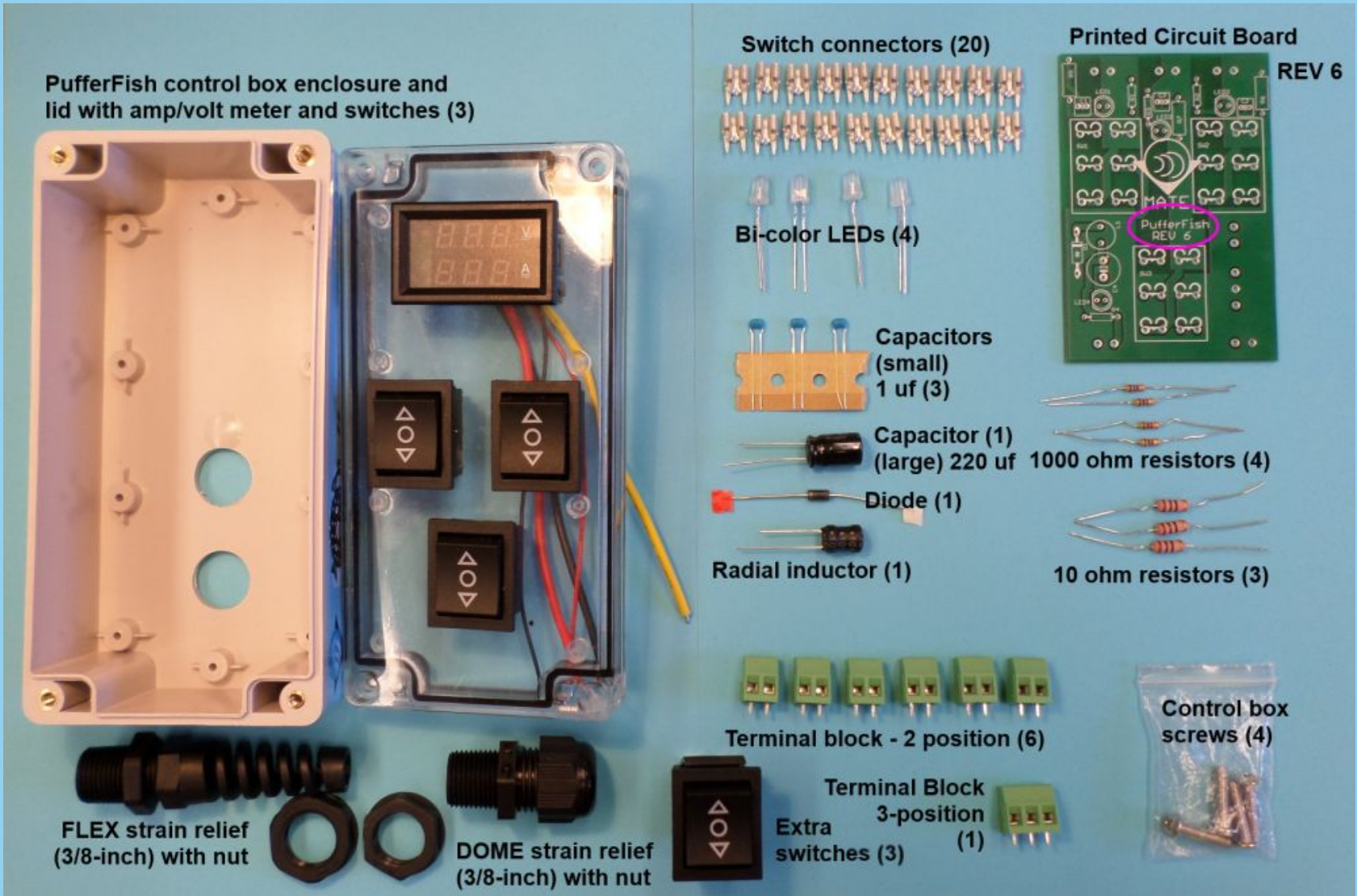
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Time, Tools, and Parts

Time Required:	1-3 hours depending on skill level
Tools required:	Soldering iron, solder (we recommend 60/40 Rosin Core Solder in .032" (0.08mm) diameter), wire snips/flush cutters, wire cutters, wire strippers (manual), utility knife, Phillips screwdriver, ⅛-inch flathead screwdriver, slotted jeweler screwdriver, ruler with metric scale.
Tools Recommended:	Solder sucker or solder wick to remove solder if you make a mistake.
Parts Required:	Pre-drilled Pufferfish project box, amp/voltmeter, Printed Circuit Board (PCB), electrical components, stress relief connectors (long and short) 3/8", lock nuts. [See photo next slide]

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PufferFish Control Box - Parts Photo

PufferFish control box enclosure and lid with amp/volt meter and switches (3)

Switch connectors (20)

Bi-color LEDs (4)

Capacitors (small) 1 uf (3)

Capacitor (1) (large) 220 uf

Diode (1)

Radial inductor (1)

Printed Circuit Board

REV 6

PufferFish REV 6

1000 ohm resistors (4)

10 ohm resistors (3)

Terminal block - 2 position (6)

Terminal Block 3-position (1)

Extra switches (3)

Control box screws (4)

FLEX strain relief (3/8-inch) with nut

DOME strain relief (3/8-inch) with nut

There is a lot to this kit and a lot to learn!

A. What are all these components and what do they do?
   - Here is a cheat sheet for you! (Please note that you will need to sign in to see this. It is free and easy.)
B. Want to learn more about simple circuits? Look at this presentation, make sure to watch the video at the beginning!
   - Quiz - what are the 3 parts of a basic circuit?
C. Want to learn more about how a double pole, double throw switch operates? Watch MATE Videos 2A, 2B and 2C.
D. Soldering is a skill. The more practice you have, the better your soldering will be. Soldering components to the PufferFish board is very important; a bad solder joint could cause the board to not function. MATE recommends practicing your soldering skills before soldering your PufferFish board.

Link to Soldering Wires and Waterproofing a Connection Presentation
Link to Soldering Components

Examine your Printed Circuit Board (PCB)

A. Begin with your printed circuit board (PCB) and identify the places labeled for LEDs (LED 1-4) and resistors (R1-7). Both sides of the board are shown here. LEDs and resistors are shown on the top-side of the board (top photograph). This means the components should be mounted on this side of the board, with the leads pushed through and soldered on the bottom-side of the board.
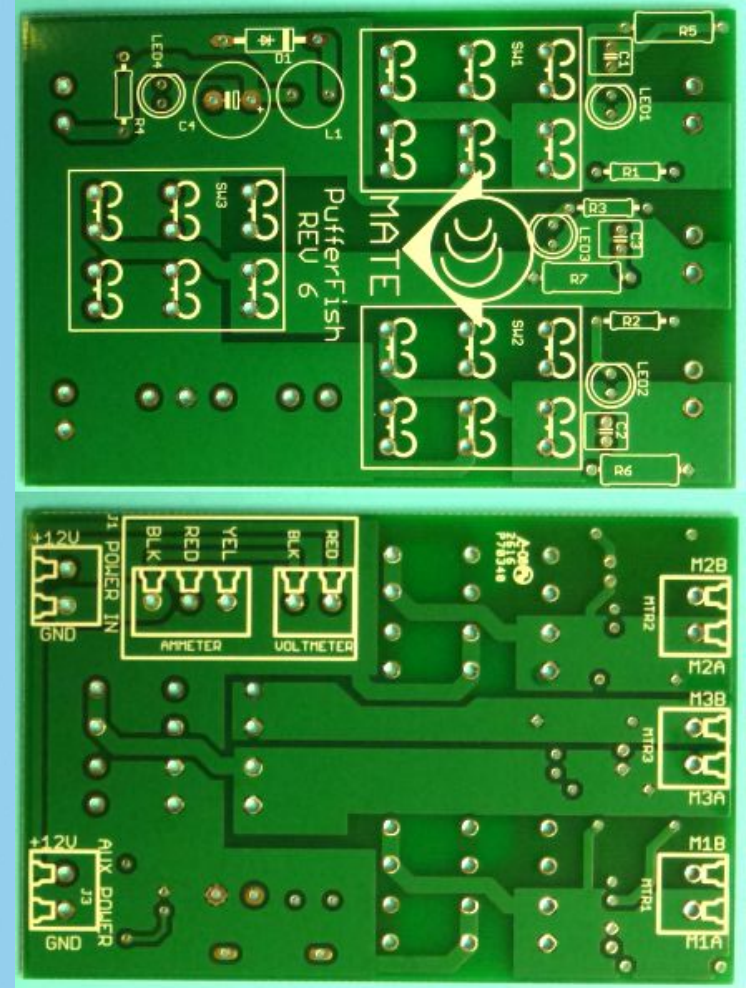
Resistors (1)

A.   Insert your 1K Ohm resistor leads (wire ends) through the front of the board (R1-4) by first pinching the wires down at a 90 degree bend from the ceramic resistor. **Orientation does not matter for resistors**.

B.   Feed the leads through the board and gently splay the ends on the back of the board . This will secure the components so they do not fall out when the board is turned over.
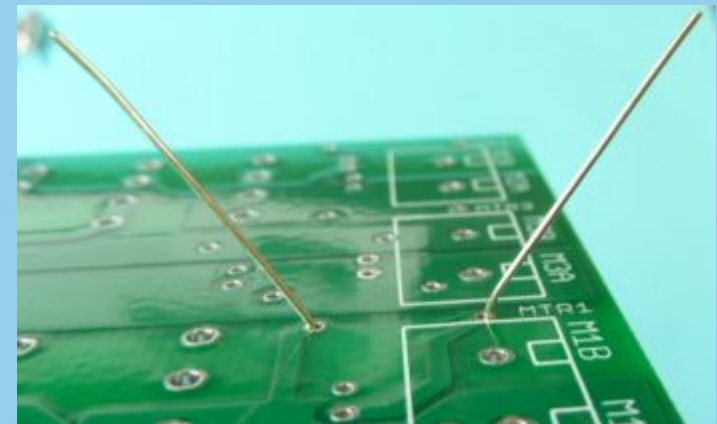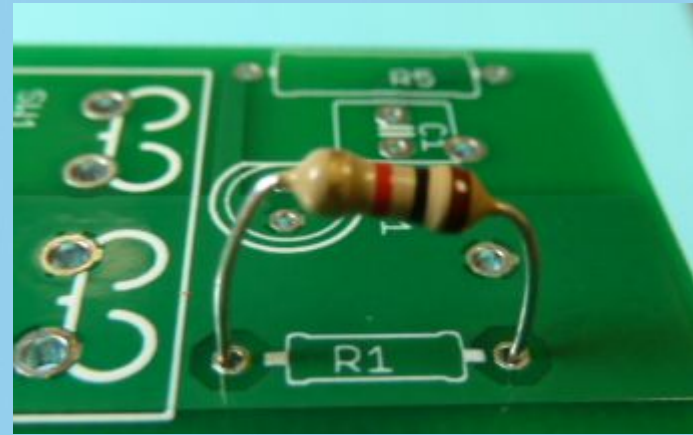
Helpful Hint: it is nice to use one of the kits PVC motor mounts as a stand to lay the PCB on when soldering.
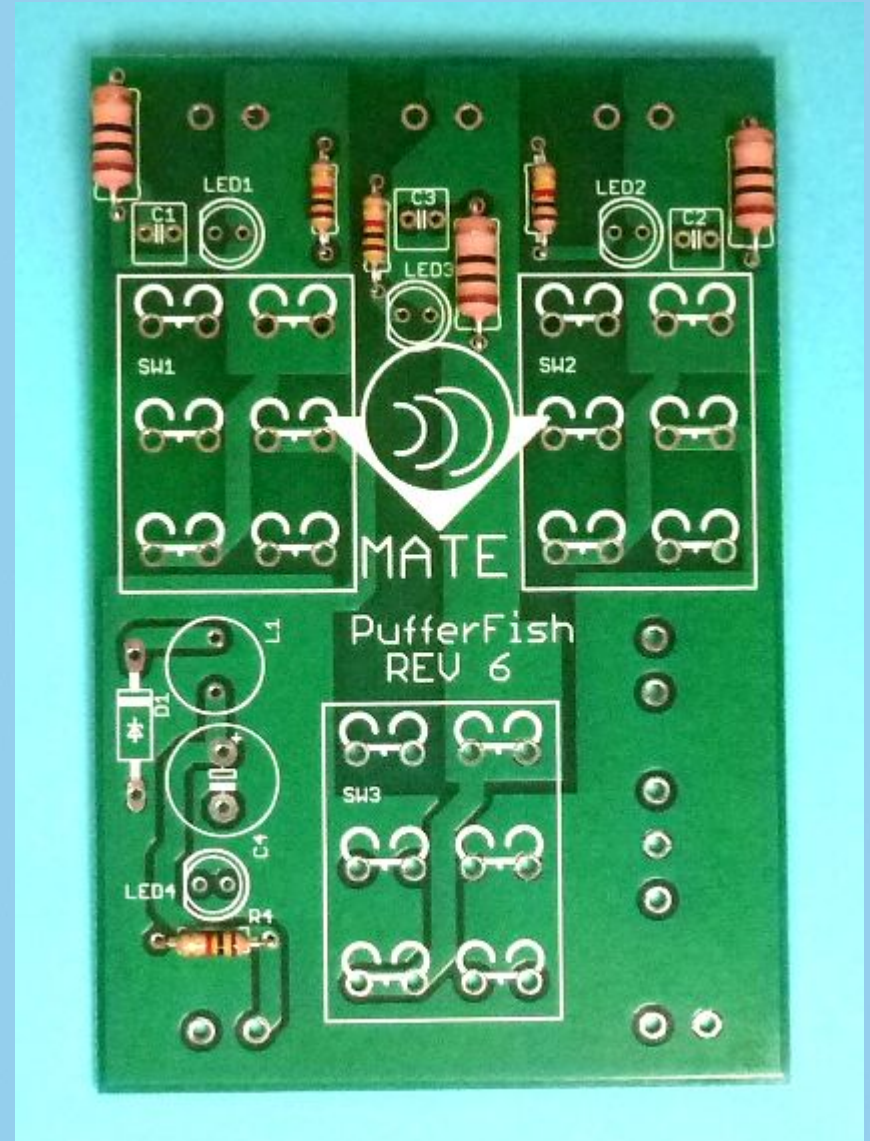
Resistors (2)

A. Solder resistors R1-4 on the back of the board; the solder joints should look like mini, shiny, silver Hershey's Kisses. Clip the ends of the leads off with wire snips/ flush cutters.

B. Insert the three large 10 W resistors into place (R 5-7). Solder them and snip off the excess leads.

Resistors (3)

Your PCB should now look like this.

LEDs (Light Emitting Diodes) (1)

1. Insert your LEDs (orientation **does** matter.) Look carefully at the LED; it is almost circular, but one side is **flat** and has a shorter lead. On the PCB the LED symbol is also **flat** on one side. Insert the LED so the flat side matches the PCB board and then splay and solder the leads on the back of the PCB. Clip the ends of the leads.

These are special bi-polar LEDS. The color will change with polarity change. A green LED will indicate power on. A green LED will also indicate a forward direction of the switch (red is reverse). If your LEDs light up in a way that is opposite to this, you many have inserted the LED backwards or have your power connected backwards.

Flat side

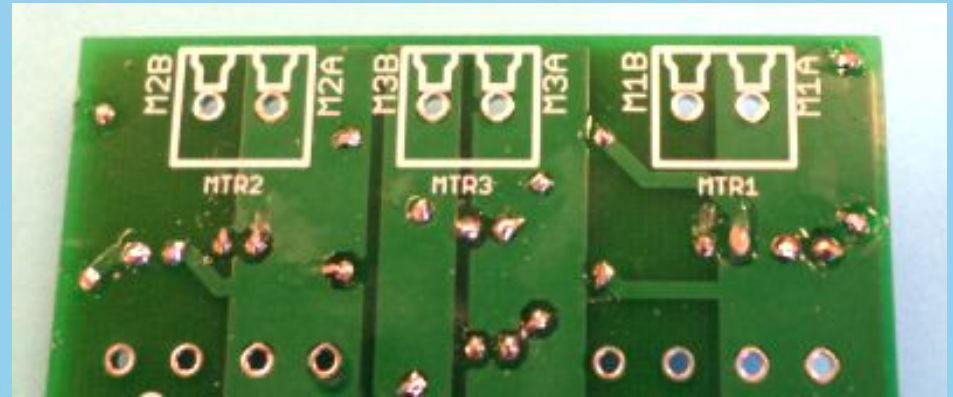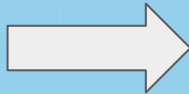LED2

C2

LEDs (2)

Your board should now look like this.
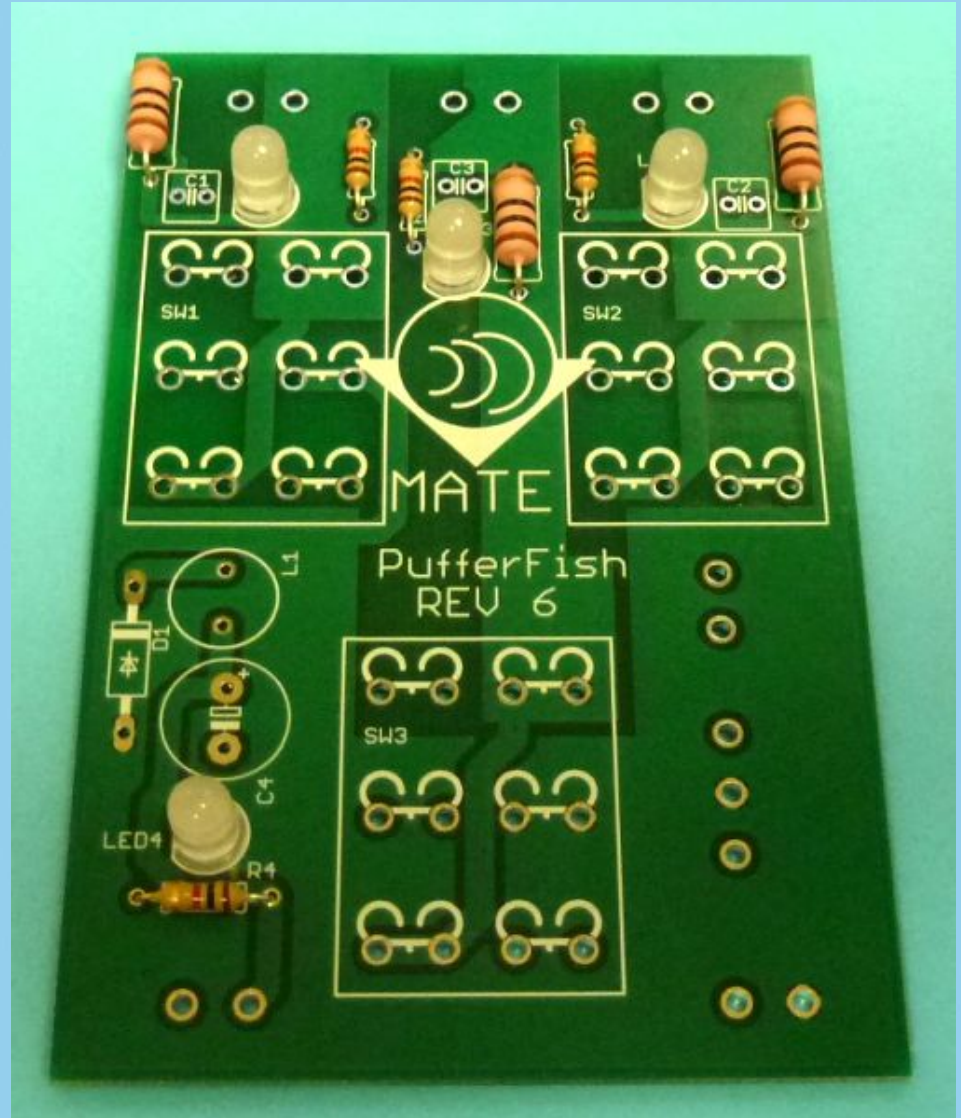
Capacitors - small (1)

Insert the three small blue capacitors and splay the leads (orientation does **not** matter.) The capacitors (1 uF) are located across the top of the board (near the larger, 10 ohm resistors) and are labeled C1-3 Solder the capacitors and clip off the excess leads.

The back of the board should look like this.

Capacitor - large (2)

The 220 uF capacitor, a larger black cylinder shaped capacitor, **does** have directionality (polarity) and needs to be inserted **correctly** into the board at C4. Note that one of the leads is longer than the other, just like the LEDs. The longer lead is positive, the shorter lead is negative.

Insert the positive, longer lead, into the C4 hole marked (+). Solder the large capacitor in place and cut the excess leads.
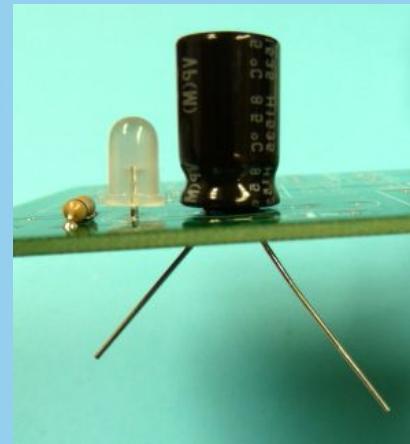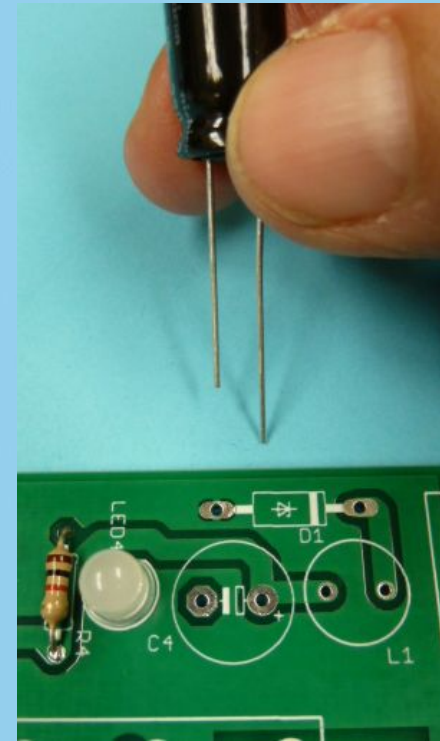
Diode (1)

Insert the diode on the footprint labeled D1. Again, it is very important that the **polarity** of the diode is correct (it is oriented correctly).

Make sure the silver stripe on the diode **matches** the white stripe printed on the board.

Solder the diode and clip any excess leads.


Stripe

Inductor (1)

Insert the radial inductor into the last circle, labeled L1. The printed side of the inductor should face out (towards the diode and nearest edge [left edge] of the board).

Solder the inductor and clip off any excess leads.

printed side

Power In Terminal blocks (1)

A. Attach a 2 wire terminal block to the *Power In* box on the **backside** of the board (align wire holes with the square on the board .

B. Use electrical tape to hold the terminal block *firmly* in place. Solder the pins on the **frontside** of the board.
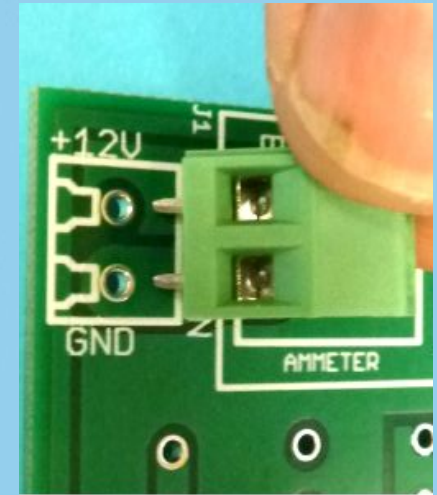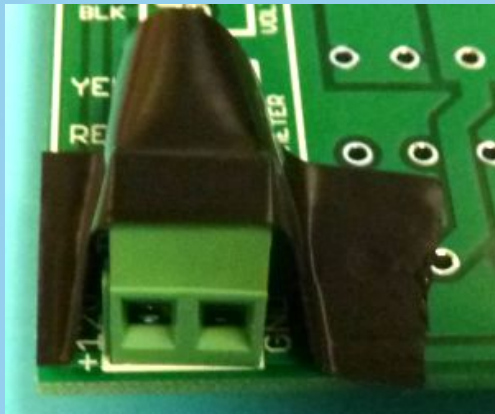
Make sure the terminal block is secure before soldering. A loose terminal block may not conduct electricity!

Meter Terminal Blocks (1)

A. Solder the 3 wire terminal block into the AMMETER rectangle on the backside of the board. Solder the pins on the frontside of the board.
B. Solder a 2 wire terminal block into the VOLTMETER rectangle on the backside of the board. Solder the pins on the frontside of the board.
C. **Make sure the blocks are firmly in place before you solder!**
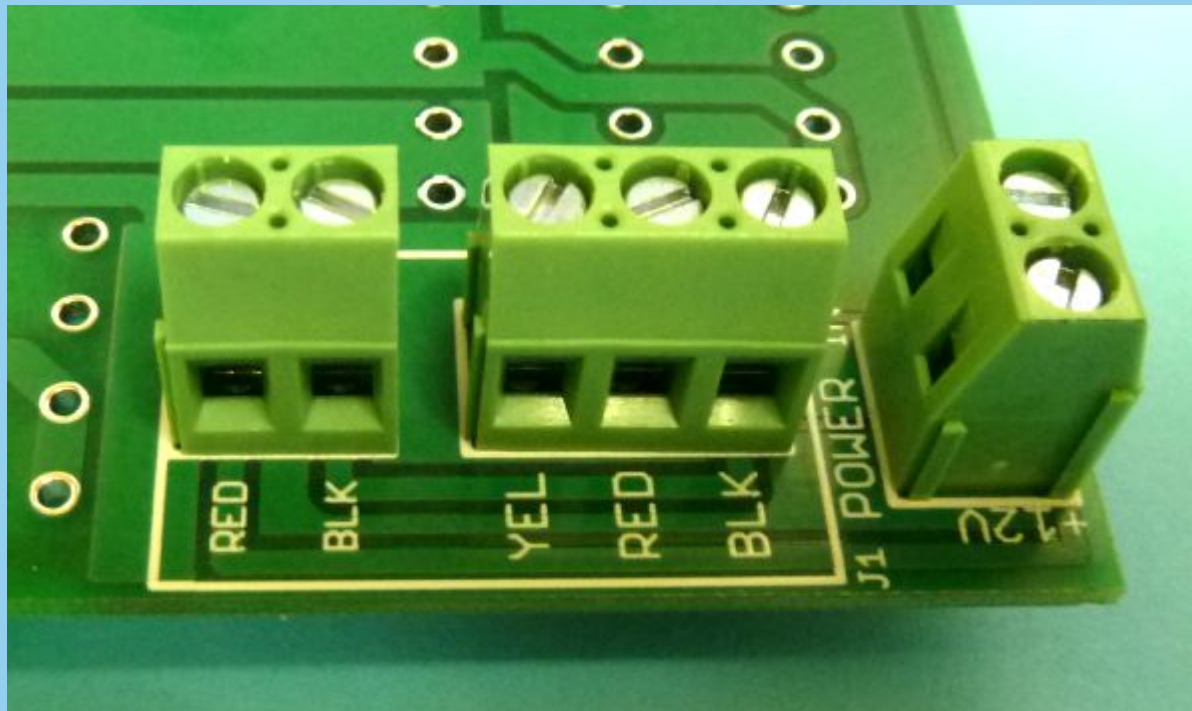
STOP
Do not solder the remaining terminal blocks at this time.

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Solder the Switch Connector Pins

A. Use the extra switches in the kit and mount all the connector pins **neatly** on the switch. Make sure they are all the **same** orientation. Do not push the pins all the way down on the switch. They should be secure, but not pushed all the way down.

B. Insert the pins into the switch pad of the board. Make sure the orientation of the switch pins matches the board icons. All the pins should be seated neatly in the board.
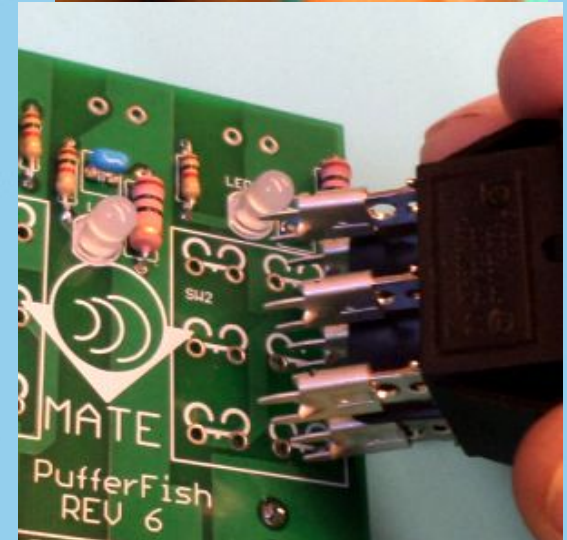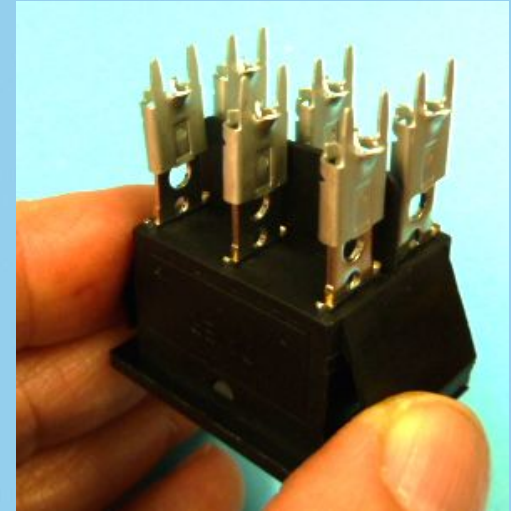
# Solder the Switch Connector Pins

A. Solder the pins on the back of the board.

B. Once all twelve solder joints have been made, repeat these steps with the other two extra switches and other two switch locations.

TIP: When soldering these heavy pins, use the side of the soldering iron tip rather than the tip. This provides better thermal transfer and a better solder connection.

Solder all twelve pins.
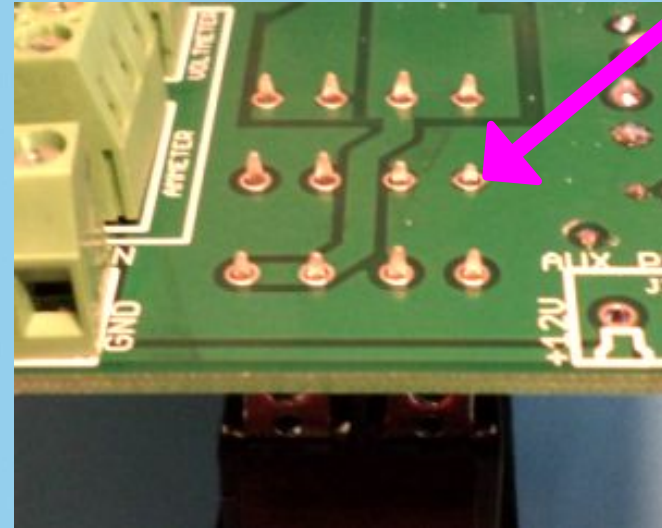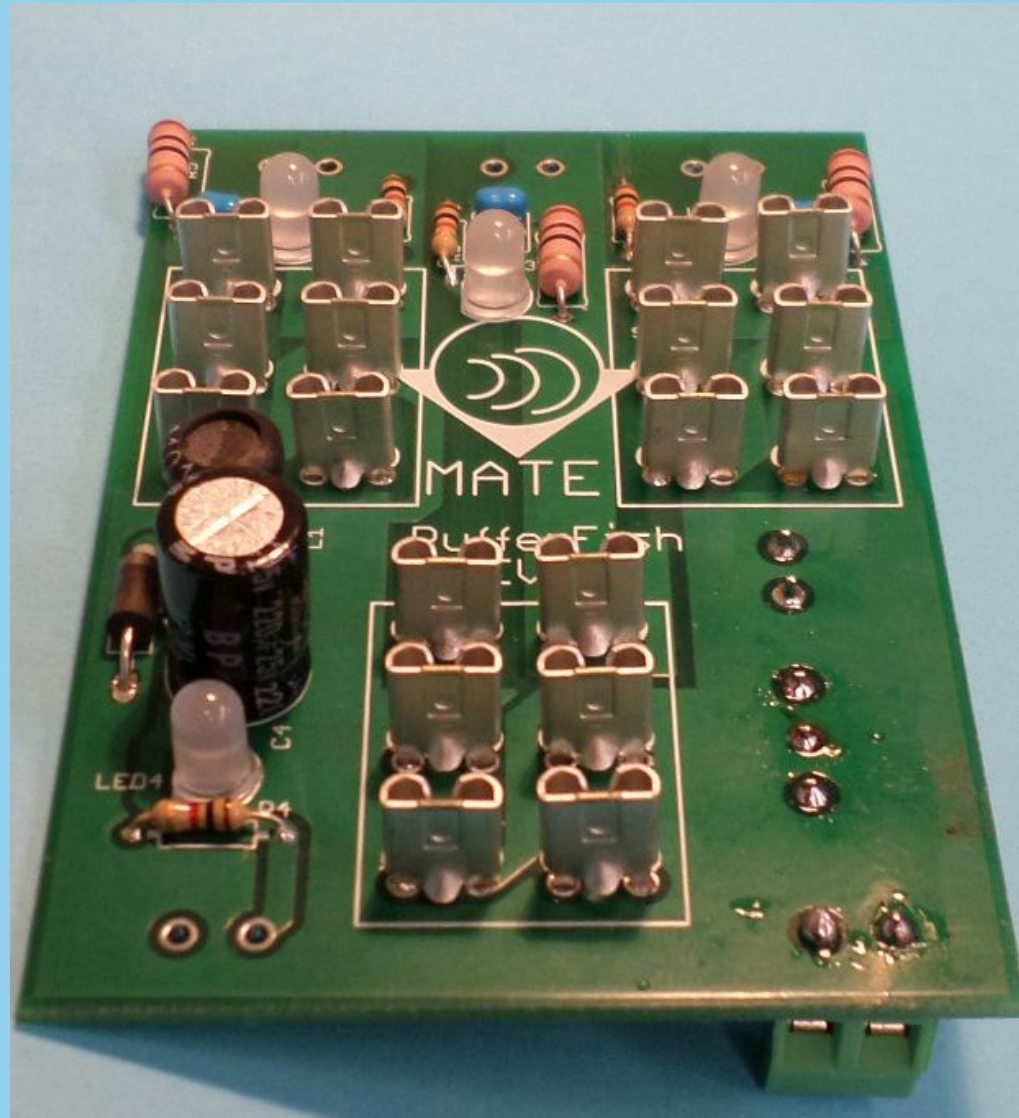
Testing The Board

Leave your switches attached, but if you did remove them, your board should look like the picture on the right. All 18 switch pins should be in installed.

Your board should look like the picture on the next slide.

With your three extra switches installed, this is a good point to test your board to make sure all the components are soldered correctly and are working.
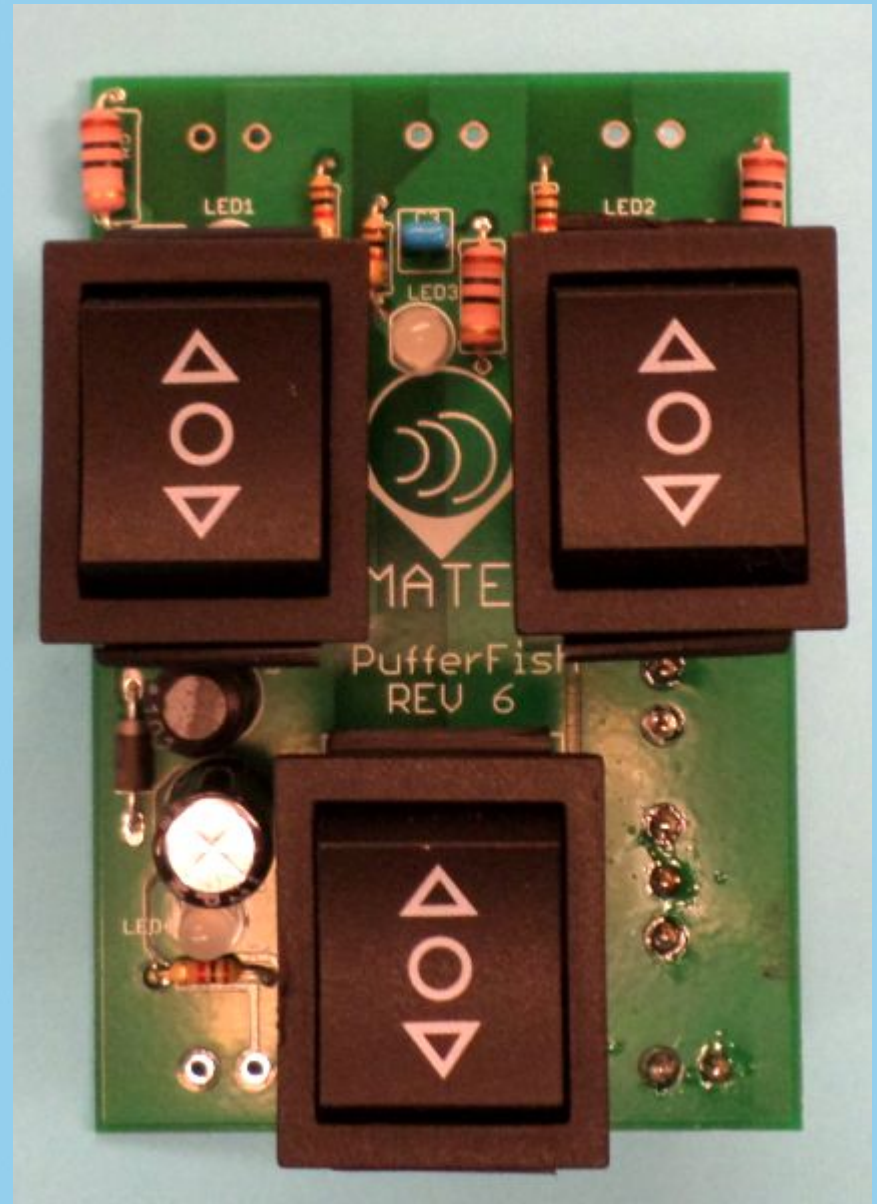
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Testing The Board (1)

Your board should look like the board on the right, having used the three extra switches included with the kit.
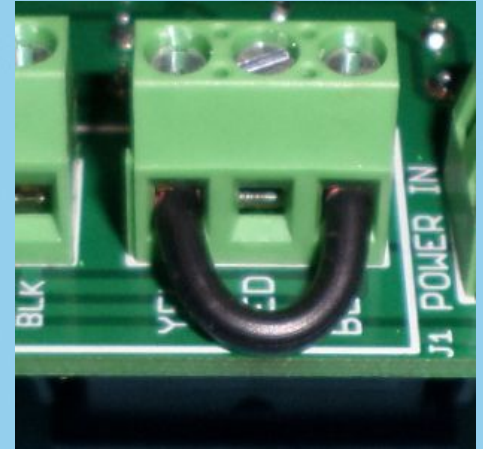
With the switches installed, you can test the board.

A jumper must be used to bridge the amp meter. Cut a 3 cm length of 16 or 18 gauge black wire and strip the ends approximately 5 mm.

Testing The Board (2)

Install the jumper wire between the black and yellow slots on the amp meter 3-position terminal block.
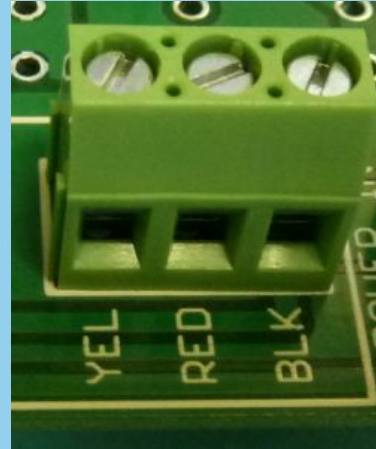
Insert the red lead from your multi-meter into the +12V position on the **Power In** terminal block. Insert the black lead from your multi-meter into the GND position on the Power In terminal block.
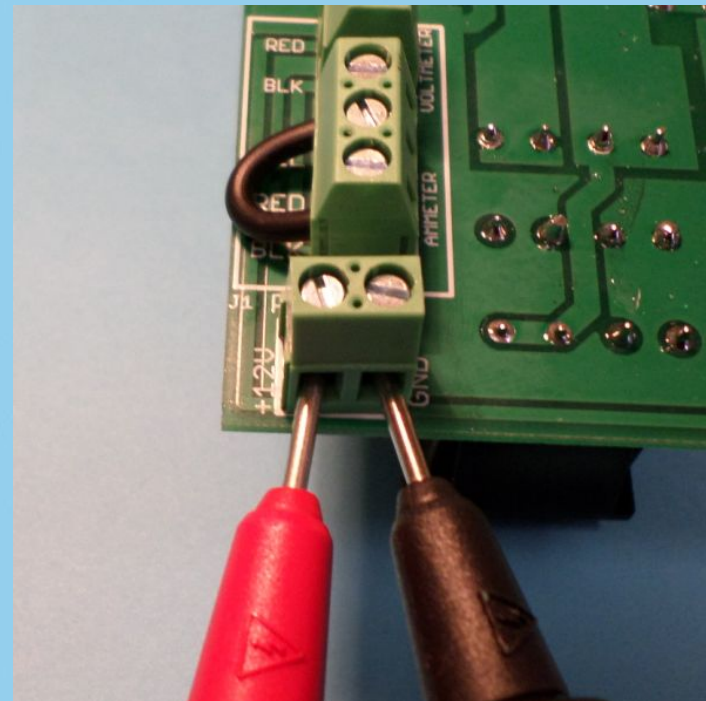
Hint: You can use a flat headed screwdriver to secure the leads into the positions.

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Testing The Board for Short Circuits (3)

This test will identify the presence of short circuits on the board.

- Turn your meter to OHMS.

- The meter should read greather than 1MΩ. (Note: The meter may start low and slowly climb to greather than 1MΩ).

- Push one of your switches UP and hold it. The meter should drop for a few seconds to 0.00 ohms, then move back to greater than 1MΩ.

- Repeat the process for DOWN on that switch.

- Repeat the process for the other two switches.

- If your controller passes all six tests (all three switches, both directions), MOVE ON. If it fails, inspect the solder joints on both sides of the board for solder bridges. If you solder looks good, and only one switch failed, try installing a different switch into the pins.

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Testing The Board (4)

Keep the jumper wire installed, remove the meter wires.

WEAR SAFETY GLASSES! If the large capacitor was installed incorrectly, it can explode when connected!

Use a length of red/black power wire to connect the **Power In** terminal block to a 6-volt or 9-volt battery.
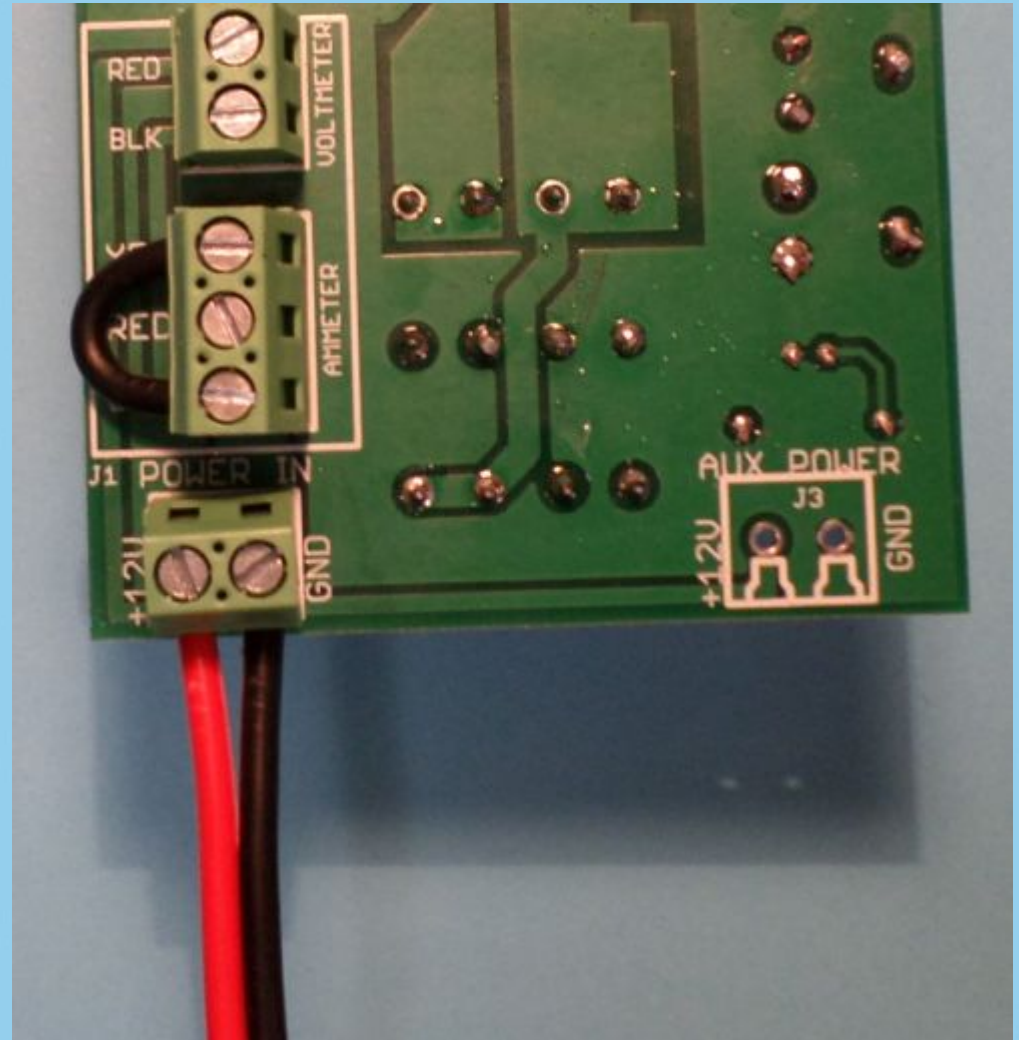
Testing The Board (5)

LED4 is the power indicator. If LED 4 shines green, the board is getting power. If LED4 shines red, the board is getting power, but the LED was installed backwards. If LED 4 is not shining, check the battery connections, the solder joints, and check whether the diode was installed correctly (polarity).

Testing the switches

LED 1, LED 2 and LED 3 are the indicators for each switch. Push the top left switch UP. LED 1 should show green. Push the top left switch DOWN. LED 1 should show red.

Repeat for the bottom middle switch and the top right switch. When pushed UP, the corresponding LED should be green. When pushed DOWN, the corresponding LED should be red.
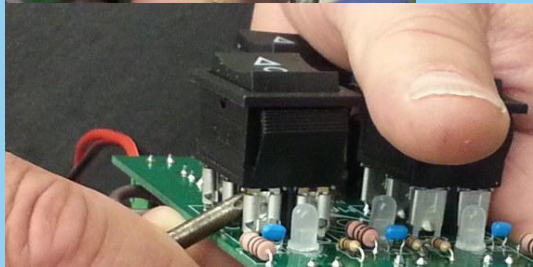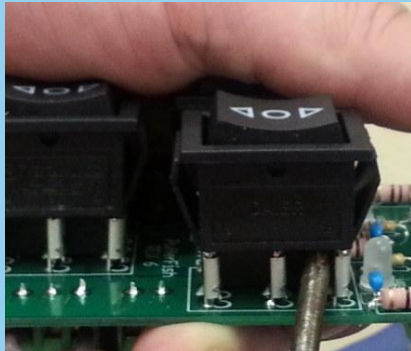
Remove the jumper on the amp meter when testing is done.

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Remove the Switches from the Connector Pins.

Remove all three switches from the pins. If you pushed them down hard on the pins, you may need to use a screwdriver to remove them. If needed, use the screwdriver to slowly pry the switches up one side at a time.

To

Aux Power Terminal block (1)

A. Attach a 2 wire terminal block to the *Aux Power* box on the **backside** of the board (align wire holes with the square on the board).

B. Use electrical tape to hold the terminal block *firmly* in place. Solder the pins on the **frontside** of the board.
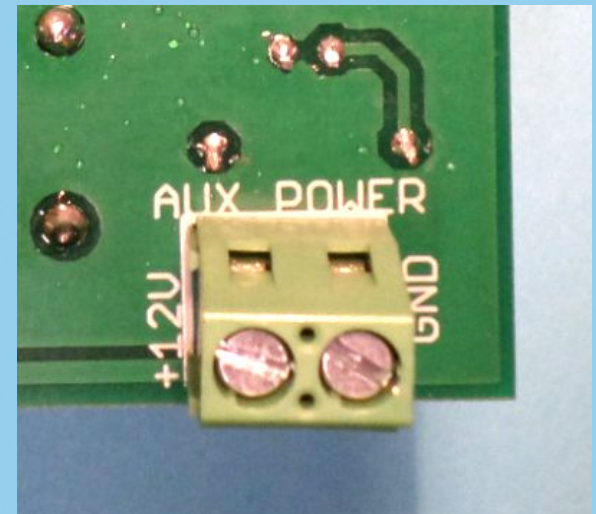
Make sure the terminal block is secure before soldering.
A loose terminal block may not conduct electricity!

Inserting Switches

If you removed switches from the lid to complete testing, insert them back into the lid of the control box enclosure. The switches will click into place. Squeeze the plastic tabs on the short ends if it is too difficult to insert the switches.

If you used the three spare switches as recommended, the three switches should still be installed in the control box lid.
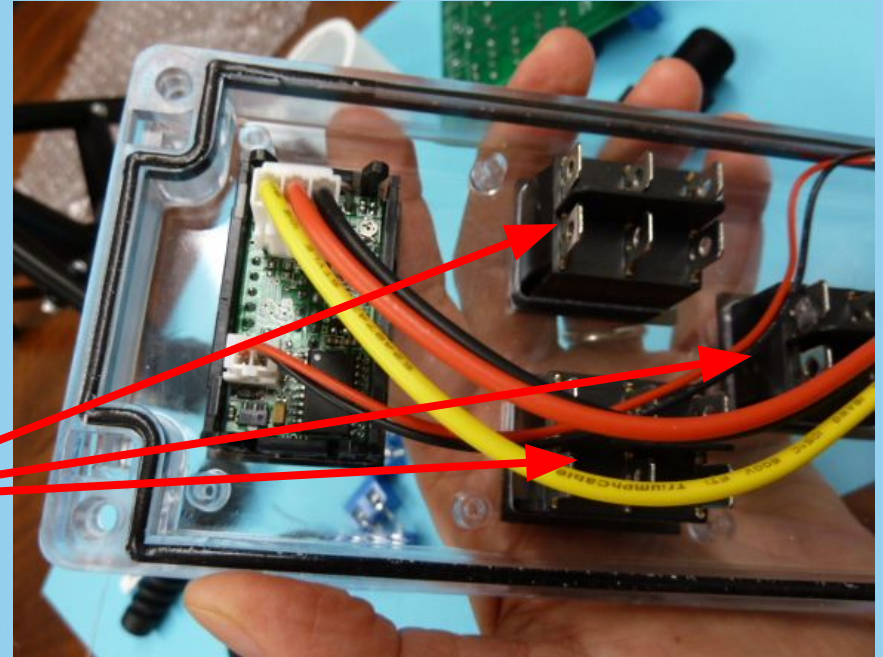
There is no polarity with the switches, they can be inserted in either direction.

Connecting the Volt/amp meter (1)

Disconnect the wires from the volt/amp meter by squeezing the white plastic connector and pulling; the plastic connector will slide off of the volt/amp meter pins.
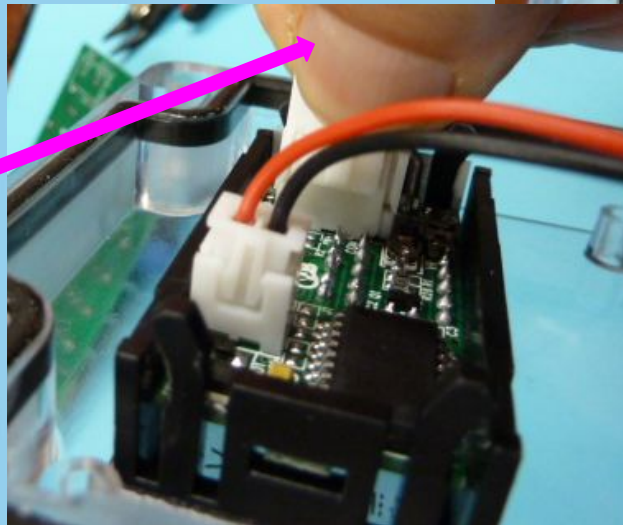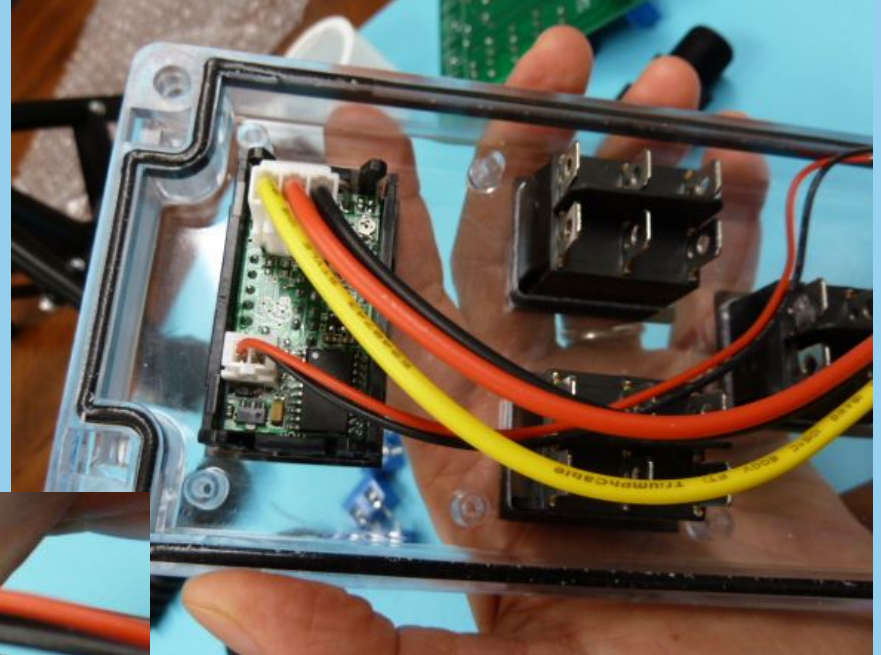
Squeeze and pull

Attach the volt/amp meter wires to the terminal blocks on the circuit board (1)

A. Strip about 1 cm off of the thicker amp/volt meter wires.
B. Strip about 1.5 cm off the thinner amp/volt meter wires. Double over the metal wires in the thinner wires to create a larger surface area (see next slide).

Note: The wires come with approximately 0.5 cm stripped off, but more plastic sheathing needs to be removed.

Different Amp/Volt Meters

VERY IMPORTANT!!! READ CAREFULLY!

There are two different amp/volt meters for the PufferFish REV6. You may have been sent either of these meters with your kit.

METER 1: Three thicker wires - **Black**, **Red** and **Yellow**. Two thinner wires - Black and Red. If you have this meter, follow the instructions for METER 1.

METER 2: Two thick wires - **Black** and **Red**. Three thinner wires - Black, Red and Yellow. If you have this meter, follow the instructions for METER 2.

Meter 1

Meter 2

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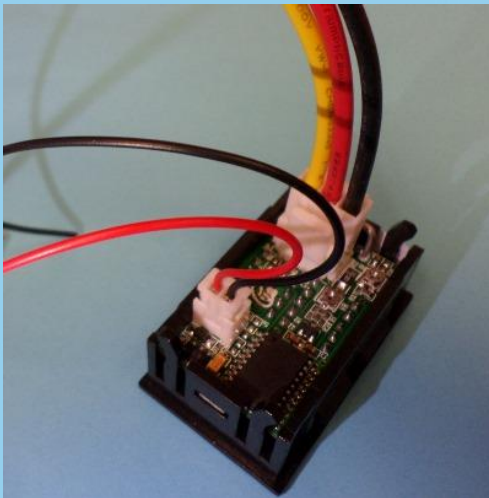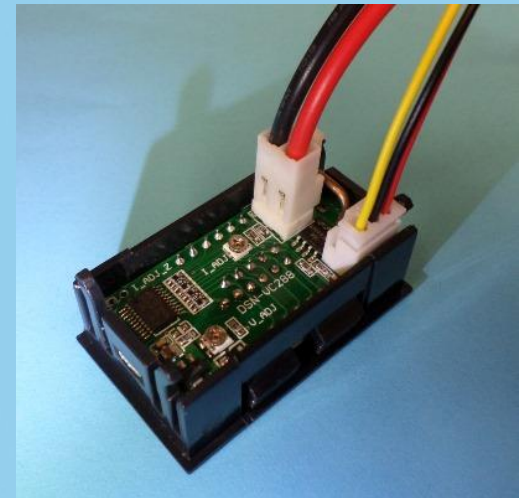
METER 1
Attach the volt/amp meter wires to the terminal blocks on the circuit board (2)

A. The three thicker wires (yellow, red, black) go the amp meter. Insert the wires into their respective color stations. Use the small ⅛-inch screwdriver to secure the wire into each station.

B. The two thinner wires (red, black) go to the voltmeter. Insert the wires into their respective color stations. Use the ⅛-inch screwdriver to secure the wire into each station.

C. Give each wire a gentle pull to make sure all five wires are secure.
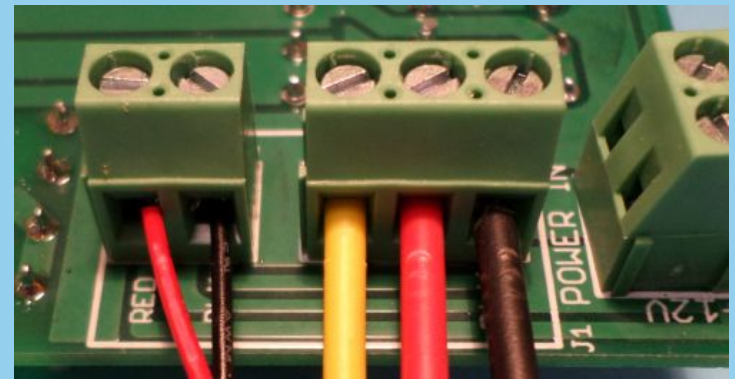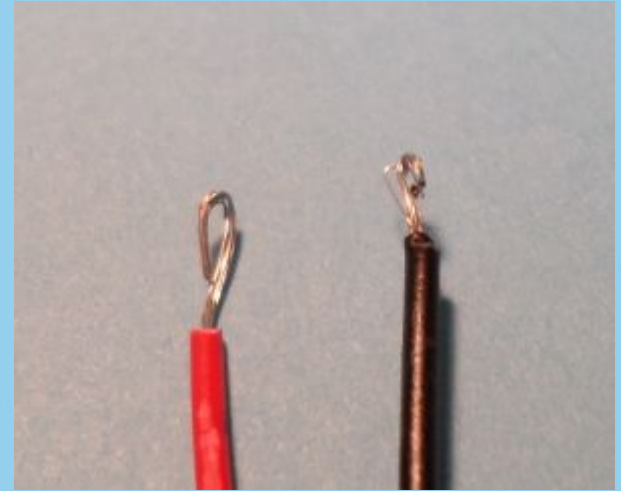
METER 2: Attach the volt/amp meter wires to the terminal blocks on the circuit board (2)

A. The **thicker BLACK** wire from the meter goes into the terminal labeled "BLK" on the ammeter three-terminal block.

B. The thinner yellow wire from the meter goes into the terminal labeled "RED" on the ammeter three-terminal block.

C. The **thicker RED** wire from the meter goes into the terminal labeled "YEL" on the ammeter three-terminal block.

D. The thinner red wire from the meter goes into the terminal labeled "RED" on the voltmeter two-terminal block.

E. The thinner black wire from the meter goes into the terminal labeled "BLK" on the voltmeter two-terminal block.

Use the ⅛-inch screwdriver to secure the wire into each station.

Give each wire a gentle pull to make sure all five wires are secure.

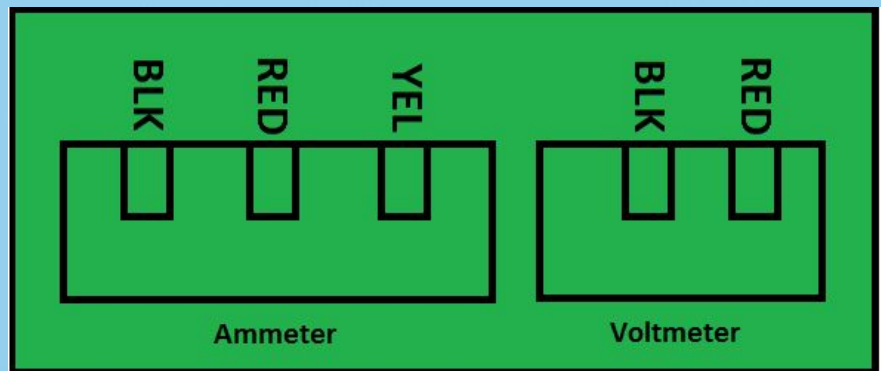BLK RED YEL   BLK RED

Ammeter   Voltmeter

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METER 2

Attach the volt/amp meter wires to the terminal blocks on the circuit board (3)

Motor Terminal blocks (1)

A. Attach the remaining three 2-station wire terminal block to the **MOTOR** boxes on the **backside** of the board (align wire holes with the square on the board .

B. Use electrical tape to hold the terminal blocks *firmly* in place. Solder the pins on the **frontside** of the board.

   Hint: It may be easiest to tape down the two outer terminal blocks and soldering them, then return and solder the middle terminal block
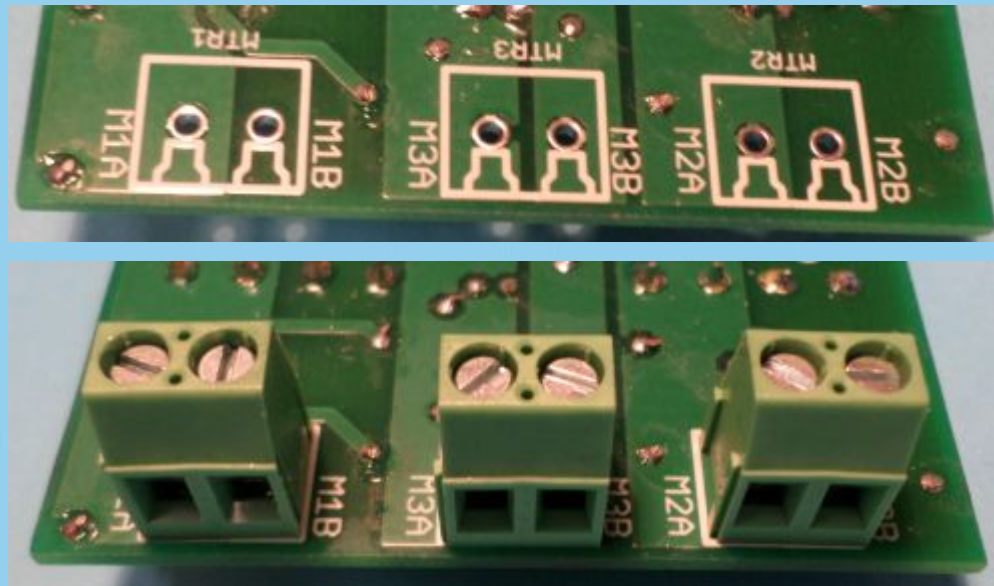
C. Make sure all three motor terminal blocks are securely connected to the printed circuit board.

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Test the Circuit Board (7)

A. Use the power cord with fuse holder (make sure the fuse is installed) to test the circuit board.
B. If you have not completed the power cord, see the power cord instructions.
C. Strip 0.5 cm from the end of the wires without the Anderson Powerpoles.
D. Insert the red wire into the +12V station and the black wire into the GND station of the terminal block POWER IN. Use the ⅛-inch screwdriver to secure the wires. Give the wires a gentle pull to verify they are secure.

Completed power wire
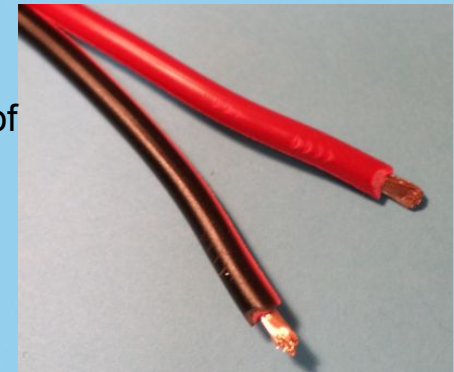
Stripped ends of power wire

Power wires installed into PCB

Test the Circuit Board (8)

A. Plug the Anderson Powerpole connectors into the power source. LED 4 should shine green.

B. Push the top left switch UP. LED 1 should shine green. Insert the leads from a multi-meter into terminal block MTR 1 (red into M1A and black into M1B). The voltage shown should be the same as the source voltage.

C. Push the top left switch DOWN. LED 1 should shine red. Insert the leads from a multi-meter into terminal block MTR 1 (red into M1A and black into M1B). The voltage shown should be the same as the source voltage but display a negative sign.

D. Repeat steps B and C for Motor 2 (top right) and Motor 3 (bottom center).

E. Unplug from the power source.

If the LEDs do not come on, or you do not read full voltage on the meter, check all the soldering connections.

Connect the circuit board to the switches (1)

A. Line up all 18 switch connectors with the 18 posts on the back of the switches. Once all 18 are lined up, push the switches in the lid of the control box **ALL THE WAY DOWN** onto the switch connectors. The switches will snap into place.

B. Double check to make sure all 18 posts are inserted correctly into the 18 switch connectors.

C. Plug the volt/amp meter wire connectors back into the volt/amp meter. The plastic connectors will snap into place.
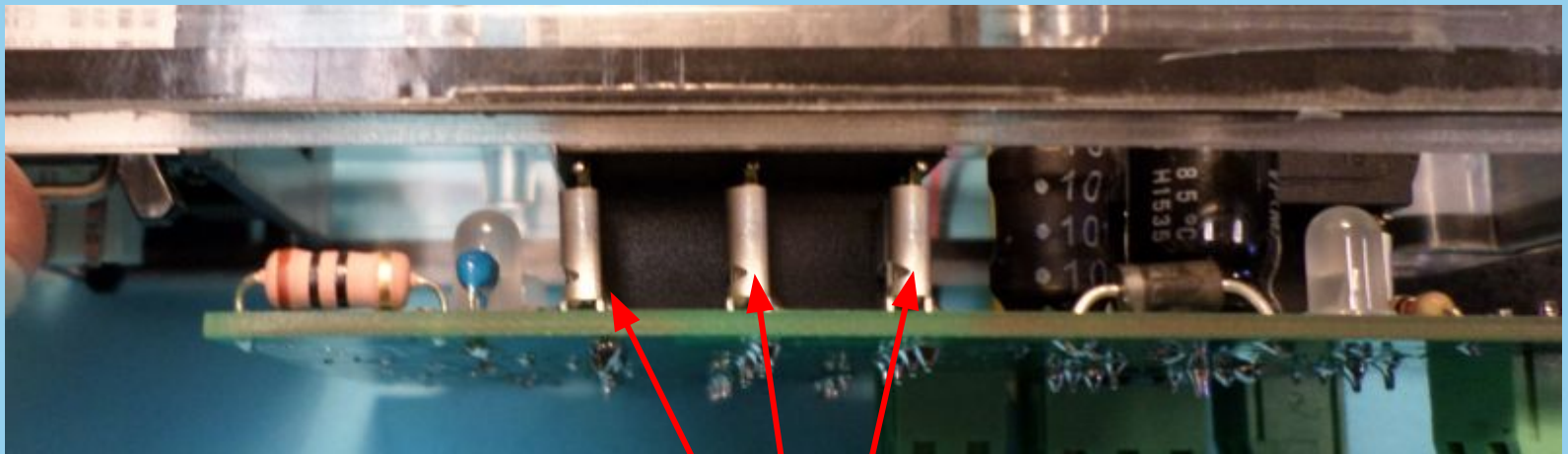
Connections are all the way down.

Test the Circuit Board (9)

A. Plug the Anderson Powerpole connectors into the power source. LED 4 should shine green.

B. Check the voltage on the meter installed into the lid. It should be nearly the same as the voltage of the power source.

C. Push the top left switch UP. LED 1 should shine green. Insert the leads from a multi-meter into terminal block MTR 1 (red into M1A and black into M1B). The voltage shown should be the same as the voltage shown on the meter on the control box lid.

D. Push the top left switch DOWN. LED 1 should shine red. Insert the leads from a multi-meter into termnal block MTR 1 (red into M1A and black into M1B). The voltage shown should be teh same as the voltage shown on the meter on the control box lid.

E. Repeat steps B and C for Motor 2 (top right) and Motor 3 (bottom center).

F. Unplug from power source.

If everything is working ...

Congratulations. You have a working PufferFish control box.

There is one more thing we want to do:

Insert the power wire through the strain relief.

Strain relief (1)

There are four strain relief connectors included in the PufferFish kit. Use the smaller two included with the control box. They are the ⅜-inch FLEX strain relief connector (longer pig-tail) and the ⅜-inch DOME strain relief connector.

Strain relief (1)

The strain relief connectors are installed into the two holes in the bottom of the PufferFish control box.

A. Insert the FLEX strain relief connector into the hole nearest the center of the box. Push the connector through and attach the nut on the inside of the control box to secure the strain relief to the box.

B. Insert the DOME strain relief connector into the hole furthest from the center of the box. Push the connector through and attach the nut on the inside of the control box to secure the strain relief to the box.

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Strain relief (2)

A. Remove the red and black wires from the ***Power In*** terminal block.

B. Run the red and black wires through the DOME strain relief connector. Push the wires through the strain relief from the outside of the control box to the inside of the control box.

C. Re-attach the red and black power wires to the ***Power In*** terminal block.

To Anderson Powerpoles

PufferFish

MTS
marine technology society

Strain relief (3) and Closing the Box

A. Pull any excess power wire through the Dome strain relief. When all the excess wire is pulled through, twist the Dome clockwise to tighten its gasket down over the power wires.

Hint: Make sure your power wires stay inserted into the **Power In** terminal block when pulling on them.

Line up the lid with the control box and use the four control box screws to secure the lid onto the control box. Power up the control box again and test the system one more time.

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Finished … almost

The control box is completed. Eventually the top end of the tether will be connected to the three *Motor* terminal blocks.

Information on attaching the top end of tether wire into the three tether terminal blocks will be included in the Tether section.

UPDATES

Oct 25, 2016: **Volt / amp meter wires**. Some meters have thicker (lower gauge) voltmeter wires and thinner (higher gauge) amp meter wires. Some meters are the other way around, thicker amp meter wires. Slides #31 and #32 were altered to reflect this and leave the document more general (usable for both models of meters). MG.

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