

Electronics Technology and Robotics III

Final ROV Construction

- **Administration:**
 - Prayer
- **Review:**
 - The final Remotely Operated Vehicle (ROV) assembly is made up of some of the components that we have already discussed and built:
 - For the frame see:
http://cornerstonerobotics.org/curriculum/lessons_year3/eriii_5_structure_materials3_build_frame.pdf
 - For the pressure canister see:
http://cornerstonerobotics.org/curriculum/lessons_year3/eriii_8_pressure_hulls_canisters3_build_canister.pdf
 - For the control box and tether see:
http://cornerstonerobotics.org/curriculum/lessons_year3/eriii_17_power_systems5_wire_power_system.pdf
- **Installing the Cable Gland into the Aluminum Canister End Cap:**
 - Materials:
 - 1 – Lapp S1234 Grey Liquid Tight Nonmetallic Connector (Cable Gland) Source:
<http://www.alliedelec.com/search/productdetail.aspx?SKU=70123233>
 - 1 – Aluminum Canister End Cap, See Lesson 8
 - 1 – $\frac{3}{4}$ " x 14 NPT Tap
 - 1 – 59/64" Drill Bit
 - Nylon Tape
 - Procedure:
 - We group all the canister wires into one gland to minimize the number of holes drilled and tapped. To reduce the cost of the drill, drill chuck, and tap, you may wish to separate the wires and drill several smaller holes into the end cap.
 - Using a drill press to keep the drill bit and tap aligned properly, drill a pilot hole into the center of the aluminum canister end cap constructed in Lesson 8. The recommended drill speed is 1000 rpm.

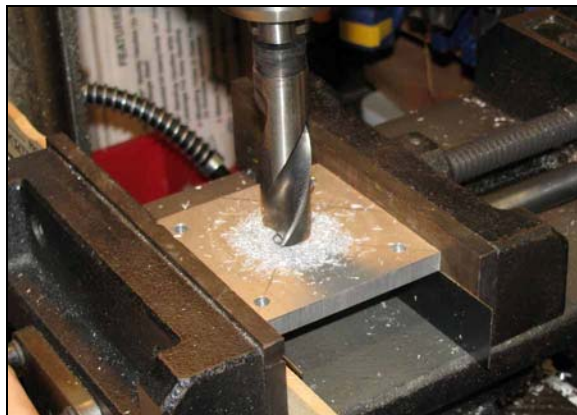


Figure 1: Drilling the Pilot Hole into the End Cap

- Insert the $\frac{3}{4}$ " x 14 NPT tap into the 1" keyed drill chuck. Use both hands to rotate the chuck (Figure 2) and cut the threads into the cable gland pilot hole (Figure 3). The tap is tapered, so extend the tap at least half way through the pilot hole (Figure 3).



Figure 2: Hand Tapping with a Drill Press



Figure 3: Gland Hole Tapped

- Apply nylon tape around the gland threading and screw the gland into the canister end cap (Figure 4).



Figure 4: Gland in Canister End Cap

- **Epoxy the Wires that Enter the Pressure Cylinder:**
 - Materials:
 - 1 – 5/8” x 0.014 x 2” Long (5 cm) Round Brass Tube
 - Clear Epoxy Potting Compound (we use 3M Scotch-Weld Adhesive DP-270 (Allied Electronics: <http://www.alliedelec.com/search/productdetail.aspx?SKU=70113955>))
 - EPX Applicator Tool (Allied Electronics: <http://www.alliedelec.com/search/productdetail.aspx?SKU=70039961>)
 - EPX(TM) Helical Mixing Nozzle (Allied Electronics: <http://www.alliedelec.com/search/productdetail.aspx?SKU=70039962>)
 - ROV Tether from Lesson 17.
 - Procedure:
 - Cut all of the wires at the vehicle end of the tether to the same length.
 - Using a flaring tool, flare out one end of the brass tube (Figure 5).

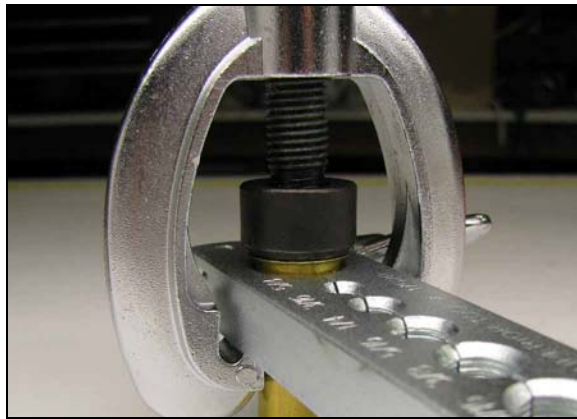


Figure 5: Flaring One End of the Brass Tube

- Insert all of the wires **expect** the 25’ – 16/2 AWG stranded wire cable into the brass tube with about 4” (10 cm) of wires protruding from the end of the tube.

- Apply electrical tape between all of the wires at the non-flared end of the brass tube; no two wires should be touching (Figure 6).

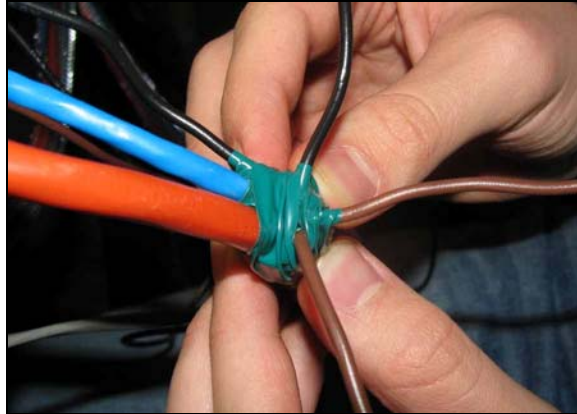


Figure 6: Seal Non-flared End of Brass Tube with Electrical Tape

- Shot the epoxy into the open end of the brass tube (Figure 7) and then let the epoxy set for 24 hours.



Figure 7: Epoxy Brass Tubing

- **Connecting the Vertical Thruster Motor Wires:**
 - Materials:
 - Clear Epoxy Potting Compound (we use 3M Scotch-Weld Adhesive DP-270)
 - EPX Applicator Tool
 - EPX(TM) Helical Mixing Nozzle
 - 1 – 3" x 1/2" ID x 3/8" OD Clear Vinyl Tubing
 - ROV Tether from Lesson 17.
 - Procedure:
 - Determine the final location where the vertical thruster wires and the 25' 16/2 AWG stranded wire cable connection will be. I suggest that you do not shorten the thruster wires since you may want to modify your ROV and need the extra wire length in the future.
 - Cut the 16/2 AWG stranded wire cable to the proper length.
 - Place the 1/2" vinyl tubing over the cable before you solder the wires together.
 - Solder the 16/2 AWG stranded wire cable wires to the vertical thruster wires. Be sure to insert the heat shrink tubing over the wires before soldering. Stagger your wire connections.



Figure 8: Vertical Thruster Connection

- Slip the vinyl tube over the splice and seal one end of the vinyl tube by taping between the wires (Figure 9).
- Shot the epoxy into the open end of the tube (Figure 9) and let the epoxy set for 24 hours.



Figure 9: Squeeze Epoxy into the Vinyl Tube

- **Control Printed Circuit Board (PCB):**
 - The only part of the ROV that you need to fabricate is the PCB. Then you will attach the connecting wires to its terminals.
 - The PCB is one sided to make for simple chemical etching. Because the board is one sided, there are a few jumper wires that must be added where traces would otherwise cross each other.
 - We recommend 1/16" thickness for the PCB to avoid damage to the traces when you are attaching the control wires to the connector terminal blocks. In Figure 10, the traces were compromised when the 1/32" thick board bent while attaching the control wires.

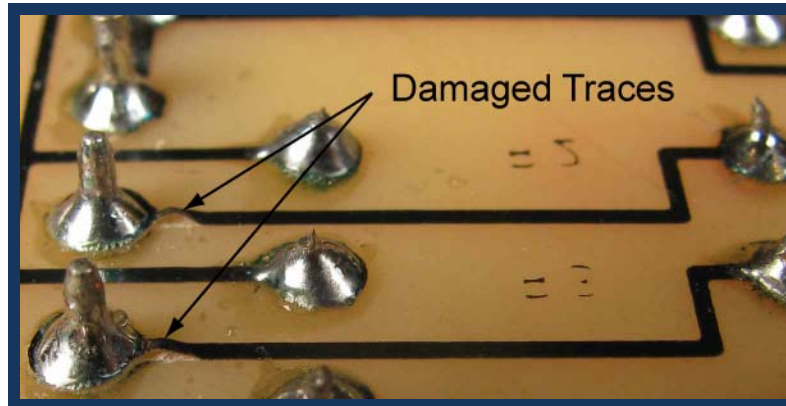


Figure 10: Traces Damaged by Bending 1/32" Printed Circuit Board

o PCB Parts List:

ROV PCB Parts

Updated 9/15/12

Part Label	Part Description	Supplier	Supplier Part #	Unit Cost	Quantity	Total Cost	Notes:
IC1	PIC16F88	microchipdirect.com	PIC16F88-I/P	\$2.60	1	\$2.60	Purchased in quantities of 1 - 25
IC1 Socket	18 Pin Socket 0.30" Width	Jameco	112231	\$0.16	1	\$0.16	Purchased in quantities of 10-90
IC2,3	+5V 1A Voltage Regulator T-220 Package	Jameco	51262	\$0.29	2	\$0.58	Purchased in quantities of 1-9
X1,2,4,5	Connector Terminal Blocks 2 Position 16A	Jameco	2094485	\$0.39	4	\$1.56	Purchased in quantities of 1-9
X3	Connector Terminal Blocks 4 Position 16A	Jameco	2124429	\$0.65	1	\$0.65	Purchased in quantities of 1-9
C1,3	0.33 uF Capacitor	Jameco	138237	\$0.15	2	\$0.30	Purchased in quantities of 10-90
C2,4	0.1 uF Capacitor	Jameco	25523	\$0.08	2	\$0.16	Purchased in quantities of 10-90
R1	4.7K 1/2W Resistor	Jameco	661677	\$0.05	1	\$0.05	Purchased in quantities of 100-900
R2 - R5	10K 1/4W Resistors	Jameco	691104	\$0.04	4	\$0.16	Purchased in quantities of 100-900
R6 - R9	1K 1/4W Resistors	Jameco	690865	\$0.04	4	\$0.16	Purchased in quantities of 100-900
R10 - R14	1K 1/2W Resistors	Jameco	661503	\$0.05	5	\$0.25	Purchased in quantities of 100-900
LED1	Red LED	Jameco	333973	\$0.12	1	\$0.12	Purchased in quantities of 10-90
LED2 - LED5	Green LED	Jameco	334086	\$0.10	4	\$0.40	Purchased in quantities of 10-90
Q1 - Q4	PN2907A NPN Transistor TO-92 Package	Jameco	178520	\$0.05	4	\$0.20	Purchased in quantities of 10-90
D1 - D4	1N5817 Schottky Diode	Jameco	177949	\$0.14	4	\$0.56	Purchased in quantities of 10-90
K1 - K4	Relay SPDT 8 Amps DC, 5V Coil	Jameco	187151	\$1.49	4	\$5.96	Purchased in quantities of 1-9
PCB	MG Chemicals 9x6 in Printed Circuit Board 1/16" Thick Single Sided Presensitized (Makes 3 Boards)	Allied Electronics	70125850	\$12.45	1	\$4.15	Purchased in quantities of 1+
Total:						\$18.02	Costs exclude shipping & sales tax

Vendor Name	Website	Telephone
Jameco	www.jameco.com	1-800-831-4242
MicrochipDirect	www.microchipdirect.com	1-888-624-7435
Allied Electronics	www.alliedelec.com	1-866-433-5722

Table 1: PCB Parts List

- o The first step in fabricating the PCB is cutting the board to the proper size: 2 5/8" x 6".
- o Next, print the PCB positive trace artwork onto a sheet of transparency film for copiers. We use the 3M PP2500 transparency film. For the PCB trace layout artwork, see: http://cornerstonerobotics.org/schematics/year3_control_board1_abeled.pdf
- o Follow the MG Chemicals positive photofabrication process training guide at:
 - <http://www.mgchemicals.com/tech-support/instructional-guides/prototyping-positive-illustrated/>
 - <http://www.mgchemicals.com/tech-support/instructional-guides/prototyping-positive-instructions/> These instructions are printed in Appendix A.
 - <http://www.youtube.com/watch?v= sdcucoWj4E>

- MG Chemicals Photofabrication kits are available at:
 - Starter Kits:
 - http://www.jameco.com/webapp/wcs/stores/servlet/Product_10001_10001_2121017_-1 or
 - http://www.jameco.com/webapp/wcs/stores/servlet/Product_10001_10001_2113244_-1
 - Exposure Kit:
 - http://www.jameco.com/webapp/wcs/stores/servlet/Product_10001_10001_2121025_-1?CID=PDF
 - Etching Tank Kit:
 - http://www.jameco.com/webapp/wcs/stores/servlet/Product_10001_10001_2121033_-1?CID=PDF (416-ES) or
 - <http://www.alliedelec.com/search/productdetail.aspx?sku=70125730> (416-E)
 - Positive Developer (MG # 418-500 ml):
 - <http://www.alliedelec.com/search/productdetail.aspx?SKU=70125802>
 - Ferric Chloride Etching Solution (MG # 415-4L)
 - <http://www.alliedelec.com/search/productdetail.aspx?SKU=70125797>
- Use a #56 drill bit to drill the holes for the terminal blocks X1-X5, the voltage regulators IC2 and IC3, the diodes D1-D4, and the relays K1-K4.
- Drill all of the other component holes with a #67 drill bit.
- Layout the components in their correct placement on the component side of the board and solder them to the traces on the solder side of the board. Refer to Figure 12.
- Note: X1 – X5 should be fitted together on your board. The PCB artwork was revised to accommodate this after the photo in Figure 12 was taken.
- PCB Parts Placement (Component Side):

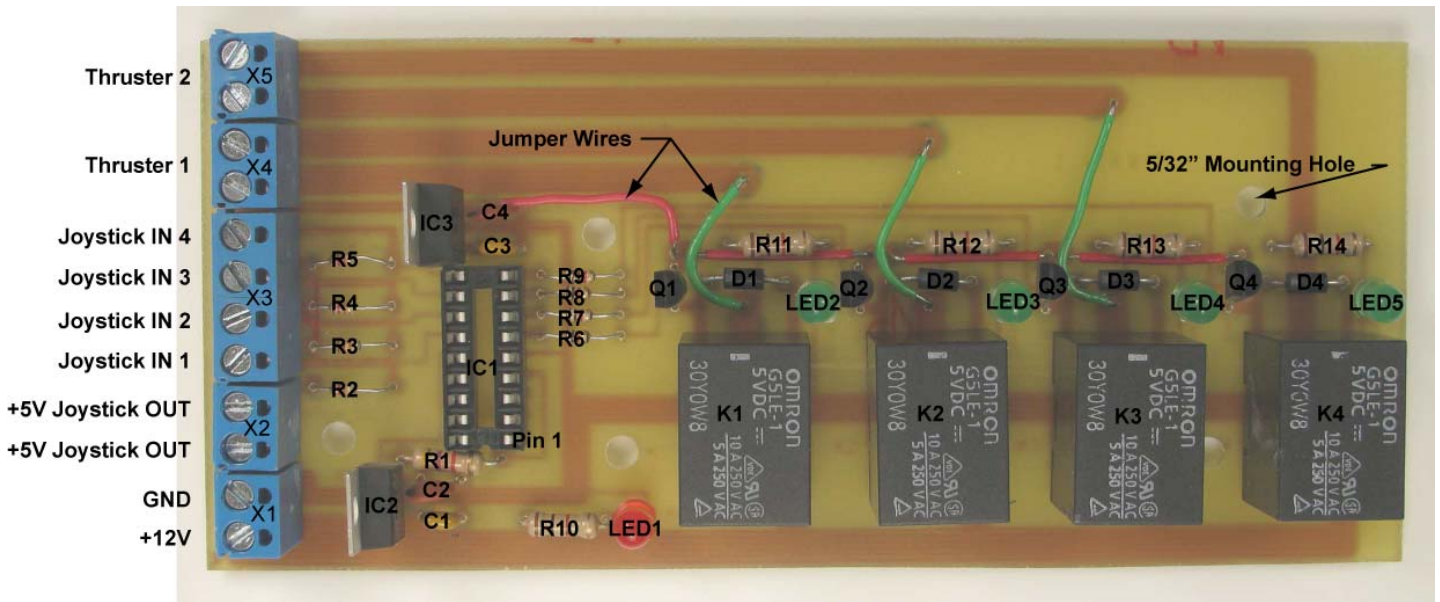


Figure 12: Component Layout on the Component Side of the PCB

- **Mounting the PCB to the Canister End Cap:**

- **Materials:**

- 2" Wd x 7" Lg x 1/8" Tk Aluminum Bar
- 5 - #6-32 x 3/4" Stainless Steel Screws
- 2 - #6-32 x 1/4" Stainless Steel Screws
- 5 - #6 Stainless Steel Nuts
- 7 - #6 Stainless Steel Washers
- 5 - #6 x 1/4" Nylon Spacers
- 1 - Tube Loctite Threadlocker

- **Procedure:**

- Cut and drill the aluminum bar to the dimensions in the Figure 4 below.
- Bend the bar 90 degrees on the bend line as shown.

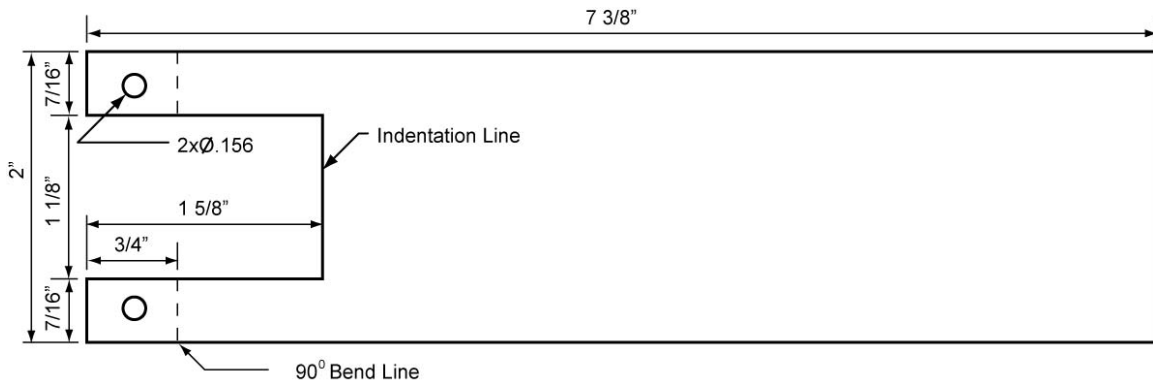


Figure 13: PCB Mounting Bracket

- Align the PCB on the mounting bracket. See Figure 14.

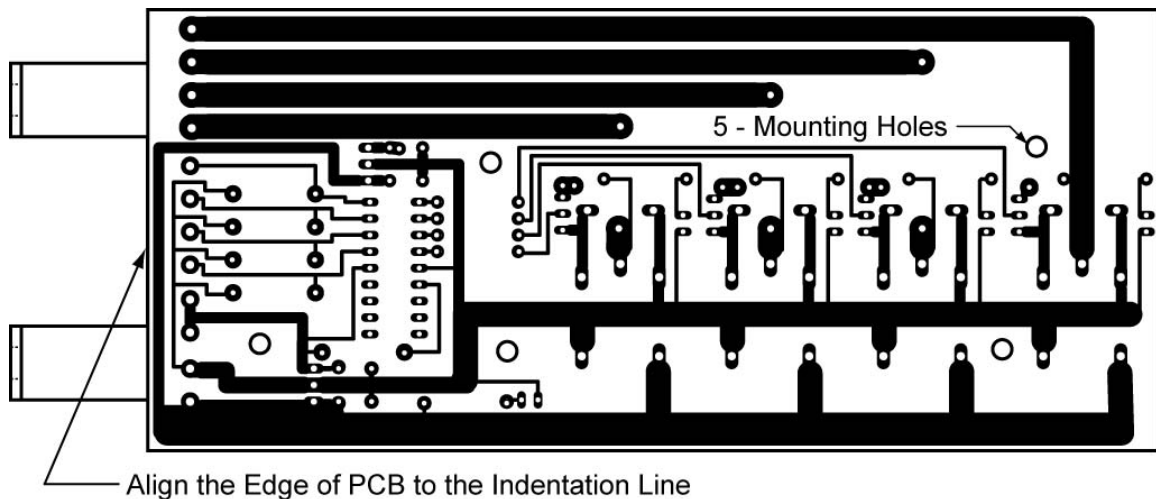


Figure 14: PCB Alignment and Hole Placement

- Transfer the hole locations from the PCB onto the mounting bracket and drill with 5/32" drill bit.

- Locate the mounting bracket on the end cap so that it straddles the gland (Figure 15).

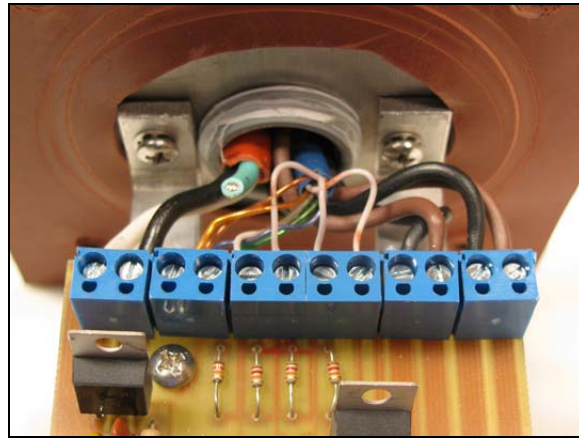


Figure 15: PCB Mounting Bracket Straddling the Gland

- Mark the two mounting screw [blind holes](#) and drill using a #36 drill bit. **Be careful not to drill all the way through the end cap.**
- Tap the two holes with a #6-32 [bottoming tap](#).
- Secure the mounting bracket to the end cap with 2 - #6-32 x 1/4" stainless steel screws and Loctite Threadlocker.
- Attach the PCB to the mounting bracket with 5 - #6-32 x 3/4" stainless steel screws and 5 #6 x 1/4" nylon spacers. Refer to Figure 16.

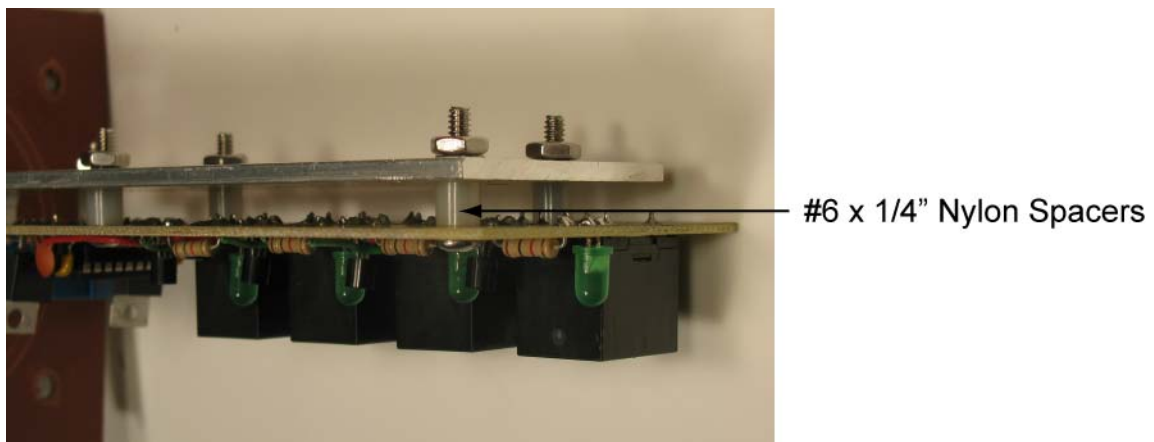


Figure 16: Mounting the PCB to the Mounting Bracket

- **Connecting the Tether to the PCB:**
 - First, connect the 16/3 AWG extension cord to the +12V and GND lugs on the X1 terminal block. See Figure 17 for the correct location. The extension cord black wire in Figure 17 is used for the ground wire, as it is used in many low voltage circuits, but this is incorrect, irresponsible and dangerous when performing home electrical wiring. Also notice in Figure 17 that the green extension cord wire was cut short since it was not used.
 - Next, connect all four of the solid color wires in the Cat-5E cable to the +5V Joystick OUT terminal blocks (two wires to each connection on X2). Both connections are electrically connected together so the order of the wire attachment is irrelevant.

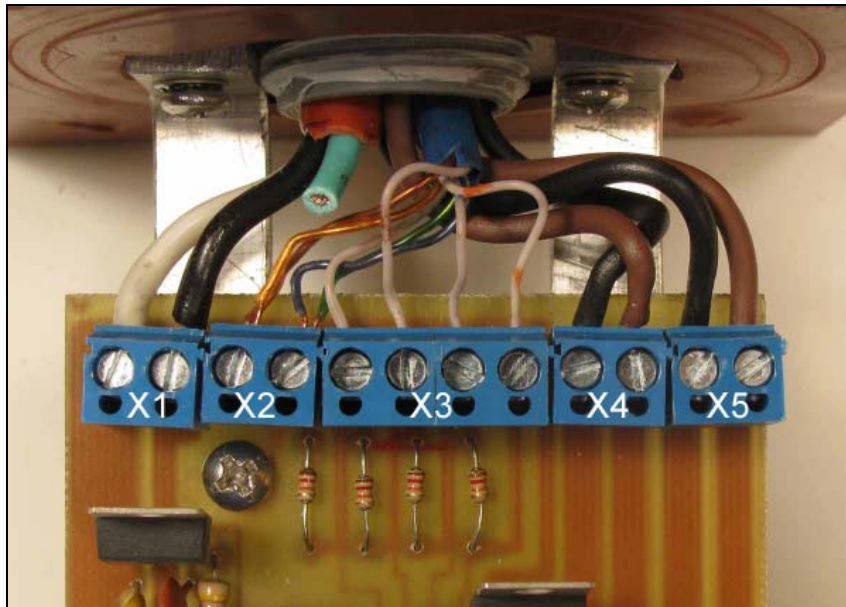


Figure 17: Connections to the PCB Terminal Blocks

- Now connect the thruster connections to terminal blocks X4 and X5 as shown in Figure 17.

- Connect the striped Cat 5e wires to the terminal blocks on PCB as shown in Figure 19. The wire order must be consistent with the control box in Figure 18.

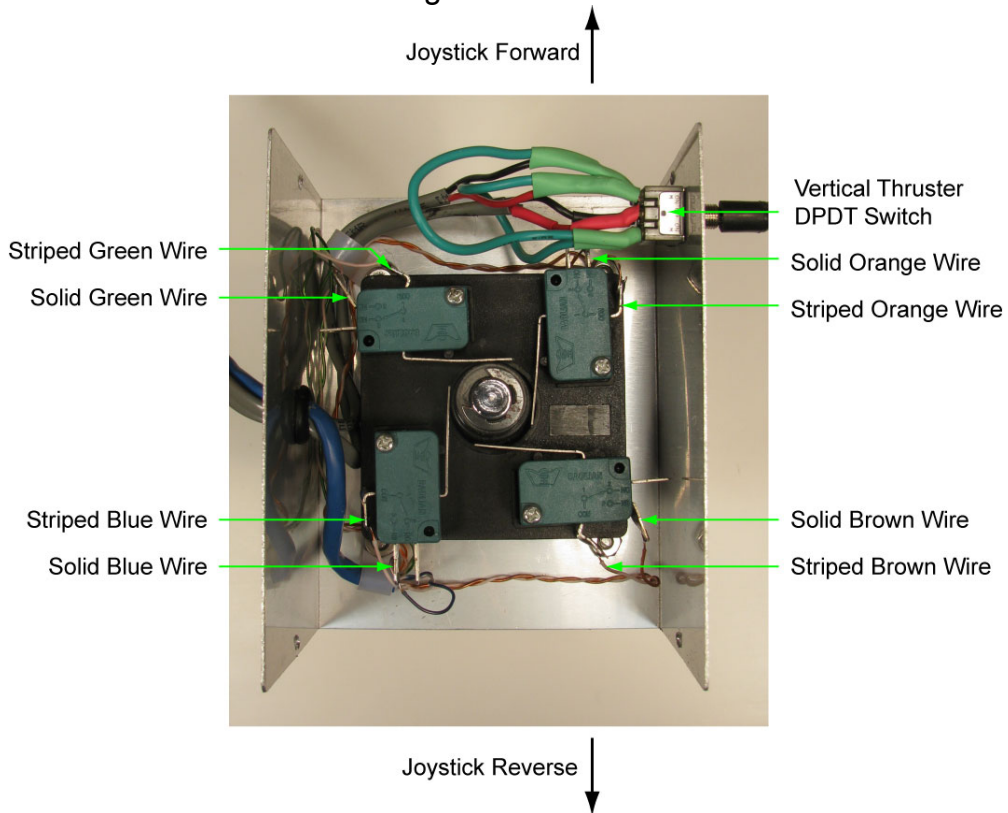


Figure 18: Control Box Cat 5e Connections

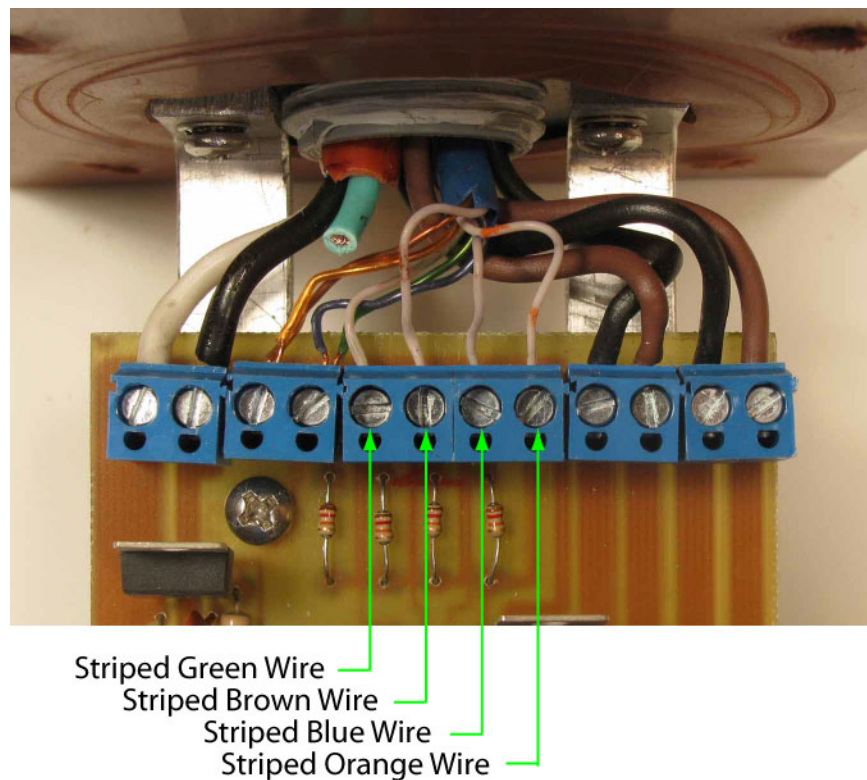


Figure 19: PCB Cat 5e Connections

- Programming the PIC16F88:
 - Code in .pbp format:
http://cornerstonerobotics.org/code/year3/year3_mini_rov.pb_p
 - Code in .pdf format:
http://cornerstonerobotics.org/code/year3/year3_mini_rov.pdf or look on page 15.
- Checking the PCB Connections before Closing the Pressure Canister:
 - Connect power to the tether. The power LED1 and the four relay LEDs (LED2 - LED5) should light.
 - Push the joystick forward and check the direction of the thrusters by feeling the airflow produced by the thrusters. If the airflow is not correct, then move the Cat 5e connections on terminal block X3, reverse the polarity of the thruster connections, or reverse the hand of the propellers on the thrusters to create proper airflow.
 - Now check the other joystick positions and verify the proper thruster reaction. Corrections can be made by rearranging the Cat 5e connections on terminal block X3, reversing the polarity of the thruster connections, or reversing the hand of the propellers on the thrusters.
- **Final Assembly:**
 - Seal the pressure canister and mount it on the frame. Your ROV is now ready for mounting whatever tools your mission requires.
 - After attaching the tools, trim the ROV for the desired buoyancy, pitch, and roll.
 - The ROV is prepared for the mission.

- **PIC16F88 Program:**

E:\year3_mini_rov.pbp

```
'-----Title-----
' File.....year3_mini_rov.pbp
' Started....2/18/13
' Microcontroller used: Microchip Technology PIC16F88
'                       microchip.com
' PicBasic Pro Code: micro-Engineering Labs, Inc.
'                       melabs.com

'-----Program Description-----

' The program controls the thruster relays on the
' Cornerstone Robotics Year 3 Mini-ROV.
'
' If both PIC16F88 outputs to a thruster are HIGH,
' the thruster will not rotate. If one output
' (say RB0) is HIGH and the other output (RB1)
' is LOW, the thruster will turn. If RB0 is
' set LOW and RB1 is set HIGH, the thruster will
' turn in the opposite direction. In the default
' position (the joystick in a neutral position),
' all PIC16F88 outputs (RB0 - RB3) to both
' thrusters are set HIGH, so the thrusters do
' not rotate.

'-----Initialization-----

    TRISB = %11110000      ' Set pins RB0-RB3 as outputs
                          ' and pins RB4-RB7 as inputs

    ANSEL = 0              ' Set Analog Select Register to
                          ' all digital I/O.

    OSCCON = $60           ' Set the internal oscillator in the
                          ' 16F88 to 4 MHz

    PORTB = %00001111     ' With the joystick in the neutral
                          ' position (no switches are activated),
                          ' set pins RB0-RB3 to 1 (HIGH) and RB4-RB7
                          ' to 0 (LOW). HIGH to all of the thruster
                          ' outputs (RB0-RB3) turns the thrusters OFF.
                          ' A LOW to one of the thruster outputs
                          ' allows current to flow through the PNP
                          ' transistor which closes the relay which
                          ' turns the thruster ON. LOW to input
                          ' pins RB4-RB7 reflects that the input
                          ' switches are not activated.

'-----Main Code-----

start:

    IF PORTB.4 = 1 THEN GOTO forward  ' If the joystick is pushed
                                      ' forward, making pin RB4 go
```

```

' HIGH, the program jumps to
' the "forward" label below.
IF PORTB.5 = 1 THEN GOTO backward
IF PORTB.6 = 1 THEN GOTO right
IF PORTB.7 = 1 THEN GOTO left
PORTB = %00001111
' If the joystick switches are not
' activated (RB4-RB7 = 0), all of
' the thruster outputs are held
' HIGH (RB0-RB3 = 1) which turns all
' thrusters OFF.
PAUSE 5
' Wait 5 ms
GOTO start
' Program is directed back to the "start"
' label.

END

forward:
PORTB = %00011010
' With RB0 set LOW and RB1 set HIGH, the
' thruster connected to those pins will
' rotate. Similarly, with RB2 set LOW and
' RB3 set HIGH, the other thruster will
' rotate. The input RB4 is set HIGH to
' reflect the state of the switch
' connected to RB4.
PAUSE 5
' Wait 5 ms
GOTO start

backward:
PORTB = %00100101
' Outputs reverse the direction of
' the thruster rotation from
' the forward direction.
PAUSE 5
GOTO start

right:
PORTB = %01000110
PAUSE 5
GOTO start

left:
PORTB = %10001001
PAUSE 5
GOTO start
```


Appendix A

Instructions for the Basic Positive Prototyping Process

This is the simplest prototyping process supported by MG Chemicals, using pre-sensitized boards to prototype single sided circuits.

1. Setup

Protect surrounding areas from developer and etchant splashes. Plastic is ideal for this. Work under safe light conditions, a 40W incandescent bulb works well. Do not work under fluorescent light. Just prior to exposure remove white protective film from presensitized board. Peel it back carefully.

2. Exposing your board

For best results, use M.G. Chemicals **Exposure Kit** (Cat. No. 416-X), however, any inexpensive lamp fixture that will hold one or more 18" fluorescent tubes is suitable.

Directions: Place presensitized board, copper-side toward exposure source. Positive film artwork should be laid onto "presensitized" copper side of board and position as desired. Artwork should be placed printed side down to prevent light leakage through the side of the transparency, and should have been produced by a 600 dpi printer or better. A glass weight should then be used to cover artwork ensuring no light will pass under traces (Approx. 3mm glass thickness or greater works best). **Use a 10 minute exposure time at a distance of 5 inches.**

3. Developing your board

The development process removes any photoresist which was exposed through the film positive to ultraviolet light.

Warning: Developer contains sodium hydroxide and is highly corrosive. Wear rubber gloves & eye protection while using it. Avoid contact with eyes and skin. Flush thoroughly with water for 15 minutes if it is splashed in eyes or on the skin.

Directions: Using rubber gloves and eye protection, **dilute one part [M.G. Developer](#)** (Cat. No. 418) **with ten parts tepid water** (weaker is better than stronger). In a plastic tray. Immerse the board copper side up into the developer, and you will quickly see an image appear while lightly brushing the resist with a foam brush. This should be completed within one to two minutes. Immediately neutralize development action by rinsing the board with water. The exposed resist must be removed from the board as soon as possible. When you are done the developing stage, the only resist remaining will be covering what you want your circuit to be. The rest should be completely removed.

4. Etching your board

For best results, use the [Professional Etching Process Kit](#) (Cat. No. 416-E) or [Economy Etching Kit](#) (Cat. No.416-ES).

The most popular etchant is **Ferric Chloride** (Cat. No. 415), an aqueous solution which dissolves most metals. Use this solution undiluted, and be sure to completely cover your board.

Warning: This solution is normally heated up during use, generating unpleasant and caustic vapors, it is very important to have adequate ventilation. Use only glass or plastic containers. Keep out of reach of children. May cause burns or stain. Avoid contact with skin, eyes or clothing. Store in plastic container. Wear eye protection and rubber gloves.

Directions: If you use ferric chloride cold, it will take a long time to etch the board. To speed up etching, heat up the solution. A simple way of doing this is to immerse the ferric chloride bottle or jug into hot water, adding or changing the water to keep it heating. A thermostat controlled crock pot is also an effective way to heat ferric chloride as is thermostatically controlled submersible heaters – glass enclosed such as an aquarium heater. An ideal etching temperature is 50°C (120°F). Be careful not to overheat it. The absolute maximum working temperature is about 57°C or 135°F. The warmer your etch solution, the faster your boards will etch. Ferric chloride solution can be used over and over again, until it becomes saturated with copper. As the solution becomes more saturated, the etching time will increase. Agitation assists in removing unwanted copper faster. This can be accomplished by using air bubbles from two aquarium air wands with an aquarium air pump. Do not use aquarium “air stone”. The etching process can be assisted by brushing the unwanted copper with a foam brush while the board is submerged in the ferric chloride. After the etching process is completed, wash thoroughly under running water. Do not remove the remaining resist protecting your circuit or image; it protects the copper from oxidation.

5. Soldering your board

Removal of resist is not necessary when soldering components to your board. By leaving the resist on, your circuit is protected from oxidation. Tin plating your board is not necessary. When soldering, the heat disintegrates the resist underneath the solder resulting in an excellent bond.

► Watch this process on [video](#)