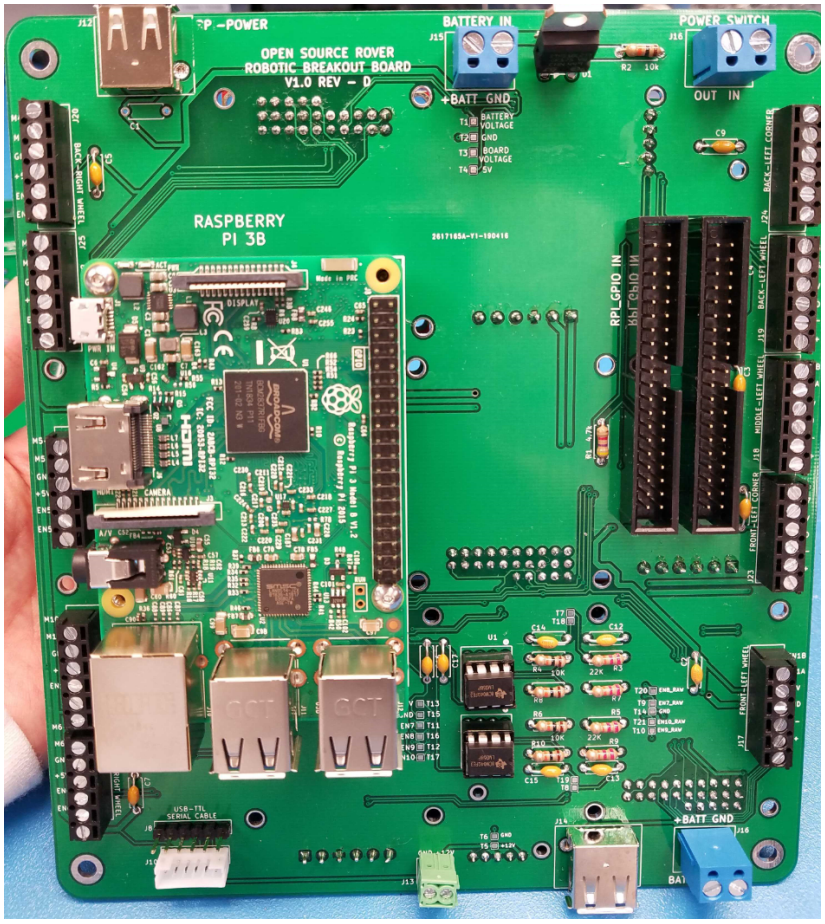

Open Source Rover: PCB Assembly Instructions

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Jet Propulsion Laboratory
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Contents

1 PCB Assembly

1.1 Control Board Assembly

1.1.1 Motor & RoboClaw Connectors

Table 1: Parts/Tools Necessary

Item	Ref	Qty	Image	Item	Ref	Qty	Image
OSR Control Board	E1	1		6 Pos Side Term Block	E3	10	
6 Pos Top Term Block	E4	5		5 Pos Header socket	E5	5	
5 Pos Header socket	E6	5		Soder Iron	N/A		

1. Begin by soldering the 6 Position Side entry terminal blocks **E3** into the **top** side of the PCB, on the edge of the board as shown in Figure 1. These terminal blocks will run motor power, encoder power, and encoder signals between the motors/encoders and the RoboClaw motor controllers. The 6 terminal blocks will each be labeled with schematic reference designators J17-J26 on the PCB. Be sure that the wire terminals face **OUTWARD** (away from the center of the board) on all of these connectors.

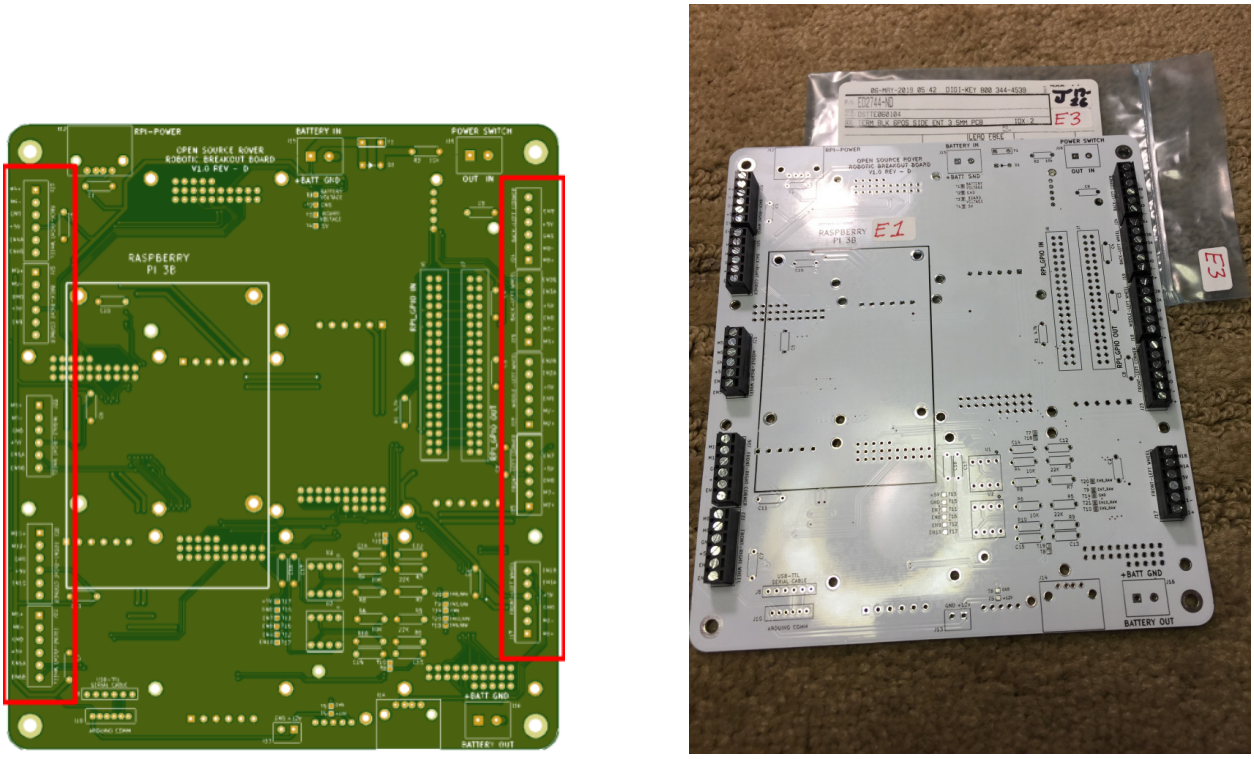


Figure 1: Assembly Step 1

2. On the **bottom** of the board, solder the 6 Position top entry terminal blocks **E4**. They will be labeled with schematic reference designators J1-5. The orientation of the wire terminal face should be AWAY from the each of RoboClaw outlines (see Figure 2). These terminals will run battery power and +/- motor signals to the RoboClaw motor controllers from the PCB.

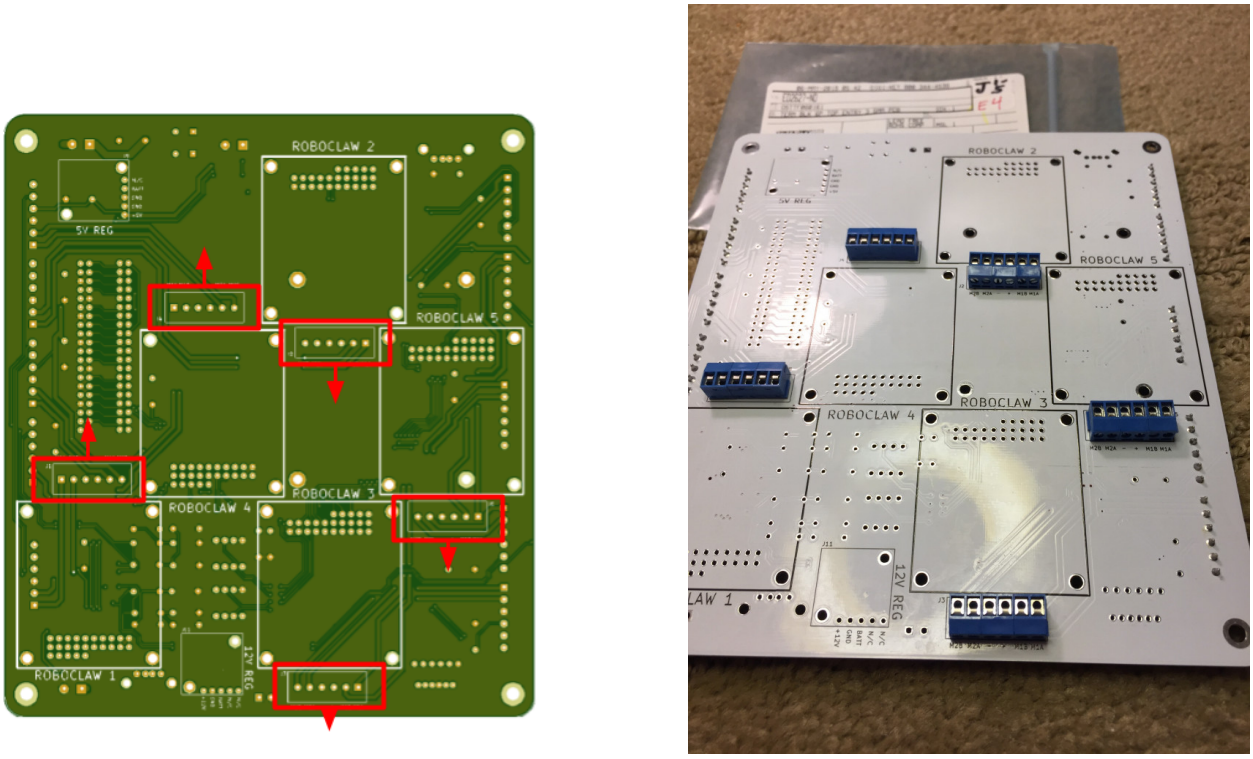


Figure 2: Assembly Step 2

3. On the **bottom** of the board, solder the 20-position female socket header connector **E5** and the 5-position female socket header connector **E6**. They will be labeled with reference designators RoboClaw 1-5. These are the digital signal pins for the RoboClaw motor controllers.

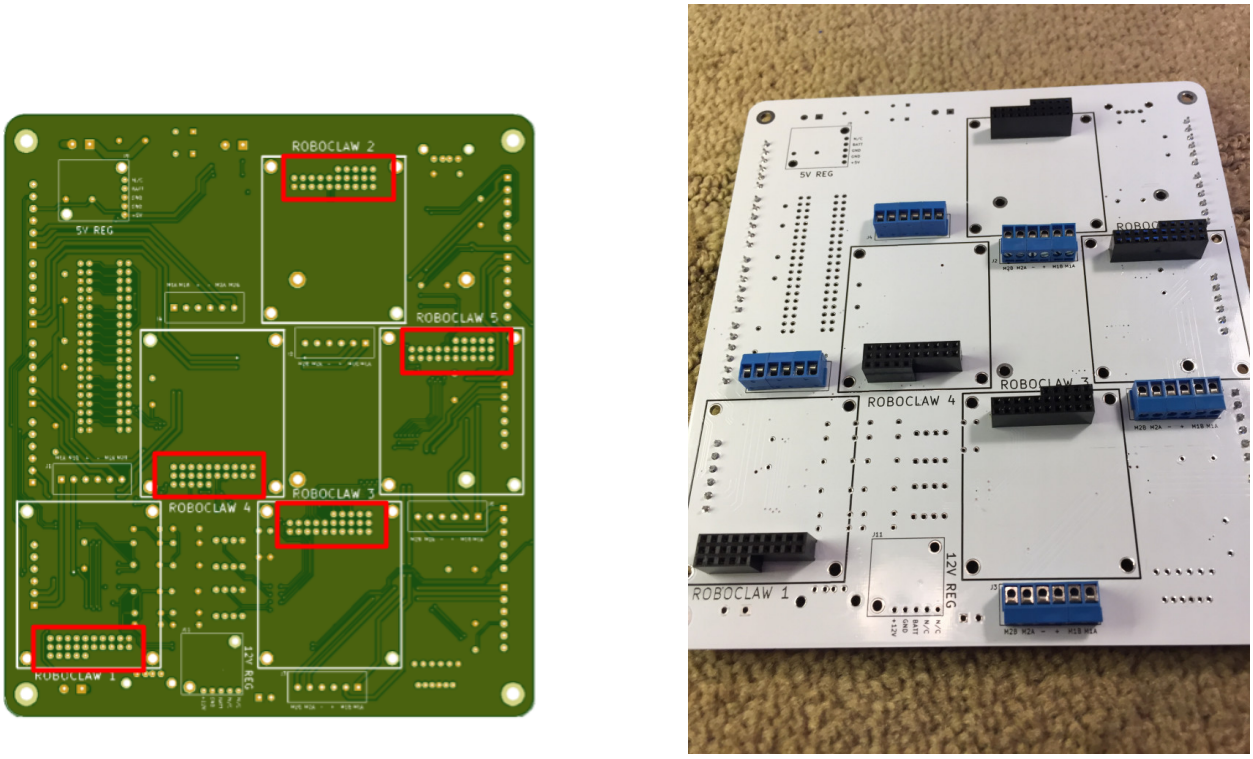


Figure 3: Assembly Step 3

1.1.2 Resistors and Capacitors

Table 2: Parts/Tools Necessary

Item	Ref	Qty	Image	Item	Ref	Qty	Image
OSR Control Board	E1	1		4.7K 1/4 Watt Resistor	E7	1	
10K 1/4 Watt Resistor	E8	4		22K 1/4 Watt Resistor	E9	4	
10K 1/2 Watt Resistor	E10	1		100nF Capacitor	E11	16	

1. On the **top** of the board, solder the resistors and capacitors by comparing the reference designator on the board to the part number listed in the table below. Some of these capacitors are used to store energy for powering components (to help protect against voltage fluctuations). Others are used as noise filtering mechanisms on analog signals

(particularly to smooth the encoder signals). The resistors are needed to control the voltage across various components.

Table 3: Resistor/Capacitor reference

Item	Parts list Ref	Schematic/Board Ref
4.7K 1/4 Watt Res	E7	R1
10K 1/4 Watt Res	E8	R4,6,8,10
22K 1/4 Watt Res	E9	R3,5,7,9
10K 1/2 Watt Res	E10	R2
100nF Cap	E11	C1-17

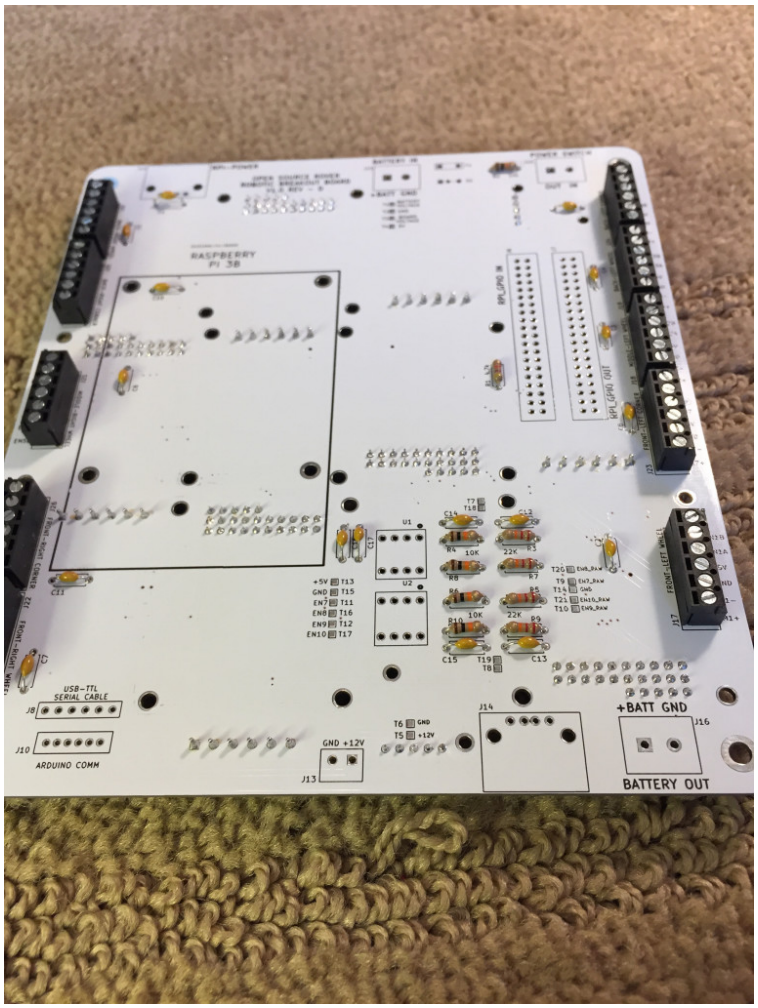


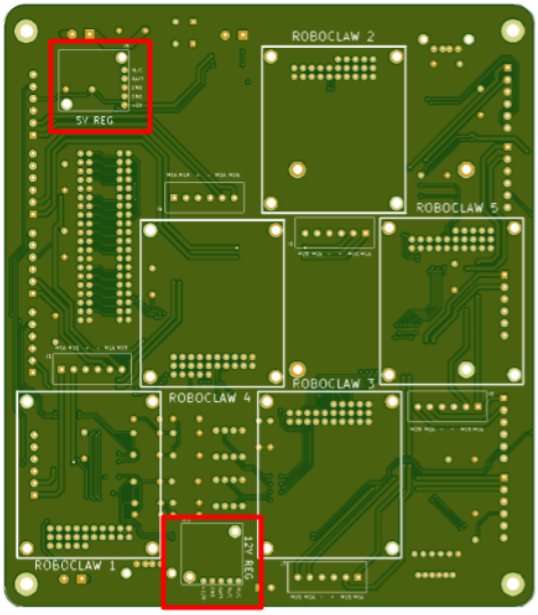
Figure 4: Resistor and Capacitor soldering

1.1.3 Voltage Regulator connectors

Table 4: Parts/Tools Necessary

Item	Ref	Qty	Image	Item	Ref	Qty	Image
OSR Control Board	E1	1		5 Pos Header socket	E6	2	
				Soder Iron	N/A		

1. On the **bottom** of the board, solder the 5-position female header sockets **E6**. The sockets will have schematic reference designators of J9 and J11. These connectors are what the 12V and 5V voltage regulators will slot into.



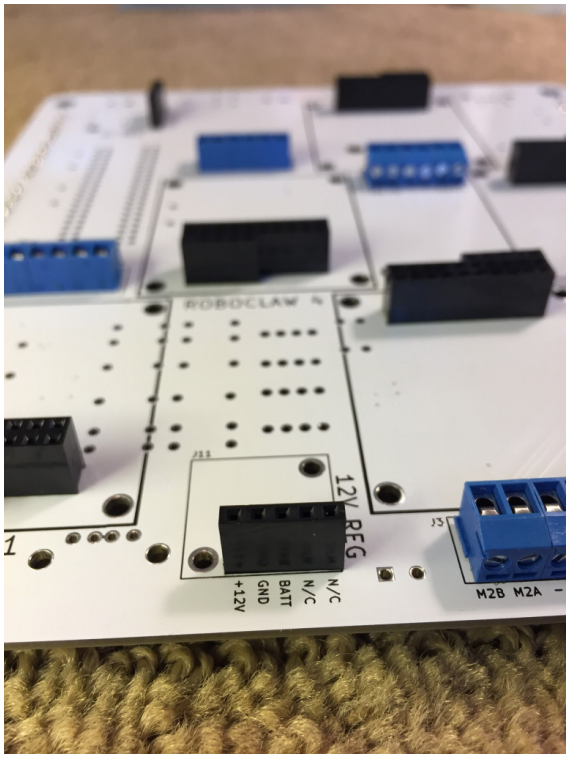


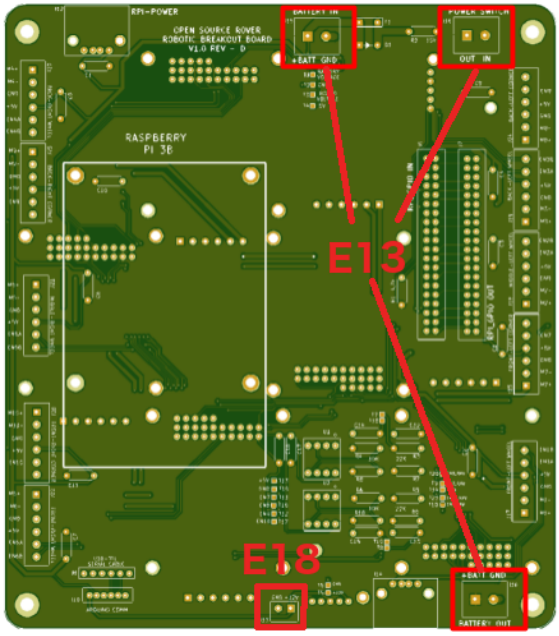
Figure 5: Assembly Step 5

1.1.4 Power Connectors

Table 5: Parts/Tools Necessary

Item	Ref	Qty	Image	Item	Ref	Qty	Image
OSR Control Board	E1	1		2 Pos Side Terminal Block	E12	3	
2 Position 2.5mm Terminal Block	E18	1		Soder Iron	N/A		

1. On the **top** of the board, solder the 2-position side entry terminal blocks **E13**. These will have schematic reference designators J14-16. Ensure that the wire terminals on these componenets face **OUTWARDS**. Also on the **top** of the board, solder the remaining 2-position 2.5mm terminal block **E18** (schematic reference designator J12).



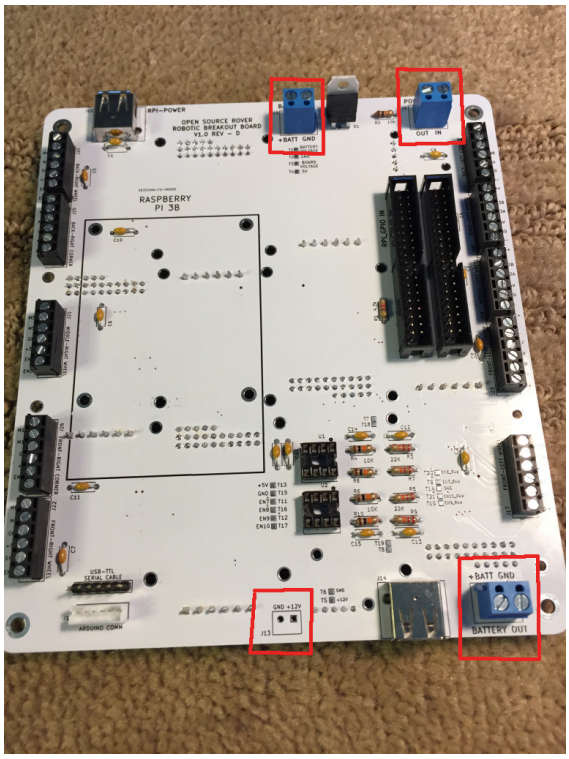


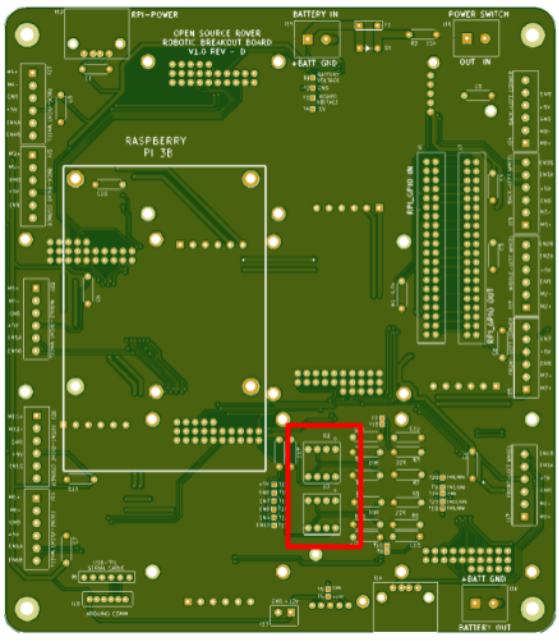
Figure 6: Assembly Step 6

1.1.5 Op amp DIP socket

Table 6: Parts/Tools Necessary

Item	Ref	Qty	Image	Item	Ref	Qty	Image
OSR Control Board	E1	1		8 Pin DIP Socket	E33	2	
				Soder Iron	N/A		

1. On the **top** of the board, solder the 8 Pin DIP sockets **E33**. They will have schematic reference designators U1-2. Orientation of these sockets does not matter, but note that you WILL (later, in another document) need to plug in the Op-Amp chips themselves, and orientation of those chips is important when you eventually complete that step.



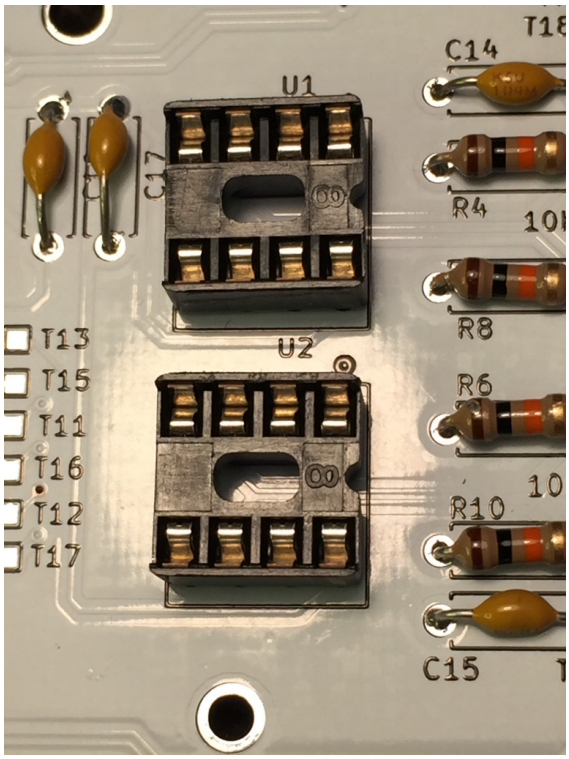


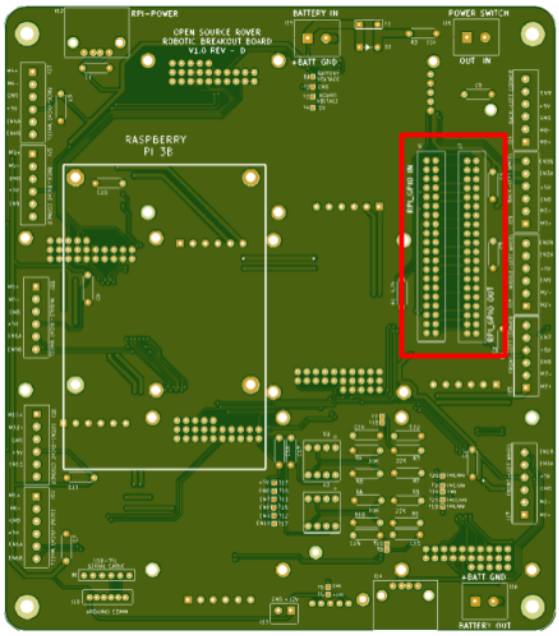
Figure 7: Assembly Step 7

1.1.6 RPi GPIO connector and misc headers

Table 7: Parts/Tools Necessary

Item	Ref	Qty	Image	Item	Ref	Qty	Image
OSR Control Board	E1	1		40 Pin Header connector	E13	2	
40 Position Header Pins	E15	1		6 Position JST Connector	E14	1	
				Soder Iron	N/A		

1. On the **top** of the board, solder the 40-position header connectors **E13**. The clocking notch on the headers should face **OUTWARD** as shown in Figure 7. The schematic reference designators are J6 and J7.



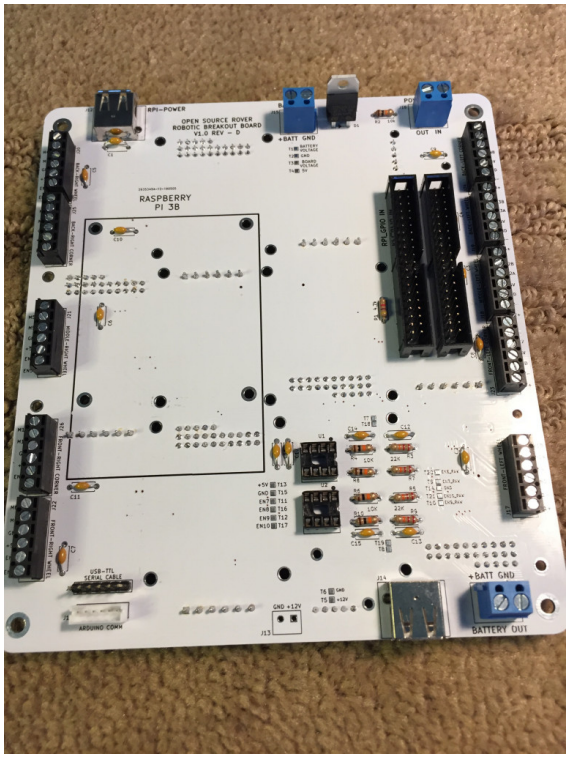


Figure 8: Assembly Step 8

2. Take the 40 pin header pins **E15** and break off a 6-pin segment. On the **top** of the board, solder the 6-pin segment into schematic reference designator J8. Then, solder

the JST connector **E14** into the J10 schematic reference designator. The opening in the pins on the JST connector should face **INWARD** as shown in Figure 9.

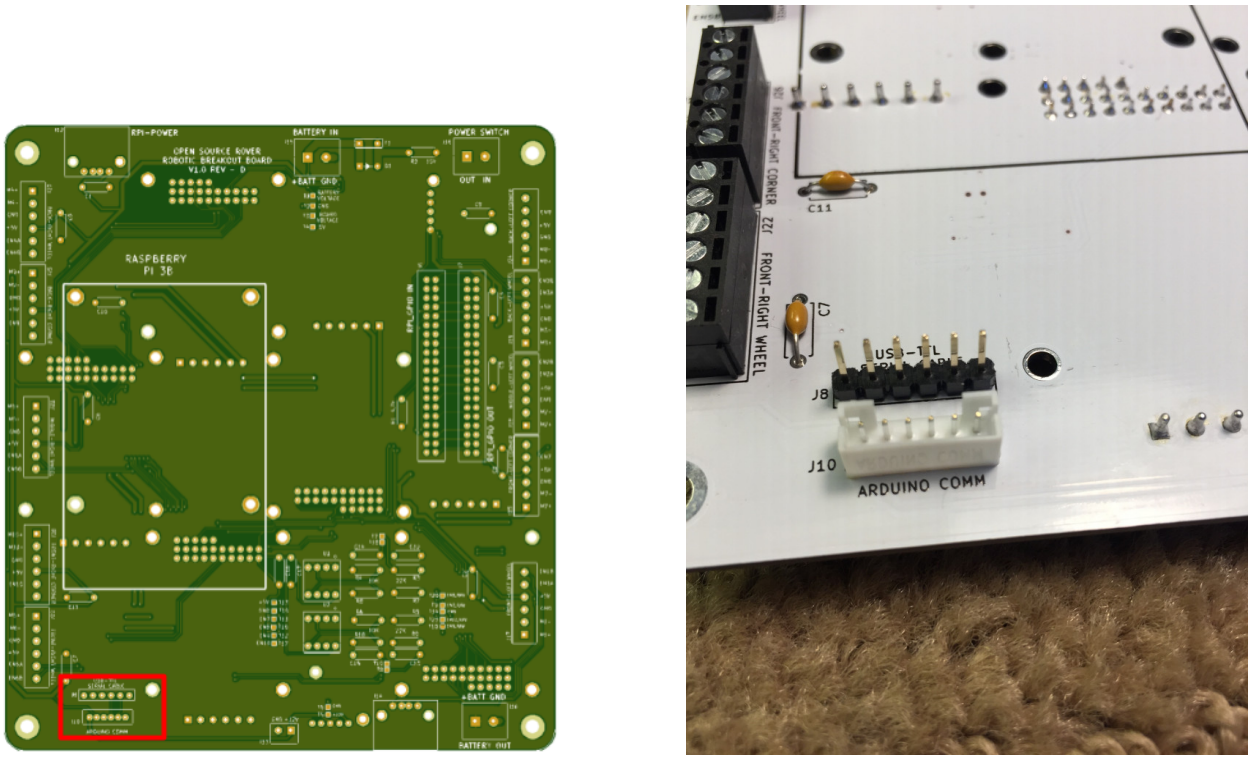


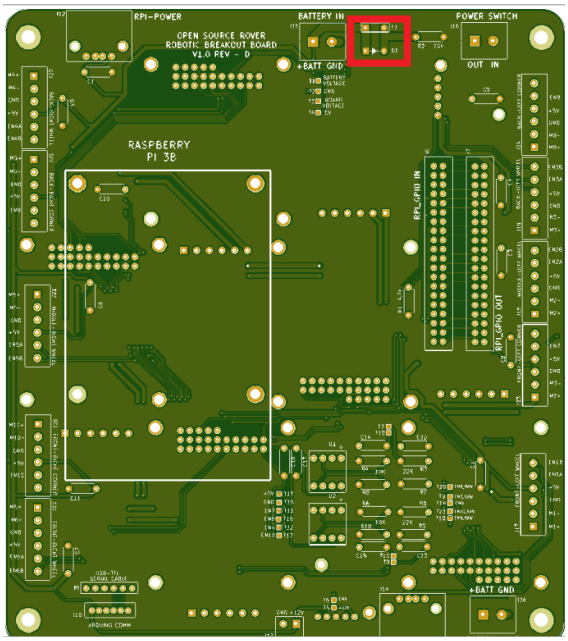
Figure 9: Assembly Step 9

1.1.7 Fuse and Diode

Table 8: Parts/Tools Necessary

Item	Ref	Qty	Image	Item	Ref	Qty	Image
OSR Control Board	E1	1		10 Amp Fuse	E16	1	
Diode	E17	1		Soder Iron	N/A		

1. Solder the fuse **E16** and diode **E17** onto the top of the board into schematic reference designators F1 (fuse) and D1 (diode). **Pay careful attention to the direction that the Diode is mounted on the board**, as it will only work in one direction!



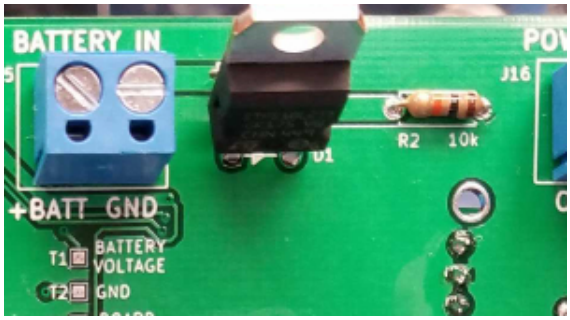


Figure 10: Fuse and Diode Soldering

1.1.8 USB connectors

Table 9: Parts/Tools Necessary

Item	Ref	Qty	Image	Item	Ref	Qty	Image
OSR Control Board	E1	1		USB Connector	E34	2	
				Soder Iron	N/A		

1. On the **top** of the board, solder the USB Connector **E34**. It will have reference designator J12 and J14.

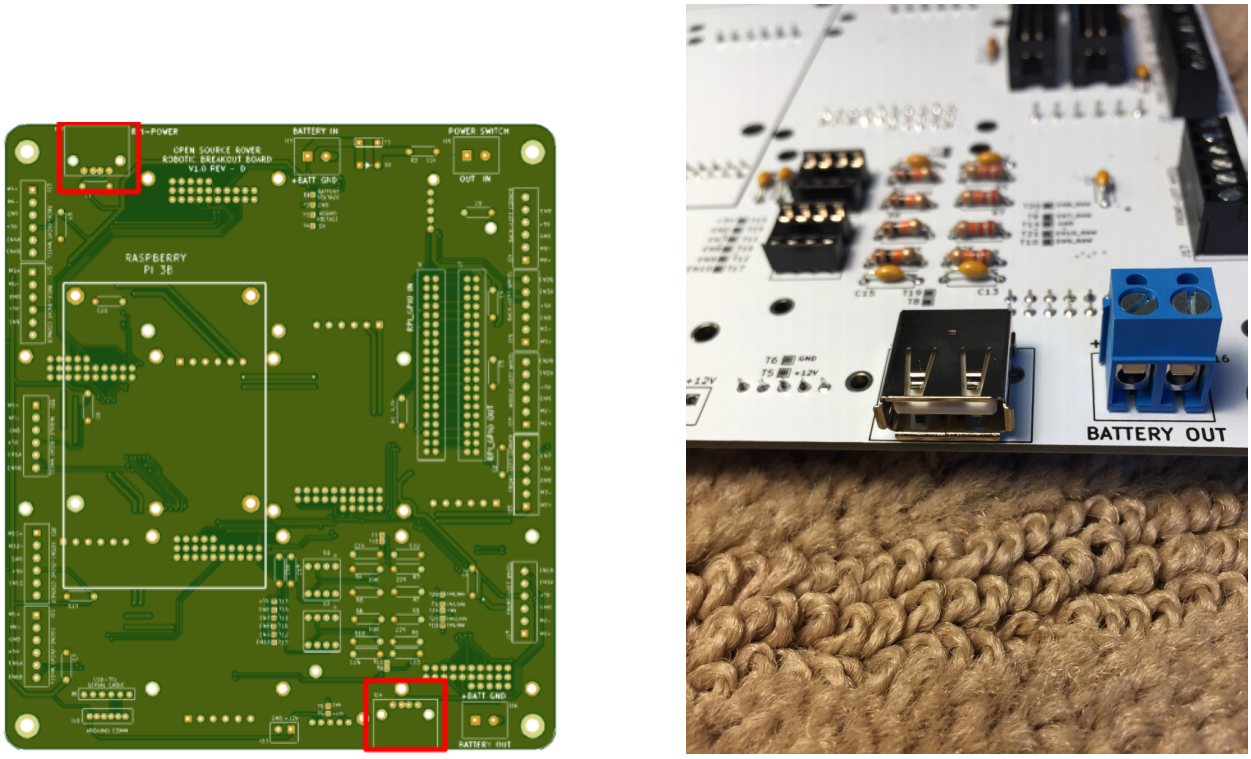
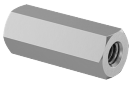
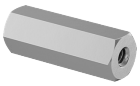
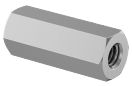


Figure 11: Assembly Step 10

1.1.9 Standoffs

Table 10: Parts/Tools Necessary

Item	Ref	Qty	Image	Item	Ref	Qty	Image
#6-32 Threaded Standoff	T4	4		#4-40 Threaded Standoff	T5	20	
#2-56 Threaded Standoff	T6	4		M2.5 Threaded Standoff	T7	4	
#6-32 3/8" Button Head Screw	B2	4		#4-40 1/4" Button head Screw	B8	40	
#2-56 1/4" Button head Screw	B13	8		M2.5 x 6mm	B10	8	

1. **Board mounting Standoffs:** Take the #6-32 Standoffs **T4** and attach them on the outter 4 mounting holes using screws **B2**. These go on the bottom side of the board,

as shown below. These will be what attached the board to the robot chassis.

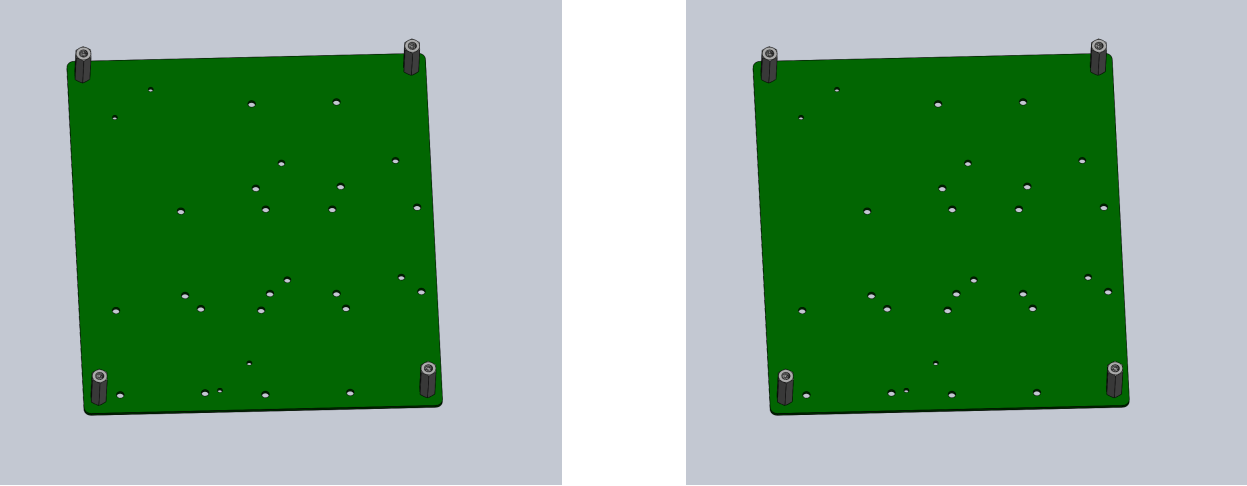


Figure 12: Mounting Standoffs

2. **RoboClaw mounting Standoffs:** Take the #4-40 Standoffs **T5** and attach them using screws **B8** on the bottom side of the board. You can tell the RoboClaw mounting holes as the ones that are inside the RoboClaw Silk Screen rectangle.

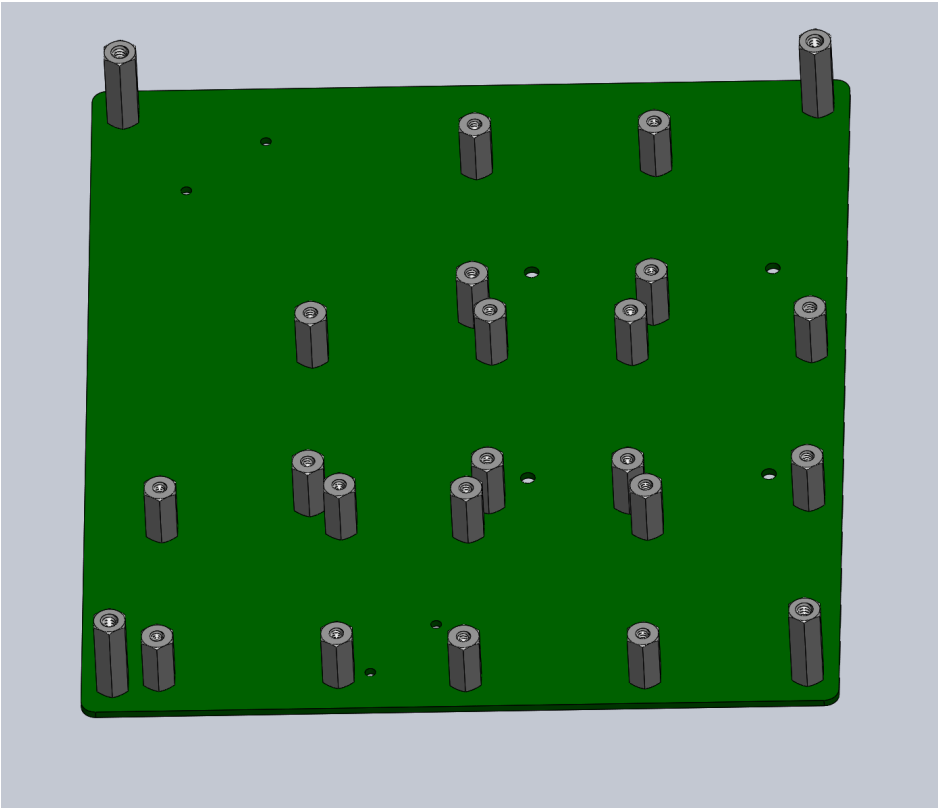


Figure 13: RoboClaw Mounting Standoffs

3. **Voltage Regulator Standoffs:** Take the #2-56 Standoffs **T6** and attach them to the bottom of the board using screws **B13**.

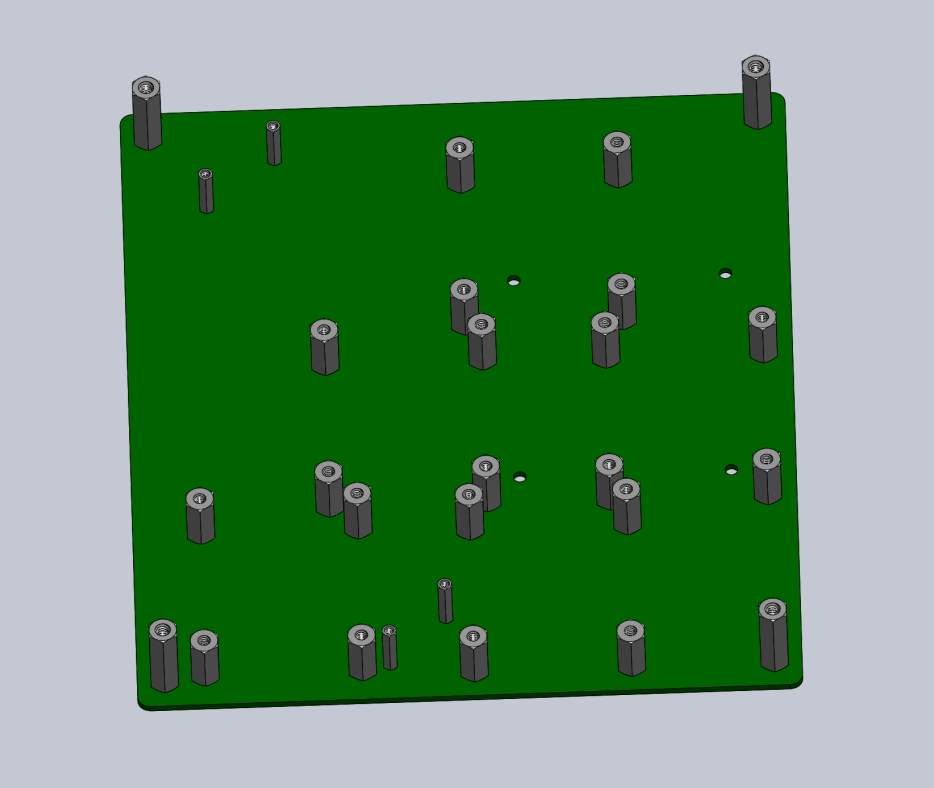


Figure 14: Voltage regulator Mounting Standoffs

4. **Raspberry Pi Standoffs:** Take the M2.5 Standoffs **T7** and attach them to the top of the board using screws **B10**.

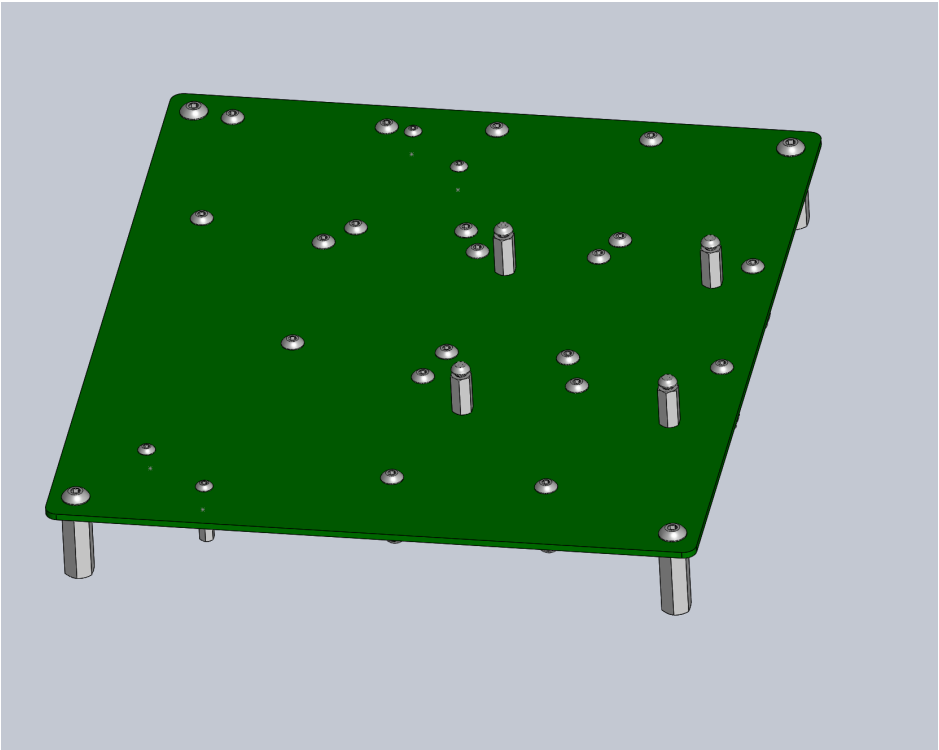


Figure 15: Raspberry Pi Standoffs

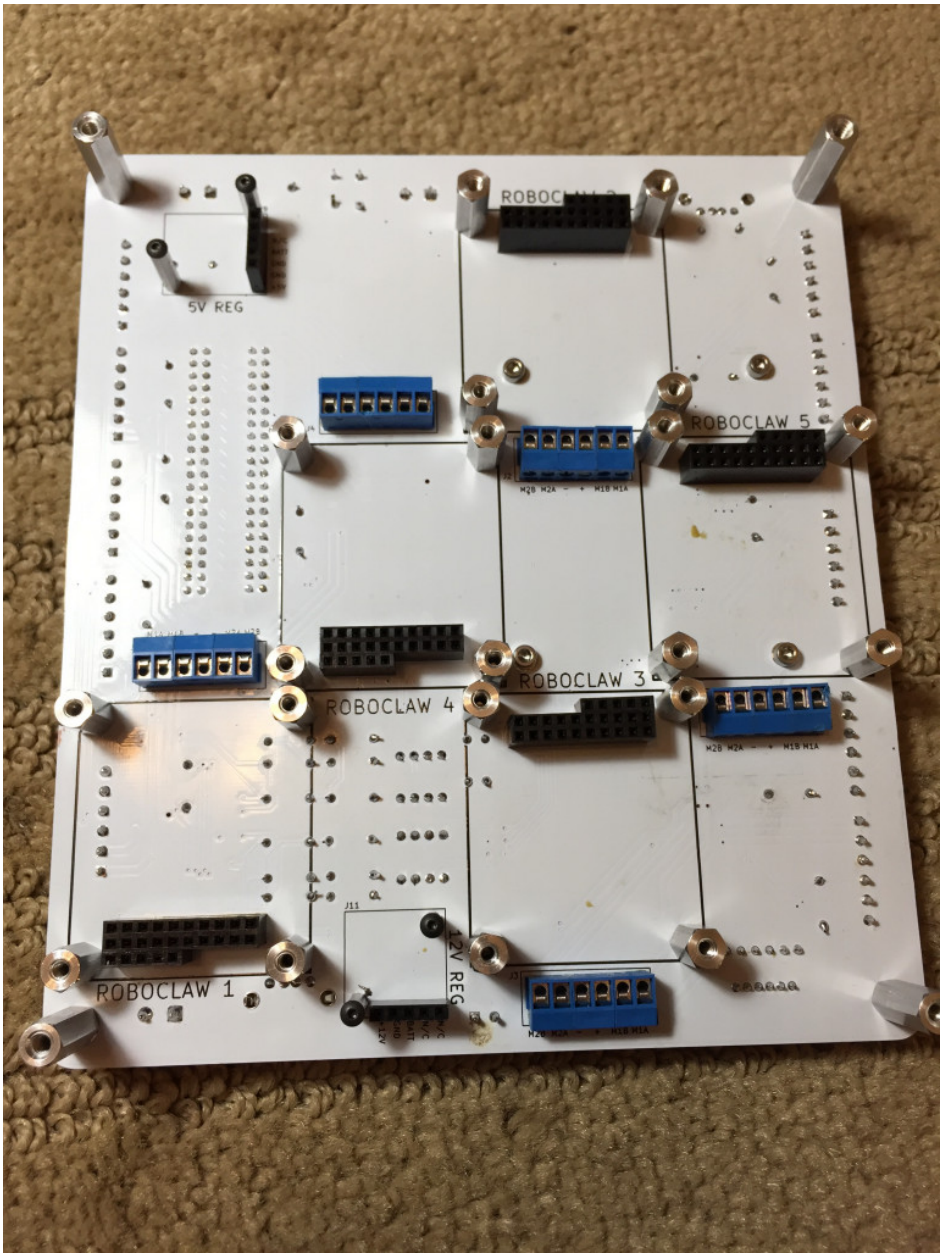
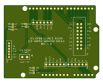


Figure 16: 0.1 Pitch headers

1.2 Arduino Sheild Assembly

Table 11: Parts/Tools Necessary

Item	Ref	Qty	Image	Item	Ref	Qty	Image
Arduino Sheild	E2	1		2 Position Term Block	E18	1	
2x8 Shrouded Header pins	E19	1		1x6 JST header pins	E14	1	
1x40 0.1 Pitch Header pins	E15	1					

Below are the images of the assembled arduino sheild from the top and bottom. Refer to these images for the coming instrucutions if any orientation for connectors is unclear.

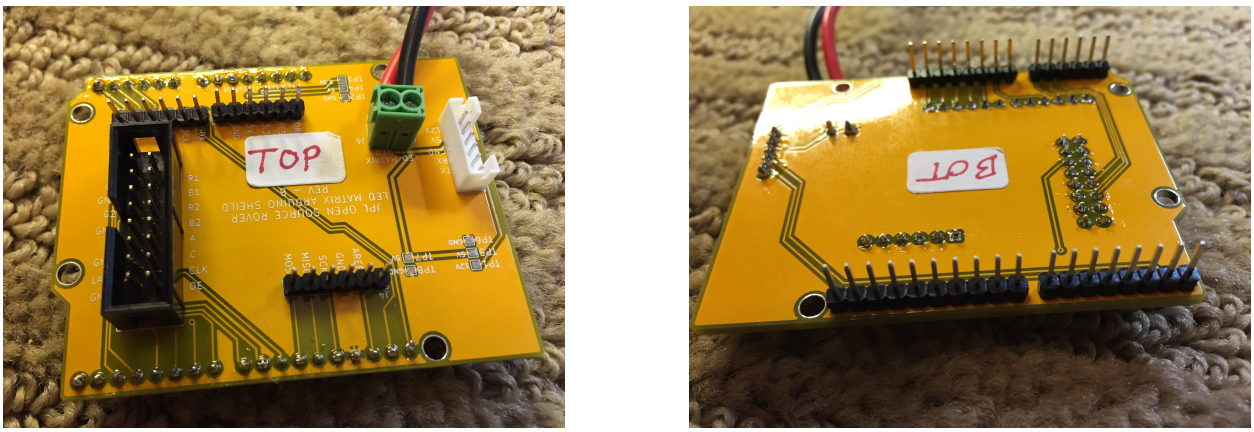


Figure 17: Assembled Arduino Sheild

1. Begin by taking the 2 Position Terminal Block **E18** and soldering it to top of the board at the J6 connector, such that the screw terminals face outwards on the board.

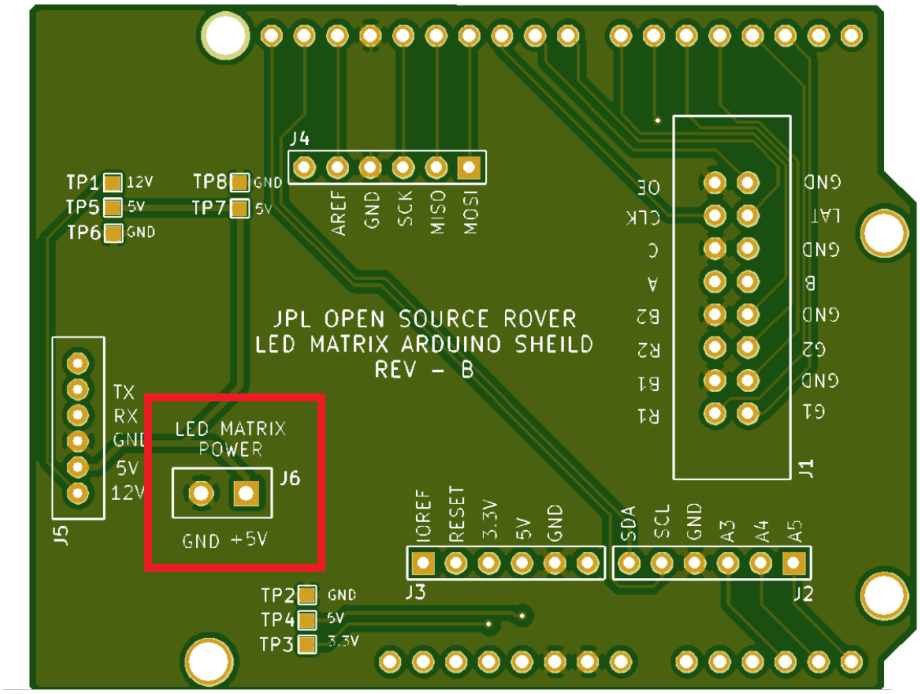


Figure 18: Terminal Block assembly

2. Solder the 1x6 JST connector **E14** onto the top of the board at the J5 connector, such that the notch in the connector faces inward to the board.

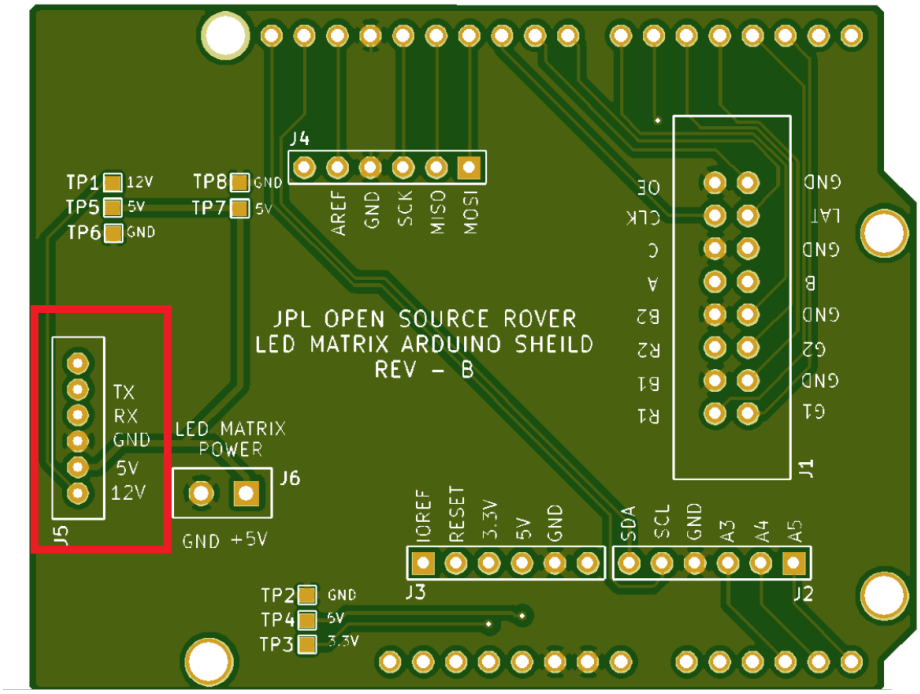


Figure 19: JST assembly

3. Solder the 2x8 Shourded header pins connector **E19** to the top of the board at connector **J1** such that the notch faces

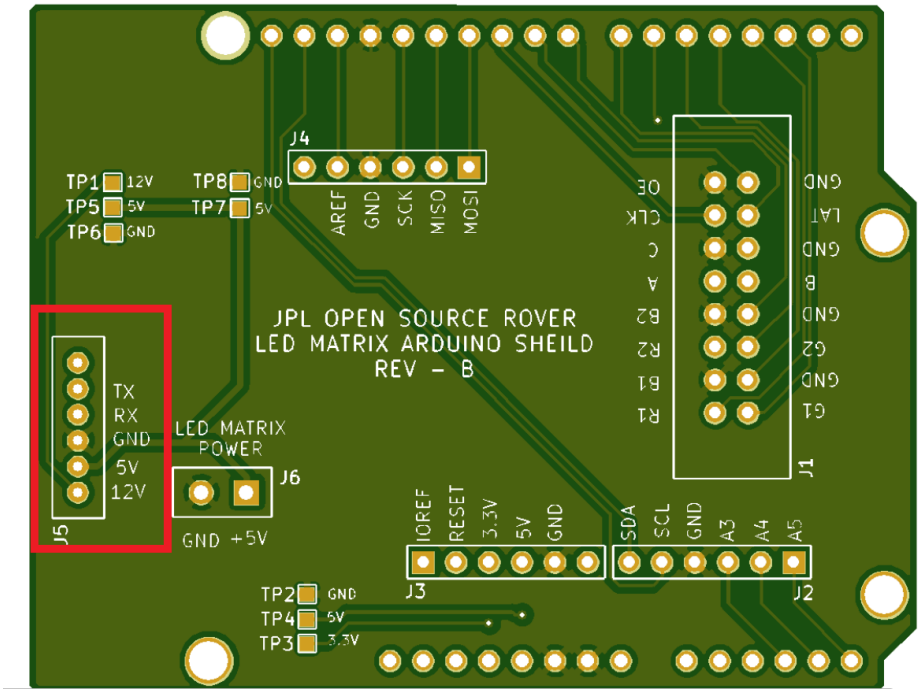


Figure 20: Terminal Block assembly

4. Solder the 0.1 pitch header pins **E15** to the J2, 3 and 4 on the top side of the board.

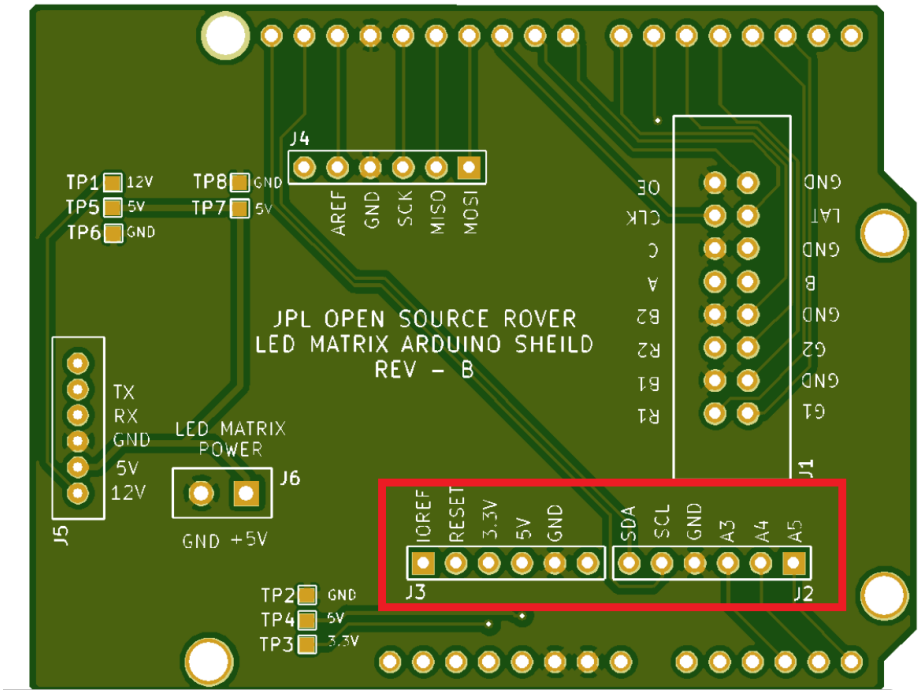


Figure 21: 0.1 Pitch headers

5. Solder the 0.1 pitch header pins **E15** to the bottom side of the board in the remaining hole sets.

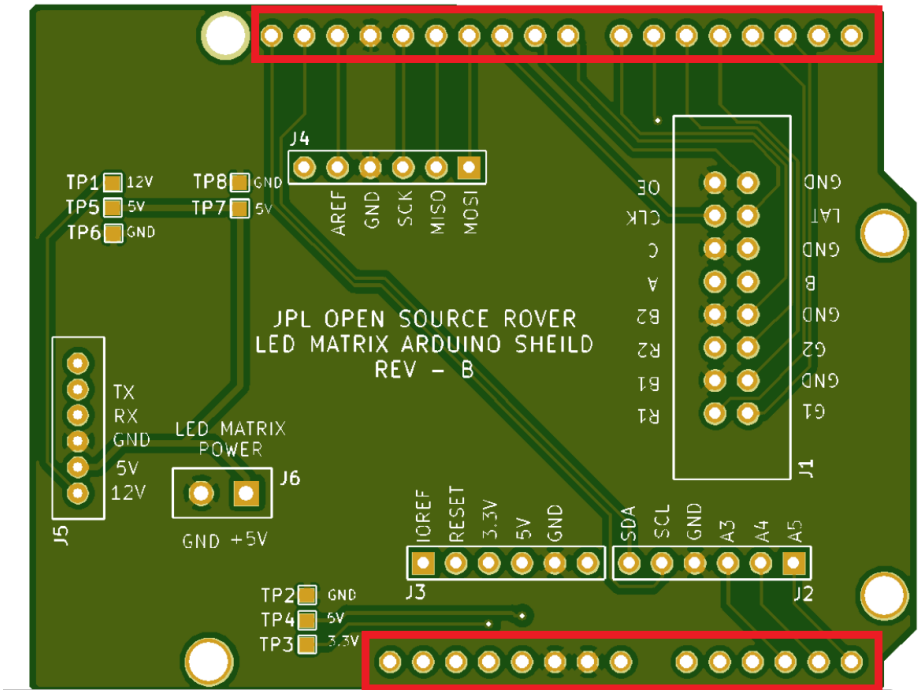


Figure 22: 0.1 Pitch headers

2 Component Integration and Testing

This next section will go over the process of integrating the electronics onto the Control Board and the testing to verify at each step that the board/components are working as expect. You should perform this section with the board outside of the robot chassis. It is important to do these steps one at time so we can verify each step of the way that electronics are working as intended, so we do not accidnetally break one of our components by plugging something else in wrong.

2.1 Control Board Testing

2.1.1 Power Distribution System

Table 12: Parts/Tools Necessary

Item	Ref	Qty	Image	Item	Ref	Qty	Image
OSR Control Board	E1	1		Battery	E36	1	
Tamiya Battery Connectors	E35	1		Red 24 AWG	W1	1	
Black 24 AWG	W2	1		5V Regulator	E22	1	
12V Regulator	E23	1		RoboClaw Motor Controller	E20	5	
Op-Amp LM358P	E25	2		Micro USB Cable	E27	1	
GPIO Ribbon Cable	E28	1					

1. Begin by powering the board. In order to do this we will be bypassing the switch and volt meter, so this connection will look a little bit different than when you fully install the board into the rover. Insert the red wire on the Tamiya Battery Connector **E35**

into the IN terminal on connector **J16**, and the black wire to the GND terminal on the connector **J15**.

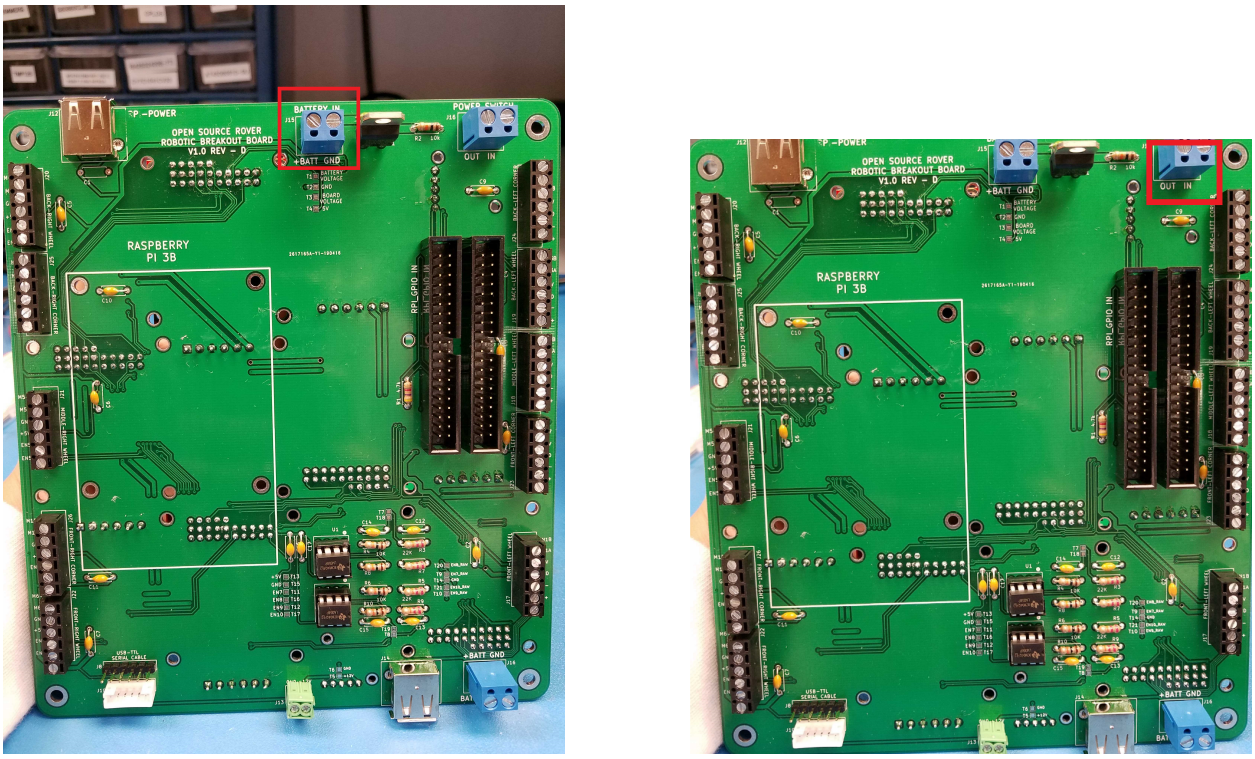


Figure 23: Test Step 1

2. Using a Digital Multimeter (DMM) probe the voltage accross the test points T1 and T2. These will tell you the voltage level that the board is at, which is the direct voltage of the battery. Verify that from T1 to T2 reads a positive number, and is between 12V and 16.7V depending on the charge state of your battery.

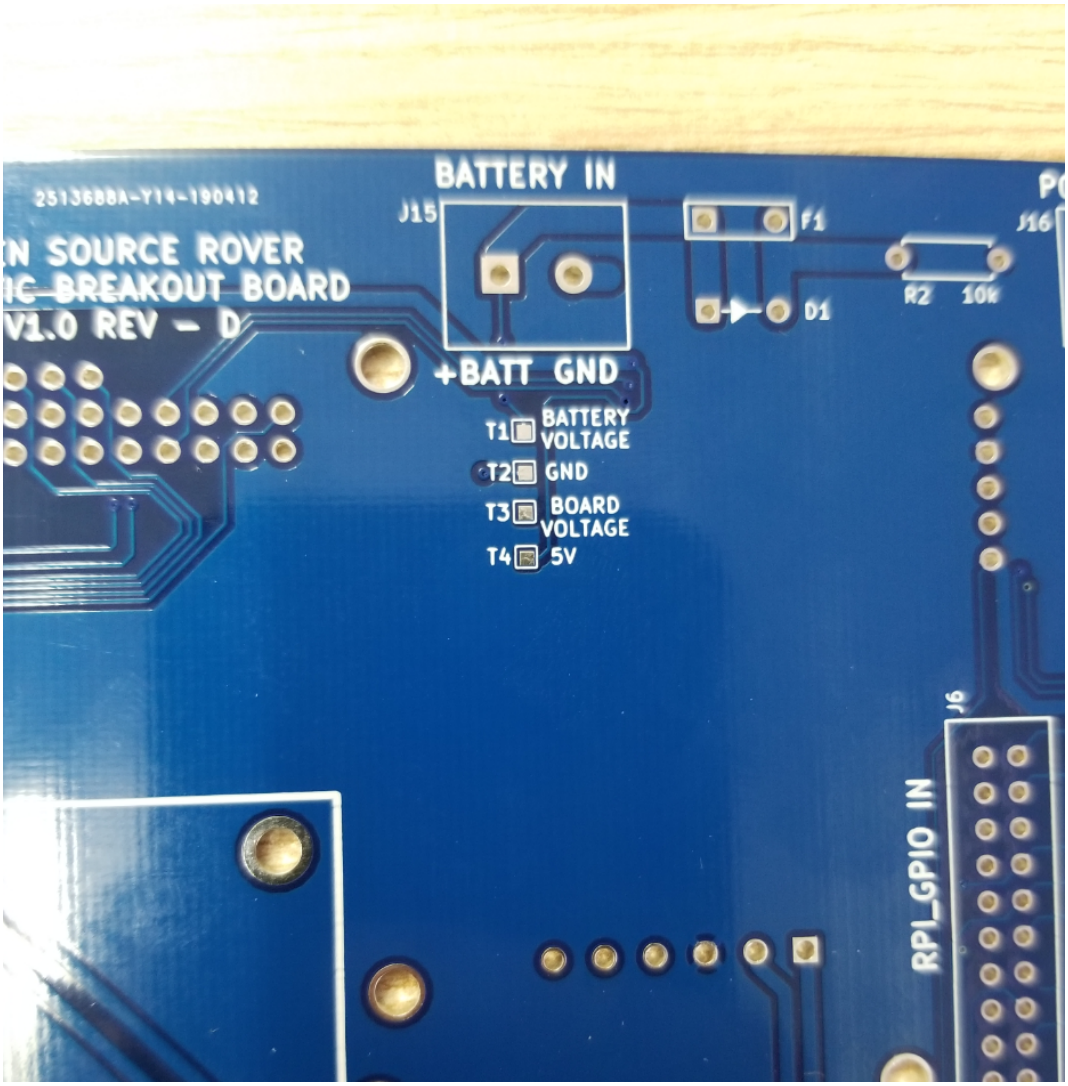


Figure 24: Test pads

3. Next jumper wires need to be made to connect the RoboClaw motor controller Power terminals to the RoboClaws. Unplug the tamiya battery connector (in future steps I will not explicity say to unplug the battery, but at each step while inserting components and working on the board you should disconnect the battery). Take the red and black 24 AWG wires **W1 and W2** and cut 15 segements of 2 inches of each, so that you have 15 red and 15 black pieces. Using wire strippers strip the ends at about 0.1 inches at each end. Insert these into the terminal blocks on the RoboClaw Motor Controllers **E20** in the following way:

Table 13: Parts/Tools Necessary

Terminal	Wire Color
M1A	Red
M1B	Black
+	Red
-	Black
M2A	Red
M2B	Black

4. Starting by inserting one of the Roboclaws into the slot on the bottom of the board labeled ROBOCLAW 2. Connect the wires directly accross to from RoboClaw motor terminal block to the terminal block on the control board.

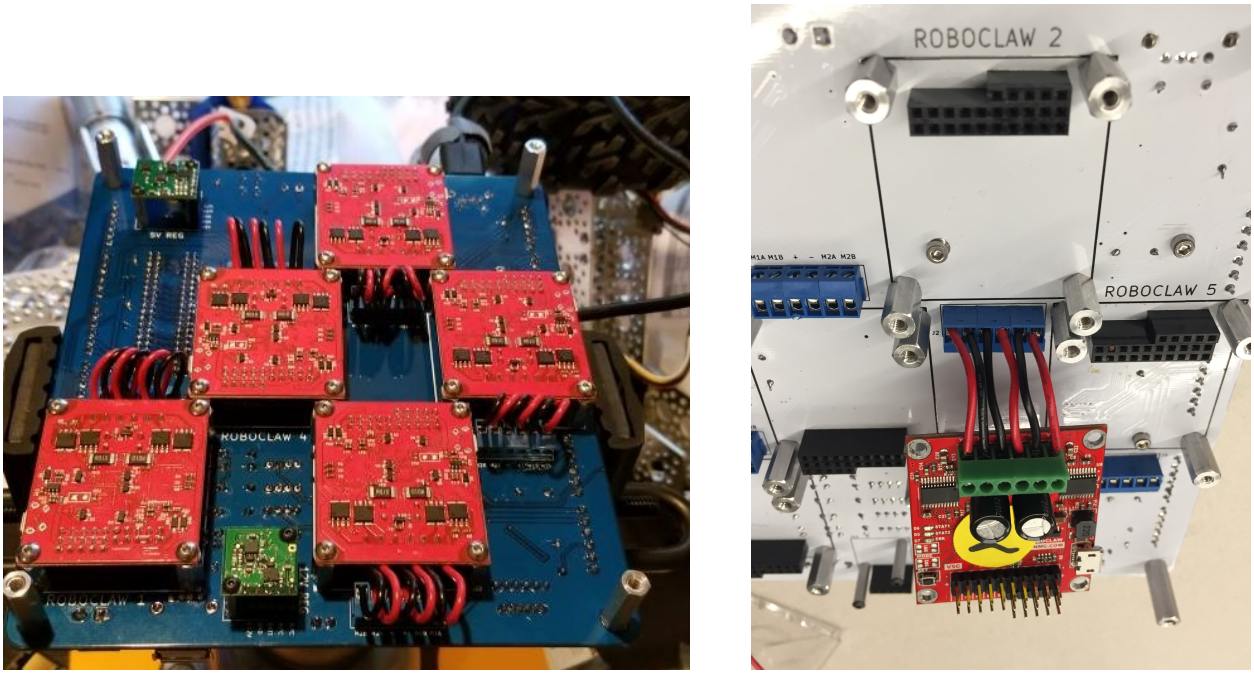


Figure 25: RoboClaw power/motor wires

5. Plug in the battery. an LED on the RoboClaw will turn on, verify that it is green. If it is red it means there is an error. Error codes can be traced by looking at the roboclaw user manual:

- https://www.basicmicro.com/downloads

6. Repeat this process one RoboClaw at a time until all 5 RoboClaws have been plugged into the board, following the order of 2, 3, 4, 1, 5

7. Take the two voltage regulators **E23 and 24** and solder on their header pins, on the top side of the board (the side with large capacitors on it).

8. Insert the 5V regulator into the control board. Then test from Testpoint T4 to T2 and verify that it reads 5V. If it does not make sure the 5V regulator is slotted in properly.

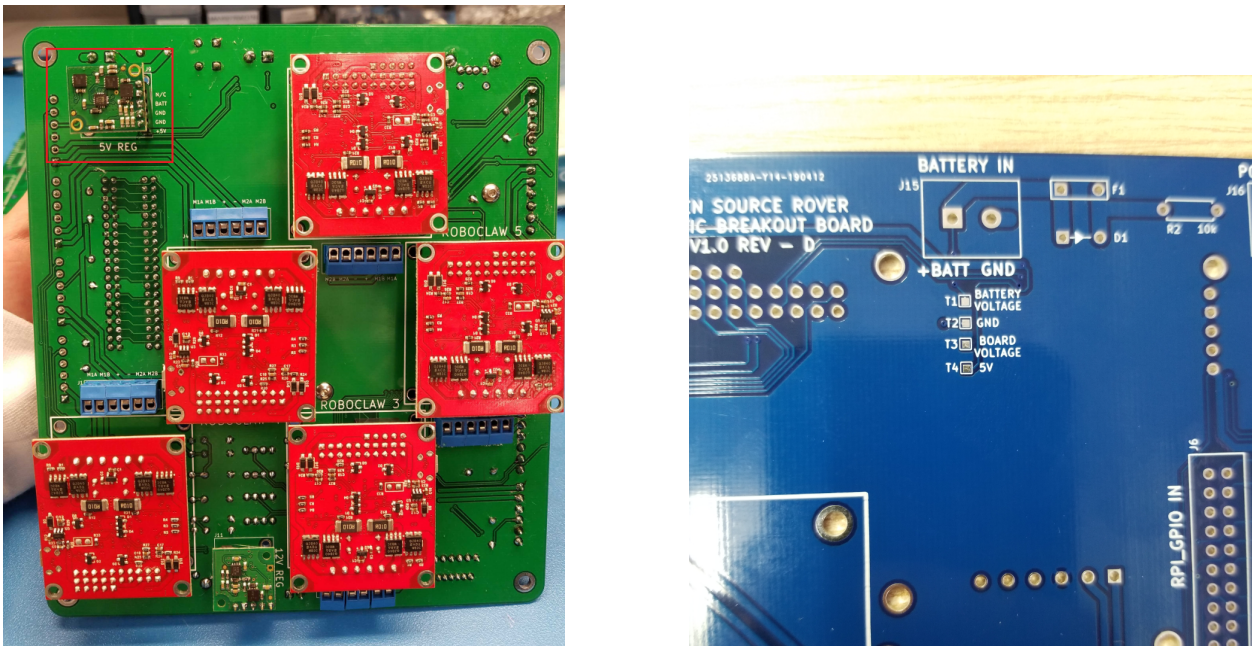


Figure 26: Test Step 5

9. Insert the 12V regulator into the control board. Then test from Testpoint T5 to T6 and verify that it reads 12V. If it does not make sure the 12V regulator is slotted in properly.

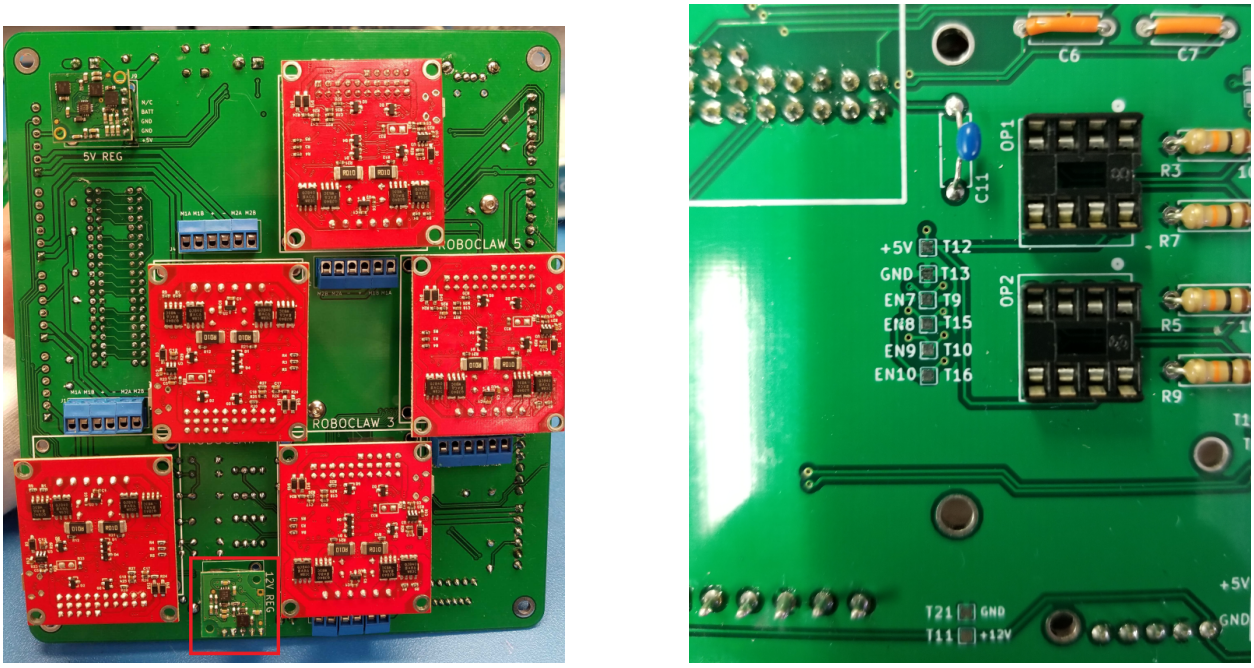


Figure 27: Test Step 6

If all voltage test points read expected values and all the RoboClaw motor Controllers have green LEDs then the power systems has been verified and you are ready to move onto testing and setup of the motor controllers.

2.2 Op-Amp Integration

1. Press the Op-Amp LM358P **E25** into the slots in the 8 Position DIP socket. Take careful note of the direction of the chip in the DIP socket, as the notch MUST face the correct direction.

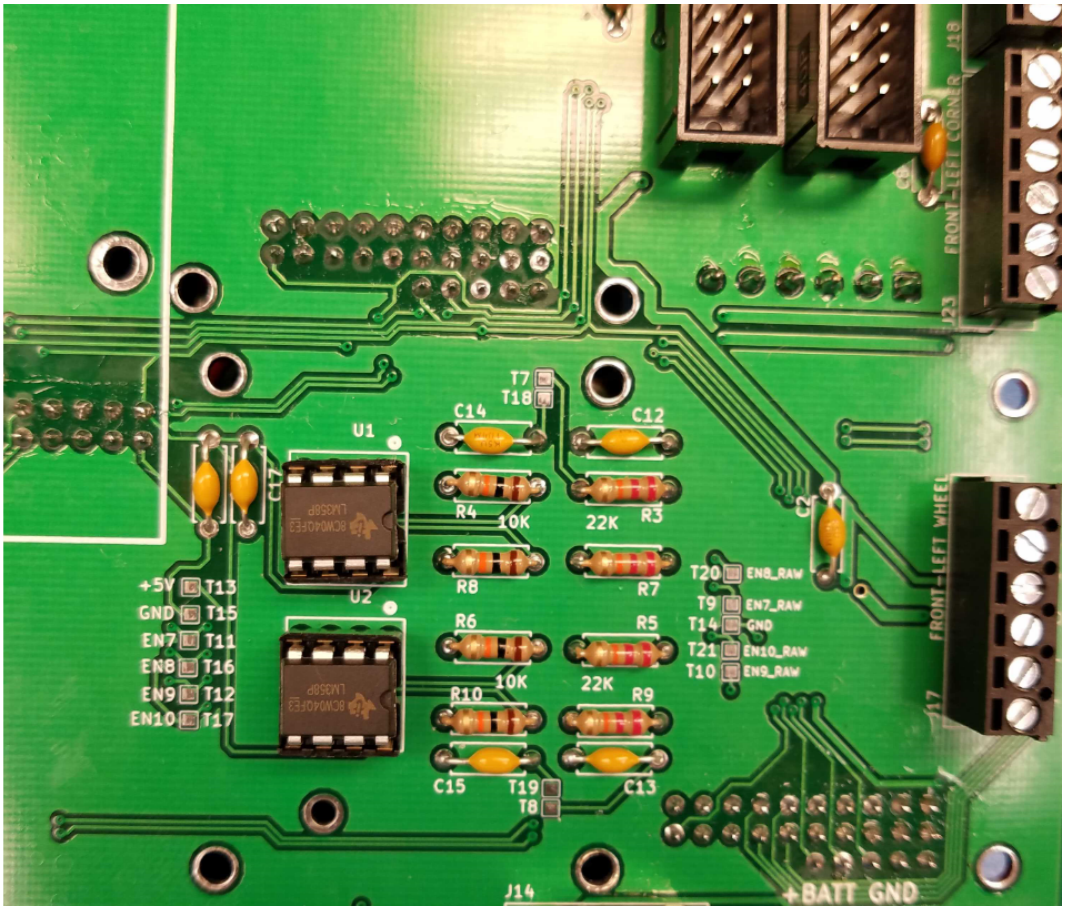


Figure 28: Op-amp integration

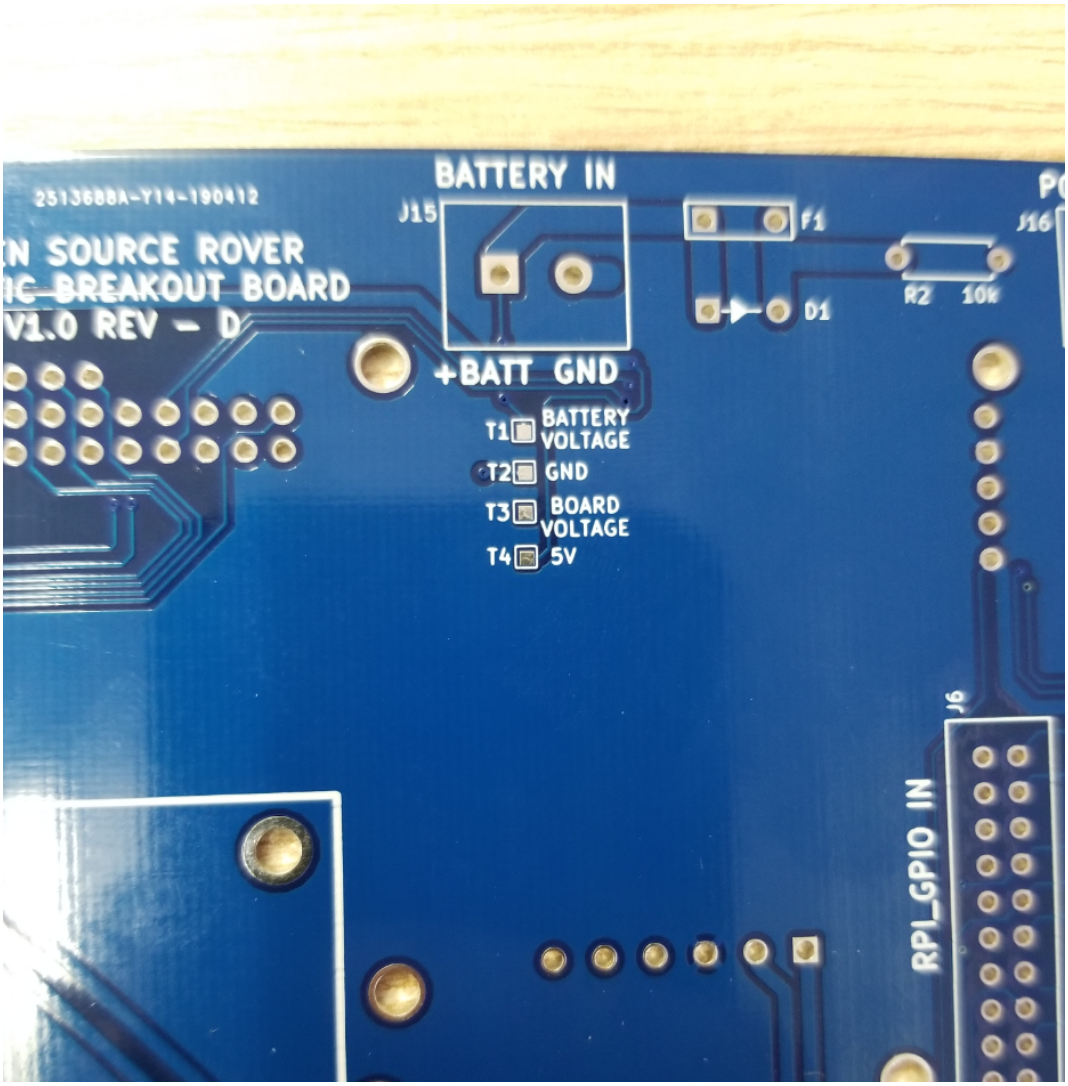


Figure 29: Test pads

2.2.1 RoboClaw Testing and Verification

In this section you will be going one by and and testing the operation of the RoboClaw Motor controllers. You will be doing this by using the GUI provided by the manufacturer of the motor contollers. The GUI can be found at the following link, under general downloads, then BasicMicro Motion Studio

- https://www.basicmicro.com/downloads

To use the GUI insert a USB to micro USB cable from your computer to the motor controller

you are going to be testing. For this step in the testing procedure we found it easiest to test using a set of male-male jumper wires, connected between the motor terminal being tested and the motor. Any way you wish to connect the wires from the terminal block to the motor wires is fine though.

2.2.2 Drive Motor Blocks

Do the following procedure for the terminal blocks labeled J17-22, these correspond to the driving motors for the rover. Make sure that while you are plugging in connections your board is powered off. The terminal blocks correspond to the motor controlelrs/outputs in the following manner:

Table 14: Parts/Tools Necessary

Terminal Block Label	RoboClaw Board Label	Motor Output Channel
J17	RC1	M1
J18	RC1	M2
J19	RC2	M1
J20	RC2	M2
J21	RC3	M1
J22	RC3	M2

1. Connect the wires in the following manner

Table 15: Parts/Tools Necessary

Signal	Terminal Block Label	Motor Connector Wire Color
Motor (+)	M+	Red
Motor (-)	M-	Black
Ground	GND	Green
+5V	+5V	Blue
Encoder A	ENA	Yellow
Encoder B	ENB	White

2. Power on the board, after a minute in the Basic Motion GUI you should see an available device appear. It might require an update to proceed, have it install the latest firmware update and then connect to the device.

3. Click on the PWM tab. We will use this to send a PWM signal to the motor and test that connections are all made correctly to the motor/encoder.

4. Slowly move the slide bar for the corresponding motor output channel (Either M1 or M2 from the above table) for the terminal you are testing. Verify that the motor spins (we will worry about direction later), and that the encoder value is also changing (we'll worry about it increasing or decreasing correctly later as well). Switch direction of the slide bar and verify that it spins the other direction and the encoder value does the opposite of previous as well. If these are not happening then go back and check that you are using the correct Motor controller, terminal block etc. If all that is correct you will have to begin testing solder contact between the componenets on the board itself.

5. Repeat this process for all the drive motor terminal blocks, labeled J17-22.

2.2.3 Corner Motor Blocks

Do the following procedure for the terminal blocks labeled J23-26. These correspond to the Corner motos for the rover. Terminal blocks correspond to the motor controllers/outputs in the following manner:

Table 16: Parts/Tools Necessary

Terminal Block Label	RoboClaw Board Label	Motor Output Channel
J23	RC4	M1
J24	RC4	M2
J25	RC5	M1
J26	RC5	M2

1. Connect the wires to the motor in the following manner

Table 17: Parts/Tools Necessary

Signal	Terminal Block Label	Motor Connector Wire Color
Motor (+)	M+	Red
Motor (-)	M-	Black

2. The main different between the drive and corner motor system is the encoders used. We want to test the voltage division circuit used on the Control board, which will expect up to a 5V signal in from the Absolute Hall effect encoder. To simulate this connect the +5V terminal on the motor terminal block straight into the ENA signal in the same terminal block.

3. Connect to the motor contoller in the Basic Motion GUI. Under the General settings tab under Encoders change the type of Encoder from Quadrature to Absolute. You should see that the encoder values change to a number somewhere around 1600. As long as it is a fairly constant value and is in the range of 1400-2000 then everything is working. If that is not recheck that the OP-amp is installed in the correct direction. If this number still isn't correct then make sure you correctly installed all the resistors/capacitors in the assembly steps.

4. Under the PWM tab move the slide bar and verify that the motor spins accordingly.

5. Repeat this process for all the corner motor terminal blocks, labeled J23-26.

2.2.4 Raspberry Pi Install

Next up is to verify that power to the Raspberry Pi is working. For this you'll need a working operating system install on the SD card. Look foward to the Software Install steps to get the install instructions of that.

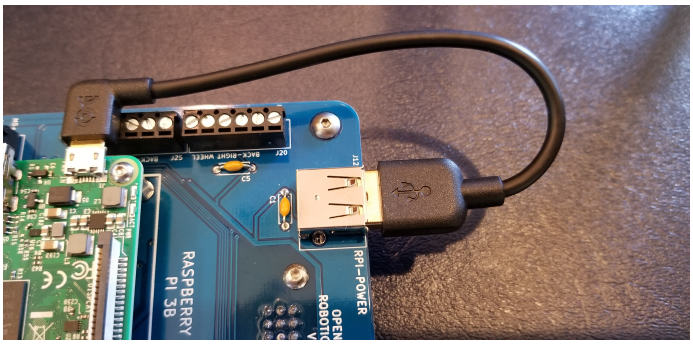
INSERT LINK TO SOFTWARE DOC?

Table 18: Parts/Tools Necessary

Item	Ref	Qty	Image	Item	Ref	Qty	Image
OSR Control Board	E1	1		Raspbery Pi 3B	E21	1	
40 Pin Ribbon Cable	E29	1		USB to Micro USB Cable	E27	1	

1. Insert the Raspberry Pi into the Board, making sure that the USB ports face downward on the board. Figure 30 show this orientation.

2. Plug in the micro USB cable **E27** to the USB power port labeled J12 and the Raspberry Pi. Then Plug in the ribbon Cable **E29** into the Raspberry Pi GPIO header pins and the **J6** 40 pin GPIO connector.



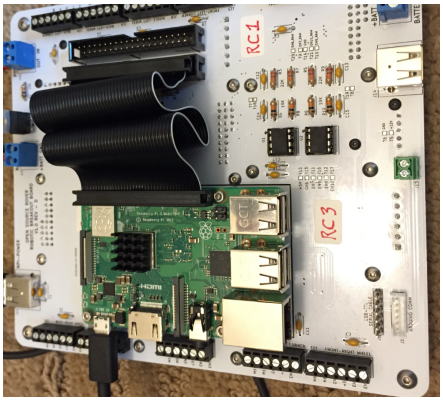
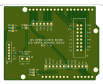


Figure 30: RPi Install

2.3 Arduino Sheild Testing

Table 19: Parts/Tools Necessary

Item	Ref	Qty	Image	Item	Ref	Qty	Image
Arduino Sheild	E2	1		Arduino Uno	E24	1	
1x6 JST Cable	E26	1		16x32 LED Matrix	E37	1	

The testing of the arduino board is dependant on finishing the control board and having it tested fully. Slot the Arduino Uno onto the bottom of the Arduino sheild, matching the footprints.

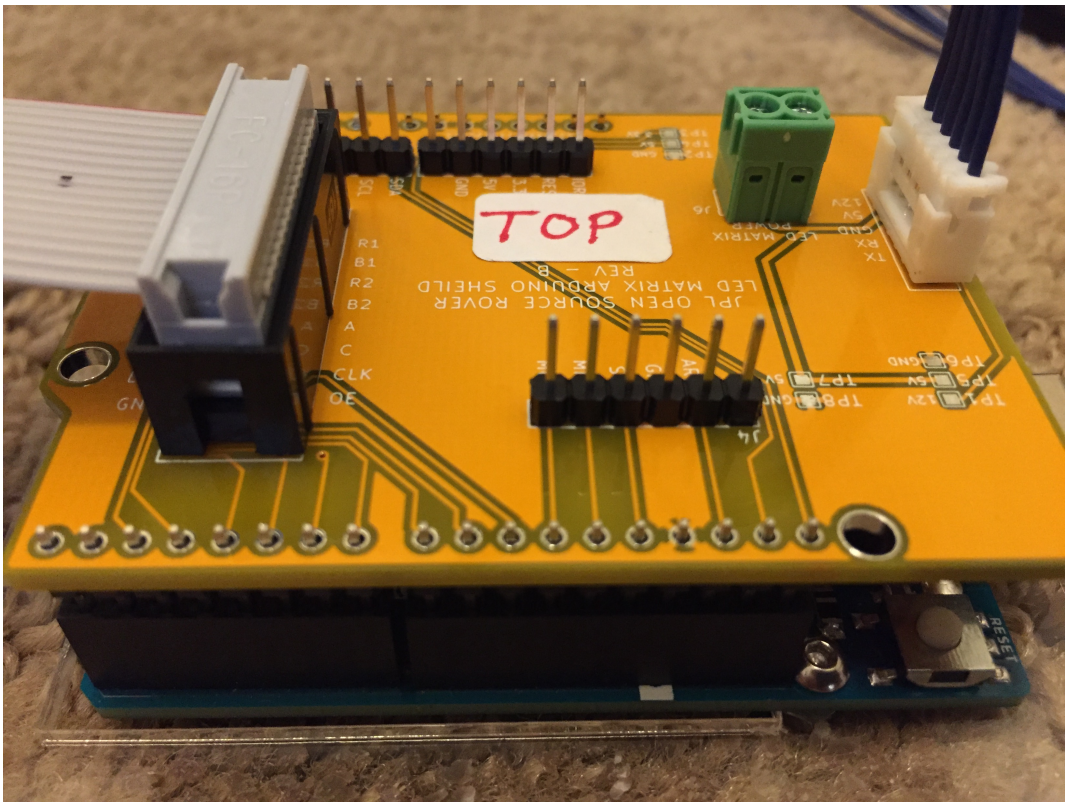


Figure 31: Arduino Sheild Mounted

1. Plug in the 1x6 JST cable **E26** into the Arduino sheild and the Control board. This cable will run 12V, 5V, GND, and two serial communication lines from the main rover to the Arduino sheild to run the screen in the head. This will rely on you having already tested the 5V and 12V regulators on the control board and verifying that they work correctly.

2. Using a Digital Multimeter probe the following test pads and verify their voltages:

   - TP1 to TP6 should read +12V. This voltage powers the Arduino Uno board
   - TP5 to TP6 should read +5V. This voltage powers the LED Matrix and runs the LEDs on it

- TP4 to TP2 should read +5V. This is the 5V converter on the Arduino board
- TP3 to TP2 should read +3.3V. This is the 3.3V converter on the Arduino board

If all the above test points read the correct voltages then the Arduino Sheild board is working correctly.

3 Flashing the Arduino Code

In this section we will be flashing the code that runs on the arduino to control the LED matrix in the head. The following steps should be performed on your laptop or development machine (not the raspberry pi)

1. Install the Arduino IDE used for loading code onto the arduino:

   https://www.arduino.cc/en/Main/Software

2. Clone the code repo:

   (a) git clone https://github.com/nasa-jpl/osr-rover-code.git

   (b) git checkout osr-ROS

   (c) git pull

3. Build our custom library:

   (a) Select the downloaded Arduino folder and create a .ZIP file from it

   (b) Rename the Zip file to OsrScreen.zip

4. Load the sketch onto the Arduino

   (a) Unplug the Arduino sheild JST cable so the Arduino isn't powered by the control board

   (b) Connect the Arduino to your development machine with USB cable

(c) Open Arduino IDE

(d) Select Sketch - Include Library - Add .Zip Library

(e) Select the OsrScreen.zip folder created previously

(f) Click the Upload button in the Sketch Window

5. To load the example in the Arduino IDE:

(a) File - Examples - OsrScreen - OsrScreen