Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science
Workshop
Building a Variable Speed Drive

Introduction: In this lab we will construct a variable output buck converter, which will control the speed of a DC motor. This buck converter will feature the totem-pole topology, a highly utilized circuit structure with applications in power electronic converters, amplifiers, and device controllers.

Exercise 1: Build a Square Wave Generator

In this exercise you will build a variable duty cycle square wave generator as pictured below. A schematic for the square wave generator can be found on page 2.

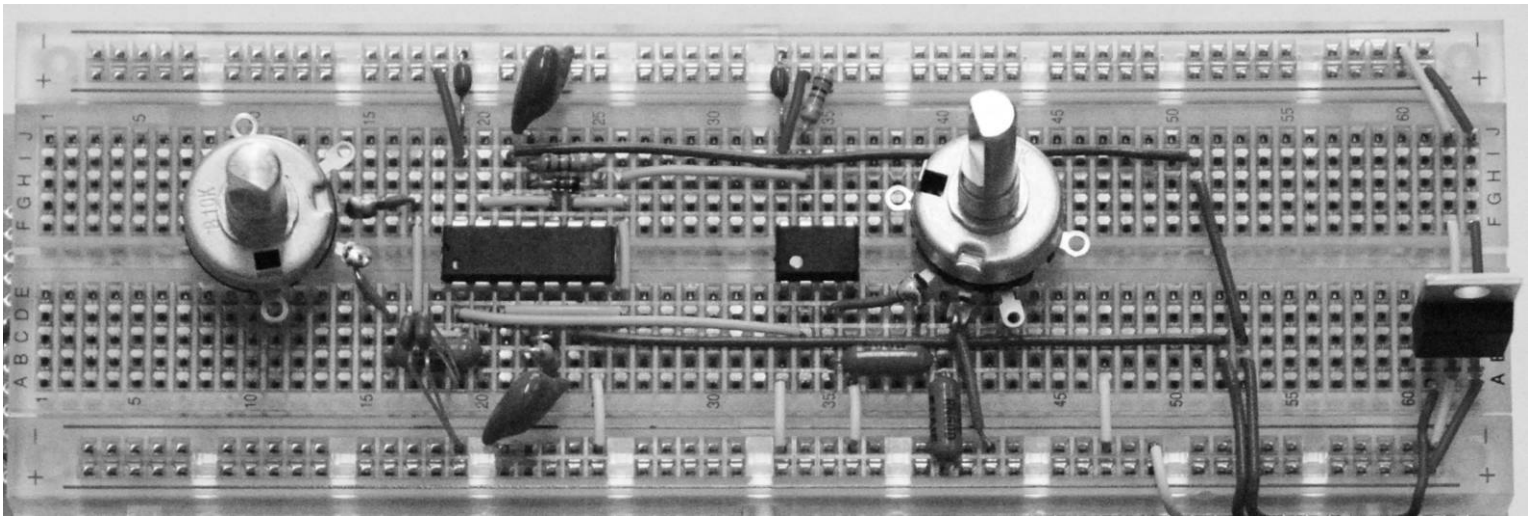


Figure 1. Square Wave Generator

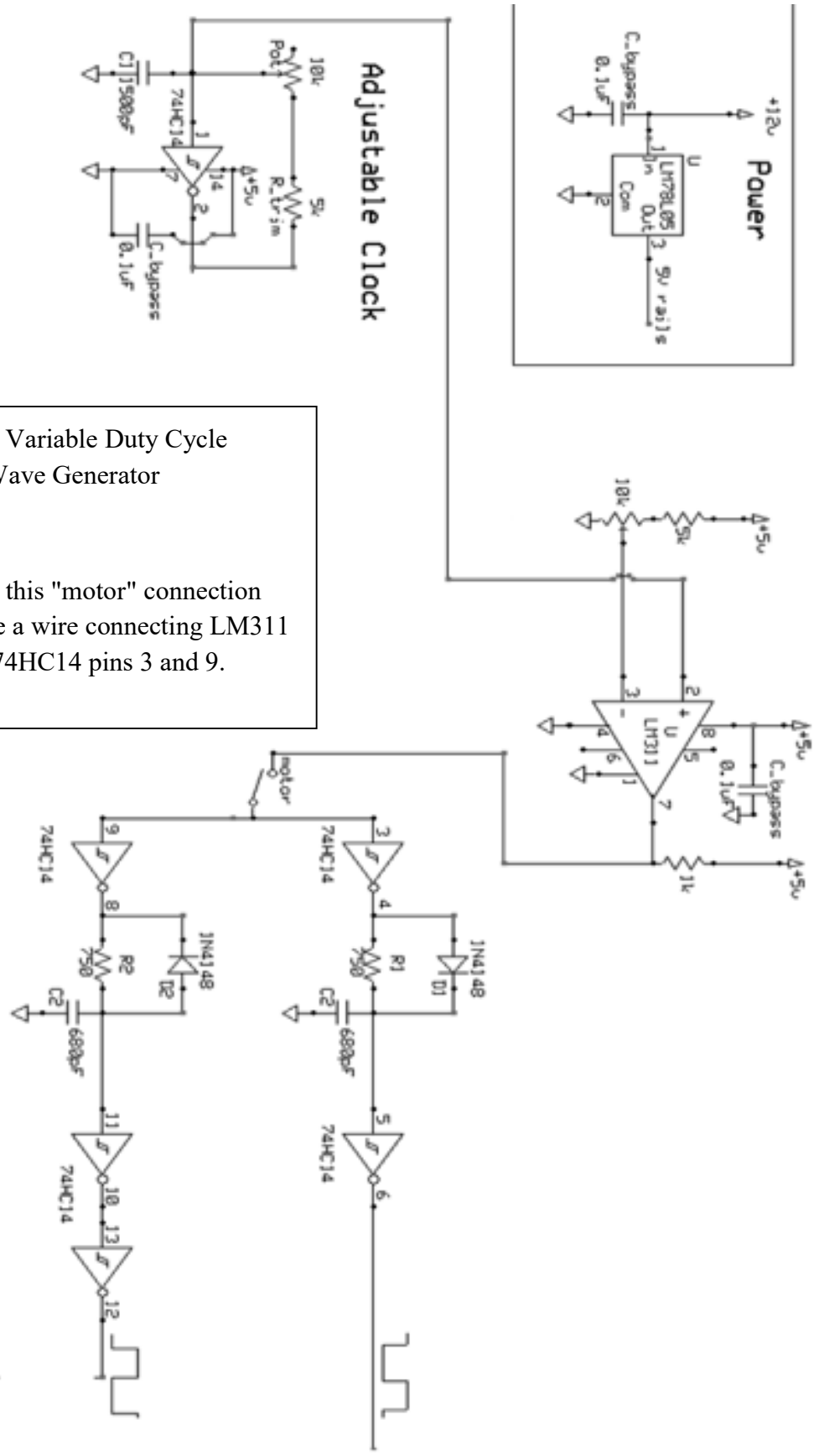


Figure 2. Variable Duty Cycle Square Wave Generator

For now, this "motor" connection should be a wire connecting LM311 pin 7 to 74HC14 pins 3 and 9.

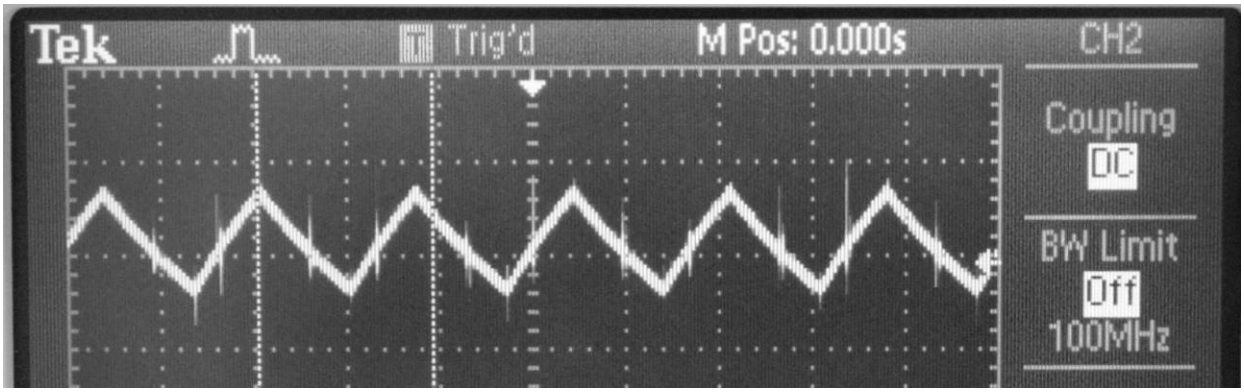
For this exercise you will need the following parts:

Part	*Number*	*Description*
Breadboard	1	
LM7805	1	Voltage Regulator
74HC14	1	Hex Inverter
1N4148	2	Diode
.1uF Ceramic Cap	3	
680pF Ceramic Cap	2	
1500pF Ceramic Cap	1	
750 Ω Resistor	2	
5k Ω Resistor	2	
1k Ω Resistor	1	
LM311	1	Comparator
10k Potentiometer	2	

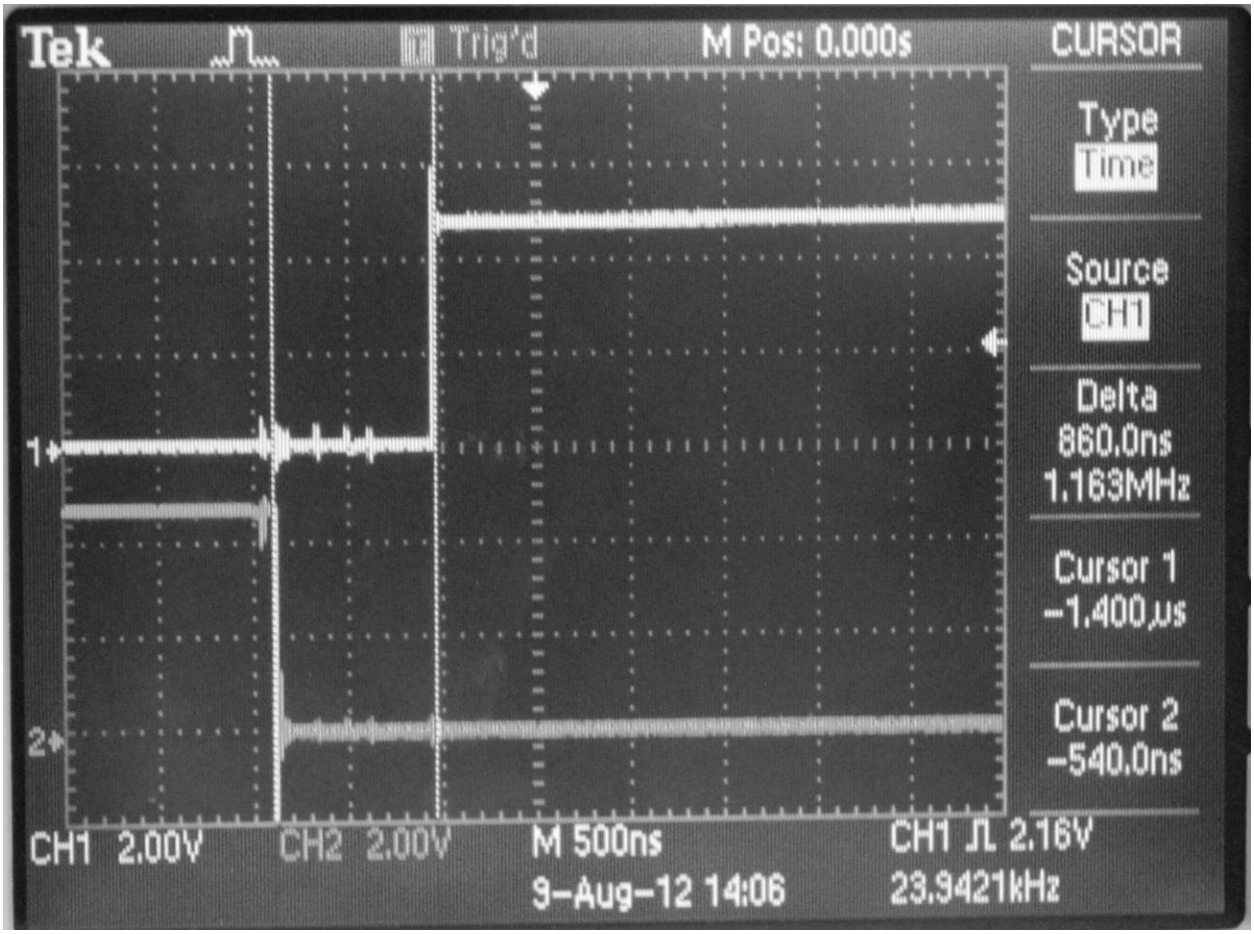
Procedure and Tips:

1- Do not place the circuits too close to each other. Give yourself enough space to work.
2- Make sure to utilize the power and ground rails on your breadboard (the two furthest rails on each side of the bread board).
3- Use the oscilloscope and test the output of each stage of the circuit to make sure it provides the desired wave form.

Once you are done, verify with an Oscilloscope that the output of pin 1 on the 7414 looks something like this:



Also verify that pins 6 and 12 on the 7414 are not both high at the same time and look something like this:



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Exercise 2: Build Totem Pole Circuit on PCB

Figure 3 shows a completed Totem Pole on the PCB. A schematic for this circuit is shown in Figure 4. Make sure to solder the testing wires on the back of the PCB as shown in Figs. 5 and 6.

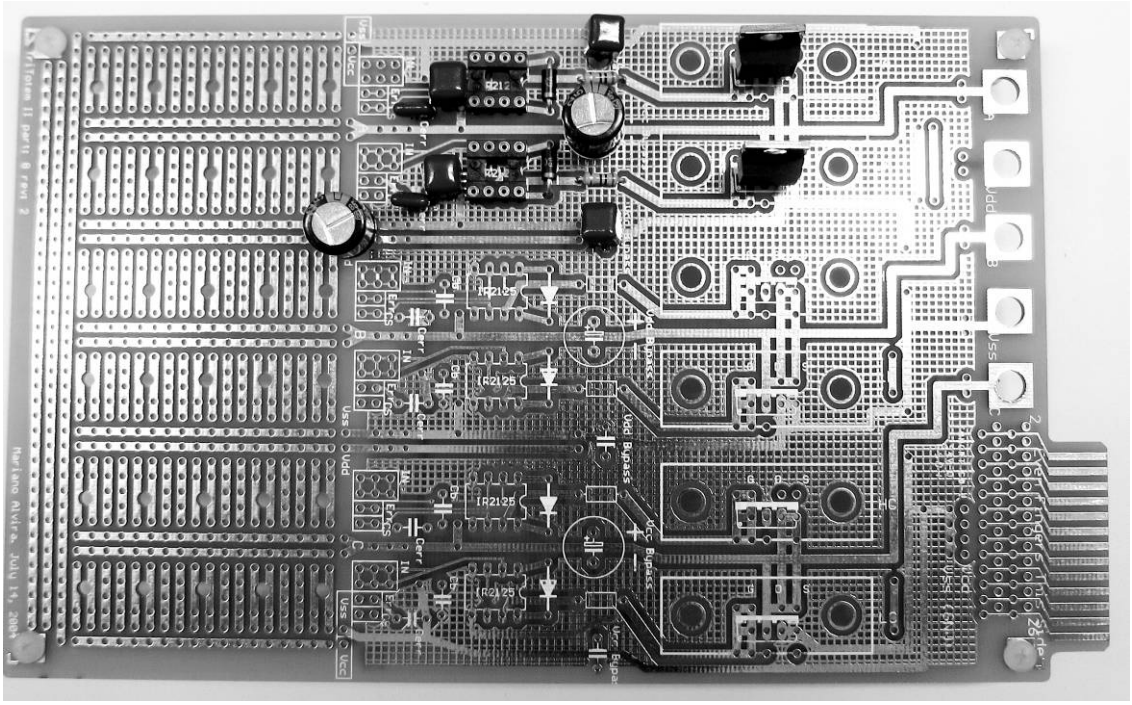

Figure 3 (a). Totem Pole on PCB

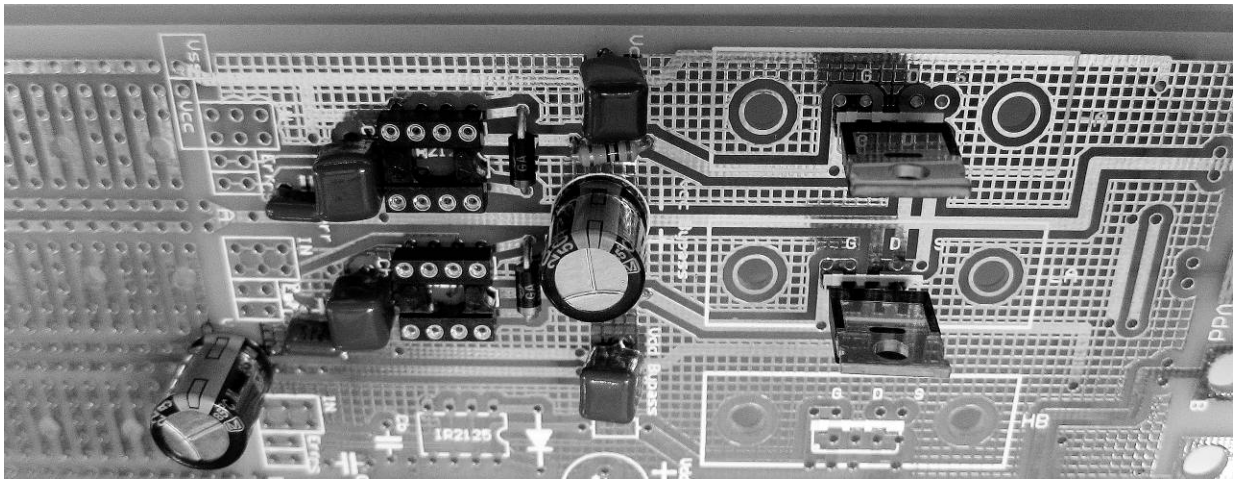

Figure 3 (b). Close-up view of components you should solder on to PCB.

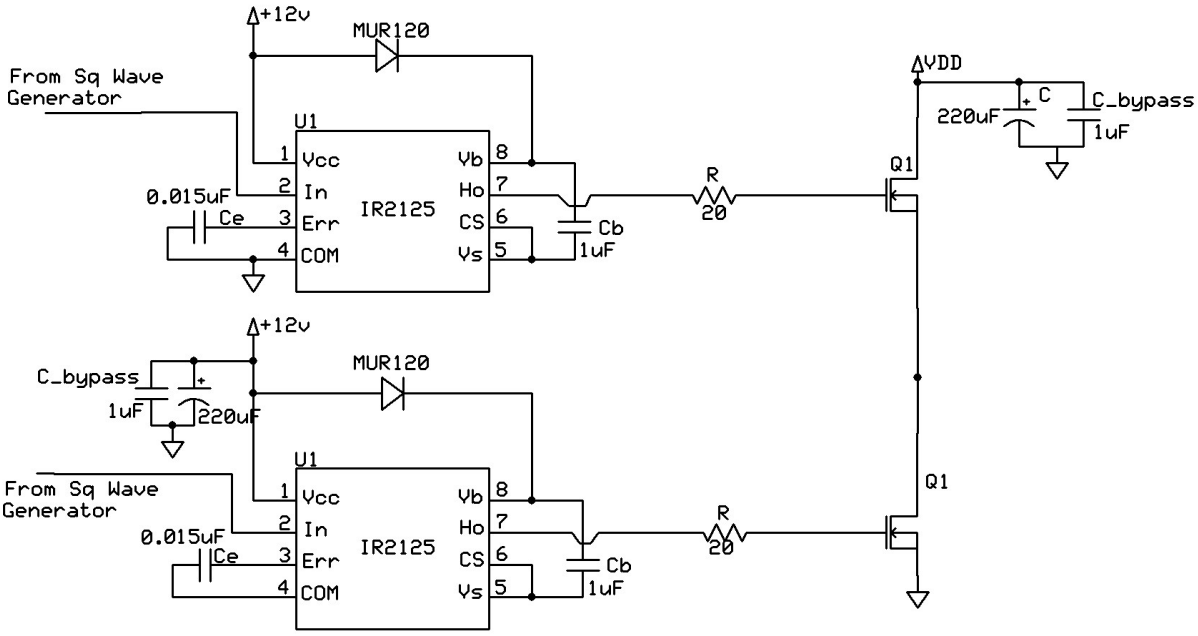

Figure 4: Totem Pole Schematic

The parts needed for this exercise are:

Part	***Number***	***Description***
PCB	1	For the Totem pole
1uF Cap	4	Gate Driver
220uF 50V Cap	2	Capacitor
20 Ω resistor	2	Resistor
MUR120	2	Diode
8 pin DIP socket	2	Socket for Gate driver
IR2125	2	Gate Driver
Plastic stand off / screws	4	
IR540	2	MOSFET
Cable	1	Cable with clips on both end
Terminal Post Screw	3	
0.015uf Cap	2	Capacitor

Procedure and Tips:

1- Place the components in their designated space. Start with smaller components for ease of soldering.
2- When you solder use your soldering tip on the area to heat it up, and then place the solder until it starts to flow.

Guide to Soldering: Sequence to put the components for ease of soldering

Sequence of placing on PCB	***Part***	***Location/ Marking on the PCB***
1	20 Ω resistor	
2	MUR120	Symbol of diode (Check polarity before soldering: cathode is marked as white line on the diode)
3	8 pin DIP socket	Don't solder the IR 2125 directly on the PCB. Use this socket instead. The notch on the socket is its top. Align this with the PCB marking.
4	0.015uF	Place these capacitors on the marking as C_{err}
5	1uF	Place these capacitors on two C_b , V_{cc} Bypass and V_{dd} Bypass
6	220uF 50V Cap	Place these capacitors on V_{cc} Bypass (slots marked with circle and a polarity) and between V_{dd} and V_{ss}. Make sure the polarity of the capacitor is correct (V_{ss} should be the negative pin)
7	Plastic stand off with screw	Place plastic standoff at the four corners and firmly tight it with screws
8	IR540	Solder IR540. Make sure the polarity is correct. The Base of the device is shown with bold lines on the board)
9	Solder	Use solder to bridge the 5^{th} and 6^{th} pin on the IR2125 gate driver chip. (The pin number is counted anti-clockwise starting from the top left i.e. with notch on the top, first left pin is number 1 while first right pin is number 8.) Refer to Figure 5.
10	IR2125	Put the gate drivers on the 8 pin DIP sockets.

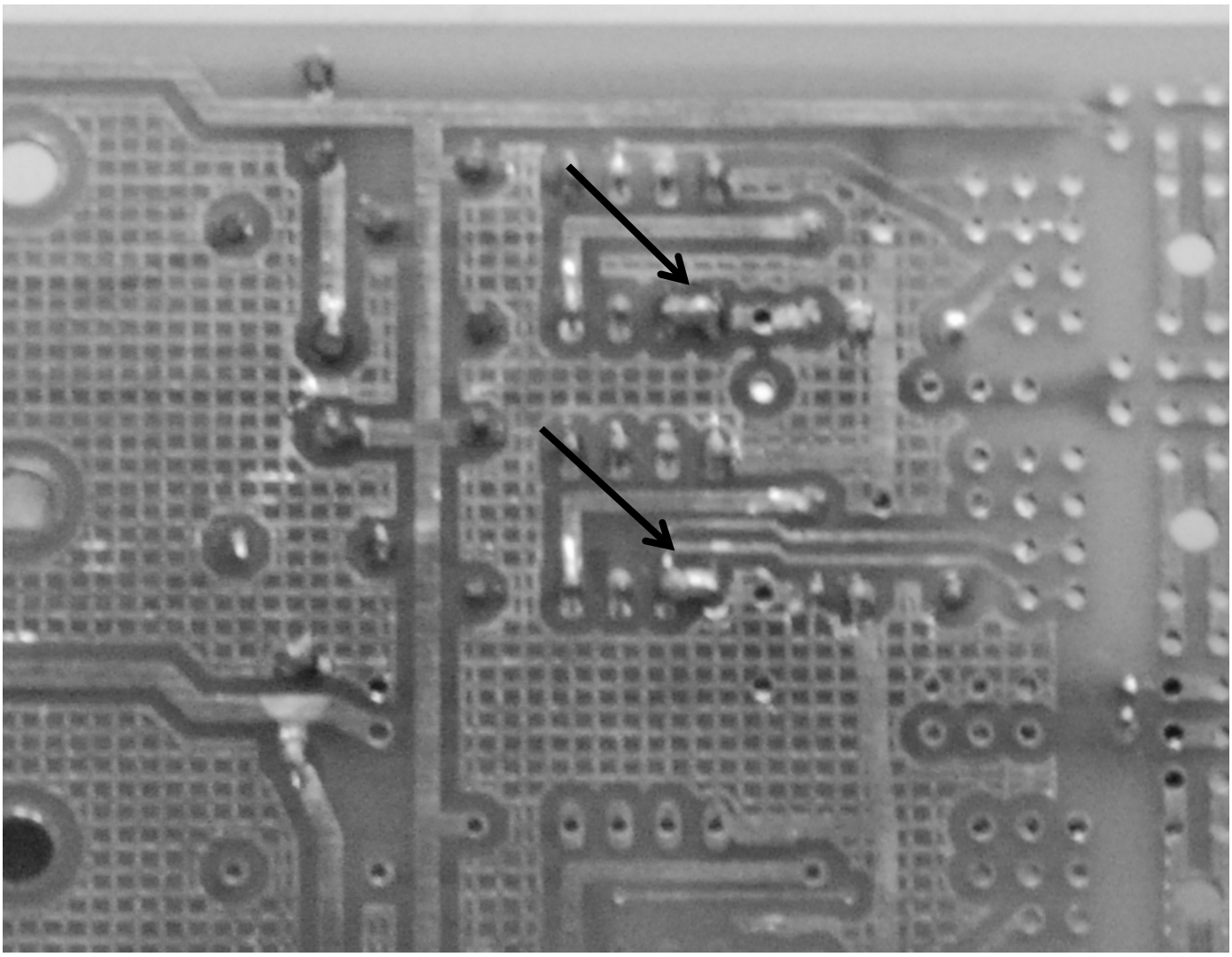

Figure 5. Solder Bridge on Bottom of PCB (the fingers of the PCB are to the left)

3- One you are finished soldering all the components, use a multi-meter to test for shorts on the board. Test for shorts from Vcc to Vss, Vdd to Vss and Vcc to Vdd.
4- Place testing wires as shown in Figures 6, 7, and 8. These are 2 wires that run from IN section to Finger Connections. Be careful to not short the cables. Check the finger connections with multimeter to check for shorts.

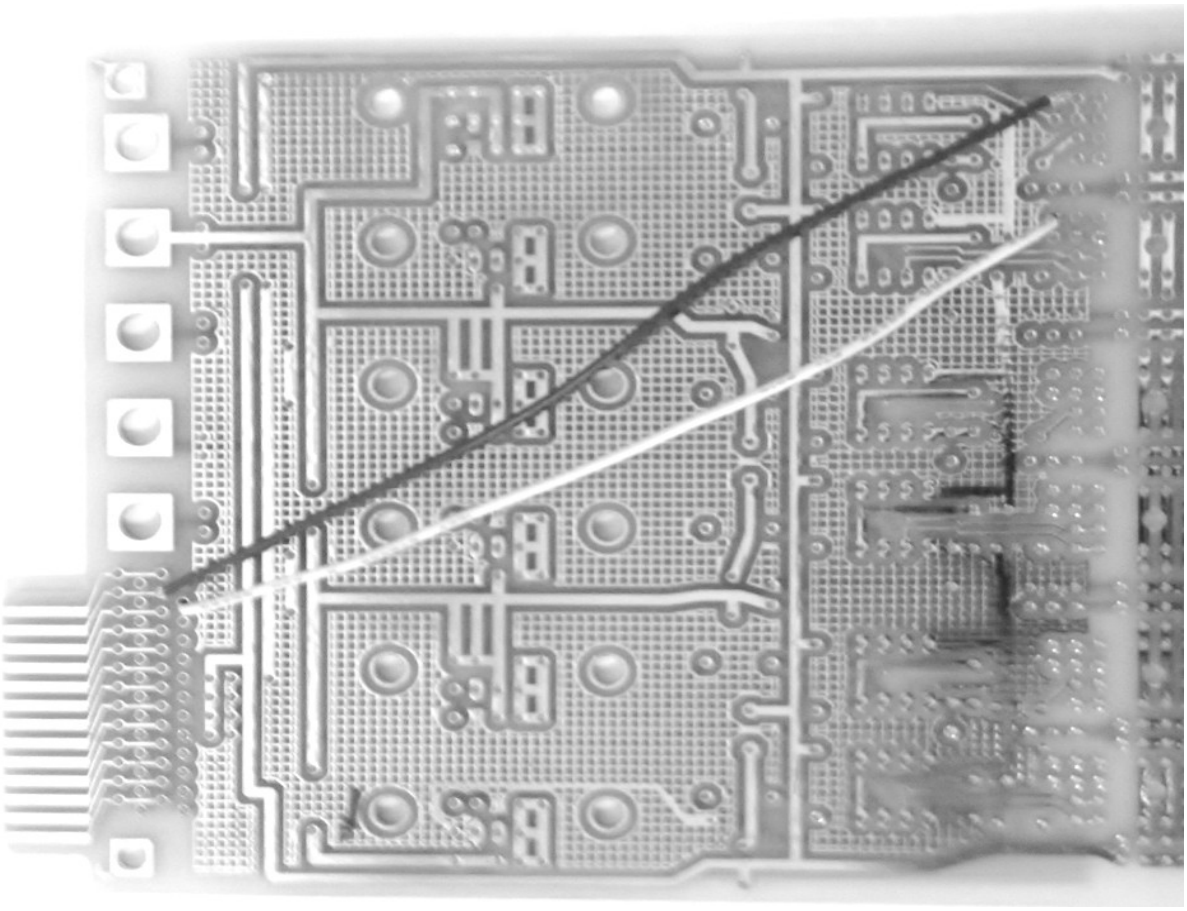

Figure 6. Testing Wire Connections

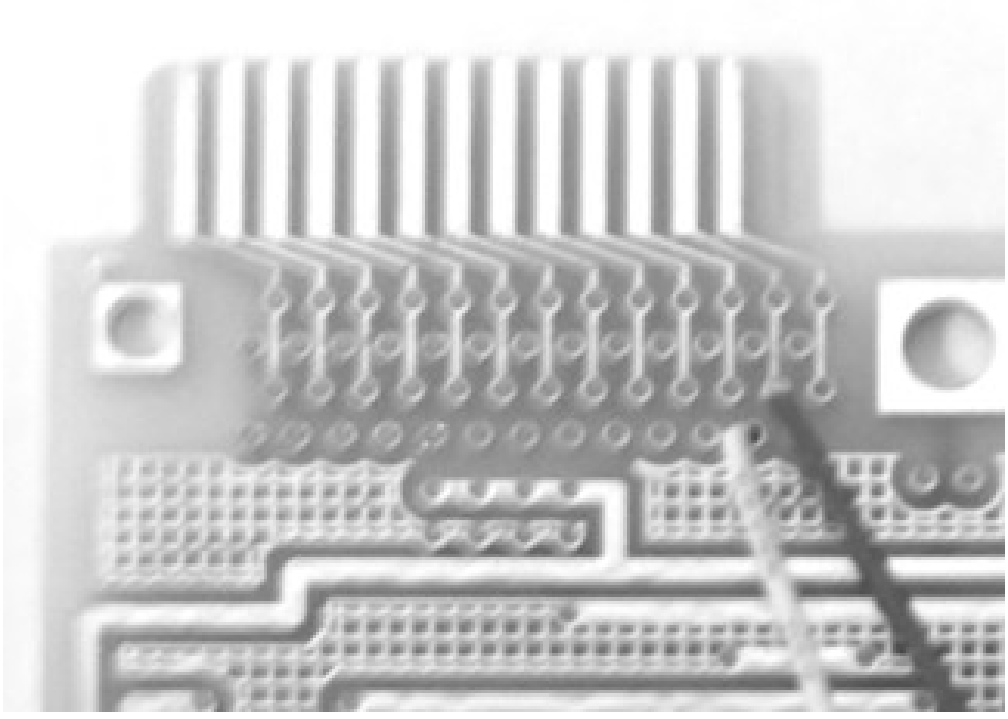

Figure 7. Closeup of Testing Wire Connections (on back)

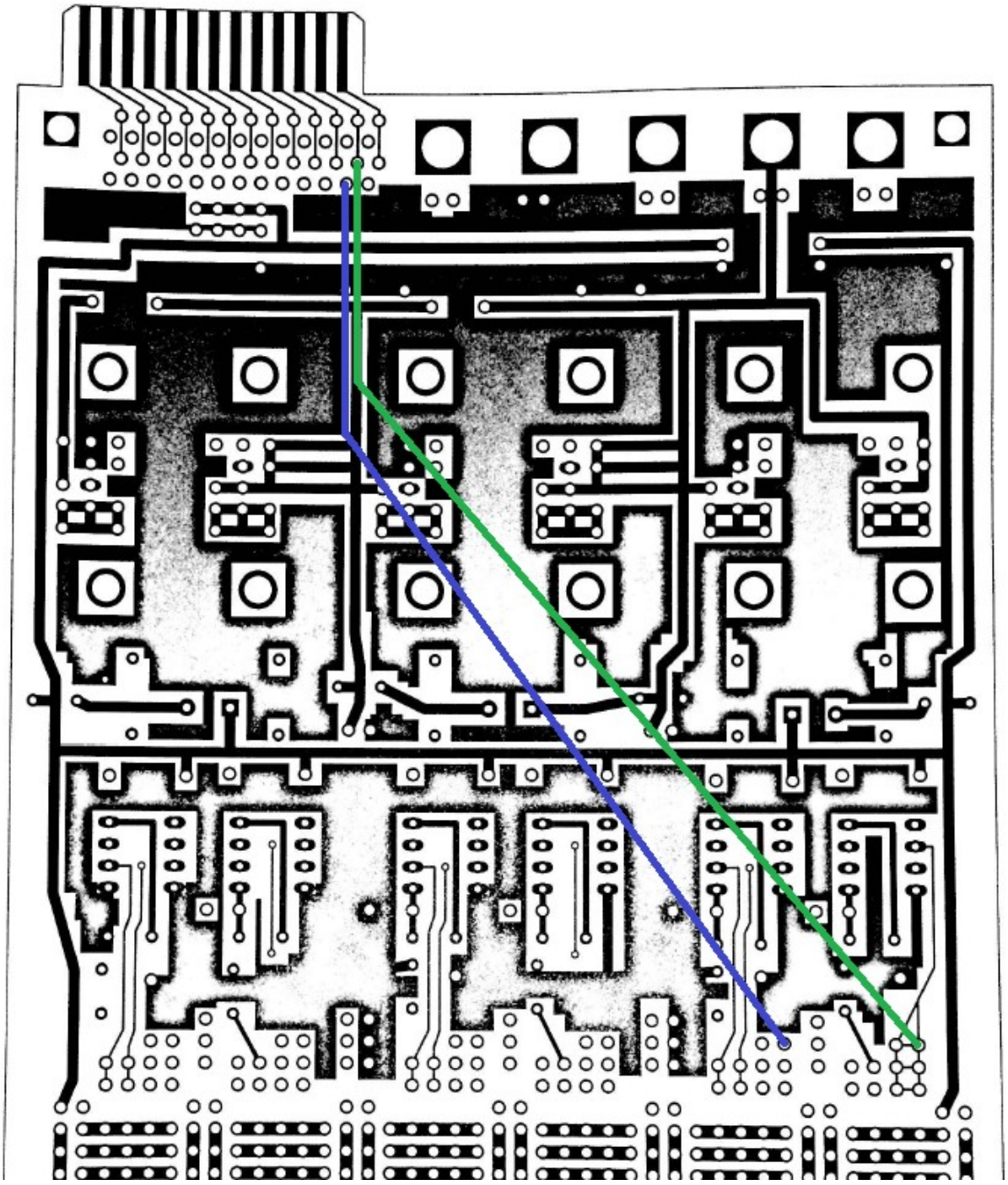

Figure 8. Testing Wire Connections (on back)

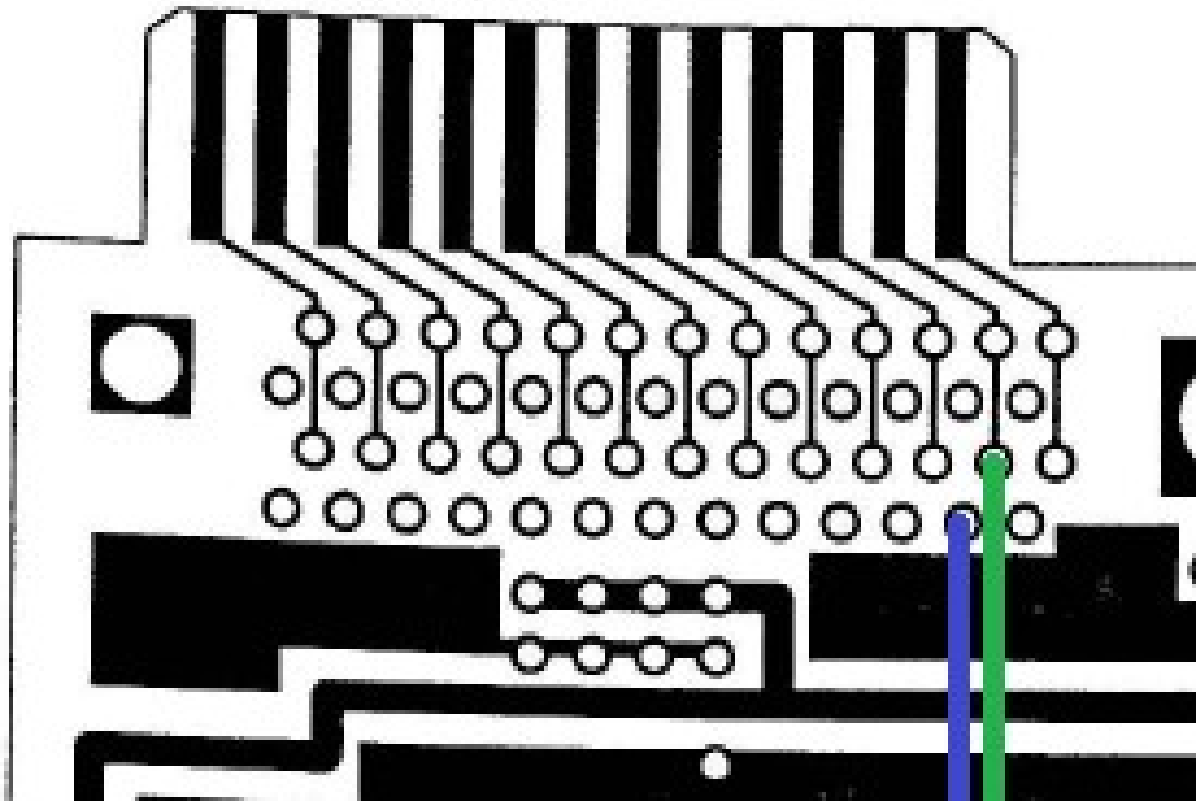

Figure 9. Closeup of Testing Wire Connections (on back)
solder wire in the hole where the line ends

5- Also connect two more wires from Finger connections to Vss and Vcc. Please refer to Figures 10 and 11.

6- Connect 10-32 bolts and nuts in terminal positions A, Vdd, and Vss, as shown on the right side of Figure 12.

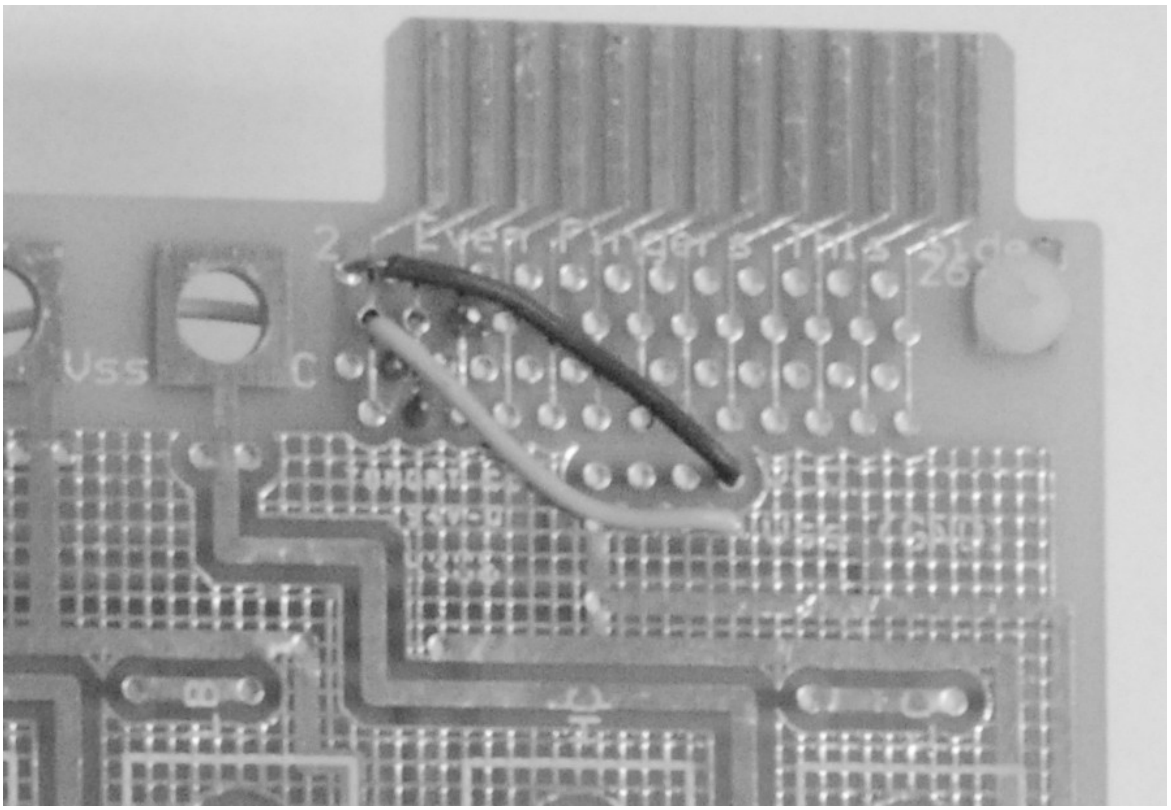

Figure 10. Close up of Testing Wire Connections (on front)

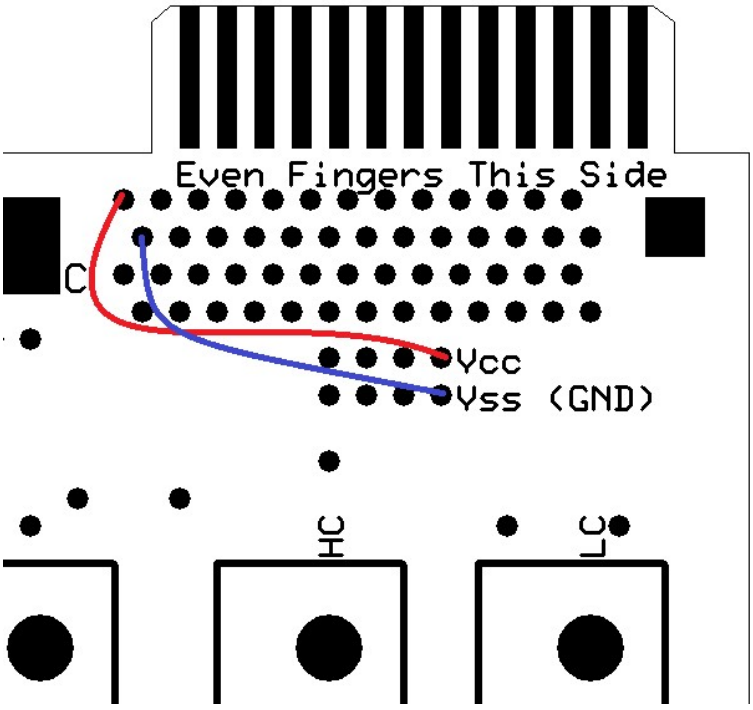

Figure 11. Close up of Testing Wire Connections (on front)
solder wire in the hole where the line ends

7- Once you are finished soldering all the components, use a multimeter to test for shorts on the board. Test for shorts from 12V to ground, Vdd to ground, 5V to ground, 12V to 5V, 12V to Vdd, and 5V to Vdd.

After testing for these shorts, find a Teaching Assistant to test your board on the board tester. A "top side" or component side photograph of a finished board is shown below:

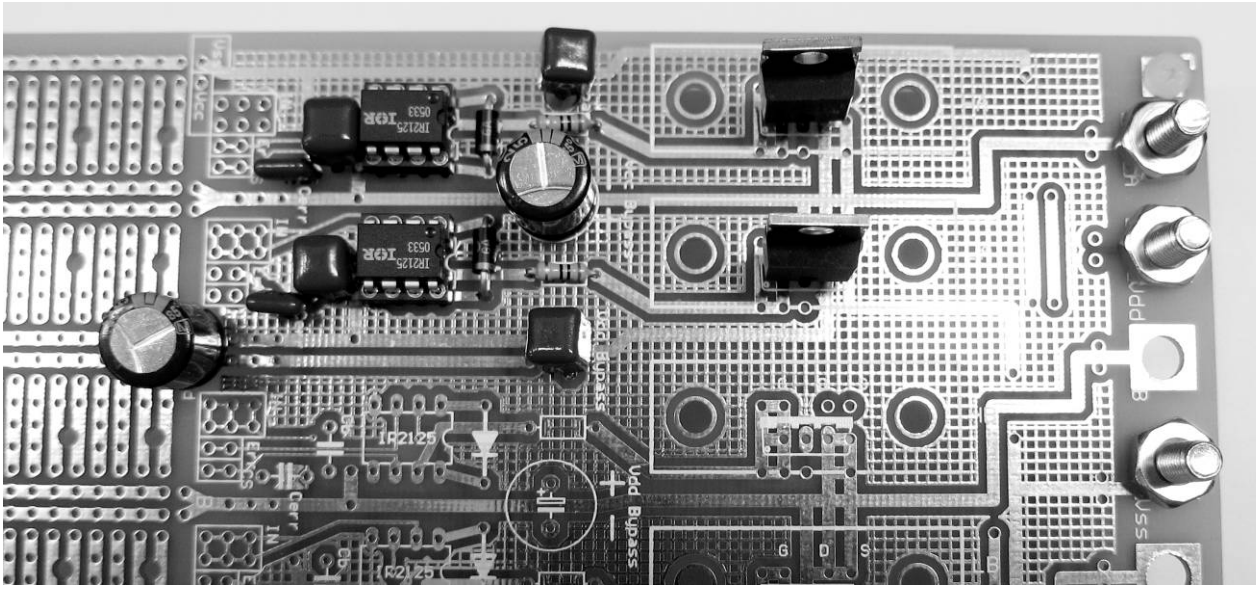

Figure 12. "Top side" view of finished board.

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Exercise 3: Connect the Breadboard and Motor to the PCB.

1- Secure the breadboard to the PCB using two zip-tie fasteners as shown in Figure 13.

2- Make the following four electrical connections between your breadboard and PCB:

1) 12V (pin 1 of the LM7805) to Vcc
2) Pin 6 of the 7414 to the input (pin 2) of the high side IR2125
3) Pin 12 of the 7414 to the input (pin 2) of the low side IR2125
4) Ground to Vss

Note that the high side IR2125 is on the left when the fingers are pointing upwards. A schematic for these connections is shown in Figure 14.

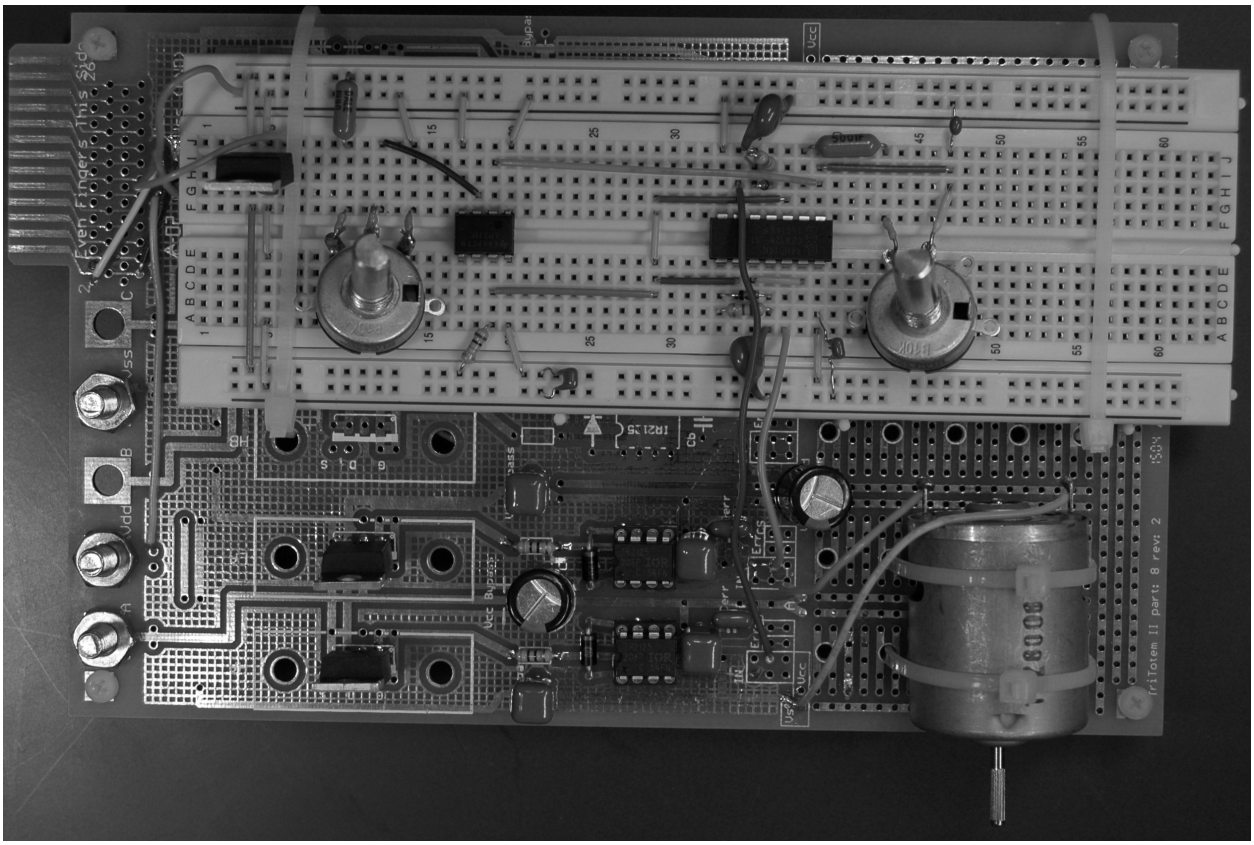

Figure 13. Completed Breadboard Connected to PCB

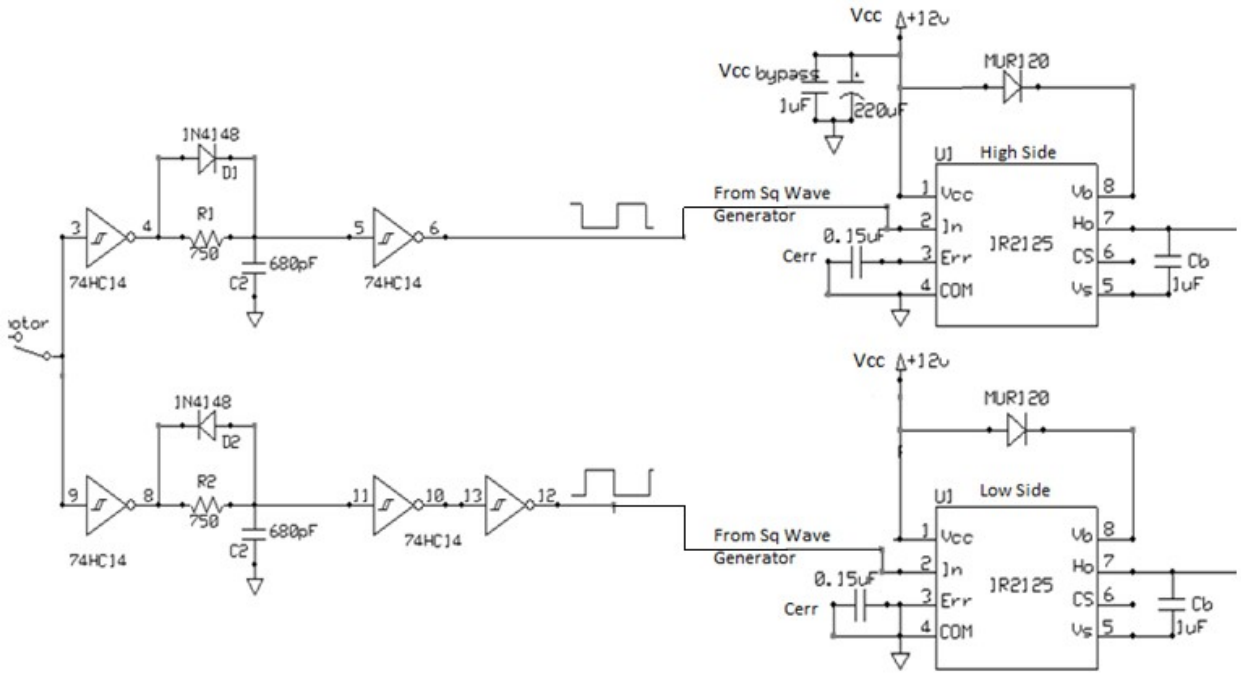

Figure 14. Schematic showing breadboard connected to PCB

3- Secure the DC motor to the PCB using two zip-tie fasteners as shown in Figure 13.

4- Make the following electrical connections between the motor and the PCB:

   1) Terminal 1 (red mark) of motor to A on PCB
   2) Terminal 2 of motor to Vss

5- Connect Vdd to Vcc on your PCB. This final step ensures that the totem circuit, the IR2125 MOSFET drivers, and the LM7805, which regulates the 5 V control circuit rail, can all be powered from a single DC source.

If the circuit is assembled correctly you will be able to vary the speed of the DC motor by rotating the potentiometer controlling duty cycle. Once complete, demonstrate your circuit to a TA.