2. Voltage Regulator

1. Place the TRC-11 PCB on the workbench. This PCB is double-sided with two layers of copper foil laminated on both sides of an insulating material called FR4. FR4 is a composite material composed of woven fiberglass cloth with an epoxy resin binder. If the circuit is low density, single-sided PCBs are preferred for their low cost. The *solder* side is coated with a green-colored *solder-mask* layer to prevent soldering in unwanted locations. Solder can only be done at locations where the solder mask is absent. The exposed copper at those locations is coated with a thin layer of solder to ease the soldering and to prevent corrosion of the copper. The other side of the PCB is the *component* side. This side has an *overlay* (or silkscreen) layer showing the positions and designations (like R1) of the components. TRC-11 PCB is a relatively large board, designed with very comfortable spaces between components to ease the soldering. Actually, the same circuit can be fit on a board half the size easily with less separation between the components. The board can be made even smaller, if the board has components are both sides, and all components are *surface-mount*.

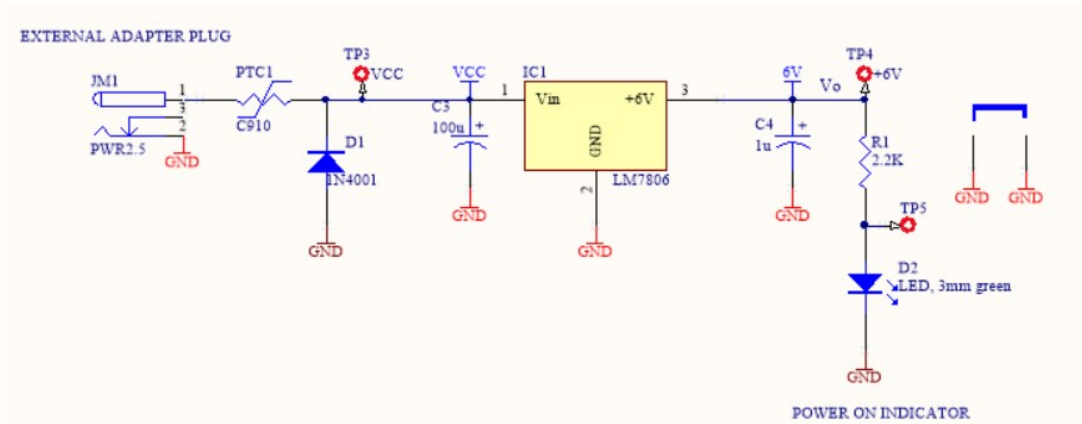

Figure 2: Schematic of the voltage regulator

Designator	Comment	Description
C3	100u	Electrolytic Capacitor, Polarized, 16V
C4	1u	Electrolytic Capacitor, Polarized, 50V
D1	1N4001	Diode
D2	LED, 3mm green	Light-Emitting-Diode
IC1	LM7806	Linear voltage regulator, 6V
JM1	PWR2.5	Low Voltage Power Supply Connector
PTC1	C910	PTC
R1	2.2K	Resistor, carbon film, axial leaded, 1/4W

Figure 3: Bill of materials for the voltage regulator

2. Find the VOLTAGE REGULATOR region on the PCB.

3. Mount and solder JM1, 2.5 mm external adapter jack. Power adapter plug enters into this jack.

4. Mount and solder PTC1. Trim the leads of the PTC at the other side of the PCB using a side cutter.

5. It is a good idea to solder a wire loop in test points (TP) and between GND points as shown in the photos. These will make the connection with an oscilloscope probe easy. Solder loops of wire at the test points, TP3, TP4, and TP5.

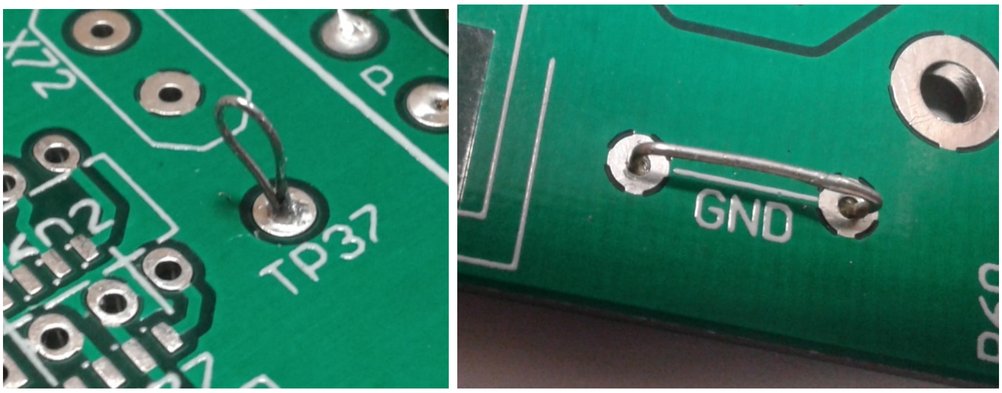

Figure 4: Photos of a test point and a ground wire loop.

6. Solder both ends of a wire between the holes marked GND (near IC1). You can use the clipped leads of the PTC for this purpose. You need this wire to make the ground connection to the oscilloscope probe.
7. Measure the power adapter output DC voltage between TP3 and GND using the oscilloscope. For this purpose, you should set the coupling of the oscilloscope channel to DC. The ripple on the output should be too small to observe.

$V_{TP3}=$ 12.7 V

2.7. GRADE:

8. Set the multimeter in "diode test" mode. Connect the multimeter leads across the 1N4001 diode. In this mode, the multimeter applies a current (about 1 mA) through the diode and measures the voltage across it. When the diode is reverse biased, the multimeter displays "OL".

   This diode is used to protect TRC-11 in case a reverse voltage is applied to the power adapter jack. With a reverse voltage, it conducts and PTC heats up, and goes into a high impedance state to protect the circuit and the diode. Mount and solder D1.

D1: V_F (from measurement in forward direction, red lead on anode) = 0.609V
D1: V_F (from measurement in reverse direction, red lead on cathode) = 0V

2.8. GRADE:

9. The voltage regulator generates +6 V necessary for the operation of TRC-11 using +12 V input voltage. Install IC1 (7806) and bend it so that its metal backside touches the PCB. Align the hole of IC1 with the hole on the PCB. Use the screw and nut through the holes to secure the IC1 in place. The copper region under the regulator acts like a *heat sink*. A heat sink has a large area which allows radiation of dissipated power into the air. Solder its leads. 7806 is a +6V voltage regulator. Its output voltage should remain at a constant +6V even though its input voltage may vary.
10. Electrolytic capacitors are large value capacitors with a polarity. They contain a liquid electrolyte in their case. The negative pin is usually marked with a white bar on the capacitor case. Set the multimeter to Ω position and adjust your multimeter to x.xxx kΩ scale by successively pressing

the RANGE button. Touch the leads of the electrolytic capacitor to each other to discharge the capacitor. Connect the red (positive) lead of the multimeter to the positive terminal of the capacitor and the black (negative) lead of the multimeter to the negative terminal of the capacitor. Observe that the resistance reading changes with time. As the capacitor is fully charged, the resistance becomes infinity. Measure the time to reach infinity. You can use this method to test the integrity of an electrolytic capacitor.

If the electrolyte of the capacitor dries up due to long-time exposure to high temperature, the capacitor loses its value, and it should be replaced.* Repeat the resistance measurement procedure for the smaller electrolytic capacitor. To test the 1μF capacitor, set your multimeter to x.xxx MΩ position. Measure the time to reach infinity. If your multimeter has a capacitance scale, use that mode to measure the capacitance value.

Install C3 (watch the polarity) and C4 (watch the polarity) on the PCB and solder them. Both capacitors are needed for a proper operation of the voltage regulator. Connect the power adapter. Measure and record the output voltage, V_o, at TP4, with one decimal unit accuracy.

C3: Time to reach ∞ = 2.6s
C4: Time to reach ∞ = 2.43s
C4 (measured value, if your multimeter has capacitance scale) =

2.10. GRADE:

TP6: V_o= 6.19V

2.10. GRADE:

11. Read the color code of R1. Referring to the color-code table on page 36 determine the nominal resistance value. Measure the resistance value using the multimeter. Record the values. Mount and solder the resistance R1.

R1: Colors: Red, Red , Gold

R1: R(nominal)= 2.2 k ohm

R1: R(measured)= 2.181 K ohm

2.11. GRADE:

TP6: V_{DC}= 6.0V

2.11. GRADE:

12. We would like to investigate the electrical difference between a green and a red LED. Inspect the red light-emitting-diode (LED), D70. Install the diode D70 in place of D2. Its longer lead is its positive terminal. Do not solder it. Measure the voltage between TP5 and GND using DC-V scale of the multimeter. Remove the red LED after measurement.

*Dried up electrolytic capacitors are a common reason of the failure of many analog circuits.

13. Inspect the 3mm green light-emitting-diode (LED), D2. Its longer lead is its positive terminal. From the datasheet of the LED on page 399, find the range of forward voltage (V_F). Solder the diode D2 in its place.

14. Measure the voltage between TP5 and GND. Is it different than the red LED? Different colored LED's have different voltage drops. Calculate the current flowing through it using Eq. 2.75 on page 73.

D70(red LED): V_F(measured)= 1.881V

D2(green LED): V_F(range)= 1.8-2.2V (Data from page 399 the datasheet of D2)

D2(green LED): V_F(measured)= 1.874V

D2(green LED): I_D(calculated)= 33.363 mA

2.14. GRADE:

15. Connect the multimeter between TP4 and GND as an ammeter (not voltmeter) at the highest scale (should be larger than 2 A) to find the short-circuit current, I_{short}, value. Record the current after it reached the steady state.

TP4 to GND: I_{short}= 0.522A

2.15. GRADE:

16. Remove the ammeter leads and connect the multimeter between TP4 and GND as a voltmeter. Record the supply voltage.

TP5: V_o= 6.01V

2.16. GRADE:

CHECK POINT: