Build a Fast Circuit Breaker

If you operate a large layout, you probably know how frustrating isolating a short circuit can be. Of course there are many solutions for pinpointing a short, but not all of them offer the kind of protection that delicate electronic equipment may require. This is particularly important if you operate using DCC. All DCC power supplies offer circuit protection, but if you have a system that has sufficient power to operate multiple trains simultaneously, the built-in protection may not be sufficient for smaller localized shorts. I found out the hard way when a locomotive entered a reverse-polarized turnout frog, which heated and warped the gearbox before the system detected the short.

One solution is to divide your layout into separate power blocks, with a circuit protector for each section. There are many excellent protection devices on the market, but they can be pricey, so there is a trade-off between cost and the number of power sections you can protect. I have built, installed and tested 10 units described here on the division's modular layout

This clinic provides instructions for building effective, low-cost breakers that are easily constructed. The design was originally published by David G. Steer in the August 1967 issue of Model Railroader. He adapted a design originally intended for Hi-fi audio applications, which means that it is well-suited for DCC applications which operate in the same frequency ranges. (Of course DCC did not exist at the time of publication, but the author tested it with a pioneering Astrac system.) I have tested this design in series with a commercial protection circuit (TTX Power Shield) and found that it trips faster than the commercial unit. This means that you can use it to protect sub-districts, such as a yard, without affecting the entire layout.

This clinic describes two construction methods:

- Using perforated circuit boards or other substrates
- Making and using printed circuit boards

The first method is preferable if you want to make only a few. The second method is advantageous if you want to make many.

Figure 1 shows a layout for a printed circuit board, but the same layout applies to using perforated breadboards. Appendix B provides a layout etching mask.

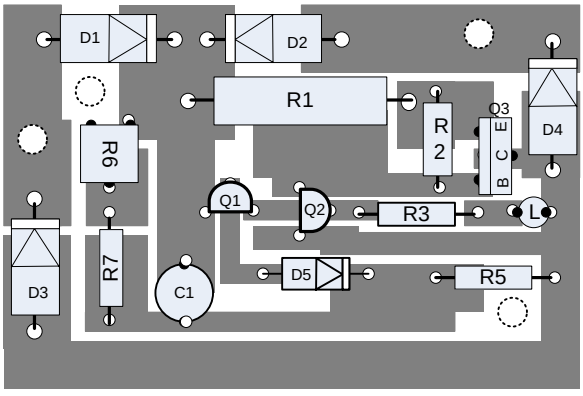

Figure 1: Circuit Diagram (Actual Size)

The electrical components include:

- D1 – D4: 1N5400 diodes rated at 3a
- D5: 1N4001 diode, rated at 1a
- R1: 0.5 ohm 5 watt resistor
- R2, R7: 100 ohm, ½ watt resistor
- R3: 150 ohm, 5 (½) watt resistor (The original design called for a 5 watt resistor, but using an LED [component L] in place of an incandescent lamp reduces power consumption to a safe level)
- R5: 3300 ohm, ½ watt resistor
- R6: 2000 ohm potentiometer
- Q2, Q3: PN2907 Transistor (TO-92)
- Q1: TIP42C Transistor (rated 6a) (TO-220)
- Heat sink for TIP42C (the transistor can become quite hot when a short occurs)
- C1: 0.008 mfd capacitor (or 0.01 mfd)
- L: T-1 ¾ LED (any color) – optional

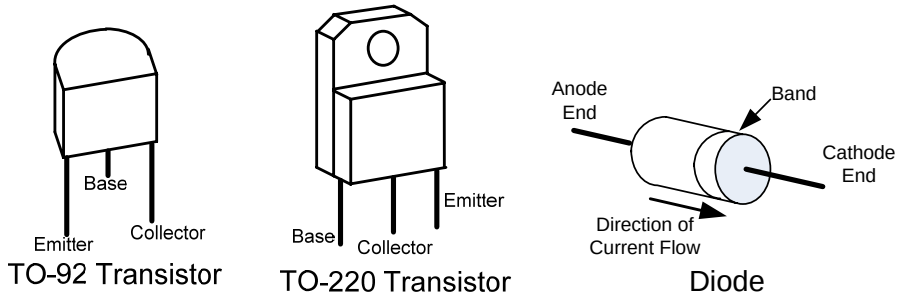

Figure 2: Electrical Component Configurations

Soldering techniques

Use a good quality pencil iron and rosin core solder that is designated for electrical work. Avoid acid core solders: the acid will remain active and will eventually eat away the smaller wires. The rosin flux in the solder core will "wet" the component, transfer heat and enable the solder to flow freely. When soldering, be careful to avoid cold solder joints. Ensure your iron is hot enough to heat the component you are soldering. A good joint will flow smoothly along the wire and copper terminal. It will not look like a volcano crater. The instruction sequence will install the larger components that require more heat first.

Non-printed circuit board method

You may use a perforated circuit board cut to size or a piece of 1/8" hardboard (Masonite) cut to size. Masonite is more economical, but you must drill holes for the components. When installing components, bend the leads so that they will intersect the leads of the components they must attach to. Ensure that they do not accidently touch

other leads. In a few places you will probably have to install jumpers, as between R7, C1, D5 and R5. You will also need to provide for external connections. I recommend small brass or copper tabs soldered to either D1 or D3 and D2 and D4. For a perf-board you will probably need to enlarge the holes for D1 through D4 which have heavier leads. If you use a Masonite circuit board, be aware that the terminal leads of the potentiometer, R6, may not extend completely through the board and you will have to solder extensions to the terminals.

Figures 3 and 4 show what the unit might look like when assembled using a stock perfboard. In Figure 3, two 1 ohm resistors (purchased from Radio Shack) wired in parallel provide the required 0.5 ohm resistor (which Radio Shack does not stock.) Figure 4 shows the back side. The wires extending from either side provide the external connections to your track and power supply.

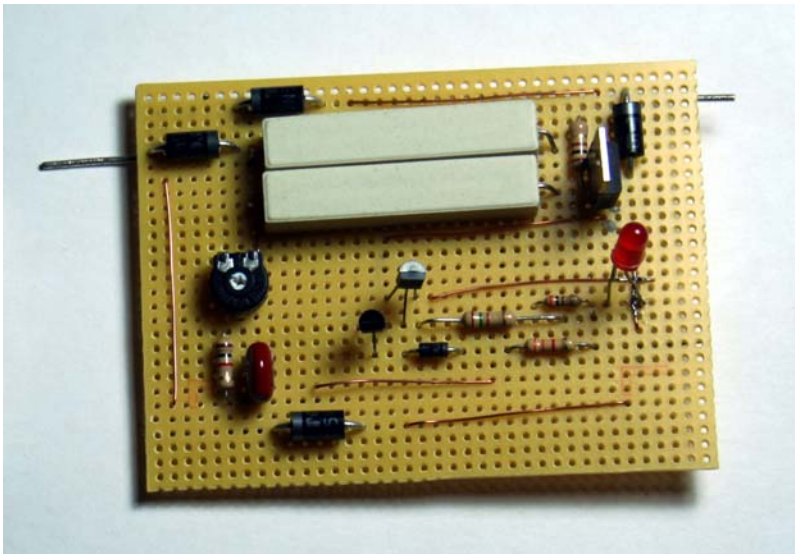

Figure 3: Perfboard Assembly Top Side

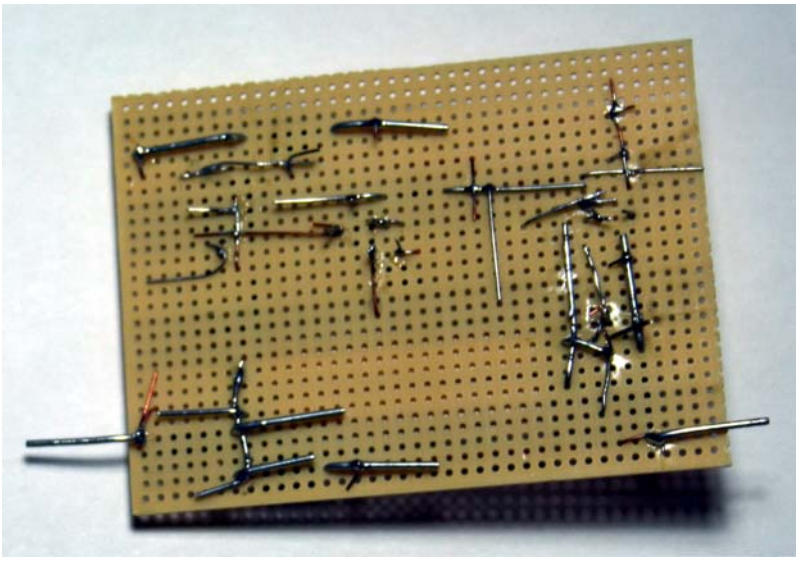

Figure 4: Perfboard Assembly Back Side

Assembly Instructions

When adding diodes, resistors, and capacitors do not trim any of the leads until you have completed and tested the entire assembly. You may need the extra length to connect to another component that you forgot. I recommend making all solder connections underneath the circuit board.

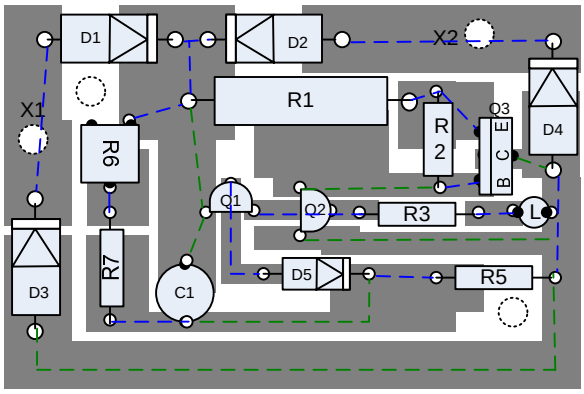

Figure 5: Perfboard Underboard Component Connections
Blue: connections are made using component leads
Green: connections are made using jumper wires

1. Insert diodes D1 and D2 and solder the cathode leads together. Observe the polarity orientation, shown in Figure 5. Diodes usually have a silver band at one end that indicates the direction the arrow points. Bend one lead in the direction of the R1 connection.

2. Insert diode D3 and solder the cathode lead of D3 to the anode lead of D1. If you are providing an external attachment tab, X1, solder the tab to this connection.

3. Insert diode D4 and solder the cathode lead of D4 to the anode lead of D2. If you are providing an external attachment tab, X2, solder the tab to this connection. Bend the anode lead in the direction of L1 and R5. You will need to provide a jumper wire to solder the anode lead of D4 to the anode lead of D1. Refer to Figure 5 for approximate jumper connections.

4. Insert Resistors R1 and R2. Resistors are not polarized so their orientation is not critical. Solder one lead of R1 to the D1 and D2 cathode connection.

5. Insert transistor Q1 observing its orientation (Refer to Figure 5). Solder the emitter terminal to the junction of R1 and R2. Solder the collector terminal to the anode lead of D4. Solder the base terminal to the opposite lead of R2.

6. Insert potentiometer R6. Note that it has three terminals and one terminal has no connection. Solder one terminal to the extension of the R1 lead. (This should also connect to the cathode connection between D1 and D2.)

7. Insert resistor R7 and solder one lead to the "center" terminal of R6.

8. Insert transistor Q3, a TO-92 PN2907, again observing its orientation. (Refer to Figure 5). Solder the emitter terminal, E, to the junction of D1 and D2 cathodes and R1. The other terminals will be connected later.

9. Insert transistor Q2, a TO-92 PN2907, again observing its orientation. (Refer to Figure 5). Solder the emitter terminal, E, to the junction between R2 and the base of Q1. You may need to provide a jumper wire here. The other terminals will be connected later.

10. Insert resistor R3 bend and solder one lead to the base of Q2 and to the collector, C, of Q3. The lead should be long enough to reach both transistors.

11. Insert diode D5, observing its orientation. Bend and solder the anode lead to the base terminal, B, of Q3. Q3 should now have all three terminals connected.

12. Insert Resistor R5 and bend and solder one lead to the cathode lead of D5. Bend and solder the other lead to the anode lead of D4.

13. Insert Capacitor C1 (it does not have polarity). Bend and solder one lead to the emitter, E. of Q3 and the junction of the cathodes of D1 and D2, R1 and one terminal of R6. Bend and solder the other lead to the unconnected lead of R7.

14. Solder a jumper between the junction of C1 and R7 and the junction of the D5 cathode and R5.

15. Insert the LED L1. Solder the anode lead to the free lead of R3 and the cathode lead to the anode lead of D4. LEDs typically have a flat area in the flange at the bottom of the case next to the cathode. Alternatively you may connect the LED remotely with wire leads so that it may be displayed on a control panel, a fascia board or the roadbed where it will be more visible. You may also mount one LED on the circuit board and a second LED for remote viewing.

16. Your circuit is now complete. Visually check it for good solder joints and prepare it for testing, described below. Do not trim any leads until you have successfully tested the unit in case you need to relocate any connections, but ensure that no leads are accidently touching where unintended

17. Following a successful test, trim any excess length from the leads and install the heat sink. You are now ready to install the unit on your layout

Printed circuit board method

If you want to use a printed circuit board, transfer the mask shown in Appendix B to a printed circuit template, then to a copper clad board following the manufacturer's instructions. The mask master must be a mirror image of what you want on the board. After etching the board, drill the component mounting holes. I have made the connecting copper conductors as wide as possible to reduce the amount of copper that must be etched and to reduce resistance to maximize current flow. Figure 6 shows the circuit board layout and Figure 7 shows a completed circuit board assembly with a heat sink attached to the TIP42C transistor.

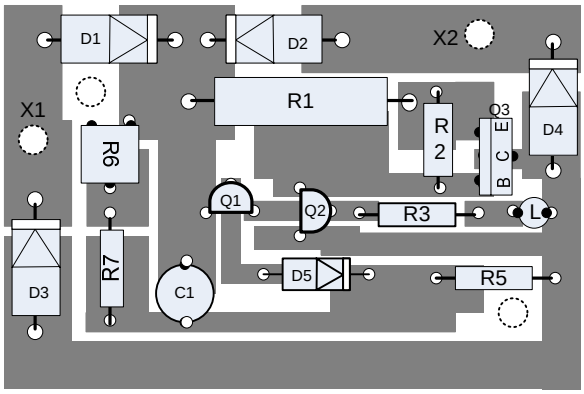

Figure 6: Printed Circuit Board Component Locations

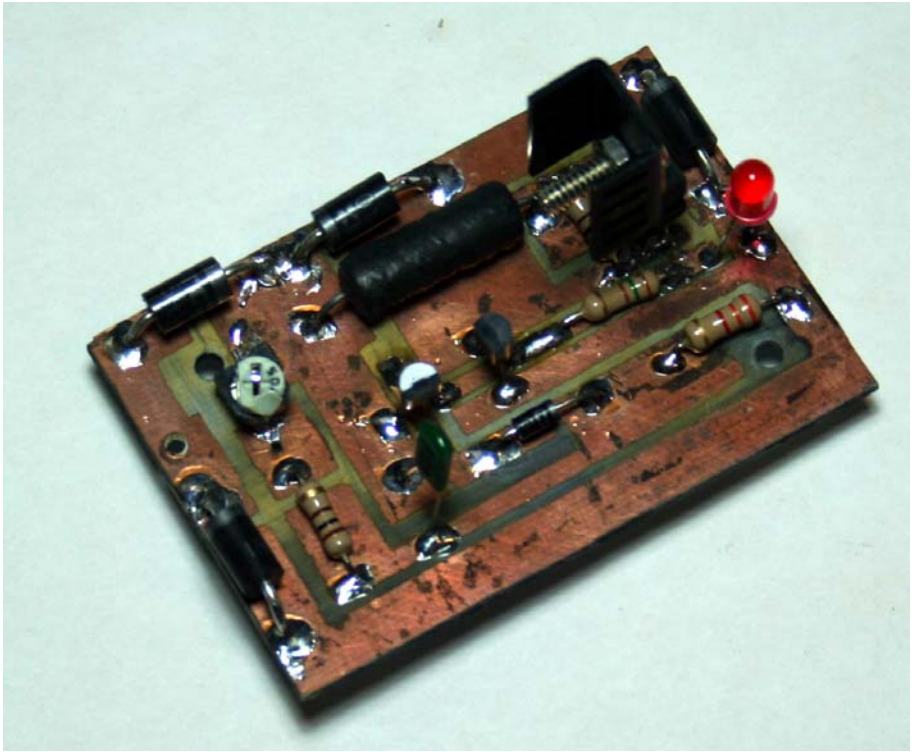

Figure 7: Printed Circuit Assembly

Board Preparation

Decide whether you want to solder components from the top or bottom. I prefer to solder from the top, but your raw mask must be a mirror image so that it transfers correctly to the board. If you solder from the bottom, transfer the original image to the board, where it will appear as a mirror image. After etching and cleaning, drill the mounting holes. A #60 drill will work for most components, but the holes for D1-D4 may require a #55 drill to accommodate the thicker leads. I prefer to drill the holes between D2 and D4 and D1 and D3 with a #43 drill, then tap for a 4-40 machine screw to provide connections to the track and power supply. The other holes next to R5 and R6 are for screws for mounting the circuit board and do not touch any copper material. Etching a printed circuit board seems like a lot of extra work, but it greatly simplifies final assembly and helps to avoid errors.

Assembly Instructions

1. Begin by inserting D1 through D4, observing the correct polarity, and soldering the leads to the circuit board. Diodes usually have a silver band at one end that indicates the direction the arrow points. Refer to Figure 2.

2. Insert Resistors R1 and R2 and solder to circuit board. Resistors are not polarized so their orientation is not critical.

3. Insert potentiometer R6 and solder to circuit board. Note that one terminal has no connection.

4. Insert resistor R7 and solder to the circuit board.

5. Insert transistor Q1 and solder to the circuit board. It is important to observe the orientation. The emitter E, base B and collector C are usually not identified so refer to Figure 2). If you have a transistor tester (often integrated with a digital multi-meter) use it to verify the position of the terminals.

6. Insert transistor Q2 and solder to the circuit board observing the correct orientation as shown in Figure 1.

7. Insert transistor Q3 and solder to the circuit board observing the correct orientation.

8. Insert resistor R3 and solder to the circuit board.

9. Insert diode D5, observing polarity, and solder to the circuit board.

10. Insert resistor R5 and solder to the circuit board.

11. Insert resistor R7 and solder to the circuit board.

12. Insert capacitor C1 and solder to the circuit board. This capacitor is not polarized so it may be oriented in either direction.

13. Insert the LED L1 and solder to the circuit board. LEDs typically have a flat area in the flange at the bottom of the case next to the cathode. Alternatively you may connect the LED remotely with wire leads so that it may be displayed on a control panel, a fascia board or the roadbed where it will be more visible. You may also mount one LED on the circuit board and a second LED for remote viewing.

14. Your circuit is now complete. Visually check it for good solder joints and prepare it for testing. Do not trim any leads until you have successfully tested the unit in case you need to relocate any connections, but ensure that no leads are accidently touching.

15. Following a successful test, trim any excess length from the leads and install the heat sink. You are now ready to install the unit on your layout

Configuring and Testing the Unit

To test your completed assembly you will need a power supply. There are several possibilities.

- Your layout power supply
- An older power pack with either AC or DC outputs or both.
- Any available 12 v. AC output transformer.

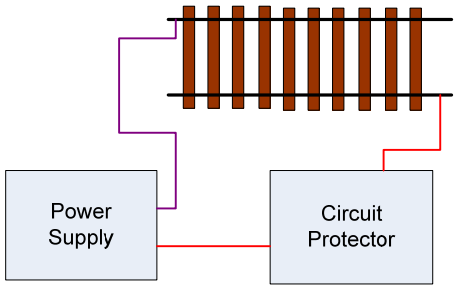

Figure 8: Circuit Protector Connection

Figure 7 shows how you connect your Circuit protector to a track block, but you do not need track for testing. Simply connect one lead of your power supply to one terminal of the Circuit protector. Connect the other terminal of the Circuit Protector to a load of some kind: a locomotive, motor, a lamp or something that will not trip the protection mechanism of your power supply. With the power on, the LED may or may not illuminate. If it lights up, adjust the potentiometer R6 until it just extinguishes. Now create a short circuit between the input and output of the Circuit Protector. The LED should now illuminate and power to the track will be interrupted. You may need to make a final adjustment to R6.

Appendix A: Parts List

All parts can be obtained from All Electronics (mail order). Prices are for single quantities. Lower prices are available for larger quantities.

All Electronics
14928 Oxnard St.
Van Nuys, CA 91411
800-826-5432 (phone for mail orders)

Component	Specification	Catalog #	Quantity	Cost Ea.
Transistor	TIP42C	TIP42C	1	.45
Transistor	PN2907	PN2907	2	.15
Diode	1N5400	1N5400	4	.20
Diode	1N4001	1N4001	1	.07
Resistor	.5 ohm 5w	.5 ohm 5w	1	.33
Resistor	100 ohm .5w	100 ohm .5w	2	.05
Resistor	150 ohm .5w	150 ohm .5w	1	.05
Resistor	3.3K ohm .5w	3.3K ohm .5w	1	.05
Potentiometer	5K ohm	TPS-5K	1	.25
Capacitor	.001 μfd	RMC-102	1	.10
LED	T-1 3/4 Red	LED-1	1 (or 2)	.10
Heat Sink		HS-325	1	.25

I have not included the cost of the board since you have many options. All Electronics offers copper-clad boards for making printed circuit boards for $8.00 for a 6 x 12 inch board. This would be sufficient to make 12 individual printed circuit boards.

Appendix B: Printed Circuit Board Masks

Figure B1 shows two printed circuit masks. Use the mask on the left to for creating circuit boards that will be soldered from the back. Otherwise use the mirror image mask on the right if you intend to solder components from the top. You may copy either image from a Word file and past it multiple times onto a new Word file to create an image that will fit onto an 8 ½ x 11 transfer sheet. Take the Word file print it onto the Press-N-Peel transfer sheet using a laser printer. If you don't have a laser printer, take it to a local copy center.

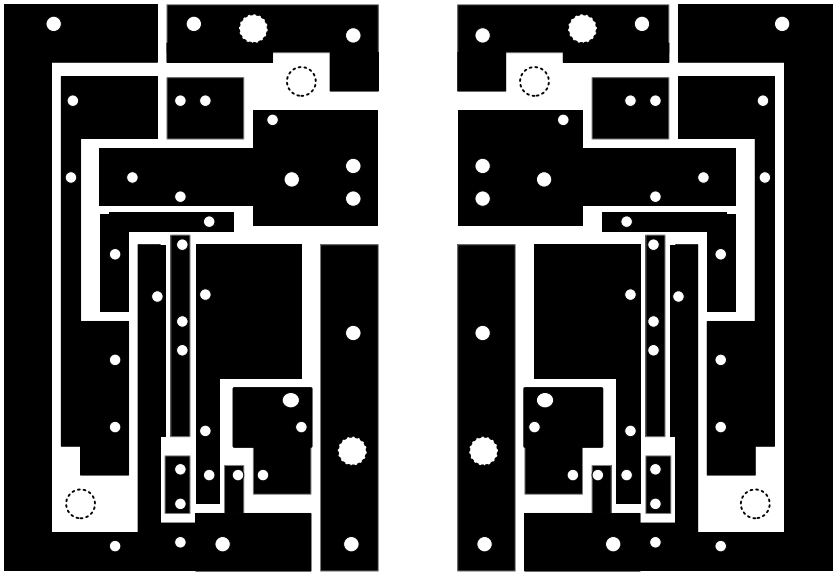

Figure B1: Printed Circuit masks for Techniks Press-N-Peel Transfers

Transfer the image to a copper-clad board using a hot iron (refer to the manufacturer's instructions. Hint: I have found that transferring small images 3 x 4 inches or smaller works better that trying to transfer one large image. If the image doesn't iron on completely, fill-in the missing areas with an indelible black marker before etching. (I found out the hard way that water-based markers don't work.) Any kind of plastic tape will work also.

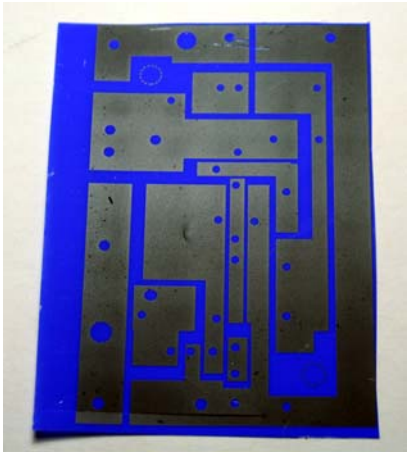

Figure B2: Printed Circuit Mask Using Techniks Press-N-Peel Material