Radio Procab Battery Charger

Updated 3/7/08 (added PowerCab and Cab04 implementations)
By Mark Schutzer

Overview: This document describes the modifications that I did to my radio Procabs to install an internal battery charger. The charger allows NIMH batteries to be recharged anytime the Procab is plugged into the cab bus.

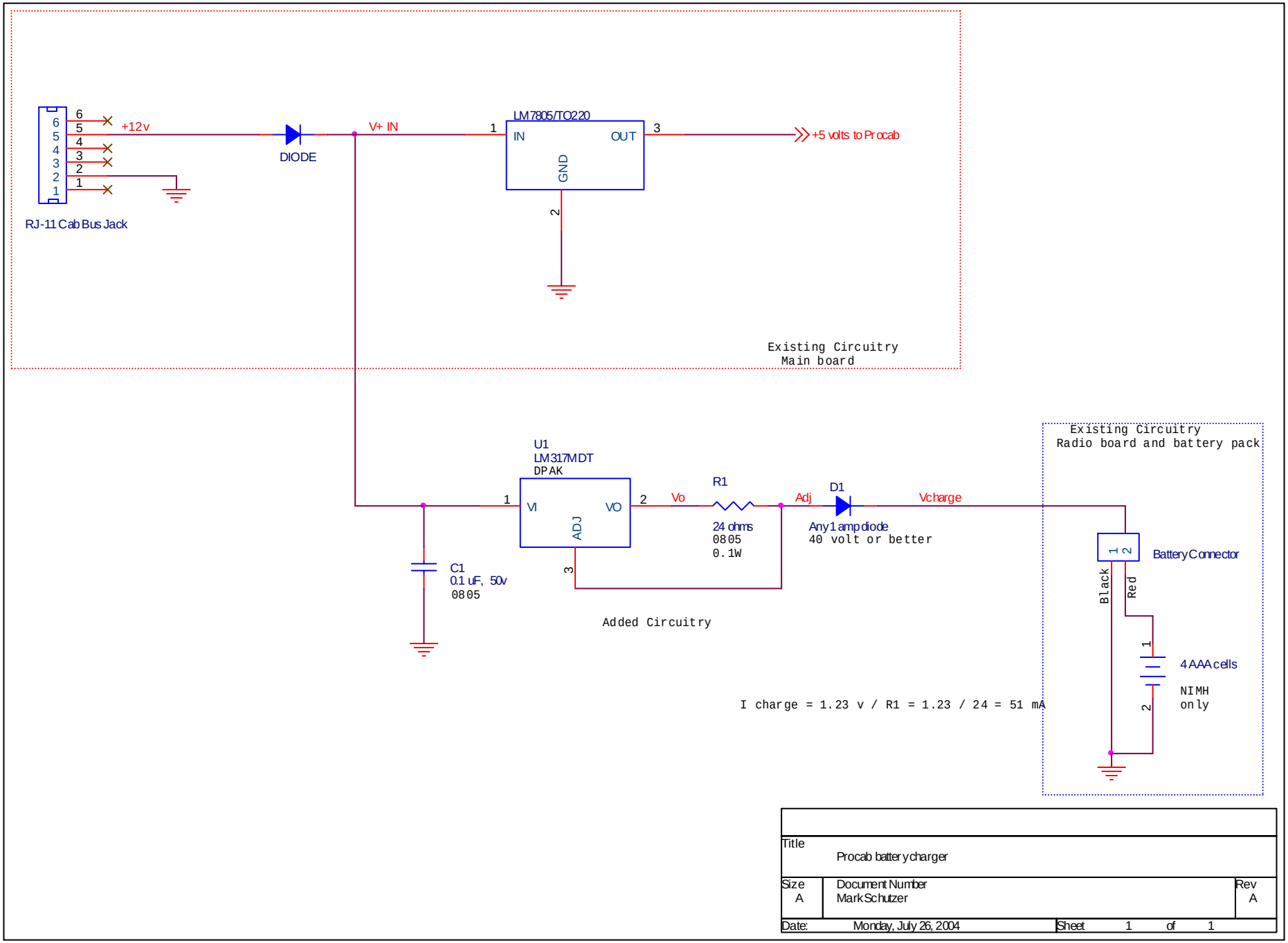
Warning: While this is a simple circuit it involves soldering small surface mount components to the internal printed circuit board and the modifications should be only attempted by those with sufficient electrical assembly skills. Also note that this is not endorsed by NCE and may impact the warranty of the unit. **Remove the batteries before opening the case of the Procab!**

Circuit Description: Please refer to the schematic diagram on the next page when reading the following description. The battery charger circuit is a constant current source built from a LM317M regulator IC. As shown on the next page the charger consists of four components, one capacitor, one LM317M regulator, one resistor, and one diode. The LM317M acts a constant current source because it always tries to maintain a constant voltage of 1.23 volts between the pins of VO (voltage out) and ADJ (adjust). By placing a resistor between these pins a constant current source equal to 1.23 v / (value of R1) is created. In this case a resistor of 24 ohms was chosen resulting in a current source of 1.23 v / 24Ω = 51 mA.

Standard NIMH rechargeable AAA cells have a capacity that ranges from 750 mA hours to 850 mA hours depending on the battery brand. While NIMH batteries can be charged in under two hours this requires a complex charger that automatically turns off at full charge. The objective here was a very simple charger that could be more or less left on indefinitely without the damaging the batteries. Battery chargers are typically rated based on that capacity of the batteries they are charging, if the battery is a 750 mA hour battery and the charger can charge at 750 mA then the charger would be rated at one C, where C equals the ratio of the charge rate compared to the capacity of the battery. If the charger charged at 375 mA and the battery capacity was 750 mA hours then the charge rate would be 375 / 750 = ½ C.

Trickle chargers are typically defined by a charge rate of 0.1C or less. While NICAD batteries can be charged almost indefinitely at 0.1C without damage NIMH batteries are somewhat more sensitive from the documentation I can find. For this charger I chose a charge rate of 0.07C (51 mA / 750 mA hours) for a couple of reasons. First I wanted to stay less than 0.1C to minimize the potential for battery damage due to long term over charging, and second I wanted to limit the amount of extra current pulled from the cab bus. Approximately 50 mA of charge current seemed to be a good compromise.

When charging a battery requires more energy than its capacity to be restored to a full charge. The amount of charge energy needed is typically 160% of the battery capacity. That is why the typical 0.1C (1/10 C) charger takes 16 hours to recharge instead of 10 hours. So for this trickle charger with a rate of 0.07C the time to fully charge the batteries will be 160% / 0.07 C = 23 hours. Basically a nice round 24 hours to recharge…


6
5
4
3
2
1
+12v
RJ-11 Cab Bus Jack
DIODE
V+ IN
LM7805/TO220
IN
OUT
GND
+5 volts to Procab
Existing Circuitry
Main board
U1
LM317MDT
DPAK
VI
VO
ADJ
Vo
R1
24 ohms
0805
0.1W
Adj
D1
Any 1 amp diode
40 volt or better
Vcharge
C1
0.1 uF, 50v
0805
Added Circuitry
Existing Circuitry
Radio board and battery pack
Battery Connector
Black
Red
4 AAA cells
NIMH
only
I charge = 1.23 v / R1 = 1.23 / 24 = 51 mA
Title
Procab battery charger
Size
A
Document Number
Mark Schutzer
Rev
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Monday, July 26, 2004
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To complete the circuit description I should mention the two supporting components for the regulator. A diode has been placed in series with the charger output to prevent the battery current from flowing back into the regulator when the Procab is disconnected from the cab bus. A 0.1 uF capacitor has been placed from the regulator input to ground to filter noise and to provide stability for the regulator input. (This 0.1uF capacitor can be considered optional)

Construction: When I opened my Procabs I found that there were numerous traces and pads on the pc board that were not used for anything. I took advantage of these unused traces to build the charger right on the main board. To implement the charger required two minor trace cuts and one wire jumper (or zero ohm resistor).

I should also point out that there are probably lots of different board versions and each one may be different, my two Procabs are board revision A and board revision D and there are some minor differences between them. You should use **caution** if your board revision is different as the traces and pads may be different than shown here.

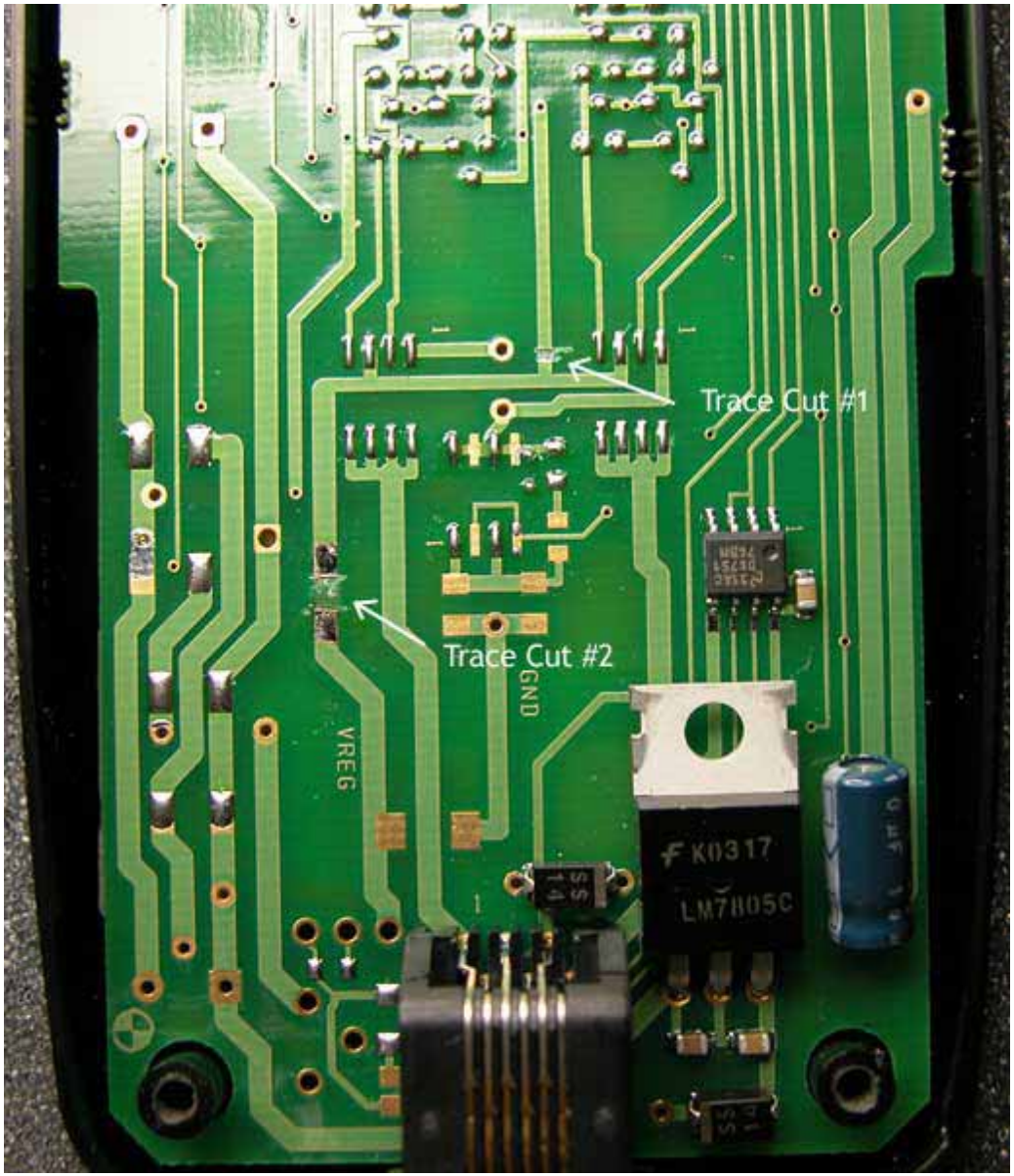
Parts List:

Qty	Part Number	Description	Digikey #	Cost
1	LM317MDT	Adjustable Regulator (Natl. Semi.)	LM317MDT-ND	$1.13 ea
1	0.1 uF, 50 volt, X7R	0805 surface mount capacitor	478-1395-1-ND *	$2.75 for 10 (Avx)
1	24Ω, 5%, .1 watt	0805 surface mount resistor	P 24 ACT-ND *	$0.77 for 10 (Panasonic)
1	1 amp, 40 volt	SMA package, surface mount diode	MBRA140CT-ND *	$0.31 ea (IR)

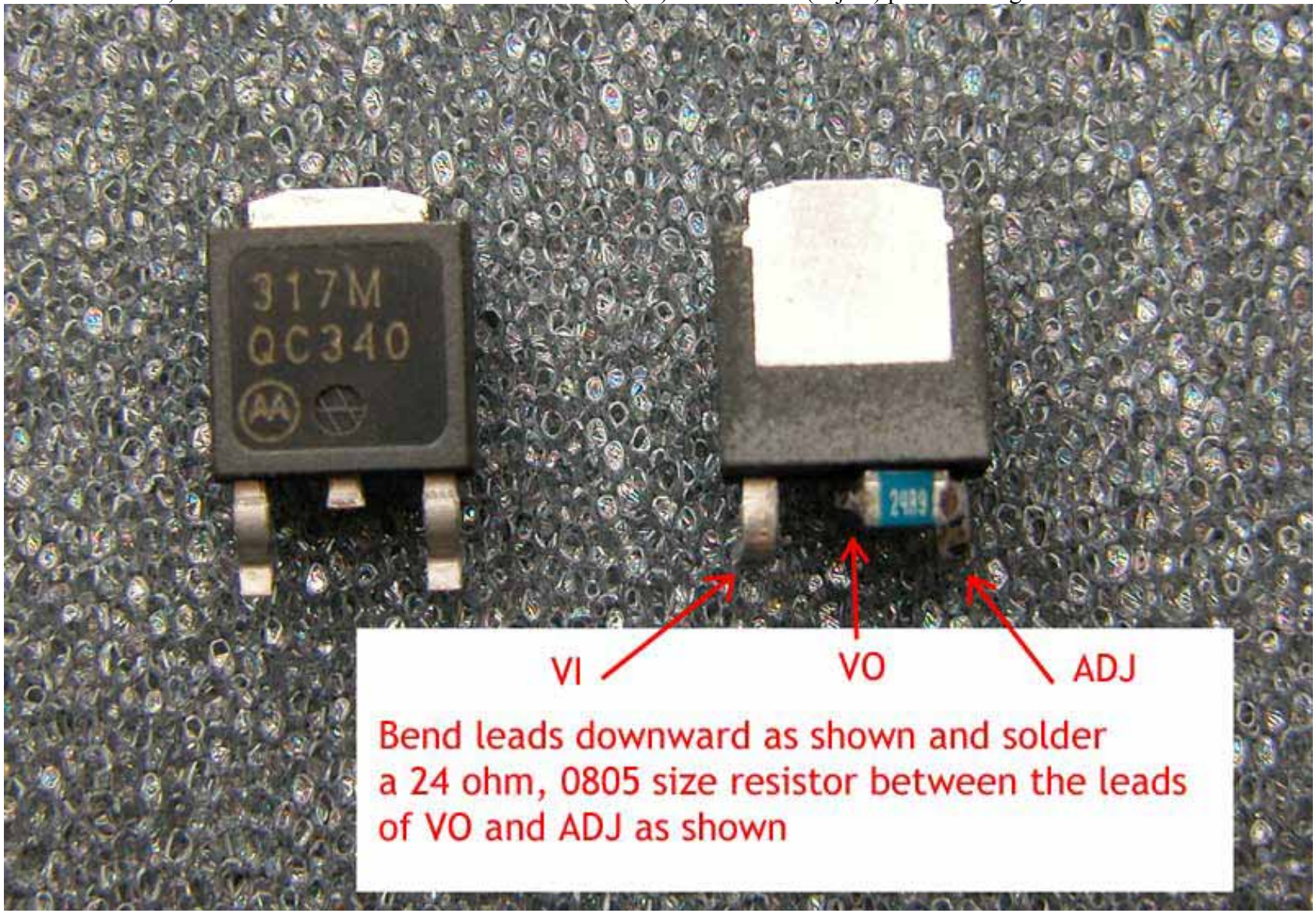
Other notes: A good source for the surface mount diodes can be the stock lighting boards that come out of locos when you install your DCC decoders. Athearn Genesis units each contain 6 surface mount diodes that will work just fine. That's where I got the diodes that I used in my two Procabs. All of the other parts can be purchased online from DigiKey electronics at http://www.digikey.com

* Digikey carries these parts from many different suppliers, only one part number is shown as an example.

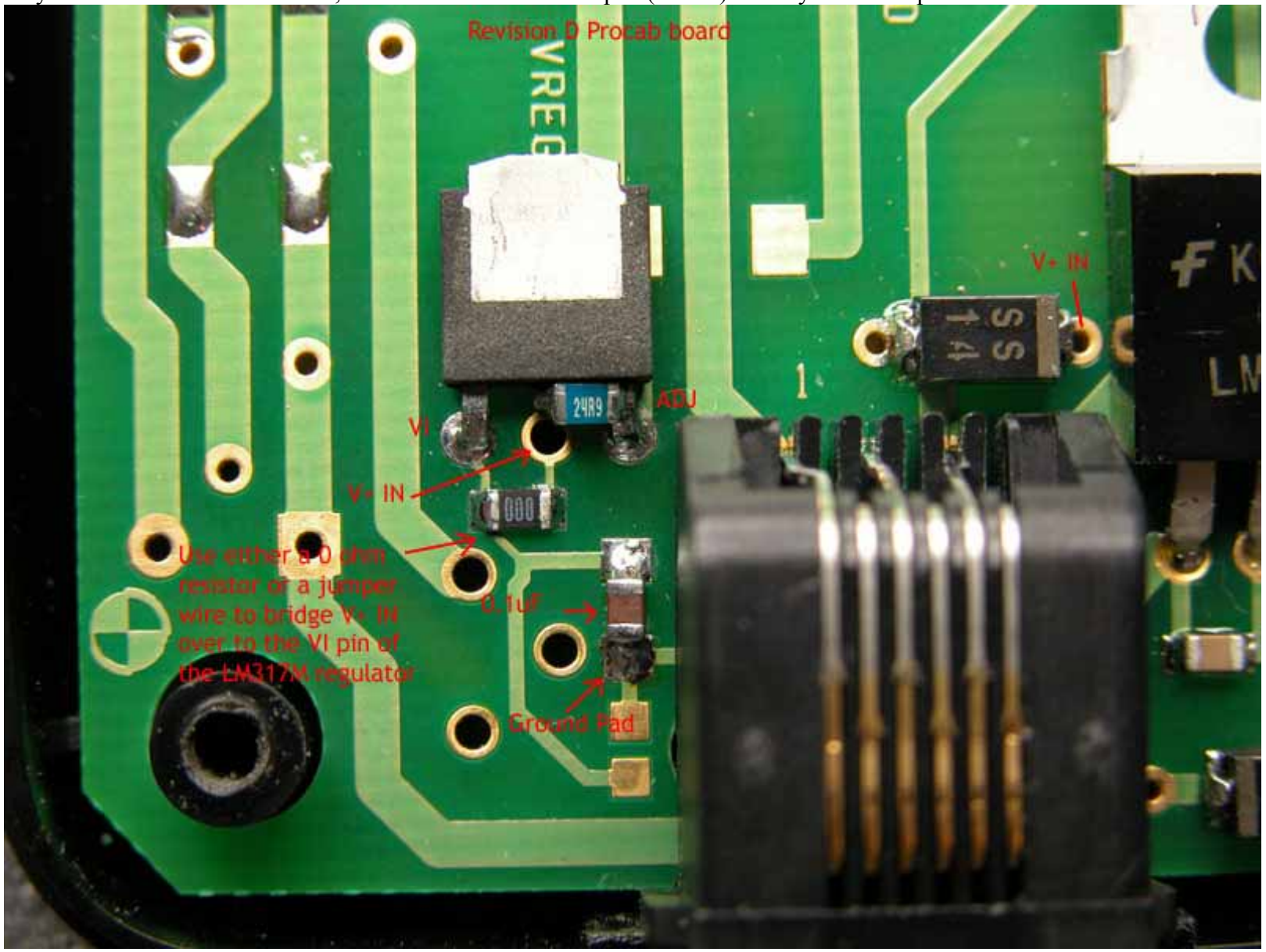
Step 1: The following photos show the modifications on a revision D printed circuit board. Cut the traces in the two locations as shown in the following photograph. Using a Xacto knife carefully trim the traces as shown, and scrape off the green soldermask around the area shown as trace cut #2. Tin the pads with solder as the diode will be soldered across trace cut #2.



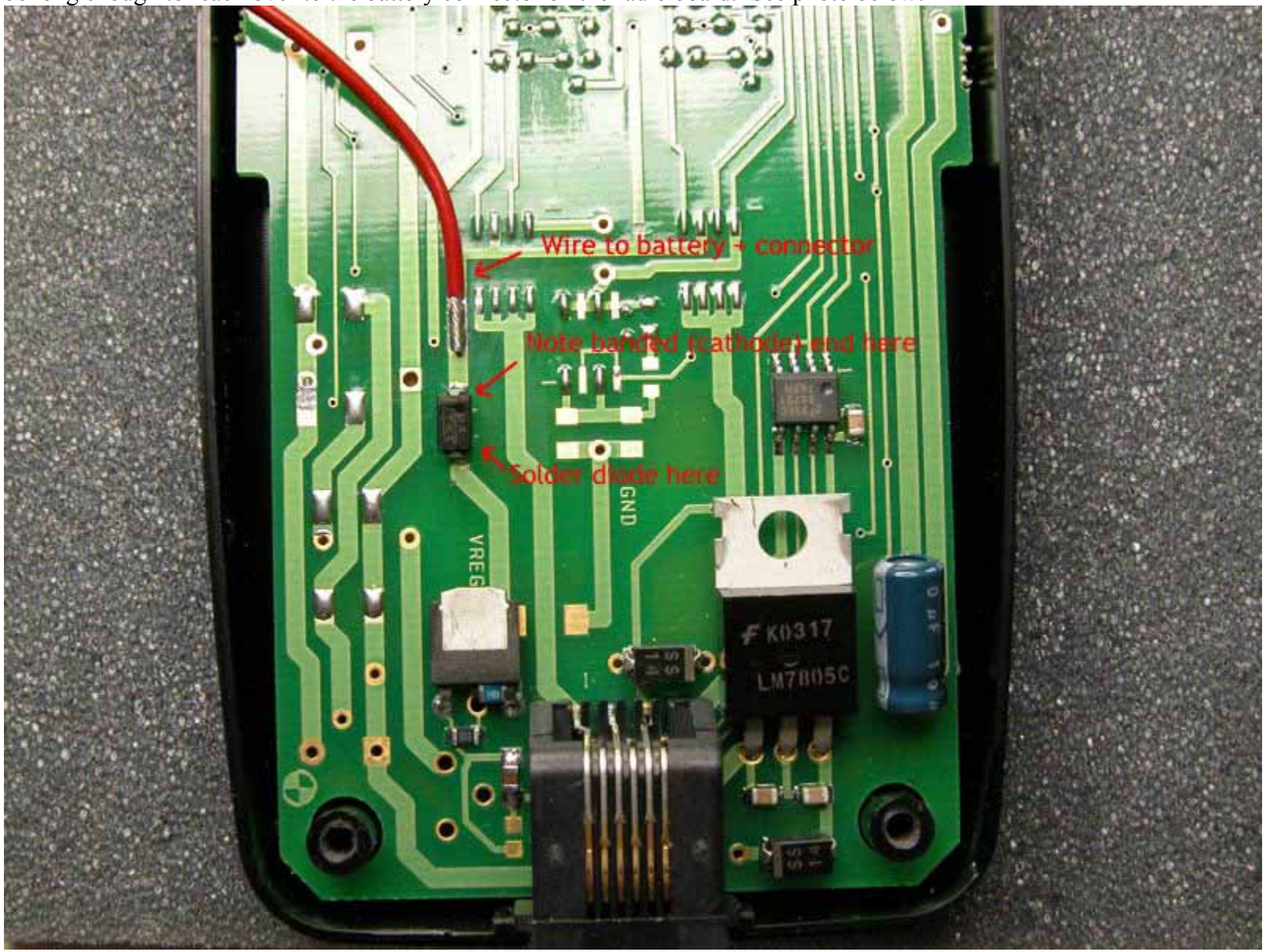
Step 2: Prepare the regulator. For this design a surface mount "DPAK" style LM317M regulator is used. Referring to the photo below turn the part over so that back side is facing up, then using a pair of needle nose pliers bend the two leads down as shown. Solder a 24 ohm, 0805 resistor between the short middle lead (Vo) and the ADJ (adjust) pin on the right side.



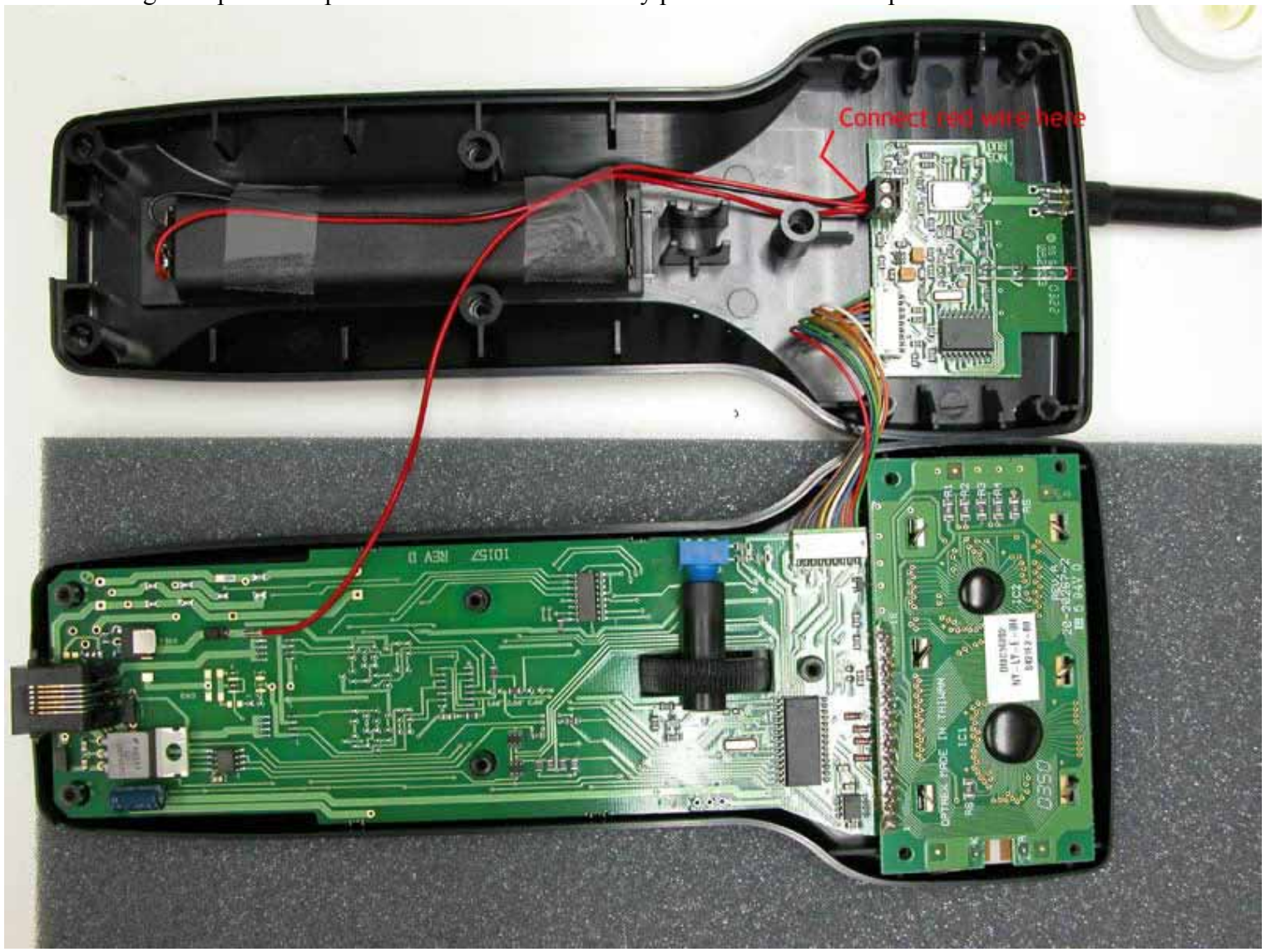
Step 3: Solder the regulator, capacitor, and jumper onto the board. See the photo below for the location of the various components. In the photo a zero ohm resistor is used to jumper the V+ IN pad (under the middle of the regulator) over to VI of the regulator. A small piece of wire could be used just as easily if a zero ohm jumper is not available. Note also that the short middle lead of the regulator only connects to the 24Ω resistor, it does not connect to the pad (V+ IN) directly under the pin!



Step 4: Solder the diode across trace cut #2 as shown. Note that the banded end (cathode) should be facing the top of the Procab board as shown. Also scrape off the green soldermask just above the diode and solder a wire (red preferably) to this trace. This wire should be long enough to reach over to the battery connector on the radio board. See photo below:

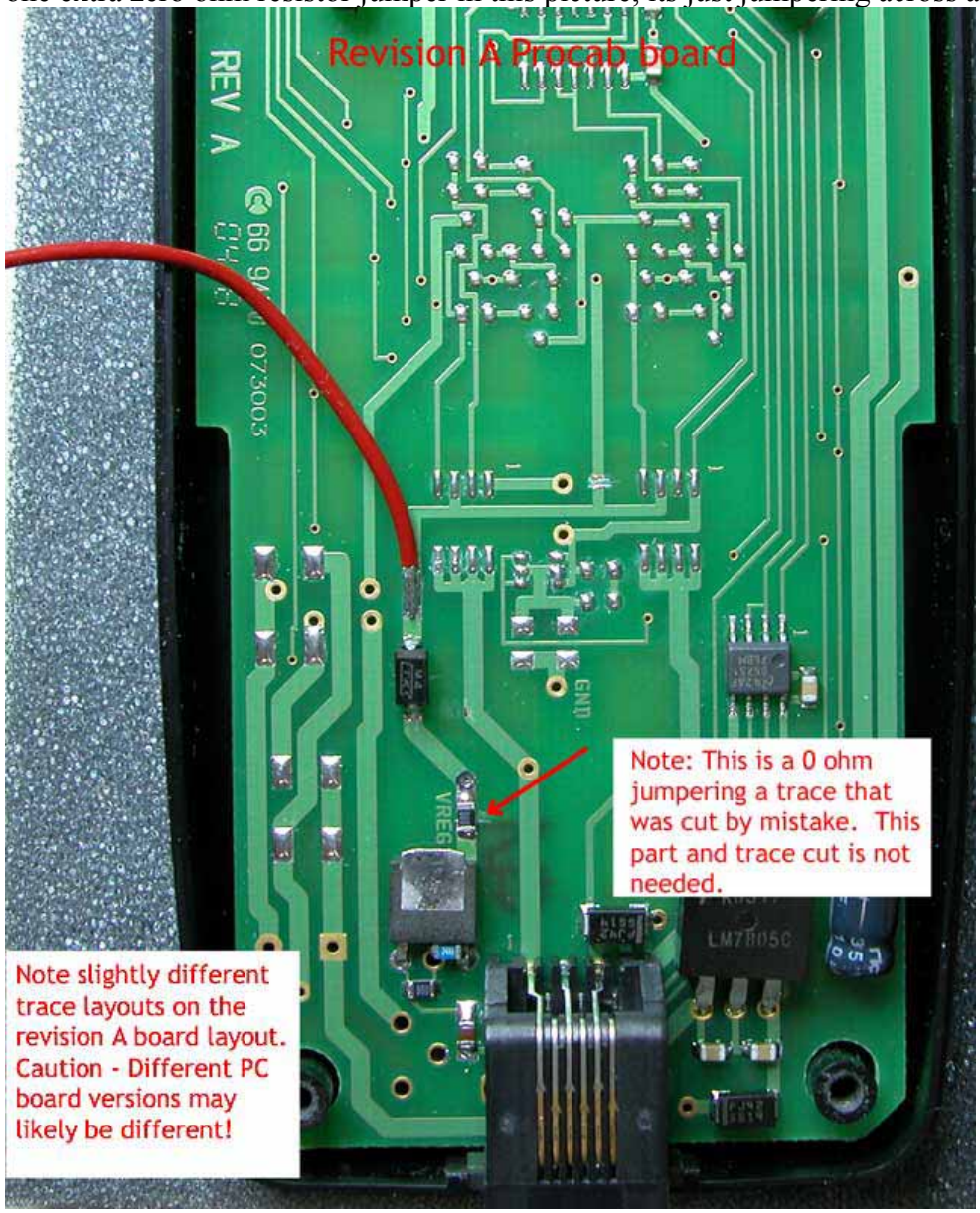


Step 5: Testing and connecting the output to the battery pack. Before connecting the charger output to the battery pack it is strongly recommended that you test the function of the charger. To test the circuit you will need a multimeter capable of reading DC amps. To test the charging current set the multimeter to a 300 mA range or larger and connect the red wire output of the charger to the red lead on the multimeter. Connect the black lead from the multimeter to a ground point, the big metal tab on the LM7805C regulator (shown on the right hand side of the previous picture) is a good ground point. Now connect the cable from the cab bus to the Procab. If the charger is working correctly the meter should read about 51 mA (.051A). If the test was successful, disconnect the cab bus cable and wire the charger output to the positive terminal of the battery pack as shown in the picture below:



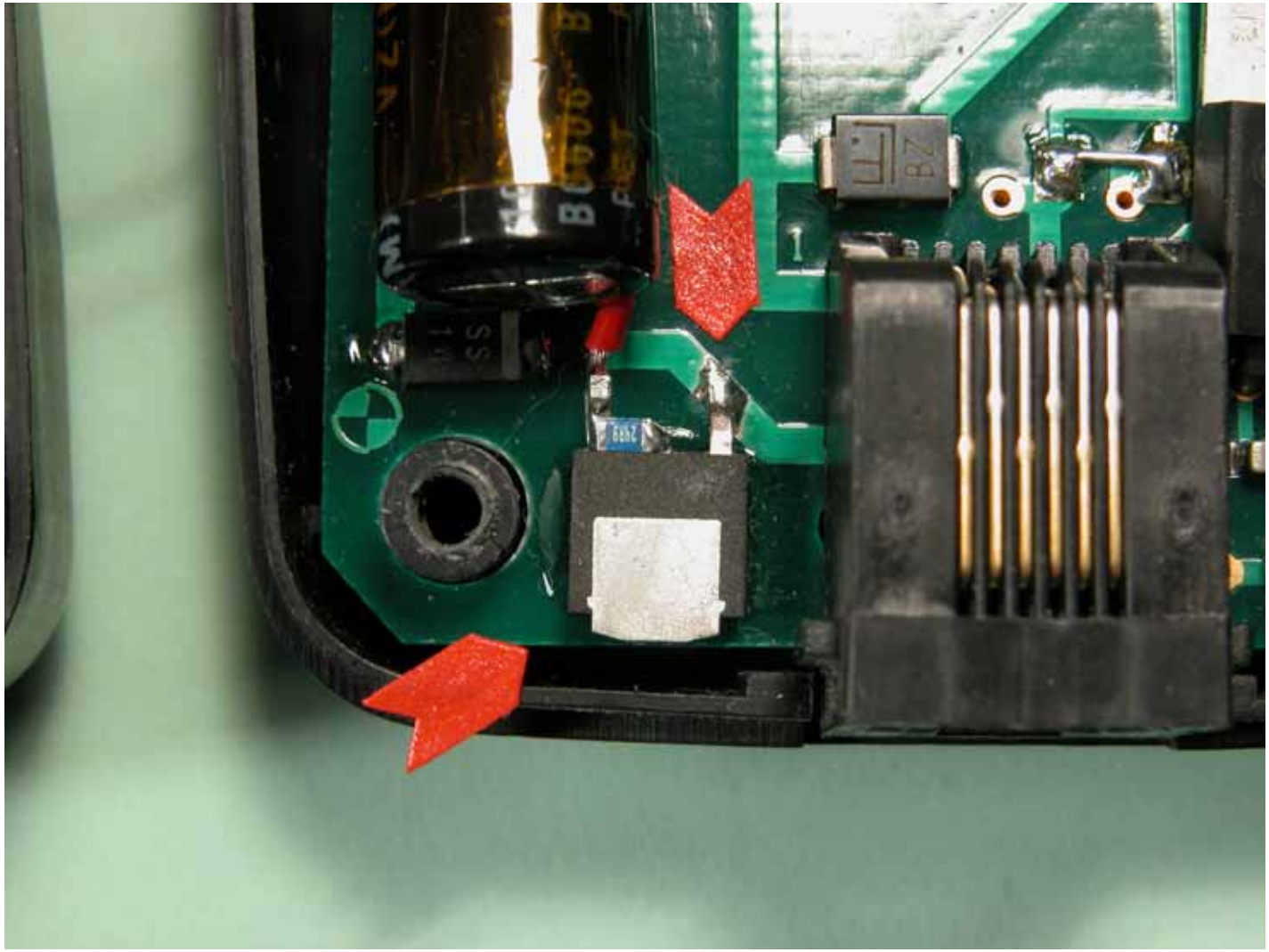
Step 6: Reassemble everything and you're done…

Other versions: Here's a picture of my other Procab which is slightly different as it is a Revision A circuit board. Please ignore the one extra zero ohm resistor jumper in this picture, its just jumpering across an inadvertent trace cut.



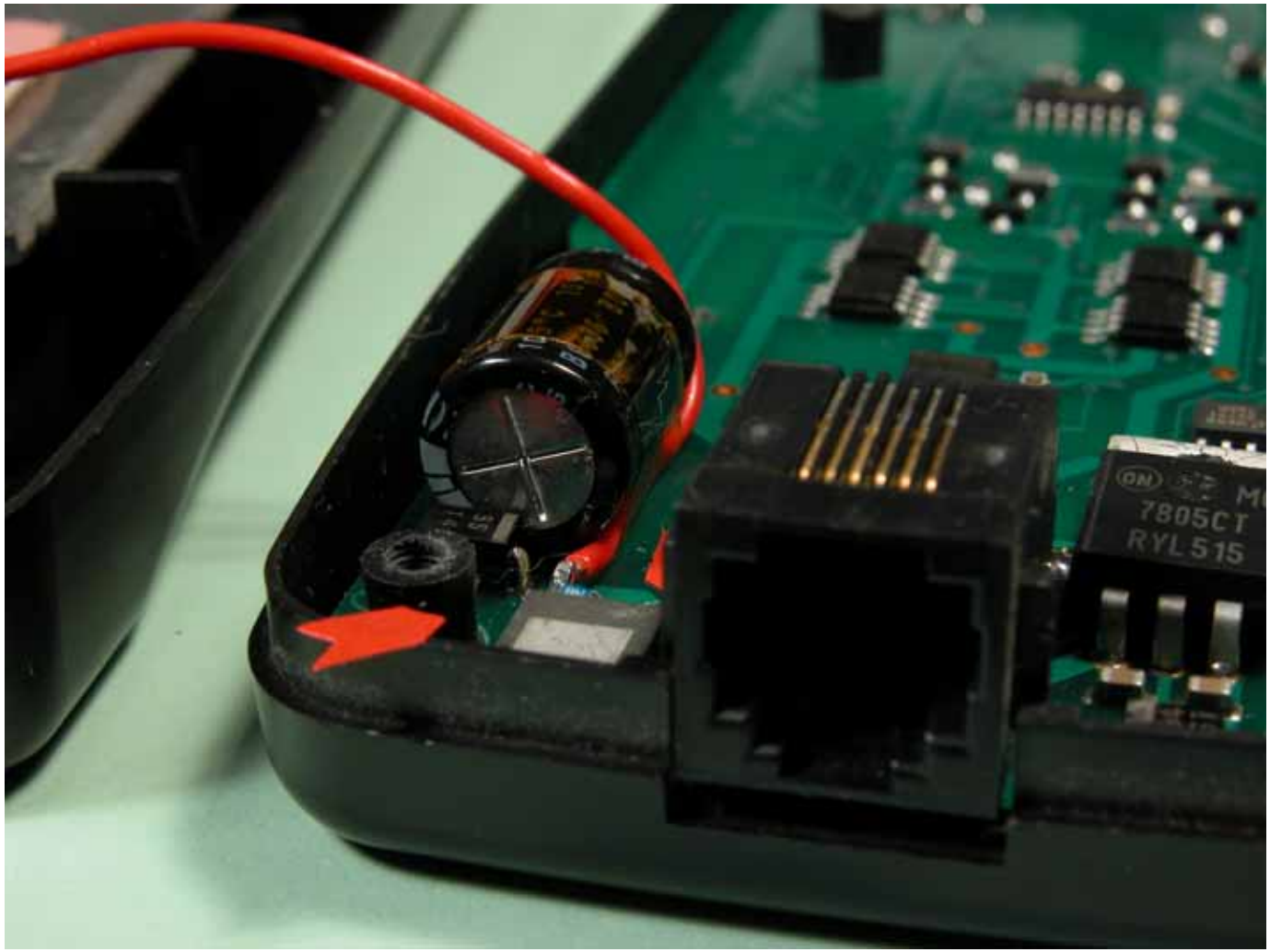
Newest version ProCab and PowerCab boards:

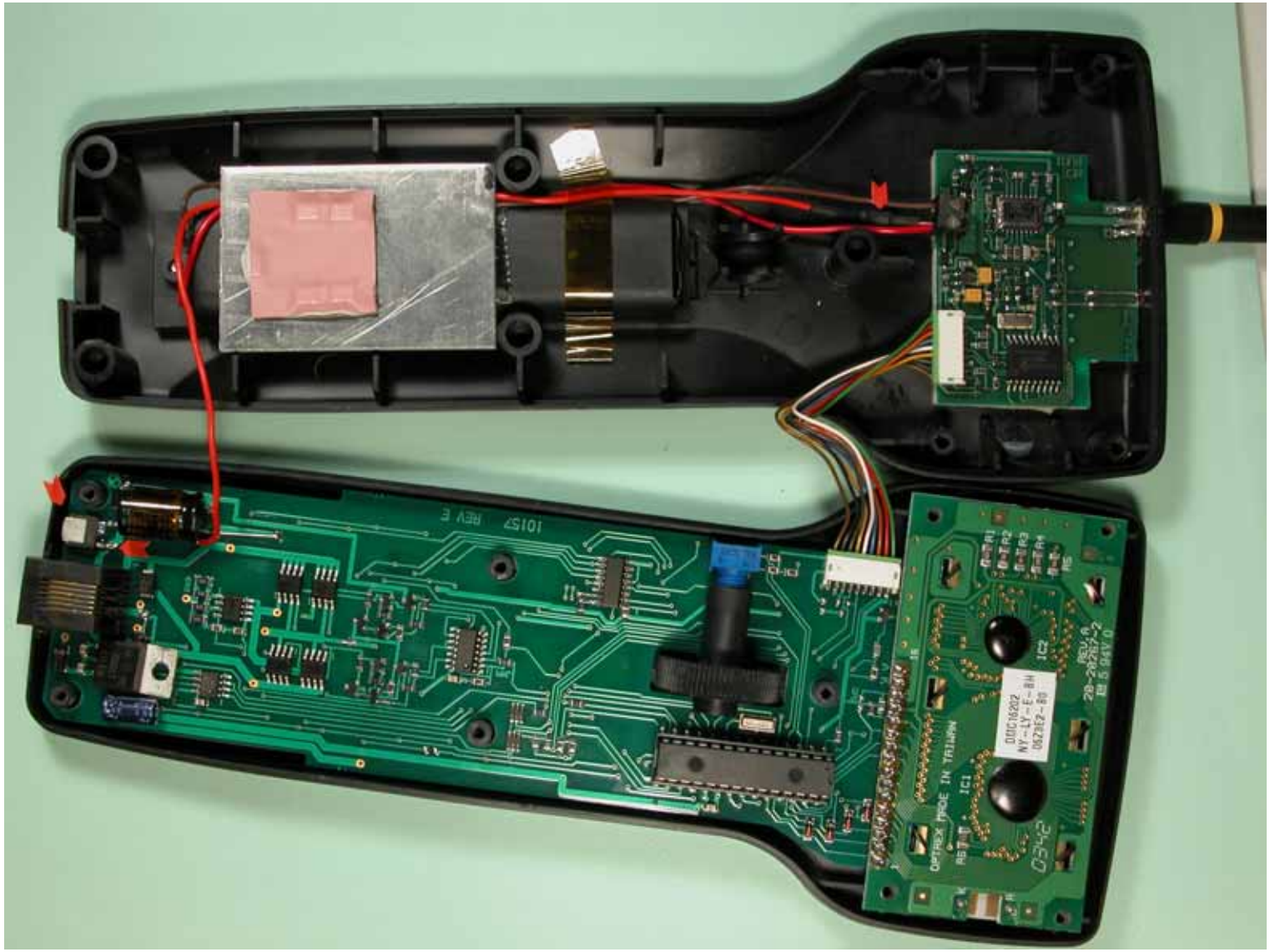
The latest version of the ProCab / PowerCab main board is labeled 10157 Rev E. This board has all the parts stuffed (especially in a PowerCab case) and as such there is not a nice convenient place to tack the regulator in place. The following pictures show how I implemented the charger in my PowerCab-R.



This photo shows how I connected the regulator to the angled +12 volt trace that is right next to the cab bus jack. Since only one pin is soldered to the trace I used a little bit of 5 minute epoxy and glued the regulator to the board to give it some extra support.

I soldered a wire to the output of the regulator (red wire on the left most pin) and then taped the wire to big round capacitor to provide some mechanical support for the wire. See photo below:





This photo shows the entire installation with the red wire connecting to positive radio board battery terminal. Since there really wasn't a good place to put the diode that needs connect to the output of the regulator I just used a leaded 1N4001 diode and wired it in line with the red wire. This is what is under the black heat shrink tubing right where the red wire connects to the positive screw terminal.

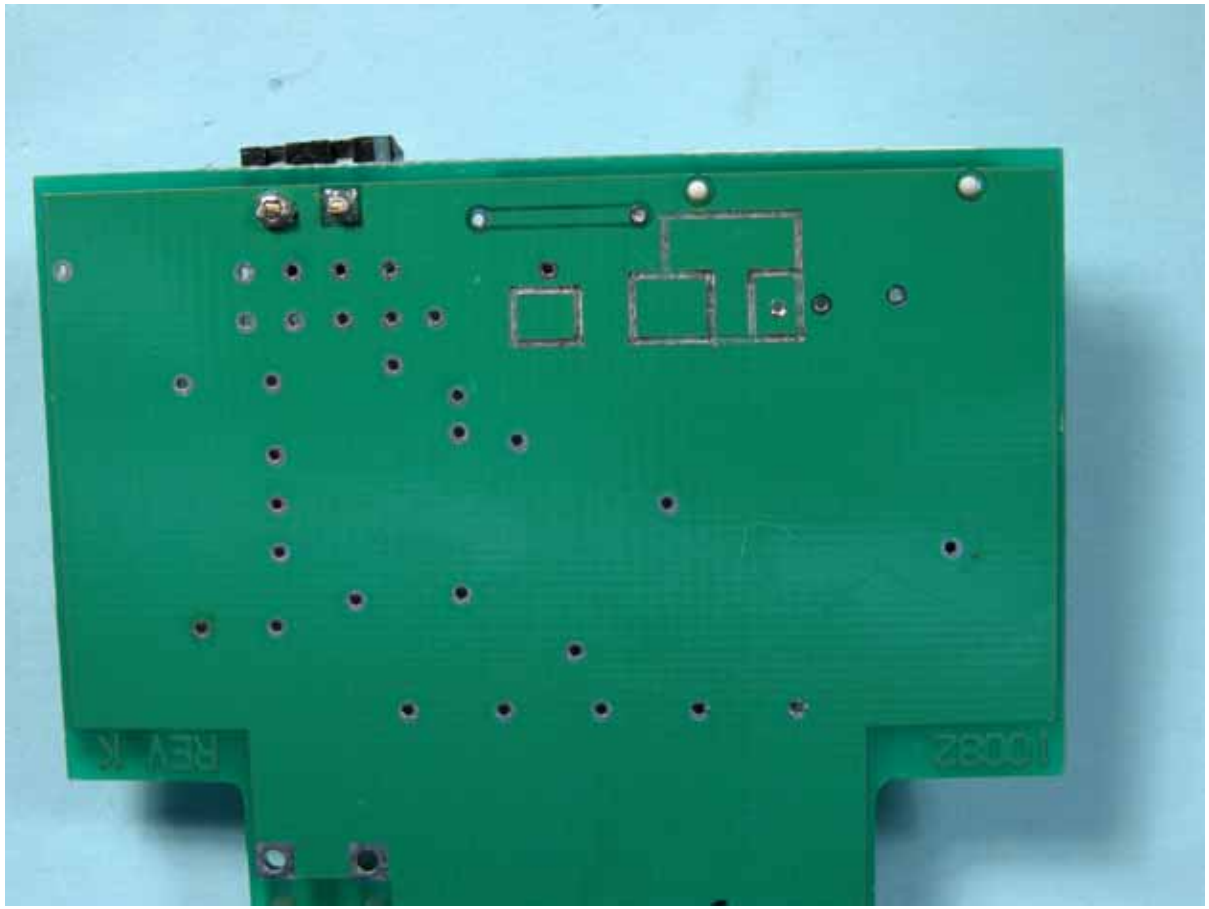
This photo shows a close up of the diode that is inline with the red wire coming from the regulator. While you can't actually see the diode because it is under the black heat shrink tubing, the banded end (cathode) of the diode should be connected to the screw terminal.

Another alternate implementation:

All the previous implementations depend on tacking the charger parts somewhere on the printed circuit board in the cab. Unfortunately there are a LOT of different versions of the PC boards, and when you try and install the charger in a Cab04 you have a completely different PC board to deal with. When I went to put the charger in a Cab04-r I found that there really wasn't a good location to put the parts on the cab's PC board.

So rather than put the charger on the cab's PC board I put the charger on the back of the radio board itself. This has the advantage of being the same regardless of the type of cab.

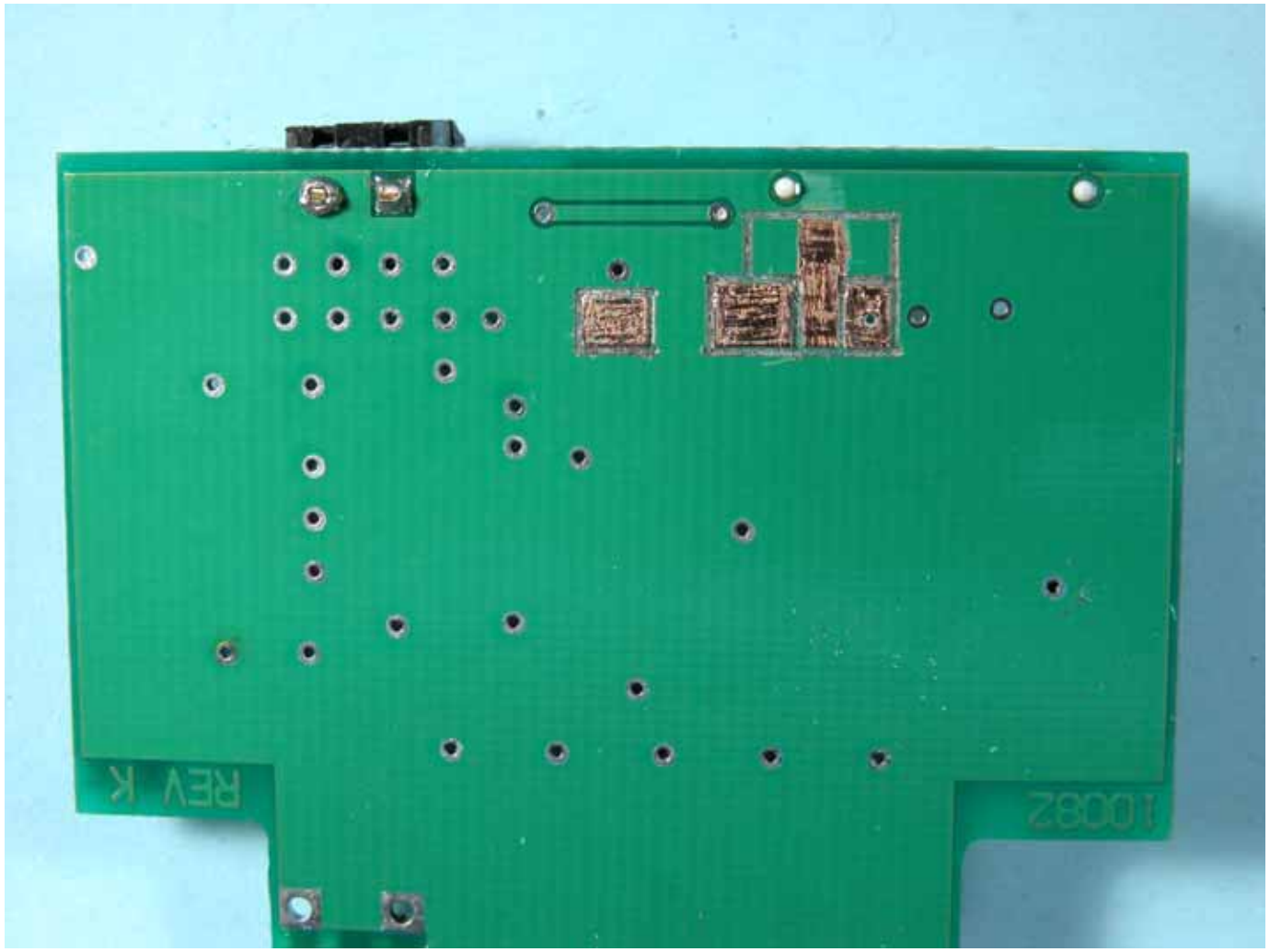
To do this I cut some pads out of the ground plane on the back of the radio board. See the photo below:



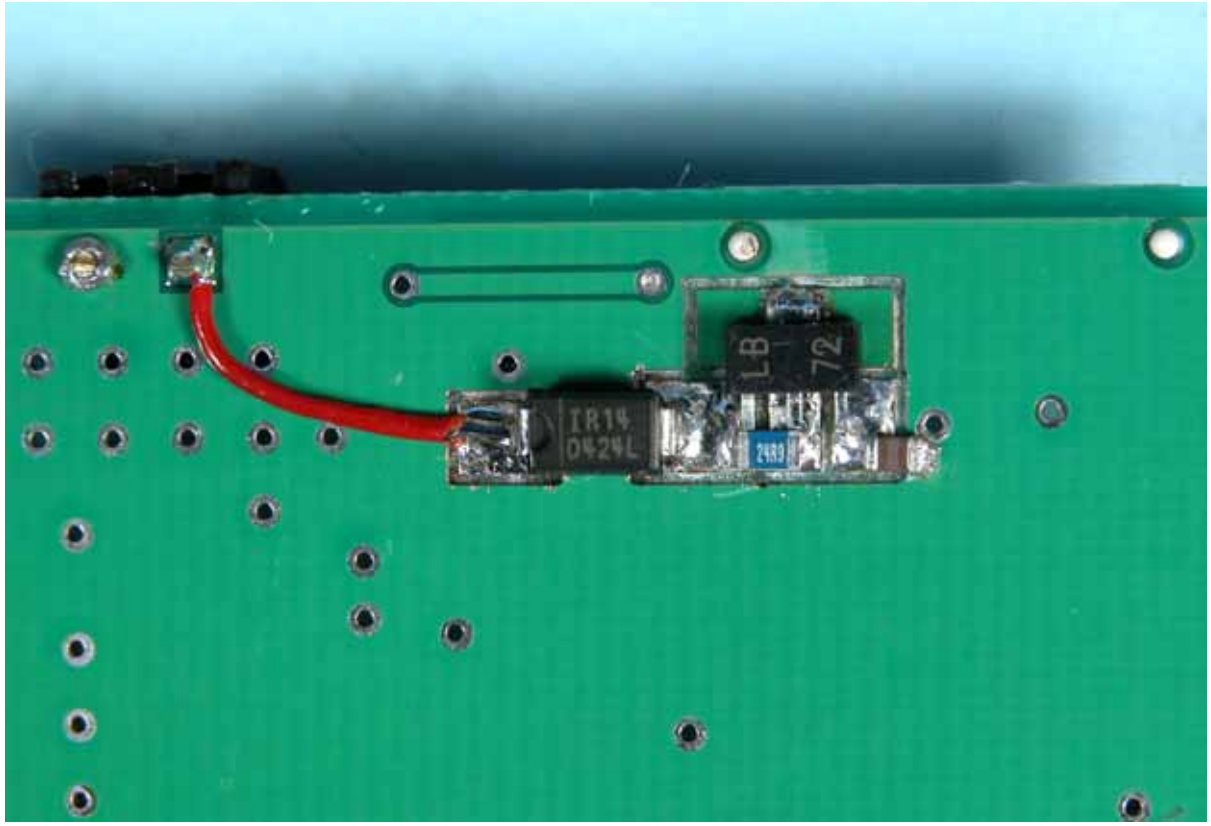
After cutting out the pads I scraped the green soldermask off the pads and drilled a hole in the center of pad on the right. This pad is the +12 volt input to the regulator and the hole is for a feed through wire that will connect to +12 volts on the topside of the PC board.

For this implementation I used a LM317L in a different smaller package. The part number of this version is LM317LIPK.

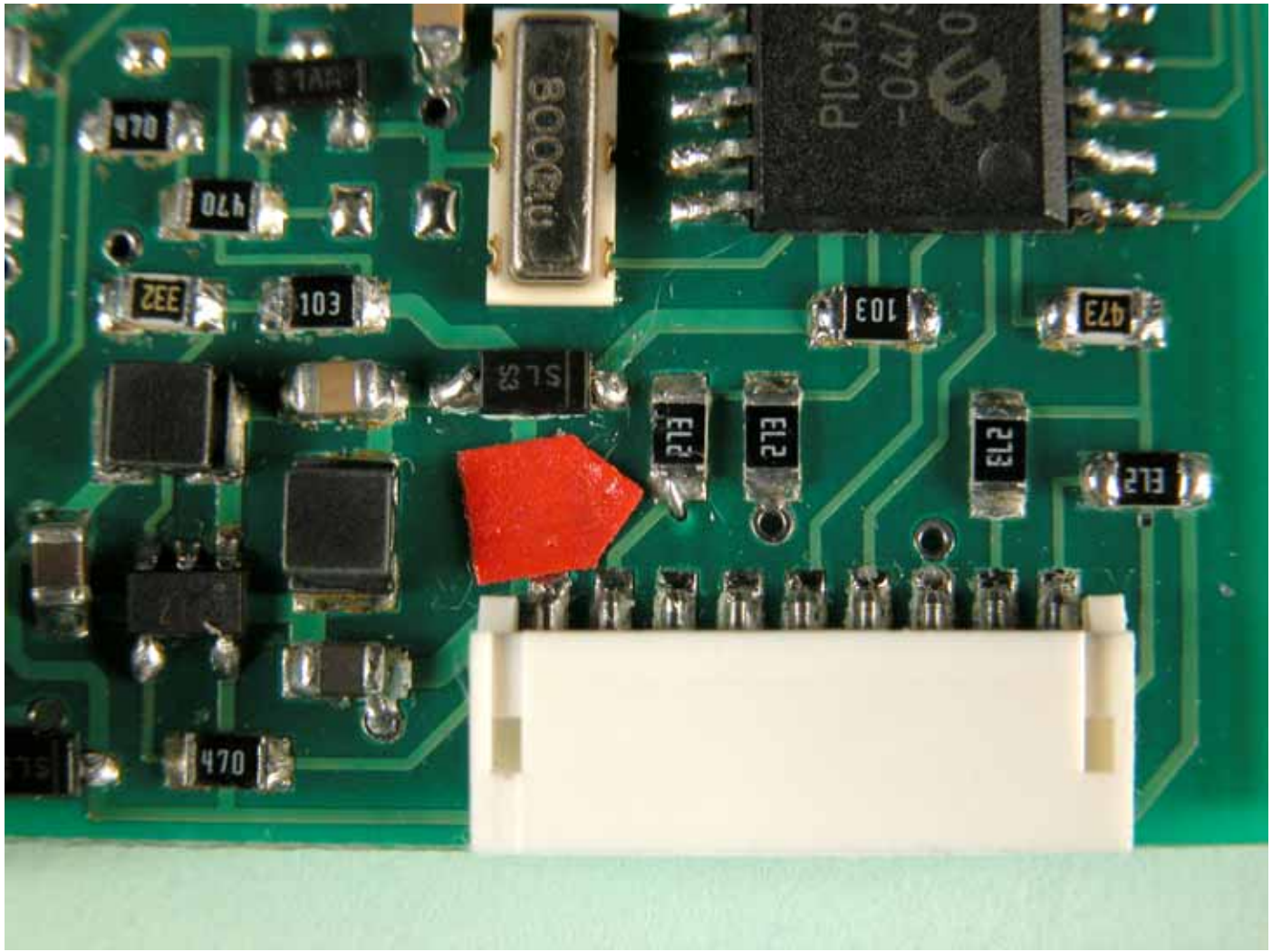
Here is a picture with the soldermask scraped off:



And here is a picture of the complete charger with all the components installed. The red wire connects the output of the diode over to the pin that is connected to the positive screw terminal.



And here is a picture of the top side of the board showing where the feed through wire solders on the end of the resistor labeled 273. (at the point of the red arrow).



This implementation is clearly not the easiest way to make the charger, but it is nice and small. This is more of an example of what you can do rather than what I would recommend. To do this you have to very good soldering skills and the ability to work with very small surface mount parts. This implementation is clearly not for everyone.

Yet another implementation idea

If you don't want to mess around soldering on the cab's PC boards you could just as easily get a small piece of prototyping Perfboard and build the parts up on a separate little board. If you use the leaded version of the parts you could just wire the parts up on the Perfboard and put some insulating tape around them and just use wire leads to connect up the input, output and ground.

The point is that there are many ways to implement this little circuit and this write up shows you some examples of what I have done on my cabs.

Other comments and tips:

Once the charger is in place regular Alkaline batteries CANNOT be used in the Procab. Charging standard batteries can cause them to leak, or worse possibly explode. I would strongly recommend that a label be stuck on the back of the battery door that says **"rechargeable batteries only"**

Since the Procabs are now drawing more current from the cab bus it becomes important to provide an additional +12 voltage source to the cab bus if more than a couple Procabs are going to be plugged in. NCE's or Tony's UTP patch panel provides a convenient jack that can be connected to an external wall wart supply.

The extra wall wart supply also allows you to charge your radio Procabs without having to power up your command station. After an operating session just power down the command station and plug your Procabs into the command bus and they will be fully recharged the next day.

Here's another tip, if the Procab is off when plugged into the command bus the display backlight comes on and stays on the whole time the Procab is plugged in. If you turn the radio on, and then plug into the bus, the radio turns off, but the display backlight stays in the power saving mode (it turns off 5 seconds after a key press). If you're concerned about the backlight life, turn the radio on first, then plug in, and the backlight will be off for the whole charging time.

Closing:

I hope the write up proves to be helpful to you should you try to implement a charger for your cabs. If you have any questions I can be contacted by email at mark@markschutzer.com and I also have a website of some of my model work at http://markschutzer.com