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Modifying the Miniboots CW Amplifier for SSB Operation

On the face of it, turning a class C power amplifier intended for CW operation into a linear amplifier suitable for SSB mode requires nothing more than a biasing circuit that will allow the amplifier to be biased for class AB operation. But is it as simple as that? What are the practical considerations of making the change?

This article shows you how to modify my original Miniboots Amplifier design to be able to operate linear modes such as SSB and PSK31. NorCal kitted my design -- see Note 5 at the end of the article for technical details and information on how to obtain the kit.

As with any solid state circuit heat is the enemy, even though the transistor used in this case is the fairly rugged IRF510. Forward biasing the amplifier in order to place it in class AB operation necessarily raises the quiescent current through the device. In this case, the minimum current required to produce reliably linear amplification is 100 milliamps[1]. Will that change alone require a commensurate increase in size of the heat sink for the transistor?

In some published amplifier circuits[2], the biasing circuit is activated only during transmit, so that there is no current running through the amplifier during receive periods. Will that be necessary in this case, in order to reduce heating?

Will temperature compensation be required for the biasing circuit in order to prevent thermal runaway and destruction of the IRF510?

In order to reliably amplify an SSB signal, the amp needs to remain linear so that there is no discernable distortion of the signal. This means that both the quiescent current through the transistor and the temperature of the transistor need to be kept within practical limits.

In this case, the Mosfet used, the IRF510, is fairly rugged and is relatively immune to thermal runaway[3]. Temperature control of the device, and therefore quiescent current stabilization, is accomplished to a practical level by simply providing sufficient heat sinking. This means both providing a heat sink of sufficient size and paying close attention to details such as providing heat sink compound, ensuring that the transistor bolts tightly to the heat sink, and ensuring that there is full contact between the transistor, the TO-220 insulator and the heat sink in order to maximize heat transfer.

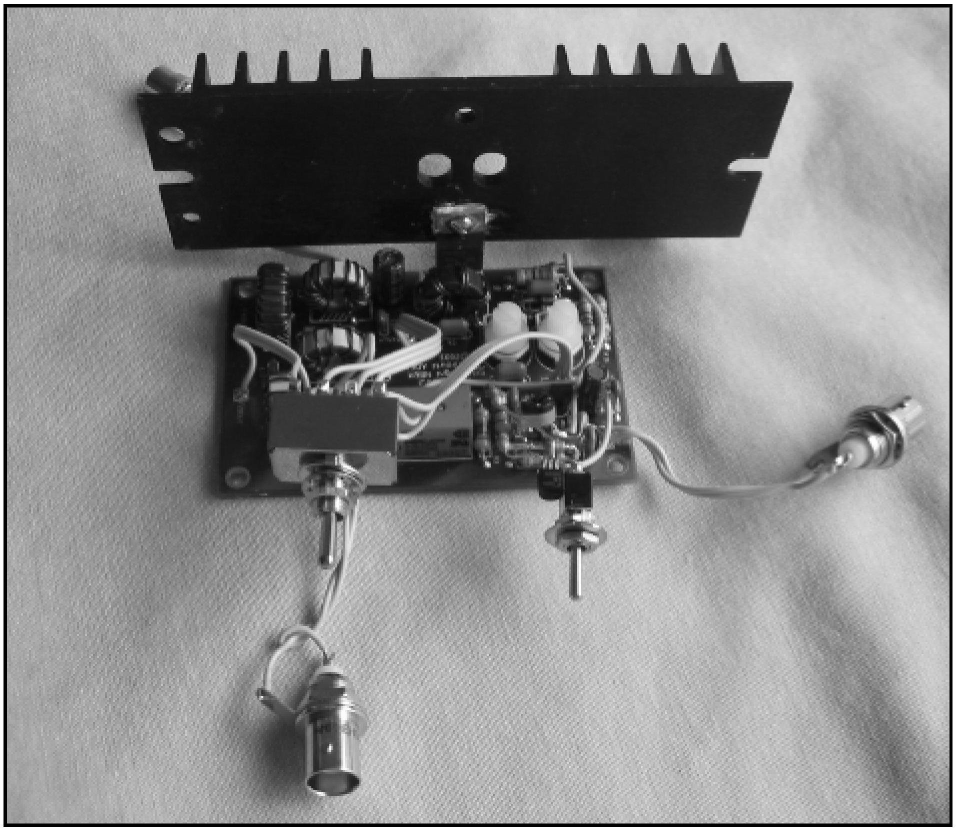


Figure 1: Miniboots SSB/CW Version, PSK-31 Ready

Simply bolting the transistor to an aluminum case, utilizing the insulator provided, is not going to be enough, especially if you want to operate the Miniboots amp in a 100% duty cycle mode such as PSK-31.

For initial testing, a simple biasing circuit, consisting of S1, R12, D5, RV3, and C20, was added to the Miniboots amp, as shown next in Figure 2.

In order to add the biasing circuit, the normally grounded end of R7 was lifted from the corresponding hole in the circuit

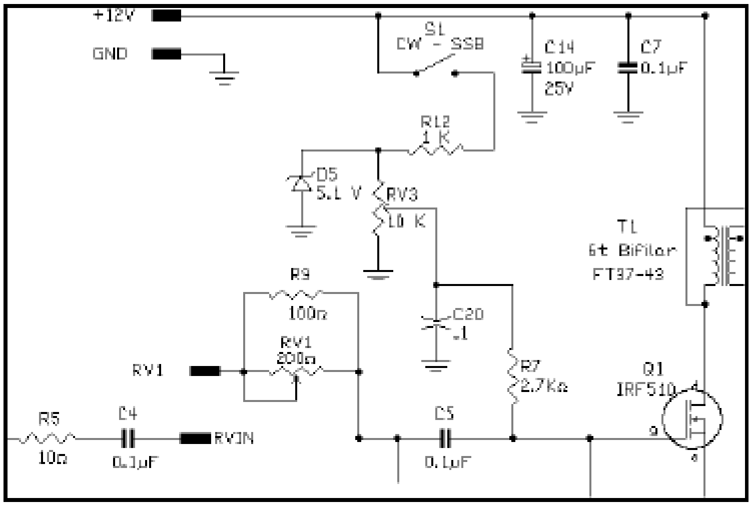


Figure 2: Simple biasing circuit is added to the Miniboots design

board and a short length of hookup wire was connected between the lifted end of R7 and the junction of C20 and RV3, as shown in below in Figure 3.

The additional components needed for the biasing circuit and T/R switching could be added to the Miniboots amp in a variety of ways, including making use of a small "daughter board", which could be attached to the inside of the case. I chose to use the "Ugly" method, as will be shown later.

A Milliammeter was connected in series with the DC supply line, and the quiescent current set at 100 milliamps.

In tests conducted both off and on the air, while monitoring both quiescent current through the amplifier and heating of the Mosfet, it was found that, with just one TO-220 type aluminum heat sink bolted directly to the transistor, in the open air, the quiescent current remained below 150 milliamps during reasonable length transmit periods, and returned to the 100 milliamp level during receive periods. This indicated that a larger heat sink might well keep device heating, and, therefore quiescent current, well under control.

Monitored audio quality of off the air tests indicated no distortion. All stations contacted in on-the-air testing were asked to make a critical report on audio quality, and all responded with favorable reports.

Once initial testing was done, Q3 and R13 were added to the circuit in order to have the bias circuit switched on and off for transmit and receive periods, respectively. By doing this, not only is current drain minimized, but cooling of the Mosfet is enhanced, by virtue of its not carrying 100 milliamps of quiescent current during receive periods, as shown in Figure 4.

Following the "Ugly" method of construction, the grounded ends of D1 and R4 were used as attachment points for the grounded end of RV3 and the grounded ends of C20 and D5. See Figure 5 on the next page for clarification.

Because of the low current requirements of the Mosfet biasing circuit, all resistors used are ¼ watt units, and RV3 is a subminiature trimpot.

As seen in the initial picture of the SSB/CW modified Miniboots, a relatively large heat sink was bolted directly to the metal tab of the IRF510. This was done to test the feasibility of operating the amplifier in PSK-31 mode.

This heat sink has a body that is .125" thick, is 1.75" high, over 4.0" wide, including its attachment wings, and with ten ribs which stand out .375" from the main body of the heat sink. This is a little bit of overkill, but what it did prove was that by using a large enough heat sink, the Miniboots Amp with the SSB Mod could be used as a linear for PSK-31 operation. The Mosfet only got detectably warm during long transmission periods in that 100% duty cycle mode.

The entire SSB Modified Miniboots circuit is shown in Figure 6.

As always, testing and modification will continue. If you choose to add this simple biasing circuit to your Miniboots Amplifier, I recommend first adjusting the output level for no more than 5 Watts. You should also perform enough testing to be sure that the heat sink you are using is up to the task of keeping the Mosfet at a reasonable operating temperature. This will help ensure that your signal remains undistorted and the transistor is protected from destruction.

I am pleased with the experimental results so far! It shows that the Miniboots can be a very useful addition to the QRP SSB voice and digital modes of operation as well as for CW. I hope your results will be as good as mine.

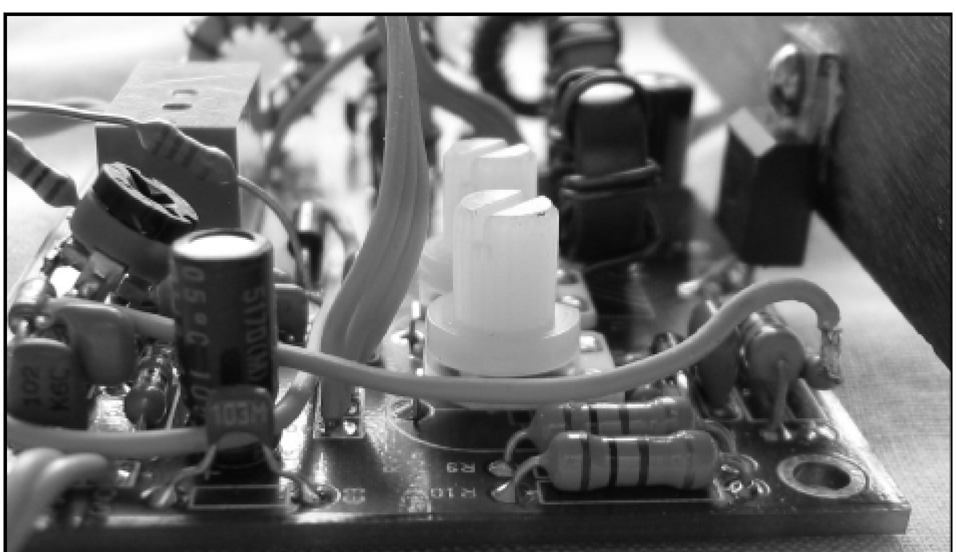


Figure 3: One end of R7 is lifted and connected by hookup wire to C20/RV3

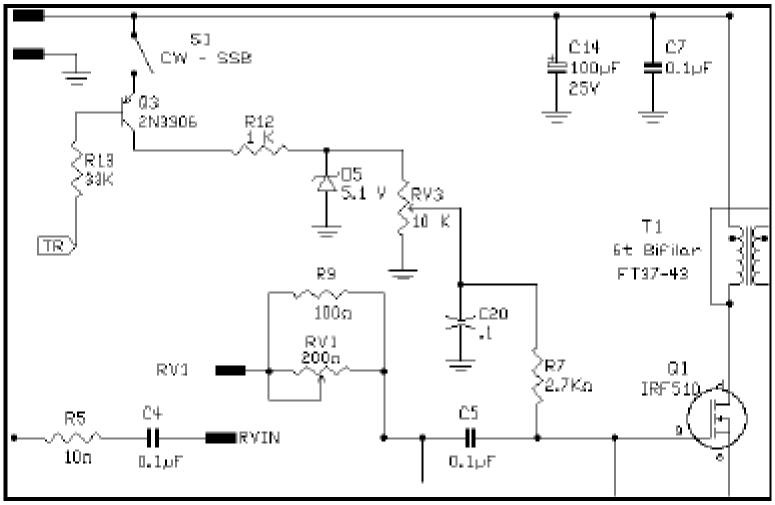


Figure 4: Q13, R3 and S1 added to allow switching bias circuit on/off during Tx/Rx periods

NOTES

1. Hayward, Wes, W7ZOI, Experimental Methods in RF Design

2. Hayward, Wes, W7ZOI, Lewallen, Roy, W7EL, DeMaw, Doug, W1FB, various publications

3. DeMaw, Doug, W1FB's Design Notebook

4. You may contact the author by email at NB6M@aol.com, or by postal mail at: 2379 Saint George Drive, Concord, CA 94520.

5. The original Miniboots Amp Kit provides a full "QRP gallon" (5-Watt output) from a 750mW-to-1W input CW drive signal. It comes with BNC connectors, all board mounted parts and a high quality silk screened, solder masked, plated through hole pc board. All you have to add is the power connector of your choice and a case. See full kit details and ordering information on the AmQRP web site at http://www.amqrp.org/kits/miniboots/index.html.

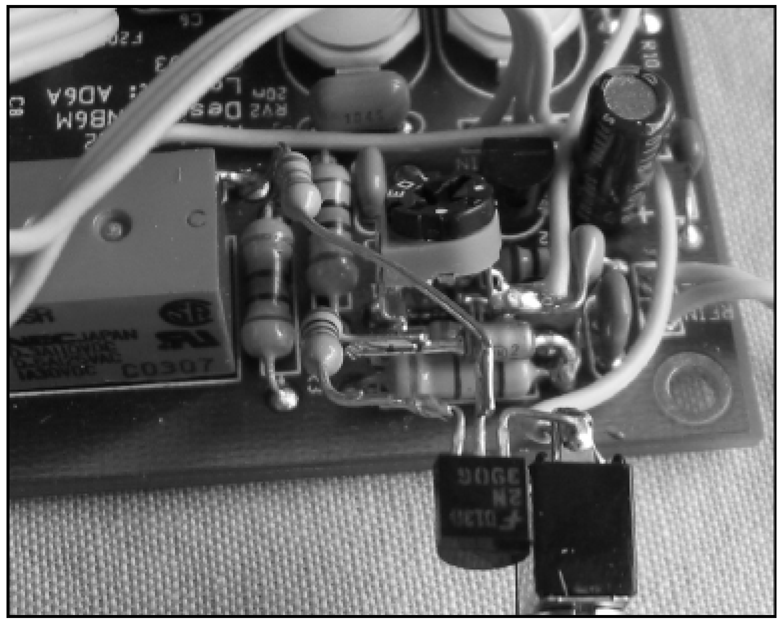


Figure 5: "Ugly" construction techniques shown here for D1, R4 and RV3. Also shown here is Q3 mounted by its emitter to the back of S1, with R12 connecting its collector to the junction of D5 and RV3, and with one lead of R13 shown connected to its base.

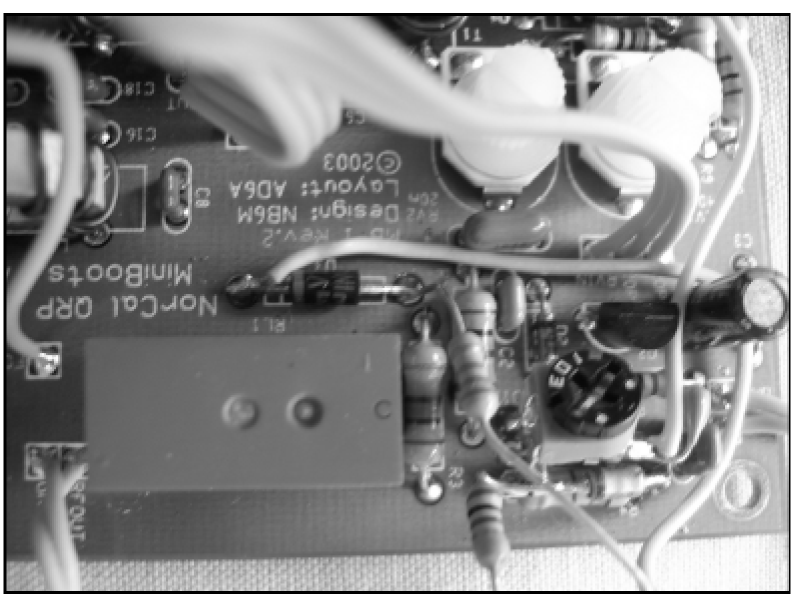
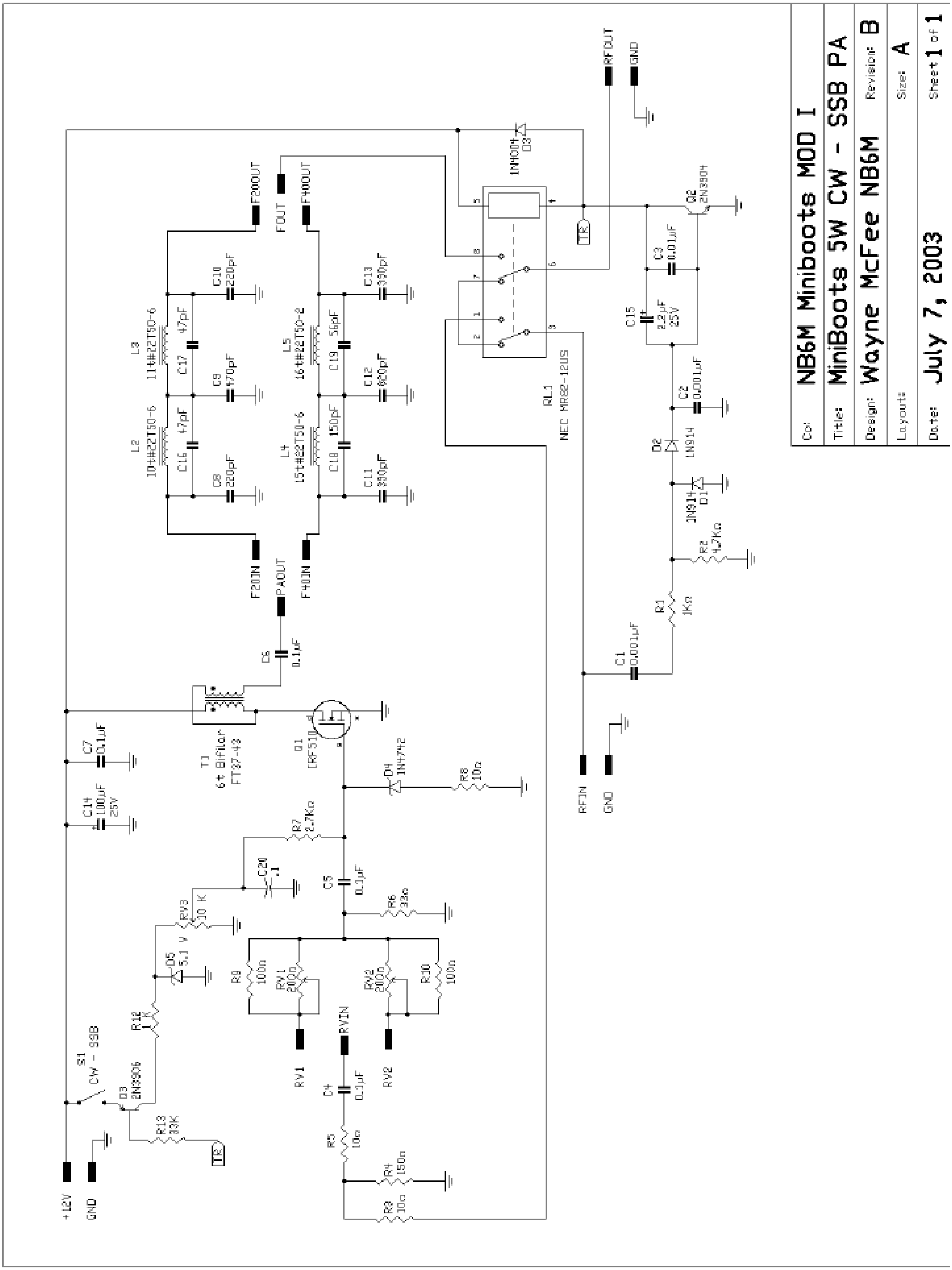


Figure 6: The cathode and anode of D3 were used as attachment points for the 12 Volt and T/R lines running to S1 and the base of Q3. This photo also gives another view of the attachment points of C20, the 0.1 cap in lower right, RV3, the 10 K trimpot, and D5, the silver diode below RV3. Also shown are R13, the 33K resistor connected from the anode of D3 to the base of Q3, and R12, which goes between the collector of Q3 and the junction of D5 and RV3.


Co:
NB6M Miniboots MOD I
Title: MiniBoots 5W CW - SSB PA
Design: Wayne McFee NB6M
Revision: B
Layout:
Size: A
Date: July 7, 2003
Sheet 1 of 1
RFOUT
GND
1N4004
D3
2N3904
Q2
TR
C3 0.01µF
C15 2.2µF 25V
C2 0.001µF
D2 1N914
D1 1N914
R2 4.7KΩ
R1 1KΩ
C1 0.001µF
RL1
NEC MR82-12US
RFIN
GND
F20OUT
FOUT
F40OUT
L3 11t#22T50-6
L2 10t#22T50-6
L5 16t#22T50-2
L4 15t#22T50-6
C10 220pF
C17 47pF
C9 470pF
C16 47pF
C8 220pF
C13 390pF
C19 56pF
C12 820pF
C18 150pF
C11 390pF
F20IN
PAOUT
F40IN
C6 0.1µF
T1 6t Bifilar FT37-43
Q1 IRF510
D4 1N4742
R8 10Ω
C7 0.1µF
C14 100µF 25V
R7 2.7KΩ
C20 .1
C5 0.1µF
RV3 10 K
R6 33Ω
D5 5.1 V
R9 100Ω
RV1 200Ω
RV2 200Ω
R10 100Ω
R12 1 K
RV1
RVIN
RV2
S1 CW - SSB
Q3 2N3906
C4 0.1µF
R13 33K
TR
R5 10Ω
R4 150Ω
R3 10Ω
+12V
GND