looking at about +40 volts, the MOSFET will begin conducting most enthusiastically.

To temper the enthusiasm of this conduction we install the remaining parts of the current source, R1, Q3, R6, C3, and R7. When current begins flowing through the MOSFET, voltage is developed across .33 ohm resistor R1 which will equal .33 volts for each amp of current flow. Q3, a PNP transistor, is set up so t[…] across R1. Bipolar transistors [...] where they will begin to conduc[...] Emitter voltage approaches .66 volt[...] voltage across R1 gets to about .6[...] conduct.

By comparison, MOSFETS begin [...] and 5 volts, and are quite variable [...] parts which is why we use a Bipola[...] digress...

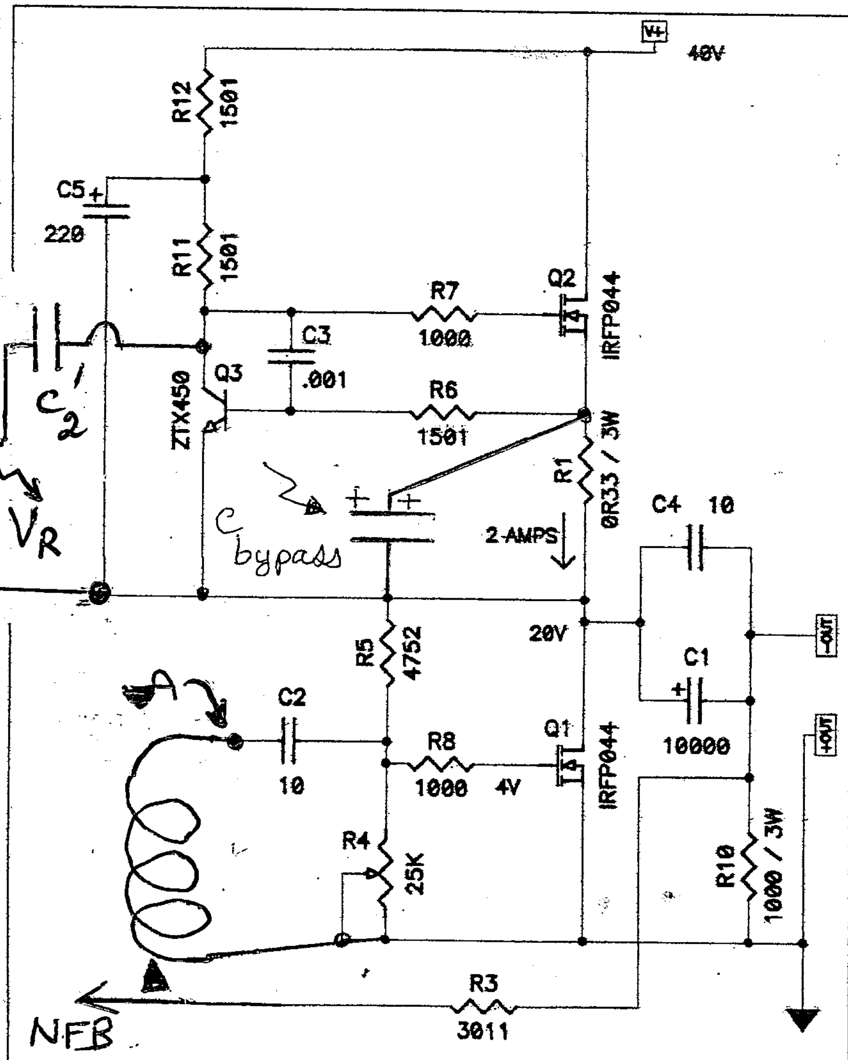

FIGURE 1. Candidate F6 #1

RESISTOR VALUES ARE 3 DIGIT AND MULTIPLIER AT .25 WATT UNLESS NOTED
CAPACITORS ARE IN MICROFARADS UNLESS NOTED. ELECTROLYTICS ARE 50V

When Q3 begins to conduct, it limits the Gate voltage of Q2, and this forms a little feedback mechanism which limits the voltage across R1 at about .66 volts. R6, R7, and C3 are there to help make this arrangement stable and reliable, and we could possibly omit these, but we won't.

If the voltage across R1 is a stable and constant .66 volts, then the current through R1 is a stable and constant 2 amps, and that means the current through Q2 is a stable and constant 2 amps, and so we have a 2 amp stable and constant current source. For Drain voltages reasonably within the values of the power supply provided, the current will be fairly constant and good enough for this amplifier.

An Alternative Approach

There is more than one way to skin a current source, and Figure 2 shows an alternative circuit that performs the same function but with an N channel MOSFET instead of a P channel type. In this circuit, the corresponding parts retain the same reference numbers as Figure 1, with Q2 becoming an N channel part, Q3 becoming an NPN part, and R11 changing value from 10 K ohms to 1.5 K ohms.

The function of this circuit is identical to Figure 1 except that it has been turned upside down. The Gate of Q2 now has to go positive relative to the Source pin to achieve conduction, and so on. To keep the current through R11 fairly constant as it was with the previous version we have added R12 and C5 which "bootstrap" the AC voltage at the junction of R11 and R12 so that the AC voltage variation seen across R11 is low.

The performance of this circuit is virtually identical to that of Figure 1, and is documented in Figures 3 through 5. One advantage to the circuit of Figure 2 is that it uses the same device as the gain transistor, both being the cheaper and more easily obtained N channel types. The more crucial advantage to this innovation is that it can be further developed into a current variable current source as seen in the Pass Labs Aleph amplifiers.

Before we do that, let's make note of the performance of the circuit of Figure 2. Figure 3 shows the harmonic distortion curve versus output power into an 8 ohm load, and we see that this rises smoothly from about .1% at .1 watts, to about 2% at 10 watts. This is mostly second order harmonic distortion until you get above 10 watts, and by about 18 watts rms you are clipping the output with peaks at 36 watts. This is more power than we got out of previous editions of the Zen Amp by virtue of greater power supply voltage at 40 volts. Into 4 ohms, the amplifier clips at about 9 watts rms.

Figure 4 shows distortion vs frequency into the same 8 ohms at 1 watt levels, and we see an increase at high frequencies with a knee in the curve at about 6 KHz. The increase at high frequencies is due largely to nonlinearities in the input capacitance of power MOSFETs and is an unwelcome feature that we have to live with in this device. We minimize