

De-Lite Amplifier

by Nelson Pass

Introduction

The third annual Burning Amp Festival was held in San Francisco last October, drawing a couple hundred DIY Audio enthusiasts, many from long distances. At previous BAF gatherings I have simply brought a truckload of parts that might appeal to DIYers, but this year an announcement went out that I would have a *presentation*. It was news to me, but a quick talk is a lot less effort than hauling a ton (literally) of parts, so I decided to pretend it was my idea.

Procrastination being as much a part of my life as anyone else's, I found myself two days before the event having nothing prepared. What better opportunity to throw together something *totally easy* for beginners...

Most of you have never built an amplifier, and this article is intended to get you to do it. One of the biggest problems helping people to take the leap into building their own electronics is offering something really easy but satisfying – a simple but exotic project with low barriers and cheap satisfaction.

This power amplifier is just such a piece of low hanging fruit.

In 33 years of creating DIY projects I recall that one of the most popular was 1997's Son of Zen (www.passlabs.com), a single-stage no-feedback Class A design using two N channel Mosfets arranged as a single balanced differential pair. It remains one of the simplest amplifiers I have written up.

The Pass-DIY Gallery has examples of SOZ amplifiers, usually featuring totally over-the-top metal work and giant heat sinks and power resistors – more so than other designs. Apparently there is a breed of he-man DIYers who can saw, machine, drill, bend, glue, weld, bolt, cut, and solder with confidence but who break into a sweat when confronted with the three legged critters.

So here's an amplifier that carries some marketable buzz words: Depletion-mode FET, Single-ended Class A, no negative feedback, current source output and glows in the dark.

And only one transistor.

The Simplest Amplifier

I wanted an amplifier easy enough to lure unsuspecting audiophiles away from blind consumerism and down the slippery slopes of DIY obsession.

So on the Thursday night before BAF I took my scrappiest piece of wood and glued a heat sink and transformer to it and let it sit overnight.

Halfway done - just like that!

The following afternoon I populated it with screw-on terminal blocks, power cord, fuse, diode bridge, two big electrolytic capacitors, a one ohm power resistor, two 300 watt light bulbs (with sockets), two RCA connectors, two smaller electrolytic capacitors, two small resistors and two power Mosfet transistors.

An hour of point-to-point wiring, and *Voila!* A stereo power amplifier.

Figure 1 shows what it looked like at Burning Amp Festival:



(photo courtesy of Dana Brock)

You see that it glows comfortably and does not require an “on” light.

Figure 2 shows the schematic with the supply and one of the two channels:

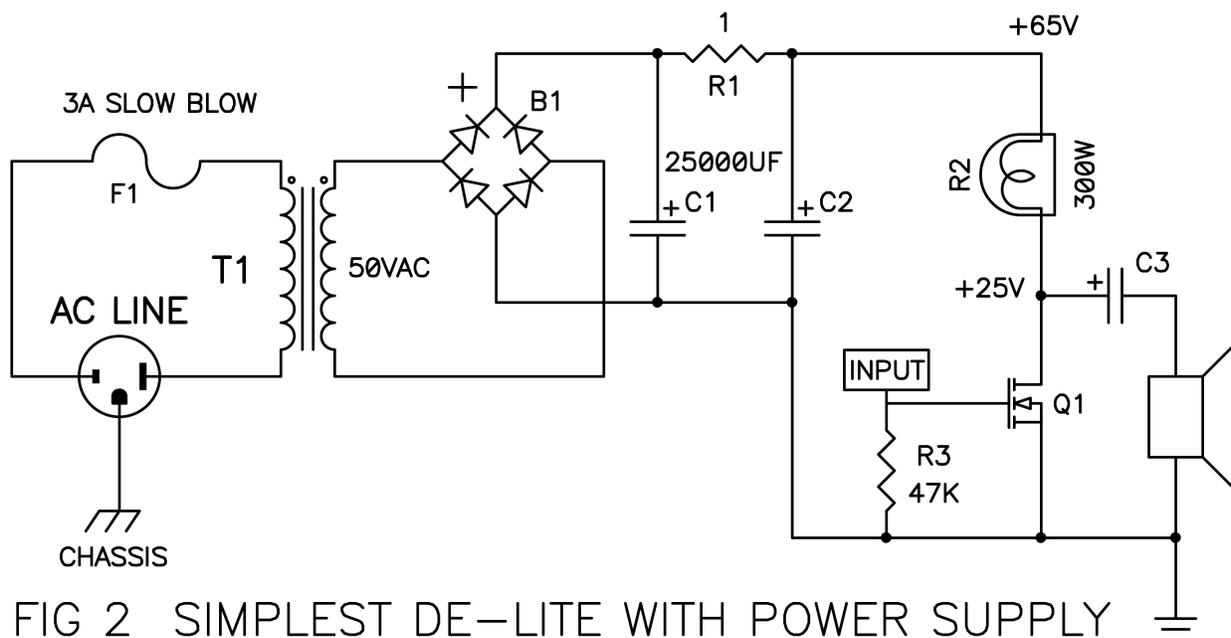


FIG 2 SIMPLEST DE-LITE WITH POWER SUPPLY

Nothing magical about the supply – I chose a CRC filter configuration to take out some of the voltage ripple and get the noise down a bit. The diode bridge, power resistor, and Mosfets should be mounted on the heat sink as seen in Figure 1, as they dissipate quite a bit of heat. R1 is going to dissipate as much as 20 watts, and the Mosfets will dissipate as much as 55 watts each, so don't scrimp on the heat sinking. If you choose to build this amplifier and its variations as a monoblock, then you can get away with less, but don't fool around. The power transformer should be rated at at least twice the actual draw, so you should figure on 350+ VA rating *per channel*.

I used power supply capacitors at 25,000 uF, but feel free to use more. Maybe lots more. The supply voltages we will be seeing start at 65 volts and go as high as 100 volts DC, so it will be good to get caps rated at this. The rectifier bridge is a standard 35 amp 400 volt type, a very common part. Perhaps you will want to try those snazzy fast/soft recover diodes you read about, but save it for later.

This supply is the bare minimum, but it will get the job done, and you can improve on it in your free time. Remember SAFETY FIRST – use a fuse and insulate the AC line connections. Try not to start a fire or electrocute anyone. The article Zen Variations #3 is a decent start if you want to explore power supply issues and safety further.

The Mosfet will develop its output across a 300 watt (120V) light bulb which I bought from McMaster-Carr along with some sockets. The clear glass ones look the best. The output capacitor C3 protects the speaker from the DC voltage seen at the Drain pin of the Mosfet. If your speaker drivers are capacitively coupled already by a crossover filter, you might eliminate this capacitor, and of course you can use a better capacitor than my 10,000 uF 50V electrolytic. 1,000 uF of polypropylene capacitance will get you down to around 30 Hz or so, and larger values will get you lower, if you can afford them.

The output impedance of the amplifier is essentially that of the light bulb, which is about 20 ohms or a little more, depending on the DC voltage across it. If you want, you can easily substitute a 16 to 25 ohm power resistor instead of the light bulb, but it's not as much fun or attractive in the dark.

The input resistor R3 to ground gives the Gate a DC connection to ground, so that you don't depend on the preamp to provide this and the Mosfet doesn't start acting strange. If you know your preamp has this and you're not a scaredy-cat, then you can do without it. With it, the input impedance of the amplifier is essentially the value of this resistor, which is not critical.

The amp worked the first time I plugged it in, and Figure 3 shows the distortion curve:

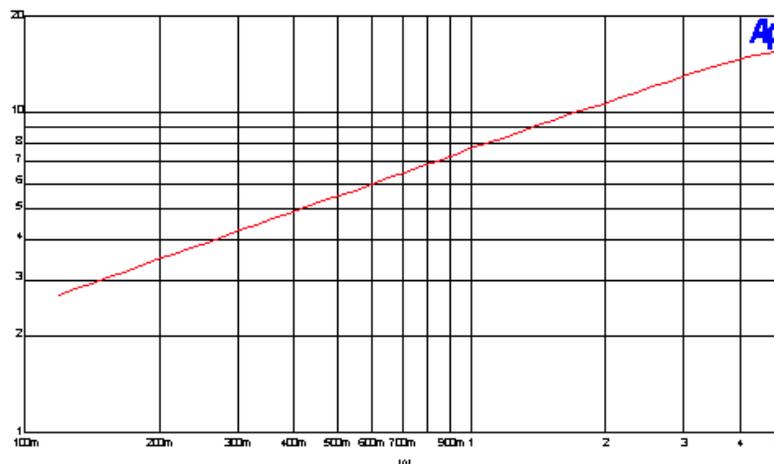


FIG 3 THD vs OUTPUT

2 watts of power into 8 ohms with about 10 percent distortion (I've seen worse).

I hooked it up to a pair of full range speakers in open baffles and gave it a listen: On the plus side, it has plenty of gain. On the minus side, the 2nd harmonic distortion is high, even at low power. If you own efficient speakers (like 93 to 100 dB/watt) and listen to simple music (a vocal and guitar for example), then

this amp might take care of you, but it will get congested pretty quickly with orchestral crescendos.

In the meantime **it does play music**, and you can spend some quality time educating your ear and learning a bit about it before we take up a soldering iron to make it better.

By the way, please note that the circuit as presented has a rather large turn-on and turn-off thump. You can power it up and down slowly with a Variac, or you can short the output terminals to ground during turn-on and turn-off (I used clip leads) so as to protect delicate drivers. The Variac solution is a particularly good one, as it allows you to adjust the voltage easily, and we will be doing some of that later. There are some decent ones starting at \$49 at www.mpja.com and if you're going to get addicted to building power amps you might as well get this purchase over with.

Note that there is no input static protection, so exercise a little care when connecting your preamp to the input. Also, there are no “gate stopper” resistors on the Gate pin of the transistors. If by chance your Mosfet looks like it's misbehaving, then 47 ohms or so in series with the Gate might be appropriate.

Depletion Mode Mosfets

This transistor is an unusual part, the Ixys IXTH20N50 *depletion mode* Mosfet. I got them from Digikey for about 6 bucks (and I had to buy 60). If you don't want 60 of them, then look around or check the group buys at www.diyaudio.com.

There's a reason to try *depletion mode* Mosfets instead of usual *enhancement mode* devices. Mosfets conduct current based on the relative voltage between the Gate and Source pins. *N channel* Mosfets (like this one) conduct more current as the Gate becomes more positive with respect to the Source. In enhancement mode N channel Mosfets, the transistor is turned off when the Gate is at the same voltage as the Source. With depletion mode N channel Mosfets, current flows when the Gate and Source are at the same voltage, and it takes a negative Gate voltage to turn off the device. Figure 4 shows the characteristic curves of the two types.

You can see from the curves that it takes a few volts of V_{gs} to get the enhancement mode device going, but the depletion mode part conducts with no encouragement. In the case of the Ixys IXTH20N50 in our amplifier, the current is around 1.7 amps when the both the Gate and Source are grounded.

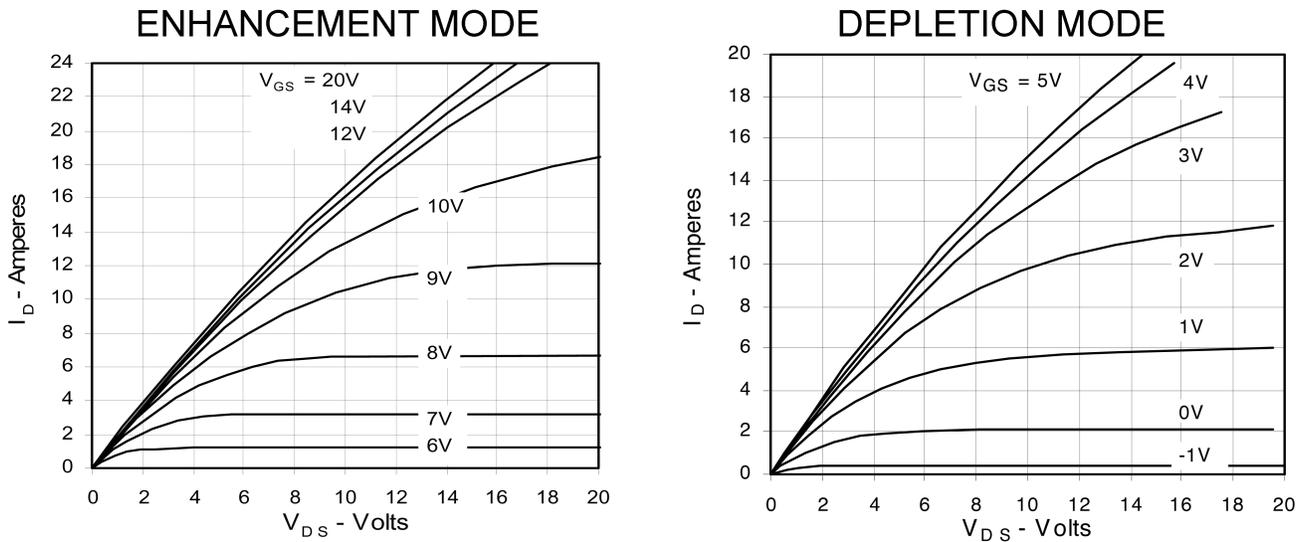


FIG 4 MOSFET CHARACTERISTIC CURVES

Well, that's convenient – Our little amplifier doesn't need any additional circuitry to set the Class A bias current. Like tubes, depletion mode FETs can be self-biasing, and that makes the amplifier simpler. And simple is the *raison d'etre* of this design.

Version 2

The first effort works, but with the high distortion, it's hard not to want to monkey with it. After you have basked in the glow of accomplishment and light bulbs for a while, perhaps you will feel ready for a little more effort.

In this case, that means a couple more parts. Placing a power resistor on the Source of the Mosfet will lower the gain and distortion. After a little testing, I settled on a 1 ohm power resistor, as seen in the schematic of Figure 5. Frugal guy that I am, I used the same resistor as in the power supply.

This takes the gain down to about 13 dB and lowers the distortion. Of course adding just one part would be too easy - we still need to keep the Gate and Source at the same voltage, so we end up moving the input resistor as in Figure 5. Incidentally, this will raise the input impedance to 4 or 5 times the value of the resistor. This is the amplifier that was demonstrated at Burning Amp with a lower supply voltage, but afterwards I decided that it sounded better with 80 volts as shown here.

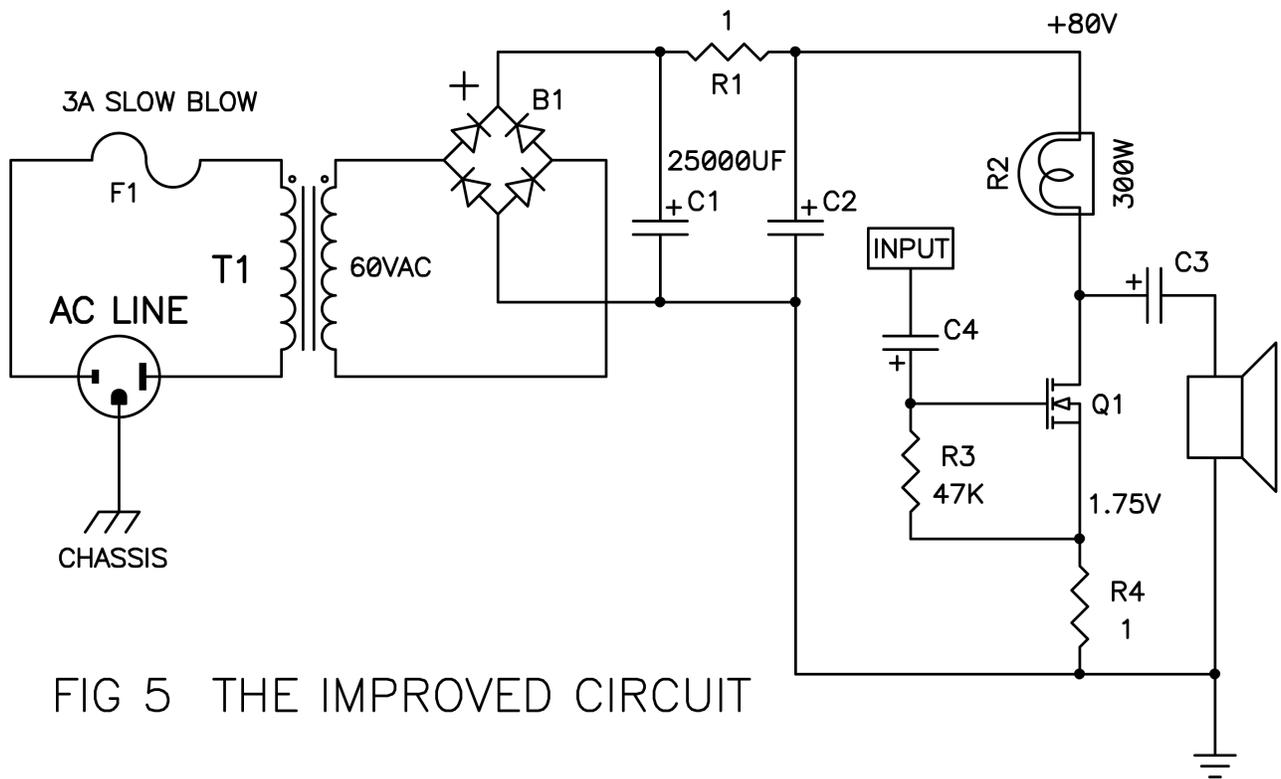


FIG 5 THE IMPROVED CIRCUIT

And now we need an input capacitor because the input has a non-zero DC voltage (same 1.75V as across the new Source resistor), unless you are certain that your preamp is capacitively coupled and has no resistor to ground at the output. 10 uF is a fine value.

Figure 6 shows the distortion vs output power into 8 ohms after these changes.

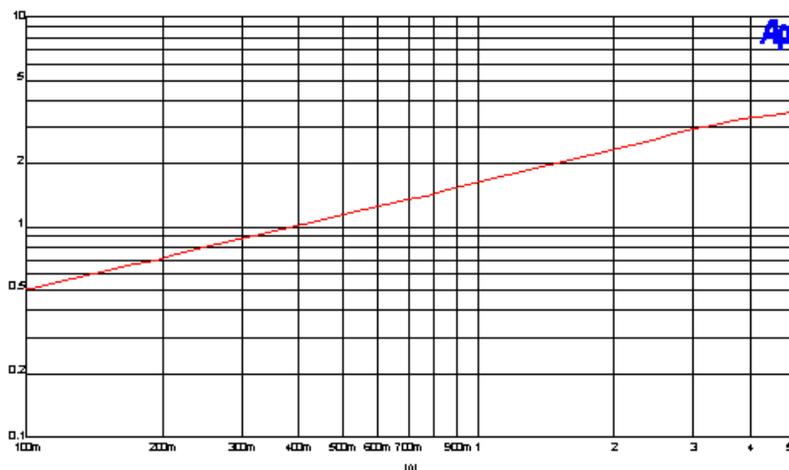


FIG 6 THD VS OUTPUT WITH 1 OHM DEGENERATION

This version (with a lower supply voltage) was played to an audience at BAF, driving a pair of field coil Lowther PM6A full range drivers with Eminence Beta 15 woofers, all mounted up in a pair of BOBs (the Big Open Baffle project - coming soon). In conversations with attendees, I heard unanimous (if polite) praise of the sound.

Well OK, it's a little more complicated now, but it sounds so much better. The mid-band distortion is now comparable to either a really good 300B SET (single-ended triode) *without* negative feedback or perhaps an ordinary one *with* feedback. There is still more we can do, but perhaps this is a good time to stop and have another listen.

Version 3

So maybe you really don't like that input capacitor. I know lots of people who hate them, laying awake at night. There is an alternative that gets rid of it, which is a slightly different Ixys part number, IXTH6N50D2. It runs at about the same current but with a negative Gate to Source voltage equal to the voltage across the Source resistors of Fig 5. This results in approximately the same bias current with the Gate referenced to ground, thus no need for the capacitor. This is seen in the circuit of Figure 7.

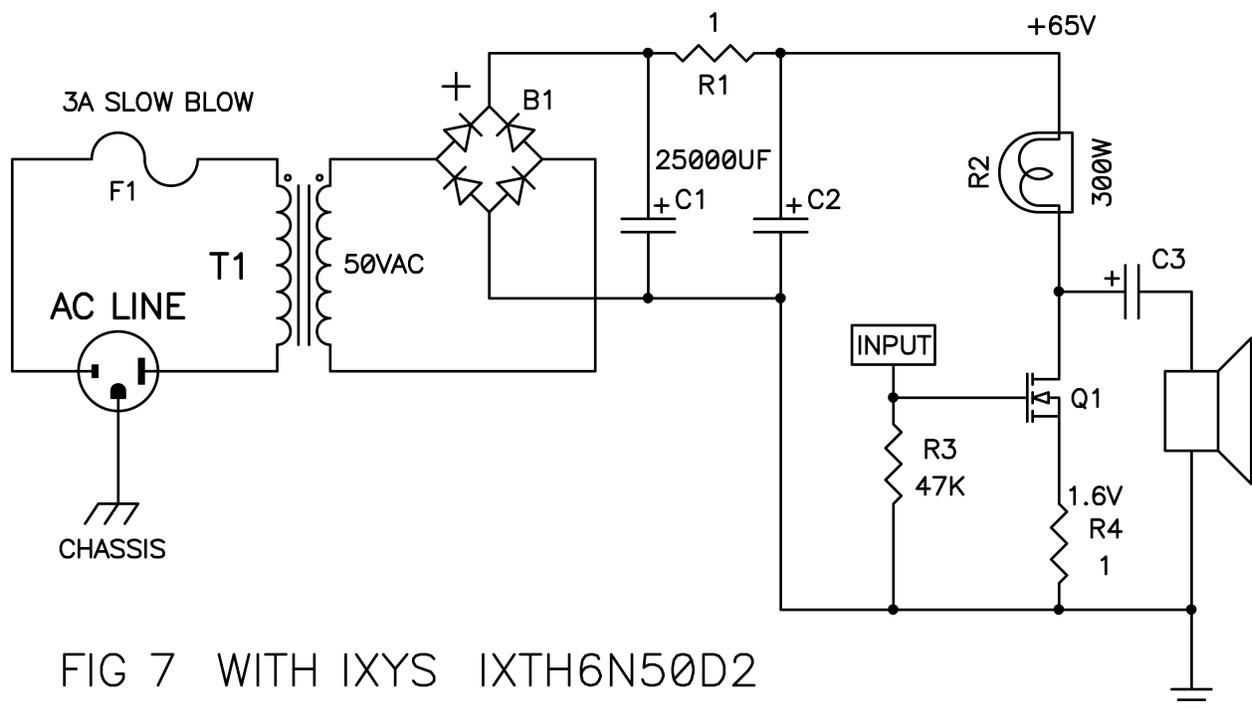


FIG 7 WITH IXYS IXTH6N50D2

As an added bonus, the distortion is about 30% lower than that of the IXTH20N50, as seen in Figure 8:

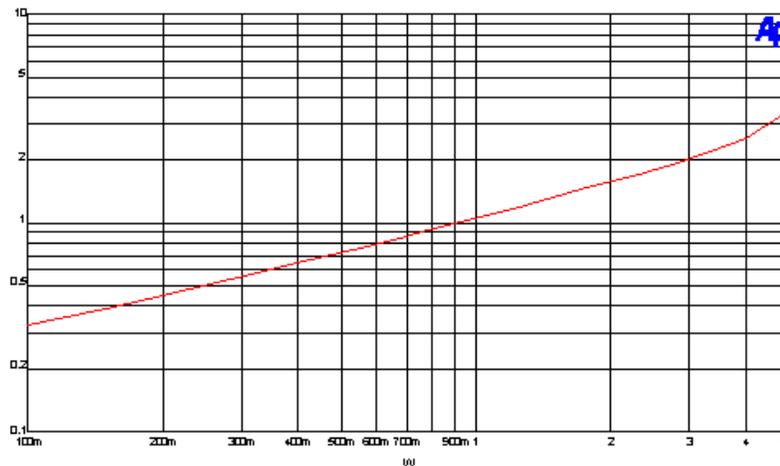


FIG 8 THD VS OUTPUT IXTH6N50D2

Definitely better, no? We pause in rejoicing to note that the IXTH6N50D2 has a little more input capacitance which is also more non-linear than the IXTH20N50. This will raise the distortion at the top end if driven by a preamp with a high source impedance, otherwise the distortion figure should be flat across the audio band.

I don't think this will be an issue unless you run this device with a "passive preamp" with a high source impedance. I surmise that since the gain of this amplifier is not so high, most of you will be using an active preamp anyway.

De-Lux De-Lite

We are not at all finished. First we can crank up the voltage and current a bit. Figure 9 shows the distortion curve of Figure 5 operated at 100V DC supply and bias current of 2.2 amps.

As the light bulb glows brighter, the distortion continues to decline and the power increases. And the transistor runs hotter, so take care that you have enough heat sink. We are getting into the 50 to 60 watt dissipation territory for devices which are rated at 300 watts, and with care mounting the transistor, it should be plenty fine if you can put your hand on the sink for 10 seconds (50-55 deg C.)

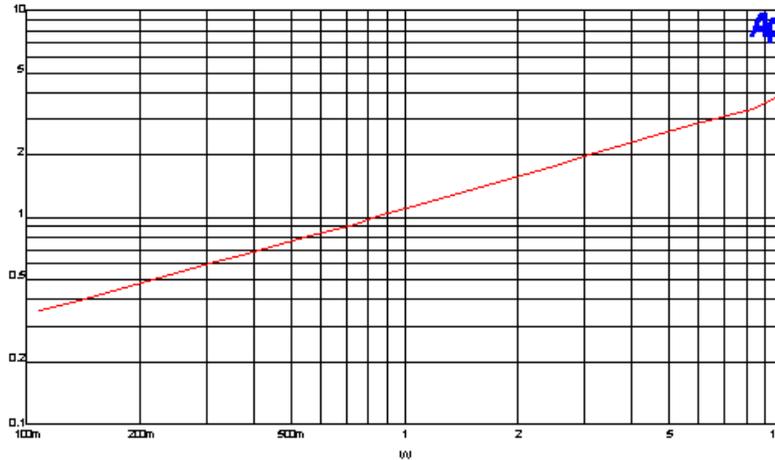


FIG 9 IXTH20N50D, 100V SUPPLY, 2.2A

We can do much the same for the IXTH6N50D2, and Figure 10 shows the circuit of Figure 7 at 100V DC and 2.2 A. This requires a Gate voltage in between the Source and Ground voltage, so we adjust the input bias with a potentiometer as shown. Typically a 10K pot will end up being adjusted for about 25V DC at the Drain of the transistor. If you want to use an enhancement mode part (an IRFP240 for example) you can obtain the positive Gate voltage needed by tapping the potentiometer to the Drain of the transistor instead of the Source.

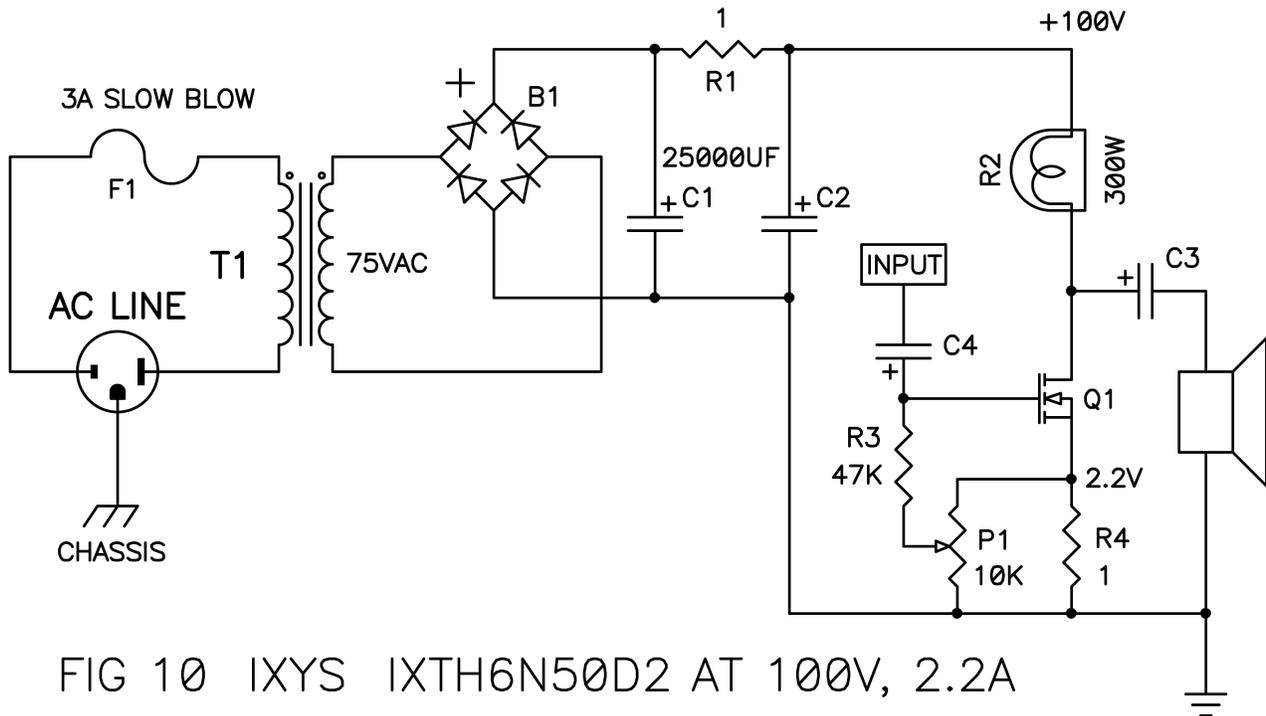


FIG 10 IXYS IXTH6N50D2 AT 100V, 2.2A

Its performance offers more improvement, as seen by the distortion curve of Figure 11. Now we are surpassing the 300B SETs *without* feedback, and are into the zone of good 300B SETs *with* feedback.

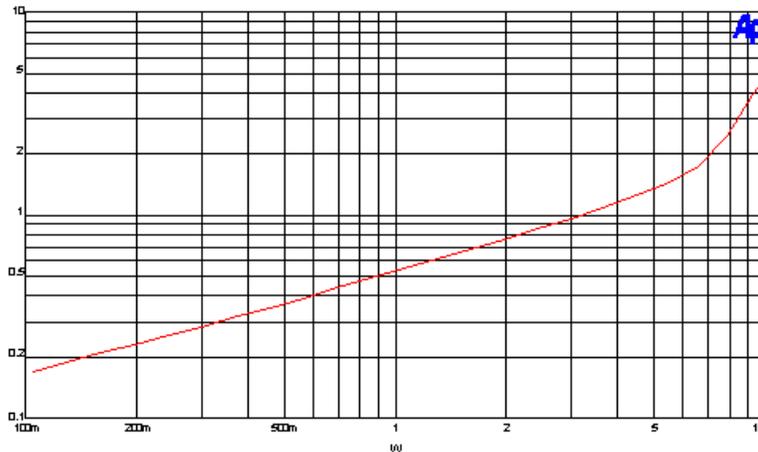


FIG 11 IXTH6N50D2 AT 100V SUPPLY, 2.2A

In general, transistors will vary in their bias voltage values, as will your supply voltage and also the actual resistance of your light bulb. The potentiometer arrangement in Figure 10 is an easy way to deal with any case where the Source and/or Drain voltages are not close to the examples shown here.

We can stop right there and be pretty happy. To give you a taste of what to expect from even better transistors coming out of the labs these days, I have a distortion curve from a part which is not yet on the market but which you will eventually be able to drop right in. Figure 12 shows a depletion mode power JFET placed in the circuit of Figure 7 but with an 80 volt supply.

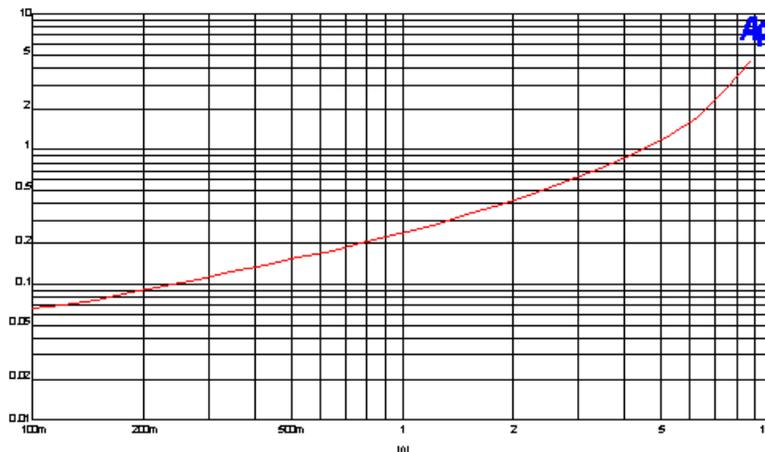


FIG 12 DEPLETION JFET @ 80V SUPPLY, 1.8A

At 1 watt, the distortion here is about 30 dB lower than our first effort. You can do better than this still, but given the current state of transistor art you will probably have to make the amplifier more complicated; adding more parts, more gain stages, active current sources, feedback, and whatnot.

Without doing that you can still take advantage of improvements offered by power supply filter and regulator circuits as shown in Zen Variations #3. These will reduce noise and add more stability.

You can also think about an input and output switch for protection. The input switch is closed when you want to safely connect and disconnect input leads and avoid any possibility that static discharge will damage the Gate of the Mosfet.

Alternatively you can put some back-to-back Zener diodes at the input to ground for that. However it seems every time I present a schematic that shows some form of circuit protection like this, DIYers insist that it sounds better without it.

You can use a big *knife switch* like in the Frankenstein movies to ground the output when the amp is being turned on and off to avoid damaging little girlie-man full range drivers. Or perhaps one of you advanced DIYers will offer up a circuit to do these things automatically.

Zen Variations #3 is a good place to see examples of grounding safety and means of isolating against ground loops, and I sincerely recommend that you pay close attention to this issue to prevent possible injury. Keep in mind that you are playing with voltages that should always be respected.

Stone Soup

We started out with with a totally minimalist piece intended to get you off your butt and building something. Like Stone Soup, the initial result wasn't very impressive, but with small incremental additions it became a pretty special amplifier. You are invited to share questions, comments, photos and improvements on the friendly *no-question-is-too-dumb* De-Lite thread in the Pass Labs forum at:

www.diyaudio.com