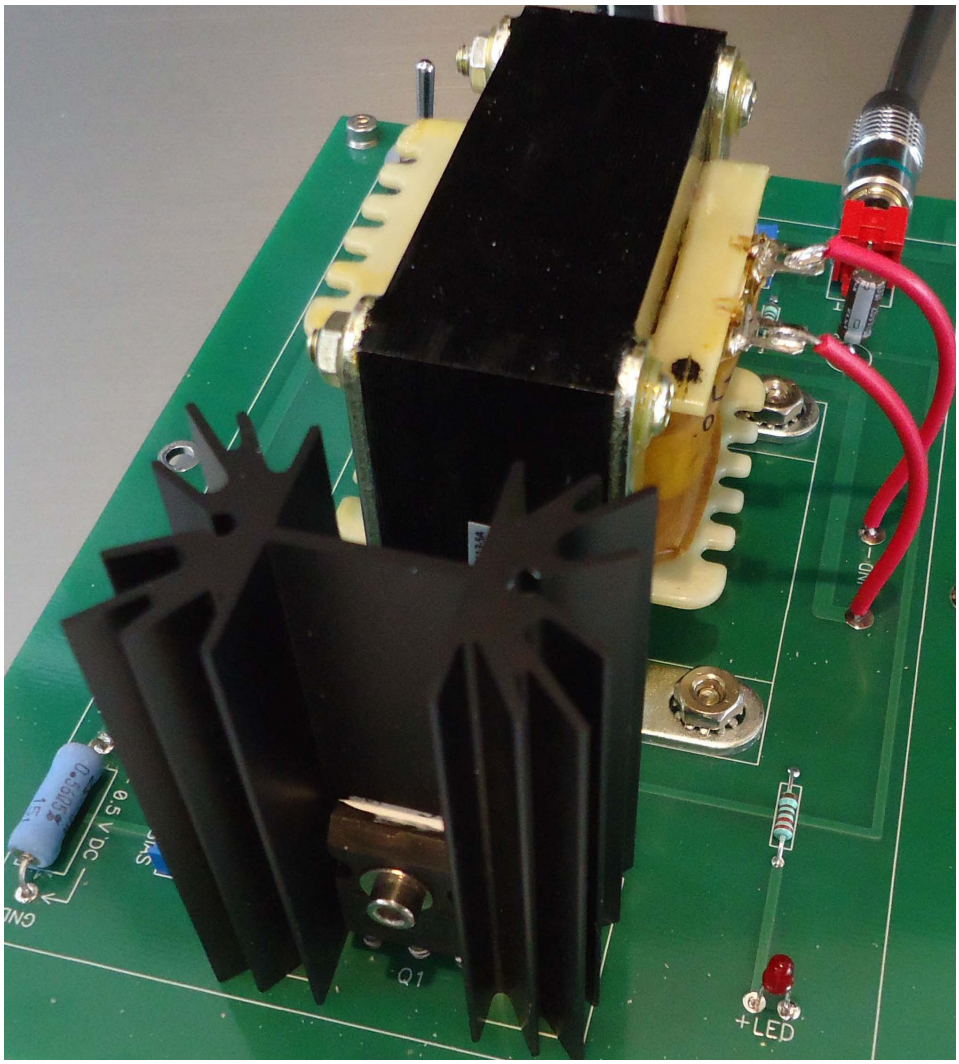
THE *ZENDUCTOR* AMPLIFIER
BURNING AMP 2023

Mike Rothacher and Nelson Pass



The first Zen Amplifier was a project presented in 1994 in Audio Amateur Magazine. It featured a single gain stage and offered the sound of “one transistor clapping” and has been the basis for a number of variations. Mike and I decided that it would be an excellent theme for this year's Amp Camp at the 2023 Burning Amp Festival.

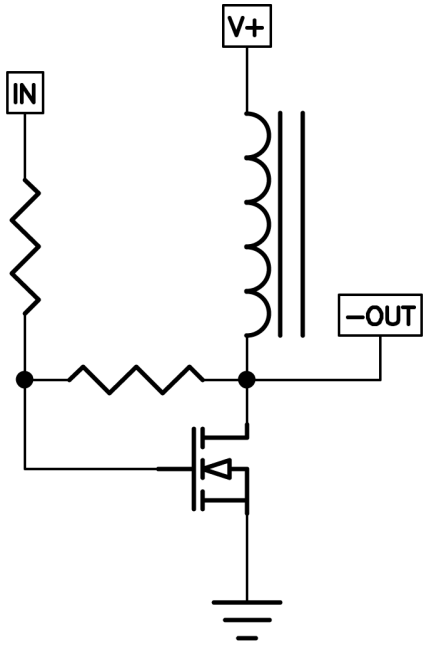
We wanted a simple single-ended single stage easy design with lots of sex appeal. Mike had some inexpensive Triad power inductors (coils) and was interested in using them in an amplifier using a single power Mosfet. His original concept used the Mosfet as a follower with the inductor connected between the Mosfet Source pin and Ground.

It worked very well, with the attractive quality of a single gain device, however it had only current gain, no voltage gain. As an alternative we decided to reverse the position of the inductor to connect between the Drain of the Mosfet and the positive supply. This gives lots of voltage gain which comes at the expense of higher distortion.

However you can use some feedback to trade the excess voltage gain into lower distortion. *Ugh! Feedback! No Likee!*

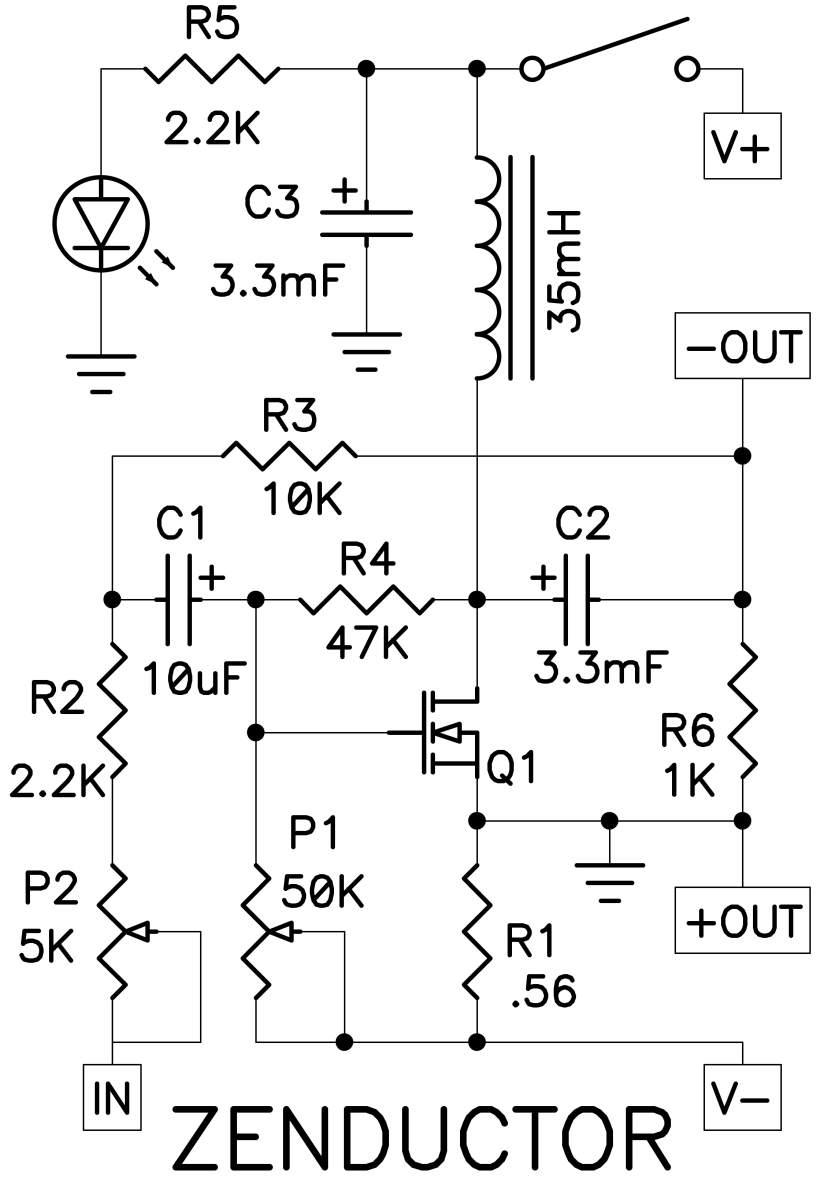
However there is a form of local feedback commonly called *Schade feedback* described long ago by O.E. Schade where a local loop around a single gain device can be used to not only lower the distortion and the output impedance but also make the device emulate a Triode character. *Hmmm... Maybe Not So Bad....*

Here is a simplified schematic of what the project ultimately became:



You can see an N channel Mosfet with the Source pin at ground and the Drain connected to an inductor coil which in turn sees a positive voltage power supply. A simple *Schade* feedback network connects the input signal, the Gate of the Mosfet and the output.

Of course there are going to be more parts than this, if only to provide the right DC voltage values to make it work, so here's the actual schematic that we finally settled on:

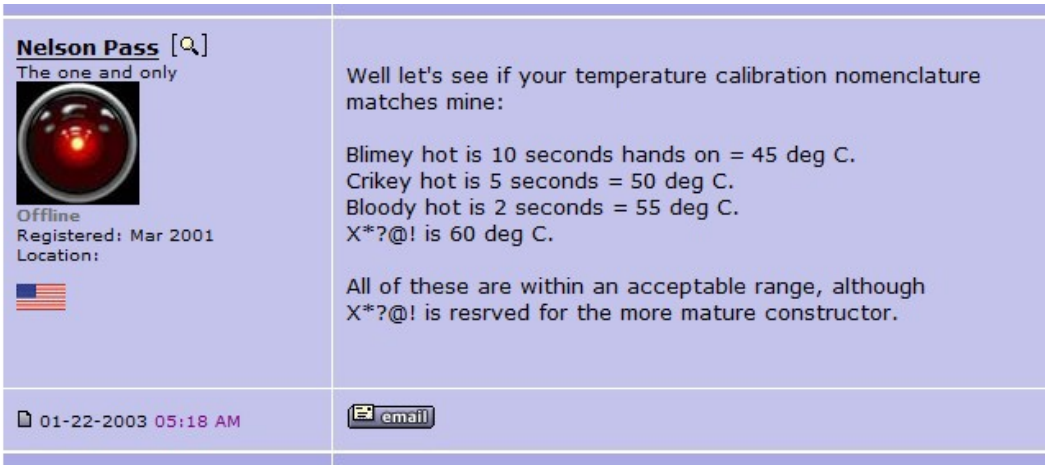


R1 is a power resistor used to stabilize the Mosfet bias current of about 1 amp over a range of temperatures. Without it the bias current would wander up dramatically with temperature, however, the circuit is arranged such that this resistor doesn't degenerate the gain transistor.

R2 and R3 are the *Schade* feedback network, and they set the amplifier gain. Potentiometer P2 in series with R2 allows gain adjustment from 0 dB up to +10 dB. This adjustment affects the gain and the distortion and the input impedance of the amplifier, and you can play with it as you like, keeping in mind that at 0 dB the input impedance is about 8 Kohm and at 10 dB it's about 3 Kohm.

R4 and P1 set the bias current of the Mosfet, and P1 is adjusted so as to create a value of 0.5V DC across the power resistor R1. It is important that this voltage value is correct – too low and the performance suffers. Too high and the temperature of the Mosfet mounted on its heat sink will be high. It's already plenty high, and the bias will drift upwards as the heat sink gets hotter.

You will need a DC voltmeter. We are aiming to have that voltage settle in at 0.5V, and we arrive at this slowly. You want to start at around 0.4V and then watch it drift up, adjusting it in small steps, as it will tend to overshoot if you go directly to the target value. This is best done in an environment similar to where the amp will be located, and it should be checked again there. The 0.5V setting will give about a 50 deg C. sink temperature above the environment. This is hot, and you can expect to only be able to touch the sink momentarily.



This is well beyond Crikey hot, but will not break the Mosfet. Pretend the sink is a big power tube, and treat it with the appropriate caution.

And yes, there are three capacitors in the circuit – gotta have 'em. One to bypass the supply and two to block DC bias voltages.

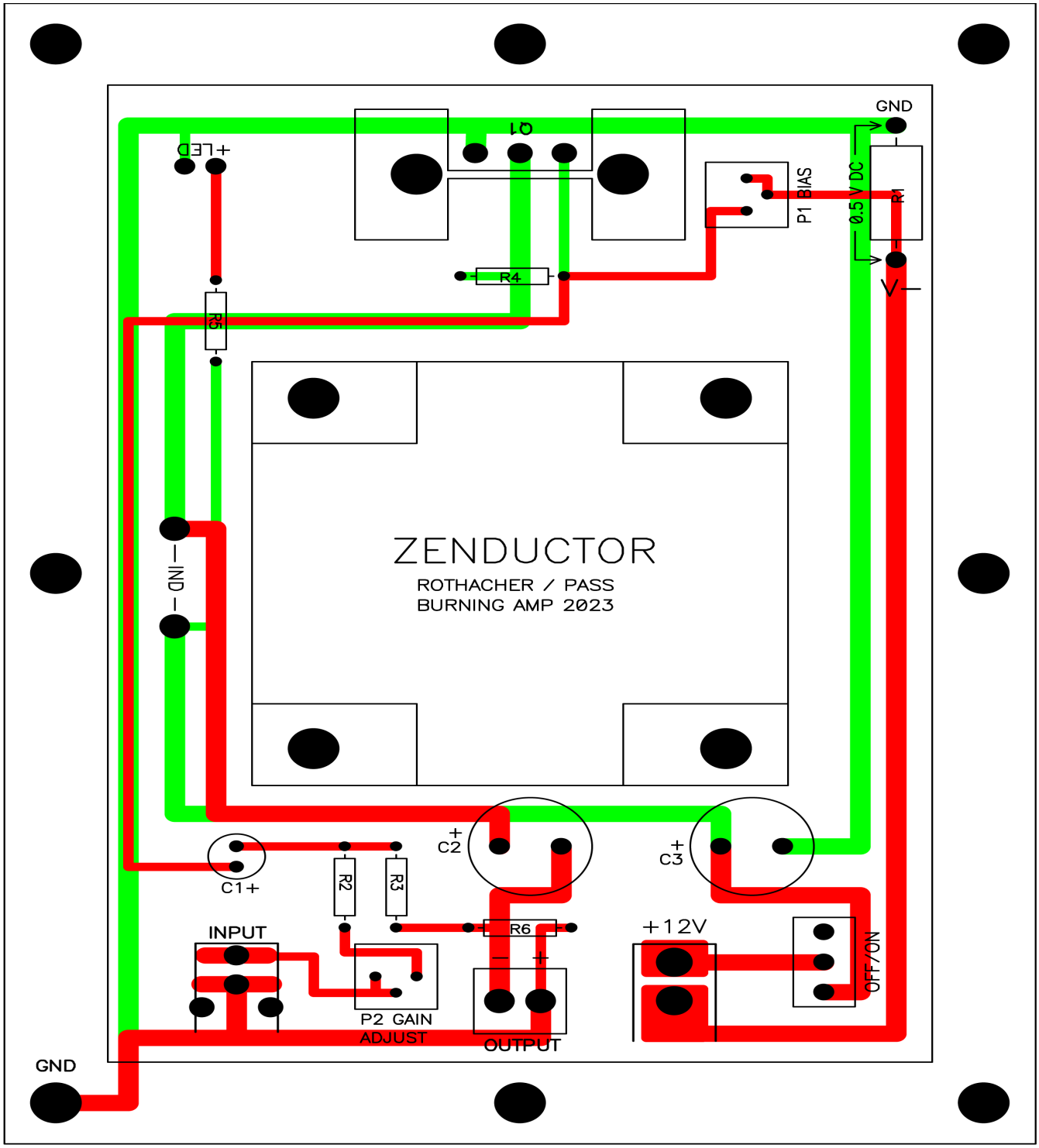
The kits at BAF will contain everything needed. Here is the Bill Of Materials for the amplifier:

ZENDUCTOR BOM

PARTS ARE FOR PAIR OF CHANNELS

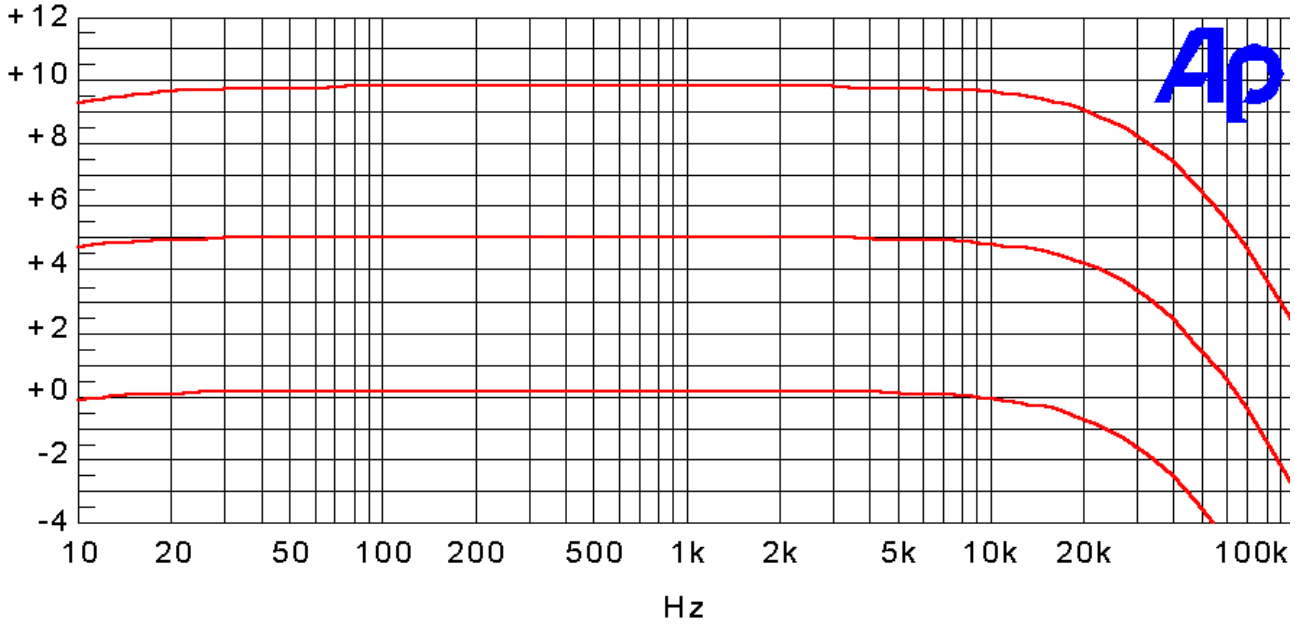
PART #	DESC	QTY	COMMENT		
PCB	PCB	2	ZENDUCTOR PC BOARD		
	POWER SUPPLY	2	12V 3A DESKTOP		ISOLATED 2 PRONG AC
Q1	IRFP048	2	N CHANNEL POWER FET		
	INDUCTOR 35mH 2A	2	TRIAD C-56U		
	HEAT SINK	2	AAVID PC MOUNT	DIGIKEY	HS380-ND
	POWER CONN	2	CUI PC MOUNT	DIGIKEY	CP-037AH-ND
	SWITCH	2	SPDT SWITCH PC MOUNT	DIGIKEY	EG2355-ND
	INPUT RCA	2	RCA INPUT PC MOUNT	DIGIKEY	RCJ-046
	OUTPUT CONN	2	TERM BLOCK 5MM 2 POS	DIGIKEY	ED1609-ND
P1	50K OHM POT	2	BIAS POTENTIOMETER	DIGIKEY	3386P-1-503LF
P2	5K OHM POT	2	GAIN POTENTIOMETER	DIGIKEY	3386P-1-502LF
LED	LED	2		DIGIKEY	160-1853-ND
R1	.56 OHM RESISTOR	2	3W	DIGIKEY	RR03JR56TB
R2, R5	2.2K RESISTOR	4	0.4W	DIGIKEY	SFR2500002211FR500
R3	10K RESISTOR	2	.4W	DIGIKEY	SFR2500001002FR500
R4	47K RESISTOR	2	.4W	DIGIKEY	SFR2500004752FR500
R6	1K RESISTOR	2	.4W	DIGIKEY	SFR2500001001FR500
C1	CAPACITOR 10UF 25V	1		DIGIKEY	604-RCRBD100K1TC11300T
C2, 3	CAPACITOR 3300UF 25V	2		DIGIKEY	1189-4062-ND
	SCREW M3X8 SOCKET	2			TRANSISTOR – HEAT SINK
	KEPNUT M3	2			TRANSISTOR – HEAT SINK
	WASHER 6-32 X 0.5” D	2			TRANSISTOR – HEAT SINK
	THERMAL GREASE				TRANSISTOR – HEAT SINK
	SCREW 6-32 X 3/8”	4	6-32 X 3/8”		INDUCTOR MOUNT
	KEPNUT 6-32	4	KEPNUT 6-32		INDUCTOR MOUNT
	SCREW 6-32 X 1/4”	4	6-32 X 1/4”		PCB FEET/MOUNT
	STANDOFF 6-32	4	6-32 X 3/8”		PCB FEET/MOUNT
	WIRE	1	1' @ 20G		

Here is the PC board, red on top, green underneath.



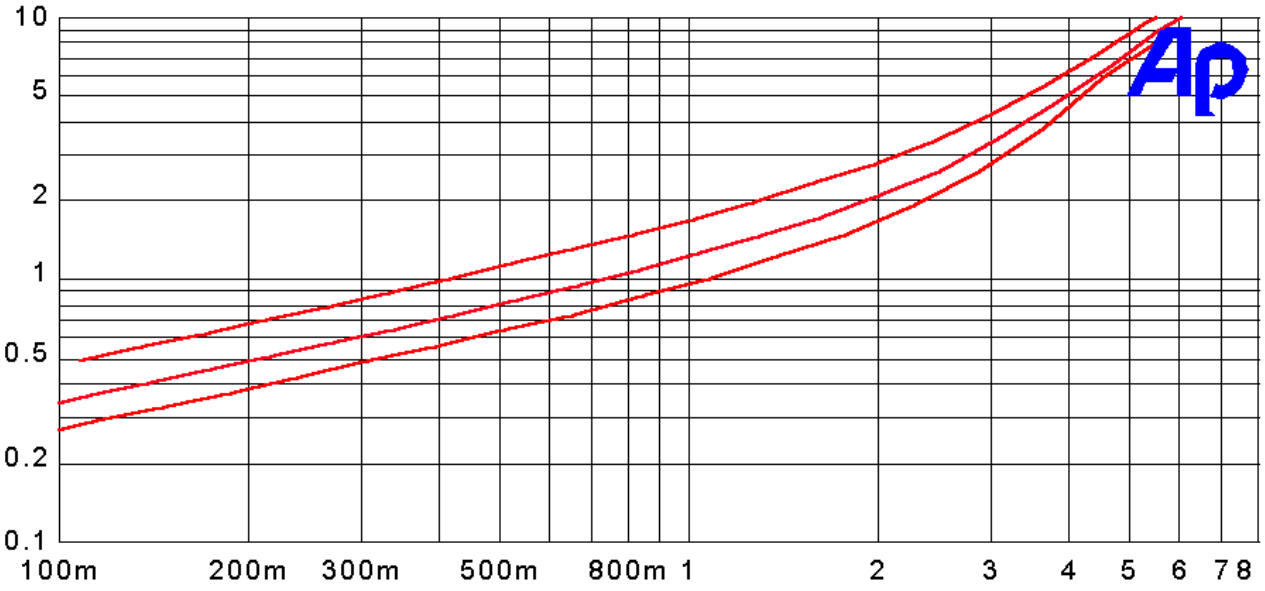
In the following curves, the gain has been set to 0 dB, +5 dB and +10 dB and the load is 8 ohms.

Response curve into 8 ohms showing gain settings:



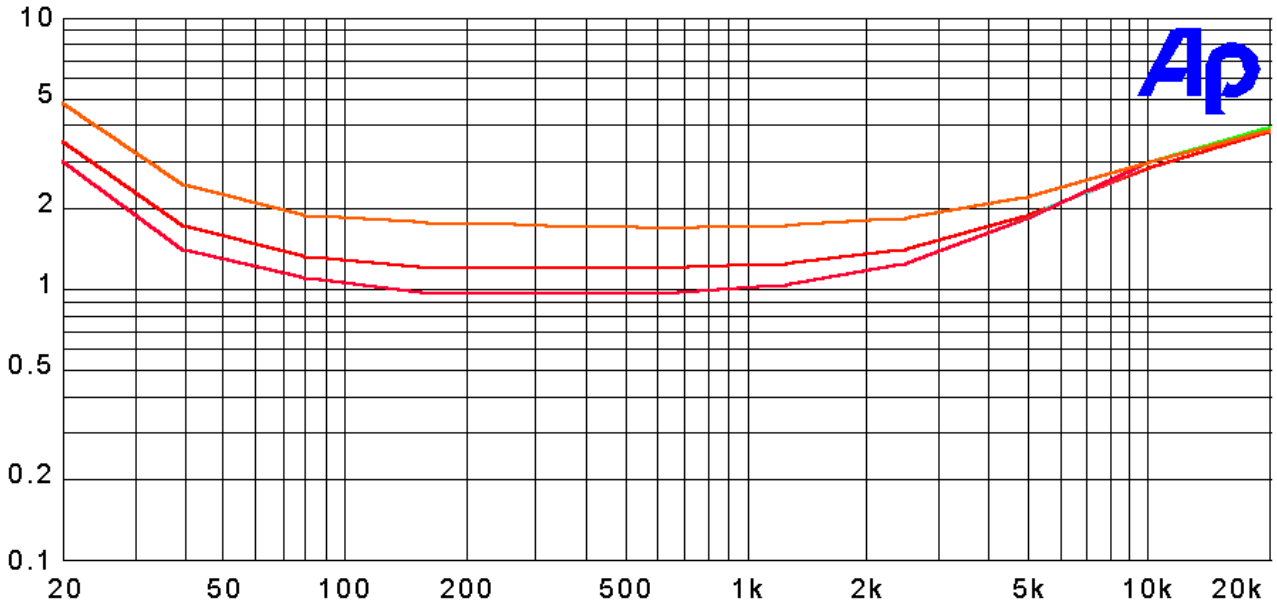
RESPONSE VS GAIN AT 0dB 5dB 10dB

Percent harmonic distortion vs output into 8 ohms:



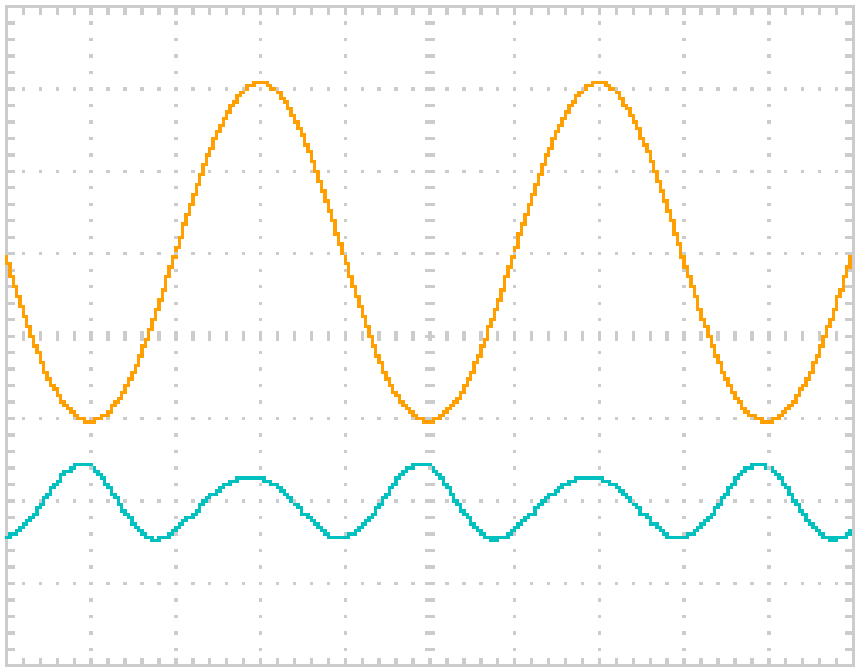
% THD vs OUTPUT WATTS @ 8 OHMS

Distortion percentage at 1 watt over the audio frequency range:



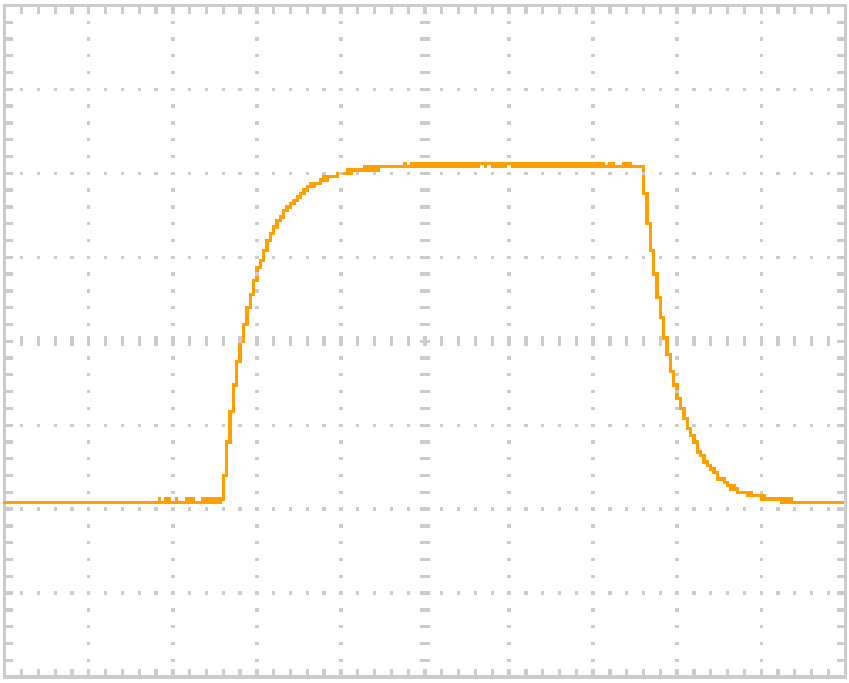
% THD vs FREQUENCY @ 8 OHMS 1 WATT

Distortion waveform at 1 watt showing the 2nd harmonic character:



DISTORTION WAVE @ 1W

And here is the 10 Khtz square wave at 2 watts into 8 ohms:



SQUARE WAVE @ 10 KHZ

Lastly, the Damping Factor is 10 into 8 ohms with the 5 dB setting.

NP's commentary: Surprisingly good sound. Very Triode-like, with excellent detail and smooth quality with vocals and strings. The positive phase 2nd harmonic adds warmth to the midrange, but doesn't seem to damage the spatial presentation as might be expected.

With these power and distortion figures, I would presume the amp will particularly appeal to efficient full range drivers, but I was surprised when I hooked them up to my SR-1's, an 87 dB sensitivity and 3 ohm impedance. That they drove them at all was hardly expected, much less well, but they sounded good. In general though, 8 ohms and 90+ dB sensitivity is probably what you would want, and even then you wouldn't probably aim them at disco music. All I can say is that so far everyone who's heard it has liked it...

A few words from Mike:

Here's a little preemptive truth-telling: I have a nostalgia problem. I say this as I clutch my mint-condition 1994 second issue of Audio Amateur magazine with "Zen" emblazoned in four-inch blue calligraphy on the front cover. When that issue arrived, I was already living vicariously through the Triode Mafia, binging on schematics from Sound Practices, dreaming of building one of those sweet minimal, single-ended works of audio art. But, alas, high-voltage, and high price tags kept me in the shadows.

But then, dropped on my doorstep, comes an article by Nelson Pass, the guy who did the "A40", and the guy who famously almost died from over exposure to loudspeakers (talk about suffering for your art). The Zen article detailed a single-stage, single-ended amplifier that I could *actually* build, and this started a lifelong obsession which corrupts me to this day.

Flash forward thirty years, I have grey hair…and lots of amps, lots of plans for amps, lots of parts for amps. What can I say? It keeps me off the streets. So, when Nelson generously invited me to contribute to the BAF 2023 build camp project, I was thrilled to say the least. Now for clarity, my contribution generally amounted to cheerleading, cajoling, radical brainstorming, a little prototyping, imposing unreasonable constraints, and choosing the color of the solder mask. From the start, I had my heart set on a super beginner-friendly project. I wanted a 12V power supply. I wanted monoblocks (because monoblocks are cool). It had to be ridiculously easy to assemble. It had to have a nice hunk of iron in it. It had to sound like a sweet little flea-watt SE tube amp. And, to top it off, it had to be cheap.
All totally unreasonable. And yet…

Nelson disappeared into his lab for a few days, some clanging and banging could be heard, a few bright blue flashes and puffs of ozone perhaps, and then he emerged with Zenductor!

It was awfully nice of Nelson to let me play along on this one. I had a ton of fun. It's a great little project that I'm confident you will enjoy building and listening too. If you have been waiting in the shadows to learn to solder and build some amplifiers of your own, seize this moment and be fearless!

After Afterword from NP:

It was all his idea, I just removed parts from the schematic ;)

Construction Tips

OK, you have the parts. You have a soldering iron and you know how to solder. You have a multimeter and a small screwdriver and hex socket driver set. Your wife is letting you use the kitchen table for an hour. You're ready to go...

The fabulous Jim Tiemann, "6L6" at diyAudio will have a build guide out any minute, but we will lay out a few basics just in case.

Start by comparing the parts you have with the BOM. If it's all there:

Install the resistors first. Use your multimeter to check the resistance before you install and solder.

Then install the potentiometers. Since there is a 5K and 50K there might be some confusion. The 5K is "502" and the 50K is "503". Check with the multimeter as well.

Then the power connector labeled "+12V", The input and output connectors and the switch. It is usually helpful to solder one pin and then get them seated properly before soldering the rest of the pins. Then the three capacitors. Pay close attention to the "+" markings on the pc board and note that the "-" side of the capacitors is clearly marked.

At this point it might be useful to install the four stand-offs that function as feet either in the four corners or on the sides/front as you like. Use the 6-32 X 1/4” socket head screws, not the 6-32 x 3/8”

Then install the inductor with the four 6-32 x 3/8” with the socket heads and 6/32 lock nuts and small washers. You can place the inductor on top (like me) or underneath, but remember to align its terminals with the holes on the board, and put the socket heads on the opposite side of the pc board from the inductor. If there is a photo, take a look at that. Install and solder two wires from the inductor terminals to the holes on the pc board. It doesn't matter which lead goes in which hole.

Install the LED with the long lead going into the hole with the “+”.

Last part: Handle the power Mosfet with care as it is sensitive to damage from static electricity. Smear a thin layer of silicon grease on the metal surface of the Mosfet and attach it Mosfet with the M3 screw and nut and large flat washer to the surface of the sink as you will see in the picture of the amp, where the washer is between the top surface of the Mosfet and the head of the screw. Don't tighten it yet.

Install the sink and Mosfet into the holes on the pc board – the outlines on the board will guide you. If your soldering iron is powerful enough, solder the two heat sink pins to the board, but try not to cook the Mosfet too much. If your soldering iron won't cut it, then save that for another day – the sink will sit fairly snug as it is.

Tighten up the Mosfet to the sink so that that there is a good reasonably tight connection. This is important as the Mosfet will dissipate about 11 watts and will get hot, so you want the thermal resistance between the Mosfet and sink to be low.

OK, now turn the P1 bias at P2 gain pots to full counterclockwise. Attach the Multimeter leads, and set it to read in the range of 0.5V (usually the 2V range). Plug in the 12V power connector.

Now slowly turn the P1 pot clockwise until the voltage across the R1 power resistor reads about 0.4V.

Now become the model of patience...

The bias current of the Mosfet depends partly on the temperature of the transistor. As the heat sink warms up, the bias will increase, so we will start out at 0.4V and watch the voltages across R1 increase until it reaches about 0.5V and then start very gently turning the pot counterclockwise to keep it at 0.5V. Don't get excited as it continues to drift up, it can go higher, just bring it back down and eventually it will settle in.

This is best done at the room temperature where you plan on using it, and you may find yourself adjusting again on occasion, but no big deal. At the 0.5V figure you are at spec, and the surface temperature of the sink will be about 50 deg C above the ambient, or something like 70 deg C. That's quite hot, but the Mosfet will be OK, it's rated higher than that.

Just be aware that it's a hazard and don't let your kids and pets handle it. If it enhances your illusion of tubey sound, just remember that it's about as hot as a power tube would be and treat it with respect.

The P2 gain pot trades voltage gain off against feedback and input impedance. Set it wherever it makes you happy, knowing that more gain equals less feedback more distortion and lower input impedance and hopefully you will find the setting that works for you.

I think that's all there is. If you have questions, problems or comments post them in the Zenductor thread, Pass Labs forum:

www.diyAudio.com

Dedicated to the mighty ZM, patron saint of audio magnetism.
Thanks to WBS for the part # correction.