ZENDUCTOR 2 - BAF 2024 AMP CAMP

by Nelson Pass

Last year's Amp Camp was a big success with the first edition of the Zenductor amplifier, a single-ended Class A design which used a single power Mosfet transistor operating *Common Source* mode (voltage + current gain) into a big inductor (= fancy name for coil). Credit where it is due, the original design idea came from Mike Rothacher and I helped convert it to a kit and also gave it a snappy name ;)

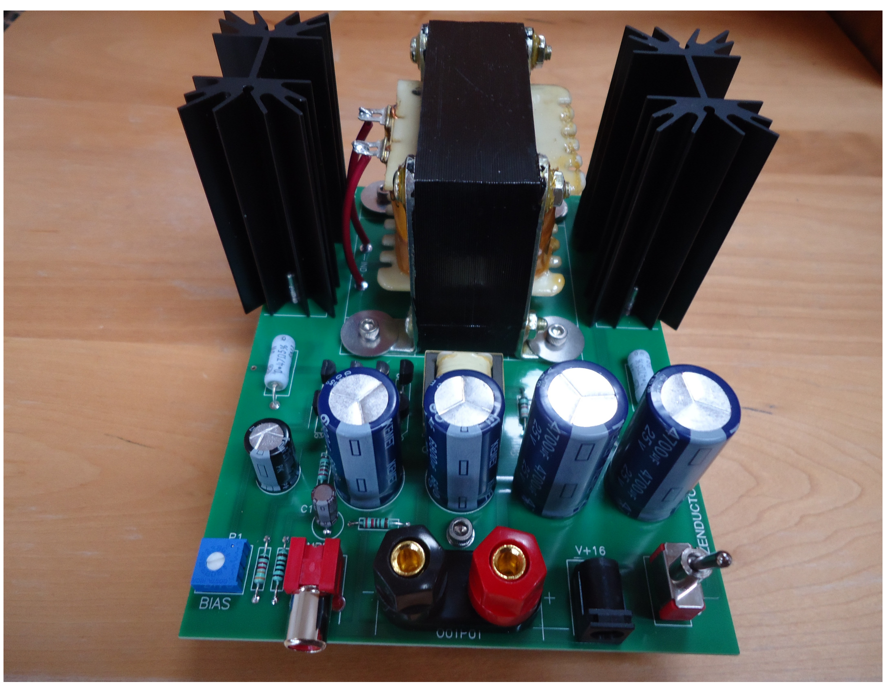
A monoblock mounted on an open circuit board with one little heat sink and using a desktop switching power supply, it delivered about 5 watts of power and quite good sound. Amazingly, all the amplifiers at the event worked well and everyone went home happy.

The fundamental trick with the inductor is that it stores magnetic energy from the DC bias current through the output circuit, and delivers it back as AC voltage, nearly doubling the maximum output voltage and efficiency of this circuit.

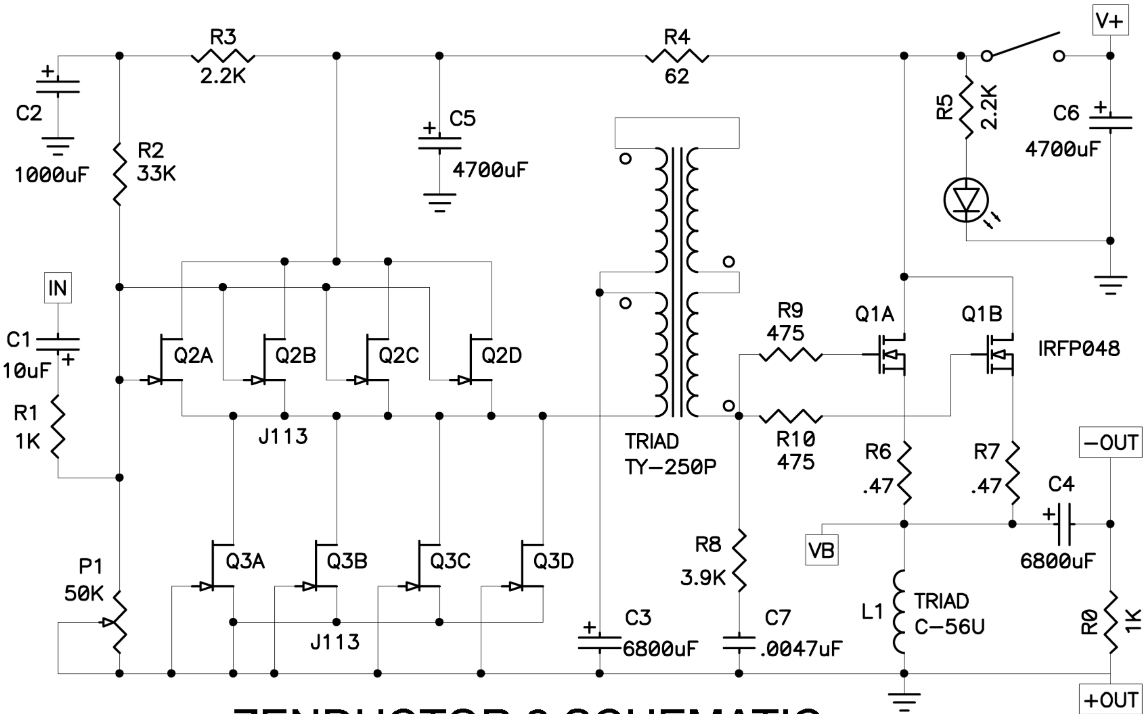
This year it was decided to up the game by creating a more powerful and advanced version using two power Mosfets in parallel operating in Common Drain (follower) mode. This approach offers only current gain, not voltage gain, and the Mosfets are preceded by a Jfet buffer stage driving a small voltage step-up transformer giving 8 dB of voltage gain.

Where the original delivered something like 3 watts at 3% distortion into 8 ohms, this version is good up to 10 watts at about 1% in addition to having a much higher damping factor.

And unlike the earlier version, Zenductor achieves this without negative feedback.



Zenductor 2 is a little more complex than the original. Here is the schematic:



ZENDUCTOR 2 SCHEMATIC

What you see on the right hand side is a parallel pair of N channel power Mosfets Q1A and Q1B operating in Common Drain mode which form the power output stage. They are biased as single-ended Class A followers with their bias (standing DC current) flowing though L1 - a large inductor to ground, giving rise to the “Zenductor” name. This bias current, set by P1 somewhere between 1 amp and 1.5 amps, sets up the stored magnetic energy in the circuit which greatly increases the maximum AC voltage and current swing at the output.

In this way the amplifier can deliver AC output voltage to the loudspeaker nearly twice that of the power supply voltage. In an “ideal” case, it would allow an amplifier to deliver 32 volts peak to peak with only a 16 volt supply. If the inductor were to be replaced by a constant current source or a complementary output transistor with the same supply voltage and current, the “ideal” version of the circuit would deliver ¼ of the power.

Being that the output stage is simply a voltage follower, contributing only current gain, the amplifier needs to get it's 8 dB of voltage gain from an earlier stage, which we see to the left in the form of the Triad step-up transformer driven by a parallel array of Q2 Jfet transistors operated as followers, they being biased in single-ended Class A by an equal number of Q3 transistors forming a constant current source.

Everything else in the schematic is for support. The potentiometer adjusts the bias of the output stage at a DC current value of 1.0 to 1.4 Volts from VB to ground. This voltage across the inductor gives a bias figure of VB/.9 based on the 0.9 ohms resistance of the inductor, so we have options of bias from about 1.1 amps to 1.5 amps. Worth checking is the voltage across R6 and R7 to ensure they are both reasonably sharing the current, within 0.1 volts.

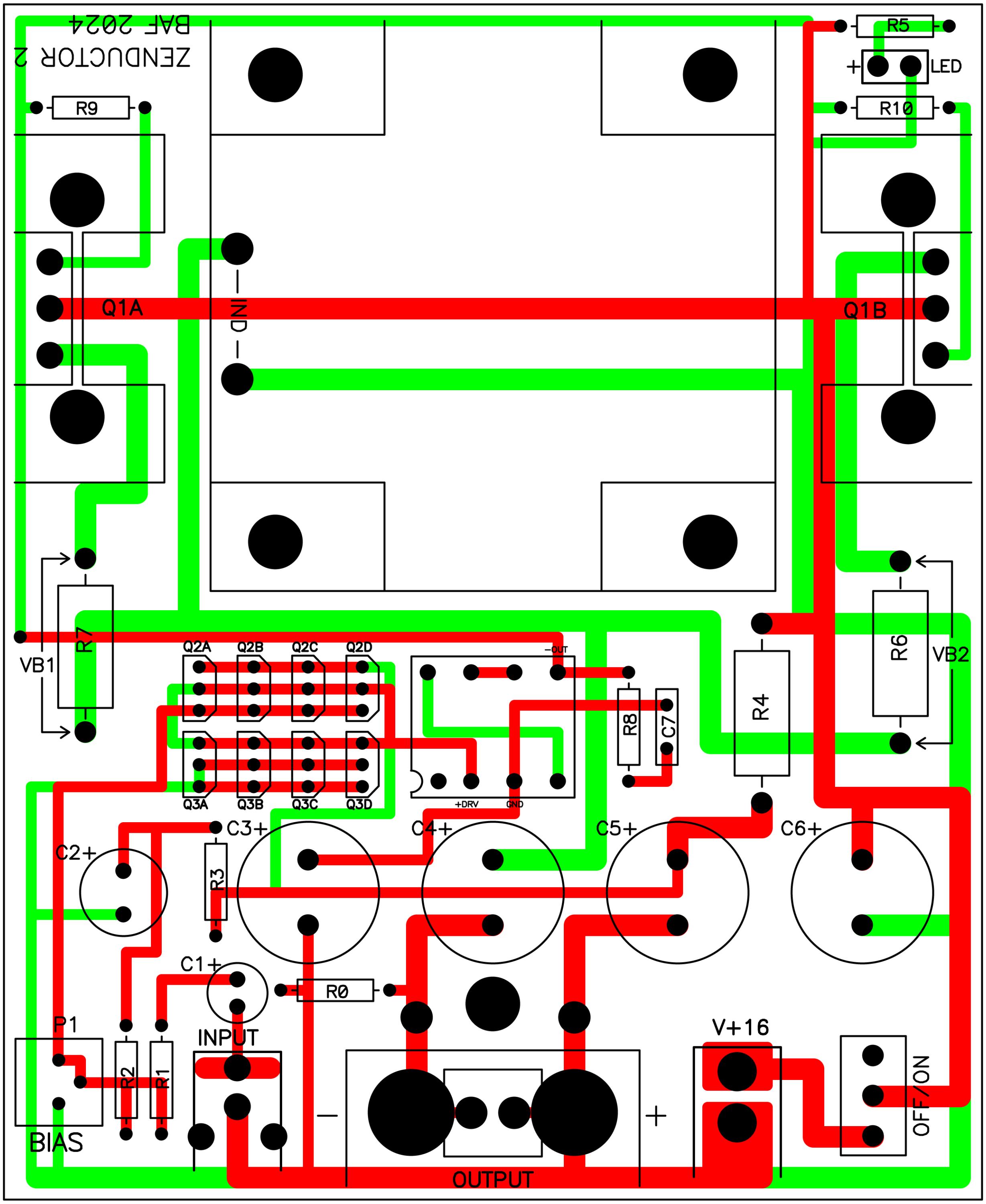
Following is the Bill of Materials for two channels:

BAF 2024 ZENDUCTOR 2 BOM — PER KIT

10/09/24

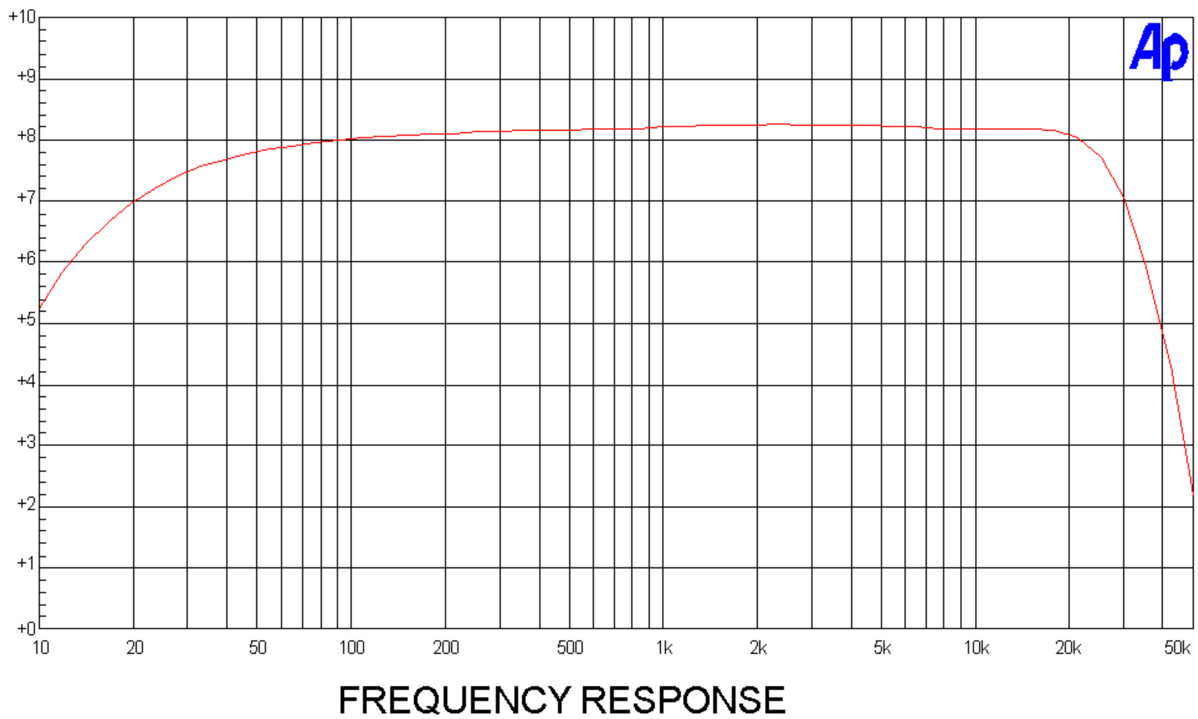
ITEM	DES.	QTY
PC BOARD		2
POWER SUPPLY		2
INDUCTOR	TRIAD C-56U	2
TRANSFORMER	TRIAD TY-250P	2
HEAT SINK		4
SWITCH		2
DC JACK		2
INPUT RCA CONNECTOR		2
OUTPUT BANANA CONN PAIR		2
POTENTIOMETER 50K	P1	2
IRFP048 NCH MOSFET – MATCHED	Q1	4
J113 JFET – MATCHED	Q2, Q3	16
LED	LED	2
.0047uF CAP	C7	2
10 uF CAP	C1	2
1000UF CAP	C2	2
4700uF CAP	C5, 6	4
6800uF CAP	C3, 4	4
0.47 OHM 2W	R6, R7	4
62 OHM 1W	R4	2
475 OHM 0.4W	R9, R10	4
1K OHM 0,4W	R0, R1	4
2.2K OHM 0,4W	R3, R5	4
3.9K	R8	2
33K OHM 0,4W	R2	2
STANDOFFS 6-32		6
8 MM SCREWS		4
8 MM LOCK NUTS		4
#6 SCREWS		10
#6 NUTS		4
#6 LARGE WASHERS		8
18G WIRE PCB-INDUCTOR	2.2” .2” ENDS	4
18G WIRE PCB-OUTPUT	1.2” .2” ENDS	4

This is what the PC board looks like, Red on top, Green on the bottom:

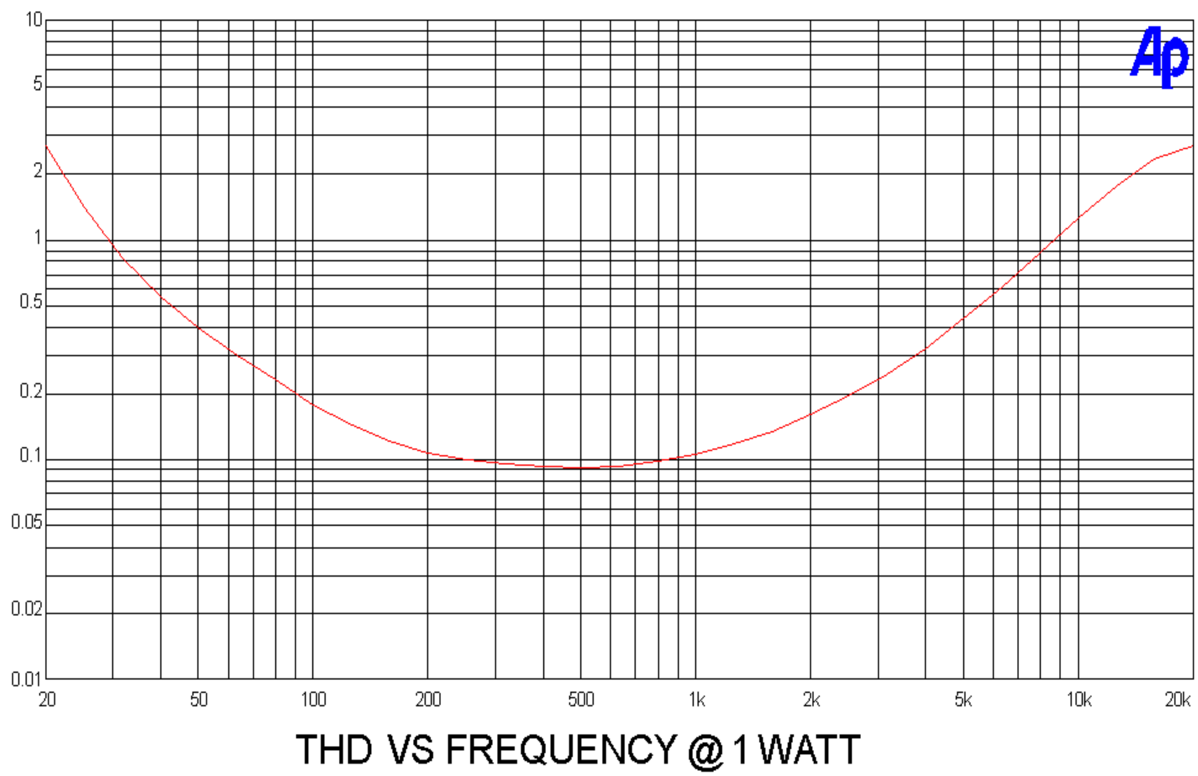


ZENDUCTOR 2 PCB (RED = TOP LAYER)

Here is the frequency response curve into 8 ohms, -3 dB down at 10 Hz and 40 Khz:



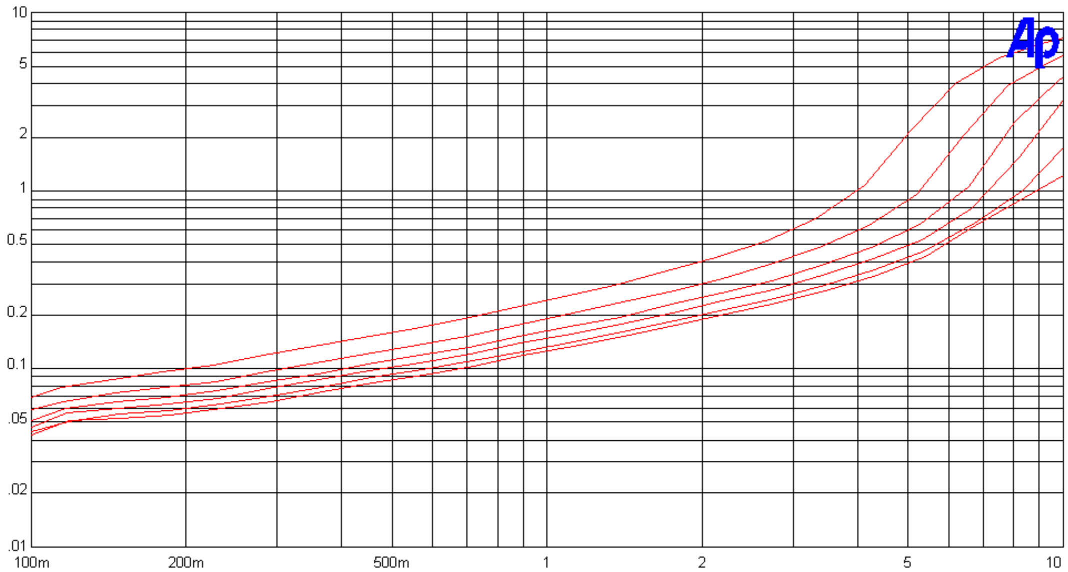
The distortion vs frequency into 8 ohms at 1 watt:



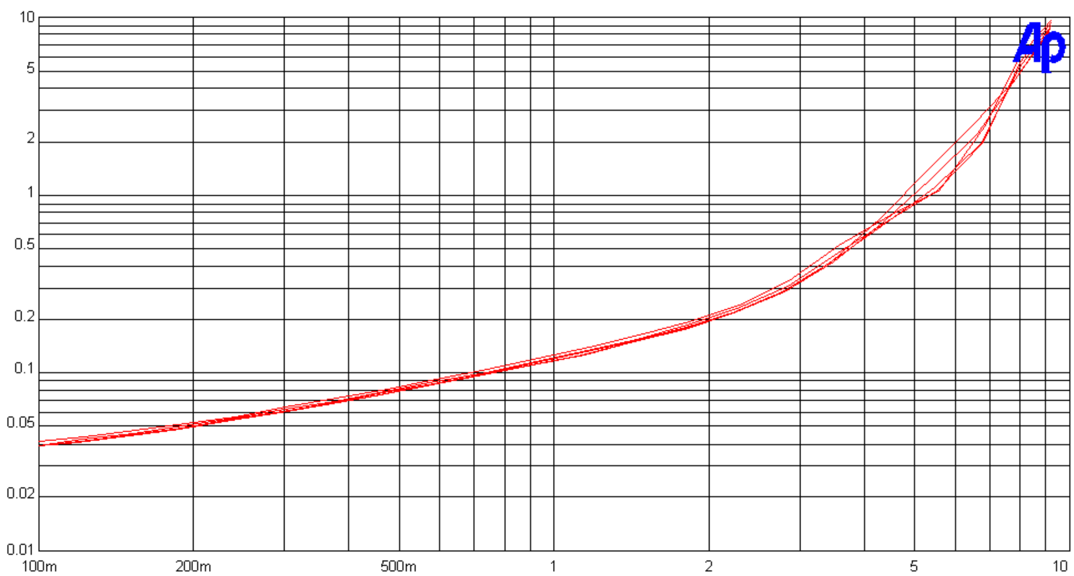
Worth noting, the output impedance is about 0.4 ohms for a damping factor of 20.

“Negative phase 2nd harmonic” is the desired signature of this amplifier, and is a major contributor to its subjective qualities. In the following curves we will note that the harmonic distortion is very much 2nd with a negative phase character, similar to that of Triode tubes. This is true from the lowest power levels to where the distortion deviates significantly from a “straight line” on the logarithmic scale, at which point we see a signficant increase of 3rd harmonic.

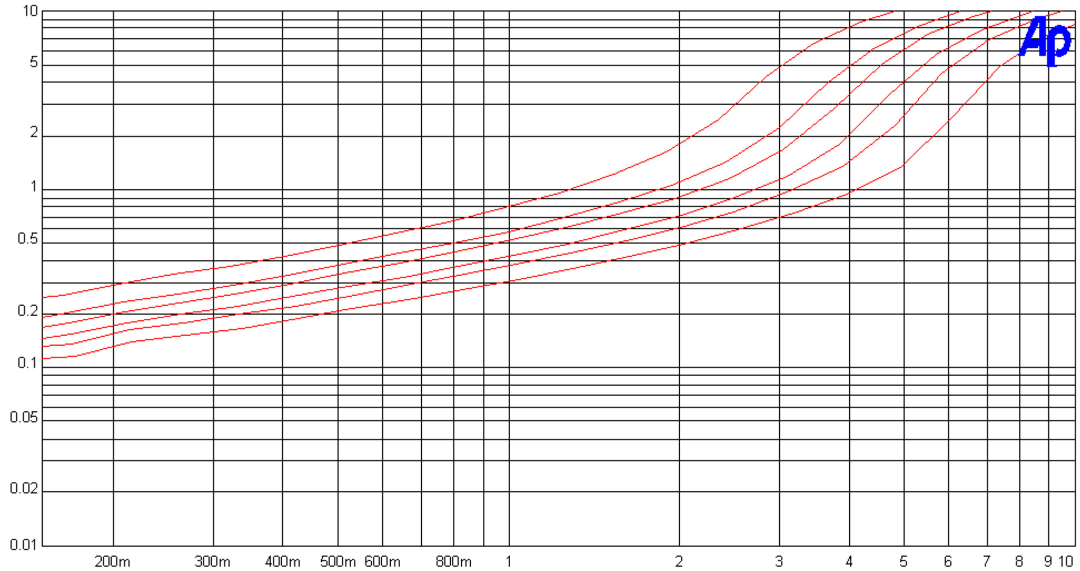
Here are the 1 Khz harmonic distortion curves versus output power at 8, 16, and ohm loads. Each set of curves is for a range of bias settings, ranging from 1.0 Volts across the inductor to 1.4 volts – the curves with least distortion are for 1.4 Volts, the highest being 1.0 Volts.



DISTORTION VS OUTPUT WATTS, 8 OHM LOAD, BIAS 1.0V TO 1.4V



DISTORTION VS OUTPUT WATTS, 16 OHM LOAD, BIAS 1.0V TO 1.4V



DISTORTION VS OUTPUT WATTS, 4 OHM LOAD, BIAS 1.0 TO 1.4V

You see that each set of curves reflect the performance versus the current bias adjustment of the channel. When you first apply power to the newly built amplifier, you will want the bias set to the minimum (0) with the bias potentiometer set to full counter-clockwise. After confirming that it is not emitting smoke or lightning bolts, you can adjust the bias upward while measuring the voltage across the inductor terminals. Start with 1.0 volts DC and watch it for a minute or so. If it doesn't wander much, then you can give it a signal source and a loudspeaker.

The power supply on the BAF kit is 16 volts DC, and in some kits the ground is also attached to AC ground. If you find that you have a ground loop as evidenced by humming noise from the speaker, you can try a grounding adaptor to try to eliminate the loop. If it doesn't make a noise difference then leave the amp grounded at the wall outlet.

You have seen that the distortion and power performance is dependent on the DC bias across the inductor as is temperatures of the heat sinks At 1.0 Volt bias you may find them at +35 degrees C. or so *above* the ambient temperature, and at 1.4 Volts more like +50 degrees. At these temperatures you will find them too hot to touch for more than a second.

If you are running 16 ohm speakers, you will find that a setting of 1.0 or 1.1 Volts is quite adequate, as the performance valies only slightly with bias. At 8 ohms, you should be pretty happy with 1.2 or 1.3 volts, and if you want the full 10 watts or are running 4 ohm loads you will want to check out values up to 1.4 Volts.

When you adjust the bias, make a point of checking on it after a short time to trim it up, as it will wander a bit as the sink termperature changes.

An important point – these heat sinks run hot, and you should make every effort to keep them well ventilated, even considering a fan if necessary. It's not so much a matter of reliablity of the output devices as it is a safety issue – you don't want children or pets to be injured, so use your best judgment.

Also it's worth noting that the red output terminal is a ground potential, and the black terminal is live with AC signal. This is because we invert the absolute phase of the signal going to the Mosfets so that they will have a negative 2^{nd} harmonic character (instead of positive) and then we restore the absolute phase at the output.

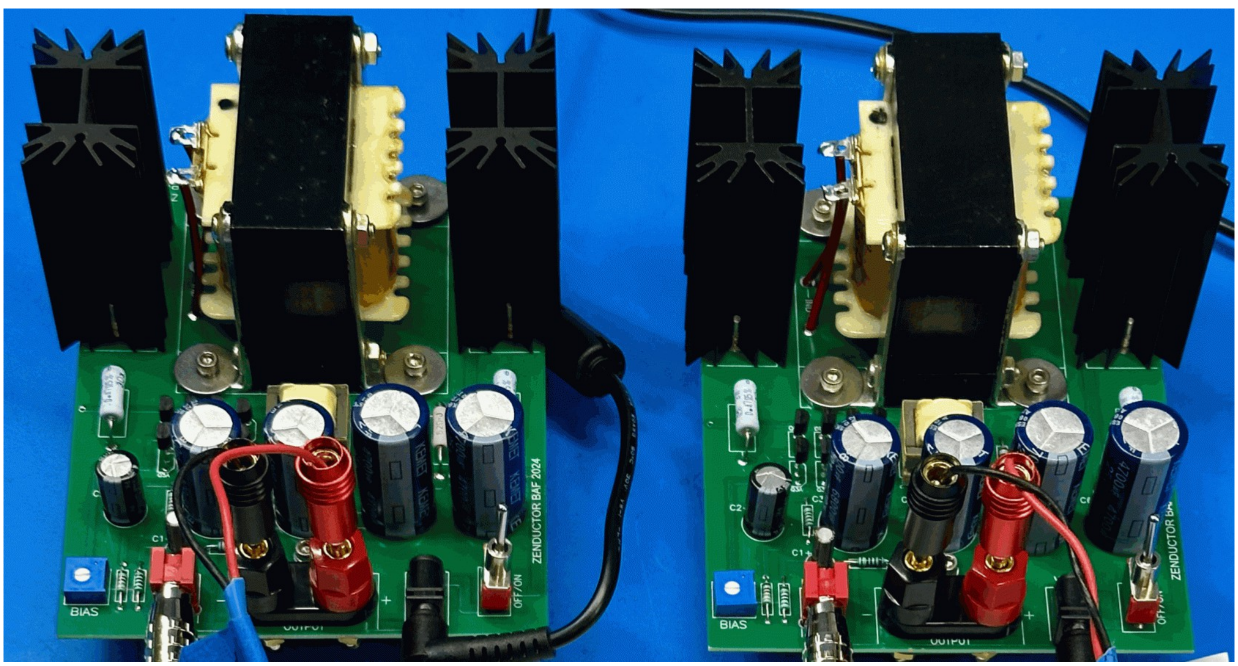
This amplifier has a personality, and it's all about sonic character. It isn't going to get awards for the usual objective measurements – power, efficiency, distortion, bandwidth, damping factor. (Did I leave anything out?)

For maximum entertainment, I suggest you review all the objective deficiencies of the amplifer before you listen to it. (warm it up for 15 minutes first). I think you will be in for a surprise.

Even after living with them driving my SR1's (86 dB sensitivity at 3.8 ohms) I am still surprised at the clarity, warmth and space the amplifiers deliver.

And if you put them on less demanding loudspeakers, if could be that your search is over.

Just ask 6L6, here is his pair....



Many thanks to Jim, Mike and Vincent for all your help.