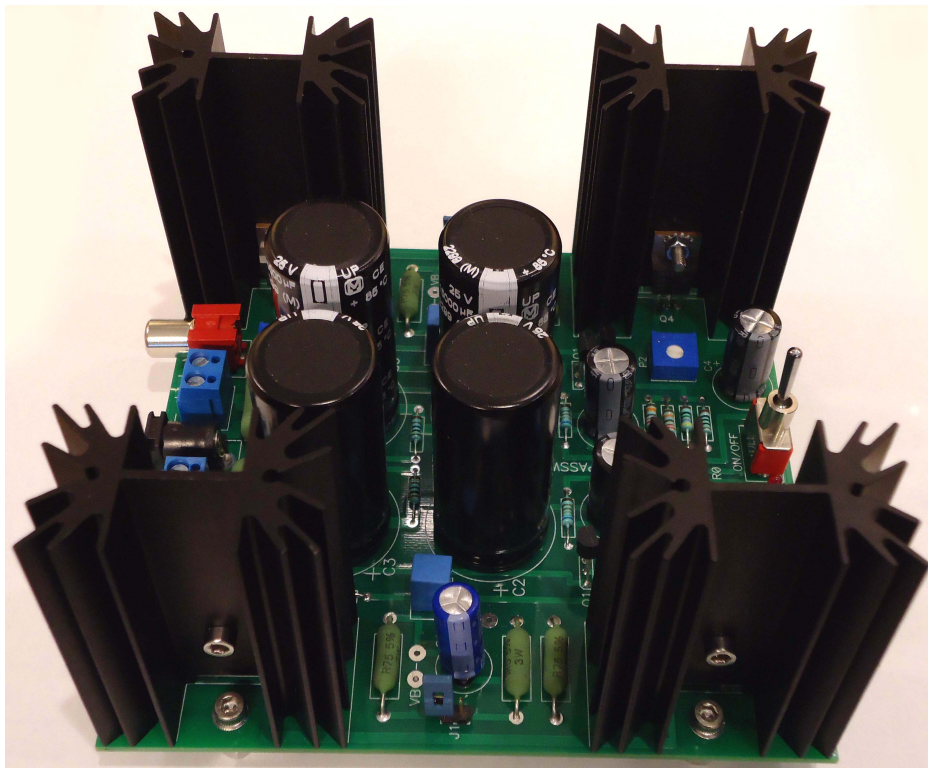
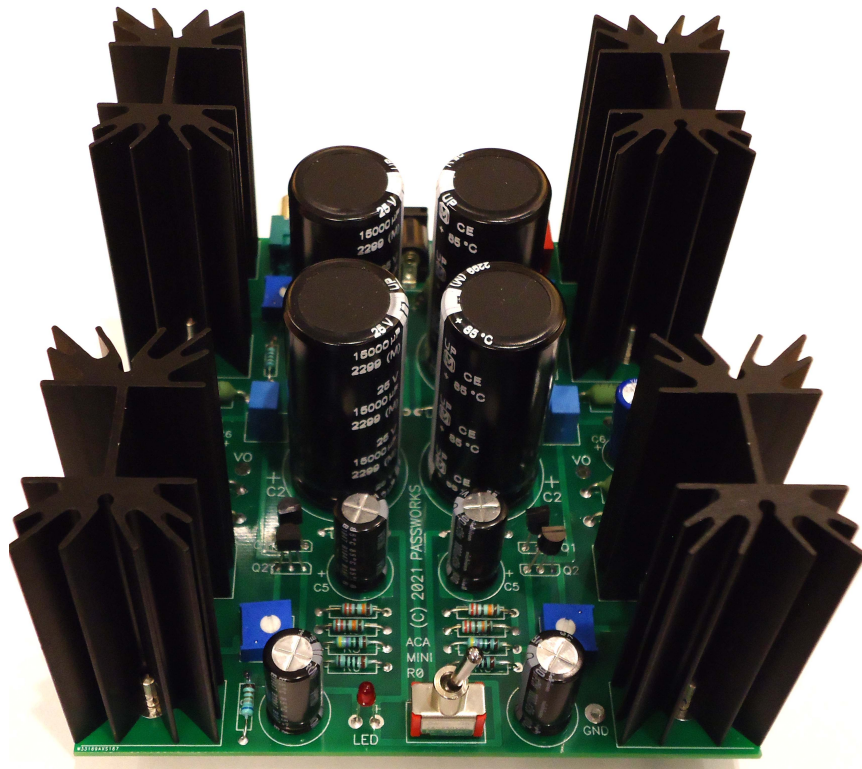
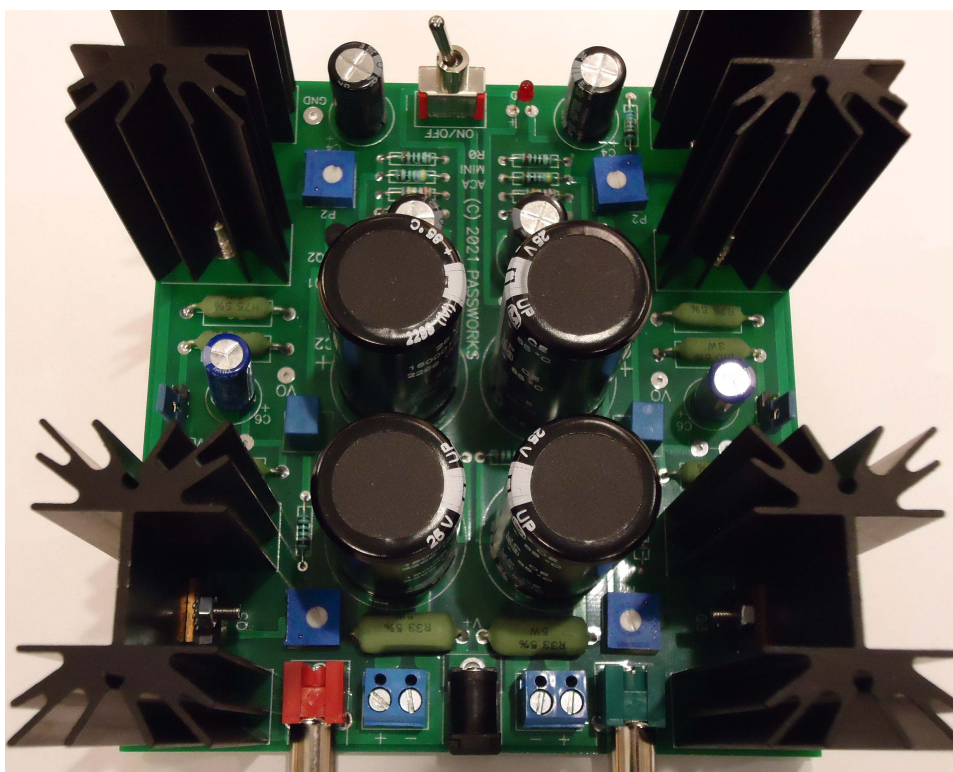
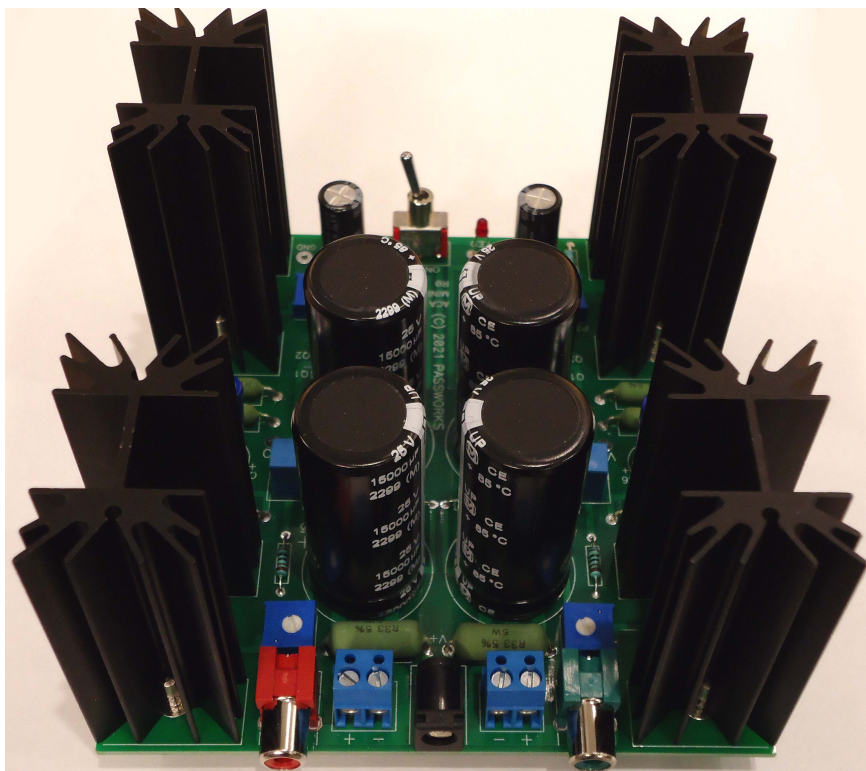


This is part 2

Pictures are cheap, so here are some more to assist you in assembly:





Now let's talk about the other element in the design.

The most astute will have noticed in the schematic that there is an R11 in series with C6 and a jumper, all these in parallel with R8, the degenerating resistor for Q3.

As always, there is a story. When I evaluated the original prototypes I noticed that the amplifier has a strong “negative phase 2<sup>nd</sup> harmonic” character. Personally, I like this in my little amplifiers, as it has a charming single-ended tube-like character (although some SE tube amplifiers don't have it) that seems to go with efficient speakers played at reasonably low levels, particularly speakers of the full-range variety.

This effect is obviously an illusion, but then this is entertainment, not dialysis.

Nevertheless, it is interesting to check out the variations that can be had in a simple circuit.

We note that this 2<sup>nd</sup> harmonic character is the mostly result of the differences between Q3 and Q4, where the P channel Mosfet on top has lower gain than the N channel. That's fine if you like your negative-phase second, but maybe not so much if, like many audiophiles, you prefer lower distortion.

However, this is adjustable by varying the degeneration on the output devices. Slightly lowering the resistance on Q3 will raise the gain, improving the balanced between Q3 and Q4 and lowering the amount of 2<sup>nd</sup> harmonic. You could do this by simply using a lower value resistor, but we find that this results in greater bias drift with temperature.

However, you can parallel R8 with an RC network consisting of a power resistor in series with a capacitor to get the same effect for AC, leaving the DC character alone. Typical values for the resistor would be from zero to several ohms. In the case of this circuit, it works out that something from about .75 ohms to 1.5 ohms does the trick.

That leaves the decision as to the C value. We want the effect to operate down to below the lowest frequency of interest, maybe something like 10 Hz. For a 1 ohm resistor we would need something like 16,000 uF. A quick look at the offerings at Digikey and Mouser reveals that they start at around \$3.

How about Super Capacitors? **3.3 Farads for 60 cents!** The RC time constant on these is come out to about .05 Hz. Looks good, sez I, but what's wrong with them?

After testing some, I came to the conclusion that for this purpose, nothing wrong at all, and so this kit comes with 3.3 F / 1 ohm degeneration. You can plug and unplug the jumper while the amp is running and observe the difference. Certainly you can substitute other resistance values in instead of 1 ohm, no problem if you own a soldering iron (and we have already established that you do).

Another item, the choice of power supply. The Meanwell supplies in the kit are quiet, they charge the big supply filter caps well, and they are isolated from AC ground, so no ground loops. You can use anything else you like, however I recommend that you keep the voltage to the 24 volt figure - many of the parts here are rated at 25 volts, which is fine as they are not worked hard, but exceeding that is not a good idea.

Lastly, you will have noticed that there is no chassis provided with this kit. This is where you are on your own. Beyond the aesthetic considerations, a chassis provides additional hazard safety. 24 volts is not a lot, and the heat sinks on top are at 12V, but you still would not want these exposed to toddlers or small animals.

Also there is a certain amount of heat coming off the fins on the sinks - at 5 watts each, the temperature rise is about 25 deg C. (5 deg C per watt), which is plenty warm but not dangerous. However, this is in open air, so your enclosure wants to be well ventilated, so you want a chassis which balances these considerations.

Some of you will just let it sit on the shelf without a chassis, which you can do, given that the connectors are all on the pc board. If you take that approach, then do so with some caution.

Looking at the project pictures posted on-line at diyAudio, I am confident you will find the creatively appropriate solution.

## Construction Notes

This is a pretty straightforward deal, with a few details.

Before you solder anything:

Make sure the input jacks are fully snapped down into the board top.

Double check the polarity of all caps.

Double check the numbers on the transistors.

All transistors in the kit with the same numbers on them are matched, no worries.

As we did not end up with the complete quantity of Linear Systems Jfets in the desired matches, we substituted the same Toshiba matched parts in some of the kits. Don't worry, they are fine.

And the output devices are the Harris versions of the IRF520 and IRF9520.

The heat sinks expect to be soldered to the pc board. Don't worry, this does not require a big soldering iron, just a little patience.

Save installation of the transistors for last. The TO-220 output devices will slide right into their spots on the sinks and are fastened to the sinks with **modest torque** on the metric hardware provided.

I recommend old fashioned tin/lead solder - it melts at a lower temperature and is much easier to rework.

If you need a solder sucker, I recommend the Soldapullit. I have several, but I've only had to use one for 20 years or so - and I use it a lot.

## Adjustment

Before you fire it up the first time, you want to have all four of the trim pots on the board set to counterclockwise position, which is minimum (zero) bias for the output stage.

You need a good multimeter, and ideally it will have pointy probes for looking at the DC voltages on little labeled pads/holes provided.

We will be measuring two voltages during the adjustment of each channel and adjusting the pots P1 and P2 to get these voltages where we want them. All adjustments should have halfway goals - if you want to go from 2 to 3 on something, then go to 2.5 first. Also, both P1 and P2 affect both the bias current and the output DC value, so adjustments will be made in an alternating fashion. One channel at a time is a good idea.

Also a good idea is to do this where the room temperature approximates actual usage, since the bias current does drift a bit with the ambient temperature.

Initially we bias the amplifier low and let the bias drift up as the temperature of the transistors rises. Most of the time the bias will drift up about 50% or so from cold to hot operation.

The two voltages on each channel are the bias current (measured as the DC voltage between the two pads labeled VB) which is the voltage divided by 0.75 ohms, and the DC output voltage, which is between the single pad labeled GND at the front of the board and the pads labeled VO (one for each channel).

Initially the values will be at or close to 0 volts. While keeping an eye on both the VB and VO, slowly alternately turn P1 and P2 clockwise. Eventually you will see some voltage appear (don't worry if it's a minus voltage). Oh yeah, remember to turn on the switch.

We are looking to have a VO of 11.5 volts and a VB of about 0.15 volts. Keep alternatively adjusting the pots clockwise until you get to these voltages. Sometimes you might have to back off one one pot to get both these numbers aligned.

It's a little tricky, but it doesn't have to be very accurate at this point - we will fine tune that after the amp has had a chance to warm up. When you get close to these voltages, just sit back and watch the drift, no hurry, no drama.

Ultimately you will want to be at VO of 11.5 VDC and VB of 0.30 V to 0.35 V (0.4 Amps to 0.46 Amps of current). If you have a cool room or lots of ventilation you can venture into the 0.35 V territory. If not, there is little performance penalty at 0.30 V and that's how I run them in my system. You will see some longer term temperature drift, so after you think it's stable on those voltages, keep an eye on it for an hour or so anyway.

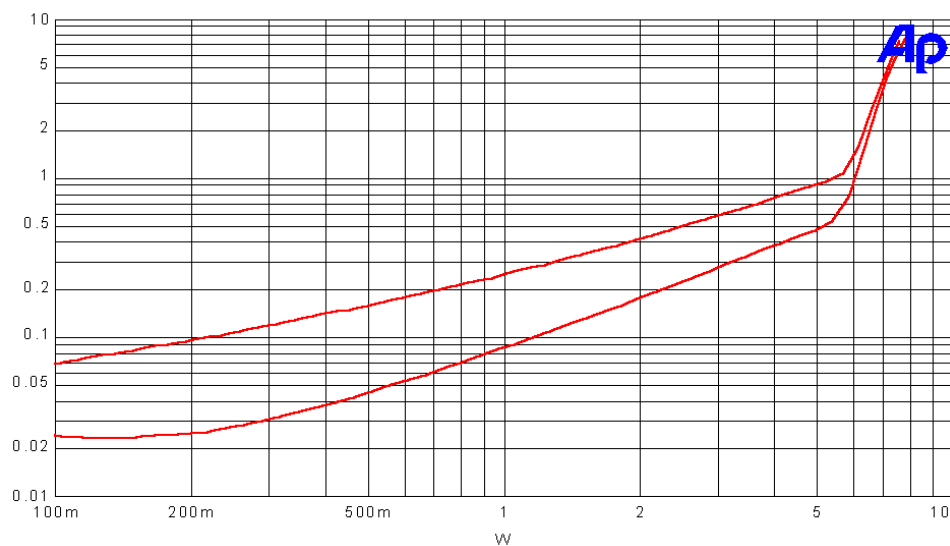
The VO is not very critical, and the range of 11.4V to 11.6 volts is plenty good enough.



## Performance

I went to the trouble of documenting the objective performance, so here it is -

The graph of the harmonic distortion at 1 kilohertz into 8 ohms



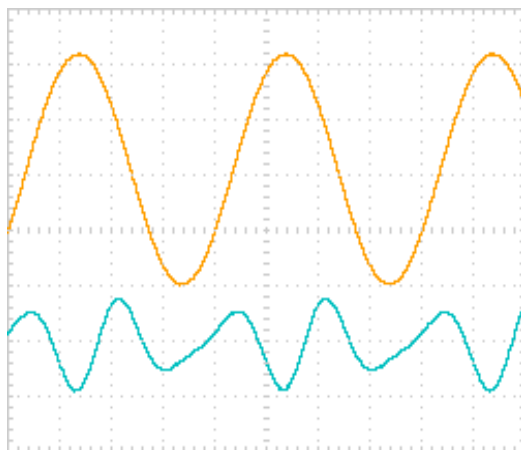
% THD VS OUTPUT POWER @ 8 OHMS

The lower curve is the distortion with the jumper in place.

Below we see an image of that distortion on an oscilloscope

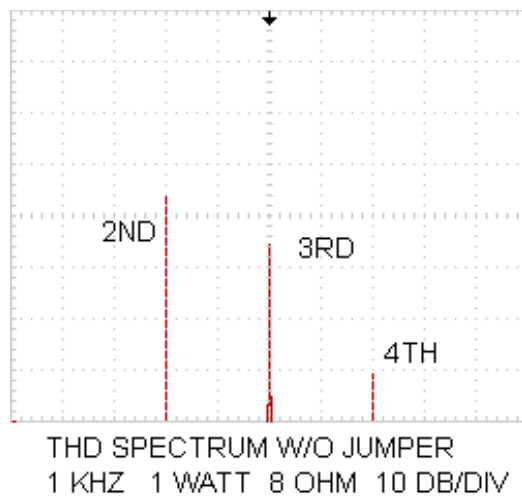
The top sine wave in orange is the fundamental 1 khz tone and the blue wave below is a magnified view of the distortion embedded in that fundamental.

It is largely second harmonic, time aligned in what i call negative phase second where the negative peaks of the distortion occur at both positive and negative peaks of the fundamental.

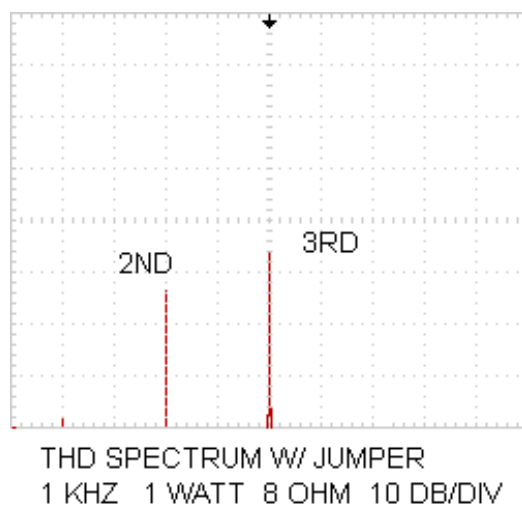
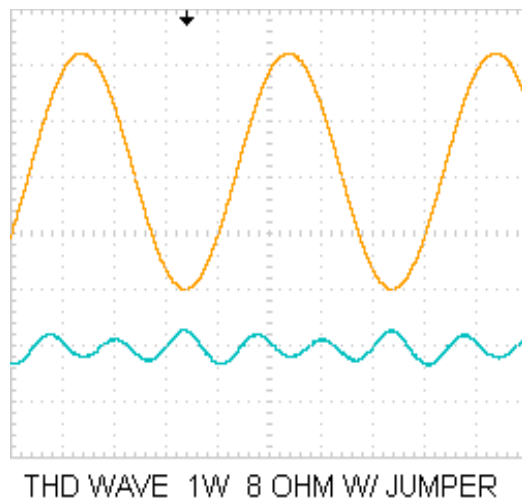


THD WAVE 1W 8 OHM W/O JUMPER

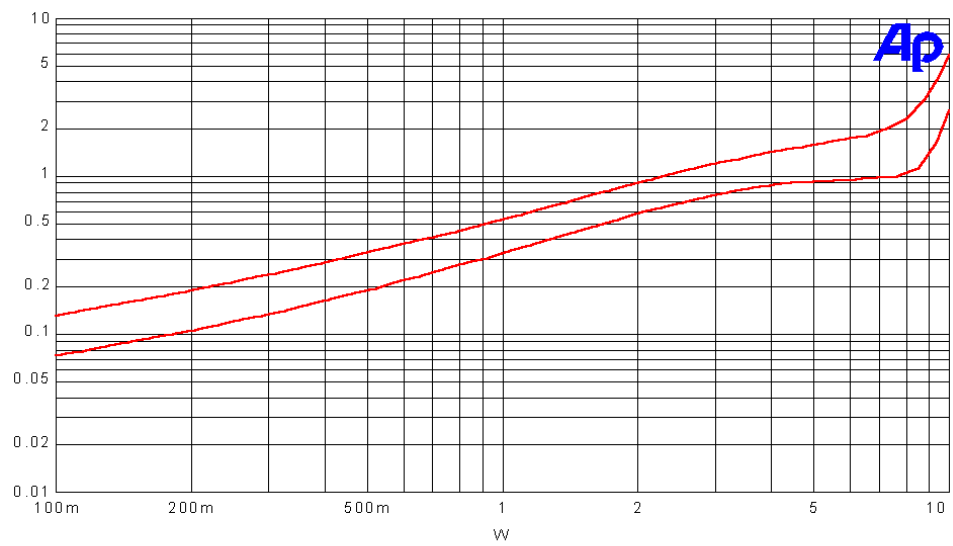
And here you see the spectral content of that blue trace on a fast fourier transform:



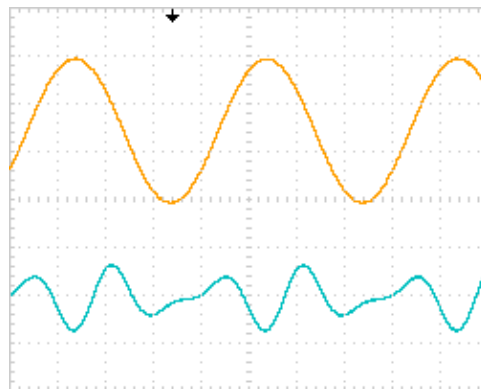
And now those same test images with the J1 jumper in place:



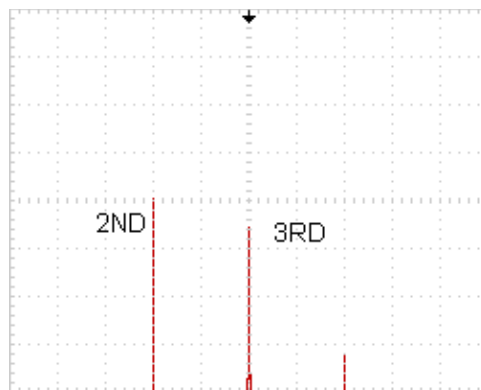
The distortion into 4 ohms:



% THD VS OUTPUT POWER @ 4 OHMS



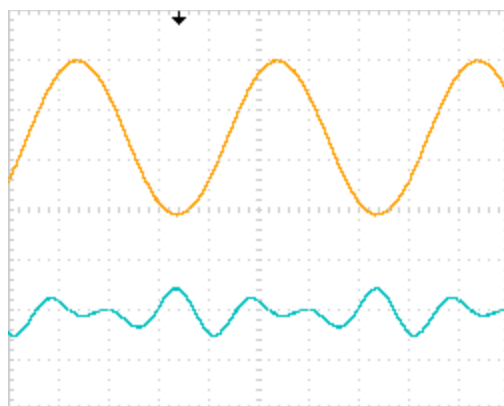
THD WAVE 1W 4 OHM W/O JUMPER



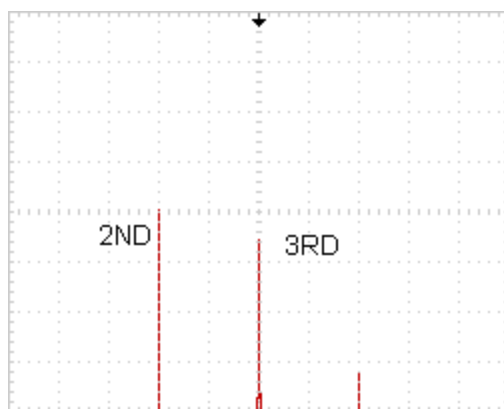
THD SPECTRUM W/O JUMPER  
1 KHZ 1 WATT 4 OHM 10 DB/DIV



With 4 ohms and the jumper in place:

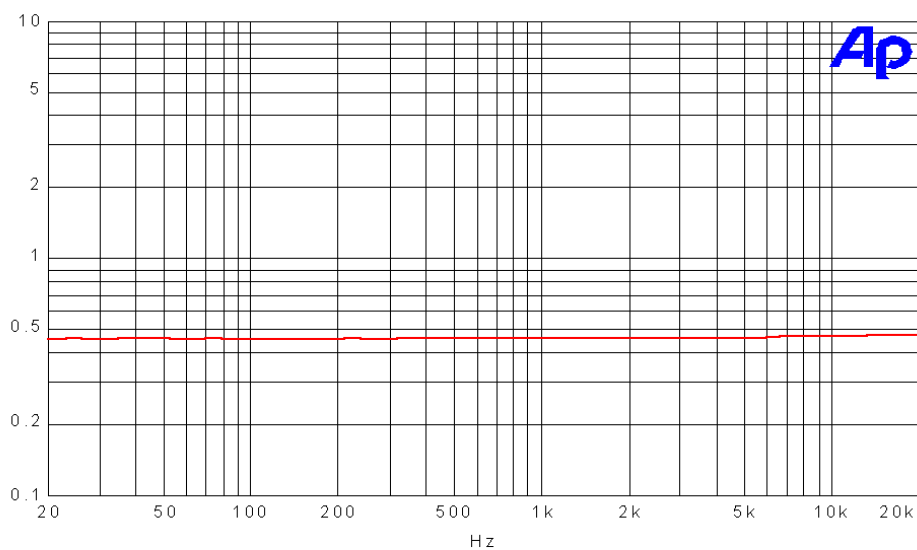


THD WAVE 1W 4 OHM W/ JUMPER



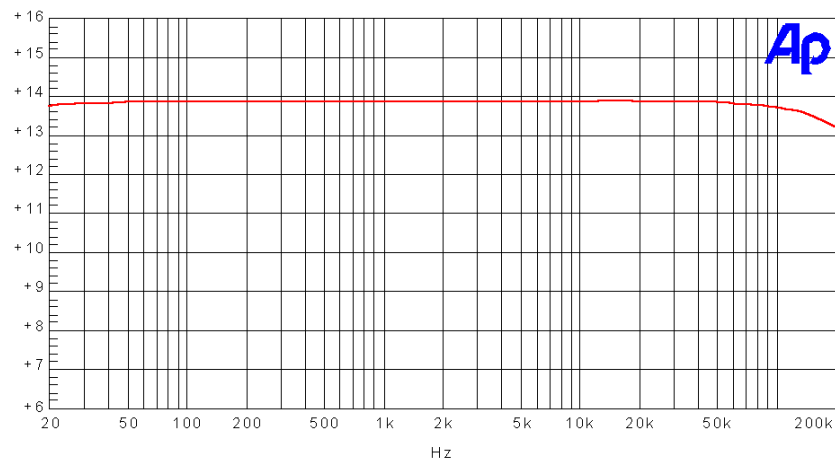
THD SPECTRUM W/O JUMPER  
1 KHZ 1 WATT 4 OHM 10 DB/DIV

Here is the distortion versus frequency, which you can see is flat across the audio band.



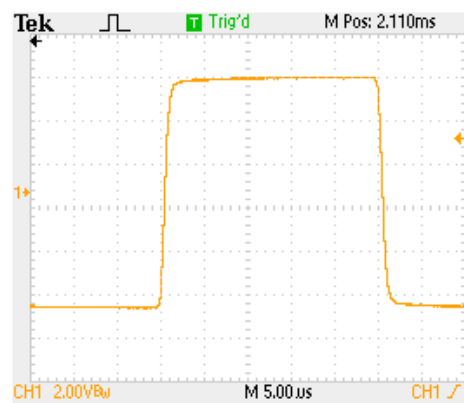
% DISTORTION VS FREQUENCY @ 1 WATT

And the frequency response:



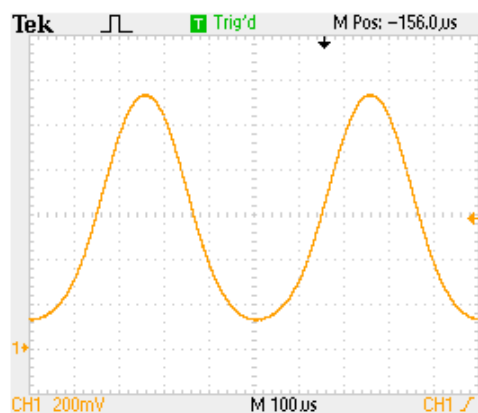
**FREQUENCY RESPONSE**

The wide bandwidth is further on display with this 20 kilohertz square wave at 2 watts



**20 KHZ SQUARE WAVE**

Lastly, here is scope image of the current through Q3 at an output of 5 watts into 8 ohms where the square-law character of the Fets delivers a generous margin for Class A operation.



**BIAS CURRENT @ 5W 8 OHMS**

Oh, and I forgot - the damping factor is about 10.

### **So there we have it.**

As I write, kits have begun their travels through the postal system and then building starts.

Of course the first one went to esteemed diyAudio member 6L6 so that he can put together his reference build guide, always a huge help.

And also of course a thread devoted to this will be found in the Pass Labs forum.

Thanks to Linear Systems for providing the expensive and hard-to-get Jfets for this project.

And thanks to the Postal workers and Fedex and UPS guys for faithfully delivering all this stuff to and from my front porch. Couldn't have done it without you...

Lastly I hope that everyone has the same great experience with this project that I did.

More to come.

(c) 11/3/21 Nelson Pass