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LITTLE FISH

Wooden boatbuilding, Lugged steel bicycle frames, computers. The usual.

Monday, 30 January 2017

Measuring a MOSFET Power Amplifier.

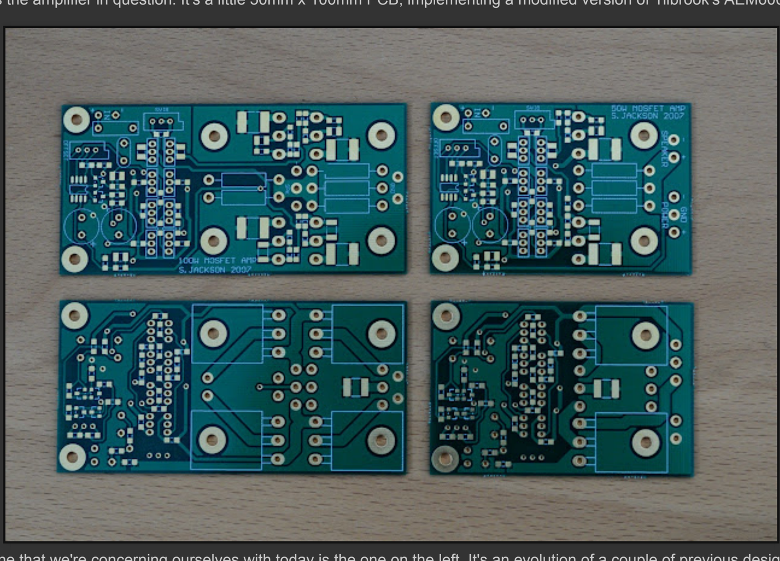
I'm on a bit of an audio kick of late. It's all about building some speakers and an amp for my study, as I stole the speakers and amp from there (some nice home-brew 2-way bookshelfs with Vifa P13WH mid-woofers and P27TG tweeters, and an old NAD 3020B) for my bedroom. Anyway, I've got a pre-existing amp design, based on David Tilbrook's AEM6000, and I've ordered the drivers to build a pair of Lynn Olsen "Ariel" MTM transmission lines. That'll make some pleasant noise, I think.

On to the amps. Back when I originally designed these amps, some 10 years ago, the distortion analyser I had had a noise floor of 0.0013%. I achieved that fairly easily so moved on. I've just bought a PCB for a super-low distortion oscillator based on the Linear Tech "AN67" circuit, which uses some scary high-gain opamps wrapped around a resonator to generate an "unmeasurably" pure tone.

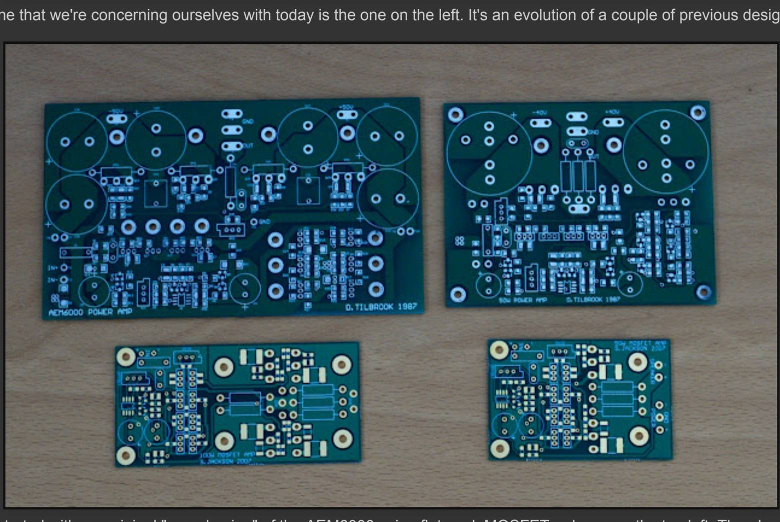
Now I've got a sniff of a world beyond 0.001%, I'm very keen to see how far I can go. Part of that's developing a whole new completely over-the-top amplifier (see previous posts), part of that is just playing with my existing amps to see what they're really capable of.

The process is straightforward. Put one together on a heatsink with a dummy load and thrown together power supply using bits from the garage, apply a stimulus from either my mac, my function generator, or my new oscillator, measure what's being put into the load with my CRO and spectrum analyser, tweak, repeat. It's a process that's quite involving.

Here's the amplifier in question. It's a little 50mm x 100mm PCB, implementing a modified version of Tilbrook's AEM6000:



The one that we're concerning ourselves with today is the one on the left. It's an evolution of a couple of previous designs:



They started with my original "repackaging" of the AEM6000 using flat-pack MOSFETs, shown on the top left. Then I made a "baby" 50W version (top right). While making that I wondered whether I could roll a version that would fit on a 50mm wide heatsink, with off-board filter caps. That resulted in the two smaller boards below. They depart from the original in that the VAS stage is no longer differential-symmetrical, as I simply couldn't see the advantage of the differential structure in Tilbrook's original. Also I made much better use of the back-side of the PCB. Whereas the original has practically nothing on the back bar the MOSFETs, this one has a fairly even spread of parts on each side. That makes it more compact and keeps [illegible]

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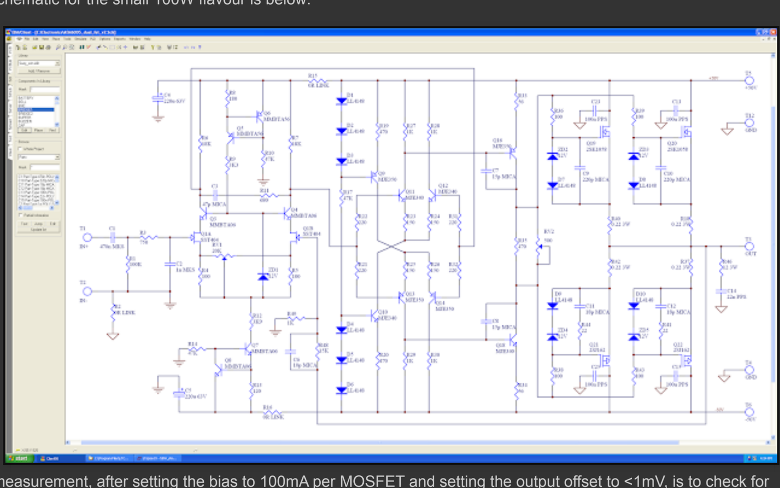

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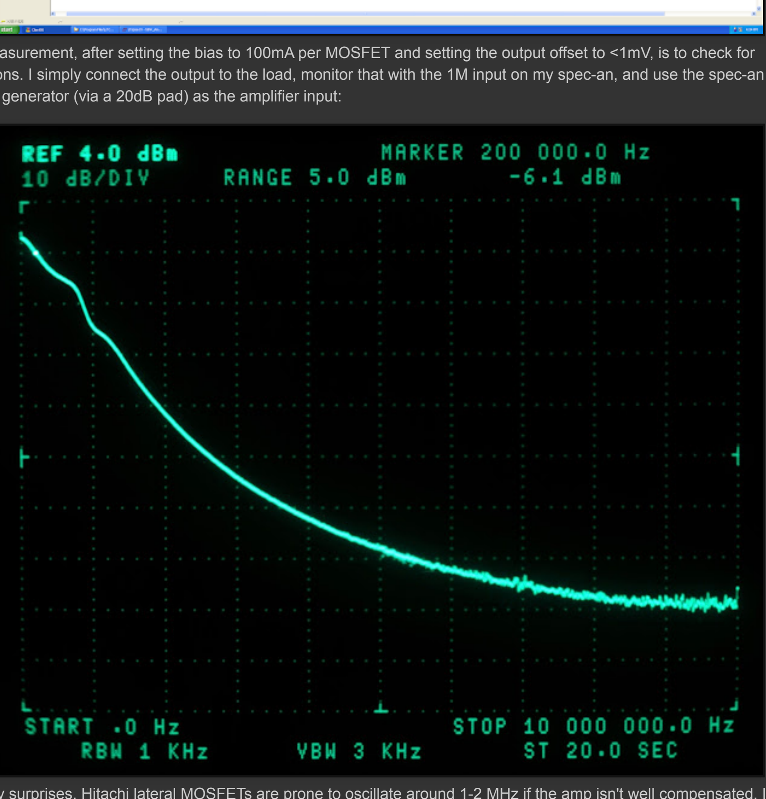

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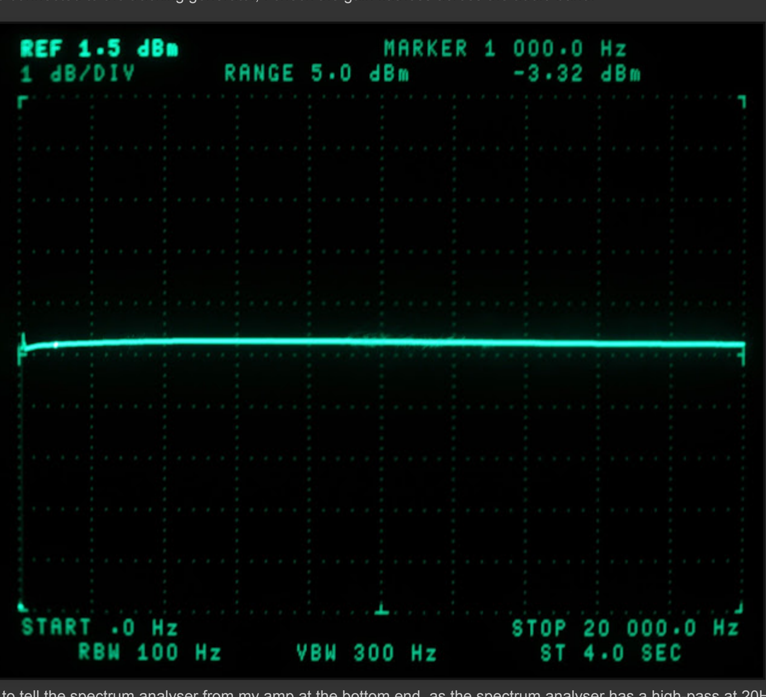

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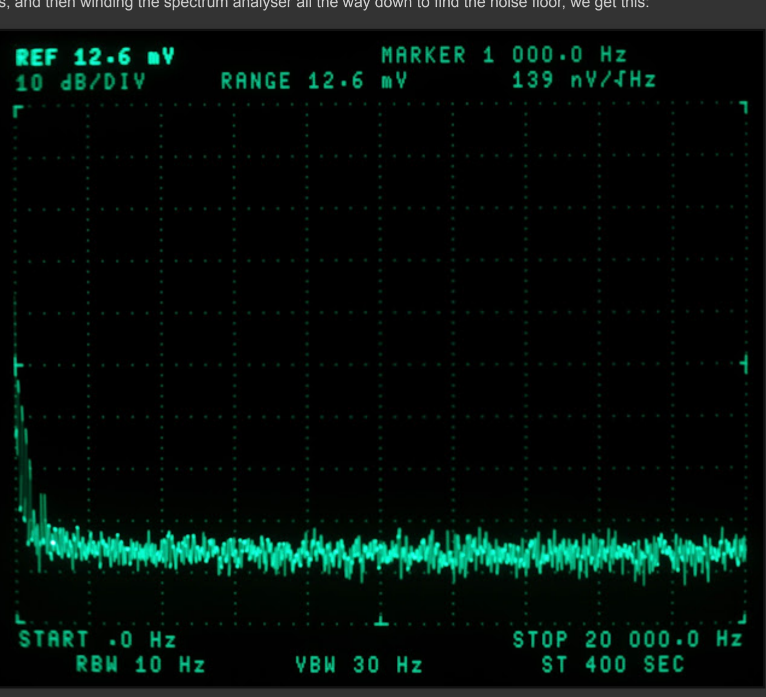

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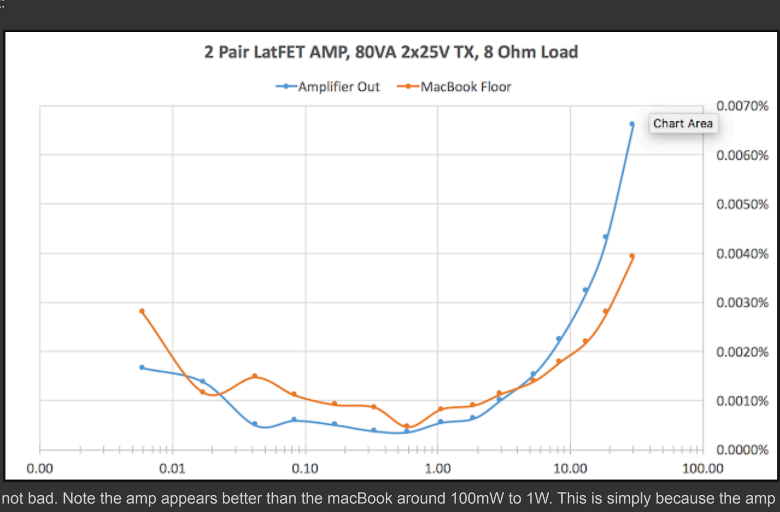
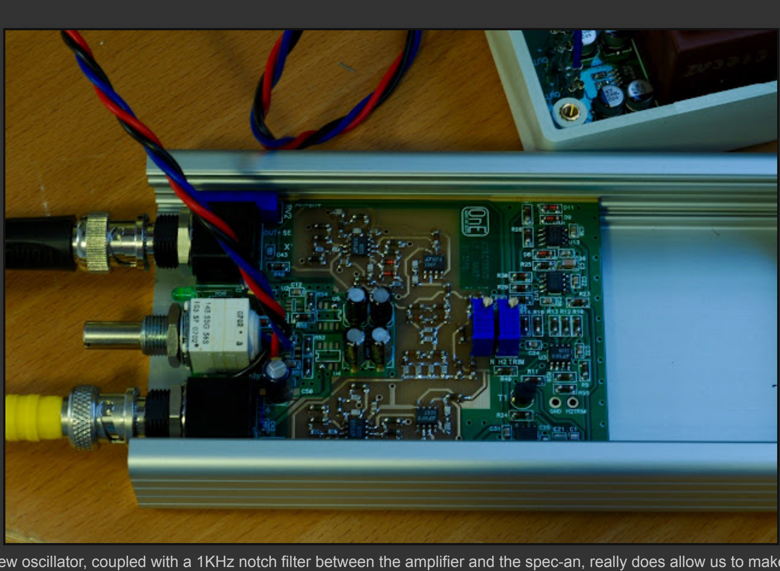
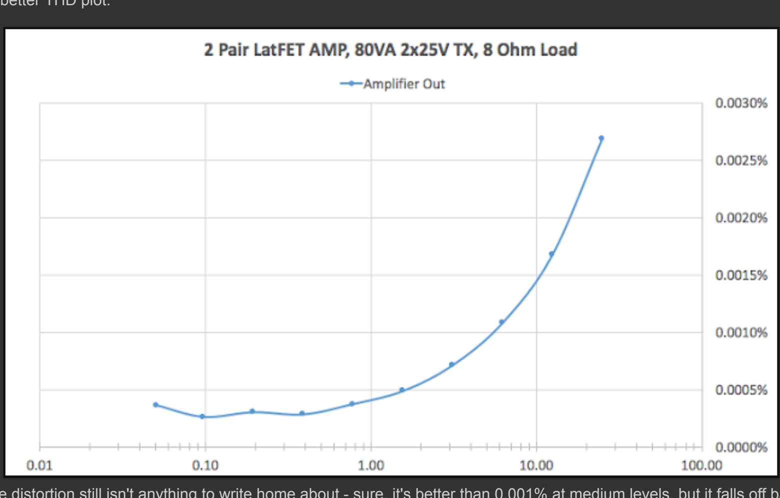


Okay, not bad. Note the amp appears better than the macBook around 100mW to 1W. This is simply because the amp provides a gain of 16, so what was buried in the noise of the spec-an without the amp, isn't with the amp. Things turn to custard after a few watts. Initially I passed that off on the wimpy 2x25V 80VA supply I was using for test, but we'll find later it's a much cooler problem.

To go deeper, I really do need a better source. So I spent some time building the 1KHz low-distortion oscillator. Here's a photo:

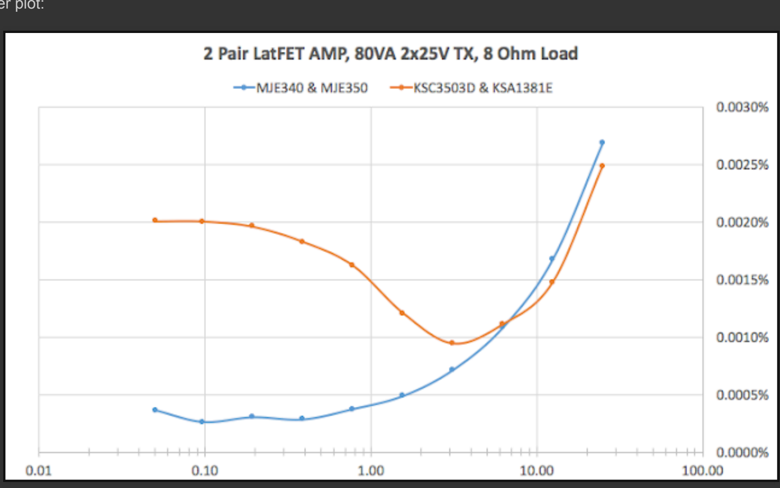


The new oscillator, coupled with a 1KHz notch filter between the amplifier and the spec-an, really does allow us to make a much better THD plot:

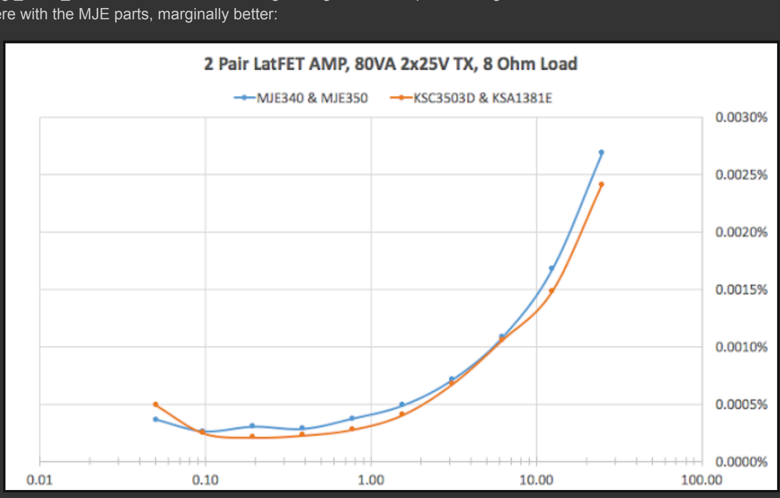


But the distortion still isn't anything to write home about - sure, it's better than 0.001% at medium levels, but it falls off badly after a few watts.

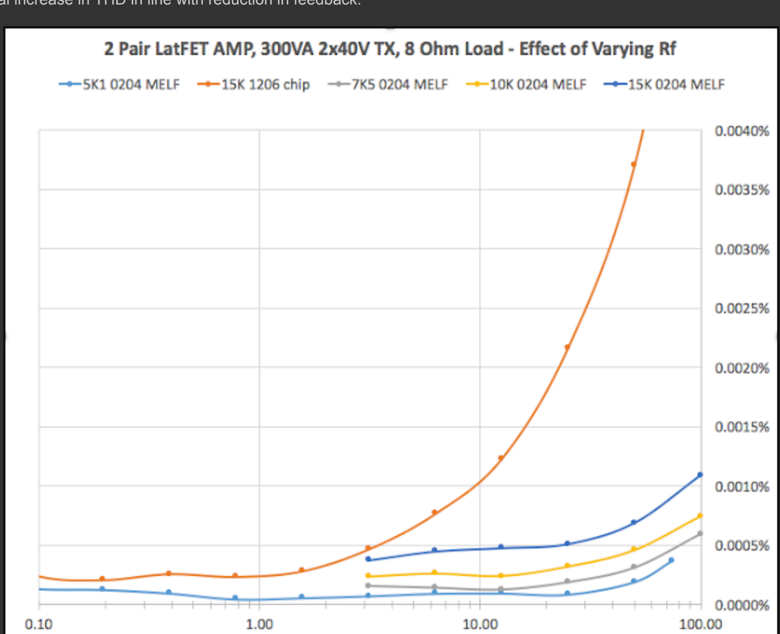
I wondered what sort of improvement I could get by substituting faster VAS and second stage transistors. The MJE340 and 350 are bullet-proof, but they're pretty slow really. I pulled them out and substituted KSC3503D & KSA1381E, then made another plot:



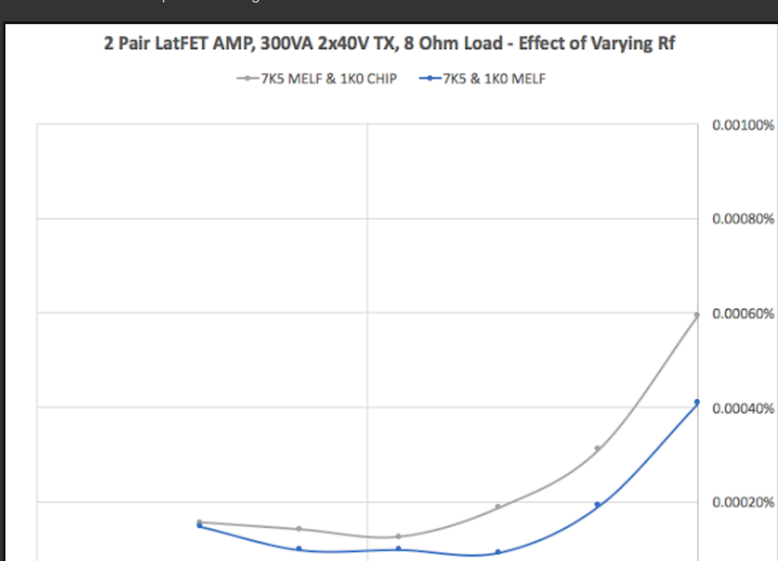
Wow, that didn't help. Much gnashing of teeth and measuring showed one of the output drivers was drawing half the current of the other one. I went to replace it, and found out I'd, ahem, forgotten to do the screw up holding it to the heatsink, so it was running _much_ hotter than it should have. Tightening the screw up fixed the god-awful distortion, and we were back where we were with the MJE parts, marginally better:



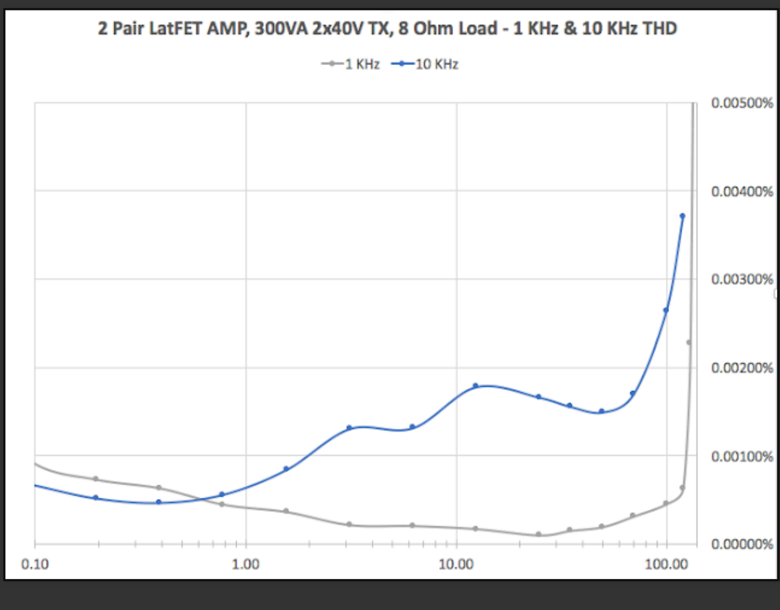
On the basis that the KSA and KSC parts are faster, and my sims showed considerably improved stability, I wondered if I could improve the THD a little by winding up the negative feedback. This has the effect of reducing the output level, but I can sort that with more gain in the preamp. So I substituted a 5K1 MELF resistor for the 15K thick-film 1206 that was setting the feedback ratio. Bam! Instant huge improvement in THD. Much better than the couple of dB that I should have gotten. So I tried a variety of other MELF resistors for Rf. All show dramatically improved THD over the 15K thick-film chip resistor, and a gradual increase in THD in line with reduction in feedback:



So next I did some reading about distortion in resistors, and found that it's actually a thing. Thick-film resistors are notorious for changing their resistance significantly with changes in applied voltage. That change in voltage directly leads to a change of division ratio, and hence to distortion - we get different gain in the peaks than we do at the zero-crossings. The MELF resistors are a thin-film that's carefully engineered for stable resistance, both with changes in temperature (+/-25ppm/deg) and voltage. So they really are worth the extra few cents. Anyway, there's a whole nother resistor in this feedback divider, and that's also a thick-film chip. Not for long:



Yeah, that's 1ppm there, right around 25W output. So finally I did a much more exhaustive measurement, carefully accounting for every harmonic at a huge range of output powers, from 100mW all the way to 140W. Then I modified the oscillator to do 10KHz and repeated the exercise. I'm rather happy with the results. This amp is lovely and clean all the way to clipping at 120W. Slew rate doesn't clobber the 10KHz THD result until around 80W. Note a peculiarity of the results where the 10KHz THD is slightly lower than the 1KHz result under 1W. I attribute this to a slight increase in noise at low frequency, both from 1/f noise and 50Hz harmonics getting into the measurement. These are reduced by 10KHz:



Posted by Suzy at 09:35

6 comments:

Raphael Pereira said...

Hello Suzy,

Finaly today i found your web page again!

Let me make a simple question, Do you have some substitutes
for the SST404, new part numbers pleased, and for the output mosfets.
I'm from Brazil, and it's verry dificult two buy some parts.
The ones you used stay obsolet at this days.
Thanks for you attention!

11 April 2018 at 20:21

Suzy said...

CAlogic still make the SST404, and it's sold by Future Electronics.
http://www.futureelectronics.com/en/technologies/semiconductors/discretes/transistors/jfets/Pages/8958308-SST404-LF.aspx?IM=0

If you're doing your own layout, the U401 is the same thing in a through-hole package, but with better match between the two JFETs, for improved output DC. They're also available from Future Electronics.
http://www.futureelectronics.com/en/technologies/semiconductors/discretes/transistors/jfets/Pages/4319869-U401.aspx?IM=0

12 April 2018 at 08:02

Suzy said...

I've been using Exicon ECX10P20 and ECX10N20 output devices. They're a drop-in replacement for the 2SK1058 & 2SJ162. They're distributed by profusion: http://www.profusionplc.com/type/lateral-mosfet

12 April 2018 at 08:16

Synonymous said...

Hi Suzy,

Can you explain the usage and how you came to the values of C9 C10 C11 C12 and R's 41 and 44 on the gates of the laterals please. Why are they different for both the P and N. In other works, I've seen either rod elliott use just a capacitor on the 1058, or both using a 10pf.

Thanks for any insight.
S

18 July 2020 at 02:02

Suzy said...

Hi S,

The rationale behind adding a capacitor to the N-channel MOSFET is simply to roughly balance the gate capacitance of the N and P-channel parts, to get roughly equivalent step response. I added a series R-C combination on the P-channel FET just to allow finer tweakability.

The values are not at all critical, and indeed as you've noted other amps omit them or use simpler schemes. I find that as the OLG goes up you need to pay more attention to small stuff like this to keep the amplifier from oscillating.

18 July 2020 at 09:12

Tim said...

Hi Suzy,

In the past I have seen and tested several power transistors 2N3055 and mosfets used in both switch mode power supplies and audio amplifier in the past that had failed and found that there were replacement components in Australia which did not even come close to the manufacturers specifications, this along with cost of hobby electronics fustration of finding hard to get compents and cheap imported items available seemed to produce a decline in hobby electronics in Australia over many years, and is still happening.

29 August 2020 at 20:13

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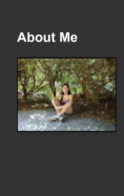

Suzy

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