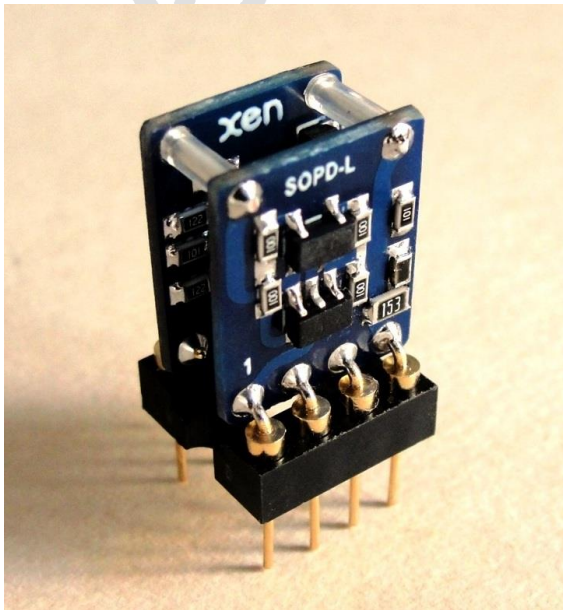


Discrete Opamp with Thermal Symmetry -- SOPA

XEN Audio

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The first topology that was built was the XEN SOPA. As already described previously, this features a biasing scheme for the second stage that is thermally symmetrical self-compensating. Small changes in the current of the frontend CCS will have the same net effect on both top and bottom halves of the second stage, such that they compensate each other.

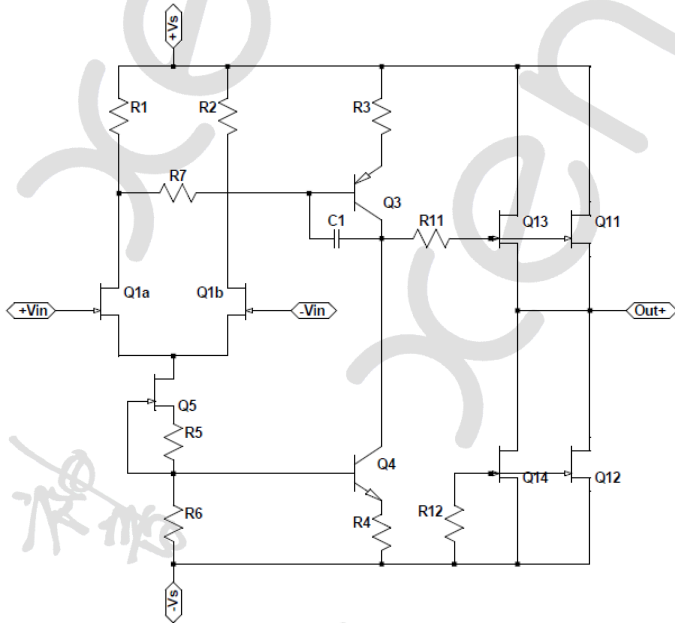


Fig. 1 XEN SOPA Schematics

For best possible thermal tracking of the circuit, dual N-JFETs were used in both the input and the output stages. Two pairs of JFETs were used for the output, biased at 4mA each, in order to limit the thermal dissipation for each device. Although there are NPN-PNP dual BJTs, these are not of the low-noise variant. Hence single devices were deployed at those locations instead.

Mechanical Layout

In our previous attempts, we tried to squeeze everything on a 10x10mm PCB, including the DIP8 pins. As anyone who attempted the same before would know, those pins are at rather inconvenient locations.

This time round, we also want to make dual opamps possible on the same 10x10mm footprint. Some commercial solutions resort to vertical sticking for the dual version, and increase the PCB size some 15x15mm. This may not be a direct replacement for DIP8 IC opamps if the original PCB has a tight layout. Furthermore, with one PCB directly above another with a small air gap in between, we considered this as a less-than-ideal thermal layout.

Instead, we choose to adopt the vertical PCB solution also seen in commercial offerings. The two PCBs are soldered onto a standard DIP8 header with bended-round pins. Two insulated cross braces not only provide structural stability, but also acts as power supply rails across the two boards. Each of the actual PCBs measures 10x13mm. So the whole dual opamp still conforms to the 10x10mm set out at the beginning. And we could, if so wish, easily put an aluminium extrusion over it all and still be less than 12x12mm. Such metal shielding restricts convection cooling, and is only really effective when they can be connected to Gnd electrically.

Measured Performances

In general, the measured performance of the prototype agrees well with simulations. As the predicted unity-gain bandwidth was beyond equipment capability, the bandwidth was measured with a gain of 10 instead. This turned out to be at 500kHz -3dB, and was slew rate limited. The output load (whether 10k or 1k) had little effect on the performance, as long as the maximum Class A output current was not exceeded (5mA in this particular prototype).

10kHz square wave demonstrated the designed slew rate limit of 4V/ μ s. This was essential to ensure unity gain stability. No overshoot could be observed, even at unity gain.

Distortion was measured using an Audio Precision SYS2722 distortion analyser. This was carried out at 1kHz and 5kHz, 2Vrms output, with the opamp configured for a gain of +10 (18k / 2k feedback network). The results are summarised as follows :

Freq	RL	H2	H3
Hz	ohm	dB	dB
1k	10k	-102	-123
1k	1k	-102	-113
5k	10k	-96	-115
5k	1k	-93	-100

As expected, distortion was higher at 5kHz due to reduced NFB, but less than 10dB worse compared to 1kHz. The load resistance had little effect on the second harmonics, only on the third, which was some 10dB lower. With 1k load at 2Vrms, the output current was more than half of the Class A bias of the output stage. Input referenced noise was measured to be 2.5nV / $\sqrt{\text{Hz}}$. DC offset was trimmed to < 2mV at the output, and they stayed stable within +/-1mV over 30 minutes. Not bad for a closed-loop gain of 10.

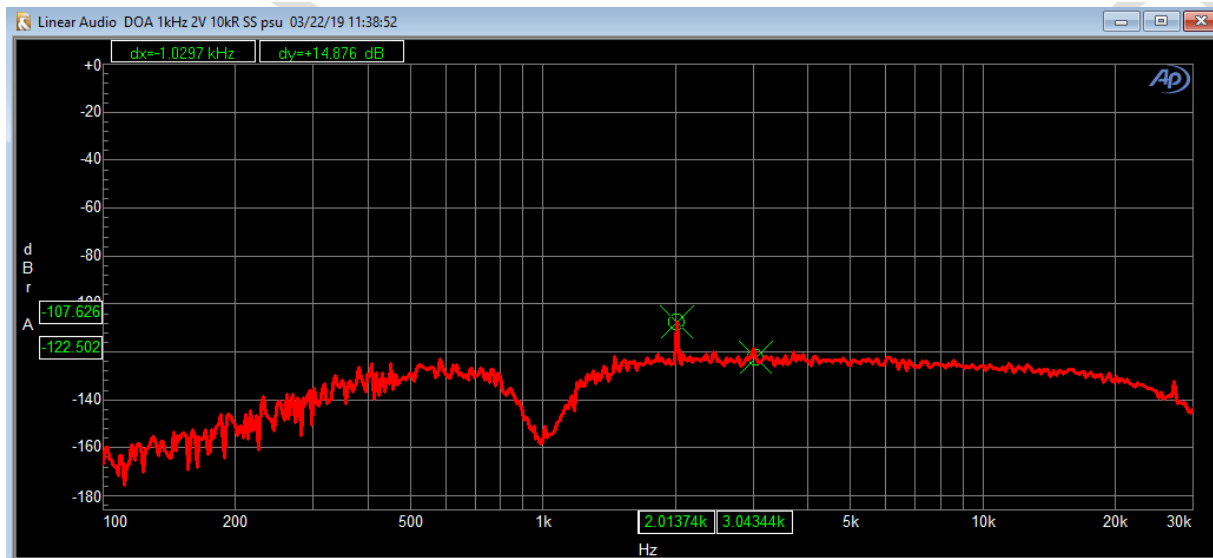


Fig. 2 Distortion Spectrum at 1kHz, 2Vrms out (notched)

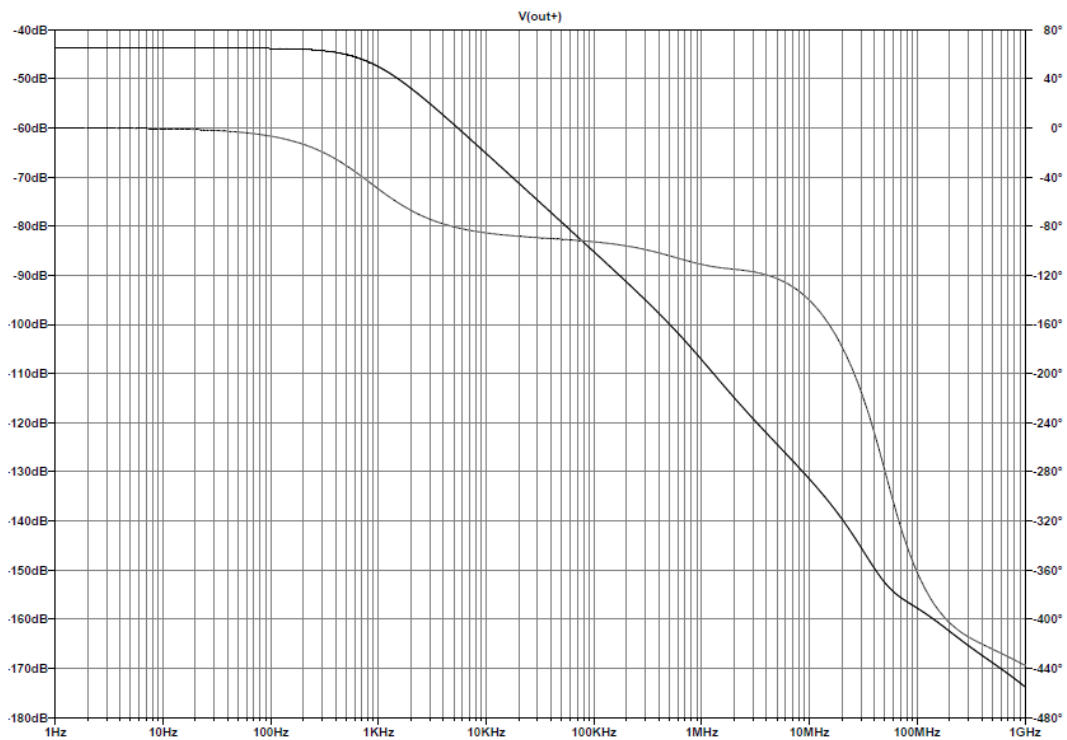


Fig. 3 Simulated Open Loop Characteristics (input level at -120dB)