

Pass Electrostatic Headphones Amplifier Concept Cascode MOSFET Version

XEN Audio

December 2013

Introduction

While searching for a solid state electrostatic headphone amplifier circuit for a friend, we bumped into a concept schematics published by Nelson in 2010¹. It was meant to make use of the Semisouth SJEP170R550 power JFET. The schematics has no component values. A private conversation with Nelson confirmed that it had never been built. So it has remained a concept till today.

Circuit Adjustments

As we bought some SJEP170R550's a couple of years back, we thought we should take the challenge to make this a working circuit. The SJEP170R550 has high voltage capabilities, coupled with low capacitances, making it ideal for the job. However, the leakage current at the gate remains a concern, and a buffer at the input adds complexity. As they have now become unobtainium, a widely-available alternative would be very desirable.

The Fairchild FQP30N80C turns out to be a good alternative. It will take a maximum of 800V, has similarly low capacitances and also similar transconductances. Since there was no intention to go beyond 800V anyhow, this would be ideal for the job.

The result of some hours of simulations can be showed here. The values are probably not 100% optimised, nor are they critical. (One could replace 5M by 4.7M, etc.) Performance in Spice is quite decent though. Closed loop gain is 500x. Bandwidth is 4Hz to 100kHz at -3dB. Distortion in differential mode is around -80dB at 100Vrms differential output at 10kHz, assuming -30dB even-harmonics cancellation in balanced mode (so proper matching is mandatory). Input impedance is 20k balanced, not bad for an inverting amplifier. Note that cascoding is essential to ensure decent bandwidth without resorting to much lower input impedance values. Each of the cascoding MOSFETs will dissipate about 10W, which is no issue at all because of the low R_{th-jc} . The driver MOSFETs will see 1/10 of that. So no thermal issues for those at all.

The current source for the diff pair does not see much voltage (~4.5V). Almost anything that gives 50mA will do. To be absolutely safe, the IXCP10M90S or DN2540 with the appropriate degeneration resistor could be considered. Power supply is single rail 800V 55mA, and a suitable HV shunt regulators could easily be found on the forums. There are quite a few high voltage, high dissipation components in the circuit. Particular attention should therefore be paid to the voltage and thermal ratings of the components. The 3k output resistors are optional, but they seem to be common practice in commercial electrostatic headphone amplifiers.

So apart from the fact that this has output decoupling caps (the load itself is almost pure capacitive anyhow), is single ended, and has global negative feedback, this simple circuit topology is a very decent performer. After all, none of the solid state electrostatic headphone amplifier around that I know of, DIY or otherwise²⁻⁶, is fully complementary and has no global feedback.

All thanks to Nelson for sharing the idea with us in the first place. ☺

References

1. <http://www.diyaudio.com/forums/pass-labs/153030-semisouth-jfets-what-they-good-3.html#post2178227>
2. http://headwize.com/?page_id=967
3. <http://gilmore.chem.northwestern.edu/kgsshvproduction.pdf>
4. <http://gilmore.chem.northwestern.edu/srm323aorig.pdf>
5. <http://gilmore.chem.northwestern.edu/liquidlightning.pdf>
6. http://www.high-amp.de/html/transistor_v4_eng.html