

The DAO SE, an All-FET, Zero- Global-Feedback, Pure Class A Headphone Amplifier (Part 1)

XEN Audio
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Background

As early as 2006, Nelson Pass first published an article, the Zen Version 8, where he introduced a power JFET from Loveltech, the LU1014D. In an subsequent article, the Zen Version 9, he described how the triode characteristics could be put to use by introducing the so-called Cascode Modulation, in which the V_{ds} of the LU1014 was made to vary with drain current, in order to obtain the triode load line.

Although the company Loveltech no longer exist, and the device LU1014D has become obsolete, they are still available, at affordable prices and in sufficient quantities for DIY purposes from an electronic surplus dealer in the USA.

Using the cascoded LU1014D in the same way as described by Pass, in a Zero-Global-Feedback (ZGF) circuit, is somewhat problematic. Pass uses a bias of 1.3A for the LU1014, in combination with a source resistor of 0.68R. At this current, the transconductance Y_{fs} is about 4S. This means the total effective source resistance, which also equals the output impedance (Z_{out}) in a source follower, for example, is about 0.93 ohm. Thus, to use the cascoded LU1014 as a source follower to drive speakers with a reasonable Z_{out} of say 0.1R would require 9 FETs in parallel, and a total bias of 12A. That is a bit high. Hence for power amplifier applications, the only sensible way is to use the LU1014 in a circuit with negative feedback, of which the Zen Version 9 is a good example. Unless of course one is willing to use a cap (of say 47000uF) in parallel with the source resistor, or to use a diode with about 1V forward voltage at 1.3A bias, like in the F5T. Even then, one would still need 4 FETs in parallel, with a total bias of 5A.

Experiments by XEN Audio has demonstrated that the same triode characteristics can also be obtained at a lower bias current of typically 200mA and a V_{gs} of -1.3V, by using the right combination of cascode voltage and cascode modulation. The transconductance of the LU1014 under these conditions is about 1S. Thus, even when using a total degeneration of about 6.5R, the effective Z_{out} is about 7.5R. This is sufficiently low in source follower mode for a headphone amplifier. The 200mA bias also provides plenty of margins for a rich Class A. The cascoded LU1014D is thus an ideal candidate for a Source Follower Headphone Buffer circuit.

This was first published in The DIY Audio forum in :
<http://www.diyaudio.com/forums/headphone-systems/95841-mosfet-follower-headphone-amplifier.html#post1130743>

The Triode Curve of the cascoded LU1014 was published at :
<http://www.diyaudio.com/forums/pass-labs/128571-some-other-source-follower-configurations.html#post1595867>

Further related links can be found at :
<http://www.diyaudio.com/forums/headphones/95841-mosfet-follower-headphone-amplifier.html#post1130805>
<http://www.diyaudio.com/forums/headphones/95841-mosfet-follower-headphone-amplifier-2.html#post2133200>

Only one brave person, Steenoe, went ahead then to build a prototype of the standard circuit, followed later by the TCS (Taylor Current Source) version with more driving power. His comments on both versions, as well as those who build the same afterwards following his positive experience, can be found in Appendix 1.

As one can see, the basic DAO JFET follower is a rather competent performer on its own, whether in the standard source follower, or the TCS version. Many have recently been asking for PCBs, and we also want to do a new build with audio grade components and slightly revised schematics. The result of this is the DAO SE Headphone Amplifier (Special Edition), as we call it.

To make the design more versatile for headphones of any impedance, we decided to include in the new design two additional but optional modules. A Head Amp Gain Stage (HAGS) based on the XCEN configuration provides a gain of 5, without global feedback, in case people wish to use a high impedance headphone in combination with a low-signal-level source. For our own use, we decided to also add a Meier passive cross-feed filter at the input, buffered by a JFET follower. All circuitries are thus all-FET, zero-global-feedback, and pure Class A. One of the XEN team members wanted a volume control on top. So we incorporated a TKD conductive-plastic pot between the cross-feed buffer and the HAGS for that purpose.

For power supply, we continued our tradition to prefer to use batteries. For example, 32 pieces of LiFePo4 1100mAh can provide each channel with +/- 26V supply for about 4.5 hours. The same space will also hold a transformer up to 110mm diameter and 55mm height, which corresponds to a standard toroidal transformer of > 250VA (sufficient even for 2x LM3886 chip amp). The actual consumption of all three circuits is in the order of 25W for 2 channels together.

This completes the basic configuration of the design.

Appendix 1 Builders' Comments of the DAO Follower

"Steenoe
10th February 2007

The sound is extremely detailed and direct without getting annoying at any point. It sounds crystal clear and very good indeed. The mini-Zenamp sounds a bit more romantic in comparison. I will do an A/B test later to better give an account of it.

The amp has plenty of power for my Beyerdynamics DT880's, which sounds very, very good with EUVL's amp. The detailed sound is some of the best I have heard yet. Details are just clearly cut out. On many records, they add some artificial soundstage and eccho's and so on. If the technician didn't do a good job, EUVL's amp will tell you through a good pair of cans.

I found myself laughing a couple of times, for that reason.

Thanks for posting the circuit, Patrick. This amp is absolutely a keeper

<http://www.diyaudio.com/forums/headphones/95841-mosfet-follower-headphone-amplifier.html#post1131708>

6 Sept 2009

I have built one more DAO, this time with the Taylor mod, and it sounds great indeed. The Taylor mod added a bit more transparency, which is now approaching electrostatic territory. The best I heard yet with dynamic headphones.

The difference from the original DAO is subtle, which is not surprising since it is already a very good headphone amp. The one with the Taylor is just that tad better though, so it is absolutely worthwhile to implement the Taylor mod.

Overall it sounds very organic and natural with clear clean highs and deep firm lows. No sign of listening fatigue at any volume level, even for long listening periods. It also has the music in a firm grip at all times, even at high levels and massive music it never gets muddy in the sound. I can easily live with this headphone amp Attached is a pic of the test setup, with the Taylor hanging in the lower right corner of each board. The supply is a shared 160VA 2x18V donut, with 40.000uF and 1,8mH in a CLC configuration for each channel. It is dead quiet without signal.

<http://www.diyaudio.com/forums/pass-labs/128571-some-other-source-follower-configurations.html#post1603771>

A few other builders followed after Steen's positive experiences :

"jameshillj
1 July 2009

With the DAO follower amp, it's about "the best thing out there since sliced bread" for any phones from the Grado RS-1s, K170 AKGs and the Senn 650s. Not the cheapest thing, and a bit power hungry with a total consumption of about 75watts both channels (including both the supplies). However, even without the fancy input ccts, this Taylored DOA follower must rank up there with some of the best headamps ever built.

<http://www.diyaudio.com/forums/pass-labs/139907-downscaling-zen-v-9-use-headamp.html#post1869562>

"Gordy
27 March 2010

A friend (who lurks here, but is not a member) has built the non-Taylor'd version of DAO and says that it performs very good, and better than every commercial headphone amp he has tried. All credit to Patrick / EUVL.

<http://www.diyaudio.com/forums/headphones/95841-mosfet-follower-headphone-amplifier-3.html#post2133565>

And a remark about the circuitry itself :

"John Curl
19 June 2010

EUVL, you have the right spirit for the Blowtorch thread. You have made an example of a most elegant approach to making a headphone amp. Simple, yet not too simple, sophisticated where it gives improvement, and your own take on the optimum output stages. Well done!

<http://www.diyaudio.com/forums/analog-line-level/146693-john-curls-blowtorch-preamplifier-part-ii-96.html#post2221319>