Taylor Current Source

In August 2008, we published an article titled "Alternative Configurations of the simple JFET Source Follower". This can be found in :
http://www.diyaudio.com/forums/pass-labs/128571-some-other-source-follower-configurations.html

All of these configurations involve the use of some current sensing means, e.g. a resistor, at the upper driver FET to drive the current source at the negative rail, such that the output current is not entirely provided by the driver, but also by the current source. This has a similar function as Nelson Pass' famous Aleph Current Source, though using a different principle more akin to the White Follower. Potential advantage of the current source (the lower FET) modulation is reduced output impedance and improved current driving capability. This can be particularly useful when driving low impedance loads. Also when implemented properly, the push-pull nature of the modulated current source can be used to reduce even order harmonics, especially 2^{nd} harmonics.

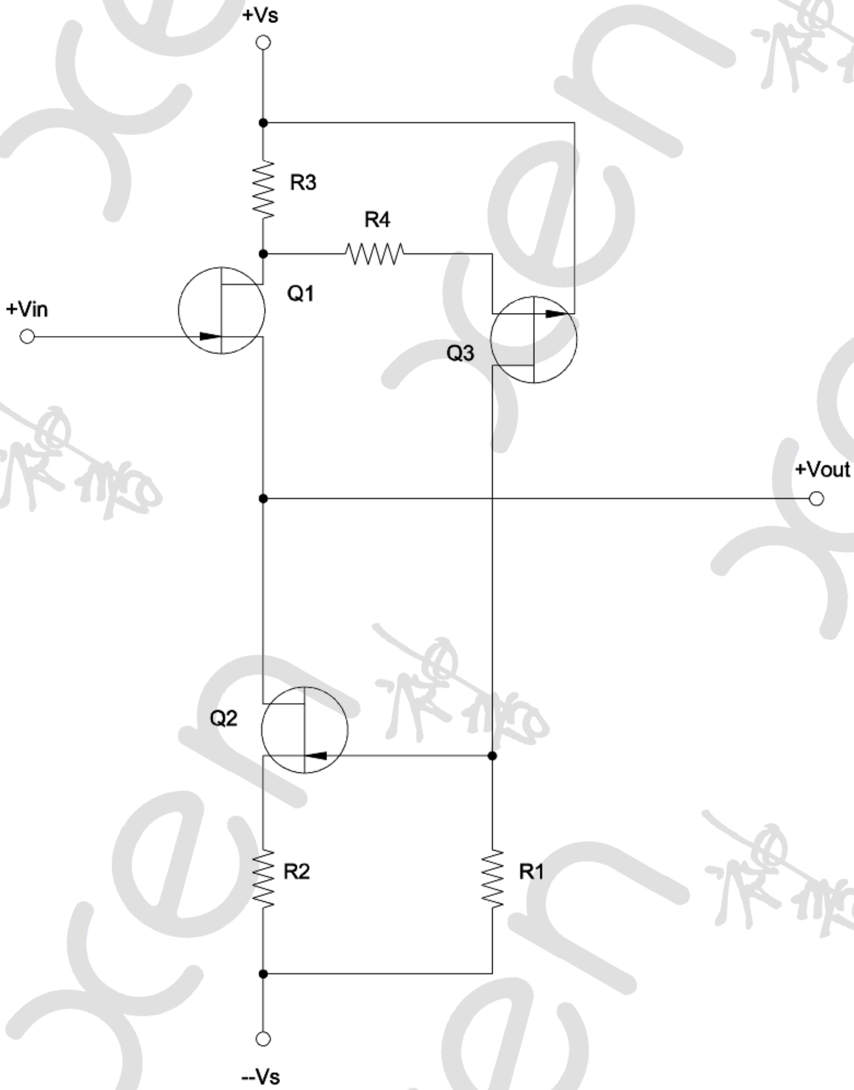
One of the configurations described in the article is the Taylor Current Source published by TubeCAD : http://www.tubecad.com/2004/blog0023.htm

The circuit published there uses a PNP bipolar transistor for driving a MOSFET current source, and requires a biasing means at the base of the PNP transistor. A self-biasing JFET version suitable for driving a JFET follower was also described in our own article mentioned above.

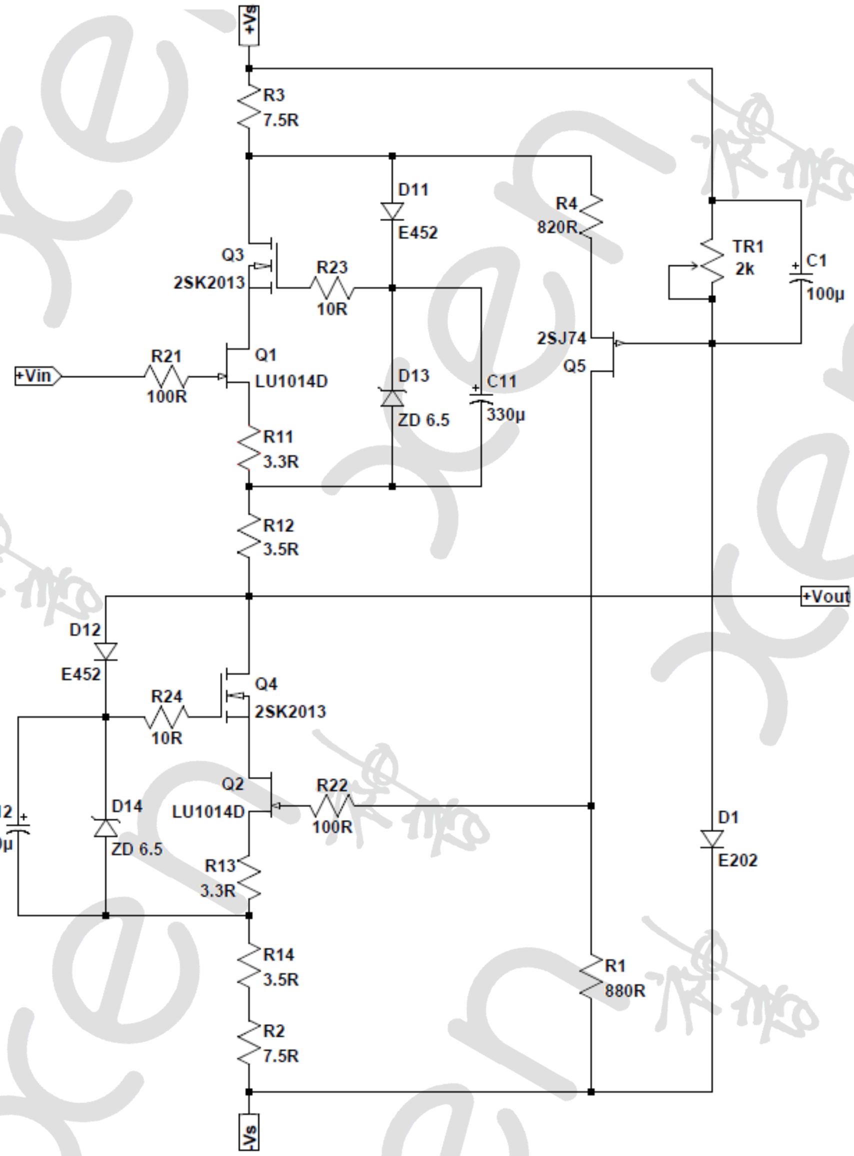
Although this latter, self-biasing version is simple and elegant in circuitry terms, it does have some limitations. For example, both the bias of the power stage as well as the modulation circuit would have an effect on the DC output level as well as the driving current ratio. This means that the values of the four resistors around the modulation circuit have to be realigned in case of a bias or device change, making circuit standardisation difficult, even though we managed to come up with a simple spread sheet which allows a first order calculation of these values, based on driver stage and modulation circuit bias. Furthermore, since the 2SJ103 used in the modulation circuit is heavily degenerated to round some 3mA bias, it is operating at its quadratic regime. As such, the resulting circuit generally has higher 2^{nd} order, and likely also 3^{rd} order than the standard version. It just proves that the standard DAO circuit itself is very hard to beat.

In the interest of ease of construction by the general public, we developed a revised version that uses an additional current regulating diode, a trimmer resistor and a capacitor to drive the gate of the modulating device at an intermediate voltage between the two rails. This version was actually also published in our 2008 article. Similar to the TubeCAD circuit, the modulating device may be a PNP bipolar transistor, but we prefer to use a high transconductance P-JFET, such as the now difficult-to-get 2SJ74. The current ratio is pre-set by fixed values of the 4 resistors, whereas the output DC can be separately adjusted by the trimmer. As a bonus, the high Yfs of the 2SJ74 also help to reduce 2^{nd} and 3^{rd} order distortions back to the level of the standard circuit or better, with the added bonus of lower distortion levels beyond 4^{th} order. If one is in the procession of a distortion meter, the 2^{nd} (& 3^{rd}) harmonics can be adjusted quite easily via R4, whereas the trimmer is used to readjust the DC offset in an iterative manner. In theory one can reduce the 2^{nd} harmonics this way to zero, though at the expense of increased 4^{th}, which is not necessary an improvement sound wise. In any case a means is provided such that the harmonic spectrum can be adjusted to taste. This will be the circuit that we recommend for most builders.

The TCS, because of its better current driving capability, is also capable of a higher bandwidth than the standard version, given the same load. It does, however, show a slight (< 1dB) overshoot at high frequencies. The DAO buffer works best when loaded with 66 ohm or less. So if your headphone is very inductive at high frequencies, it is worth considering a Zoebel network in parallel at the output.



DAO Power Buffer with Self-Biasing JFET Taylor Current Source, Simplified Schematics
Q1, Q2 to be replaced by the JFET triode cell.
Q3 is 2SJ103BL.



DAO Power Buffer using JFET Taylor Current Source with fixed Vg, Simplified Schematics
Q1, Q2 to be replaced by the JFET triode cell.

The High-Current Low-Impedance Version

Suppose you have a low impedance headphone (say 30 ohm or below), and you want to optimise your DAO power buffer for even better current driving capability and even lower output impedance. Is that possible ?

The answer is yes. One can reduce the value of the lower resistor of the triode cell to e.g. 1 ohm or less. This results in a high bias of > 300mA. The output impedance in the standard version will also reduce to about 5 ohm. Using the TCS version will further reduce this to about 2.6 ohm, as well as a maximum Class A current of > 600mA. That is a RMS power of 3.6W even for a 20-ohm phone, and 5.4W for 30 ohm. This abundance of power serve is responsible for the capability of the DAO to drive low impedance loads with such ease and sovereignty. When using such low impedance loads, you may of course also consider reducing the rail voltages while increasing bias for optimal efficiency.

Driving the Hifiman HE-6 with a custom-designed DAO TCS-HP

Someone drew my attention to the new Class a Headphone Amplifier by Audio Note which is designed to drove the power-hungry Hifiman HE-6 headphone. The HE-6 has a planar magnet design which is particularly inefficient, and requires 6W low-distortion driving power into a 50-ohm impedance. This is equivalent to +/- 25V, 500mA. This is beyond the capability of the DAO, in any of the above variants.

The voltage limitation is easy to solve by simply increasing rail voltage. The high output current can only be delivered at low distortion by increasing the bias from the current 200mA to something like 500mA. The dissipation of the LU1014 (about 1.5W) would not be an issue, but the dissipation of the cascode device would be about 14W, a bit high for a TO220 device for long term reliability. But this can be substituted readily by a TO-247 device such as the 2SK1529.

The task is then to redesign the triode cell to operate at 500mA bias. This must be possible, since the same device exhibits triode behaviour in the DAO at 200mA, while in Nelson Pass' ZEN Version 9 at about 1.3A. Indeed, after some simulation and experimentation, a triode cell configuration was found that can be biased at 500mA. A DAO TCS-HP using this triode cell with +/-32V rails will deliver 6W into 50 ohm with under -80dB THD. Output impedance is about 2 ohm. And this is achieved without any global feedback or even local feedback, as in case of a complementary CFP buffer such as the well-known John Linsley Hood design.

However, as there are very few DIYer's who own the HE-6, and we do not intend to dish out 1,400 USD just to prove a circuit, this will remain a design study on paper and simulations only. In accordance with our established practice, we shall not publish any schematics that has not been proven experimentally, even though we do have confidence in our simulations.

Can we go even higher power with the DAO circuit ? Of course. If we use the same triode cell as in the ZEN Version 9 in a DAO TCS, we'll be able to deliver at least 700mA with low distortion, and 2.5A in Class A. Voltage is not really a problem, since the 2SK1529 can handle 32W dissipation with a suitable heat sink, and one can also use multiple MOSFETs in parallel for the cascode device. Output impedance of such as a DAO with TCS would be about 0.5 ohm.

Beyond that, we can always use 2 or 3 triode cells in parallel. Bandwidth would decrease as a result, but it would still be well over 200kHz, a decade beyond the audio band.

In the following sections, we shall refocus ourselves back onto the "original" DAO SE design.