The Open-Source Directly-Heated Triode Electrostatic Headphone Amplifier (OSDEHA)

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Warning: This DIY project involves high voltage. Individuals utilizing the information provided must possess expert knowledge, adhere to stringent safety precautions, and accept all risks associated with electrical work. The authors and contributors of this project expressly disclaim any liability for injuries or damages arising from the use or misuse of this information.

THIS DOCUMENT IS UNDER CONSTRUCTION

1. OVERVIEW

This document describes an audio amplifier for electrostatic headphones. The design of the amplifier is targeted at DIY builders and is published as open hardware (see Sec. 3).

Electrostatic headphones operate on audio signals characterized by high voltage and low current. This is the domain of vacuum tubes, making them most suitable as drivers for e-stats. While there exist a number of tube amplifiers for e-stat headphones, many of these designs do not utilize directly-heated triodes (DHTs), which exhibit outstanding linearity and sound quality.

The OSDEHA uses DHT tubes for its output stage and implements the following design goals:

- The audio output is taken directly from the anodes of the DHT output tubes. There are no transformer or capacitors to transfer the power to the headphones.
- The amplifier input takes balanced input at signal levels of modern audio sources (mostly DACs these days).
- The design prioritizes the quality of audio reproduction and electronic design rather than on low cost.
- The amplifier should be reasonably compact, and all units and boards should fit in one single chassis.

There is a public discussion thread of the OSDEHA at diyAudio.[1]

2. AMPLIFIER CIRCUIT

2.1. Driving electrostatic headphones

Electrostatic headphones use three electrodes. The two outer electrodes (stators) are fixed, while the one in the center (diaphragm) is free to move. The diaphragm is biased relative to the stators at a high voltage. The audio signal is applied to the stators in opposite polarity, forming an electric field that controls the movement of the charged diaphragm. For low-distortion operation, the charge on the diaphragm needs to be held constant.[2] The electrical impedance of an estat headphone is largely determined by the capacitance of the two stators, which typically corresponds to about 100 pF.[3]

The requirements for the voltage swing of the amplifier output are determined by the headphone sensitivity and the required sound pressure level. An experiment using different genres of well-recorded music showed that an undistorted peak-to-peak swing of the bipolar output voltage of 1.3 kV would be nice to have.[4] The corresponding current swing was also measured in the same experiment (about 4 mA), but driving the 100 pF load to full output at 20 kHz (and higher) requires larger peak currents of about 20 mA.[5]

2.2. Output Stage

Fig. 1 shows the conceptual layout of the OSDEHA, using two DHTs in a push-pull arrangement to provide the symmetric, bipolar output needed to drive estat headphones. For efficient transfer of the audio power to the headphone, the AC impedance of the anode loads must be larger than that of the headphone (several M■). This cannot be achieved by passive anode-load resistors, so active constant-current sources (CCSs) are used in this position. The CCS loads also improve the linearity and voltage gain of the amplifier, and suppress ripple and noise from the B+ rails.

The DC level of the amplifier output should be near GND and centered between B+ and B-. The CCS loads therefore need to drop the DC voltage from B+ to GND, and the DHT tubes drop the same amount of voltage from GND to B-. The output DC level could be zeroed by biasing the tubes accordingly, but would be prone to drift of the output tubes. A better control of the output DC is achieved by using a "gyrator" CCS as conceived by Ale Moglia.[6] This circuit works as a CCS in the audio/AC domain, but automagically adjusts the DC operating current to achieve a predefined DC voltage point. The gyrator therefore maintains the output DC level despite any thermal drift or aging of the DHT tubes.

3. LICENSE INFORMATION

Source location: https://github.com/mbrennwa/OSDEHA

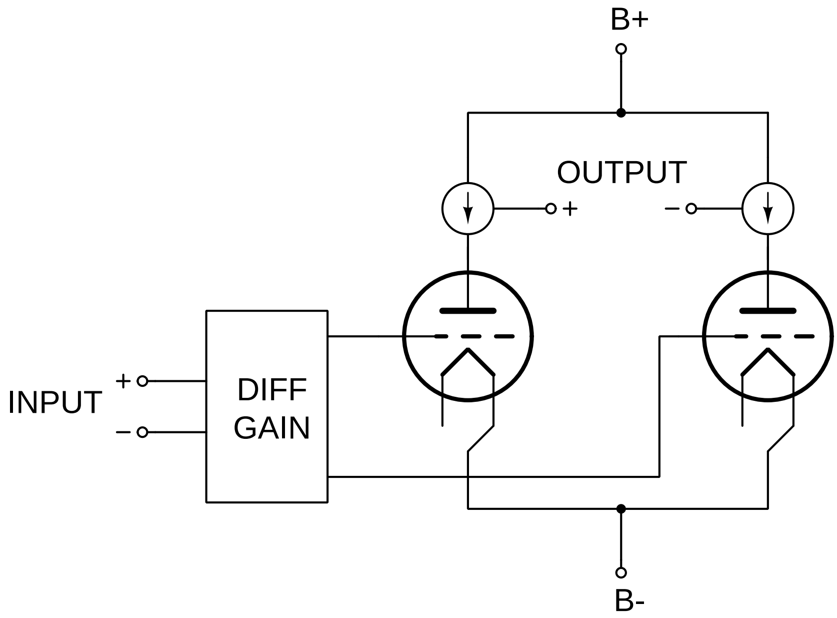

Figure 1: Conceptual layout of the OSDEHA: differential input, gain stage stage, and push-pull DHT output stage.

As per CERN-OHL-S v2 section 4, should You produce hardware based on this source, You must where practicable maintain the Source Location visible on the external case of the OSDEHA or other products you make using this source.

REFERENCES

[1] https://www.diyaudio.com/community/threads/open-source-dht-estat-headphone-amp-osdeh 407679.

[2] http://www.high-amp.de/html/electrostatic-principle.html.

[3] https://www.diyaudio.com/community/threads/open-source-dht-estat-headphone-amp-osdeh 407679/post-7567130.

[4] https://www.diyaudio.com/community/threads/open-source-dht-estat-headphone-amp-osdeh 407679/post-7572339.

[5] https://www.diyaudio.com/community/threads/open-source-dht-estat-headphone-amp-osdeh 407679/post-7565754.

[6] https://www.bartola.co.uk/valves/tag/ale-moglia-gyrator.