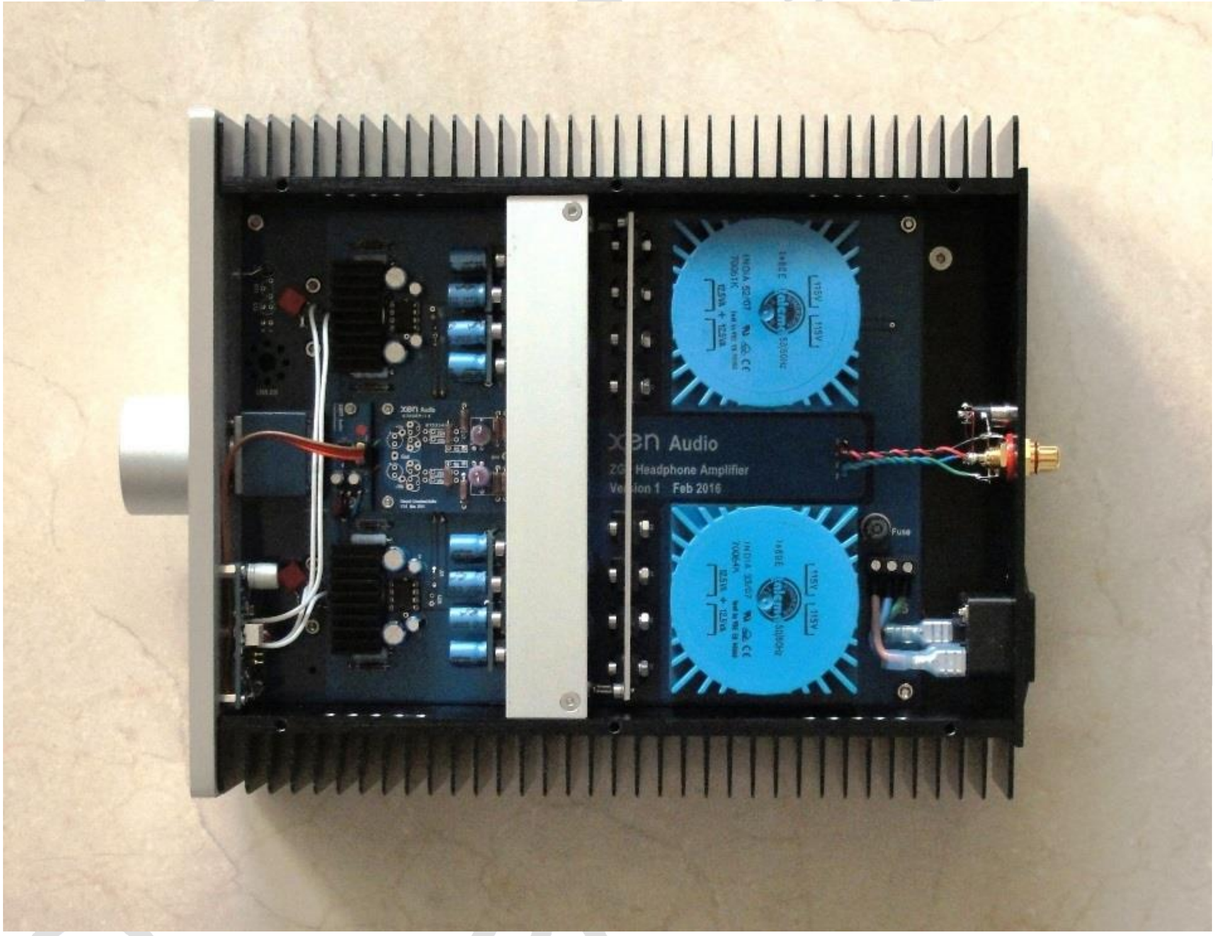
ZGF Desktop Headphone Amplifier
XEN Audio
July 2016



Background

Earlier we published a portable headphone amplifier based on the AD844 in open loop, followed by an open loop buffer [1]. The final solution for the portable uses output of the AD844 at pin 5, driving a discrete LH0033, with 24mA output bias.

Now that this is finished, it is time to proceed to the desktop version. The portable version is limited by the battery operation in terms of maximum Class A output current, as well as output impedance. For a desktop version, one would of course wish to improve on those. So while keeping the AD844 gain stage, a unity gain buffer with high input impedance (> 10M ohm), low output impedance (< 1ohm), and high bias current (>100mA) needs to be found.

The High-Power Output Stage

The (discrete) LH0033 used in the final version of the ZGF-Portable satisfies only the first requirement. The output impedance is > 2ohm, and output stage bias is only about 20mA. Getting it to 100mA would mean 5x in parallel. Not a very elegant solution, apart from being expensive, but also not totally unrealistic.

Then I stumbled onto a Russian site [2] where they showed a clever way of increasing the output power of the LH0033 by adding a Sziklai booster. The (still available as NOS) LH0033G is ideal for this, as it already provides separate pins for the input and output stages makes it ideal for this exploitation. The original schematics uses MJE200 / MJE210 pair from On Semi, but I find that the Sanken 2SC4883A / 2SA1859A are even better in almost every aspect. The emitter resistors used were 3.3R as in the F5-HA, and the biasing resistors (connected to pin 12-1 and 9-10 of the LH0033G) were 200R. The resulting output bias was about 150mA and was stable. The LH0033 also has offset adjustment pins (6-7). And the offset adjustment is a simple current source degeneration, a nice feature allowing simple adjustment with one resistor. Once the DC offset has been trimmed at pin 6-7 of the LH0033G, it remains stable to just a few mV over an hour. So much so that I did not even bother to use the AD844 servo board even though it was already soldered and ready to be implemented. In my particular example, 1R between pins 6-7 increased the DC output voltage by 10mV.

The final output impedance was measured to be about 0.1 ohm, and the amplifier was stable even with no load. But as one would expect with any Sziklai output stage, it didn't like the reactance of my AKG K-701, and had to be tamed with a Zobel network (I used 27R-220nF) at the output. Once this is done, the frequency response is a smooth first order drop with 300kHz bandwidth (-3dB). And 100kHz square wave shows no overshoot.

This is a very useful output buffer for any headphone amplifier with zero global feedback, whether you use an AD844 as gain stage, or tubes, or transformer, or whatever else that does not necessarily has a low output impedance. There is no need to add another buffer in between. And all devices are leaded with 2.54mm pitch, making it ideal for Vero board P2P build.

A Little Discrete ……

Heh, but you cannot rely on the LH0033 being available for long !!!!!

Very true, but the nice thing about the LH0033 is that it is actually not a single chip, but a so-called multi-chip package, with individual dies for the transistors and resistors mounted onto a ceramic substrate, and connected together by wire bonding. They won't make them like this anymore, as it will be too expensive. But this means that there is enough room within the package that we can actually make a discrete version out of SOT23 SMD devices. So for continuity into the future, I designed an adaptor board using all discrete Toshiba SMD JFETs (2SK208GR) and BJTs (2SC3324BL / 2SA1312BL), all of them low noise devices. And we should have no supply problems for the next 5 years, with similar or even better performance to the original.

Wanting to be Different

Although the rest of the amplifier has a lot of similarities to the F5-HA, I wanted to do a few things differently, just for the sake of it.

Firstly I wanted to make it an exercise to see how I could build it using a standard 2107 case without any special machined parts. The rectifiers and the LM3x7 Cap multipliers actually do not dissipate too much heat, so I just bolted them to standard aluminium strips and angles available from normal home DIY stores. And they were fine as such, with temperature no higher than 40°C on the TO220 devices. But I also added a thermal conduction path (via brass standoffs and stranded copper wires) from the aluminium extrusions to the bottom plate of the 2107 case. This in turn is thermally connected to the side heatsinks. The special large-size angles in the original F5-HA layout are no longer needed. And anyone with a battery powered drill will be able to implement what is shown here with some mechanical skill.

I adapted the original top plate of the 2107 case and used it as bottom plate instead, to provide some venting. One can then swap the bottom plate to the top, but I thought it would look much nicer to replace this with an anti-static, tinted transparent acrylic of the same size. With 6 plastic washers between the acrylic and the heatsink, the top plate I now also vented. But I also drilled additional holes along the top edge of the size heatsinks for additional ventilation. This is straightly speaking not necessary, since the heatsinks are hardly warm to the finger.

The LH0033G does get hot. And as it does so, the bias of the Sanken transistors also increases. A heat sink is therefore mandatory. With the sinks shown, the steady state temperature of the LH0033G was about 40°C, and the increase in output bias was within 10% or so. In any case, the Sanken devices, the PSU as shown, and the 2107 case will all be able to cope with 200mA bias or more without difficulties. So we are quite safe with any bias drift.

Passive Cross Feed with Integrated Volume Control

Then I also wanted to make use of our XEN modified RK27 ladder attenuator [3]. As a further simplification, we developed a fully passive line-level cross feed which also incorporates a 10k log pot as volume control. Simply put, we just replaced R2 (5.5k) of the XEN modified Danyuk cross feed with a 12k resistor in parallel with the 10k log pot. The output is now taken from the wiper of the log pot [4]. As the AD844 has an input impedance of 10M // 2p, I did away with the JFET buffer of the cross feed altogether. For the F5-HA, however, it is still recommended to retain the buffer, but now between the pot and F5 input.

And as 1/4" TRRS plugs and sockets are non-existent, and I do want to use the same 4-wire phones as on the ZGF-Portable, the choice of a 5-pin mini-XLR as output socket is an easy one. It also have enough threads to cope with the 8mm thick front panel.

Now that there is no longer a need for the power supply for the cross feed buffer, it provides a ready solution to supply +/-12V to the SHPP protection board instead [5]. On the left channel, R41,42 originally meant for the LDR CCS power supply can now be use instead to drive a 3mm blue LED on the front panel with the desired brightness.

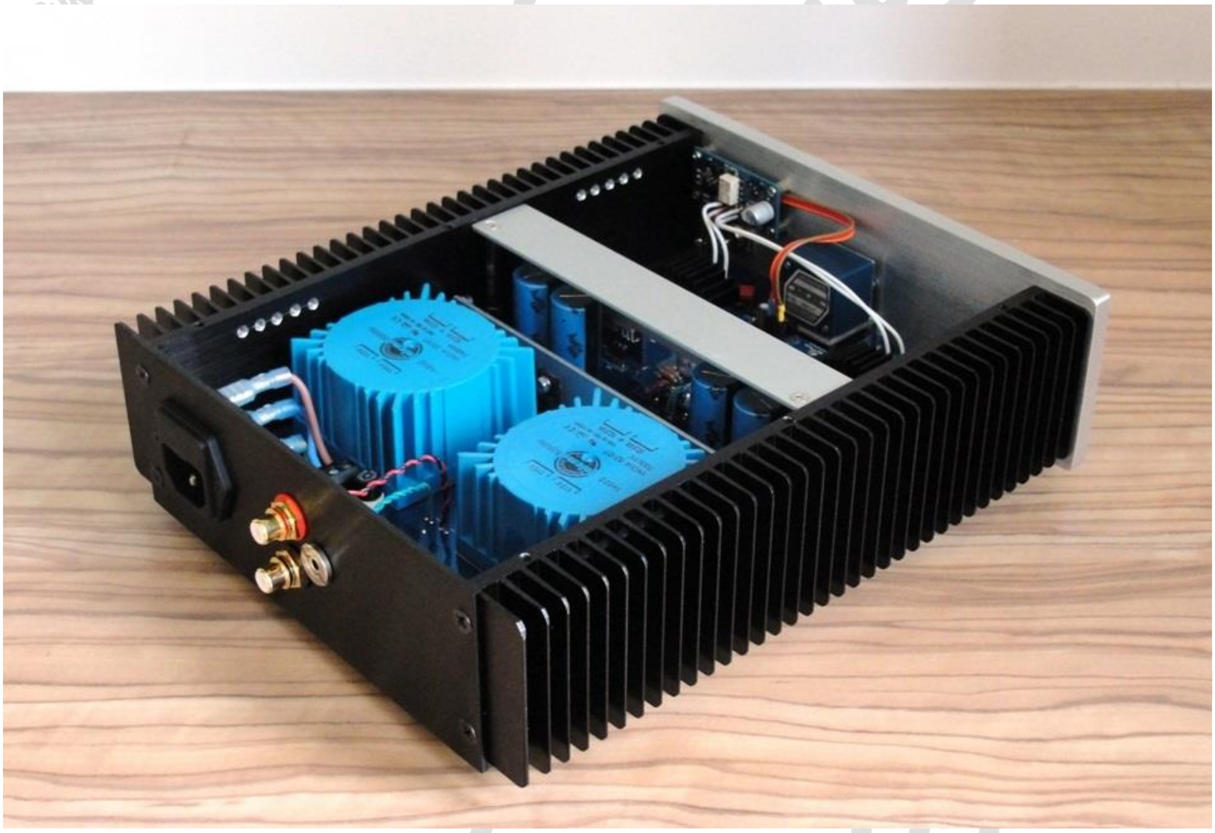
Concluding

So here it is. An almost all-IC-based, pure-Class-A, minimalistic high-power headphone amplifier with no global feedback but still excellent performance, yet requiring no matching and very little or no (if you use a DC servo) adjustments. An amplifier that can be built by anyone without sophisticated equipment or tools.

And the sound ?
I leave you to judge for yourselves. But I am certainly keeping mine. ☺

References

1. http://xen-audio.com/documents/xen-zgf/XEN%20ZGF%20Portable%20Description%20V1.pdf
2. http://www.audioportal.com/showthread.php/51629-%D0%A0%D0%B8%D0%B6%D1%81%D0%BA%D0%B8%D0%B9-%D0%B1%D1%83%D1%84%D0%B5%D1%80-3
3. http://www.diyaudio.com/forums/headphone-systems/225577-dao-se-all-fet-class-zgf-headphone-amplifier-4.html#post4347276
4. http://www.diyaudio.com/forums/pass-labs/271926-f5-headamp-11.html#post4759695
5. http://www.diyaudio.com/forums/headphone-systems/292681-xen-shpp-simple-headphone-protection.html



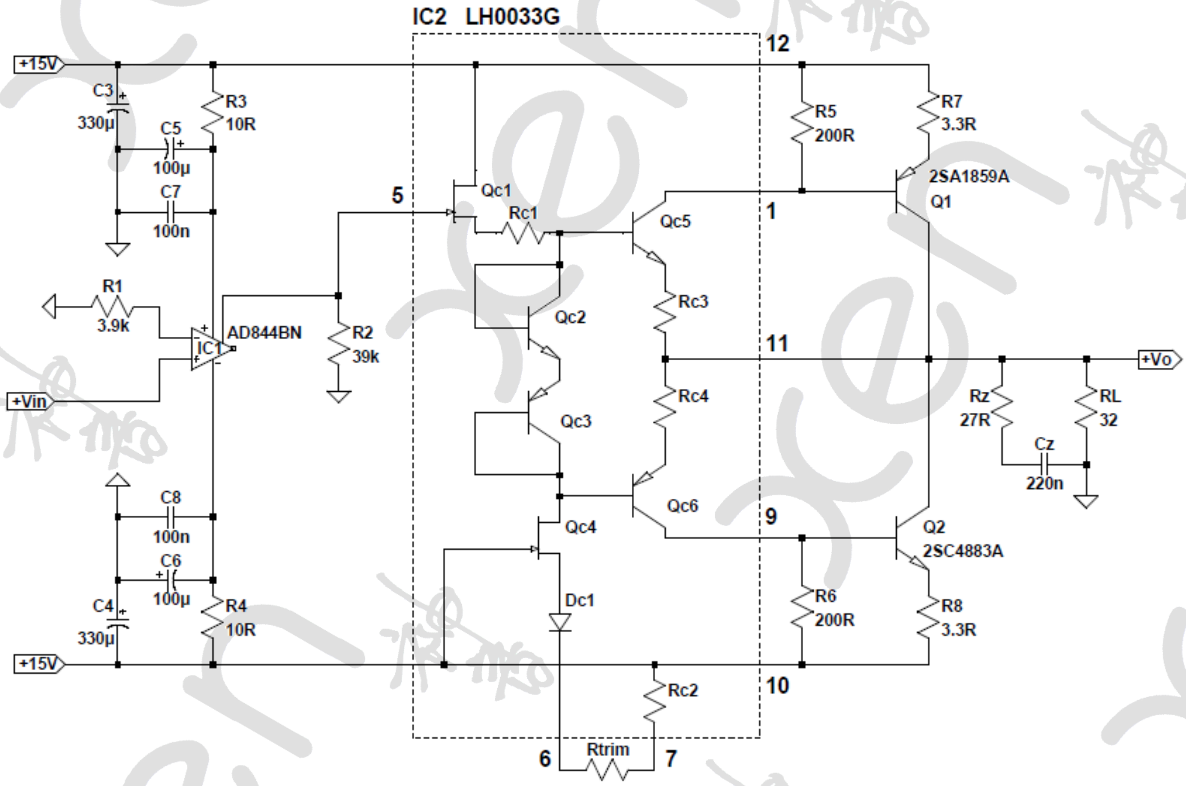


Figure 1 ZGF Desktop V1 Schematics

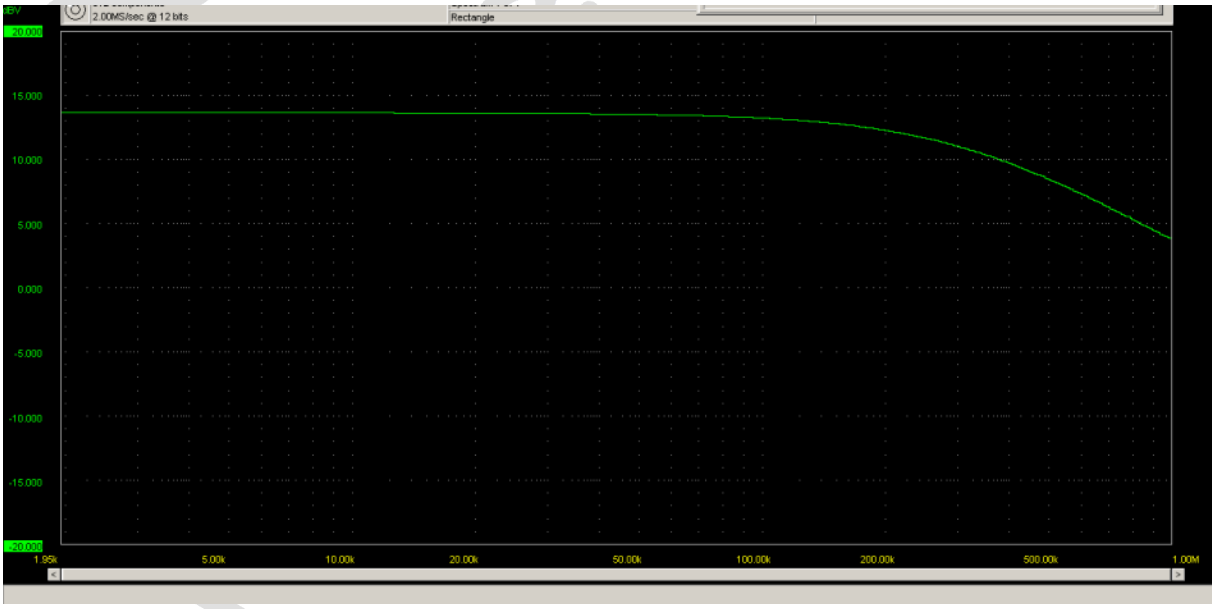


Figure 2 Frequency Reponse with Load

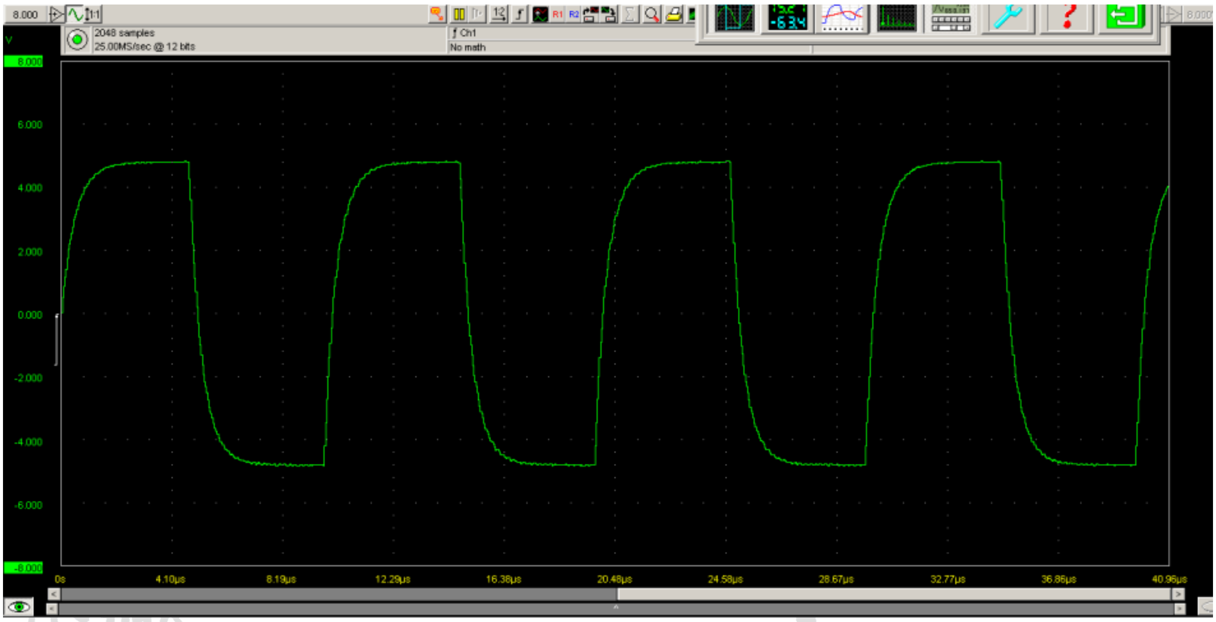


Figure 3 100kHz Square Wave

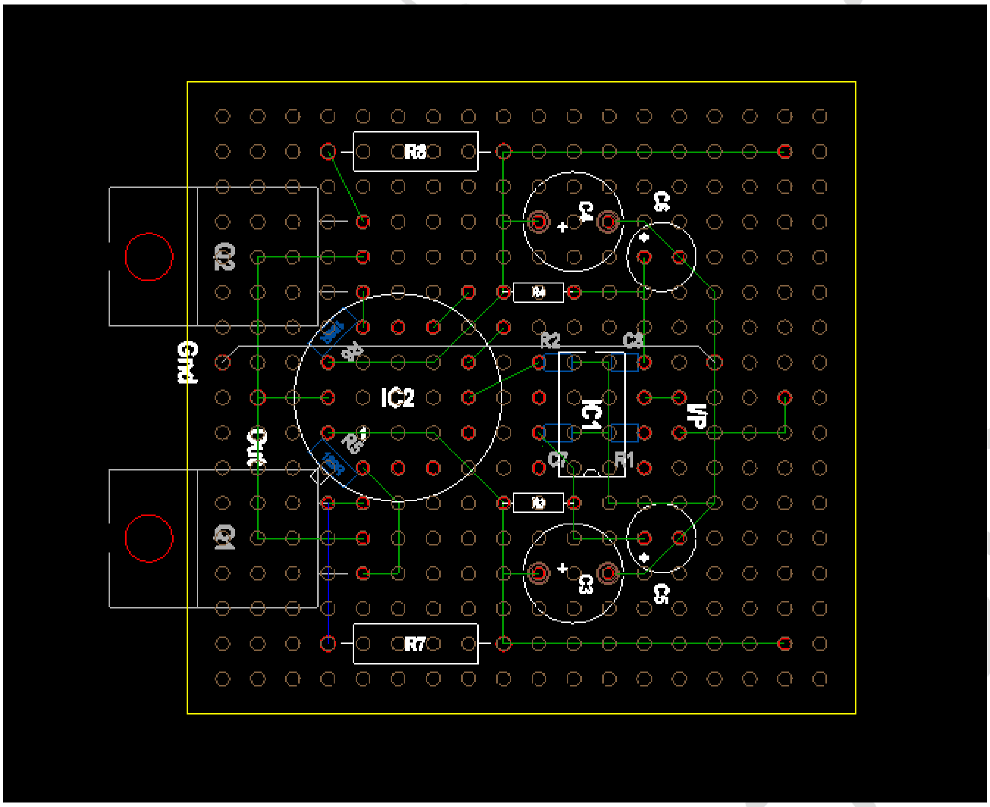


Figure 4 ZGF Desktop Vero Layout

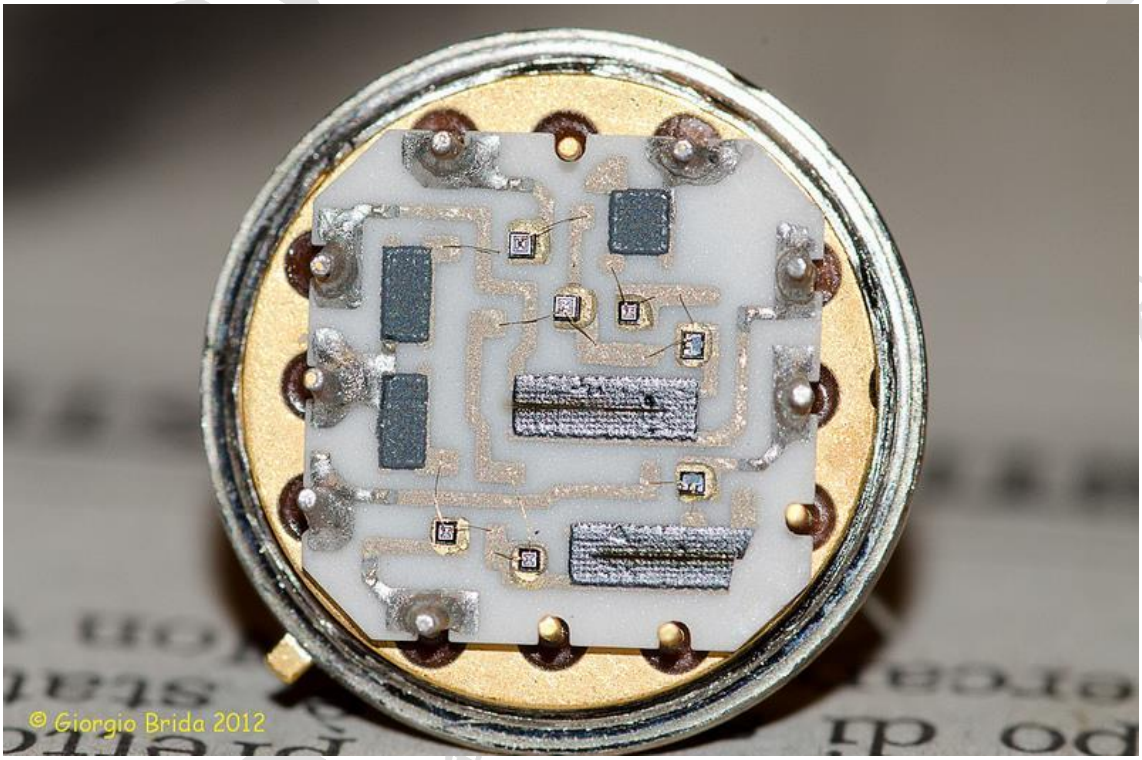


Figure 5 LH0033G Inside

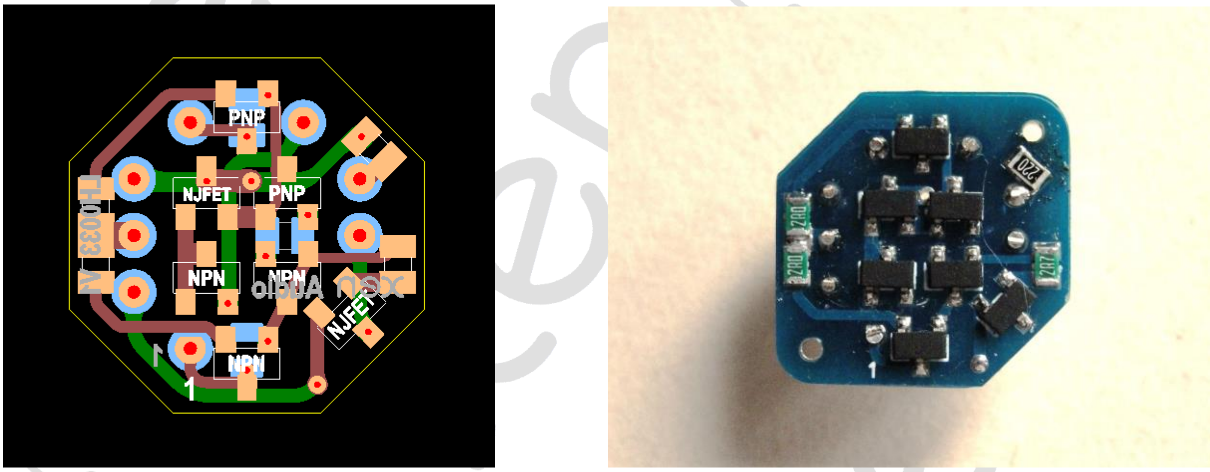
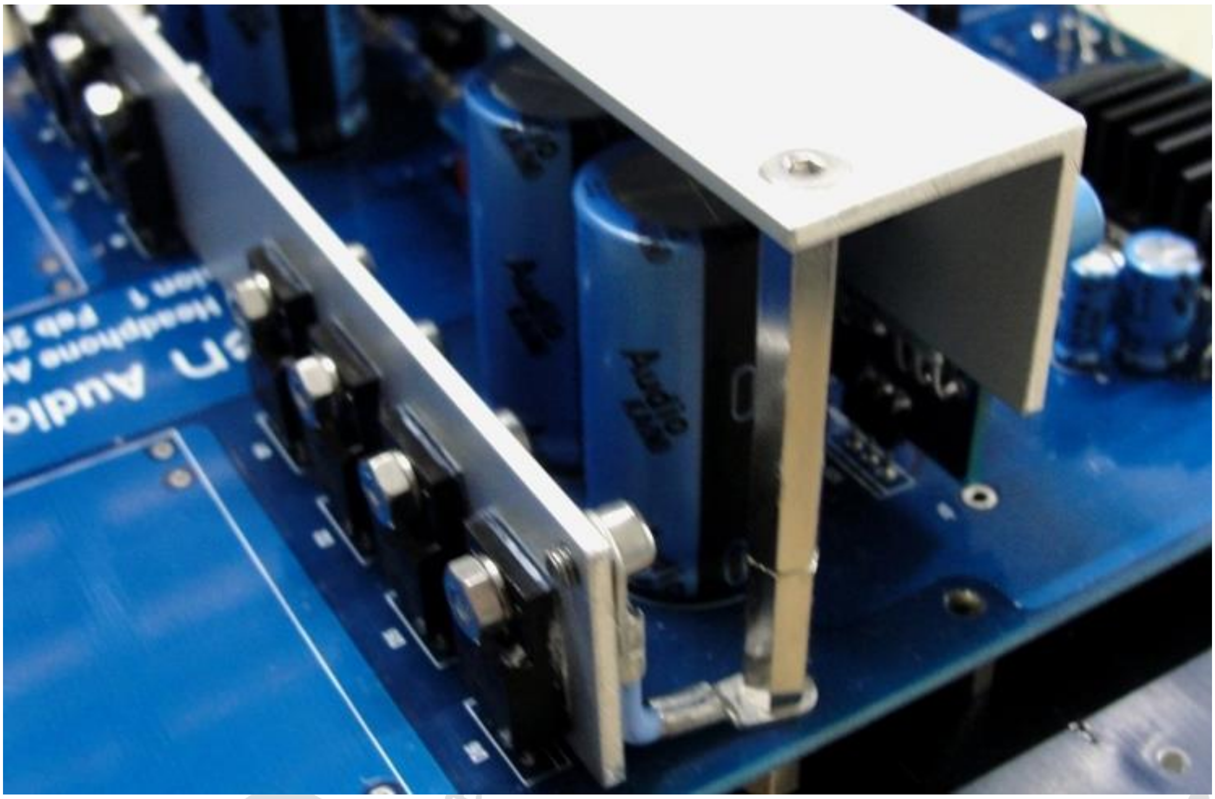


Figure 6 XEN SMD Discrete LH0033



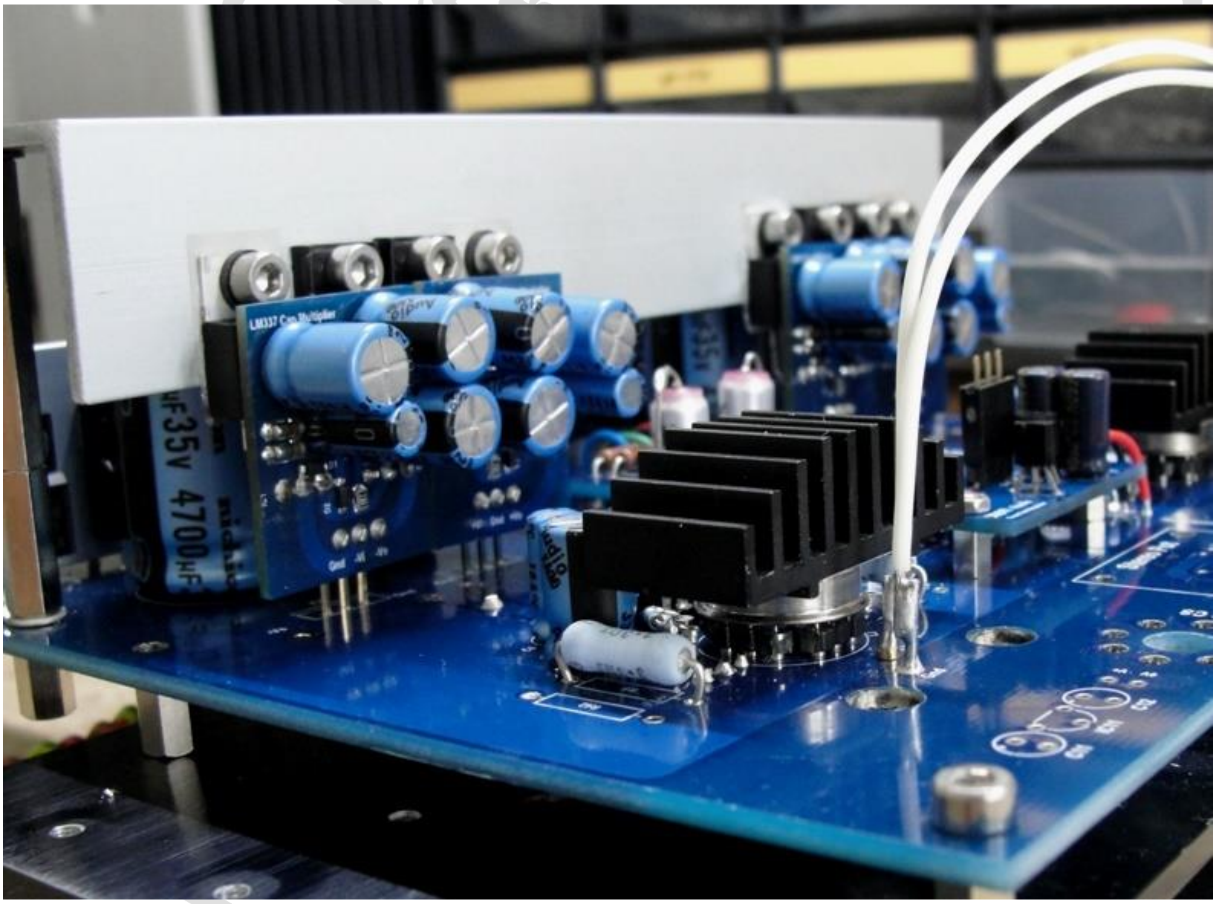


Figure 7 **Thermal Management**

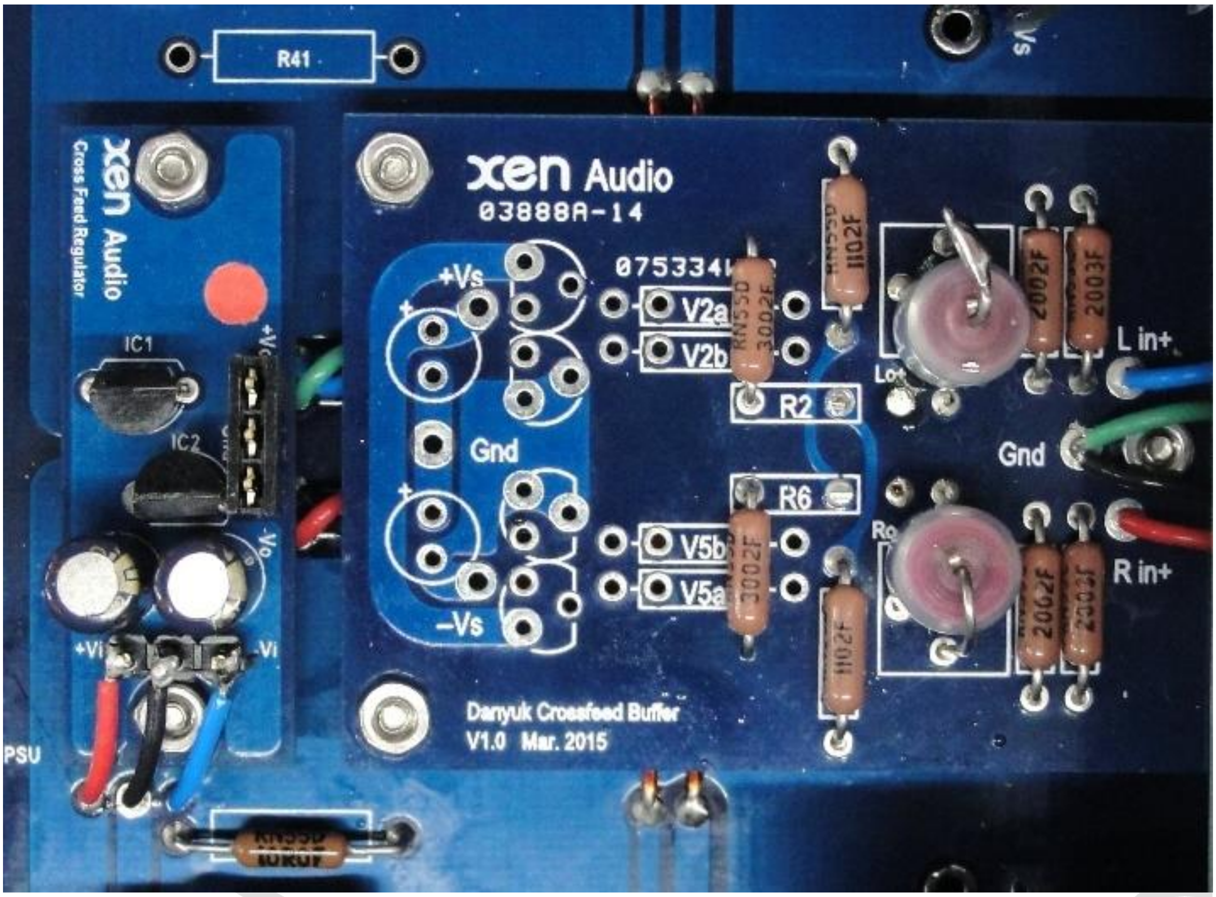


Figure 8 **Passive XEN Modified Danyuk Cross Feed**

Figure 9 **Top Ventilation**

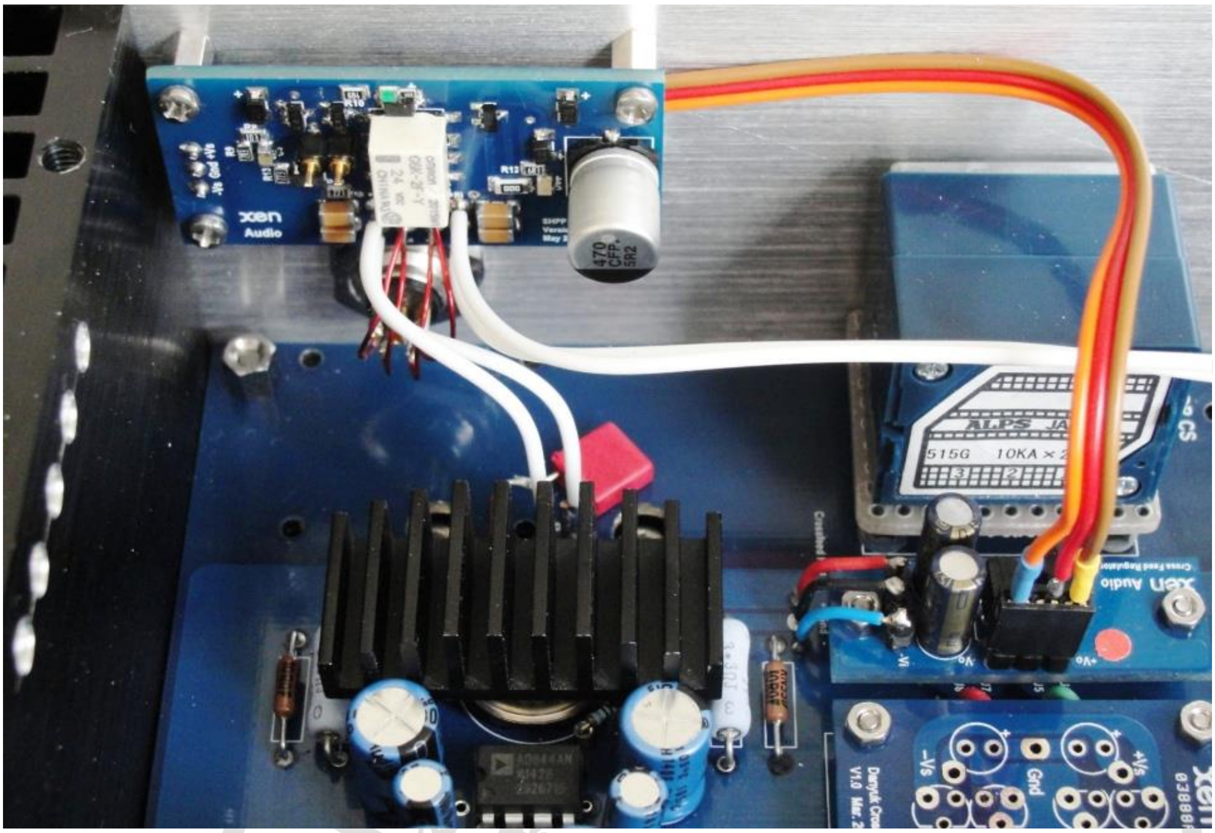


Figure 10 XEN Simple Headphone Protection Module &
XEN Modified ALPS RK27 Susumu Ladder Attenuator

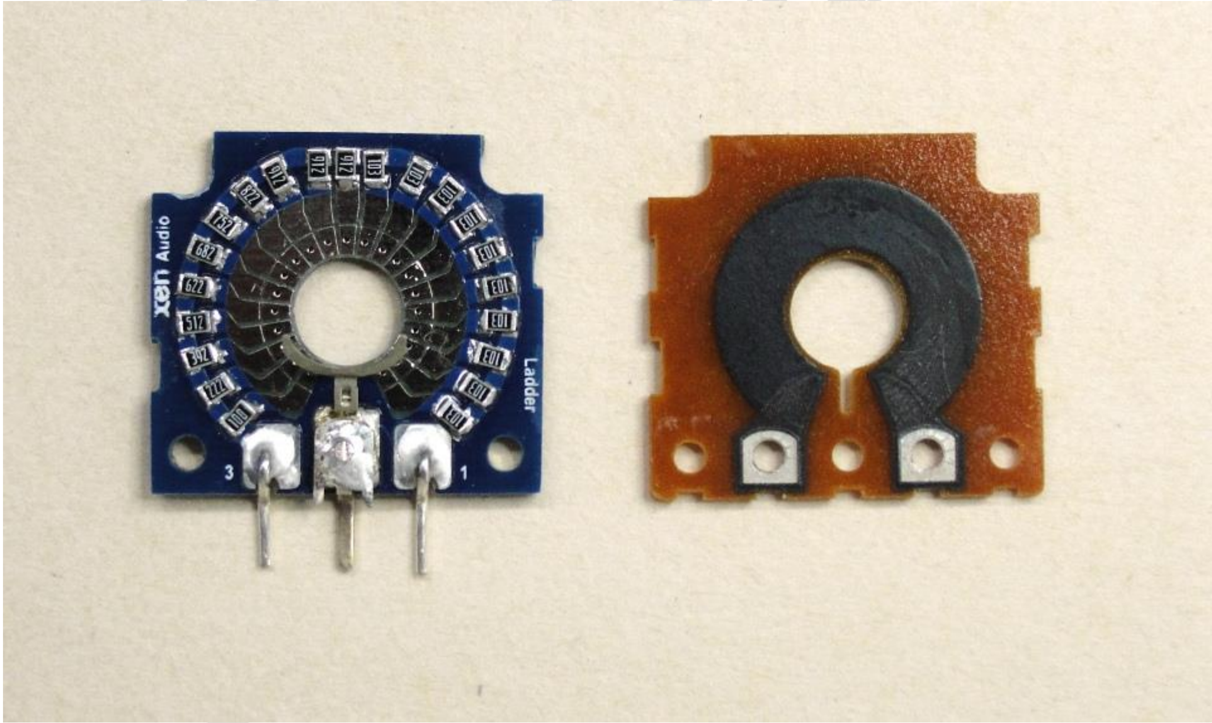


Figure 11 Wafer for XEN Modified ALPS RK27 Susumu Ladder Attenuator vs. Original