The TubeSociety 2022 OTL Hybrid Tube Amplifier

TubeSociety designed a non-feedback hybrid amplifier with a tube driver and a push-pull MOSFET output section. The result? Fifty watts of real tube power!

By
Menno van der Veen
Photos by Erwin Reins

Photo 1: This is the finished version of the TubeSociety 2022 OTL Hybrid Tube Amplifier, a non-feedback hybrid desogn with a tube driver and a push-pull MOSFET output section.

Every year TubeSociety designs and builds a new type of tube amplifier; see my website for an overview of all our projects [1]. In 2022 we chose to go in a new direction, inspired by the European Triode Festival where output-transformer-less (OTL) amps were compared. Our new amplifier, the TubeSociety (TS) 2022 OTL Hybrid Tube Amplifier, has a highly linearized tube driver section followed by a metal–oxide–semiconductor field-effect transistor (MOSFET) push-pull output stage. See original details in [2] a Dutch language document. Without any global negative feedback, this design (**Photo 1**) shows the beautiful tube amp's spacious sound character and mild overdrive, plus a lot of power.

The ECC88 Driver Stage

The tube driver section is shown on the left side of **Figure 1**. We used an ECC88 tube with an effective voltage gain almost equal to the μ of the ECC88. The standard anode resistor is replaced by a current source M1, which is loaded by R11=1MΩ (inside the power stage). This high impedance anode load creates an almost horizontal load line in the ECC88 characteristics (**Figure 2**). Consequently, the effective tube plate resistance is constant, and the second-harmonic distortion is minimal.

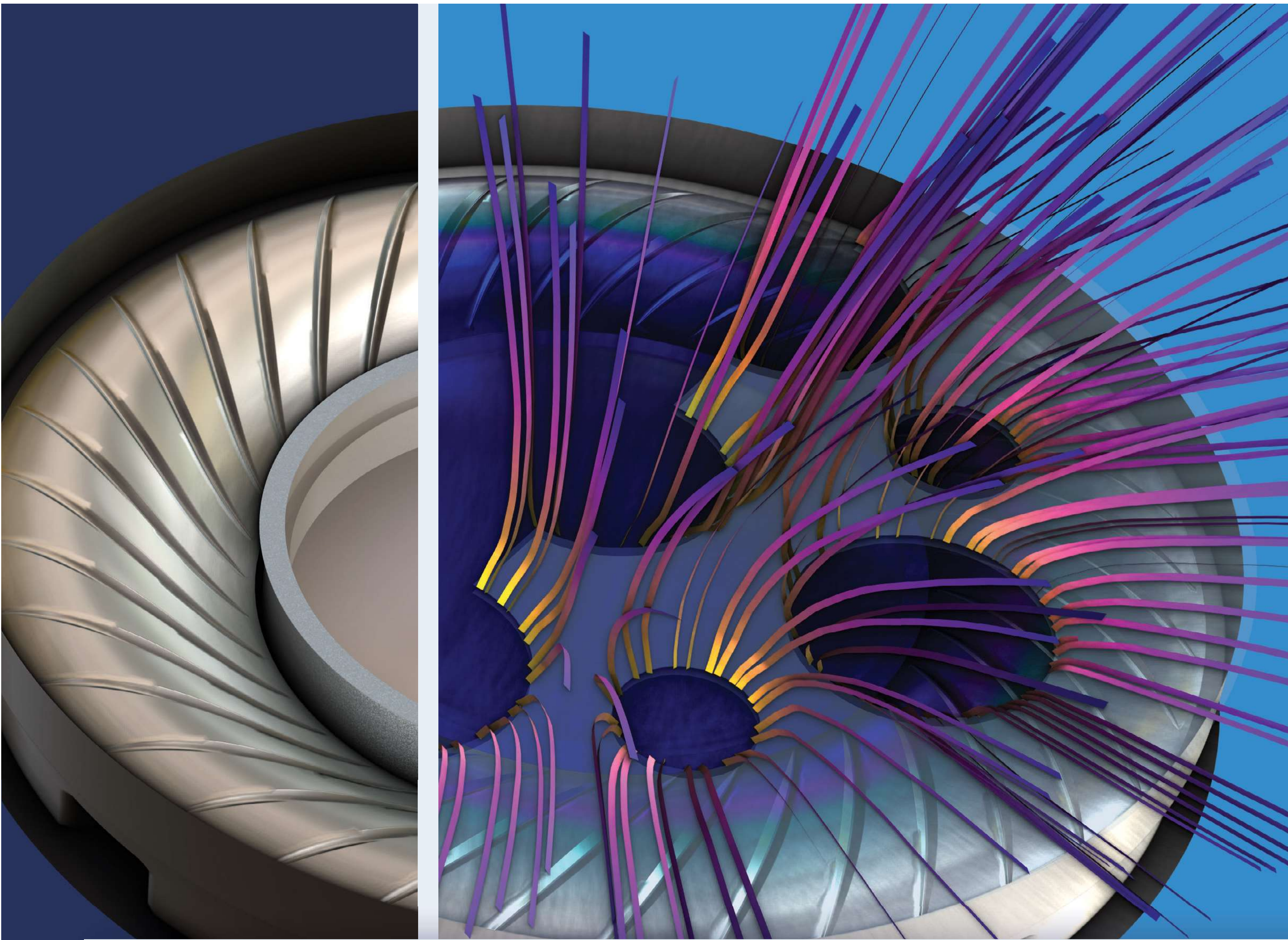
In this simple circuit the tube's gain and output impedance are highly linearized. In our final publication model Erwin Reins paralleled the two triodes inside one ECC88 tube for smallest effective plate resistance and optimal linearity (**Photo 2**).

The cathode resistor shall be trimmed with R17 to set Va=150V DC. The current source MOSFET M1 needs a heatsink (20K/W) to prevent drift of its operation point. It still amazes us how simple this driver section is, how small its distortions are, and how natural it sounds.

The Exicon MOSFETs Power Stage

Dolf Koch advised us to use a non-feedback MOSFET push-pull circuit because of its excellent dynamic behavior [3]. The circuit, shown in the mid and the right sections of Figure 1, consists of a source follower M3, which creates a negligible load to the tube driver section. M3 drives the two power MOSFETs M2 and M5 in push-pull mode. The trim pots R12 and R24 set the desired quiescent currents through M2 and M5, see more details later. Below R12 and R24 the M4-CCS (constant current source) further linearizes M3. Use trim pot R14 for equal and symmetrical clipping of the 4Ω to 8Ω loaded output.

Because the power stage is asymmetrically powered, the output needs the output capacitor C6



to prevent any DC through the loudspeaker. The effective voltage gain of this power stage is close to 0.7 x. This implies that the voltage gain of the complete amp is only created by the ECC88 with its large clean dynamic headroom. These factors already explain why our amp sounds "tube-like."

The Power Supply

The power supply section, shown in **Figure 3**, is very straightforward. Erwin applied one mains transformer per channel to prevent any possible crosstalk between the stereo channels. However, the complete stereo amp also is happy with one mains transformer. See the link to my website for details as to where to obtain one [4].

The high voltage section (B+/B-) of 250V DC for the ECC88 driver circuit is de-hummed with our standard Menno Super C-FET (MSCF) circuit. The MOSFETs power section needs the simple low voltage circuit (P+/P-) of 2×31V DC in series, rectified and buffered with 10,000µF capacitors. The filament supply section (6.3V AC) for the ECC88 does not need any treatment. However, apply the Tentlabs heater supply (see Sources) if you wish the least amount

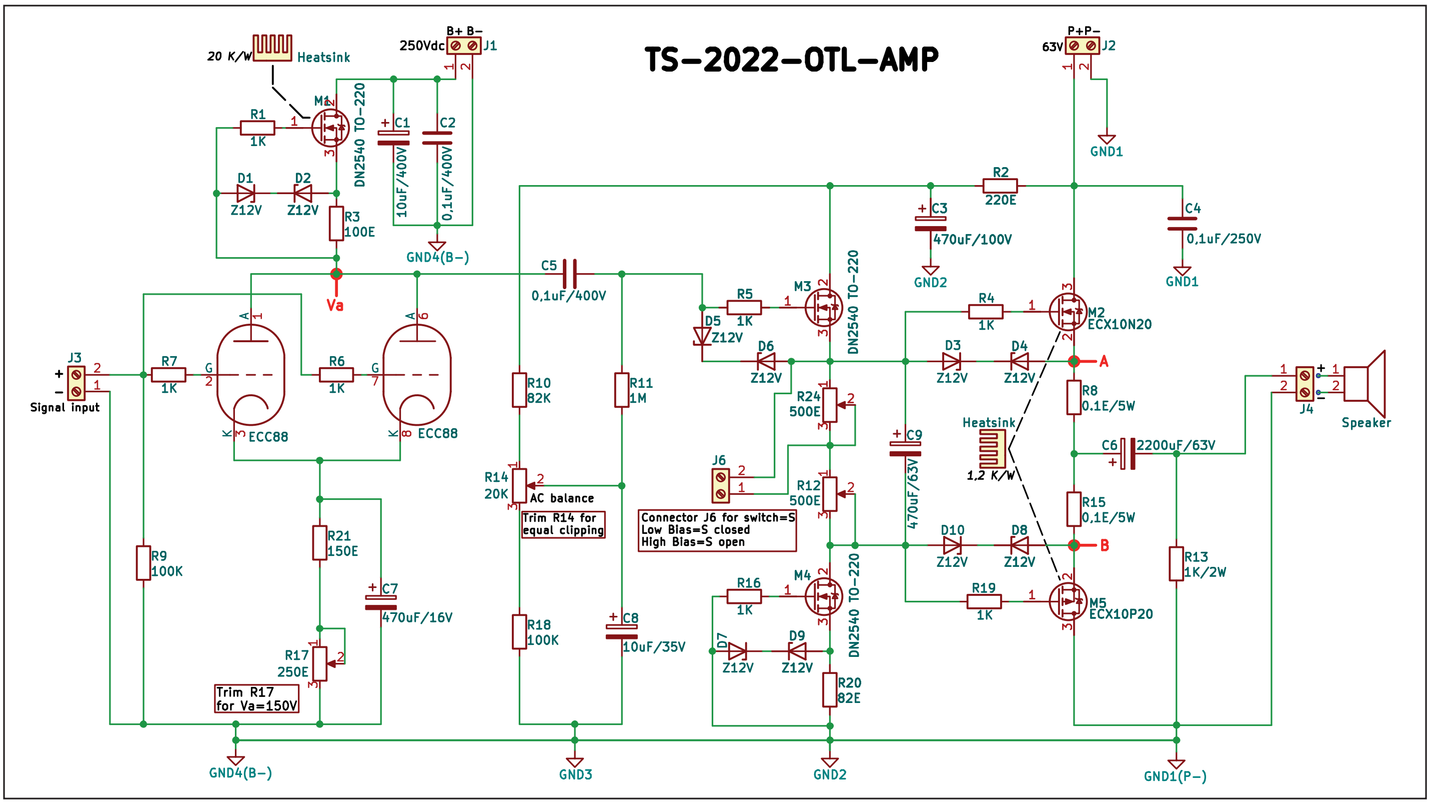


Figure 1: This is the complete audio circuit of the TS-OTL amplifier. The driver section is on the left; in the middle the source follower; and the MOSFET power section is on the right side.

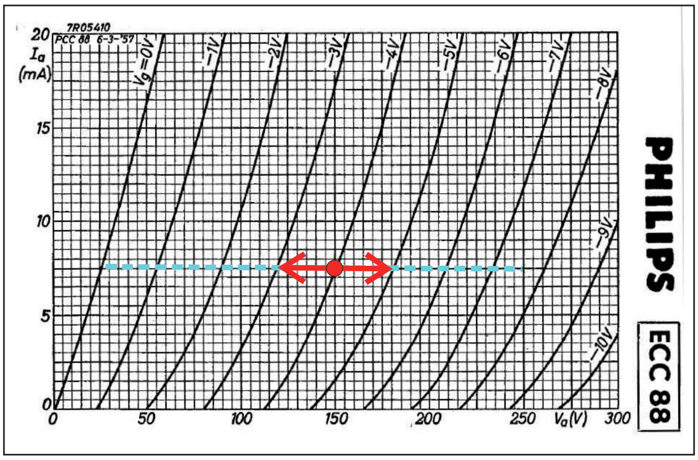


Figure 2: This graph shows the dynamic load line per triode in the ECC88 characteristics. The red section shows what is used. The total headroom (blue) is much larger, delivering mild overdrive.

Photo 2: This amplifier, built by Erwin Reins, parallelled the two triodes inside one ECC88 tube for smallest effective plate resistance and optimal linearity.

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of hum. The power supply PCBs are prepared for these modules.

Also, for any future helpful op-amp circuits, a ±12V DC supply is available. The complete power supply is placed on one PCB, which can feed the stereo amplifier. But as said, Erwin applied two mains transformers and two power supply PCBs.

About the Construction

Erwin constructed his version with the power and

Figure 3: This schematic shows the power supply section of the amplifier.

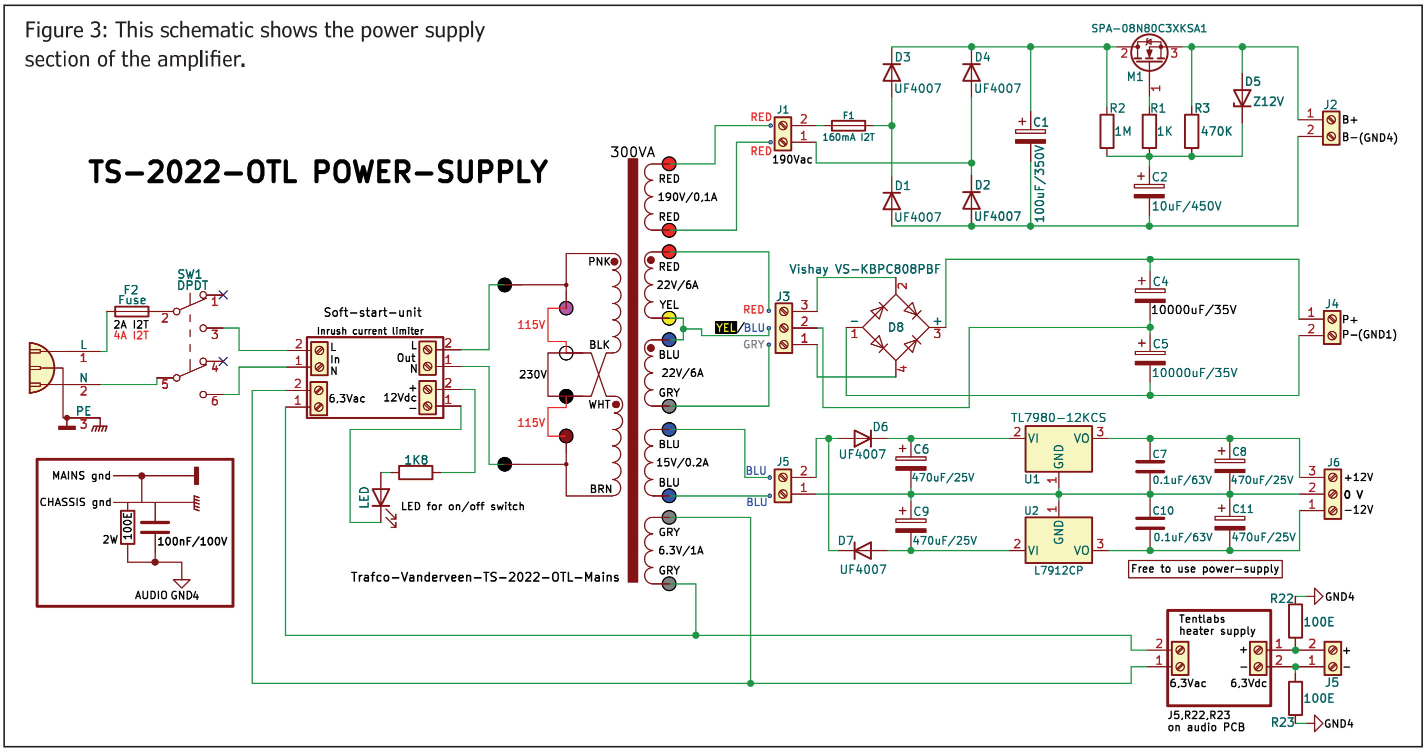

Photo 3: Erwin Reins constructed his version of the amplifer with the power and amp sections separated by the heatsinks.

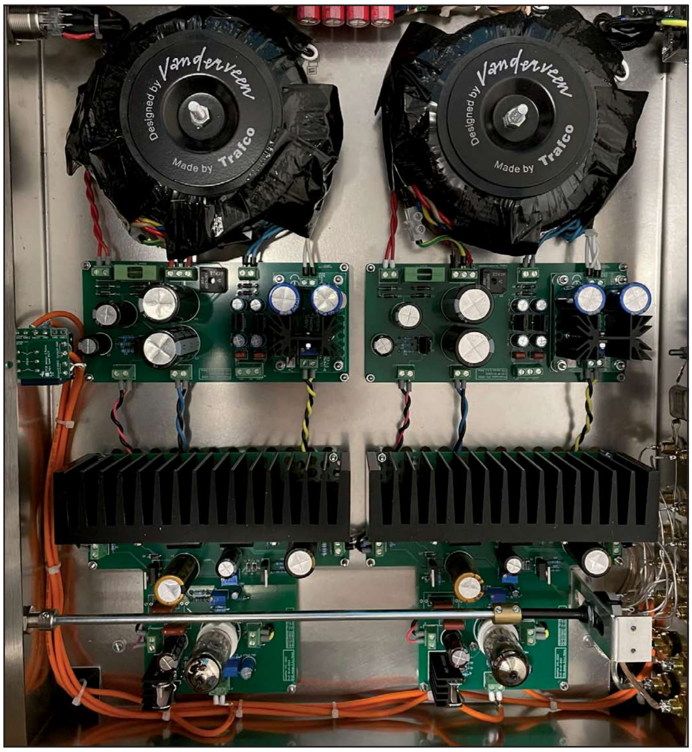

Photo 4: Here is the top view of Erwin's TubeSociety OTL Amplifier.

amp sections separated by the heatsinks (**Photo 3**). The heatsinks in the middle are mandatory for the MOSFETs M2,M5. Per channel they need one heatsink with a thermal resistance of 1.2K/W per channel. Only MOSFET M1 needs a small heatsink with a thermal resistance of around 20K/W. **Photo 4** shows the inside of Erwin's TS OTL Amplifier. At the input Erwin applied a stereo volume control (Alps 50k-Audio) and a channel selector. Neither one are drawn in the circuit. The decision will be yours if you decide to build it.

It might be wise to apply a soft-start mains circuit because two mains toroidal power transformers together can draw a large start-up current, possibly blowing the mains fuse. The Meten en/aan Buizenversterkers website has more details about such a circuit (see Sources).

When you apply only one mains-transformer, a soft-start is not obligatory when you use so-called I2T-fuses, which can handle heavy start-up currents. My experience is that the standard slow-blow fuses are not sturdy enough. Information about how to obtain all the amp and power and soft-start PCBs are also available on the Meten en/aan Buizenversterkers website.

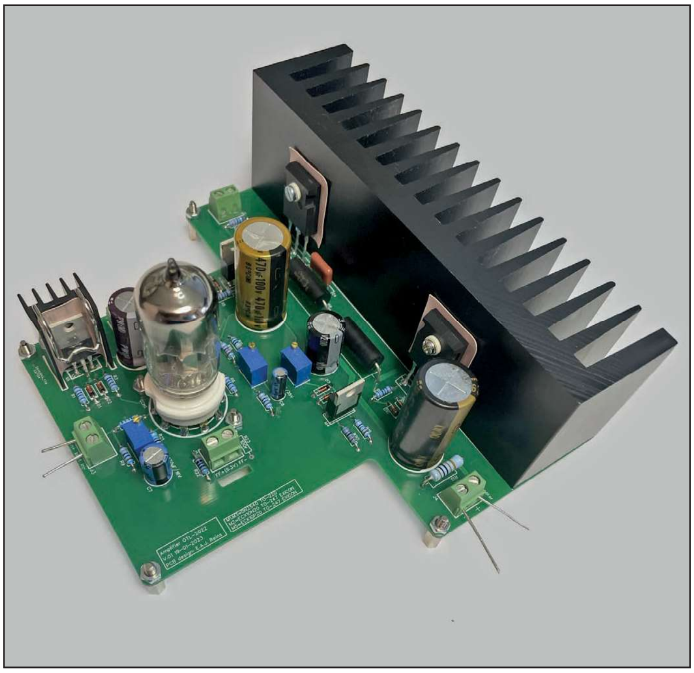

Photo 5: The complete amplifier channel is shown here.

Photo 6: Here is a look at some of the many TubeSociety students.

Playing with Quiescent Currents

For temperature drift reasons Exicon advises an optimal quiescent current Io of 150mA through M2 and M5. TubeSociety students, Frank Leegstra, Peter Groeneveld, and Robert-Jan Hoeksma, researched if this is also the best when focusing on the harmonic distortion. Remember that we don't apply any negative feedback over the amplifier section, consequently the quiescent current controls mainly the distortion. They noticed that raising Io from 20mA to 400mA brings improvement; however, anything above 400mA brings no further improvements.

Based on these results, we advise the following sequence. First, with S-closed, trim R12 for Io=100mA, which equals V_{AB}=20 mV DC. Next, with S-open, trim R24 for Io=400mA (V_{AB}=80mV DC).

Translating this to where you only see the position of S—with S-closed, the amp is great for background music during the day and with S -open, the power heatsinks will get rather hot. **Photo 5** shows the complete amplifier channel. Take a nice drink, relax, and enjoy your beautiful music in the quiet evening. And don't

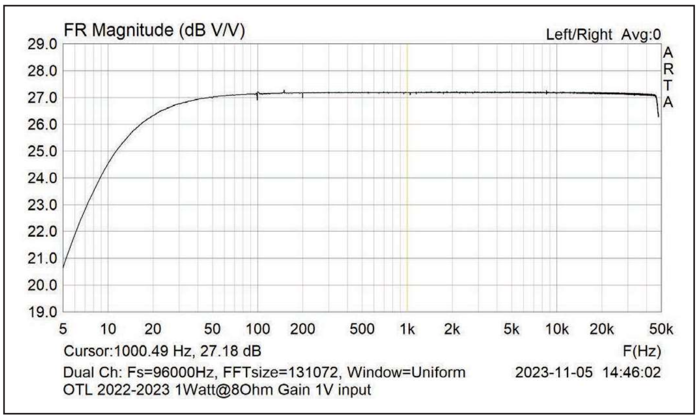

Figure 4: This graph shows the frequency range up to 50kHz. However, its highest -3dB frequency is at 650kHz.

About the Author

Menno van der Veen studied Physics at the Groningen-University in the Netherlands and graduated on measuring doting-concentration in semiconductor wafers. For more than 14 years he taught physics, wrote many review articles for high-end audio magazines, worked as a sound engineer in a small alternative theater, and was sound coordinator for big outdoor events. In 1985, he founded his own engineering firm with a focus on tube amplifiers and toroidal output transformers. He published his research in Audio Engineering Society (AES) papers and books and was chairman of the Dutch AES section. In 2005, he started his bi-weekly TubeSociety Saturday school. His Trans-focus began around 2011 and the results were published in *audioXpress*. In his private time, he plays and researches electronic guitars and respective valve amplifiers and effect pedals. Herein lays the basis of his love for music and electronics and art.

forget to switch off the amp when you go to sleep. We can say this is a "green" amp because of its limited power consumption, but better not to leave it on.

Measurements with Arta-2-TS

Our measurements were made with my Arta-2 measurement unit, which was recently updated by my students (some of whom

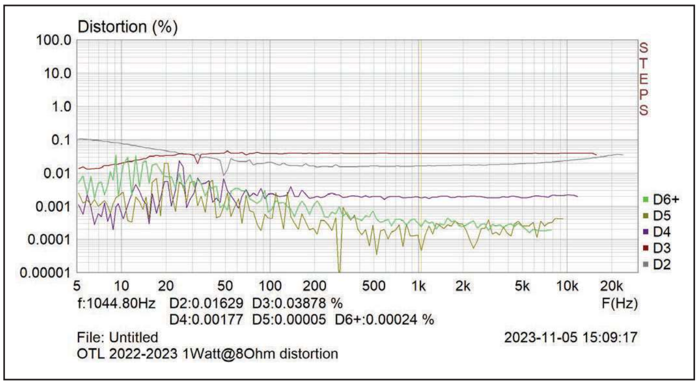

Figure 5: This graph details the small tube-like distortion of the amplifier.

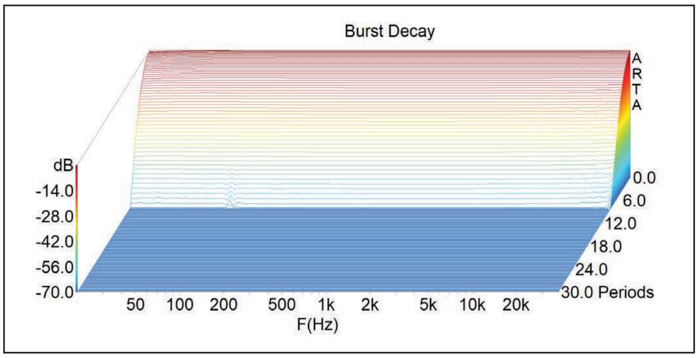

Figure 6: The burst decay shows the amplifier's clean behavior in the time-domain.

are shown in **Photo 6**) to the Arta-2-TS version and is now available for everyone (see Sources). The output power of this amp is 50W in 4Ω speakers and 32W in 8Ω speakers. The -3dB frequency range goes from 10Hz to 650kHz, which is more than wide enough for our application, as shown in **Figure 4**. The total effective gain from input to loaded output is 22.4 x (= 27dB), which equals a 631mVrms input sensitivity for 50W in a 4Ω speaker.

Figure 5 shows the distortion as function of frequency, measured at 400mA quiescent current and at 1W in 8Ω. Please note the suppressed D2 component (this is a consequence of push-pull) and the nice decline of the higher harmonics (again an indication for tube sound character). Don't underestimate these results—this is a brilliant example of desired behavior.

In **Figure 6** we measured the time-behavior of the amp. No resonances and the like are noticeable, which we translate as: "this amp sounds quick."

Figure 7 shows the output impedance of the amplifier as a function of the frequency. On the left side, the influence of the output capacitor-6 is visible, causing less loudspeaker damping at the lowest

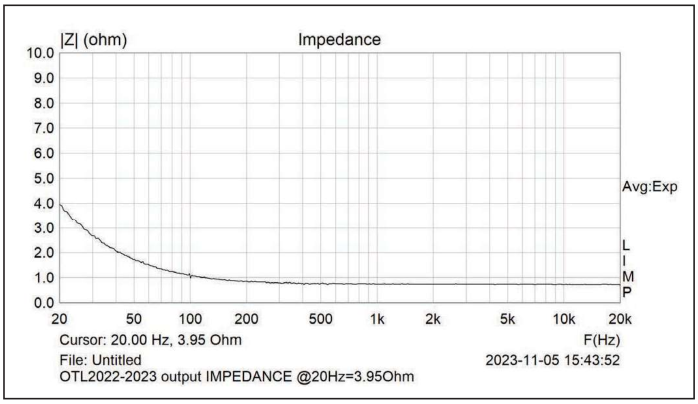

Figure 7: This graph shows the amplifier's output impedance.

References

[1] "Projecten TubeSociety," Vanderveen ir. Bureau & TubeSociety, https://mennovanderveen.nl/index.php/nl/tubesociety/projecten-tubesociety

[2] "Projecten TubeSociety," Vanderveen ir. Bureau & TubeSociety, https://mennovanderveen.nl/index.php/nl/tubesociety/projecten-tubesociety select project TS-2022, download a-TS-2022-OTL_Erwin-Reins.pdf

[3] Koch Amps, www.koch-amps.com

[4] "TS-2022-OTL-MAINS," Vanderveen ir. Bureau & TubeSociety, https://mennovanderveen.nl/index.php/nl/producten/valve-power-transformers/ts-2022-otl-mains-detail

Sources

ARTA-2-TS 2023 Black edition
Meten en/aan Buizenversterkers | www.meten-en-aan-buizenversterkers.nl/product/11979049/arta-2-ts-2023-black-edition

Inrush current limiter for power transformers
Meten en/aan Buizenversterkers |
www.meten-en-aan-buizenversterkers.nl/product/9333516/inschakelstroombegrenzer-voor-voedingstransformatoren

TS-OTL 2022 PCBs
Meten en/aan Buizenversterkers | www.meten-en-aan-buizenversterkers.nl/product/10739084/ts-otl-2022

Heater Supply
Tentlabs | www.tentlabsshop.com/DetailServlet?detailID=670

frequencies, which can be advantageous. See the "growling base remark" in the next Overdrive section.

About the Overdrive

About 35 years ago Dolf Koch and I designed and produced our successful non-feedback UL40-S stereo tube amplifier kit. This amp behaved beautifully, being clean at normal to loud levels and with soft overdrive distortion when driven to its limits. In our present TubeSociety amplifier I again aimed to achieve such behavior by not using global negative feedback. You might know that I am an active guitar player, where I almost never can use high-end amps (too dry sounding character, too large damping factor, sharp clipping). But it is totally different with this TS 2022 OTL Hybrid Tube amplifier. I like this beast: "it is dynamic as hell." For me, this also is favorable in high end. A listener expressed this about the amplifier: "Now I hear the acoustic base growling, full, and deep, very realistic. I don't hear specifications: I hear music!". Shall we start a discussion about "the real truth" versus "musicality"? Not from me, I think both are valuable.

Subjective Opinion and Conclusions

I like this amp and favor it for my guitars and loud music at a party. I also like this amp at about $80dB_{SPL}$ high-end levels in my living room and lab. It shows spacious details, and its soundstage is not inside the speakers, but everywhere in my listening room, which is important for me. The total atmosphere is friendly and musical. As I said earlier: "This really is high end and extremely pleasant." What more can I say?

Author Acknowledgments: You might think that creating this amp was an easy task. The reality is different: it was a "tour de force." More than a year before my students started to build, I wandered around with some ideas in my head. Next, I gave my students some guidelines, a pen on paper circuit, and there they went. It took several months for them to make a working prototype, which we tested and further improved, supported by profound calculations from Pierre Touzelet. Therefore, to all my students plus Dolf Koch and Pierre Touzelet: Thank you so much: together we did it again!