The Vanderveen Trans PP80 Valve Amplifier

This new push-pull (PP) valve amplifier, featuring the Trans technique, delivers 80W power, refined resolution, valve-sound envelopment, and low distortion plus good speaker damping. And… the amp is simple to construct.

By
Menno van der Veen

Photo 1: A completed version of the VDV Trans Push-Pull 80 Valve Amplifier.

This valve amplifier is the next step in my Trans research, with earlier single-ended Trans designs published in previous *audioXpress* editions [1,2,3,4]. In this article, we present the new push-pull version (**Photo 1**). I say "we" because my TubeSociety students, Erwin Reins and Hans Gubbens, strongly supported this effort by making prototypes.

To start, I will provide a short summary of the Trans essentials [4]. Trans uses local feedback only around the power tube while the output transformer is outside this feedback loop. The power tube is driven by a voltage controlled current source plus one resistor R** between the anode and the control-grid. Then all the voltage amplification of the power tube is used to correct its internal distortions. **Figure 1** shows a visualization of the Trans concept. The local Trans-feedback also makes the power tube's plate resistances very small, thus preventing magnetic distortions inside the output transformer [5].

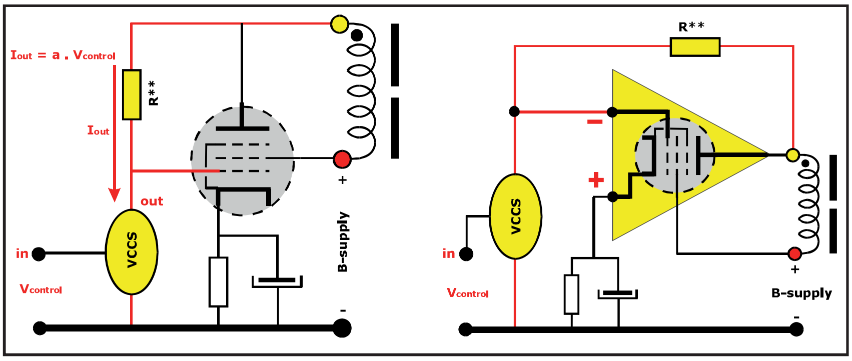

Figure 1: The Trans principle is detailed with a tube and an equal tube op-amp circuit.

In summary about Trans: Its local feedback is a soft local feedback technique that lowers power tube and OPT distortions. Years ago, when I started with Trans, I said: "I have gold in my hands." This observation has not changed during the research that has followed.

Power Supply Demands

The great advantage of my earlier published single-ended amplifiers is their constant current demand. The power supply can be simple, however, it needs good hum-rejection. The B+ voltage will not change under loud or soft music reproduction.

However, the situation in Class-AB push-pull amplifiers is totally different. With soft music (Class-A), we only have to deal with the constant quiescent currents. However, with louder music in Class-B, the tube's peak currents can rise up to eight times. So, the power supply encounters a large and changing power demand and consequently its B+ voltage will change/sag.

The Trans circuit uses DC-coupling between the anode and the control grid. If B+ changes in Class-B,

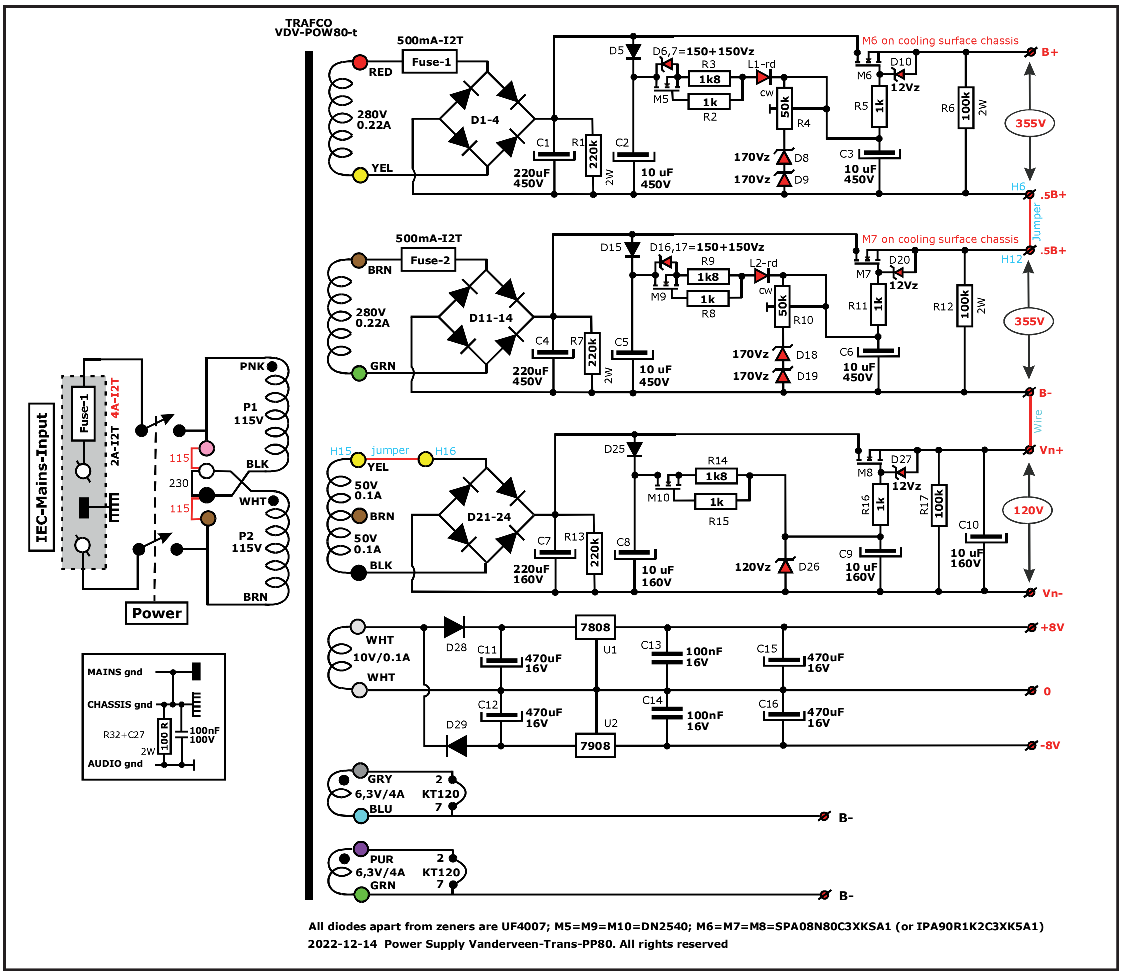

Figure 2: This schematic shows the VDV Trans PP80's power supply.

the quiescent operating point will change as well, pushing the tube away from its operating point. This means: we need a new B+ supply, which I discuss next.

The Power Supply Circuit

The power supply circuit is shown in **Figure 2**. Here, again, I applied a MOSFET for soft start and suppression of hum components. New are the Zener diodes, which create voltage stabilization.

Using high voltage (280V AC) winding, a small current source drives a constant current of 1mA traveling through a red LED (to show that the supply functions), then through a trimmer potentiometer (trimpot) of 50kΩ, and finally through a 340V Zener diode (2 × 170 Vz in series). Because the 1mA current is constant, we get a constant voltage at the tappers of the trim pots R4 and R10. This stabilized voltage is fed to the gates of the M6, and 7 power field-effect transistors (FETs).

When the trimpot is at maximum (clockwise), the supply output is about 390V DC unloaded. When we trim this output voltage to the requested constant 355V DC, we have enough headroom to deal with transformer regulation and hum, and all the variations in mains-voltage and Class-A-B current demands. Because we have twice this circuit in series, a total B+ = 710V DC is available to be fed to the center tap of the output transformer. Also ½B+ = 355V DC is available to power the screen grids of the power tubes. **Figure 3** shows an impression of the Power Supply PCB.

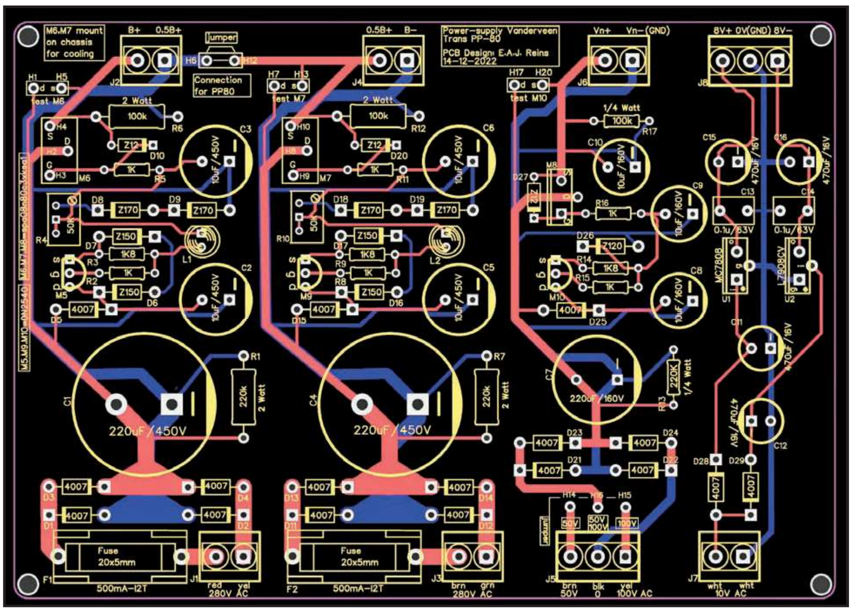

Figure 3: The power supply's PCB, shown here, is 150mm × 105mm.

Balanced Input Plus Phase Splitter

The power stage of the amplifier needs to be driven by a high-quality phase splitter with amplification factors of +1 and -1. **Figure 4** shows the circuit.

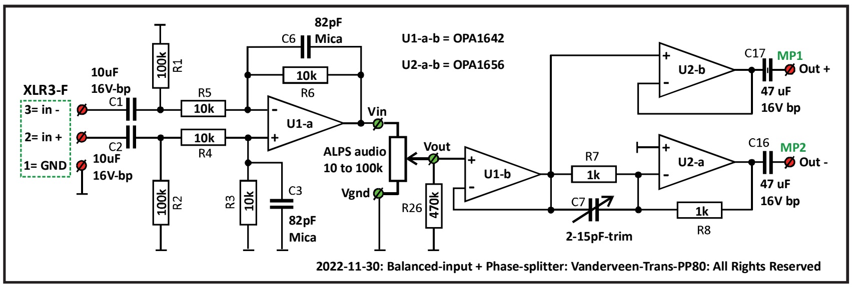

Figure 4: This is the schematic for the balanced input plus phase splitter.

The circuit around U1-a is a textbook balanced input circuit. Not much to say about it except that its high-frequency range is limited by C3,6 to prevent a square wave overshoot.

When you apply unbalanced music sources (RCA), you don't need the U1-a circuit. In that case, connect your input signal directly to Vin (to the top of the Alps volume control, which is not connected to the output of U1-a). Or use a toggle switch (see more about this later) to choose between unbalanced and balanced inputs.

Compared to the simple U1-a circuit, the Alps volume potentiometer plus U1-b circuit is special. The OPA1642 is a dedicated op-amp with constant input capacitance (6pF), which is not reacting on the amplitude of the input signal. Its f-3H high-frequency roll-off will not react on the amplitude of the signal nor will it create changing phase delays. This prevents phase and harmonic distortions, which trained ears can notice. This small circuit largely improves the quality of the volume control. I have never heard such clean Alps behavior.

The actual phase splitter is realized with U2, where U2-a amplifies -1x and U2-b +1x. Any difference in time delay inside U2-a and U2-b can be trimmed to zero with the trim capacitor C7, to create exactly 180 degrees phase difference up to 1MHz. I will discuss later in the article how to trim C7 to its optimal setting.

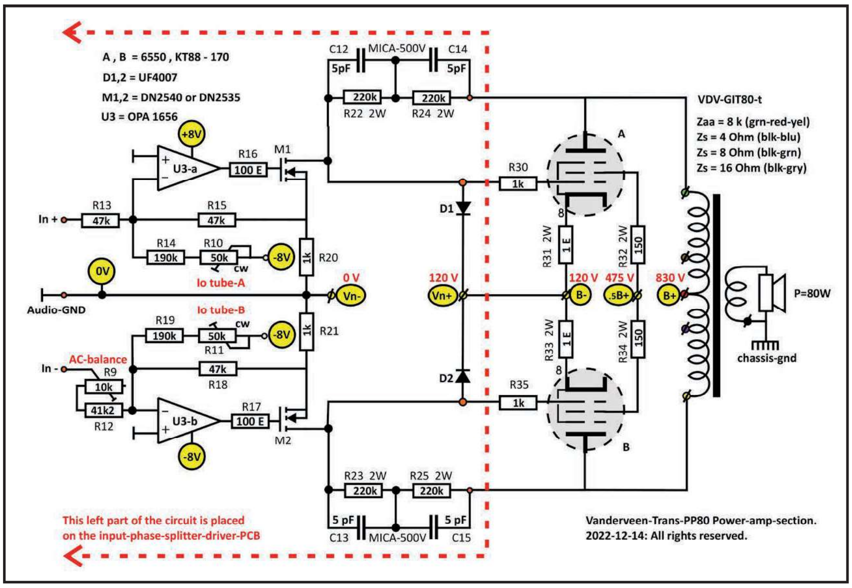

Figure 5: This schematic shows the Trans PP80's power amplifier section.

Photo 2: These Trans monoblocks were designed by Hans Gubbens.

The Trans PP80 Power Amplifier Circuit

Seeing the circuit shown in **Figure 5**, you might wonder: Is that all there is? Yes, this simple circuit delivers 80W and gives you all the details you might need. Let's discuss it.

The actual voltage-controlled current sources are the FETs M1,2, each being totally controlled by the low distortion op-amps U3-a,b (= OPA1656). This results in extremely linear current sources, which are temperature compensated as well.

Because of the DC-coupling to the control grids of the power tubes, the anode quiescent currents can also be controlled by U3-a,b and set with R10 and R11 to Io = 60mA per tube, meaning 60mV DC over the 1Ω cathode resistors R31 and R33.

The resistance numbers of the upper PP section are used in the next formulas. Each op-amp amplifies A = R15/R13 = 1x. Therefore, the transconductance of each complete current source is given by:

$$g = (Vin/R20) / Vin = 1/R20 = 1 \text{ mA/V}$$

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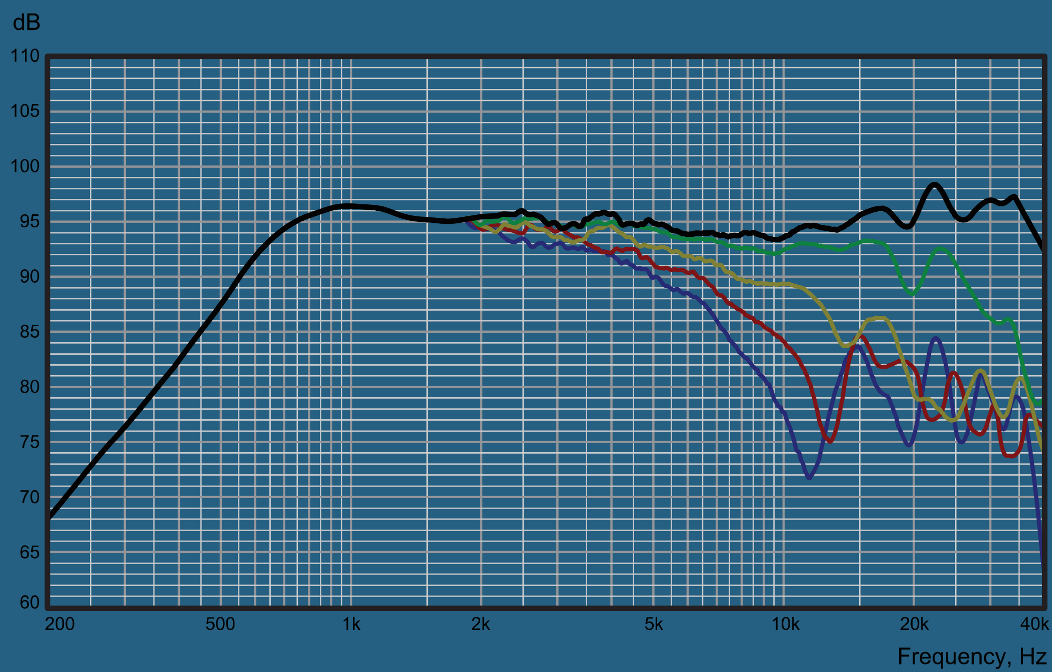

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The amplification from each input to each power tube anode is:

$$A_{1/2} = (R22 + R24) \cdot g = 440\ x = 52\ dB$$

The voltage amplification of the total push-pull (PP) amp from both inputs to the Zs = 4Ω secondary tap of the output transformer needs its opt-turns-ratio correction plus a factor of 2 because the primary Zaa = 8kΩ is push-pull driven:

$$A_{T,4} = 2 \cdot A_{1/2} \cdot \sqrt{(Zs/Zaa)} = 19.7\ x = 25.9\ dB$$

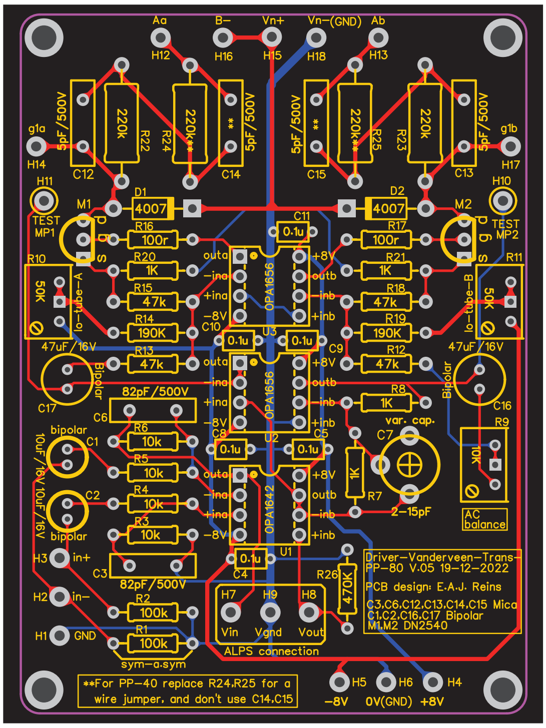

Figure 6: This image shows the PCB for the input phase splitter and driver section (90mm × 65mm).

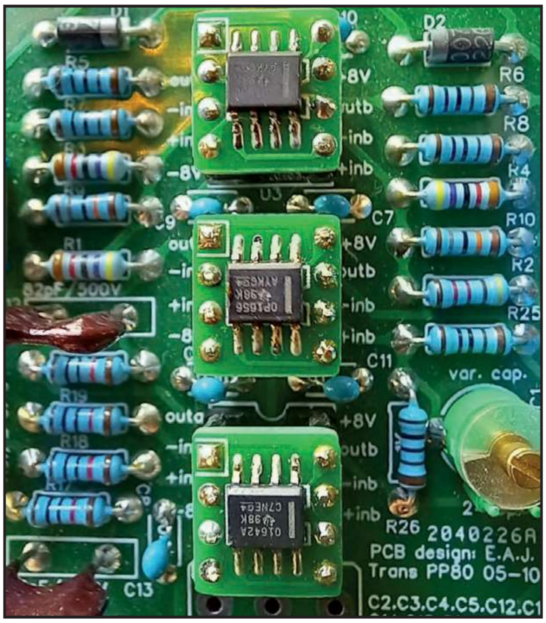

Photo 3: Here, the SOIC8-DIP8 adaptors have been added to enable easy op-amp exchange or repair.

Next, we shall subtract the losses of the winding resistances Rip = 100Ω and Ris4 = 0.16Ω of the Git80-t output transformer resulting in:

$$A_{eff,4} = A_{T,4} \cdot Zs / (Rip \cdot Zs/Zaa + Ris + Zs) = 18.7\ x = 25.4\ dB$$

Please notice that the voltage amplification of the total Trans PP80 amplifier is only determined by the resistors mentioned in this section and the turns ratio and resistances of the Git80-t output transformer windings. You can imagine that high-quality resistors and the Git80-t opt (no resonances and low leakage) are mandatory in this design. [For the diehards: in $A_{eff,4}$ the small Trans plate resistances of the output tubes are not taken into account, but the validity will be shown in the section entitled "Measurements."]

I have already heard comments about this Trans design such as: "Menno, you are using ugly semiconductor stuff to control a valve amplifier: shame on you!" My response: With highest quality op-amps with effective gain of 1x, I create clean current sources with ultra-small distortions. Notice that the first-order-low-pass open-loop-gain of the op-amps is fully available for all these corrections. Next, each power tube corrects itself, only using its own tube-transfer function. So, the actual sound character is from the power tubes only. Even the sound character of the OPT is excluded because of the small Trans plate resistances of the power tubes [5]. For these reasons, I call this Trans PP design a pure valve design.

[For the diehards: I am fully aware of the different opinions about "the sound of circuits." I conducted a lot of research in this area. For instance, I compared this new design with my earlier Trans SE versions and earlier Trans PP amps [6]. There no op-amps were applied, just the fewest discrete components, even all tube circuits, and so on. My observation is that this newest Trans PP80 design sounds superior in details and envelopment]. Enough for now. Let's start constructing this amplifier.

Construction of the Amplifier

This article shows several photos detailing how Erwin Reins made the amplifier, the case he used, and how he placed the components. Let it inspire you. Monoblocks are also a good choice. **Photo 2** shows the versions built by Hans Gubbens. As I often say to my students: "A new amp starts with dreaming about how it looks."

Visit my website, www.mennovanderveen.nl, [7], to download all the extra information about the PCBs plus the detailed PCB schematics in which all connection points are clearly indicated, as well as where to find the transformers, the start-up procedure, and so on. Assuming that you have studied that material, I will now focus on the major construction issues.

The Input Phase Splitter Driver PCB

Figure 6 shows the actual driver PCB in detail. This image shows how to place all its components. Please notice the orientation of the Io trimpots (turn completely counter-clockwise) and the AC balance trimpot (leave in mid-position) and of the high-frequency trimmer C7. **Photo 3** shows the SOIC8-DIP8 adapters that we applied to enable easy op-amp exchange or repair. Do not yet connect the Alps volume potentiometer.

Figure 7 shows how to trim C7 to its optimal position. You need a 1MHz-sine-1Vrms function generator signal and a two channel oscilloscope (for instance the Pico-2204). Only for this test: use two 9V DC batteries to deliver power to the PCB. Wire the signal cables as indicated.

Trim C7 until a straight line is obtained in the Lissajoux A-B scope presentation. Having done that, leave C7 alone. The phase-splitter will stay long term stable up to 1MHz. Next remove all cables and batteries.

Figure 8 shows how you can wire your inputs to balanced (XLR) or unbalanced (RCA) with the help of a double-pole miniature toggle switch (on-none-on). The wiring of the Alps is also shown.

Wiring the Power Amp Audio Section and the Supply

Next you can place the driver PCB in your amplifier case, preferably between the power tubes (or very close to them) for the shortest wiring to the power tube sockets to prevent any oscillation. **Figure 9** offers more details.

You might place the tubes, the transformers, and the PCBs at other positions. However, please lay all wires to their connecting points as indicated. This drawing (Figure 9) carefully takes all the currents and ground-loops into account, preventing the large power tube currents from entering the sensitive driver section. I have not explained anything about the wires from the Pow80-t transformer to the power supply PCB because I think it is self-explanatory. However, the comments made about FETs M6,7 are very important. These FETs become hot (4W of heat at least) and do need the cooling of the aluminum or steel chassis.

Also not shown are the 6.3 filament wires (indicated with f). Twist them and connect to pins 2 and 7 of each power tube socket. The primary winding of the Git80-t has two unused UL-taps. These Brown and Orange wires need proper isolation. Don't cut them as you might wish to use them later.

When you study the images of the Erwin Amp (**Photo 4**), you see that he applies a mains switch-on delay circuit. In my amps and drawings, I applied special I2t- or T-fuses, which can handle the large inrush currents of toroidal mains transformers.

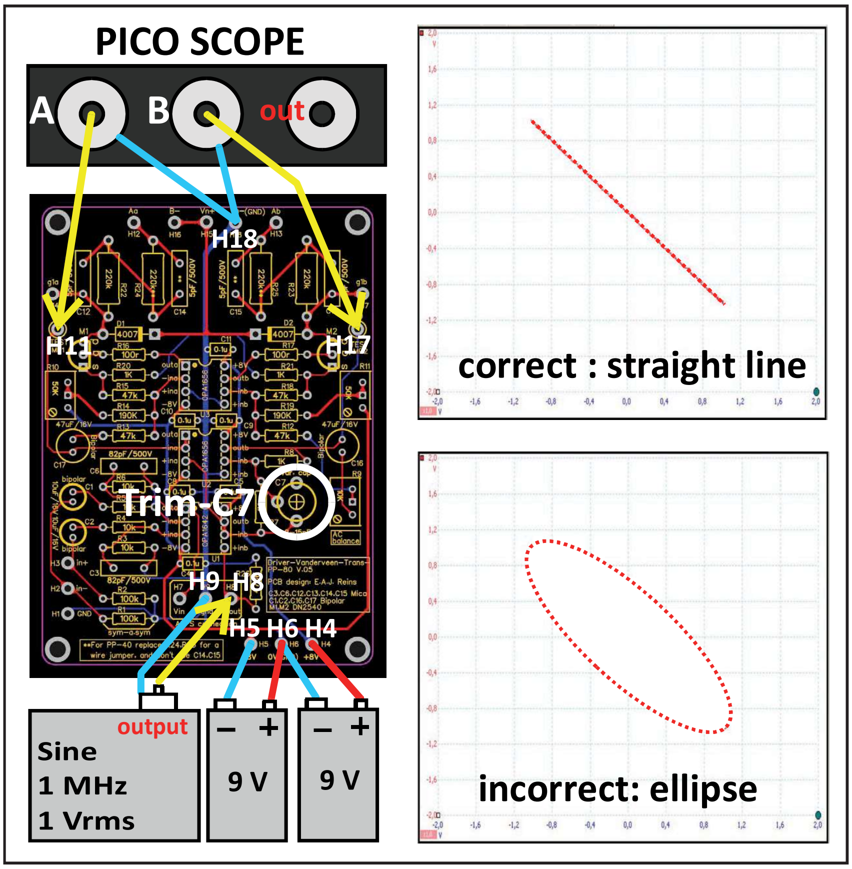

Figure 7: This diagram details how to trim C7 with a 1MHz sine wave and an oscilloscope.

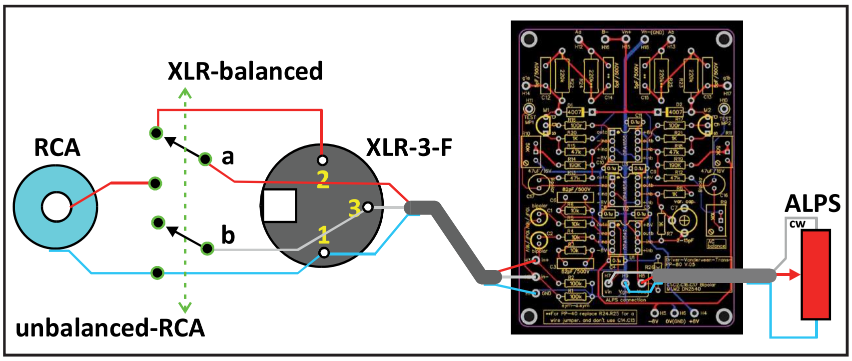

Figure 8: You can wire your inputs to balanced (XLR) or unbalanced (RCA) with the help of a double-pole miniature toggle switch.

About the OPT and Some Safety Tips

Don't place the toroidal OPT very close to (or on top of) the mains-toroidal. The recommended minimum distance is at least 2cm to prevent noticeable hum in your loudspeakers. Please don't forget to connect the secondary black wire (the null wire) to the chassis. I have never experienced voltage sparks between the primary and secondary windings inside my toroidals OPTs; that's not the issue. It is the capacitive coupling between the primary and the secondary that can cause AC voltage coupling into the secondary, especially at higher frequencies. It is not harmful, but it can influence the results of your measurements. Proper grounding prevents such issues.

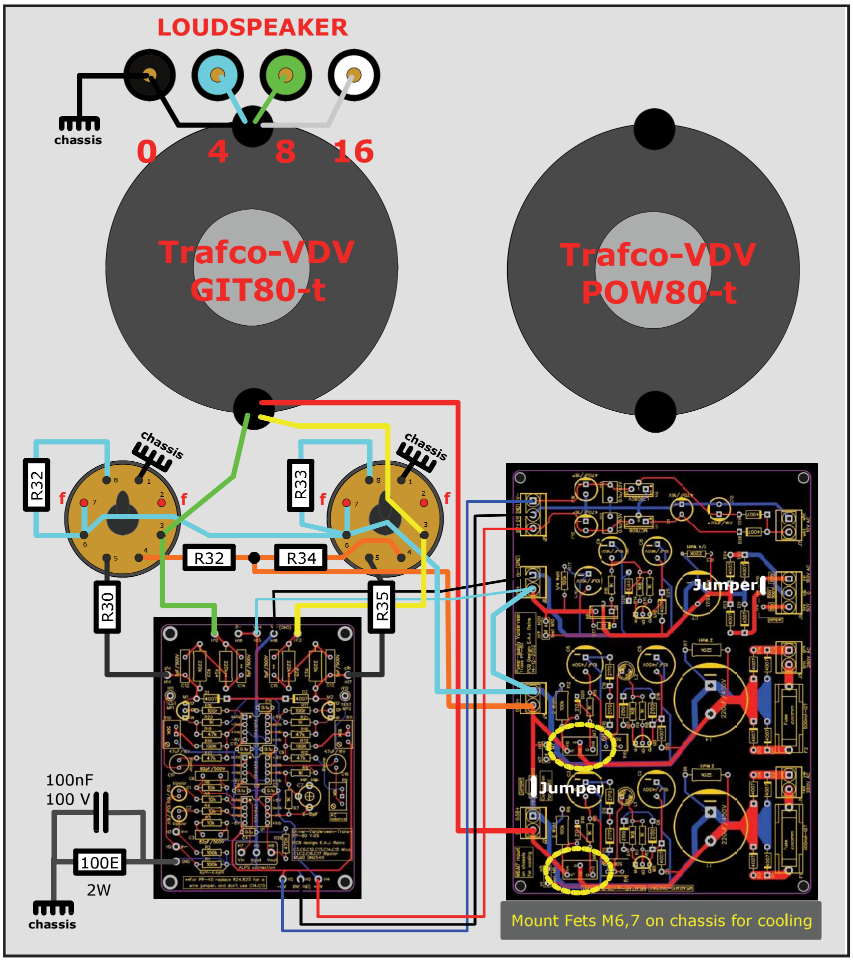

Figure 9: Place the driver's PCB in your amplifier case, preferably between the power tubes.

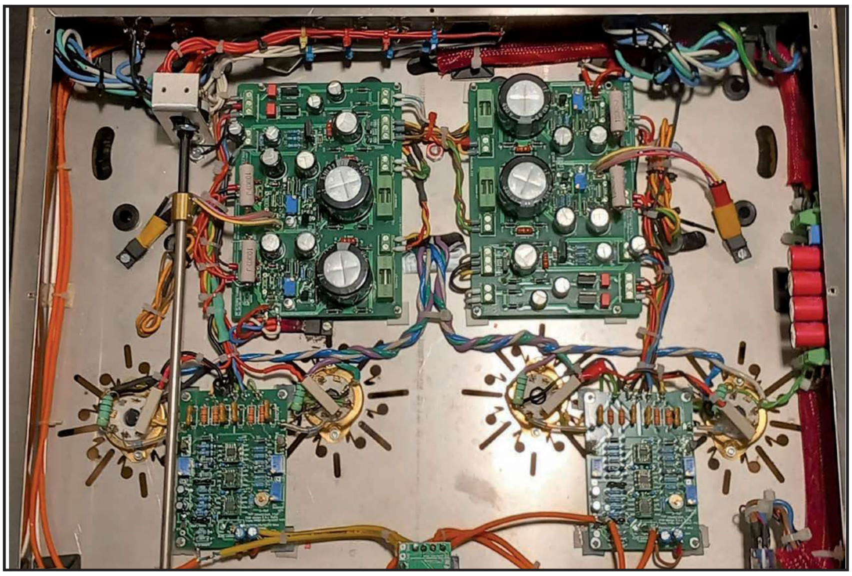

Photo 4: Here is a bottom view of the Erwin Reins amplifier, in this image you see that he applies a mains switch-on delay circuit.

If you apply KT88 to KT170 power tubes, then the foot section of the tube contains a silver-colored shielding ring, which is connected to pin 1 of the tube socket. Connect pin 1 to the chassis to prevent any possible voltage difference between this ring and the chassis, which might be harmful if you touch both the chassis and the ring at the same time.

Start-Up Document

I tried to make the start-up procedure a short document, but describing all the precautions and the proper actions and sequence takes too many words and too much space. Therefore, I have decided to make this important start-up document available on my website [7].

Measurement Results

Unless otherwise indicated: All measurements are performed in a 4Ω load at +6 dBV = 2 Vrms = 1W in 4Ω load. We mostly listen and judge at that level and below.

Figure 10 shows the gain and frequency range of the amplifier. Measured is 25.1dB gain while 25.4dB is calculated earlier. This small difference will be discussed in the output impedance measurement. The -3dB frequencies start below 5Hz and are above 60kHz. Figure 10 shows no resonances in the amplifier, and **Figure 11** confirms that result. Only a small negligible 50Hz residual is visible.

Next, **Figure 12** shows the harmonic components of a 1kHz sine test signal. You see the declining character while all are small. For me, it remains remarkable that the simple Trans technique is so powerful in reducing distortions! Also nice to notice that harmonics above three have a much smaller magnitude. As I stated earlier, this proves that my op-amps have enough open-loop gain to firmly reduce higher harmonics and to maintain the tube character of the sound. But I have a bit more to say about harmonics, which is not visible in Figure 12. Please look at **Figure 13**. The distortion components are measured for all frequencies from 5Hz to 20kHz, providing extra insight.

From 5Hz to 20Hz, all harmonics are larger than at 1kHz, caused by the magnetic properties of the core of the OPT (core distortions are proportional to 1/f). Due to the small Trans plate resistances of the power tubes, these distortions are not excessive, only 0.04% THD at 20Hz. This is the next bit of proof of the Trans miracle.

Above 1kHz, the components H2 and H3 and H4 rise with frequency, which is caused by a tiny imbalance inside the power tubes and OPT. Should they be matched to an equalness better than 0.05% at 10kHz? An impossible heck of a job. Because of their small magnitude, I paid no further attention to this. (Global negative feedback corrects such imbalances, but at a cost: You lose the free open tube sound character, but that is another story).

The last measurement, **Figure 14**, shows the output impedance of the amplifier at the 4Ω output taps. The result is 0.36Ω at 1kHz, meaning a damping factor DF4 = 11. This is large enough for most tube amp applications, and we get this result without any global negative feedback. [For the diehards: Backward calculation now

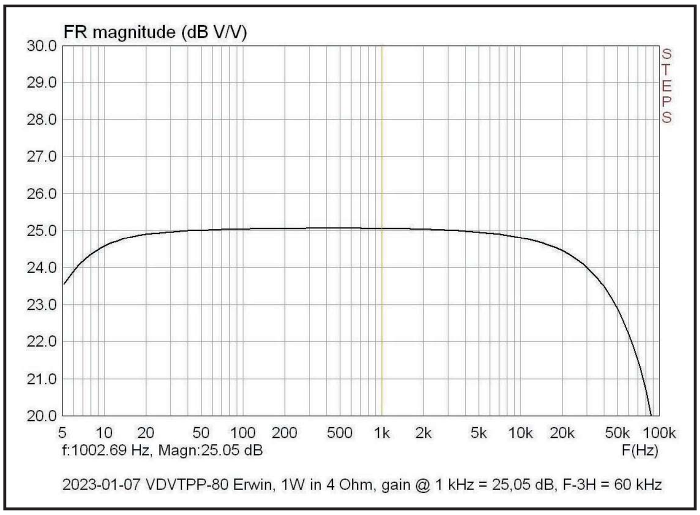

Figure 10: This graph depicts the gain and frequency range of the Trans PP80 amplifier.

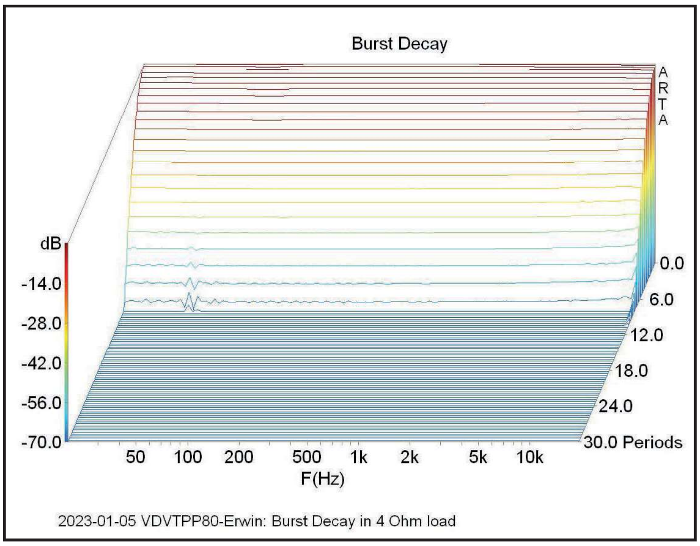

Figure 11: This measurement clearly shows the absence of any nasty resonances.

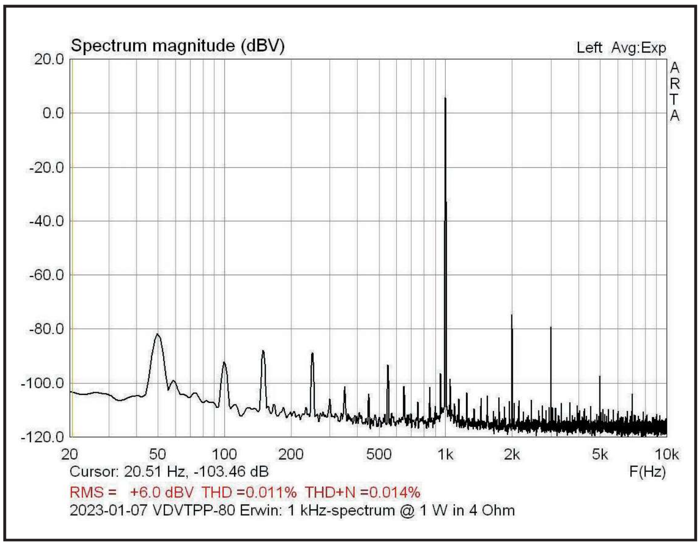

Figure 12: This measurement reveals the 1kHz distortion spectrum; notice the declining magnitude of higher harmonics.

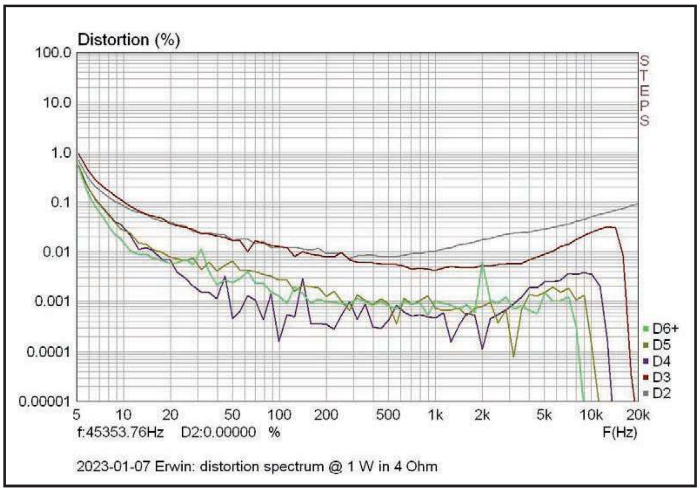

Figure 13: The harmonic spectrum from 5Hz to 20kHz is shown in this graph.

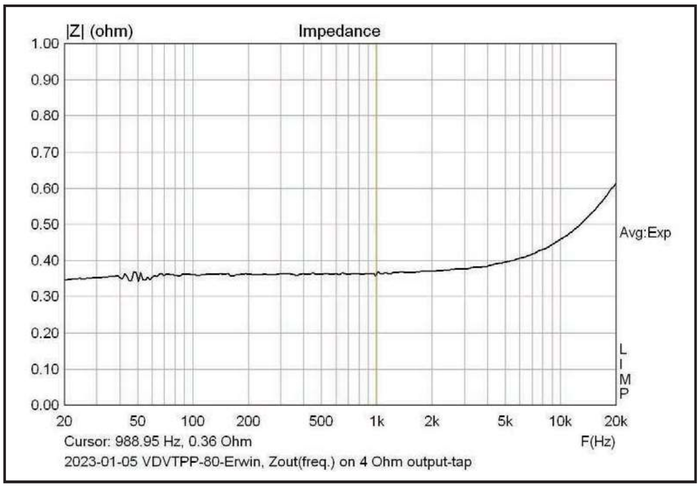

Figure 14: The output impedance Zout is shown at the 4Ω taps.

delivers an effective plate resistance per power tube of rp = 150Ω. This is far better than any triode plate resistance].

Was I right to neglect these tube plate resistances in the gain calculation? Recalculating the last formula with 2 × rp = 300Ω added, results in $A_{eff,4}$ = 25.2dB (measured 25.1dB). The 0.2dB difference between 25.4dB and 25.2dB equals only a 2.3% linear mismatch. When you take component tolerances into account you get the same mismatch. That's why I dared to neglect 2 × rp.

What causes the rise of Zout above 5 kHz? It is the leakage inductance Lsp of the OPT. Trans does nothing to correct that. So, Lsp must be small, which is the case in my toroidal Git80-t. Try this with EI-type transformers with their larger leakage and you will be disappointed when applying Trans. With EI you absolutely need global negative feedback (NFB), including the OPT to create a Zout behavior as in this Trans design.

The Subjective Side

I hope you were able to read the subjective comments about my earlier Trans SE designs. They all have in common the idea that Trans sounds "Tube." All have more details and space than my previous global feedback or no-feedback designs. The new Trans PP80 has exactly the same properties plus better refined resolution and space and details as well as a quicker cleaner bass response (which is logical because Lp is much larger in push-pull). That is the essence—a major leap forward. Understandable? I think so, thanks to the contribution of the clean current sources, while maintaining the specific tube sound from the power tubes. Is more power a contributor to these observations? Yes, but normally I do not play my music that loud. I think improved control is the major factor.

Conclusions and Summary

The research question was: Will Trans work well in a push-pull configuration? The answer is: Even better than expected. The new amp has 80W of output power, is very stable, provides good speaker damping with little distortion, and sounds "Tube." This exercise taught me a new way of designing. Think in component transfer functions and research the influence of each transfer on the final sound character. Chose which transfer you wish to dominate and make all others super-clean. The Trans PP80 proves that such an approach works well. This raises my next research question. Nowadays, we have amps with 1ppm distortion. I clearly hear their good qualities. However, my ears prefer minimal amounts of distortion. Then I better hear space and environment. Is this like the idea that a little salt or grease improves the taste? Does minimal distinct distortion improve hearing?

Author Acknowledgements: The creation of this new Trans amplifier was only possible thanks to the intensive support of my TubeSociety students Erwin Reins and Hans Gubbens. Without their work, the realization of the amplifier would not have happened. I also thank the European Triode Festival (ETF) organization and Audio Vereniging Midden Nederland (AVMN) and all my TubeSociety students. There I found the platforms to expose my new concepts to trained ears. Their comments were of the utmost importance, replacing my pride by solid knowledge and preventing me to be too subjective.

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. After that he taught physics for a number of years. Meanwhile, he wrote many review articles for high-end audio magazines. He also was a sound engineer-coordinator in a theater and at outdoor festivals. In 1985, he founded his 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, their valve amplifiers, and effect pedals. Here lays the basis of his love for music and electronics and art.

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