You Can DIY!

TubeSociety 2A3-300B-SE Amplifier Project (Part 1)

Experimentation Leads to Success

Photo 1: Menno van der Veen is pictured with members of the TubeSociety community.

Menno van der Veen designed five challenging 300B-SE amplifiers for his students. Part 1 of this two-part article discusses his TubeSociety academy in the Netherlands and details the first four amplifiers. Part 2 of the article will describe the fifth amplifier, plus provide information about the power supplies and construction.

By
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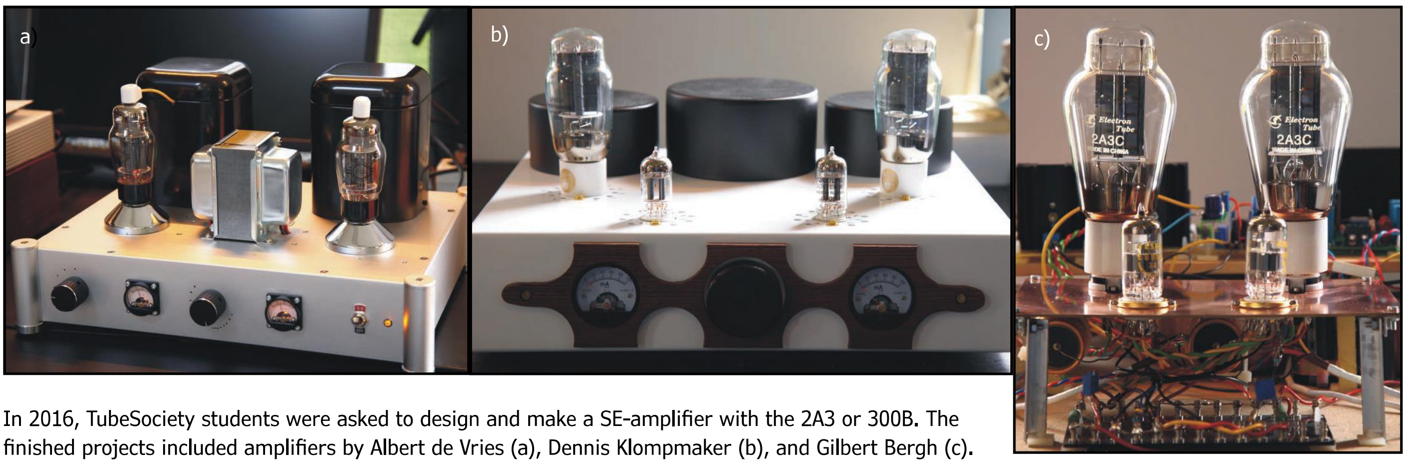
(The Netherlands)

About 12 years ago, I started my TubeSociety academy[1], where I try to teach my TubeSociety students to become the best designers and constructors of tube amplifiers. Once a student said: "I don't wish to be a copier, I want to do it all by myself." That is a rather hefty saying, but it describes exactly the spirit in my biweekly Saturday school (see **Photo 1**). Besides explaining standard stuff such as Ohm's law and characteristics of tubes, I also select a year's topic. In 2016, I asked students to "design and make a SE-amplifier with the 2A3 or 300B" tubes. After one year of hard study and labor, the final results were striking (see **Photo 2**).

These fantastic designs did not occur by accident or good luck, but were founded on literature study, intensive cooperation among all the students and me, sharing new ideas and helping those who required assistance. We built on each other shoulders.

Imagine that next year's project would be "make a race car." A starting foundation would be very helpful. For instance a chassis, some wheels, and a motor. This is exactly what I provided at the



In 2016, TubeSociety students were asked to design and make a SE-amplifier with the 2A3 or 300B. The finished projects included amplifiers by Albert de Vries (a), Dennis Klompmaker (b), and Gilbert Bergh (c). (Photos courtesy of Yeb de Witte)

Photo 3: Menno van der Veen's Amplifier 1 is an FET driver stage plus 300B in 2A3 configuration.

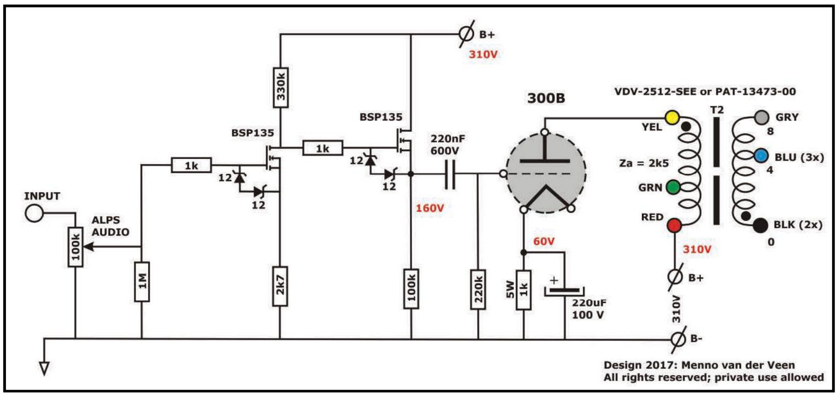


Figure 1: This is a schematic of the audio section for Amplifier 1.

start: some conceptual schematics[2] plus a student support group who organized casing and a set of standard components. After that we all (including me) started to design and showed our results during lessons. This fine cooperation made the year's end a great happening. We all were happy with the high quality of our final products.

To support my students "on the road," I designed five SE-amps and shared my results. Through this process, I taught them the knowledge they needed to build their own ampliers.

Amplifier 1

Amplifier 1 was designed with a field-effect transistor (FET) driver stage plus 300 B vacuum tubes in a 2A3 configuration (see **Photo 3**). The concept of the audio-signal stage is shown in **Figure 1**. To begin, I applied BSP135 FETs in a very simple clean driver stage. I added a source follower, to compensate for the rather large grid capacitance (Miller influence) of the 300B. Almost every student used my VDV-2512-SEE single-ended toroidal output transformer[3]. However, I applied a sample transformer that my Chinese student Zhou Ke sent to me for evaluation. His OPT was designed for the 2A3 with 2.5 kΩ primary impedance and a quiescent current of 60 mA. For that reason I set the 300B in that specific operation point. Surely not optimal for the 300B, but, this was a fine opportunity to test the Zhou Ke OPT.

At each FET, I placed two 12 V Zener diodes between the source and the gate to protect the amplifier at start-up. The total harmonic distortion (THD) of only the driver section is 0.8 % at 1 kHz at maximum output power of 4 W, way below the 300B distortion. **Photo 4** shows the interior of the amplifier as it is being built.

The most important measurement results are shown in **Figures 2–5**. I took the measurements with the Arta programs developed by Ivo Mateljan[4]. For

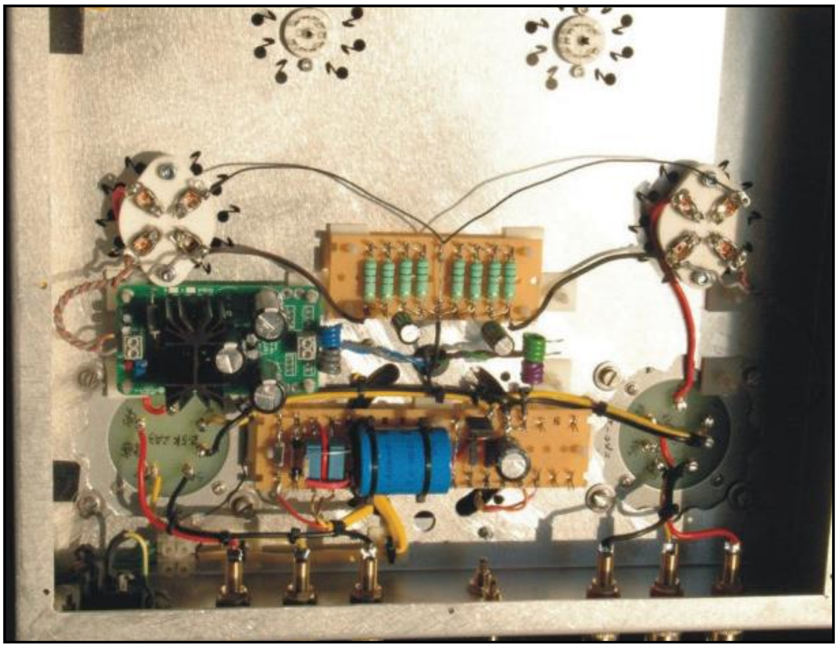


Photo 4: This is an inside view of van der Veen's Amplifier 1.

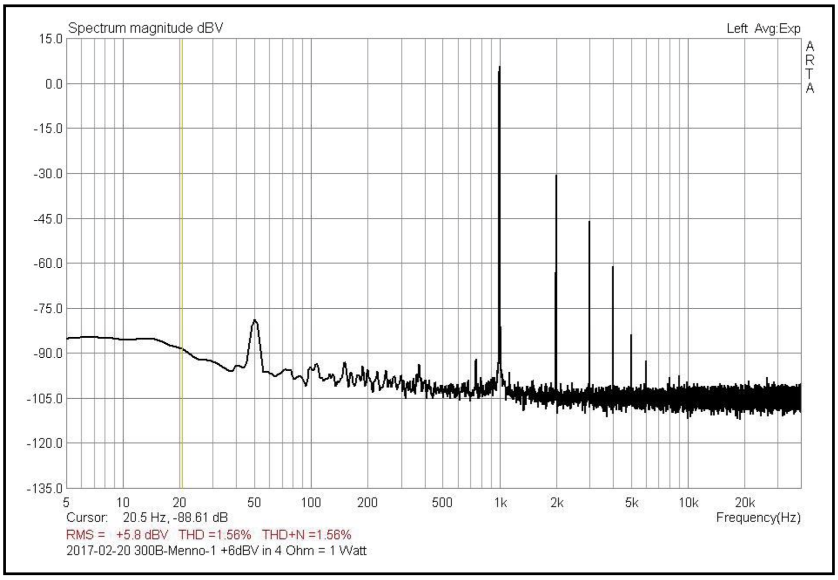


Figure 2: Amplifier 1 is shown with a 1 kHz spectrum at 1 W in 4 Ω.

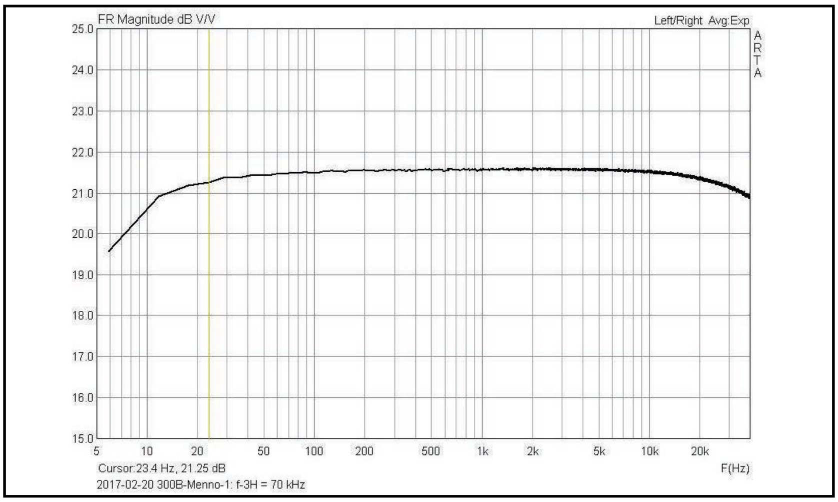


Figure 3: Amplifier 1 is shown with gain and frequency range at 1 W in 4 Ω.

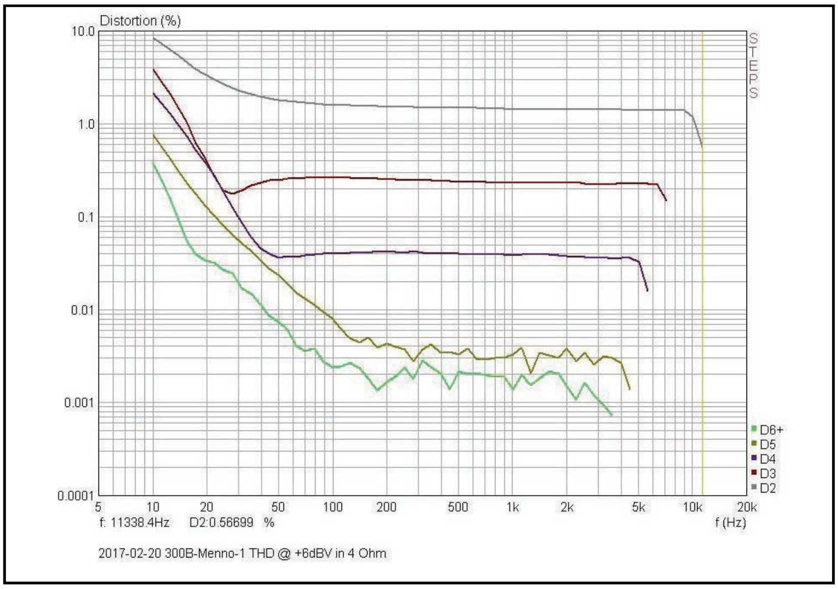


Figure 4: Amplifier 1 is shown with harmonics at 1 W in 4 Ω.

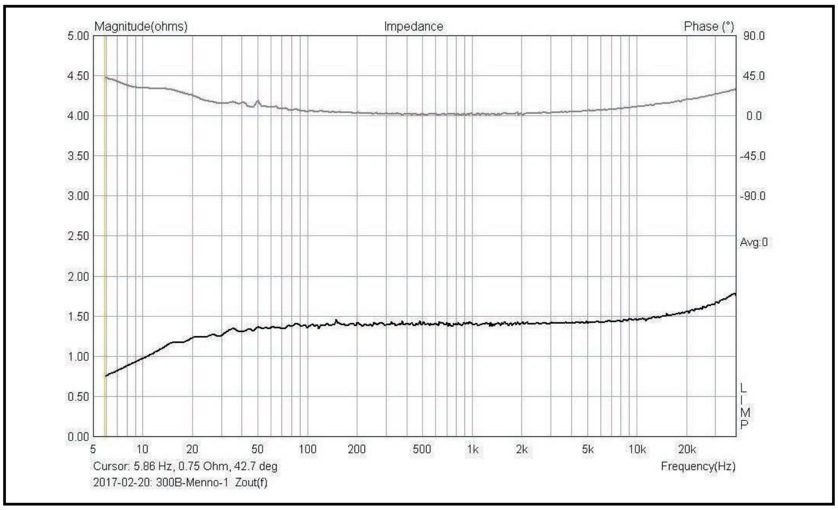


Figure 5: Amplifier 1 is shown with output impedance (lower curve) at 4 Ω tap. The upper curve is the electrical phase of the impedance (right hand scale).

my TubeSociety students, I designed a special sound card interface, called Arta-2 (see **Photo 5**), which is fully described on my website[5]. With a big smile my students call it "the poor man's Audio Precision." I know that Audio Precision is much better, but isn't that a compliment? Feel free to copy this powerful calibrated device for your private use. (Any business-related manufacturers are only allowed to use it with my approval provided in writing.)

As for the measurements, you might ask why I mostly measure at 1 W in 4 Ω. I use excellent horn loudspeakers[6]. With only 1 W I get 99 dBSPL, which is very loud. Mostly I will listen below this level. So, I measure at the 1 W level and below, not at super output powers. My listening room is not a disco.

The harmonic spectrum shown in Figure 4 nicely follows the masking curve of our ear. This behavior is preferred in most literature. I will explain later why I disagree. The frequency range shown in Figure 5 extends without any resonance to -3 dB at 70 kHz. The OPT alone, driven by a 800 Ω voltage source, extends to -3 dB at 100 kHz without any ringing, which is excellent. So, I gave Zhou Ke my compliments.

Figure 5 shows the specific small output impedance of triode SE-amp. This is excellent behavior, because the lower the tube's plate resistance, the lower the magnetic distortion in the output transformer. This conclusion is based on the famous research of Allen Partridge. At the lowest frequencies, the starting shrinking impedance of the primary inductance Lp of the OPT is noticeable[7]. At the highest frequencies, the onset of the influence of the primary leakage inductance Lsp is just visible. Both effects are almost outside our effective hearing range and hardly influence the perception.

Conclusion: The measurements show a healthy amplifier with many goodies according to today's standards in SE-amp design. But how does it sound? The amp sounds warm, however, with it has too many second harmonics, preventing micro details from being heard. This character did not impress me, but it functioned. Not that bad for a first try.

Amplifier 2—Focus on the Coupling Capacitor

Amplifier 1 and Amplifier 2 are exactly the same except that in Amplifier 2, we changed the brand of the u22/630V coupling capacitor. The students and I listened to the following types: the Jensen Silver foil; the Jensen Copper foil; the Mundorf Mcap Silver/Gold/Oil; the Russian Pio K40Y:9; the Koweg; the LCR PCHVSWF; the Lcap KPSd; the Siemens MKP; the Wima-red MKP10; and several other unmarked brands.

The results were striking. The sequence of this list shows our appreciation, with the Jensen Silver foil as the absolute winner. The Jensen Copper foil was somewhat less compared to the Jensen Silver foil. The Mundorf Mcap Silver/Gold/Oil was next on the declining scale and so on.

The observations were as follows: Nothing was changed in volume, only the capacitors interchanged, followed by an almost blind listening test (because no one knew what to expect). With the Jensen Silver foil, the sound stage was open, fluent, deep, no sharp character, friendly and warm, highly attractive human-like sound character. With the other capacitors on the list, these good observations declined until the sound character became flat and not attractive at all. Next, I

Photo 5: The Arta-2 measuring unit can be connected to a sound card.

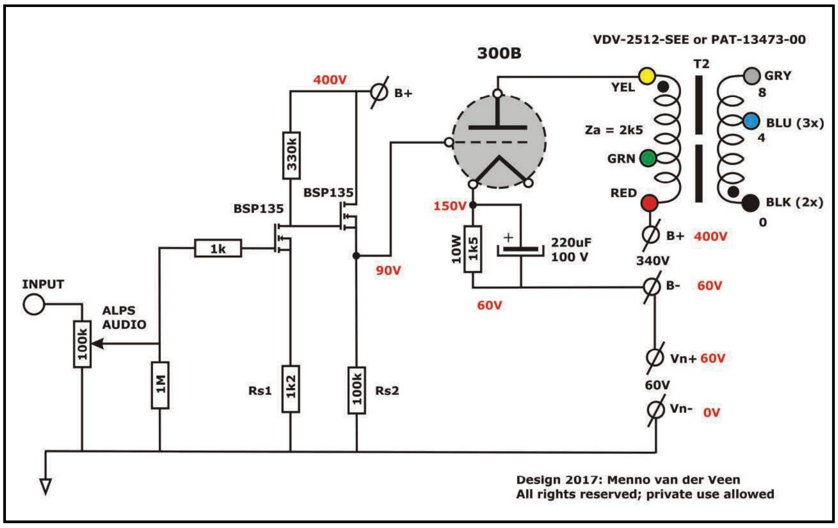


Figure 6: Here is the schematic used for Amplifier 3.

performed standard measurements of the distortions (as I did in Figure 4) and I noticed no differences between the various capacitors.

Consequently I am forced to a rather stringent reformulation of my conclusions of Amplifier 1: "The subjective quality of the amp is mainly influenced by only one component: the coupling capacitor."

It was impossible to measure any effect with my standard measurements. They seem to be invalid in judging subjective sound quality. Let me be cautious here: The measurements are valid in showing good design, but that is not the topic of this discussion. I am well aware of the influence of construction and materials in coupling capacitors. I even wrote an Audio Engineering Society (AES) paper[8] about some of those remarkable effects. That is not my problem. It is that conclusions drawn from standard accepted measurements seem to be invalid when you wish to say something about the appreciation of an amplifier's sound. Therefore, I shall use my standard measurements only to determine the health of the design. I will not be able derive conclusions from them about how it sounds.

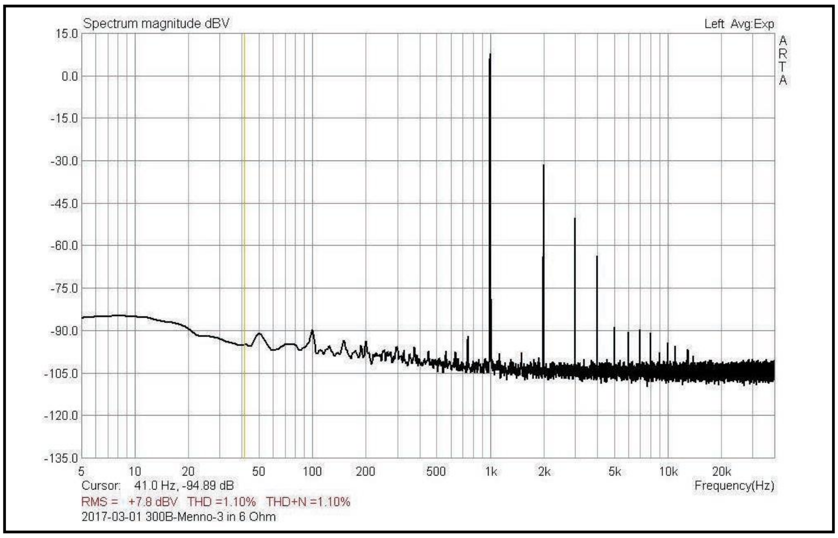


Figure 7: Amplifier 3 is shown with a 1 kHz harmonic spectrum.

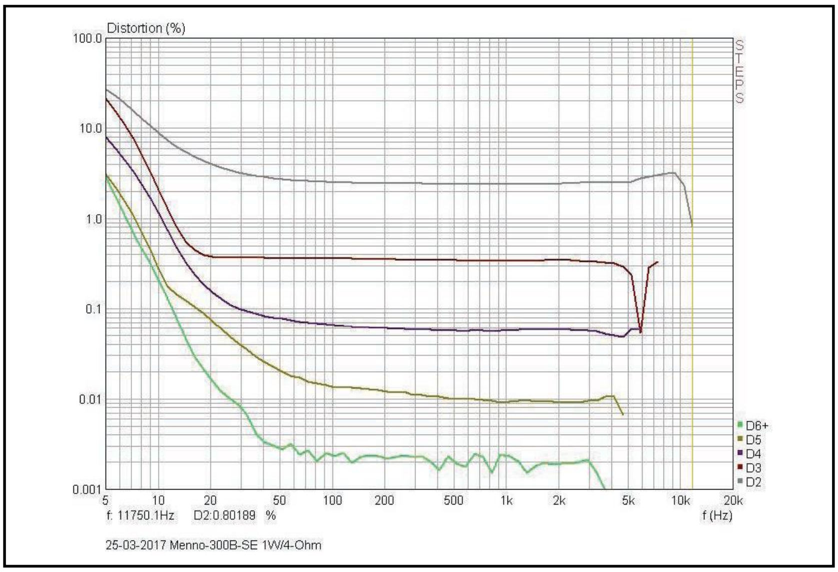


Figure 8: Amplifier 3 is shown with with harmonics at 1 W.

A last small remark: If the coupling capacitor has such a huge influence, why not the same for resistors or transformer core steel or ...... I understand that people are willing to spend thousands of euros (or dollars) to get the sound character they want, to approach the holy grail. Is this the way to proceed for me and my students? I decided not to continue down this expensive trail, but to use another way of thinking. Let's see what this brings us.

Conclusion: The simple Amplifier 1 sounds amazing when you apply Jensen Silver in oil coupling capacitors. They are expensive but surely you get audio value for the money.

Amplifier 3—FET Driver Stage, No Coupling Capacitor Nor Zener Diodes

If the coupling capacitor has such a huge influence, why not remove it by changing the circuit into direct coupling? I also noticed that the protecting 12 V Zener diodes have a leakage current in the micro ampère range, creating noticeable distortions. So, I got rid of them (see **Figure 6**).

Two voltage sources are applied. (I will provide more detail in Part 2 of this article.) The B+ supply delivers 340 V and sends 60 mA current through the primary of the OPT, through the 300B, through its cathode resistor of 1.5 kΩ, back to the B- side of the supply. However, the B- side is NOT grounded, but lifted 60 V above ground by means of the second supply Vn. Consequently, the filament cathode of the 300B is at (60 + 60 mA × 1.5 kΩ) = 150 V above ground.

The FET source follower has its output +90 V above ground, which can be trimmed with Rs1. Under this condition the grid of the 300B is 60 V lower in potential than the filament cathode. This corresponds with an operating point of Vak = 250 V and Io = 60 mA of the 300B. Drifting in time or by changes in Vmains are counteracted by the rather large cathode resistor Rk = 1.5 kΩ. As you see, the coupling capacitor and protecting Zener diodes are not present anymore. Also note that the current capabilities of the B-supply are large (about 120 mA for stereo in this set up), while the very "clean" Vn only has to deliver a few milliamps (see **Figure 7** and **Figure 8**).

In Figure 7, the higher harmonics 5, 6, 7, and 8 are less suppressed. The harmonic 2, 3, 4 levels are a little smaller than in Amplifier 1 and Amplifier 2, but the difference is not very convincing.

So, how does this amp sound? The sound character is close to that of Amplifier 2 with the Jensen Copper foil capacitor. Lots of space and depth, but not all the details are totally clear, I still observe a curtain (= second harmonics), but lesser than that found in Amplifier 1. My wife Annemieke said, "The sound character is a little too bright." And the measurement shown in Figure 7 confirms this observation by the higher levels of harmonics 5 and above.

Conclusion: Not all is optimal yet, removing C-coupling seems to be a promising route. Let me continue this in Amplifier 4 to improve further the sound.

Amplifier 4—Introducing 300B-TRANS

As you might know, I have written a book about valve amplifiers with transconductance[9]. It describes a study where a voltage controlled current source and the final power tube are combined. This results in extra low impedance drive of the output transformers. So, I am going to apply this Trans-concept in Amplifier 4.

My idea was as follows: Suppose I change the first FET into a voltage controlled current source.

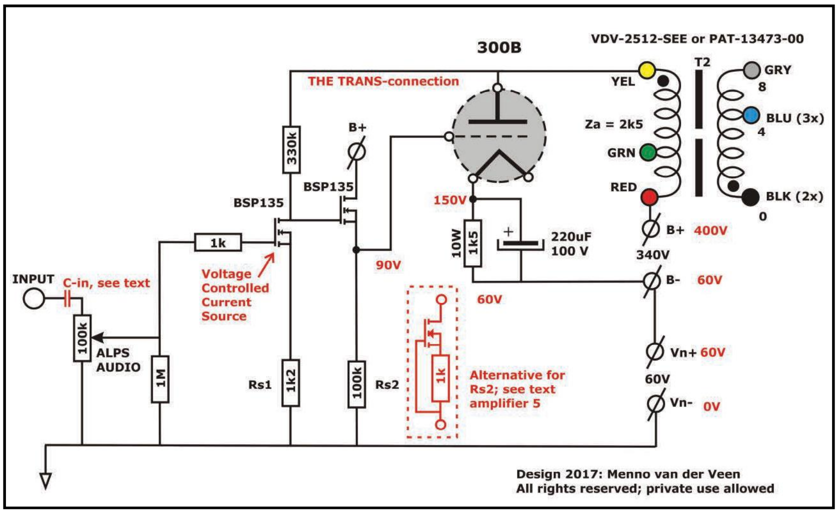


Figure 9: For Amplifier 4, van der Veen experiments with transconductance.

The second FET can stay in place. It is a mandatory source follower to suppress the influence of the grid capacitance of the 300B. Only one connection needs to be changed. At the first FET, the 330 kΩ resistor from drain to B+ shall now be connected to the anode of the 300B (see **Figure 9**). The correct operation point can be trimmed with Rs1, as in the previous amplifier.

The more I apply this very simple schematic, the better it pleases me. You can linearize the voltage controlled current source even further by measuring the AC-music-voltage over Rs1. Next, compare this voltage with the input signal, by means of a

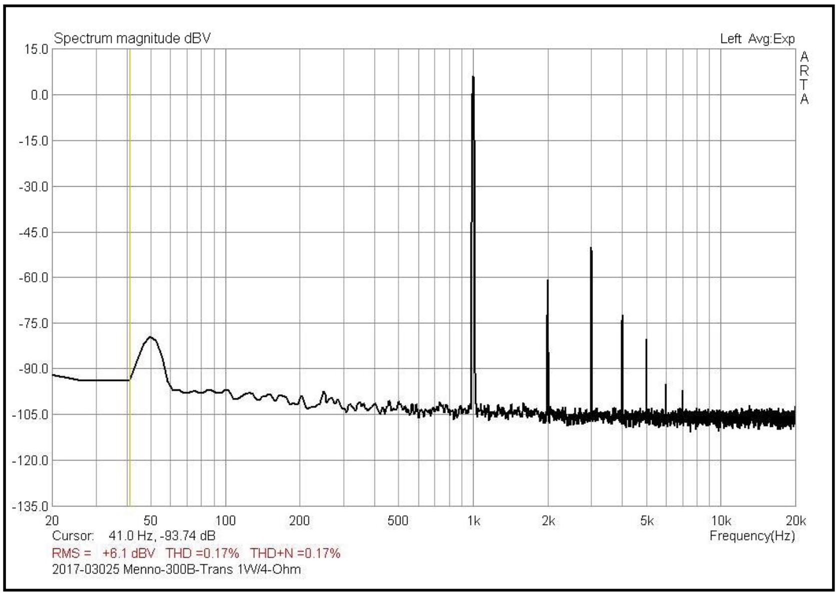


Figure 10: Amplifier 4 is shown with 300B-Trans 1 kHz spectrum.

About the Author

Menno van der Veen studied engineering physics at the university. He taught physics at an upper secondary school and teacher trainings college. At the age of 40, he founded his engineering firm with a focus on tube amplifiers and toroidal output transformers. He wrote many articles and books about these subjects. About 12 years ago, he also started his TubeSociety academy. Tube-amp research, consultancy, design, teaching and playing the guitar are the main activities of his present work.

differential op-amp circuit and let the op-amps output drive the gate of the first FET. This local feedback approach will produce better measurements, but subjectively I hardly noticed improvements. So, I did not apply this more complex approach.

Before studying the measurement results, let me be honest. The 300B is a legend, the best creation ever. Now I come along and apply transconductance, and this technique creates negative feedback over this famous tube. Have I gone crazy? I will be killing all the specialties of the 300B by applying feedback!

I know, I humbly bend my head. But maybe you will allow me some defense. It really was not my goal to provide feedback to the 300B, because transconductance works optimally when you use a good pentode instead of a a 300B. However, the 300B was already on the chassis and the current source was there, as the source follower. The challenge was irresistible. I couldn't stop myself from doing this. **Figures 10–13** show the measurement results.

Figure 10 clearly shows that the second harmonic is largely suppressed. Now we don't see the regular harmonic decline under the masking curve. Understanding this is not difficult: the 300B-Trans is internally fedback, creating almost equal distance and constant slopes of the more vertical gridlines of the Ia-Vak-Vgk characteristics. The standard curved characteristics are straitened, also in the limiting range at low anode currents. Consequently, the second harmonic distortion gets less.

Figure 11 shows that the frequency range is almost flat, because of the much smaller plate resistance of the 300B-Trans configuration, suppressing the influence of Lp and Cip and the Lsp of the OPT.

Figure 12 shows many interesting results. At very low frequencies (below 20 Hz) the OPT-steel-core distortions are dominant. Going from 20 Hz to 1 kHz, the second harmonic decline is caused by the lesser influence of the primary inductance Lp of the OPT on the effective load line (less oval). Above 1 kHz and higher you see the second harmonic increasing again because of decreasing impedance of the effective primary capacitor Cip inside the OPT, making the load line oval again. The third and higher harmonics are smaller than in earlier trials, suppressed to a lesser extent than the second, which can be understood from the famous research by Peter Baxandall and Douglas Self[10].

Figure 13 clearly shows the internal Trans-feedback on the 300B. The output impedance is almost (mu – 1) times smaller than in earlier trials. At highest frequencies the influence of the leakage inductance Lsp of the OPT again is visible.

In general: Rather drastic changes compared to earlier amps are observed. Fortunately, these

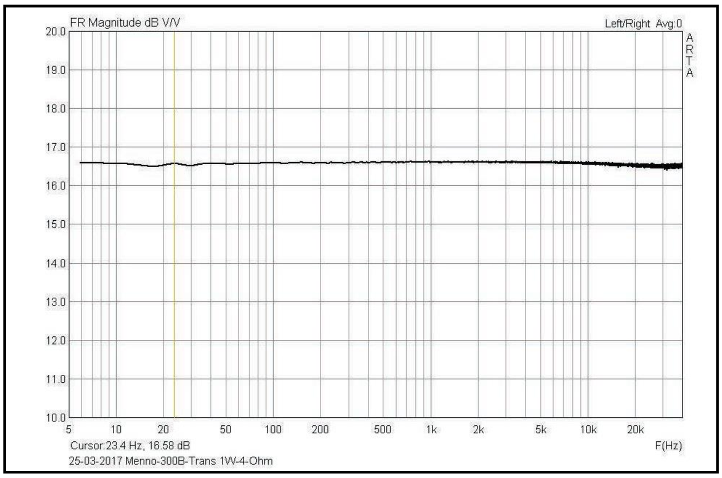


Figure 11: Amplifier 4 is shown with a 300-Trans frequency range.

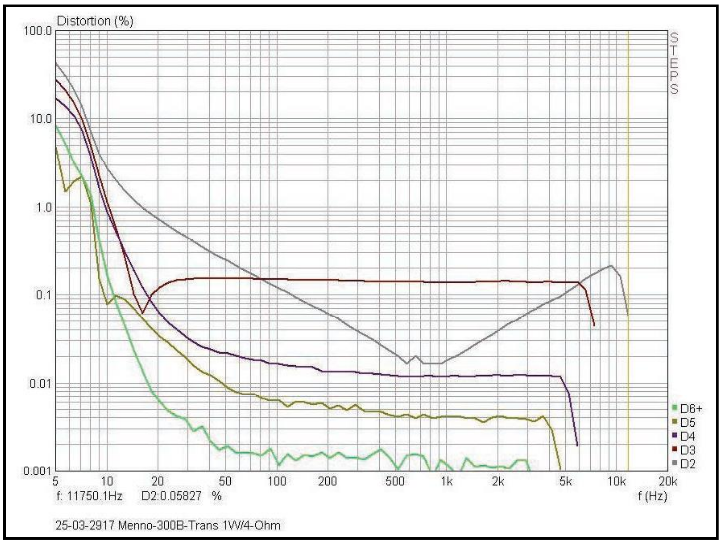


Figure 12: These are the 300B-Trans distortions for Amplifier 4.

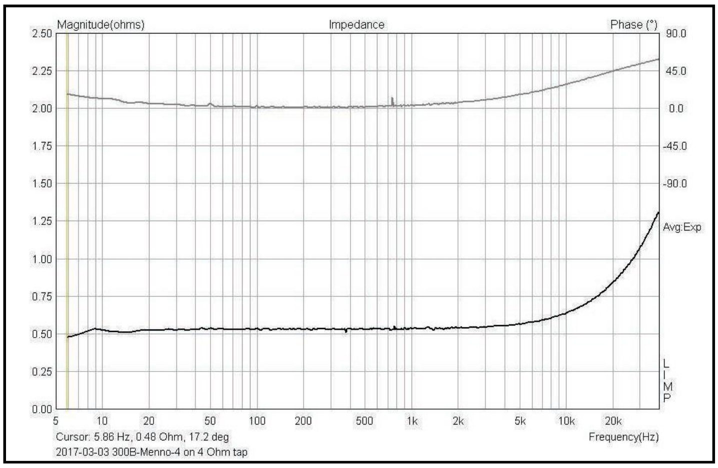


Figure 13: This is the Trans output impedance (lower curve) at 4 Ω tap for Amplifier 4. The upper curve is the phase of the impedance (right hand scale).

changes are fully described in my Trans book. The "power" of transconductance is large; don't underestimate this technique for several reasons:

- You can use pentode power tubes with their 50% efficiency (instead of 25% with triodes)
- You get better linearity than with triodes (smaller THD)
- The effective plate resistance with Trans (around 100 Ω to 300 Ω) is smaller than with good 300B triodes (around 800 Ω)
- Consequently the magnetic distortions in the OPT decline at least a factor 2 to 3 (6 to 9 dB)
- The local Trans feedback is only around the power tube and does not include the fog and smear creating hysteresis of the core of the OPT. This feedback loop is intrinsic linear.

Subjective observations: Yep, here we go! Lots of details and embracement, the depth picture is excellent. No curtain anymore. This is how I like the natural open sound character. Let's have a bottle of wine and listen for hours into the late night. I have had this experience before. But usually the next day, with some headache, the joy slowly disappears. However, with Amplifier 4, my appreciation remained, even grew. Students and friends were invited for listening. In my opinion, I approached the holy grail a little bit. I consider this amplifier as a very good design, I am proud of it.

I could have stopped my supportive research for my TubeSociety students at this moment. But one day I accidentally connected a faulty device with a lot DC-offset voltage to the input of the amplifier and misfortune struck me. Flash, a spark rain, severe hum, smoke, and other bad things. I had red 300B anodes and a broken filament because I plugged in the precious hot tubes too hastily. I easily could have prevented all that by adding a high-quality input capacitor (1 µF non polar) before the volume control (see the red in Figure 9). But I actually broke the amplifier, so I had to build a new one. I decided to offer my students another challenging alternative.

I will describe Amplifier 5 in Part 2 of this article series for the May issue of *audioXpress* .

Resources

[1] M. van der Veen, "TS-2016: 2A3/300B-SE AMPLIFIER," TubeSociety 2016 project (in English), http://mennovanderveen.nl/nl/tube_2016.html

[2] M. van der Veen, TS-2106 Starting concepts and schematics, http://mennovanderveen.nl/nl/download/ts2016/2A3-300B_concepts.pdf

[3] M. van der Veen, Toroidal Output Transformer T2: VDV-2512-SEE or PAT-13473-00, https://mennovanderveen.nl/eng/download/vatsea/Transformers-specs.pdf

[4] Ivo Mateljan, Audio Measurement and Analysis Software, www.artalabs.hr.

[5-1] M. van der Veen, "How to make your own Arta-2 calibrated measurement device," https://mennovanderveen.nl/nl/download/arta/ARTA-2 manual-ijken-meten-schema-pcb-boormal.zip

[5-2] M. van der Veen, Arta-2 demonstration (in Dutch), www.youtube.com/watch?v=LLpPy5oPCBY

[6] Quintafila Niagara MSR, www.quintafila.it

[7] M. van der Veen: "Signal level and frequency dependent losses inside audio signal transformers and how to prevent those," 130th Audio Engineering Society (AES) Convention paper, May 2011, http://mennovanderveen.nl/nl/download/download_5.pdf

[8] M. van der Veen, H. van Maanen: "Non linear distortions in capacitors," 124th Audio Engineering Society (AES) Convention paper, May 2008, http://mennovanderveen.nl/nl/download/download_4.pdf

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[9-2] M. van der Veen, *Vanderveen Trans Tube Amplifier*; Elektor, www.elektor.de/trans-roehrenverstaerker, ISBN: 978-3-89576-307-6

[9-3] M. van der Veen, *Vanderveen Trans Valve Amplifiers*; Elektor, www.elektor.com/vanderveen-trans-tube-amplifiers, ISBN: 978-1-907920-34-9

[10] P. Baxandall and D. Self, *Baxandall and Self on Audio Power, Linear Audio,* www.linearaudio.net, ISBN 978-94-90929-03-9