

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

Saving the Best for Last

In the first part of this article, I described, four 300B single-ended (SE) amplifiers. Now, I will discuss the fifth amplifier, detailing the power supply section and the construction. At the end of the article, I will discuss my conclusions about this experience.

By
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(The Netherlands)



The first three amplifiers discussed in Part 1 all exhibited a general behavior. They had rather large total harmonic distortion (THD), where the second and third and higher harmonics decline in amplitude. The fourth amplifier (the 300B-Trans) strongly deviated from this behavior by showing remarkably less THD, higher speaker damping, and the second harmonic was much smaller than the third. This behavior allows the micro details to be clearly heard. In Amplifier 5 (see **Photo 1**), I attempted a different route to reach for the same excellent results I achieved with Amplifier 4.

Use a Tube Driver

The blown Amplifier 4 taught me that DC-coupling can be very nasty. So, back to input or coupling capacitors, but they needed to be of excellent quality. So, for Amplifier 5, I decided to use a high-quality tube driver. I did many experiments, with mu-stage and the like, but these circuits did

not fully satisfy me, mainly because of the lack of available research time.

Then, I thought, "suppose I use tube circuitry with real current sources instead of cathode and anode resistors, would that be the right way to go?" **Figure 1** shows the resulting schematics. I also changed the operation point of the 300B.

My earlier experiments had shown that the 2A3 setting might be great for the 2A3, but not for the 300B. Now I use $V_{ak} = 340\text{ V}$, $I_o = 90\text{ mA}$, $V_{gk} = -70\text{ V}$ and $Z_a = 3.5\text{ k}\Omega$ primary impedance by loading the $4\text{ }\Omega$ secondary tap with an almost $6\text{ }\Omega$ speaker. Remember $Z_a/Z_s = (N_p/N_s)^2$, where the turn numbers N_p and N_s are fixed. Changing Z_s automatically changes the primary impedance Z_a in ratio.

The BSP135 current source (1.2 mA) in the first anode creates an almost horizontal load line, thus lowering the distortion of the first amplifier stage (see **Photo 2**). The second tube section acts as a cathode follower. Its distortions are minimized by

Photo 1: Amplifier 5 was the final amplifier Menno van der Veen made for the TubeSociety 2A3-300B SE Amplifier Project.

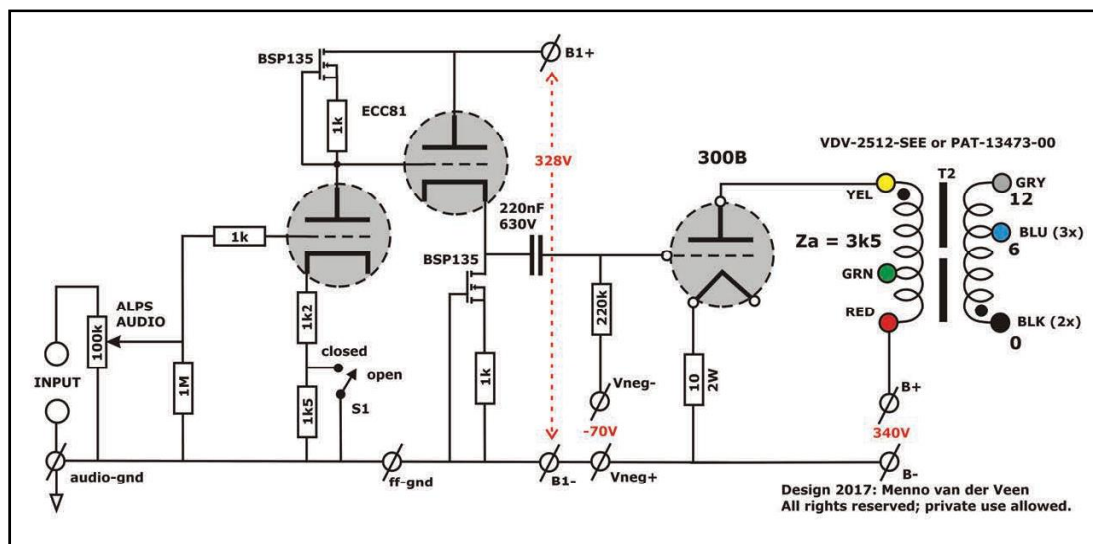


Figure 1: I used this schematic to build Amplifier 5.

the second BSP135 current source. This current source is also applicable in Amplifier 4.

The operating point (anode voltage) of the first triode can be changed by closing S1. With open S1 the cathode follower output is at 190 V above ground; with closed S1 the output is at 120 V. The circuit is able to drive the 220 kΩ grid resistor of the 300B. I know that 50 kΩ is prescribed for setting the operation point with negative grid voltage. However 50 kΩ would be a too heavy load for this driver section. With my Svetlana 300B, the operation point stays stable with $R_g = 220 \text{ k}\Omega$. To explain the functionality of S1, I will discuss this amp with S1 = open and with S1 = closed.

S1 Open

When you compare **Figure 2** with the measurement shown in Figure 7 from Part 1 of this article series, you see that the THD has gone



Photo 2: Here is the simple construction of the constant current source.

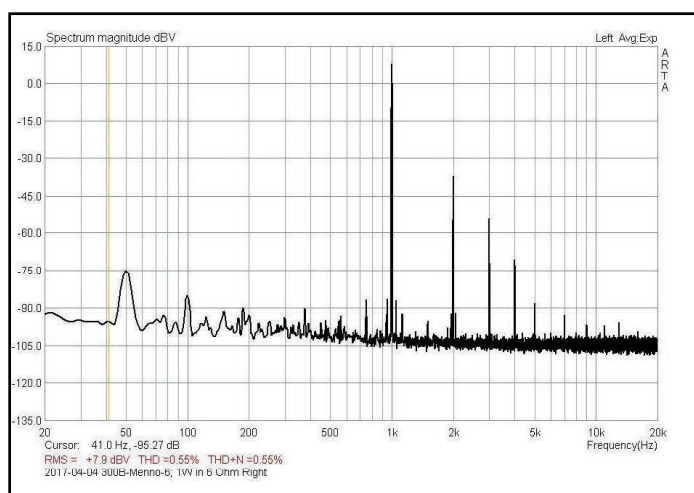


Figure 2: Amplifier 5 with S1 = open is measured at 1 W in 6 Ω load.

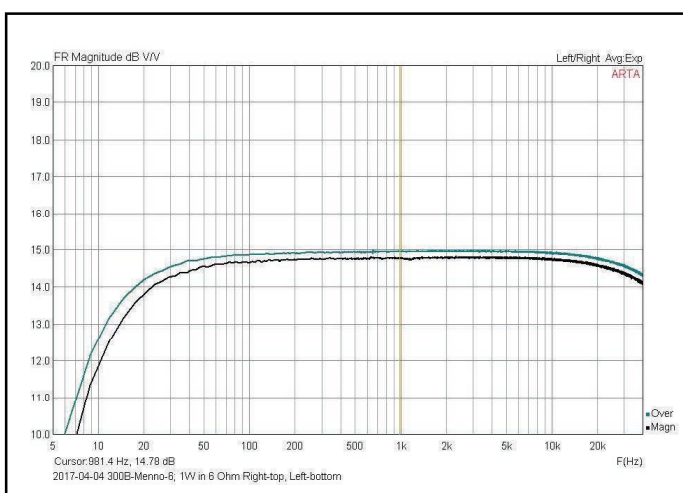


Figure 3: Amplifier 5 with S1=open is shown with left and right channels.

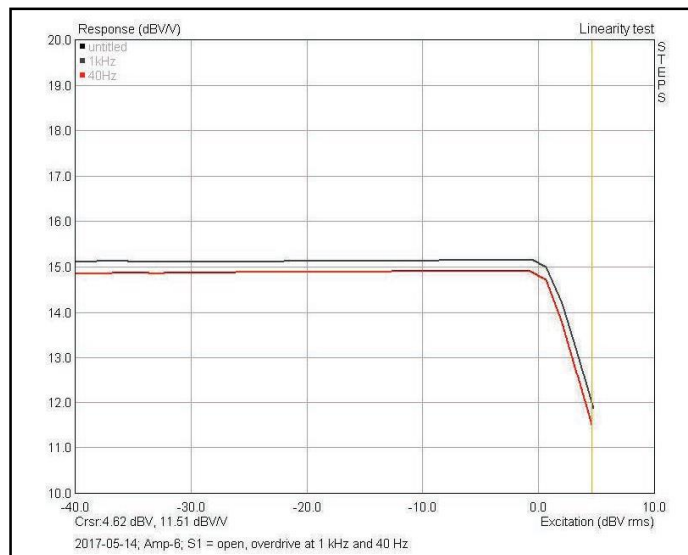
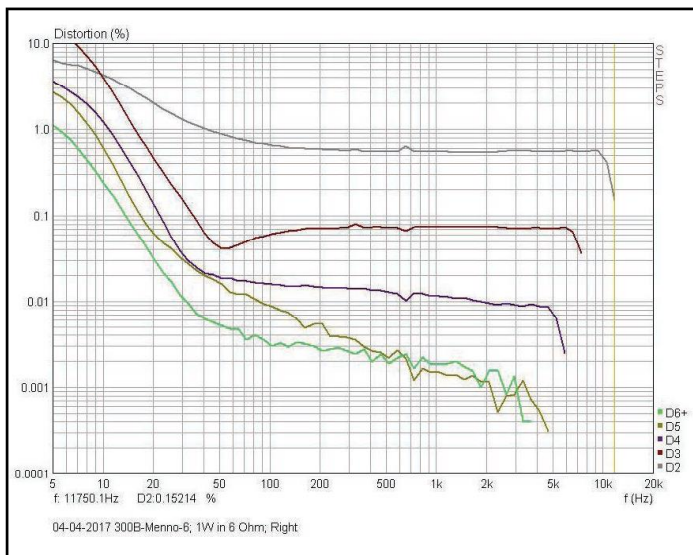


Figure 4: Amplifier 5 is measured with distortions at 1 W in 6 Ω .

Figure 5: Amplifier 5 is shown with linearity at 1 kHz and 40 Hz (red).

down by a factor of two. This is mainly caused by the improved operating point of the 300B.

The frequency range shown in **Figure 3** is as wide as before and gives no reason for concern. However, I also want to mention to please measure the f-range at full power, to check that no slew limiting occurs (that happens when dV/dt is too small) in the audio range up to at least 20 kHz. I checked this and there is no reason for concern with Amplifier 5.

However, the reason why I mention this is because I noticed with some other amps a strange low-to mid-frequency blur when playing a CD containing a nightingale recording. With a nightingale recording, there is often louder high-frequency information present. If dV/dt is too

small, the amplifier can't handle those signals, resulting in the blur that I mentioned. It took me a while to discover its cause. That's why I share this experience now.

Harmonics as function of frequency are shown in **Figure 4**. It is rather standard behavior and we have seen this before.

Figure 5 shows the linearity ($= 20 \cdot \log[V_{out}/V_{in}]$) expressed in dBV/V as function of V_{in} for 1 kHz and 40 Hz. Overdrive occurs around $V_{in} = 0$ dBV ($= 1$ Vrms). The overdrive knee is rather soft (it also sounds "soft"), and no core saturation is detected at 40 Hz.

This is a healthy 300B design—7 W output power (at 10% THD) and an output impedance of 1.5 Ω at the 6 Ω tap. There is also a standard accepted

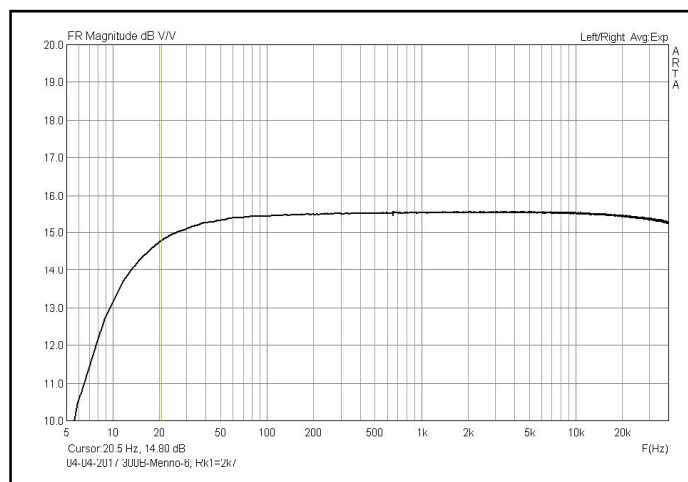
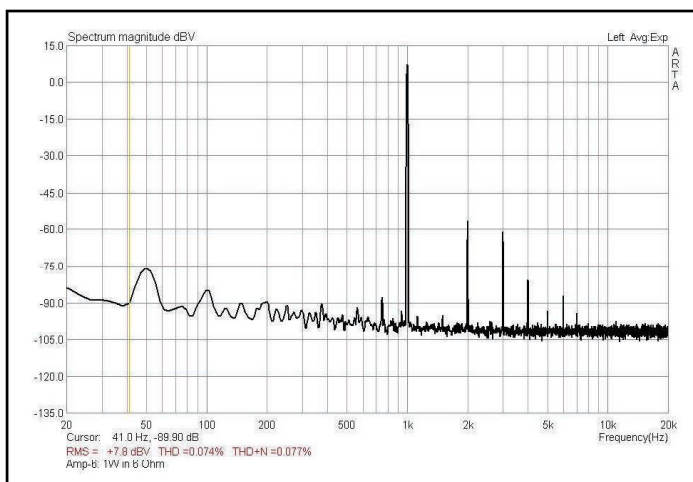


Figure 6: Amplifier 5 with S1 = closed is measured at 1 W in 6 Ω load.

Figure 7: This is the frequency range measured for Amplifier 5.

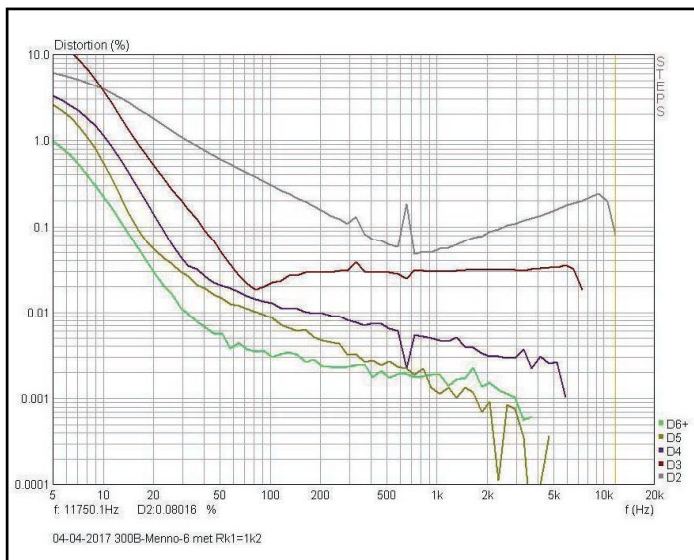


Figure 8: Amplifier 5 is measured with distortions at 1 W in 6 Ω .

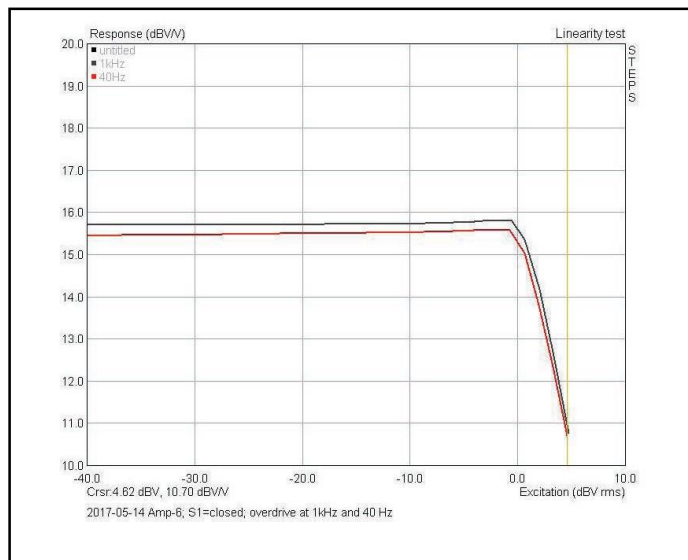


Figure 9: Amplifier 5 is shown with linearity at 1 kHz and 40 Hz.

decline in harmonics, which stay under the 1 kHz masking curve plus a wide enough frequency range.

How does this amplifier sound? Warm, an embracing open sound stage, easy to listen to, but again a curtain caused by the second harmonics. I have heard better, especially with Amplifier 4. So, let us now close S1.

S1 Closed

Figure 6 already shows that the harmonics are largely suppressed. The frequency range and amplification in **Figure 7** are almost the same as with S2 = open (compare to Figure 3). This is as expected because the first input triode has a current source at the anode. Then the amplification is hardly influenced by how large R-cathode is and is almost equal to the mu-factor of the first triode.

Figure 8 shows in full detail what is happening. The harmonics 2, 3, and 4 are smaller than with S2 = open (compare to Figure 4). This behavior is almost equal to what the Trans was doing, although I do not apply any negative local feedback. What happens is that the driver section pre-distorts in an inverse manner the signal to the grid of the 300B. The driver and the 300B distortions together compensate for each other, resulting in a very small effective total distortion. Again we see below 20 Hz the dominant core distortion. From 20 Hz to 1 kHz, we see in the second harmonic the decreasing oval load line effect of L_p . Above 1 kHz to 20 kHz, we again notice the oval load line effect of C_{ip} . This pre-distortion technique is a very effective way to suppress the distortion of the complete amplifier.

Figure 9 shows the linearity, which we compare to Figure 5. Now the overdrive-knee is more abrupt. The tonal character of overdrive sounds “sharper” than it did with all the other amplifiers discussed in Part 1 of this article. In my opinion, this is the only disadvantage. However, the solution is simple: Don’t play it that loud.

In my subjective opinion, this fifth amplifier with S1 = closed has many fine details, there is

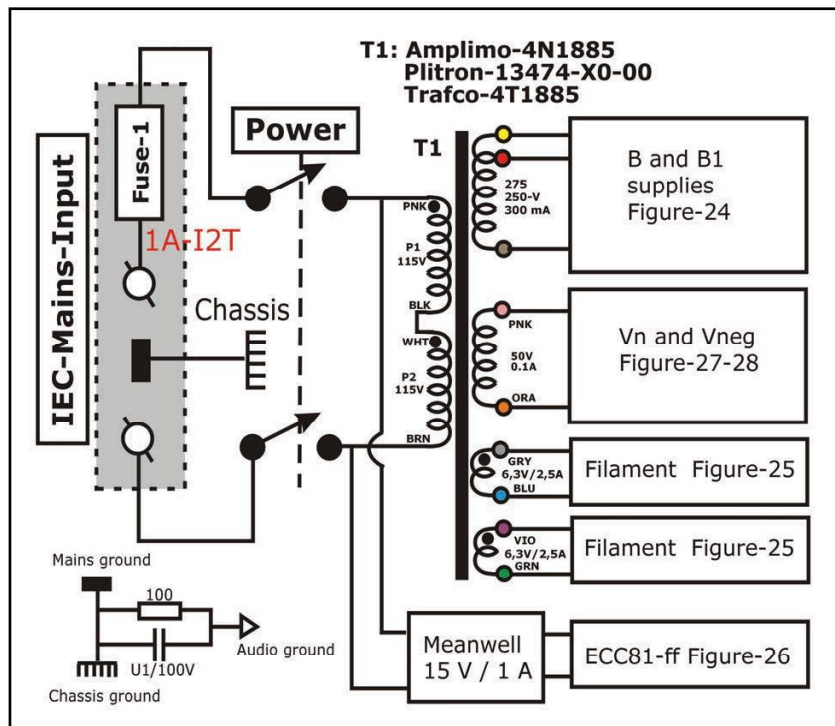


Figure 10: Here are the primary mains connections and grounding. The 230 VAC connection is shown. For 115 VAC connect BLK to BRN and connect WHT to PNK.

Photo 3: Here is the R/C-coupling between chassis and audio-ground.

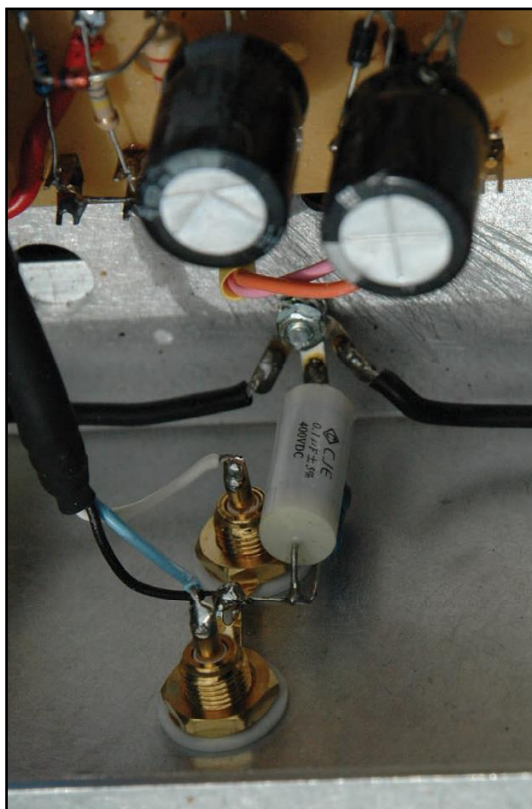


Photo 4: This is the toroidal power transformer for Amplifier 5. On top of it, the Meanwell AC/DC converter plus slow-start for the ECC81 filament.

no curtain, a wide and deep open soundstage, it's embracing, has excellent tonal balance, and is almost comparable to all the goodies of Amplifier 4. Even after late hours listening into the night and over the next few days, Amplifier 5's character stays convincing. Now, with classical tube driver section and modern current sources, I am again close to my goal. This soundstage is honest, usable for critical evaluation of a recording and enjoyable listening with total focus on the music. This design, as with Amplifier 4, pleases me.

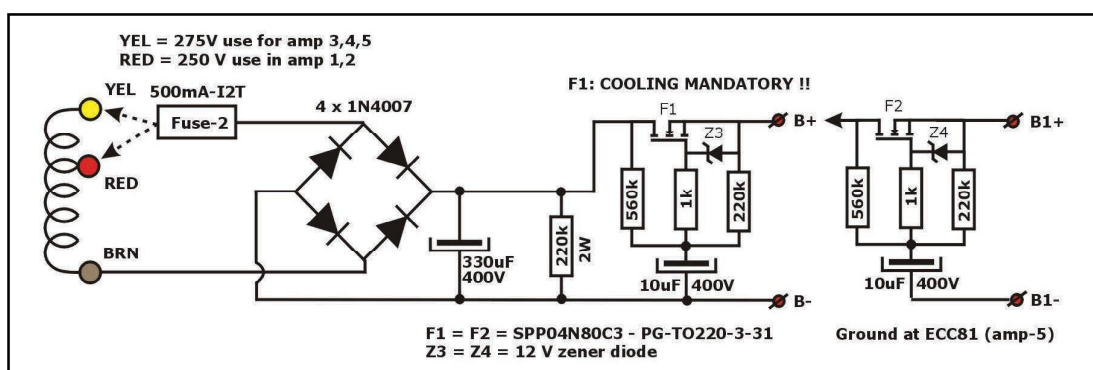
This last amplifier completed my support to my students. Next, I will discuss the power supplies and how I constructed my Amplifier 5, followed by some conclusions.

Power Supplies and Construction

A general overview of the complete power supply section is shown in **Figure 10**. The power transformer^[1] is a toroidal. How the mains are connected is shown as well. Mark the regional voltage in your country. Here, in Europe, it is 230 VAC (two primaries in series, as drawn). America has 115 VAC, where the two primaries shall be in parallel.

The bottom left side of Figure 10 shows how to ground this amplifier. The mains-ground is directly connected to the chassis for reasons of safety. The audio-ground is connected (at the input of the amplifier) to the chassis via a parallel R-C circuit of 100 Ω and 100 nF (see **Photo 3**). This special

Figure 11: This shows the high voltage supplies B and B1 for Amplifier 5.



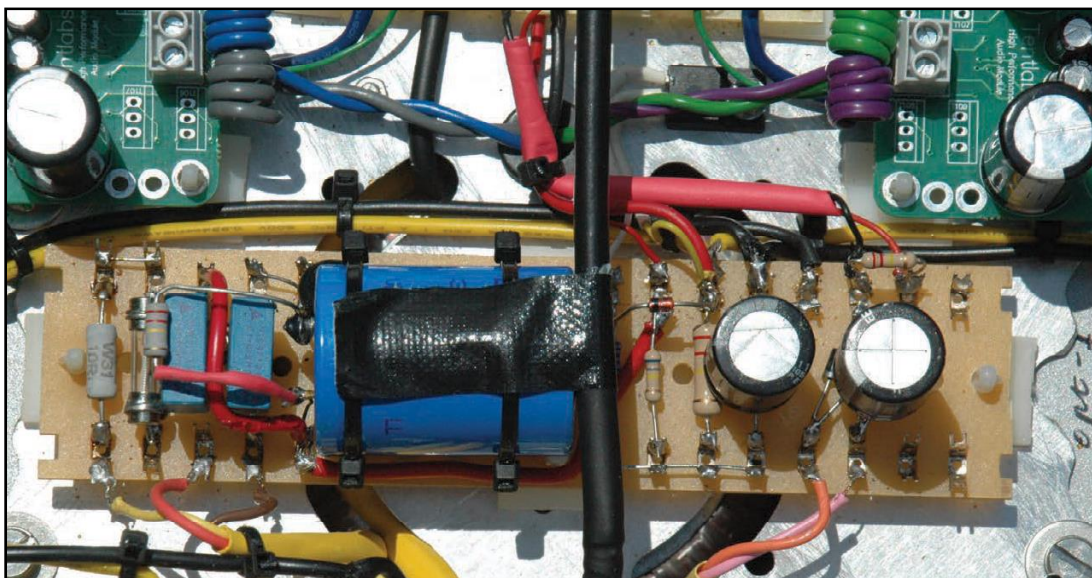


Photo 5: Practical realization of the B+ and Vneg supplies.

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.

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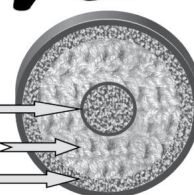
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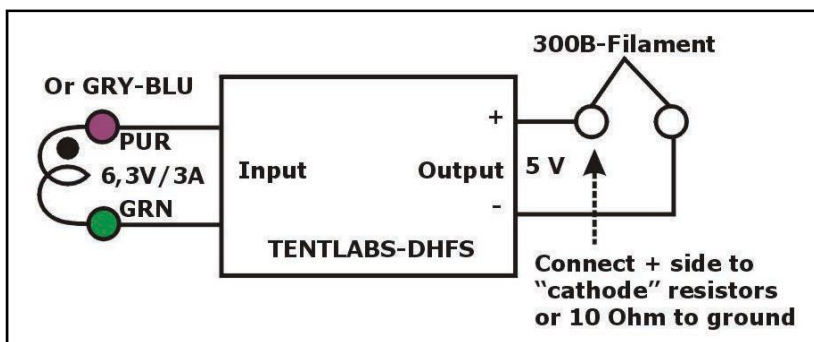


Figure 12: This is the 300B 5V filament supply (two of them are needed for stereo).

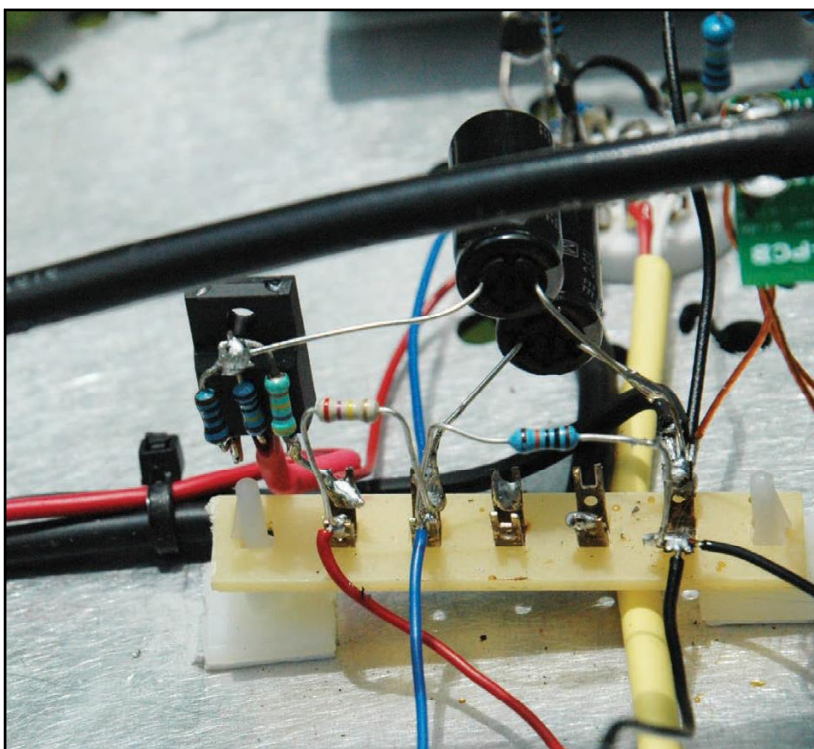


Photo 6: The B1+ supply is placed close to the ECC81 tubes.

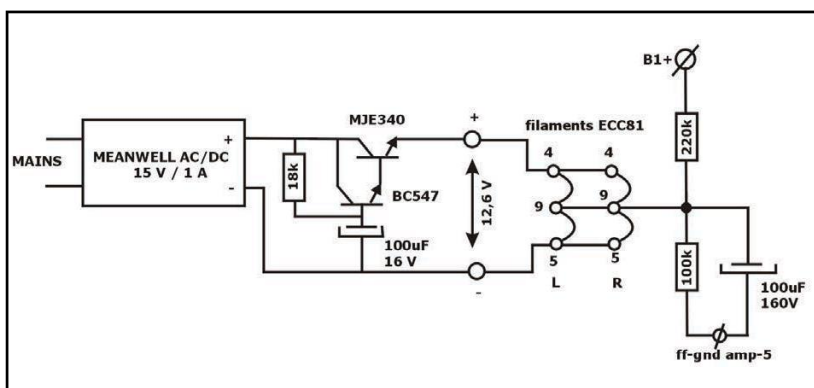


Figure 13: This schematic shows the ECC81 ff supply in Amplifier 5.

connection prevents humming ground loops. **Photo 4** shows the toroidal power transformer.

Figure 11 shows the schematics of the B+ and B1+ supplies. **Photo 5** shows the interior of Amplifier 5.

The high voltage winding (250 V or 275 V) is rectified, buffered by 330 $\mu\text{F}/400\text{ V}$ and fed into SPP04N80C3, the special TO220-isolated power field-effect transistor (FET). The capacitor at the gate of 10 $\mu\text{F}/400\text{ V}$ is slowly loaded by the drain-resistor of 560 k Ω . This creates a very slow start-up of the high voltage B+.

The first FET after rectification should be cooled on the chassis. It dissipates a maximum heat of $2 \times 90\text{ mA} \times 12\text{ V}$ between drain and source. The heat equals 2.2 W, which demands this extra cooling. Please note that the 1 kHz gate-resistor should be placed very close to the gate of F1 (and also at F2), to prevent nasty oscillations. The B1+ supply repeats the circuit of the first FET, but dissipates almost no heat: Some milliamps times 12 V is 0.1 W; no cooling mandatory. The output impedance of both FET circuits is 2.5 Ω at frequencies above 20 Hz. Therefore, no further electrolytic caps between B+ and B- are needed. The ripple voltage at the B+ output is smaller than 1 mVRMS under full current load.

Figure 12 shows the schematic of the 300B filament supply. **Photo 6** shows the actual filament supply placed on Amplifier 5.

On the power transformer are two 6.3 V secondary windings. Per 300B, a winding is used and fed into the Tentlabs Direct Heated Filament Supply (DHFS)^[2]. The output is trimmed for 5 V and connected to the 300B filament. The positive (+) output shall be connected to the cathode resistors or to the 10 Ω grounding-resistor, as indicated in the amplifier schematics. The Tentlabs DHFS is silent and acts as a current source, preventing audio currents from entering the supply circuit. I am impressed by its silence and resulting clear sound. Remember: Each 300B has its own 6.3 V secondary winding and its own DHFS. There are no interconnections between the two independent 300B filament circuits.

The filament of the two ECC81 tubes in Amplifier 5 *cannot* be connected to the existing 6.3 V windings, because these winding are only meant for the 300B and should stay completely free of any other connection or use. Therefore, I applied a Meanwell AC/DC converter, which converts 90 to 230 VAC mains into a DC voltage of 15 V (see **Figure 13**).

Its output got a slow start circuit (no flash-on

in filaments) around MJE340 plus BC547. Some cooling is necessary for the MJE340 because the total heat is 0.6 A times (15 to 12.6) V = 1.44 W. The filament output is lifted to B1+/3 V to prevent too large voltages between filaments and cathodes of the ECC81. This circuit is also extremely silent and no influence on the amplifiers output is detected.

In Amplifier 3 and Amplifier 4 (described in Part 1 of this article series), an extra clean voltage V_n is applied to lift the B-supply 60 V above ground (see **Figure 14**). The 50 V winding on the power transformer is used.

In Amplifier 5, a simpler version of V_n is applied, called V_{neg} (see **Figure 15**). Photo 5 (the right side) shows how it actually looks on the amplifier. Negligible current is asked from this supply. That is why this circuit is very simple.

Never try to improve these circuits by means of Zener diode clamping or DC stabilization. If the mains voltage rises, so will B+ and so will the V_n or V_{neg} , thus compensating drift of the operation point through changes in V-mains.

Also note that in the V_n and V_{neg} supplies no surges have been used. These two supplies

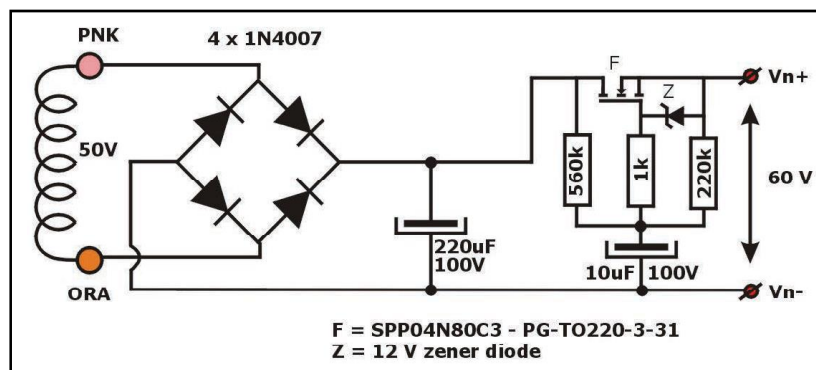


Figure 14: V_n = 60 V supply for Amplifier 3 and Amplifier 4 (detailed in the first part of the article). Place 1 k Ω very close to FET F.

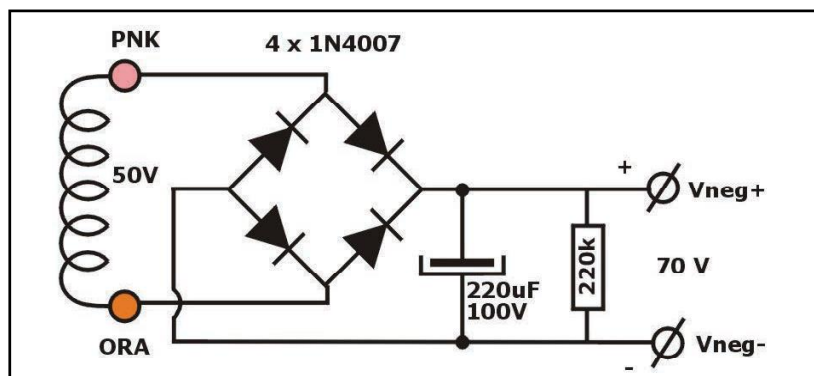


Figure 15: Amplifier 5 is shown with V_{neg} = -70 V supply.

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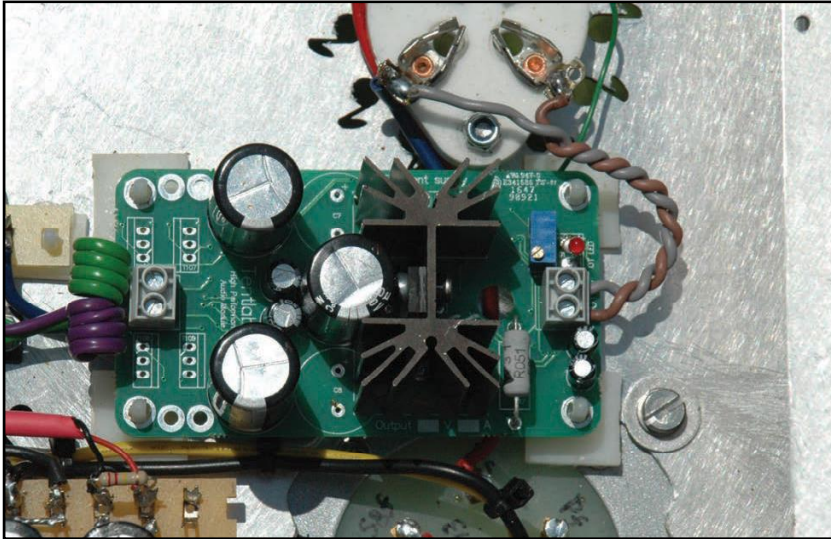


Photo 7: I used the Tentlabs filament supply for 300B.

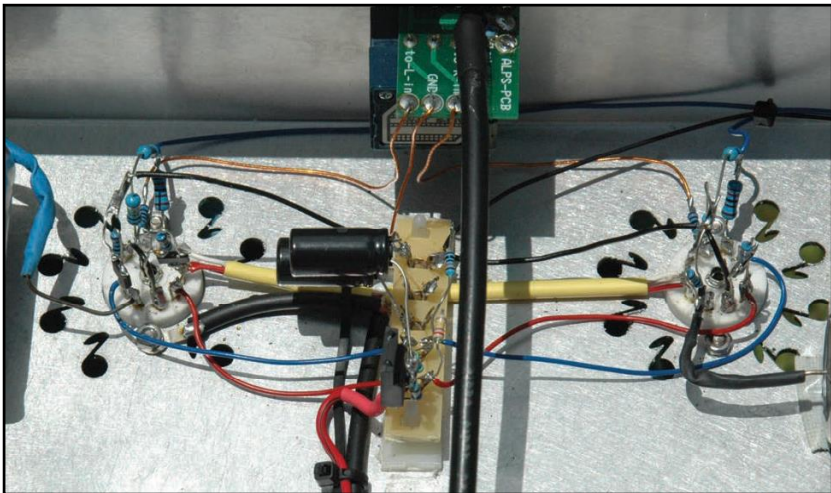


Photo 8: These are the ECC81 sections. The CCS circuits are very small, hardly visible, and mounted directly on the tube sockets.

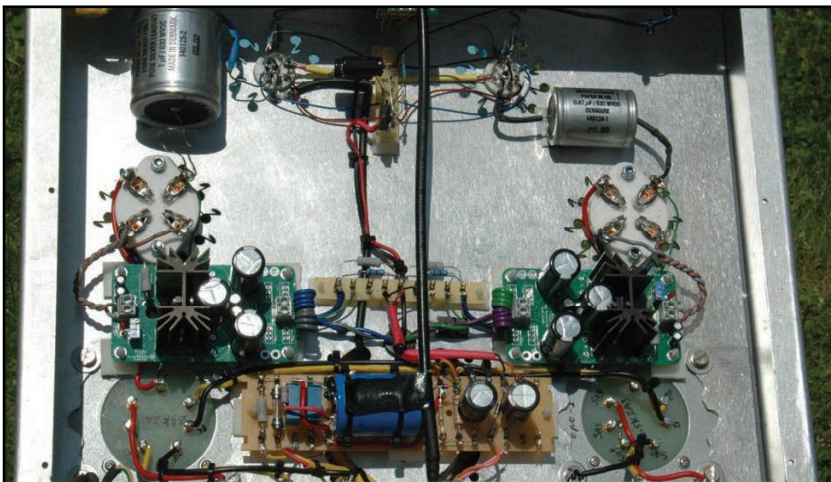


Photo 9: This is the overview of the inside of Amplifier 5. I used two extra-large Jensen silver in oil capacitors because I had them in stock. The prescribed $\mu 22/600$ V versions are smaller.

always should function, otherwise the 2A3 or the 300B valves will certainly see their life shortened because their anode currents will surpass the maximum limits due to the possible absence of V_n or V_{neg} .

Photos 7–9 give a conclusive general overview of Amplifier 5's construction.

Conclusions

Based on my long experience with push-pull valve amplifiers, plus the findings of this SE research, I would like to draw some conclusions.

If your goal is to hear as many details as possible, then the amplifier's THD should be as low as possible. You can apply massive overall negative feedback (Bruno Putzeys^[3]), or local feedback around the output tube (as in Amplifier 4), or massive local feedback (Frank Blöbbaum^[4]) or pre-distortion compensation (as in Amplifier 5 with $S1 = \text{closed}$). Knowing what the magnetic hysteresis in OPT-core does with the sound, I prefer local feedback in front of the OPT. Please don't include the OPT in the feedback path.

If you wish the music to embrace you, then THD may be present, especially the second harmonic, but details get lost.


The coupling capacitor's brand and construction are of the utmost importance to hear the embracing and details in a non-feedback design. Exactly the same can be said about the quality of the resistors and OPT-core material. For this research project, I did not proof it by my own measurements. In the literature, there is an abundance of the highest quality proof^[5,6] available to show low-level defects caused by components. The ear can detect them.

Designing a fine ("fine" is a subjective property) amplifier is an art. The general understanding is that (in SE amplifiers) local feedback or pre-distortion weakens the second harmonic and hardly the third. This research has proven that the third and higher can be attenuated as well, although not as much as the second. Peter Baxandall's research (discussed in Part 1 of this article series) shows the harmonics above 2 are the first to rise in level with the amount of feedback. However, that was measured on a JFET. In tube circuitry, apparently, things are a little different. It is not the first time that I notice the third and higher harmonics to decline directly with the amount of negative feedback.

There is a general opinion that the harmonics in a fine amplifier should decline regularly with their number. They all should stay under the masking curve of a constant tone. My research

does not support that rule. Lowering the second harmonic (as in Amplifier 4 and Amplifier 5) below the level of the third largely improves the hearing of details without effecting the embracing character of the sound. I surely agree that higher harmonics (above the third) should decline regularly. Personally, I consider the second harmonic to be a warm "curtain" creator.

More and more I give my tube amplifiers a damping factor below 10. Higher values by means of overall negative feedback give the amplifier a "flat" character. Then the sound stays close to the speakers and does not freely vibrate everywhere in the listening room.

Testing your amp at a 1 W level and below is a sensible thing to do. But please don't forget to measure the power bandwidth up to the highest frequencies to detect presence of slew rate limiting induced distortion. Full power bandwidth up to 20 kHz stays mandatory. 

Author's Note: Teaching students really is a joy. The greatest reward is to see the gladness in their

Resources

[1] Power transformer -T1

For Western Europe: <https://www.ringkertrafo.nl/shop/high-end-audio/voedingstrafo-s/719/4n1885-voedingstrafo-voor-buizenversterkers-103va.html>

For Nafta: Plitron 13474-X0-00, www.plitron.com

For Eastern Europe: Trafco 4T1885, www.trafco.rs

[2] TentLabs, <http://tentlabs.com/Components/Tubeamp/Tubefilament/index.html>

[3] Linear Audio, www.linearaudio.nl

[4] F. Blöbbaum, "Multiple Transconductance Amplifiers Part 1," *Linear Audio*, Volume 6; ISBN: 978-949092-9077, www.linearaudio.net

[5] B. Hofer (Audio Precision), "Master Class about Quality of Components," <https://youtu.be/HsPNGVwCrhw>

[6] J. Prymac, "Capacitor EDA models with Compensations for Frequency, Temperature and DC Bias," 2010 Capacitor and Resistor Technology Symposium (CARTS) Conference, March 2010.

[7] AudioMagic, www.audiomagic.nl

eyes. Many thanks to Peter van Willenswaard^[7] for proofreading this manuscript and sharing his valuable experience. My wife Annemieke made a fantastic lunch for every TubeSociety meeting—a real feast. And I want to praise my students, who constructed such high-quality amplifiers!



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