By A J van Doorn

Octode Amplifier

Can the pentode and triode live happily ever after in this new octo tube amp design?

Since the golden vacuum-valve age has come to an end, only triodes and pentodes are used for the construction of new valve amplifiers, all operating in accordance with the following modes: triode-ultra-linear-pentode. Along these lines, many engineers have designed and built the ultimate amplifier, only to discover a primarily new way of heating a room. Clearly, most new amps are just modern versions of those good old Telefunken 1960 amplifiers.

THREE MODES

At first all amplifiers were in *triode mode*. **Figure 1A** shows a PP (push-pull) triode stage. The balanced signal from the drivers modulates the triode, and the plate current variation powers the speaker. This system gives quite a good damping to the speakers, but the efficiency is low. A pair of EL34s, triode connected, will consume over 50W, but the output is only 16W, so the efficiency is about 30%.

The *pentode* is a current source with a high plate resistance. As you can see in **Fig. 1B**, here the screen grids are connected to the +HT supply. Without negative voltage feedback, this system gives no damping at all, but outputs much more power than the triode version. The same pair of EL34s in class AB delivers 35W, giving an efficiency of 70%.

Instead of connecting the screen grids to the plate or the +HT, some clever individual connected them to a tap on the primary winding of the OPT (output transformer), which resulted in the *UL mode* (**Fig. 1C**). As you can see on p. 4 of the 1957 GEC book *The Design of an Audio Frequency Amplifier*, sliding this tap from the center (0%) to the plate (100%) changes the pentode more and more into a triode. With this tap at 43%, the best results were obtained with respect to power output and distortion. Ever since,

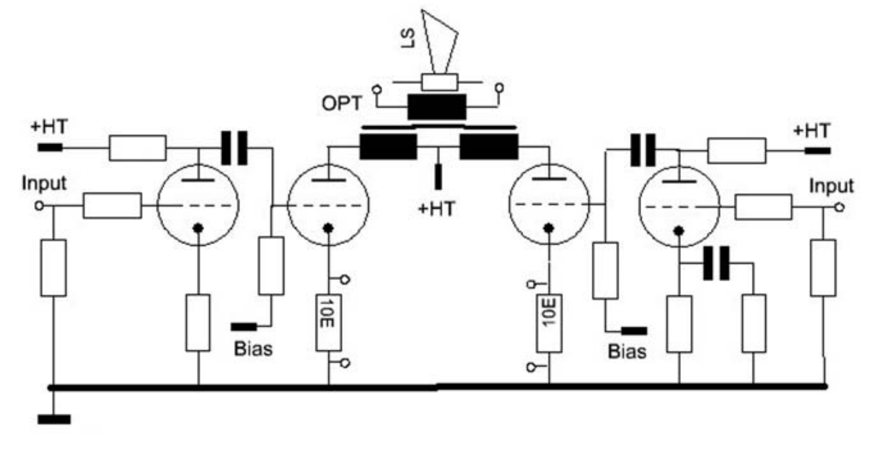

FIGURE 1A: Triode mode.

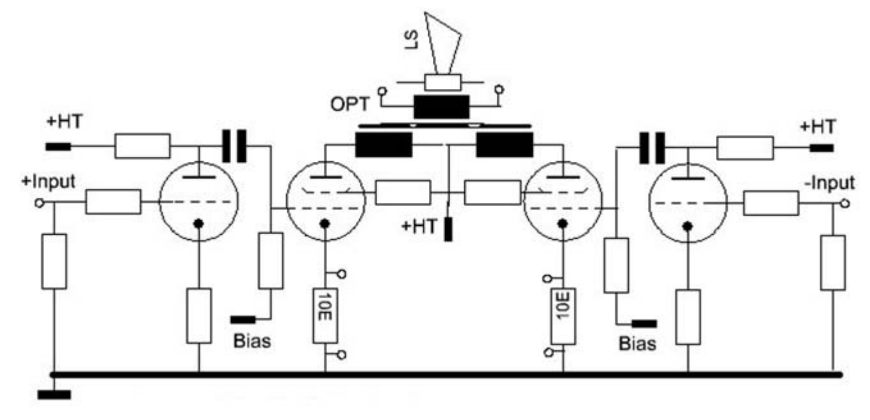

FIGURE 1B: Pentode mode.

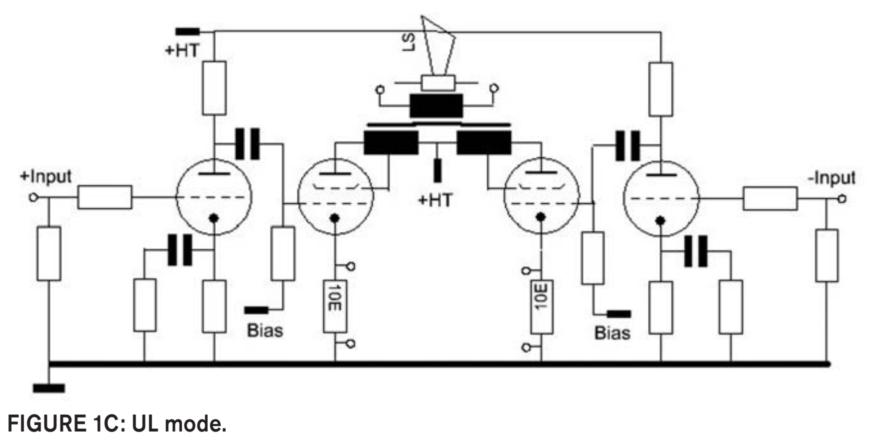

FIGURE 1C: UL mode.

PHOTO 1: Audio Aero SE monoblock. This big, heavy machine includes power supply (right) and the big triode 211 and tetrode 813 (left).

PHOTO 2: Stereo SE Octode amplifier. In front you see the 6L6 assisting pentodes. With a switch you can engage either the 300Bs or the triode-connected KT88s. For this kind of amplifier a special OPT was made by Tribute Audio (pieter@tribue-audio.nl).

no significant progress has been made in the development of valve amplifiers. You can copy this book from Pete Millet's website. However, unbeknownst to most people, there is another mode.

EXTENDED CLASS A MODE

In this mode a pair of power triodes shares the speaker load with a pair of pentodes, each one in parallel with a triode but in class B mode, combining the well-known advantages of both triode and pentode. Some of these amps may have been made in earlier times, but—perhaps for commercial reasons—amps working in the UL mode dominated, but now the only company that still makes these kinds of amplifiers is Audio Aero in Toulouse, France (audioaero.com). They make a beautiful 40W SE amp with a 211 triode and a 813 tetrode, and a 60W P-P amp with a pair of EL34 triodes assisted by KT88 pentodes. Believe me, all these amps sound extremely well.

Many people may think that the characteristics of triode and pentode are mutually exclusive, but if you do it correctly the Ext-A mode works very well. The triode in class A addresses musicality and damping, while the pentode in class B delivers the extra power and increases the system speed.

Figure 1D shows the basic operation of the Ext "A" mode. Here the triode requires the full input signal, while the pentode gets only part of it, which should give the right amount of assistance to the class A working triode. Too much power from the pentode will overmodulate the plate voltage and consequently cut the top of the triode plate current, leading to a lot of distortion. Because both triode and pentode share a part of the plate load, each one will see a higher plate impedance than the nominal impedance of the OPT.

If the pentode gives twice the triode power and the OPT has an impedance of 3200Ω, then the triode sees a plate load of 3 × 3200 = 9600Ω, and the pentode a load of 3/2 × 3200 = 4800Ω. With this high plate load, the triode always works in class A, giving a low distortion, reasonable damping, and a moderate power output. When idling, there is a power consumption of (2 × 26) + (2 × 10) = 72W, and with an output of 50W it increases to about 110W. However, it would be nice if the pentodes also contributed to a low plate resistance of the system. In the Ext A mode, the triode and pentode may seem to be a happy couple, but they aren't really married. I solved this problem with the following system.

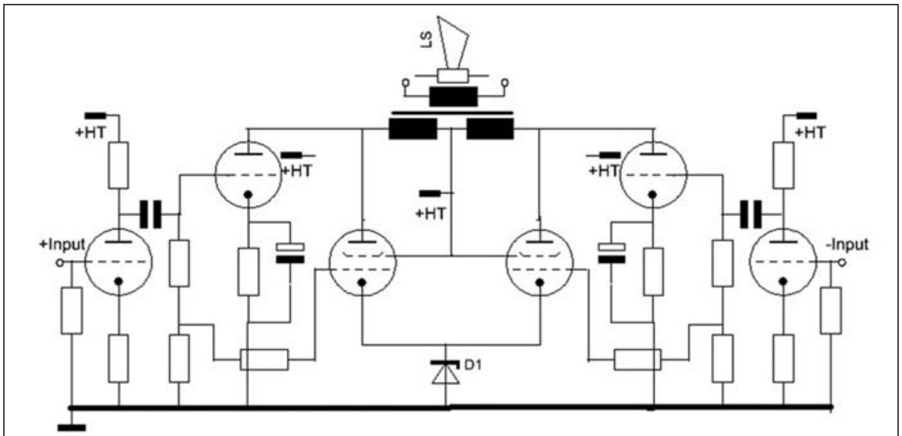

FIGURE 1D: Extended A mode.

OCTODE MODE

Here the triode and pentode act like one big triode, but with eight electrodes, I call it octode mode. **Figure 1E** shows how it works. As usual, the input signal modulates the triode. The current of the triode is monitored by a small resistor in its cathode lead and amplified by a triode, which works as an I/V converter giving an input signal to the pentode that is a perfect copy of the triode current.

So the pentode delivers the same, but higher, plate current as the triode to the OPT. But beware of the phase; otherwise, a powerful oscillator will occur. By varying the signal to the pentode, you can control the amount of assistance the triode gets. Without a signal on the pentode, the triode will work in class AB, because the plate load of the OPT is relatively low.

Increasing the signal to the pentode increases the output as well. However, at

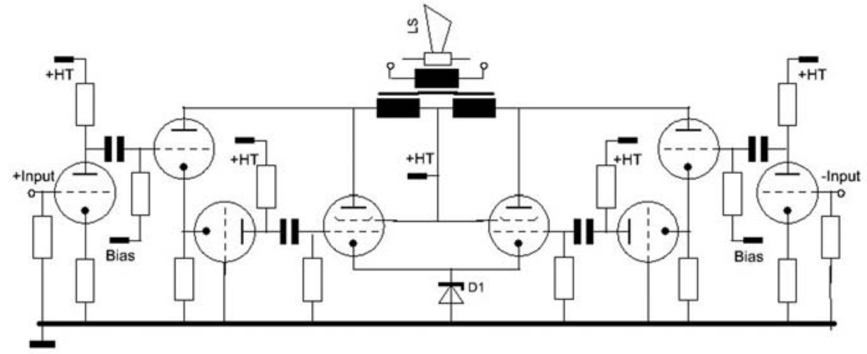

FIGURE 1E: Octode mode principle.

a certain level the triode current variation will decrease, but this isn't a problem. The triode may deliver a little less power, but the system damping will be very good. In general the pentodes output two to three times the triode power. Less pentode assistance means less power but more of a triode sound. More assistance means more power and damping and a little more pentode sound.

The main advantage of this system is that without any negative feedback there isn't any crossover distortion but a very high damping of the speaker. Because any current variation of the triode is amplified by the pentode, the plate resistance is very low as well. Say the plate resistance of the triode is 900Ω and the total current variation is three times the current of the triode, then the plate resistance will only be a mere 300Ω.

DAMPING

So the combination of pentode slaved to the triode current leads to a large total current variation, consequently giving a rather low plate resistance and very good damping to the speakers. The couple works as a big single triode system but with far less power consumption than a multiple triode amplifier. This is quite like a happily married couple: the pentode is the spouse who is doing the hard work, while the other spouse (triode) keeps all well under control.

Regarding damping, the voice coil of the speaker has a rather high DC resistance, mostly about 50% of its nominal impedance. Even with an amplifier with zero output impedance, this resistor will always be in the speaker line.

I don't know why I so seldom heard a proper sound out of these famous high power, zero distortion, zero impedance amps. My son has Sonus Faber speakers connected to all kinds of good amplifiers, from hybrid to MOSFET to tube. Now he has two Octode mode 60W monoblocks that I made for him, and he'll never give them back.

The guy that delivered a SACD to him could not believe his ears. After installing the Cambridge SACD player, he was very impressed and wondered how all this fantastic sound came from a valved amplifier.

The octode mode amplifier is nothing more than a class A triode amplifier assisted by a class B pentode amplifier sharing a common OPT (output transformer). A PP (push-pull) triode amplifier has a low efficiency and, even with the moderate power output, it still works in class AB. For example, two EL34s consume 54W, outputting 16W. The plate load is 5000Ω, and the output impedance is 3500Ω.

Consuming 80W, a pair of KT88s will output 30W with a plate load of 4kΩ and an output impedance of 2500Ω. Without the use of feedback, none of these have good speaker-damping.

In the octode mode the two triodes are assisted by a pair of pentodes, not only to increase the power output, but also to lower the output impedance. Say the OPT has a primary impedance of 3200Ω and the primary AC current is 100mA; then the primary AC voltage is 320V, giving a power output of 32W. With 10W output the triode stays in class A mode with a plate current of 32mA AC, so the pentodes must deliver 100 - 32 = 68mA AC. This means that the plate load seen by the triodes is 10kΩ, and 4700Ω for the pentodes.

Being in class B, the peak plate current in the pentode is then below 200mA—no problem for a valve such as the 6L6. However, due to the assistance of the pentodes, the output impedance of the amplifier drops to 10/32 × 3500 = 1100Ω. Measured on the 8Ω secondary, this means an inner resistance of 1100/3200 × 8 = 2.7Ω. If the DC coil resistance of the loudspeaker is 5.3Ω, then the total DC resistance in the speaker line is 8Ω and the amp will act as a constant power source.

With a primary voltage of 320V AC, the plate voltage swings ±230V, and because the minimum plate voltage the EL34 needs is 150V, the high voltage under full load must be at least 380V DC. **Figure 2** shows the schematics of the amplifier, with its bias circuit plus a block diagram of the different stages.

STAGE 1

The first stage is a voltage amplifier with a 6922 double triode. Resistor R2 sets the input impedance to 47K, but you can change this value. The grid stopper R1 prevents oscillations and Rf signals from entering the amplifier.

Helped by the Miller-effect, the triode forms such an efficient high-pass filter that resistor R3 and capacitor C1 were needed to compensate for the loss in treble. The valve amplifies the input signal about 18× (25dB). The next valve

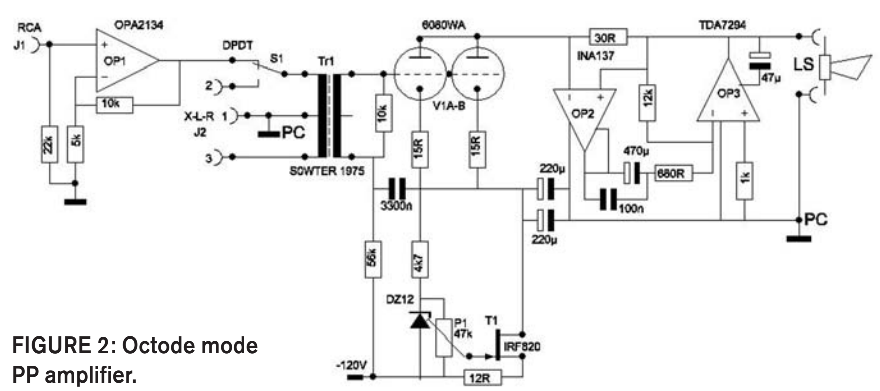

FIGURE 2: Octode mode PP amplifier.

is just a zero gain phase splitter, coupled by the capacitors C2 and C3 to the next stage. . .

STAGE 2

Resistors R10 and R11 are grid 1 stoppers, and resistors R12 and R13 are the bleeders, connected to the negative bias circuit. The EL34s are triode connected, and resistors R15 and R16 connect the screen grids to the plates, which, in turn, are connected to the OPT primary. Resistors R8 and R9 connect the cathodes of the EL34s to ground, serving as plate current sensors and sending a current reference signal to the next stage. . .

STAGE 3

The third stage acts as an I/V converter. The AC signals from R8 and R9, being an exact copy of the plate current modulation of the EL34s, are amplified 25× (28dB) by the 6922 triodes and, via capacitors C4 and C6, sent to grid 1 of the pentodes in the next stage. . .

STAGE 4

Here R20 and R23 are the grid stoppers for the 6L6s, which are biased by the bleeders R19 and R22. The cathodes of the 6L6s are grounded by resistors R21 and R24 (12Ω), so the DC current of the pentodes can be set by measuring the voltage drop; 240mV is a plate current of 20mA in each pentode. The screen grids of the 6L6 pentodes are connected to the +HT by resistors R25 and 26.

The plates of the 6L6s are also connected to the primary of the OPT. Note that because V5-6 invert the phase of the signals coming from the EL34s, the plate connections of the 6L6 pentodes must be reversed as well. If you do it incorrectly, a powerful AC generator and maybe a damaged tweeter will be the outcome. I had quite good OPTs on hand but for this amplifier I ordered two OPTs from Peter of Tribute-Audio, surely the best you can get.

BIAS CIRCUIT

The -44V bias voltage comes from a single rectified 30V AC, and the 12V zener D3 drops it to -32V, which is about the maximum you need to set the 6L6s in class B. The 12V zener D2 again lowers the bias to -20V to set the plate current of the EL34 triodes. In general, when the mains voltage varies, the plate current of V3+4 and V7+8 will vary accordingly, but this current variation is partly compensated by the change in the bias voltage. But there is still quite a high change in plate current left. In this bias system, a change in the mains voltage (hence the plate voltage) of 10% will vary the bias voltage 20%, leading to an almost stable plate current.

WIRING

Figure 3 shows the wiring of one channel of the octode amplifier. From left to right, you see stages 1, 2, 3, and 4. Using a pair of three-terminal boards will allow you to connect all parts to these TBs and the valve sockets. Use twisted wire pairs for the filaments (F).

As mentioned above, double-check the wires going to the OPT. This amplifier may look a bit complicated, but is quite easy to make if you view it as two different PP amplifiers on a single chassis. I suppose that for people making such an amplifier, there's no need to describe for maybe the thousandth time how to make a proper power supply. Just be sure that it delivers a HT (+Hv or plate voltage) of about 380V DC with a no-load current of 200mA and a full-load current of 350mA per channel.

The high voltage power supply I use myself is a bit smaller, but this only drops the maximum power out, not the performance. As you know, the filaments will at 6.3V AC consume about 2× (1.6 + 0.9 + 0.6) = 6.2A. If hum is a problem, make a center tap on the 6.3V with two 220Ω resistors and connect this center to a small positive voltage.

STARTING UP

Putting this amplifier into operation is easy if you start up without the power valves in place and use a Variac to gently increase the incoming mains voltage. Be sure that both filament and bias voltages are OK. To limit the no-load plate voltage, don't turn the Variac all the way up. Check the input stage with the phase splitter for proper operation. Set all the bias voltages to their maximum negative value. Now insert the two EL34s and watch the plate currents.

After warming up the amp a bit, adjust the mains voltage and then the negative bias voltage for 2000mV DC on the cathodes, giving a plate current of 75mA. Connect an 8Ω load to the 8Ω tap of the OPT. Hook up your generator and adjust the output to 4V AC (2W).

Now the I/V converter should get a signal of about 400mV from the cathodes of the EL34s and amplify it to a signal of about 10V AC on the grids of the 6L6s (not in place). Remove the 8Ω load and note the increase of the output voltage. I measured 7.3V AC so the triode-only output impedance is (7.3 - 4) × 2 = 6.6Ω. Disconnect the mains, switch off the generator, and insert the 6L6 pentodes.

Power up and adjust the pentode plate currents to 20mA that is 240mV DC at the resistors R21 + R24. Reconnect the 8Ω ballast and adjust the input output for an output of 4V AC; remove the 8Ω ballast to check the no-load output volt-

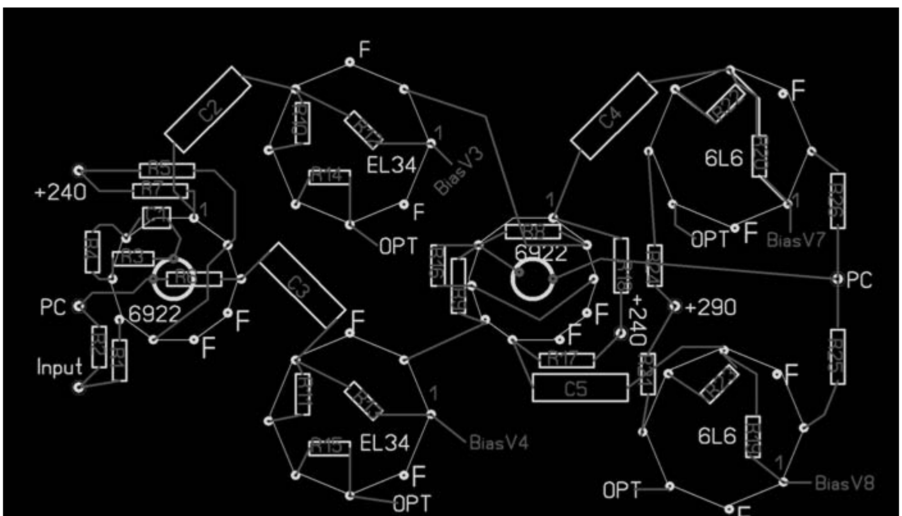

FIGURE 3: Wiring octode amplifier.

CONTRIBUTORS

Neville Roberts ("New Approach to Tube Design," p. 6), a graduate in Physics from the University of Bath, is a Chartered Scientist, Chartered Engineer, Chartered Physicist, and a Fellow of the IEE (now the Institution of Engineering and Technology). He joined the UK National Health Service (NHS) in 1992 having held various positions in the fields of science, electronic engineering, and information technology both in the Ministry of Defence and in the private sector. He is currently the Director of Information Technology for NHS Somerset. Neville has also been involved in the design of high fidelity audio equipment since 1975 and has been a freelance journalist since 2001 writing technical articles and equipment reviews, mainly for a UK Hi-Fi magazine.

Jan Didden ("The Essex Echo: Audio According to Hawksford, Pt. 1," p. 12) built his first OTL amp with 807 tubes 35 years ago. He has built speakers, preamps, and tape recorders, but is most interested in power amps, especially using error correction as discussed by Hawksford. Many of his projects have been published by *audioXpress*. Now retired from a career with the Netherlands Airforce and NATO, he tries to complete all those half-finished projects accumulated for lack of time. He now also has the time to travel to interesting audio events and interview audio luminaries. His projects are documented on his Linear Audio website.

Ed Simon ("Distortion Meter," p. 22) received his B.S.E.E. at Carnegie-Mellon University. He has installed over 500 sound systems at venues including Jacob's Field, Cleveland, Ohio; MCI Center, Washington D.C.; Museum of Modern Art Restaurants, New York; The Coliseum, Nashville, Tenn.; The Forum, Los Angeles; Fisher Cats Stadium, Manchester, N.H.

AJ van Doorn ("Octode Amplifier," p. 30) resides in The Netherlands.

Greg Koster (Review of Guru QM10 Speakers, p. 36) has written reviews for *The $ensible Sound*.

James Frane (Review: Lipinski L-707 Loudspeaker, p. 39) has written for *The Audiophile Voice* from at least 2002 to present, as well as *The $ensible Sound*.

PHOTO 3: PP octode amp under construction. In the center are the triode-connected EL34s and the 6L6 pentodes to the right and left.

age again. I measured 5.4V AC, which means that the output impedance has dropped to $(5.4 - 4) \times 2 = 2.8\Omega$. This is close to the estimated values, but can vary due to losses in the OPT.

MEASUREMENTS

The plate dissipation of the EL34s is well below their maximum of 30W, and for the 6L6s it's under 10W, so a long tube life can be expected—this is especially important with the new valves coming from the Eastern countries. I measured the distortion with a 4V AC output and found 0.08% 2nd and 0.01% 3rd harmonics for this octode mode amplifier.

Concerning the bandwith I measured the following with respect to a 1kHz signal:

20Hz	-0.9dB	50Hz	-0.3dB
2kHz	0.0dB	20kHz	-0.1dB
40kHz	–0.3dB	60kHz	-1.0dB

aX

COMPONENT LIST

C1	= 15n
C2-5	= 1µF-Kimber 400V DC
C6, C7	= 220µ-elco 63V DC
D1, D2	= 12V zener
D3	= 1N4002
P1-4	= 10k
R1	= 1k
R3	= 1k2
R4	= 4k7
R5	= 82k 1W
R6, R7	= 27k 1W
R8, R9	= 27E
R10, R11	= 1k
R12, R13	= 270k
R14, R15, R25, R26	= 220E
R16	= 1k8
R17, R18	= 68k 1W
R19, R22	= 330k
R20, R23	= 1k
R21, R24	= 12E
R27	= 3k3
R29	= 47k
V1, V2, V5, V6	= 6922
V3, V4	= EL34
V7, V8	= 6V6
OPT Tribute Audio	40W
Prim: 3200Ω sec :8Ω	

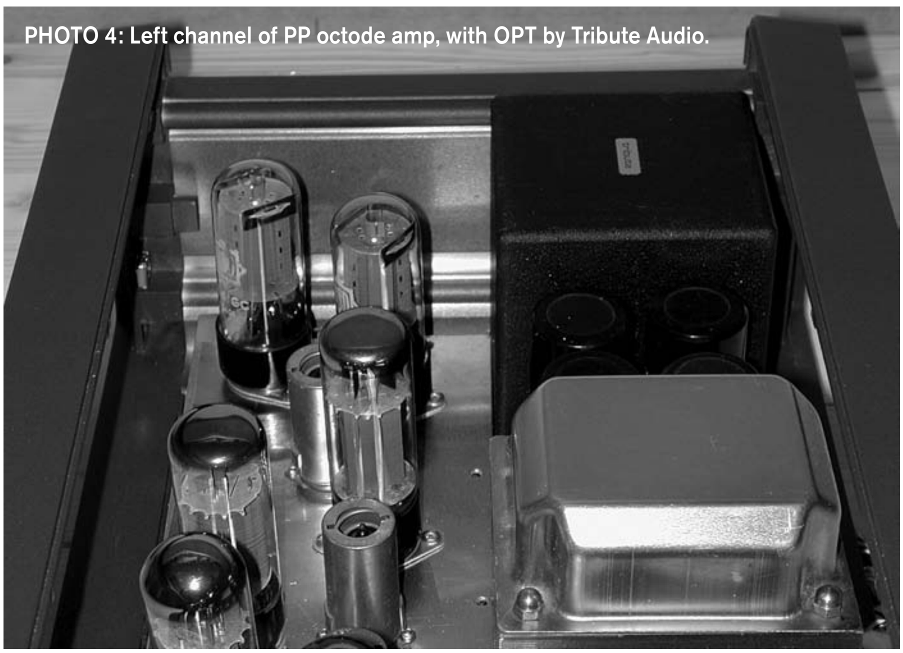

PHOTO 4: Left channel of PP octode amp, with OPT by Tribute Audio.