GLASS AUDIO

6336-A-BASED ALL TRIODE P.P. AMP

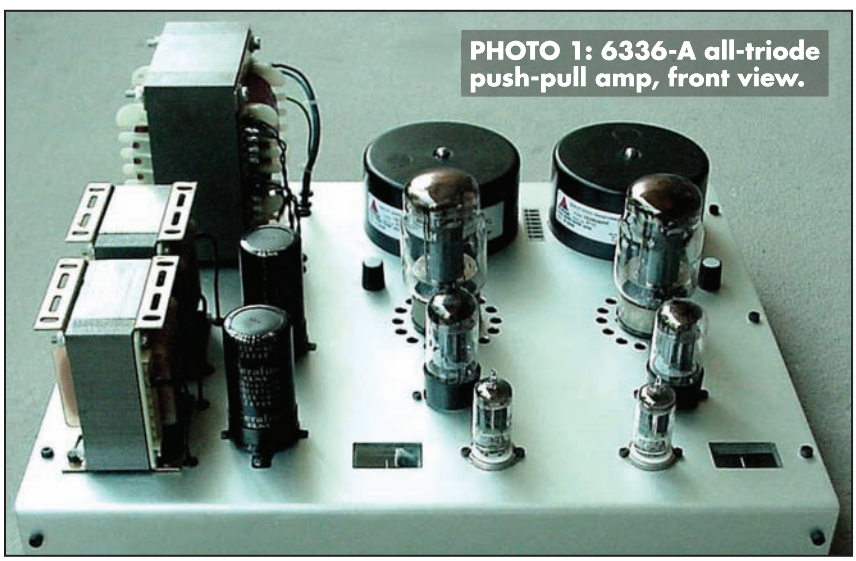

PHOTO 1: 6336-A all-triode push-pull amp, front view.

This amp design features the 6336-A power triode tube, along with push-pull class A operation, no overall feedback, low distortion, approximately 20W of output power, reliability, and high-performance sound.

BY KEES HEUVELMAN & WIM DE HAAN

One of my favorite small signal tubes is the 5687, which I have used in several designs with very good results. Its specs are outstanding and the sound is therefore really musical. The result can be a very dynamic and evolving/bold sound.

I generally use the 5687 made by General Electric, but I have also used the Philips/ECG with success. In previous applications I used a very basic grounded cathode circuit with standard values—Ra=15K and Rk=680E—and with a decoupled cathode resistor. I achieved the best results with the two systems in parallel. The 5687 tube is an easy-to-use medium-gain tube with a very low Rp. Moreover, it's low-priced and easy obtainable.

INPUT STAGE

In this design (*Photos 1* and *2*) I wished to use a different circuit as input stage. Some time ago I ordered the Tube Cad Circuit simulation program and played with it on many occasions. This tool provides many interesting details, including circuits, one of which is the so-called current sourced grounded cathode amplifier. In this circuit the plate resistor is replaced with a triode-based current source, which results in more gain and better PSRR.

According to Tube Cad, each triode exhibits a certain amount of transconductance, which is the degree to which the flow of current through the device changes as a response to a change in grid voltage relative to the cathode. By dividing the idle current by the transconductance, an input overload voltage results (Vth). If this Vth voltage is exceeded in a negatively charged way relative to the cathode voltage, the tube stops conducting any current. This voltage serves as a rough figure of merit for a tube circuit, as the higher the value, usually the better the sound. Because this Vth is much higher than in my standard grounded cathode circuit, I chose this circuit. The basic idea for the circuit is shown in *Fig. 1*.

In other applications I noticed that a mu-follower (looks quite similar to

the used circuit) with the signal taken from bottom triode anode sounded surprisingly better than if taken from the cathode of the upper triode—this was confirmed by several other hobbyists. The relatively high output impedance of the circuit is less important, because the following driver stage will have a high input-impedance.

Throughout this amplifier, I used WIMA FKP caps as coupling capacitors. These low-priced capacitors give very good sonic results. Feel free to use more "dedicated" audio capacitors such as Hovland, MIT, or Jensen, which I've used before, but this time I stayed with the FKPs.

PHASE SPLITTER

I chose a long-tail circuit as phase splitter/driver stage. This widely used circuit yields fair gain and fair balance—it is perfect for the job. In this application I chose the 6SN7 in a configuration with a current source, which I built around a small transistor with LEDs as voltage reference and added a potentiometer P2 to adjust the circuit for current and for minimal distortion. I used an additional potentiometer P1 to adjust the AC symmetry/balance of the long tail.

In the original concept the current source was intended to be connected to a negative voltage. However, to keep things simple, and because of good results with the prototype, I built the final amplifier without using this option. Reference voltage is taken from the main high-voltage supply using a simple resistor.

The 5687 input circuit and the 6SN7-based phase splitter yield enough gain to make the overall circuit work without overall feedback. Because of the relatively low gain, feedback is not possible using this configuration, though one of the design goals was no use of overall feedback. Overall gain/sensitivity of the design is about 20dB, which is a good figure.

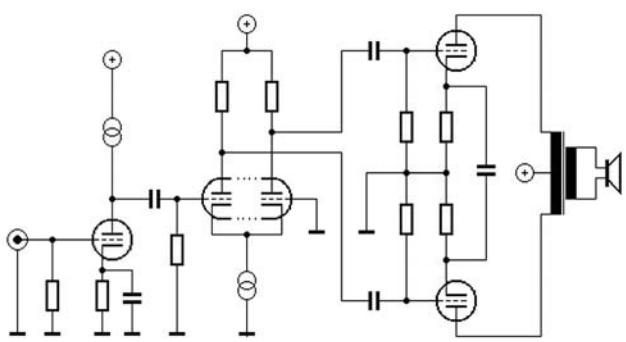

FIGURE 1: Basic circuit of the 6336-A based amplifier.

OUTPUT STAGE

In searching for the perfect output tube, I discovered that initially the choice was more difficult than expected. The transmitter tubes are not my choice; I consider the very high voltages a problem. The 300B tube is out-of-budget, and, for example, a 50C-A10 is expensive and rare. The 6AS7/6080 is an option. However, after listening to a 6336-A-based amplifier and knowing that I had several of them somewhere in a shoebox, I made my choice just like that.

The 6336-A tube is intended for power supply use and contains two separate triode systems (***Fig. 2***). Mu is as low as 2 and power consumption is as high as 5A at 6.3V; maximum plate dissipation is 30W. Because plate resistance is very low, the 6336-A tube can be used in output transformerless (OTL) circuits. Another choice is the 6528, which is very similar to the 6336-A, but mu is 9. This would make it easier to drive, though this tube is very rare. Strangely enough, not too many circuits can be found using the 6336-A—not on the net, in magazines, or other publications. However, I know that Luxman designed a push-pull amplifier (the KMQ80) using the 6336-A; unfortunately I was unable to obtain a copy of the circuit diagram.

I used the 6336-A in full class-A using cathode bias. It would work perfectly well with low primary impedance to yield high output power; however, my goal was for a high 8k load for low-distortion figures with less output power. Output power is less important.

Because output transformers are sensitive to DC unbalance, I added a small meter and a variable resistor to

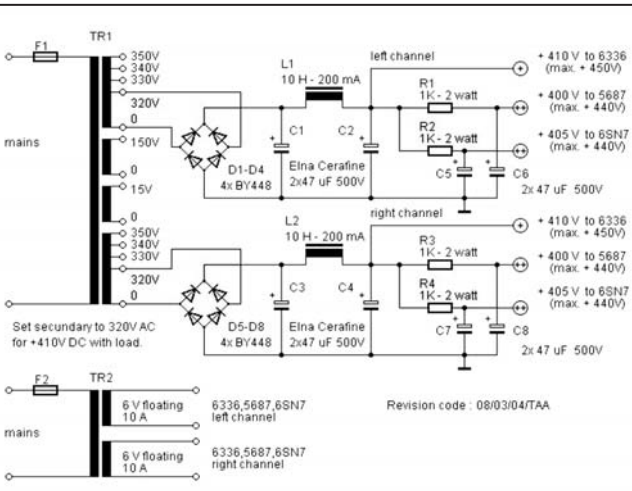

FIGURE 2: Power supply 6336 amplifier for two channels.

PHOTO 2: 6336-A all-triode push-pull amp, top view.

the cathode circuit to solve this problem. Selecting the 6336-A for balance would be impossible to do. This circuit is optimized for toroidal output transformers, such as those manufactured by Amplimo/Plitron.

Due to the high transconductance, cathode bias is the only option. Negative bias will not give the 6336-A the stability it needs. In my attempts to use negative bias, I had no good results. With cathode bias, the 6336-A worked without problems and stability was excellent.

You must take special care with the cathode resistors of the 6336-A. The high bias voltage and current will produce enormous heat; each resistor will need to dissipate more than 7W. Because of the class-A operation, the 6336-A becomes really hot, so preheating the tube for some minutes before switching the main high-voltage is necessary.

BIASING THE 6336-A

In the original concept, the 6336-A was intended to dissipate around 25W. Using the tube's Chatham datasheet, I selected a 1450Ω resistor for biasing the 6336-A, thus using an effective anode voltage of 335V (power supply, cathode bias). In this case, bias voltage would be around 114V; bias current would be approximately 70–80mA.

The prototype used two 680Ω resistors in series as cathode resistors; balancing was done with a tandem 100Ω potentiometer (***Fig. 3***). Because these are hard to find, I chose the configuration as drawn in the final circuit (***Fig. 4***).

In the final design, the mains transformer has an option for four secondary windings: 320V, 330V, 340V, and 350V. I set the high voltage using the 320V winding, yielding a +410V DC voltage with all loads attached. The amplifier worked very well and beyond all expectations. Bias voltage is around 100V, giving a 70mA bias current per triode.

Because of the high bias voltage and current, the bias resistors dissipate a serious amount of heat. Beware of this! In ***Photo 3*** and ***Fig. 5*** you can see how to "implant" the 25W resistors. The 2mm aluminum main chassis is used as a heatsink; the eight 25W resistors are mounted on an aluminum u-bar that is affixed to the chassis. Airflow should be more than adequate; but you might consider installing a small fan just to keep the air flowing. I chose

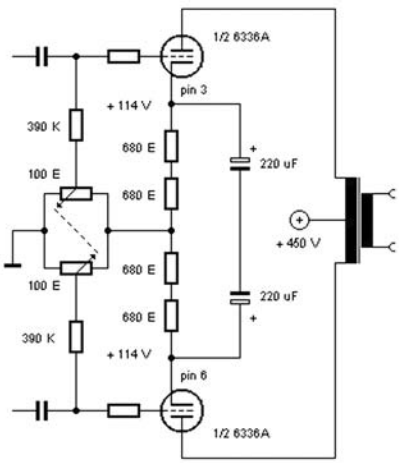

FIGURE 3: Alternative output circuit 6336-A using a tandem 100Ω potentiometer.

the 25W rating to give the amplifier its reliability; 12W resistors would work fine in this case, though these heat-sinked 25W resistors are bulletproof (***Photo 4***).

Some readers may wonder about the connection of the cathode bypass capacitors of the 6336-A tube. The configuration acts like a push-pull stage with one common cathode resistor without bypass. The two separate cathode resistors provide DC stability for the 6336-A. Its DC performance is very stable and therefore very reliable.

The 6336-A has relatively high distortion figures. Using a high load impedance and with bypass capacitors as shown in the circuit, the 6336-A shows very low distortion figures (0.12% at 1W/1kHz). The bypass capacitors are used for AC coupling. I found distortion to be lower than if each cathode resistor had its own capacitor directly connected to ground. You notice this clearly when the amp is driven into its limits.

OPTIONAL DRIVER STAGE

The 6336-A tube turns out to be a difficult load for the long-tail circuit. Measuring the prototype, I encountered a high rolloff at 70kHz. The output transformer specs show something different, so the circuit must be the limiting factor. The toroidal transformer shows a high cutoff response of 130kHz. With an additional driver stage—a cathode follower using a 6SN7—the amplifier measured up to as high as 130kHz (–3dB). I located the cause and solved the problem. However, I built the final amplifier without use of this circuit. I chose simplicity instead. The final amplifier measures up to 70kHz, which is still a very good figure.

OUTPUT TRANSFORMER

In previous projects I used Hammond and Audio Note transformers, both with good results; though in this project I chose a toroidal output transformer made by Amplimo—the VDV 8020. The primary impedance of this toroidal transformer is 8kΩ and is intended for EL84 push-pull use. Frequency response is exceptional with –3dB points at 2Hz and 134kHz; power rating is 20W.

This good performance is due to an extremely high coupling factor, very low leakage inductances, low internal capacitances, and no conflicting resonances below 100kHz. This is achieved through the use of multi-sectioned windings together with special combinations of series and parallel connections. The multi-segment secondary winding has a 5Ω impedance, suitable for both 4 and 8Ω loudspeakers.

In 1993, Amplimo (the Netherlands) was the first company to supply toroidal output transformers with a quality factor (synonymous with frequency range) greater than 290,000. Plitron distributes these toroidal transformers in the US and Canada. An alternative transformer is the Hammond 1650 F (7K6/25W), which is a great value for your money.

ADJUSTMENTS

The sections of the 6SN7 used in the long tail are not equal, so I added P1, which should be adjusted in such a way that the AC voltages of the two

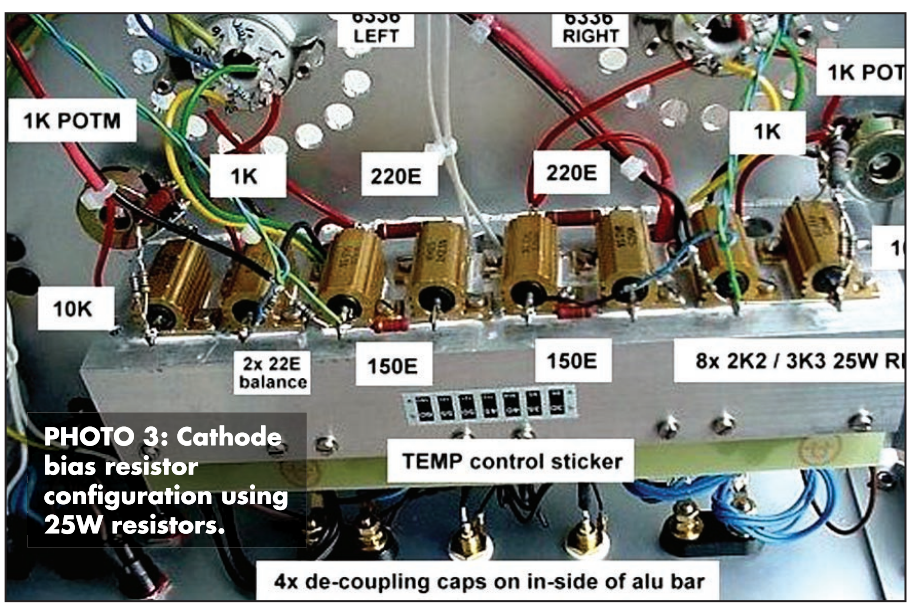

PHOTO 3: Cathode bias resistor configuration using 25W resistors.

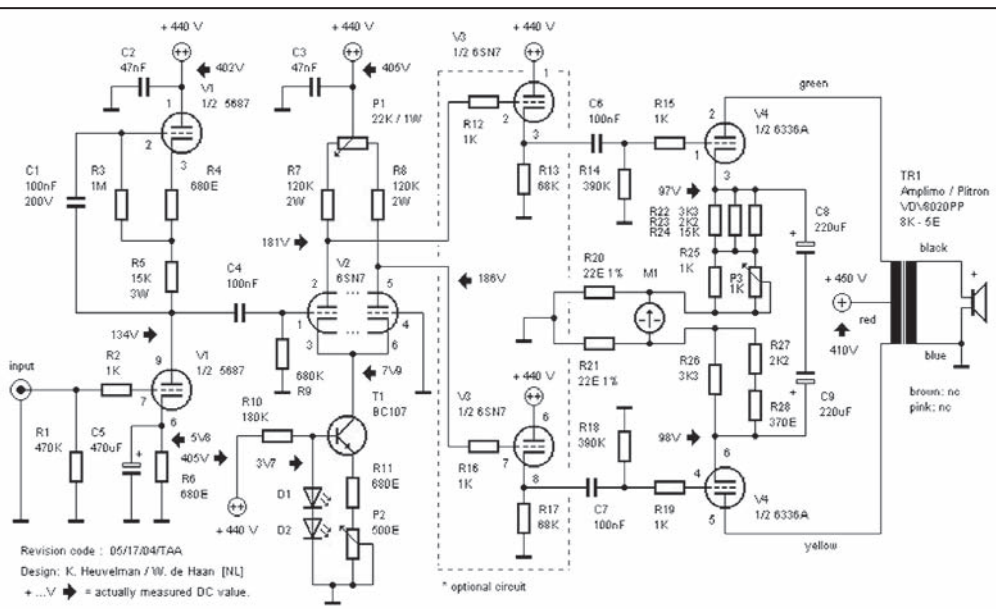

FIGURE 4: Complete circuit 6336-A based push-pull amplifier.

anodes of the 6SN7 systems are equal. You might attach a 1kHz test signal to the input of the amp and measure the anodes for AC voltage. If not, turn P1 to the point where the voltages are equal. This completes the adjustment.

The current source of the long tail is set by P2. You should adjust it in such a way that voltage measured at the cathodes of the 6SN7 is approximately +8V (this will rise to approximately 9.6V at +450V PSU). If you can obtain a distortion analyzer, try to adjust the output distortion to a minimum, again, using P2.

The DC unbalance in the output stage should be adjustable, because selecting the 6336-A for balance would be impossible to do. I added P3 and adjusted it so that the meter M1 is exactly in the middle. Voltage across the meter is zero, because the measured voltages across resistor R20 and R21 are equal. So current through one-half of the 6336-A is equal to the other. With some output transformers, this unbalance is not as important; however, toroidal output transformers are very sensitive for this DC unbalance. With the circuit as shown, unbalance can be less than 1mA.

I used a low-cost analog tuning device, which is intended for "tuning" FM tuners (***Photo 5***). Sensitivity should be 50 or 100µA, so adjustment is done easily in this way. R20 and R21 should be ±1% or better.

Trying several 6336-A tubes, I noticed that the RCA and Tung Sol yielded low distortion and high output. The Cetron measures worse. The Raytheon is adequate if the cathode de-coupling capacitors are connected as shown in ***Fig. 5***.

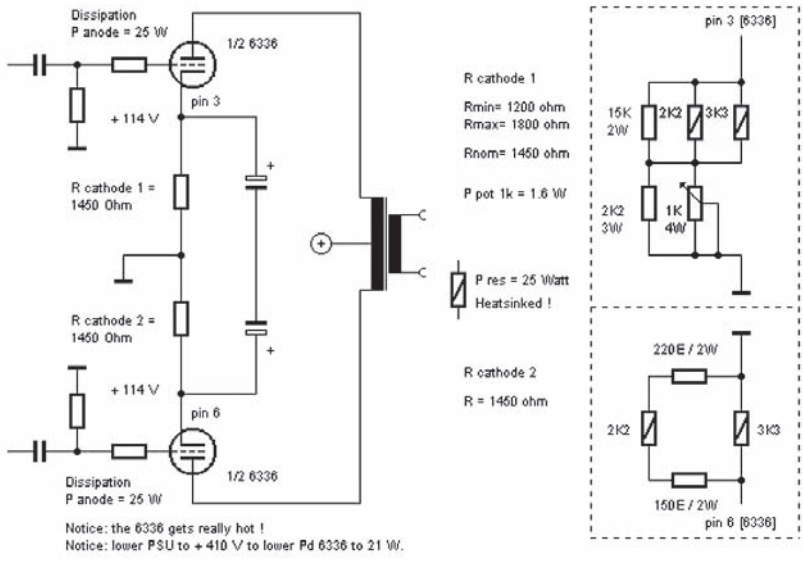

FIGURE 5: Output stage 6336-A.

SPECIFICATIONS

0.07% distortion at 1W/1kHz.
17W into 5Ω at 1% distortion.

F (–3dB) = 2Hz – 70kHz; with additional 6SN7 cathode follower circuit up to 130kHz.

All measurements using a Tung Sol 6336-A output tube, circuit set to +450V DC.

POWER SUPPLY SUGGESTION

The high-voltage supply is straightforward, with no particular precautions to consider (Fig. 2). However, heater supply should be left floating or should be related to +150V; otherwise, the 5687 heater-to-cathode voltage will exceed its maximum value. This applies also to the 6SN7 as used in the optional cathode follower. Another option is connecting the secondary winding with a capacitor to ground. Be careful with the 5687 and the 6336-A, which draw together almost 6A of heater current.

The final amplifier uses a custom-made power transformer with several secondary windings; however, DC voltage should not exceed +450V. If so, capacitors C1 and C2 will become overloaded and the 6336-A will be pushed to its limits or, even worse, exceed its maximum rating. During power-up the tubes are not conducting yet, so high voltage during this period could exceed the maximum rating of the capacitors. Please be aware of this. Pre-heating the tubes for several minutes should be mandatory (especially the output tubes), and in this case powering-up should be no problem using the 500V-rated capacitors.

A FINAL WORD

The amplifier shows very low distortion figures, but the drawback is the amount of heat and low efficiency. This design is not too complicated nor too difficult to build, though you need to pay attention to details—for example, the bias resistors, because heat circulates around the 6336-A output tubes. This amplifier is very reliable; it's worked for over eight months without any problems or additional adjustments.

The sound is very open and sound stage is extremely good. Bass is outstanding—dry, punchy, bold, and very precise. Amazingly enough it combines very well with my DIY low sensitivity, low impedance Dynaudio speakers (a Dynaudio Craft look-a-like). Keith Jarrett's *At the Blue Note* is reproduced in an excellent and astonishing way; drums, bass, and piano are so alive. Barry White's opening track from the *Staying Power* CD sounds even more involving.

Tuck & Patty's "Friends in High Places" from *Dream* is a difficult task for many systems, though it is reproduced in a way you like it to be. Music is really dynamic—no stress. You forget all about the electronics.

One of my favorite works for solo piano, Cesar Franck's Prelude, Chorale et Fugue played by Russian pianist Evelina Vorontsova, is reproduced in an astonishing way. All drama, emotions, and virtuosity of this pianist can be felt. Also, I've been using the

SOURCES

TubeCad/GlassWare
www.tubecad.com
Amplimo Toroidal Transformers
www.amplimo.nl (distributor for Europe)
Plitron Toroidal Transformers
www.plitron.com (distributor for the US and Canada)
Circuits drawn with sPlan 3.0
www.abacom-online.de

FOR ADDITIONAL HELP

Web: *www.wdehaan.demon.nl/*
E-mail: *wim@wdehaan.demon.nl*

- RCA 6336-A at 1W: 0.12% distortion with cathode de-coupling capacitors connected as used in circuit; 0.06% with cathode de-coupling capacitors connected directly to ground.
- RCA 6336-A at 10W: 0.65% distortion caps as in circuit; 0.88% caps to ground.
- Cetron 6336-B at 1W: 0.12% distortion caps as in circuit; 0.1% caps to ground.
- Cetron 6336-B at 10W: 0.1% distortion caps as in circuit; 1.45% caps to ground.
- Raytheon 6336-A at 1W: 0.07% distortion caps as in circuit; 0.27% caps to ground.
- Raytheon 6336-A at 10W: 0.6% distortion caps as in circuit; 1.6% caps to ground.
- Tung Sol 6336-A at 1W: 0.07% distortion caps as in circuit; 0.12% caps to ground.
- Tung Sol 6336-A at 10W: 0.4% distortion caps as in circuit; 0.75% caps to ground.

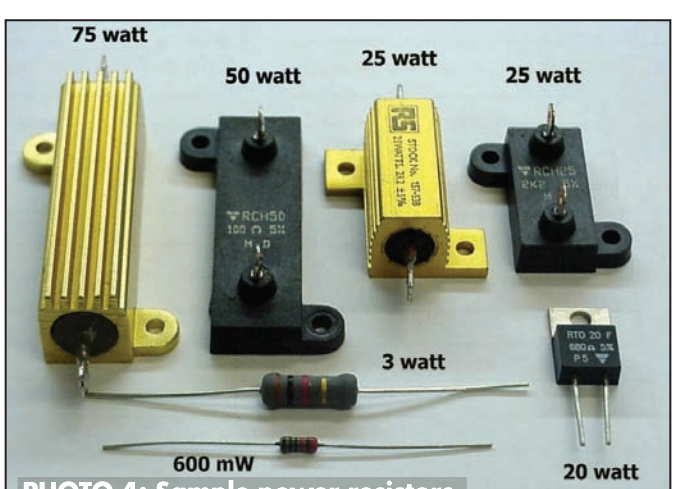

PHOTO 4: Sample power resistors.

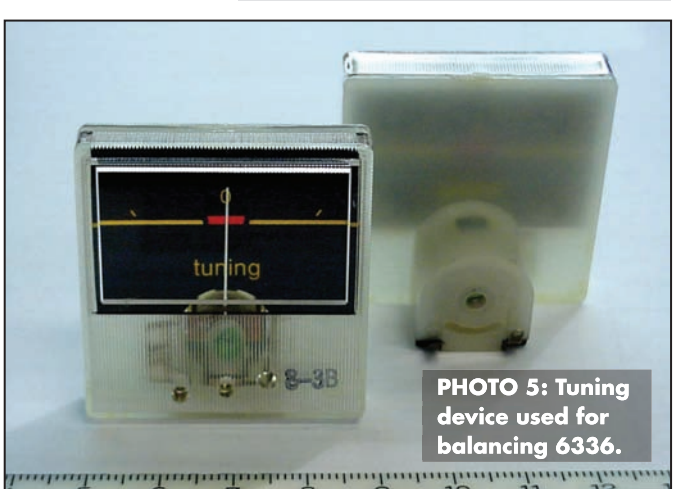

PHOTO 5: Tuning device used for balancing 6336.

Dynaudio Esotar tweeters for the last ten years or so, and still they come up now and then with a new secret, which is now revealed by this 6336-A-based amp.

Again, using triodes only, no feedback and an output tube that's not intended for audio use, it is possible to build an amplifier with good specs and good sound, combined with reliability and sustainability. ■

ABOUT THE AUTHORS...

Kees Heuvelman *is a retired engineer and technician with much knowledge of tube theory, schematics, and applications. He has designed dozens of tube amplifiers using the EL34, 6550, KT88, 5998, and 300B. He is also a great admirer of composers such as Beethoven and Mahler.*

Wim de Haan *is a medical engineer and technician interested in audio electronics. His original projects included DA converters, (active) loudspeakers, tube amplifiers, and hybrid amplifiers. Most of all he is a music lover—from John Scofield to Café del Mar to Keith Jarrett—and he is really into classical piano music.*

EQUIPMENT USED

Distortion analyzer:
Hewlett-Packard HP 333A
AC true RMS voltmeter:
Philips PM 2454B
Generator: ELV SG 1000 audio low distortion generator
Oscilloscope: Philips PM 3211

PARTS LIST:
SUGGESTED POWER SUPPLY

R1, R2, R3, R4	1k/2W
C1-C2, C3-C4	2× 47µF/500V (ELNA Cerafine)
C5, C6, C7, C8	47µF/500V
D1-D4, D5-D8	4× BY448 (silicon diode 1500V/4A20ns or equivalent)
L1, L2	Choke 10H/200mA
TR1	0 – 320V/330V/340V/350V + 0 – 320V/330V/340V/350V (350mA + 350mA)
TR2	6V + 6V (120VA)

AMPLIFIER PARTS LIST

R1	470k
R2, R15, R19	1k
R3	1M
R4, R6, R11	680E
R5	15k/3W
R7, R8	120k/2W
R9	680k
R10	180k/3W
R12, R16	1k**
R13, R17	68k/2W**
R14, R18	390k
R20, R21	22E/1%
R22, R26	3k3/25W*
R23, R27	2k2/25W *
R24	15k
R25	1k/3W
R28	370Ω

[220E/2W in series with 150E/2W]

All resistors 600mW, unless otherwise specified.
** Resistor on heatsink.*
*** Only to be used with additional circuitry.*

P1	22k/1W
P2	500E/0.5W
P3	1k/5W
C1	100nF/200V
C2, C3	47nF/1200V
C4, C6, C7	100nF/400V
C5	470µF/16V
C8, C9	220µF/200V
T1	BC107B or equivalent
D1, D2	LED green 5mm
V1	5687
V2	6SN7
V3	6SN7**
V4	6336A

*** Only to be used with additional circuitry.*

M1	100µA–0–100µA
TR1	Output transformer 8k/20W (Amplimo VDV8020PP or equivalent)