Vacuum Tube Valley®

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Rectifiers for Audio

Tube Rectifiers: From AC to DC

History, Technical Data and Types

Moth Positive Ground Amp

SE 300B Performance Bargain

Vintage Hi Fi From Brazil

1957 AUD-8009 Amp and Preamp

Display until 3/1/02

VTV Issue # 17
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Dedication to World Peace

Our thoughts and prayers are with the souls who perished during the recent catastrophies at the World Trade Center and the Pentagon. Whatever your religion or beliefs, we urge you to pray or meditate for world peace and harmony.

Technical Corrections

If you notice any technical or historical errors in VTV articles, please email or mail us your findings. Some of you out there know facts we are not aware of. We will print the corrections in a subsequent issue and credit the source. Thanks for your cooperation.

Bay Area Tube Show a Sucess

The First Annual Bay Area Tube Festival was a success with 140+ attendees. Ben Reginato organized the event and the host was Rich Curtis. The show was held at the Randall Museum in San Francisco which has an auditorium perfect for sonic comparisons of tube amplifiers.

The focus of the event was medium power single-ended triode amplifiers and horn speakers. Presenters included John Atwood (One Electron) Jack Elliano (Electra-Print), Dr. Bruce Edgar (EdgarHorn) and other notables.

Topics discussed included chassis and wiring layout techniques, SE circuit designs and horn speaker theories. There was a lively panel discussion afterwards including the presenters with Eric Barbour (Matasonix), Kara Chafee (DeHavilland), Scott Frankland (Wavestream Audio) that covered a wide variety of topics.

For more information and photos of this event, go to our website homepage at: www.vacuumtube.com

Beware of Internet News Group BS

In VTV issue #14 we did an overview of problems with the Internet. This included scam artists, eBay ripoffs, identity theft, and news group nonsense. We are displeased with the continued abuse, misinformation, slander and libel going on in **unmoderated audio newsgroups**. A small core of aggressive ego maniacs and obsessive cheapskates continue to dominate audio chat areas with their intimidating tactics.

These self-appointed gurus have virtually no credibility and no accountability for the BS and other misinformation they spew out to unsuspecting novices. Beware, the Internet is a sewer, especially in unmoderated newsgroups.

Announcement from PM Components

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Quality Articles Wanted for VTV

Vacuum Tube Valley is looking for high quality articles on audio and tube history, do-it-yourself tube or speaker projects, book reviews, interviews, and other topics of interest.

Vacuum Tube Valley is published quarterly for electronic enthusiasts interested in the colorful past, present and future of vacuum tube electronics. **Note New Lower Rates!**

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A Vintage Amplifier From Brazil

By Carlos Alberto Fazano

The Hi-Fi boom started just after WWII when N.D.T Williamson, of England, developed his famous audio circuit. Since 1948, many entrepreneurs came forth in the audio business, including Quad, Leak, McIntosh, Fisher and Marantz. During the late 1940s, the first high fidelity equipment available in the Brazilian market were of the imported console type. The massive cabinetry usually comprised a radio tuner, a preamplifier, a separate audio amplifier, a turntable and loudspeaker system.

For historical purposes, the audio industry was born in Brazil about 1950. Unfortunately, much valuable information about its beginning is unavailable. Thus, this article is an overview of an audio piece produced by one of Brazil's well-known names: Standard Electrica S/A -SESA.

The Industry Behind the Circuitry

Originally, the Brazilian audio industry employed audio circuit topology of that time such as push-pull triodes, push-pull triodes with negative feedback and later on, the Williamson and Hafler-Keroes approaches. To supply the emerging audio industry demand for components such as valves, resistors, capacitors and the all-important audio output transformers, much importing had to be done. Eventually these parts were manufactured locally, allowing companies to launch a factory-assembled amplifier and finally, like in the USA, kits were introduced at a lower cost than assembled instruments. Thus was the Brazilian Hi-Fi boom started.

A Word about Standard Electrica S/A-SESA

As part of ITT - International Telephone and Telegraph - USA, established in Brazil in 1927, Standard Electrica S/A-SESA became a Brazilian company in 1938. Located in Rio de Janeiro, SESA started as a small radio shop assembling transmitters and as the dealer for International Western Electric Co., supplying aftermarket services to Brazilian broadcasting radio stations. In spite of its former activities in broadcasting and telephone businesses, SESA expanded into the manufacture of radios, electrical components and audio equipment in 1948. In 1953, SESA began the manufacture, under V-M license, of record players used in their famous phonographs, sold under the trade name Super Auditorium (SA). Due to business circumstances, the company ceased operations in 1975.

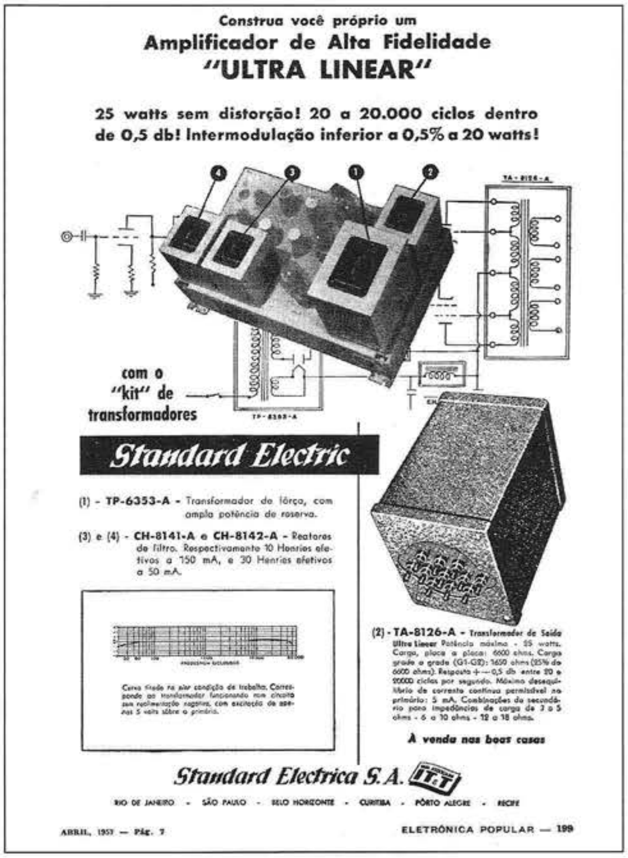
AUD 8009 Amplifier and Remote Preamp

AUD 8009 Amplifier

Model AUD 8009/A1 Hi-Fi Amplifier

I was introduced to the audio world in 1957. During my school days I used to listen to jazz music on my family's Standard Electrica radio-phonograph. This apparatus was a home entertainment masterpiece, and since then I have been in love with the products manufactured by this remarkable company. It was always a pleasure to see an AUD 8009/A1 amplifier when visiting a friend's shop. As usual among collectors, after some discussions, a swapping arrangement was made and so, I finally got the complete amplifier set. This was a 25 watt RMS hi-fi amplifier on a sturdy chassis including its power supply and separate preamp control center. The set was sold factory assembled or in kit form. Originally, the amplifier design employed the classic Williamson circuit by using two 807 beam power tetrode output valves. Its output transformer had an extremely wide response characteristic, and its leakage inductance and distributed capacitance were kept to a minimum. The output transformer's secondary winding allowed several speaker impedance connections such as: 3-5, 6-10 and 12-18 ohms.

The power supply consisted of a massive power transformer, a full-wave rectifier 5U4G valve and two filter chokes: 10 Henry @150mA and 30 Henry at 50mA. The preamp section consisted of one 12AX7 and one 12J5 mounted on a floating sub-chassis supported by four rubber cushions in the main amplifier chassis. The remote


Construa você próprio um
Amplificador de Alta Fidelidade
"ULTRA LINEAR"

25 watts sem distorção! 20 a 20.000 ciclos dentro de 0,5 db! Intermodulação inferior a 0,5% a 20 watts!

com o "kit" de transformadores

Standard Electric

(1) - TP-6353-A - Transformador de fôrça, com ampla potência de reserva.

(3) e (4) - CH-8141-A e CH-8142-A - Reatores de filtro. Respectivamente 10 Henries efetivos a 150 mA, e 30 Henries efetivos a 50 mA.

(2) - TA-8126-A - Transformador de Saída Ultra Linear Potência máxima - 25 watts. Carga, placa a placa: 6600 ohms. Carga grade a grade (G1-G2): 1650 ohms (25% de 6600 ohms). Resposta +—0,5 db entre 20 e 20000 ciclos por segundo. Máximo desequilíbrio de corrente contínua permissível no primário: 5 mA. Combinações do secundário para impedâncias de carga de 3 a 5 ohms - 6 a 10 ohms - 12 a 18 ohms.

À venda nas boas casas

Standard Electrica S.A.

RIO DE JANEIRO - SÃO PAULO - BELO HORIZONTE - CURITIBA - PÔRTO ALEGRE - RECIFE

ABRIL, 1957 — Pág. 7 ELETRÔNICA POPULAR — 199

control unit, connected to the amplifier via a cable, featured volume, bass and treble controls as well as a selector switch for radio and phono modes. The remote control center used two 12AX7 and two 12AU7 valves.

Factory Specifications for the AUD 8009/A1:

25 Watts Sustained Power Output

0.5% @40-20,000 Hz Harmonic Distortion

40-20,000 Hz +/- 0.1dB Frequency Response

Damping Factor 10

0.9VRMS for 25 Watts Out Sensitivity

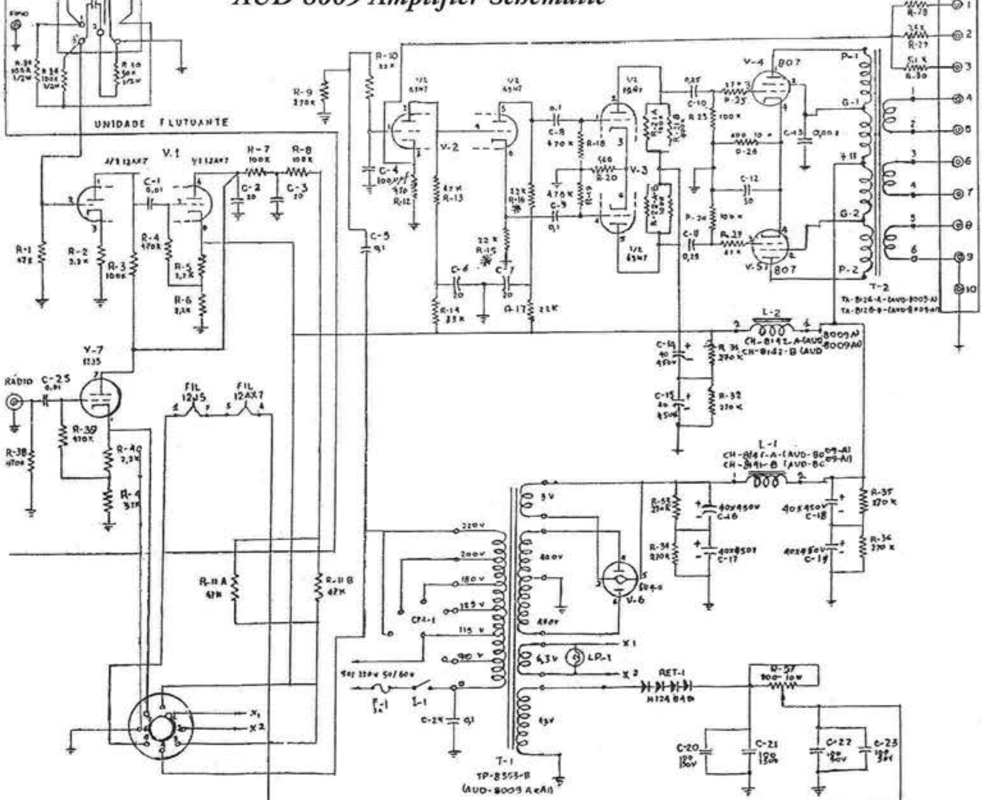
330 Watts Power Consumption

The Restoration Approach

In spite of its age, almost 40 years, the set was not in bad shape. As in any restoration procedure, appearance and electrical performance of the apparatus were considered. On the test bench all components such as capacitors, resistors, etc. were checked and the defective ones were replaced. The same happened with the valves in the set and the two 807s were replaced with a new matched pair.

I needed to make a decision about either restoring or modifying the amplifier. I chose to upgrade the circuit design with the the help of an article entitled "Improving the Williamson Amplifier" by Talbot M. Wright, published originally in the magazine Electronic World, and reprinted in the Brazilian magazine Antenna in 1963. This circuit improvement consisted of changing five resistors to obtain more suitable bias and nominal voltages for the two 6SN7 valves. Regarding the preamp, only the volume pot was changed. The other controls were checked and cleaned. I already commented on the set's appearance being in fairly good shape. Only a few scratches in the power amplifier's gray lacquered finish were apparent. It was, therefore, left original to avoid damaging the nameplate during a refinishing operation. The wooden cabinet for the preamp was completely refurbished in order to obtain its original lacquered tone.

AUD 8009 Amplifier Schematic



Amplifier Use and Listening Tests

As mentioned above, model AUD 8009/A1 was just a high fidelity monoblock power amplifier. Unfortunately, it was not so easy to find another similar unit for assembling a stereophonic amplifying system. I had to audition the amplifier in mono mode with the following system: University 6201 Coaxial 12 inch speaker, FM tuner from FREMO (Brazil Telefunken). As usual, when powering up valve amplifiers, power was applied slowly using a variac. The amp performed well, but some additional work needed to be done to complete the restoration for reliable operation. Upon fixing the set, I found it to perform brilliantly with plenty of headroom, airy high frequency and a tight bass. The sound stage was a little bit limited, probably due to monophonic operation.

Finale

In spite of the great technological evolution, it is quite interesting to note that nowadays many audiophiles believe the audio scene is going in cycles. Old equipment is just as good as the latest stuff. The Model AUD 8009/A1 is a perfect example of this viewpoint. Upon careful technical and listening evaluation it can be considered a piece from the Glory Days, a true classical valve amplifier from the golden era of high fidelity.

Acknowledgements

My sincere thanks to Orlando Galhardi and Guy Lietard for their advice on the Standard Electrica S/A amplifiers. Also to Jario Casoy who kindly helped me to obtain the amplifier photographs.

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About the Author

Carlos Alberto Fazano, Brazilian, holds a degree in chemistry and has published two books on laboratory instrumentation. As a life-long enthusiast of high-quality sound reproduction and a shortwave listener, he studied electronics by assembling valve radios and audio amplifiers. This started his strong interest in the early days of the electronic age. Notwithstanding his daily professional activities, Fazano has always reserved time to study the evolution of electronic technology, and has published several articles in the AWA Old Timer's Bulletin, as well as the English magazine, Radio Bygones.

Tube-O-Vibe Project

By Scott Swartz

One of the most famous guitar effect pedals is the Univibe. The sound this pedal produces has been utilized on many classic recordings by artists such as Jimi Hendrix, Stevie Ray Vaughn, and Robin Trower. The signal path in the original is solid state using low quality discrete transistors, which got me thinking about the possibility of a tube-based Vibe design. The concept of tube warmth combined with the swirl of the Vibe circuit seemed to have promise, so I went about designing one.

The first hurdle in the design was to determine if the required circuit, implemented with tubes, could fit into an enclosure of practical size for effect pedal use. I did several layouts using standard enclosures as manufactured by Hammond, LMB, etc., and settled on a Hammond sloped front box that is approximately 10" wide by 10" deep by 4" high. This enclosure provides a reasonable compromise between part density and size. It was necessary to add an internal divider to provide additional mounting surfaces. The divider also shields the circuitry from the transformers.

Circuit Design

A technical analysis of the original Univibe reveals that it is a fairly primitive phase shifter, which is a circuit that takes an input, shifts the phase, and mixes the phase shifted signal with the original signal. The mixed signal contains notches and a peak at certain frequencies, and the notches and peak are swept up and down in frequency by the Low Frequency Oscillator (LFO). The result of this action is the characteristic swirling sound quality associated with phase shifters. A schematic of the original solid state design can be viewed at www.eden.com/~keen/univibe/univibe.gif.

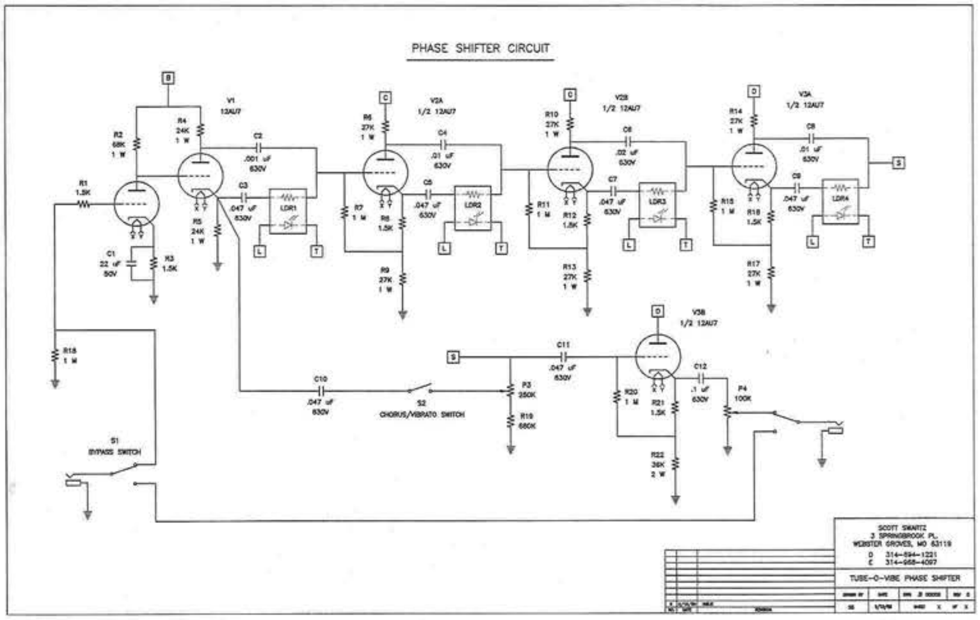
The basic circuit topology of the original is retained in this design, but I changed the details to better utilize tube gain stages. The signal path in my tube design is much shorter, with the audio signal going through approximately half the number of devices. Using tubes also allows all signal caps to be film, whereas the original has six electrolytics in series in the signal path! A detailed description of each stage follows.

Input Stage

The input stage consists of a 12AU7 gain stage direct coupled to the first phase splitter. Since each phase stage operates at a gain of approximately 0.9, some gain is required to bring the output level back up to the input.

Phase Shift Stages

Each phase shifting stage consists of a 12AU7 split load phase inverter with a small value capacitor connected to



the inverted output and a large value capacitor in series with a Light Dependent Resistor (LDR) connected to the non-inverted output. The second lead of the LDR and the small value capacitor are connected. The result of this connection is that high frequencies go through the small value capacitor due to its low reactance at high frequencies and the lowest frequencies go through the LDR branch due to its low reactance at low frequencies. At middle frequencies, the output is a summation of the two signals (remember that the inputs to the small value capacitor/LDR junction are 180 degrees out of phase) and will have varying phase shift as the relative reactance of the two branches varies. The four stage circuit used here will create a 3 dB peak at the frequency where the shift is 90 degrees per stage, and two frequency notches at the frequencies where the shift is 45 degrees and 135 degrees per stage. The frequencies of the notches and peaks are swept by the LFO as it varies the resistance of the LDRs.

Mixer Stage

The phase shifted output is mixed with the dry signal by use of a simple passive circuit utilizing a potentiometer. The mixer can be disconnected by means of a switch which gives an output of 100% effected signal. Since a slow phase change is perceived as a pitch change, the effect is, therefore, electronic vibrato.

The LFO

The original Univibe used a unique phase shift oscillator that works, but the wave form is rather distorted. In preliminary experiments I found that a low distortion sine wave gives a more even pulse to the sound, so I constructed the LFO using an IC function generator, the Intersil ICL8038. One big advantage to this approach is that an external rate control foot pedal can be easily incorporated as the IC is designed to accept a sweep voltage. I have isolated the pedal from the IC with an LDR to allow use of both high impedance volume pedals, and lower impedance synthesizer CV pedals. Any pedal with a pot value between 10K and 1 Meg will work. The speed adjust is arranged so that depressing the pedal will increase the rate beyond the rate set by the speed knob on the top panel. A detailed data sheet on the ICL8038 is available at www.intersil.com/data/fn/fn2/fn2864/FN2864.pdf.

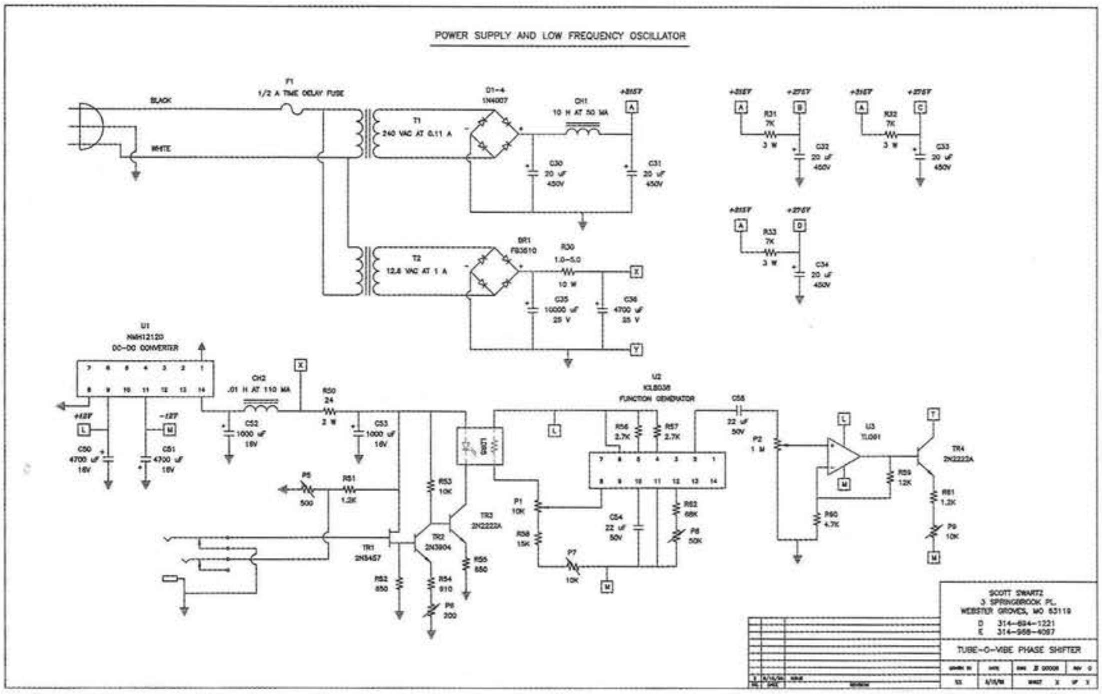
The sine wave output of the function generator is coupled to an opamp set to provide a gain of about 2.5 so the wave available to drive the phase shift LDRs is about 5.5 Vrms maximum. The LFO depth control is placed at the opamp input and the output of the opamp drives the base of a 2N2222A transistor, which modulates the current through the phase shift LDRs.

Output Buffer

The output of the mixer stage is connected to the output buffer, which utilizes a 12AU7 cathode follower stage with a tap on the cathode resistor to provide proper bias. This "bootstrap" arrangement gives a very high input impedance. A volume control is placed after the buffer to match the output level with the level present when the effect is bypassed.

Power Supply

The power supply uses a Magnatek VPS230110 transformer with a 230V secondary rated at 110ma. A bridge rectifier constructed with 1N4007 diodes and a pi filter consisting of a Hammond 10 H, 50



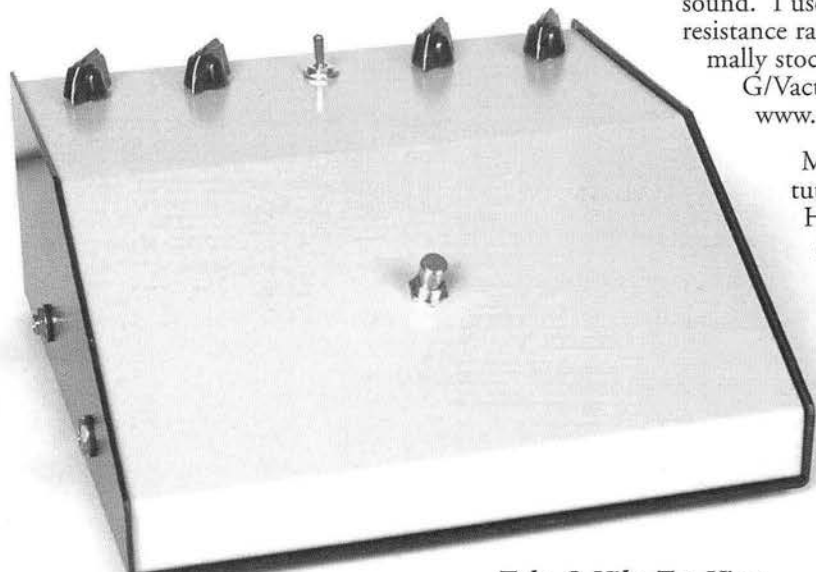
ma choke and two 20 uF filter capacitors complete the raw supply. The DC filament supply uses a transformer rated at 12.6 VAC one amp, a bridge rectifier, a filter cap, and a dropping resistor to give 12.6 VDC. The LFO and the LDR driver also operate from this supply.

Ground loops can sometimes be an issue when two or more AC powered devices are in the same signal path. I utilized several concepts during construction to minimize this possibility. The grounding arrangement used on the prototype was a centrally located ground buss. Circuit grounds were grouped together by stage, and the groups run back to the buss with a single wire. This technique seems to work as well as true star grounding but is easier to implement. The chassis is connected to the buss at a single point. The input and output jack grounds are isolated from the chassis, connecting directly to the ground buss. The isolation can be accomplished by using plastic body jacks or using insulating shoulder washers. Using the concepts above, I had no hum problems with the unit. Hum and noise concerns are critical in an effects pedal since the signal strength entering and leaving is around 50 mV.

Component Choices

This circuit is forgiving with respect to the brand of tubes used since many of the stages operate at unity gain, so any decent 12AU7 will work fine. The most critical is the first tube since it provides the signal gain. All resistors in the audio circuit are carbon composition; I find the carbon comps to have a much smoother sound, especially on high frequencies. All capacitors in the signal path are SBE 716Ps, which to my ears have a warm, somewhat vintage sound. Passive components are very subjective and I encourage you to experiment. The response time and resistance range of the LDRs has a big impact on the sound. I used the Vactec VTL5C3, which has the correct resistance range and the fastest response of any LDR normally stocked by the major distributors. EG & G/Vactec has extensive information on LDRs at www.egginc.com/Opto-110/vactrols.htm.

Many of the components listed, or close substitutes, could be purchased at surplus stores. Hardware items such as jacks, power cord, tube sockets, etc. are are up to the builder to source.



Tube O Vibe Top View

Construction

The layout is designed around a readily available Hammond enclosure, part number 1456KK4WHBU. The power supply components are mounted on the base of the enclosure and the entire circuit is wired on the top of the enclosure and an internal divider. Because of the enclosure design and the packaging constraints, it is necessary to have wires connecting the top and the base of the enclosure. The design minimizes these connections to the maximum extent possible. To separate the enclosure, a pair of wires for the B+ and a pair of wires for the filament must be unsoldered and the input, output and speed pedal jacks have to be unbolted.

Constructing the sections of the Tube-O-Vibe in the correct sequence and carefully testing each section before moving to the next is essential, because of the part density and limited access. I recommend the following order of construction:

1. Lay out location of power supply components on the enclosure base, and mark and drill the holes.

2. Mount the power and filament transformers onto the enclosure base. Wire the 120 VAC input components such as line cord, fuse, etc.

3. Wire the filament DC supply components including the bridge, filter cap, dropping resistor, and terminal strip. The terminal strip is where the pair of wires that carry the filament power to the circuit will connect.

4. Wire the B+ supply components, including the bridge diodes, filter caps, and choke. The output of the pi filter connects to a terminal strip where the pair of wires that carry B+ to the circuit will connect.

5. Verify that the power supply is operating correctly before moving to the next step. Test the filament supply with a 25 ohm, 10 watt resistor and adjust the dropping resistor to get 12.6 VDC. The B+ should measure about 360 VDC with no load. Make sure to bleed the filter caps after the test!

With the power supply complete, work can begin on the audio and LFO sections.

6. Mark and drill the holes that connect the internal divider at the back of the enclosure top. Temporarily mount the internal divider and verify that the correct space is available above the divider. The area of contact between the divider and the enclosure top should be sanded to assure good electrical continuity. Next, measure where the middle of the lower flange of the divider will meet the enclosure base, then mark and drill the base only. Assemble the enclosure and mark matching holes onto the lower flange of the divider. Drill the divider for sheet metal screws, since a nut on the interior would be inaccessible.

7. Mount the tube sockets and the terminal strips that attach to the internal divider.

8. The majority of the audio circuit components are mounted on eyelet boards similar to those used on vintage guitar amps. Using a suitable phenolic laminate material (such as Grade XX Garolite), make the eyelet boards as shown on page 7. Note that each has an associated insulating panel the same size but without eyelet holes that mounts underneath the eyelet board. Mount the eyelet boards in the location shown on the interior of the enclosure top. I used threaded standoffs epoxied to the enclosure top interior to mount the eyelet board to, so I didn't have screw heads on the enclosure exterior. After the eyelet boards are mounted, lay out and drill the holes for the bypass switch, the input and output jacks, and the speed pedal jacks.

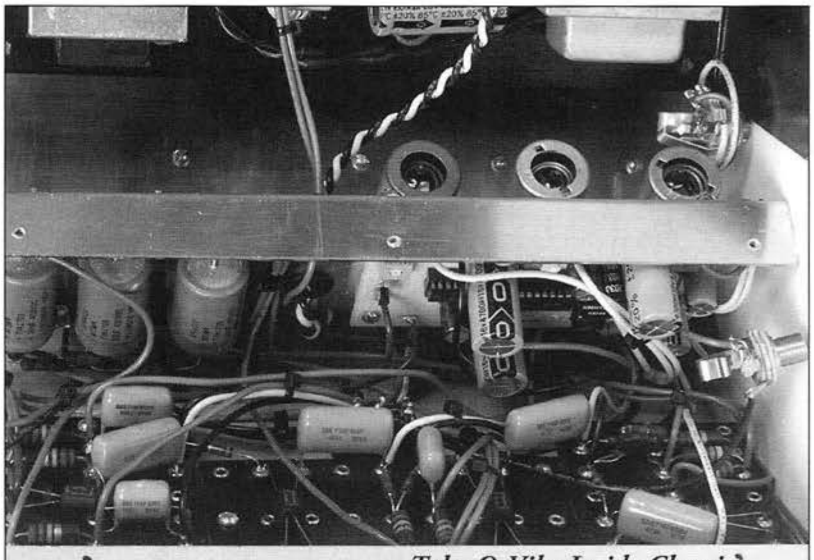
9. The LFO components are mounted on a piece of perfboard that is 2.50"x 4.50". Spacers are used to raise the perfboard, preventing components on the underside of the board from grounding to the divider. Mark and drill the holes on the internal divider where the perfboard will mount.

10. Begin wiring the LFO and its associated components on the perfboard. Once the circuit is wired, temporarily connect the speed pedal jack and the speed and depth pots, apply 12.6 VDC, and test it using an oscilloscope and/or frequency counter. The LFO should be fully operational before work begins on the audio section. The circuit as shown on the schematic gives a range of 1 Hz to 7 Hz at 5.50 Vrms maximum. The range can be easily changed by twiddling the values in the voltage divider that applies the control voltage to pin 8 of the ICL8038. Note that the speed increases as the voltage at pin 8 decreases. This means the circuitry that interfaces the speed pedal must work inversely, i.e., as the pedal is depressed transistor TR3 moves toward cutoff, decreasing the current through LDR5. The LDR resistance should vary between 1K and 10K at the extremes of the gate voltage on TR1. Adjusting the value of the TR2 emitter and collector resistors and/or adjusting P5 and P6 may be required to get the correct LDR resistance range. The speed pedal jack must have a switching arrangement so the gate of TR1 is grounded when a pedal is not inserted; I used a "closed tip, closed ring" jack.

11. Mount the pots, bypass switch, and the phase shift/vibrato switch to the enclosure top and solder overlength wires to the terminals.

12. Solder the components that mount between the tube sockets and the terminal strips on the top of the divider. These include R1, R3, R5, R18, R20, R21, R22, C1, C11, and C12. Run an overlength wire from the terminal

The Governor has just announced that the 6SN7 is now the official state tube of California...



Tube-O-Vibe Inside Chassis

that connects to R1; this wire will connect to the bypass switch.

13. Mount the filter capacitors and distribution resistors to the terminal strips on the vertical surface of the divider. Connect overlength wires to each power supply node; these will connect to the eyelet boards.

14. Solder wires to each terminal on the tube sockets; these will connect to the eyelet boards. Make sure to use a color coding scheme for the wires to reduce confusion when the wires are soldered to the eyelet boards. These wires should be cut somewhat overlength at this point since the exact length is not known until components are soldered onto the eyelet boards.

At this point, the divider can be bolted to the enclosure top since all components that will be inaccessible have overlength leads.

15. Solder the LDRs in place on the eyelet boards and install the interconnecting wiring. Temporarily connect the LDR cells and the LFO board, set the LFO for a slow sweep, and check each LDR resistance element to verify that the resistance is sweeping properly. The desired range is 10K to 100K as the LFO sweeps. The sweep range and the center point can be adjusted by using P6. Verify with a scope that at high depth settings transistor TR4 is not reaching cutoff, and that current through the LDRs is a smooth sine wave. It will be necessary to temporarily solder a 20uF capacitor to the emitter of TR4 to view this signal, since TR4 is operating from the +/- 12V split supply. The scope ground cannot be connected to the negative rail.

16. Permanently mount the LFO board; cut to length and solder the wires coming from the speed and depth pots. The 12.6 VDC power for the LFO board is provided by wires connecting to pins 4 and 5 of V1.

17. Solder the rest of the components to the eyelet boards. Solder the overlength leads to the appropriate points. I recommend tack soldering and leaving the wires overlength at this point so the enclosure halves can be separated a large distance, while proper operation of the circuit is verified.

18. Important parameter to experiment with at this point are the value of capacitors C2, C4, C6, and C8. These capacitors move the frequency location of the notches and have a large impact on the sound. The original used .015 uF, .22 uF, .47 uF, and .0047 uF with 100K grid resistors in these locations. As the grid resistors in the tube design are 1M, the caps for an exact "clone" would be .0015 uF, .022 uF, .047 uF, and 470 pF. After much experimentation, I settled upon values of .001 uF, .01 uF, .02 uF, and .01 uF. For capacitors C3, C5, C7 and C9 the original used 1 uF with a 100K grid resistor, so a "clone" would use 0.1 uF. To tighten the low end of the wet signal, I decreased these to .047 uF. Another parameter you may wish to re-adjust at this point is P6. This control moves the center point of the LDR resistance, which also impacts the frequency location of the notches.

19. The wires connecting the jacks, bypass switch, and tube sockets to the eyelet boards and the B+ and filament wires can now be cut to final length and soldered. Make sure to leave them long enough that it is possible to separate the enclosure halves for future service. Bolt the jacks in place and install the screws that connect the enclosure halves. The unit should now be complete.

Possible Modifications

Here are several modifications that readers may want to consider if building this design.

-Have a custom enclosure made that separates components in a more convenient manner. Since this is a prototype, I accepted the limitations of the Hammond enclosure.

-Other tube types could be used. Any medium mu dual triodes, such as 6CG7, 5963, 12AV7, etc. will work without component value changes, and with a few changes 5687, 7119, etc. could be used. I often use octal SN7s; I determined after completion of the prototype these will fit with a bit of re-engineering.

-As mentioned above, experimenting with the phase shift capacitors has a big impact on the sound.

-The LFO could be made switchable between sine, triangle, and square wave.

-The filaments could be wired in series, and a 37.8 VDC supply used to power them and the LFO. The LFO could be arranged to operate from a single supply, but note that the ICL8038 is rated for 30 VDC maximum, so a regulator would have to be added.

The Sound

The effect adds very little general noise and sweep noise is low also. Due to the well filtered B+ and the DC filaments there is no hum added and the bypass is hard-wired, so there is no signal degradation when the effect is off (unlike the Univibe!).

Since the whole purpose of guitar effects is to color the sound, the relative merit of effects is very subjective. Having stated that, I have done A/B comparisons with two high quality solid state phase shifters, the Ibanez PH99 and the Moogerfooger 12 Stage Phaser, or the Tube-O-Vibe sounds warmer and more vintage than either of them. After playing through the Tube-O-Vibe and then switching in either of these pedals, the solid state edge is definitely noticeable. The overall sound of the Tube-O-Vibe has elements of phaser, wah, and a dash of tremolo to my ears. The solid state units have the classic early 70s "squishy" sound. They sound good also, but are definitely a different flavor. I do not own a Univibe, or one of the clones currently on the market, but since I made a fair number of changes to the design, the comparison probably doesn't mean much. I have listened to the sound files on the internet of the clones and, based on these, I would say the Tube-O-Vibe has more 70s phase shifter in its sonic mix but retains some of the primitive quality of the Univibe.

Summary

I became interested in tube electronics as a method to improve my electric guitar tone, and, I am interested in practical designs that I can use to make better music. This design achieves this goal, and I use it regularly when playing. It creates a unique phase shifter sound with excellent parameter control.

Private individuals may build this project for their own personal use. If you want to use this proprietary design for commercial purposes, VTV can put you in contact with Scott Swartz for licensing which includes consultation, improvements, updates, and more.

Supplier Addresses

The following is a list of suppliers where some of the major components for this project were purchased. They are listed alphabetically; no ranking of merit is implied.

Angela Instruments
10830 Guilford Rd., Suite 309
Annapolis Junction, MD 20701
301-725-0451
www.angela.com

Antique Electronic Supply
6221 S. Maple Ave.
Tempe, AZ 85283
480-820-5411
www.tubesandmore.com

Mouser Electronics
800-346-6873
www.mouser.com

Newark Electronics
800-463-9275
www.newark.com

6SN7 Line Stage Project

By Richard Sears ©2001 All Rights Reserved

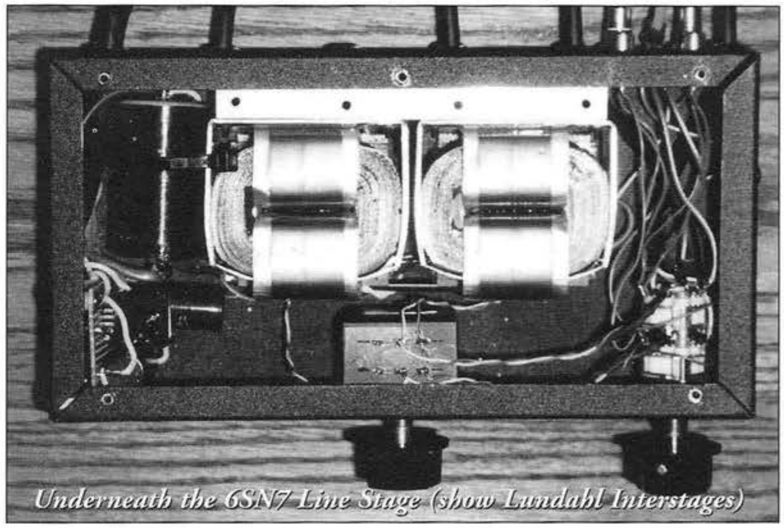
Introduction

This line stage was designed as a companion for the KT88 (triode) mono-block power amplifier project that will appear in the next issue of VTV. The output is in balanced format, connected to each power amplifier using XLR connectors. It can accept either balanced or unbalanced inputs. The balanced input format is provided specifically to accept the signal from a CD player, which I equipped with the Sowter type 8347 DAC signal transformers. This transformer provides an elegant solution to the issue of elimination of all silicon elements from the analog signal path of a CD source.

Design Description

A 6SN7 long-tailed-pair is connected as a Class A push-pull stage using the Lundahl 1660 PP interstage transformer. The secondaries are configured so as to provide a 2.25+2.25 : 1+1 step-down. To minimize square wave overshoot, a 4.02k resistance is placed in parallel with each secondary phase. The plate resistance of a 6SN7 at the operating point is approximately 7.2k. This is reduced by the square of the step-down ratio, 5.06, thus the impedance at each secondary is 1.42k. This is in parallel with 4.02k resulting in an output impedance for each phase of 1.05k. An advantage of the transformer coupled output is that it permits isolation. The secondary centre-tap is shown not grounded at the line stage, but rather at the power amplifier end. This eliminates the possibility of ground loop interference.

The tail is returned to 175V via an 11k resistance, while the transformer primary centre-tap is supplied with a B+ at 185V. Both grids are referenced to ground using 681k leak resistors. The inputs are selected using an Elma 4 pole rotary switch. For unbalanced inputs, the phase grid is grounded by the switch. The volume control design is a little unusual. I had experimented with connecting a volume control potentiometer as a variable shunt to ground, the pass signal being attenuated using a series resistance. In this way, the "pass" signal is connected directly and not via the potentiometer wiper. Even using high quality Alps potentiometers, this technique results in a readily discernible improvement in clarity.

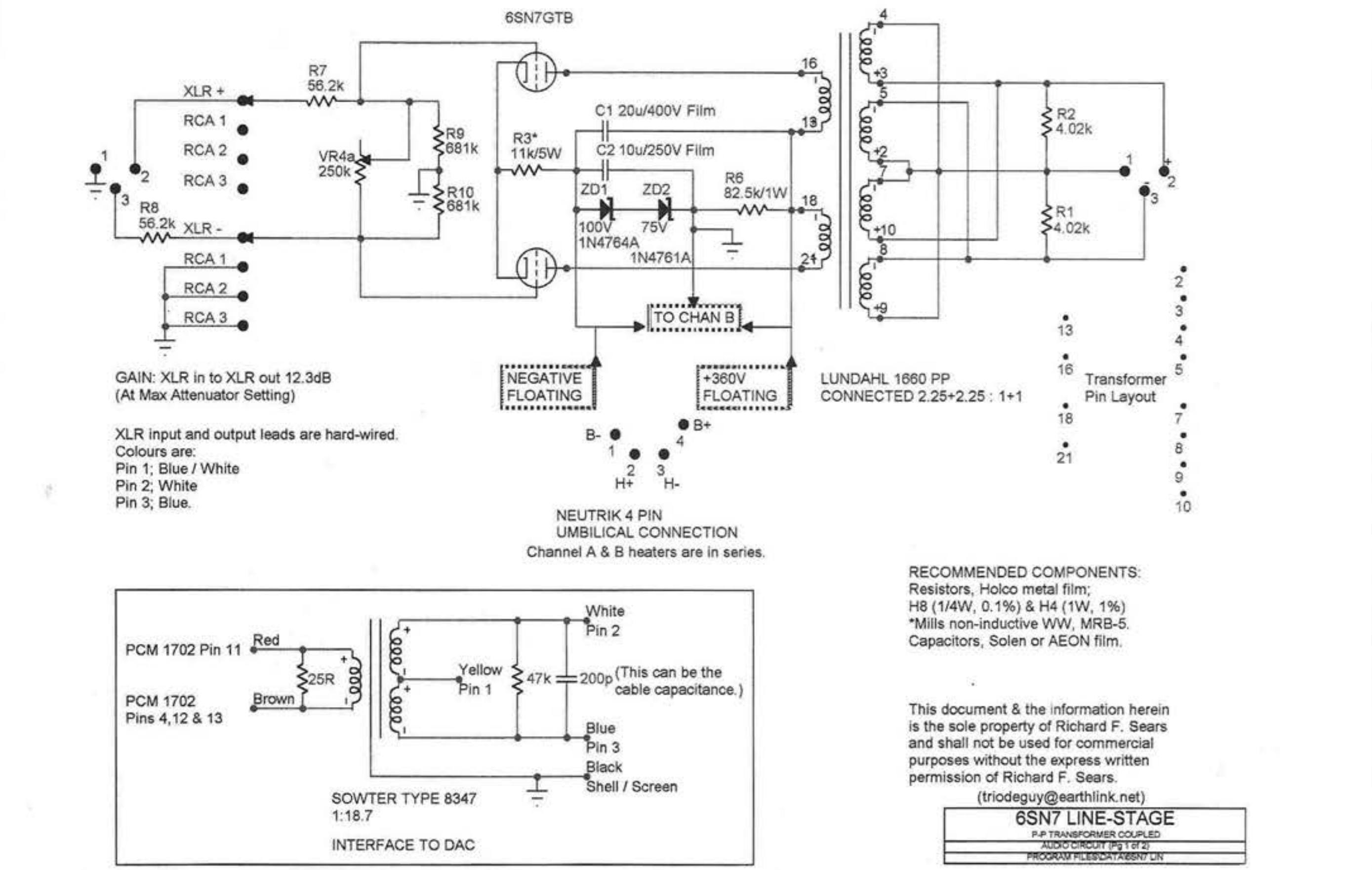


Underneath the 6SN7 Line Stage (show Lundahl Interstages)

By providing an equal value resistance in both phases of the balanced inputs, the potentiometer can be used as a variable cancellation shunt between the phases, thereby eliminating the need for four matched potentiometers in a stereo balanced line-stage. The choice of series resistance value needs a little thought. First, it must be high enough in value such that when the shunt is approaching zero, the load presented is acceptable to all sources which are to be used. Second, it must be small enough in value that the HF roll-off resulting by it acting in combination with the Miller capacitance of the 6SN7 is acceptable. The value of 51.1k results in an HF pole at the plate far above that due to the interstage transformer. This is due in part to the rising load reactance presented to the plate with frequency by the transformer.

6SN7 Line Stage with Power Supply

In designing source line output stages, I aim to keep the source impedance below 5k. Taking the transformer coupled DAC as an example: The I/V resistance is 25 ohms while the step-up is 1:18.7 resulting in an impedance transformation of 1:350 and thus a reflected secondary impedance



of 8.74k. This is in parallel with a 47k resistor placed across the secondary (per Sowter recommendation) giving a balanced source impedance of 7.4k or 1.84k for each phase. In balanced input mode, the minimum load presented is 2 X 51.1k, thus significantly greater than 10X the source impedance.

Measured Performance of the Line Stage

Intermodulation Distortion - SMPTE using unbalanced input (60Hz / 7kHz mixed 4:1):

(The IMD measurements were taken using a Heathkit IM-5248 analyzer.)

0.3Vrms	0.028%
1Vrms	0.012%
3Vrms	0.039%

THD: (*The THD measurements were taken using HP339a analyzer.*)

	100Hz	1kHz	5kHz
.1Vrms	0.047%	0.035%	0.081%
.3Vrms	0.015%	0.012%	0.026%
1Vrms	0.03%	0.0065%	0.010%
3Vrms	0.035%	0.016%	0.015%

Bandwidth: -1dB - 18Hz to 20kHz

-3dB - 10Hz to 38kHz

Voltage gain: 12.3dB balanced in to balanced out

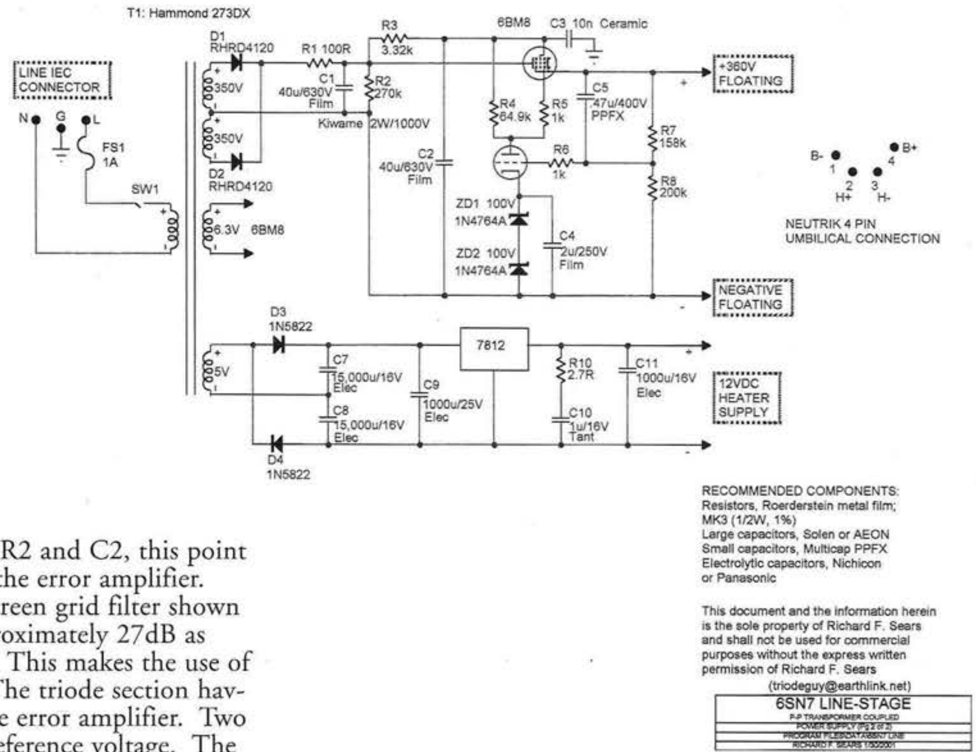
Input impedance (Minimum): 56kohm, unbalanced; 112kohm, balanced

Signal to noise ratio: 82dB unweighted (referred to 1.6Vrms)

NOTE: These measurements reflect the "least good" channel. An interesting point is that both the IMD and the THD increase at lower signal levels. Previously, I had encountered the same behavior while breadboarding a similar circuit using push-pull interstage transformers. I suspect that this is due to the B-H "kink" about the zero becoming an increasingly large percentage of a small signal.

Power Supply

I used an adapted surplus regulated power supply. 360V from the supply is biased to 175V below ground and 185V above ground using one 100V and one 75V zener diode. Theses diodes do not have to support any significant current draw because the ground rail thus created is simply acting as a bias voltage source for the 6SN7 grids. The zener bias current is developed using a 1W / 82.5k resistor between ground and +185V for a bias current of 2mA. A design for a suitable regulated supply is shown.



While a well filtered unregulated supply is also suitable, I have a strong preference for regulation because, among other things, it minimizes the impact of the antics of the utility company on the performance of my system! The suggested power supply uses a standard Hammond transformer. Low noise FRED diodes are specified to rectify the AC. The peak voltage is developed across C1. R1 serves to limit the peak rectification current. The regulator uses the pentode section of a 6BM8 for the series regulator element to handle the total current of 33mA. The screen grid supply is further filtered by R2 and C2, this point also serving as the B+ supply to the error amplifier. The use of a pentode with the screen grid filter shown increases ripple rejection by approximately 27dB as compared to the use of a triode. This makes the use of a DC input filter unnecessary. The triode section having a mu of 70 serves well for the error amplifier. Two 100V zener diodes provide the reference voltage. The zener diodes are biased at 2mA by the error amplifier plate current. The power supply is bypassed at the line-stage with a 10uF film capacitor across the zener string and a 20uF film capacitor across the 360V points.

DC Heater Supply

The two 6SN7 heaters are connected in series to permit the simple application of a 12V regulator. The raw DC is developed using a voltage doubler from a 5V winding. Note that the current capacity of the winding has to be 2.8 times that drawn by the load. The 6SN7s are connected in series, and thus the current the winding has to support is 1.68A. The DC is regulated at 12V using a 7812 regulator mounted on a heat sink. 5V in my experience is a little marginal with respect to drop-out of the 7812. It is important, therefore, to combine the large capacitors specified with the low forward drop of the 1N5822 Schottky diodes. The use of Schottky diodes will help to mitigate the noise resulting from the high charging currents. Additionally, a 2.7 ohm / 1uF Zobel network is placed across the output of the regulator to enhance RF rejection. Note, if you place the regulator away from its DC source, it is a good idea to include an additional 1000uF capacitor, located within two inches of the regulator.

Construction

Interstage transformers are susceptible to induced hum from power transformers and wiring carrying heavy ripple currents. The sensitivity of the open frame Lundahl transformer is accentuated by the location of the transformer at a low signal level stage. For this reason, I strongly recommend that you use a separate chassis for both the B+ and heater supplies. This recommendation includes the heater regulator. (I installed mine inside the line stage chassis since there was no room inside the adapted surplus power supply.) I found it necessary to add pre-filtering (2ohm and 10,000uF) to reduce the ripple on the incoming DC to a level that did not affect the nearby interstage transformer. If you do not wish to do this, at least use a toriodal power transformer with a rating well in excess of the power requirement, 25W. This is to ensure that the torroid cannot saturate. While the stray field of a toroid operating within the rating is very low, the efficiency of the toroidal core causes abrupt onset of saturation if it is over-run, in which case the leakage field is very pronounced. Such over-run may not be obvious when considering rms current requirements only. It is necessary also to ensure that the peak rectification currents will not saturate the core causing bursts of noise at at 1/120sec intervals. I would suggest a unit rated at least for 60VA. I used a Neutrik 4 pin connector to interface the line stage umbilical to the power supply.

SAFETY: Allow a minimum of three minutes for the polypropylene capacitors to bleed down via the bleed resistors. Do not work on the circuits without removing the line cord from the IEC receptacle and waiting for at least three minutes. Use a voltmeter to check that the capacitors have discharged.

The author and VTV cannot accept responsibility for your ability to work safely with the high voltages present in vacuum tube circuits.

Rectifiers for Audio

By Eric Barbour

1. Intro

Audio enthusiasts and tube collectors tend to focus on the development of the amplifying triode, as well as its multi-gridded progeny. Yet they were all derived from the diodes invented by Edison and Fleming. And without vacuum rectifiers, radio and electronics would not have developed to the extent they have--because everything would still be run from A and B battery banks. Thanks to some new publications and assistance from well-known tube collectors, we have partly deciphered the development of the full-wave rectifier tube.

2. The Essential History

The triode was developed from the diode, yet the diode was only an afterthought in the history of radio and electronics. Early audio amplifiers for fixed use (such as telephone repeater amplifiers or movie sound) often used triodes as power rectifiers. Good examples are the Western Electric types 10, 42 and 43A. Each used 4 power triodes, two as amplifiers and two as rectifiers. Wasteful, but also sensible, as it eliminated the need to stock an extra tube type. Early radio transmitters also used diode-connected triodes for rectification of AC power.

Prior to 1925, numerous types of half-wave vacuum and gas rectifiers were offered for sale. Most of these devices are poorly documented in existing references. Even the best, Gerry Tyne's ***Saga of the Vacuum Tube***, barely mentions rectifiers. They are rarely well-represented in museum collections, being just afterthoughts in the history of tube design. Many were just tungsten-filament power triodes with the grid left out, as in the DeForest Oscillion "singer Audion" rectifier of 1917, used to power an early transmitter, which led to DeForests's DR, HR and PR rectifiers of the mid-1920s. Marconi-Osram types U1 and U2, dating from 1917-18 and supplied to the British Admiralty, were also intended to power transmitting triodes.

Sylvania 5Z4, RCA 5Z4 elements and perforated cover

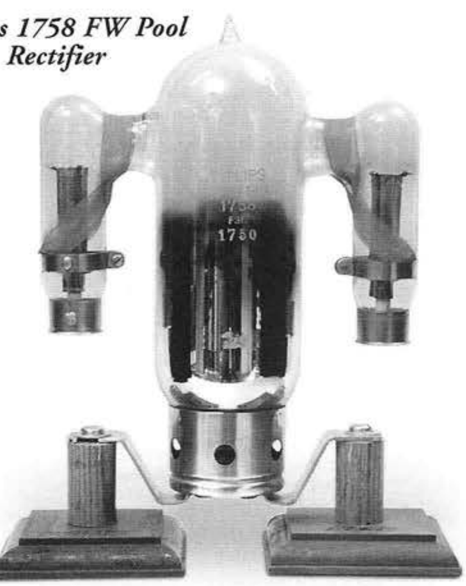
One of GE's major inventions prior to World War I was the TB1 "Kenotron" half-wave high-vacuum rectifier, which was supplied in limited quantities to the U.S. Army during WWI. It was apparently not commercialized until the UV-216 (1921). Its filament was plain tungsten. The thoriated-filament version UV-216B appeared in 1925. The UX-281 (1927) replaced it quickly, thanks to an oxide-coated filament capable of passing 85 mA. The 81 had a long commercial life--manufacture was believed to continue into the 1990s.

We will mention in passing the argon-filled high-pressure rectifiers most commonly called "Tungar" bulbs (after the GE trademark). Introduced in 1917, they were low voltage devices only, and were intended for battery chargers. They usually had low-voltage, high current filaments. Tungars ran very hot, were extremely inefficient (typical voltage drop was 10 volts, often more than the final DC reaching the battery), and were none too reliable. Yet early copper-oxide and selenium rectifier stacks were so much worse that no one minded. Tungar bulbs predated high-voltage plate power rectifiers, and represent the grandfather technology, having been widely manufactured and readily available.

National Union Full Wave Tungar Bulb

Another forgotten early rectifier is the so-called mercury pool type. It was used only by well-heeled commercial customers, and survived until after WW2 in large industrial applications. It was cold-cathode in nature, with a small "cathode spot" formed on the surface of

Philips 1758 FW Pool Rectifier



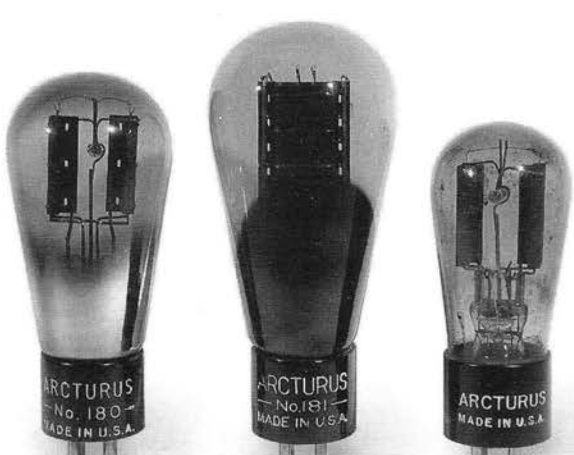
the small mercury pool in the bottom via an extra arcing electrode. Often made in low-voltage form, for lighting systems (12 or 24 volts), pool rectifiers were usually full-wave (in fact, variants were made with up to six, and even twelve, anode arms, for use with polyphase AC power systems), yet had a major disadvantage: occasional back-arcing could destroy the very equipment being powered. This has always

Mesh Plate 280 with filaments lit

Telefunken AZ11 with German octal base

been a problem with any mercury-vapor devices. So, collectors know very little about pool rectifiers, a situation not helped by the lack of standard types. Most such devices were custom-made on a one-off basis, at great cost. Among the few having a standard number were the Philips 1063A and 1758 of the early 1920s.

All of our references seem to agree: M-OV developed the first commercial full-wave vacuum rectifier for receiving sets, the U5 of 1925 (or 1926, depending on which textbook you are reading). This valve used the 4-pin "British" basing of the



Arcturus Blue Glass: 180, 181, 182

period, whose pins resembled the modern-day banana plug. The U5 was derived from the half-wave U4 and had a thoriated tungsten filament, an Osram speciality at the time. The popular HMV "Radiogram" and GECoPhone 3130 sets of 1929-30 used U5 rectifiers to transform AC mains power into DC power for plates. Smaller valve manufacturer Burndept produced the full-wave U695 at about the same time---unfortunately M-OV, being the giant with the golden reputation, usually gets the credit (Burndept's primary business was receiver manufacture, and they went bankrupt in 1927 anyway). U5 led directly to the early oxide-filament type U9. The full-wave U8, with its thoriated filament, was remarkably comparable to the later 5U4G, capable of putting out 500vDC at 120 mA.

By comparison, the first American full-wave vacuum rectifier was apparently a mistake. Westinghouse introduced the UV-196 about the same time M-OV came out with the U5. Unfortunately, Westinghouse engineers screwed up: the 196 had wiring for two separate filament/cathodes, but a common anode. This required two separate and insulated filament windings, plus a connection to the brass base shell (five-pin bases did not yet exist). After this device failed to win a market, GE and RCA showed the UX-213 in September. It followed the more usual scheme of a full-wave rectifier, although it was only capable of 65 mA at 170v. It led to the wildly popular UX-280 of 1927, which came close to being the universal rectifier tube. The 80 was seen in millions of American-produced radio sets, and saw manufacture from 1927 until the 1980s, in a variety of glass envelopes. A gas-filled 80, called 80S, was made in Europe. The 80 was later rebased to make the 5Y3G.

American developments often followed from gas rectifiers or mercury-vapor types, usually aimed at the huge projected market for battery eliminators to operate receivers from AC mains power. The Amrad "S" type later became the popular BH, widely used in late-1920s B battery eliminators for radio sets. The humble (though high-priced) BH was the start of the giant Raytheon Corporation. In spite of Raytheon's later dominance in commercial radar systems, it grew up on the sales of costly rectifier tubes for use in early AC-powered radios. Many similar power rectifiers were made by small firms, such as the "Rectobulb" made by the National Radio Tube Co. of San Francisco. Many such "start-up" firms appeared during the 1920s, and few survived the Depression. The large firms were the primary forces of rectifier development--RCA's early mercury rectifiers 82 and 83 led to vacuum devices of great importance.

Some people seem to believe that mainland-European tube manufacture was right up to or ahead of the American and British developments. Our research seems to indicate otherwise. Philips is a case in point. Apart from low-production pool rectifiers, the first Philips rectifier was apparently the 1018 (1925), a low-voltage gas-filled device with a side-contact base, intended for use in a Philips-made battery charger. Their first vacuum rectifier was apparently the half-wave 373 (1926), and the popular 506 (1927) was apparently their first full-wave device. As with most similar devices, it had an English 4-pin base and a 4-

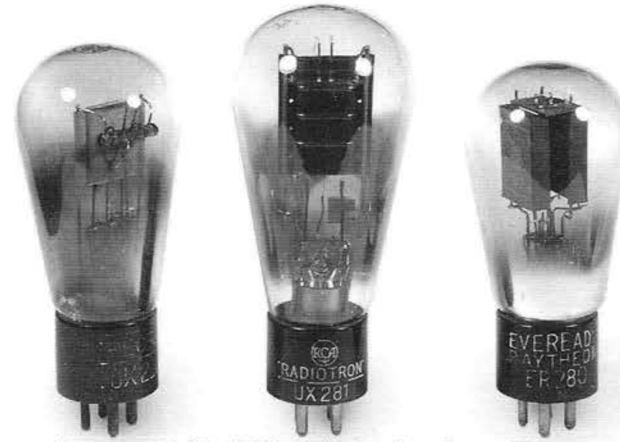
volt filament. Well after the UX-280, Philips introduced the similar 1560 (1928), which could be had with an American or an English base. Until the octal base and American-type standards took hold, Philips, like M-OV, made many full-wave vacuum rectifiers with slightly varying ratings and European-style bases--mainly English or side-contact. There were other small firms in the Netherlands making tubes--again, very few introduced innovative products.

Developments at other European factories apparently also lagged behind the American and UK originals---we have been unable to verify any harder facts, due to the lack of well-researched and believable documentation. French firms such as La Radiotechnique, CGR, Visseaux, and many others did little research, often preferring to make versions of British radio valves. The WWI "R" type triodes were frequently copied.

The first full-wave rectifier to use the newfangled indirect-heated cathode is believed to be the British Mazda UU6 of 1929. The indirect heating allowed slower warmup, thus applying plate power to the amplifier tubes on a delay and helping to prevent "cathode stripping" on oxided cathodes. It was a good idea, although less necessary as tube cathodes improved over the years.

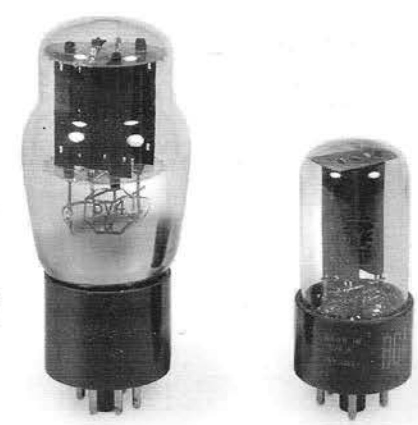
Half-wave rectifiers were often seen in early professional radio equipment--the greater cost of using 2 tubes, instead of one, kept them mostly out of receiving sets. Many were like the Mazda U4020 and M-OV A1178, wherein those firms simply took off-the-line pentodes and strapped the grids to the cathode. By 1933, the half-wave rectifiers of simple design had virtually become obsolete for receiving sets, only to be revived that same year as indirect-heated half-wave diodes for use in AC-DC radio sets. First to be developed is believed to be Lissen's U16. The insulation between the heater and cathode allowed the use of series heater strings, which became almost ubiquitous in tubed TV sets after 1956, and important in low-cost radios, starting in the late 1930s and continuing until the transistor killed off tubes in consumer equipment. Large half-wave gas or mercury diodes continued to be seen in radio transmitter power supplies, until recent years.

Many full-wave rectifiers were made in Europe previous to the American octal base. It's difficult to get information on them, especially about when they were introduced and by whom. The vast majority used a 4-volt or 2-volt filament, making them incompatible with modern equipment. Most had the British 4-pin base and were substitutes for each other, while the same European companies making substitutes were also attempting to push their own unique base designs onto radio designers--examples include the Philips Rimlock base, the side-contact base and the strange "German Octal" base. In spite of the variety appearing here, M-OV was the big innovator, with most of the "firsts." In the UK, a short list would include the Brimar R1 thru R3; Cossor's 4/100BU, 441U, 442BU, 460BU, and 506BU (the latter a copy of the Philips 506); Ediswan/Mazda's UU series, some also made by Lissen; Ferranti's R series; Hivac's UU60s and UU120s; Mullard's DW and FW series and AX50; and Tungsram UK's

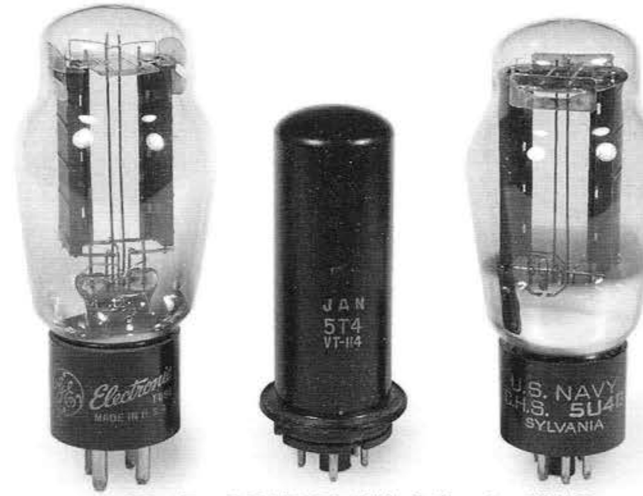


Rectron 216B, RCA UX281, Raytheon ER280

RV120/350. The Tungsram company started as a firm in Ujpest, Hungary, which had some manufacturing in the UK--the two production facilities later became separate, with different product lines. Mullard also had a later IW and UR series, all indirectly heated. Again, most of the above had 4-volt filaments and British 4-pin basing, and were considered obsolete by 1945. (UR rectifiers had 20v or 30v filament voltages for series strings.)



RCA 5V4G, RCA 5Y3GT



GE 5Z3, RCA/JAN 5T4, Sylvania 5U4G

In Germany, tube developments flowed mostly from telephone-system requirements for repeater amplifiers. Most R&D was done by Siemens & Halske or AEG-Telefunken. The RG series of rectifiers was made by Telefunken as companions to their mid-1920s RE and RS

GE 5R4GYB, GE 5R4GYA, RCA 5R4G

Sylvania 5U4GB, GE 5U4GB, Sylvania 5X4G

series of radio triodes. All the RG series were apparently half-wave and had the usual 4-volt filaments and unique four-pin bases. As for post-1929 full-wave rectifiers, the Telefunken AZxx series had the greatest importance. Most had side-contact, Rimlock or "German Octal" bases, and we believe all of them had 4-volt filaments, making them unusable in modern amps.

Be warned--some pre-WWII British tubes, such as Mazda's UU6, UU7 and UU8, used the "Mazda octal" base. It looks very like the American octal, and was claimed to be compatible--however, its dimensions are slightly different. Plugging an NOS tube having such a base into a modern octal socket can result in damage to the base or the socket. Most of the types that had this base were made by Mazda and had 4-volt filaments, making them of little use today.

Note that this article does not cover 7-pin or 9-pin miniature rectifiers, nor does it cover the later novar and Compactron types or special-duty diodes. A lengthy book could also be written about larger industrial rectifiers, intended for powering transmitting tubes; we will skip over those devices, as they were used only very rarely in audio amplifiers.

3. Modern Types

Since RCA was the prime licensee for the American octal base, most of the early rectifier tubes on this base were RCA developments. The first was claimed to be the 83V, offered in 1934 and directly derived from the 83 mercury rectifier. There was also the 1-V, a vacuum type of low power capability intended for early automotive radios. Mercury or gas-filled rectifiers were also made for car radios, culminating in the cold-cathode 0Z4.

We could write another book about cold-cathode rectifiers--they were not used much outside of early radios. A rare item for collectors is the full-wave rectifier tube offered briefly by Atwater-Kent in 1927. The AK607 was a cold-cathode device for use in early B-battery eliminators. Allegedly it was made by Sylvania under exclusive contract, and was considered unreliable, replaced quickly with the UX-280. The AK607 looks like two tube grids with wire cathodes inside, obviously a "bodge." None of our textbooks mentions it, yet it is well known among tube collectors.

The 80, meanwhile, was enlarged to make the 5Z3 of 1933, in response to calls for more power capability. These early types had 4-pin bases. RCA then "octalized" the 5Z3, producing the 5Z4. The first version was copied from and resembled the "catkin" valves already being produced in England by M-OV. It had a pair of tubular metal anodes, containing vacuum and filaments. The upper ends were swaged shut, while the filament connections came through glass bead seals on the bottom. Both were mounted on an octal base and encased in an outer safety envelope of perforated metal. Other major firms produced it under license. This construction proved too costly to manufacture, so later 5Z4s were in conventional metal or ST envelopes. The 80 was subsequently made into the metal 5Y3 of 1936, then the glass 5Y3G. All of the most common 5-volt octal rectifiers appeared between 1935 and 1937.

Vacuum types lagged hot-cathode mercury rectifiers for a very good reason; mercury vapor diodes tend to have much lower forward voltage drop than vacuum diodes of the same dimensions. Plus, large lamp manufacturers (who constituted almost all the early tube makers) already had experience with making pool rectifiers and gas lamps. Mercury rectifiers are commonplace in older transmitting equipment and other high-power devices which operate at 1000v or more. This has contributed to the continued manufacture of 866As and 872As by Richardson/Cetron in the USA. Although more noisy than vacuum types, and certainly less reliable, persons desiring better performance should look into mercury-vapor rectifiers! (Oops, sorry, small ones are getting difficult to find and will never be made again, due to current severe restrictions on the commercial use of toxic mercury.)

4. Registration of Early Octal Rectifiers with EIA

(courtesy of Ludwell Sibley, Tube Collector's Association)

5Z4	7 May 1935
5Y3	6 June 1936

5X4G	26 May 1936
5W4	1 May 1936
5V4G	26 April 1936
5U4G	27 July 1936
5T4 (metal)	4 Feb 1937

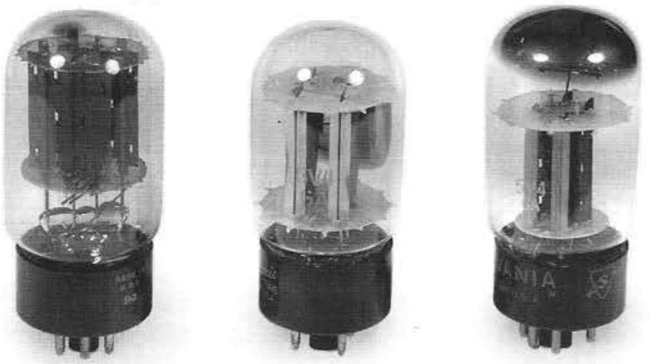
Many of the most common types appeared after WWII. The 5Y3, which started as an octal 80, became a standard for powering smaller radios and test equipment; so many variations were produced post war that we cannot possibly list them all. Among the best was the 6087, made by GE. And the pinnacle of this small rectifier type would have to be the Bendix TE-45, later called 6853. It was an even more ruggedized version of their earlier TE-22/6106, and has VERY slow warmup--more than a minute. The 6853 might be the last octal rectifier ever developed, appearing in 1963. That's late--by then, almost all industrial electronics had switched to silicon diodes. Only TV sets and very cheap table radios were still using rectifier tubes, and those were series-string types. The rare 5AZ4 was a Sylvania loktal version of the 5Y3, while the 6.3V types 7Y4 and 7Z4 were lower in ratings. Ironically, all-loktal radios were usually powered by common 5Y3s instead of loktal rectifiers.

The popular 5U4G was considered a high-power type for a long time. It was far more commonplace than any other large types--indeed, most people have little awareness of very similar rectifiers, such as the 5AS4 or 5AW4. The 5U4 went through many, many changes and versions--too many to mention. Super-premiums include the ruggedized Sylvania 5931 and the Western Electric 274A/B (more on these below). The common GE 5U4GB, with straight-sided envelope and button base, is a very tough tube and should not be discounted. It was manufactured by the tens of millions, so they must have gotten it right.

We must note here that there were two EIA pinout standards for octal rectifiers-- the most common is the original 5Z4, with anodes on pins 4 and 6 and heater/cathode on 2 and 8. This follows the EIA standards 5DA, 5L, and 5T (and the obscure 8HE), the only differences being the presence or absence of a cathode sleeve (which was always connected to pin 8). The 5Y3, 5U4, 5R4, 5V4 and most European octal types (including all GZ3x types) conformed to this system. The 5X4 and 5Y4 used the EIA base 5Q, which had anodes on 3 and 5, filament on 7 and 8--so those types are not plug-in replacements for the commoner 5T basing. Also bear in mind that 5AR4s draw only 1.9 amps on their heater, so 5U4 types cannot be substituted for them.

There are a few very obscure exceptions to this pinout scheme. The 5DJ4 is very similar to the 5U4, but has incompatible pinout 8KS. The 5CU4 is capable of higher current and lower voltage than the 5U4, and has incompatible basing 8KD. And there were several series-string rectifiers (50Y6, 117Z6, 50Y7, etc.) and damper diodes on octal bases. None can be used in modern or vintage amplifiers without considerable modification.

Military Octal Rectifier Types: Sylvania 5931, RCA 5690, Raytheon 5R4WGB



RCA 5V4GA, GE 5V4GA, Sylvania 5V4GA

Western Electric 274A and 274B

Bendix made other full-wave rectifiers, though most of them were 6X5 variants. 6X5s were popular in radio gear and are almost never seen in audio equipment. That also brings up the odd fact that rectifier tubes are still using 5-volt heaters, even though 6.3 volts has become the standard for the few receiving tubes being manufactured. Because the use of such rectifiers requires a separate well-insulated filament winding on the power transformer, and because of sheer inertia and the continued use of

Mullard GZ34 (wide base), Amperex GZ34, Sylvania GZ34

types 5AR4 and 5U4 in new equipment, we are stuck with 5 volts for the future. It had nothing to do with hum reduction, efficiency, or "magical sound"--it's just another historical accident.

Amperex Bugle Boy GZ34 Metal Base (1950s)

Audiophiles like to pay excessive prices for the RCA "Special Red" duotriodes 5691 and 5692. Yet those same dudes have no interest in the matching rectifier, the 5690. Because it is a very odd device, and its pinout is unique, nobody pays it any attention today. The 5690 is two totally separate half-wave rectifiers, with separate 6.3v heaters. It was extremely rugged, for use in avionics and computer systems. Unfortunately, it was replaced by silicon diodes very quickly, and saw almost no use in known equipment. It seems RCA was arrogant enough to believe they could force a nonstandard rectifier on the world. They tried this much later, with special-pinout audio tubes--and had better luck. More on this in a future VTV article.

Chinese GZ34, Russian GZ34, Svetlana 5U4G

The 5R4GY was developed at the end of WWII to address the need for a rectifier that could handle higher voltages than the 5U4G. Its peak inverse voltage rating of 2800V was almost twice that of the 5U4G. Warmup is very quick, which must be allowed for in equipment design. It was so widely used in military equipment that a super-rugged version, the 5R4WGB, appeared in 1948. This was a major product of the small firm Chatham (later absorbed by Tung-Sol), as well as Raytheon and Cetron. Uncounted millions were used in Vietnam-era American military aircraft and ships, which is why they are still easily found, even 20 years after manufacture ceased. Their rugged design and massive silicone-filled bases contributed to their common slang name: "potato mashers." 5R4WGBs are still seen in surplus shops, though I would recommend against using them in any new designs.

Western Electric made very few vacuum power rectifiers. It seems that WE's engineering staff regarded rectifiers as low importance, so they simply didn't develop very many, other than some large types for use in radio transmitters, such as the 214A, 219A and 222A. Indeed, after 1945, most Bell System telephone network equipment was powered by 5Y3s, 5U4s or 5R4WGBs bought from other firms. Not counting cold-cathode or radio detector types, the only small rectifiers WE made before 1940 were the half-wave 217A (1922), the mercury-vapor 249A-C (1929-34), 253A (1931), 301A (1937), and 314A (1937); the high-voltage 324A (1938); a few Tungar-like rectifiers for battery charging; the 6Z4-like 345A; and the 6X5-like 351A.

And finally, the only standard 5-volt versions, the much-worshipped and overpriced 274A-B (1931-35). The only difference between the A and B was the octal base on the latter. We must comment that the present street price of $1000-up for an NOS 274B is ridiculous, given that it is basically a well-made 5U4. All the other small WE types saw very little use outside the specific equipment they were designed for. WE's higher production costs must have been responsible for this situation. The only small rectifiers WE introduced after WWII were the 9-pin miniature 412A and the rare 422A (both 1948), the latter another 5U4 version which appears to be a modified 421A/5998 dual triode minus the grids. The 5998 was used in regulated power supplies as the pass device, as well as a cathode follower in early computer core memories--it is very similar to the 6AS7G. It was manufactured by Tung-Sol under contract to WE, along with 422As.

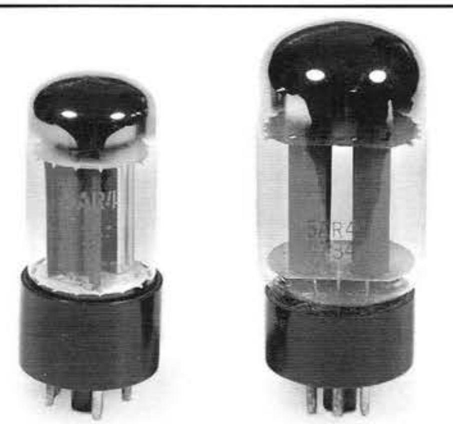
Even though British companies were on the forefront of rectifier development in the 1920s, by 1935 they had resorted to producing variations of American types on octal bases. Mullard's GZ30 was a 5Z4 replacement, the GZ31 was a 5U4, the GZ32 was an uprated 5V4, and GZ33 and GZ37 were like indirectly-heated 5U4s. I can find no evidence that a GZ35, 36, 38 or 39 were made. GZ tubes with other numbering, such as GZ40, had other base types. Currently many hi-fi amps are being equipped with surplus CV378s, which are simply British army versions of the GZ32. One sees them in Cary Audio products. Mark my words--when that small supply runs out, those excellent rectifiers will be impossible to find, and costly.

In spite of the impressions of modern audio-tube users, the 5AR4/GZ34 came very late in the game. It was introduced by Philips at the same time as the EL34, and was intended to power EL34 audio amplifiers. Unlike most previous rectifiers, it had a button base and a short envelope from the start--allowing the design to be used in low-profile hi-fi equipment. One sees an occasional mid-1950s audio amp which used a 5U4 mounted on its side; the GZ34 put an end to that.

The earliest GZ34 versions, made by Philips, Mullard and Telefunken, had the same metal base ring as the early EL34. Although branded by other manufacturers, it is probable that many of the early metal-based GZ34s were made by Philips in Holland. The later version, with the plain bakelite base, was made by Mullard in vast numbers from about 1957 until 1982. Versions with wider bakelite bases were made during the 1957-61 period. And like the EL34, both GE and Sylvania started making their own 5AR4 in 1969-70 until the late 1980s, simply because they were sick of rebranding Mullard GZ34s.

M-OV made a few octal rectifiers similar to American types, such as the U50 (like 5Z4) and U52 (indirectly heated, replaces either 5R4 or 5U4). Their GZ34 version was called U77. M-OV's famous AUDIO AMPLIFIERS booklet usually recommended a U77, U50, U52 or 5U4 to power KT66, KT77 or KT88 amps. For really large amps, they recommended full-wave bridges made of four xenon-filled GXU1s or GXU50s.

Because of all those Dynaco hi-fi amps and



GE 5AR4, Sylvania 5AR4 (USA-Made)

Metal-Based Mullard GZ34 (1950s), Genalex U52 (1960), and Russian (Svetlana) 5U4C (1950s)

FULL-WAVE RECTIFIER **GZ34**

Indirectly heated full-wave rectifier primarily intended for use in a.c. mains operated equipment.

HEATER

V_h	5.0	V
I_h	1.9	A

LIMITING VALUES

P.I.V. max.	1.5	kV
$i_{a(pk)}$ max.	750	mA
C max.	60	µF

$V_{a(r.m.s.)}$	2×300	2×350	2×400	2×450	2×500	2×550	V
Capacitor input							
I_{out} max.	250	250	250	250	200	160	mA
R_{lim} min. (per anode)	50	75	100	125	150	175	Ω
Choke input							
I_{out} max.	250	250	250	250	250	225	mA
R_{lim} min. (per anode)	0	0	0	0	0	0	Ω

TYPICAL OPERATING CONDITIONS

Capacitor input

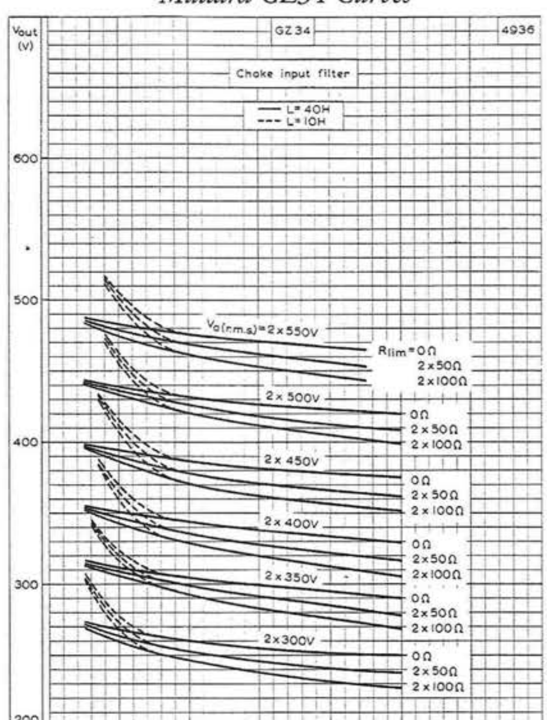
$V_{a(r.m.s.)}$ (V)	I_{out} (mA)	C (µF)	R_{lim} (per anode) (Ω)	V_{out} (V)
2×300	250	60	75	330
2×350	250	60	100	380
2×400	250	60	125	430
2×450	250	60	150	480
2×500	200	60	175	560
2×550	160	60	200	640

Choke Input

$V_{a(r.m.s.)}$ (V)	I_{out} (mA)	L (H)	R_{lim} (per anode) (Ω)	V_{out} (V)
2×300	250	10	0	250
2×350	250	10	0	290
2×400	250	10	0	330
2×450	250	10	0	375
2×500	250	10	0	420
2×550	225	10	0	465

Mullard GZ34 Electrical Specifications

Mullard GZ34 Curves



CHOKE INPUT FILTER REGULATION CURVES

Tube Rectifier Table

Type	Filament	Rated PIVmax	Iout	DC Forward drop
<150 mA DC output rating:				
5AZ4	5v, 2A	1400v	125 mA	60v
5CG4	5v, 2A	1400	125	no rating
5W4, GT	5v, 1.5A	1400	100	45
5Y3, G	5v, 2A	1400	125	60
5Y3GT	5v, 2A	1400	125	50
5Z4,GT	5v, 2A	1400	125	20
5690	6.3v, 2.4A	1120	125	17
6087	5v, 2A	1400	125	50
6106	5v, 1.7A	1550	125	60
6853	5v, 1.7A	1550	125	60
GZ30	5v, 2A	1400	125	71 max
R52	5v, 2A	700 vct max	125	no rating
U50	5v, 2A	700 vct max	120	no rating
150-250 mA DC output rating:				
5AR4/GZ34	5v, 1.9A	1500v	250 mA	30v
5AW4	5v, 3.7A	1550	250	46
5AX4GT	5v, 2.5A	1400	175	46
5R4G/GY/GA	5v, 2.0A	2800	250	67
5R4GYB	5v, 2.0A	3100	250	63
5T4	5v, 2.0A	1550	225	45
5U4G	5v, 3.0A	1550	225	44
5U4GA	5v, 3.0A	1550	250	44
5U4GB	5v, 3.0A	1550	275	50
5V4G/GA	5v, 2.0A	1400	175	25
274B	5v, 2.0A	1550	225	no rating
GZ33	5v, 2.8A	1250	250	no rating
GZ37	5v, 2.8A	1000 vct max	250	no rating
52KU	5v, 2.0A	1000 vct max	150	no rating
53KU	5v, 2.8A	1000 vct max	250	no rating
54KU	5v, 2.0A	700 vct max	250	no rating
U52	5v, 2.25A	1000 vct max	250	no rating
U54	5v, 2.8A	1000 vct max	250	no rating
>250 mA DC output rating:				
5AS4	5v, 3.0A	1550v	275 mA	50v
5AT4	5v, 5.5A	1550	800	30
5AU4	5v, 3.75A	1400	325	50
5V3	5v, 3.8A	1400	350	47
5V3A	5v, 3.0A	1550	415	42
422A	5v, 3.0A	1800	400	no rating
5931	5v, 3.0A	1700	300	47
GZ32	5v, 2.8A	1000 vct max	300	no rating
CV378	same as GZ32			

Basic Data on Full-Wave Octal Rectifiers With 5Y3-Like Basing

WARNING: You should never, ever substitute a rectifier in your amp whose filament draws more current than the rectifier the amp was designed for! Nor should you try to use a rectifier which isn't rated for the DC output current needed. If your amp uses a 5AR4, do NOT try a 5Y3, 5U4, U5x or CV378--no matter how tempting it is.

Ratings for some types can vary from one maker to another--following are believed the most commonly-seen ratings.

guitar amps that used it, manufacture of GZ34/5AR4 types continues in Russia and China, though at very low levels compared to audio output tubes. Indeed, the only other vacuum rectifiers still being made (except for a few exotic high-voltage devices) are believed to be the Svetlana 5U4G and 6D22S. The former was used in millions of pieces of Soviet electronics, while the latter was the damper diode seen in color TV sets made by Positron Electronintorg of St. Petersburg (now defunct). Only by accident are these types still available; the Svetlana-Malevishera affiliate factory which has produced them for decades is still there, though hanging by a thread.

4. Why They Can Sound Different

Firstly, we need to comment on the urban legend that the 5R4 sounds better than the 5U4 when used to power a SE tube amp. As Norm Braithwaite points out, the amp's transformer saturates less with a 5R4 rectifier than with a 5U4, because the 5R4 drops more voltage, thus passing less current (the tube's bias voltage not having been adjusted by the geniuses who did these tests)--thus, less distortion due to less saturation.

Second, because different tube manufacturers used similar-but-different cathode materials, the short-pulse emission characteristics of a given tube can be less or more than a similar type that otherwise tests the same. Full-current emission (sometimes called "charge-limit emission") is rarely given as an official rating. In the case of small octal rectifiers, it was not regarded as being important. This is usually most noticeable with guitar amps, which are often run deep into clipping and have poorly filtered plate supplies.

If you want a recommendation, we can't do that--every amplifier responds differently. However, we can give some pointers.

1) Design your power supply to be clean and well-regulated. This can be done with electronic regulators. However, we seriously question the need for this. Adequate plate-supply filter capacitance, with all amplification stages decoupled separately, will do far more for the performance

of an amp than swapping rectifier tubes. DIYers have more freedom than the buyers of commercial products, because the manufacturers of amps often try to cut corners and save money, and the most obvious way is to leave out decoupling stages.

2) Single-ended Class-A tube amps can be sensitive to rectifier choice, usually for reasons such as we have already mentioned--not for good reasons, mind you. A properly designed SE triode amp should NOT be sensitive to the type of rectifier tube--and push-pull amps will tend to be even less sensitive. Class-A tube amps do not need huge quantities of filter capacitance, for much the same reasons. (Provided they are well-designed, something which is often not the case.)

3) If you are blessed with a vintage amplifier, stick to the type of tube it was designed to use. Don't experiment blindly. Due to the lower quality of modern valves (and resulting lower plate voltages being run in modern tube amps), NOS GZ34s would be strongly recommended for vintage amps such as the Dynaco Mk. III, which is very hard on rectifiers. For that matter, if you want to make your vintage amp last, get a Variac or autotransformer and set it to produce AC mains voltage 20% less than the stuff coming out of the wall socket. Yes, you will get a little less power output--but your tubes will be very, very happy, and so will the power transformer.

4) The "best" is a relative term. If you want the best rectifier tube, go with mercury vapor--provided you are willing to deal with scarcity, and the threat of mercury poisoning if a tube is broken. The best rectifier from the standpoint of ultimate performance is clearly the FRED diode, not any rectifier tube. However, if you insist on a VACUUM rectifier tube, the best performance overall probably comes from damper diodes. They are ideal for DIY, since they are cheap and plentiful.

The Ultimate Octal Rectifier--You Never Heard of It!

Our "best" rectifier isn't the 5R4WGB "potato masher" so often seen in ***Sound Practices*** projects; it isn't the 5931, or the red-base 5690 (which saw little use anyway), nor is it any of the Bendix Red Bank types. Chatham (later Tung-Sol), Raytheon and Hytron produced a tube that makes ALL other octal vacuum rectifiers look wimpy. The number is 5AT4. You want more figures? OK, the 5AT4 was introduced in 1959, and was very rarely used. We have only seen it in high-current regulated power supplies. Production ceased in the 1980s. It is capable of supplying up to 550 volts at 800 mA, into a choke-fed filter. Is that enough for you? And it would be amusing to watch some idiot buy a Chatham 5AT4 (it is indeed very scarce and hard to find) and plug the tube into their 5AR4 socket and get a nice cloud of smoke, as the power transformer burns up. Alas, the 5AT4's heater draws 5.5 amps at 5 volts. Don't say you weren't warned!

Chatham 5AT4

5. Exit

As a final note, we must warn that the vacuum rectifier might not be a viable product for the future. Very few modern guitar amps use tube rectifiers; those that do are currently going through surplus stock of the Svetlana 5Y4S/5U4G, which is the only such tube still made. At least three new 5AR4 versions have been made in the last 10 years, two by Sovtek/Reflector and one from China. It is hoped that the current Reflector version, called GZ34EH, will prove to be decently reliable, because in a few years it may be the only game in town--though there is rumored to be a very good GZ34 coming soon from JJ Electronic. Very few high-end audio manufacturers use rectifier tubes, since they are convinced that semiconductor diodes give superior performance (silicon certainly is much more economical). Persons who feel that the vacuum rectifier is a valid product, and who want it to stick around for a while, should support what manufacturing still exists; and not call dealer after dealer, frantically looking for NOS bargains. Soon there won't be any.

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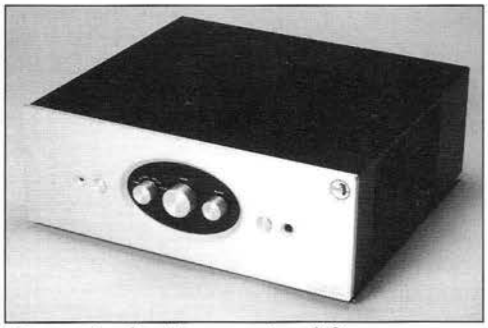
Our thanks to Norm Braithwaite, John Eckland, Bill Condon, Igor Popov and Ludwell Sibley for their invaluable assistance in researching this subject. Igor provided a copy of the rare WIRELESS WORLD Valve Directory which made it possible to examine prewar British rectifier data.

Rogue Audio Tempest Amplifier

A VTV Product Review

By David Bardes

Not too long ago, I was auditioning some speakers in a local hi-end shop. I had been shopping around for a pair of speakers, but auditioning speakers at the local dealers was disappointing because they always had the speakers hooked up to some "buzz saw" solid state amp. When the music started playing this time, however, there was no glassy haze, no gritty bite, and no brute force dynamics. My head snapped back to the equipment rack and there was what appeared to be yet another transistor farm hidden behind a sculpted aluminum faceplate. But looks can be deceiving....



Rogue Audio Tempest Amplifier

This was my first experience with the Tempest from Rogue Audio. Mark O'Brien has taken a great sounding KT88 push-pull amp design and placed it in a full-featured package that will appeal to a much wider audience than just us tube-heads. The Tempest has the look and feel of "high-end", but delivers first rate tube sound. The thick aluminum faceplate and smooth-turning aluminum knobs give the amp that "ooh, ah" appeal, and setting the tubes inside the chassis dramatically improves the wife approval factor. In my opinion, a smart design for a very competitive marketplace.

The Tempest is an integrated, 60-watt per channel amp with some very flexible features. One can use the onboard preamp, but if you want to use a separate preamp, shunt switches are provided. On the back, gold plated RCA jacks provide 5 inputs and active and passive preamp outputs. The power switch, mute switch, balance, and a selector knob are on the front. A remote volume control is also included. But for me the winning feature was a set of switches on the main circuit board that allows for an easy transition from ultralinear operation to triode operation.

A look under the cover reveals a tidy circuit board and chassis layout. The selector knob has a rod that extends to the actual selector switch at the back of the amp to keep circuit paths short. Sizeable polypropylene coupling caps were also in evidence. Lastly, a fan is used to keep the chassis and tubes cool. At first I thought it was strange that the fan blew the warm air out the side of the chassis and not the top, but in a crowded rack, side-draft cooling may be the way to go.

A couple of niggling details. The amp has a phono input but does not contain a phono stage. Mark said that he felt sure that folks who bought this amp would have their own ideas about phono stage amplification, but customer feedback has been otherwise. Don't let this stop you from considering this amp however, just know that the amp is missing this feature. The other nitpick is the volume remote control which I found a little difficult to use. The range and off-axis sensitivity is quite good, but the volume steps are too large. I found myself always wanting a volume setting in between what was offered by the remote.

The amp sounded smooth and well balanced right out of the box, although it did break in some, and no apologies were needed when first listening to the Tempest. As a pass/fail test, I compared the Tempest to my vintage Citation II. At $2195 I expect an amp to sound better than even this tried and true classic. The Tempest was smoother and had a larger soundstage which made the Tempest easily more musical than the Citation. The Citation sounded more powerful, but that is most likely the sound of all that Hegeman feedback. The Tempest was also very quiet even when hooked up to my Klipsch Horns with the volume knob cranked up.

My personal listening diet is mostly jazz, and the Tempest handled intimate trio and quartet recordings with aplomb. For example, Paul Desmond's sax had full color and emotion while playing ***Gone With the Wind*** (Dave Brubeck Quartet). No, I didn't mistake the Tempest for an SE amp, and it didn't have the single ended "glow" on this recording, but bass lines were more dynamic and distinct, and the genius of Eugene Wright's upright bass style was clearly revealed with the Tempest.

Moving to other musical genres, the Tempest was even more impressive. Rachmaninoff's Concerto in C Minor for Piano and Orchestra was stormy and windswept as it played through the Tempest. The piano played distinctly in the foreground even with the orchestra swelling to a full crescendo. There was no hint of congestion or confusion and there was plenty of headroom, even at loud volumes. Pop recordings had plenty of thump and pacing. The Tempest made Candy Dulfer's version of ***Pick Up The Pieces (The Best of Candy Dulfer)*** driving and rhythmic.

When I switched the amp into triode mode, I expected a reduction in volume and sensitivity, but that was not the case; if anything the amp sounded more powerful. I'm sure, however, less sensitive speakers would reveal the power difference between the triode and ultralinear settings. What did change was the sound quality of the amp. I was expecting maybe a little bigger soundstage and a sweeter high, yet what I heard was an opening of the midbass and lower midrange. Now there was real warmth and detail across the entire frequency spectrum. Low level detail increased and reverb and ambiance cues were heightened.

Andreas Vollenweider's electric harp plays in a bath of reverb with delicate long sustains in **The Five Curtains** (**Book of Roses**, Andreas Vollenweider). This selection has been turned to mush with other amps in my living room, but the triode configured Tempest provided the detail and dynamics to carry it off in style. Revisiting earlier selections proved again and again the musicality of the triode setting.

The Rogue Audio Tempest is a full-featured integrated amp that is super musical in triode mode, and quite respectable in ultralinear mode. That one has the option to choose which is best makes this amp a standout. For those music lovers who don't know from tubes, the conservative design and ease of operation make the amp less intimidating. For tube enthusiasts there are lots of tube rolling options, and the natural tube sound we know and love.

The scale is 1 to 5 with a score of 5 being the very best

Overall Rating: 4.5

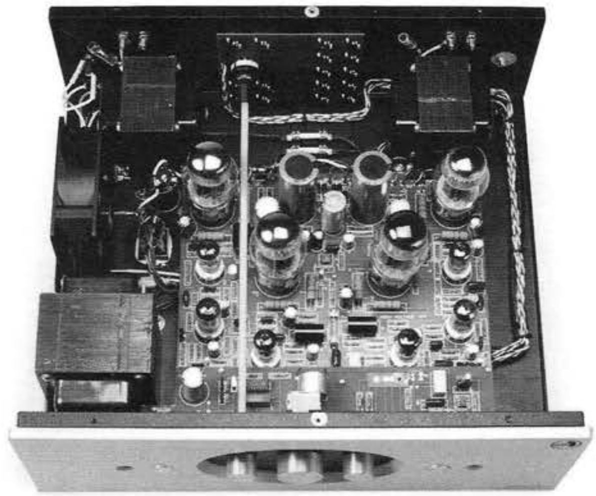
Test System Components:

Jolida JD 603 CD player with Mullard CV4004 tubes in the analog output section

BL S38 loudspeakers (I used the 4 ohm tap on the amp for my review)

Homebrew fine wire speaker cables using three strands of 30 awg silver-coated copper wire in a kynar jacket

Rogue Audio Tempest Amplifier (top view)



TEK LINE PC -12 Signature power cords for both the amp and CD player

VSE Super Clear interconnects

Rogue Audio Inc.
675 Route 209 Sciota, PA 18354
570-992-9901 www.rogueaudio.com

Rogue Tempest Specifications:
MSRP: $2195 with remote

Output Power: 60 watts per channel

Tube Compliment: 4, KT88s (Sovtek); 4, 12AU7s (Jan Phillips); and 2, 12AX7s (Sovtek)

Frequency Response: 10 Hz -20Khz

THD: < 1% at rated power

Input Sensitivity: 1 volt RMS

Dimensions in inches: 18.25 W x 15.75 D x 7 H

Weight: 60 lbs.

Power Requirements: 115/230 V - 50/60 Hz

Tempest	Dynamic Range	Transparency	Frequency Extension
Ultralinear	4	4	4
Triode	4.25	4.25	4.5

Tempest	Dimensionality	Pace and Rhythm	Musical Involvement
Ultralinear	4	4	4.25
Triode	4.5	4.25	4.75

Book Review: Two Books About M-OV

A VTV Book Review

By Eric Barbour

For years, we at VTV have decried the lack of historical information about British valve manufacturers. While American organizations such as the TCA have been able to rescue priceless collections such as the RCA archive, the UK valve industry appears to have disappeared almost completely, leaving few traces.

Marconi-Osram Valve, one of the best UK firms, is a case in point. Although M-OV dominated the manufacture of commercial and industrial valves, and had many "firsts" to its credit, the only remaining building from M-OV's home facility at Brook Green, Hammersmith, London, is now a Tesco supermarket. When M-OV quietly closed its doors in 1988, the world lost one of its most obsessively perfectionist valve manufacturers. This fact is only now becoming apparent, mainly thanks to two books that have been published since 1999.

Noted Australian collector Fin Stewart produced the first such book, about two years ago. At first it was distributed only by TCA member Al Jones, although it is now available from antique-radio parts dealers. Fin's book is a solid and well-researched document about how M-OV was founded and how it matured through the pre-WWII period. As with many tube factories, M-OV started out as the Robertson Lamp Works, making carbon-filament Edison electric bulbs. Later, as a division of the giant part-RCA-owned General Electric Company (not directly related to the American GE), it became Osram Lamp Works, then Osram Valves and Lamps, then Marconi-Osram, and finally simply GEC or Genalex. For most of its history, its radio valves bore either the Marconi or the Osram trademark, and only later did the "Genalex" name appear, mostly applied to hi-fi audio tubes such as the KT series. And its status as the best of British valve manufacture is ironic, as the GEC firm was originally bankrolled by German expatriates Hugo Hirst and Gustav Byng. Even more ironic is Fin's revelation that after Hirst retired in 1943, the firm floundered due to mismanagement, and was nearly taken over by English Electric in 1963.

The history of M-OV is well summarized in Fin's book, including a listing of all their low-power valve products, pre-1939 and post-1940 and including cross-references to UK military CV and VT numbers and to commercial types. This list is handy, as M-OV insisted upon using their own unique numbering system rather than the European system. Even though they made an EF86, they insisted upon calling it Z729. The post-1940 list appears to end sometime in the late 1950s, as the KT77 and KT88 are not mentioned.

Fin even includes a list of experimental types, having designators beginning with A and E. These were usually not made available to the public and are little known today. Many were made for a single customer, usually affiliate firms Marconi or EMI, and for special jobs.

Fin's book was barely off the press when VTV received a copy of an even newer book, THE SAGA OF MARCONI-OSRAM VALVE. Written by former M-OV employees Barry Vyse and George Jessop, SAGA is packed with technical facts and small details of how M-OV developed its lasting reputation. This book is unique, as one of its authors (Jessop) worked at the subject company for 60 years! He must have known something....

There is an essential fact about the Vyse/Jessop book that makes it unique among books for tube collectors. Whereas tube factories commonly treated manufacturing processes as important trade secrets, M-OV was unusually open with their innovations. They rarely patented their processes, and often shared them with competitors such as Mullard and Cossor. This odd tradition carries on with the SAGA book. Vyse and Jessop reveal lots and lots of details about how the valves were actually made. There is sufficient detail in this book to allow a smart engineer to produce very good reproductions of many of M-OV's popular receiving valves. Cathode materials, anode materials, tooling design, vacuum processing, on and on. Anyone having the nerve (or insanity, if you like) to start a new tube factory would be a fool not to read the SAGA book. It contains massive quantities of detail, unique in the vintage-electronics world, thus making it a priceless document.

SAGA, like Fin's book, concentrates on the development of radio valves, from primitive tungsten-filament triodes, through the Round R-series of WWI types, and including the T and MT series. Much coverage is offered of the 1928-1935 period, the age of the "dull emitter" DE series and of the rise of the oxided filament and indirect heating.

And SAGA has the only coverage of M-OV's early CAT series of high-power transmitting valves, which were among the first to use external anodes and water cooling. I have never seen any treatment of the CAT series, except for very rare original data sheets. SAGA devotes a whole chapter to them. I did not know that the 150 kW CAT14, still one of the most powerful triodes ever built, was developed before 1930. Also covered in detail is the WWII period, including M-OV products such as the GT1C gas relay valves which were used in the "Colossus" codebreaking machines--among the first electronic computers ever built.

Neither book is perfect, however. The Stewart book is obviously a photocopied, velox-bound home production; the illustrations are not very well reproduced, and the text appears to have been laid out on an old IBM typewriter. The SAGA book is much more attractive, was professionally bound and laid out, and has illustrations of good quality; however, it suffers from a lot of run-on sentences and poor punctuation, and would have benefited from more professional copy-editing. Reading it can be slow going.

That said, we would recommend that serious students of UK valve manufacture obtain both books. Stewart takes a more distant and historical view, while Vyse and Jessop have produced more of a personal memoir of M-OV's internal operation. The books cover the early days of the factory in good detail, yet are otherwise quite divergent. They appear to complement each other.

If the reader has any interest in just why M-OV has retained such a strong reputation for high quality, either of these books will suffice. If more detail is wanted about how M-OV valves were manufactured, the SAGA book is highly recommended. Audio tube users can no longer claim that the "secrets" of M-OV products are unknown or lost. Manufacturing good-quality valves is not a magical art, just a vanishing one.

One last note--judging from these books, M-OV is gone for good. There have been persistent reports that the KT88 will be revived, under specialist manufacture somewhere in the UK and distributed by Western Electric. However, since these reports have been going on for more than 10 years, and since the M-OV oldtimers are now dying off (indeed, George Jessop died shortly after his book was printed), we are still waiting to see a revival of this M-OV classic.

History of GEC and the Marconi-Osram Valve, written and published by Fin Stewart, Dec.1998. 132 pages. Suggested. retail US$25.00. Fin Stewart, Cockerdale, 380 Bulga Rd, Wingham NSW 2429 Australia.

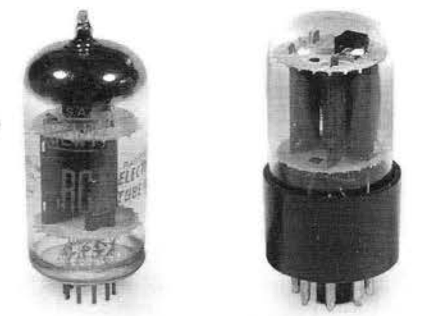
The Saga of Marconi-Osram Valve, by Barry Vyse and George Jessop, Vyse Ltd, 2000. 346 pages. Suggested retail UKP35 hardback, UKP25 softback. Vyse Ltd, 14 Cranbourne Drive, Pinner, Middlesex HA5 1BZ, UK.

Both books now available from Antique Electronic Supply.

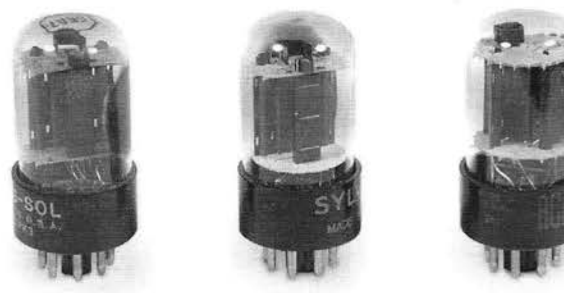
Dumpster Tubes: Dissimilar Dual Triodes

By John Atwood

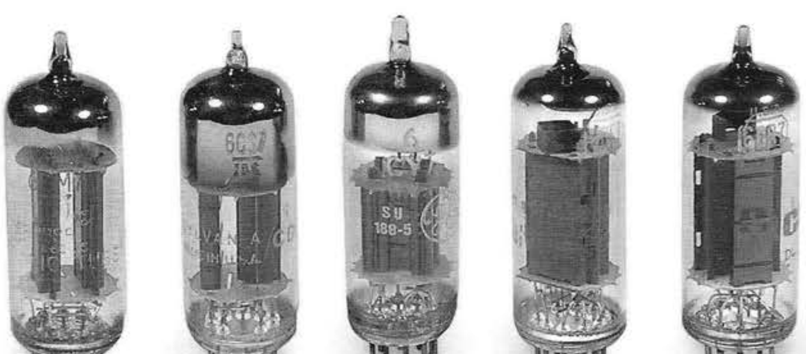
In the last issue of VTV, vertical output triodes were described, including dual triodes with identical sections. This time we will look at dissimilar dual triodes for vertical sweep applications. As mentioned earlier, this is solely an American type of tube, since the Europeans and eastern-bloc countries nearly always used pentode vertical output stages. While dual triodes such as the 6SN7GTB or 6BL7GTA served the purpose of vertical oscillator and power amplifier well for early televisions, the advent of 110 degree picture tubes and color television raised the power levels needed for both horizontal and vertical deflection. At the same time, cost pressures favored combining the vertical oscillator and output tubes. Since the oscillator triode did not have to handle high power, it was more economical to spend the tube cost and heater power on only one power triode, leading to the dissimilar dual triodes.



GE 6EW7 and RCA 6DN7



Tung-Sol 6EA7, Sylvania 6EM7, RCA 6GL7

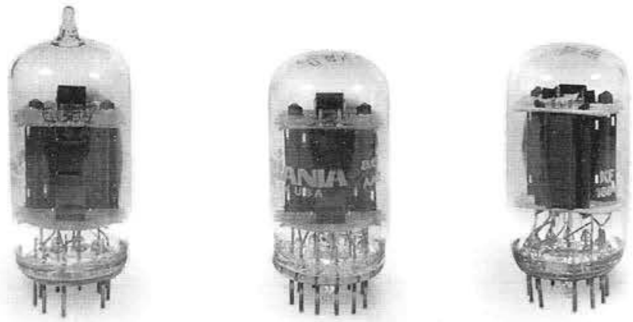


Westinghouse 6CM7, Sylvania 6CS7, GE 6CY7, RCA 6DE7 and RCA 6DR7

The first dissimilar dual triodes were intended for compact, lower-cost sets, and were in the 9-pin noval format. The 6CM7 and 6CS7 were typical. At first the oscillator was a medium-mu triode, similar to one half of a 6CG7, and the output triode was also medium-mu, but with lower plate resistance and higher power ratings. A change in American television design in the mid-1950s brought about the need for a different dissimilar triode. Up until then, the oscillator was almost always a blocking oscillator that used a small transformer to provide the required positive feedback. The vertical output stage then amplified the modified sawtooth signal from the blocking oscillator. Medium-mu triodes worked best as these oscillators. To cut costs, the oscillator transformer was eliminated and the circuit changed to an astable multi-vibrator (free-running sawtooth oscillator) with one of the two tubes being the power output triode. To get the best efficiency, the power triode needed low mu and low plate resistance, and to make up the gain, a high-mu triode was used for the first stage. The result were the miniature 6CY7 and 6DR7 and the octal 6EA7/6EM7/6GL7 types. Some TV engineers still liked the medium-mu first stage, so tubes like the 6DE7 and 6DN7 were produced.

When high power was needed, as in most sets by the late 1950s, the larger envelope of the octal types was preferred. However, by the early 1960s, there was a push to eliminate the octal base and use more modern all-glass envelopes. Each major manufacturer introduced their preferred types. Sylvania introduced a series of T-9 tubes that were as large as octals, but had regular 9-pin miniature (noval) bases. The 6EW7 and 6FR7 are examples of these. General Electric was pushing their compactron tubes, and even though the various sweep tubes did not need all 12 pins, the larger envelope handled the high power well. Vertical sweep compactrons include the 6FJ7, the 6FM7, and the 6FY7. RCA developed the novar series of power tubes with a large-diameter 9-pin base, represented by the 6GF7. All these different types got designed into millions of TV sets, so nearly all tube manufacturers ended up making some or all of the competing types. The second-tier manufacturers, such as Tung-Sol and CBS-Hytron, as well as many of the Japanese producers, second-sourced these types, too.

Table 1 lists the important characteristics of the American vertical sweep dissimilar triodes. The pin connections of the octal types are the same as the 6SN7GT,



Sylvania 6GF7, Sylvania 6FM7 and RCA 6FM7

but the other types vary, so a tube manual should be consulted for their pin connections. Table 2 lists the series-string variants of the 6.3 volt types listed in table 1. Often series-string types are more available, so if you are willing to provide a non-standard heater voltage, you will have access to lots of cheap but good tubes.

One reason the dissimilar vertical sweep dual triodes do well in audio applications is that the high-power requirements dictate a large internal structure. Even the low-power triode is built large and strong, much like the triodes of a 6SN7GT. These large structures have larger spacings between elements, which leads to better linearity. However, they can be somewhat microphonic, so they should be avoided for low-level signal stages. As with any dual triode, there is the issue of electron coupling between the two sections. This is no worse in the dissimilar dual triodes, but some of the 9-pin novar types, such as the 6CY7, 6DE7, and 6DR7, have an internal shield between sections that is connected to the cathode of the power triode.

Dissimilar dual triodes have several applications in the tube audio world. The combination of a high-mu triode and low-Rp triode in one envelope can make a simple tube regulator. One constraint to keep in mind with this application is the maximum heater-cathode voltage: +200V cathode-to-heater or -100V cathode to heater. Thus if a 350V output regulator is being designed, the heater must be floated to at least +150 Volts. The MFA Luminescence preamp uses the 6EM7 tube as a regulator.

A dissimilar dual triode can be used for a simple, low-power single-ended power amplifier. About 1 to 2 watts can be obtained. Doc Bottlehead's S.E.X. Amplifier uses the 6DN7 this way. Back in the 1960s, Heathkit used a 6DE7 as a screen modulator amplifier in their DX-60 ham radio transmitter.

Series-String Variants

Name	Vfil	Ifil	Prototype
8CM7	8.4	0.45	6CM7
8CS7	8.4	0.45	6CS7
8CY7	7.9	0.6	6CY7
10DA7	10.5	0.6	6DA7
10DE7	9.7	0.6	6DE7
10DR7	9.7	0.6	6DR7
10EM7	9.7	0.6	6EM7
10EW7	9.7	0.6	6EW7
10FD7	9.7	0.6	6FD7
10FR7	9.7	0.6	6FR7
10GF7	9.7	0.6	6GF7
11CY7	11.0	0.45	6CY7
11FY7	11.0	0.6	6FY7
13DE7	13.0	0.45	6DE7
13DR7	13.0	0.45	6DR7
13EM7	13.0	0.45	6EM7
13FD7	13.0	0.45	6FD7
13FM7	13.0	0.45	6FM7
13FR7	13.0	0.45	6FR7
13GF7	13.0	0.45	6GF7
15EA7	14.8	0.45	6EA7
15EW7	14.8	0.45	6EW7
15FM7	14.8	0.45	6FM7
15FY7	14.7	0.45	6FY7
19DE7	19.4	0.3	6DE7
19EW7	18.9	0.3	6EW7

Table 2

Table 1

			low-power section			high-power section		
Name	Base	Ifil	Pdmax	mu	gm	Pdmax	mu	Rp
6BN7	noval	0.75	1.6	28	2000	8.2	12	2200
6CM7	noval	0.6	1.45	21	2000	6	18	4100
6CS7	noval	0.6	1.4	17	2200	7	15.5	3450
6CY7	noval	0.75	1	68	1300	5.5	5	920
6DA7	noval	1.0	2.2	20	2600	6.5	6.3	1100
6DE7	noval	0.9	1.5	17.5	2000	7	6	925
6DN7	octal	0.9	1	22.5	2500	10	15.4	2000
6DR7	noval	0.9	1	64	1600	7	6	925
6EA7	octal	1.05	1	66	2200	10	5.5	920
6EM7	octal	0.925	1.5	64	1600	10	5.4	750
6EW7	noval *	0.9	1.5	17.5	2000	10	6	800
6FJ7	compactron	0.9	1	22.5	2500	10	5.5	920
6FM7	compactron	1.05	1	66	2200	10	5.5	920
6FR7	noval *	0.925	1.5	68	1600	10	5.4	750
6FY7	compactron	1.05	1	65	1600	7	6	920
6GF7	novar	0.985	1.5	64	1600	11	5.4	750
6GL7	octal	1.05	1	66	2200	10	5	780
10EG7	octal	0.6 †	1.5	17.5	2000	10	6	800

* - T-9 bulb (1⅛" dia.) † - 9.7V filament Pdmax normalized to "Design Maximum" ratings.

With the increased interest in using interstage transformers in tube amplifiers, dissimilar triodes can be especially convenient. The low-Rp power triode is ideal as a transformer driver. Tubes with high-mu low-power sections, though, will often give too much overall voltage gain, unless feedback is used. Tubes such as the 6DE7, 6DN7 and 6EW7 are better-suited to this application. The experimental RF-driven 300B amplifier, described in VTV issue 15, page 16, uses a 6EW7 as a driver tube.

Again, these TV dumpster tubes are still around, and in the case of these dissimilar triodes, are quite useful for audio applications!

References:

1. **Essential Characteristics**, General Electric Co., , 1974

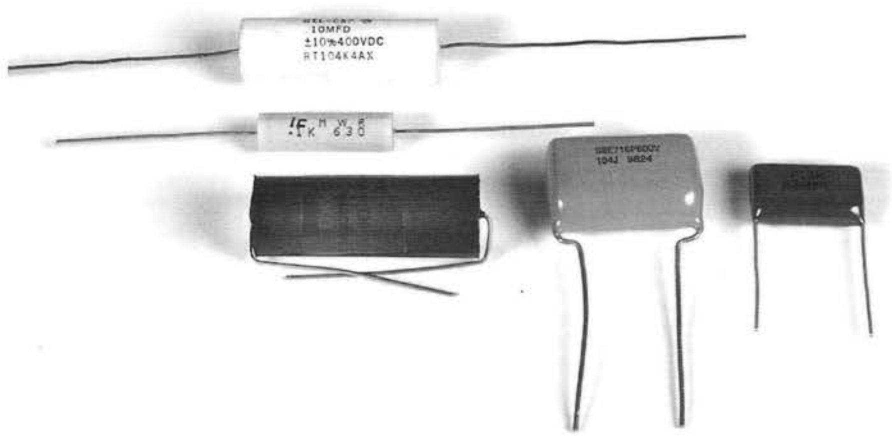
How to Determine the Outer Foil of a Film Capacitor

By Eric Barbour

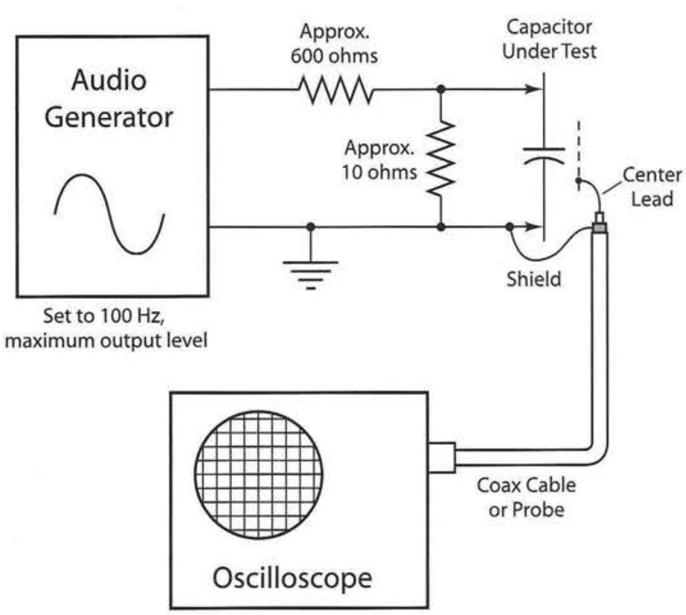
First, let's get one thing clear: although the connection of a film capacitor can have an effect on the sound of a tube amplifier, we feel that people worry about this issue excessively. All mass-produced capacitors will have a consistent construction, so that the outer foil will always be connected to the lead on a given end. This end is usually--but not always--the end marked with a stripe or the end at which the text marking begins. So long as the capacitors are installed consistently throughout an audio circuit, any effect caused by the capacitive coupling of the outer foil to other circuitry will be consistent between the two channels of a stereo system.

However, we at VTV do get a surprising number of inquiries about the technical method for determining the outer foil. Many cheapskate DIYers like to mess around with junk-box or flea-market capacitors, yet there is no guarantee that a random capacitor will have its outer foil connected to a given lead. So, we will explain how to find the outer foil of a two-lead film or paper capacitor. It's simpler than most people think. This method works for axial or radial types, and for any kind of film or foil.

All you need are an audio signal generator, a good oscilloscope with 1-megohm or higher input impedance, two resistors and a strip of aluminum foil narrower than the capacitor is long. As shown in the schematic, connect the capacitor to the signal generator through a resistive divider. Then wrap the foil around the capacitor (being careful not to short it to one of the leads) and attach the scope lead to it. If the outer foil is connected to the "hot" side of the divider, you will see a very small signal on the scope; if the outer foil is grounded, you'll see nothing on the scope.



Capacitors (Top left to right): Rel-Cap, IC-MWR, Silver Ultra-Tone, 716P Orange Drop, Nichicon



Setup for finding the outer foil of a capacitor.

If you are testing a metal-cased capacitor with glass end seals (such as Sprague Vitamin Qs, etc.), the outer case usually floats with respect to the two leads. Just connect your scope probe to the case and proceed as before. Some such sealed capacitors have one lead permanently connected to the case, which also has a threaded mounting nipple, as seen in some Vitamin Qs which are meant for chassis mounting. Usually those types have the outer foil connected to the case anyway. See how easy that was? Now you can show other DIYers how to find an arcane bit of information.

A Philosophy of Safety for the Home Constructor

By John Atwood, Technical Editor

What is one of the main differences between commercial audio equipment (both pro and consumer) and home construction projects? Yes, mass-production, cost-engineering, and fancy instruction manuals come with commercial equipment, but the biggest difference is that they are required to meet strict product safety standards. In some cases companies are allowed to "self-certify," and in other cases the equipment must be tested by an independent test laboratory. The rules vary between countries. All equipment sold into the European Union must be certified and have the "CE" mark before it can be sold. In the United States, it is legal to sell uncertified equipment, but most insurance companies will not insure companies that sell potentially dangerous products that are uncertified. Within the United States, there are certain localities that require special certification, such as the City of Los Angeles.

So what does product safety have to do with the home constructor? If your latest amplifier project shorts-out, starts a fire, and burns down your house, many insurance companies would still pay the claim. But building equipment to avoid personal and property damage is not hard, and is much easier than rebuilding a house or replacing an electrocuted spouse! This article will outline the general philosophy of safety and give specific details on how to build safer equipment. The primary focus will be on American standards and customs, as covered by UL (Underwriter's Labs) requirements. Some material covering European standards will be given as well.

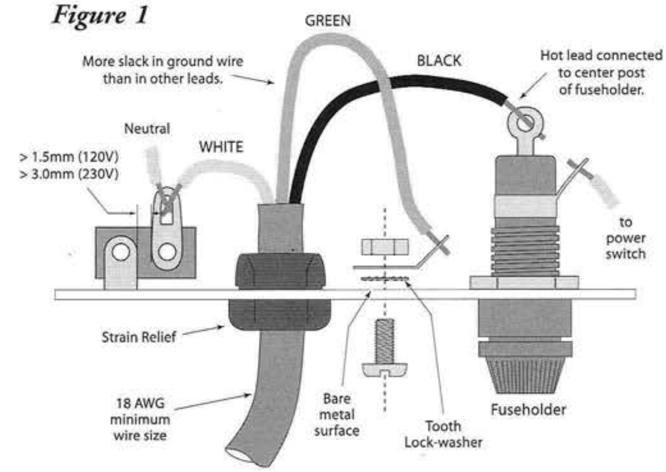
The official safety standards for audio/radio equipment are listed at the end of this article. They are quite detailed and cover things like creepage distance, insulation flammability, drop tests, etc. They are also quite expensive -- hundreds of dollars each. To truly meet safety requirements, these standards must be followed by trained engineers, and the equipment successfully evaluated by a qualified lab. The information here is intended to let equipment builders be aware of some safety concerns and to help them build safety into their projects.

The home builder of tube-type equipment confronts three major safety concerns: electric shock, burns, and fire. The degree of protection depends on the ultimate environment of the equipment. A bench prototype in a lab that can be only accessed by the responsible builder could have exposed high voltages and hot tubes that would be unthinkable if it were being used in a child-care center! However, even if you think that only careful people will be around your latest breadboard creation, beware of the unexpected: cleaning ladies, guests, pets, etc. Even if you are a hermit, it is prudent to build to basic safety standards so that you won't accidently electrocute yourself or burn-down your house.

Electric Shock

UL recognizes any AC voltage over 24.7 volts rms or DC voltage over 60 volts as hazardous. The actual degree of shock hazard of course depends on many factors, but the voltages present in nearly all tube equipment present serious and often fatal hazards. The two main sources of high voltage are the power line (120 or 230 VAC), and the "B+" plate supply voltage.

Figure 1



The philosophy of protection against shocks is twofold: 1. prevent any high voltages from being touched, and 2. prevent high voltages from appearing where they can be touched if any component or wire fails or short-circuits to any adjacent conductor. The first requirement is straightforward: make sure any high voltages are either enclosed or well insulated. Using those cool-looking all-metal plate caps on your 807s is no good if the tubes are exposed. Testing agencies use an "articulated finger" to simulate someone poking around the equipment. High voltage shorts to the finger are grounds for disqualification.

The second requirement for preventing shocks due to failures or shorts is more complex. Often builders will say "that component will never fail!" However, engineers know all too well Murphy's Law: that anything that can fail will fail, usually at the worst time. A wire could come loose and short to the chassis. The insulating sleeve on a capacitor could crack. A short-circuit in an output transformer could pull the secondary (and hence the speaker leads) to the full B+ voltage -- and the amp still runs! Given that problems like these are relatively rare, you don't have to get too paranoid and guard against double faults. But any fault should call attention to itself (before electrocution), otherwise it becomes an invisible "latent fault." Then the second fault could cause electrocution.

The most common and effective method of preventing shock hazards due to component or wiring failure is to use a safety ground. This is more than just a third wire in the power cord--it requires that all accessible conductive surfaces be securely connected to the safety ground so that any unwanted charge is drained to ground. If there is a hard short, the safety ground will blow a fuse or trip a circuit breaker, disabling the equipment and alerting the user to a problem. The idea is that it is better for the equipment to be dead than the user. The only place in industry where safety protection like this can be ignored is where shut down of the equipment could endanger lives, i.e., a nuclear plant controller or railway brake system. Home construction projects rarely fall into this category.

An alternative to a safety ground is "double insulation." This is used on things like electric drills, TVs, radios, etc. where a two-wire cord is used. Two layers of insulation are used so that even if one is compromised, the unit is still safe. This is nearly impossible to do for things like hifi equipment, ham radio equipment, guitar amps, computers, test equipment, etc., since the chassis is usually connected to externally-accessible points such as input jacks, antenna connections, or speaker connections. The result is that these kinds of equipment all come with three-wire grounded power cords.

But the audio enthusiast will complain "It hums with the three wire cord. I cut off the ground prong and it works great!" This is a sign that there is a ground loop between equipment in the system. Well-designed equipment won't inject hum into other equipment, but this is an imperfect world. The temptation to defeat the safety ground is great. But you (or your survivor) may have to face dealing with an electrocution. The litigation that could develop around an intentional defeat of the safety ground is mind-boggling! If you have hum problems, track them down and eliminate ground loops in other ways. One way is to use an isolation transformer to power the problem equipment.

The National Electric Code (NEC) still requires continuity of the safety ground, though. Another approach is to use transformer-balanced power- -instead of a hot and neutral, there are equal but opposite phases, each one-half the line voltage. See http://www.equitech.com/ and http://www.posthorn.com/Furman_3.html for more information on this.

There are differences between North American (120V) wiring standards and 230-volt standards that the home constructor may come across. In North America, one side of the incoming power is grounded at the power meter; this is called the neutral wire. The wire at 120V is the hot wire. The safety ground wire is run separately from the neutral. In correctly-wired installations, there is little problem with leaving the neutral connected to the equipment when it is turned off. A simple SPST switch in the hot line can be used as the power switch, as long as the equipment is not permanently wired to the power line. In some 230V systems, particularly where 3-phase wiring is used, both power conductors are "hot" relative to the earth ground. In these cases, both power leads are switched using a DPST switch. In any system, the safety ground is ***never*** switched.

The standard color codes for the two systems are:

	120V	**230V**
Hot	Black	Brown
Neutral	White	Blue
Ground(Earth)	Green	Green w/yellow stripe

There are several UL requirements for power line fusing and wiring that are summarized in figure 1. The first is that all wiring before the fuse be at least 18 gauge or bigger. Most home constructors will likely use 16 or 14 gauge wires. This is to insure that if there is a short that relies on the 20-amp circuit breaker in the house to trip, the wiring has low enough resistance to trip it. The hot lead (black in America, brown in Europe) should go to the inner post of the fuse holder. There are two reasons for this: if the fuse holder breaks and the outer shell shorts to the chassis, the fuse will blow. It also prevents the fuse from being "hot" and giving a shock if the fuse is replaced while the unit is plugged-in. The ground lead (green in America, green with a yellow stripe in Europe) should go directly to a ground lug firmly attached to the chassis. Either a toothed lock washer or toothed ground lug is required to break through any metal oxides. If the chassis is painted or anodized, the metal around the ground lug needs to be either masked or scraped so that the lug attaches to bare metal. Figure 1 shows a screw and nut attaching the ground lug, but a pressed-in metal stud is even better. The ground lead should have more slack than the other leads. If the cord gets pulled loose, the ground wire will be the last to go. A good cord strain relief, such as the Heyco type, should be used. Never run a power cord or any other wires that experience stress through bare metal holes.

The European safety standards require that a power cord be replaceable by the user. Since most users are non-technical, a plug and socket scheme is generally used, the IEC type being the most common. The requirements for power wiring (minimum wire gauge, direct grounding, etc.) are the same as mentioned above. I personally favor using wired-in power cords, since every connection raises the chances of bad contacts or unexpected unplugging. If I am the builder as well as the user, I am presumably skilled enough to replace the cord. The IEC plugs have the grave disadvantage that they are easy to pull out accidentally. The old Hubbell "Twist-Lock" plugs and sockets, such as used on older Tektronix scopes, are more reliable. On the other hand, pre-molded IEC cord sets are readily available.

All conductive surfaces that can be touched by the user must be firmly connected to the green-wire safety ground. Don't rely on screws through painted or anodized panels. If metal-to-metal contact cannot be assured, use a pressed-in screw or a ground lug with teeth and run a separate ground wire to the panel. By the way, in audio systems, this kind of grounding will reduce hum.

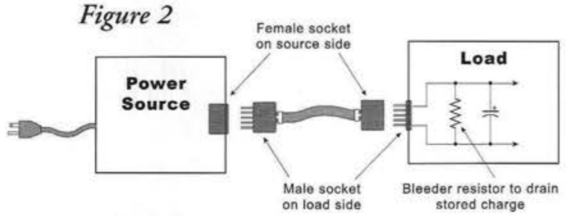
Since virtually all tube-type equipment uses hazardous voltages, care must be taken that these voltages are not exposed to the unwary user. Taking an open-bottom lab prototype to the living room for testing is fine, if super vised, but the bottom of the finished project should be protected from inquisitive children or careless cleaning ladies. Care must be taken that high voltages never appear on terminals that normally are considered "safe."

In a capacitively-coupled line-output stage, the output side of the capacitor can float to the plate voltage when nothing is connected to the output. This is especially a problem with very large capacitors or paper types that may have some leakage. The solution is to put a high-value resistor, say 1 Megohm, to ground. This drains any hazardous charge, and eliminates pops when plugging in other equipment.

Another case where "safe" terminals can become hazardous is if there is a primary-to-secondary short in the output transformer. This is actually not uncommon, especially in heavily interleaved transformers. A single short can bring both speaker terminals to the B+ voltage. Touching the speaker terminals while, say, moving the speakers, could be fatal! The solution is to make sure there is a low-resistance path to ground. Feedback amplifiers already have this, but some single-ended amps don't. Ground a terminal of the secondary. A short will then (hopefully!) blow the fuse.

If there are separate chassis that are connected by cables, care must be taken regarding the "sex" of any connectors. It should not be possible to touch hazardous voltages on any male pins, either on a cable or a chassis-mount socket. This means that the male pins have to point towards the power source, as shown in Figure 2. This is the opposite of

Figure 2



the scheme used in low-level audio connectors, such as XLR connectors. Don't mix hazardous voltages and audio signals in the same connector. This is good practice, not just for safety but for low hum and noise. UL and IEC require that any hazardous voltages on exposed terminals discharge to non-hazardous levels within two seconds of unplugging.

High-voltage capacitors used in tube-type equipment store energy. The voltages on them can remain for days if there is no discharge path. For completely enclosed equipment, this might not appear to be a problem, but is a risk to anyone modifying or repairing the equipment. If the stored charge on capacitors can be touched on male terminals, then promptly discharging the capacitor is required when the equipment is unplugged. The normal solution to this is to make sure there are "bleeder" resistors across all high voltage lines. These bleed-off any stored charge. The value of the bleeder resistors is a trade-off of power dissipation and time-to-discharge. Lower values discharge faster, but burn more power.

Burns and Broken Glass

Open chassis with exposed tubes are the most romantic way to view tube equipment, but they would not be able to pass a safety approval. The main problem is the possibility of unwary users getting burned on hot tubes. The maximum allowable temperature for accessible but not normally-touched parts is 65 degrees C, per the IEC 60065 and UL 6500 spec. Most power tubes get far hotter than this. Tubes are fragile and easily broken. A broken tube can cut, and also can expose hazardous voltages if the unit is powered-up.

The easiest solution to protect tubes from unwary users is to put a cage over the chassis. Various perforated metals are available from sheet-metal suppliers. However, make sure that there is enough ventilation so that too much heat doesn't build up.

Fire

There are many ways tube audio equipment can cause fires. Carbon-composition resistors can burst into flames when overloaded. Power or output transformers can internally short and overheat. High voltage supplies can arc over. Or there can be a simple short-circuit in the wiring that can cause over-heating. The chance of fire is greatly reduced by good construction practices. However, any component can break down or short-circuit, and protection is needed to prevent these faults from starting fires.

It is important to make sure flammable materials are kept away from sources of ignition. Resistors and large capacitors are liable to burst into flames when overloaded or internally shorted. They should not be near flammable material, such as non-heat resistant plastics (acrylic, polystyrene, etc.) or wood. Where there is a choice, consider using "flame-proof" metal oxide power resistors. These resistors are designed to open-circuit upon overloads, without producing flames. Many home constructors like using wood in their designs. Keep the wood parts away from any potential heat or flame-causing components. Consider lining the wood with sheet metal. This not only reduces the fire hazard, but provides shielding if the metal is grounded.

The most important aspect of fire prevention in electronic equipment is adequate fusing. You might wonder "why not just rely on the 20-amp circuit breaker protecting the house wiring?" Well, this circuit breaker does protect the power cord and power line wiring inside the amplifier. But what happens if, say, an output tube shorts to ground? There will be an immediate increase in B+ current, but the resistance of the output transformer and power supply filters keep the current draw from the wall outlet to well below 20 amps. However, many hundreds of watts of power is pouring into the amp, and at some point the heat build-up will cause something to burn. The key to providing protection is to insure that a fuse or breaker will open up if ***any*** component causes an overload.

Fuses and circuit breakers have time dependencies on how they open up. There are curves that relate the amount of overloading versus the speed of opening. Engineers use

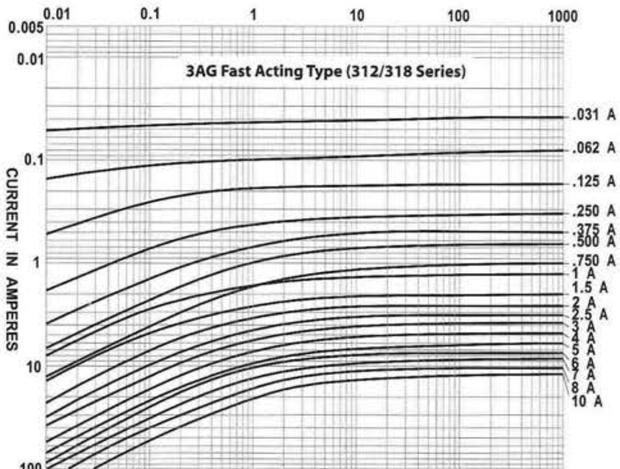


Figure 3 courtesy of Littelfuse, Inc.

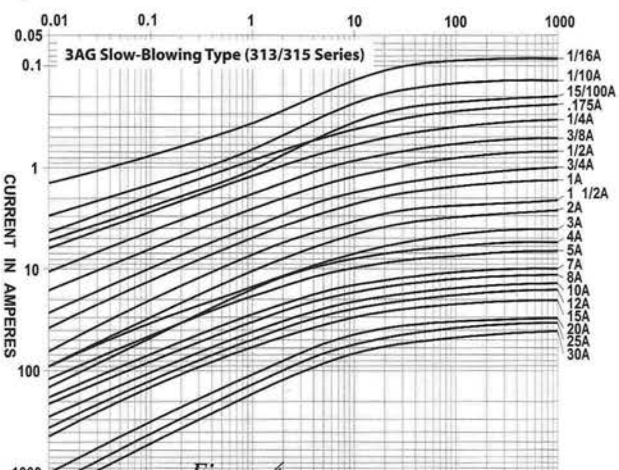


Figure 4 courtesy of Littelfuse, Inc.

these curves to "coordinate" protection, in other words, to make sure that the fuse or breaker nearest the fault is the one that opens first. Figures 3 and 4 show the curves for the common "3AG" glass fuses. The slow-blowing fuses are intended for applications where there is a large initial surge current upon turn-on. Examples would be vacuum tube filament supplies and DC power supplies with large filter capacitors. The fast-blowing types are for applications that do not normally have surges, such as the B+ supply to tubes.

Fuses are temperature-activated devices, so they will tend to open prematurely if they are in a hot environment. An example of this comes from experience with the Randall Amplifier (VTV issue 6). There are two fuses inside the chassis to protect the output tubes and output transformer. The normal current through each of them is about 120mA. Originally 3/8 amp (375mA) fast-blowing fuses were used. However, in some cases the fuses would spontaneously blow for no reason, only after the amp had been on for a long time. The high temperature inside the amp was lowering the opening current. Replacing them with 1/2 amp fuses solved this problem and still provided good protection.

It is often hard to accurately predict the best line fuse value to use, since capacitor-input power supplies have highly non-linear currents. The best way in these cases is by trial and error. Pick a fuse lower than the expected maximum rms current, and try it out. If it blows, put in the next higher size. Find the minimum value that doesn't unnecessarily blow. If UL or EU approved equipment starts blowing fuses, don't put in fuses larger than the specified value. Find out why the fuses are blowing and fix it.

When restoring old equipment, check that the correct value of fuse is installed. Some older hifi equipment and most old radios did not have fuses. If you use these on a regular basis, it is strongly recommended that you put in a line fuse. I have (more than once) had power transformers in old radios short out and start to smoke. If I hadn't been around, there would have been fires.

The ultimate test of fusing is to simulate a short-circuit. When I was in college and working as a technician for the music department, we used to build a lot of our own equipment. My boss, an engineer from Bell Labs who supervised us on the weekends, would test power supplies we built by shorting the output with an old screwdriver! Sparks would fly, but if the fuse didn't blow, we had to fix it. This drastic test is hard on electrolytic capacitors, but is the only real way to know that you have protection. This is the ultimate test, but unless you are an old hand at bench safety, I don't recommend that you deliberately short out your equipment.

I offer this "philosophy" as a learning tool to alert builders to some of the more important safety issues and references for further study. Taking the measures spelled - out herein will not unfailingly protect you from harm. If you have not educated yourself in electrical safety, you should not attempt a project using either high voltages or high currents.

References:

1. **IEC 60065:1998 - "Audio, video and similar electronic apparatus - Safety requirements"** - European Union safety standard, (http://www.iec.ch/)

2. **UL 6500 - Audio/Video and Musical Instrument Apparatus for Household, Commercial, and Similar General Use** - American safety standard. Replaces earlier standards UL 1270 and UL 1492. Is essentially a marked-up copy of the IEC 60065 standard, (http://www.ul.com/av/radios.html)

3. **C22-2 No.1-98 "Audio, Video and Similar Electronic Equipment"** - Canadian safety standard, (http://www.csa-intl.org/)

4. **NFPA 70 - NEC 1999 National Electric Code** - American standard for household and business wiring

5. **Journal of the Audio Engineering Society**, Volume 43, No. 6 (June 1995) - Whole issue dedicated to "Shields and Grounds: Safety, Power Mains, Studio, Cable and Equipment," (http://www.aes.org/publications/other.cfm#3)

Moth Audio's Positive Ground Amp

A Review by David Bardes

How many times have you listened to a single ended amp and wished that you could keep that SE magic but add some crispness and punch? There are some conventional solutions: use a high voltage transmitting tube such as the 811 or 845, or keep the "usual suspect" triodes and use a parallel or push-pull topology. These solutions work but are expensive to implement, and use more watts to achieve this goal. With just a handful of parts and some rearranging of the basic SE circuit, Moth Audio has come up with an elegant and cost effective solution in their Positive Ground Amp.

Instead of supplying B+ to the plate via the output transformer as conventional SE amps do, here power (B+) is supplied to the cathode of the driver and output tubes, and the plates are tied to ground. The plate of the 300B is direct coupled to an autoformer, with the taps on the autoformer providing the impedance match for the speaker. According to Craig Uthus, the designer of the amp, autoformers have several advantages over transformers because their construction is so much simpler. This certainly keeps costs down, but the lack of a secondary winding and super close coupling give real phase shift and frequency bandwidth advantages. He also states that autoformers have much closer tolerances so using them gives real left and right channel symmetry, impossible to achieve with conventional transformers without careful testing and matching.

Moth Audio Positive Ground Amp with AV 300BBL Power Triodes

I asked Craig about his choice of driver tubes for this amp, the 6AN4. He said this tube has the high mu and low plate resistance needed to drive the 300B. It is plentiful and inexpensive, making it a perfect choice for this amp. And used in the reactance drive circuit, the 6AN4 provides ample voltage swing in a single gain stage.

Our review sample was a prototype and lacked the ray-gun gothic styling that I associate with Moth Audio gear. The prototype was strictly a utilitarian design, much like vintage Dynaco amps. The production amp keeps all the same parts but pushes the tubes to the front of the long and narrow chassis, and adds the option of a cage. Our prototype has the on/off switch and a volume knob on the front, with the power cord, RCA jacks, and speaker binding posts on the rear. In the production amps, the on/off switch will be moved to the side.

I placed the amp in my system and set the bias for the 300Bs using the two trim pots on the top of the chassis and my DVM (At Moth Audio's suggestion, I set the bias at 75ma). Back on the couch with the CD player remote in my eager hands, I let the first CD spin and was treated to the best sound ever to come out of my Klipsch Horns!

Compared to my very good Assemblage 300B amp, the Positive Ground Amp was livelier and more dynamic. The soundstage was deeper and I was hearing more low level detail in the music. It sounded like it had twice the power of the Assemblage amp! When I listened to Ron Carter playing Ray Bryant's ***Cubano Chant*** (**When Skies are Grey**, Ron Carter), Ron's upright bass was rich, full, and deep. The drum solo was more realistic through this amp than any amp I've had in my living room. This amp doesn't have the punch the 60 watt, push-pull Rogue Audio Tempest does (see my review of the Tempest in this issue), but it is closer to having that push-pull grip than any low watt SE amp I've heard. And it still retains all that harmonic information that makes SE amps so appealing.

When I was listening to Duke Robillard and Herb Ellis play ***Blue Brew (Conversations in Swing Guitar***, Duke Robillard and Herb Ellis), subtle differences in their guitar tones were revealed. I noticed great pacing and small tonal changes in the ride cymbal sound as the drumstick struck a little bit closer or further away from the cymbal's edge. In Henry Mancini's song **Dreamsville** as performed by Dave Grusin and Diana Krall (**Two for the Road**,

Dave Grusin), voice, piano and guitar all had a richness that I had not heard from other amps.

I also played some symphonic music, which is a difficult task for SE amps. In a recording of Mozart's 25th Symphony in G Minor performed by the Berlin Philharmonic Orchestra, the Positive Ground amp held up very well to the Mozart's complex and dynamic musical score. I noticed good room ambience even during musical peaks, and again the pacing was right on.

While I still prefer symphonic music played through a more muscular amp, the Positive Ground amp turned in a great performance, and didn't turn Mozart into mush. I wish I had the opportunity to do some tube rolling. The amp came with Chinese made carbon plate 300Bs identical to the tubes in my Assemblage amp (although without any brand name silk screened on the glass). These are great inexpensive tubes, but there are a lot of choices in 300B tubes today, and having the ability to set the bias points makes for lots of possibilities. I also wonder what a different rectification scheme would do for this amp. In a nod to economics, solid state diodes are used. It may be that tube rectification would have little influence on this amp, then again maybe it would make it that much better.

Moth Audio has an exciting new product in their Positive Ground amp. By turning the SE circuit upside down, and substituting autoformers for the transformers, Craig Uthus has proven that circuit topology is more important than expensive audiophile brand parts. He has put a whole lot of sound in a mid-priced 300B SE amplifier.

The scale is 1 to 5 with a score of 5 being the very best

Overall Rating: 4.75

Test System Components:
Jolida JD 603 CD player with Mullard CV4004 tubes in the analog output section, Klipsch Klipschorn speakers with updated crossover, T35B tweeters and JBL D130 woofers, homebrew fine wire speaker cables using three strands of 30 awg silver-coated copper wire in a kynar jacket, TEK LINE PC-12 Signature power cords for both the amp and CD player and VSE Super Clear interconnects.

Moth Positive Ground Specifications
MSRP: $1695

Output Power: 10 watts per channel

Tube Compliment: 2) 6AN4's, 300B tubes not included

Frequency Response: -3dB at 10Hz and 50kHz

Dimensions in inches: 9 W x 17 D x 8 H without cage

Weight: 33 lbs.

Power Requirements: 115V 60 Hz

	Dynamic Range	Transparency	Frequency Extension
Positive Ground	4.5	4.5	4.5
Tempest	4.25	4.25	4.5

	Dimensionality	Pace and Rhythm	Musical Involvement
Positive Ground	4.5	5.0	5.0
Tempest	4.25	4.25	4.75

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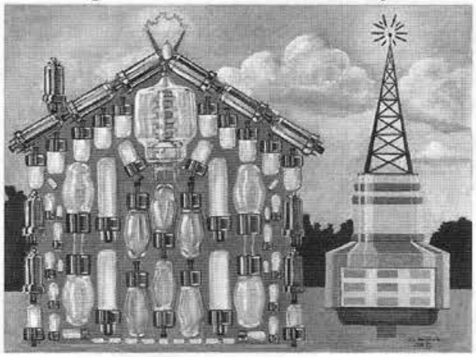

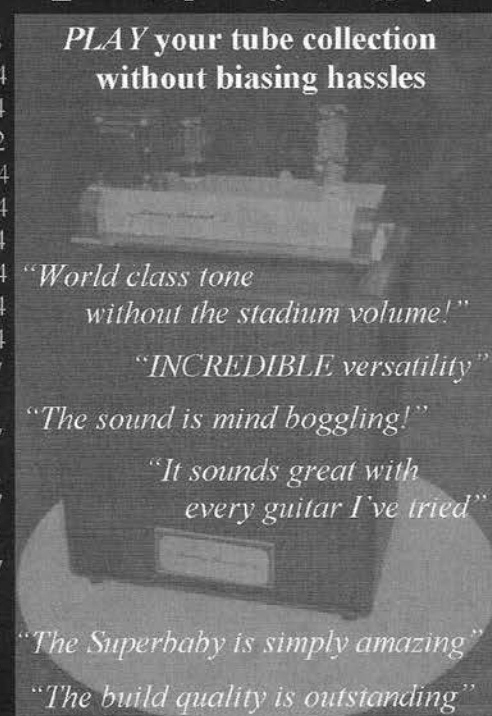

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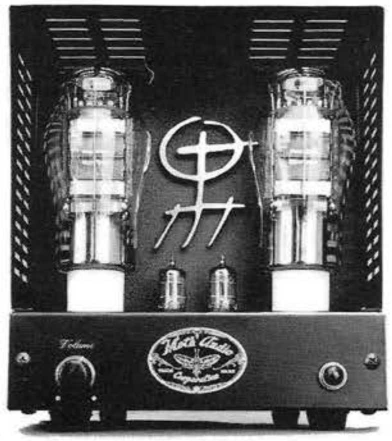

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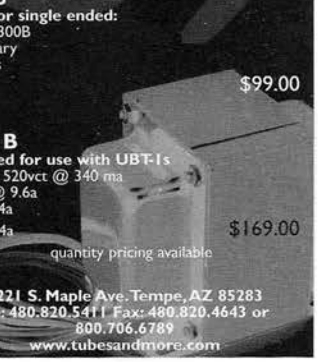

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