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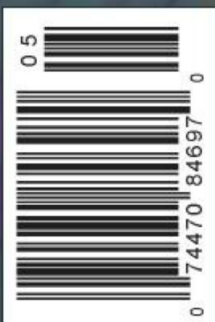
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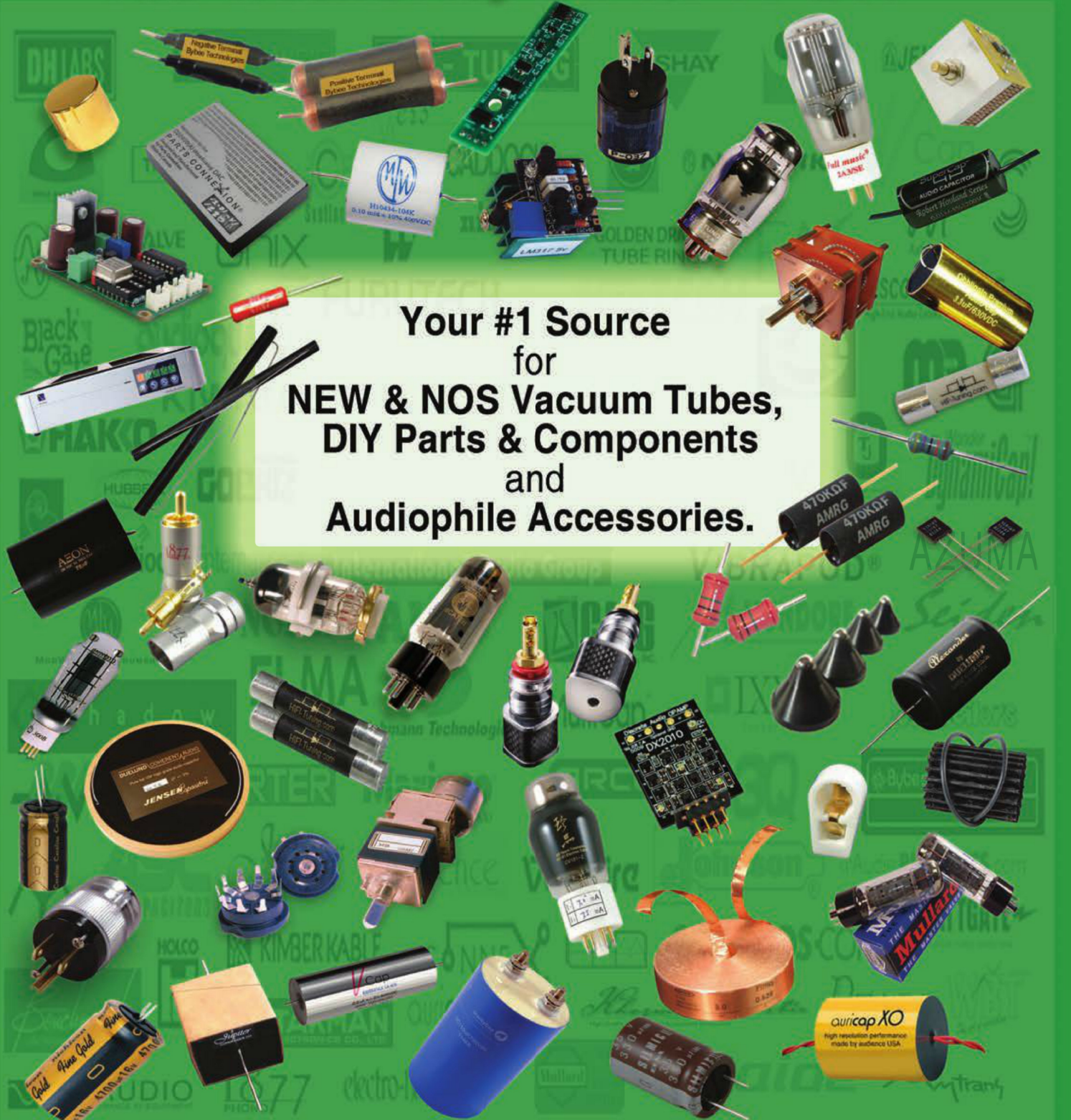


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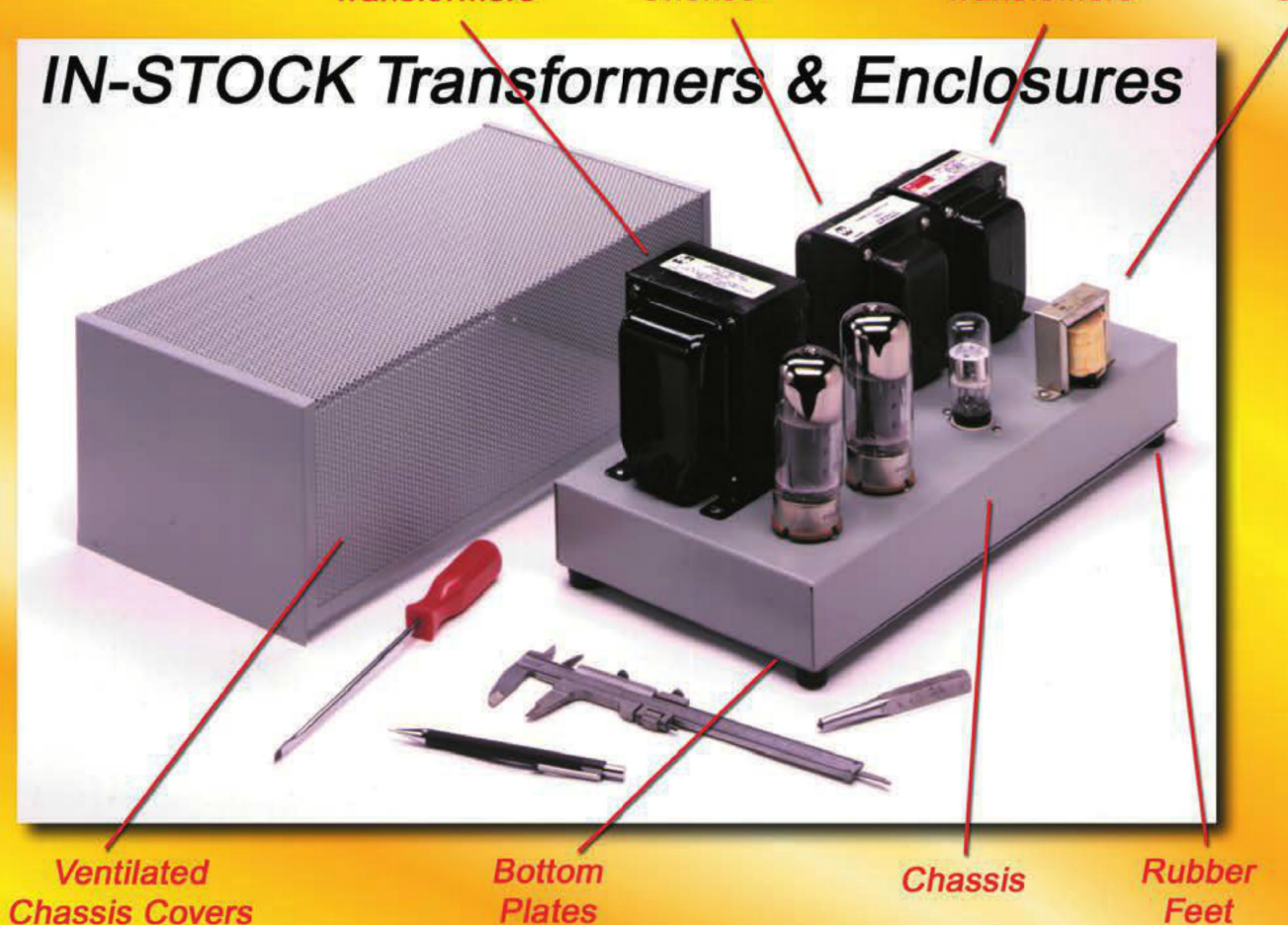
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Glass Tubes Abound

It's that time of year. May is the month that glass audio aficionados and enthusiasts receive an *audioXpress* issue packed with articles on tube-related projects. So, without further delay, let's get to the good stuff.

Turn to page 17 to start reading the 2012 Glass Audio section. The first article details Robert Nance Dee's "Merlyn" battery tube amplifier design. The innovative microcontroller-free project features affordable components, including the tubes.

On page 24, we present a system notably larger than the aforementioned Merlyn design. Dr. Gregory Charvat's 7' vacuum tube home theater system—which he calls "Frankenstein"—features 23 tubes! Charvat details the overall system architecture.

Bill Reeve wraps up the special "Glass Audio" section with an article about how to repurpose antique vacuum tube radios. Check out how he turned a 1948 portable tube radio into an MP3 amplifier!

Just because Reeve's article ended the Glass Audio section of the magazine doesn't mean we asked our hard-working tube columnist to take a month off. Flip to page 13 to read Richard Honeycutt's article, "Hollow-State Power Amplifiers." Honeycutt writes: "When we think of power amplifiers, we have to consider a performance metric about which we have not had a lot to say: efficiency." Simply put, efficiency matters!

Think we're done with tubes? Think again. On page 38 is an interview with audio guru and tube lover Stuart Yaniger.

The rest of this issue includes thought-provoking content about speakers, drivers, and audio components.

On page 8, Mike Klasco and Steve Tatarunis describe the acoustical qualities of adhesive joints and cone treatments. They cover the topics of surround to cone, surround to frame, adhesives, joints, and more.

The last column in the issue is Vance Dickason's review of the Faital Pro HF104 compression driver (p. 33). Dickason presents the results of his tests and details some of the driver's unique features.

Regards,

C.J. Abate
editor@audioxpress.com

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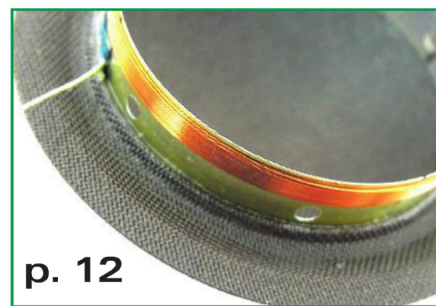


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Acoustical Qualities of Adhesive Joints and Cone Treatments

Using different adhesives can alter sound qualities



In the early 1980s, it seemed that just a glance would be enough to separate the efforts of Asian engineers to duplicate high-quality European golden samples. Now, decades later, it is down to almost invisible elements that separate the European speaker components from many of the Asian designs. Still, when trying to capture the qualities of the “golden samples” from Germany, Denmark, Italy, etc.—even when using the identical cones and domes—there are subtle differences in sound quality.

Part of the missing magic is the lack of consideration and understanding of the acoustical characteristics of the loudspeaker’s many glue joints, which just happens to be the subject matter of this month’s column. The various joints and the contribution of the selected adhesive to the sound quality of these joints will be discussed, along with cone and diaphragm coatings.

Authors’ note: For readers who are curious but do not want to plow through the next 2,000 words, here are the headlines: If the speaker designer needs to tame an upper mid-range peak (perhaps due to cone beaming), some remedy can be achieved by the usage of a lossy (viscous) adhesive. In a cone driver, this adhesive would be used to attach the surround to the cone or at the triple joint (the junction of the cone, spider, and voice coil). On the other extreme, such as a tweeter or compression driver, where sound transmission through the adhesive joint must be preserved, a low-viscosity adhesive that cures to a hard thin joint can be beneficial as it will not absorb the higher frequencies passing through it. Thick joints in tweeters are rarely a good idea as they can result in sloppy parts placement if proper jigging is not used (as thick joints leave room for an uneven application). Anyway, on to the details.

First to be addressed will be the surround-to-cone and surround-to-frame joints. The second joint to be examined will

be the diaphragm (cone or dome) to the voice coil bobbin. On a cone speaker, this is called the triple joint, where the voice coil bobbin meets the spider ID and cone neck. On a dome tweeter, this is where the dome meets the bobbin. Finally, we will consider the acoustical contribution of the adhesive between the frame and the magnet’s top plate.

How can the glue joint influence sound quality? Imagine the glue joint as an acoustical filter. If the glue is gummy rather than hard such as “rubberized” adhesive, then there will be a partial absorption of the higher frequencies. This is the tan delta or the loss of (sound) energy through a material (in our case the glue joint). Sometimes on a woofer with an untamed mid-range peak, this is just what is needed. Other times a soft joint will degrade the performance of an otherwise good tweeter design.

SURROUND-TO-CONE AND SURROUND-TO-FRAME

No discussion of the well-behaved speaker is complete without attention to the nature of edge resonance and its contribution to response anomalies. Let’s review the sound energy path through the cone speaker. The vibrational energy is created when an electrical signal is passed through the speaker’s voice coil. The coil is located within a magnetic field and the alternating current of the audio signal causes the coil to respond backward and forward in a mechanical analogy to the electrical audio signal.

The voice coil is wound onto a bobbin and the vibration energy passes up through the bobbin and into the cone. As the vibration moves through the cone, it is attenuated (particularly the higher frequencies). Eventually, the vibration reaches the end of the cone, passes through the adhesive joint between the cone and surround (see **Photo 1**), and then moves through the surround. Some

energy reaches the glue joint between the surround and frame, and passes into the frame, and some energy reflects back into the surround, back through the joint, and into the cone.

Due to the sound energy loss through the various materials, some reflected energy passes back into the cone out of phase and tuned to a narrow frequency band. On a 4" mid-range speaker, this might be around 1,200 Hz, while a large woofer may have an edge resonance of 600 Hz. A major consideration to the edge-resonance frequency is the characteristic of the surround. Since this energy is not in phase with the signal passing up the cone, it causes an out-of-phase cancellation resulting in an edge-resonance notch in the response.

The adhesive joints at the cone/surround and surround/frame are the speaker engineer’s last chance to absorb the edge resonance. There are quite a few tricks that can be used at the joint between the surround and the cone to minimize edge resonance. One European speaker manufacturer uses an uneven number of chords, when trimming the outside diameter of the cone, rather than an OD circle. This chord varies the distance between the ID of the cone and the edge, widening the Q of the edge resonance slightly (see **Photo 2**). On tweeters and compression drivers, a scalloped edge has been used with excellent results.

A large overlap between the surround and cone enables a large glue joint. The large joint, in conjunction with a “goosey”

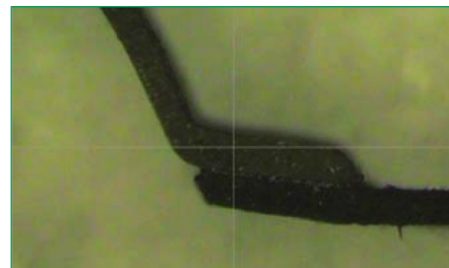


Photo 1: The cross section of cone-surround attach (Source: Dr. Kurt Müller, GmbH & Co. KG)

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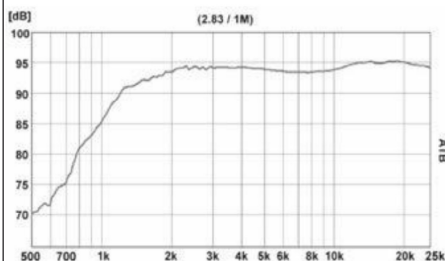


The AMT tweeter was first introduced by Dr. Oskar Heil in the early 70's. Over the years many companies have experimented with Dr. Heil's design to offer their own versions of air motion tweeters. Although the AMT design seems simple at first glance, it is actually very difficult to achieve an AMT tweeter with exceptional sound.

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Photo 2: A cone body with an uneven edge
 (Source: Dr. Kurt Müller, GmbH & Co. KG)

adhesive, increases losses, and improves the strength of the joint. Urethane adhesives—both one- and two-component—provide good adhesion to the many different cone and surround materials, while providing the high lossiness and reduced edge-cancellation results. Especially difficult-to-bond materials may require the use of an adhesion enhancer or primer before bonding.

REDUCE THE PROBLEM IN THE CONE

We can look at higher-frequency behavior in a speaker cone as a “lossy transmission line.” The sound transmission loss of the acoustical signal traveling up the voice coil within the cone is a significant factor in edge resonance. The deader the cone, the more the upper range will be attenuated. You can make the cone lossier by using poly pulp, wool, or latex in the cone paper slurry. Secondary treatments, such as butyl or other gummy coatings, can be painted or sprayed on the cone. All this assumes you want the woofer's response to say out of the midrange.

REDUCE THE PROBLEM IN THE SURROUND

In two-way speaker system designs, you need the woofer's response to extend up to (or beyond) the tweeter crossover frequency.

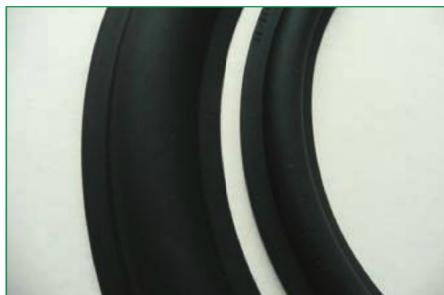


Photo 3: Large and small roll surrounds
 (Source: Dr. Kurt Müller, GmbH & Co. KG)

Here, you need the surround itself to tame its edge-resonance problems. The contour of the surround can minimize reflections. A larger roll will shift the resonance lower in frequency, the cone material's absorption will be less, and the energy in the resonance band reaching the surround will be greater. Smaller roll size will move the edge resonance upward, but the excursion capability of the speaker is reduced (see **Photo 3**). One way around this is the M and W (accordion) surrounds, where multiple small corrugations are used. I have had my best luck with M surrounds over the years, while the triple and quadruple cloth edges perform well but tend to buzz a bit (see **Photo 4**).

Just using common sense in the selection of the surround's shape can help. Use a larger radius instead of sharp transitions between the roll and the surround attach (see **Figure 1** and **Figure 2**).

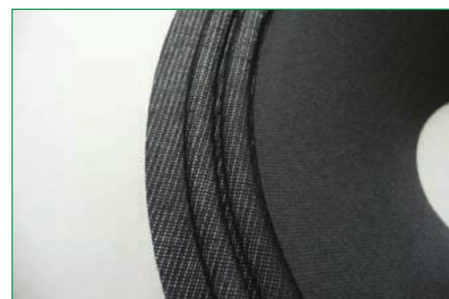


Photo 4: An M surround (Source: Dr. Kurt Müller, GmbH & Co. KG)

Then there is the surround material itself. Butyl rubber has good lossy characteristics, but often rubber surrounds are too costly and too heavy. Santoprene is lighter and less expensive, but its lossy characteristics have not matched that of butyl rubber.

THE TRIPLE JOINT

We can also try to reduce the problem (such as peaky rise in the upper midrange) at the neck joint (see **Photo 5**). If too much high-frequency energy is reaching the surround, you can filter it out before it gets to the cone. If the speaker is for an electric guitar and the cone bending (cone cry) is a desired signature, then a hard joint may be desirable. If an extended-range speaker with smooth off-axis response is what you are looking for, then try a soft adhesive at the neck to decouple the midrange from the cone in conjunction with a curvilinear (curved cone body) profile and mount the

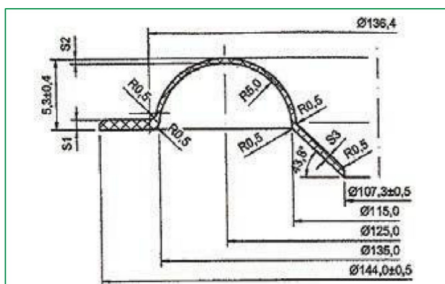


Figure 1: A sharp transition radius (Source: Dr. Kurt Müller, GmbH & Co. KG)

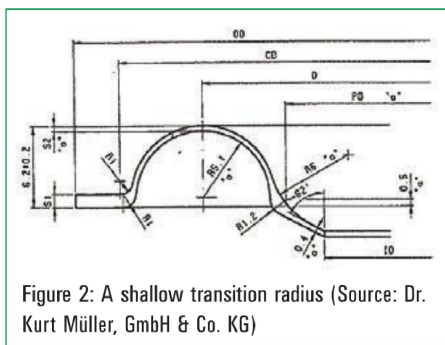


Figure 2: A shallow transition radius (Source: Dr. Kurt Müller, GmbH & Co. KG)



Photo 5: A neck joint (Source: Minneapolis Speaker Company (MISCO))

dust cap directly to the bobbin for extended top-end.

The spider's sound radiation does not get much attention. If you want to get an idea of what the spider is doing, try building up the speaker without the cone or dust cap. Compare the response and sensitivity of this coneless speaker to the response and sensitivity of the complete speaker, and you will realize how much the spider contributes (or detracts from) the speaker's sound quality. The output of the spider can create comb filter anomalies in the speaker's mid-range response and this is sometimes the "mystery" variable in a speaker's response during mass production. Fibers like cotton tend to absorb more resin in the dry season and less resin when there is high humidity. The spiders that attain their stiffness with stronger fibers and appropriate fabric weave rather than being loaded up with phenolic make less noise.

Alternatively, a secondary bead of ure-

thane adhesive at both the neck joint and the periphery of the spider will reduce the spider's radiation and reduce the likelihood of the spider fibers fracturing where a rigid epoxy has wicked. For this application, a two-part urethane might be a good choice.

We discussed that the neck joint is one of the most critical junctures for the speaker's mechanical integrity. Consider the concentration of forces at this point, especially if the voice coil diameter is small and excursion high. The joints between spider, cone apex, and bobbin, will all apply shear, peel, and mixed loading to this bonded joint. If the bobbin is aluminum, then the adhesive must also have a high-thermal tolerance. Since this joint is directly in line with the voice coil bobbin, impulsive transients will test its shock strength. Added to this process are control considerations, such as cure time, getting the bead of adhesive to stay where put without dripping down onto the voice coil or wicking into the spider fabric, only to have the fibers fracture in the field, etc. You are not likely to find one adhesive that has all the characteristics you want, so why not consider using two adhesives?

On woofers, where reliability and sound quality are the foremost issues, you might consider the use of an epoxy adhesive as the main joint and an additional outer coat or bead of urethane for damping.

TWEETER PATROL

The tweeter bobbin to diaphragm joint has its own set of problems (see **Photo 6**). The moving mass of a tweeter diaphragm is so small that the mass of the adhesive becomes a significant variable. Precision adhesive dispensers (and we do not mean ketchup or soy sauce squeeze bottles) are mandatory. Even the usual automated dispensers commonly found at most speaker factories are marginal when it comes to absolute uniformity. Positive volume displacement pumps and precision valves are critical pieces of equipment when it comes to accurate and repeatable dispensing of the bobbin-to-diaphragm adhesive. The same adhesive bead should be dispensed whether the factory temperature is cold or hot. (Temperature can affect adhesive viscosity and flow rate, resulting in variations in the mass of the joint.) The same adhesive bead should also be dispensed whether the adhesive is fresh or has been sitting out for hours, and whether the dispenser is full or almost empty. Another factor not



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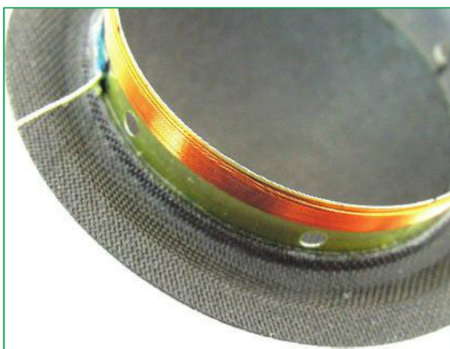


Photo 6: A tweeter bobbin connected to a diaphragm joint (Source: Tymphany Corp.)

often considered is the solids content of the adhesive and the dispersion of these solids within the solvent. When the adhesives are dispensed, the solvents blow off leaving the solids. Even if a consistent volume of adhesive is dispensed, if the solids content varies, so will the glue joint on the tweeter.

But even with the perfect dispenser, the right adhesive characteristics are still critical. Manufacturers still using rubber-modified epoxies and other sol-

vent-based adhesives are struggling to reach 20 kHz with their tweeters—and they are not likely to get there. A thick, soft, and uneven adhesive joint between the bobbin and dome is not the path to extended and uniform top-end response.

What most leading speaker manufacturers have learned is that the adhesive joint between the dome and bobbin must be a thin hard film, such as a cyanoacrylate (CA) or acrylic. A low-viscosity adhesive goes on thin, has minimal mass, and so unit-to-unit variations and high-frequency losses are insignificant. CAs can be tricky to work with in high-humidity environments. While there are all sorts of solutions to controlling the humidity in the area of the joint, you still must also keep the surface moisture of the parts low. Expiration and shelf life of CAs can also be a problem.

APPLICATION OF URETHANE ADHESIVES AND RESINS

Many years ago, Raymond Cooke,

founder of KEF, the famous British loudspeaker company, gave a talk. One of his favorite topics was the importance of isolating the resonances of the speaker driver (frame, etc.) from the enclosure's baffle. Once the frame/magnetic structure resonances got into the baffle, the sonic damage was done. The large radiating surface of the baffle would soon dump the resonances into the listening room.

A similar situation exists within the woofer itself. Most woofers use a stamped steel frame and these can suffer from "bell" resonances. To control and isolate the structural resonances of the woofer, urethanes can be used to bond the magnetic structure and frame.

The lossy characteristics of the urethane will help absorb some of the unwanted resonance in the frame. This approach is very common in European-built woofers.

Next month we'll continue to explore the loudspeaker, specifically the frame and the changing considerations of the politics of magnetic structures. *ax*

MEMBER PROFILE

Member Name: Tom Perazella

Location: Maryland

Education: BS, University of California, Berkley

Occupation: President of the Rockville chapter of the Izaak Walton League of America

Member Status: Tom subscribes to

audioXpress and *Voice Coil*. He has been a subscriber since at least 1996.

Affiliations: Tom is a member the Audio Engineering Society.

Audio Interests: Tom is interested in speakers with wide flat bandwidth, controlled radiation pattern and high dynamic range.

Most Recent Purchase: He recently bought a crown studio reference amplifier.

His current audio and video setup comprises the following:

- A custom pre-amp that Tom built
- A Sony 707ESD CD player
- A Sony XDR-F1HD tuner
- A dual 701 turntable on a custom isolation base with a Shure Ultra 500 cartridge
- A Behringer DEQ2496 electronic EQ
- A Behringer DCX2496 electronic crossover
- A Crown macroreference high-channel amplifier
- Three Audiosource Amp three mid-channel amplifiers
- Two "Plate" low-channel amplifiers
- Electronic speaker protection that Tom built
- Two Bohlender Graebener RD75 planar magnetic high-channel speakers in dipole baffles
- 12 Peerless 831727 10" CC Line woofers in dipole baffles for mid-bass channel speakers
- Two Dayton 15" DVC woofers in sealed boxes for low-channel speakers
- A Terk Leapfrog remote control extender

Current Audio Projects: He is now working on an Audio Artistry CBT36KIT.

Dream System: "My dream system is the current system that was the subject of the articles 'On Angels Wings' and 'Dipole Mid Bass' that ran in *audioXpress*. Most of the equipment used to drive the system was described in the articles," Tom said.



Thomas Perazella testing one of his many speakers

Hollow-State Power Amplifiers

Maximum power output differs from maximum efficiency



When we think of power amplifiers, we have to consider a performance metric about which we have not had a lot to say: efficiency. Contrary to the beliefs of marketing departments, efficiency does not mean “degree of excellence” or any other such unquantifiable property. Efficiency, represented as η , has a specific meaning:

$$\eta = \frac{P_{OUT}}{P_{IN}}$$

P_{OUT} is the useful output power, and P_{IN} is the total input power.

Strictly, we would need to include the power necessary to heat the filaments of the tubes—and we would include this power if our concern were related to room heating by a power amplifier, or to environmental effects of amplifier operation. But since our concern is amplifier performance, we will not include this power. The output power will be considered to be the power fed to the load (speakers), and the input power will be the product of the B^+ voltage and the average plate current.

All the small-signal amplifiers we have discussed in previous columns operated in Class A. The output wave was an essentially accurate larger version of the input wave.

Figure 1 shows a single-ended Class A power amplifier. Since the load for an audio power amplifier is usually a speaker (about 8- Ω impedance), an output transformer is required to present the output tube with a suitably high-load impedance.

It turns out that if we split the job between two tubes, and let one handle the positive half of the output while the other handles the negative half (Class B operation), we can greatly improve efficiency. This matters—apart from environ-

mental and economic concerns—because even the 6550 output tube, which is a high-power vacuum tube, has a maximum plate dissipation of 35 W. It is a fact that the maximum efficiency of a Class A stage is 25%, so the plate dissipation of the tube must be 75% of the total input power, or three times the output power. Thus, a 6550 is limited to a maximum output power of 11.67 W (i.e., 35 W/3) in Class A operation. Class A amplifiers can be connected in either parallel or push-pull, so that two or more tubes share the load, making higher-output Class A amplifiers possible. However, the maximum efficiency is still 25% for Class A. We will discuss Class B amplifiers in the next column.

It is important to remember that the conditions for maximum power output and maximum efficiency are not the same. As we approach the conditions for maximum power output, the input power increases more steeply than the output power. For maximum power output, the load impedance must equal the source impedance. For a tube power amplifier, the load impedance is the impedance of the output transformer primary. The source impedance is the plate resistance of the tube. For maximum efficiency, the load impedance should be as large as possible compared to the source impedance. In this way, the output current is small, so the power wasted by dissipation in the source (in this case, output current squared multiplied by plate resistance) is small. In actual tube power amplifier designs, a compromise between maximum power and maximum efficiency is usually reached.

SINGLE-ENDED CLASS A AMPS

Let's look first at single-ended Class A amplifiers. The circuit shown in **Figure 1** represents a common approach. For maximum output power, the impedance presented by the primary of the transformer should equal the plate resistance of the

triode. Larger values of load resistance will provide higher gain and higher efficiency. If R_L is twice r_p , the maximum output power is only reduced by 0.5 dB (11%). If R_L is four times r_p , maximum power is reduced by about 2 dB (36%). So the actual load resistance or impedance is not critical.

By the way, although the impedance of a speaker is not pure resistance, its actual character—resistive, inductive, or capacitive—is quite complex and dependent upon the speaker system design. These niceties can safely be ignored so that we can usually analyze amplifiers as if the speaker loads were resistive. In the design of a new amplifier, the component values in the negative feedback loop should be tweaked to ensure stability with any load that is likely to be connected.

For example, a 2A3 power triode with 250 V on the plate, and biased for 60 mA quiescent (no-signal) plate current, has a plate resistance of 800 Ω , but the 1973 *RCA Tube Manual* recommends a load resistance of 2500 Ω . One-electron.com recommends their UBT-3 output transformer, with a primary impedance of 3,000 Ω , for this application. Antique Electronic Supply lists a variety of output transformers having primary impedances from 2,000 Ω

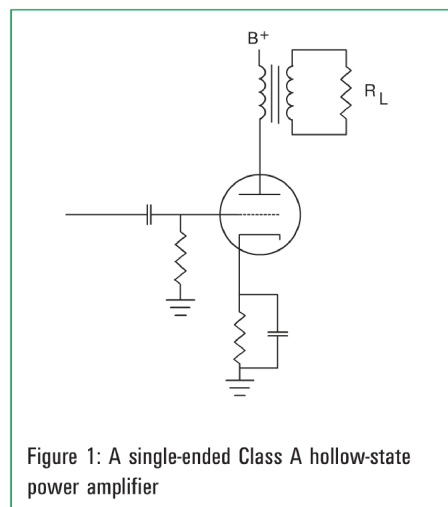


Figure 1: A single-ended Class A hollow-state power amplifier

center-tapped (CT) to 6,200- Ω CT. For a single-ended amplifier, you can use half of the primary, so you could load the output tube with as little as 1,000 Ω .

The power output of a single-ended triode power amplifier is given by:

$$P_{OUT} = \frac{\mu^2 v_G^2 R_L}{(r_p + R_L)^2}$$

v_G is the RMS signal voltage applied to the grid.

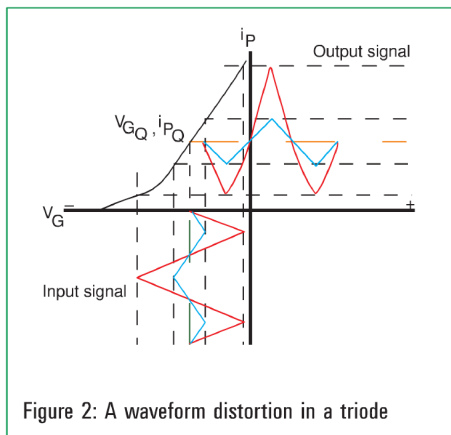
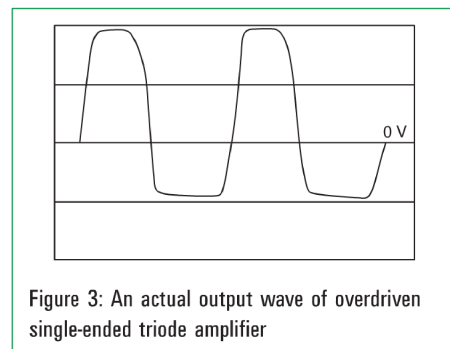


Figure 2 illustrates what happens when perfect triangle waves of two different amplitudes are amplified by a triode. The blue, lower-amplitude wave simply appears at the output with a larger amplitude. But the red, high-amplitude wave appears distorted at the output. (Notice that the upper and lower half-cycles are no longer equal.)

In order to understand why this happens, recognize that in the figure, the input signal, instantaneous grid-to-cathode voltage (horizontal axis), is graphed versus time (green vertical axis). The curved line in the upper left portion of the figure is the characteristic curve of the triode. It shows instantaneous plate current results from a given grid-to-cathode voltage. The output signal is instantaneous plate current (vertical axis) graphed versus time (coral horizontal axis).

The time axis in the centers of the input and output signals intersect the characteristic curve at a point that represents zero signal—the quiescent point, at which instantaneous grid voltage and plate current are v_{GQ} and i_{PQ} , respectively. Since the characteristic curve is not a straight line, identical positive and negative changes in v_G above and



below v_{GQ} do not produce identical negative and positive changes in i_p below and above i_{PQ} , so the output waveform is distorted.

Figure 3 shows the actual output wave from a single-ended triode amplifier, such as we have been discussing, overdriven with a sine wave. Again, note that the negative half-cycle is more squashed than the positive half-cycle. This is indicative of a significant proportion of the distortion products being even-order harmonics.

PUSH-PULL TRIODE AMPLIFIERS

As mentioned earlier, if two triodes are connected so that they share the load, greater output can be obtained, and this can be done using either Class A or Class B bias-



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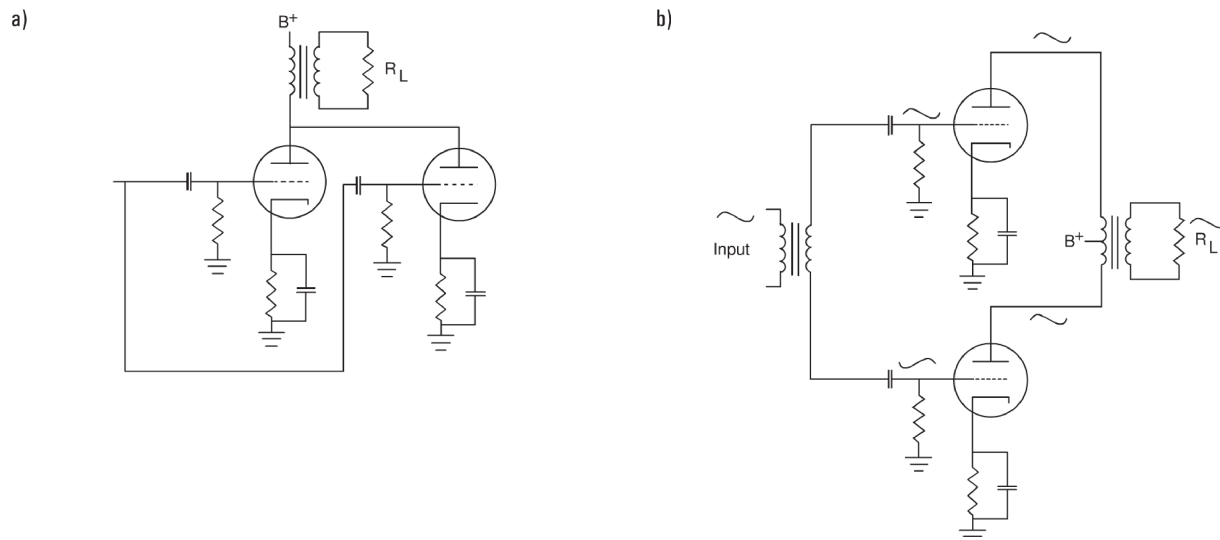


Figure 4: A parallel triode amplifier (a) and a push-pull triode amplifier (b)

ing. Let's look at two ways in which triodes can share the load even with Class A biasing: parallel and Class A push-pull. These are shown in **Figure 4**.

The parallel configuration is exactly as you would expect. Both triodes are fed the same signal, and the output voltage across the transformer primary is developed by the combined plate current of both. The transformer primary impedance should be half the value needed for a single-ended triode amplifier. The available output power is essentially doubled compared to that of the single-ended circuit.

The push-pull circuit, which has been around since the 1920s, uses one or more pairs of output tubes in which the plate of one tube of each pair is connected to one end of the output transformer. The B^+ supply feeds the transformer through a center tap in the primary winding. (Push-pull circuits can also be built using transistors. Transistor push-pull amplifiers seldom use output transformers.) Thus when the signal drives the grid of either tube less negative so that plate current increases, the net direction of current flow in the primary depends upon the difference in the plate currents. In a push-pull circuit, the input signal is fed through a transformer so that the signals to the grids are out of phase. Thus, positive input at the input transformer primary causes a positive voltage to appear on the grid of the top tube in **Figure 4 b**, and a negative voltage at the grid of the bottom tube. In turn, the plate current of the

top tube increases, and the plate current of the lower tube decreases. The net primary current in the output transformer produces a positive voltage at the top of the load, as depicted in the figure.

Class A push-pull circuits have no power

or efficiency advantage over parallel Class A circuits. However, the push-pull connection does cancel out even-order harmonic distortion, because of one tube's nonlinearity being opposite the other's. **Figure 5** shows the output wave from an overdriven push-



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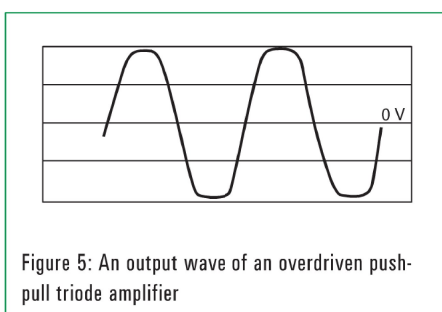
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Alan Sircom, Editor - June 2011

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pull triode amplifier with a sine-wave input.

Notice that the positive and negative half-cycles are symmetrical about the 0-V horizontal axis. The only harmonic distortion products present are odd-order.

Although cathode bias can be used with push-pull amplifiers, fixed bias is often used instead to allow the bias to be adjusted for differences between the actual tubes used. The principles discussed in this column also apply to pentode amplifiers.

Since triodes were invented before pentodes, and push-pull designs also came later, naturally single-ended triode power amplifiers were the first to be manufactured. In the 1930s, there were

still things to be learned about making a push-pull amplifier sound good. So, many small movie theaters continued to use the Western Electric single-triode Class A power amplifiers, which produced an output power of about 3 W. Larger cinemas used the version having three triodes in parallel, which produced about 10 W. With the all-horn speaker systems of the time (boasting efficiencies in the 25% to 50% range), acceptable sound levels were produced.

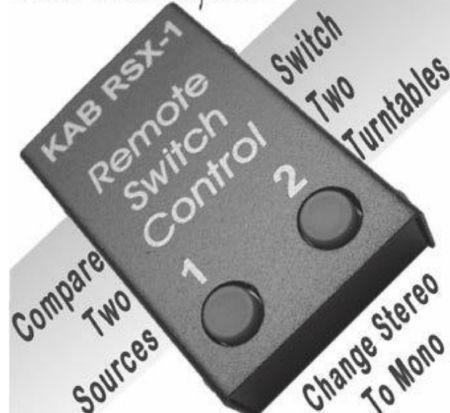
By the 1950s almost all power amplifiers, except those in small musical instrument amps, used push-pull outputs. Over the years, though, some purists have clung to the single-ended triode amplifiers, and some high-end home stereo amplifiers use such designs. The reason is that some people consider the sound of a triode power amplifier to be more pleasing than that of a pentode amplifier. We will consider the science behind such opinions—both physical science and psychoacoustic science—in a future column.

Next month, we'll focus on the Class B (and variants) push-pull amplifiers' design challenges and circuitry options. *aX*

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An Audiophile's Battery Tube Amp

The innovative "Merlyn" amp defies preconceived notions

By Robert Nance Dee (United States)

Before I present this amplifier to the readers, I would like to talk about the design process and the importance of keeping an open mind throughout that process. The best designers don't limit their component selections. That is, if a tube suits their application and they see it as the best design solution, they use it without hesitation, likewise for semiconductors. The belief that tubes are antediluvian passé devices is as myopic as the belief that only the latest cutting-edge op-amp should ever be considered. All devices should be evaluated as possible components in modern designs. To believe any less equates to a design that fails to achieve its full potential.

Just as flawed is the belief that only a specific component will ever give a superb result. This, along with the false premise that cost is the prime delineator of sound quality, leaves a final design severely compromised and closes the door on future discoveries that might offer better sound.

With that said, I would like to introduce "Merlyn," an extraordinary amplifier that physically defines the above statement (see **Photo 1**). I could go into a liturgy of accolades, but I would rather have the readers experience for themselves what the result of an open mind and

an inexpensive tube can do. So, in this spirit, I have made the design as accessible as possible to the widest possible field of audio enthusiasts. Unlike several of my other designs, there are no microcontrollers and all the components are inexpensive and readily available, including the tubes.

This is a hybrid design, and I ask those individuals biased to one topology or the other to evaluate this amplifier and decide if my fully inclusive design philosophy has true merit.

THE BATTERY TUBE

The tubes in this amplifier were originally designed for battery operation in portable and semi-portable applications during the 1940s and 50s. As the transistor—with greater ruggedness and lower power requirements—replaced the tube in the late 1950s, these tubes faded into the background. However, until that point they were the device to use when rugged, low-power amplification was required.

After careful evaluation, I settled on the 1T4 tube in this project. Like the rest of the family of battery tubes from this era, it has a

directly heated cathode that draws approximately 50 mA when powered and runs on a relatively low-plate voltage. I used approximately 60 V in this application which opens the design to experimenters who are less comfortable working with plate voltages in the hundreds of volts. This, however, is not a tube running outside its design parameters like many of the other low-voltage tube designs proliferating the Internet.

My personal view, after extensive listening and testing, is that there is a distinct benefit to the directly heated cathode. It has an airiness and immediacy that I don't find in remotely heated cathodes, but again I will let the individual builders de-



Photo 1: The Merlyn

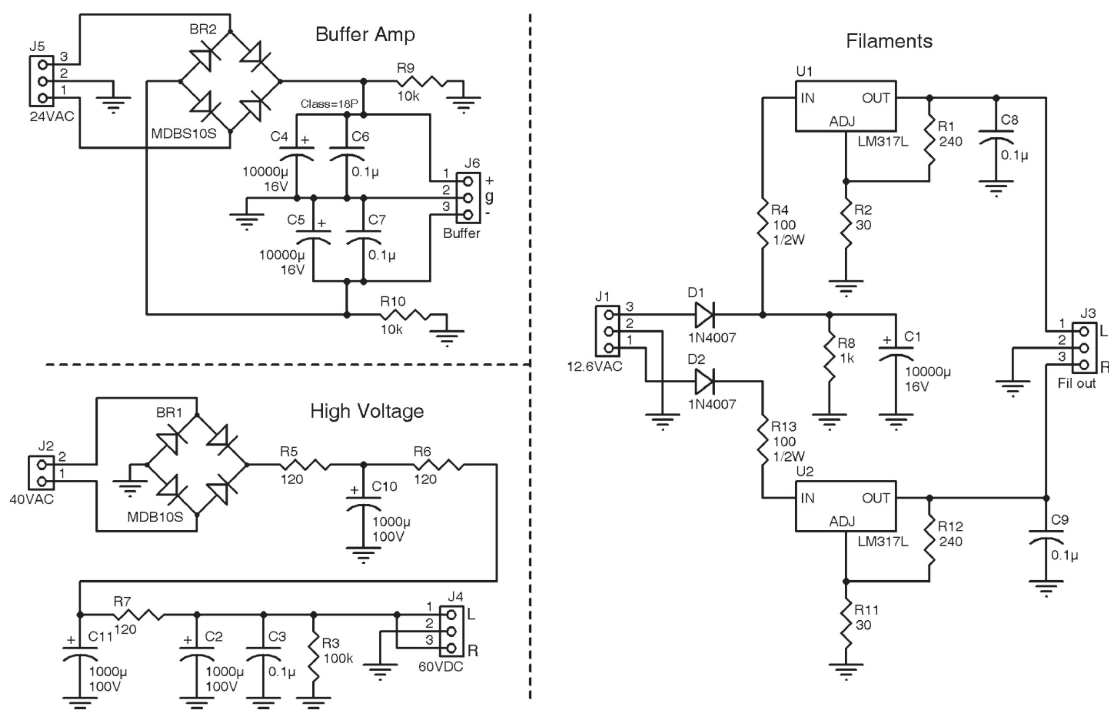


Figure 1: The schematic for the 1T4 power supply

cide the validity of this statement. All I ask is that you give this tube a fair opportunity to display its virtues.

THE POWER SUPPLY

Living off the power grid I find it very appealing to have a tube amplifier that uses as much power as a nightlight, and I took special care in this design to limit those devices and circuits that have reduced efficiency (see **Figure 1**). The THS4631 uses three terminal regulators but it draws marginal power. The Ha3-5002s carry the load of headphones (if you decide to use this aspect of the circuit) so I ran them directly from the filter circuit. The power supply rejection ratio (PSRR) is very high and any noise is not carried to the outputs in either the 4631s or the 5002s.

One point about the power supply, I used three 1,000 μF capacitors and 120- Ω resistors in the high-voltage section to smooth out the plate voltage and give a relatively slow power ramp up transition. It takes about 2 to 3 seconds for the filaments and the power to reach full potential, again extending tube life (see **Photo 2**).

THE TUBE CIRCUIT

I kept the tube circuit as simple as possible (see **Figure 2**). The input departs from the normal typology in the fact that the potentiometer is before the input capacitor. This is to keep the delicate input bias on the control grid from being effected by external

influences. Normally, biased directly heated filament tubes attain their bias from the voltage differential across their filaments. The grid bias is about -0.400 V close to the recommended 0-V bias from the *RCA Tube Manual*. You can experiment with other biases and bias schemes but this gives a good result. You may notice that I used a 100-k Ω potentiometer. You can use less if you know the input device you are using can drive a relatively

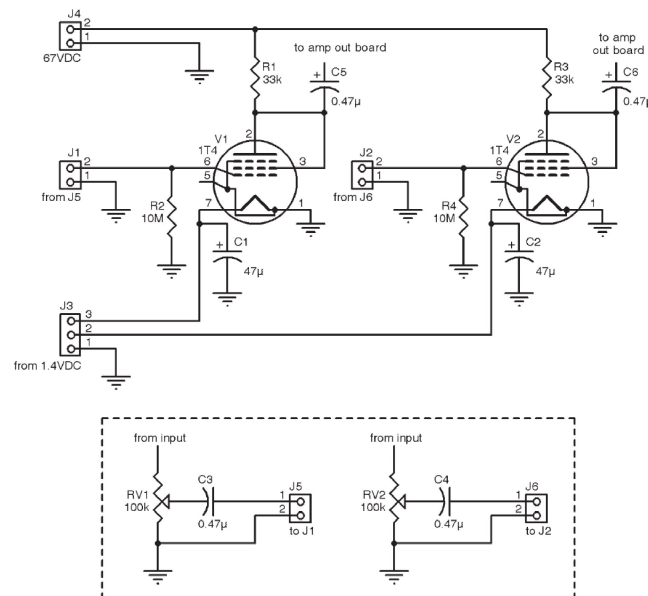


Figure 2: The schematic for the 1T4 tube



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Photo 2: The tube amp's power supply

low impedance.

The other property of concern is the gain, which I purposely kept low, about 15 db. I wanted the influence of this tube's dynamic sound. Further amplification went to the THS4631, which doubled the tube's gain. Today's input devices, MP3, CD, etc., put out a relatively high-level signal and even MC phono cartridges have high-gain circuits so I don't feel the need to over drive those signals.

THE OUTPUT BOARD

This basic circuit is used in several of my amplifiers, both tube and transistor. The THS4631 area is a new edition thanks to Jan Didden. He raised this device as a possible alternative to the HA3-5002, the driving devices in the "The 5002 Project" (*audioXpress*, February 2012). While I still like the 5002 for hard driving outputs, they can be awkward to bias when not driven directly by low-impedance devices. The bias scheme I have been using worked well enough, but a better topology is driving them directly with another device, like the THS4631 (see **Figure 3**). This eliminates the need for bias potentiometers and also keeps any power supply noise from entering the audio line.

If you are not going to use this amp with headphones you can eliminate the 5002 and run directly on the THS4631. Don't, however, leave out the load resistor on the THS4631. In this circuit, I wanted to keep the load on the 1T4 as

low as possible so I used high-value resistors in the 4631 circuit (see **Photo 3**). Without the output load on the chip problems can occur, as I learned the hard way! With headphones I personally like the 5002s, they are robust and drive well. The 39- Ω resistors keep them from blowing but keep series resistors in line with the output to your power amps simply because accidentally shorting the outputs can burn up the 39- Ω resistors and eventually kill the 5002s.

The "anti pop" circuit works well and keeps any spikes from the tube output capacitor during turn on from feeding through to your expensive headphones or power amps.

THE INPUT/OUTPUT BOARD

I like using relays to shift inputs, but usually I use microcontrollers to shift inputs. Since I wanted to keep this design accessible to the largest audience possible, I used a counter (CD4017) and a simple normally open (NO) push button switch to change the inputs (see **Figure 4**). Ideally, the signal and the ground should be isolated but that would mean adding another relay for each circuit, which I wanted to avoid. By all means, set up your design to do this if you like. Also, as in my other designs, I use different color LEDs for each input. This eliminates the need for text on my case faces and gives me a quick visual indication of the output I'm on (see **Photo 4**). This is another design feature that has worked

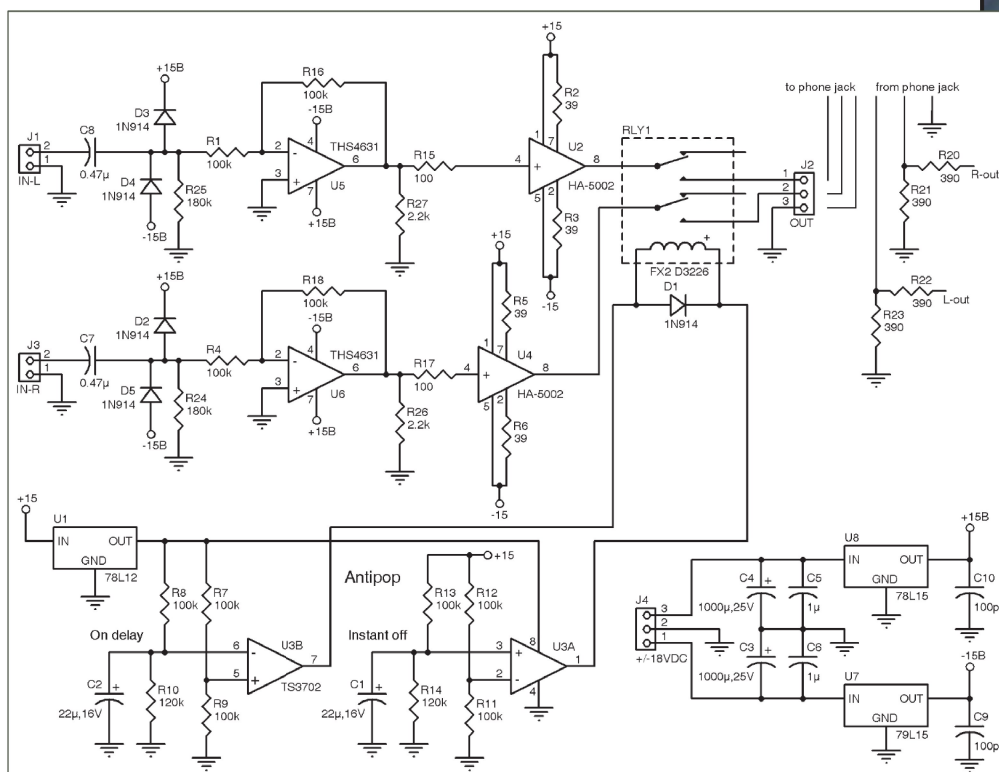


Figure 3: The schematic for the 1T4 amp output

well for me over the years but you can leave them off your input/output board if you like.

CONSTRUCTION

The tube circuits are hand wired without circuit boards. I used ceramic sockets (seven pin). The RCA manual recommends shielding the bases for noise, and under my tubes I used a metal brass shielding plate with contained LEDs under my tubes. The tops of the tubes do not need to be shielded but you certainly can shield the complete tube, if you like. Personally, I like to see my tubes in a design whenever I can.

The rest of the circuits are simply built from PCBs and the top and bottom artwork are available at www.audioamateur.com for those of you capable of fabricating your own boards.

Keep your wiring shielded and ground the circuits well. I have very little noise in this amp, so if you do find odd hums, etc., check your wiring and tube setup.

NOISE IN TUBE AMPLIFIERS

I often hear builders complain about a hum or buzz in tube amplifiers. Here are some things you can do.

First, make sure you have all your lines shielded and are using a good ground system. If you have a few millivolts noise on your output, but still hear a hum in your speakers or phones, then you might have too much gain for your setup. You can tell this by the position of your volume control potentiometer. If you constantly listen to music with your potentiometer in the lower quarter, or even the lower 10th of its revolution point, then you have too much gain. Power amplifiers, in my view, have too much gain for the most part. Why do we need 20-db gain in a power amp after 20 to 25 db in a pre-amp? Well, we really don't, but manufacturers don't have the liberties that we do. If they sent out their amps with 6-db gain, which is where I set my power amp gain, they would run into trouble. Good power amps

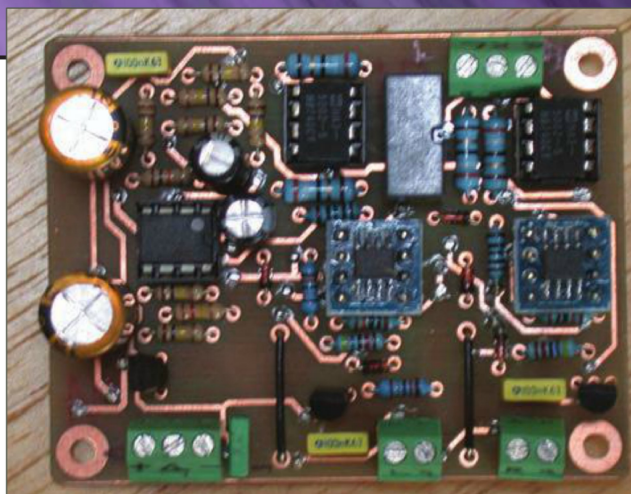


Photo 3: The output board



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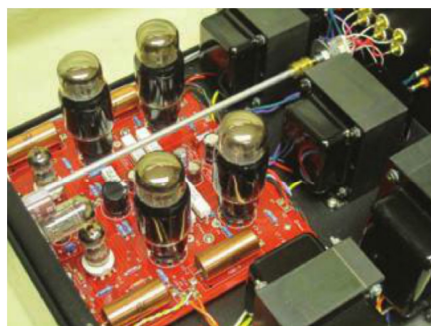
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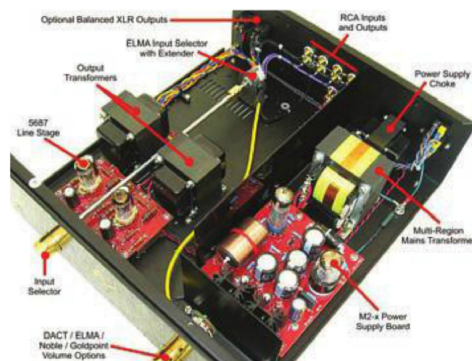
L 4 EL34i 35W



NEW : L 3 EL84i 20W



L 1 EL84i 17W



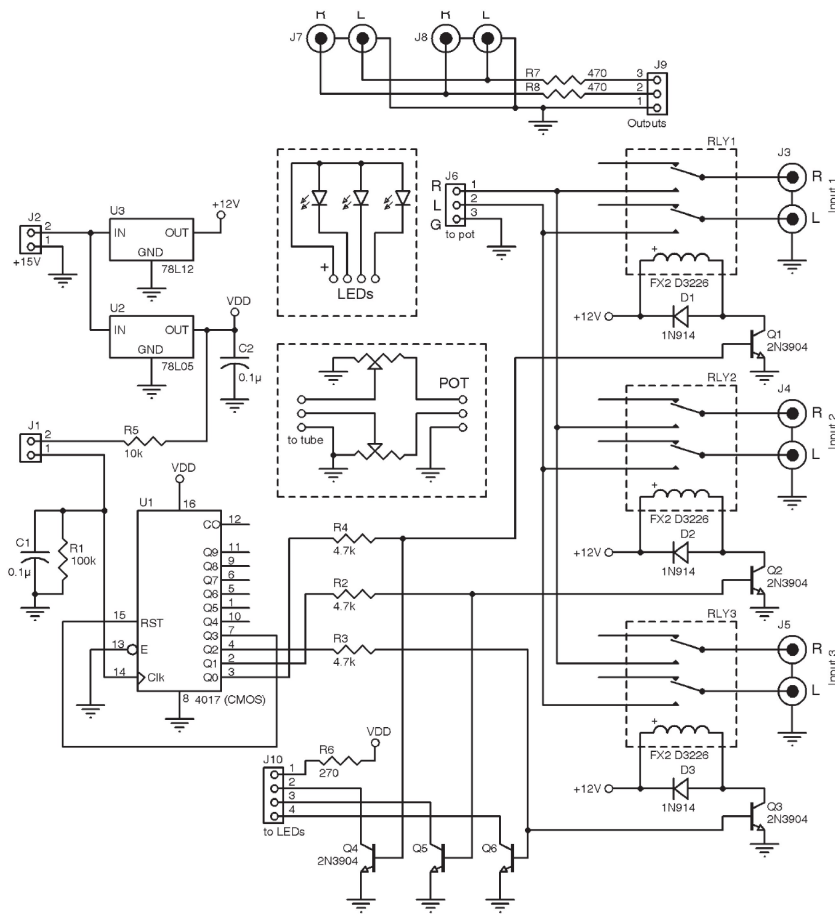


Figure 4: The schematic for the 1T4 amp input

should have a way to limit gain, a potentiometer or divider network, for example. You can build your own device into your amps to cut the gain.

On tube pre-amps you can cut the noise, especially if you use very sensitive or high-efficiency phones, by cutting the gain. You can even cut the gain to the output stage on some amps with a simple metal film resistor divider. On Merlyn, you can change the gain resistors on the

THS4631 (R4 and R1). On my personal amp, I use 47 k Ω because my headphones are not especially sensitive but you can use the 100-k Ω value shown in the schematic.

I did not use fancy transformers for this design. The plate transformer is one that has been sold by AllElectronics for years. It's 40 V at 250 mA and costs \$2.50 (as of March 2012). I used a 12.6-V, 300-mA transformer for the filaments and a 24-V center tapped at 300 or 600 mA for amp board. I tapped off the power supply (+18 V) output to drive the relays on the input board. All the transform-

ers cost under \$15. The tubes cost under \$5, even using coveted Mullard's cost under \$15 for the pair.

The capacitors on the powerboard also need some clarification. You can use 85° caps for everything but C3. For C3, use 105°. Here are capacitor sizes if you use my artwork:

- C1, C4, C5 = 20 mm dia., 10 mm pitch
- C2, C10, C11 = 26 mm $\times$ 10 mm

This project costs well under \$75 from start to finish and the sound will equal the best designs and embarrass lesser designs and poorer recordings. Listen for yourselves. The first reaction I get from this amp, when audiophiles and non-audiophiles listen to it, is a big smile! I did not run a long list of specs. The FFTs and other data showed no anomalies. *aX*

Editor's note: Robert Nance Dee provided supplemental information for the project. All of the information, including a list of materials, the bills of materials, additional figures, and top and bottom artwork is available at www.audioamateur.com.

SOURCES

33220A Arbitrary generator
34410A Bench meter
Agilent | www.agilent.com

334A Distortion analyzer
6632A Power supply
6207B Power supply
Hewlett-Packard | www.hp.com

Labcenter Spice
NI Spice
Labcenter Electronics | www.labcenter.com

Labcenter Spice
NI Spice
National Instruments | www.ni.com

SPECIFICATIONS

- Bandwidth Less than 5 Hz to greater than 100 kHz
- Distortion Less than 0.2%

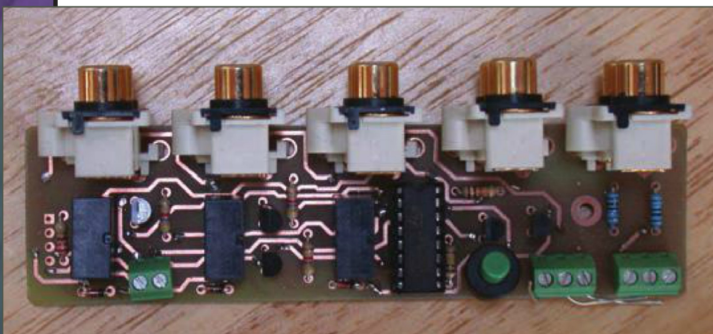


Photo 4: The input-output board

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Vacuum Tube Home Theater System (Part 1)

System Architecture

A “monster” system uses 23 vacuum tubes

By Dr. Gregory L. Charvat

Deployed in my college dorm room, it quickly earned the name, “Frankenstein.” It’s a home theater system built using 23 vacuum tubes, including 10 EL34s, five 12AU7s, seven 12AX7s, and one 5U4G, providing 373 W of root-mean-squared (RMS) average power across five channels (see **Photo 1**). It was a true monster powered by 535 VDC of plate voltage, over 20 A of filament current, protected by a 10-A main circuit breaker and over a dozen 3AG fuses. Power and status indication is provided by light bulbs, not boring LEDs. All of this is mounted in a 7' tall military surplus equipment rack from World War II, enameled in black crinkle paint and emblazoned with chrome accents. Until now, DVD rentals never sounded so good.

Most of the analog signal chain is implemented using vacuum tubes. Consumer electronics provide the audio signals to be amplified and routed appropriately. Vacuum tubes are desirable in a home theater system because they provide that inexplicable smooth and warm tube sound for movie soundtracks. In addition, vacuum tube power amplifiers are capable of producing high-peak power, accurately reproducing the most hair-raising action scenes.

This is the first of a two-part series on how to build a vacuum tube home theater system. In this article, I will describe the system architecture, functionality, and circuit-level details on audio signal routing and power distribution. In the next article, the power amplifier designs that provide relatively high-peak power for movies, with considerable dynamic range, will be discussed.

AUDIO TRANSFER SWITCH AND SURROUND PRE-AMPLIFIER

“Frankenstein” supports two operating modes—high-fidelity stereo and home theater. Complete diagrams are shown in **Figure 1** and **Figure 2**. The audio transfer switch and surround pre-amplifier controls are routed to the power amplifiers (see **Photos 2, 3, 4**). There are five tube power amplifiers. The quad power amplifier is made up of four tube amplifiers built into one chassis providing 80-W RMS each for the front R and L speakers and the rear R and L speakers. The mono-block power amplifier provides 52-W RMS for the sub woofer.

Dolby 5.1 and DTS is decoded by a surround processor providing six channels of analog output, digital volume control, and selection of multiple digital ports. The bitstream output from a DVD player is fed into the surround processor. Of the six analog outputs from the surround processor, five are fed into the audio transfer switch and surround pre-amplifier (see **Figure 3**). These include front R/L, surround R/L, and subwoofer, which are fed into J1–J5 respectively. The center channel is optional and can be fed into a center channel power amplifier but this is not included here because the center channel is mixed into the front R and L channels inside of the surround processor. Connections are provided in the form of a 120-VAC switched bus facilitating the future addition of a center channel that is only powered on when in the system is in surround mode.

Output from the surround processor is too low to drive the power amplifiers directly therefore each channel is amplified by a 12AX7 triode preamplifier (V1–V3).



Photo 1: The Frankenstein, a vacuum tube home theater system

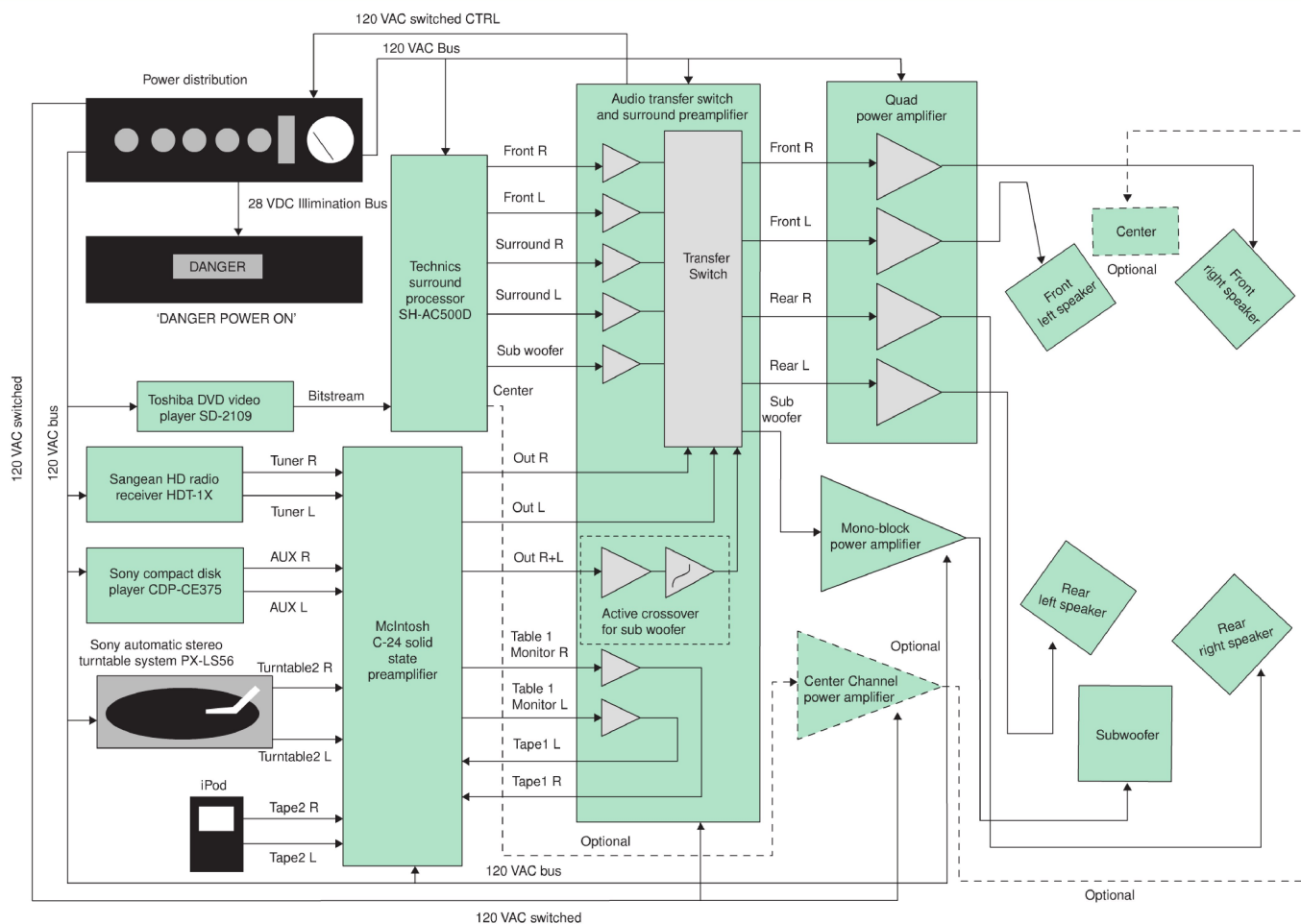


Figure 1: Block diagram

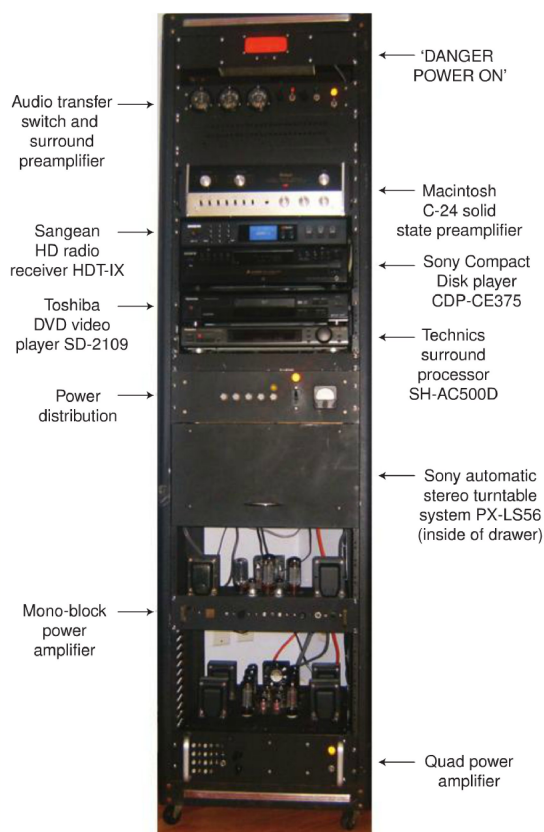


Figure 2: Call-out diagram

Direct bias is used in each preamplifier provided by an op-amp circuit (U1), but, a cathode bias could be utilized similar to that used in.^[1]

The amplified output from the surround processor is fed into a transfer switch matrix made up of U2 and U3, which are analog devices, ADG333A analog switches. It was observed while testing an earlier design that small signal relays used in the transfer switch matrix caused an audible "pop" on the output of the power amplifiers while changing modes. This could not be suppressed sufficiently, which lead to the use of the ADG333As that do not cause any audible switching noise.

High fidelity stereo is sourced by a McIntosh C-24 solid-state pre-amplifier. The C-24 is a convenient pre-amplifier for selecting audio sources, adjusting treble, bass, loudness contour, and adjustment of volume. An HD radio receiver is fed into the tuner R and L input ports, a CD player is fed into the AUX ports, a turntable is fed into the Turntable 2 ports, and an iPod is fed into the Tape 2 ports. The output of Tape 1 monitor ports are fed into J6 and J8 in the audio transfer switch and surround pre-amplifier where they are amplified by two triodes from a 12AX7 (V4) then fed back out through J7 and J9 to the Tape 1 input ports on the C-24. This allows the C-24 to function as a hybrid tube and solid-state preamplifier and provides a signal boost when low-level iPod audio is fed into the C-24.

Out R and Out L from the C-24 is fed directly into the switch matrix through J12 and 13. Out R+L is fed into J17 and through the solid-state switch U3 then into an active crossover circuit consisting of a 12AX7 triode pre-amplifier and a second-order Sallen Key active low-pass filter (U5) where, the cut-off frequency can be adjusted by RV2 located on the rear panel.^[2] This



Photo 2: The transfer switch and surround pre-amplifier



Photo 3: The inside of the transfer switch and surround pre-amplifier



Photo 4: A rear view of the transfer switch and surround pre-amplifier showing rear-panel audio input and output connections

crossover circuit can be placed in-line or bypassed by switch SW3 located on the front panel.

The surround and high-fidelity mode is controlled by SW2 on the front panel. Closing SW2 enables surround sound mode by routing the amplified output of the surround processor to all of the power amplifiers. When SW2 is closed, +5 V is fed out J18 through the 120-VAC switched CTRL line to the power distribution, which then energizes the 120-VAC switched bus to power the optional center channel power amplifier.

Opening SW2 enables high-fidelity mode by routing Out R from the C-24 to the inputs of the Front R and Rear R power amplifiers that reside within the quad power amplifier. Leaving SW2 open routes Out L from the C-24 to the inputs of the Front L and Rear L power amplifiers that reside within the quad power amplifier. In addition, the output of the active crossover circuit is routed to the mono-block power amplifier, which powers the subwoofer.

POWER DISTRIBUTION

Power to all equipment is supplied by 120 VAC line voltage. The power distribution system (see **Photos 5, 6, 7**) filters in-



Photo 5: The power distribution



Photo 6: Inside the front of the power distribution, showing 120-VAC outlets and relay driver

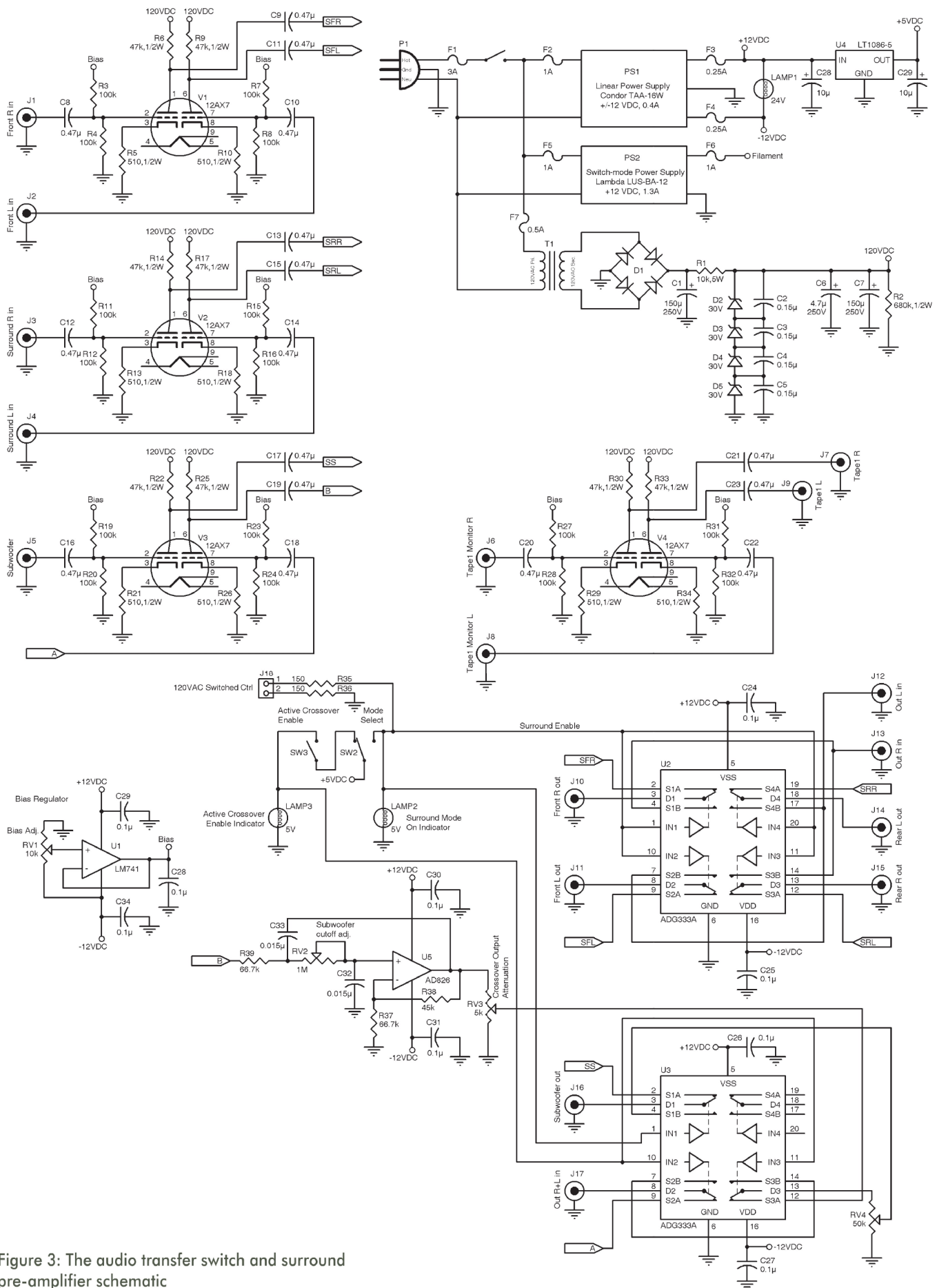


Photo 7: An inside view of the rear of the power distribution showing front-panel fuses

coming line voltage from transients, provides a common ground point for all power cords to reduce ground-loop hum, and controls power to the optional center channel power amplifier.

The power distribution schematic is shown in **Figure 4**. Line voltage is fed in through P1. The hot line is fed through a 10-A circuit breaker BRKR1, through AC amp meter MTR1 and through line voltage filter FL1. The neutral line is also fed through FL1. System power is turned on by closing BRKR1. The hot output of FL1 is bussed out to fuses F1–6 and the neutral is bussed out to J1–J4, transformer T1, and relay K1. F1–5 are located on the front panel for trouble-shooting purposes.

The 120 VAC is fed to the quad power amplifier through J1, where J1 is protected by a 10-A fuse, F1. The 120 VAC is fed to the mono-block power amplifier through J2 where, J2 is protected by a 3-A fuse, F2. The surround audio transfer switch and surround pre-amplifier, C-24, the surround processor, and all other audio sources are powered by the 120 VAC from J3, where J3 is protected by a 3-A fuse, F3. One additional outlet is provided by J4, which powers the turntable. J5 is reserved for the optional center channel power amplifier. Power to J5 is controlled by the relay K1. K1 is controlled by an optically isolated relay control circuit, which is enabled by a +5-V signal from the 120 VAC Switched CTRL line fed through J8. Lamp1 indicates that main system power is on. Lamp2 indicates that power to the optional center channel power amplifier is on. A 28 VDC is provided by the relay control circuit to illuminate the “DANGER: POWER ON” sign at the top of the



rack. Additional decorative lighting can be added to the 28-VDC illumination bus.

PLUG IN YOUR AMPLIFIERS

The core of this vacuum tube home theater is the power distribution and the audio transfer switch and surround pre-amplifier. These provide the infrastructure, enabling the use of tube audio amplifiers in a home theater application that supports both high-fidelity and surround sound modes. Consumer audio components are used for the surround processing, DVD player, digital, and analog audio sources. Tubes were used for surround pre-amplification and as part of the active crossover circuit. Using this architecture, you could use your tube amplifiers, substitute a different surround processor, or try other components.

In Part 2 of this series, vacuum tube power amplifiers will be developed specifically for action movies that push the limits of maximum power of the EL34 pentode. The objective is to achieve high peak power for those brief periods of loud action while limiting the design to use readily available vacuum tubes. *aX*

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- [1] G. L. Charvat, "Portable Tube Pre-amp," *audioXpress*, March 2010.
- [2] D. Lancaster, *Active Filter Cookbook*, 17th edition, Synergetics Press, Thatcher, AZ, 1995.

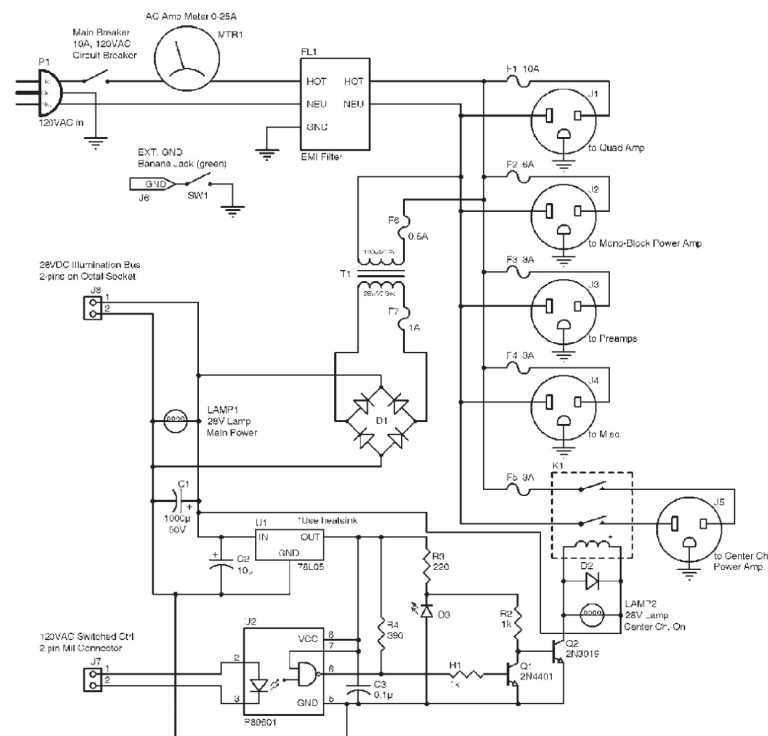


Figure 4: The power distribution schematic

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Repurposing Antique Radios as Tube Amplifiers

Learn how to give new life to vintage radios

By Bill Reeve

Manufactured from the 1930s through the 1960s, vacuum tube radios often contain high quality audio amplifiers at the end of their RF signal chain. You can repurpose these radios into vintage, low-power tube amplifiers—without marring them in any way or detracting from their original charm and functionality as working analog radios.

Wood-cased radios have especially good sound quality, and the battery compartments in antique “portable” radios (like the Philco 48-360 or the Zenith Transoceanics) provide perfect locations for additional circuitry. When restored properly, large furniture-style radios that were built for “high fidelity” (like the late 1930s and early 1940s Philco console radios) can fill a room with rich beautiful sound.

The three most significant recommendations I can make concerning restoring old mains-referenced electronics are: be sure to install a polarized power cord; add a fuse at the hot mains power entry; and if necessary, re-wire the external power entry so that the on/off knob switches the hot mains wire so that the internal chassis is neutral-referenced.

ACCESSIBLE RESTORATION RESOURCES

Many organizations and websites are dedicated to the restoration and collection of antique tube radios. Definitely check out [www.antique-](http://www.antique-radio.com)

Warning: Antique tube radios contain dangerously high, mains-referenced voltages. Always use an isolation transformer when powering a radio in the shop. Never work on a radio when it is powered, and discharge high-voltage capacitors to avoid electrical shock. Do not attempt any repair or modification of mains-powered electronics unless you understand electrical safety.

radio.com, www.antique-radios.org, www.dxzone.com/catalog/Antique_Radios/Clubs, and [\[dio.it\]\(http://dio.it\). Searching the web for subjects like “replacing capacitors in old radios” yields interesting advice. Ad-](http://www.antiquera-</p>
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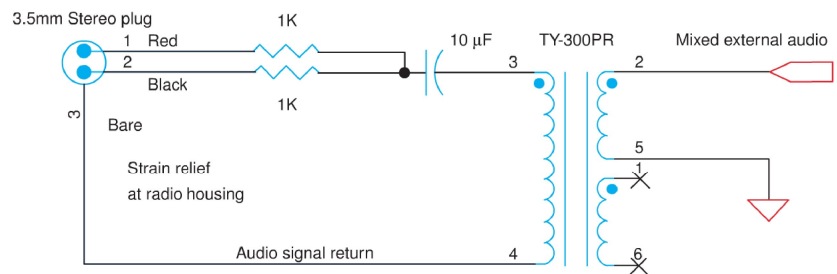


Figure 1: An inexpensive circuit for mixing an MP3 player's stereo audio signals safely into an antique radio. None of the component values are critical.

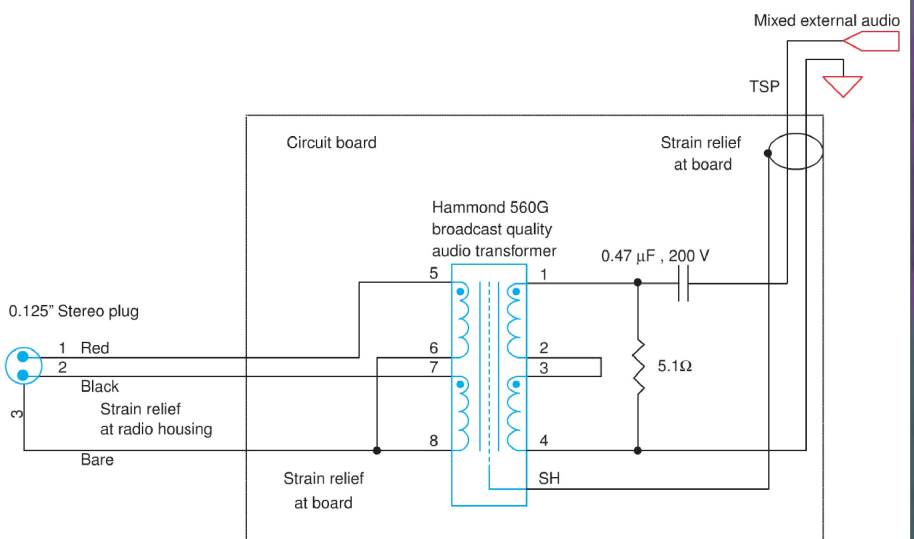


Figure 2: A high-fidelity circuit for mixing external stereo audio signals safely into an antique radio.

ditionally, there are many excellent books describing radio restoration, the “Books, etc. for sale” link at the website www.antiqueradio.com is an excellent place to start.

Because of this available supply of restoration information, this article will focus on circuit modifications designed to repurpose these antique radios into amplifiers, without altering their appearance or original radio functionality.

SIMPLE CIRCUITS

The simple circuits described in this article perform two functions. They mix an external line-level stereo signal (typically from an MP3 player or computer) and reference it to the radio’s circuit. They also use the radio’s on/off knob to switch this external signal to the radio’s audio amplifier.

There is not one circuit that will work for every antique radio. (Original schematics for antique tube radios are available on the web www.justradios.com). But the circuits described here can be adapted to any radio topology. All the parts can be ordered from an electronics supplier like Digi-Key, and the circuit can be soldered on a prototyping printed circuit board (such as RadioShack P/N 276-168B).

EXTERNAL AUDIO MIXING

Figure 1 and **Figure 2** show some examples of circuit schematics that



Photo 1: A 1948 Philco portable tube radio restored and repurposed as an MP3 amplifier

mix the line-level stereo audio signals together (almost all tube radios are monophonic), while providing galvanic isolation from high voltages within the radio. **Figure 1** shows an inexpensive solution suitable for most table-top radios. These radios have relatively small speakers that are unable to reproduce deep bass, so an inexpensive audio transformer (available from on-line distributors) does the job. I picked up a bucket of Tamura TY-300PR transformers for \$0.50 each at an electronics surplus store, and similar transformers are commercially available. Alternatively, the Hammond 560G shown in **Figure 2** is an expensive, high-

quality audio transformer suitable to high-fidelity radios (like the furniture-sized Philco consoles). A less expensive (and fine-sounding) alternative is the Hammond 148A. I use Belden 9154 twisted, shielded audio cable for wiring internal to the radio, but twisted, 24-gauge wire will work well. An 8' long audio cable with a 3.5-mm stereo jack on each end can be cut in half to make input cables for two radios, or you can use the cord from trashed ear-buds. You can route the audio cable out the back of the chassis. **Photo 1** is a photograph of a 1948 Philco portable tube radio restored and used as an MP3 player amplifier.

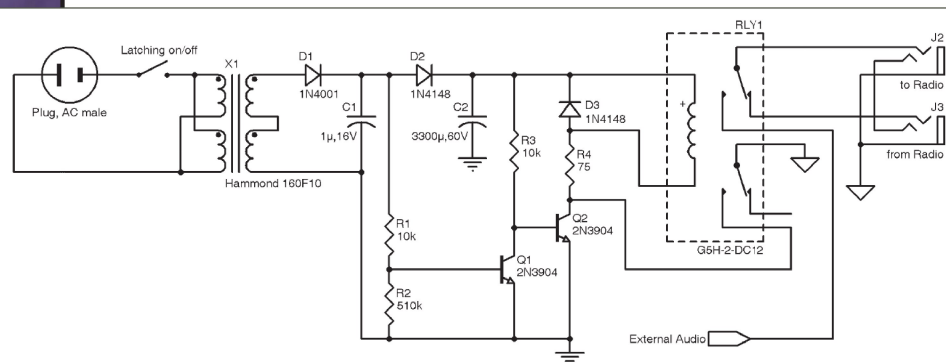


Figure 3: A transformer-powered circuit for switching between internal and external audio signals, using the radio's existing on/off knob

AUDIO SWITCHING USING THE RADIO'S ON/OFF KNOB

After creating the mixed, radio-referenced signal, the next step is to build a circuit that switches the voltage driving the radio's audio amplifier between its own internal broadcast and the external audio signal. **Figure 3** illustrates this audio routing control using the radio's existing front panel power knob. Turn the radio on, and it behaves like the old analog radio it was designed to be (after the tubes warm up). However,

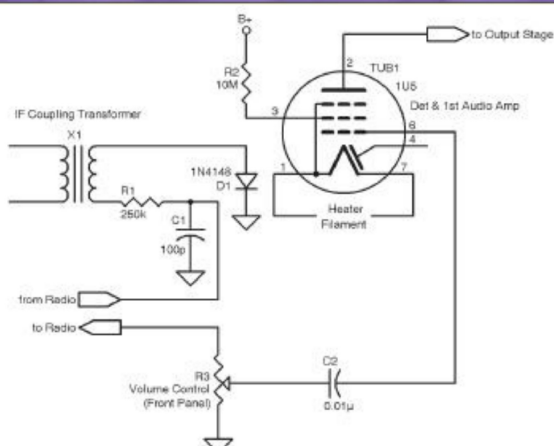


Figure 4: A modified detector and first audio amplifier to allow external signal injection

if you turn the radio off, then on again within a few of seconds, the external audio signal is routed to the radio's tube amplifier and speaker.

The circuit shown in **Figure 3** uses a transformer to create the low voltage used by the switching circuit. There are many alternative power transformers available, and many methods of creating a transformerless power supply. Use your favorite.

In **Figure 3**, the connector in that is labeled "From radio" represents the audio signal coming from the radio's AM detector circuit, and the connector labeled "To radio" is the selected audio (either the radio station broadcast, or the MP3 player signal) that we are sending back to the

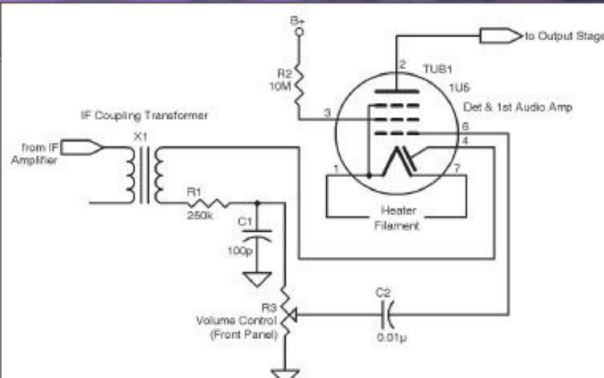


Figure 5: A typical tube radio combined detector and first audio amplifier

radio's audio amplifier. **Figure 4** shows how these signals interface to the radio circuit.

When the radio is initially powered on, the lower 2N3904 transistor turns on. This pulls down the base of the higher transistor, turning it off and keeping the relay coil de-energized. In this state, the radio audio is routed through the relay to the radio's audio circuit. When the radio power is switched off, the lower transistor switches off and allows the upper transistor (powered for a few seconds by the large capacitor) to turn the relay on. The relay latches itself on through its lower contact. In this configuration, the relay routes the external audio signal to the radio's volume control, and from there it feeds the radio's output amplifier. If the radio is switched back on within a few seconds, this state is maintained, and

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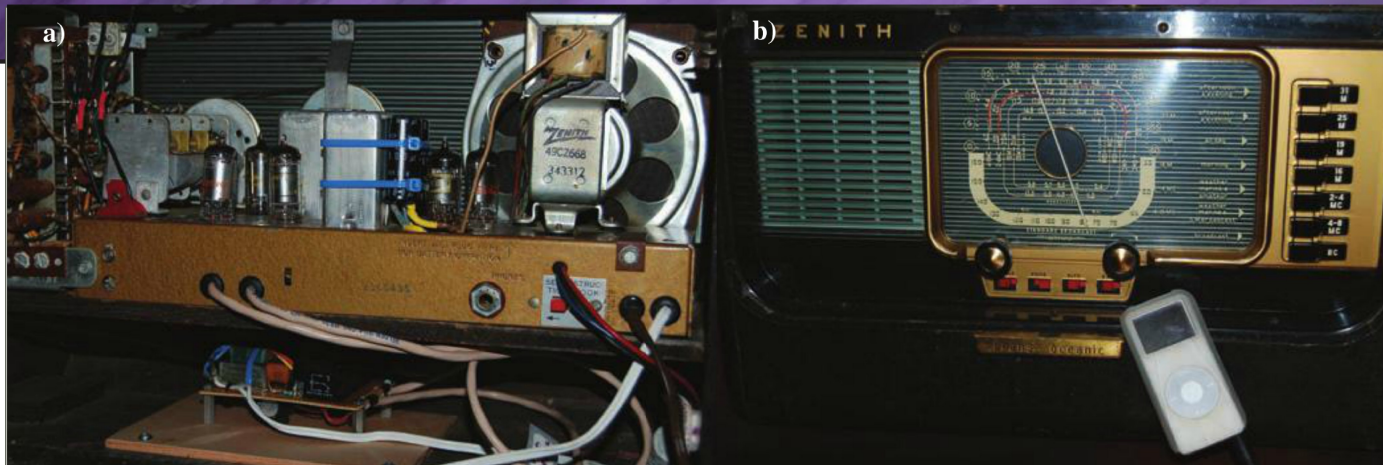


Photo 2a: The inside view of a Zenith Transoceanic AM/shortwave radio restored and augmented as an MP3 audio amplifier. b: This is an outside view of the repurposed Zenith Transoceanic AM/shortwave radio.

the radio serves as a tube amplifier with its volume still controlled by the radio's volume knob. When the radio is eventually turned off, the circuit discharges and returns to its original radio configuration.

Now that we can switch the signal to the tube amplifier, we need to modify the radio's circuit to accommodate our external audio signal. We will examine a representative radio circuit. The volume control knob is usually the best place to switch in our audio signal. **Figure 5** shows a typical circuit adjacent to the volume control potentiom-

eter in an antique radio. The IF (intermediate frequency) signal (which has been mixed down from the received RF signal) is rectified by the diode of the 1U5 tube (1U5, pin 4) and low-pass filtered (to remove the IF frequency content) before being presented to the volume control knob as an audio signal.

We hijack the signal between the low pass filter and the volume potentiometer (see **Figure 5**) and route it to our switching circuit. Also, to reduce the radio signal bleed thorough into the first audio amplifier (because the IF signal's rectifying diode and the audio amplifier pentode are in the same tube), we can replace the vacuum tube diode with a semiconductor diode.

The next photos (see **Photo 2a** and **Photo 2b**) show our additional circuit mounted in the lower (battery) compartment of a Zenith Transoceanic AM/shortwave receiver. Note the new high-voltage (B⁺) capacitors (part of the radio's restoration) attached to a transformer housing with blue tie wraps. The added circuit board that performs the audio re-routing is mounting to a 0.125" maple plywood base, using screws countersunk from underneath. The plywood is securely screwed to the inside base of the radio housing. Rubber grommets are added wherever cables pass through the radio's steel frame.

Careful, patient workmanship is the key to a safe and successful radio restoration, and the reward for adding the capability to play external audio is a classic amplifier with vintage tube sound. *aX*

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The Faital Pro HF104 Coupled with Its STH100 Horn

A compact high-end home audio driver put to the test



Photo 1: The Faital Pro HF104 compression driver

The driver I'll cover in this month's review is the Faital Pro HF104 compression driver coupled with Faital's STH100 horn (see **Photo 1**). Faital's HF104 is an interesting compression driver and has several unique features. This includes a Ketone polymer annular-shaped diaphragm and a radial-shaped phase plug. The throat diameter is 25.4 mm (1.0") and is coupled to a 28-mm (1.5") diameter voice coil wound on a Kapton former with copper-clad aluminum wire. Other features include a case aluminum body, 40-W AES-rated power handling (80 W maximum), and solderable aircraft terminals. The horn supplied with the HF104 driver is Faital's 1.0" throat 80 H × 70 V short elliptical tractrix flare STH100.

Testing commenced using the LinearX LMS analyzer to produce the 300-point stepped sine wave impedance plot shown in **Figure 1**. Note that the solid curve shows the HF104 mounted on the STH100 horn and the dashed curve represents the compression driver without the horn. With a 5.5-Ω DCR, the minimum impedance of the HF104/STH100 was 76.9 Ω at 7.9 kHz.

For the next test sequence, I mounted the Faital HF104/STH100 on top of an enclosure with a 15" × 14" baffle and proceeded to measure both the horizontal and vertical on- and off-axis at 2.83 V/1 m using a 100-point gated sine wave sweep. **Figure 2** displays the on-axis of the compression driver/horn combination and shows the sensitivity to be about 109 dB, somewhat higher than the specified 108 dB from Faital's published data. The SPL profile measures ±4.0 dB from 1 kHz to 10 kHz (recommended crossover frequency for the HF104 is a minimum

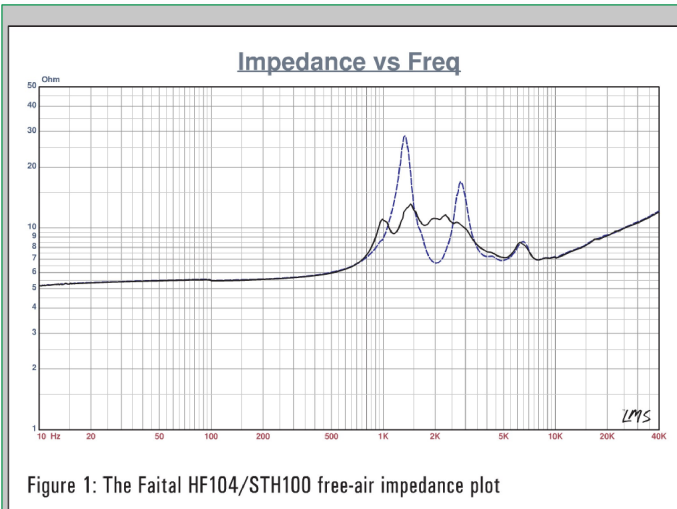


Figure 1: The Faital HF104/STH100 free-air impedance plot

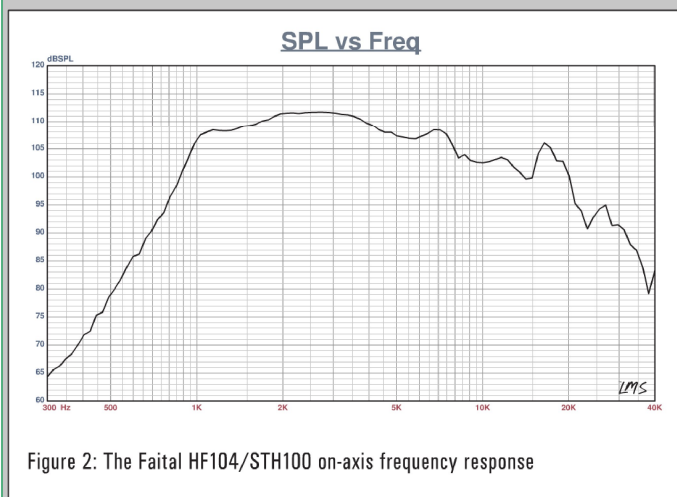


Figure 2: The Faital HF104/STH100 on-axis frequency response

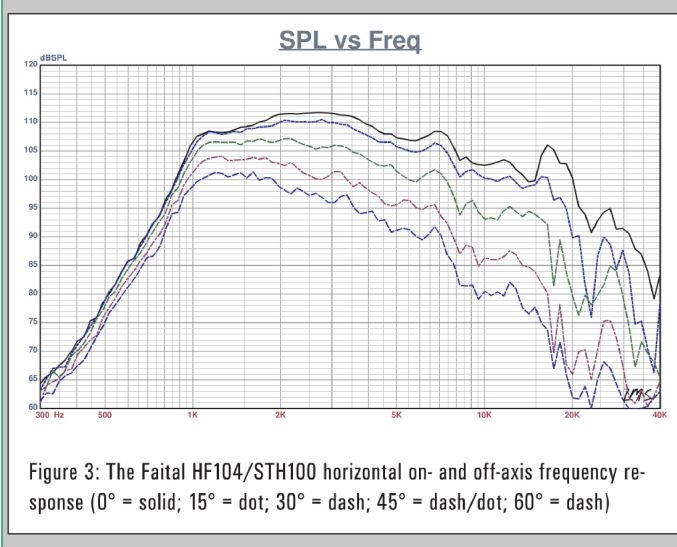


Figure 3: The Faital HF104/STH100 horizontal on- and off-axis frequency response (0° = solid; 15° = dot; 30° = dash; 45° = dash/dot; 60° = dash)

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of 1.7 kHz with a second-order network). Since the coverage of this horn is 80 H × 70 V, you wouldn't expect much of a difference in the horizontal and vertical off-axis plots, which is indeed true as seen in **Figure 3** for the horizontal orientation and **Figure 4** for the vertical ori-

entation. **Figure 5** gives the two-sample SPL comparison, showing both samples to be closely matched.

For the remaining battery of tests, I employed the Listen, Inc. SoundCheck analyzer, 0.25" SCM microphone and power supply (courtesy of Listen, Inc.) to measure distort-

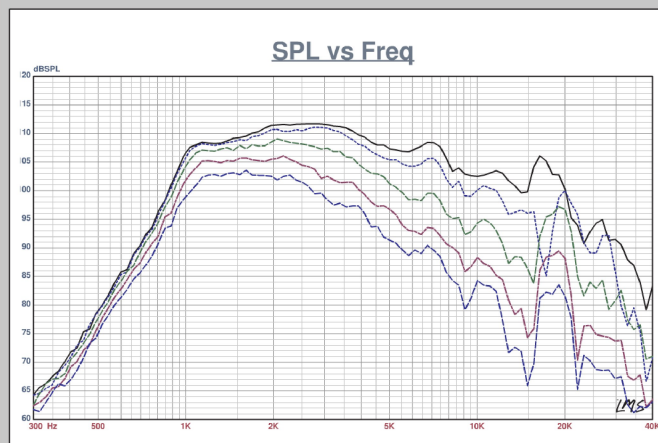


Figure 4: The Faital HF104/STH100 vertical on- and off-axis frequency response (0° = solid; 15° = dot; 30° = dash; 45° = dash/dot; 60° = dash)

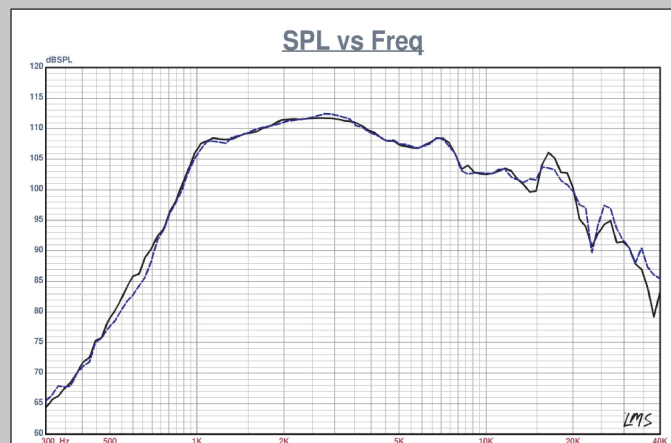
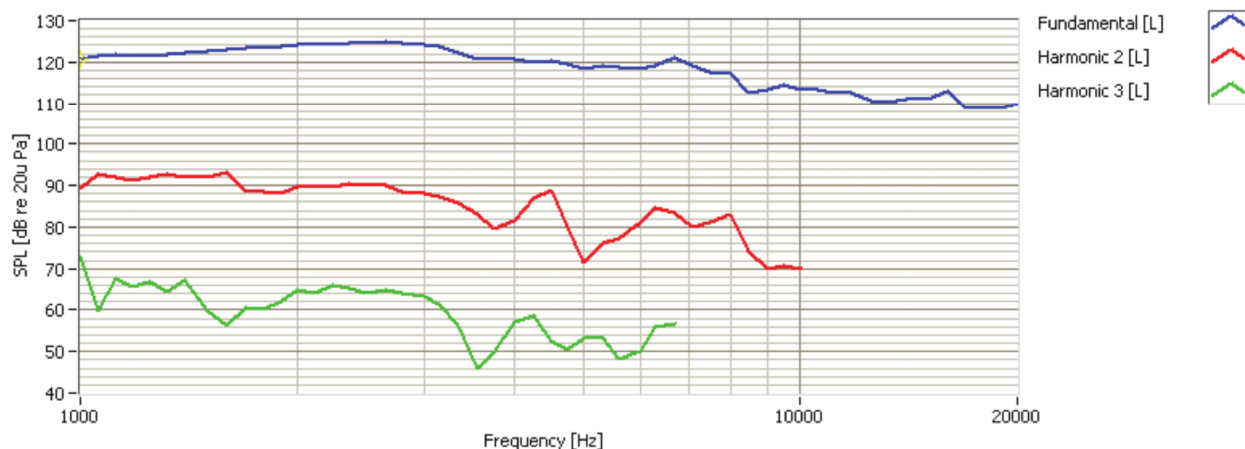


Figure 5: Faital HF104/STH100 two sample SPL comparison

Response and Harmonics



Distortion

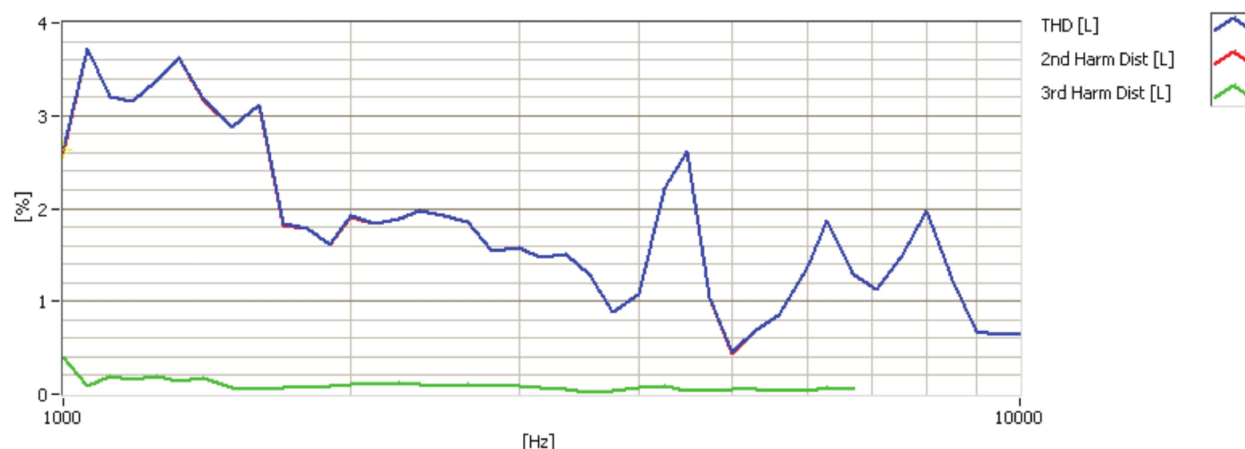


Figure 6: Faital HF104/STH100 SoundCheck distortion plot

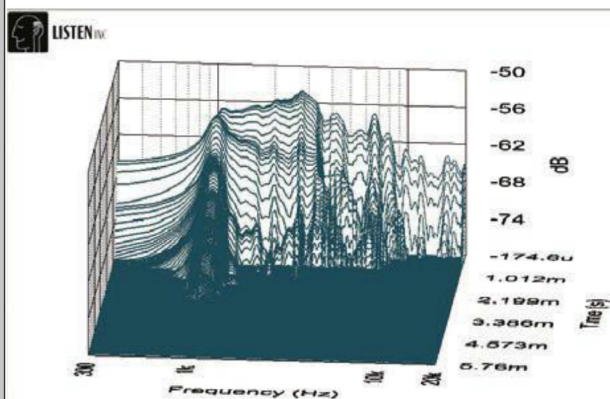


Figure 7: Faltal HF104/STH100 SoundCheck CSD waterfall plot

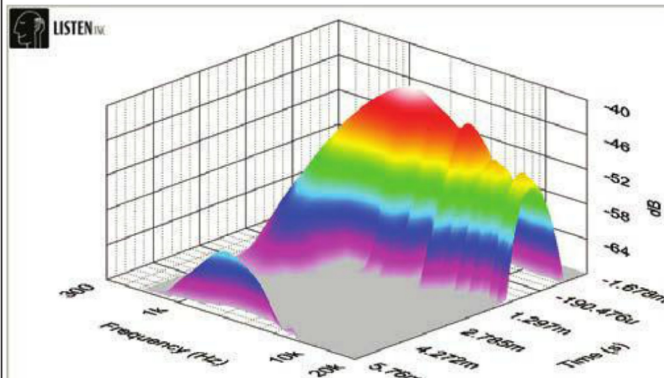


Figure 8: Faltal HF104/STH100 SoundCheck Wigner-Ville plot

tion and generate time frequency plots.

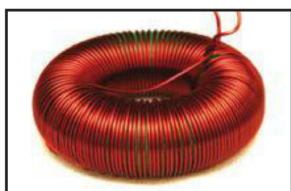
For the distortion measurement, the HF104/STH100 combination was mounted with the same baffle as used for the frequency response measurements, and the SPL set to 104 dB at 1 m (1.94 V) using a noise stimulus, and then the distortion measured with the Listen, Inc. microphone placed 10 cm from the mouth of the horn. This produced the distortion curves shown in **Figure 6**. I then used SoundCheck to get a 2.83 V/1 m impulse response for this driver and imported the data into Listen, Inc.'s

SoundMap Time/Frequency software. The resulting CSD waterfall plot is given in **Figure 7** and the STFT plot in **Figure 8**.

While I haven't had a chance to verify this, I have been told that the Ketone polymer diaphragm yields a smooth subjective performance. Again, from the above data, the HF104/STH100 looks like a nice addition to the Faltal Pro lineup of pro sound compression drivers.

For more about Faltal pro sound products, visit the company website at www.faltalpro.com. **ax**

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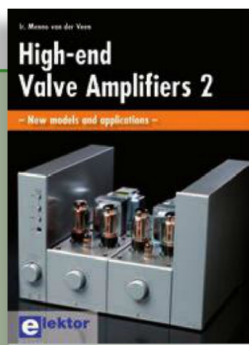
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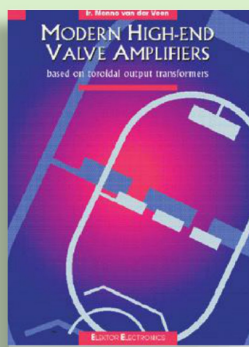


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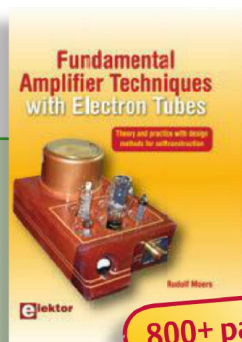
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Audiophile Still Loves Tube Electronics

A renaissance man discusses tubes, music, recording equipment, and more

SHANNON BECKER: Where do you live and work?

STUART YANIGER: Austin, Texas, the live music capital of the United States. I was aware of this before I came here, but really, I had no idea of how true it was! There's so much music and so many great musicians here.

Austin is not much like the rest of Texas. It's quite a bit like Silicon Valley, but with its own distinctive flavor (and an extra 30° of heat). I moved here from California, with a short stop in Montana, about three years ago.

SHANNON: You are a technologist and an inventor specializing in polymer science. Tell us more about what you do?

STUART: I'm still trying to figure out what I'm going to do when I grow up. These days, my work is verging on biology. But I still have a love for my original specialty, electrically conductive polymers, and I still haven't totally gotten this out of my system. If I can get some time in a good synthetic lab, I have some ideas.

SHANNON: You have been designing and building with tubes and tube circuits for 45 years. How and why did you first get interested in tubes? What keeps you interested today?

STUART: As a nerdy kid, I got a ham radio license. Being a fairly broke, nerdy kid, I had to build a lot of my own equipment. So I was sort of forced to learn electronics. In my teens, I got very serious about music, so my efforts went down in frequency. (Sorry, very bad joke.) This was the 1960s, and tubes were still the easiest and most reliable way to make small electrical signals bigger. I think there's a natural tendency to consider the technologies of one's youth as somehow "normal" or "natural," and maybe that's why I have an irrational love for tube electronics.

SHANNON: I've heard you enjoy the music scene in Austin, TX. Do you play an instrument or have a favorite music genre?

STUART: I play flute and guitar, and can get

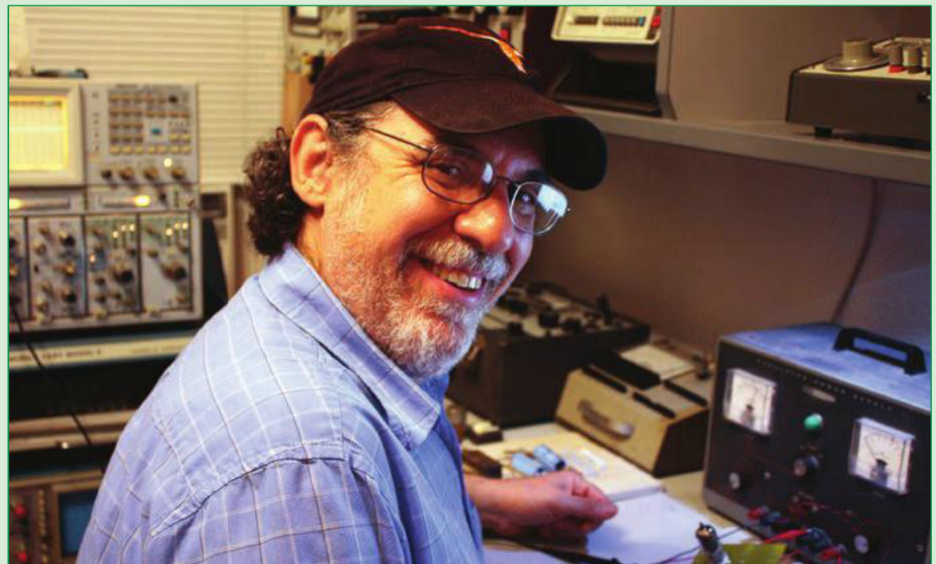


Photo 1: Stuart Yaniger working at his "immaculately organized" lab bench (Cynthia Wenslow photo)

by on bass.

I grew up in Baltimore, MD, and in those days, there was an amazingly lively jazz scene. So, that certainly shaped my listening habits. After my move to Austin, I was overwhelmed by the talent of guys like Lee Barber, Erik Hokkanen, Matt Sever, Southpaw Jones, Robert Ellis, Steve James, James McMurtry, and many others—people who are doing real, direct, and creative things. The other cool thing about the Austin music scene is how friendly and accessible the musicians are. I take my son—he's 11 years old now—to many shows with me. He's gotten accustomed to the idea that when you go to a concert, the musicians will all know your Dad and play your favorite songs. Two of them (Matt Sever and Southpaw Jones) even wrote songs to fit a title that my son suggested. Check out Southpaw's version of "Big Fat Boy" on YouTube; it's a wonderful song.

SHANNON: You have written several audio-related articles. How did you get started writing?

STUART: Blame Jan Didden. As a youngster, I used to devour *Audio Amateur* whenever a new issue appeared. And, I reread older issues until I had them nearly memorized. The later appearance of *Speaker Builder* and *Glass Audio* didn't

slow me down. It was more fuel for my imagination. I particularly liked Jan's articles, which were always straightforward and educational. His writing was always about the technology, not about him, which I particularly liked. When I discovered the diyAudio.com website about 10 years ago, he was an active participant. I was very impressed that I could actually talk to this guy! We've since struck up what has become a very close friendship.

Jan liked the stuff I posted on [diyAudio](http://diyAudio.com) and strongly encouraged me to write and submit an article to *audioXpress*. His hints on "do this, don't do that" were the difference between me being a frustrated author and a published author. That article was a real source of pride for me. I was finally contributing to those pages that I had spent so many hours perusing. Since then, Jan has started a "bookzine" called *Linear Audio*, and I've been writing pretty regularly for it. I would also like to do another aX article at some point.

SHANNON: You wrote a great article for *audioXpress* in February 2009, "The ImPasse Pre-amplifier." It's a pre-amp to drive a pair of Nelson Pass's First Watt F4s in balanced mono. The F4 is a unity gain amplifier requiring a pre-amplifier capable of driving the full expected output swing. As two channels of the F4 should be able to swing 40 V in Class-A, for

100 W of output power, the pre-amp needed to capable of delivering 28.3 VRMS. How did you come up with the design? Do you still use it?

STUART: Thanks for the kind words. Like most of my articles, this was intended as a pedagogical exercise as well as a construction project.

The design was pretty straightforward, though the discussion on cathodyne phase splitter source impedances that it spawned made it quite controversial. The design was done for a friend of mine, Mark Cronander, who runs the operations at diyAudio.com. Mark had built the F4s, wanted something to drive it, and had a very complex solid state unit lined up. I wanted to see if I could equal or exceed the complex transistor design with a hybrid tube unit with a much lower parts count. Surprisingly, it worked! Since my system doesn't need anything like that kind of gain, the major sections of the pre-amp were repurposed. The case now houses a six-channel version of the Heretical pre-amp, a unity gain pre that's on my website. The Heretical controls the output volume of a modified Behringer DCX2496 (Jan Didden's passive RC output mods).

SHANNON: Can you tell us about your website, www.syclotron.com? Why did you start it? And where do you want to go with it?

STUART: A combination of pure vanity, curiosity about using WordPress, and a wife who is an expert coder and wanted to set it up for me. It also is a vehicle for me to make updates, improvements, and rethinking of my projects easily available.

I'll probably continue using it as a site for supplementary information on articles and projects that I publish and a repository for things that just don't fit elsewhere but might be useful (i.e., my RIAA noise calculator or the rebuild of the NHT 3.3 speakers). I keep promising myself to start blogging and include the outrageous and non-PC things I say verbally, but that's the sort of thing that can come back and haunt you! I also want to add music and record reviews.

As I do more recording, samples of those will be up there as well. What the world needs is true high-resolution recordings, not the phony stuff made from upsampled 16/44 or mastered from low dynamic range analog tape. And I think the musicians I record are wonderfully talented people whose sounds deserve to be preserved without alteration.

SHANNON: Where do you get your design ideas?

STUART: Usually, I start with defining specifically what I want a gizmo to do. With a tight definition of goals, the design usually comes flopping out by itself. All I need to do is make sure that the proposed design hits the target. Choice of target depends on what I happen to need in my system at any given moment, what a friend might need, or what a magazine editor tells me he needs. So, that's the "where." As for "from whom," besides Jan Didden, I've cheerfully stolen ideas from David Berning (the most original and creative designer in the tube world), Scott Wurcer (maybe the best chip designer out there, and someone who has recently done some terrific work on microphones), and Morgan Jones (who wrote the definitive modern text on tube amplifiers). Morgan and I have had a particularly fruitful interaction—you can see his fingerprints all over my designs. And there's a lot of stuff in the new edition of his book that came out of our correspondence and conversations.

SHANNON: What was your most memorable design? Tell us about the project.

STUART: Most memorable was a failed experiment from about 1980 that I did with Murray Zeligman (a brilliant designer who ought to be better-known). It was an OTL power amp designed by brute-force methods, using 6528 dual triodes—32 of them! The inspiration was a surplus NASA shaker table that had banks of 6528s, so why not find a use for them? It worked as planned, but the heat output and energy draw were crazy-bad. I think we ended up running it for a total of 30 minutes before deciding that this was not our best idea!

SHANNON: What are you working on now? Do you have any new projects in the works?

STUART: My main project now is recording and building recording equipment, especially mikes and pre-amps. I do most of my recording in high-resolution formats (24/96) with no compression or other manipulation, just natural sound. You can hear a few of them on Soundcloud (<http://soundcloud.com/stuart-yaniger>). I've been using ribbon mikes in Blumlein configuration, but the "Army of Kittens" recording on Soundcloud was done with Scott Wurcer's small diaphragm condensers. My microphone pre-amps are a work in progress, ribbon mike

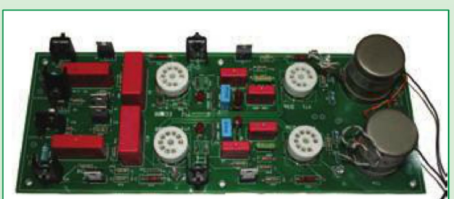


Photo 2: Yaniger's latest version of the His Master's Noise RIAA tube phono stage for moving coil cartridges. The circuit board design was by aX author Jack Walton. (Cynthia Wenslow photo)

output is on the low side of anemic, so the same low-noise design tricks that worked with my MC stage "His Master's Noise," published at diyAudio.com) come into play here as well. I've been delighted at how well simple chips like THAT1512 and SSM2019 perform regarding noise, dynamic range, and common-mode rejection.

On the bench at the moment is a pre-amp for moving magnet phono cartridges. I'm very unhappy with most current designs and want to see if I can do it better. It uses a balanced input, which can be tricky but can bring great rewards. One big issue that I'm tackling is input capacitance. The usual ECC83/12AX7 approach and the brute-force high mu high-gm triode approach have severe problems with Miller capaci-

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tance, and some of the better MMs don't like more than 150 pF or so. Cascoding can help, but it brings a whole new set of problems like non-existent power supply rejection. Part of my challenge is parts. I have a lovely design, which just can't be duplicated because some of the critical parts just aren't made anymore and fakes abound. Since I want to publish this as a buildable project, that design had to be discarded despite its simplicity and good performance.

SHANNON: You once shared a secret: "All electronics are not created equal." Do you mind elaborating on that thought and sharing your opinion of what makes great electronics?

STUART: And some electronics are more equal than others. Line amplifiers—it's a no brainer to design and build a pre-amp with low enough distortion, noise, and source impedance to be audibly transparent. You could do it with tubes, FETs, bipolars, ICs, whatever. On the opposite ends of the analog chain (mike and phono pre-amps on the left, power amps on the right) things get more difficult in both design and implementation. A good phono or mike pre-amp is about the hardest thing to design

well, and even if you know what you're doing, the tradeoffs are sobering.

SHANNON: Do you have any advice for *audioXpress* readers who are considering building their own amplifiers?

STUART: First, basic instrumentation. Trying to do audio without things like oscilloscopes, voltmeters, and signal generators is like trying to build a car without wrenches. Knowing how to use your instruments, and knowing their limitations, is crucial to success in anything beyond simple kit-building. A smart user with a cheap oscilloscope will get better and more meaningful data than a naïve user with a state-of-the-art oscilloscope with all the bells, whistles, and fancy probes, but no scope at all is crippling.

Second (and I'm afraid that this will turn off many people), a willingness to judge design ideas by listening. Not by seeing, not by processing of preconceptions and unconscious prejudices, but actually listening. This means good, controlled blind testing. Trust your ears, but don't trust that lying brain of yours.

Third, and perhaps most important, is to lay out the engineering requirements first. It's

impossible to know if you've hit the target if you haven't put one on the wall to shoot at!

SHANNON: There has been a long-running debate between tube and solid state amplifier aficionados? Do you have a personal preference, and if so, why?

STUART: There's no reason that an amp can't be designed and built with tubes, transistors, ICs, or any other analog amplification device. I confess, though, that the anacrophile in me just loves tubes.

As far as preference, I manage to annoy everyone. In my designs, I tend to pick the technologies that work the best in the overall system. For example, in my MC phono pre-amp (His Master's Noise), I mixed tubes, MOSFETs, LEDs, ICs, and bipolar transistors. MOSFETs are terrific for constant current sources, the LEDs are excellent low-noise constant voltage sources, and bipolar transistors are rugged, high-performance elements in power supply regulators. The tubes do the amplification work, bringing low grid current, low distortion, and high-dynamic range to the table.

To illustrate my point about my designs annoying people, I was showing the schematic of my prototype to Morgan Jones at one of the European Triode Festivals. Tim de Paravicini happened by, looked over my shoulder, jabbed at the schematic with his finger and exclaimed, "This is an absolutely terrible design!" Morgan asked what Tim thought was wrong with it. Tim replied, "In the 1930s when people designed these sorts of things with tubes, no one would have used LEDs or MOSFETs. There were no such things!" Tim was quite sincerely annoyed. Nonetheless, the pre-amp worked great, several other people have successfully built it, and the Earth is still rotating on its axis.

That said, I've used tubes in designs where a solid-state approach could give better objective performance, though perhaps not better subjective performance. The power amp I use for the midrange and treble of my speakers, for example (the Red Light District). But just because a modern Lexus can accelerate and corner objectively better than a 1958 Austin Healy Sprite doesn't mean I'd rather have the Lexus.

SHANNON: Imagine you have a big budget and tons of free time on your hands to build your audio "dream system." What would it include and why?

STUART: I'd be tempted to build a perfor-

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mance studio and hire great musicians to come play for me! And record them, of course.

Okay, this is a very unpopular thing to say in hobby audio, but... there's really not much of a technical challenge anymore to getting an electrical signal from the microphone to the loudspeaker terminals relatively unmolested. I still enjoy designing and building that stuff, but I don't kid myself that I'm doing anything that's really advancing the state of the art in audio. I'm doing the equivalent of crossword puzzles or sudoku instead of writing literature or opening new fields in mathematics.

The real challenges are in formats. The idea of taking a three-dimensional sound field, compressing it into two one-dimensional signals, then trying to recreate that sound field from the radically compressed information using two spaced transducers is crazy. The astonishing thing is that it works as well as it does. So my dream system would not be stereo, and the electronics would be (from an audiophile point of view) nothing exotic or special. The real work would be format and transducers. And the room, of course. I've dreamed of having a dedicated listening and recording space, and if I ever win the lottery, that's second on the list of priorities (first is a wood-burning pizza oven).

The interesting hardware that I just don't have time and money for include phono cartridges (I'd love to experiment with strain gauges and FM) and exotic speaker drivers (ionic or plasma). It would be interesting to experiment with speakers that turn the usual equations upside-down. In our current paradigm, the piston area is fixed and the displacement varies. What would happen if the displacement were fixed and the piston area varied?

SHANNON: A lot has changed in audio technology during the past few decades. What changes do you consider positive? Any negative?

STUART: Things are better now than ever in nearly all ways. Recording, data storage, and duplication are robust and high performance. I have a little TASCAM portable recorder that vastly outperforms the heavy and fiddly Ampex 351 I started out with. It's quieter, lower distortion, higher bandwidth, and stores several hours of recordings on a \$10 chip. It runs for eight hours on a couple of penlight batteries, is the size of a TV remote control, and costs about what a couple reels of tape do.

The Internet has allowed better distribution

channels, both for music and for parts; I love the idea of a few clicks on a website and the box of parts appears on my doorstep in a day or two. I love the ability of musicians to bypass the record company gatekeepers and promote/distribute their music themselves. I love the concept of abandoning physical data formats and being able to upload and download music as files, independent of media.

Home computers have revolutionized what hobbyists can do. Speaker and amplifier measurements that were exotic and expensive a few years ago (e.g., FFT, MLS, multitone analysis) are now stunningly cheap and easy. When I first saw Bill Waslo's IMP article in *Speaker Builder*, I grinned ear to ear, ordered the kit immediately, and knew that everything had changed for hobbyists.

The negative is how the technology is being applied in recording. The loudness wars in music production are notorious, and it just pains me to see excessive compression, EQ, fake ambience, deliberate distortion, and rococo multitracking absolutely ruin what are delightful acoustic sounds. I shudder every time I hear the words "plug in." Someone once said that the CD medium is terrific, it's the CDs that suck, and I think that expresses it perfectly. *ax*

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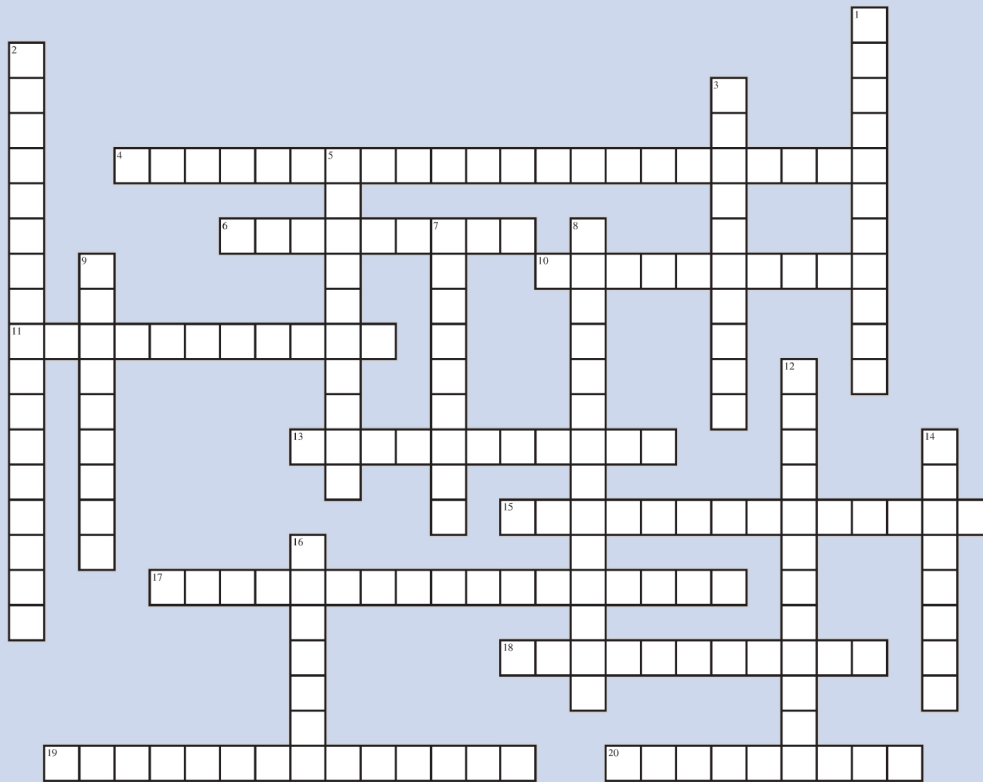
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Editor's Note: Answers to this puzzle will appear in the next issue.

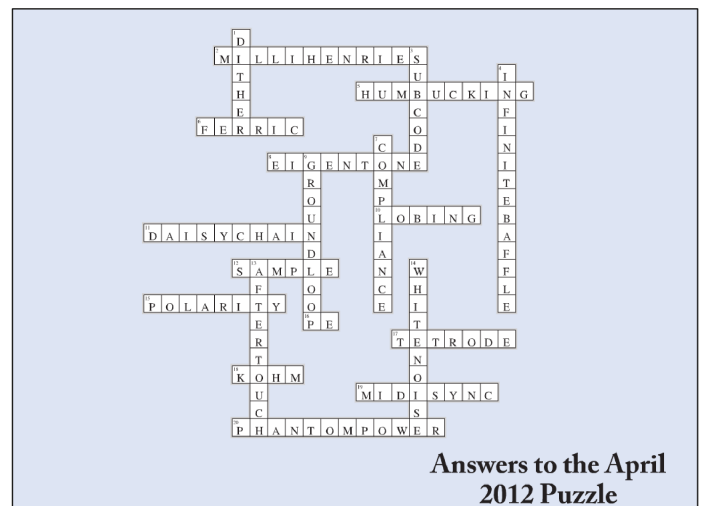
ACROSS

4. Named after Peter Baxandall, this exhibits a gently rising slope (or falling if you are cutting at a certain frequency), which may sound more natural, depending upon its application. (three words)
6. Something that happens at irregular intervals
10. Used in reference to headphones. They rest on the ear rather than enclosing the ear.
11. A form of synchronization where the slave device does not stay resolved to the master (two words)
13. Sometimes components in an audio device become or are sensitive to vibration, and convert that vibration into audio signals
15. A term describing a condition where two or more signals are nearly synchronized
17. The delay that occurs between the time that audio is presented and the time that the data is presented to the output of the converter for processing or storage by other components in the system (two words)
18. A small supplementary cone attached to the voice coil of a speaker for the purpose of producing and radiating high-frequency content more effectively than the larger speaker cone (two words)
19. A type of speaker cabinet design where the speaker driver's output from the front of the cone is separated and isolated from the output from the rear of the cone (two words)
20. Being quiet or still or inactive

DOWN

1. This is the steepness of a filter's attenuation. (two words)
2. A special version of the standard way audio WAV audio file format developed by the EBU in 1996 and commonly used by PCs (three words)

3. The process of dropping samples from a stream of oversampled digital audio data
5. A word coined by the Sony Corp. and applied to their headphone design
7. A simulated electrical load, frequently used in the testing of audio equipment or radio transmitters (two words)
8. A term used to characterize certain loudspeakers (two words)
9. Any stage or point in an audio/video signal path where the level of the signal can be adjusted or amplified (two words)
12. A quadrasonic sound system divides music or other sound into four different parts and plays each part through a separate speaker
14. The process of combining several tracks together and re-recording them onto another track
16. A chemical compound with iron as its primary component



Answers to the April
2012 Puzzle



The 12AY7/6072A EH, a small signal, twin tube

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The 12AY7/6072A EH is a small signal, twin triode tube from electro-harmonix. Almost all Fender Tweed-era amplifiers used the 12AY7 in their first pre-amp stage. Tone aficionados know and revere the distinctive “Tweed” sound and the 12AY7, with its linear characteristics and minimal microphonics, is an integral part of that magic.

If you own a later model Fender with a 12AX7 in the first pre-amp stage, you can replace it with the 12AY7 EH to capture some of the signature tone of a Tweed-era Fender. The lower mu factor of the 12AY7/6072A EH also spreads the sweep of the gain and volume controls, making it easier to find the perfect sweet spot. The higher transconductance and linearity of the tube make the response very touch sensitive and expressive.

The 12AY7/6072A EH can also be used in later model Marshall amplifiers to lower the background noise of the preamp and get the gain structure closer to Plexi and early 1970s Marshalls. In fact, changing the first tube to a 12AY7 EH in any guitar amp will create a warmer vintage tone.

The 12AY7/6072A EH retails for around \$14. For more information, visit www.ehx.com.

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then evaluate adjustment with the real-time analyzer.

TigApp was founded in 2011 by a group of people who discovered the great potential of iOS devices and decided to develop useful and entertaining applications.

This application serves as a reference generator of sounds. Audio Audit contains six functions.

The Tone function is a frequency generator that allows you to search the whole frequency spectrum and at the same time you can analyze sound from your speakers with Real Time Analyzer (RTA) included in Audio Audit.

The Stereo function makes sure you have correctly connected or built speakers.

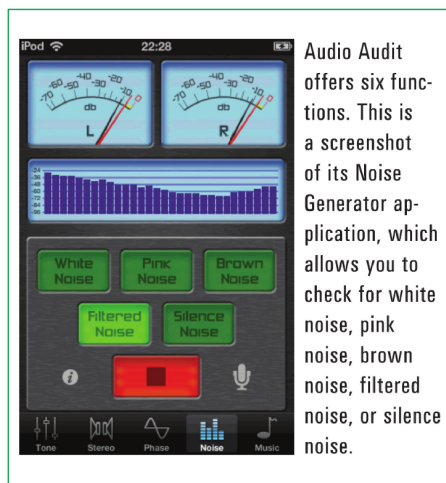
The Phase function tests whether you have all speaker cables connected properly. If you place the speakers in invert phase closer and facing each other, there is a significant volume decrease.

The Noise Generator allows you to use the Audio Audit as a reference tone generator to check frequency responses or the adverse influence of room.

The Music function contains six reference tracks. And, the RTA analyzes the signal from a microphone or line-in input to determine the quality of your audio system and correct the setting of your equalizer.

The application is functional from iOS version 4, but the iOS version 5 is recommended. It has been tested on iPod, iPad, iPhone 3GS, iPhone4, and 4S.

You can try Audio Audit for free when you download the link: www.itunes.com/apps/AudioAuditFree. For more information, go to www.tigapp.com/audioaudit. **aX**



Audio Audit offers six functions. This is a screenshot of its Noise Generator application, which allows you to check for white noise, pink noise, brown noise, filtered noise, or silence noise.

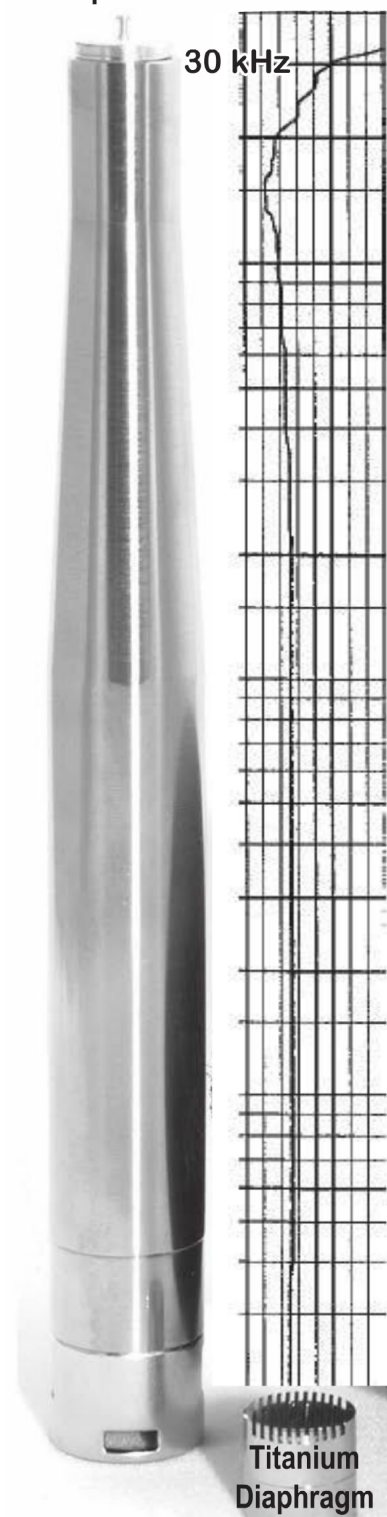
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CONTRIBUTORS

Gregory L. Charvat ("Vacuum Tube Home Theater System (Part 1): System Architecture" p. 24) grew up in the metro Detroit area, where at a young age he would take apart old television sets and radios. Greg eventually started making amateur radio equipment in high school, a radio telescope, and developed numerous radar systems while in college. He earned his PhD in electrical engineering in 2007, his MSEE in 2003, and BSEE in 2002 from Michigan State University. He was a technical staff member at the MIT Lincoln Laboratory from September of 2007 to November 2011. He has taught short radar courses at the MIT, and he co-founded Butterfly Network, Inc. Greg authored or co-authored seven journals, 23 proceedings, one magazine article, and eight seminars on topics such as applied electromagnetics, synthetic aperture radar (SAR), and phased array radar systems, RF and vacuum tube audio design.

Robert Nance Dee ("An Audiophile's Battery Tube Amp," p. 17) is a retired electronics engineer. He worked with the first military computers, has several patents, and has written many magazine articles. He enjoys machining, watch making, bicycling, cabinet making, and philosophy. He is an amateur arborist, an environmentalist, and a vegetarian who thinks his life is a hobby. His passion for audio, in every form, spans 50 years and started in high school while working part time in a radio/television repair shop. He lives off the grid in a house he built, surrounded by animals and fruit trees in the Catskill Mountains. His audio projects are named after his animals and friends.

Vance Dickason ("The Faital Pro HF104 Coupled with its STH100 Horn," p. 33) has been working as a professional in the loudspeaker industry since 1974. He is the author of the *Loudspeaker Design Cookbook*—which is now in its 7th edition and published in English, French, German, Dutch, Italian, Spanish, and Portuguese—and *The Loudspeaker Recipes*. Vance is currently the editor of *Voice Coil: The Periodical for the Loudspeaker Industry*, which is published monthly.

Richard Honeycutt ("Hollow-State Power Amplifiers," p. 13) has been an audio enthusiast, musician, recording engineer, broadcast radio engineer (FCC First Class Commercial licensee since 1969), radio announcer, electronics repairman, tube guitar amplifier designer, speaker system designer, pro-sound/video designer, and college electronics teacher. He is now a consultant in acoustics and electroacoustics. He possesses a PhD in Electroacoustics from the Union Institute, and lives in Lexington, NC, with his wife Betty Jane, near his daughter Alyson, her husband, and two of Richard's three grandchildren.

Mike Klasco ("Acoustical Qualities of Adhesive Joints and Cone Treatments," p. 8) is the president of Menlo Scientific Ltd., a consulting firm for the loudspeaker industry, located in Richmond, CA. He is the organizer of the Loudspeaker University seminars for speaker engineers. Mike contributes monthly to *audioXpress*. He specializes in materials and fabrication techniques to enhance speaker performance.

Bill Reeve ("Repurposing Antique Radios as Tube Amplifiers," p. 29) is a director at Lockheed Martin Corporation in Palo Alto, CA. He has graduate engineering degrees from the Colorado School of Mines, The University of California, Berkeley, as well as a master's degree in Electrical Engineering from Santa Clara University.

Steve Tatarunis ("Acoustical Qualities of Adhesive Joints and Cone Treatments," p. 8) is a senior engineer at Menlo Scientific and a 30-year veteran of the loudspeaker industry. He runs Menlo's Boston-area test lab where he tests speakers, microphones, headsets, and other audio devices for Menlo's clients.

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