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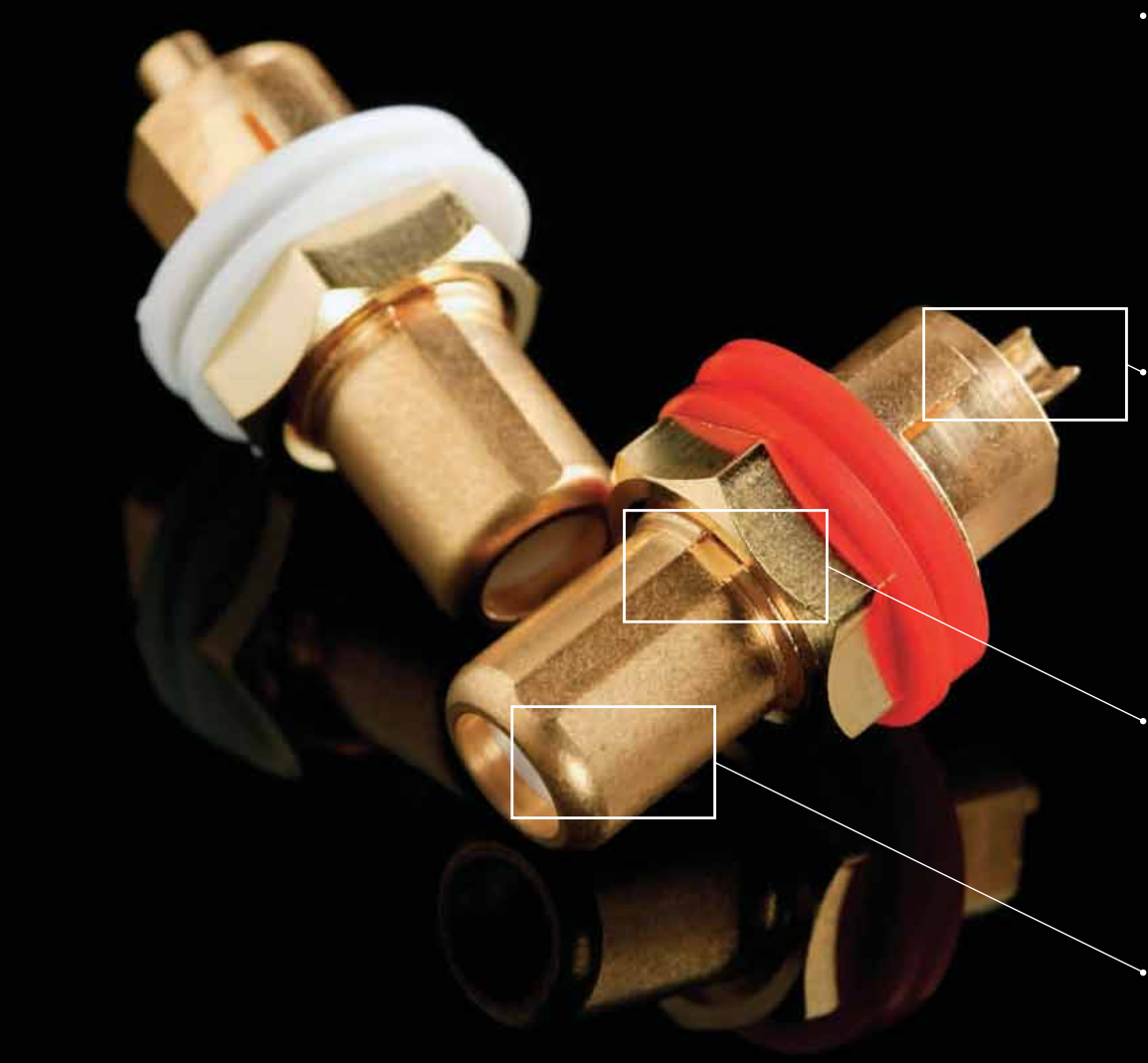

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Our heartfelt thanks to all of you who took the time to send us your opinions about a digital vs. print version of *audioXpress*. We very much appreciate the many implied and fully expressed sentiments regarding how much *audioXpress* means to you. As expected, the preference is split 50/50, and we will offer *aX* in both formats, beginning with the March issue.

Your continued support of our efforts will allow *aX* to be published with an eye to the future. Digital delivery is something every publisher/publishing house is employing to satisfy subscribers, while, at the same time, keeping costs down. Digital allows for much quicker and more accurate delivery. Our overseas subscribers will benefit most from this new delivery format.

For those who choose it, the print version will arrive in your mailbox as usual.

For over 40 years, I have had the pleasure of—and have been committed to—providing you with the best audio DIY articles. It is a responsibility I take seriously, and this magazine's longevity is testament to the success of that commitment. The journey we are on is not digital vs print. It is the enjoyment and enthusiasm we share for reading about audio equipment. Of course, the end result is the reproduction of the music we love on equipment we may have built or fixed ourselves.

So, my friends, we move on to another era of *audioXpress* in a new decade ahead.

My best wishes to all.—ETD

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The Sweet Spot

What you can do to ensure the best possible sound from your system.

Every audiophile understands the concept of the "sweet spot," that happy balance of conditions that elicits the best possible sound. It can be a particular listening spot, the best positioning of loudspeakers, or the fortuitous combination of components which complement each other perfectly. It should be no surprise that the desire for the best performance takes the search for the sweet spot into the interiors of the components themselves.

This article will concern itself with finding the sweet spot for each gain device in audio amplifiers. It is a commonly held belief in audio that the best amplifiers are composed of one or more active gain stages, each made as intrinsically linear as possible before negative feedback is applied to further improve performance.

Taken to the extreme, linear stage = *good*/negative feedback = *bad*. The latter half of that statement is the subject of controversy, but there is no argument about linear stages being good.

Achieving intrinsically low distortion in active devices (tubes or transistors) is usually not easy. You can use good parts, see to it that they have adequate voltage and current available, and use them in topologies that play to their strengths. These are the basics, and this is what you generally see when you examine schematics of popular amplifiers.

However, each individual device has a sweet spot where its performance is the best—often dramatically better—and finding that sweet spot is a powerful technique for maximizing the performance. I am writing about this because after years of communicating with DIYers and many professionals, I have discovered that this is a poorly understood concept, and I have seen many circuits which have failed to take advantage of it.

For every gain device, there is a number which characterizes the amount of gain. When you talk about distortion, you are talking about the alteration of the amount of gain in the device as the conditions change. The gain of a tube or transistor is altered primarily by changes in voltage across the device, current through the device, and the temperature of the device. Changes in any of these conditions change the gain, and all gain changes produce distortion. More precisely, they *are* the distortion.

Of course, the concept of a sweet spot depends on having an idea of what constitutes the best performance. It could be that you want the lowest measured distortion, a particular mix or phase of harmonics in the distortion waveform, the greatest efficiency, greatest power, or simply the best subjective experience when you listen to it. The sweet spot is whatever you want—after all, *you* are the designer.

I BRAKE FOR TUTORIALS

If you don't mind a few basics, let's look at examples of gain devices in generic circuits, starting with a triode (**Fig. 1**). This illustration shows simplified examples of the two most common gain stages using any kind of gain device, and the device pins are the Grid, Cathode, and Plate. In both cases the input signal appears at the Grid and variation of voltage between the Grid and Cathode causes a change in the current flow from the Plate to the Cathode. (All the examples you will see are simplified, and omit DC bias that may be present on the pins except for the V+ supply).

In Common-Cathode mode, the tube develops both current and voltage gain, and the output is taken off the plate, inverted in phase, and usually increased in amplitude. In Common-Plate mode, the tube seeks merely to have the Cathode voltage follow the Grid voltage, so the output voltage is ideally the same as the input, but with some current gain. That is why it's called a follower.

For both modes you would normally look for the sweet spot—the conditions giving the best performance—by varying the values of the supply V+, the value of the load resistance, and the bias current through the device. Inevitably there will

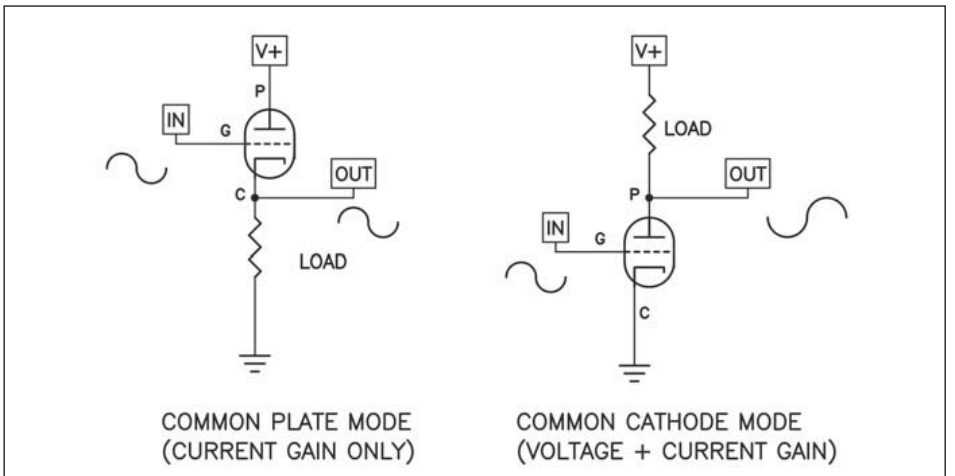

FIGURE 1: Triode single-ended Class A.

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be some combination of these which is the best. Sometimes one of the circuit conditions is fixed; often it is the load value, in which case you vary the other conditions—the supply voltage and the bias.

In all of the examples later, I have chosen to simply look at Common-Plate (or Common-Drain/Common-Collector) performance, but the same ideas apply to Common-Cathode (or Source or Emitter) operation. Actually, Common-Drain circuits would seem to offer the least opportunity for improvement—as followers enjoying 100% degenerative feedback, they already have a much lower distortion character than Common-Source circuits. But you will see that even they can be improved, often dramatically, if you find the sweet spot.

Figure 2 shows the example of the JFET counterparts to the tube circuits seen above. Here the pins are Gate, Source, and Drain. In the Common-Drain follower, the input voltage pretty much follows the output voltage, and in the Common-Source amplifier, the output is inverted and has both voltage and current gain available. **Figure 3** shows the MOSFET example, which has the same pin designations as the JFET.

And last, **Fig. 4** is the example of a bipolar transistor, where the pins are Base, Emitter, and Collector. The choice of a particular type of gain device—tube or transistor—is often arbitrary, but ideally it plays to the particular strength of the device for a given application. In principle you can substitute one type for another, but as a practical matter, there is usually a good reason for the selection of one over the others.

It doesn't matter in terms of the idea of finding the sweet spot—the terrain changes a bit, but the game remains the same.

GETTING TO THE SWEET SPOT

For any of the above circuit types and devices, if you start with reasonable textbook values for the circuit, you will get reasonable performance. If you start to play with the values a little bit, you will find that the performance changes for better or worse. Often you will find a combination of voltage and resistor values which give a lot better than the generic performance. That's the sweet spot.

If you have a distortion analyzer, you could simply run through the range of combinations of values and select the result you like best. If you simply want good measurements, you might be able to stop there. If you are looking for better subjec-

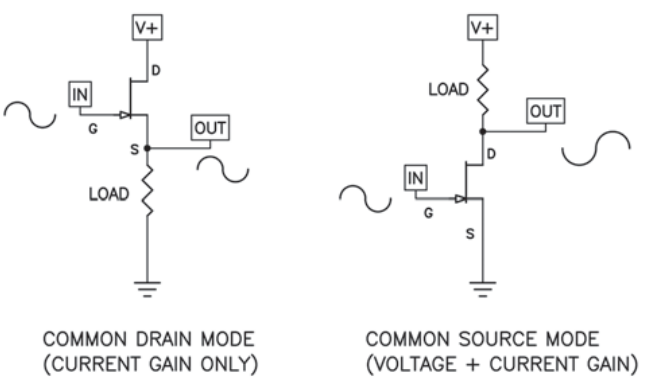

FIGURE 2: JFET single-ended Class A.

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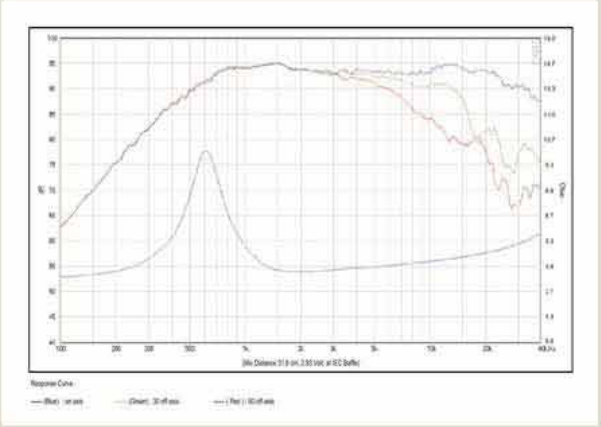

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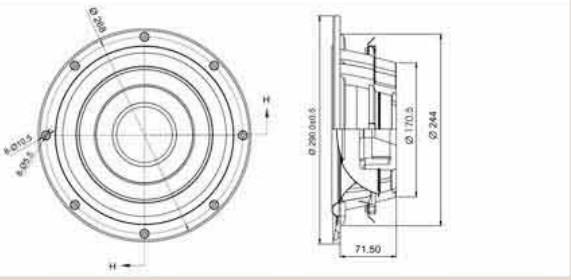

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tive performance, you might find this a good place to start your listening.

What creates the existence of the sweet spot in gain devices? To see where this comes from, look at the characteristics of some tubes and transistors.

Let's start with a simple big triode, the 300B. This curve (**Fig. 5**) shows the Plate-to-Cathode current as a function of Grid voltage, with each curve representing a fixed value of plate voltage. Looking at this figure, you see that the lines are curved—the more current, the faster they rise. **Figure 6** is a different view of the same character, but with the current plotted as a function of the Plate voltage, with each line representing a fixed value for Grid voltage.

These lines are also curved with a shape very similar to the previous graph. A perfectly linear tube will have these lines in both graphs perfectly straight and equally spaced. Any deviation from that would be distortion. Looking at the curved lines, you can see that there is quite a bit of distortion.

For a given Plate voltage, the current increases exponentially with the Grid voltage, in what is known as a square law characteristic, resulting in second harmonic distortion. For a given Grid voltage, the current increases exponentially with the Plate voltage, also a square law and also creating second harmonic distortion.

In this curve the Y-axis is still the plate current, but the X-axis is now the Plate voltage, and each line represents the Grid voltage. It looks familiar—just as the plate current is an exponential function of Plate voltage, it is also an exponential function of the Grid voltage. This is a particularly important observation with respect

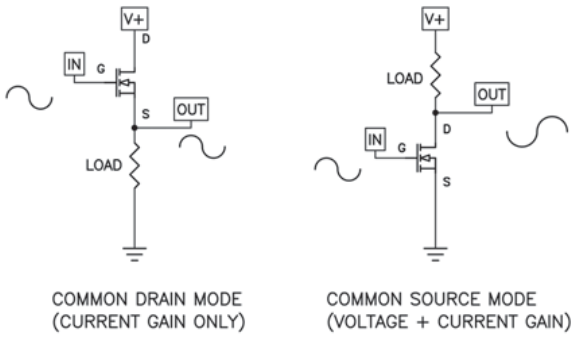

FIGURE 3: MOSFET single-ended Class A.

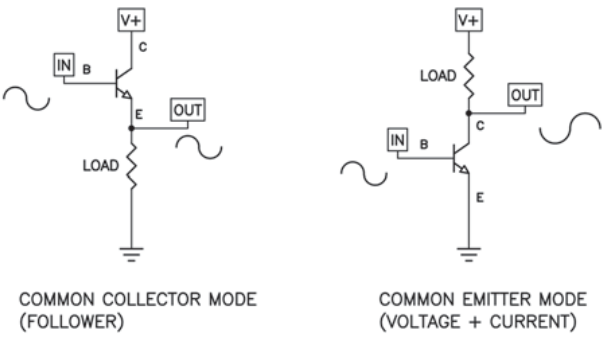

FIGURE 4: Bipolar transistor.

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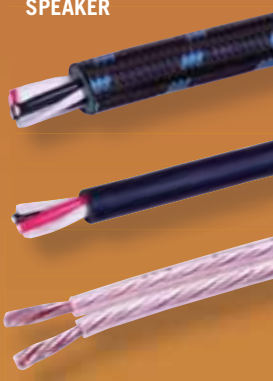

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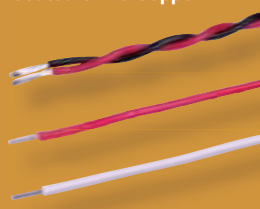

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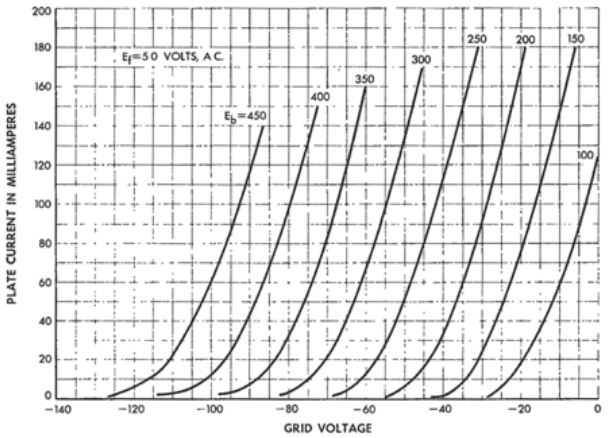

FIGURE 5: 300B transfer curve vs. grid voltage.

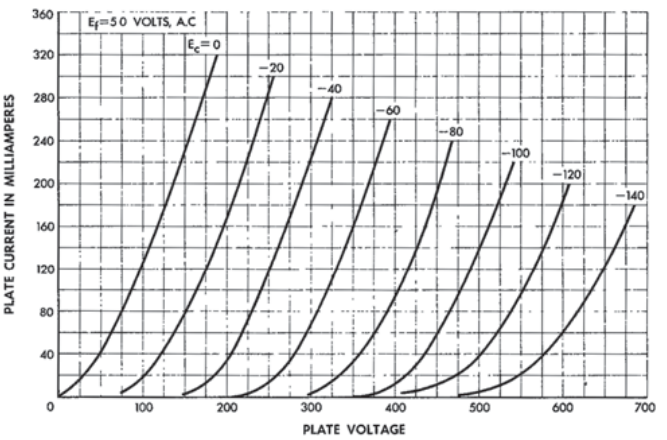

FIGURE 6: 300B transfer curve vs. plate voltage.

to finding the sweet spot.

THE DEAL

Ordinarily in a tube amplifying an AC signal, a positive change in Grid voltage causes an *increase* in Plate current and is accompanied by a *decrease* in Plate voltage. The gain due to Plate current *increases*, and the gain due to Plate voltage *decreases*. The opposite happens when the Grid voltage goes negative.

These two gain variations tend to cancel each other, resulting in more constant gain and lower distortion. If you choose your conditions so that the simultaneous gain increases and decreases are equal, you can lower the distortion a lot.

This technique is occasionally referred to as *load-line cancellation*. It is called that because the range of the device's operation sits on a line in the transfer curve, and the particular shape and position of that line results in minimum distortion.

By some criteria, this would be the sweet spot. At this point you will probably find that your second harmonic has largely disappeared and you are left with some third harmonic. This is because you can't completely cancel two square law distortions without leaving a cubic trace—the third harmonic.

So, how much distortion reduction? On a clear day, you can think in terms of a 90% reduction, as seen in the **Fig. 7** curve, where a triode follower is operated at a high plate voltage giving the upper distortion curve. Without changing the load or the current, I simply reduced the Plate voltage until the gain dependence on Plate voltage matched the gain dependence on Plate current (as determined by lowest distortion at 1V) and ran the lower curve.

I think you can agree that this is a significant reduction, roughly equivalent to what you would see with 20dB of negative feedback, except that you have not attached a negative feedback loop and the output gain and impedance of the circuit remain about the same.

Because of the square law characteristics of the devices, the primary distortion is second harmonic in content, and when you cancel two second harmonics, you find that the remainder is a third harmonic. The original second harmonic looks like **Fig. 8** on an oscilloscope viewing the output of a distortion analyzer.

After cancellation, the harmonic content looks like **Fig. 9**. If your criterion instead is a particular harmonic content or harmonic phase, a deviation from this point in either direction will give you second harmonic back with its phase depending on which way you went, and you can tweak this in relation to the amplitude of the third harmonic if you like. There is a reason why triodes are popular in single-ended applications—their gain dependence on Plate voltage is quite strong and makes for easy load-line cancellation.

Load-line cancellation is available in the other types of gain devices, including pentodes, JFETs, MOSFETs and bipolar transistors, but they take more subtle advantage of load-line cancellation. In many cases it is easier to find the sweet spot with push-pull operation. You will see real-world examples of both single-ended and push-pull later, but first, consider the characteristics of the other devices.

This technique also applies to pentode tubes, although it will not be quite the same. The transfer curve of the pentode is much the same with regard to grid voltage, but the current variation due to Plate voltage is different. **Figure 10** is the transfer curve of a pentode.

Here you see a family of curves which indicate that the gain (transconductance) increases exponentially with Plate current, but has less variation with

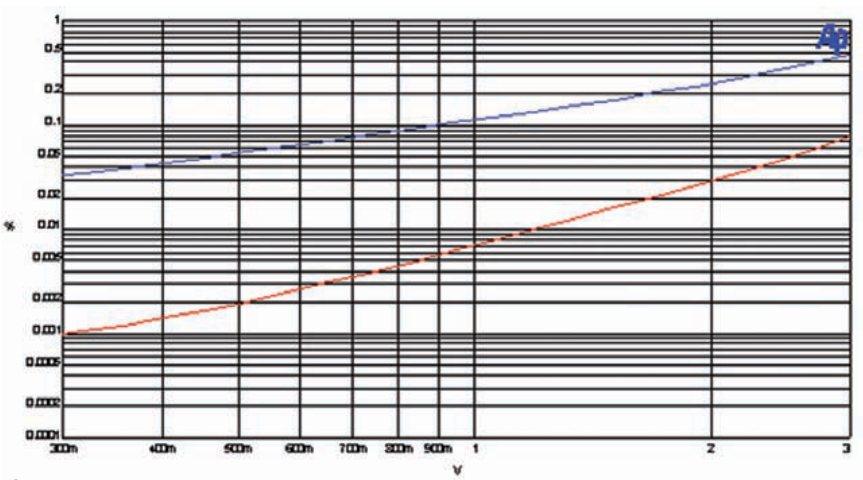

FIGURE 7: Triode distortion.

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respect to Plate voltage as compared to the triode. You can still vary the voltage, current, and load parameters to find the sweet spot, but it will be in a different place.

JFETs have the exponential current versus Gate voltage but enjoy a wider variety of transfer characters situated between triode and pentode and are generally well suited to exploit the concept of a sweet spot in single-ended Class A circuits.

JFETs come in both enhancement mode and depletion mode, the primary difference being the DC voltage required on the Gate to turn them on. Depending on the dimensions of the Gate structure on the chip, the transistor can exhibit pentode or triode characteristics, or an in-between "mixed mode." **Figure 11** is the curve of an enhancement mode power JFET, and **Fig. 12** is the curve of a depletion mode power JFET.

You will note that these aren't the tiny little signal JFETs that everyone is accustomed to. These are examples of the new generation of high-power JFETs coming out of the labs. In the 1970s, when Yamaha and Sony produced power JFET devices for use in their own amplifiers, it created some excitement among audiophiles. Unfortunately, it seems that they were ahead of their time, and now those parts are quite rare.

Fortunately, totally new devices show promise in modern power amplifiers, both as switches and linear amplifying parts—tomorrow's transistors (*at tomorrow's prices*). For power JFETs, the Ids dependence on Vds is partly a function of the Gate channel depth on the chip. The pentode-like character is seen in high current power "Vertical" JFETs, and the triode-like character is seen in SITs (Static Induction Transistor).

The enhancement mode power JFETs do well in single-ended Class A applications and can take advantage of load-line cancellation. My samples of depletion

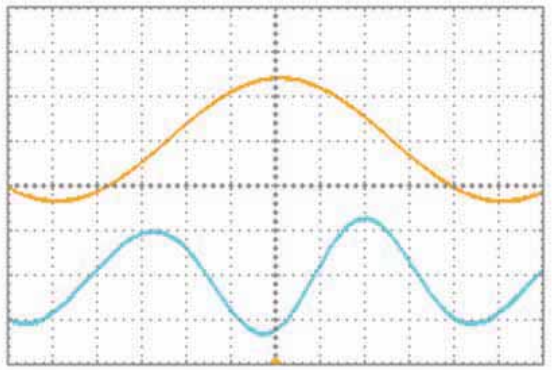

FIGURE 8: Second harmonic distortion.

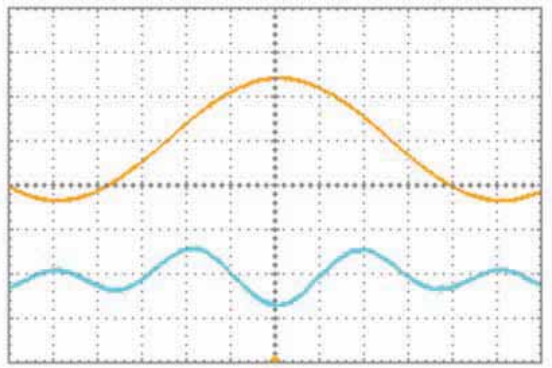

FIGURE 9: Third harmonic remaining after load-line cancellation.

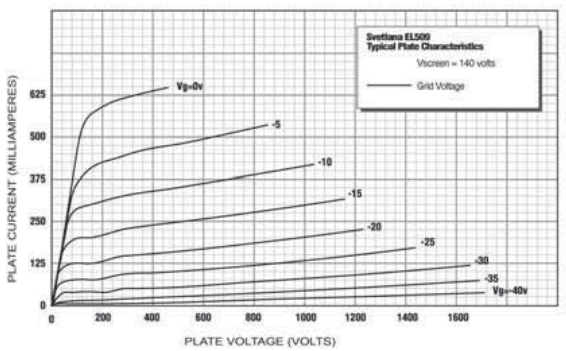

FIGURE 10: Pentode transfer curve.

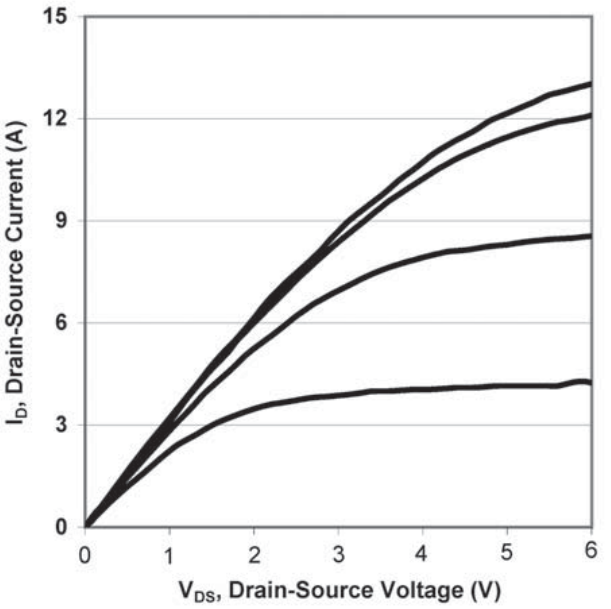

FIGURE 11: Enhancement mode JFET.

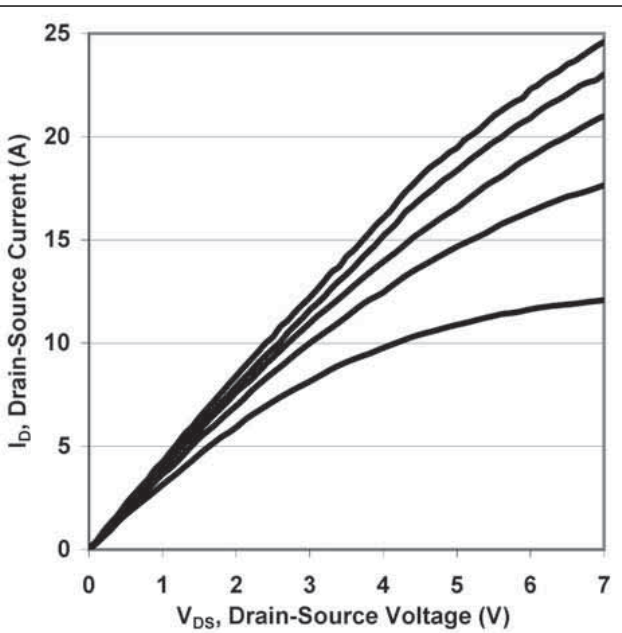

FIGURE 12: Depletion mode JFET.

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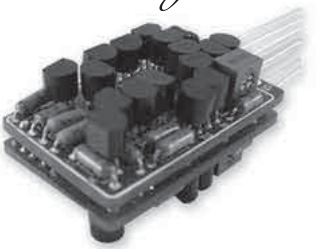

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mode JFETs have a more pronounced voltage dependence, and are thus even more interesting.

Figure 13 is an example of a JFET follower whose characteristic is mostly "pentode-like." The upper curve reflects the distortion at V+ voltage near the device rating, and the lower curve shows the distortion cancellation available by searching for the "sweet spot" at a lower supply voltage. You can see that at 1V output, the distortion has been reduced by about 85%. Alternatively, you could have adjusted the bias current or the load resistance, and also tried for best performance at some higher voltage than 1V out.

This example was of one of those "little" JFET devices, but it works with parts of all sizes. You must remember that this cancellation is there somewhere, and you might want to go looking for it. Also keep in mind that the sweet spot is a bit different for every part, even within the same part types, and you will want to consider expending the effort for each individual part for the absolute in performance.

This is important when you change out tubes in an amplifier, as every tube-ophile knows they are all different. Setting them to a generic bias current does not guarantee the sweet spot for a given tube. You might want to consider how you can vary the supply voltage and the bias while evaluating the performance.

Figure 14 is an example of a power MOSFET's transfer curve. Power MOSFETs have a character somewhat similar to a pentode. The Plate has been replaced by the Drain, the Grid has become the Gate, and the Cathode is now the Source. You see from this diagram that the gain increases with Ids, but there is not a lot of dependence on Vds above a few volts.

At just a couple of volts you operate in what is known as the "linear" region of the MOSFET, where there is strong dependence. You can work the load-line in this region effectively, but it is not a popular technique for a number of good practical reasons. Fortunately, for many MOSFETs operating in Class A, the distortion of the current transfer curve is low enough that you can still find the cancellation for a pentode type voltage characteristic—just go looking for it.

And, of course, someone is going to ask, "What about bipolar transistors?" It so happens that bipolars have a sweet spot also. **Figure 15** is an example of the current gain figure of an ordinary NPN transistor versus Collector current.

There is also a dependence on Vce known as the Early effect, a slight straight line dependency increasing with voltage. As with other devices, finding the sweet spot for a bipolar device means locating the point where these variations result in distortion cancellation.

In **Fig. 16** you see the gain versus current curve of an NPN power transistor showing some gain dependence versus Collector current. Above a couple of volts, the variation is much less and forms a fairly linear straight line with voltage.

Of course, you can work these two curves. The distortion curve in **Fig. 17** shows a follower circuit like the others,

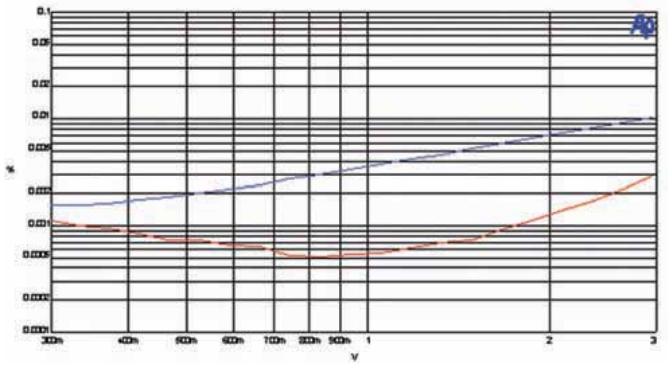

FIGURE 13: Single-ended JFET distortion.

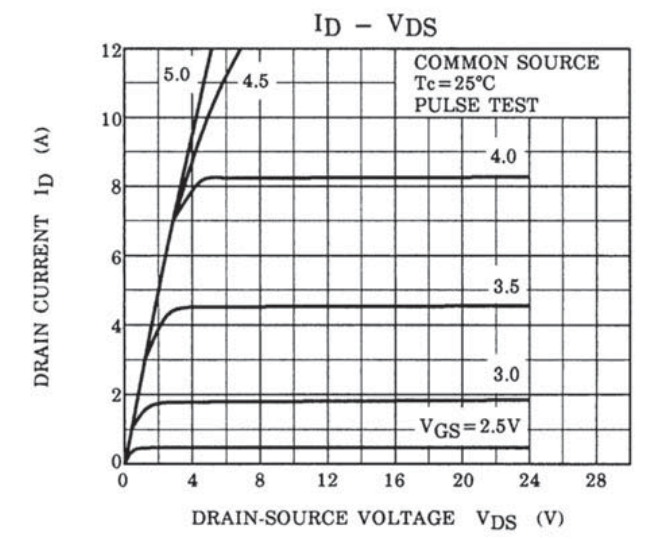

FIGURE 14: MOSFET transfer curve.

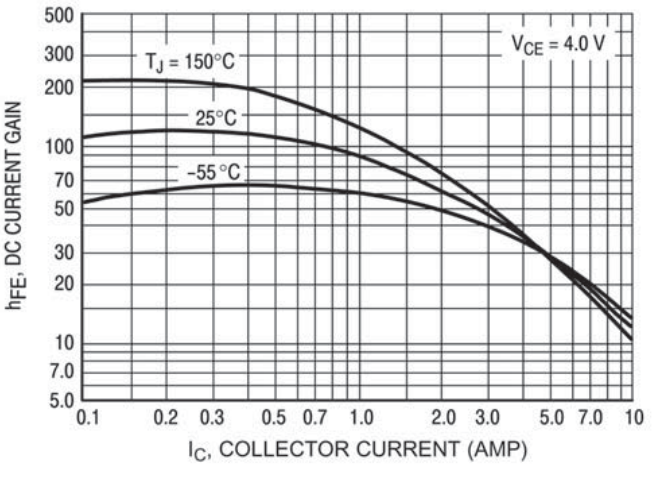

FIGURE 15: Bipolar transfer vs. current.

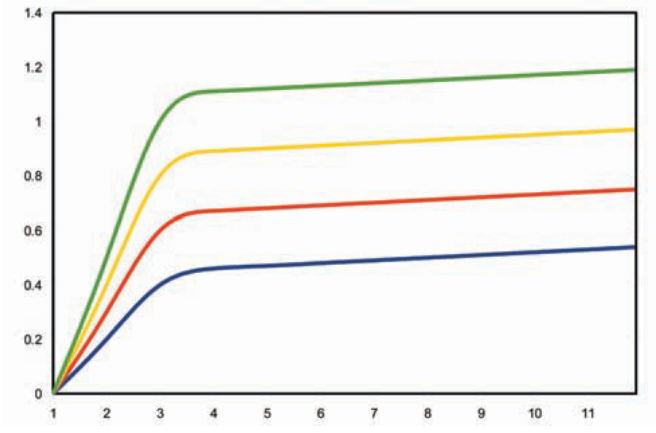

FIGURE 16: Bipolar transistor transfer curve vs. voltage.

but with a bipolar transistor. The upper trace is with a high supply voltage, and the lower trace is the reduced voltage. The reduction in distortion is less dramatic, but it's still about 7 or 8dB better.

PUSH-PULL OPERATION

Of course, single-ended Class A is not the only way to operate gain devices. Large reductions in distortion can be had by operating gain devices in push-pull, where two similar devices operate in balanced opposition such that their second harmonic characteristic is naturally cancelled. On the left in **Fig. 18**, you see a pair of JFET followers operated push-pull.

So where's the sweet spot for this sort of circuit? It's there if you go looking for it. The sets of curves in **Figs. 19–21** show three techniques for getting a pair of these devices into the sweet spot.

First, you can take the "regular" follower in **Fig. 18** (left) and simply vary the supply voltages a bit. The curves in **Fig. 19** show distortion for two examples, the upper curve being with two equal supply voltage values. The lower curve shows what can happen if you vary only one of the supply voltages.

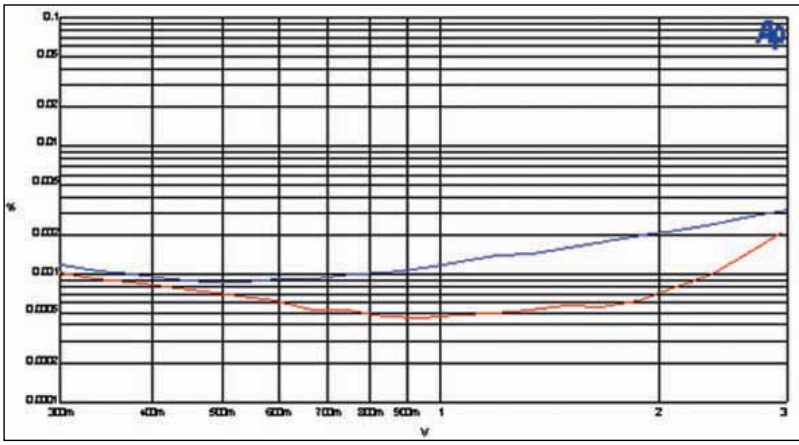

FIGURE 17: Bipolar transistor distortion.

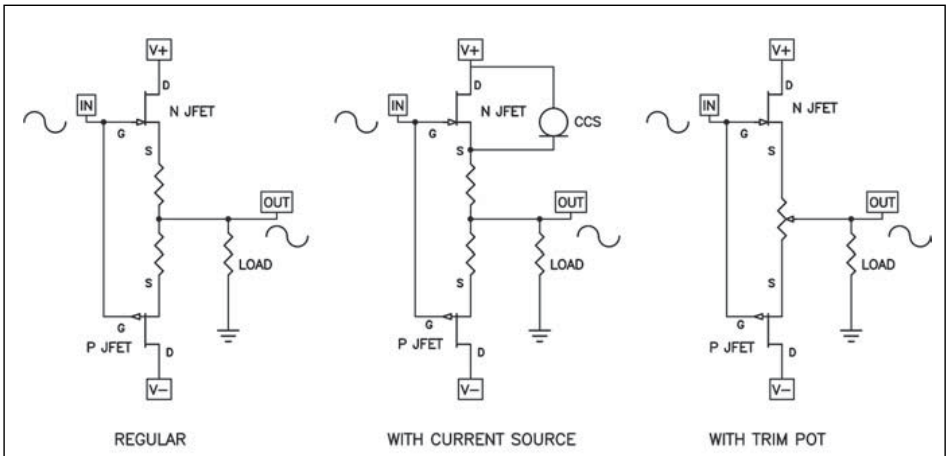

FIGURE 18: Push-pull JFET followers.

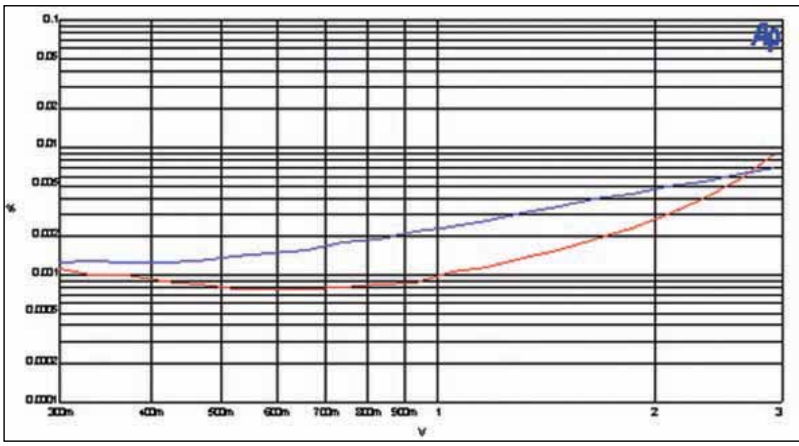

FIGURE 19: Push-pull JFET distortion with different V+.

Figure 20 shows a technique we employ at Pass Labs—the use of some single-ended bias in a push-pull output stage to reduce distortion. The distortion curve shows what you can get if you simply put a small value current source in parallel with one of the JFETs as shown in the **Fig. 18** (middle) circuit. The current source displaces the bias current values on the JFETs until they achieve a more perfect distortion cancellation.

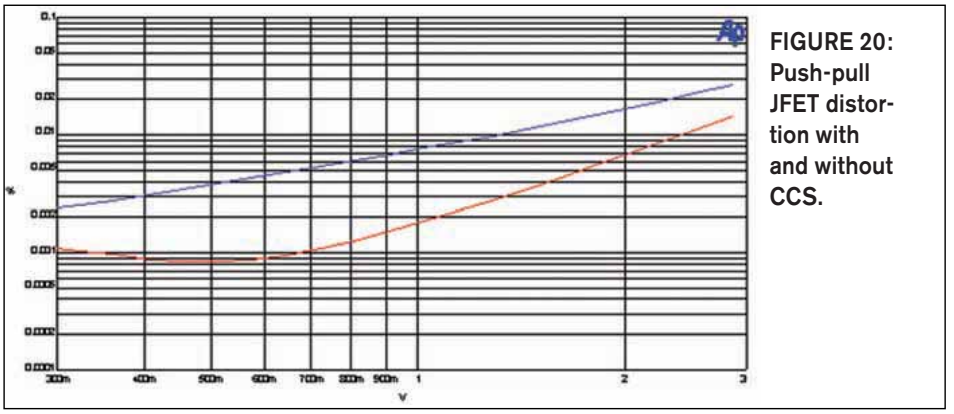

FIGURE 20: Push-pull JFET distortion with and without CCS.

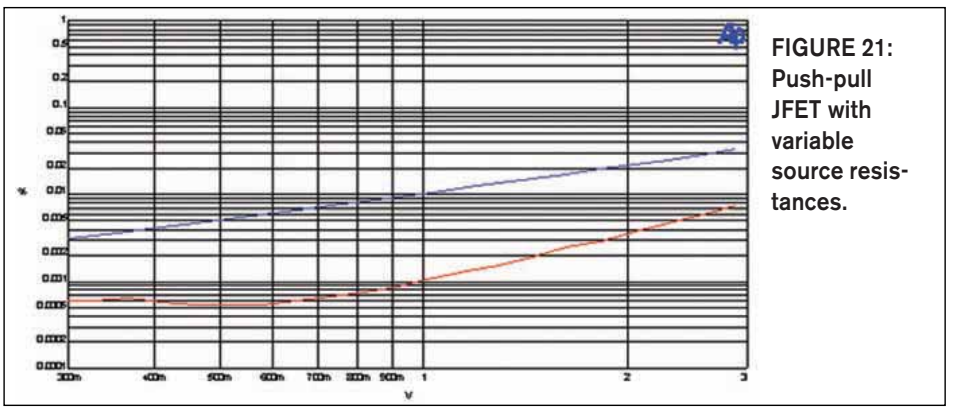

FIGURE 21: Push-pull JFET with variable source resistances.

There is yet another way, shown by the circuit on the right in **Fig. 18**, which involves the use of a trim potentiometer instead of the Source resistors of the "regular" circuit. **Figure 21** shows that a simple adjustment of the pot can drop the distortion by 90% without having significant effect on the other aspects of performance.

TEMPERATURE

There is one last important variable affecting performance and the location of the sweet spot—temperature. All of these gain devices have transfer curves which are some function of the temperature of the device. All those transfer curves I have shown you will be different if you vary the temperature.

Conceivably you could adjust for the sweet spot by varying the temperature. More practically, you will want to see to it that your circuits have reached their ordinary operating temperature before adjusting for the last bit of performance.

CASCODING, PARALLELING, AND TRANSFORMING

So what do you do if it's impractical to find the optimal load-line in a given circuit? Occasionally the sweet spot occurs at voltage values that are impractically low, or at currents that are higher than a device can handle for a given voltage. Here are three things that a designer can do to get into the zone:

The first is cascoding, where the gain device is coupled with a Common-Gate/Common-Grid/Common-Base (depending on the type of device!) tube or transistor which adds practically no influence of its own but which allows a more arbitrary DC and AC voltage across the gain device. **Figure 22** shows a couple of examples, using JFETs in both Common-Drain and Common-Source circuits.

The top JFET is the cascode device, and its Source voltage, which will be seen by the Drain of the JFET below it, is set by Vref. The idea is that the cascoding device provides a "voltage umbrella" for the gain JFET, and all manner of voltages can appear at the output of the circuit

while the gain device sees all, a portion, or none of it.

It's pretty easy to get into the sweet spot using a cascode, and if you want to explore this in some more detail, I recommend "Zen Variations #9," available at www.passlabs.com or *aX* 5/06, p. 6. This article explores getting the lowest possible distortion from an amplifier using a single stage with a power JFET having a high current rating, but a low voltage and dissipation rating.

Another way to get into the zone of the sweet spot is to parallel devices. There are times when the load is too low (and you can't change it) or the voltage is too high, but often you can mitigate this situation by operating devices in parallel. This way you can limit the dissipation of each device, and the load appears as a multiple of the number of devices.

The third method is to use a transformer, which allows you a flexible range of voltages and currents through the device while delivering the appropriate values to the load. Tube amplifiers do it all the time, and it gives the extra flexibility that then allows you to adjust for the sweet spot.

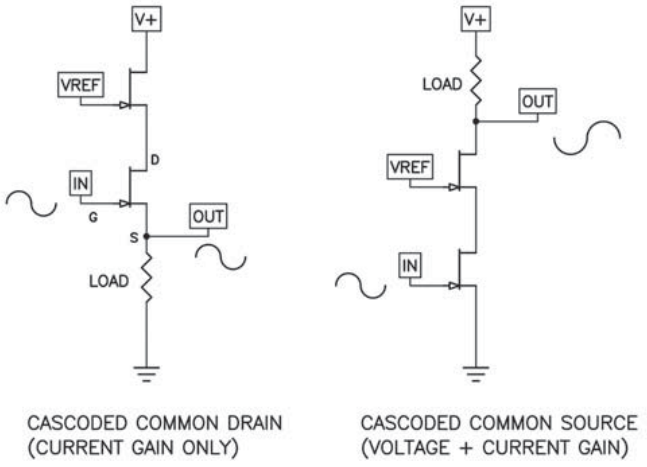

FIGURE 22: Cascode operation.

THERE'S A SMALL CATCH

All the loads you have examined are resistors. Many times that is all you need to work with anyway, but when it comes to loudspeaker drivers and passive crossovers, you must contend with loads which are also reactive and which vary in impedance. This can be a problem when the load-line that gives the best performance depends on resistance. A reactive load will take it out of the sweet spot.

This is particularly true for tube amplifiers operating single-ended Class A without feedback—much of the performance depends on triode load-line cancellation. These amplifiers are particularly appreciative of resistive loads, and if you have this situation, it's worth considering ways to flatten the load impedance, giving a more resistive load for the amplifier.

There is another solution to this problem if you employ cascoding. Again, "Zen Variations #9" includes a technique I have dubbed "Cascode Modulation," in which the gain device can be made to see controlled load-line voltage variations which are only a function of the output current, and not related to the output voltage. In this way, the sweet spot is preserved into any load reactance or impedance, and it is very easily dialed in by adjusting a couple of resistor values. In the Zen example, you get a 90% improvement in distortion by simply attaching the cascode's voltage to a different spot, without changing any values or any other characteristics.

CONCLUSION

So there you have it. As an audiophile you want the best performance, and you probably aren't above spending money and trying tweaks of various sorts to help you get it. But there are real improvements that can be had without extra accessories or emptying your wallet.

Amplifying circuitry can be made better without more complexity and without more feedback. The best part of this for do-it-yourselfers is that you can do this on your own bench, costing mostly just the time it takes to tweak the circuit and evaluate the results. Moreover, this approach is not seen on the factory floor—for most manufacturers it's simply too time consuming to do, and the rest probably never heard of it.

So here's your chance to make simple high-quality audio amplifiers better than ever. Buy yourself a cheap used distortion analyzer and go for it. *aX*

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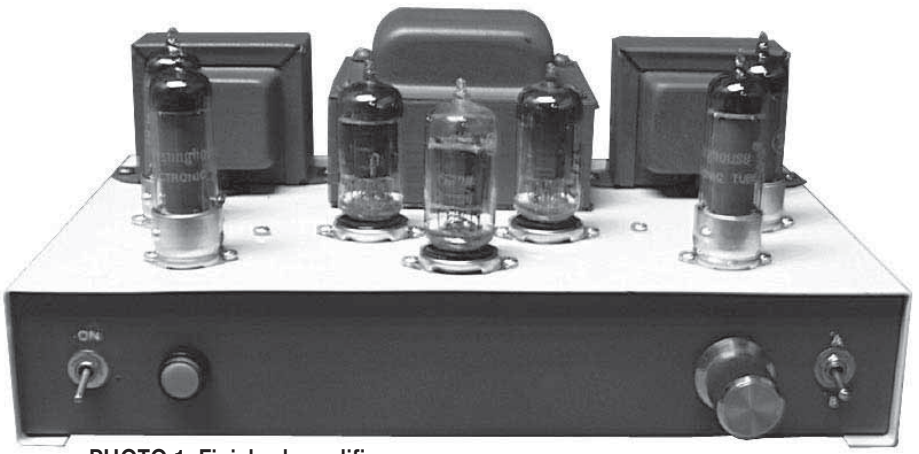


PHOTO 1: Finished amplifier.

love building stuff! It makes no difference if it is from wood, metal, plastic, or scrap. This is my relaxation therapy. I don't mind spending money for this, but if you have read my previous articles, you know I am also basically thrifty (some would say cheap). The last tube amp I built cost me a small fortune (over $500, with the output transformers costing $150 each) even with scrounging, and I don't believe most hobbyists really care to spend this kind of money routinely.

I decided to embark on a project to see how inexpensively an average hobbyist can build a high-quality tube amp (**Photo 1**) with ample power to drive most speakers. I set $150 as my goal, which includes everything down to the hardware and the tubes! I will walk you through the project from design to execution and the final listening test.

TRANSFORMERS

The first step is to get the "iron." Transformers can be very expensive, but if you watch eBay™ you can find some real bargains. Look for complete "off brand" integrated tube amps from the 60s using tubes that are no longer commonly available. These might include 6BM8, 7355, 7027, 7212, and the like. Because tubes for many of these aren't easily available, many sellers just want to dump the amps. If you buy a complete chassis, you might even be able to lower your cost further if the chassis includes switches, knobs, and sockets, in addition to the transformers. (This is always a challenge for me, because I prefer to see whether I can fix the unit rather than parting it out.) I found a set of output transformers and a power transformer from a Harman-Kardon A-100 integrated amp. I contacted the seller to see whether he still had the chassis and he said he threw it out (not much of a scrounger, I guess). I successfully bid on them at $62, including flat rate shipping.

TUBES

Because I had used about one-third of my budget already, I needed to pick a simple circuit and inexpensive tubes. I also wanted to get at least 15W RMS per channel. I checked prices of output tubes—6L6s, EL34s, 6BQ5s, 6550s, or KT88s—and found it was going to be tough to stay within the budget. 6V6s looked pretty good, but they tend to bring about $10 each for good quality.

Sometime back I bought a pair of chassis with Dynaco 410 outputs on each one. These amps used a 7199 driver/phase inverter, and a pair of 6AQ5s as outputs. They were probably from some commercial recording monitor amp. I bought the chassis primarily for the transformers, but like a lot of stuff that

PHOTO 2: Dynaco 6AQ5 amps.

enters my shop, I decided to try to revive them, instead of parting them out.

They were constructed very well, and used oil caps for coupling. I reverse-engineered the circuit. They were wired for ultralinear operation. Each required a filament supply and relatively filtered HV DC. I dug up a suitable power transformer, and designed a base and chassis top around them. They turned out pretty well and sounded wonderful, very neutral, and natural (**Photo 2**).

The 6AQ5, a 7-pin miniature version of the 6V6 octal tube, is pretty cheap. A quick check of online auctions showed that they were selling for about $2-3 each for NOS tubes. I bought ten NOS Westinghouse branded, in sleeves of five, for $18 total with shipping. The only drawback is that these tubes have a maximum plate voltage rating of 275V (I will discuss how to deal with this later).

There are thousands of schematics for tube amps out there, and I am sure many of you have a favorite. Several of my previous articles centered on using a Pilot 410 circuit. As I have discussed before, you can use a wide variety of transformers and tubes with this circuit and modify values accordingly (*audioXpress* 12/05).

I decided to use the Pilot circuit as the basis for this amp. I needed three dual triode tubes for the preamp, driver, and phase inverters (**Fig. 1**). The goal of low cost moved me to the 12AU7, which is probably the most common dual triode tube in the world, and so is also very economical. With the exception of Telefunkens, Mullards, and the like, you can buy these tubes NOS for less than $4 each and sometimes snag 20 used ones for $10-15.

I don't believe in spending much money for "black plate," "gray plate," "d getter," "triple mica support," "military," or "clear top" tubes. Except for very specific situations, these are generally a waste of money. (Before you write *audioXpress* with your outrage, please consider doing randomized double-blinded listening tests and publishing the results). Can you hear differences in tubes? Yes, you can, but how much and will it make a difference in the pleasure you get from the amplifier?

CHASSIS

With the selection of my transformers and tubes, it was time for a suitable chassis. In keeping with my thrifty theme, I dug out a few things I had stashed. A couple of months ago I was in one of my favorite surplus stores (Gateway Electronics, St. Louis) and stumbled across some very nice enclosures that had previously housed a switching system for parallel port printers. These were pretty solid, with a powder coat beige finish. The sockets, switch, and internal wiring were gone, but the price was $4 each.

I bought all three and put them in my storage area. I took out one of these and arranged the transformers and tube sockets on the top and decided that it would work just fine. **Photo 3** shows a silver front panel, which, carefully using a single-edge razor blade, I lifted and

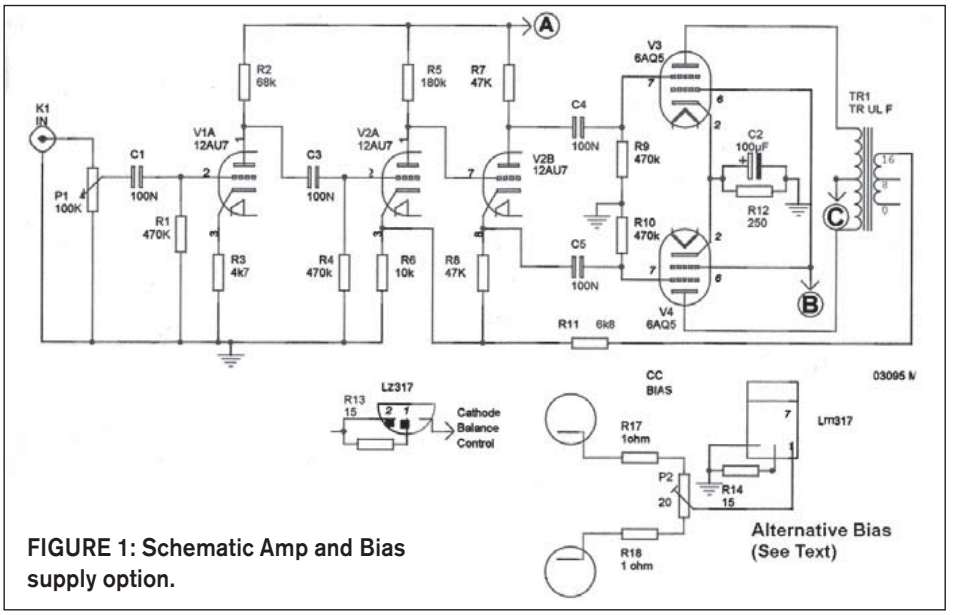


FIGURE 1: Schematic Amp and Bias supply option.

cleaned up with a little "goo gone.™"

I started by making some aluminum panels to fill the rear holes, and bolted them using the predrilled chassis holes. The center one was conveniently filled with a barrier strip, for speaker connections. I decided to add a few dollars to the project by including two sets of input jacks and a front panel selector switch. A power switch, pilot light, and volume control completed the front panel. The transformers had a little light rust, so I painted them with a Rustoleum™ Textured brown finish. (I thought it would contrast nicely with the beige powder coat.) I also painted the front and back panel portion of the cabinet with the same paint.

Before you try to paint powder coat finishes, you must rough up the surface with some fine sandpaper or Scotch-brite™ pad. If you don't, the paint will *not* stick, and will flake off over time. (This is another reason that powder coat is such a great product. It is not only extremely durable, but dirt, grime, and even paint won't stick to it.)

While the paint was drying, I punched and drilled the holes for tube sockets, transformers, and wire grommet holes (**Photo 4**). When you are using a clamshell-type chassis, it is extremely important to locate components carefully. A small metal machinist ruler is very handy for measuring potential interference between the top and lower chassis parts. Because of the compact nature of this amplifier, this step is essential.

WIRING

Once I mounted the top chassis components, I started the wiring process. I prefer to begin with filament wiring, twisting the leads together and routing them close to the chassis and as far away from the input grids of the preamp and driver tubes (**Photo 5**).

Next, I laid out the high voltage section, taking special care to allow easy access to the decoupling resistors between the power supply capacitors (I knew I would need to play with some of the values to get the voltages right for the various tubes). The overall high voltage that feeds the output transformers can't exceed 275V for the plates of the 6AQ5 tubes, so you may need to make some adjustments. Harman-Kardon (and Fisher) commonly used a single non-center tapped high voltage winding, so a voltage doubler is necessary. If your transformer has a center tap, your power supply can be a little simpler (and cost less).

I proceeded to wiring the output stage and worked forward to the phase inverter and driver sections. My builds progress whenever I have an hour to spare, so I make a copy of the schematic and check off each component as I wire the amp. I also use a marker to label connection points directly on the bottom of the chassis. Typically these include high voltage and feedback connections. This allows me to check voltages quickly on startup and for later fine-tuning.

When starting a build, I collect all the resistors and capacitors and place them in a container on my bench. This helps to keep track of what wiring is done and what needs to be done. When I am out of parts and everything is checked off the schematic, I know I am close to being finished. It is a good idea to take a break after you complete your wiring, and then come back and verify the wiring before you fire up. **Photo 6** shows the completed power supply wiring and one channel of the amp wiring.

Then I wired the bottom half of the clamshell, which included all the input, output, and AC wiring. I wanted to be able to wire the two parts together and still be able to open them on the bench

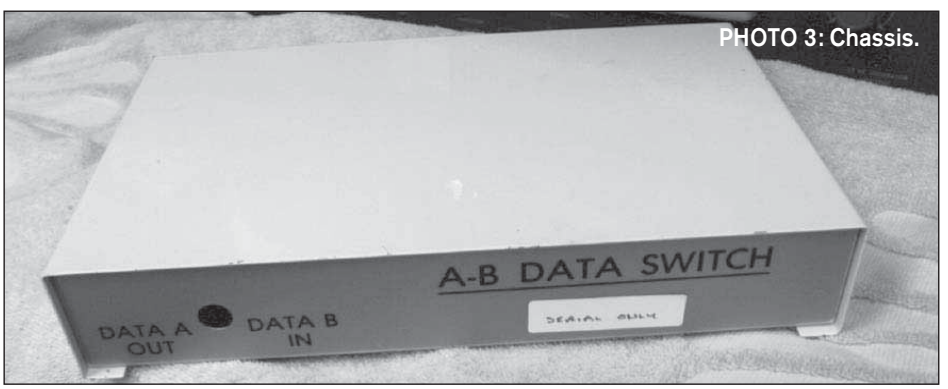


PHOTO 3: Chassis.

for service, so wire routing becomes an issue. The AC and input wiring are separated as far as they can be. I had been concerned with the length of the shielded cable from the volume control to the preamp tube. I decided that if I had a hum problem I would shorten them, but it turned out there were no issues.

STARTUP

Firing up the completed amp, I was greeted with a howl, which generally means you have the primary and secondary of the output transformers out of phase. A quick switch of the primary windings solved that problem. (One of these days I am going to build the phase-checking device featured in *Glass Audio* 10/99 by Charles Hansen.) On the second startup, as I neared 100V AC on the primary of the power transformer, I measured about 270V DC at the plates of the output tubes, so I would need to make some adjustment of the high voltage.

The first decoupling resistor in the power supply was a 50Ω 10W between the voltage doubler and the rest of the power supply. Some experimenting indicated that I was going to need about 500Ω. I first put a 10W unit in, but it became uncomfortably warm. Digging around, I found a 430Ω 25W unit that I had scrounged from some military surplus and it worked just fine, becoming a little warm to the touch. The parts list indicates two 1K 10W resistors, which you need to parallel. Now the measured voltage at the plates at 120V AC on the primary was 262V DC. Measurement of plate voltages on the preamp, driver, and phase inverter tubes was lower than I liked, so I adjusted the decoupling resistor values to get in the ballpark.

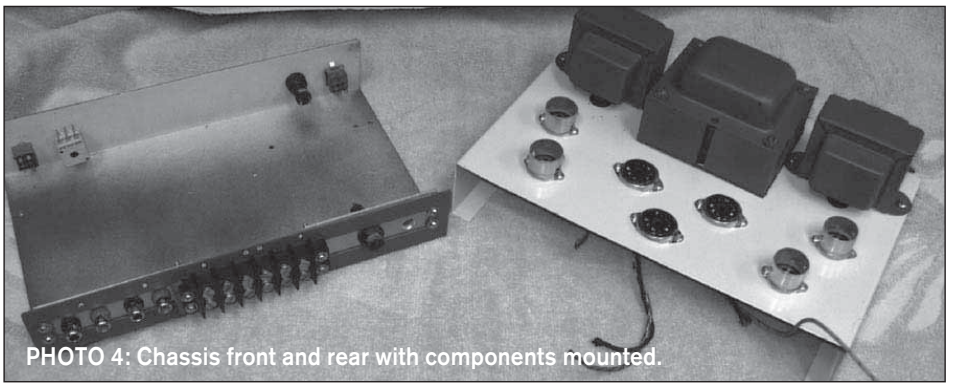


PHOTO 4: Chassis front and rear with components mounted.

Parts List

Resistors
8- 470K ½W
2 - 4.7K ½W
4- 47K ½W
2- 10K ½W
2- 68K ½W
2- 180K ½W
2- 220K ½W at $.20 each
1- 100K 1W
1- 2.7K 1W at $.25 each
1- 10K 5W at $1.70
2- 1K 10W at $1.75
Dual 100K to 250K pot $2
Total for resistors $12.20

Capacitors
4- 100nF 400V film capacitors at $.48 ..... $1.92
4- 4.7nF 400V film capacitors at $. 57 ..... $2.28
4- 22µF 350V electrolytic caps at $1.86 ..... $7.44
1- 47µF 350V electrolytic cap at $2.85 ..... $2.85
Total for capacitors $14.49

Hardware
4- 7 pin tube sockets at $.45 ..... $1.80
3- 9 pin tube sockets at $.95 ..... $2.85
1- Miniature SPST toggle at $ 1.95 ..... $1.95
1- Miniature DPDT toggle at $2.50 ..... $2.50
4- RCA input jacks at $.50 ..... $2
1- 6 terminal barrier strip at $2 ..... $2
4- Terminal strips $.75 ..... $3
1- Line cord at $2 ..... $2
1- Fuse holder and fuse at $1.75 ..... $1.75
Bolt hardware at $4 ..... $4
Computer serial switch box $4
4- Grommets at $.35 ..... $1.40
1- Knob (no cost- whatever you have) 00
Total for hardware $24.30

Transformers
HK 100 at $62 ..... $62
3- 12AU7s (used) at $5 each $15
4- 6AQ5s (NOS) at $4 each $16
Total for tubes $31
Subtotal so far $143.99

Standard Bias System
2- 100µF 50V electrolytic caps at $1.50 each $3
2- 250Ω 5W resistors at $ 1.70 each $3.40
2- 100Ω 2W resistors at $ .35 ..... $.70
Total $5.20
..... OR

CCS Bias
2- LM317 voltage regulators at $.35 ..... $.70
4- 1Ω ½W resistors at $.15 ..... $.60
2- 25Ω ½W potentiometers at $3 ..... $6
2- 15Ω ½W resistors $.15 ..... $.30
Total $7.60

Total for complete amplifier $149.19 (standard bias) or $151.59 (CCS)

I listened to this amp with a variety of sources and material and it has turned out to be very accurate, clean, quiet, and a real pleasure to be around. It was capable with room-filling volume with a variety of speakers. I think it sounded best with my vintage JBL L 100s.

FURTHER DEVELOPMENT

I have been surfing the DIYaudio forum and was interested in using a constant-current source (CCS) for the bias on the output tubes, so I decided to try it in this amp. This requires a few extra parts that are not included in the cost of this project, so I will list them separately, if you want to try it. The only issue with this circuit is that it may push you over $150 (it is close to a wash since you are eliminating two 5W resistors and a 100µF electrolytic per channel). Also, in order to try it, you will need to remove the 2-100Ω resistors in the filament supply (to ground). (**Fig 1** and **2**)

The 15Ω resistor sets the current at 80mA total for both tubes (40mA per tube). Center the pot, and then using a DVM, read voltage across the 1Ω resistors, and set the pot for 40mV across each resistor. Measure alternately across each resistor and balance the two tubes in each channel. After about one hour of operation, check and reset them. Check periodically.

The formula for figuring the value for the resistor is 1.25 divided by the total current draw for both tubes (in amperes).

1.25/0.08A = 15.63Ω (15 is close enough)

Once you have calculated the value, you can select the LM317 that fits your application. For this amp I could probably have used the LZ version (size of a small plastic transistor), but since I had a large stock of TO220 317s, this is what I used. If you want to use this circuit with KT88s, 6550s, and the like, you will need to use the HV version of the 317 (LM317HV).

I was truly amazed at the difference in the sound of this amplifier with modification (special thanks to Bruce H at DIY Audio forums for his tutelage). This mod opened up the soundstage considerably and really helped enforce the bass reproduction.

At this point I am extremely happy with this little "sweetie." The ultimate test was to take it to Larry's (my McIntosh friend). His first impression was that it was "cute," but after we listened to it for 30 minutes he was pretty impressed. When I told him the total cost, his response was "amazement" and an unprintable expletive.

I am pretty confident that any of you can build a similar amplifier at a similar cost. I urge you to give it a try; it just might become one of your favorites.

I am always happy to answer questions and entertain suggestions and opinions from *audioXpress* readers. However, I want to remind the armchair quarterbacks that I am just a hobbyist, not an engineer. If your comments are meant to show how lofty your thought process is, I urge you to write an article, rather than write me. I can be reached at Tuninfork@aol.com. *aX*

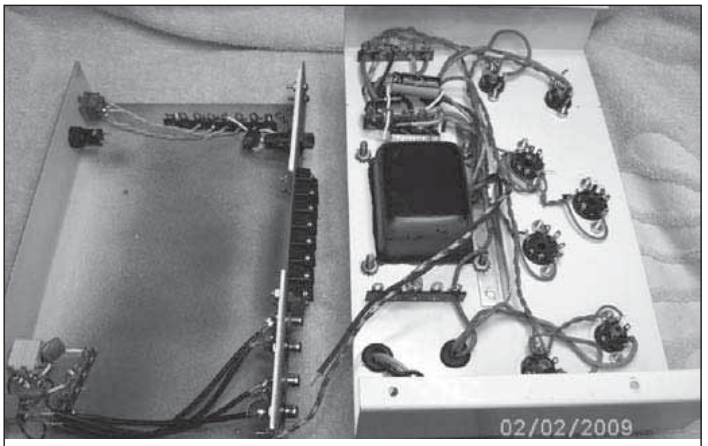


PHOTO 5: Filament and HV wiring.

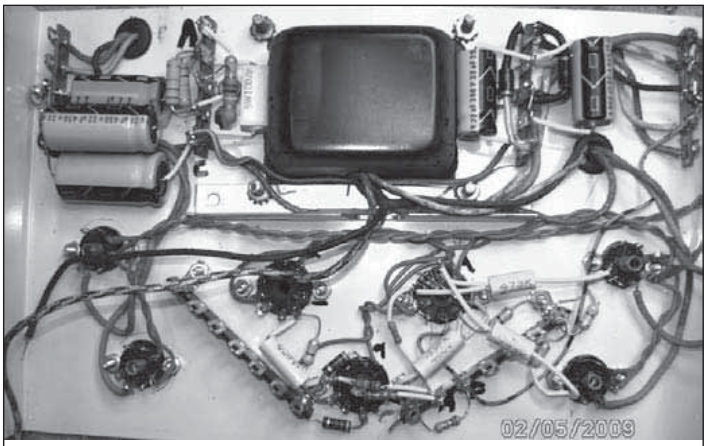


PHOTO 6: Half-complete chassis wiring.

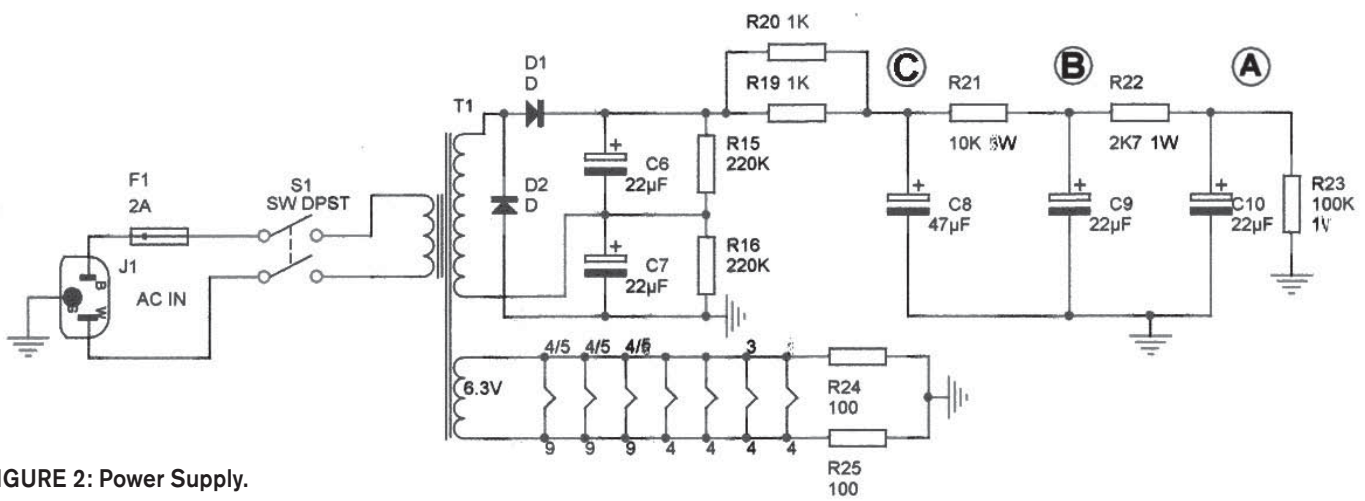


FIGURE 2: Power Supply.

Borbely RIAA with Tubes Revisited

Here's a rework of a fan favorite: a phono preamp that includes new features and improvements.

In the October 2003 *aX*, I described a stereo phono preamplifier using 5842 triodes and an equalization scheme that was inspired by an article written by Erno Borbely nearly 25 years ago for *The Audio Amateur*. Several readers built 5842 preamplifiers, including a gentleman in the United Kingdom who called it a "living, breathing instrument," for which I'm very grateful. Since that original article, I've made many changes to the unit and present them here. The preamplifier remains the centerpiece of my system and I use it constantly, often playing several records per day.

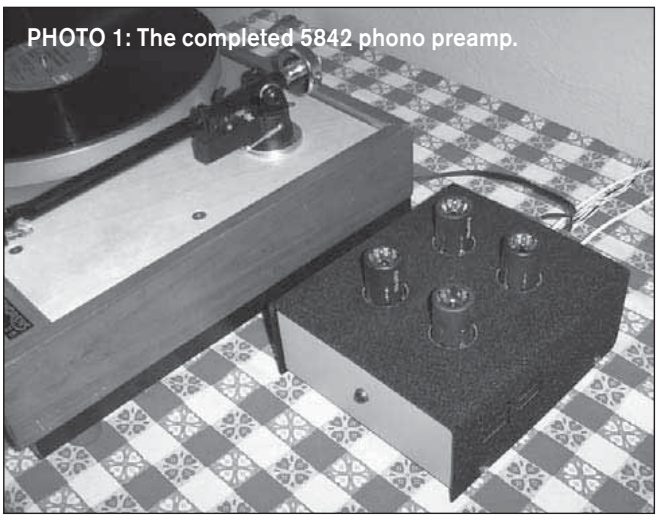


PHOTO 1: The completed 5842 phono preamp.

THE CIRCUIT

Borbely's approach to a phono preamp in 1985 can be described as half-active and half-passive; a linear gain stage up front is followed by a passive low-pass filter for the RIAA 75µs rolloff and an active shelving equalizer for the 500Hz/50Hz low-frequency boost. My preamplifier replaced Borbely's discrete transistor circuitry with two very high-transconductance frame-grid tubes, and the result was very good subjective and measured performance. I've elected to keep the basic topology of this circuit intact through all the changes. A common-cathode amplifier stage provides voltage gain at the input, followed by an RC low-pass filter; then a second amplifier stage with anode-follower negative feedback implements the RIAA bass boost courtesy of a series capacitor in the feedback impedance. With only two active devices, it's indeed a very simple circuit.

Design revisions encompass the following: a new biasing scheme and operating point, a redesigned low-frequency section that offers higher overall gain, a modification to the extreme high-frequency response of the preamplifier, and special attention paid to equalization accuracy and component technology. The result is a preamplifier that is a major improvement over the original in both objective and subjective terms.

BIASED OPINION

Rather than a traditional cathode bias resistor with bypass capacitor, each stage of the updated preamplifier (**Fig. 1**) uses a Lumex SSL-LX5093ID LED to set its cathode voltage, a technique inspired by Morgan Jones in the third edition of his book *Valve Amplifiers* (available from Old Colony Sound Lab, www.audioxpress.com). The first time I saw LED bias—circa 1999—in the first stage of a power amplifier, my reaction was to make fun of it. Using a nonlinear device in the very circuit position from which the input signal is derived seemed ridiculous at the time. Mr. Jones made a very convincing argument, however, so I tried it and *listened* to the difference. It turned out to be a very significant sonic improvement.

LED bias has pros and cons. LEDs tend to drop a constant voltage over a fairly wide range of operating current. This means that their dynamic resistance is very low. I extrapolated 13Ω from the manufacturer's datasheet at the chosen operating point of 15mA and used it in my computations. The significant advantage of this is that a cathode bypass capacitor is no longer needed. The downside is that the constant-voltage behavior more or less constitutes fixed bias, losing the cathode resistor's inherent advantage of providing DC feedback to stabilize the tube's operating point. This is of particular

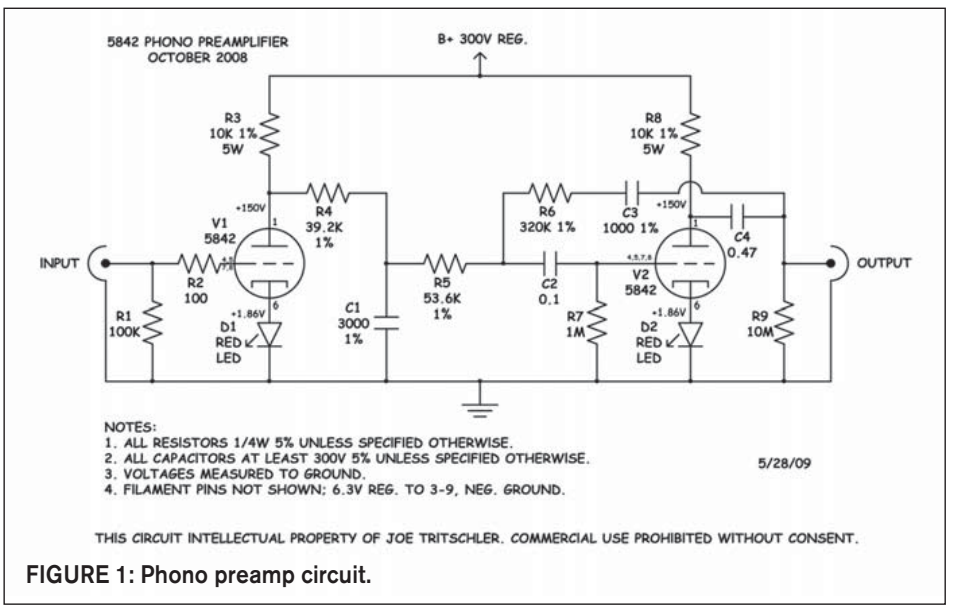


FIGURE 1: Phono preamp circuit.

concern with high-transconductance tubes since, by definition, small changes in bias produce large variations in plate current.

As it turned out, I did need to plug in a few different combinations of 5842s to find pairs that biased similarly channel-to-channel, but the improvement in sound was most worthwhile. Incidentally, there's nothing special about these particular Lumex LEDs; they were simply available locally in surplus. Morgan refers to "cheap red LEDs" in his book, but I tested a few different types and they do differ slightly in voltage (and presumably resistance), and seem to be very consistent within a given part number.

My theory is that a cathode bypass capacitor is likely to be much more audible than any power supply bypass capacitor. The reason is that even though the dynamic plate current of a single-ended amplifier stage flows through both of them, any AC voltage developed by the power supply capacitor across its impedance (including nonlinearities and parasitic components) will be attenuated by the amplifier's power supply rejection (which is high in this circuit). Whereas, any nonlinear AC signals appearing across the cathode bypass capacitor are placed right into the input grid-to-cathode signal and *amplified*. This effect seems most pronounced in high-transconductance stages.

Switching to LED bias in this preamplifier brought out reverb tails and other nuances that had previously been missing, probably due to electrolytic capacitor imperfections. Of all the component changes made, this was the most audible, resulting in a major improvement in detail and a clearer, less-fatiguing sound overall.

MORE GAIN, PLEASE

One complaint with the original 5842 preamplifier circuit was that it had only about 34dB of gain at 1kHz. This was barely enough for use with a moving-magnet cartridge, provided you were driving a line stage or very sensitive power amplifiers. Because I prefer not to use a line stage at all if I can get away with it, a few more dB overall seemed a worthwhile objective. The original preamplifier set the second-stage mid-band gain to unity, rising to the required +20dB below 50Hz.

It occurred to me that if I could set the mid-band gain to exactly 20dB below the open-loop gain of the stage by adjusting the feedback network, then every drop of available gain could be squeezed out of the circuit at low frequencies where maximum gain is required by the RIAA equalization. The result is an overall gain of about 40dB at 1kHz, which is enough to drive my triode monoblock power amplifiers without further amplification. I performed the computations assuming a 100kΩ load on the output, as presented by the stepped Daven attenuators on my power amps. With a moving-magnet cartridge, the output is within a few dB of CD level, which is close enough for my system. It allows me to switch directly between the two at the amplifiers with only a couple clicks of the volume controls.

ULTRASONIC STUFF

Conspicuously absent from the revised circuit is a shelving resistor in the low-pass filter which was previously used to insert a 50kHz zero into the response, supposedly to compensate for the deliberately limited boost capabilities of record-cutting equalization. The idea, apparently endorsed by many designers, is that this compensation audibly reduces high-frequency phase distortion. I did a subjective comparison between networks with and without the 50kHz zero and concluded that I actually preferred the sound without it.

Worth mentioning is that allowing the HF response to roll off seems to reduce the subjective effect of record surface noise and pops. Given that the interaction between cartridge inductance, cable/arm/preamp capacitance, and input resistance already forms a second-order low-pass filter that has a much greater effect on frequency response than a simple 50kHz first-order low-pass filter during recording, it seems a moot point anyway. Golden-eared audiophiles with ultrasonic hearing (or maybe their dogs) are entitled to their preference, but I no longer believe in implementing this HF shelf.

With regard to cartridge inductance and loading, I choppped the cable on my Rega/Origin Live tonearm to about a foot in length and located the preamplifier immediately adjacent to it, greatly reducing shunt capacitance and audibly improving high-end response. Ray Futrell wrote a good article on the subject a few years ago in *aX* ("The LP Terminator," January 2003). I was able to increase the preamplifier input terminating resistor to 100kΩ

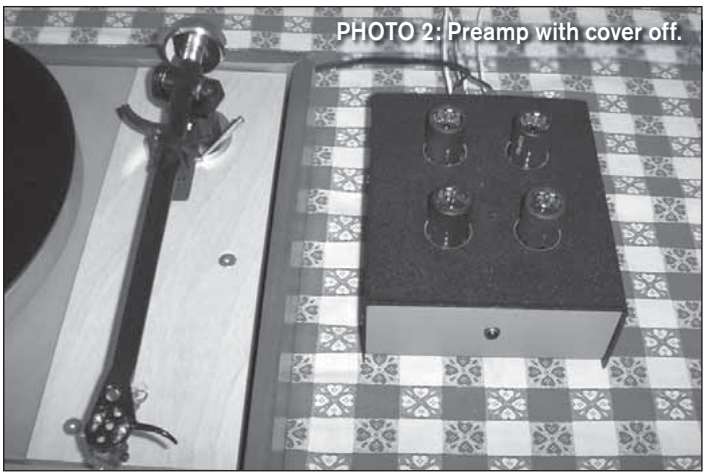


PHOTO 2: Preamp with cover off.

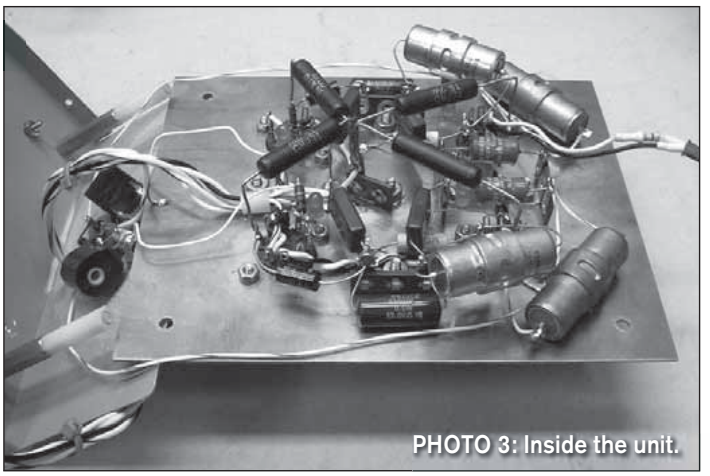


PHOTO 3: Inside the unit.

with only a slight response peak a little over 20kHz with my particular cartridge.

PARTS IS PARTS

In my original article, I stated that I preferred the sound of carbon composition resistors despite their relatively poor objective noise performance. Several readers took exception to this, mostly on the grounds that they also suffer from poor tolerance and drift. Well, you guys were right: Carbon comps really aren't stable enough for complex equalization networks, particularly those that must be both accurate to a reference standard and precise channel-to-channel. I now reserve them solely for restoration of older equipment and occasionally in grid-stopper applications.

I prefer non-inductive precision wirewound resistors by Shallcross, Ultraohm, Mepco, and Daven for their sound and accuracy, but if you don't have access to them, you can use regular metal films with perfectly acceptable results. For plate-load resistors, I used 7W half-percent non-inductives made by Tepro, but any quality wirewound of at least 5W would work, provided it's within the specified tolerance of 1%.

The blocking capacitors make a subtly audible difference, but I wouldn't lose sleep over it. I happen to really enjoy the sound of extended-film/paper-in-oil Sprague Vitamin-Qs (196P-series) and also use them in my power amps (and even the crossover capacitors on my horn tweeters). But, like the non-inductive resistors, if you don't have a good supply of them, it's certainly not the end of the world. I had some SBE 716P polypropylene film-and-foil "orange drop" capacitors in there for a while and they sounded very good; maybe a little "artificially detailed" for my tastes, but it's an entirely subjective call.

The equalization capacitors are old-style 1% silver micas, which is a very controversial choice. Many folks seem to find them metallic sounding and some engineers have reported hysteresis distortion with them. I've found that placing a large DC bias across them (in this case, the plate voltage of the stage, which should negate any hysteresis effects) makes a world of difference, and they sound truly transparent to my ears. I use the old types which are reportedly made of cleaved sheets of natural mica, as opposed to modern ones which are a ground-up slurry. But again, don't sweat the small stuff. The precision polypropylene film-and-foil types available now would probably work and sound just fine if you don't choose to use micas.

TUBES AND WIRE

The 1980s JAN Raytheon 5842Qs that were very plentiful a few years ago work fine in the second stage of the amplifier, but I had a little trouble with them in the front-end due to microphonics. I ended up scavenging some late-60s Amperexes, which were much quieter. Strangely enough, these seem to have much more subjective bass response than the Raytheons, but only in the first stage; probably because the second amplifier stage has a negative feedback loop. The extra bass is lovely, but this type of thing can drive an electrical engineer crazy. The short IERC heatsink/shields are nice if you can find them.

Does the type of wire used really make that much of a sonic difference? The engineer in me doubts it at audio frequencies, but, then again, it *seems* to. I used Teflon-insulated silver-plated stranded hookup wire because I had access to it. No question Teflon is much more forgiving toward soldering technique.

Photo 3 shows my preamplifier in its current modified state, still on the same piece of copper-clad PC board material as the original with the same phenolic tube sockets. I have changed nearly every other component. All connections on the board are component-to-component, with the copper cladding forming an excellent ground plane.

POWER SUPPLY

At the moment, I'm using a tube-regulated Gen-Rad laboratory power supply from the 1960s, which is especially nice because it's not mine (thanks, Chris). It provides very well regulated 300V B+ and 6.3V filament supplies, both of which are essential

if you don't plan any further power-supply decoupling. The preamp draws 60mA from the B+ and 1.2A for the filaments. I included a 1nF silver-mica capacitor inside the preamplifier as a precaution to shunt any rising impedance at RF due to stray inductance in the B+ power supply umbilical, but it worked just fine without it.

MEASURED SPECS

Photo 4 shows the actual measured frequency response of the preamp using a Tektronix SG 505 MOD WQ oscillator and a Tektronix AA 501 distortion analyzer as a precision AC voltmeter. The response is indeed very flat; I didn't need to do any empirical tweaking of the calculated circuit values. The low frequency response is about 1dB underdamped from around 20 to 50Hz, which is likely due to the presence of three capacitors within the second stage feedback loop. My rationale for this design choice is that I preferred the sound with this configuration; maybe it's because both blocking capacitors are subject to negative feedback. Stability is ensured regardless because the amp runs open loop at VLF.

At 20kHz the response is down a little over 1dB, but it starts to rise again, becoming underdamped by 4dB at 100kHz. This is probably due to the negative feedback loop as well; in this case, an HF pole at the grid of the second stage interacts with an output pole caused mostly by stray capacitance imposed by the test equipment and interconnecting cables, which should be similar to conditions encountered in actual use.

In the middle of the passband, where it really counts (my use of Edgar midrange horns reinforces my strong belief in this philosophy), the response is flat from 200Hz to 5kHz, with only a 0.1dB crest at the 75µs RIAA turnover point. This is certainly flatter than my (pretty darn flat) speakers. Gain measured 41.2dB in one channel and 41.3dB in the other, and the "A"-weighted noise with inputs shorted is -76 and -75dB, respectively, referred to a typical moving-magnet input level of 4mV. Subjective noise level is negligible; even at very high volume levels, I hear nothing when switching from CD to LP.

LISTENING & CONCLUSION

How does it sound? Well, if a meteor were to crash through my roof and wipe out my entire system, I'd spend the insurance money on parts to build another preamp exactly like this one. *But seriously, folks. . .* I believe this is about the best I can do. My friends really seem to like it, too—and some of them have *very* expensive tastes in audio gear. For those who can't afford to build something quite this exotic, there's a much cheaper version of the circuit that sounds almost as good. But that'll have to wait until next time.

THANKS

Many thanks to my father Tony Tritschler, an exceptional audio engineer and loudspeaker expert without whom I wouldn't have a system at all; to Duke Fecteau, Bob Jones, Larry Mehal, Curtis Welch, Fred Garber, and all my audio buddies for good times and invaluable feedback; to Roger Hughes at Midwest Surplus Electronics in Fairborn, Ohio, who has been taking IOUs and giving me good-natured grief for almost 15 years now; and to Chris Ivan, a first-rate tech and tremendous source of knowledge from whom I've stolen almost *all* of my electronic components, and whose hi-fi system I've shamelessly imitated almost entirely. *aX*

5842 Preamplifier Parts List

R1	100kΩ ¼W 5%
R2	100Ω ¼W 5%
R3, R8	10kΩ 5W 1%
R4	39.2kΩ ¼W 1%
R5	53.6kΩ ¼W 1%
R6	320kΩ ¼W 1%
R7	1MΩ ¼W 5%
R9	10MΩ ¼W 5%
C1	3000pF 300V 1%
C2	0.1µF 400V 10%
C3	1000pF 300V 1%
C4	0.47µF 400V 10%
V1, V2	5842
D1, D2	Lumex SSL-LX5093ID LED

RIAA Equalization Measurement chart
(75µs, 318µs, 3180µs)

Freq.	Ref. gain	L gain	L error	R gain	R error
10Hz	+19.7dB	+19.8dB	+0.1dB	+20.0dB	+0.3dB
20Hz	+19.3dB	+20.1dB	+0.8dB	+20.3dB	+1.0dB
50Hz (3180µs)	+16.9dB	+17.5dB	+0.6dB	+17.7dB	+0.8dB
100Hz	+13.1dB	+13.2dB	+0.1dB	+13.3dB	+0.2dB
200Hz	+8.2dB	+8.2dB	0.0dB	+8.2dB	0.0dB
500Hz (318µs)	+2.6dB	+2.6dB	0.0dB	+2.6dB	0.0dB
1kHz	0.0dB	0	0	0	0
2.12kHz (75µs)	-2.9dB	-2.8dB	+0.1dB	-2.8dB	+0.1dB
5kHz	-8.2dB	-8.2dB	0.0	-8.2dB	0.0
10kHz	-13.7dB	-14.1dB	-0.4dB	-14.1dB	-0.4dB
20kHz	-19.6dB	-20.8dB	-1.2dB	-20.8dB	-1.2dB
50kHz	-27.5dB	-28.2dB	-0.7dB	-28.4dB	-0.9dB
100kHz	-33.6dB	-29.4dB	+4.2dB	-29.9dB	+3.7dB

By Jan Didden

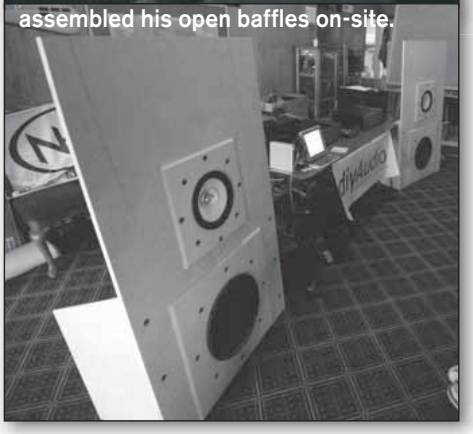
Burning Amplifier 2009

This year's edition (third) brought out the best of audio DIY on a professional level.

The BAF event is organized by the editor of what is perhaps the largest online DIY audio community, www.diyaudio.com. With 100,000+ members, clearly only a fraction would attend BAF, but the spirit was there anyway. With generous support from Audio Amateur Inc., Elektor Electronics USA, and NHT, BAF09 had a full smorgasbord of listening sessions, presentations, and great ad-hoc discussions.

PHOTO 1: Jack Hidley of NHT talked about crossover issues (all photos by Dana Brock.

PHOTOS 2A and 2B: John van Halen assembled his open baffles on-site.



Jack Hidley of NHT (**Photo 1**) has been an avid supporter of BAF from the first edition; I still remember his fascinating demo of the Klippel loudspeaker measurement system in 2007. This year Jack gave a presentation on the design considerations at the lower crossover point in three-way speaker systems. Such a crossover point typically is around 80 to 150Hz, which can be problematic as driver impedances can vary wildly in this frequency range and passive crossovers don't work well with varying load impedances. But Jack showed that if you carefully match the crossover to the driver and the enclosure mechanical rolloff, you can get a satisfactory solution. He had an interesting comment that you don't hear often from a speaker manufacturer: It is worthwhile to spend good money for crossover and driver modeling software because even the best driver will suffer from a non-optimal crossover, and trial and error is not only tedious but also doesn't guarantee that you will actually find the optimum.

Open baffle speakers (**Photos 2A** and **2B**) were assembled on-site by John van Halen, and the modular construction was used to rapidly switch from PM5 Lowthers to Feastrex drivers. Both wideband high-efficiency drivers (supported by a 15″ Eminence woofer) delivered pleasant-sounding music from several amplifiers. The Feastrex ones are built on request only and are very expensive field coil drivers.

One highlight of the day was the presentation by Nelson Pass (**Photo 3**) of an extremely simple power amplifier that "even a lawyer could build," as someone remarked. That was also Nelson's motivation to design it: an amp that anybody who has been put off by a seemingly complex design now would no longer have any excuse not to build. And simple it is: just *one* power MOSFET (an IXYS IXTH20N50 20A, 500V depletion mode MOSFET). With this depletion mode normally-on device, biasing is automatic, and with just a source resistor to linearize it, the amp delivered some 5W of high-quality sound through the open-baffle speakers.

Linear Integrated Systems (LS) presented their range of very low noise JFET devices replacing those popular Toshibas from way back when. They had samples of the N-channel LSK170, the P-channel LSJ74, and the dual N-channel LSK389. The singles are available at different IDSS value groupings, and on the request of John Curl, who is an avid user of those devices, Linear Systems has added a –D group to the LSJ74 with an unusually high IDSS range of 20-30mA. John told me that although in his view the Linear Systems devices were not quite as quiet as the Toshibas, they were

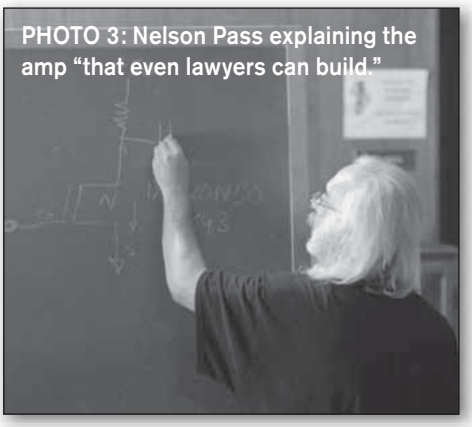


PHOTO 3: Nelson Pass explaining the amp "that even lawyers can build."

PHOTO 4: AMB audio (Ti Kan) amplifier in stock case with custom faceplate.

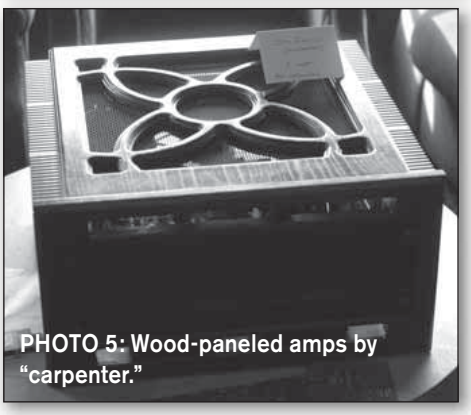


PHOTO 5: Wood-paneled amps by "carpenter."

very good devices, and he was happy that there now also was a higher IDSS version.

LS also had a nice all-FET power amplifier with all Linear Systems devices up to the output, which used vintage 2SJ60 V-FETs. The only thing left for LS now is to recreate those output devices.

The bulk of the show, of course, consisted of designs and projects by DIYers—from the very professional-looking units by Ti Kan (AMB audio; **Photo 4**) and the wood retro looking stuff by—what's in a name—carpenter (**Photo 5**), to "steampunk" designs (**Photo 6**). These designs reflected audio equipment engineering as an art form, a synthesis between the music flowing from DACs and amps and speakers as well as the visually stimulating look of the realizations.

The range of technologies used was also diverse: Mark Brasfield (audioman54), who, until recently worked with Bob Pease at National, demonstrated a system almost completely built with National analog products, from LME49600s and 49710s in the DAC power supply regulators, via the LME49713s in the amplifier input stages (metal can, of course) to the LME49811 power amp Vas and driver stages. Only the DAC itself (AKM4396) and the output power Darlingtons came from another manufacturer. At the other end of the spectrum was Jack (Electra-Print) Elliano's creation (demonstrated by his associate Edwin Yang) with 211 transmitting tubes in SE class A2 mode, outputting 45W in (gasp!) grid current mode (**Photo 7**).

The technical creativity award goes to David Gravereaux (davygrvy), who dismantled a radar speed gun and pointed the beam at his speaker's cone. Connecting the demodulated output of the radar unit to a scope showed him a waveform representing the cone excursion. The cone velocity is not high enough to generate a Doppler frequency, but the phase shift between emitted and received wave is sufficient to show asymmetric movement, and compression at high output levels was clearly visible. A sort of poor man's Klippel system that can help you operate your drivers in their linear region.

One thing audio amateurs apparently are not very good at is planning. Last year I worked on Mark's (Variac) F4 amp until 5:00 in the morning of the show, and then Nelson Pass himself still needed to put the finishing touches on it during the event. This year Nelson mentioned that he designed and built his super-simple amp the day before the show. Ron of Linear Systems noted that he finished his all-FET amp at 6:00 in the morning on the day itself. What more testimony do you want for absolute dedication?

Times have passed when audio DIY was looked upon as an irrelevant pastime by those who didn't quite get it. The participation of accomplished designers such as Nelson Pass from Pass Labs, John Curl of Parasound fame, and Siegfried Linkwitz of Linkwitz Lab made it clear that even if you don't make your career in audio, you can still contribute to it at a professional level. Audio amateurs and DIYers spend lots of money and time to realize their vision with great enthusiasm and persistence, and the reward is a great-sounding and great looking piece of equipment or speaker. The recognition of your peers—whether it is online at www.diyaudio.com or at an event like BAF—makes it all worthwhile. I am looking forward to next year's edition, and rumor has it that there will be more separate rooms for system auditioning. Be there and be counted at www.burningamp.com! *aX*

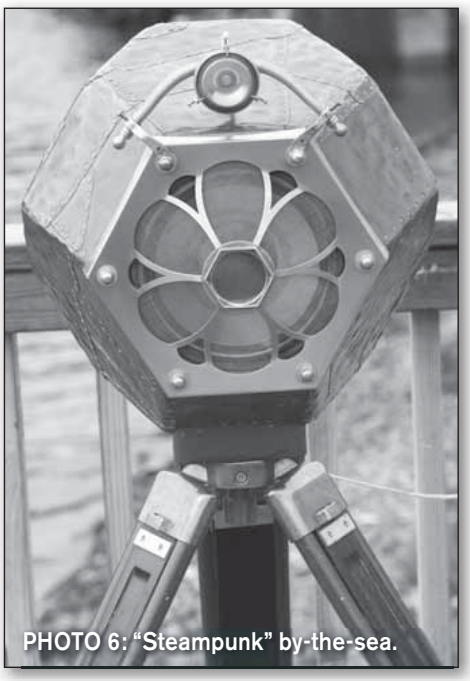


PHOTO 6: "Steampunk" by-the-sea.


PHOTO 7: Wirewriggler's F4s driven by Stuart Yaniger's Impasse preamp.

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AC Filters. . . and Other Noisy Issues

Discover the key to better audio and video.

PHOTO 1: AC filters for DVD player, HDTV, Blu-ray, and power amp, plus example NEC-IEC adapter.

any years ago, my retired parents moved to a rural setting, where I visited them often with my then-young family. I was introduced to a neighbor, Mr. Moore, who spent WWII in China installing runway lighting at airports used by the Allies. I said, "I'm very glad to meet someone with your background, because I always have trouble debugging my electronic projects." The unforgettable reply: "It's simple. There's no such thing as electrical problems, it's all mechanical. If there's a place for the electrons to go, they'll go."

INTRODUCTION

In a piecemeal hobbyist fashion, I have installed AC line filters in the power cords leading to four of my electronic entertainment components (**Photo 1**). I have also improved other connections (described later).

The sophisticated AC line treatment systems appearing periodically in *aX* [1,2] have my admiration, but my experimenter's approach is to isolate the components of the entertainment system from each other as well as from the noisy world surrounding them, and identify "guilty parties," if, in fact, there are any.

I launched this project after replacing a 27″ CRT NTSC television with a 52″ LCD HDTV screen. Several items needed upgrading in support of this very significant advancement in home theater presentation, so I began the effort with the simple S-video connection from my now old but much modified Sony DVD player.

ELECTRONS ON THE GO

S-Video. I use my first (cheapie) S-video cable to test the Sony DVD player on a computer—partly to evaluate the improvement over using a composite video connection (the only input available on the old NTSC TV), and partly to see whether the S-video electronics in the player survived my intrusive modifications, which, I am thankful, they did.

I soon wished to send even better video from the Sony to the HDTV screen, so I used a Mogami S-video cable. Color purity and image sharpness improved significantly. Now I was hooked—on to the next candidate. Video certainly offers near-instant gratification from improvements.

DVD Player Filters. With all those digital circuits in the DVD player (and HDTV), I suspected that the player might be contaminating the AC line. So after testing a single-stage AC line filter, I used a two-stage version to feed the DVD player. Picture quality and audio improved slightly over a single-stage line filter, which by itself made a very welcome improvement in both video and sound.

AC is fed to the filter box with a three-wire cable, while the player is supplied through the original two-conductor type cable. The ground lead of the three-wire cable carries filtered noise back to the wall outlet ground.

The DVD player contains a switching power supply, and the new TV almost certainly does too, so I wanted to see whether they were victimizing my audio. In all fairness, some of the blame for contaminated AC must be shared by the three nearby cell-phone towers and a supermarket/shopping center.

Stereo. One guinea pig for an AC filter was the preamp. Again, I assembled a single-stage 10A filter-in-a-box, which sounded worse on both my, and another, preamp compared to no filter. I examined the filter and found it to be very old, having been ordered perhaps 20 years ago, so I replaced it with a new filter. Still no improvement for some reason, so I plugged the preamp directly into an outlet. The unused preamp filter now cleans power for the recently added Blu-ray player, and again improvements are obvious.

I made a generously proportioned 20A filter-in-a-box to feed the power amplifier. I figured that if it didn't improve much there, I could always put it into service on the HDTV. But, in fact, it cleaned up the audio even more, yielding better low-level detail, musical harmonics, and other welcome sonic benefits. Highly recommended.

HDTV

I spent a few pleasant evenings becoming familiar with the improved sound from the amp filter. Then it struck me that it might be worthwhile to test it on the HDTV set. So one night I ex-

Timing Is Everything...

It's not surprising that many Audiophiles lie somewhere between reticent and hysterical when it comes to digital and DSP.
One could argue that CD's highly touted promise of "Perfect sound forever" nearly killed-off enthusiasm for high-end audio altogether!

As good or bad as the source may be though, the 'elephant in the room' is that our 80-year old passive loudspeakers are the weakest link to sonic epiphanies. Even the best passive speakers decimate the timing and amplitude accuracy of the signal driving them, but not until adding ten to a hundred times more distortion. Passive speakers even wreak havoc on the signal itself by presenting infinitely different loads under infinitely different dynamic conditions over ten octaves, so amplifiers are forced to use soul-destroying negative feedback to compensate.

DEQX-HD™ invites you to think beyond eight decades of passive speakers; its new HDP3 stereo preamp processor provides up to 3-way linear-phase active crossovers that reduce the load to each amplifier from ten to about four octaves, dramatically reducing IM distortion. It quarantines bass, midrange and highs to each driver's 4-octave comfort zone; much less than allowed by passive crossovers, providing higher volume of complex content with lower distortion and higher resolution.

Also unique to DEQX-HD™ is its ability not just to correct amplitude and timing between drivers (time alignment) but also within drivers (frequency dependent phase or group delay correction). Of course you don't need to know what or how to correct hundreds of different frequency groups independently, HDP3's set-up software running via USB on your Windows (or Intel Mac) notebook prompts you through the whole process automatically. You can make the necessary anechoic measurements without an anechoic chamber and it generates the correction in 32-bit resolution. Only when your speakers are fixed is it time for room correction!

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The HDP3 stereo preamp provides DEQX-HD™ processing. Two analogue and two digital inputs and six outputs provide up to 3-way active crossovers. Audiophile transparency, analogue power supply and analogue tracking volume control follow all six DACs. Remote-control not shown.

The President's Message - Arizona Audiophile Club Newsletter editorial by Adam Goldfine - September 2009:

"I've been saying that digital signal processing is the future of high-end audio for some time now, but my experiences over the last couple of months have firmly cemented that notion in my mind. Audiophiles, being purists at heart, have typically eschewed the idea of using any sort of processing or equalization in the signal path, and in the past I feel that has been a valid approach. But things are changing, technology is improving and those days are over."

"Using the DEQX HDP-3 to anechoically correct my already excellent Wilson Benesch loudspeakers in both the time and frequency domain and provide room correction resulted in some of the most stunning music reproduction I've ever heard. I will have more to say about this in my upcoming review (for 'Positive feedback'), but I can unequivocally state that there is no way to accomplish the same level of improvement for anywhere near the price and it may be impossible to achieve the high level of performance provided by DSP without it."

But don't take our word for the added advantages of going active...

Review of DEQX-HD™-based Tikandi active speakers by Chris Groppi; Secrets of Home Theatre and High Fidelity - October 2009:

"In Use - The Tikandi system is the best music reproduction system I have ever had in my listening room, regardless of price, and is one of the best sounding systems I have ever heard in any room... One of the things Larry played for me was an audiophile epiphany. He played Japanese drumming track from the YG Acoustics demo CD. This track was recorded with gigantic dynamic range. In real life, drums are loud. Very loud. We turned up the Tikandis until Larry started to get uncomfortable about blowing something up. I just sat there like the Memorex guy with a stupid grin on my face. The power delivered by the drums was something I have NEVER heard from a stereo system. It wasn't that it was just loud. Lots of speakers can play loud. It was the sharpness of the transients, the subterranean frequency extension, and the shocking dynamic contrasts that did the business..."

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Timing Is Everything

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changed the TV power strip and amp filter to see whether video improvements might appear.

The already successful-looking DVD images experienced welcome improvements in color rendering, nuance, and sharpness. There was no going back—I kept the new line filter connected to the HDTV while I quickly placed an order for components for a dedicated amp filter. Meanwhile off-the-air programs sharpened up.

There is a three-wire power cord on the HDTV, so I made very sure all wires in its added filter assembly were of the correct polarity. Evidently, the HDTV contains a noise filter which uses the ground, and cares about line polarity.

FILTER COMPONENTS

Mail-order electronics suppliers carry a large variety of AC line filters. Their manufacturers, via the Internet, offer abundant documentation covering specific applications. So far, I have applied 10A and 20A filters hoping to keep impedance low for useful frequencies. Evidently this is succeeding, since the transient response of my electronics, both aurally and visually, appears to serve the most demanding program material.

The filter enclosures are sheet aluminum, cast alloy, and plastic. Any safe closed box will do. Both threaded and "fast-on" terminals are present on the filters, so I use insulated crimp-on wire terminations to suit. I always triple-check the hot, neutral, and ground connections. I replaced the two-wire outlets that served my entertainment electronics with three-wire many years ago, and made very sure they were polarized correctly.

AC cord wiring is accompanied by many choices. Contributor M. Danbury has found that generous conductors composed of the highest number of the smallest copper strands sound and display the best, so that's my choice also, having compared cords.

Sturdy, well-made AC line plugs and sockets are preferred (you can see some remaining budget plugs in **Photo 1**). The best AC hardware I have found is made by Marinco, sometimes available locally, otherwise orderable over the Internet. Their very high quality makes installation a pure pleasure.

CONTACT!

Years ago, I read an account in which someone polished the prongs on audio-component AC plugs, so I tested this on my own growing population of plugs. The technique I applied was to polish the brass prongs with fine "crocus cloth," a fabric-backed metal-polishing system with a coating somewhat coarser than polishing-wheel rouge. I even took pains to polish in the direction of the long dimension of the prongs. The resulting surface finish feels "soapy" to the touch; quite a contrast to the as-milled metal.

The final AC tweak was to plug the amplifier filter into an outlet as far away as possible from the one supplying the HDTV. The music improved significantly in overtones and detail, and careful viewing showed detail and color purity gains in the video. The "third dimension"—video depth—now appears to be much better than in the past.

DIGITITIS

Years ago, during the assembly of my preamp, I became impatient and wired the input jacks with enameled solid copper wire. Two by two I replaced them with Teflon-insulated coaxial cable, to the betterment of the sound. The latest such replacement was in the circuit used for two-channel audio from the Blu-ray player.

I noted a sonic improvement in the "cleanness" of the upper midrange and highs while playing the *I, Robot* Blu-ray, but then began paying close attention to what was on the TV screen. Easily seen were improved image sharpness and subtleties in color rendering.

Digital sources seem to produce a halo of electronic haze within and near them, a fact I had not adequately appreciated. I do now[3,4].

CONCLUSION

When the electrons you receive are the ones you actually use, things both look and sound far better for it. Home theater and stereo are very worthy of the best electrons. That means locating line filters inside the audio and video components where the AC cord first enters the box, which I haven't done, but will in the future.

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aX

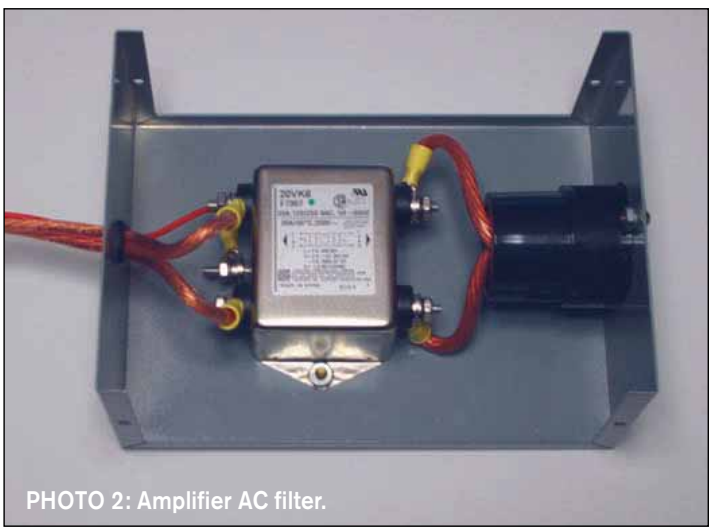

PHOTO 2: Amplifier AC filter.

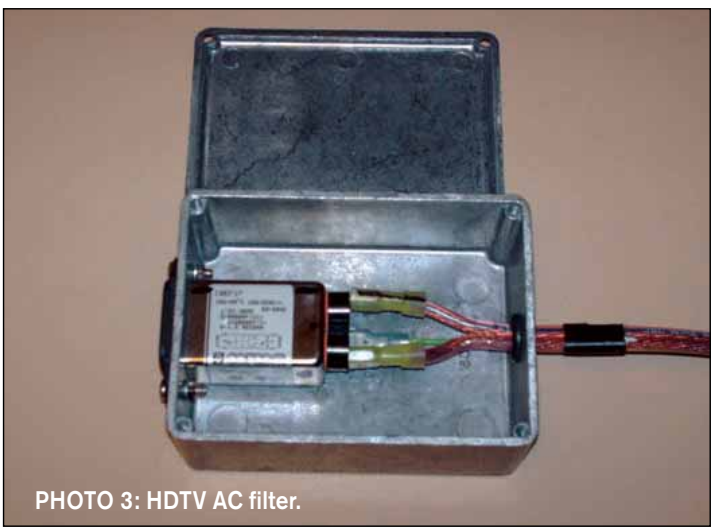

PHOTO 3: HDTV AC filter.

By Jan Didden

The CableCaddy

If you're like me, you have tens, maybe hundreds, of cables lying around your lab and your house. Interlinks, mains cords, scope probes, banana-tipped test leads, bits of crocodile-tipped test wires, you name it. And you never can find the ones you need because they are buried inside a heap of other stuff.

I decided to make short shrift of these frustrations and build the CableCaddy. This contraption consists of the remains of a retired office chair and some rails for wall-mount shelf holders. It requires an hour with drill and screwdriver, and a precision-engineered special-purpose tool (PEST).

I disassembled the office chair, saving the central pillar mounted on the wheeled feet, as the base for the CableCaddy. Next, I drilled holes in the central pillar to attach the shelf mount rails (**Photo 1**). You need to do this carefully to equally space the holes around the pillar. A keen eye and triple checking is helpful.

I drilled two opposite holes first and then used calipers to mark the third hole and drilled the two remaining ones. Depending on the size of the pillar, getting the nuts inside is either very hard or almost impossible. So I constructed the PEST (**Photo 2**) to help with that. With some care and trial and error, it'll work.

With the four rails fixed to the pillar, I attached them at the top with a short length of aluminum tubing of a similar diameter as the pillar (**Photo 3**). That's it. **Photo 4** shows the CableCaddy with only a fraction of its intended load, but after just a week of use, I can't imagine how I stayed sane without it (yes, there are some that will maintain I didn't).

Have fun! *aX*

PHOTO 1: Rails fixed to base pillar.

PHOTO 2: The PEST.

PHOTO 3: Fixing the rails at the top.

PHOTO 4: CableCaddy ready for duty.

Comparing Speakers

By Howard Ferstler

When I review speakers, I make a point of doing my continuous (20-second) averaging room/power curves (moving a microphone slowly over a 1 × 1 × 5′ area at head level at the listening couch) with an AudioControl SA-3051 RTA. This gives me a good idea of just how effectively a speaker pair can deliver flat power to a typical listening area. It continues to amaze me that a simple measurement such as this can do such a good job of dissecting the spectral balance of a group of speakers in a good room. Invariably, speakers that do well with this measurement sound more realistic to me than those that do not. At least this is the case with really good recordings.

> "Just how tricky is it to level-match a pair of speakers for a decent A/B comparison?"

PLACEMENT

In addition, to validate my measurement discoveries, I always perform level-matched A/B comparisons between the units under test and some "reference" models I keep on hand. (The primary measurements are nearly always done in one room, and the primary comparisons are nearly always done in another, to weed out both negative and positive room-related anomalies.) Because those reference systems are pretty good, and also because I attempt to compare speakers with similar conceptual approaches to good sound and similar placement requirements, A/B evaluations can possibly do more to make a review worthwhile than the measured curves. Certainly, they are as important as the latter.

I have also pointed out in some of my reviews that when I do level-matched comparisons of stereo pairs, I try to set up the systems AB – AB style, as opposed to AB – BA. (In this case, each of the two units in one pair is A and each of the two units in the other pair is B.) I also position them on a mid-distance soundstage that is reasonably well centered in relation to my seating position. This arrangement keeps the units in each pair the same distance apart, although it does make it tricky to determine precisely and quickly which pair has the most exacting center focus.

While some critics make a big deal out of center focus and precise imaging stability in the middle of the soundstage, I consider enveloping spaciousness, breadth, and frontal blending to be more important. However, there is no doubt that good central focus can be very important with solo performances, particularly those dealing with the voice. In any case, when listening for proper center focus, my AB – AB arrangement only requires me to shift my head somewhat left and right to the sides when doing the A/B switching. On the other hand, when listening for spaciousness, breadth, and frontal blending, I can listen critically, enjoy the sound, and sit still.

OK, so we know that placing speakers for comparison work is tricky, and involves compromises. But what about the above-noted level-matching issue? Just how tricky is it to level-match a pair of speakers for a decent A/B comparison?

RANDOM NOISE

In the old days, I remember reading about how some reviewers would level-match speaker pairs being compared by feeding each amplifier a single-frequency signal (often 1kHz) and then using an SPL meter to get them equally loud at that point. (No matter what approach you use, you need two stereo amps and a line-level switching feature to do level-matched stereo-speaker comparisons, with at least one amp having level controls.) While this seemed OK on paper, the problem is that it did not consider the often very different response curves exhibited by each pair of speakers.

One speaker pair might have a peak at that frequency and the other might be flat or even have a dip there, and the result would be a significant mismatch in their overall adjustment levels. Once matched up that way, one pair might sound considerably louder than the other with musical source materials, with the result being that the listener would probably consider it more dynamic, more revealing of detail at frequency extremes, and just plain more transparent sounding than its less-loud playing competition.

(Note that *intentional* mismatching of this kind was also sometimes used, and no doubt may often still be used, by unscrupulous dealers eager to make sure that a pair they wanted to sell performed more impressively than a pair set up to be a reticent, muffled, and anemic-sounding straw man.)

Anyway, there is a problem with using a single-frequency tone to level-match speakers. (Note that when level-matching amps for comparison purposes, this approach should work OK, because decent amps typically exhibit very flat frequency-response curves, at least in the midrange.) Consequently, conscientious reviewers (and sales clerks, and enthusiasts wanting to know the facts) will use a randomized series of tones such as pink or white noise when setting up speakers for level-matched comparisons.

Now, you would think that using random noise along with an SPL meter would work like a charm. After all, the meter reads the total, average, wide-bandwidth output of the speakers, and so it should allow you to match up levels and get things just right.

Unfortunately, this may not always (or even normally) be the case. One problem is that, besides exhibiting sharp peaks, speaker pairs being compared may have

broad-bandwidth bulges and slopes in their response curves, with the spread and tilt of the bulges and slopes differing considerably. For example, I recently auditioned a pair of speakers that were reasonably flat in the midrange and treble, but which had a considerably elevated bass range. (This was no doubt the result of a voicing decision on the part of the designer.) If a system like that were given a random-noise feed (particularly with broadband pink noise) and was level-matched against a system that had flatter response in the bass range, the bass-heavy system would tend to sound less loud with standard program source materials. Even if both systems had reasonably similar bass outputs in the middle- and upper-bass range, but one had further extension into the low-bass range, doing a random-noise level matching with an SPL meter would give a false impression of relative levels.

That is, the person doing the level adjusting would back off the amp gain for the bass-heavy (or extended-bass) speaker, because the SPL meter would be reading the average broadband output. While the bass-heavy system might have its problems (the one I auditioned and decided not to waste time reviewing did), it certainly did not deserve to have them highlighted by a mismatching job during the setup procedure for the A/B comparison.

The same kind of thing, of course, can happen when one pair of speakers in an A/B comparison is somewhat bright in the treble compared to the second pair. Indeed, here things can become even more tricky, because if one system is flat out to 20kHz (unusual) and the other rolls off somewhat above 10kHz (not unusual at all), we would again have problems matching average SPL readouts fairly with random noise and a meter.

So, it appears that single-frequency inputs and random-noise inputs can ***both*** be problematic when trying to level-match speaker pairs for A/B comparisons.

So, what do we do about it? Well, my solution involves measuring each pair with my RTA and then adjusting levels so that the two curves overlap, particularly in the midrange, as much as possible. While this cannot work to perfection (particularly with speakers exhibiting gross frequency-response anomalies), it certainly allows the listener to adjust levels in such a way that the performance advantages (or disadvantages) of each speaker pair are presented in the most workable way possible.

For those who do not have access to 1/3-octave RTA analyzers, there is still a nifty solution: the human ear. Yep, rather than let a mindless electromechanical device such as an SPL meter play misleading games with a random-noise input, you can simply listen to the random-noise source and then adjust levels so the speakers appear to be reproducing the input equally loud. This is not a perfect solution, but neither is my RTA approach, and it certainly has the potential to work better than the above-noted single-frequency approach or the broadband random noise approach in combination with an SPL meter.

TWO MORE POINTS

First, while pink noise is *de rigueur* when performing RTA measurements, in most cases you will get more mileage with the "ear-use" approach if you employ a white-noise source. Remember, pink noise delivers equal energy per octave, while white noise delivers equal energy with frequency. Consequently, with both SPL measurements and with the use of the ear, a pink-noise source will have an impact on the bass/treble balance of the systems. It is hard to set up levels this way, even by ear, and so using white noise (which to the ear emphasizes mid-frequency energy better) makes it easier to match things up with two pairs of speakers.

Second, when you want to do things precisely, it might be a good idea to level-match each side one at a time instead of doing it globally with the speakers in each pair operating together. That way, anomalies resulting from one of the amps possibly having slightly unbalanced outputs that would impact left-right soundstage balance would be eliminated. (One- or two-dB channel-balance differences are not unusual at all with amps, particularly with versions that have level controls that look equally adjusted or balance controls that are not truly centered at the vertical mark.) Heck, it might even be possible for both amps to be slightly biased in opposite directions, which would make the soundstaging differences even worse. (Note, for the same reason, I also suggest doing this kind of "one channel at a time" balancing job when A/B comparing amplifiers that are feeding one pair of speakers.)

Anyway, the bottom line is that you need to get those speaker levels as similar as possible when doing A/B comparisons. And it is also important to get the systems physically set up in such a way that neither is at a disadvantage when it comes to soundstage spread and the ability to deliver a balanced presentation. Do this with two really good pairs of speakers and you might be shocked to discover just how alike they can sound at times. Screw up the level matching and placement and you might be equally shocked at just how different the two groupings sound—even if all four are identical models.

Interestingly, several decades ago speaker designer (and head man at Acoustic Research Corporation, and father of the acoustic-suspension woofer and dome tweeter and midrange drivers) Edgar Villchur did a series of live-versus-recorded demonstrations with AR-3 speakers and a string quartet. The recordings were very carefully made outdoors, so as to eliminate any hall reverb from the recorded sound (the microphone placement was tedious and demanding, because of radiation-pattern artifacts with live instruments), and the demos involved the quartet and recording basically being compared A/B style in several different ways, with the quartet sometimes pretending to play while the recording produced the sound. Needless to say, the levels were carefully matched, and most of the people in the audiences were hard pressed to detect differences. (Some of those detectable differences involved analog tape hiss.)

This tells me two things. First, Villchur knew how to impressively demonstrate his speakers, which went a long way toward making AR as successful as it was in the 1960s. Second, with proper equalization (the treble output of the speakers, which normally had a shallow rolloff above the midrange, was boosted about 5dB by means of the preamp tone control) and careful placement, really good speakers have been able to deliver subjectively perfect sound for decades. ***rr***

CORRECTION

A. J. van Doorn's "Octode Amplifier" in the November issue contains an incorrect figure. The correct caption and figure are included here (**Fig. 1**).—Eds.

NO NEW TUBE

I just received my November issue of *audioXpress* and read the article on "New Approach to Tube Design" by Neville Roberts. I was disappointed that the article gave only subjective analysis of the new tube. As an engineer as well as an audiophile, I take any subjective reviews with a "grain of salt." A set of characteristic curves (plate current versus plate voltage with constant grid voltage) comparing the new tube with a 12AX7 would have been a good comparison. Before I spend $40 for a tube, I would really like to know whether I am getting my money's worth. I have a box of "new old stock" 12AX7s that sound great. Is this tube that much better for $40?

Douglas Thomson
w4voc@bellsouth.net

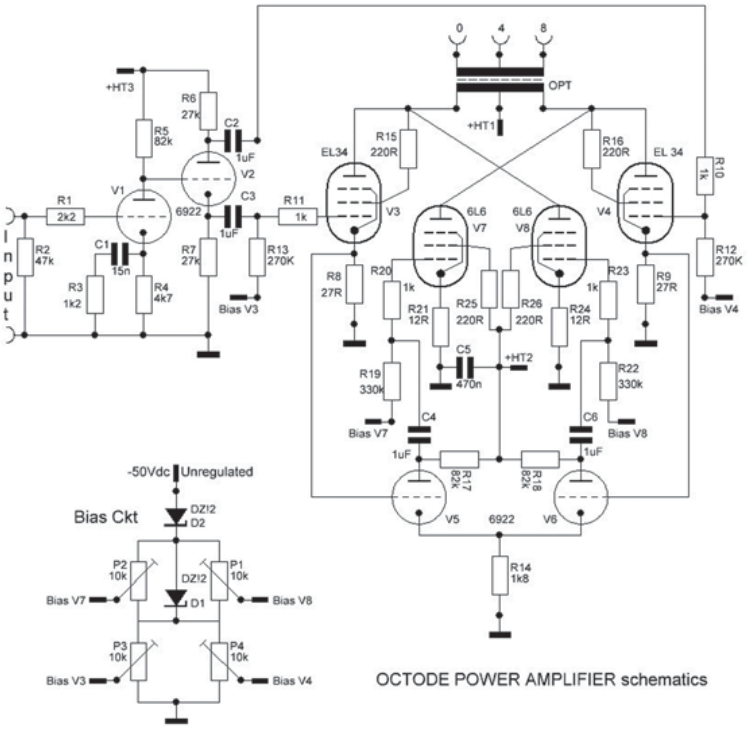

FIGURE 1: Octode power amp.

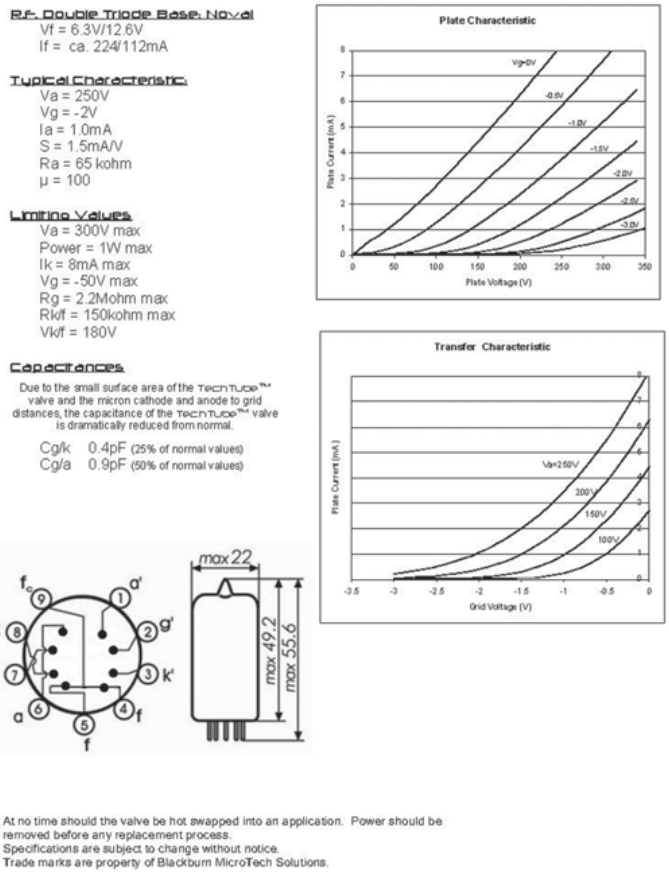

FIGURE 2: E813CC tube characteristics.

Neville Roberts responds:

Thank you very much for your letter and raising this very important issue. I, too, have an electronic engineering background and am very interested in the technical characteristics of the tubes. I think you are right that it would have been a good idea for me to have included some characteristic curves for the E813CC, as shown in *Fig. 2*.

However, I have appreciated over the years that an assessment based on the measurements of electronic components tells you very little about how the component will actually sound. From an audiophile point of view, I am most interested in how good the music sounds when using a particular tube, and the only way to do that is to listen to it in action. I therefore believe that a subjective analysis where I try and convey to the reader the effect the tube has on the music (perhaps using a similar approach to how you would describe a fine wine!) is of most value to help you decide if you want to spend your hard-earned money on them. I also have used some new old stock Mullards that sound fantastic and really suit the kind of music I listen to.

At the end of the day, personal preference has an important part to play. While I consider a "...wonderful tube smoothness..." to be an asset, others may be looking for a brighter, harder sound. The characteristic curves won't tell you that!

As we reported last month, the source of the E813CC, English manufacturer Micro Tech Solutions, has declared bankruptcy and will thus no longer be producing this tube.—Eds.

OP AMPS

I've read (and re-read) the review article on the Burson Audio Modules in *audioXpress,* October 2009, p. 30. While I don't like saying this, it left me confused about several points. As it tests the Burson op amp, it isn't clear to me what the exact hookup is. Unity gain, but is it inverting or non-inverting? There is also the graphics issue of B/W display of what were originally four separate color traces within Figs. 1-4, making differentiation impossible.

What is most befuddling is exactly how (or why) the module(s) were connected into a CD player, with external power supplies ranging from ±6V to ±24V in order to make THD+N tests with an Audio Precision test set. Huh? Couldn't they have been plugged into a simple and defined bench setup such as a gain-of-5X non-inverting line stage for the THD+N tests, then later connected into the CD player for listening tests?

But, one thing reviewer Ed Simon said that I do agree with relates to the datasheet; namely, *"In conclusion Burson has produced a poor datasheet that does not live up to their product."* The brief specifications listed below were taken from the Burson website 10/23/2009 (http://www.bursonaudio.com/burson_opamp.htm).

- Working voltage: ±12-25V DC
- Current Draw: 19mA (each module)
- THD: Less than 0.0007%
- Dimensions: 39mm × 10mm × 29mm, (single) 39mm × 23mm × 29mm (double)
- Weight: 19g

Op Amp Distortion Tests: *Been there, Done that!*

After reading about the above, I was left to wonder about progress with our audio testing. In a predecessor to *audioXpress*, *The Audio Amateur*, I published a series on distortion in IC op amps, way back in 1977, as "Slewing Induced Distortion in Audio Amplifiers, Parts 1-4." Later on I received a 1979 AES fellowship, based in part on that work. The testing was later updated into a standardized series of tests within *Audio IC Op Amp Applications, 2nd and 3rd Ed.*, Howard W. Sams, 1978, 1987.

I don't wish to belabor this old work, but to now point out an even more modern upgrade and considerable expansion of it. Samuel Groner has done just this in a fascinating study, the most recent version of which features 59 op amps, both IC and discrete. This 434-page work is found at his website op amp distortion study page, http://www.sg-acoustics.ch/analogue_audio/ic_opamps/index.html (Note: see opamp_distortion.pdf , a large ~35meg file).

In general terms Samuel's tests include the original precepts of isolating the device under test (DUT) for both input- and output-related nonlinearities, as well as basic transfer distortion properties, exercising it in both inverting and non-inverting modes, at multiple signal levels

CONTRIBUTORS

Edward T. Dell, Jr. (Editorial, p. 6) is editor/publisher of *audioXpress, Voice Coil*, and *Multi Media Manufacturer* magazines.

Nelson Pass ("The Sweet Spot," p. 8) is the proprietor of Pass Laboratories and a frequent contributor to *audioXpress*.

Bruce Brown ("15 Watts per Channel for Less Than $150," p. 22) is a registered pharmacist who works in the medical research area for a major pharmaceutical company. He has been experimenting with electronics for over 35 years, remaining actively interested in electronics, building kits, and "home brew" audio. Online auctions have stimulated new interests. He currently uses many restored and homebuilt audio amplifiers and welcomes communication about vintage equipment and restorations. He can be reached at Tuninfork@aol.com.

Joe Tritschler ("Borbely RIAA with Tubes Revisited," p. 27) is still working on his Ph.D. in electrical engineering at Wright State University in Dayton, Ohio, but plans to finish by June 2010. He really enjoys adjunct teaching and has toured the world playing guitar with Deke Dickerson's Eccofonics and his own group, the Mad River Outlaws. He may be contacted at info@crazyjoe.org.

Jan Didden ("Burning Amplifier 2009," p. 31 and "The Cable Caddy," p. 37) built his first OTL amp with 807 tubes 35 years ago. He has built speakers, preamps, and tape recorders, but is most interested in power amps, especially using error correction as discussed by Hawksford. Many of his projects have been published by *audioXpress*. Now retired from a career with the Netherlands Airforce and NATO, he tries to complete all those half-finished projects accumulated for lack of time. He now also has the time to travel to interesting audio events and interview audio luminaries. His projects are documented on his Linear Audio website.

Darcy Staggs ("AC Filters. . . and Other Noisy Issues," p. 34) is a retired engineer. His work experience began with the Apollo project, then defense analysis, writing management software at IBM in Stockholm Sweden, and later more defense analysis back in the US. His later years were occupied as a consulting engineer for a firm that dealt with product design, machine design, business development, and any other fascinating challenge that came in the front door.

Howard Ferstler ("Comparing Speakers," p. 38) is semi retired from the audio-journalism business. However, recent experiences while doing a few interesting speaker evaluations triggered in him an urge to explain some comparison procedures to interested readers.

and multiple noise gains. In addition to the original swept THD+N tests, his new tests add FFT plots, and a critical additional test for non-inverting mode input stage nonlinearity (i.e., source-Z sensitivity). Test equipment screen plots include analysis of the distortion residue both in time domain and FFT forms, which have the value of offering an at-a-glance assessment of the harmonics generated within a given DUT. The best amplifiers show the lowest harmonic generation, with noise-dominated distortion residue for most loading conditions, and relatively small changes between inverting/non-inverting modes, and against varying source Z.

Taking a case in point, germane to the above Burson amplifier tests are Samuel's test series of a Burson Mk II op amp, listed on page 105-109 of the October 19 revision. It will be useful for readers of the magazine to study these tests, and compare them with some of the other amplifier results. Samuel also notes that this amplifier design may be similar to the Audio-GD "OPA-Earth" discrete op amp circuit (http://www.audio-gd.com/En%20audio-gd.htm). Test results

for this amplifier are also included, on page 87-95 of the October 19 revision.

An application point that may be subtle among all of this is that low-noise (and typically high-C input) FET-based amplifiers can be particularly susceptible to nonlinear distortion with increasing source Z. The Burson op amp appears to be such a design (according to the quoted PNs), and the OPA-Earth is such (according to the published schematic). Unfortunately, it is quite easy to see such conditions in a preamp, with, say, a typical 50kΩ volume pot, where the worst-case source Z is 12.5kΩ.

I hope readers will find this additional testing information useful toward better understanding of op amp performance. Perhaps the editors can encourage Samuel Groner to write up something on his tests, for a future issue?

Walt Jung
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Ed Simon responds:

As noted in Walt Jung's letter, several issues benefit from clarification.

The actual test circuit used was as simple as possible. The output of the device under test was tied back to the inverting input, and the signal was fed into the non-inverting input directly from my AP Series 2 with a low source impedance of 50Ω. The load resistor was in parallel with the AP's input. The power source was my variable bench supply monitored by a Fluke model 85 DVM.

The plots were reproduced in black and white, making them difficult to read. Colored versions are posted on the *aX* website (www.audioxpress.com). As a simple explanation on all of the plots, the highest level of distortion was from the lowest value of resistor (100Ω) used for a load. The other loads all group so tightly it is very difficult to see any differences.

The most important item Walt mentioned is a website by Sam Groner at http://www.sg-acoustics.ch/analogue_audio/ic_opamps/index.html. There you can find a comprehensive report on the performance of 59 IC and discrete design op amps, under the heading of "opamp_distortion.pdf," a large ~35meg file.

The test results section on the Burson groups is with a similar (but not quite the same) unit. My thanks to Walt for improving the review and pointing out this valuable website. *aX*

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