

## Link of the Month

### Steve Bench's Web Page

<http://members.aol.com/sbench101/>

I have thank reader Morgan Lundberg for the link to Steve's web page. I almost fell out of chair when I followed the link. Steve Bench has performed a true service for us tubeholics. His web page is devoted to tube topics that cannot be found elsewhere, such as a battery powered RIAA phono stage or "Directly Heated Triodes operated with lower voltage on the filaments." The part swappers will despair upon seeing experiments, spreadsheets, formulas, curve traces, and solid-state devices in the schematics, but the intellectually rigorous will delight.

The best complement I can pay Mr. Bench is to say that if I had seen his web page several years ago, I probably would not have felt the need to create this journal. Definitely add this site to your favorites.

## E-Mail

### E-Mail from where?

The rule has been to omit last names and e-mail addresses unless the writer had clearly expressed for their inclusion. This rule will continue. However, a few readers have asked that all e-mails include the country of the sender. I like this idea and hope to see these inclusions. So please where are you from?



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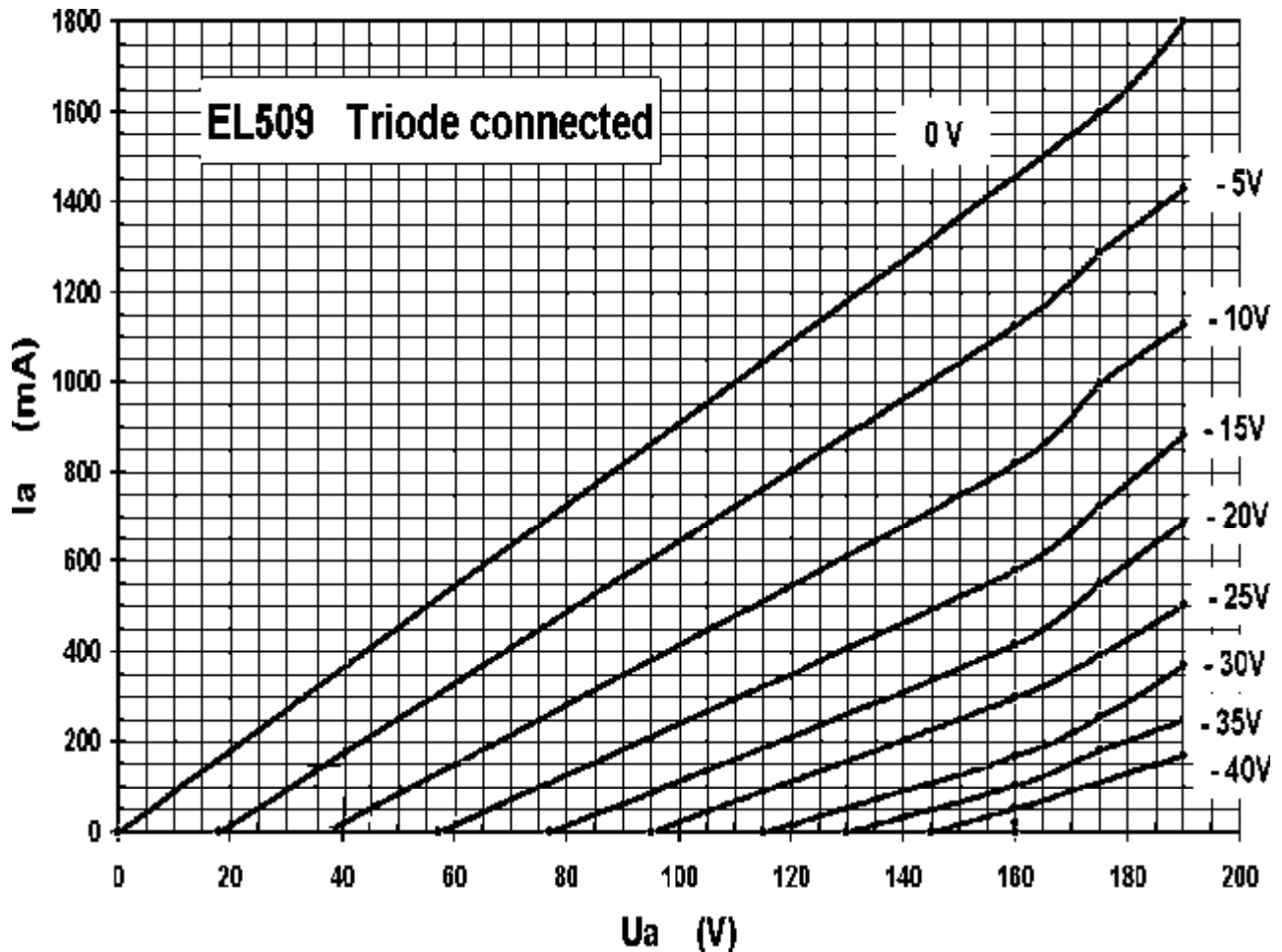
### Subject: low-power OTL

I deeply appreciate your efforts with the *Tube CAD journal*, and I read them frequently, although as a beginner there is very little I can contribute.

However, in your April-May 2001 edition "emails" section, you address the question of a low-power OTL amp, and expressed a wish for triode-connected curves for the EL509. Well, here they are! I hope this helps.

I am interested in the forthcoming 4W OTL article, although I am looking for a quality "one watt" amp for using with my 105 dB/W JBL 2404 treble horns above 5 kHz. So if you come up with a real cheapie version without too much extra work over your 4W design, I would probably take it on!

Grant  
Adelaide, Australia



I have to thank you and other readers for the curves. The curves display a huge potential current draw 170 volts (0 grid voltage) of 1550 mA. At this point, the  $\mu$  is about 7 and the  $r_p$  is about 110 ohms and the  $G_m$  is about  $65,000\mu S$ . Thus the output impedance of this tube when used a cathode follower would be about 15 ohms. In other words, this tube is a good choice for OTL fans.

The curves seem to have a problem area at the -25 volt grid line: it seems to be too close to the -20 line. My guess is that the grid voltage was off the mark. If anyone has seen an *actual* accurate curve tracer scan of this tube in the triode-connected mode, please let us know if I am right about what I see.

As for a 1 watt OTL amplifier, I promise to add it to the next issue. I want to model the curves mathematically first so that I can better evaluate what the EL509 needs to work best.

But as the amplifier will undoubtedly run in Class-AB, you can refer to the 4 watt amplifier as a 1 watt Class-A amplifier. In other words, all Class-AB amplifiers are also Class-A amplifiers up to some wattage, which can be as high as 60% or as low as 0.1% of the total output wattage. Unfortunately, it is not the B+ voltage that sets the Class-A boundary, but the idle current.

The big problem tube OTL amplifier face is having to deliver the high current needed to drive the low impedance loudspeaker. One watt into 8 ohms requires a peak current delivery of 500 mA, as  $(0.5^2 \times 8) / 2 = 1$ . Which means that a total of four EL509s is needed to meet the 250 mA idle current demand of the push-pull amplifier. If the load impedance were 285 ohms, then the same 500 mA peak current swing would yield 35 Class-A watts. What the world needs is a great 100 ohm loudspeaker!

2nd e-mail from Grant

**Subject: hybrid amps article**

The hybrid amps article in *Tube CAD Journal*, April-May 2001, inspires me to ask you about the topology of a current amplifying (current output linearly proportional to voltage input) hybrid amplifier of the tube input, solid state output type (T>SS). It is probably too late to influence your next hybrid amps article, but you may be interested in addressing this issue in your e-mail section.

I ask about this because I have seen some discussion of how the speaker driver, particularly the dominant moving coil type, is more like an electric motor than a resistor. There is merit in driving this with a power amplifier (power out linearly proportional to voltage in), but failing this goal, a current amplifier also has merits compared to the standard voltage amplifier.

I am keen to experiment with a hybrid current amplifier, but being somewhat of a novice, I need some guidance. Your *Tube CAD Journal* tutorials are the most understandable and practical that I have seen.

Ideally, I would ask you to comment on the following:--

- 1) A hybrid T>SS power amp, as defined above (voltage to power) for driving typical speakers.
- 2) A hybrid T>SS current amp (voltage to current) for driving typical speakers. If #1 above is not feasible, I would appreciate any detail on a topology that might work here.
- 3) A hybrid T>SS current amp (current input to current output) for driving typical speakers. The current input is of interest because many DACs have current outputs, so maybe there is potential for tapping directly to the DAC output.

I believe your next hybrid amp article will address single ended T>SS topologies, hopefully with choke loads that are not unobtainable, or

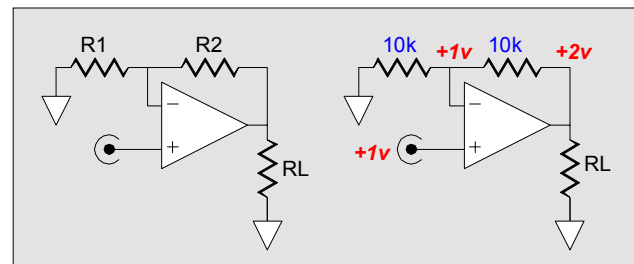
with an alternative to choke loads. It is the single-ended application that interests me most, and I hope that your response, if you have one, caters for single ended topologies.

Grant S

Adelaide, Australia

Grant, you are no beginner, not if you can frame your questions as well as you do. You obviously understand the big overview, which is much more important than the particulars.

The prevailing model has been that an amplifier should function as a voltage source, i. e. zero output impedance and a perfect step-up ratio between input and output; In other words, a voltage-to-voltage amplifier.



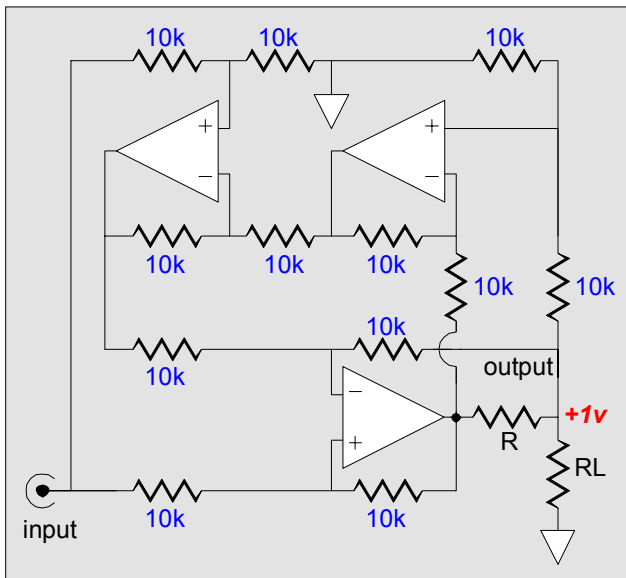
Voltage-to-voltage amplifier  
 $V_{out} = V_{in}(R1 + R2) / R1$

But as you point out, three other models are equally possible. Voltage-to-power is your first alternative. Here the assumption is that the load has a complex impedance; In other words, it is not a pure resistance. For if the load is a pure resistance, the common voltage-to-voltage (voltage source) amplifier will also serve as a voltage-to-power amplifier. But when the load impedance is as squirrely as is a normal loudspeaker, the voltage-to-power amplifier will break the fixed ratio between input and output voltage. For example, when the loudspeaker hits its box resonance, the impedance can spike fourfold, which would prompt the voltage-to-power amplifier to increase its output voltage by twofold. ( $W = V^2R$ ; thus 1W and 2R = 2V)

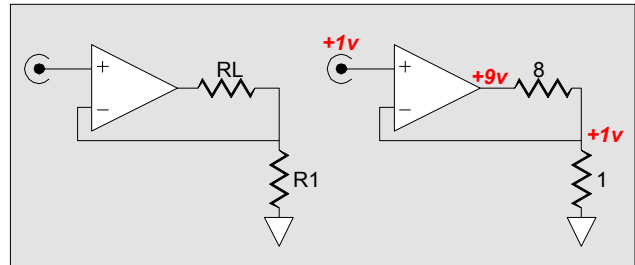
How such as magic trick accomplished? Not easily, I fear. Feedback of both the current and the voltage into the load is taken and effectively multiplied against each other and whose product equals a constant defined by the input voltage across resistor R. The insertion of this small series resistor with the loudspeaker and the output allows a sampling of the current through the loudspeaker, while the voltage across the output can indirectly sampled through voltage dividers and Op-Amps. Ultimately, the two feedback voltages are summed and compared to the input voltage.

This alternate model might be a natural for use with tubes as output devices, if the complexities of the function can be overcome, as tubes are not voltage shy. For example, if a tube OTL amplifier saw an increase impedance, it would have the easier task of giving up current for voltage. On the other hand, if the impedance declines, the tube OTL is in trouble, as it must give up voltage for current. But as most, but certainly not all, loudspeakers have an impedance that spikes up from a nominal base line, this last scenario might not be a problem the amplifier would have to face.

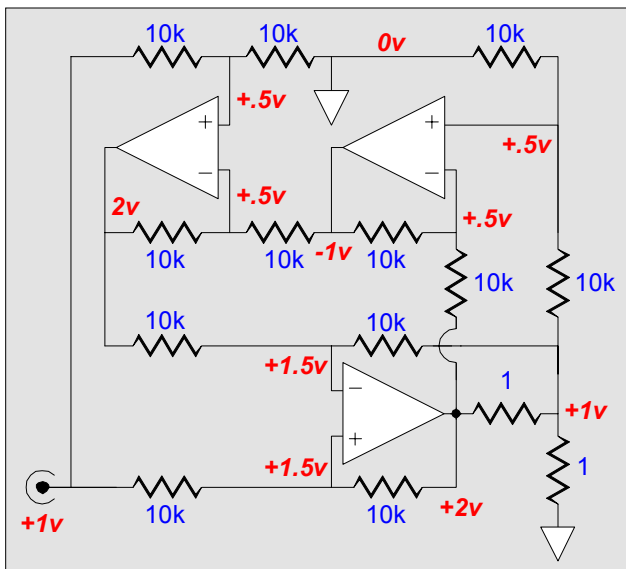
The second model is the voltage-to-current amplifier. Here an input voltage is translated into current. For example, a one volt input might equal 4 amperes of output current. What would be the output voltage? It depends entirely on the load. If the load were a dead short, the output voltage would be zero, although the full 4 amperes would be delivered into ground.



Voltage-to-Power amplifier  
 $W_{out} = V_{in}^2 / R$



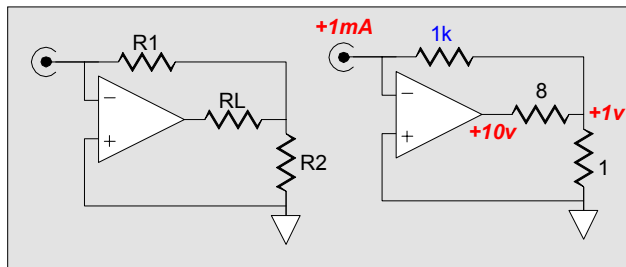
Voltage-to-current amplifier  
 $I_{out} = V_{in} / R$



This amplifier is the *inverse* of the voltage-to-voltage amplifier to which we are so accustomed. Where the voltage amplifier is damaged by direct short to ground, as the amplifier strives to deliver infinite current into 0 ohms, the current amplifier is damaged by complete open circuits, as the amplifier strives to infinitely increase its output voltage to bring the current inline with its voltage-to-current ratio. Where the voltage amplifier has an output impedance approaching zero, the current amplifier has an output impedance approaching infinity. Obviously, pentodes hold a better hand in this regard compared to triodes, as the pentode enjoys a much higher plate impedance.

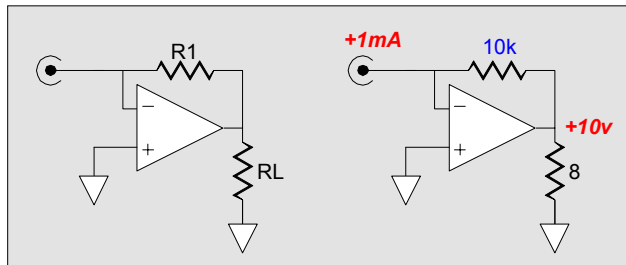
Once again, a small valued resistor is placed in series with the load and ground. A sampling of the voltage across this resistor reveals the current flowing into the load. So only a single feedback loop is required.

The third model is the current-to-current amplifier. Like the voltage-to-current amplifier, this amplifier has an infinitely high output impedance, but differs in that its input functions as a dead short, as the input is current not voltage.



Current-to-current amplifier  
 $I_{out} = I_{in}R1 / R2$

The fourth model is the current-to-voltage amplifier, AKA the I-to-V converter. This circuit appears in all single unit CD players, as the output of the DAC is in current. (Those DACs that yield a voltage output have internal to their package an I-to-V converter.)



Of all these models, the voltage-to-current amplifier is probably the easiest to achieve with vacuum tubes. Feedback is taken from the cathode (or cathodes) of the output tubes, which radically increases the effective  $r_p$  of the tube.

One possible benefit to be derived from such a topology is the accompanying decrease in power supply noise from the output stage's, as the high  $r_p$  makes a poor voltage divider with the reflected impedance on the primary of the output transformer. But do expect transformer distortion to increase simultaneously.

For homework, I recommend finding a fascinating article from early 80's in the *Journal of the Audio Engineering Society, JAES*, written by Malcolm J Hawksford. Unfortunately, I have lost my copy. This article explains the many advantages that derive from driving loudspeaker with voltage-to-current amplifiers.

**Subject: OTL output impedance**

I have built the driver circuit similar to your differential circuit on [www.tubecad.com/april\\_may\\_2001](http://www.tubecad.com/april_may_2001). I used this to driver a totem pole of 2 x 6C33C (total just 2 tubes). I found that the output impedance is about 23 ohm as follow:

- Load 8.7 ohms
- No load output 40v p-p
- Loaded output 11v p-p
- $Z_o = (40-11)/(11/8.7)=29/1.26=22.9$  ohm

The expected impedance is that of 2 cathode follower in parallel:  
 $(R_p/1+u)/2 = (100/1+3)/2 = 12.5$  ohm.

Well this is what I have measured, do you think this accurate?

Also, the other single tube driver on the same page is actually a Futterman variation, too claimed to have lower output impedance of  $(R_p/(2+2u))$  i.e. about 13 ohms with 2 x 6C33C, I have built this circuit before, but I unfortunately I didn't (forget to) measure the output impedance.

So, would appreciate if you can please explain the difference between the two circuits, as to which one has lower output impedance. I have read this article beside your web magazine:

<http://members.aol.com/aria3/otlpaper/otlhist.htm>

p. k.  
 Malaysia

Two reasons for the higher output impedance present themselves. The first that the  $r_p$  of a triode is not a constant. It like the

transconductance varies throughout the tube's operating range. The  $\mu$ , AKA amplification factor, comes the closest to being a constant. Thus the  $r_p$  maybe much higher at the chosen bias point and thus result in the higher output impedance. Increasing the idle current tends to lower the output impedance by virtue of moving to a lower  $r_p$  point on the plate curves.

The second reason is the more likely culprit. My guess is that the amplifier is being run in Class-AB, as true Class-A operation would exceed the dissipation limit for the 6C33. The formula you provided is only accurate for Class-A amplifiers, as only when both tubes are conducting *hard* does the output impedance fall to one half that of a single cathode follower.

What is the answer to lowering the output impedance of your amplifier? You can add more gain to the amplifier and then wrap a feedback loop across it. Or you can use a low-winding-ratio output transformer. The impedance ratio of a output transformer is equal to the square of the winding ratio. Thus a winding ratio of 5 equals an impedance ratio of 25, which would lower the output impedance of your amplifier to less than one ohm. I understand that a output transformer ruins the OTL feature, but it is a practical choice if your goal is a feedback free amplifier with a very low output impedance. The only other alternative is to use more output tubes in parallel.

## 2nd E-Mail

Thanks for the reply. Yes the amplifier is running in Class-AB, plate voltage is 150v and the idle current is about 200 mA. The impedance I gave was for zero feedback. So the impedance is as high as Circlotron bridge amplifier's.

In actual operation, I use only the feedback port around the phase splitter. With 12AT7, it lowers the impedance down to about 1.5 ohm and yet it still has some gain (about 3.5 @ full power) and with 6H0PI (Russian tube) to about 2.5 ohms. It sounds more open this way than it does with any global feedback method (although the out impedance would be much lower, but it

sounds more like a transistor amplifier with lot of feedback).

I like the sound of this arrangement best. If I use both feedback loops at once, it doesn't sound that good either.

So my choice is to use only feedback around phase split with high gain tube like 12AT7, then again 6H30PI is much more linear and thus sounds more accurate (especially in low bass) than 12AT7. Even with 2.5 ohms  $Z_o$ , it sounds good on my cheap Roe Anderson with 8" woofers. I think 2.5 ohms  $Z_o$  is not too bad after all, is it? The other option to lower the  $Z_o$  is doubling the number of output tube, so  $Z_o$  now is  $1.5/2=0.75$  ohm. What else can I do to lower  $Z_o$  using only feedback to phase splitter?

I also prefer very short feedback loops (a triode is effectively a tube with a built-in short feedback loop). Theory dictates otherwise: one global feedback loop allows the greatest reduction of distortion. Yet you and I are not pleased with the results. My guess is that we need a better theory, a more complete one, one that falls I line with perception.

Until then, I recommend that you try replacing the 12AT7 with a 5965. I have had some great results with this tube. But as it has a lower  $\mu$  than the 12AT7, do not expect any further reduction in gain, and consequently, no further reduction in output impedance. One possibility is the 12BZ7. This tube is effectively two 12AX7s in parallel. Its  $\mu$  is 100; its  $r_p$ , 32k, its  $G_m$ , 3200 $\mu$ S. This tube will result in a higher output impedance, but this might be for the good, as the 6C33 is often used with very large valued grid stopping resistors, for example 10k to 100k. Topologically, using a cascaded differential amplifier will increase the gain of the phase splitter as would using pentodes instead of triodes in the existing differential amplifier. But I am not convinced that the lower output impedance is all that important. With a critically tuned bass reflex sub-woofer maybe, but then we are unlikely to want use an expense, low wattage tube OTL amplifier for driving that load.

As for the performance difference between the circotron bridge amplifier output stage and the totem pole output stage, there is none, as long as the same tubes, the same idle current, and the same drive voltage is provided. I was distressed the first time I saw an electronic textbook treat the two circuits identically. "Wait a minute, these circuits are totally different?" I thought to myself. And they are in terms of ease of setting up bias points and living within the heater-to-cathode voltage limits, *but not in electrical terms*. The electrons do not know that they are in a long-named circuit: they just flow and their flow is governed by the voltage relationships and impedances in the circuit. To the electron, the both circuits are identical. Our eyes disagree. But then our eyes do not have to move the loudspeaker's diaphragm back and forth.

#### **Subject: Dynamic Bias for SE Amp**

Many like the sound of SE amplifiers, but most of us think the output power is not enough unless high efficiency speakers are used.

In Feb. 1990 issue of MJ, there's an article regarding Dynamic Bias for SE Amp. It looks quite promising, the bias point keeps shifting when signal level changed. It uses a power tube with  $P_a = 85W$ . At idle, the average current is about 40mA (30W dissipation) and about 90 mA (30W output and 35W dissipation) at full power. Is it possible to apply same idea to 300B in order to have 16 to 20 W in Class A1 output or even more in A2?

Eric  
California, USA

I do not have that issue, so I cannot comment on the circuit. But I can say that I leery of trying to milk too much out of an amplifier. It seems to me that we seldom get to have our cake and to eat it the same time.

My worry is that the auto-bias adjustment will come too late, after the crescendo has

passed. I do think, however, that a two idle current states would be nice in a tube amplifier, one low current mode for background listening and one high current mode for serious listening and showing off to our audiophile friends.

A simple toggle switch on the front panel is all that is needed. In one position, the bias voltage is say  $-100$  volts and in the other say  $-80$  volts. This two mode feature would greatly extend the life of some very expensive tubes.

#### **Subject: April/May issue errors**

First of all, thank you very much for *Tube CAD Journal*. I can't tell you how much your magazine has taught me about tube circuit design.

Anyway, I have a comment a question about the latest issue. First the comment: I believe that several of the schematics have a small error in them. In most of the schematics, you have drawn n-channel MOSFETs with the arrow pointing out. The correct symbol for an n-channel MOSFET has the arrow pointed in. It's confusingly the exact opposite of bipolar transistors, where the arrow always points out for NPN devices.

Second, could you tell me your sources for several of the MOSFETs mentioned in the issue. I haven't been able to track down either the BUZ900/905 series or the Toshiba 2SK2013.

Thanks, and thanks again for such a great service.

Jon  
Berkeley, California

Thanks for the kind words. I assume that (early on) you downloaded the PDF version of the issue, as the PN mistake was caught and the issue reposted with the correct symbols. Try the website today and see if the correct schematics made it. (Having 4000 readers re-download the issue is going to financially hurt the webzine, as the web hosting service charges a bandwidth penalty, which the journal's increasing

popularity constantly incurs; in fact, it has pushed it into the porno-site level of access.)

As for the MOSFETs, I once found a source for the BUZ900/905s through the Google search engine, but I did not save it to either hard-drive or paper. I believe the price was about \$9 each. If you or (anyone else) do find a source, please relay it back to me and I will in turn relay it on to the readers.

### **Subject: variable mu/remote cutoff tubes?**

How about some commentary on the so-called "variable mu" aka remote cutoff circuit designs? I may have missed an article on this subject in the *Tube CAD Journal*, and if so, please point me in the correct direction. <g>

Older audio compressor/limiters used this design technique as an early sort of VCA, and as a "child" who grew up on the cusp of solid state and vacuum tubes, it's all a bit voodoo to me.

Thanks for a great webzine!

Bri

Variable mu triodes have their uses and Eric Barbour of the late Svetlana and the late *Glass Audio* is probably the most knowledgeable fellow when it comes to using these tubes in modern circuitry. (He has started a company that makes tube based music synthesizers.)

### **Subject: McIntosh amplifier**

As a reader of your invaluable Journal, I am surprised to see that no article has appeared about the McIntosh circuit. The circlotron being a variant of it, it could be interesting to have a look into this structure for your readers enjoyment and their general education...

Charles R.  
Paris, France.

The problem with the McIntosh circuit is that it requires a specially made output transformer, which limits its universality.

Still, the amplifier is an intriguing one, as it effectively makes for a very clean, very lean Class-AB2 amplifier. And yes there is an echo of the circlotron about it.

The best explication for this circuit is found in Howard Tremaine's *Audio Cyclopedia*, section 12.231. Yet, I beg to differ with Tremaine's explanation for the merit of the amplifier. My take is that it is not the amplifier's ability to accept more feedback due to its output transformer's tight inductive circuit. Rather my guess is that because so much of the driver circuit finds its path to the B+ through the primary winding, the primary winding is never actually severed from a path to ground.

In contrast, in a transformer coupled Class-AB and Class-B push-pull amplifier, each output tube ceases conduction during part of large waveforms. This cessation of a current draw unloads one half of the primary, which can provoke huge voltage spikes and even momentary oscillations. An analogy can be made with a garage door spring snapping while it is under tension. Class-A amplifiers, either single-ended or push-pull do not release the winding during the entire waveform.

The McIntosh amplifier's driver stage, output tube's screens, and cathode followers cross couple to the opposing output tube's connection to the primary; thus always providing some "tension" to the winding. In other words, I believe that using a different driver stage power supply connection and triodes as output tubes would deprive this amplifier of much of its distinction. In contrast, the advantage of the original circlotron circuit is that used an output transformer. Thus the primary is always enclosed in a current path, even when one output tube ceases to conduct. So the main reason given for wanting to build an OTL amplifier might be misguided. Output transformers are too weak a link, so they must be eliminated we are told. But if the distortion the transformer gives rise to is born from misusing the transformer in a non-Class-A circuit, then why not use the transformer correctly instead of eliminating it.

A transformer coupled output on a circlotron amplifier has many advantages. We can use better triodes than the 6AS7, such as the EL34 and KT88 or the 300B and 2A3. We can stop worrying about damaging the loudspeaker when an output tube shorts out. We can use low impedance loudspeakers. And finally we can stop needless heating our living rooms with 40 output tubes. ([Be sure to read the final e-mail.](#))

(I remember reading an article from the early 60s in Radio Electronics by Crowhurst, I believe, that showed how to use two output transformers per channel in a pseudo McIntosh topology. Remember in the McIntosh, the cathodes saw the same transformer impedance as did the plates.)

### Subject: MC Phono Stage

First of all I would like to thank you for your excellent web magazine and the information provided. I have learned a lot about tubes thanks to you. I have build the line stage from September 98 GlassWare tube circuits the Constant Current Draw Grounded Cathode (CCDGC) amplifier topology (grounded Cathode amplifier cascaded into a Cathode Follower) using the **12BH7** and I was wondering if I can place another Cathode Follower from March 99 (using the **12BH7**) after the input connectors and before the 100K potentiometer for having stable input resistance, and not a resistance that depends on the potentiometer's position.

I also sending you a phono stage preamp [schematic](#) I build 4 years ago and I want your opinion about possible modification. Will we see a tube MC phono stage suitable for low output MC cartridges at the near future?

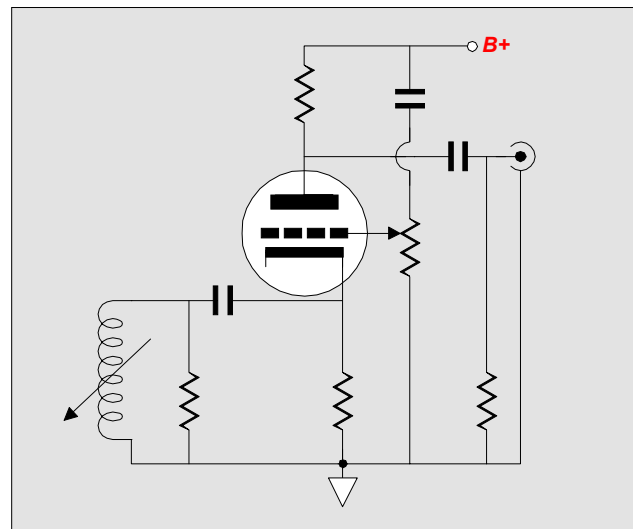
Konstantin T  
GREECE

The potentiometer presents a constant fixed load on the circuit preceding it, but not to the circuit following it. As the potentiometer's scraper reaches each end of its travel it presents

either zero or the preceding stage's output impedance (usually very low) to the grid of the input tube of the line stage. The worst case increase in impedance occurs at the -6 db position, as the potentiometer's output impedance at this position is one quarter of the potentiometer's total resistance. Adding an extra cathode follower will increase the input impedance that the previous stage sees, but do nothing to increase the high frequency bandwidth of the line stage. Alternatively, adding the cathode follower after the potentiometer will extend the bandwidth of the line stage.

As for an MC phono stage, one thought I have had is that the ground-grid amplifier might be a great choice for an MC phono cartridge.

MC cartridges need to be heavily loaded to control their electro-motive resonances. This is usually accomplished by shunting the cartridge with a low valued resistor or a large valued capacitor. But why not use the ground-grid's low input impedance for this task? The DC offset can be eliminated with a coupling capacitor, albeit a large valued one.



Pre-preamp for MC cartridges

The bigger advantage this topology offers is that it can be configured to cancel much of the power supply noise that leaks to the plate. This trick requires feeding some of the power supply noise to the otherwise normally grounded grid.

One capacitor and one potentiometer is all that is needed. The potentiometer is adjusted until the greatest null in output noise is reached. Which tube to use? I would look into using a triode connected EF86 or even a 6AC7, although a paralleled 12BZ7 might be the best choice.

As for your phono preamp, I would try eliminating the cathode resistors and use a 1.5 volt battery to bias all the 12AX7s. This will require one more coupling capacitor in the signal path, but it would also greatly lower the power supply noise at the output and increase the gain, while lowering the output impedance. This means the first resistor in the passive RIAA equalization network will have to be correspondingly increased in value.

#### **Subject: SRPP**

Hi , I was just looking at the May 2000 article on the SRPP circuit. Early on you wrote. "Just what "SRPP" means is uncertain; maybe it stands for Series Regulated Push-Pull amplifier or Single-Ended Reflexive Push-Pull amplifier." Recently I have had the good fortune to be able to talk to a few "old timers", and, whenever this circuit comes up in conversation they always refer to it as shunt regulated push pull. (The other day I saw some notes on the web by a retired Electrical Engineering professor who referred to it the same way.)

Funnily enough, when you first say "SRPP" they don't make the connection .

Hope this is of some interest to you. Your articles are of big time interest to a lot of people . Keep up the great work !!!!!

Thanks for the information. I am surprised that I hadn't listed that variation. I have many names for this circuit: SEPP, totem pole, cathode follower cascode, and cascaded cathode follower.

In the 1943 patent, the following sentence appears: "A further object is to provide a current amplifying means which acts as its own regulator of its own power source." This must be where the "regulated" entered the SRPP.

#### **Subject: preamp circuit**

First, thanks for the great journal. It always gives me great pleasure just trying to understand what is going on. Despite the fact that my knowledge is limited, it hasn't stopped me from building many projects....and I continue to learn.

I am going to try a preamp circuit next....I've bought your Tube CAD software, and in reading the journal I've come across 2 circuits that look interesting: 1) your "ultra-linear" type preamp using a CF output stage and 2) your common cathode design.

I know you don't play favorites with circuits, but could you tell me which one I should rather build and why? Of course, we are all limited in the number of projects we can undertake....and I'm trying to obviously get the best sonics. I will probably go whole hog and transformer couple the output dependent on the price.

Dan D

Dan, it all depends on the purpose for the preamp. If the intended use is a line stage amplifier, then I recommend the common cathode amplifier. It does not invert the phase. It readily accepts a feedback loop. It offers a very high input impedance and a very wide bandwidth.

On the other hand, the ultra-linear cascode offers an very high gain without usual accompanying high distortion. This circuit would prove useful in a phono or microphone preamp. If used as a line stage amplifier, the gain will probably prove to high, although this will depend on the tube used. Transformer coupling this circuit with a step-down output transformer will help eat up much of the gain and greatly reduce the output impedance.

#### **Subject: B+ Supply.**

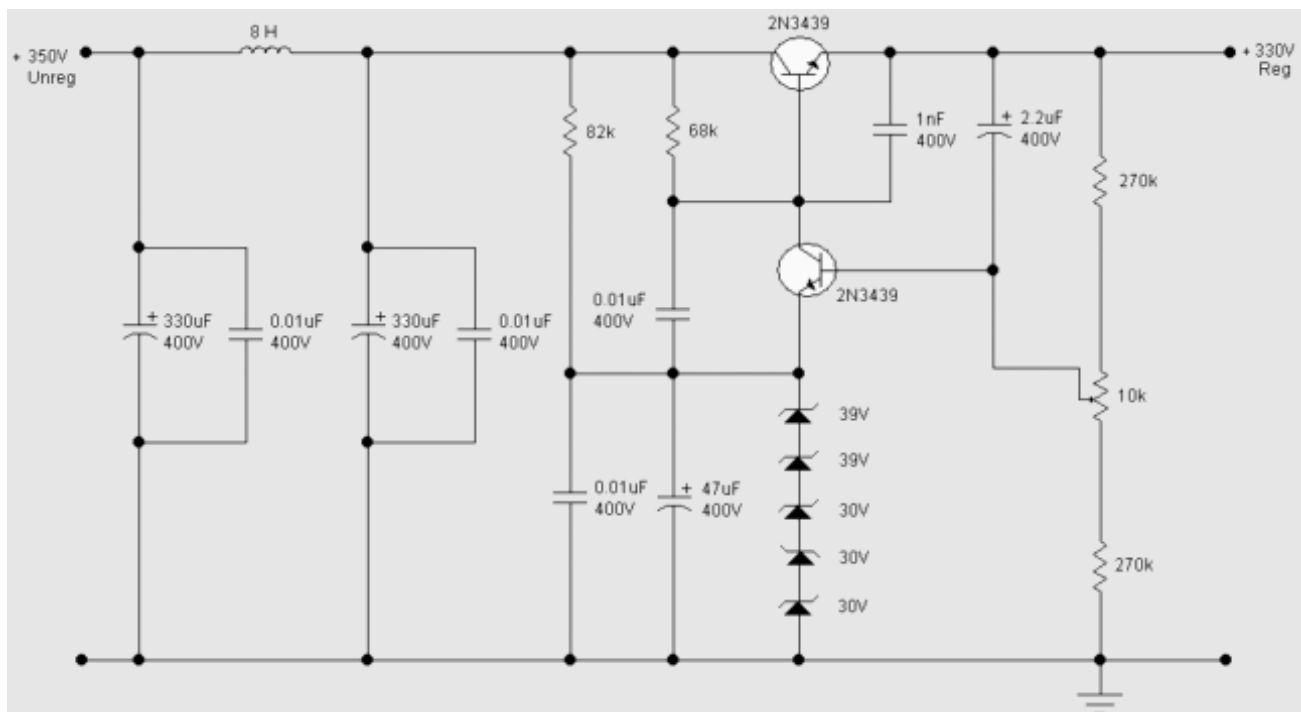
I really enjoy reading your E-Journal. Thanks for a great article on Hybrid amps. Though I am still not decided which way to go, I found this article very helpful in making a lot of things more clear. [Last issue's article on hybrids. Ed.]

When I started making tube gear (about a couple of months ago) I looked around for a good SS B+ regulator and I soon discovered the scarcity of "good" and "simple" regulators out there. After gathering a bunch of different designs, including the ones published in your journal, I tried these designs out using my Electronic Workbench 5 software and found them to be extremely sensitive to load changes and a bit noisy. Then I tried to tweak these designs to make them more "stiff" and/or less noisy.

At the end the design I am sending you won because of its simplicity and extremely low noise (it is fairly stiff too.) To make sure that the simulation actually was correct I made three supplies. The first one was the un-tweaked version of the attached design. Second was the tweaked design (see the attached gif) and the third was your circuit of the month (GlassWare Feb '99). I tried them with my newly built 5687 based SRPP pre-amp. I also measured them using my Goldstar 20MHz Oscilloscope. The measurements, though not the same, were pretty close to the EWB predictions. Most importantly, this design passed the listening. Everyone preferred the sound of this regulator.

I think anybody looking for a simple yet effective B+ regulator should give this circuit a try.

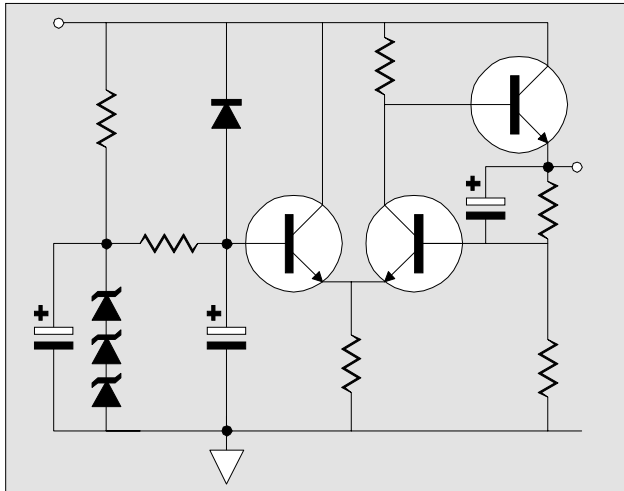
Shahzad I. M.  
Pakistan



I have to admit that I am puzzled by the results of your tests and by your regulator. The first thing I note is the use of an 8 Henry choke. This choke must have a large DCR, which must displace some voltage across its leads. Given that the raw B+ voltage is only 350 volts and that the output volt is 330 volts, just how much headroom does your regulator or any other regulator have in this arrangement?

A line voltage drop of only 3% will probably force the regulator out of regulation. And given that you are using such a large valued choke, why bother with the solid-state regulation? How does the line stage sound without the regulator? And given the miniscule voltage differential that the active portion of the regulator sees, is it possible that other topologies would perform better given more voltage in which to operate?

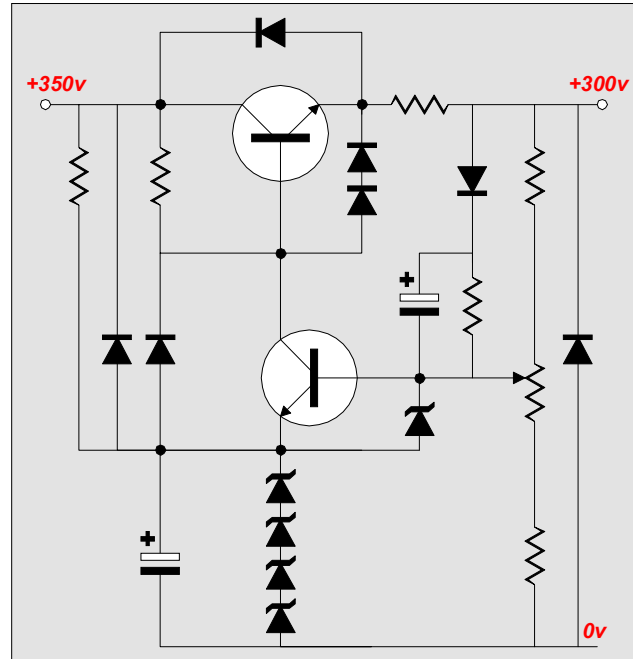
Furthermore, I just cannot believe that a string of zeners, even a string that is bypassed with a 47 $\mu$ F capacitor, can be all that quiet. Zeners are commonly used as noise sources. If I were to keep discrete transistor flavor of your regulator, I would arrange the zeners so that their noise generation would be further isolated.



Zener noise elimination

Having played with many transistor based high-voltage regulators, I can warn you that at some moment the regulator will probably die. Maybe a tube will momentarily arc-over or a fuse will blow or the wall voltage will spike for a few milliseconds or maybe a transistor will just give up facing high-voltage differentials at turn-on and turn-off. Short circuit protection can be added, but it will both slightly increase the output impedance and the complexity of the regulator. So the recommendation I make is to bathe the circuit in diodes. With the diodes in place, you have a small chance of surviving a direct short of the output to ground.

I have built two transistor regulators similar to your design that have worked flawlessly for a year or so and then just died without explanation. The addition of the protecting diodes helps, but I am still nervous. This is where tube high-voltage regulators shine. I own two HP 711A high-voltage regulators. These marvelous units are tube based and are rugged. I have shorted the output more times than I care to admit and they keep on working.



An excellent book that covers high-voltage regulators can be had in the Tektronix' *Circuit Concepts* series, titled *Power Supply Circuits*. This book by Kenneth Arthur is written from the perspective of a manufacturer that does not want to see equipment returned for repairs. A second choice is the Kepco *Power Supply Handbook*, by Paul Birman. This book covers the issues surrounding the use of feedback loops in regulator quite nicely.

On the other hand, floating type solid-state high-voltage regulators have satisfied me as being vastly, vastly quieter and more reliable. High quality Op-Amps are amazingly quiet, as are IC voltage references. By combining these two technologies into one regulator, we get a very low noise output. I have used the floating regulator in high gain phono stages and always have had the regulator's noise swamped out by the tube's contribution. And I have seen an industrial floating high-voltage regulator that puts out 2500 volts with 10 mV adjustment increments (DAC generated voltage reference) with almost no noise due to the Op-Amp's extremely low noise and high gain.

Even the lowly LM741 has a huge amount of DC gain compared to the single transistor amplifier.

This gain provides feedback that wraps around the MOSFET's already low output impedance and reduces it milliohms. Additionally, by purposely limiting the Op-Amp's power supply voltage, we build in a current limit for the pass device MOSFET of sorts. Adding a handful of diodes makes the regulator much more robust.

One liability, however, of the floating regulator, like all high bandwidth IC circuits, is that it requires careful attention to its physical layout, particularly if tweak, high slew, high bandwidth ICs are used. (I have seen perfectly reliable high-voltage regulators fail or break into oscillation when the slow LM741s and electrolytic capacitors were replaced with ultra-fast wide-bandwidth ICs and polypropylene capacitors.) It is common for the negative power supply pin of an Op-Amp to have a much poorer PSRR than its positive power supply pin. Consequently, a small high quality bypass capacitor should be attached right at the negative power supply pin.

In sum, I am puzzled by the results from your experiments as they are at odds with those I and other experimenters have undertaken. Possibly the values of the floating regulator from the GlassWare article are too small in value. Possibly your implementation was mis-wired. Something went wrong: BB guns do not outshoot 357s.

I do repeat the recommendation that you try the choke based pi filter by itself. Because your line stage draws a constant current, it makes very little demands on the power supply. Thus low noise is primary requirement. It might be a very ear-opening experiment. And I plan on re-measuring the floating regulators I have built.

#### **Subject: current regulated heater CCT**

I have built a line stage using a 12BH7 as a plate loaded voltage amplifier, which has an all tube shunt regulated HT supply that operates without feedback.

I have been using DC voltage regulated heater supply and have been entertaining the idea of

using a current regulated supply instead.

I have plans to use the circuit from your JULY 2000 archive on current regulated heaters. I like the simplicity here and actually require the same 6.3V @ 900 mA that you have set for the example.

I would very much like to ask you the following questions for clarification:

1) Within what range of values should the cap after the LM317 be?

2) are schottky diodes ok to use in this circuit?

3) will the supply require any additional filtering, or will rectified 12V winding with voltage dropping resistor to 10V be fine?

Shane C.

AUSTRALIA

The LM317 will work without any capacitor, but I recommend a value of about 1 to 10K $\mu$ F across the heater element, if only to further decrease the inrush current into the heater at turn-on. The LM317 will oscillate within a certain range of values, but anything over 100 $\mu$ F is certainly safe.

Yes, Schottky diodes are an excellent choice because of the lower voltage drop across these rectifiers and their high speed.

I would worry about giving the regulator enough voltage to play with, as there is a dropout voltage that should always be exceeded. So the 6.3 volts of the heater must be added to the 1.25 volts of the LM317's internal reference and then added to the about 2 volts dropout voltage and then further added to a line voltage brownout safety margin, say 2 volts. The total is close to the full 12 volts.

#### **Subject: Negative high voltage regulator**

I am currently trying to build my first own tube amp. I still haven't decided yet if it would be the Leak TL/10 or a 807 PP amp I found in the *Fi Primer*. I have no questions about the circuits as I plan to build them exactly as they are. What I would like is to have a regulated power supply for my amplifier.

I found one article on the net (I guess it was published in [GlassWare Tube Circuit of the Month archive](#)), which I think is a perfect design for this purpose. The circuit uses a floating regulator, which then drives a high voltage MOS-n-FET. The problem is that the transistor would probably dissipate quite some power (approx. 150-250 mA for the TL/10, and almost 500 mA for other amp at 50V drop), so it would need a large heat sink. As the drain of the transistor is almost always connected to its package (i.e. TO-3, TO-220 etc.) that means that the whole heat sink would be at around 300V above ground (which is the chassis of the amplifier). Therefore I'd have to isolate the heat sink from the amplifier chassis, which is a great disadvantage.

A negative voltage regulator could solve the problem. What I have in mind is to use some lower power MOSFET (which would then also have lower gate-to-source capacitance) as a driver for a NPN high voltage bipolar transistor. (I guess I could also use a n-channel MOSFET alone.) Almost all of power NPN-s (MOS-n-FETs) have their collector (drain) connected to the package, and the collector (drain) would of course be at the ground potential. Therefore I wouldn't have to isolate the heat sink from the chassis, the amp could then be much smaller. I could then also use the package of the NPN (MOS-n-FET) as the grounding point.

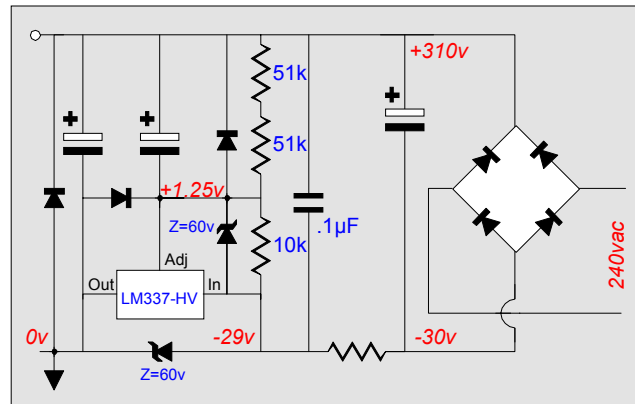
As I lack the knowledge to design such a regulator on my own, I am asking you for recommendations. I also think that such a regulator could be cheaper, smaller and offer better regulation than those expensive high current - high inductance chokes.

Damir,  
Slovenia

First of all, I must point out that any pass device can be electrically isolated from the heat sink with mica washers and plastic screws. Furthermore, many MOSFETs come entirely encased in plastic. In other words, isolating the pass device from the chassis is not big of a deal.

Still a negative voltage regulator has its merits. In fact, I have meant to write an article just this topic since the first issue. So rather than short change the topic with a short reply, I will definitely write that article for the next issue.

But here is a teaser to hold you until then.



### Subject: Thanks

Thank you for your efforts and thanks for a great moment in my life. I started reading the *Tube CAD Journal* a little over a year ago. It was all over my head, but I read all the articles all the same and I have printed every issue so I can read them offline. At first the articles made as little sense to me as did all the articles in *Glass Audio*. (I could make sense of many of the articles in *Sound Practices*, but unfortunately I believe that was due to many of the authors actually knowing as little about tube electronics as I did.) But after rereading your articles, something different happened: I finally got it! I kept reading the words "conduction" and "current" over and over again. Then I realized that it is current that makes every thing work in electronics. Now voltage takes a back seat in my mind. I know you have stressed this point several times, but it took a lot to push voltage away from the center stage.

For example, I could not understand how a cascode circuit worked because as I saw it the bottom tube's B+ voltage was locked by the top tube, so there could be no amplification. The fact that **there is amplification** and a lot of it bothered me to no end. Then I got it. The top tube's plate resistor is the same current path as the top and bottom tubes. Bingo. Amplification.

You have given me my Rosetta stone. I have gone over all the schematics I have and now I understand how they work in general terms. I still have much to learn, but with the *Tube CAD Journal* I have a helping hand. Thanks again.

As for my great moment, this breakthrough in understanding is not it. My tube aficionado friends and I have a tube expert of sorts. Everything dealing with tubes must be passed through him for his approval. He is **the Tube Man** or at so I thought: I was convinced that I could never know more about the inner workings of a tube circuit than the Tube Man.

Recently, I had decided that I wanted to increase the idle current in my single-ended amplifier (300B based and cathode biased) and I pretty much knew what needed to be done. I mentioned my desire in front of my buddies and the guru. He explained that it was very difficult to change the idle current in a cathode biased amplifier. Puzzled why that should be so, I showed him the schematic to my amplifier and asked what needed to be changed. His reply was that the small valued power supply resistor needed to be changed! I asked if increasing its value would increase or decrease the idle current. His reply was that it was difficult to say. I then asked if decreasing the cathode resistor value would be a better choice. He acted as if a stupid child had asked a how to create atomic fusion. The cathode resistor is not changeable he told me. I was undaunted and asked if someone were to change it anyway, would decreasing its value increase or decrease the current flow through the tube. He didn't know. My tube expert was clothesless.

I will still listen to his advice on the sonic differences between tube brands (he has had a wide experience with different tubes and owns several hundred tubes), but not on the merits of the tubes parameters (he confuses  $\mu$  for Gm) nor the circuits they could be used in. I have no desire to replace him as the group's expert or guru. This was my great moment, the moment I realized that I could understand tube circuits on my own.

Mark

Boston, Massachusetts, USA

You are welcome. Yes, *current* is the first thing to look into when trying to understand a new circuit. I have seen one tube circuit novice puzzle over the notion that one while one tube is completely turned off in a Class-B amplifier it is effectively not there, in spite of the voltage present on its plate. "But there's 700 volts on the plate!" he said to me. I finally offered him a thought experiment wherein a push-pull Class-A amplifier is transformed into a Class-B, manually. I told him to imagine that the amplifier is in use and whenever the output signal goes positive, the output tube that sees the decreasing grid voltage is immediately yanked out of its socket. And when the output signal goes negative, the is pushed back into its socket and the other tube is yanked out. After hearing this example the light bulb went on in his head. No current, no circuit.

Thanks for the great story about your guru. Tube gurus are one of things I dislike most about tube audio. It takes so little to be a tube guru. Just a passing knowledge of one or two circuits and a lot of shamefulness is all that is required.

I was once at a party and the hostess rushed over to me and told me that I had to meet this fellow who designed tube amplifiers! I met him and I was stunned to learn that he was completely clueless. Now ignorance is only ugly when it is accompanied by arrogance. He was ignorant. He didn't know that capacitors block DC current flow and he had no idea of how a transformer worked. He was arrogant. He was smug in his belief that he was supreme in his ability to design great tube amplifiers based on his ability to swap tubes and capacitors. What else could be possibly evolved in the design of an amplifier? I only asked questions and listened in horror to vastness of his ignorance.

This was a sad moment for me. A great moment, however, happened 15 years ago when a audiophile friend and I went to breakfast in Davenport California, a small sleepy coastal town 5 miles north of Santa Cruz.

We were eating our omelets when a young women sat 15 feet behind my friend and began

to play a large harp. After a few minutes of live music passed, I asked my friend what he thought of the sound system. He became animated.

“So that’s it. That’s why you wanted to come to this restaurant: let me guess these new age hippies are too cheap to buy a new stereo and they are running some old Dyna gear. And they probably are running the original tubes,” he said triumphantly to me.

He then cocked his ear and said, “Yes, definitely tube gear, notice the flabby bottom end and the rolled off highs.”

“What about the mids,” I asked.

“Sure it sounds smooth, but too smooth, artificially smooth, no bite...just too romantic don’t you think?” he replied.

“You’re right, it sounds just like tube gear to me,” was my answer.

When we then got up to leave and my friend turned around to see the harpist still playing and gasped. A truly great moment.

### **Subject: ParaFeed Single-Ended OTL**

Please excuse my English. I admire your journal. It is the densest concentration of tube circuit information I have found anywhere. So please do not stop publishing.

I have a question for JRB. Couldn’t an OTL amplifier be designed along the design principles of a para-feed single-ended amplifier...minus the output transformer? The speaker would connect to the junction between the output tube’s plates and the choke. Of course, a large valued coupling capacitor would be called for (.1F for example).

Since single-ended amplifiers are half as efficient as the push-pull amplifiers, I am guessing that four EL-509’s would deliver about 40 to 50 watts.

What do you think? If such an amplifier is possible, many of us who need a more powerful amplifier would be very happy.

Paulo S.

? South America ?

Do not worry too much about the journal, as I believe the sale of the article related software will save the day. Of course, I assume you will be among the first to buy a program so as to ensure the continuation of the journal ;)

Yes, certainly an OTL para-feed amplifier is possible, but it maybe not as desirable as you would hope. In a nutshell, the amplifier must run in strict Class-A mode, not the advertising copy Class-A mode. Now 40 watts of RMS power would demand at the very least 80 watts of dissipation, as the maximum theoretical efficiency of an inductively loaded Class-A amplifier is 50%. That is 50% with perfect output devices but vacuum tubes are not perfect output devices. For example, the plate curves for the EL509 on the previous page show that if we want to prevent any positive grid voltages, the 0v grid-line splits the area of useful operation in half. And even this halving assumes that the load equals the rp of the EL509; but as the effective rp of four EL509s is about 30 ohms, we can expect a further quartering of the potential efficiency. What we are left with is about 10% efficiency. Thus 40 watts of output power requires 400 watts of output stage dissipation, which far exceeds the limit of the four EL509s. So at least a doubling of the number of output tubes is needed.

The point that need clearing up in in your e-mail is the part about the relative efficiencies of output stage topologies. The efficiency difference between a single-ended and a push-pull Class-A amplifier is zero, both are 50% efficient if inductively loaded. (If constant current source load, both are 25% efficient; resistive loaded, 12.5%.) In other words, 8 output tubes in a totem-pole push-pull Class-A amplifier equal 8 output tubes in a single-ended Class-A amplifier. In the push-pull version, the output tubes must see an idle current equal to half the peak output current; for example, if the peak output current swing is 2 amperes, then the idle current must equal 1 ampere and as totem-pole amplifier has four output tubes in parallel per bank, each tube must draw 250 mA at idle.

On the other hand, in the single-ended amplifier the output tubes must see an idle current equal to the peak output current; for example, if the peak output current swing is 2 amperes, then the idle current must equal 2 amperes, with eight output tubes in parallel, each tube must draw 250 mA at idle.

The problem an SE para-feed OTL is that 40 watts of output implies 3.16 amperes of peak current, which in turn implies 400 mA of idle current per output tube in the single-ended amplifier. This current against the B+ voltage of 170 VDC equals 68 watts of dissipation! If we back off the idle current, the output wattage falls quickly, as halving the idle current quarters the output wattage.

So eight EL509s would only yield about 10 watts of output power. Of course, this just might be the price we have to pay for a truly great sounding amplifier, possibly the best amplifier in the world. Still, the inefficiency glares.

Bytheday, the coupling capacitor may not even be needed, if a negative power supply is used and the choke's DCR is sufficiently low enough. Remember a perfect inductor displaces no voltage, as it has no resistance. A real life inductors are made of wire that carries a resistance, but if the wire gauge is low enough, the DCR can be as low as 0.05 ohms, which will drop 0.2 volts with an idle current of 4 amperes, an amount of DC offset that is unlikely to cause too much trouble.

Turning this idea on its head results in configuring the output tubes as cathode followers, which will greatly reduces the output impedance, the choke's required inductance, and the distortion. And in this topology, we can forgo the negative power supply.

So in sum, I do not think that you and those readers in need of more power are going to be happy this single-ended OTL. The advantage of the push-pull amplifier is that it allows Class-AB operation of the tubes, which greatly increases the life span and power output of the devices. Maybe MOSFETs in place of the EL509 would be a more practical choice in a para-feed.

**Subject: Solid-state 6L6**

Have you ever seen a "solid-state 6L6" device that could be plugged into a tube socket?

I picture a circuit that would use high-voltage HEXFETs or something like that.

Chuck  
?

The April 2001 issue of Electronics World holds an article on such a device. Although 1,000 volt MOSFETs are available, my fear is that the MOSFET will die when it sees an over voltage due to inductive kickbacks from the reactive part of the loudspeaker.

**Subject: EL509**

I read your magazine with much attention and it is indeed a follow-up for glass-audio. Data sheets for the EL 509 you can find on

[www.machmat.com](http://www.machmat.com) ( a Dutch tube maniac)

I saw there the triode-connected 509 and I didn't like what I saw. Very strange curves. I bought some Siemens Pl 509, just for experimenting. I think the EL 504 is a similar tube of half the power but more audio quality.

I read about your idea of getting the output power from the grid. Half a year ago I read something about this on the internet, but I don't know where.

They said the grid could be used for a low impedance output. The grid dissipation is smaller than the plate but with lower voltage you could get the same output current. Sorry but you are not the first with this idea.

Keep on writing about tubes and I'll keep on reading it.

Steven  
Netherlands

Yes, I agree the EL509 curves do look strange. The problem with testing a high current tube like the EL509 is that the curve tracer must be up to the task. Maybe some of the wobbling at the end of the grid lines at the higher voltages

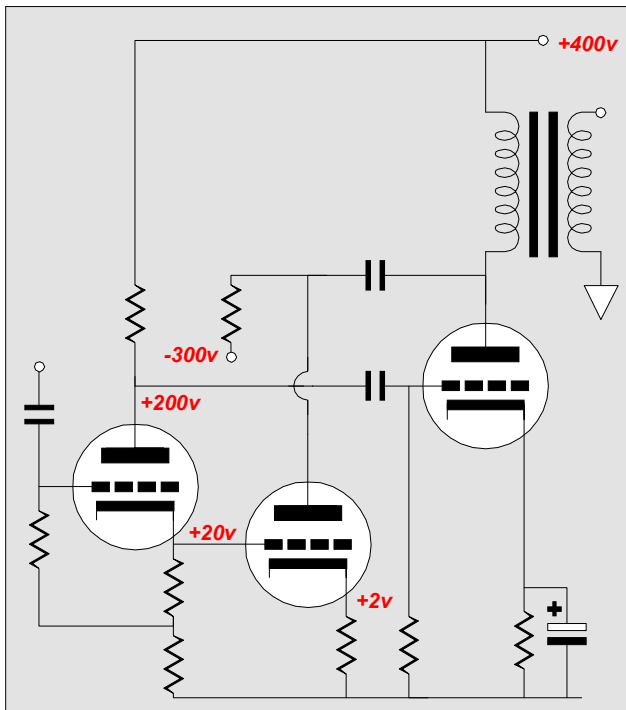
is due to the curve tracers power supply collapsing.

As for the inverted or grid amplifier, the idea is a very old one. At least 70 years old. It is briefly mentioned (page 209) in Frederick Emmons Terman's *Electronics and Radio Engineering*, 1955, McGraw-Hill. (Bytheway, he was the father of Silicon Valley.)

Be sure to follow the [Link of the Month](#) in this issue, as Steve Bench covers this topic in great detail at his site.

I once designed a power amplifier that used this topology to relay the signal from the output tube's plates in a push-pull amplifier to the driver stage to allow a feedback loop to be formed, but I but I never built it. (Maybe I should for article fodder.) When the plate in the inverted amplifier is at a voltage negative to the cathode, it loses all of its  $r_p$  and becomes an ultra-high impedance input. The grid, on the other hand, develops an extremely low "rp" (rg?). My aim was to use the grid as if it were the cathode and couple it to a conventional ground-cathode amplifier's cathode.

What derailed this design path was an alternative circuit, the grounded-grid plate follower, which eliminated the need for the coupling capacitor and the huge negative power supply voltage. This circuit uses the plate as an input and the cathode as the output, which leaves the grid as the reference point. Like the cathode follower it does not invert the voltage phase of the input signal and it has a very low output impedance. Unlike the cathode follower, this circuit does not have unity gain output; in fact it has very little gain, roughly  $1/\mu$ . In addition, its input impedance is vastly greater than that of the cathode follower. What it does do rather nicely is allow large DC voltage shifts to be made.



Inverted amplifier providing a feedback path

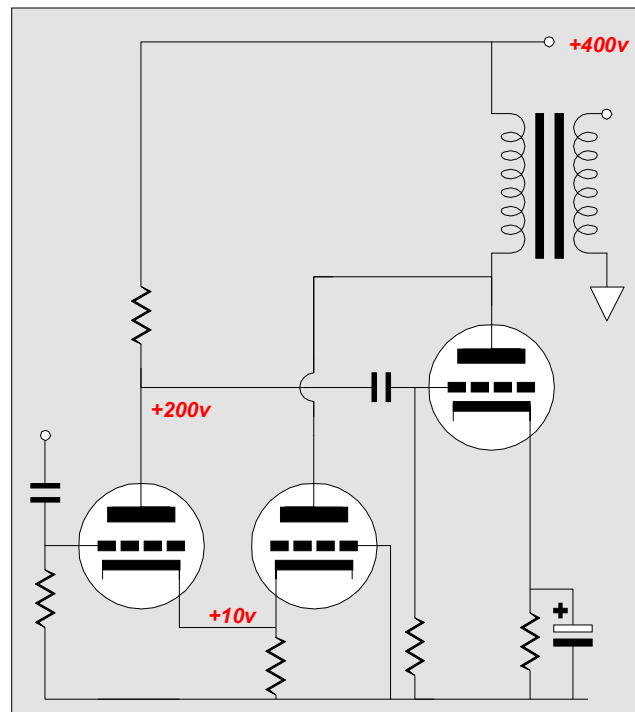


Plate follower providing a feedback path

In past issues, I have bemoaned the lack of an intelligent taxonomy of the basic tube circuits (and I have decried the general naming practice of tube circuits, i.e. no system). I proposed that the triode, MOSFET, FET, and transistor elemental circuits should be organized and named according to the following order: input, reference, output. Thus the grounded-cathode amplifier would be described as a grid-cathode-plate amplifier or GKP for short; a grounded-

source amplifier, as a gate-source-drain amplifier or GSD for short. The advantage to such a system is that, like the periodic table of elements, the holes are readily apparent, which prompts us to fill in the blanks.

Current Names	Input	Ref.	Output	New Names
Grounded-Cathode	Grid	Cathode	Plate	GKP
Cathode Follower	Grid	Plate	Cathode	GPK
Grounded-Grid	Cathode	Grid	Plate	KGP
Unnamed	Cathode	Plate	Grid	KPG
Plate-Follower	Plate	Grid	Cathode	PGK
Inverted	Plate	Cathode	Grid	PKG

### Subject: portable headphone amplifier

Thank you for an excellent publication, which is building into a powerful resource for all those who are interested in valves (which of course is what we call them over here!).

Your article on a 'portable' headphone amplifier was interesting, particularly as you decided not to use battery valves. There are of course many battery valves available at cheap prices, and they have the advantage of low LT consumption (25 mA at 1.4 V for the DX96 series) and equally low HT consumption (a few mA at 90 V). The DL92/94 would make an excellent battery headphone amplifier, and the HT consumption would be very low if they were used in push pull biasing largely into class B.

But even in SE class A the maximum consumption would be 10 mA. I have recently made up a battery pack consisting of a single D cell and 10 PP3 batteries for this purpose. You can get cheap alkaline PP3s from Walgreen if you live in the USA. Forget Energizers etc they are far too expensive.

There is also the DL33/35 octal output valves which look excellent and give good performance. All battery pentodes can be strapped as triodes and make good AF amplifiers. The DF91 (1T4) has an anode

impedance of about 10 k and a mu of about 8 when used in this way.

Simon B.

Brighton, UNITED KINGDOM

Thanks for the information. Battery tubes are definitely worth looking into. There a whole group of vacuum tubes designed for use in car radios that use the car's battery to supply both the heater voltage and the plate voltage! The 12DS7 and the 12DZ6 are capable of putting out a huge amount of current with only 10 volts on their plates.

The reason I avoided these tubes was to keep the tube sourcing easy. Which was something of a mistake, as special tasks require special tubes.

### Subject: 6N3P preamp, do you have some advice?

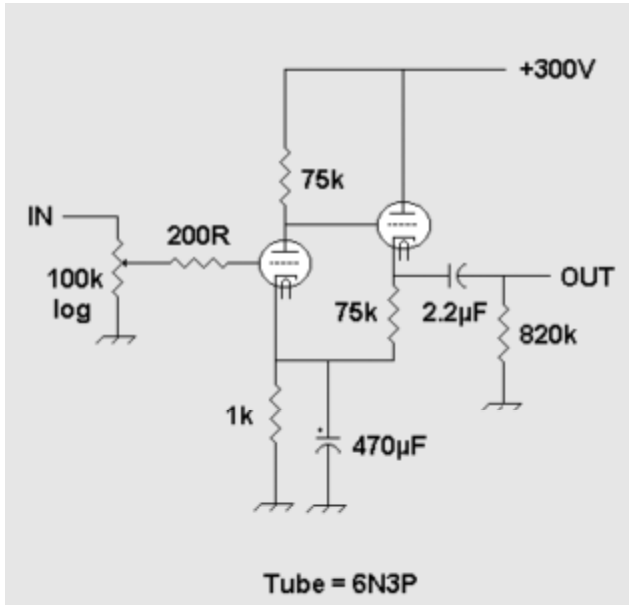
Thanks for a great webzine and great software! Recently I bought your Tube CAD program from Antique Electronic Supply and I have been playing with it for a while. From a sale I acquired several tubes from the former USSR including the 6N3P and I would like to design a simple line-level preamp with these. I was thinking of a constant current ground cathode amplifier and I have come up with the following part values (see schematic on next page). Two prototypes which I have made seem to perform well (when tested with sine and square waves and looking at the output on a scope). Even a 100 kHz square wave (4 Vpp output) looks good. But I have not yet performed listening tests as the dedicated PSU is not finished. My 6N3P tubes seem to have tight tolerances. They show almost identical measurements and they aren't microphonic. Maybe they were meant for the military. Current draw of the preamp is about 4 mA/channel. Measured voltage gain 25.3 (channel 1) and 25.8 (channel 2).

Do you have any suggestions or advice? Should I bypass the electrolytic cap with polystyrenes, for example? Forgive me for bothering you, I was just wondering if I had

overlooked something or made any mistakes.

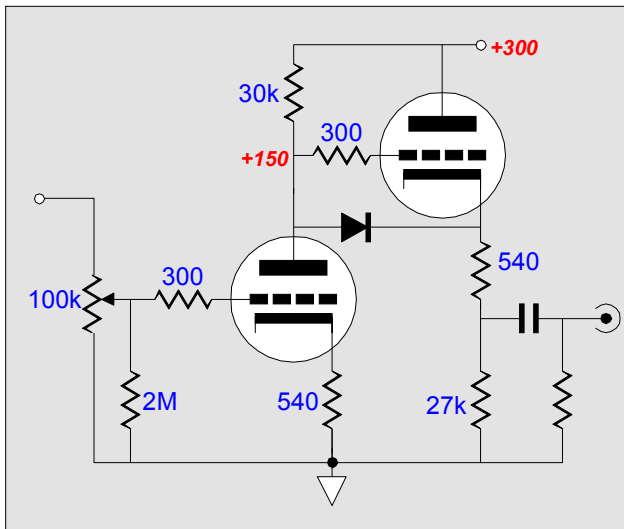
Aren  
Groningen, Netherlands

PS The 6N3P is a Russian equivalent of the 2C51 and 5670. In Cyrillic script it is written as 6H3PI.



Aren's line stage

I would use a much lower plate resistor value and use an unbypassed cathode resistor, as I believe a lower gain and a higher current draw could only improve the sound of this line stage.



Remake of Aren's line stage

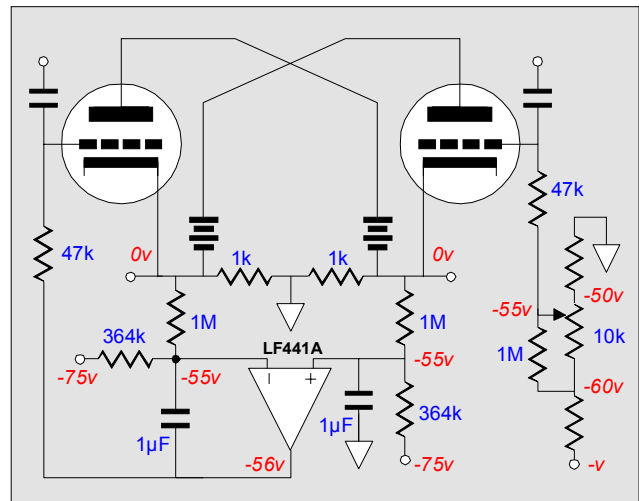
The circuit above makes all the changes. Gain should be roughly half of the mu and the output impedance less than 1k. Build both circuits and have a shoot-out between them.

**Subject: active DC offset correction**

I'm sorry if you've heard this too many times before, but I'm hoping you would address the question of active DC offset correction in class AB Circlotron OTL amps. I think I've seen a commercial offering of such a circuit somewhere on the 'Net, but can't remember where. I also understand that a certain well-renowned tube amp designer (let's call him Batman ;-)) has designed such a circuit that works, but is unwilling to reveal any details.

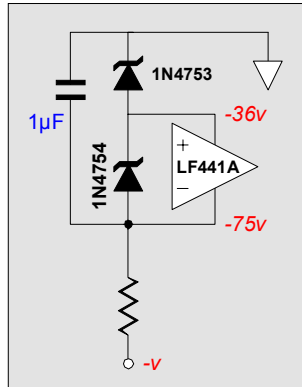
Morgan  
Sweden

Here is what I came up off the top of my head. The mistake many would make would be to try to zero both triodes simultaneously by applying two DC correction circuits. I believe that would upset the bias point. The workaround is to make only one triode's cathode match the other's. This will match the idle currents and eliminate the offset, as the equal idle currents will define a zero volt differential between cathodes.



Active DC offset correction for the circlotron output stage

The IC is the LF441, which has a .5 mV offset and draws almost no current. The zeners establish the artificial floating negative PS for the IC. The resistor in series with these zeners will have to be adjusted to yield the break voltages.



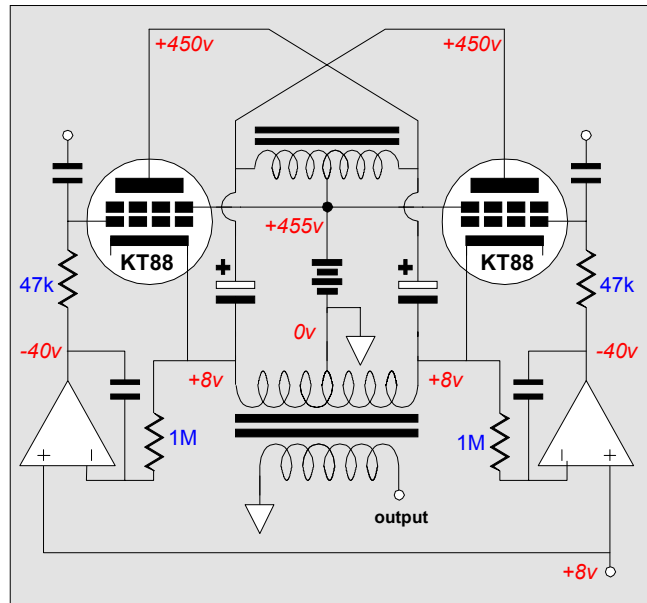
I recommend bridging the IC's inputs with two low-leakage diodes to protect the IC, although the IC may come pre-protected.

Before applying this circuit to a 60W power amp, I would test bench the design with a 12AU7 in place of the many 6AS7s and see how it behaves with some huge tone bursts (40 VPP). My guess is that the music will sufficiently fall outside of the time constants to prevent any problems.

Understand that this circuit is not an auto-bias circuit; it only auto corrects DC offsets. The idle current is still set by the potentiometer.

On the other hand, if the amplifier were to be run in TRUE Class-A mode, then DC offset correction and auto-bias could be implemented. It is unlikely that anyone will be willing to forgo the practicality of Class-AB operation in the direct coupled version of this amplifier. However, if an output transformer is used, then Class-A operation makes more sense.

In the circuit above, the two Op-Amps compare the DC voltage developed across the DCR of the output transformer's primary to the reference voltage of 8 volts. The output tube's conduction is then adjusted to equalize the input's of the Op-Amps.

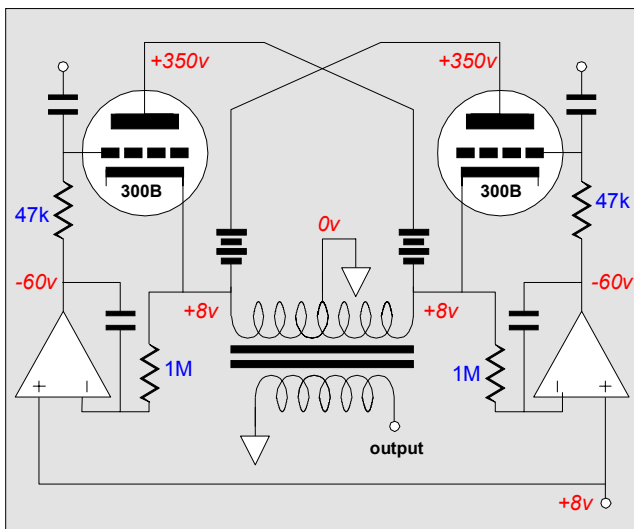


Circular, single power supply, ultra-linear KT8 based Class-A amplifier with auto-bias

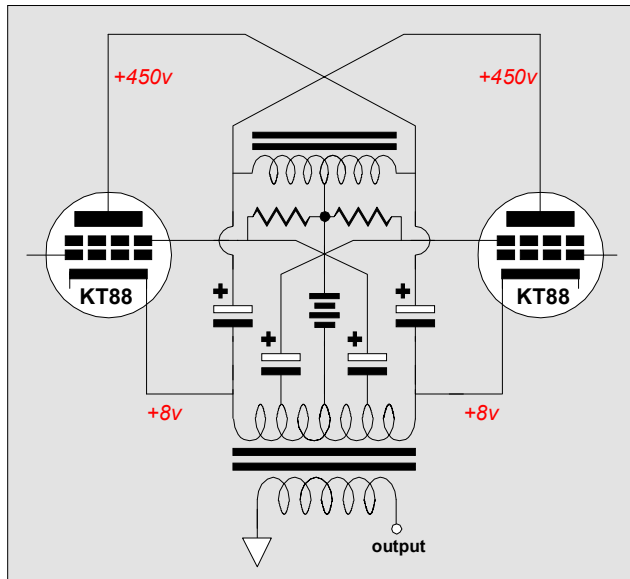
In the above amplifier, all the stops have pulled. The center-tapped choke allow the use of a single power supply, which can be used to feed the screens either the opposing plate voltage or a constant voltage or 50% of the cathode-to-plate voltage swing. The choke is meant to decouple the two power supply capacitors not to provide any further filtration. Of course, in a true Class-A amplifier, much of the power supply will drop out of the output.

Why brother with such an elaborate scheme? In an earlier letter, we covered the advantages of always keeping the whole of the primary under tension. This scheme allows us to run the output stage in a lean Class-AB and yet always keep the primary under load.

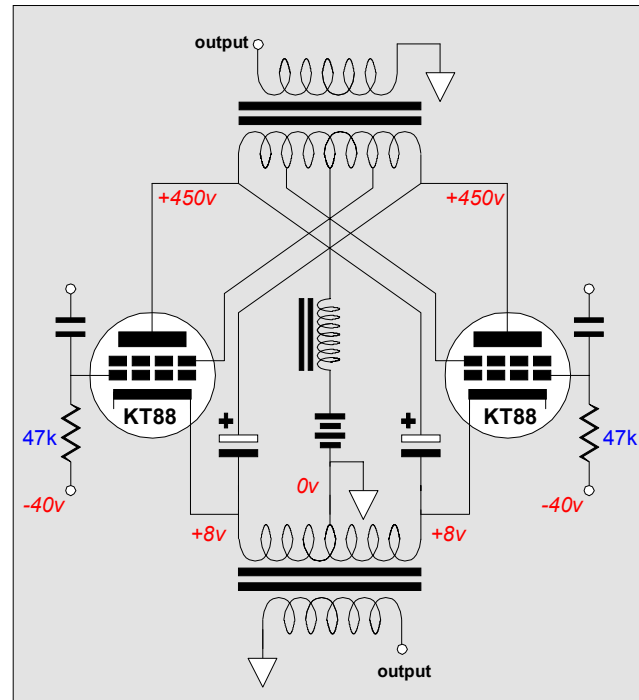
The ultra-linear aspect will no doubt confuse many readers. The key to understanding it is to reference every voltage relationship to the output tube's cathode, not ground. Here the screen sees 50% of the cathode-to-plate voltage swing.



If the output transformer come with ultra-linear taps, they can be used by cross-coupling the taps the screens via a coupling capacitor. This arrangement offers the advantage of using a lower screen voltage than the plate voltage. A lower screen voltage is easier on the tube and it allows to use tubes such as the EL509 that have a much lower maximum screen rating than the plate.



Alternatively, two output transformers can be used in place of the transformer/choke combination. The outputs are wired in parallel and the cathodes and plates see the same load impedance. A choke might be needed to decouple the power supply. (Without this choke, it might be difficult to ensure that the whole of the primaries are always fully loaded because of the short circuiting through the power supply. In theory, the choke is unnecessary, as center-taps do not move. Experimentation is required. Experimentation is all important. Unlike the glossy audiophile magazines, this journal does not present circuits as pre-masticated packages, shrink-wrapped, glossy, with no thought required. Of course, thought-free circuits is what the majority of audiophiles want, but the readers of this journal are a breed apart. A voltage meter and function generator are enough to perform numerous tests on tube circuits, while adding an oscilloscope is even more helpful.)



Circular, single power supply, ultra-linear KT88 based, two output transformer amplifier

In the circuit above, two output transformers are used (here is a use for old Stereo-70s) and the 33% ultra-linear taps are cross-coupled so as to yield 33% of the entire primary to the output tubes. In a Class-B amplifier, each output tube sees one fourth of the primary winding's impedance, but in this circuit, each output tube sees the full primary impedance even in Class-B, thus the need to cross-couple.

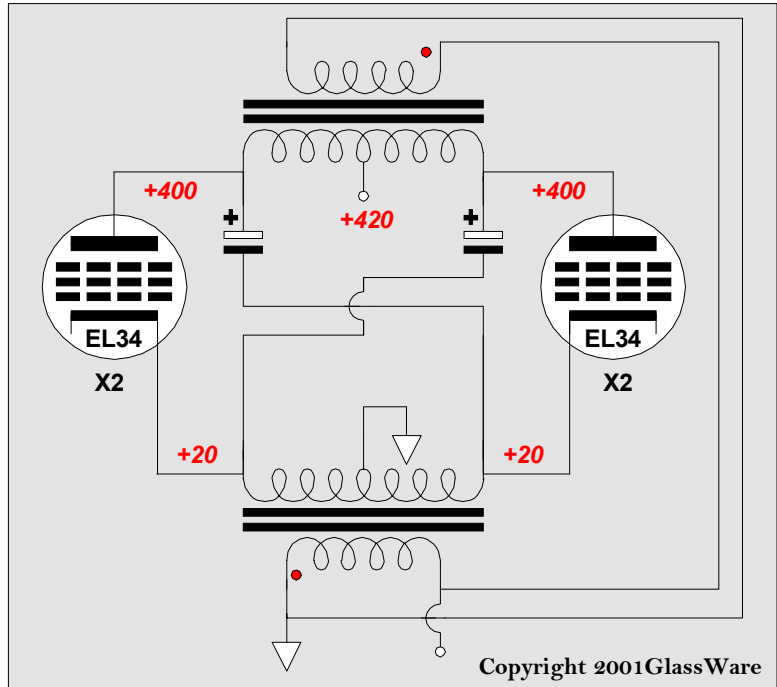
Speaking of the Dynaco ST-70, this amplifier would make an excellent test bench for the following idea. The stereo amplifier's two output transformers and four EL34s can be used to create a mono-block amplifier. Because the output tubes are nested in between two output transformers, the PSRR of this setup is -6 dB. In other words, half of what noise appears at the top transformer's center-tap is present at the EL34's cathode. This halving results from the two transformer secondaries defining a 50% voltage divider, as each reflects the same impedance from the load impedance. Thus, the output tubes need to see half of the power supply noise at their grids as well, if the power supply noise is not to be amplified.

The schematic to the right displays the basic output stage configuration. The output tubes can be wired in triode mode or pentode or ultra-linear. The DC voltage present on the cathodes is due to the DCR of the transformer's primary against the idle current of the output tubes.

In the schematic below, a suitable driver stage is shown. Since the output stage works as a push-pull cathode follower, the drive voltages needed are great. This means that both high gain and a large output voltage swing are required. The 6072s provide the gain and the 5687s provide the voltage swing and offer the required 50% power supply noise reduction....

I better stop now or I will have an entire article written. (A friend asked how I can write more than two or three articles per lifetime without running out of topics!)

As for the tight lips, I am amazed by cloak of secrecy surrounding obvious circuits. I have seen a grown man reverently clutch a wrinkled sheet of paper with some super-top-secret circuit drawn in pencil by some exalted tube guru, whose name could only be whispered.

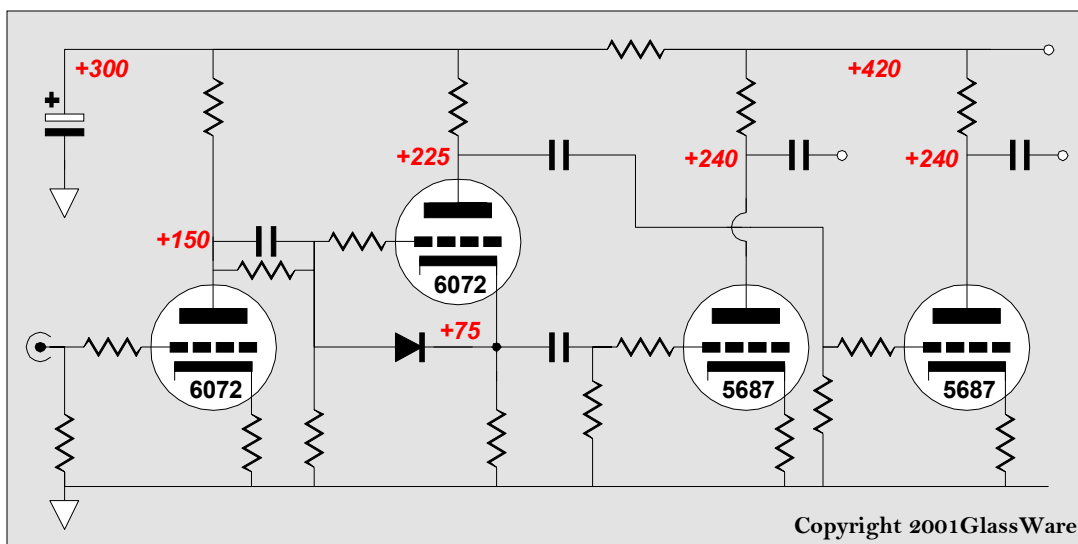


TCJ Circlotron Output Stage

And when I pried it free from his sweaty palms, I could not help but cry with laughter: a grounded-cathode amplifier that uses a 6FQ7! Wow!

If you or anyone else try these circuits, let me know how they work out.

[Editor](#)



Driver stage for TCJ Circlotron output stage