VALVE

VINTAGE AUDIO LISTENERS AND VALVE ENTHUSIASTS
1127 N.W. BRITE STAR LANE, POULSBO, WA 98370

coming this February- are you ready for S.E.X.?*

Want to try the single ended sound but don't know if you'll like it?

Heard that you need pricey new speakers if you go single ended?

Been reading that full range drivers are cool?

There's a way to try single ended full range sound without busting your audio budget. The *Single Ended eXperimentation kit.

For around $200 you'll get a kit composed of a breadboard style, one watt single ended stereo amp using one 6DN7 tube per channel, much like Dave Dintenfass' sweet sounding amp described in this issue, and a pair of open baffle, efficient loudspeakers using two full range 5" aluminum cone drivers per channel.

This kit will be super easy to build (the prototype took about an hour for amp *and* speakers),will sound very nice, and can serve as the basic platform for hours of entertaining modification. We'll publish lots of update and mod information in future issues of VALVE.

To get the price as low as possible, I need to know how many kits to produce. If you are interested, give me a call, send me a note, or fax me.

We'll audition the prototype at the February meeting. Come hear it!

DAN

There's nothing much better than low risk S.E.X.*

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VALVE

VINTAGE AUDIO LISTENERS AND VALVE ENTHUSIASTS

SPECIAL ISSUE -

SINGLE WATT
SINGLE TUBE
SINGLE ENDED

Dave Dintenfass designs and builds a pure and simple flea power amp for his Lowthers!

upcoming meetings

Ultimate Vintage Speaker Shootout!
QUAD vs. Lowther vs. Voice of the Theatre
January 7, 1996 12 Noon
At Electronic Tonalities, Poulsbo

The S.E.X. kit - a single ended amp and speaker kit
February 4, 1996
Location TBA

volume 3
number 1
January
1996

VALVE

is the newsletter of
Vintage Audio Listeners and Valve Enthusiasts,
dedicated to the preservation and dissemination of thermionic valve and vintage audio knowledge.

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Rates:
Membership/Subscriptions:
$ 25.00 a year (12 issues)
Foreign Subscriptions:
$ 35.00 a year (12 issues)
Please makes checks payable to VALVE

editor's thing

Bottleheads, we have an awesome special issue for you this month.

It all started when Dave showed up at the December meeting with this wild schematic for a one tube SE amp.

Well, I takes a look at the map and goes to my junk box (like I only have one... OK junk *room*) and pulls out the necessary parts. I throws them on the bench, plugs in the iron, and says to Dave, "OK smart guy, let's see just how good this idea is".

Twenty minutes later everybody is Shutting Up and Listening. Shoot, this little bugger sounded *good*, even though we miswired it.

Yeah sure, it's only a watt. No, we didn't use sterling silver resistors or oil filled tube sockets. But we had so damned much fun that we got carried away and spent twenty more minutes building a cool full range speaker to go with the amp. Oops, that's for later.

Dave was so stoked that he went home and built a real, on-a-metal-chassis pair of the mono bottles (the 20 minute version was a breadboard affair), and refined the design greatly.

He came back two weeks later and hooked them up to the Whamos. Wow, these little amps are sweet!

So sweet that we decided to share the wealth and print the full schematics for Dave's version, *along* with the full design rationale. That way you can design your own version, using the same formulae Dave used to derive his design.

And bottlebuds, this is just the start. I'm working on a kit version of this amp, along with a kit version of that speaker I 'oopsed' about a couple of paragraphs ago. I'm busting my butt to keep the price below $200. That's right, two hunert bucks for the amp *and* the speaks.

I'll show off the kit, and Dave will show off his amps at the February meeting.

But wait, you say, it's only January. What about the January 7 meeting?

Hold on to your hats, folks. We're gonna put three all time favorite vintage speaks in the same room for the Vintage Speaker Shootout of 1996. Dassrite, LOWTHER, QUAD and ALTEC.

We'll have Dave's totally 'restored by Doug' PM7A Acoustas, Eric's mint ESL's, and Eric's rebuilt A7's (those ones that Eric stores at my house because he still has his listening room filled with pinball machines).

We'll run them each with the World Audio SE amp that Lowther's Tony Glynn likes so much that he tries to buy it from me every once in a while (the amp kicks butt with the other speaks too, I've tried it on all of them).

And we'll play with my new and improved tube output CD player, sporting a new Mu-follower topology, shielded digital chips, more power supply beef, and some of my new Skennythang interconnects. ------------------------------->

I have let my prejudices already pick what I think will be the winner. Bring your own stubborn opinion along, and join us for an afternoon of big time speaker wrestling.

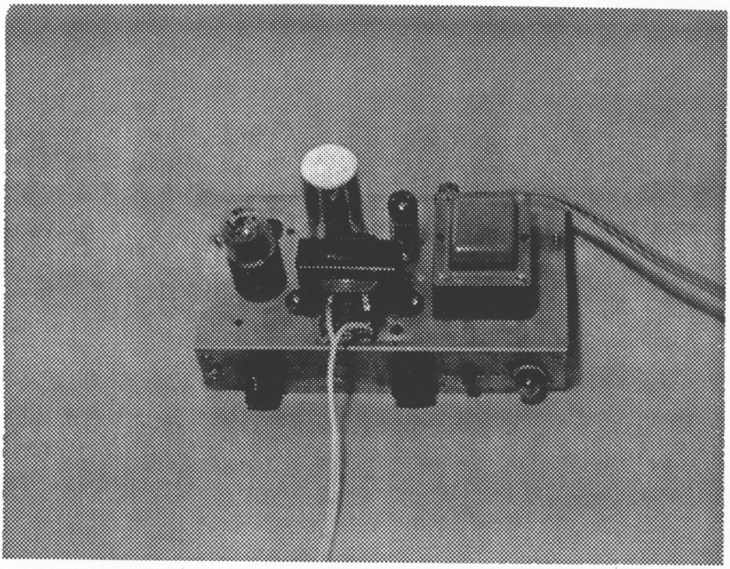
Wow, only a couple of column inches left. Better squeeze in that Crazy Eric Lenius, the Fisher King, will be climbing on our masthead as Audio Archaeologist. That means he'll be supplying us with lots of cool, obscure schematics and old advertising in future issues. Also joining page two will be Paul Joppa as our Resident Smart Guy. Paul will be contributing more choice knowledge nuggets like his primer on tube operating points.

Oh yeah, I'll publish complete info on building your own Superwhamodynes later this year too.

Grab your irons, boys, we're gonna be heatin' it up this year!

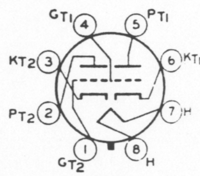
Don't let the blue smoke out,

DAN



The amp, built on an old Newcomb phonograph amp chassis. The larger tube is the 6DN7 driver and output stage, the smaller tube is the 6X4 rectifier.

6DN7 MEDIUM-MU DUAL TRIODE



8BD

Glass octal type used as combined vertical-deflection-oscillator and vertical-deflection-amplifier tube in television receivers. Outlines section, 13B; requires octal socket. Heater: volts (ac/dc), 6.3; amperes, 0.9; maximum heater-cathode volts, ±200 peak, 100 average.

Class A_1 Amplifier

CHARACTERISTICS	Unit No.1	Unit No.2	
Plate Voltage	250	250	volts
Grid Voltage	—8	—9.5	volts
Amplification Factor	22.5	15.4	
Plate Resistance (Approx.)	9000	2000	ohms
Transconductance	2500	7700	μmhos
Plate Current	8	41	mA
Grid Voltage (Approx.) for plate current of 10 μA	—18	—	volts
Grid Voltage (Approx.) for plate current of 50 μA	—	—23	volts

Vertical-Deflection Oscillator and Amplifier

For operation in a 525-line, 30-frame system

MAXIMUM RATINGS (Design-Maximum Values)	Unit No.1 Oscillator	Unit No.2 Amplifier	
DC Plate Voltage	350	550	volts
Peak Positive-Pulse Plate Voltage#	—	2500	volts
Peak Negative-Pulse Grid Voltage	400	250	mA
Peak Cathode Current	—	150	mA
Average Cathode Current	—	50	mA
Plate Dissipation	1	10	watts
MAXIMUM CIRCUIT VALUES			
Grid-Circuit Resistance:			
For fixed-bias operation	2.2	2.2	megohms
For cathode-bias operation	2.2	—	megohms

Pulse duration must not exceed 15% of a vertical scanning cycle (2.5 milliseconds).

One-watt fun with the 6DN7

by David Dintenfass, VALVE

Many years ago, someone proclaimed "what this country needs is a good five-cent cigar." A few decades later, Paul Klipsch came along and proclaimed, "what this country needs is a good five-watt amplifier" (and presumably, a Klipschorn to go with it). Being somewhat of a minimalist myself, I have tremendous respect for Mr. Klipsch's sage advice, despite the fact that I've never cared for the sound of his beloved K-horn, which I find harsh, penetrating, and fatiguing. Still, the audio world would be a nicer place had more audiophiles followed his advice.

Fade to black and fast-forward 30 years. As many of you know, a few months back I bought a pair of Lowther PM6-A drivers in Acousta cabinets from a fellow VALVE member. Shortly thereafter, I remarked to Dan, "what I need is a good one-watt amplifier." But where to begin?

Well, some time ago I uncovered some single-ended, Triad S-28X audio output transformers. Now before you wet your pants in envy, take a deep breath and I'll explain why these are *not* the next-best-thing to a prize chunk of Magnequest output iron. For one thing, these transformers were not designed for triode applications, nor do they have "dc-to-light" bandwidth. They have a spec'd frequency response of 50 Hz to 12 kHz, dissipation of five watts (40 mA max primary current), and a 7.5K primary. I *told* you not to get excited...

But what excited me were the secondary taps. This transformer has a 4/8/16 ohm taps plus a 500-ohm tap (a personal favorite of mine, given my penchant for vintage broadcast gear). I figured if I could make a go with this output iron, I'd have output taps for any speaker in the house, provided they were efficient enough, plus a tap for my Jensen coaxial with the 500-ohm voice coil (which might sound decent enough when I rebuilt its crossover).

Dan suggested that I use this transformer with a type 10 (a small power triode dating back to the 1930s) or a 45, both of which require high-impedance plate loads. These were good suggestions (and I hope to try them soon) but right now I wanted something a bit less exotic. I wanted something that I could prototype quickly, without building a dedicated filament supply for oddball voltages (being the paranoid type, I refuse to run antique tube filaments without an adjustable supply). So the project stagnated for a few weeks.

As it happens, George Wright's frame-grid preamp design (featured in the November VALVE newsletter) got me interested in those dual asymmetrical triodes used as vertical oscillators in television sets. You may remember that George used a 6EM7 in the preamp's regulated power supply. This family of tubes has intrigued me, so I wondered if such a tube might be useful in a compact, low-wattage power amp.

Unfortunately, the plate resistance for the power triode section in many of these tubes is too low—about 800 ohms (which is typical since the small-signal section is often a high-mu triode and the power section a low-mu triode). This makes finding suitable output iron difficult and pretty much ruled out the nice little S-28X transformers with their 7.5K primaries. While thumbing through an old *Radio-master* catalog I discovered that Triad made the S-29X, a similar unit with a 5K primary, but I figured finding a pair of those would be pretty difficult. After all, it's hard enough finding *any* vintage single-ended iron, and what you find tends to be of distinctly mediocre quality. Still, I wasn't willing to plunk down $$$ for a pair of new single-ended transformers, particularly since there's no way my as-yet-unborn flea-power amplifier would require a massive SE output transformer. I thought about using a UTC 600-ohm to 4/8/16-ohm transformer I have, but I wasn't sure how much dc current I could put on the primary and besides, I only have one of these units.

A few weeks later, I was poking around in an ex-TV serviceman's tube caddy in a local electronics surplus store, when I happened across a 6DN7. It looked similar to the 6EM7 but its plate assemblies were perpendicular, not parallel.

When I got home, I looked in my RCA tube manual and I realized that the 6DN7 was an asymmetrical pair of medium-mu triodes, with the output section having a plate resistance of 2K—high enough to work comfortably with my output iron.

The next step was to measure the Lowther driver and determine the typical impedance. Using an old General Radio LCR meter, I measured 12 ohms @ 1 kHz, so I calculated what the nominal primary impedance would be if I loaded the 16-ohm tap with 12 ohms.

I'm no math whiz, but I know that the square of the turns ratio is the impedance ratio. So, if you square-root 7500 ohms and then square-root 16 ohms, you get a turns ratio of approximately 22:1 for the 16-ohm tap. If you crunch the numbers further, you realize that loading the 16-ohm tap with 12 ohms gives you a primary impedance around 5.6K.

Around the same time, fellow VALVE member Paul Joppa mentioned that, as a general rule-of-thumb, you can use an output transformer with a primary impedance anywhere from twice to five times the plate resistance of the output tube. For example, think of a 2A3—it has a plate resistance of 800 ohms and is often used with a transformer having a 2.5K primary (about 3x the plate resistance).

Obviously, the closer you get to twice the plate resistance gives you more output power (very important to people trying to squeeze every milliwatt from a single 2A3 or 300B) but using a lighter plate load gives you lower distortion, if you can hack the loss of power.

This cheered me considerably. Since the Lowther voice-coil impedance was around 12 ohms, a 5.6K load on the 6DN7 represented 2.8x its plate resistance—a loading damn close to the magic 3x figure used in the classic circuits (such as the typical 2A3 loading already mentioned).

Now that you've read this far, I must confess that I'm pretty much a neophyte when it comes to amplifier design. I've never *designed* an amplifier before, despite having built and repaired electronics projects of one sort or another for over twenty years. So I figured a one-tube project like this would be a good start. Also, I knew I could count on fellow VALVE members to help if I got stuck.

At the outset, I decided that the amplifier would remain simple, with no extra tubes (other than a rectifier). I also wanted to use cathode bias, which in addition to its other salutary effects, ensures long tube life since there's no separate bias supply to fail. And I would use a moderate amount of negative feedback, if necessary, to compensate for the weak high-end response of the output transformer.

Finally, I didn't have characteristic curves for the 6DN7 so I decided to proceed using some suggested values given in the tube manual. I suppose I could have found curves for a individual tubes that closely matched the characteristics of each triode section and gone from there, but I was eager to get started.

Determining plate currents

Despite fifteen years as a technical writer, I had never read the beginning of the RCA tube manual very carefully. It's amazing how much information is in there. So I starting reading. And there is was—a simple formula for determining the cathode resistor. You take the grid bias voltage required for zero-signal plate current (disregarding the polarity), multiply it by 1000, and divide by the desired plate current (in milliamps) and you get the value of the cathode resistor.

The characteristics of the 6DN7 are, for the power triode, –9.5 volts grid bias and 41 mA max plate current. Since extended tube life was one of my goals, I decided to limit the plate current to 30 mA. So, cranking the numbers, I got 9500/30 which is about 316 ohms. A 330-ohm cathode resistor is close enough.

For the 6DN7's small-signal triode, the characteristic are –8 volts grid bias and max plate current of 8 mA. A wiser, more experienced friend cautioned me that small-signal tubes are never run anywhere near their maximum plate current. He suggested using a 2.2K cathode resistor. Doing the math, this yields a plate current of 3.6 mA, well under the maximum.

Sizing bypass capacitors

Since I figured I'd need some amount of feedback, I decided to bypass the cathode resistors to get the extra gain. I decided to use some small 100 uF low-ESR electrolytics. I also had some nice 20 uF film caps. I decided to use one type in the first stage and the other in the second stage. As it happens, I should have reversed the position of these caps, and you'll see why in a moment.

After building my prototype, I dug through my library and found a good textbook for this sort of thing. It's called *Principles of Electron Devices* by Angelo Gillie (published in 1962 by McGraw Hill) and is a good, no-nonsense design book for solid-state and vacuum-tube circuits. There's enough math in there to make basic design decisions but thankfully, no calculus.

In this book, Mr. Gillie suggests that the bypass capacitor—at the lowest frequency desired—should have a capacitive reactance (Xc) no more than 10 percent of the cathode resistor value. So for the 330-ohm cathode resistor in the power section, I should have used a bypass cap with an Xc equal to 33 ohms if I wanted good response down to 40 Hz. Conveniently, there are examples in the book. These show that the cap size should equal $1/(2\pi f_{min} X_c)$. So if we drop in the numbers, we get 1/(6.28)(40)(33). That's a value of 120 uF.

Using the same formula for the first section, we get a recommended bypass cap of 18 uF. So you see, I should have used the 100 uF in the second stage and the 20 uF in the first stage (note on the schematic that I did just the opposite). As it turns out, this mismatch didn't seem to make much difference, but next time I'll reverse the caps.

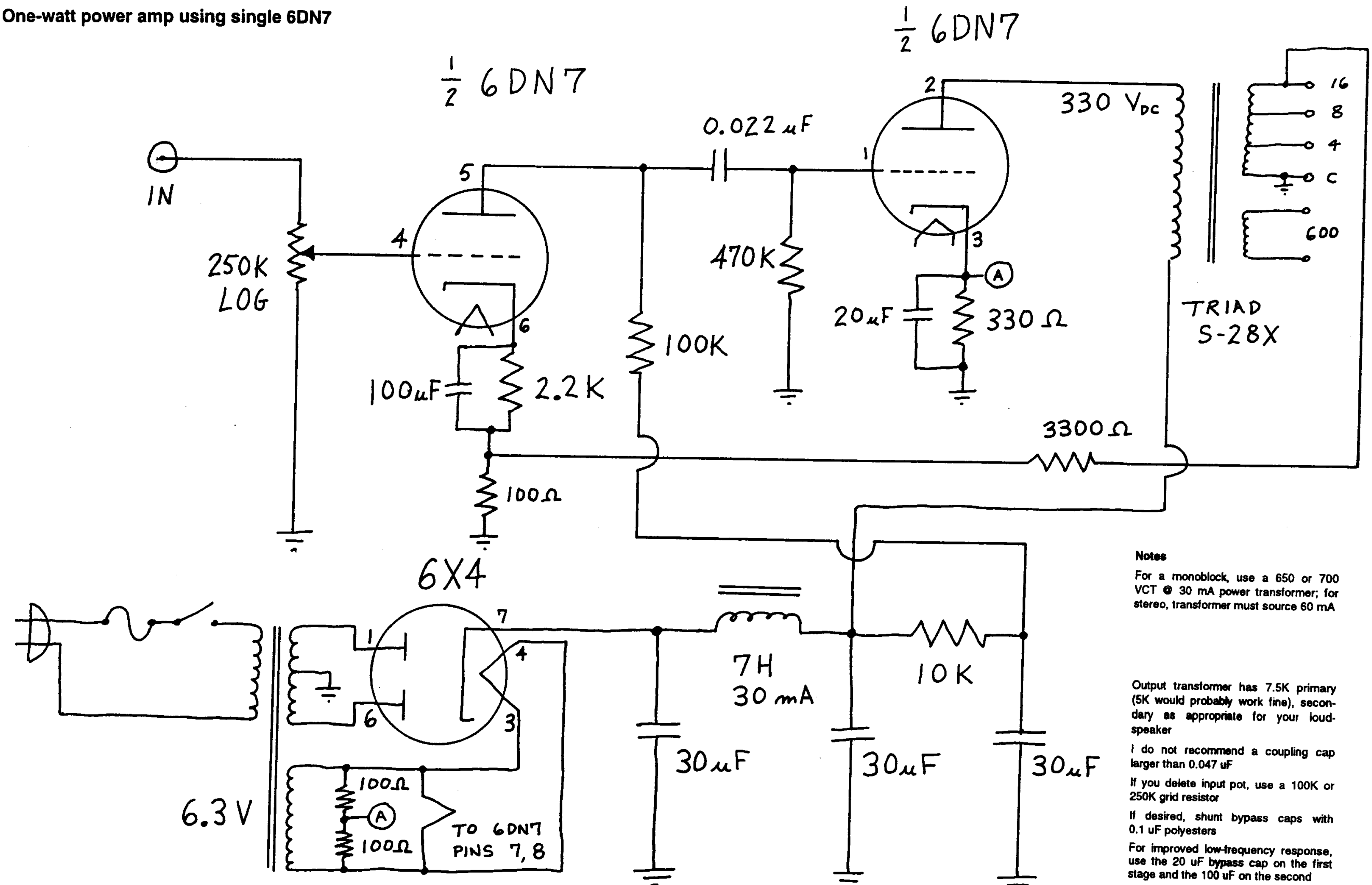
The power supply

The 6DN7 is a fairly robust tube since it was designed for television service. Maximum plate-voltage ratings are 550 Vdc for the power section and 350 Vdc for the small-signal section. Max plate dissipation is 10 watts and 1 watt, respectively. With 30 mA plate current on the output section, plate voltage should not exceed 330 Vdc (330 V x 0.030 A = 9.9 watts).

For convenience, I decided to prototype the amp on a Newcomb phonograph amplifier chassis since it already had a useable power supply (350 Vdc @ 50 mA). After carefully removing the original output transformer, I installed a new triple 30 uF electrolytic can. I retained the capacitor-input power supply circuit but I did add a small 7 Henry choke.

To power the first half of the 6DN7, I used a 10K resistor between the second and third filter capacitors. With a plate current of 3.6 mils, that yields about 315 volts (3.6 mA x 10K = a 36-volt drop from the 350 Vdc supply).

One-watt power amp using single 6DN7



Notes

For a monoblock, use a 650 or 700 VCT @ 30 mA power transformer; for stereo, transformer must source 60 mA

Output transformer has 7.5K primary (5K would probably work fine), secondary as appropriate for your loudspeaker

I do not recommend a coupling cap larger than 0.047 uF

If you delete input pot, use a 100K or 250K grid resistor

If desired, shunt bypass caps with 0.1 uF polyesters

For improved low-frequency response, use the 20 uF bypass cap on the first stage and the 100 uF on the second

A quick word here about those Newcomb phonographs. Unlike most portable phonographs which were of ac/dc cheapo series-filament design, the Newcomb units (ubiquitous in elementary and secondary schools throughout the 50s, 60s, and 70s) had a real power transformer and a rather nice circuit topology which featured a single-ended ultralinear output transformer with an 8-ohm tap! Tube complement was a 6X4 rectifier and a 6AV6 high-mu triode/twin diode (the diodes were unused and therefore grounded) driving a single 6BQ5 or 7189.

The little Newcomb amp puts out a surprisingly clean five watts and it sounds amazingly good—if you cut out the tone controls and install a nice polyester coupling cap. I have one of these amps in my office driving a small two-way Infinity ported enclosure. In a future VALVE article, I'll profile this amp a bit more since I plan to build a stereo version (I've carefully removed and set aside two of these transformers).

Okay, let's get back to the 6DN7 amplifier. The dc resistance of the output transformer primary is 540 ohms. Given a plate current of 30 mA, we can count on a voltage drop of approximately 16 volts through the transformer primary, bringing the plate voltage down to just a bit over 330 volts (after I built the amplifier, I discovered that the supply voltage sags enough to produce almost exactly 330 volts on the plate). Ideally, I'd prefer 275 volts to lower plate dissipation to 8.25 watts, but there wasn't room to add the extra choke for a choke-input supply.

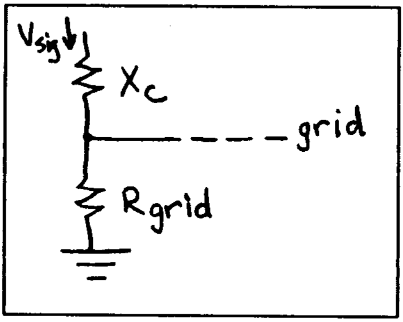
I like the 6X4 rectifier since it's indirectly heated and should delay the application of B+ just enough to lessen my worries about cathode-stripping the 6DN7. Still, when I build a two-chassis stereo version of this amp, I'll use a 30-second time-delay relay on the rectifier filament (probably a 5Y3 since the power transformer I've dug out has a separate 5-volt secondary).

Other components

At this point, I needed to find an appropriate value for the plate resistor for the first half of the 6DN7. One of my consultants suggested 100K. Traditionally, an approximate value for the plate resistor is calculated by taking the plate voltage over the plate current. Since I calculated a plate voltage of 314 volts after allowing for the 36-volt drop across the 10K resistor, 100K was indeed a good suggestion (314V/0.0036A = 87.2K).

Finally, I needed values for the RC-coupling circuit. From the RCA tube manual, the minimum grid resistor for the 6DN7 output section is 2.2 Megohm—but that's for fixed bias. For some reason, there's no value given for cathode bias, although 2.2 meg is the value given for the first section for both fixed and cathode bias). I decided that the lack of data was due to the peculiarities of television use (keep in mind that nobody was using this tube for audio) and decided to go ahead and use 470K since I'd seen that value used in many circuits. I think 470K is a common value because it's low enough to reduce hum pickup in the grid circuit yet high enough to ensure adequate sensitivity. Actually, we need a grid resistor for two reasons—to drain excess electrons from the grid of the next stage (this ensures proper biasing) and to form our RC-coupling network.

Now for the coupling capacitor. If you redraw the coupling cap and the grid resistor, you can see that what you have is essentially a voltage divider.



At middle and high frequencies, the coupling cap is essentially transparent to the input signal since its capacitive reactance (Xc) is small compared to the 470K resistor. This means that nearly all the voltage drop is across the resistor, which is a good thing.

As the input signal decreases in frequency, at some point that coupling cap is going to start behaving like a resistor (we'll ignore the phase shift in this discussion). Decrease the signal frequency enough, and there will be significant voltage drop across the coupling cap—enough so that the remaining voltage drop across the grid resistor will be noticeable. When the drop across the grid resistor is about 70 percent of its value at middle frequencies, that's the –3 dB point for the low end.

By rearranging a simple voltage-divider formula, you can easily find the critical value of Xc that will produce a 3 dB loss across the grid resistor. The formula is (Rgrid/0.707) – (Rgrid). With a 470K grid resistor, the magic value for Xc is 195K. Then you can calculate the size of the coupling cap you need for a desired frequency response.

Or if you're like me, you can look in your junk box and find a coupling cap of the approximate size and see if the low-end response will be tolerable. In this case, I found a 0.022 Vitamin Q oil cap so I decided to use it and see what all the fuss is about these caps, though I'm sure a polyester cap would have been fine.

The rest of the math is simple. Using some algebra (which can be a stretch for a math-impaired guy like me), you can rearrange the classic formula $Xc = 1/(2\pi fC)$, where f is the critical frequency, to produce this one: Low Freq Cutoff = $1/(2\pi CX_c)$. So, dropping in the numbers we get 1/(6.28)(0.022 uF)(195K). This works perfectly as long as you don't forget that 0.022 uF is 0.022×10^{-6} and 195K is 195×10^{3}.

This yields a calculated –3 dB point of approximately 37 Hz (after building the amp, I measured and found this point to be at 38 Hz, which is pretty damn close). This is just fine since the Lowthers do not have an extended low end—and after years of listening to Quad ESLs, I consider a respectable low end to go down to 40 Hz and no more. Also, the Triad output transformer has a spec'd response only down to 50 Hz, so I figured it would be safer not to saturate the core (and risk adding more distortion) with a lot of low-frequency information. As it turned out, adding feedback extended the low-end response from 38 to 32 Hz.

If you decide to build this amp, you might want to use a 0.047 uF cap. This lowers the 3 dB rolloff point to 18 Hz. I would not use a value larger than this—instability might result, particularly if you use feedback.

Some amplifiers use a "grid stopper" resistor between the RC-coupling network and the grid of the power tube—a 1K resistor is typical. This has something to do with recovery from overloads on peak signals and can reduce ringing on transients. I did not use a grid-stopper, but perhaps the next time around I will add one and see if it makes a difference.

Breadboard attempt at Dan's

We "breadboarded" this first version of my 6DN7 amplifier at the December VALVE meeting with mixed results. For some reason, the prototype mono amplifier just couldn't seem to drive one of Dan's "Superwhamodyne" speakers with any degree of satisfaction. The Whamos are efficient (96 dB SPL), so something was clearly wrong. We agreed that the amp sounded nice but was horribly underpowered.

A week later, I called Dan and revealed the problem. To my acute embarrassment, I realized that I'd wired the 6DN7 backwards! We were using the small-signal triode as the output tube! Let this be a lesson to you, gentle reader—

carefully note the pin-out labels on the diagram in your tube manual. With a dual triode, don't assume that the triode on the left is the first element and the one on the right the second. With the 6DN7, it was just the opposite.

Testing the prototype

A week later, I completed the first prototype 6DN7 monoblock on the Newcomb chassis. It sounded smooth, effortless, and had a real sense of presence on the Lowther. For a signal source, I used a nice old H.H. Scott LT-10 mono FM tuner that I'd re-capped and aligned some months ago. Everything sounded nice. I spent a lot of time listening to chamber music on KING and vintage jazz on KPLU and KBCS.

Out of laziness, I used a 1-meg input pot since it was already on the Newcomb chassis. In a moment, you'll see why this was a bad decision.

Hum-busting

At this point, the only problem was an alarming amount of hum, particularly when I turned up the input pot (with or without an input signal). After consulting with George, Dan, and my trusty textbook, I realized that the input grid resistance was too high. I added a 560K from the grid to ground, and that killed most of the hum.

But there was *still* some hum. I thought it might be heater/cathode leakage since the hum did change slightly with different 6DN7s. While going through my 6DN7 tube stash, I noticed that RCA, Westinghouse, and some GE types have parallel filaments for each triode section, while some GE types have a series filament (you can see the filament wire crossing from one section to the other at the top of the tube). There didn't seem to be much hum difference (or, for that matter, sonic performance) with either type.

Since I had installed an octal socket for the electrolytic can on this chassis, I tried using a triple 10 uF filter can instead of the triple 30 uF can to see if the hum changed. I noticed no significant change.

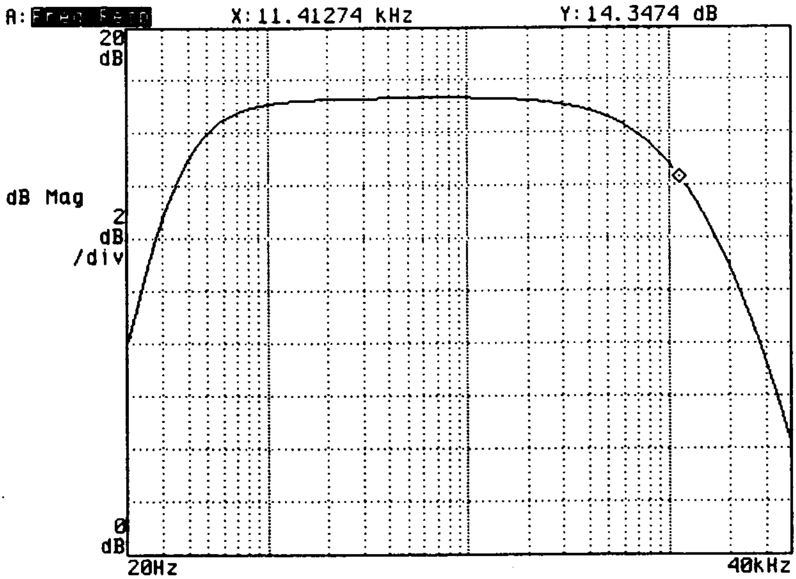
Then I called George and asked for advice. He suggested an old hum-busting trick—put a 100-ohm resistor on each filament line, then tie the other end of the resistors to a common point at the cathode of the output tube (in this case, at the cathode of the power section of the 6DN7). This reduced hum markedly, though I can still hear a bit of it if I put my ear next to the Lowther. But it's not enough to worry about.

As an aside, some amount of hum with speakers this efficient (the Lowther PM6-A is rated at around 100 dB in the Acousta cabinet) is simply a fact of life. But I think my solution brought it down to workable levels. Using dc on power tubes seems to be all the rage today, particularly for people using direct-heated triodes, but I'm not convinced that's the answer—in fact, there's some legitimate concern that using dc on power tubes actually decreases tube life.

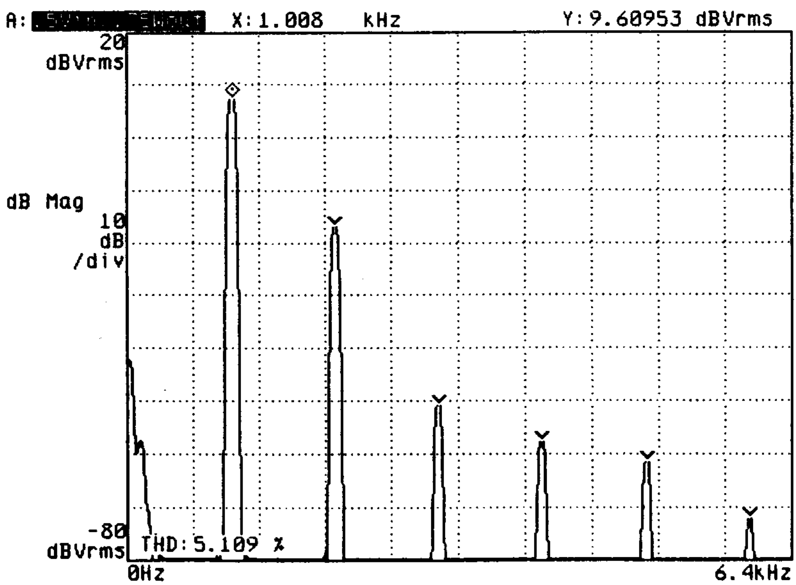
Distortion and freq. response

Despite my favorable first impressions of the prototype amp, some measurements were in order. After assembling a second prototype, I gathered several fellow "bottleheads" and headed over to Dan's on a non-VALVE weekend in December. There, we auditioned the amps and made some measurements after changing the output taps to 8 ohms. Performance was very impressive at low-to-moderate levels, though at more demanding levels, the little amp really did "run out of steam."

Distortion readings were acceptable. With a 0.5 Vrms input, we measured a 3/4 watt output into a 12-ohm non-inductive load, THD was about 5 percent, with nearly all of that being 2nd harmonic distortion. When you examine the distortion spectrum (shown elsewhere in this article), note that the 3rd harmonic is 60 dB down—that translates to 0.1 percent of the distortion product.



Frequency Response (no feedback); Y-scale is 2 dB per division



Distortion spectrum (no feedback) at 3/4-watt output; Y-scale is 10 dB per division

I suspect this is why many people prefer the sound of SE triode amps. Since the second harmonic of a musical component sounds an octave above the fundamental, it's a rather musical effect and does not sound unpleasant to our ears. Perhaps it even masks the odd-order harmonics (this seems to make sense since psycho-acoustic studies have shown that louder sounds can mask softer sounds).

At 2 watts into 12 ohms, the THD figure approached 9 percent. That's a bit high for my comfort zone, so I decided that this really was a one-watt amplifier.

Frequency response measurements were somewhat disappointing. Although the low-end response was acceptable (3 dB rolloff at approximately 40 Hz), the high end was really soft, with a 3 dB rolloff at 12 kHz. Even more alarming, with the input pot turned down a bit, the high end dropped still further—down to 8 kHz with the input pot only a quarter of the way up! At this point, we left Dan's and I resolved to fix this problem.

Another friend suggested that I might bypass the bypass caps with 0.1 uF polyesters (I've seen this done in many modern amplifier designs). In some cases, large capacitors can have enough inductance to diminish high-end response. So I tacked in some 0.068 uF caps, but this didn't make any difference. I left them in, however.

After further consultation, I realized that sticking with a 1-meg input pot was a terrible mistake. Due to shunt capacitance, high-end response is compromised with such a high-impedance pot. While you don't have to go overboard and use a 10K input pot (a bad idea unless your preamp has a cathode-follower output or is a solid-state rig), using a 250K input pot is a nice compromise. Incidentally, this is a good reason why you *should not* use shielded cable from the pot to the grid of the input tube in a power amp—doing so adds needless capacitance (besides, if your chassis is well shielded, you won't need the shielded cable).

So I found a 250K log pot and tried it. Success! This high end was still heading south at 12 kHz, but the input pot was no longer contributing to the problem. (By the way, just use a 100K grid resistor in place of the pot if you plan to use a preamp with this amp.)

Adding feedback

An easy, effective way to add some negative feedback is to connect a series resistor between the 16-ohm transformer tap and the cathode of the first amplifier stage. A typical value for the feedback resistor is 6800 ohms for a pentode output tube. My consultants suggested 3900 or 3300 ohms to start with, since a triode output stage has lower gain. I used 3300 ohms, and I used a switch to remove the feedback at will.

Another suggestion was to add a 100-ohm resistor between the cathode resistor and ground and inserting the feedback between the two resistors—the bypass cap now goes only around the upper resistor, which in this case is the 2.2K cathode resistor. This effectively removes the cathode resistor and the bypass cap from the feedback path, making more efficient use of the feedback voltage.

Don't forget to ground the common speaker terminal if you decide to use feedback. You must have a ground reference for the feedback voltage!

I was shocked at how little feedback was required to effect a change. I measured the output voltage across the 12-ohm load with and without feedback, and at the maximum useable output level, the voltage dropped from 3.25 Vrms to 2.75 Vrms across the load (you can calculate the dB change by dividing the two voltage outputs, then taking the log of this value and multiplying by 20). That's a change of 1.45 dB! In power terms, that's a reduction from 0.88 watts to 0.63 watts.

As it turned out, adding just 1.5 dB of feedback helped considerably. The 3 dB rolloff point moved up to 15 kHz on the high end and down to 32 Hz on the low end. At low levels, the distortion went down by about 3 dB with feedback in use. Since the Lowther doesn't have much output beyond 15 kHz (or if it does, you'll never hear it if you're a bit off-axis), I called the amp "done" when I extended the response out to 15 kHz.

Typical low-level distortion figures were encouraging. At 0.25 Vrms in, the measured distortion went from 2.3 percent THD without feedback to 1.5 percent with feedback. Output power fell from 0.24 watts to 0.16 watts, but as you'll see in a moment, this level of output power is more than enough to drive the Lowther.

Some final words

I'd heard that all you needed with a Lowther speaker was a one-watt amplifier. In fact, one watt would "make your ears bleed." I have to say that the Lowther enthusiasts aren't kidding. One watt is *more than enough* power!

Incidentally, as much as I like the sound of the Lowthers, I'm not ready to trade in my Quads. While the Lowthers have a wonderful smooth sound, if you push them, you are made aware that sound is coming from a box, not from thin air. Also, when you listen to large orchestral pieces, the massed strings do get a bit blurred. But at low levels, the sound is magical, particularly for chamber music and small jazz combos. Of course, at any level (and with any music), the dynamics and transient response are stunning.

Now let's get back to quantitative test results. Just for grins, I assembled a test system down in the shop. I used the 6DN7 monoblock with the feedback switch, a Magnavox CDB-582 CD player, and a single Lowther. For source material, I used a borrowed copy of "The Sound of Everest," a nice sampler CD produced by Vanguard Classics. To monitor the output, I connected my Ballantine 300D VTVM across the speaker terminals.

At moderately-loud listening levels on dense orchestral passages (for example, during an excerpt from Mussorgsky's "Pictures at an Exhibition"), I measured no more than 0.5 Vrms. Like most VTVMs, the Ballantine measures average voltage but displays Vrms—this is accurate for sine waves, but decidedly inaccurate for complex waveforms (music, for instance). Also, the meter movement is probably much too damped to read anything approaching peak levels. That said, let's suppose that what I really measured was something approaching 1 Vpeak. Into 12 ohms, that's still less than 1/10 of a watt! So I'd say one watt is plenty of power.

Acknowledgments

I'd like to thank VALVE members Dan Schmalle, Paul Joppa, and Doug Grove for their helpful advice. I must also thank soon-to-be-VALVE-member George Wright for his extraordinarily wise counsel on this project. George kept me "out of the weeds" on several occasions and has graciously shared his 30+ years of home-brewing experience. Without George, I'd never have learned as much as fast as I did.

For additional circuit suggestions and helpful ideas on this and previous projects, I must thank three other friends: Pete Peters (Seattle), John Shriver (Arlington, Massachusetts), and Scott Dorsey (Williamsburg, Virginia).

Also, a thank you to some of my former teachers at North Seattle Community College (specifically, Linda Wilkinson, Frank Jump, and John Hagans) who gave me a thorough overview of basic electronics during 1994/1995 and thus unknowingly helped me with this and other projects.

Lastly, a thank-you to my dear (and patient) wife Laurie, who has endured yet another of my electronics obsessions with remarkably good humor.

corrections

- The model boat motor isolation mounts used by Tim Lollar to quiet his noisy AES SE-1 power transformer were Octura brand. Tim suggests using the medium to small size. He got his at Webster's Hobby, 185th & Aurora.

- Tim also wants to set the record straight about where his SE-1 came from. It was the amp reviewed in Stereophile, not the one covered in Sound Practices.

- One more time on the correction to the regulated supply diagram in November's Wright preamp article. The grid of V4A should be connected to the plate of V4B, not the B+ line.

dinkin'around

Here's one that I can't remember anybody talking about before.

I'm sitting in the shop with the CD player running. Katlyn is up two floors taking a nap in her crib, so I have the baby monitor sitting next to me.

It's making all this hashy static, so I pick it up and move it over a bit. I just happen to move it closer to the CD player, which has its cover removed to accomodate my tube output hack.

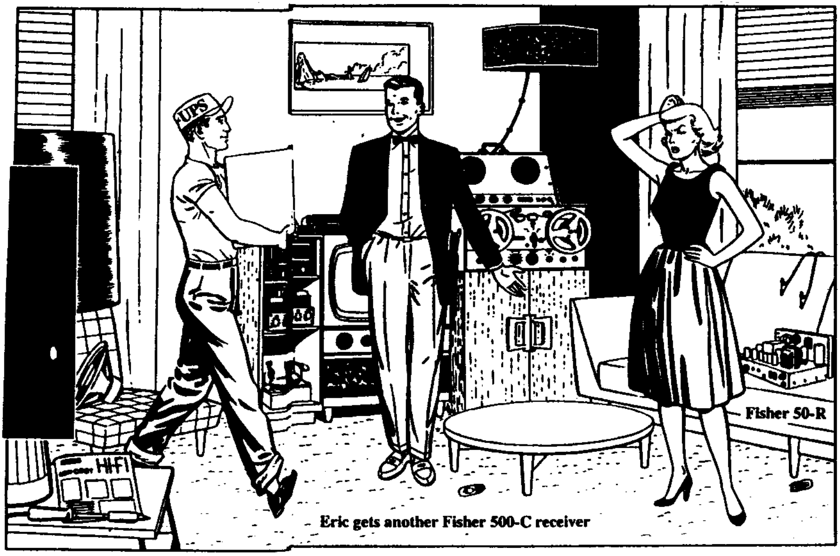
The hash gets louder.

I pick up the monitor and start passing it close to various chips inside the player and the digital chips make the monitor go crazy!

Now these chips are real close to the low level lines taking the DAC analog output out to the tube stage. So I bent up a tiny rectangular box shaped shield to just cover the worst offending chip, and lined it with PVC tape to keep from shorting any pins. A wire soldered to the shield was connected to the nearest ground jumper.

The hash dropped considerably.

I think this might be a worthwhile easy tweak to incorporate into a CD player RFI reduction scheme.



Eric gets another Fisher 500-C receiver

did you just tune in? here's what's happened so far...

Back issues

Volume 1 - 1994 issues - $20
a Williamson amp; Dyna Stereo 70 mod bake-off; converting the Stereo 70 to 6GH8's; a QUAD system; triode input Dyna MkIII; MkIII vertical tasting; smoothing impedance curves; Altec A7; Ampexes, Nagras and ribbon mikes; Triophoni, a 6CK4 amp; audio at the 1939 World's Fair; books for collectors and builders; V.T. vs. R.M.A. cross reference; FM tuner tube substitutions; Big Mac attack - the MI 200; 6L6 shootout; a vintage "audessy"; more FM tuner mods; vintage radio mods; Heathkit rectifiers; PAS heater mod.

Volume 2 - 1995 issues - $20
Rectifier shootout, tube vs. solid; FM 1000 recap and meters; single ended 10 amp; triode output W-4; Optimus 990 - speaker for SE?; star grounds; tuner shootout; Living Stereo, vinyl or CD?; World Audio SE integrated; firin' up - smoke checking; Brook 12A schematic; 6C33 vs. 3C33; Heathkit power transformers; 6B4's + Magnequest = SEcstasy; W5 mods; triode operating points; Dyna restorations; Marantz 7,8 and Scott LK150 impressions; hackable vintage gear; Quasimodo - PP 805 amp; restoring a Scott 340 in 75 minutes; a dream system for 78's; cartridges and styli for 78's; Restoring a Lowther, part 1&2: easy tube CD output hack; 6ER5 phono preamp: 304TL & 450TH SE operating points; hypothetical DC ESL amps.

And here's what we hope to have in 1996:
Single Watt, Single Tube, Single Ended, an amp for Lowthers; the Vintage Speaker shootout of 1996, QUAD vs. Lowther vs. A7; the Single Ended eXperimenter's kit, amp and speaks for $200; a Heathkit W-1 thru W-5 shootout; a new, improved tube CD output; Eico HF 60 vs. HF 50 vs. HF 89; how to build the Superwhamodyne, a speaker for single ended amps; and a whole lot more!