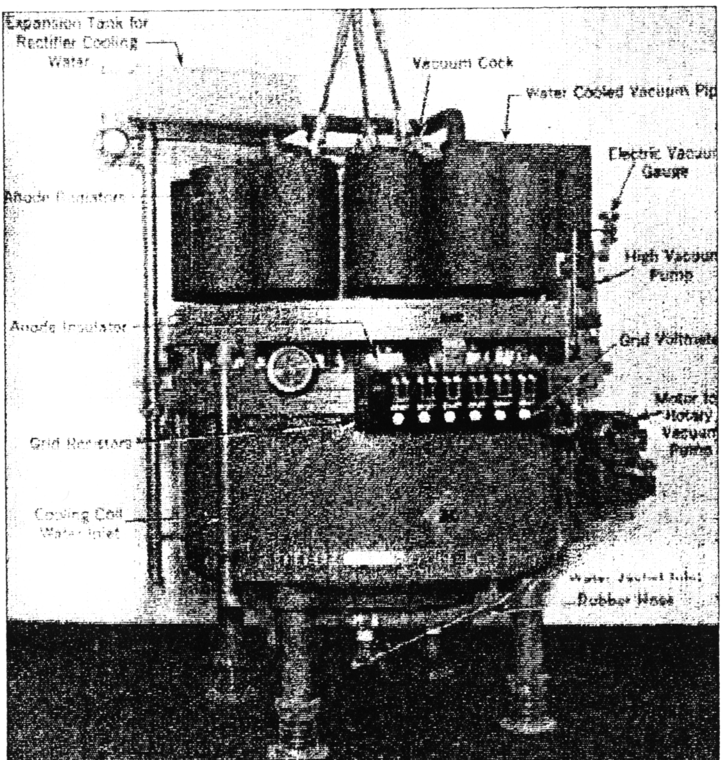
VALVE
PO BOX 2786
Poulsbo, WA 98370

VALVE

special issue: Dave and friends design and build a double 6DN7 push-pull amplifier with transformer input



The big daddy of rectifiers -
an Allis-Chalmers steel-tank mercury-arc rectifier
- for that special project-

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VALVE

the monthly magazine
for tube audio eXperimenters

Editor and Publisher
Dan "Dr. Bottlehead" Schmalle
Chief Administrator
Eileen "In Charge" Schmalle
Contributing Editors
David "Full Track" Dintenfass
Doug "Lazarus" Grove
Resident Smart Guy
Paul "Braniac" Joppa
Audio Archivist
Crazy Eric Lenius, the Fisher King, P.E.
Mapmaker
George "Always" Wright

Our mailing address:
VALVE
P.O. Box 2786
Poulsbo, WA 98370
by phone: 360-697-1936
fax: 360-697-3348
e-mail FKQF17A@prodigy.com

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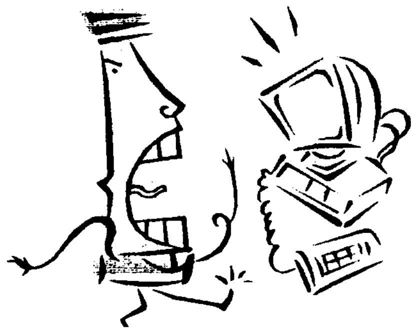


the new format

OK, I think we have something good going here. Dave suggested I try the new Microsoft Publisher 97 to produce this issue. Man, this is a nice program.

In an effort to bring our quality up to the level of our friends at SP and VTV, this issue is a major revamp. New, more readable fonts, a little copy protection in the form of the Mr. Bottlehead watermark, and some improved graphic stunts.

To celebrate this change we bring you another special project issue. If you keep up with the hardest of the hardcore DIYers, you know that the some of the hottest developments in the past few months revolve around the use of interstage transformers. Yeah, I know, some of you are shaking your heads, but, as usual, a little 'modern technology' applied to this technique from the early days of radio yields some pretty cool results.

"Full Track" has given us another very thorough article on the design rationale and actual construction of a low cost IT coupled amp, using one of our favorite "unknown" tubes, the 6DN7.

This is the start of what I think will be an interesting chain of developments over the next few months. We have some pretty interesting circuits coming your way.

Paul is helping me considerably in designing an SE 805 amp, we have some PP designs that seem to rival SE (did I say that?), and I am pushing to get a couple of interesting SEX amp conversions in to the next issue or two. Think 6B4 and 300B. Then there's George's circuits to boot!

For speaks we have some interesting thoughts on tapered pipes coming up soon, and we'll be getting an early look at the hot new cabinet kit from the Lowther Club of America.

Stay tuned for more fun,

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 MI200; 6L6 shootout; a vintage "audessey"; 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.

What we hope to have in 1996 ($25):
Single Watt, Single Tube, Single Ended, an amp for Lowthers; the Vintage Speaker Shootout of 1996, QUAD vs. Lowther, vs. A7; the Voigt Loudspeaker, the Single Ended eXperimenter's kit; cathode coupled SE 6AS7 amp; how to build the Superwhamodyne; refoaming AR woofers; mesh plate tubes; rebuilding QUADS; QUAD amp filter surgery, single gain stage amps, the Brooklet, a choke loaded PP 6080 amp, transformer coupled PP 6DN7 amp, and a whole lot more!

double push-pull fun with the 6DN7

The full-track mono guy does the push-pull thing with his favorite tube!

by David Dintenfass

Technical Consultants: George Wright, Paul Joppa

Let me say right now that I'm incredibly happy with my one-watt, single-ended 6DN7 amp (see the January issue of VALVE). I see no reason for any more power when driving my Lowther PM6-A in Acousta cabinets. On the other hand, a few more watts would be nice when driving slightly less-efficient speakers.

Rather then trying to pour more testosterone into my single-ended 6DN7 design, I decided to go push-pull. I wanted an amp that was cheap and easy to build, yet one that was a little on the oddball side. What I ended up with was a happy little four-watt power amp that sounds pretty damn good. And while it doesn't have quite the low-level detail and dynamics of a large single-ended amp, it does have a very smooth sound and extremely low distortion.

my favorite tube

As you may recall from my last article, my favorite family of tubes are the asymmetrical dual triodes used as combined vertical oscillator/amplifier in late 1950s television sets. The 6DN7 is one such tube—and what makes the 6DN7 attractive to audio cheapskates is its rather high plate resistance of 2000 ohms. Such a high plate resistance, while not uncommon for small power pentodes, is rather unusual for power triodes. What this buys you is the ability to use all those little 8–10K plate-to-plate output transformers that nobody else wants.

'Tis a sad fact indeed that by the time good output transformers were available in the 1950s and early 60s, only a few lunatic hobbyists (and practically no commercial manufacturers) were building triode amps. Consequently, ten-to-fifteen watt 2A3-friendly vintage iron (characterized by a 5000-ohm plate-to-plate primary) is nearly impossible to find. And priced accordingly.

Using a pair of 6DN7s lets us avoid the madness. At least for now—like all television tubes, eventually the supply will dwindle and prices will inflate beyond reason (and don't count on Svetlana to tool up for a Russian 6DN7 anytime soon). So while I hesitate to sing praises of my favorite affordable small triode, I am reasonably convinced that most of you reading this do not have speakers efficient enough to justify building one-watt SE or four-watt PP 6DN7 amps. *Hint: If you really want to build the four-watt amp, build a pair of Dan's Whamodynes to go with them.*

Of course, if prices should inflate, you can always use the 6FJ7. This tube uses a 12-pin duodecar base (unlike the 6DN7, which has an octal base). Personally, I like "compactron" tubes so I'm inclined to build the final version of this amp using 6FJ7s.

Another nice thing about the 6DN7/6FJ7 is that you get a small-signal triode in the same envelope. While this keeps the tube-count down in single-ended designs, it gave me a chance here to go with two stages of push-pull amplification (more on that a bit later).

finding output iron

To sniff out suitable iron, look for anything with a push-pull pair of 6V6s. That includes small hi-fi amps from the late 40s and early 50s and plenty of off-the-shelf commercial and broadcast gear up through the late 50s.

Chances are this type of stuff has a transformer with an 8K or 10K plate-to-plate primary. Either is perfectly adequate for the 6DN7/6FJ7.

Now before we jump headlong into discussion about tranformer loading, it's important to draw a distinction between loading for single-ended amps and for push-pull amps.

For a single-ended output stage, it's good to load the tube at 2.5 to 3 times its plate resistance. For push-pull however, heavier loading (say, at twice the plate resistance) is often used since the push-pull topology cancels the second harmonic distortion that results from heavier loading. Happily, this means we can be less fussy about output iron for our little 6DN7 push-pull project.

If you're technically-inclined, check out the related sidebar on tube loading, courtesy of fellow bottlehead and "resident smart guy" Paul Joppa.

I scavenged my output transformers from a pair of scrapped-out Magnecord PT6-J tape recorders from the early 50s. Since I had seen

seen the SAMS Photofacts on this unit, I knew it had a 10K plate-to-plate load (I also measured it with an impedance bridge, taking care to terminate the secondary with the proper resistance). The only drawback is that it doesn't have an 8-ohm tap. But it's got a 4-ohm tap, a 16-ohm tap, and a 600-ohm tap.

Before you copycats follow my lead, be advised that not all Magnecords had push-pull outputs. By the mid 50s, Magnecord made consumer versions of their broadcast decks (often in red or brown cases) which had considerably cheaper electronics with cathode-follower outputs. Only the broadcast models had push-pull transformers since they were designed to drive broadcast lines or a monitor speaker.

Another place to look might be some console radios from the late 40s and early 50s. These often had 6V6 outputs. While I'm not recommending that you trash good units, broken-down examples are often found in thrift-stores and at some of the larger radio swap meets.

Even some 6L6 gear (such as the HH Scott 99D integrated mono amps) had output transformers with 8K primaries. Others, however, used transformers with 6600-ohm primaries, so do your homework before removing parts.

The idea here is to find decent iron, but don't waste your time and bucks looking for the spectacular vintage iron (UTC and Peerless units, for example). Since flea-power push-pull designs don't push the transformer core near its saturation, linearity should be reasonable even with standard, off-the-shelf transformer—provided of course, that the output iron isn't truly wretched.

Besides, what do you care if the high end starts rolling off at 15 or 16 kHz? Unless your amp uses lots of feedback, amplitude flatness in the 20 to 40 kHz range is not required for routine listening pleasure. In fact, extended frequency response became necessary only when high-feedback amplifiers became popular in the 1950s—and only then to ensure stable amplifier operation.

Now if you're a bass freak, you may find that low-end response may suffer with cheaper transformers. There simply may not be enough iron in them. Remember, you need a certain amount of inductance (determined

(Continued on page 7)

Double push-pull amp specs (16 W load)

Amplitude flatness	±0.5 dB, 25 Hz to 20 kHz
3 dB rolloff points	20 Hz, 25 kHz
Total harmonic distortion @ 1 kHz	0.7% (1 watt) 5% (4 watts)
Intermodulation distortion (SMPTE)	2.5% (1 watt) 20% (4 watts)
Hum and noise	Better than 80 dB referenced to one-watt output
Voltage gain	27 dB

Loading output tubes

by Paul Joppa

In single-ended operation, the maximum power is obtained when the plate load is twice the plate resistance. Generally, a lighter load is used (say, three times the plate resistance) since it reduces distortion significantly while reducing power very little. Since the distortion is mostly second harmonic, which is canceled in push-pull, heavier loading (typically, twice the plate resistance) is acceptable with push-pull. As long as each tube conducts at the most negative grid voltage, it remains in class A. For the "reference" operating point (see my previous article in *VALVE*), even a perfectly linear tube is not cut off until the load resistance is reduced to 1.58 times the plate resistance. For the 6DN7, this suggests 8K as the ideal load, with a load no heavier than 6.3K; at the other extreme, loads as light as 10–12K are acceptable, with minimal loss of power.

But it gets tricky here. Tubes are not really linear devices—in other words, they don't always follow the simple Child's Law with constant mu for varying voltage and current. All triodes, to a greater or lesser extent, show a bunching up of the plate characteristic lines at low current and/or high voltage. This means you can reduce the plate load resistance even further without leaving class A by an amount that depends on the tube's linearity. Or you could raise the plate voltage and reduce the current but still keep the same load resistance. Either way, the circuit will begin to behave like class AB without actually leaving class A. In a single-ended configuration, this produces lots of second-harmonic distortion, so it's a bad thing. But in push-pull, it means more efficient operation and more power output—a good thing!

Of course, like class AB, the full-power average current exceeds the quiescent current by a larger margin so bias stability becomes important—in extreme cases requiring the use of fixed bias.

Now back to the 6DN7. To retain the advantages of cathode bias and stay out of this quasi-class AB region, you don't want to go much lower than a 6–8K load (plate-to-plate), and 8K would be ideal for a 2K plate resistance. But remember, that resistance is spec'd at 250 volts and 40 mA. When you run the 6DN7 at 300 volts and with less plate current (about 30 mA), the plate resistance is higher—at least 2.3K and probably more, so a good plate load might be pretty close to 10K. In practice, I'd expect a wide range to work fairly well, probably anything between 6K to 15K.

(Continued from page 5)

by the number of turns and the size of the core) to ensure adequate bass response and to keep the core from saturating at low frequencies (which causes distortion).

One way to prevent this is to go easy on the coupling caps. Far too often home-brewers of the "bigger-is-better" school will toss in a pair of 1.5 mF coupling caps in a design where the maximum value should be 0.05 mF. If you kill the extreme low frequencies before they hit the output transformer, you'll make the amplifier a lot more stable.

Now sometimes expensive transformers *are* necessary. For instance, when I built a microphone preamp a few years back, I shelled out for some Jensen input transformers, and they were worth every penny.

But you've got to keep this in perspective. Microphone transformers are special-purpose widgets that have things even the best output transformers don't need—triple mu-metal shields, electrostatic (Faraday) shields between windings, and nickel-alloy cores. With small push-pull output transformers, all an expensive price-tag usually ensures is more careful assembly and interleaved windings. Single-ended transformers, on the other hand, require careful air-gapping and a huge core to provide enough inductance, plus a lot of interleaving to ensure good high-end response with such a large core. And with the exception of "boutique" transformers (most of which are designed for single-ended applications and sometimes feature silver wire and other exotica), there's very little difference in the raw materials used.

budget push-pull

I'm convinced that you can build a wonderful little push-pull amp with modest output iron. In fact, one of the finest amplifiers I've ever heard was a Brook 12A—and If you ever saw how one of these little ten-watt wonders was assembled, you'd understand what I'm saying. The Brook was a garage-built amp. It used nothing exotic. No silver wire, no copper chassis, no fancy transformers. You could build one of these yourself. And it had a rather small, pedestrian output transformer—almost certainly a standard-issue item from one of the big transformer makers.

I believe the secret to the Brook was the combination of a low-feedback, push-pull low-mu triode design and a good driver circuit (which used a tapped choke in the ten-watt model). While some might argue that the Brook's good sound was due more to the use of direct-heated triodes (a pair of 2A3s) than anything else, I'm not yet convinced. Incidentally, now that famous tapped choke used in the Brook is again being manufactured (thanks to Mike Lafevre at Magnequest), expect more "Brook inspired" amp designs in future issues of *VALVE*.

circuit topology

Given my interest in vintage broadcast gear, I decided to use the pair of 6DN7s in a double push-pull stage and an interstage transformer for a phase-splitter to feed the first half of the 6DN7s.

To drive the interstage transformer, I originally used a single 6J5 metal triode in traditional plate-coupled configuration, with a small amount of negative feedback injected at the cathode. After experimenting a bit, I realized I didn't need the extra sensitivity that 6J5 provided—all it did was add noise (and reminded me just how microphonic 6J5s can be). So I decided to abondon the 6J5 stage and simply drive the input of the interstage transformer directly. As it turns out, this works very nicely.

For unbalanced inputs (for example, from the output of a typical preamp), ground one side of the interstage primary. Since the primary of the interstage is 10K, be sure your preamp's output impedance is 10K or less.

Due to the balanced nature of this design, the distortion is quite low without global feedback. If you want to add it, you can put a 100-ohm resistor in series with the ground side of the interstage primary (see schematic) and inject the feedback from the 16-ohm transformer tap via an appropriate feedback resistor (start with 47K, but you'll need to experiment for best results). *Don't forget to ground the common tap on the output transformer secondary if you add feedback.*

For balanced inputs, connect the ground shield on your input cable to the ground bus and connect the hot and neutral inputs to the interstage primary. If your balanced feed needs to see something less than 10K, shunt the primary with an appropriate resistor (for example, 600 ohms to terminate a 600-ohm balanced line). Forget about global feedback with the balanced configuration—there really isn't a good way to add it.

why the interstage iron?

In any push-pull amp, the phase-splitter (also called the "inverter") is a critical component since it sets the balance for the push-pull stage. A phase-splitter can be a passive device (a transformer) or an active device (a vacuum tube).

The ubiquitous *Cathodyne* (sometimes called a split-load inverter, or *concertina* inverter) is an example of an active inverter which uses a single triode stage. This takes advantage of that fact that in a single gain stage, the signal developed across a cathode resistor is out-of-phase with the signal across the plate resistor. For years, controversy raged over whether the Cathodyne maintained its balance at high frequencies—one camp argued that the higher impedance of the plate circuit is more sensitive to stray capacitance, thus introducing high-end rolloff and consequent phase shifting. Another camp maintainted that any imbalance of this nature was automatically corrected (the exact reason why is beyond my understanding).

Still, the Cathodyne inverter was enormously successful. It was cheap, it was easy, and it worked quite well most of the time. You'll find the Cathodyne inverter used in many of the classic hi-fi amps. Typical front ends used a dual medium-mu triode (6SN7 or 12AU7) or a pentode/triode tube (6AN8 or 7199) to provide initial voltage gain before splitting the signal at the second half of the tube. When amp designers pinched pennies (for example, David Hafler of Dynaco fame), the output of the inverter went directly to the output tubes. Other amps, such as the classic Williamson (and Heathkit variants) inserted a push-pull driver stage between the inverter and output stages, usually, a 6SN7.

As I mentioned, phase imbalance due to poor inverter design means that at some frequencies, one side of the push-pull stage is fed too much (or too little) of the input signal, causing distortion. And while this is minimized in the better designs, an active phase-splitter does require an extra tube and associated components. In contrast, a transformer phase-splitter has consistent balance that doesn't degrade over time. But there's no free lunch. As we'll see, finding a good interstage transformer is not a trivial task.

about interstage transformers

Dating back to the 1930s, many commercial and broadcast amplifiers used multiple push-pull stages or a combination of single-ended and push-pull stages. Older triodes didn't have a lot of voltage gain, so interstage transformers were used. Given that transformers can match impedances easily, they could provide an optimal plate load for a preceeding gain stage, then step up the voltage for the following gain stage without loading the grid of that tube. In other words, "free" voltage gain, which meant fewer tubes (which were *very* expensive in the early days).

For battery-powered radio equipment, fewer tubes meant cheaper radios, with less battery drain. And since transformer-coupled stages don't need plate resistors, yet another source of wasted power was eliminated.

Interstage transformers simplified amplifier design and ensured durability. Which is why, for example, jukebox amplifiers from the 1930s and early 40s used them. Typical configuration was a simple four-tube amplifier using a 56 to drive a pair of 2A3s through an interstage transformer (the fourth tube was a usually a 5Z3 rectifier).

Before we go any further, keep in mind that we're speaking here of interstage transformers for *audio-frequency circuits*. For radio-frequency circuits (such as the RF and IF section of your typical AM or FM tuner), transformer-coupled stages are pretty much the only way to fly—and have been in continuous use for these applications right up to the present day. That's because at high frequencies, interstage transformers can be made small and cheap, with powdered iron cores. And they can be easily tuned to pass only certain frequencies.

now here's the rub

Sounds too good to be true, doesn't it? Well, there were (and still are) some serious constraints. Good audio-frequency interstage transformers are difficult to manufacture. Early designs were simply awful, with limited frequency response and lots of distortion.

Later, when good iron and improved vacuum tubes were available, interstage transformers and multiple push-pull stages were used in broadcast gear since harmonic distortion (mostly the second harmonic) and hum are canceled at each push-pull stage. And nothing couples a single-ended stage to a push-pull stage (or a push-pull stage to another push-pull stage) quite as elegantly as an interstage transformer. So long after the battery-powered radios of the 1920s were gone,

Parts list for amplifier (per channel)	
Capacitors	0.047 mF/400V film (2) 100 mF/50V electrolytic (2) 10 mF/400V electrolytic (2)
Resistors*	39K (1%) 1/2-watt (2) 1.8K 1/2-watt (1) 100K (1%) 1/2-watt (2) 470K 1/2-watt (2) 1K 1/2-watt (2) 220W 2-watt (2) 2 Meg 1/2-watt (2) 100W 2-watt linear pot (1)
Output transformer	8–10K plate-to-plate, 10 watts
Interstage transformer	10K–90K (1:3) nickel-core Antique Radio Supply part no. PT-157
Tubes	6DN7 or 6FJ7 (2)

*** For lowest distortion, use 1% resistors where noted**

widespread use of high-level 600-ohm balanced lines whenever an audio signal traveled from point A to point B. Such balanced lines made possible the use of long, unshielded runs of twisted-pair telephone cable for program distribution.

Of course, broadcast equipment was designed primarily for reliability—distortion specs and general fidelity of this gear did not keep pace with the explosive growth of the commercial hi-fi scene by the mid 1950s. While interstage transformers kept the parts count low and the reliability high in the world of broadcast amplifiers, the times were a-changing...

On the post-war commercial hi-fi scene, interstage transformers went the way of the buggy whip. As power pentodes and tetrodes became popular in the early 1950s, interstage iron wasn't needed since the new crop of power tubes were far easier to drive. That's because only a very small voltage swing is required on the grid of a pentode or tetrode to effect a significant change in plate current—unlike low-mu triodes like the 2A3, where you need huge voltage swings to vary plate current.

gone, interstage transformers were still around.

Multiple push-pull

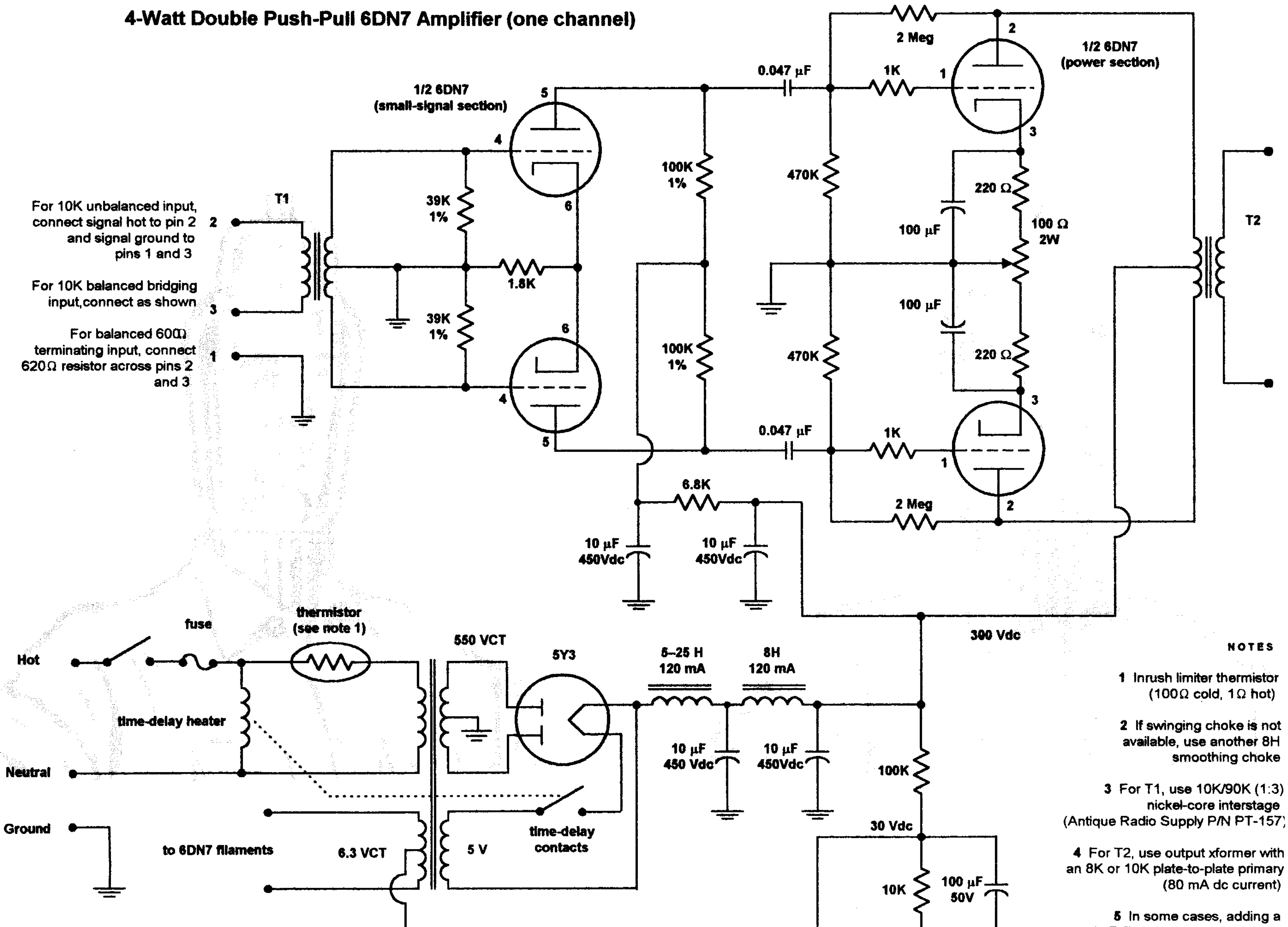
Related to the discussion of interstage transformers is the use of multiple push-pull stages. In the early days, the easiest way to design such stages was to use interstage transformers, though later on, multiple push-pull stages were RC-coupled.

Back at the radio station, multiple push-pull stages were often used to ensure rugged, reliable service and to reduce hum and second-harmonic distortion. Hum-reduction, in fact, was a way of life in the technical side of the broadcast business and influenced the design of just about everything, including the

With the exception of the 6AS7, even the hard-core DIY fanatics weren't using interstage transformers. You could get better transient response—without an extra chunk of expensive iron in the signal path—with a well-designed active inverter stage. And if you wanted to use feedback to extend frequency response and lower distortion, forget about an interstage transformer. The additional phase shift incurred with two transformers in the signal path made feedback exceptionally tricky and amplifier performance highly load-dependent.

Incidentally, if you're curious about the 6AS7

4-Watt Double Push-Pull 6DN7 Amplifier (one channel)



NOTES

1 Inrush limiter thermistor (100Ω cold, 1Ω hot)

2 If swinging choke is not available, use another 8H smoothing choke

3 For T1, use 10K/90K (1:3) nickel-core interstage (Antique Radio Supply P/N PT-157)

4 For T2, use output xformer with an 8K or 10K plate-to-plate primary (80 mA dc current)

5 In some cases, adding a 1 µF film cap across the output xformer primary may improve high-frequency response

(which enjoyed a brief popularity in the late 40s/early 50s), see the McProud articles in Volume 1 of Old Colony's *Audio Anthology* reprint.

Modern interstage transformers

Today, it's nearly impossible to find good interstage transformers, particularly ones that can drive a pair of low-mu triodes directly. This has to do with the number of turns required, the small wire size, and the need to have enough iron to avoid saturating the core with plate current.

Most interstage transformers are single-ended (with a tapped secondary), so core saturation is always a concern. With unbalanced dc on a transformer winding, the core will saturate (introducing terrifying amounts of distortion) without an air gap. And using an air gap lowers the primary inductance, which forces the transformer designer to use lots more iron. And so on.

Core saturation is not as problematic with microphone transformers since normally, there's no dc bias on the input of a microphone transformer (we'll skip discussions of phantom powering for condenser microphones at this point). However, you can still saturate the core with a strong audio signal, particularly when there's lots of low-frequency information.

Today, the almost non-existent demand for good interstage transformers makes them exceedingly expensive. Most of the people making single-ended output transformers cannot wind interstage transformers. The tiny wire size and the sheer number of turns involved requires costly, specialized equipment. As of this writing, the only people stateside who can probably wind a decent interstage transformer are Jensen Transformers. In my opinion, they also make some of the world's best microphone transformers and they make some pretty neat tube-to-line output transformers too (but nothing large enough to drive speakers). *However, I'm not sure they make anything that operates with dc bias (such as an interstage transformer would require).*

If you're serious about custom-wound interstage transformers, another vendor to consider is Sowter Transformers of Ipswich, England. Like Jensen Transformers over here, Sowter has an incredible reputation among British studio engineers, particularly with regard to microphone transformers. Sowter makes all sorts of audio and power transformers too, and their company literature says that they make custom interstage units as well. Sowter's prices are reasonable (even with the added hassles of currency exchange).

A few of the Japanese high-end transformer makers have interstage unit available. However, they are extremely costly and are rather large units designed for driving high-power triodes.

let's use the cheap stuff

I figured if I was going to design an amp with an interstage transformer, I wanted to find an inexpensive, off-the-self item so those of you reading this could build this amp too. That's why I decided to use the world's most affordable interstage transformer. *Didn't know there was such a thing, did you?*

Check out the Antique Electronic Supply catalog. They have a deluxe replacement-grade interstage unit with a nickel core for $12 (they have an iron-cored version for $9). This is a pretty standard interstage unit with a 1:3 overall turns ratio (that's a 1:9 impedance ratio) with a centertapped secondary. This transformer is designed for a split 90K termination (45K from each leg of the secondary to the centertap) to provide a primary impedance of 10K.

Both types are made in Mexico and were designed for the antique-radio crowd, not hi-fi people. Feeling flush at the time, I decided to pop for the $12 nickel-cored version. As it turns out, this transformer isn't bad—*if you don't overload it.* This means not putting anything more than 3 mA or so on the primary—even though the catalog lists maximum dc on the primary at 10 mA (which is probably okay for the iron-cored version).

Nickel cores are often used in small-signal applications since they give better low-level linearity. Nickel (or more precisely, the special nickel alloy used for transformer laminations) has far better permeability (and less residual magnetism) than the standard transformer iron. In simplistic terms, this means that as the magnetic flux in the transformer core changes direction—which it will, given that we're feeding an ac signal into the primary—there's less residual magnetism to overcome (less hysteresis) with markedly better linearity. That means less distortion. (Unfortunately, a nickel core also saturates much more readily, which is why you won't find this material used in output transform-

parts list for amplifier (power supply)

Capacitors [1]	10 mF/400V oil or electrolytics (4)
Chokes [2]	120 mA 5–25 Henry swinging choke 120 mA 8 Henry smoothing choke
Transformer [3]	550 VCT @120 mA, 5 Vac @2A, 6.3 Vac @ 4A
Time-delay relay	Normally-open 30-second delay with 110–125 Vac heater (Amperite 117NO30)
Tube	5Y3 (1)

[1] Two of these caps are on the amplifier chassis

[2] swinging choke isn't available, use two smoothing chokes

[3] Ratings are for stereo power supply; also, note that each 6DN7 heater draws 0.9 amps—use transformer with adequate 6.3-volt winding

If using a capacitor-input power supply, use 500 VCT power transformer

ers.)

For this application, we can get away with a cheap interstage transformer since we're not using it to drive output tubes directly—rather, *we're using it to drive the driver tubes.* This avoids the possibility of saturating the core with audio from a high-level driver stage (something which is a real concern if you use an interstage transformer to drive a pair of 2A3s).

However, you must take extreme care not saturate the core with any plate current from a preceding gain stage. More than a few mA of dc plate current on the primary will get you into trouble. In my original prototype, I used a 6J5 circuit with a 1K cathode resistor and 150 volts on the plate. This yields a plate current of 8 mA. When I powered on for the first time, the amp sounded terrible.

With some trepidation, I hauled out the old Heathkit AA-1 distortion analyzer and measured 30 percent intermodulation distortion, even at reduced levels. Since the distortion did not vary much with input level, I guessed (correctly, as it turns out) that I was saturating the interstage transformer primary with too much plate current from the 6J5 circuit. Subsequently, I reduced the plate current to 3 mA by changing the 6J5 cathode resistor to 2.2K and lowering the plate voltage to 135 volts. Although this worked, I decided to abondon the 6J5 entirely. It's nice to no longer worry about dc bias on the interstage primary!

component selection

As I mentioned earlier, my push-pull amp is essentially two mirror-image copies of my single-tube, single-ended 6DN7 design featured in the January 1996 issue of *VALVE* with some refinements. For one thing, I doubled the size of the coupling caps to improve low-end response (now that we have a push-pull transformer, we can expect improved bass response). Secondly, I lowered the plate supply a bit, from 330 to 300 volts to reduce plate dissipation on the output section of each tube.

I also opted to stick with cathode bias. With fixed bias, you can squeeze more power from the output tubes, but the potential for disaster is very great should the bias supply fail, and bias balance is far more critical and must be readjusted as the output tubes age. Cathode bias, on the other hand, is pretty much selfbalancing and generally produces less distortion for a given amount of power.

I did include a dc bias-balance pot to minimize hum (My friend Pete Peters has suggested that this may also reduce THD, but only if the driver stage has near-perfect balance). To set the dc-balance pot, short the amplifier input, then adjust for minimum hum at the output. Note that unless your speakers are incredibly efficient (and you're in a quiet room), you may need to use headphones to hear any hum.

For icing on the cake, you can add a 20K balance pot to feed the plate resistors in the first push-pull stage. If you have a harmonic distortion analyzer, you can feed a test signal into the amp and adjust the ac balance of the driver stage for minimum distortion. This isn't necessary, however, and I didn't include this feature in my prototype unit since I used one-percent plate resistors. (If you include this pot, reduce each plate resistor from 100K to approximately 90K.)

power supply

This was pretty straightforward, and designed with an eye toward simplicity and long life. It also requires virtually no maintenance. It's a conventional choke-input supply with a few twists (all credits for the twists belong to George Wright, who suggested them).

There's a stock 117-volt normally-open time-delay relay. This turns on the 5Y3 filament after 30 seconds to delay application of B+ to the tubes. There's also a small thermistor on the primary of the power transformer to lessen "turn-on shock" and drop the primary voltage slightly (not a bad idea since line voltages routinely push the 125 Vac mark).

To reduce hum, I used a 100K/10K voltage divider and fed the resulting 30 Vdc into the centertap of the 6.3-volt filament winding. The floats the heaters above ground and reduces heater-to-cathode leakage. If you don't have a centertap on the filament supply, add one by using two 100-ohm resistors (a technique which I used in the single-ended 6DN7 amp).

"smoke testing"

As I mentioned earlier, intermodulation distortion was outrageous due to the 8 mA dc current on the interstage primary. Once I reduced the 6J5 plate current, things behaved nicely. But before I chucked the 6J5 circuit, I wanted to verify that the problem was with the interstage transformer. So I tacked in an old UTC A-19 interstage transformer. This has the same turns ratio (1:3 overall) but it worked much better. Not only was there far less distortion, but there was much more gain—an immediate tip-off that I'd been saturating the AES unit (once you saturate a transformer core, the peak-to-peak value doesn't increase at the secondary, no matter how large a signal you stuff into the primary).

In all fairness, the UTC probably has a conventional iron core and thus didn't saturate as fast as the nickel-cored AES unit. However, the AES unit actually worked *better* than the UTC interstage once I reduced the plate current! Less distortion, better high-end response!

adding feedback

Initially, I used 7 dB of global feedback via a 15K resistor from the 16-ohm secondary tap to the cathode of the 6J5. The feedback lowered intermodulation distortion significantly, from approximately 3 percent to 1.7 percent (2 watts output). It also extended the frequency response, which was now 3 dB down at 12 Hz and 32 kHz. However, I now measured a pronounced 6 dB hump centered around 22 kHz (extending downward to 5 kHz). Such are the hazards of "stacked" transformers.

To reduce the hump, I increased the feedback resistor to 47K (which lowered global feedback to 3 dB). At George's suggestion, I also added some local feedback using 2 Meg resistors from the plate to the grid of the output section. While distortion went up slightly, the response flattened considerably. The 3 dB point at the top end was 22 kHz. Overall voltage gain was still generous, at 25 dB.

Then I reinstalled the AES interstage transformer. The high-end response was even better! The 3 dB point was now 30 kHz (with a low-end rolloff at 30 Hz). Intermodulation distortion was quite low—about 0.5 percent under 1 watt and rising to about 22 percent at 4 watts (which told me that maximum power was indeed 4 watts).

After letting the project sit for a few weeks, I decided the design was too complex, and the parts count was edging up uncomfortably. That's when I decided to abondon the 6J5 driver stage and forget about using global feedback. The input signal would go directly into the interstage primary.

Test results for the simplified design were impressive. With a 16-ohm load, 3 dB points were 25 Hz and 25 kHz with a 1.75 dB hump were 25 Hz and 25 kHz with a 1.75 dB hump at 17 kHz. Voltage gain was 25 dB—exactly what it was with global feedback and the extra (and noisy) 6J5 gain stage. Total harmonic distortion was low—0.7 percent at one watt, 5 percent at four watts. Intermodulation was also acceptable—2.5 percent at one watt, 20 percent at four watts.

To smooth the 17 kHz hump, I changed the loading resistors on the interstage secondary from 47K to 39K. This flattened the hump nicely without rolling off the high end.

construction hints

Since the interstage transformer secondary leads are not color-coded, you may want to determine their orientation to ensure that you don't have an overall phase inversion. Using a dual-trace oscilloscope and a signal generator, feed the test signal into the transformer primary, then compare the input signal to the output signal (put one scope channel on the primary and the other on the secondary). Of course, you can always wait until you build the amp, then feed the generator into the amplifier input and monitor across the speaker leads.

If you don't have an oscilloscope, you can still test the interstage transformer. You'll need a signal generator and an ac voltmeter. Connect the primary and secondary in series (ignore the center-tapped leads), then apply the test signal *to the primary leads only* but measure the output voltage across both primary and secondary. Now reverse the secondary leads and see if the signal decreases or increases. In effect, you're configuring the transformer as an autotransformer and seeing if the secondary bucks the input signal (out-of-phase condition) or boosts the signal (in-phase condition).

This technique is useful only for transformers with relatively narrow turns ratios (such as our interstage transformer with its 1:3 ratio). For output transformers, the turns ratio is so large that you're not likely to determine whether you're bucking or boosting. But in most cases, the output transformer's leads are color-coded (blue is the hot side of the primary; brown is the low side).

I prototyped the amplifier on a scrapped-out Magnecord record/play chassis. Nothing fancy here, but I did use a ground bus for the signal ground (if you don't have bus bar, find a piece of #12 Romex and break out your wire stripper). Connect this bus to the chassis at one point only. If you have a power supply on a separate chassis, consider keeping the ground bus isolated from the amplifier chassis entirely. In my case, I used a separate ground wire to connect the power supply chassis and the amplifier chassis. I ran a second wire (connected to the ground bus) from the amp to the power supply and made contact to the power supply chassis at one point only.

I see no reason to use a copper chassis for power amplifier construction, at least not for anything other than cosmetic reasons (which may be good enough for you—personally, I don't care for polished copper). For one thing, the signal levels just aren't low enough to require an ultra-conductive electrostatic shield. Steel or aluminum is entirely serviceable. The only possible justification would be if you're also using the chassis as a signal ground—but decades of commercial and radio-amateur construction practice have demonstrated that for lowest noise, it's best to use separate signal and chassis grounds when you have transformers on the chassis (this has to do with stray magnetic fields inducing circulating currents in the chassis ground).

Finally, be sure to use moderately heavy wire for the filament leads (those 6DN7s draw a respectible amount of heater current). Twist the leads and route them away from signal leads (if you need to cross signal leads, do so at right angles). And while we're on the subject, don't even think about using the chassis as a ground return for one side of the filament line. Mass-market radio and hi-fi manufacturers did this to save a few pennies on wire, but this practice induces hum like nobody's business.

acknowledgments

Kudos and thanks to the "usual suspects" (and fellow VALVE members) George Wright, Paul Joppa, and Dan Schmalle. I'd also like to thank Pete Peters (Seattle, Washington) for additional technical review. Yet more thanks to those of you who made it to the April meeting for admiring my prototype unit.

possible sources for interstage transformers

The interstage transformer from Antique Electronic Supply is entirely adequate, and it's cheap. Nonetheless, if you'd like additional information about custom-wound transformers, you might contact the following vendors. Disclaimer—I have not contacted any of these manufacturers, but I do know that Sowter now has interstage transformers available.

Jensen Transformers Inc.

Jensen Transformers Inc.
7135 Hayvenhurst Ave
Van Nuys, California 91406
(818) 374-5857 (voice)
(818) 763-4574 (FAX)

Sowter Transformers (EA Sowter, Ltd)
PO Box 36
Ipswich IP1 2EL, United Kingdom
01473-252794 (voice)
01473-236188 (FAX)

next month:

⇒ **the "iron maiden", a transformer coupled 6080 amp**
⇒ **the "brookson", a PP amp with SE sound potential**
⇒ **calculating A2 operating points**
⇒ **tapered quarter wave tube enclosure for the S.E.X. driver**
⇒ **baby "O" mods**
⇒ **an a bunch more stuff!**

tubes on tape

VALVE member Mike States announces the release of a new 11-song cassette by the band WILD FRONTIER called "Spirit of Adventure".

The music is a blend of melodic rock/country/folk/blues. Since it doesn't fit neatly into any category, WILD FRONTIER calls it "American Classic".

Three years in the making and re-making, the songs were recorded all analogue with a variety of vintage tube and Class A discrete devices at the front end

"We used Neumann and Sony tube mics, RCA ribbon 44's and 77's, Ampex and Manley tube mic preamps and a variety of tube and vintage compressors by Gates, Collins, RCA, Neve, UREI and Manley," says Mike States, chief engineer and co-producer.

"Everyone has been commenting about how thick and tubey the songs sound. That's what we wanted. It's the antithesis of digital," States adds.

Cassettes are available for $12 postage-paid to Wild Frontier, Box 81485, Fairbanks, AK 99708.

We were sent a copy to have on hand for auditions on our new/old Nakamichi 1000. As Mike says, the tube sound really comes through nicely.

Introducing Brooklyn. Push-pull transformers that sound single-ended.

Single-ended transformers have gorgeous inner detailing due to their air gap.
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B15	10,000 CT	20W	50	5	$125
B17	9,000 CT	30W	50	5	$140
B18	8,000 CT	15W	45	5	$120
B20	6,600 CT	30W	70	7	$140
B21	5,000 CT	20W	80	8	$120
B23	4,000 CT	50W	100	10	$150
B24	3,000 CT	15W	75	7.5	$125
B27	1,500 CT	30W	150	15	$135

Note: Above units available with Ultralinear taps for an additional $6.00 per unit
Secondary impedances far all units are 2,4,8,12 & 16 ohms.
Guaranteed minimum frequency response is +/- 1 dB, 30Hz to 20 kHz.
All units supplied with vertical bell end caps.
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Cherryville, PA 18033
(215) 288-4816

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To purchase any of these products, please send your order and payment to:

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3516 So. 262nd, Kent WA 98032-7047

For further information, please leave a message at (206) 859-3592

cravings

for sale:

Karlson K-15 speaker box with documentation for loading Altec 416 or 515B to create a mono subwoofer. Needs to be refinished. $75, you pick up please.

Pair mono PP 6B4G Simplex 1027A amps (consecutive S/N). Super clean with quality parts (Jensen caps, etc.) and mucho documentation. $600.

Dewald tube integrated stereo amp. Collectable 50's styling, $60.

RCA 5CP1-A round scope tube, NOS, $30.

Pair E-core low DCR 8 ohm 500Hz speaker coils $20.

Delmonico stereo tube table radio with schematic - lights up but no sound, $35.

Pair MOODY SMALL HORN loudspeakers. Fostex 8 inch co-ax with planar tweeter in 23-1/2" wide x 27-1/4" high x16-1/2" deep rear loaded cabinet. 92dB sensitivity, high quality outboard crossover and very smooth sound quality. Ready to finish, $600. You pick up please.

Tom Vetromile
206-546-0857

wanted:

Passive NAB schematics for 7.5 ips and 15 ips

REL precedent tuner

Jim Dowdy
770-451-0087
fax: 770-451-5684

september

The September meeting was a fun one. Here's a quick run down of what we heard:

John brought a TL speak using a Focal 7" mid-bass and a Dynaudio Esotech tweeter. The crossover had yet to be developed, so we fooled with some ideas, and John will return with a modded version in the future.
John also brought an amp based on Herb Reichert's Flesh and Blood circuit. It used the FS-030's which usually reside on John's Baby O's. A nice amp, but I gotta say, not up to the Baby O's level. Blame it on the Golden Dragon 300Bs? We only measured about 3.5W out at 5% THD, and by comparison the S.E.X. amps were richer, with better bass.

Paul brought an improved version of the 417A amp, with a better power supply. This thing has got potential!

doc's hot tip:

Dave knocked me out with an improved version of the "Brooklet" 6080 amp he struggled with last month. This time it had a better power supply and an output transformer that would take the high (125mA) current load of the 6080. This amp uses the center tapped inductor offered by Magnequest, to load the driver plates.

Guys, you know I am a dyed-in-the-wool SE man. This amp is so close to SEX that I had a hard time telling them apart, save for the higher power of the Brooklet. The only other amp I would say that about is a Brook 12A. This center tapped choke is a must try item! They are reasonable, and Mike Lafevre has a good supply on hand. What are you waiting for? I bet they would be a knockout fitted in to your favorite old Williamson type amp.

We hope to be trying this amp with the Brooklyn B27 air gapped output transformer soon. To say my expectations are high is an understatement.

To top this off, Dave brought his best DAT taped concert yet. He will bring one he says is even better to the October meeting. Wow!

Doc B.

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