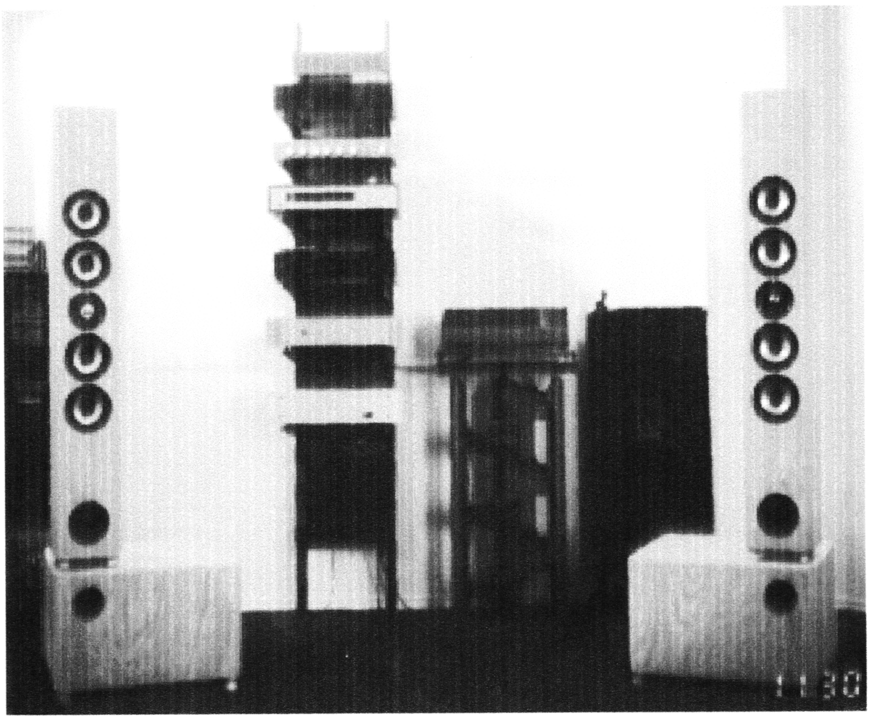
VALVE

in this issue:

Whamos - variations on a theme
Build the weirdest interconnect on the planet
Winding a SE output trans - part 1
letters on battery bias, TQWT, S.E.X.



Jim Flower's Superwhamodynes

volume 4, number 1 **January 1997**

VALVE

the monthly magazine
for tube audio eXperimenters

Our mailing address:
VALVE
P.O. Box 2786
Poulsbo, WA 98370
by phone: 360-697-1936
(hours: 9-6 PST, Mon -Sat)
fax: 360-697-3348
e-mail FKQF17A@prodigy.com

Rates:
Membership/Subscriptions:
$25.00 per year (12 issues)
Foreign Subscriptions:
$35.00 per year (12 issues)
Please make checks payable to VALVE
MC/VISA/AMEX accepted

VALVE *in no way assumes responsibility for anyone harming themselves through exposure to the contents of this magazine. We believe electrons flow from minus to plus, and that they can kill you along the way if you're not careful. Vacuum tube audio equipment operates at potentially lethal voltages. Always treat it with respect.*

editor's thing

Yo Bottleheads,

Happy New Year! Our first issue for '97 is red hot. Along with carrying on our developments of last year's projects, we will be adding some fresh angles on tube DIY for the ever growing segment of subscribers who are ready to jump into creating their own designs.

I've gotten lots of calls the last six months from folks who are envious of those who work up the gonzo designs we put in the pages of VALVE, and say, "I wish I was as cool as those studs who work up those gonzo designs in VALVE. I bet they're real chick magnets."

Well, fret no longer bottleheads.

Each month we will tackle a particular aspect of amp design, hopefully at a level that doesn't lose the neophytes and doesn't bore you amp-a-month types.

What's for starters? One of the most critical parts of the whole deal, the output transformer. Yup, Jim Flowers is gonna show you how to design and wind your own single ended output transformer.

And the man himself, Magnequest's Mike Lefevre, will offer commentary on the story as it develops.

Now this won't be a cake walk. If you really want to roll your own you'll have to do a little math here and there. You guys call me and tell me you want to know how to design. But then you say you don't like to figure stuff out on your own. Guess what? Can't have it both ways, bottlehead. Designers use math!

We will attempt to give you the tools you need to INVENT your own stuff. This won't be "use brand X caps because they have a more piquant image and a well traveled midrange clarification". This will be "to figure out the cathode resistor value, start with the basics, V=IR.

And hey, if you come up with ideas for what you would like to see covered the next few months, let me know.

But be forewarned, most guys who come to me with an idea for an article get talked into writing it!

Don't let the blue smoke out,

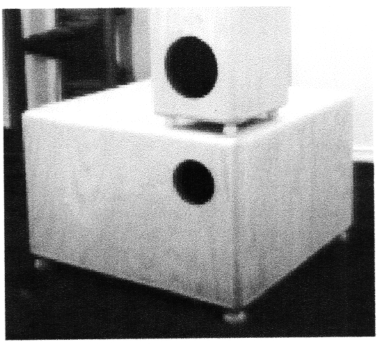
Dr. Bottlehead

on the cover

Jim Flowers has been a busy boy. Along with putting together this month's new series on winding a single ended output transformer, Jim has recently completed his vision of the Superwhamodynes. Here's what he has to say about them:

"Please find enclosed one dollar for Crazy Eric and the visual proof that the Whamos are finished. I worked way too hard on the cabinet exterior to avoid shamelessly showing it off.

I deviated ever so slightly from the supplied plans to fit my construction goals. Most obvious, I cut circular vents to keep with the rounded motif. The vents are fitted flush with black Radio Shack speaker-grill foam (reversed to hide the squares). The flat part of the tower's face is 6 inches wide but the overall width was increased to 7.5 inches to allow for rounded corners.



The cabinet depth was shortened to maintain the interior volume. After cutting the tower panels to the new dimensions, I read (too late) about the golden ratio of cabinet dimensions. I have violated that rule by changing to a more squarish cross section. It apparently hasn't caused any major harm because the speaks sound quite good.

I found the 12 gauge too hard to work with and substituted double runs (twisted together) of 16 gauge solid core (or was it 18 gauge?). The speaker binding posts are cut into the bottom of the cabinets instead of the back side like most speakers.

The cabinets are braced throughout with additional bracing at the Frankenpoints. I'll probably add even more bracing to the subs. Additionally, I might bolt the towers to the subs because I have a 4 yr old and a 2 yr old who love to topple things over." JF

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.

Volume 3 - 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, and Brookson, choke loaded PP 6080 amps; transformer coupled PP 6DN7 amp; the Iron Maiden; Building the Lowther Club Medallion; the TQWT, a tapered pipe enclosure.

how to make the best (and wierdest) interconnects you ever heard

by Bill "Wahrmayun" Wells

Geez, what can I say. This is out there with painting blue lacquer on everything and stuffing your CD player with green lights. Wireman called me one day and basically said, "Don't ask any questions, just build the things exactly like I say."
I did, and the spendy long crystal copper superconducting magnet wire interconnects I was using between the DAC and the preamp are now neatly coiled on the shelf as backups. I pulled John Tucker's chain the other day by making him listen to the long crystal jobs all afternoon while we auditioned a couple of his DACs. Just as he was leaving I put these "butt nekked and spread wide" jobs online instead. He looked amused and surprised until the music started. Then he just looked surprised..
A warning-
These are the most impractical interconnects you will ever use. The bare wires try to short on everything, including each other, and they are extremely difficult to route from one piece of equipment to the next. I'm lucky to have a fairly EMI free listening room, but I imagine these interconnects would pick up hum in a 'dirty' environment. However, if your listening room is 'clean', they are most definitely worth the hassle!
Here's Wireman's special Kentucky style recipe:

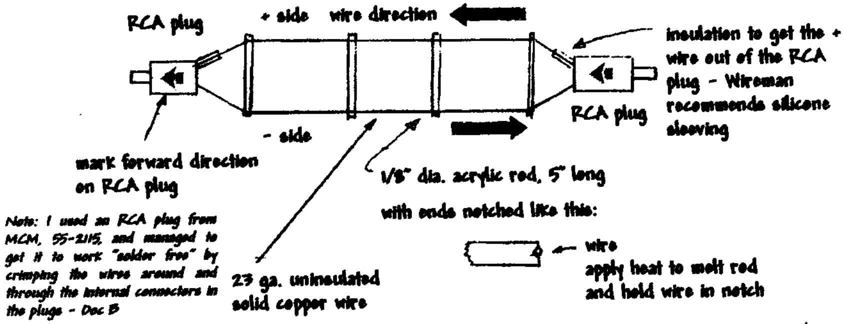
To get over the "shock", the finished cable will look like this:

Now for the fun part. You'll have to orient the wire for forward direction!
To do this, take your spool of wire and turn down the end of the wire 1/8". Reel off 3 or 4 foot, cut and do the same thing again.
You now have two wires.
Next thing you need is a metal dome tweeter - not a good one!
Now hook up one wire to your amp's + side and hold the turn down end to your tweeter's + side.
Then, the other wire with the turndown end, hook it to your amp's - side, and hold the - wire to your tweeter's - side.
Turn on music - not loud!
Then listen.
Then reverse the wires.
Then listen.
Boy is there a difference! When the wires are backward the sound can't get out of the tweeter, plus, you can hear distortion!
The next thing to do is assemble a pair of interconnects. Very simple, just follow the diagram.
Let's talk about a few other things:

- Wire - you can use 22,23 or 24 gauge wire, just so it's solid copper uninsulated. The difference between 22/24 gauge is 22 gauge will have more bass, less highs; 24 gauge less bass, more highs - so?
- RCAs - The small sizes are "best", the larger sizes "hold" too much, they "slow" transient speed and are "additive" to the sound. I use the Cardas GRCH. Well, RCAs are like capacitors - the best RCA is none. Can anyone come up with a workable solution?
- Solder - Use silver bearing solder.

How do they sound? I've A/B'd them against some of the best, $375-$800, and "those" sound like the garbage can!

Good listening,
The Wireman



winding your own single ended output transformer part one

by Jim Flowers

I've read well written articles about building single-ended tube amplifiers which made me want to make one for myself. The reality of completing such a project always ran into the same snag, I'm too cheap to spend the big dollars for the output iron. Suitable power supply transformers can be found as surplus, but I apparently live in an output transformer poor part of the country. I'm also amazed by what some of you can find in your junk box or at the swap meet. Well maybe not you, but some of the guys who author the tube amplifier articles in Sound Practices or Glass Audio can go to their junk box and unearth a spare Acrosound transformer for the type 50 output tubes he has collecting dust on a shelf.

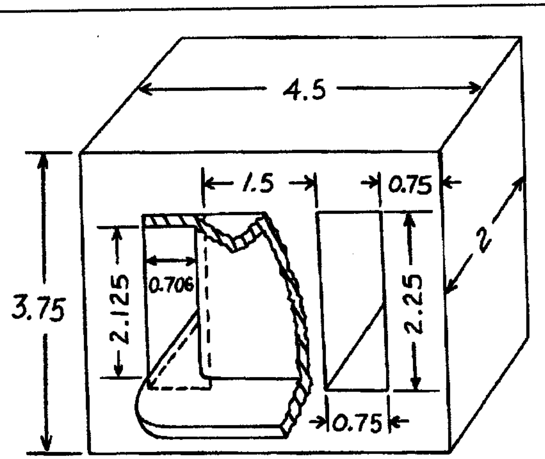


figure 1 - scrap transformer

I thought I might some day cure my case of junk box envy by winding my own single-ended output transformer (SE OT). A decision to build the Superwhamodynes cemented the commitment to build the OT at the same time. The information I used for the design was gleaned from many sources found in several libraries. (See Table 1 for a reference list.) I never found a "How To Build A Single-Ended Output Transformer From Scratch" cookbook. I hope to present what I did in such a way that the reader can not only follow along, but leverage the information for his own design as well.

A Caveat

Successfully building an audio transformer will emphasize the difference between design and implementation of that design. This is mainly because the integrity of the mechanical structure contributes to the electrical response in a way that is not adequately accounted for by the design formula. Even if the equations and models were complete, the builder's craftsmanship and attention to detail would still factor heavily into the success of turning schematic into product. In other words, the math will only get you so far, and at some point, you just have to build the darn thing and see how it turns out. In this case, the cost of learning by mistake is mostly one of time not money. And it can be a lot of time too. Carefully winding over a half mile of wire inch by inch is better measured with a calendar than a stopwatch.

Some details are left out, but the references should help fill in the blanks. These references can help turn black art into science. Certainly you have friends who shake their heads in disbelief at your pursuit of vintage electronics, and winding you own transformer will only further convince them of your lunacy. But besides that kind of fun, you'll come away with a better understanding of how a transformer is made; and consequently, a better appreciation of why a good SE OT costs as much as it does (and superb one even more than that).

Core Salvage

I thought a 10 watt design would be a good starting point and set out to find suitable materials. The basic ingredients of an OT are laminations, wire, and insulation. A pair of scrap $5 power supply transformers were chosen to provide the laminations. Figure 1 shows the general dimensions of what I got for my five dollars.

A transformer winding shop would probably be willing to sell laminations (and wire and insulation too). If you prefer to cannibalize a surplus transformer as I did, I suggest the following rule of thumb when choosing a victim: allow at least one pound of weight for every watt of output power. Pick a transformer with thin laminations that you think you can get apart - avoid encapsulated or canned iron.

Clean up the outside, strip the paint, and remove any mounting hardware if possible. The transformers I disassembled had a potting compound (looked similar to epoxy) that held the screws in so tight that I broke a screw trying to remove it. Heating the transformer in an oven (about 300 degrees) softened the,potting compound so that the screws came out easily.

Once the screws are out, the core can be disassembled. I have destroyed the first lamination of every transformer that I had to pry apart. This outer most lamination was made of thinner material and shaped differently from the others (an elongated E). I think this is called a keeper. Whatever its real name was, it's called trash now.

To remove a lamination, I cut it free from the core using a razor blade knife and a putty knife. The I-shaped laminations come free easily using only the razor knife. The E-shaped laminations are a little trickier because the middle section (tongue) is buried inside the coil bobbin. Work the razor knife around the outside edge and then slide the putty knife into the center of the core. The lamination should pop free without prying or any permanent bending.

The core required frequent trips to the oven to keep the potting compound soft enough to pull apart. That's not so bad as it provided worthwhile rests from a rather tedious job. You'll need to experiment to find the best temperature to work with. I used a Black & Decker Workmate to hold the hot transformer steady while I pulled it apart.

After removal, each lamination may retain a splotchy, thin skinned covering of potting residue on its surface. While this can be removed with solvent, I left it on to use as a "glue" when the core is reassembled. Clean off any large accumulations than might keep the laminations from stacking neatly.

After the core is apart, the coil can be unwrapped. Salvage the terminals for later use. Unwrapping the coil reveals the inner construction; this might provide useful tips on how to assemble the winding later. I didn't salvage the wire; it was either too short or the wrong gauge. I prefer to wind with straighter, less kinked wire anyway. (Winding is challenging enough with fresh wire.) The thick wire in your scrap transformer might be of more use. Perhaps as a 0.36 mH air core inductor for a loudspeaker crossover.

If you are not interested in coil archeology, a hacksaw might be the best way to get at the core. Use the finest pitch blade available to make several cuts on both sides. After cutting, split the winding and peel it off of the core. This procedure can also be helpful when modifying (as opposed to cannibalizing) a power supply transformer. Normally, the primary winding is next to the core and it's only the secondary windings that are to be removed. Surgical precision using the, hacksaw can remove the secondary windings while leaving the primary intact.

Take care not to damage the coil bobbin. I suggest that you don't take apart the transformer until your design is finished and you are ready to build.

Electrical Design

I figured an 845 could live a long and relatively stress free life when developing only 10 watts of output power. Furthermore, there's plenty of room for more power should I decide I need it. But for the moment, the operating conditions are approximately 700 volts on the plate, -86 volts on the grid, and 90 mA bias current.

According to RCA, the 845's plate resistance measures 1700 ohms.One rule of thumb estimates loading a triode at 4 times its plate resistance. Another rule says that loading a triode at 2 times its plate resistance gives maximum power output. Let's choose somewhere in between, say 3 times the plate resistance. Therefore, the OT needs to make an 8 ohm speaker load appear to be 3 x 1700 = 5100 ohms. The required OT turns ratio N is:

$$N = \mathrm{sqrt}(5100 / 8) = 25.3$$

For every 25 turns of wire on the primary, there is 1 turn of wire on the secondary. The next step is to determine the total number of turns needed for the primary.

For those of you uncomfortable with using RCA's specification of a 1700 ohm plate resistance, or the determination of a suitable load, forget about the output tube for now and just think of this as a design for a single-ended 5.1 kohm transformer at 90 mA of bias current.

The primary winding of the OT is an inductor. When the OT is coupled to the output tube, a high-pass series RL circuit is formed. Ignoring the winding resistances, R is the parallel combination of the output tube plate resistance and the "transformer impedance"; i.e., the load resistance reflected into the primary (5100 ohms nominal). For a series RL circuit, the -1dB point occurs approximately where the inductive reactance equals twice the series resistance:

$$wL = 2R = 2 \times pi \times (\text{Frequency at -1dB}) \times L$$

In this case, the frequency cutoff is inversely proportional to inductance. More inductance means a lower frequency cutoff point. As above, for the 845 use Rp = 1700. Determine the minimum inductance required for 1dB down at 20 Hz. Rearranging and solving for L:

$$L = 2R / [2 \times pi \times (\text{Frequency at -1dB})] = (1700 // 5100) / (pi \times 20) = 20.3 \text{ H}$$

Note that this is a minimum inductance figure. Also note that this is more stringent than the typical specification of -3dB. The -3dB point requires half this much inductance (10 H). Phase shift is about 27 degrees at -1dB; whereas, it's 45 degrees at -3dB. According to the Radiotron Designer's Handbook, choosing the -1dB point results in fairly low distortion, but still lower distortion ("good fidelity" as they put it) requires keeping the phase angle less than 15 degrees. To get only 15 degrees, the response must down only 0.3dB at 20 Hz, and that requires 1.9 times as much inductance as calculated above.

There's another reason for increasing the inductance. The harmonic distortion is directly proportional to the ratio of the primary reactance to the source resistance (see references 11, 12). The distortion is lowered as the ratio climbs (at this point the ratio = wL/R = 2). Improving the ratio requires lowering the resistance or increasing the inductance. The resistance can be lowered by changing to an output tube whose plate resistance is smaller. Since the tube has already been specified, the remaining option is to raise the primary inductance.

Based on the hope of phase and distortion improvements, I chose to bump the design goal an unscientific 50% higher. That makes the design value approximately 31 H. You may decide otherwise.

The next step is to determine the number of turns of wire in the primary that will provide 31 henries of inductance when wound around an iron core. Dig through any electromagnetics book and you'll stumble across the inductance equation for an iron core inductor:

$$L = (3.19\ NT^2\ u\ CSA) / (MPL \times 10^8)$$

where:
NT = the number of turns of wire around the core
u = the effective permeability of the core material
CSA = the cross-sectional area of the core in square inches
MPL = the magnetic path length of the core in inches

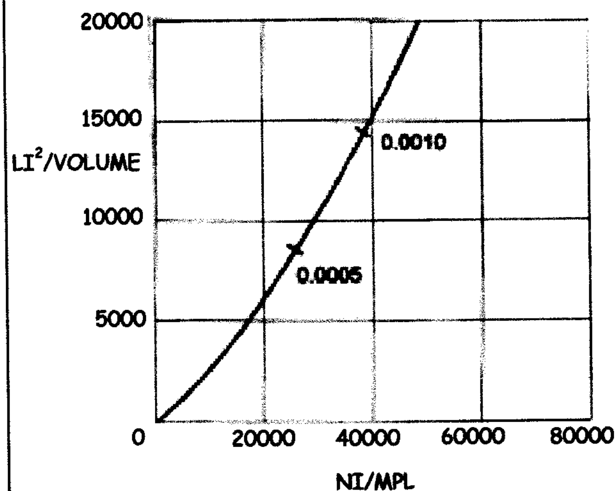


figure 2 - Hanna curve for Silicon Steel, 60Hz, 1 kG

It seems straight forward enough to rearrange and solve for NT. Armed with a ruler, one can measure the core dimensions to calculate A and MPL. We just need to get a handle on the permeability u. Turns out that u is an elusive animal as you electromagnet heads out there already know. It depends largely on the working conditions and composition of the iron in the OT core. Permeability can be determined from B-H curves, and manufacturers of core products have B-H curves for each type of core material. Unfortunately, I haven't found "scrap iron" as a core material in any of the standard curves. Published ring sample values for permeability range into the tens of thousands or higher, and some transformer designs use guesstimates in the low thousands, but the SE OT has an added degree of difficulty.

The working conditions of an SE OT has a dc bias current that will saturate the core if left unchecked. Saturation means gross non-linearity which is a bad thing for audio. "Gapping" the core cures the dc saturation problem, but greatly lowers the effective u (into the hundreds), which lowers the inductance. More inductance, not less, is desirable for low frequency response. So the consequence of adding an air gap must be compensated for by adding more turns or using a core of larger cross-sectional area or both. Changing the number of turns or the core size changes the working conditions of the iron which changes u which changes.......you get the picture. The cyclical nature of this iterative process is vicious indeed.

At this point it would be really useful to find a relationship involving L and N that is independent of u. Luckily, others have wrestled with this problem before and found a general solution. One such method involves the use of Hanna curves. There are specific Hanna curves for specific core materials. Once again, "scrap iron" does not appear but let's assume that non-oriented 4% silicon steel (Figure 2) is close enough. Use of these curves also requires the volume of the core, the cross-sectional area of the core, and the magnetic path length of the core. See references 1,2,9,11 for Hanna curves.

Figure 3 shows a typical core made up of E-I laminations. One E and one I lamination are paired together to form the flux path for the magnetic circuit. Many E-I pairs are stacked on top of each other to build a core of sufficient cross-sectional area needed to carry the flux. More flux implies a need for more cross-sectional area much like more electrical current implies a larger gauge of wire. It's obvious that a physical break occurs where the flux must travel from the E lamination to its paired I lamination (and vice-versa). This break in the magnetic circuit lowers the effective permeability of the core material. Normally, the E and its paired I lamination are placed as close as possible together to minimize the effect of this break. To further minimize the fringing effects, the orientation of the E-I pairs are alternated as the core is built up. Most power supply transformers and push-pull OT cores are assembled in this way.

Iron core inductors carrying a large dc bias require a gapped core. In this construction, the E-I pairs are not alternated. All of the E laminations are stacked on one side and an equal number of I laminations are stacked on the other. The two stacks are placed next to each other but separated by a certain amount of space forming a gap. A spacer of non-ferromagnetic, non-conductive material is used to physically hold the gap to a specific size (Figure 4). So in this construction, the air gap is not actually air at all. Due to the choice of material for the spacer, the gap appears to be air (permeability = 1) as far as the magnetic circuit is concerned.

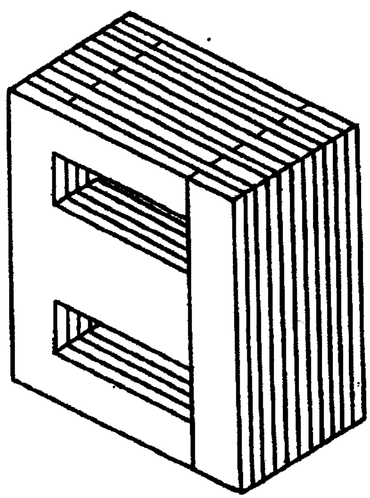


figure 3 - typical core

Figure 5 shows the flux path in an E-I pair. Note that there are two equal, parallel paths. The middle leg of the E lam (tongue) is twice as wide as the outer legs (limbs) to maintain constant flux density in the core. Also note that each flux path crosses the gap twice. The thickness of the spacer is only half of the actual gap length. Power supply chokes (polarized inductors) and SE OTs can be assembled in this way.

All cores using laminations rely on oxide coatings to electrically isolate the laminations from each other. Otherwise eddy currents form, sapping efficiency or in a worse case scenario, causing the transformer to malfunction, overheat and possibly self-destruct. It is vitally important that proper assembly is done to avoid shorting the laminations together.

The width of the middle leg of the E lamination multiplied by the height of the stack of the laminations gives the core cross-sectional area (CSA). Because the core is not a solid material but is made up of a stack of thin sheets, the cross-sectional area is not 100% magnetically useful. A stacking factor (SF) is applied to account for the small, unwanted air spaces that exist between the laminations. Care in assembly, flatness of the laminations, thickness of the laminations, presence of burrs or any foreign objects trapped between the laminations all contribute to the stacking factor. The core cross-sectional area can be calculated using:

CSA = SF x Tongue Width x Stack Height

The scrap power transformer I used yielded a 2 inch high stack of 0.014 inch thick laminations with a tongue width of 1.5 inches. For 0.014 inch thick laminations, I found a reference that used SF = 0.98 , while another one cited an SF = 0.92. Because I'm an amateur stacking used laminations, I set SF = 0.9. The cross-sectional area is:

CSA = 0.9 x 1.5 x 2 = 2.7 square inches

The volume of the core is the magnetic path length (MPL) multiplied by the cross-sectional area of the core:

Volume = MPL x CSA

The MPL is the average length of the path traveled by the flux in one circuit of the core. Assuming the flux path to be rectangular, from Figure 5 it can be seen:

MPL = 2F + 2E + 4D

Assuming the flux path to be a rounded rectangle as drawn in Figure 5, the length becomes:

MPL = 2F + 2E + pi x D

The scrap power transformer core I used has a magnetic path length of 9 inches. Therefore:

Volume = 9 x 2.7 = 24.3 cubic inches

Now to the Hanna curve (Figure 2). The Hanna curve relates the direct current energy stored in the core per unit volume(Y-axis) to the magnetizing field (X-axis). The X-axis is expressed in units of:

NT I / MPL

where:

NT = the number of turns
I = the dc bias in milliamps
MPL = the magnetic path length in inches

The Y-axis is expressed in units of:

$L I^2$ / Volume
where:

L = the inductance in henries
MPL = the magnetic path length in inches
Volume = the core volume in cubic inches

The dc bias current in the OT is the bias current in the output tube. The 845 is biased at 90 milliamps. So

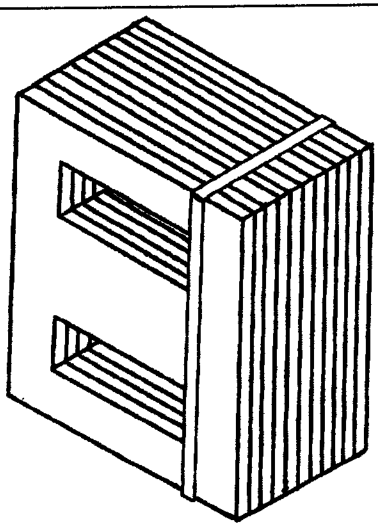


figure 4 - Gapped core

Y = $L I^2$/Volume = 31 x $(90)^2$/24.3 = 10,300

Intersecting the curve at Y = 10,300 gives X = 30,000. Rearranging and solving for NT:

NT = X MPL/I = 30000 x 9/90 = 3000 turns

At the curve intersection point the gap-MPL ratio is 0.0007. Therefore the gap length is:

Gap Length = 0.0007 x MPL = 6.3 mils

The spacer thickness is half of the gap length. Spacer thickness is about 3 mils. This size gap maximizes the inductance which would be fine for a smoothing choke. It is important that the OT be linear; the actual gap will be adjusted experimentally.

The transformer turns ratio for 5100 ohms is 25.3 to 1. Therefore, the secondary will have:

Number of turns in secondary =
3000 / 25.3 = 119 turns

It is important to note that these values are for first approximations. The particular Hanna curve in Figure 2 is for silicon steel exercised at low induction which may not accurately represent the SE OT being designed. (The Hanna curve is often used to design smoothing chokes.) When it comes to the actual construction of the coil windings, it may not be possible to get the exact number of calculated turns anyway. As you will see, designing the coil layout will be a juggling of wire diameters, winding layers, and insulation all trying to fit within the core window. It sometimes reminds me of the "measure with a micrometer, mark it with chalk, cut it with a chainsaw" approach. It would be helpful to get a feel for the accuracy of these preliminary design values.

The voltage equation can be used to get a feel for the validity of the transformer design estimates. The flux density B is:

= V x 10^8 / (25.8 FF CSA NT Freq)

where:

V = the applied rms voltage
FF = the form factor = 1.11 for a sine wave
CSA = the core cross-sectional area in square inches
NT = the number of turns
Freq = the frequency of the applied signal

Ignoring losses, the power P in the primary equals the power in the secondary (10 watts into 8 ohms). The load reflected into the primary is R = 5100 ohms. So the applied voltage is:

V = sqrt(P R) = sqrt(10 x 5100) = 226 Vrms

The Hanna curve was determined at a frequency of 60 Hz. Solving for the flux density:

$B = 226 \times 10^8/(25.8 \times 1.11 \times 3 \times 3000 \times 60)$
$= 1460$ gausses $= 1.46$ kG

The family of Hanna curves for silicon steel have a slope that is directly proportional to the maximum flux density. The particular curve used was plotted for an induction of 1 kG which is slightly less than the calculated value. This means that the approximate design values based on the 1 kG curve shouldn't be too far off, and the error is on the conservative side. An iron core inductor designed and built this way should turn out slightly better (more inductance, fewer turns) than predicted by curve alone.

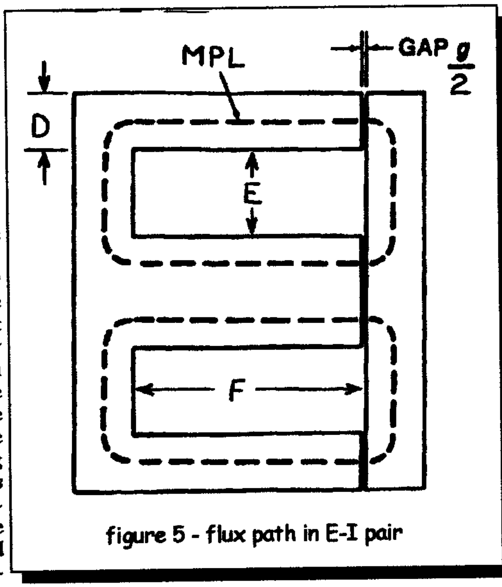


figure 5 - flux path in E-I pair

Thus far it's been determined that 3000 turns of wire are needed for the primary and another 119 turns for the secondary. The next step is to decide how to fit these turns on a bobbin in the space available (window). Also, the physical positioning of these windings (coil layout) will determine the leakage inductance and winding capacitance of the OT. These parasitics are present through out the full frequency range but only begin to show their effects as the frequency rises. Since they can't be eliminated, the goal becomes to smartly arrange the windings in such a way that keeps their effects above the audible range (high frequency rolloff above 20 kHz).

Next month:
taming parasitics, the physical design, and insulation

Reference List

1. "Reference Data for Radio Engineers", Chapter 13 of 6th edition

2. "Practical Transformer Design Handbook", Eric Lowden

3. "Handbook Of Transformer Design And Applications", William Flanagan

4. "Transformers For Electronic Circuits", Nathan Grossner

5. N. Crowhurst, "Electronic Engineering", Leakage Inductance, 4/49, pg. 129

6. N. Crowhurst, "Electronic Engineering", Winding Capacitance, 11/49, pg. 417

7. N. Crowhurst, "Electronic Engineering", Winding Space Determination, 8/51, pg. 302

8. "Radio Receiver Design Vol II", K. R. Sturley

9. "Electrical Engineers' Handbook", Pender & McIlwain, Chapter 3 of the 4th edition

10. Dr. Tom Hodgson, "Sound Practices", To Be, or Not To Be, Linear!, issue 10, pg. 37

11. "Radiotron Designer's Handbook", section on output transformers

12. James Moir, "Glass Audio", Output Transformers, 2/94 pg. 24, 3/94, pg. 30

13. C. R. Hanna, "Trans. A.I.E.E.", Design of Reactances and Transformers Which Carry Direct Current, 2/29

etters

Dan,

I just wanted to yell at you about an article in your October 96 VALVE. In the push pull 6DN7 amp, Dave drops a hint about using an amperite 117N030 relay for wonderful service in delaying the B+ until the fils warm up.
What a shitter... they cost $64.50 each (!) ... ack!
I did some looking and couldn't find any kind of time delay device for under about 45 bucks that could switch 5V@2A.
I'm bitching 'cause I got all excited and it turned out that two relays cost more than the amp itself!
Sigh.
Sorry to rant, but who else would listen?

Tom Ronan, Chicago

Huh?
Well, I guess a guy like Dave, who has a junk pile even bigger than mine, forgets that some of this stuff isn't lying around in everybody's basement.

battery bias and heaters

Aloha Dan:

I just had lithium batteries installed in my C-J PV 12 to set the grid bias, and another battery and charger for the heaters, and then took out the local feedback so it's operating as pure triode.
Talk about moving up to the next level. The noise floor just dropped dramatically. Emerging from the blackness are low level textures and harmonics that are just so natural and relaxed. It's like hooking up megabucks Siltecs, that is, "kinder and gentler", and getting the "high definition" without being aggressive, bright or forward.
That immense amount of fine low level textures and harmonics reminds me of a Joule Electra LA200 (that's where I got the idea of setting the grid bias with a battery). The Joule has a darker, more chocolatey character, with tons of emotional content. Although I haven't heard George Wright's preamps, I bet you lunch that installing batteries will make that unit real scary.

Aloha,
Hiroshi Ito, Honolulu
PS - We also tried that tip in Positive Feedback about putting DC in caps. It works! And it's a killer! Did it on the tweeter crossover circuits for both a Klipschorn and DIY horn system. Wow, the music had a clarity and ease that was just staggering.

I spoke with George about battery bias, that is, replacing the cathode resistors of the 6ER5s with 1.56v batteries (positive to the cathode of the tube and negative to ground). He says go for it in the phono stage of the Wright Phono preamp, but don't do the line stage because the cathode resistor in that stage is run unbypassed to create degenerative feedback, which would be eliminated if the cathode resistor were replaced with a battery.

S.E.X. in Tokyo

Dear Dan,

Your S.E.X. kit amps have served, as promised, as a wonderful introduction to tube electronics. And in fact beat the previously built Kit One amp for low level listening, having better low end. The Kit One, designed around a PC board, didn't really serve as much of a learning experience, although the sonic results proved outstanding.
I spent the first couple of months with the S.E.X. amps running full pelt into a pair of Spendor LS3/5As - not only that, but with only 100 Japanese volts going into the primary for power! They are much more at home with a step-up transformer and Superwhamodynes! Looking forward to bolting on the Magnequest O.T.s. More fun.
Wasn't too struck by the stacked diode mod. Yes, the sound was definitely fuller and smoother - piano played hard lost some of its digital edge, but I missed the depth of imag-

(Continued on page 14)

ing. The first thing that struck me about the Whamos was this totally satisfying depth and 3Dism. The 1Kohmers are back in place.
Would love to waffle on about technical stuff, but don't have it in me. As a novice I'm enjoying the learning experience, but I wish that VALVE would put out a few beginner's articles. Basic rules of thumb stuff that novices could base further studies on. How about that?

Robin Watson, Tokyo

This fax from Robin was dated 11/16/96. About the same time Robin mailed a few more observations and a very cool T-shirt which sports the cover of the May '96 Superwhaomdyne! issue. Thanks for the shirt, Robin! Here's some choice bits from this communiqué:

Answer my faxes you bugger! No, seriously, many thanks for helping me along in my "initiation". It's a never ending, unceasingly involving business to be in and I envy your position to be able to at least make a go of something business-wise that you obviously have a love for. The magazine literally 'hums' with enthusiasm.
Yes, I will rant on a bit about the amps and speaks - they really sound unbelievably good to me.
I totally agree with your point about the venue sound coming through. The soundstage seems to swaddle around the boxes - now I'm sounding like one of 'those people'.....
The tower alone sounds great if put on target style stands, bringing the tweet up to ear level, sure enough. Using a step-up transformer on the S.E.X. amps made me realize how much I was missing - more power and less distortion. Yep, Audio Note should hide their face in shame.

Robin had ordered a pair of the first run of TFA-204 output transformers, and when I faxed him to tell him they were due in a few weeks, I asked him if he would please try the LED mod of the mu follower cathode resistor and bypass cap, after he installs the TFA-204s, and give us an update on the sound. This reply is from 12/19/96:

Your fax at 4 a.m. *(Sorry Robin)* got my biorythms in a twist, so here I am penning a quick reply. Once again your words of wisdom have fired my imagination... one of these days I'm going to quit this teaching lark and ship myself off somewhere on a course of no return with 35 years' worth of TFA-204s as ballast and an infrared LED to guide my way in the dark....
Actually I've been thinking about replacing some components in the S.E.X. amps - upgrading resistors and caps - but the prospect of Akihabara (electric town!) and it's seething masses sets nerves on edge more than any cheap electrolytics do. Thanks very much for the amp suggestions; if the LEDs are a standard rating.... Hell, what am I trying to say- could you pop those LEDs you suggest in with the OTs?Some of these street traders don't take kindly to ignoramuses, foreigners at that, trying to speak a language they don't understand In a language they don't understand, if you get my drift.
If it means your running to Raydeau Shaque (I like that one!) then don't worry - you've got better things to be getting on with,. you lucky fella.
I have to mention my listening room is pitifully small (Japan!) and I have a hunch that the diode-mod would be more suited to larger rooms, given its up-front demonstration. The possibilities are endless: Big/Small Room switch!
The Whamos and amps will be getting an audition at my engineering friend Kinji's house on Saturday. He's my one, single audio soulmate over here. I'm waiting for him to retire from his busy profession so I can get him to teach me all he knows! Looking forward to hearing what his old vintage Luxman PP amp sounds like against SE - thru the Whamodynes!
Oh, and as for subscription renewal: in answer to your question... "do bears shit in the woods?"

All the best,

Robin

Thanks so much for sharing your adventures Robin!
I think I should use these letters as an excuse to fill y'all in on the state of S.E.X. in Poulsbo.
My own set of amps now sports the following:

- TFA-204s, running zero feedback
- The LED mod on the cathode of the mu follower
- a 200 ohm wirewound for the cathode resistor of the output stage (replaces the 270 ohm 1 watt resistor going from B3 to ground, and voids my warranty!)
- soon to be installed 47 mfd cap in the second stage of the power supply filter (across terminals 5 & 6), replacing the existing 10 mfd cap
- Siderial caps replacing the stock .47 polypropylene coupling cap (terminals A1 & A5) and the .1 mfd polypropylene cap (terminals A5 and 9) in the mu follower circuit.

- Vampire Wire replacing all jumper wires
- Amperex 6DN7s (you're on your own finding these - I don't have any more)

I lucked out and ended up with a bone stock pair of amps in the shop for comparison recently.
Here's what I hear:
The stock amp is damned good! A bit rolled off on top, but the fairly high inductance of the long primary winding gives great bass and midrange for the size of the trans.
The TFA-204 modded amp gets better top end and more defined localization (these of course go hand in hand) and bass remains tight and rich.
The Siderials offered a great improvement in smoothness, and the 47 mfd filter takes already low hum even lower, for use with 100dB+ speaks.
The 200 ohm wirewound gets the plate current of the 6DN7 outputs running flat out, maybe even a bit above max, depending on you line voltage, but the tubes seem to handle it OK. I have had only one tube go soft after eight months at this current level.
With all these improvements, I like this amp better than the Shisido/Loftin-White style 6SF5/2A3 circuit you guys liked at the last meeting.
For S.E.X. mods, I'd put it second behind John Tucker's active loaded direct coupled 2A3 circuit-
but discussion of that sweetheart will be saved for a later date.
You definitely see more power at this current, maybe 5 watts, but the power trans gets HOT.
The power trans has been the one item which I felt could stand some improvement in the kit. Consequently we are in the early stages of getting a new, more versatile power transformer design, under the advisement of Mike Lafevre.
If we can do it at a reasonable cost, we will try to incorporate a bit more current handling capacity, a pair of 2.5V windings, and a split "international" style primary.
It will be designed to retrofit on all existing kits.
We don't have a firm design yet, let alone a finished product to deliver, so please don't bother asking about availability for a month or so.
But when they come out, with a pair of these babies and Mike L's passionate fury for new inductor designs, the opportunities become truly exciting. Think 2A3s, 300Bs, Loftin White... how about a 6J5/300B interstage coupled amp, with IT by Magnequest, or a 2A3 parallel feed amp with nickel core TFA-204s?
- Doc B.

TQWT

Regarding Vol 3 No 11, page 13, would you or Marc Veyer clarify in a future issue whether the carpet felt behind the driver contains a cutout to allow the backwave from the driver to enter the rear chamber. Perhaps my puzzlement stems from transmission line designs where the channel from the back of the driver to the port is open (except for the wool stuffing)

Regis Valentine, Old Greenwich, CT

Alas, I have not had a chance to check with Marc, but I suspect that carpet pad is solid. This would allow only the lower frequencies through, while cutting the midrange, thus avoiding the dreaded "hollow bass" sound.
I have been playing with a pipe of about twice the cross section, built by John Carey for his PM7As (don't bother, this pipe sucks with Lowthers) and find I can still hear bass down around 50-60Hz. Truly amazing little driver, that MCM 55-1290.
I used fiberglass lining instead of carpet felt, and found the bass a bit hollow. Some fiberfill in the bottom of the pipe, just above the mouth, seemed to help this.
But my main problem with the single driver concept using the 55-1290 has been that I like my top end air, and I think the speak works best in a two way configuration, with a tweet sitting on top. I have been experimenting with some tweets, and so far the tweeter and crossover used on the Superwhamodyne works best, with an L-pad installed to bring the tweet down to the 90-91 dB of the woofer.
As an aside, I tried cutting the dust cover off a 55-1290 to see if I could extend the highs for full range use. It seems to help, however I'm not so sure about how flat the response is. It may be peaking around 7-8 kHz.
Allan Rosenthal has been using the two way setup, biamped with a Kit One on the bass and a S.E.X. amp on the tweet, and says he likes the midrange image of this setup better than the Superwhamos. He also says he doesn't notice that much loss of bass relative to the Whamos in a small room, and that the bass is more homogenous than it is in the Whamos.
My experiences have been the reverse, with my pipe sounding a bit boomy and one noteish, and definitely not going as deep as the Superwhamo, but I am using a large, tight room and a fatter pipe.
My (John Carey built) pipe is big enough that it will barely accommodate the full Whamo tower speaker complement. The position of the drivers in their vertical array leave only one

woofer in the optimal position near the center of the pipe, but I think it sounds pretty close to the full Superwhamodyne, but a bit too thick in the midrange.

I have used the fiberglas as Marc suggested using the carpet pad, blocking the upper midrange from escaping out the back. I have also tried removing it down to the top of the internal divider, and find little difference in the sound. The full on Superwhamodyne system holds an advantage in the 'realism' factor and clarity, as well as the deep bass. By comparison, this new Whampipe has a nice full lower mid sound that many folks might lust after.

One interesting observation during a lot of speaker play last month is how different these MCM driver configurations sound in different rooms.

The Superwhamos are very tight, with balanced, solid bass, and crisp presence in my treated, concrete basement listening room, and they sound even better at the concrete floored, carpeted, double layer sheet rock walled and tube trap treated 12 x 20 room at Nuts About Hi Fi. Upstairs in my wood frame, flexy bare wood floor and partially curtained 14x20 living room, they get "home theatre" in the bass and quite laid back on top. To me they sound like very different speakers .

I suspect the subs may be a bit more efficient than the towers., with a small peak around 110 Hz, a slight depression around 75 Hz, and a larger peak around 50Hz. Who else but yours truly could have ended up with an ass backwards combination like that? I would like to hear from anyone who has tried building the Superwhamo subs with a bit larger back chamber, which would lower efficiency and shift the passband down to boot. You might get away with this lowered pass band in the woofer, and hear even deeper bass. Cool.

I will be working up a chamber that could be added on to the bottom of the existing subwoofer to increase the rear chamber size.

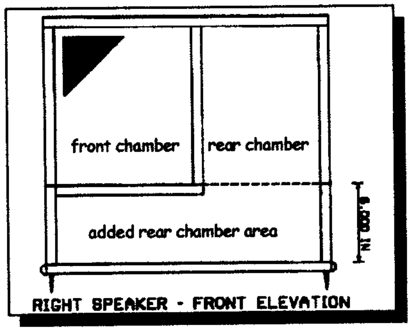
The chamber could be a 19.5" x 19.5" x 6" (internal dimensions) extension of the bottom of the subwoofer. The bottom of the back chamber would be cut open to combine with this added volume. This would raise the tweeter above the ideal seated listening height. Response might be from 32-86 Hz, with potential peaks in the sub's response equalizing with the rolloff of the tower.

NOTE:

This is a purely speculative idea. This kind of mod may reduce sensitivity too much, and it may take some patience to optimize the back chamber volume.

The two way pipes sounded better in the upstairs room. The difficulty I had with the hollow bass and tough integration of the tweet crossover in the two driver, two way version doesn't seem to matter as much in such a lively room.

One more intriguing possibility with this tapered pipe business came to me after reading David Weems' article on tapered pipes from Speaker Builder a few years back. His rules of thumb for designing a pipe indicate that the pipe could be much smaller in cross section. The pipe's cross sectional area at the bottom needs to be only about 2.5 times the piston area of the driver, and the area behind the driver should be about equal to the piston area



of the driver, plus or minus 20%.

The effective area of the driver is roughly 12 square inches, so the pipe's cross sectional dimensions could be roughly 5 inches by 6 inches, plus a bit to allow for the thickness of the inner baffle.

If you wanted to eXperiment with a full range speaker for a smaller room, this minimalist design would be a pretty cool starting point. Try removing the dust cover if you go full range....- Doc B.

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

Recent developments have led us to an even better sound! If you've been waiting to try a Brooklyn transformer, wait no longer. This month we are incorporating improvements in the core construction that give even better bass response, making Brooklyn transformers the best entry level push pull transformers going.

PART #	PRIMARY IMPEDANCE	POWER LEVEL	MAX. PRIMARY DCMA PER SIDE	DCMA UNBAL	RETAIL EACH
B14	12,000 CT	10W	40	4	$100
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

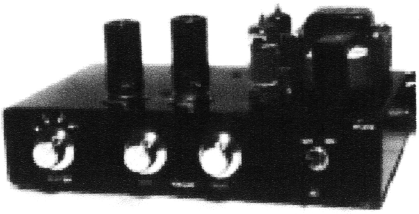
Note: Above units available with Ultralinear taps for an additional $6.00 per unit
Secondary impedances far all units are 2,4,8,12 & 16 ohms.
Guaranteed minimum frequency response is +/- 1 dB, 30Hz to 20 kHz.
All units supplied with vertical bell end caps.
All prices herein are special introductory - prices subject to change without notice.

Brooklyn

Brooklyn, P.O. Box 967
Cherryville, PA 18033
(215) 288-4816

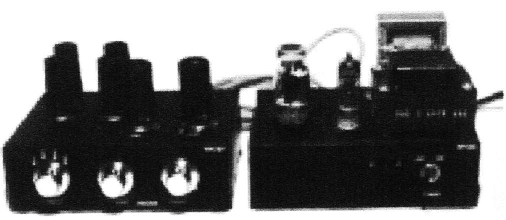
Where Push-Pull meets Single-Ended

WRIGHT Sound Company



The **WLA10 line amp** with 4 inputs for those who don't need the phono section. Dubbed by those that have listened, as the best sounding line amp they have ever heard, tube or solid state. All this for $300.00 plus $17.50 shipping and handling in the continental U.S., WA res. please add 8.2% sales tax.

The **WPP100A phono preamp**, the most natural sounding unit on the market today, is available at $450 plus $17.50 shipping and handling in the continental U.S., WA residents please add 8.2% sales tax. The WPP100A has gold RCA connectors, and a new WPS02 power supply with a power switch and plate and filament indicators. The performance is better than the original version, which beat all the competition in listening tests by members of **VALVE** and other audiophiles who have had the pleasure of reviewing this product.



Now available to **VALVE** members, and those who have tried S.E.X. amps, the **WPL10V complete line amp/ phono stage** component. This basic model has the quality of the WPP100A, with the additions of a selector switch with phono plus three other line inputs and volume controls to make this the center of that great new S.E.Xy sound system. No longer do you need to wait for a great sounding addition to have great S.E.X., and at just $575 U.S. funds plus $17.50 shipping and handling, you can get this fully assembled preamp/line amp delivered to your door in the continental U.S., WA residents add 8.2%. The WPL10V is designed to be a cost effective basic chassis type, constructed with all the great stuff that goes into the WPP100A. We made it especially for you S.E.X. owners and **VALVE** members who want the most out of your system for the least out of your pocket. I must add that this product will work with almost any power amp you now have or may purchase, so with or without S.E.X. this is a great addition to the WRIGHT line. Stay tuned for future models.

Please send your order and payment to:

WRIGHT Sound Company

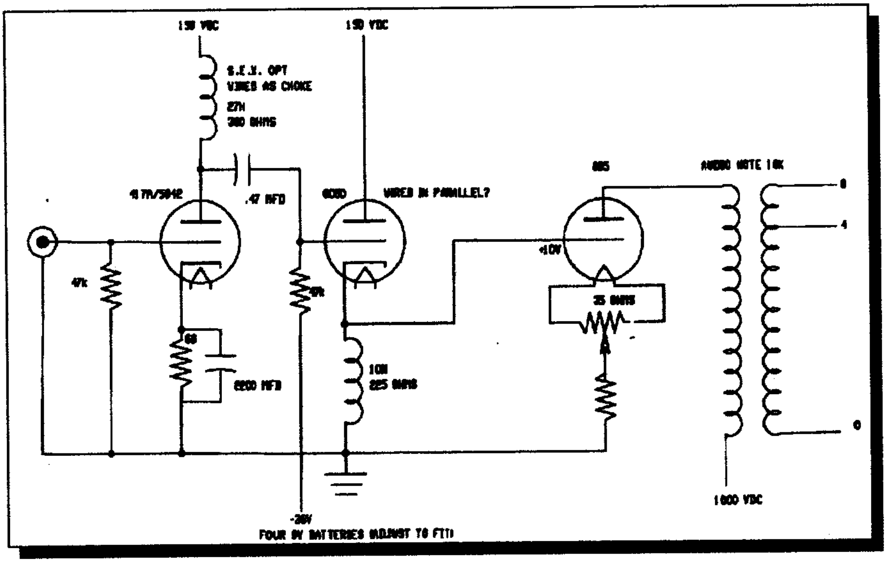
3516 So. 262nd, Kent WA 98032-7047

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

Please note: These items are individually hand built, and current high demand can

A2 Brute' update

As the $100 speaker contest draws nigh, I must concede that this amp will not be ready for the January 15th event. But we will finish it eventually!
Here's how she roughs out (actually there's even more junk that will get added later, like maybe two EM84 input level indicators, maybe a 913 CRT to show interchannel phase at the output, and shunt regulator tubes for each stage):



The 805 runs class A2 (hence the name, homey), 1000V at 100 mA, into an Audio Note 10K SE output transformer. The 6080 cathode follower runs at 150V and 100mA, with -36V bias on the grid, and supplies the needed 50mA to drive the 805 grid to its full positive swing. The 10H 110mA choke loads the cathode.
The 805 grid will run at about +10V, so the cathode resistor on the 805 will be small, if necessary at all. Hey, like I said, this is still rough!
Like all good class B tubes, the 805 has mondo gain, maybe a mu of 40, so the lack of gain of the cathode follower is not too big an issue.
The 417A/5842 input tube is pretty standard stuff, running about 150V at about 25 mA, with a nifty choke load on the plate, which will conveniently be supplied by a S.E.X. kit output transformer primary (27H), with the secondary connected in series.
The power supplies are pretty standard stuff for now, we just happened to have a big pile of chokes and lots of extra voltage available in our power transformers, so we went choke crazy.
The 1000V supply will use a power trans with 1000, 1250, and 1500V taps, so we can grossly adjust our B+ there. 3B28 gaseous rectifiers go full wave into a 5-20H swinging choke. Next a 100 mfd 2.5kV oil cap from (no shit) the Oak Ridge Nuclear Power Plant.
Then a 10H smoothing choke. That pretty well takes up the first of three 17x15x4 chassis, so we put the second 100 mfd 2.5kV cap on the amp chassis. The two 805's will draw 200 mA total at idle, and this PS is rated 300 mA, so we have lots 'o' current headroom.
The third chassis will house the supply for the 6080s and 417s, which starts with a Variac supplying AC to a 325-0-325 at 255 mA transformer, running into a 5U4. From there we will go into a 3-14H swinging choke, a 525 mfd at 450V cap, a 5H smoothing choke, a 525 mfd at 450V cap, yet ANOTHER 5H choke, and yet ANOTHER 525 mfd cap!
All the filament transformers except the one for the 3B28s will be on this chassis as well. We will use four 9V batteries for a super stable, reliable bias supply on the 6080.

Serious!

cravings

For Sale:

Audio Research D-75 tube amp	$800
Dynaco Stereo 70 tube amps	$269 ea.
Heathkit W5 tube amps	$450 pr.
Dynaco SCA35 integrated	$169
JBL L112 speakers	$450 pr.
JBL L100 speakers	$350 pr.
JBL L110 speakers	$350 pr.
Celestion L600 speakers	$500 pr.
Klipsch Cornwall speakers	$600 pr.

Classic Audio, 206-706-1561, Wed-Sun 11-6

For Sale:
Edgarhorns, original 3-way design
- BBC aluminum dome tweeter
- Dynaudio D54 midrange
- ElectroVoice EV 15L woofer
- MIT caps

100dB efficient
Cost $1300 to build, asking $650, you pick up in Irvine, CA.
Allan Rosenthal, 714-246-5979

Wanted:
Lafeyette LA 70/Kt 400 mono amp, dead or alive - will buy or trade?
Ed Coleman 360-678-7414,
e-mail ecoleman@whidbey.net

Heeeelp!
I'm getting buried in speaks!
Come pick up my nifty Magnepan MGIIAs, in their original grill cloth and cartons. Just bring $300 with you and they're yours.
While you're here, talk me out of my Newform ribbon tweeters for $175 the pair, Audax 5.25" Aerogel woofers for $90 the pair, Dynaudio D-28 AFs that need a little terminal lug repair for $35 the pair, and I'll throw in a pair of the good old Radio Shack ribbon tweets for good measure.
Heck, flash me $550 and I'll help you load the whole works in your truck!
Doc B, 360-607-1936, Mon-Sat 9-6

Trade:
Anybody interested in a mismatched pair of good used ST style 50s? I will trade them for a matched pair of good 'murican 845s. No Chicom tubes, folks. Doc B. 360-607-1936.

Wanted:
Still buying NOS 6DN7s, paying $3 each.
Doc B. 360-697-1936.

For Sale:
- Op Amp Labs phono pre head, with octal plug in modules. Three modules alone cost $120. With gold RCAs
- MFA 50Hz chip subwoofer crossover, with volume pots, summing switch, gold RCAs. Uses two 9 Volt batteries - $200
- 27 Wima MKP10 .22@1kV, list over $10 each.
- many more caps, including GEC polystyrene .033 @ 350V

Wanted:
- Tango XE20s or better
- Cerafines @ 500V
- Edison Price Posts

All items in good condition.
P.J. Finneson, PO Box 232, Bonanza, OR 97623
message phone: 541-884-7262.

february

John Tucker has his system up and running these days, with his new Exemplars, his tube output DAC, and some direct coupled 6B4 amps with FS 030s that are killers.
He doesn't know it yet, but I've tentatively scheduled the February meeting for his house, 12 noon, Sunday, February 2nd.
Call me for confirmation of this deal and directions.

march

Had the good fortune of being introduced to Joe Bermudez of Mobile Fidelity Sound Labs at WCES.
Joe will be doing a demo for the PAS in March. He has offered to come and do a demo for us the next evening.
We will try to arrange a venue and get this together!

tweak of the month

Tom Woodbury sends us this tweak of the month:
A best buy in used turntables is a Thorens TD 145. Tom considers it better than the current production TD 320.
Two tweaks for best performance-
1 tighten the bearings in the arm
2 try a cork mat on the platter
Be sure you mount a Thorens of this vintage on a really solid base. They are quite susceptible to vibration, as the arm is mounted together with the platter, on a lightly sprung subchassis.