

Junk Box Tube Amp Jubilee

This tube amp project celebrates the joy of producing a high-quality product for very little investment.

By Bruce W. Brown, RPh.,
and Larry DeRuyter

I recently finished a pair of complicated monoblocks ("70 Watts of McIntosh Power," 1/90 *Glass Audio*), a project that took almost a year to complete. Not only did it take a long time to find all the parts and do the layout and wiring, but the final testing and setup also dragged on. I had lost nearly all enthusiasm for the project before I finished.

Luckily, the final product turned out to be superb: powerful, quiet, and extremely musical. These are the best-sounding amplifiers I own! When my buddy Larry and I were auditioning them, we discussed the problem of running out of steam before completion of a major project.

A PROJECT TAKES SHAPE

He proceeded to pull out a couple of small monoblocks and hooked them up for me. (Larry and I spend lots of time discussing different types of tube and transistorized equipment. We frequently evaluate each other's projects and suggest improvements.) Larry tends to be very biased about his power amps. He prefers the unity-coupled McIntosh transformers and frequently restores McIntosh tube amps. He has not been impressed with the ultralinear Dynaco or Heathkit amps I have restored or built.

His small monoblocks sounded wonderful and impressive. I assumed they were McIntosh circuits, but was quite surprised when he told me they were

built using some Fisher 400 output transformers I had given him. He based these amplifiers on a circuit for a Pilot AA-410 amp that appeared in Feb. '02 *aX* in the Classics Circuitry section (p. 72). See **Fig. 1**.

His amps used 1½ 12AU7s, a 5Y3GT, and two 6L6s. I was surprised that such a simple circuit could sound so good and decided I needed to build a pair. Larry said he had experimented with a variety of preamp and phase inverter tubes and found that most common ones worked very well with few modifications.

My first inclination was to order some transformers, but the more I thought about it, the more it made sense to build these from what I had on hand and see how "non-critical" they really were to the final sound. I was fortunate enough to acquire an original Pilot AA-410 and after listening to it for a while, I decided to build a stereo amplifier (**Photo 1**). Because this is a "junk box" project, I will give several design options, and I hope you will find most of the parts already in your shop. I think you will be impressed with your efforts.

You're probably asking yourself, "Why are these guys building so many of these things?" The answer is simple: You can build them with a wide variety of different parts, the wiring is very simple, and they sound wonderful!

If you wish to build the amp as shown in the original schematic, you can order all the

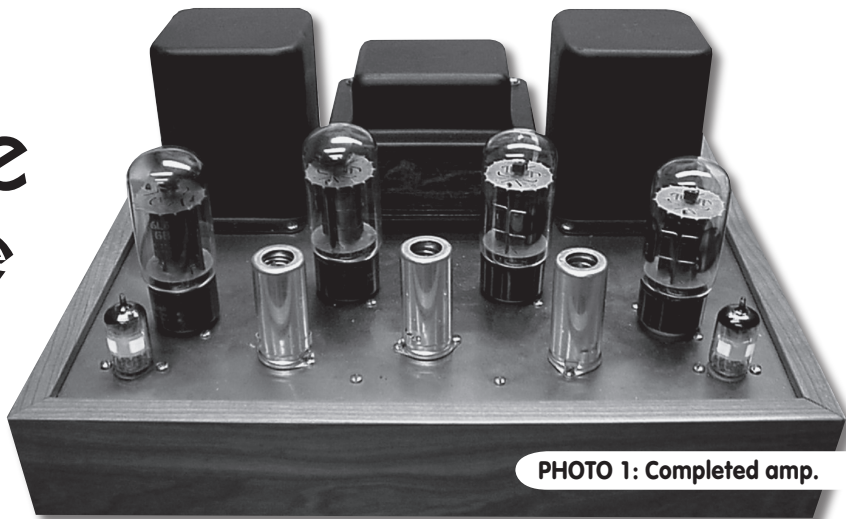
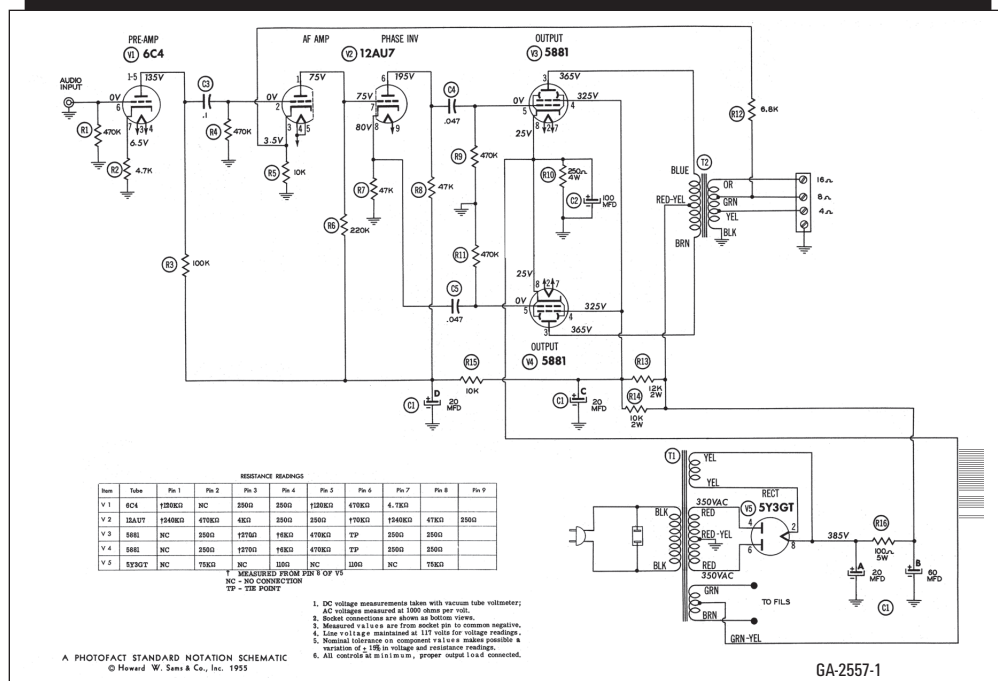


PHOTO 1: Completed amp.

FIGURE 1: Original Pilot AA-410 amp circuit.



parts from a variety of suppliers, or dig into your extra-parts box and see what you can come up with. You can use virtually any output transformer designed to be used with push-pull 6L6s, 5881s, 7591s, 6BQ5s, or even an EL34 transformer (although the heavier iron is more than you need). You can use ultralinear-type transformers and just tape off the extra taps.

I had a very nice pair of potted transformers from some '50s-vintage Heathkit A-9 mono integrated amps I had picked up for a reasonable price. You can probably locate some Heath, Fisher, Sherwood, or other manufacturer transformers from a junked unit or one with a bad power transformer. As I mentioned earlier, Larry used a pair that I salvaged from a Fisher 400 receiver with an open power transformer. The chassis was missing all the tubes and the face was gone when I picked it up, so it was not a candidate for restoration.

HEATH 9C OUTPUT AND FISHER POWER TRANSFORMERS

If you cannot locate a set of output transformers (**Photo 2**), you can order new ones, such as Hammond P-T1620s or P-T1650Fs, from Antique Electronic Supply (though this sort of defeats the purpose of the project!). The kind of power transformer(s) you select depends on whether you are going to build a set of monoblocks or a stereo amplifier (the route I chose for this article).

If you are building monoblocks, you will need a power transformer that will supply about 700V CT at about 125-150mA, double the current for a stereo

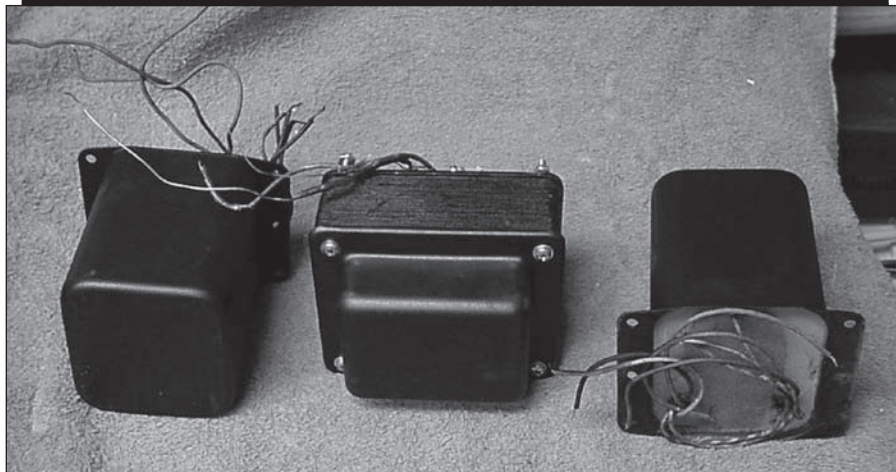
amp. It will also need to supply the filament voltages for the tubes you select as well as the rectifier tube, if you use one. Again, if nothing you have will work, you can use a new Hammond power transformer, such as P-T273CZ or P-T273BX. When you have selected your preamp, phase inverter, rectifier, and output tubes, find the transformer current needed from **Tables 1 and 2**.

You can use miniature, octal, or even loctal tubes. These medium- μ triodes are commonly used and readily available. The original design used a 6C4 as the AF amp, but you can use one-half of a 12AU7 (or if you are building a stereo amp use one-half for each channel). The second tube is a phase inverter; the original used a 12AU7, which is what I used, but feel free to select whatever medium- μ dual triode you prefer.

I chose three 12AU7s plus the four 6L6s for a total filament draw of 4.5A. I prefer to be conservative, so I tried for a 5A 6.3V tap. There are several options for the power-supply section (discussed later). If you use a tube rectifier, you will also need a 5V supply at the appropriate current. **Table 2** lists some appropriate tube rectifiers; you probably have one in your spare tube box.

I hope you have suitable transformers. If not, you need one that supplies around 700V center tapped, or 350V or 175V with no tap. The options allow use of any of these voltages. Make sure they supply enough current for your mono or stereo application. If you do not have the exact high voltage, you can tailor the power supply to deliver the voltages you need.

PHOTO 2: Sample transformers.



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TABLE 1*

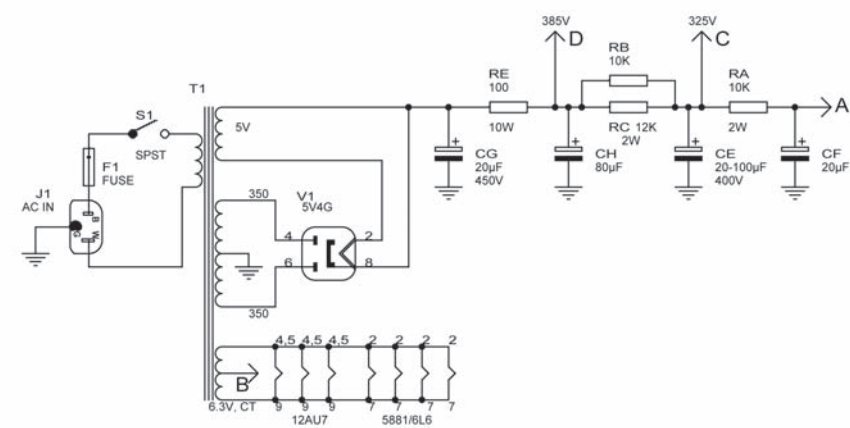
TUBES	Filament	Max Plate	Max Plate	Base
	Current	Current	Voltage	
6C4	0.15A	11mA	300V DC	miniature triode
6J5	0.3A	20mA	300V DC	octal triode
12AU7	0.3A	11mA	330V DC	miniature dual triode
6SN7	0.5A	9mA	300V DC	octal dual triode
7N7	0.8A	9mA	300V DC	loctal dual triode
6L6/G/B	0.9A	88mA	360V DC	beam power tube
6L6-GC	0.9A	116mA	450V DC	beam power tube
5881	0.9A	80mA	400V DC	beam power tube

TABLE 2*

Tube	Filament	Max Plate	Max Plate	Voltage Drop
	Current	Voltage	Current	
5AR4	1.9A	450V	250mA	
5Y3	2.0A	350V	125mA	-50 at 125mA
5Y4	2.0A	350V	150mA	-60 at 125mA
5U4	3.0A	450V	225mA	-44 at 225mA
5V4	2.0A	375V	175mA	-47 at 175mA
5R4	2.0A	750V	650mA	-67 at 250mA
5Z3	3.0A	350V	225mA	-58 at 225mA
5V3	3.0A	415V	1200mA	-46 at 350mA

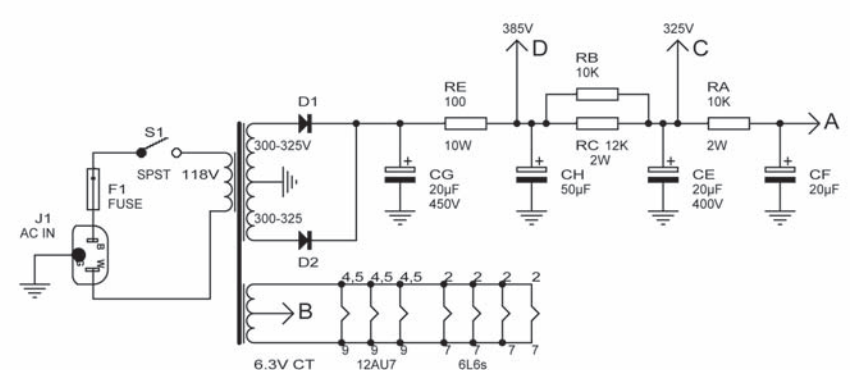
*RCA receiving tube manual RC-20/essential characteristics-GE

FIGURE 2: Power supply option 1.



G-2557-2

FIGURE 3: Power supply option 2.



G-2557-3

The original circuit (Fig. 1) specified a capacitance of 20mF, 80mF, followed by 20µF and 20µF. I used 20µF, then 100µF, and 50-100µF for the last two sections. If you have an assortment of transformers, it is a good idea to breadboard the power supply, and decide which combination works best. You only need to complete the power supply to the output transformer center tap, because if the voltage here is right, everything else will fall into place.

POWER SUPPLY OPTION 1

Figure 2 uses the stock type circuit and a transformer of 650-700VCT on the HV secondary. If you use a secondary close to 650 VCT, you need a 5AR4 rectifier, which is very efficient and will pass the most voltage. Likewise, if your transformer is above 725, use a 5R4, which will drop the voltage. I use 5R4s in Dynaco Mark 3s to lower the operating voltage of the power supply. These amps originally used 5AR4s with 525V electrolytics in the power supply and were manufactured when line voltage was typically 110V.

With today's line voltages of 120-125V, it is common to see Mark 3s with 550V on the electrolytic; this is not a healthy situation. By using a 5R4 instead of a 5AR4, I can drop the power-supply voltage under 500V. This preserves electrolytics as well as tubes and transformers.

Remember, the rectifier you choose must be able to handle the current your amplifier will draw. Do not try to use 5Ys or 5Vs for a stereo amp (Table 2). Unloaded, the voltage at D should be around 475-490V DC. To test your actual loaded voltage, you can temporarily connect a 5kΩ 10W resistor between point D and ground and measure the voltage at D to ground. If this reading is above 400V, you will need to increase the value of resistor RE.

You could also insert a choke, 7-15H, at the appropriate current rating instead of RE. If your voltage is really high, you can insert a choke before C6. This will drop voltage considerably, but the choke may have a mechanical hum. Ideally, you would like 385V DC loaded. If your voltage is lower than 360V, you can decrease the value of RE.

If your transformer has the center tap on the 6.3V winding, great; if not, you will need two 100Ω 2W resistors for the

biasing. If things are good at this point, you can skip to actual construction; if not, go on to Option 2.

POWER SUPPLY OPTION 2

If you have a transformer with 600 to 650 VCT, you can use semiconductor rectifiers instead of a tube (Fig. 3). Semiconductors are more efficient, so you will get higher DC voltages.

Is there a difference in sound between tube and silicon rectifiers? Yes, there sometimes is, but whether it justifies buying a new power transformer so that you can use a tube is completely up to you. Follow the same procedure as in option 1 for fine-tuning your HV supply.

POWER SUPPLY OPTION 3

Sounds strange, but you may have a toroidal transformer with two 175V secondaries or a transformer with a 315-350V untapped secondary. In this situation, you would use a full-wave bridge rectifier (Fig. 4). Use 600V 1A diodes and continue to fine-tune, as in options 1 and 2.

POWER SUPPLY OPTION 4

This option uses a voltage doubler and a transformer with a secondary of 150 to 175V (Fig. 5). I used this option because I had a really nice Fisher transformer with a 110 and 187V tapped secondary at 1A current (a little overkill for this amp, but it worked fine). It also had a 4.7A non-tapped 6.3V secondary as well as a 6.0V 1A secondary. I was able to use the 1A for the indicator tubes and the 4.7A winding for the 12AU7s and the four 6L6s.

You can use a variety of values for CA, CB, CC, and CD; I used 200 μ F -300V electrolytics. Remember that putting these in series is the equivalent of 100 μ F at 600V. My initial unloaded voltage, at point D, was over 500V DC, so I needed some drop.

I used 10H chokes instead of RE, and built duplicate high-voltage supplies from the voltage doublers circuit so I could use two small chokes, because I did not have one big enough to handle the total current. At first this seems excessive, but for the price of a couple resistors and a few electrolytics, I saved myself the cost of a single big piece of iron. This is the fun part of this project: making use of the parts you have on hand (Fig. 8).

You may need to increase or decrease

FIGURE 4: Power supply option 3.

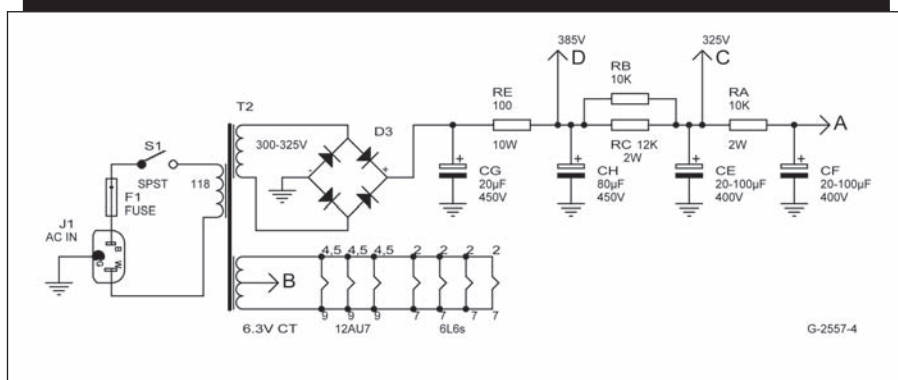
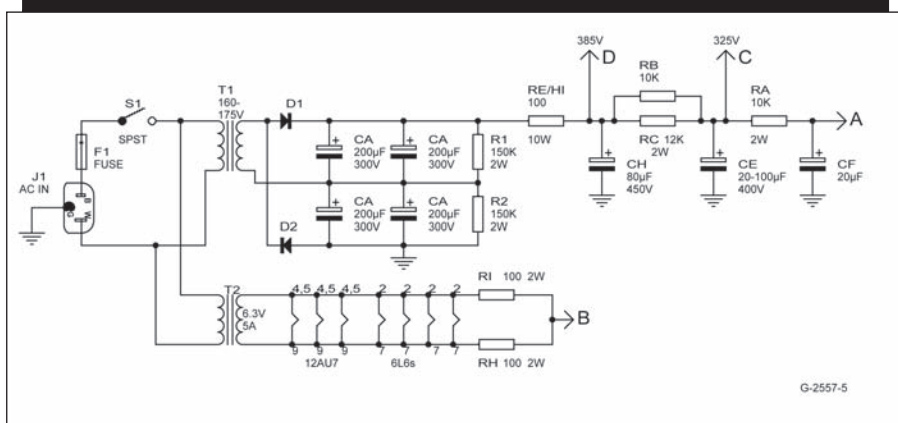


FIGURE 5: Power supply option 4.



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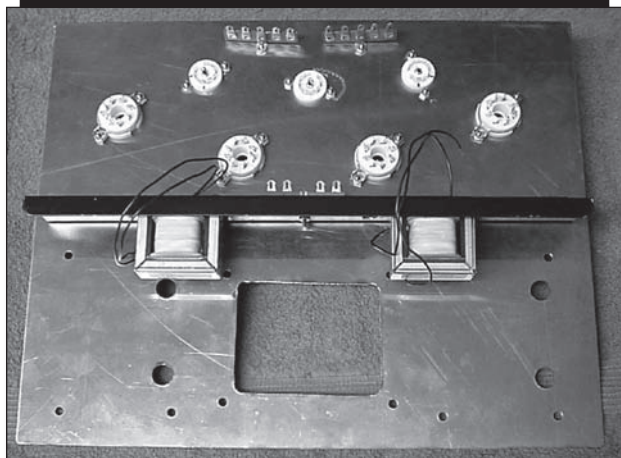
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PHOTO 3: Stainless-steel chassis machined (no level indicator sockets).



the value of RE/H1 to get close to the 385V loaded power-supply voltage. The original circuit uses self-biasing, and for this it uses the center tap of the 6L6 filament supply. Because my transformer did not have a center tap, I used two 100Ω 2W resistors, as shown in **Fig. 5**.

STEREO AMP

Now that you have selected your power transformer—and, I hope, your out-

put transformers—you need to prepare your chassis. Use a piece of cardboard to lay out your transformers and tube sockets. Try not to crowd everything in a small chassis, which can make wiring and service difficult. You can use a new commercial chassis, a used empty chassis, or you can roll your own.

I built my amp on a flat plate and then made a box to fit (**Photo 3**). Use mild steel, aluminum, copper, brass, or just about any metal heavy enough to support your iron. Larry provided me with a very nice piece of stainless steel. (Luckily I was able to convince him to do the machine work for me—stainless is nice to look at, but tough to drill and machine.) You need sharp drill bits, a good drill press, and a carbide die or Dremel™-type grinder to cut your holes. I recommend you measure

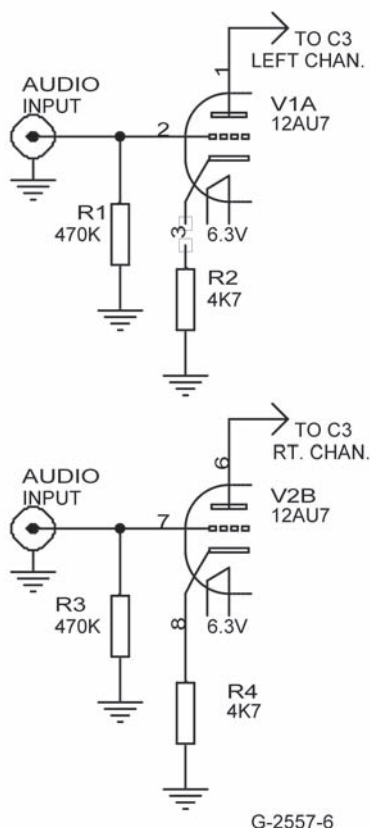
twice before you cut and drill!

I normally mount my chokes on top of the chassis, but Larry likes to place shielding in his amps, so he mounted my chokes on the shielding. Another option for this amp is to wire for audio level indicators. I have always liked the looks of tube level meters but have never built an amp with them, so I decided to add them to this one (**Fig. 7**).

You also need to consider input and output connectors and your options for level controls and input switches. I use level controls on my amplifiers because they allow me to use the amp directly with a CD player or tuner without the use of a preamp/control center. They also allow adjustment of the balance between the speakers (with monoblocks). You may choose to add an input selector with jacks for additional inputs.

You can build a simple box with butt-joined corners to hold the flat chassis, but I used ½" solid cherry, cut to the width that would allow me to recess the top and the bottom and still allow for clearance of the shield and construction. I

FIGURE 6: Stereo amp.

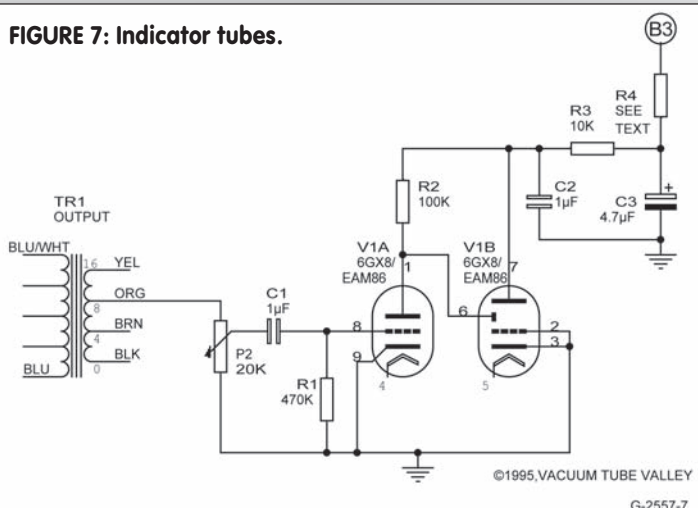


TUBE LEVEL METERS

Indicator tubes can add character to any tube amp. There are a variety of tubes still available and many different circuits for their use. I encourage you to research and locate the style you want to use before you punch holes in the chassis.

I include the circuit plan designed by Daniel Steele for a Stereo 70 (**Fig. 7**). His article was featured in *Vacuum Tube Valley* (Issue 3, Volume 1, Winter 1995). It uses 6GX8/EAM86 indicators. I was able to find several of them listed in online auctions and purchased them for less than \$10 each. In the schematic the input is connected to the 8Ω tap on the output transformer. The 20k pot is used to get the level of indication you desire for the volume set. Adjust the value of R4 to give you approximately 200V on terminal 7 tube socket. ■

FIGURE 7: Indicator tubes.



started with pieces longer than I was going to need and ran them through the tablesaw to cut a 1/4" deep slot for the chassis. Once you get the fit you like, glue the front and sides together. I used a picture frame clamp and an air brad gun to tack the front and sides together. I used screws to attach the back, which allow for disassembly to slide the chassis out. I also glued and nailed some blocks in the inside corners to strengthen the wood joints.

When the glue was dry, I removed the back and used a saber saw and router to cut an opening for another small stainless plate for the input jacks and level control. I used some surface-mount output strips, but you can use binding posts if you prefer. Once all the pieces fit, I sanded the cherry and applied three coats of polyurethane, sanding lightly between coats. Set the case aside and begin work on wiring the amp.

I prefer to wire the power supply first, and then work from the output transformers forward. Because I used a transformer with voltage doublers, my layout may be significantly different from yours. I had a large assortment of electrolytics, which I purchased from Electronic Goldmine. I recommend that you twist the filament wires together to minimize AC hum.

As I said earlier, the transformer I used did not have a center tap on the filament winding, and because it is necessary to use this to bias the output tubes, I used two 100Ω 2W resistors hooked as shown in **Fig. 4**. Once the power supply is wired, you can perform a power-up test to check voltages. You can also insert the tubes at this point to make sure the filament wiring is correct.

CAPS SELECTION

Before proceeding to the amp wiring, I would like to discuss the selection of coupling capacitors and resistors in the audio section. I use 1 and 2W carbon film or metal film resistors in audio circuits. They are stable and quiet, and I prefer having a little safety margin.

Today's metal film resistors are considerably smaller than carbon composition resistors of the same wattage, even though space is not an issue in this amp. (Some people swear by NOS carbon composition resistors; I generally swear at

them. They can be an elusive source of noise and frustration in a finished amp.) Use what works for you.

I use solid 18- or 20-gauge wire with high temperature insulation, trying to color-code my wiring using green for AC, black for grounding, red for high voltage, and yellow and white or blue for audio.

Coupling capacitors are another issue. I did not believe that capacitors sounded different until I started trying various types. You can hear a difference between a 40-year-old "Black Beauty" and a new film capacitor. I have tried all kinds of newer caps, and prefer Illinois™ film caps or Solen Fast™ caps. I have also had good luck with white "Wonder Caps" in triode amps. The Illinois types are very inexpensive, Solens are reasonable, and Wonders, a little more expensive. Larry prefers "Orange Drops." I would not recommend spending much money on premium caps.

I have found that this amplifier circuit is not very critical, and because there are only three coupling caps in the circuit, you can experience a savings here. I believe that capacitors tend to change a little as they "break in." After about 20 hours of use, film caps tend to mellow a little; I think they do sound better after a little use. Believe what you want and build it the way you want, it's your baby!

POWER-SUPPLY WIRING

It is time to wire the amplifier portion (**Photo 4**). As I mentioned earlier, I prefer to start at the output and work forward. If you cannot reach the sockets with the

leads, you can use pin 1 (which is not tied to tube elements) of the 6L6 sockets as a tie point for the 0.047 coupling caps that go to the phase inverter pins 6 and 8. I used a terminal strip to remotely mount resistors R3, R6, and R8 with wires running power to the input and phase inverter tubes.

Preventing ground loops is very important, and the best way to avoid them is to use a master ground bus wire. This bus wire runs from the input of the amplifier and is grounded to the chassis only at this point. Attach each resistor and capacitor ground to this wire. Once you have completed the amplifier section(s), check your wiring; or better yet, have someone else check your wiring. (Larry was kind enough to check mine.)

Photo 5 shows my completed stereo amplifier; as noted, your actual amplifier will vary from this, depending on the power supply you use.

There is a wrong way, an adequate way, and an optimal way to fire up a new amp for a first-time checkout:

1. **WRONG WAY**—Stuff in the tubes, hook up expensive speakers and an audio source, and turn on the power switch!
2. **ADEQUATE WAY**—Stuff in the tubes, hook up inexpensive speakers and an audio source, and hook up the power through an ordinary 100W household lamp and turn on power.
3. **RIGHT WAY**—Stuff in the tubes, hook up inexpensive speakers or dummy load, and the audio source, and plug the amplifier into a Variac. I like to use speakers instead of a dummy

PHOTO 4: Power-supply wiring.

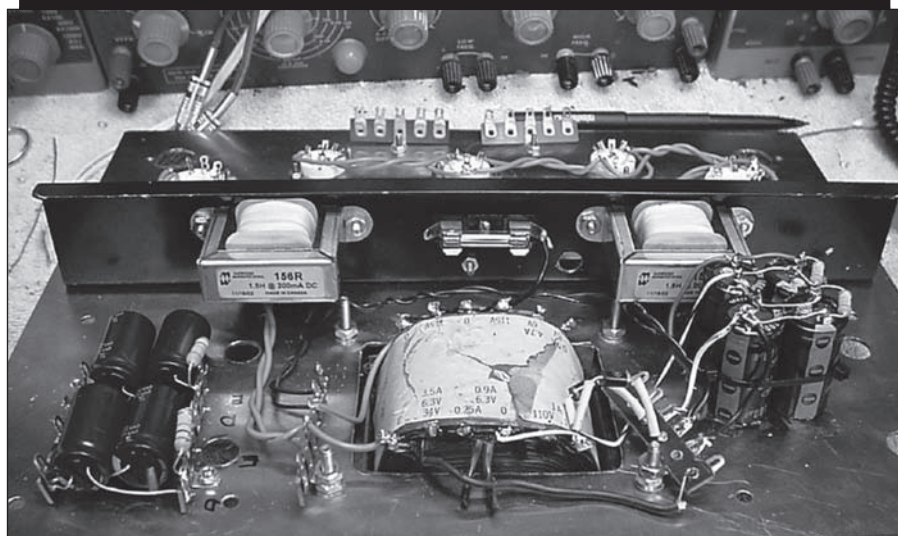
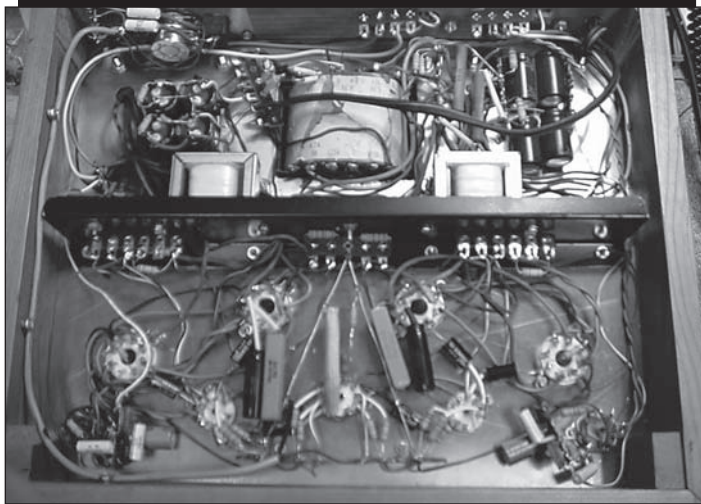


PHOTO 5: Completed stereo amplifier.



load, because sometimes the primary and secondary output windings of the output transformers will be out of phase, which will result in an obnoxious howl as you first fire up the amplifier. Attach your voltmeter to the power supply and bring up the voltage slowly. Watch and listen for signs of problems, such as burning, arching, popping, crackling, hum, feedback, or, worst of all, smoke.

I usually bring line voltage up to about

90-100V and check everything. I then reach 120 and check the power-supply voltages again. If the voltage at point D is between 375-395V, everything else should fall in line. If the voltages are close and none of the other "bummers" have occurred, slowly bring the volume level up. You should be rewarded with music! If the howl I mentioned earlier occurs, reverse the primary winding connections of the output transformers to the plates of the output tubes.

Some amplifier layouts, especially home-built units, can result in high-frequency oscillation that is difficult to isolate without the use of an oscilloscope. It usually occurs in the input high gain stage. Dynaco, Heath, and even Marantz

used a very simple solution that I sometimes find useful. If you are concerned about this issue, connect a 15k resistor in series with a 50-100mF ceramic disk or mica high voltage capacitor from the plate of the first input tube to ground. This does not affect the sound of the amplifier, but will prevent this high-frequency oscillation, which can be very damaging to the tweeters of your speakers.

At this point you can fine-tune the voltages. If the voltage at point D is low, decrease the value of the 10W resistor pair RE. If the voltage is high, you can increase the value. Once the voltage is right at D, the rest should fall in line. If they are not exactly where you want them, adjust the values of RA, RB+C, R8, R6, and R3. Most amps will tolerate a 10-20% voltage range.

After running the amp for 20 minutes, check voltages again and use the "hand touch test" on the transformers. If the power transformer is more than warm, you may have excessive current draw. Look carefully at the output tubes for hot spots.

If your filament current is too close to the maximum, you can shorten the life of the power transformer. Also, if you use a rectifier tube, make sure the transformer current rating is appropriate for the tube you are using. Use of a rectifier tube that draws 3A on a 2A winding will destroy the transformer after a short period of time.

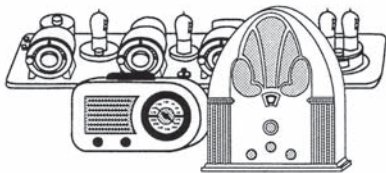
Further tweaking can be helpful; Larry recommends tailoring the feedback resistor R12 and the bias resistor R10. By changing the value of R12 from 6.8k to 10k-12k, you can substantially increase the bass your amp produces. Larry also recommends increasing the value of R10 from 250Ω to 390Ω, which will lower the bias on the output tubes and extend their life without a significant change in sound or power output. These are great little amplifiers, and you should have fun experimenting.

Be aware of the high voltage current draw at heavy amplifier loads. My torture test involves using my JBL 200s at fairly high levels. I have noted some transistor amps perform perfectly in my shop, but do not do well with the JBLs.

These speakers have 15" woofers with a horn compression driver and weigh over 100 lbs each. They have a recom-

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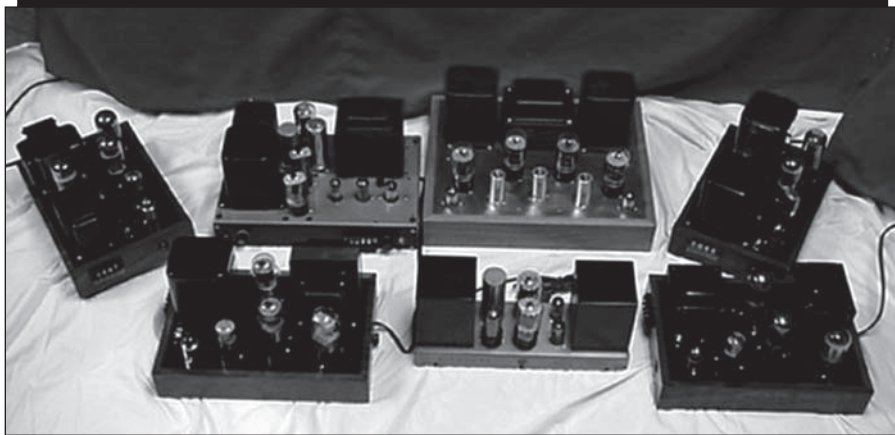
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PHOTO 6: Author's finished amplifiers.



mended minimum drive of 100W and will generally uncover weaknesses in amplifiers very quickly. I have found that the Pilot clones vary considerably in the "hand test" as described previously, and that changing the value of R10 cools down the power transformer accordingly.

Larry and I have each built a number of these amplifiers (Photo 6). The photo shows L to R rear: Larry's monoblock with Fisher Transformers, Bruce's monoblock built on Heath W 5 chassis with Heathkit A-9 output and Baldwin organ power transformer, Bruce's stereo Amp

from article, Bruce's monoblock with Knightkit integrated amp power and output transformers; front, L to R: Larry's monoblock with Heathkit 9A output and unknown power transformer, Bruce's original pilot AA 410, Larry's monoblock with Heathkit AA 100 output and power transformer. The long skinny one in the center is an original Pilot AA 410. As you can see, they are quite different in appearance and makeup, but they all perform very well. I hope that yours do, too. With a set of vintage speakers, such as Dynaco A25s, KLHs, or Advents and a good input source, you will enjoy the sound. *ax*

PARTS LIST (ONE INDICATOR-DOUBLE FOR STEREO)

1-20k linear pot or trimmer
1-470k 1/2W resistor
1-100k 1/2W resistor
1-10k 1/2W resistor
1-50-150k 1W resistor (see text)
1-1µF 450V film capacitor
1-0.1µF 450V film capacitor
1-4.7µF 450V electrolytic capacitor

PARTS LIST SINGLE MONOBLOCK PILOT 410

R1, R4, R9, R11- 470K 1/2W resistor (AES R-E470K)
R2- 4.7k 1/2W resistor (AES R-E4.7K)
R3- 100k 1/2 or 1W resistor (AES R-E100K)
R5- 10k 1/2 or 1W resistor (AES R-E10K)
R6- 220k 1/2 or 1W resistor (AES R-E220K)
R7, R8- 47k 1/2 or 1W resistor (AES R-E47K)
R10- 250-390Ω 5W resistor (SEE TEXT) (R-Q250-R-Q390)
R12- 6.8k-12k 2W resistor (SEE TEXT) (R-F6.8K to R-F12K)
R13- 12k 2W resistor (this is a duplicate from the power supply section) (R-F12K)
R14- 10k 2W resistor (this is a duplicate from the power supply section) (R-F10K)
R15- 10k 2W resistor (this is a duplicate from the power supply section) (R-F10K)
R16/H1- 100Ω 10W resistor (this is duplicated from power supply schematic, see text) (RR100)
C2-100-500µF 300V electrolytics (see text and select based on power supply)
C3- 0.1µF 630V film capacitor (AES Illinois C-TD1-630 or Solen C-FSD1-630)
C4, C5- 0.047µF 630V film capacitor (AES C-TD047-630 OR Solen C-FSD47-630)
V1- Preamp tube- medium mu triode (see text)
V2- AF amp/phase inverter tube medium mu dual triode (see text)
V3, V4- Output tubes-5881 or 6L6
V5- Rectifier 5Y3GT-see text (this is a duplicate from the power supply section-see options 1, 2, 3, or 4)
T1- Power transformer (see text; this is a duplicate from the power supply section)(AES P-T274AX)
T2- Output transformer (see text) (AES P-T1650G)

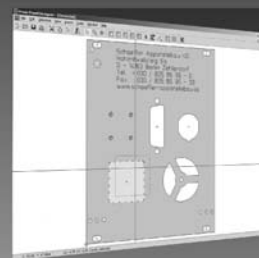
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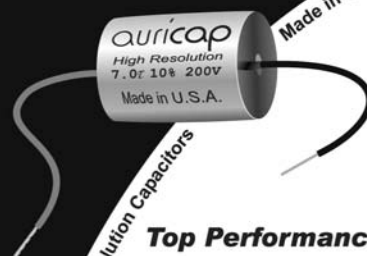


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