SRPP POWER

The search for the best way
to get five watts out of a 6AS7

by Flemming Madsen

I am an electronic engineer and teacher here in Iceland. I began experimenting with audio about 30 years ago, beginning with Voigt pipes and transistor amps. For the last 13 years, I have been concentrating on tube amps, mosfets with tube drivers and direct drive electrostatic speakers.

The SRPP project in this article began as a sound check on a Class A2 driver for a Svetlana 811-10/572-10 amp intended to drive my 7′ high, 1.5′ wide full range electrostatics. I needed a driver with about 50 mA current capability and at least 50 V RMS. The easiest way to get this is using a pass tube like 6AS7 or its equivalent, the 6080.

I had good experiences using 6080 tubes in a PP amp for the electrostatics. The tube is very rugged. I have driven it for every day in 2 years now with max. dissipation but at higher voltages than recommended and no failures have come up so far.

To check out the sound of the driver, I built an amp with 6SL7 and 6AS7 in SRPP using output transformers from a scrapped Dynaco Stereo 35. This amp lived in my workshop for about a year. Everyone who heard that amp was surprised how good it sounded. It had powerful rich bass and clear engaging midrange. The amp was built using metal film resistors and both electrolytics and polyprops in the signal path—in other words, an amp built of crap.

I always tell my students that building tube amps will save the world, and I try the best I can to let them get the bacterium *highfideli-itis*.

One day I woke up to the fact that my student were making a horrible mess of some measurements on the lab table. It looked like a certain kind of Italian food. Then I could do nothing else but ask (in reality I *roared*) “what in h.... can we do to teach you work more systematically?”

They answered as a chorus:“What about building a tube amp?” I warned them, “But it will cost you money.” I saw a lot of work planning it. “That’s all right, we will pay,” they answered. So, there was nothing I could do other than begin thinking about a project that was easy to build, good sounding, and cost next to nothing.

Soon I built a prototype around the SRPP 6AS7 amp in the workshop, putting a 6SN7 preamp in front of it with relay-controlled input switching. The original idea was to control the input switching with TTL logic, but in the end only one out of nine worked. The fact is that *logic is crap*—every tube freak knows that!

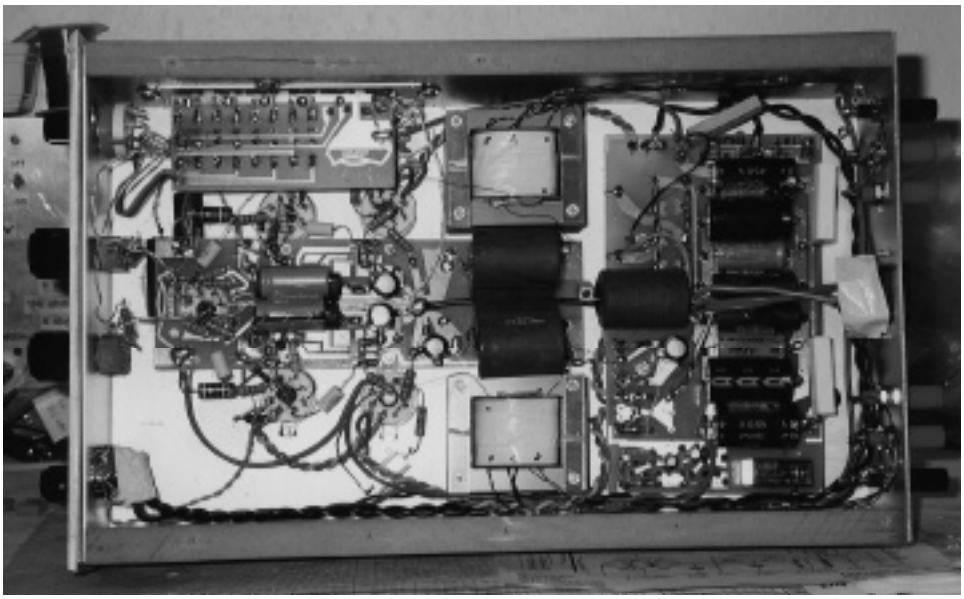
We ended up with a simple switch to control the relays, and it has the added benefit that the switch remains in the same position as you left it last time you used the amp.

You can copy the amp as described below or use it as a platform for experiments. In the process of describing it, I will relate some of my experiences and insights about amp building to you.

But, remember I am not god—I only sound that way when I come forward with my opinions. You must be a critical reader, make your own decisions, and listen critically to *your* results before you’ll get an amp that matches your equipment. That costs a lot of sweat and tears, but in the end you will have learned a lot.

Don’t expect to be satisfied—if so, you would be the first that had been cured of perfectionism. Here you have a chance to get into tube amp building at low cost. Our amp cost about $430. All the items were gotten from four different companies. Most of the parts from Circlewood London. A little from ELFA Sweden. The tubes from Billington. The transformer iron and forms were provided by the local transformer maker. I will make a list on the Internet together with the PCBs and other drawings of the amp.

The platform described here is easy to change to other kinds of output stages with around maximum 15W power capability. The power supply is good and easy to match tubes from 2A3, 300B, EL519 and 6C33B, providing enough current for them all. Of course, you have to change output transformers to match the output tubes. You also must have separate windings for the filaments if using directly heated triodes.



If this is your first project, then it is best to follow the description. You can always upgrade later and would be much better prepared for it.

Input Stag es

The input switch is built on a PCB with integrated phono plugs and DPDT relays controlled with 5V from the heater supply. The diodes over the coils are there to kill clicking noise. The way the input plugs and relays are mounted on the board, the signal path is as short as possible. The advantage with relay switching is that you don´t have the usual long cabling to a switch of often questionable quality. Good switches don´t come cheap. The relays are cheap and hermetically sealed.

Templates of the PCBs used as well as some wiring diagrams are available on www.soundpractices.com/srpp.html in PDF format.

There are two volume controls, one for each channel. It is difficult to get stereo volume pots that actually match. I think that we DIYers end up buying the crap that factories do not want, and pay 10 times more for it! Two volume pots is simpler and better and costs less than a stereo volume pot and a balance pot. I like the two volume control system best. You can get used to using two controls very fast.

The volume control is made as a voltage divider with a fixed resistor in series with the potentiometer. It sounds better that way. The signal goes through a good resistor (carbon composition or Allen Bradleys). The cost is a loss of gain but often this is not a problem.

I think that components shunting signal have lesser impact on the sound than components that the signal goes through. Logically, it is strange, because the current goes through both the shunt and the series items. As we know, a lot in the hifi scene remains unexplained, therefore if you feel it is better, let it be. At least you will feel better about it.

Have your own philosophy, be thoughtful about it, and don´t let anyone mix into it.

A good example about philosophy is how it is possible to build good gramophones with light and stiff materials with a little damping. Alternatively, build it heavy with materials with a lot of damping. Both kinds can be good sounding. But don´t try to mix the philosophies! If you damp the light built one the sound dies. Lightening the heavy one makes it resonate.

Before you modify hifi equipment, you must figure out the philosophy behind the construction. You can try make the light phone stiffer or improve damping of the heavy one. If you try the opposite, the sound will change radically and in most cases for the worse. If you hear big differences, then there is something wrong. OK... I think it is time to come back to the amp project.

The preamp tube is one-half 12SN7 for each channel. It is a plain plate-coupled connection without a bypass cap on the cathode resistor. It is possible to change the sound a bit by changing the plate resistor. For more body, try 12k and for lighter and more liquid sound, use 27kΩ. Anything between is also usable and largely a question of taste and speakers.

You can also try bypassing the cathode resistor with 220µF/10V HQ electrolytic, it will give more punch and a more massive sound.

I used the 12SN7 because of my experience of the amp in my workshop with a 6SN7 SRPP preamp. The tube sounds thinner plate coupled than in SRPP. It is alright if your speakers are not too bright. Perhaps it is better to use 6SN7 and step the heater voltage down from 12V with a 10Ω/10W resistor.

Then you have the choice of a lot of different brands of tubes and they differ a lot in sound. I like the ones with the triangular plates best, the 6SN7WGTA from RCA, for example.

With bright sounding speakers such as Lowthers, I would try the 5687 as preamp. It has a more full-bodied sound without losing the details. The plate resistor would be 7.5k–12k/5W and cathode resistor 330–390Ω/1W. The step down resistor from power supply changed to 6.8kΩ/5W. I have not tried it, but I think it would be a better preamp in this kind of system. Be aware of the different pin connections when you use this tube.

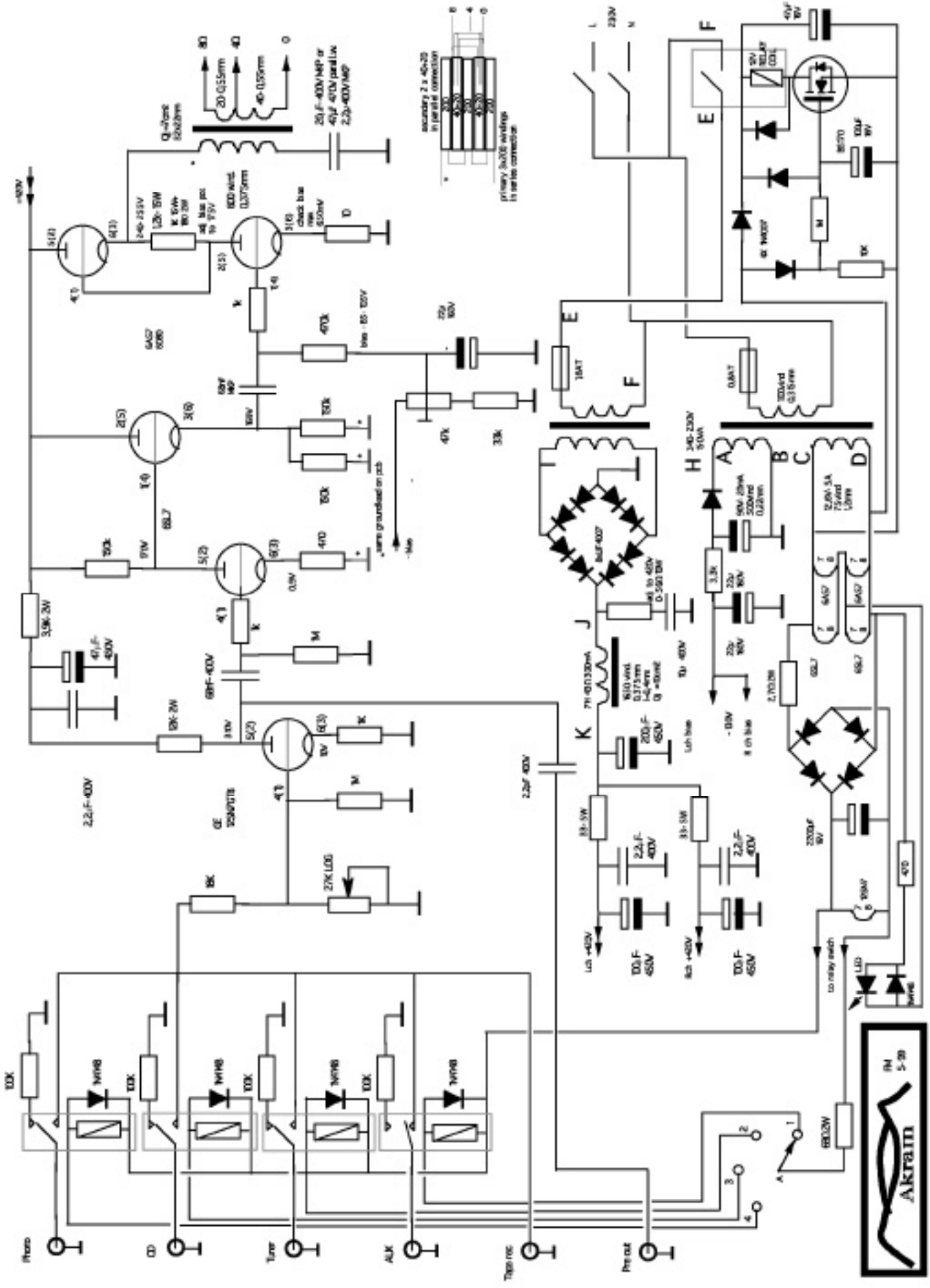
Don't try 12AU7—OK, it is full bodied, but dull and lacking details and a very sloppy bass. I think that a lot of that talk about tube sound with sloppy bass and rounded creamy sound is because of that tube. It was widely used for many years.

I have made a preamp output on the amp, but it is not capable of driving any length of cable. Connecting anything deteriorates the sound on the outputs. Actually, it would be better to use the jacks for an extra input.

Or use it as output from the output tube to drive a separate bigger power stage with, for example, 572-10s. I am thinking about trying this out. Perhaps a description on that later. With such a stage it would be possible to wake up normal 88dB cigarbox speakers, from the so called "high-end class." Wonder why it is called high-end? Were the constructors high when they made it? Or perhaps they tried to high-end their income by manufacturing these undynamic speakers with such high power requirements?

Driv er Stage

It is my experience that voltage amplifiers make much more of a footprint on sound than current amplifiers. Therefore,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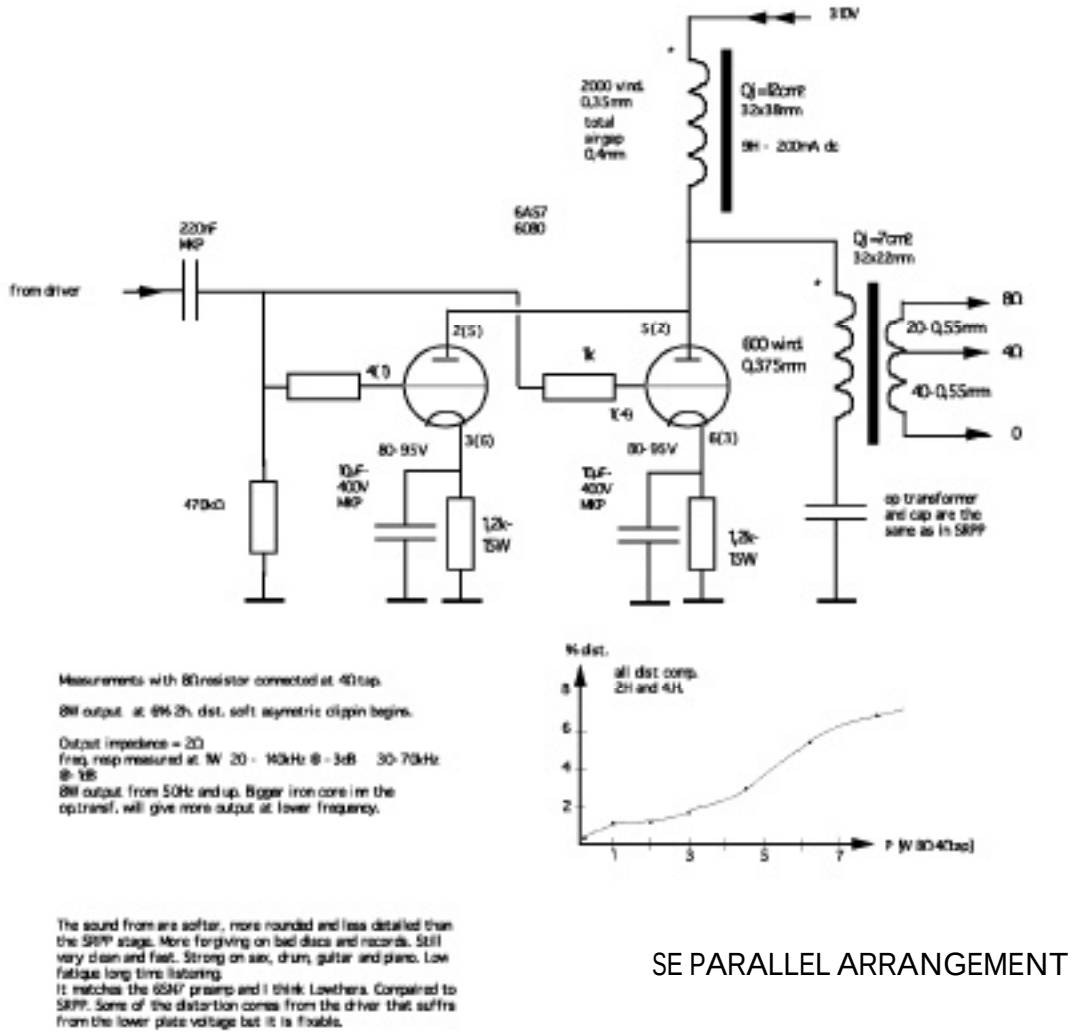


SE PARALLEL ARRANGEMENT

the driver stage and preamp contribute at least 70% of the sound from a triode amp. It is from here by far that most of the voltage amplification comes from. The output tube has little voltage gain compared to the others in triode amplification. The primary stages are mostly responsible for the outcome of the amplifier.

To get enough drive to the power tube, the driver must have high voltage gain. The output tube requires about 70V RMS drive with little distortion. The 6SL7 is good for this. I love the 6SL7— it is fast, clean, and not too clinical.

First I tried SRPP driver with 1kΩ cathode resistors. It sounded fine, but the tube gods don't like putting identical couplings after each other. SRPP 6SL7 is a little rounded but not too much. Also, 6SN7 is fine (very clean) in SRPP but you will lose about 10 dB of voltage gain compared with the 6SL7. It would be worth trying 6SL7 preamp and 6SN7 driver, let me know if anybody tries it.

I also tried SRPP 12AX7 in my workshop. Actually, I have the choice with a switch, so that I could compare different hookups. It is fine but, as with 6SN7, there are big differences between brands. Some sound almost as dull as 12AU7 (bah) and some are fast and powerful (Sovtek WXGTA).

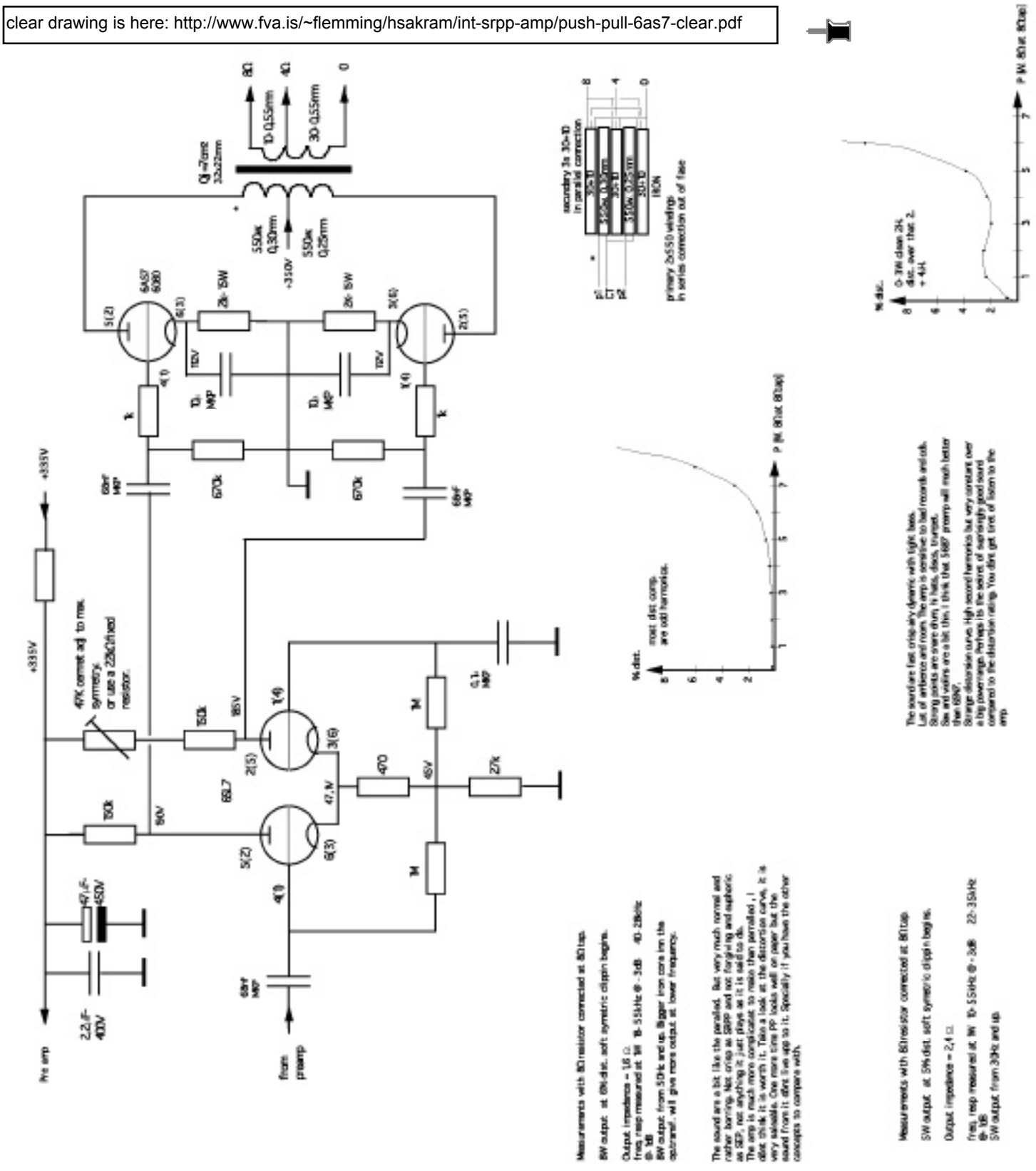
In the end, I chose a plate-coupled 6SL7 DC connected to a cathode follower to get good voltage drive and lower output impedance. I decided not to connect two SRPP stages after each other. The good priests say it is not wise and sometimes, like it or not, you have to listen to the tube gods. They say weaknesses will accumulate.

I am not sure this rule is entirely appropriate here because of the different tubes and very different working conditions. The output tube is heavily loaded by the speaker impedance and the driver is lightly loaded by the very high input impedance of the power tube paralled with a 470kΩ bias resistor. The sound is crisper with plate load/cathode follower. By trial and error, I selected the plate and cathode resistors and ended up with 150K and 75kΩ. That made the lowest distortion on the output and a fast, clean, and crisp sound that matched the 92dB Voigt pipe speakers most of my students have. On my Focals, I find it a bit cold, but the sound is not far from a 2A3 I made for a friend.

For coupling caps I ended up using Wima MKP10 polyprops. Later I tried Audio Note aluminum foil/paper in oil but I was surprised how little difference they made. To excuse my bad hearing, it was difficult for me to compare the cap because of the long break-in period of the paper and oils.

The coupling caps are small, 68nF pp and

clear drawing is here: http://www.fva.is/~flemming/hsakram/int-srpp-amp/push-pull-6as7-clear.pdf



PUSH-PULL ARRANGEMENT

47nF AN, compared with normal practice. This is because I wanted a small amount of filtering—together the coupling caps make a high pass filter of about 10Hz. There is no reason to force the power tube to pump too much subsonic audio from warped records into a transformer that will just eat the current without transferring it. The low frequencies, although not audible, will modulate higher frequencies in the power tube and the power supply will be heavy loaded, so you will get nothing instead.

In the beginning, I did not like this driver because of the two stage configuration. But, in reality, SRPP and my follower also are two stage amps. But you don´t see it as easily. The cathode follower is just put on top of the plate coupled stage. I never tried my follower in this amp. Long ago, I gave it up. It has never sounded right for me. It eats detail compared with SRPP.

In most cases, I like the SRPP best. The sound is clean and human and doesn't change a lot with the working point. In other words, when the tube gets old and tired you won´t hear it very much. The shunt regulated push pull is an easy and forgiving friend to work with. I prefer it in all amp stages from line level and up. While it works for me, I also know that other DIYers have had bad experiences with the SRPP.

Output Stage

The output stage is plain SRPP with the lower half DC biased. The 1kΩ resistor in the grid of the lower tube is to prevent the tube from oscillating. I am not sure if it has to be there. I have not had problems of that kind, perhaps because I always use a grid stopper resistor and always try to make all wiring as short as possible.

The bias voltage is fed to the tube through a 470kΩ resistor. The bias voltage differs a lot from tube to tube, also the halves can differ substantially. This is one of the biggest problems with the 6AS7 and other pass tubes.

In the school project, we had the opportunity to swap tubes so that everybody got tubes that were fairly close in bias voltage. It is preferable to have the bias voltage high to get the highest power from the tube. A tube with higher bias voltage tolerates higher drive voltage before it will eat the upper half of the drive signal with the grid to cathode diode. Higher bias also means more current swing with less input.

In my circuit, the upper half of the tube works as a current source that tries to help the lower tube to draw current. When the plate on the lower tube goes higher, the grid of the upper one also goes higher (less negative). Therefore the cathode follows the grid and the upper tube opens up more for the current through it.

The voltage gain of any SRPP is about the same as mu, in the case of 6AS7, a voltage gain of about two. That is very low, and to make bad worse, under load I have measured input and output voltages to be the same, a voltage gain of only one. Therefore, the 6AS7 as SRPP output tube is only a current amplifier—and therefore has much less impact on sound than you would think.

The 10Ω in the cathode of the lower half, has two different purposes. First, it makes current measurements easy. Voltage across the resistor divided by 10 is the idle current of the tube. Secondly, if the tube should short circuit or lose bias, the resistor will blow up and stop further destruction in the amp and power supply.

The output signal from the output tube is AC coupled through a cap to the step-down transformer. The cap is put in the ground connection of the transformer. I chose this connection because it's my experience that harsh (lifted highs—subjective not measured) sounding caps in series with signal sound dull when used as decoupling caps. In the amp here we have two harsh sounding polypropylenes in the signal path of the voltage amplifier stages. If my theory is right, it must be fine to use a harsh sounding pp in the decoupling of the output transformer, to balance the overall sound. At least I hear it that way. But perhaps it's because I think it is right. Psychology and hifi have a lot in common. No answer is absolutely right, and there are different theories about the same problems.

I have used 47µF electrolytic paralled with 2.2µF MKP. I also have tried 2 x10 µF paralled. I expected better top end and worse bottom. But again the break-in time of the change spoiled the direct comparison. I must admit I can't remember small sound differences for days or weeks. After that long of a time, I only can say whether I like the change or not. It becomes, as always, a matter of taste. Try it yourself and make your own responsible choice. Life is not meant to be easy.

Output transf ormer

The SRPP output stage has an measured output impedance of about 200Ω. Therefore, a matching impedance between 800-1kΩ would be about right. The primary-secondary ratio should therefore be √ (800/8) or 10 to 1. The old Dynaco transformers I began with had about that ratio, when the 8Ω tap was used as secondary and the primary was taken between the two screen grid taps. The amp worked fine with the Dynacos. The bottom was very powerful but the top-end lacked a bit of air. I think you can use many different push pull transformers in this amp, both old and new ones. However, I prefer to wind the transformers myself.

In the school project, we wound our own transformers. It is by far the cheapest route and easier than many think. I also think that it is good to learn how.

There is a lot of fuss about the difficulties of transformer winding. Very true, it is difficult to wind an Ongaku transformer with 16kΩ primary impedance at 20 Hz (127H and pr/sec= 45/1), a lot of DC current through it, and to insulate for 3000V DC on the primary. Oh yes, that costs a lot of work and skill. I think it would be cheaper to buy that kind of transformer, compared to the work required winding it.

But, come on, we can wind a transformer with no DC current through it, a 10:1 ratio, and a primary inductance about 10H. That will give you 800Ω at 12 Hz. Our homemade transformers perform well. They measure <10Hz– 120kHz within -2dB. We used M6 iron from the local transformer supplier. The core was 32 x 22mm (Qj = 7cm2). The windings were interleaved 5 times. In other words, 3 primary windings series connected and between them 2 secondary windings paralled. See the specs and wire dimensions in the schematic.

Our transformers perform better than the Dynacos in the treble but not in the bottom end. When measuring the amp, 20 Hz sine waves have distortion when the output voltage exceeds 3 V into 8Ω. More iron will cure that problem.

Next spring, when my students build an amp, I will double the iron core. The bigger core will store more energy for the bottom end. The E and I laminations are put into the coil 5 and 5 together, making a little air gap in the core and linearizing it. The sound will be lighter and less

mechanical, and the break-in period much reduced.

I always use non-magnetic brass screws and insulate both sides of the transformer with fiberglass PCB. It is best not to use pots and frames made of scrap iron from old cars. At least, if you use this crap put thick cardboard or PCB spacers between them and the iron core. Don't forget to isolate the brass screws. Any connection between the sides produces loss in the transformer, and it is the last thing you want in an audio transformer. If you don't do what I suggest, you will end up with an amp that looks nice but sounds mechanical and compressed. Fellows, the choice is yours.

Perhaps later I will write an article on transformer winding, derived from an old Danish book I found. It is easy and the transformers work well using the modern materials of today.

Transformers are far from perfect on the test bench, but it is surprising how little impact they have on the sound. Caps measure near-perfect compared to transformers, but have a lot more impact on the sound than anyone should expect. Nature is strange.

Power Supply

The power supply is very plain. No tube rectifier is used in order to hold the costs down. It is much simpler to use a bridge rectifier. Only one winding is required for this, you must use additional windings for tube rectifier. In our project we recycled transformers that we had been given from an aluminum plant nearby. Therefore, we have two power transformers one for plate supply and one for heater and bias.

The high voltage rectifier is built around 8 UF4007 diodes, an ultra-fast equivalent of 1N4007 1000V/1A diodes. I series connected them two in each branch so that they can withstand 2 kV in reverse. Really, it is not necessary, but I like it better because if one gives up, the other can do the work alone.

I remember waking up in the middle of the night when a diode in my old Dynaco power amp had given up, the power transformer overheated, and all the black stuff in it had began to boil. It stinks, I tell you—I get bad feelings thinking about it today, 15 years later!

The output voltage from the transformer is 340V@600mA, more than enough. But remember at the place where overkill is a must, a bigger power transformer is always better. After rectification, the voltage is decoupled with a 10µF MKP/400V cap, in series with it is a 10W resistor between 0 and 56Ω. It allows adjustment of the output voltage from the supply by changing the resistor. With no cap, the supply gives out about 300V and with 10µF it gives about 450V when the amp is loading the supply.

After the adjusting cap is a 7H choke @300mA. The airgap in the choke is adjusted with 2 sheets of ordinary writing paper(80g-m2 paper is 0,1 mm = 4 mil), it will make an airgap that is 0,2 mm. The paper is placed between the E and I laminations. All the E blades are together at the same side, then the two sheets of paper cut in size, and then all the I iron together on top.

It is easier to screw the choke together if you apply about 10 V dc to the coil. Then the magnetic field in the iron core will hold the choke together while you are working on it.

After the choke are filter cap banks made of two 100µF@450V caps paralled. After that, the left and right channels are isolated with 33Ω/5W resistors and then decoupled once more with 100µF paralled with 2.2µF MKP, one for each channel. The preamp is further decoupled by 47µF paralled with 2.2µF after the 3.9KΩ voltage dropping resistor feeding the preamp tube.

The bias supply is rectified with only one diode UF4007. One is enough because the bias draws next to nothing in current. But it is preferable to decouple it well to get rid of garbage and noise from the AC power lines and switching noise from the rectifier diodes. Any noise on the bias voltage line will be injected directly into the drive signal of the output tube.

The heater supply is also very plain. Output tube and driver are heated with AC. Left and right channels are series connected to the 12.6V output of the transformer. The preamp tube is heated with 12VDC after rectification. I hard wired the bridge rectifier and cap directly on the preamp tube to get as little switching noise as possible. The lead length between the rectifier and the cap is nearly zero. The output voltage is adjusted by the 2.7Ω/2W resistor and it also compresses switching noise by lowering loading currents to the 2200µF cap—it takes a longer time to load the cap, therefore the rise time of the noise goes down, and it is easier to get rid of by decoupling.

The control voltage to the input switch is taken from the heater supply and stepped down to match the 5V relays. It may be necessary to adjust the resistor if you use different relays than I did.

The power supply is mounted on a PCB. I like best to use it upside down. The advantage is that you don't have to loosen the PCB every time changes are made. The only thing to be careful of is that it is strongly advisable to mount the caps at least 2 mm over the copper foils. The insulation is not made to withstand 450V constantly for years with a lot of heat.

You can get the PCB design on the net. I have used this power supply PCB for years in all kinds of tube amps as a universal assembly like the input switch PCB.

On one side of the PCB there is a little timer connected to a relay that switches on the plate transformer 1-2 minutes after the heater and bias. This is done to protect the caps in the power supply from more than 450V in the start up period. The power tubes also will last longer, the cathodes will not miss electrons in the start up when they are too cold to emit enough electrons to provide high currents. This is also called cathode stripping.

Don't forget to phase the power transformers correctly. Measure the AC voltage between earth and the chassis. When you get the lowest voltage you have found the right connection to the power line, so mark the cords with live and common. If you have not done this already, you must do it with all your equipment one at a time, they must not be connected together, and the ground lead must be disconnected while you do the measurements. By doing this you minimize the ground currents between all your equipment. Soundstage improves and the sound gets cleaner.

Practical things

The amp is built on an anodized aluminum plate. The template will be on the net in PDF 1:1.

The power transformers and choke are placed on top of the chassis together with the tubes. The output transformers are under the chassis. The sides are made of 16 mm MDF form and the front plate of 4 mm aluplate. The text on the front is made with dry transfer symbols.

All the ground connections are star-grounded. To make life easier, I made a PCB to mount between the tubes with all the ground connections and space for bias components. It too is available on the net.

Use a loose power cord and a connector so that you have the opportunity to switch power cords. Make them yourselves. Thick braided wires work well. You can get inspiration in *The Cable Cookbook* from Allen Wright. It is a must-have book.

Use good wiring between the input switch, volume pots and preamp tube. It is best to use twisted wires. Or better yet, silver foils from Allen Wright. I don't like shielded cables—they eat the soundstage. Make the connections as identical as possible for left and right channels. That also enhances soundstage. I have placed the input switching board in the front of the amp to make signal paths as short as they can be.

After finishing the amp, apply power in steps. Begin by checking the power supply without any tubes in the amp. Adjust the bias voltages to –90V, check the heater voltages and high tension. Put in the tubes and adjust the plate voltage on the lower power tube to 180V. Check the voltage across the 10Ω cathode resistor—it must never exceed 0.7V. If it does, you may have to lower the supply voltage by adjusting the resistor in series with the 10µF power supply cap. Readjust the amp after an hour when everything has gotten hot.

Let the amp play music, or better yet, use an XLO burn-in disk for at least two days and finish up with the demagnetizing tracks on the disk.

Use two 10Ω/10W resistors as a dummy load for the break-in period, to protect cat and neighbors while you are at work. You can listen to the amp after a short time but the full break-in period is much longer, so be prepared for changes for the next month at least. Let the amp play as much as possible. It is not enough to just have it on, it must play signal to become softer with time.

Also fix the absolute phase before you listen critically, again using the XLO disk. This disk is one of the best things the high-end guys have come up with. I can't live without it.

I have not investigated silver foil wires for the loudspeakers but I use copper foil 5mm wide made of foil from the local transformer supplier. He uses the foil for electrostatic screens between primary and secondary windings in power transformers. Strip down the foil and insulate it with a good tape and you have a good and cheap speaker cable.

Somebody might ask, "Why SRPP instead of a cathode follower?" I thought the same way and even tried it, but got only about 2 watts from it and much worse overall performance. I dropped it without thinking about why it performed so badly. I think I must have done something wrong, but I don't care.

The distortion of the SRPP amp is clean 2nd harmonic to about 3V output and then the amp gives more and more 3rd harmonic until clipping begins at about 6V into 8Ω.

Some tubes gives 5.5V before clipping and others about 6.5V. I have a pair of RCAs that give 7V. The performance is about the same as 2A3s are capable of. The sound doesn't differ much from a 2A3 SE amp ("Baby Ongaku" with home-wound transformers) I compared it with.

Close at last

To complete this article, I will give you alternative connections of the 6AS7 power stage with the component values and a brief subjective description of the sound and the measured performance.

The differences in sound are not very big but the power performances and measurements differ a lot. I tried to let some of my fellow patients with a high degree of *highfideli-itis* make comparisons in an AB listener test of three different amps: SRPP, push pull Class A, and paralled SE parafeed. On nine different records every amp was named best amp three times!

But there were problems with the preamp. I used one of the 12SN7s as preamp into all the amp inputs at the same time. We knew that the preamp wasent that great and, what's more, it did not have capability to drive all the tested amps at the same time.

So, I will not put to much authority in this formal "test." Instead I will give a brief subjective description of how I find the long term sound from the different coupled outputstages, together with the data and distortion curves.

Another thing is that AB tests seem to magnify small differences compared to long-term listening. Perhaps records, gramophone, amplifier, speakers and the soul of the listener must be burned-in together before anybody can make critiques of anything.

OK, we are back again to a combination of psychology, perfectionism and engineering, blended with religion and an expensive world-wide disease nobody can, or even tries, to cure, called *highfideli-itis*.

So, make your own choices and don't expect to be fully satisfied with the sound of your equipment. If that happens, then you are getting old…start making yourself a coffin out of your VOT speakers!