Power Supplies: Commentary for Consumers

(c) Nelson Pass, Pass Labs

Intro: Electricity and Hydraulics.

Lots of people don't understand electricity, but they do understand plumbing. Hydraulics provides a good analogy in understanding basic electrical flow. Wire is a pipe. Water pressure is voltage. Water flow is electrical current. Lakes and storage tanks are capacitors. Diodes are one-way valves. Tubes and transistors are faucets.

The entire power circuitry of an amplifier can be seen as a community water system. The sun, driving the weather cycle, deposits water on the landscape, and it collects in a lake behind a dam. The community draws water as needed through pipes. In the winter, the rain collects in the lake, and the water pressure increases as it fills. In the summer the water level falls, and so does the pressure. When the community draws more water than usual, the level goes down more, and it often takes more than one season to build it back up.

In an amplifier, your utility, house wiring, power cord, and transformer provide the rain. The capacitor bank is the reservoir. The capacitors receive electrical charge every 1/120th of a second, reflecting two pulses of current from the transformer for every cycle of the 60 Hz sine wave provided by the power company.

These pulses are of relatively short duration, and it is up to the power supply capacitors to store energy during the 6 millisecond or so electrical drought that occurs between charge pulses. We want a constant voltage (water level) from our power supply, and this is usually achieved by the use of large capacitors which store more charge, and large transformers which provide as much charge as is needed. You get the idea.

Since we are not designing amplifiers here, but rather trying to get a handle on what constitutes quality in a market full of hype, I want to talk about some general ideas and comment on some of the common approaches used by manufacturers. Understand that we simply want a constant, noise-free, voltage to be available from a power supply, regardless of how much demand we place on it.

Bigger and heavier is better. Bigger transformers and wires load down less. Big capacitors hold more charge.

Is there such a thing as too big? Certainly there are diminishing returns as we get bigger. When a transformer is delivering 1 watt to a preamp circuit, going from a thousand watt rating to two kilowatts isn't going to buy you much improvement. This consideration is not much of a deterrent to the average audiophile, however.

Power transformers.

The best power transformers are toroids, with donut shaped magnetic cores. They pack the most power for weight and size, and they make less noise. Toroidal transformers have to be rated at a minimum of several times the intended wattage because the power is delivered in short pulses to the capacitors.

Typically, a Class AB stereo amplifier rated at 200 watts per channel continuously should be capable of delivering 700 watts or so, and this means a transformer rating of about 2000 watts. Anything less means non-continuous operation. This might be alright for a class AB amplifier where maximum continuous operation is not required.

If the stereo amplifier is rated 200 watts per channel pure Class A, it will draw about 1000 watts all the time, meaning that about 3000 watts of power transformer is called for, no less.

Now a toroidal transformer delivers about 30 watts per pound, so a 3000 watt toroid will weight about 100 lbs, maybe more. The rest of such an amplifier will probably weigh about as much, so if you are looking at a 200 watt per channel stereo Class A amplifier, you will want to see if it weighs at least 200 lbs.

One pound of weight for every 2 watts is a good litmus test for evaluating Class A amplifiers. An amplifier weighing less might not be pure Class A. It might be almost Class A, or it might be one of the many products which achieve a Class A designation through trick circuitry.

To lower noise still further, toroids are sometimes encapsulated in metal cans. To reduce magnetic radiation, these cans are usually, but not always, made of steel. This is good, but be aware that in the past, at least one company has used a small transformer in a big can, and made up the difference with sand.

Capacitors.

Because of the high capacitance values required, power supply capacitors are almost invariably electrolytic in construction. The capacitors you see in power amplifiers are rated in terms of capacitance in micro-farads, voltage, and current. A typical value for capacitance of one of the big cans is 25,000 micro-farads, or .025 farads. A farad is a big thing; that capacitance which will lose 1 volt after delivering 1 amp for 1 second. In a power amplifier drawing an 8 amp bias, like our 200 watt stereo Class A example, this means a power supply ripple of about .06 volt rms.

Most of the time, you want to see a total of at least 100,000 micro-farads, which for our example gives a ripple of about .6 volts. This is pretty good, representing about 1% of the total supply voltage. Smaller amplifiers can get by with less, big amps require more.

Big electrolytic capacitors have a small amount of inductance, or "coilness", in their makeup, a result of the spiral winding of the capacitive film. To reduce the effect of this inductance, film capacitors which have low inductance are often placed in parallel, so that at high frequencies the current flows a little more easily.

An examination of the numbers will provide some insight here. It is common for the inductance of a large electrolytic capacitor to cause its impedance to begin increasing at about 10 KHz so that its impedance is a large fraction of an ohm at 100 KHz. Placing a film cap in parallel will keep the impedance to .1 ohm or so above this frequency.

Is this important because audio has real power at these frequencies? No. Audio has power which declines at about 12 dB/octave above 5 Khz, and real musical slew rate figures are a fraction of a volt per microsecond, meaning that practically no power is needed at 100 KHz.

However, high frequency impedance can be important to the stability of the amplifier, particularly with more complex circuits, as the source impedance of the power supply starts figuring into the feedback at frequencies of a mega-Hertz or so. Interestingly, some designers have depended on a particular source impedance of the supply at these frequencies for stability, thus it is possible to destabilize the amplifier circuit by paralleling film capacitors across the electrolytics. In general, however, film caps in the power supplies are a good sign from the consumer's standpoint.

Inductors.

As much as we often try to eliminate inductance in capacitors and wiring, inductors in the form of coils can be used to improve the performance of power supplies. Placing inductance and capacitors on the AC line to form filters will reduce both incoming and outgoing high frequency noise. Large inductors in series with the transformer primaries and secondaries can be used to stretch the duration of the charge pulse to the power supply capacitors, improving regulation and reducing noise. Large inductors in combination with multiple power supply capacitors can form "pi" filters to reduce the noise on the supply lines.

Inductors are very useful, but they cost money. Their use in power amplifier supplies is an indication that the manufacturer has an unusually strong commitment to performance.

Wire.

Audiophiles love wire. Perhaps the appeal lies in the accessibility to understanding. Perhaps not. In any case, I like my wire thick and short, and made out of pure soft metals such as copper or silver. I like it terminated tightly and soldered where possible.

Rectifiers.

Yeah, sure, rectifiers are important, after all, the AC has to get converted to DC, but I don't like the fast recovery types that some audiophiles have raved about. Fast recovery means that they withstand many amps and volts in a tenth of a few nano-seconds, something we don't see very often on the old 60 Hz AC line. They are essential element in switching power supplies, but for regular "linear" power supplies, I much prefer SLOW diodes, and we create them by placing small capacitor circuits across the diodes, which greatly reduces radiated noise.

Regulation

Active linear regulation is a great way to make the supply voltage constant. Unfortunately it is not usually done properly. In the past, some amplifiers using active regulation have been criticized for a lack of apparent dynamics, and this has given the technique a lesser reputation than it deserves.

Properly done, linear regulation has to go beyond the cursory requirements of the amplifier ratings. The regulator should be capable of ten times the current of the continuous output of the amplifier channel. The regulator should be preceded and followed by large capacitances with values comparable to those needed for unregulated circuits. The transformer size still needs to be as big as that used in an unregulated circuit.

Approached in this manner, linear active regulation delivers the goods.

A far less expensive approach achieves some of the regulation goals, and that is to regulate or otherwise isolate the low power front end of the amplifier, leaving the output stage looking at an unregulated supply. This can be accomplished with entirely separate supplies, active regulation, or with as little as two resistors and two capacitors.

Another way to regulate is by using constant current sources, which feed the circuit a constant current that does not fluctuate with supply voltage. A good constant current source can improve regulation for low power front end circuits by a factor of 100, and combined with supply voltage regulation, gives really excellent performance at little cost.

You can also bias the output stage with a constant high current source to create a single-ended Class A amplifier. I'm not joking.

Switching Supplies

The advantages of switching supplies revolve around low weight, low material cost, and their ability to actively regulate at no additional cost. Noise is a potential problem with switching supplies, but is solvable by physically isolating and filtering the supply, in other words, by spending money.

This can be a deep subject, but suffice it to say that I believe that some of the same caveats apply to switching supplies as linear regulators. Again, they should be rated far beyond the nominal current requirements of the amplifier circuit, particularly as the switchers I have seen usually degrade badly beyond their ratings. Also, it helps if the power supply capacitors before and after the switcher are very substantial. This is typically not the case, since one of the primary motivations to use switchers is to save money.

More sophisticate use of switching circuitry, such as Bob Carver's is more than I would care to tackle here, but you can certainly get a lucid explanation from him.

Mono Operation

We all know what Mono means, which is a one channel amplifier. Of course, for a channel which does not have to share power resources, it mean an improvement, since in a given size box it can have twice as much transformer and capacitor bank. The other intent is to physically and electrically isolate each power amplifier channel from every other, meeting only at the AC line, and sometimes not even there. This way, whatever is happening on one channel has minimal influence on the others.

Mono operation is very desirable in high end systems, but of course it is expensive. A modest compromise is offered by "dual-mono" operation, in which two channels share the same chassis and power cord, but have separate transformers and supply capacitors. This achieves much of the isolation desired at lesser cost.

Battery Operation

Just about total isolation. Near zero noise. Costs a mint.

Conclusion

So what have we learned here? In general it takes big money to buy the big hardware to make really good power amplifier supplies.

Some of the approaches commented on here result in only marginal improvements, but they are measurable. It is not necessary when contemplating these aspects of power supply design to get into a debate of objective versus subjective performance.   There is only the issue of how much you are willing to invest in diminishing returns.

Engineering being the science of compromise, each manufacturer draws their own cost/benefit line, and it has been my experience that most manufacturers are quite conscientious about this. The degree of sophistication and massiveness of a supply has the context of the price of the product, and your expectations should be scaled accordingly.

As a consumer, you want the best sound you can get. You can accomplish that through critical listening. As a secondary goal, we all like to get what seems to be good hardware value, and we want to know that that the manufacturer has actually put some real money into the product which costs a small fortune. If you can read the specs or look under the hood, the power supply, being one of the most expensive parts of the amp, usually is a good indicator. It should be the biggest and heaviest part of the amplifier.

What if you don't want to go through the trouble but still want your money's worth? Get at least 15 pounds of amplifier for each thousand dollars spent.