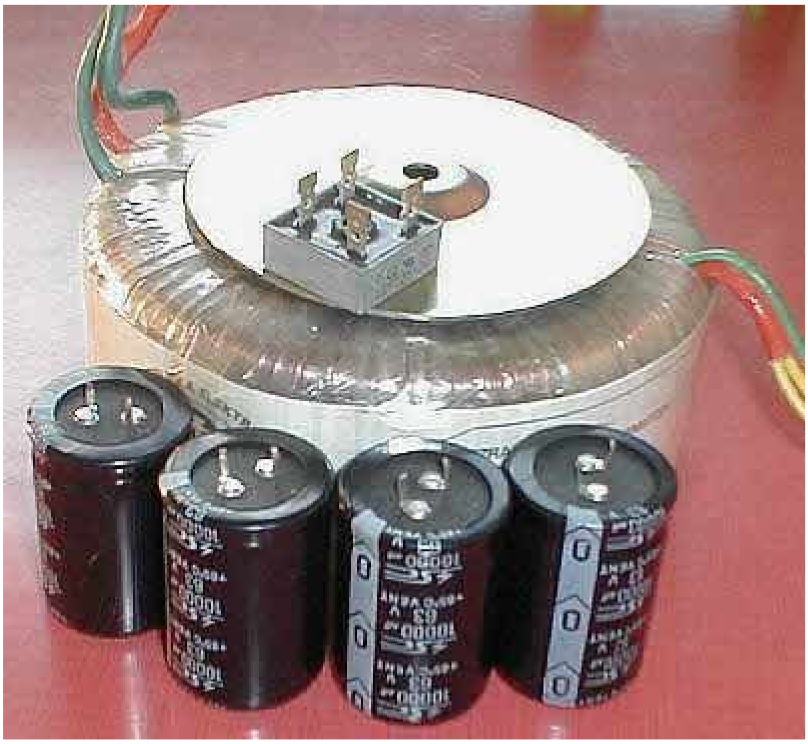
Solid State Power Amplifier Supply

Part I



[Italian version]

Many of us have over the years come across amplifiers, mostly from reputable sources and at rather steep prices, which have made us want to have them. More often than not, two aspects have drawn our attention - the bass and the treble.

Somehow, probably due to our non-linear hearing, which is at its best in the midrange, and probably because we take the midrange for granted ("Well, if it doesn't do midrange, what does it do?"), we pay least attention to it. But there are other reasons too - good bass is not easy to obtain and has most valve designers working many a night, and good treble has been the slippery side of solid state amps for about as long as they exist.

In practice, both can be obtained, with some care and a little applied knowledge, since many designers have contributed to our pool of knowledge, sometimes less and sometimes more successfully.
However, obtaining better bass lines is never ever a job unto itself - one simply cannot improve only the bass, as any improvement in the bass will necessarily cause improvements elsewhere too, perhaps to a lesser degree, but there all the same, as we shall see.

The treble however is an entirely different matter. To be good, it requires many decisions to be made in the early amplifier development stages, many of which cannot be changed later on, or perhaps can, but after long, hard work, frequently not worth the time and trouble.
However, far too few people realize that to obtain good treble from a solid state power amp, one either starts or finishes with the power supply, just the same as for the bass. This work needs to be done however we look at it.

Regulated or not?

It is sometimes implied that fully electronically regulated power amplifier supplies will yield better results than classic, capacitor smoothed ones. That may be the case, but there are many obstacles along the way for it to be really so.
For a start, a regulated power supply can be visualized as in fact another power amplifier, of same or better power ratings than the one being regulated. Then, it needs to be fast, very fast, so it can respond to sudden peaks demanded by music - this makes it still more expensive to design and make. Obviously, a lot more space will be required within the amp, to accommodate additional electronics, some of which requires just as much heat sinking as the basic audio electronics - so, heavier, bulkier, much more expensive.

Also, fully regulated power supplies are "stiff" - this means that they will work up to a level and no more, period. They could make it easier to double the power into half the load, but they will not allow for dynamic power bursts much above the nominal rating.
They could be made to allow for it, but that would make them still more expensive and massive.

To this day, I have heard only one product with fully regulated power supplies which sounded right (and then some!), and that is Levinson. All others of the same breed sounded very well defined but somehow shut in, too controlled for my liking. And their prices and sizes were, well, generous.

What happens is briefly this - with regulators, we want to decrease the voltage as much as we can to keep our regulator transistors well within their Safe Operating Area (SOAR), but above the absolute necessity.
If we have a say 50W/8 Ohm output, that requires 28.3V peak voltage, so we'll very likely regulate at say 32V. However, in case of unregulated power supplies, our lines will be say 34V at peak output, rising to say 36-38V off load. Working backwards, our regulated amp will start to clip at 32V, minus voltage drops on amplifier transistors (say 1.3 V for driver and output stage), which is 30.7V, or 59.2W/8 Ohms. In case of unregulated supplies, assuming good dimensioning, our voltage will drop only 1-2V below off load voltage because the capacitors will supply short term power, which will allow us an output of (38-2-1.3) 34.7V, or 75.7W/8 Ohms.

When the load is halved, i.e. when it is 4 Ohms, a regulated power supply will allow double the power (assuming it's designed to do so), but with the same limitations as above.
Typically, it will start to limit available current at loads below 4 Ohms, while a capacitor smoothed one will also do so, but to a much lesser extent, at least in peaks.

Obviously, fully regulated power supplies are not practical in typical power amplifiers running in class AB.
Pure class A is quite a different story, as it draws constant currents, so electronic regulation has a much simpler job to do. However, do not throw it out yet - we do need full regulation in a power amp.

The voltage section of the power amplifier runs in pure class A, hence drawing constant currents; since it amplifies voltages, its current requirements are both fixed and low. On the other hand, voltage gain stages should have no idea what kind of load is being driven, and they introduce voltage drops over every stage, thus forcing us to increase power supply lines in order to realize the full potential of the amp.
So, we could - and I believe should, always! - use full regulation for supply lines to our voltage amplifier stages.

The benefits are many. First, additional filtering is applied where it will do most good, thus improving our signal to noise ratio.
Second, voltage gain stages are definitely and completely cut off from any influence on current consumption and dynamic regimes of the output stage proper.
Third, we can easily and safely increase the supply line voltages to the voltage amp so we compensate for inherent voltage drops, which allows us to use the output stage's capabilities in full. And fourth, we can effectively drop the output stage voltage somewhat over what it would have been if no regulation was applied. This in turn allows us to keep the transistors more within their SOAR and to draw larger currents from them, since voltages are lower. All that without any losses, and in fact, with many gains.

The added price is not bad at all, since full regulation can be executed with very few components, all depending on specific situation. We can even go a step further and make our regulated supplies a little more powerful, so that in case of a bipolar output stage with a double driver preceding the output stage the first, still a relatively low power driver stage, is also fed by regulated power supplies.
This will be a significant improvement, I think, in both load tolerance and consistency of drive - so I use it in all my power amplifiers.

So, to wrap up - full voltage regulation should be applied to all stages of a power amplifier except the driver and final output stages, which for the sake of dynamics, especially into difficult loads, and economy, should be kept on capacitor smoothed supplies.

Assumption - only one

Whenever dealing with practical issues, given the range of possibilities, we must assume something. Here, I will assume we are talking about the power amplifier's current gain stages.
They use up the vast majority of the power drawn by an amplifier, since it is they who must tackle the load we call "loudspeakers". While conveniently dubbed "8 Ohm" loads, in reality they often have impedance drops to half or less their nominal value, and with significant phase shifts, all of which may cause a power amplifier's current gain stages to effectively see loads of 3 Ohms or less.

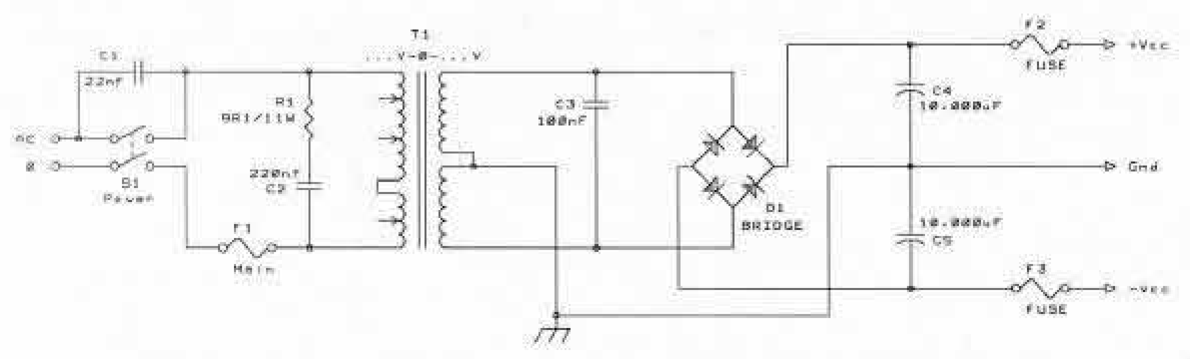
To make matters worse, two additional factors must be taken into account. One is that many aberrations of speaker impedance will not show up in classic testing procedures since they are by their nature of transient character, and so cannot be seen in classic sweep tests.
This subject was, to the best of my knowledge, first seriously discussed in the amp community by Prof Matti Otala, in his IEEE publications in mid-seventies. Even if I'm wrong about my dates, that's still no less than 25 years, enough for many advances to be made.
The second factor is the fact that loudspeakers change their characteristics as they heat up in use, just the same as amplifiers do, and here we have additional problems to think of - their new interactions after say 30 minutes of hard work by all parties concerned.

Therefore, being an optimist, I choose to be pessimistic about the driven loads; that way, when I run into a nicely behaved, easy to drive speaker, I am happy because my amp grabs it and controls it completely.
And when I run into a difficult and very complex load, I'm not worried, because that's what I've been expecting anyway, so life is still rosy for me.

So, call me a member of the Krell race (the mythical perished civilization from the SF film "Forbidden Planet", 1956, where Dan D'Agostino, owner and designer of Krell Industries probably got the name), but I will assume that I will be dealing with a 2 Ohm load, and less in peaks only. It will cost me money, but hey, this is audio, so costs are immaterial.

The Components

A power supply consists of basically three elements - the power transformer, the rectifier and the filter capacitors. Optionally, you could use a line filter before the power transformer, and possibly some method of soft switching if you have very large capacitor banks, so as to avoid blowing your line fuse every time you turn your power amp on.



There are many possible variations on this basic theme, each with its advantages and drawbacks. Because I need to assume something, I'll skip various delay schemes, possible filters and so forth and concentrate on the essence.

Diagram 1 shows a typical commercial unit power amp power supply. Very simple - transformer, one token filter behind it, a full wave bridge rectifier and a pair of electrolytic capacitors. Its advantages are twofold - it's cheap and it's simple to implement. All that, and it works, too!

However, its drawbacks are many. Such simplicity requires great quality of components to give audiophile grade results - the less parts you use, the better they need to be as there are no compensations down the line.
Furthermore, because it's cheap, all too often in practice, you'll find a rather small, sometimes appallingly small power transformer, low grade caps and a definitely undersized bridge rectifier. Don't even think about its cooling - very likely it will consist of discrete diodes rather than being a block.

The net result is that rectification is up to full wave standards (i.e. transformer secondary voltage x sq. root of 2, or times 1.41), but the purity of the assumed DC will be rather poor. High frequency behavior will be very doubtful, and generally way below audiophile grade.
Since power transformers in commercial units are made in all possible ways except using the generous dimensioning method, you can expect some dirty supply under stress - this will cause flawed transient response, and the unit will probably sound washed out, flat and uninspiring.

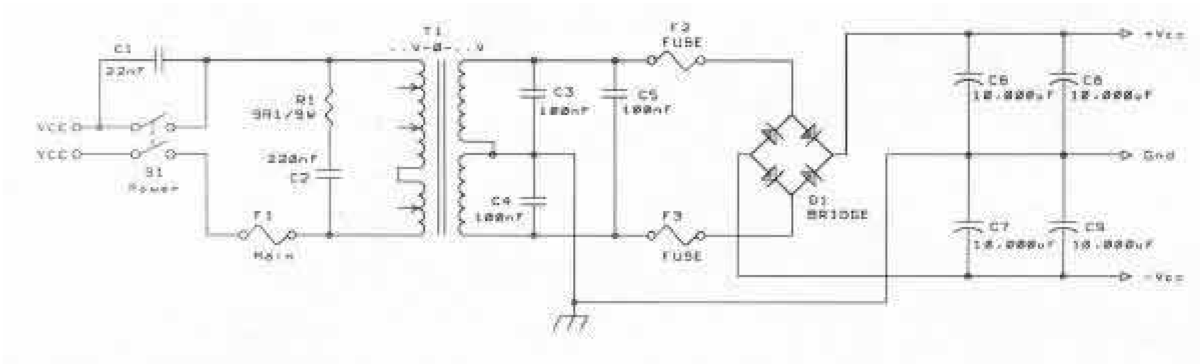


Diagram 2 shows a better commercial power supply, usually found in mid-priced equipment. Now we see two more small value filter caps before the bridge rectifier, and another pair after the large value filter capacitors. The first pair is there to filter out the high frequency noise, as is the second pair. This method will provide cleaner power supply in terms of high frequency rubbish which shouldn't be there, but somehow always is.
It is also reasonable to assume - though not strictly and always true! - that anyone bothering with all that has also previously made a better choice regarding transformer capacity and quality and has endowed the amp with a better quality bridge rectifier.

But even so, it remains to be verified what exactly does "more generous" mean. It may well turn out that even by a seemingly large increase of say +20...30%, the power transformer is still just a borderline case.

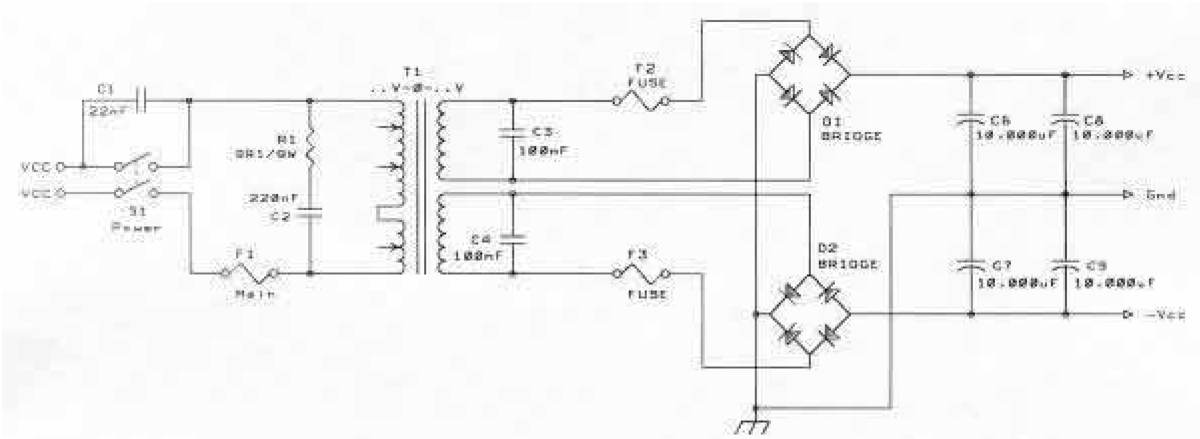


Diagram 3 shows a serious power supply. Here we have double the filter capacity from the previous case, something that in itself cannot be bad. However, it may not be so good either.

You see, filter capacitors should be just that, FILTER capacitors, their energy storage function being of secondary importance. In many commercial units, these roles are present but reversed - larger value capacitors are used not only for filtering, which they cannot help but do, but also to act as energy reservoirs.
Of course, they always act that way, but the point is that they tend to be increased in capacity to cover for inadequate power transformer size and/or performance.
In such cases, you are not very likely to find high quality capacitors inside, but rather those of commercial quality. There are two basic reasons for this. The first is that they are cheap, and can be made to look good on ad photos and in ad sales blurb.
The second is that by connecting two capacitors in parallel, one not only doubles their energy reserves, but also cuts their output impedance in half. This is of course quite true, and in practice works every time without fail, but in essence is much less than we are led to believe.

So halved output impedance may still be above the values obtainable by using a single pair of high quality capacitors. Also, this view completely disregards capacitor charge and discharge speeds - good quality caps are expensive precisely because they are, among other things, very fast.
By way of example, a typical commercial value capacitor, rated at 10,000uF/63V and costing some Euro 8-9, will have a speed of 30-40V/uS at best. An equivalent Elna for Audio series black, costing some Euro 15-25, will have a speed in the range of 80-90V/uS, i.e. at the very worst, double the speed of the best case in commercial cap land. A Siemens Sikorel cap, costing some Euro 20-30, will slew at over 100V/uS - but at a price.

And this is hard to ignore if you want good quality sound. What's the use of ultra fast electronics, capable of tremendous speeds, if they will be bogged down by slow capacitors, which will appear as speed limiters? I can't help being sarcastic here - this is why in so many cases the advertised amp speed is never achieved in real life.
Many manufacturers measure the speed of the input stage only, and far too few of the overall amplifier - the second group will always show much less impressive results. So beware of wild figures, they are most probably not truly representative of the amp as a whole, on an input-to-output basis.

Go to Part 2

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