Designing a PSU with DuncanAmps PSUD II by DHTROB
… For SE amplifiers (Translation by Bas Horneman)
(Rob also thanked Matthijs de Vries in his original article)

(Ed.: I read Rob's excellent hands-on guide on his webpage dhtrob.com and asked if I could translate it and subsequently publish it. This is the result, I hope you'll enjoy reading it as much as I have. Please excuse some of the terms which might not be standard in describing certain behaviour…but translations take a lot of time…and my focus was to get it out there. Rob also asked me to specify that this guide is meant specifically for Single Ended amplifiers)

What makes a "good PSU"? There are many ways to skin a cat. But I think we can all agree that the PSU should be quiet, no 100Hz/120Hz hum. The PSU should be fast in order to deliver, without hesitation, the demand for energy across the entire audio spectrum. The harmonics of ripple should also be suppressed. For a supply to be fast, it needs to have as little resistance as possible.

With the help of DuncanAmps PSU-designer (Free software), we can easily simulate the behaviour of our PSU. Obviously our PSU should be sufficiently quiet, but we must not forget the HF behaviour of our supply. Because our mains supply is very "dirty" there should be various filters in our supply to keep the HF out of our supply. The advantage of this is that we can leave out mains-filters.

A well designed power supply has an optimal Q-factor (damping). This means that the supply is capable of restoring in a clean way the lost energy very quickly. When a supply is too slow… or too fast (overshoot), it will be audible.

A class A amplifier's PSU consisting out of one Pi filter (L-C) can have an optimal Q when the L (Choke) has high induction and low dcR followed by a "suitably" valued capacitor. A rule of thumb however is unfortunately not possible. We do fortunately have a formula : Q = 1/Rdc * SQRT (L/C). Thus low dcR, high L and a low value C will give a high Q. The Q should be around 0.7, however this often does not compute in a power supply because there are more factors at work. Once again the PSU designer is an excellent tool that can provide you with insight about these factors.

A low dcR on the secondaries (Rsec) of your power transformers, say less than 200ohms is responsible for spikes in your PSU because of the capacitors will be "pulling" at your transformer. This introduces unwanted harmonics. We would do well to damp these spikes . We can do this by increasing the duty cycle. The duty cycle is determined by the dcR of the secondaries of your transformer.

A duty-cycle of 10% means that for a short period 10 times the continuous current demand is drawn,. In the case of a 10% duty cycle it will be 1A with a continuous current of 100mA. With the same 100mA continuous current demand a duty-cycle of 50% will cause spikes of only 200mA. We can increase the duty-cycle by adding in series with the anode of the rectifier tube (or diodes), resistance in the form of resistors.

Following these resistors we could additionally place a little capacitor (10-40nF) parallel across the anodes to get rid of some HF.

The value of the capacitor can be large or small, this is dependent on the above. When the power supply has not been designed well, the flanks are steep and pass too much HF, while a better designed power supply will have less problems with this.

In short, simply increasing the value of the capacitor is not necessarily the solution. The purpose is to have the supply be critically damped. Multiple RC/LC sections will lead to less predictable behaviour. A good analogy would be to use the suspension of a car : The suspension should not be too soft nor too hard. Neither result in pleasant driving. Multiple sections could be compared to multiple cars on top of each other… creating as you would expect, chaotic behaviour. Our goal as I see it should thus be one single section.

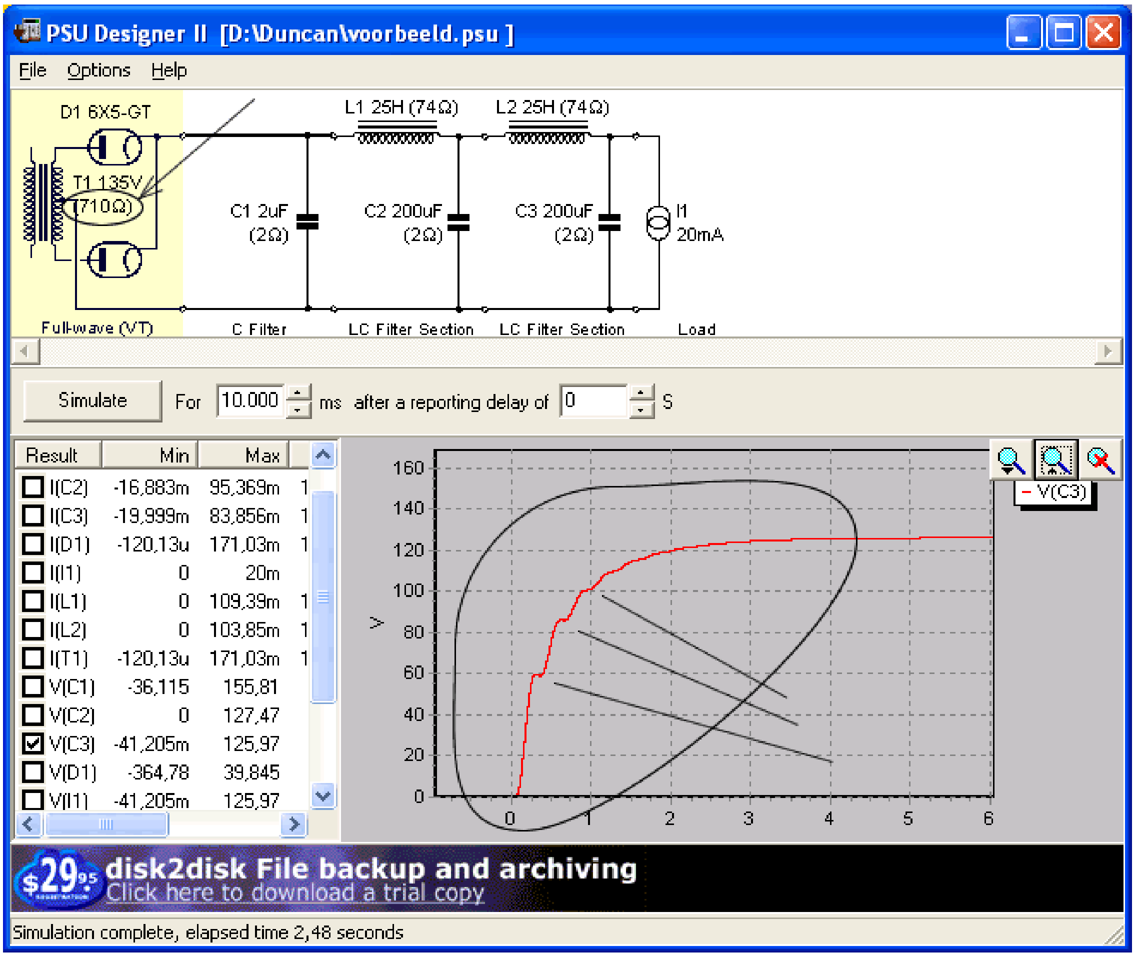
Channel separation can simply be realized by adding an extra RC section with a low value resistor and low value capacitor in order to remove HF from our PSU supply. The cut-off frequency should be chosen just above the audio spectrum IMO, a safe Figure is 50kHz or higher. Use Fc = 1/ (2*pi*R*C). When implemented like this the small capacitor will supply our amplifier and can therefore be a high quality type, which often is a better cap soundwize. The preceding capacitor will "fill" or "charge" this smaller cap.

I will use three real world examples to demonstrate how one could tune one's amps.
1.) Optimizing my preamplifier "Mystique"
2.) Optimizing the driver stage PSU of my "Tyran" (Next edition)
3.) Optimizing the output stage PSU of my "Tyran" power amplifier. (Next edition)

1.) Optimizing my preamplifier PSU "Mystique"

This PSU is built up using Tribute transformers. 1 Power transformer and 2 chokes. The caps are 2uF paper in oil types and 4 * 100uF BlackGate NH's in super-E-cap configuration. When fed into the PSUD it looks as seen below in *Figure 1*. (The 373 rectifier cannot be found in the PSUD database but the 6X5 is "ballpark" enough)

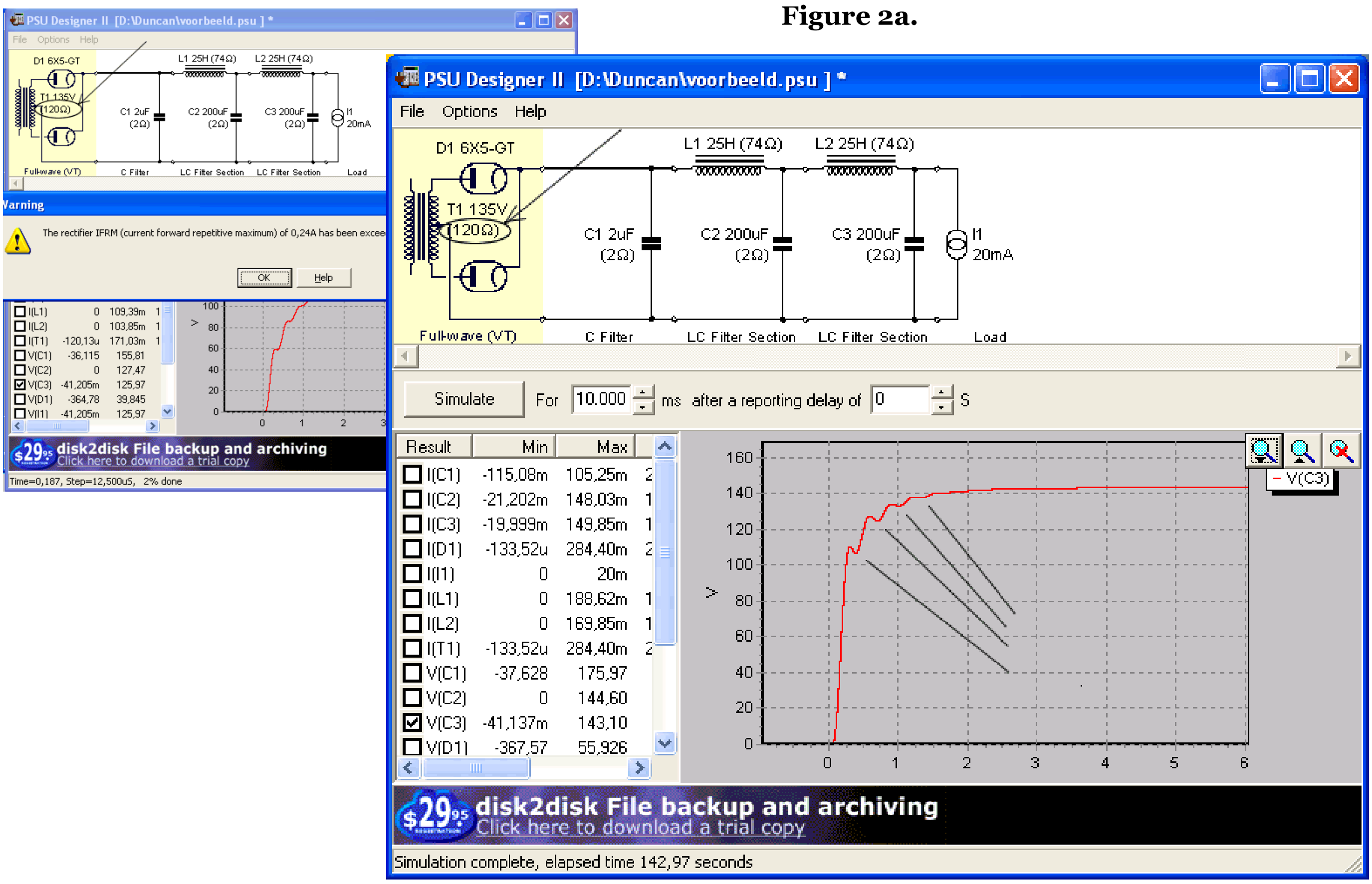
Figure 1.



The first thing you might notice is that the dcR of the secondary winding is relatively high. This is a good thing in my book. Furthermore you will notice that the voltage "comes up" with what looks like ripple but is in fact "ringing" or with pulses. And that it takes a fair amount of time to stabilize. Tribute seems to know how a power transformer for tube rectified PSU's should be wound. Have a look at *Figure 2.* to see what a more typical value dcR is for a secondary, say 120ohm. The simulation will indicate that the rectifier will have too much current drawn for short period of time! If we accept the warning, you will see that in *Figure 2a*, our supply comes up with even more "ringing"

Figure 2.

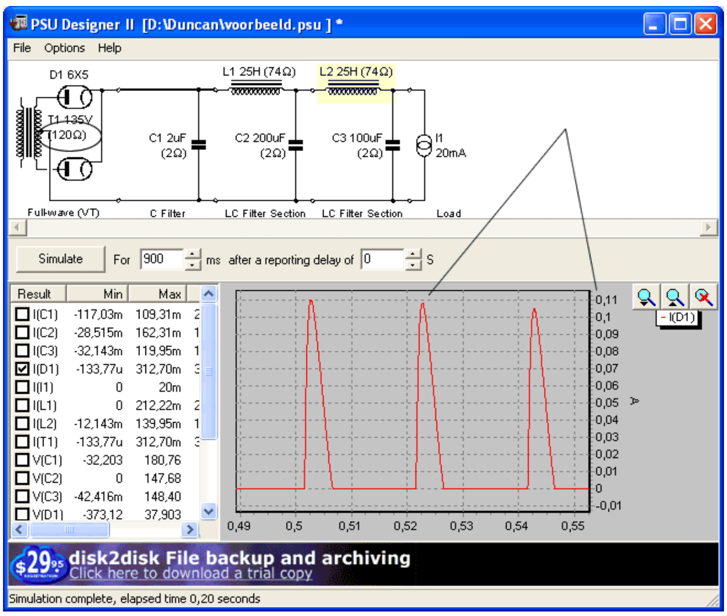
Figure 2a.



When we compare it with our first simulation (*Figure 1*) we see that this time (*Figure 2a*) the voltage can be seen to look like it has even more “ringing”. This will introduce harmonics of these peaks (HF) every time energy is demanded.

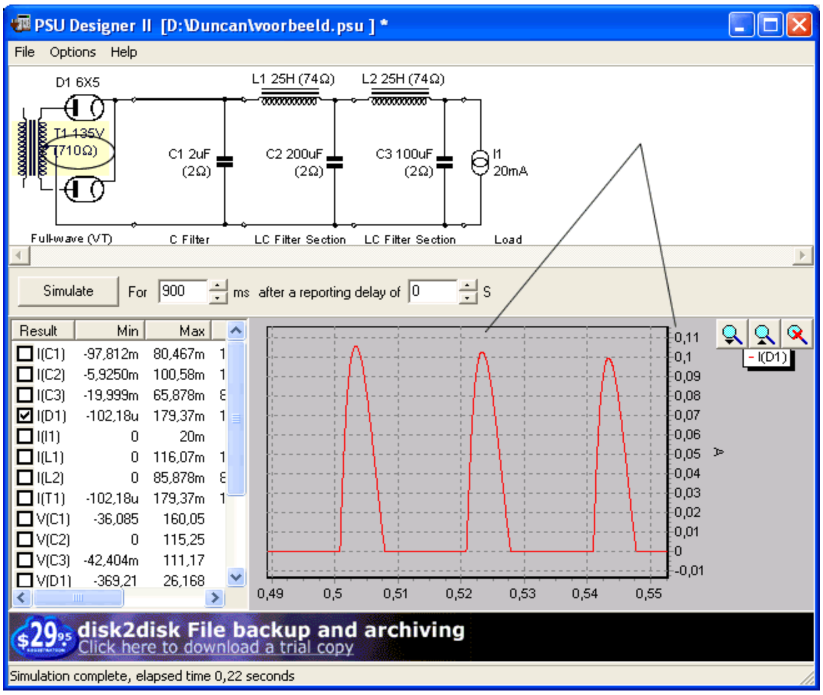
If we now look at the “Q-factor” (I(D1)) we’ll see that on average more than 100mA is drawn while our circuit only draws 20mA continuous. With very steep flanks on the “peaks”. (See *Figure 3*)

Figure 3.



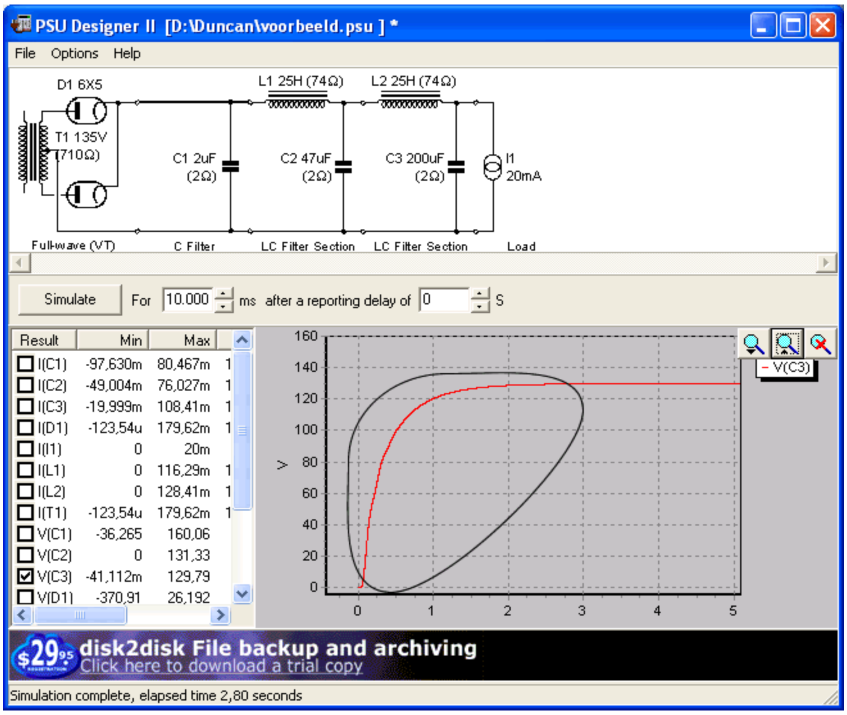
Returning our secondary to a dcR of 710 ohm's rids us of the steep flanks and peaks and generates us sinusoidal waves instead. (See *Figure 4*)

Figure 4.



Having demonstrated our point, we'll use the 710 ohm secondary but we will now reduce the value of our C2, the second capacitor in our PSU. In *Figure 5* you will see that our PSU "comes up" without ringing/pulsating. Notice however that in *Figure 5* our PSU takes 2 milliseconds to stabilize.

Figure 5.



If we now also decrease the value of C3, the third cap in the PSU. A keen observer will spot that our PSU is now "up to speed" inside of 2milliseconds *Figure 6*. In other words our PSU has become *faster!* By using *less* capacitance. But our ringing or pulses are back!

Figure 6.

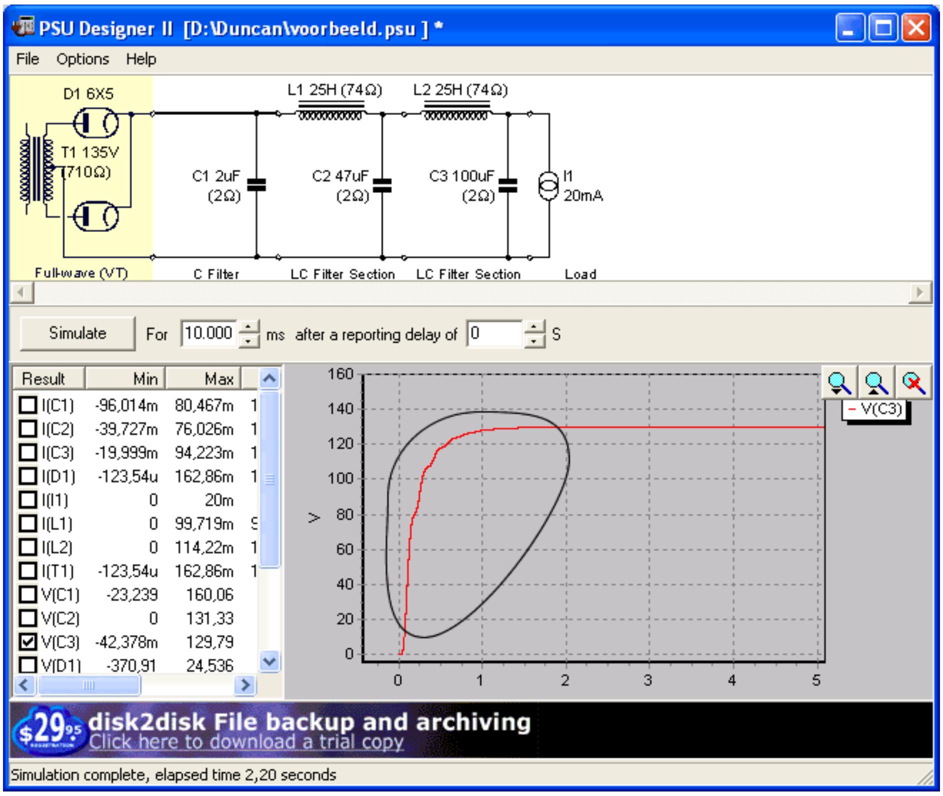
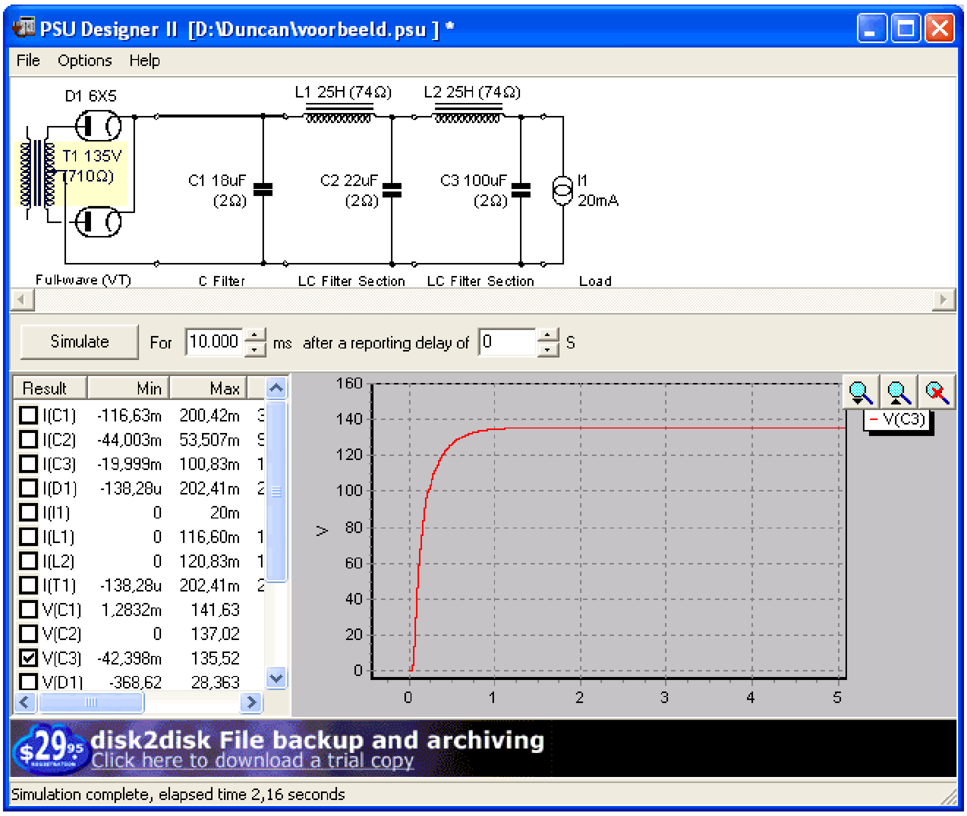
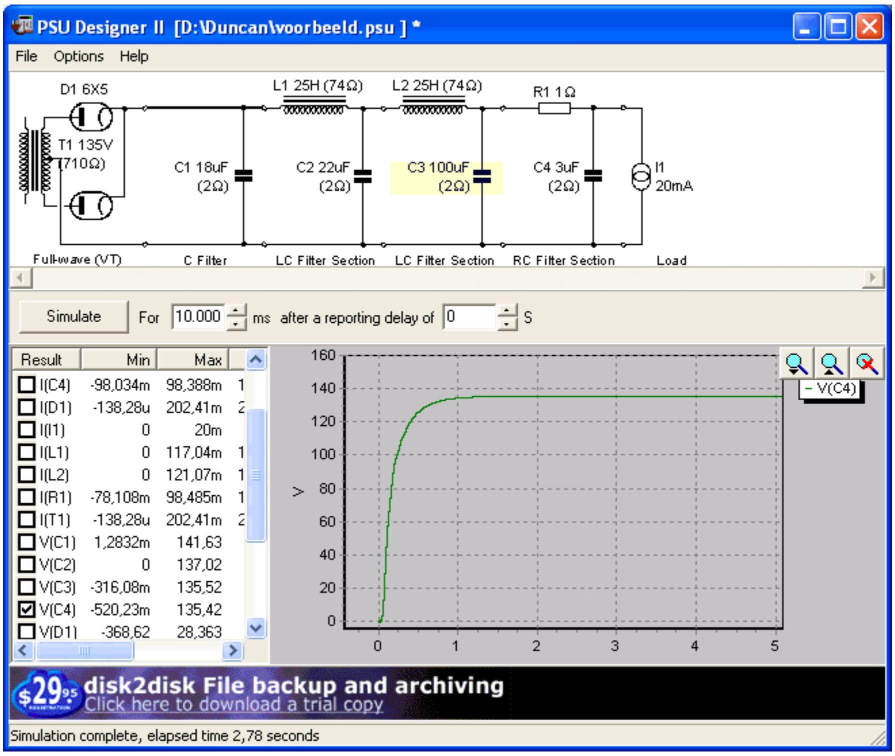


Figure 7.



In *Figure 7* we have "played around" with capacitance to get rid of the "ringing". And our PSU is even faster than before, stabilizing at around 1 millisecond. Let's add an extra RC network for our channel separation. (See Figure 8).

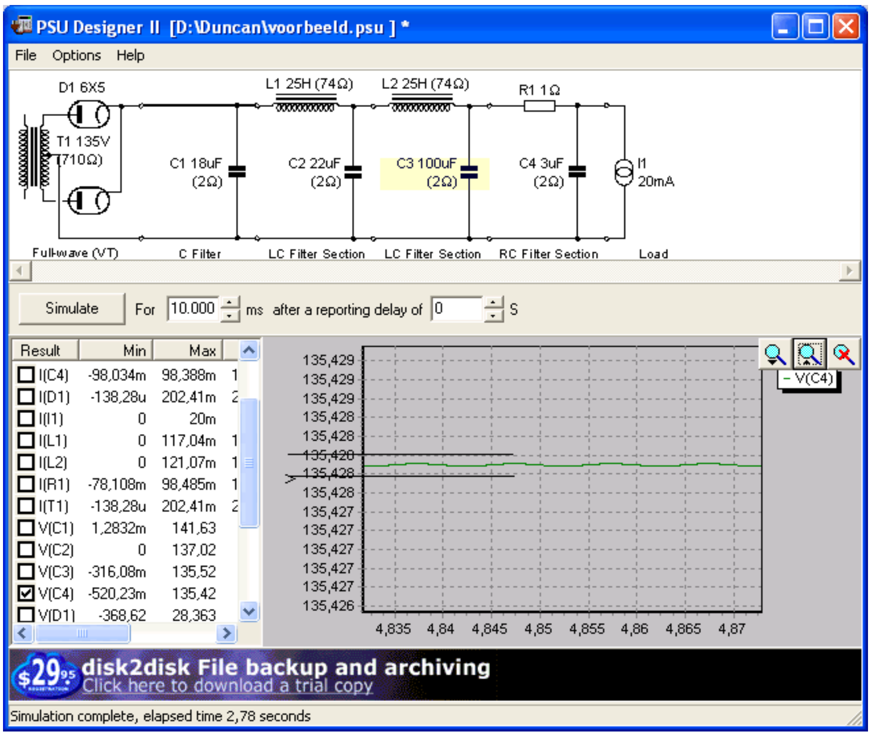
Figure 8.



Result	Min	Max
I(C4)	-98,034m	98,388m
I(D1)	-138,28u	202,41m
I(I1)	0	20m
I(L1)	0	117,04m
I(L2)	0	121,07m
I(R1)	-78,108m	98,485m
I(T1)	-138,28u	202,41m
V(C1)	1,2832m	141,63
V(C2)	0	137,02
V(C3)	-316,08m	135,52
V(C4)	-520,23m	135,42
V(D1)	-368,62	28,363

In *Figure 8* we have created, with 1 ohm/1W and a 3uF paper in oil capacitor, channel separation which filters above 53 kHz. Removing HF…. and supplying our amplifier's "energy" demand with a high quality capacitor. Our PSU is now faster, more stable and has less HF. Last but not least it is now *quieter* than my initial PSU with less capacitance! (*See Figure 9*)

Figure 9.



Result	Min	Max
I(C4)	-98,034m	98,388m
I(D1)	-138,28u	202,41m
I(I1)	0	20m
I(L1)	0	117,04m
I(L2)	0	121,07m
I(R1)	-78,108m	98,485m
I(T1)	-138,28u	202,41m
V(C1)	1,2832m	141,63
V(C2)	0	137,02
V(C3)	-316,08m	135,52
V(C4)	-520,23m	135,42
V(D1)	-368,62	28,363

Let us now simplify our PSU by putting our chokes in series and altering the capacitance so that we can suffice with one Pi filter. As you can see our PSU has become a little slower, but I can tell you that it performs audibly better!

Figure 10.

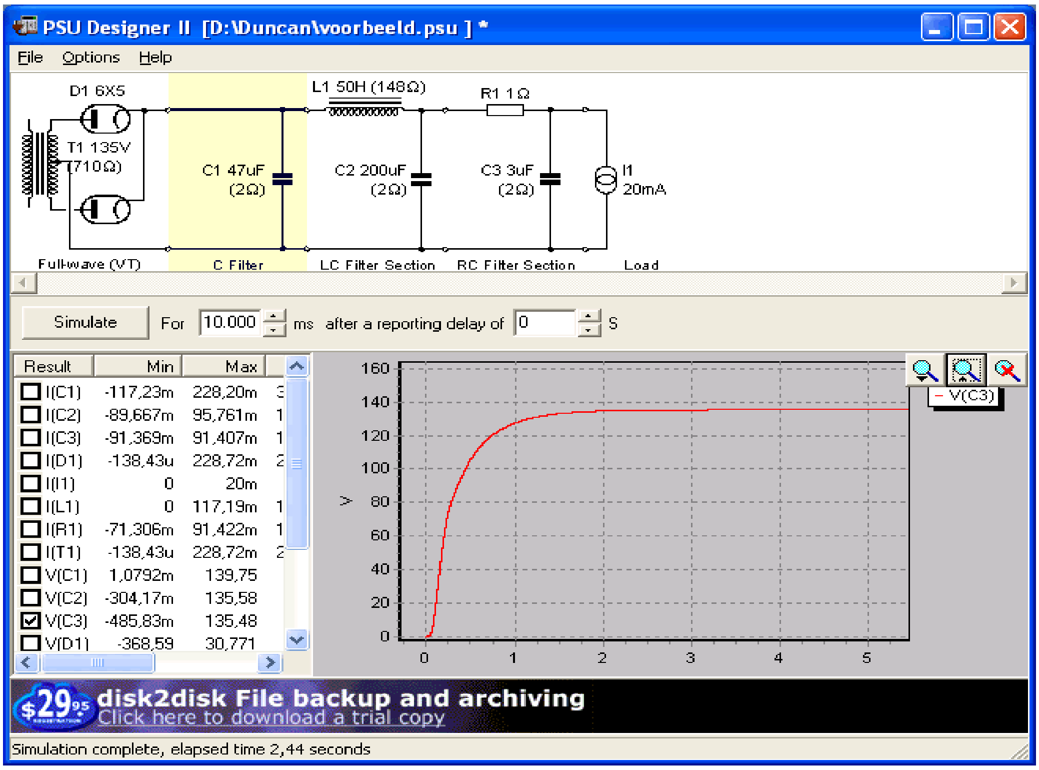
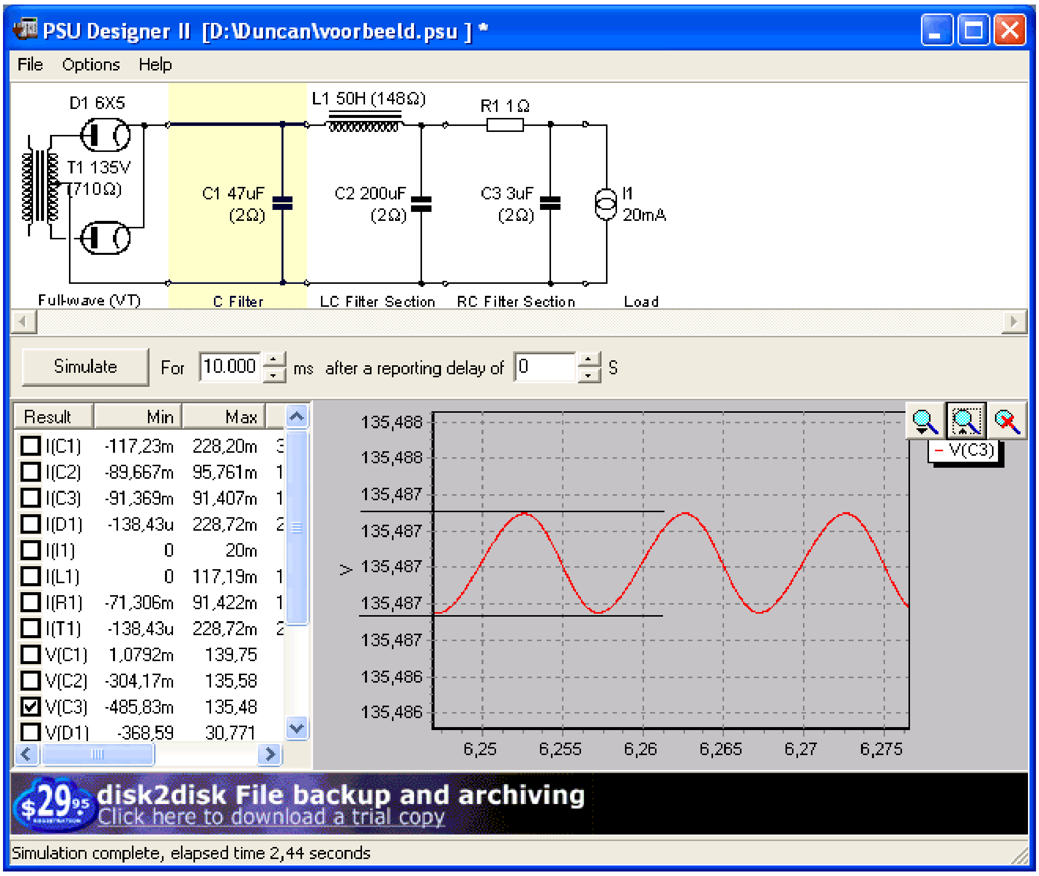
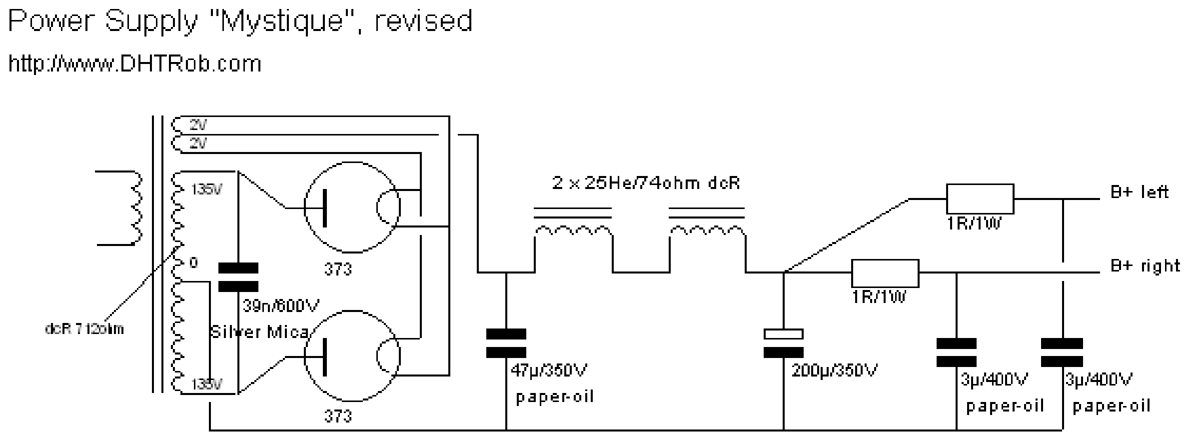


Figure 11.



We have more ripple now (*Figure 11*)… but 3 millivolts b+ is perfectly acceptable for a preamplifier.

I suppose it is slightly contradictory to what we have been doing. But if we would have implemented a choke that would have been 50H at a dcR of 25R we could lower the value of our first capacitor and have a faster PSU still. Maybe something I'll do in the future. For now see below my current schematic.



The proof of the pudding is in the eating.
Does my amplifier now sound better with this power supply? The answer is an unreserved yes! The low and mids especially are literally faster and better defined since I implemented this PSU. And the highs are "cleaner" with a "darker/blacker" background because of the last RC filter (HF) and the 39nF Silver Mica cap that were switched parallel to the anodes of my tube rectifiers.

Rob's site can be found over at http://www.dhtrob.com

The picture below is one of Rob's experiments! (9 chokes in the psu!!!) (Ed.: I'd like Rob to explain the "logic" behind this psu ;-))