150W SE AMP BLOG: the mean machine - Part 1

I will use this blog page to share my findings on the development of a very powerful, yet refined single ended amplifier. I started this project several years ago and have been working on it since.

For the last two years, I have been using this amplifier almost exclusively to drive my main speakers. Keep in mind that it is not the typical nicely crafted good looking DIY amplifier, but rather a highly experimental machine which is very user unfriendly and very dangerous to operate.

A friend of mine called them 'the mean machine' upon seeing the amplifiers.
I fully agree with him … the intensive orange red glow of the anode structure has a seductive attraction to people visiting my listening room.

This tube would be my favorite device to power up the electrical chair in case it was needed for me. However, this is not likely to happen in the near future. Let's get serious now!

The early days

I have designed quite a lot of push–pull and single ended amplifiers in the past that made use of amorphous output transformers, various directly and indirectly heated power tubes and I experimented with different kinds of tube stabilized power supplies (series as well as shunt).

After quite a while, I noticed that single ended amplifiers did the right things for me. However, the low power aspect of this concept proved to be a bottleneck on some extreme recordings in my very specific case.

I have a very large dedicated listening room at my disposal (lucky me) and my speakers have a rather low sensitivity of around 88 dB/W/m. I got interested in the idea to develop a high power single ended amplifier probably running on one tube.

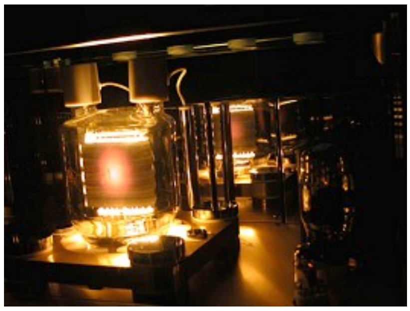
Personally, I am a great fan of the WE300B as is Dick van de Merwe which we all know as 'triodedick' (also involved in audio-creative).
The most easy and logic way would have been to make a double or a quadruple SE 300B amp.

The challenge

But, as usual, I needed a challenge to proceed. The basic idea was to design and build a >100W SE triode tube amplifier featuring one directly heated tube as I like simplicity. But simplicity comes at a price. After some research on the internet, I did read about the famous 833 based Wavac amplifier that was covered in a Stereophile article.

Wavac 833 amplifier

silvercore 833 amplifier

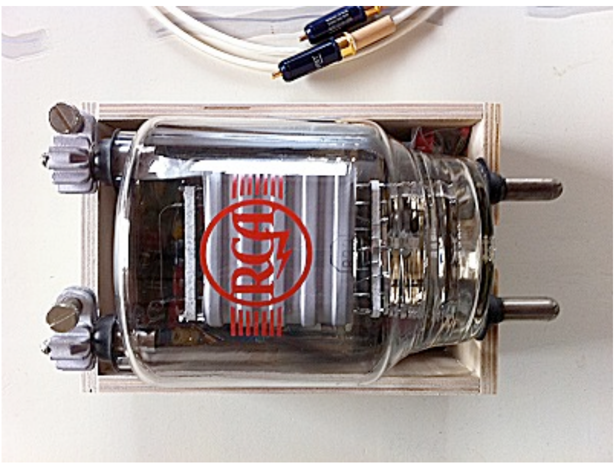


glowing red @ 300W

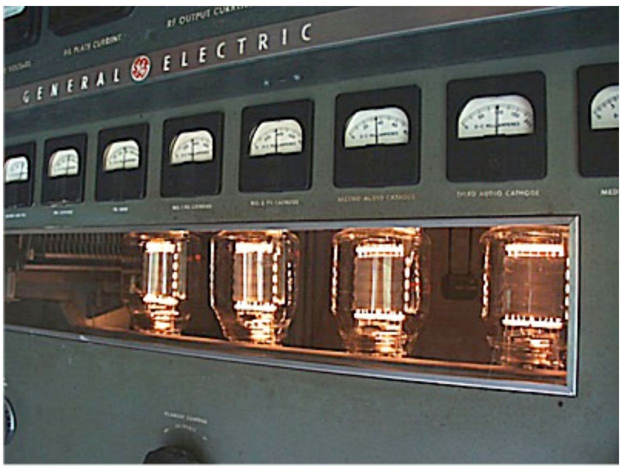
I started to work on an amplifier that runs into class A2 and used the well-known directly heated 833A transmitter tube. I had never been working with "class A2 operation" and the high voltages required to run the 833A. I also got in touch with Stéphane Puechmorel who already had a lot of experience with these tubes and even higher powered versions such as the GM-100 monster tube. He advised me to look for RCA or GE NOS tubes.

Gathering key components

I made a call to Michael Wiams from Halfin and I was pleased to hear that NOS 833A tubes were readily available from stock at a very reasonable price. I immediately ordered a pair of RCA tubes.



my RCA 833A tube

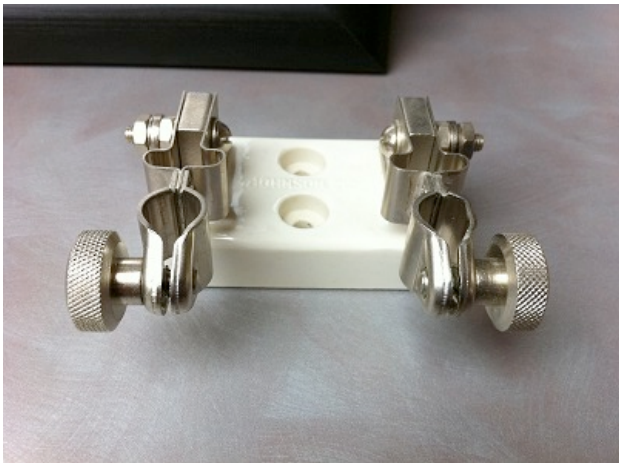


ooh, these red glowing tubes ...

Upon arriving home, the first idea that crossed my mind was to light the filament as this was some sort of lighthouse tube. I did not have 10V -10A at hand and I also noticed that the terminals were not really compatible with the standard stuff we all know. After some time, I got connected to a Dutch guy, [Reinhout Devries](). He was a few years ahead of me with a similar project. His 833A amplifier was already operational and very well built using an impressive amount of magnetic components.

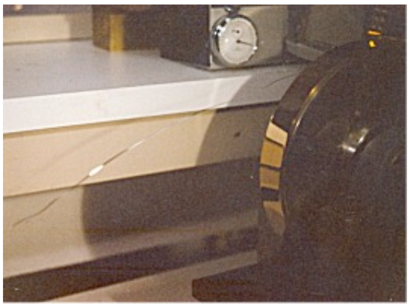
This must have been the heaviest amplifier I have ever seen. During a visit at his place, I noticed that he had very nice filament connectors. I was able to buy a pair of these (new in original box!) and went back home with a satisfied feeling.

833A filament connector out of the box



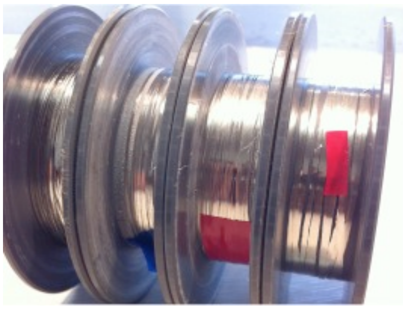
833A filament connector close-up

Next problem to be tackled was the output transformer. I had very good experience with the use of amorphous output transformers for SE as well as PP operation. Amorphous metals were also the main topic of my Ph.D. research many years ago. I actually produced my own amorphous metal strips as well as quasi-crystal ribbons. In the picture, you can actually see the ribbon coming off the rotating polished copper wheel.



from melt to ribbon

the machine



the result

I decided to do myself a favor and I bought the largest amorphous double C cores (for domestic use) that were available from Metglas. These cores had a net cross section area of 46 cm2 which should do the job.
At this point, I had the iron but not yet the transformer. I had the tube but not yet the driver scheme or the power supply. It's time to investigate the 833A datasheet! Enough for now, … I will keep you posted as this is quite a long story to cover :-)

Initial choice of operating points

This tube is not so well suited to operate in class A1. I found out that 100 Watts class A1 can be achieved with a plate voltage of around 3kV. The difficulty and cost of a project rises considerably when hitting these kind of voltages.

In general, this tube is operated in A2 mode where the grid draws considerable current. Wavac operates the tube at a very low plate voltage of around 850V with a positive voltage on the grid resulting in a massive standing current.

However, as a result of this choice, the damping factor suffers badly. Wavac solves this by applying local feedback around the output tube using CFB. I did not want to use feedback in the first place. Later on, I discovered that other people adopted the so called zero grid bias operation. This results in an operating point of around 1250V-250 mA and aload of 5K. I settled on these values as it seemed to be a good compromise.

Driver schematics for the output tube: phase 1

Looking at the grid characteristics learned me that I would need to supply around 200 mAp to the grid of the output tube in order to get around 150W out of the amplifier.

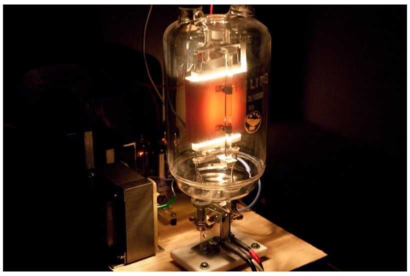
The driver impedance should also be low to drive the grid of the output tube accurately. Since the output tube is working in A2, the grid cannot be coupled through a capacitor. Most people make use of a 300B driver that is coupled to a 4:1 stepdown interstage transformer. The result is a nice relative low output resistance but there is a price to pay.

The 300B will be used to it’s limits as the AC plate voltages will be 4 times higher compared to the input voltage needed at the grid of the power tube. An easy calculation tells us that the full voltage potential of the 300B is needed leading to quite a large amount of unwanted distortion.

I chose for a different approach by using a cathode follower since I could not live with that extra distortion. In contrast, the follower option yields a very linear transfer curve, low distortion, large headroom and very low output impedance.

At first, I used a power mosfet to do the job. This choice was inspired by the high current demands that I needed. I used a BUZ type lateral mosfet from Magnatec which has some audiophile following.

Plenty of headroom and of course a very, very low output impedance which essentially equals the inverse of the massive transconductance. The source resistor should be as high as possible on the one hand but cannot be made to high since it needs to pass 0.25A of current without resorting to a kV type negative high voltage supply.



European 833A near equivalent

Lateral BUZ901P Mosfet transistor

designer Velissarios behind his beefy 833 amplifier

The choke loaded cathode follower

Using a dc coupled driver scheme is certainly not new to drive a tube in A2, but it is certainly the best way to do it. Using FETs to drive a high power tube was already done by Tubelab , called powerdrive.
It is even possible to improve the buffering action of this stage.

The solution to this problem is quite simple: use a current source or put an induction beneath the source (or cathode).

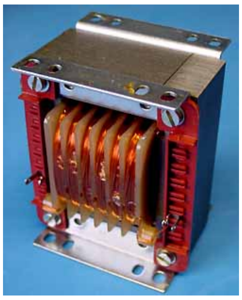
Since we are making magnetic products at Monolith Magnetics, I settled on the inductor. The inductor is not even mission critical regarding parasitic winding capacitance since it is located at the cathode side and as such is driven by a lowish impedance.

This was good news, and a reliable and simple solution to the conflicting design demands. These are the kind of solutions that I like the most.

Simple, reliable and without compromises with regard to technical performance. I performed some measurements that looked really very good.

Insane 1kW 833A PP amplifier

Mr Tubelab in action



low parasitic choke

The Input stage

I was now in need for a suitable input stage that provided me the necessary gain. As the driver stage was dc coupled to the output, the input stage was capacitor coupled to the driver stage using a high quality coupling capacitor. I tried quite a lot of configurations and I finally ended up with a SRPP after extensive listening tests. In general, I am not a big fan of SRPP, but I was inspired by an article of my good friend triodedick. He published an article of a basic preamplifier called the classic one.

In essence, it was a SRPP input stage followed by a cathode follower and he infiormed me that he was surprised by the subjevtive result. He told me that he got inspired by the the scheamtics of the Audionote Ongaku. I immediately build the input stage and had to admit that me too, I became of believer of the SRPP cathode follower topology. I was now in the position to find a suitable input tube. It needed quite a lot of gain. I was looking for a double triode with a rather low plate resistance because of the ever present high input capacitance of the MOSFET. The 6H30 seemed to be a good option, altough the amplification factor was somewhat borderline.

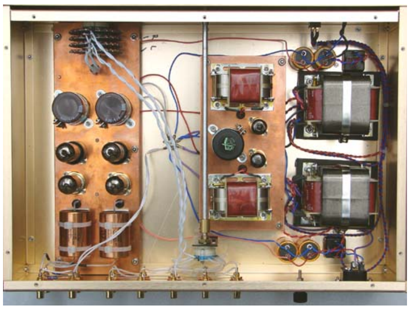
I would have preffered a 6SL7 tube, certainly after I stumbled on an article that stated that the ECC83b and 6SL7 are very well suited for SRPP operation. However, the plate resistance is far to high to drive the input capacitance of the BUZ901P mosfet. So, I moved on with the 6H30 as it is used by many reputed audio manufacteres such as Balanced Audio Technology, Audio Research .

To my surprise, I even found the much praised DR version in my personal stock. The classic one approach from Dick was now implmented using a 6H30DR as a front end and a BUZ901P lateral mosfet follower dc coupled to the power tube. One difference can be spotted.

I am using a coupling cap between the 6H30 and the follower. This was the price to pay since I needed to dc couple the source of the mosfet with the grid of my output tube. However, you can also look at it in a positive way.

The capacitor is located in a position where there is a pure voltage transfer and we can voice our amplifer by swapping different caps.

6H30 tube

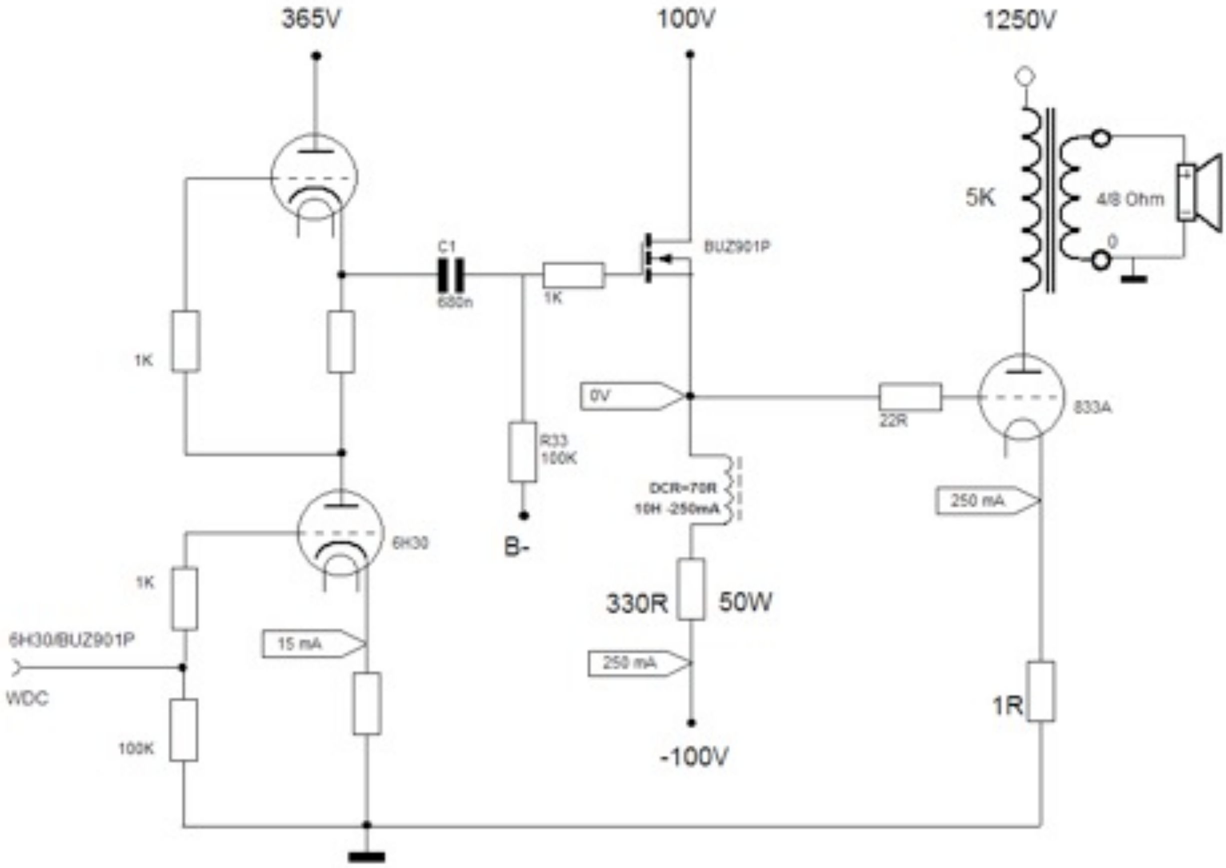


Triodedick's Classic One preamp

the famous Audionote Ongaku

The full schematic phase 1

The schematic reveals a fairly simple topology.



the schematic of the phase 1 833A SE amplifier

Did I like the result?

This was my starting point that triggered further investigation. I certainly sounded powerful, very powerful. You could surely say it had all the benefits and sonic signature of a SE amplifier, altough not at the very same level as a original Western Electric 300B. It also measured quite remarkable for a high power tube amplifier without feedback. However, the damping factor of the amplifier was rather low.
Since I am using very large bass reflex loudspeakers, there was a need to implement some changes. I was wondering what would happen if i would raise the high voltage. This would mean a higher load impedance, automatically leading to a higher damping factor. This would also mean that I would abandon the zero bias bias point. This could also result in auditive changes as the first watt is the most important one. Moving to higher voltages could also reduce the grid current demands substantially. Perhaps I could use a tube to drive the output tube? Due to the much reduced input capacitance, I could use my beloved ECC35 tubes ... things got really interesting. Stay tuned .. although you will need to be patient since my time is limited.

Moving towards more lethal conditions

As suggested in the previous article, I wanted to apply substantially higher voltages at the plate of the 833A / TB3-1000 tube. There are a lot of things to be gained such as a better damping factor, but also a driver stage that does not need to rely on a high current solid state device. Some quick calculations proved that a 2KV setting would deliver a good compromise. Yves supplied me with the appropriate power transformers and I got things moving.

I remember an article from John Camille describing a shunt regulated 211 single ended amplifier (Kyrie) that stated that operating the 211 at high plate voltage (1250V) proved to be essential to deliver the goods in subjective terms . I put 2KV on the plate without changing anything else, and indeed, I have to admit that the sound clarfied, there was a clear sparkle in the sound that was not there on the low plate voltage setting.

Next to that, I increased the primary impedance to a higher level by replacing the original 5K bobbin with a 12 K version. Running at around 140mA delivered the maximum power of around 150W.

Driver schematics for the output tube: using a tube as a follower

Looking at the grid characteristics learned me that I would need to supply around 60mAp to the grid of the output tube in order to enable the full potential of the tube. This means that there were plenty of suitable candidates. At first, I tested triodes and/or triode wired pentodes or beam tertrodes.

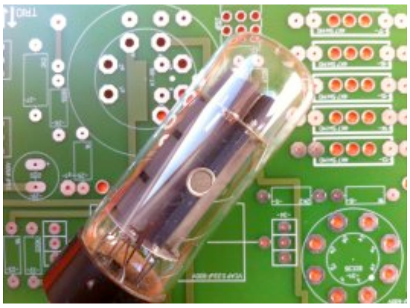
Replacing the mosfet with a tube immediately improved the sonics of the amplifier, the sound being more agile and more microdetail was present. Perhaps it has to do with the rather high input capacitance of the solid state device I used. It is well known that loading a tube stage with a high capacitance device is not the best option soundwise. I made some sort of universal connector to swap driver tubes.

I started with one of my favorites, black plate NOS 6AS7G which rewarded me with a very nice subjective performance. However, these kind of tubes are kwown to be prone to arc over and since the driver tube was dc coupled to the grid of the output tube ... It was time to source a good replacement. I evaluated many tubes such as 6C33C, EL34, KT88 (NOS Gold Lion), EL156 (octal version), 8417 and even a vintage WE 300B was tested. I settled on a new production triode strapped EL34 running at 80 mA. 8417 was very very good, however quite difficulot to source.

Another benefit of the high operating current condition is that you obtain the full transconductance of the tube being 12mA/V. Being configured as a follower, this means that a low 80R output resistance can be accomplished and the power tube is driven in a stiff manner.

Looks even better this way :-)

Different kind of tubes I evaluated



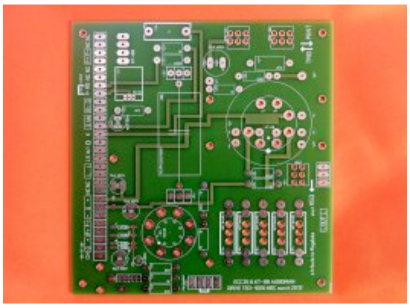
EL34 with zirconium getter

Pentode connected driver stage

I have built quite a lot of mu stages in the past. Allan Kimmel (inventor of the mu-stage) goes into great lengths promoting a pentode as a follower.

The reason being the fact that there exist quite a lot of high transconductance pentodes and that the transconductance is independant of the voltage applied to the tube if operated in it's intended region.
Another benefit is the much lower plate to grid parasitic capacitance. Installing a few switches did the job. Well, it clearly sounded different.

There was more muscle in the sound mix. However, the triode configuration proved better in the ambient retrieval of the recording. To me, it all depends on personal tatste and can be used to voice the amplifier and it's for free: the flip of a switch does the job.



driver PCB I developed to enable A2 operation

13E1 high gm tube

stuffed PCB board equipped with connector

The Input stage and the technical performance of the driver stage

Because of the much reduced capacitance presented by the tube based follower stage, I was able to pick tubes with a higher amplification factor such as some exotic NOS 6SL7 and ECC35. I have been using this tube for quite a long time in my amplifier with great succes.

The output resistance of the SRPP configuration proved to be 25K as it should be. The complete driver stage should have a bandwidth of over 300 kHz because of the low input capacitance of the pentode strapped EL34 follower.

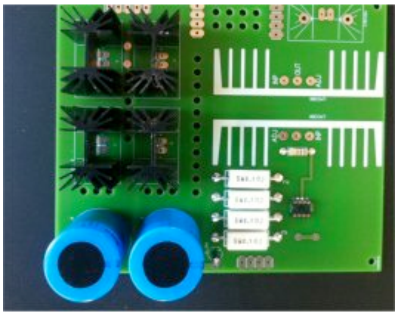
I verified the bandwidth of the complete driver stage and to my surpise I got no better than 100 kHz. Not bad at all but substantially less than my expectations, ..calculations.

Swapping the 6SL7 with a Red Base 5692 resulted in 350 kHz and I am very satisfied with the sound and technical performance. I still want to resolve the mystery of the extra 35pF that I am not able to pinpoint.

An alternative would be the application of a cascode based current source using the exteremely low capacitance LND150 mosfet as developed by Gary Pimm. This could give me extra amplifcation while still delivering frequency bandwdth.

I plan to investigate this in the future.

Red Base 5692

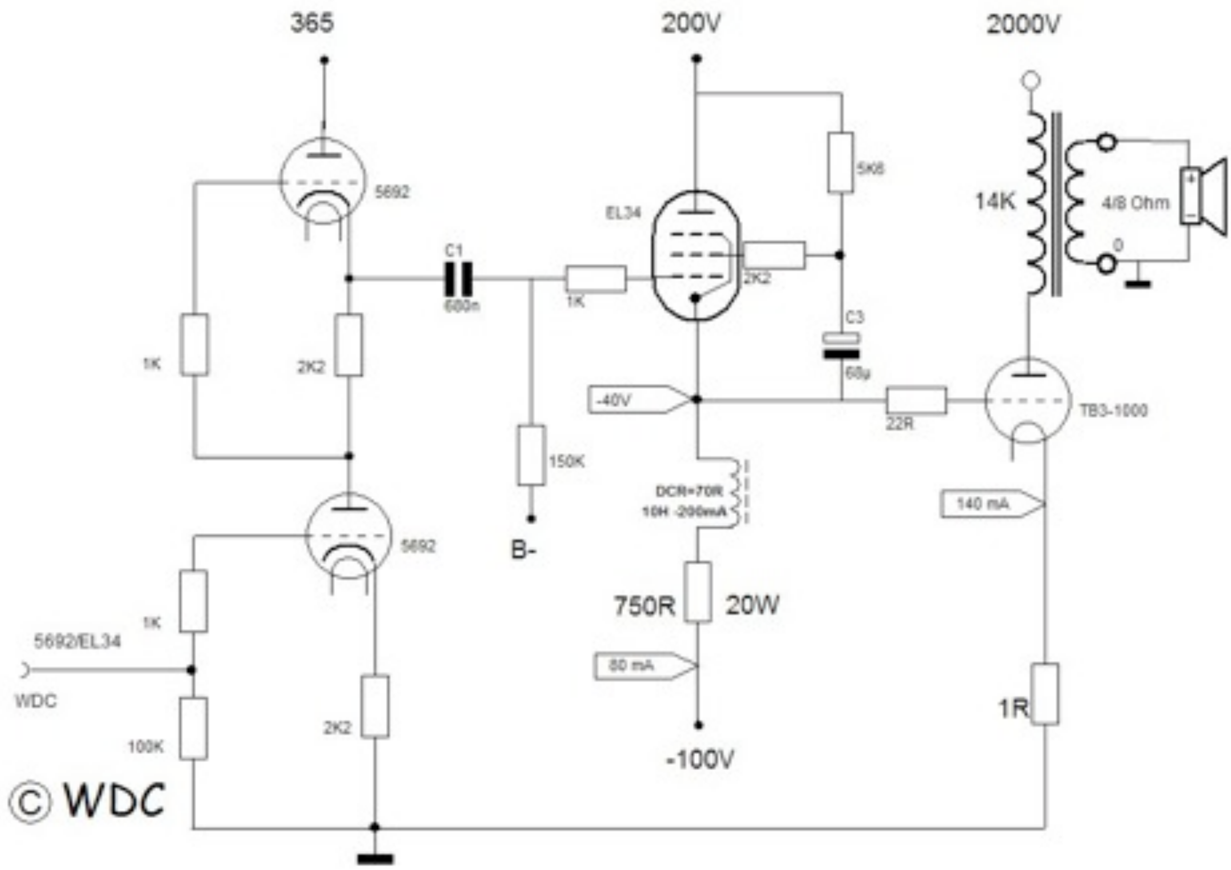


CCS 8A in progress

Mullard ECC35

The full schematic phase 2

The schematic reveals a fairly simple topology.



the schematic of the phase 2 833A - TB3/1000 SE amplifier

Time to order thick anodised front plates?

At the end of my previous article, I had some questions that I wanted to resolve. Many of them have been answered.

In the meanwhile, I have been rewarded with a nice sounding amplifier. Is there still room for another iteration, or should I clean up the amplifier? moving it from this highly experimental state towards a more commercial look boosting thick shiny front plates.

Well, I developed an 8A constant current source PCB to power the mighty filaments. I also have a bunch of 3B28 Xenon recifiers that I would like to use and I would like to play a little bit with different transformer materials.

Currently, I am using 192 kHz usb audio as reference material! As you see , I am not yet ready ...stay tuned,