Lilienthal Engineering

Audio transformers, HiFi output transformers, Guitar output transformers, Special quality transformers, Line transformers, Input transformers, Interstage transformers, HF signal transformers.

100 amplifiers – part 1, 1916 -1954.

I frequently change, update, delete or add stuff to the articles “100 amplifiers…”. Please, do drop me a note if there is anything you would like to comment or add. For matters of these articles, please write to : “100amplifiers at gmail. com”

You can help. I am always interested in pictures of the amplifiers here, (These will be credited to you) just as you are welcome to suggest interesting power amplifier designs from the period of 1916 to 1982.

Thanx…

The first 70 years of vacuum tube/thermionic valve audio amplifiers.

I have redrawn most of the schematics. The point is to make the circuits clear and understandable at a glance. In the case of a stereo, integrated amplifier or receiver, I show only one **power amplifier** channel. I have not altered a single component or connection (Unless mentioned) , but I have removed most that had nothing to do with the actual amplifier. This could be text about the colours of wire leads, extra connectors, jacks for measuring, meter circuits, pre amplifiers,component designations and numbers etc. All of such that is relevant for service of the original amplifier, but disturbs the reading of the circuit.

Radiodyne by Atwater Kent 4340 Model 10, 1923 from the collection of Ernie Hite, Photo: Charlotte ARC.

An good example of the beauty and decorative handcraftsmanship of these early amplifiers.

Here we go: **The Amplifier Compendium.**

———————————————————————————

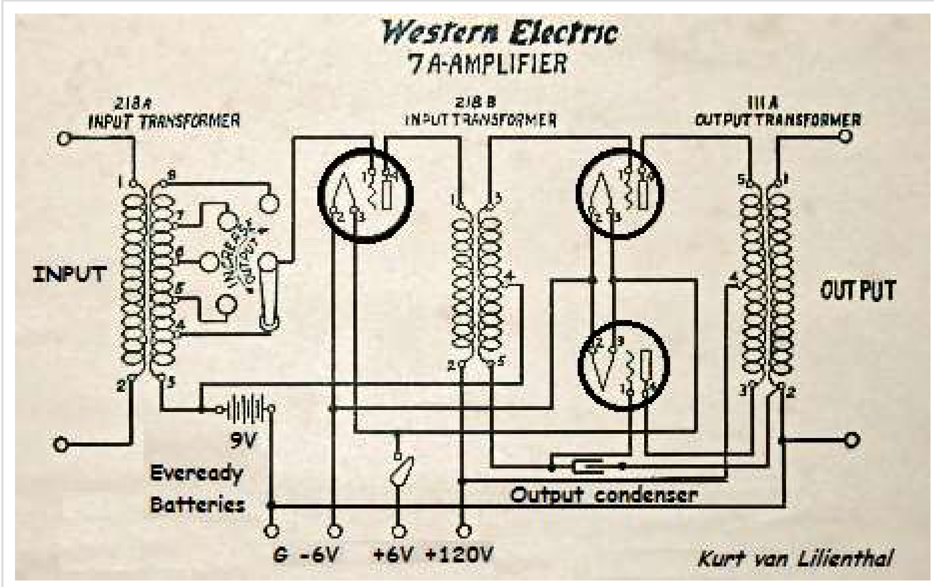
The Pliotron by Irving Langmuir, 1916. (No schematic available as of writing)
In 1916 Irving Langmuir, General Electric designed a full
working amplifier based on a high vacuum triode – he named it "The Pliotron". This is the first true full wave amplifier that I have been able to find. All others before this was merely detectors, that at best amplified a positive or negative part of the wave or rectified it into a modulated phase signal as they were gas filled, soft vacuum devices and negative grid bias was not applied.(Read more about the birth of amplifiers in the preface to this compendium)

Langmuir achieved a perfectly good understanding of the electron flow and against the mainstream he made hard vacuum tubes and vastly improved the filament. In fact he and Heinrich G. Barkhausen, Germany wrote most of the formulas we have used ever since when computing valve circuits.

If you happen to have a copy of Langmuir's early pliotron, please, send a copy to me. We need honor the good Irving Langmuir here in the company of where he belongs.

We owe a lot to Langmuir.
Time to lift your hats, gentlemen….and bend…..bend deep..

————————————————————————————-



Western Electric, 7A , 1922-24 ?

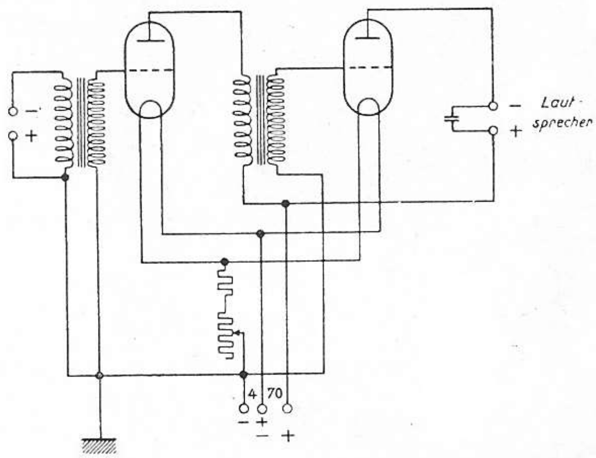
Flawless design, no hum, no resistor noise, no capacitor blocking. This is my absolute favorite Western Electric amplifier design. At the days it was made the components was not anything to brag about, but keep in mind that this was a repeater amplifier – made for telephone communication. Build it today with high quality tubes and transformers and you will have an absolute top class amplifier. Western Electric was a sub-division under the Bell lab. (Graham Bell – ding ding , does this name ring a bell ?)

The ball shape of the early tubes was simply because that the technology of glass was already incorporated in the automobile industry by the use of Edison's incandescent light bulb.

I have been told by **Roger A Modjeski** (Music Reference, Beveridge etc.) that this amplifier was a set for domestic use – it came with a speaker. The WE 7A was made to amplify headphone type early radios.

Western Electric, 7A, from the collection of Ernie Hite, Photo: Charlotte ARC

I will swing my hat to this – one of the first amplifiers ever made.



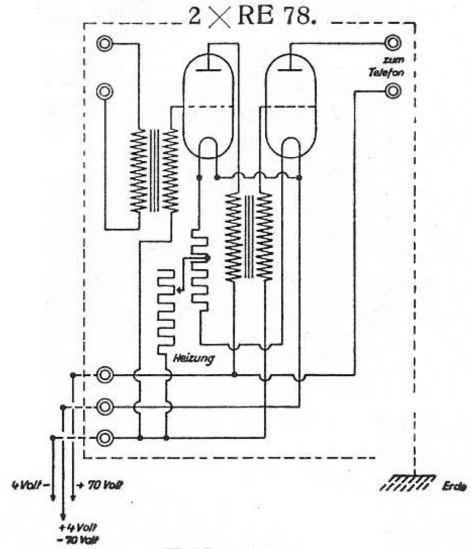
Detektorverstärker.

Röhrenbestückung: 2 × RE 78.

1924

Niederfrequenz-
Verstärker AII

2 × RE 78.



NF-Verstärker

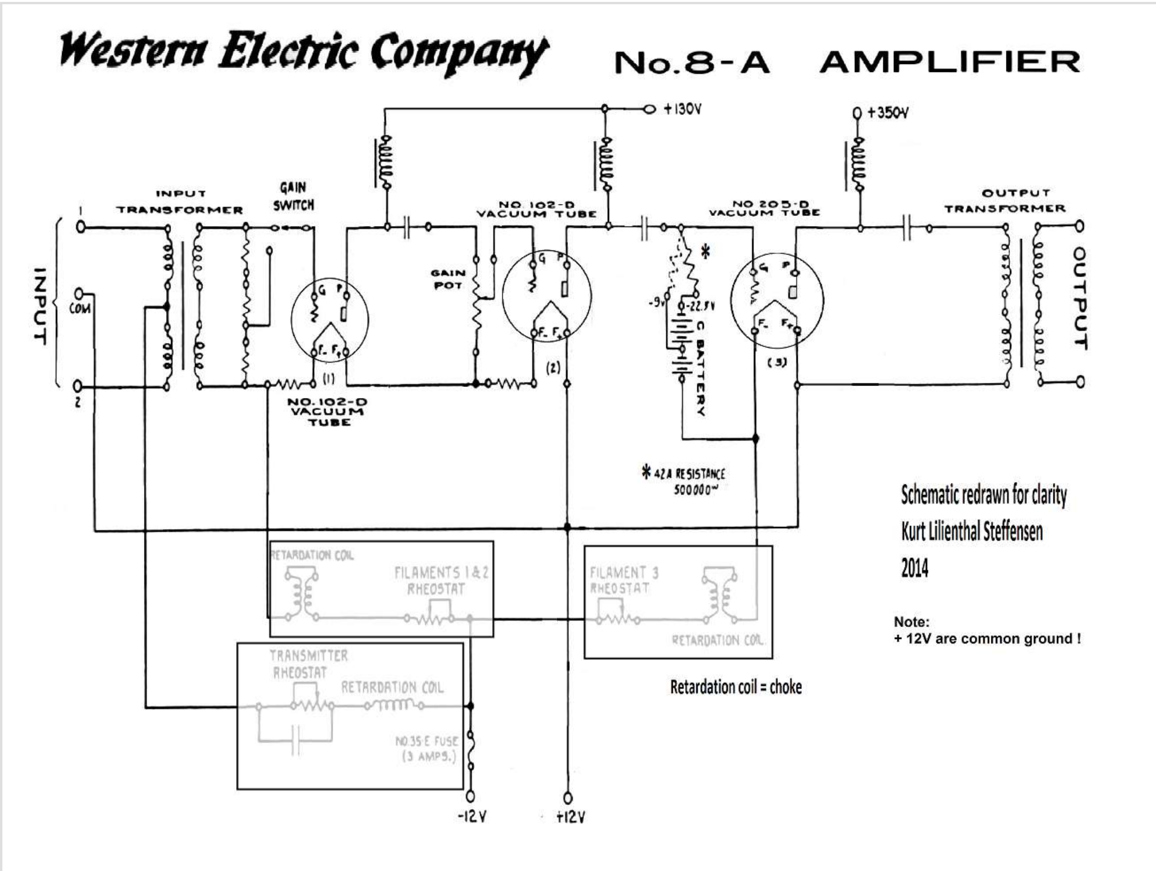
1924

(Suggested by yours truly)

AEG, RE 78, 1924.

These two amplifiers are actually flawless in the sense that just like the WE no 7A, they are operated exactly as we later learned to be the "optimal" method. No fumbling here, meine Herren. A similar amplifier made today with high quality components will be a true high end device. AEG was founded by Emil Rathenau in 1883. At that time it was competing with Siemens und Halske but as early as 1903 the two companies jointed and formed a division called Telefunken. (A peculiar side note – the same year as these two 1924 amplifiers was introduced, Siemens invented the ribbon band microphone. I am sure it was a lot better than the common carbon microphone) A.E.G = *Allgemeine Elektrizitäts-Gesellschaft* which in english means: General Electric Company. Now that is indeed funny.

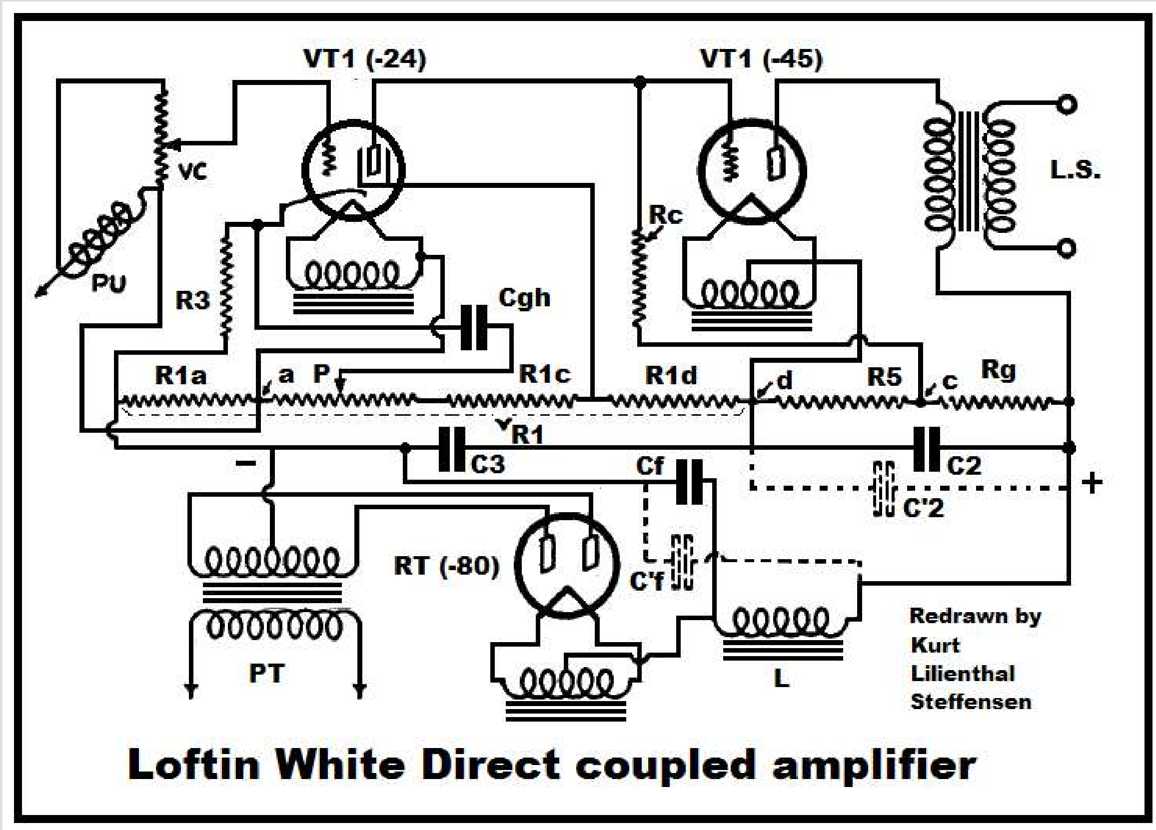
Hats off to Emil Rathenau, Werner von Siemens, Johann Georg Halske and all these German pioneers.



Western Electric 8A/B, 205D, (1925 ?)

A very early W.E. all iron SE amp. Two transformer coupled 102D stages and a 205D output. It is all battery operated, which means that at the days of its origin there were no hum at all, as the main net was not yet developed. The “unlogic” tube symbol probably came from Deforest. Funny that they refers to the chokes as “Retardation” coils……

This is indeed a beauty.

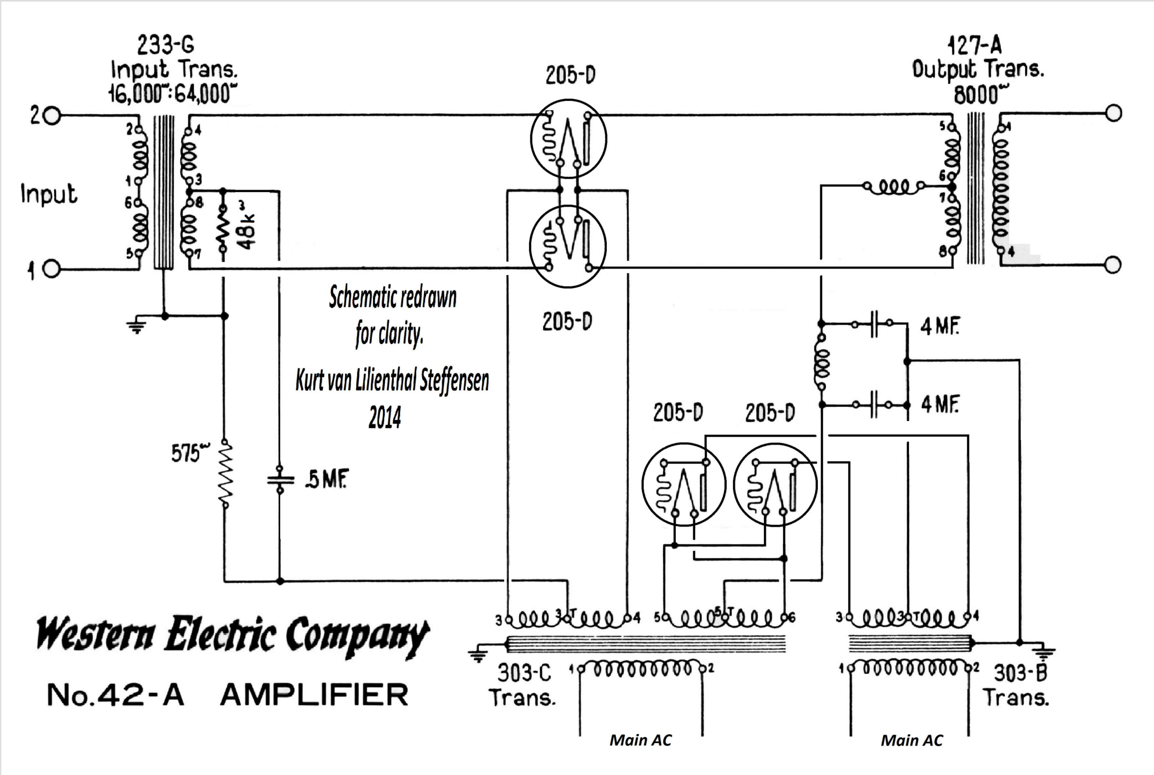


Loftin & White, 1929.

These early Joes; Loftin and Whites was the first to get rid of that leaky, lousy and expensive capacitor they made back in the 1920's. Direct coupled power amplifiers were quite common in the early 1930's. Capacitors were expensive and poor and often quite unreliable. We are lucky to live in times of which passive components are no longer of such a limiting factor.

I like the idea of direct coupling simply because it has no capacitors to mess up the phase, limit the LF and to steer into recovery problems. But I think it comes at a price. First of all we need a lot of high Voltage and that is not really what I long for, secondly and more importantly the danger of errors. In a DC coupled power amplifier any runaway, bad soldering, poor pin contact are most likely to lead to catastrophic failure killing the output tube and possible damage to rectifiers, chokes and so on. I really care too much about my precious triode darlings in order to fully trust that nothing will ever go wrong. These reasons was exactly why the "Direct coupled amplifiers" were abounded as quickly as they had been adapted.

This original L & W uses a 24 pentode to drive the 45 power triode – directly…..650 Volts of power behind. L & W benefits from the use of a tetrode as the sg2 is fixed in the current loop, thus assist in maintaining the DC values as intended.
These guys were brave in more than one way – and at least we need to touch the hat in honor to Loftin and White…Well done, guys.



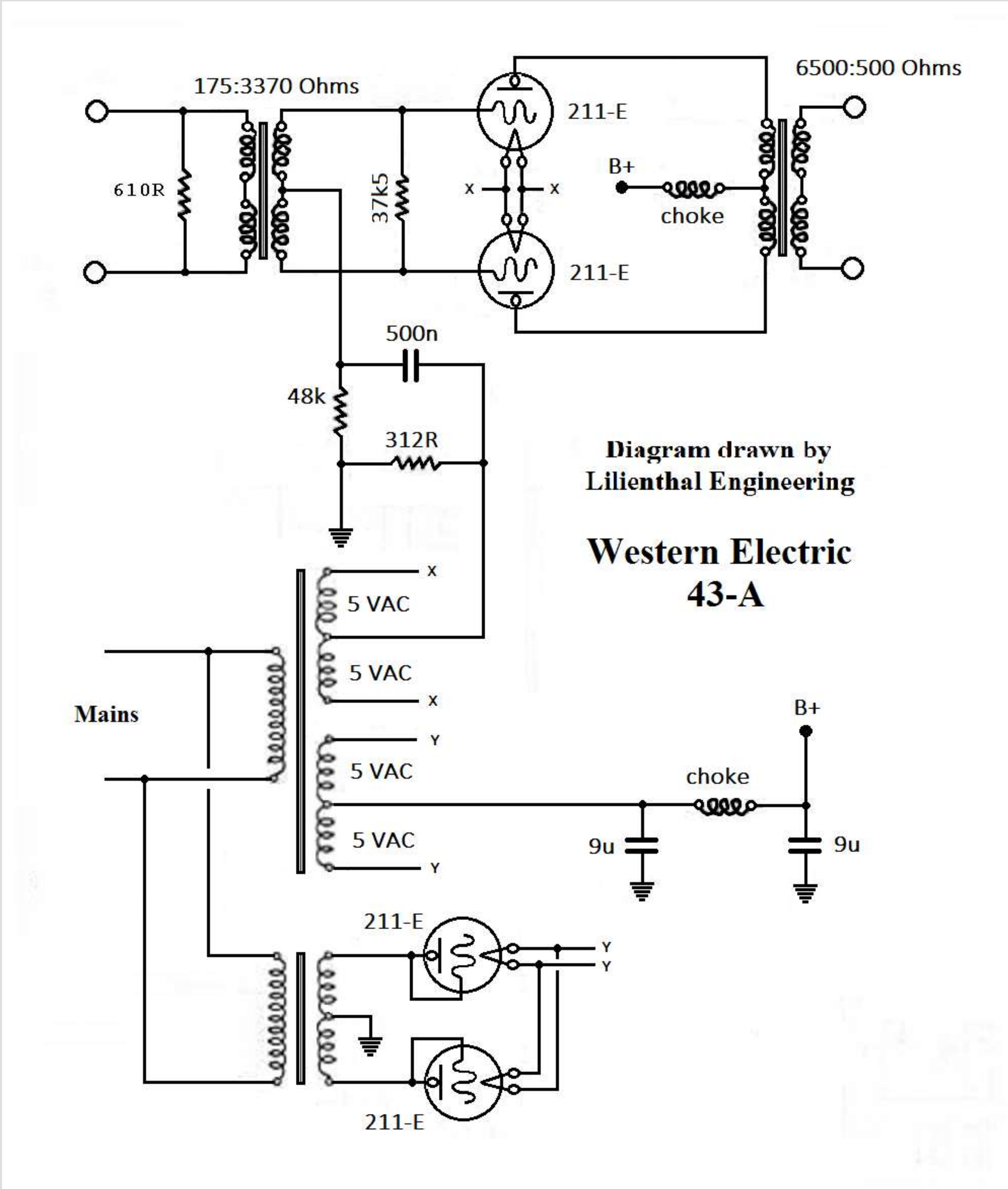
Western Electric 42A, 205D PP and 205D rectifiers.(1925 ?)

Pheew….I like the simplicity….Tubes and iron really goes well hand in hand…Input phase-splitter and step up. Thats the way I like it. We would not need that much gain today, but we can trade it for a better transformer.

(Picture from “Soundup.ru”)

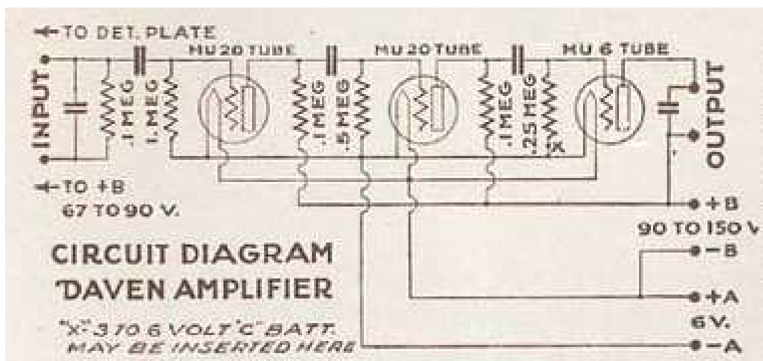
The 575 Ohm resistor is the common cathode returns of the two 205 power tubes. The 48k Ohm and 0.5uF forms a weird HF pass filter, however as there is no signal from ground to the center tap of the secondary (common mode), it does not make a lot of sense. But it does couple unbalanced high freq artifacts onto ground. The undecoupled choke ahead of the output transformer acts as a “constant current” inductor. This will improve the linearity and reduce distortion and is still used today by some “cost no issue” hardcore tube audiophiles. Anyway – this is pretty much a plug and play amplifier. Add a volume pot and you are there. That is – if you can get your hands on some 205D’s. Although Push Pull was not a new invention as it had been used for small signal amplifiers and oscillators, the 42A was one of the first PP power amplifier.

WE 25B (Not shown) is a SE version of the 42A darling.



Western Electric 43A, 211 PP and 211 rectifiers. (1928 ?)

43A is the same circuit as 42A….Only big as a desk….and 211's instead of 205D's. Much much larger transformers too. This is about as simple as it gets. Awesome.



(Suggested by Joe Roberts)

Daven Resistance Coupled Amplifier, 1926.

This is most likely the worlds first all resistor and capacitor amplifier.Simplicity speaks – a cute little 3 stage SE thing. It looks like modern SE amplifiers, the batteries would make it advanced High End.. Keep in mind that an OPT (Output Transformer) are supposed to be applied at the low power output. No hum from rectified products here. No main supply nets to disturb either.(1926)

Excellent.

The Daven RC coupled amplifier. From the collection of Ernie Hite, Photo. Charlotte ARC

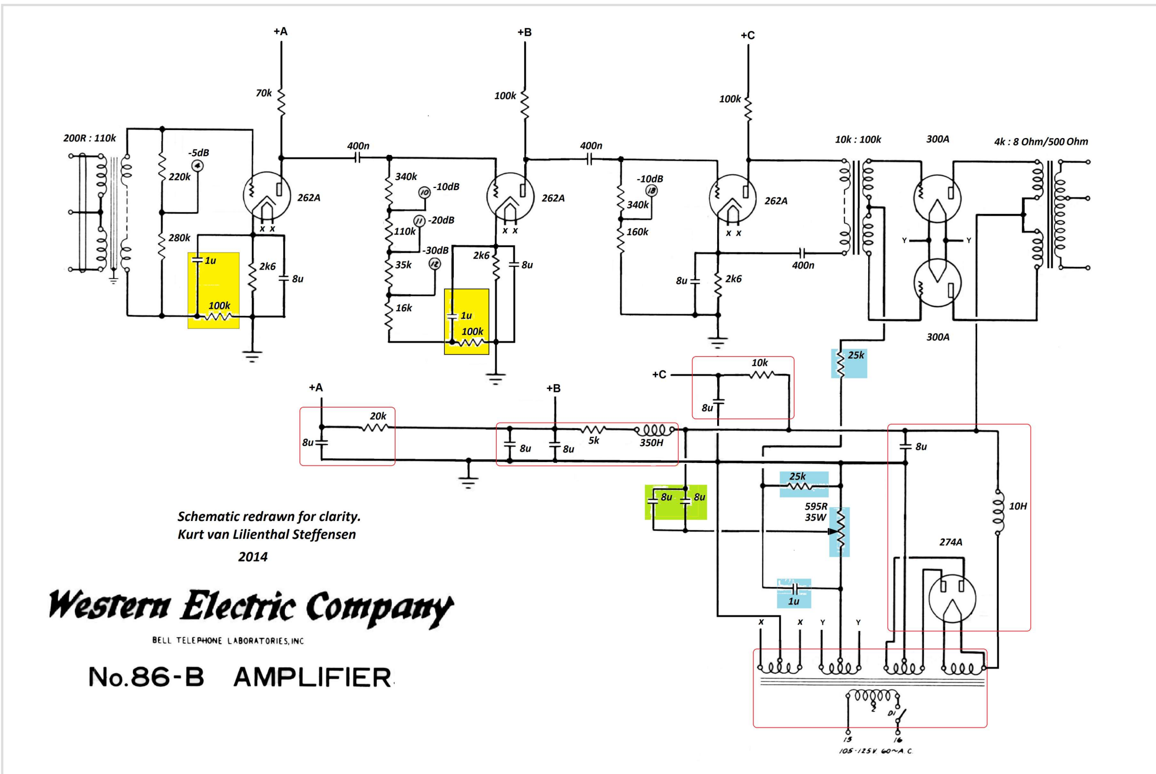
Global Negative Feedback , 1928

Harold Black and Harry Nyquist, Bell Labs. gave us the feedback scheme. I am sure that the hardcore kiss DHSET fans questions this idea,
but trust me, we would not be any good without feedback.
That said – I love the simple non feedback SET too….

In the early days of telephone communication problems with noise and distortion was a big issue.The guys at Bell and WE struggled to find solutions for communication. Better repeater amplifiers and microphones was a top priority. Lots of noise, weak signals and high distortion was just a part of the deal. Keep in mind that tubes had just entered the communication technology a few years before.

Long distance was in particular a problem due to the series of repeaters. In 1925 AT &T gave the task of coming up with a solution for this problem to Harold Black at Bell Labs. At the late 1927 Harold Black presented a negative feedback amplifier with a distortion reduction of 100.000:1 and a freq range from 4 Hz to 45 kHz, according to IEEE. The Swede Nyquist, also at Bell Labs, worked out the maths behind the negative feedback scheme. In 1928 Black applied for the patent.

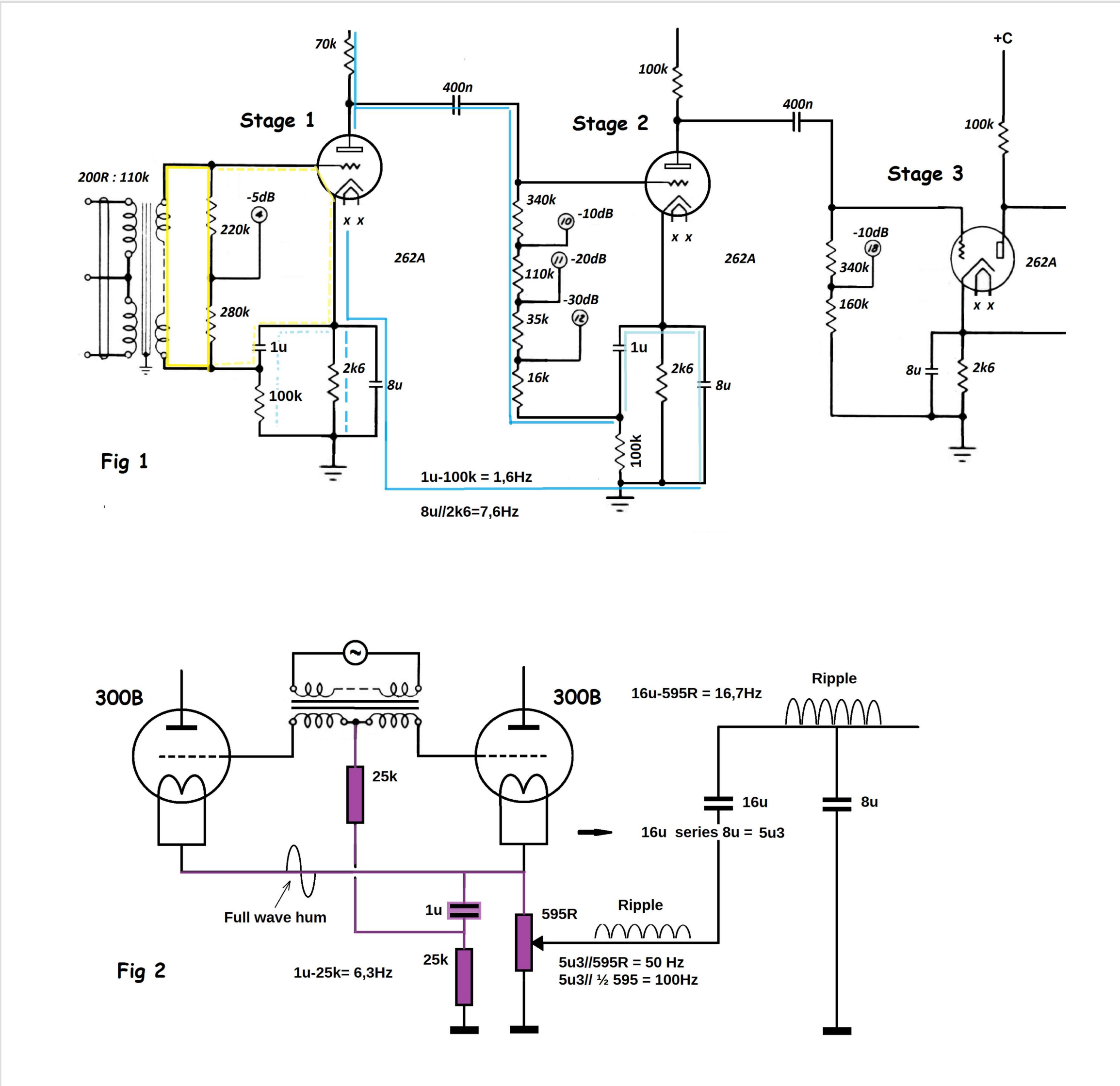
http://www.ieee.org/documents/proc_scanpast0211.pdf



(Suggested by Jan Schlatved)

Western Electric 86A/B, 300A PP (1934 ?)

I can dig that….Transformer input, two 262A triodes, then a 262A coupled to a transformer phase splitter…274A rectifier…..At first glance it appears pretty normal, but then you spot something weird. Look at the components I have marked in yellow. The secondary side of input transformer are **not** connected directly to ground. It refers to ground DC vice via a 100k Ohm resistor. The grounded side of the transformer are AC vice connected to the cathode of the 262 via a 1uF capacitor. This is very unusual indeed. It is not feedback as the amplification at the cathode is less than 1 and the signals are feed to ground via the 8u capacitor and the 2k6 Ohm resistor. Neither is there any signal at the 100k resistor, hence it does not seem to do anything important.I suspect this is done in order to save an expensive input transformer in case of plate to grid breakdown of the 262A. Remember that this was still early days and tubes were not all that reliable. Same thing applies the second stage, however, here the circuit is quite different. Third stage are straight from the textbook. But a similar arrangement are made at the output. I have marked these components in blue. The 595 Ohm resistor is a common cathode circuit from the two 300A's. Nothing weird about that. But do note that the cathode decoupling capacitor may be adjusted as the 595 Ohm resistor is a rheostat. (Variable resistor). It is also worth to note that this capacitor (Marked in green) are not referred to ground directly, but returns to ground via the PSU capacitors. Again quite unusual and I do not think it is of any advantage. **Peter Sikking,** Berlin (see: http://ultra-fi.blogspot.dk) raised some very good and relevant questions that made me dig a little deeper into these Western Electric quirks. I have drawn the first 3 stages and the output stage in a manner that may make it easier to comprehend what is indeed going on.



Alright, lets look at the first stage in **fig 1**. The signal path/current loop of the input transformer (Marked with yellow) are mainly passing through the two series resistors of 220k and 280k Ohms. A very small fraction of the current will pass through the grid, cathode and the 1u capacitor. These input signals can not pass to ground and the 100k Ohm resistor will have no input signal present. The amplified signal current of the 262 will have to pass through the cathode into ground. Now, the 2k6 cathode resistor are bypassed by 8u, which will lead (short) all signals above 7,6Hz to ground. Frequencies below 7,6Hz will pass through the 2k6 Ohms resistor that “shunts” the series connection of the 1u cap and 100k Ohms resistor. Hence there is NO feedback returned to the secondary winding loop of the input transformer. As I mentioned above, I am sure that the 100k Ohm resistor is there to protect the thin wires in the secondary winding of that transformer in case of failure of the 262A. It would be bad to business for WE if a simple and rather common thing such as this would bring the entire show down and mean an expensive transformer repair.

The second stage is a little different. Here the output current loop of the previous stage input is also part of the input loop of the 2 stage 262A.This means that the INPUT signals WILL pass through the 1u capacitor to the parallel of the 2k6 and 8u into ground. Only a fraction will pass through the 100k resistor. The cathode AC signals from the 262 will also pass through the 8u and 2k6 resistor to ground. Hence there is no feedback here either. I have no explanation to why the 1u capacitor is here, other that common practice of WE.

That brings us to the output stage shown in **fig 2**. Yes, here the WE guys are doing it again. They really loved that little trick in the first decade of amplifier engineering. It is often claimed that this WE trick was a feedback thing pulled in order to cancel imperfections. I fail to see how this can be the case. All the purple marked wires and components are common mode, which means that it does not make any sense to apply feedback here, being that positive or negative as it has no effect. In practice there is bound to be some imperfections and imbalances are certain. The transformers were not particularly good in those days and deviations even in the best matched tubes are as certain as amen at the church. But even if feedback was possible, the signal at the cathodes are in phase with the signals at the grid. Again I would say that the two 25k Ohms resistors protects the interstage secondary winding and this may be the cause of these.

There is another twist about the WE power stage. The common cathode resistor of 595 Ohms has a wiper, here a 16u are attached and returned to ground via the 8u PSU capacitor. So – what is the purpose of this arrangement ? Lets first see how it works as a decoupling of the common cathode resistor. First of all it is a common mode point. In theory there should be nothing to decouple, but imbalance are unavoidable hence it will decouple these. Decoupling of such will remove these imbalances from the cathode resistor but it will not fully cancel – sometimes quite the opposite, but maybe they was not aware of that back then.

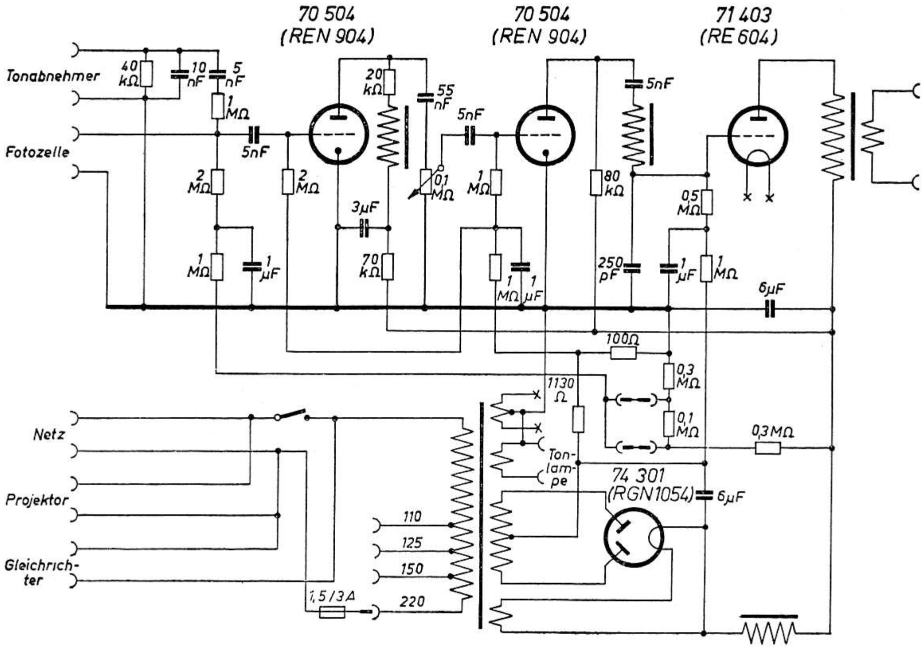
As the resistor is variable it will change the degree of amplitude, as well as frequency. Turned full up to the cathode, the cathode will be exposed to a decoupling of 16u in series with 8u = 5u3 and the decoupling freq in parallel with the full 595 resistor will be 50 Hz. This means that above 50 Hz the audio signals are coupled to ground via the series network of the 16u and 8u. Below 50 Hz the gain will fall due to the local FB. At the midpoint of the resistor this freq will be 100Hz, but divided between the “two” resistors halfs of the 595 Ohms resistor. This is all from the point of view if local feedback was indeed possible, but being a common mode configuration negative FB is only possible to the individual opposite phase grids of the 300B´s (or any earlier stage). Imbalances can only be truly dealt with by a large cathode resistor, best of all a “constant current sink” /active cathode resistor. This is quite the opposite of decoupling. When the wiper of the 595 Ohms resistor are turned all down to ground, the 16u capacitor is effectively out of the cathode circuit and acts as an additional 16u capacitor to the 8u (16+8= 24u)

The other common theory is that the 16u capacitor couples power supply noise, meaning ripple to the cathodes of the 300B’s in order to cancel noise. Lets see if this is possible. First of all – the common cathode resistor is a common mode point of the balanced push pull stage. A signal applied here will by nature be common for both tubes, hence rejected. Secondly the ripple noise produced by the power supply are present at both plates of the 300B’s, thus also rejected to a very high degree. Finally the ripples coupled to the cathode resistor via the 16u cap are in phase with the common B+, meaning positive feedback. Hardly a good method for cancellation. The last part of the noise cancellation theory is that the ripple noise exposed at the cathode resistor are supposed to cancel hum. But as hum is a full wave swinging positive and negative and the ripples are rectified full wave to the same phase, it will only reduce hum at every second part of the fullwave, the other part will be amplified by the positive feedback of both being in same phase. Hardly a good idea.

Finally it is also unusual that the capacitor at the driver tube are placed in the ground side rather that the “hot” side. This arrangement place the primary side of the transformer at the B+ DC and builds a capacitive potential between the primary and secondary windings.. Quite unnecessary, but a thing that is easy to forgive as this was still early days of electronics. The components marked with red are power supply components. Despite these minor peculiarities, I really like this circuit. It has personality and character. If you consider to make a copy of this classic WE , I suggest that you avoid the first input transformer/tube stage. All that gain is of no use for modern signal sources.

The Voltage to the OPT should be between 4-450V and some 400 Volts for the second Voltage amplifier stage and driver stage. The quality of the inter-stage transformer and OPT are crucial in order to make it all worth the effort.

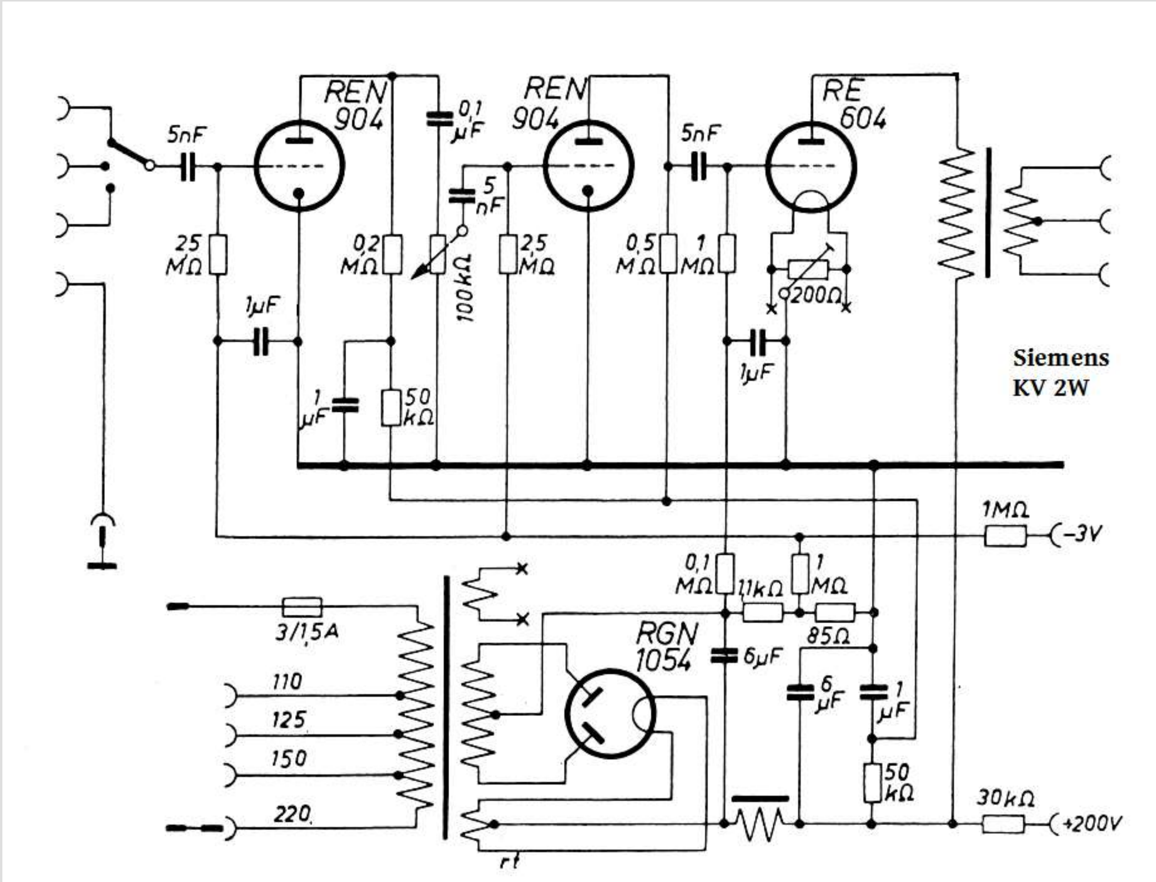
A true WE classic.



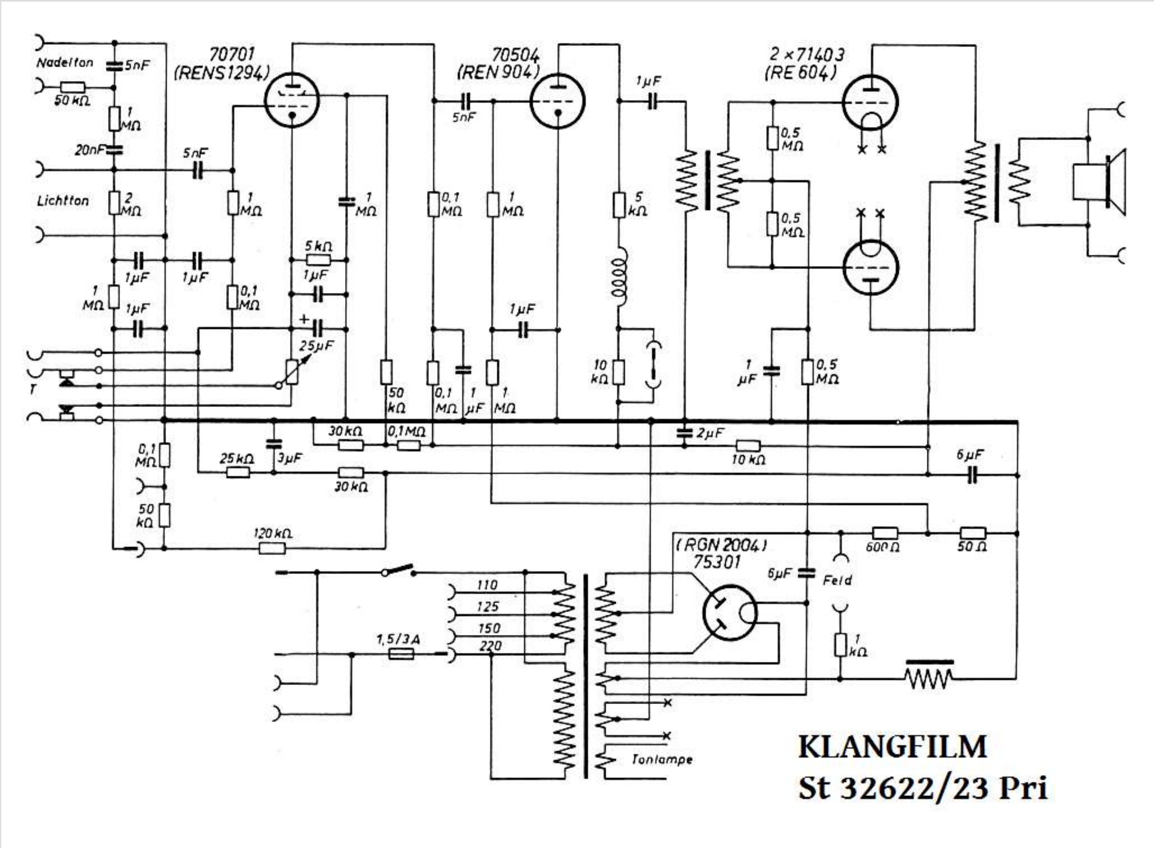
KLANGFILM
Bionette 31620 Pri

Siemens, KLANGFILM and Telefunken RE604 amplifiers , 1928 to 1936.

The RE604 triode was introduced in 1928 (a year before the British PX4 and American WE 300A) and was widely used until 1936 when the successor AD1 slowly took over. The Klangfilm Bionette shown above is a brilliant example of the series of amplifiers made for cinema, theatre and similar PA by Klangfilm and Siemens. The Bionette is cleverly biased from the network in the current loop of the PSU that works in a manner like cathode bias. The parafeed choke plate loads of the first two stages is a wonderful touch. I do not quite understand why they would place a 20k Ohms resistor in series with the choke as it reduces the Q factor quite a lot, but I guess they wanted to reduce the plate Voltage. I can’t help smiling when I see the odd way the signal from the second stage choke is returned to the grid of the RE604. It most certainly works, although I am not sure I would want to do it that way.



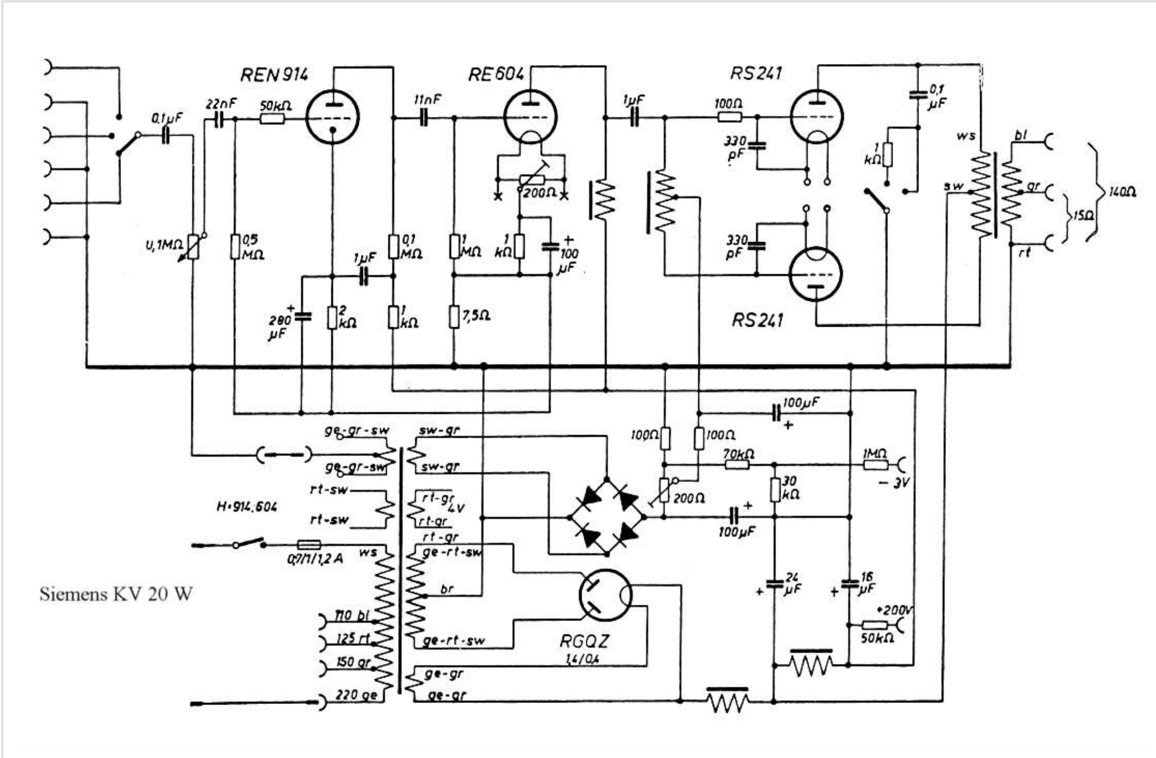
Above is another typical amplifier made by the German trio. This one is a **Siemens KV2** and it is remarkable similar to the Klangfilm. (The Siemens , Klangfilm often were) This one however has resistor loaded anodes. Should you happen to have a pair of RE604's both of these circuits are good candidates for a modern amplifier – a little modification needed of course. The signal filters must go and the signal capacitors, as well as the smoothing capacitors are too small for modern use.



The Klangfilm St-32 622, RE604 PP, 1928-32 are partly made with the same current loop bias as the SE versions. The first stage RENS1294, listed as a HF *exponential* pentode (Whatever that means) has the auto cathode bias that we are familiar with. The second stage is a nice interstage triode phase splitter – again – however – with that degrading resistor in series. (Is it there to protect the primary winding in case of tube failure ?)

A field coil speaker may be employed, should you happen to have such laying around.

The last amplifier from the German gang I would like to show you from the period of late 1920's to early 1930's is a Push Pull *power driven* triode amp.

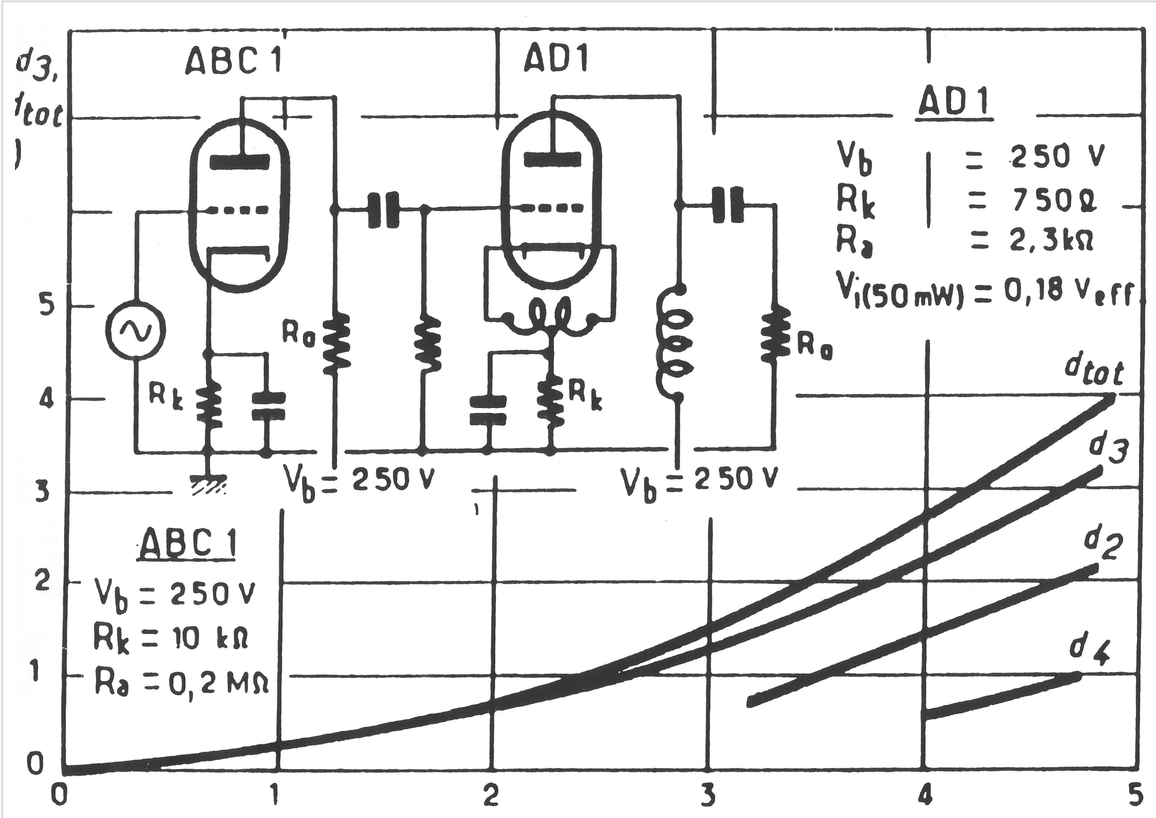


Siemens KV20W , RS241 PP, 1928-1930.

Power triode parafeed phase splitter… This application was a big deal a few years ago and is still a popular circuit amongst hardcore vacuum audiophiles. (No pond intended) I like the parafeed approach, although I personally prefers a regular interstage. Do note that there is feedback from the second stage RE604 to the first stage REN904, as the cathode of REN904 are returned to ground via the 7,5 Ohm cathode resistor of the RE604. Nice ! Two chokes to smooth – I like that too.

I am a little puzzled about the four diode symbols that shows the rectifier bridge for the negative bias Voltage. What kind of diodes were available back then ? Cats whisker ? I realise that the silicon diode was invented in Germany around 1900 and used in crystal detectors, but I was not aware that they were used as a rectifier 10 years before WW2.

Great design..

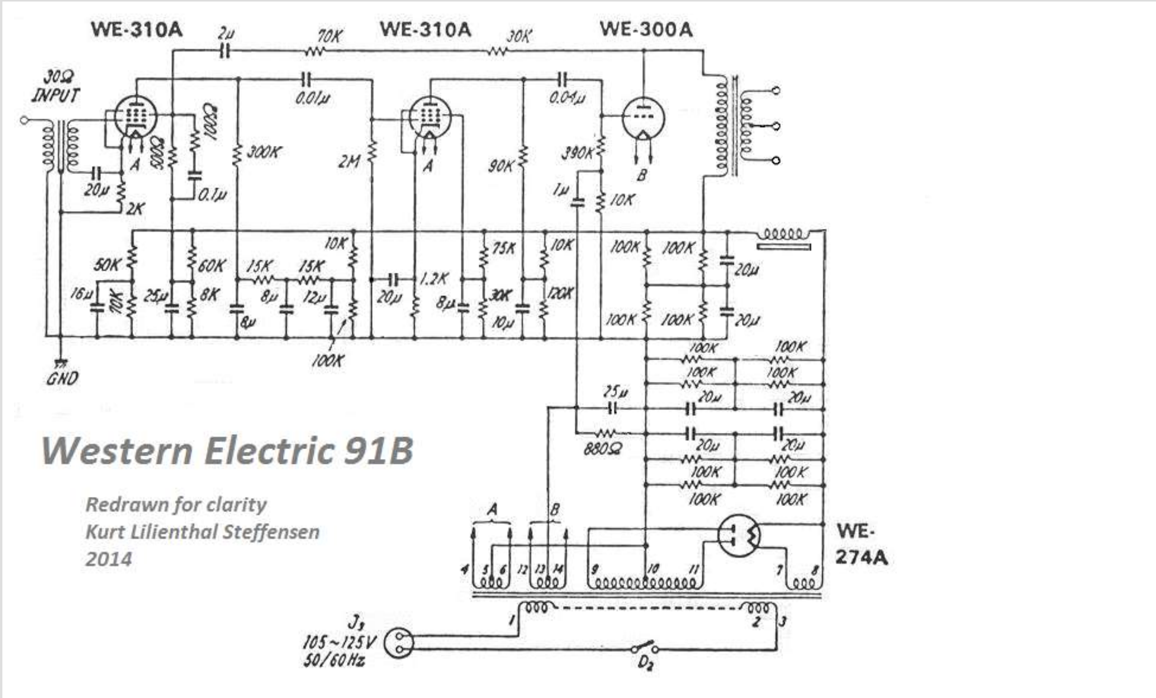


(Suggested by yours truly)

Philips app. Note: SE ABC1+AD1. 1930's

AD1 was introduced in 1936 as an improved version of the common RE604. The circuit above was a typical SE amp of this period. Literally a textbook example. At 1 Watt out the distortion are very low indeed – even at 2 Watts it is below 1% ! A 2500 Ohms output transformer and a valve regulated power supply providing some 250 to 300V will make this little circuit a top class audio amplifier. (See my article series about regulators) If you do not like the two diodes in the ABC1, you may swap to AC2. Both of these triodes are very linear and the u is around 28-30. If you do not like the anode caps, you may even swap to a 6J5 or 6SN7 for stereo. For absolute top results use an anode choke or inter-stage trannie for the pre amplifier triode. In fact 90% of all class A 15W triodes will fit this circuit as long as you adjust the cathode resistor accordingly. (Consult the data sheets)

Nice and simple.



Western Electric 91A/B, 300A, (1933 ?)
Iron input, 310A, 310A, 300A OPT.

This amplifier is equipped with four amplifying stages !. First the input transformer, then the two 310's and finally a little gain from the 300A.. Note the 1u capacitor coupled from the Voltage divider (made of 390k and 10k) to the humvice "neutral" midpoint of the filament cathode. This would as such equal feedback (Like a cathode follower) , but as the decoupling of the cathode resistor removes the AC signals here, the 1u cap and Voltage divider does not do much. In practice the 1u is returned to ground via the 25u, hence forms a low pass filter that bypasses the 10k to ground. I fail to see the point of this network and would simply remove it.

Looking at the PSU , we note the use of series capacitors and resistor network around these. Despite what is often claimed by hardcore WE fans, there is absolutely NO advantage, whatsoever, by doing this. The reason why WE did it this way, was due to the poor technology of capacitors back then. In order to obtain a "high" value of capacitance and not to overloading these by excessive Voltage, it was very sensible to connect these in series and in order to balance the Voltage for the "loose" and drifting capacitors of the time a Voltage divider by means of the resistors were made. It is as simple as that. Today we would replace the entire mess around the first capacitor with a single 20u/600V of good quality. And the one after the choke with a single 10u/600V.

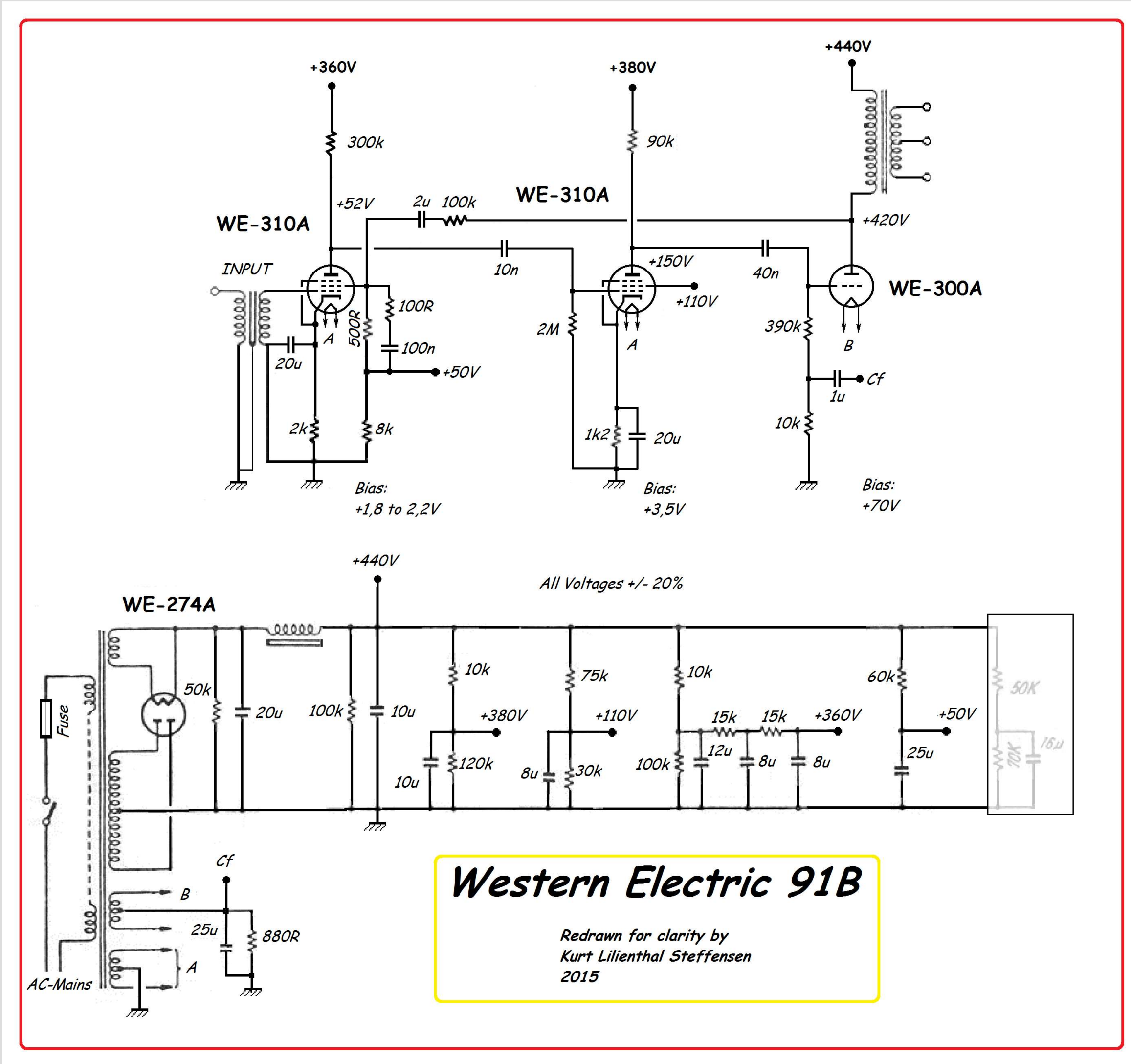
Most of the special WE tricks were made to improve stability and to insure safe long term use. A PSU choke of 10H would be fine. a choke of 5H will do and 20H would be very good.

(Pix from “westernlabo.com)

As in most of the vintage amplifiers the gain/sensitivity is way too high for use today .All though it made a lot of sense for use in the 1930’s cinema movie soundtracks from where signals were low, it is also a noise and distortion machine. In particular as we do not need all that gain. The remedy, however is simple..
Remove a stage or two (Sometimes even three) and you are there.

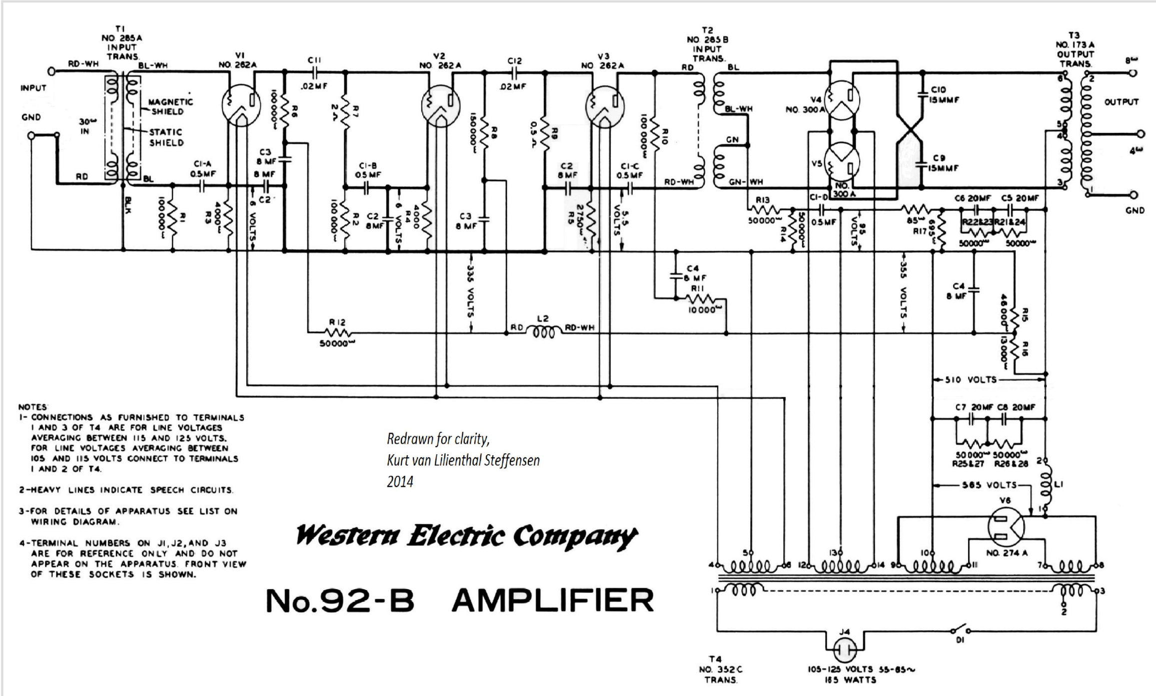
In this case it is relatively easy for a single 310A to serve as the Voltage amplifying stage as well as the driver for a 300A, the 300A being auto biased with a grid resistor of 500k Ohm. I would place an input volume pot before the 310A and it is worth trying to triode couple it. (Two stages might be necessary in particular if you would want to use feedback)

By the way – have you spotted and error in this schematic ? No..?….Well, the grid at the first tube has no ground. This is not good. The secondary of the input transformer needs to be grounded. I have redrawn the schematic for easy read, but I kept that error, for the amusement of it. This schematic has circulated in the die hard SET soceity for years and I think it is time that someone draws attention to this serious drawing error. Apart from this it is indeed a nice amplifier….80 years on the back…and still rocking…



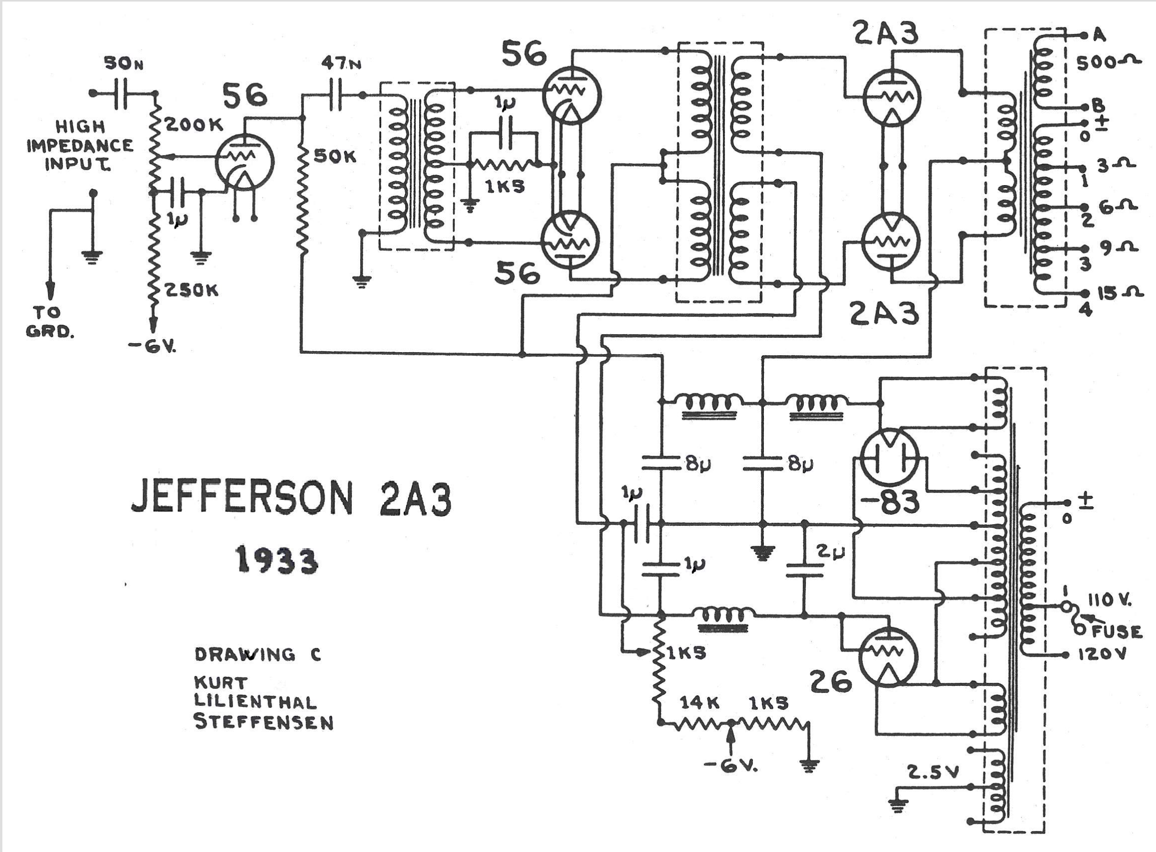
Western Electric 91B

I have received several emails regarding difficulties in understanding/reading the old WE schematics. Actually they are not that difficult, it is rather that we are unfamiliar with the way they were drawn. Anyway – here it is drawn with the PSU and amplifier separated. Parallel components are drawn as single components, just as WE would have used had they access to modern components. Apart from the Cf return, this is indeed a textbook circuit.



Western Electric 92B

Pretty much the same as WE 86B. Shortly after this amplifier was released, WE changed the orientation of the small pin at the side of the socket at the 300A, in order to make it fit the old 205D sockets. The new othervice 100% identical tube was called 300B.



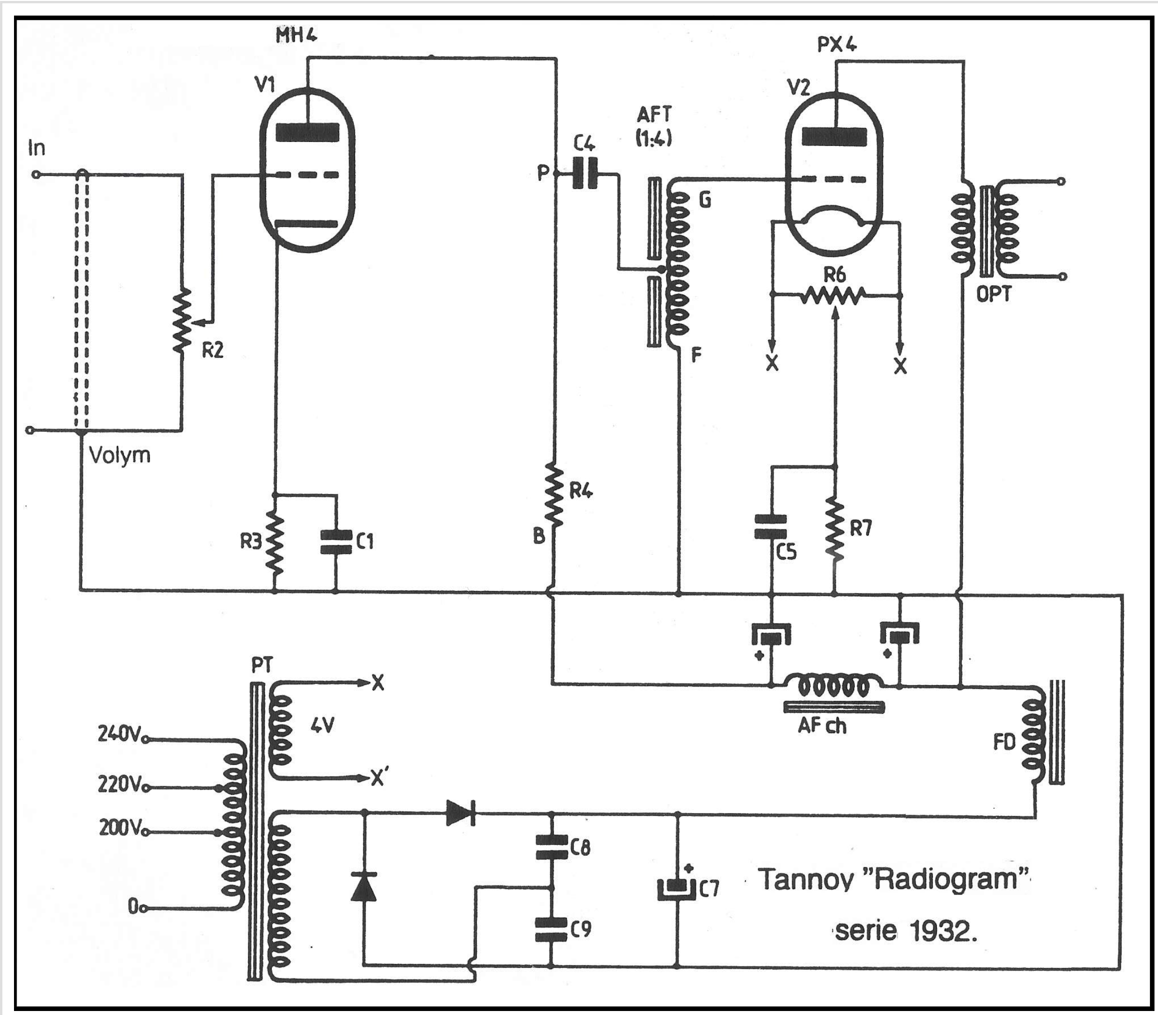
(Suggested by yours truly)

Jefferson, 2A3 PP. 1933

I could just as well have chosen yet another WE design, but WE never used the 2A3 workinghorse.
Jefferson uses an active biased 56 triode to drive the transformer phase splitter, then two 56's coupled in balanced PP to transformer drive the 2A3's PP output stage. I do think that the active bias of the input 56 is slightly overkill. I would change it to the sweeter sounding autobias and at the same time get rid of the input cap. A cathode resistor of about 1k2 – 1k8 will decoupled by 22-47u will do fine. The 56 triode is an extremely linear and good sounding triode, very close in data and performance to 6J5 and 6SN7. The u of 56 is a low 12-14, but that is plenty in this fine circuit. Note that the secondary of the driver transformer are divided into two windings. This allows individual bias for the two 2A3's. Jefferson has one fixed and the other adjustable for DC balance.

The PSU is made of a strong 83 mercury rectifier choke input and another choke to smooth the DC, yet a diode coupled 26 triode to rectify and another choke to smooth the bias Voltage. Very nice indeed. Today we can swap the 6u paper capacitors to something a little larger. 22-47u would not hurt. The two interstage transformers could be about 1:1 or 1:3. The output transformer is 4-6 kOhm. 250-300VDC will drive the whole thing in a nice and proper manner.

This is a pretty advanced design for the time, guys, a 80 year old circuit that would be considered as extravagant High End today. (with the input modified that is)
Hats off to ***Jefferson***, Gentlemen…..



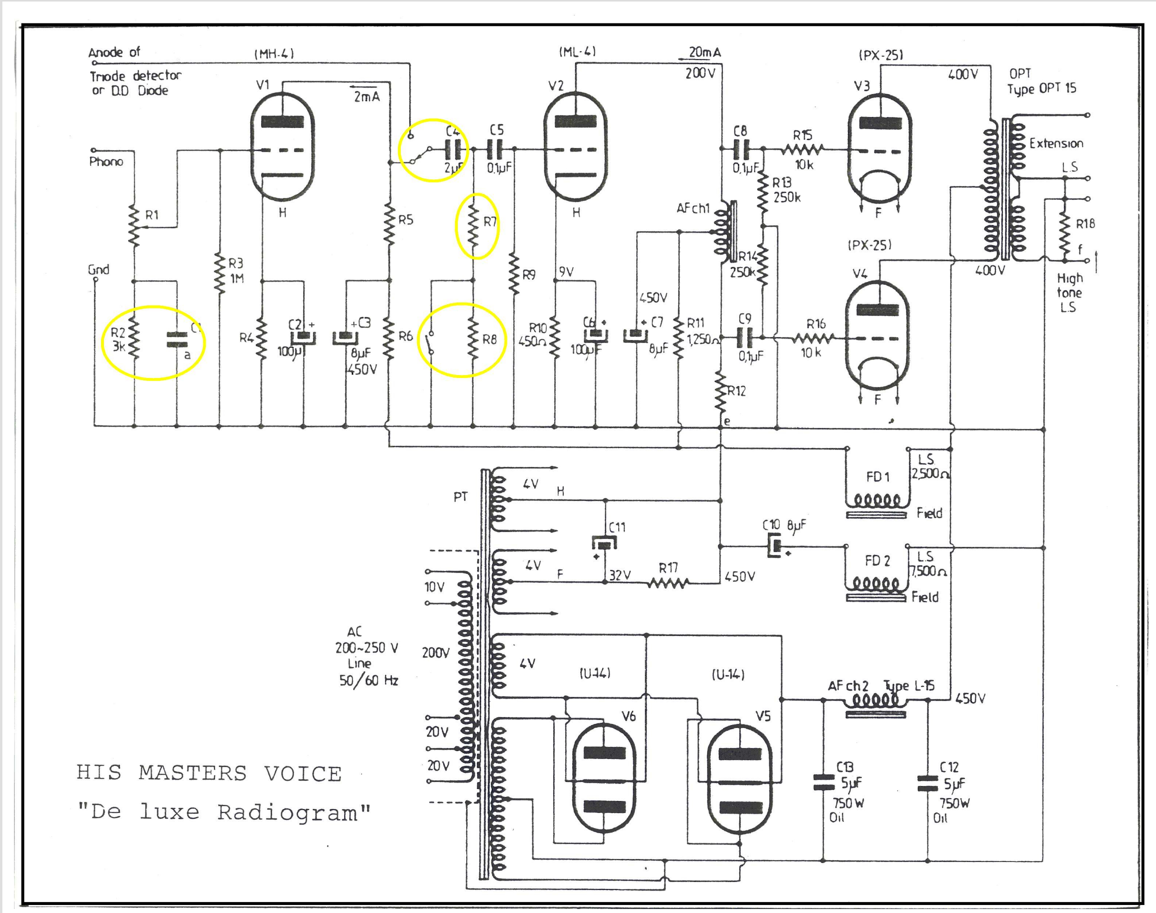
Tannoy , PX4 SE, 1932

This schematic are redrawn from Jean Hiraga's good book. Nice straight forward design. Note the parafeed driver and the 1:4 step up ratio at the tapped autotransformer.

Roger Modjeski,(Music Reference), kindly points out that It is also worth to note the metal selenium rectifiers.Such was made of a series of anode and cathode cells, separated by a thin layer of Selenium. These rectifiers were rarely used in audio amplifiers* , possible due to relatively high costs, a limit of 25V per cell, large size and highly toxic fumes in case of failure. The HT Voltage doubler that Tannoy uses here are possible due to the metal rectifiers.

(The Siemens Klangfilm KV20W, 1928-30 had metal rectifiers installed too.)

Anyway it is a good example of the typical English Single End amplifier as they were used in the domestic radios. This one obviously had a "gramophone" as well.

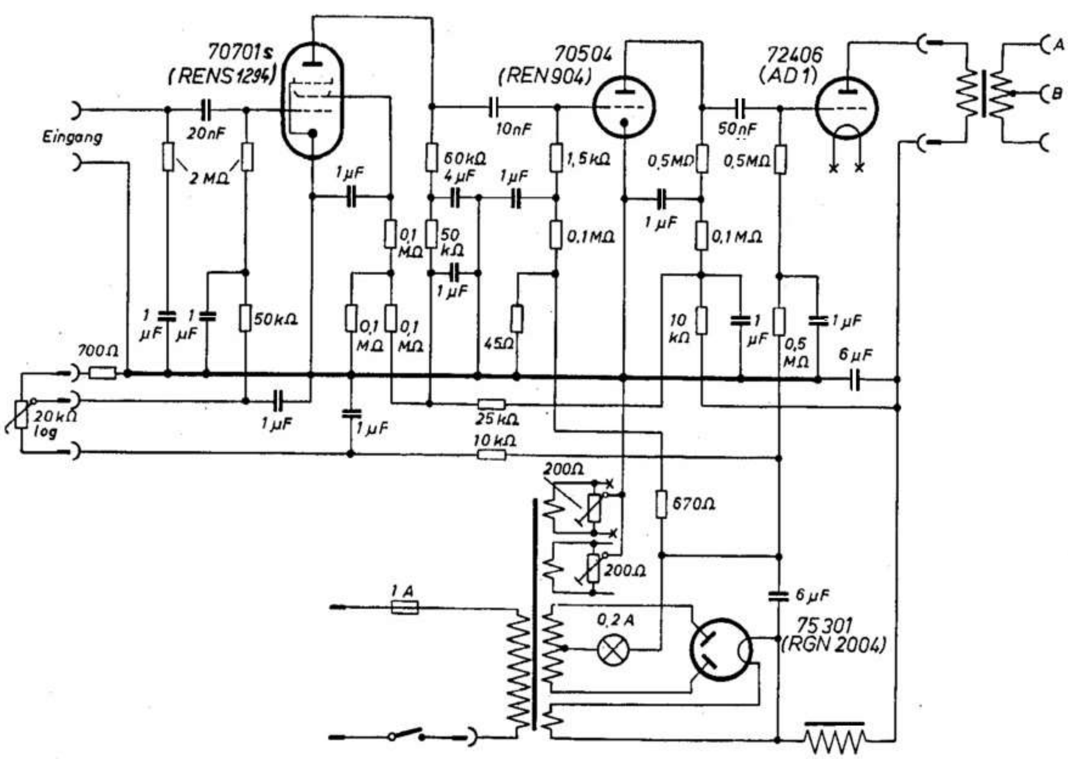


Kurt:

His Masters Voice, "De Luxe radiogram" PX25 PP, 1930s

A very good typical English prewar Push Pull type. There was a lot of fine made English amplifiers during the 1930's. PX4, PX5, PX25, DA30, DO30 just to mention a few of the common British 1930's power triodes. The circuit is pretty conventional, but it is worth to note the simple choke phase-splitter and the use of the two field coil speakers to smooth the DC. Certainly a circuit to consider when building your triode push pull. The components marked with yellow should just be deleted for modern hifi use.

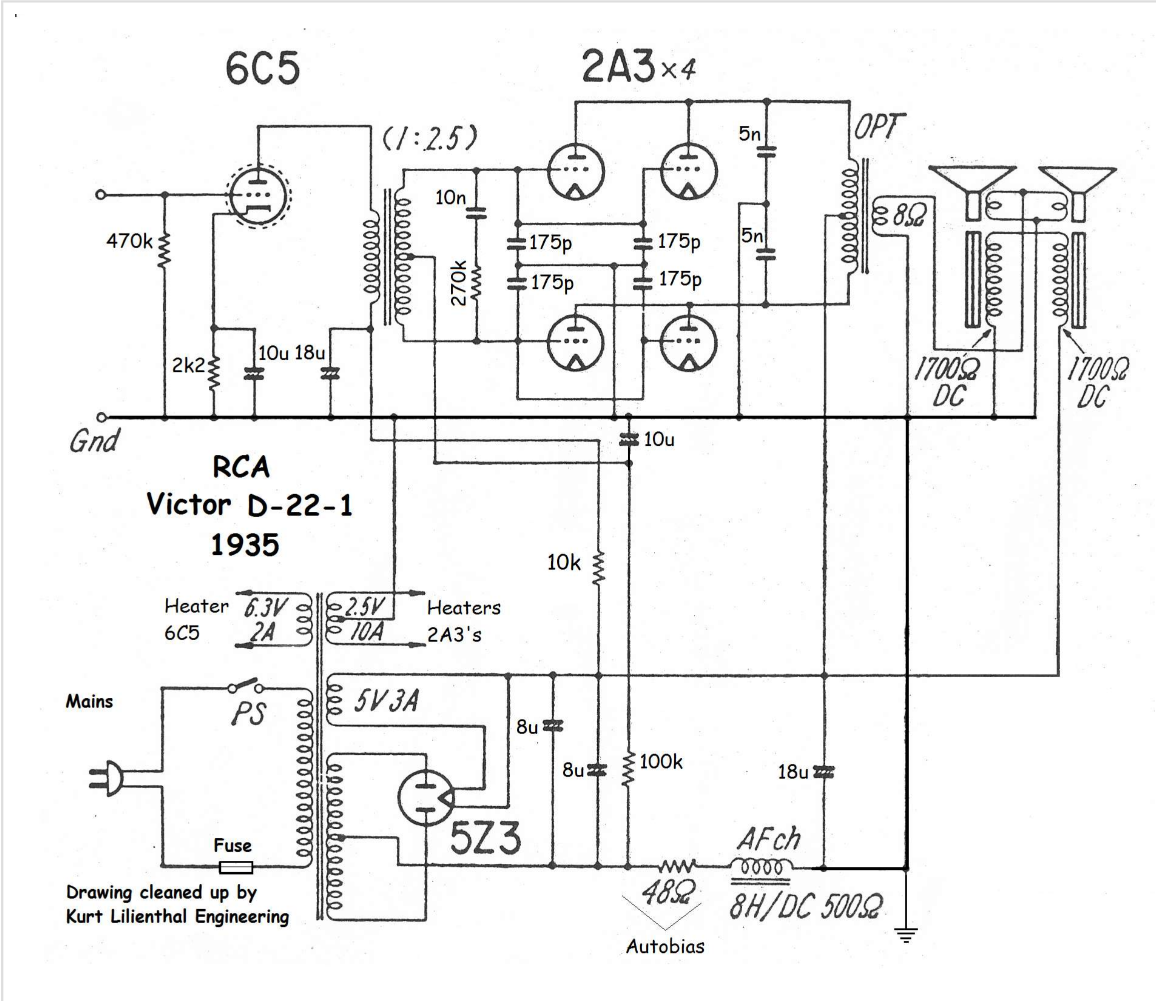
Note that the bass and treble speaker are connected to two individual windings at the OPT. This is certainly my cup of tea, – I'd say…

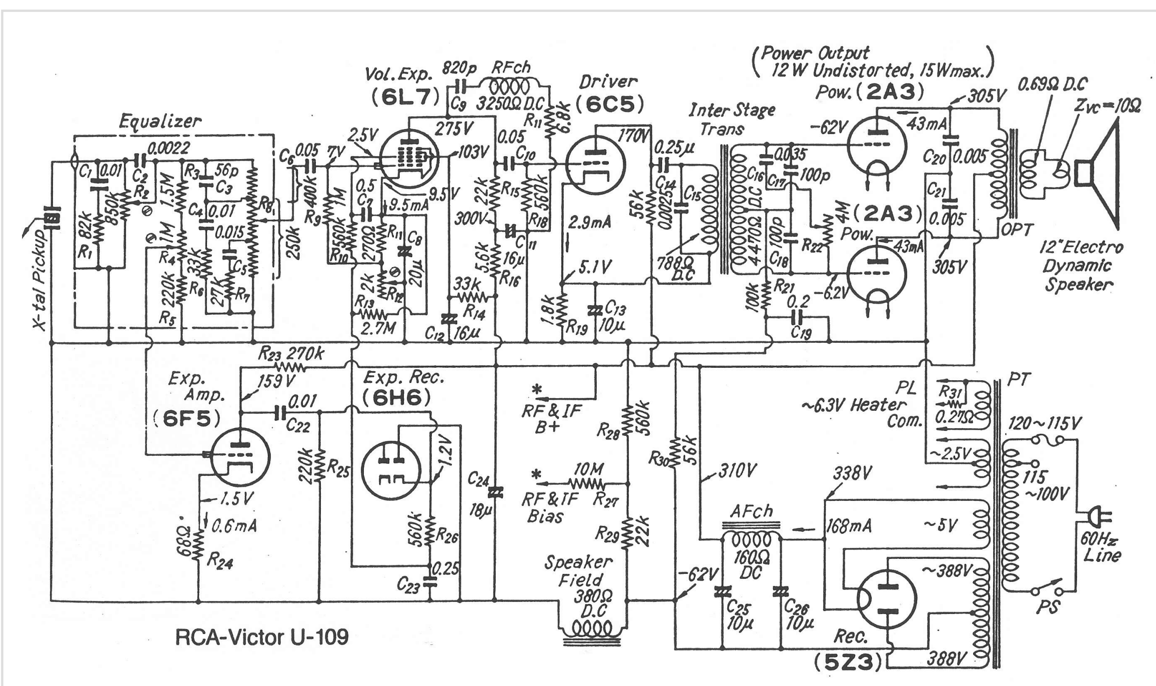


Klangfilm **Kontroll-Verstärker 32700 pri**

Klangfilm KV32700 , AD1 , 1936-38

The famous AD1 triode replaced the older RE604 in the midst of the 1930's. AD1 was to become the most common used power triode on continent Europe for the following 7-8 years. It was placed in countless radio's and small class A or AB power amplifiers. Although this "pro-use" Klangfilm amplifier is not as straight forward as it may seem at glance, it is a good example of such application. Note the grounded cathodes, the Voltage divider (45R and 670R) in the current loop of the PSU and the clever use of the lamp as ballast. It deserves a deeper analyse and I will probably get back to this fascinating design later. In the meantime it is here for you to admire.





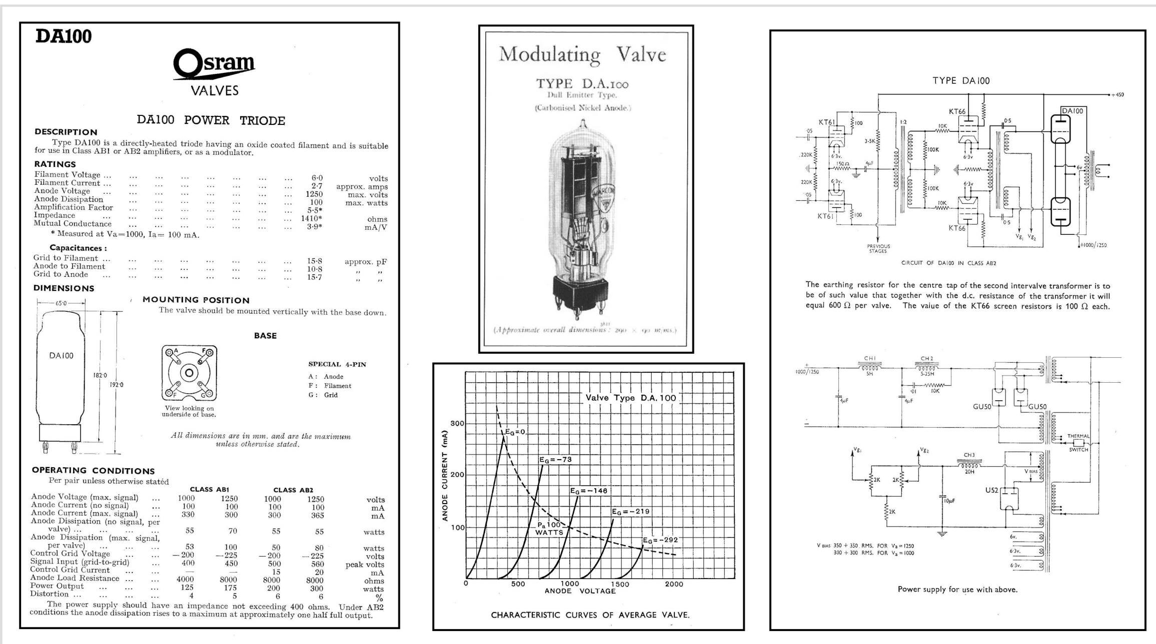
(Suggested by Joe Roberts)

Victor RCA (R-15) , 245 PP, 1930-31

I am not certain that neither of these are the one Joe suggests. But these are all the RCA Victor push pull schematics I have from that period. I have not been able to track down a model called R-15. Anyway – these are both very interesting schematics. The D-22 is a straightforward design – nice auto bias via the current through the 48 Ohms resistor. Two electro dynamic speakers of which the coils are NOT used for smoothing. I wonder why. The OPT should be about 1200 Ohms.

The U-109 are pretty similar to the D-22. If you ignore the preamplifier it is nothing but a 6C5 triode driving an interstage phase-splitter – just the way we like it. The volume expander was not a bad idea then, considering the poor quality of signal sources.

Nice indeed. I will keep looking for the R-15 schematic – any help here appreciated.



Osram DA100 PP , ca 1936

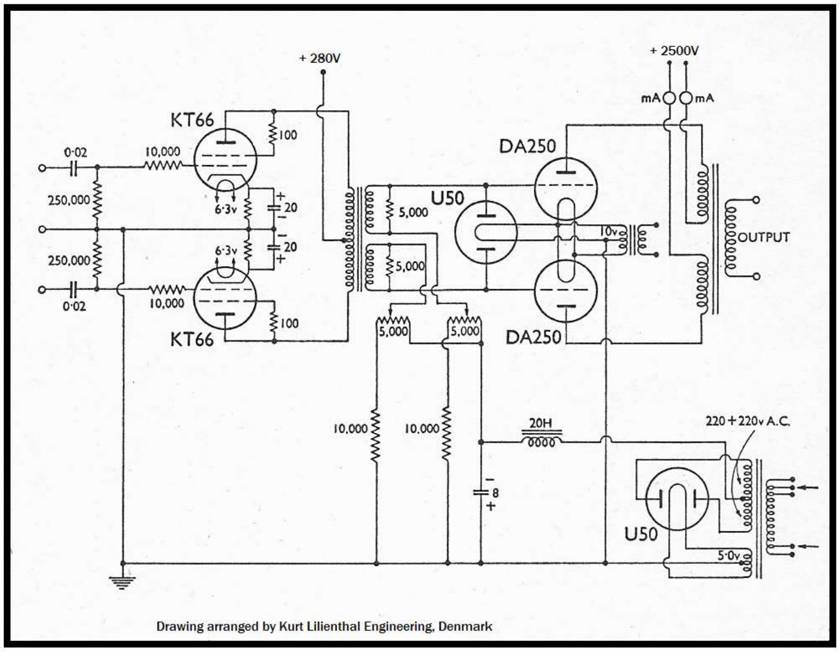
(The schematic above is from the 1951 Osram valve manual part 1, but it was published as a PA/cinema amplifier in the pre WW2 Osram manuals)

This an Osram *power driven* amplifier. The DA100 was introduced in 1936 as type number NT36. In the schematic shown the DA100's runs in class AB and will produce between 100 and 300 W, depending on load and plate Voltage. It is a fascinating design, but I doubt that this circuit will ever be built again in its original form. 4 pcs of DA100's are very hard to fetch, yet another quartet of KT66's. Still it is good to learn from and we may build it from more commonly available valves. The DA100 compares very well to the 845 or the Russian GM70. New production KT66, 6L6G, EL34 or EL37 is indeed available. The KT61 is not that hard to find, but any of the similar pentodes/tetrodes will do, just as long as you remember to adjust the cathode resistors.

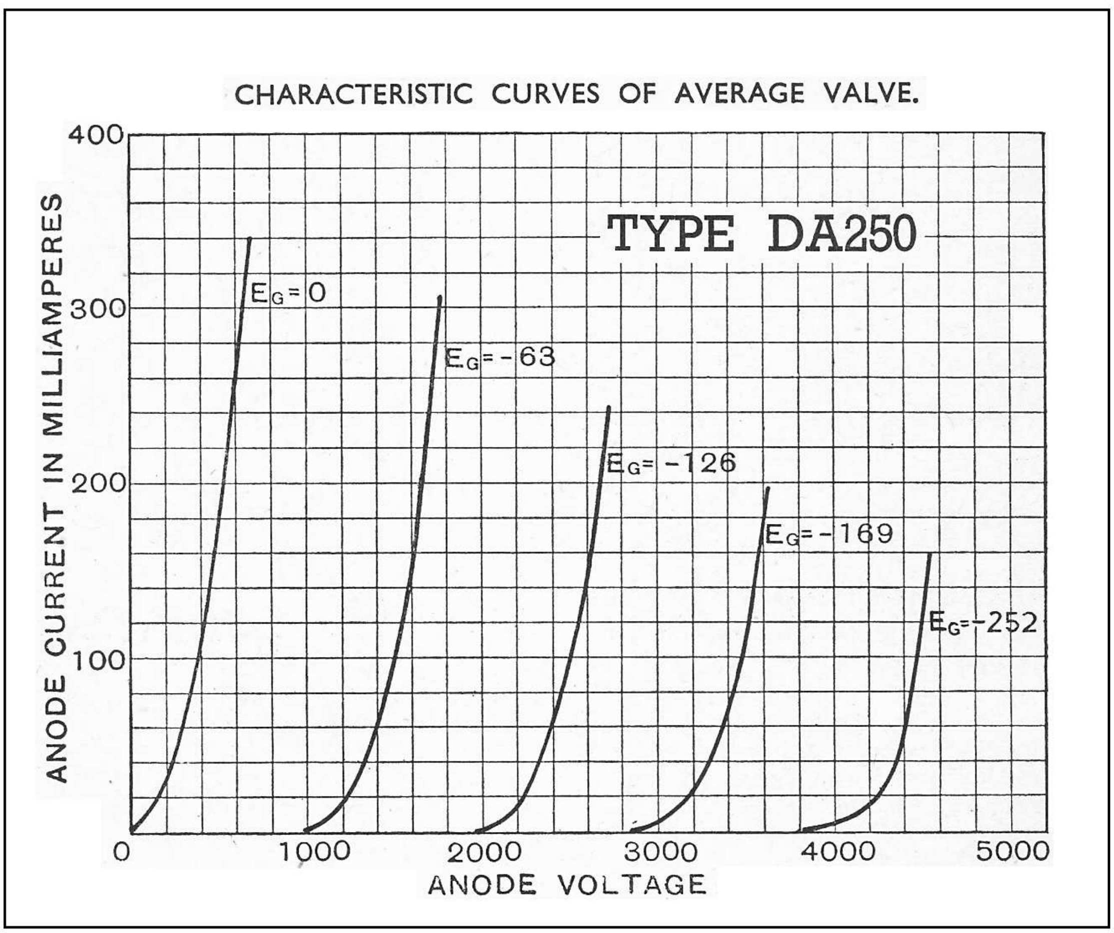
The operation conditions shows it is possible to dial in more than 100 W with a load of 4000 Ω and an impressive THD at only 4%. Keep in mind that this is without feedback !

Should you happen to need 300 Watts of class AB, all you need is a massive 3-500 Watt OPT of 8000Ω and some 1250 Volts for the plates. Now this calls for an almost sacred respect. But we can triumph that. How about a DA250 push pull ?

TYPE DA250



Typical circuit for Class AB1 push pull with DA250 valves. The U50 is included in order to prevent the "trigger effect" due to the reversal of grid current during periods of excess input Voltage.

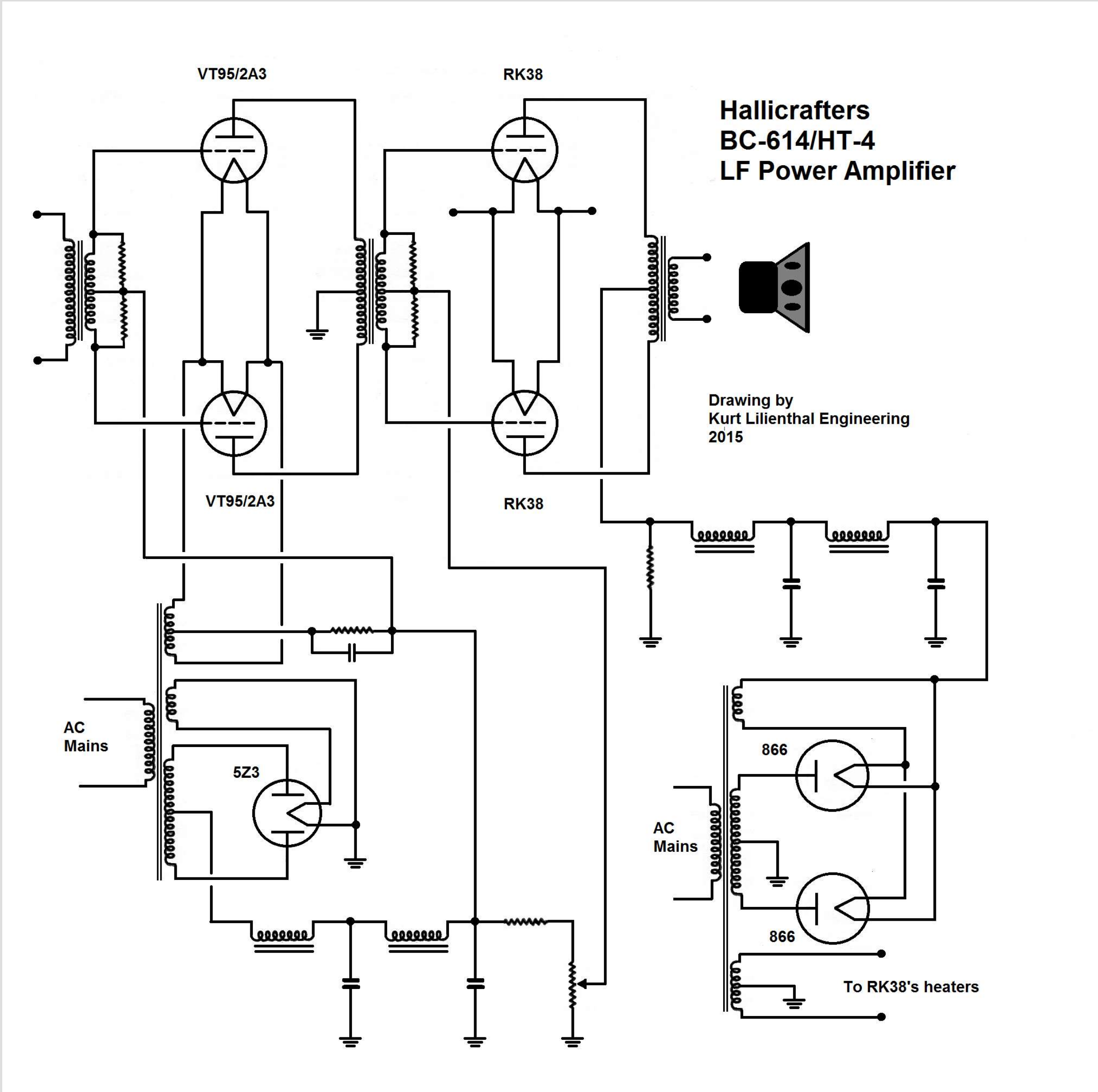


Osram DA250 PP, 1930´s

This is indeed a monster amplifier. The British DA250 triode is similar to the Western Electric 212. Transformer power driven valve amplifiers has become quite popular again. These amplifiers are considered as the top of the best possible audio amplifiers amongst the hardcore valve amplifier audiophiles. Ken Kessler from the UK, HiFi News Magazine had the Marantz T1 in for a listen in 1997. According to K.K. it was a bombshell and made the best HiFi system he had ever experienced. Ken Kessler went so far as to rate this amplifier as the best ever made. The “secret” behind these power driven amplifiers are the transformers. I will reveal all about it in an article serie about power driven amplifiers, that I am still working on.

Now, this DA250 amplifiers is an extremist amongst the extreme. As a single end triode the DA250 will deliver up to 90 Watts ! (Plate Voltage: 2500 Volts, cathode current: 100mA, load: 17-18kΩ !) In the application schematic above the plate Voltage is supposed to be 2500 Volts and the OPT should present a load of 12000 Ω. If we adjust the bias to a total of 100mA, we may obtain 400 Watt’s Class AB with a driver Voltage swing of ca 160 V peak. Grid current will be negligible and the THD will be below 5% ! If the driver accepts up to 20 mA of grid current, we can drive the DA250 pair into an unbelievable 800 Watt’s of massive power. A Voltage swing of up to 220 V peak is necessary and the output ask the PSU to deliver a current of 500mA. (1250 Watt’s) Yet, the THD according to Osram is less than 6%. I do not personally support the THD scheme, but in an amplifier without any feedback, THD figures witness about linearity.

I say hats off to the jumbo triodes from the golden age and we better bend to the engineers from Marconi Osram, better known as MO-valve and Gold Lion the team behind a number of famous valves. MO-valve was associated with G.E.C. England.



(Suggested by Joe Roberts)

Hallicrafters HT- 5 and

Hallicrafters BC-614 speech amplifier, WW2,

After a long search I found some info about these two amplifiers. HT-5 was an audio mixer amplifier made to drive the PA speech (Or modulator ?) for the BC-614/HT-4 system. BC-614 was a combined transmitter and PA-amplifier/modulator.

Very interesting (and exotic) pick, Joe…This set will bring you more than 300 Watt's class B. That ought to do it I guess. It is interesting that the 2A3 power amplifier are configured with negative Voltage compared to ground. Before you jump to any conclusions about the advantages or disadvantages about this, keep in mind that the tubes do not know the difference. The cathodes are the absolute references and therefor it works exactly as normal. The reason why Hallicrafters performed this little trick was that they needed a good power supply for the negative bias to the RK38 grids. And simply in order to spare resources they wicely chose to use this PSU for the 2A3 power amplifier as well. Nothing more, nothing less. After all this amplifier are pretty conventional – except for the high power. We can actually "back engineer" the whole mess. RK38 is a Thoriated

Tungsten filament, Tantalum plate high u triode capable of 100 Watts of plate dissipation. The maximum plate Volts are given as 3000 Volts. Heaters are hungry 8 Amperes at 5 Volts. A typical class B audio freq set up is as follows:

Plate Voltage : 2000 Volts
Bias: – 52 Volts
Idle current: 35mA
Plate to plate load:16000 Ohms
Peak to peak drive:360 Volts
Power max drive: 6 Watts/40mA grid current
Power out: 330 Watts

I will bet my favorite triodes that this is exactly what Halli's are doing. (+/- 20%)

The 2A3 stage would be a regular class A – some 300 Volts and 5k Ohms load. It only needs to deliver 6 Watts, so you can run it pretty much how you like.

"Why" – you may ask, "why the heck does Joe like an old dusty class B, WW2 military speech amplifier" ? (Good question, thank you) Well, I can not speak for Joe, but I believe I know why. First of all, despite being a class B amplifier the first few Watts from this monster are actually genuine direct heated triode class A. Secondly, there is not a single capacitor in the signal path and that can be heard. The power supplies are well regulated; choke input plus another smoothing choke for the 2A3 stage and mercury double choke smoothed for the RK38 power amp. Finally inductors (transformers) are in practice the optimal load for any tube as it forces the distortion down (compared to a resistor load) and the transformer responds to the current by "kicking back" as much Voltage as the tube could ever ask for. On top on that the DC idle Voltage losses in a transformer/choke load are only what amounts to the copper resistance of the winding wire. Of course a class A output would be better and I am pretty sure that either extreme end of the audio band are ignored in the speech amplifier. After all it was meant as a tool of spitting angry orders to your men at safe distance during WW2 – or something like that.

Anyway – damn interesting design, thank you for drawing our attention to that odd amplifier, Joe.

DA41

Osram VALVES

DA41 POWER TRIODE

DESCRIPTION

Type DA41 is a power triode with carbon anode and fitted with a thoriated tungsten dull emitter filament and designed mainly for use in pairs in a positive grid drive Class B push-pull audio frequency amplifier. Under suitable conditions an output of up to 175 watts may be obtained from a pair of DA41 valves operating at an anode voltage of 1,000.

The valve is designed to operate under the zero grid bias condition, so effecting a considerable saving by avoiding the necessity for a separate grid bias supply.

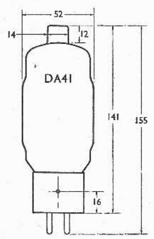
RATINGS

Filament Voltage		7·5	volts
Filament Current		2·5	approx. amps
Anode Voltage		1000	max. volts
Anode Dissipation		40	max. watts
Amplification Factor	measured at Va = 1000; Wa = 40	62	
Impedance	measured at Va = 1000; Wa = 40	17,500	ohms
Mutual Conductance	measured at Va = 1000; Wa = 40	3·6	mA/V

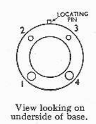
Capacitances:

Anode to Control Grid	5·9	approx. pF
Control Grid to Filament	10·0	„ „
Anode to Filament	1·8	„ „

DIMENSIONS



BASE



AMERICAN MEDIUM 4-PIN BAYONET

1: Filament.
2: Not connected.
3: Control Grid.
4: Filament.
Top Cap: Anode.

All dimensions are in m/m and are max. except where otherwise stated.

Patchworked by Kurt Lilienthal Steffensen

TYPE DA41

OPERATING CONDITIONS

Per pair of valves; push-pull. Class B.

Anode Voltage	1000	volts
Grid Voltage	0	volts
Anode Current (zero signal)	44	approx. mA
Anode Current (max. signal)	280	approx. mA
Load Resistance (anode to anode)	7000	ohms
Signal Input (grid to grid)	220	peak volts
Grid Current (max. signal)	30	approx. mA
Power Output	175	watts
Distortion	5	%

It will be found that the anode dissipation at approximately one half maximum output will exceed 40 watts per valve: this is permissible as it is intermittent. It is not possible to dissipate this wattage for long periods but normal speech and music, because of their intermittent nature, do not cause any overload.

Typical Circuit.

The circuit shown is suggested as a simple arrangement giving good quality. The driver stage consists of a pair of triode-connected KT61 valves in push-pull, cathode-coupled to the output stage by a " bridged transformer."

The resistors R1 and R2 in the cathode circuit of the KT61 valves are added in series with each half-primary to make up a total of 300 ohms to provide automatic bias for the KT61 valve.

In this arrangement of driver circuit, the pre-driver stage must supply a comparatively large signal voltage to the driver—slightly more in fact than the input to the DA41—and for this purpose two triode-connected Z63 or L63 valves in push-pull are used with a coupling transformer having a ratio of 1 : 3. This transformer should be designed to give an undistorted secondary voltage of about 85 + 85 volts R.M.S.

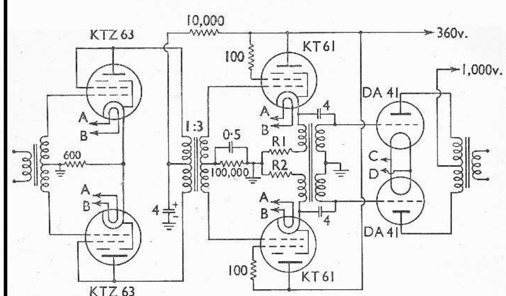
The Z63 valves have a common bias resistor of 600 ohms, no by-pass capacitor being required. The input transformer need only give an undistorted secondary voltage of 6+6 volts R.M.S. and may have any suitable ratio.

A suitable mains unit is also shown. Bi-phase half-wave rectification with two GU50 valves provides H.T. power for the DA41 stage and a smaller unit with a vacuum rectifier supplies the driver and pre-driver positions. It is essential that some form of delayed switching system is used in the GU50 circuit.*

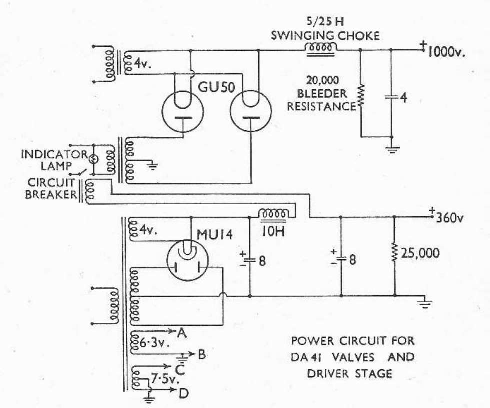
* For operating data see page 122 for GU50 valve.

The circuit information given does not imply any licence under any patents which may be involved.

TYPE DA41

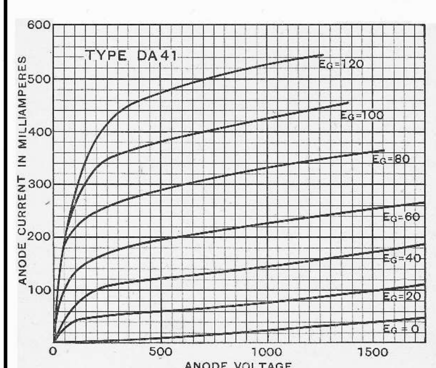


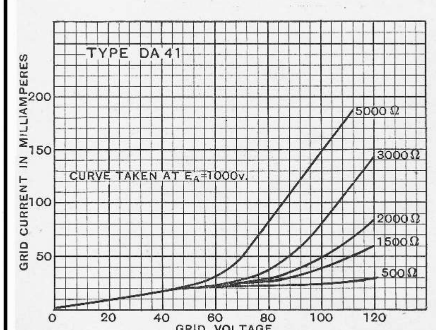
USE OF CATHODE COUPLING AND BRIDGED TRANSFORMER FOR DRIVING A PAIR OF DA41 VALVES



POWER CIRCUIT FOR DA41 VALVES AND DRIVER STAGE

TYPE DA41





CHARACTERISTIC CURVES OF AVERAGE VALVE.

Osram DA41, class B amplifier. 1940

The illustration above, pretty much says it all. It is a genuine 0 Volt bias output stage. It probably draws some 25mA idle per DA41. (25 Watts plate dissipation) It will work with a 5000 Ω OPT , probably even add a few Watts of power, but Osram recommends 7000 Ω. I am quite impressed by the relative low distortion despite the lack of feedback. It is relatively easy to convert the circuit to a 805, 211 or 845. All you need to do is to adapt the filament Voltage and use a suitable cathode resistor. KT61 may be replaced by a similar power valve, say a 6V6G, 6F6G or 6Y6G. The KTZ63's may be swapped to same or EL84, even a pair of triodes with a medium u will do the job. (ECC85 may be a good candidate).

DA41's are available at reasonable prices. There is no real equivalent to DA41/CV1076, but the TZ40 and VT76 are pretty close and readable changeable. A better triode would be the Brown Boveri T50-1, but these are quite rare.

WW PAB-1. Photo from US Militaria forum.

(Suggested by Joe Roberts)

WE beachmaster PAB-1, WW2

Gee – here we go again with an amplifier to fight nazi's…

Very large amplifier used by US army at D-day…Hence the nickname, as I understand it.

The tubes seems to be: 1 x 6E5, 2 x 805, 2 x 836, 2 x 6V6GT, 1 x 6L7GT, 1 x 5Y3GT

That is all I know about this amplifier….it is rare as rocking horse shit. Don't expect to fall over one of these at the local fleamarket – less two of them…

Western Electric Company

No. 124-B AMPLIFIER

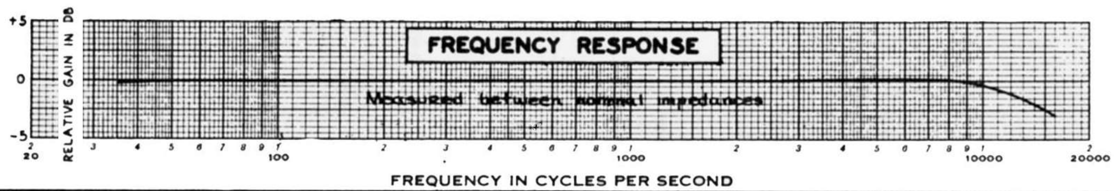
GENERAL

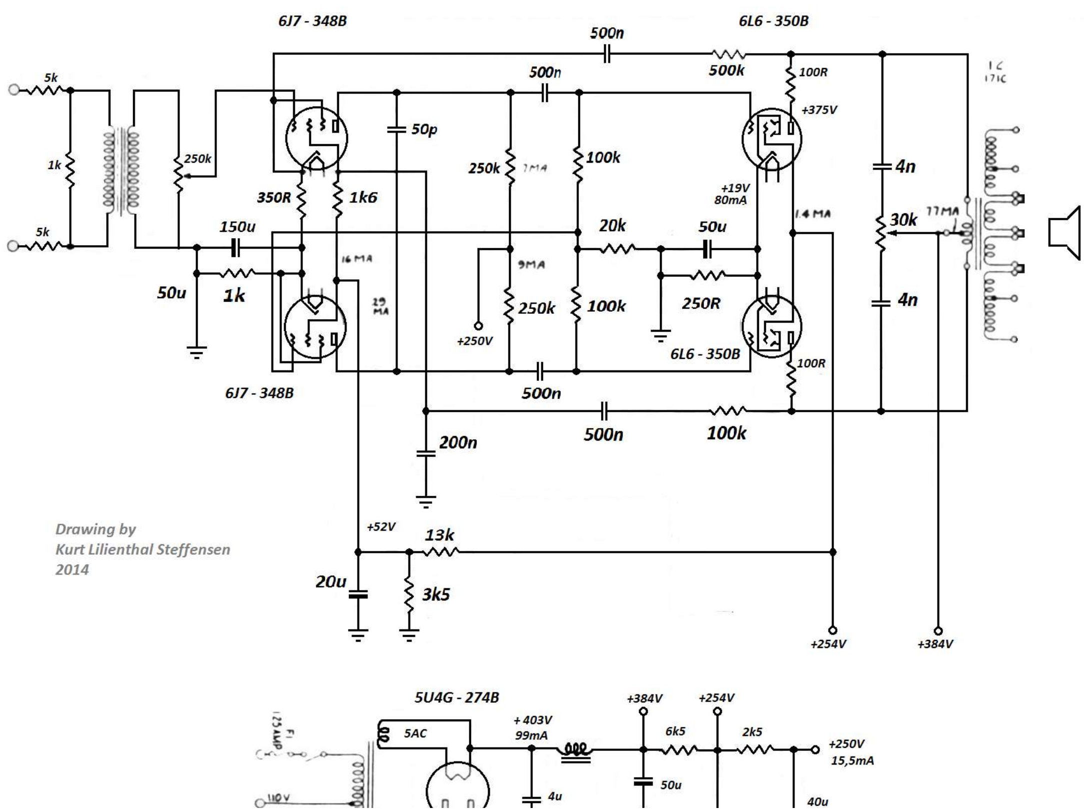
This is a power amplifier similar to the 94-type, intended for general use in the telephone plant.

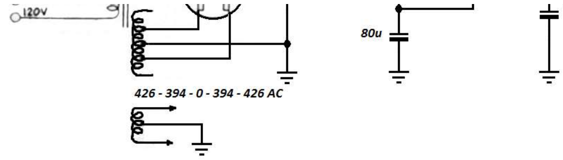
ELECTRICAL CHARACTERISTICS

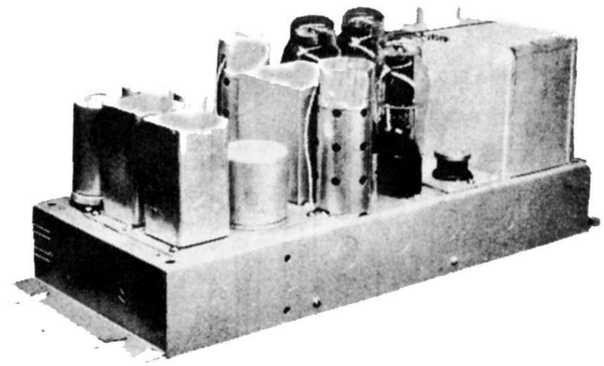
Gain Control	38 db in 2 db steps
Load Impedance	1-1200 ohms Nominal load impedances - 600, 150, 30, 16, 7.5 or 1.75 ohms, terminals 13 and 14 See strapping data on schematic
Internal Output Impedance	3/4 of nominal load impedance With strapping for 600 ohm load impedance, the use of terminals 16 and 17 gives an internal output impedance of 600 ohms.
Output Power	12 watts, 2.0% total harmonics at 400 cycles into nominal load impedance May be reconnected for 20 watts with 5% harmonic content
Output Noise	Unweighted, -37 db relative to .001 watt

4-15-41









Bjørn Kolbrek suggests this amp, also one of Joe Roberts long time favorites:

Western Electric 124A, 350B PP, (1941 ?)

Yes, this is good engineering….Excellent simple design. Only thing I regret is that they do not use the input trannie to split the phase. This is such an obvious solution, that I struggle to comprehend why they didn't do it. These amps fetch golden prices nowadays.

Nice indeed.

The end of the terrible and absurd World War II, sadly also marked the end of class A power triodes.The need for efficiency, low cost and small sizes made pentodes/tetrodes take over. Nothing wrong with the new valve technology, but the sonic qualities offered by triodes got lost as well.

The most commonly used power triodes for audio ca.1926 to 1939 was (In no particular order):

2A3
45
50
300B
RE604
RS241
AD1
PX4
PX25

High power triodes was mainly used for public address purposes, such as cinema, speech and broadcast.

211
845
DA60

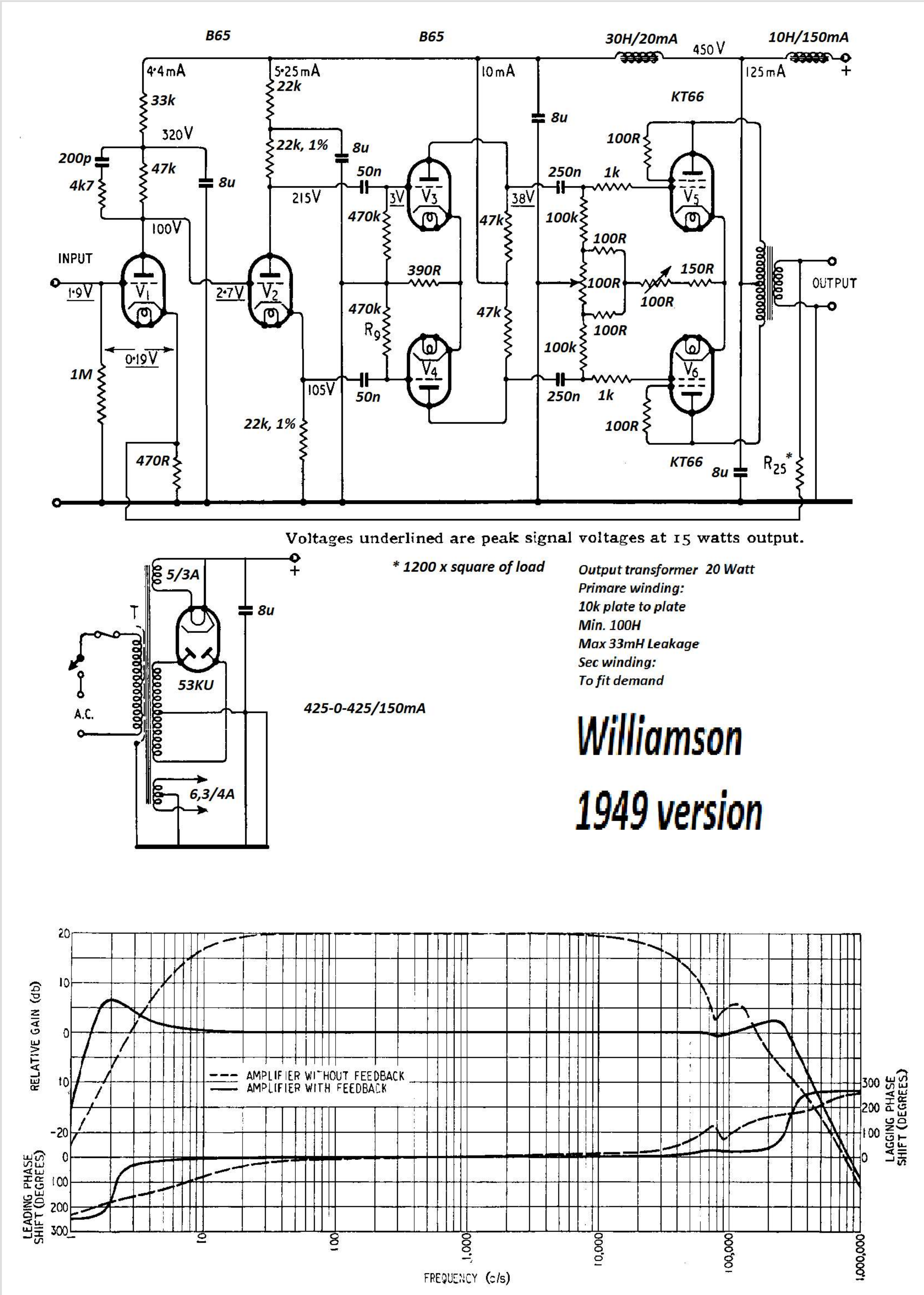
DA100
DA250
RS237

Philips held the patent for pentodes and these were widely used in Europe from the early 1930's. Most valve manufacturers in Europe produced pentodes on a license basis from Philips.
AL4, CL4, EL3, PT625 just to mention a few.

In the early 1930's Marconi Osram, UK and RCA, USA met with a plan to break the popular demand for the Philip's pentodes. Tetrodes were well known for their tendency to "kink" and other instabilities. In a close collaboration MO-valve and RCA developed a power tetrode, that compared well to the qualities of a pentode. Hence in 1936 RCA introduced the 6L6 metal and MO introduced their version KT66. These were to become some of the most successful power tubes ever for audio. In particular the improved glass version of 6L6. 6L6G's are to this day the most commonly used power tube in electric guitar amplifiers. (Closely seconded by the later EL34.)

The period after WW2 and up to the late 1950's was never the less very exciting because of the intelligent ingenuity and imagination. Wonderfull amplifiers were made during this period and high quality reliable passive components was developed. Relatively few power tubes/valves were developed in the 1950's for audio. EL34, EL37, EL84, KT77, KT88, 6550, 7027, 8417 comes to mind. The technology of electron tubes peaked from 1958 to 1962. Nuvistors and Ceramic planar tubes was the receiving tube technology at its highest. Everybody knew however, that it was only a matter of time before transistors would take over. Further development of electron tubes was cancelled. G.E., USA designed some ceramic tubes and Tung-Sol designed a series of high current triodes in the 1960's. In Europe a few similar extremes was developed, but silicon solid state took over entirely.

Post WW 2 and up to about 1954:



Williamson (Cooking and the WW team) , KT66 PP, 1947

– possible the most copied audio circuit of all times.

Perhaps a copy itself of Mitchell's

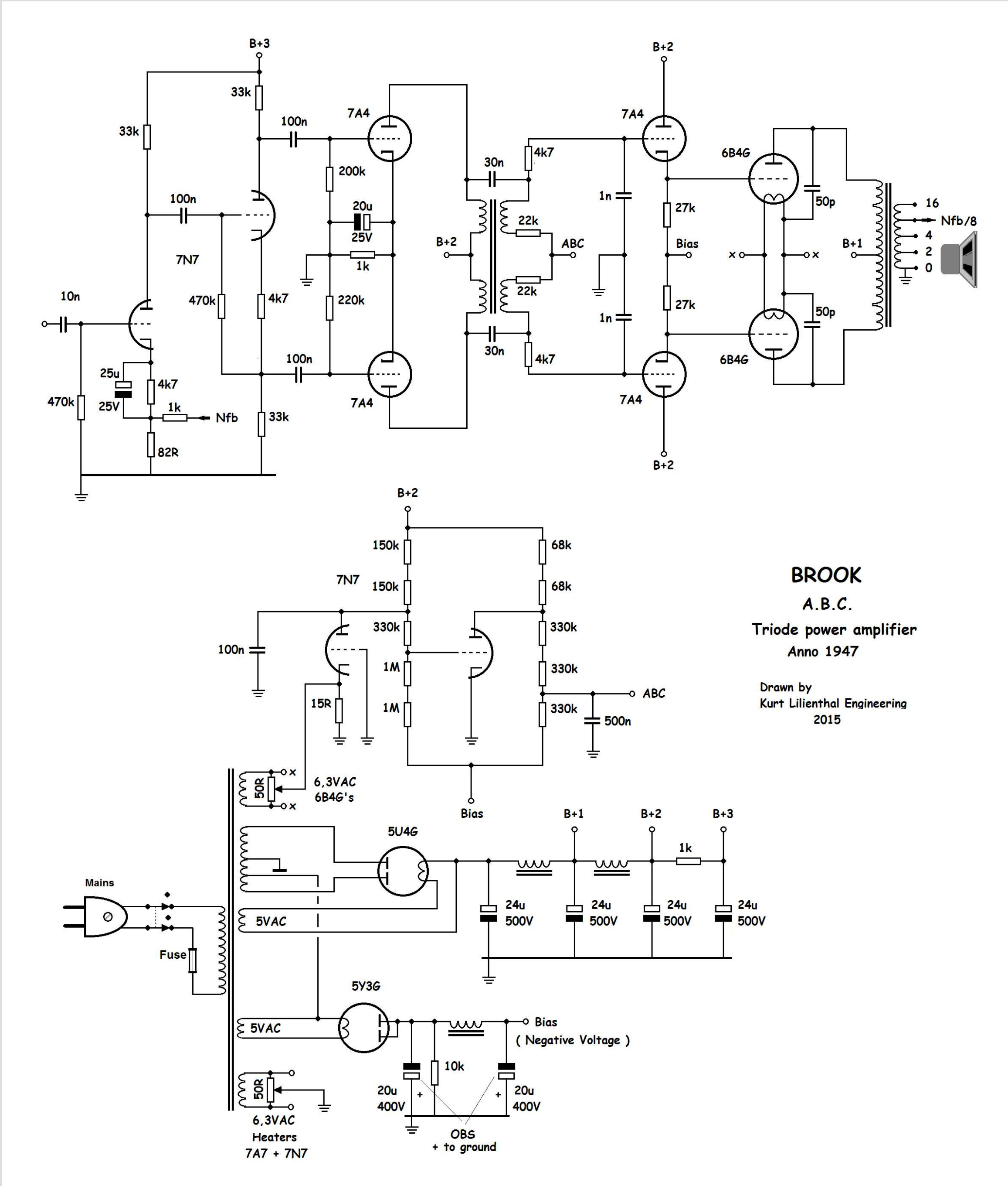
circuits @ 1945 according to Jean Hiraga ? (I need to look further into that)

The Williamson design was the culmination in a series of articles brought in WW under the name "The quality amplifier". The article serie began in 1924 by W.T. Cocking.
David Theodore Nelson Williamson was employed by MO-valve, England and later by Ferranti , Scotland until 1960. The Williamson amplifier was never patented or commercial produced but appeared as an article in the Wireless World
magazine in 1947. On the other hand Williamson was at the time when the amplifier was designed, employed by MO-valve the maker of KT66, B65 and 53KU and this could very well explain the generosity. According to sources MO-valve had an intern paper with the Williamson design as early as 1944.

Looking at Cooking's design a few years earlier it is almost impossible to imagine why it should be such a landmark to imply a thing as simple as a preamplifier before the cathodyne/concertino/split load phase splitter. After all what we need to make a good PP amplifier would be: Output stage, driver, phase splitter and a pre amplifier. Williamson did just that. The first stage pre amplifier are DC coupled to the cathodyne phase splitter that feeds the driver with an almost perfect opposite phase signal. By means of a good and well designed OPT and the simple design, it is possible to use a great deal of global feedback and this is the cause for the good performance characteristics of the Williamson.

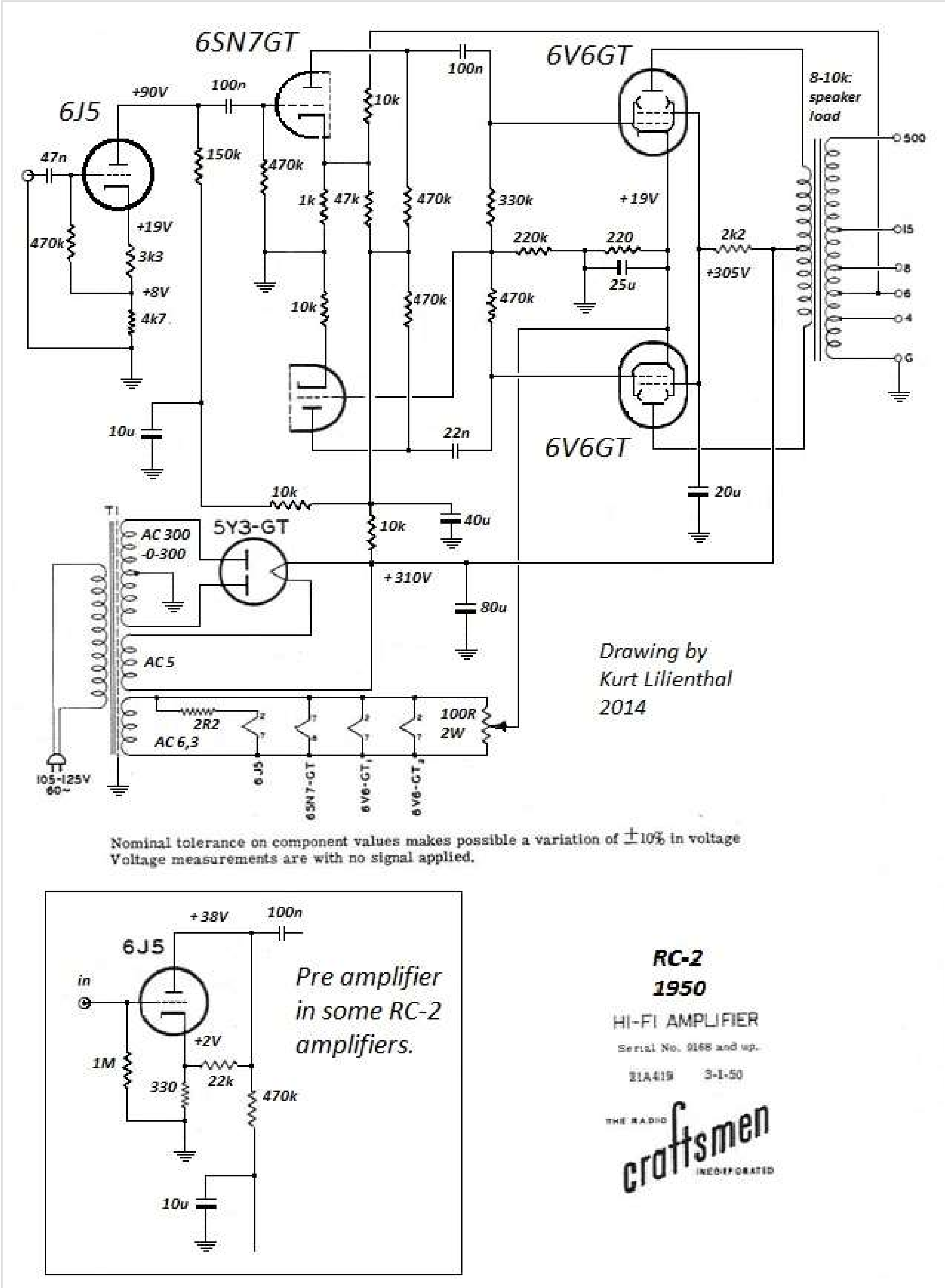
The amplifier often appeared in USA magazines based on 807's as output valves, likely because of the vast supply of post war surplus 807's. Some two years later a slightly better version was published in Wireless World.
The circuit is a masterpiece in simplicity and audio engineering.
The amplifier became a legend and an icon. I will follow up on this design in a series of articles, hunting the ultimative Williamson design. Stay tuned, please.
Hats full off and down to the ground, Gents….We owe a lot to Williamson, Cocking and the Wireless World team.

Update: I have recently come by further exciting info about Williamson and this design. Turns out it is older than thought and that it was originally made with PX25 triodes. More to come about this later.



Brook, A.B.C. – triode power amplifier, 1947.

It took a while for me to find a good schematic, then another while to draw it into something possible to read, but here it is – in all its pride and joy. It was designed by J.R. Edinger and Lincoln Walsh. I will go much deeper into this wonderful design later.

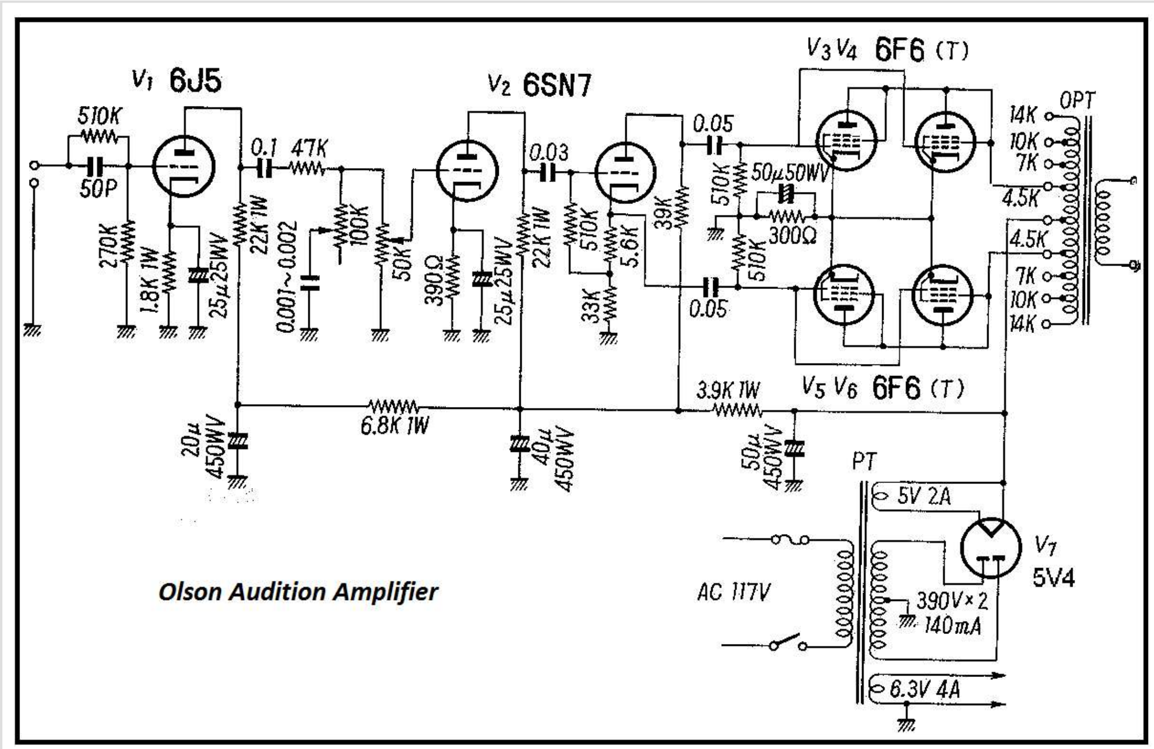


(Suggested by Francis)

Craftsmen RC-2, 6V6GT PP, 1947

Yes, this is elegant no nonce design. Total of three stage:Input 6J5 (= ½ 6SN7) , 6SN7 long tail phase splitter (without capacitor) also acting as driver to the 6V6 PP stage. I would reject to the massive 470k Ohm plate resistors. The 6SN7's are clearly under biased. I would reduce these by a factor 10 or so and reduce the FB as well.

No feedback to the first stage.That's it. 77 years on the back and it is still sensible engineering… Nice……



(Suggested by yours truly)

Harry Olson, Experimental 4 x 6F6 triode, 1946-50

Triode coupled PP non feedback audition amp (1946-47 ?)

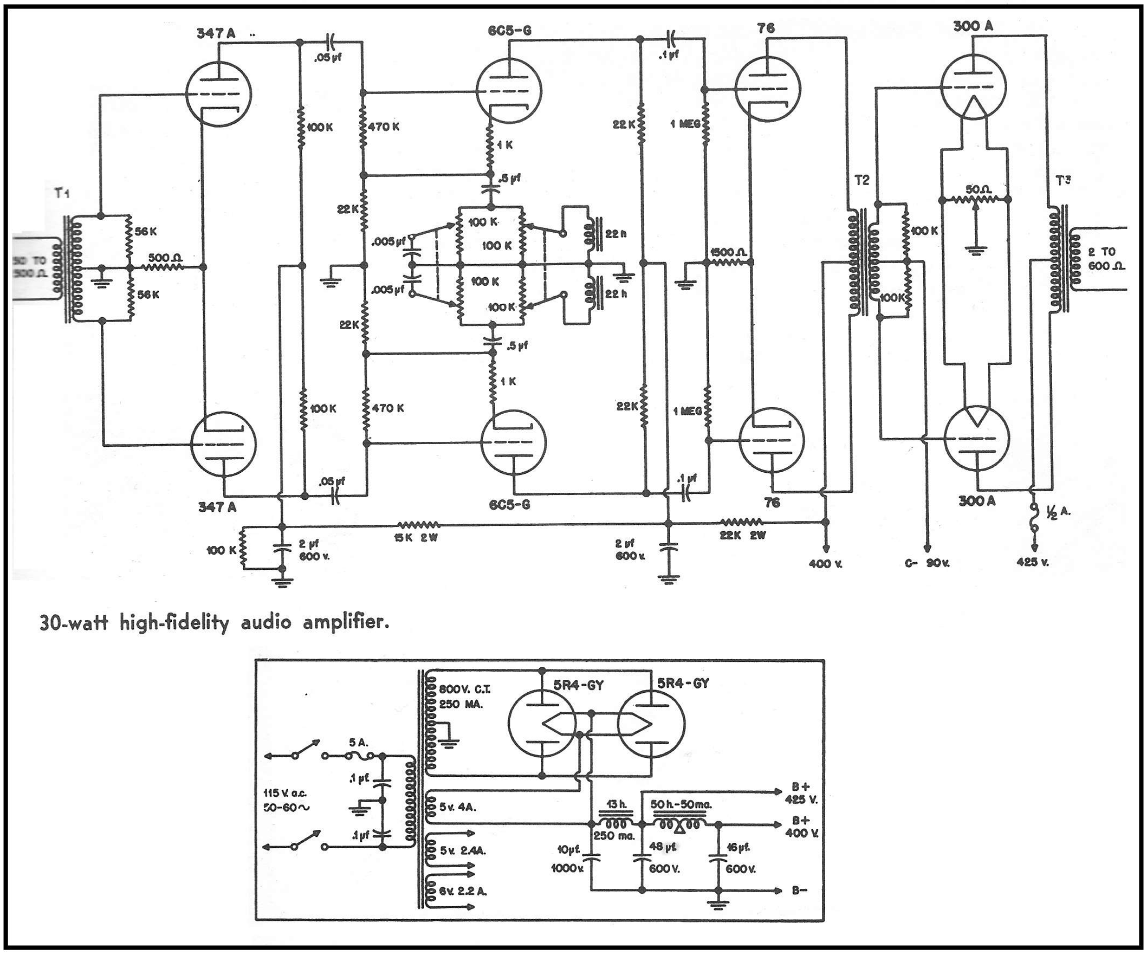
Published 1950, used to perform certain psycho acoustic experiments. Never commercially produced.

Very elegant design. Despite 2′ and 3′ harmonic products below 0.4% at 400 Hz up to 7 Watts and against all mainstream it had no feedback at all. Below 2 Watts these harmonics are actually below 0.1% !. The working points are well chosen and the 2 harmonics from the first stage 6J5 are cancelled by the half 6SN7 voltage amplifier stage. 6SN7 is nothing but a twin triode version of 6J5.

The output transformer is RCA 214-T1 for universal use.

Tremendous design.

Hats of to Harry Olson.

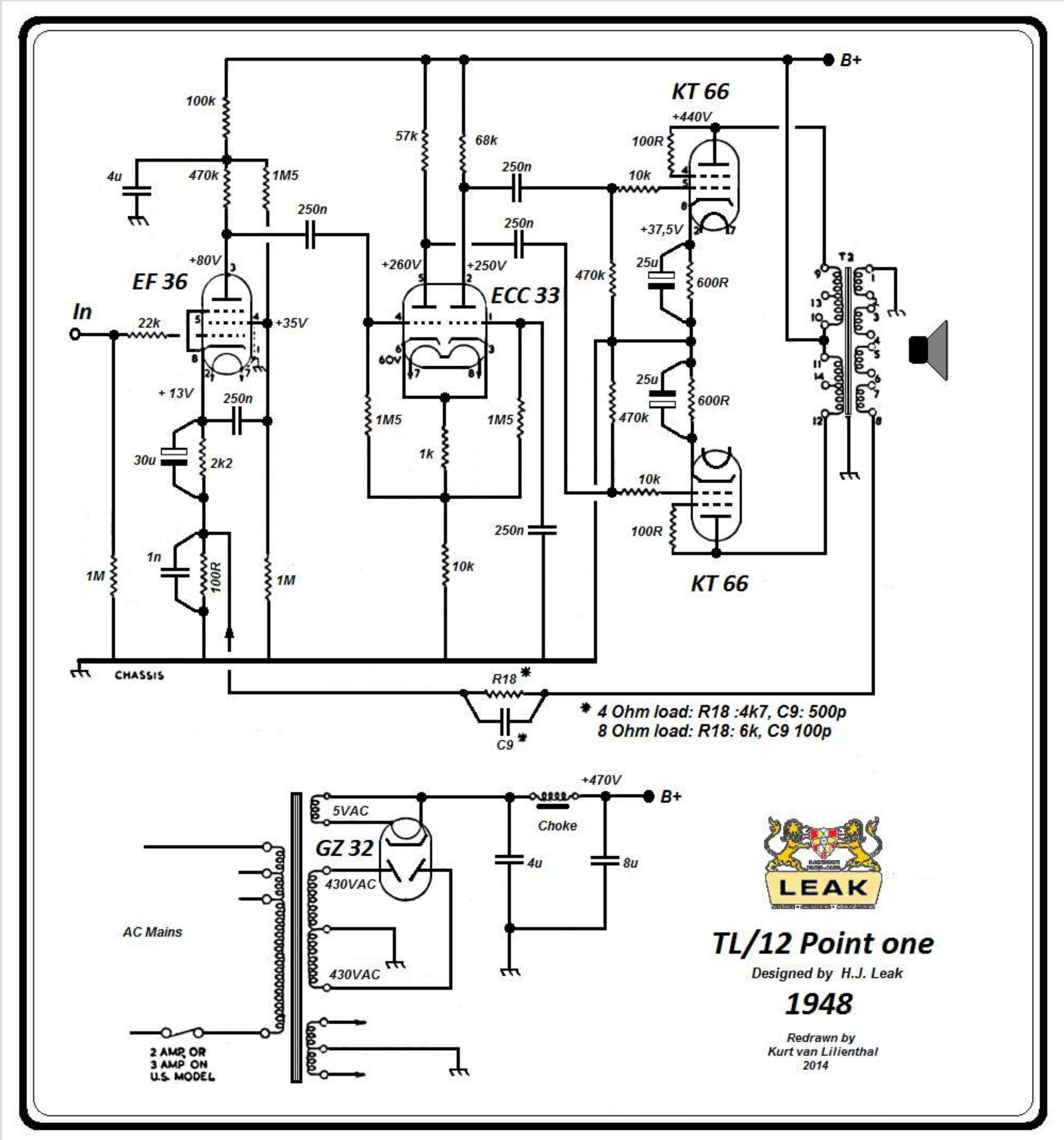


30-watt high-fidelity audio amplifier.

(Suggested by yours truly)

Curtiss Schafer, 300B PP, 1947, published in Audio magazine.
Cool and well thought through none feedback triode design against the mainstream. Battery driven bias ! A little dangerous, I would say, but most certainly hum free. I would remove the clever tone circuit and the 347A stage. I would probably also swap the 5R4's to 5U4's or GZ34's for better regulation. That would also make it possible to reduce the AC main by some Volts or better yet – make a choke input supply. It is a very nice amplifier , though, and I will dig further into such tube driven transformer amplifiers in articles to be published here in time.

Excellent design – I'd lift my hat to this.



LEAK point 1, KT66 PP, 1948

Harold J. Leak, London, England, was the first to
release a commercial HiFi product on the market with THD less than 0.1%.
Hence the name ”point one”.

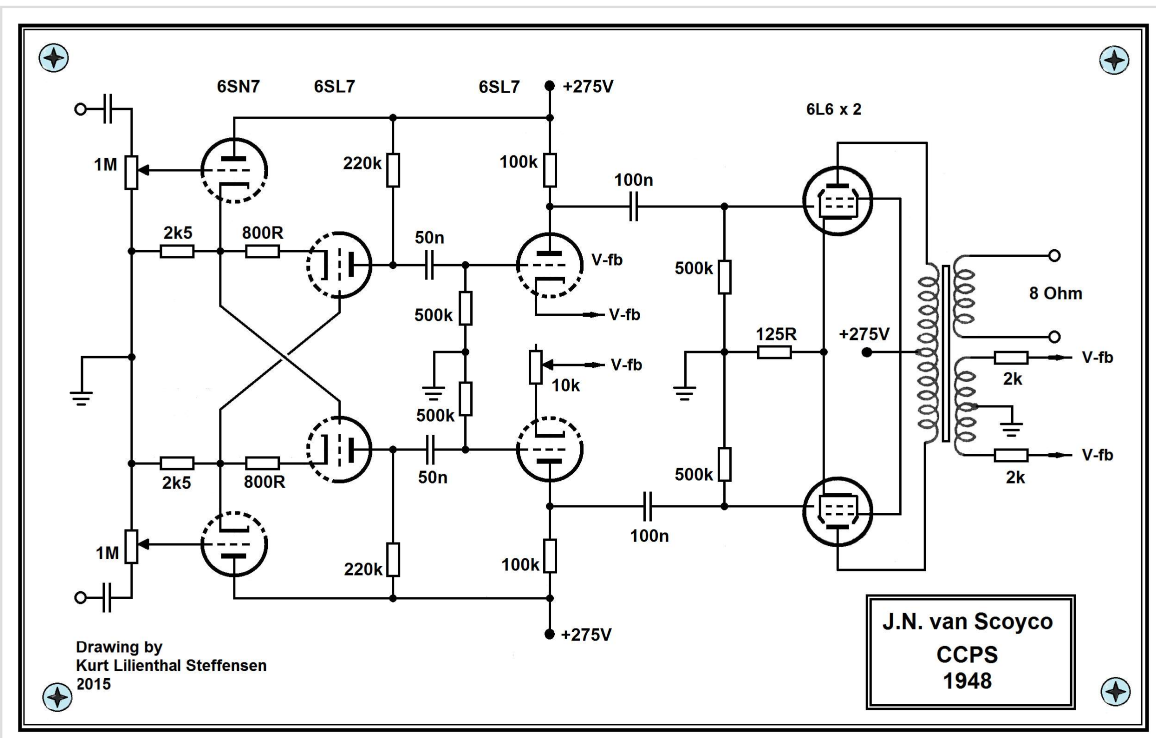
You might wonder how Harold Leak pulled that trick. Well, he did it with excessive feedback due to high overall gain, a good output transformer and a lot of intensive engineering. Simplicity is not necessarily an easy task – far from in fact. Looking at stage one we find that the EF36 are strapped as a Pentode for highest possible amplification. ECC33 is a high slope, medium mu twin triode, coupled with reasonable low plate resistors for better bandwidth to give an additional amplification of about 22, which is nice for a stage being both phase splitter and driver.. Do also note the high value grid resistors at the KT66's makes them easier to drive. The 10k grid stoppers are there in order to prevent oscillation, due to the high overall feedback. All of this and the fact that Leak only demanded some 12 Watts of output from the triode coupled KT66's allows the

ECC33 to drive the output stage with a minimum of distortion. A simple, yet efficient solution. Leak supplied a number of "Point one's" to BBC, often modified for specific purposes.

It is possible to swap the EF37 to EF36 or even 6J7, without any problems. The ECC33 may also be replaced by a 6SN7. And if you do not have any KT66's at hand you may use a cheaper 6L6GB/C or 5881.If you happen to have an EL37, that one will fit in nicely.

I really like this "Mullard 5-20″ design and of you do not care about the high gain, simply strap the EF37 as a triode.

I quite like the later EL84 PP better, though…But modification is a very good idea.



Scoyco , Cross Coupled Phase Splitter, 6L6 PP, 1948

This is the original CCPS design by Scoyco published in "Engineering Dept." Nov. 1948. The circuit was not aimed exclusively for audio, in fact phase splitting was only a secondary merit of the circuit. The circuit was developed for instrumentation and investigation of two individual signals, above ground. This is not a task suitable for our common single end input amplifiers. Scoyco's circuit is a genuine differential amplifier. This means that it amplifies the *difference* between the inputs. Such feature comes in very handy for a phase splitter, thus the widespread perception of it as a phase splitter. It is a highly versatile circuit, capable of countless applications, other vice difficult with traditional amplifiers. But why not ask Scoyco himself to explain the potentials of the circuit……

Scoyco:*" It is often desirable that the input circuit operate with either single ended or pushpull input signals and produce balanced push pull output voltages with either type of input. Low input capacitance and low sensitivity to hum and variations' in plate supply voltages are also valuable characteristics of an input circuit. The cross coupled circuit combines these desirable properties with a large dynamic range of input signals. It will also function as a mixer for 'two input signals giving pushpull output voltages with output voltages which are proportional to the difference of the two input voltages. – Applications in audio systems include combined mixing and phase inversion, novel tone control circuits, and an unusual method of obtaining volume expansion or compression*."

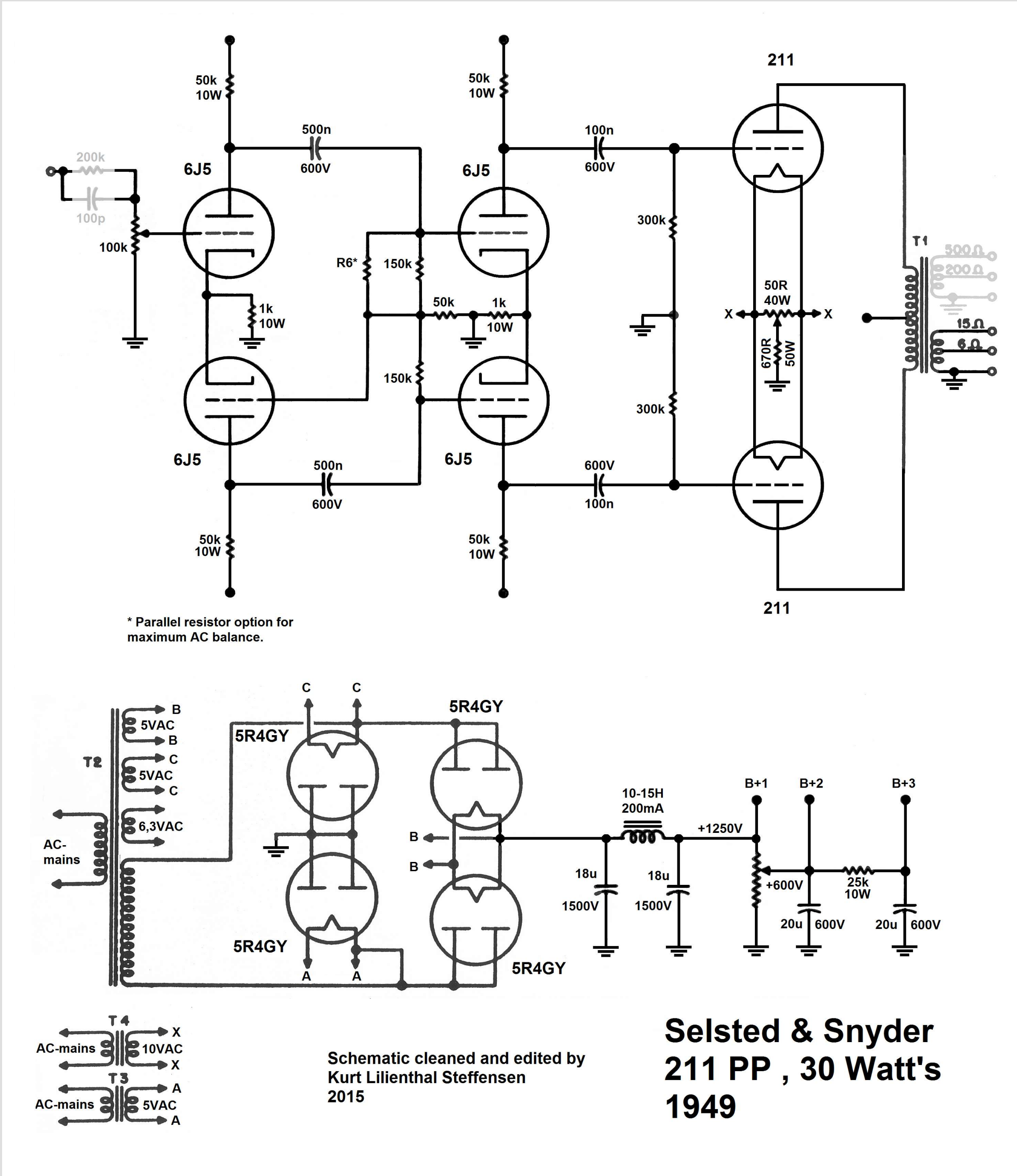
In the CCSP amplifier above consisting of the 3 twin triodes (6 triodes in total) , Scoyco's circuit are performing the entire signal processing needed to amplify the input signal, dividing it into two signals of opposite phase and finally driving the two 6L6's. That is not bad for a single circuit. the first two triodes , 6SN7, are strapped as conventional cathode followers.

Scoyco explains: *"The circuit of the cross coupled stage is shown in Fig. 1. Tubes V, and V. are connected as cathode followers. The grid voltage of V, is the difference of the output voltage of V, and V, and the grid voltage of V, is equal in magnitude to that of V2 but opposite in phase. If symmetry of tube and circuit parameters is maintained the voltage at the plate of V. is equal in magnitude to the voltage at the plate of V. but differs in phase by 180 degrees*."

Very elegant indeed. I cant help thinking that V2 is not really doing much. I wonder if a fixed resistor (or a current sink) would not be a more linear and stable solution ?

Anyway – the amplifier that Scoyco demonstrates in the circuit shown is only meant as a technical note of the use as an audio amplifier.The 6SL7 is a notorious poor driver and the Voltage scheme for the entire amplifier is not optimal. If you would like to play with this extravagant circuit (I will 😉 , I suggest that you look at Marshall's CCPS amps and in particular White's Powrtron. Both can be found here in part 1.

SO – now we know, that is was not Audio Research or Kyokka that invented the CCPS, neither was it Marshal, White or Fraser…In fact it was…..**Dr. C. W. Lampson**, Princeton University, Maryland in 1945. At least he and Scoyco cross developed it indepently of one another, just after WW2.



Selsted & Snyder, 211 PP , 1949

This is a wonderfull design carried out by the two gentlemen Walter T. Selsted and Ross H. Snyder. The 211/VT-4C is a tremendous triode with outstanding sonic qualities. Here the 211's are driven in pure class A and the most crucial elements in securing the excellent merits from the 211 is the quality of the OPT, the driver and the PSU. (More or less in that order) Selsted and Snyder chose a universal/multi tapped transformer from UTC , possible not the best choice, but never the less the freq response of this amplifiers is only 1dB down at 20kHz and 3dB down at 20 Hz at 30 Watts output. Keep in mind that this is a non feedback amplifier and 6J5's are possibly not the best drivers at a 600V supply. Intermodulation at 10W is less than 1% and 5% at 25 W, not impressive – but nice.

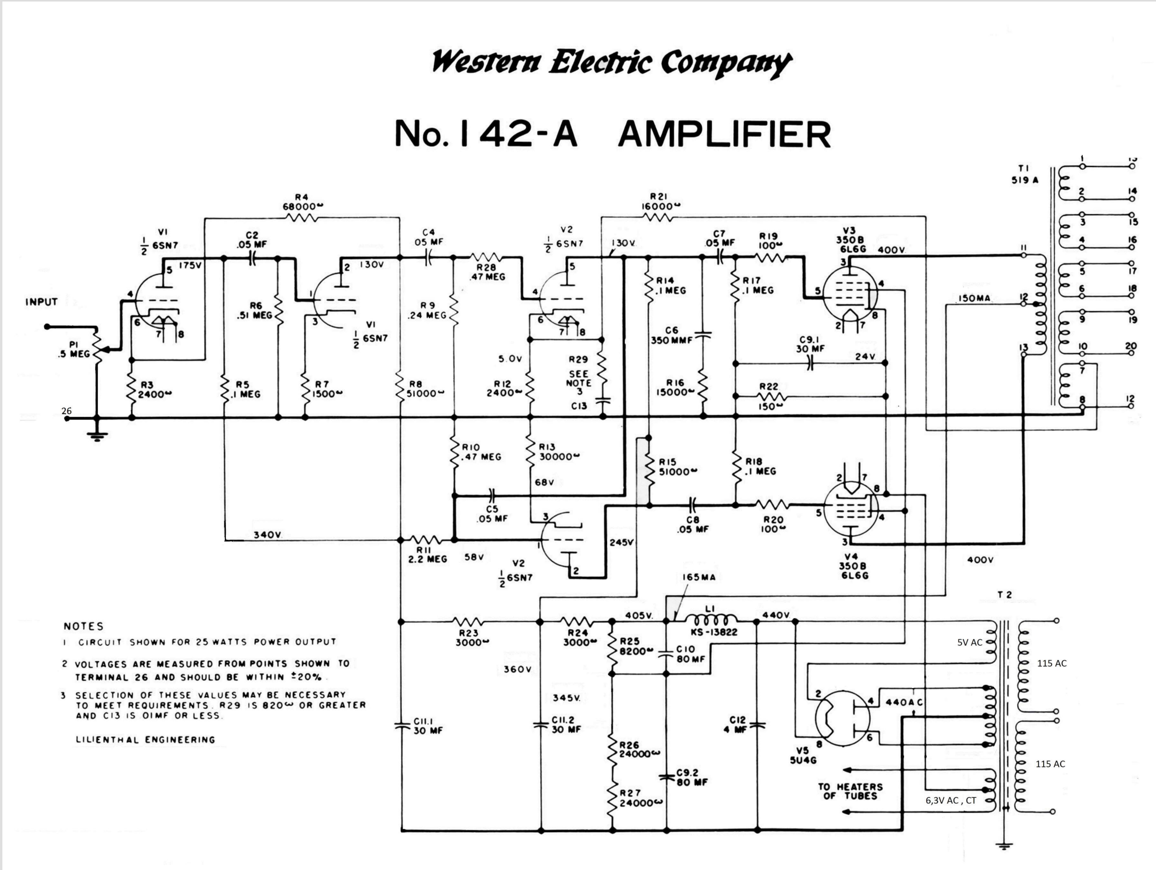
Although that 6J5's are single triode versions of the 6SN7's, I would not recommend using 6SN7's due to the high Voltage supply. A better solution today would possible be 6CG7 as the first triode and 12BH7, 5687 or the new ECC99 as the driver. This would have the additional advantage that the Voltage supply may be increased by 100 to 200 Volts. The four 6J5's only need an input Voltage of about 100 mV to drive the amplifier to full rated power. (Total gain of ca. 85 dB) Thats a little close to the edge for modern signal sources, in my opinion.I would prefer 1 to 2 V RMS input for full rated power.

The resistor marked R6 may be found by trial and error. Try with values between 1-2 M Ohms. The input series resistor of 200k and the parallel capacitor, should be omitted as modern signal sources have no problems driving a 100k Ohm load.

A little word on the power supply. 5R4G's are cheap and capable of very high peak inverse Voltages. But the Voltage losses are high in particular when bridged. This results in a rather soft Voltage supply meaning less good Voltage regulation. It is vital to use a good smoothing choke and if possible do increase the values of the PSU capacitors. If maintaining the use of 5R4G's, consider to increase the second capacitor to 30-50uF. (Min. 1500 VDC) The 100k 200 W slider (potentiometer) is a silly solution , although I understand why it was picked. (High wattage sliders were rather common as WW2 surplus back then) I would suggest a Voltage divider made of a 10-12k 50W alu-clad resistor connected to +1250V then a 10-15k Ohm 30-40W pot. and finally a 68k 15W to ground. This will also allow further smoothing by means of capacitors at the connections.

The output transformer must present a load of 8000 Ohms or more. The higher the impedance, the lower the distortion, but sadly also lower available power. This is a compromise at your choice. The open circuit induction must be min. 80 Henry. The isolation should be very good (Toroids not recommended) and it must be capable of min. 120mA DC continuously.

The B+ and heater Voltages may be taken from one or more main transformer – whatever you may have at hand. But do take care that the 5 VAC transformers are well isolated. (Min. 2500 V guaranteed between windings and core)

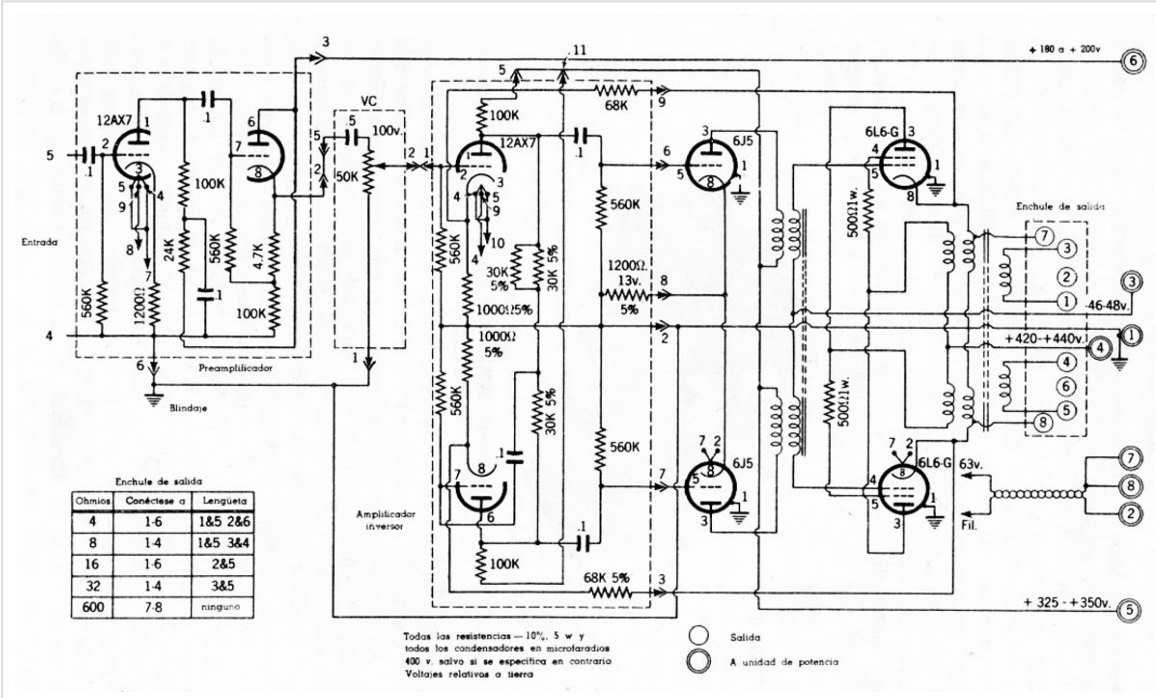


(Suggested by yours truly)

Western Electric 142A, 350B/6L6GC PP, 1948-52 ?

KS designation possible McIntosh. There is no global feedback here, but rather two short feedback loops. I am not fan of more than one loop, but when made this particular way the two loops does not interfere with one another. Thats the way to do it. The phase splitter, however is unusual and I am not certain that I would want to do it this way. In order to outbalance the amplitude difference between the two phase signals, WE chose to bias one of the phase splitter triodes by DC directly from the B+. Why not use a Williamson design with a close to perfect split load phase ? We could still maintain the two independent feedback loops, – I believe.

Well, I really like this amp. Perhaps my favorite WE modern design…



(Suggested by Joe Roberts)

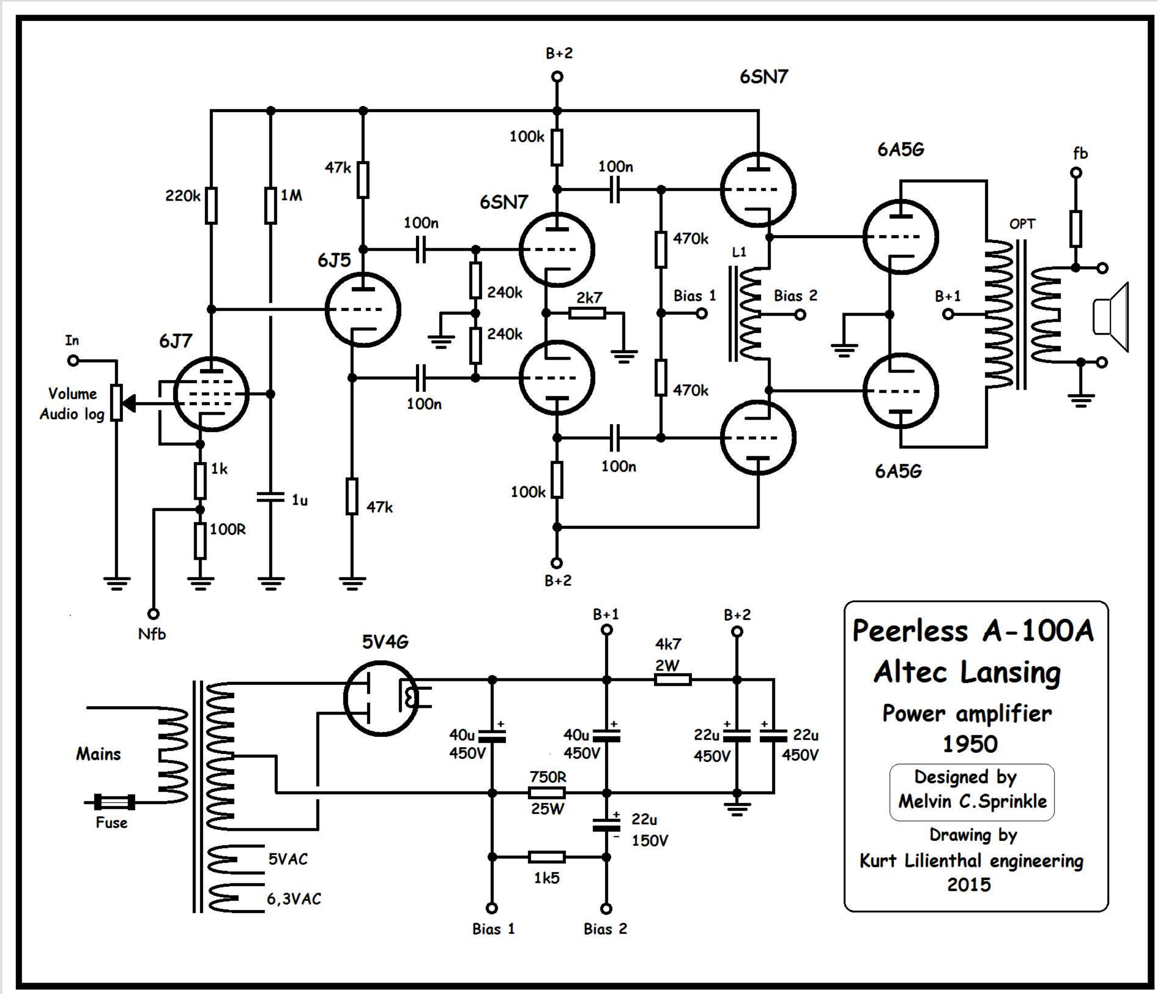
McIntosh 50W-1, 6L6G PP, 1949

At first glance it looks terrible complicated, but this is actually merely due to the way it is drawn. I might clean it up one day. In the meantime if we ignore the 12AX7 pre-amplifier/cathode follower, (In my opinion not needed for modern high signal levels anyway) , the actual amp consist of the 3 stages: 12AX7, 6J5 and 6L6G. The input 12AX7 Voltage amplifier forms the phase splitter as well. If I were to do it this way today, I would use a 12AY7 with solid state CCS for common cathodes and then ground one input side/grid for single end input. I really like the 6J5 interstage driver with active bias for the 6L6G's.

The amplifier also uses an bifilar wound primary OPT from which the winding is split into two windings in order to load the plate as well as the cathodes of the power tubes. Symmetric feedback from the cathodes of the 6L6's to the 12AX7 cathodes.

Sadly it is a class B stage. If you have one of these amps, I suggest that you bias it into the class AB area. You will loose some power, but you will gain in quality.

In later designs Mac pushed the scheme over the edge and was forced to compensate with capacitors and even chokes in series with the plate of the output tubes. Talk about two steps ahead and one back.
Frank McIntosh patented the circuit as the "Unity coupling". Insisting design and care for the detail made it work.
Well done, Frank….



(Suggested by Joe Roberts)

Altec Peerless A-100A, 6A5 PP, 1949

Ah yes…I know this amp. Designed by Melvin Sprinkle..one of my favorite engineers from the era. In 1936 Western Electric formed "**All Tec**hnical services" supposedly a division dedicated to service and maintaining of the pro-audio equipment made by W:E. But it didnt take long before Altec became a producer of high end professional gear themselves.In 1946 Altec took over a bankrupt the Lansing company and formed the famous Altec Lansing company. That lead to the production of the famous duplex and coaxial speakers, as well as the highly regarded "Voice of theatre" PA speaker systems.As early as 1947 Altec acquired the famous transformer company Peerless and the rest is history.

Back to the A-100A amplifier. This is a Williamson design with a twist, (Ignoring the pre amp, that I have left out)
The famous A-100A amplifier was sold as a kit called: "Peerless 10722″ or factory assembled as "Peerless A-100A". The amplifier appeared as an article/ad in the US magazine "Radio & television news", may issue 1950. There is more to this amplifier than meets the eye at first glance. The input stage is a pentode strapped 6J7, nothing special about that. If you have one of these amps at home, I suggest to triode couple that tube. Or better swop to a triode strapped 6SJ7. Next stage is a 6J5 phase splitter. The reason for the 6J5, rather than the twin triode 6SN7 here is the simple that it was made at the times of mono (6SN7 = two 6J5's) The cathode coupled

driver stage is a clever Sprinkle solution. This and the use of output triodes are the main reason why this is such a good sounding Williamson design. I would like to give the word to Mr. Sprinkle himself – in absentia. Sprinkle:" ***The legion of audio enthusiasts who have stuck by their triode amplifiers through thick and thin have been a hardy lot. They have been assailed by the beam power camp and have been deserted by commercial amplifier engineers, but through it all have held the bridge like Horatius. Through all the controversy they have always maintained that "triodes sound better."***

I could not agree more. Sprinkle regrets that despite the better sonic qualities, the efficiency of triodes are rather poor. Personally, I do not mint that much, but most certainly better efficiency is not a bad thing. In theory it is possible to achieve about 50% efficiency from a pair of triodes in a PP class A set up. In practice, however, this is very difficult as it takes current as well as high Voltage swing in order to drive the triodes to maximum swing. A regular plate loaded driver can provide the swing, but the plate resistance are too high to provide current drive. A cathode follower will provide the necessary current, due to the low z-out, but it can not offer the needed Voltage swing. Sprinkle's trick are simple, the cathode driven induction assures the wanted Voltage swing.

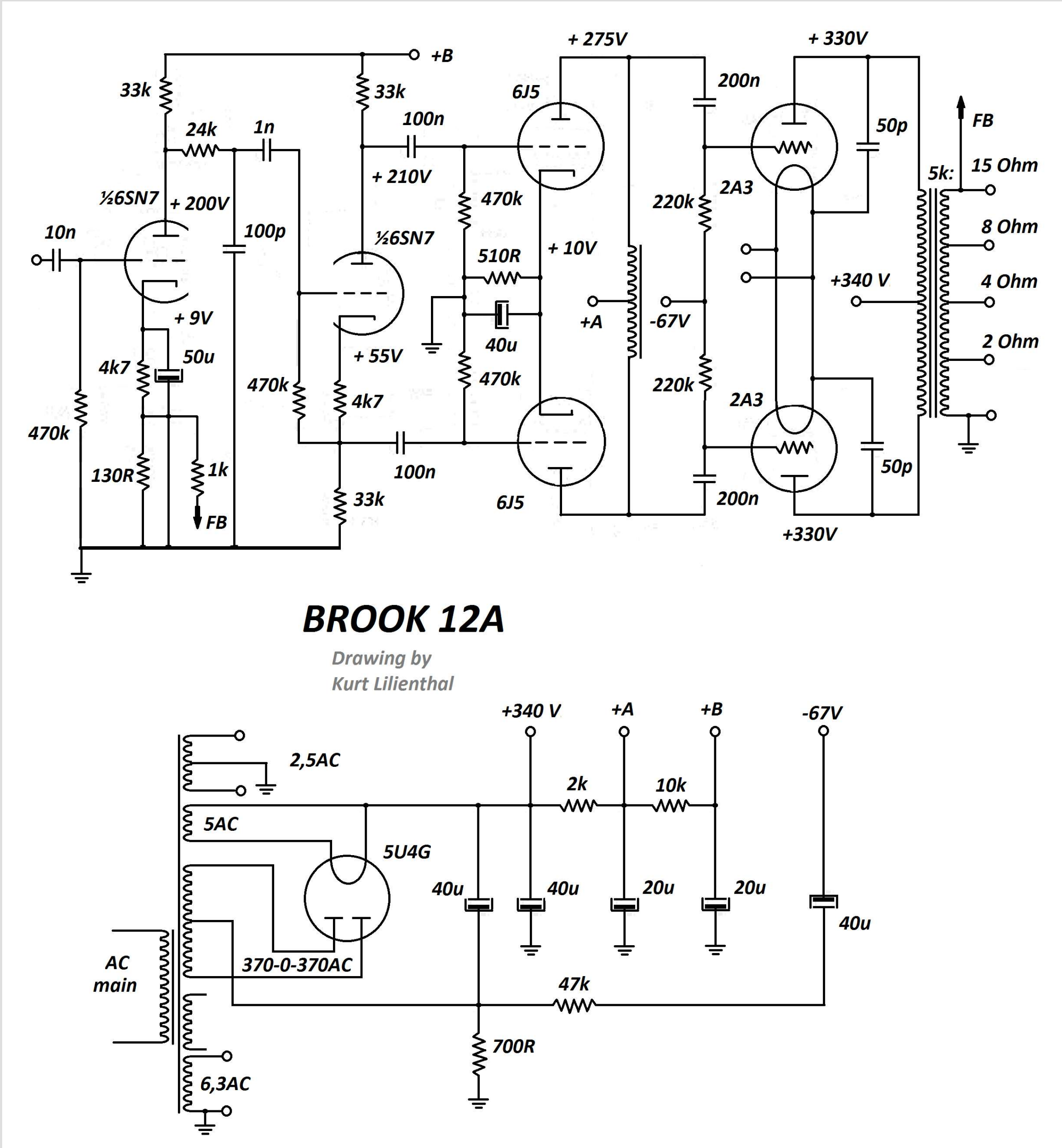
Sprinkle: "*Recently the writer has become interested in a circuit which makes possible 18.6 watts output from a pair of 6A5 tubes at a distortion of 5% total harmonics! This represents an efficiency of 49.3 %, a truly remarkable achievement. The amazing performance is made possible by two factors:*
(1) A good output transformer and
(2) use of a cathode follower driver."

The output transformer that Sprinkle praise are the well known Peerless S-240-Q. This is a 20 Watts, 5000 Ohm to 0-4-8-16 PP transformer, It accepts up to 90mA common current and a 9mA unbalance.

Sprinkle: *Most audio enthusiasts are familiar with conventional resistance or transformer coupling to Class A or AB, amplifiers. These systems are quite satisfactory within certain limitations, but fail when Class AB, operation is approached. The fundamental reason is that when the grid of a tube is driven positive, instantaneously, there is a flow of electrons to the grid, which when they flow through the grid resistor, or even an interstage transformer, produce a voltage which is additive to the tube's bias. The effect is the same as the bias developed in an oscillator's grid leak due to grid current. In the usual Class AB, design a special transformer, called a driver transformer, is used, which is a stepdown transformer.*
*In order to supply enough signal with a stepdown turns ratio, and also to supply power to the grids of the final when they draw grid current, it has been necessary to use a power tube as a driver. Another factor that touches a sore spot in constructors is the cost of a good driver transformer. The cathode follower driver overcomes these limitations. It has been pointed out that a cathode follower is not a voltage amplifier, i.e., the output voltage can approach but not exceed the input signal. However, and this is not as widely known, a cathode follower can be a power amplifie*r."

It is possible to interchange 6J5's, 6SN7's and 6CG7's without further change than sockets/socket layout.
The 6A5G is similar to the European R120. A stereo version sharing the power supply would demand half the values of the power supply resistors and up to double the values of the electrolytics. It may also be a good idea, to use either two 5V4's, a 5U4G or a pair of silicon diodes for rectification.

Thanks a lot to Melvin Sprinkle for this classic and many other good Altec/Peerless designs during the 1950's.



(Suggested by JC Morrison)

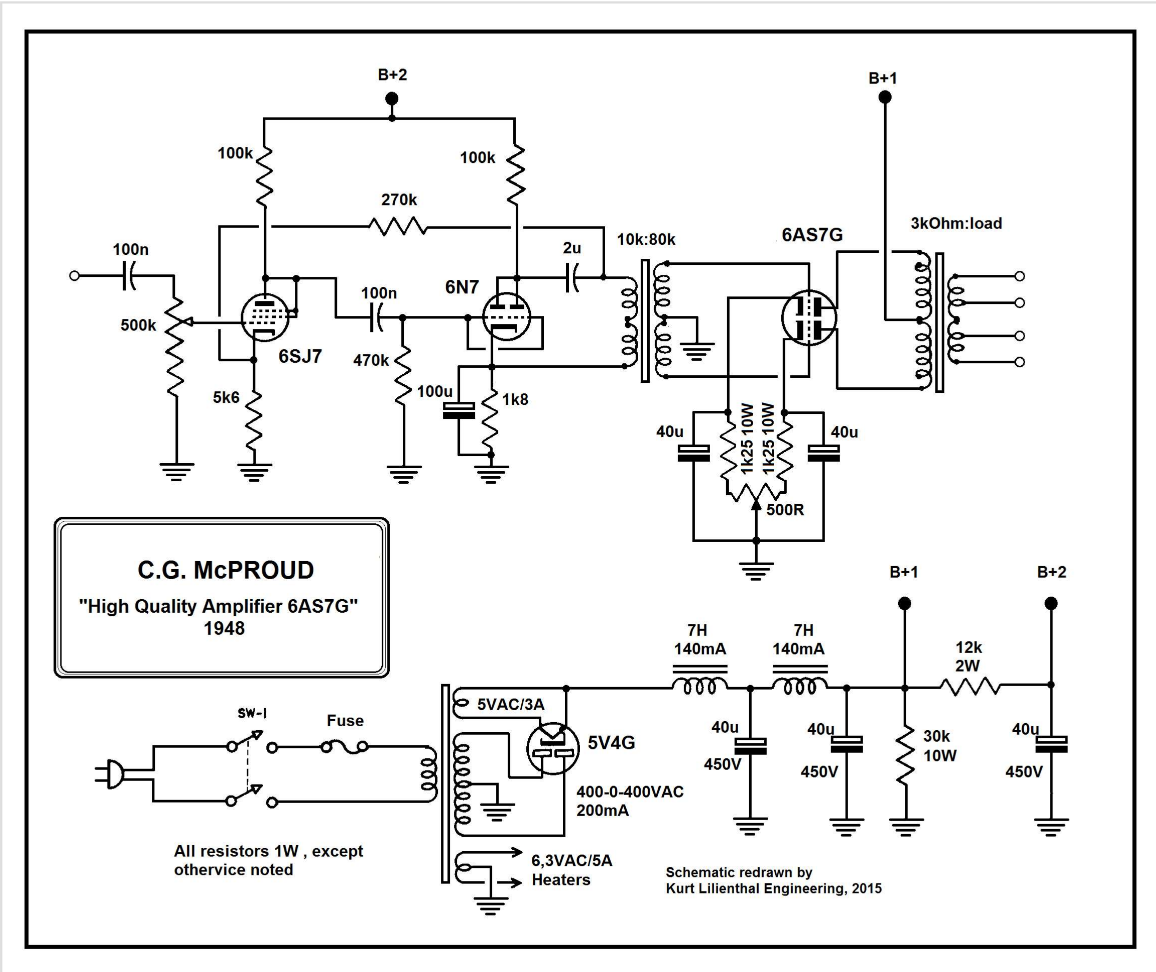
Brook 12A, 2A3 PP, (1949-50)

Williamson circuit. When I first looked at this circuit, I thought there was a mistake in the SAMS Photo schematics. There often are in my experience. However as I looked at it I realised that this was a clever and unusual way to obtain the bias for the two 2A3's. The PSU are not referred directly to ground, but through the 700 Ohms power resistor. The loss over this are used to bias the 2A3's….He he….very smart… This is a pretty much flawless design. Low values of plate resistors improves HF freq and pulse response. The choke loaded 6J5 driver can drive the 2A3's to Kingdom come..What more can we ask for ?

The later 1955 version 22A was pretty much identical, except it used 12AU7 direct coupled, 6C4 drivers and another OPT, without the 600 Ohm winding.(Had 2, 4, 8 and 16 Ohm taps)

12A had a preamplifier to match with it called 12A3.

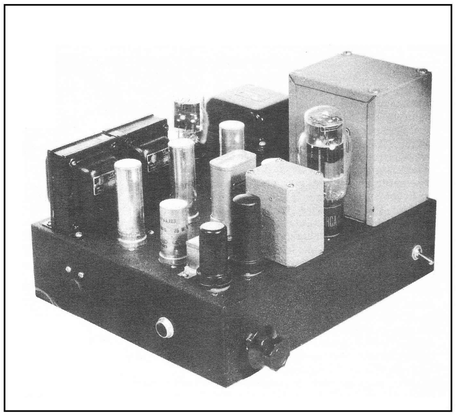
Yummie good engineering.



McProud 6AS7G PP, 1948

C.G. McProud founded the famous magazine “Audio Engineering” , in 1947. The magazine still exist as “Journal of Audio Engineering Society” – in short “JAES”. It was for many years my favorite magazine as a lot of the most important articles about audio appeared in this magazine. (There are some reprints of earlier articles out there in form of volumes called “Audio Anthology”. These are available from the excellent publisher “Audio Amateur” and “Old Colony Lab”)

From 1948 to about 1952 McProud designed several amplifiers based on the twin triode 6AS7G. He was quite fond of that relatively new power triode and found it compared well – perhaps slightly better than a pair of 2A3/6B4G/6A3.



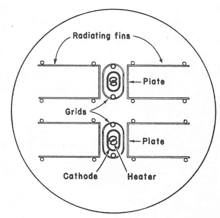


Fig. 1. Cross-section of element structure of the new 6AS7G, showing the unique plate construction with adequate area for heat radiation. Grid radiators are alternately above and below the element structure.

6AS7G

AUDIO AMPLIFIER SERVICE
Values are for each unit

Maximum Ratings, Design Center Values:

PLATE VOLTAGE	250 max.	volts
PLATE CURRENT	125 max.	ma
PLATE DISSIPATION	13 max.	watts
PEAK HEATER-CATHODE VOLTAGE		
Heater negative with respect to cathode	300 max.	volts
Heater positive with respect to cathode	300 max.	volts

Typical operation, Class A_1 push-pull amplifier. Unless otherwise specified, values are for both units.

Plate	200	250	volts
Grid	–90	–125	volts
Cathode Resistor (per unit)	1500	2500	ohms
Peak AF grid to grid voltage	180	250	volts
Zero signal plate current	120	100	ma
Max. signal plate current	128	106	ma
Effective load resistance (plate to plate)	4000	6000	ohms
Total harmonic distortion (less than)	4	4	per cent
Max. signal power output	11	13	watts
Amplification Factor (per unit)	2.0	2.0	

*It is essential that precaution be taken in equipment design to prevent subjecting the tube to full load current of 250 ma before its cathodes have reached normal operating temperature. The cathodes require approximately 15 seconds to attain normal operating temperature. Unless this precaution is observed, the cathodes will be seriously damaged, if not completely ruined. In speech amplifier service, as indicated under typical operating conditions, the plate voltage may be applied simultaneously with the filament voltage.

Fig.1

The max plate dissipation for a pair of 2A3's is 2 x 15W , as for a single twin triode 6AS7G it is 2 x 13W. The ri (plate resistance) for a 6AS7G triode is quite lower than a 2A3, but the amplification factor of a 6AS7G is only 2 , a little less than half that of a 2A3. This means that the Voltage swing needed to drive the 6AS7G is much higher. Bias for a class A coupled 2A3 at 250V at the plate is -45V. As can be seen in table 1 in Fig.1, the 6AS7G under the same conditions employs a bias of -125V. This means that the 6AS7G demands a Voltage swing almost three times higher than the 2A3 for full output. McProud solves the puzzle by means of a step up interstage and a parallel coupled twin triode.

The triode coupled 6SJ7 drives the parallel coupled 6N7 via a 100kΩ plate load. This is on the high side and it affects the HF roll off, but we need a high Voltage swing here as well, in order to "drive the driver". The 6N7 alone is responsible for the actual drive and phase splitting by means of the parafeed interstage transformer. This is indeed a heavy burden to put on that tiny 6N7 and I believe this is the weak link in this amplifier. The 6N7 twin triode does not allow plate dissipation of more than 1W per triode , meaning a total of only 2W. The ri (plate resistance) is relatively high , some 11.000 Ω and a transconductance of some 3200 per section. I would expect a 6F6, 6Y6 or 6V6 to do the job better. These are capable of more current and higher Voltage swing (= current "swing" to the interstage) and if prefered they all work nice as triodes and this would mean a lower ri, hence better grip of the interstage step up and lower distortion.

Apropos distortion. the THD is low considering the lack of feedback – 4% according to McProud's table in Fig 1. The intermodulation distortion for the 6AS7G amp, Fig. 2 , is nice up to about 1W , then it seems to skyrocket. The slope of the curve is steam beyond some 4-6W . This is actually not quite as bad as it may seem – intermodulation challenges most amplifiers as they are getting close to max power output. Lets try to compare it with something familiar. I am sure most of us has heard the Williamson design as it is quite difficult not to meet such animal, being the most popular tube amplifier design ever. I chosed Sprinkle and Sarser's version as it was nearby and the intermodulation curves came with it.

At first glance we might consider the Williamson to be much better – as would be expected – this one being a pair of triode coupled 807's, 25W plate dissipation and 20dB of global feedback. But take a closer look, please. At low levels the Williamson is indeed better as it should be, due to the feedback. But the slope of the curve is indeed the same as the McProud amplifier, despite this one only have feedback from the second stage.(Via the 270k at the primary of the interstage returned to the 6SJ7 cathode)

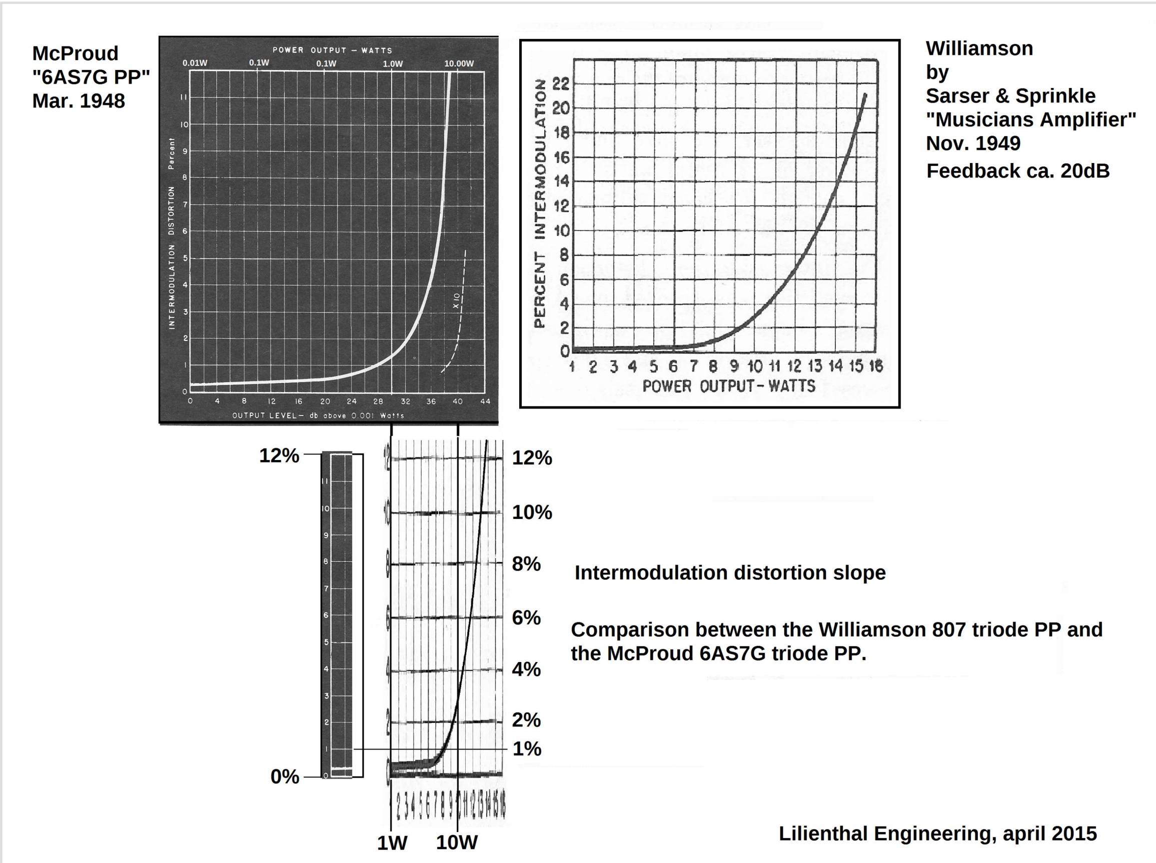


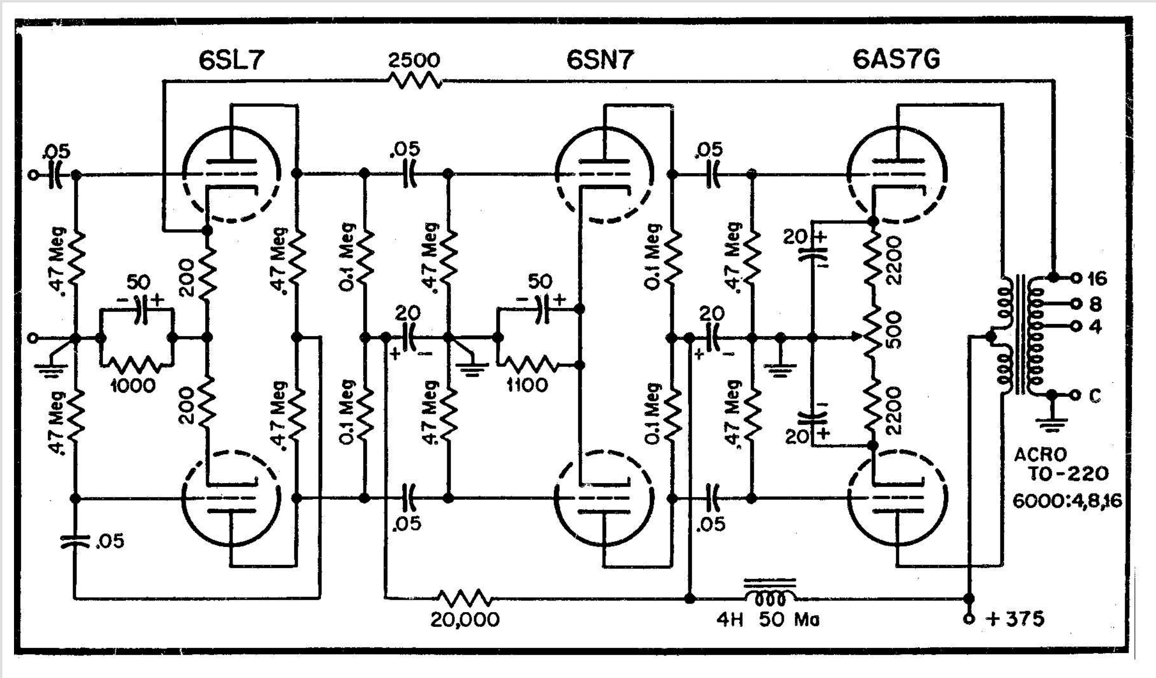
Fig.2

It is difficult directly to compare the two curves as the Williamson has a 0 point at 1W and a max distortion of 25%, and the McProud a = point at 1 mW and a max of 12%. But with a little "photoshopping" I have managed to squeeze the dynamic area of the Williamson curve in to the same area of the McProd curve – the 1W and 10W being the X-coordinate references and at the Y-axis I have matched the distortion coordinate points as well. It is now possible to compare the slopes of the two curves and they are actually quite identical. The slope of the Williamson may in fact even be a little worse that the McProud.

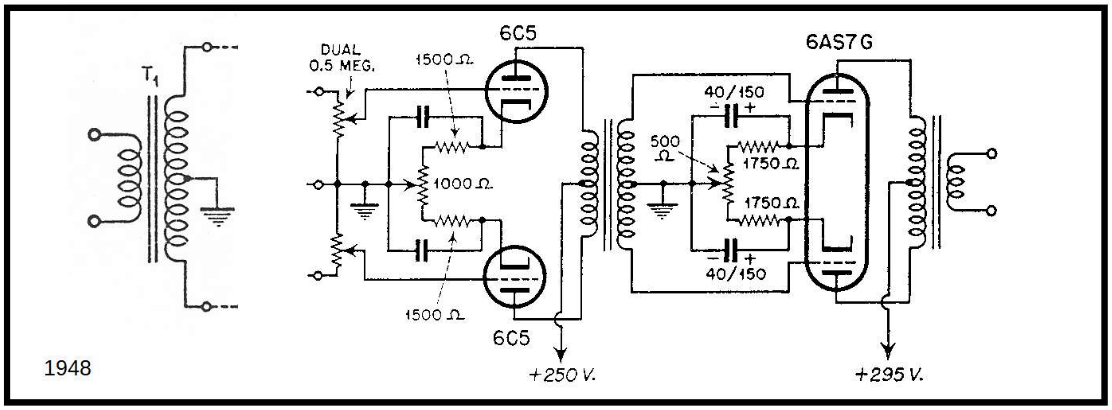
If we apply the same amount of global feedback to the McProud it would probably measure equally well at low signals and vice versa. Both amplifiers may be rated as 12 Watters, – less such at lower distortion and more at higher distortion. We are in a way comparing apples with pears.

McProud made a few minor improvements (according to himself) to this design, the most significant was a swop of the triode coupled 6SJ7 to a 7A4 (≈ 6J5) triode. I dont know if there is indeed an improvement in, as the 6SJ7 is amazingly good as a triode. But there you go 🙂

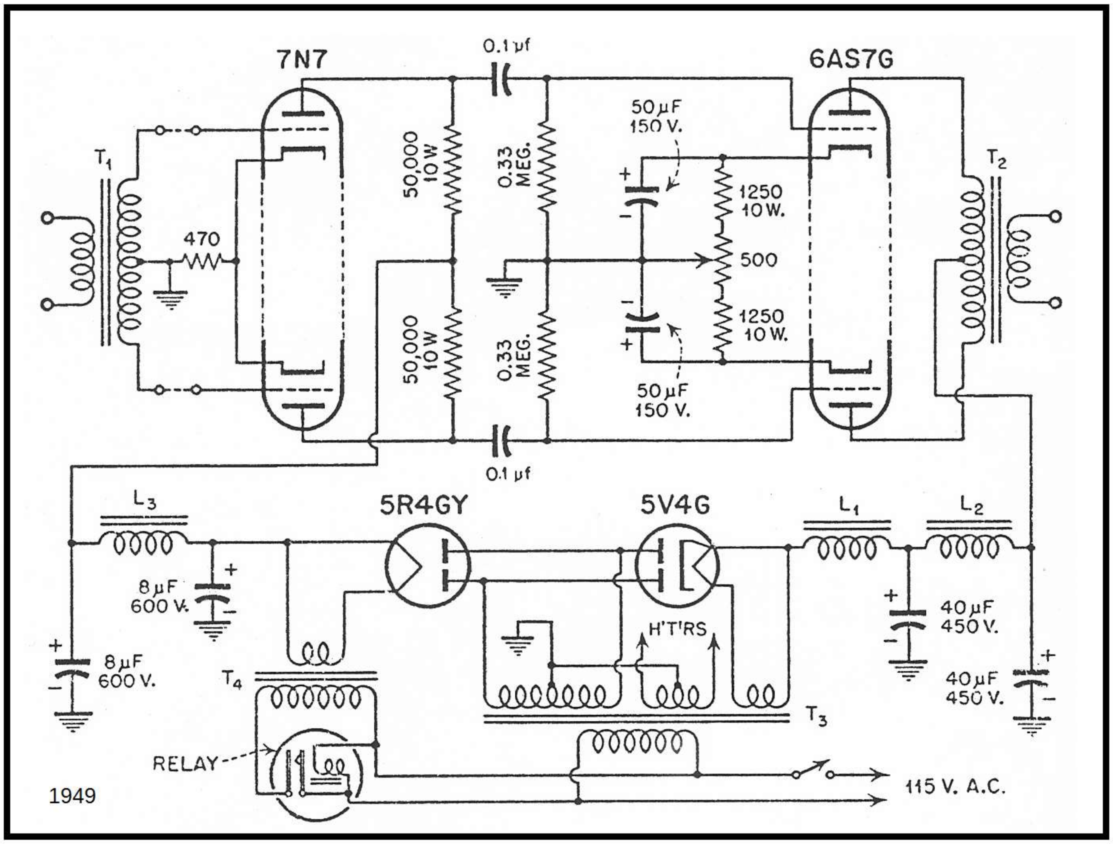
We might as well, get over and done with the 6AS7G power amps. Here is a few more of that breed.



.This is an **unknown 6AS7G PP** design from my archives. Looks like a typical 1950's "Audio Eng." drawing. Nice symmetric design, I trust it sounds good. (Please, drop me a note if you know its origin)



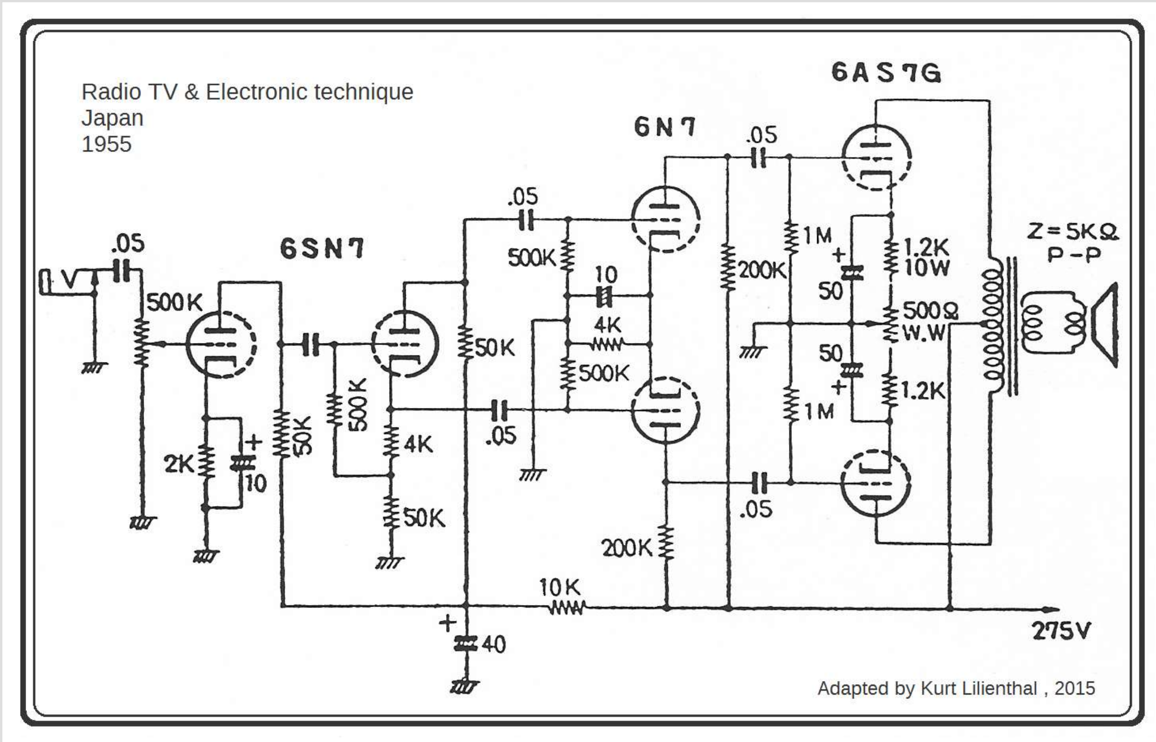
6AS7G design by John van Heijenoort. Patchword by Kurt Lilienthal Steffensen, Denmark



Jan van Heijenoort, 6AS7G PP, 1948 and 1949.

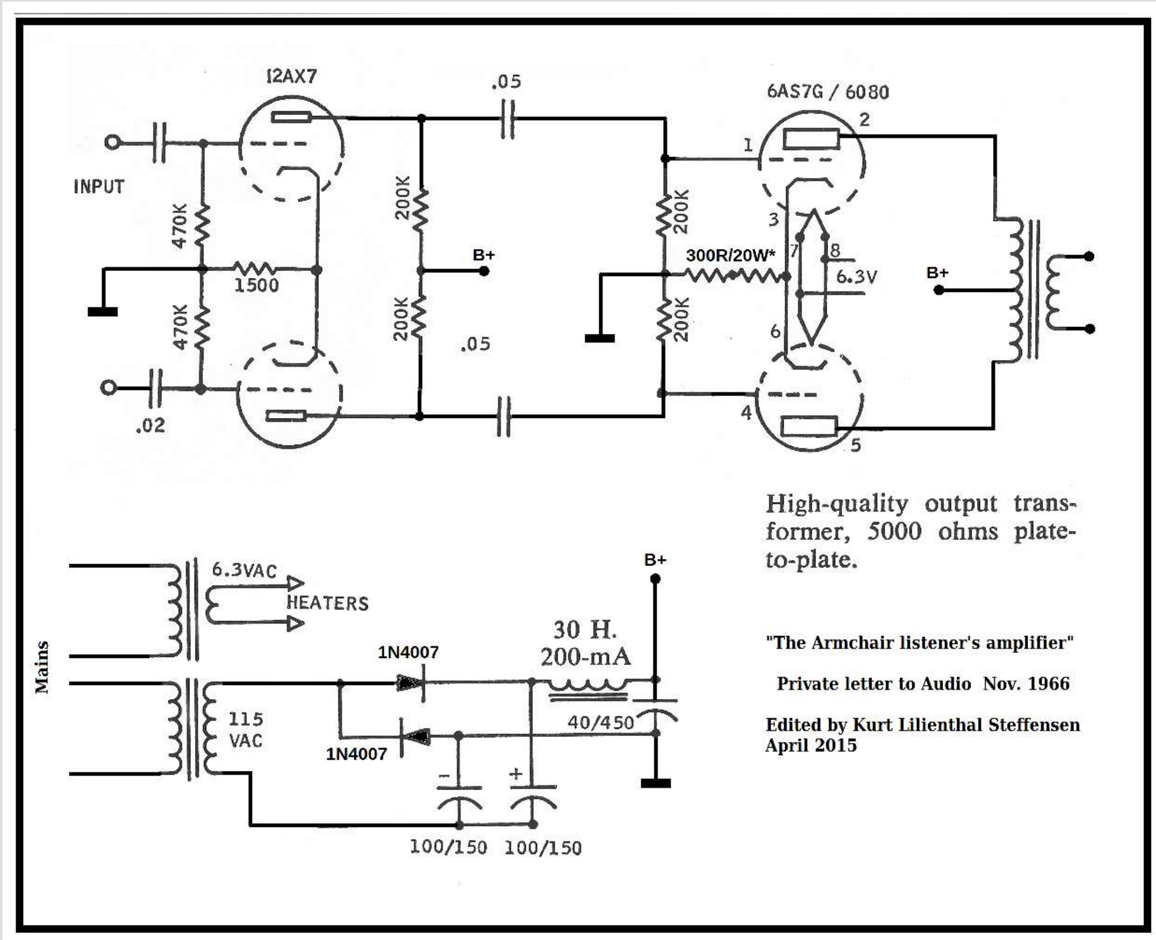
These two amplifiers was published in Audio Engineering as "Techni-Briefs". Heijenoort was inspired by McProud's earlier designs and expresses his enthusiasm about the 6AS7G, which he claims is "superior to the 2A3's in every respect". The first design was meant to be driven directly from the discriminator (tuner) and a modified crystal pick up.   Heijenoort prefered live concert FM transmissions as the best signal source in the 1940's. I can vote for that too , at least way up in the 1990's here in Denmark.Heijenoort keeps praising the 6AS7G's as shown as the most natural amplifier he had ever heard. He is obviously a diehard 6AS7G fan. In the 1949 version he adds an input transformer and slightly modifies the thing. It is worth to note that Heijenoort supplies a higher Voltage to the driver stage. This is indeed the way to do it if you want to drive these low gain triodes to the full monkey.(Higher B+ allows higher Voltage swing)

Excellent design. I actually like it better than McProuds original.



Williamson 6AS7G, 1955.

Unknown designer, appeared in the Japanese "Radio TV and Electronics technique" magazine, 1955. Not much to say about this amplifier – it pretty much speaks for itself.

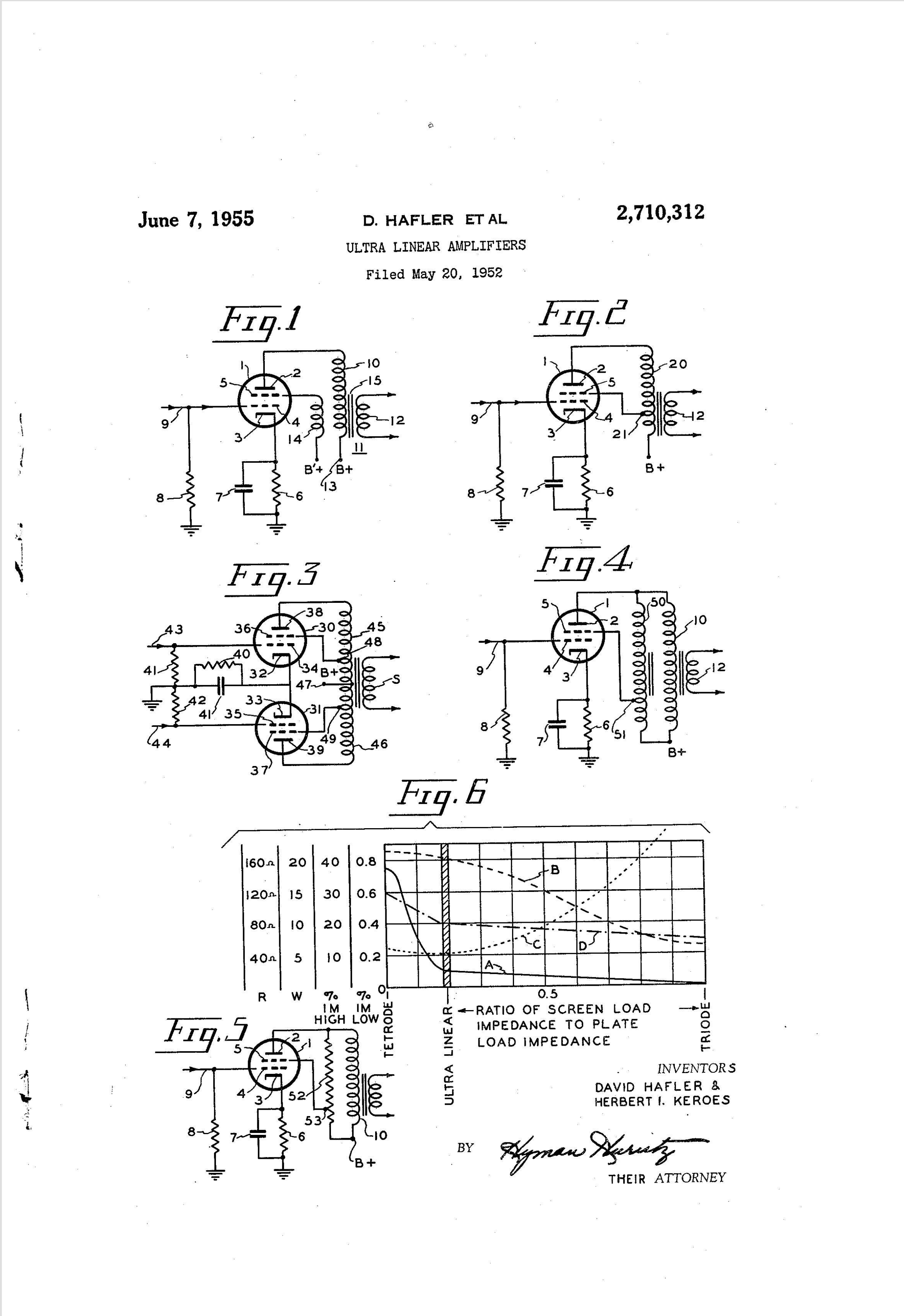


The armchair listener's amplifier, 1966

This amplifier appeared as a reader's letter to the Audio Magazine, Nov. 1966. I have edited it, as despite the super simplistic diagram it had several errors in it. I have also changed the main supply scheme as the B+ was tapped directly from the AC-mains. This is a "no go" ! Life is too valuable, in order to spare a proper main transformer. The Voltage doubler is an efficient method of using a single winding to do all the high Voltage. Just remember that you need twice the current as well. In the end Volt Ampere is Volt Ampere.

I quite doubt that the 12AX7 will drive the 6AS7 to its full power, but I am sure that it will deliver some 4-5 Watts without too much troubles. Perhaps a ECC85 or 12BH7 would do a better job here. The input is balanced, but it is possible to ground one side of the 12AX7 and make a single end input. The resulting AC unbalance may be cancelled by different plate resistors or for better results , use a FET/bipolar common Constant Current Source at the cathodes. A negative Voltage of some 10-15 Volts would be of advantage here.

This is the final 6AS7G amplifier, I will show here. I will at a later time pick up the thread about the huge family of series regulator tubes.



Keroes & Hafler Ultra Linear ,1952/55.

The so called ultra linear operation are normally associated with Keroes and Hafler. This is actually not fair as none of them invented this circuit. Several others made the circuit many years before K&H, for instance Telefunken in 1940 and not least Blumlein's patent of 1937. In Europe the circuit was relatively well known, thus according to European patent laws it was not possible to claim a patent for the circuit. American patent offices, however are much more liberal and do not seem to care for such formality.**Thomas Danley**, (Danley sound labs. – probably the best power speakers ever made) once told me in a mail that a guy had been granted a patent for the electrodynamic loudspeaker – this was in the late 1990's ! 😉

Anway Acro transformers, owned by Keroes was issued the patent, hence able to collect royalties for many years. K & H promoted the wonders of the recent acquired patent very well indeed. The articles and flyers published by these two gentlemen basically created a school of power amplifier design and Ultra Lineare has ever since been the most popular OPT coupling for audio. Not much to say about the idea as it is pretty much self explaining. There is no real optimal point of where to make the UL tapping as it is a trade off, depending upon many variables and it is case sensitive.The feedback current to sg2 modulates the inner impedance of the output tubes, creating a weird distortion that may not appear when investigated by sinewaves. Often we use the 43% claimed by Keroes and Hafler , but really that was a gimmick. The closer we get to triode strapping, the more linear, but less the power and vice versa. Any pentode or tetrode may in principle be objected to UL circuit.

It is a clever compromise between the linearity of triode strapping and the efficiency of pentodes/tetrodes, but it does come at a price. Kiebert rarely used UL and prominent persons such as **Williamson and Peter Walker** (QUAD) questioned the claims by Keroes and Hafler. The following appeared in an article written by Williamson and Walker for Wireless World, sep-1952*:" Articles have recently been published in the United States claiming the superiority of a so-called " ultra-linear " output circuit in which the output valves are used as tetrodes,with negative feedback applied non-linearly by connecting the screens to a tap on the primary of the output transformer. It is stated that the performance is audibly improved over that of triodes with similar degrees of negative feedback. The present writers do not believe this claim.*

The circuitry which forms the basis of these American claims for " ultra-linearity " and higher efficiency has, in fact, been familiar in this country for several years, and the technique has been further developed and used in a commercially produced high-quality amplifier."

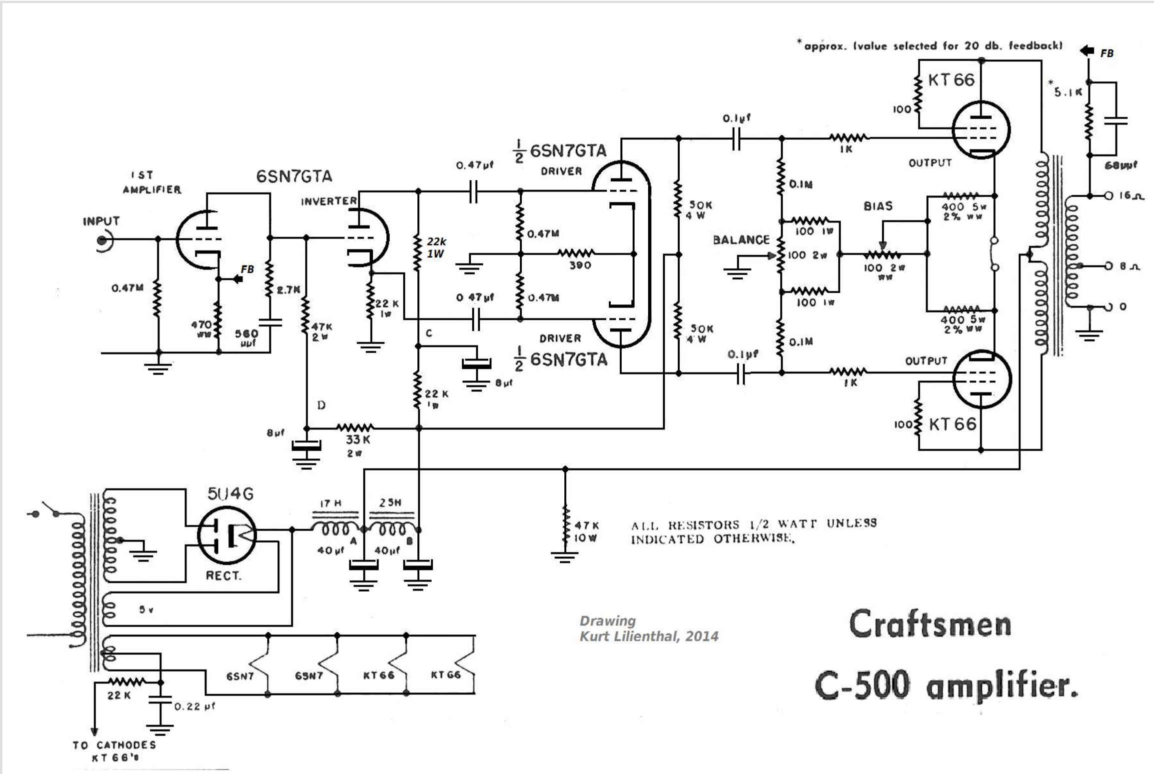
Of course Williamson and Walker had a significant point. The Ultra Linear operation that Keroes sold as being *better* than triodes was simply the speech of a salesman. Walker had been using "Ultra linear" as well as cathode feedback windings for some years, but he never claimed that they were better than triode operation, neither did he claim a patent for the idea.

McIntosh patented the similar "unity coupling" in the late 1940's – it was granted in 1949 – according to my informations. It is my belief that McIntosh used the cathode FB winding before Walker , but frankly I don't know.

Update March 2015: I accidently found a letter written by Peter Walker to Wireless World, Dec. 54 in which Walker claims that he drew attention to this application as early as 1943. The "British gang" obviously prefered cathode loading to sg2 loading. Used this way the degeneration also applies to triodes. Keep in mind that Blumlein was English and that he and Walker must have known about one another – at least by name.

Thats all, folks.

.____



(Suggested by Francis)

Craftsmen model 500, KT66 PP, 1950

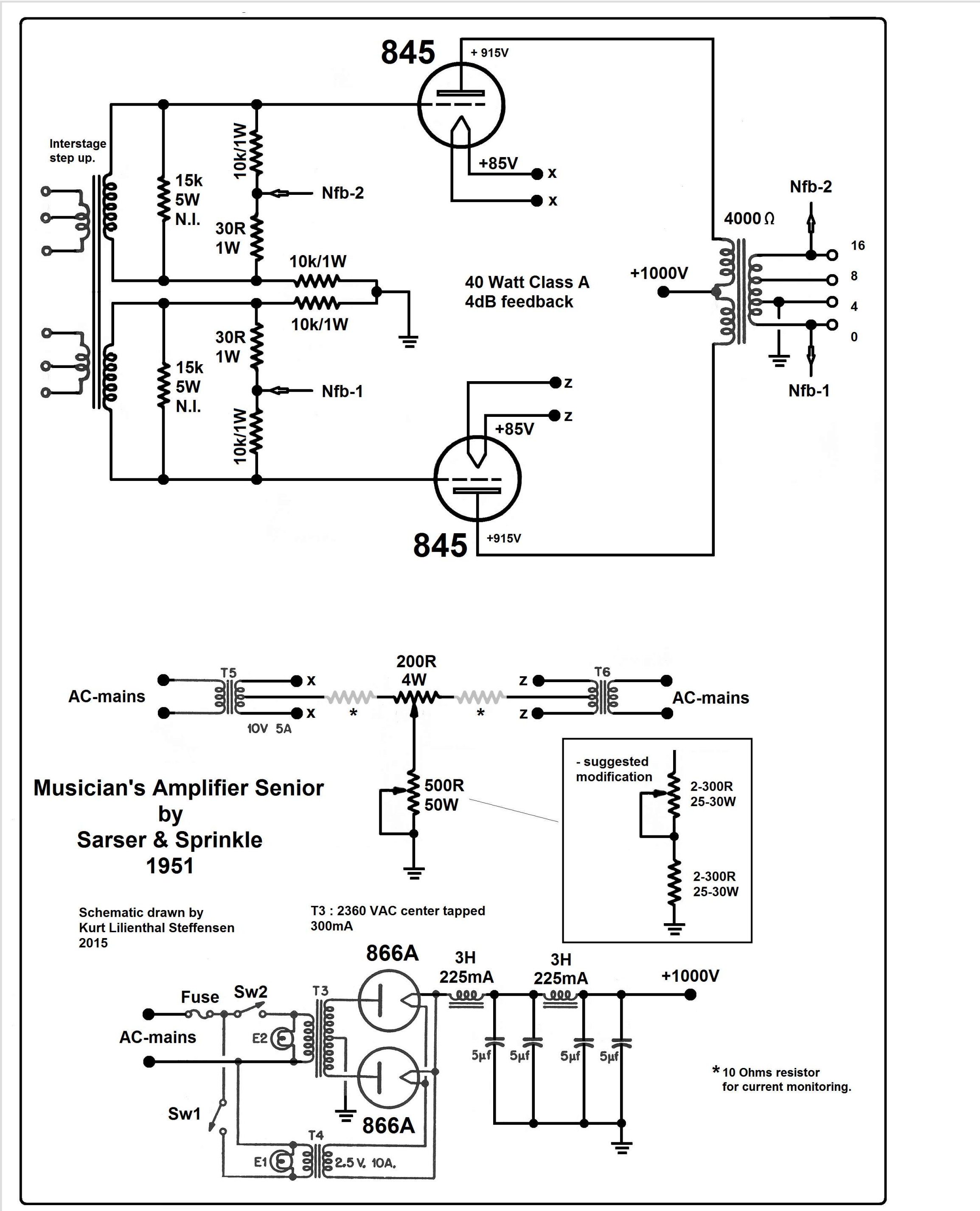
There seems to be several 500 models ?

Yes – another classic Williamson design. Simple and elegant. Choke PSU input – nice..Do also note that the filaments are lifted and referred to the cathodes of the KT66's. This improves the noise (hum) figures and may prolong tube life. Fully adjustable bias level and DC balance, despite auto bias. It has to be WW pot's in order to last, I believe, but yet another good detail. Not much need/room for modifications. This circuit are pretty much mature. I would look into the plate Voltages of the first two stages, though. The two Voltage dividers 22k and 33k, clearly indicate that it is possible to raise the plate Voltage to these triodes. 8V, 8mA at 250 V plate would be very nice indeed.

Interesting – and a little weird – that this Williamson circuit are licensed from Western Electric. Quoting radiomuseum:*"The Radio Craftsmen" seems to be founded in 1947 by John Cashman who before worked at Hallicrafters Radio Company. The schematics-licenses often came from Western Electric or RCA.*

Ed Miller and Sid Smith were the two major engineers until mid 50's. Ed Miller was the founder of Sherwood when he left RC in 1952 or 1953. Sid Smith left 1953 and joined Marantz where he got 1954 the post as chief engineer. "

We have then here drawn threads between Western Electric, Hallicrafters, RCA, Sherwood and Marantz. Not to speak of Altec Lansing and so forth and so back…
Interesting indeed….



Musicians Amplifier Senior, 845 PP , 1951

This amplifier was one in the series of amplifiers by Sarser & Sprinkle known as the "Musician's amplifier". The first one was a Williamson design that Sprinkle slightly modified and converted to US tube types 807 and 6SN7. The amplifier shown here was meant as a high quality amplifier primarily for domestic record cutting applications. (And alternative to expensive tape recording back then) It is supposed to be driven by the Williamson amplifier – but of course any suitable amplifier may be used as long as it is capable of driving the interstage transformer. The musicians senior will provide 40 Watts of sparkling triode class A. The freq response merely limited by the quality of the OPT.

845 is a tremendous good triode. It was originally developed as one of the strings in a series of 50 Watt triodes. 845 is the low u version , 211 is the medium u and 805 is the high u version. The production techniques and materials for tubes improved fast and most of the original 50 Watt's series are capable of plate dissipation between 75 and 125 Watts.

As no one needs a 5-600 Ohms output and no one cuts their own home vinyls anymore (Well – I am sure there is one or two out there doing exactly that) – I have shown the amplifier with a "regular" tapped 0-4-8-16 Ohm output transformer. The 4 Ohms tap are grounded, hence providing a balanced configuration for feedback to the grids of the 845's. The fb totals to a very modest 4dB. It may be entirely omitted without affecting the overall performance much. Sprinkle suggested a load of 4000 Ω to the 845's. I suspect that was a qualified compromise in order to achieve the additional 500 Ω winding for cutting. A better load would be 5000 to 8000 Ω. The B+ Voltage are not critical. anything from 800 to 1200 Volts will do.

PSU: The main transformer supplying the B+ is a 1180 – 0 – 1180 VAC, 300mA type. The chokes may be anything from 2-3 H and up. They must be able to handle at least 250mA and isolation must be very high. (3-5kV tested)   I have moved the two chokes from the ground leg of which they were originally inserted to the positive Voltage line. It makes no difference at all for the task, as it does not matter where in the loop these are positioned. In fact it is nice to have them at ground potential as it demands less with regards to isolation. But the secondary of the main transformer are "connected" to ground via the parasitic distributed capacitance, hence it may very well introduce noise products related to the alternating mains freq. These will not be cancelled by the smoothing circuit. In practice a little experimentation may decide the best place for the chokes.

The capacitors are paper oil, but a series of modern electrolytics and suitable bleeders in parallel with a good high Voltage capacitor may be a better solution. (Rifa may be our optimal choice) This series of electrolytics may be decoupled by a high quality high Voltage capacitor.

The adjustable cathode return resistor is a risky business and absolutely unnecessary. I would insist that it is divided into a fixed value and an adjustable value. Say 2-300 Ω each. It would also be a very good idea to implement a small resistor of 1 to 10 Ω in the legs of each center tap of the cathode return in the heater supplies for the 845's. This will allow measurement of DC balance and individual bias value. (I have indicated these resistors at the schematic) It may alternatively be measured via the copper resistance of the primary windings, but this is a troublesome and very dangerous method.

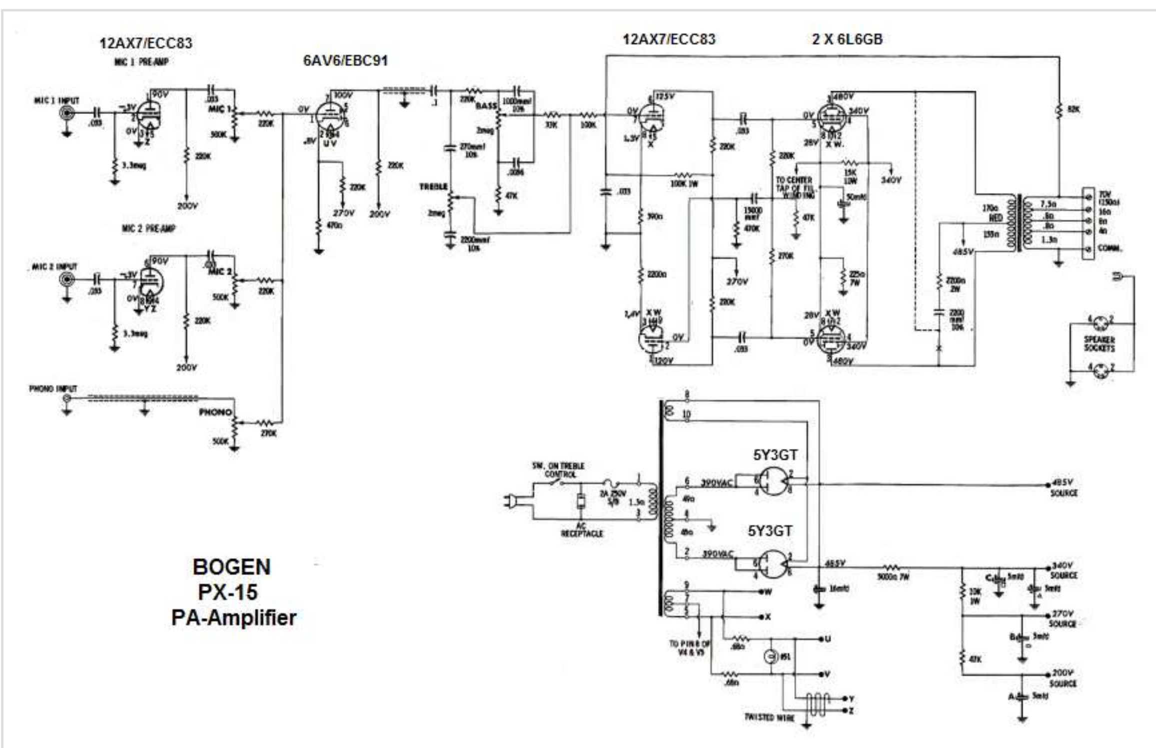
The amplifier: The two gentlemen behind this amplifier drives the 845's pretty hard. The idle current are adjusted to 125mA per tube resulting in an idle plate dissipation of 114 Watts ! (+ 915V at the plates due to copper loss at the primaries) The reasoning behind this torture is that Sprinkle and Sarser adjusted the 845's to the lowest possible IM distortion at 40 Watts out. "Increased tube failure. if any, will be a low price to pay for lower distortion on records" – they stated (Audio Engineering, Jan. 1951). Well, this may have been the case in the days of which a surplus 845 was cheaper than a 12AX7. But today we cant afford that luxury. Anyway a much better solution is to provide a higher load to the 845's. 4k Ohms is definitely at the low side , 5k is better and even 10k will not be too much.

Finally a word of warning. Do not attempt to build these high Voltage amplifiers unless you are fully aware of what you are doing and knows how to assemble it into a safe and reliable construction. (Mechanical as well as electrical)

To quote Sarser & Sprinkle: "USE EXTREME CARE WHEN WORKING ON THIS POWER SUPPLY.THE HIGH VOLTAGE PRESENT IS LETHAL.YOUR FIRST SHOCK MAY BE YOUR LAST, AND DEATH IS SO PERMANENT". (Yes, they wrote this in high capitals)

Sprinkle was probably best known for his work with Altec Lansing and Peerless. Sarser was a professional musician playing the violin in classical orchestras. Both were dedicated audiophiles.

It was actually not unusual to design a high power amplifier, meant to be power driven by means of power tubes. Other power driven audio amplifiers from this period:



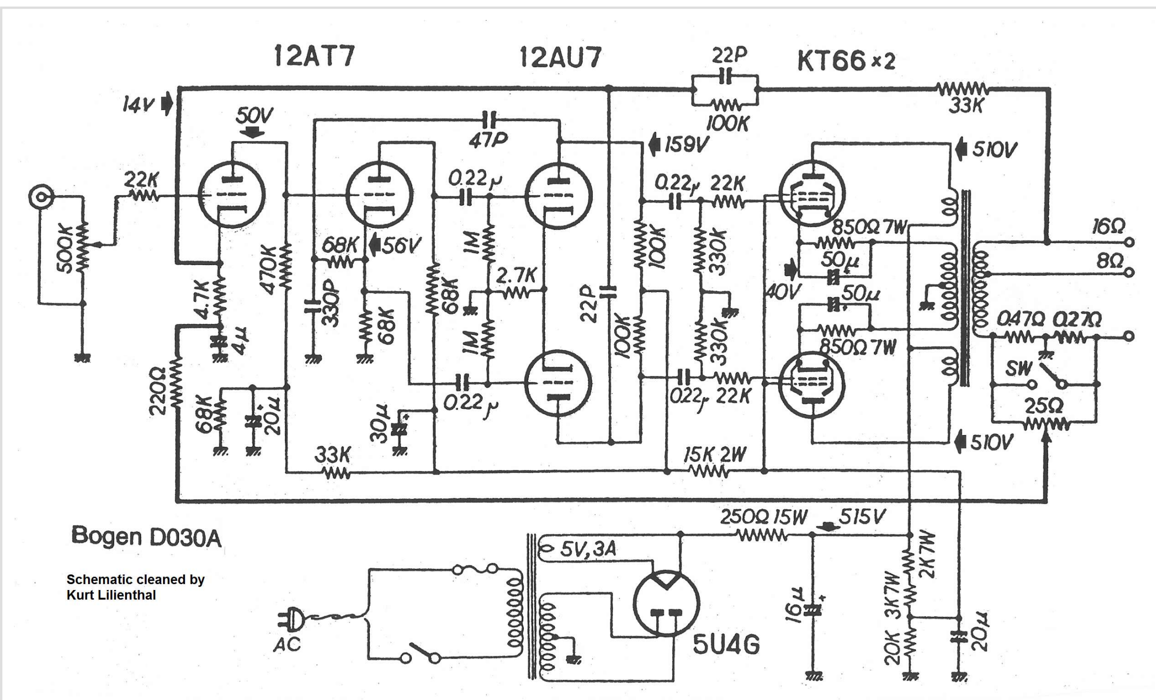
(Suggested by Francis)

Bogen PX-15, 6L6G PP, 1951

Design by David Bogen.
I am sorry for the poor quality of the schematic, but I have not yet been able to find a better copy. I do have several other interesting Bogen schematics in my library, though that I might upload in time.

The Bogen PX15 is a design with a 12AH7 twin triode used as input Voltage amplifier and second stage Voltage amplifier.The driver and phase splitter is a paraphase coupled 6SL7. The high impedance 6SL7 is not the best driver choice in my opinion. PX15 is equipped with two stage LC tone controls. That is quite impressive, as although LC designs are the best filters, they are also by far the most expensive. The cathode Voltage for the two 6L6G's are provide by the means of the idle current of the 6L6G's to feeding the filaments of the pre amplifier tubes. That is a pretty unusual pull. PX15 has an additional input stage made of a 12SJ7 pentode, but no individual volume pot, thus the noise from the 12SJ7 are present at all times. If I do not find a good copy of the schematic, I will draw a new one and upload it here.

But as we are now talking about Bogen amplifiers, I would like to use the opportunity to discuss the Bogen DO30, KT66 PP.

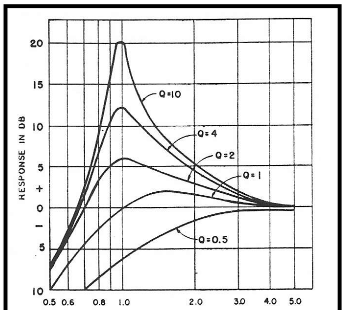


Bogen DO30A, KT66 PP, 1954

There was in particular two main features of fashion amongst audio amplifier design during the 1950's. The best known being the "ultra Linear" or distributed load and one that still lives on. The other feature was a mere suspect design often referred to as "variable damping". It is sad that the variable damping did not survive as there is several splendid virtues associated with that circuit. The Bogen DO30 is a rather conventional Williamson design, but it is equipped with exactly this simple, yet complex feature. The reason I picked the DO30 as an example of this circuit is that unlike most of the "damping" amplifiers of the period, the Bogen DO30 uses standard components to apply the adjustment. Thus it is possible for anyone to try the idea for themselves and judge whether they like it or not. The DO30 uses conventional feedback via the loop at top of the schematic – 33k to 22p//100k returned to the cathode of the 12AT7 input triode. The variable damping or *current feedback* for a better term, are made of the resistor network 200R, 25R pot and not least the two small resistors R47 and R27 of which the latter are in series with the speaker load. This means that the current passing through the speaker develops a proportional Voltage over these resistors that may be returned to the input cathode as current feedback. The actual circuit of the two current sensing resistors are grounded between these. This means that if the Voltage is taken from the R27 Ohm resistor alone, positive current feedback are applied and if the Voltage are taken from the R47 Ohms resistor (facing towards the output sec winding) negative current fb are applied. The 25 Ohm potentiometer adjusts this. If this pot are places between the values of these two resistors (about 1/3) , the AC Voltage developed are cancelled and hence set in neutral position. In other words the 25 Ohm resistor and the two small sensing resistors form a bridge circuit.

Now, what is the point of this variable damping or current feedback. Well, this is indeed a can of worms and much to complicated to get in details with here, but lets read the headlines. The damping factor is a simple relation between the "inner resistance" of the amplifier (z-out or ri) also known as the generator impedance and the impedance of the actual load , meaning loudspeaker. DF = Q = speaker impedance/z-out. At least this is the theory, in the real world it is much more complicated and a thing that often is forgotten or ignored is that a real speaker also reveals a resistance made of the copper winding. An 8 Ohms speaker will usually show a copper resistance of 5-6 Ohms. Hence no matter how much damping – how high the damping factor the speaker will always be affected by the copper resistance as a series equivalent as well. Despite this paradoxical fact, current feedback works, both as positive and negative feedback and also due to the fact that what really drives the speaker is not the Voltage across it, but the current that passes through it. (This is also why I like current fb)

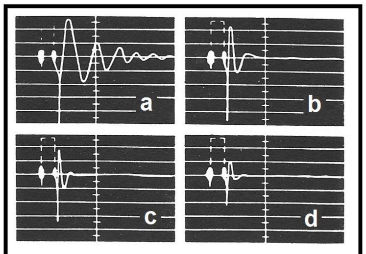
But lets stick to the conventional theory here and discuss what *also* happens without the complication of further worms. (If interested, please read my article "Power distortion" at the "PEARL archive" created by Bill Perkins, Canada) All speakers has ringing, oscillations and similar naughties being worst around the resonance point or points. Our bass speakers (woofers to some of you – woof woof) has a large and serious resonance usually around 20 to 50 Hz. This is an area we would be best served by staying away from. FAR away in fact as the resonance point are also a point that is impossible to control. It responses to even the slightest stimuli – even a fraction of a Watt is more than plenty to trigger the problems: distortion and "wild" diaphragm movements. The bad thing is that is not possible to avoid that frequency with a conventional amplifier. With regards to ringing, lets put it another way. Say we expose our speaker to a transient, being that a drum beat, a hard accord on a piano or whatever. This will give the speaker a kick and as everything else that is kicked it needs a little time to settle at its rest point. It moves forwards as supposed, but then back kicks and perhaps a little ripple before it stops moving. These ringings equals to distortion and can be very nasty to listen to if not controlled. Control means *damping = damping factor = Q*. But damping is a relative matter – too much damping is just as bad as too little damping. Critical damping is when damping equals to Q = 0,5. Not two sets of speaker are exact alike and the necessary damping depends upon a number of variable, not easy to calculate, not speaking about the conflict in damping from the point of view of transient response and overshoot. The easiest, most simple way to handle this unpredictable scenario is by variable DF. This will allow you to adjust it yourself, according to your specific speakers, set up and listening room, not least your personal taste and preferences.



Damping expressed as Q.

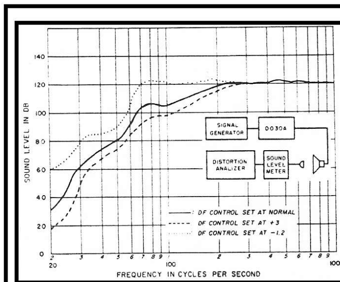
Actual frequency/resonant frequency

Critical damping = Q 0.5



Sound pressure waveforms showing the effect of amplifier DF on acoustical transient response of a loudspeaker system. Solid line shows motion of speaker cone after application of square pulse (dashed line).

a = DF + 0,1
b = DF +3
c = DF "infinite"
d = DF - 1,2



Curves showing the effect of amplifier DF on distortion generated by loudspeaker system. 5% harmonic distortion contours are shown. Normal DF is equal to +30.

_________ : DF control at normal

_ _ _ _ _ _ _ _: DF control set at +3

. . . . : DF control set at -1,2

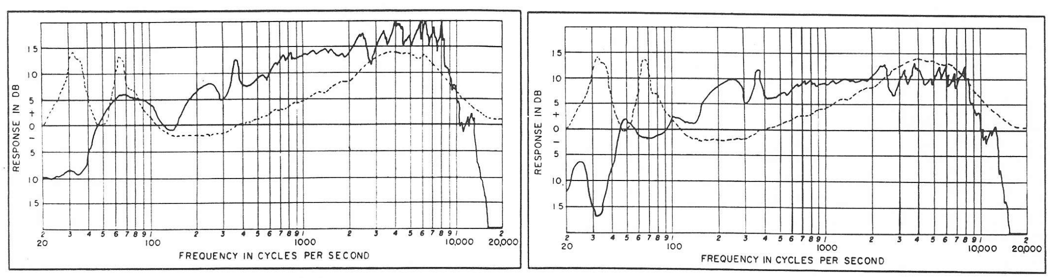


Fig. 8. (left). Sound pressure response of 15-in. coaxial speaker mounted in 8 cu. ft. bass-reflex enclosure with amplifier DF set at +3. Dotted line represents impedance of speaker. Fig. 9 (right). Sound pressure response of speaker of Fig. 8 with amplifier DF set at −1.2.

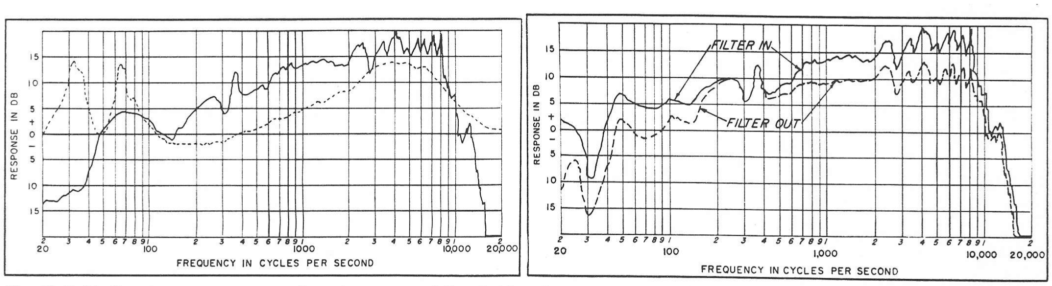
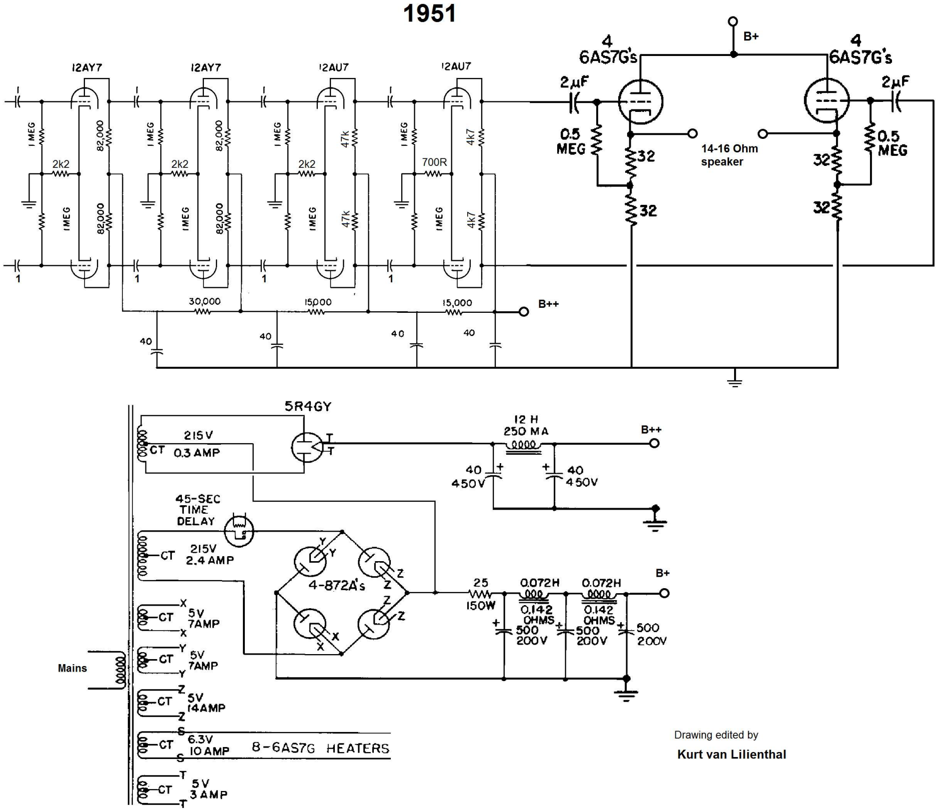


Fig. 10 (left). Sound pressure response of speaker system of Fig. 8 driven by commercial laboratory standard amplifier which has fixed DF of +10. Compare with Fig. 8. Fig. 11 (right). Sound pressure responses of speaker system of Fig. 8 showing effect of 300-cps filter. Dashed curve is same as solid curve of Fig. 9.

Above some hard evidence copied from Bogen lab results. This shows that it is worth to experiment with current feedback or current drive. The figures pretty much speaks for themselves, but note how the amplifier are keeping away from the dangerous high impedance at woofer resonance in fig. 9.

We might dig a little deeper into these matters if there is interest. Please, provide feedback to me at: 100amplifiers “at” gmail.com

Fletcher and Cooke's cathode follower OTL
1951



Tubes per channel:

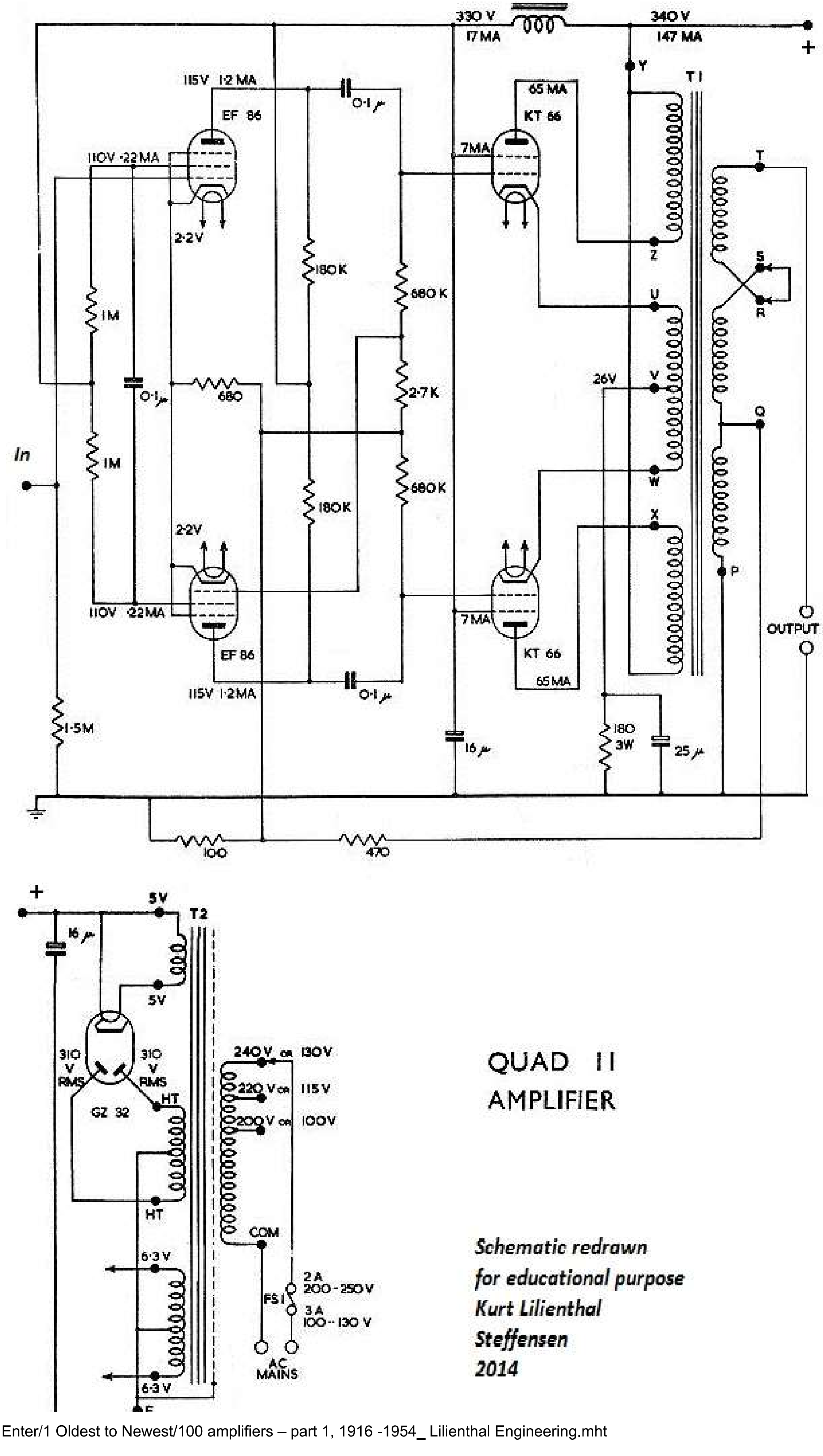
Number of 6AS7G Tubes in Stage	4	8	12	16	20
Plate Supply Current (ma)	1,000	2,000	3,000	4,000	4,600
Plate Supply Voltage (volts)	167	199	231	263	282
Push or Pull Composite Tube Characteristics					
Plate Current (amp)	0.50	1.00	1.50	2.00	2.30
Ions Conductance (µmhos)	28,000	56,000	84,000	112,000	140,000
Plate Resistance (ohms)	70	35	23.33	17.5	14
Cathode Resistance (ohms)	64	64	64	64	64
Bias Voltage (volts)	32	32	33	37	41
Follower Resistance (ohms)	23.67	11.67	7.78	5.83	4.67
Generator Resistance (ohms)	46	23.33	15.56	11.67	9.33
Load Resistance (ohms)	14.22	14.22	14.22	14.22	14.22
Damping Resistance (ohms)	34.33	19.72	13.87	10.69	8.69
Audio Power to Speaker (watts)	1.58	6.32	14.22	22.78	33.38
Audio Power to Cathode Resistors (watts)	0.20	0.79	1.78	2.85	4.17
Voltage across Load (volts)	5.0	10.0	15.0	19.0	23.0
Amplification	0.156	0.253	0.319	0.369	0.402
Power Gain (db)	36.5	37.0	37.2	37.5	37.5
Drive Voltage (Push or Pull) volts (rms)	16.0	19.7	23.5	25.7	28.7
Total Power Input (watts) (x 2 for stereo version)	320	640	960	1,280	1,600
Overall Efficiency (percent)	0.5	1	1.5	1.78	2.09

(Suggested by yours truly)

Fletcher & Cooke's cathode follower OTL, 1951

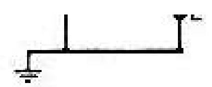
This extremely ambiguous design appeared in the November issue of the American "Electronics". It is pretty unusual for the time and even today it would be considered as a rather extreme design. Capacitors and transformers were a weak link in those days, all though considerable improvements had taken place, compared to the components available before WW2. The best paper oil capacitors and C-core transformers were very expensive. Fletcher and Cooke's goal was to make an amplifier capable of reproducing signals from 2 to 200.000 Hz. The reason is not that we a able to hear such extreme frequencies, neither that any audio signal source would deliver such a range. But in order to avoid phase shifts in the audio range of 20-20.000 Hz, such extreme is actually necessary. Luckily phase deviations beyond some 7-10 kHz means little or nothing, as the human perception system ignores the multiple reflections of such high notes. Other vice we could not stand listening to most speakers or signal sources. Output transformers stretching to some 40-60 kHz will do, but most certainly 100 kHz or higher is better. I like the philosophy and ideas behind this amplifier and I adore that no means were spared in order to reach the goal. Fletcher and Cooke suggests five versions of the amplifier, the smallest one using four 6AS7G's per channel, the largest one using twenty pieces per channel. This is very extreme, even considering that the two gentlemen were only making a mono version, as stereo was not yet commercially available. (stereo was released in 1958) The version shown in the schematic is the 8 tube type, delivering some 6 Watts. The largest version capable of 33 Watts will need 1600 Watts continuously from the mains. A stereo version 3200 Watts ! , the heaters alone will draw 40 x 2,5 A = 100 Amperes. Such animal will be a nightmare with regards to balance, heat and possible failure. How do we match or balance 40 twin triodes ?. LOTS of heavy and expensive iron. Very difficult to build as well. A better choice of output tube would be the 6336 or much better 7241/7242, 6C33 and similar. If you wish to build one of these amplifiers, I will be happy to provide you with the transformers, but really we would make a better, cheaper and much more reliable amplifier with a good output transformer. Even if we kept the 6AS7's as output tubes – two such would bring you some 5 Watts with a decent output transformer. Anyway – to the hardcore OTL fans that wants to make a Fletcher Cooke, I suggest that you sacrifice any two of the first four stages in the pre-amplifier. We really do not need that much amplification anymore. I would also suggest that you alter the low freq roll off, that is the same at all stages. Such method provokes low freq oscillation related distortion phenomenons. Go in 1/3 – higher or lower – either resistor or capacitor.

I love the no compromise attitude of this amplifier, despite it being an OTL design.



QUAD II
AMPLIFIER

Schematic redrawn for educational purpose Kurt Lilienthal Steffensen 2014

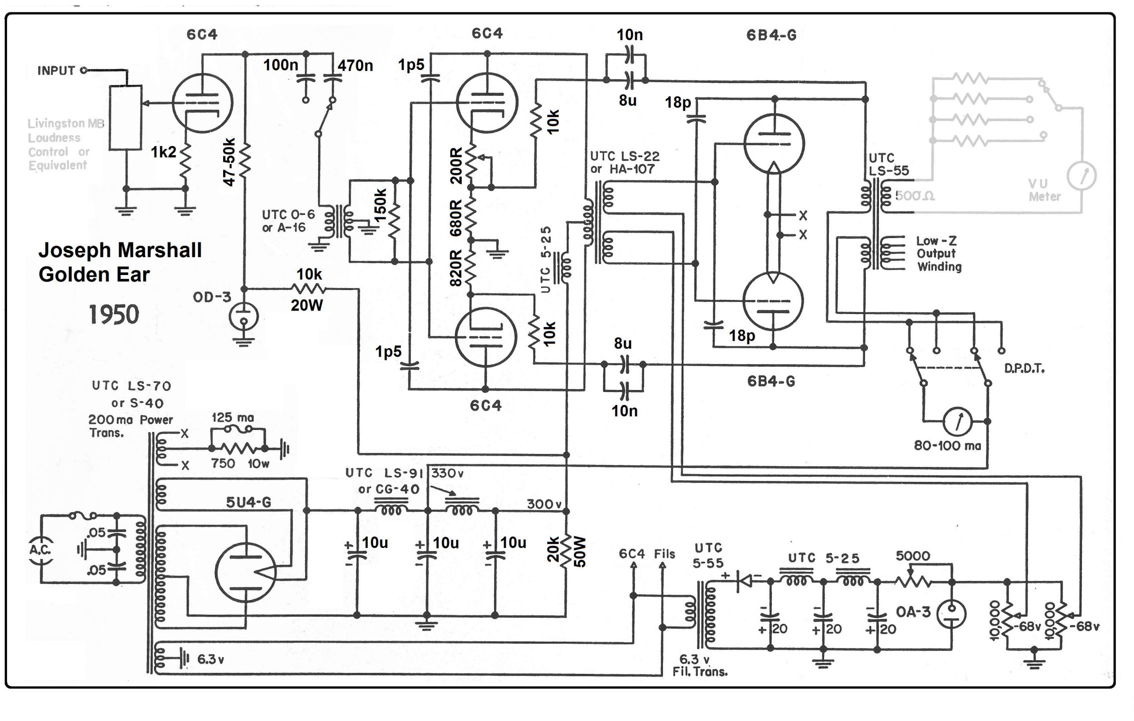


QUAD II. KT66 PP, 1953

Peter Walker made this classic to come
with his best known classic – the famous electrostatic speaker.
This amplifier has never been a real favorite of mine. The output stage is good, but I always converts the two EF86 to two twin triodes into a Williamson or other. Is that blasfemic ?

I have not yet been able to verify if Walker or McIntosh was the first to use the "distributed load" configuration. But Walker and Williamson experimented with Plate/sg2/cathode loading very early on (according to an article by the two gentlemen that appeared in WW in the 1950's), but decided to leave out the sg2 loading. They apparently disliked the name "Ultra Linear" and did not like that application much.

The QUAD II is indeed a nice amp and the aesthetic design is timeless.



GOLDEN EAR AMP by Joseph Marshall, 1950

The "Golden Ear" amplifier is not a particular amplifier as most seem to believe, but a series of schematics by Joseph Marshall. These appeared as construction articles in US magazines such as Radio Electronics and Audio. It is difficult to estimate exactly how many amplifiers Marshall designed using that term, but I know of six types of which the first was published in the April issue of Audio, 1950. (Shown above)

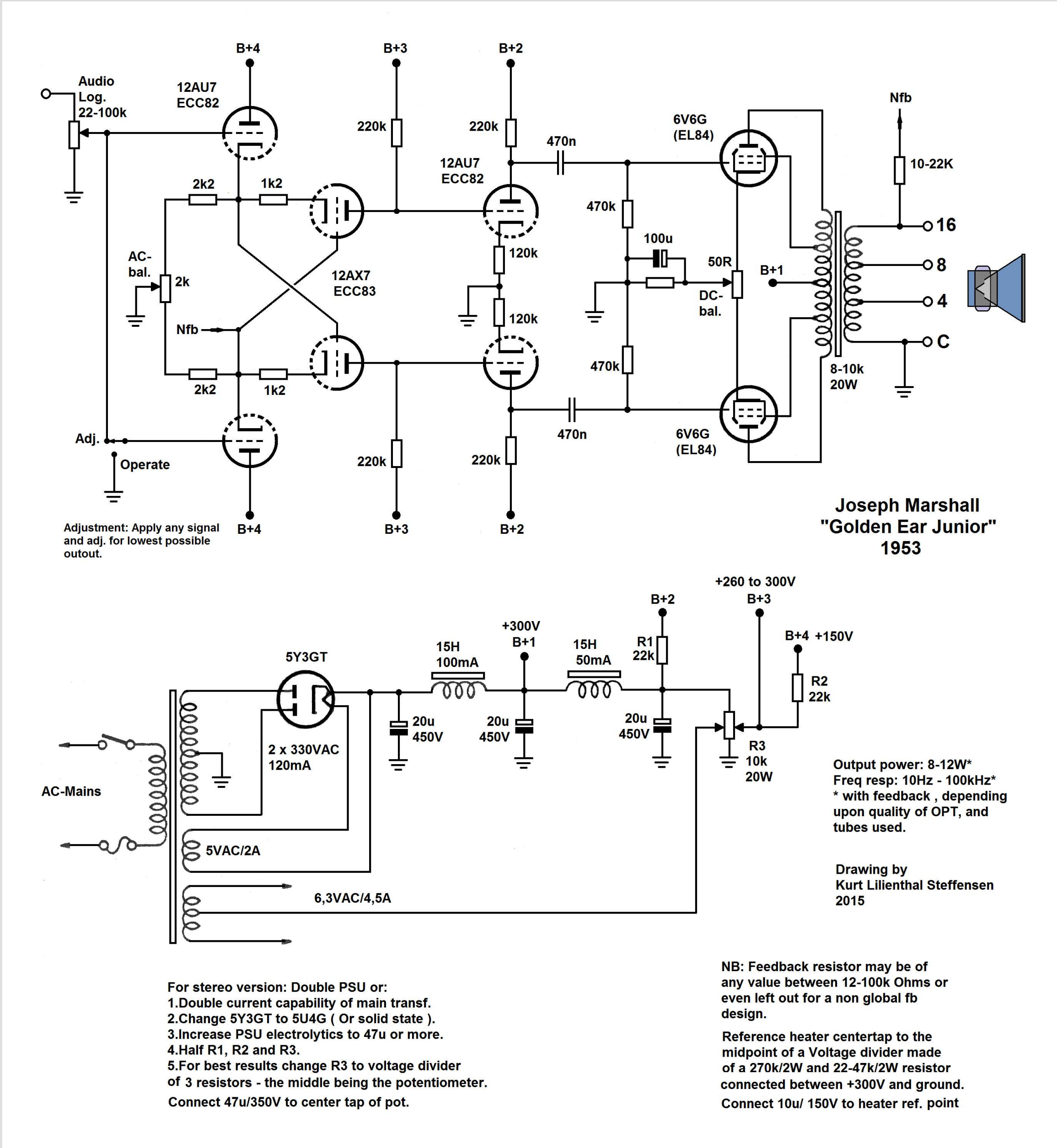
The first Golden Ear amplifier was an all triode transformer coupled amplifier using 6B4G at the output.

A letter by B.E. Beggs to Audio, May 1950 showing once again how hard it is to "be the first" :

"*Sir: I note with interest the article "For Golden Ears Only," by Joseph Marshall, in which he states that the amplifier represents the nearest approach to perfection achieved in three years of experimentation. I further note "with the exception of a few elements, which may lift eyebrows slightly," that my eyebrows were lifted more than slightly. Upon reading the article with care and studying the schematic, I discovered to my amazement that the circuit is very similar to one published by the writer in the January 1946 issue of Electronics in which the circuit appears on page 155. My design utilized essentially the same basic feedback circuits, the identical transformers, and the center- tapped choke to maintain the driver output in Class A. I should like to congratulate Mr. Marshall on doing a fine bit of test work and on applying to my original circuit the cross neutralization as described by Paul W. Klipsch in the same magazine some sixteen years ago. George E. Beggs, Jr*"

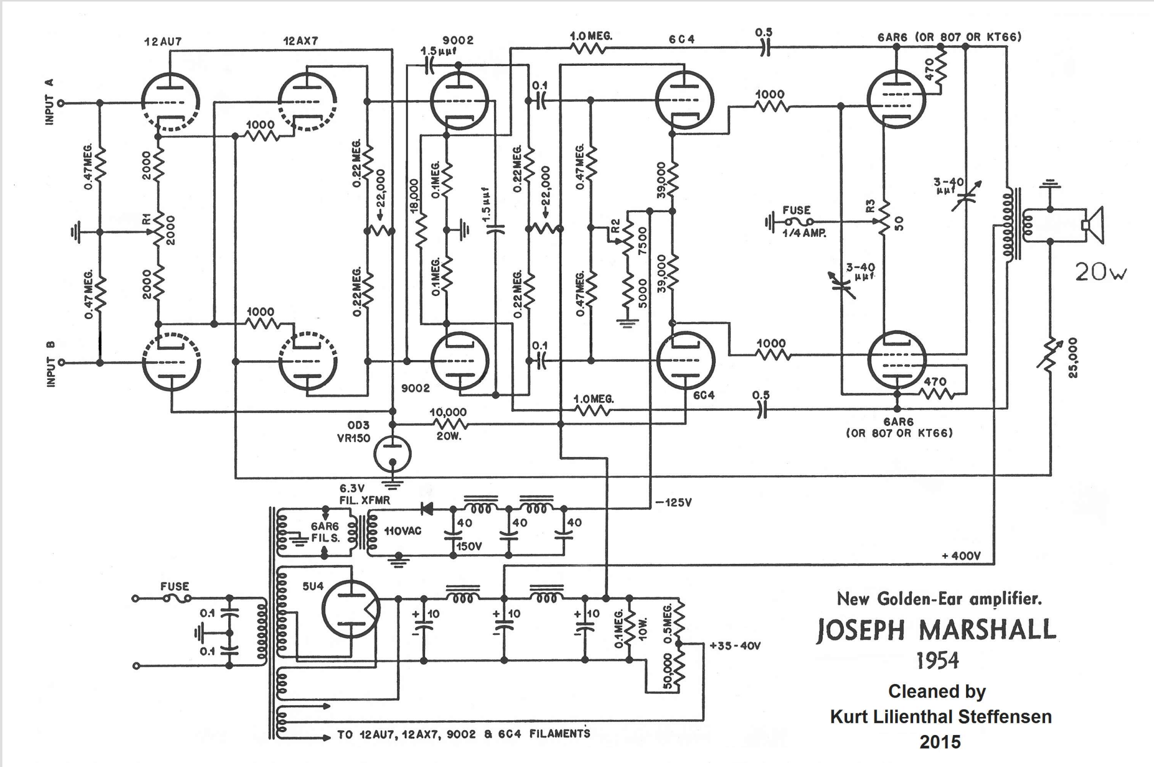
The later models all applied the cross coupled phase splitter that we would today possible consider the trademark of the Golden Ear amplifiers. (The cross couple was developed by J.N. van Scoyoc, 1948)

NOTE: I AM NOT QUITE DONE WITH THE VIGNETTES ABOUT THE GOLDEN EARS, BUT DUE TO SOME MAILS REGARDING THESE AMPLIFIERS, I HAVE DECIDED TO PUBLISH THE SCHEMATICS AND TEXT AS IS. – MORE TO COME LATER.



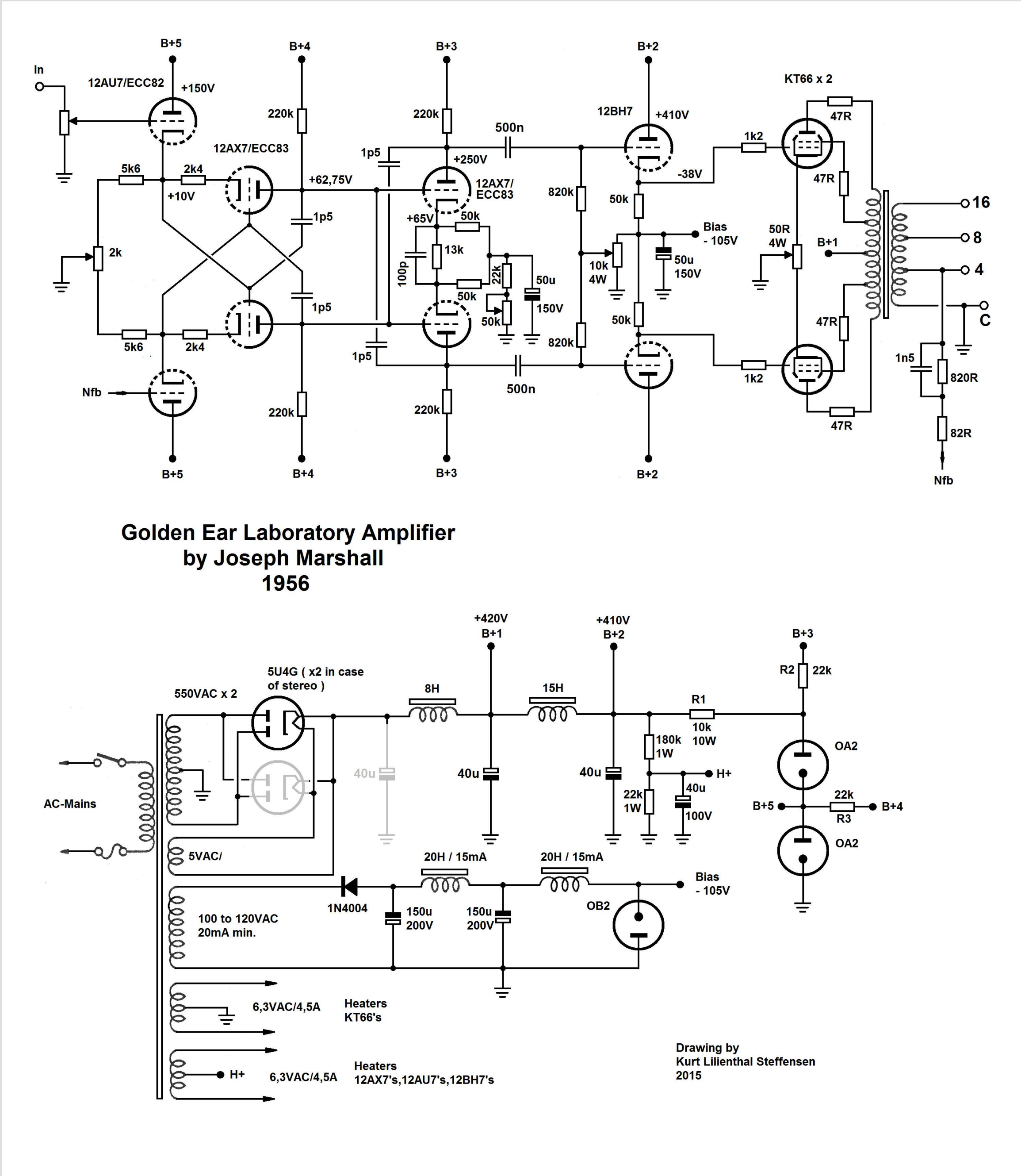
GOLDEN EAR JUNIOR, Marshall, 6V6G PP, 1953

This amplifier appeared in Radio Electronics,Nov. 1953.



GOLDEN EAR, Marshall, 6AR6 PP, 1954

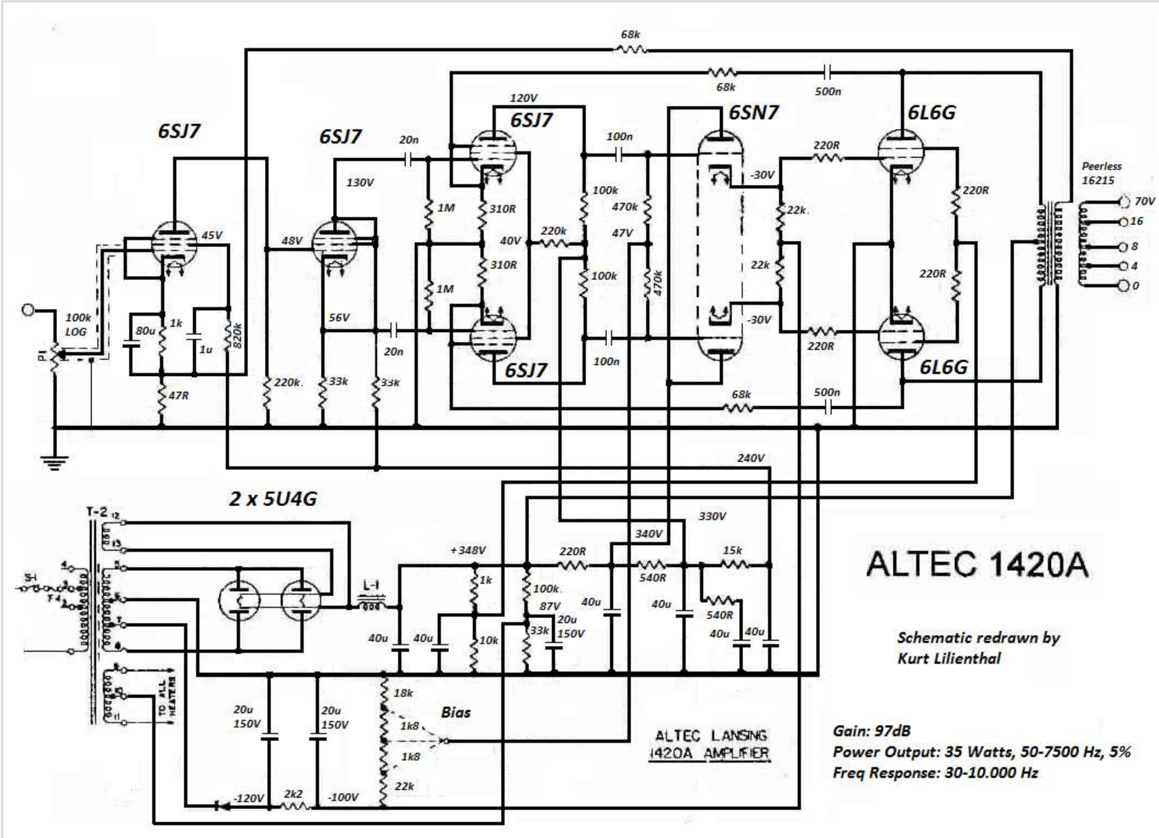
This amplifier appeared in Audio magazine, Jan. 1954.



GOLDEN EAR LABORATORY, Marshall, KT66 PP, 1954

This was the culmination of the Golden Ear amplifier series. It was published in Radio Electronics, Aug. and Sep. 1956. (I seems to remember, however, that Marshall later made yet another amplifier design – something like "guilding the musicians amp" ?)

Anyway I will discuss these interesting Golden Ear amps in a little more detail later on. For now the schematics are here for you to enjoy.

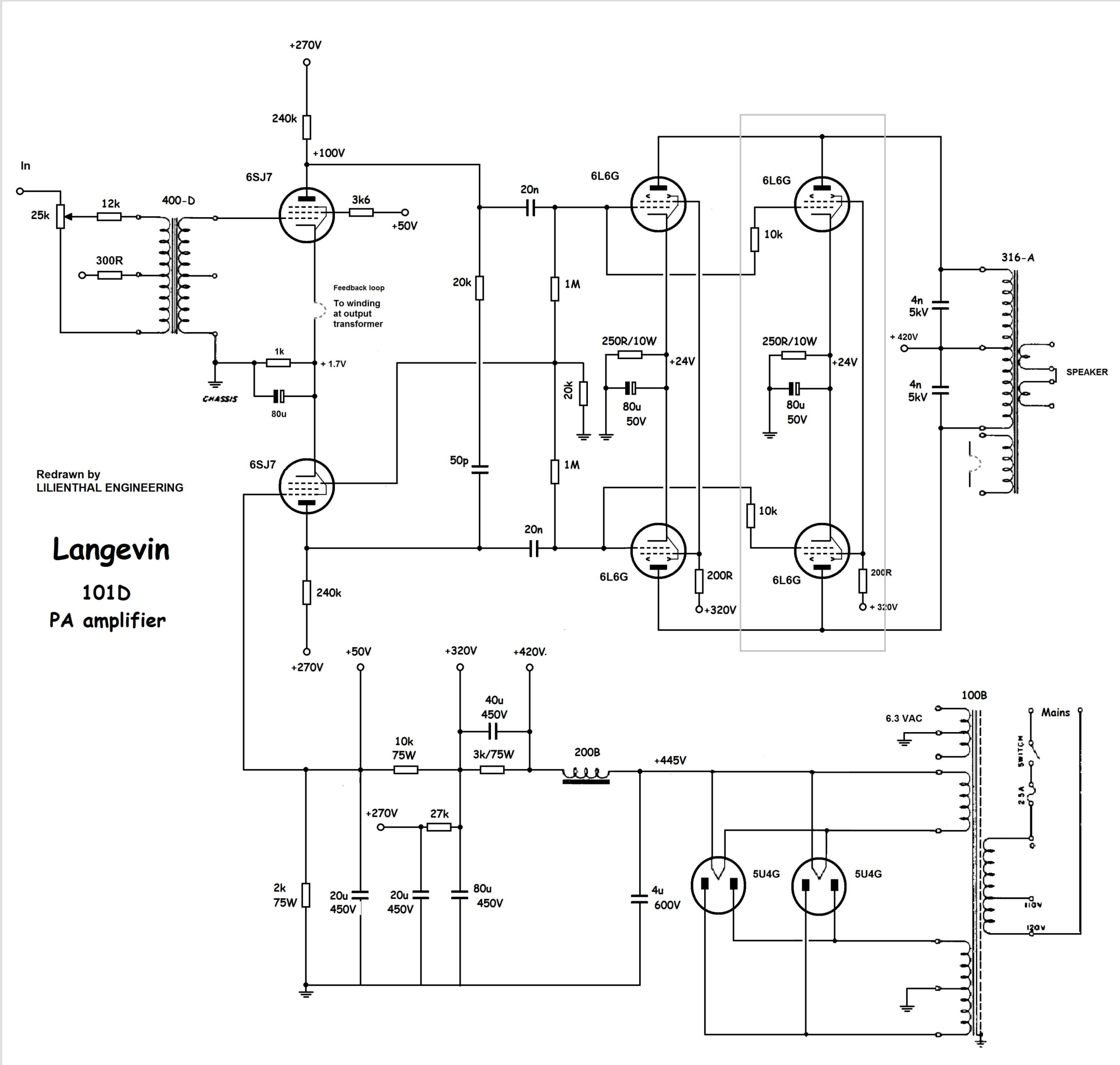


(Suggested by Joe Roberts)

Altec 1420, 6L6G PP, early 1950's

Williamson design, PSU choke input, filaments lifted, two parallel 5U4's..Nice…Cathode follower driver with direct bias….Even more nice…. 97dB's of gain, though !…Nah – not for this Viking. I would triode strap ALL the 6SJ7's. 6SJ7 are smashing good as a triode. That would cool the amplification and improve headroom as well as freq response and transient merits. I would also AC couple from first stage Voltage amp to phase splitter in order to increase the plate Voltage. A plate choke would come in handy here. The power stage are driven in to grid current AB2.. I would adjust to AB1 and sacrifice a little power. Some 20-25 Watts should be possible.

Great amp…

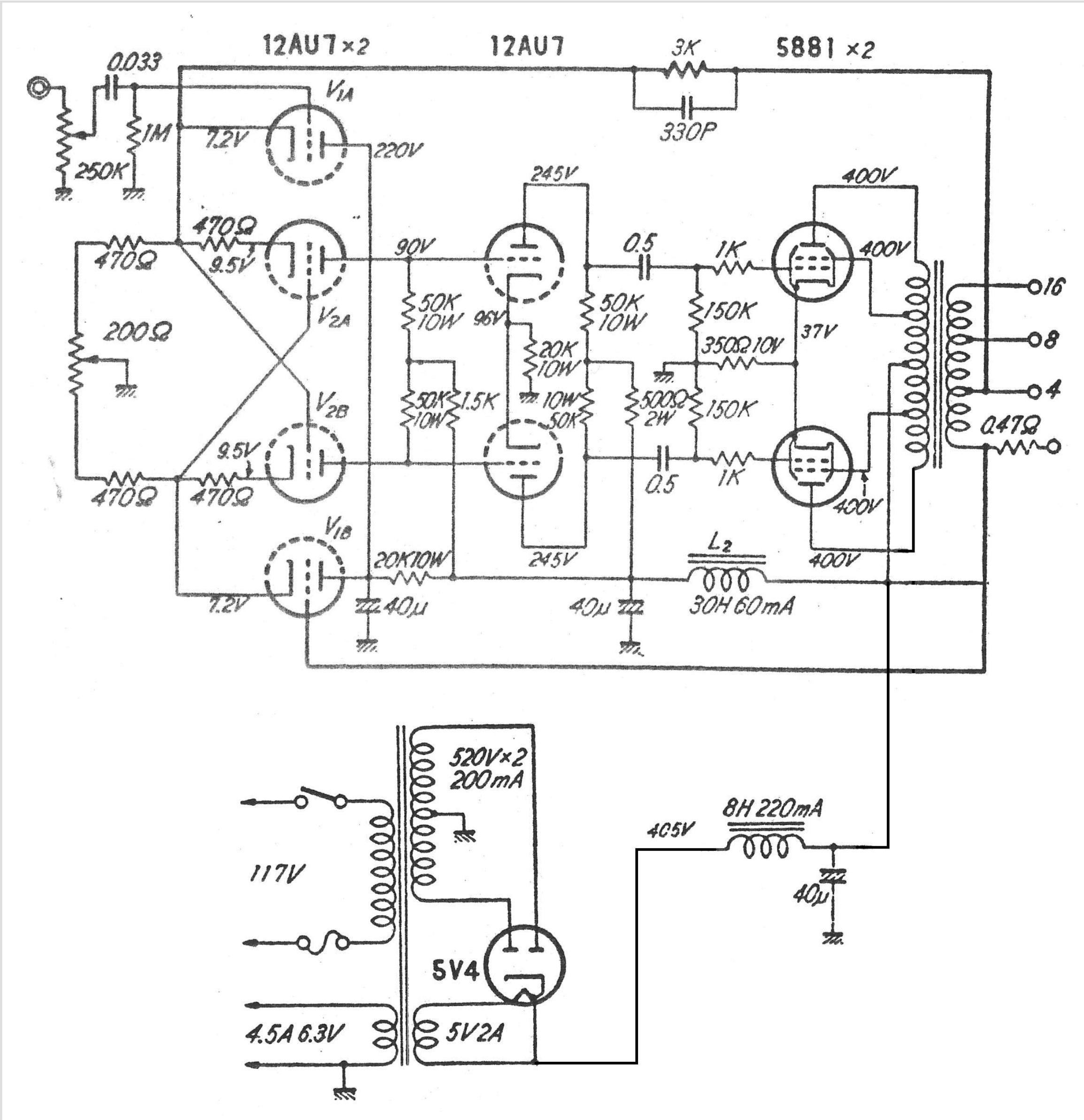


Langevin 101D, 4 x 6L6G PP, ca. 1952

This Langevin (W.E. regie) is a nice straight forward proven high quality design, just as I like them, but it comes with a twist or two. The floating paraphase phase splitter also acts as Voltage amplifier and driver. Nothing weird about that, but almost as a W.E trademark the possible transformer phase split option is ignored. This is a “feature” of W.E. design, that will remain as a mystery to me. The feedback is incorporated by means of a tertiary fed to only one part of the signal halfs. Another mysterious solution. Why not use a center tap and feed it back as a balanced signal ? Or simply use the secondary with a grounded midpoint. I suspect that WE did not trust the winding techniques back then to be accurate enough for phase splitting. It was most certainly possible, but maybe they did not considered it worth the extra cost to make a precision transformer.

Do also note that the OPT is compensated by means of two 4n capacitors. This amplifier was certainly made for steady state PA use, rather than best possible domestic reproduction. A modern version or possible modification would be to apply balanced fb and take full advantage of the input transformer by letting this so the phase splitting as well. That would also allow the two 6SJ7’s to be triode coupled. 6SJ7’s performs outstanding as triodes. If you do not need the extra power a pair of

6L6G's will deliver some 40-50 Watt's into a load of 4-6k. The original Langevin OPT would be 2-3k Ohm.



White Sound, Powrtron 5881 PP, 1953.

I have never heard or seen this amp in real life, but it sure deserves to be mentioned here. It appeared first time in the US magazine "Audio" , november 1953.

Stan White – the designer of this amplifier is a hard core Joe. He is scientist in physics and meteorology and audiophile music lover. White designed some remarkable speakers in the 1940's and 50's. Some of these designs are still being produced today.

Some 10-15 years ago, a German HiFi magazine managed to get their hands on this old amplifier. They were stunned about the high quality and 3D stage. The circuit is simple, but do not let that fool you. A lot of effort has been put in to this amplifier in order to maintain as little phase shift as possible. Do also note the use of choke input PSU for better regulation. According to White Voltage regulation is of the utmost importance. I could not agree more.

Stan White, 2001: "When revisiting the POWRTRON design, it was discovered that there have been many improvements in electronic components since 1953. The electrolytic capacitors for power supplies have higher voltage capability and much higher capacitance. There are now non-inductive coupling capacitors that have lower ESR and are more compact. There are non-inductive wire wound resisters, frame grid audio triodes, beefed up EL34, 5AR4 tubes etc. Transformers have better high voltage insulation, better transformer iron and better lead wires. Pots are more reliable etc. The life of modern amplifiers can be better than it was 50 years ago. All of these things are improvements over 1950's amplifiers. With the upgraded parts, lower distortion and longer life is achieved. There are those who feel that amplifiers made from obsolete designs with obsolete parts are better. If shorter life span and high distortion are "better" then better has been redefined. Jack Benny's Maxwell does not perform better than 2002 Volvo's. This is so even though a Maxwell costs more in today's market."

I am perfectly in agreement with White here as well.

White also says:" Many audio parameters are physics based and generally not dealt with by electrical engineers. This is one reason POWRTRON is different. POWRTRON was designed with physics criteria, not electrical engineering cook book techniques."

I think this statement will be recognized by many DIY geeks…..

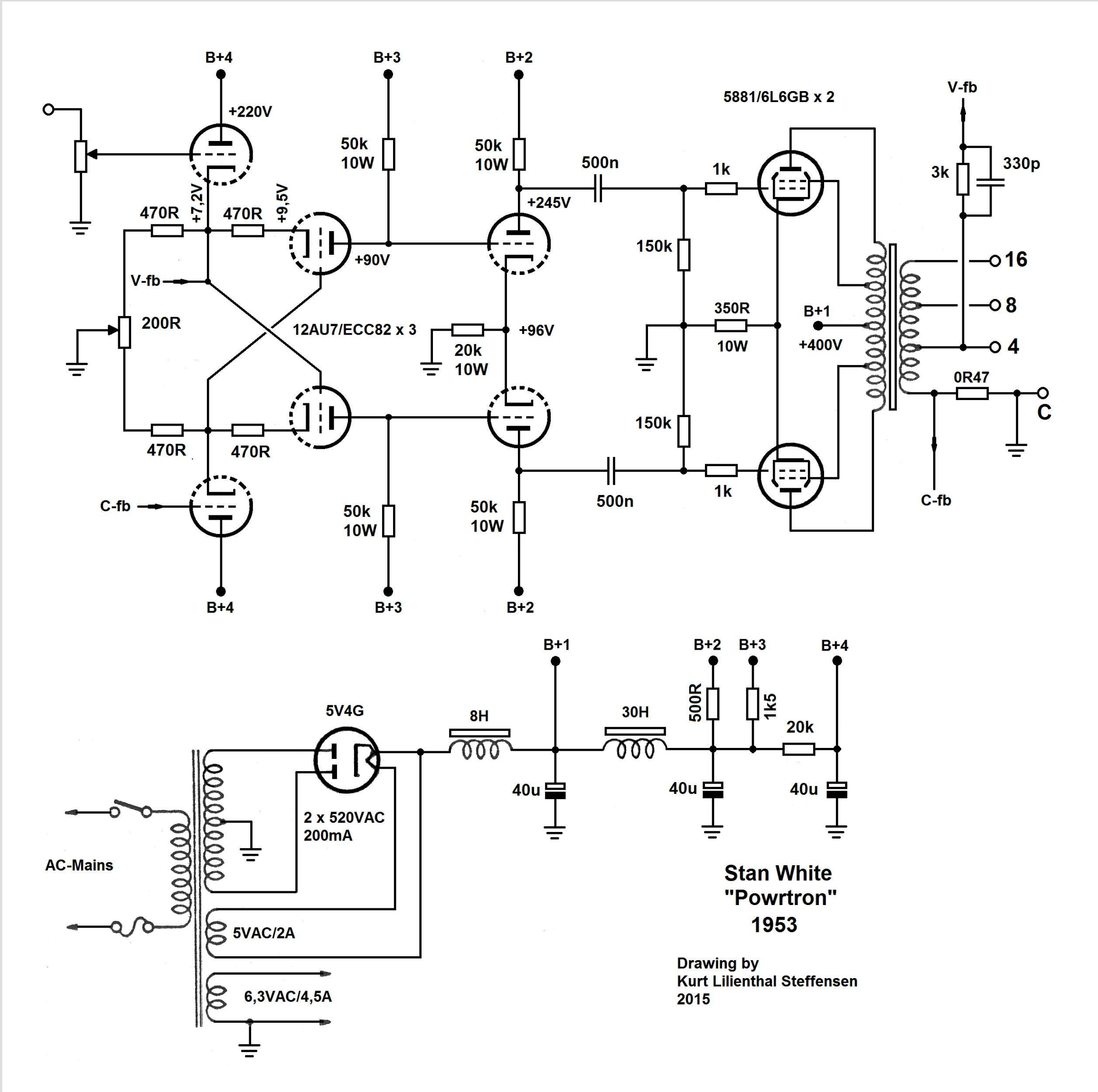
And no, this particular power tron it is not a bad spelling from my side, White wanted it to be spelled without an "E"…….

I have received some letters regarding this amplifier. Ralf, Germany finds the schematic confusing and asks me to explain how it works. It is actually pretty straight forward – I have redrawn the schematic below and trust it is now easy to see what is going on.(I have left out the input cap and the 1M Ohms resistor) Lots of info in text books and at the internet about the cross coupled and many other phase splitters. I would like to use this opportunity to recommend **John Broskie's** EXCELLENT tube site: **www.tubecad.com**

This site is first class top reading. It is fun, interesting, original and educational. What else can you possible ask.? Ah yes – it IS free………….!

J.B. is a master into the art of equivalent circuits and virtual design. This gives the word "armchair designer" a new meaning. Dont challenge this man in the discipline of equivalent circuits. He is capable of turning a classic volkswagen into a Skt. Bernard dog or a danish blonde into danish bacon. (Hmm…………that may not always be *that* hard)

Here is a link to John's notes on basic strapping of triodes: http://www.glass-ware.com/Tube%20CAD%20Circuit%20Guide.pdf



Stan Whites "Powrtron" , 1953.

The cross coupled phase splitter needs a low z source to drive it, hence the use of cathode followers at the input. Do note that White uses **current** as well as **Voltage** feedback forming **power feedback**, this is indeed what defines the White "Powrtron".

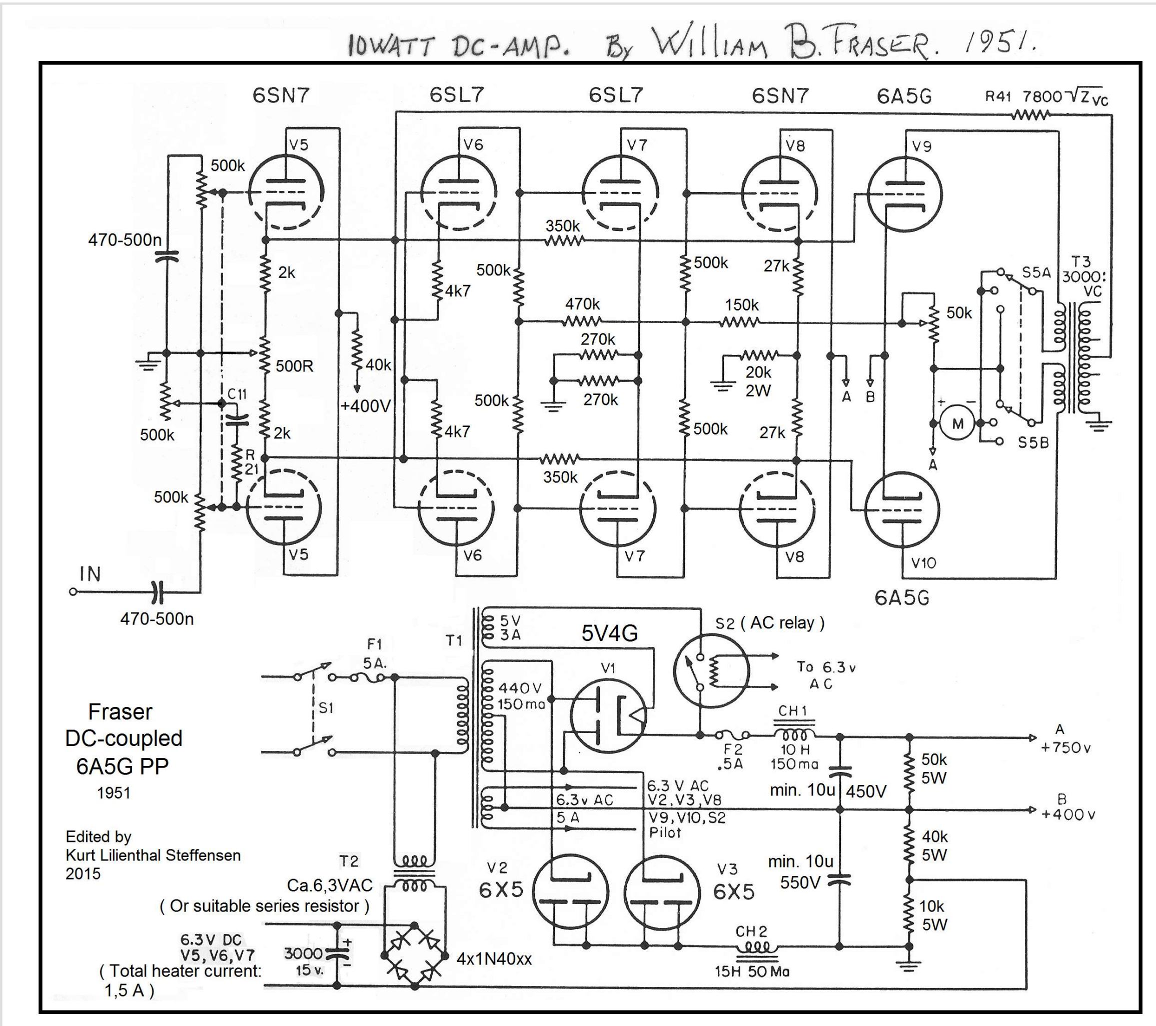
I have received another letter from Mr. (FH) Gibbert, München. Thank you very much.

Mr. Gibbert's kindly points out that this amplifier is based upon the "Golden Ear" design by Joseph Marshall and that the cross coupled phase splitter was first brought to light by "someone called Socoyoc".

I am in agreement here, at least with regards to the cross coupled phase splitter. It might have appeared in my original text (Now edited) that I honored the cross coupled phase splitter to Stan White. But it was never meant that way and to my best knowledge neither did Stan White ever postulated. I do however believe that the Powrtron circuit is an original design by White – although he may very well have been inspired by Marshall.(That was the purpose of Marshall articles anyhow – please, see also my vignette about Marshall's Golden Ear amplifiers)

It would be difficult to use the C.C.P.S. in any design with a pair of output tubes and not resemble other such designs. White's amplifier differs from Marshall's later Golden Ear designs (The first Golden Ear did *not* use CCPS) in a major way by the use of global current and Voltage to establish power feedback.

Talking about these early designs with CCPS, here is another one – that precedes both of the designs by the two mentioned gentlemen.



Fraser, DC coupled 6A5G , 1951

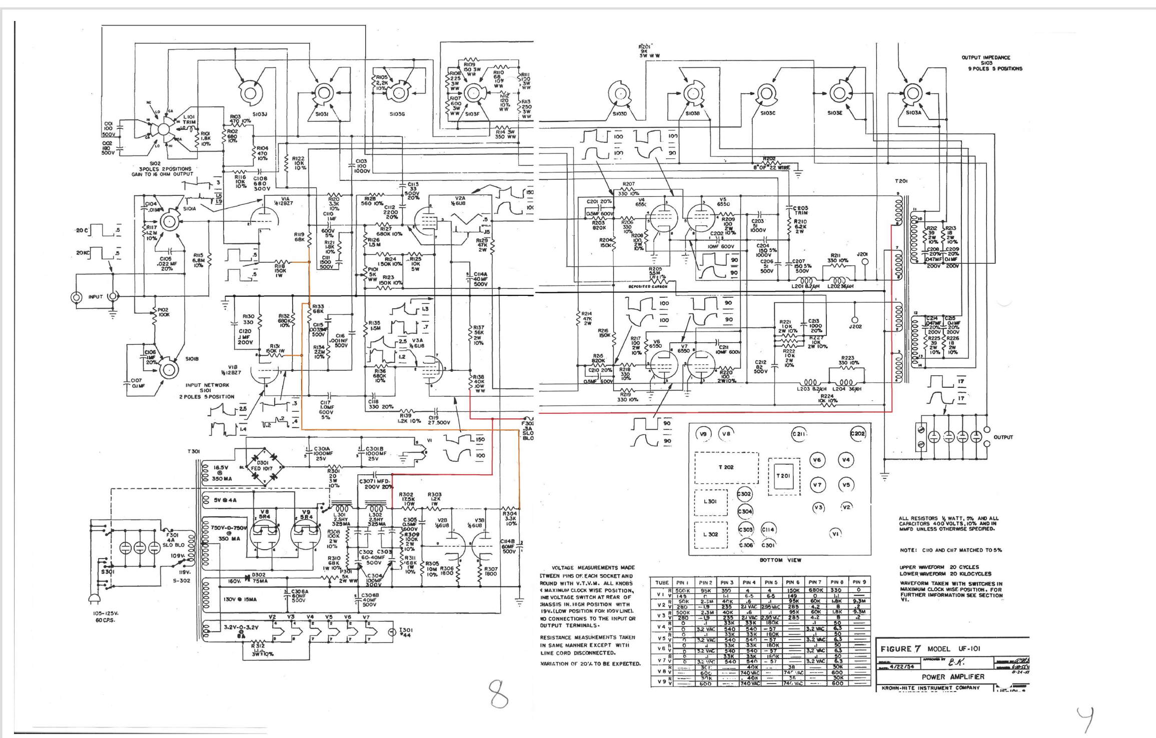
A major advantage in the use of CCPS is that due to lack of capacitors, there is almost no phase shift way up in the kHz range. This allows the use of a very large amount of feedback, thus the impressive specifications of these amps. Fraser takes this to another extreme by the direct coupling to the output stage as well. It is a fragile circuit in case of any – even a minor flaw in the current path. But it may very well be worth the chance – nothing ventured , nothing gained.

Fraser even glows the entire CCPS by means of DC current. (This is 1951 !) Hats of to Mr. Fraser.

The Cross Coupled phase splitter was developed by J.N. van Scoyoc and appeared the first time in Radio electronic engineering edition., Nov. 1948. (The original design apparently used an input transformer ! ?)

It is difficult to find further information about Stan White. Untill recently he had a website ”www.stan-white.org” , but it is now closed. This could sadly be due to the passing of White (He must be an older man by now)
The text I have quoted by Stan White was taken from this homepage when it was still going. White apparently produced some weird speakers called ”the shot-glass speaker” until very recently.
In the June 1956 edition of US Audio an advertisement from Stan White announces a motional fb tweeter capable of squarewaves up to 70kHz ! I wonder what ever happened to that speaker ?

Hats off to Mr. Powrtron



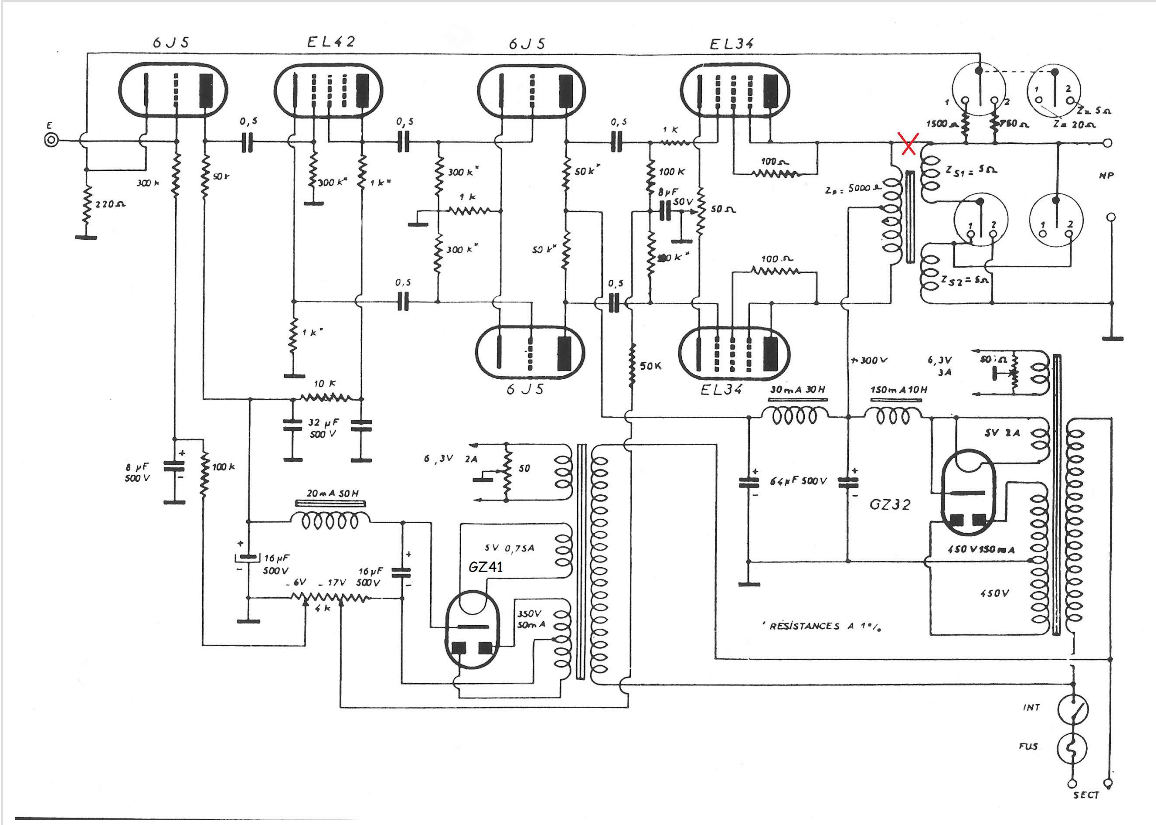
(Suggested by yours truly)
Krohn Hite UF-101, 4 x 6550 PP, @1954

Designed by Dick Burwen. A grand tour in advanced design to fight THD.
I don’t know how it sounds (It was a laboratory amp) , but at 50Watts it measured:0.005%@1kHz, 0.03%@15Hz and 0.02%@10kHz. IM distortion 0.005% at 100W peak.
Less than 0.0015% at 35W – 1kHz.

Phase deviation max 2 degrees 15Hz to 30 kHz
Load 2,4,8, and 16 Ohms.

The use of the three multi switches and the way it is drawn, makes it almost impossible to overlook the circuit in my opinion. This amplifier is unusual in many ways. It uses a plate and cathode loading similar to McIntosh, but the output stage does not appear to be symmetrical. While looking at it, it strikes me that it is kind of a large sinewave and square generator.It looks to me as it is engineered with the oscilloscope as the reference and by means of strategically well placed capacitors and positive as well as negative feedback it is forced into good square and sine behaviour. The signal at the plate of the upper input triode are distorted beyond recognition, but then later forced into a square again. This is bad engineering from an audio sonic point of view, but it is a master stroke if you want to design a lab/industrial power amp for test purpose. And this is exactly what Burwen was doing. Keep in mind that this amplifier was meant for use as a power source of low distorted sine and square signals, for vibrating and power test in the audio range. And this task are well accomplished.

I have discussed the amplifier slightly with Dick Burwen and he told me that the limiting factor back then, when it was designed, was the OPT. He wished he could had used some of the later available, like McinTosh's.
Never the less we need to lift the hat to these impressive figures – probably the lowest on any valve power amplifier design.
BTW, Dich Burwen hates valve amplifiers and considers them as – I quote. " A vacuum tube amplifier should really be regarded as a nice piece of furniture with wires, that glows in the dark"
He he….mine sure does…

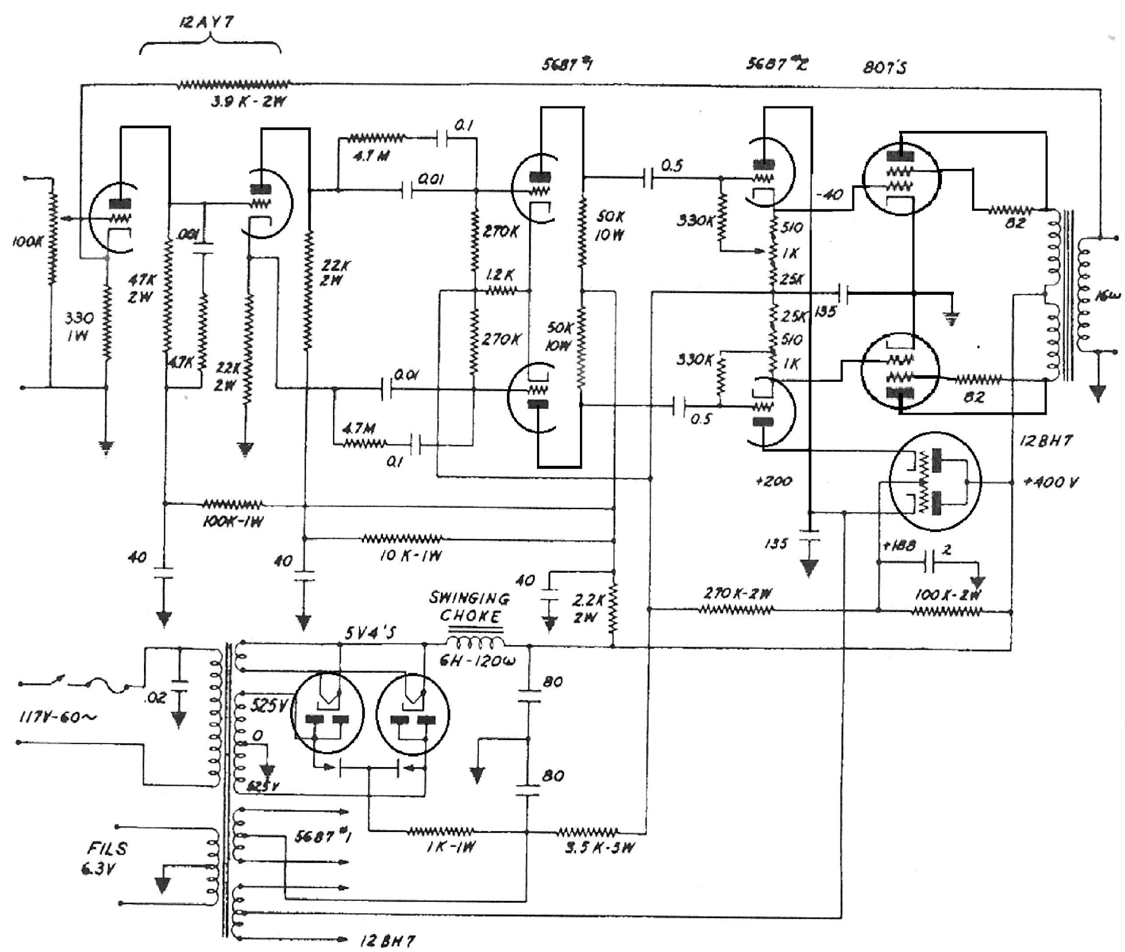


A.J.Andrieu, EL34PP, 1954

This amplifier appeared in the French “Revue du Son” , marc , 1954. I dont know why it is drawn in that silly way, but if you look at it carefully you will spot the well known Williamson. Why then – you might ask, do I want it here. Well, this is a very clever Williamson design and no means were spared over quality. It is a full Williamson with two power full output valves and two power supplies, yet Monsieur Andrieu was only heading for 7,5W class A. But there is more to this amp than quality over quantity. The first input triode are active biased via the current loop at the GZ31 PSU. I do not quite understand why this should be a necessity , but it provides “high gain” (6J5=6SN7= u20) and it allows feedback to the full cathode resistor. Note that as a result there is also a DC potential of a few Volts at the grid of this valve and there ought to be an input capacitor incorporated. The input 6J5 are AC coupled to the phase splitter EL42 with a 100nF cap. This allows higher Voltage at the first triode, but introduce some phase shift as well. Capacitor phase shift means nothing in a non feedback amplifier, but it limits the possible amount of global feedback. The two PSU is a luxury method of Voltage supply isolation. Here the first two stages are completely isolated from the driver/output stage.

The clever thing about this amp is actually the phase splitter. EL42 is a low microphonic small rim-lock base 6 Watt’s power pentode. Here it is triode coupled, which means that due to the high current and low ri compared to a regular 6SN7, ECC82 or so, the split resistors can be made very small. In this design they are only 1k Ohms, which is a fraction of the usual 22-100k Ohms. By means of this little trick the capacitive influence of the AC balance , both with regards to frequency and HF linearity are practically eliminated. And it will drive the driver stage with ease. In other words the Concertino phase splitter are carried to its optimal limits. This is indeed a Williamson to talk about.

Bien fait, M. Andrieu.



Kiebert 45-watt amplifier.

(Suggested by yours truly)

Kiebert's 45 W Williamson, 1954,

Very cool designer – top class circuits – one of the few at my top 5 list. Yet , Kiebert is as good as unknown in the DIY community as well as else where…..This is sad in my opinion, because Kiebert was so much ahead of the others at the time and still to this day his circuits are way better than the 99%. I wonder why nobody discusses his circuits and why no one has copied or learned from these master class designs…?

Anyway – Kiebert was a hardcore Williamson fan. He did not use any of the values from the original circuit – he hardly used anything at all, except the circuit blocks. Kiebert was fast to spot the weaknesses in the components and feedback scheme of the Williamson, but also to recognize that the circuit itself was close to ideal. . When we look at the circuits of Kiebert we can actually sense that these are circuits of high technical insight and that they are very carefully designed. Nothing is random or made from what was at hand. Starting at the input, Kiebert uses a 100 k Ohm pot ! ..Now this is in the mid 1950's and some 30-40 years ahead in time. So much better that the usual 0.5 to 1 M or more, that was common way up to relative recent.. Then he uses the 12AY7 instead of the usual 12AX7. This alone improves all merits of the amplifier, from noise to freq response. Then a 5687 as driver, which provides a lot of headroom, in fact oceans of such compared to 12AX7, 12AT7, 6SN7 etc. This is indeed very clever and again way ahead from the usual at that time, even compared to 90% of todays driver topology. Kiebert always used 12AY7 as input and phase splitter, followed by a 5687 as the driver. This is a combination that I have learned to value and used from time to time myself. But Kiebert does not stop there. He really wants the power and juice out of that driver – hence the cathode follower…..same headroom 5687. And why not avoid the AC coupling, drive directly and bias at the same time….

Kiebert continues the tour de force and wants to hold that cathode follower tight by Voltage regulation from a 12BH7. Do also note the clever filament scheme, the use of swinging choke input, and two parallel 5V4/GZ34 for best possible regulation and soft start to prolong tube life. I wonder why he used the filter constants to bypass the plate resistor at the input and to the grids of the 5687. I am also a little puzzled by the 82 Ohm resistor at sg2 of the 807's. Why not a 100 Ohm ? But then with Kibert I just know there is a good reason and I won't question this. I am amused by the weird way Kiebert draws his circuits. Dont you just love these miles long resistors ? I have redrawn the circuit a little as it was kind of a mess….I spotted an error in the circuit while doing so, that I felt was amusing, hence I left it there….. Do you see it ?

I will give you a hint….Look at the PSU…..

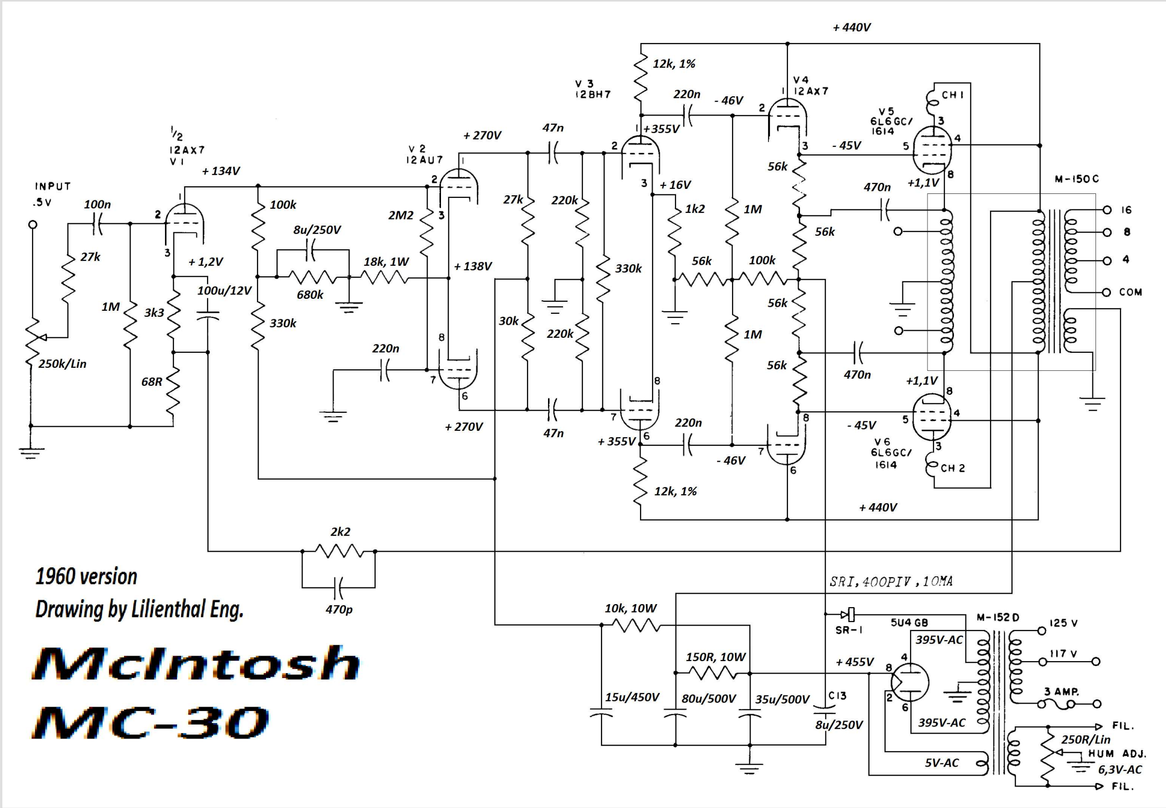
Yup , Kiebert uses solid state to supply the negative bias. That is good engineering too….Have you found the mistake….?……These two solid state diodes are turned 180 degrees….The negative side faces to the AC instead of the bias…. He he…..

Sadly this model is a class B design, however all we need to do is to adjust it in to the class A area and we are all flying.

Apparently Kiebert fancied the 807's as most of the designs I know from his hand uses these. He did make a 70 Watt 6146 PP and a 100 Watt 4 x 300B PP for BBC.
Kiebert took a few cool audio power amp patents in 1959 as well.

Kiebert you were a sleeper't, but now you are a keeber't……I hope that I have hereby printed your name into the modern audio society.

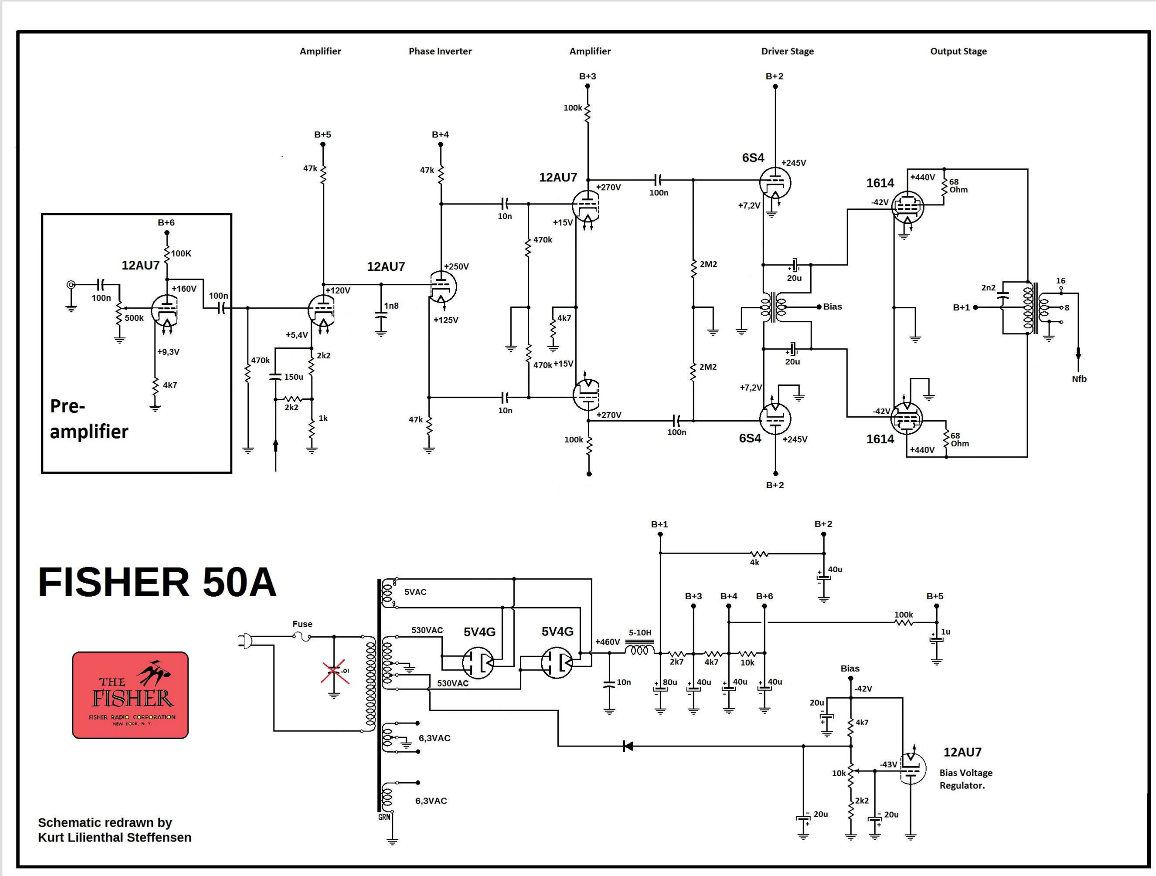
Hats off to Kiebert.



Mcintosh MC30, 6L6GC/1614, 1954

Frank McIntosh took the Unity Winding scheme to a further extreme with regards to feedback. For one reason or the other the MacIntosh team found it necessary to add inductors in series with the plate to avoid HF oscillations.This amplifier have positive feedback from OPT to the driver !. Mac uses a 12AX7 in the driver circuit – this is normally a “no go”, but in this case it is all right as he uses it coupled as a cathode follower. 12AX7 are not a bad CF, due to the high u. I would never use it , though…But there you go…

Not much more to say about this amplifier. If you want a class B amplifier with lots of feedback, I suppose this is good engineering. I personally like the earlier models better.



Fisher 50A, 1614 PP, 1954

As far as I know Fisher made 3 versions of this *all triode* coupled amplifier. The 55A being the last. The difference between model 50A and the 50AZ are minor. The 50AZ uses 6CL4's for the driver stage. The Fishers 50 series came with separate preamplifiers and tuners.

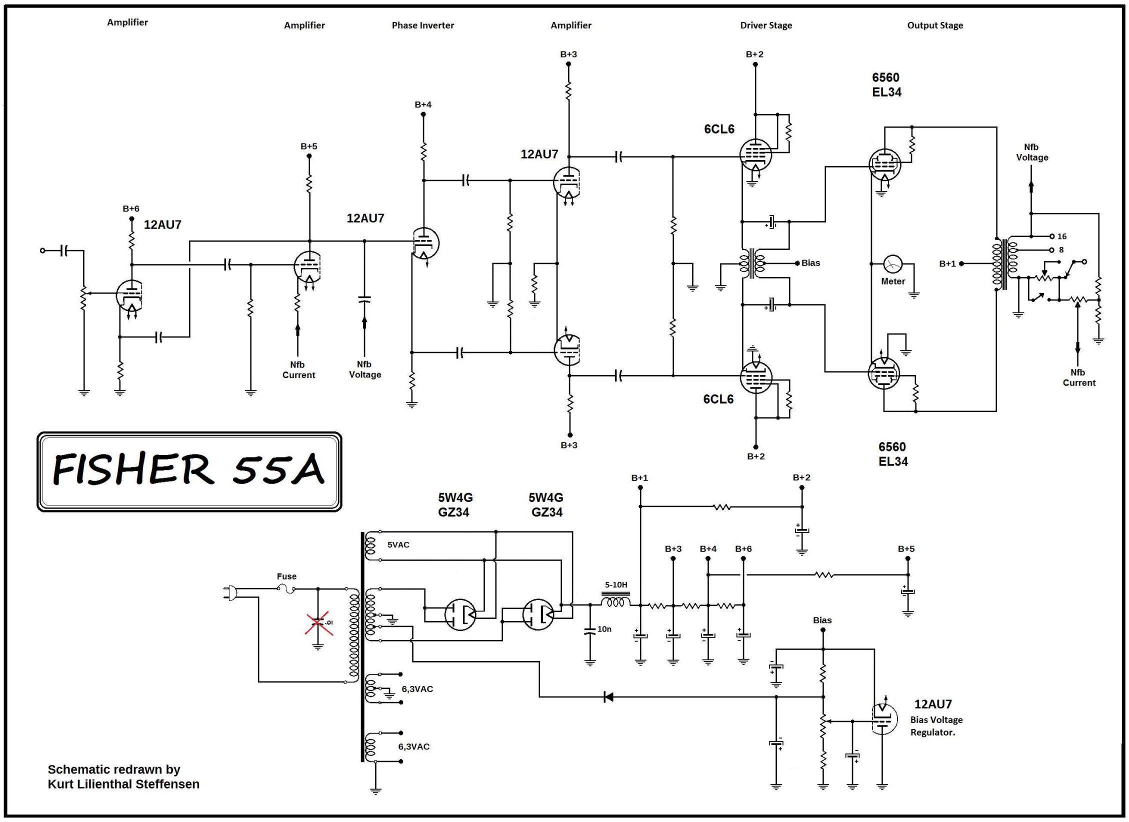
What we are looking at here is obviously a Williamson design, but it has a few unique details that parts it from the mainstream. The bias Voltage is regulated, which is very nice and unusual. But the best part is the interstage driver. It is a quite radical solution, as the 1614's are not really difficult to drive, all though it does need a higher Voltage swing, being strapped as a triode . With a transformer it is possible to drive the 1614's,way in to the peaks of class B if needed. By placing the transformer at the cathodes of the two 6S4's the output impedance of these is very low. This means that the transformer will be delivering its best and current in plenty to feed the hungry grids of a class AB2 or B stage. I will reveal one of my "secret tricks" here. If you want to learn how to get the best of a class A amplifier, learn how make a class B amplifier. All the tricks in the book for class B, translates to high quality when used in a class A application. All of them !

Pix from: www.soundup.ru

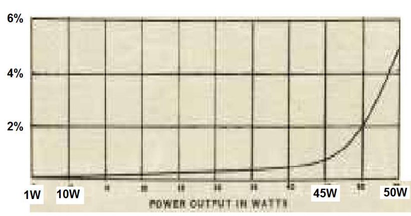
The feedback network to the cathode of the 12AU7 is quite weird. The series combination of the 150u and the 2k2 is in parallel with the 2k2 cathode resistor, which means that the feedback signal to the 1k is distributed between these. This means that further phase shift takes place as far as I can tell. I will need to investigate that a little closer one day. If you have any bids on the course of this network, please do not hesitate to drop me a mail.

The 1614 are metal envelope tubes, rather similar to 6L6. I personally prefer the later glass types.The two 5V4G rectifiers maintains a stiff and low z power supply. Note the choke input that regulates well, just as it smooths and cleans up. Very good engineering indeed.

The “extra” pre-amplifier that I have framed does not do any good in a modern world of line level signals. I would simply skip it. I would also suggest that a 12AX7 or pentode would do a better job as the bias regulator, due to higher gain. This could be a 6AV6, 8AV6 or 12AV6.(Different heater Voltage) These are all single 12AX7 triodes with a pair of diodes. Maybe it would actually be possible to make use of these diodes for the bias Voltage ?



Intermodulation distortion, less than 2% at 50W, 0,8% at 45W , 0,4% at 10W . (Measured 40 Hz/7000 Hz - 4:1)



Fisher 55A , 6550/EL34 PP, 1956?

The 55A is pretty much the same as the 50's. But the differences plays a major role. First we note the input is different. There is feedback from the plate of the second 12AU7 triode to the cathode of the first input triode. Then we note the popular variable power damping feature of the early 1950's. This means the a small part of the current signal is feedback to the cathode of the second triode. This triode is grounded via the fb network at the output. Further there is Voltage fb from the 16 Ω tap to the grid of the phase splitter.

As much as I like the current/Voltage fb approach, a thing I call "Power Feedback" *, but you may call it whatever you prefer – as much do I worry about *feedback inside feedback*. Perhaps loops within loops is a better term. In the 55A the Voltage fb to the grid of the phase splitter is also fed back to the cathode of the input, hence it introduces a "false" signal that is again fed forward and returned and so on. This means a complex distortion phenomenons, that does not show up in a regular THD test. It may however be found in a spectrum analysis as high order harmonics in orders of say the 9'th to as high as the 100'th or more. I have not heard this Fisher 55A and the intermodulation data above, indicate that Fisher to some degree had it under control. I would however suggest – at least to experiment with removing the first input triode, thus the fb to this. Feedback is not an absolute science in my opinion, as we do not yet know how to evaluate the complex signal we know as music. The power feedback may also benefit from some experimentations in the form of trial and errors , as it is so complex and case sensitive. This applies to any amplifier in my opinion.

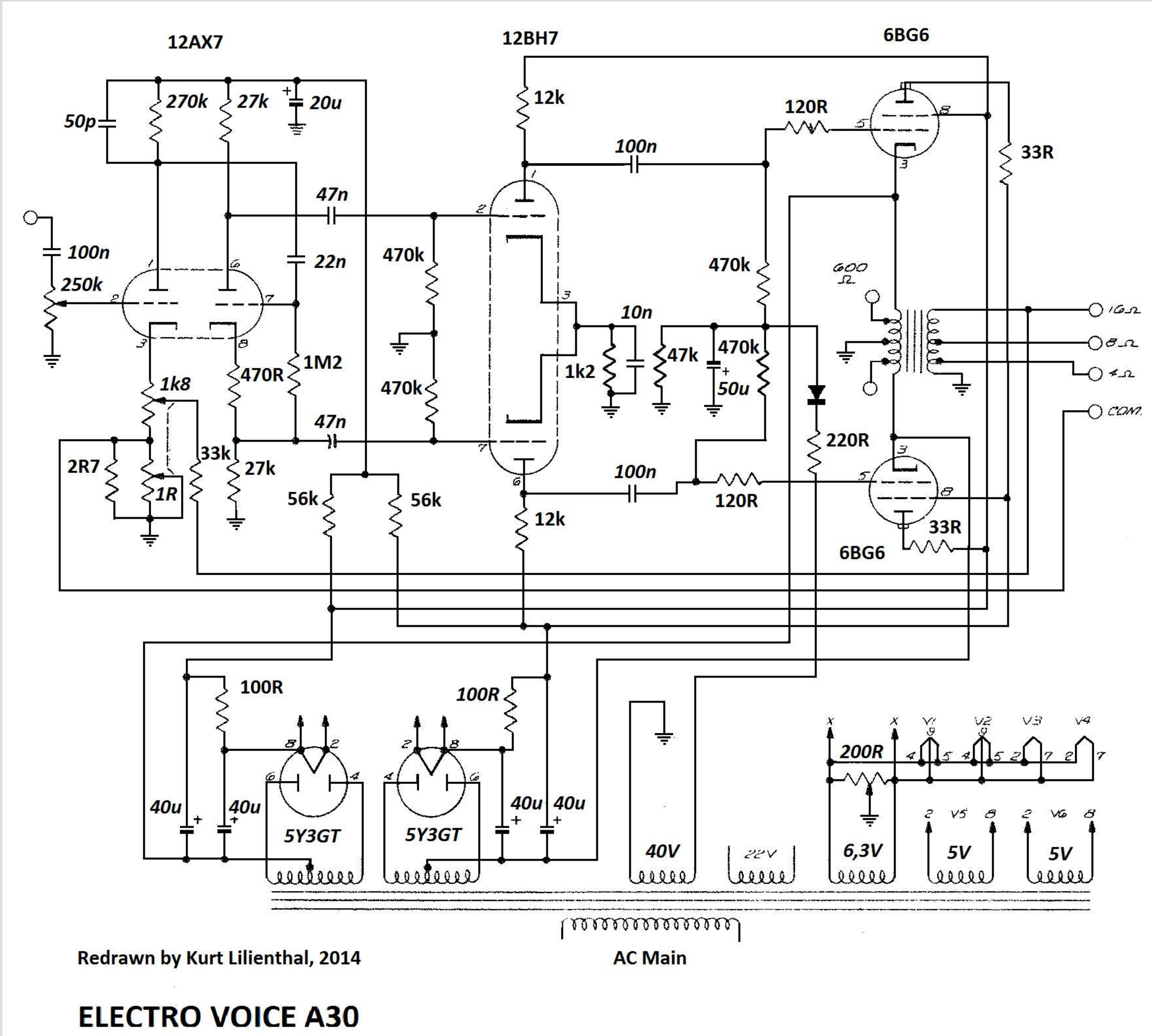
Do also note that the HF canceling capacitor over the primary winding at the OPT is now removed. Possible due to the new fb scheme or a better OPT. (Or both)

The driver tubes in the 55A are changed once again, these are now a pair of triode coupled 6CL6's. The output tubes is a pair triode of coupled 6550's or EL34's. Fisher recommended both. The parallel rectifier's is 5W4G's or GZ34's, also per Fisher's advice..

The output tubes are grounded via the small resistor in the current monitoring meter. It is a neat feature to be able to read the current when adjusting bias, but it is relatively useless as it only measures the total current of the two tubes. It does not tell if there is any *difference* between the two tubes. I always recommend to use a resistor of 1-10 Ohm at each individual cathode leg of the output tubes.

I really like the ingenuity of the Fisher 50 series and I feel they are well worth some effort in experimentations. Certainly they are good templates for an extra high quality audio amplifier.

Hats off to the fishermen.



Electro Voice A-30, 6BG6 PP, 1954

The Circlotron by Alpha Wiggins (Now, thats a name..) of Electro Voice. The A-series of power amplifiers made by E.V. in the 1950's are good examples of the innovation during the aftermath of WW2. Damping factor control via current feedback and a number of ways to incorporate the OPT into local feedback or simply distributing the load via the cathodes and/or the screen grid was popular in the 1950's. Electro Voice made use of DF control and Cathode loaded OPT. But they brought the CF loading scheme a little further by the use of the so called "Circlotron".

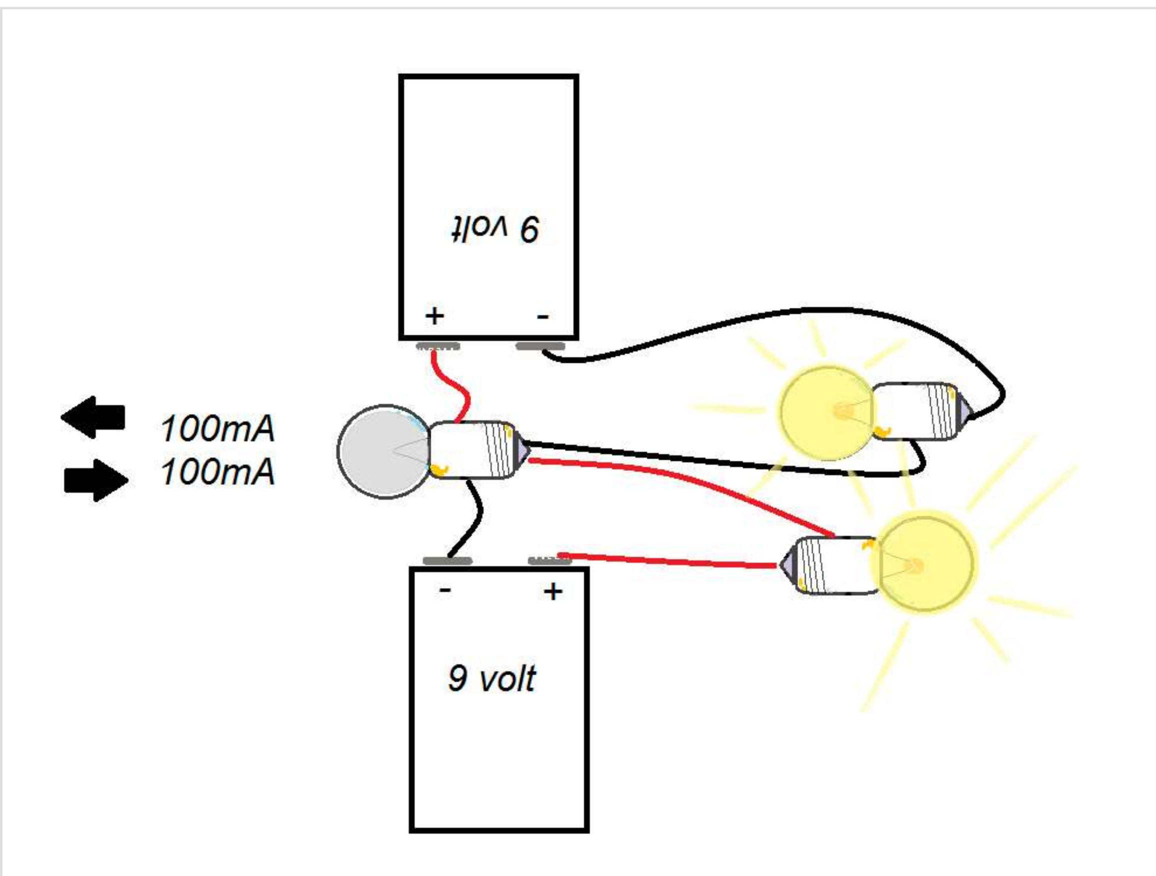
The Circlotron is a bright circuit. The use of separate power supplies for the two output tubes allows the two current loops to be braided with one another via the load (OPT or speaker) , hence acting in parallel AC-vice. The major advantage of this is that the load needs only be 25% of that of a conventional power stage, of which the output tubes works in series. A pair of 6BG6 operated in a traditional PP configuration would need a load of say 8000 Ohms plate to plate, but as a Circlotron only 2000 Ohms or less.(EV loaded them with 1000-1600 Ohms) This allows us to wind a better output transformer as the winding turns ratio is equally lower. But there is yet another advantage of the Circlotron. The entire primary winding represents a full load to both tubes as the circuit is a common bridge. This means that signal current will always pass the full primary, hence no switching issues can occur. This spells good transient response as well as the best suitable class B design – to the best of my knowledge. It is often claimed that the Circlotron is only good for class B. This is not true. *The Circlotron is equally good in any class of operation*. I will dig much further into this clever circuit in a dedicated DIY article later on.

The A-30 is a conventional Williamson design, however with Circlotron output and DF control. The output stage are operated in the area between class AB2 and B.

The 12AX7 and 12BH7 Williamson design was used in the entire A series of E.V. down to the very values of each component.

There is two to three versions of this amplifier. The early ones had 6BG6's at the output, later models were swapped to 1614. (Similar to 807)

The E.V. A-series: (Numbers refers to power out in Watt's)
A15: 2 x EL84
A20: 2 x 6V6
A30: 2 x 6BG6, 1614 or 807
A50: 2 x 6550
A100: 4 x 6550
A430: 2 x 6BG6



Circlotron explained.

The two PSU leads current into the transformer from opposite directions, thereby cancelling the current in the transformer. It sounds a little weird and might look a little weird too – but it is actually quite simple. Now imagine that we connect a battery to a lamp. The lamp will draw current from the battery and by such it will lighten up. The current is said to run from + to – . If we connect a battery more – 100% like the first, only with *opposite* polarisation a current of the exact same magnitude will run in the opposite direction, meaning no Voltage difference, hence NO current. (+ 100ma – 100mA) = 0 mA.

As these two "forces" are 100% equal they will cancel one another and the lamp will no longer lighten up. In the case of a circlotron we must imagine that the tubes are in series with the batteries, here shown as the lighting lamps and that the dark lamp is the output transformer. Hence, no current passes through the transformer. The Circlotron circuit is not quite as simple as the batteries and lamps illustration, but the principle is spot on the same.

The purpose of removing DC currents from the OPT is that it allows us to make a better transformer or at least make better use of the one we have. In a conventional Push Pull configuration the tubes works in *series* from a signal point of view. This means that the load must be twice that of a single tube. In case of the Circlotron the two tubes works in *parallel* , meaning half the load of a single tube or 25% that of the load for a traditional Push Pull series arrangement. The Circlotron seems to be used only as a cathode loaded amplifier. I have no idea why, as it may just as well be implemented as a plate loaded amplifier.

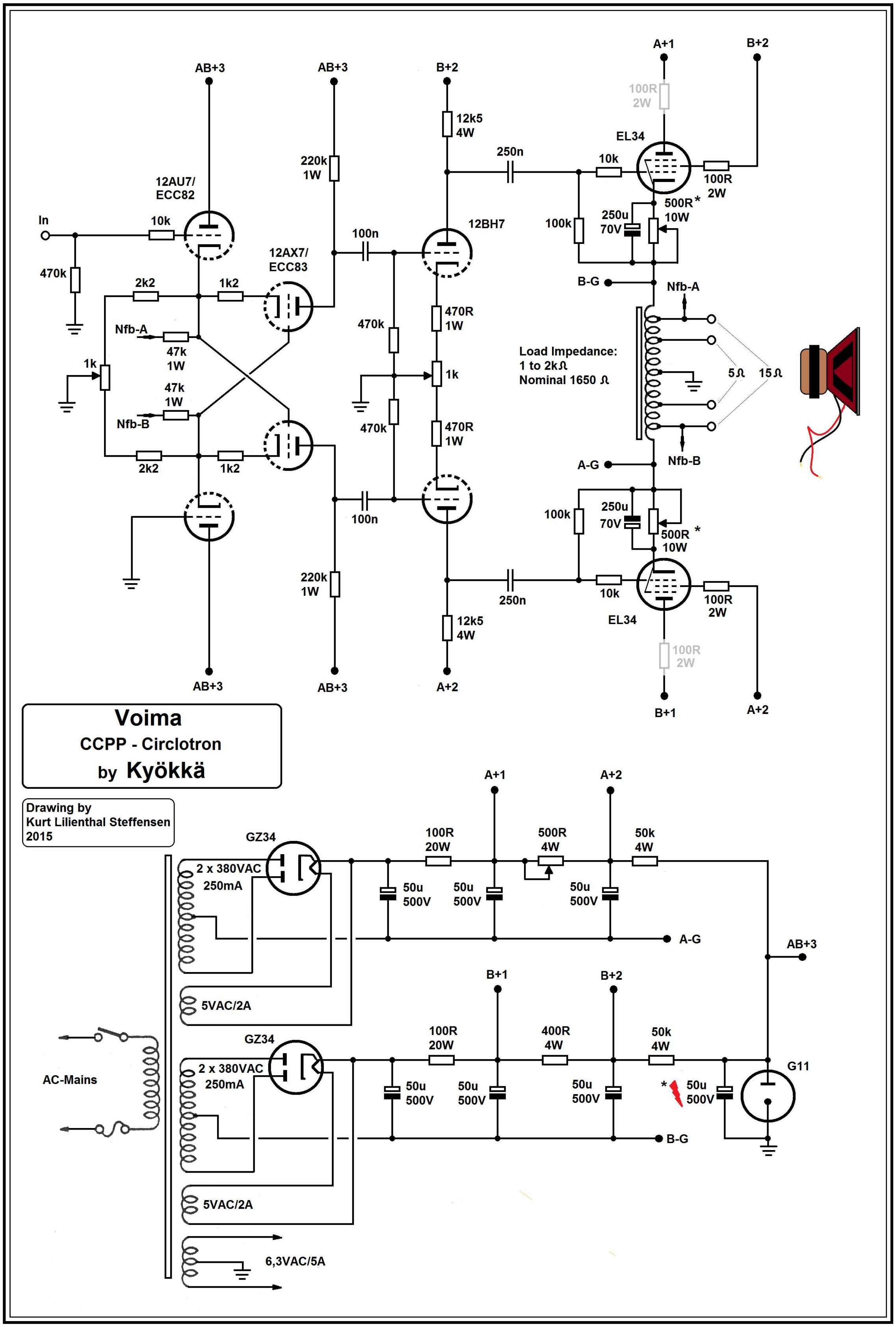
In many ways the circuit is similar to the Philips PPP, Sinclair Peterson, Futterman, Coulter etc. As Thorbjørn Lien from Norway pointed out in a discussion we had, Frank MacIntosh makes a similar trick , only with one single PSU.
In my opinion the Circlotron circuits are the best we know for OTL amplifiers, but dangerous to the speakers in case of failure.

Wiggins was not the only one that happened to think in the terms of a "currentless" bridged output transformer. We know that at least two other patents based on that idea was filed in that period.

Cecil T. Hall was the first to apply: June 7, 1951. This was granted, thus published March 29, 1955
US Pat no: 2705265
Tapio M. Köykkä, Finland applied Sep 2, 1952 and was granted and published Nov 10, 1954
Finnish Pat no: 27 223
Alpha M. Wiggins applied March 1, 1954 and was granted/published march 25, 1958
US pat n.O 2828 369
Update: I have recently learned that in 1953 two years after Koykka had filed his patent, he published the circuit in the German Funktechnik 7/1953. That lead to an attractive job offer from Westinghouse as well as a request for a license by Electro Voice (Wiggins). Koykka thanked no to the Westinghouse job, but granted the license to Electro Voice only to find that the following year Wiggins himself applied for a patent covering that circuit in USA. What a gentleman !
Anyway , Wiggins gave the circuit that simple name that allows us to distinguish this particular circuit from other similar circuits. Wiggins later on learned that Hall was in fact the first to apply for

a patent and he had to settle for an agreement with Hall. Koykka never got a dime. Koykka's patent was only valid in Scandinavia.

More can be learned about this inventive and brilliant mind at: http://www.kolumbus.fi/epap/voimaradio/



~~**VOIMA cinema amplifier by T.M. Köykkä, Finland, EL34 PP, ca. 1958-60**~~

UPDATE, March 28.

As of writing, I am no longer sure that this design is indeed by Koykka !
I have four sources of this schematic with minor or no differences. None of the sources offers any documentation or reference. It appeared in the German magazine "Funkschau" 1960 No.9 as "PPP Kinoverstärker mit kreuz gekoppelter Vorstufe" , but no further identification. What is written below is still valid, only I doubt the amplifier is designed by Koykka. I will update as soon as I know more.

This is indeed a BEAUTIFUL and captivating design. Much better than the Electro Voice circuits. Balanced feedback to the balanced phase splitter (As it should be, but often is not) and possible the most astute use of the grounded OPT. (Tapped autotransformer) Stunning symmetry from a single end input signal. This is SO clever and simple.

The impedance of the OPT shall be some 1000 to 2000 Ω. The exact value is not critical.

There is a few issues to this almost perfect design worth to mention.

1) The 50u capacitor shunting the Voltage reg. G11 , is a very bad idea. It will decrease the lifespan of the G11 drastically and It may lead to oscillations and all sorts of problems. It may have been an error at the schematic I have at hand, as a *small* capacitor may be fine. (50n may be all right, but go for as small value as possible or none at all) The capacitor will cancel noise.

2) The 500Ω cathode potentiometer of the EL34's should be replaced by a fixed value (2-300) and a pot.(2-300) in order to avoid adjustment into the high current area.

3) I would also question the 100R resistors in series with the plates of the EL34's. I do not know why Koykka wanted it here, but I suspect in order to prevent runaway. A better approach is cancel this resistor and instead increase the sg2 resistor to some 220-470 Ω.

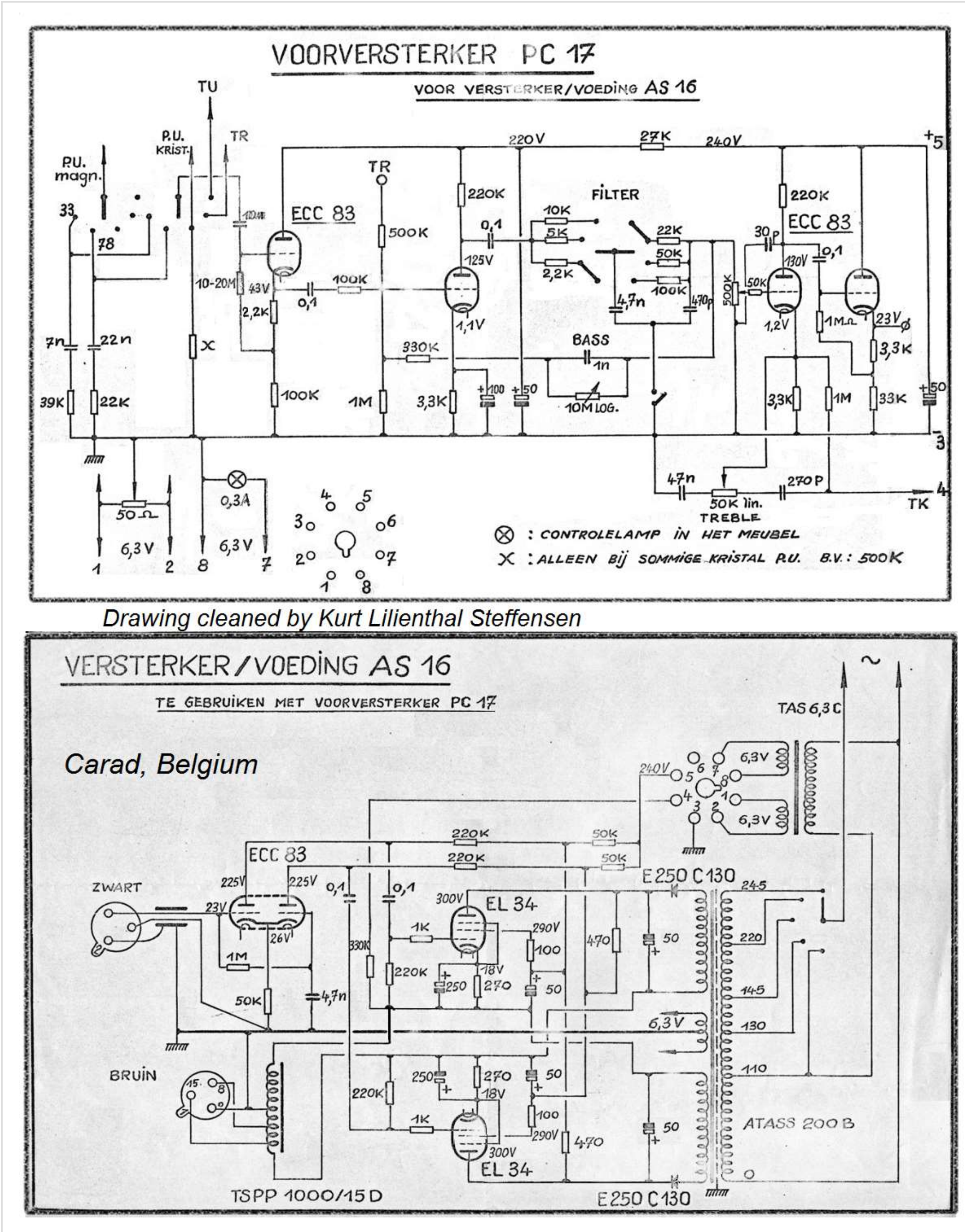
It would recommend smoothing chokes in place of the 100R/20W resistors. Whilst we are at it perhaps a full DC-coupled CCPP ala´ White's Powrtron. (In order to get rid of the ECC83 , that does not fit well into my ears) I would maintain the 12BH7 driver.

Koykka made several variations over this amplifier. Some used ECC85 as input valve, multi tapped OPT and so on. The Voima amplifiers are very rare as few was build. Koykka supplied the market in Finland and most likely had some export to Russia. (I have seen some of his schematics with Cyrillic markings)

Koykka probably would not mind me calling his design for Circlotron. I think the name is good, because we all know the specific circuit it refers to. PPP does not implicit calls for two PSU – Circlotron does.

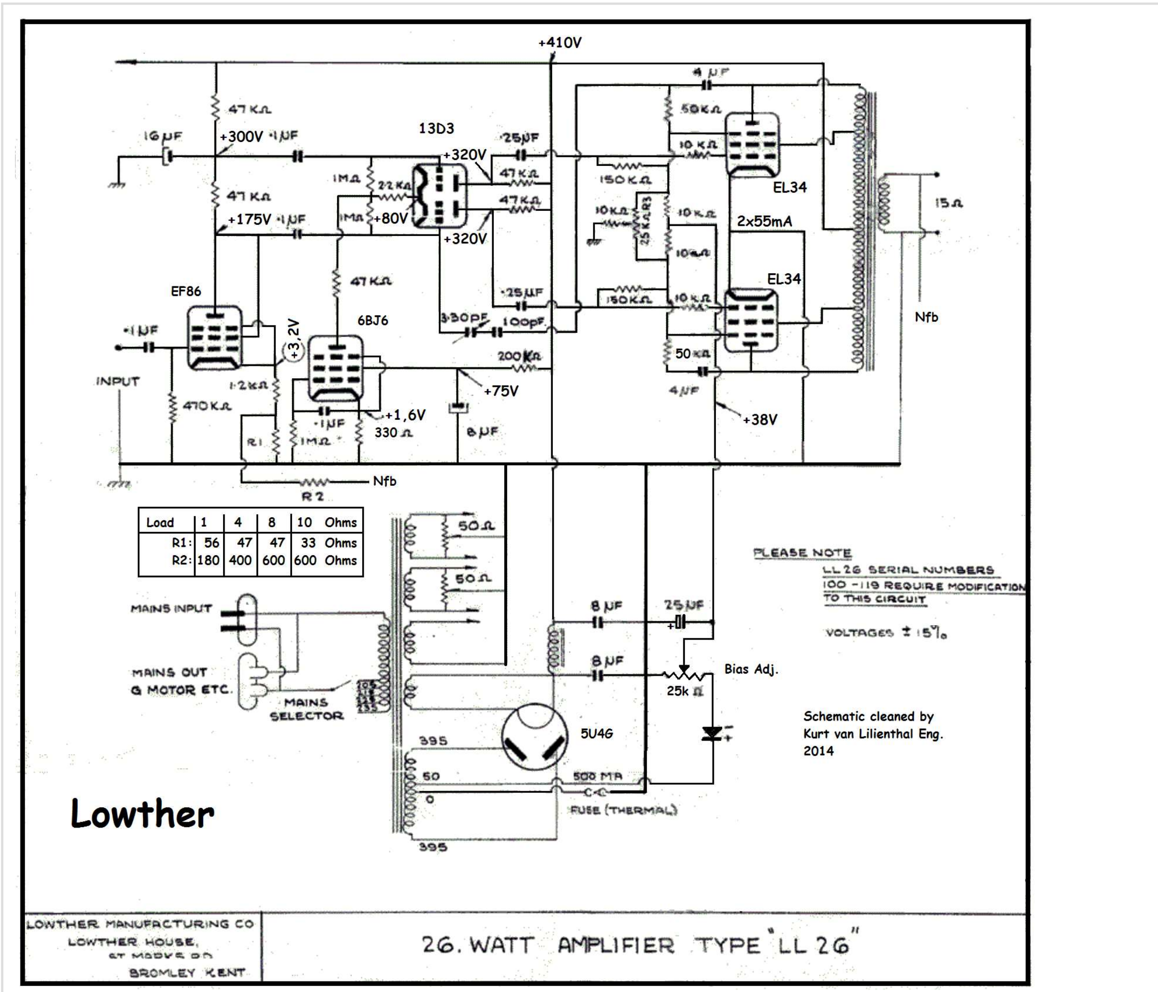
Hats of to T.M. Köykkä, gentlemen……………..

Here is another typical, but little known circuit from the golden days of PPP/Circlotron.



Carad Radiogram , EL34 PPP , ca 1960

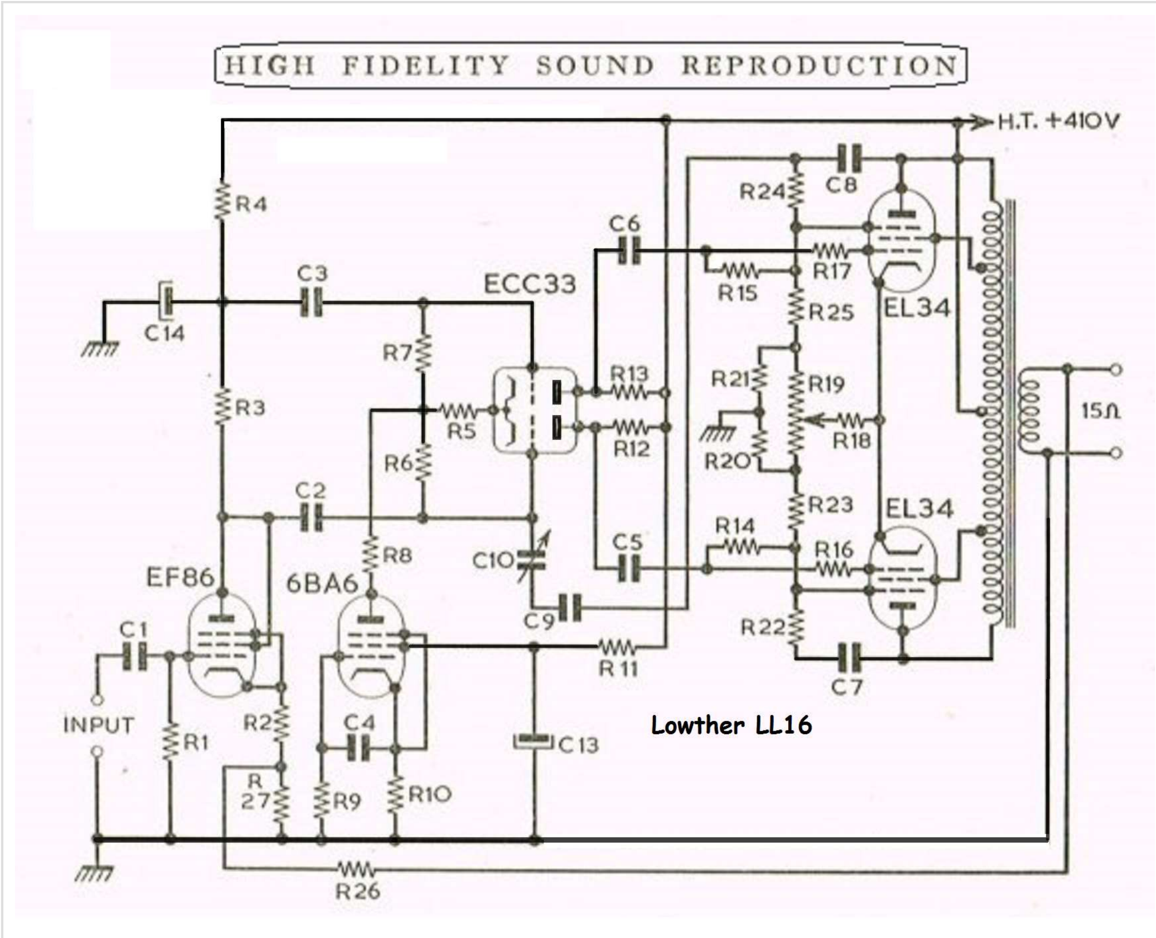
Carad was located in Belgium and produced a number of products for audio, but are probably best known for their production of components, such as switches. I have kept the pre-amplifier simply because the second ECC83 is part of the power amplifier. It provides bias to the phase splitter by means of the direct coupling. Apropos note the CF input for pick up. That is very unusual and it is merely a impedance changer. The upper high freq of this amplifier is sadly limited by the ECC83 driver, that will begin to fall already below 20 kHz, due to its high z-out. The output transformer (Tapped auto) may be wound to go well beyond 200 kHz.



Lowther LL26 , EL34PP , 1959

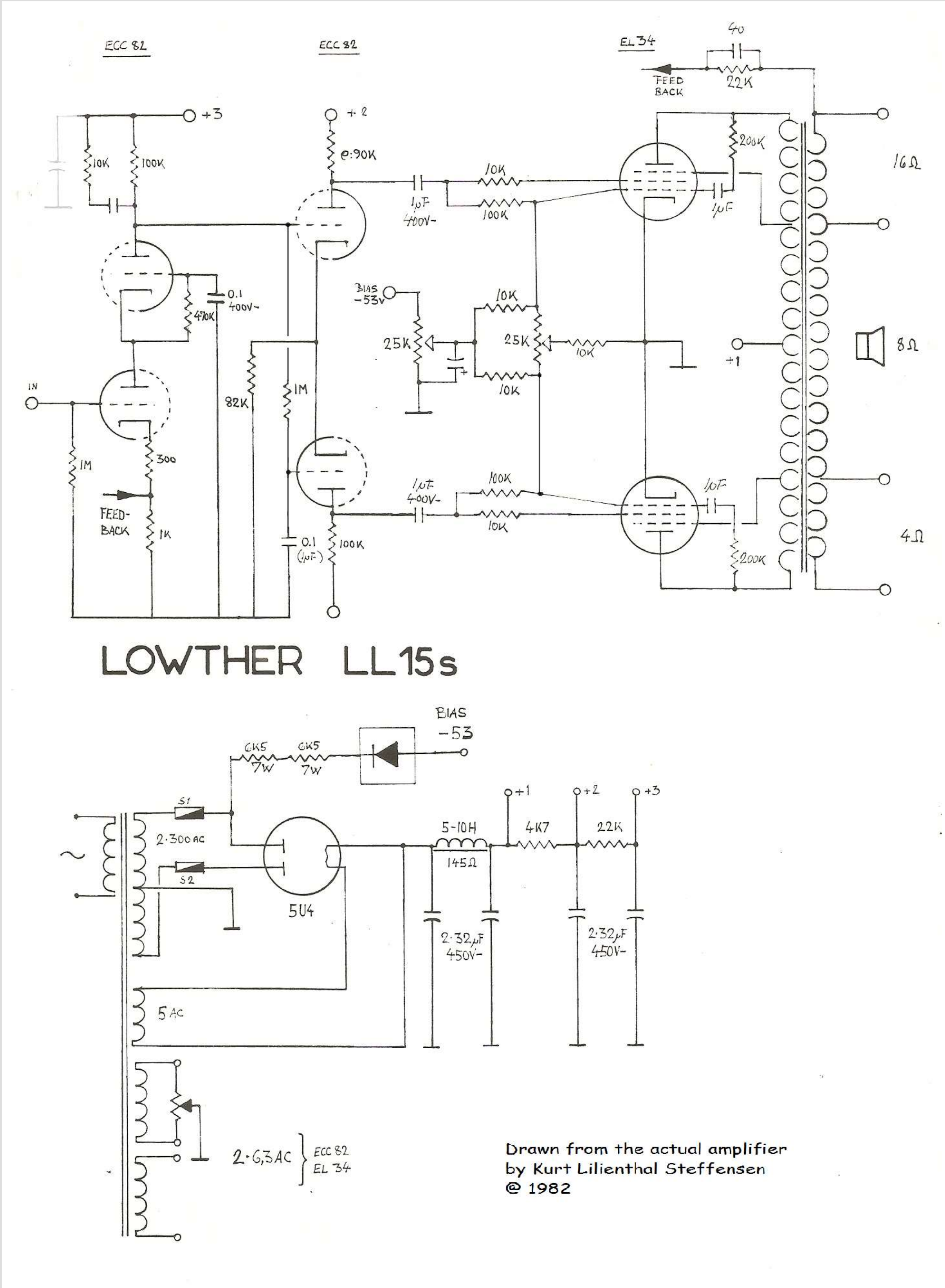
Lowther Voight are best known for their famous PM 2, -4, -6 loudspeakers, but they actually made quite a few amplifiers as well.
Paul Voight (1901-1981) began his career at JE Hough ltd. in 1922 and already then he developed several speaker units of which the later models are based. In the midst 1930's Voight met with O.P. Lowther and they formed the Lowther Voight cooperation. It has not been possible for me to find schematics for the early 1930's Lowther amplifiers , but I have a few diagrams from the 1950's production.

The LL16 and 26 is the familiar Mullard 520 circuit, but they differs in one or two significant aspects. The first thing we notice is that the input pentodes is triode-coupled. This is not a major change, but it improves the sonic quality over the 520 by quite a margin. Next thing to notice it the long tail /Schmidt phase splitter with a pentode current sink. These two little details in combination drastically improves the Mullard 520 circuit in my opinion.



Lowther LL16, EL34 PP, 1955

The LL16 is almost a clone of the LL26 and the same comments apply here .



Lowther LL15, EL34 PP, 1959

The LL15 is quite similar to the Mullard 520, but instead of the input pentode, Lowther decided to use a cascoded ECC82. The AC unbalance are here kept under control by the means of different anode resistors at the driver. Quite nice – I had this amplifier several decades ago, but I cant remember in detail how it sounded. I may have tweaked and played with it – it is all in the mist. Anyway, it went to a better home as new adventures kept coming in those days.

This concludes part 1 of “100 amplifiers..” , so far – but I often add new material or edit the articles.

If you have found any errors, bad language or stupid postulates for my part or would otherwise comment on this project, please, feel free to drop me an email. (100amplifiers “at” gmail.com)

Thank you for reading.

Please go to part 2: http://lilienthalengineering.com/audio-transformers-and-coils/100-amplifiers-part-2-1955-78