Refurbishment Report
of a
Roost / Funkshun Dual Drive
Tube Amplifier

From Martin Schweizer

<u>Safety hint:</u>
All tube amps could have dangerously high voltages inside. Even if they are switched OFF or disconnected from power line. Do not attempt to work on live equipment without proper training. If you have no experience or any basic knowledge on high voltage circuit, ask for support from an experienced expert.

17.09.2021 Vaihingen an der Enz

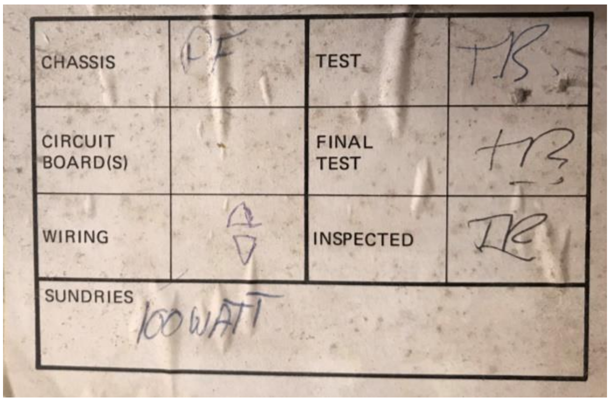
Funkshun Dual Drive

"Funkshun amps were made by Roost, Southend on Sea, England. They can be recognised by the near unique fibre laminated wood cabinets with fibre angle riveted on all edges. A limited run of these amps was made by Roost for sale by the Funkshun music shop in Northampton. The production is rumoured to be about 50 units. Late 1970s to early 1980s." [Source: https://jedistar.com/funkshun/]

The Model under investigation is a one channel amp head with the possibility of harmonic overdrive of the 2nd tube stage (DRIVE). With a foot switch an adjustable boost (OVERDRIVE) of the overdrive can be added. No Reverb which is available at other variants of the Funkshun.

Serial number: CV 002
On the power transformer there is a marker giving a hint to October 1978.

It is the 100Watt model with a quad of EL34 in the output stage. The initials T.B. give the hint that Terry Bateman was the one who tested and inspected the amp.



Problem description:
The amp is not operating after being in stock for several years in an old barn.

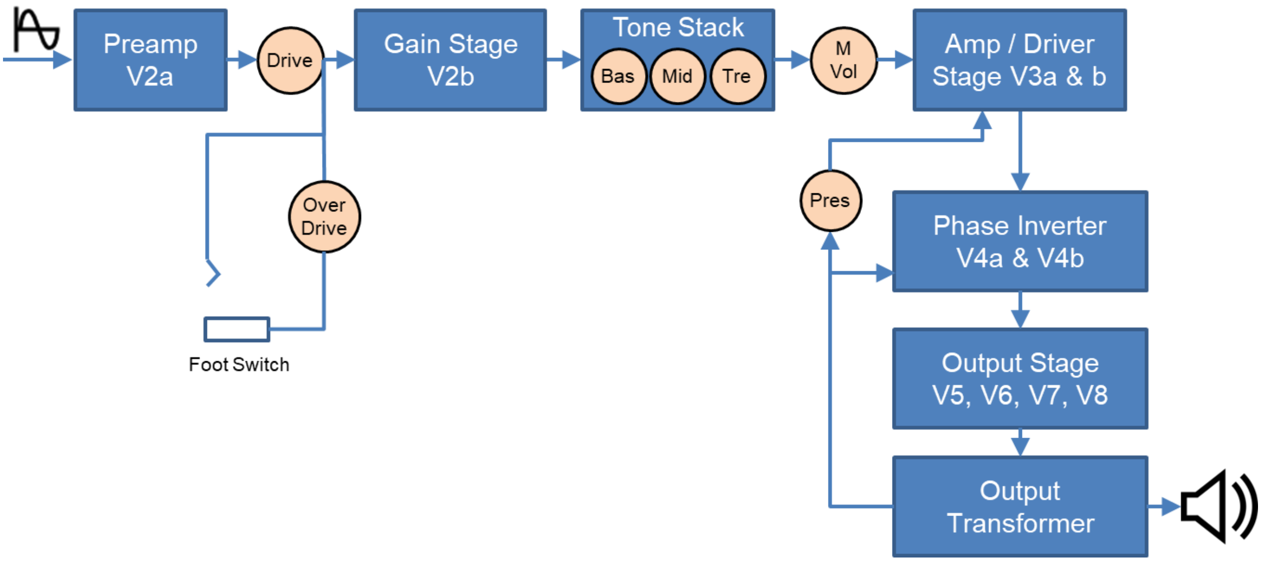
Content

1. Schematic

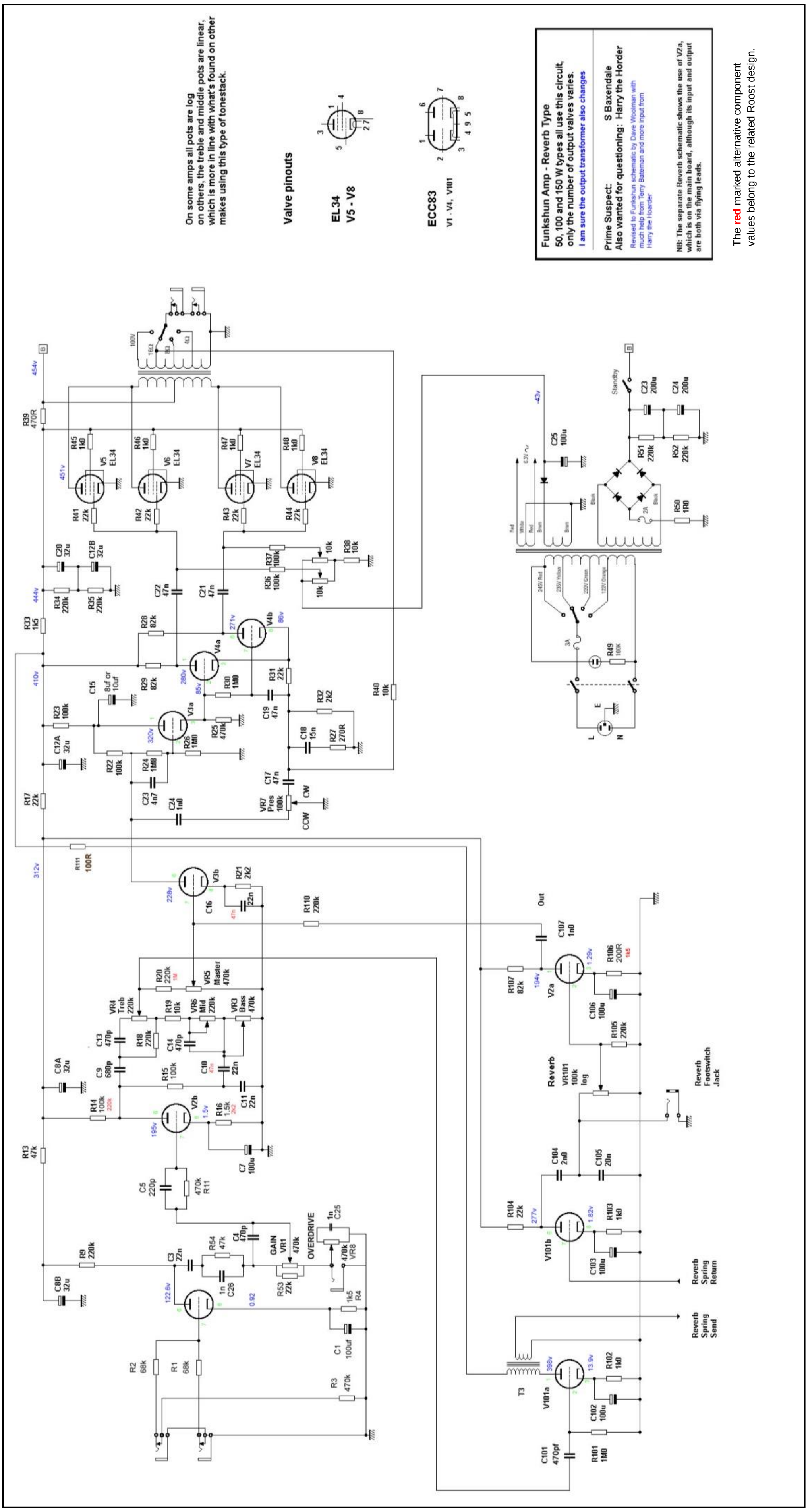
1.1. Block diagram of circuit

The model under investigation is a one channel amp with two inputs. A HIGH gain input normally for guitars and LOW gain input breaking down the amplitude of an input signal to half. The possibility of harmonic overdrive of the 2nd tube stage can be adjusted (DRIVE). An additional boost (OVERDRIVE) of the overdrive can be added. This additional boost can be switched ON and OFF with a foot switch. No Reverb which is available at other variants of the Funkshun Dual Drive.

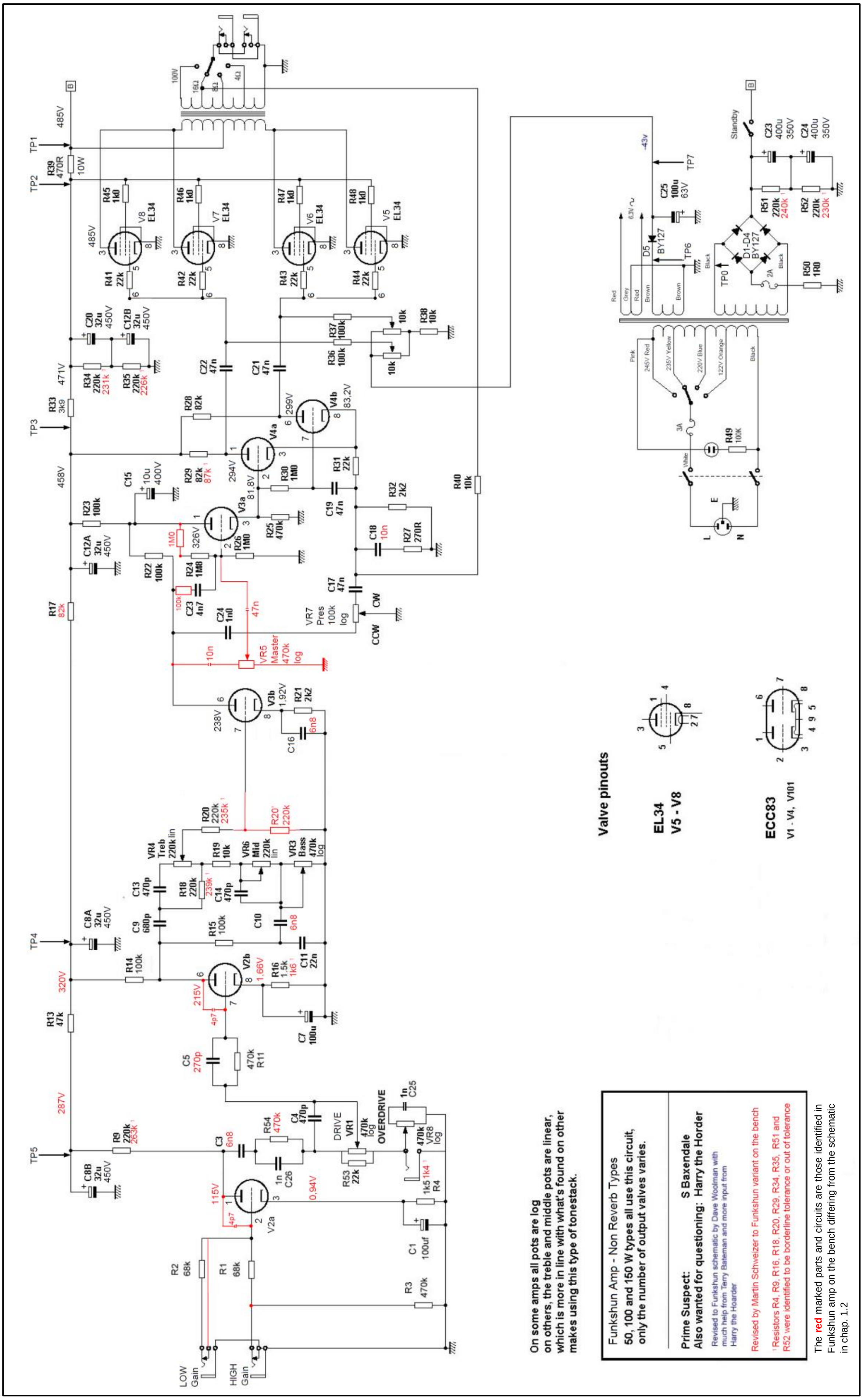
A schematic for the Funkshun Dual Drive is available in the world-wide web at:
1.) https://www.tube-town.de/ttforum/index.php/topic,20564.msg208310.html#msg208310
2.) http://forum.metropoulos.net/viewtopic.php?t=26698
Be aware that there are also some people using the quite similar schematics from the Roost amplifier: e.g. https://www.tapatalk.com/groups/generalroostdiscussionforum/funkshun-100w-dual-drive-reverb-combo-schematic-t229.html?
In chap. 1.2 one of those schematics is shown. The basic circuit design is the same, as Roost is the manufacturer of the amp. At some places the values of the components slightly differ (red marked alternative component values). None of those schematics is exactly fitting to the Funkshun Dual Drive on the bench (without reverb). The schematic in chap. 1.3 shows the circuits of the amp on the bench how it came in with visible modifications. Chap. 1.20 finally shows the circuit of the Funkshun Dual Drive after finishing the refurbishment. Target of the refurbishing has been to rebuild the original state as much as possible. Only some minor modifications have been made.
Based on the schematic in Chap. 1.2 the basic circuit architecture is summarized in the following block diagram:

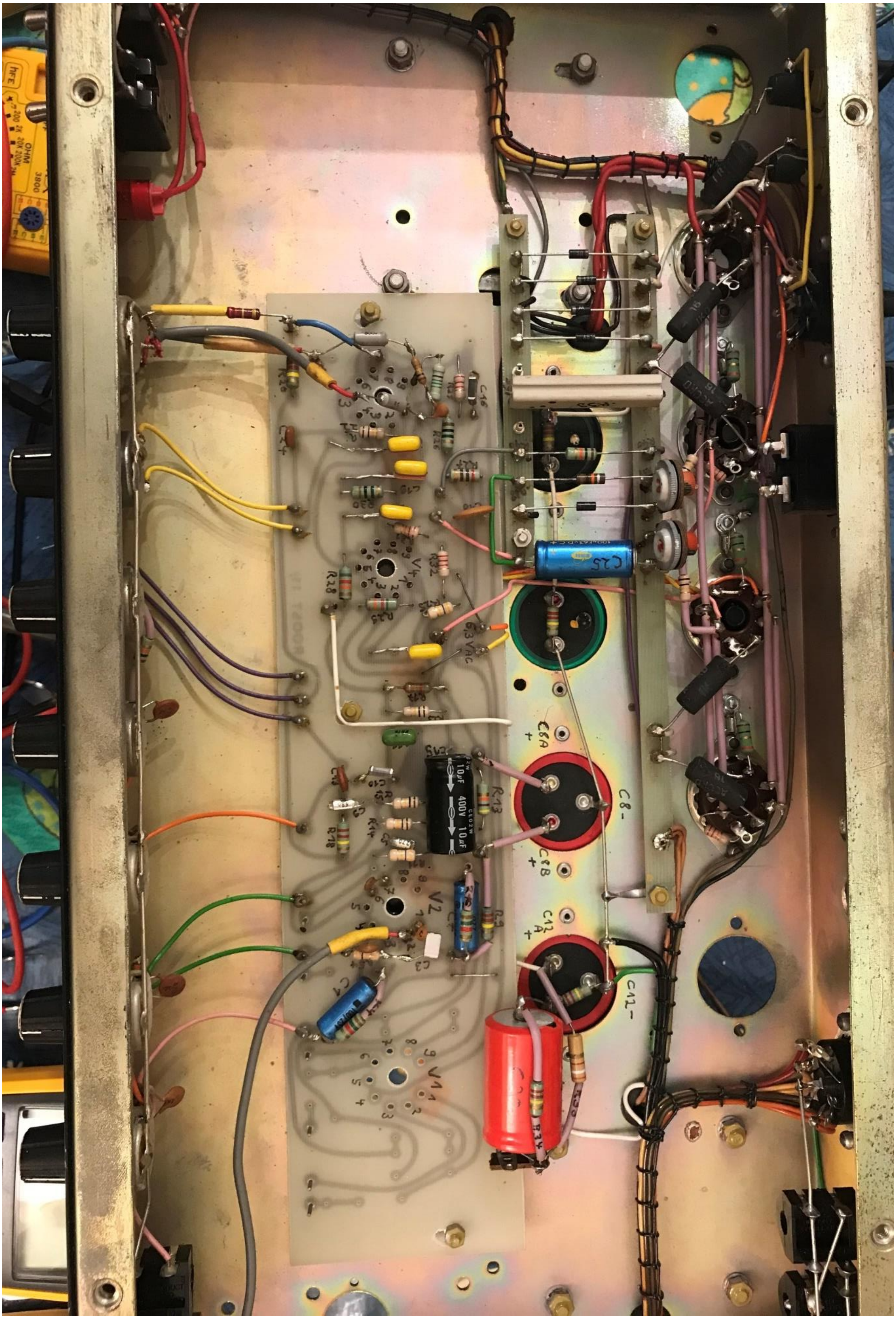


1.2. Schematic of Funkshun Dual Drive with Reverb



1.3. Schematic and Layout of Funkshun Dual Drive Like-it-was



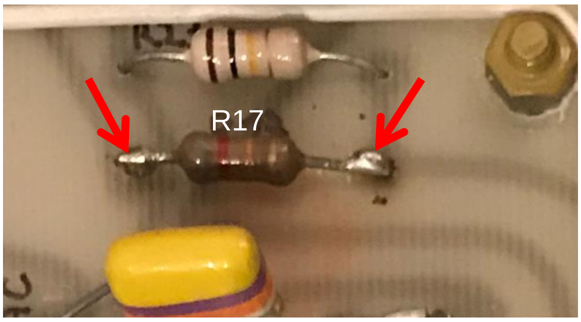

C8-
C12-
400V 10µF

1.4. High voltage DC Supply and Biasing of Preamp

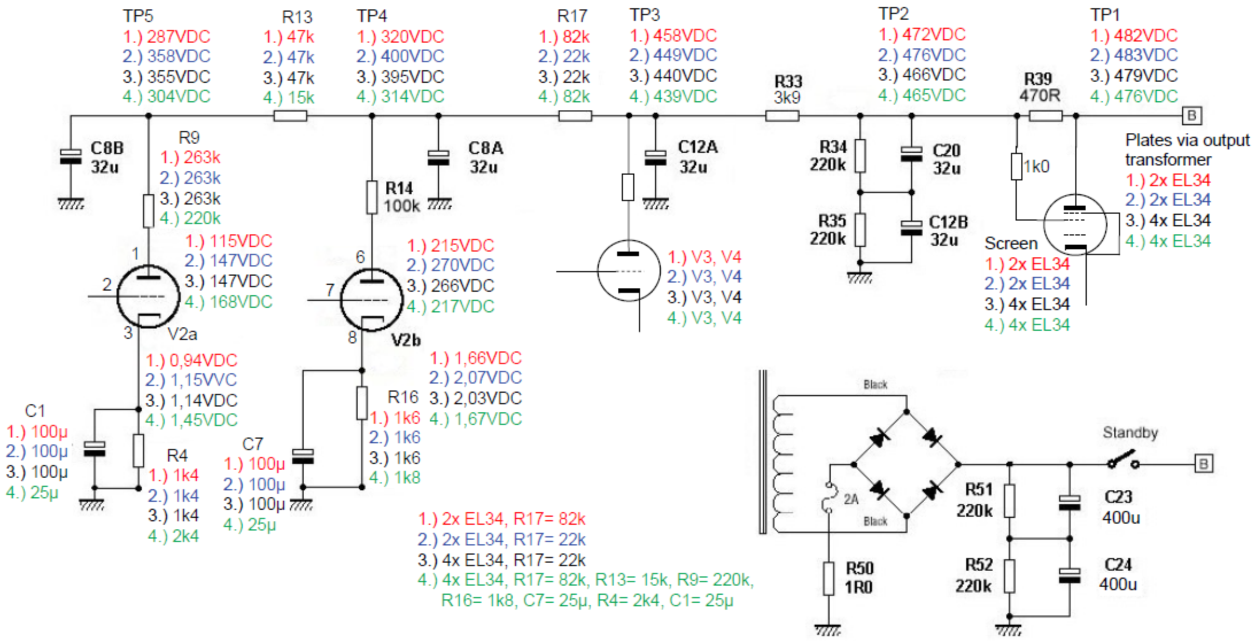
The DC high voltage will be provided by a full bridge solid state rectifier. To reduce the ripple on the supply voltage there are several filtering stages. The voltages used out of this chain have different values depending on the resistors and the current the single tube are pulling. And to make it more complex the current at each tube is depending on the applied voltage.

In the third stage the resistor R33 is differing from circuit drawings which could be found in WWW. Here instead of 1,5kΩ a 3,9kΩ value is equipped. As this looks like original equipped at the manufacturer, the reason for this difference must be the missing additional ECC83 triode powered from this stage in case of the Funkshun reverb variant. When the current of this driver triode for the reverb spring is missing R33 has to be enlarged to achieve the same voltage drop for the following filtering stage.

The resistor R17 for the next filtering stage was obviously already modified with an 82kΩ resistor (see picture right hand). As the reverb model powers two additional triodes, the 22kΩ from the schematic might be not adequate. The dimensioning of R17 will be discussed further below.



Overview of different configuration:

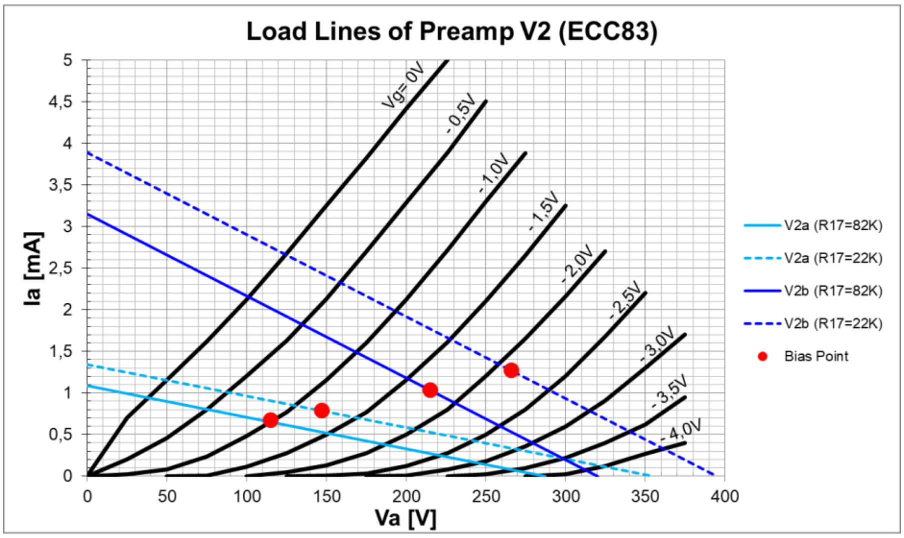


The extract of the schematic above shows the voltage drop over the different filtering stages for different configurations:

1.) two equipped EL34 in the output stage and R17= 82kΩ (like it was)
2.) two equipped EL34 in the output stage and R17= 22kΩ
3.) four equipped EL34 in the output stage and R17= 22kΩ
4.) four equipped EL34 in the output stage, R17= 82kΩ, R13= 15kΩ, R9= 220kΩ, R16= 1,8kΩ, C7= 25µF, R4= 2,4kΩ, C1= 25µF

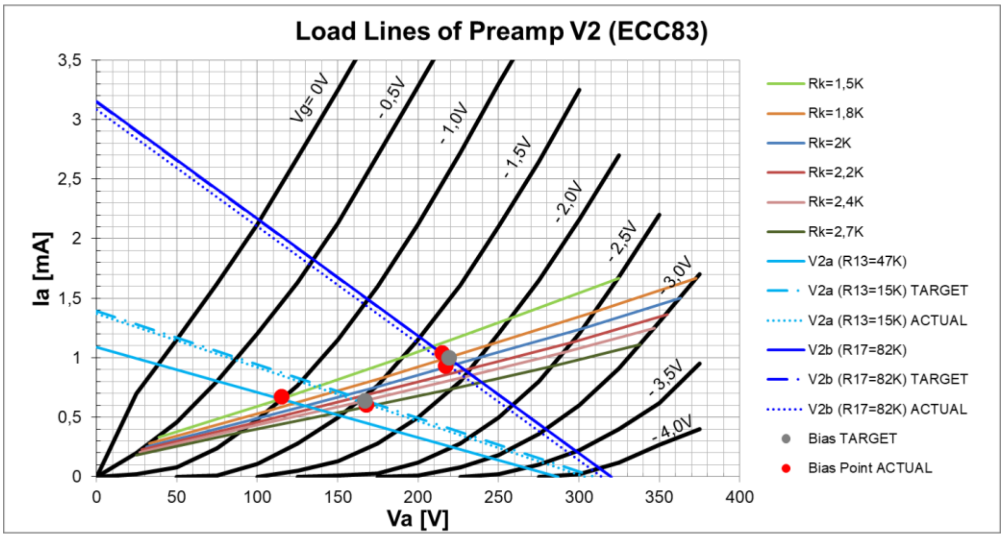
Filtering stages variant 1 is the configuration like-it-was. With R17 = 82kΩ and R13= 47kΩ it shows the lowest supply voltage in the first two preamp stages. This favours an earlier distortion and less headroom for an increasing input signal. Together with the modifications in chap. 1.9 a higher distortion was perhaps the motivation for this adaption.
Filtering stages variant 2 with R17 = 22kΩ increases the voltages at the first two preamp stages. V2a /V2b are operated with higher voltages providing more available headroom.
Filtering stages variant 3 is like filtering stages variant 2 but with 4 equipped EL34 tubes. It shows the impact of the power consumption of those two additional tubes on the voltages of the whole chain of filtering stages.
Filtering stages variant 4 with R17= 82kΩ, R13= 15kΩ and four equipped EL34 in the output stage also takes further changes into account (R9= 220kΩ, R16= 1,8kΩ, C7= 25µF, R4= 2,4kΩ, C1= 25µF) which have also impact on the supplying voltage. The definition of this configuration is derived and discussed further below taking the operation conditions of 1st and 2nd preamp stage into account.

How the preamp will operate under filtering stage variant 1 and filtering stage variant 3?



The solid lines show the application as it was given in the Funkshun on the bench (Filtering stage variant 1. The solid, bright blue line shows the input stage V2a with the less steep load line as here the anode resistor is 263kΩ (220kΩ carbon composition resistor already out of tolerance; see chap. 1.13) leading to a higher amplification. The input stage is relatively hot biased leading to cut-off clipping when the input signal has an amplitude bigger than ~1V.
The solid, dark blue line shows the load line for the 2nd stage V2b in the preamp which produces by overdriving the distorted audio signal. The 2nd stage is ideally biased ([1] Blencowe, chap.1.16). Between 1V and 1,5V signal amplitude at the input of this 2nd stage the harmonic distortion will start ([1] Blencowe, chap.1.11).
Changing the resistor R17 from 82kΩ to 22kΩ (Filtering stage variant 3) leads to higher supply voltage in the preamp. This shifted the load lines to higher anode currents and also resulted in bigger available headroom (dashed lines). For V2a bias point is still too hot for an optimal usage of the available linear input range. For V2b the bias point is still ideally but the bigger headroom leads to less distortion at the same input level. More significant is the fact, that already a signal level of ~0,5Vpp at the input of V2b exceeds the maximum allowed value of 300V between anode and cathode of an ECC83. Therefore, the filtering stages variant 3 has to be excluded as the permanent operation configuration.

How should the circuit diagram at V2 be redesigned to have optimal used headroom at input stage, achieve enough overdrive at the 2nd stage for a sufficient distortion and operate the ECC83 tube always inside specification?



The solid lines are again showing the application as it was given in the Funkshun on the bench (Filtering stage variant 1 and the dashed lines show the TARGET respectively the ACTUAL achieved with variant 4 which will be derived in the following.

For the 2nd stage of the preamp the chosen target voltage for supply is set back to 320VDC (dash dotted line is hidden behind the solid dark blue line). This ensures operation within specification and provides the headroom needed for enough harmonic distortion. For the biasing the so-called cathode load lines according to [1] Blencowe (chap.1.10) are added to the chart for different R_k between 1,5kΩ and 2,7kΩ (coloured solid lines; see legend of chart). The bias point for each R_k value can be derived as the crossing point between load line and the corresponding cathode load line. The originally equipped R16= 1,5kΩ (measured value 1,6kΩ) will be substituted by 1,8kΩ.

As the supply voltage of the input stage of the preamp is one filtering stage further, this voltage will be lower than 320VDC. As target voltage 310VDC supply was defined (dash dotted, bride blue line). This provides slightly higher headroom. The bias point was shifted more to the centre of the available headroom. With R4= R_k= 2,4kΩ a wider range of input signal can be linear amplified.

Under this condition the V2a will draw a quiescence current of 0,64mA and V2b of 1,0mA. As this is quite similar to the current of filtering stage variant 1, R17 will be set back to 82kΩ. To achieve only 10V further voltage drop with the defined quiescence current for V2a, the resistor R13 in the successor filtering stage of supply voltage has to be set to 15kΩ.

The two dotted lines show the measured results after the design for filtering stages variant 4 was implemented (see chap. 3.12). The actual values hit the TARGET within the tolerances of the tube specification. They are slightly below TARGET which is even better for safety reason.

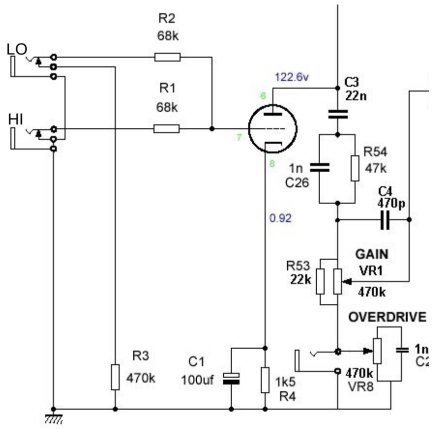
The two stages of the preamp are fully bypassed with the 100µF (C1, C7). According to the discussion in chap. 1.11 a sufficient value which is typically used is 25µF.

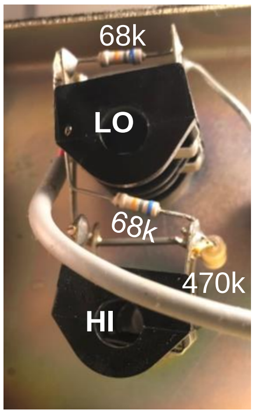
Conclusion:

Filtering variant 4 is the optimal design to provide wider headroom at the input stage and the operation condition of the 2nd stage will ensure the possibility from clean to heavy harmonic distorted sound. Therefore, the design will be realized within the Funkshun on the bench (see chap. 3.12).

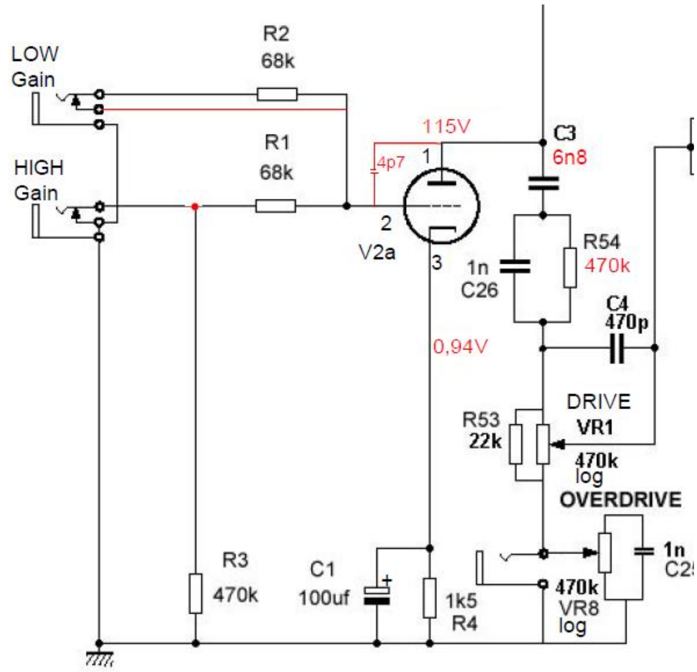
1.5. Amplifier Input Network

In all available schematics the input network for the two inputs looks like the circuit shown right. There is a LOW gain and HIGH gain input. The components R1 – R3 are mounted directly on the input jack sockets. A shielded wire is used to connect it to the preamp tube on the PCB.





But checking the amp on the bench it has been found to be slightly different. The components and the wiring at the input jack sockets seem to be still originally assembled. This design corresponds to the input network of OX-Hiwatt which is close to Roost design, (hiwatt.org/Schematics/DR_Pre2InputJP.gif) as both companies manufactured in the same town in England.

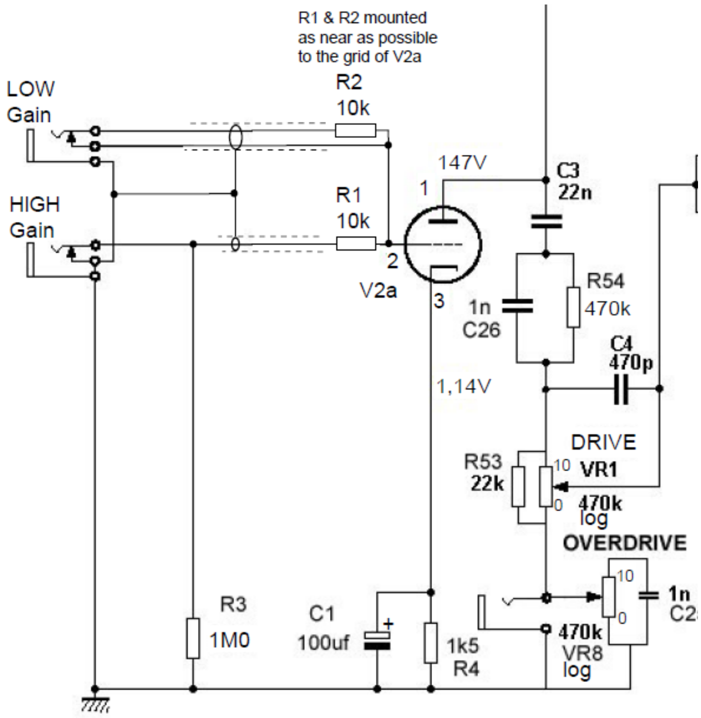


The advantage of this design in comparison to the standard design ([1] Blencowe, chap.4.6) is that High gain is not using both resistors (R1, R2) in parallel (→ 34k).

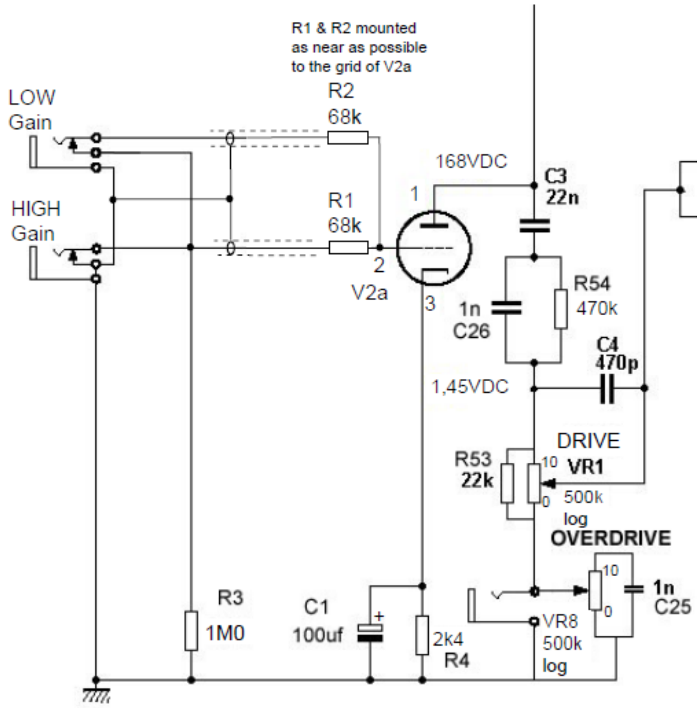
R1 and R2 are the grid stopper and R3 is the grid leak. Normally the grid stopper should be as near as possible to the grid of the tube. The grid leak can be mounted on the jack socket. The typical value is 1MΩ instead of the used 470kΩ. 1MΩ is used in order to not attenuate the signal too much from the guitar pick up. Such attenuation leads to a loss of brilliance in the signal ([3] Zollner].

The grid stopper has to limit the grid current and protect the input against radio noise as it is low pass filter together with the ~ 100pF between grid and cathode. The grid stopper is also the main source of noise ([1] Blencowe, chap.3.2; [3] Zollner, chap. 10.1.7). *The minimum input resistance that consumer audio gear expects to see is 10k. This produces less than half the noise of the conventional 68k*.

Therefore, the design on the right side was implemented first. Only 10k as grid stopper mounted as near as possible to the tube.

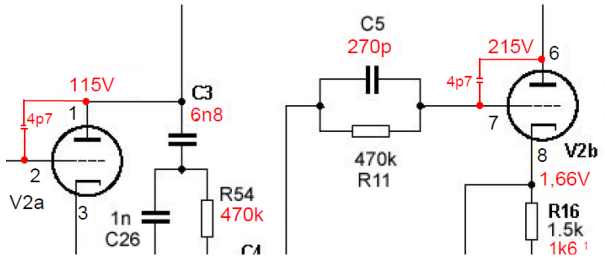


To exclude any impact on hum noise this circuit design was removed during the investigation of hum noise reduction (see also chap. 3.11). Instead, the classic Fender design has been implemented (see schematic right side).
Even there could be no impact observed, the classic Fender design is kept to avoid effort for changing back.
The grid leak of 1M0 is mounted directly to the input jacks. Shielded wires are used to connect the jacks with the board. The two grid stopper resistors R1 & R2 are mounted as near as possible to V2 tube. The shield is connected to ground only at the input jack's side (see chap.3.15).



1.6. Additional Filter Capacitors at V2

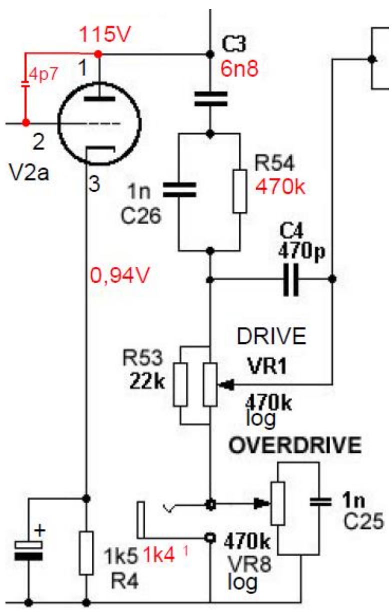
At the preamp tube V2 both inputs are modified with an additional 4,7pF capacitor between grid and plate. Such a circuit design could be neither found in the literature about guitar amps nor in schematics of other amps. Besides the positive effect on hum noise at higher frequencies (see chap.3.11), they have a significant impact on the transfer function of the preamp in total (see chap. 3.6).



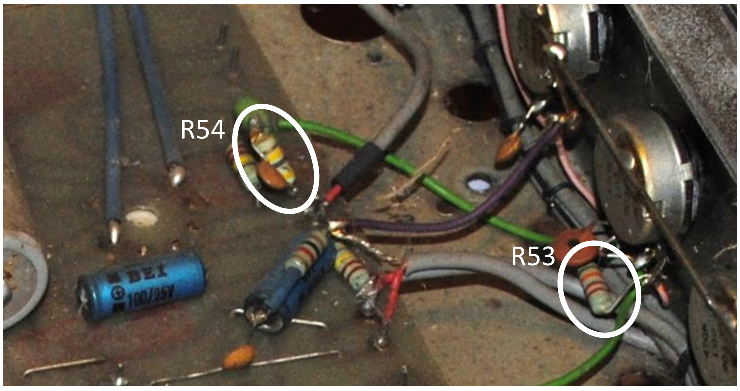
Conclusion:
To avoid an audible influence on the audio signal the two additional 4,7pF are finally removed.

1.7. Coupling and Filters between V2a and V2b

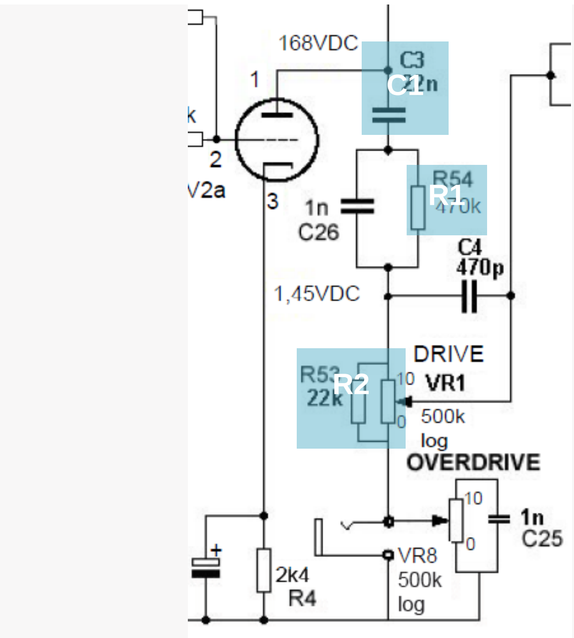
The schematic between 1st stage preamp V2a and 2nd stage preamp V2b is unique and nothing similar could be found at the big three - Fender, Marshall and Vox.
Before going to details of this filter combination with the two control pots DRIVE and OVERDRIVE the value of R54 has to be clarified. All available Funkshun schematics contain a R54= 47kΩ resistor. The similar Roost and Hiwatt amplifiers do not use such a R54 placed in parallel to a 1nF capacitor.
Indeed, the Funkshun on the bench is equipped with R54= 470kΩ (see picture right). Even it looks originally equipped by the manufacturer during the hum noise investigation in chap. 3.11 the value was substituted to this 47kΩ from schematic.
While characterization of the signal path between V2 up to V4 first doubts using 47kΩ instead of 470kΩ appeared.



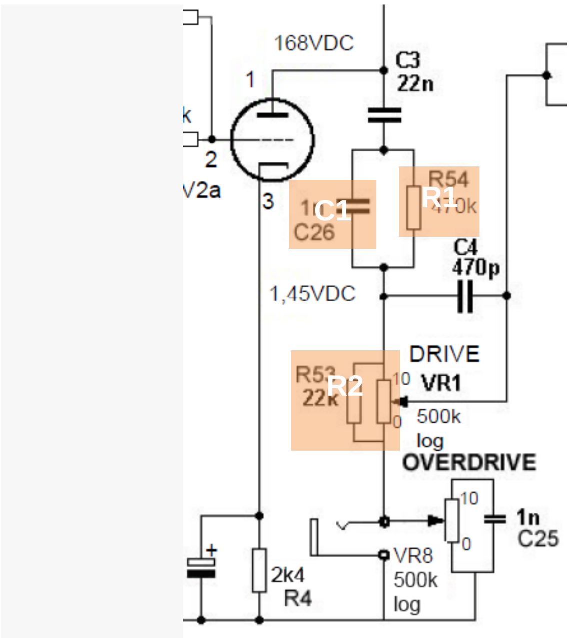
The R54= 470kΩ and R53= 22kΩ combination could be confirmed on a picture (see right) from a thread at ampgarage forum (“Funkshun/Roost 100W chassis”). The colour code of the two resistors allows a reliable identification.



Besides the two pots DRIVE and OVERDRIVE (cascaded control of gain) the circuit can be seen as combination an attenuating high pass filter combined with a high pass shelving filter. The high pass filter decouples the audio signal from DC supply of V2a pin 1. How does the circuit work in combination with the high pass shelving filter? What is the difference between R54= 47kΩ and R54= 470kΩ?



Attenuating High Pass Filter



High Pass Shelving Filter

For the attenuating High Pass Filter the cut-off frequency where the pass band starts can be calculated as ([1] Blencowe, chap. 4.12):

$$f_{Hipass} = \frac{1}{2\pi C1(R1 + R2)}$$

For the High Pass Shelving Filter, the lower corner frequency where this filter starts to increase the gain is calculated with ([1] Blencowe, chap. 4.14):

$$f_{Lower} = \frac{1}{2\pi C1 R1}$$

While the upper corner frequency of full gain is calculated with:

$$f_{Upper} = \frac{1}{2\pi C1(R1 \parallel R2)}$$

With those formulas the behaviour of the circuit is calculated for different used part values

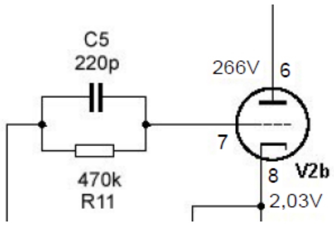
Values in the circuit					High Pass Shelving Filter						High Pass Filter		
Var	C26 [nF]	R54 [kΩ]	R53 [kΩ]	VR1 [kΩ]	C1=C26	R1= R54 [kΩ]	R2 = R53‖VR1	f_{Lower} [Hz]	f_{Upper} [Hz]	A	C= C3 [nF]	R=R54+(R53‖VR1)	f_{Hipass} [Hz]
A	1	470	22	500	1	470	21	339	7891	0,043	22	491	15
B	1	47	22	500	1	47	21	3386	10939	0,310	22	68	106
C	1	68	33	500	1	68	31	2341	7482	0,313	22	99	73
D	1	470	∞	500	1	470	500	339	657	0,515	22	970	7
E	10	68	33	500	10	68	31	234	748	0,313	22	99	73
F	1	470	22	500	1	470	21	339	7891	0,043	6,8	491	48

The yellow marked variant A. shows the results for the finally used R54= 470kΩ and R53= 22kΩ combination. How does it work?
To decouple the audio signal from supply DC of V2a pin 1 the High Pass Filter will cut-off below 15Hz, which means the whole audio range starting at ~20Hz can pass unattenuated. The High Pass shelving filter starts to open at 339Hz and then ramp up till reaching the plateau at 7891Hz. This results in a strong increasing brightness with increasing frequency. Perhaps this creates the special sound of this amp.
Using the part characteristics of variant B (corresponding to circuit diagram in chap. 1.2) the situation is totally different. The attenuating high pass filter starts to block below 106Hz already, which is quite high and leads to real bright sound. The High Pass Shelving Filter in that combination has less impact, because the ramp up starts at 3386 and arrives at the plateau at 10939Hz. This is above the provided tone frequency range of a guitar and therefore only affects the harmonic overtones within the sound. It is unlikely that this could be the intended design.
Variant C is a calculation trial to reduce the cut-off frequency of the High Pass Filter. 73Hz is still within the audio range, but in modern amps (e.g. Marshall) this is common “to promote a tighter, more punchy sound” ([1] Blencowe, chap. 4.12). But the ramp up range of the High Pass Shelving Filter remains in a range above the provided tone frequency range of a guitar (82Hz - 1184Hz).
The calculation of variant D is to demonstrate the role of R53 which is parallel to VR1. The change at the cut-off frequency of the attenuating high pass filter from 15 Hz down to 7Hz has no impact to the sound. The starting frequency of the ramp up in the high pass shelving filter remains 339, but it is already reaching the plateau at 657Hz. Still a significant difference to variant A.
Variant E is the mathematical trial of further optimizing the variant C by also changing the capacitor C26. The changed value of C26 transferred the ramp up of the High Pass Shelving Filter back into the frequency range provided at the input. In variant A the frequency width of the ramp up is still wider.
Variant F finally documents the situation in the Funkshun on the bench like-it-was. The high pass shelving filter is identical to variant A. The attenuating high pass filter has a slightly higher cut-off frequency (C3= 6,8nF), which would also be okay for a guitar signal.
In chap. 3.21 the significant difference between variant A and variant B could be demonstrated in a measurement of the transfer function over frequency.

<u>Conclusion:</u>
The R54= 470kΩ / R53= 22kΩ combination (variant A) including C3= 22nF is the one which will be finally implemented, as it is assumed to be the intended design. This is confirmed by the actual assembly in at least two independent amps. Also, the measurement in chap. 3.21 confirms the derived behaviour.
This conclusion also means that the available circuit diagrams in the world-wide web are not correct at the position R54.

1.8. Blocking Distortion / Low-Pass Shelving Filter

To avoid blocking distortion the input at 2nd preamp stage is protected by a grid stopper R11 with a parallel capacitor C5. Together with the not visible $C_{in} \cong 100pF$ of the tube between grid and ground this is a low-pass shelving filter ([1] Blencowe, chap. 4.15). The cut-off frequency where this filter starts to attenuate can be calculated as:



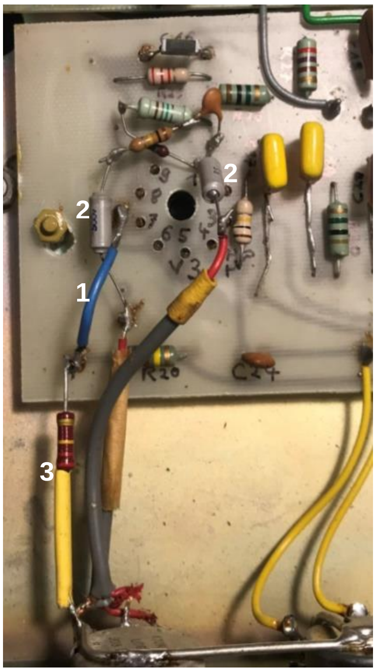
$$f = \frac{1}{2\pi(C5 + C_{in})}$$

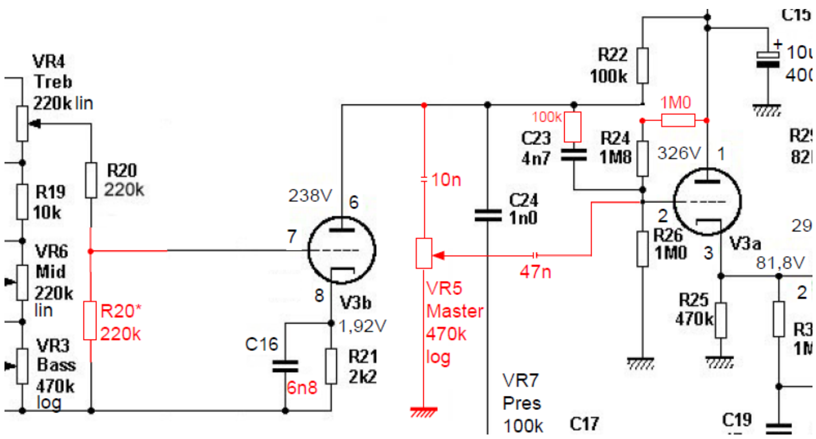
With the typical values the cut-off frequency will be at ~1058Hz. The C5 in the Funkshun on the bench was equipped with 270pF (it looks like originally equipped) which will lead to a slightly reduced cut-off frequency at 915Hz.

Conclusion:
While substituting C5 (see chap. 3.7) the value is set back to the one found in the circuit diagram: 220pF. This is leading to less loss of treble.

1.9. Master Volume Modifications

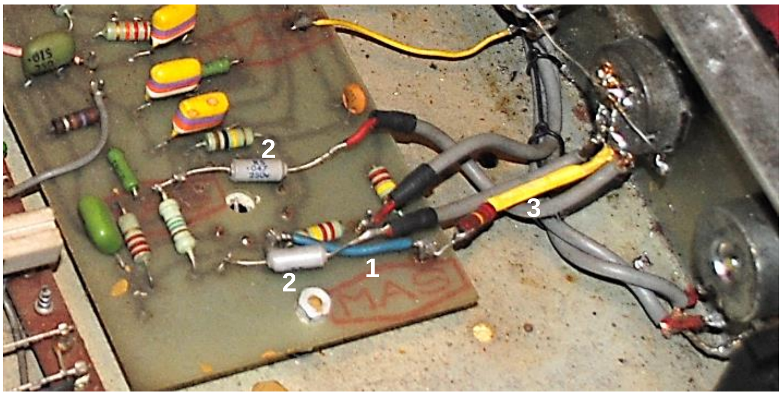
The Funkshun on the bench has a significant modification at the master volume. Comparing with original schematic the VR5 potentiometer has been shifted from the position between tone stack and the amplification stage V3b to a position after this amplification stage at the input of the cathode follower stage V3a.





The motivation for this change might be to provide higher signal levels to the output stage and have more distortion. Nevertheless, the modifications have been done in a rough and flying soldering style. Therefore, they will be removed and master volume will be integrated again in its original position.

While searching for information of the Funkshun amp in the world-wide web it was found that this modification is not unique. The photo on the right side from a thread at ampgarage forum ("Funkshun/Roost 100W chassis") shows a quite similar modification using the same blue wire (1), the same two grey capacitors (2) and the same additional 220kΩ resistor with the yellow isolation tube.



Furthermore on photos in a "Roost Amplifier" report on Metropoulos Forum such a change can be identified (using a red wire instead a blue one, but same capacitors and same soldering style).

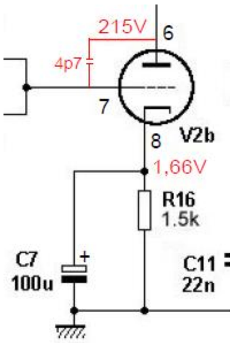
Conclusion:
The shift of the master volume in the signal path seems to be a common modification. The style and the used components might be a hint that it was done in the same workshop. The Funkshun on the bench contains additional changes beyond this modification.
In chap. 3.8 those modification will be totally removed and the original design will be re-implemented.

1.10. Tone Stack

In the tone stack the bass coupling capacitors C10 was modified (see picture on the right side). A 6,8nF cap was mounted. It has been replaced with 22nF according to the schematic (chap. 3.7).

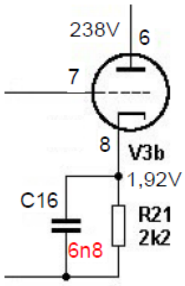
1.11. Cathode Bypass Capacitors

The preamp stages V2a, V2b and V3b were operated as common-cathode amplifier with cathode biasing ([1] Blencowe, chap. 1.18).
V2a and V2b were identical biased with R4= R16 = R_k= 1,5kΩ and a cathode bypass capacitor C1= C7= C_k= 100µF. To have full gain over the complete audio frequency range and to avoid cathode degeneration the cathode has to be fully bypassed. According to [1] Blencowe (chap. 1.18) the cut-off frequency below which the gain decreases can be calculated from the R_k / C_k combination as:

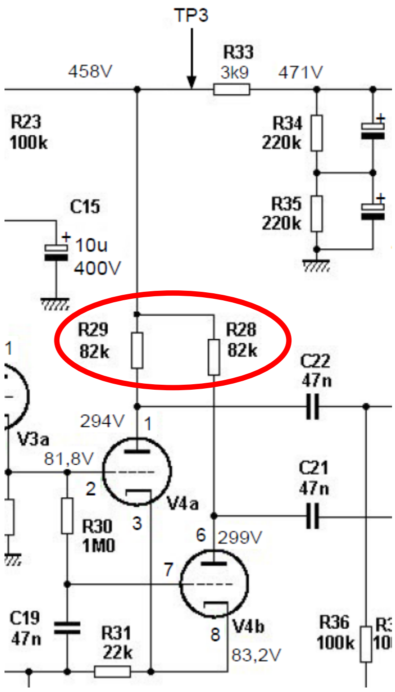


$$f = \frac{1}{2\pi\, R_k C_k}$$

With the 1,5kΩ / 100µF combination used here this frequency is ~1Hz; far below the audio range. The most common used combination is 1,5kΩ / 25µF with f≈ 4,2Hz. In [3] Zollner (chap. 10.10.1) there is a wide and good overview of cathode bypassing in different amps. Also providing some background info why this wide variety exists. In the combination with at least 1,5kΩ cathode resistor R_k the cathode bypass capacitor C_k has not to be bigger than 25µF to ensure full bypassing.
The preamp stage V3b was equipped with a modified combination 2,2kΩ / 6,8nF leading to f≈ 10,6kHz. This means more or less the whole audio range remains on the minimum gain. According to the circuit diagram the Funkshun should be equipped with 22nF (f≈ 3,3kHz) and the original Roost is equipped with 47nF (f≈ 1,5kHz). The treble boost starting at 1,5kHz respectively 3,3kHz is already above the provided frequency range of a guitar (82Hz - 1184Hz).
The advantage to operate this stage on lower gain level (see also measurement A.25 or B.25 in chap. 2.9) is to reduce distortion and to provide increased headroom.



1.12. Anode Load Resistors at Phase Inverter

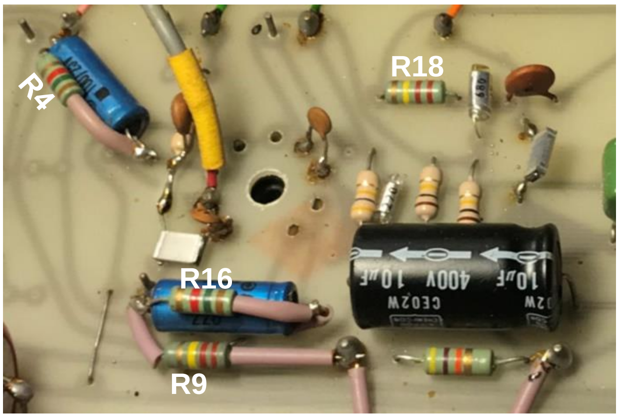


The anode load resistors R29 and R28 of the phase inverter (tube V4) are both at 82kΩ. It is defined like that in all the available schematics. The Funkshun on the bench is following this design with originally equipped components.
According to the theory of such kind of phase inverters ([1] Blencowe, chap. 9.9; [3] Zollner, chap.10.4.4) same load resistors would create different output levels in the two paths leading to distortion in the output stage. As output from V4a would be higher than output from V4b (see measurements in chap. 2.9, B.28.a and B.28.b the anode load resistor of V4b should be higher to compensate this. Typical combination is 82kΩ/ 100kΩ but as the Funkshun is near Hiwatt the 82kΩ/91kΩ from there (hiwatt.org/Schematics/DR_Pre2InputJP.gif) was taken over.

Conclusion:
Substitute the anode load resistor R28 with a 91kΩ value (see also chap. 3.5).

1.13. Carbon Composition Resistors

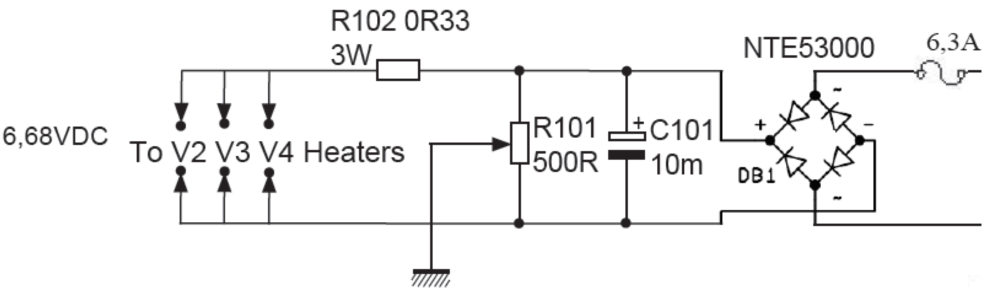
Some of the resistors in the circuit are carbon composition resistors. This type of resistor has the behaviour to shift during lifetime to a higher resistance. As indicated in the like-it-was circuit diagram R4, R9, R16, R18, R20 and R29 are out of tolerance or borderline. Especially R9 with 263kΩ instead of 220kΩ might influence the operation.



Conclusion:
Substitute the carbon composition resistors if they differ significantly from specified value. (see also chap. 3.17)

1.14. DC Heater for Preamp

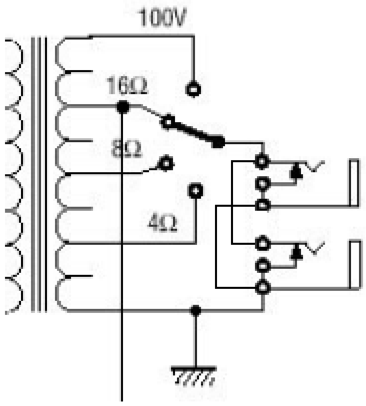
To reduce the hum of an amp the preamp tubes in some designs are foreseen to heat with DC voltage (e.g., Marshall JTM 60). In chap. 3.11 it is demonstrated that this method can also be applied at the Funkshun. Therefore, the following design will be added on a small supplement board:



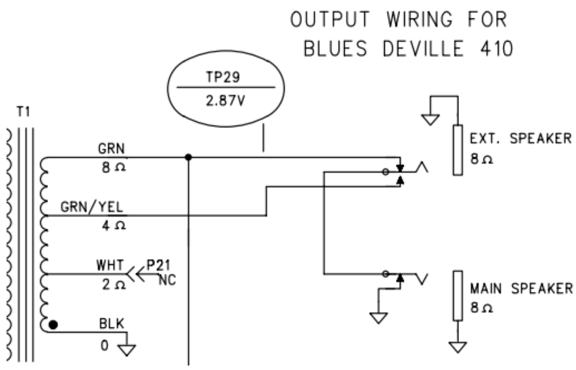
This rectifier board uses the AC heater voltage parallel to the heater of the power stage. The used NTE53000 is a full bridge rectifier for Urmax= 200V and a forward current If= 10A. To smooth the rectified voltage a 10mF capacitor is added.
According to [1] Blencowe (chap.3.16) a humdinger pot was added to balance the heater supply. With this variable tap asymmetries in the heater circuit can be compensated. While adding this artificial tap the original center trap of the heater supply directly at the transformer is disconnected.
After rectifying the AC heater supply of 6,69VAC$_{eff}$ the provided DC voltage is 7,04VDC. For further reduction the R102 0R33/3W is added in the design. With that resistor the final DC heater supply for the preamp drop down to 6,68VDC.

1.15. <u>Speaker Exit at Output Transformer</u>

The loudspeaker output of the Funkshun is equipped with two jacks and an impedance selector at the output transformer. The wiring of the two speaker jacks at Funkshun on the bench is differing to all available schematics of the Funkshun / Roost (see chap. 1.2). In those plans the two jacks are serial arranged. This means the impedances have to be added in case two speaker cabinets are connected. In reality they are wired to be parallel which means that the reciprocal of the single impedances of two connected speaker cabinets have to be added to receive the reciprocal of the total. Nevertheless, in both cases the impedance selector has to be adapted adequately when changing from one cabinet arrangement to a double cabinet operation. Optimum operation is given, when the total impedance of the speaker load matches perfectly to the power stage output.

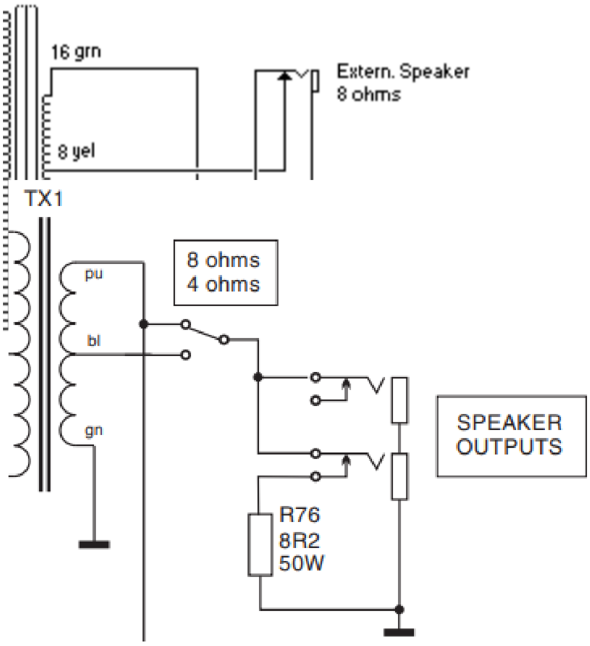


Which of the two possibilities - serial or parallel - is more robust in the case of adding a second speaker cabinet without readjusting the impedance selector?
According to [5] Keen (Amp/output transformer/tubes W/ a mismatched speaker load?) the general rule is: “It's almost never low impedance that kills an output transformer; it's too high an impedance.” In an example he discussed what happens if two 8Ω speakers are connected first serial and then parallel to the 8Ω output of an output transformer. At 2:1 lower-than-matched load (which corresponds parallel wiring) is not unreasonable at all. The other way around at 2:1 higher-than-matched load (which corresponds serial wiring) is worse, but for most amps this size of mismatch isn’t able to kill the output transformer. Therefore, almost all schematic of different amps providing two jacks use parallel wiring.
Some amps with different impedances providing output transformers and two jacks use a tricky schematic (for example Fender Blues Deville 410) instead of an impedance selector. When a second 8Ω speaker beside the main speaker will be added it will be added parallel and the output transformer switches automatically to 4Ω.



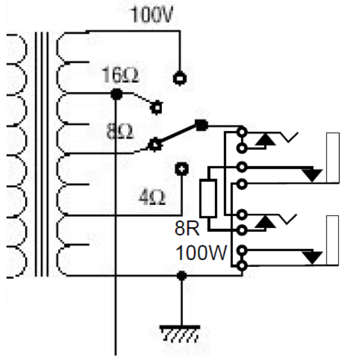
Nevertheless, this arrangement can also lead to mismatched speaker condition, when one 8Ω speaker cabinet is connected to external speaker jack.

The remaining question is: How can the never allowed operation “without speaker load” be avoided? In case of an amplifier head unit with separated speaker cabinet the risk of forgetting the speaker connection is not neglectable.
The Ampeg amplifiers (e.g. V3 use an arrangement with a 250Ω power resistor (10W). In case of forgotten connection, the load at the output transformer is 250Ω. With this high impedance it is of course in contradiction to the above mentioned rule of overmatching. Perhaps the Ampeg designer in former times had no real high power 8Ω resistor available like in our days.



This hypothesis is supported within the schematic of the Koch Twintone from March 2001. Here an 8,2Ω high power resistor is used in the design. This 8,2Ω/50W will be a substitute load in case of a forgotten speaker connection. The disadvantage of this design is obvious in case that a single speaker cabinet is used. Connecting an 8Ω speaker cabinet to the upper jack will lead in total to an impedance of 4Ω as R76 is still in parallel. Using the lower jack is leading to total 8Ω impedance as the R76 will be switched OFF.

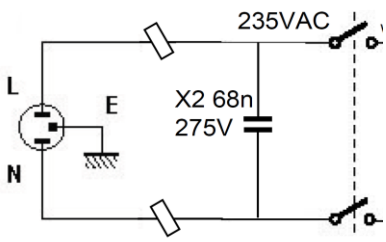
Conclusion:
Finally best of best is transferred to the Funkshun schematic. An 8Ω/100W resistor is used within a slightly modified design. Independently of which jack is used or even both, the 8Ω high power resistor will be switched OFF. If both jacks are used the loads are parallel wired (see chap. 3.18).



1.16. Mains Supply Input Filter

The transformer is connected via the mains switch directly with mains supply. There is no net filter to avoid disturbances occurring in the supply net (e.g. switching of high current consuming devices).
Unfortunately, there is not enough space to mount a complete filter unit. For example, like Schafner FN9222.
Therefore, a substitute with an X2 capacitor 68nF 275VAC (PME271M568MR30) and two ferrite rings could be designed to provide a certain protection of the amp against disturbance from the mains supply.

Conclusion:
Add EMC protection with X2 capacitor 68nF 275VAC (PME271M568MR30) and two ferrite rings (see chap. 3.19).



1.17. Standby Switch

The Funkshun amp is equipped with a standby switch which is usual in many tube guitar amps. According to [4] Blencowe (Power and Standby Switches) the general mentioned argument, that the standby switch will avoid cathode stripping and allow preheating, is wrong from a technical point of view. Even the high voltage tube amps running with 500 to 600V are far away from the voltages necessary to achieve cathode stripping. Only in guitar tube amps such a standby switch can be found. Hifi audio tube amps never have a standby switch. Nevertheless, both effects were often discussed to shorten the life of the tubes.
Blencowe [4] reports negative effects of the standby switch as cathode poisoning and hot-switching. Cathode poisoning: *"When a valve cathode is fully heated but no anode current is allowed to flow for long periods of time (several hours), a high-resistance chemical layer can grow between the cathode tube and the oxide coating."*
The hot-switching can play only a significant role when a valve rectifier is used. There the best solution will be to avoid a standby switch at all. But also in case of silicon rectifier it is not necessary. In order to reduce the arcing which might occur at high DC voltage switching, a resistor (i.e. 47kOhm 2W) is recommended.
Furthermore in [3] Zollner (chap. 10.5.9) there is a controversial, contradicting discussion about standby switches. The unclear design requirements for a standby switch can also be verified by checking many schematics of different amp manufactures. All variants with and without at different places in the circuit are available.
In chap. 3.23 investigations at the Funkshun to clarify this situation are reported. Besides the practical advantage of mute switch (also very practical when servicing the amp) the only advantage of the standby switch directly observed in the Funkshun is the stepwise charge-up of those many, large capacitors in the filter network of the high voltage supply.

Conclusion:
Keep the standby switch in the Funkshun on the bench as it is. When starting the cold amp always switch standby immediately after mains switch. Do not run the amp over hours in standby mode.
For the Funkshun on the bench, in chap. 3.23 it is demonstrated that neither the arcing of hot switching nor the risk of unreduced high voltage at the preamp stages is relevant.

1.18. Diodes in the Rectifier

According to circuit diagram the rectifier of the Funkshun on the bench was working with four BY127 diodes. During the investigation to reduce hum noise (see chap. 3.11) they have been substituted to exclude impact from defective diodes. The UF4007 has been selected as a type with a smaller reverse recover time. This leads to a softer switching and therefore should avoid the rectifier induced heater hum ([1] Blencowe, chap.3.15). The investigation of chap. 3.23 showed surge currents up to 12A for a few milliseconds. Even the UF4007 is robust enough for surge current up to 30A (8,3ms) finally a more robust type with 3A average forward current and the same small recovery time is assembled: UF5408.
Comparison of important characteristics of the BY127 diode with other typical diodes:

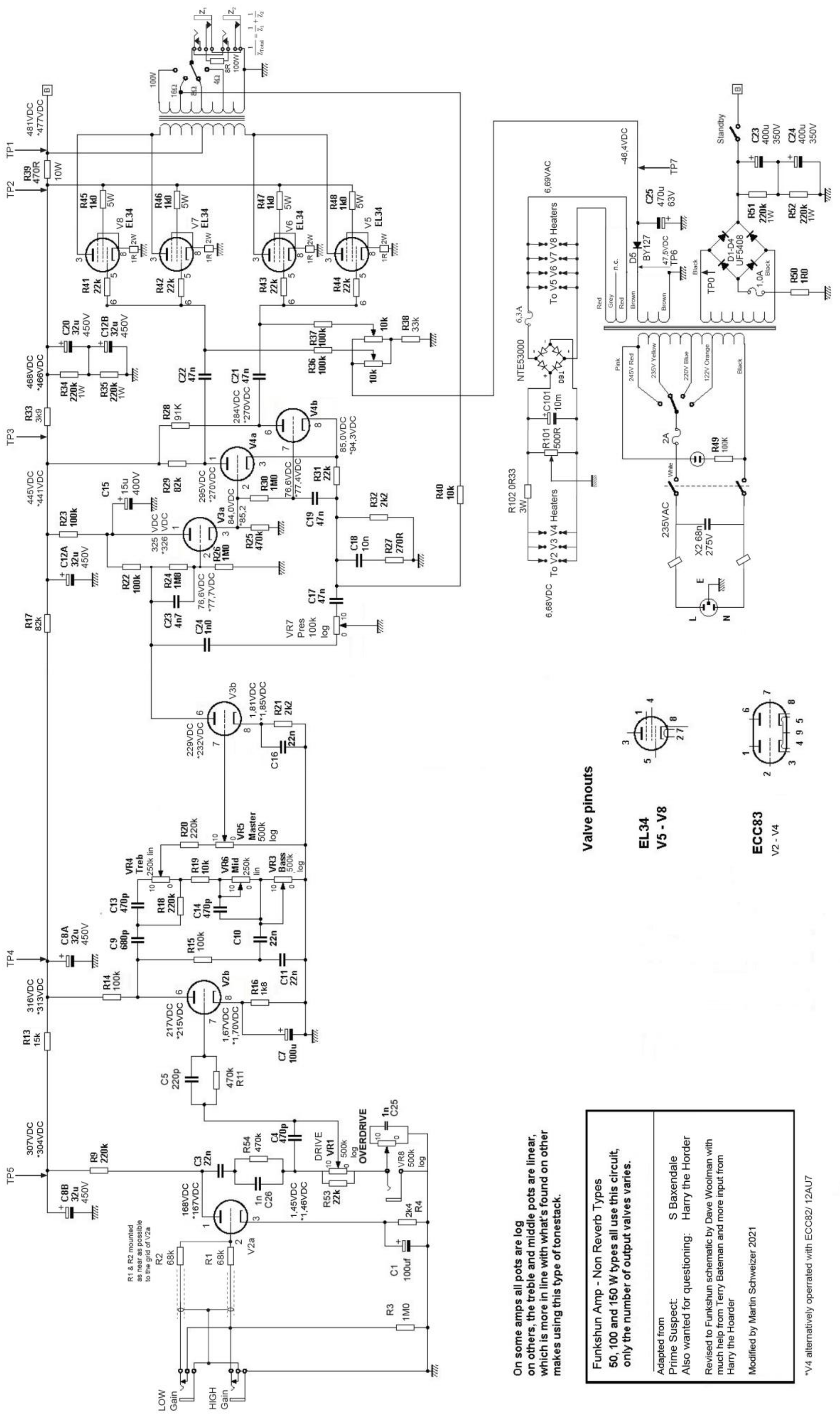
Component	Average Forward Current	Working Peak Reverse Voltage	Reverse Recovery Time	8.3 ms. peak forward surge current
BY127	1,0A	800V	2,0µs	50A
1N4007	1,0A	1000V	2,0µs	30A
UF4007	1,0A	1000V	0,075µs= 75ns	30A
UF5408	3,0A	1000V	0,075µs= 75ns	150A

Conclusion:
Finally, the rectifier of the Funkshun is equipped with diode type UF5408 (3A; 1000V) which is ultra-fast and more robust than the originally assembled BY127.

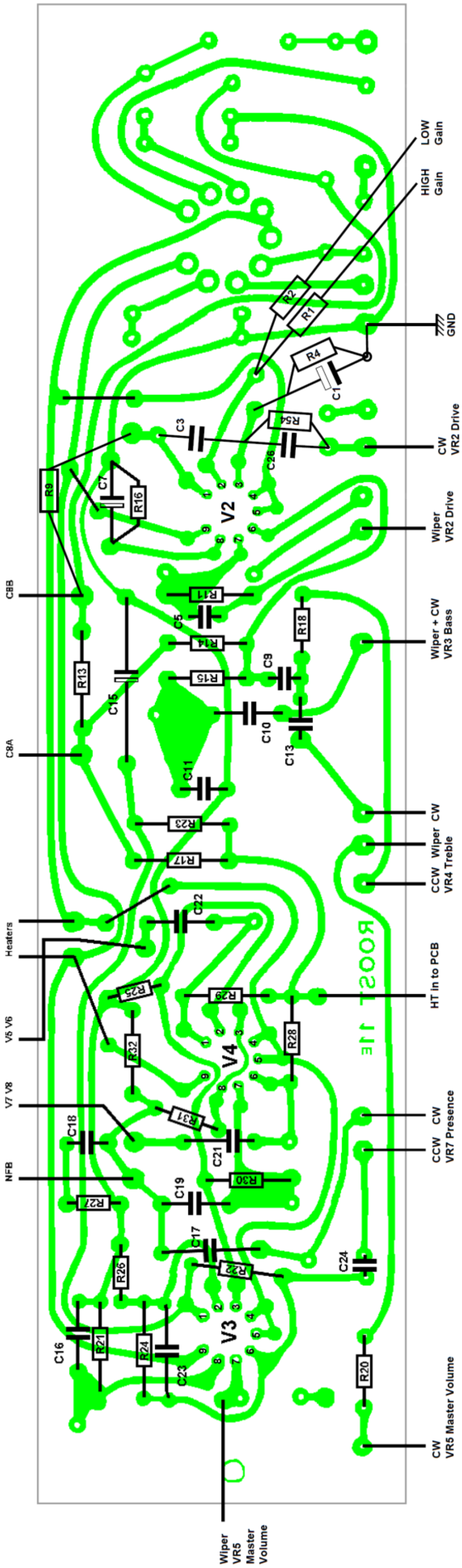
1.19. **Fusing**

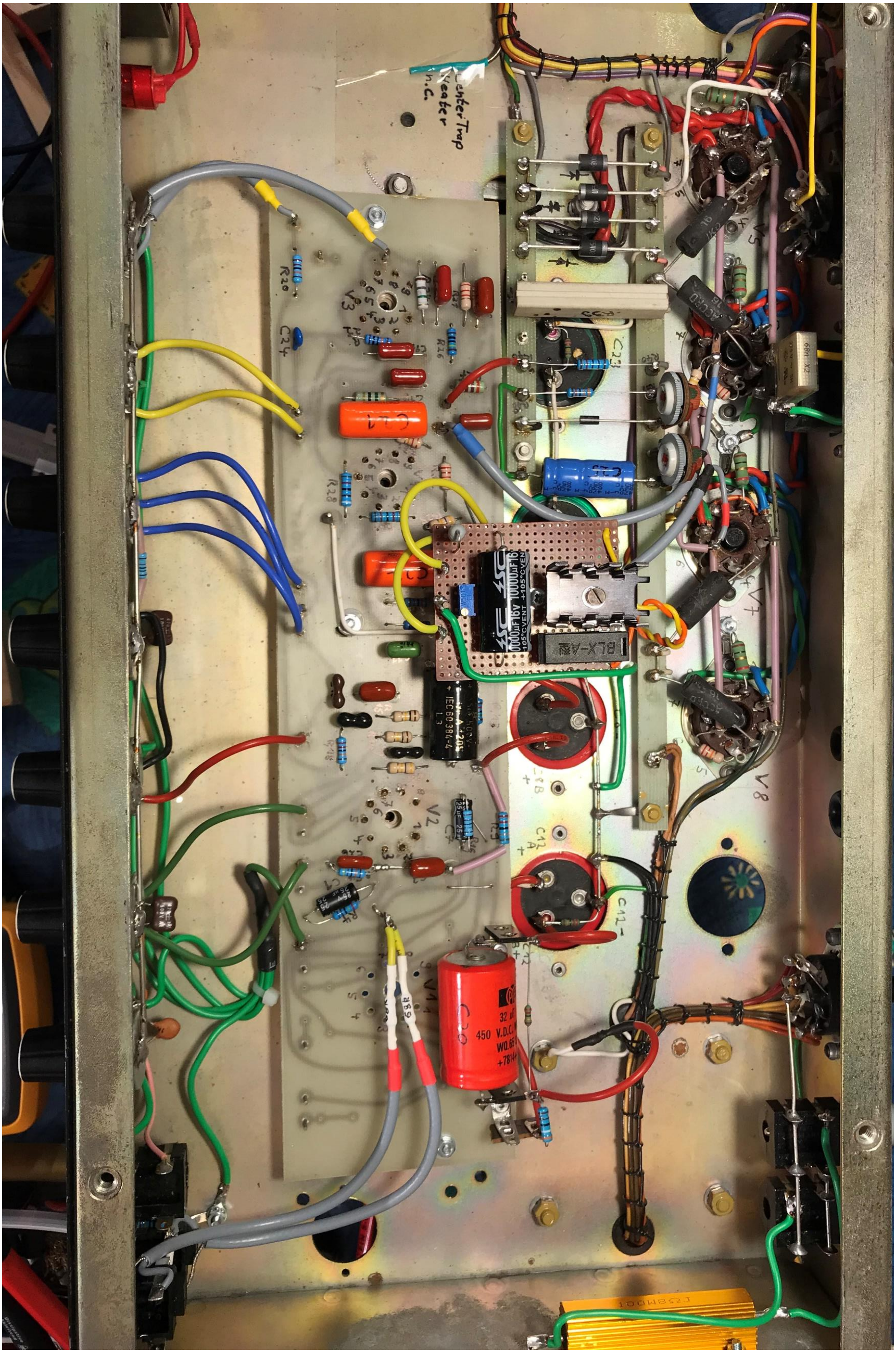
The Funkshun amp has two fuses mounted in holders on the rear side. One in the primary circuit of the mains transformer (rated 3A) and one for the HT supply (rated 2A). No further fuses inside the chassis for the heater supply or the bias voltage are necessary.
The measurements in chap. 3.1 show that the main fuse is overrated. In order to make the protection more sensitive the values were adapted based on current consumption measurements to T2,0A.
According to [4] Blencowe (Fusing) the position of the HT supply fuse at the HT DC side of the rectifier is not ideal. A better protection can be achieved with the position of the fuse directly after the transformer at the AC side of the rectifier. As there could not be added a fuse easily in that position due to the topography of the circuit, the original fuse holder at the back panel has been kept and the value has been reduced down to T1,0A. This value is also in accordance with the measurements in chap. 3.23.
For the heater no fuse is foreseen due to the simplicity of the circuit. But by adding a rectifier for a DC heater for the preamp the need for fusing at least for this part of the heater is given. Therefore, a fuse has been added at the AC side of the rectifier. Based on measurements (chap. 3.20) a T6,3A is specified.

1.20. Schematic of Funkshun on the Bench after Refurbishing



Layout of equipped PCB:

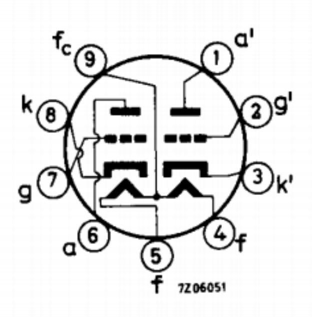




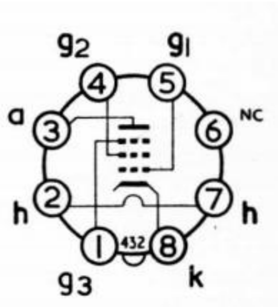
2. Analysis of Amplifier before Rework

2.1. Characterization of the Tubes with Tube Tester

ECC83= 12AX7 =7025



EL34



Tube	Pin	V_f	V_a	V_{g1}	V_{g2}	I_a	I_{a_Tab*}
V2 ECC83[1]	1	6,3V	+250V	-2,0V	-/-	0,7mA	1,2mA
V2 ECC83[1]	6	6,3V	+250V	-2,0V	-/-	0,7mA	1,2mA
V3 ECC83[1]	1	6,3V	+250V	-2,0V	-/-	0,7mA	1,2mA
V3 ECC83[1]	6	6,3V	+250V	-2,0V	-/-	0,7mA	1,2mA
V4 ECC83[1]	1	6,3V	+250V	-2,0V	-/-	0,5mA	1,2mA
V3 ECC83[1]	6	6,3V	+250V	-2,0V	-/-	0,6mA	1,2mA
V5 EL34[2]		6,3V	+250V	-13,5V	+250V	72mA	75mA
V6 EL34[2]		6,3V	+250V	-13,5V	+250V	80mA	75mA
V7 EL34[2]		6,3V	+250V	-13,5V	+250V	81mA	75mA
V7 EL34[2]		6,3V	+250V	-13,5V	+250V	70mA	75mA

[1]Siemens ECC83 (=12AX7=7025) [2]Telefunken EL34 *Valve Data Manual Edition 20

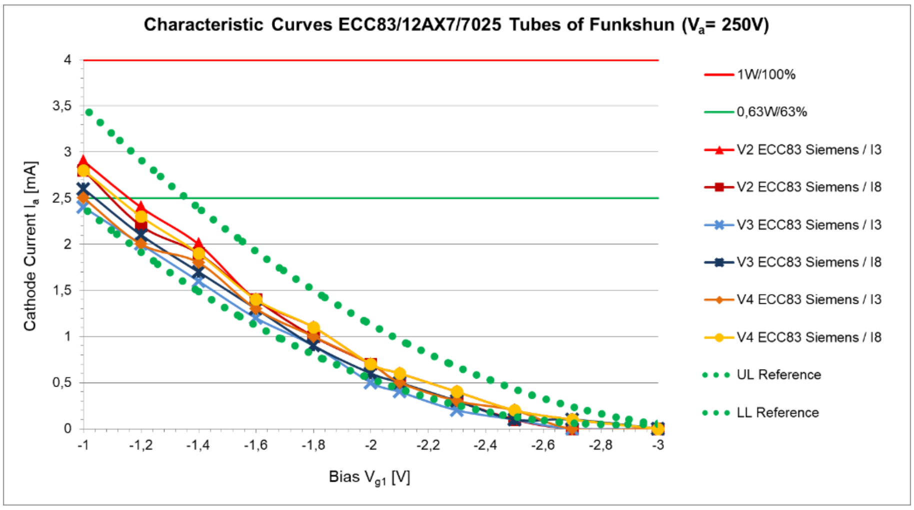
After cleaning the tubes there were no damages outside or inside visible. The table above shows the measured cathode current on the tube tester.

Conclusion:

Although the three Siemens ECC83 from the preamp stages are significantly below the given value from the valve data manual, the currents are absolutely fine according to experience with new ECC83 type tubes. The quad of Telefunken EL34 from the output stage also shows the expected values, but they look more like two matched pairs than a matched quad. In order to get better qualified judgement on the tubes, the characteristic curves of all tubes under conditions near those in the amp circuit has been recorded.

Preamp Tubes ECC83

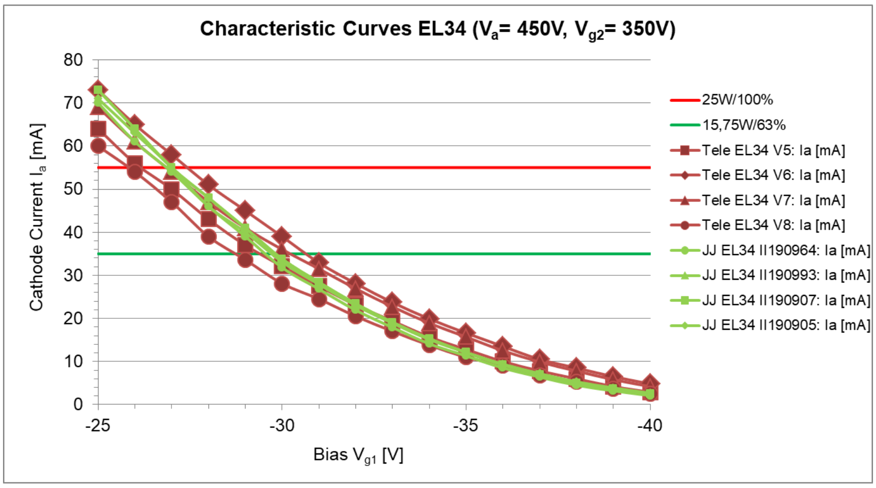
The chart shows the cathode current in dependence of the bias voltage for all three Siemens ECC83 double triodes out the Funkshun. The two green doted lines show a lower limit LL and upper limit UL for such a type of tube based on measurements with several new, unused tubes from stock.



Conclusion:

In comparison to the new tubes, the three Siemens ECC83 tubes out of the Funkshun are absolutely fine and can stay in the circuit.

Output Stage EL34



In comparison to a matched quad of new JJ EL34-II Red Label tubes the quad of Telefunken EL34 from the Funkshun show a comparable behaviour. Nevertheless, for a good matched quad, the characteristic curves differ already significantly.
To have a better optimized arrangement of the tubes in the output stage V5 & V8 were plugged in for one phase and V6 & V7 for the opposite phase. As the Funkshun has two independent bias adjustments, the differences in the cathode current can be balanced.
With all tubes back in the chassis the amp was powered. But when toggling the standby switch to supply high voltage to the tubes, there was a short cicuit and the main fuse blow again. A small smoke cloud indicated that the short is coming from the output stage: EL34 tube V8 or the output transformer.
After taking the tubes off and disconnecting the center trap of the primary side of the output transformer, the windings of it could be checked. 27Ω each half of it to center trap and no short to ground.
In the next step the EL34 tube are checked for shorts /shunts between the pins with the multi meter. Each single pin respectively to all other pins:

Tube	Test result
EL34 V5	No short / shunt. Only 2 and 7 (heater)
EL34 V6	No short / shunt. Only 2 and 7 (heater)
EL34 V7	No short / shunt. Only 2 and 7 (heater)
EL34 V8	Short between plate (3) and 2 & 7 (heater)

How was this basic fault not detected during characteristic curve check on the tube tester?
Going back on the tube tester with EL34 V8 confirmed the already made measurements. In the tube tester the heater supply and the plate supply are totally independent from an electric potential point of view. This fundamental difference requires always a simple pin short/shunt test besides measuring the characteristic curves on the tube tester.
Pin short/shunt tests for the preamp tubes:

Tube	Test result
ECC83 V2	No short / shunt. Only 4, 5 and 9 (heater)
ECC83 V3	No short / shunt. Only 4, 5 and 9 (heater)
ECC83 V4	No short / shunt. Only 4, 5 and 9 (heater)

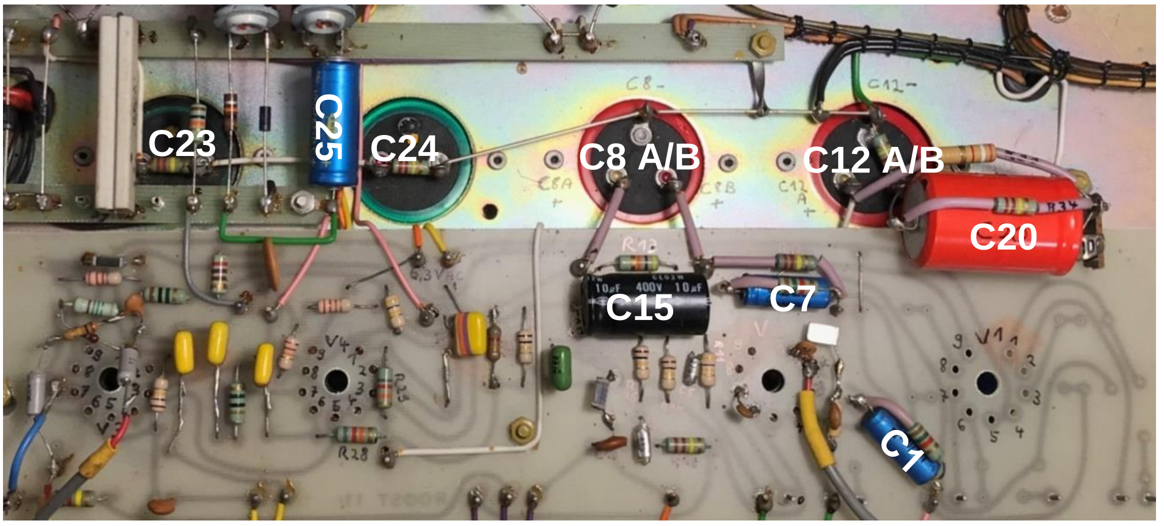
Even the ECC83 V2 has no shorts and an absolutely fine characteristic curve, this tube is conspicuous. When switching ON the heater at a “cold” tube there is a bright enlightening visible for a short moment. This observation is also reproducible at the tube tester. Thus an artefact in the circuit board can be excluded.

Conclusion:

As the characteristic curves of the Telefunken EL34 quad out of the Funkshun differ significantly to each other and one tube (V8) has a short, the new JJ EL34 II Red Label quad (used as reference in the chart) will be used to replace them.

2.2. Electrolytic Capacitors

The larger capacitors in the Funkshun especially those to smooth the high voltage are electrolytic capacitors. This type of capacitor could lose its electrolyte over lifetime and therefore losing its function; especially under the hot environmental conditions in an amp.



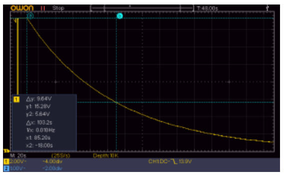
Before operating the amplifier, those capacitors were measured with a multi meter providing such a measurement possibility. As the parts are inside a circuit with other electronic components surrounded the measured values could differ from the real value of the single capacitor.

Component	ACTUAL[1]	ACTUAL[2]	TARGET	Discharge Resistor[3]	Discharge Time[4]	$C_{Discharge}$ [5]
C23	435µF	415µF	400µF/350V	243k	103,2s	424µF
C24	408µF	389µF	400µF/350V	243k	96,8s	398µF
C20	47µF	44µF	32µF/450V	234k	10,3s	44µF
C15	12µF	11µF	10µF/400V	527k	32,1s	61µF
C12A	43µF	41µF	32µF/450V	443k	49,4s	112µF[6]
C12B	42µF	40µF	32µF/450V	231k	13,3s	58µF
C8A	39µF	38µF	32µF/450V	523k	58,0s	111µF[7]
C8B	36µF	35µF	32µF/450V	573k	49,4s	86µF[7]
C25	109µF	91µF	100µF/100V	20k	2,15s	107µF
C1	-/-	134µF	100µF/25V	1,4k	0,306s	218µF
C7	-/-	160µF	100µF/25V	1,6k	0,376s	235µF

[1]Value measured in the circuit with FLUKE15B®
[2]Value measured in the circuit with F meter DM6013L
[3]Measured value at the pins of the capacitor
[4]Discharge time for 0,367 × V_0
[5]Discharge value = Discharge time / Discharge resistor
[6]Value seems to be sum with parallel C12B
[7]Value seems to be sum of parallel C12A + C12B

The last three columns in the table are the result of a second fundamental capacitor check.
With an external power supply the single capacitors will be charged up to 15,3V. After disconnection of the supply the capacitor will discharge and with the oscillography the voltage drops over time can be recorded. According the physical function describing this discharge the capacity can be calculated with the time $T_{1/e}$ till this V_0= 15,3V is dropped to 1/e×V0 = 5,64V. In this special case the following dependence is given:

$$C = \frac{R_{Discharge}}{T_{1/e}}$$



Conclusion:

Even some of the measurement seems to be not plausible; overall the electrolytic capacitor looked fine. So there is no need for any exchange.

2.3. Mains Voltage Selection Switch

The Amplifier will be operated with selection of “235V” mains supply on the rear panel. The measured AC voltage provided from mains is slightly varying between 236VAC and 239VAC.

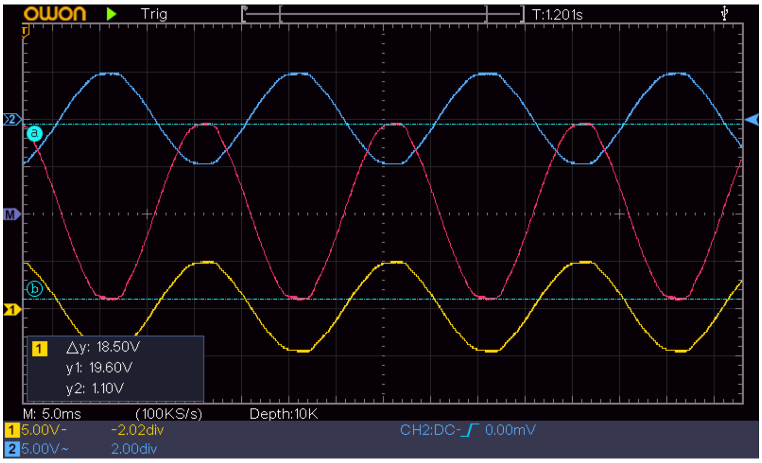
2.4. Tube Heating Supply

All tubes will be supplied with nominal 6.3VAC directly from the transformer. There is a center trap which is grounded.

Test Point	Pin	Voltage*
Heater V2 - V8	V6 Pin7/Pin2	6,86VAC

*Measured with multi meter FLUKE_15B®

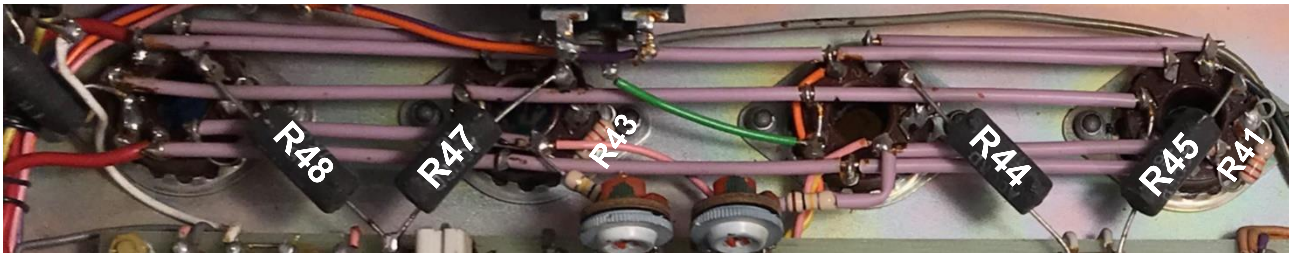
A.1) (79_001): U_{Heat} AC
CH1= Phase 1 U_{Heat}
Ch2= Phase 2 U_{Heat}
U_{Heiz} AC (Magenta, 50Hz): 18,6VSS → 9,3VS → 6,6Veff (assuming a perfect sine wave)
The multi meter shows a slightly higher value as the shape of the voltage curve is differing from a perfect sine wave.



In the Funkshun there is no separate fuse for the heater circuit. The nominal current from three ECC83 (each 0,3A) and four EL34 (each 1,5A) lies at 6,9A. The protection is given by the fuse in the primary circuit of the transformer. As the amp on the bench contains no reverb, the power consumption is significantly below the specified 3A fuse in the schematic. To ensure a more sensitive protection it will be reduced to 2A slow blow (T2,0A) based on power consumption measures (see chap. 3.1).

2.5. Grid and Screen Stopper Resistors at Output Stage

Check of the grid stopper resistors R41-R44 in the output stage. The resistors are mounted directly on the tube sockets using the not connected pin6 of the tube/socket as solder terminal.



Component	ACTUAL*	NOMINAL	Remark
R41 (V8)	22,28k	22k	✓
R42 (V7)	21,64k	22k	✓
R43 (V6)	21,78k	22k	✓
R44 (V5)	21,60k	22k	✓
R45 (V8)	1,022k	1k	✓
R46 (V7)	1,006k	1k	✓
R47 (V6)	1,004k	1k	✓
R48 (V5)	1,015k	1k	✓

*Measured without V5 –V8 tubes in the socket

Conclusion:
The grid and screen stopper resistors show no abnormalities in the measured values. The surfaces of the components have no cracks and no hints for thermal overload. There solder points look good. No hint for loose contacts. No substitute necessary.

2.6. High Voltage Supply

As in one of the EL34 tubes in the output stage the plate is shortened to the heater (see chap. 2.1), the amp was operated only with two EL34 tubes: V6 and V7. Static measurements with multi meter at different points in the circuit were taken (test points TPx are marked in the adapted schematic chap. 1.20):

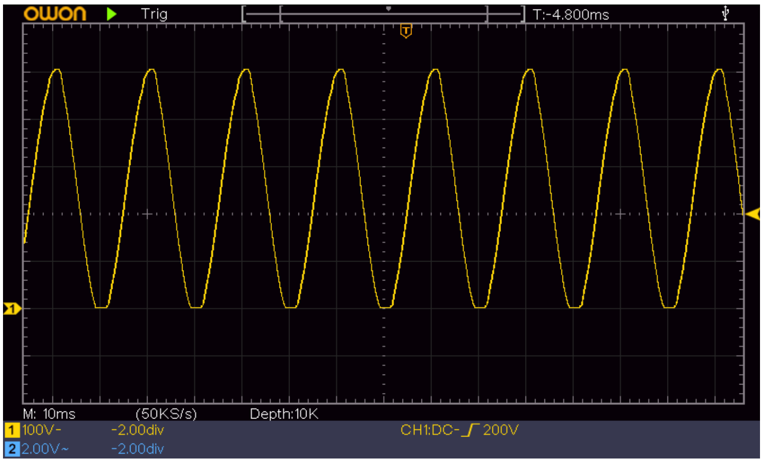
Test Point	Pin	Voltage*
transformer secondary HT	Black/Black	364VAC
after rectifier	TP1	+482VDC
after R39 470R	TP2	+471VDC
after R33 3k9	TP3	+447VDC
after R17 82k	TP4	+305VDC
after R13 47k	TP5	+278VDC
V2 /ECC83	1	+112DC
V2 /ECC83	6	+211VDC
V3 /ECC83	1	+326VDC
V3 /ECC83	6	+238VDC
V4 /ECC83	1	+294VDC
V4 /ECC83	6	+299VDC
V6 /EL34	3	+485VDC
V7 /EL34	3	+485VDC

*Measured with multi meter FLUKE_15B®

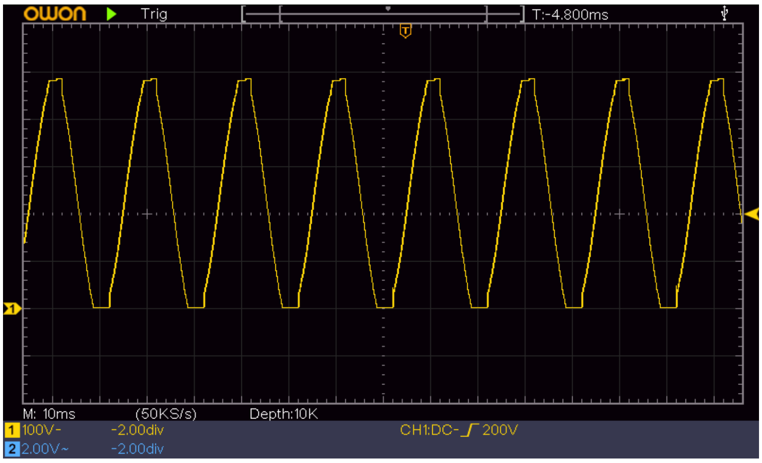
Ripple on DC High Voltage

All measurements were made with no signal at amplifier‘s input. All pots at front panel were at 5 unless otherwise noted.

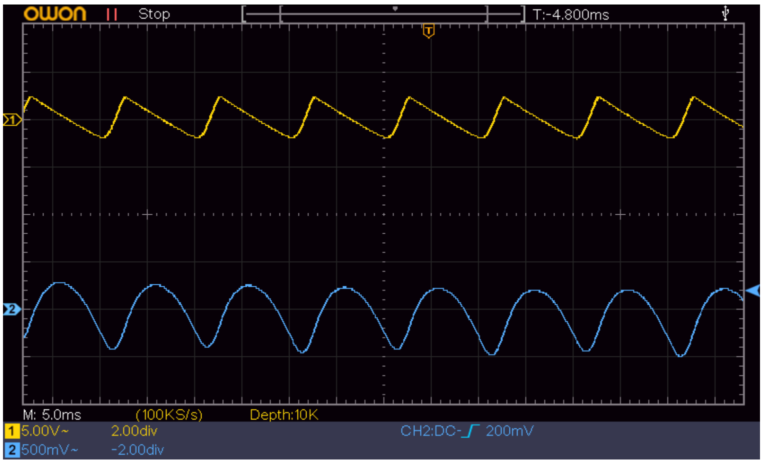
A.3.a) (83_000) High voltage
Ch1= TP0 from transformer
500VSS 50Hz.
High voltage OFF (standby)
The opposite side of the transformer shows the same curve but shifted by half a period.



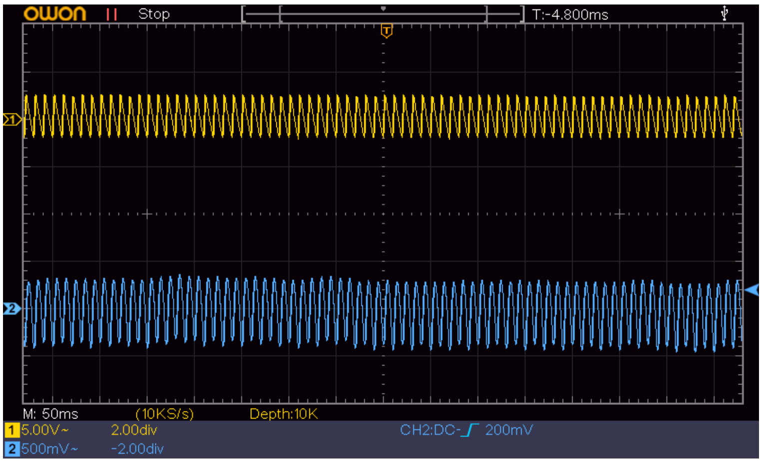
A.3.b) (83_001) High voltage
Ch1= TP0 from transformer
490VSS 50Hz.
High voltage ON
Under load the HT transformer output gets slightly reduced.
The opposite side of the transformer shows the same curve but shifted by half a period.



A.4.a) (81_000) DC high voltage
Ch1= TP1 +482VDC/ after rectifier
4,5V 100Hz ripple (~0,9%)
Ch2= TP2 +471VDC/ after R39
650mV 100Hz ripple (~0,1%)

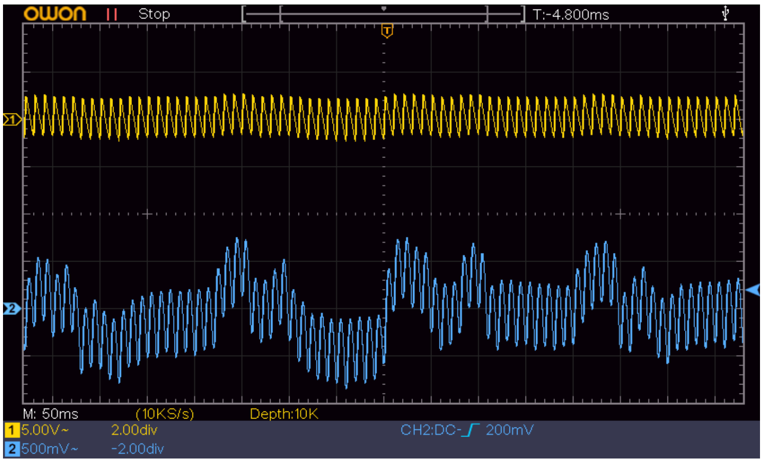


A.4.b) (81_001) DC high voltage
Ch1= TP1 +482VDC/ after rectifier
Ch2= TP2 +471VDC/ after R39
Only ~300mV fluctuation at TP2



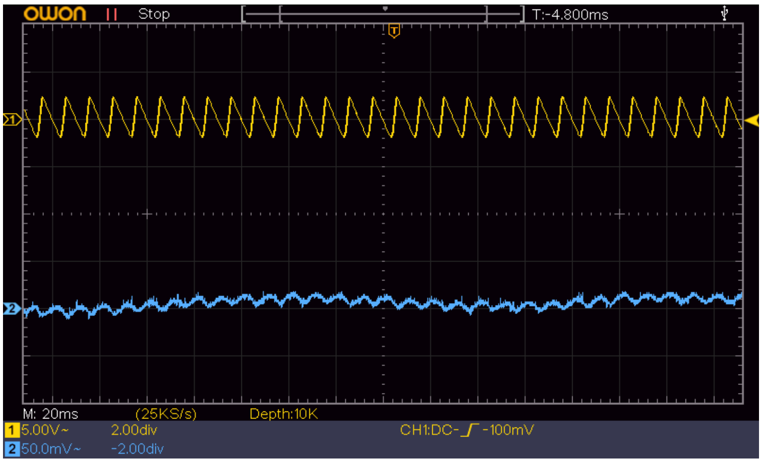
A.4.c) (81_002) DC high voltage
Ch1= TP1 +482VDC/ after rectifier
Ch2= TP2 +471VDC/ after R39

Knocking at the EL34 tubes is directly visible due to microphony of the tubes.

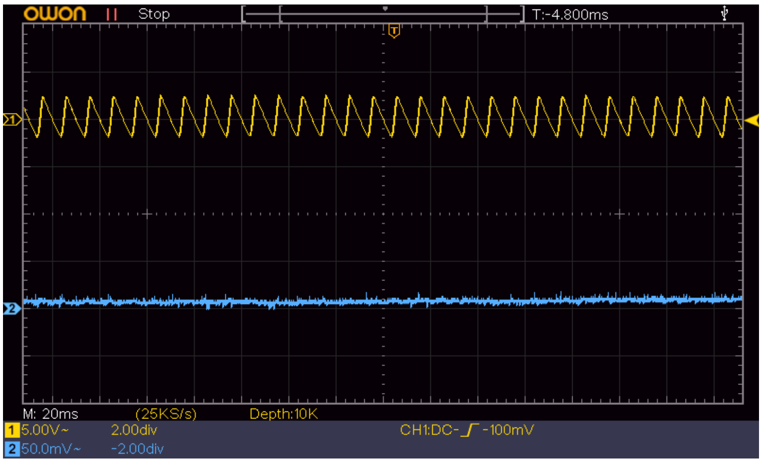


A.5) (81_003) DC high voltage
Ch1= TP1 +482VDC/ after rectifier
Ch2= TP3 +447VDC/ after R33

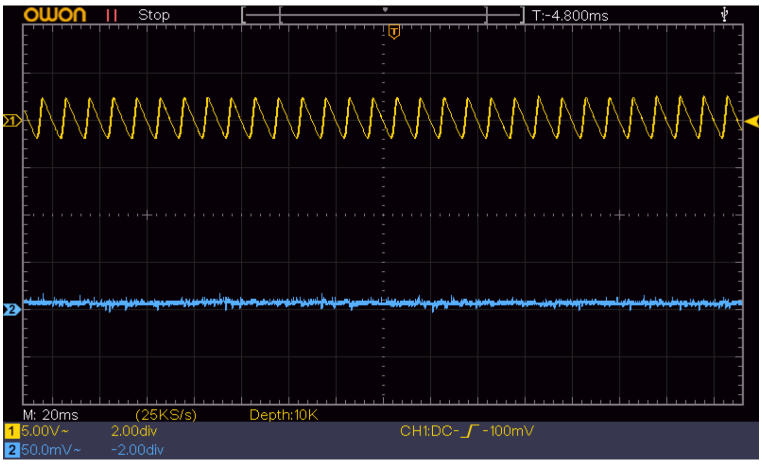
Neglectable ripple and fluctuation after R33.



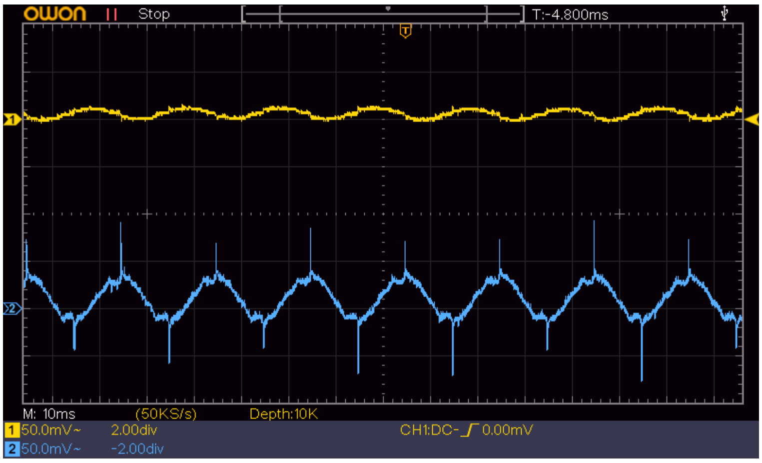
A.6) (81_004) DC high voltage
Ch1= TP1 +482VDC/ after rectifier
Ch2= TP4 +305VDC/ at C8A
No ripple or fluctuation at C8A



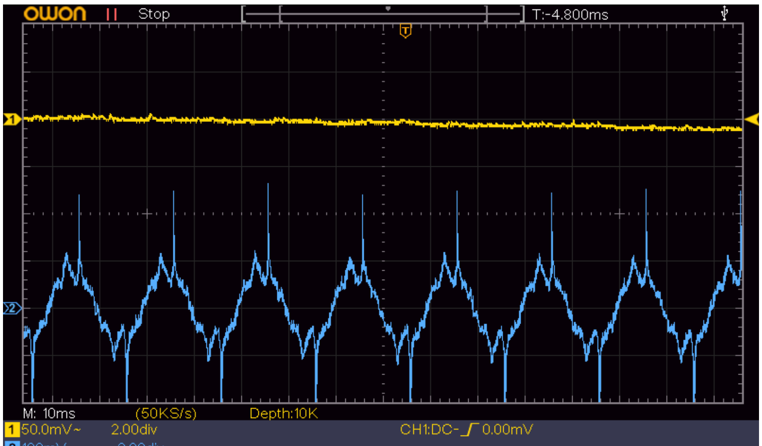
A.7) (81_005) DC high voltage
Ch1= TP1 +482VDC/ after rectifier
Ch2= TP5 +278VDC/ at C8B
No ripple or fluctuation at C8B



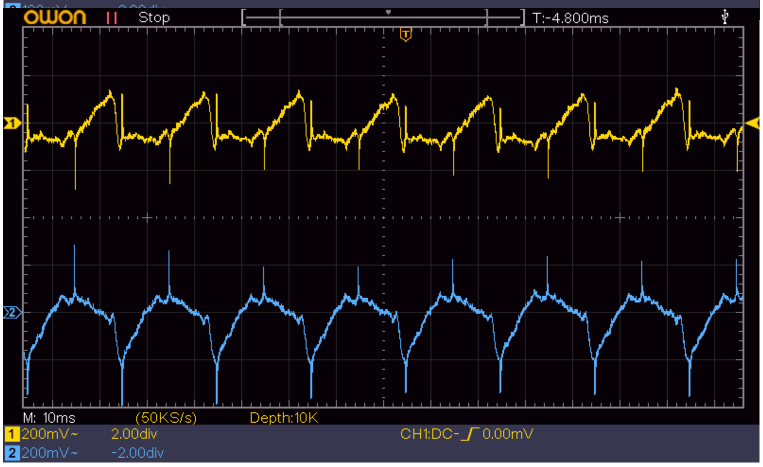
A.8) (82_003) Anodes V2 ECC83
Ch1= V2 / Pin1 (+112VDC)
20mV 50Hz ripple (~0,02%)
Ch2= V2 / Pin6 (+211VDC)
50mV 50Hz ripple (~0,02%)
The 50Hz ripple is coupling from the heater of the tube. The visible regular spikes might be caused by the diode switching in the bridge rectifier.
This is the tube with enlightening effect at “cold” switch ON, but further investigation in chap. 3.11 could not confirm this.



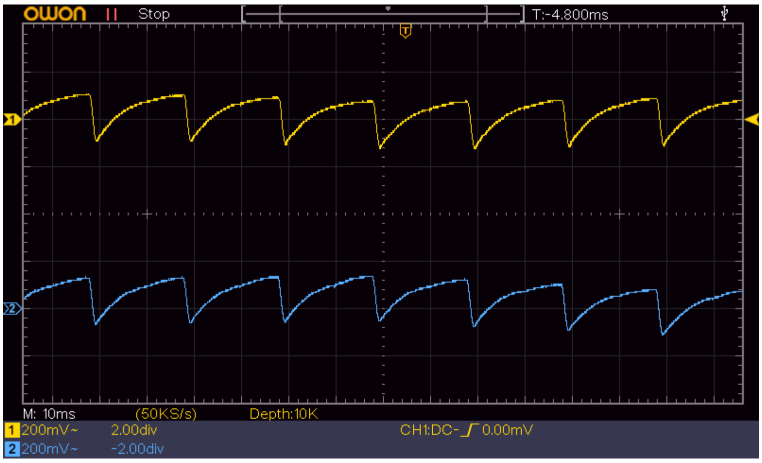
A.9) (82_004) Anodes V3 ECC83
Ch1= V3 / Pin1 (+326VDC)
No ripple at all
Ch2= V3 / Pin6 (+238VDC)
200mV 50Hz ripple (~0,08%)
The 50Hz ripple is coupling from the heater of the tube. The visible regular spikes (100Hz) might be caused by the diode switching in the bridge rectifier.



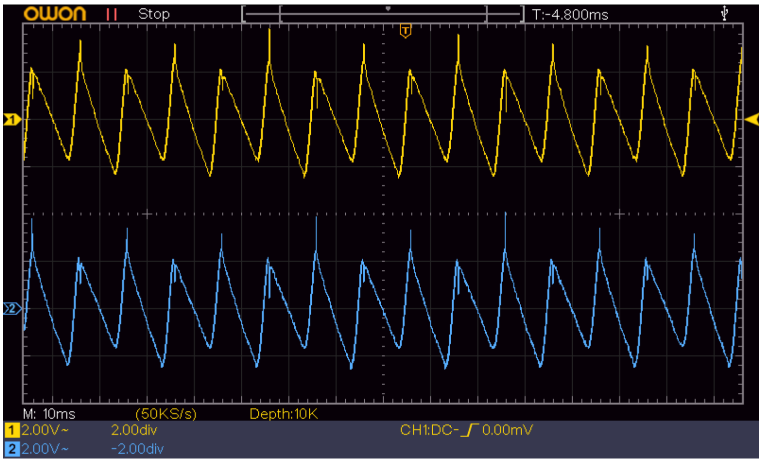
A.10.a) (82_005) Anodes V4 ECC83
Ch1= V4 / Pin1 (+294VDC)
200mV 50Hz ripple & hum (~0,07%)
Ch2= V4 / Pin6 (+299VDC)
280mV 50Hz ripple & hum (~0,09%)
The visible regular spikes (100Hz) might be caused by the diode switching in the bridge rectifier.



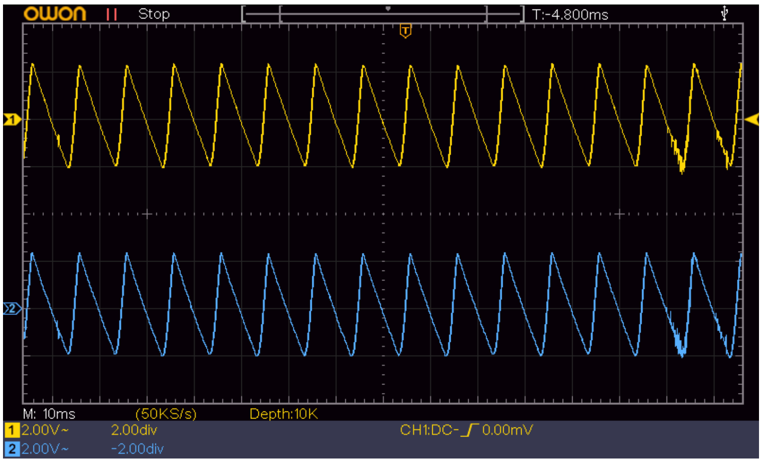
A.10.b) (82_006) Anodes V4 ECC83
Ch1= V4 /Pin1 (+294VDC)
200mV 50Hz ripple (~0,07%)
Ch2= V4 / Pin6 (+299VDC)
200mV 50Hz ripple (~0,07%)
If Master Volume is set to zero. The hum is gone. Therefore, the hum must be coupling in via signal path. The 50Hz ripple now can be identified as the remaining ripple from the bias of output stages. Same shape and magnitude as A.15.b). Test points are only separated by C21 resp. C22.



A.11.a) (82_009) Anodes V6 & V7
Ch1= V6 / Pin3 EL34 (+485VDC)
4V 100Hz ripple & hum (~0,8%)
Ch2= V7 / Pin3 EL34 (+485VDC)
4V 100Hz ripple & hum (~0,8%)
The basic 100Hz ripple is the remaining ripple on HT supply.



A.11.b) (82_008) Anodes V6 & V7
Ch1= V6 / Pin3 EL34 (+485VDC)
4,4V 100Hz ripple (~0,9%)
Ch2= V7 / Pin3 EL34 (+485VDC)
4,4V 100Hz ripple (~0,9%)
The Master Volume is set to zero. The basic 100Hz ripple from HT supply is still there. While the hum with 100Hz spike from the rectifier is gone. Therefore, the hum must couple in via signal path.



2.7. Cathode Voltages at Preamp Tubes

Static measurements with multi meter at cathodes of the tubes within the preamp:

Test Point	Pin	Voltage*
V2 /ECC83	3	+0,91VDC
V2 /ECC83	8	+1,63VDC
V3 /ECC83	3	+81,8VDC
V3 /ECC83	8	+1,92VDC
V4 /ECC83	3	+83,2VDC
V4 /ECC83	8	+83,2VDC

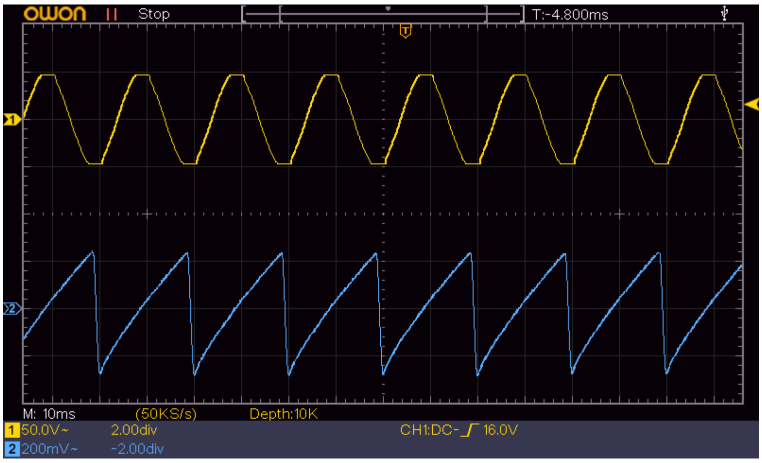
*Measured with multi meter FLUKE_15B®

At V2 there could be no disturbance identified with the scope. At V3a and V4 the already at the anodes visible hum with spikes depending on Master Volume was observed.

2.8. Bias at Output Stage

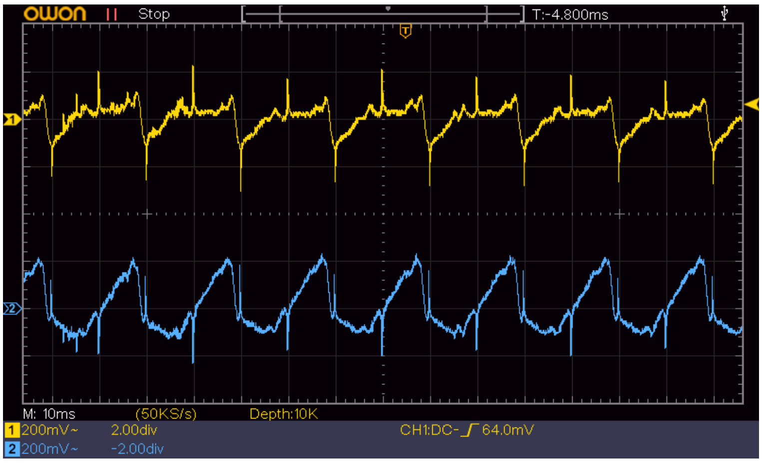
The bias voltage to operate the output stage is simply made with a single path rectifier.

A.14) (82_000) Bias Voltage before and after rectifying diode BY127
Ch1= TP6 transformer output
99Vpp → 49Vmax → 34,7VeffAC (assuming a perfect sine wave form)
Ch2= TP7 after diode -46,3VDC
520mV 50Hz ripple (~1,1%)

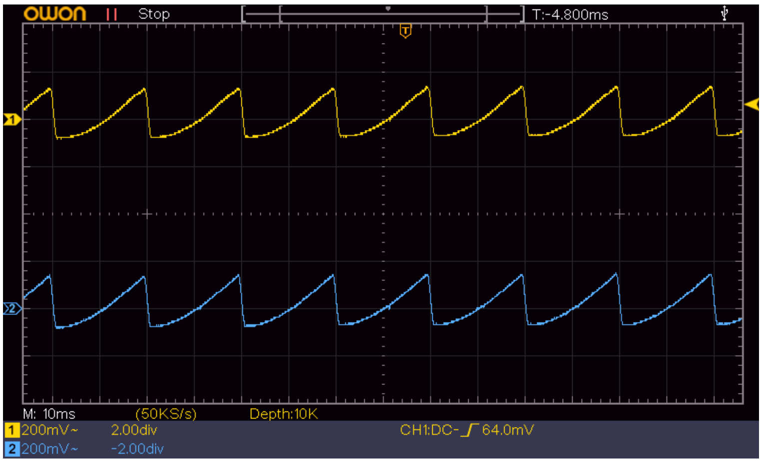


A.15.a) (82_001) Bias voltages before grid resistors
Ch1= V6 / Pin 6 -41,2VDC
Ch2= V7 / Pin 6 -41,6VDC

The observed behaviour is the same as in A.10.a) as the test points are separated only by C22 resp. C21.



A.15.b) (82_002) Bias voltages before grid resistors
Ch1= V6 / Pin 6 -41,2VDC
Ch2= V7 / Pin 6 -41,6VDC
The Master Volume was set to zero. The basic 100Hz ripple from HT supply is still there. While the hum with 100Hz spike from the rectifier is gone. Therefore, the hum would be coupling in via signal path.

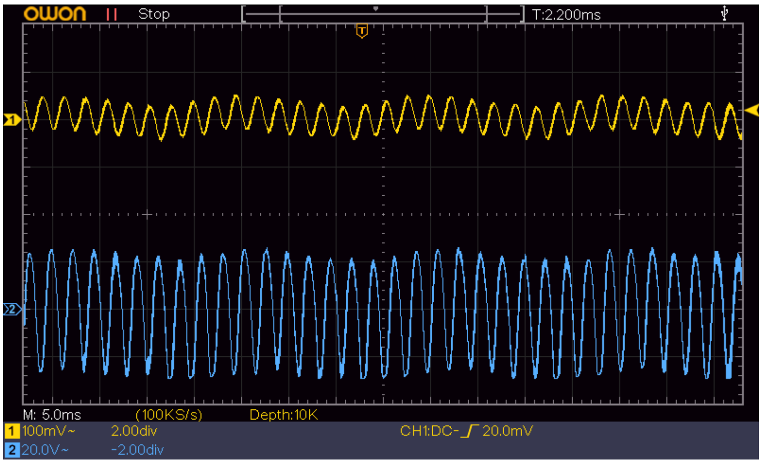


2.9. Checking the Signal Path

440Hz sin wave from the generator was given to the input and checked at different points along the signal path towards the speaker output. All pots at front panel were at 5 unless otherwise specified.

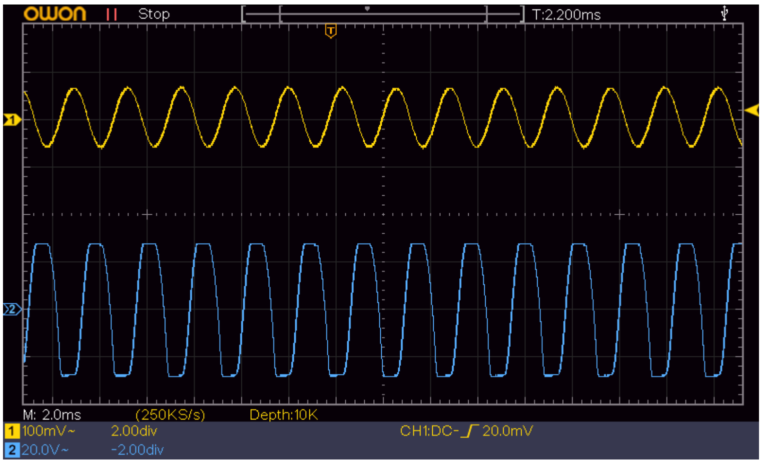
A.20.a) (94_000)
Complete signal path LOW gain input
Ch1= V2a ECC83 / Pin 2
Ch2= 8Ohm speaker simulator

Input (70mVpp) and consequently output (50Vpp) signal noisy due to bad contact at the input jack. Overall gain factor: ~714.



A.20.b) (94_002)
Complete signal path HIGH gain input
Ch1= V2a ECC83 / Pin 2
Ch2= 8Ohm speaker simulator

Input signal of 130mVpp arrives at the speaker simulator with 56Vpp. Overall gain factor: ~431. The sine wave is cut



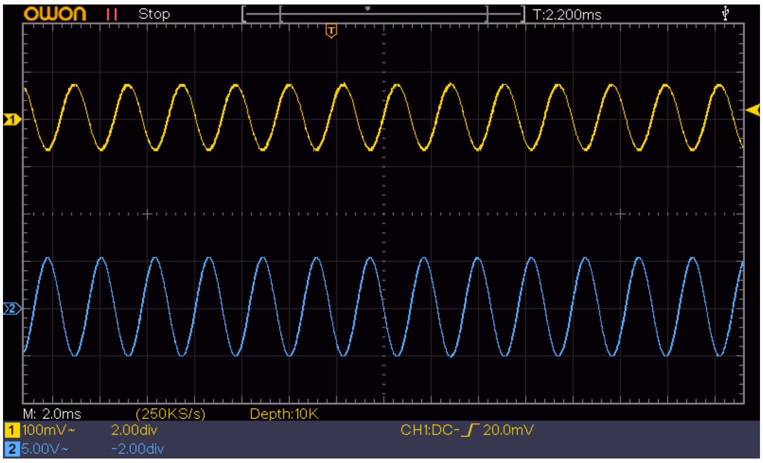
Conclusion:

The input signal arrives at the speaker. In case of using the HIGH gain input the signal seems to be clipped. The detailed tracing of the signal path will demonstrate that this limitation is by an overdriven output stage.

Signal path step by step for input HIGH with Overdrive

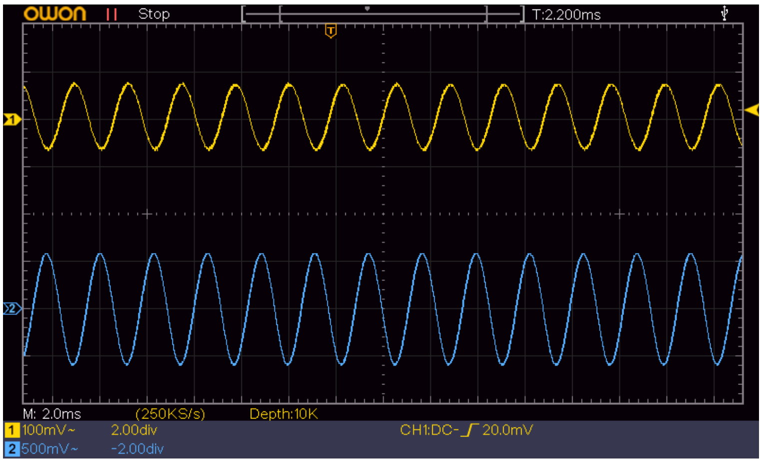
A.21) (94_003) Preamp V2a
Ch1= V2a ECC83 / Pin 2
Ch2= V2a ECC83 / Pin 1

Calm signal without noise:
Input (140mVpp) → Output (10,5Vpp)
Gain factor Preamp: ~75
This is a really huge amplification in the preamp.



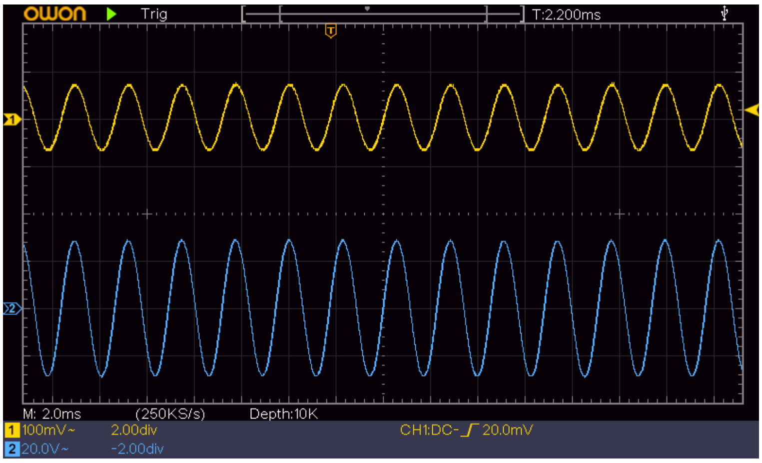
A.22) (94_005) 2nd stage V2b
Input
Ch1= V2a ECC83 / Pin 2
Ch2= V2b ECC83 / Pin 7

Overdrive circuit reduces the signal by a factor of ~0,11
1,2Vpp provided after overdrive stage for input at 2nd stage.



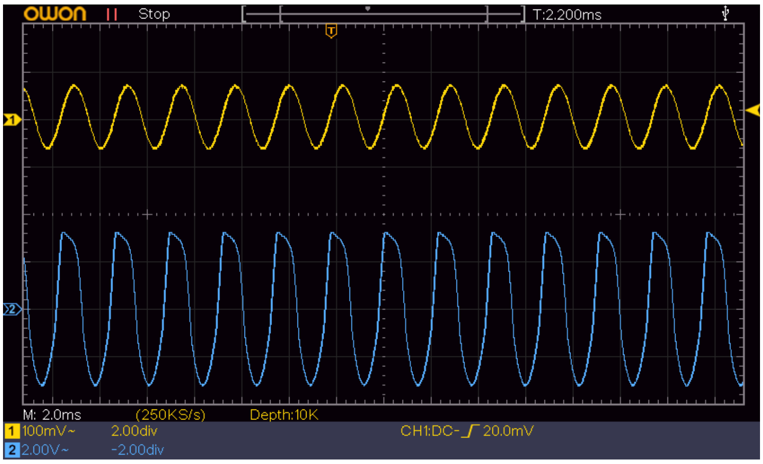
A.23) (94_006) 2nd stage V2b
Output
Ch1= V2a ECC83 / Pin 2
Ch2= V2b ECC83 / Pin 6

56Vpp at output of 2nd stage →
Gain factor 2nd stage: ~47
56Vpp will be provided for the tone stack



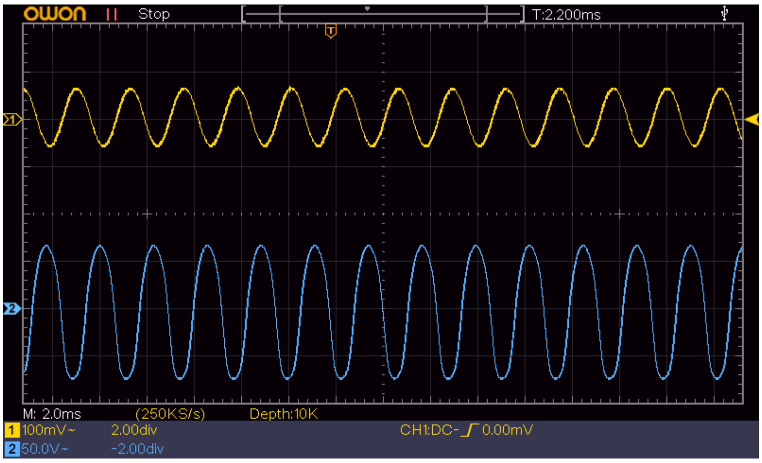
A.24) (94_008) 3rd stage V3b
Input - After tone stack
Ch1= V2a ECC83 / Pin 2
Ch2= V3b ECC83 / Pin 7

Tone stack reduces input by a factor of ~0,11 down to 6,4Vpp.
Distortion gets more visible



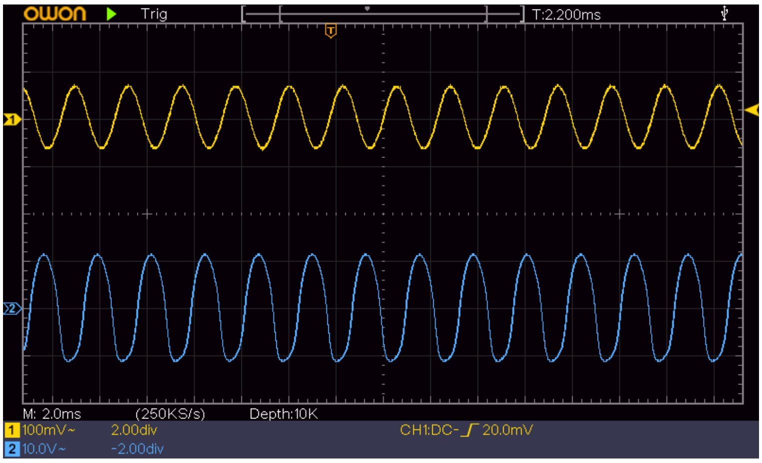
A.25) (96_000) 3rd stage V3b
Output
Ch1= V2a ECC83 / Pin 2
Ch2= V3b ECC83 / Pin 6

3rd stage provides 140Vpp →
Gain factor 3rd stage: ~21,9



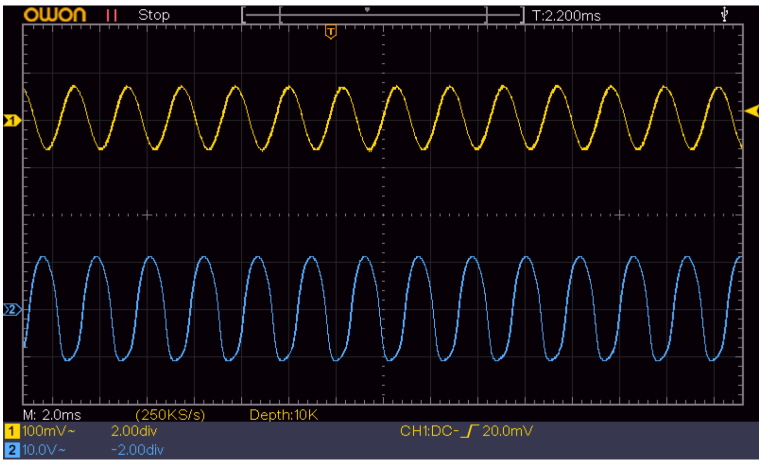
A.26) (94_009) 4th stage V3a
Input – cathode follower to drive phase inverter
Ch1= V2a ECC83 / Pin 2
Ch2= V3a ECC83 / Pin 2

23Vpp sine wave with visible distortion



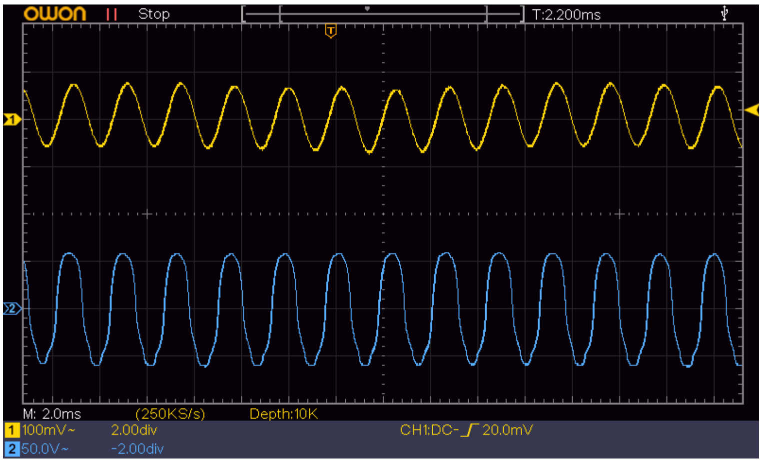
A.27) (94_011) 4th stage V3a
Output cathode follower
= Phase inverter Input V4a
Ch1= V2a ECC83 / Pin 2
Ch2= V3a ECC83 / Pin 3
= V4a ECC83 / Pin 2

The cathode follower V3a reduces the input by a factor ~0,95 down to 22Vpp



A.28.a) (94_012) Phase inverter A
Output phase inverter V4a
Ch1= V2a ECC83 / Pin 2
Ch2= V4a ECC83 / Pin 1 (C22)

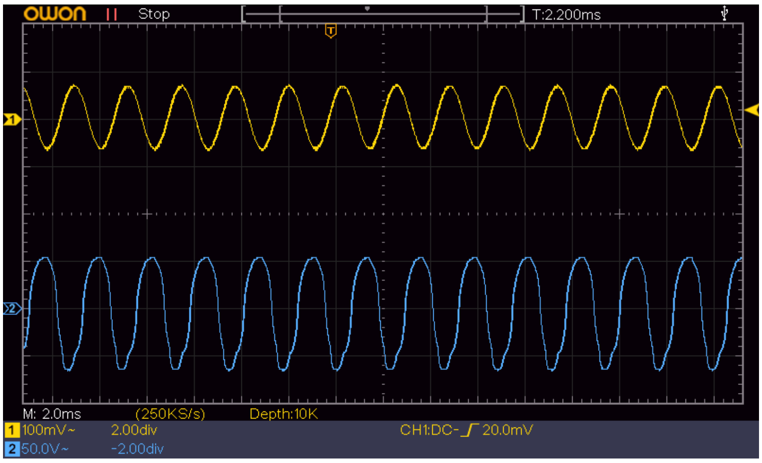
Channel A of the phase inverter provides 120Vpp → Gain factor: ~5,45



A.28.b) (94_014) Phase inverter B
Output phase inverter V4b
Ch1= V2a ECC83 / Pin 2
Ch2= V4b ECC83 / Pin 6 (C21)

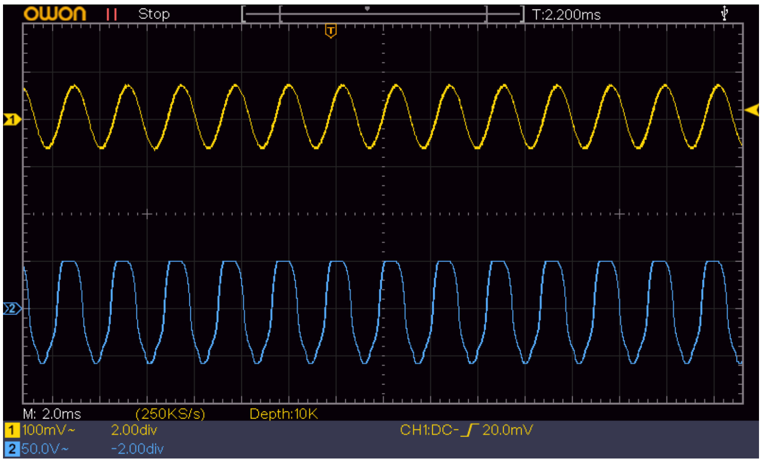
Channel B of the phase inverter provides 120Vpp → Gain factor: ~5,45

The two output signals of the phase inverter seem to be symmetric.



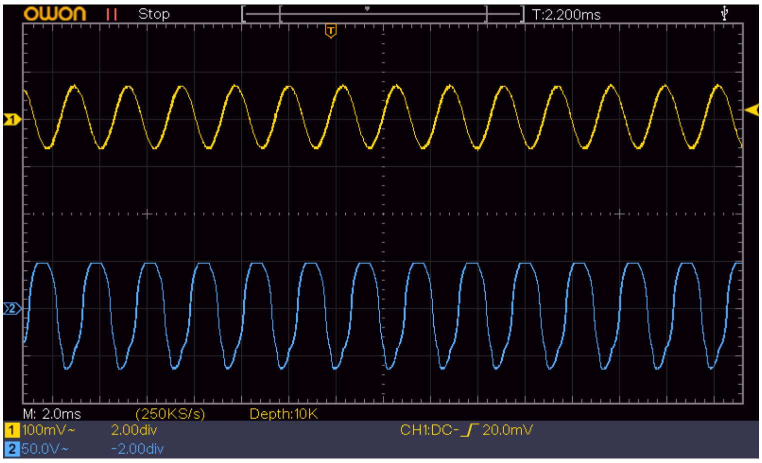
A.29.a) (94_015) Output stage A
Input of Output stage A: V7
Ch1= V2a ECC83 / Pin 2
Ch2= V7 EL34 / Pin 5

The 120Vpp provided from the phase inverter is cut hard at approx. +50V due to the bias voltage of approx. -47V. This is the limit at input of the EL34 tube!



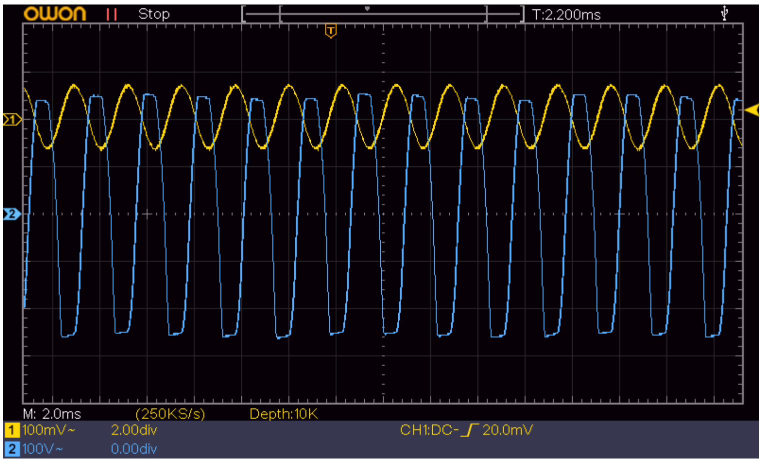
A.29.b) (94_016) Output stage B
Input of Output stage B: V6
Ch1= V2a ECC83 / Pin 2
Ch2= V6 EL34 / Pin 5

The 120Vpp provided from the phase inverter is cut hard at approx. +50V due to the bias voltage of approx. -47V. This is the limit at input of the EL34 tube!



A.30.a) (94_017) Output stage A
Output of Output stage A: V7
Ch1= V2a ECC83 / Pin 2
Ch2= V7 EL34 / Pin 3

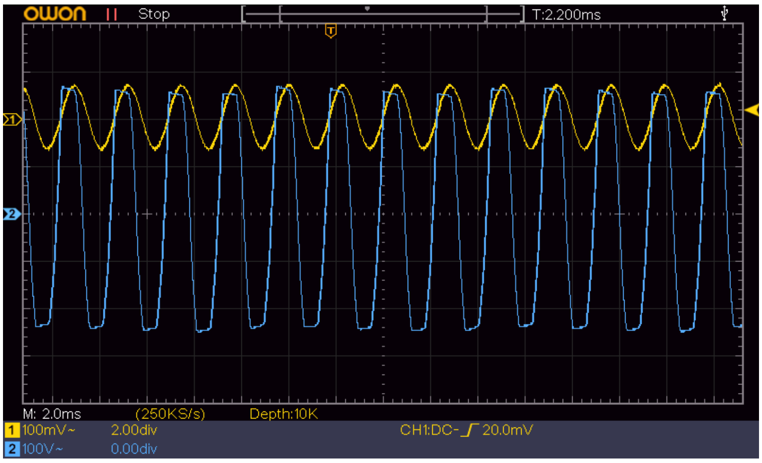
Output stage A with 500Vpp →
Gain factor: ~4,5
The output stage EL34 tube is absolutely at the limit!



A.30.b) (94_018) Output stage B
Output of Output stage B: V6
Ch1= V2a ECC83 / Pin 2
Ch2= V6 EL34 / Pin 3

Output stage B with 500Vpp →
Gain factor: ~4,5

The output stage EL34 tube is absolutely at the limit!

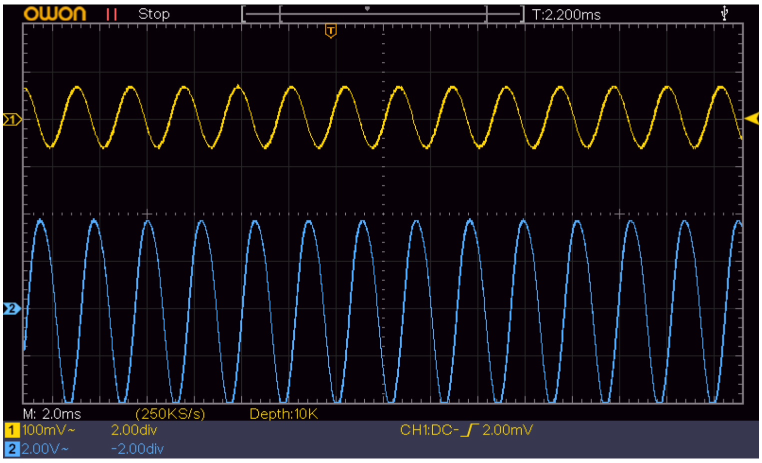


Conclusion:
Although the master volume is only at 5 from 10, the output stage is already at its physical limit. The sine wave is cut hard at the edges. The modifications of the topology at the audio path in the amp on the bench is likely the reason, why the signal amplitude from the entrance at the phase inverter on is too high.

Signal path step by step for input HIGH without Overdrive

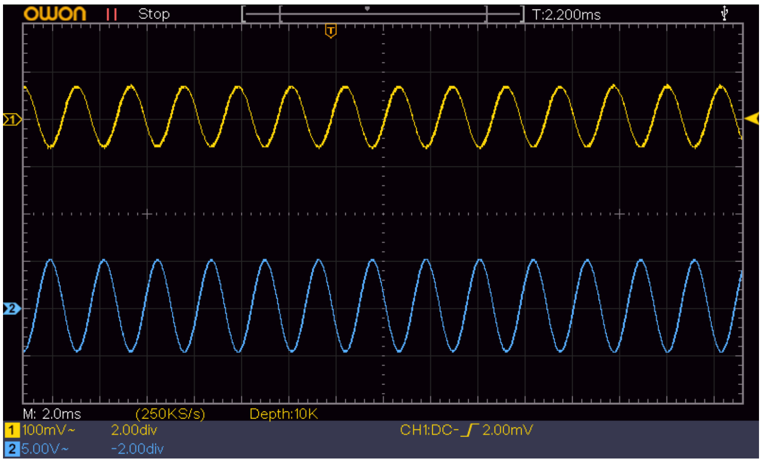
To have a cleaner signal along the signal path, the measurements have been repeated without using the OVERDRIVE. Thus, less signal amplitude already from the 2nd stage on is available.

B.20) (97_000) Complete path
Ch1= V2a ECC83 / Pin 2
Ch2= 8Ohm speaker simulator
Input signal of 130mVpp arrives at the speaker simulator with 7,8Vpp. Overall gain factor: ~60.
This is much more the situation known from other amplifiers with EL34 output stage. Be aware that the output stage power is only half due to operation with only two tubes instead of a quad of EL34.



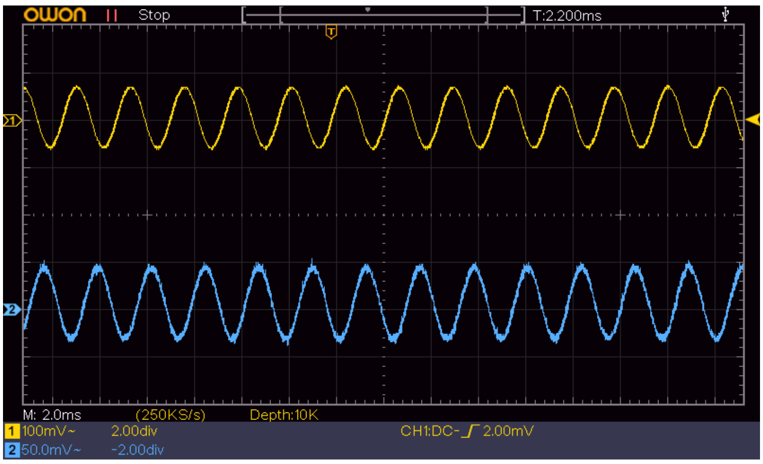
B.21) (97_001) Preamp V2a
Ch1= V2a ECC83 / Pin 2
Ch2= V2a ECC83 / Pin 1

Calm signal without noise:
Input (130mVpp) → Output (9,5Vpp)
Gain factor preamp: ~73
This huge amplification in this preamp stage is caused by the big anode load resistor of 200kΩ.



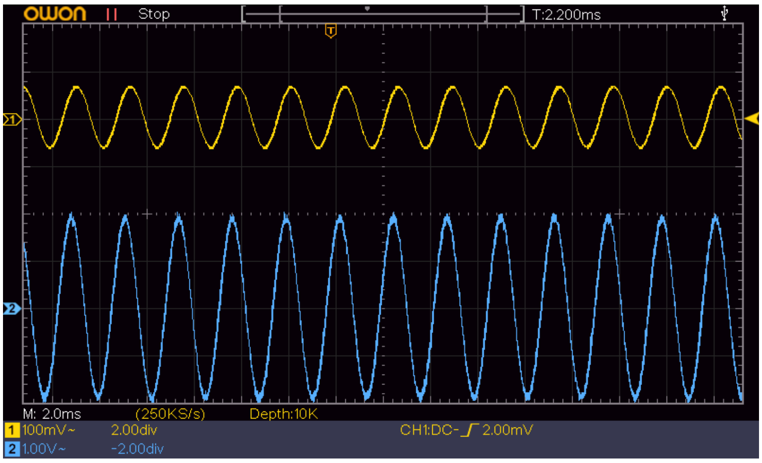
B.22) (97_002) 2nd stage V2b Input
Ch1= V2a ECC83 / Pin 2
Ch2= V2b ECC83 / Pin 7

Overdrive circuit reduces the signal by a factor of ~0,008
75mVpp provided after overdrive circuit as input at 2nd stage.



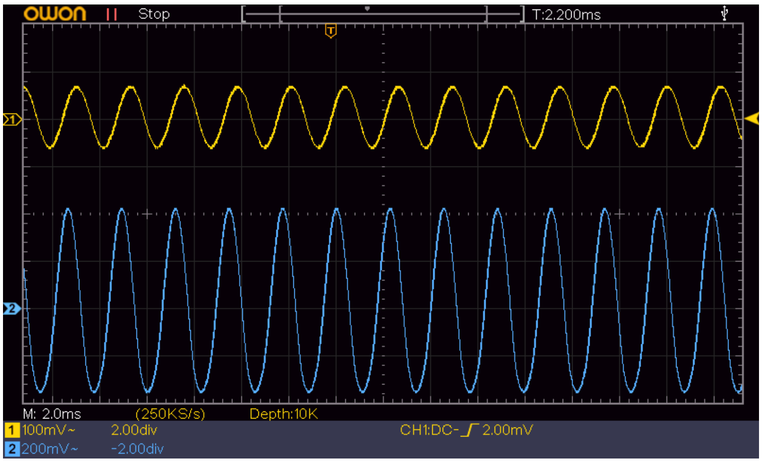
B.23) (97_003) 2nd stage V2b
Output
Ch1= V2a ECC83 / Pin 2
Ch2= V2b ECC83 / Pin 6

3,8Vpp at output of 2nd stage →
Gain factor 2nd stage: ~51
3,8Vpp will be provided for the tone stack



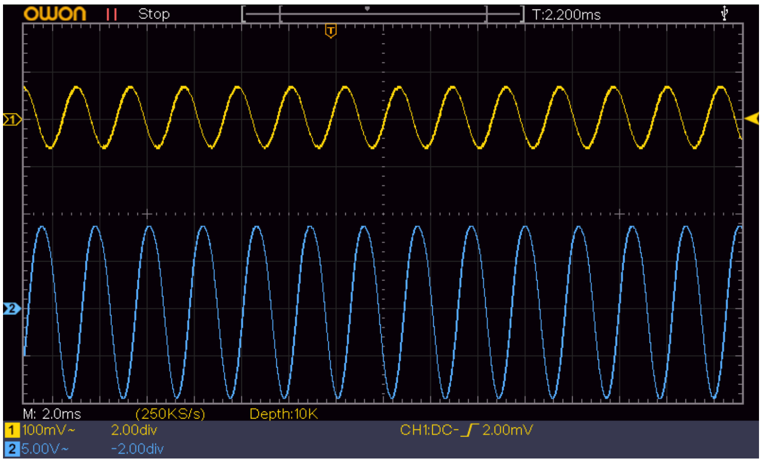
B.24) (97_004) 3rd stage V3b
Input - After tone stack
Ch1= V2a ECC83 / Pin 2
Ch2= V3b ECC83 / Pin 7

Tone stack reduces input by a factor of ~0,2 down to 760mVpp.



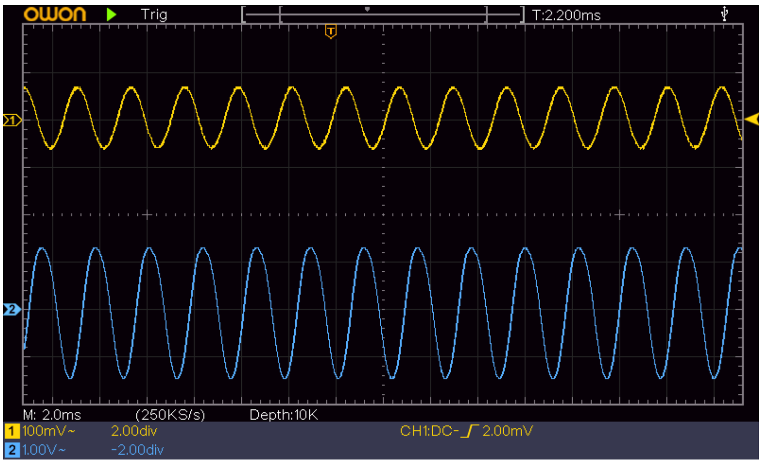
B.25) (97_005) 3rd stage V3b
Output
Ch1= V2a ECC83 / Pin 2
Ch2= V3b ECC83 / Pin 6

3rd stage provides 18Vpp →
Gain factor 3rd stage: ~24
Gain is reduced due to partially bypassed cathode (see chap. 1.11).



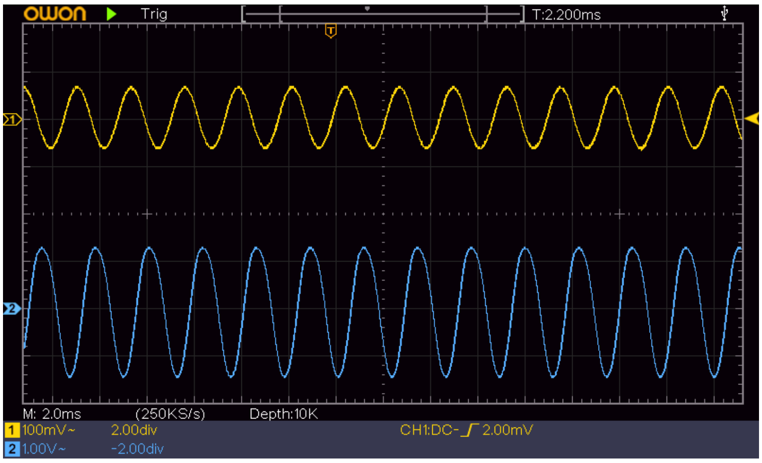
B.26) (97_006) 4th stage V3a
Input – cathode follower to drive phase inverter
Ch1= V2a ECC83 / Pin 2
Ch2= V3a ECC83 / Pin 2

2,8Vpp sine wave at input of the cathode follower



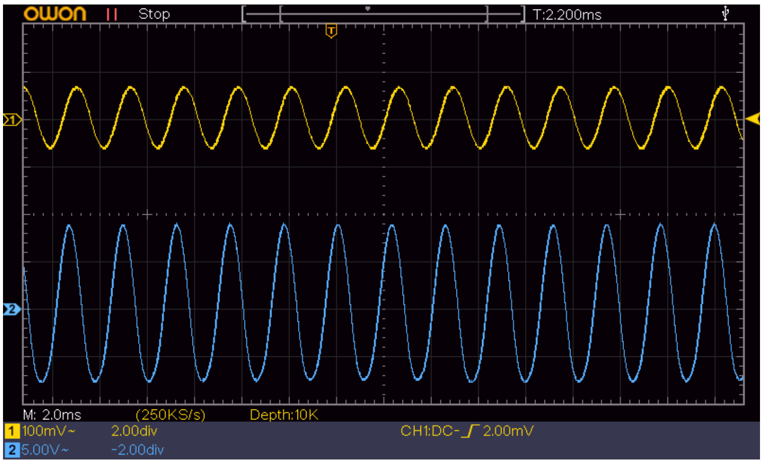
B.27) (97_007) 4th stage V3a
= Phase inverter Input V4a
Ch1= V2a ECC83 / Pin 2
Ch2= V3a ECC83 / Pin 3
= V4a ECC83 / Pin 2

The cathode follower V3a keeps the amplitude at 2,8Vpp (gain: ~1,0)



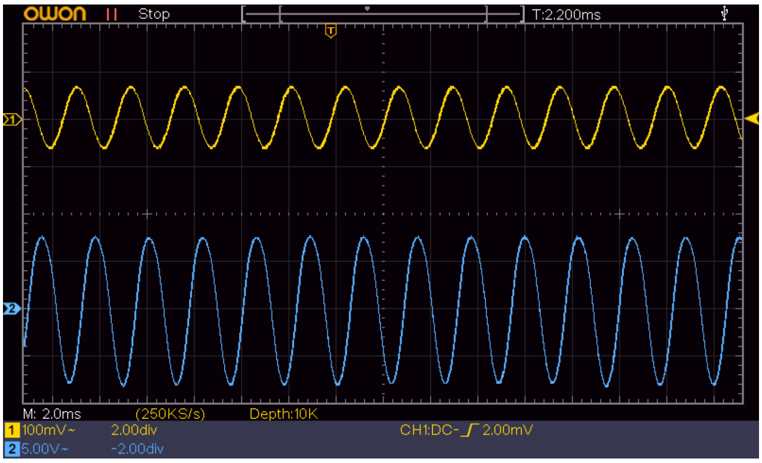
B.28.a) (97_008) Phase inverter A
Output phase inverter V4a
Ch1= V2a ECC83 / Pin 2
Ch2= V4a ECC83 / Pin 1 (C22)

Channel A of the phase inverter provides 16Vpp → Gain factor: ~5,7



B.28.b) (97_009) Phase inverter B
Output phase inverter V4b
Ch1= V2a ECC83 / Pin 2
Ch2= V4b ECC83 / Pin 6 (C21)

Channel B of the phase inverter provides 15,2Vpp → Gain factor: ~5,4

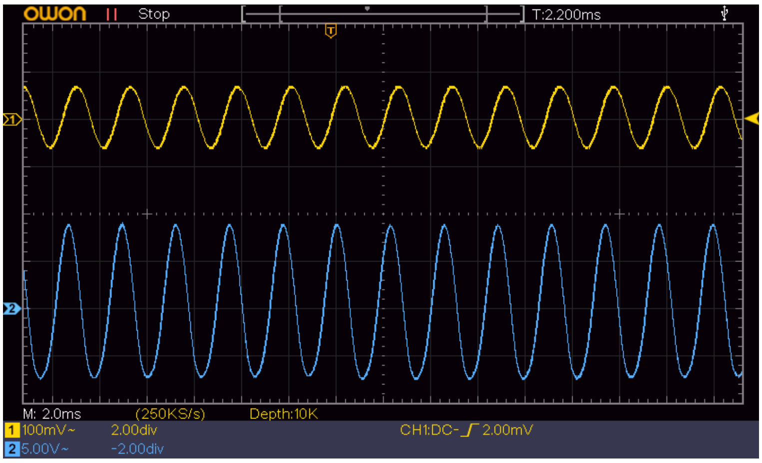


Conclusion:

Phase inverter output A (B.28.a) is inverted to input signal (B.27) while phase inverter output B (B.28.b) has the same phase as the input. The peak peak value of the two output signals of the phase inverter is slightly (~5%) different. As the two parts of the phase inverter are operated with the same anode load resistor value of 82KΩ it was expected that signal A is higher (see also chap. 1.12).

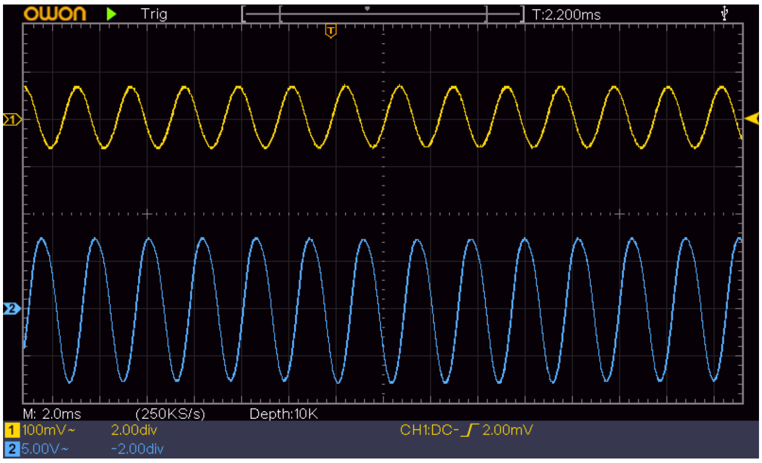
B.29.a) (97_010) Output stage A
Input of Output stage A: V7
Ch1= V2a ECC83 / Pin 2
Ch2= V7 EL34 / Pin 5

16,5Vpp from phase converter A arrives at the input of the V7 EL34 tube. As expected, the above observed limitation is gone.



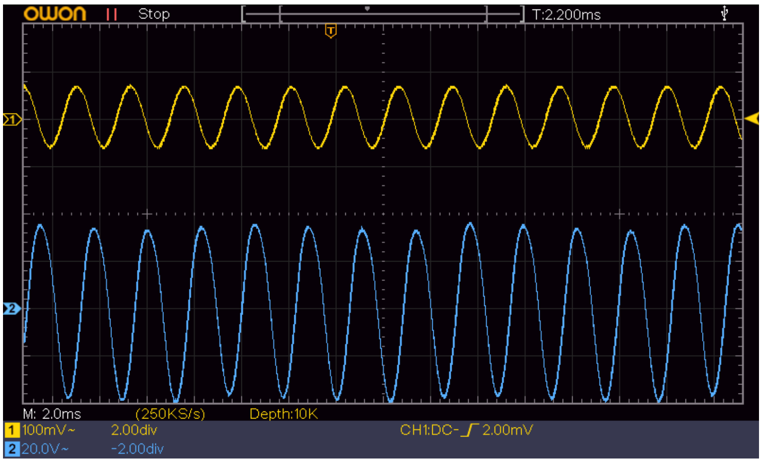
B.29.b) (97_011) Output stage B
Input of Output stage B: V6
Ch1= V2a ECC83 / Pin 2
Ch2= V6 EL34 / Pin 5

15Vpp from phase converter B arrives at the input of the V6 EL34 tube.
As expected, the limitation observed with OVERDRIVE is gone.
The amplitude asymmetry between the two phases is about 9%.



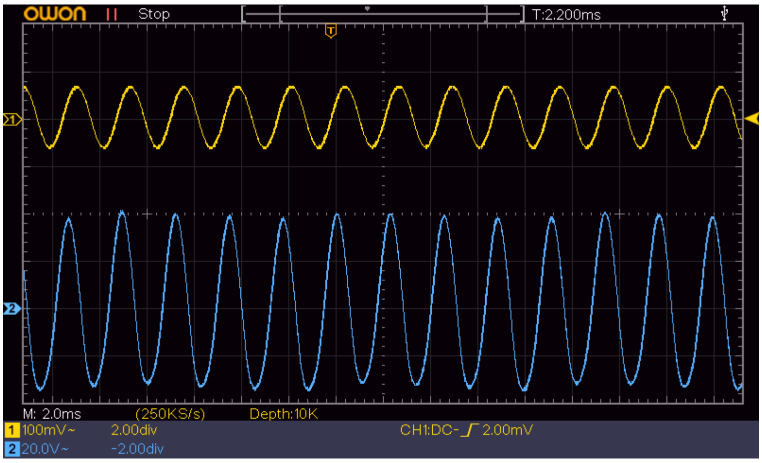
B.30.a) (97_012) Output stage A
Output of Output stage A: V7
Ch1= V2a ECC83 / Pin 2
Ch2= V7 EL34 / Pin 3

Output stage A with 70Vpp →
Gain factor: ~4,2
As expected, the limitation observed with OVERDRIVE is gone.



B.30.b) (97_013) Output stage B
Output of Output stage B: V6
Ch1= V2a ECC83 / Pin 2
Ch2= V6 EL34 / Pin 3

Output stage B with 72Vpp →
Gain factor: ~4,2
As expected, the limitation observed with OVERDRIVE is gone.



3. Special Investigations and Exchanges / Modifications

3.1. Main Fuse blown

The main fuse in the circuit on the primary side of the transformer was found to be blown. Instead of the specified 3A it was a 2,5A, but this was not the reason for the failure. The reason for the blown fuse was identified in chap. 2.1: One of the EL34 tubes has a short between heater and anode plate.
Measured current with all 7 tubes equipped (Multi meter instead of fuse at primary side):

Power ON (cold tubes)	After ~10s	HT activated (Standby OFF)
0,84ACA	0,32ACA	0,52ACA

To achieve a more sensitive protection (see also chap. 2.4) a 2A slow blow (T2,0A) will be equipped instead of the specified 3A fuse.

3.2. Mains and Standby Switch corroded

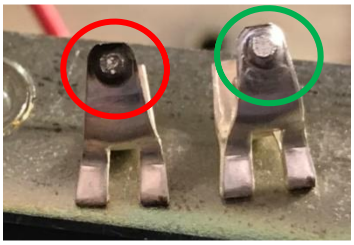
The standby switch was found to be unable to switch ON. As those old toggle switches are assembled with screws, they can be easily disassembled.

Toggle switches in the front panel

Open standby switch corroded

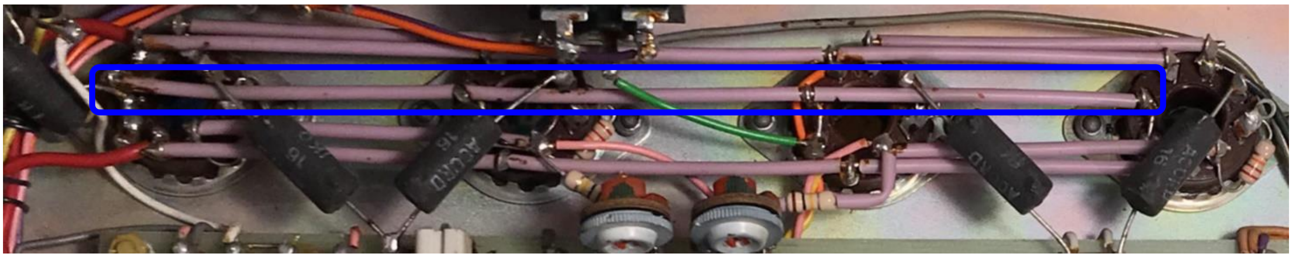
Open standby switch cleaned

The internal view with dismounted toggle stick showed that the "toggle dumbbell" was totally corroded (red oval). With a fiberglass pen the silver-plated surfaces could be cleaned (green oval).

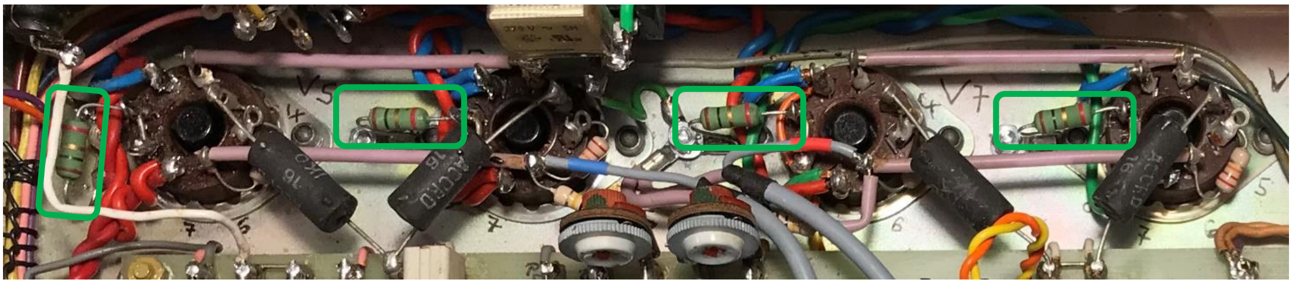


Even the mains switch was still working it was also disassembled and cleaned. The picture shows the two toggle pieces of this bipolar switch. The right contact was already cleaned while the left piece is still with corroded surface.
After the re-assembly both switches were checked with multi meter for correct and proper switching.

3.3. Integrate Shunt Resistors to measure Cathode Current

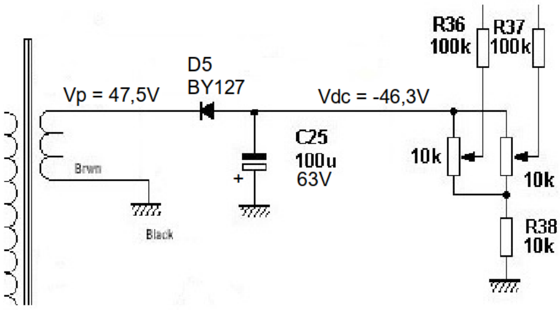


To allow the measurement of the cathode current directly without any adapter shunt resistors were integrated in the ground connection of the EL34 V5 – V8 in the output stage. Therefore, the common grounding (see blue frame in the picture above) was removed and substituted with a ground connection including a shunt resistor 1Ω / 2W / 2% at each single tube (see green frames in picture below).

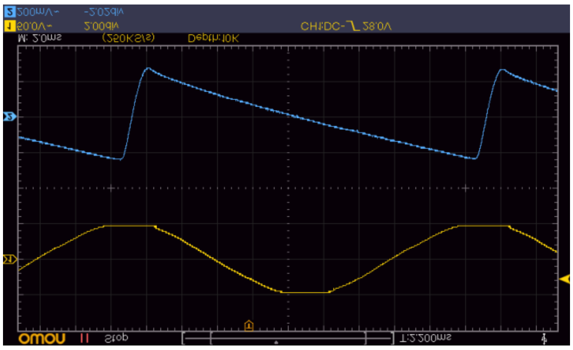


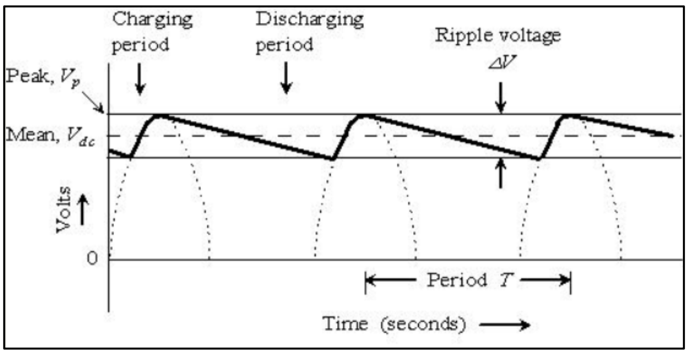
3.4. Optimization of Bias at Output Stage

The bias voltage to operate the output stage is simply made with a half wave rectifier.



As bias voltage is a negative voltage the measured curve (92_001: CH1= AC voltage before rectifying diode By127 D5; CH2= ripple voltage in output circuit) is vertically mirrored for an easy comparison with the typical explaining schematic from literature beside (https://learning.uonbi.ac.ke/courses/SPH307/scormPackages/path_2/):





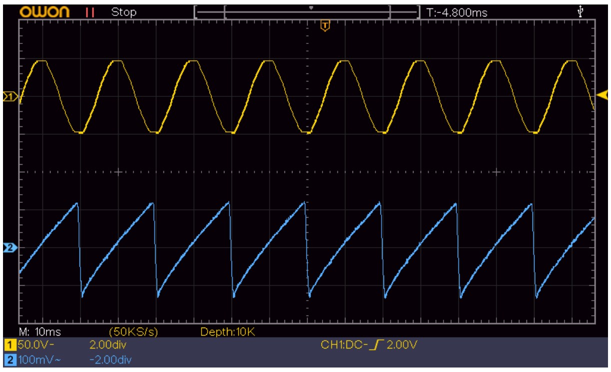
The size of the ripple ΔV after rectifying depends on size of the smoothing capacitor C_{smooth} (here C25 100µF), the load resistance R_L (here 15kΩ), the peak value of the output voltage V_P (here 47,5V) and the Period T respectively the frequency f_{ripple} (here 50Hz as it is a half wave rectifier):

$$\Delta V = \frac{V_P}{R_L \cdot f_{ripple} \cdot C_{smooth}}$$

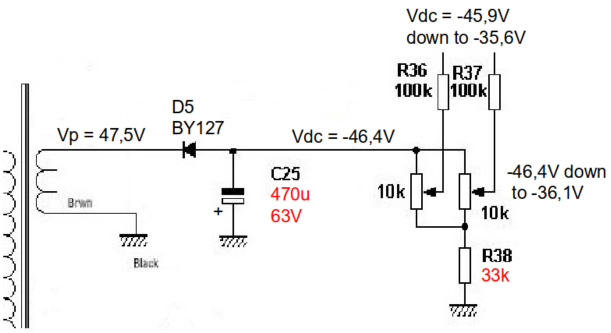
This formula is an approximation only valid for the case discharging period is approximately equal to period T (https://www.youtube.com/watch?v=ruEYtTYePRk&app=desktop). In reality this formula slightly overestimates the values. In the given circuit the measured ΔV is at 520mV (see also A.14 in chap. 2.8) versus a calculated value of 633mV.
Now it is easy to decide how the ripple on the bias voltage can be further reduced to ensure a cleaner operation of the output stage, even the 1,1% accuracy of the Funkshun can be found also in many other guitar amps.
By simply clipping in an additional 100µF parallel to C25, the ripple voltage is reduced by a factor of two as expected by the formula.

I.1) (85_000) Ch1= TP6 transformer output
95VPP → 47,5Vmax → 33,6VeffAC
Ch2= TP7 after diode -46,3VDC
260mV 50Hz ripple (~0,5%)

The ripple on the bias voltage was cut to half by doubling the smoothing capacitor C25 (see also A.14 in chap. 2.8).



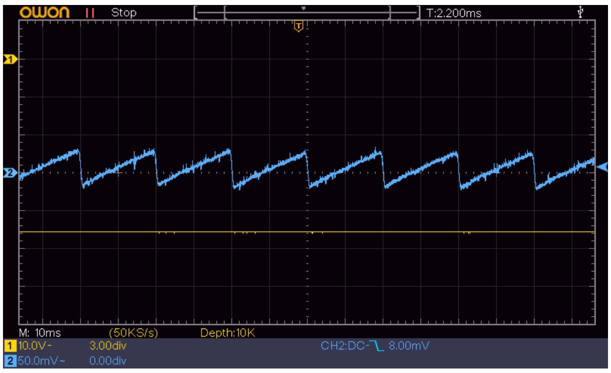
For final optimization two things were modified in the bias circuit. First the C25 was substituted by a 470µF /63V capacitor, which is today available in the same size as the build in 100µF /63V from the 1970s. And second the R38 will be set to 33kΩ, which makes the two trim pots more sensitive (whole turn to cover approx. 7V range) and also supports further ripple reduction.



According to the formula above ΔV should be reduced by a factor of ~12 down to somewhere at 50mV.

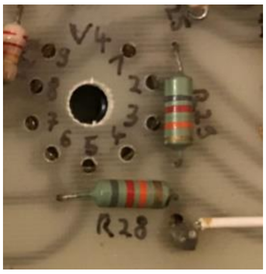
I.2) (104_000) Ripple of Bias with HT
Ch1 & Ch2= TP7 after diode
-46,4VDC
ΔV 45mV 50Hz ripple (~0,1%)

The ripple on the bias voltage could be reduced as expected by the calculation for ΔV.

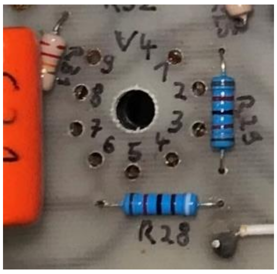


3.5. Dissimilar Anode Resistors at Phase Inverter

As discussed in chap. 1.12 and measured in chap. 2.9 (B.28.a and B.28.b) the load resistors at the phase inverter have to be adapted to achieve symmetric signals from the phase inverter for the output stage to avoid distortion.



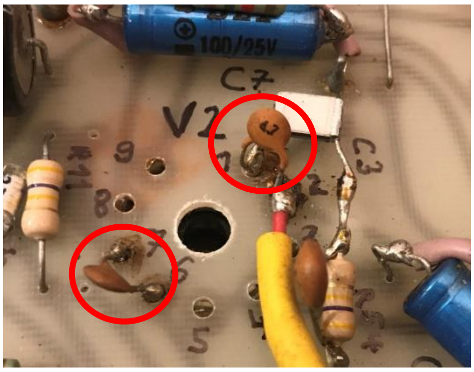
Previous: R28= R29= 82kΩ



Final design: R28= 91kΩ R29= 82kΩ

3.6. Remove Additional Filter Capacitors at V2

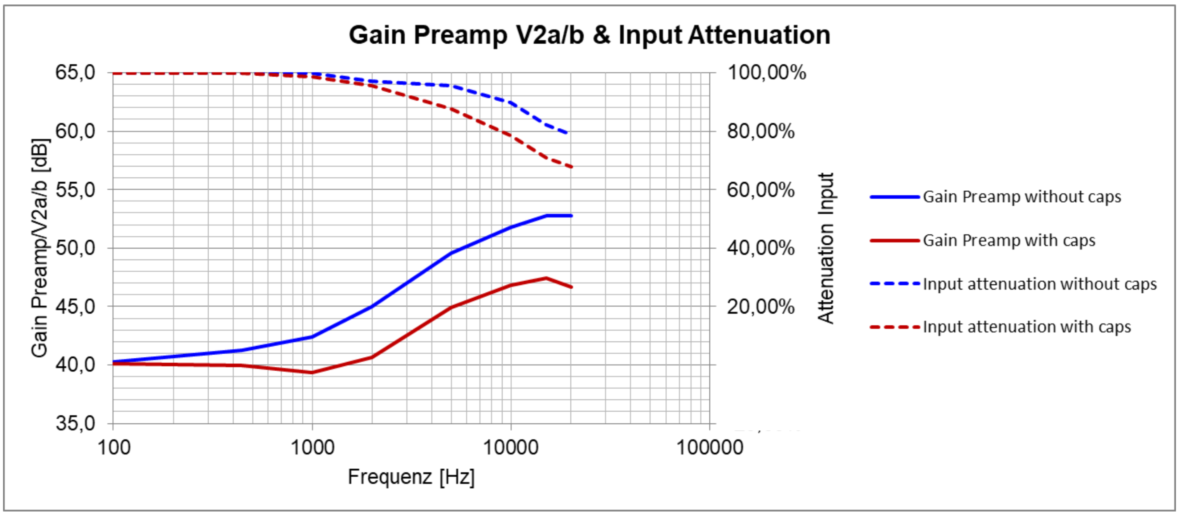
There are additional filter capacitors of 4,7pF between grid and plate of V2 mounted. As already discussed in chap. 1.6 they are removed.



Additional caps between grid and plate of V2

Without caps

During the investigation of hum noise reduction in chap. 3.11 it was found that those additional caps have an impact to the noise behaviour. As they start to reduce the noise between 1kHz and 2kHz the question came up “Which impact do they have on the audio signal?”



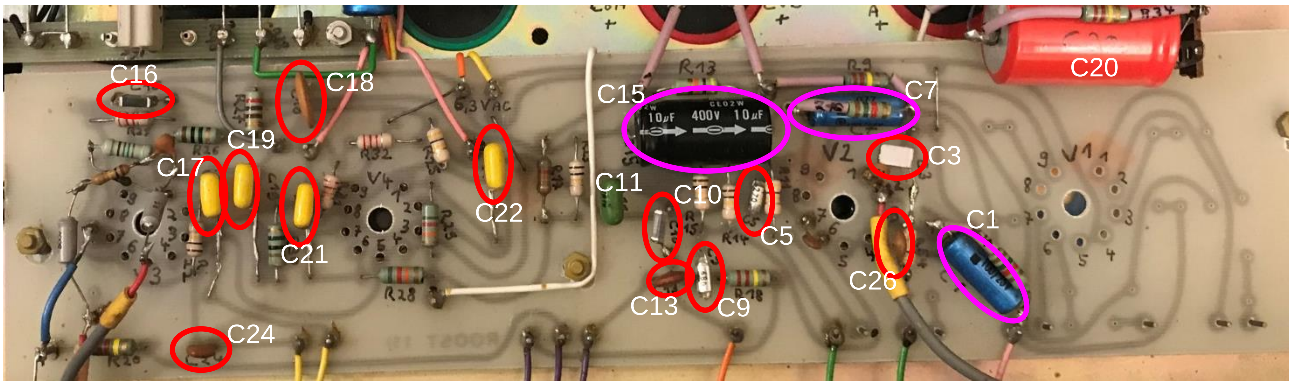
Therefore, the transfer function in total for the first two amp stages in the tube V2 is measured using sine waves at the input with different frequencies. VR8 OVERDRIVE was kept at zero, while VR1

DRIVE is set to half scale (Level 5). Note: the measurements were done after R54 was corrected to 47kΩ and the preamp circuit was redesigned (see chap. 3.12).
The attenuation curves show the real attenuation due to the tube circuit as the amplitudes are nominated to the "natural" decreasing amplitude of the sine generator over frequency at a pure 1MΩ load. The transfer function is calculated in dB from the quotient of amplitude at pin 2 through the amplitude at pin 6 of V2.
The impact of the additional caps is significant. The input at the first stage gets about 10%more attenuated than without starting at approximately 2kHz. The total transfer function shows a loss of frequencies around 1kHz and a roughly 5dB lower gain for frequencies above 2kHz. This is leading to treble loss.

Conclusion:
The additional capacitors between grid and anode at first two stages of the preamp lead to a loss of brightness. This loss of brightness leads also to hum noise reduction in frequency range above 1-2kHz. As the impact on the amplified signal is significant the capacitors will be removed permanently to avoid unwanted impact on the audio signal.

3.7. Substitute Capacitors on Printed Board

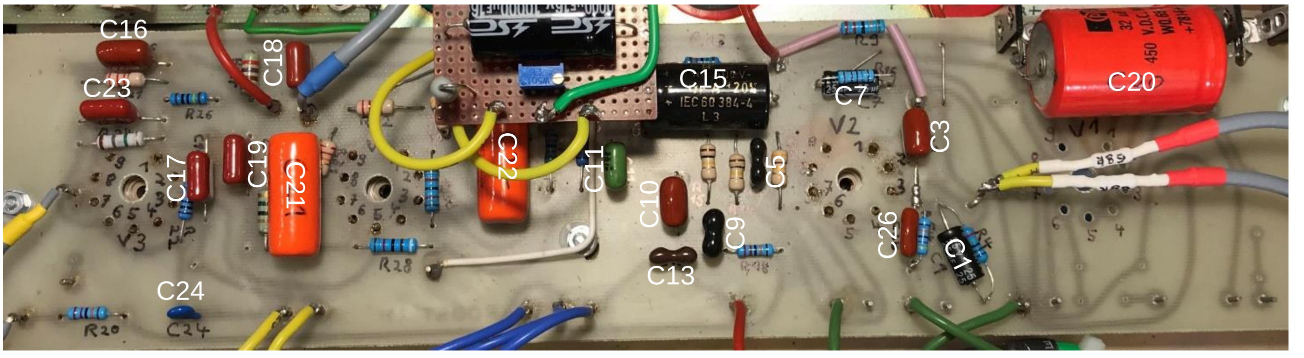
In a first step all capacitors on the printed board were substituted except the electrolytic capacitors C1, C7, C15, C20 and the C11 in the tone stack (red markers). In a second step after the investigation in chap. 3.11 and chap. 3.12 also the electrolytic capacitors C1, C7, C15 (magenta markers) were substituted.



Component	Actual	Substitute	Remark
C16	6,8nF*	22nF	Polypropylene film 630V
C18	10nF	10nF	Polypropylene film 630V
C17	47nF	47nF	Polypropylene film 630V
C19	47nF	47nF	Polypropylene film 630V
C24	1nF	1nF	Ceramic 500V
C21	47nF	47nF	Orange Drop715P 600V
C22	47nF	47nF	Orange Drop715P 600V
C10	6,8nF*	22nF	Polypropylene film 630V
C13	470pF	470pF	Mica Silver 500V
C9	680pF	680pF	Mica Silver 500V
C5	270pF	220pF	Mica Silver 500V
C3	6,8nF*	22nF	Polypropylene film 630V
C26	1nF	1nF	Polypropylene film 630V
C1	100µF	25µF	Elco 25V
C7	100µF	25µF	Elco 25V
C15	10µF	15µF	F&T Elco 500V

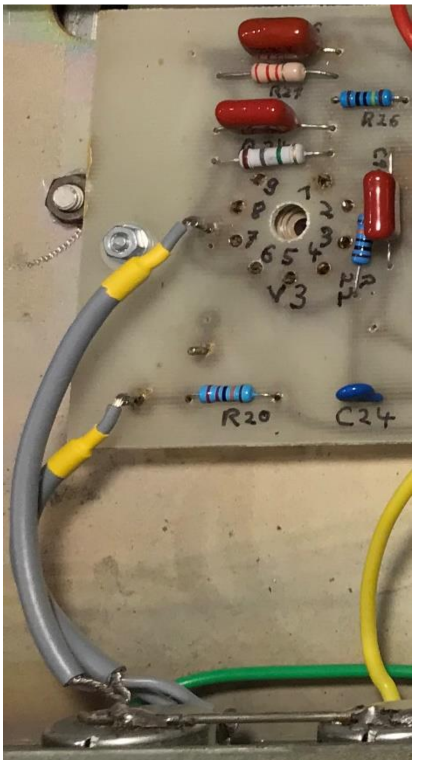
*Component changed within a former modification

The originally equipped polystyrene capacitor C5 had a value of 270pF. In chap. 1.8 it was discussed to reduce this value back to the typical value ([1] Blencowe, chap. 4.15.) of 220pF which can be found also in all schematics for the Funkshun.
The cathode bypass capacitor values C1 and C7 were reduced to necessary / typical value according to the discussion in chap. 1.11.
The filter cap C15 was substituted with a slightly higher capacity (15µF instead of 10µF) and a higher dielectric strength (450V instead of 400V).
Board after exchange:

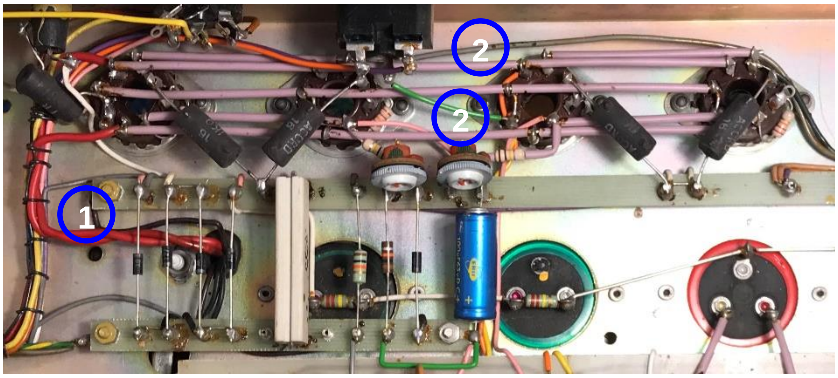


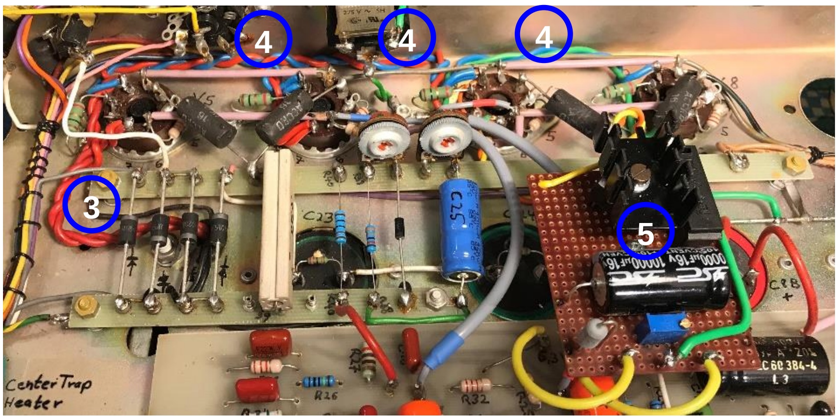
3.8. Remove Master Volume Modifications

As discussed in chap. 1.9 the master volume modification will be removed totally and the original design according circuit diagram is re-installed.
The PCB with the modification (left picture) shows a chaotic wiring made in a “flying” soldering style.
After removing the modification, the wiring is clean and much simpler without “flying” components.



3.9. Optimize Lead Dress of the Heater Supply





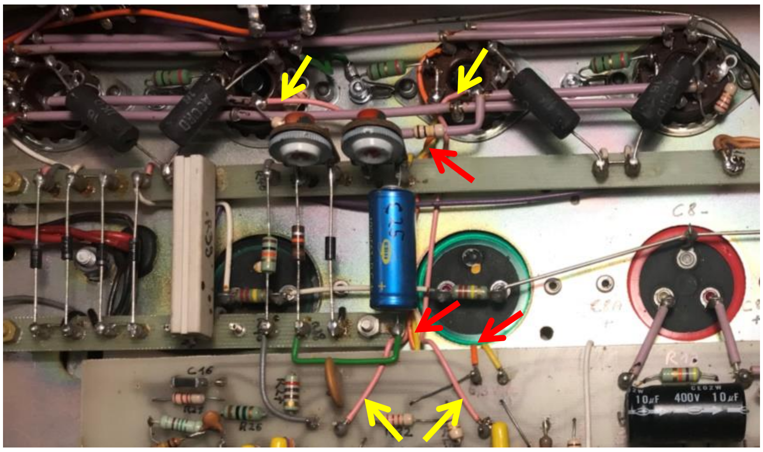
To minimize the hum introduced from the 6,3AC heating the lead dress of the heater wiring has been optimized. According to [1] (Blencowe, chap. 3.14) tight and proper twisted wires have been mounted.

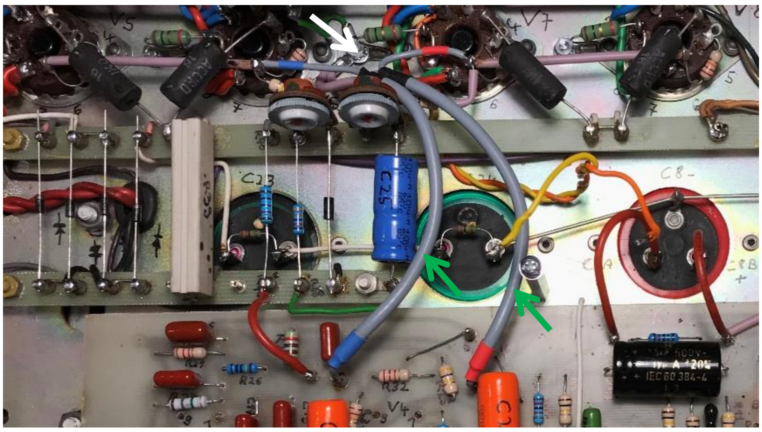
The upper picture right hand shows like-it-was. The two red wires coming from the transformer are only slightly twisted (1). Purple insulated rods (2) that are not twisted at all are used between the individual EL34 tubes.

The lower picture right hand shows the topology after rework. Tight twisted wires (3) well-spaced from the signal path as most as possible in the corner of the chassis (4).

Also visible is the added DC converter for the DC heater of the preamp (see chap. 3.20).

3.10. Shielded Signal Transfer to Output Stage





The two phases of the audio signal from preamp stage (phase inverter) on the PCB to the output stage at the rear side of the chassis were realized with the two pink unshielded wires indicated with yellow arrows in the picture on the right side. Unfortunately, it was routed down to the chassis near the big filter cap C24. But even worse, the two lines are all the way under C25 parallel to the twisted lines of the tube heating (orange and yellow wires indicated by the red arrows).

To lower the risk to get distortion on the signals, the unshielded wires were removed and substituted by shielded wires (green arrows) grounded on one side (white arrow). Additional to that the routing was changed to keep more distance to wiring on the base of the chassis.

On the lower picture the small add on board with the DC converter of the heater is disassembled to have an unobstructed view on the changed wires.

3.11. Reduce Hum Noise

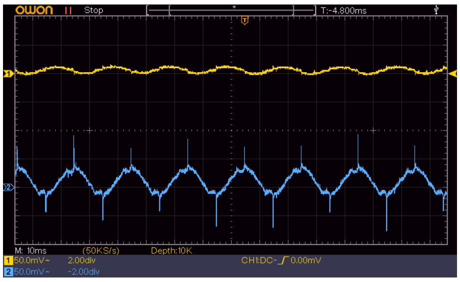
The modifications so far described in chap.3, especially those in chap. 3.9 (lead dress) and chap. 3.10 (shielded signal path) should support the reduction of hum noise. The investigations and measurements indeed indicate that the hum noise is still on a high audible level. A further effort has to be done.

Potential Impact from Full Bridge Rectifier

In chap. 2.6 regular spikes (100Hz) on the DC Voltage supply of the preamp tubes were observed. Typically, such spikes might be caused be the diode switching in the bridge rectifier ([1] Blencowe, chap.3.15).

For example:

A.8) (82_003) Anodes V2 ECC83
Ch1= V2 / Pin1 (+112VDC)
20mV 50Hz ripple (~0,02%)
Ch2= V2 / Pin6 (+211VDC)
50mV 50Hz ripple (~0,02%)

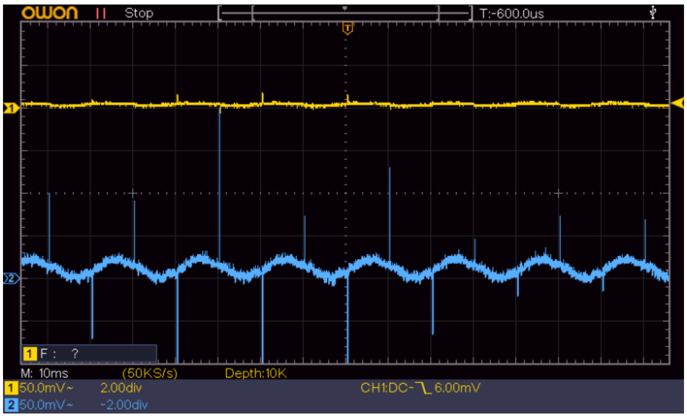


All measures in the following were taken with no signal at input /shortened input and all pots at the front panel at position 5 which is half of full scale. Deviations from that will be mentioned.

Reproduction of measurement A.8:

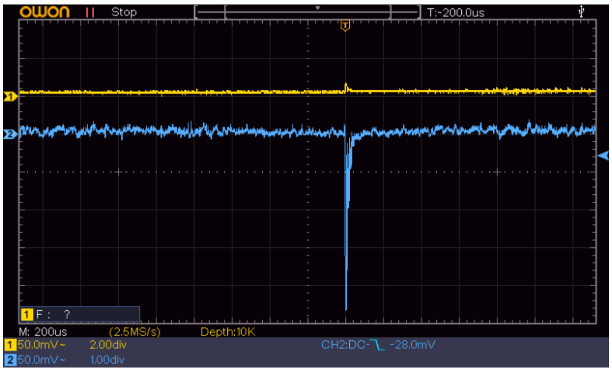
I.3.a) (107_000) Anodes V2 ECC83
Ch1= V2 / Pin1 (+144VDC)
10mV 50Hz ripple (~0,007%)
Ch2= V2 / Pin6 (+264VDC)
25mV 50Hz ripple (~0,01%)

The 50Hz ripple could be reduced roughly by a factor of two, but the 100Hz spikes from the rectifier diodes are still there. They look even worse.



Zoom in to see the spike in detail:

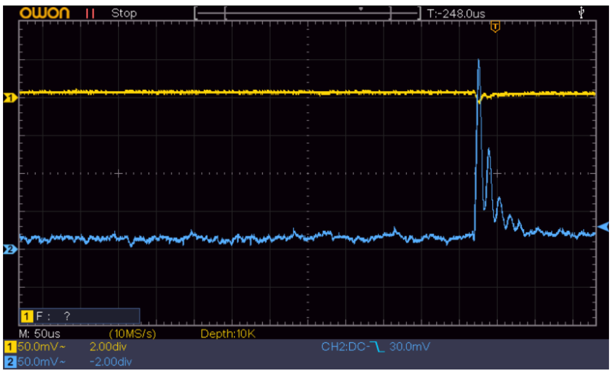
I.3.b) (111_000) Anodes V2 negative spike
Ch1= V2 / Pin1 (+144VDC)
Ch2= V2 / Pin6 (+264VDC)



Further zoom in:

I.3.c) (109_001) Anodes V2 positive spike
Ch1= V2 / Pin1 (+144VDC)
Ch2= V2 / Pin6 (+264VDC)

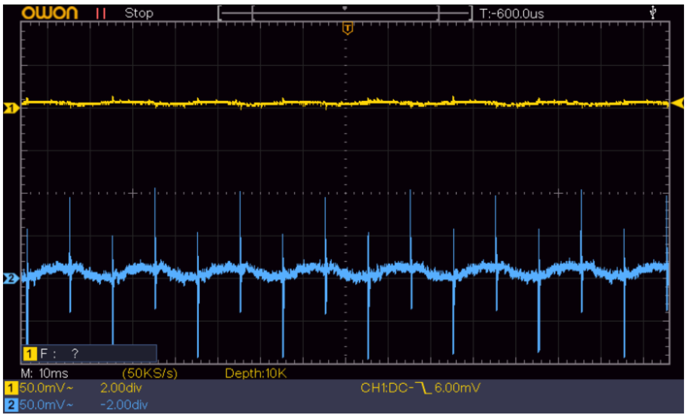
The damped oscillation in the spike has a frequency of about 67kHz.



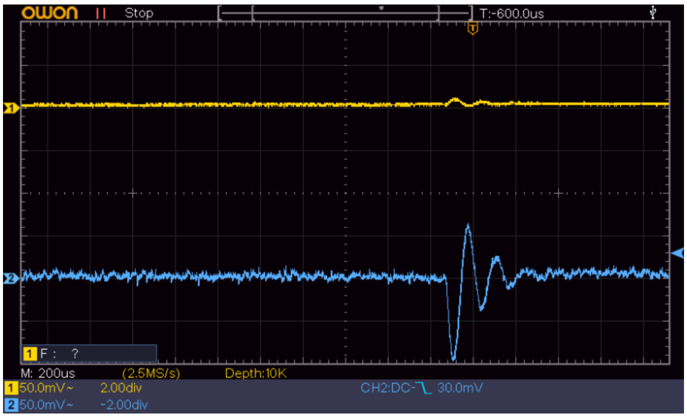
To avoid the spikes caused by the switching of the diodes it is usual to put 100nF capacitors parallel to the diodes of the rectifier.

With parallel capacitors:

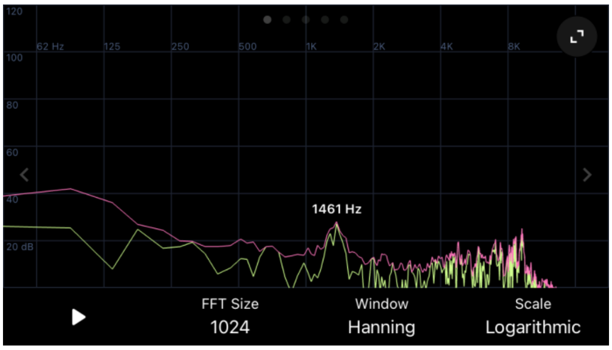
I.4.a) (108_000) Anodes V2 ECC83
Ch1= V2 / Pin1 (+144VDC)
Ch2= V2 / Pin6 (+264VDC)
The 100Hz spikes on Ch2 look different. Now each spike goes in both directions, since before they went alternating to only one direction.



Zoom in:
I.4.b) (108_001) Anodes V2 negative spike
Ch1= V2 / Pin1 (+144VDC)
Ch2= V2 / Pin6 (+264VDC)
The damped oscillation in the spike has now a frequency of about 12,5kHz.

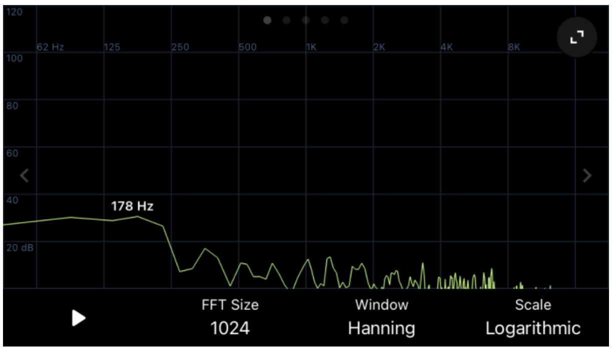


Adding the four 100nF capacitor leads also to an audible hum from the circuit itself, as the speaker at the output was substituted with an 8Ω power resistor. The capacitors seem to be the source for it. The frequency spectrum on the right shows a significant peak around 1460Hz. It was taken with the App “Dezibel X”(~20cm distance, dBZ).



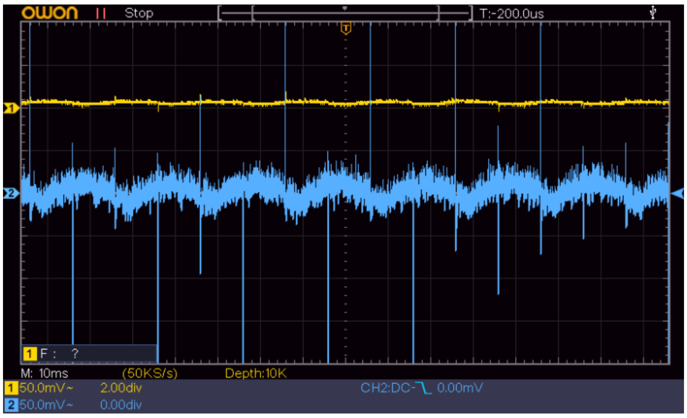
Beside that some irregular disturbances at the voltages on pin 1 and pin 6 starts to appear after several minutes of operating time. The impact of those disturbances was also visible in an increasing cathode current.

Further operation with the additional capacitors is stopped and the four components were removed from the circuit. To compare the audible hum from the circuit a second audio frequency spectrum was taken without the audible hum from the PCB. The 1461Hz noise is totally gone (see spectrum right).

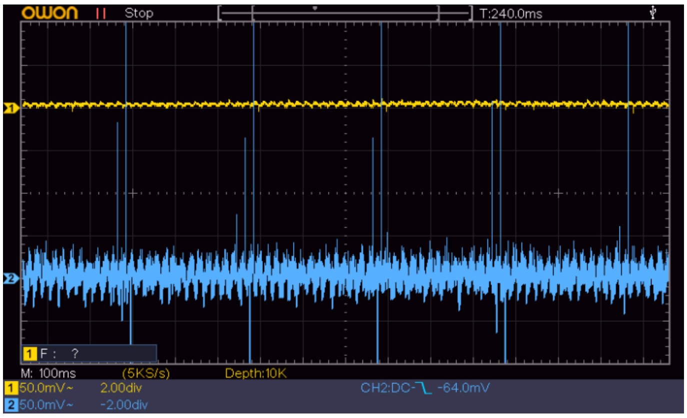


To view the hum over the complete signal path the signal at the 8Ω speaker simulator was monitored.

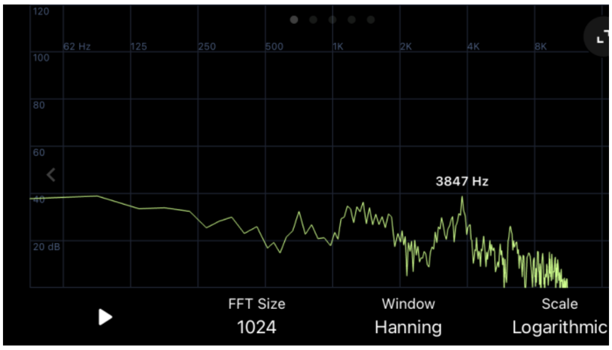
I.5.a) (110_000) Total hum
Ch1= V2 / Pin1 (+144VDC)
Ch2= 8Ω speaker simulator
The 100Hz spikes are also visible at the end of the audio signal path.



Zoom out:
I.5.b) (111_002) Total hum
Ch1= V2 / Pin1 (+144VDC)
Ch2= 8Ω speaker simulator
The appearance of the 100Hz spike show a regular pattern with a repetition period of 300ms / 3,3Hz. Where does it come from?

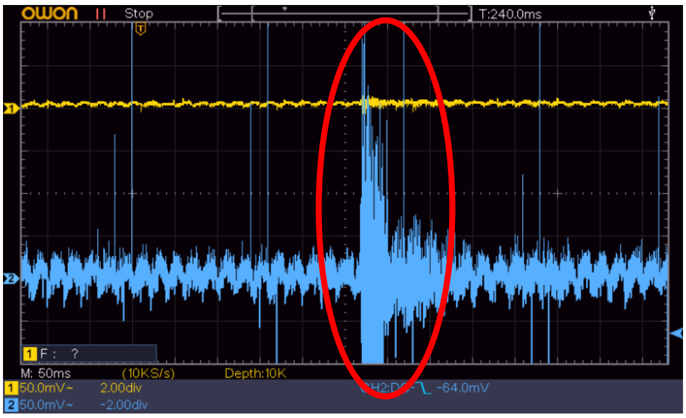


Substituting the 8Ω speaker simulator with real speaker audible result of such a noise can be recorded. A wide spectrum between 500Hz and 8kHz shows a continuous hum. The regular 100Hz spikes are not audible. The level of hum is depending on all the volume pots down the signal path to the output. The screenshot on the right (IMG_0382) is taken with all pots at 5



When checking the impact of mechanical vibration, it was found that the whole chassis, the PCB and also the components of the rectifier are very sensitive to a very light ticking with a wooden stick. Especially at the V2 tube extremely light ticking leads already to big disturbances.

I.6) (111_003) Microphony of V2 / Total hum
Ch1= V2 / Pin1 (+144VDC)
Ch2= 8Ω speaker simulator

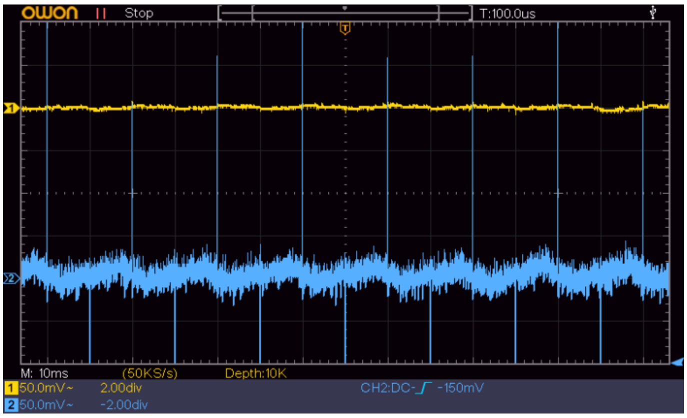


Slight ticking to the glass tube of V2 is significantly visible (RED circle). If the 8Ω Simulator is substituted by the real speaker the V2 tube is really reacting like a microphone recording audible ringing of the glass tube (further investigation see chap. 3.13)

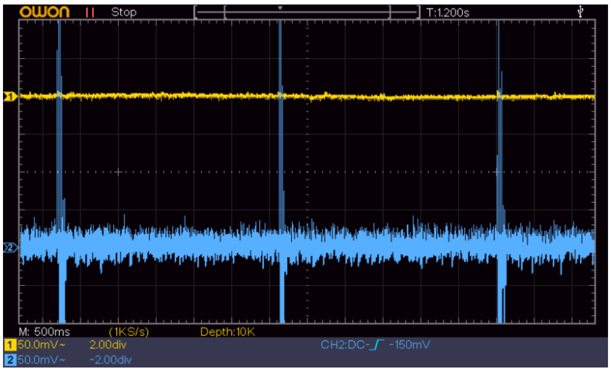
<u>Potentially Defect Diodes BY127 in the High Voltage Rectifier</u>

In order to minimize the impact of the diode switching ([1] Blencowe, chap.3.15), a type with faster recovery time would be a softer switch in the rectifier. Therefore, the UF4007 was selected as a replacement (see also chap. 1.18 and 3.24).

I.7.a) (116_000) Total hum / UF4007
Ch1= V2 / Pin1 (+144VDC)
Ch2= 8Ω speaker simulator
In comparison to I.5.a) no significant change is visible.

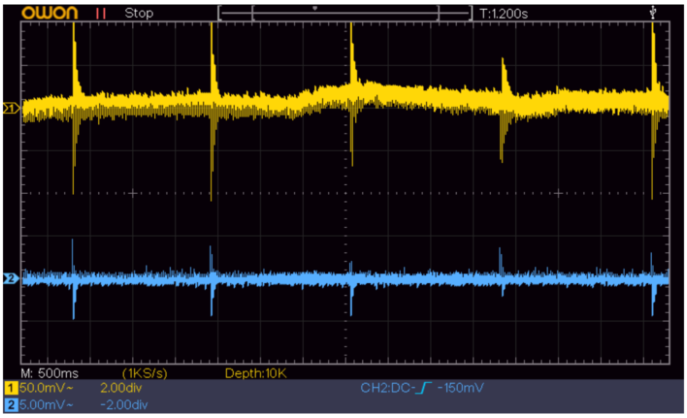


Zoom out
I.7.b) (116_001) Total hum / UF4007
Ch1= V2 / Pin1 (+144VDC)
Ch2= 8Ω speaker simulator
In comparison to I.5.b) the period of the regular disturbances has changed from 300ms / 3,3Hz to 3000ms /0,33Hz.



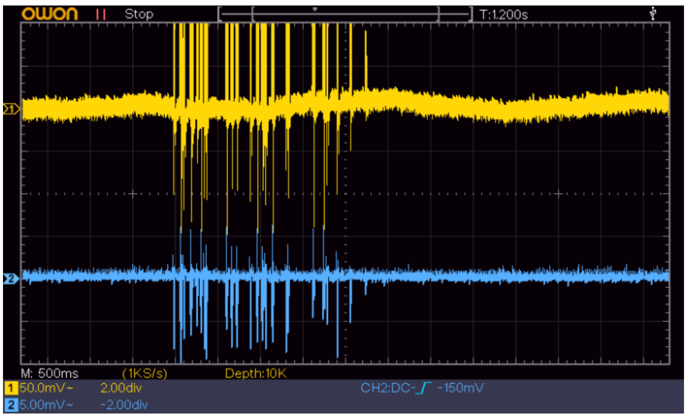
Those disturbances enter the signal path already between V2a and V2b.

I.8.a) (116_002) V2b OUT / IN
Ch1= V2 / Pin6 (+264VDC)
Ch2= V2 before R11 at Pin 7
Already before R11 at the Input of V2b the regular disturbances are visible and will be amplified in this tube stage.

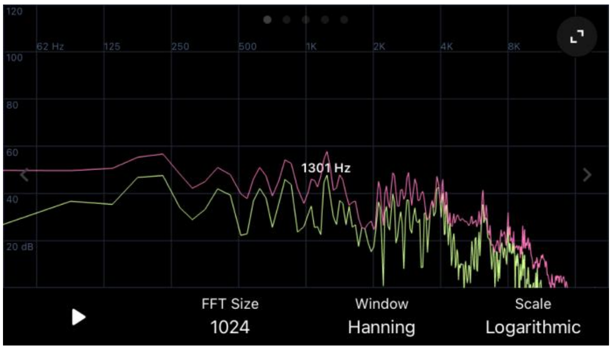


Apart from the continuous hum sometimes bursts of spikes appear. This phenomenon was observed in the HW configuration at the beginning as well as after the exchange of the diodes in the rectifier.

I.8.b) (116_003) V2b OUT / IN
Ch1= V2 / Pin6 (+264VDC)
Ch2= V2 before R11 at Pin 7
Already before R11 at the Input of V2b the regular disturbances are visible and will be amplified in this tube stage.



Those bursts of 100Hz spikes will be audible as popping and crackling disturbances. This shows the recorded audio spectrum at the right hand side (IMG_0449) when a speaker is connected to the output instead of the 8Ω speaker simulator.
To exclude a defect of the tube itself, the V2 tube was exchanged with a new JJ ECC83S. This S type tube has a tension grid and should be less sensitive for microphony. After the exchange the behaviour was absolutely the same as before.



Conclusions:

- Using parallel capacitors to the rectifying diodes, or exchanging the diodes itself with soft switching diodes UF4007 showed minor impact on the 100Hz spikes in the signal. They could not be eliminated. => The diodes were not defect, but the UF4007 were kept in the circuit due to better specification.
- As the 100Hz spikes appears in periodic bunches with repetition frequencies below the audio range. Those disturbances are not audible.
- The investigations and changes so far done could half the 50Hz impact from the heater voltage.
- The input stage is very microphonic. The behaviour stays the same even after putting in a new tension grid tube for testing.

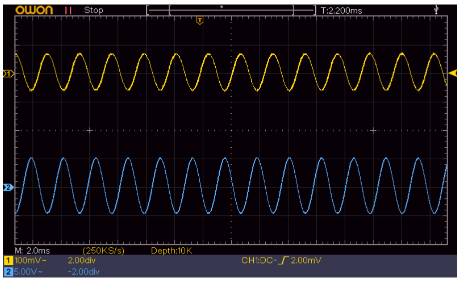
Potentially Defect Filter Cap

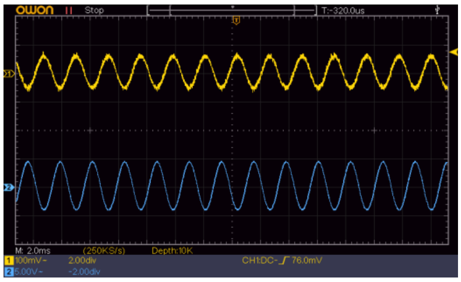
The microphony was not only observed by ticking on the glass body of the tube V2. All over the chassis and the PCB certain sensitivity is given.
In the gear page forum (thegearpage.net) there was also such a hypersensitive microphony reported. Tube exchange could not manage to control the behaviour. It was discussed that also bad filter caps might be the root cause for such phenomena. The reported solution confirmed this: *"After reading your post I first replaced the big filter caps, no luck, then I replaced the smaller ones that followed the main ones. The amp works perfect now even with the old warn out tubes in it."*

The filter caps were checked in chap. 2.2 with different methods. All of them seemed to be okay, even C15, C1 and C7 showed conspicuous behaviour. While double check of C15, a black circle around the connecting lead at the negative pole of this elco was discovered. It looks like a burn mark from a brake through, especially because of the brown coloured circle next to it.
C15 was substituted by an F&T capacitor with a slightly higher capacity (15µF instead of 10µF) and a higher dielectric strength (450V instead of 400V).

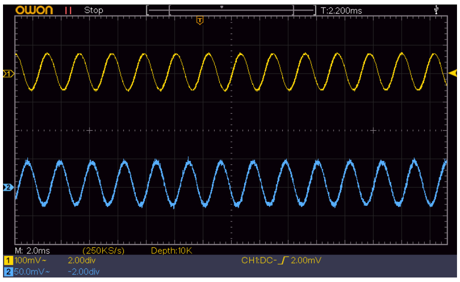
How does the preamps stage look with signal at the input?
Comparison of current preamp signals to those measured before modifications / changes (chap. 2.9). All pots on the front panel at 5 which is half scale except OVERDRIVE at 0.

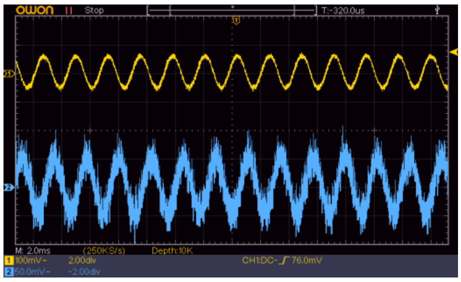
I.10) Preamp V2a
Input / Output
Ch1= V2a ECC83 / Pin 2
Ch2= V2a ECC83 / Pin 1


Before: B.21) 97_001

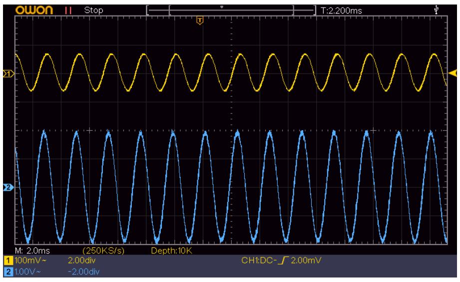

Current: 118_000

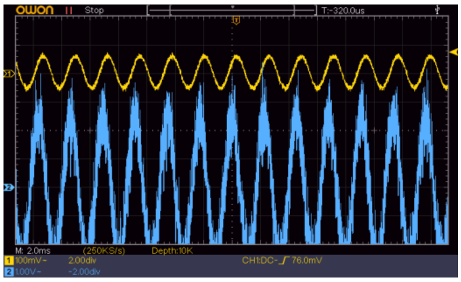
I.11) 2nd stage V2b
Input
Ch1= V2a ECC83 / Pin 2
Ch2= V2b ECC83 / Pin 7


Before: B.22) 97_002


Current: 118_001

I.12) 2nd stage V2b
Output
Ch1= V2a ECC83 / Pin 2
Ch2= V2b ECC83 / Pin 6


Before: B.23) 97_003


Current: 118_002

The first stage still shows the same behaviour even the input is slightly disturbed. But 2nd stage of preamp shows totally worse signals. The conclusion already made above can be confirmed. The disturbances enter the signal path in this stage of the preamp.
After those measurements the cap C15 has been exchanged. Even the capacitor looked conspicuous, no impact on the audio signal quality after exchange. The behaviour of the audio signal stayed absolutely the same.
Double check with no signal reproduces the characteristics already seen in I.7.b)

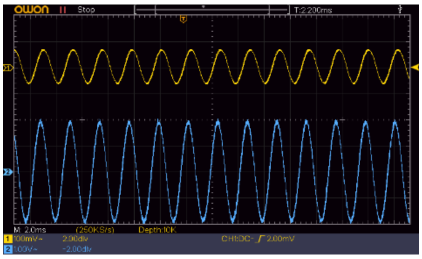
Conclusion:

- The filter cap C15 looked conspicuous at the negative lead, but the exchange of it could not support at all to get rid of the hum entering the audio signal path between input stage and 2nd stage of the first tube.
- Checking the 1st and 2nd input stage of the preamp with an audio signal shows clearly that the current behaviour is worse than before.

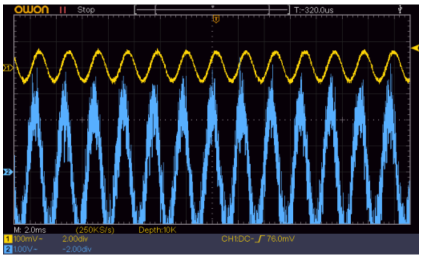
Impact of Additional Filter Capacitors at V2

Measurement with the small re-assembled filter caps 4,7pF (see chap. 1.6) showed that the observed noise on the signal identified in I.11 and I.12 (see last section above) can be switched OFF with them. The status "Before" is visible again. Those caps at V2 between grid and anode in each of the two triodes will "short" the inputs for higher frequencies. They have a significant impact and lead to loss of brightness (see chap. 3.6).
Fortunately, this hum noise of the signal is above the audible range and all efforts to reduce the hum noise in total makes the two caps more or less obsolete. This can be demonstrated by direct comparing I.12 with the final design FB.23 (chap.4.6), where the ground design is changed (see below) and the two caps are not mounted anymore.

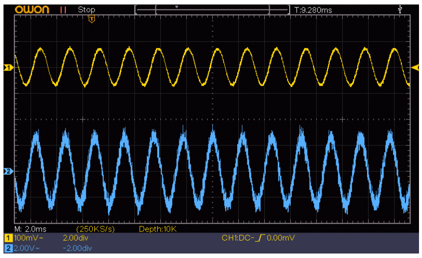
I.14) 2nd stage V2b Output
Ch1= V2a ECC83 / Pin 2
Ch2= V2b ECC83 / Pin 6



Before: B.23) 97_003



Current: I.12) 118_002

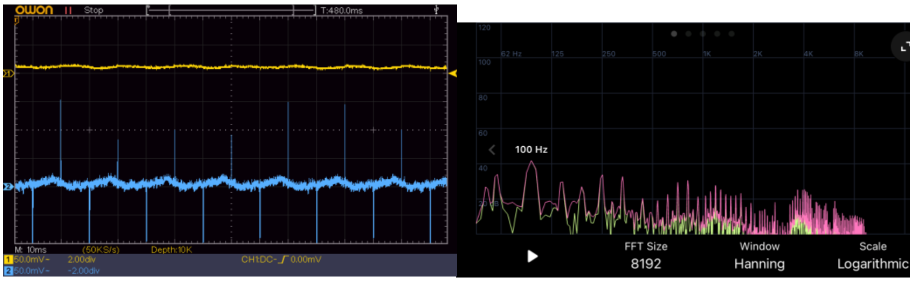


Final: FB23) 187_003

Impact of DC Heating for Preamp

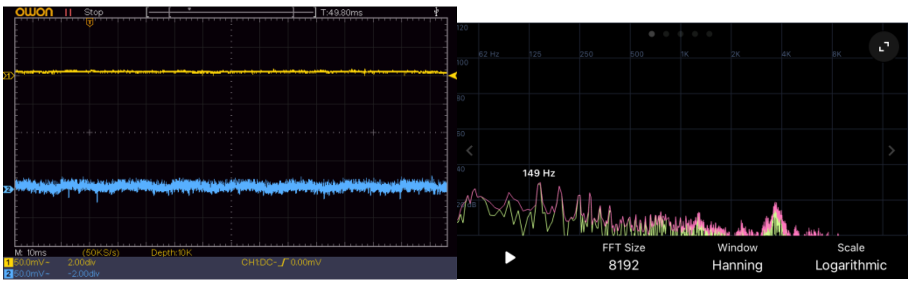
After replacing the carbon composition resistors (see chap. 3.17) the following status has been measured (all pots at front panel which means half scale) with the existing AC heating of all tubes:

I.15) (124_001) Total hum
AC heater
Ch1= V2 / Pin1 (+168VDC)
Ch2= 8Ω speaker simulator
(IMG_0765) Dezibel X
~20cm distance/ dBZ



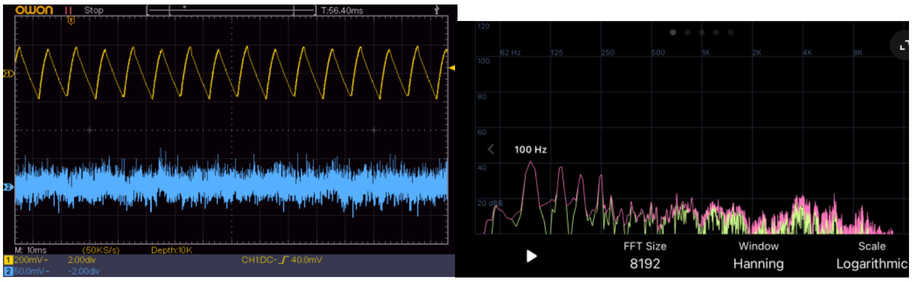
Note: The audio spectrum above 1kHz is relatively clean as during this measurement the two small caps at V2 between Grid/ Input and Anode/ Output were still assembled. The ground design was already adapted to "Single" grounded (see below).
To demonstrate the basic impact of DC heating the preamp tubes on the PCB have been separately supplied with an external, independent DC power supply. The provided 6,3VigDC are absolutely flat. No ripple could be measured. Having this heater voltage connected without any potential relation to the amp, leads to big 50Hz hum with ~100mVpp at the speaker. Therefore, the external supply voltage gets grounded symmetrically to chassis with 100Ω resistors.

I.16) (127_000) Total hum
DC heater external supply
Ch1= V2 / Pin1 (+168VDC)
Ch2= 8Ω speaker simulator
(IMG_0781) Dezibel X
~20cm distance/ dBZ



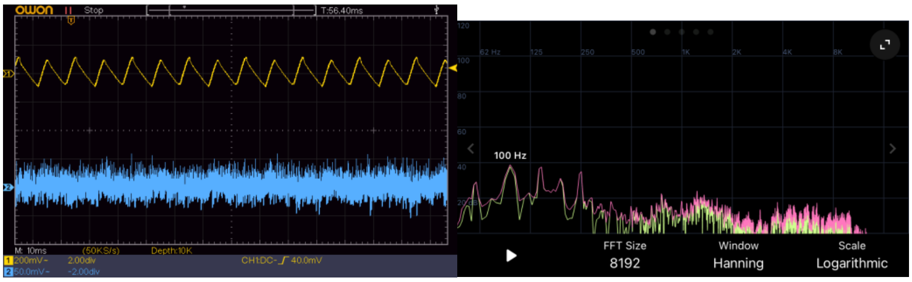
Any coupling from the heater voltage to the high voltage supply on pin1 of V2 is gone. After some tests with a simple electronic breadboard to dimension the components the circuit from chap. 1.14 has been assembled on a small, additional PBC (see chap. 3.20). With this circuit the following result is achieved:

I.17) (144_009) Total hum
DC heater with 10mF cap
Ch1= DC Heater +
Ch2= 8Ω speaker
(IMG_1001) Dezibel X
~20cm distance/ dBZ



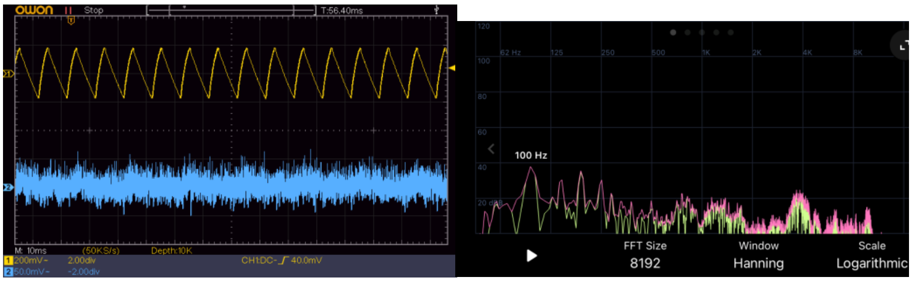
With a 10mF elco to smooth the rectified voltage a ripple of 324mVpp remains. Doubling the capacity of this filter cap to 20mF leads to approximately half remaining ripple (192Vpp) on the heater supply voltage but the audible hum noise stays nearly unchanged. Due to this marginal impact the filter cap value in the circuit stays at 10mF.

I.18) (144_010) Total hum
DC heater with 20mF cap
Ch1= DC Heater +
Ch2= 8Ω speaker
(IMG_0999) Dezibel X
~20cm distance/ dBZ



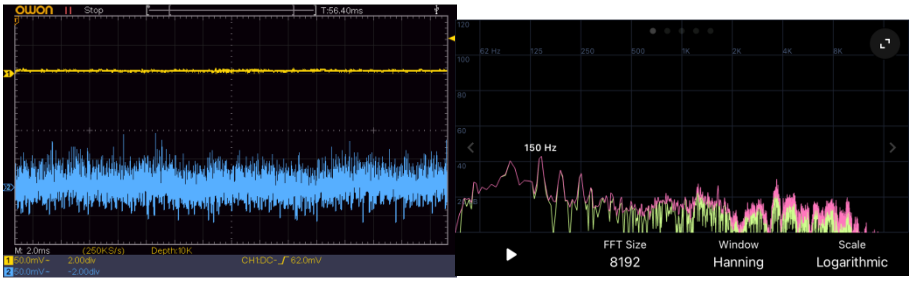
So far, the center trap of the 6,3VAC has been grounded and additionally the rectified heater voltage is symmetrically grounded with the two 100Ω resistors. This double balanced grounding should be avoided for hum reason. Therefore, the center trap has been disconnected.

I.19) (144_012) Total hum
CT heater AC open
Ch1= DC Heater +
Ch2= 8Ω speaker
(IMG_1003) Dezibel X
~20cm distance/ dBZ



For further optimization the symmetric grounding has been replaced with a so called “humdinger” ([1] Blencowe, chap.3.16). This makes the symmetry adjustable. With that step also the 2x 4,7pF caps at the inputs of V2 are removed.

I.20) (154_000) Total hum
w/o 4p7Cs / Humdinger
Ch1= V1 Pin 1
Ch2= 8Ω speaker
(IMG_1089) Dezibel X
~20cm distance/ dBZ



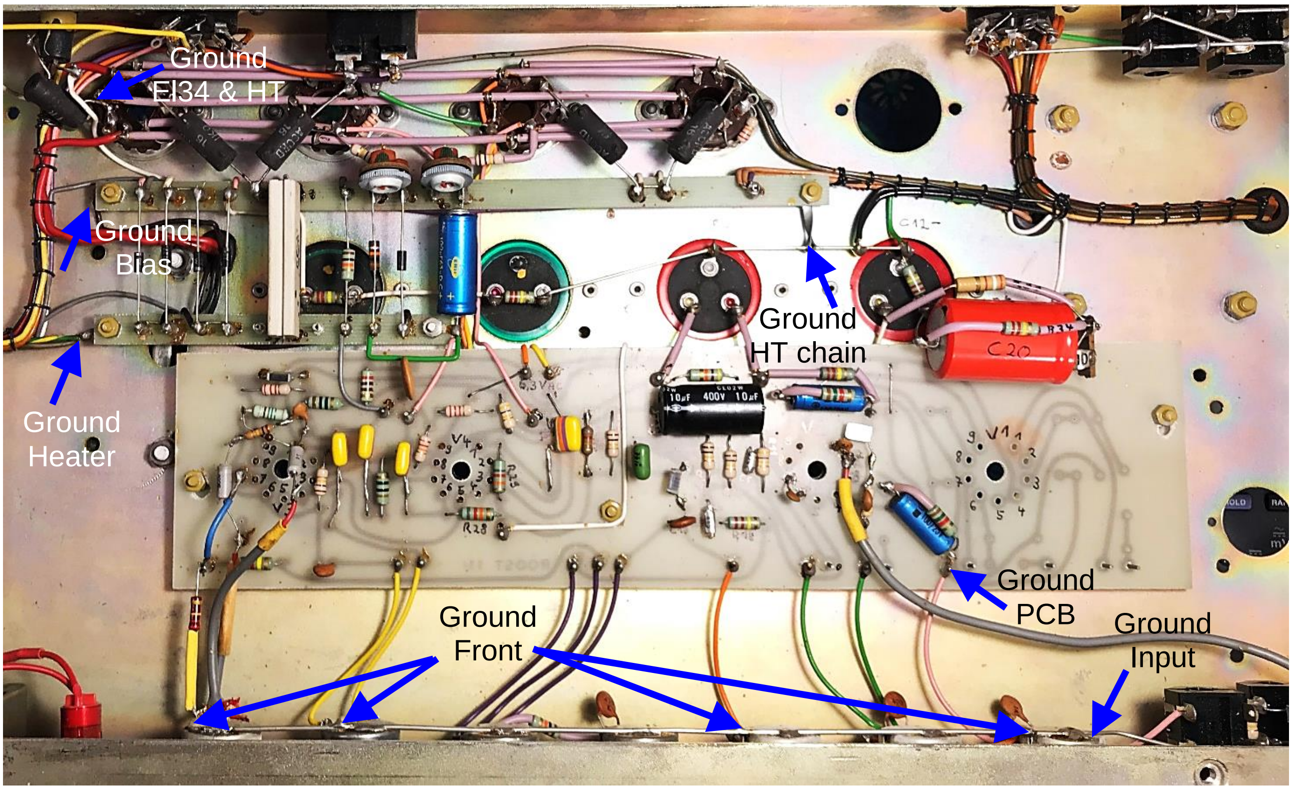
<u>Conclusion:</u>

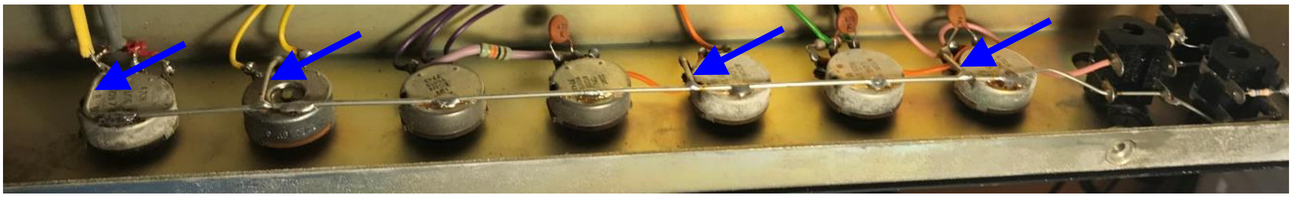
Rectifying the heater voltage before supplying the tubes on the preamp PCB leads to a less disturbed audio signal. Especially the so far observed spikes are gone.

Potential Impact of Grounding

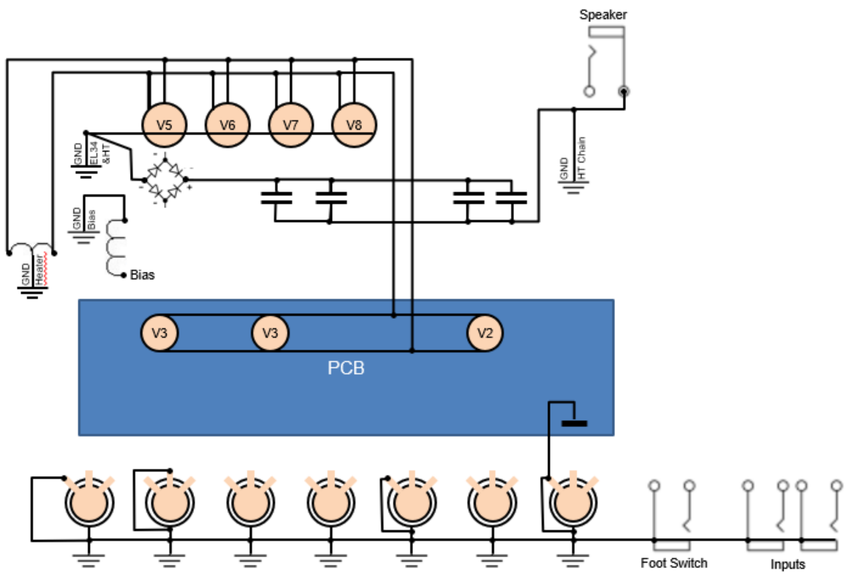
As described in [1] Blencowe (chap. 15) suitable ground scheme is necessary to avoid noisy behaviour. Suitable means not using the chassis everywhere as ground. The ideal amp has only one connection between ground and chassis near the signal input jack.

Grounding design before:

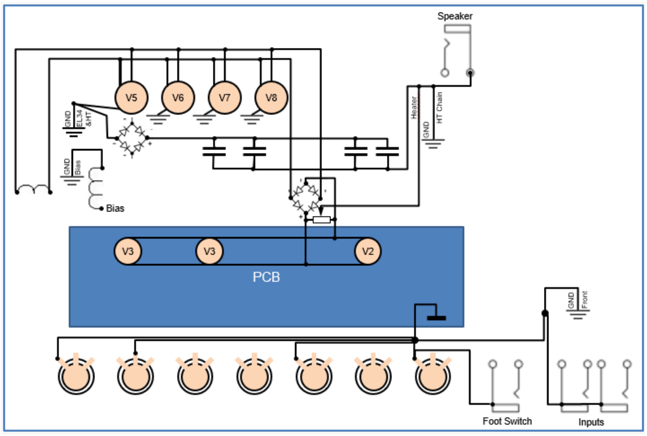




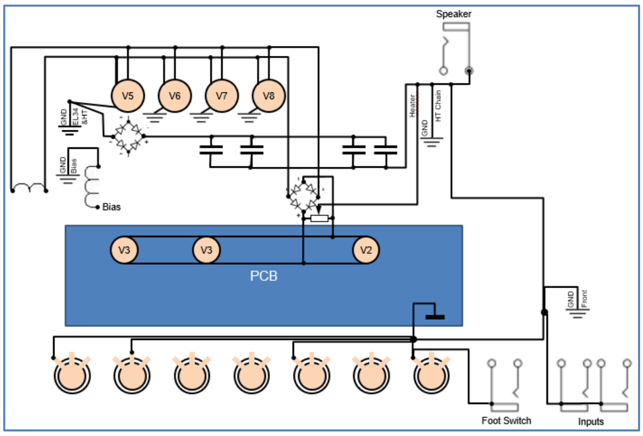
In the schematic of the mass concept like-it-was it is obvious that especially at the front panel the “taking-mass-everywhere” is not according the literature (e.g. [1] Blencowe, chap. 15).



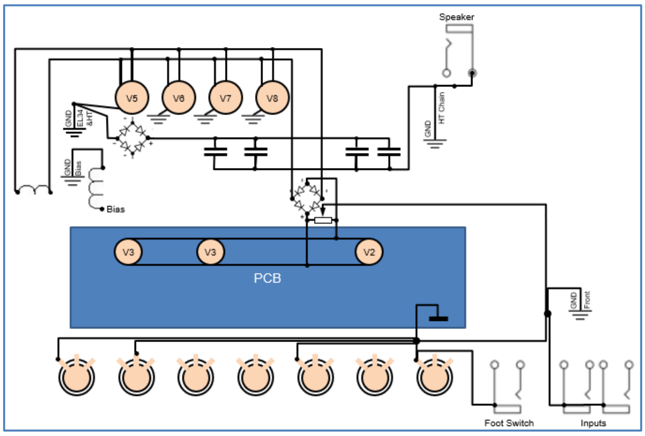
The following four ground designs have been assembled to measure the audible hum noise. The finally chosen grounding strictly separates the ground connection to chassis for the preamp (connection near input jack) and the power stage on the rear side of the chassis. The other three one are only slight variation of it.



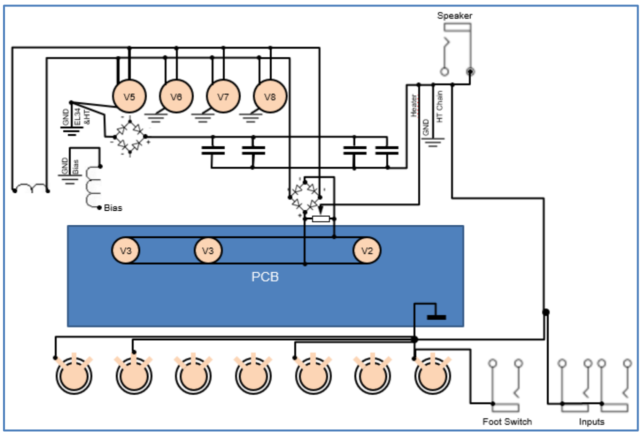
“Final” grounding



“Double” grounding

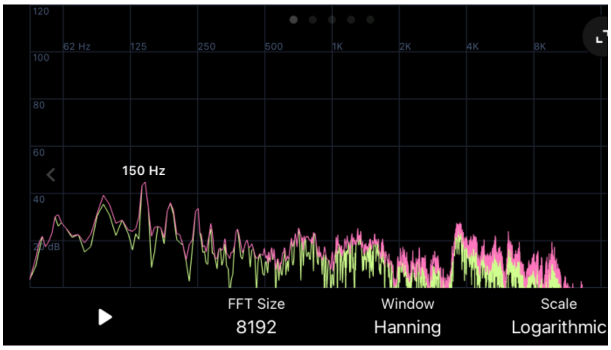


Heater ground variation

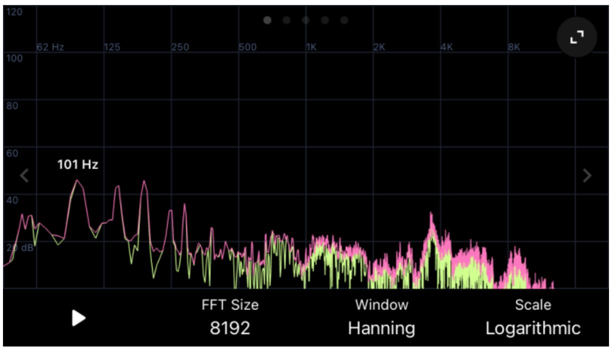


“Single” grounding

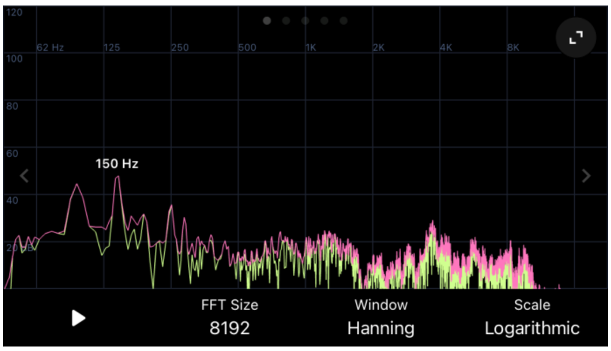
Dezibel X; ~20cm distance/ dBZ



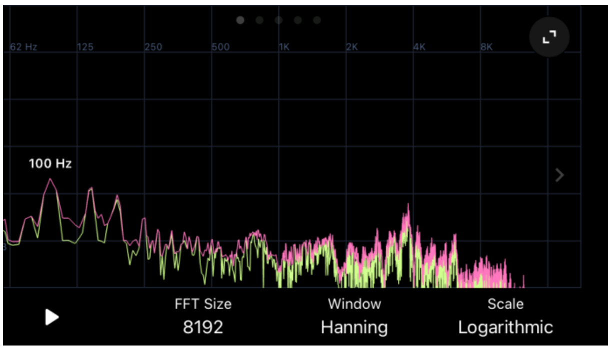
“Final” grounding (IMG_1100)



“Double” grounding (IMG_1101)



Heater ground variation (IMG_1102)

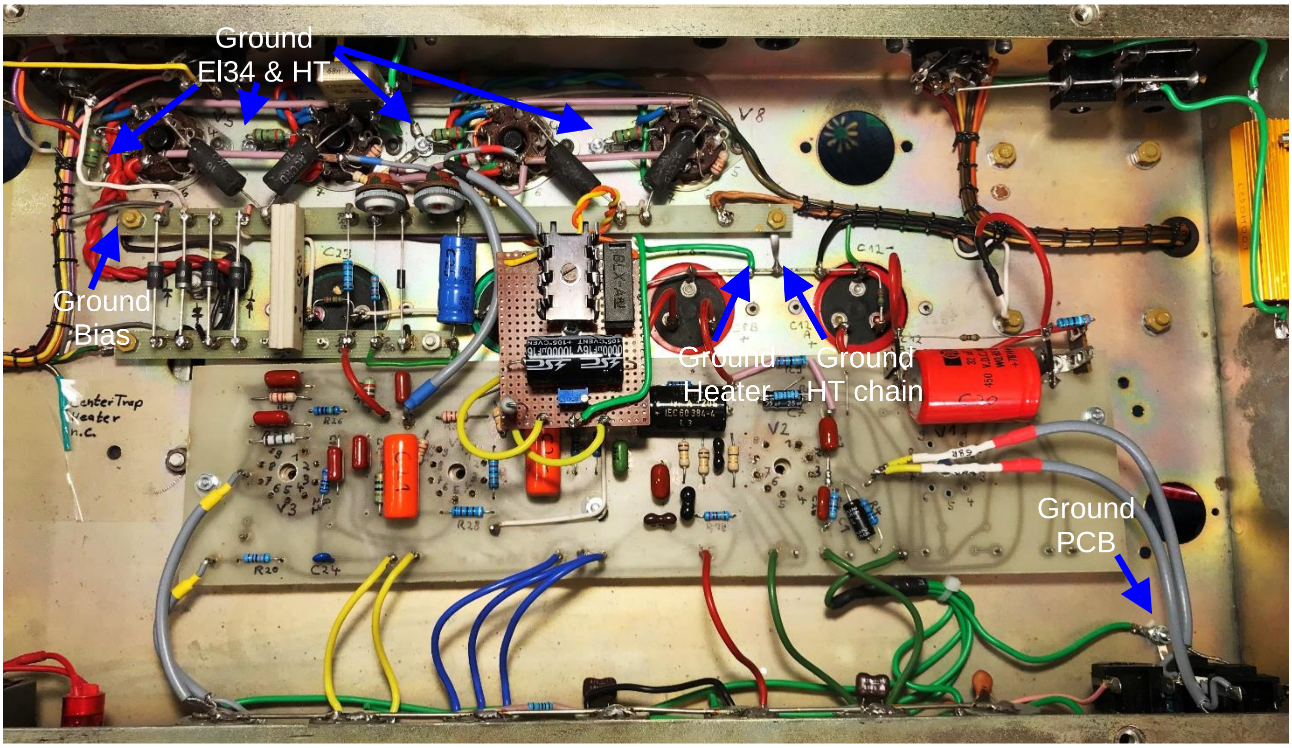


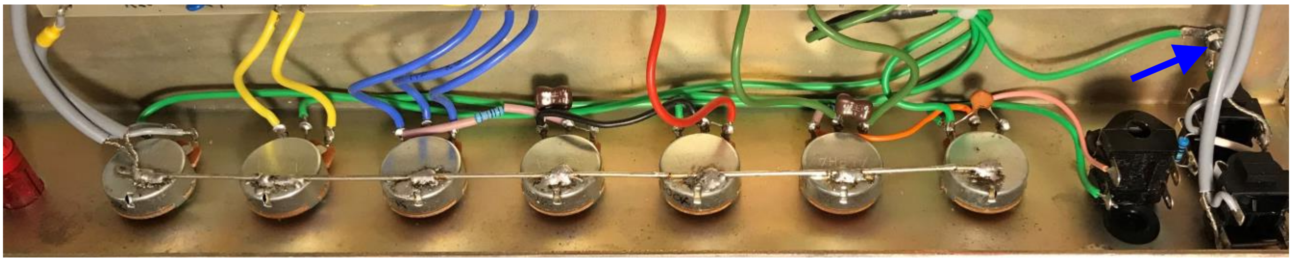
“Single” grounding (IMG_1103)

Conclusion:

The differences between the different configurations are only marginal. Taking the whole audible range into account the “final” grounding design show slightly advantages. As this design is nearest to the ideal concept the literature recommends (e.g. [1] Blencowe, chap. 15).

Final ground design:





3.12. Redesign Input and 2nd Stage of Preamp

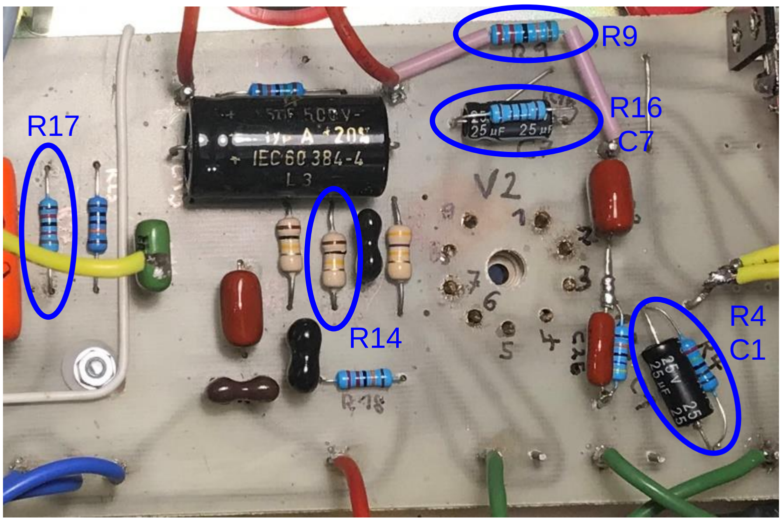
In chap.1.4 the redesign of the input and 2nd stage of preamp has been evaluated.

In the supply voltage line:

R17= 82kΩ, R13= 15kΩ,
R9= 220kΩ, R14= 100kΩ

And at the cathodes:

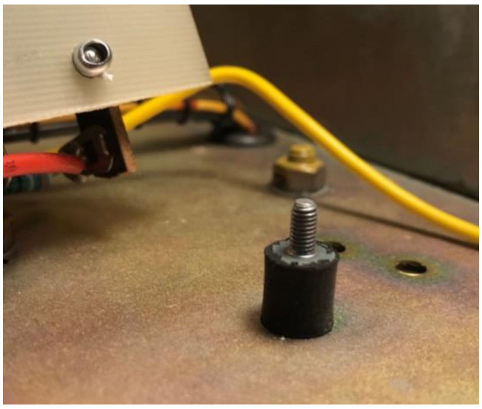
R16= 1,8kΩ, C7= 25µF,
R4= 2,4kΩ, C1= 25µF



3.13. Reduce Microphony

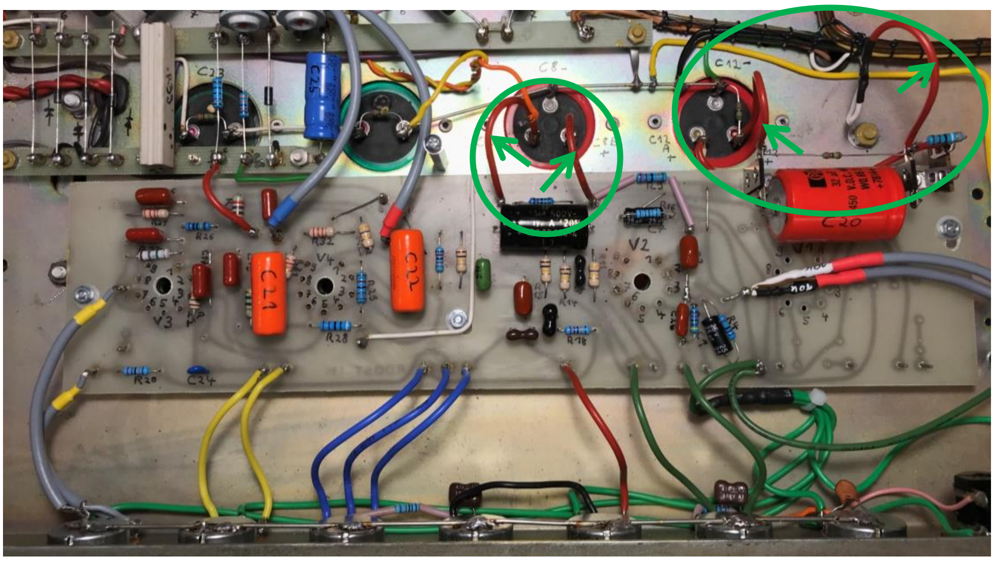
In chap. 3.11 microphony was observed as a side effect.

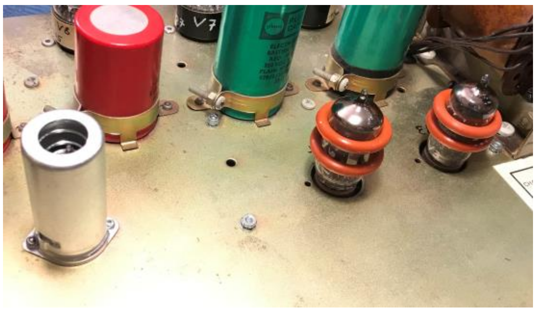
I.6) (111_003) Microphony of V2 / Total hum
Ch1= V2 / Pin1 (+144VDC)
Ch2= 8Ω speaker simulator
Slight ticking to the glass tube of V2 is significantly visible (RED circle). The tube is reacting like a microphone recording audible ringing of the glass tube.



Microphony can be caused by the tubes itself of by (ceramic) capacitors. After all the changes made, the capacitors will be excluded. The V2 tube itself was also temporary exchanged to a JJ ECC83S without any audible impact. As the sensitivity is more or less everywhere on the chassis the only remaining possibility is to mechanically decouple the tubes as much as possible from the chassis ([1] Blencowe, chap. 3.19); especially the high gaining V2 (gain factor 70) at the input stage. A convenient method to do so is to use rubber made shock damper for mounting the PCB and an airy wiring with high flexible electric wires.

The picture shows the wiring of the PCB to the chassis after the exchange of the previous very stiff electric wires. Especially the changes in the green marked areas lead to good mechanical decoupling.





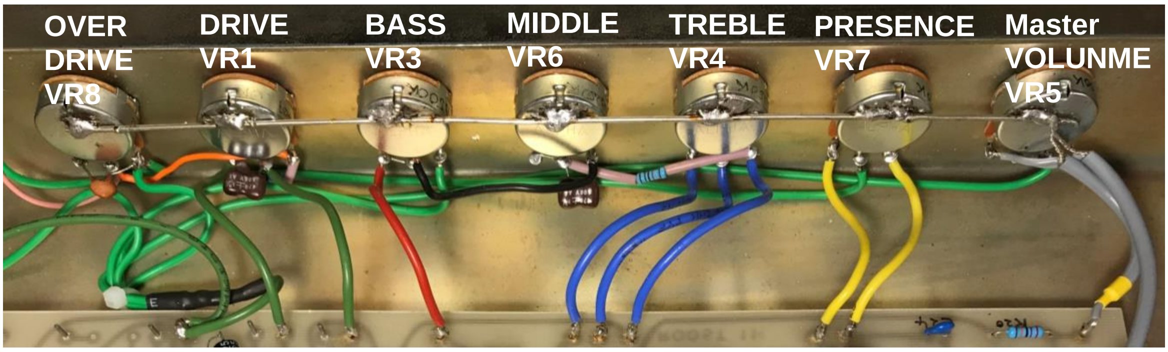
On the top side of the chassis the shielding of V2 is mounted with a reduced spring in the head thus leading to reduced direct coupling of the tube to chassis. All other tubes of the preamp will get the typical silicone O ring dampers.

Conclusion:

With all those mechanical measures the sensibility for microphony of the chassis could be reduced by an estimated factor of two.

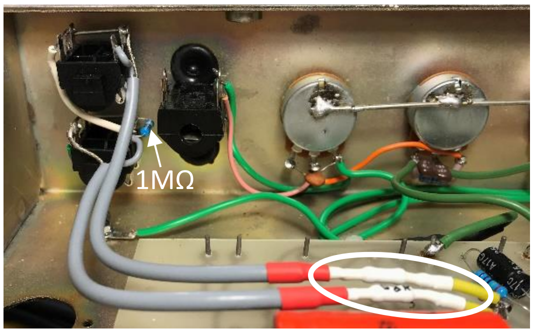
3.14. Exchange the Potentimeters at the Front Panel

At the first operation of the amp it was found that the first (OVERDRIVE) and the last (MASTER VOLUME) poti on the front panel are producing audible noise when they have been turned. They were exchanged and the remaining potis have been cleaned with TUNER 600. But while going on with the tests those pots have gotten worse. They have started to feel mechanical scratching while turning. Therefore, finally all pots were exchanged. The previous 470kΩ log and 220kΩ lin were exchanged by 500kΩ log and 250kΩ in due to availability at the provider TubeTown. Within the application in the schematic this should make no significant difference. With this exchange also the R53 and C54 at VR1 (DRIVE), C14 at VR6 (MIDDLE) and R18 between VR6 (MIDDLE) and VR4 (TREBLE) were exchanged. The picture below shows the final status:



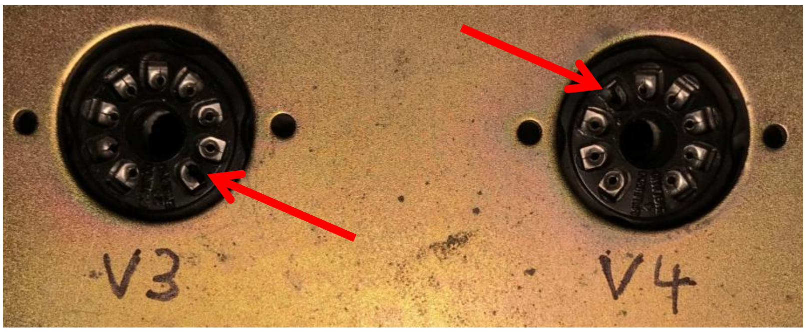
3.15. Modify Amplifier Input Network

The input network is changed according to the discussion in chap. 1.5 to the classic Fender design of an input network. Next to this change also the two jack sockets at the front panel are replaced, as they showed already bad contacting due to oxidation on the contact surfaces.
The 1MΩ load at the high impedance input is directly mounted on the socket. The two 68kΩ resistors are mounted as near as possible to the tube input within the shielded wires covered by the white shrink tube (white cercle).



3.16. Exchange of Noval Tube Sockets

Almost at the very end of the refurbishing it has been discovered that two of the three noval tube sockets in the preamp are each damaged at one pin (see picture right side).



Before

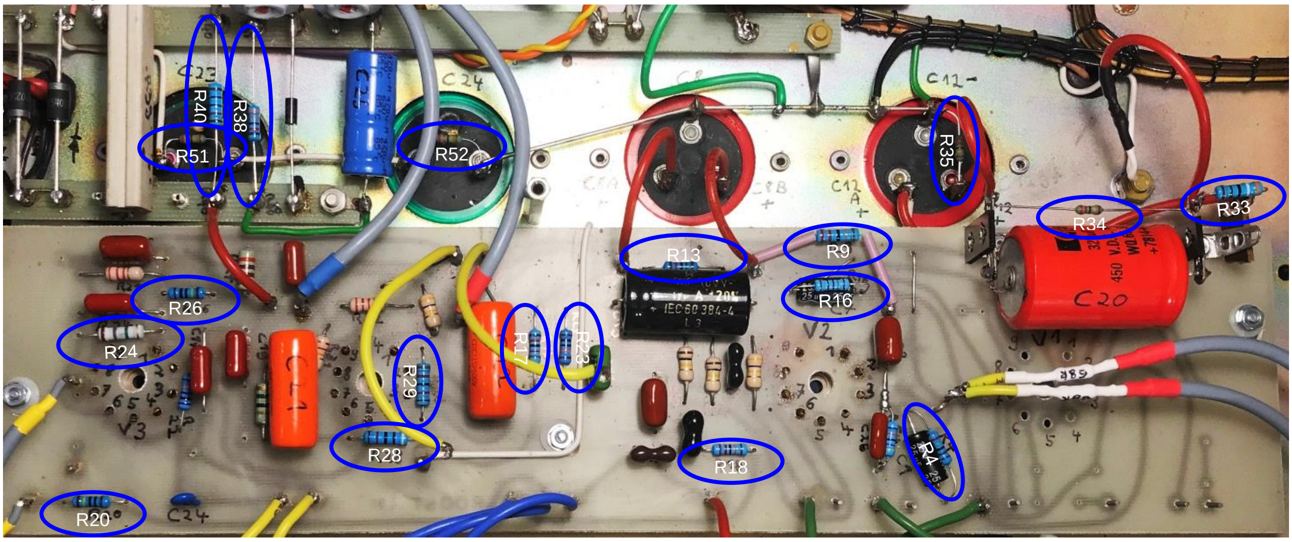
After replacement

3.17. Exchange Carbon Composition Resistors

During the analysis of like-it-was schematic, many of the carbon composition resistors were found to be borderline tolerance or already out of tolerance (see chap. 1.13). Therefore, almost all resistors of that type are substituted.

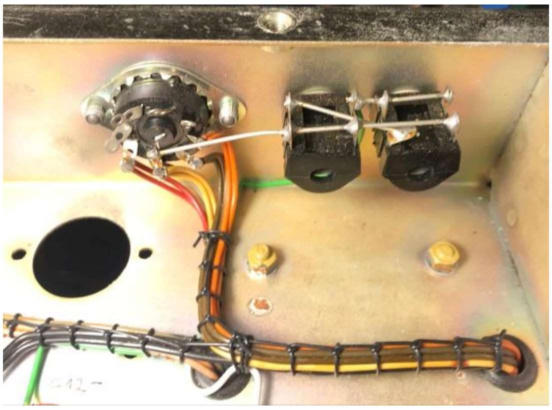
Component	Previous	Final	Remark
R4	1k4	2k4; ±1%; 0,5W	see chap. 3.12
R9	263k	220k; ±1%; 1W	see chap. 3.12
R13	47k	15k; ±1%; 0,5W	see chap. 3.12
R16	1k6	1k8; ±1%; 0,5W	see chap. 3.12
R17	82k	82k; ±1%; 0,5W	
R18	239k	220k; ±1%; 0,5W	
R20	235k	220k; ±1%; 0,5W	
R23	100k	100k; ±1%; 0,5W	
R24	1M8	1M8; ±1%; 1W	
R26	1M	1M; ±1%; 0,5W	
R28	83k	91k; ±1 %; 1W	
R29	87k	82k; ±1 %; 1W	
R33	3k9	3k9; ±1 %; 1W	
R38	10k	33k; ±1%; 0,5W	see chap. 3.4
R40	10k	10k; ±1%; 1W	
R34	231k	220k; ±1%; 1W	tiny size
R35	226k	220k; ±1%; 1W	tiny size
R51	240k	220k; ±1%; 1W	tiny size
R52	230k	220k; ±1%; 1W	tiny size

The replaced resistors:

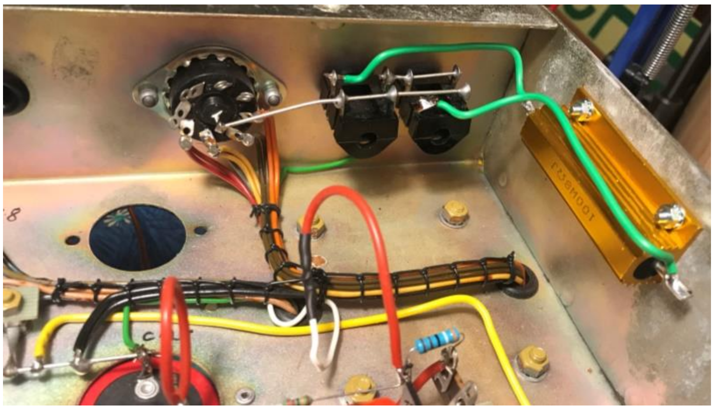


3.18. Modify Topology of Speaker Outputs

As discussed in chap. 1.15 the circuit design of the two output jacks after the impedance selector will be changed to be robust against forgotten speaker connection. Therefore, an 8Ω/100W resistor will be added to chassis:



Previous design



Final design: output topology with 8Ω/100W power resistor

Before assembling the power resistor, the two jacks especially the switching contacts were cleaned with a brass brush and some TUNER 600 spray.

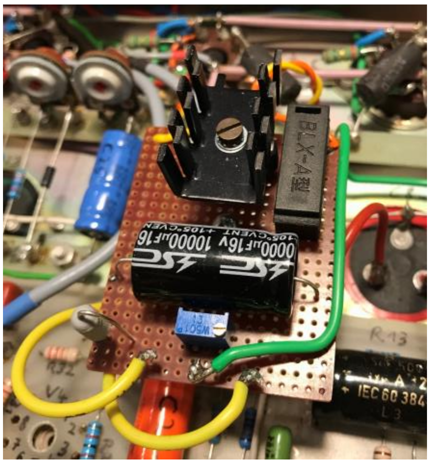
3.19. Add Mains Supply Filter

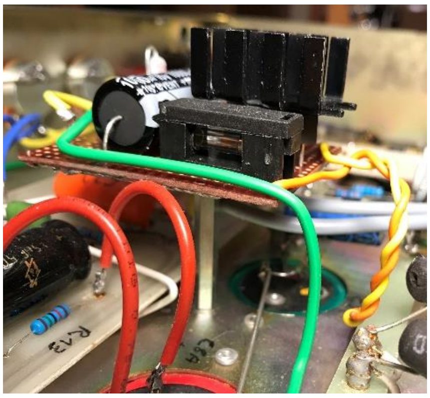
As discussed in chap. 1.16 the mains supply input will be protected with an X2 capacitor 68nF 275VAC (PME271M568MR30) and two ferrite rings.

Previous design without EMC protection

Final design with X2 capacitor and 2 ferrite rings

3.20. DC Heater for the Preamp Tubes





After demonstrating the impact of switching preamp to DC heating (chap. 3.11) the AC heater voltage is rectified with a full bridge rectifier before getting applied to the main PCB with the preamp circuit. The schematic is already discussed in chap. 1.14. It is mounted on a small PCB fixed on the distance holder 40mm above the chassis. By chance the chassis contains already a hole in right position.

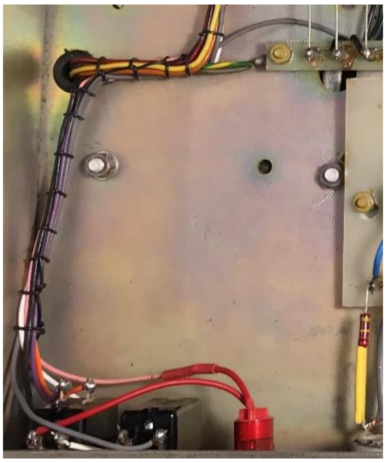
The board is protected with a miniature 5×20mm glass body cartridge fuse. According to Blencowe [4] "*it is easier and safer to interrupt AC than DC.*" Therefore, the fuse is placed on the AC side before the rectifier. To specify the fuse the current is measured when starting with cold tubes.

Power ON (cold tubes)	After ~10s
3,34ACA	1,23ACA

The current after ~10s matches quite well with the theoretical value of heating three ECC83: 3 x 0,3A. Finally, the fuse is equipped with T6,3A

To provide a better cooling to the full bridge rectifier a heat sink is mounted on housing of the NTE53000. The part itself is mounted with distance to the PCB (~5mm).

To manage the electrical heater balancing a humdinger pot is integrated ([1] Blencowe, chap.3.16). This tap can only be affective if the original center tap of the heater supply directly at the transformer is disconnected.

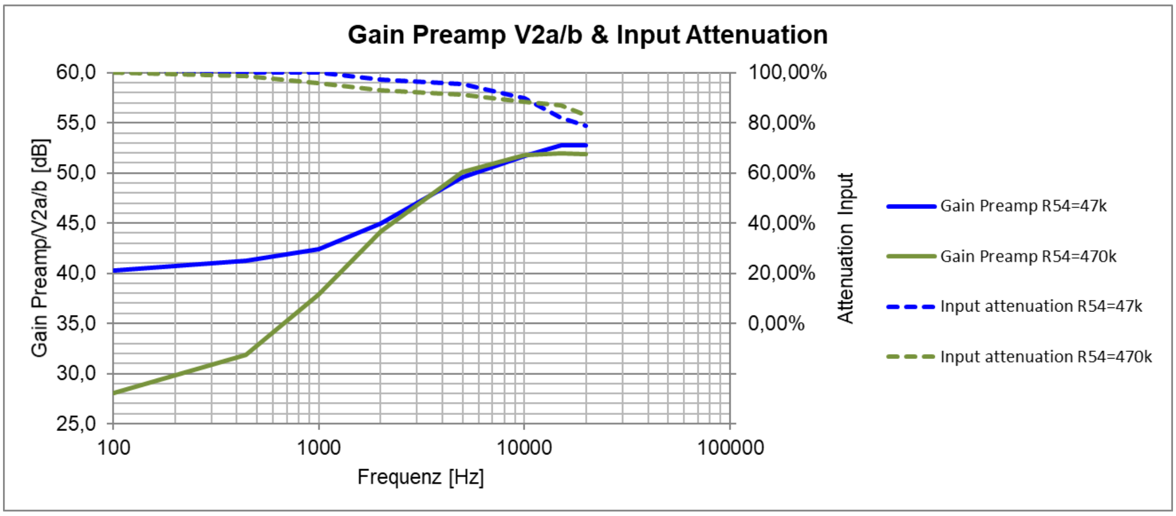


Before

After

3.21. Filter Network between V2a & V2b

Finally, the filter network between V2a & V2b has been equipped according to the conclusion of chap. 1.7. Even the investigations in chap. 3.11 showed a better signal to noise ratio with the too small equipped R54= 47kΩ.
As the discussed variant A and variant B were realized on the PCB the transition curve over frequency of both are measured.



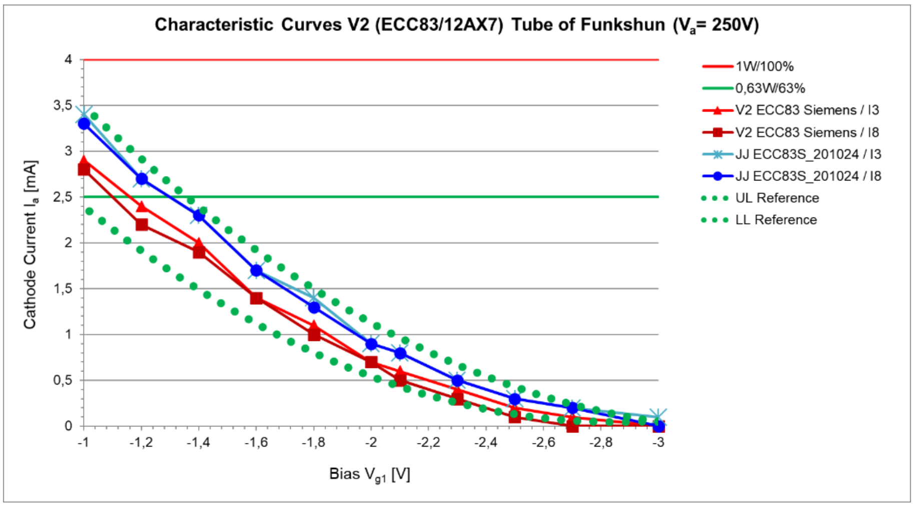
The attenuation curves show the real attenuation due to the tube circuit as the amplitudes are nominated to the "natural" decreasing amplitude of the sine generator over frequency at a pure 1MΩ load. The transfer function is calculated in dB from the quotient of amplitude at pin 2 through the amplitude at pin 6 of V2.
The observed behaviour of the two transition curves perfectly correlates with the theoretical calculation on it in chap. 1.7.

3.22. Re-Tubing

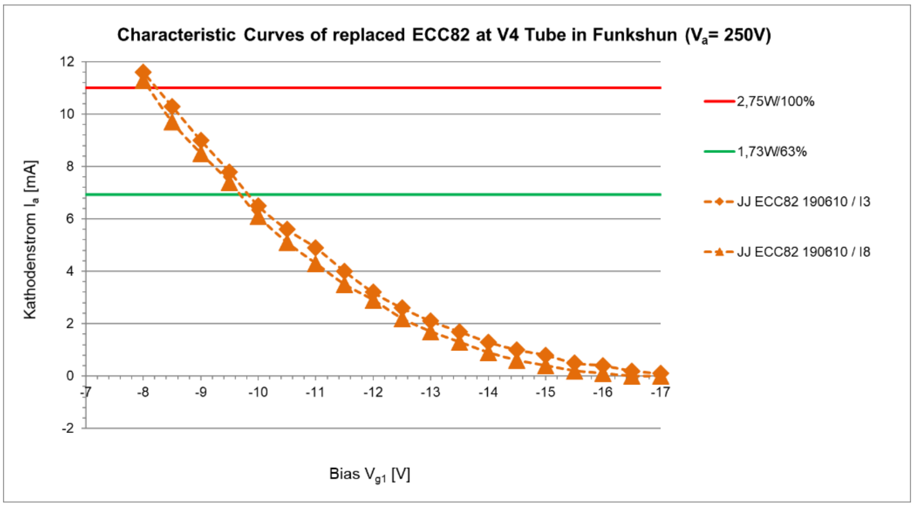
In chap. 2.1 the tubes of the Funkshun are characterized in detail. As one of the EL34 have a short between heater and anode, a new quad of EL34 (JJ EL34 II Red Label) is mounted. This new quad shows also significantly less microphony when ticking to their glass tubes.

All ECC83 show no abnormalities during the characterization on the tube tester. During the hum noise investigation in chap. 3.11 also no clear dependence of the old ECC83 via temporary exchanges could be identified. Finally, V2 is substituted by a new JJ-ECC83S, which has a tension grid and because of that should be less sensitive for microphony.

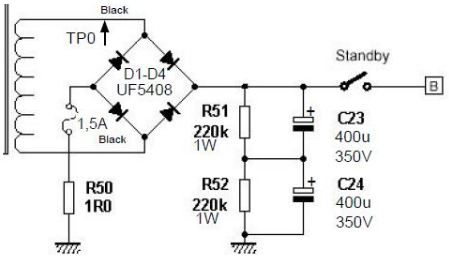
The chart below shows the comparison of the characteristic curves between the “old” V2 Siemens ECC83 and the replacement JJ ECC83S. Both are inside the tolerance limits for new ECC83 tubes (green dotted lines).



During final characterization in chap. 4 investigations with an ECC82 in the socket of the phase inverter V4 have been made. The ECC82 in that position has the advantage that ECC82 with higher current can drive the output level more stable. And the lower amplification is marginal as the signal levels at the input of the output stage still can reach saturation. The chart below shows the characteristic curves for the replaces JJ ECC82.



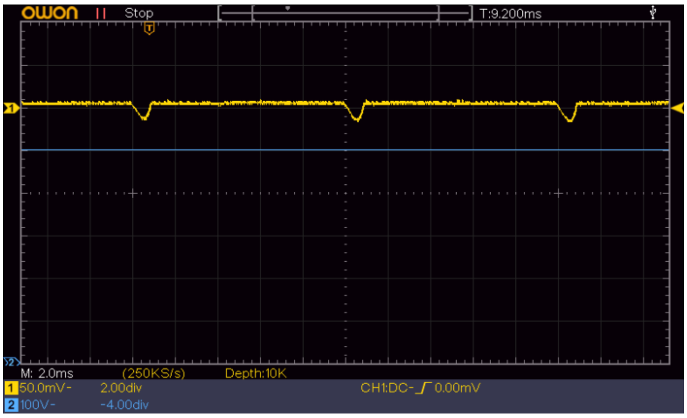
3.23. High Voltage Power Consumption



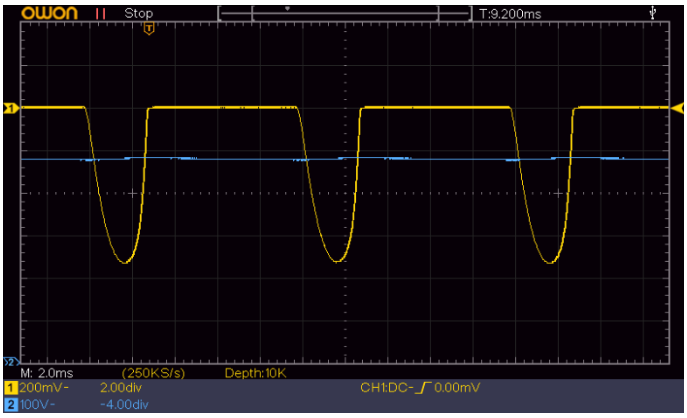
The role of the standby switch is discussed controversial and contradicting in chap. 1.17. In this chapter some investigations are done to derive the real needs of the amp. The high voltage current in the Funkshun can be made visible easily by measuring the voltage drop at R50. At this shunt resistor of 1Ω in the high voltage circuit the voltage corresponds 1:1 to the current.

At first the behaviour under stable operating conditions in a warmed-up amp with no signal at the input and all pots at 5 is measured.

I.21.a) (194.000) Dissipation pulses in Standby → no HT load
Ch1= R50 shunt
Ch2= Output rectifier
The 100Hz load pulses of the capacitors C23 and C24 due to loss of charge with maximum 21mA are visible. The output of the rectifier is approx. at 500V.

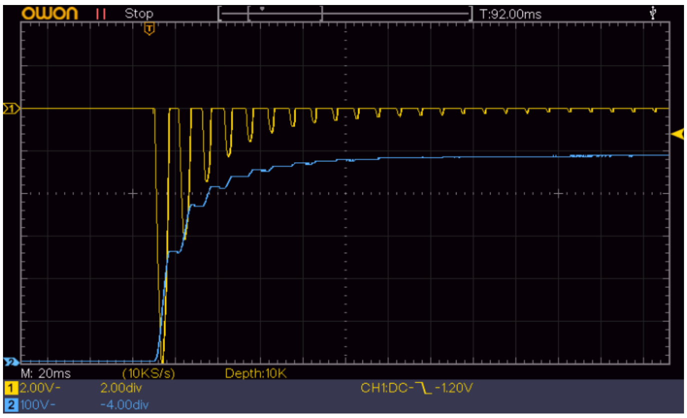


I.21.b) (194.001) Dissipation pulses Standby OFF → with HT load
Ch1= R50 shunt
Ch2= Output rectifier
Now the 100Hz load pulses are significantly bigger (max. 728mA) as the high voltage has to provide the anode current for all tubes. The rectifier output drops down to approx. 480V.



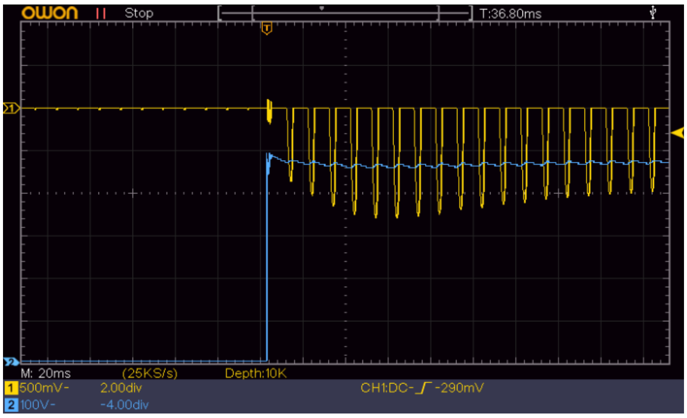
What happens when the amp is switched ON with “empty” (remaining voltage <1V) C23/C24 capacitors? Only the mains switch is toggled. Standy switch stays in “Standby”/ HT OFF.

I.21.c) (194.010) Charge pulses C23/C24 in Standby OFF → no extra HT load
Ch1= R50 shunt
Ch2= Output rectifier
As the capacitors are empty the first load pulse goes up to 12A. After approx. 200ms the capacitors are charged and the stable situation of I.21.a is reached.

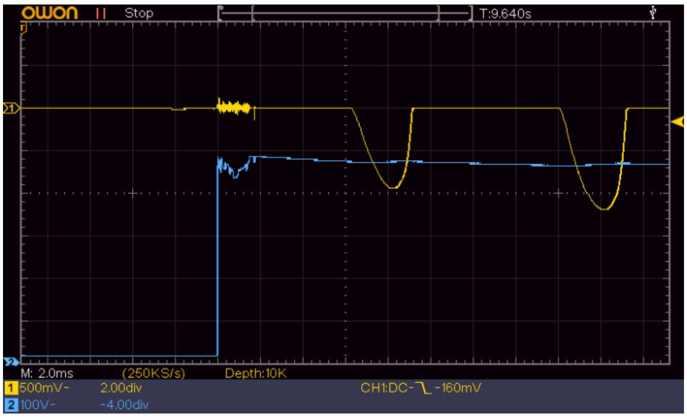


How does the situation look when HT is swichted ON with empty capacitors C20/C12/C8? The whole amp is therefore already warmed-up, which means C23/C24 are charged and the pre-heated tubes can immediately start operating.

I.22.a) (194.002) Charge pulses HT ON
Ch1= R50 shunt
Ch2= TP1
As the capacitors C20/C12/C8 are empty the first load pulses reach after 50ms a maximum of 1,2A. After approx. 1s they reach the stable plateau of 728mA in I.21.b.

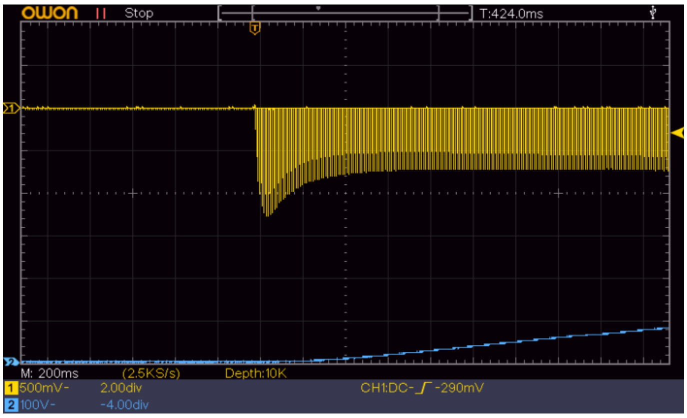


I.22.b) (166.004) Charge pulses HT ON; zoom of the switch arcing
Ch1= R50 shunt
Ch2= TP1
The arcing caused by the switch bouncing is neglectable.

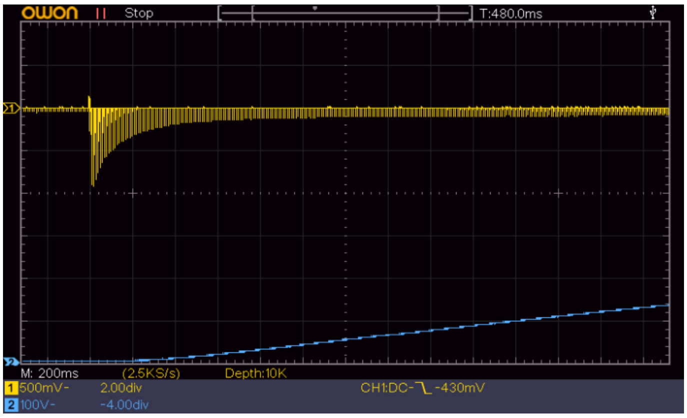


How does HT develops at the last filter step (TP5) when HT is swichted ON with empty capacitors C20/C12/C8? The whole amp is therefore already warmed-up, which means C23/C24 are charged and the pre-heated tubes can immediately start operating.

I.23.a) (194.005) Charge pulses Standby OFF/ HT ON; pre-heated, warm tubes.
Ch1= R50 shunt
Ch2= TP5
As the capacitors C20/C12/C8 are empty the first load pulses reach after 50ms a maximum of 1,2A. After approx. 1s they reach the stable plateau of 728mA in I.21b.
At TP5 the voltage rises slowly and reaches the final plateau at 308V after approx. 11s.



How is the situation at TP5 when HT is swichted ON immediately after C23/C24 are charged, before the heater in the tubes reaches operation condition?



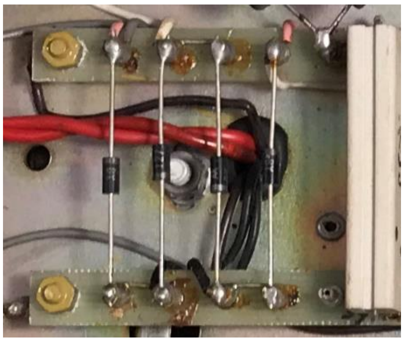
I.23.b) (194.008) Charge pulses Standby OFF/ HT ON; cold, non-emitting tubes
Ch1= R50 shunt
Ch2= TP5
The basic behaviour is the same as in I.23.a. The peak value and the plateau of the load pulse (Ch1) are smaller as the load by the anode currents of the tubes is missing.
The voltage at TP5 is also rising slowly. Due to the missing anode currents the full voltage of TP1 is expected at TP5 as long as there is no current in the filter network.

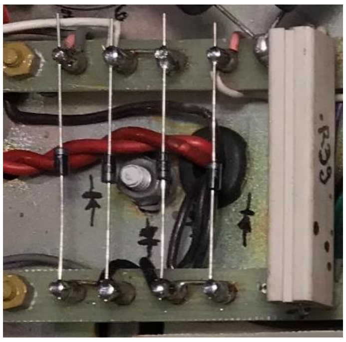
Conclusions:

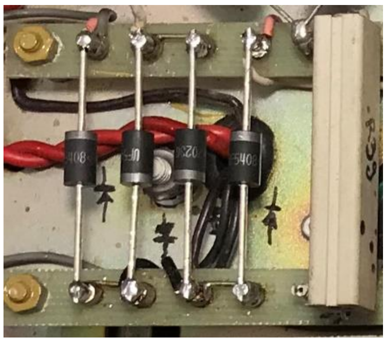
- Based on I.21.b and I.21.c a T1,0A fuse for the HT instead of the specified 2,0A in the schematic is enough and makes the protection more sensitive.
- The standby switch divides the load to charge the empty filter capacitors into two parts. This leads to less stress at switch ON for the transformer.
- When toggling the standby switch (Standby OFF/ HT ON) before the tubes are ready for operation (no anode current) the theoretical situation that the full HT from the rectifier also reaches the first stage in the preamp is not observed. This means that “two early” toggling of the Standby switch (still no anode current) leads not to a temporarily critical situation at the preamp.

3.24. Rectifier Diodes

In chap. 1.18 the originally assembled BY127 in the high voltage rectifier is already compared with the first replacement UF4007 during hum noise investigation (see also chap. 3.11) and the second replacement UF5408 after the current consumption measurements (see also chap. 3.23).


Original BY127


1st replacement: UF4007


2nd replacement: UF5498

Finally, the rectifier of the Funkshun is equipped with diode type UF5408 (3A; 1000V) which is ultra-fast and more robust than the originally assembled BY127.

4. Characteristics after Refurbishing

4.1. Mains Voltage Selection Switch

As already stated in chap. 2.3 the “235V” selected at the switch in the rear panel fits best to the provided main voltage supply between 236VAC and 239VAC.

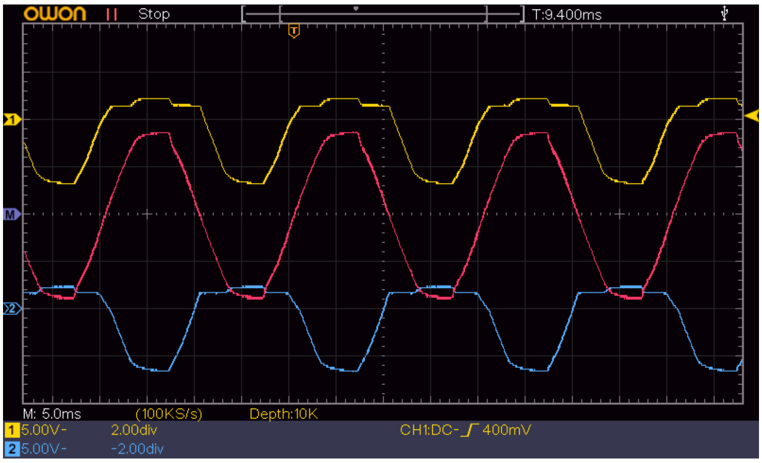
4.2. Tube Heating Supply

The quad of EL34 in the output stage will supplied with nominal 6,3VAC directly from the transformer, while the three tubes in the preamp on the PCB will be supplied with rectified nominal 6,3VDC.

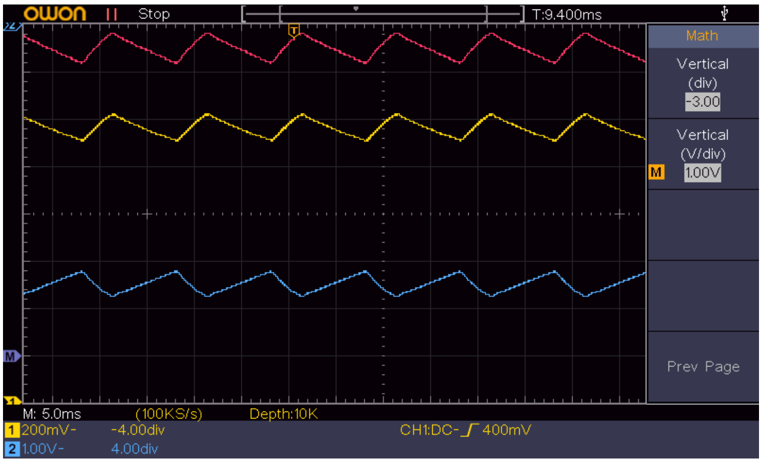
Mains supply	Test point	Pin	Voltage*
236VAC	AC heater V5-V8	Pin7/Pin2	6,64VAC
236VAC	DC heater V2-V4	Pin”+”/Pin”-“	6,66VDC

*Measured with multi meter FLUKE 15B®

F.1) (176_002): U_{Heat} AC
CH1= Phase 1 / V8_Pin2 U_{Heat}
Ch2= Phase 2 / V8_Pin 7U_{Heat}
U_{Heat} AC (Magenta, 50Hz): 17,4Vpp → 8,7Vp → 6,15Veff (assuming perfect sine wave behaviour)
The multi meter (no TRMS) shows a slightly higher value as the shape of the voltage curve is differing from a perfect sine wave.
The significant deviation of the wave forms of the two phases from a sine is due to the impact of the diode from the rectifier module to create DC heating voltage.



F.2) (176_001): U_{Heat} DC
U_{Heat} DC: 6,20VDC with 0,6V 100Hz Rippel (Magenta)
The multi meter shows an averaged value of 6,66VDC. The “humdinger” is already adjusted to minimize hum noise.



4.3. High Voltage Supply

Test Point	Pin	Voltage V4= ECC83*	Voltage V4= ECC82*
transformer secondary HT	Black/Black	363VAC	363VAC
after rectifier	TP1	+481VDC	+477VDC
after R39 470R	TP2	+468VDC	+466VDC
after R33 3k9	TP3	+445VDC	+441VDC
after R17 82k	TP4	+316VVDC	+313VDC
after R13 15k	TP5	+307VDC	+304VDC
V2 /ECC83	1	+168VDC	+167DC
V2 /ECC83	6	+217VDC	+215VDC
V3 /ECC83	1	+325VDC	+326VDC
V3 /ECC83	6	+229VDC	+232VDC
V4	1	+295VDC	+270VDC
V4	6	+284VDC	+270VDC
V5&V6 /EL34 Pin 3	3	+479VDC	+477VDC
V7&V8 /EL34 Pin 3	3	+478VDC	+477VDC

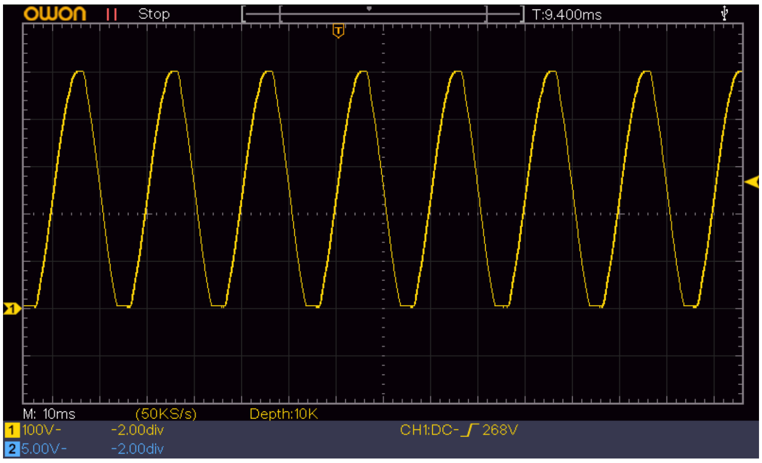
*Measured with multi meter FLUKE 15B®

The values measured here differ from those before rework as the HT supply chain was adapted (see chap. 3.12 and chap. 1.4). The voltages with V4= ECC83 are slightly higher as the voltages with V4= ECC82 due to higher current consumption of the ECC82.

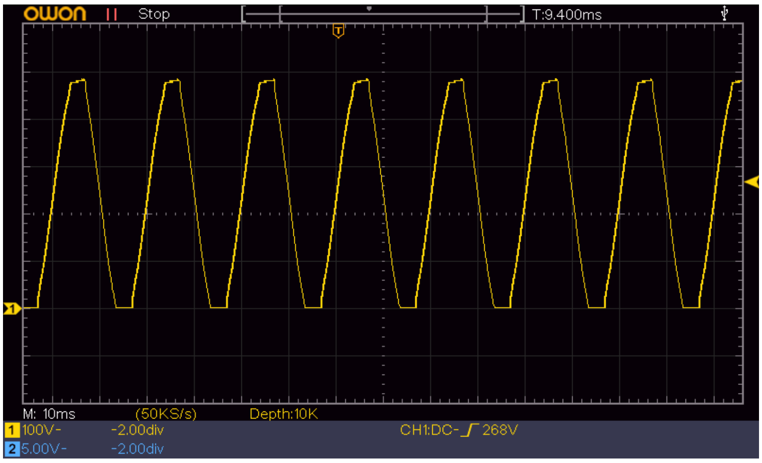
Ripple on DC High Voltage

All measurements were made with no signal at amplifier‘s input and an assembled V4= EC83. For an ECC82 at V4 the voltage levels slightly change, but not the qualitative behaviour. All pots at front panel were at 5 unless otherwise noted.

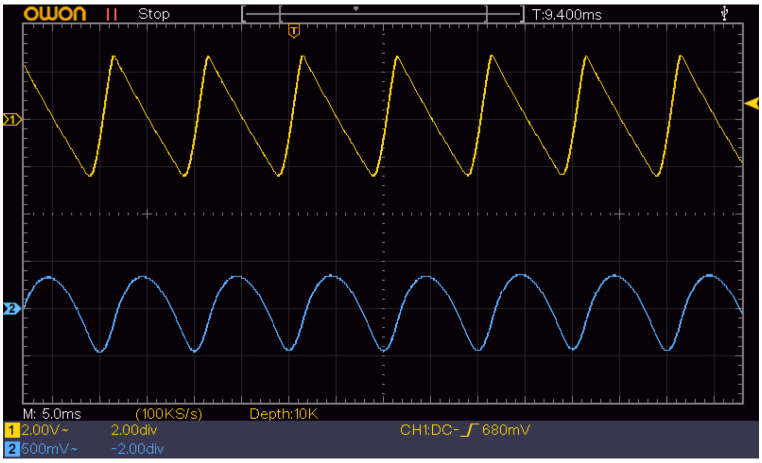
F.3.a) (177_004) High voltage
Ch1= TP0 from transformer
500Vpp 50Hz.
High voltage OFF (standby)
The opposite side of the transformer shows the same curve but shifted by half a period.



F.3.b) (177_002) High voltage
Ch1= TP0 from transformer
490Vpp 50Hz.
High voltage ON
Under load the HT transformer output gets slightly reduced.
The opposite side of the transformer shows the same curve but shifted by half a period.

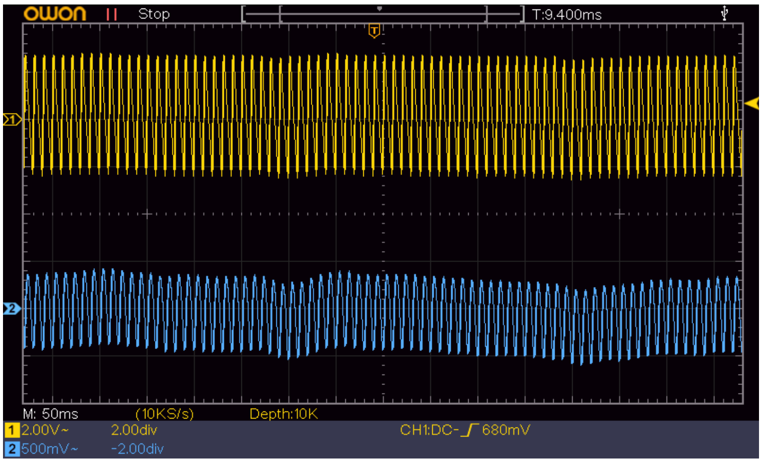


F.4.a) (177_005) DC high voltage
Ch1= TP1 +481VDC/ after rectifier
5V 100Hz ripple (~1%)
Ch2= TP2 +466VDC/ after R39
780mV 100Hz ripple (~0,2%)



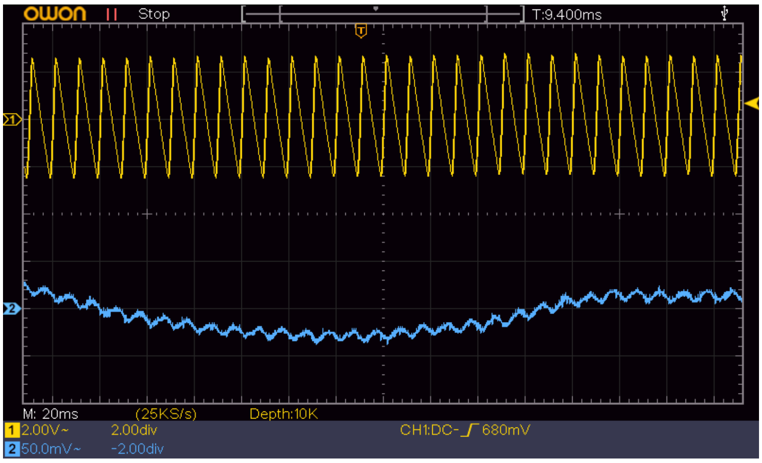
F.4.b) (177_006) DC high voltage
Ch1= TP1 +481VDC/ after rectifier
Ch2= TP2 +468VDC/ after R39
~100mV fluctuation at TP2

Not recorded but observed:
Knocking at the EL34 tubes is significant less sensitive than before!

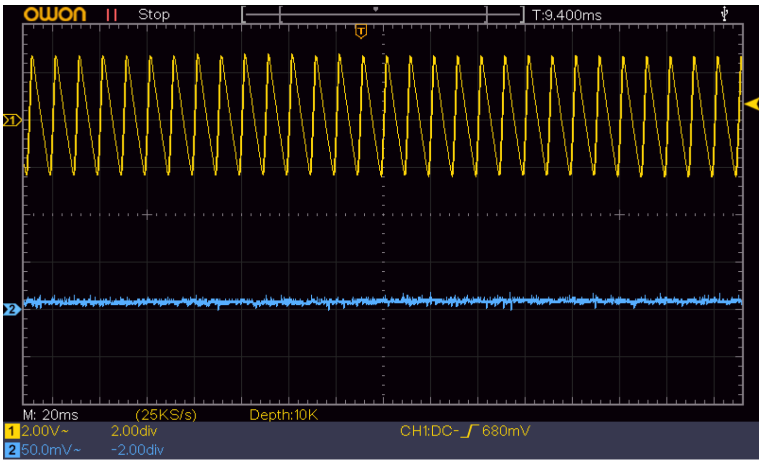


F.5) (177_007) DC high voltage
Ch1= TP1 +481VDC/ after rectifier
Ch2= TP3 +445VDC/ after R33

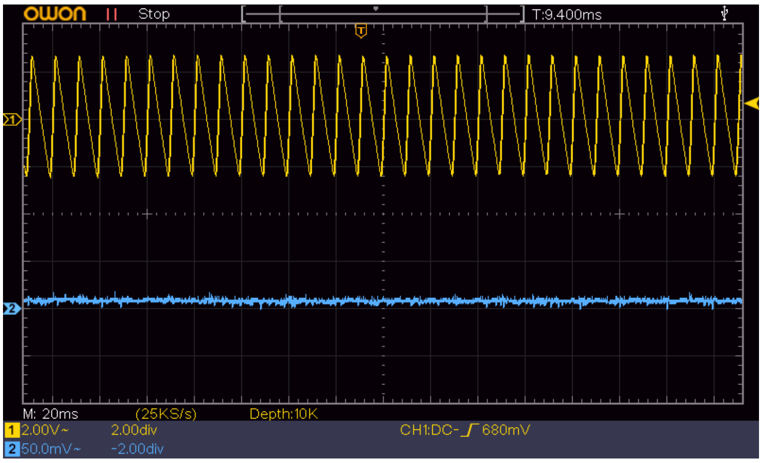
Neglectable (~20mV) and fluctuation (~50mV) after R33.



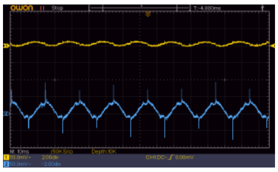
F.6) (177_008) DC high voltage
Ch1= TP1 +481VDC/ after rectifier
Ch2= TP4 +316VDC/ at C8A
No ripple or fluctuation at C8A

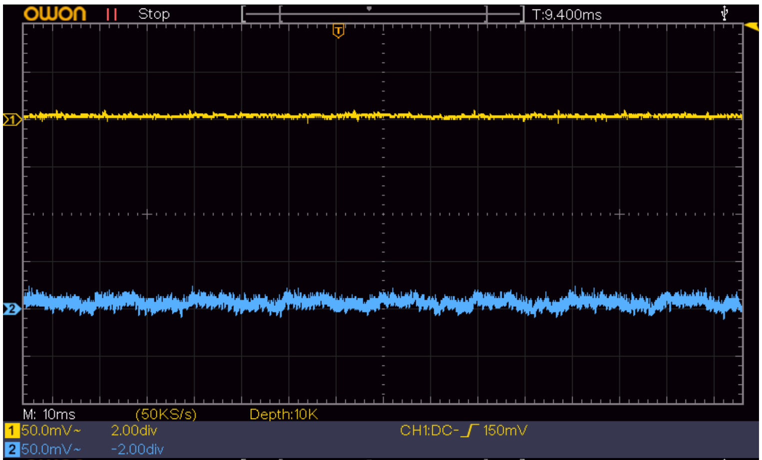


F.7) (177_009) DC high voltage
Ch1= TP1 +481VDC/ after rectifier
Ch2= TP5 +307VDC/ at C8B
No ripple or fluctuation at C8B

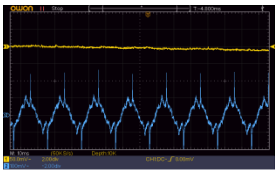


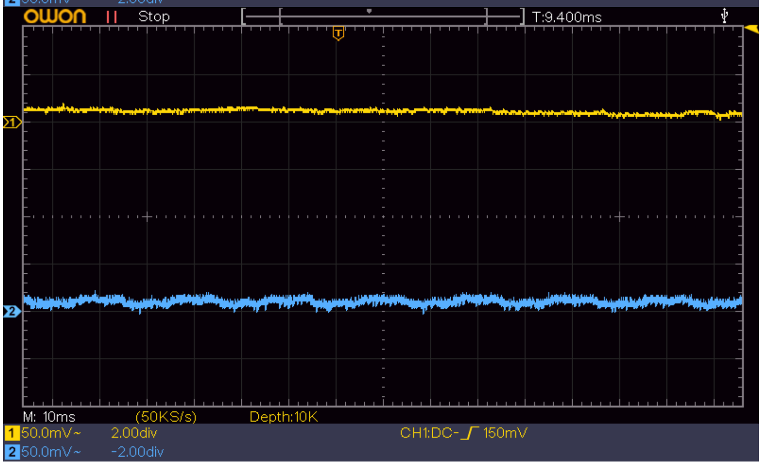
F.8) (177_010) Anodes V2 ECC83
Ch1= V2 / Pin1 (+168VDC) no ripple
Ch2= V2 / Pin6 (+217VDC)
20mV noise (~0,01%).
The noise on the supply of V2 (see A.8) in chap. 2.6) is significantly reduced.
Note: V2 is substituted with a frame grid JJ_ECC83S.





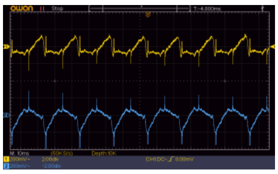
F.9) (177_012) Anodes V3 ECC83
Ch1= V3 / Pin1 (+325VDC)
No ripple at all
Ch2= V3 / Pin6 (+229VDC)
~20mV noise (~0,009%)
The noise on the supply of V2 (see also A.9) is significantly reduced.

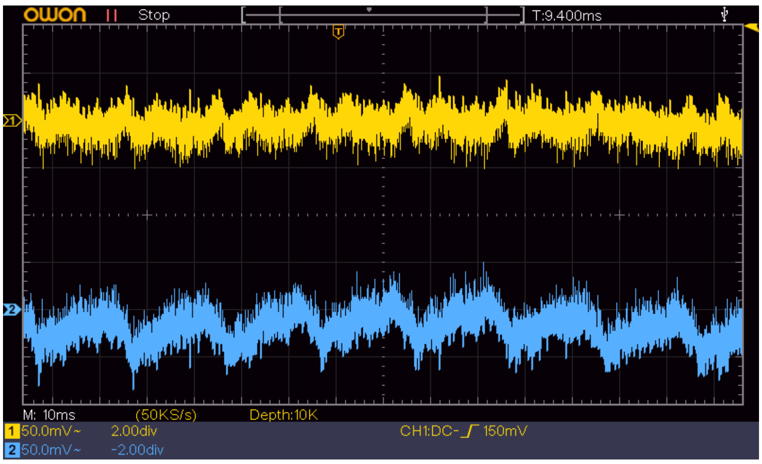




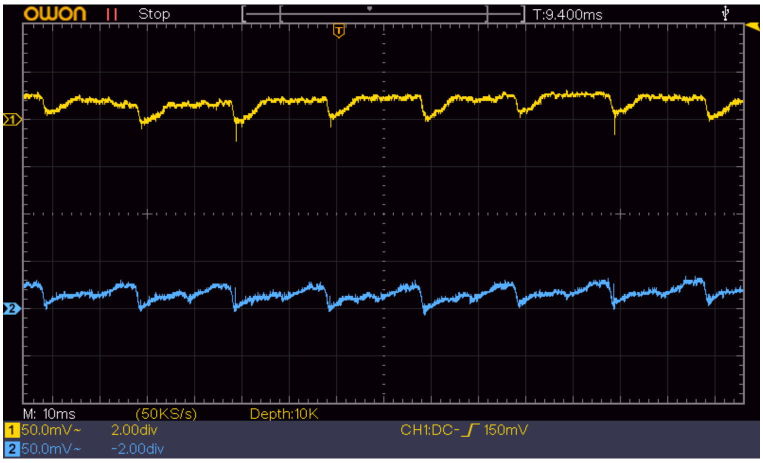
F.10.a) (177_013) Anodes V4 ECC83
Ch1= V4 / Pin1 (+295VDC)
~50mV noise (~0,02%)
Ch2= V4 / Pin6 (+284VDC)
120mV 50Hz ripple & hum (~0,09%)

This situation in comparison to A.10.a) shows a significant big improvement.

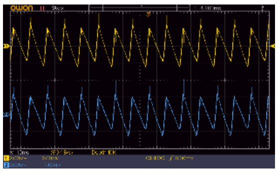


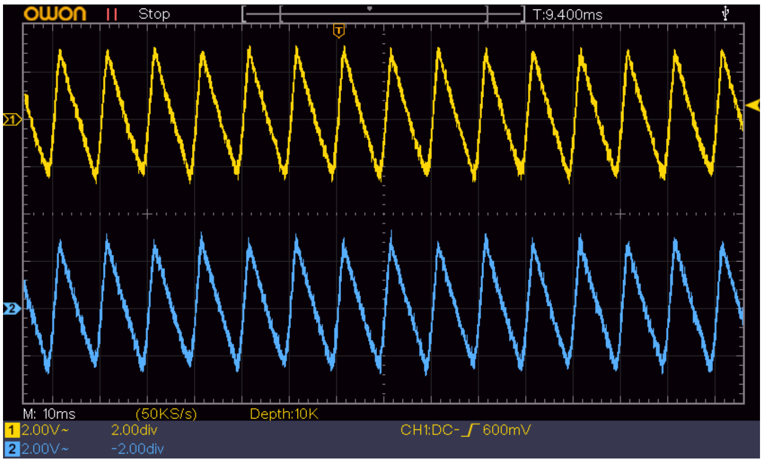


F.10.b) (177_015) Anodes V4 ECC83
Ch1= V4 / Pin1 (+295VDC)
50mV 50Hz ripple (~0,02%)
Ch2= V4 / Pin6 (+284VDC)
50mV 50Hz ripple (~0,02%)
The Master Volume was set to zero. The hum coupling via signal path is gone. The remaining 50Hz ripple is approx. 8 times smaller due to a smoother bias voltage supply. (see also A.10.b)

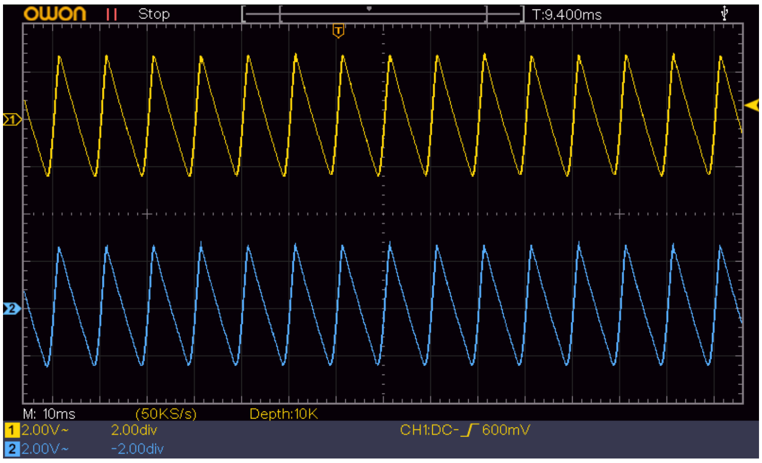


F.11.a) (177_016) Anodes V5/V6 & V7/V8
Ch1= V5/V6 / Pin3 EL34 (+479VDC)
Ch2= V7/V8 / Pin3 EL34 (+478VDC)
4,9V 100Hz ripple & hum (~1%)
The basic 100Hz ripple is the remaining ripple on HT supply.
Significant less disturbances via signal path than in A.11.a.





F.11.b) (177_017) Anodes V5/V6 & V7/V8
Ch1= V5/V6 / Pin3 EL34 (+479VDC)
Ch2= V7/V8 / Pin3 EL34 (+478VDC)
4,9V 100Hz ripple (~1%)
The Master Volume is set to zero. The disturbances via signal path are gone. The basic 100Hz ripple from HT supply is still there. This remaining ripple on HT supply is slightly bigger than before (~0,9% → ~1%).



<u>Conclusion:</u>
The 50Hz hum from the heater including the spikes from the diodes in the HT supply of the preamp has been successfully eliminated. The remaining ripple of the bias voltage has been also significantly reduced.
In total the refurbishment leads to a HT supply which is more stable and less disturbed.

4.4. Cathode Voltages at Preamp Tubes

Static measurements with multi meter at cathodes of the tubes within the preamp:

Test Point	Pin	Voltage*
V2 /ECC83	3	+1,46VDC
V2 /ECC83	8	+1,70VDC
V3 /ECC83	2	+77,7VDC
V3 /ECC83	8	+1,85VDC
V3/V4	3/2	+85,2VDC
V4 /ECC82	3= 8	+94,3VDC
V4 /ECC82	7	+77,4VDC

*Measured with multi meter FLUKE_15B®

4.5. Bias at Output Stage

Bias Adjustment

In chap. 2.1 it is discussed that the output stage tubes will be substituted with a new quad of JJ EL34 II Red Label. According to Ted Weber's Bias Calculator [6] bias settings for safe plate dissipation of a class AB should be 70% of max plate dissipation (EL34 = 25W). To have a further safety margin for the output stage 63% is the target for the working point. With the two independent bias pots the current is adjusted according to those 63% at the measured anode voltage. The anode voltage is checked directly at pin 6 of the tubes.

Mains Supply*	Tube	Anode Voltage*	Cathode Current* (Target**)	Bias before grid resistor*
236VAC	V5 / EL34	479VDC	31,5mA (32,9mA)	-48,2VDC
236VAC	V6 / EL34	479VDC	33,0mA (32,9mA)	-48,2VDC
236VAC	V7 / EL34	478VDC	33,0mA (32,9mA)	-48,2VDC
236VAC	V8 / EL34	478VDC	32,5mA (32,9mA)	-48,2VDC

* All voltages measured with FLUKE 15B®

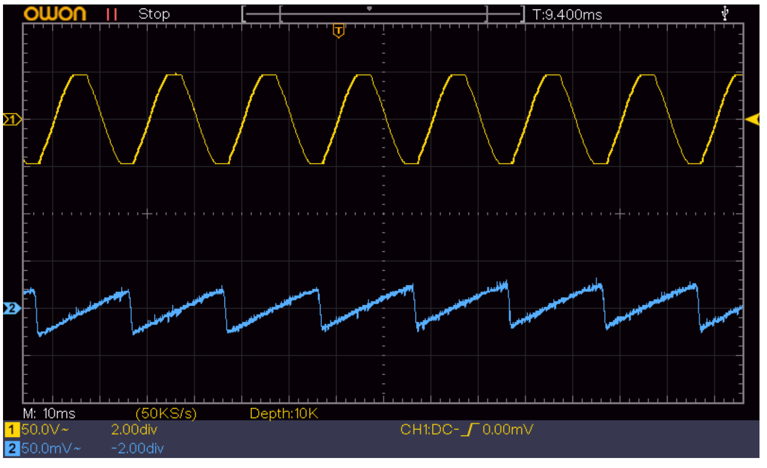
** Target = 0,63 x 25W / 478V

Ripple on Bias Voltage

As a result of the optimization of chap. 3.4 the remaining ripple of the bias voltage could be reduced by a factor of ~12.

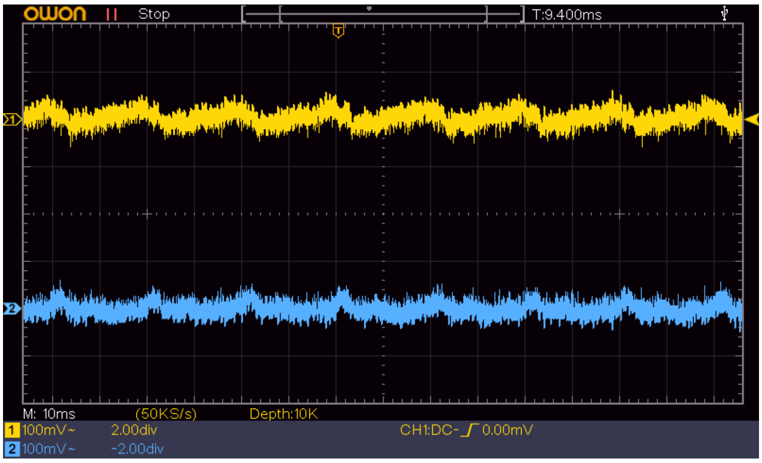
F.14) (177_018) Bias Voltage before and after rectifying diode BY127
Ch1= TP6 transformer output
94Vpp → 47Vmax → 33,2VeffAC (assuming perfect sine wave form; with FLUKE_B15®:34,4VeffAC)
Ch2= TP7 after diode -46,2VDC
42mV 50Hz ripple (~0,09%)

Ripple is a factor of 12 smaller than before optimization (see A.14).

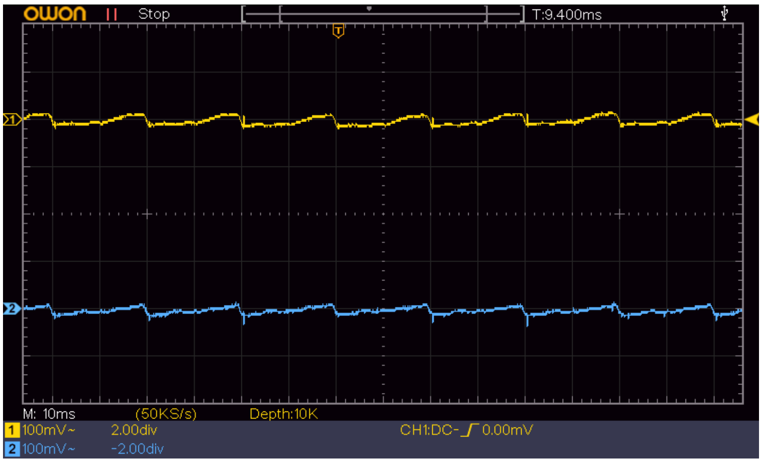


F.15.a) (177_019) Bias voltages before grid resistors
Ch1= V5/V6 / Pin 6 -42,8VDC
Ch2= V7/V8 / Pin 6 -42,8VDC

The observed behaviour is the same as in F.10.a) as the test points are separated only by C22 resp. C21. (Note: Ch1 and Ch2 are vice versa)



F.15.b) (177_020) Bias voltages before grid resistors
Ch1= V5/V6./ Pin 6 -42,8VDC
Ch2= V7/V8 / Pin 6 -42,8VDC
The Master Volume was set to zero. The hum coupling via signal path is gone. The remaining 50Hz ripple is approx. 7 times smaller than before due to a smoother bias voltage supply (see also A.15.b).



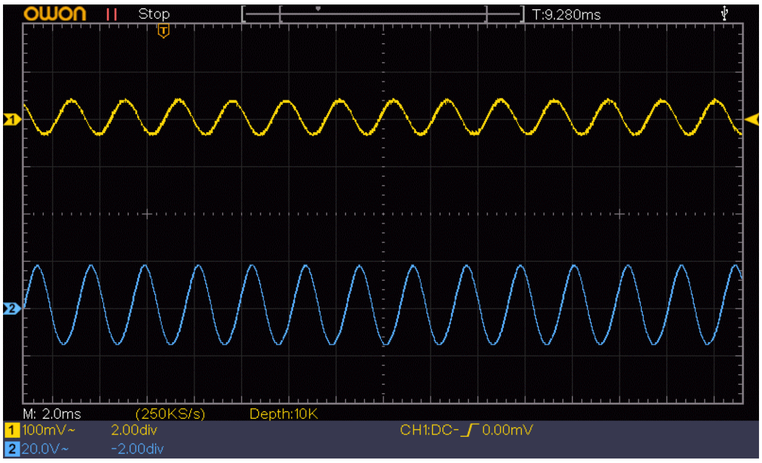
Conclusion:
The remaining 50Hz ripple on the bias voltage is successful reduced from 520mV / ~1,1% to 42mV / ~0,09%.

4.6. Characterizing the Signal Path

440Hz sin wave from the generator was given to the input and checked at different points along the signal path towards the speaker output. All pots at front panel were at 5 unless otherwise specified.

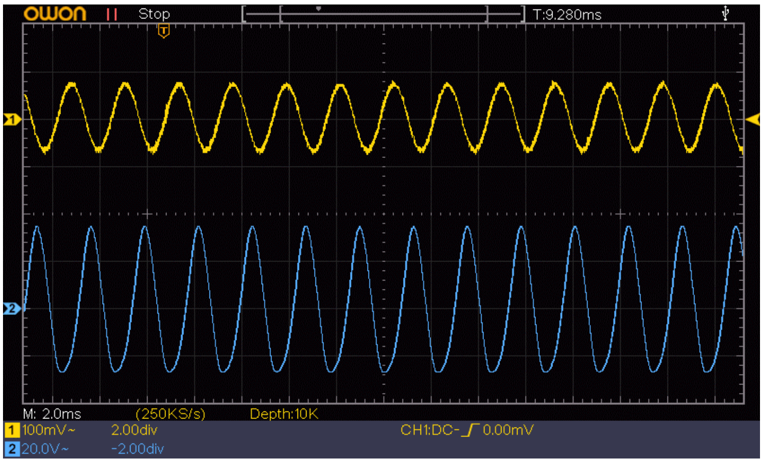
FA.20.a) (190_001)
Complete signal path LOW gain input
Ch1= V2a ECC83 / Pin 2
Ch2= 8Ohm speaker simulator

Input (72mVpp) and output (34Vpp) signal stable. Overall gain factor: ~472



FA.20.b) (190_000)
Complete signal path HIGH gain input
Ch1= V2a ECC83 / Pin 2
Ch2= 8Ohm speaker simulator

Input signal of 138mVpp arrives at the speaker simulator with 61,2Vpp. Overall gain factor: ~443.



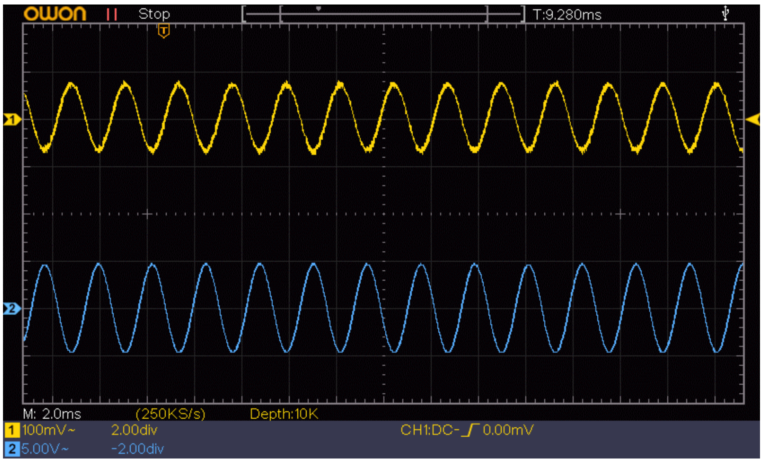
Conclusion:

The input signal arrives stable at the speaker. Before refurbishing the signal were not so stable. The signal amplitudes differ from those before due a modified topology within the signal path (e.g. biasing of V2, removing master volume modification, substituting V4 with ECC82, 4 EL34 instead of 2 EL34).

Signal path step by step for input HIGH with Overdrive

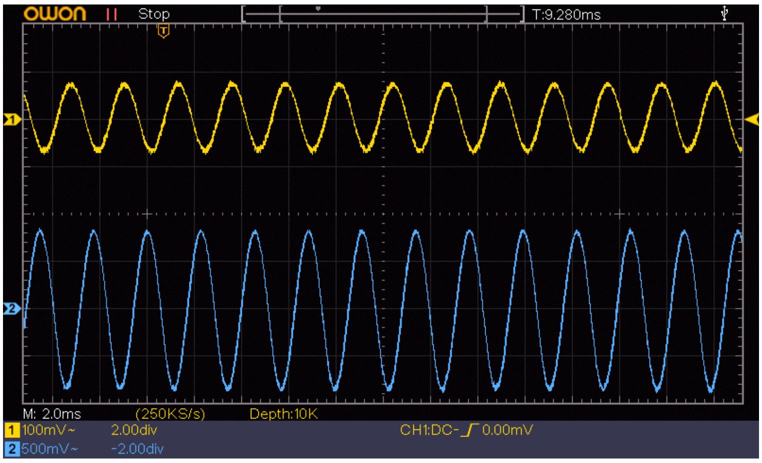
FA.21) (190_002) Preamp V2a
Ch1= V2a ECC83 / Pin 2
Ch2= V2a ECC83 / Pin 1

Calm signal without noise:
Input (138mVpp) → Output (9,2Vpp)
Gain factor Preamp: ~67



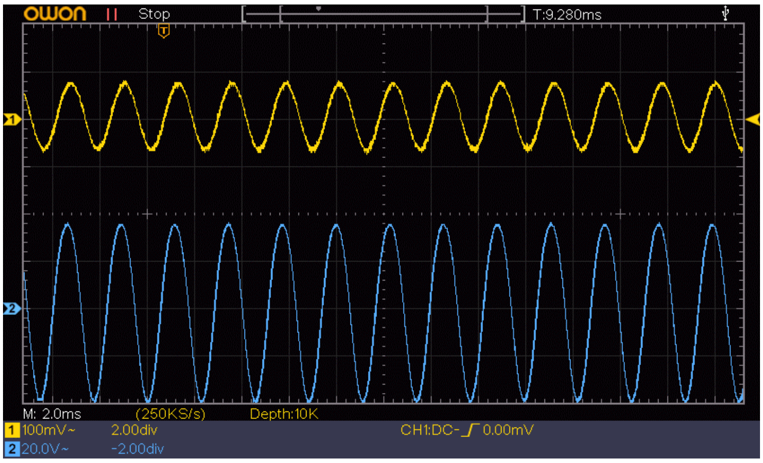
FA.22) (190_003) 2nd stage V2b Input
Ch1= V2a ECC83 / Pin 2
Ch2= V2b ECC83 / Pin 7

Overdrive circuit reduces the signal by a factor of ~0,18
1,66Vpp provided after overdrive stage for input at 2nd stage.



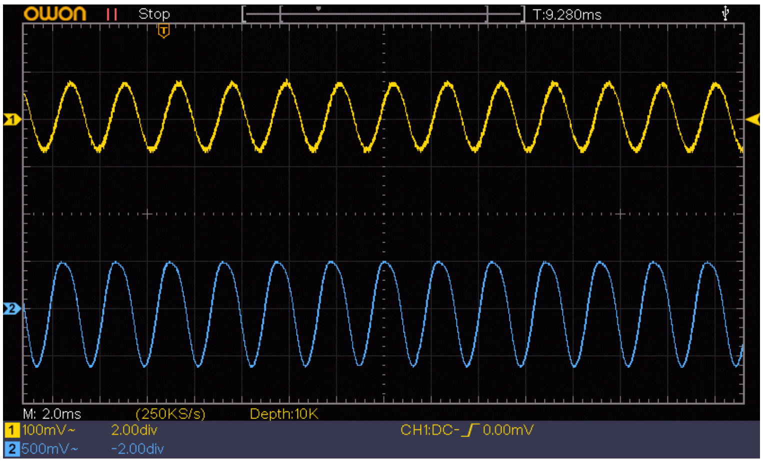
FA.23) (190_004) 2nd stage V2b Output
Ch1= V2a ECC83 / Pin 2
Ch2= V2b ECC83 / Pin 6

74,4Vpp at output of 2nd stage →
Gain factor 2nd stage: ~45
74,4Vpp will be provided for the tone stack
Distortion visible as deviation from the perfect sine wave.



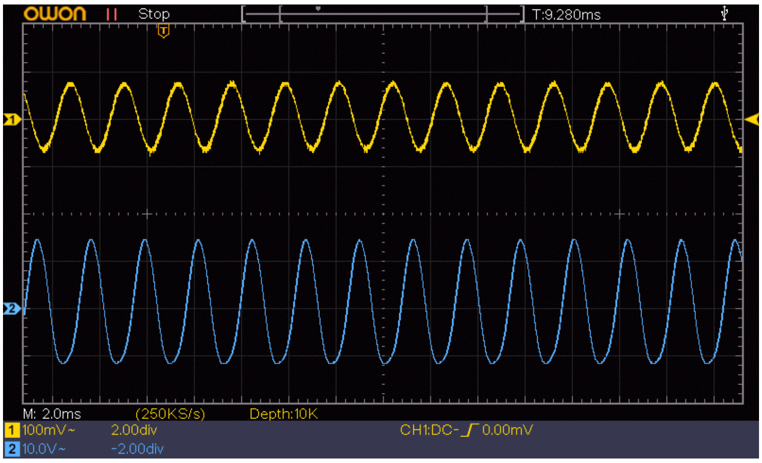
FA.24) (190_005) 3rd stage V3b
Input - After tone stack
Ch1= V2a ECC83 / Pin 2
Ch2= V3b ECC83 / Pin 7

Tone stack reduces input by a factor of ~0,015 down to 1,09Vpp.



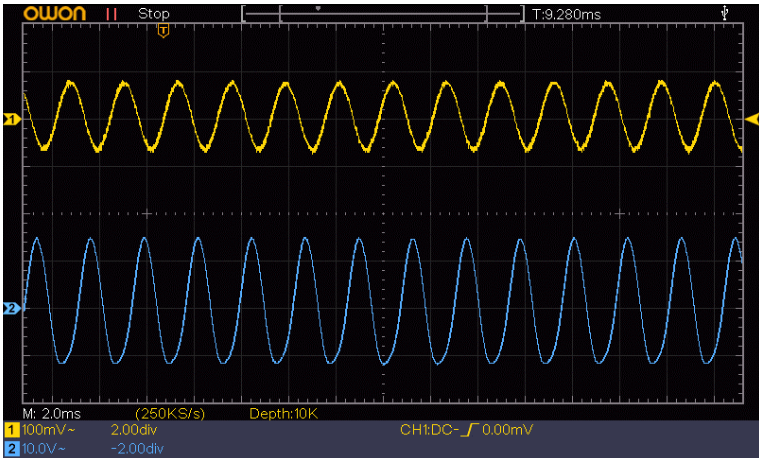
FA.25) (190_006) 3rd stage V3b
Output
Ch1= V2a ECC83 / Pin 2
Ch2= V3b ECC83 / Pin 6

3rd stage provides 26Vpp →
Gain factor 3rd stage: ~24



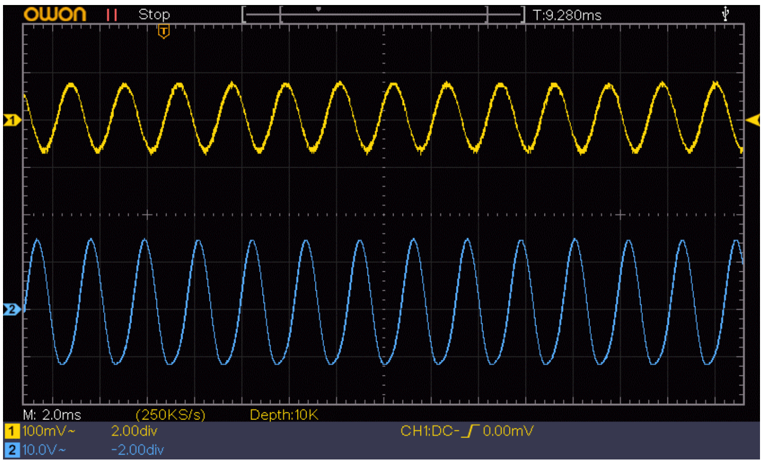
FA.26) (190_007) 4th stage V3a
Input – cathode follower to drive phase inverter
Ch1= V2a ECC83 / Pin 2
Ch2= V3a ECC83 / Pin 2

26Vpp at the input of the cathode follower.



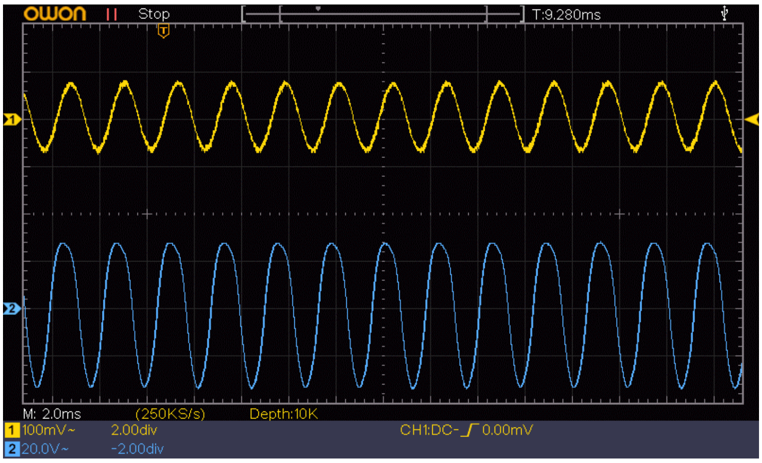
FA.27) (190_008) 4th stage V3a
Output cathode follower
= Phase inverter Input V4a
Ch1= V2a ECC83 / Pin 2
Ch2= V3a ECC83 / Pin 3
= V4a ECC82 / Pin 2

The cathode follower V3a (gain: ~1,0) provides 26Vpp for the phase inverter.



FA.28.a) (190_009) Phase inverter A
Output phase inverter V4a
Ch1= V2a ECC83 / Pin 2
Ch2= V4a ECC82 / Pin 1 (C22)

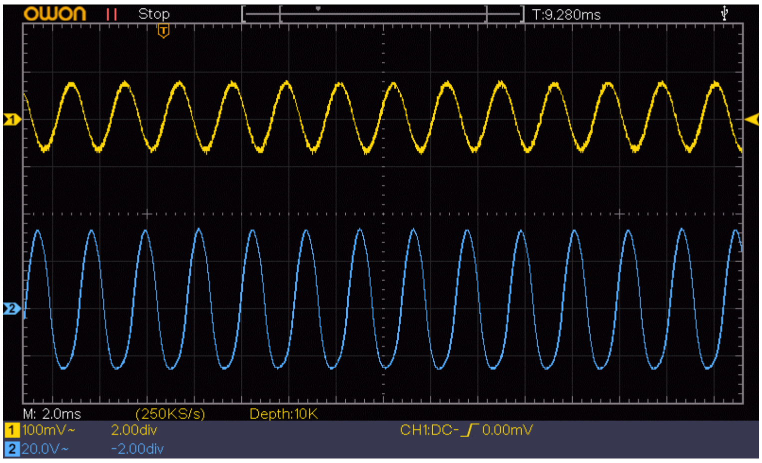
Channel A of the phase inverter provides 62Vpp → Gain factor: ~2,4 Gain factor is roughly the half due to the usage of an ECC82 instead of an ECC83.



FA.28.b) (190_010) Phase inverter B
Output phase inverter V4b
Ch1= V2a ECC83 / Pin 2
Ch2= V4b ECC82 / Pin 6 (C21)

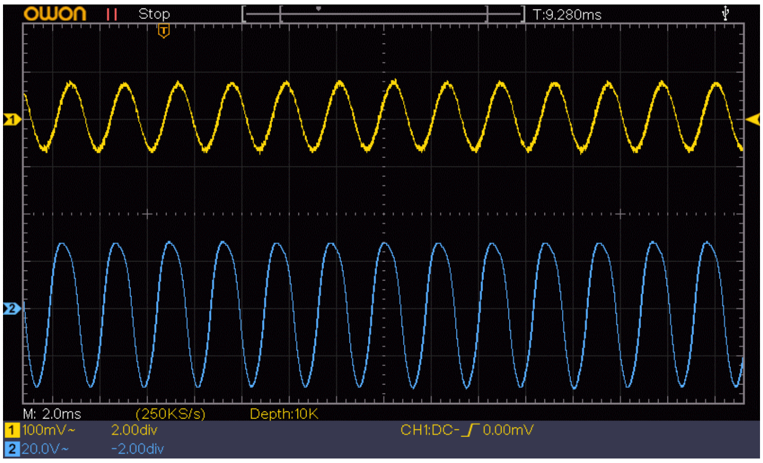
Channel B of the phase inverter provides 60Vpp → Gain factor: ~2,3

The two output signals of the phase inverter are slightly asymmetric.



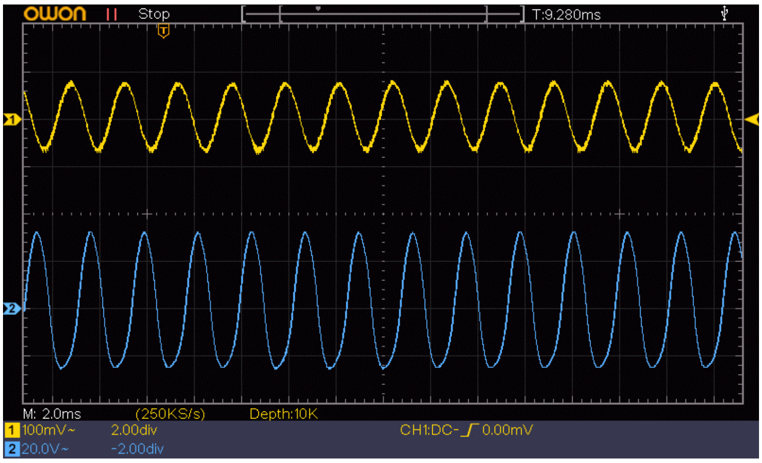
FA.29.a) (190_011) Output stage A
Input of Output stage A: V7/V8
Ch1= V2a ECC83 / Pin 2
Ch2= V7 EL34 / Pin 5

62Vpp from phase inverter output A arrives at input of output stage A.



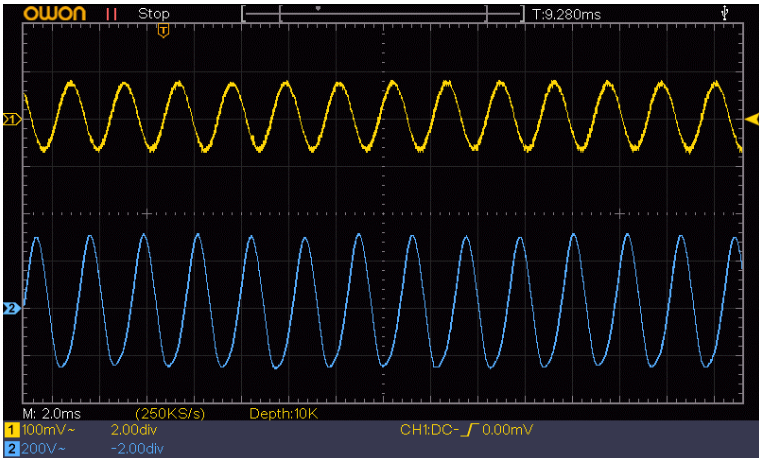
FA.29.b) (190_012) Output stage B
Input of Output stage B: V5/V6
Ch1= V2a ECC83 / Pin 2
Ch2= V6 EL34 / Pin 5

58Vpp from phase inverter output B arrives at input of output stage B.



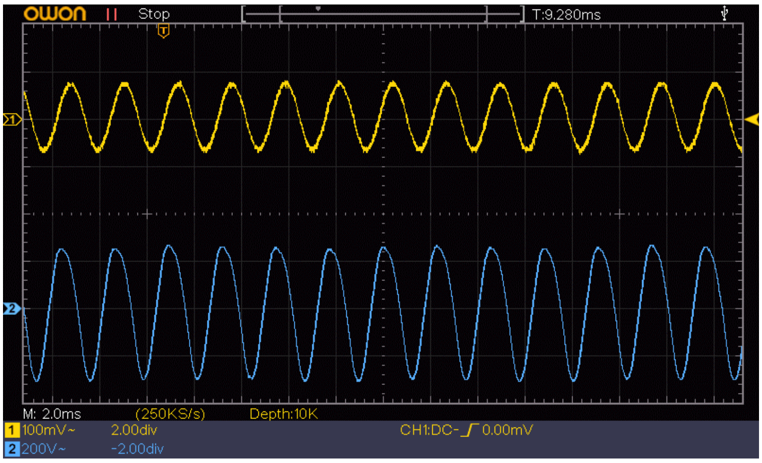
FA.30.a) (190_013) Output stage A
Output of Output stage A: V7/V8
Ch1= V2a ECC83 / Pin 2
Ch2= V7 EL34 / Pin 3

Output stage A with 560Vpp →
Gain factor: ~9,0



FA.30.b) (190_014) Output stage B
Output of Output stage B: V5/V6
Ch1= V2a ECC83 / Pin 2
Ch2= V6 EL34 / Pin 3

Output stage B with 560Vpp →
Gain factor: ~9,6



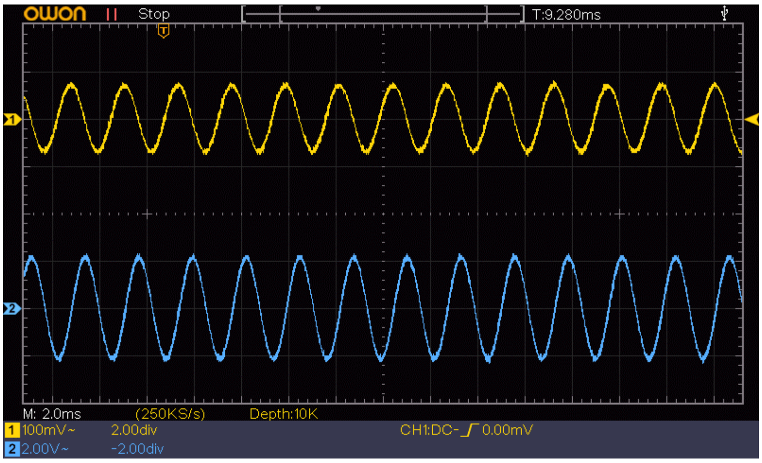
Conclusion:

Due to the changes of the topology in the audio path (e.g. (e.g. biasing of V2, removing master volume modification, substituting V4 with ECC82, 4 EL34 instead of 2 EL34) the signal levels at all stages are still below hard cut-off limitations with all control pots at 5, which is half scale.

Signal path step by step for input HIGH without Overdrive

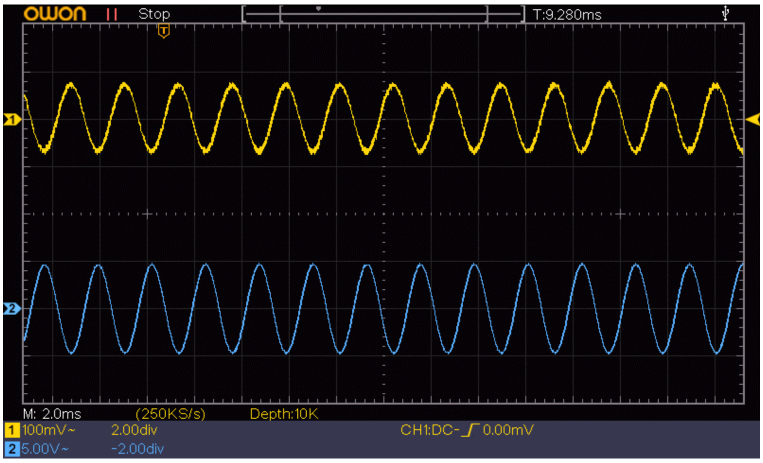
To document a cleaner signal along the signal path, the characterization has been repeated without using the OVERDRIVE. Thus, less signal amplitude already from the 2nd stage on is used.

FB.20) (187_000) Complete path
Ch1= V2a ECC83 / Pin 2
Ch2= 8Ohm speaker simulator
Input signal of 138mVpp arrives at the speaker simulator with 4,3Vpp. Overall gain factor: ~31.
In total signal amplitude and gain is roughly half compared to B.20. The output stage is using a quad of tubes instead of a pair which doubles the amplification in the EL34 stage, but the changed audio path topology is leading to lower signal in the preamp.

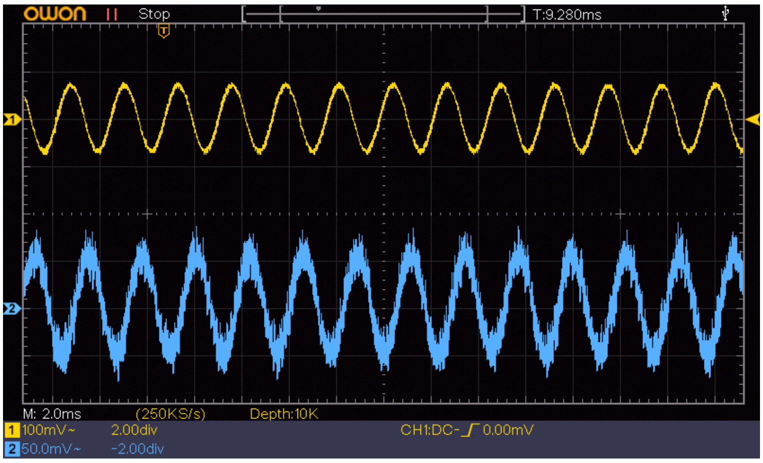


FB.21) (187_001) Preamp V2a
Ch1= V2a ECC83 / Pin 2
Ch2= V2a ECC83 / Pin 1

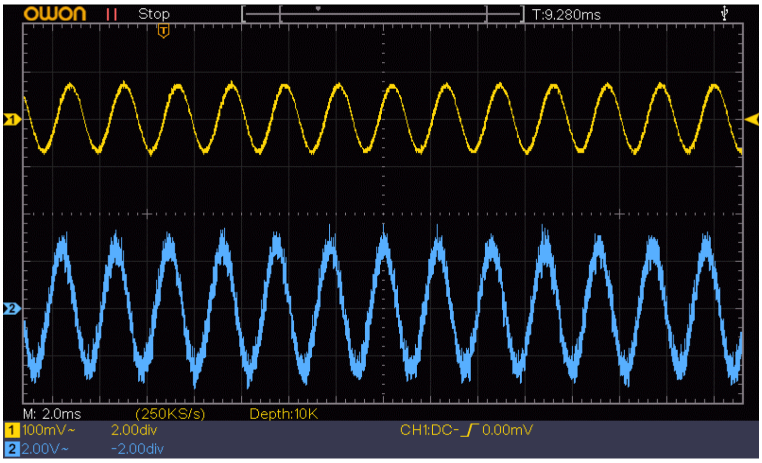
Calm signal without noise:
Input (138mVpp) → Output (9,4Vpp)
Gain factor preamp: ~68



FB.22) (187_002) 2nd stage V2b Input
Ch1= V2a ECC83 / Pin 2
Ch2= V2b ECC83 / Pin 7
The filter combination between 1st stage and 2nd stage reduces the signal by a factor of ~0,012 (no Overdrive!)
111mVpp provided after overdrive circuit as input at 2nd stage.
The noise on the signal is now higher because of the removed additional caps at V2 (see B.22, chap. 2.9).

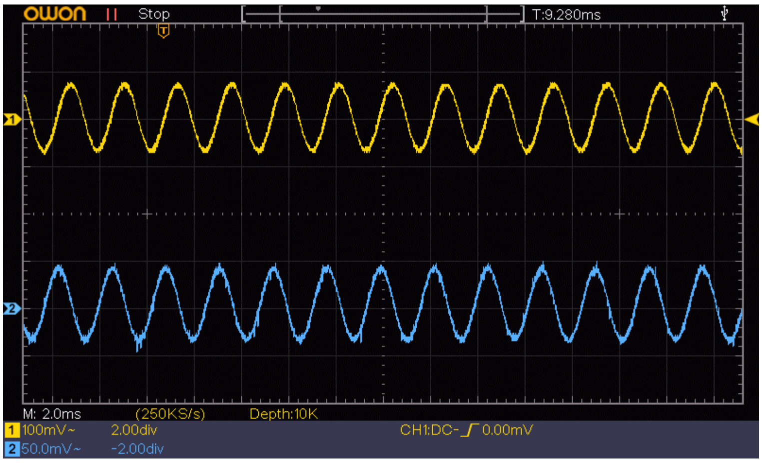


FB.23) (187_003) 2nd stage V2b Output
Ch1= V2a ECC83 / Pin 2
Ch2= V2b ECC83 / Pin 6
5,1Vpp at output of 2nd stage →
Gain factor 2nd stage: ~46
5,1Vpp will be provided for the tone stack. The noise on the signal is slightly higher than before (B.23) because of the removed additional caps at V2 (see chap. 2.9), but still in a neglectable range.



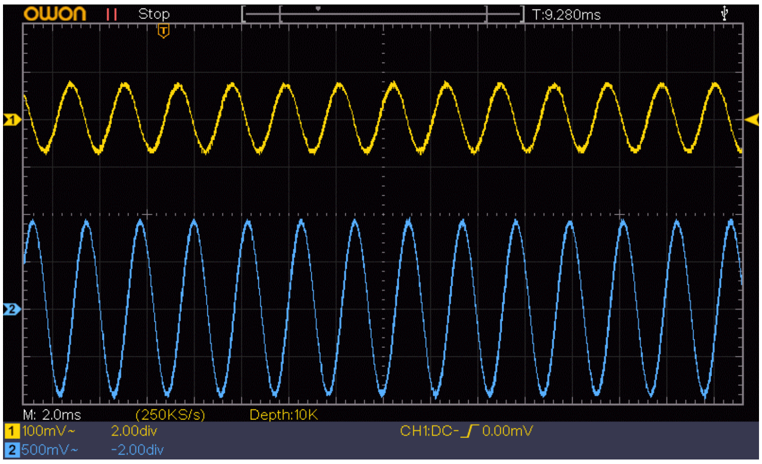
FB.24) (187_004) 3rd stage V3b Input - After tone stack
Ch1= V2a ECC83 / Pin 2
Ch2= V3b ECC83 / Pin 7

Tone stack reduces input by a factor of ~0,015 down to 77mVpp. This is approximately 10 times less than before (B.20) due the removal of the Master Volume modifications (see chap. 3.8).



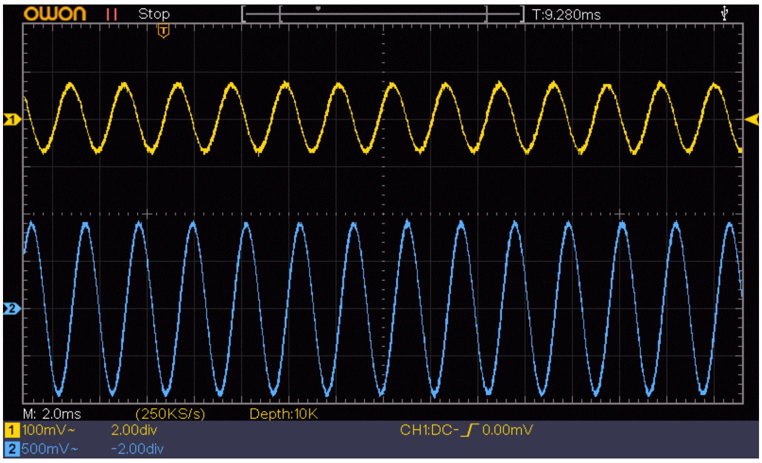
FB.25) (187_005) 3rd stage V3b Output
Ch1= V2a ECC83 / Pin 2
Ch2= V3b ECC83 / Pin 6

3rd stage provides 1,8Vpp →
Gain factor 3rd stage: ~23
Gain is reduced due to partially bypassed cathode (see chap. 1.11).



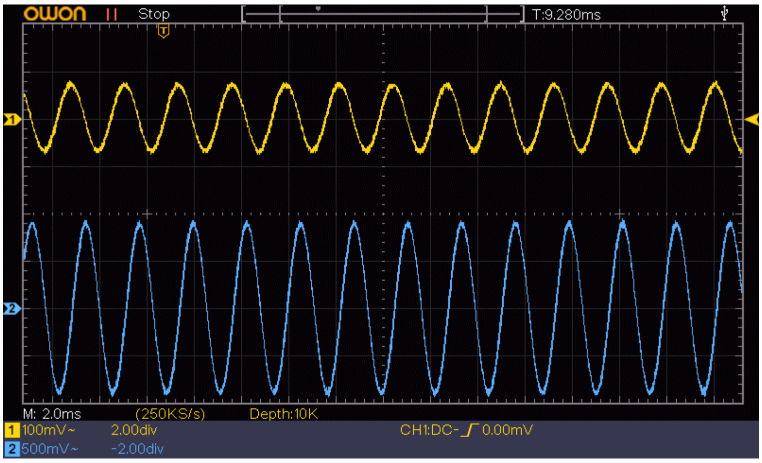
FB.26) (187_006) 4th stage V3a Input – cathode follower to drive phase inverter
Ch1= V2a ECC83 / Pin 2
Ch2= V3a ECC83 / Pin 2

1,8Vpp at the input of the cathode follower



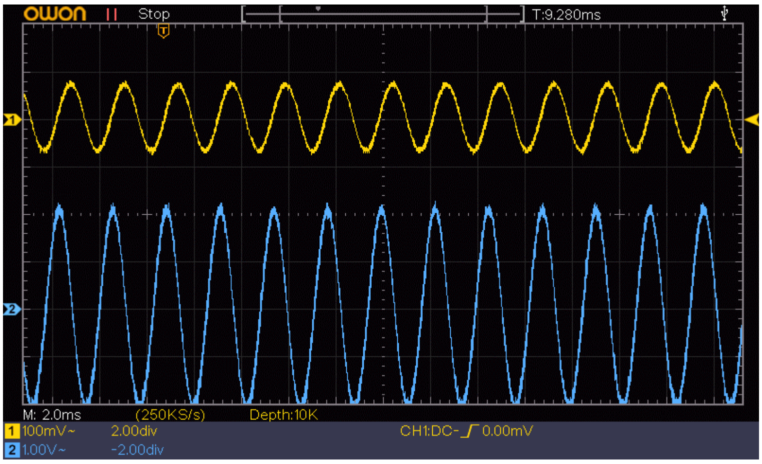
FB.27) (187_007) 4th stage V3a
Output cathode follower
= Phase inverter Input V4a
Ch1= V2a ECC83 / Pin 2
Ch2= V3a ECC83 / Pin 3
= V4a ECC82 / Pin 2

The cathode follower V3a keeps the amplitude at 1,8Vpp (gain: ~1,0)



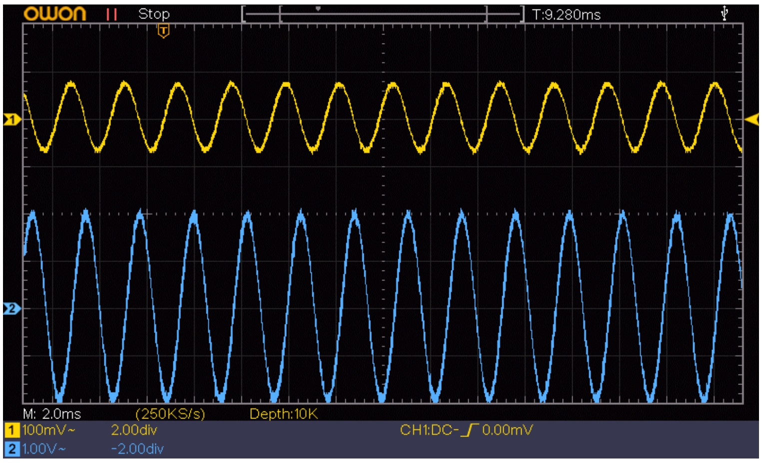
FB.28.a) (187_008) Phase inverter A
Output phase inverter V4a
Ch1= V2a ECC83 / Pin 2
Ch2= V4a ECC82 / Pin 1 (C22)

Channel A of the phase inverter provides 4Vpp → Gain factor: ~2,2



FB.28.b) (187_009) Phase inverter B
Output phase inverter V4b
Ch1= V2a ECC83 / Pin 2
Ch2= V4b ECC82 / Pin 6 (C21)

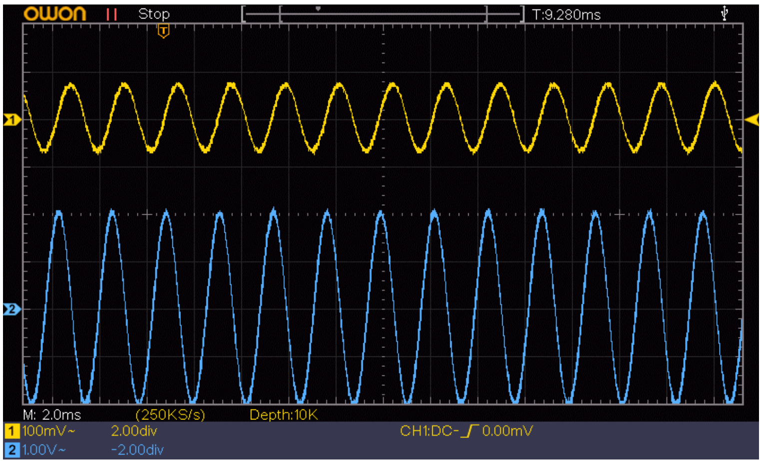
Channel B of the phase inverter provides 3,9Vpp → Gain factor: ~2,2



Phase inverter output A (FB.28.a) is inverted to input signal (FB.27) while phase inverter output B (FB.28.b) has the same phase then the input. The peak-to-peak value of the two output signals of the phase inverter is marginal different (~2,5%). As the two parts of the phase inverter are now operated with different anode load resistor values (82KΩ, 91KΩ). (see also chap. 1.12) the difference between the two channels could be reduced from ~9% (compare with B.29.a and B.29.b; chap. 2.9) down to ~2,5%.

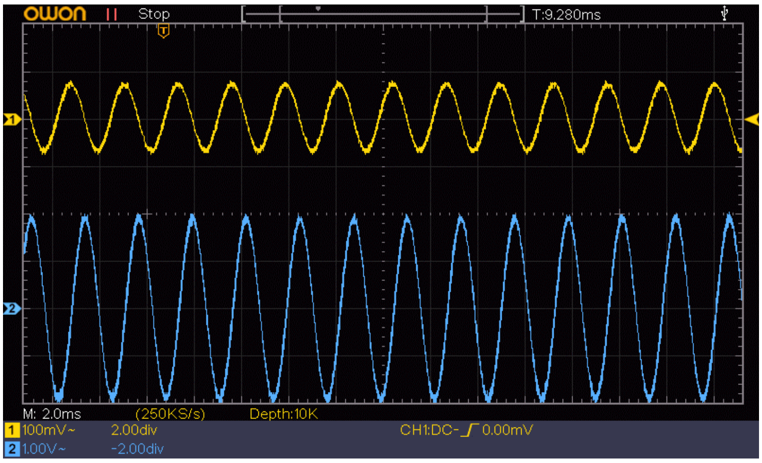
FB.29.a) (187_010) Output stage A
Input of Output stage A: V7/V8
Ch1= V2a ECC83 / Pin 2
Ch2= V7 EL34 / Pin 5

The 4Vpp from phase converter A arrives at the input of the V7/V8 EL34 tubes.



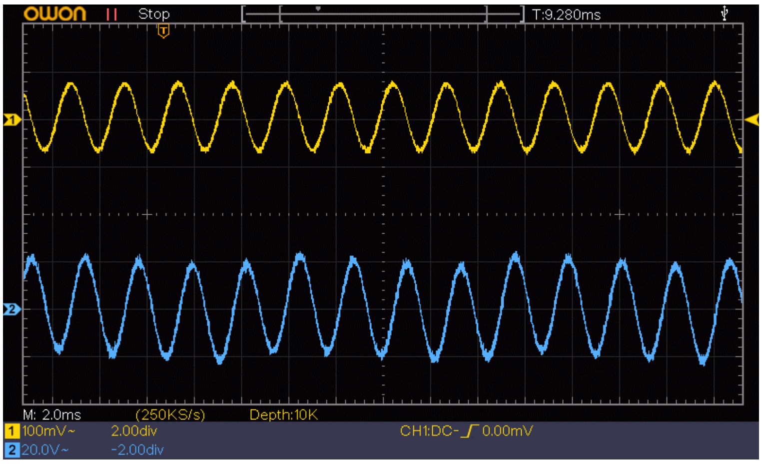
FB.29.b) (187_011) Output stage B
Input of Output stage B: V5/V6
Ch1= V2a ECC83 / Pin 2
Ch2= V6 EL34 / Pin 5

The 3,9Vpp from phase converter B arrives at the input of the V5/V6 EL34 tube.



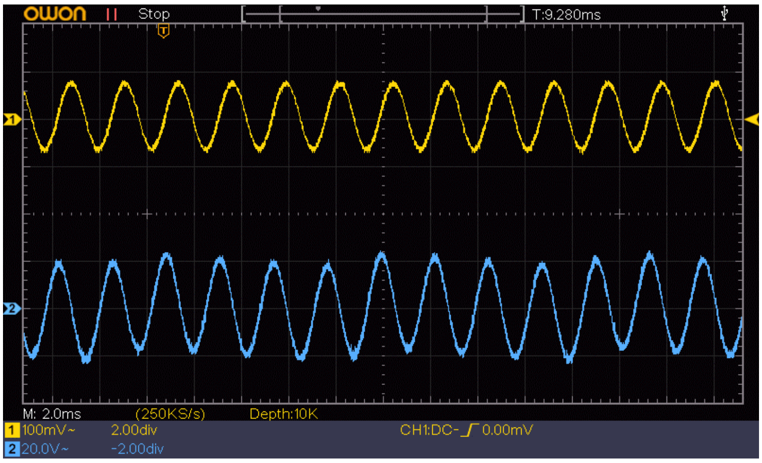
FB.30.a) (187_012) Output stage A
Output of Output stage A: V7/V8
Ch1= V2a ECC83 / Pin 2
Ch2= V7 EL34 / Pin 3

Output stage A with 38Vpp →
Gain factor: ~9,5



FB.30.b) (187_014) Output stage B
Output of Output stage B: V5/V6
Ch1= V2a ECC83 / Pin 2
Ch2= V6 EL34 / Pin 3

Output stage B with 39Vpp →
Gain factor: ~10,0

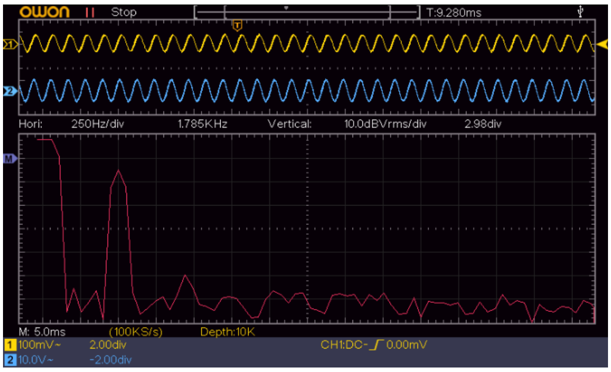


Signal characterization of overdriven signal

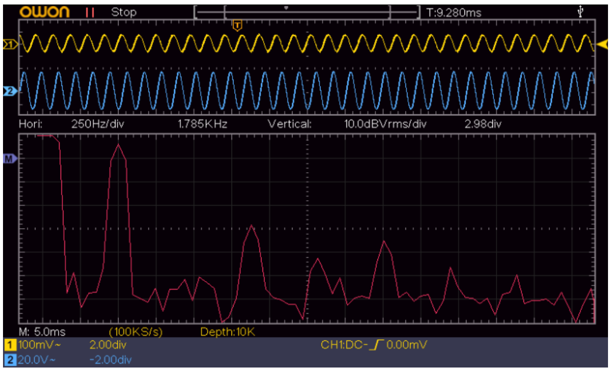
As discussed in chap. 1.4, the overdrive is created in the 2nd stage of preamp V2b. According to the load line the distortion should start somewhere above 500mVpp signal at the input of V2b. To verify the behaviour the standard 440Hz signal with 138mVpp was applied at HI input and the fast Fourier transform (FFT) of the amplified signal was recorded.

400mVpp at the input of V2b

For this record DRIVE 8 and OVERDRIVE 0 at the front pots was set.
F.35.a) (191_001) Output 2nd stage V2b
Ch1= V2a ECC83 / Pin 2
Ch2= V2b ECC83 / Pin 6
The FFT of Ch2 shows the main frequency at 440Hz and an already starting peak at 880Hz (2nd). The 440Hz test signal can be considered as clean.

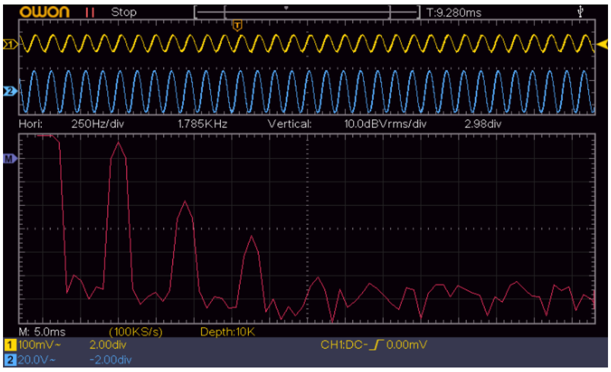


What is the impact of the further stages to the output on the speaker?
F.35.b) (191_002) Impact of total amp at MASTER VOLUME 8 (tone stack all 5)
Ch1= V2a ECC83 / Pin 2
Ch2= 8Ω speaker simulator
The FFT of Ch2 shows the main frequency at 440Hz. The additional peaks at 1320Hz (3rd) and 2200Hz (5th) disappear when the MASTER VOLUME is reduced.



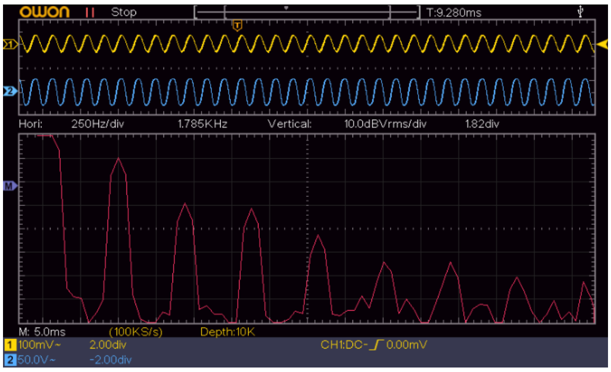
1,55Vpp at the input of V2b

F.36) (191_003) Output 2nd stage V2b
Ch1= V2a ECC83 / Pin 2
Ch2= V2b ECC83 /Pin 6
The FFT of Ch2 shows the main frequency at 440Hz. The additional peaks at 880Hz (2nd), 1320Hz (3rd) and 1760Hz (4th) are created within overdriven V2b



3,1Vpp at the input of V2b

F.37) (191_005) Output 2nd stage V2b
Ch1= V2a ECC83 / Pin 2
Ch2= V2b ECC83 /Pin 6
The FFT of Ch2 shows the fundamental frequency at 440Hz and all higher even and odd multiples of it.

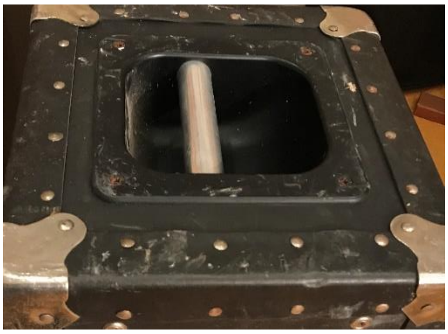


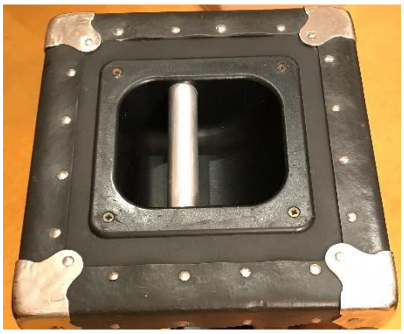
Conclusions:

- The second stage V2b creates harmonic distortion with all higher even and odd multiples of the base frequency.
- Further harmonic distortion of the power stage favours the odd multiples of the base frequency.

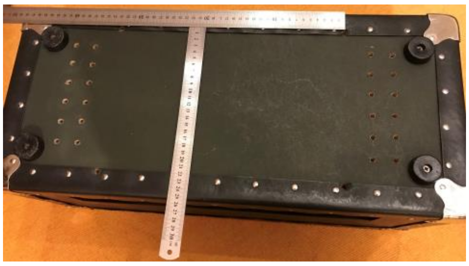
4.7. Re-assembly of the Chassis to the Housing

First the Funkshun characteristic case has been carefully cleaned. For the case corner and the rivets metal polish was used. A plastic care was used for the fibre laminated surfaces and the fibre angle riveted on all edges. The difference before and after is simply visible on the two pictures right.





On the bottom of the case a further opening for cooling has been added.



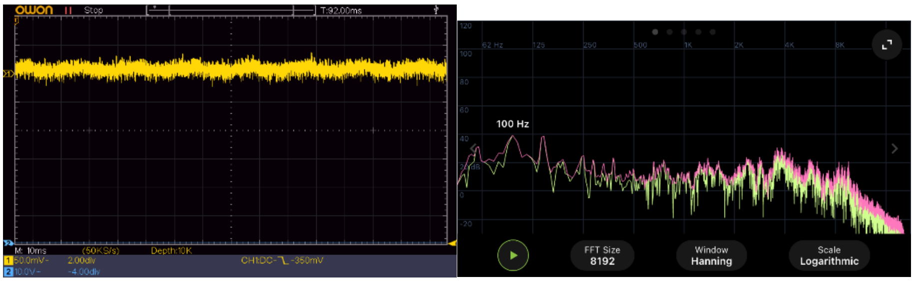
The opening was exactly placed above respectively below the cooling sink of the rectifier for the DC heater supply. Inside the case a self-adhesive aluminium foil was mounted to provide a better shielding for the chassis which is open at that side. In most of the Fender amps such shielding foil is assembled.

With the re-assembled chassis in the case:

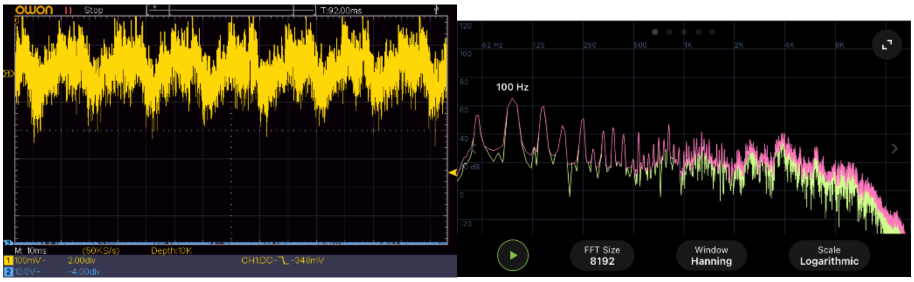
4.8. Noise Level and final Sound Check

For the completely assembled amp the noise level is documented. For this measurement all pot at the front panel are set to 5 which means half of full scale.

F.40) (196_000) No Signal at inputs and shortened
Ch1= 8Ω speaker
(IMG_2372) Dezibel X
~20cm distance/ dBZ
~30mVpp noise on electrical signal at speaker.



F.40) (196_001) Sound generator connected but no signal applied.
Ch1= 8Ω speaker
(IMG_2373) Dezibel X
~20cm distance/ dBZ
~200mVpp noise on electrical signal at speaker



Soundcheck

As measured above, the noise level with shortened inputs is low. The noise level more or less depends on all pots at the front panel. Connecting a guitar (single coil pickups) this couples much more noise in. Especially if the guitar gets nearer to the amp itself (not the speaker).
Powerful sound in both channels with very good, long reverberation (sustain). The sound can be varied from bass-heavy, muffled to extremely bright. This wide range of variation is also audible when varying the distortion.

5. Summary

5.1. Detected Failures / Modifications

- The blown fuse at primary side of mains transformer (nominal 3A) was substituted by T2,0A (see chap. 2.4, chap. 3.1).
- The two toggle switches were disassembled and the corroded contacts cleaned. Especially the Standby switch was out of function (see chap. 3.2).
- To allow the measurement of the cathode current of the tubes in the output stage directly without any adapter shunt resistors were integrated in the ground connection of the EL34 V5 – V8 in the output stage (see chap. 3.3).
- With a modified circuit in the supply of the bias voltage (bigger filter capacitor and bigger load resistor to lower the current) the remaining 50Hz ripple could be reduced from 520mV (~1,1%) down to 45mV (~0,1%) (see chap. 3.4).
- Due to similar anode resistors at the phase inverter slightly different signal amplitudes were observed (see chap. 2.9 → B.28.a and B.28.b). Therefore, dissimilar anode resistors R29= 82kΩ and R28= 91kΩ were assembled to create same signal amplitude. For the final assembled ECC82 the asymmetry could be reduced from ~5% down to 2,5% (see chap. 1.12, chap. 3.5 and chap. 4.6 → FB.28.a and FB.28.b)
- In the Funkshun on the bench two small capacitors each 4,7pF between grid and plate of V2 were mounted. This modification is assumed to be made for noise reduction. They were removed as the impact on the frequency transfer behaviour is judged to be too big (see chap. 3.6).
- In a first step all capacitors on the printed board were substituted except the Elcos C1, C7, C15, C20 and the C11 in the tone stack. In a second step after the investigation in chap. 3.11 and chap. 3.12 also the Elcos C1, C7, C15 were substituted (see chap. 3.7).
- A less professional looking modification at the master volume was removed and the original circuit was rebuilt (see chap. 1.9 and chap. 3.8).
- To optimize lead dress of the heater supply the wiring of the 6,3VAC was substituted by strong twisted harness (see chap. 3.9).
- To transfer the audio signal from the preamp on the PCB to the output stage directly mounted on the chassis, the used simple wires were replaced by shielded wires grounding the shield at output stage / chassis side. (see chap. 3.10)
- Many investigations for hum noise reduction were made. With a DC heating supply for the preamp and a changed ground design the disturbances in the signal path could be reduced significantly. (see chap. 3.11)
- The input and 2nd stage of the preamp was redesigned. It was readjusted with new components in a proper way to ensure biggest headroom at input stage and a steady transition from clean to distorted at 2nd stage (see chap. 3.12 and chap. 1.4).
- To reduce microphony at the preamp stages the PCB is mechanically decoupled from the chassis. Therefore, all wire connections to the board are replaced with high flexible silicone wires. The distance holder to fix the PCB in the chassis are substituted with rubber made damper (see chap. 3.13).
- As some of potentiometers at front panel start to scratch and produce audible noise all were exchanged (see chap. 3.14).
- The input network is adapted to the classic Fender circuit. The jack sockets are replaced and the grid stopper resistor is placed are far as possible to the input stage (see chap. 3.15).

- All three tube sockets of the preamp mounted on the PCB are exchanged as two of them showed broken contacts (see chap. 3.16).
- Almost all the carbon composition resistors have been exchanged, since many of them were already out of tolerance or borderline (see chap. 3.17).
- The topology of the speaker outputs has been modified to be robust in case the speaker connection between amp head and speaker cabinet was forgotten to plug in. Therefore. an 8Ω/100W power resistor was added to the chassis (see chap. 3.18 and chap. 1.15).
- To provide a certain robustness against disturbances from the mains supply net an EMC filter was added to supply input (see chap. 3.19 and chap. 1.16).
- The heating supply at the preamp for the tubes mounted on the PCB the heater supply has been switched to DC voltage. This has been achieved by adding an additional small board with a full bridge rectifier. The DC part of the heater supply is fused with its own 6,3A fuse (see chap. 3.20 and chap. 1.14).
- The analysis of the very specific filter network of the Funkshun between first preamp stage V2a and the overdrive stage V2b makes the special sound of this amp visible. It indicates also that the available circuit diagram in the world-wide web seems to be incorrect in the position of R54 (see chap. 3.21 and chap. 1.7).
- The investigation of power consumption in the high voltage circuit demonstrated that a fuse of 1A is sufficient for this circuit (see chap. 3.23 and chap. 1.17)
- In the output stage the EL34 V8 tube has a short between plate and the heater. This was the root cause for the blown fuse. The quad of EL34 in the output stage is substituted with a new matched quad (JJ EL34 II Red Label) (see chap. 3.22 and chap. 2.1).
- To optimize the input stage the ECC83 tube in position V2 is substituted with JJ ECC83S. This tension grid type of ECC83 promises less microphony (see chap. 3.22)
- As the Funkshun provided very high signal levels at the input of the output stage the original Siemens ECC83 phase inverter tube V4 was replaced by a JJ ECC82. This provides smaller signal amplification but due to higher cathode current this tube type is able to drive the output stage more stable (see chap. 3.22).
- The investigation on the power consumption of the HT supply confirmed the reduced fuse for this circuit. The results also show that there no risk for the Funkshun to toggle the standby switch to early (no anode current due to still non-emitting cathode) an therefore apply the full HT voltage to (see chap. 3.23).
- The diodes of the high voltage rectifier of the Funkshun were replaced with diode type UF5408 (3A; 1000V) which is ultra-fast and more robust than the originally assembled BY127. (see chap. 3.24)

6. Overview of exchanged / added Components

Component	Previous	Final	Remark	Cost [€]
Exchange/ add fuses				
Main fuse	2,5A	[1]T2,0A	slow	0,30
HT fuse	2,0A	[1]T1,0A	slow	0,30
Heater fuse	-/-	[1]T6,3A	slow	0,30
Shunt resistors to measure bias				
1R	-/-	[2]1Ohm/2W	+/-2% Tolerance	0,27
1R	-/-	[2]1Ohm/2W	+/-2% Tolerance	0,27
1R	-/-	[2]1Ohm/2W	+/-2% Tolerance	0,27
1R	-/-	[2]1Ohm/2W	+/-2% Tolerance	0,27
Tubes				
V5 – V8	Telefunken EL34	[2]JJ EL34 II Red Label	TT XMatching Quad	67,44
V4	Siemens ECC83	[2]JJ ECC82		8,15
V2	Siemens ECC83	[2]JJ ECC83S	Tension grid balanced	14,90
Damper	-/-	[2]4pcs	Silicone damper	1,88
V02 – V04	3× Plastic	[2]3× Ceramic	Mycalex Sockel	4,95
Modifications bias supply				
C25	100µF/63V	[2]470µF/63V		1,95
R38	10kΩ	[1]33kΩ/0,5W		0,01
Replace capacitors on PCB				
C16	6,8nF*	[2]22nF	Polypropylene 630V	0,45
C18	10nF	[1]10nF	Polypropylene 630V	0,90
C17	47nF	[1]47nF	Polypropylene 630V	0,90
C19	47nF	[1]47nF	Polypropylene 630V	0,90
C24	1nF	[1]1nF	Ceramic 500V	0,10
C21	47nF	[2]47nF	Orange Drop715P 600V	1,96
C22	47nF	[2]47nF	Orange Drop715P 600V	1,96
C10	6,8nF*	[2]22nF	Polypropylene film 630V	0,44
C13	470pF	[1]470pF	Mica Silver 500V	1,20
C9	680pF	[2]680pF	Mica Silver 500V	0,85
C5	270pF	[2]220pF	Mica Silver 500V	0,57
C3	6,8nF*	[2]22nF	Polypropylene 630V	0,44
C26	1nF	[2]1nF	Polypropylene 630V	0,53
C1	100µF	[1]25µF	Elco 25V	0,50
C7	100µF	[1]25µF	Elco 25V	0,50
C15	10µF	[2]15µF	F&T Elco 500V	2,14
Reduce microphony				
PCB holder	-/-	[1]3pcs; M3×8mm	Rubber made shock damper	6,90
Exchange potentiometers at front panel				
VR8	470k log	[2]500k log	0,25W / 0.25W	1,30
VR1	470k log	[2]500k log	0,25W / 0.25W	1,30
VR3	470k log	[2]500k log	0,25W / 0.25W	1,30
VR6	220k lin	[2]250k lin	0,5W / 500V	1,30
VR4	220k lin	[2]250k lin	0,5W / 500V	1,30
VR7	100k log	[2]100k log	0,25W / 0.25W	1,30
VR5	470k log	[2]500k log	0,25W / 0.25W	1,30

Component	Previous	Final	Remark	Cost [€]
Replaced input jack sockets				
Low Gain		[2]Neutrik NMJ4HC-S	6,3 mm, mono, geschaltet	1,17
High Gain		[2]Neutrik NMJ4HC-S	6,3 mm, mono, geschaltet	1,17
Replaced resistors				
R4	1k4	[1]2k4 ±1%; 0,5W	Metal film	0,01
R9	263k	[1]220k ±1%; 1W	Metal film	0,01
R13	47k	[1]15k ±1%; 0,5W	Metal film	0,01
R16	1k6	[1]1k8 ±1%; 0,5W	Metal film	0,01
R17	82k	[1] 82k ±1%; 0,5W	Metal film	0,01
R18	239k	[1]220k ±1%; 0,5W	Metal film	0,01
R20	235k	[1]220k ±1%; 0,5W	Metal film	0,01
R23	100k	[1]100k ±1%; 0,5W	Metal film	0,01
R24	1M8	[1]1M8 ±1%; 1W	Metal film	0,66
R26	1M	[1]1M ±1%; 0,5W	Metal film	0,01
R28	83k	[1]91k ±1%; 1W	Metal film	0,01
R29	87k	[1]82k ±1%; 1W	Metal film	0,01
R33	3k9	[1]3k9 ±1%; 1W	Metal film	0,01
R38	10k	[1]33k ±1%; 0,5W	Metal film	0,01
R40	10k	[1]10k ±1%; 1W	Metal film	0,01
R34	231k	[2]220k ±1%; 1W	[2]Tiny size	0,13
R35	226k	[2]220k ±1%; 1W	[2]Tiny size	0,13
R51	240k	[2]220k ±1%; 1W	[2]Tiny size	0,13
R52	230k	[2]220k ±1%; 1W	[2]Tiny size	0,13
Output topology				
Load	-/-	[1]8R; 100W		3,58
EMC filter for mains supply				
-/-	none	[1]68nF 275V	PME271M568MR30	5,91
-/-	none	[1]Ferrite ring	D 10 mm, H 5 mm	0,10
-/-	none	[1]Ferrite ring	D 10 mm, H 5 mm	0,10
DC heater for preamp				
Rectifier	-/-	[1]NTE53000	Full bridge rectifies	4,92
Heat sink	-/-	[2]16 K/W	16 K/W	0,68
C101	-/-	[2]10µF; 16V	Filter cap	1,88
R101	-/-	[1]500R	Trim potentiometer	0,65
R102	-/-	[1]0R33; 3W	Voltage reducer	0,23
Fuse holder	-/-	[1]5×20mm	For PCB mounting	2,80
Bread board	-/-	[2]Grid 2,54mm	~60×50 mm	0,60
Mounting	-/-	M3×40mm	40mm height	0,24
HT rectifier diodes				
D1-D4	BY127	[2]1UF5408	Substitute 1A -> 3A	2,68
			Summe	**159,63€**

[1]eBay
[2]TubeTown

7. References

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[6] Ted Weber's Bias Calculator: https://tedweber.com/bias-calc/

DONE

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