



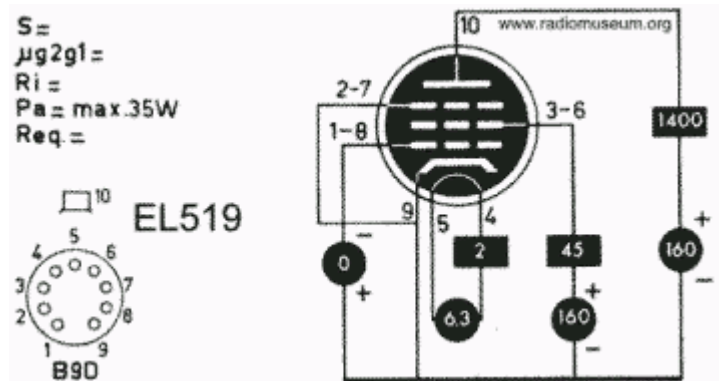
F5NPV – V85NPV

Amateur Radio – Ham Radio – Radioamateur

EL519/6P45S(6П45C) 300w HF AMPLIFIER



EL519/6P45S (6П45C) Tube Amplifier



Tube 6P45S is a EL519 equivalent



300w amplifier



4w input on 20m

This following one using a single 6P45S and provide about 130 up to 150w



150W amplifier with one tube with N7DDC ATU display on the front panel



With about 1.5w input , this tiny amplifier is providing about 50w output. With 3w i can have about 70w

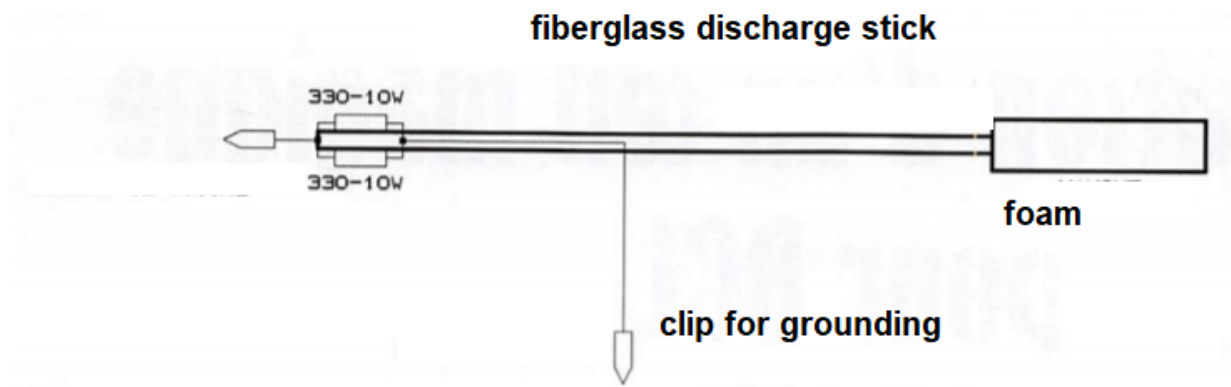
SAFETY



Tube/valve amplifiers are using high voltage “HV” as a reminder it can kill . Any mistake will put you in big trouble.

When working on Tube amplifier :

- The amplifier should be unplug from the power supply
- Drop all jewelery from your neck or rings, bracelet from your hands and fingers
- The use of discharge/grounding stick is MANDATORY in order to ensure all capacitors are discharged.
- The discharge stick still always connected to the anode for security purpose (At the end of the stick i made a little hook and each time i am working in the amplifier , my stick is ALWAYS hook to the tube anode)



The Genesis

For years now , some guys keep telling me : do not use EL519 or 6P45S tube , they are not good , they are not performing well , this kind of tube is for citizen band . Most of the time they have never used this kind of tube and because it was used during the citizen band era , this kind of tube is definitely and obviously bad.

As a amateur radio , the main challenge is sometimes to use something not design for one purpose and make it work for a design you are targetting.

When people keep telling me without providing me factual evidence that **a well design amplifier** using EL519 or 6P45S tube is not performing..... Well well well i will find out by myself !

To be completely accurate , talking about EL519 nowadays is not relevant since this tube is really hard to find with a decent price . On the other hand , the 6P45S tube which is a beam powered TETRODE is a close cousin and will do the job . I guess i should replace this webpage title with “**6P45S 300w HF AMPLIFIER**”

On this webpage your will find a description for 3 amplifiers using E519 aka 6P45S tubes:

-300w amplifier using 2 tubes → My QRO amplifier . i use this amplifier mostly when propagation is poor .

I use this amplifier likely :

- About 10w up to 100w FT8 and digital modes
- About 250w CW
- About 200w up to 300w SSB

-600w amplifier using 4 tubes : this is a test amplifier and do no have it anymore .

-150w amplifier using a single tube → **this is my main amplifier** , since all my TRX are low power (means less than 10watts), i use this amplifier on current basis . A great device performing really well all modes.

I use this tiny amplifier likely :

- About 10w up to 50w FT8 and digital modes
- About 70 TO 120w CW
- About 80w up to 120w SSB

Reference websites

http://f4eoh.free.fr/amplificateur_hf_2_x_el519_197.htm

<https://pa0fri.home.xs4all.nl/Lineairs/FrinearPG400/fripg400.htm>

<https://f6crp.pagesperso-orange.fr/tech/PL159.htm>

<http://www.qrp4u.de/docs/de/PL519/index.htm>

<https://pa0fri.home.xs4all.nl/Lineairs/Frinear150/fri150eng.htm>

This website is my main reference since it is a compilation from QST and ARRL Handbooks (A must to read) : <http://www.somis.org/>

Requirements

I am targeting about 100 up to 300w for my SDR and UBITX transceivers (5 to 20w output) but i really want to minimize the amplifier size.

Frequency range from 80m up to 10m bands including WARC

in the current webpage you will also some results with 2 other amplifiers using EL519 (6P45S) tubes.

- A 600w Amplifier using 4 tubes (this amplifier was sold few months ago since i do not need such QRO Power)
- A 150w Amplifier using 1 tube only. I use this amplifier everyday and is by far the one i prefer. Simple , easy and just enough power according my needs.

Constraints

The main and major constraint using EL519/6P45S tube is regarding the Forced cooling system you will need to implement . Basically this kind of tube output power limitation is according the temperature envelope . I am using a 220VAC fan which is obviously noisy .

With this forced air cooling system , i can use both amplifier during long PSK31 QSO without any issue .

Experimentation

During the 80s and the 90s i used to build QRO HF Linear amplifier (QQE06/40, 811,813, 4CX1500 ,4-400Z, 3-500z) and one day one of my good friend gave me a citizen band amplifier based on EL519. The conversion was easy and i was very satisfied about the amplifier performance using this kind of tube. After coming back to this hobby few years ago , i keep in mind this kind of amplifier since it is using a low plate voltage (about 700 up to 1000volts with definitely less arcing issue) and to be honest i was not ready to put my hands again into 2000 or even 3000Volts. Tetrode/Pentode tubes amplifier with grid grounded are very easy to build and the biasing is just a piece of cake to achieve. The simplicity of the build is the point i was focusing.

EL/PL 519 tubes are dedicated to TV purpose during the 70s , therefore this kind of tube are able to be used for HF. With some experimentation , testing and fine tuning the EL519 is able to provide a great linear amplifier in all respects.

Nowadays it is very difficult to find EL519 tubes , therefore you can find equivalent in Russia or Ukraine with the **6P45S** or **6п45с**. **These Tubes are in fact better compare to the original EL519. Currently the tube i am using are the 6P45S ([6P45C](https://thetubestore.com) (thetubestore.com))**

Inside a miniature tube (this is a pentode)



All parts are coming from a Citizen band amplifier i bought during a Ham Expo. I keep mostly the transformer , the plate HV filter capacitors, The variable capacitor (50pf) and the casing which is perfect regarding the size

EL519 vs 6P45S

Visually the EL519 can be found with 2 format. A bulky one and a thin one .

For Philips and Siemens , the EL519 is a Pentode dedicated to line deflection for TV SET. They have a a smaller diameter

For Svetlana it is a Beam powered Tetrode. This tube is bigger and more bulky compare to the Philips one.

Very confusing since a massive production was in place during the 60s .

The 6P45S tube is according the datasheet is also a High Performance Beam Power **Tetrode** (The genuine EL519 is a pentode). The size is almost identical compare to the Svetlana one.

The main benefit regarding the 6P45S is the capability of the cathode to handle about 1amp current. The slope is also interesting with 40 à 60 mA/V. In addition the plate is able to handle high current. Like the MOSFET transistor , the 6P45S is dedicated for switching purpose which not suitable in theory for linear amplification. This is the theory but with a grid grounded design triode style , the tube is able to provide a great larity among all the HF Band from 80m up to 10m. Hereafter measurement for my single tube amplifier with 3w input.

input	80m	60m	40m**	30m **	20m	17m	15m	12m	10m
3w	75w	70w	80w	80w	60w	60w	60w	60w	60w

Single tube peromances with 3w input , grounded grids cathode driven with 25ma idling current

Differences according the datasheet : almost identical for the Svetlana and the 6P45S. For the Philips, the heater current is 2 amp (2.5 amp for the 6P45S). The dissipation power por the plate is 35w for the 6P45S.

Performances and benchmark : According the test i did , the 6P45S is performing a bit better . When a genuine EL519 from Philips is providing you 100w , the 6P45S or EL519 from Svetlana are providing about 120w. According all the tests i perform the 6P45S is performing better compare to genuine EL519 . According the spectral purity or spurious i did not find any differences.

You can find easily some 6P45S on EBAY and the price magnitude is from **10 up to 20 Euros**. A 811 tube will cost about 40 up to 60 Euros , a 813 is about 60 Euros and a 572B is about above 100 euros and not genuine and will not last long. The 6P45S for even 20 euros is still a good bargain

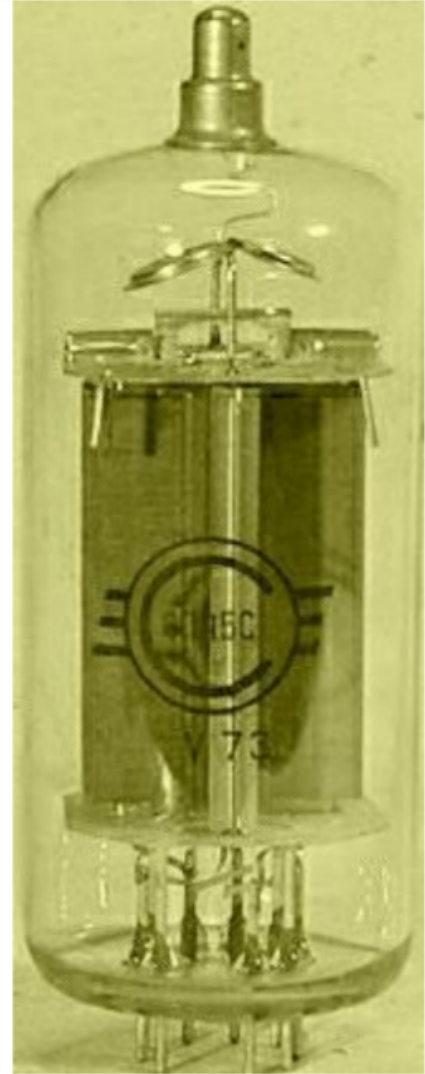
I am using the 6P45S tube for more than 2 years now almost daily all modes , and definitely this tube is great with decent performance.



Full size PL519



Full size 6P45C



Full size 6P45C

6P45S a Beam powered Tetrode

To keep it simple , a beam powered Tetrode aka the 6P45S is a kind of alternative for the Pentode . In a beam powered tetrode the grid are reported to the cathode in order to beam the electron flow efficiently to the anode (The plate). They serve to form the electrons passing between the cathode and anode into a beam with only a small lateral spread. This will maximize the electron density to the anode. This specification will assist for an easy biasing of the tube.

- The beam tetrode is more power-efficient delivering a peak envelope power typically three times the valve anode dissipation. The design produced more output power than a similar pentode.
- It assist to reduce the capacitance grid-anode by interposing an electrostatic screen at HF earth potential and will assist for output PI network (Tank)
- It introduce significantly less third-harmonic distortion into the signal compare to the pentode.
- A pair of beam-forming plates was added at the two ends of the oval grid structure to focus the electron stream into a pair of beams 180 degrees apart.
(The pentode added a third grid.)

The most famous beam powered tetrode is maybe the 4CX250B which is a reference for U/Vhf amplifier.

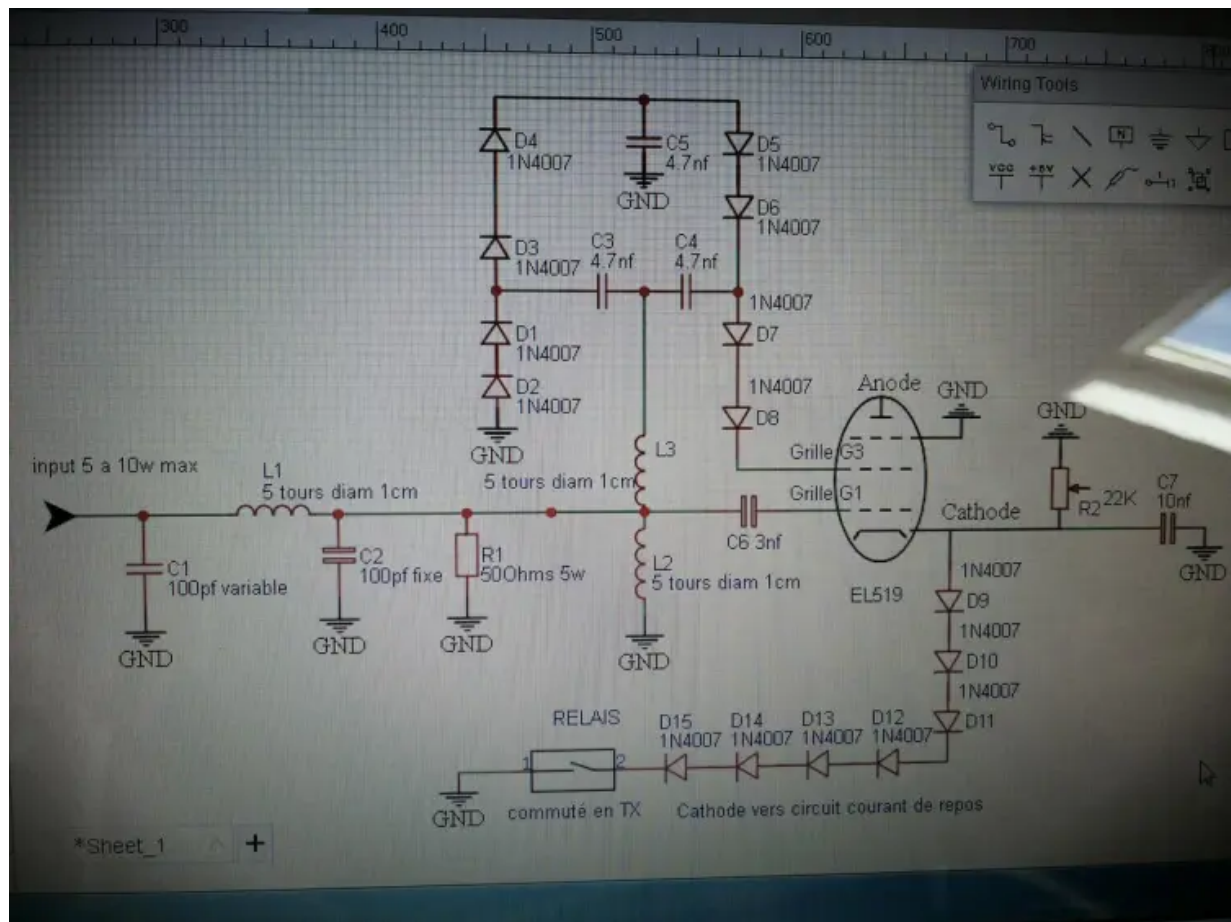
Some other famous tetrode valves used for RF amplification : GU-74b / 4CX800A / GU-34B / 4CX1000 / GU-43B / 807 / GU-33B / GU-78B / GS-36B / 4CX400Abea

Design tentative

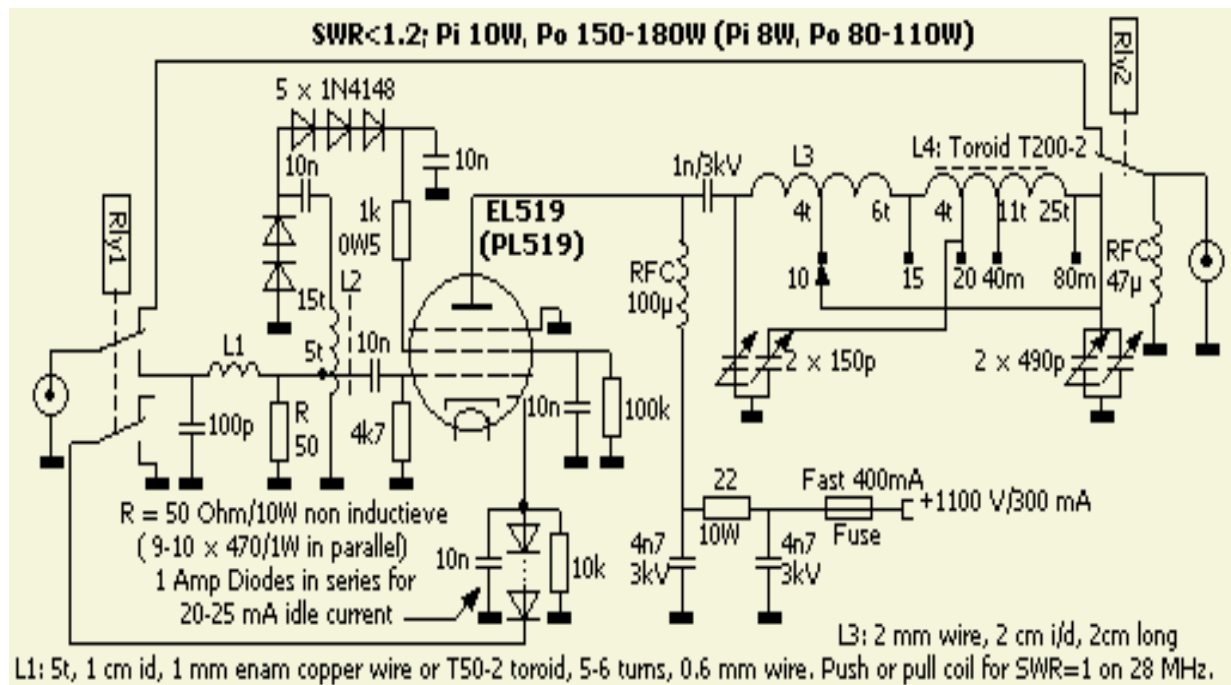
Experimentation with the 2 following design initially with another casing , output , Capacitors and state of the art input and output PI Network.

Basically it was working but was far from perfect and was not able to reach the correct Q with the PI output circuit.

-With the first design just below which is grid-driven, the output power was really low and IMD was too much on 20 and 40m band.

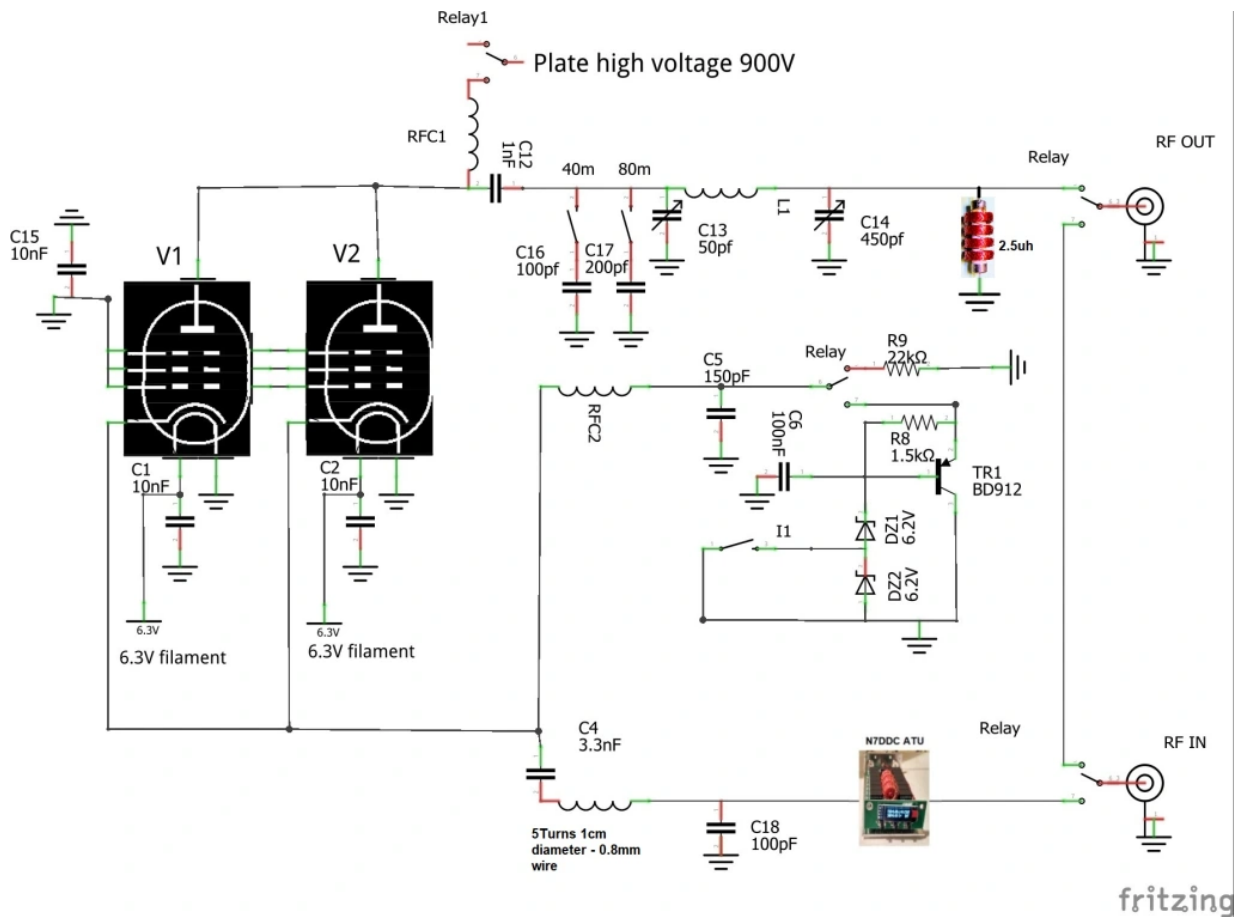


With the following one , the IMD was acceptable but same the output power was not satisfactory (Less than 100w with 2 x EL519 for 5w input)



FINAL DESIGN

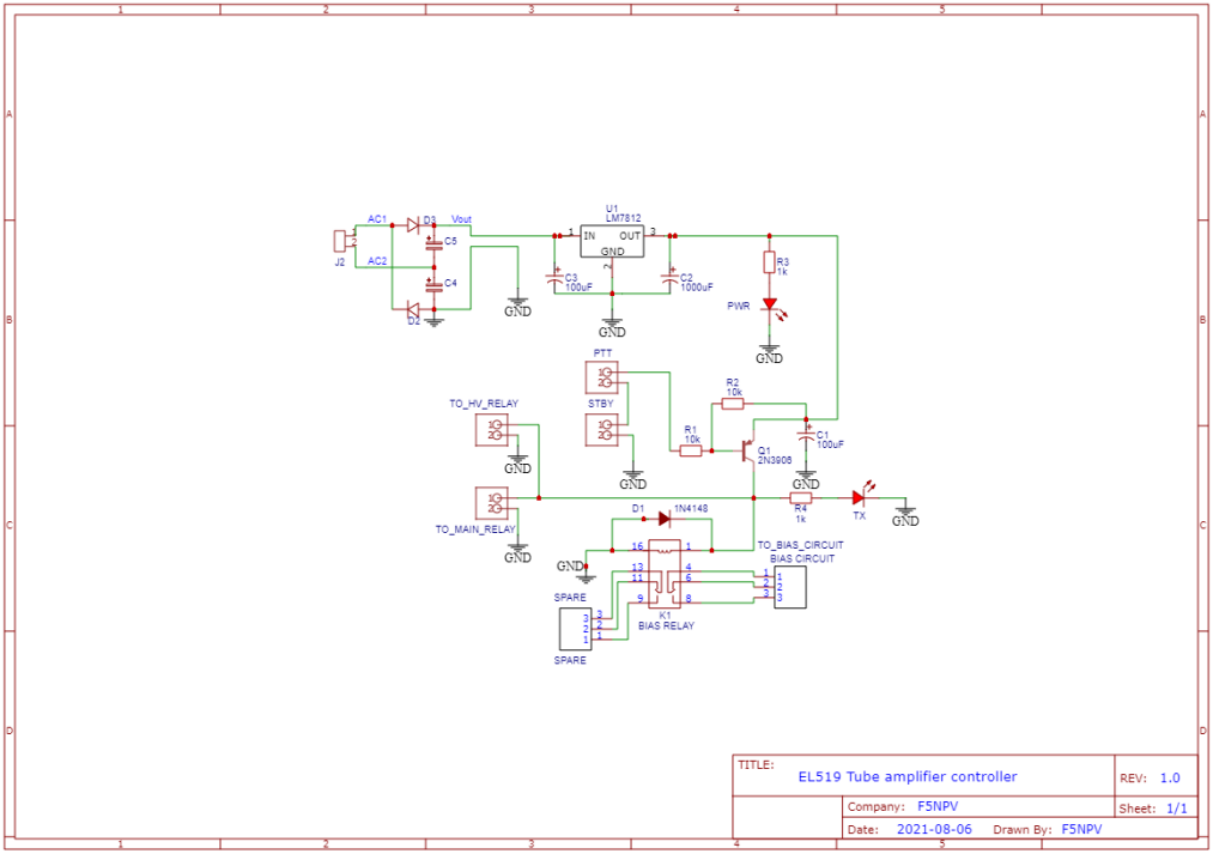
After testing grid input driven with cathode biasing , i have decided to test the Cathode "K" driven input with a different biasing. After some discussion on a ham radio forum , i remove the PI network i design and choose a simple T200-2 Toroid core with different plate and load capacitors . I notice also that i make it very complicated with the previous build regarding the input with some dedicated input impedance adapter circuit. The N7DDC ATU in line in the TX circuit is solving all input issue and headache. The casing from the Citizen Band amplifier fulfill my requirements regarding the size.

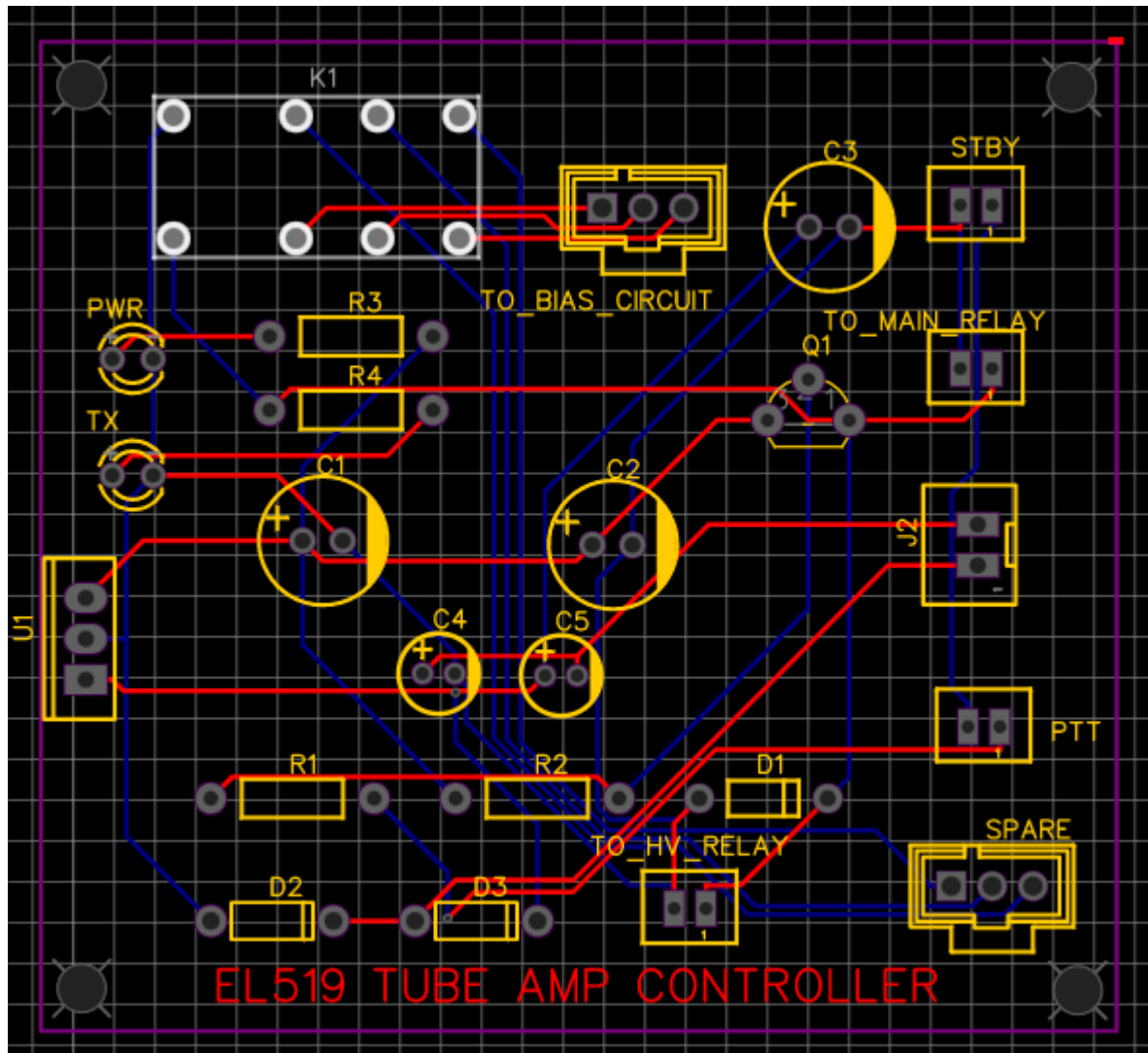


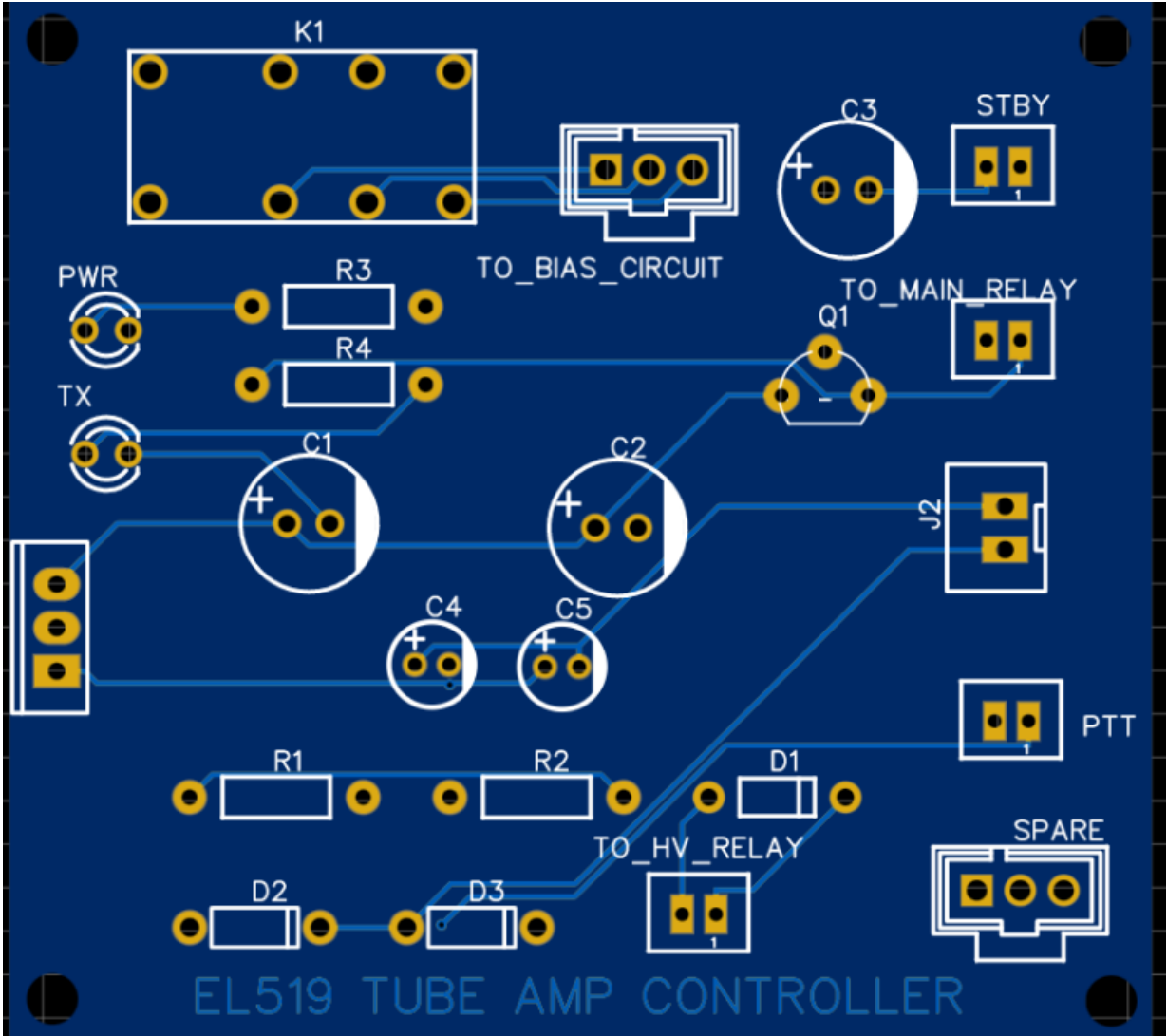
Amplifier Controller

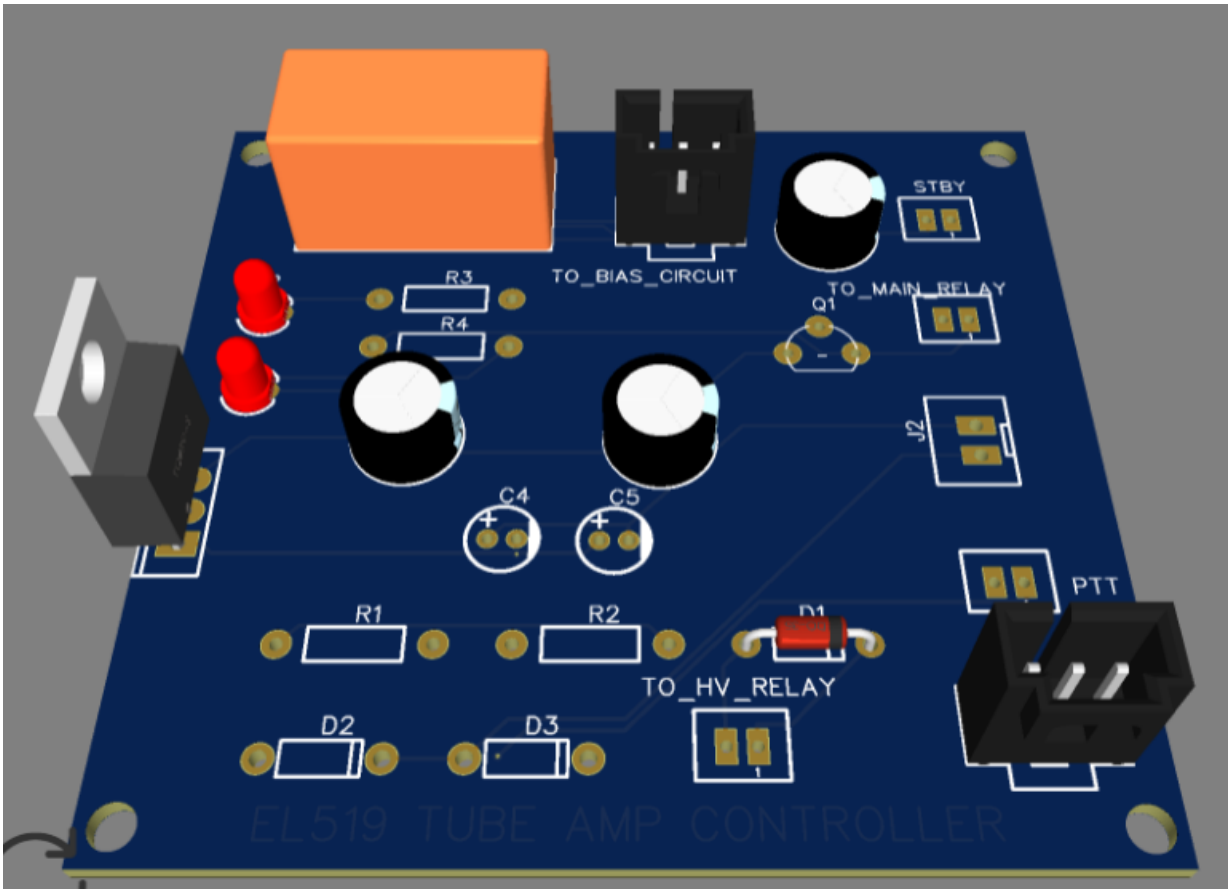
This little circuit is to provide the Relays switching from the PTT. The voltage is from the 6.3vac from the filament with a voltage doubler. This circuit is also controlling the main RF and HV relays

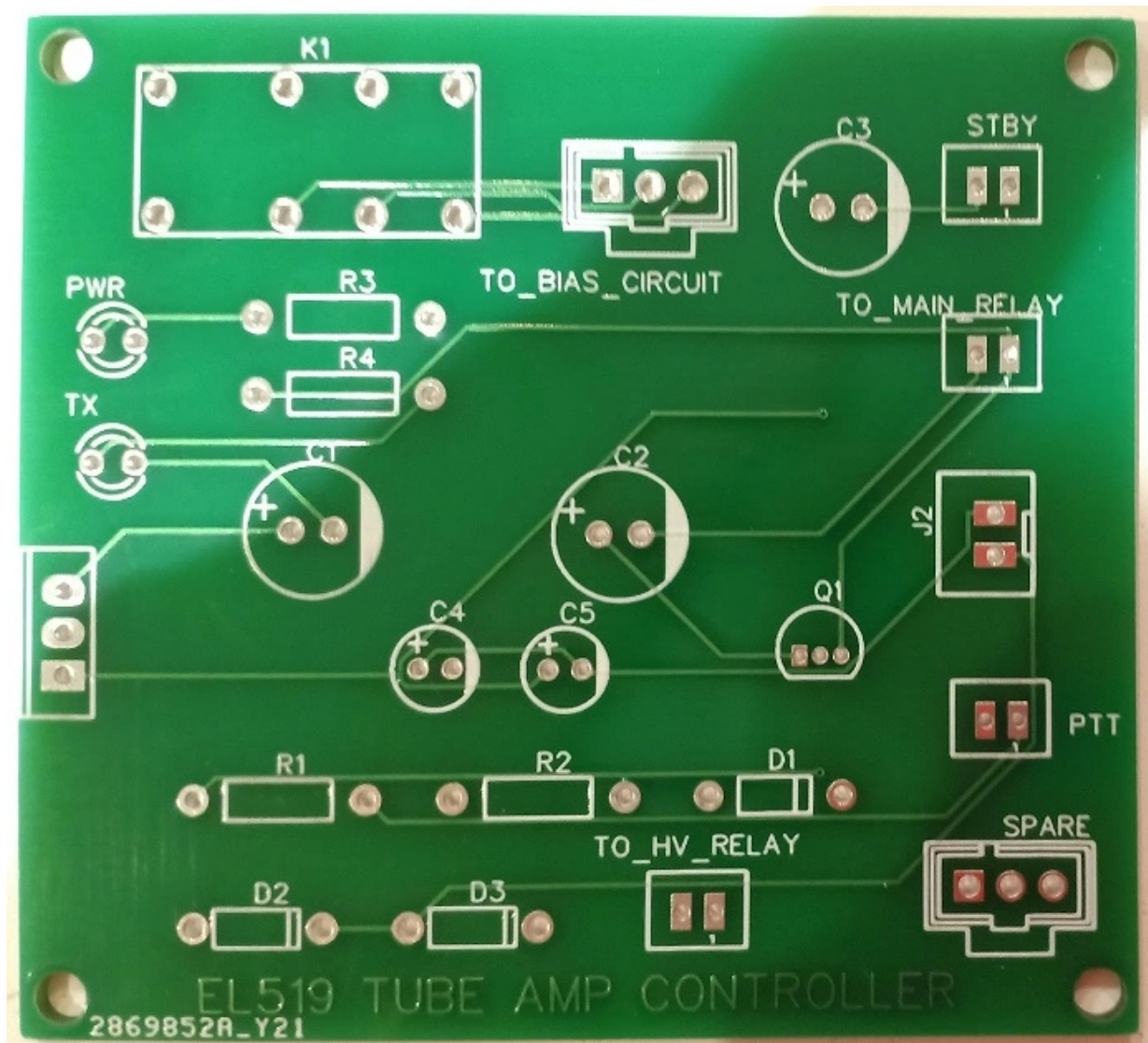
More details and gerber files are here : <https://easyeda.com/F5NPV>









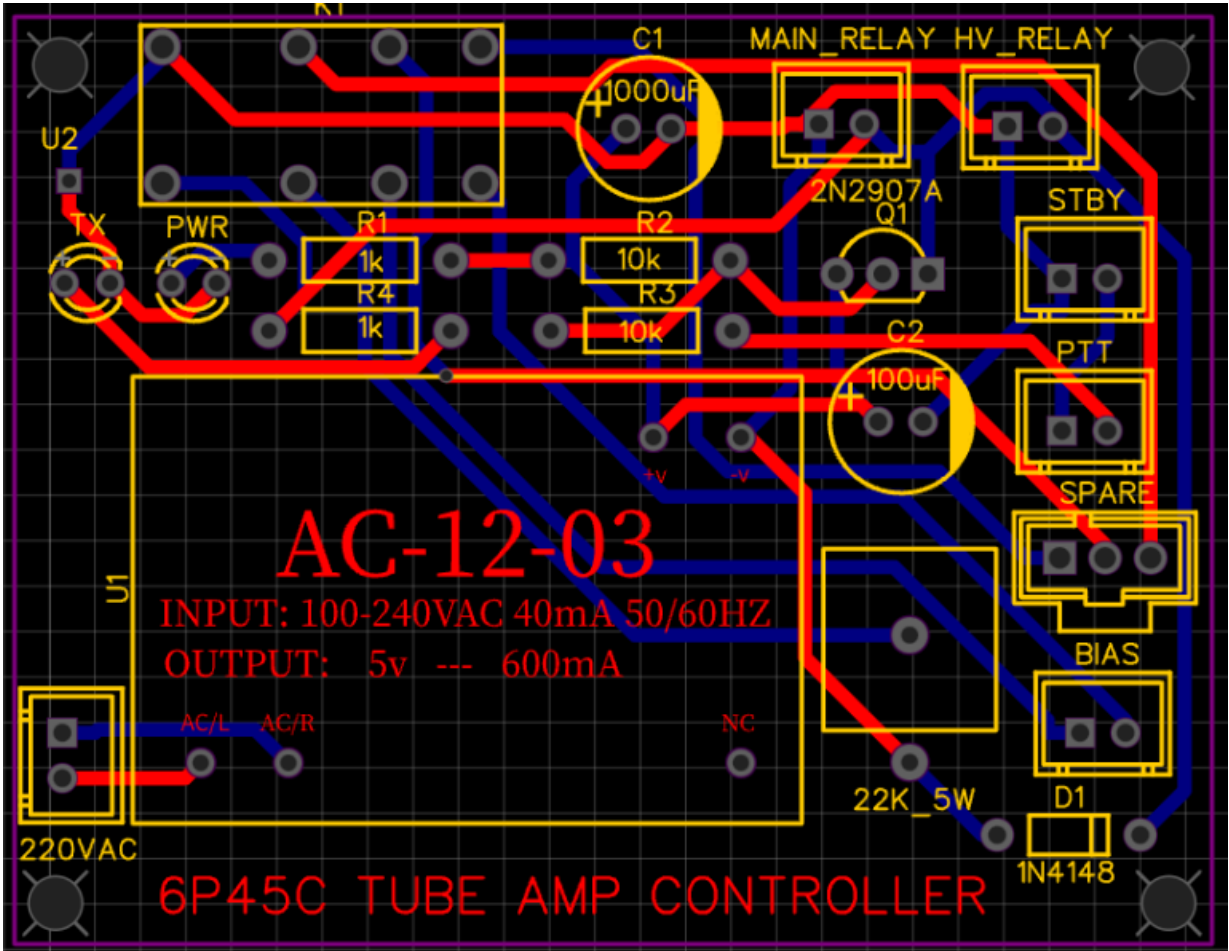
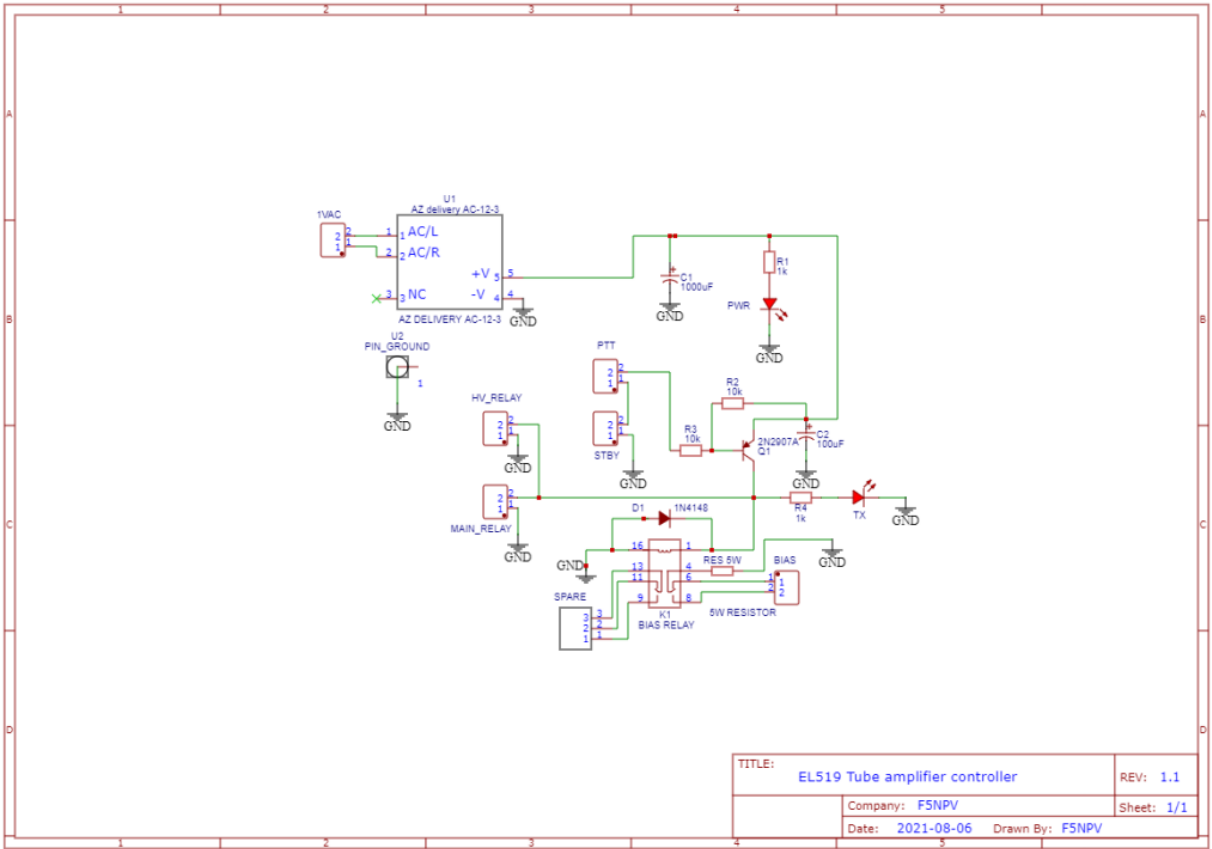


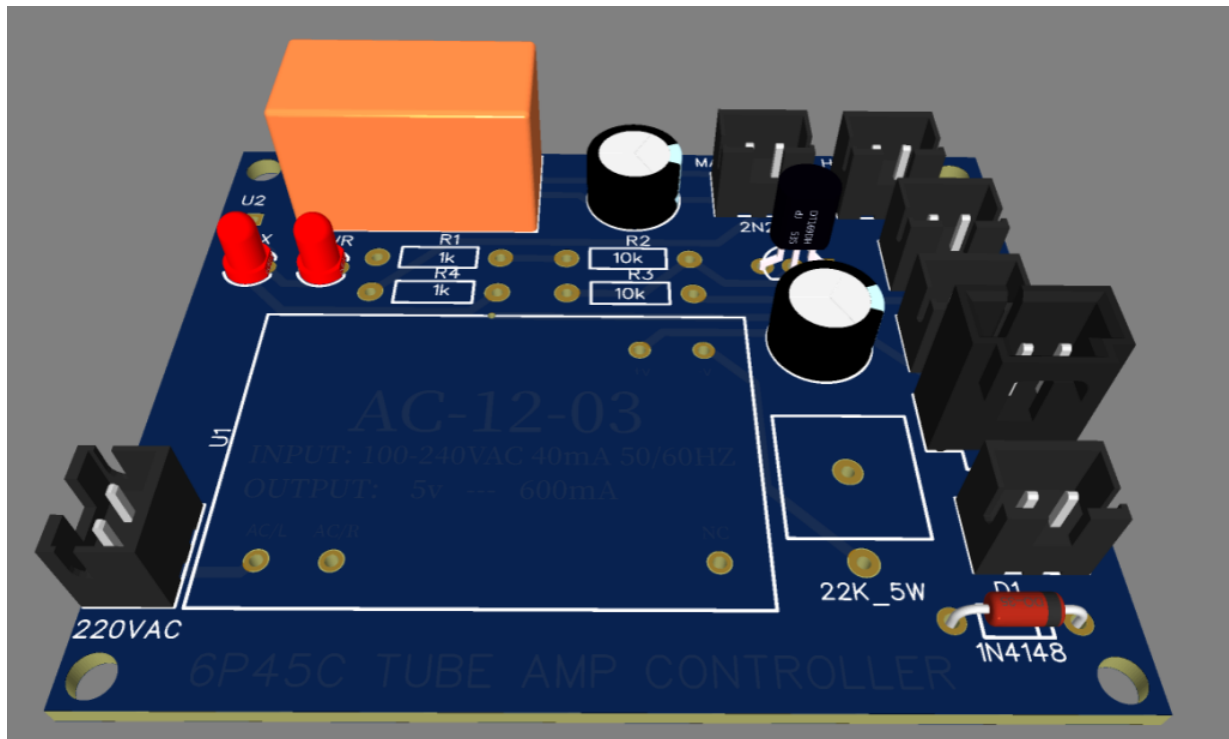
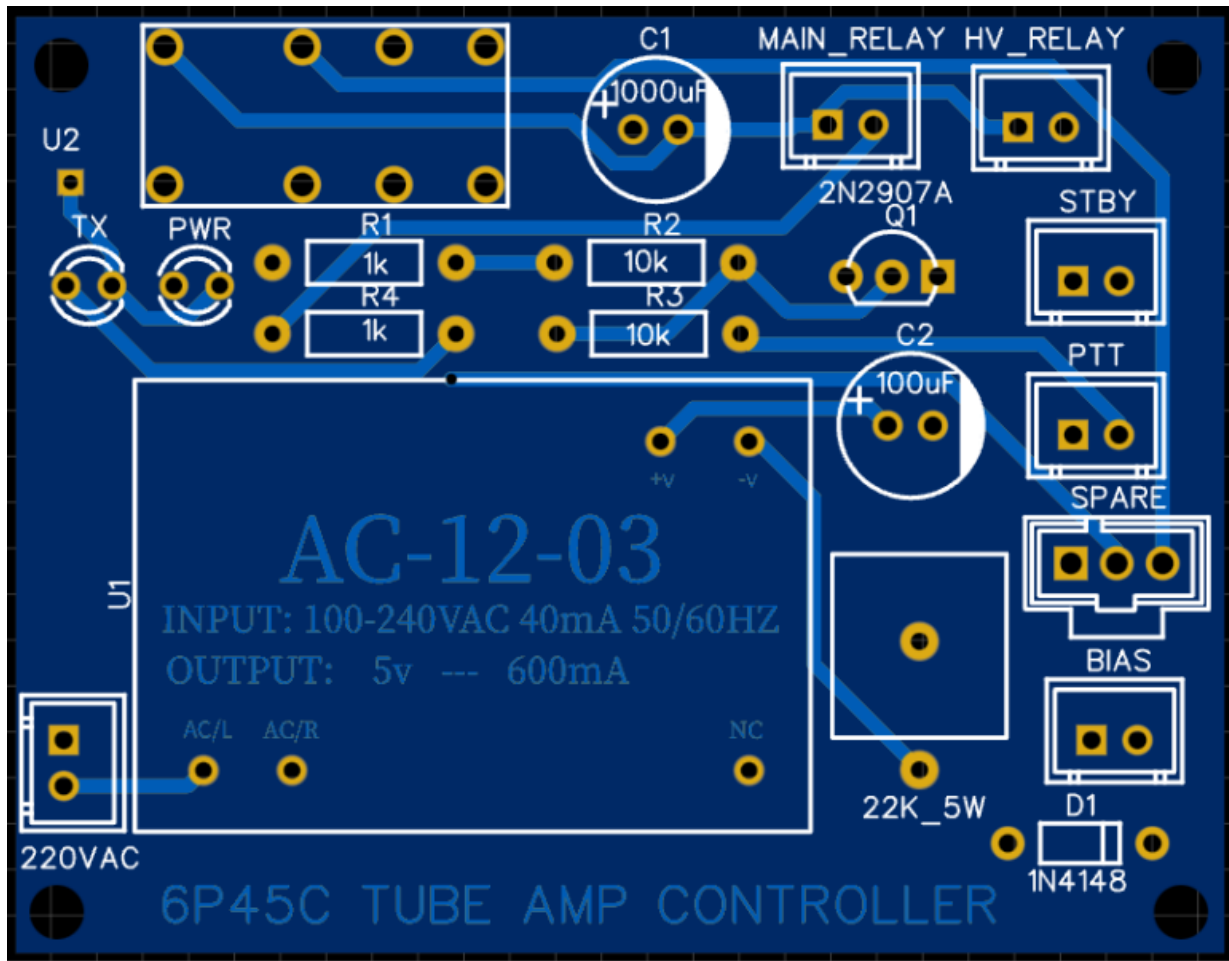
Amplifier controller from the 220Vac

The following design is an upgrade from the previous one in order to be more universal and can be use with other amplifier. This circuit is including the "cut-off" cathode resistor

For the rectifier you can use the AZ Delivery AC-12-03:







Both Controller:





Cathode "K" vs Grid input

Grid G1 input driven:

In the grid driven amplifier the driver is presented with relatively high impedance and hence can develop a large grid-cathode voltage swing requiring little drive power. The cathode driven amplifier requires a much higher drive power to obtain the same grid-cathode voltage swing. The gain criterion is the RF output power versus the RF input power, so the gain is lower when cathode driven – often very much lower!

The tetrode or pentode linear amplifier is usually grid driven in order to take advantage of the inherent high gain of the tube.

A grid-driven amplifier can be driven into the grid current region under proper circumstances. In any case, the input circuit will be loaded by the tube grid. The no-grid current case will have the input conductance loading, while the grid-current case will have this degree of loading plus grid-current loading. It is therefore desirable (and necessary in the grid-current case) to swamp the input circuit with an appropriate non-inductive resistor. The resistor will maintain an almost constant load on the driver and minimize the effects of any nonlinearity in grid loading.

My initial experimentation was with Grid driven input which is in theory supposed to be really suitable for my SDR transceivers since with a grid (G1) input is perfect with only up to 5w input. The test i perform provide me the following results :

-Modulation was good , therefore sometime i have some distortions.

-Spectral purity was not so good and i have some issue with IMD in particular on the 20m band which is one the band i use the most.

-The Biasing was a bit tedious to achieve and was never satisfactory regarding the current i should apply.

Cathode "K" input driven :

The cathode driven valve has a much lower potential gain than a grounded cathode grid driven amplifier. This is because the input and output currents are in phase, whereas in the grid driven amplifier they are 180° out of phase. The cathode current flowing to ground through the input network impedance is resisting the input drive signal. The result is that the impedance seen by the driving source is now very low. The current being in phase forms a type of negative feedback signal and this **to some extent enhances the linearity**.

The cathode driven amplifier may use either triode, tetrode, or pentode tubes. The drive signal is applied to the cathode in this class of operation. This technique is often referred to as **grounded grid** since the control grid is usually at radio frequency ground.

The cathode-driven amplifier is particularly suitable for high power stages using high-mu triodes in the HF and VHF region. This class of operation normally eliminates the need for neutralization, as the control grid screens the anode from the input circuit.

The power gain for suitable tetrode Class AB cathode-driven amplifiers is in the order of 7 to 20. The actual tube power gain is very nearly the ratio of radio frequency anode voltage to radio-frequency cathode voltage because the fundamental component of the anode current is common to the input and output circuits.

-With a Cathode input in theory you will need more input power (Thats why i did not used it at the early stage of the experimentation). Cathode RF input is able to provide about 13dB amplification, means with about 4 to 5w input you can get about 100w output (One tube).

-In fact with a perfect tuning at the input , the output power surprising me and immediately the results were really promising . After few adjustment on the output PI network tank , i manage the provide the output power i was targeting (300w with 20w input) and even above. The cathode input is allowing about up to 40w input but obviously not recommended due to IMD and harmonics level.

-Cathode input is providing the best spectral purity by far compare to the Grid input. The cathode input is more tolerant regarding the input power and offering a wider range

and magnitude regarding the input power you can apply, The Grid input was less tolerant regarding the input power level and magnitude (Overloading).

-The biasing is really easier to achieve and after few adjustment according the Quiescent current and voltage , the result is really satisfactory. As long as the quiescent current and voltage is kept up and stable , your amplifier will operate nicely without any splatters or spurious.

-All reports provide me a very good and cristal clear modulation without any clipping or distortion.

Cathode-driven principle

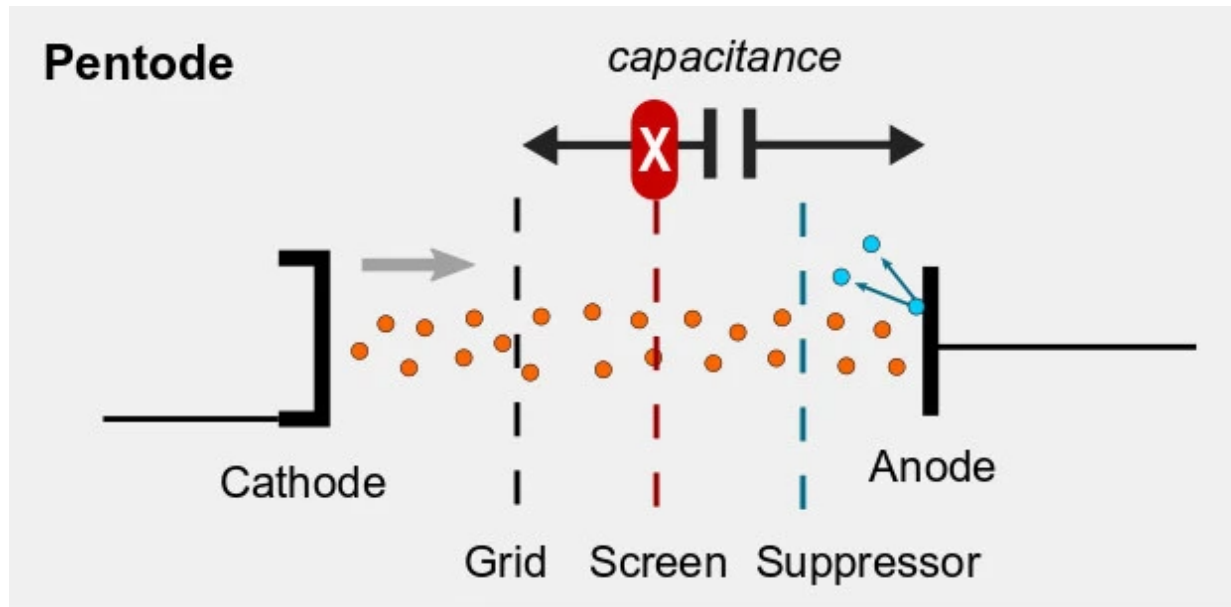
The most common configuration for Class AB operation is grid-driven. Since grid amplification as well as grid-to-screen amplification takes place, the resulting power gain is high. Class AB amplifiers can also be cathode-driven if the tube is a tetrode or pentode. The grid is tied and reported to the cathode. Thus, the grid-voltage is always 0V and no grid-current flows. The screen is grounded. The input signal is applied to the cathode/grid. Because input signal voltage is applied between the grid and the screen, grid-to-screen amplification takes place. However, since the grid is tied to the cathode and the cathode is the referential , during the negative swing of the modulation , the grid since it is reported to the cathode regarding the reference from 0v , the potential will because positive and the tube will provide amplification. Although the power gain is low (13db or less) but linearity is excellent.

A grounded-grid tube with a Cathode driven will provide the benefit of cancelling the capacitance plate/anode grid since the grid tap to the ground. This will assist for the output PI network tank.

Tetrodes and pentodes usually work well in grounded-grid operation. Since tetrodes and pentodes typically have a grid-to-screen amplification factor of about 5, its easy to assume that they offer an advantage over triodes in Class AB grounded-grid operation. However, grounding the grid and the screen stops grid-to-screen amplification. Applying DC screen-voltage does NOT increase gain because grid-to-screen amplification can not take place unless input signal voltage is applied between the grid and the screen. For tetrode tube grid are reported to the cathode and vice et versa and will be able to be biased.

The maximum available power in Class AB grid grounded is more than double the anode-dissipation rating.

This increases input/output isolation, eliminating feedback path which can cause instability.



Cathode driven tube is asymmetrical and when RF is applied at the input the voltage excursion (Positive and negative swing) will provide different stages and input impedance to the tube.

-During the positive sine swing of the RF through the cathode, the Grids will be more negative relative to the cathode and the tube will be Idling and even cut-off → The input will have a high impedance. The positive swing and high impedance are supposed to provide more IMD, but according with IMD measurement I did not notice any IMD increase. Since the grid is tied to the cathode and you lose drive on positive cathode cycles.

-During the negative sine swing of the RF through the cathode, the voltage excursion and swing will provide more anode-cathode voltage and current and the tube will amplify since the grounded-grid is relatively positive → The input impedance will be low.

This asymmetrical tube conduction causes the RF voltage between cathode and grid to contribute to amplifier output by adding effective anode-to-cathode voltage swing which will provide a great linearity and amplification.

You can compare this principle with a 2 stroke engine with during one stage you have no amplification and a tube cut-off and a stage with a biasing providing an amplification. The cathode RF swing can really be compared to an engine crankshaft/flywheel revolution (Some old timers call this principle the "flywheel effect")

If you just press the PTT and without any RF at the input, the Anode-cathode voltage and current should be very residual (No more than 25ma for one tube). The amplifier should swing smoothly only according to the modulation. The anode current should swing also according to the modulation swing.

if not, your amplifier is probably in Class C or A and will be not linear at all. This is mostly the case with amplifiers coming from the Citizen band.

Since all voltage are reported to the grid, it will act as a screen between the Anode and the Cathode. Generally speaking the tube gain will be about 13db and compare to a tube with RF input to the grid the amplification will be less (a grid-driven tube can provide up to 20db amplification). This kind of circuit is providing less gain but you do not need any tube neutralization and this kind of circuit is cancelling any self oscillation (Far more stable). In addition you do not need any other power supply for the grid since the bias voltage is provided by the RF swing. 13db = for 5w input you will have about 100w output which is not bad at all.

Input impedance of grounded-grid triode or pentode amplifier is average low, complex, and also non-linear. Tuned input network tunes out reactive (C) component, and also linearizes tube input impedance via flywheel effect. The N7DDC tiny tuner will assist for a perfect input tuning.

Cathode-Driven Operation

The most common configuration for Class AB1 operation is grid-driven. Since grid amplification as well as grid-to-screen amplification takes place, the resulting power gain is high. Class AB1 amplifiers can also be cathode-driven if the tube is a tetrode or pentode. The grid is tied to the cathode. Thus, the grid-voltage is always 0V—so no grid-current flows. The screen is grounded. The input signal is applied to the cathode/grid. Because input signal voltage is applied between the grid and the screen, grid-to-screen amplification takes place. linearity is excellent. **The Collins 30S-1 is an example of a cathode-driven Class AB1 amplifier.**

we have a tube operating in AB1 with a grid-to-cathode bias voltage of +/-12 volts (2 x 6.2v zener diodes). As long as the grid voltage is not very much positive with respect to the cathode, the grid-cathode path will not show grid current. The positive grid to cathode voltage is 12 volts, we know the positive cathode swing cannot exceed around +12 volts on peaks. Otherwise the control grid will start looking positive with respect to the cathode.

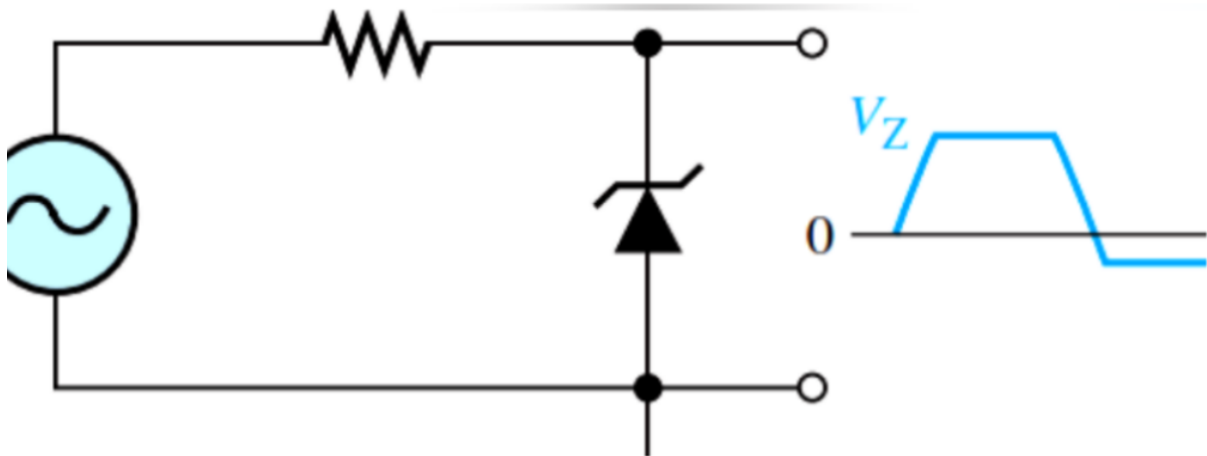
This means the cathode could not have much more than +12 volts positive on peaks. With a sine wave, this is 24 volts peak-to-peak voltage at the cathode. The flywheel

will provide different stages to the tube from Cut-off/idling up to maximum amplification.

Zener diodes can be used in AC and RF applications to limit voltage swings to desired levels. Below Figure shows the basic ways the limiting action of a zener diode can be used.

A zener used to limit the positive peak of RF input positive swing from the cathode to the selected zener voltage. During the negative alternation, the zener acts as a forward-biased diode and limits the negative voltage.

Cathode driven is largely set by the ratio of driving impedance to output impedance of the tube. The output and input are technically in series.



This would take the grid right up to the point of zero current, where any additional voltage would cause grid current (because the grid would go positive since this voltage from the cathode is reported to the Grids).

Grounded Grid benefit

One reason for this is simplicity. Ground the grid(s), cathode driven. Only 2 power supplies are needed

- The filament supply voltage and

- The anode supply voltage .

The addition of a zener diode in the cathode circuit will provide the biasing and **the filament voltage through a doubler will provide the voltage to the circuit control and relays**

When a zener is used as cathode bias, it will have the same effect as placing -ve DC on the grids → Simple isn't it ?

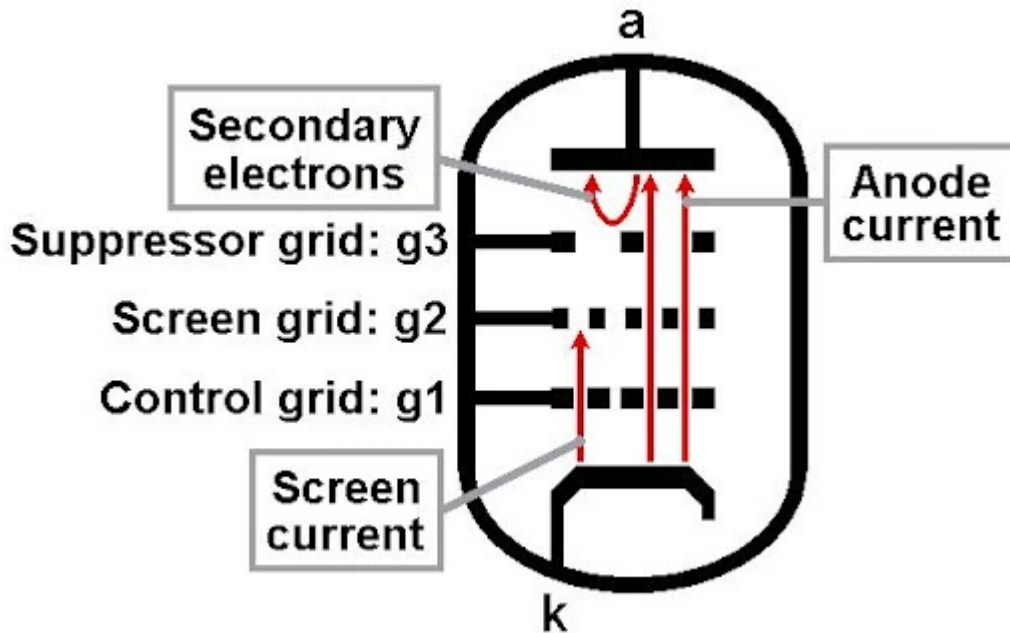
Needless to say that compare with a LDMOS or FET amplifier , this simplicity and amplification gain is effortless and still relevant even nowadays.

Neutralization is theoretically not needed because the grounded grid(s) shield the output element, the anode, from the input element, the cathode. This theory work perfectly with 6P45S tube and no toxic self oscillation was noticed since i am using this kind of tube.

Grounded-grid amplifiers are virtually always stable at the operating frequency because the reactance of the feedback C is too high at HF to allow regeneration. This is fortunate because there is no way of neutralizing a single ended grounded-grid amplifier. Another advantage is flexibility. Almost any tetrode, pentode, or high-Mu triode from the junk box will work. Linearity is usually good and the typical power gain from 10db to 13db which is acceptable.

Since the 6P45S is a tetrode , a cathode driven/grounded-grid amplifier will be perfect and suitable for RF class A, B or AB amplification. In addition the output and input are technically in series regarding the impedance.

Biasing, idling and Cutt-off in details



Cutt-off:

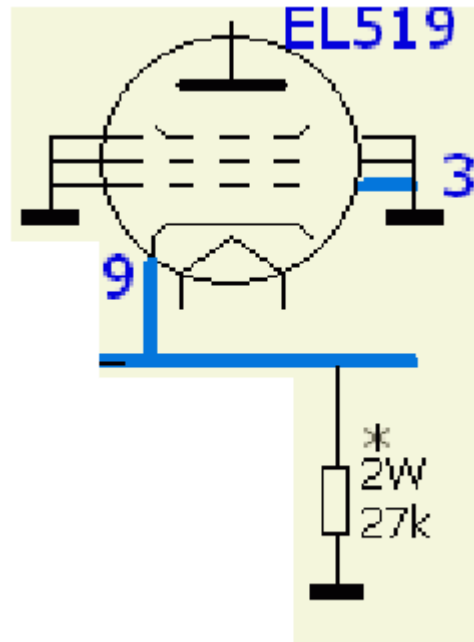
Cut-off means the current flow are blocked blocking and the tube is resting. when the tube is cut off so that no space current (screen/grid or anode current) will flow, or when the excitation and screen/grid voltage are low.

The cut-off current is determine by the voltage Grid-cathode and the current between Ground-cathode. The grids are grounded and the cathode shall be positive in order to provide the biasing for any amplification and current between the cathode and the plate (Anode). With a relay and a 22k up to 50k resistor , the circuit will "disconnect " the cathode . This "disconnection" will provide a null current for the cathode and anode (Very residual in fact) . The cathode voltage will be above the "cut-off" and the tube will be blocked without any cathode and anode current. This circuit will also assist during receive mode without any anode voltage. it will ensure the tube is really in stby mode without any self -oscillation.

The role of the resistor (grounded) in the biasing circuit is to provide the Cut off to the tube peak-to-peak resting without any PTT or RF. The value of this resistor should be tested and for 2 EL519 tube , the overall idling current is about 50ma and considering about 300w with 1000vdc anode voltage the resistor power handling should be at least about 2W. The value is about 15k up to 50k Ohm for the EL519 . this should be tested when you swap with new tubes . Just switch on the amplifier , apply the High Voltage and the tube should be without current in the anode circuit . As mentioned before , all voltage are reported to the cathode with first the grounded grids. Routing the cathode to the ground with the resistor will put de facto also the grids to the ground potential and will prevent any electron flow between the cathode and the plate. **The tube is blocked**

and the “cut-off” circuit will reduce the cathode current during receive mode. The cut-off will help the tubes to last longer with a very residual current. The resistor will prevent cathode current soaring/leaking and will establish a Bias Cut-off for the tube.

The valve will only conduct when the PTT is activate and the cut-off will put the valve in STANDBY mode (Blocked).



The resistor value is not critical and the magnitude is from 15k up to 47k

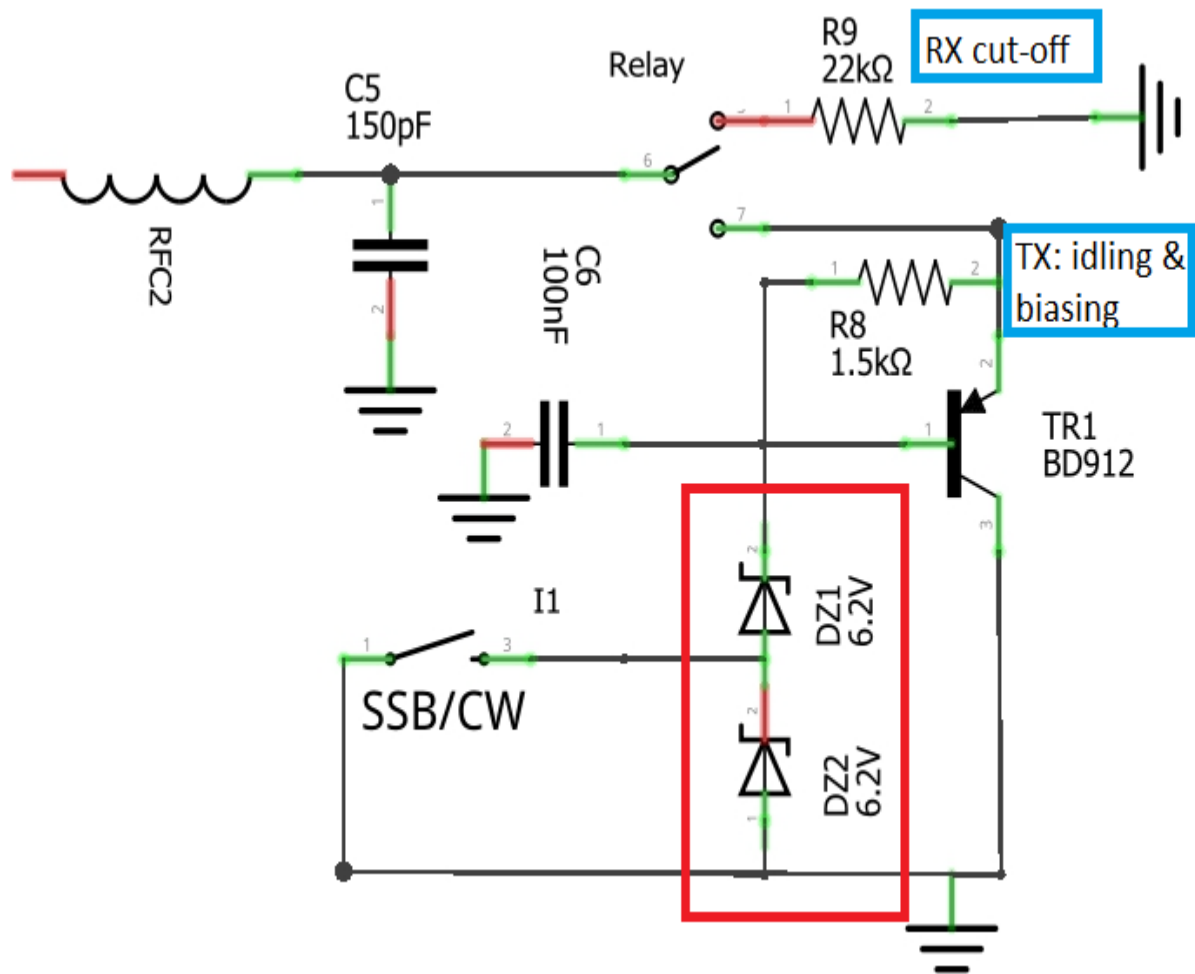
Idling current or Qpoint:

This part is the most important:

The Idling current is setup by the voltage grid-cathode. The grid is grounded so the cathode should be at the positive potential before the cut-off in order to achieve the idling current.

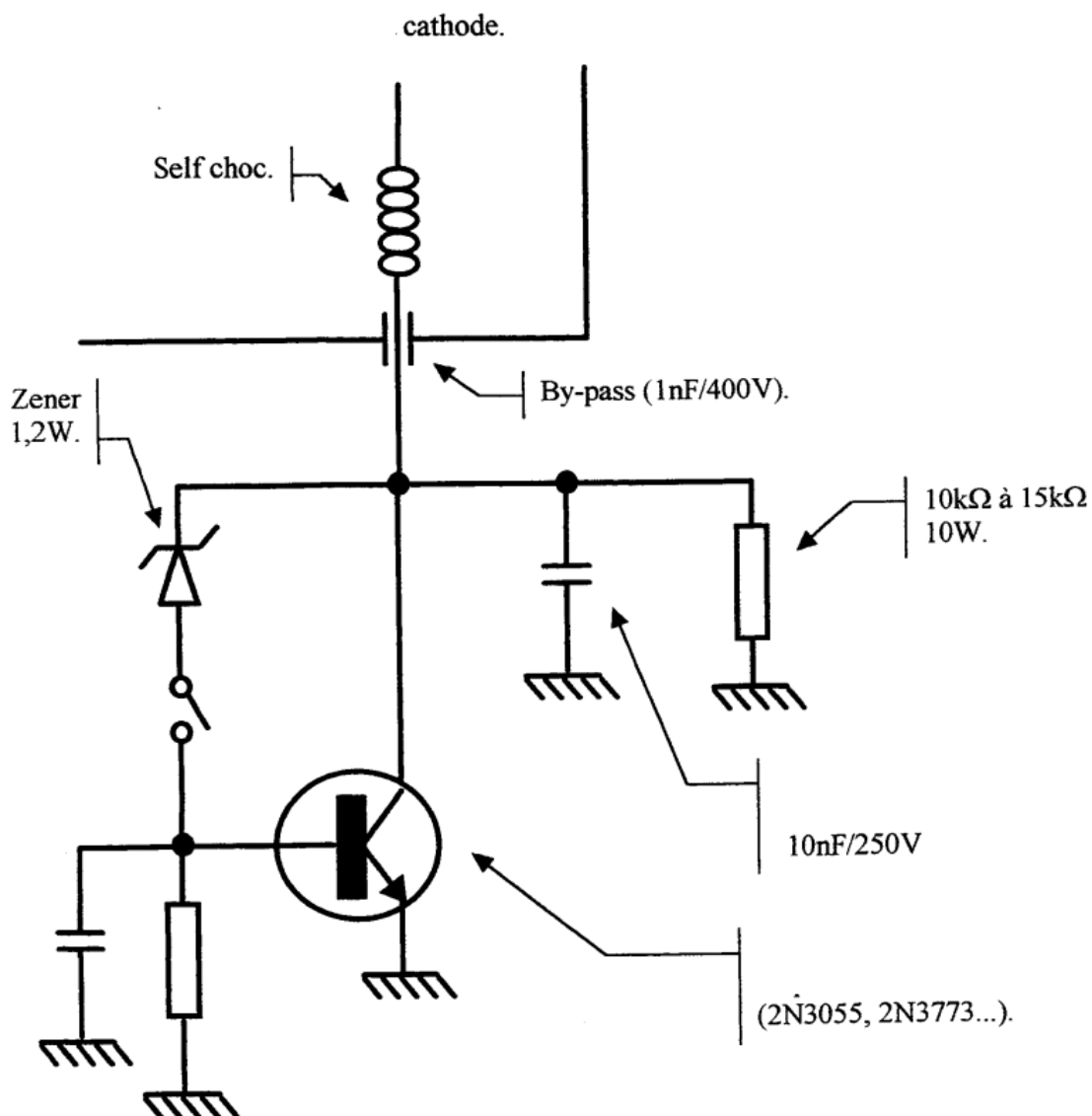
The valve will only conduct when the PTT is activated

To do so , the cathode should be connected to regulated voltage system. The zener diode will provide the capability to maintain a constant positive bias voltage reference whatever the current is going through. In parallel of the zener diode a resistor will provide the opportunity to adjust the idling current. A 5W resistor (R8 on the schematic)is enough and you can also use a potentioment to achieve the same result.



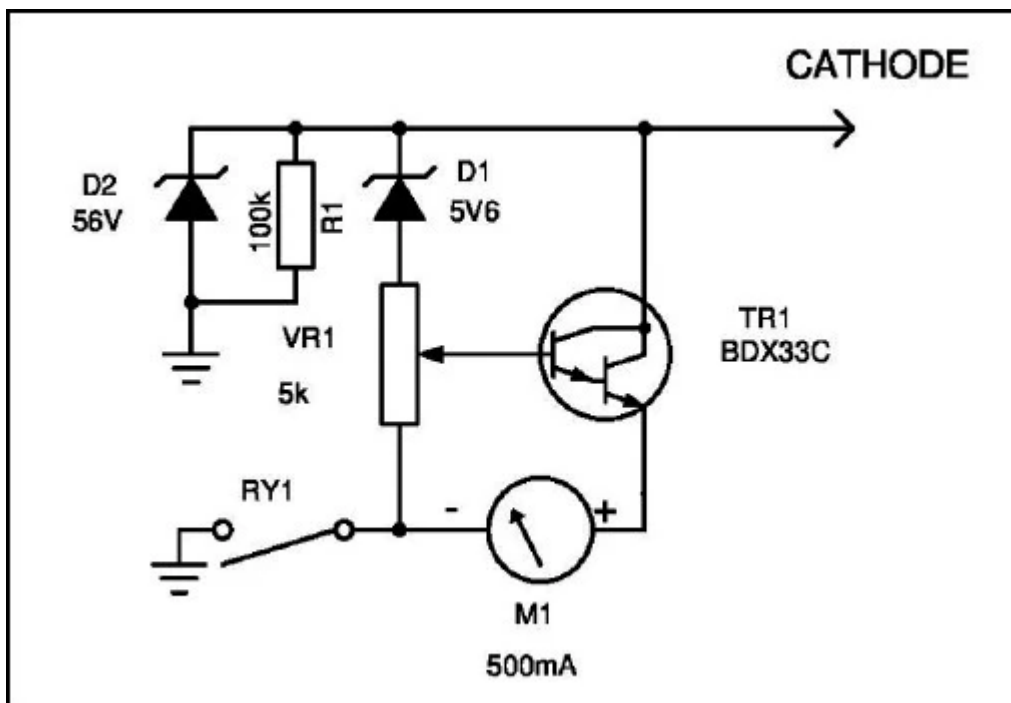
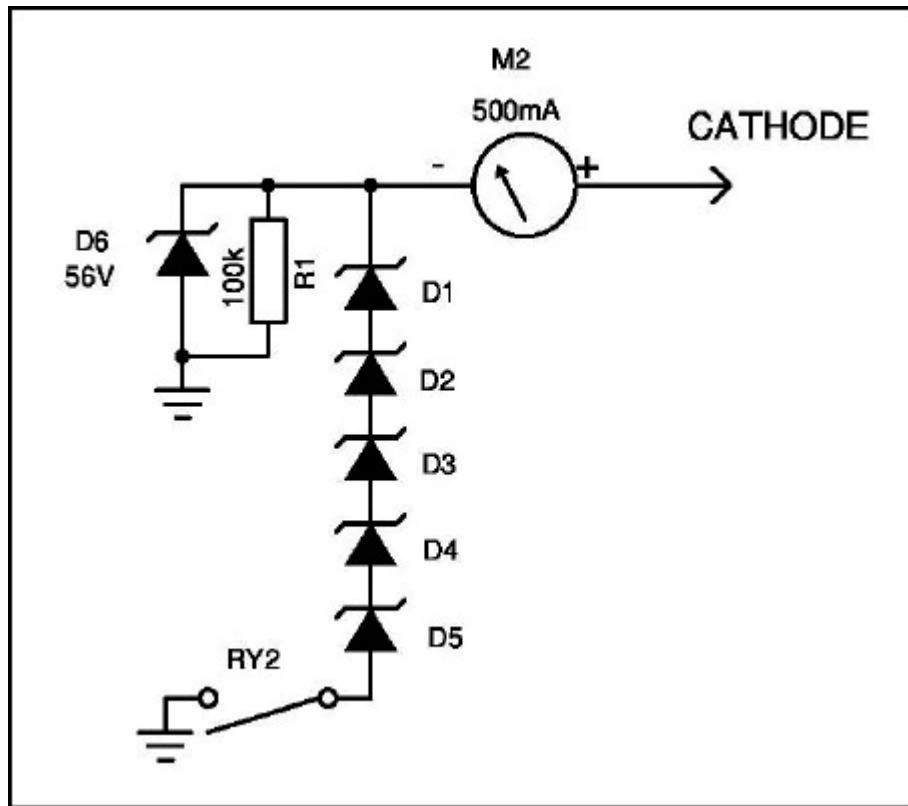
Alternative design :

The following design is working also very well



Some other example can be found here with pretty much the same principle :

<https://rutlib5.com/book/30339/p/11>



The cathode bypass is connected to the collector of an NPN Darlington transistor. This transistor has the cathode current meter in the emitter line and a relay contact. The relay is operated by the PTT control line so it is open on receive and closed on transmit. The base of TR1 is biased by a Zener diode and a low value potentiometer to set the required collector voltage. Across the collector to ground a high value Zener and a high value resistor in parallel are used for cut-off biasing when the PTT relay is open. All the cathode current flows to ground through the transistor and the current meter. The meter indicates the anode current plus any grid current. The circuit will hold the set bias

voltage constant between a few milliamps and 1A peak current. The value of the Zener sets the minimum bias voltage and will require selecting to suit the valve in use.

During the Idling current tuning i was using a potentiometer and when i was satisfy with the result , i replace the potentiometer with a resistor with the noted value from the potentiometer.

When you just trigger the PTT with high voltage to the anode and do not apply RF from the transmitter , we call the the "Bias idling" and cut-off is removed . At this stage the biasing circuit will provide an **Idling current** (standing current) which is about 50ma for 2 tubes in the biasing circuit. The biasing circuit is should be equipped with a VU-meter in order to measure this biasing idling current. As a reference for 6P45S the "idling Current" should be around 20 up to 25ma for one tube. The idling point is the current between the cathode and the ground and since the grids are reported to the cathode this will be applied to the grids also since the are at zero volt potential. The only current you should have is the idling current when you key the PTT. The idling current will assist to provide a linear amplifier for almost all HF bands since it is providing a stable reference. Ideally , if you are using 2 or 4 tubes , the idling current should be adjusted for each tubes since all tubes has its own characteristics. For my amplifiers since i have tubes in spares i manage to mix tubes with the same idling current. In order to do so you just need to put only one tube and check the idling current and doing that will all tubes you are planning to use. When you manage to identify a matching idling current between tubes , put them together. When i have some spare time i will certainly modify the biasin/idling and use independantly one circuit for one tube. **This is the key to obtain a perfectly linear amplifier.** Currently i am fortunate since all my tubes are matching together but if i need to replace one tube i am not sure at all it will match with the others. The idling stage is providing the reference to the tube in the middle of the active regions and make it ready for any amplification during the input signal sine swing.

For a class AB biasing the idling current should be about 40% up to 50% of the anode/cathode current .

For 1000V anode voltage with a 100w output , 50% idling current (means for 50w which is 50% of 100w) is $50\text{w}/1000\text{V} = 50\text{ma}$. The good practice is about 75% of the current value → so 20 up to 40ma will be perfect.

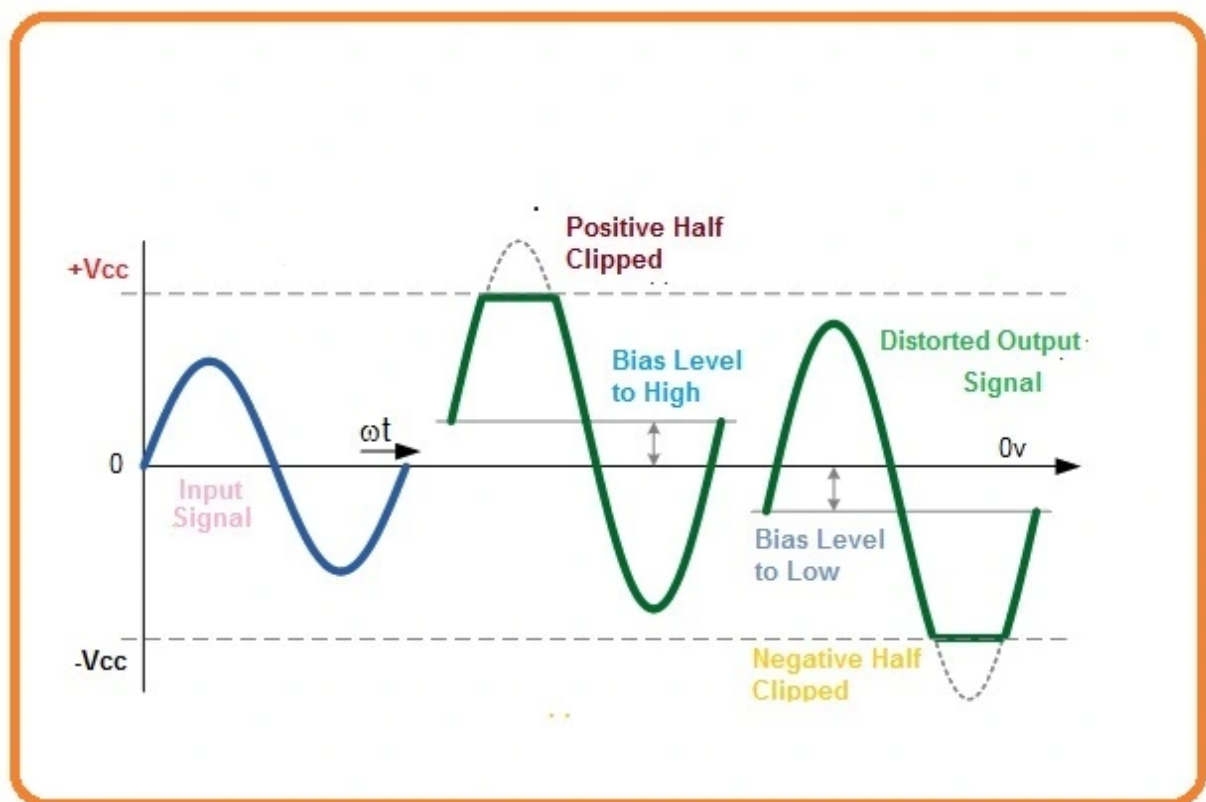
Another method to setup your idling current is to use a variable resistor for R8 (During my test i use a 2k potentiometer). You need also a 2 tones generator with a tinySA . You simply adjust R8 until you find a perfect output spectrum on the TinySA. When i did this test i manage to fine tune accuratly my idling current. Generally when you have adjusted the idling current for class B or AB2 , the

anode/plate is showing about 10 to 20w output for 2 6P45S when idling (I am about 10w)

This idling current is really important in order to provide a good linearity, output power especially for SSB mode during the RF input sine swing (IMD). A non linear RF amplifier will provide a bad energy transfer, this is caused by a bad filament voltage, bad biasing voltage and a fuzzy idling current → IMD and Splatters. Q point of biasing at the wrong location (not balance) on line of load or if we apply voltage beyond amplifier capacity due to these effects the output signal will not create the exact desired waveform (Half clipped). In a simple way, we can say that it is amplifier distortion. If you have not enough current means the Q point is too low, the amplifier will reach too often the cut-off point and will provide a lot of clipping. If too high the saturation point will be reached too often and will provide distortion. In both cases your waveform maybe be half clipped or even worst. In few words the Idling current should be adjusted precisely in the active region of the tube which is about 25ma for the 6P45S.

During idling the Anode/plate current should be almost null, if not your amplifier class A or C and will provide terrible splatters.

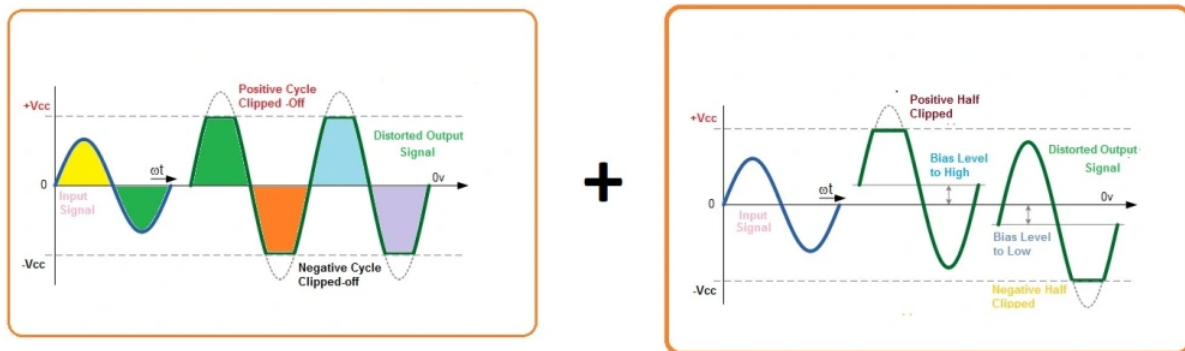
Hereafter a picture to summarize the importance of the Idling current and voltage. In addition it is providing evidence of using tube with the same tolerance is mandatory (Paired tube)



Example with Ameritron AL811 using 572B Tubes

As an example is you have an AMERITRON AL811 with 811 tube and you want to replace the 811 with 572B → The Idling and QPOINT Current for AL811 is 100ma (50ma per tube). if you are using instead 572b the idling Qpoint current should be about 80ma . If you look carefully to the picture above the idling will be unbalanced and not centered → Half clipping and distortion for sure and can be even worst when using chinese made tube since the idling current is fuzzy and even worst with tube with different tolerance.

In addition for a AL811 the plate voltage is low to be used with 572B which is requiring about 2500vdc on the plate → To achieve the same output power , some guys are driving the amplifier with more power → Amplitude clipping distortion + Clipping Qpoint Distortion will make the things even worst



Biassing:

The main purpose of the biasing is to provide and maintain a continuous voltage between the cathode and the ground + the voltage from the RF input in order to provide a current between the cathode and ground especially if the grids are grounded and reported to the cathode. This current will fluctuate from the Idling current up to a maximum when the RF is applied . In SSB mode this current and voltage will fluctuate and swing with the rythme of the modulation. The Biasing will assist to provide a great linearity to your amplifier .

Bias circuits is intended to get the tube conducting a middle amount of current. so that when an input signal is added to the bias, the output signal is a larger (in some sense) copy of the input signal riding on some bias produced average voltage, with acceptable distortion (neither hitting completely on or completely off at the peaks of the signal).

This voltage applied during transmit will determine the amplification level and for the EL519/6P45S tube this voltage a about 9 up to 15volts (In fact during the negative swing -9 up to -15volts reported to the grids previously referenced to 0v → during the negative swing the grid will be at +9 or 15v → the tube is unlock and will amplify) for an optimum amplification without producing spurious and to keep the spectral purity

pretty much clean. In order to do so, we need to connect the Cathode and the Ground to a voltage regulation system with a sufficient voltage level to bias the tube.

The purpose of biasing is to establish a stable operating point (Q-point or Quiescent). The linear region of a tube or transistor is the region of operation within saturation and cutoff. The main goal is to keep the Q-point in the middle of the active region. It is pretty much like a tennis player will stay in the middle of the court and not on the deep left or right of the court. This is the key to provide a linear amplification free of distortion and clipping (We call this issue negative/positive and half clipped)

Just above we saw about when the tube is blocked "cut-off" without any electron between the Cathode and the plate, the biasing is the other way around when we need to unlock the tube and to provide a significant amount of electron flow and current between the cathode and the Plate (anode). This is like tap water and more you open the tap more you have water. The tube biasing is pretty much the same. We need to apply the sufficient voltage in order to regulate the electron flow between the cathode and the plate.

Without any RF input the potential between the cathode and the grids will be null thus the biasing voltage will be zero volt. When a RF input sine voltage is applied it will be reported from the cathode to the grids a negative biasing voltage. During the "flywheel" negative stage the tube will provide amplification, and during the "flywheel" positive sine swing the tube is blocked. Charge and discharge of the capacitors in fact will assist to keep only the positive swing and buffering the "flywheel" effect.

The issue to solve is to maintain a stable voltage even when RF is applied to the cathode. The RF when applied will provide such voltage and the zener diode will provide the ability to maintain this voltage to a stable level (constant voltage design). To do so, simply add a zener diode when PTT and RF are in action. **The cathode will be polarized when using 2 x 6.2v zener means about -12volts → Since the grids are grounded at zero volt potential and reported to the cathode, the Grid biasing potential is +12v thanks to the zener diodes. This all the magic and this can be done only when using tubes.**

Therefore using simply a zener diode with any current protection system will need a high current zener diode which is not easy to find and expensive. The solution is to add a transistor to regulate the current and the power will be handled by the transistor instead of the diode. With this kind of circuit only a 1/2 w zener diode is necessary.

Why not using a resistor without a Zener diode? Without any RF we can, but when the RF is applied the RF current at the ANODE/CATHODE will increase, increasing also the voltage and factually will modify the biasing voltage. More power you use, more polarisation/biasing voltage/current you have and the amplifier will not

providing A or B class anymore because the voltage will be too high and instead you will have a class C amplifier which is less linear output power and some distortion.

Using zener diodes in the cathode network, instead of being returned to the supply 0V rail, is connected via a circuit to maintain a constant +12V between ground and the cathode we have the ideal solution. This could be a simple Zener diode regulator therefore the anode current varies the current through the Zener also varies, but it remains constant at +12V. It requires quite a high power Zener diode to make it work when the anode current is high. Using a transistor will act as a ballast for the current to avoid the current flow through the Zener diode (Simple, isn't it?).

During the positive peaks on the cathode (grid negative) the plate current is cut, while plate voltage swings at nearly twice the supply voltage due to the flywheel effect.

During the negative swing on the cathode (the grid will become positive) current on the anode will start to increase when you reach the value of the zener diode means we are using the negative peak of the RF input swing to provide amplification.

Therefore during the positive swing the +12v provided will assist to flatten the modulation in particular during SSB

In grounded grid topology the cathode returns to ground via an input resonant network which can be RF grounded at the bottom end. The grid is at 0V relative to the power supply and the bias voltage, if required, means that the cathode needs to be lifted above ground by the required voltage to obtain the correct biasing point. If the Valve requires, for example, -20V grid-cathode to establish the correct operating condition, it means the cathode needs to be raised above ground so that it is now at -20V. In other words it is the same as a cathode biased amplifier with a resistor in the cathode to ground. **For the 6P45 the biasing region is from -10 up to -15 volts** to obtain decent performances for cathode driven design and grids biasing. This voltage will insure a good linearity without spurious

You can easily test it and just put the 22Kohm resistor on the cathode circuit and you will notice a difference regarding the output power (You should apply the same input power). Using the Zener diode circuit is providing a linear and consistent output power in all bands.

Why using a transistor in addition with the Zener Diode. The transistor will act as a current regulator and will handle this current. The diode will be protected from the current surge and the current at the zener diode will be very stable. Only a small part of the cathode current will go through t

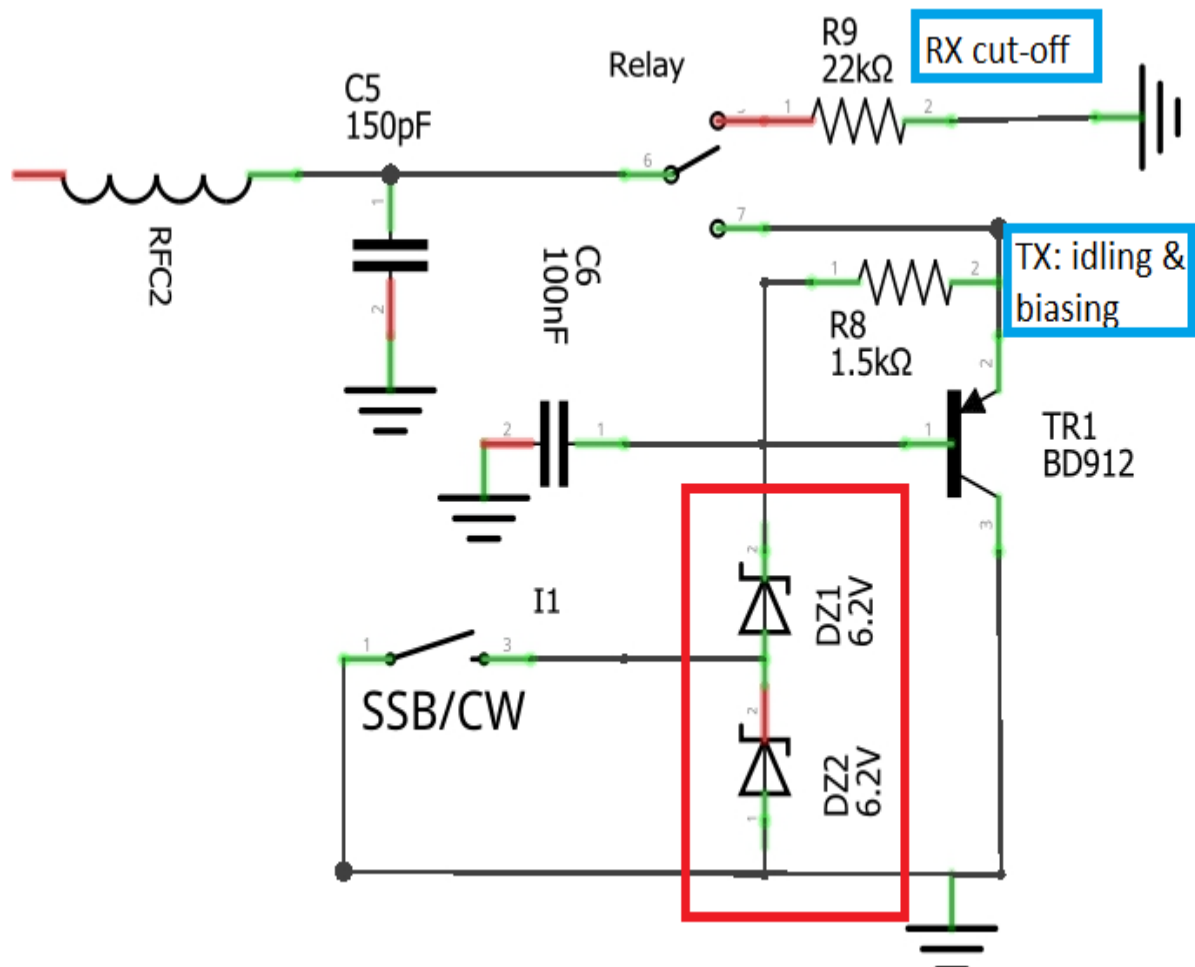
How it works : the Base/emitter of the Transistor will be about 0.6v, but when RF is applied the Cathode voltage will increase and at the BASE/EMITTER junction , the transistor will increase instantly its the collector current , this will decrease the cathode voltage and regulate it . This cathode voltage will remain all the time at the zener diode value minus 0.6v. This circuit is by far the most simple and all my amplifier are or were design with this kind of biasing/polarisation circuit without any issue . Tube are able to provide such simplicity.

For my amplifier i add a switch to use one or 2 zener diode for the Biasing :

-1 zener diode for CW and digital modes

-2 zener diode for SSB

Generally speaking , the biasing voltage for tube is from a very low voltage from few volts up to 30v . This should be tested but for EL519/6P45S tubes is about 10 to 15vdc. Two 6.2v zener diodes will provide about 12vdc biasing which is no so bad for this kind of tube (in fact the voltage with this circuit for the grids reported to the cathode is -12V) .



Biassing idling point calculation :

The biasing idling point generally for class A or B RF amplifier with 1000v plate voltage with a dissipation of 35w is about 25ma for one tube. This is mostly the good practice but obviously must be tested since it can be slightly different according the tube you are using.

To calculate it , you can use :

$$P = I \times V$$

P is the power rating of the power tube, I is the bias current, and V is the plate voltage of the tube.

$$I = \frac{P}{V}$$

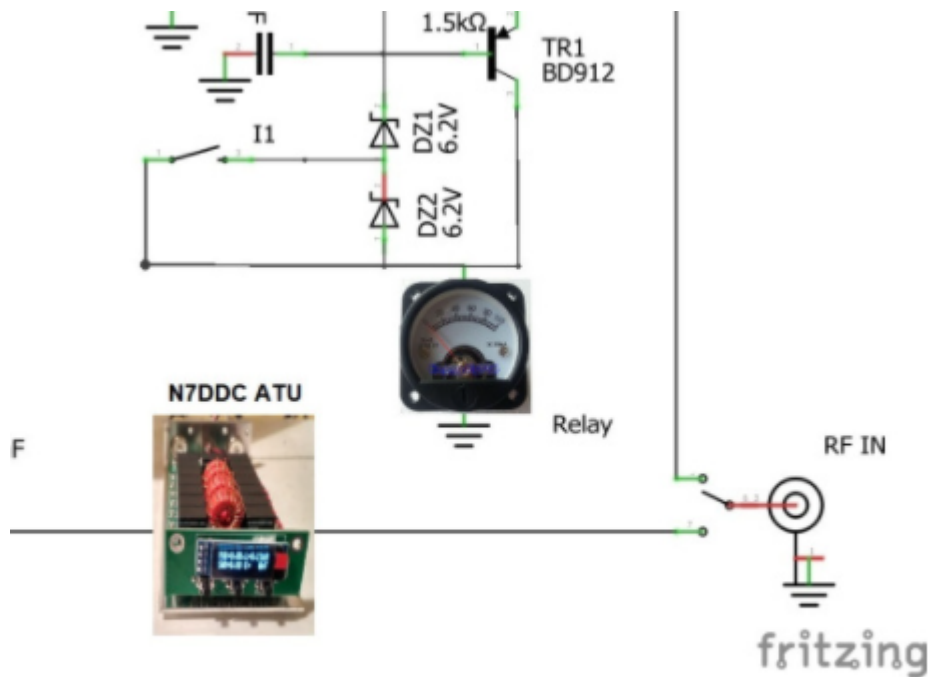
When biasing to 70% which is recommended for this kind of tube you simply multiply the answer by that number divided by 100 according the percentage. the Variable is x.

$$I = \frac{x}{100} \times \frac{P}{V}$$

For the 6P45S will a 35w plate dissipation , 1000v plate voltage and 70% biasing point you will obtain 24.50 mA.

Since the idling current is really important for IMD and to avoid splatters , you should verify the output spectrum with a TinySA and a 2 tones generator. As mentioned above you can use also a 2k potentiometer in place of R8 to verify and fine tune your idling current.

To monitor the Biassing and idling as followed:



Example : Few months ago after working on this amplifier i did not attention but by mistake i broke one of the leg of the BD912 Transistor. A Fellow ham operator warn me about my modulation which was very distorted. After testing on a dummy load with another TRX to monitor my transmission it was confirmed i had a serious issue. After opening and checkingt my idling current it was confirmed i had an issue with my biasing circuit. The BD912 replacement immediately cure my issue . The main extent : **Biasing properly the amplifier is damn crucial !**

Summarize:

Cut-off : According with the proposed polarisation/biasing design described here , when the zener diode is disconnected from the cathode during RX the transistor will be blocked . Connecting the Cathode to the ground with 10k up to 47k resistor will put the cathode a the negative (ground) potential → The tube will be blocked and no current will be notice at the anode (Plate) . This will reduce the standby current in cathode during receive→ **This is the cut-off**

Biasing: When the zener diode are connected to the cathode and RF is applied during transmit the cathode will have some voltage from the RF plus the polarisation voltage reported by the grids . This voltage will fluctuate a bit due to the variation of the RF and this will imply a significant increase of the electron current between the cathode and the anode (plate) during the negative swing → **The input signal will be amplified and the zener diode will regulate the biasing voltage according to the swing from the RF and modulation .**

Idling current : When you just trigger the PTT and do not apply a power from the transmitter you will have no power. The amplifier is ready to amplify the signal when RF is applied and the Biasing will regulate the electron and current flow between the cathode and the plate and will adjust the Qpoint in the middle of the tube active and effective region. **As i said this this the key in order to provide a clean and linear amplifier**

Grids

Since this amplifier is using grids grounded system, all grids shall be wired to the earth potential. I just add a 10nf capacitor to ensure less possible spurious reported to grids.

Input tuning : N7DDC ATU

The key is to provide the best input adaptation in order to ensure the perfect linearity of the amplifier and in addition to enhance the spectral purity.

The tuned input should ***always*** be located as close to the cathode circuit

Generally speaking we are talking about an average input value since this impedance will fluctuate widely according the positive (high impedance which is almost infinite) and negative (Low impedance) swing of the RF sine wave input signal. According some test with my SARK100 analyzer i was able to determine an instantaneous impedance from 20 up to 25 ohm. This instantaneous input impedance is just a reference since the input impedance will swing from the infinite down to about 17 Ohm . According this issue a single broadband transformer will not be able to tune properly the input efficiently. The other solution is to add a non inductive 50ohm resistor at the input in order for the transceiver to “see” a perfect $50 \pm j0$ ohms. This solution is great for the transceiver but will not assist according the performance of the amplifier from the input. The overall Q of the amplifier will be affected → The input impedance of a cathode driven stage is ***dynamic*** (Input impedance swing), with the tube’s driving impedance changing with parameters like drive power and how the amplifier is loaded or tuned. Obviously if you are planning this kind of amplifier in AM mode, then to some extent the problem is alleviated as the impedance does not vary by such a large amount, because the constant carrier level causes the cathode impedance to be more constant. But SSB varies from zero drive power up to peak value.

For an amplifier located some distance from the driver, an improvement in intermodulation distortion can be realized by tuning the cathode circuit. When the driver is located very close to the amplifier (1/10 wavelength, or so) other means may be used to minimize the nonlinear loading of the cathode driven stage.

Using this kind of tuner to drive the input is possible only if the input impedance is close but not quite right for your exciter.

The dynamic cathode impedance, where cathode impedance changes with drive level, prevents us from accurately adjusting the tuned input system of a typical cathode driven amplifier at very low power. This prevents accurate use of an antenna analyzer to adjust the tuned input while using the operating PA tube as a load. **The input system should always be adjusted near full output power under normal operating conditions**

The main issue was regarding only 3w to 5w input from my SDR , i loose too much power at the input circuit with the previous design (Especially with the non-inductive 50R resistor which is acting also as an attenuator in the input circuit). I did some test without any circuit at the input and realize the SWR was always below 2:1 in all bands and was almost perfect for 20 and 17m bands. I remove the input circuit and immediately i manage to achieve above 150w with SDR TRX and 5w input (with the previous design , the output power was barely above 70w up to 110w).

Initially , the input circuit was a standard PI network using a switch according the band i am using but nowadays i am using simply a N7DDC tiny tuner which is perfect with the low power availibilty from my transceivers. This tuner is not degrading the input signal too much and losses are about 20% maximum.

The input impedance of the EL519/6P45S's is not known. Using the Sark100 and Nano VNA i manage to found out the average input impedance for amateur bands is averaging 15 Ω -27 Ω , the average real part was about 22 Ω .

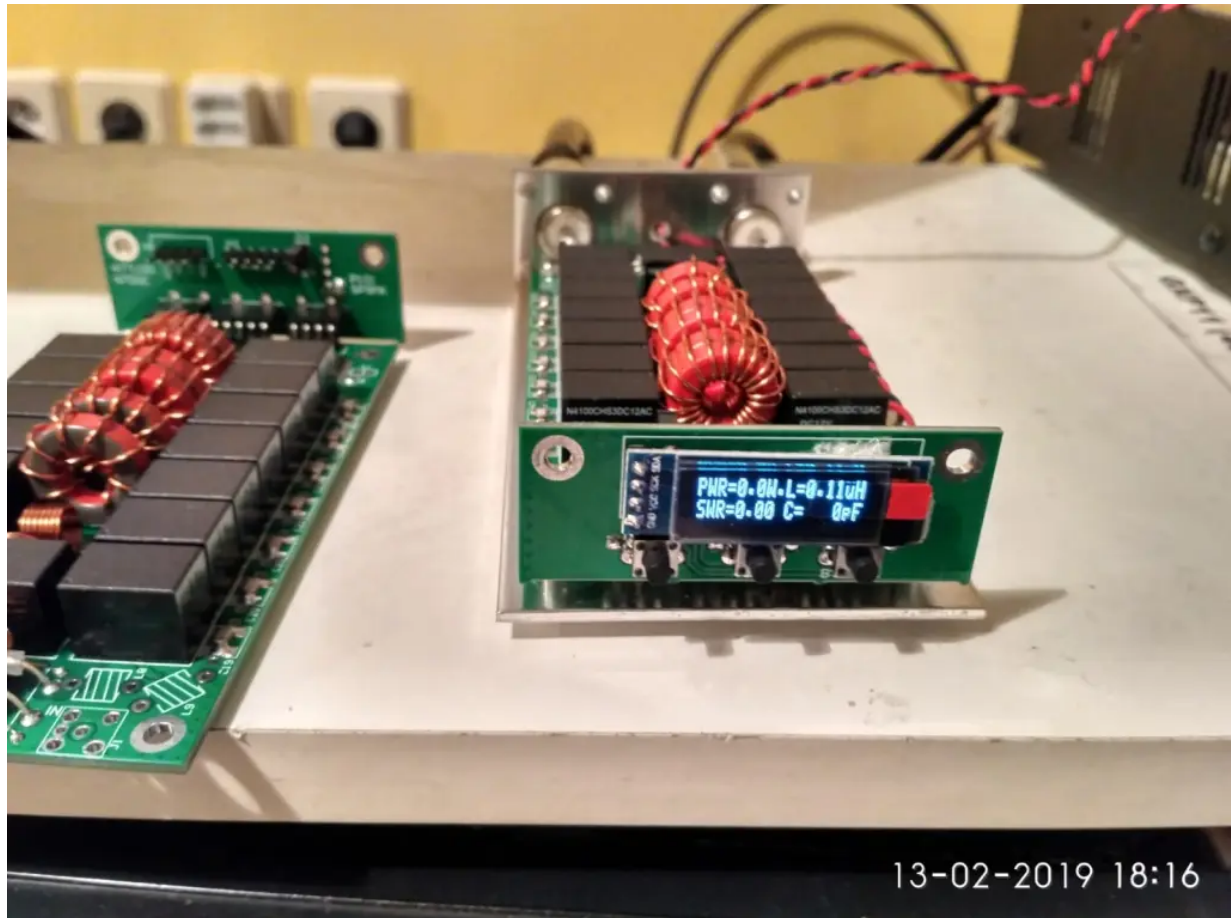
I simply integrate the N7DDC ATU kit in line at the input and manage to remove the 50R Non-inductive resistor . This solution is providing a kind of adjustable capacitor and inductance at the input and will act as a standard PI network and will introduce at the input inductive reactance or capacitive reactance according the band you are using. When driving a tuned input in a grounded-grid amplifier, filter reactance interacts with the input reactance in the tuned input. This system is introducing a kind of buffer since a tuned input circuit is in series with and out of phase with the anode. This “buffer” will slow down the impedance input swing and will obviously provide a better Q . The very good thing and benefit from the N7DDC tiny tuner is the ability to display the input inductance and capacitance on the OLED display .

Currently the SWR in all band is almost perfect and it is really assisting for the spectral purity and performance of the amplifier. Needless to say it is improving also the linearity of the amplifier. The integration is straight forward and i just add 2 additional SO239 plug at the rear of the amplifier for the input/output of the ATU in line with the RF relay. The ATU is used only during transmit. This ATU is simply perfect and cheap and manage perfectly input impedance from 15 Ω -27 Ω . In addition this tiny tuner is

providing a full automatic tuning feature which is very convenient. This technology mix from Tube vintage and modern PIC is something very interesting.

The ATU was bought as a kit but I swap the toroids with more performing one. Currently the loss from the ATU are not significant and even difficult to measure.

The input tuning is totally automatic and really quick.



Using the N7DDC ATU is providing a great linearity and a perfect tuned input for the amplifier. **With and without it is day and night** and for example with 5 watts input on 40m with an almost perfect SWR at the input the amplifier is providing about 170 up to 200w, without the ATU with a standard 1:4 transformer and a non-inductive resistor, the output power is dropping significantly to 110w. The main benefit of the N7DDC ATU is the automation and you can setup the ATU in automatic mode (Mine is setup to an automatic tune trigger with a SWR > 1.3:1). Most of the time the SWR is about 1.05 up to 1.2:1.

Bear in mind Grounded Grids amplifier, the input is in series with the output. All of the anode waveform is impressed across the input circuit. It is a series circuit for the anode right back through the cathode. A great linear input will provide best IMD results.

Check on the following Websites , you will find a complete explanation for how to tune the ATU EEPROM cells

<https://radioaficion.com/news/automatic-antenna-tuner-kit/>

[Click to access ATU-100 Extended Board User Manual eng.pdf](#)

To setup the EEPROM you will need a PICKIT3 programmer

Some documentation in French : [http://www.la-tour.info/uts/3_schemas_doc/PIC -
_Mettre un fichier hex dans un PIC.pdf](http://www.la-tour.info/uts/3_schemas_doc/PIC_-_Mettre_un_fichier_hex_dans_un_PIC.pdf)

My EEPROM setup are the following :

Cell 02 — automatic activation cell. If you plan to use the device without additional buttons, you can enable the automatic mode by setting the value to **01**. The default value is 00. With this value according the SWR threshold setup in the following Cell 04 you do not need to press any button , it is fully automatic and working very well

Cell 04 — cell to set the threshold settings in automatic mode.

It is recorded in the format: the first number is the SWR integer part, the second number is the tenths. The default value is 13. That is, when the automatic mode is activated, the tuning process will be triggered when the SWR is above **1.3** and when it changes to (1.3 — 1)

Since i am using low power TRX with less of 5w you need to adjust the following EEPROM Cell 05:

Cell 05 — minimum power cell required to start the setup.

Recorded in the format: the first number – tens of watts, the second number is watts. The default value is 05, that is, the tuning will only work at an input power is at least 5 watts or above. I adjust this parameter to **03 (3watts)**.

BOM

R1,R2=5R 3W

R4,R5,R6 = 390k

R8 = 1.5K or a potentiometer if you want to adjust manually the biasing current

R7 = 10R 5w

R9 = 22K 5W

C4 =3.3nf

C1,C2,C15 = 10nf

C5,C6 = 150pf

C8,C9,C10 = 150uf 450v

C12 = 1nf 5000v

DZ1,DZ2 = zener 6.2v

C13 = variable 50pf 2000v

C14 = variable 450pf 1000v

C16 = 100pf 3000v

C17 = 200pf 3000v

TR1 : BD912

RFC2 : 50 turns 0.5mm / 1 cm diameter

L1 : using a t200-2 toroid 27 turns and **you shall solder the band switch directly on**

L1 (This part is the most important, before doing that the output power was about 200w , with the band switch solder directly on the toroid the output power increase significantly to 350/380w with only 20w input on 7Mhz, 10Mhz and 14Mhz).

RFC1 for 160M, generally the plate choke should be around 250 μ H but since this amplifier is not tailored for this band , to cover the entire HF band the plate choke RFC1 Should be from 100 μ H up to 150 μ H. My RFC choke is about 130uh

RFC1 : 200 Turns with 0.5mm enamelled copper wire / 19mm diameter. The coil lenght is about 11cm.

COST

-Zetagi BV135 amplifier without tubes from a Ham Expo : 25 Euros

-N7DDC ATU (kit) : 34 Euros (Not mandatory)

-T200-2 Toroid : 10 Euros

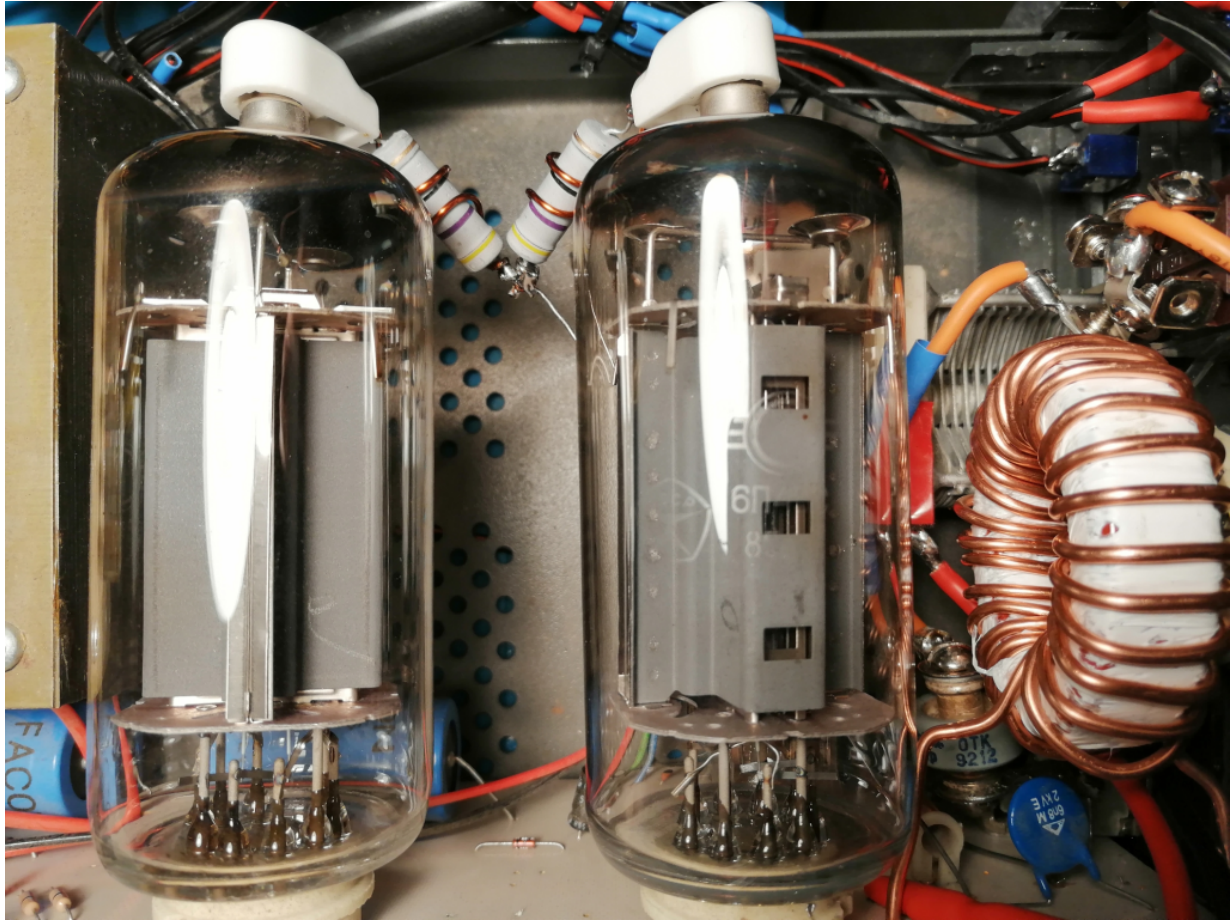
-450pf Variable air capacitor 1000volts from my stock bought 10 Euros many years ago

-Misc : 25 Euros (Band switch and band commutator)

Total : 104 Euros (With the ATU) for about 300w output (I have already some tubes and bought 2 new one as a spare for 34 Euros from Ukraine). With some study , calculation , experimentation and testing you can achieve a decent solid state amplifier which will last for ever and very easy to repare!

It is all about Amateur Radio guys !

The [RM-BLA-350 300W SOLID STATE AMPLIFIER](#) from the market will cost you 800 Euros with not the same life expectancy!



If you need brand new tubes , i highly recommend this ebay vendor (I bought 2 tubes and the output power was beyond my expectation) : <https://www.ebay.fr/itm/6P45S-EL509-EL519-6K6G-Svetlana-Output-Beam-Tetrode-NOS-Lot-1pcs-or-more/274366181153?hash=item3fe17faf21:g:34YAAOSw6Spevdg6>

Band commutator : <https://www.ebay.fr/itm/NOS-2x11-rotary-switch-made-by-ITT-W-Germany-in-80s-hi-quality-military-stock/261465143585?ssPageName=STRK%3AMEBIDX%3AIT&trksid=p2057872.m2749.l2649>

This design was the one which provide me the best results in terms of output power , linearity , spurious and IMD.

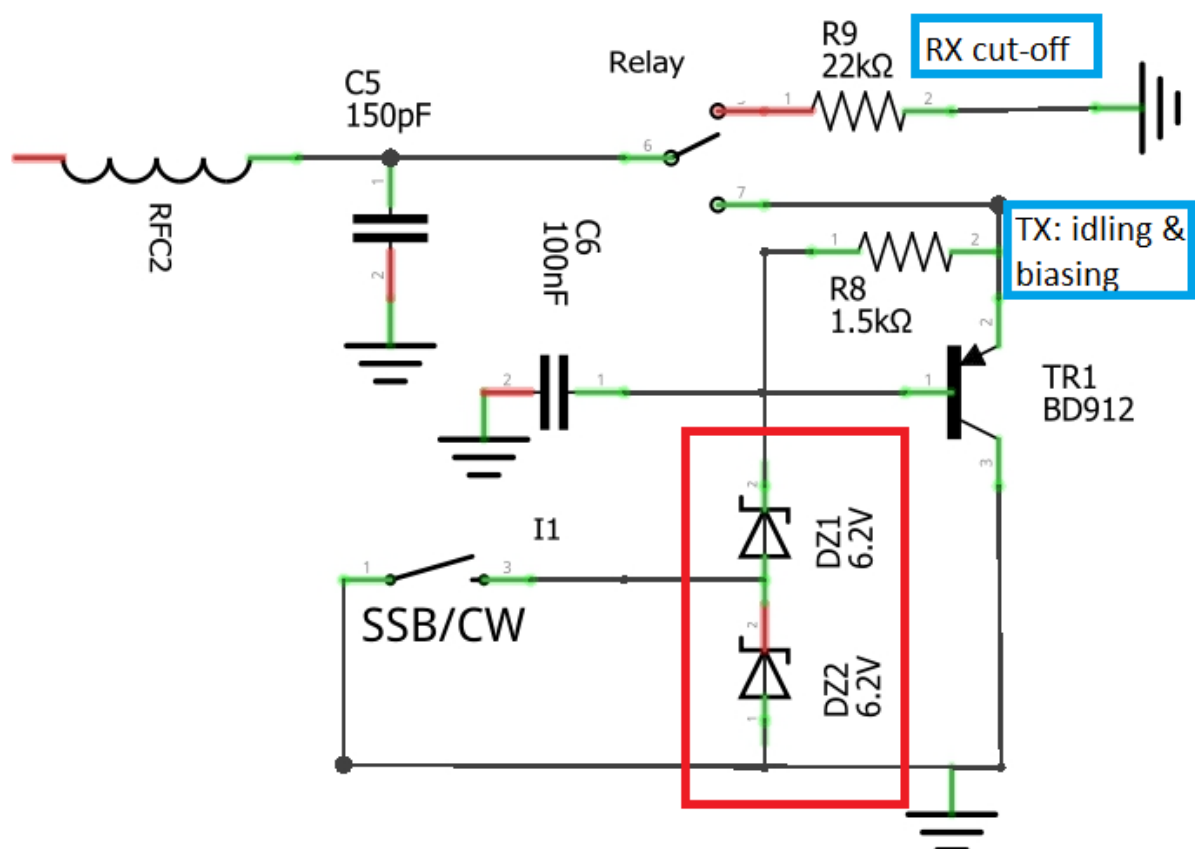
One EL519 is capable of providing more than 200 watts PEP output when used with forced air-cooling. The valve seems to be virtually indestructible with its performance limited only by envelope temperature. The EL519 is capable of sustaining over 1.1 kV on its plate (Not recommended and limit the plate voltage below 1000vdc). 2 tubes are able to provide easily 250 up to 300w if your input and output circuit are well design.

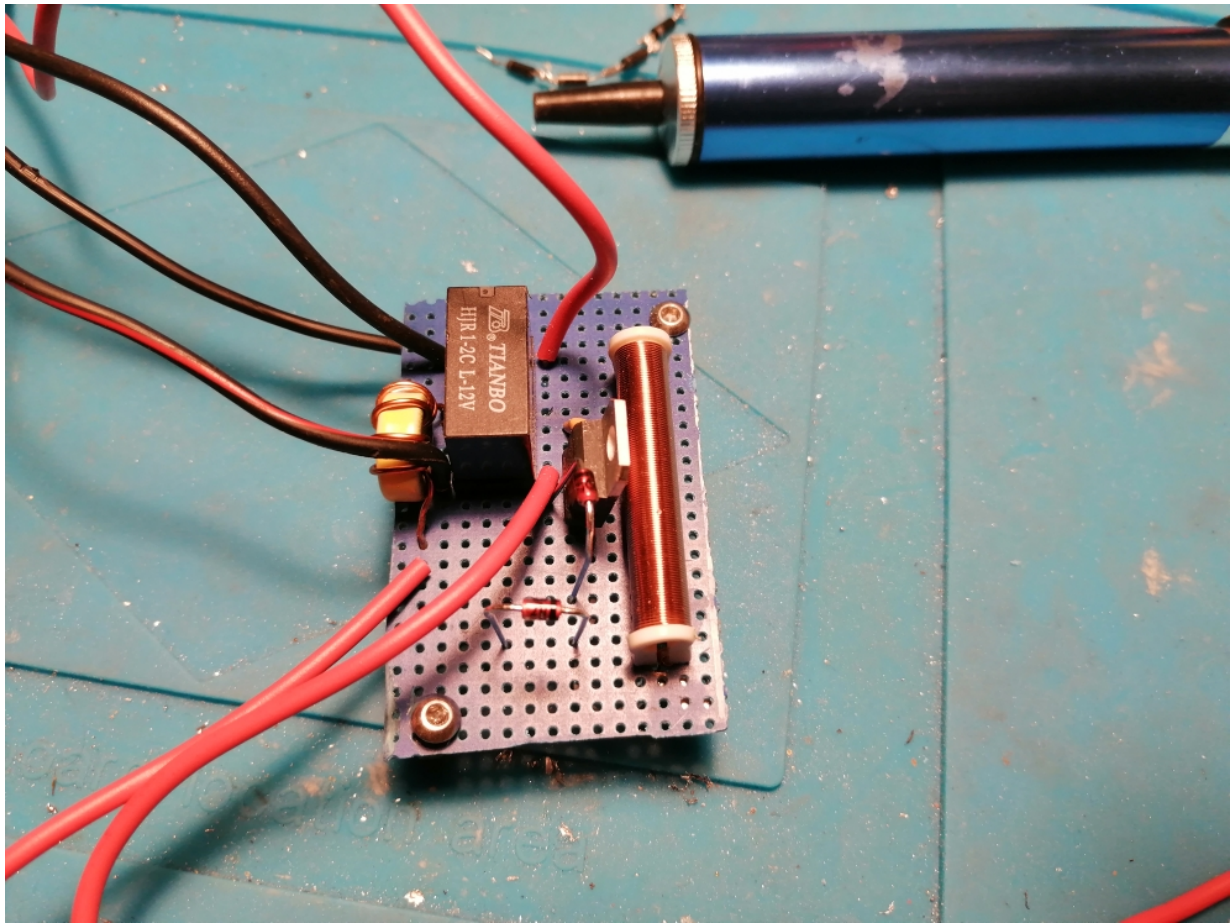
Cathode biasing circuit with relay

The biasing circuit is very simple , grids are grounded and adding a 22k up to 47k resistor between the cathode and the ground make grids negative respect to the cathode ,that means cathode is positive respect to the grids: in tubes all voltages are reported to the cathode and the zener diodes will provide the forward voltage drop to hold the idling plate current via RFC. You can also use a string of diodes (5 to 7 1N4148 diodes) to achieve the same result. With a transistor (BD246C or BD912) and two zener diodes (6.2v) you can select the right bias for SSB or CW with a simple switch i add on the front panel. You can also replace the R8 resistor with a potentiometer in order to adjust manually the biasing current. This kind of design will provide a class AB amplifier (Since the Tube is biased with a "cut-off" provided by the cathode biasing) , which is not the best in terms of distortion and efficiency, but with the limitation of 20w max input and mostly the anode voltage below 1000vdc , the modulation is perfect and i did not notice any clipping or distortion whatsoever.

You can also test with 9.2v Zener diodes if the current (25ma per tube) or biasing (from 12 up to 15vdc) is not satisfactory.

Biasing circuit directly solder on the main circuit and you can use BD912 or BD246 to trigger the biasing voltage and diode current protection.





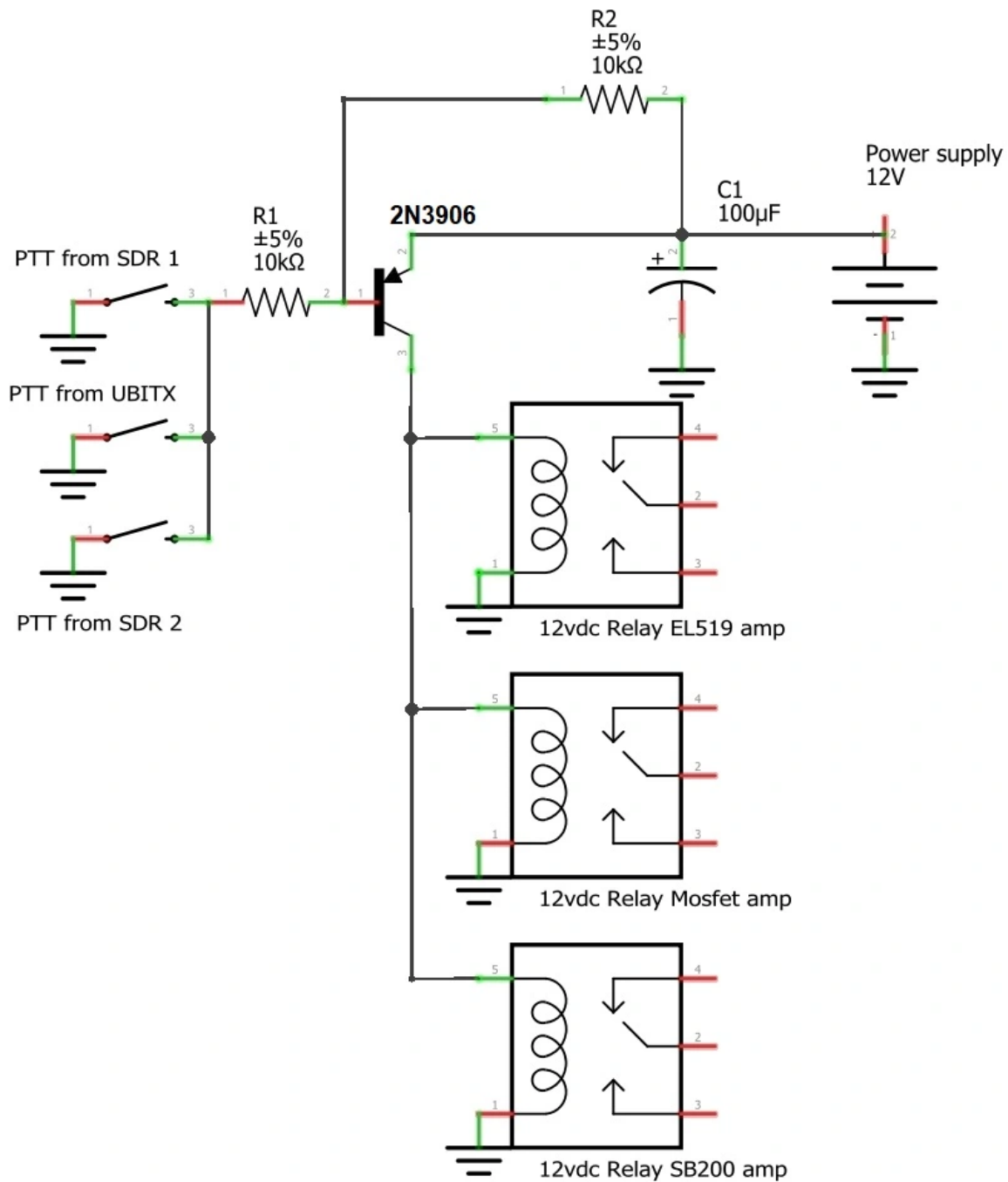
The current is about 20ma per tubes (about 40 to 50ma total) which providing a great modulation



With this simple circuit , the tubes will conduct only when triggered through the relay (PTT) . Since this design is using grounded grids ,the biasing circuit shall be properly isolated with an RFC to prevent any RF disturbances from the input. The RFC i am using is about 67uh inductor.

PTT and Relay control

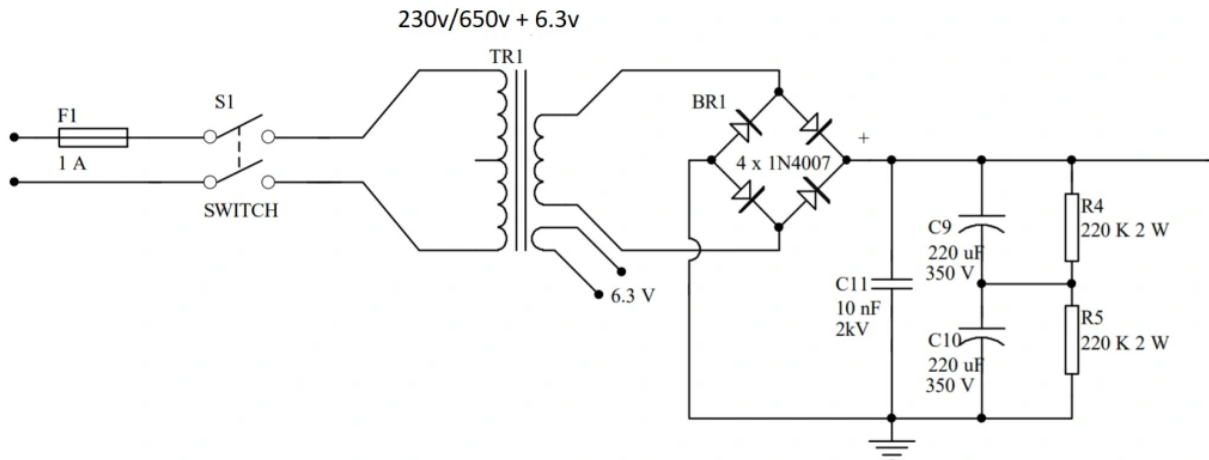
i am not using any VOX system but only a control from the transceiver. With this system i control the main HF and the BIAS relay. In addition this interface is able to control other devices.



fritzing

HV 900vdc Power supply

The main benefit of using only 900V for the anode is to lower the plate load impedance. Increasing the HV will increase the plate load impedance.



EL519/509/6P45S

The EL519/509 tubes were dedicated for TV Set and the 6P45S was produced in USSR.

6n45c is a beam power tetrode intended for use in class A, AB or B audio amplifiers and for **class B or C RF amplification**. Close manufacturing specification tolerances and improved high voltage processing provides improved reliability and superior performance.

Why i like this kind of tubes :

-The size ,compare to other tubes , the EL509/519 is really smaller for almost the same performance for example compare to a 811 or 813.

-simply because they are almost unbreakable and if you do not stress them too much with permanent damage , this kind of tube will last for ever.

-Tube stability : without any biasing and with voltage apply to the anode , the tube remain really stable without any anode current or self-oscillation. Compare to the other tubes i used in the past , **the EL519/6P45S are by far the more stable**. The pentode was developed from the tetrode tube by the addition of a third grid, the suppressor grid. This served to prevent secondary emission electrons emitted by the plate from reaching the screen grid, which caused instability and parasitic oscillations in the tetr. According my experience with tube , the Pentode/Tetrode is by far more stable compare to a Triode

-Anode (plate) voltage is not so high compare to other tubes and you can have up to 200W (with 20w input which is the maximum) with only one tube (130 to 150W is more realistic) with only 900vdc plate voltage (750vdc loaded).

-The biasing is really easy and you just need diodes or zener diodes with pnp or npn simple transistor (up to your choice).

-Compare to other tubes , the cut-off (Means the tube is in stby with no current from the anode/plate) is really easy to achieve with EL519 tubes. With simply ground the cathode through a 22k up to 47k resistor is doing the job and believe me you tube will last for ever with this kind of design. Simplicity is sometimes the best choice. This design is for security purpose since i never noticed any self-oscillation with this kind of tube , talking about cut-off status is mostly for common language sentence apply to tubes. In fact it is not mandatory for EL519 tubes but **highly recommended**.

-With only 2 tubes you can have about 200W for digital modes and up to 220/280W for SSB and CW.

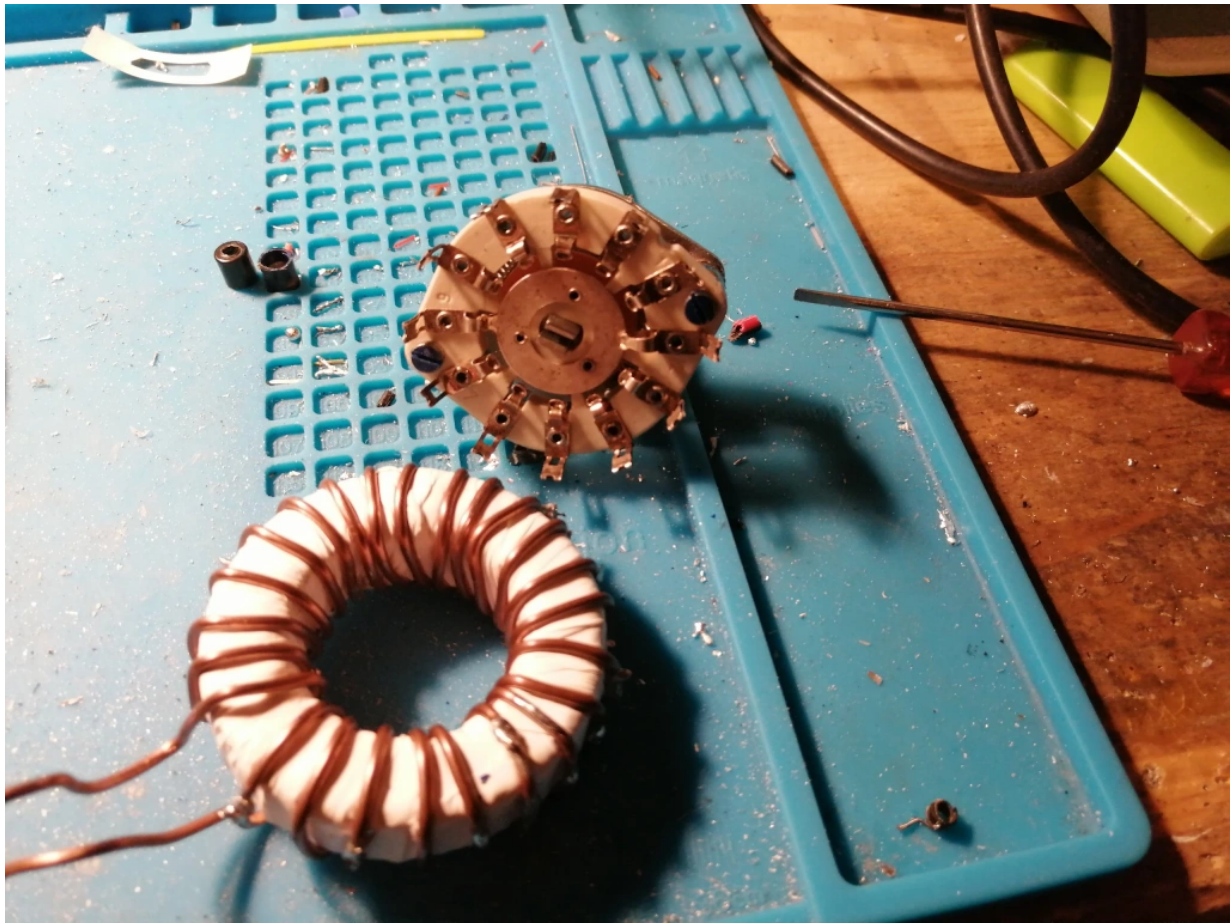
OUTPUT PI NETWORK TANK

The second surprise was regarding the Output PI circuit using just a single T200-2 Coil. Because the capacitance for two EL-519 is very high i was not sure to achieve a decent "Q" for the final .But we are using a cathode drivend and grounded grid the capacitance will be lower and will really assist for the Q of the amplifier. In addition since i really was to minimize the size , the output capacitors are only 50fp and 450pf but another surprise the tuning was really easy to achieve for 40 up to 15m bands with only 27 turns on the T200-2. Additional switchable capacitor of 100pf for the 60m/40m bands and 200pf for 80m. This should be tested with different value according your design. Due to high output capacitance for grid-driven , this circuit was not working well . If you decide to go for a grid-driven amplifier , you will need a standard PI network circuit.

The switching for 40/60 and 80m is achieved with this kind of heavy duty switch:

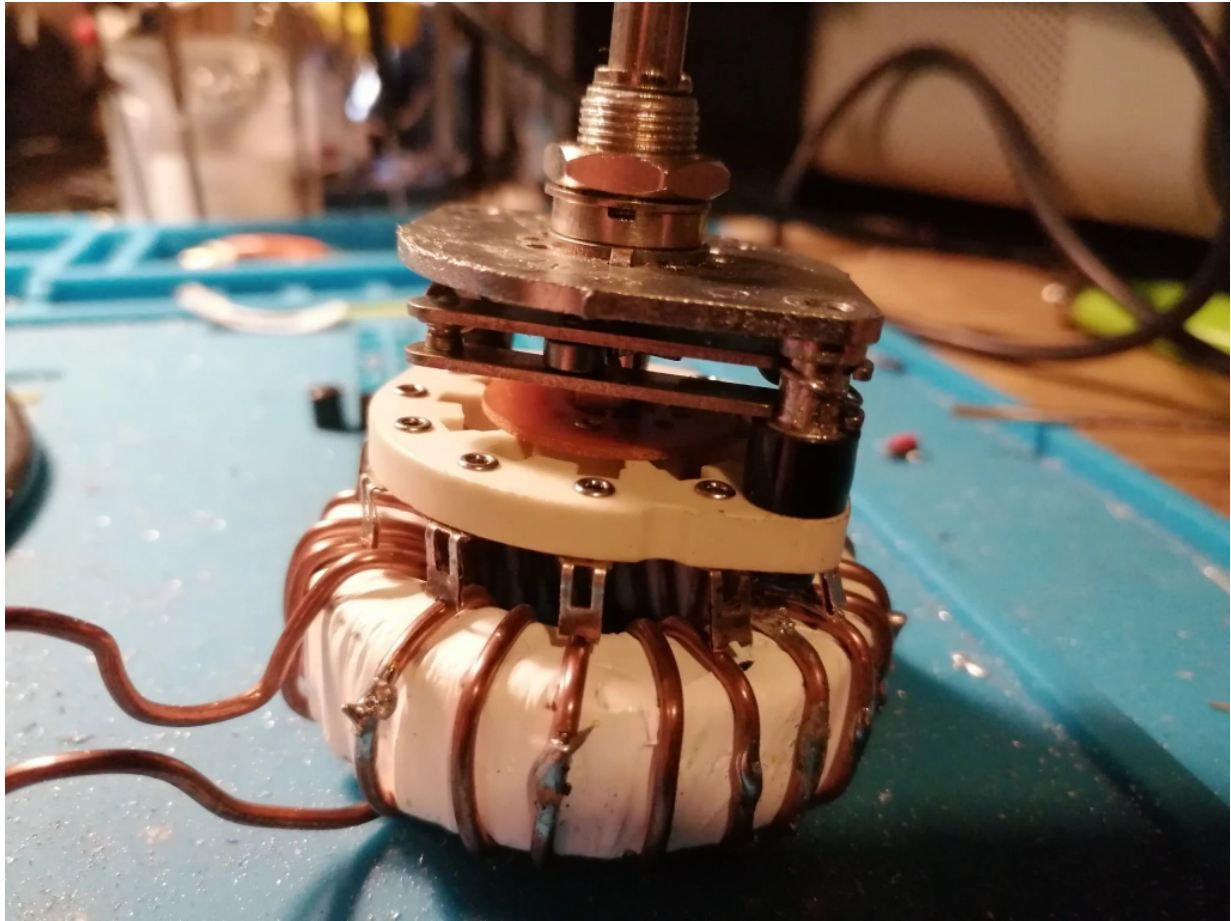


The T200-2 shall be be wrapped with Teflon and i am using 1.5mm copper wire.



Winding 27 turns (1.5mm copper wire) is proving about 10uh





-Regarding the anode and the PI filter , this kind of tube is providing the ability to build a PI Circuit with only a T200-2 coil and you will be able to tune the amplifier from 80 up to 15 m .The coil is wound with 27 turns only and i just need an additional switchable capacitor of 100pf for the 60m band and 200pf for 80m . The size of the PI circuit will limit the overall size of the amplifier (The 2 variable capacitors of the PI Network are 50pf and 450pf only).**As mentioned above , solder the band switch directly on L1 (T200-2 toroid) really improve the output “Q” , the tuning and overall performance.** Compare to my initial and previous PI network design it is day and night really.

RECOMMENDATION

The main issue is regarding the cooling and for this kind of tube **forced air cooling is mandatory** and this is what i did with a big fan on the top of the tubes. The main result , i can use this amplifier even with Digital modes likely FT8 without any problem and perform a run test during one hour on a dummy load easily. The tubes remain warm and not glowing at all during FT8 or long PSK31 QSO with up to 250W output.

With about 2 to 5 W driving power the output is 60 up to 170 W which is perfect with my SDR transceivers , With 10-15 W is providing about 200 up to 250 W output and 20 W input is able to provide up to 300 W (even more for 40 and 30m) The quiescent

current at 900 V is about 10mA up to 20ma (about 45ma in total) i can select with a switch using only one zener diode in the biasing circuit.

After many test you need to ensure the plate voltage is not over 1000volts because it will provide IMD and spurious. Below 1000 Volts , i have noticed a significant reduction of the IMD and with 900vdc the spurious are more than 47dB down in some bands. The spurious magnitude is better than -42db which is not so bad considering this kind of tubes are not dedicated for this purpose.

One important part we always go through is regarding the heater voltage . IT SHALL BE ACCURATE AS POSSIBLE , IF NOT = The tube will not last very long and your amplifier spectral purity will be affected (even if the heater voltage is lower than the requested one)

In fact this amplifier is more than enough according my needs and the different test i made during pillup with my W8JK antenna : i do not need more power and my other EL519 amplifier will be decommissioned (the casing is too big) since the size of this one **is only 16X10X25cm** (It is really small for a 300W tube amplifier) , i have started a LDMOS amplifier project using 50vdc voltage + LPF + security device, fan and radiator is almost 3 times the size of this amplifier for about the same output power , from now my LDMOS amplifier project is postponed since this i am not sure the effort is worth the final result. The 50vdc 15amp power supply is even bigger than this amplifier LOL!!!!!!!

The lack of room and space was a real challenge , but building a PI output network using a **T200-2 core solder directly on the band switch was a great choice** and i manage to save some space



The process of tuning a RF amplifier using pentodes is much easier than on tetrodes, however, here, too, incorrect tuning can significantly spoil the signal quality and increase the intensity of spurious emissions.

1. Instead of giving a single-frequency signal, or as it is often called, “carrier”, the amplifier shall be checked with dual tone generator.
2. During your initial testing , the temperature magnitude shall be checked. If you have some temperature too high there is a good chance your amplifier is not tune properly and the PI output network maybe not performing well

Such tuning methods lead either to an overvoltage , and these are nonlinear distortions and an increased level of harmonics, or to an undervoltage mode, and this is a loss of efficiency and power due to overheating of the lamps.

To properly configure and fine tune your amplifier, you must:

1. Determine what level of limiting (peak) power will be used.
2. Adjust to the maximum output power when a **single-frequency** signal (carrier) is fed from the transceiver at its maximum (peak) level.
3. When working on the air, do not exceed this level, **under any circumstances**.

The definition of the peak level depends on the type of modulation and the purpose of using the amplifier shortly after tuning. This is a full power mode, a light mode, which is especially desirable in contests, a very light mode, for everyday communication on the air, in different modes (SSB, CW, AM, RTTY, etc.), in other words use your amplifier with full power only when you need . Most of the time the very light mode is sufficient.

Most of the time i am using this amplifier with the following power:

-30 to 70w for FT8 , PSK and RTTY

-50 up to 100w for CW

-100 up to 200w for SSB

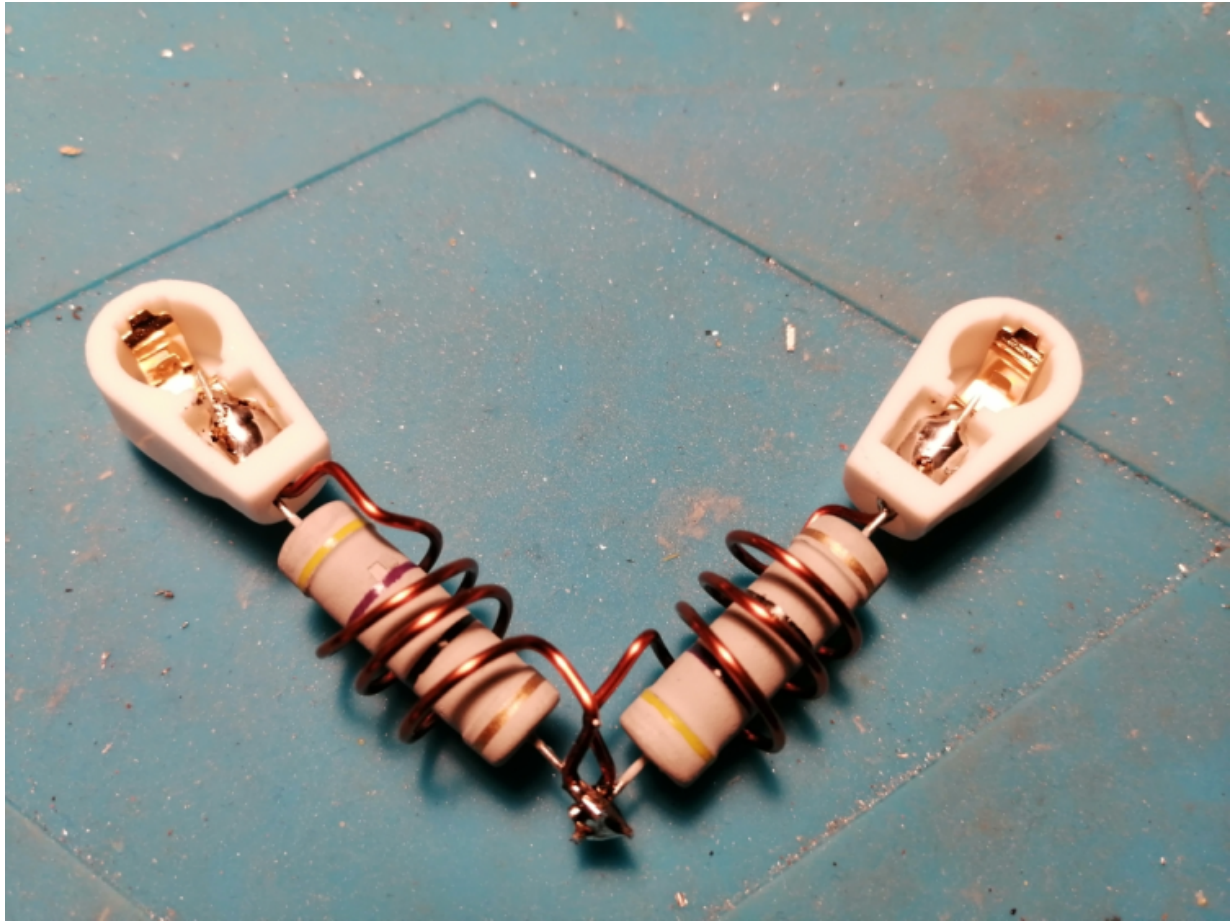
PARASITIC SUPPRESSOR

Parasitic suppression is the insertion of RF current with a high impedance circuit in order to filter the fundamental to avoid Parasitic spurious for frequencies above 100 Mhz. In addition this circuit is assisting to prevent tube/valve nasty self-oscillation (or unwanted oscillations especially when using 2 tubes in parallel). Parasitic oscillation takes place where the tube's output capacitance resonates with lead inductance between the plate and the Pi network tuning capacitor.

In order to reduce the tendency of an active device to oscillate at/near its frequency limit, a parasitic suppressor reduces gain above the highest frequency of operation by adding series reactance (XL). A low resistance (with low reactance) is then placed in shunt (parallel), to broaden the response. This circuit will act as a short cut for unwanted frequencies

Non-inductive resistor shall be used

47R 5w resistor / 3 turns 0.8mm



RECONDITIONING EL/PL 519 or 509 TUBES

Few months ago i manage to grab from a guy and for free some EL509 and 519 tubes and the guy told me they are mostly dead and do not provide any power. Btw i grab them in order to perform a recovery process and reactivate them.

At home , i check them and 3 tubes are really dead since the filament is now powered anymore but the 5 of them seems to be healthy and no shortcut between grid , cathode and filament are noticed. almost no output power was noticed for the 5 remaining EL509/519 tubes

The recovery process is pretty much simple for this kind of tube and in fact what we need to do is to reactivate them thanks to the chemistry. After many years in a storage , tubes are producing non-necessary gaz inside and the vacuum will be not perfect . Heating up the tube will remove the non-necessary gaz inside and the vacuum will be optimum. This process will optimize the cathode and will prevent some arcing due to improper vacuum and residue of gas inside the tube.

-Disconnect the plate voltage and heat the tube for at least one hour with the filaments without any fan. Myself i heat up during the filament during 3 hours. If you are not in a rush , warm it during 24 hours.

-Reconnect the plate , activate the fan and get the tube to draw the specified idling current while holding down the PTT switch. The idling for this kind of tube is about 20 to 25 ma , so you need to insure this current is stable and in the range of 10 up to 40ma. If no current or with a high current , the tube is dead and there is nothing you can do about it. Then leave to stand for at least an hour (3 hours will be perfect). To prevent any oscillation during the process, the output should be connected to a dummy load. After this and if everything remains stable the drive may gradually be increased to the specified value or to the maximum plate current. This process named also the "Tube cooking" during the old time will reactivate a chemical diffusion process and gas in order for electron to circulate between the grid , cathode and anode without any contamination. Bear in mind a vacuum valve is not perfectly waterproof and some contamination may occur. The tube cooking process will assist the cleaning of the impurity inside your tube. The is process is really important because if some contamination occurs , the impurity may involve some flash-over between the grid and cathode or with the plate.

The main result was pretty successful and the 5 tubes were back in life and will provide spare or maybe the oportunity to build another amplifier.

The good thing about EL509 and EL519 is they can be mixed together without any problem . In fact the pairing between them is not really mandatory.

Pamper your Tube

What i learn from the Navy as a radio engineer :

-The worst threatment for a tube is the frequent switching on and off . The filament is not able to be warm up and cool down too often. In the Navy we had some tube transmitters using QB4-1100 ,4CX1500, 3CX1500 and 4CX5000 and they are permanently transmitting , obviously with a proper cooling system. The tubes for these transmitters can last for 8000 up to 10000 hours without any issue and even after we replace them , the tubes still in the very good condition . How it is possible : simply because the filament are never switch off and the cooling system was good.

Some people think this is the number of hours a tube can last. in fact it is mostly (but not only) related to the number of time you switch on and off the amplifier . If you know that you are using your amplifier many times during a day , do not switch off the amplifier , just leave it like that.



The Fan is on the top of the tubes (forced cooling with a 220vac fan)

AMPLIFIER performance

For testing purpose only with 30w input the amplifier is able to provide up to 450w on 40m band, therefore you are reaching at this stage the limitation of the tubes and **not recommended**. The IMD are not compliant to FCC , ITU or your country rules apply to radiocommunication.

The maximum input power is about 20w/30w in order to keep the spectral purity.

The maximum Output Power is from 80m up to 20m , above the output power is decreasing from about 10% up to 50% on 10m band

-3 to 5w = 70 to 200w (Which is perfect for my SDR transceivers)

-10 to 15w = 200 to 280w (Which is perfect with my UBITX)

-15 to 20w = 220 to 350w (The IRF530 Amplifier as a driver with both UBITX and SDR)

IMD3 are about -40dbm down to -47dbm and no spurious or TVI at home or the neighborhood are notice.

Performance in details

All my TRX are equipped at the output with In-Line *Low Pass Filter* in order to drive the amplifier. The output of the amplifier is also equipped with In-Line *Low Pass Filter*.

The cut-off frequency for the filters is 54Mhz with at least 55db attenuation.

Output Power with brand new tubes 6P45S from Ukraine

The following table is the test i perform with CW pure carrier on a dummy load and obviously it is the CW PEP power ((Peak Envelop Power) = Average power with a CW pure signal). So it is not so bad considering this amplifier is using only two 6P45S.

input	80m	60m	40m**	30m	20m	17m	15m	12m	10m
4w	100w	110w	120w	120w	110w	80w	70w	60w	60w
10w	180w	190w	270w	230w	220w	140w	110w	100w	110w
15w	240w	250w	330w	270w	270w	200w	170w	150w	150w
<u>20w*</u>	290w	300w	350w	340w	340w	300w	240w	200w	170w

All test were performed with a dummy load and CW pure carrier

Note * : **20w input** is the maximum power this amplifier can handle. Above will result IMD and splatters

Note** : On 40m band the output power is astonishing, In SSB/CW modulated , the peak output power is about **350watts** with only 20/22w input. (The Vpeak is about 380volts)

All measurements are checked also with my Digital Oscilloscope using a probe.

(Vpeak X Vpeak) / 400 will provide you the output power (This formula is for 50 ohms).

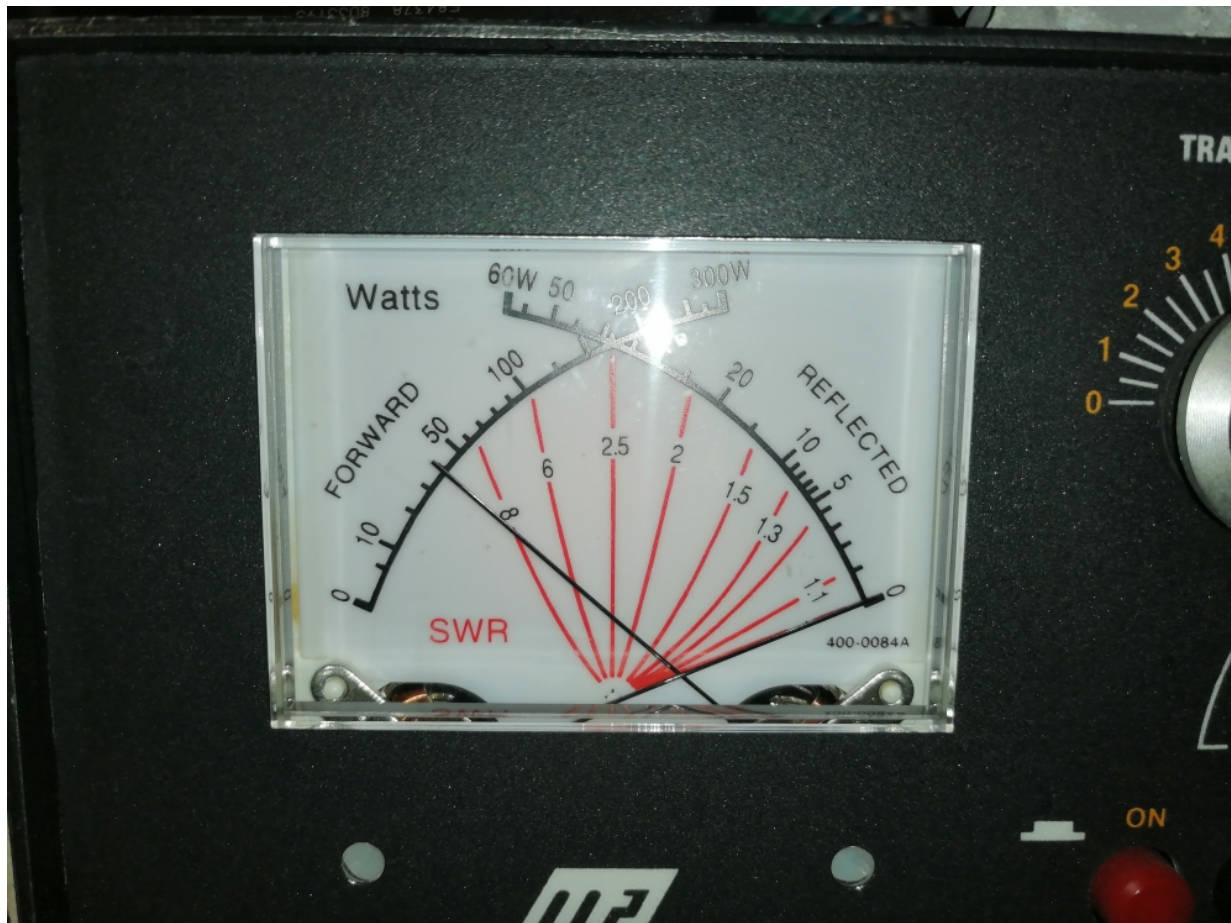
Remember, Vpeak x 2 = Volts P-P

Results with pictures

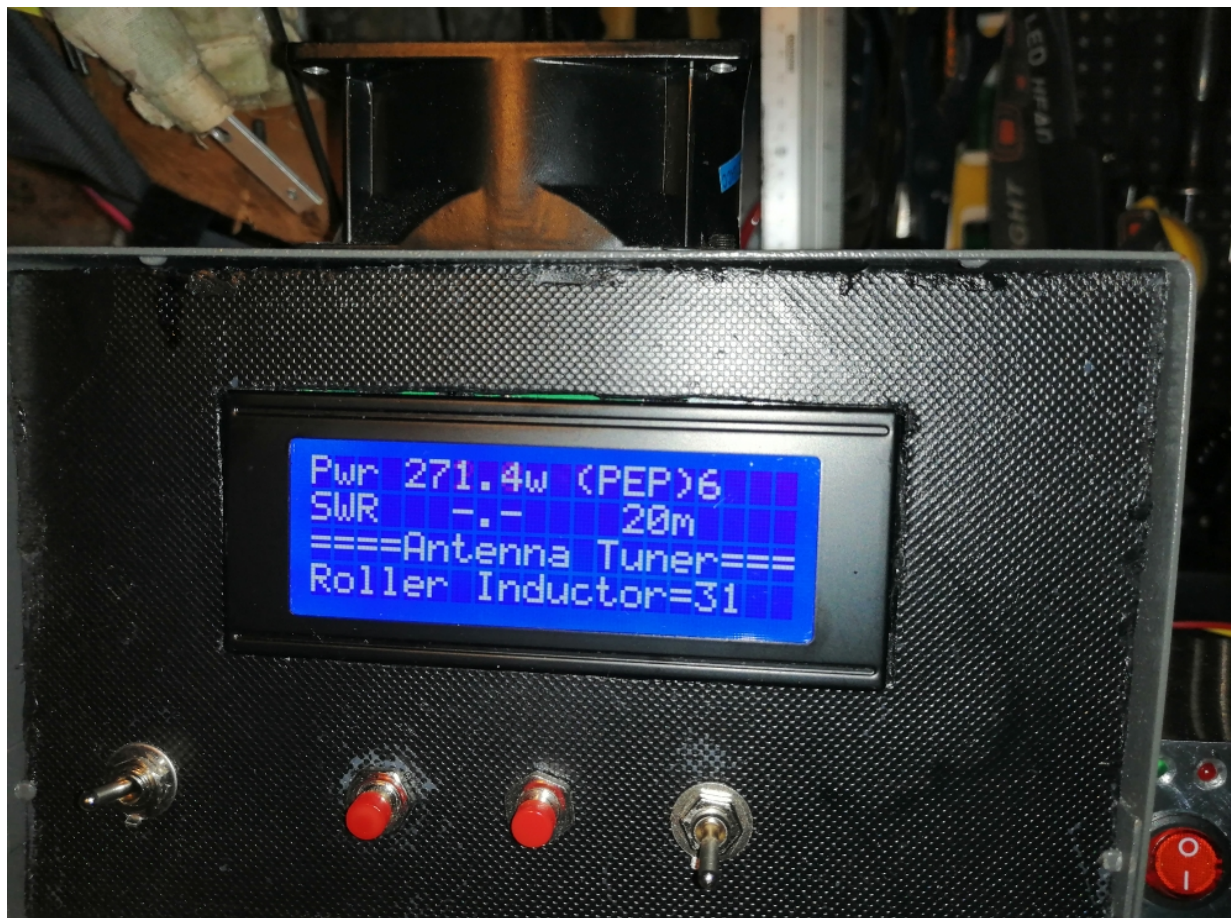
After finalizing the input circuit , the PI Network and the biasing , the results are really great. Tube temperature is OK and input SWR is not so bad.



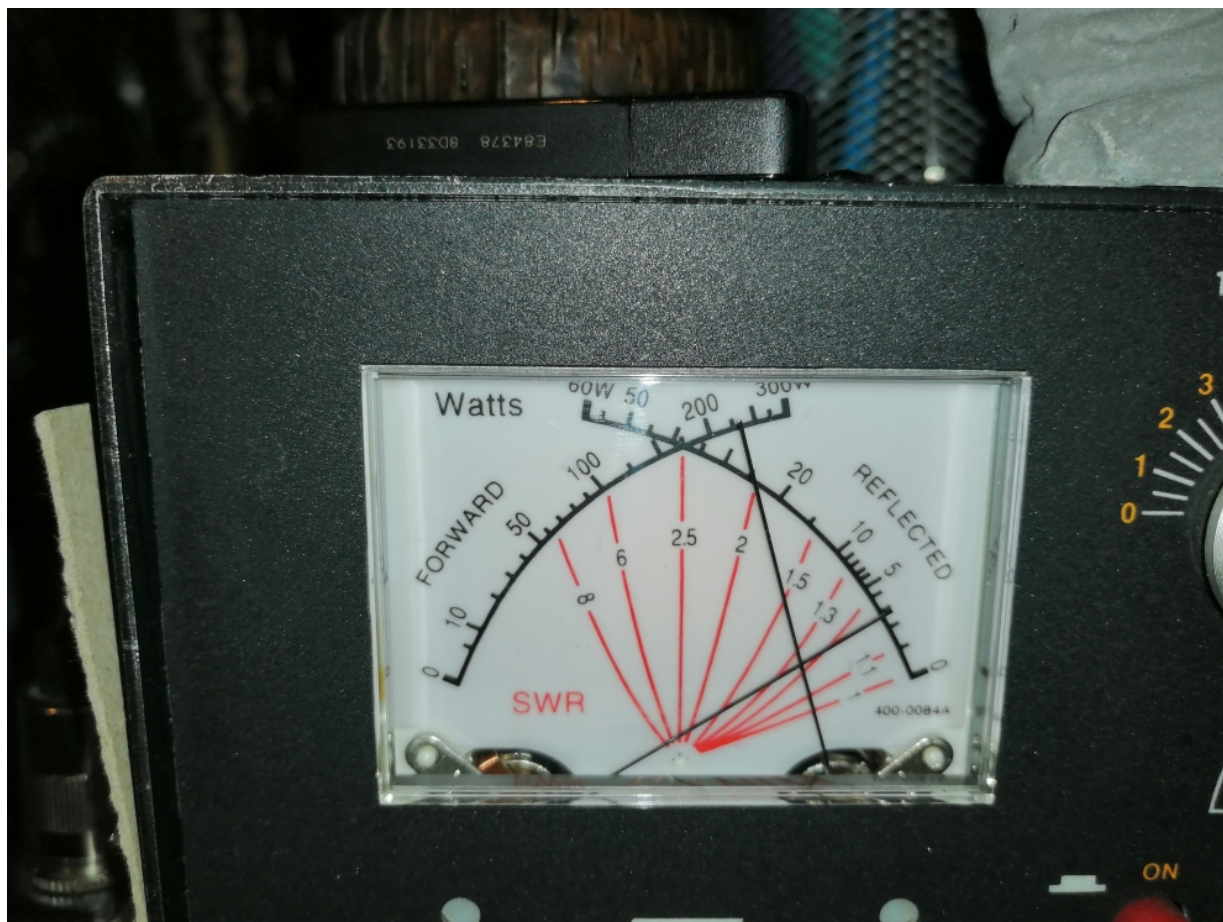
3w input 140w output on 20m



2W input with a great SWR on 20m band



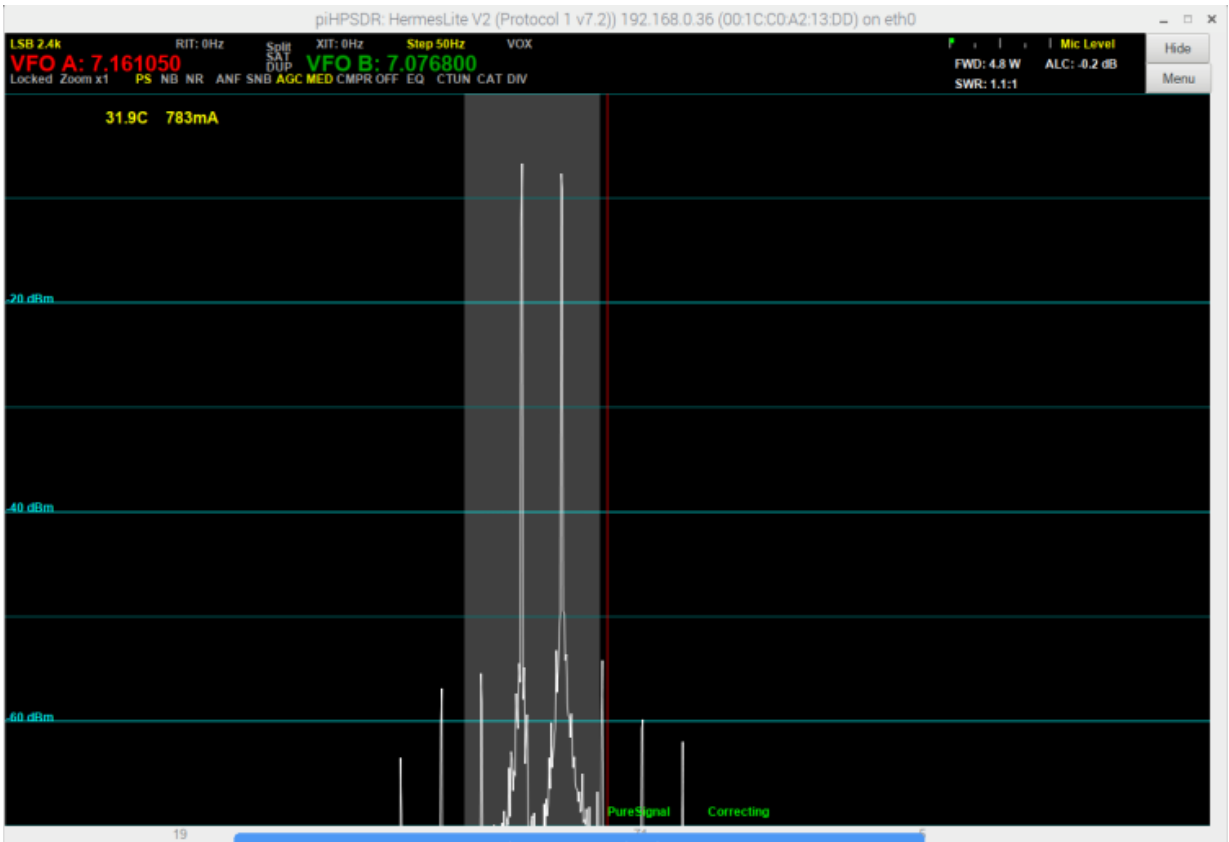
15w input 280w output



Great SWR with 10w input on 30m band

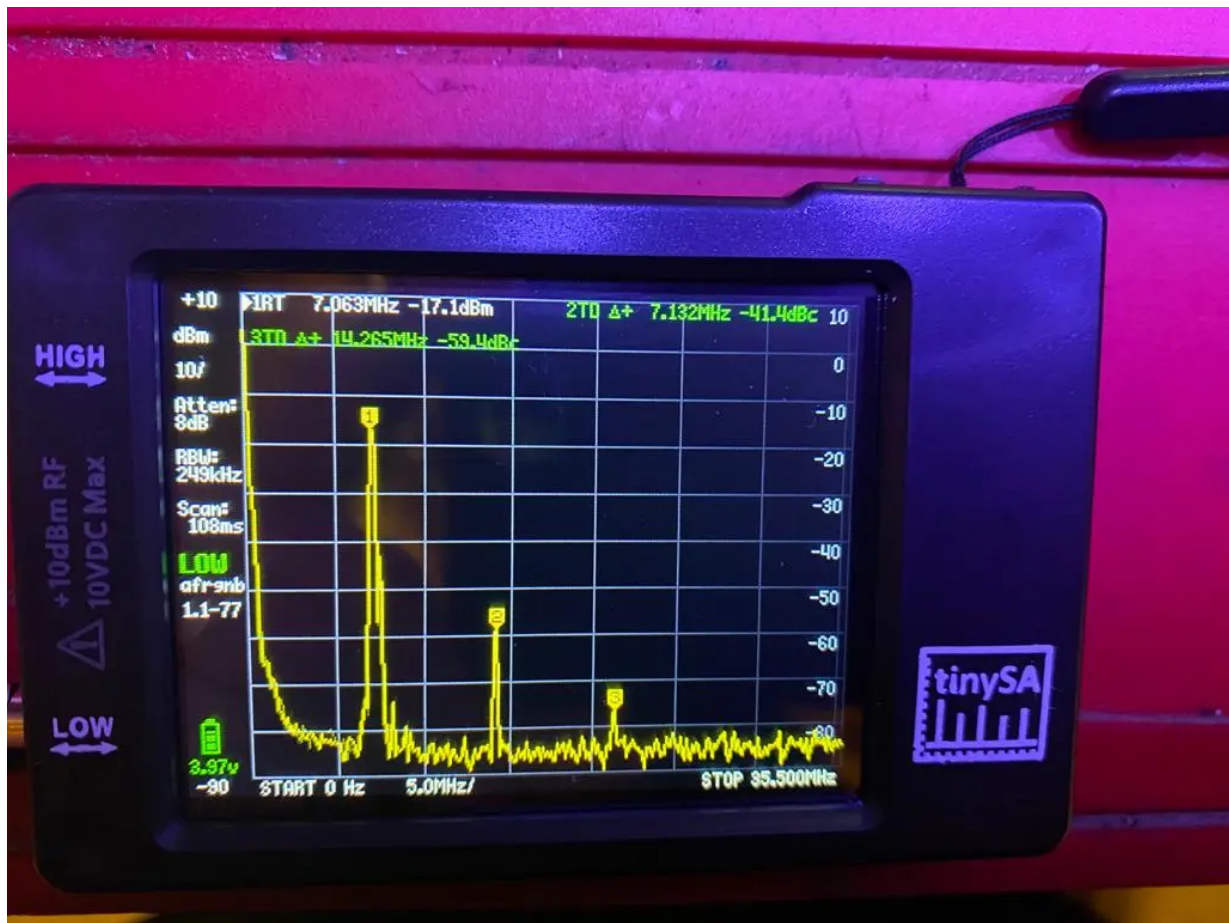


with 20w power input



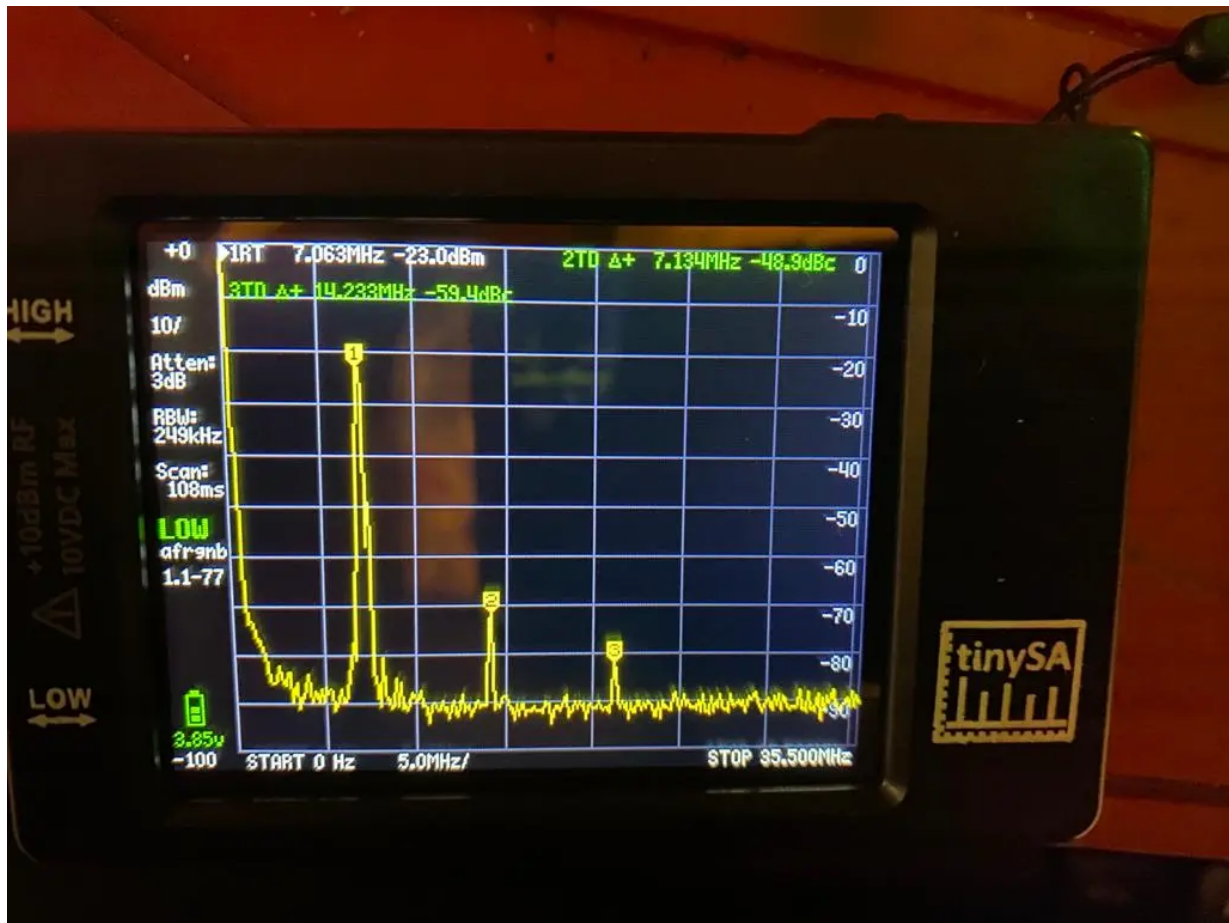
Spectral Purity on 40m with 250w output with very good IMD

At 350w the harmonics are barely acceptable



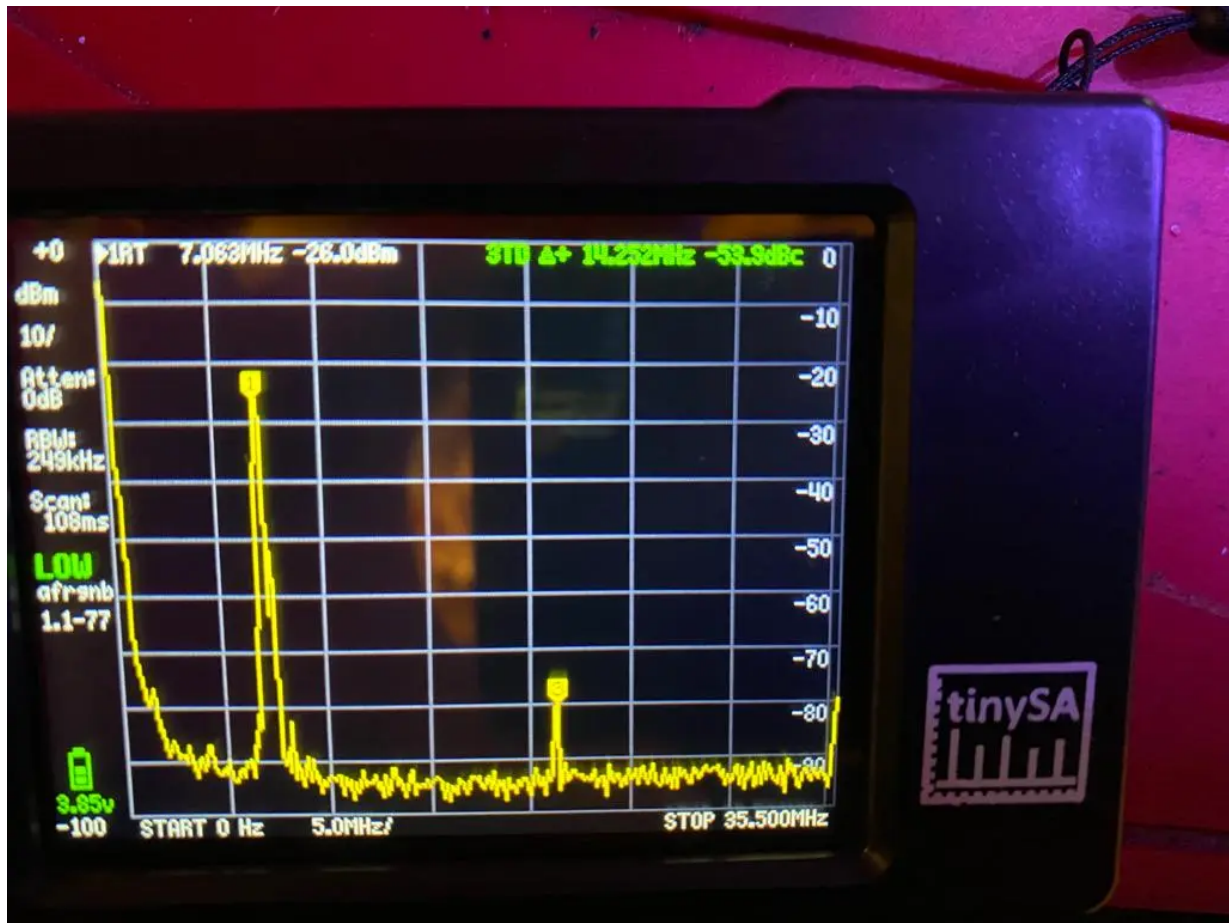
350w Output

With 300w , the harmonics are acceptable and the spectral purity is not bad at all



300w Output

With 250 up to 270w the spectral purity is excellent



PI NETWORK for tube amplifier and “Q” factor

The “Q” factor is the reactance matching network using a RLC output circuit. The main purpose of a RLC output circuit for tube amplifier is to adjust the load impedance and the source impedance in order to transfer the maximum energy without any attenuation on the fundamental and generating harmonics to the antenna. This circuit is deeply link to frequency , bandwidth and filtering).

The PI network is a symmetrical circuit and Q factor is the way to measure loss in a resonant circuit . “Tuning” a PI Network is the correct sentence since it is deeply link to a Frequency.

Since a PI network is an attenuator, this feature will assist the fine tuning to filter and attenuate harmonics.

Obviously , I am not going to details all calculation and theory regarding this kind of circuit but focus on what we are looking for the implementation of this circuit in an HF power amplifier.

The “Q” factor is a standard threshold defining the quality of a PI network and the ability of this circuit to transfer energy from the tube plate which have its own capacitance and reactance , through a RLC circuit to the antenna which have also its own reactance and capacitance.

To be straight forward as a common standard , a “Q” factor of 10 or 12 is considered as a great result. To achieve this goal , the choice of the component especially , the variable capacitor will be the key and critical. Bear in mind that a Q factor will be perfect if your circuit is perfectly tuned your circuit at the resonant frequency providing low current on the capacitors and attenuating the harmonics efficiently. With the example below , the Q factor is also high but the circuit is not matching perfectly on the resonant frequency and providing very high current with losses and a high Q.

Generally we prefer to say the best Q and not the highest Q is the Best.

As I mention above with soldering the band switch directly is improving significantly the dielectric and contribute to enhance que Q factor significantly

As an example, I will take my amplifier with is built with a 50pf and 450pf variable capacitors including of course the inductor. Using EL519 is providing some constraints regarding the output capacitance value.

After saying that , we are able to say that this PI network using this range of value will not able to provide the best Q factor in the all spectrum. Considering the high output capacitance of the EL519 tube , the “tuning” of the PI network for frequencies above 14Mhz is tedious with the result of high current and losses, which is demonstrated in the table (Preformance details)

To be perfect with using 2 EL519 , my PI network should be tailored as described hereafter.

anode load (R_a) according the anode voltage and current	$V_a = 900 \text{ V}/0.5 \text{ A}$: $R_a = 900 \div (1.87 \times 0.5) = 932 \Omega$.
The anode-circuit must transfer energy and the circulating current amplification factor Q will assist to suppress the generated higher harmonics. A loaded-circuit Q of 10–12 will provide an efficient suppression of harmonics and practical values of C and L.	$Q = 5$ up to 10,
loaded circuit-impedance	$Z_a = R_a \div Q = 932 \div 10 = 93 \Omega$.
The tuning or plate capacitor-C (=Ct) is mostly responsible for circuit-resonance, which occurs at the frequency we are targeting	$Z_{ct} = 93 \Omega$.
For 28 MHz this becomes:	$C_t = 10^6 \div (2\pi \times 28 \times 93) = 30 \text{ pF}$ (This is good since i am using a 50pf capacitor) but unfortunately the high anode capacitance from the tubes is involving a capacitor range from 3fp up to 50pf and my capacitor minimum value is 12pf which is too high and i will need to compensate with the inductance value. The Q factor then will obviously decrease
Anode Impédance	$93 \div 50 = 1.85$ Which is terribly low
Anode capacitance	$\sqrt{1.87} = 1.32$.
The loading capacitor (=C_L), should have a value of :	$30 \text{ (pF)} \times 1.32 = 40 \text{ pF}$.
We need to calculate the suitable coil for 28Mhz	$R_a + R_{load} = 93 + 1.87 = 95 \Omega$.
Inductance (T200-2)	$L = R_s \div 2\pi f = 95 \div (2\pi \times 28) = 1.5 \mu\text{H}$. And unfortunately I do not have this inductance value since the band switch is directly solder on the core . I did a test with simply a 2 turns and half coil diameter of 3cm,

	3cm long (I try also with 2 turns only 1uh roughly) and I have a perfect tune for 28 Mhz and the power is climbing up to 270w .
--	--

My PI network regarding the input capacitor is not really matching and resonnant for 28Mhz and unfortunately my coil is not providing the correct inductance value for the frequencies above 25Mhz and in addition the high capacitance at from the Tube anode is not helping either resulting very low Q factor and poor efficiency. For this frequency , the PI network is not matching and i will need to add a small 2 to 5 turns coil in order to make it perfect and this is what i did in order to experiment the above calculation. The main issue is : i do not have the space for a 2 or 3 cm coil . This amplifier is a compromise and maybe one day I will install it into a bigger casing which allow me to design a suitable PI network for the upper band especially the 28Mhz. Btw , 100w on 28Mhz is not so bad at all and combine with my SB200 iconic amplifier i can have up to 550w on 28Mhz.

SETUP your PI NETWORK

The above calculation is assisting you to build your PI network using the correct Capacitor and inductance value. Now it is time to setup the PI NETWORK according the bands your are using.

The following methodoly is used for all my tube amplifiers for many years now.

You will need simply a NANOVNA or an analyzer like the MFJ259

We need now to determine the anode impedance and generally speaking you can use the following formula:

$Z_a = V_a \div (1.87 \times I_a)$, in which:
Z_a = the (common) anode (or plate-)impedance, (in Ohms),
I_a = the (total) anode current at max. power, (in Amperes),
V_a = the applied anode voltage, (in Volts).

According this amplifier :

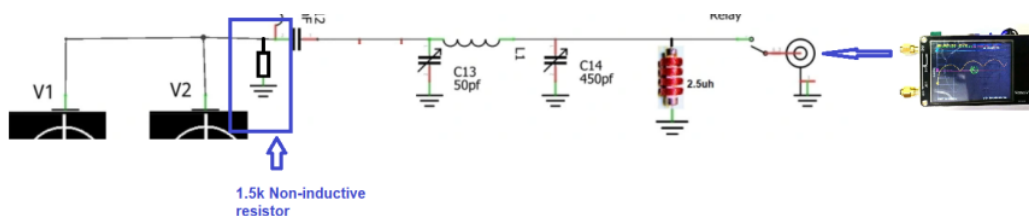
- $I_a = 350\text{ma}$

- $V_a = 1000\text{vdc}$
- $I_a = 350\text{ma}$
- $V_a = 1000\text{vdc}$
- $Z_a = V_a \div (1.87 \times I_a) \rightarrow 1000 \div (1.87 \times 0.350) \rightarrow Z_a = 1.5\text{k}$

The process :

- The amplifier and tube are switch off
- The anode high voltage should be disconnected
- The tubes are connected to the PI network
- The NANOvna is connected a the output
- we use a 1.5k resistor in parallel with the anode of both tubes
- a Wire with a clip to tap on the different area of the coil and inductance

The process is is simple and you just need to clip the wire on the inductor/coil , move the plate and load capacitors in order to achieve $Z = 50\text{ ohm}$ on the NANOvna. You need to repeat it for each bands and note the position of the clip on the inductor/coil. When done you just need to finalize the setup with a properly solder wire from the band switch and test it in normal condition with all voltage applied to the tube.



The main benefit of this methodology is the setup can be performed without any high voltage on the tube . In terms of safety it is really good.

Summarize

The experimentation with different biasing and PI network was really interesting and the final result is really exceeding my expectation in particular for the 3 main bands i am using (40, 30 and 20m bands).

Building this amplifier was fun, obviously the EL519/6P45S Tetrode tube is not the best performer and choice but with some patience, experimentation and testing , you can achieve a decent result . The modulation and HF purity are great and so far even for digital mode this amplifier is able to sustain long TX keying without any temperature issue since i put some effort on the forced cooling system with a big 220V fan just on

the top of both EL519 (Just remember , for this kind of tube , a forced cooling is **MANDATORY**)

The lack of space was a real challenge for the implementation, especially for the front panel but so far i manage to implement everything and still need to work on the 10m band to achieve better performance.

As mentioned above , since all parts are coming from old Citizen band amplifier, the final result is really cost-effective. With commercial product to achieve the same result you will need to spend above 500 Euros for sure (The overall project cost is about 100 Euros). This kind of project will bring you to the tube technology. Vacuum tubes still reliable if you need some QRO output power.

The size constraints is limiting the frequency range and currently the amplifier is working perfectly from 80m up to 15m bands , i still have resonant frequency constraints due to the final PI network design for the 10 meter band. An additional coil will compensate the capacitance on 10m band. I still scratching my head regarding the implementation of an additional coil in the final PI Network.

Watching tube amplifier glowing in the dark is something unique with a very special appeal and building your own device is always something interesting.

100 up to 300watts , believe me is more than enough to enjoy Ham radio communication and QSO with a good antenna. Most of the time i am running this amplifier with 200 up to 260w and this is more than enough.



260w on 20m band

EL519 – 150W Amplifier

Since all my TRX are low power , i was thinking to build or refurbish a tiny tube amplifier . My target is to provide an output power from 60 up to 120w . Using one EL519/6P45S Tube will allow me to reach my goal.

This Amplifier is my main one and use it on daily basis. The output power is more than enough according my needs.

You can find very usefull information in the following website for single valve amplifiers:

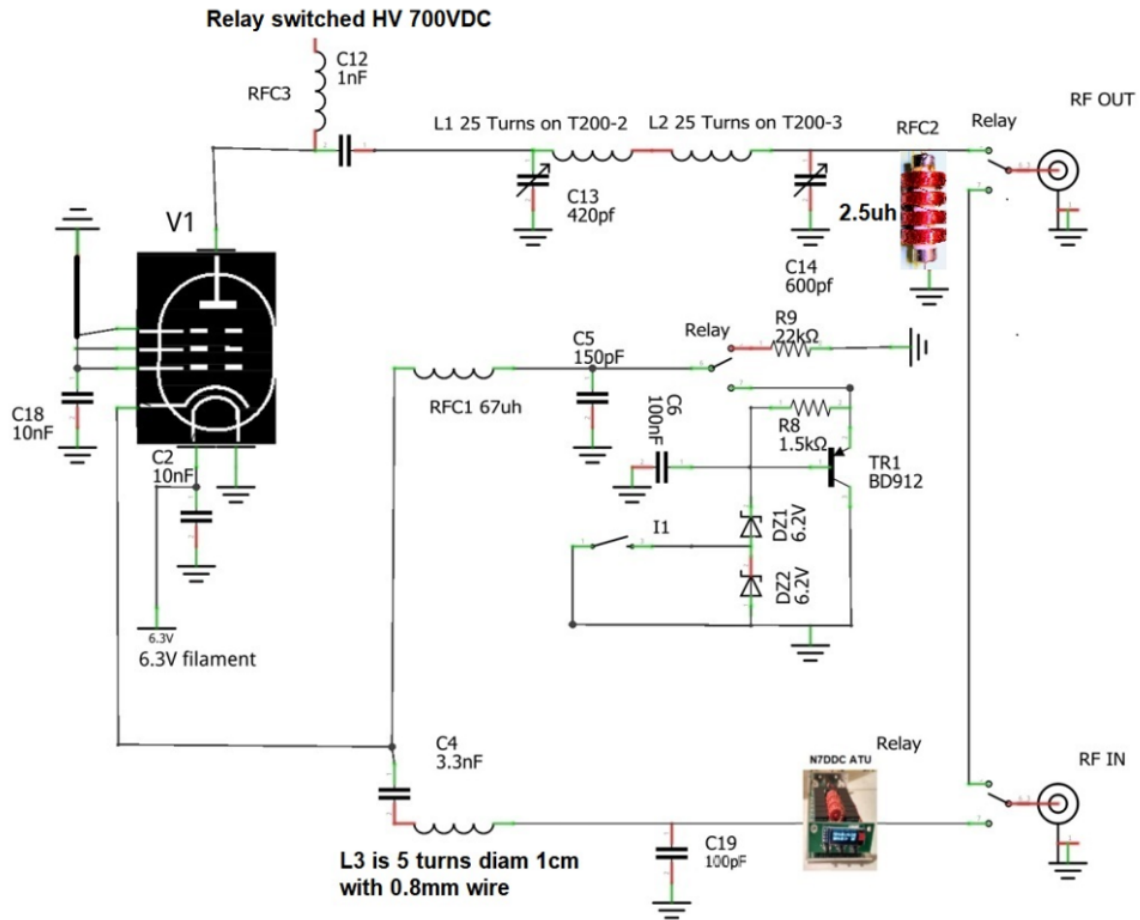
<https://f6crp.pagesperso-orange.fr/tech/PL159.htm>

<http://www.qrp4u.de/docs/de/PL519/index.htm>

<https://pa0fri.home.xs4all.nl/Lineairs/Erinear150/fri150eng.htm>

Few days ago , i manage to recover a very old citizen band amplifier from Zetagi . This is the BV-131 using one tube only. The amplifier was in a good shape and the refurbishment and conversion to access all amateur bands was straight forward.

The most amazing is according the plate voltage is only 700vdc which is very low.



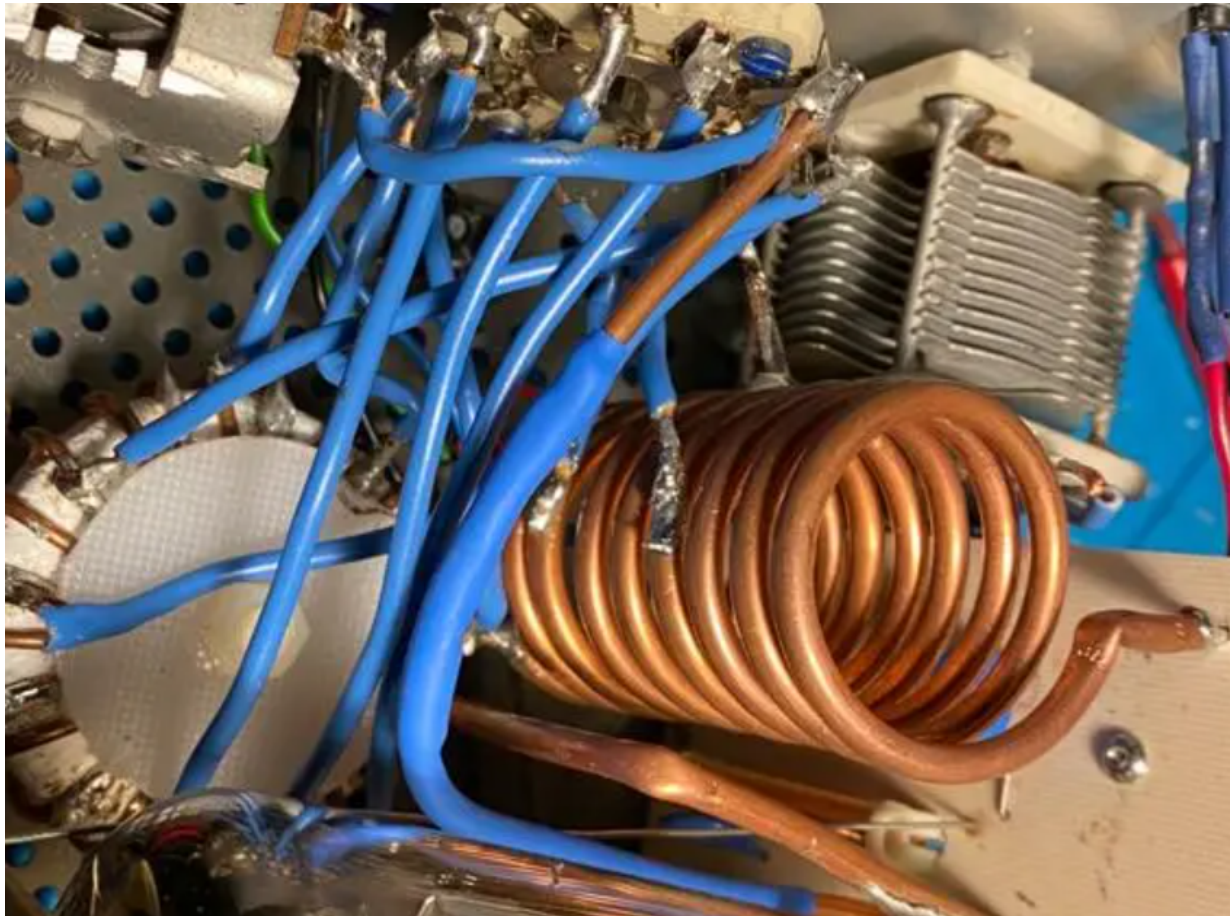
The principle is identical regarding the main schematic and the only difference is regarding the PI network. Since i have some room and space inside the casing , i manage to integrate a classical PI network .

Amplifier Controller

I use exactly the same from the 300W Amplifier.

This little circuit is to provide the Relays switching from the PTT. The voltage is from the 6.3vac from the filament with a voltage doubler. This circuit is also controlling the main and HV Relays.

Output PI Network and RFC



The PI network is using a T200 core with 25 turns with an additional inductor 5 cm diameter with 9 Turns .

RFC2 : <https://paraset.nl/sh/product/rf-choke-25-mh/>

L3 and RFC1 : <http://www.elektrodump.nl/nl/hf-smoorspoelen/1690-hoogfrequent-smoorspoel.html>

The biasing circuit is also identical and using 2 zener (6.2V) diodes but without any switching for the diodes.

The plate capacitor is about 420pf 1kv

The load capacitor is about 600pf 500v

Obviously , i am using a forced air cooling with a 220vac fan on the top of the tube.

Performance in details :

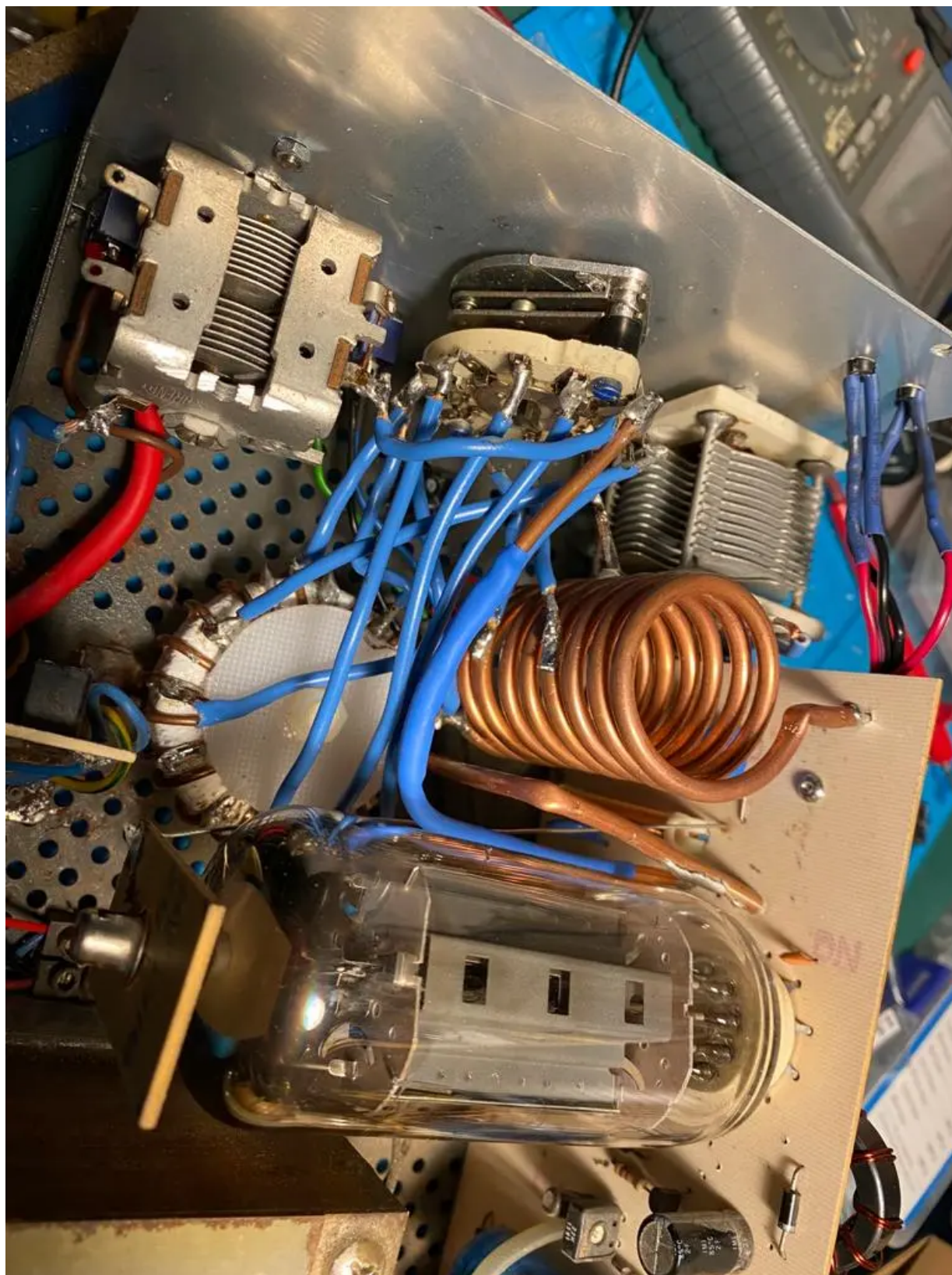
So it is not so bad considering this amplifier is using only **a single** 6P45S with 700vdc for the plate (anode)

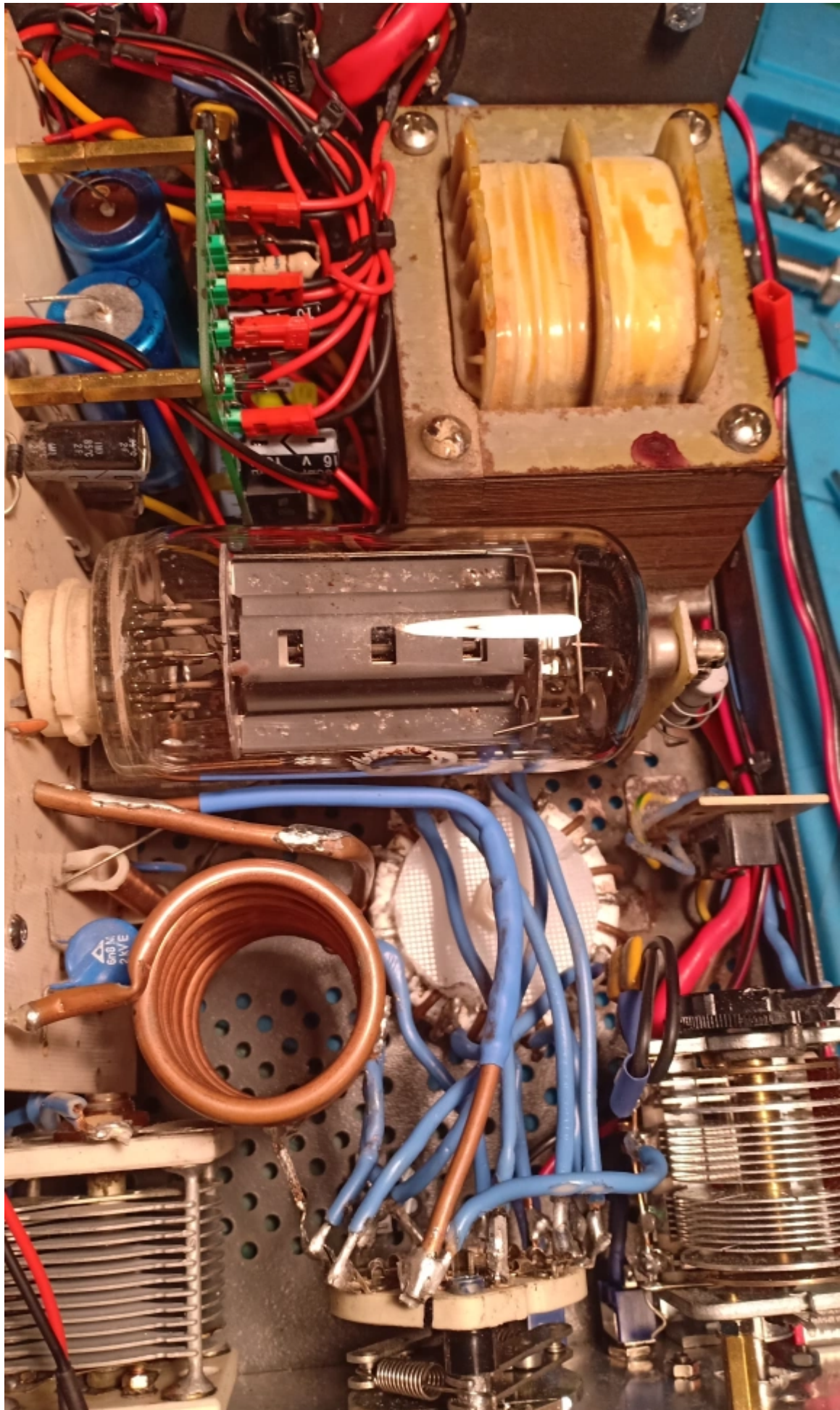
input	80m	60m	40m**	30m **	20m	17m	15m	12m	10m
3w	75w	70w	80w	80w	60w	60w	60w	60w	60w
5w	90w	90w	120w	130w	100w	100w	110w	90w	70w
7w	120w	110w	140w	140w	120w	120w	120w	110w	90w
10w*	145w	140w	160w	170w	140w	140w	130w	125w	120w

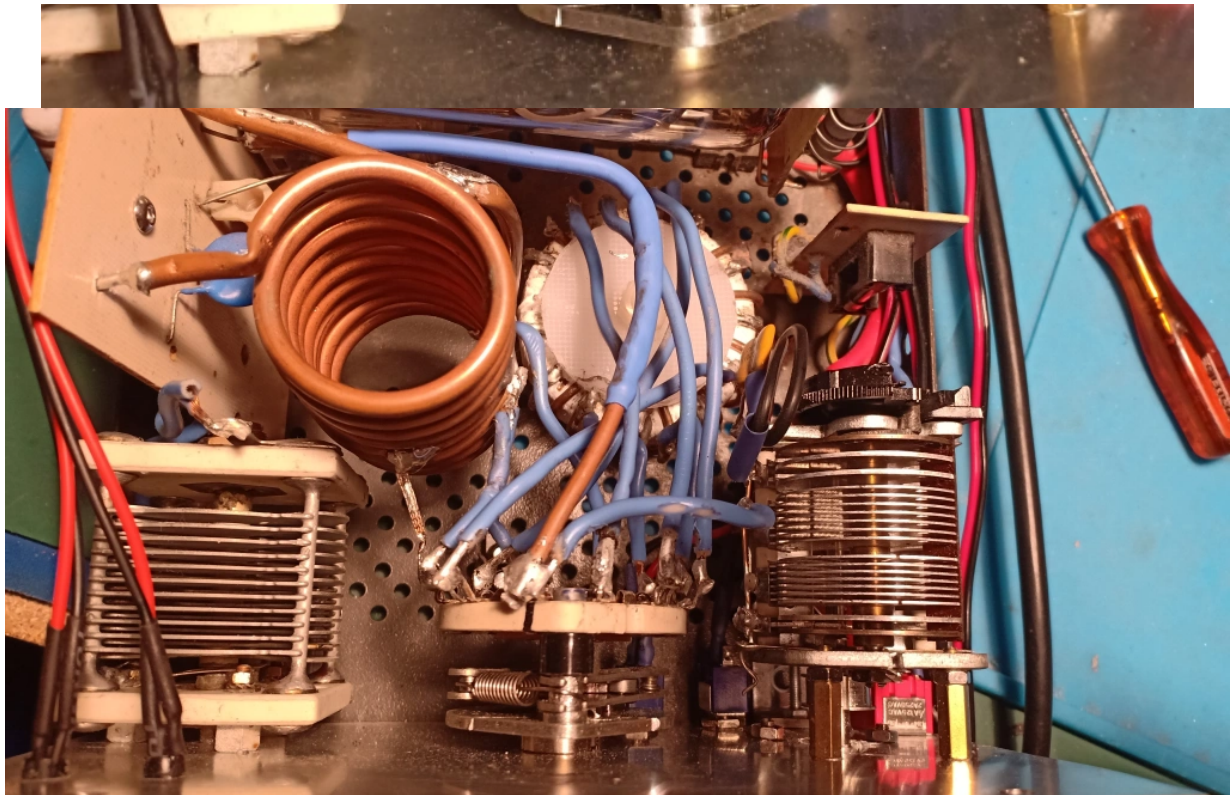
All test were performed with a dummy load and CW pure carrier

Note * : 10w input is the maximum power this amplifier can handle. Above will or may result IMD and splatters

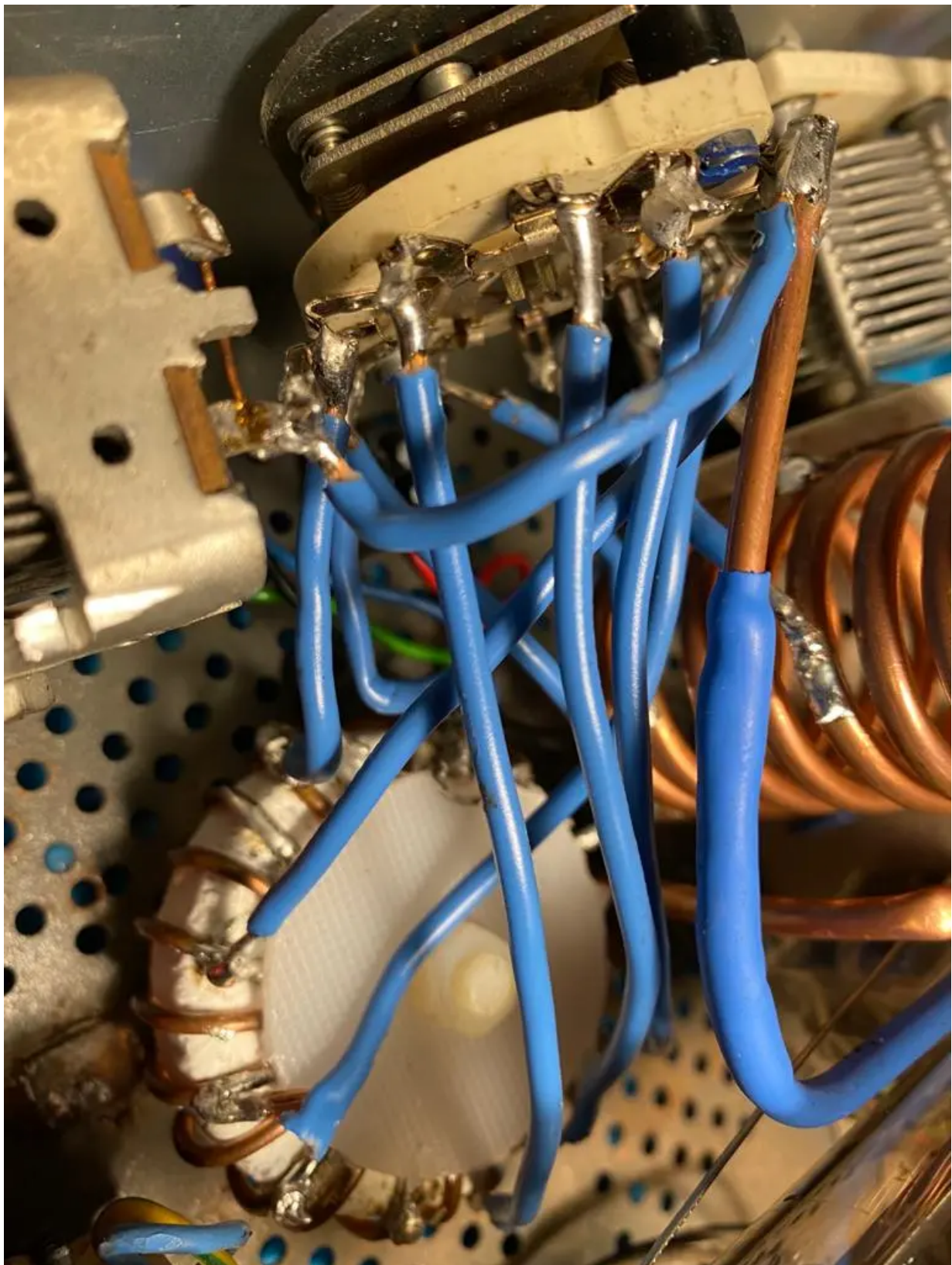
Note :** On 40m and 30m bands the output power is astonishing, In SSB/CW modulated , the peak output power is about **160watts** with only 10w input (The Vpeak is about 250 volts)







The input variable capacitor is only a 1kv and output a 500v since the power and HV are not so high.



The biasing circuit (The most important part for linearity, IMD and modulation quality)

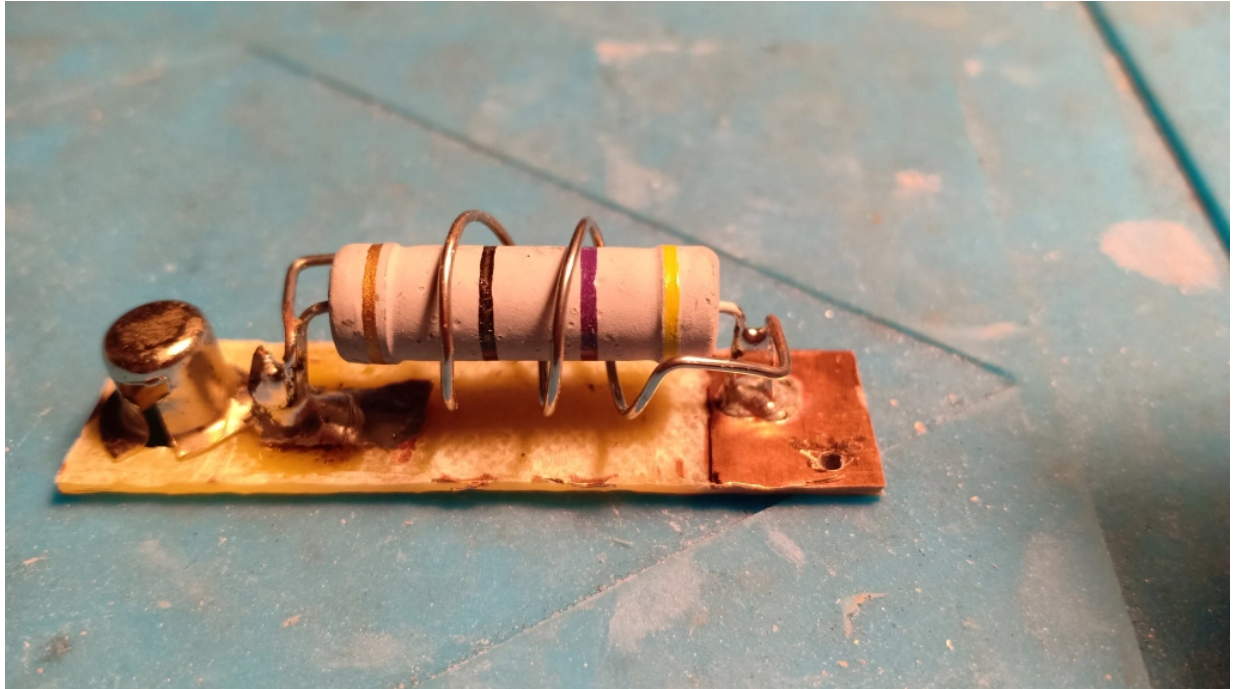


Note at the bottom of the picture the RFC and filter choke at the amplifier output. This RFC is acting as a fuse in case of short circuit with the high voltage and but also as a choke filter . For the biasing circuit i am using two 67uh chokes (the biasing relay is not in the picture).

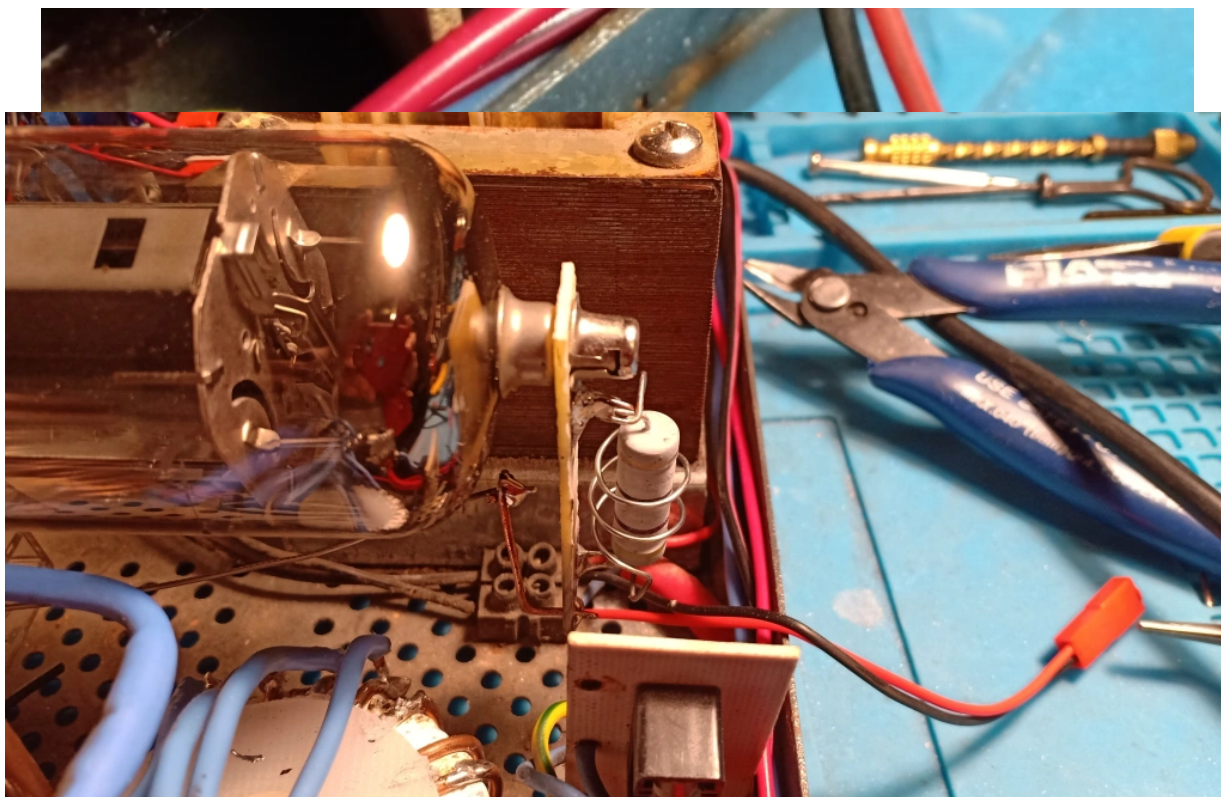
The idling (Quiescent) current is about 30ma. Bear in mind the quiescent current and the biasing are the key for a clean and nice linear output signal and your neighborhood will appreciate.

PARASITIC SUPPRESSOR

I am using 2 turns copper wire around a 3 up to 5 Watts resistor. Non-inductive resistors shall be used







The Amplifier size is really reasonable , considering it is solid stade without any additional power supply , it is not so bad.





The forced air cooling fan is bulky but terribly efficient . Even during long PSK31 QSO , the amplifier remains just warm .





Integration of the N7DDC ATU



The integration of the N7DDC ATU in the circuit input is providing a great linearity for the amplifier. As mentioned above, a good input circuit and adaptation is assisting for the output power. The OLED display is providing a great monitoring input data (Power, capacitance, inductance, SWR and losses). From 80m up to 10m bands, with the ATU the SWR at the input is less than 1.3:1, therefore for the 40m and 30m in fact the ATU is not necessary since the input impedance is already close to $50 \pm j0$ ohms with an almost perfect SWR at the input.

Outcomes

A really great project, straight forward and this amplifier is working really well. Most of the time I am using it with about 80 up to 120w output (ssb and CW) with a great spectral quality.

By far this is the amplifier I like the most. Not so bulky, easy to tune and very linear among the all HF band. The output power is just fine according my needs and roughly with only 3w input I can have from 60 up to 80w which is perfect.

I am using the amplifier a lot for FT8 with about 10w/30w output and PSK31 with 45w output.

I am still chasing on the net for a tiny VU-METER to monitor the biasing and idling current but also the high voltage. Since the amplifier front panel is not so big it is very

difficult to find a small or tiny Vu-meter to fit the front panel.

Total cost : **85 euros only**

CTE GALAXI 1000 REFURBISHMENT

Few months ago i manage to grab from a guy a very old CTE GALAXI 1000 which was used during the 80's . This amplifier was in an attic for about 20 years and was not working any more. I have it for free and manage to refurbish it.

The amplifier initial design using five EL519 with one as a driver. This amplifier is providing up to 700 watts. I remove the EL519 from the drive and use only the EL519 from the output (4 x EL519). I have replaced the EL519 with 6P45S to put this amplifier on steroids.

I use exactly the same design regarding the biasing and output PI network but due to high output capacitance using 4 tubes , i need to add some additional high voltage switched capacitors on the the Output PI network. i bought a N7DDC ATU as a kit and the ATU will be directly inside the enclosure to drive and tune properly the input from the transceiver. i am planning to add a 1602 LCD on the front panel to monitor the ATU.

The T200-2 is winded with 1.2mm copper wire with currently 25 turns

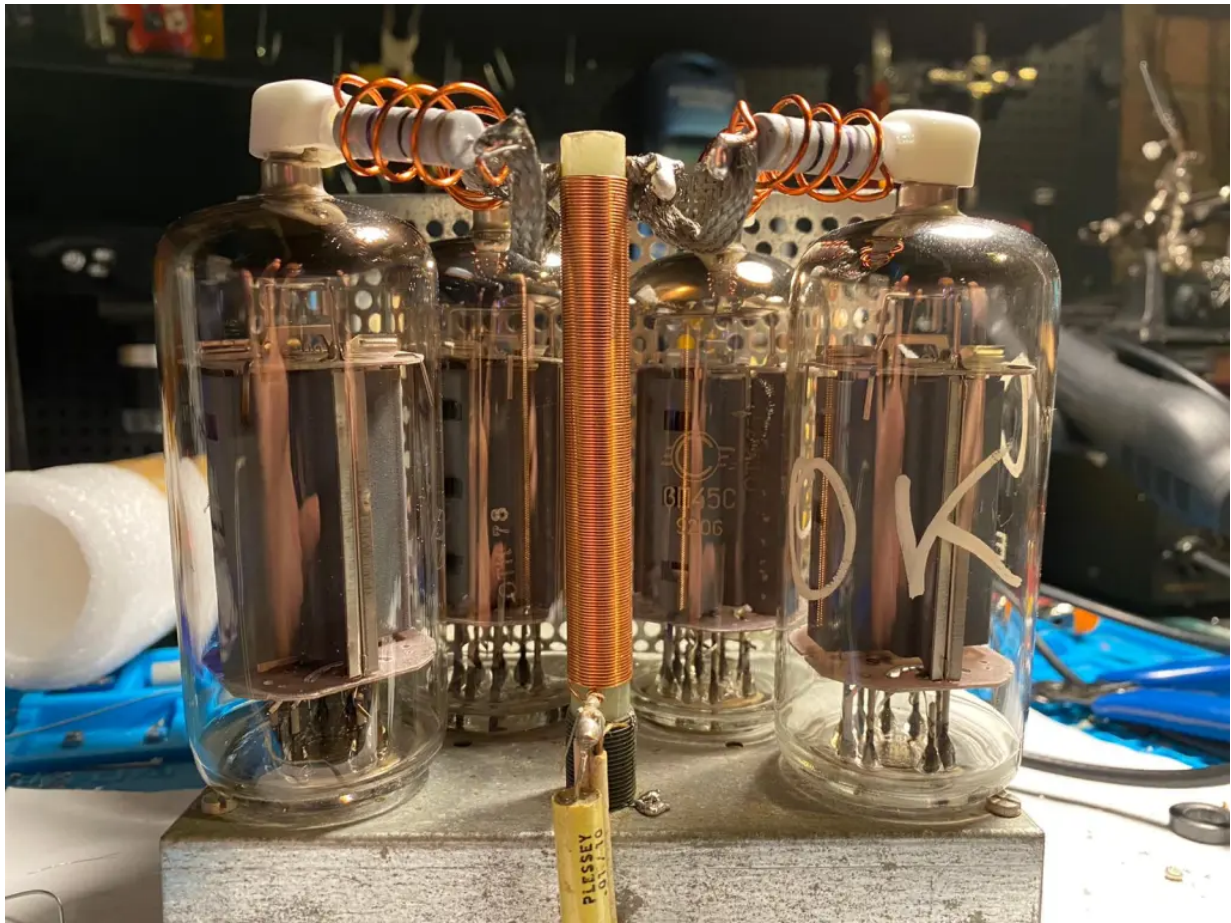
This Amplifier is working from 80m up to 10m bands.

With 20 watts input this amplifier is providing about 300w output and with 40w i have about 500w up to 600w output. you can feed the cathode at the input with up to 60 watts and keep a great spectral purity.

So i just need to finalize the N7DDC integration and to put a 220Vac Fan on the top of the tubes for an efficient forced cooling system (mandatory). when done i will finalize also the front panel labelling.

Some pictures for the work in progress;





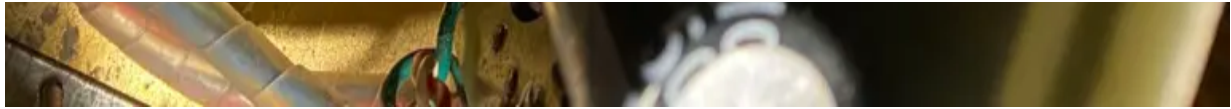


The PI NETWORK with a T200-2 Core



The high voltage PCB was totally refurbished with new Diodes and capacitor





On the top of the picture , the cooling fan automation system



Additional 200 and 100pf capacitor at the Output of the PI Network



Additional 300 and 100pf capacitor at the INPUT of the PI NETWORK

The work still on going but so far this amplifier is working very well . Definitly is more bulky but nothing to complain since i have it for free. With 50 to 70w input this amplifier is able to provide about 700w with ease.

CTE GALAXI 1000 FINAL TOUCH

i am done :

-N7DDC is implemented and in fact i do not need any display since this device is really reliable.

-Biasing and cutt-off are done, the Idling is about 120ma. For the Cut-off resistance i am using a 16k 2w resistor. For the biasing i am using the same biasing circuit from the 300w amplifier but i put 2 x 67uh inductors to provide a better insulation from the RF input.

-Input balun : i insert a 4:1 Balun in order to maintain a low input SWR . With the balun the input impedance is from 30 Ω - 47 Ω (On 30m band the impedance is about 47 Ω). The SWR value is below 2:1 from 80m up to 10m. So the N7DDC ATU is only triggered for some bands only.

-Forced cooling fan with automation system . The fan will also continue to work up to 3 minutes after the amplifier switch off.

-The amplifier is using 6P45S tubes



Biassing with the input transformer. The relay is not the picture and the 16k resistor is on the left of the picture. The BD912 is underneath the resistor



The final touch

Performances :

The following table is the test i perform with CW pure carrier on a dummy load and obviously it is the CW PEP power (Peak Envelop Power) = Average power with a CW pure signal. So it is not so bad considering this amplifier is using 4 x 6P45S.

input	80m	60m	40m	30m	20m	17m	15m	12m	10m
4w	45w	45w	45w	45w	40w	35w	40w	30w	20w
10w	180w	190w	220w	230w	220w	140w	110w	100w	110w
20w	300w	350w	330w	350w	270w	270w	270w	150w	150w
40w**	550w	550w	570w	590w	540w	550w	540w	500w	370w*

All test were performed with a dummy load and CW pure carrier

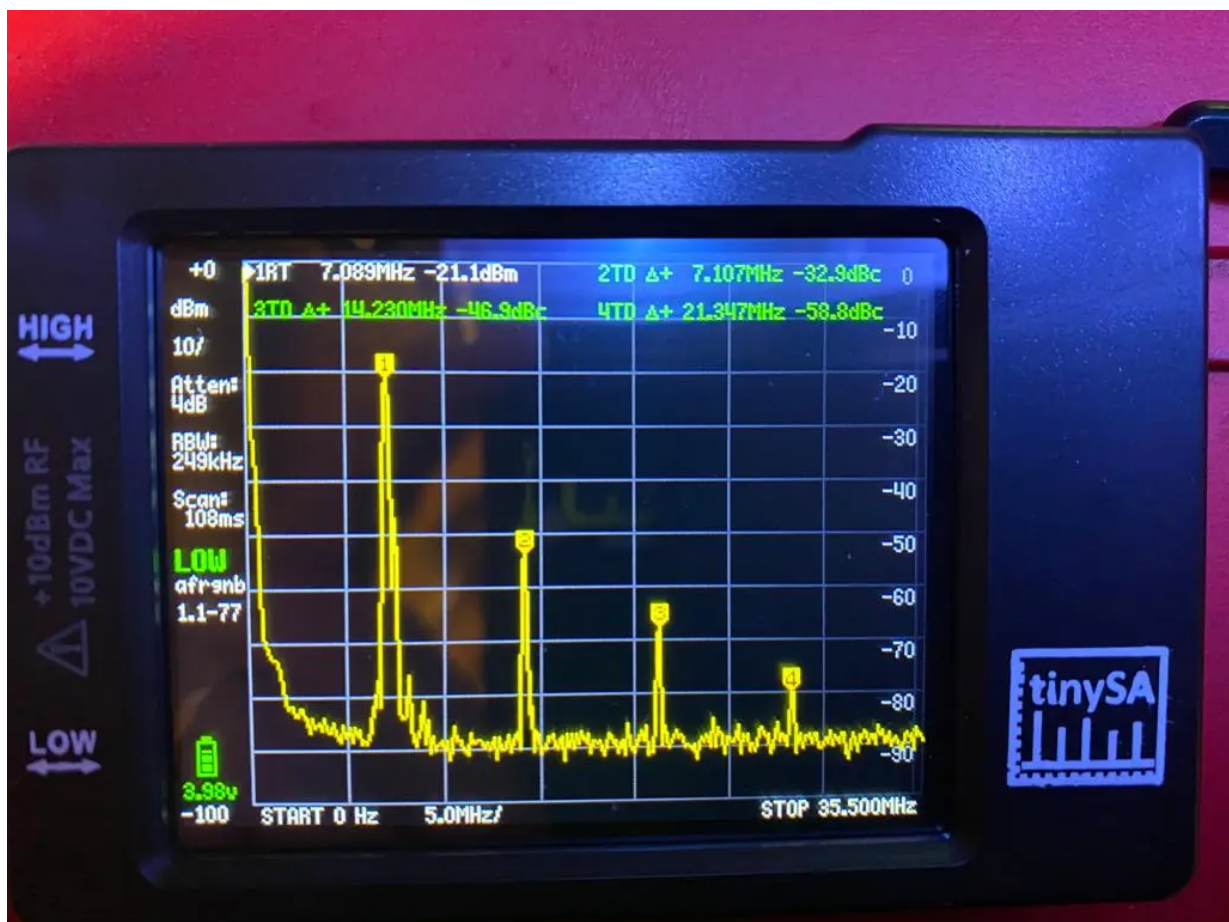
Since this amplifier is using 4 tubes , the input power needs to be a bit higher. According the spectrum purity requirements , the best results are with up to **40w** input. I can push until 60w but the spectrum quality is decreasing a bit (Nothing serious).

Some ham radio builders are using up to 100w input for 4xEL519 with great success. The amplifier linearity is very good thanks to the biasing circuit. Before the Biasing in place with the Cut-off resistor the results for the output power was not good at all. Even to find the dip/resonance with the output PI Network was difficult to achieve.

This refurbishment was easy and since i have already a good experience and according the time spent with the tiny 300w amplifier , it was really straight forward and the only adjustment i made is regarding the input transformer and the input/output capacitors i need to add on PI output network. The output transformers for both amplifiers are strickly identical . initially i put a LC circuit for the input fine tuning but since the N7DDC ATU is performing well i am not using it (Just lazy to remove it!).

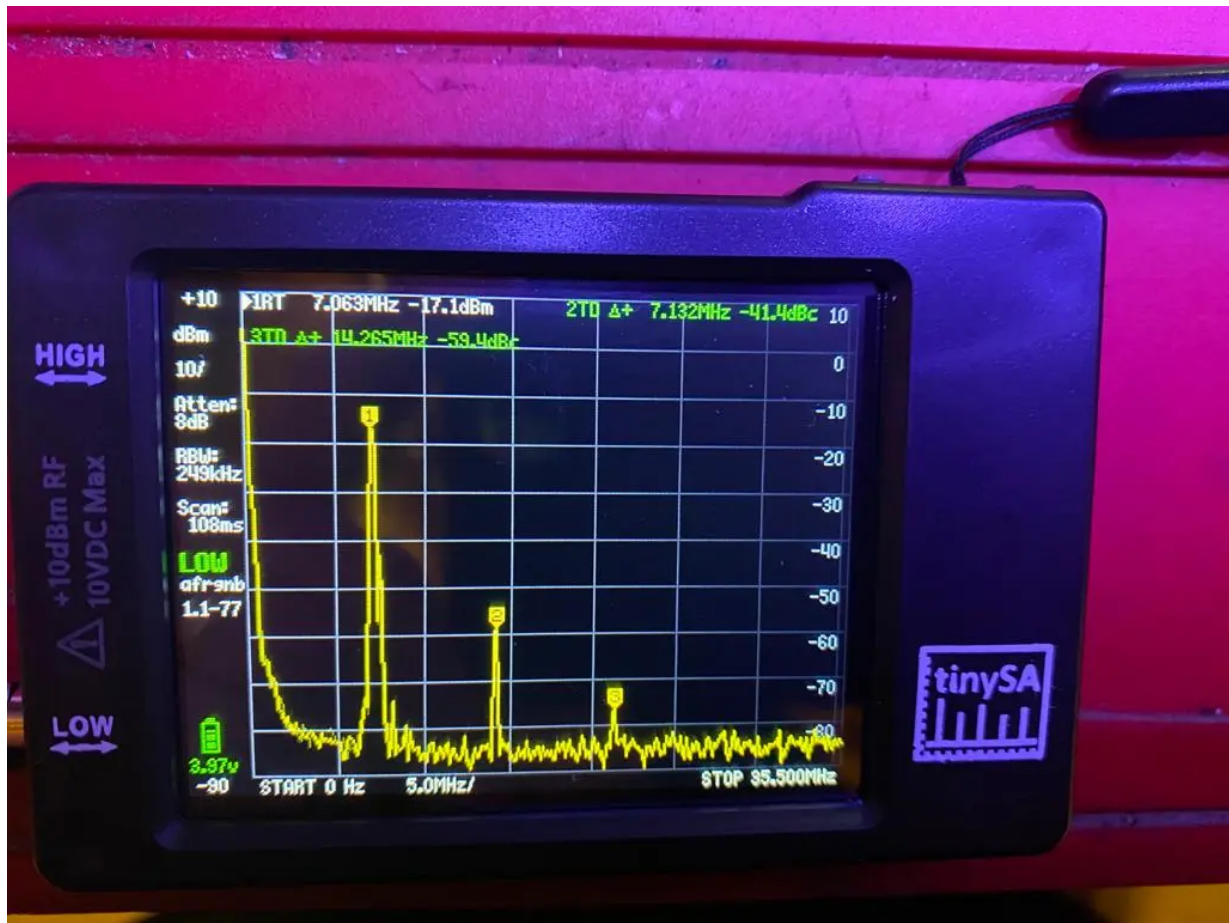
Spectral :

Hereafter the spectral on 7Mhz with about 700w output and dual tone. Input power about 60w. homemade RF coupler – 1kw Dummy load without any inline filter



with 100 input the output is not so great , so the limit for this amplifier is about 40 up 60w input

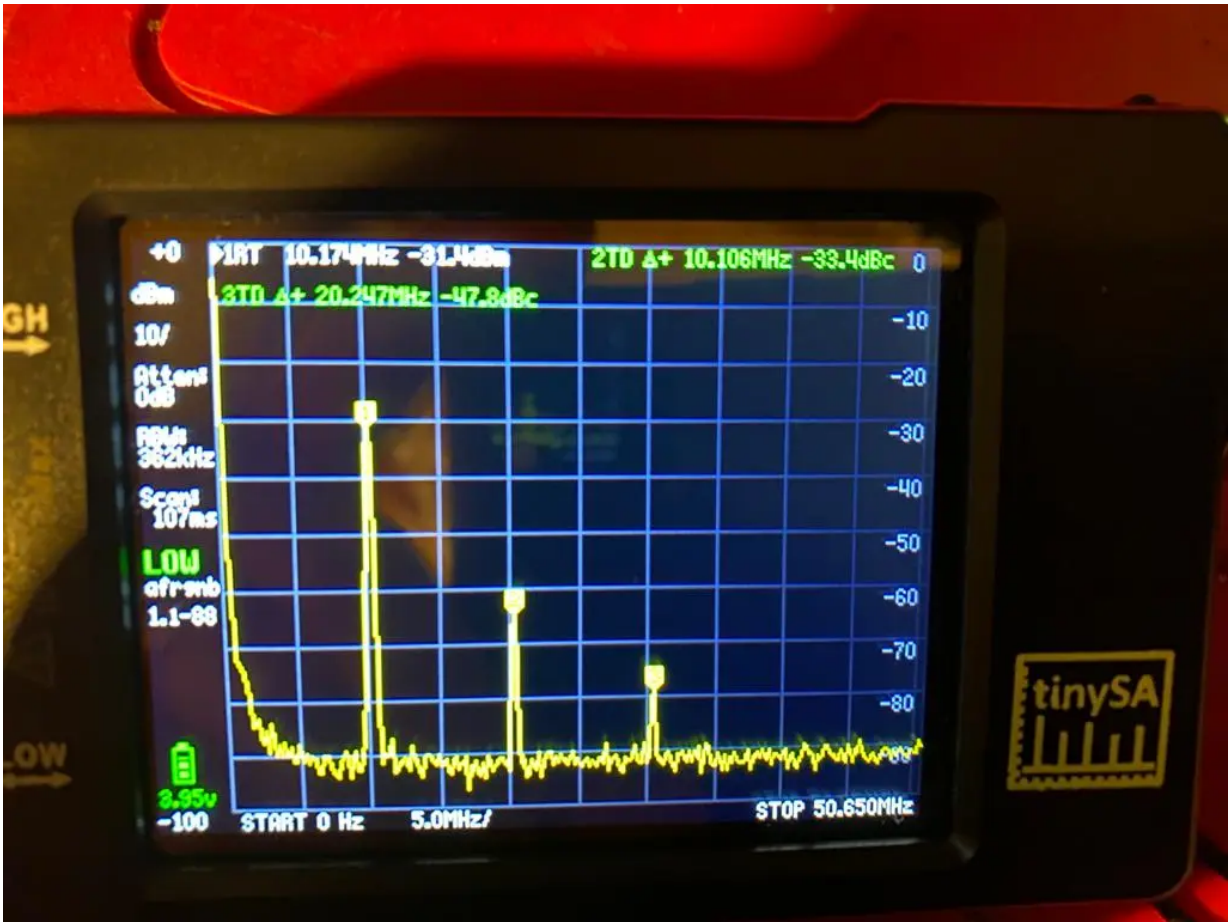
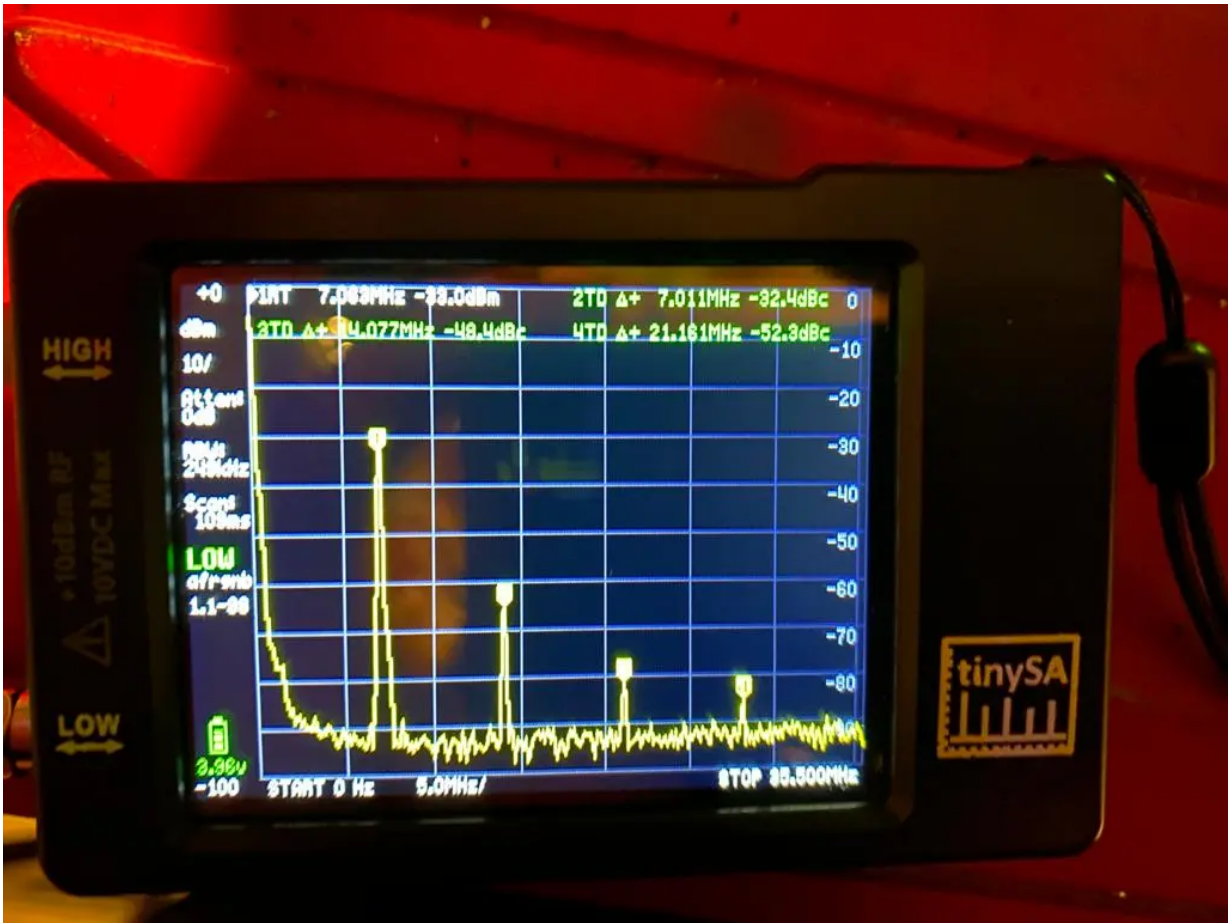
Hereafter the spectral on 7Mhz with about 700w output and dual tone with Pure signal. Input power about 60w. homemade RF coupler – 1kw Dummy load without any inline filter

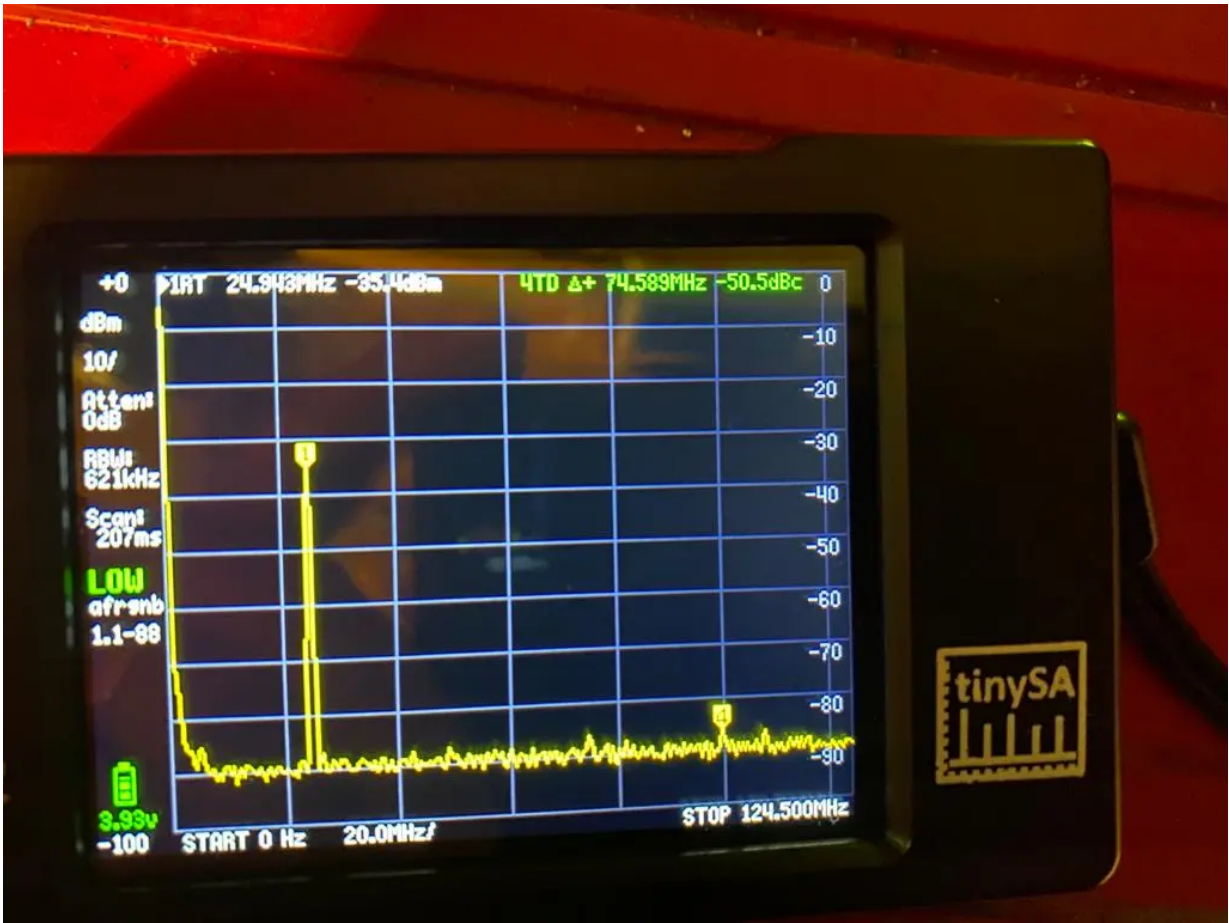


700w , getting better

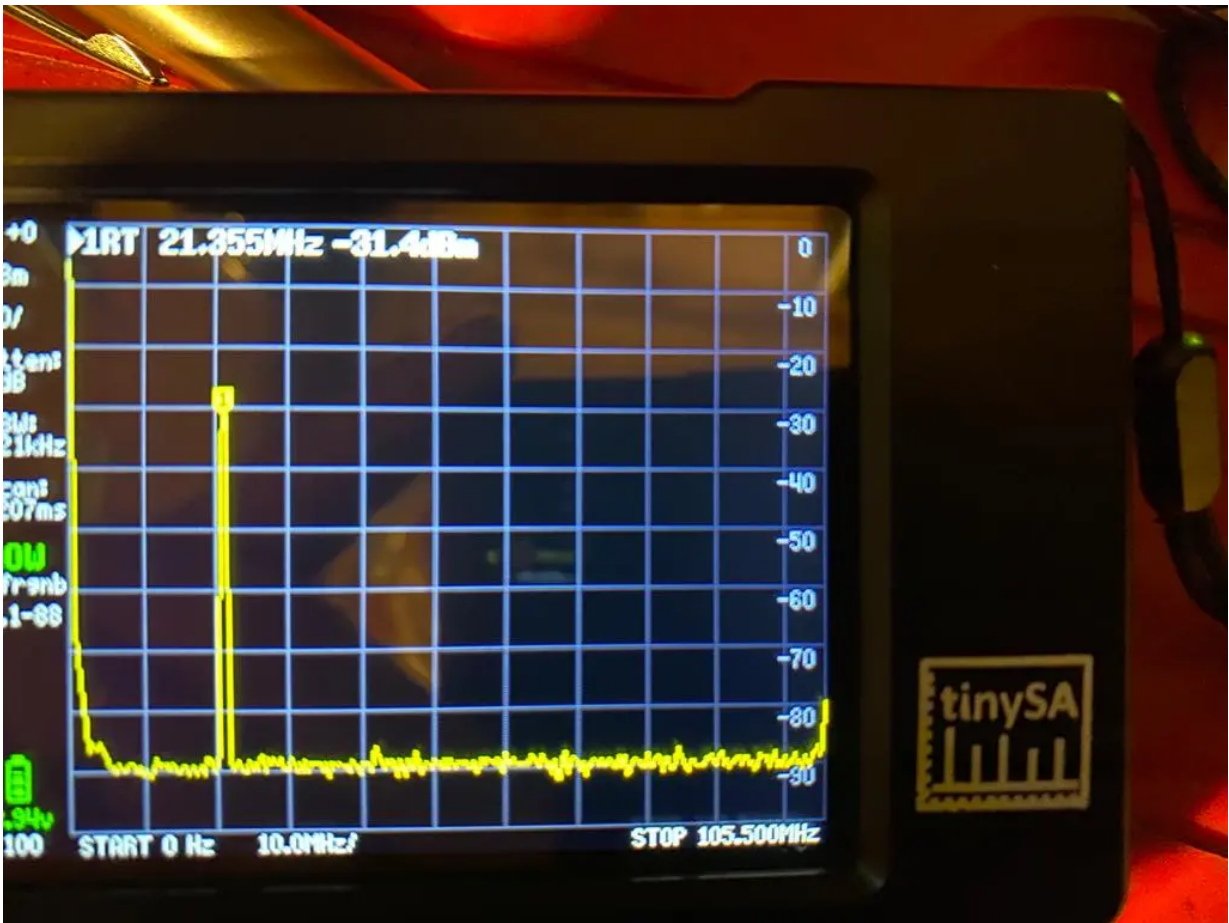
Overall spectrum measurement

400w output with Inline filter – homemade RF coupler – 1kw Dummy load

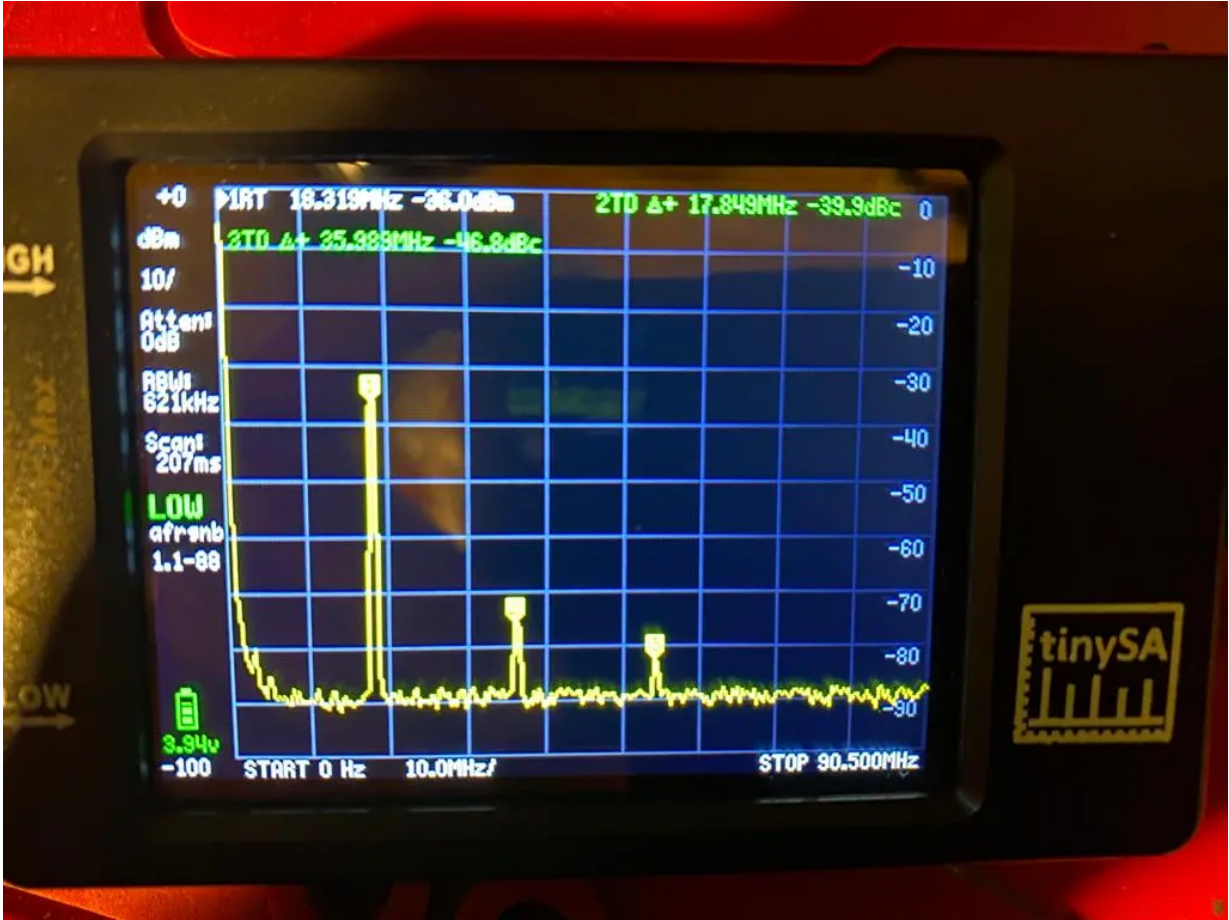


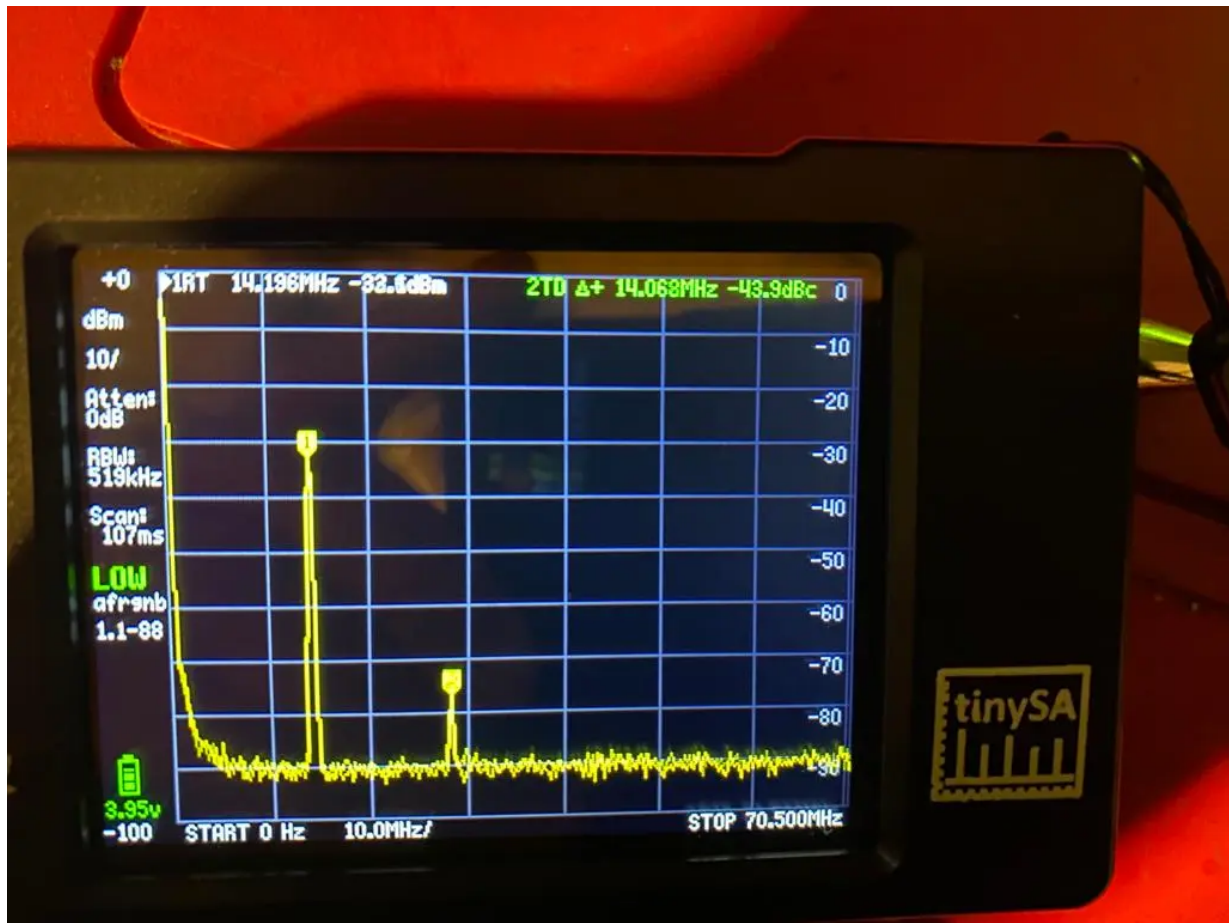


600w output , not bad at all

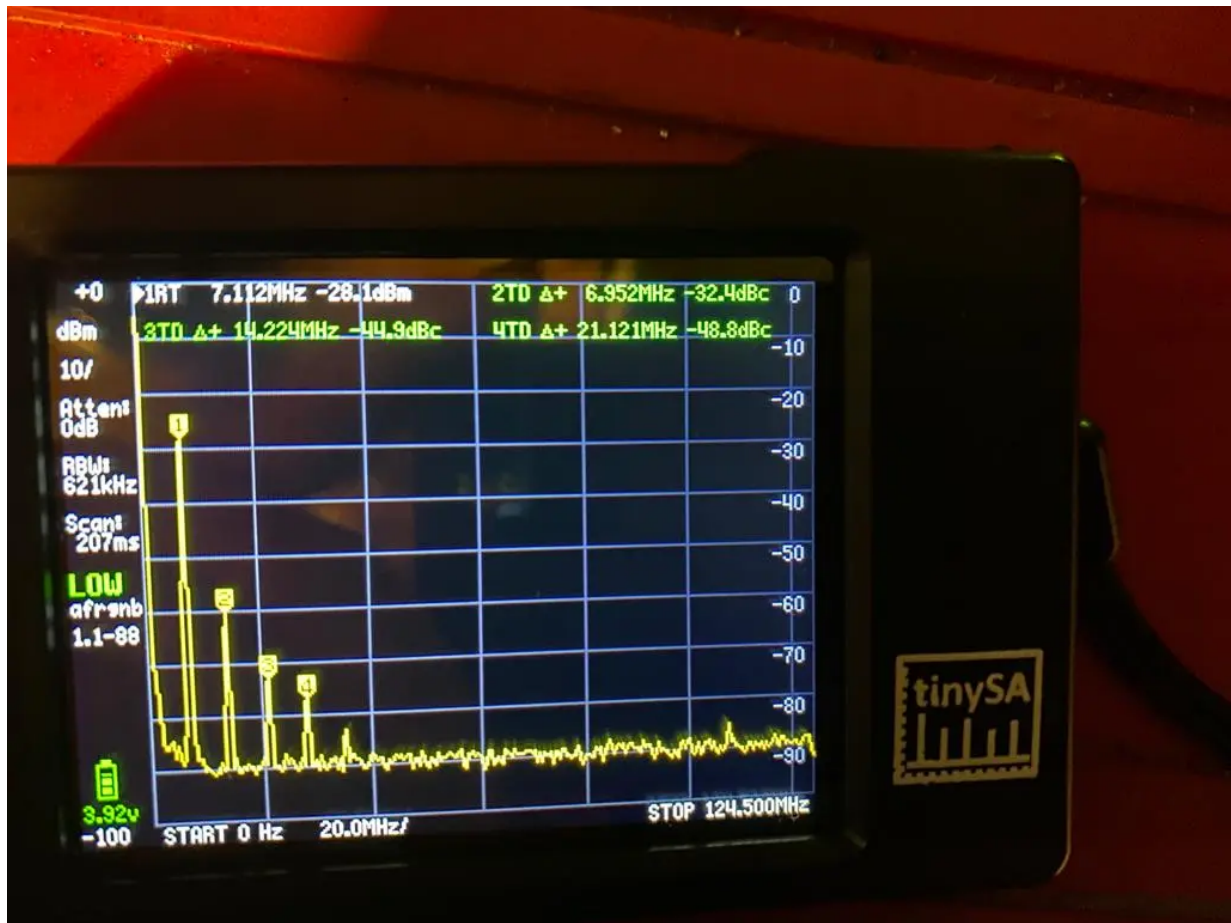


40w inputand 500w output = simply perfect





Overall HF band with 7mhz and 800w output without any inline filter nor pure signal



Refurbishment cost

- The Amplifier which was in a really bad shape : Free
- The N7DDC ATU kit : 23 Euros
- PCB Rebuild : 20 euros
- 6P45S TUBES = 64 Euros (16Euros each)
- 220vac Fan : 10 Euros
- For the other materials like the Switches , the T200-2 core and misc i have already in my junk and i will say the overall misc cost is about 30 Euros.

Overall refurbishment cost : about **150 Euros** only for a nice 800w vintage refurbished amplifier.

Update : this amplifier is not longer in my shack and was sold to a fellow ham radio . he is using it now for one month and working perfectly.

Conclusion

–**EL519/6P45S tubes are fragile** : well well well !!! what i can say they are not , i did a lot of experimentation during many build involving a lot lot of stress to the tube and so far i did not notice they are fragile. i like PSK31 QSO and after many years using the same tubes , they still providing me the same output power.

–**Using EL519/6P45S for digital modes is not suitable:** Please check my log 50% of my QSO are using Digital mode and even with long PSK31 QSO almost everyday for years i did not notice any issue . They are performing really well during long PSK31 QSO and using the same tube for 3 years now every day and do not notice any downgrade of the tube performance.

–**The size and power supply make it too big** : as i said , the size of the 300w EL519 Amplifier is half the size of my LDMOS amplifier for roughly the same output power. For the 700W amplifier , the size is about the same compare to a 500/700w LDMOS amplifier.

–**This kind of tube does not last for long:** Well after few years using almost daily this kind of amplifier i still using the same valves for 3 years (I cannot say the same with my 572B from my SB200 amplifier).

– **EL519/6P45S are providing distortion , IMD ans spurious:** Please check the measurement screenshots from this page . In addition i do not have a single spurious disturbing my neighbourhood which is urban very dense . A good biasing , input and output PI filter is providing a great spectral purity . During SSB QSO , all reported a great spectrum , without any AF distortion or clipping . With a bad biasing., design and obviously with a bad input all amplifiers are providing spurious whatever the technology you are using.

I will let the Guru guys to argue about EL519 and 6P45S tubes but the Pentode and tetrode are the evolution of the Triode and can provide a lot of benefit for RF amplifying. Generally speaking, Pentodes / Tetrode can have higher current output and a wider output voltage swing. The anode/plate can even be at a lower voltage than the screen grid yet still amplify well. EL519 Tubes are almost unaffected by changes in supply voltage, and can thus operate with more poorly stabilized supplies than triodes and will provide the opportunity to simplify a lot the voltage circuit to feed the Anode (The plate).

A pentode/tetrode are usually more efficient , with a lower power drive signal compare to to a Triode . The pentode tube/valve is also named enhanced triode. In any case a tube has a wider dynamic and can be used in a wider frequency magnitude compare to a

transistor. **BUT BE CAREFUL A BADLY TUNE INPUT AND OUTPUT (PI Network) , A PENTODE AND ESPECIALLY THE TETRODE TUBE WILL PRODUCE MORE SPURIOUS COMPARE TO A TRIODE.** the pentode/tetrode are more sensitive to load impedance variations and may clip more sharply. The TETRODE output stage tends to produce more high-order distortion products than a comparable triode if the design In particular the input is not optimized.

Since EL509 / EL519 / 6KG6 tubes were widely used during the Citizen Band era but unfortunately with poor design to keep the price very low and with very bad input from the transceivers ,some guys keep saying those tube/valve (EL519) are not suitable for Amateur Radio and RF amplification . The website as a reference is for sure : [FRINEAR-400PG a passive grid HF amplifier with 4 × PL519\(EL519\).\(xs4all.nl\)](https://xs4all.nl/frinear-400pg-a-passive-grid-hf-amplifier-with-4-x-pl519-el519) . On this website you find a lot information and many example with some build from Amateur Radio from all around the world.

The initial usage and design for 6P45S tetrode tubes was also RF Class A or B amplification. During my time in the Navy i was using and maintain a 1KW transceiver using 6KG6 and i can tell you this transceiver was really something unique.

Few Times i start a QSO and the receive station is mentioning about the quality of the signal and the audio and when i mention i am using 6P45S tube some guys keep mentioning this tube is not suitable for RF amplification despite the Fact my RF spectrum and audio are very clean. When asking if they use this kind of tube they just saying this tube was used during Citizen Band Era and was bad but never build this kind of amplifier using 6P45S tube nor they have ever build a tube RF amplifier for most of them. **Definitly urban legend remains very strong.**

For those who have some doubt I am using this kind of amplifier using 6P45S tubes for years and all reported a great and sharp spectrum from their waterfall . The Audio is absolutly without any clipping and the carrier is not producing any splatters. You have the choice to use commercial amplifiers for some well known to be arcing machine and needless to mention regarding all defects and issues reported by many Old Men. I open once an AMERITRON (AL811) amplifier and to access to the different stages and circuits is a total **search and rescue operation** and a real pain to troubleshoot it. You will pay this kind of product more than 1000 Euros.

Thats all folks and enjoy your build ! Dip the plate and peak the grids....

29 thoughts on “EL519/6P45S(6Π45C) 300w HF AMPLIFIER”

Nasos

August 6, 2021 at 6:07 pm

Congratulations on the construction and presentation

RFC1,RFC2 : 50 turns 0.5mm / 1 cm diameter, how much μH should it be?

L3 : 5 turns 10 mm what is the diameter of the wire?

Thank you

★ Like

[Reply](#)

F5NPV

August 6, 2021 at 7:48 pm

According RFC1 and RFC2 you need at least to achieve about 60 up to 100 μH .

As far i can remember i reach about 75 μH . a good alternative is Choke i found

here : <http://www.elektrodump.nl/nl/hf-smoorspoelen/1690-hoogfrequent-smoorspoel.html> , for the ouput choke i found here a great one :

<https://paraset.nl/sh/product/rf-choke-25-mh/>

For L3 the diameter is 0.8mm (Therefore it is not critical since the inpup power is from 5 up to 20w)

73s Didier

★ Like

[Reply](#)

Nasos

August 6, 2021 at 10:42 pm

Thanks for your answer

★ Like

[F5NPV](#)**August 7, 2021 at 8:34 am**

Hello Nasos

I built many amplifiers already using 811,813, 4-400Z and 4CX1500 but amplifiers using 6P45C tubes are by far the most stable and easier to build, the High voltage is only from 700 up 900vdc . Regarding the spectral purity and IMD , the performance are identical compare to my SB200 from heathkit using 572B. During all SSB QSO ,all are reporting a very good audio quality without any distortion or clipping. i use a lot the 150w amplifier for digital modes (PSK and FT8) without any issue. The major constraints is definitely the forced air colling system which is a bit noisy of course., apart from that no issue at all .

Enjoy your build and 73s

Didier



Nasos**August 30, 2021 at 9:18 pm**

Hello Didier

I did a conversion from Alan Jumbo CB linear 2×519 but the tuner (N7DDC ATU) can't tune to 15~10 meters, without removing the ATU, is there another way to adjust capacitor or coil ?
Thank you and 73'

[Reply](#)

[F5NPV](#)**August 30, 2021 at 10:29 pm**

Hello, i assume you are using the N7DDC in the input circuit . With 2 tubes you should be able to tune . in the input circuit you should have an inductor (5 turns 1cm diameter) in parallel wirth a 100 up to 150pf . without the tuner the input SWR should be about 2:1 maximum at the input for 15 and 10 meters band . On

7Mhz the SWR should be almost perfect. Maybe you should try with another value for the input capacitor. One more thing you can try is to remove C4 (3.3nf) just after the inductor at the input in my schematic. In fact when using the N7DDC ATU You dont need the C4 capacitor.

★ Like

[Reply](#)

Nasos

September 6, 2021 at 6:43 pm

Hello Didier

I made the changes and everything is fine up to 15 meters. But there is a large consumption in the quiescent current of 200 mA and the tubes blush. Why is this happening?

73'

★ Like

[Reply](#)

F5NPV

September 6, 2021 at 7:18 pm

Hello , 200ma is far too much for quiescent current . what you can do is to use only one tube , connect between the cathode and the ground a 27k apply the High voltage to the anode without any RF at the input. if the quiescent current is almost null it is OK , then connect directly to the cathode and the ground about 6 or 7 1N4148 diodes in series and same with the HV on the anode/plate , the quiescent current should be from 20 up to 40ma maximum .It should be ok . if you still have an issue maybe there is something wrong with your output circuit. The tube blush because some self-oscillation which is very bad and the tube can be really damage. Test it only with one tube and after with another tube.

★ Like

[Reply](#)

Nasos**September 6, 2021 at 11:47 pm**

Hello Didier

thanks for the reply and help

I did a measurement and the cathode short-circuits to ground when it is the tuner ATU connected

I will do the tests that you said

Thank you 73'

[Reply](#)

F5NPV**September 7, 2021 at 1:19 pm**

If your Tube are self-oscillating maybe you need to check and to be sure the grids are properly grounded . You can add also a 10nf capacitor between the grid and the ground.

[Reply](#)

marconigr**September 17, 2021 at 11:38 pm**

Very good job !!! I would like to made this but in 160m .What changes will be made in diagram ? I am little confused ...if I drive the system with grid1 with bias in grid1 around -40volt and 300v in screen ?

I have a pll am with 25w max power and I would like to made a linear in 160m



[Reply](#)

F5NPV**September 18, 2021 at 5:31 pm**

Hello, you can feed and bias the tube with -40 and 300v screen voltage . the gain will be better compare to grid grounded configuration . I did not choose this configuration since you need to feed the tube with many voltage and prefer to keep it simple . the gain i have is about 12db and this enough for me .according with the diagram you need to add the voltage you are targetting for the biasing and mostly to design a dedicated controller. Btw you can start simple with a grid grounded configuration and with 2 tubes you should have about 300w with 25w input . If you are not satisfy you can move to another biasing with minor modification of the circuit board.

73s Didier

★ Like

[Reply](#)

Charalampos Kioroglou**September 20, 2021 at 5:13 pm**

Hi my friend

i have test it with 450v and one tube for test .The result is with 12w input i have 30w output .I have problem with am modulation .I have negative watt output with music but the output from pll is plus watt .

I have in Cathode 2 x zener 7.5v

★ Like

F5NPV**September 20, 2021 at 5:30 pm**

with 450v for the plate it is not so bad considering this is AM mode , i guess with 900v you will have a better result and reach above 50w which is not bad for AM mode and only one tube

**marconigr****September 20, 2021 at 10:35 pm**

What will be done if add extra 2 zener in schema ? Will be have better am modulation ? Will be increase power ?



marconigr**September 20, 2021 at 10:53 pm**

Also in my test in 160m I use as rfc1 choke 2.5mh .Is wrong ?

[Reply](#)

F5NPV**September 20, 2021 at 11:12 pm**

for 160M generally the plate choke should be around 250 μ H. to cover the entire HF band your plate choke RFC1 Should be from 100 μ H up to 250 μ H

[Reply](#)

Charalampos Kioroglou**September 25, 2021 at 4:36 pm**

Hi my friend

how many watt must have potentiometer if replace R8 in transistor ?What will be change in your schema if i would like better modulation in am ?

What will be change in your schema if add extra 2 519 tube (Totally 4 pieces) ?



[Reply](#)

[F5NPV](#)**September 26, 2021 at 7:48 pm**

Hello,

For AM mode you should use a different driven system and my recommendation is to Bias G1 and G2 with alternatively -60Vdc for G1 and about +150vdc to G2 in order to provide a better efficiency. The screen should be grounded and you will drive the amplifier on G1 (Grid driven) . You can test to drive on G2 if the linearity is not good with G1 . Using the design from my website is great for SSB mostly; Adding more tubes with the initial design is not so difficult but you will need to use voltage transformer to sustain the addition of tubes (current). Minor adjustment on the PI Network should be necessary since the addition of tube will modify the output capacitance.

★ Like

[Reply](#)

marconigr**October 13, 2021 at 4:06 pm**

What will be done if add more zener ? Will be change power or modulation ?
Finally if replace as you say resistant 1.5k with potentiometer what will be the advantage ?

Thanks for your info

★ Like

[F5NPV](#)**October 13, 2021 at 8:46 pm**

The Zener diode is with different value can change the modulation quality and if your idling voltage and current are not good , the amplifier will produce a lot of splatters. In the design you have already 2 zener and you just need to tap and use one or 2 diodes with just adding a switch . For CW and AM only

one diode should be OK , for SSB using 2 diodes will provide a better biasing voltage swing and obviously a better modulation without splatters and bad IMD. The variable resistor will assist for the idling current adjustment. which is about 25ma per tube. Generally you check and setup the idling current with a variable resistor and when done you can replace with a resistor according the value you find . For this kind of tube is quit easy to achieve about 25ma idling current

In my opinion , with this kind of tube it will be difficult to achieve more than 50w up to 60w per tube means about 100 up to maybe 120w with 2 tubes. AM modulation envelope and carrier will prevent to achieve the power you can have with SSB or CW (Generally it is divided by 2). AM mode is 100% linear modulation with equal positive and negative swing . In AM mode to achieve 100w you will need to tailor your system for about 300w up to 400w. AM mode efficiency is terrible.

100-watt PEP AM amplifier would have:

- 25 watts carrier power, as seen on any type of power meter without modulation
- 37.5 watts average power, as seen on an average reading power meter with full, steady, modulation
- 100 watts PEP, as seen on a true peak reading power meter with full modulation

→For peak efficiency is around 60% maximum carrier efficiency at less than 30% and you really should consider 20-25% as a good carrier efficiency.

★ Like

marconigr

October 13, 2021 at 4:53 pm

Hi again if drive from

Grid1 with -60Vdc BIAS must I keep the same schematic in cathode ?

★ Like

[Reply](#)

F5NPV

October 13, 2021 at 8:41 pm

Hello , as i said biasing differently this kind of tube will involve a very different schematic . You'd have to build a grid bias supply and convert to a grounded cathode/filament configuration. Neutralization could be problematic. In my opinion the amplifieer should be C class.

AM or SSB it's all amplitude modulation. When a carrier is amplitude-modulated with a pure sine wave, up to $\frac{1}{3}$ (33 percent) of the overall signal power is contained in the sidebands. The other $\frac{2}{3}$ of the signal power is contained in the carrier, which does not contribute to the transfer of information. With a complex modulating signal such as voice the sidebands generally contain 20 to 25 percent of the overall signal power; thus the carrier consumes 75 to 80 percent of the power. This makes AM an inefficient mode.

★ Like

[Reply](#)

[Mel Mastrogiovann](#)

October 21, 2021 at 1:55 pm

Greetings! Very helpful advice within this post! It's the little changes that will make the most significant changes. Many thanks for sharing!

★ Like

[Reply](#)

[Brock Hilderman](#)

October 23, 2021 at 4:45 pm

After I originally left a comment I appear to have clicked the -Notify me when new comments are added- checkbox and from now on whenever a comment is added I recieve 4 emails with the exact same comment. Perhaps there is a means you are able to remove me from that service? Many thanks!

★ Like

[Reply](#)

[F5NPV](#)**October 24, 2021 at 8:19 am**

Hello , i did not remove you but i think this WordPress behaviour with some comments and according the email you are using , the wordpress system is seeing you as a spam

★ Like

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Nasos**January 13, 2022 at 11:25 am**

Hello Didier and Happy new Year
where can i put to monitor the biasing in the cathode or in the transistor BD912
Thank you

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[F5NPV](#)**January 13, 2022 at 12:01 pm**

Hello and Happy new year to you . You can monitor the Biasing with the BD912 Circuit. In the webpage i just add a picture and schematic for the Biasing monitoring .

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Nasos**January 13, 2022 at 12:24 pm**

Thank you for the reply and help



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