



Practical Valve Linear Amplifier Construction

(or "Life's too short for QRP")

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Background

- Got frustrated with the morning ops because many were running legal limit and couldn't hear my 50W
- When I mention valve amp to others, many shy away because of the dangerous voltages involved
- Wanted to share my experiences/challenges in building a 70cm valve PA



But First ...

The VK3HZ Patented ...

4C's of Amateur Projects

Many of us have many projects at various stages of construction.

There might be some logic behind the chaos ...



The 4 C's of AR Projects

1. Conception

The formation of a plan for the project. Research the options and flesh out the design of the project in some detail. Identification of “hard-to-get” and/or expensive items is a fundamental part of this stage. (It may be driven by them)



The 4 C's of AR Projects

2. Collection

Collecting the “hard-to-get” / expensive parts. This step may last years. It may result in a major revision of the Concept, if the “hard-to-get” part is, in fact, “impossible-to-get”.



The 4 C's of AR Projects

3. Construction

Obtain all the readily available parts, do the metal bashing and put it all together.



The 4 C's of AR Projects

4. Cursing and Consternation

The setting into operation of the project, which can result in much frustration. Most likely to be an iterative process, where bugs are gradually ironed out over time until, finally, the project is finished (maybe)!



The 4 C's of AR Projects

- Any homebrewer will have a number of projects running in parallel and at various stages along the 4 C's path
- That's why most of us have a workshop full of "junk" that will be used in a project ... one day ...



The 70cm PA - Conception

1. Conception

A 70cm amplifier capable of giving legal-limit output when driven by my current rig (50W).



The 70cm PA - Conception

- Solid State vs. Valve (“Hollow State”)

Solid State

- + Instant-on, Quiet (?), Safe Voltages
- High power difficult, Distortion, Fragile, Current

Valve

- + Easy power, Puts up a Fight, HiFi
- Lethal Voltages, Blower



The 70cm PA - Conception

- Triode vs. Tetrode

Triode

- Lower gain

Tetrode

- Screen supply and management
- Neutralisation



The 70cm PA - Conception

- Multi vs. Single Tube
 - Related more to 4CX250B designs, already eliminated
 - 8874 (400W triode) can deliver 500W. Two would be less stressed, lower IM but balancing complicates design
 - So single, bigger triode



The 70cm PA - Conception

- With the fall of the Iron Curtain, the Russian surplus market is booming. Russian transmitting tubes are available new (NOS – New Old Stock) at very cheap prices compared to US/European
- The GS35b was the best match -(perhaps a little more than needed) -and \$US105 landed each



The 70cm PA - Conception

GS35b

Anode Ratings:

Dissipation: 1500W (2500W with water cooling)

Max Voltage: 3kV (4kV without problems)

Max Current: 1.5A

Grid Dissipation: 26W

Heater:

Voltage: 12.6V

Current: 3A

Max Frequency: 1000 MHz

The 70cm PA - Conception



8874

8877

GS35b

The 70cm PA - Conception



Anode



Grid / Cathode

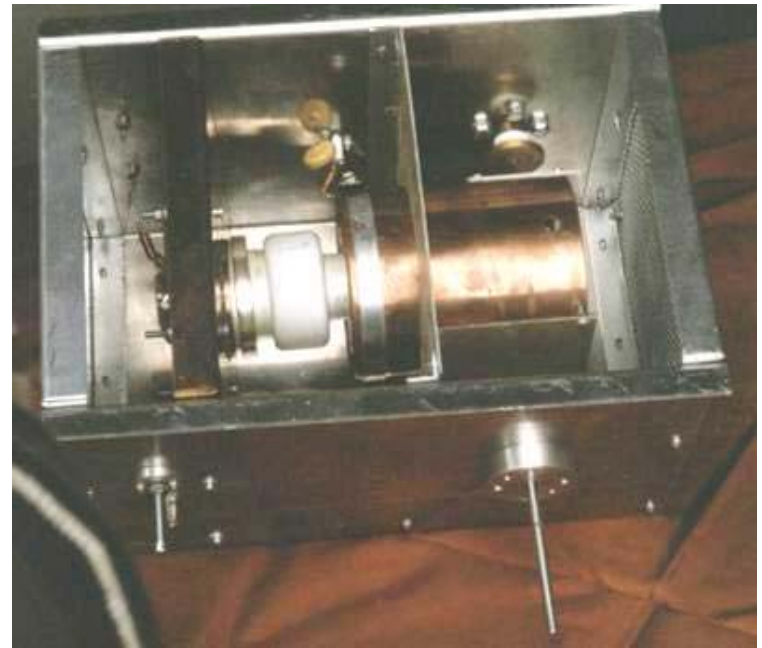


The 70cm PA - Conception

- So what design?
- The QRO site (www.nd2x.net) is dedicated to amplifier designs using Russian tubes
- The design by PA3CSG stood out as being simple to build, repeatable and effective

The 70cm PA - Conception

- Uses a $\frac{1}{2}$ wave coaxial plate line that surrounds the (large!) cooler, eliminating stray effects
- Simple cooling arrangement – no need for teflon chimneys
- Simple tuning / loading setup (although not my favoured way of doing it)



PA3CSG GS35b PA



The 70cm PA - Conception

- Need to power it, so a PSU of 3 - 4kV at >0.5 amps is required too
- Hard-to-get / Expensive bits
 - GS35b tube (no socket needed)
 - Power transformer
 - High voltage bypass capacitors (maybe)
 - Blower
 - Antenna coaxial relay
 - High Voltage Connectors



The 70cm PA - Collection

- GS35b obtained from Dr Alex Gavva (UR4LL). 2 tubes had to be shipped in 3 parcels (2 with coolers – 2.5kg each - and one with 2 tubes)
- Already had a power transformer – 2900VAC @ 600mA. Probably the most difficult and/or expensive item to find. Consider rectifier / filter options. Microwave oven transformers. Switching supply (www.wattsunlimited.com)

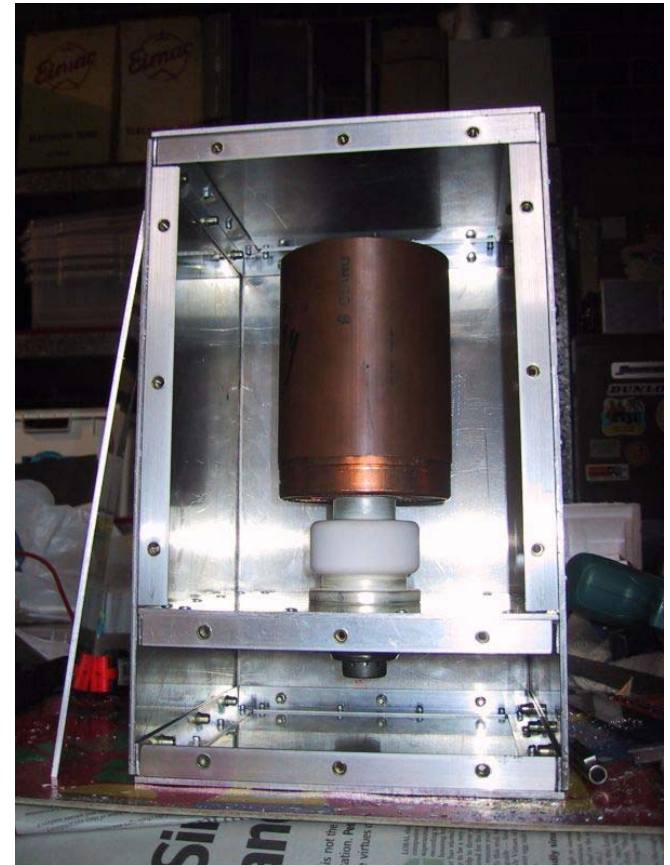


The 70cm PA - Collection

- 500pF 5kV Centralab caps on VKHAM. Could source from the US. Teflon sandwich cap could also be an option
- Blowers picked up at a White Elephant sale. Need to check that it can push enough air at the estimated back-pressure. DC option.
- Transco “Y” relay picked up on US EBay
- MHV connectors (BNC-like with extended insulators) from Rojone. Teflon coax to carry HV to RF deck.

The 70cm PA - Metalwork

- Simple box 200 x 200 x 300 with single partition
- 3mm Alu plate. Supplier will usually cut plate to size for nominal fee per cut
- Alu angle with rivet bushes to hold box together
- Hole in partition to mount tube grid ring.



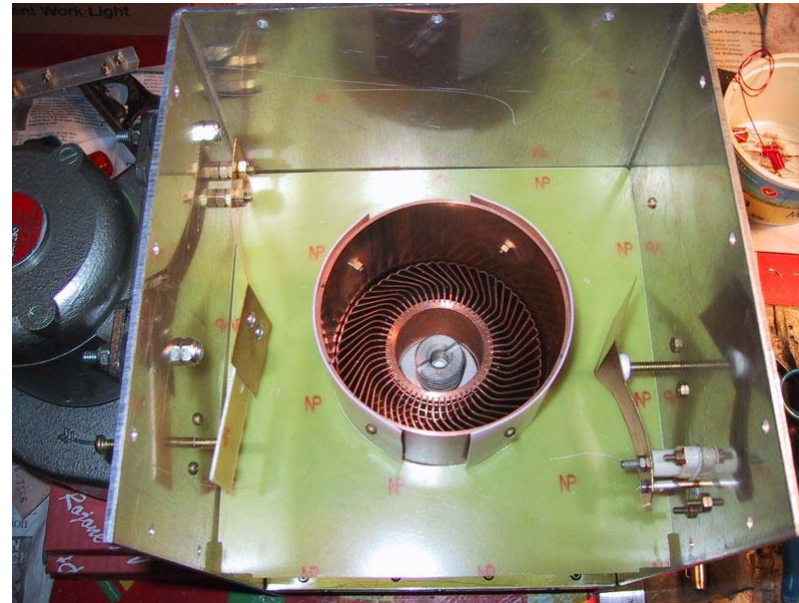
The 70cm PA – Anode Line

- $\frac{1}{2}$ wave coaxial line - 125mm length of 4" copper pipe. Available from scrap metal merchants
- Fabricated brass “hose clamp” at anode end to bring HV in via RFC
- Alu angle holds tube in place. No socket required!



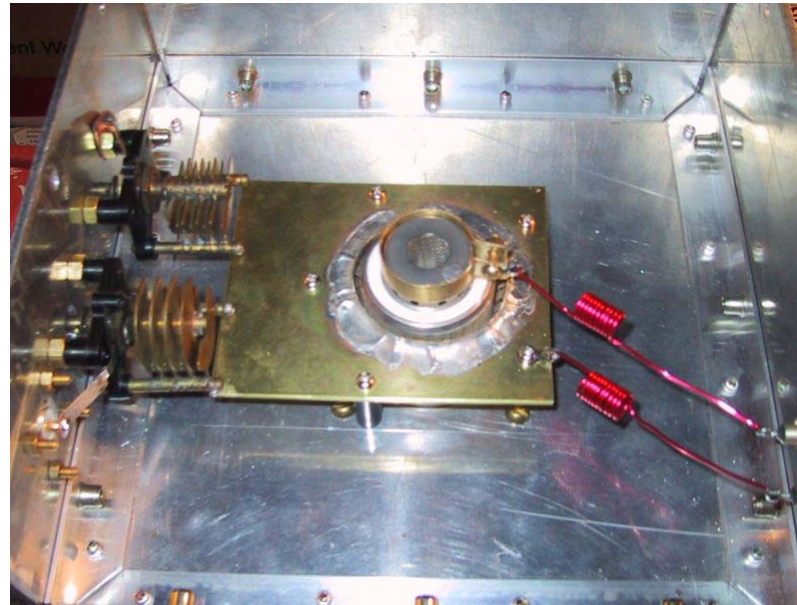
The 70cm PA – Tuning

- Phosphor bronze flappers pushed by threaded brass shafts for tuning and loading. Teflon sheet insulator to prevent short.
- Fibreglass PCB material (no copper!) as air barrier halfway along line (voltage minimum)



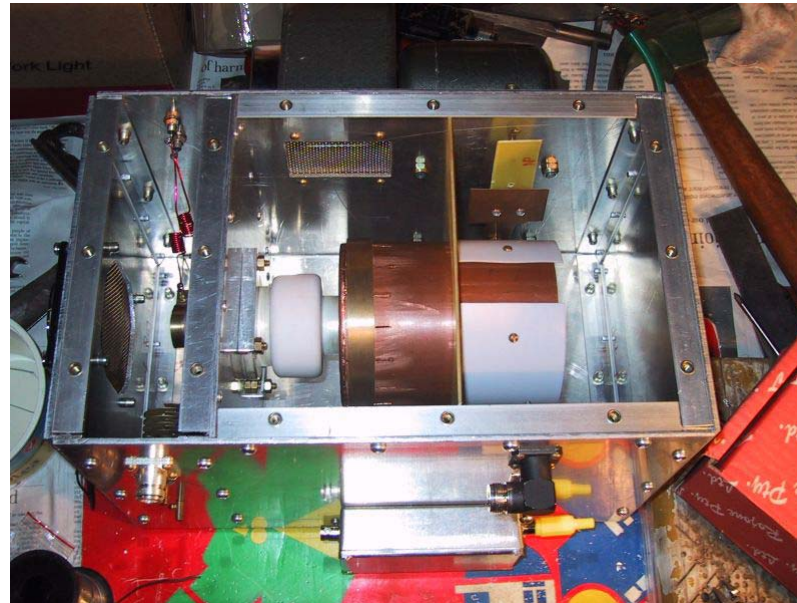
The 70cm PA – Input Line

- Brass sheet as input tuned line. Finger stock around hole in centre to connect to tube
- Two variable caps needed (~ 5 pF)
- Fabricated “hose clamp” to connect to heater pin (cathode connected to other side of heater)



The 70cm PA - Cooling

- Blower blows onto lower part of tube in anode compartment, up through cooler, exiting at end
- Brass flywire mesh over all air holes as shield
- Airflow monitor
- Separate muffin fan to cool heater / cathode pins



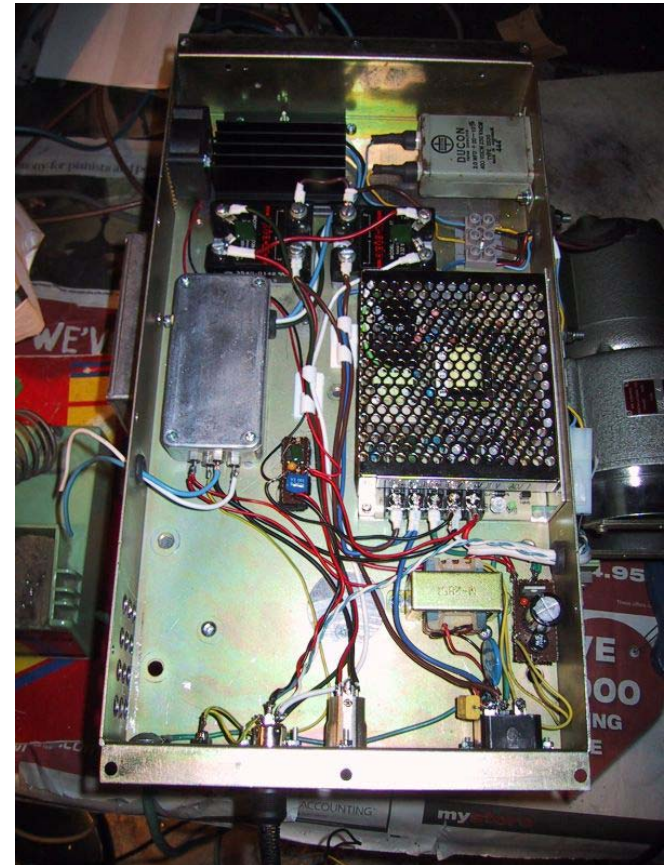


The 70cm PA – HV Feed

- MHV connector on diecast box mounted to outside of anode compartment
- Inside diecast box, RFC and bypass cap plus HV monitor 1000:1 divider
- Ceramic feedthrough into anode compartment
- Centralab 500pF bypass to RFC connected to anode strap

The 70cm PA – Control Circuit

- 240V into RF deck for Blower, Heater supply (sequenced), Aux 12V supply
- Heater supplied by 12V 40W switching supply. Adjustable, current-limited and regulated
- “Heater Ready” 90 sec timer (was 555, now 4060)
- Adjustable bias supply (22V for 100mA) based on G3SEK triode control board circuit
- Electronic PTT via Opto-isolator





HV Power Supply - Safety

- This PSU will deliver up to 4.3kV and up to 1A. THIS WILL KILL YOU.
- **SAFETY, SAFETY, SAFETY**
- See previous point
- Double Insulation Theory – It takes at least 2 failures before safety is compromised



HV Power Supply - Safety Tips

- Avoid working on exposed, live HV circuitry unless absolutely necessary (e.g. testing PSU)
- Don't work on HV when tired or after a few grogs. Be Alert.
- Don't allow distractions – close the door
- Don't wear headphones, tie, metal zippered jacket ...
- Keep one hand in pocket

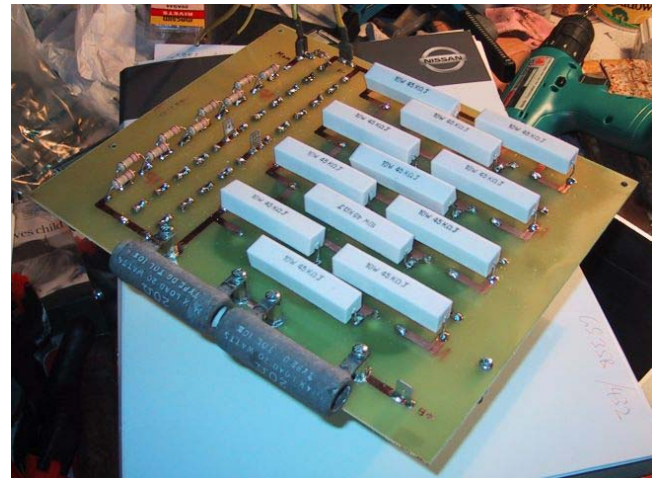
HV Power Supply - Safety

- Interlock on PSU lid to remove power / short HV line
- Bright indicators for power standby / on
- HV meter on front panel of PSU
- Proper HV connectors (not RF or Millen) with earth-shielded cable
- Separate earth to everything
- Shorting stick ("Jesus stick")



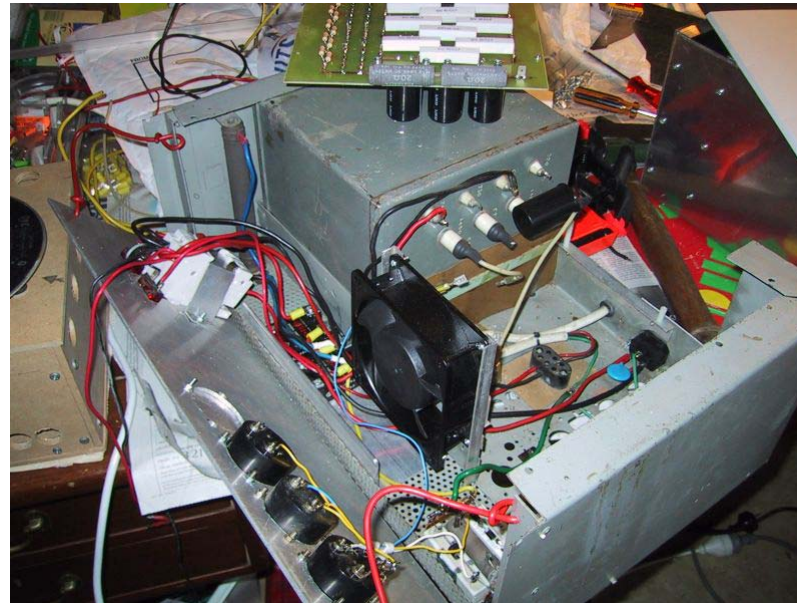
HV Power Supply

- 6 x IN5408 series rectifier diodes – no equalising resistors or capacitors are needed
- 12 x 470uF 400V electros in series
- 45K 10W bleeders
- HV monitor circuit
- Glitch protection resistors



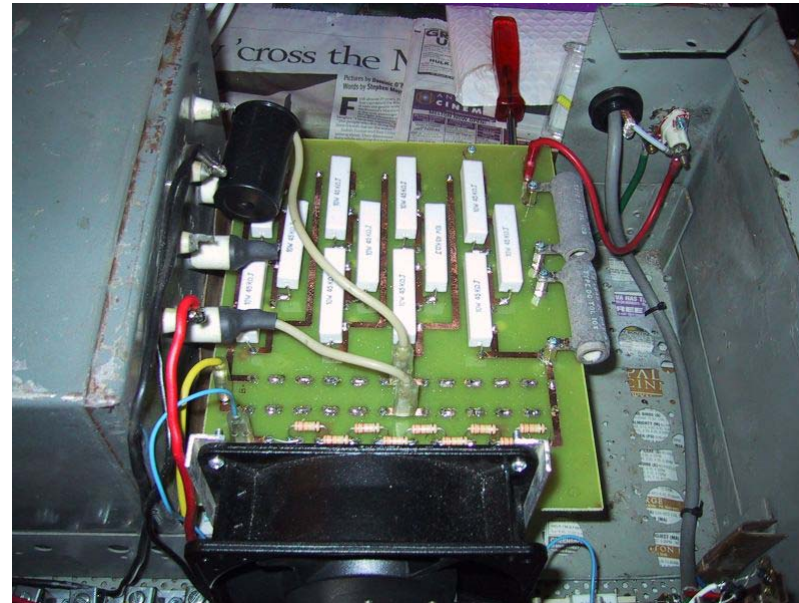
HV Power Supply

- Will handle multiple RF decks (one at a time!)
- Large current metering shunts with protection diodes
- Automatic shutdown of PSU to prevent damage from sustained short
- Protect the transformer with secondary fuse
- Soft start circuit



HV Power Supply

- Limit HV fault current using 20 ohms per kV large wirewound resistor in series
- HV connection at rear. Connector on RF deck.
- Fan to cool bleeders (60W) and transformer
- Possible future mod – 2kV supply for 23cm



Control Box

- Everything built to be remotely controlled and monitored
- Handles up to 3 RF decks (2, 70, 23)
- Sequences startup and handles relay switching using PICAXE (soon)
- Metering of HV, Ia, Ig, P fwd, P ref





Cursing and Consternation

- A number of things can be done, or must be done, before HV is applied to the RF deck
- Test metering circuits. Apply DC currents to metering shunts and check/adjust for correct readings. Can be lead astray, or even damage tube, if readings are incorrect
- If you have access to one, try Hi-Pot testing the anode circuitry up to 10kV
- Check blower airflow is adequate by measuring back-pressure



RF Cold Testing

- Initial testing of RF deck WITH NO HV CONNECTED
- With everything, including tube, in place, put equivalent anode load resistance from tube end of anode line to ground. $RL = 1.2 * Va / Ia$
- Feed low level RF back into output connector through SWR meter and adjust tuning and loading for 1:1. (Or use MFJ) If it won't match, something is wrong. Also check that controls are not at their limits
- With heater on, feed very low level RF into input and tune input circuit for min SWR



Tube Conditioning

- Tubes are unused, but old and so probably gassy. They will flashover if HV is applied straight away.
- Run heater only (and blower) for 24 hours
- Bring HV up gradually with high value current-limiting resistors to limit current if flashover
- Gradually bring up RF level at, say, half HV level
- Finally, at full HV level, run up RF level and give the tube a toasting!
- This will normally be done in parallel with getting the RF deck going.



PSU Testing

- The time has come to fire up the HV PSU
- A large Variac and HV probe are essential items
- Check that soft-start will work at low mains voltage. If not, bypass it for now.
- Connect HV probe ready to measure HV and voltage division across filter caps (ALWAYS measure voltage w.r.t ground). Caps may need to form (new caps SHOULD be OK)



PSU Testing

- Slowly bring mains up to say $\frac{1}{4}$.
- Check that each filter cap has the same voltage across it (i.e. $\frac{1}{12} * HV$, $\frac{2}{12} * HV$...). If not, wait a while and see if cap "forms".
- If OK, gradually (10 mins) bring HV up to full, checking voltages as you go, and leave there for a while.
- Turn off, wait for caps to discharge, short caps.



PSU Testing

- Connect HV to RF deck through current limiting, with heater on. Do later stages of tube conditioning, gradually bringing volts up
- Reconnect soft-start and try a switch-on
- If transformer “boings” or lights flicker (or worse) immediately at switch on, soft-start is not working or R is too small. If “boing” at end of soft-start time, R is too large.

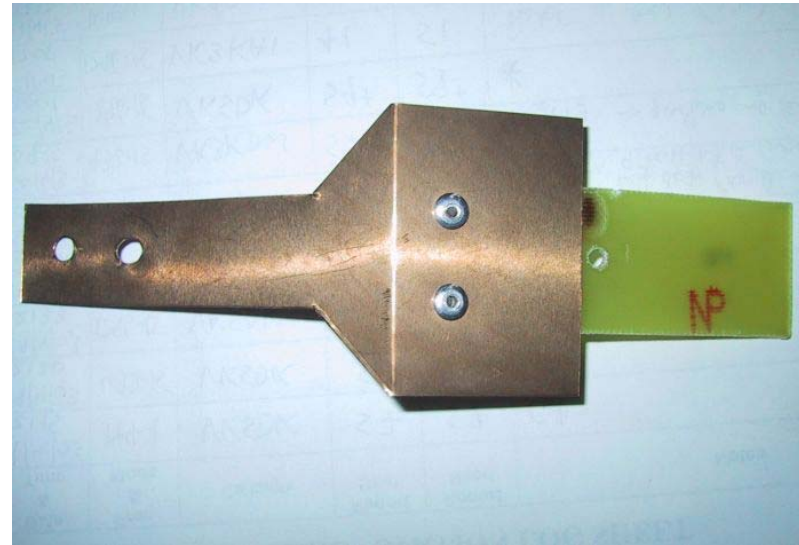


RF Testing

- With heater warm, HV at half maximum, key up PA and adjust bias to set standing current
- Apply a small amount of drive. Tune input for minimum SWR. Tune output for max output. Check anode current dip coincides with RF peak (or very nearly)
- Repeat above step, gradually increasing drive to max.
- Repeat above with HV at full level.
- Keep eye on I_p and I_g and max ratings

My "Challenges"

- Bias pass transistor shorted because of inadequate heatsinking. Tube pulled 900mA from PSU for a while (Hummm...) and was well run-in afterwards!
- Fibreglass on the tuning flapper was fried by RF (at 100W only). Teflon block was added.



Results

- 20W drive gives 400W out (all day)
- On test, 50W gave 1kW with 2kW input (3.3kV @ 600mA) – 50% efficiency.
100mA grid current
- Slight tuning drift (5%), only from cold





Conclusions

- A legal-limit valve amplifier for 70cm can be built relatively easily with only basic workshop facilities
- The power supply and the control circuitry take more time to build than the RF deck
- Only a few hard-to-get parts



Links

- QRO Site – www.nd2x.net
- GS35B Data - www.nd2x.net/gs35b.html
- PA3CSG PA - www.nd2x.net/PA3CSG.html
- G3SEK Triode Board - www.ifwtech.co.uk/g3sek
- RF Parts Company - www.rfparts.com
- Surplus Sales of Nebraska - www.surplussales.com
- Eimac “Care and Feeding of Power Grid Tubes” - www.cpii.com/eimac/cfmain.htm