

# REFORMED QUAD-II POWER AMPLIFIERS.

Last update, June 2014.



Those of you with a keen eye will realize the pictured amps above are not quite like original Quad II amps. How come there are blue and red LEDs glowing?

This pair of amps were re-built in 2006, and I rebuilt other pairs in 1998 and 2010 for my customers.

I've owned another pair of originals I bought cheaply at a garage sale which await being given "singing lessons" even more drastic than shown in many schematics below.

This page is about the range of possible improvements between basic and complex.

Unless you have good electronic knowledge and experience, I suggest you limit your efforts to basic improvements.

These will include :-

1. Total replacement of all R&C with modern metal film R and MKP coupling caps and new electrolytics.
2. Replace GZ32 with GZ34, which allows the original 16uF + 16uF caps to be replaced with 33uF + 33uF.
3. Remove original 180r and 25uF cap between cathode FB winding CT and 0V and replace with a wire link.
4. Disconnect ends of cathode FB winding from KT66 cathodes, and connect parallel networks of 390r/5W + 470uF/63V between each winding end and each KT66 cathode.
5. If the original Quad 22 unit is not to be used, Install an RCA input chassis socket near original Jones plug and connect to EF86 input grid to facilitate connection of modern RCA cabling

6. If the Quad 22 unit is not to be used, remove original Bulgin mains input socket plug and instal IEC chassis plug and a mains switch to allow independent operation of both left and right channel power amps. Make sure amp metal chassis is connected to Earth terminal on IEC input.

[illegible]

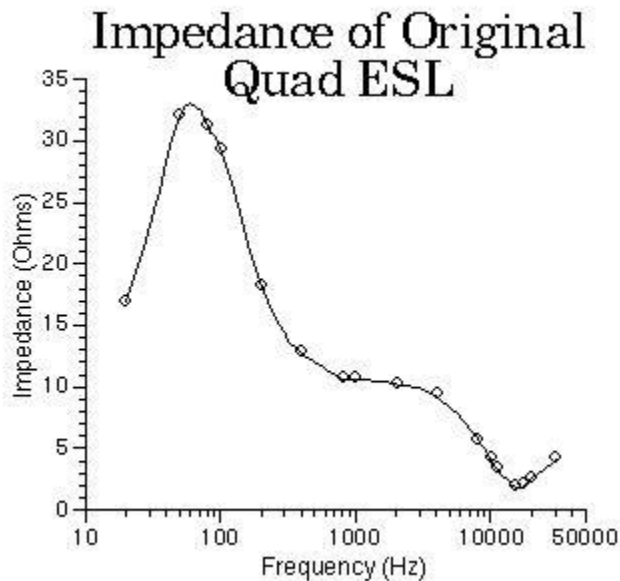
There was a Quad One amp which preceded Quad-II amps for when there was only single channel sound. When stereo recordings became possible the Quad-II mono amps were built to allow exclusive use of the Quad-22 "control unit" aka preamp. Many might say Peter Walker was a genius, and one who gave excellent hi-fi sound to a world which was otherwise dull and restricted and full of products with little real merit.

Between 1950 and 1960, arguments raged about which amp was best, the Quad, Leak, Williamson, Radford, or some USA brands. For many in Australia the cost of such exotic imported hi-fi gear was extremely high so a small number of hi-fi enthusiasts built their own amps after reading magazine articles published in magazines such as Wireless World, or Radio, TV and Hobbies, which later became Electronics World and Electronics Australia respectively. I have repaired or re-built some of these amateur efforts which were so often riddled with terrible mistakes, very unsafe construction, very poor component choice, all indicating that fools with no money had been at work.

The original Quad-II could make 20Watts which were needed to get the best sound from Quad's ESL57

which had rather low sensitivity of around 83dB/W/M. The ESL57 were produced after Quad-II amps and were limited to levels which may not meet modern expectations which includes much higher bass levels. ESL57 was a "full range" giving barely adequate bass. ESL impedance varies hugely from 33 ohms at 80Hz to 1.8 ohms at 18kHz. In the main AF power band 80Hz and 700Hz, average Z is above 20ohms, and Z does not fall to 8r0 until about 5kHz.

## Graph 1.



Graph 1 shows ESL57 impedance vs frequency and is fairly accurate.

Because the speaker impedance varies so much the amount of power needed varies with frequency. The Quad-II amp can develop enough output voltage at low F to get sufficient class A1 power for F between 40Hz and 100Hz and clean class AB1 power for 100Hz to 1kHz. As F rises above 1kHz the amount of power needed reduces while at the same time the speaker Z reduces so that the outcome allows full range operation without much overloading or clipping most of the time.

Therefore it can be said Quad-II is fairly well matched to ESL57 in the main power band. The more anyone thinks about ESL57 and tube amps, the more they should realize ESL57 are easy speakers to power, and that a humble tube amp can power them very well,

( providing teenagers are not allowed near the volume or tone controls ).

Quad-II can make only 3.5Watts with load of 1.8 ohms. And ESL57 have minimum  $Z = 1.8r$  at 18kHz, but the HF music power above 7kHz is usually very low, and usually less than -20dB below bass levels.

Quad-II or any other 20Watt amp may not drive ESL57 as loudly as expected today. Therefore the use of a dynamic bass speaker for 20Hz to 150Hz with its own amp plus active crossover will allow Quad-II to give a marginally higher level for everything above 150Hz. ESL57 cannot be driven too loud by a more powerful amp because the ESL panels begin to arc which can damage panels and the amp.

For the ordinary person living in 1960, there were many brands of dynamic speakers which could be used with Quad-II. Fewer are now available which have high  $Z$  and high sensitivity, and flat response and low THD and IMD.

In January 2007, I was asked to examine a pair of Quad-II amps, one of which had badly overheated during summer weather. I removed the single 180r  $R_k$  and shorted  $C_k$  25uF. I installed bias networks to each KT66 cathodes, 470r plus 1,000uF/63V between cathodes and ends of CFB windings. The CFB winding CT was taken to 0V. The amp then ran with better regulated  $E_k$  for each KT66. I found no other faults.

But one amp failed after the initial repairs. One had burned one 470r open and one of the 63V rated 1,000uF caps had shorted, and after only an hour powering the owner's pair of ESL57 speakers.

The KT66 survived the experience because the owner turned off the amp soon enough. I examined his ESL57 speakers and found one with arcing mid-treble panel, a common fault in ancient ESL57, and expensive to repair. The panel arced when signals went above about 2Vac. Arcing of a panel means the amp has a short circuit for a load during the arcing, and this causes excessive signal currents and dc currents in the amp. One KT66 went into "thermal runaway." The 1.0 amp mains fuse did not blow. The the mains transformer became so hot it expelled some of its internal tar based potting compound. What a mess! This clearly illustrates the messy way in which tube amps can fail because of faulty 50 year old speakers, and the absence of any active protection circuit. I repaired the amps a second time, but fitted active protection circuits.

I think the amp owner bought a new pair of speakers.

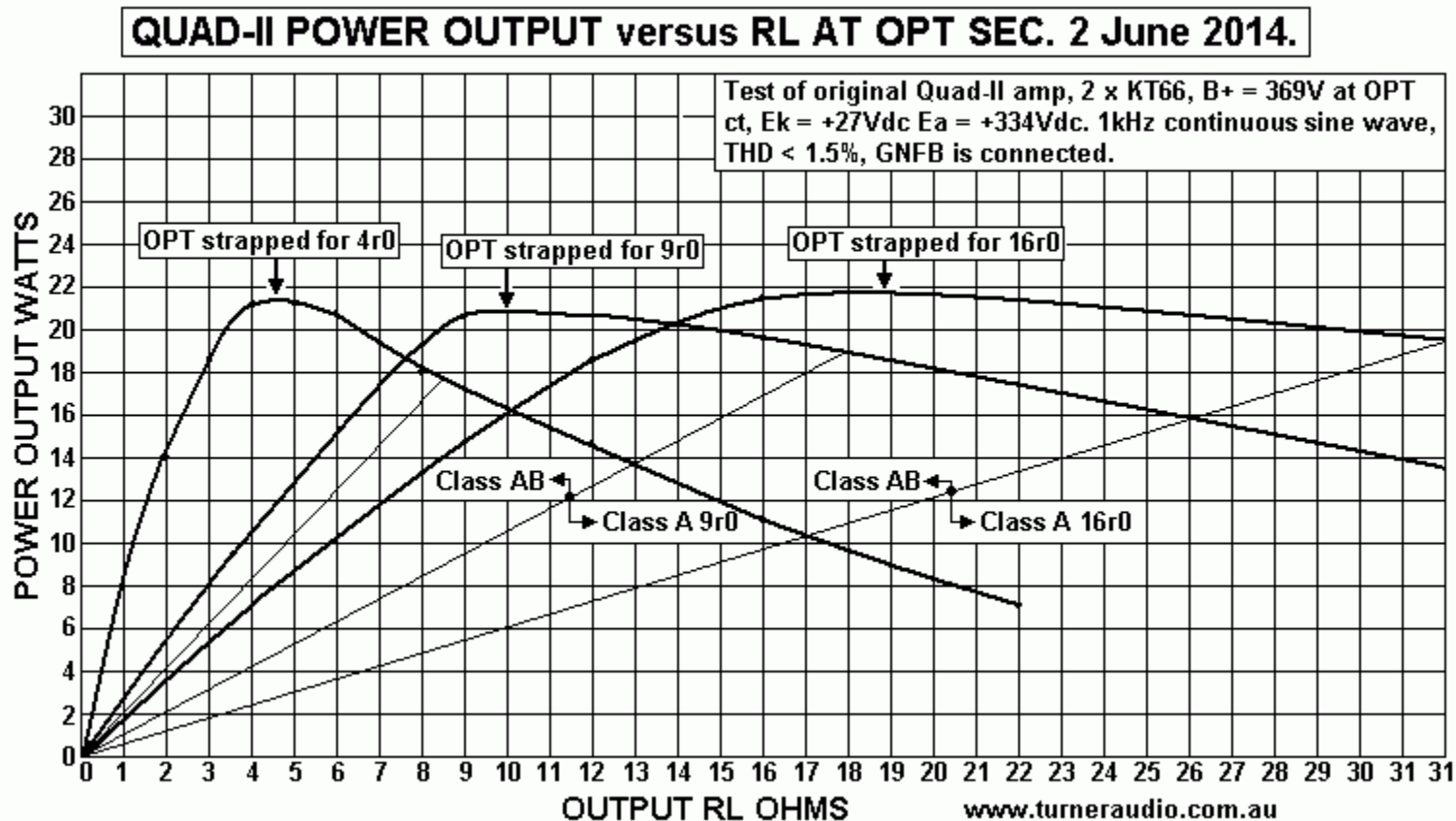
## Quad-II operation.

Quad-II have been said to offer fine class A performance, and the amount of class A depends on the idle Pda of the tube, and with KT66, up about 43% of the Idle Pda can be converted to class A1 power.

Quad-II have B+ at OPT CT = +370Vdc, and Ek is +27Vdc, and this means Ikdc for both KT66 =  $E_k / R_k = 27V / 180r = 150mA$ dc. Of this, about 10mA is screen current, with anode Idc = 140mA dc.

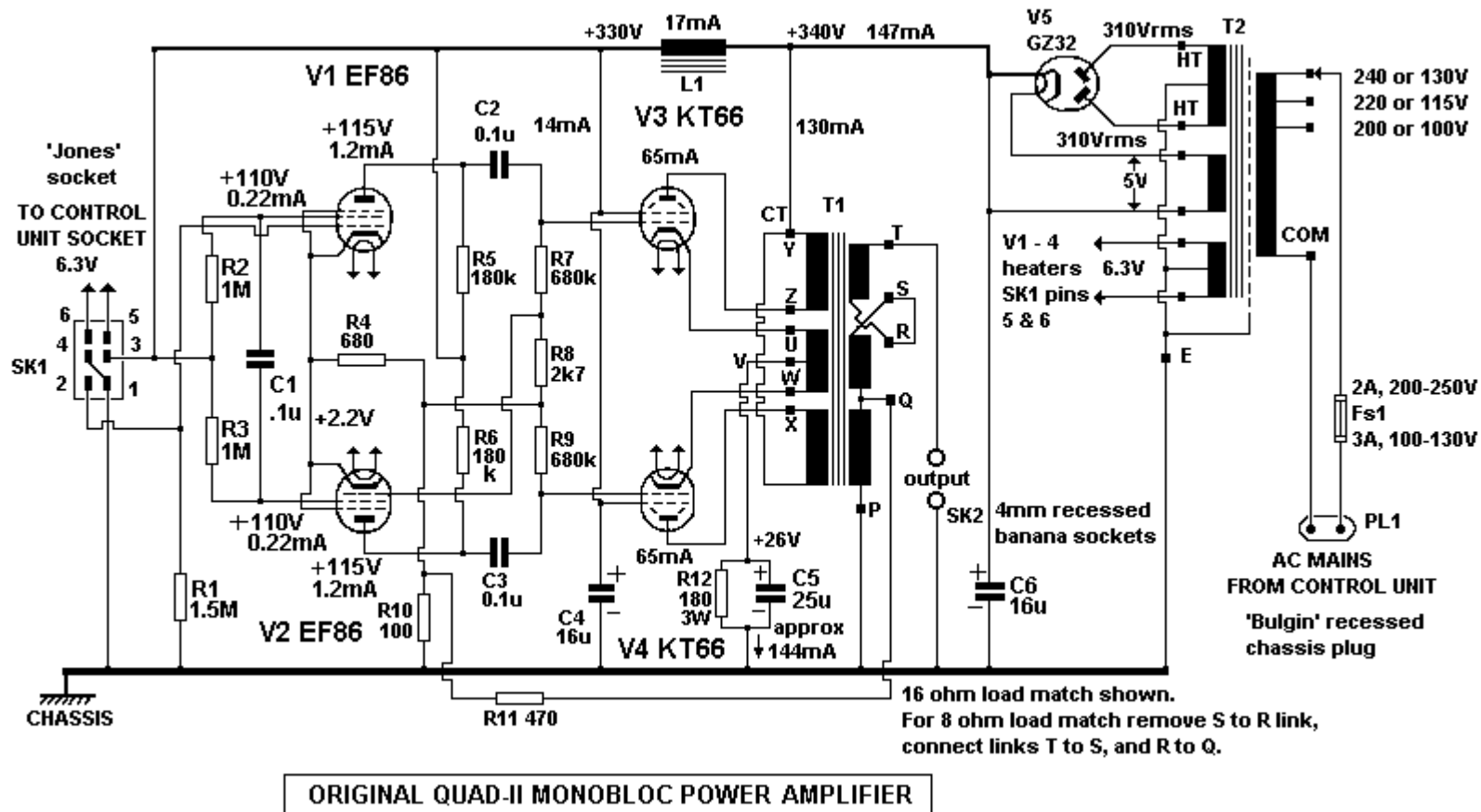
The Ea for KT66 is Vdc between anode and cathode. About 9Vdc is across each 1/2 primary winding so that  $E_a = +370V - 9V - 27V = +334V$ dc. For both KT66, heat is produced at idle and is calculated  $P_{da} + P_{g2} = E_a \times I_{kdc} = 334V \times 0.15A = 50.1$  Watts. Of this, Pda alone = 47Watts.

## Graph 2.



Graph 2 shows the maximum power levels where THD < 1.5% and available with the two advertised methods of OPT strappings for either 9r0 or 16r0, and the never advertised strapping for 4r0.

**Fig 1.** The original Quad II monobloc amplifier schematic :-  
Part numbers are the same as the original schematic.



I copied a good 50 year old paper copy of the schematic which I hope everyone finds easy to read.

The Quad-II OPT has two ways of strapping the OPT secondary. One way = 16 ohms, other is for 9 ohms.

This means that speakers between 6r and 20r are best used with the 9r0 strapping, and speakers of above 12r should have OPT strapped for "16r0".

There is no recommended strapping for a "4r0" match which would best suit speakers between 3r0 and 10r0. An "illegal" load match to 4 ohms is possible if the wire from speaker terminal to point T on the OPT is moved

to point Q. The existing links between T, S, R, and Q may all be ignored because the two windings between T and Q cannot be used. The match for 4 ohms only uses 1/2 the secondary winding turns and the winding losses are higher than the two recommended load matching for either 16r0 or 8r0.

Some might say Peter Walker made a mistake by not having one more turret terminal to allow all the secondary turns to be used for 4r0 load matching, to keep the winding losses as low as for 9r0 and 16r0.

Despite the high winding losses with the "illegal" 4r0 link of speaker to point Q, the power available is not much worse than for other load matching. Graph 2 shows the measured power and it speaks for itself.

***Go forth ye hi-fi listeners, connect ye 4 ohms speakers to point Q, and may music delight thee.***

Further down this page I have details about how to alter the secondary winding connections inside the potted OPT. This labour will give you a few more Watts of maximum output power, and you be the judge if its worth it.

The Quad-II overload behaviour is fairly benign. Most PP output stages with cathode biasing will suffer increasing  $E_k$  when driven hard in class AB. This means the grid bias is increased and the tubes become over biased and THD can increase tenfold. But in Quad-II, I found that it was difficult to cause more than +10% rise in  $E_k$  with any load up to clipping where grid current in KT66 had just begun. The B+ did not sag more than -10% when clipping was reached. The EF86 clip when grid current begins because they cannot drive a low Z load. I conclude Quad-II has fairly good inherent ability to withstand BRIEFLY excessive signal levels. Most output tubes withstand brief excessive saturation where instantaneous Pda or Pdg2 exceed ratings temporarily. But if Vdc and Idc conditions change for long enough, output tubes will overheat badly and a tube or two is doomed unless the amp is turned off.

To get lower winding losses requires replacement OPTs. I have a pair already made with cores much larger than those used by Quad, and which will be used in a pair of Quad-II with fixed bias and KT88 and triode inputs. The whole amp layout will be changed. The original chassis and PT are OK and from that basis I will have a very fine pair of 40Watt amps. The original Quad-II OPTs will go to replace some very poor OPTs in another amp.

But while retaining original Quad-II OPT, better technical performance and sound is possible if the original circuit is upgraded with modern R&C parts unavailable in 1955 and including high capacitance electrolytic capacitors.

There is no need for GZ32 or GZ34 which are best replaced with silicon diodes.

The use of a couple of LEDS and a couple of small bjts can now be used for protection circuits and bias balance indication to make sure an owner knows how his amp is going, and if there is a faulty output tube.

This is prudent in an age where modern people are just not used to the unexpected and perhaps smoky

failure of the primitive amplifiers of the 1950s, and there is now no Quad Company Support guy you can depend on for service or new Quad parts.

The quiescent bias anode currents of the output tubes change as tubes age. The two currents easily so different because there is only one shared "cathode bias" network of R12 180r and C5 25uF. And with aging, the tube grids begin conducting small but unwanted grid currents even at idle so the Eg1 may rise to a positive Vdc above the bias supply point at top of R10, 100r. The Vdc measured across R10 should be about +0.23Vdc. The chosen value of grid bias R7, R9, of 680k is much too high. After 50 years, typical R values go to 750k. The high values were chosen to allow the weak EF86 to operate without reducing the voltage gain by having RL too low. But the +Vdc which appears across the 680k in an aging KT66 causes the idle current to go higher which raises tube temperature which causes even more +Vdc across 680k and and more heating. This is an unwanted positive feedback mechanism.

The Vdc measured normally across the 680k should be no more than +1V, so between KT66 grids and 0V, you don't want to see more than +1.25Vdc. I have seen KT66 at near the end of their life with +9V at the grid at idle and with 90mA of anode current with slightly red hot anodes. This is disastrous for the music, and such a tube continues to overheat insidiously before finally melting down internally, and perhaps terminally damaging a power and / or an output transformer. If ONE KT66 begins to conduct too much Ia, the Ek rises with high current in R12 180r. This rise in Ek tends to turn off the Iadc in other KT66.

The output tubes rarely ever age at the same speed. So while 90mA may be flowing in one tube, there may be 40 mA in the other and there is a net 50mAdc flow across the primary which can magnetically saturate the OPT core to cause bad distortion because the OPT core has no air gap and was designed for well balanced and equal Iadc = 70mA in each output tube.

The effects just described can be worse if the old Hunts 0.1uF coupling caps to EF86 anodes have become leaky, further increasing the positive grid voltage. I recently found two such 0.1uF caps had become 400k resistors. The KT66 had high +Vdc at each grid, saturating both KT66 to have about 500mA flow in R12 180r, so it fused open fairly soon.

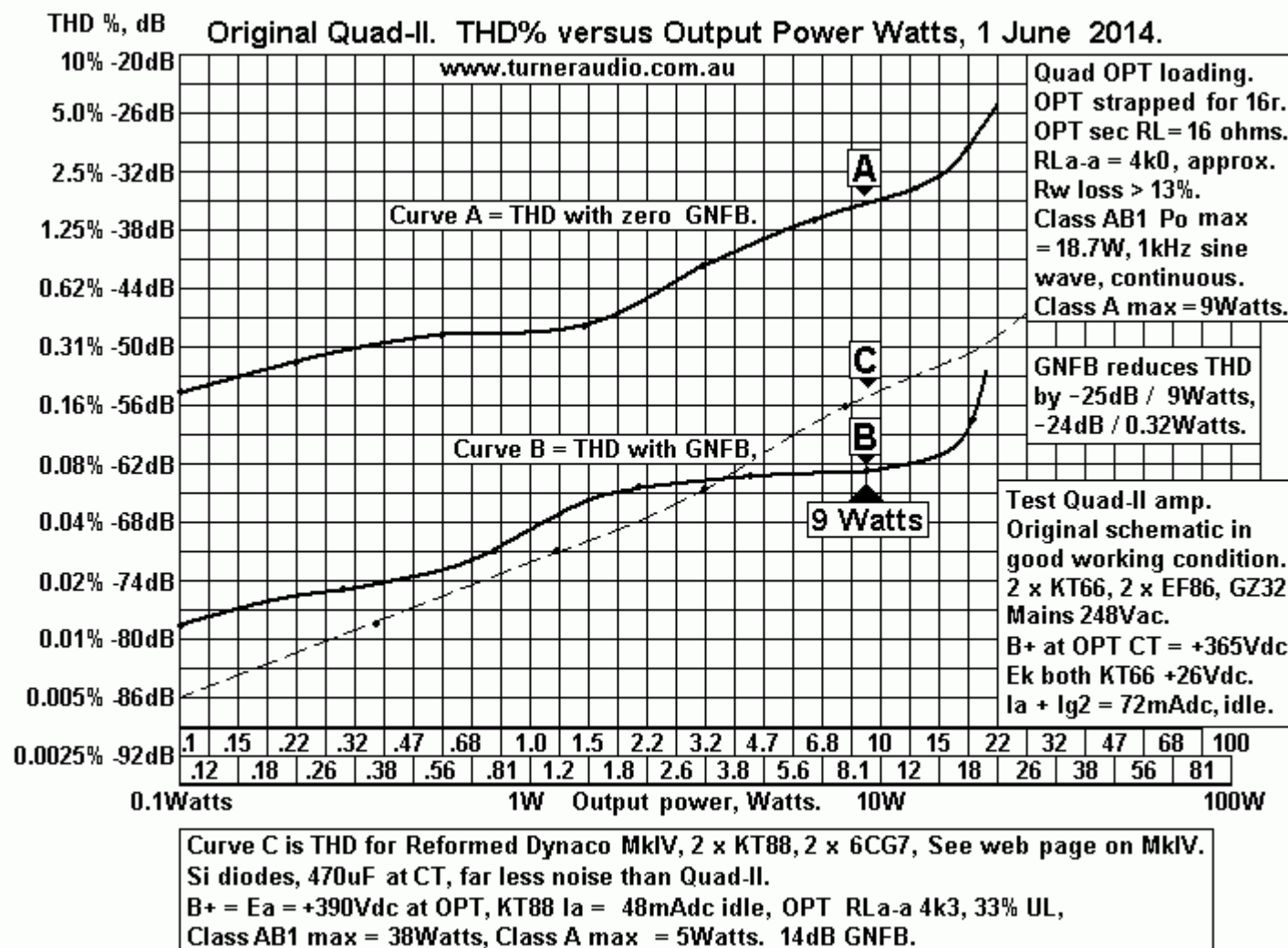
In the original amps the EF86 input tubes are set up in what is called a "floating paraphase phase inverter". It means a fraction of the output from V1 anode is applied to V2 grid to achieve two equal amplitude drive signals to the KT66. The R4, 7, 8, 9 all "float" on top of the global NFB network. The feed from V1 anode to V2 grid is 6dB of positive FB. You may think the distortion is increased 6dB as a result of the PFB.



But the feed allows V1 and V2 to be a balanced amp and most even numbered H are reduced. Odd H may increase because of the PFB. In practice it is not a serious fault, because output tube THD will always be much higher than drive amp THD even with the PFB.

In many Quad-II I have seen, they have not been serviced anyone qualified and output tubes have unbalanced anode currents and resistance values have changed and signals to each output tube grids are badly unbalanced. THD can measure up to 10 times more than it should at all levels.

## Graph 3.



**Curve A** for original Quad-II without any Global Negative Feedback.

To measure this, the R10 100r is shunted to 0V, therefore not allowing the fed back voltage from Vo to appear at V2 grid via R8 and at under R4 680r.

The amp has 16r0 load connected to OPT with 16r0 strapping, so this is class AB1 working and the first 9Watts are pure class A.

One can say that because the EF86 driver amp has low THD compared to output stage, then the measured THD without GNFB is mainly due to KT66. Notice that the THD goes up to about 2.9% at clipping, and is 2% at 9Watts. It would worse if there was no CFB winding which makes the KT66 act like they would if triode connected without CFB. However, the CFB allows the higher Po max than when KT66 are triode connected.

**Curve B** is for the same amp but with normal GNFB, ie, with no shunt across R10.

The average reduction of THD is about -24dB. At low levels, with 0.040Vrms input, the Vo = 4.67Vrms with zero GNFB, and 0.48Vrms with GNFB, so the NFB gives about -20dB gain reduction.

The gain reduction with GNFB should be equal to THD reduction and probably there is a less simply explained phenomena in the interaction of NFB network and V1 & V2 tubes.

This is not a bad set of measurements. THD spectra is mainly 3H at all levels but has many higher H present. At low levels, and when viewing the THD on oscilloscope, its envelope is much modulated by rectifier noise. Some diode switching noise is present.

The THD curves are for class AB1 Po, and have uneven curvatures between low and high levels. This indicates there is some THD cancellation or addition between input / driver stages and KT66.

I measured the THD with 32 ohms with the 16r0 links and for pure class A maximum, and with the GNFB the THD was below 0.1% at 20 Watts. What more could anyone want?

## **Curve C.**

This is for a MkIV Dynaco Monobloc I recently re-engineered.

See [Dynaco-mkIV-reformed.html](http://dynaco-mkiv-reformed.html)

Now this is a very cheeky sneaky move of mine. But whenever considering amps, we should always be prepared to compare one amp with another, lest we loose understanding of "better" or "worse."

Notice the THD curve is almost a straight line. That will be due to the very low THD input / driver I have in MkIV which uses 6CG7, which qualifies to be the King Of Little Triodes.

The reformed MkIV was tested with the same RLa-a as for Quad-II, about 4k3. The output load is 4r0, less than the minimum 6r0 I recommend. The MkIV has 33% UL taps with KT88, and 6CG7

The MkIV has 14dB with 4r0 load, some 10dB less than Quad-II, yet the Dynaco has THD at -6dB lower up to 2.2Watts. The Dynaco gives 38Watts class AB1 max with 4r0, and only 5 Watts for pure class A. So while the Quad has less than 0.1% THD at 9Watts, the Dynaco has 0.2% because it has moved into class AB1 working. But the THD spectra in Dynaco THD is mainly 3H + slight 2H but has much less other rubbish we see in Quad-II spectra. The majority of listening is done with amp power less than 2Watts.

I doubt sometimes that "extra heat is worth the ears", but then my customers told me otherwise.

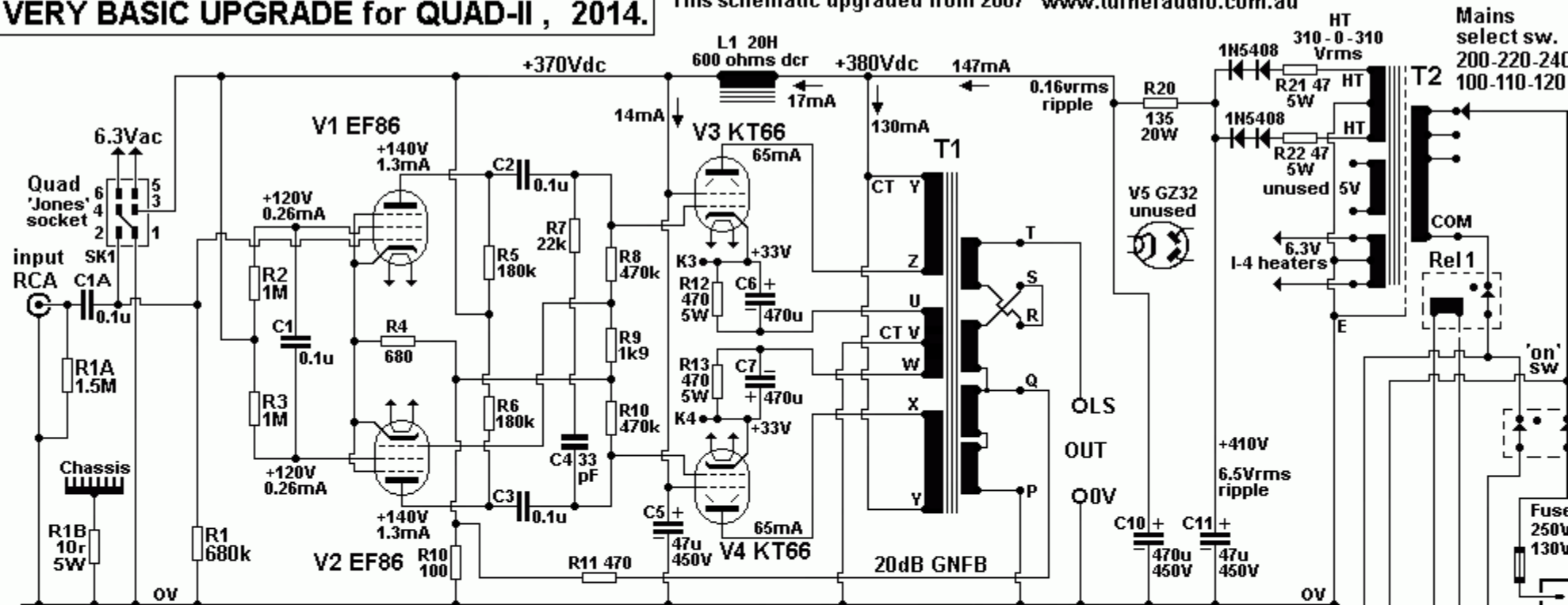
I can conclude that if one is to re-furbish such grand but somewhat limited old amps, it is always possible to improve the circuit behavior to get a better measuring and better sounding amp.

[illegible]

**Fig 2.** Basic Reformed Quad-II schematic....

**VERY BASIC UPGRADE for QUAD-II , 2014.**

This schematic upgraded from 2007 [www.turneraudio.com.au](http://www.turneraudio.com.au)



1950s Bulgin plug must be removed and replaced with IEC chassis socket with inbuilt mains fuse. Each amp of each channel to have mains switch.

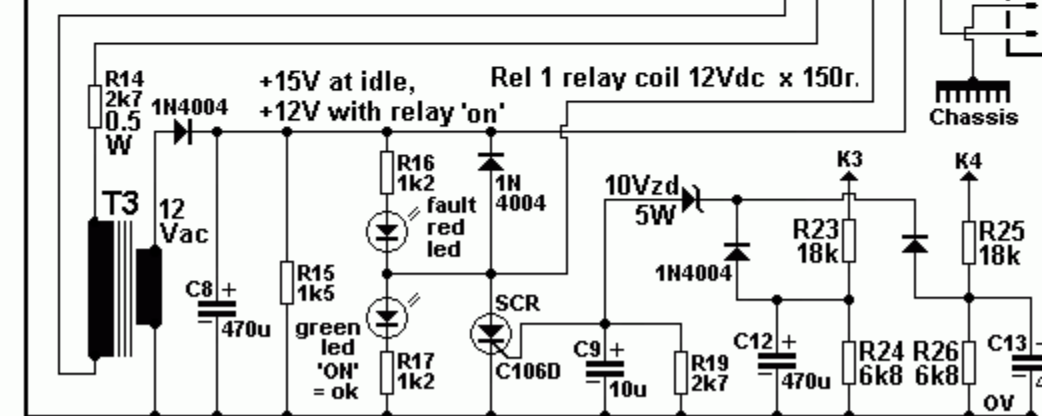
**5VA Auxilliary T3  
mains voltage  
is either 115V  
or 240V**

### OUTPUT TRANSFORMER SPEAKER MATCH SETTINGS !!!!

For 12ohm to 40ohm, Yelo lead from LS to T, link S to R.  
For 8ohms to 16 ohms, Yelo lead from LS to T, link T to S, R to Q.  
For 3 ohms to 10 ohms, Yelo lead from LS to Q. link T to S, R to Q.  
Do NOT use any speaker with less ohms than ohm range listed.  
For example, do not use 4 ohm speaker with 12-40 ohm links.

**PROTECTION.**

When either cathode Ek rises to +50Vdc,  $I_{kdc} = 106\text{mA}$ . Vdc at top of C12 or C13 rises to +12V, SCR latches on with +0.68V at gate. Amp has mains Neutral to T2 opened and amp is turned off, green LED goes out, red LED turns on until amp reset by switching off, then on after 2 secs.



**Active protection against excessive cathode DC current, on 70mm x 40mm board.**

The component numbers used here don't relate to any component numbers in the original schematic except by coincidence. This schematic is a re-drawn version I did in 2007, and includes slight changes.

More improvements could be done but the above has what I consider to be the minimum.

Improvements include...

1, Remove old 2 pin mains Bulgin chassis socket to rubbish bin. Instal IEC 3 pin mains chassis plug with 2AG mains fuse included for standard IEC mains cable.

This may infuriate those wanting to keep the Quad-22 preamp arrangement intact. Safety comes first, and if you ignore this step 1, then don't blame me if you electrocute yourself, or family member.

2. Instal mains on-off DPST rocker switch. Bypass switches with 10nF 2kV ceramics, ( not shown ).

3. Instal RCA input socket just near existing Jones socket for Quad-22 preamp. If you doubt you'd ever spoil your listening with an original Quad-22 control unit, then remove the Jones socket.  
Note C1A and R1A to deal with Vdc swings in external preamps.

4. Connect R1B between 0V at Jones plug and the chassis. This interrupts mains earth loops which can cause hum with other audio gear connected, preamps, CD players etc.

5. Remove grey box with 16+16uF caps inside and put in rubbish bin. Disconnect HT windings and 5Vac heater windings from GZ32 valve socket. Decide if you really must have a dead tube in your amp to make it look right. Instal well thought out terminal strips to allow the B+ rectifier circuitry to be built.  
Do not try to use GZ32 as a slow turn on series diode for B+ rail. I tried, and it didn't work out.

The HT is rectified with 1N5408 silicon diodes through current limiting R21, R22, 47r/5W into C11 47uF. This gives B+ = + 405Vdc approx when mains are 245Vac and mains taps are soldered for maximum possible. I removed the the mains adjustment switch on original amps.  
At C11, 100Hz ripple voltage = 6.5Vac. R20/135r plus C10/470 uF filter ripple voltage to 0.15Vac at OPT CT. This is a vast improvement on original amps where Vr at CT = 18Vac. PSU noise is reduced by -40dB.

6. Instal the 470uF laying on side under chassis and alongside 47uF. The 47uF is minimum value, *and you could have any value above up to 470uF*, because the 47r plus HT winding resistance prevents excessive peak currents charging the caps.

The 470uF has much lower reactance than 16uF and anchors the CT to 0V to minimize rectifier noise getting into signal path. Although B+ soars to +450V at turn, it settles back to about +390V at the OPT CT after KT66 draw current within 20 seconds. Modern 450V rated caps will cope OK with this operation condition. The B+ applied to KT66 screens should be very well filtered and stabilized. The original Quad-II choke is retained but screen plus input stage B+ is anchored to 0V with 47uF, another minimum value. The 100Hz ripple at C5 47uF is less than 1mVac.

7. The two KT66 cathodes are individually biased with R12 & C6 and R13 & C7 networks of 470r / 5W and 470uF respectively. These networks are connected between pin 8 on KT66 sockets and the wires leading from ends of the cathode feedback winding on OPT. Make sure the POSITIVE end of cap connects to pin 8 for cathode on KT66 socket.

Under dynamic music conditions the very slow time constant of the cathode bias networks prevent much movement of the cathode Ek even when music peaks reach up to clipping levels in class AB1.

The balancing of the KT66 cathode currents is automatic with the two bias networks, and as the tubes age their current imbalance is negligible compared to the original biasing with a common Rk.

The original 180r & 25uF bypass cap are removed, and a wire link soldered across the two turrets for these parts. This connects the cathode feedback winding CT to 0V. The theoretical Rk for each tube should be 360r, twice 180r, but 470r gives just slightly less Idc, and good control of Ek.

The later Quad-II-Forty has individual cathode biasing.

8. The stability of Quad-II with its high total amount of NFB is not unconditional, and pure capacitance loads of 0.22uF with links set for 8r0 will cause HF oscillation.

To ensure unconditional HF stability, the network of R7 & C4 is connected between V3 and V4 grids. This reduces open loop gain and phase shift of V1 and V2 above 20kHz.

9. The Fig 2 basic schematic for V1 and V2 unchanged from original. But R8 & R10 680k may be reduced to 470k without much lessening of EF86 gain, and to give a lower biasing Rg for KT66. But R9 2k7 must be changed to 1k8 to retain the correct feed to V2 grid. The B+ applied to EF86 stage is higher than in original Quad-II so slightly more Idc flows so the pentode Gm increases thus gain with 470k is not much different to any original Quad-II.

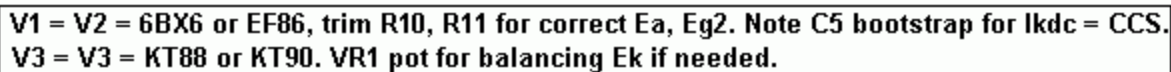
10. The bottom part of Fig 2 schematic shows the active protection provided by the group of





**Fig 3.** More Reformed Quad-II schematic....

[www.turneraudio.com.au](http://www.turneraudio.com.au)

[illegible]

**See website page about Quad-II mods for more details on circuit operation and OPT details.**

Fig 3 component numbers do NOT relate to any numbers in original Quad-II or any other schematic except by coincidence.

HT is rectified with silicon diodes through current limiting 47r to a 100uF. B+ to OPT CT is filtered with CRC using 100uF - 200r - 470uF, to get 100Hz ripple at OPT CT > 0.06V. The original Quad-II choke is retained to filter the output tube Eg2 and B+ for input/driver tubes. The intention for this design was to retain nearly original working conditions for the output tubes which in this case were to be KT90 instead of KT66. The amp owner already had an 8585 amp I made which used 4 x KT90 per channel, and he liked these tubes. I found the KT90EH made in Russia to be extremely reliable. With the CRC filter AND the silicon diodes, the B+ voltage drop across 200r is quite tolerable, and the +380Vdc is actually higher than in original Quad-II with struggling GZ32 with high effective series resistance.

In Fig 3 the production of the B+ voltage is similar to Fig 2.

The KT90 gave a lower amplifier output resistance than KT66, slightly lower THD and better maximum current ability to cope with the RL-a load of 4k2 including high winding resistances when 8r0 is connected and with OPT links set for 9r0.

The two KT90 cathodes are individually biased with R15 & C7 and R16 & C8 networks of 470r / 10W and 1,000 uF / 63V respectively. Under dynamic music conditions the very slow time constant of the bias circuit prevents much movement of Ek cathode bias.

Balancing of each output tube Ikdc bias is mostly automatic but in this pair of amps I included use of a low -Vdc supply so that output tube grid voltage can be adjusted from about 0V to -8V which is enough to get good Ikdc balance. See VR1, 10 pot, linear, wire wound, and 3Watt rated.

The condition of bias balance or any tube fault is monitored by the 2 LED which should glow at equal brightness when Ik for each tube is within 5% of being equal. I did use a pair of red LEDs in amps for 2006, but this schematic above shows YELLOW LED for showing balance.

***I have now ( 2014) included the active protection circuit*** with SCR and green LED for "amp on" and red LED to indicate amp is turned off internally because of some fault because of excessive Ikdc in output tubes.

The bias balance is easy via a 6.3mm chassis hole and use of thumb nail or small blade to turn a screw head flush with chassis side. The screw is end of 6.3mm pot shaft with a slot for a blade.

GZ32 and the Jones 6 pin input socket have been removed to rubbish bin. The 470uF B+ cap may be mounted where GZ32 and its socket used to be. It is good practice to place a metal plate shield between 470uF cap and the output tube standing nearby, so prevent the cap getting too hot from radiated heat from output tube, which shortens its life.

The 5Vac heater winding for GZ32 is connected in series with one end of the 6.3V heater winding which has a CT to 0V. Thus there is an available 8.2Vac voltage quite able to drive voltage doubler circuits to produce + / 10Vdc. The + 10Vdc is CRC filtered for 6.3Vdc to V1, V2 heaters. The -10Vdc feeds the bias balance pot.

V1 and V2 are ideally EF80 / 6BX6, which are a "sharp cut off pentode" with 1,001 uses and which has about 50% higher gm than EF86 when compared using same Ia and Ea and Eg2. I have the 6BX6 set up as a long-tail pair differential amp and WITHOUT the PARAPHASE connection which was used in the original Quad-II circuits. This means the odd number HD of V1 is not fed to grid of V2, so the 2 tubes produce less THD. There is good balancing of even number HD currents at commoned cathodes because the Rk is a high enough value.

The V1 & V2 cathodes are supplied by a B- rail = -380Vdc produced with diodes from HT winding. The -380V is filtered with RCRC and a virtually constant current is supplied to commoned cathodes of V1 & V2. I have used 3 series resistors ( R12 + R26 ) to avoid excessive Vdc across any one R.

The bottom of R12 22k has been bootstrapped with 10uF to the GNFB applied to grid of V2. This makes R12 act like a resistance far greater than 22k. There will be about 0.2Vac across 22k, so Iac = 0.009mA. Vk to 0V = 1.72Vac (max approx), so the effective R looking down into R12 = 190k. The bootstrapping should make V1 Va output no more than 2% above V2 Va output. For closer Va balance, use about 4M7 across R16 330k.

In later Quad-II mods I have used a MJE340 as a CCS for commoned cathodes for differential amps.

The amp protection and bias balance circuit requires a small 5VA 240V : 12V transformer, T3, mounted somewhere conveniently under the chassis. This provides power for the small circuit board used for the solid state devices

The picture image at the top left of the page shows the amp balance LEDS with equal brightness.

With KT90 there is 25 watts AB into 8 ohms with slightly more into 4 ohms, and Rout = 0.78 ohms.

Some folks would hang me from an old oak tree after hotting up a Quad II amp like I have. But I have thought about what happens in a fault situation resulting from bias failure, shorted or saturated output tube, shorted speaker cables, shorted coupling caps etc, etc.

Once the bias balance LEDs have been adjusted for equal brightness, any change in output tube  $I_{adc}$  will always make one LED glow more brightly than the other, which tells an owner to re-balance the bias. When the tubes continue aging and becoming more unmatched, the owner runs out of turn on the pot and he cannot adjust the pot for balanced bias currents and equal LED brightness. This tells the owner to replace one or both output tubes. If the owner ignores the LEDs, then  $I_{adc}$  in one output tube may rise into the dangerous region where a tube is too hot. Many owners ignore such things and do not hear the degradation of music. When a tube has too much  $I_{adc}$ , the  $E_k$  will rise enough to send a signal to the SCR which turns off the amp automatically to save a huge expense on PT or OPT etc. The owner cannot ignore this.

I thought bigger output tubes like KT88, KT90, or 6550 may overheat the output transformer primary winding and power transformer windings if one or both tubes were to fail and become saturated with current resulting in a maximum of about 1Amp dc from the power supply.

But such a failure would blow a slow 0.5A mains fuse. I tried a slow blow 0.5A which worked OK instead of the original 2A fuse shown on the original amp schematic. I've always thought the 2A fuse value was too high for original Quads with 220V to 250V mains.

A typical intermediate level fault is where ONE output tube conducts maximum  $I_{dc}$  before it melts down to become a pure short circuit between anode and cathode. This condition of thermal runaway creates overheating in OPT and PT before an output tube becomes a short, or goes open.

I tried placing 1k $\Omega$  from the OPT CT to 0V to simulate a serious but intermediate fault event. This generated  $I_{dc} = 350\text{mA}$ . A 0.5A slow-blow mains fuse blew after a 3 second delay. But 2A fuse would not blow, so fuse could probably be 0.75A fast blow, but a 0.5A slow offers sensitive protection.

Fuses suffer heating / cooling cycles at each turn on. The cycles fatigue the wire in fuse, so the more sensitive the fuse, the more you get "nuisance fuse blows" after some weeks or months of use, so a compromise is to use a 0.75A slow fuse, and never leave the amps turned on overnight, especially in hot weather.

If one output tube were to conduct say 200mA $I_{dc}$  for say 5 minutes, then the  $E_k$  will rise to +97Vdc. This may well cause the 1,000 $\mu\text{F}$  bypass cap rated for 63V to become a short circuit and then  $I_{kdc}$  will increase to a maximum possible and the mains fuse should blow soon enough. KT66 saturated current is about 300mA $I_{dc}$ , but KT90 may conduct 500mA $I_{dc}$ . If there is a continual 500mA $I_{dc}$  in 1/2 the primary of Quad-II OPT which has  $R_w = 167\Omega$ , then 41Watts of heat is generated in the 1/2 primary winding. Unless the amp is turned off well before  $I_{adc}$  reaches 500mA, the OPT winding will fuse open well before you can feel the OPT getting HOT.

Even KT66 with max 300mA Idc will produce 15Watts of heat in 1/2 the primary which will damage or fuse the winding.

Its no good to use a fuse between cathode to CFB winding because it will have to be 200mA rated to avoid nuisance blowing. If additional fuses are to be used, place one 0.5A slow blows between each end of HT winding and subsequent R and diodes. ***It is ALWAYS better*** to have an active protection circuit.

With the output terminals short circuited, and the input signal turned up high into gross overload, a 0.5A mains fuse will not blow because the power supply anode current in the seriously overloaded condition only increases by just over twice to 250mA which isn't enough to make such a low value mains fuse blow unless the gross overload is sustained for minutes which is long enough for tubes to overheat, get red hot anodes, then go into thermal runaway. Such a sustained fault like this is very unlikely to occur because either silence from the shorted output or gross distortion of sound would alert an owner that something is wrong and he/she would turn things off and investigate speaker connections or speaker condition integrity.

If one of two speakers is suspected of causing silence or high distortions, then reverse the speakers to opposite amp channels and if the problem follows the change of channels then the speakers have a problem but amps are probably OK.

In the 2006 amps I didn't provide any means of automatic turn off of the B+ for the whole amp if cathode Ek rose too high as in the Fig 2 schematic. This was similar practice to a pair of amps I modded in 1999. I felt that the owner would keep a fairly close eye on the bias balance LEDs which will tell him if something is wrong. Well, that owner has Gone Upstairs and who knows who will use the amps now?

My upgraded 2014 schematic of this ***2006 amp includes the active protection***. Since 2006, I have made circuit boards small enough to fit in any amplifier I ever worked on.

The slow blow 0.5A fuse has proved to be quite reliable, and it survives the in-rush current at turn on. The slow blow fuse will tolerate short time input current surges maybe up to 1.5A, but will blow when the AVERAGE current goes just over 0.5 Amps and stays there for some time.

The Quad II set up as the above schematic draws 88Watts, so with 245V mains the input current average is 0.36A.

This is less than in the original Quad-II which has the GZ32 heaters consuming about 12 Watts more.

KT90 are perfectly interchangeable with KT66 and draw the same idle current. But KT90 can produce a outright maximum of 30Watts instead of 22 Watts with KT66. KT90 heater current is 1.6A instead of KT66 at 1.3A but it is OK because these amps were designed to have add on tubed preamps and tuners which will never be used with this pair of amps.

The musical performance includes tighter bass and more controlled and detailed treble, so I have to say  
KT90 in Quad-II sounds better.  
KT88 / 6550 can be used OK.



The right image has the whole system in trial use before sending it off to my customer, although GZ32 are not plugged in to keep it looking original.

On the left image you can see the IEC shielded mains socket that replaces the Bulgin original. The old Quad-II recessed 4 mm banana sockets were replaced with something from some retired HP test gear because the originals had cracked aging plastic and from years of speaker cables being wrenched sideways. The new signal input socket is Canare 75 ohm RCA which replaces the 6 way "Jones" socket

used in the original amps. The terminals are mounted on a white fibreglass panel. The appearance was not important; the SOUND and the RELIABILITY were the important issues.

Shielded interconnect cables from a preamp should only be used since the speaker output cables are close to the amp input. I did try using unshielded dual foil cables which were close to the speaker cables. No HF oscillations occurred, probably because the live input cable is tied to the low impedance of the cathode follower in the preamp. But I do not like unshielded twisted pair or flat foil interconnects because they often pick up switching noise and other noise from nearby mains cabling and these cable types are fragile, and always break sooner or later. I quite like RG58 coax cable for interconnects.

A very much modified Quad 22 control units is to the left of the power amps and is fully described in my page on Quad 22 mods. The separate preamp power supply is on the shelf below the two amps. The 2 power amps and preamp each has a mains turn on switch.

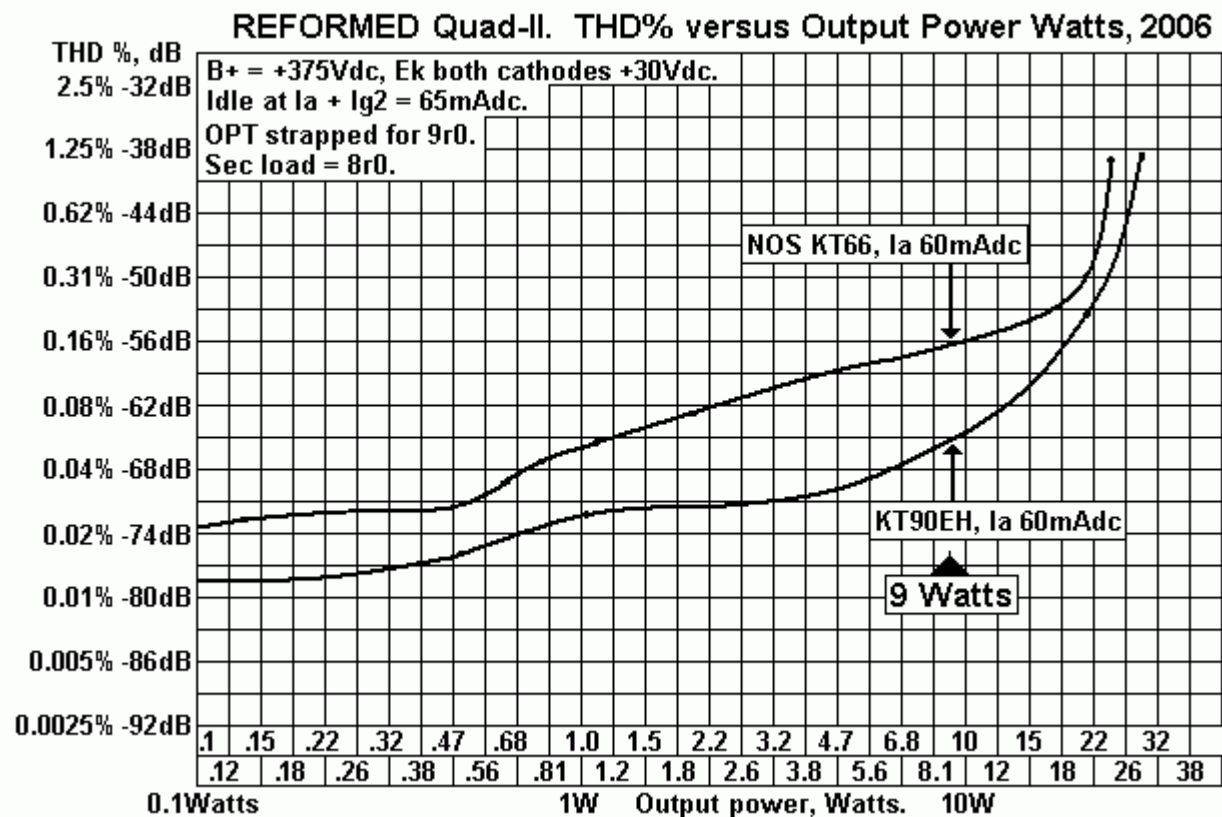
For each power amp I used a blue "on" LED and red mains on switch placed in an aluminium panel to cover holes for original mains voltage settings, something not needed since the 240V mains in Oz rarely varies, and is always over 240V unless it is a cold night in winter. There is never any need to employ the other two lower mains voltage settings.

Blue LED are too bright with say 4mA, and they run tolerably bright with about 0.25mA. Owners prefer blue, but I prefer green for "on" using a plain diffused 5mm dia type which runs on 4mA.

For those who worry about THD, here is....

**Graph 4.**





The above graph 4 is ***drawn on logarithmic axis for both THD and output Power.***

The test is for the Fig 3 REFORMED schematic of reformed Quad-II, and shows results for KT66 and KT90 with same loading in the same circuit with same GNFB which is much less than in original Quad-II amps.

((((( However, in 2014 I have tested an original Quad-II amp with exact original schematic and in fair condition, and the THD is plotted in Graph 3 above on this page. ))))))

In Graph 4 you can see that at onset of visible waveform flats on CRO, ie, amp clipping, both KT66 and KT90 produce about 1% THD at 21Watts and 24Watts into 8 ohms respectively.

KT90 have an average of 1/2 the THD produced by KT66, but make 1/3 of THD at 3Watts which covers most listening levels.

KT90 make 0.03% at 3W, 0.1% at 14W.

The curves with all their kinks are typical class AB tube amp measurements when driven with pentodes which produce more THD than triodes. But at clipping the THD and IMD does not matter as much as at normal levels  $< 3\text{Watts}$ . This is where our focus on the soloist is intense, but really, anything below 0.05% is not too bad, considering tube amp artifacts are less objectionable than solid state's. The trend for the KT90 to have half the THD of the KT66 continues below  $1/4\text{Watt}$ . In 2006, it was difficult for me to measure THD accurately because at  $1/4\text{ Watt}$   $V_o = 1.41\text{Vrms}$ , and if  $\text{THD} = 0.01\%$ , then the THD voltage is  $0.141\text{mV}$ , and noise can be easily  $0.5\text{mV}$  which obscures observation on CRO of the THD. The noise becomes the dominant artifact at low volume. If noise =  $0.5\text{mV}$ , and does not increase at say  $14\text{Watts}$  where  $V_o = 10.6\text{Vrms}$ , then SNR is said to be  $-86.5\text{ dB}$  which is quite acceptable.

I also tried measuring THD with loads between 4 ohms and no load at all. With a 16 ohm load connected to the the amp set for 8 ohms, at 1Watt the THD is 6 dB less than with 8 ohms, and with 4 ohms its about twice what the 8 ohm produces. At low levels of below 2 Watts which covers much listening for many people, any load down to 4 ohms is OK, and KT90 give around 1/2 the THD of KT66 for all loads.

The measured output impedance with KT66 in my circuit is 1.2 ohms, and with KT90 it is 0.9 ohms approx. I also tried Russian 6550EH which gave similar THD to the Russian KT90EH, and  $R_{out} = 1.0$  ohm.

The other thing to bear in mind is that I have 15dB GNFB used in my reformed Quad-II. In the original Quad-II with paraphase circuit for EF86, there is about 21dB NFB, or 6dB more.

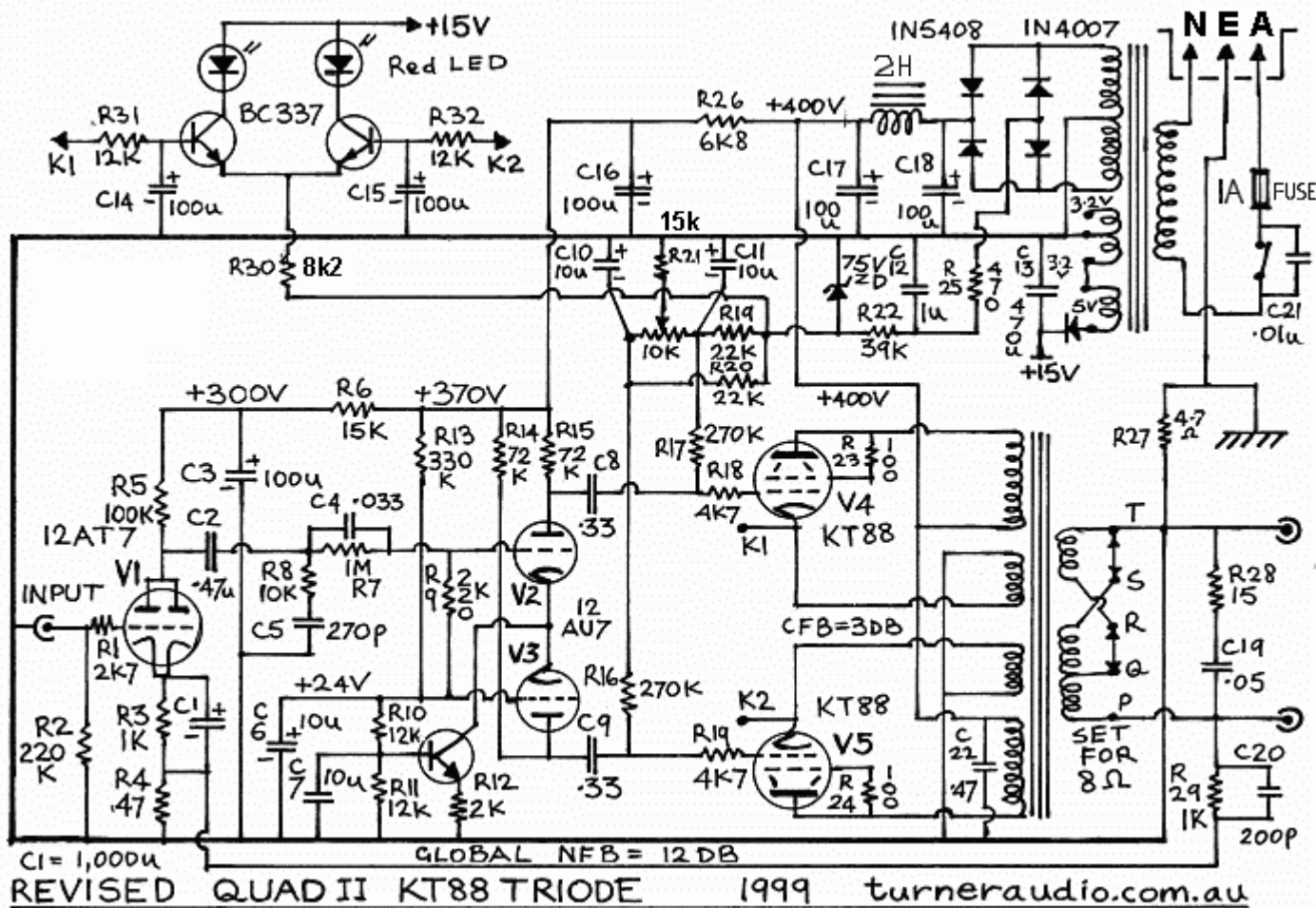
Now from graph 3 above, and with KT66 in original amps, I got 0.07% THD at 9Watts. In Graph 3 with KT90, and at 9Watts, I get 0.06%, and Rout is lower than original.

So, I get better THD results with 1/2 the applied GNFB.

[illegible]

## The first Quad-II mods I did in 1998-1999.

**Fig 4.** Schematic of the first reformed Quad II I attempted in 1999, using KT88 in triode, plus triode input tubes instead of the EF86 pentodes.



The hand drawn schematic was done 3 years before I went online or had a PC or scanner. Part numbers have no intentional resemblance to any other Quad-II schematics on this page. With mains at 250Vac I found I had B+ = + 410Vdc after diodes into 100uF C18 with KT88 triodes as I show.

There is no picture of the amp, but GZ32 and Quad-II choke was removed, and a new aluminium box mounted above chassis and snug between OPT and PT and about 85mm high. This box had ventilation holes to allow air flow from below chassis into box and out of box side away from nearby output tubes. Inside the box I fitted a 2H anode choke and other PSU caps. Fixed bias is used for about 55mA per KT88 connected as triodes.

The original 20H Quad-II choke does not filter B+ anode supply for KT66. With original 16uF + 16uF caps, there is barely enough CLC hum filtering for B+ for KT66 screens and EF86 anodes. The anode supply in original amp was from first 16uF after GZ32 and anode B+ filtering is quite unacceptable by today's standards.

It is better to have an anode filter choke which is at least as large as original 20H choke, but with  $R_w < 40r$  so wire size will be higher and turns much reduced, hence L will be lower. The minimum L value should be 2H but can be 4H but it would be almost impossible to make a choke of 4H with  $R_w = 40r$ , and with air gap to suit 150mA<sub>dc</sub>, and using wasteless pattern E&I and no larger than the original Quad-II choke. However, a clever DIYer will allow an anode choke to be taller than original, and will fit it inside a box with el-caps. And box can be snugly between OPT and PT boxes above chassis and be up to same height, same style of metalwork, but with ventilation, and painted to match the battleship grey paint used by Quad, and which perhaps was once used in WW2 for camouflaging military gear during Britain's terrible summer and winter weather.

The higher B+ voltage suits triode operation because of the limitation of triode anode voltage swing in class AB1 because of grid current.

This schematic gave 20Watts in triode class AB1 and measures very well. In 1999, I used only 12dB GNFB which is much less than original Quad II. The amount of local cathode FB in the output stage is not high because the triode gain is only half that for tetrode-with-CFB. and fixed  $E_{g2}$ . The effective CFB is only 3dB. When trioded output tubes are used, just enough local CFB exists to compensate for the high winding resistance losses in the OPT. Better than nothing though.

The total CFB + GNFB applied was about 15 dB.

I first EL34 in triode with only 6dB GNFB but the owner said it gave poor dynamics when compared to the owner's other 10Watt amp with 6GW8 output tubes in ultralinear with about 16dB of global NFB.

The use of KT88 in triode and 12dB GNFB delivered the kind of vibrant and accurate dynamics he was looking for.

You just cannot use Quad II amps without global NFB because the output resistance will be too high even with triode wired output tubes.  $R_{out}$  was less than 1r0 as I have it with 12dB GNFB and KT88 triodes.

Original Quad-II amps with KT66 without GNFB have and only local CFB have  $R_{out} = 9$  ohms measured when OPT is strapped for 9r0.

With KT88 in triode, and without GNFB the  $R_{out} = 5$  ohms and still too high for any speaker.

The GNFB reduces the 5r0 to 1r0.



Fig 4A.

# Quad-II amp, KT88 triodes, 1999. Redrawn 23 June 2014

For PSU, Protect, etc, see sheet 2, 23 June 2014.

OPT links	RwP 334r	Sec	RwS	S loss%	RwP+S loss%	OPT ZR	TR
LS to T, S to R.	7.9% loss	16r	2.16r	11.9	19.8	243:1	15.6:1
LS to T, S-T, Q-R.	7.9% loss	9r	1.08r	10.1	18	432:1	20.8:1
LS to Q.	7.9% loss	4r	0.72r	15.2	23	972:1	31.2:1

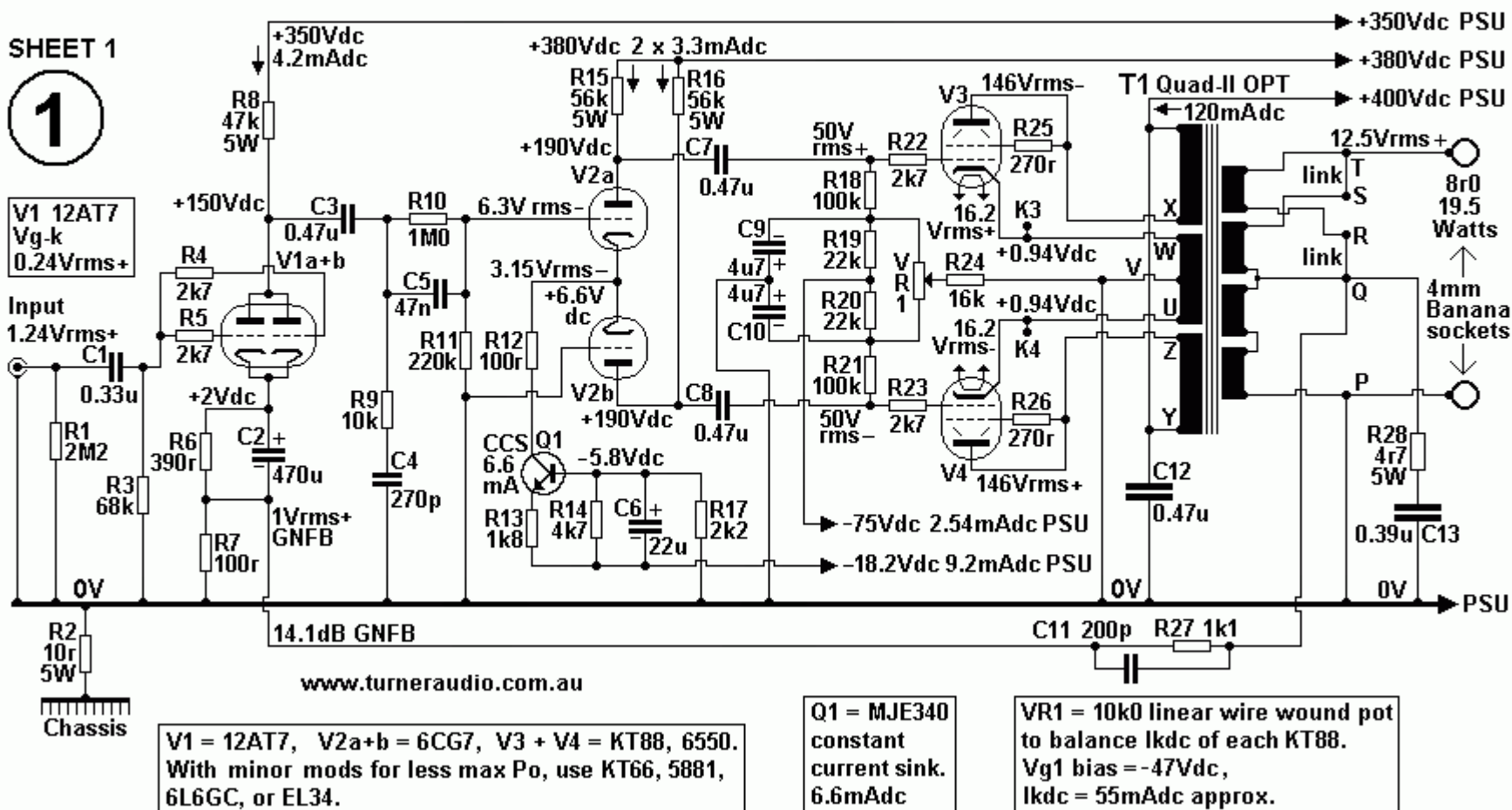


Fig 4A shows what I would do with trioded KT88 in Quad-II now. Notice the higher B+ for V1 12AT7, and 6CG7 V2a + V2b with increase of Iadc, to give better dynamics. The CCS is fed from a negative rail to maximize the Ea and to get a larger possible Va swing at low THD. GNFB is increased 2dB. Just remember R9&C4, C11&R27, R28&C13 are arranged for what I think will give unconditional HF stability with the amount of GNFB which is derived from point Q, and not from speaker

output terminal. This schematic requires that the OPT anode and cathode connections are reversed to get correct phase for GNFB. This is not shown clearly in my old 1999 Fig 4 schematic.

**Fig 4B.**



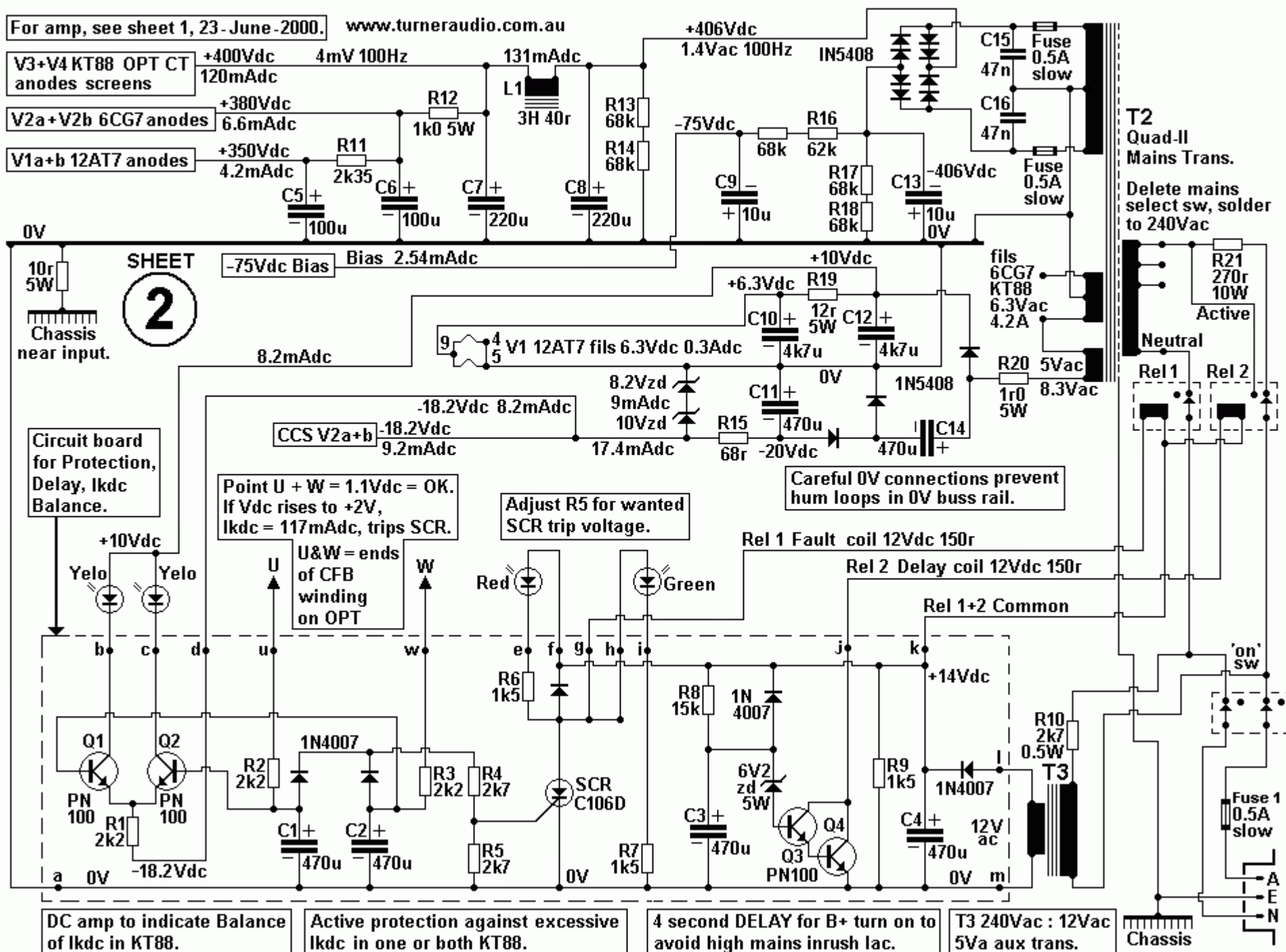
# Quad-II amp, KT88 triodes, 1999. PSU, protect, bias balance. Redrawn 23 June 2014.

For amp, see sheet 1, 23-June-2000. [www.turneraudio.com.au](http://www.turneraudio.com.au)

V3+V4 KT88 OPT CT  
anodes screens

V2a+V2b 6CG7 anodes

V1a+b 12AT7 anodes



[illegible]

**Fig 5.**

REFORMED QUAD-II AMP. August 2010.

For PSU details etc, See  
REFORMED QUAD-II PSU + PROTECTION. August 2010.

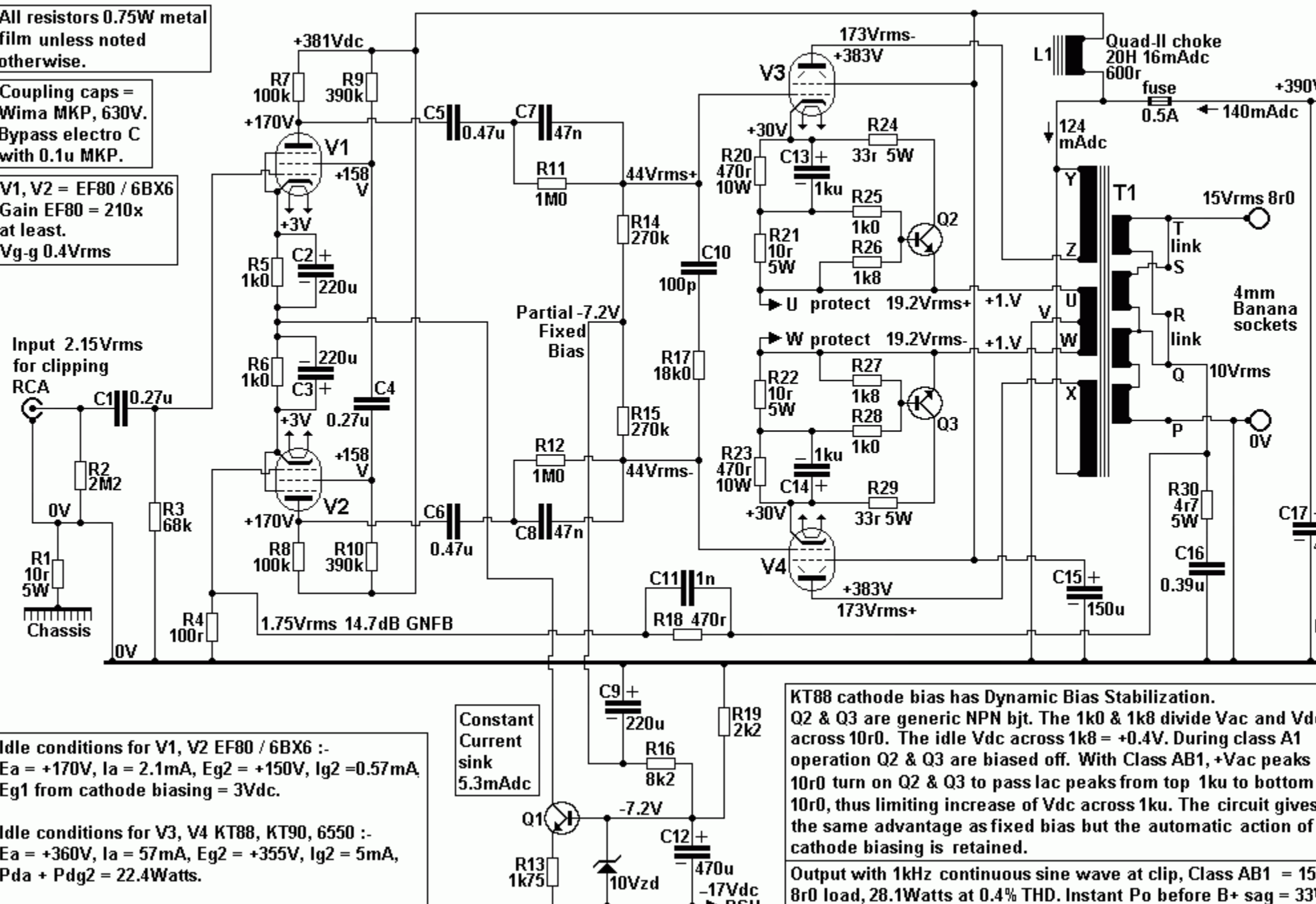
[www.turneraudio.com.au](http://www.turneraudio.com.au)

OPT links	RwP 334r	Sec	RwS	S loss%	RwP+S loss%	OPT ZR
LS to T, S to R.	7.9% loss	16r	2.16r	11.9	19.8	243:1
LS to T, S-T, Q-R.	7.9% loss	9r	1.08r	10.1	18	432:1
LS to Q.	7.9% loss	4r	0.72r	15.2	23	972:1

**All resistors 0.75W metal film unless noted otherwise.**

Coupling caps =  
Wima MKP, 630V.  
Bypass electro C  
with 0.1u MKP.

V1, V2 = EF80 / 6BX6  
Gain EF80 = 210x  
at least.  
Vg-g 0.4Vrms



**Idle conditions for V1, V2 EF80 / 6BX6 :-**  
 $E_a = +170V$ ,  $I_a = 2.1mA$ ,  $E_{g2} = +150V$ ,  $I_{g2} = 0.57mA$ ,  
 $E_{g1}$  from cathode biasing =  $3V_{dc}$ .

**Idle conditions for V3, V4 KT88, KT90, 6550 :-**  
 $E_a = +360V$ ,  $I_a = 57mA$ ,  $E_{g2} = +355V$ ,  $I_{g2} = 5mA$ ,  
 $P_{da} + P_{dg2} = 22.4Watts$ .

**KT88 cathode bias has Dynamic Bias Stabilization.**

Q2 & Q3 are generic NPN bjt. The 1k0 & 1k8 divide Vac and Vd across 10r0. The idle Vdc across 1k8 = +0.4V. During class A1 operation Q2 & Q3 are biased off. With Class AB1, +Vac peaks 10r0 turn on Q2 & Q3 to pass iac peaks from top 1ku to bottom 10r0, thus limiting increase of Vdc across 1ku. The circuit gives the same advantage as fixed bias but the automatic action of cathode biasing is retained.

Output with 1kHz continuous sine wave at clip, Class AB1 = 15  
8r0 load, 28.1Watts at 0.4% THD. Instant Po before B+ sag = 33

Fig 5 schematic is similar to Fig 3 above.

I have Q1 MJE340 for CCS to V1, V2 cathodes.

I have Q2 & Q3, TIP31C, for Dynamic Bias Stabilization for cathode bias.

I included the pair of BJT in this amp because it prevents any rise in  $E_k$  across C13, C14 due to rectification effects of signal cathode currents of KT88 during class AB operation. The KT88 can generate more maximum  $I_a$  than KT66, and the rise in  $E_k$  is greater. The BJTs still allow auto biasing to occur which save having any bias adjustment to confuse & worry any owner.

I did not include a bias balancing pot or bias balance LED indicators, but tried to minimize the active protection measures.

Over the years I found the individual cathode biasing will always give enough  $I_{dc}$  balance while ever tubes remain fairly serviceable. All that's really needed is active protection to provide a "safety net" for our fallen angels, ie, something to turn off the amp if a KT88 decides to conduct too much  $I_{dc}$ , which most will do towards the end of their life.

Fig 5 has the Quad-II OPT details shown as a table with the same anode to anode loading by OPT used for 3 different ways of linking OPT terminals Q to T, to get load matches for 16r, 9r and 4r.

The output tube loading between the two anodes may be calculated as  
 $RLa-a = ( OPT\ ZR \times [ secondary\ load + secondary\ R_w ] ) + R_w\ whole\ primary.$

In the 2010 amp I tested with 8r0 sec load with OPT links set for 9r0.

The OPT ZR = 432:1.  $R_w\ secondary = 1.08r$ .  $R_w\ primary = 334r$ .

$$RLa-a = ( 432 \times [ 8.0 + 1.08 ] ) + 334 = 3,456r + 466r + 344r = 4,256r.$$

The  $R_w$  % losses are  $100\% \times R_w\ total / Total\ RLa-a = 100\% \times ( 466 + 334 ) / 4,256 = 18.8\%$ .

This means that if we measure 28.5Watts into 8r0, the tubes must make 35.1 Watts, and 6.6Watts of heating occurs to OPT windings.

If the output load value is doubled to 16r with the same OPT links, winding losses < 10%, and if load = 4r0, winding losses > 30%.

While ever the amps produce enough clean power and without clipping for a pleasing musical experience, winding losses have little significance to listeners. However, the high  $R_w$  cheats the buying public of what could be much better with very little extra amp weight or size. The high  $R_w$  makes OPTs fragile and prone to fusing from failing tubes. The real winners from high winding losses are company accountants, always keen to minimize quality and costs of production and to be sure of getting a handsome wage. I have never ever employed an accountant.

## **Fig 6.** PSU and Protection.

# REFORMED QUAD-II AMP PSU. August 2010.

www.turneraudio.com.au

Parts within dashed line are on schematic "QUAD-II AMP, August 2010"

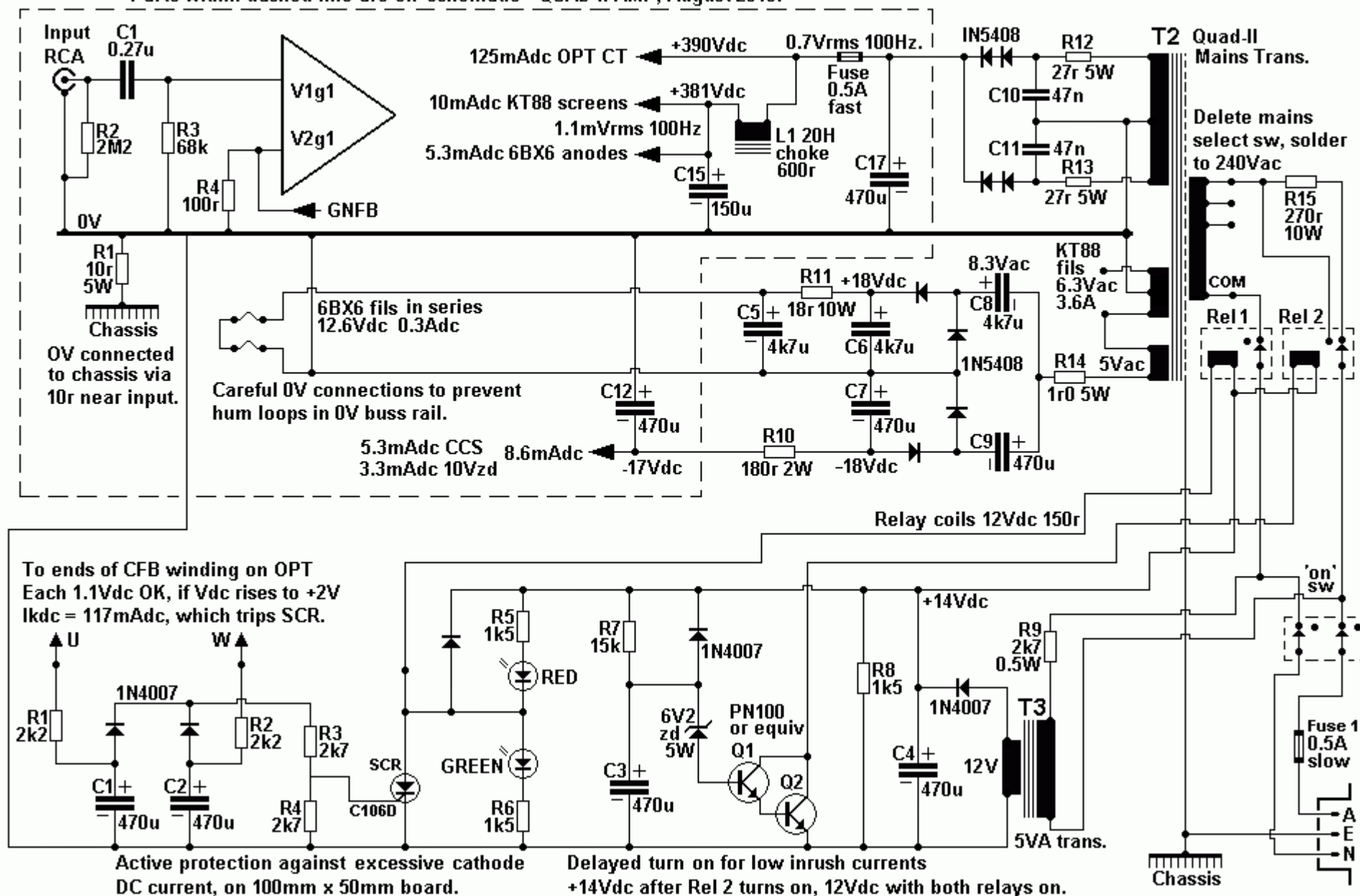




Fig 6 shows essential features of a well made amp PSU, while attempting to keep things as simple as possible. In the B+ rail, there is no CRC filter before the OPT anode primary winding. This seems an error, but I found that there is not a big reason for CRC as I have in other Quad-II amps because I wanted to keep the B+ as high as possible and well regulated with minimum series resistance. The 100Hz hum at top of C17  $470\mu\text{F} = 0.7\text{V}_{\text{rms}}$ , and is 1/25 that of an original Quad-II with a lousy  $16\mu\text{F}$  used where I have  $470\mu\text{F}$ . But if any wishes to use an extra  $220\mu\text{F}$  plus a 2H choke, then feel free, but there is not much room under the chassis or above it.

Notice there is a 0.5A fuse in series with all B+ anode Idc after C17  $470\mu\text{F}$ . This is a precaution against a sudden shorting of anode circuit to 0V. Such a short can cause the energy stored in C17 to rapidly discharge through some part of OPT anode winding which possibly may fuse the winding. Max Idc during a short could be 3Amps! It is a rare event which I have never seen.

There is a delay circuit to limit inrush current for a few seconds after each and every time the amp is turned on. The inrush current is large without R15 because the HT winding must charge directly into a large  $470\mu\text{F}$  cap. Even when amp is turned off with hot tubes, then on again within 3 seconds, the delay re-occurs and limits mains peak current due to R15  $270\Omega$  until B+ is about 2/3 full value, and then R15 is shunted by Relay 2. The inrush Iac when Rel 2 closes is no more than for initial turn on and less than 1/2 what it is without the delay circuit. The delay circuit allows a sensitive low value mains fuse without nuisance blowing.

I used 6.3Vac for ALL tube heating in 2010 but in this schematic I have used the 5Vac heater winding plus 1/2 6.3Vac heater winding to get 8.2Vac for a voltage doubler to make Vdc rails of approximately  $\pm 18\text{Vdc}$ .

+18Vdc is RC filtered down to 12.6Vdc at 0.3Adc for 6BX6 heaters in series. The -18Vdc is RC filtered for the CCS for 6BX6 common cathodes.

The protection circuit has been simplified to what I found works well. Instead of having the cathode Ek at tops of R&C cathode bias networks divided and filtered and then with diodes to gate of SCR, I have just used the winding resistance of the CFB winding, at points U and W, to give a source of Vdc which can turn on the gate of SCR. Each 1/2 of CFB winding has  $R_w = 17\Omega$  approx, so with 65mA, the  $V_{dc} = 1.1\text{Vdc}$ . If this rises to 2Vdc, then it is enough to trigger SCR with 0.67Vdc at gate and Idc cannot exceed about 120mAdc.

If the cathode bypass caps were to ever fail to a short, then the protection would work more reliably

than if the sample Vdc is taken from cathode at top of bypass caps. However, I have never ever witnessed electrolytic cap failure unless the Vdc went too high for too long, or they became so hot the liquid inside boiled. The SCR will be triggered well before electrolytic caps ever get hot or short out.

[illegible]

Fig 7.

Reformed Quad-II amp, fixed bias,  
sheet 1, 10 June 2014.

SHEET 1 For PSU, Protection, Etc, See sheet 2, 10 June 2014.

OPT links	RwP 334r	Sec	RwS	S loss%	RwP+S loss%	OPT ZR	TR
LS to T, S to R.	7.9% loss	16r	2.16r	11.9	19.8	243:1	15.6:1
LS to T, S-T, Q-R.	7.9% loss	9r	1.08r	10.1	18	432:1	20.8:1
LS to Q.	7.9% loss	4r	0.72r	15.2	23	972:1	31.2:1

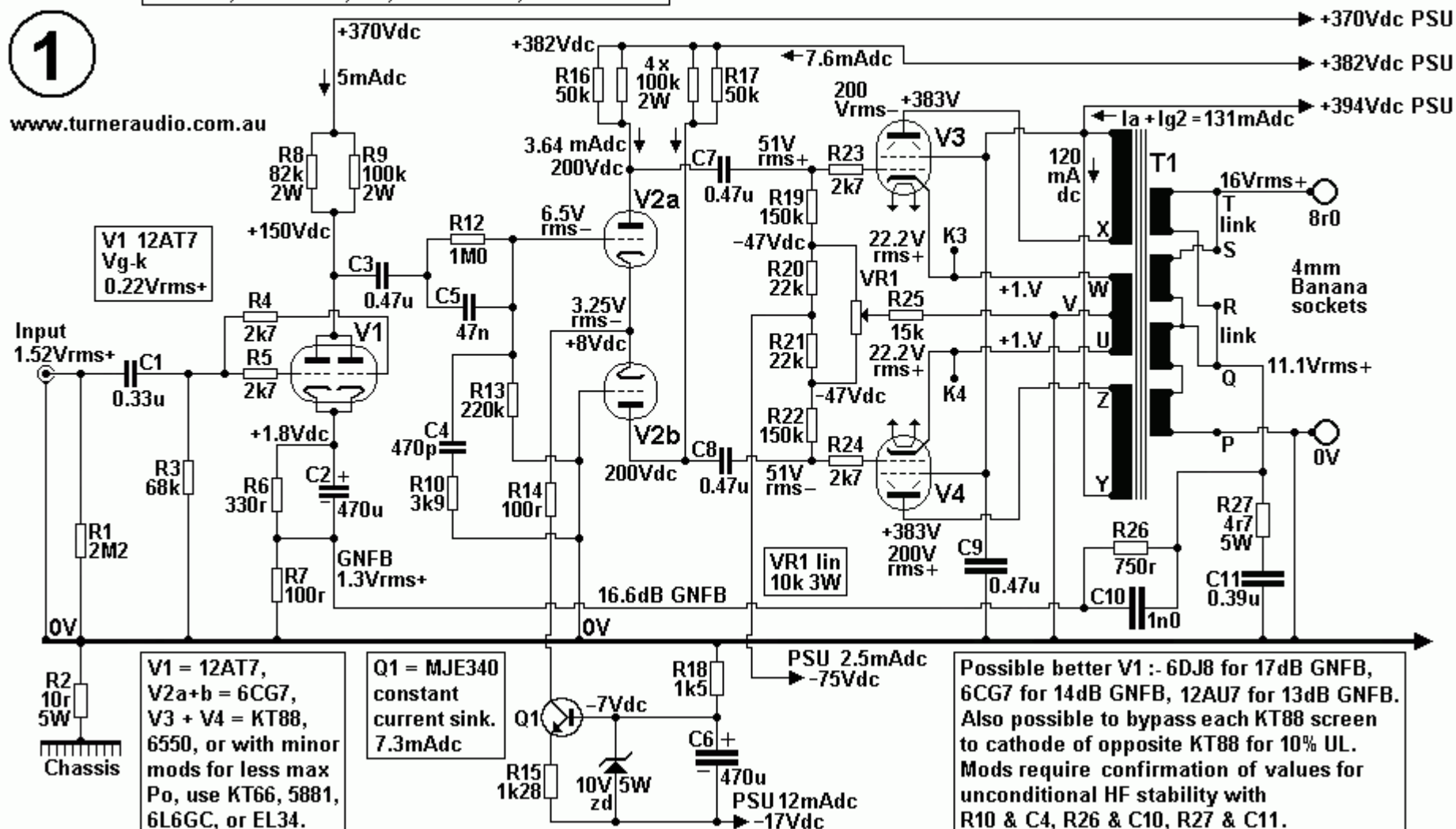


Fig 7 has taken matters further to maximize possible class AB1 Po. So I have fixed bias with an adjust pot for balance.

Instead of having 2 pentodes for input & driver stage, I have a similar arrangement to the Fig 4 above where I used SET 12AT7 V1 input and LTP driver 6CG7 V2a, V2b with MJE340 CCS. KT88 are used in tetrode-with-CFB as in original Quad-II, but with fixed bias. The triode input & driver stages have less THD than pentodes. I have not built the Fig 7 amp, but it should work better than the Fig 4 schematic.

The total amount of CFB + GNFB exceeds 20dB so there will be more tendency for HF oscillations. I have shown what I think may be required values for "critical damping", ie, open loop gain and phase shift reduction above 20kHz by parts R10, C4, R26, C10, R27, C11. The amp must not oscillate at any F above 20kHz even when loaded solely by any pure C between 0.05uF and 2uF at low levels when open loop gain is highest. The amp must be tested with a 5kHz square wave at low level, say 2V<sub>peak</sub> output and with pure C load. The square waves should not have more than 6dB of overshoot, and not more than say 4 ringing waves declining to a flat line within 100uS, or a 1/2 wave time for 5kHz. If tested with sine waves with a C load, the response should not have peaks in the response exceeding +6dB above the 1kHz levels.

Everyone building any tube amp MUST overcome the tendency of all amps to oscillate when ANY NFB is applied. The amp is a bandpass device with NFB applied around the open loop gain and there are limits to how much NFB can be applied and how much bandwidth is possible when NFB is applied. Everyone needs to understand phase shift basics.

**Fig 8.**

# Reformed Quad-II amp, fixed bias. PSU, Protection, Balance, B+ Delay. 10 June 2014.

For amp schematic see SHEET 1. 10 June 2014. [www.turneraudio.com.au](http://www.turneraudio.com.au)

SHEET 2

2

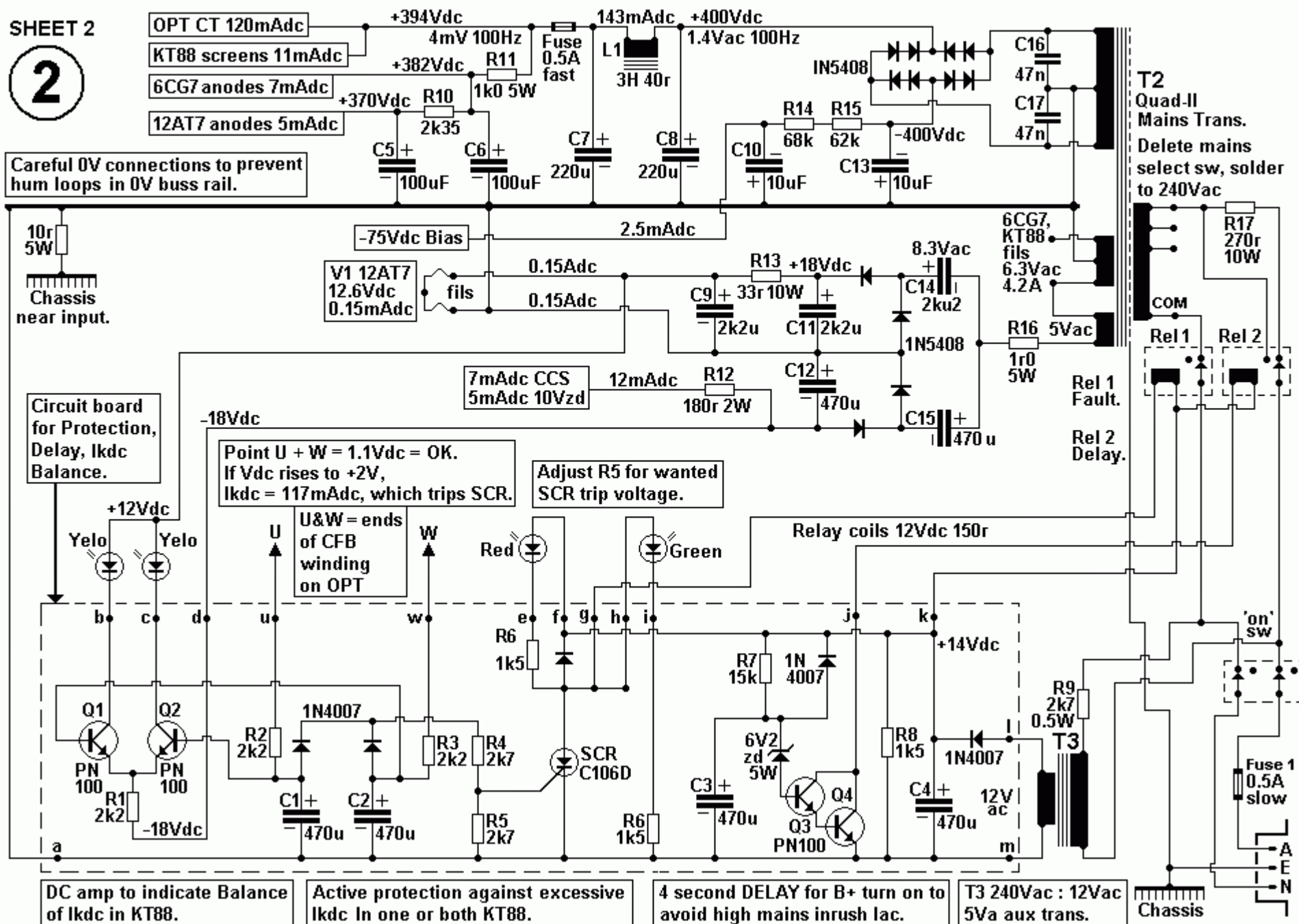


Fig 8 is the PSU schematic for Fig 7 amp.

In this one, I have HT winding charging 220uF via 1N5408 without current limiting resistors. It may seem odd, but in fact the PT has enough  $R_w$  to prevent peak charge current being too high during normal operation. The CLC filter with 220uF, 3H, 220uF have been chosen because they smooth the ripple well enough and size of parts are kept low. There is no need of the old Quad-II 20H choke.

The PSU as it is may be used for KT88 in triode if the screens are connected to anode instead of to the B+ supply at OPT CT.

There is the possible use of having each KT88 screen fed by 2k2 from OPT CT and each bypassed with 100uF to cathode of opposite KT88. This is a way of applying a 10% Ultralinear connection which increases the local screen CFB between g2 and k from 10% to 20%. It slightly reduces KT88 gain and Ra and THD. Whether it is worth the extra pair of R&C may be argued.

But I have always found class A1 operation of pentodes or tetrodes to sound best and measure best when both adequate CFB is used in conjunction with some screen signal derived from UL tap in anode winding. In this case there are no available UL taps on Quad OPT, unless one alters the OPT, and then its not much worth the trouble when some screen signal with wanted phase can be derived from cathode of opposite KT88. One could also just bypass screens to cathode of the same KT88, and then you have the KT88 acting as a pure tetrode with only CFB applied between g1 and k. This means the worse sounding H spectra in THD of pure tetrode remain, although are reduced with the CFB. The effective UL % changes H spectra favourably before the CFB is even applied.

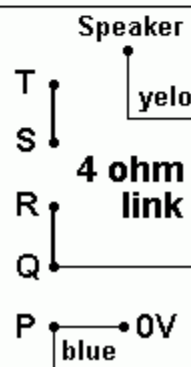
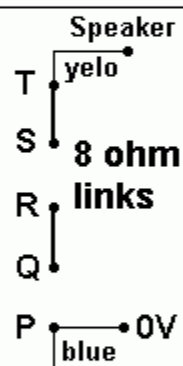
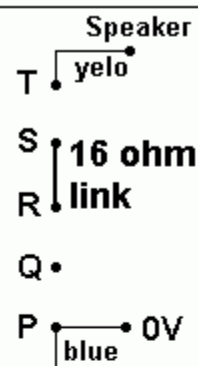
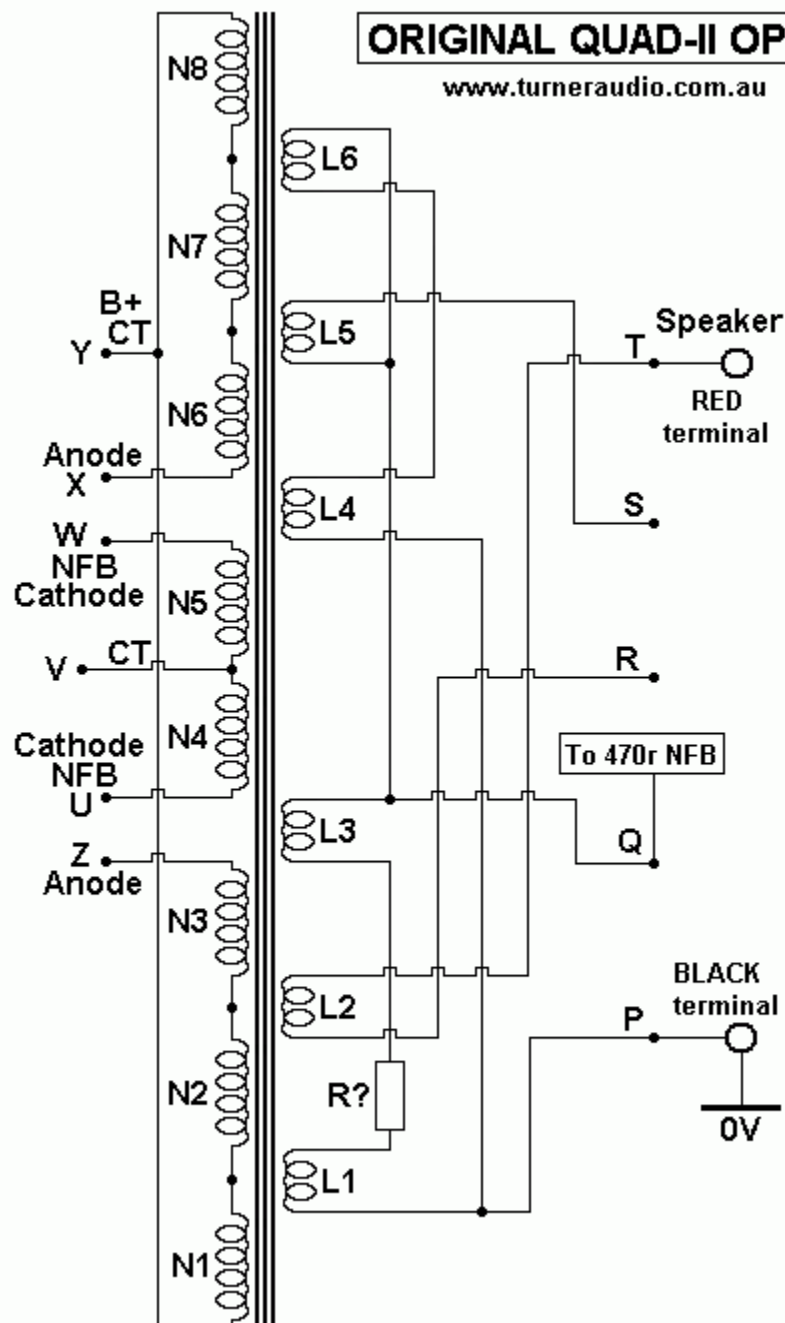
At turn on, there is a 4second delay before R17 270r is shunted by Relay 2, and the delay is long enough for B+ to rise to near +350Vdc and the Mains lac peak is kept low. The circuit board needed for small parts for delay, protection, and balance indication will need to be kept as small as possible, and made with care, and installed with screw fixing off spacers, and after removing 2 screws, the board should fold out on flexible wiring to allow access to parts.

[illegible]

**Fig 9.**

# ORIGINAL QUAD-II OPT DETAILS with ORIGINAL SECONDARY LINKS. JUNE 2014.

www.turneraudio.com.au



## Primary windings:-

N1=N2=N3=N6=N7=N8 are 6 equal winding sections with 477t. Each section has 3 layers 0.2mm Cu dia wire, 159t per layer. N4=N5 is 1 winding section, 318t. N4&N5 is layers of 0.2mm Cu dia wire with CT brought out to V.

## Secondary windings :-

L1 to L6 windings each 51t in equal single layers each 51t 0.65mm Cu dia wire. Each layer  $R_w = 0.36r$  average.

Quad-II OPT core = E&I lams,  $t = 28mm$ ,  $S = 28mm$ ,  $L = 42mm$ ,  $H = 14mm$ .

OPT fits in steel can 104high, 75mm long, 70mm wide.

Insulation. Between primary to primary layers = 0.1mm. Between primary and secondary sections = 0.3mm.

## Winding resistances.

Primaries.  $N1+N2+N3 = 120r$ ,  $N6+N7+N8 = 180r$ ,  $N4+N5 = 34r$ .  $R_w$  Primary total = 334r.

Secondaries L1 TO L6 are average 0.72 ohms.

## Rw Secondaries, standard configurations :-

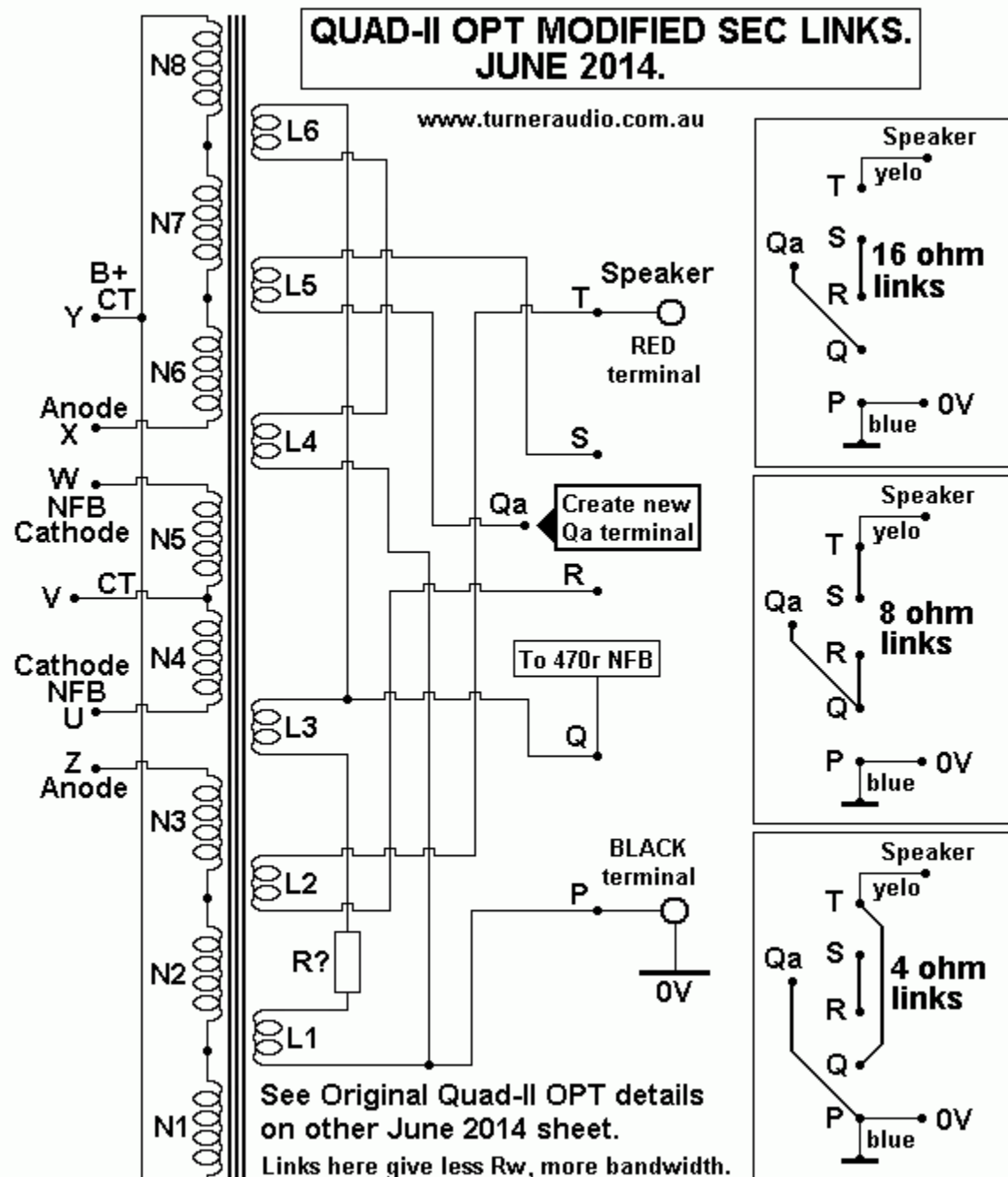
16r0 links,  $R_w S = 2.16r = 522r$  at P. Total  $R_w P+S$  at P = 857r.  
9r0 links,  $R_w S = 1.08r = 465r$  at P. Total  $R_w P+S$  at P = 799r.  
4r0 links,  $R_w S = 0.72r = 698r$  at P. Total  $R_w P+S$  at P = 1,032r.

Nominal Links	Sec RL	Pri RL a-a at a-a	Rw total at Pri	Winding loss%	Class
16r0	32r0	7,744r	857r	10%	A OK
16r0	16r0	3,872r	857r	18%	AB OK
16r0	8r0	1,936	857r	31%	AB NOT OK
9r0	18r0	7,744r	799r	9.4%	A OK
9r0	9r0	3,872r	799r	17.1%	AB OK
9r0	4.5r	1,936r	799r	29.2%	AB NOT OK
4r0	8r0	7,744r	1,032r	11.7%	A OK
4r0	4r0	3,872r	1,032r	21%	AB OK
4r0	2r0	1,936r	1,032r	34.7%	AB NOT OK



Fig 9 has details of original Quad-II OPT. For a better OPT, a much larger core and completely different design would be used to give better overall performance while being easier to wind.

Fig 10.



Improved links for 4r0 speakers.  
Remove OPT from chassis.  
Warm up OPT can to melt potting compound. Drain this to spare can.  
Remove OPT from pot. Search for L5 winding end connected to Q.  
Unsolder this. Instal 1 more turret to board for new terminal Qa. Solder L5 wire to Qa. Search for R? and remove, solder link where R was removed.

Test OPT connections with 12VAC applied across anode windings.  
Use 100r in series with 12Vac source to avoid high current if you have made a mistake and you get a short circuit.

With windings linked for 4r0 as shown, and with 12.0Vac across primary X to Z, you should measure  
From U to W = 1.33Vac,  
From P to Q = 0.43Vac,  
From Q to R = 0.21Vac,  
From R to S = 0.21Vac

With windings linked for 9r0,  
From P to Q = 0.43Vac,  
From P to T = 0.64Vac.

With windings linked for 16r0,  
From P to Q = 0.43Vac,  
From Q to R = 0.21Vac,  
From S to S = 0.21Vac,  
From P to T = 0.86Vac.

Re-assemble OPT into pot.  
Re-heat potting compound on electric frypan. Do not use gas stove. Fill pot around modified OPT. Add some clean dry sand to surface of potting mix and stir in for wanted level.

Fig 10 shows alteration to OPT secondary winding connections sealed inside pot containing the OPT. There is one turret terminal used but that could be a 2mm brass bolt with a nut. Very careful attention to what is proposed is needed, and inexperienced fools can so easily ruin a good OPT.

Also possible is the creation of OPT UL taps from anode primary turns and from joins between N1-2, N2-3, N6-7, N7-8.

Notice R?. I don't know what this R is for, or what its ohms are, but I assume it helps equalize current density in Sec windings and helps amp stability. Peter Walker had a reason for each and everything to be found, or not to be found in Quad-II amps.

Hopefully, I have given food for thought, and please enjoy the dinner with Wine of Consideration.

Happy soldering.

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