

## 1. Summary

McPherson Mk IV Amplifier for guitars.

Rodger Delfos

2-input jacks; 12AX7 for preamp; 12AX7 for tone amp and tremolo oscillator; 12AX7 for tremolo amp and cathodyne (split-load) PI; neon/LDR tremelo; fixed bias 6CA7 PP with feedback to presence pot; 2/4/8/16 $\Omega$  outputs; controls on Perspex cover with gold/black/silver/red rear graphics. Black tolex covered head box.

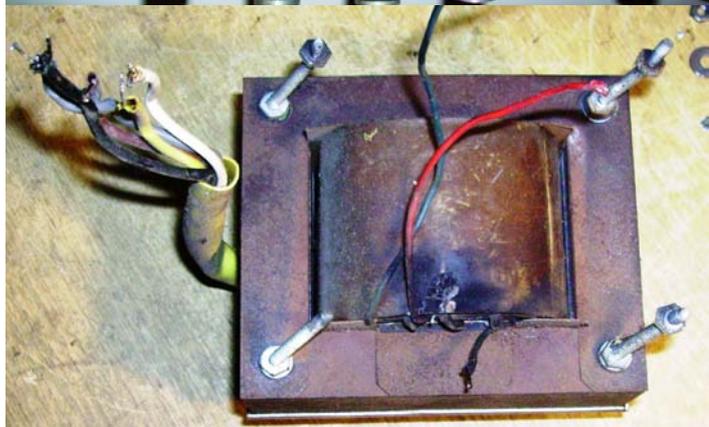
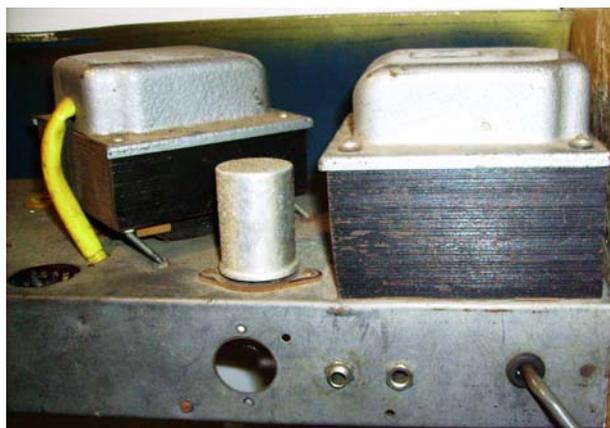
Initial condition:

One handle missing. Two knobs missing & one broken – knobs are replacements based on 1965 photos of these amps, and user information. 2 front panel fuses replaced. Chassis pre-drilled for two more 9-pin bases and one 8-pin base (probably for valve rectifier). No valves. Wiring missing between power switch and fuse and PT primary, and from secondary to main caps, and HT diodes missing. One choke and standby switch disconnected. Flashover marks on plate terminals of 6CA7 bases to heaters. Missing resistor drop from HT to screen supply. One choke and 47R common cathode 10W resistor open-circuit. OT anode lead melted – OT mounting bolts bent badly (bad crash at some stage whilst amp was on). Tremelo holder has 2x LDR, but 2<sup>nd</sup> LDR not wired in to circuit. Power switch faulty. Pots and switches need thin washer on Perspex side. Missing tremolo footswitch socket. AC plug with cracked piggyback wiper. Front Perspex panel distorted at top near closest 6CA7. Chassis rear fold spot welds failed, and solder joint failed. Box appears recovered as only two mounting holes pierced in tolex rather than the 6 holes used by chassis and drilled in to wood. Tube V3 is heated significantly by closeness to 6CA7.

Circa 1965, based on choke dates and known band photos. McPherson's made this model from possibly late 1964 till possibly late 1960's. It was there only commercial model. Started in Blue tolex, then went to black (as used on car roofs). Cabinet edges in later years were rounded over. Chassis in later years were nickel plated.

Compared to earlier version McPherson: smaller chassis size and box size. Different layout of magnetic (OT placed above chassis as getting too much feedback with normal chassis mounting. Chassis better quality and turned base edge. Reconfigured perspex front panel arrangement now fits inside box and changed graphics technique and indicator see through. Changed chokes. SS diodes. Half of input 12AX7 not used. Changed tone and tremolo circuits. Different PI and output stage.

Output Transformer	A&R OT2748. 3.4K PP (96R); 15/8/3.7/2 ohm outputs; 55W; +/-2dB 40Hz-30kHz. (As used in Oct 1962 RTV&H 55W Guitar Amp)
Power Transformer	A&R 2068; 0-230-240V; 0-175-185-195V at 200mA; 6.3V 4A; 6.3V CT 3A; ES. SL-OR-PK-BR; BR-BL-YL; GR-GR; BL-WH-BL; GR
Chokes	2x Rola CH18 6/100 (6mH 100mA 250R), dated 27 May 1964
Valves	2x 6CA7 3x 12AX7
Diode	OA211 (HT), OA210 (bias).
Caps	5x Dubilier Can 50-50uF 350V Ducon and various UCC
Tremolo	neon bulb (NE-2) and LDR (Holland, vintage)
POTs	Ducon.
Switches	Power and Standby are DPST.
Sockets	Guitar x2 (isolated from chassis); 1x tremolo footswitch. 2 output sockets wired in parallel.
Case	Plywood 15mm;



### McPherson Background

Made by Keith M McPherson who ran HI-FI & MUSIC CENTRE at 199 and 205 Dorset Rd Boronia from circa 1963 to 1972 with his son Ron (as per telephone directories). Previously Keith was listed as a Builder from 1954 to 1962, and then just as himself from 1973. Amps assembled by Keith's son Ron, and Ron Olsson (of the Mustangs). Keith started off originally in an old shop two doors from 205 Dorset Road...a long narrow, dark and very tiny joint with a ton of atmosphere.

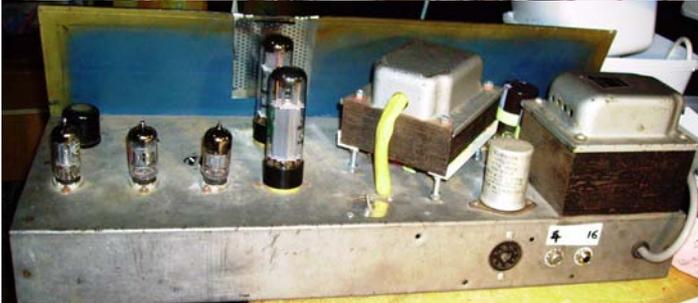
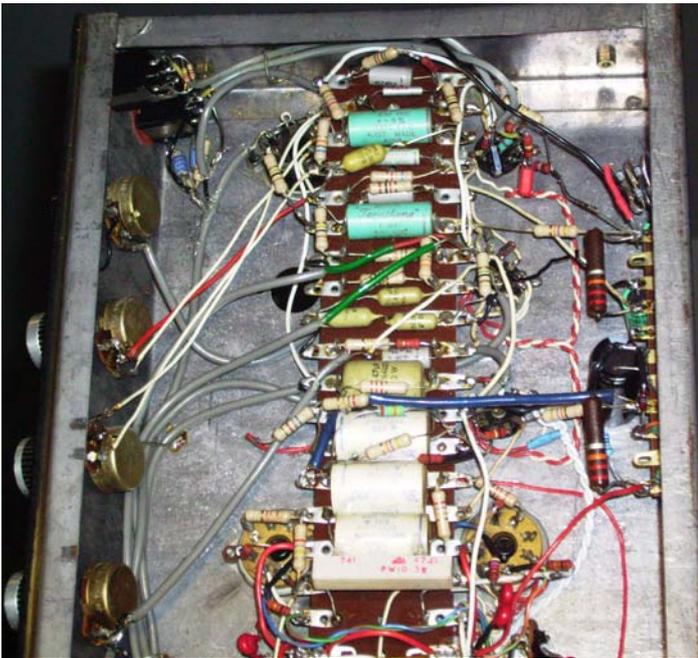
## 2. Modifications

- Repaired power switch.
- New HT ss bridge rectifier and larger main HT filter capacitors; VS2-VS4 filter caps replaced.
- Series R and NTC resistor to reduce turn-on in-rush to main filter capacitors, and smooth diode operation. Bypass resistor across standby switch to give some pre-charge.
- AC cord with internal clamp.

- Separate 1k screen resistors instead of common ? screen dropper and 50uF capacitor – stiffer supply voltage feeding screen resistors.
- Added MOV-R dampening across each half primary winding on OT.
- Reconfigured ground wiring for distributed star – grounded at output sockets for simplicity.
- Swapped input sockets to isolated switched sockets, and added tremolo footswitch socket.
- Bias 1R sense resistors in each 6CA7 cathode leg, and bias voltages and 100:1 divided VS1, and bias voltage VS5 sense wired to octal socket on rear panel for easy checking.
- Re-configured bias power supply using additional doubler, and using CT as doubler mid-point to give elevated DC heater bias. Bias pots with failsafe resistor, and more sensitive pot configuration, and capacitor decoupling.
- Previously un-used 12AX7 half is now a series connected preamp stage for heavy gain.
- Heat shield between 6CA7 and front panel.
- Parallel R across VS1 22k dropper to return preamp stage voltages (drain from half 12AX7).
- Changed cathode bias for V1A to better position operating point. Added grid leak resistor.
- Add grid stoppers on V2A and V3A to alleviate any possible blocking distortion.
- Added feedback switch.
- Separate heater winding to EL34's to spread loading on each heater winding.

To do:

- Additional output jack to allow 4, 8 and 16R connections.
- Replacement choke needed.
- Box handle to replace missing.
- Better chassis mounting bolts (ensure correct length to stop internal damage, and BSW thread).



### 3. Measurements

Voltage rails – modified circuit config.

Rail	Idle
EL34 bias	-40V, 37+37mA, 18W each
VS1	498
VS2	392
VS3	313
VS4	257
VS5	-50.5V
Heater	6.3V
Sec HT	193V
V1A	Anode 172V; cathode 1.53V
V1B	Anode 156V; cathode 1.67V
V2A	Anode 185V; cathode 1.34V
V2B	Anode 160-175V; cathode 1.4-1.5V
V3A	Anode 280V; cathode 79V
V3B	Anode 200V; cathode 1.72V
V4, V5	cathode 3.5V

Transformer primary = 7.6,8.1,8.5Ω; Original mains connected to slate/yellow.

Transformer secondary HT = 6.5,6.8Ω.

33.5,35.4,37.4 1.21,1.21 40.9,42.6

48.4,51.2,54.0 1.75,1.75 59.1,61.7

Choke resistance: 30R.

33VAC 50Hz nominal applied to half PP of output transformer

Winding	Voltage rms	Turns ratio; Impedance for 3.2K pri; Spec level; Notes
Pri P-P: BLU to BLU	66.2	
Sec: BLK to GR	1.65	40.1; 2Ω; 3220;
Sec: BLK to BR	2.28	29.0; 3.7Ω; 3111Ω;
Sec: BLK to YEL	3.37	19.64; 8Ω; 3085Ω;
Sec: BLK to WH	4.57	14.49; 15Ω; 3149Ω;

Transformer unmarked, but most likely an OT2748.

Output transformer primary DC resistance: 96Ω plate-to-plate.

Hum & Noise, 16R output, Vrms, Presence min, Feedback off, [tremolo max; speed min-max]

Top input shorted	Bass		
Treble	min	mid	max
min	42mV	55mV	420mV
mid	45mV	48mV	370mV
max	63mV	75mV	380mV (360mV) [290-480mV]

Hum & Noise, 16R output, Vrms, Presence min, Feedback off (on), [tremolo max; speed min-max]

Bottom input shorted	Bass		
Treble	min	mid	max
min	26mV	120mV	1.26V
mid	38mV	120mV [120-190mV]	1.1V
max	310mV	330mV	1.2V (1.0)

Clean output signal up to about 40Wrms, with increasing clipping up to about 80Wrms.

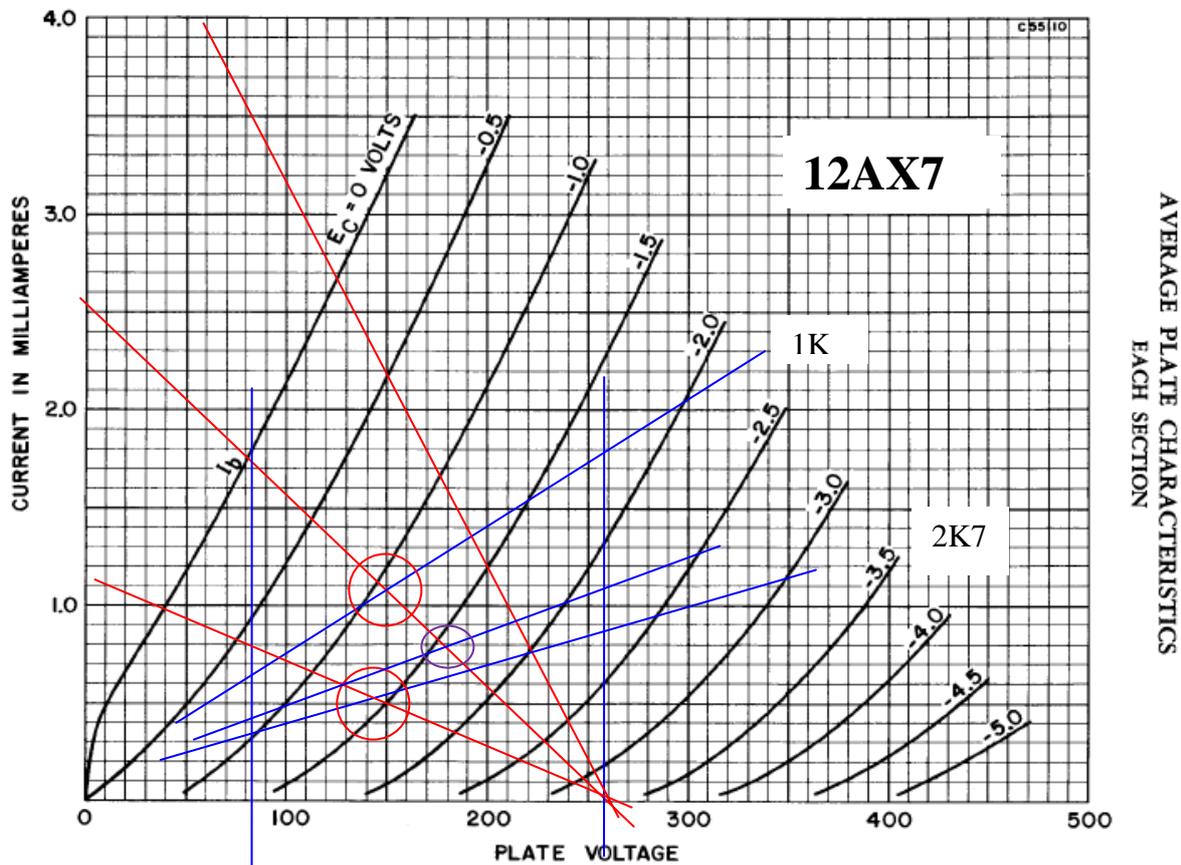
## 4. Design Info

### 4.1 Input Gain Stage

The first 12AX7, V1A has  $V_{S4} = 240V$ ;  $V_a = 132V$ ;  $R_k = 1k$ ;  $V_k = 1.0V$ ;  $I_a = 1.0mA$ ;  $R_{Ldc} = 100k$ .  
 [Raise  $V_{S4}$  to increase input headroom;  $R_k$  increased to 2k to move  $V_k = 1.6V$  to move to centre-biasing]

The input voltage swing limit is from the bias point at  $V_{gk} = -1.0V$  to  $V_{gk} = 0V$ , ie.  $2V_{pk-pk}$  or  $0.6V_{rms}$ . Referring to the loadline, the plate voltage would swing about 170V, from about 70V to 240V. This gives a nominal gain of  $60V_{pk}/1.0V_{pk} = 60$ , which correlates with Voltage gain =  $\mu \cdot R_L / (R_L + R_a) = 90 \times 60k / (60k + 40k) = 60$ ; where  $R_L \sim 60k$  (100k paralleled with 110k), and  $R_a = (240V/1mA) - 1k(\mu+1) - 100k \sim 40k$ ; for typical 12AX7  $\mu \sim 90$ .

The added pre stage using V1B has  $V_{S4} = 240V$ ;  $V_a = 140V$ ;  $R_k = 2K7$ ;  $V_k = 1.62V$ ;  $I_a = 0.6mA$ ;  $R_{Ldc} = 220k$ .



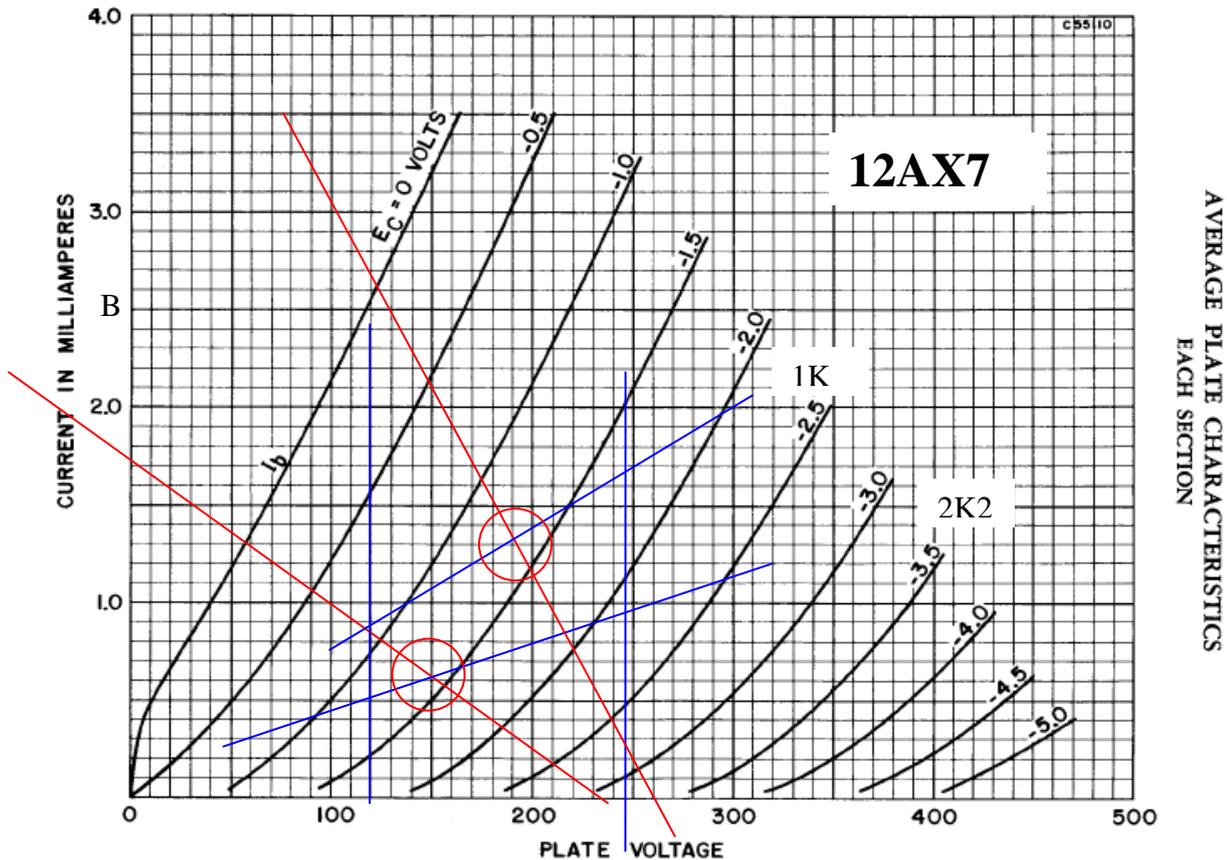
### 4.2 LFO

$V_{S3}$  at 325V. Neon NE-2 type bulb drops about 80V, but also has some effective resistance. So LFO V2B loadline based on about  $325 - 90 = 235V$ , and a resistance of about 150k.  $R_k = 2k2$ ;  $V_k = 1.29V$ ;  $V_a = 160V$ ;  $I_a = 0.59mA$ .

V2A gain stage based on  $V_{S4} = 240V$ ;  $V_a = 180V$ ;  $R_k = 1k$ ;  $V_k = 1.24$ ;  $I_a = 1.2mA$ ;  $R_{Ldc} = 47k$ . Tone stack appears to be a modified Fender configuration. [Added 56k grid stopper to alleviate overdrive at full volume and full treble]

Neon is continuously on due to bleed 330k, which draws ~0.5mA. So neon voltage drop is  $294 - 158 - (100k \times 1.1mA) = 25V$  [need to check with no oscillation].

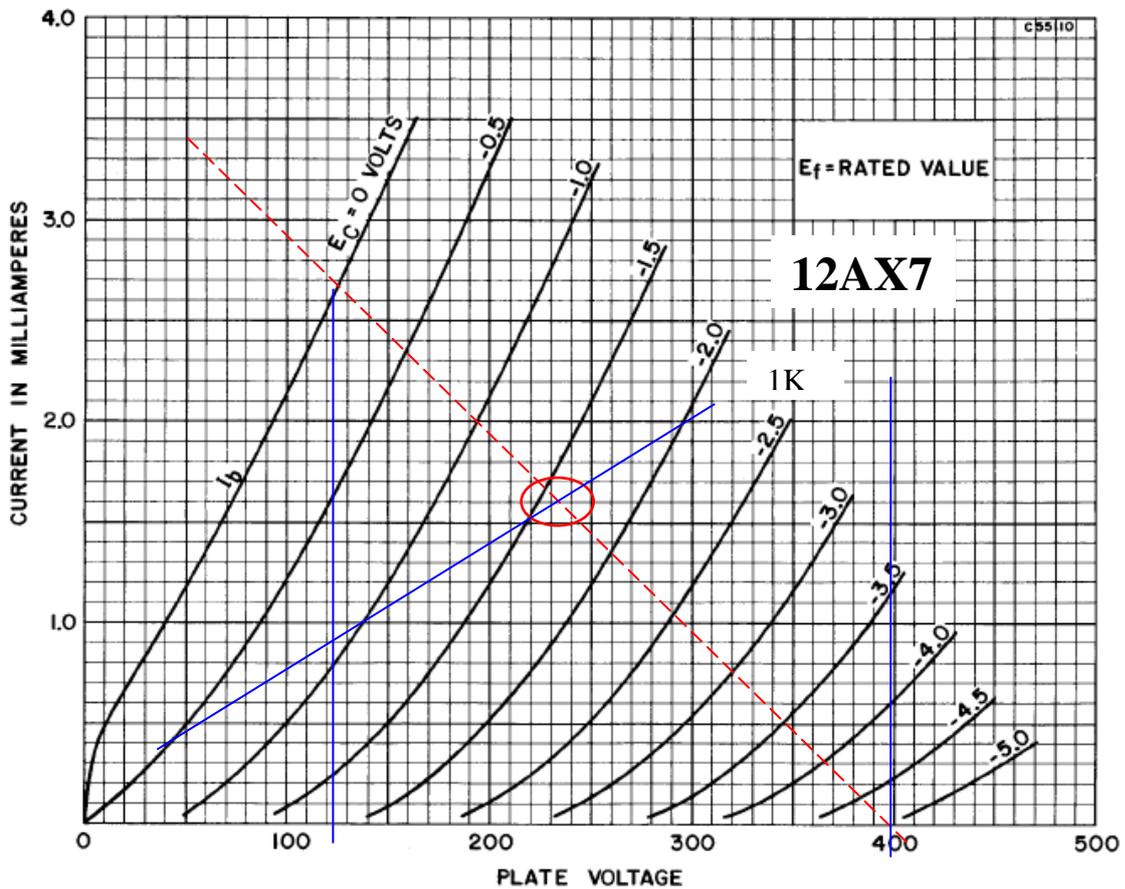
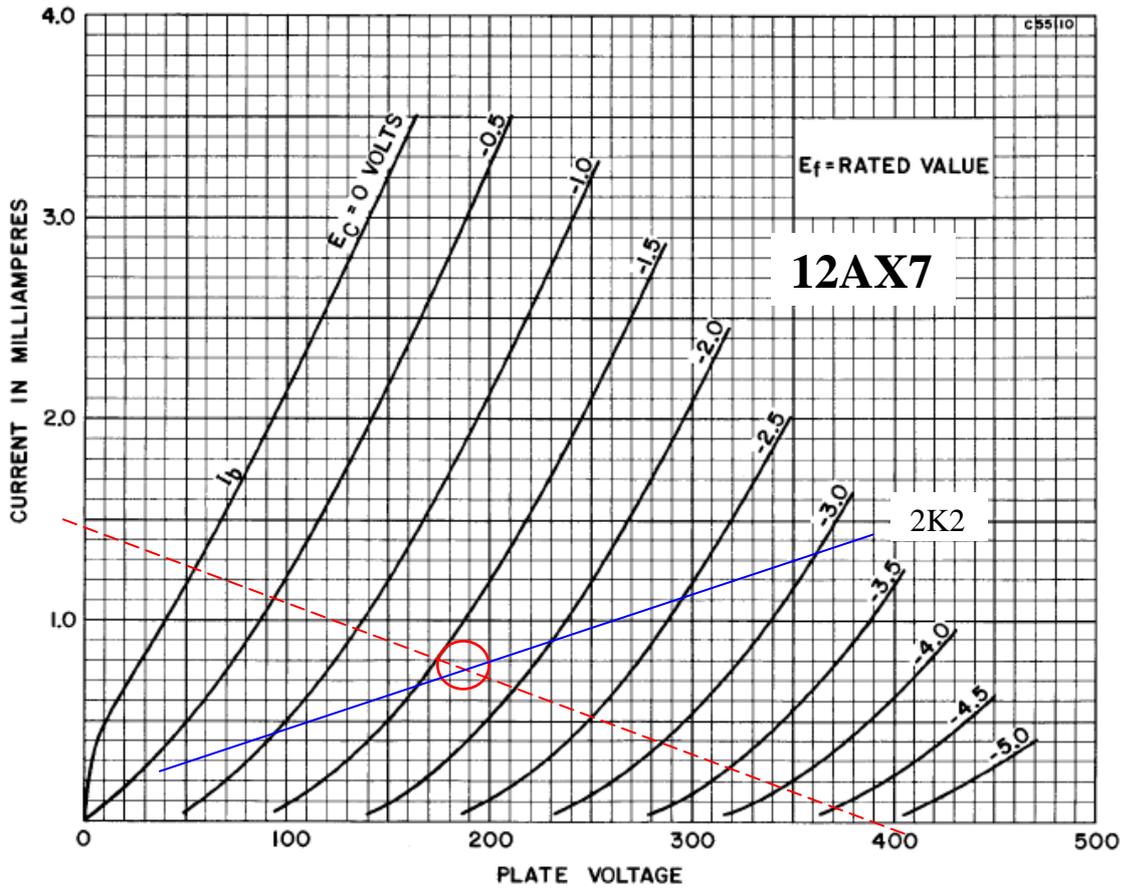
To balance the idle resistance of the LDR, it is used in a balancing bridge type circuit which has a base attenuation of about 15%. Tremolo circuit copied from Electronics Australia August 1964 article.



### 4.3 Pre and Splitter stage

V3B gain stage includes amplifier output feedback to the tapped cathode resistor, and Presence decoupling of  $R_k$ .  $V_{S2}=370V$ ;  $V_a \sim 180V$ ,  $I_a=0.73mA$ ;  $R_k=2.2k$ ;  $V_k=1.59V$ ;  $R_{Ldc}=270k$ .

V3A gain stage is cathodyne PI.  $V_{S2}=370V$ ;  $V_a=297V$ ;  $V_k=71.5V$ ,  $I_a=1.5mA$ ;  $R_k=1k$ ;  $V_k=1.5V$ ;  $R_{Ldc}=100k$ . Heater sits about  $71+24=95V$  from cathode at idle. [Increased  $V_{S2}$  to 400V; added 100k grid stopper and bypassed 1M grid-leak with 430k, to smooth out the overdrive and alleviate any blocking distortion]. PI output clipping at cut-off is initial main distortion mechanism.



#### 4.4 Output Stage

In this Class AB push-pull output stage, one tube is pushed into conduction and the other tube is pulled into cutoff, and there is a region of overlap where both tubes conduct equivalent levels of current. The cathodes are effectively grounded, and each tube operates in a fixed bias mode with a negative gate voltage. The 3.4K $\Omega$  impedance plate-to-plate OPT, presents each tube with a 1700 $\Omega$  load impedance around cross-over, moving to a 850 $\Omega$  load impedance (Class B) at high signal levels - with a resistance matched secondary load.

Determining a suitable bias current level is not an empirical design approach, rather it is based on the following recommendations:

- Start with the lowest bias current possible (ie. most negative grid bias voltage), and based on listening tests, increase the bias current until the sound character is acceptable, but:
- use the lowest possible bias current level, as this generally increases the life of the tubes, and decreases the chance of operating at excessive plate dissipation; and
- keep the bias current level below 70% of the recommended design max plate dissipation (ie.  $<0.7 \times 25 = 17.5\text{W}$ ); and
- assess the dynamic loadline to see if it moves into region of increased plate dissipation.

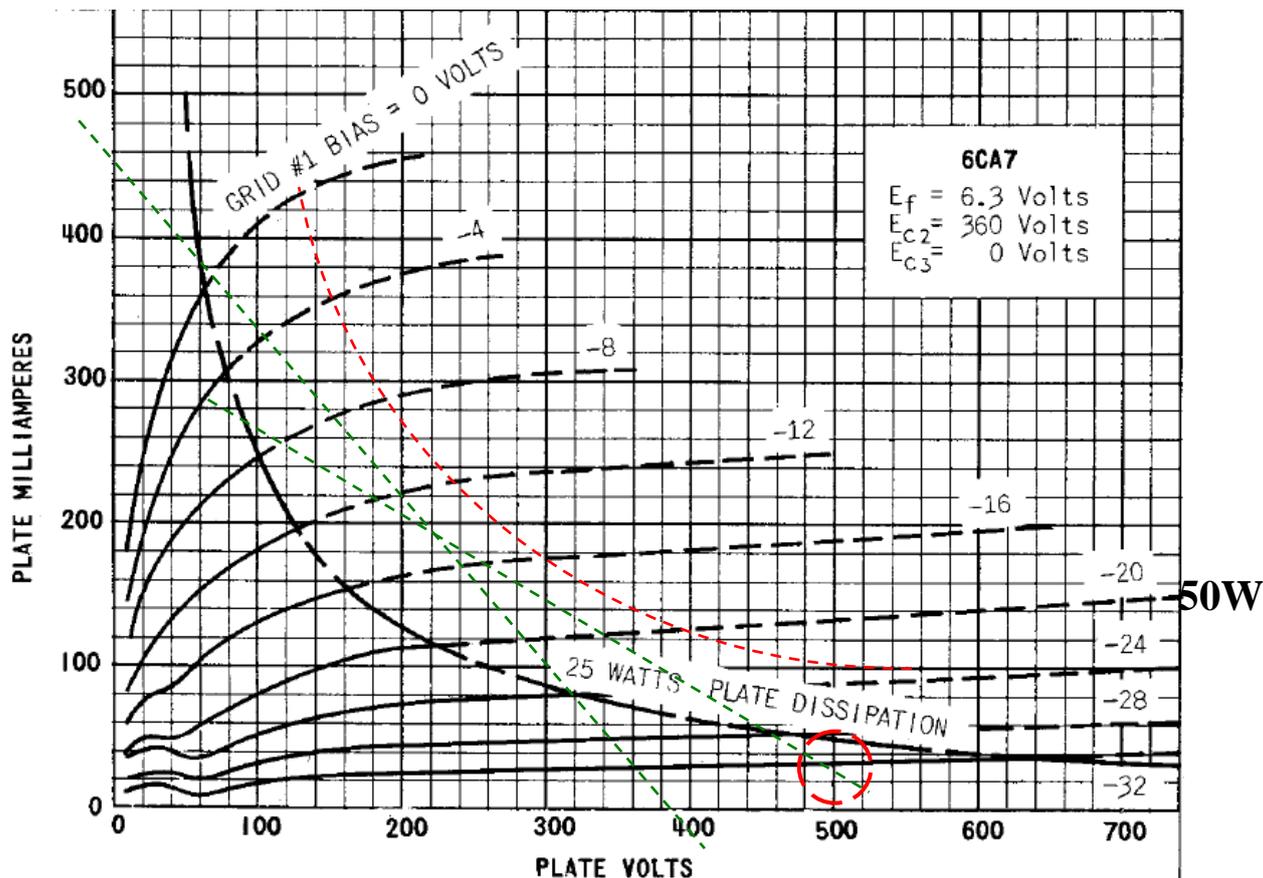
As the output loading increases, the supply voltage VS1 to the output valve plates sags from about 500V to as low as 420V. Effective plate voltage will be lower than VS1 by an amount up to ~34V due to OPT half resistance of about 48 $\Omega$ , and common cathode resistance of 47 $\Omega$ , and with a peak current of up to about 0.35A.

The recommended output valve bias current for the 6CA7 is  $I_{\text{bias}} = P_d / V_b = 17.5\text{W} / 500\text{V} = 35\text{mA}$ . The gate bias voltage required for this current is significantly influenced by the screen voltage (ie. ~-18V at  $V_s=200\text{V}$ ; ~-32V at  $V_s=300\text{V}$ ), however tube graphs are not available for higher screen levels, but can be inferred. At idle, and a screen at close to the plate voltage (~500V), and the gate bias voltage needs to be adjustable down to -48V at least.

The following graph shows the characteristic curves for 6CA7 with 360V screen voltage. The initial loadline trajectory is along a 2,500 $\Omega$  loadline for small signals where both tubes are conducting – the loadline going through the bias point. The final loadline trajectory for heavy loading (high plate current) is along a 1250 $\Omega$  loadline – this loadline is aligned with the sagged effective plate voltage of about 385V, and extends out to the 0V gate level. This 1250 $\Omega$  loadline indicates a peak plate current of ~350mA would be needed for input grid voltage reaching 0V (possibly a bit higher given the available screen voltage level).

For a peak plate current of 350mA, then the nominal output power of the amplifier would be:  $(I_{\text{pk}})^2 \times R_{\text{pp}} / 8 = 0.35 \times 0.35 \times 3.4\text{k} / 8 = 52\text{W}$ . For this maximum signal condition, the rms OPT current draw is likely about 224mA (64% of peak), and the average VS1 power consumed is about 420V x 0.224Arms = 94W, and the OPT loss is about  $(0.224)^2 \times 48\Omega = 2\text{W}$ , and the common cathode resistor loss is ~2W, so the tube plates dissipate  $94 - 52 - 2 - 2 = 38\text{W}$ , or about 19W each, which is about max design level.

During dynamic conditions, the plate dissipation mostly exceeds the 25W power contour curve shown on the graph. Each valve has an 'off' period for 50% of time, where the plate dissipation is lower than the bias level and possibly down to a few watts for most of the period when the valve is in deep cutoff due to very negative grid voltage levels. As such, the average dissipation during the "off" period brings the average down considerably, and the 'on' period dissipation can extend dynamically above the 25W curve.



The graph above indicates the achieved loadline is likely to be in the very broad knee region at  $V_g=0$  with only a little screen voltage sagging (given minimum  $V_{ak} \sim 385V$  at  $V_g=0$  condition). Datasheet indicates screen current may reach 25-30mA pk, and so screen stopper resistance can get down to about  $(385V-360V)/30mA = 1k$ . Separate screen resistors are used rather than a common resistor, and no additional capacitive filtering is used, to allow the knee to compress without any delay.

A 'Paul Ruby' zener diode circuit can be added from 0V to common grid node on each side of the PP output stage to counteract any blocking distortion under heavy overdrive, given that the PI stage can drive to over 100Vpk swing, but the max grid current is limited to about  $(100-48)/50k = 1mA$ . When the grid is driven to 0V, grid current (up to  $\sim 1mA$ ) can charge the DC bias across the PI coupling cap, which then cold-biases the grid until the coupling capacitor bias returns to normal. The rate of DC bias shift from quiescent level is about  $dV/dt = 1mA/0.27\mu F = 370 V/s$ , which for a strong 50Hz peak could cause  $\sim 370 \times 5ms = 2V$  shift. Zener conduction drains some DC bias voltage off the coupling capacitor when the grid is subsequently driven into deep cut-off. The voltage of the zener is nominally twice the nominal grid bias DC voltage ( $2 \times 30 = 60V$ ) for fixed bias configuration, however the 47R common cathode resistor increases both cathode voltages by about  $47 \times 380mA = 18V$  peak for a properly loaded output and 0V grid swing. To maintain symmetrical voltage swing into deep cut-off, the zener aims to start clipping when grid swings to  $30 + 18 = 48V$  below the nominal -30V bias midpoint, ie. zener voltage is about  $2 \times 30 + 18 = 78V$ .

Cathode biasing per se helps to minimise the level of blocking. No distinctive blocking distortion noticed, so no zener added.

#### 4.5 Power Supplies

Power switch turns on valve heaters and output valve grid bias. Added 50k pre-charge resistor across Standby switch provides  $\sim 85V$  on the HT power caps to reduce HT turn-on stress.

A diode bridge is used for the doubler diodes to generate a no load voltage of 500V with the 200V winding. 470uF 400V caps with 105C and 1.7A ripple rating are fine for doubler peak currents, and the lower esr and 5x higher capacitance achieve a much lower ripple voltage across the first set of caps. An RC filter to the next main caps would be fine, as would added series winding resistance to smooth the ripple and peak currents (approx 40R 5W to give 40V drop at 1A peak, and 12V average drop).

Added secondary winding series resistance of 7R 15W, to drop about 4Vrms at 0.6Arms (3W) under heavy loading (100W/190Vrms ~0.6A, although the current probably has a high crest factor. In addition a 15R NTC thermistor is used to alleviate peak capacitor charge current at turn-on. Total effective series resistance of 190Vrms supply is about  $(190/240)^2 \times 6 + 6.5 + 7 + 15 = 32R$ , so peak prospective current is about  $190 \times \sqrt{2} / 32 = 8.4A$ .

Idle loading on VS4 (260V) is about  $0.6 + 1.1 + 1.2mA = 2.9mA$ , so 65V drop from VS3. V2b loading on VS3 (325V) is about 0.6mA, so about 75V drop from VS2. Loading on VS2 (400V) is about  $0.8 + 1.3 = 2.1mA$ , so about 100V drop from VS1 (500V). Due to extra load from V1B, the 22k dropper from VS1 is paralleled with 100k.

To constrain cap voltage on VS2 to 450V max, a 305V zener (6x 1N4757A – 1W 51V) is placed across VS4 to draw  $(500-310)/66k = 2.9mA$  if no tubes in place (0.9W zener dissipation).

The large 220uF filter on VS2 would discharge at a rate of  $dV/dt = 5.6mA/220uF = 25V/s$ , so there is little chance of any signal modulation on the preamp and PI stage power supply rails.

A 0.01uF cap across secondary winding to shunt diode noise.

#### **4.6 Fixed bias power supply**

Two doublers are used to generate the bias voltage. One doubler generates a positive output, and the other a negative output. The AC input is 9.4V, using half of the CT tapped heater in series with the other heater winding. The CT connection becomes the mid-point voltage of the doublers, and sits at about -22VDC. The preamp heaters are connected to the CT tapped heater, so that these heaters are nominally DC elevated and connected through the CT, with significantly alleviates heater-cathode induced heater hum. The output valve heaters are powered from the other heater, which has a larger AC relative to ground, however the hum increase is negligible and the benefit is a spread heater loading.

## **5. Protection**

### **5.1 HV breakdown**

If the B+ rail shorts to ground, due to a flashover, or insulation breakdown, then a 2A fuse in the transformer secondary line provides gross failure protection by de-energising both the plate and screen rails.

### **5.2 Output open circuit**

Added a MOV (2x 2502 red 7mm type; 330VDC each) and 4k7 2W resistor across each primary, to act as a high voltage damped clamp in case the speaker load goes open circuit when significant signal is being passed.

## 6. Testing and Faultfinding

If a problem occurs then pull out power cable and check front panel fuses (2).

If fuses are ok then check AC cable and connector earth pin are good. Check standby and power switch are both off and connect AC power.

Turn power switch on, but leave standby switch off. Measure the HT voltage at the rear panel octal connector – the voltage should raise to about 80V (0.8V at connector TP7 to TP8), and all tube heaters should show correctly. Measure the bias voltage – depending on meter impedance, the reading should initially be about -48VDC (TP6 to TP8).

If above is ok, then turn on standby switch, and measure HT voltage at rear panel connector – the voltage should be about 500V (5V at connector TP7 to TP8). Also measure the bias voltage across the common cathode resistor (~3.2V at connector TP1 to TP8), and the individual cathode current sense 1R resistors (~28mV each at TP2 to TP1, and TP3 to TP1).

TP1	Output stage cathode bias 47R resistor	(+3.2VDC at idle)
TP2	Output stage 6CA7 cathode current 1R sense resistor	(~28mVDC at idle to TP1)
TP3	Output stage 6CA7 cathode current 1R sense resistor	(~28mVDC at idle to TP1)
TP4	N/C	
TP5	N/C	
TP6	Output stage negative bias rail	(-48VDC)
TP7	Output stage HT rail	(divided by 100: +5.0VDC at idle)
TP8	0V ground	

Gently remove chassis from wooden enclosure (3 screws per sides); then turn on end (transformers down – but be careful of cracking Perspex panel). Check for burnt/damaged parts. Connect dummy 4-8Ω load – or speaker - to the speaker connector.

**\*\*Danger – there is little to no protection from electric shock.\*\***

Turn on the power switch and then turn standby switch on and check voltage rail levels against table or schematic level.