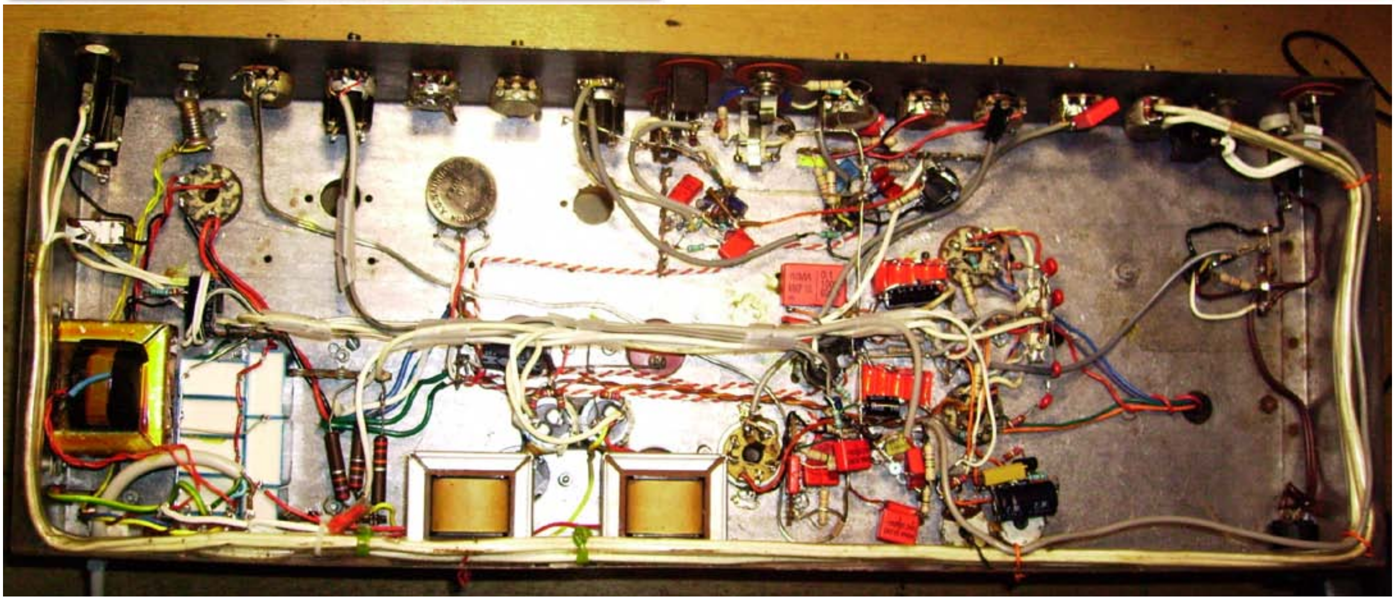
1. Summary

McPherson Twin-Channel 60W Instrument Amplifier.
$165 eBay Dec 2009.
4-input jacks for normal and tremolo; 12AX7 preamp and tone controls; 12AX7 LFO and neon/LDR tremolo; 6AN8 amp & PI; KT88 fixed-bias UL PP with feedback to presence pot; separate transformer for fixed bias with separate trim pots; 4Ω or 16Ω output; controls on front panel with graphics and Perspex cover – in blue tolex covered head box with side handles.

Initial condition:
Mains, HT & Speaker fuses broken. 8-pin valve socket output. Wiring quite messy. Chassis pre-drilled for 3 more valve bases; spot welded steel - slightly corroded; all holes hand drilled but valve and cap holes punched. Some 5M pots are bypassed by 1M; no pot knobs; one pot corroded mounting; tremolo tone pots not fitted/wired, and one 12AX7 partly wired but not connected; heater pin in 12ax7 socket broken; motley array of old electrolytics; 6AN8 triode operating at quite high voltage; mains switch dirty contact & earth leakage; ground wire loop around circuitry (not distributed star); tremolo neon/LDR mounted in valve base plug/header not operating; front panel graphic badly degraded on one side; front panel Perspex broken and cracked on one side.

Output Transformer	A&R 4008-15. 50W 40Hz-20kHz 1% rating; 5K PP, 43% UL taps; 15/3.7 ohm outputs. [KT88 UL 1963 catalog]
Power Transformer	A&R1939-200MA; 0-220-240V; 450-0-450V; 5V 3A; 6.3V 3A; 6.3V CT 3A; ES.
Aux transformer	No markings; Pri; SEC; 6.3V; ES.
Chokes	2x Rola TV306, dated 9 August 1961, 1H @ 300mA
Valves	2x KT88 GEC 'TG Z' codes (1963, July)
	5AS4 Miniwatt fitted (but chassis marked with GZ34)
	6AN8 Mullard
	2x 12AX7 fitted (one China, one Brimar), but base for another.
Diode	BTV-4 (no data)
Caps	2x Dubilier Can 50-50uF 350V
	2x 100uF 350V
	Various Ducon, UCC and Dubilier
Tremolo	neon bulb (NE-2 ?) and LDR (Holland, vintage)
POTs	IRC various – some missing, one broken.
Switches	Standby is DPST with separate NO and NC contacts (AlphaEng, Sydney)
	Two Way 240V 2A (think of some use for other contact)
	Power is DPST (Alpha) 240V 1A (think of some use for other contact)
Sockets	Instrument x3; 3x SATO Japan open style; 2x
Case	Plywood 15mm; dated June 1964 and what seems to be 'KEITH N KING' and possibly Ferntree Gully; handles are very kitchenesque; poor condition plastic cover; front panel graphic is a commercial printing on stiff paper (thin cardboard) – resurrected but a little worn; a blue textured thin vinyl covering and aluminium mesh top section; rear opening had some form of cover at one time; appears like four round rubber feet were originally fitted; front panel knobs missing;



1.1 McPherson Background

Made by Keith M McPherson who ran BORONIA HI-FI & MUSIC CENTRE at 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. Premises included 199 Dorset Rd.

The inside casing clearly has written date of June 1964 - most likely manufacture date, as KT88's and choke dates are consistent. A fainter written name appears to be KEITH N KING, and an even fainter three lines of small written text appears to have FERNTREE GULLY PHONE .... as the last line.

June 1964 indicates the amp pre-dates the likes of Lenard, Wasp, Vase, and also Phoenix. Main Australian manufacturers at that time included Maton and Goldentone. This amp is known to have been one of two prototypes made prior to making the McPherson MkIV amp that was made from late 1964/early 1965 onwards – one of the prototypes remained in the shop for many years.

1.2 Design background

6AN8 pre/PI and KT88 PP UL circuit is exact copy of Dynaco Mk3 circuit (except for missing 12pF and 750pF phase compensation caps, and power supply voltage levels), which being a kit amp was well known given the Mk2 was from 1955 and the Mk3 from 1957. Sunn started in 1965 and used the Dynaco Mk3 amp block for their 200s, as it provided relatively better bass performance (being a hi-fi amp).

One concern is the likelihood that the amp is more likely to get over-driven than perhaps was the original intent of the Dynaco Mk3. The Sunn 200s used the same output stage. The quad 6550 Sunn 2000s included 47R anode and screen resistors, probably to assist sharing. The Radiotronics 1955 Langford-smith/Chesterman reference clearly shows the screen max current level as being much below that for a similar pentode mode operation.

Screen stopper was typically recommended by tube manufacturers, but typically not deployed by amp manufacturers. Plausible advantages of fitting for UL are to limit screen current during power on; oscillation inhibiter; protection from screen internal fault or open-circuit anode; and distortion minimisation (ie. Mullard chose 1k for reporting UL distortion results, and some modern results indicate some change in harmonic balance as resistance increased).

Can't yet identify similar tone circuit, but it is somewhat similar to Sun 200s.

Tremolo spelt as 'tremelo' on front plate and the footswitch is marked 'vib' - and uses an LDR and neon bulb housed in an 8-pin connector plug that plugs into a valve base on the chassis - the LDR has Holland written on it (possibly a OPR61); the inputs have 470k series resistors going direct to vol pot – not a typical configuration; gain is very low, so may have been rejigged to a line level input.

The OPT is the premium A&R range with 40Hz 50W 1% spec, and was manufactured sometime after Jan 1960 (R&H advert).

Supply voltage measurements for Dynaco Mk3: 480V for VS2, and 6AN8 PI has 322V, 107V, 121V (pins 1-3), indicating 2.6mA PI current and 443V VS3; and 5.4mA loading from VS3 and downstream.

2. Modifications

2.1 Initial observations

The circuitry has been modified around the vibrato channel. A 12AX7 valve base and associated tag strip is partly wired, but has been disconnected. The front panel tone controls for the tremolo are not implemented, as the pot in the treble position is a 1M switched pot, but is wired only for the switch to power the tremolo neon, and the pot has a 270k resistor soldered to wiper, but no apparent other connections. Likely that tremolo inputs would go through effectively the same input circuitry and tone section, and then be mixed in with the normal channel inputs at the grid of the 6AN8 pre stage. The existing circuitry around the spare 12AX7 base suggest there were some differences in input circuit design, or that merged inputs from both sides firstly went through the unconnected 12AX7 and then in to the existing 12AX7 (as the gain with just the existing 12AX7 is quite low). The motley array of smaller electrolytic indicates either some of these parts were replaced over time. The chassis was prepared for another 3 valve small-signal bases, but no bases installed.

2.2 Basic changes made

- Power switch needed internal cleaning & then replaced due to earth leakage. Mains switch placed after fuse in active leg of primary.
- 15R NTC in series with primary. MOV across primary to reduce switch stress from turn-off transient.
- 6AN8 heater (0.45A) was wired to KT88 heater winding, which only has a 3A rating. 6AN8 heater transferred to preamp heater winding.
- Preamp heater was grounded on one side. Heater now wired through humdinger pot, and pot wiper elevated to filtered +40VDC to minimise hum, and reduce cathode-heater voltage difference on 6AN8 triode.
- 1 ohm bias current sense plus 400mA fuse (to protect OT) plus 15kΩ bypass (to bias valve to about 80V, 5mA, if fuse blows) in each KT88 cathode.
- Zener diode protected max voltage across VS3 and VS5 capacitors – even if valves not fitted.
- VS1-VS5 filter caps replaced.
- 2nd choke placed in series with 1st choke between VS1 and VS2, as choke is low inductance, high current part (1H@230mA). Most likely that original amp had VS2 ~480V due to heavier bias on KT88s, and the 2nd choke in parallel with 27k would drop little to give VS3 to be close to VS2.
- Added MOV-R dampening across each half primary winding on OT.
- Reconfigured ground wiring for distributed star; single point earth at KT88 cathode star; twisted pair cabling.
- Added 48VDC relay protection of HT if KT88 fixed bias fails; relay contacts in series, and in series with standby switch and CT fuse.
- Modified KT88 bias circuit to full bridge with series resistance and CRC filter; added protection resistor to pot wiper.
- Replace 8-pin valve socket speaker output connector with Speakon. Two 6.5mm sockets in parallel with speakon – output set for 4 ohm.
- Replacement neon fitted.

2.3 Configuration changes

- Added 2M grid leak and 220k mixer/grid stopper to 6AN8 pentode to alleviate hum pickup from pots.
- Switched output mode between UL and standard pentode PP modes – ~300V screen supply for pentode from VS4, plus 1k screen stopper. Similar cathode idle currents set by switched

loading on bias supply. No attempt to match signal gains (eg. by loading 6AN8 pentode grid leak to form divider for pentode mode).

- Tremolo side inputs rewired to unconnected 12AX7; each tremolo input to one valve half, with different biasing levels; outputs are mixed and passed to other 12AX7 input half; new switched socket to replace un-switched socket; all socket inputs insulated from chassis.
- Tremelo side circuitry a very close clone of McPherson MkIV. Normal side preamp circuitry basically as found for low gain input.

2.4 To do

- Switch ?? for 4R to 16R selection.
- Extend sense voltages to connector on rear panel for maintenance testing.

3. Measurements

Voltages:

Rail	UL	Pentode idle
KT88 bias	33mA,34mA	34mA,33mA
VS1	558	554
VS2	553	550, 253
VS3	402	392
VS4	323	300
VS5	273	253
VS6	-100	-90
VS7	-75	-36.0
VS8	-71	-
VS9	-71	-
VS10	46	51
Heater	6.6, 6.8	6.6, 6.8
Sec HT	475-0-475	475-0-475

Transformer primary = 6.1Ω. Transformer secondary HT = 34+36Ω. [53 ohm effective datasheet, for GZ34 or 5R4]

TV306: 30Ω DCR; 1.36H @ 55mAdc; 1.2H @ 110mAdc; 1H @ 230mAdc; 0.86H @ 350mAdc;

12VAC 50Hz nominal applied to output transformer

Winding	Voltage rms	Turns ratio; Impedance for 5K pri; Spec level; Notes
Pri P-P: BLU to BRN		
Sec: BLK to OR		; Ω; Ω;
Sec: BLK to YEL		; Ω; Ω;
Sec: BLK to WH		; Ω; Ω;
Sec: BLK to GRN		; Ω; ; feedback winding

Output transformer primary DC resistance: 62Ω plate-to-plate.

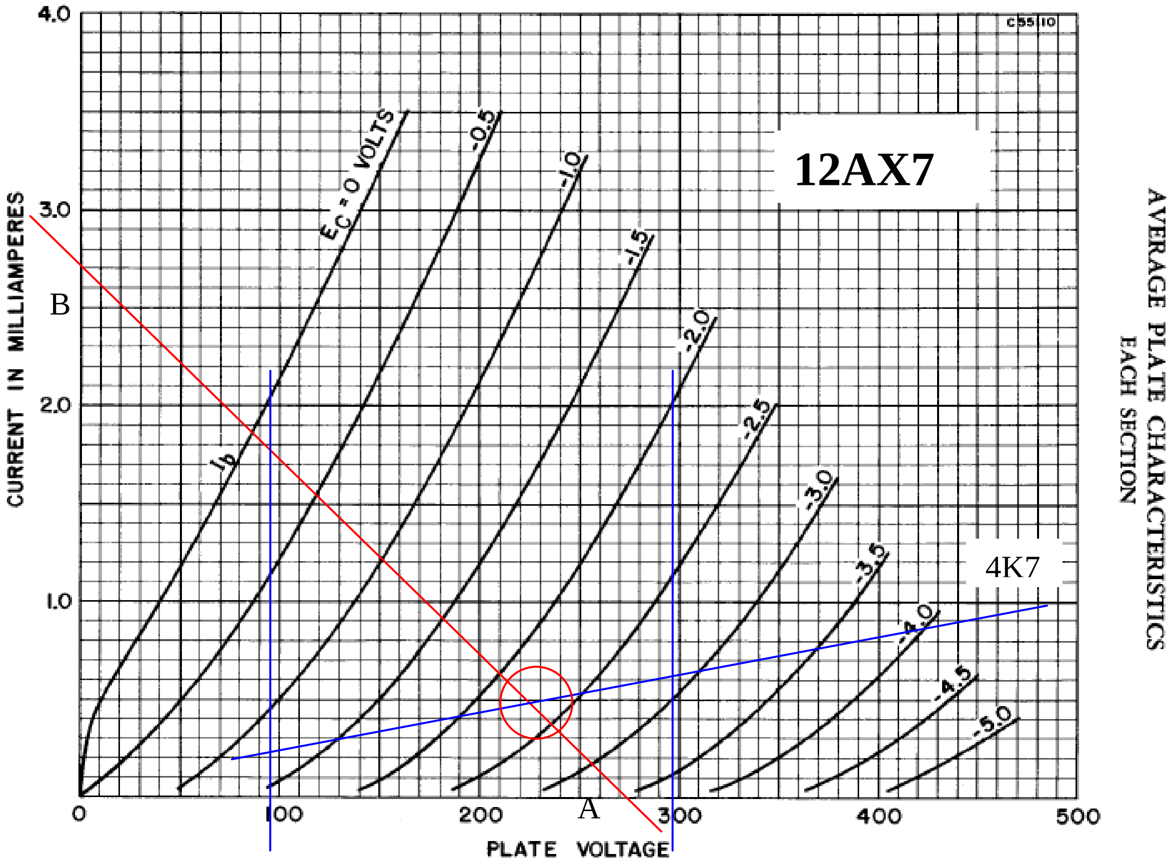
4Ω resistive load	UL		Pentode	
Output Vrms	VS2 ripple	VS2 DC	VS2 ripple	VS2 DC
0V	1.0	535	1.0	538
5V (6W)	1.14	525	1.1	534
10V (25W)	1.78	485	1.8	~490
15V (56W)		430		

Sag limited power output to about 50W in pentode mode.

4. Design Info

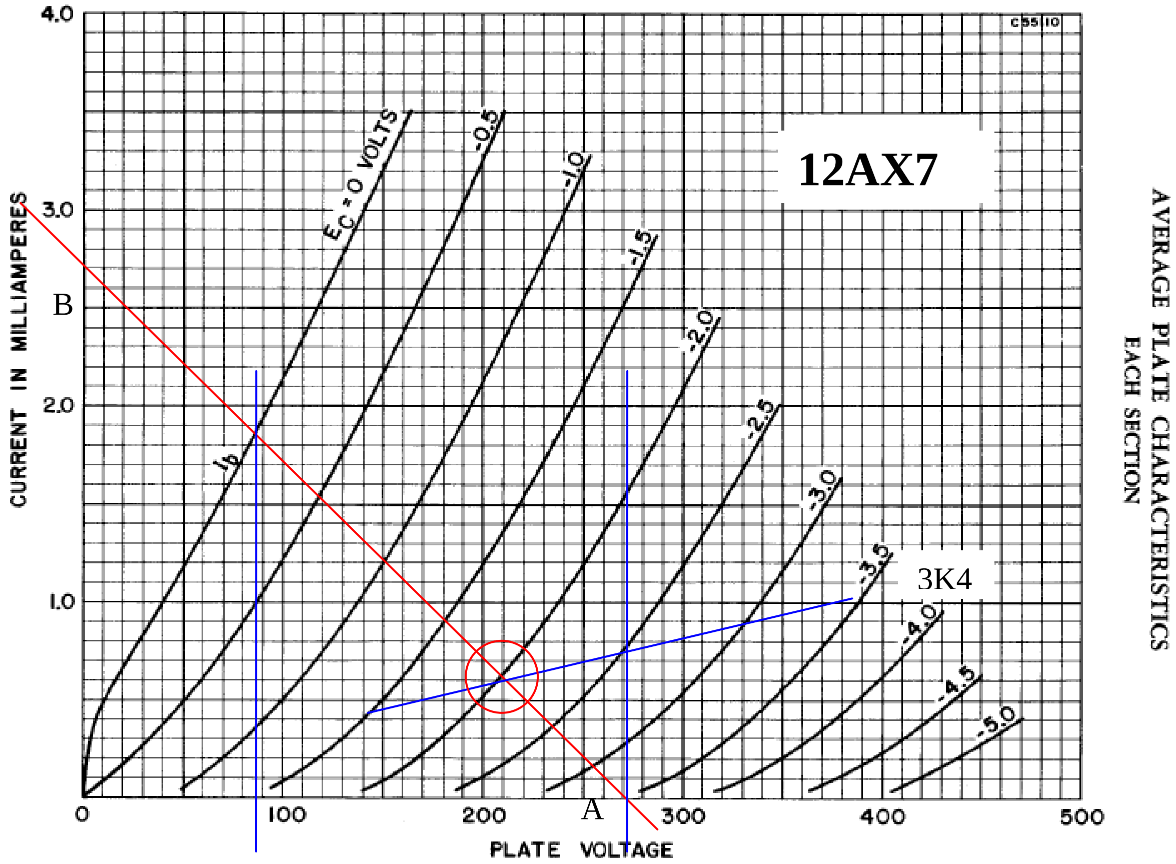
4.1 Normal Hi-gain Input Gain Stage

12AX7, V1; VS5 = 270V; Va=220V; Rk=4k7; Vk=2.2V; Ia=0.5mA; RLdc=100k.



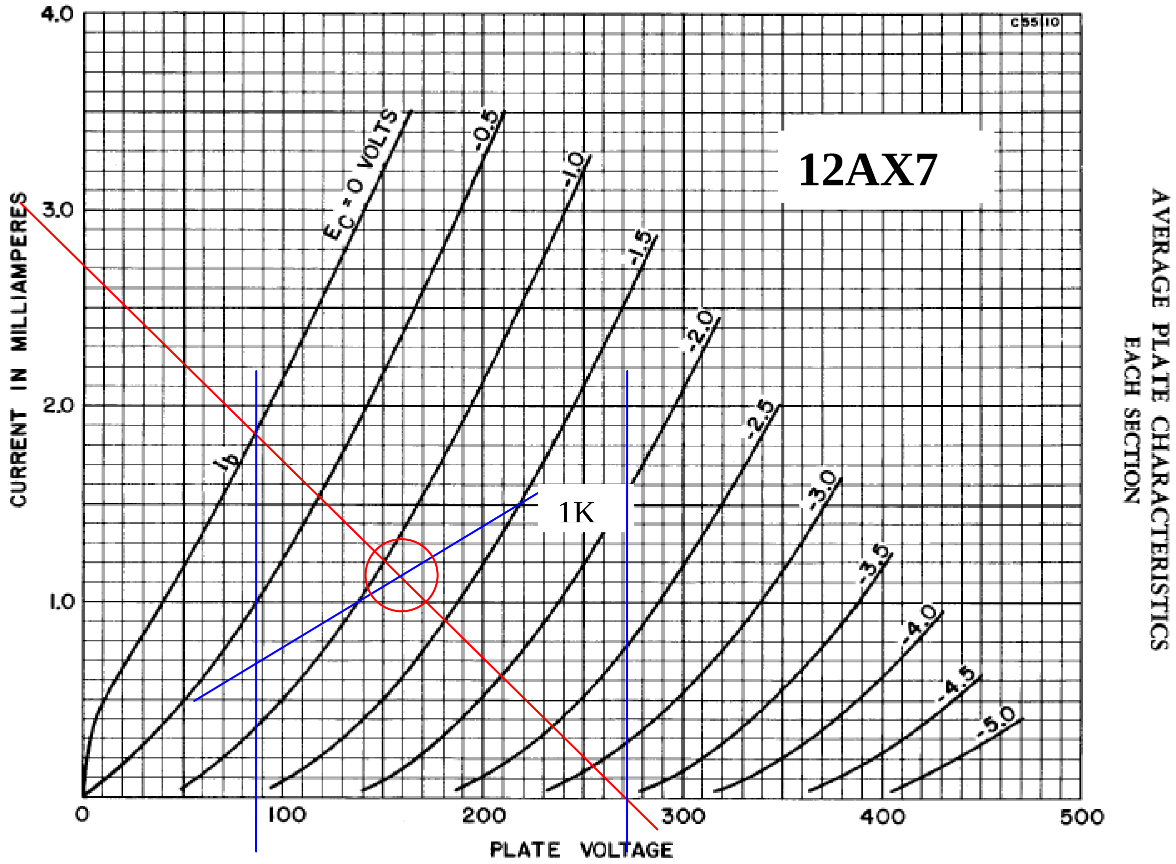
4.2 Normal Lo-gain Input Gain Stage

12AX7, V1; VS5 = 270V; Va=210V; Rk=3k4; Vk=2.0V; Ia=0.6mA; RLdc=100k.



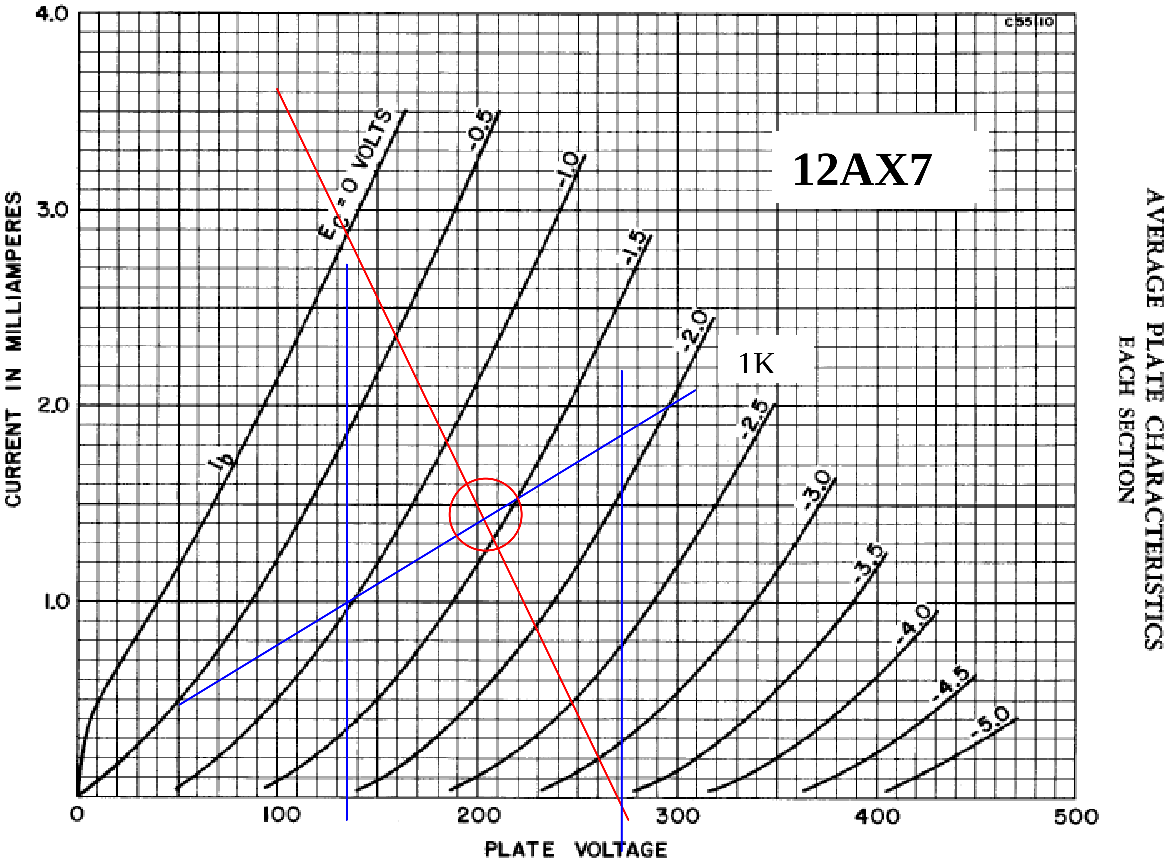
4.3 Tremelo Input Gain Stage

12AX7, V2; VS5 = 270V; Va=160V; Rk=1k; Vk=1.2V; Ia=1.1mA; RLdc=100k.



4.4 Tremelo Volume Make-up Gain Stage

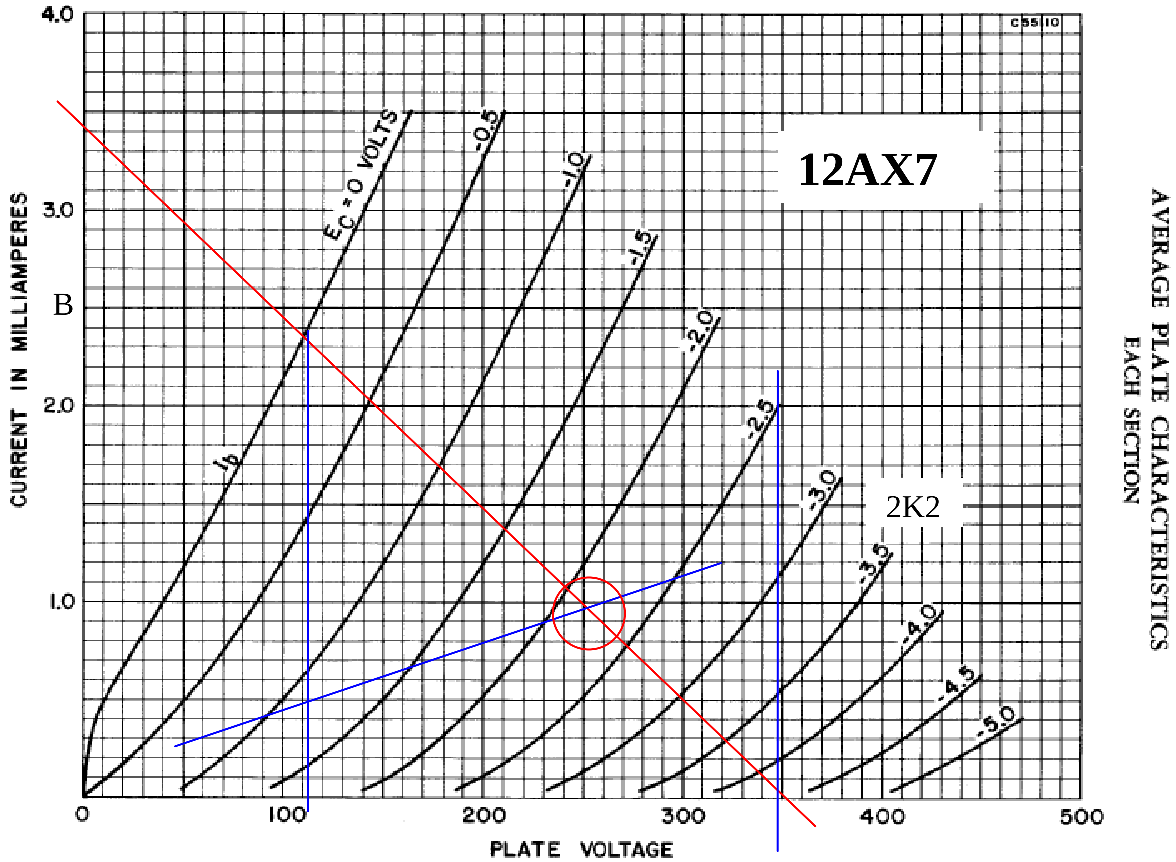
12AX7, V2; VS5 = 270V; Va=200V; Rk=1k; Vk=1.4V; Ia=1.4mA; RLdc=47k.



4.5 LFO

VS4 at 350V. Loadline indicates 1mA and 250V idle, and 2.2V cathode bias.

Neon NE-2 type bulb ionizes at about 90-110V.



4.6 Pre and Splitter stage

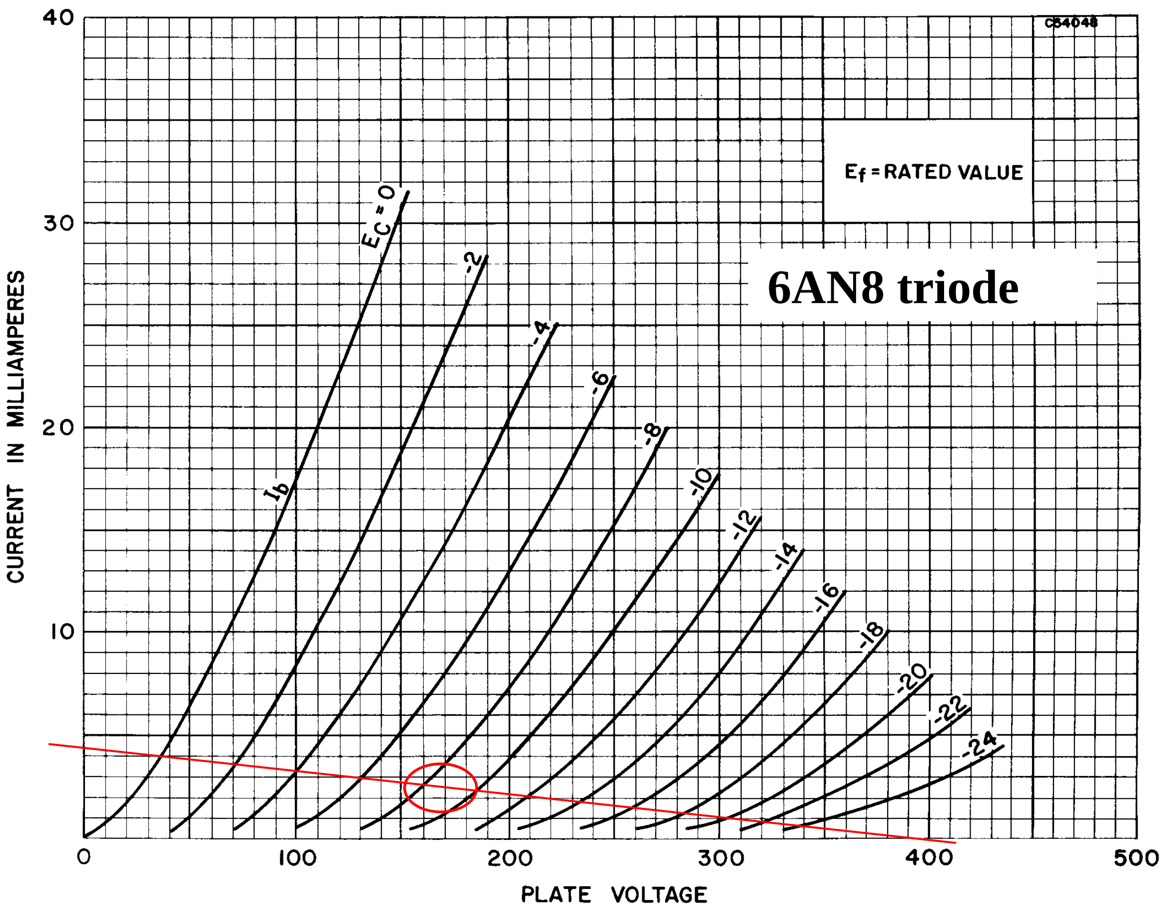
The 6AN8 pentode is used as an amplifier, with amplifier output feedback to the tapped cathode resistor. The pentode screen is biased with a 1M5 from VS4, and bypassed to the cathode with 0.1uF. The pentode output is DC coupled to the triode cathodyne PI. The voltage drop across the triode is ~40V min, and VS3 can be anything droppered from VS2, but peak triode voltage starts to get above 400V, and cathode starts to get above 100V. So based on VS3=440V, then 25% of VS3-40V = 100V across each cathodyne loading resistor gives symmetric swing.

The 6AN8 triode PI stage has plate voltage Vp axis intercept is 400V for no plate current, and the plate current Ip axis intercept is 400V / 94KΩ = 4.3mA. The preferred triode PI anode-cathode voltage at idle is about (380-40)/2=170V; 9V and 2.23mA.

Pentode gain is lowered by low screen voltage. Sunn 200S uses about 35V on the screen with 325V VS4, and 75V on the anode, whilst the 2000S shows 30V on the screen, but with VS4=300V. The pentode anode current is about (330-86)/270k = 0.9mA. Screen current is about (330-40)/1M5 = 0.19mA. So cathode voltage is about 730 x (0.9mA+0.19mA) = 0.80V.

With about 80V screen, the available grid swing is about -4V cut-off.

Screen bypass cap taken to cathode, as global nfb also goes to cathode divider (ie. can't take to 0V). Can also tailor cap size, or even use a zener and cap. Could also consider using two voltage levels on the screen, eg. 35V and say 65V for higher gain/distortion.



4.7 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 grounded, and each tube operates in a fixed bias mode with a negative gate voltage. The 5KΩ impedance plate-to-plate OPT, presents each tube with a 2500Ω load impedance around cross-over, moving to a 1250Ω load impedance (Class B) at high signal levels - with a resistance matched secondary load.

The low frequency response extends down to 40Hz for OPT spec level of 50W, and goes higher at higher frequencies before core saturation becomes excessive.

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. <25W); and
- assess the dynamic loadline to see if it moves into region of increased plate dissipation.

As the output loading increases, the supply voltage VS2 to the output valve plates sags from about 550V to well below 500V. Effective plate voltage will be lower than VS2 by an amount up to ~13V due to OPT half resistance of about 36Ω with a peak current of up to about 0.35A.

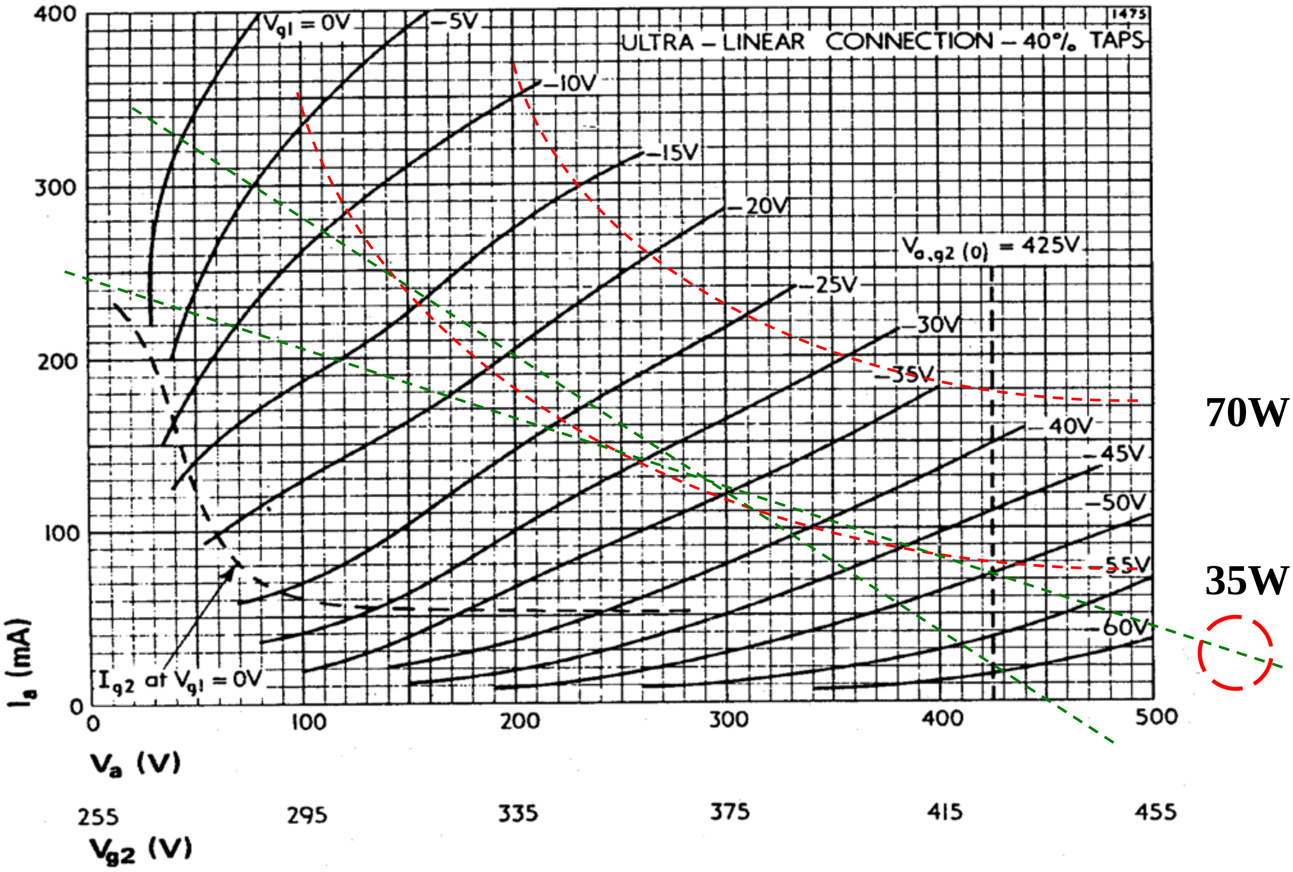
The recommended output valve bias current for the KT88 is Ibias = Pd / Vb = 25W / 550V = 45mA. The gate bias voltage required for this current is significantly influenced by the mode of operation - UL, and screen voltage in pentode mode.

The first loadline graph shows the characteristic curves for KT88 with a UL screen voltage. The initial loadline trajectory is along a 2500Ω 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 1250Ω loadline – this loadline is aligned with the sagged effective plate voltage of about 500V, and extends out to the 0V gate level. This 1250Ω loadline indicates a peak plate current of ~300mA would be needed for input grid voltage reaching 0V.

For a peak plate current of 300mA, then the nominal output power of the amplifier would be: $(Ipk)^2$ x Rpp / 8 = 0.3 x 0.3 x 5k / 8 = 56W. For this maximum signal condition, the rms OPT current draw is likely about 0.2A (64% of peak), and the average VS2 power consumed is about 450V x 0.2Arms =90W, and the OPT loss is about $(0.2)^2$ x 31Ω = 1W, so the tube plates dissipate 90 – 56W - 1W = 33W, or just under 16W each, which is reasonably below max design level.

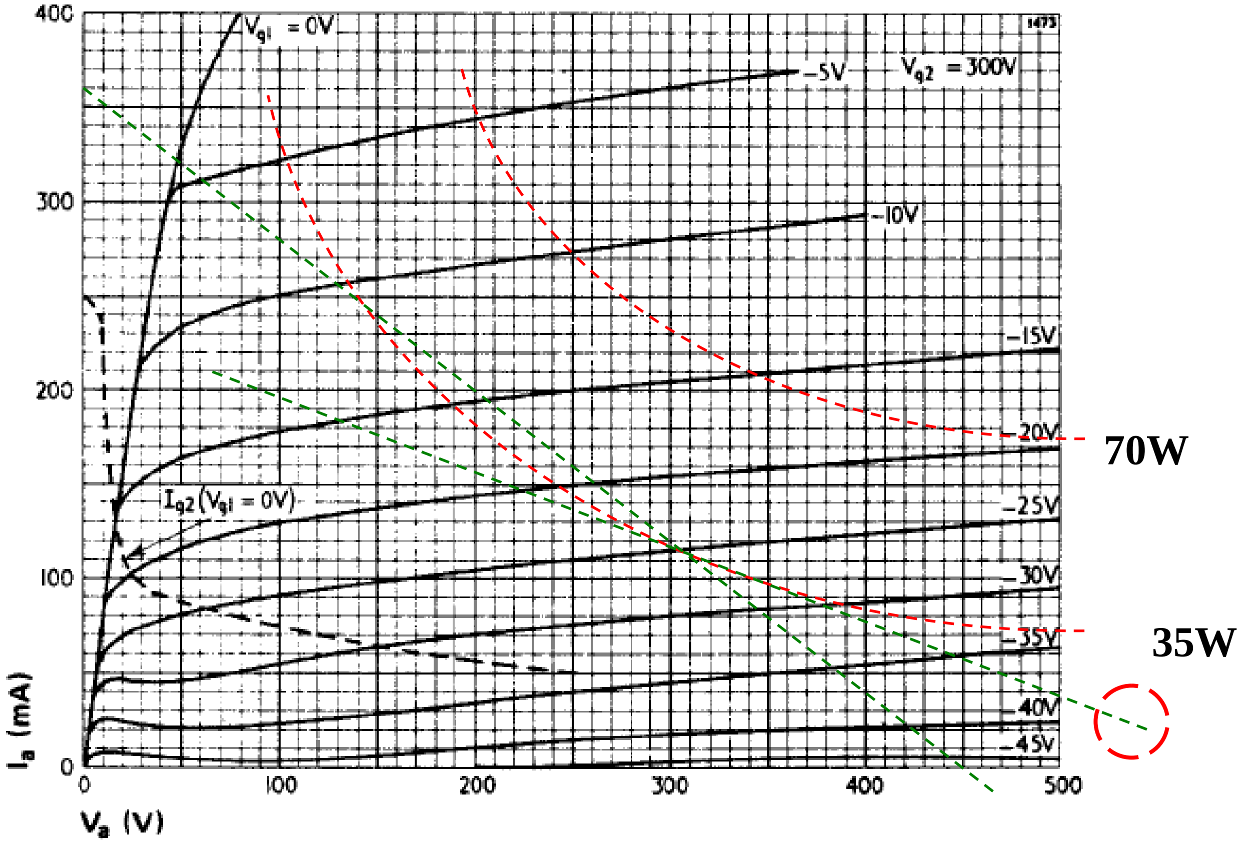
During dynamic conditions, the plate dissipation mostly exceeds the 35W power contour curve shown on the graph as VS2 hasn’t sagged. Each valve has an ‘off’ period for 50% of time, where the plate dissipation is lower than the bias level and possibly down to a few watts for most of the period when the 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 35W curve.

In UL, the screen voltage will sag and the output compress during grid swing from about -5V to 0V when a screen stopper is used - a 100R stopper will increase drop by about 10V.



In pentode mode, the screen supply VS4 will sag and the output compress as grid swing increases to 0V - a 1k stopper will increase the drop by about 80V. A screen supply of about 300V may droop screen voltage down to 200V when Vg1 approaches 0V.

The loadline indicates the achieved loadline is likely to be into the very broad knee region, depending on screen droop.



4.8 Power Supplies

Power switch turns on valve heaters and output valve grid bias. Added 270k pre-charge resistor across Standby switch to provide ~50V on the HT power caps to reduce HT turn-on stress. PT has rating in excess of requirement, so Tx regulation shouldn't be an issue.

A GZ32 full-wave centre-tapped rectifier with 450-0-450V windings provides a no load voltage of 630V. The GZ32 has limits on the effective source resistance when feeding a capacitor-input filter. The effective source resistance is comprised of the reflected power transformer primary resistance = 6.1Ω x $(450/240)^2$ = 21Ω; plus the secondary resistance = 34Ω; which sums to 55Ω. The specified min source resistance is 130Ω for 50uF input cap. Modified to use 8x 2u2F poly caps (17.6uF) to comply with no extra series resistance than inherent 55Ω. Caps rated to 760VDC. Only 7V drop across each choke at 230mA average.

Choke CH1 DC drop is 30R x 2 x 50mA = 3V at idle. GEC design level for UL fixed bias at 460V.

VS2 sag will come from many contributors: the main ones being GZ32; VS1 ripple averaging by choke; PT, OT and choke DC drop.

Idle loading from VS5 is ~ 3.6mA, from VS4 is ~ 3+3.6=6.6mA, VS3 is ~ 2.2+3+3.6=8.8mA, (50V drop to VS5 from 14k; and 90V drop from VS3 to VS4 from 14k; and 190V drop from VS2 to VS3 from 22k).

Three 1N5383 (150V) zeners used to limit VS3 cap voltage to 450V if valves are pulled. Two 1N5383 (150V) zeners used to limit VS5 cap voltage to 300V if valves are pulled.

VS2 for the output stage is choke-capacitor filtered, and will respond to dynamic loads with a 11Hz LPF response (110uF, 2H). It may be appropriate to put ~100k damping resistance across the choke [check worst-case ripple voltage] as 2H = 1k2 impedance.

The KT88 grid bias resistors are 100k, which is the datasheet max for high dissipation applications.

The bias supply is bridge rectified but with a large added series resistance to reduce harmonics in the filtered DC. VS6 ~ -100V rail with relay load and bias supply drawing ~2.3mA. 11k dropper gives VS7=75V, which is reduced to 50V when pentode mode is selected.

5. Protection

5.1 Loss of grid bias

If the grid bias supply voltage fails, then the grid will rise and become positive to cathode, and plate current will increase without control - the tube first glows cherry red, then fails. A 48VDC relay, Omron G2R-2 48V, has a coil resistance of 4.2K, with a must pickup of 34V, and a must release voltage of greater than 7.2V, and de-energises due to gross failure of the bias power supply. The relay contacts are used to disconnect the AC supply to the HT, as the series contacts are rated to break this level of AC (but not DC). If a bias failure does occur, the energy remaining in the caps will still discharge into the tubes, but is minimal.

5.2 HV breakdown

If the B+ rail shorts to ground, due to a flashover, or insulation breakdown, then a 1A fuse in the transformer secondary line provides gross failure protection by de-energising both the plate and screen rails.

5.3 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.

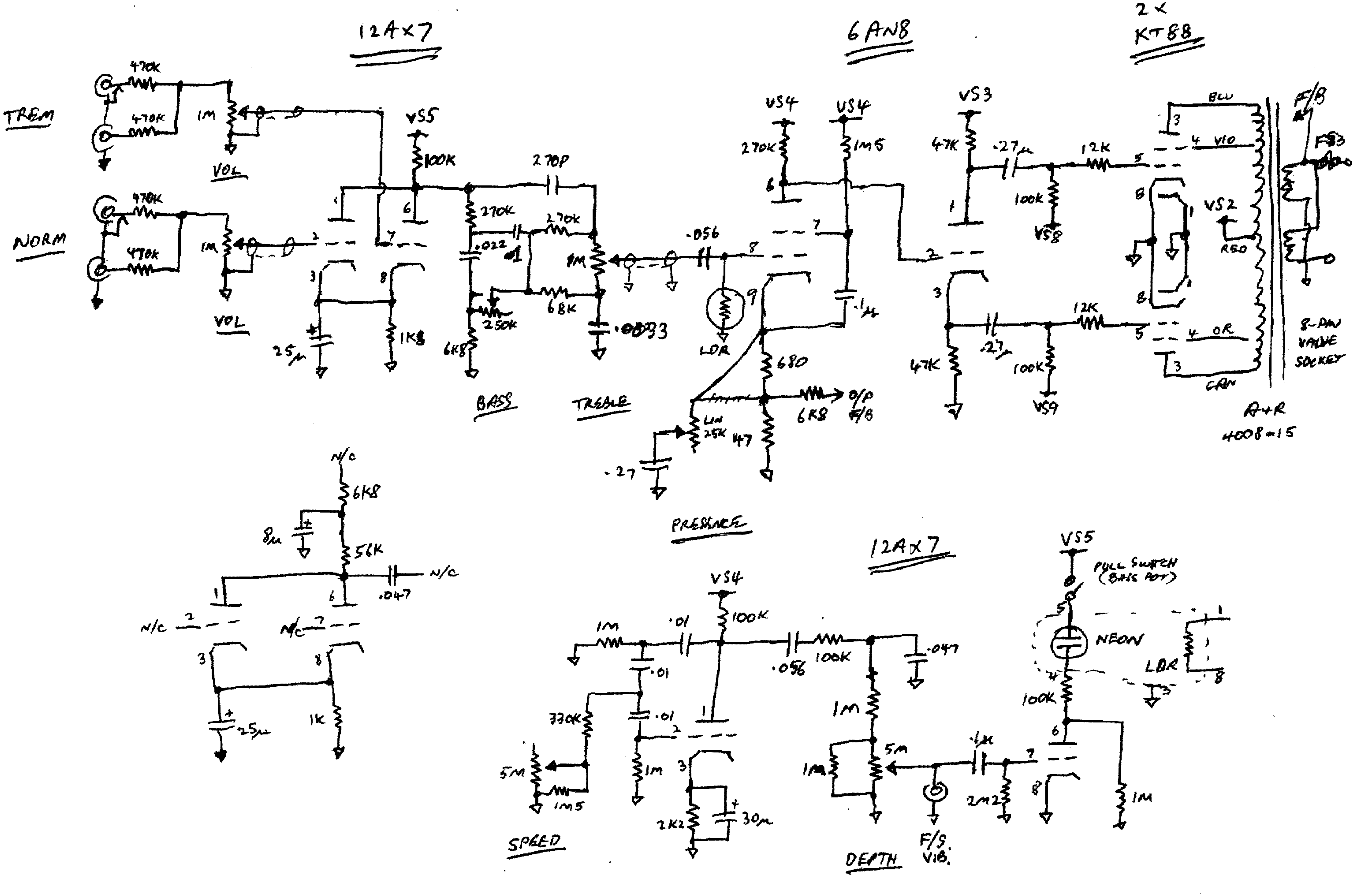
6. Testing and Faultfinding

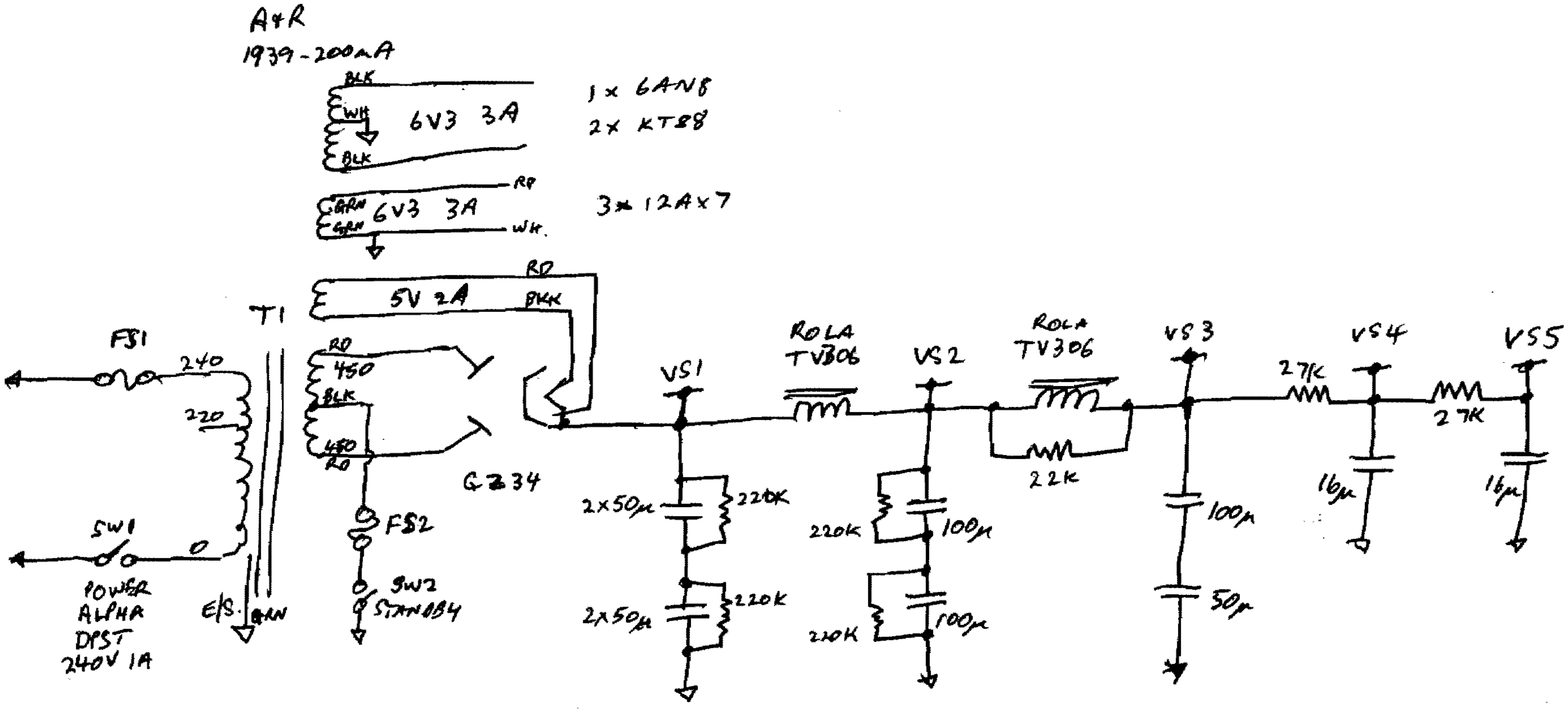
If a problem occurs then pull out power cable and check front panel fuses (3).

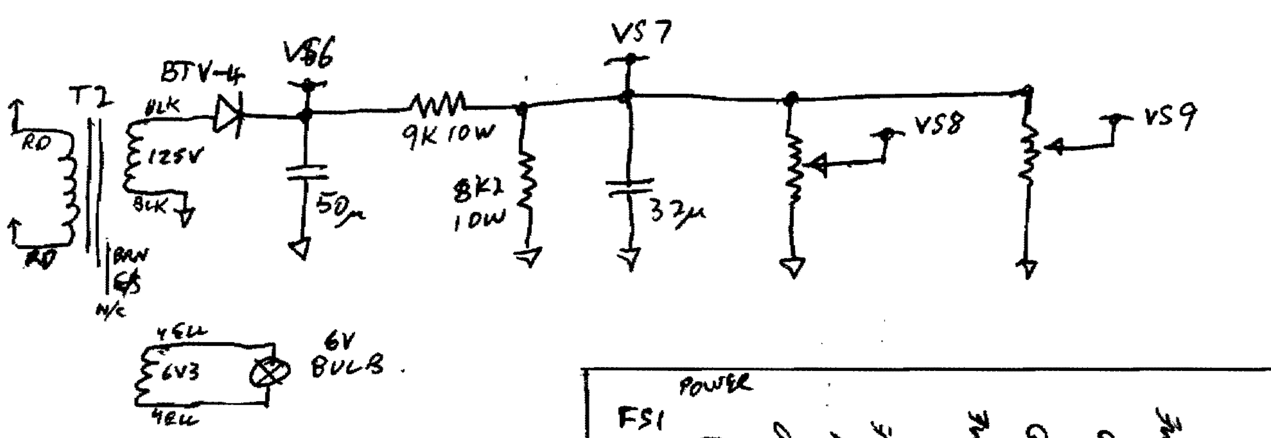
Gently remove chassis from wooden enclosure (4 bolts into base); then turn upside down. Check KT88 cathode fuses. Check for burnt/damaged parts. Connect dummy 4-8Ω load – or speaker - to the speaker connector.

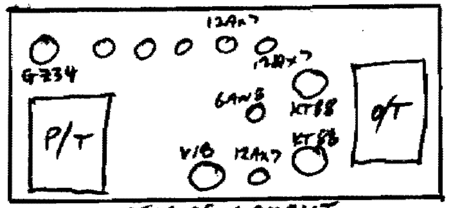
Check AC cable and connector earth pin are good. Check standby and power switch are both off and connect AC power. Turn on the power switch only and carefully check DC voltage levels VS2~50V, VS8,9=-71V. If ok then turn standby switch on and check voltage rail levels against table or schematic levels including voltage across 1Ω cathode resistors (0.035V for 35mA).

McPHERSON TWIN-CHANNEL 60W INSTRUMENT AMPLIFIER 1964

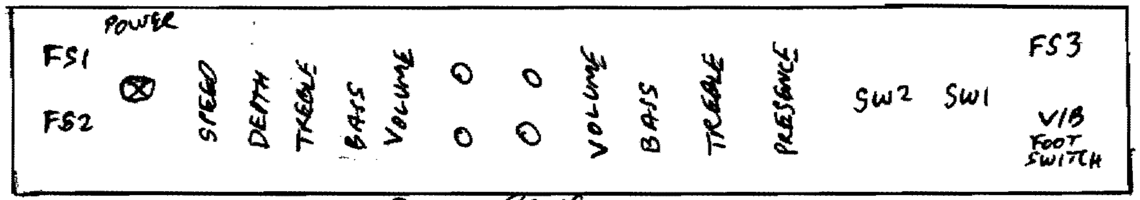




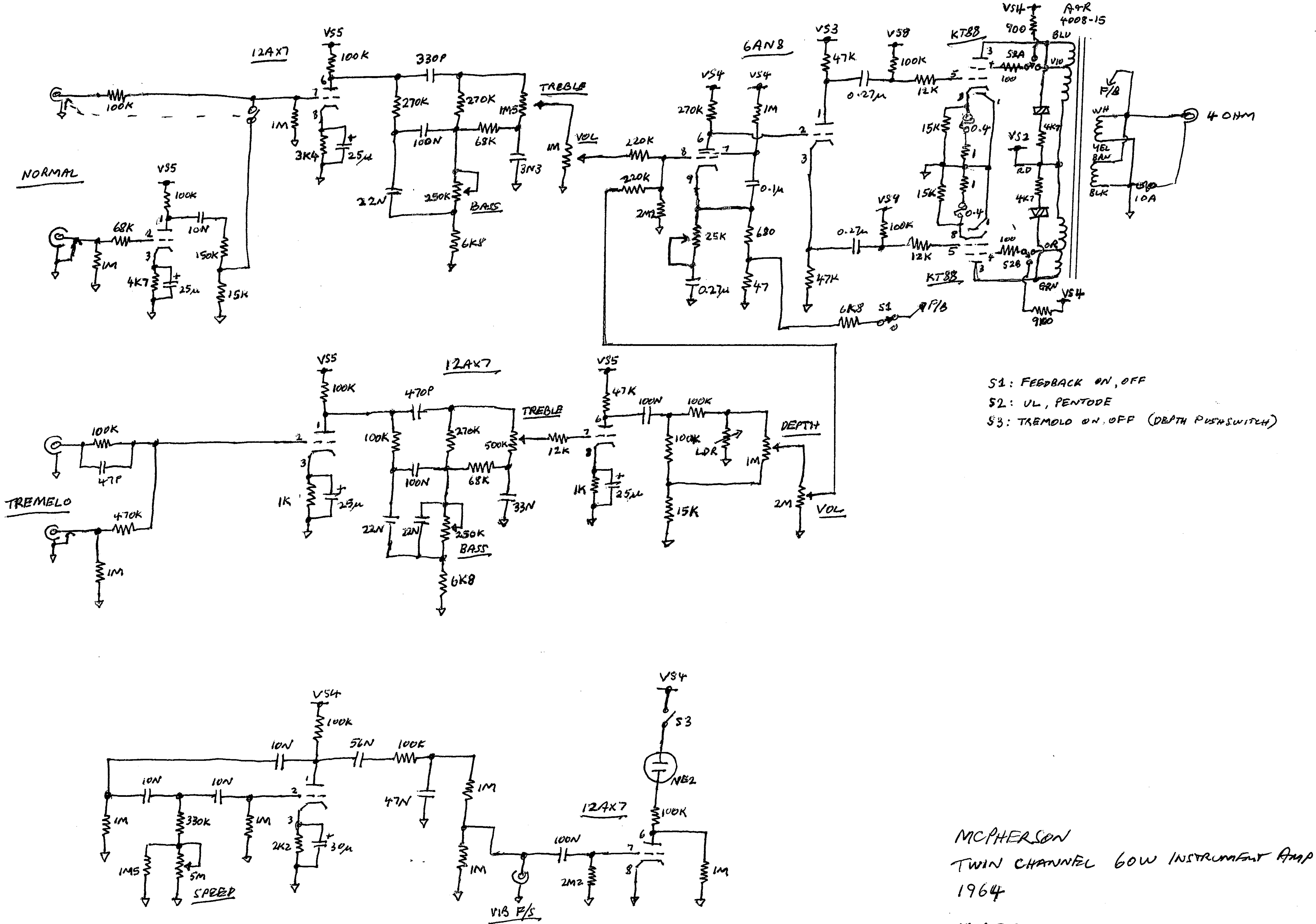




UNDERSIDE LAYOUT



FRONT PANEL



S1: FEEDBACK ON, OFF
S2: UL, PENTODE
S3: TREMOLO ON, OFF (DEPTH PUSHSWITCH)

MCPHERSON
TWIN CHANNEL 60W INSTRUMENT AMP
1964

MODIFIED 2011

A+R 1939-200mA