1. Summary

Philips Australia Amplifier Type 961, S.N. 3486. $25 eBay March 2009

1.1 Original Amplifier

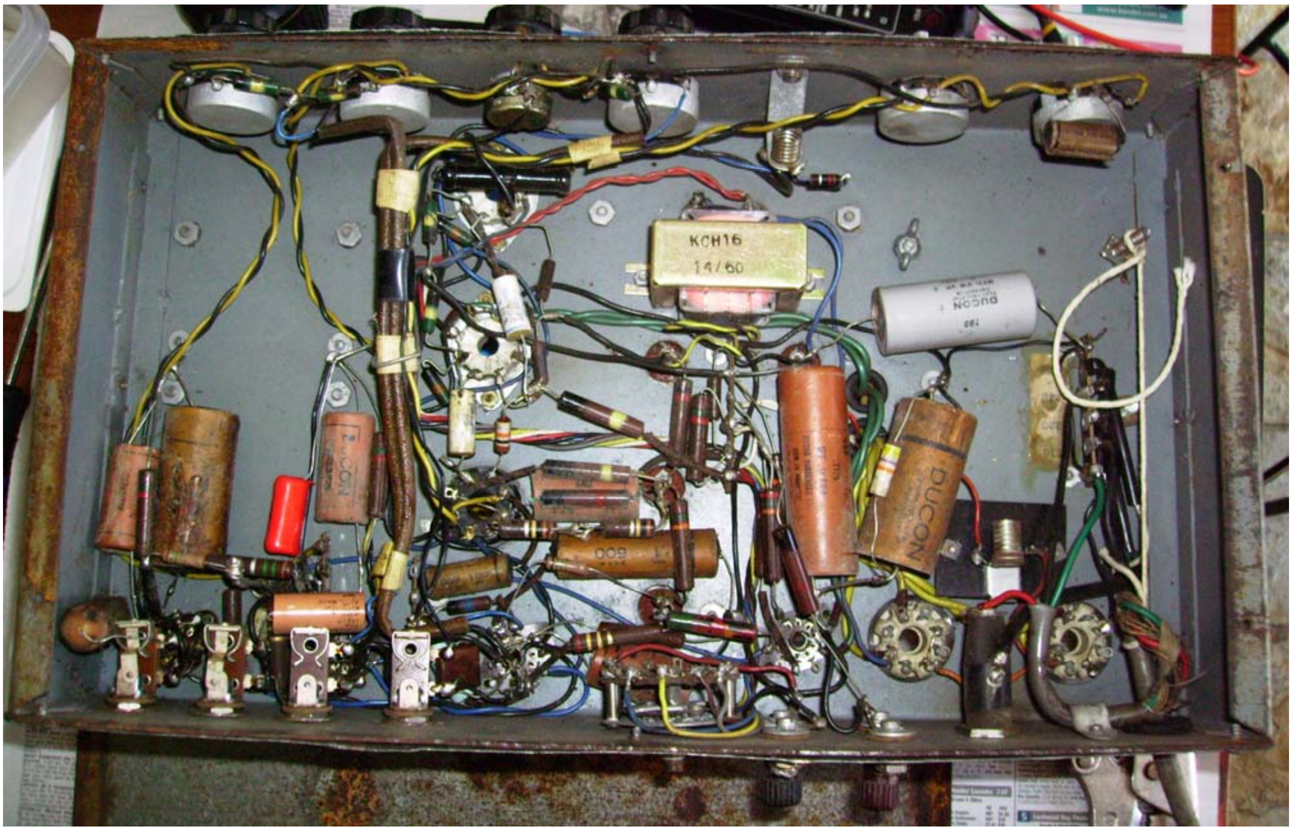
Two microphone and one P.U. input channel PA amplifier. 9-pin pentode for each microphone channel, and for summing amplifier. 6SN7 gain stage with feedback mixer, and split-load cathodyne splitter and fixed bias push-pull pentode output, with secondary side feedback. 800V plate supply from voltage doubler 5U4GB (2x) diode rectifier and capacitor input filter. Half plate supply is fed via inductor to the screen supply, with cascading resistor/cap dropping to the driver and input stage supplies. Plate voltage droops to 640V with 85W output loading, and 8W driver loading. Output stage grid bias from separate half-wave diode supply. Bass & Treble tone pots between summing and splitter stages. 5x 8-pin Octal and 4x 9-pin Novel bases total.

Power and output transformers with markings but no manufacturer. Choke from Plessey. All transformers and choke show good Megger readings. However the amplifier was not powered up in original circuit due to condition of all caps.

POTs are IRC but only BD2 or RC2 markings. Ducon caps. The 20uF is DUCONOL A. No valves.

Output Transformer	140/70/50/35 ohm outputs. Marked 880 and 2472.
Power Transformer	Marked 2402 and 1323
Choke	Plessey. Marked KCH16 and 14/60 and 10820 [possibly added later]
POTs	IRC marked BD2 and RC2.
CAPs	DUCONOL A 20mF 600V – caution may contain PCBs
	Ducon 24uF 600V
	Ducon 16uF 600V (x4)



1.2 Target Amplifier

Modify to typical guitar input stage with half 12AX7 followed by Fender tone stack and gain pot into other half 12AX7. Modify 6SN7 to Schmidt long tail pair. Retain output stage. Add extra input going through dual triode for high-gain distortion – can use 12A?7. WIP.

2. Modifications

- Replaced all resistors and capacitors.
- Guitar level input. Fender style treble/mid/bass tonestack with pots, feeding gain pot. Volume pot feeding splitter stage. Presence pot to adjust feedback into tail of splitter stage.
- Replaced the power cable.
- Added 60mm computer fan into the chassis base – add vent cutout – add vent holes around output valves. Add rubber feet to allow air flow underneath.
- Added low value cathode-to-0V resistors, with sense wires taken to 5-pin DIN for reading bias current level on each output tube.
- Split the grid bias VS5 to allow output tube bias currents to be matched.
- All wiring with zoned star ground configuration. Twisted pair and separate heater cabling. Shielded cable between sections.
- HT supplies with double the capacitance – but still substantial sag on heavy transient loading – XXX info on caps.
- Output Tranny configured for 35 ohm output using all turns on secondary windings (4 windings in parallel). This allows loading with 16 speaker if needed – and moves compression into knee region. Speakon output socket.
- Added Standby switch to secondary winding.
- HT supply fuse for over-current protection.
- MOV-R across each primary for open-circuit output protection.
- Added grid bias failure protection circuit (48V relay that pulls out if bias is lost, and isolates the HT winding).

- Hi-gain input and 12A?7 circuit with cold then warm biasing with 9mm trimpot for stage gain.
- Lo/Hi input switch to each socket.
- Indicators for standby and on.

- Use fuse in series with 1R cathode sense, and shunt with a 10k (to bias valve to about 40V, 5mA, if fuse blows).
- Lower the coupling caps in the XTRA gain sections from 10NF to 2N2F
- Mu-metal guard screen on PT and OT – placed on inner 'valve' side of PT, and both sides of OT, to reduce any field interaction with valves.
- Fan power supply – tbd.
- Connect feedback winding and check.
- Tuned humdinger to replace 25/25 balance humdinger.
- Dual gain pot – two shafts – one for pre-gain, and one for overdrive gain. Or use a dual-gang 500k-1M log, with the first gang pot used to feed both normal and overdrive, and second pot used for output of overdrive, and a switch to connect overdrive (front panel or foot). Use both stages of another 12AX7 or 12AU7 or 12AT7.

3. Measurements

Voltage rail regulation. 240VAC tap

Rail	Minimal load*	Max Load 120R series	Max Load. 0R series
VS1	800V (2.4x)	560V , 116mA , 65W	637V, 133mA, 85W
VS2	430V	263	
VS3	428V	252 , 24mA , 6W	289V, 27mA, 8W
VS4			
VS5			
VS6			
Heater 1	5.4		
Heater 2	5.4		
Heater 3	6.6		
Heater 4	6.6		
Sec HT	335	328V , 300mA , 98W	
Drop on 120R	335	37V , 300mA , 11W	-
Ripple C1		49 Vrms	57.5 Vrms
Ripple C2		57 Vrms	66.6 Vrms
Ripple C3		2.2 Vrms	2.5 Vrms
Ripple C1+C2		38 Vrms	46.8 Vrms

12uF poly for each cap C1, C2, C3. Choke between C2 and C3. VS1 across C1+C2.
Minimal load *: 5U4GB x2; 2x 6CA7 heaters; 200k on VS1; 62K on VS3; 120R in series with sec.
Max load: 5U4GB x2; 2x 6CA7 heaters; 4K8 on VS1; 10K5 on VS3; 120R in series with sec for one test.
Power transformer primary DC resistance: 3mΩ.
Power transformer secondary DC resistance: 15Ω.

12VAC 50Hz nominal applied to output transformer

Winding	Voltage rms	Turns ratio; Pri Impedance; Spec level; Relative Turns
Pri P-P: BLU to BRN	229	; Ω; N/A
Sec: BLK to GRY	25.2	9.1; 11,600 Ω; 140 Ω; 145; 100
Sec: BLK to BRN	17.7	12.9; 11,650Ω; 70Ω; 72; 70
Sec: BLK to YEL	15.2	15.1; 11,400 Ω; 50Ω; 52; 60
Sec: BLK to BLU	12.4	18.5; 12,000 Ω; 35Ω; 35; 50
Sec: RED to WH	8.6	26.6; 17 Ω; N/A Ω; feedback winding

Output transformer primary DC resistance: 61+61 Ω plate-to-plate.
Output transformer secondary DC resistance:
3 Ω BLK-GRY
1.7 // 1.9 Ω BLK-BLU
1.2 // 1.3 Ω BLU-GRY
1.1 Ω RED-WH
Secondary 35R tap was split and interleaved windings reconnected to 0R and 140R terminals to give all (4) interleaved windings acting as 35R (ie. no phantom windings left over). Given power rating of amp, this would be a suitable output for 2x 16 ohm speakers in series.

Choke inductance: tbd

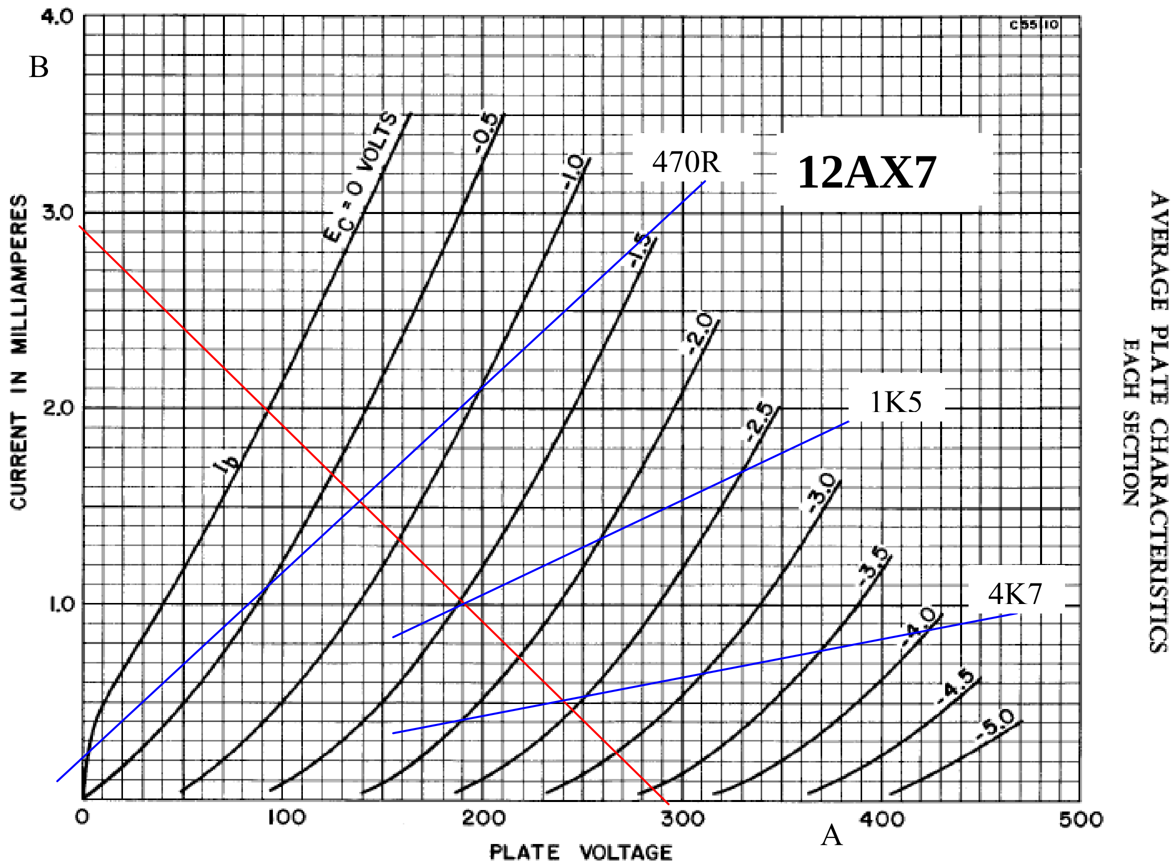
4. Design Info

4.1 Input stage option 1 – 12AX7

Four 9-pin bases are available for input stage.

Supply voltage is 290V; load resistance is 100k; and cathode resistor is 1K5. The plate voltage Vp axis intercept is 290V for no plate current, and the plate current Ip axis intercept is 290V / 101KΩ = 2.9mA (point B). The gate-cathode voltage (Ec on the graph) operating point is at Vgc=1.5Kx1mA = 1.5V, and varies with plate current through the 1k5Ω gate-cathode resistance with the characteristic shown on the graph as a line passing through Ip=1mA for Vgk=-1.5V, and through Ip=1.5mA for Vgk=-2.25V. The intersection of the two lines is the nominal biased operating point.

The input voltage swing limit is from the bias point at Vgk=-1.5V to Vgk=0V, which is about 3Vpp or 1.1Vrms. Referring to the loadline, the plate voltage would swing about 240V, from about 120V to 360V, with a mid point of 175V [265-190=75V; 190-90=100V] which is fairly symmetric. This gives a nominal gain of 175/3 = 58. Signal overload will hit compression before cut-off. Could increase cathode to 1K8.



4.2 Splitter stage option 1 – 6SN7 in long-tail config

One 8-pin Octal base is available for the splitter stage, which splits into two signals, 180deg out of phase from one another, and presents a voltage amplified drive to the push-pull output stage. The Schmidt long-tail splitter configuration was in common use by Fender/Marshall, but using 12AX7 or 12AT7. Here the aim is to use the 6SN7 twin triode in the 8-pin Octal base, as the 6SN7 was in widespread use, and came with the PA amp.

Valve	12AX7 – ECC83 - 7025	12AT7 – ECC81	6SN7
Gain	100	70	20
Current	Up to 1.2mA	10mA	9mA
mu	1600	5000	2600
Design			350V; 5mA
Rk	470R	470R	1K5
Rtail	6K8 + 4K7 presence & F/b	22K-33K	6K8 + 4K7 presence & F/b
Rgate	1M	330K	
Rload	82/100K	47K	56K
Vsupply	470V	400V-420V	400V
Applications	Fender 59 Bassman	Fender Bassman 50 Fender Bassman 135	Needs 16Vpp input. 60V p-p output.

4.2.1 400V 5.3mA loadline

The available supply voltage is about 400V. Aiming for a 400V/5.3mA = 75K loadline, then the midpoint gate bias is about -8V – hence the gate-cathode resistance required is about 8V/2.67mA = 3K, giving Rgc~1K5 as a good design start.

The plate current versus plate voltage load line for each triode is given by the equation:

$$Ip = \frac{V_p}{R_L + 2(R_K)}$$

where R_k = 1K5Ω + 6.8kΩ + 2.5kΩ = 11kΩ. Hence a load resistance of about 75K-22K = 50K is needed. The plate voltage Vp axis intercept is 400V (point A) for no plate current, and the plate current Ip axis intercept is 400V / 75KΩ = 5.3mA (point B). The gate-cathode voltage (Ec on the graph) varies with plate current through the 1K5Ω gate-cathode resistance, but with a 3kΩ characteristic, and this characteristic is shown on the graph as a line passing through Ip=4mA for Vgk=-12V, and through Ip=2mA for Vgk=-6V. The intersection of the two lines is the nominal biased operating point.

Voltage drop across tail 2.5k and 6k8 is a max of 9.3k x 5.3mA = 50V. Hence plate-cathode voltage is about 400 – 133 – 8 – 50 = 200V. Plate load resistance dissipation about 133 x133 / 50k = 0.4W. Plate dissipation idle is about 200V x 2.67mA = 0.6W.

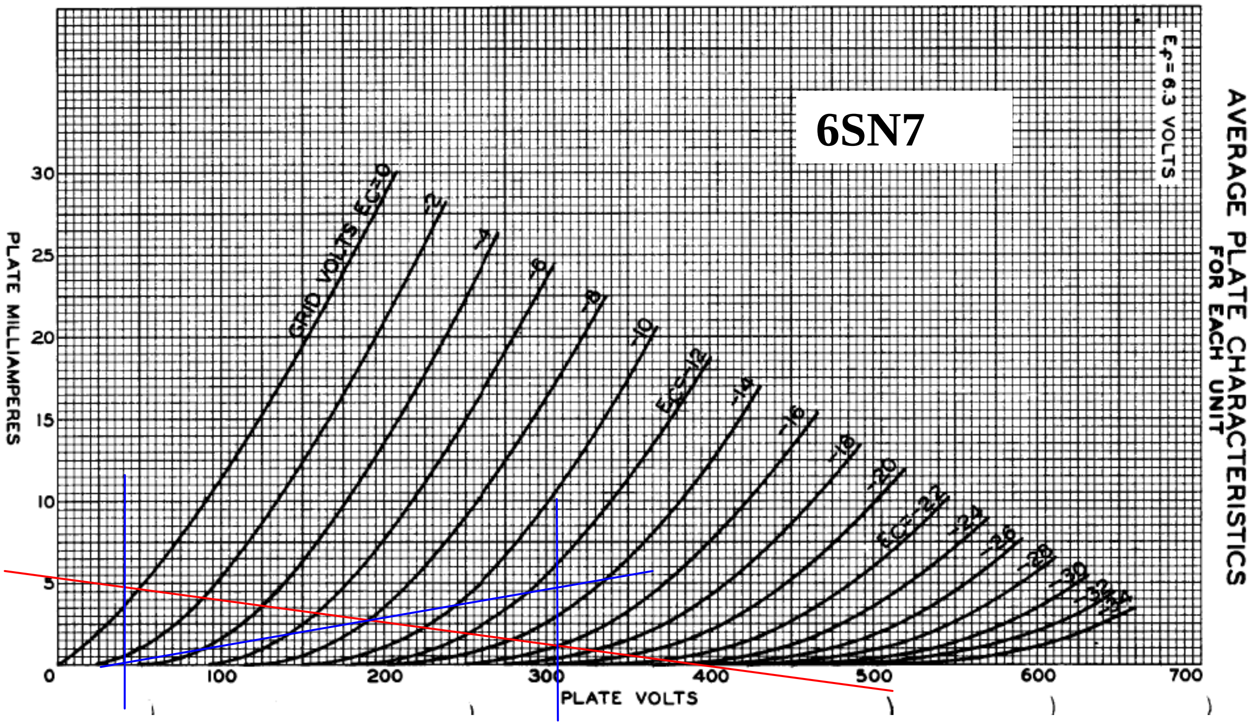
The nominal operating point levels of Vgk=-8V and Vp=190V are used to determine the parameter values of r_p and gm and μ from the 6SN7 average transfer characteristics graph (note that Eb is Vp). Note that using less than 80K loadline will reduce the available output voltage swing.

The analysis by Kuehnel shows that the gain of each triode is slightly different, due to a small level of common-mode gain adding to the out-of-phase output but subtracting from the in-phase output, which is compensated by lowering the load resistor for the out-of-phase output to 51KΩ nominal. The input voltage swing limit is from the bias point at Vgk=-8V to Vgk=0V, which is about 16Vpp or 5.7Vrms. Referring to the loadline, the plate voltage would swing about 275V, from about 55V to 330V, with a mid point of 190V [190-55=135V; 330-190=140V] which is quite symmetric. This gives a nominal gain of 275/16 = 17.

The small signal voltage gain G is about 7.5x. Hence, the signal voltage swing available to each control grid of the output stage is up to 8Vpk x 7.5 = 60Vpk, which exceeds the output stage's requirements of about 40Vpk max.

Adjusting Rgc, say from 1K to 2K, will have a significant effect on distortion.

The rated output voltage at the feedback winding is nominally √(70W x 15Ω) = 32V. The feedback voltage from the output is attenuated to 4.3% (1.4Vrms) by the 2K5 and 56K divider, with a single pole roll-off at f = 28Hz due to the 0.1uF cap bypassing 2K5.



Parameter	No signal	*Heavy load*	Notes
R_L	56k	*100k*	
Vsupply	400V	*460V*	= $V_{RLoad} + V_P + Vk$
I_P	2.5mA	*1.25mA*	From bias position
V_{gk}	-8V (-7.5V)	*-2.5V (-2.5V)*	From bias position = I_P x 2 x 1.5KΩ
Vk	55V	*29V*	= 11KΩ x 2 x I_P
V_P	200V	*300V*	= 400V – 55V - (56KΩ x I_P)
r_p	20kΩ	*65kΩ*	= ΔVpk / ΔIp
Gm	1mS	*1.5mS*	= ΔIp / ΔVgk
µ	20 [20]	*98 [98]*	Graph [= gm x r_p]
G	~7.4	*~30*	= (u/2) x R_L / (R_L + r_p)
B	.1	*.1*	= 4K7 / 47K
Headroom	16Vpp	*5.0Vpp*	

Table 1. Phase Splitter Analysis Results for 6SN7

4.3 Output Stage

In this Class AB push-pull output stage the cathodes are grounded, and each 6CA7/EL34 tube operates in a fixed bias mode with a negative gate voltage. The 12KΩ impedance plate-to-plate OPT presents signal currents into each tube with a 6KΩ impedance with both tubes conducting, to 3KΩ load impedance at higher levels.

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

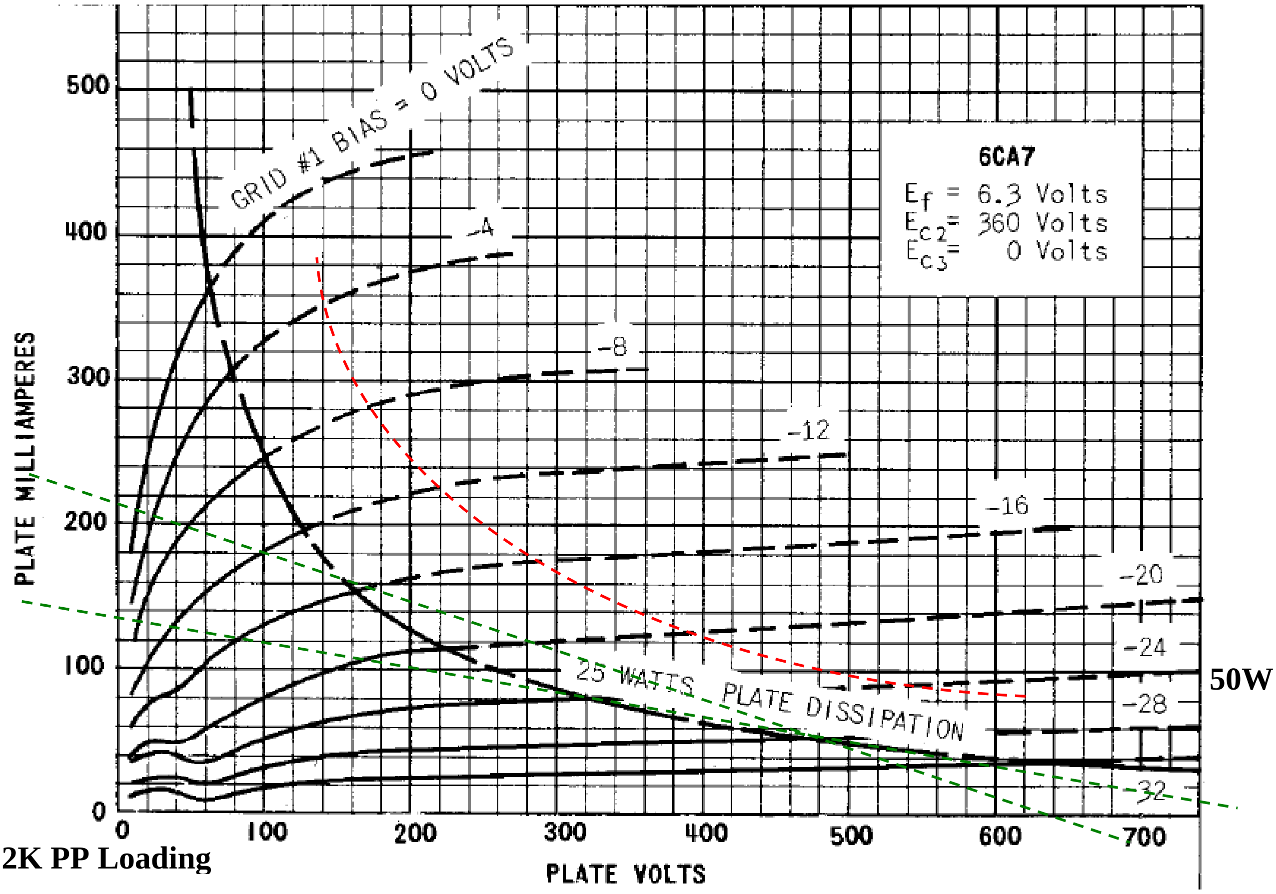
- Start with the lowest bias current possible (ie. most negative grid bias voltage), and based on listening tests, increase the bias current until the sound character is acceptable, but:
- use the lowest possible bias current level, as this generally increases the life of the tubes, and decreases the chance of operating at excessive plate dissipation; and
- keep the bias current level below 70% of the recommended design max plate dissipation (ie. 0.7x25=<18W); 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 800V towards 640V. Plate DC voltage will be lower than VS1 by an amount up to ~13V; ie. OPT half resistance of about 60Ω with a peak current of up to about 0.22A.

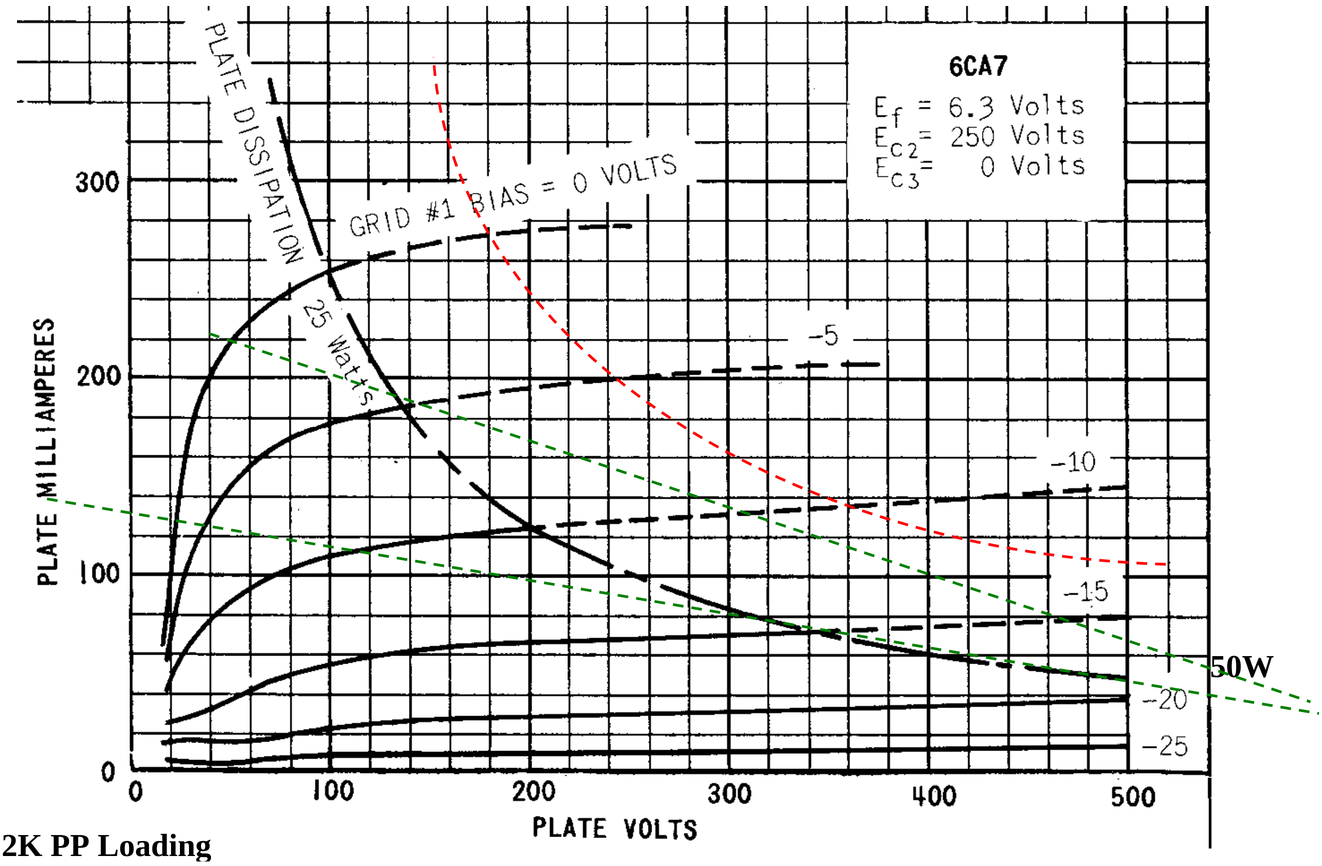
Screen voltage VS3 will vary from about 430V towards 290V under steady-state heavy load. VS2 depends on loading and capacitance ratio. VS3 will be lower than VS2 due to voltage drop across choke. Ripple on C1 and C2 is quite high, due to half-wave circuit, but this is not significant for push-pull stage performance. Ripple on VS3 is quite low due to the choke/capacitor filter. Peak screen current is likely to reach 40-50mA, so an average loading on VS3 of 2x25mA plus PI and input stages would have a worst-case level of about 10mA, with a 5V drop on the choke. Screen resistor drop is insignificant, unless increased to 1k or more.

Tung-sol curves for screen E_{C2}= 360V and 250V, 12K P-P (3K line) and 640V sagged VS1 indicates a peak plate current of 220mA and nominal clean output power of: $(Ipk)^2$ x Rpp / 8 = $(0.22)^2$ x 12k / 8 = 73W. For this Vg=0 signal condition, the rms OPT current draw is likely about 140mA (64% of peak), and the average VS1 power consumed is about 700V x 0.14Arms =98W, and the OPT loss is about $(0.14)^2$ x 60Ω = 1W, so the tube plates dissipate 98 – 73W - 1W = 24W, or about 12W each, which is well under max design level.

Bias voltage set for nominal 21mA = 15W / 700V. Turn pots clockwise to increase current.



12K PP Loading



12K PP Loading

5. Power Supplies

Two 8-pin Octal bases are available for the half-wave voltage doubler rectifier circuit which uses the 335V secondary HT winding and two isolated 5V 3A heater windings. An additional 56V winding is used for the fixed bias power supply, which originally used twin diodes from a 9-pin base valve (possibly a ?), but is modified to use silicon diodes and a low ripple design.

The 5U4GB/5AS4 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 = 3Ω x $(330/240)^2$ = 6Ω; plus the secondary resistance = 15Ω; which sums to 21Ω. The Sylvania datasheet from Sept 1958 indicates the effective source resistance should be 30-35Ω for a secondary supply of 330-335Vrms, based on each plate experiencing a peak current of 4.6A into a capacitor-input filter. With no measurements of peak current to indicate otherwise, an additional series resistor of 10-15Ω would be needed. The datasheet also requires the sum of plate currents to be less than about 240mA for Vdc/Vac~0.8 = 270V/330V, however this may also not be applicable for this half-wave, doubler config. With both plates in parallel, the voltage drop across the conducting diode should be about 44V for a total average current of 450mA, but would be substantially more during the initial peak current charging portion of diode conduction in which total current could exceed an amp. CRO waveform of diode current showed a peak current of about 1A with no added external resistance, and almost a sinusoid waveform, when working into 12uF poly caps with 85W load on V1 and 8W load on V3 - however, the condition of the diodes was not known. Decided to initially use no additional series resistance.

A 1A fuse is appropriate to include. The standby switch is bypassed by a 270K 2W to provide some bleed charging of caps whilst heaters start.

Ripple voltage at idle is 3.7Vrms on VS1, 4.5V on VS2, ~80mV on VS3. The ripple voltage on VS2 is mainly 50Hz, at a measured level of 67Vrms with a load current through the choke of 27mADC and a ripple on VS3 of 2.5Vrms. C3 impedance is 265R. Ripple attenuation is 2.5/67 = 0.037. Choke impedance is X +470R = 265 / .037 = 7160. Hence choke inductance is nominally (7160 - 470) / 2π 50 = 21 H at 30mA. [Measure choke]

A silicon diode isolator is used after the choke to feed a buffer 470uF 400V capacitor for the input stages. The operating current of the PI and input stages is less than 10mA (2-3mA for 12AX7, and 5-7mA for PI). A 1k5 series resistor plus 490R choke resistance limits peak current capacitor charging current to about 400/2k = 200mA (80Wpk). Three series zeners (2x 1N5383 150V, 1N5373 68V) limit VS4 at idle to 375V (to keep below 400V cap rating), with max current (no valves) of about (400-375)/1k5 = 17mA and zener dissipation of 6W.

A normally reverse biased diode from the large cap on VS3 back to VS1 helps discharge VS3 after power turns off.

Supply rails fall to 60VDC in 45secs after turn-off with 120K bleed on VS1.

5.1 Bias Supply

The bias supply uses a soft bridge rectifier feeding a large buffer capacitor, then a zener regulated 54V then a RC feeding a pots to provide closely bypassed independent rails for each 6CA7 grid. The protection relay is connected across the zener.

6. Protection

6.1 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 and the tubes fail. A 48VDC relay, Omron G2R-2 48V, has a coil resistance of 4.2K, and requires about 30V to operate and 8mA. A 2K7 series resistor from the zener regulated 54V rail operates the relay at about 33V. The zener operates with about 3mA, the relay takes about 8mA, and the bias circuit about 4mA. The relay de-energises due to gross failure of the bias power supply (about 20V on coil). The relay contacts are used to disconnect the secondary HT.

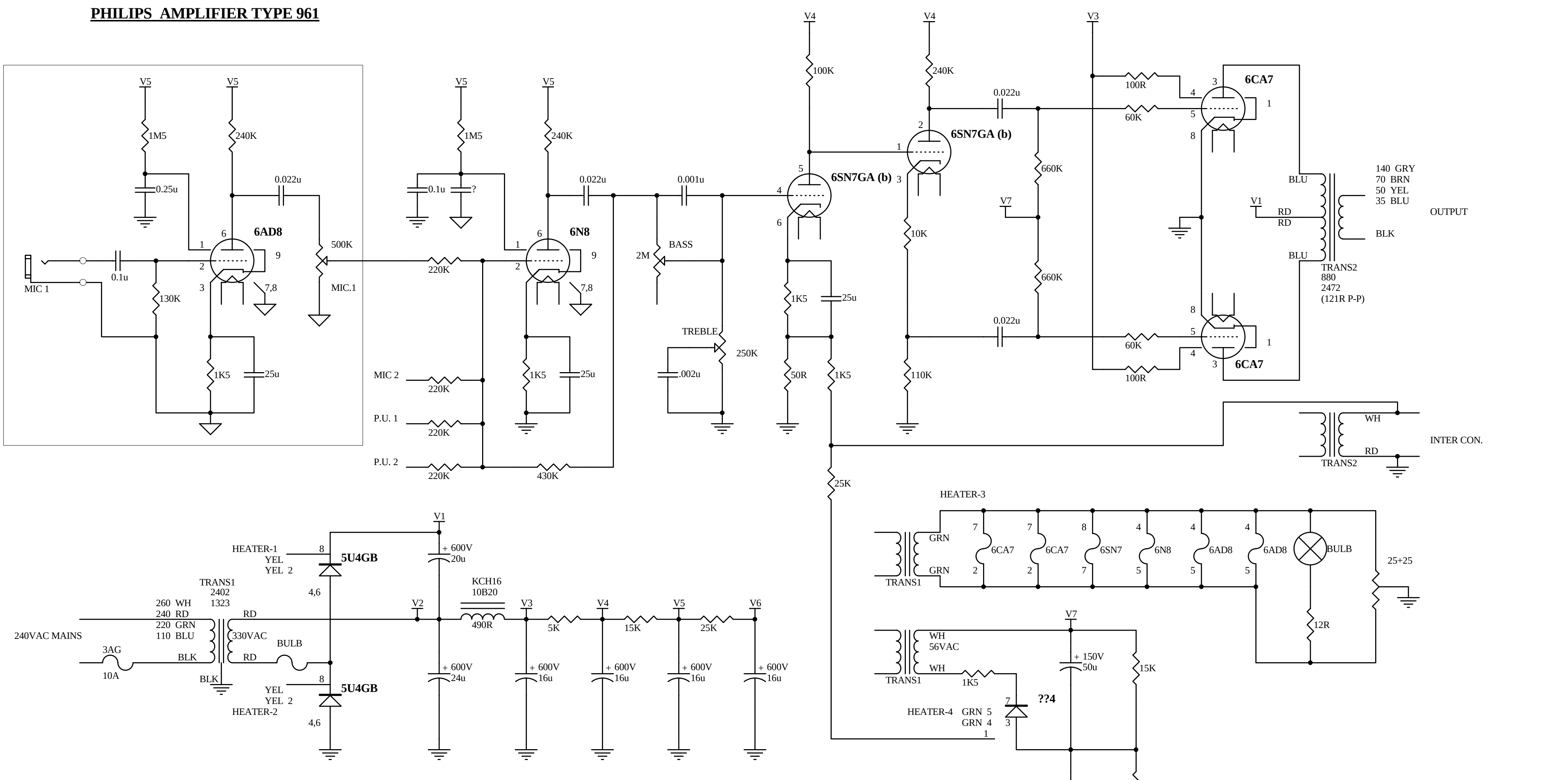
6.2 HV breakdown

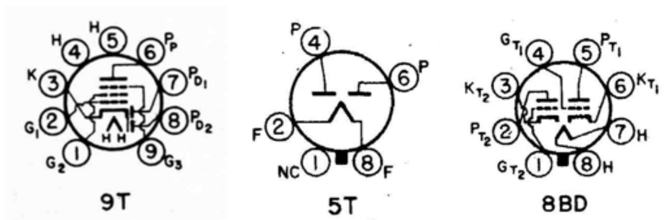
If the B+ rail shorts to ground, due to a flashover, or insulation breakdown, then a 1A fuse in the transformer secondary line provides gross failure protection by de-energising both the plate and screen rails.

6.3 Output open circuit

Three series connected 330V MOVs in series with 4k7 placed from each anode to VS1 provide overvoltage protection or each anode – dampening from about 1.1kV.

PHILIPS AMPLIFIER TYPE 961





VALVE	QTY	BASE
6CA7	2	8ET
6SN7GA	1	8BD
6N8	1	9T
6AD8	2	9T
5U4GB	2	5T
??4	1	?

VOLTAGE RAILS

RAIL	NO LOAD	LOADED
V1	V	V
V2	V	V
V3	V	V
V4	V	V
V5	V	V
V6	V	V
V7	V	V
HEATER-1	5.4V	V
HEATER-2	5.4V	V
HEATER-3	6.6V	V
HEATER-4	6.6V	V

Title

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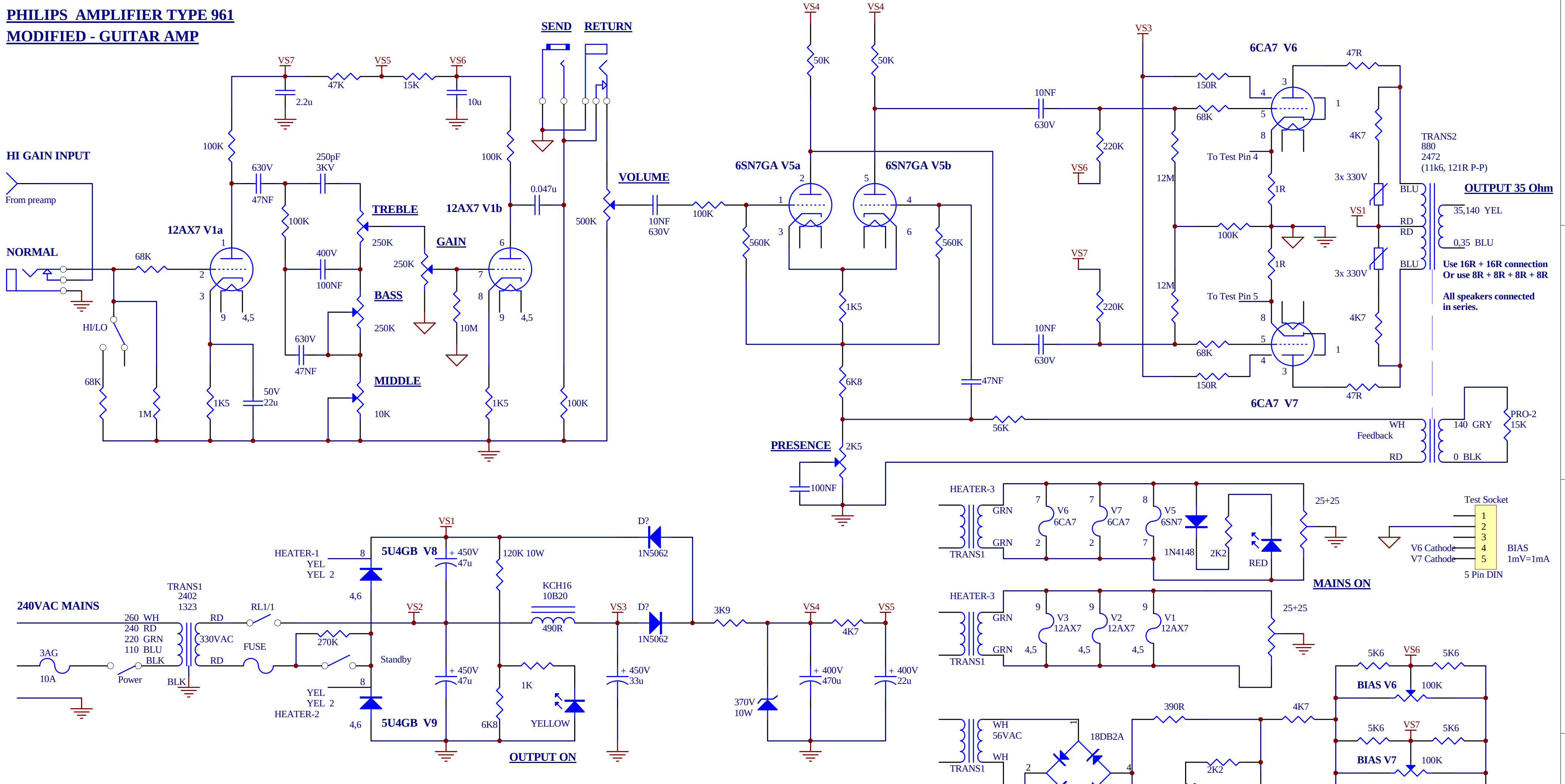
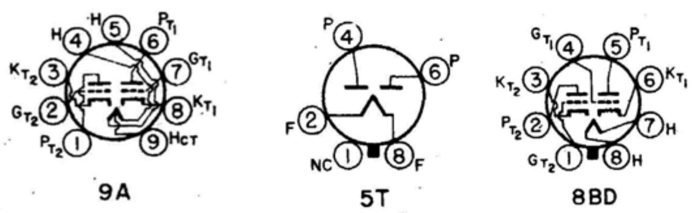
PHILIPS AMPLIFIER TYPE 961
MODIFIED - GUITAR AMP





VOLTAGE RAILS

RAIL	IDLE	LOADED	STANDBY
VS1	756V	650V	51V
VS2	378V	340V	5V
VS3	372V	310V	5V
VS4	357V	355V	
VS5	334V	335V	
VS6	318V	325V	
VS7	390V	295V	
HEATER-1	5.1V	5.1V	5.1V
HEATER-2	5.1V	5.1V	5.1V
HEATER-3	6.2V	6.2V	6.2V
HEATER-4	6.2V	6.2V	6.2V

VALVE	QTY	BASE	DESIGNATORS	BIAS
6CA7	2	8ET	V6, V7 (front)	24mA (cathode)
6SN7GA	1	8BD	V5	
12AX7	4	9A	V1, V2, V3, V4	
5U4GB	2	5T	V8, V9	

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PHILIPS AMPLIFIER TYPE 961
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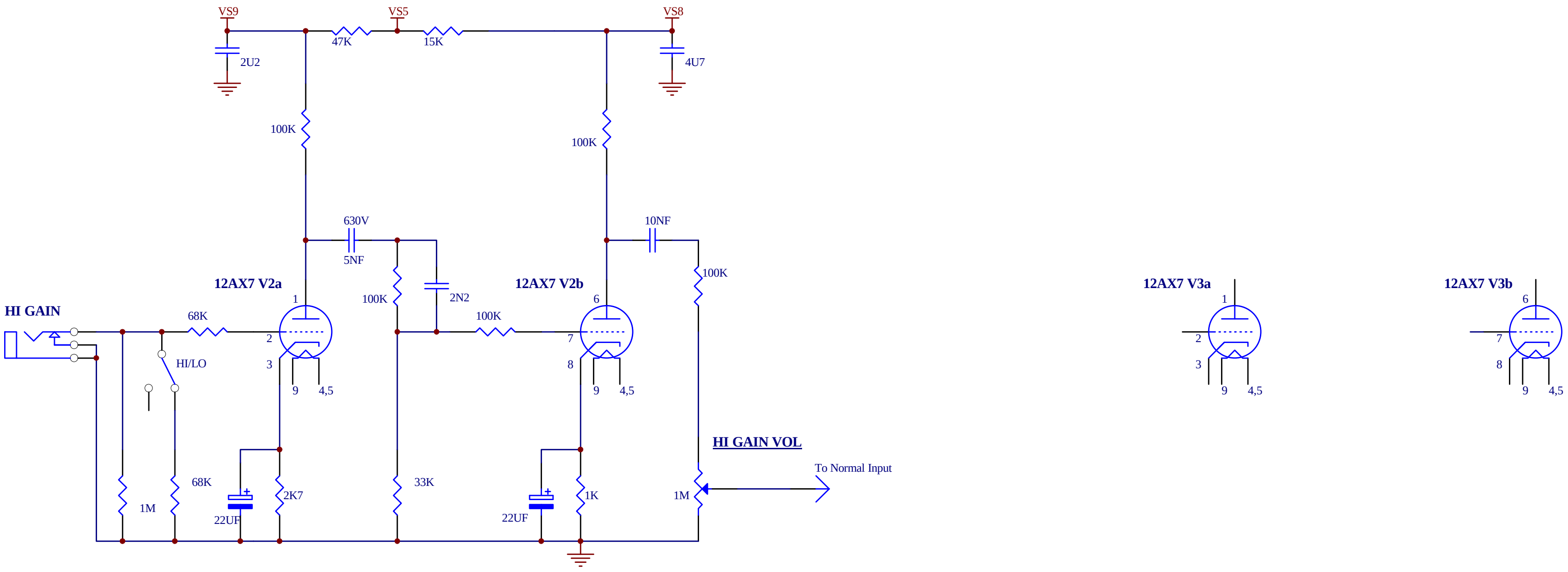

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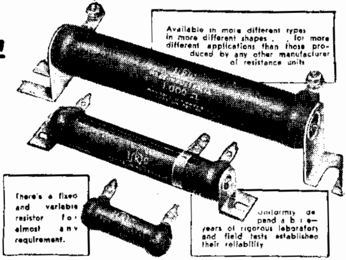

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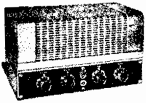

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" " 974-958	13 Watt 240V AC/6V or 12V DC	
" " 956	30 Watt AC	
" " 961	70 Watt AC	

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ADELAIDE, 119 Grenfell St. PERTH, 381 Murray St.