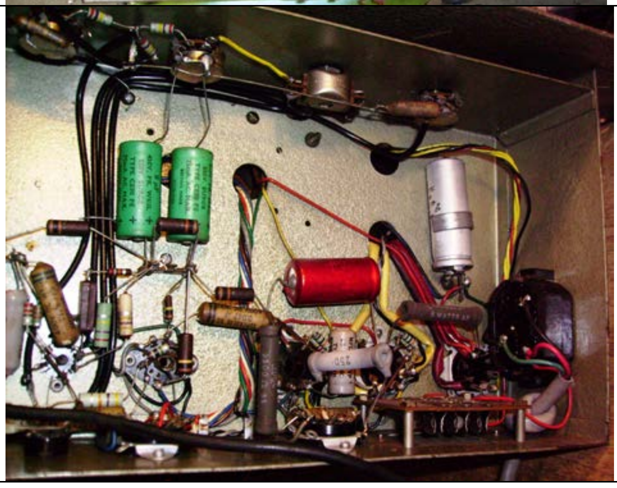
1. Summary

Audio Engineers PA 30W valve amplifier.   Sept 2014

Radio, Gram and MIC input channels 30W PA amplifier. 6AU6 pentode mode, bypassed cathode bias, mic preamp stage. 6AU6 pentode mode mixer stage with bypassed cathode bias and unbypassed output winding feedback, plate load HF filtering, RC tone network loading, and DC coupling to PI stage. 12AU7 long-tail pair PI stage. KT66 PP with common cathode bias. 5V4G rectifier with capacitor input filter for ?V PP stage B+. RC droppers for 4 supplies to stages. Line output transformer with 18/37/75/150/300Ω tappings via rear octal selector (30W model). Single heater with one side connected to cathode bias.

Output Transformer	Ferguson OP341. 8000Ω PP; 0, 18Ω, 37Ω, 75Ω, 150Ω, 300Ω ; 3.6Ω f/b.
Power Transformer	Ferguson PF792. 0-240V; 375-0-375V @ ?mA; 6V3 4A; 5V 2A.
Caps	TCC electrolytics x3: 7602, 117
	Ducon x3: 28, 48
	UCC superseal
Valves	6L6GA x2: Brimar X 8, 2J4 , 414
	5V4G x1; Radiotron 2A7
	CV4003 Mullard 631 R9D2 (12AU7 equiv)
	6AU6 x2 Mullard 8C , 88 Wd

Good general condition. Original caps – no circuitry mods, only 6L6GA replacing KT66. Open mains fusing behind panel. Probably dating around 1959 based on valve dates, and parts (MIC sockets, switches, ST bottles, front panel style, cap codes 7,8).



2. Modifications

- Added flexible edging to chassis holes and sleeved wiring.
- Fitted IEC socket/fuse/switch combo in place of fuse panel.
- PT ES to gnd.
- Added VE17 2750K MOV on PT primary.
- Add 2x 1N4007 in series with each 5V4G plate. Add HT bleed resistor.
- Fitted HT CT 5x20 fuse holder in place of AC cord inlet.
- Added EC-13 choke.
- Replaced all caps.
- Add HT bleed resistors: VS1 with 300kΩ, and VS5 with 150kΩ.
- Added 10R cathode sense to each 6L6.
- Added 270Ω PRO3 to each 6L6 screen stopper.
- Added 2x 354VDC 1mA MOVs in series per OT primary half winding.
- Added speakon output socket wired to 18Ω tap.
- Reconfigured rear-panel radio socket connections – now used for 6L6 bias voltage and divided B+ voltage testing.
- Rearranged star-grounding.
- Reconfigure MIC input stage to 6AU6 low-noise triode mode for guitar input. Remove other mixer inputs, and reduce grid stopper from 270k to 100k.
- One pot for gain from input stage. One pot for pre-PI master vol. One pot for Tone. Radio/gram switch replaced by pot for feedback/Presence (only have 250R WW pot to use).
- Added 100K grid stopper to PI input.
- Humdinger pot on heater, and connected to 0V and 50Hz minimised for no input and for vol pots maxed.
- Refit rear plaque over chassis openings
- B+ rise profile aligned with output stage loading, so no B+ overshoot on 450V e-cap, but little margin for mains above 240V.
- Reconfigured PI stage to Fender style long tail pair / Schmitt with common cathode self-bias, and Presence pot at bottom for feedback interface.

To do:

- Check 5V4
- Knobs – black chicken wing
- Front indicator bezel.
- Fill in octal hole on sidewall near mains circuitry

3. Measurements

PT and OT megger test OK
Power transformer resistances: primary 240-0V = 12 Ω ; secondary = 67+71 Ω

Rail	240Vac, 0.4A		
VS0	442Vdc 4.1Vac		
VS1	432Vdc		
VS2	403Vdc		
VS3			
VS4			
VS5			
Cathode 350Ω	30.6V; 40.1mA, 47.4mA		

Heater	6.26Vrms		
Sec HT			

12VAC 100Hz signal generator applied to half primary winding

Winding	Voltage rms	Turns ratio; Impedance for 8K pri; Spec level; Notes
Pri P-P: GRN to YEL	23.6	8k
Sec: WH to BLK	4.6	5.56; 304 Ω; 300Ω; 1000T
Sec: GRN to BLK	3.23	7.89; 149.9 Ω; 150Ω; 702T
Sec: RED to BLK	2.29	8.75; 75.3 Ω; 75Ω; 498T
Sec: YEL to BLK	1.62	9.59; 37.7 Ω; 37Ω; 352T
Sec: GRY to BLK	1.16	13.5; 19.3 Ω; 18Ω; 252T
Sec: BLU to BRN	0.50	18.8; 3.6 Ω; 3.6Ω; 109T

Output transformer primary DC resistance: 117+156Ω plate-to-plate.

The 75-150 section is effectively 13 ohm (207 turns).
The 37-75 section is effectively 1.4 ohm (149 turns).
The 18-37 section is effectively 8.5 ohm (106 turns).
The 18-75 section is effectively 4.2 ohm (255 turns).

6L6G balancing:
#2 & #4: VS1=313V; Cath=17.4V; #2 cath=36mA, screen=2.3mA; #4 cath=33mA, screen=2.2mA
#1 is less than #2-4
#3 is more than #2-4
#5 is higher than #3

1614 balancing:
VS1=300V; Cath=20.1V; #1 cath=37.5mA, screen =1.65mA; #2 cath=41.8mA, screen=2.5mA.
But then one went poor – perhaps a bad seal.

Input stage only frequency response was flat from 100Hz to 30kHz, and -3dB at 40Hz.

1W frequency response (no feedback) was fairly flat from 200Hz to 6kHz, and -3dB at 80Hz and 13kHz, with tone control at min. Tone control at max reduced -3dB to 45Hz and 1.2kHz, and reduced mid-band gain by 11dB.

Cranks about 23W into 17 ohm at 230Vac mains. Almost symmetrical clipping – quite rounded.

With a 12AU7 for PI the max output voltage for 30W is 23V across 17Ω. Voltage required at feedback point for 4dB GNFB is 3.23/1.16= 2.8x voltage on 18Ω tap (ie. 150Ω tap). If the 300Ω tap was used for feedback, the signal needs to be attenuated by 3.23/4.6 = 0.7, so a 100Ω feedback resistor to the 250Ω pot, but the max voltage on 300Ω tap is up to 23V x 4.6/1.16 = 91V, and feedback resistance has to dissipate 23W.

With a 12AT7 the PI stage gain is 2.2x the 12AU7 gain. If the 300Ω tap was used for feedback, the signal needs to be attenuated by 0.7/2.2 = 0.32, so a 530Ω feedback resistor to the 250Ω pot. Max voltage on 300Ω tap is up to 23V x 4.6/1.16 = 91V, and feedback resistance has to dissipate 10W.

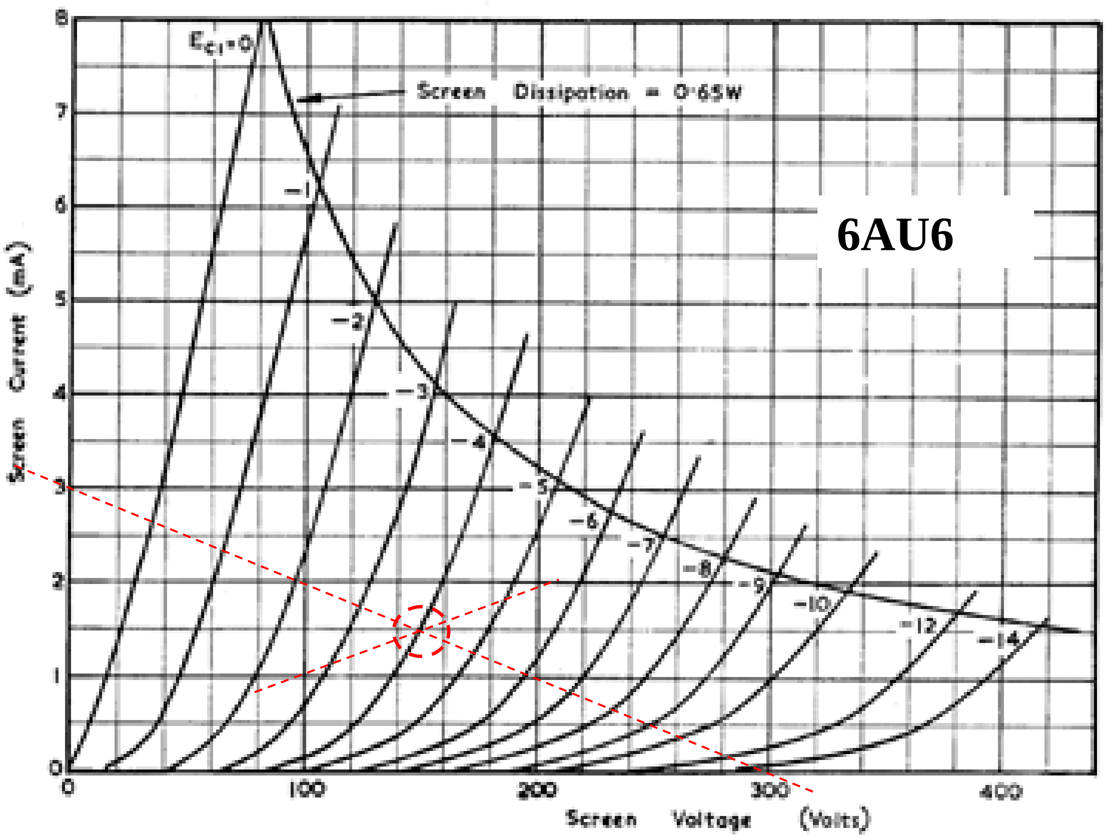
If the 150Ω tap was used for feedback, the signal needs to be attenuated by 1/2.2 = 0.45, so a 270Ω feedback resistor to the 250Ω pot. Max voltage on 150Ω tap is up to 23V x 3.23/1.16 = 64V, and feedback resistance has to dissipate 8W.

4. Design

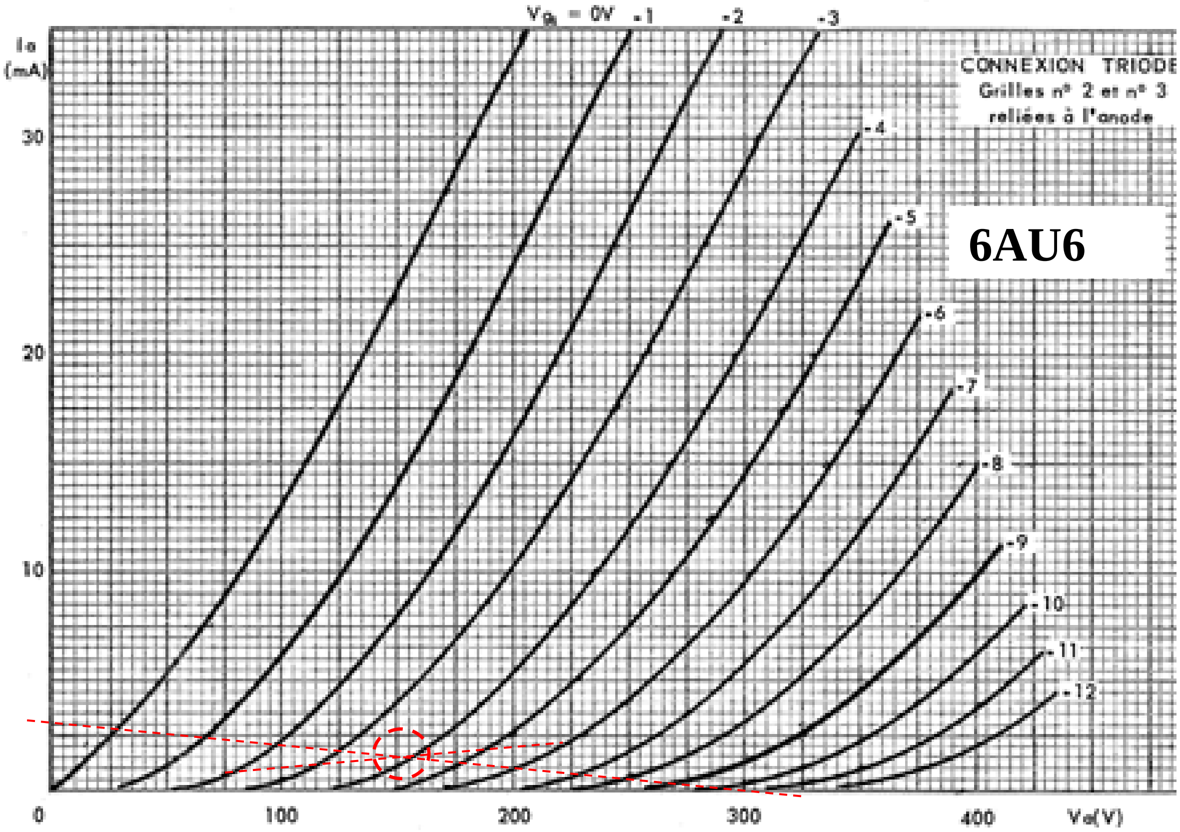
4.1 6AU6 input stage

Standard pentode configuration with 220k anode load, 2k2 cathode and 1M screen supply, with separately RC filtered 220V VS5. Measured 70V at screen and anode, and 1.6V cathode bias (0.73mA).

Voltage gain is 9.23/0.368 = x25, reducing to x24 with pot wiper at max.



Triode screen mode



Triode mode

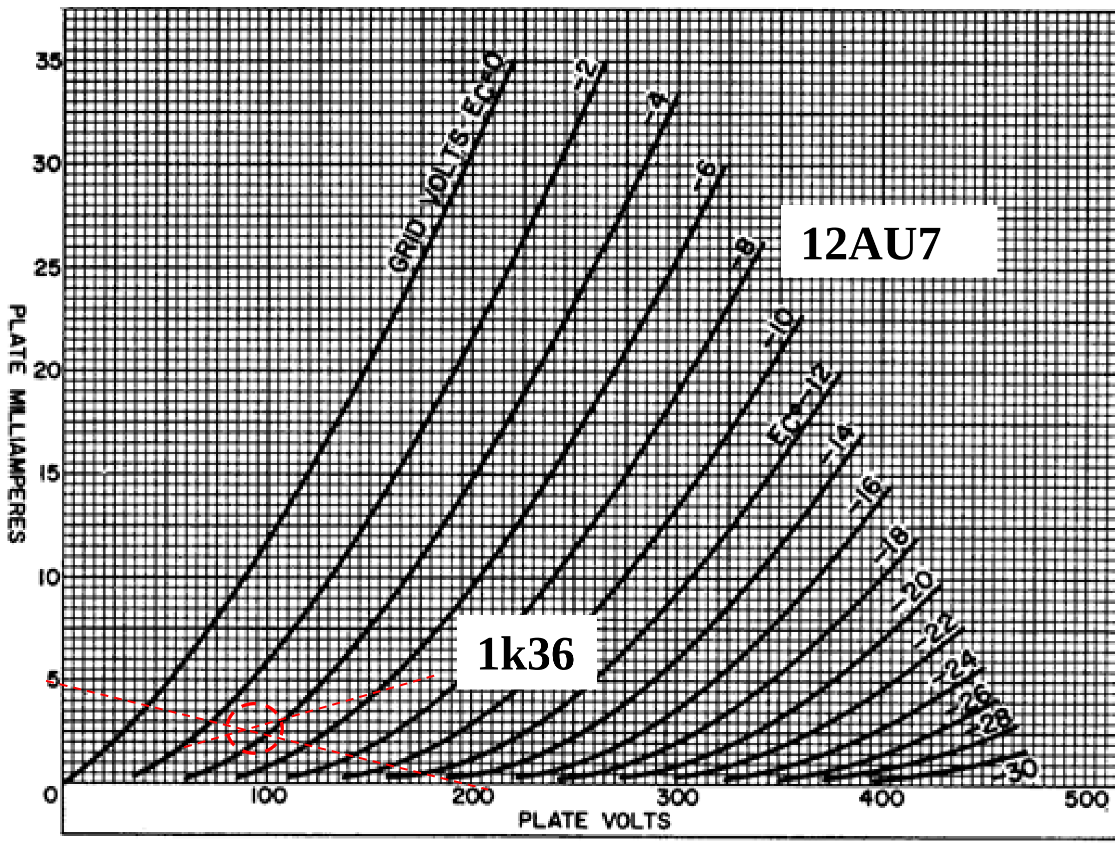
Voltage gain is 12.07/0.934 = x13 with pot wiper at min.

4.2 12AU7 PI section modified.

Modified from a DC coupled common-cathode long-tail pair PI to a Schmitt long-tail pair PI. The operating point has 97V across the tail (4.4mA through 22k), Vgk bias of 3.0V, and Vak about 190-97-3 = 90V, with B+ supply of 297 – 97 = 197V.

With 12AU7: voltage gain is 4.8/0.77 = 6.2 to pin 1 and 5.3/0.77 = 6.9 to pin 6.

With 12AT7: voltage gain is 2.2/0.159 = 13.8 to pin 1 and 2.32/0.159 = 14.6 to pin 6, so 47k on pin 6 could be reduced for better symmetry.



4.3 PP Output Stage

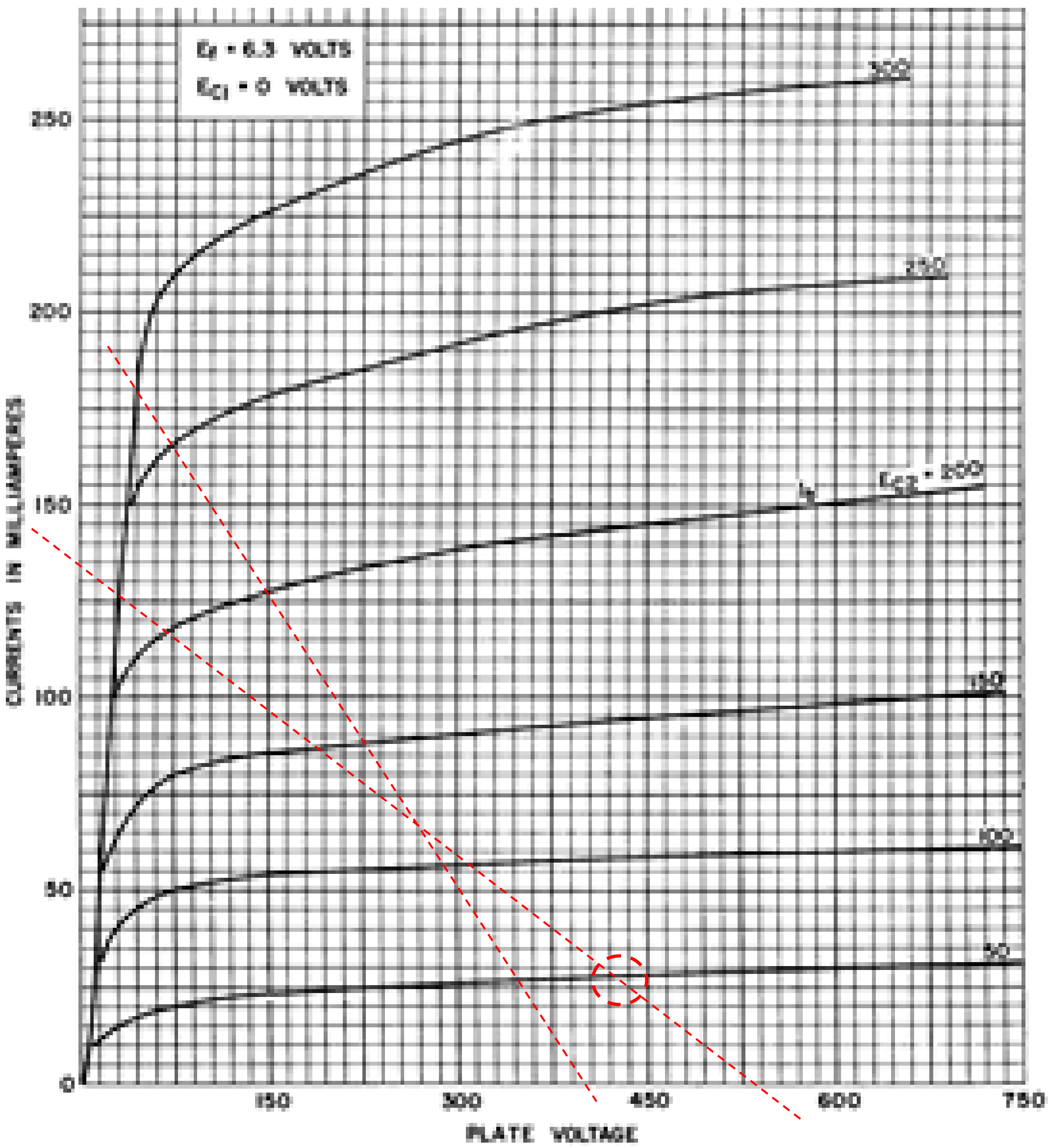
Class AB push-pull 6L6GA output stage with cathodes biased with a common resistor to ground. The 8KΩ impedance plate-to-plate OPT, presents each tube with a 2kΩ load impedance (with a matched secondary load) for larger signal currents, and 4k loading for small signal levels.

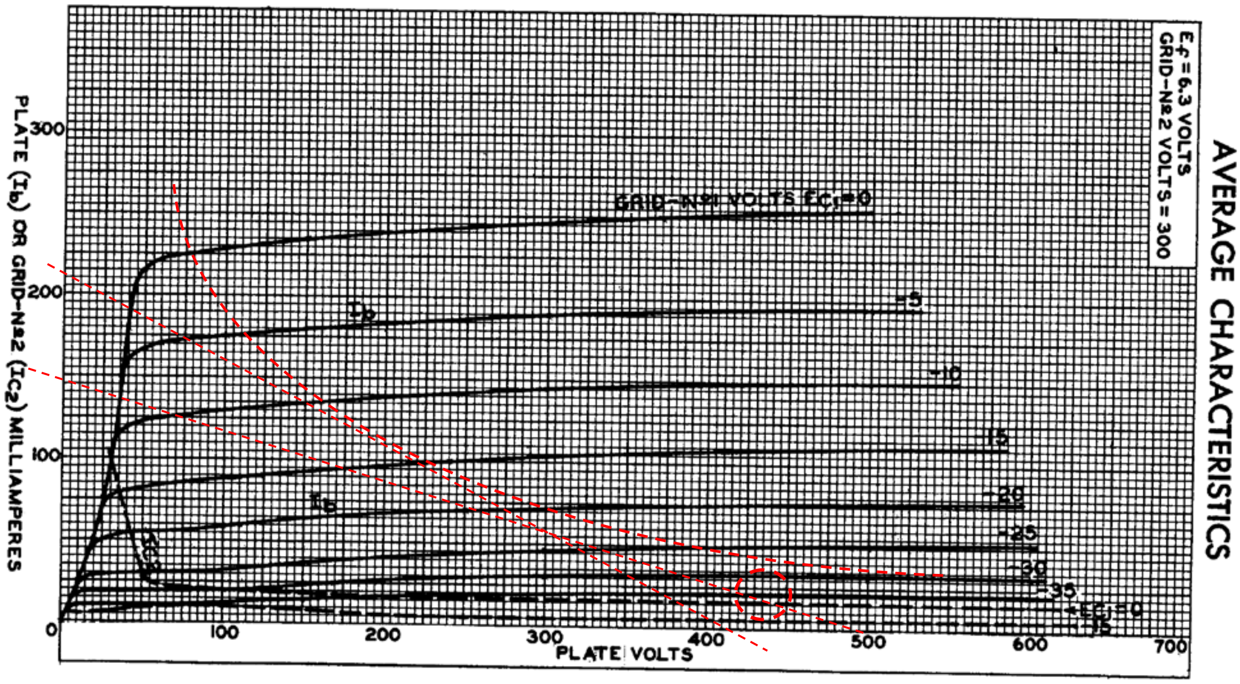
The supply voltage VS1 at idle current of 35+35mA is about 450V. Plate-cathode idle voltage will be lower than VS1 by ~21V; ie. 35mA and OPT half resistance of about 120Ω (4V), and cathode bias of 250R at 70mA (16V) – not including screen current influence.

From the plate characteristics, a screen voltage of 260V will cause the loadline to cross the knee zone. Screen current reaches up to 75-100mA. With screen dropper of 540Ω, the screen voltage could sag by 54V for 100mA, at a power dissipation of 5.4W. Cathode bias peaks at about 250x0.17=42Vpk, and 7W. VS1 would sag to about 410V for 150mA continuous load. OT winding voltage drop of about 120x0.17=20Vpk. Plate-cathode voltage would sag to about 450-20-42=390V, and peak plate current of about 160mA [PSUD2 shows VS1=405Vdc for 150mA continuous dc load].

The max design output valve bias current allowed is dependent on the maximum recommended plate dissipation of 19W for the 6L6G: Ibias(max) = Pd / Vb = 0.8*19W / (450-25)V = 35mA.

The available 6L6G require 17.4V bias for up to 36mA cathode current and screen voltage about 280V. Increasing common cathode 250Ω to 350Ω,





Voltage gain from radio-gram wiper to 17Ω load on 18Ω tap is x 6.2.

Total voltage gain is 24 x 13 x 6.2 = x1,934, so 30W to 17Ω load on 18Ω tap is 22.6V, with input sensitivity of 12mVrms, assuming no distortion.

4.4 Powering

The 5V4G 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 = 12Ω x $(375/240)^2$ = 29Ω; plus the secondary resistance = 67Ω; which sums to 96 Ω. The effective source resistance should be 100Ω for a secondary supply of 375Vrms, based on 40uF capacitor-input filter. No extra source resistance needed. Peak continuous plate current is 525mA, and a 150mA dc load causes about 550mApk. Transient peak current rating is 3.5A, and PSUD2 indicates about 2.2Apk hot start.

VS1 could peak to about 500Vdc for a few secs, even though 5V4G is indirectly heated. A 47uF 450V e-cap is just sufficient, although some pre-load should be used. Capacitor ripple is about 220mArms at 150mAdc load. Jackson 47uF 450V from RS has a 280mArms ripple rating.

A CLC filter is used to lower ripple voltage for VS1, as there is room for a small choke. The 2.8H EC-13 flouro choke retains its inductance beyond 200mAdc, and dissipates 3W at 150mA. Compared to just one 47uF filter cap, VS1 ripple is reduced from about 11Vpp to 180mVpp at idle.

6V3 heater loading: 2x 0.9A, 3x 0.3A, plus radio ?A = ~4A
5V heater loading: 2A

150mA max anticipated load on VS1 has a 140mArms continuous CT current. IEC60127-2 160mA Time-delay fuse for 375-0-375V secondary CT, based on hot start in to that max load.

Simulate period in PSUD2	20ms	40ms	100ms	500ms	continuous
Simulated RMS current	1.2A	1.06A	0.75A	0.34A	0.14A
Multiplier (based on 0.16A fuse rating)	7.5	6.6	4.7	2.1	0.88
IEC60127-2 Time-delay min limit multiplier	10	~7	~4.8	~2.9	1

Estimate primary side fuse of 1A T. Need to confirm primary side cranked current - idle current was 0.4A.

Maintenance
External monitoring via “TUNER” Octal for idle:

Octal		Combo meter	Target	Calibration
Pin1	0V			
Pin 2	Common cathode	1750 (17.5V to pin 1)	70mAdc	12.21V = 1221
Pin 3	V4 cathode	0350 (350mV to pin 2)	35mAdc	356mV = 0356
Pin 4	V5 cathode	0350 (350mV to pin 2)	35mAdc	131mV = 0129
Pin 7	VS1/100	0440 (4.4V to pin 1)	440Vdc	286V = 0281

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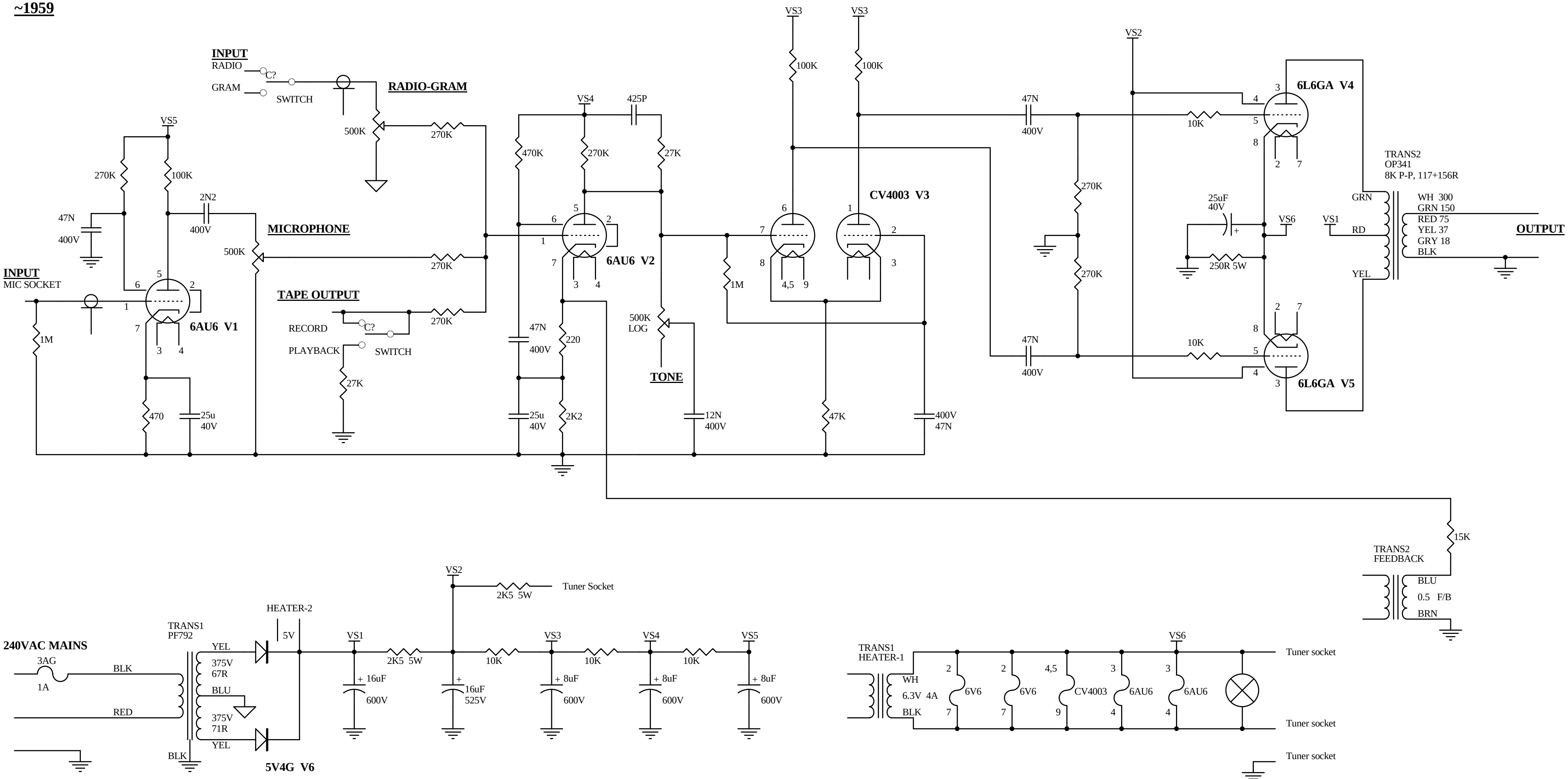

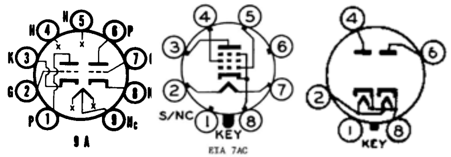

6AU6 base | CV4003 base | 6L6GA base | 5V4 base

VOLTAGE RAILS

RAIL	NO LOAD
VS1	V
VS2	V
VS3	V
VS4	V
VS5	V
VS6	V
HEATER-1	V

VALVE	QTY
6AU6	2
CV4003	1
6L6GA	2
5V4G	1

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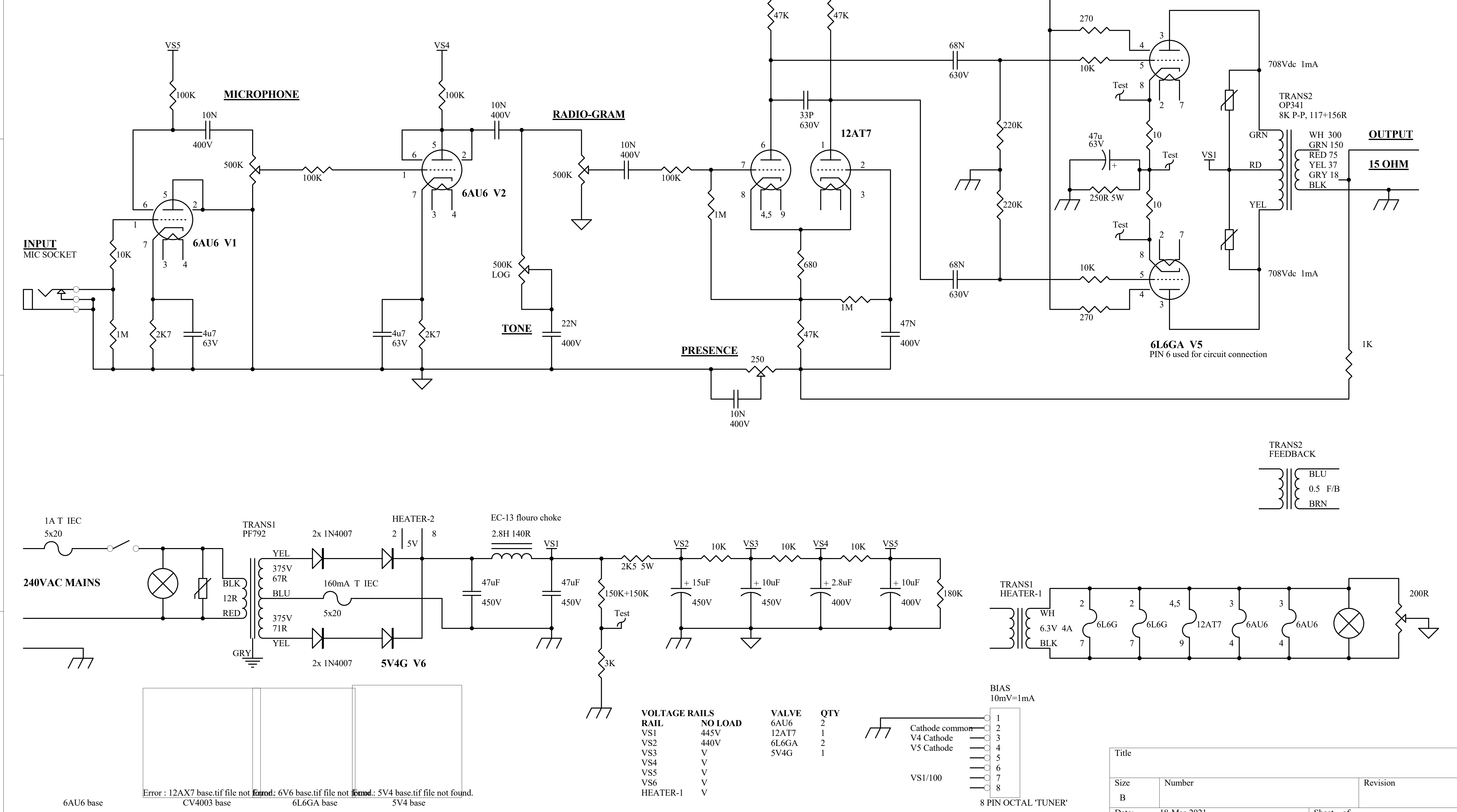

VOLTAGE RAILS

RAIL	NO LOAD
VS1	445V
VS2	440V
VS3	V
VS4	V
VS5	V
VS6	V
HEATER-1	V

VALVE	QTY
6AU6	2
12AT7	1
6L6GA	2
5V4G	1

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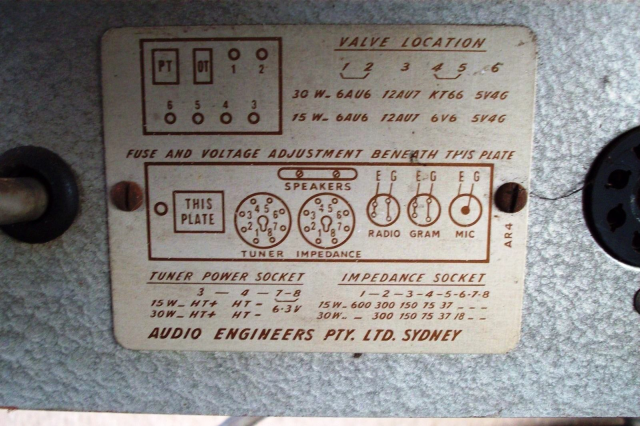

PT
OT
1 2
6 5 4 3
VALVE LOCATION
1 2 3 4 5 6
30 W - 6AU6 12AU7 KT66 5V4G
15 W - 6AU6 12AU7 6V6 5V4G
FUSE AND VOLTAGE ADJUSTMENT BENEATH THIS PLATE
SPEAKERS
THIS PLATE
E G E G E G
RADIO GRAM MIC
TUNER IMPEDANCE
AR4
TUNER POWER SOCKET
3 — 4 — 7-8
15W - HT+ HT - 6·3V
30W - HT+ HT -
IMPEDANCE SOCKET
1—2—3—4—5—6—7—8
15W - 600 300 150 75 37 - - -
30W - - 300 150 75 37 18 - -
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