1. Summary

Williamson Amplifier. eBay Sept 2014
English manufacturer – unknown.

1.1 Original Main Amplifier

Williamson Amplifier circuit – 1949 ‘new’ version.

The amp is the 1949 updated “new version” circuit of the Williamson amp circuit, but uses 807 valves with a regulated screen voltage, and has the following subtle differences:

- C1, C2 = 16u (not 8u)
- C5 = 32u (not 8u)
- C9 = 3u (not 8u)
- C10=.002uF 400V
- PT primary with 210, 230, 250V taps; secondary HT higher at 475V-0-475V; no CT for heater; 2x heaters.
- CH2 = 12H 200mA (not 10H at 150mA)

The screen voltage regulation is provided by 8k2 10W dropper from B+ to 2x VR150 in series, with 125Ω individual screen stoppers.

Components

Output Transformer	Partridge WWFB/0/ . 10-12kΩ PP primary; 0.95Ω windings configured as 34:1 turns ratio (8.5Ω output); 202+203Ω DCR. D8925
Power Transformer	Partridge TD2183; 210, 230, 250V Prim, DCR=6Ω; 470V-0-470V mA HT, DCR=91+96Ω; 6.3V 2A; 6.3V 1.5A; 5V 3A. D8923
Choke	CH1: Partridge TD2185, 12H 200mA; 158Ω DCR. D8924
	CH2: S15; 30H 15mA; 1.1kΩ DCR
CAPs	Hunts .05u (x2): HAA , IHA (1949 weeks 29&32)
	Hunts .25u (x2): HNA , HNA (1949 week 27)
	Dubilier Drilitic (x2): OE-1
	Hunts 3uF oil
	Dubilier Nitrogol 8uF 800VDC 70°C, B1292 QK
POTS	Colvern CLR.4089/22, 100Ω WW (x2)
Tubes	GZ37 Mullard brown base, I51 B8E (I5=GZ37, B=Blackburn, 1948 May)
	807 x2, Brimar, brown base, Xk1 B7C , 12 1 12
	6SN7GT x2, Brimar 2L8 383 , 3 11 12 (other is a Miniwatt 8I)
	VR150 x2, Brimar 30 , 12 1 12

Condition and Issues:

Original excellent condition. Wires numbered. All solder joints and nuts with QC paint. Pretty good star grounding, and fuse protection. Critical parts with measurement value labels. Laced cableforms. Well spaced and located parts for minimal parasitic capacitances, and OT terminals situated above chassis for short plate leads and minimal coupling to preamp circuitry. Nutserts in chassis. Unbranded, and only QC stamps visible. No thermal stress visible. Likely original 807’s, GZ37, VR150’s. Oily residue on chassis top – possibly oil/paper cap leaked. Unsure if C10 was meant to be 2nF, instead of 200pF, as a stability measure for this amp.

Old electrolytic and foil caps. Mains and secondary side wiring run in same cableforms. 807’s run at max rated anode power dissipation won’t last very long. No bleed resistor.

1.2 Dating & Background

The circuit is the new Williamson revision from August 1949. Hunts capacitors with mid 1949 date codes: HAA, IHA, HNA, HNA (weeks 19 to 32). Brimar 807's, VR150's and Mullard GZ37 all have brown bases with likely 1947, 48 dating, and same base code numbers. Partridge transformers appear to have sequential serial numbers. QC marks on chassis and tag board appear similar, but mark on small choke is different.

The June 1954 STC 807 application report provides results for 807 in pentode mode in class A PP, with the 807's idle anode dissipation at 24W.

Class 'A' Amplifier (Push-Pull):

TETRODE CONNECTION:

Plate Voltage	250	270	270	500	500	600	600	volts
Screen Voltage	250	270	270	300	300	300	300	volts
Grid Voltage	—16	—17·5	—	—27	—	—29·5	—	volts
Autobias Resistor	—	—	125	—	270	—	360	ohms
Peak AF Grid-Grid Voltage	32	35	40	54	72	59	81	volts
Plate Current (no signal)	120	134	134	100	100	80	80	mA
Plate Current (max. signal)	140	155	145	154	119	150	97	mA
Screen Current (no signal)	10	11	11	2·5	2·5	1·5	1·5	mA
Screen Current (max. signal)	16	17	17	20	16·5	17·5	17·5	mA
Output Load Impedance (plate–plate)	5000	5000	5000	8000	9000	10,000	10,000	ohms
Total Harmonic Distortion	2	2	4	2·6	2·7	2·2	4·1	%
Power Output	14·5	17·5	18·5	38	32·5	47·5	36·5	watts

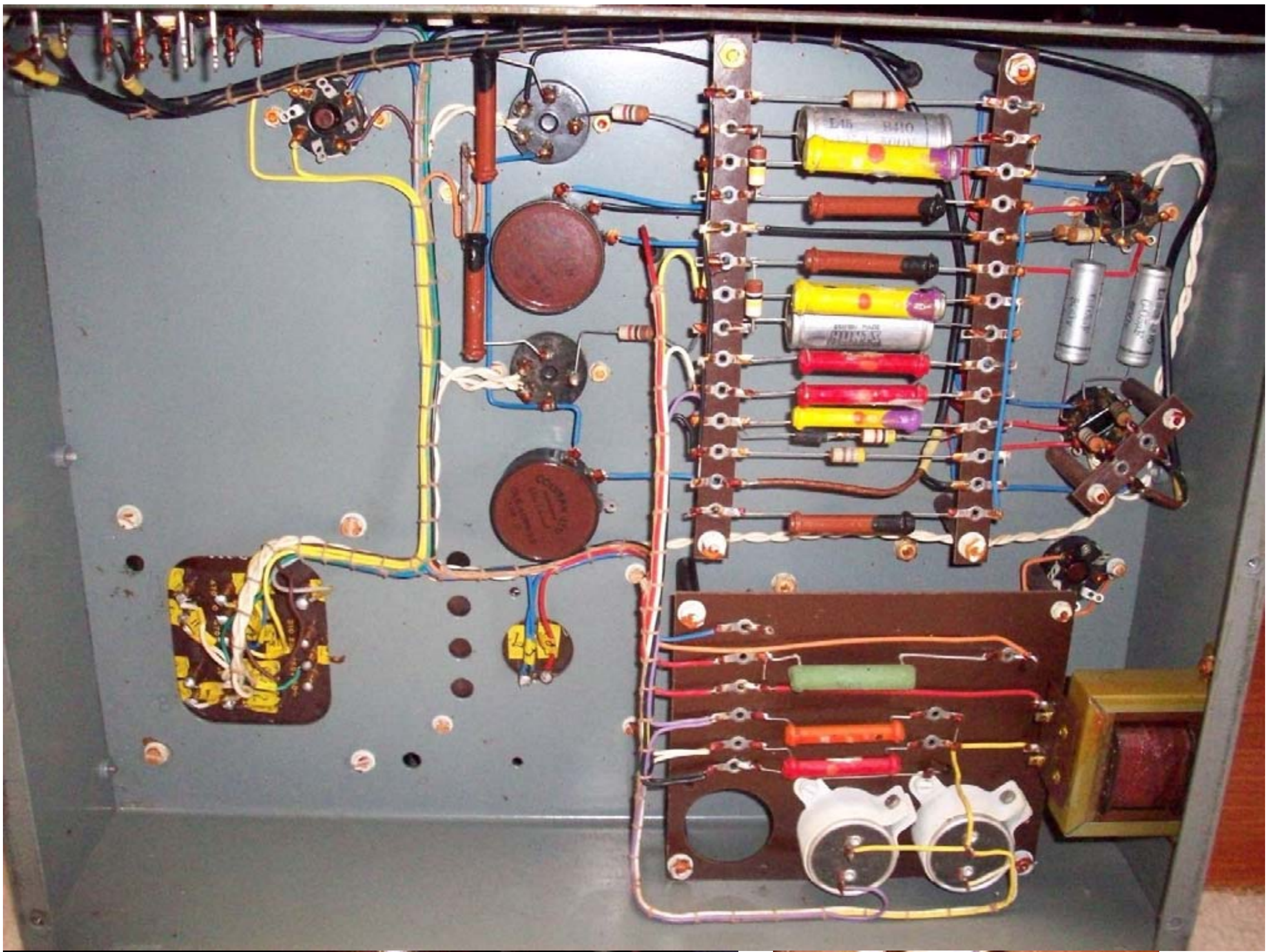
–Values are given for two valves.

The quad 807 PP class A circuit in RCA MI-12188 generated up to 65W with much higher plate voltage, and 807s biased at max design power (http://www.montagar.com/~patj/mi12188a.htm). Relative to a two valve PP, the effective cathode bias resistance was 240Ω, with 680V B+, and 315V regulated screen supply, and about 32W output.

This amp has a commercial/industrial look, with terminals for fixed wiring installation. Applications at the time would have included theatres and cinemas.

1.3 Commercial style Williamson Amplifiers

No screen-regulated 807 amps known of. From 1951 on, most commercial offerings were using ultra-linear to increase power output rating, and Partridge were offering CFB OT range.

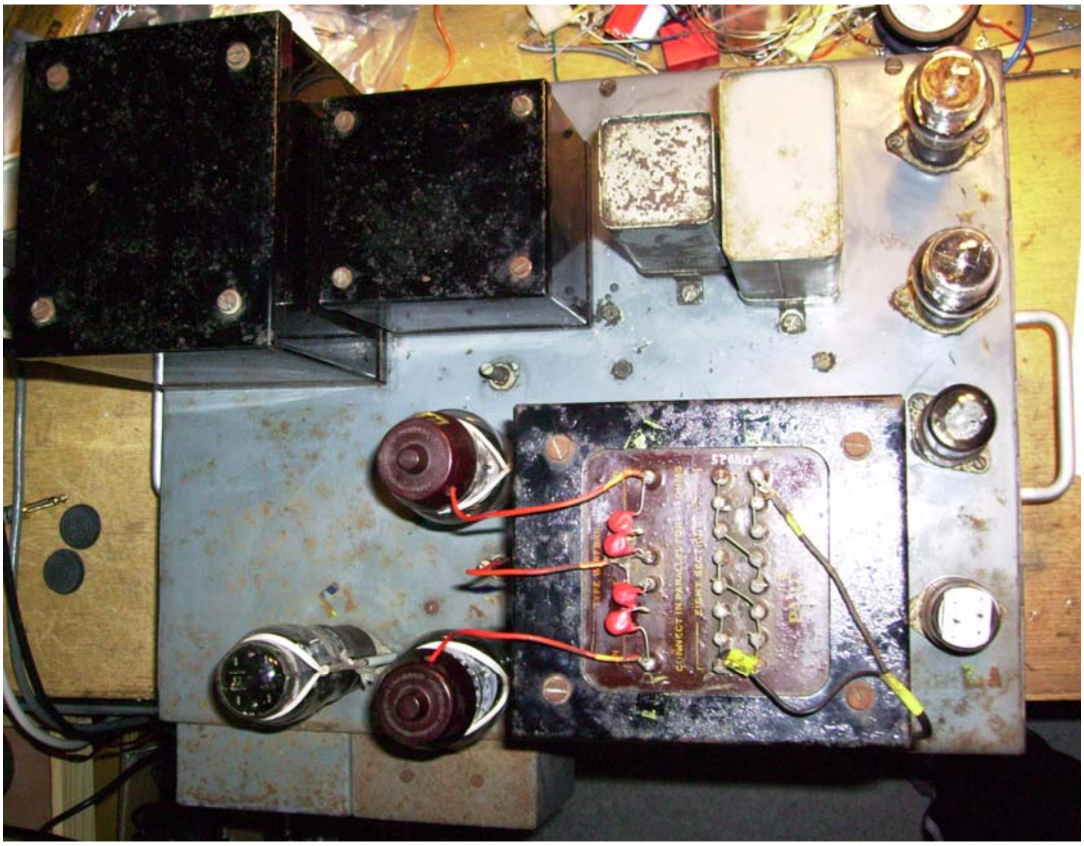


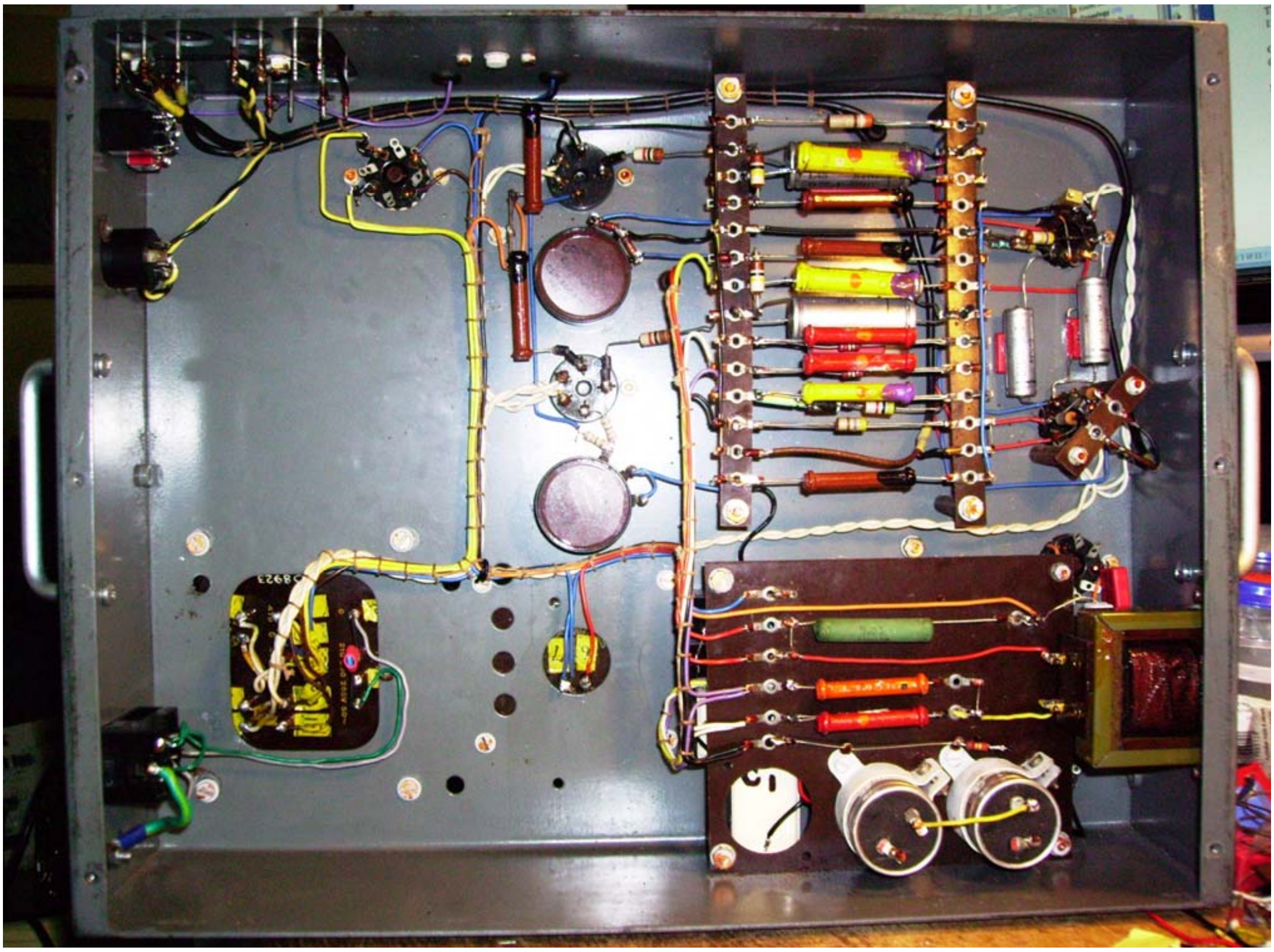
2. Modifications

- Added mains IEC socket, fuse, switch assembly plus PE chassis bolt.
- Added Speakon socket.
- Added isolated 6.5mm mono jack input with shorting switch.
- 1N4007 x2 in series to protect each GZ37 plate.
- Added MOV (431KD10) to PT primary, and use 250V tap.
- Added sense 10R for each 807 cathode for idle setting, and 807 matching.
- R21 wiper to end terminal for fail-safe operation.
- Added 2x ferrite beads to each 807 screen and grid.
- 1kΩ wiper bypasses on R17 for fail-safe operation.
- Replaced coupling caps with MKP10 0.22uF 1kVDC, and MKC10 47nF 630VDC.
- Added 660VDC MOV across each primary half winding (check SRF of primary halves and tune MOV-R).
- Added 300k 4W bleed resistor to C5 and to C8.
- Add 47nF across voltage regulators to shunt high frequency noise, and 1Ω current sense.
- Replaced HT oil and electrolytics with poly caps.
- Tuned humdinger on 6.3V preamp heater.

To do:

- Tuned main choke with parallel cap-R.
- Redundant fail-safe 300V FET-zener across VR150's. Add 470k parallel to top VR150 to start bottom VR150.
- Reconfigure OT secondary windings to 2-2-2-2 parallel series pairs (rather than 3-2-3 parallel series sections) to give 16Ω output.
- Add 2u2 back in to C9, and lower screen dropper to 5k, and raise anode dissipation to 20W – which should balance supply voltage changes.





3. Measurements

Voltage rail regulation.

Load	Idle	20W, 8.5Ω, 13.0Vrms, 800Hz.
VS1	484V; 104Vrms	467V; 113Vrms
VS2	464V; 1.5Vrms	445V; 1.8Vrms
V5,V6 cath	22.5V; 44mA, 44mA	29.3V; 58mA, 58mA
VS3	294V; 72mVrms; 15mA reg	292V; 8.8Vrms; 5mA reg
VS4,V3-4 an/cath	438V; 162V, 158V, 4.5V	421V; 4.28V
VS5, V2 an/cath	337V; 240V, 99V	323V;
VS6, V1 an/cath	296V; 95V, 1.98V	284V; 1.90V
Heater 1	6.05V	
Heater 2	6.05V	

Power transformer primary DC resistance: 6Ω: 250V; 230V; 210V; 0V.
Power transformer secondary DC resistance: 91 + 96 = 187Ω.

Choke TD2185; DCR=158Ω; 17.8H @ 54mADC; 17.2H @ 95mADC; 15.7H @ 155mADC; 14.1H @ 193mADC; 9.8H @ 252mADC;

Choke S15; DCR=1120Ω; 32H @ 8mADC; 30H @ 15mADC; 29H @ 24mADC; 28.5H @ 30mADC;

Output transformer primary DC resistance: 202+203=405Ω plate-to-plate.

R1=M; R2=34k; R3=56k; R4=560; R5=25.6k; R6=25.5k; R7=25.1k; R8=640k; R9=580k; R10=414; R11=57.4k; R13=57.8k; R14=140k; R15=960; R16=; R18=; R19=114k; R20=1.03k; R22=117; Ranode1=50; Ranode2=50; Rreg=8k65. C1=20.4u; C2=7.6u; C5=25.2u; C8=7.2u; C9=2.8u; C10=5n7.

R3=56k//330k; R4=560//3k3; R5=25.6k//220k; R6=25.5k//220k; R7=25.1k//220k; R8=640k//1M5; R9=580k//2M7; R10=414//6k8; R11=57.4k//270k; R13=57.8k//270k; R14=140k//390k; R19=114k//820k; C1=10uF; C2=10uF; C5=20uF; C8=10uF; C9=2.2uF.

OT windings configured 3-2-3 for secondary impedance match to 15.3*0.95/1.7 = 8.55Ω. Feedback R25=18k (measures 17.2k), with about 15dB gain reduction compared to no feedback. Max feedback with R25=4k7.

No feedback, 1W: 2nd -35dB, 3rd -38dB.
R25=18k, 1W: 2nd -42dB, 3rd -55dB.

Clipping style max output around 30W. Gradual increase in harmonics, with 3rd overtaking 2nd. 20W measurements show 807 screen regulation impedance is quite high at signal frequency, with regulator current dropping to min allowed.

Lowering screen regulator dropper to 5k8Ω, adds more load on VS2 and brings all circuit supply voltages back to original Williamson article. Screen supply current is (453-295)/5800= 27mA. CH2 current is 88+27+20=135mA at idle.

V3/4 supply rail current is 11mA (not 10mA). V2 supply rail current is 4.5mA (not 5.25mA). V1 supply rail current is 4.2mA (not 4.4mA). So CH1 current is 19.7mA.

Screen regulator with 5k8Ω dropper

Load	Idle	20W, 8.5Ω, 13.0Vrms, 800Hz.
VS1	475V; 108Vrms	461V; 117Vrms
VS2	453V; 1.6Vrms	436V; 1.8Vrms
V5,V6 cath	22.3V; 44mA, 44mA	29.5V; 58mA, 58mA
VS3	295V; 36mVrms; 22mA reg	294V; 4.3Vrms; 10.5mA reg, 4.6mArms
VS4,V3-4 an/cath	429V; 160V, 156V, 4.4V	421V; 4.28V
VS5, V2 an/cath	329V; 233V, 97V	323V;
VS6, V1 an/cath	289V; 93V, 1.94V	284V; 1.90V
Heater 1	6.05V	
Heater 2	6.05V	

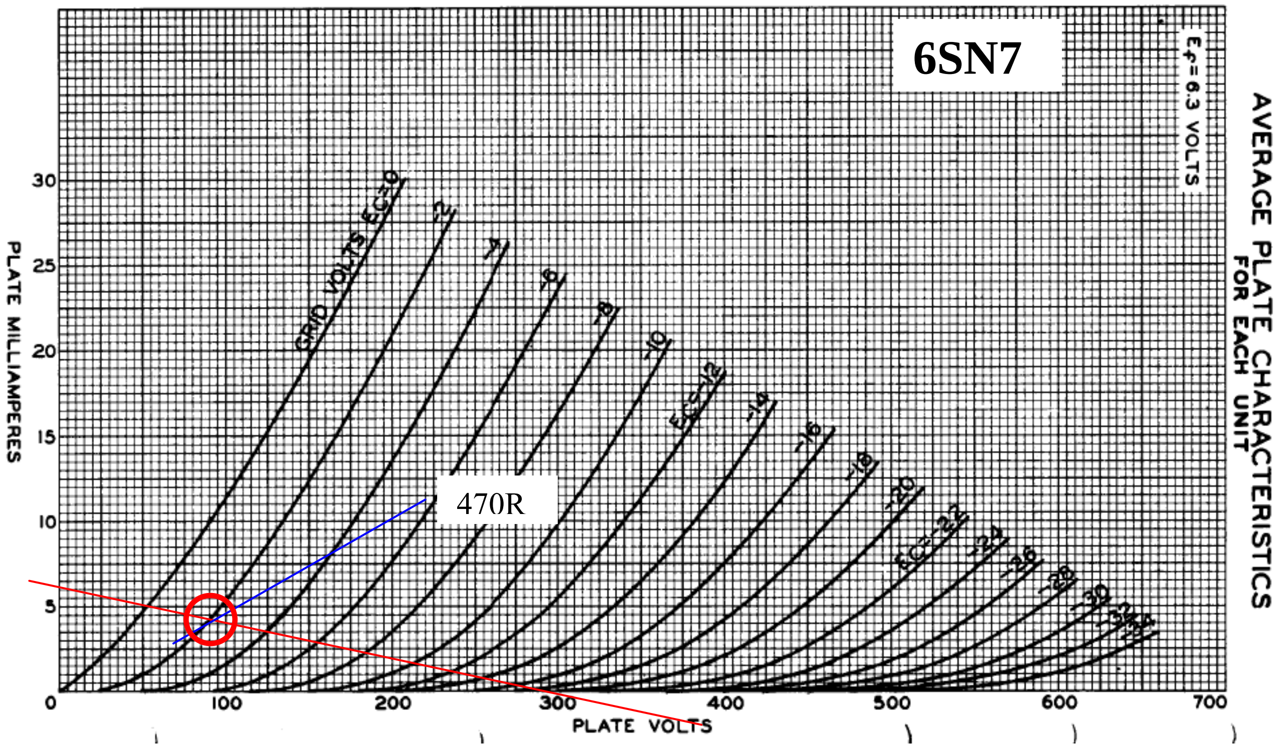
Power transformer primary DC resistance: 6Ω: 250V; 230V; 210V; 0V.

4. Design Info

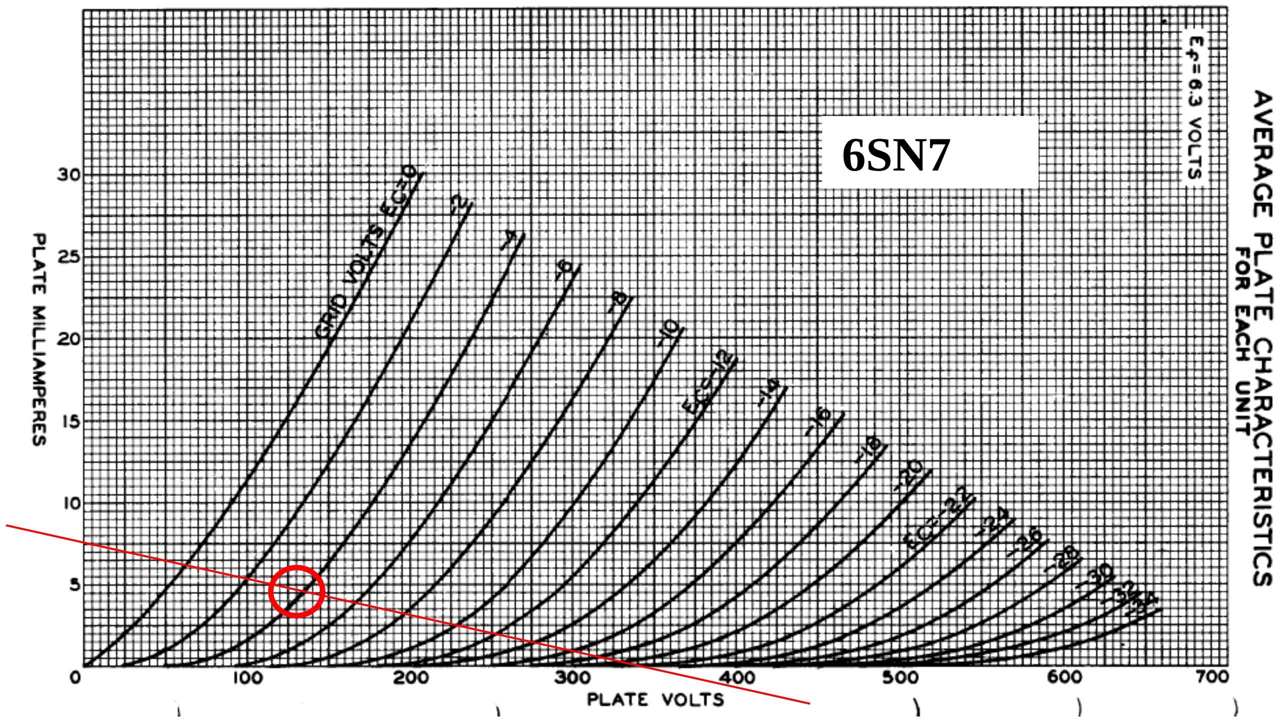
4.1 Input stage – 6SN7

Supply voltage is 289V; load resistance is 47k; and cathode resistor is 470R. The plate voltage Vp axis intercept is 290V for no plate current, and the plate current Ip axis intercept is 290V / 47KΩ = 6.2mA. The gate-cathode voltage Vg1 operating point varies with plate current through the 470Ω gate-cathode resistance (assuming no feedback) with the characteristic shown on the graph as a line passing through Ip=4mA for Vgk=-2V, and through Ip=10mA for Vg1=-4.7V. The nominal biased operating point at Vg1=2.0V.

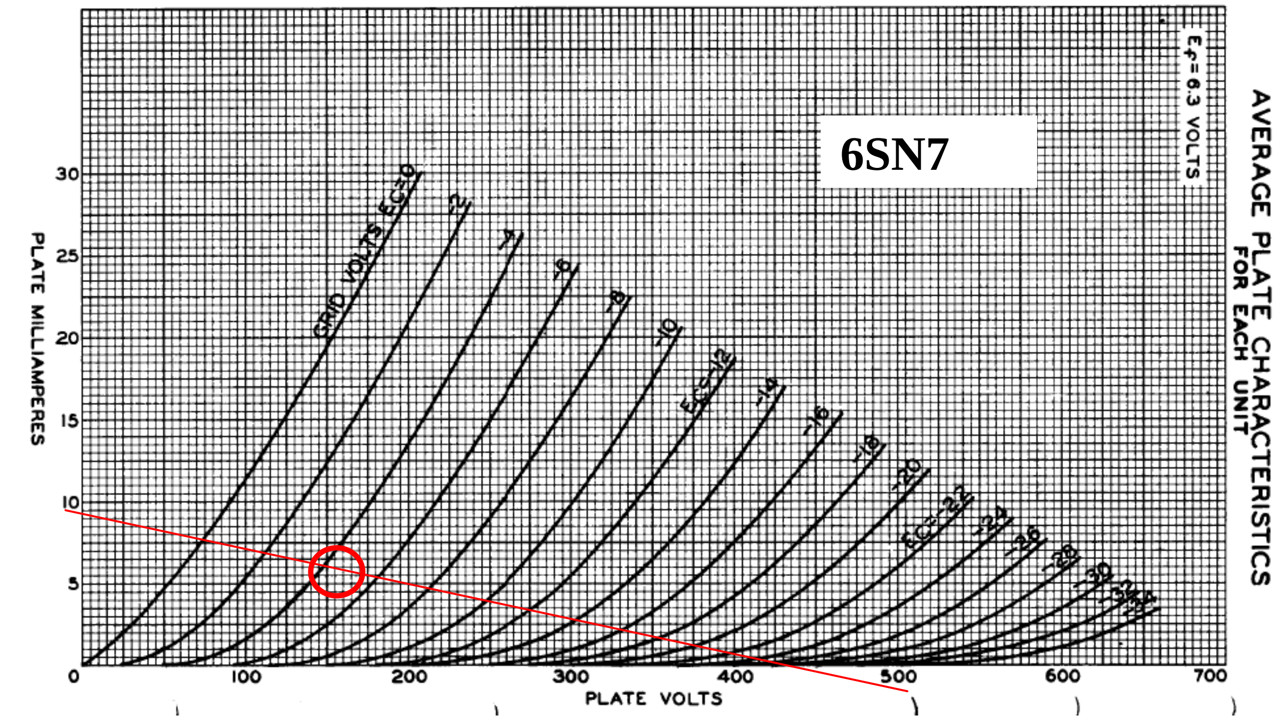
The input voltage swing limit is from the bias point at Vg1=-2.0V to Vgk=0V, which is about 4.0Vpp or 1.4Vrms. Referring to the loadline, the plate voltage would swing about 70V, from about 50V to 120V [120-85=35V; 85-50=35V; which is fairly symmetric]. This gives a nominal gain of 70/4 = 18.



4.2 Splitter stage – 6SN7 in split load config



4.3 Driver stage – 6SN7



4.4 Output Stage – 807 Pentode-connected PushPull

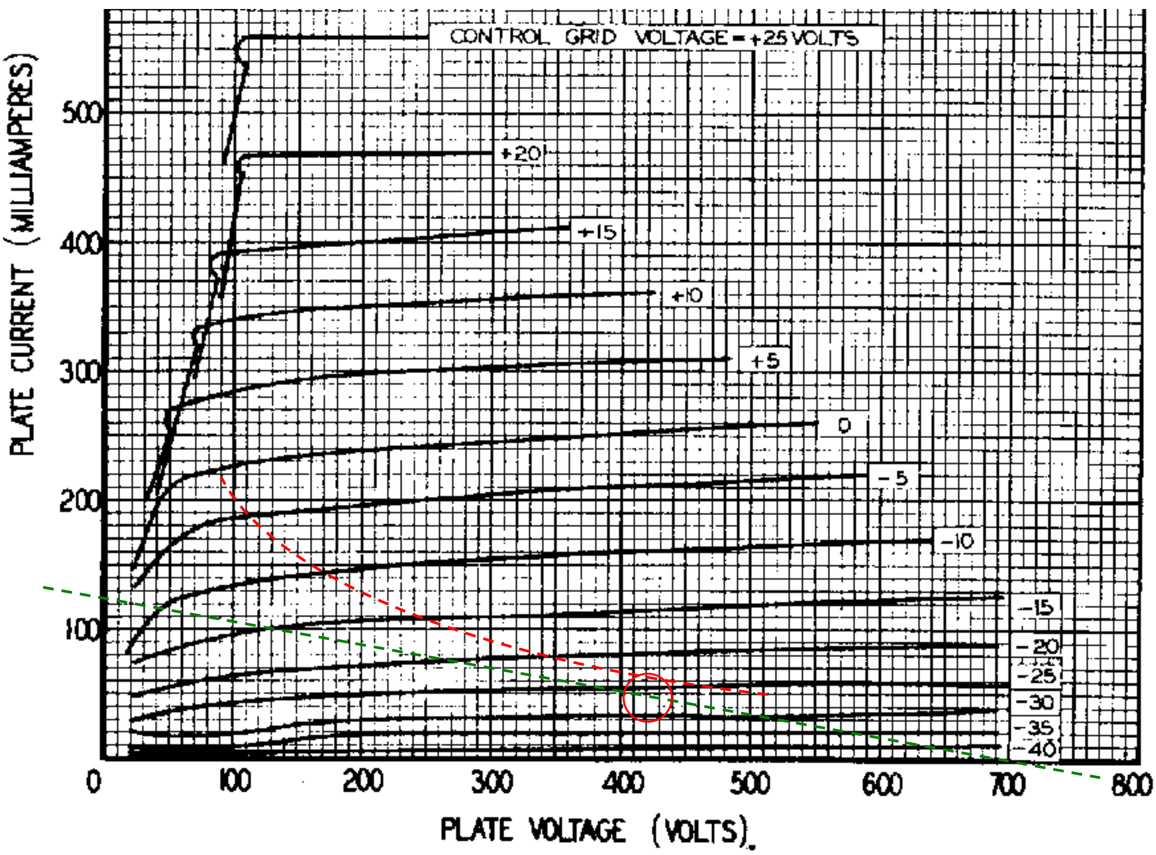
In this Class A push-pull output stage, both tubes conduct equivalent levels of current. The cathodes are raised above ground by a common unbypassed cathode resistor. A 10KΩ impedance plate-to-plate OPT presents signal currents into each tube with a 5KΩ impedance with both tubes conducting.

Plate DC voltage at idle will be lower than VS2 by an amount up to ~8V; ie. OPT half resistance of about 200Ω with idle current of 40mA. Cathode above ground by ~28V from common cathode resistance 350Ω with 80mA. Plate-cathode voltage at idle is about 500-8-28 = 465V.

Screen supply VS6 is regulated to 300V for screen currents below 20mA. Screen voltage at idle will be lower than VS6 by about 19V; common cathode voltage of 28V, and screen stopper drop of 125x0.003= 1V. Screen current at idle is likely to be ~6mA, but increase markedly as each grid approaches 0V.

Ripple on VS2 is quite low due to the capacitor/choke/capacitor filter.

Ibias(max) = Pd / Vb = 25W / 450V = 55mA, however this has been shown to give quite short valve life. A lower idle current level of 40mA is the target. With a common cathode resistance of 250Ω, grid-cathode voltage of 22.3V, the plate idle current is 2x44mA and plate dissipation (453-22-8)x0.044 = 18.6W.



4.5 Power Supplies

A standard full-wave rectifier circuit is used with 475V secondary HT windings with centre-tap to 0V, and a GZ37 full-wave rectifier. Effective PT secondary resistance = 6Ω x $(475/250)^2$ + 91 = 113Ω. The GZ37 with 4uF capacitor input and 75Ω effective transformer resistance provides 250mA with about 450VDC.

A CLC filter is used with 12H 200mA rated choke to generate VS2. The LC sections are under-damped.

Filter caps are Epcos B81130 with a 760VDC rating. The high level of idle bias and screen current draws a substantial and fairly constant 50W loading on the VS2 rail – 453Vx135mA=61W.

Both 6.3V heaters with one end grounded.

6.3V 2A heater: 2x0.9 = 1.8A
6.3V 1.5A heater: 2x0.6 = 1.2A
5V 3A heater: 2.8A

The two VR150 (OD3) in series need at least 2x185=370VDC to start, and need from 5 to 30mA operating current to maintain 2V regulation each. A 470k would commonly be put in parallel with top VR150 to allow bottom tube to start. An 8k2 (10W) resistor (measures 8k6) limits tube current to (500-300)/8k2 = 24mA after tubes have started and with no screen loading, but depends on VS2 regulation. Screen loading needs to be limited to about 20mA to maintain regulator operation, but depends on VS2 regulation.

At idle, each screen operates at ((464-294)/8k65 – 15mA)/2=2.5mA and about 270V, so there is almost no headroom for operation where plate voltage is pushed below about 60-70V (overdrive). As one 807 conducts more screen current, the other conducts less, so there is some balancing when not in overdrive. Power dissipation in 8k6Ω is 3.3W.

Lowering 8k6 to 5k8 provides 10mA more screen current headroom, with the screen supply at 27mA and the VR150 operating at about 22mA for idle.

A FET-zener could be added with a turn-on at 320V, for fault protection.

The screen regulators provide a base level choke CH2 operating current.

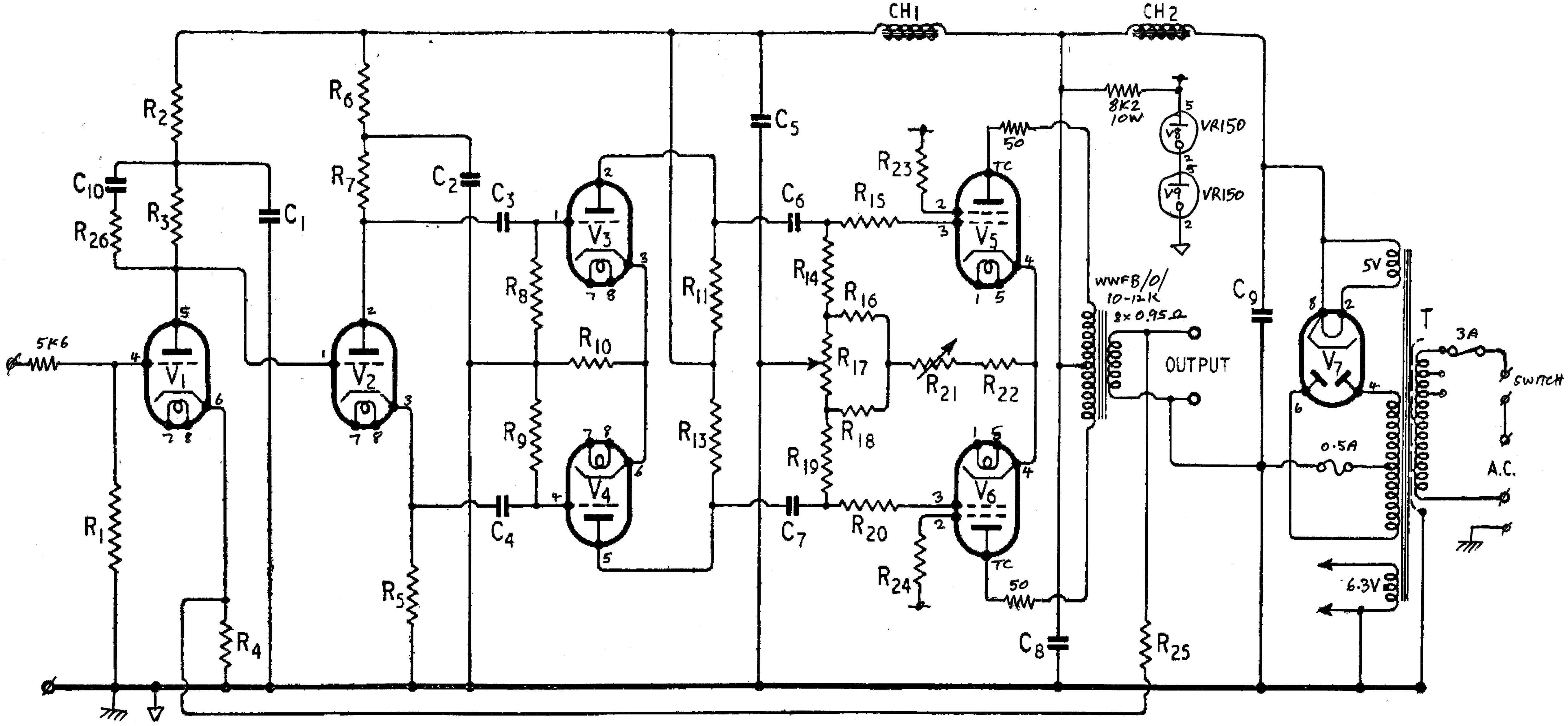


Fig. 1. Circuit diagram of complete amplifier.

R_1	1MΩ	¼ watt ± 20%
R_2	33,000Ω	1 watt ± 20%
R_3	47,000Ω	1 watt ± 20%
R_4	470Ω	¼ watt ± 10%
R_5, R_7	22,000Ω	1 watt ± 5% (or matched)
R_6	22,000Ω	1 watt ± 20%
R_8, R_9	0.47MΩ	¼ watt ± 20%
R_{10}	390Ω	¼ watt ± 10%
R_{11}, R_{13}	47,000Ω	2 watt ± 5% (or matched)

R_{14}, R_{19}	0.1MΩ	¼ watt ± 10%
R_{15}, R_{20}	1,000Ω	¼ watt ± 20%
R_{16}, R_{18}	100Ω	1 watt ± 20%
R_{17}, R_{21}	100Ω	2 watt wirewound variable
R_{22}	150Ω	3 watt ± 20%
R_{23}, R_{24}	125Ω	1 watt ± 20%
R_{25}	$1{,}200\sqrt{\text{speech coil impedance}}$	¼ watt (see table)
R_{26}	4,700Ω	¼ watt ± 20%
C_1, C_2,	16µF	500V wkg.
C_3, C_4	0.05µF	350V wkg.

C_5		32µF	
C_6, C_7		0.25µF	350V wkg.
C_9		3µF	800V wkg.
C_{10}		2nF	400V wkg.
CH_1	S15	30H at 20mA	
CH_2	TD2185	12H at 200mA	
T	TD2183	Power transformer	

Secondary 475-0-475V 150 mA, 5V. 3A, 6.3V 2A, 6.3V 1.5A

V_1, V_2 6SN7

V_3, V_4 6SN7

V_5, V_6 807 V_7 GZ37 V_8, V_9 VR150

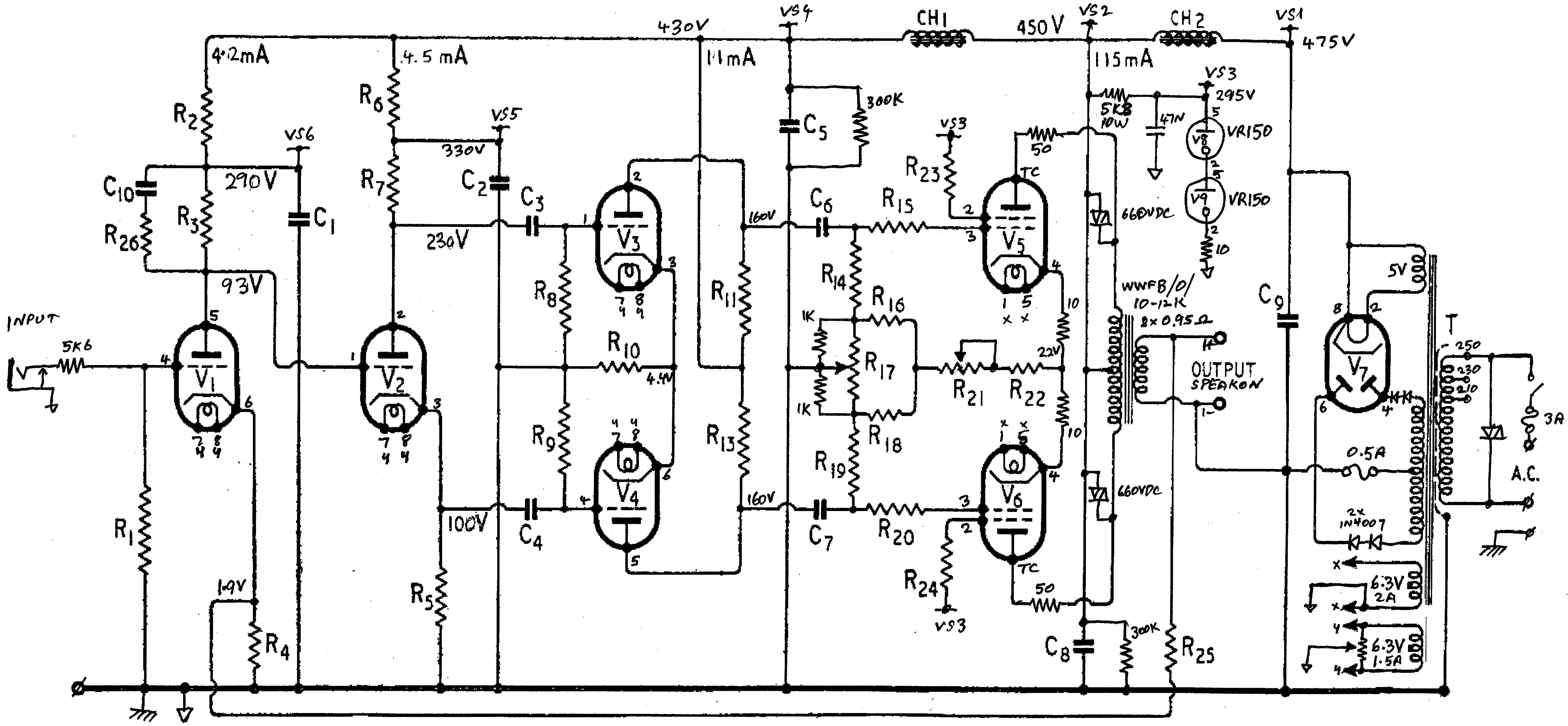


Fig. 1. Circuit diagram of complete amplifier. MODIFIED 2014. IDLE MEASUREMENTS

R_1 1MΩ
R_2 33,000Ω
R_3 47,000Ω
R_4 470Ω
R_5, R_7 22,000Ω

R_6 22,000Ω
R_8, R_9 0.47MΩ
R_{10} 390Ω
R_{11}, R_{13} 47,000Ω

R_{14}, R_{19} 0.1MΩ
R_{15}, R_{20} 1,000Ω
R_{16}, R_{18} 100Ω
R_{17}, R_{21} 100Ω

R_{22} 150Ω
R_{23}, R_{24} 125Ω
R_{25} 18 KΩ

R_{26} 4,700Ω
C_1, C_2, C_8 10 μF 500V wkg.
C_3, C_4 47nF 350V wkg.

C_5 20μF
C_6, C_7 0.22 μF 350V wkg.
C_9 2.2μF 800V wkg.
C_{10} 235 PF 400V wkg.
CH_1 S15 30H at 20mA
CH_2 TD2185 12H at 200mA
T TD2183 Power transformer
Secondary 475-0-475V 150 mA, 5V. 3A, 6.3V 2A, 6.3V 1.5A
V_1, V_2 6SN7
V_3, V_4 6SN7
V_5, V_6 807 V_7 GZ37 V_8, V_9 VR150