1. Summary

STC Type 28-SU-204 35W valve amplifier. S.N. . $70 private sale Jan 2012

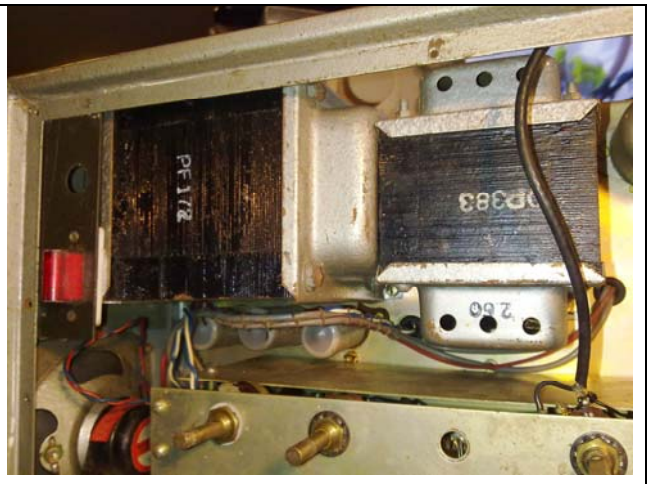
Two MIC input channel, and radio tuner unit PA amplifier. EF86 amp for mic after step-up transformer. 12AU7 mixer stage. 12AU7 tone make-up stage. 12AX7 long-tail pair PI stage. 7027A PP with combined fixed bias and cathode bias and transformer coupled feedback. 5AR4 rectifier with capacitor input filter for 600V PP stage B+. 6BW6 triode connected semi-regulated 300V supply for screens and PI, with RC droppers for 12AU7 and EF86 stages. Line output transformer with 25/50/100/125/150/300Ω tappings.

Output Transformer	Ferguson OP383 dated 2.60 9000Ω PP; 6 output winding sections 0,25R,50R,100R,125R,150R,300R. Secondary turns ratios: 0-289-408-577-645-707-1000.
Power Transformer	Ferguson PF172. dated 10-65 500-0-500V @ 200mA; 6V3 CT 4A; 6V3 3A; 5V 3A; 0-200-230-240V.
Line transformer	600 / 3.5 D2 (dated 5 Feb 1960); Rola 7W rating 600Ω to 3.5Ω.
MIC transformer	CL5244-2 (20 15 on base)
POTs	.
Caps	
Valves	7027A x2: Miniwatt 7404 274 6BW6 x1: Brimar 4M01 252 12AX7 x1: Miniwatt 338 COK EF86 x1: Mullard 8Y6 L7K3 (444) 5AR4 x1 12AU7 Mullard 160 99 (??????) 782 6N8 Miniwatt 4K 9F 6AN7 Brimar Aust 7A LT.1 C6K 6BA6 Brimar England 2A9/1224 LC
Speaker	Rola C, 4C05, dated 26 Feb 1960
Speaker transformer	600 / 3.5 E25 LINE dated 10 Jun 1960
Radio	3 valve – NSW dial

Good general condition. Well ventilated. Poor electrolytics – 3x chassis mount caps visibly damaged and disconnected and ducon pigtails added. Scorch mark near 7027A on wall. Aged resistors, especially screen stoppers and in regulator. Poor radio capacitors – AEE's cracked. Missing MIC 2 socket, top handles. PT replaced (mounting holes; 'wedged in' position; moved mains power switch position). Spare cutout for 9-pin socket. 1 original knob – 2 replacements (too large), 1 missing. Unsure if PP cathode bias is original. Faulty 5AR4. 7027A pair unbalanced.

Design issues:

- Heater to cathode voltage rating exceeded for 6BW6, as cathode is likely to be regulated 300V, and heater was used for fixed bias voltage doubler which forces heater to a slightly negative voltage. Modify by removing bias supply circuit, and just use cathode resistor bias. Heater #2 can then just be tied to 6BW6 cathode.
- Cathode bias heat dissipation. Modify by moving 300R 20W resistor to valve area.
- Too much spare gain – replace 12AX7 with 12AT7 in PI. Could modify tone to a two-pot configuration by taking over Monitor pot.
- Line output transformer. Connect 16Ω speaker from 50Ω to 125Ω tappings (used 24% of secondary turns) - 50Ω tapping is connected to ground.



2. Modifications

- New mains cord and clamp and mains switch.
- Replaced electrolytic caps, but left mustards and styroseals.
- Swapped mains active to fuse. Added MOV on PT primary.
- 400mA 5x20 fuse added to PT HT CT.
- Humdinger pot on heater #1 – disconnected CT.
- Hardwired OT output to bananas (eliminates wafer switch contact) for 16Ω speaker from 50Ω to 125Ω tappings (used 24% of secondary turns) - 50Ω tapping is connected to ground
- Removed microphone Tx and configured EF86 for guitar input. Added 47k grid stopper. All wires flexible to aid sprung base.
- Removed output feedback via line transformer to 12AU7 cathode, and increased cathode bias to 4k7 and added 4u7 bypass. Increased coupling cap to PI stage from 2N2 to 10N. Added 10k grid stopper to tone recovery 12AU7. Replaced tone input 12AU7 cathode bypass with 10u.
- Disconnected radio power and signal and removed valves. Reduced mixer resistance from 470K to 100K. Reconfigured Radio Gain pot to a pre-PI volume pot.
- Removed 1nF/2k2 network before PI. Added 150K grid stopper to PI input.
- Added 10k grid stoppers to 7027A. Added 10R cathode sense to each 7027A. Reduced grid leaks to 270k.
- Added 10k and 2x 350VDC MOVs in series per OT primary half winding.
- Removed doubler bias supply. Connectd one side of 6BW6 heater to 6BW6 cathode – this heater only goes to 6BW6, and is elevated to 300VDC.
- Removed VS3.
- Rearranged star-grounding.
- Removed relay (its coil wasn't connected !)
- Added 6.5mm switched input socket.
- Moved 300R 20W 7027A cathode bias to valve area.
- Added 274V zener to top of regulator pot, and reduced 390k divider resistor to 140k.
- Swapped 12AX7 for 12AT7 as PI.

To do:

- 5AR4 or GZ34 needed. Then do measurements (redo power output levels with different regulated screen levels - plot). Check bias voltage rise; VS1 sag; VS2 sag.

- Need three knobs – white, 30mmD, ribbed edging, o marking.
- If needed then add another valve base next to EF86 or to 12AX7.

3. Measurements

Power transformer resistances: primary 240-0V = 3.6 Ω ; secondary = 58+60 Ω

Voltage rail regulation.

Rail					
VS1					
VS2					
VS3					
Heater					
Sec HT					

3VAC 100Hz signal generator applied to 25Ω secondary winding

Winding	Voltage rms	Turns ratio; Impedance for K pri; Spec level; Notes			
Pri P-P: WH to WH	58.4	9k			
Sec: BLU to BLK	10.5	5.56;	291 Ω;	300Ω;	1000T
Sec: GRN to BLK	7.4	7.89;	145 Ω;	150Ω;	707T
Sec: YEL to BLK	6.75	8.75;	120 Ω;	125Ω;	645T
Sec: OR to BLK	6.09	9.59;	98 Ω;	100Ω;	577T
Sec: RED to BLK	4.34	13.5;	50 Ω;	50Ω;	408T
Sec: BRN to BLK	3.1	18.8;	25.4 Ω;	25Ω;	289T

Output transformer primary DC resistance:
96+102Ω plate-to-plate 9k.

The 150-300 section is effectively 26 ohm (293 turns).
The 125-150 section is effectively 1.2 ohm (62 turns).
The 100-125 section is effectively 1.4 ohm (68 turns).
The 50-100 section is effectively 8.5 ohm (169 turns).
The 25-50 section is effectively 4.2 ohm (119 turns).
The 50-125 section is effectively 16.8 ohm (237 turns).

Mic Tx CL5244-2:
DC resistances: 1-2: 13R; 3-4: 30R; 5-4: 423R
Impedance (from turns ratio) 50:350:42K

6V3 heater loading: 2x 0.9A, 1x 0.45A, 1x 0.3A = 2.6A
5V heater loading: 1.9A

MIC stage (MIC Gain pot) starts to smoothly overload at 65mVrms input, and 6.5Vrms output; large signal gain ~100.

12AU7 tone stage output (Radio Gain pot) starts to smoothly overload at 250mVrms input (MIC Gain pot), and 40Vrms output with tone at mid level; large signal gain ~160 (~13 per triode section).

12AX7 long-tail PI starts to smoothly clip at 25-30Vrms on 7027A grid, with input level from Radio Gain pot wiper of 2.2Vrms; large signal gain ~13. Amp output starts to clip at 16Vrms on 7027A grid. Need rectifier for full output measurements.

With 12AT7, and ss+R clone GZ32 rectifier:

VS1	500	550	600
VS2	300	302	304
Voutput (17Ω) start of clip	20V (24W)	22V (28W)	23V (31W)
Idle bias 7027A	38+38mA (18W) 22.2V	39.5+38mA (21W) 23.1V	42+39mA (24W) 24.0V

Frequency response at output: -3dB at 10kHz; -9dB at 20kHz; flat at 100Hz; check again.

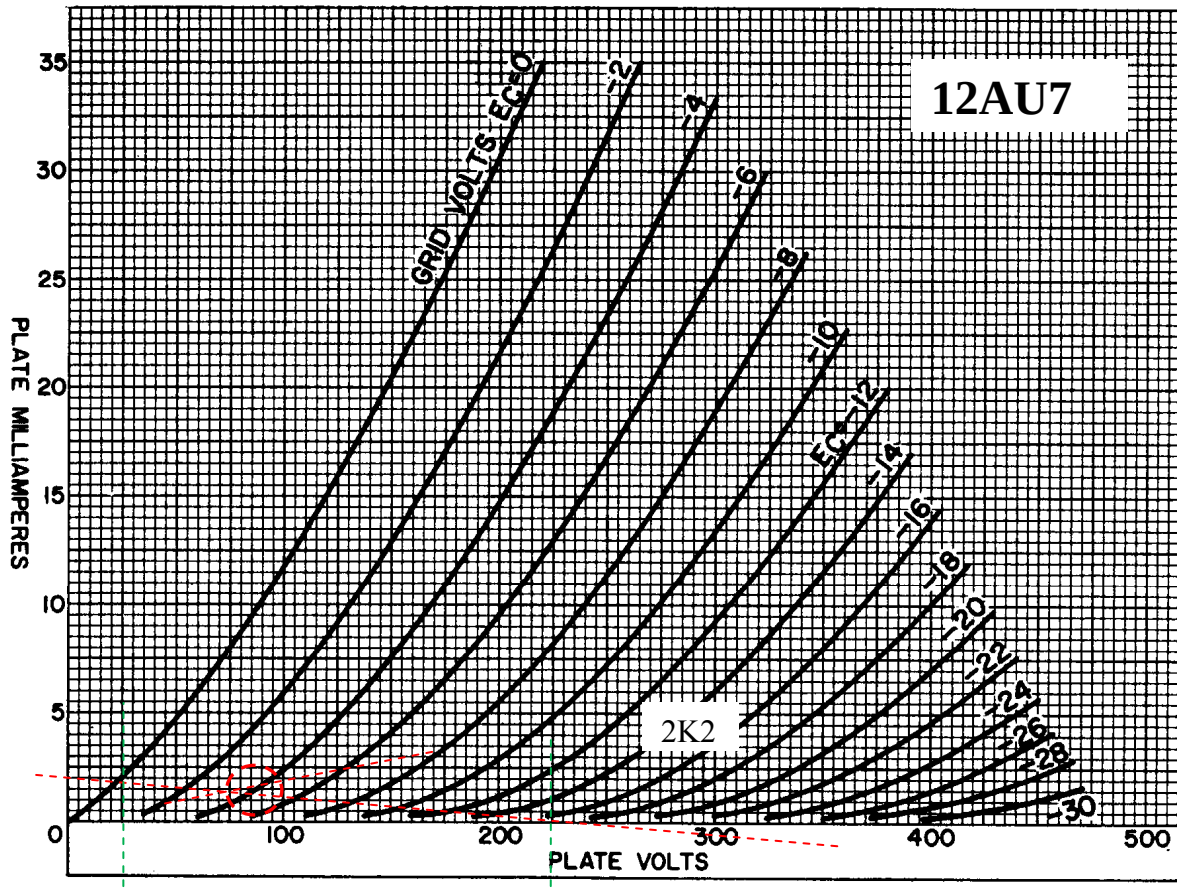
4. Design

4.1 EF86 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).

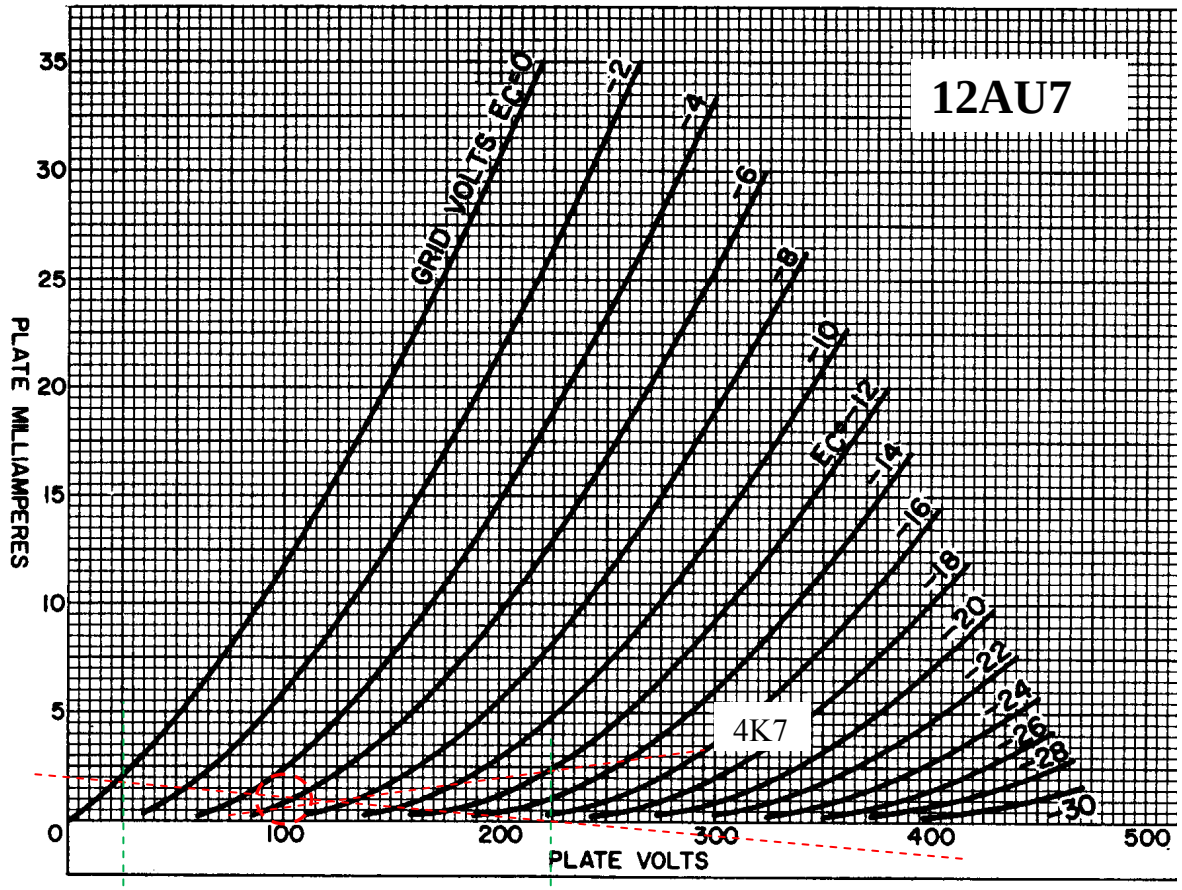
4.2 12AU7 tone driver section.

12AU7, V2A; VS4 = 232V; Va=87V; Rk=2k2; Vk=3.4V; Ia=1.45mA; RLdc=100k.



4.3 12AU7 tone recovery section.

12AU7, V2B; VS4 = 232V; Va=100V; Rk=4k7; Vk=4.8V; Ia=1.0mA; RLdc=120k.



4.4 Splitter stage – 12AX7 in long tail pair config

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

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

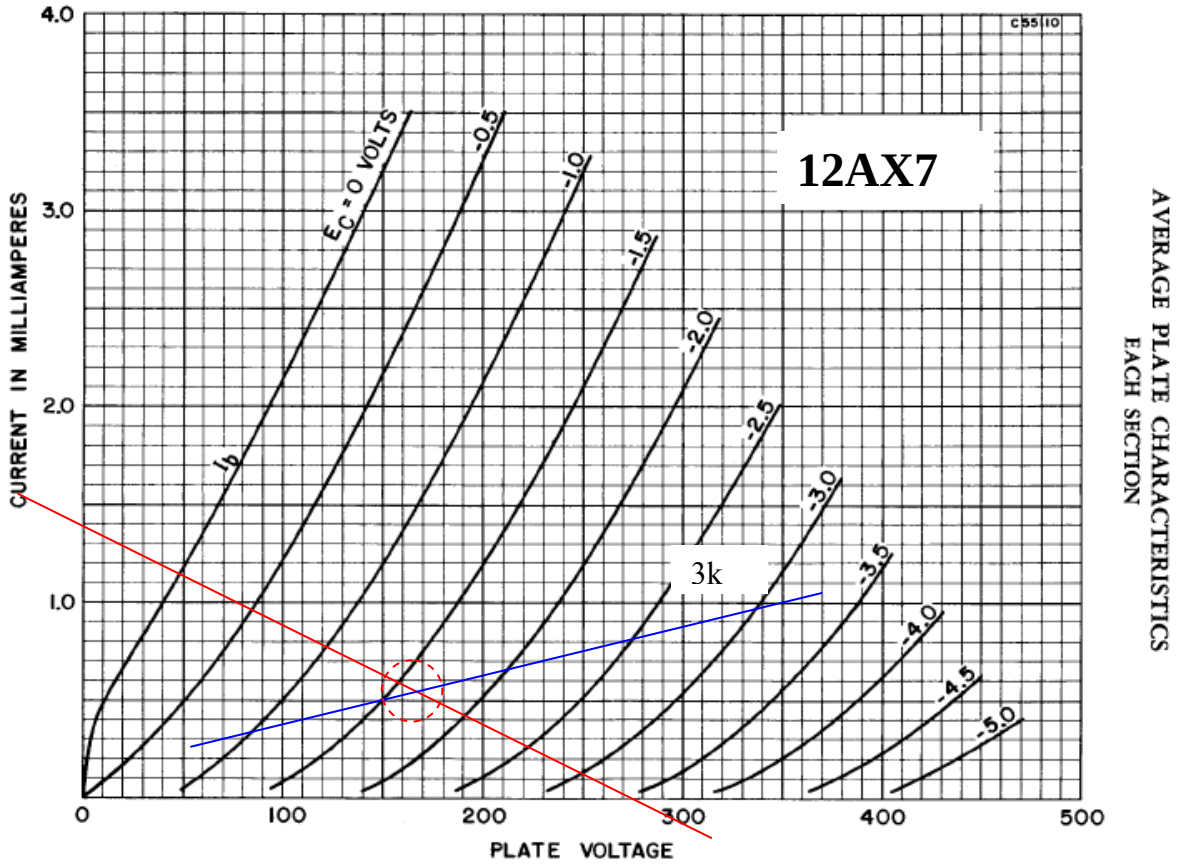
where R_k = 1k5+22k = 23.5kΩ. Hence a load line resistance of about 100K + 2x23.5k = 148k. With VS2=300V, the gate-cathode voltage varies with plate current through the 1k5 gate-cathode resistance, but with a 3k characteristic. The bias operating point of 1.7V and 0.55mA per side.

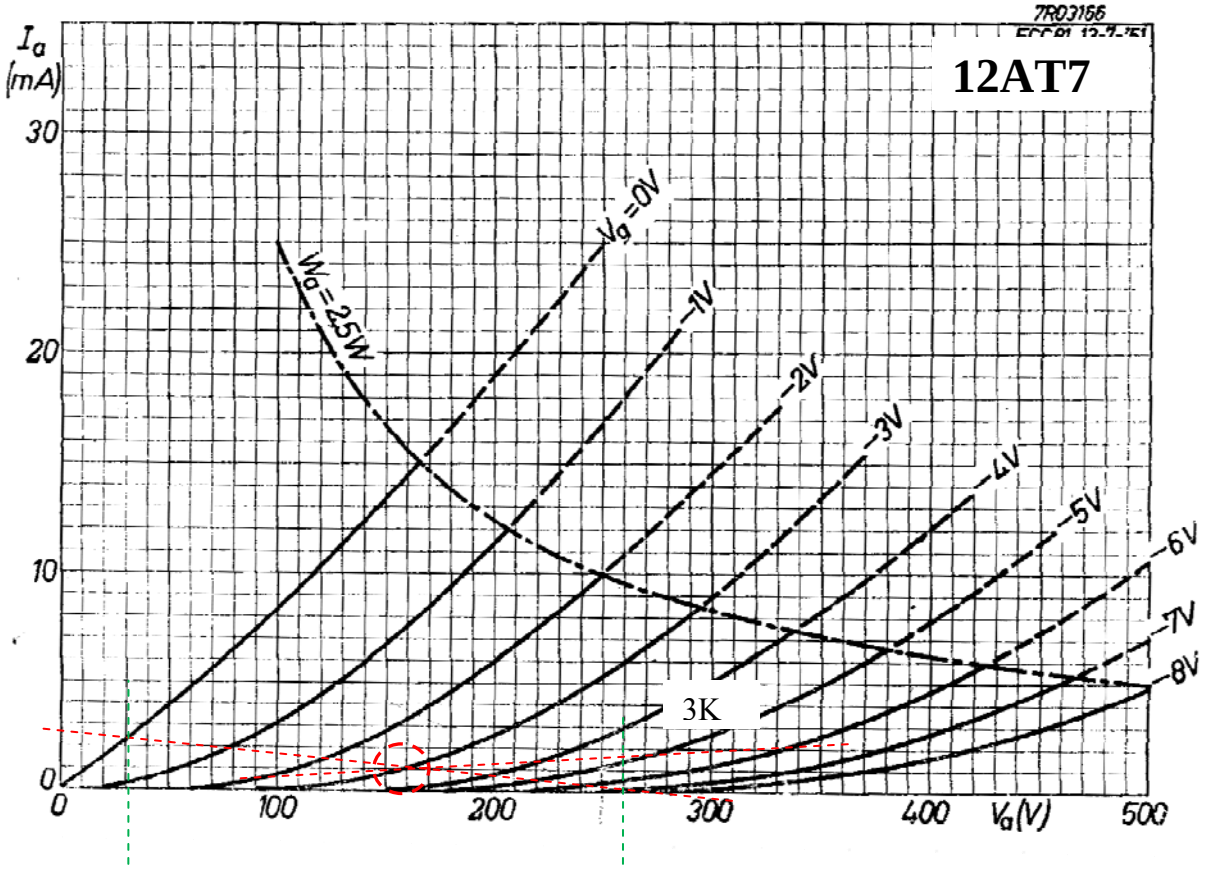
Voltage drop across tail is 22k x 1.1mA = 24V. Hence plate-cathode voltage is about 300 - 60 - 2 - 24 = 210V. Plate dissipation at idle is about 210V x 0.6mA = 0.13W.

12AX7: measured V3a=228V; V3b=222V; Vtail=25V; VRk=1.7V.
12AT7: measured V3a=200V; V3b=183V; Vtail=36V; VRk= -V.

Options:

Make	tube	tail	cathode	anode	B+
Fender 65	12AT7	22k	470	82k/100k	310
Design	12AT7	22k (44V)	1k5 (3.0V)	100k/120k	300


12AX7
AVERAGE PLATE CHARACTERISTICS
EACH SECTION
CURRENT IN MILLIAMPERES
PLATE VOLTAGE
Ec = 0 VOLTS
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
-4.0
-4.5
-5.0
Ib
3k
4.0
3.0
2.0
1.0
0
100
200
300
400
500


12AT7
Ia (mA)
Vg=0V
-1V
-2V
-3V
-4V
-5V
-6V
-7V
-8V
Wg=2.5W
3K
30
20
10
0
100
200
300
400
Va(V)
500

4.5 PP Output Stage

Class AB push-pull output stage with cathodes biased with a common resistor to ground. The 9KΩ impedance plate-to-plate OPT, presents each tube with a 2.3kΩ load impedance (with a matched secondary load) for larger signal currents, and 4.5k loading for small signal 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 35W design max plate dissipation (ie. <25W); and
- assess the dynamic loadline to see if it moves into region of increased plate dissipation.

The supply voltage VS1 at idle current of 50+50mA is about 640V. Plate-cathode idle voltage will be lower than VS1 by ~35V; ie. an idle current of 50mA, and OPT half resistance of about 100Ω (5V), and cathode bias of 300R (30V).

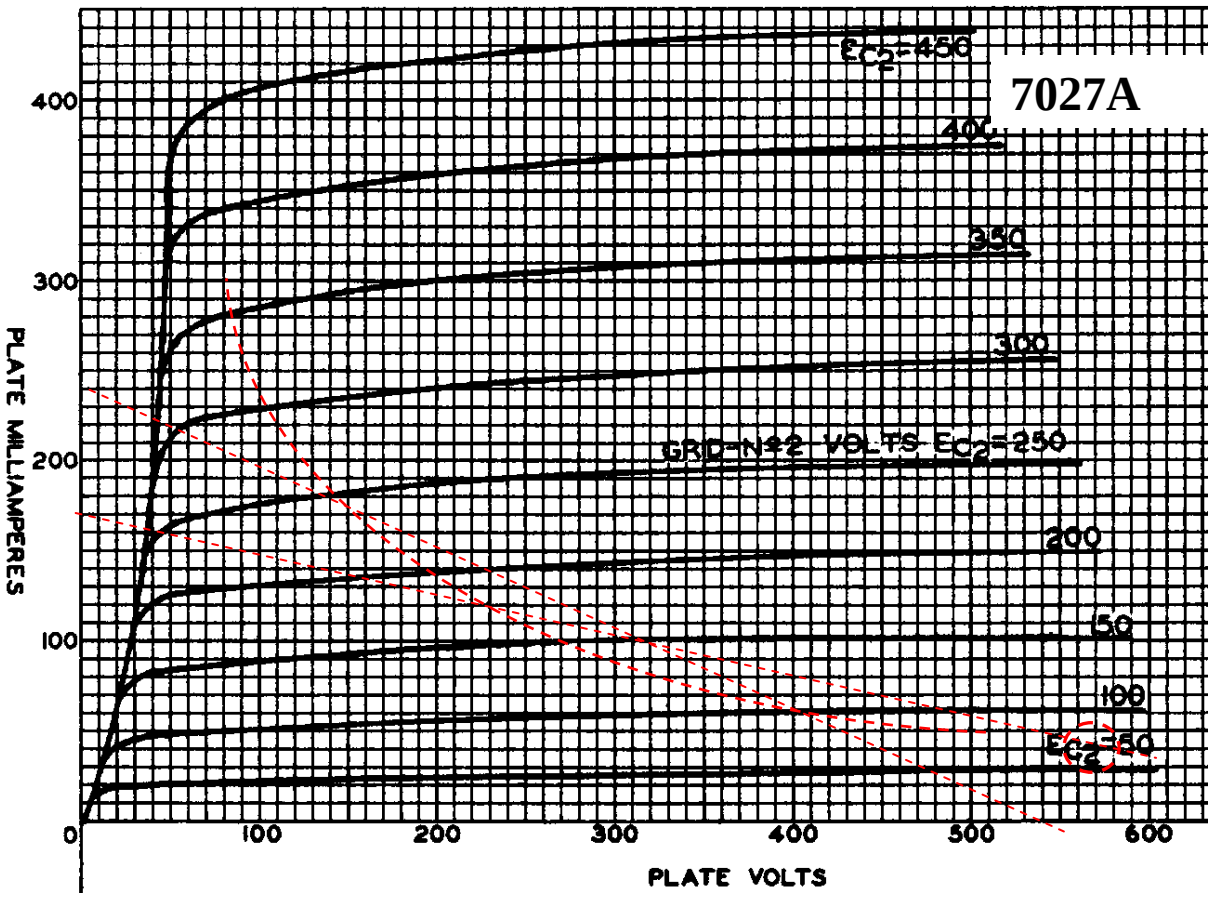
From the plate characteristics, a screen voltage of 300V at Vg1 will cross the knee zone. Screen current reaches up to 75-100mA. With screen dropper of 100Ω, the screen voltage could sag by 10V for 100mA, at a power dissipation of 1W. Cathode bias peaks at about 310x0.2=62Vpk, and 12W. VS1 would sag to about 600V for 150mA continuous load. OT winding voltage drop of about 100x0.2=20Vpk. Plate-cathode voltage would sag to about 600-20-45=535V, and peak plate current of 200-210mA.

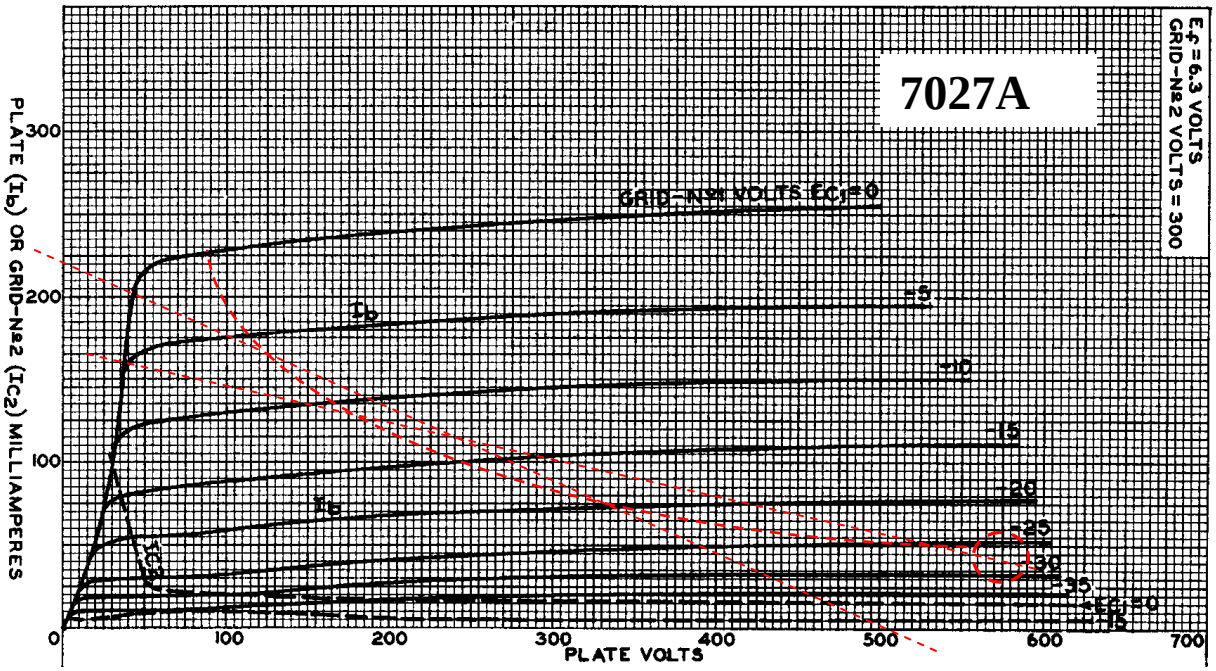
The max design output valve bias current allowed is dependent on the maximum recommended plate dissipation of 25W for the 7027A: Ibias(max) = Pd / Vb = 25W / 600V = 43mA.

The nominal output power of the amplifier will then be:
(Imax)2 x Rpp / 8 = 0.2 x 0.2 x 9k / 8 = 45W

The maximum signal average plate current is ~140mA, and with a 600V supply, the average supply power consumed is 84W, and so the tubes dissipate 84 – 45W = 40W, or 20W each.

The 100uF bypass cap on the common cathode provides a high pass filter to minimise the level of low frequency signal available to the OT. Similarly, HF low-pass filtering is appropriate to roll off signal before the OT starts entering resonances.





4.6 Powering

The 5AR4 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 = 3.5Ω x $(500/240)^2$ = 15Ω; plus the secondary resistance = 60Ω; which sums to 75Ω. The effective source resistance should be 160Ω for a secondary supply of 500Vrms, based on 40uF capacitor-

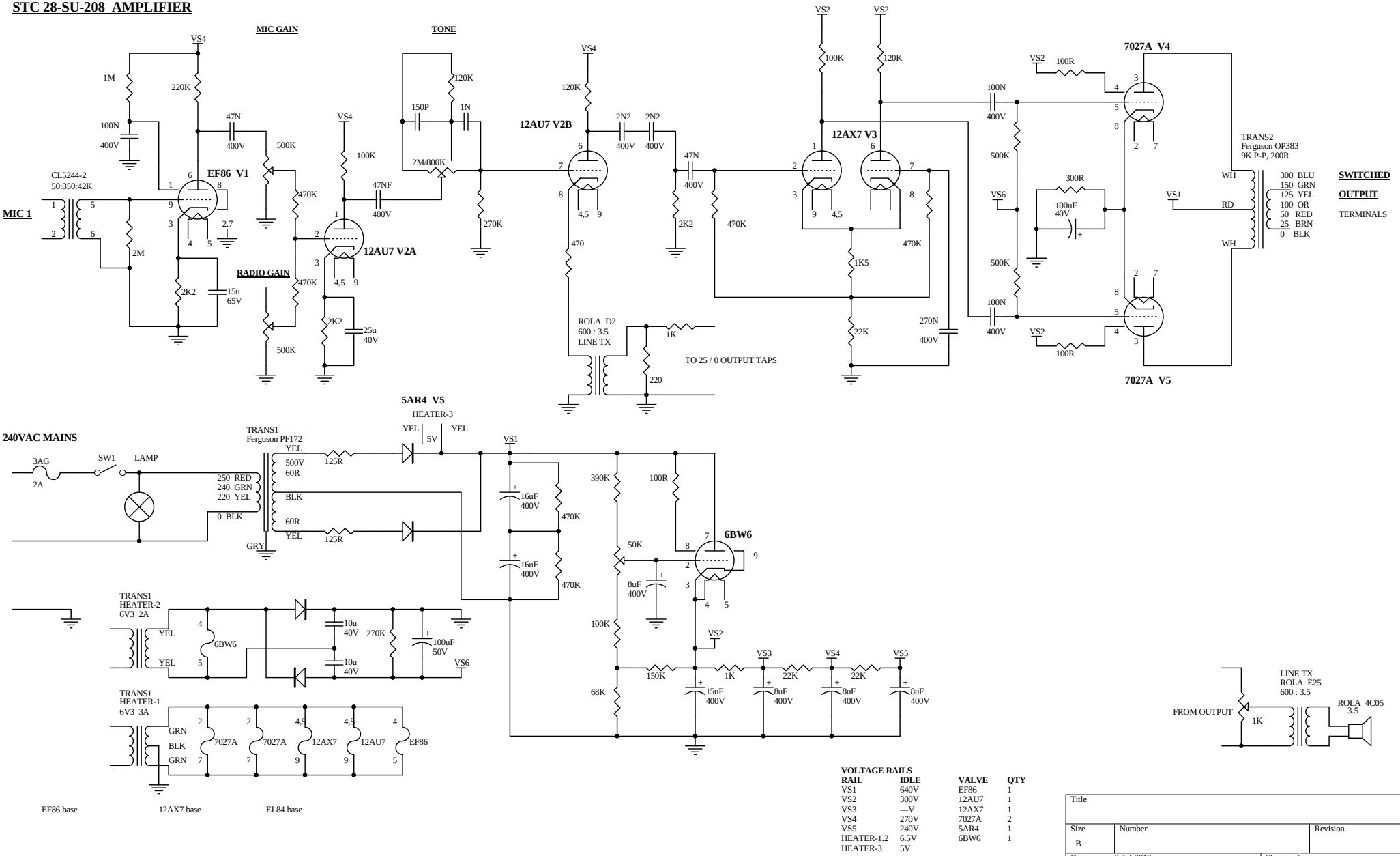
input filter, where the output DC level will sag from about 720V to just under 600V. With the 125Ω 3W series plate resistors, the total effective 200Ω resistance should allow up to 50uF filter input. VS1 ripple is 3.4Vrms at 550V and idle.

6BW6 regulator with 390K on top of pot to VS1, and 68K to ground through a 100k and 150k to cathode. Should regulate to at least 100mA loading. Heater tied to cathode – heater only used for 6BW6. Measured Vgrid=264V; VS1=600V; VS2=300V; all preamp valves in circuit but no 7027A screens. Screen voltage is only semi-regulated, and droops with VS1 due to grid voltage droop from divider, and change in required grid voltage for lower anode-cathode voltage. AC ripple on VS2 is 60mV at idle, and increases to 120mV at output clip level.

The 1N4752A 33V zener regulates at 30.4V, so 9 zeners in series regulate 6BW6 grid to about 10V above the nominal 264V for VS1, and will allow the pot to set VS2 in a range from 250-300V. 390k top divider reduced to 140k to give zener 0.4mA at VS1=480V; max zener dissipation at VS1=600V is 0.5W. Although 6BW6 grid regulates closely, the cathode-grid voltage increases with anode voltage (due to the triode operating curves for a constant VS2 load), but this is alleviated from an increasing screen load.

Heater 1 (7027A x2; 12AX7; 12AU7; EF86): 0.9+0.9+0.3+0.3+0.2 = 2.6A
Heater 2 (6BW6): 0.45A
Heater 3 (5AR4): 1.9A

STC 28-SU-208 AMPLIFIER



VOLTAGE RAILS

RAIL	IDLE
VS1	640V
VS2	300V
VS3	---V
VS4	270V
VS5	240V
HEATER-1.2	6.5V
HEATER-3	5V

VALVE	QTY
EF86	1
12AU7	1
12AX7	1
7027A	2
5AR4	1
6BW6	1

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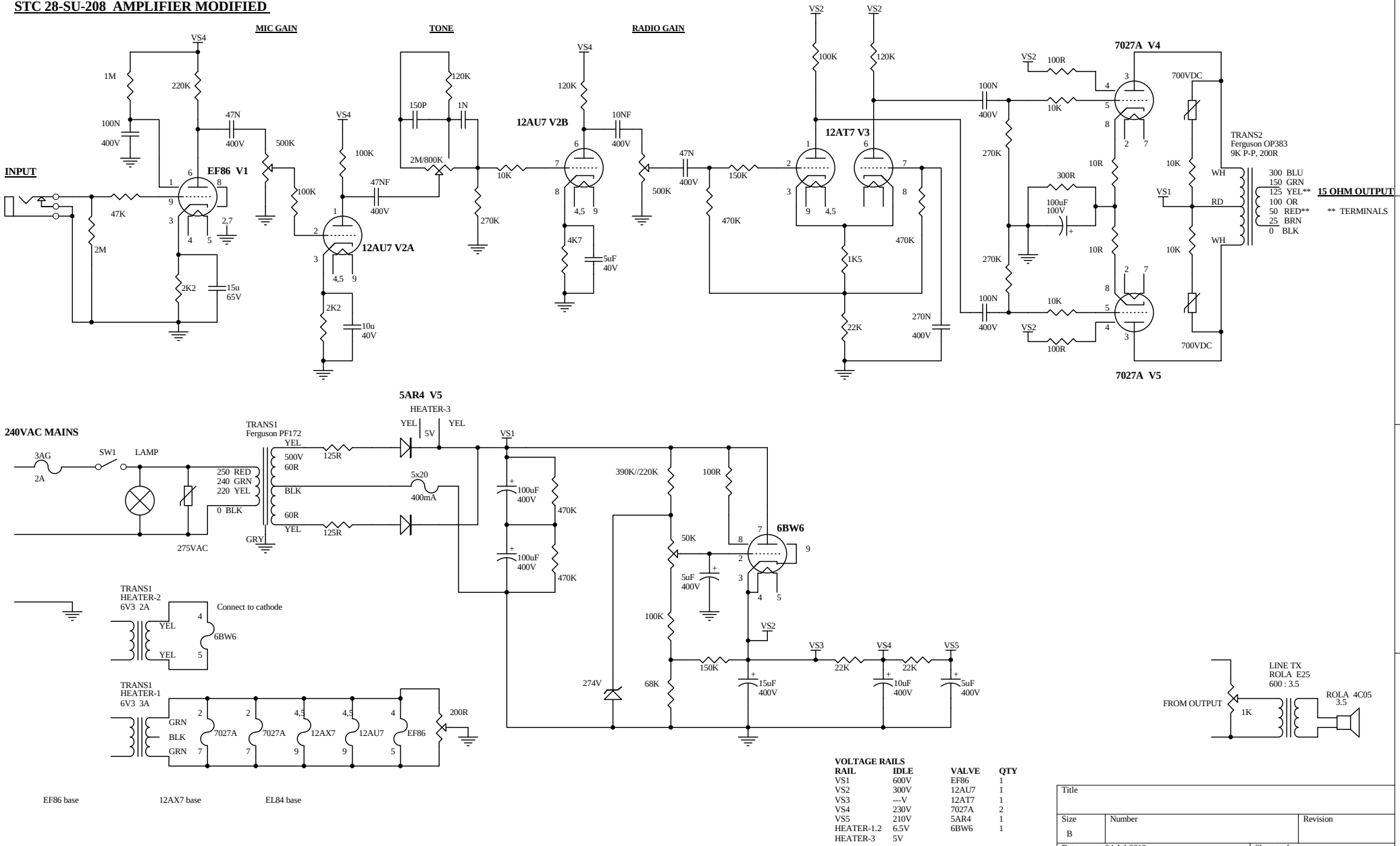

VOLTAGE RAILS

RAIL	IDLE
VS1	600V
VS2	300V
VS3	---V
VS4	230V
VS5	210V
HEATER-1.2	6.5V
HEATER-3	5V

VALVE	QTY
EF86	1
12AU7	1
12AT7	1
7027A	2
5AR4	1
6BW6	1

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