

1. Summary

VASE PA100, S.N. 116/100/ T. 6 microphone input channel mono PA amplifier.
 \$121.40 eBay Jan 2009. Purchased without valves.

Each microphone channel with BC109 input, followed by Baxandal Bass & Treble tone controls, and final BC108 output to microphone channel volume pot. The 6 microphone channels are then summed to Master Volume pot. 2x BC107 driver to 12AX7 long-tail splitter and output stage using fixed bias, push-pull KT88 tubes in Class AB1, to output transformer with 4, 8 and 15 ohm secondaries, and secondary side feedback to splitter. Output stage voltage supply from voltage doubler silicon diode rectifier and series capacitor filter, then resistor dropped to the screen supply, and then resistor dropped to the splitter supply. Step-up transformer powered from heater winding used for negative grid bias supply to output stage, and for positive transistor circuit supplies. KT88's recessed in chassis, with sheet metal heat deflector above valves, and louvre plate in base of cabinet.

- Output Transformer Ferguson OPM13A [Rated at 55W, with 15/8/3.7/2 ohm outputs]
- Power Transformer Ferguson, PVD110, 8-69, V3 [230-240-250V; 183V 200mA; 6V 4A; 6V3 CT 3A.]
- Step-up transformer Vase 70003
- POTs IRC CT545 FO 500K Likely 1965, week 45.

Prior modifications appear to be: mains cable added to replace XLR socket; extra speaker output socket added.

OPM13A not listed by A&R till after mid 1963. Filter caps dated late 1969. PVD110 datasheet from April 1961 – date stamp indicates circa 1970 manufacture for amplifier.



2. Modifications

- Restored the XLR mains socket with new insert, and made new mains connection cable with XLR plug.
- Added NTC 15R to PT primary to reduce turn-on diode stress.
- Added PT secondary fuse (2A).
- Added 10R cathode sense resistors for bias adjustment, and as poor man's fuse.
- Replaced faulty screen grid stopper and standby pre-charge resistors. Replaced old electrolytics (1969) – increased VS1 200uF series caps to 470uF; increased bias cap to 100uF; reduced VS2 cap to 15uF; replaced VS6 & VS7 caps.
- Added 750Ω 10W loading resistor on 15Ω output winding for open-circuit output protection. Added 20R and 0.22uF zobel across 15Ω output winding (36kHz).
- Channel MIC 1 input replaced with isolated socket with switch shorted tip to gnd - taken to new 12AX7a, added to main chassis, for guitar input and tone stack. Added standard Fender tone stack using existing MIC1 Bass and Treble pots, plus used MIC2 Vol pot for Mid. Replaced 4k7 feedback with new Presence control in the MIC2 Bass pot position. Placed 250k pot (MIC2 Treble pot) in series with Master Volume to provide new Overdrive control.
- Replaced MIC2 input socket with double switched socket. Output from MIC1 Volume (output of 12AX7a stage) taken to MIC2 socket through one switch as a SEND, with output of MIC6 stage switched in to 12AX7b, so that patch cable can connect to either MIC3, MIC4, MIC5, or MIC6 stage circuit input sockets (all wired in series, with Vol pot wiper taken to next stage). MIC3-MIC6 socket shorts removed. Otherwise, with no jack in MIC2 socket, the 12AX7a stage connects direct to 12AX7b stage.
- Original MIC1 and MIC2 circuits are disconnected.
- Included metal shield between TRANS2 and V1 to suppress feedback coupling.
- Reduced output stage coupling cap from 0.1uF to .047uF.
- Star grounding. Added 450V zener across VS4, to limit filter cap and 12AX7 voltage and reduce variation due to output loading. Isolated heater winding and added humdinger 200Ω pot.
- Changed step-up transformer to increase bias supply raw level to cope with protection relay loading. Added 470R to Bias transformer winding to reduce diode transient noise. Added 75V zener across VS8 to limit/regulate bias level. Added 10T 10K pot divider between VS8 and VS9 to take off a more negative bias voltage for V3 – to allow bias to be trimmed to same level with the tubes in hand. VS9b gets slightly higher bias voltage
- Reduced 220k bias feed resistance to 100k (100k = max value for fixed bias >35W).
- Added grid bias failure protection circuit (48V relay that pulls out if KT88 grid bias is lost, and isolates the HT secondary winding).
- Added 50mm computer fan behind output transformer to circulate air in cabinet, powered from 6.3VAC through voltage doubler.
- Replaced 3x output ¼” sockets with 2x ¼” locking sockets wired in parallel and 1x fixed-position selector switch for 2Ω, 4Ω, 8Ω and 15Ω winding.
- MOV (~560VDC) and 680Ω from each anode to VS1 for protection.

Future modifications could include:

- Original schematic is missing 4k7 from top of each 10k VOL pot to mixing point in 6x input channels.

3. Measurements

Rail	10K5 load on VS1 Standby / ON	3K6 on VS1 19K on VS3 ON	2K4 on VS1 19K on VS3 ON	2K on VS1 19K on VS3 ON	Standby	Standby / ON (idle)
Ip	- / 49-68mA					- / 50, 50mA
VS1	29V / 530V 28W	501V 70W	490V 100W	468V 156W	203V	127V / 504V - / 2.3Vrms
VS2	29V / 518V 2.7W	482V	471V	444V	203V	126V / 494V - / 250mVrms
VS4	28V / 454V	477V	467V	444V	203V	100V / 396V - / 20mVrms
VS5						71V / 283V - / 10mVrms
VS8	-69V / -69V	-58V / -57V			-73V	-73V / -73V 220mVrms
VS9	-6xV / -60V	-58V / -57V			-60V	-60,66V / -58,63V 90mVrms
VS6	31.6V / 30.8V	20V	19.8V	22V	42V	42V / 42V 5.5mVrms
VS7	15.6V / 15.4				16.8V	16.8V / 16.8
Heater	6.8Vrms /				7.0Vrms	6.7Vrms / 6.6Vrms
Sec HT	202.2Vrms / 201Vrms				203Vrms	202Vrms / 201Vrms 5mA / 280mA

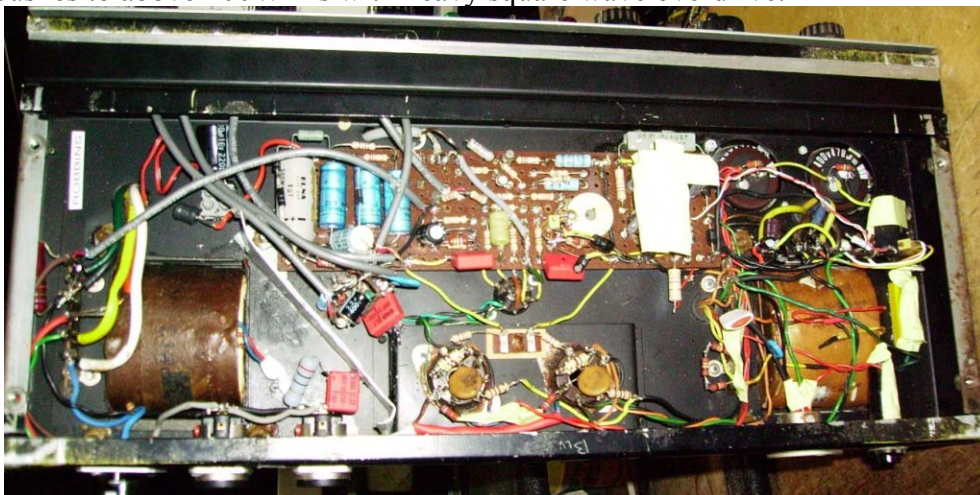
VS9 bias pot has a marking effectively at max R. Transformer primary = 5Ω; secondary HT = 5Ω.

12VAC 50Hz nominal applied to OPM13A output transformer

Winding	Voltage rms	Turns ratio; Impedance for 3K1 pri; Spec level; Notes
Pri P-P: BLU to BRN	176	
Sec: BLK to OR	4.46V	39.5; 2.0 Ω; 2 Ω;
Sec: BLK to YEL	6.05V	29.1; 3.7 Ω; 3.7Ω;
Sec: BLK to WH	9.07V	19.4; 8.2 Ω; 8Ω; "8Ω" output winding
Sec: BLK to GRN	12.36V	14.2; 15.3 Ω; 15Ω; feedback winding

Output transformer primary DC resistance: 72Ω plate-to-plate.

Plate current: 55mA and 37mA without bias trim. Trimmed both to 45mA after 10 minutes idle.
Output stage distortion becomes noticeable at 25-26Vrms into 8R (72-85Wrms) with Presence low, but output pushes to above 100Wrms with heavy square wave overdrive.



4. Design Info

Original hand-drawn circuit schematic includes some errors. Assistance provided by Graeme Whitehouse in supplying comparison circuit of VASE Trendsetter 100 Deluxe, and other background VASE info. Aim has been to make a clean working guitar amp with typical preamp and tone stack. The splitter stage and output stage are equivalent to the Fender Bassman 5F6-A circuit, except the rail voltages are somewhat higher. Design info based on [description by Ben Verellen](#) (who primarily references Richard Kuehnel's book on the Fender amp). The design discussion below supports the choice of 12AX7 and KT88, which is based on what was originally used in other VASE equipment.

4.1 Microphone preamps and PI driver

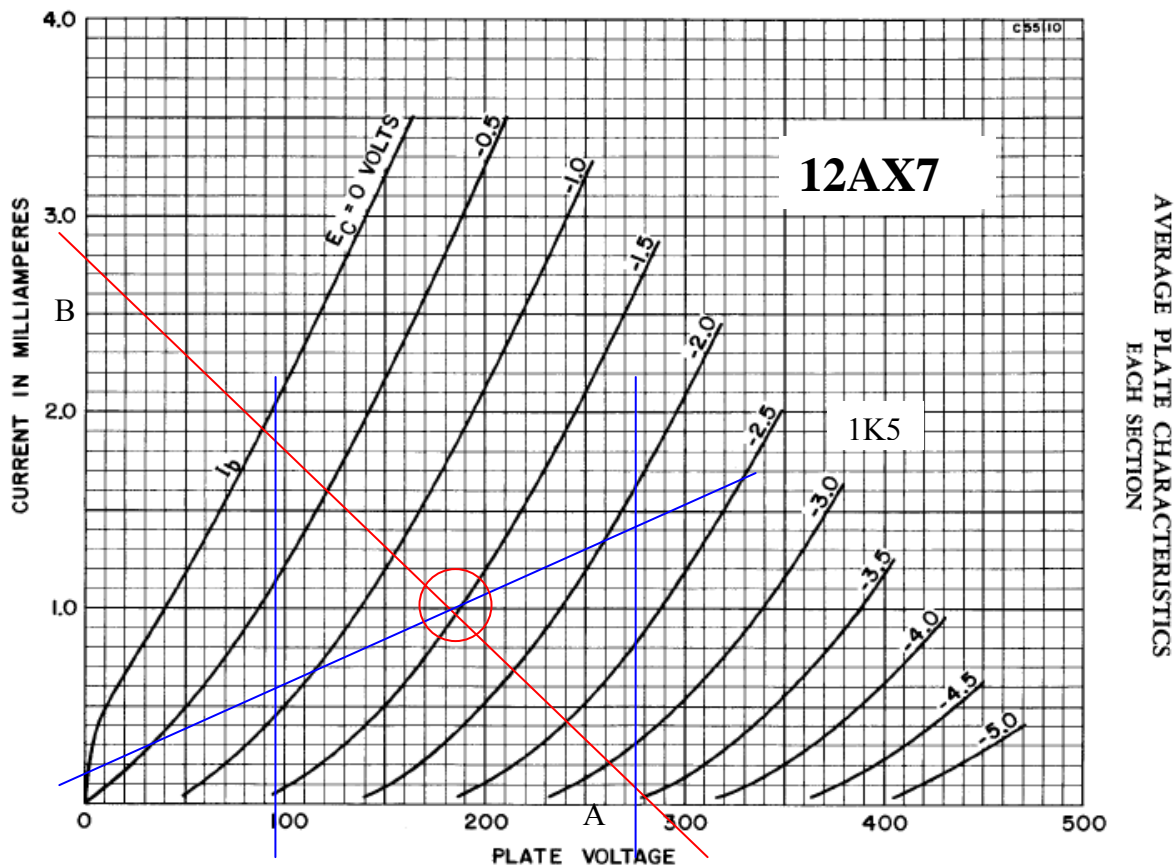
Assume 41V for VS6, and 20V for VS7, and 8V on BC109 and 11V on BC108 collectors. Each microphone channel draws $0.4+0.9=1.3\text{mA}$, so $2k7 \times 6 \times 1.3\text{mA} = 21\text{V}$ drop from VS6 to VS7. PI driver draws $0.4+2.0 = 2.4\text{mA}$, so 63V supply drops to VS6 is $2k2 \times (2.4+6 \times 1.3) = 22\text{V}$.

Each mic stage has voltage gain of about 4.

4.2 Input Gain Stage

This stage is not original. A 12AX7 was added to the chassis. For the first half 12AX7, V1A, we have plate voltage $V_p = VS5 = 280\text{V}$; $V_a=180\text{V}$; $R_k=1k5$; $V_k=1.4\text{V}$; $I_a=1.0\text{mA}$; $R_{Ldc}=100k$.

The input voltage swing limit is from the bias point at $V_{gk}=-1.5\text{V}$ to $V_{gk}=0\text{V}$, ie. 3V_{pk-pk} or 1.1V_{rms} . Referring to the loadline, the plate voltage would swing about 180V , from about 90V to 270V . This gives a nominal gain of $90\text{V}_{pk}/1.5\text{V}_{pk} = 60$, which correlates with $\text{Voltage gain} = \mu R_L / (R_L + R_a) = 100 \times 60k / (60k + 30k) = 66$; where $R_L \sim 60k$ ($100k$ paralleled with $110k$), and $R_a = (280\text{V}/1\text{mA}) - 1k5(u+1) - 100k \sim 30k$; for typical 12AX7 $\mu=100$.



4.3 Splitter stage

In this stage the input signal is split and amplified into two signals, 180° out of phase from one another, and presented to the push-pull output stage. The long-tail splitter configuration is a differential amplifier made up of the two triodes in the 12AX7 V2. DC analysis is based on capacitors as open circuits, feedback voltage is zero, and the two load resistors are both equal (at $R_L=100k\Omega$). Each triode plate circuit shares the cathode resistance to ground, and so the effective cathode resistance to each distinct triode is double the circuit value. The plate current versus plate voltage load line for each triode is given by the equation:

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

where $R_k = 1k\Omega + 6.8k\Omega + 4.7k\Omega = 12.5k\Omega$. The plate voltage V_p axis intercept is 500V (point A) for no plate current, and the plate current I_p axis intercept is $500V / 125K\Omega = 4.2mA$ (point B). The gate-cathode voltage (E_c on the graph) varies with plate current through the $1k\Omega$ gate-cathode resistance, but with a $2k\Omega$ characteristic, and this characteristic is shown on the graph as a line passing through $I_p=1mA$ for $V_{gk}=-2V$, and through $I_p=1.5mA$ for $V_{gk}=-3V$. The intersection of the two lines is the nominal biased operating point. This operating point moves when the supply voltage sags under heavy output loading, as shown by the dashed load line.

The nominal operating point levels of $V_{gk}=-2.8V$ and $V_p=350V$ are used to determine the parameter values of r_p and g_m and μ from the 12AX7 average transfer characteristics graph (note that E_b is V_p).

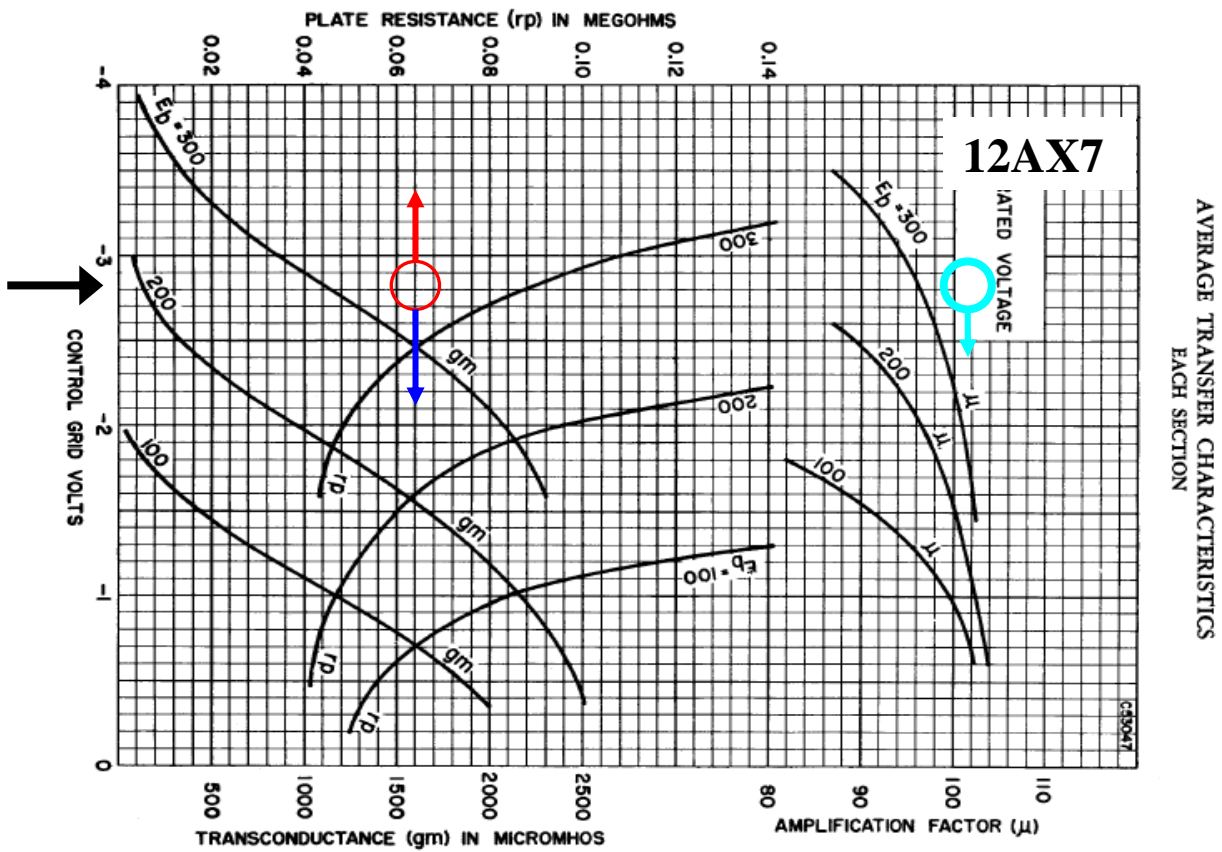
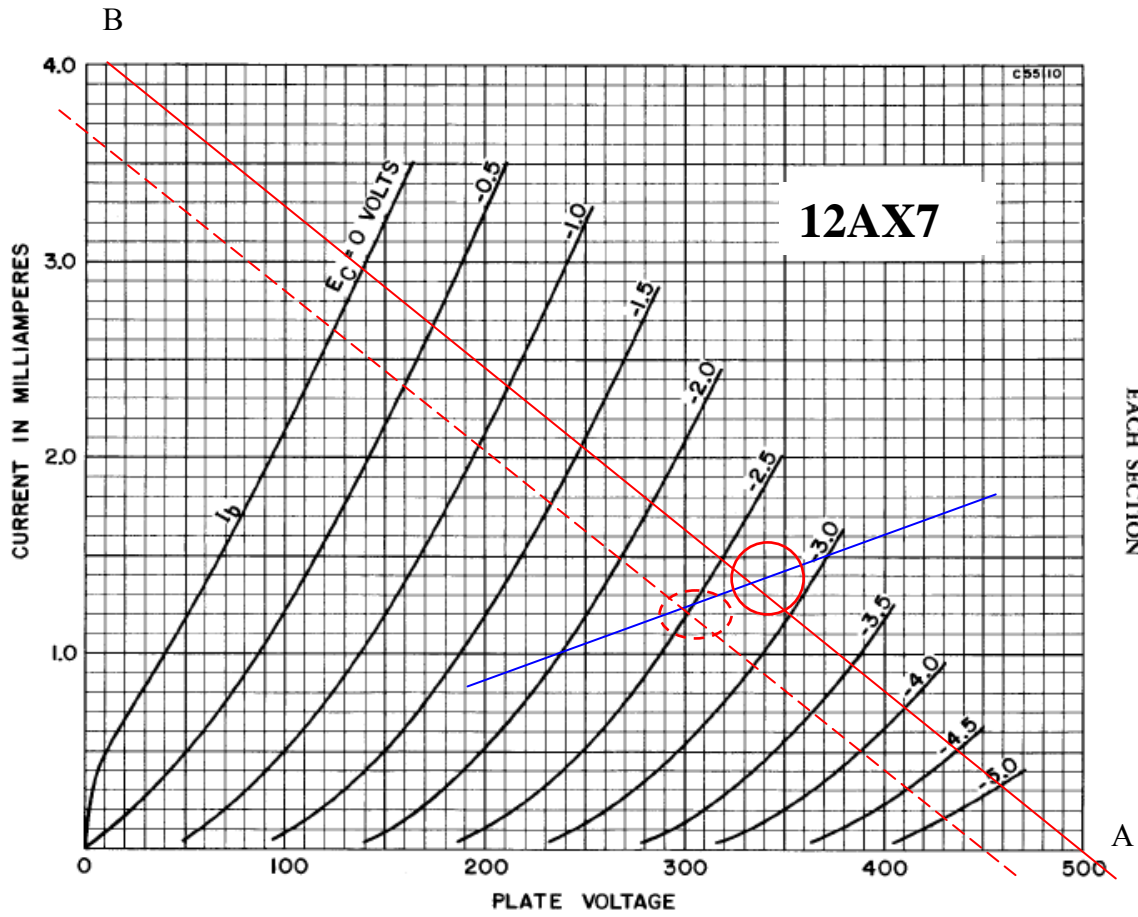
The analysis by Kuehnel shows that the gain of each triode is slightly different, due to a small level of common-mode gain adding to the out-of-phase output but subtracting from the in-phase output, which is compensated by lowering the load resistor for the out-of-phase output to $82K\Omega$ nominal. The input voltage swing limit is from the bias point at $V_{gk}=-2.7V$ to $V_{gk}=0V$, which is about $5.4V_{pp}$ or $2V_{rms}$. Referring to the loadline, the plate voltage would swing about $330V$, from about $140V$ to $470V$, with a mid point of $340V$ [$340-140=200V$; $470-340=130V$] which is not too symmetric. This gives a nominal gain of $330/5.4 = 61$.

The small-signal voltage gain G is about $30x$. Hence, the signal voltage swing available to each control grid of the output stage is up to $2.7V_{pk} \times 30 = 81V_{pk}$, which exceeds the output stage's requirements of about $60V_{pk}$ max. The voltage gain remains effectively constant as the supply voltage sags – this is shown more clearly in the 7025 datasheet. The input loading of the output stage will reduce the output voltage swing – the $220k$ bias resistors will load up to $0.4mA_{pk}$.

The rated output voltage at the feedback winding is nominally $\sqrt{(100W \times 15\Omega)} = 39V_{rms}$. The feedback voltage from the output is attenuated to 10% ($3.9V_{rms}$) by the $4K7$ and $47K$ divider, with a single pole roll-off at $f = 34Hz$ due to the $0.1\mu F$ cap bypassing $4K7$.

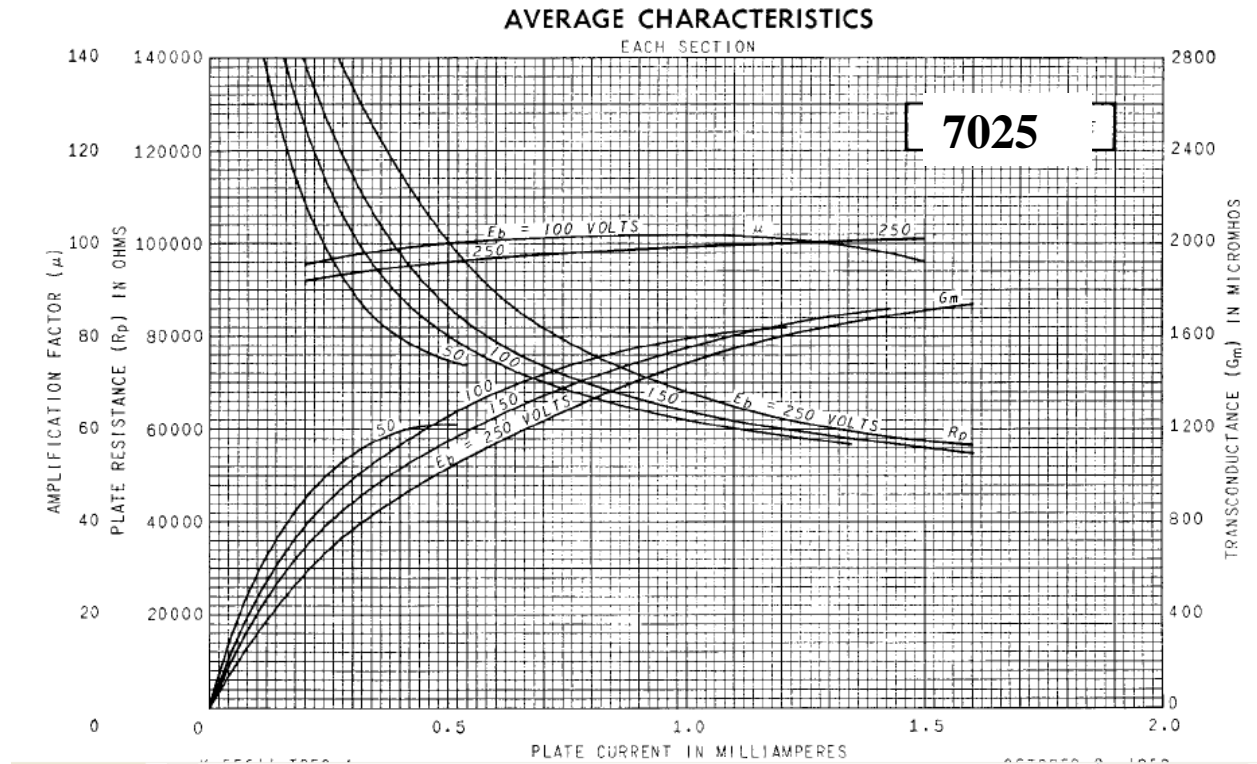
The 12AX7 was a common valve, with manufacturers such as RCA, Sylvania, GE and Tung Sol. The 'A' version has tighter heater tolerances to allow it to be used in series heater connections. The ECC83, 7025 and CV4004 are equivalent and interchangeable, and the 7025 was a low hum version. VASE used the 12AX7 as a typical preamp tube (eg. Trendsetter 100 Deluxe).

The operating values in this section are based on the original circuit conditions. The modified amp has V_{S5} lower at $400V$, due to addition of input 12AX7 – the $22k$ dropping resistor could be reduced to return to original voltage levels.



Parameter	No signal	Heavy load	Notes
R_L	100k	100k	
V_{supply}	520V	460V	$= V_{R_{Load}} + V_P + V_k$
I_p	1.4mA	1.25mA	From bias position
V_{gk}	-2.8V (-2.8V)	-2.5V (-2.5V)	From bias position $= I_p \times 2 \times 1K\Omega$
V_k	32V	29V	$= 6.8K\Omega \times 2 \times I_p$
V_p	350V	300V	$= 521V - 32V - (100K\Omega \times I_p)$
r_p	65k Ω	65k Ω	$= \Delta V_{pk} / \Delta I_p$
G_m	1.5mS	1.5mS	$= \Delta I_p / \Delta V_{gk}$
μ	102 [98]	98 [98]	Graph [= $g_m \times r_p$]
G	~30	~30	$= (u/2) \times R_L / (R_L + r_p)$
B	.1	.1	$= 4K7 / 47K$
Headroom	5.6Vpp	5.0Vpp	

Table 1. Phase Splitter Analysis Results for 12AX7



4.4 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 (class A) where both tubes conduct equivalent levels of current. The cathodes are grounded, and each tube operates in a fixed negative gate voltage bias mode. The 3K1 Ω impedance plate-to-plate OPT from Ferguson (OPM013A) presents each tube with a 1550 Ω load impedance around cross-over, moving to an 775 Ω load impedance (Class B) at high signal levels - with a resistance matched secondary load.

Guitar amp doesn't need the 40Hz low frequency response limit (OPM13A spec level for 55W), so significantly higher signal levels at higher frequencies can be accommodated before core saturation becomes excessive, as long as duty cycle is moderate.

The design maximum output valve bias current allowed for the KT88 is: $I_{bias(max)} = P_d / V_b = 25W / 500V = 50mA$. The gate bias voltage required for this current is significantly influenced by the screen voltage (ie. $\sim -18V$ at $V_s=200V$; $\sim -32V$ at $V_s=300V$), however tube graphs are not available for higher screen levels, but can be inferred. At idle, the PA100 operates the screen at close to the plate voltage ($\sim 495V$), and the gate bias voltage needs to be adjustable down to $-65V$ at least.

As the output loading increases, the supply voltage V_{S1} to the output valve plates sags from about 505V to as low as 460-470V. Effective plate voltage will be lower than V_{S1} by an amount up to $\sim 18V$ due to OPT half resistance plus cathode sense of about $36+10=46\Omega$ with a peak current of up to about 0.4A.

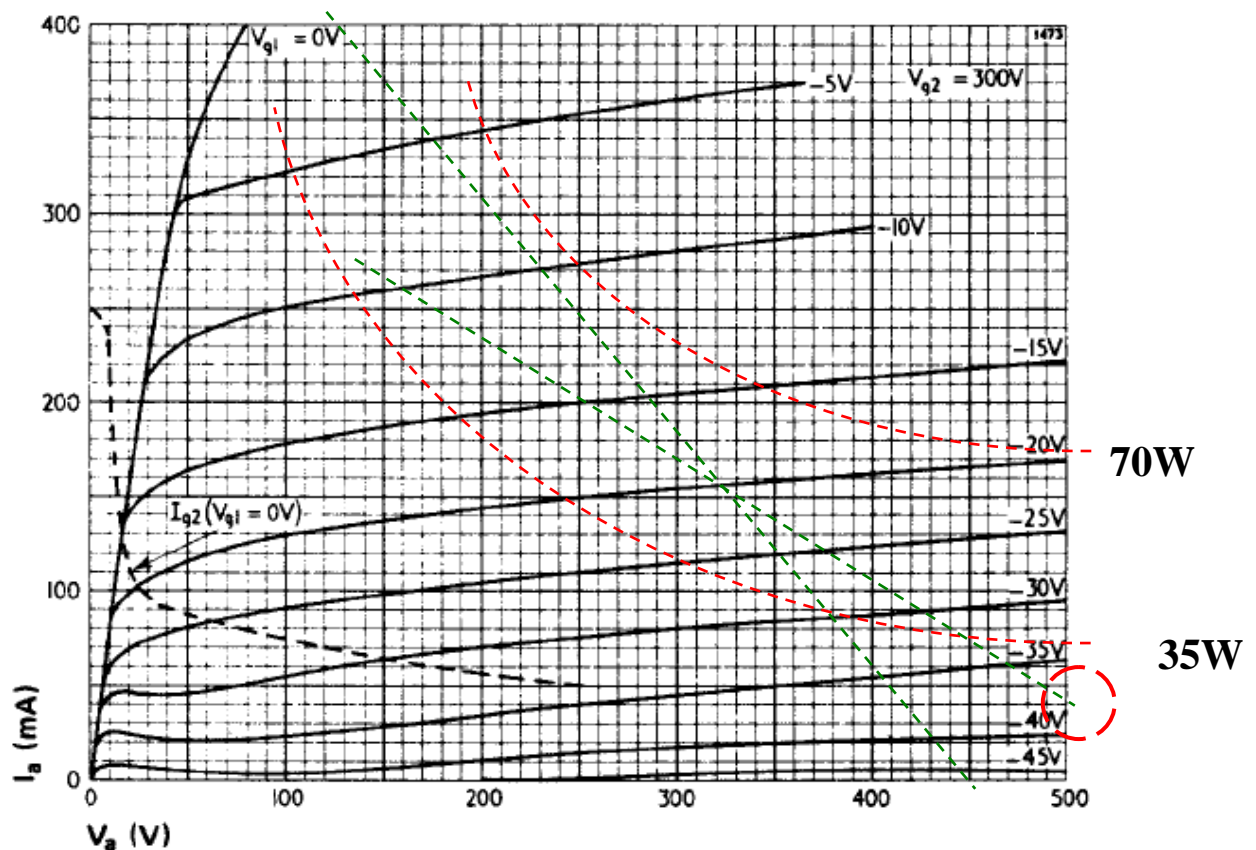
The screen supply capacitance on V_{S2} is significantly less than the plate supply capacitance and so screen supply $V_{S3}=V_{S2}$ will likely track fairly closely with V_{S1} as output loading increases. Screen current level also increases as V_g approaches 0V, possibly to over 100mA, which lowers V_{S3} by an additional $560\Omega \times 0.1A = 56V$. The voltage at the screen is further lowered by an additional $\sim 20V$ across the screen stopper resistor, hence the screen voltage may sag down to about $465V-56V-20V = 390V$ level.

The following graph shows the characteristic curves for KT88 with a fixed screen voltage of 300V. The curves for screen voltage = 375V will be somewhat similar but expanded vertically. The initial loadline trajectory is along a 1550 Ω loadline for small signals where both tubes are conducting – the loadline going through the 40mA/505V bias point. The final loadline trajectory for heavy loading (high plate current) is along a 775 Ω loadline – this loadline is aligned with the sagged effective plate voltage of about 450V, and extends out to the 0V gate level. This 775 Ω loadline indicates a peak plate current of 400mA would be needed for input grid voltage reaching 0V (possibly a bit higher given the available screen voltage level).

For a peak plate current of 400mA, then the nominal output power of the amplifier would be: $(I_{pk})^2 \times R_{pp} / 8 = 0.4 \times 0.4 \times 3k1 / 8 = 62W$. For this maximum signal condition, the rms OPT current draw is likely about 256mA (64% of peak), and the average V_{S1} power consumed is about $470V \times 0.256A_{rms} = 120W$, and the OPT loss is about $(0.256)^2 \times 72\Omega = 5W$, so the tube plates dissipate $120 - 70W - 5W = 45W$, or just under 23W each, which is about the max design level.

During dynamic conditions, the plate dissipation mostly exceeds the 35W power contour curve shown on the graph. 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.



The general textbook design process involves choosing a suitable OPT plate-plate impedance to position the $V_g=0$ and maximum plate current point at the ‘knee’ of the $V_g=0$ curve on the plate current-voltage graph. This knee position has a net minimum level of 2nd and 3rd harmonic levels, where moving away from the knee by increasing the load impedance will increase the 3rd harmonic level, and decreasing the load impedance will increase the 2nd and lower the 5th – which is generally perceived as the preferred outcome. Many amps reduce the screen grid voltage to align the loadline with the knee for a given primary impedance. As the screen grid voltage is raised or lowered, the characteristic curves expand or contract in the vertical direction. An optimum screen voltage is the one that places the knee of the $V_{g1} = 0$ curve on the load line. Operating into the knee region also maximises the output power available from the amplifier into a given loading – below the knee the max available current swing diminishes, and above the knee the max available voltage swing diminishes.

The graph above indicates the achieved loadline is likely to be below the knee, given that a $\sim 375V$ screen voltage would expand the curves upward quite significantly. As such, running a speaker with a lower than nominal output impedance (say 4-6 Ω compared to 8 Ω) would increase the loadline slope to align better with the anticipated knee – this would then require $> 400mA$ pk plate current, and increase plate dissipation, but hopefully shouldn’t push the tubes too close to the 35W max average level. Also, screen voltage sag could be increased by raising the screen stopper above 220R to move the knee down on to the loadline.

The graph also indicates the available plate voltage excursion is about $450V-100V=350V$ pk. This would transform to a $(350+350)/19.4 = 36V$ pk across an 8 Ω load, or 80Wrms output.

4.5 Power Supplies

Primary changed to orange/250V tap – to give 6.2V and 540VDC VS1 with 240VAC mains level. 48mA & 46mA. Primary taps red/240V and brown/230V not used. Secondary taps white/183V and yell-blk/173V not used. Blue to yell secondary 193V winding used.

The effective source resistance is comprised of the reflected power transformer primary resistance = $5\Omega \times (193/250)^2 = 3\Omega$; plus the secondary resistance = 5Ω ; plus cold NTC NTH13D160LA 16Ω , to sum to 24Ω .

Standby power switch turns on valve heaters, output valve gate bias, and transistor section power supplies first (turn-on surge limited to transformer and heater in-rush). A pre-charge resistor (what appeared to be a charred 20X 2W resistor) provides some pre-charging of HT power caps to minimise in-rush when switching from standby to on, and the output valve screens are disconnected in standby. Initial voltage across the standby resistor after power turn-on is about 300V during diode conduction with discharged VS1 caps. Given nominal 2W rating then resistance should be around $R = V^2/P = 45K$. Replace with 3x 10K PRO2 resistors in series. VS1 caps charge to ~130V level in standby.

A 9 ohm 12W resistor placed in series with HT secondary, to limit peak diode current to $((200 \times 1.4) - 127) / (9 + 5) = 11A_{pk}$, as secondary resistance is only 5 ohm.

The KT88 grid bias resistors are originally 220k. The datasheet recommends 100k max for high dissipation applications, and 220k max for lesser duty. The resistor values were lowered to 100k in the modified amp.

The power supply circuit is almost identical to the VASE Trandsetter 100 Deluxe, and differences may be due to prevailing design rules at the time and what parts were available.

The main 200uF supply caps are increased to 470uF in series.

Heater current on 4A winding is $1.6 + 1.6 + 0.3 + 0.3 = 3.8A$.

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 hence will de-energise due to gross failure of the bias power supply. From a 65V rail, the dropping resistor can be sized for $(65 - 35) / 4.2K = 7.1mA$, and so is $30V / 7.1mA \sim 3.9K$. The coil loads the power supply, and the bias supply needed to be modified to manage the extra load by changing the input to the stepup transformer from 3.3VAC to 6.6VAC, and adding 68V + 4V7 zeners to constrain the peak level, and secondary winding resistance to minimise diode noise. 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. Relay turn-on is at about 190VAC, VS8~58V.

5.2 HV breakdown

If the B+ rail shorts to ground, due to a flashover, or insulation breakdown, then a 0.5A fuse in the transformer secondary line would be a good choice to provide gross failure protection by de-energising both the plate and screen rails.

5.3 Output open circuit

Add a 750R 5W resistor (2W diss at 100W output) to the 15 Ω output tap, to act as a high resistance limit in case the speaker load goes open circuit. Unfortunately can't wire the 6.5mm output jack with tip switch connected to 0V, to short the output if no speaker is connected, as the sockets don't come with a switch.

6. Testing and Faultfinding

If a problem occurs then remove valves carefully first; then gently remove chassis from wooden enclosure (4 bolts into base); then turn upside down. Connect dummy 8 Ω load – or speaker - to a speaker connector.

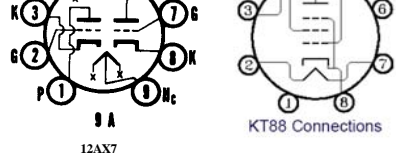
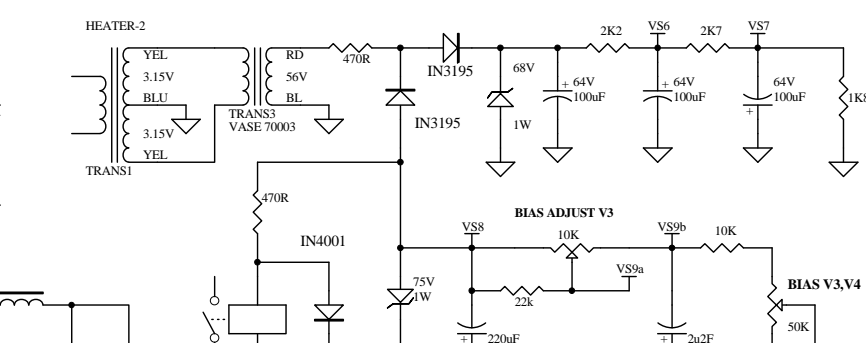
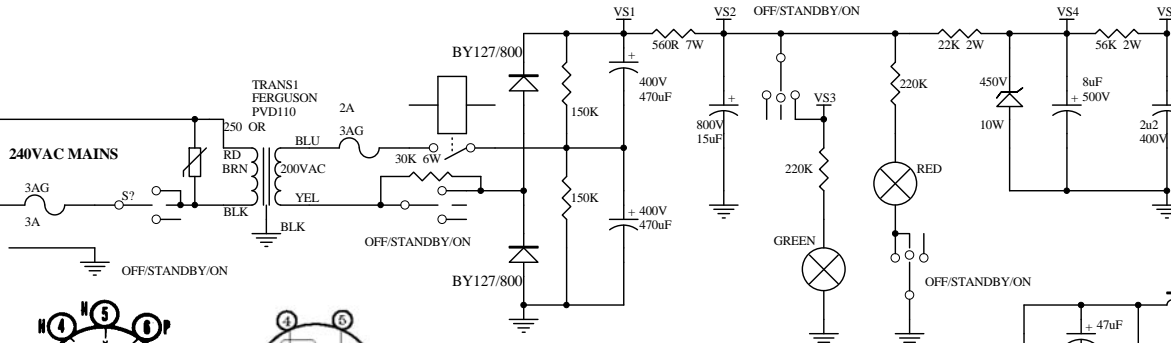
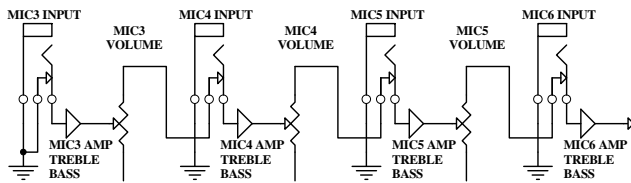
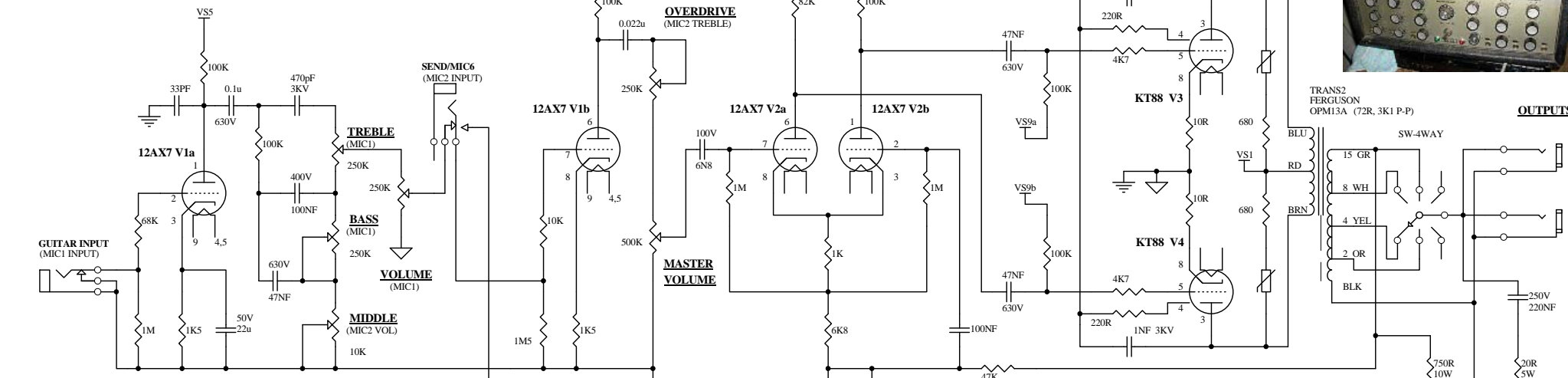
Check AC cable and connector earth pin are good. Check standby/power switch is off and connect AC power. Turn on to standby only and check voltages against table or schematic levels.

If nothing obvious then turn power ON and check VS1 level, then check KT88 cathode current using multimeter measuring voltage across 10 Ω sense resistors (0.4V for 40mA). If ok then check VS1 voltage.

If ok then apply input test signal and check for amplified signal at gate of V1b, and then at gate of V2a – but check volume pot settings.

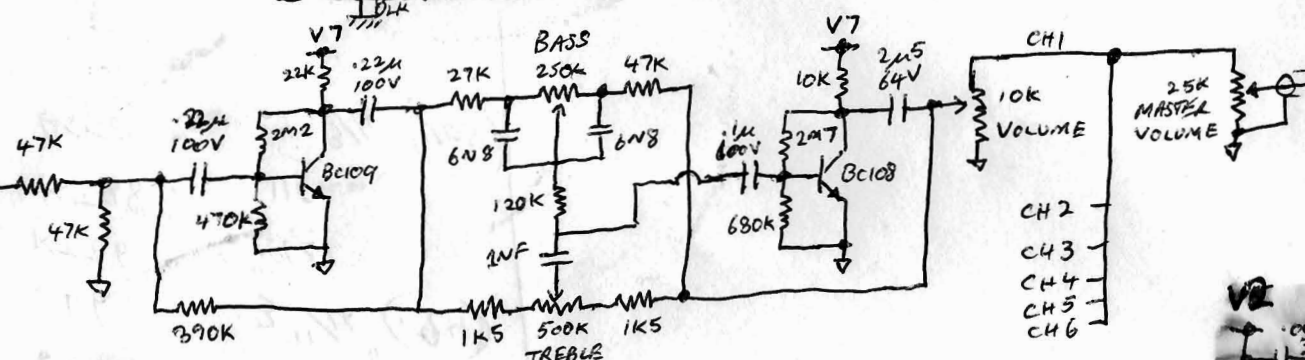
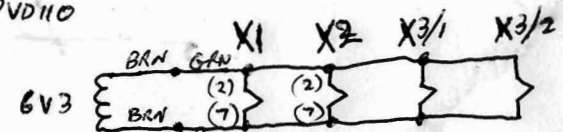
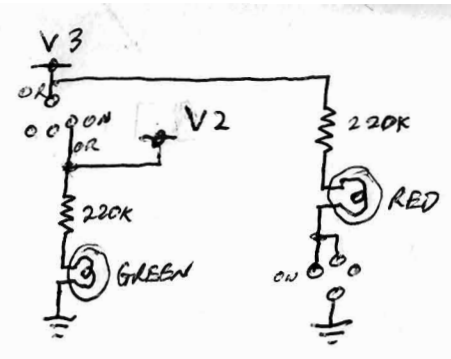
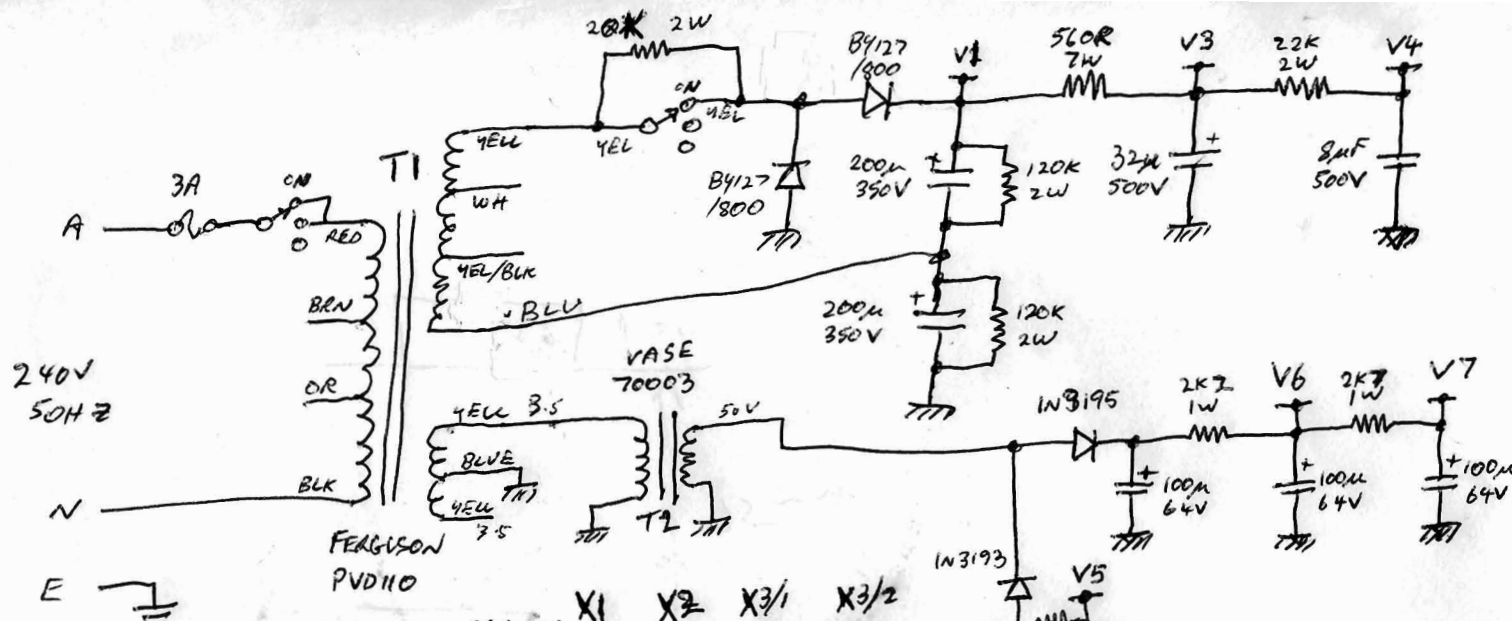
Make sure valves are not in amp when removing or inserting chassis from enclosure.

**VASE AMPLIFIER TYPE P.A.100
MODIFIED - GUITAR AMP**



VOLTAGE RAILS	NO LOAD	VALVE	QTY	BASE	DESIGNATORS
VS1	510V	KT88	2	9A	V3, V4
VS2	500V	12AX7	2		V1, V2
VS4	400V				
VSS	285V				
VS8	-73V				
VS9	-58.62V				
HEATER-1	6.6V				
HEATER-2	6.6V				

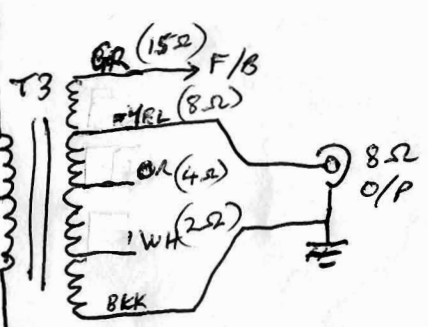
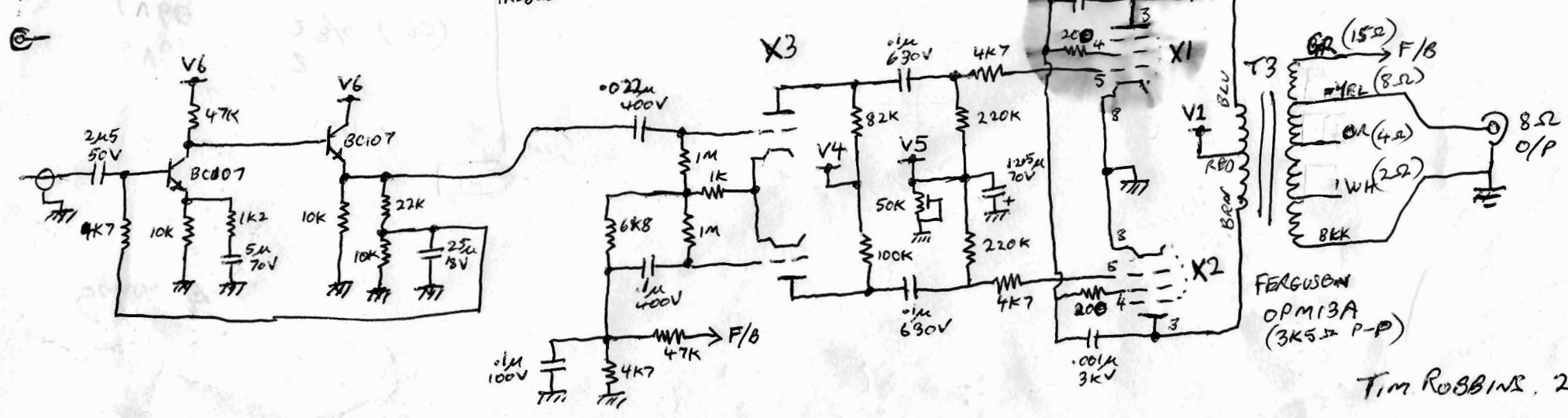
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Tim Robbins, 2009