1. Summary

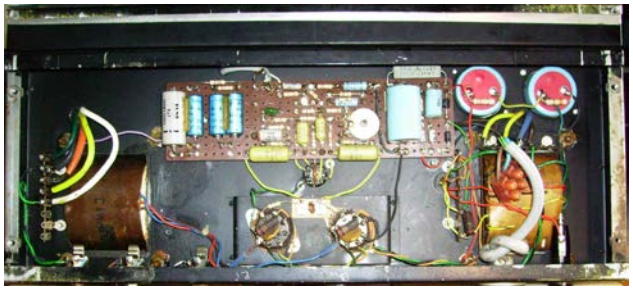
VASE PA100, S.N. 116/100/ T. 6 microphone input channel mono PA amplifier.
Jan 2009. Purchased without valves.

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

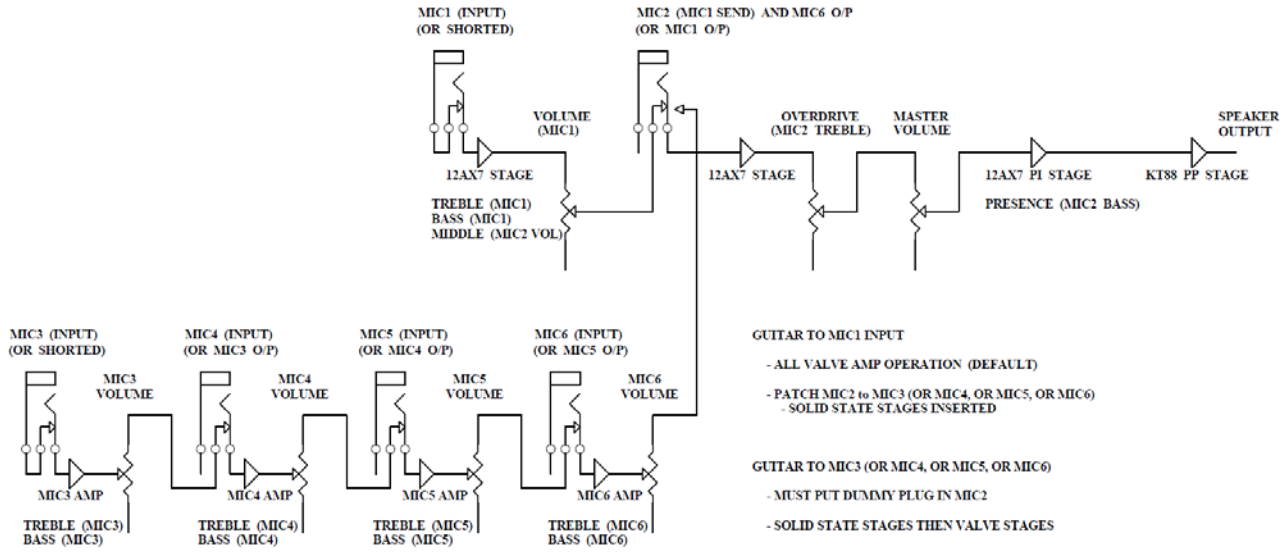
- Restored the XLR mains socket with new insert, and made new mains connection cable with XLR plug. But then replace socket with IEC / fuse combo socket. Removed 3AG existing mains fuse.
- Added NTC 15R cold, 1.7A max, to secondary winding to reduce turn-on diode and fuse stress.
- Added 5x20mm PT secondary fuse holder to rear panel (1A IEC T).
- Added 1R 0.4W cathode sense resistors for bias adjustment, and as poor man's fuse, and added parallel 150V Zener for cathode protection..
- 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.
- Channel 1 and 2 circuit boards disconnected. Channel 3-6 boards with commoned ground, and single 10ohm connection to local chassis – all socket grounds disconnected except for single link. 1uF +V bypass added to each board.
- Included metal shield between TRANS2 and V1 to suppress feedback coupling.
- Reduced output stage coupling cap from 0.1uF to .047uF.
- Star grounding, and connected Noval spigots to gnd. Added 450V zener across VS4, and 220k across VS5, to limit filter cap and 12AX7 voltage and reduce variation due to output loading.
- Isolated heater winding and added humdinger 200Ω pot, with 82k across heater to ground to supress heater-cathode voltage if humdinger fails from anode-heater arc-over.
- 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 1x ¼" locking socket and 1x Speakon socket wired in parallel. Added a fixed-position selector switch for 2Ω, 4Ω, 8Ω and 15Ω winding.
- MOV (~560VDC) and 680Ω from each anode to VS1 for protection.

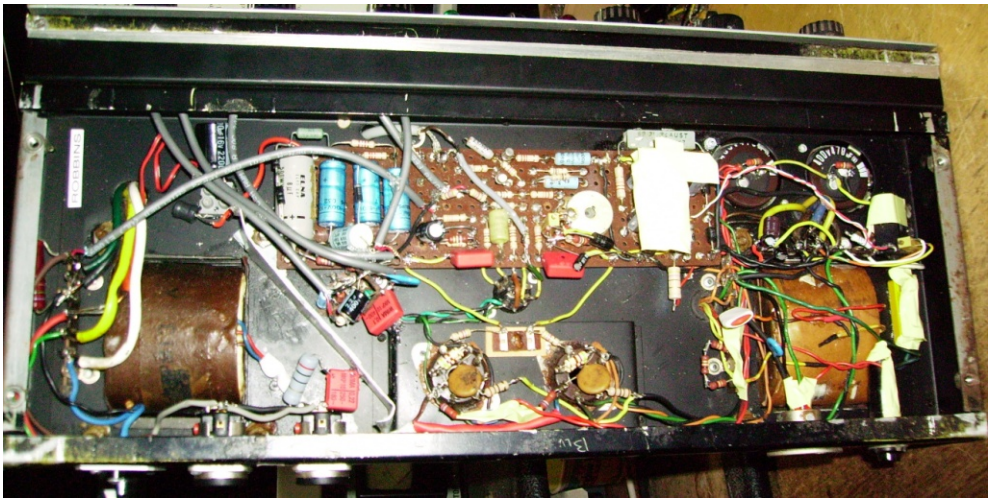
Future modifications could include:

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

- Swap noisy pots (MIC2 VOL, MIC3 VOL, MIC5 VOL, MIC6 VOL, MIC2 BASS if possible – contact cleaning doesn't improve issue much).

Modified Control Diagram





3. Measurements

Transformer primary = 5Ω; secondary HT = 5Ω. Megger ~ 400Meg at 1kVdc.

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 200mA 2.5k	468V 156W 330mA 1.5k	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.

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.

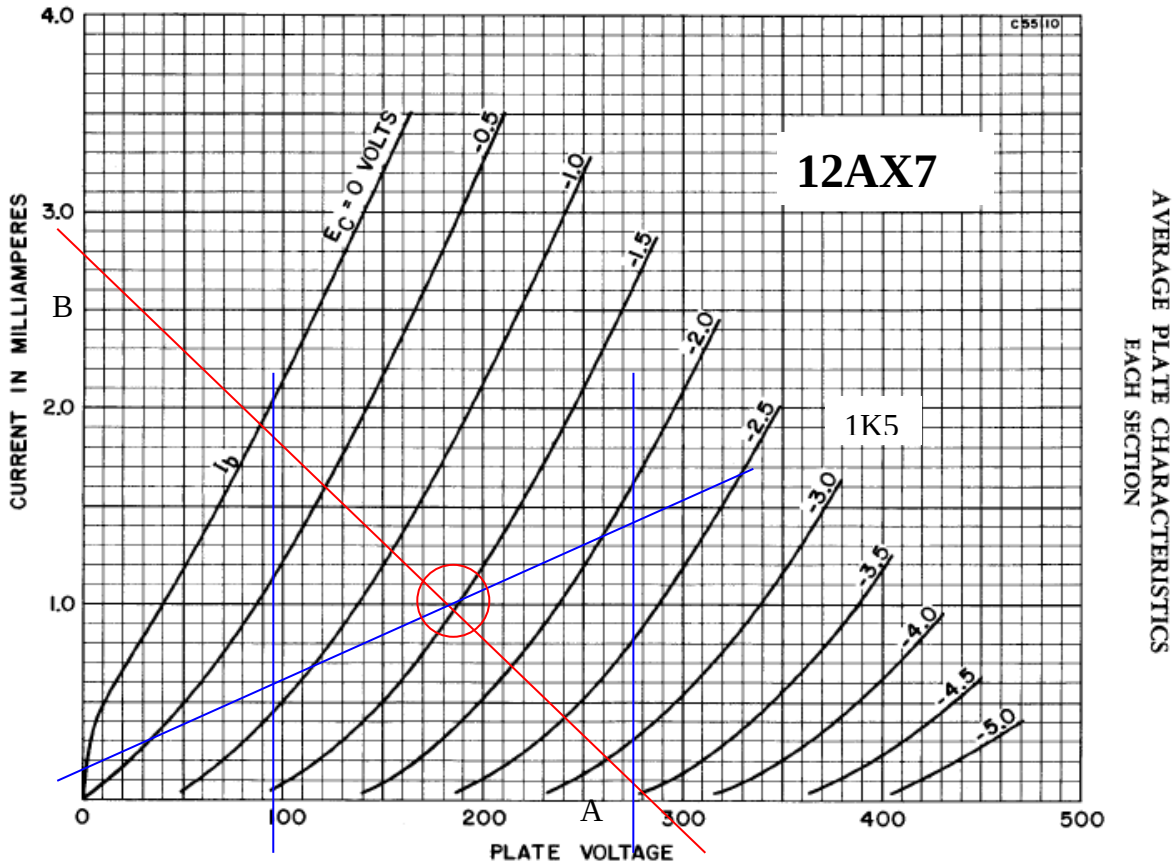
4.1 Microphone preamps and PI driver

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=1.3mA, so 2k7 x 6x1.3mA = 21V drop from VS6 to VS7. PI driver draws 0.4+2.0 = 2.4mA, so 63V supply drops to VS6 is 2k2 x (2.4+6x1.3) = 22V.

Each mic stage has voltage gain of about 4.

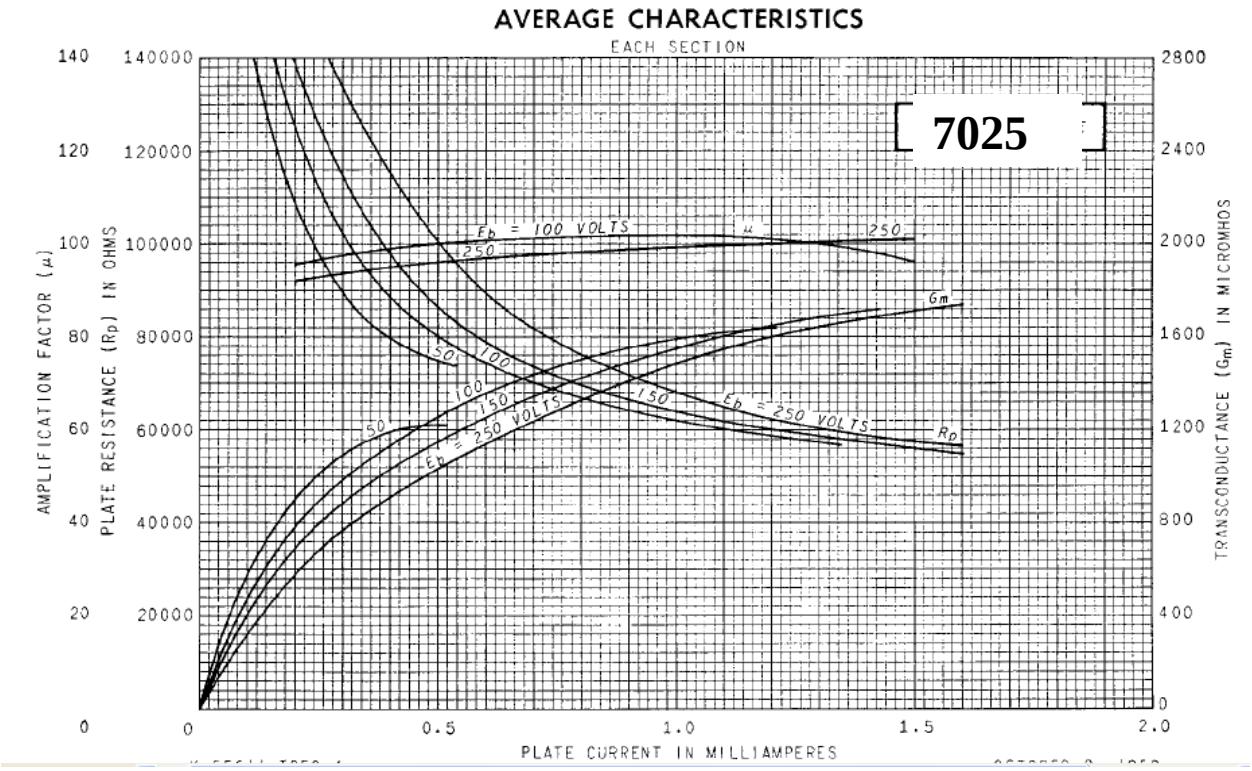
4.2 Input Gain Stage

This stage is not original. A 12AX7 was added to the chassis. For the first half 12AX7, V1A, we have plate voltage Vp = VS5 = 280V; Va=180V; Rk=1k5; Vk=1.4V; Ia=1.0mA; RLdc=100k.



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.



4.4 Output Stage

This is a Class AB push-pull fixed-bias output stage. The 3K1Ω impedance plate-to-plate OPT from Ferguson (OPM013A) presents each tube with a 1550Ω load impedance around cross-over, moving to an 775Ω load impedance (Class B) at high signal levels - with a resistance matched secondary load.

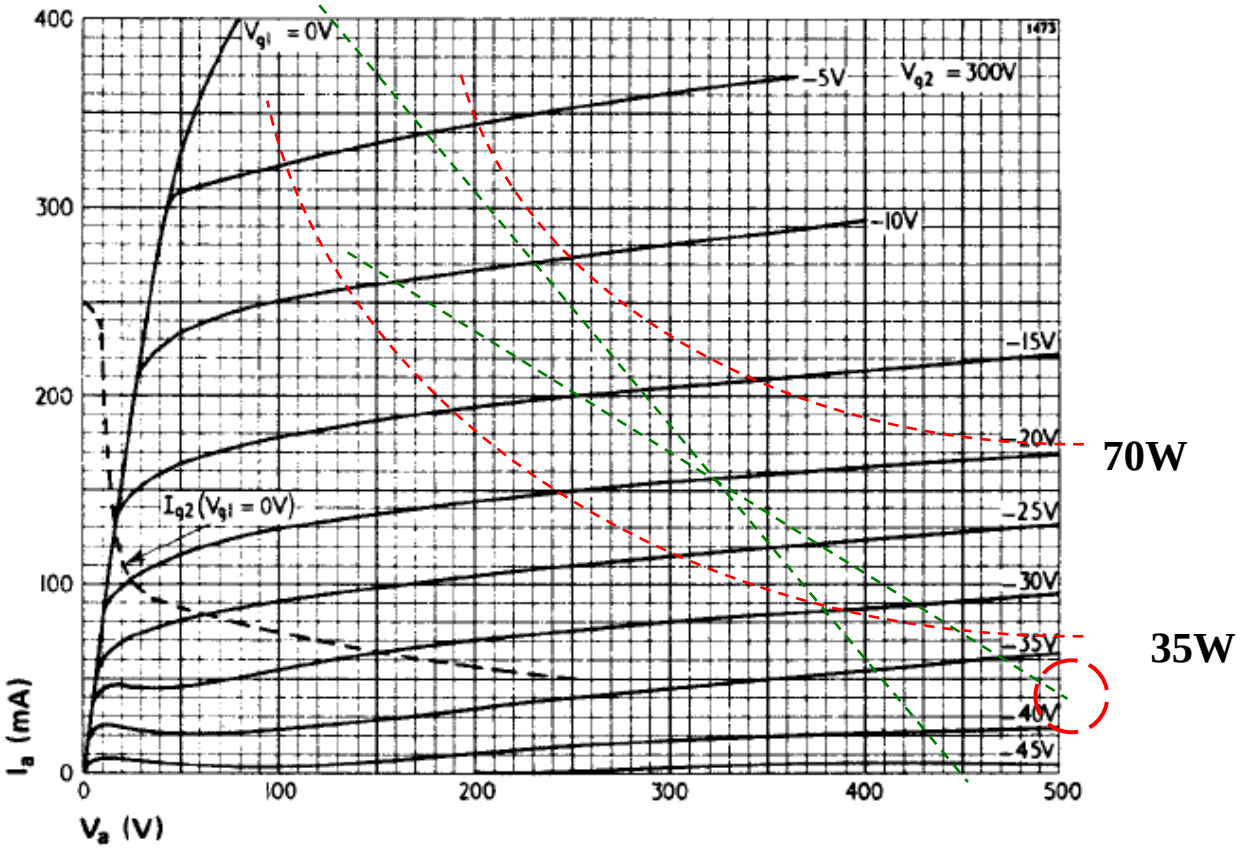
The design maximum output valve bias current allowed for the KT88 is: Ibias(max) = Pd / Vb = 25W / 500V = 50mA. The gate bias voltage required for this current is significantly influenced by the screen voltage (ie. ~-18V at Vs=200V; ~-32V at Vs=300V), however tube graphs are not available for higher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

As the output loading increases, the supply voltage VS1 to the output valve plates sags from about 505V to as low as 460-470V. Effective plate voltage will be lower than VS1 by an amount up to ~18V due to OPT half resistance plus cathode sense of about 36+10=46Ω with a peak current of up to about 0.4A.

The screen supply capacitance on VS2 is significantly less than the plate supply capacitance and so screen supply VS3=VS2 will likely track closely with VS1 as output loading increases. Screen current level also increases as Vg approaches 0V, possibly to over 100mA, which lowers VS3 by an additional 560Ω x 0.1A = 56V. The voltage at the screen is further lowered by an additional ~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 1550Ω 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 775Ω loadline – this loadline is aligned with the sagged effective plate voltage of about 450V, and extends out to the 0V gate level. This 775Ω 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: $(Ipk)^2$ x Rpp / 8 = 0.4 x 0.4 x 3k1 / 8 = 62W. For this maximum signal condition, the rms OPT current draw is likely about 256mA (64% of peak), and the average VS1 power consumed is about 470V x 0.256Arms =120W, and the OPT loss is about $(0.256)^2$ x 72Ω = 5W, so the tube plates dissipate 120 – 70W - 5W = 45W, or just under 23W each, which is about the max design level.



The graph above indicates the achieved loadline is likely to be below the knee, given that a ~ 375V screen voltage would expand the curves upward quite significantly. As such, running a speaker with a lower than nominal output impedance (say 4-6Ω compared to 8Ω) would increase the loadline slope to align better with the anticipated knee – this would then require > 400mApk 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=350Vpk. This would transform to a (350+350)/19.4 = 36Vpk across an 8Ω 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 = 5Ω x $(193/250)^2$ = 3Ω; plus the secondary resistance = 5Ω.

An NTC NTH13D160LA with 16Ω cold resistance is inserted in transformer secondary HT winding, in series with secondary side fuse, protection relay contact, and standby/on switch. In standby, the NTC will only conduct about 7mA, and so will cool down if hot. The max NTC operating current is 1.7A at 55C, so NTC will only operate at up to 50% of max rating.

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 ~100V level in standby.

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.

Doubler rectifier with 120mA hot load on 530V VS1. Max anticipated continuous VS1 load current about 200mA. IEC60127-2 1A Time-delay fuse, as max continuous winding current could reach about 860mArms. This in-rush is mitigated by the NTC in primary winding.

Simulate period in PSUD2	20ms	40ms	100ms	500ms	continuous
Simulated RMS current	11.2A	8.4A	5.4A	2.5A	0.86A
Multiplier (based on 1A fuse rating)	11.1	8.4	5.4	2.7	0.86
IEC60127-2 Time-delay min limit multiplier	10	~7	~4.8	~2.9	1

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 ~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 1A 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.

If a pin 2 to pin 3 arc causes the humdinger pot to fail, an 82k resistor to ground will hopefully limit the heater voltage rise.

5.3 Output open circuit

Add a 750R 5W resistor (2W diss at 100W output) to the 15Ω output tap, to act as a high resistance limit in case the speaker load goes open circuit.

5.4 Output stage over-current protection

A loss of bias to a KT88 may cause a continuous cathode current of up to 0.4-0.5A. The 1Ω 0.4W sense resistor may not act as a fuse for that current. An internal short from screen to grid would likely cause a larger current and blow the resistor. A 150V Zener across the 1Ω resistor provides protection to the cathode-heater interface.

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 8Ω load – or speaker - to a speaker connector.

Connect meter module to McMurdo 5-pin connector for VS1/100, and output stage cathode current sensing.

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 1Ω sense resistors (40mV 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

GUITAR INPUT (MIC1 INPUT)

12AX7 V1a

TREBLE (MIC1)

BASS (MIC1)

VOLUME (MIC1)

MIDDLE (MIC2 VOL)

SEND/MIC6 (MIC2 INPUT)

12AX7 V1b

OVERDRIVE (MIC2 TREBLE)

MASTER VOLUME

12AX7 V2a **12AX7 V2b**

PRESENCE (MIC2 BASS)

KT88 V3 **KT88 V4**

V3 Sense V4 Sense

BIAS 1mV=1mA McMURDO

TRANS2 FERGUSON OPM13A (72R, 3K1 P-P)

OUTPUTS

SW-4WAY

Feedback

MIC3 INPUT / MIC3 VOLUME / MIC3 AMP TREBLE BASS

MIC4 INPUT / MIC4 VOLUME / MIC4 AMP TREBLE BASS

MIC5 INPUT / MIC5 VOLUME / MIC5 AMP TREBLE BASS

MIC6 INPUT / MIC6 VOLUME / MIC6 AMP TREBLE BASS

HEATER-1 TRANS1 BLK 6.3V GRN

HEATER-2 TRANS1 YEL 3.15V BLU 3.15V YEL

TRANS3 VASE 70003 RD 56V BL

OFF/STANDBY/ON

240VAC MAINS IEC/FUSE COMBO

TRANS1 FERGUSON PVD110 1A IEC T 1.5A IEC T

G2R-2 48V (pulls in at 190Vac mains)

BIAS ADJUST V3

BIAS V3,V4

SET BIAS FOR 45-50mA on V3 and V4

6.3VAC Heater 2

50mm FAN

12AX7

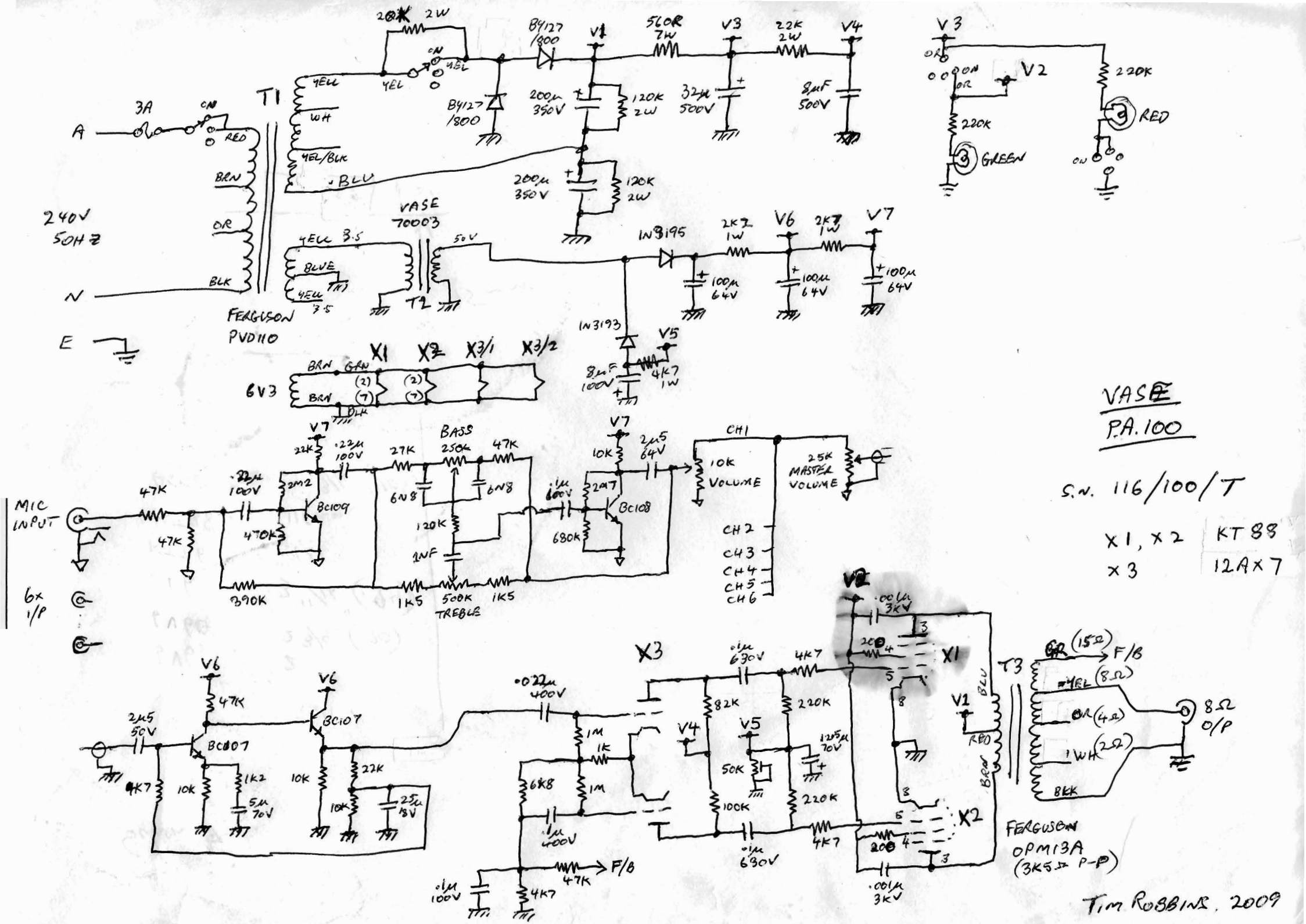
KT88 Connections

VOLTAGE RAILS

RAIL	NO LOAD
VS1	510V
VS2	500V
VS4	400V
VS5	285V
VS6	31V (TO DISCONNECTED MIXER STAGE)
VS7	15.5V (TO MIC3-MIC6 STAGES)
VS8	-73V
VS9	-58,62V
HEATER-1	6.6V
HEATER-2	6.6V

VALVE	QTY	BASE	DESIGNATORS
KT88	2	OCTAL	V3, V4
12AX7	2	9A	V1, V2

Title		
Size B	Number	Revision
Date: 15-Apr-2020	Sheet of	
File: C:\Users\robbins\AppData\Local\VirtualStore\Program Files\Design Explorer 99 SE\Examples\Pr	Drawn By:	


VASE
P.A. 100
S.N. 116/100/T
X1, X2 KT88
X3 12AX7
TIM ROBBINS. 2009
FERGUSON PVD110
FERGUSON OPM13A (3K5Ω P-P)
VASE 70003
240V 50HZ
MIC INPUT
6x I/P
8Ω O/P
CH1
CH2
CH3
CH4
CH5
CH6
10K VOLUME
25K MASTER VOLUME
BASS
TREBLE
BC109
BC108
BC107
BY127/800
IN3195
IN3193