1. Summary

Radio Television & Hobbies 100W PA Amplifier. $65 eBay Sept 2011.

July 1960 magazine kit – built circa 1964. MIC & PU input jacks; EF86 MIC preamp; 6CG7 mixer stage and split-load PI; 6CG7 common-cathode push-pull driver stage with balance pot; KT88 fixed-bias UL PP. 4.5kΩ 100W OPT with 500Ω tapped PA secondary. SS diode doubler with extra LC filter. Full bridge with CLC filtered bias supply & individual bias setting pots. Metering of cathode currents and B+ voltage.

Initial condition:

Good condition. Professional kit build. A few minor mods – VS1, VS2, VS5 electrolytics changed. OPT removed and chassis cut-out for a different OT. Hammertone finish peeling off top. Non-original valves. Meter glass cracked. Mic transformer added. Broken PU socket. KT88 socket pins slack. Heater grounding mixed with signal grounding.

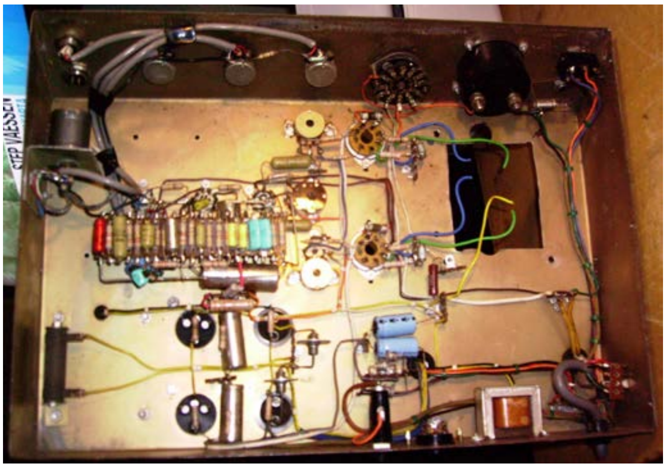
Output Transformer	removed (should be OP413 or similar)
Power Transformer	PF1546, dated 5.62; 0(BLK)-230(GRN)-240(RD)-250V(OR); 0-240V(YEL,YEL) 325mA; 90V(BRN,BRN) 10mA; Electrostatic shield (GRY); 12.6V(YEL,BLU,YEL) CT 4A.
Microphone trans	Zephyr
Chokes	CF448, dated 11.62 . 5H @ 325mA, 60R
	CF447, dated 8.63 . 20H @ 10mA, 950R
Valves	2x KT88 unbranded
	EF86 Philips 8Y3 D0J1
	12AX7 Miniwatt, ?? 4B 391
	12AT7WA, Tk1 R9F .
	Teletron bases
Diodes	2x OA214 (HT supply)
	4x SL775 (bias supply)
Caps	Dubilier Drilitic BR5166 (BR range, 51=500V) (possible date codes TC, SK, TJ); Ducon ET5C (376 date stamp); mustards
POTs	Ducon.
Meter	Master Instruments, Model S21, 1mA 100Ω

Differences from RTV&H July 1960 circuit:

- 50uF EF86 cathode bypass [25uF].
- 1N5 anode to gnd on V5 EF86. V4A anode to gnd cap 1N5. 1N5 bypass on V4B PI 33k legs.
- 56NF coupling caps from V4 PI [47NF]. 560k grid leaks on V3 [470k].
- Tone control moved to grid of V4A [anode].
- SL775 diodes in bias supply [Q8/2].
- 120k bleeders on first filter caps.
- First filter caps 220uF [100uF].
- 22k 5W dropper between VS2 & VS3 [5k 2W].
- Microphone transformer bracket replaces 6-pin socket for mixer/radio.
- No speaker impedance selector switch.

Issues

20W WW resistor in close proximity to input stage, and on winding side with higher peak voltage stress.
Tone control and PU Vol pot wired incorrectly.
6CG7 is not very common (6SN7 equiv), and requires 2x0.6=1.2A of heater.
Microphonics of EF86.
Heater arrangement – cathodyne cathode level – can't use humdinger – unbalanced loading when no mixer/radio.



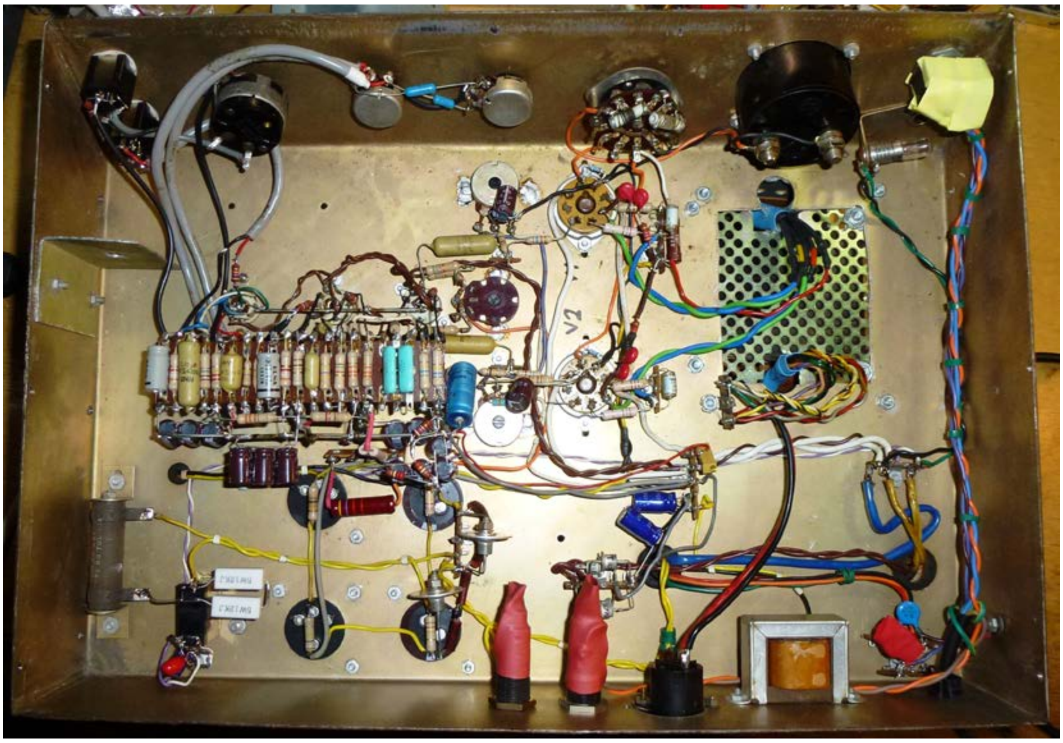
Modifications

- 16R NTC (NTH13D160LA) in series with primary to alleviate transformer in-rush and HT filter capacitor in-rush and diode stress.
- MOV (431KD10) across PT primary to reduce switch stress from turn-off transient.
- Replaced each OA214 diode with 2x UF4007 in parallel.
- Replaced 220uF first filter caps with 470uF 400V caps (up from 100uF original).
- Moved 10R 20W HT damper to capacitor filter mid-point side of winding.
- Added MOV-R (2502 GEAQ, 330VDC x2, 4k7) dampening across each half primary winding on OT.
- Returned 22k dropper to original 5k 2W.
- Removed mic transformer and mic/pickup inputs and added insulated phono jacks with 47k grid stopper and 1M grid leak to V5, EF86.

- Reconfigured P.U. input to go direct to 47k V4A grid stopper, with 1M grid leak, and switched connection to MIC Gain pot wiper from both MIC Gain pot switch and also PU jack switch (when MIC Gain pot is switched off, then no loading / interaction from MIC circuit output).
- Reconfigured P.U. Gain pot to input of V4B PI stage, with using Tone pot as per 18W Lite.
- Removed 1N5 shunts on V5, V4A, and V4B anodes.
- Added 220k grid stopper to V4B PI stage to cope with over-drive. Added 15k grid stoppers to V3 drivers.
- Added 68k protection resistors to 20k pot wipers for V1, V2, KT88 grid bias, and added 4.7uF local bypass to wipers.
- Added 2M2 to each end of driver balance pot wiper.
- Swapped output stage 0.1uF 400V coupling caps to 68nF 630V, as 400V is marginal.
- Reconfigured grounds to distributed stars.
- VS3-VS6 filter caps replaced. Added 11x33V zeners to protect replacement 400V caps on VS4-6 (downstream of 33k).
- Replacement chassis screws, and added rubber feet pads.
- KT88 cathode shunt resistors changed to 1Ω, and meter current range changed to 100mA FS (original 200mA FS range was not aligned with 0-1mA meter display - so not easy to set bias).
- Fitted OPM21A OT using custom chassis cover – 4k5 UL screen at 20% plate impedance – 4x 31.25Ω secondaries.
- Suspended V5 base off chassis.
- Changed to 12A*7 wiring for V3 and V4 (6V3 heater from pin 9 to pins 4/5), so can't use 6CG7. Reduces heater current demand by 2x0.3=0.6A.
- Replaced 8-pin valve socket speaker output connector with Speakon.   Directly wired OT to connector.
- All heaters now on one half (X-Y) of the 12V heater winding, with CT disconnected, and with 200R humdinger pot added and wiper taken to elevated and 100uF bypassed +50V.
- 4k7 5W added in series with HT winding, and bypassed with ~12 sec delay timed relay NO contact for ~280Vdc pre-charge.
- Mains fuse T 5A 3AG.
- Added HT secondary winding fuse, F1.5A.

To do:
- Fit more appropriate fuses: mains T 1.5A 3AG; sec F 0.8A 3AG.
- Cut down MIC VOL pot shaft and fit knob.
- Check pots with speaker.

OP413 is UL 100W 4.5k PP with 500, 281, 125, 31 outputs. Output windings are in 4 equal windings that can be all in parallel (31 ohm) or series (500R), or series/parallel. 31R will suit 2x 16R speakers, or quad 8R. Early OPM21A is OP413 but not UL – later version included UL. OPM21A replacement dated 12-70.




CF448
OPM21A
MIC.
P.U.
MIC. GAIN
P.U. GAIN
TONE
METER SWITCH
H.T. 1000 V.
OFF
V2 100mA
V1 100mA
MAINS
ON
OFF

Measurements

1kV megger test PT ok.

Voltages:

Rail	UL
KT88 bias	mA,mA V, V
VS1	
VS2 B+	670V
VS3	
VS4	
VS5	
VS6	
V1, V2 bias	40+40mA
VS7 bias (raw)	110Vdc, 28mVrms (117Vdc 1.3Vrms)
VS8 bias	
VS9 screen	
Heater	
Sec HT	

Transformer primary = 2.3Ω. Transformer secondary HT = 3.2Ω. [5.5 ohm effective]
Transformer secondary snubber: 10nF; 22nF 290R, 100nF 75R, 200nF 38R.

CF488: 60.3Ω DCR; 10.1Vac: 9.1H 14mA; 8.7H 35mA; 7.8H 99mA; 6.9H 181mA; 5.7H 283mAdc
CF447: 980Ω DCR; 10Vac: 26.8H 2.4mA; 24.1H 5.1mA; 20.2H 8.5mA; 16H 13.8mAdc

OPM21A output transformer primary DC resistance: 20Ω (RED-YEL), 42Ω (RED-BLU); 19.2Ω (RED-OR), 37.8Ω (RED-BLK).
OPM21A output transformer secondary winding DC resistance: 3.1 to 3.7Ω . Four groups: PNK-PUR; WH/BLK-YEL/BLK; GRN-BLK; GRY-RED/BLK.

12VAC 50Hz nominal applied to Zephyr microphone transformer

Winding	Voltage rms	Turns ratio; Impedance for 42K pri; Spec level; Notes
Sec: GRN to BLU	12.45	
PRI: RED to WH	.427	29.16; 49.4 Ω; 50Ω;
Sec: RED to BLU	1.13	11; 346 Ω; 350Ω;

Transformer secondary DC resistance: 5.8Ω (RED-WH), 16.4Ω (RED-WH).
Transformer secondary DC resistance: 1,100Ω .
Frequency response -2dB @~60Hz to 30kHz using 50 ohm input tap. Measured with 47k load and Keithley 197 DVM. Source TMC Low distortion oscillator with 40 ohm output impedance.

Meter indicates 1.00 +/-0.01 for 99.8mV (Aneng 8009) across terminals.

Input stage is clean to >20Vrms output at top of MIC Gain pot, with increasing 2H.

For clean input from input stage, 2nd stage is clean to 33Vrms at top of PU Gain pot, then soft clipping of one side.

Signal at driver stage input grid shows increase in higher order harmonics >7Vrms, but not gross rise out to 18Vrms.

40mA idle output stage provides clean signal to ~48Vrms (70W) then balanced soft clipping, across 34Ω 800W load.

Balance trim provided 2H minima – max clean still about 75W.

240Vac mains 0.6Arms idle, increasing to 1.2A cranked.

Mains surge current at turn on is ~0.8Apk (from PT and heater inrush) and suppressed by 15Ω NTC. With 4k7 5W pre-charge, VS1 rises to ~280V, and mains surge is ~4.0Apk when relay closes (B+ charging and output stage partial loading). KT88 cathode current takes a further ~30 seconds to rise up to idle level. Mains current measurements taken with LEM LA25-NP into TEK TPS2012 for one-shot capture, and comparing to Killer-Watt meter.

Then used output transformer (OT-419) from TOA 120W A512A PA amp to match the OPM21A to a 4Ω speaker. OT-419 presents full 100V secondary as 83Ω with the PP primary as 7.2Ω. With the F/B winding (3.4Ω) in series with the 100V sec, then that presents 120Ω, and so is a good match to the OPM21A configured for a 125Ω output, and with a final speaker impedance of 7.5Ω. Using an 8.5Ω load, clipping started at 100Vrms on the 125Ω output of the amp (input to the OT-419), and with 23V on the 8.5Ω 400W load, which is nominal 62W on load, and ballpark 73W at amp output (which aligns with direct 34Ω loading on amp).

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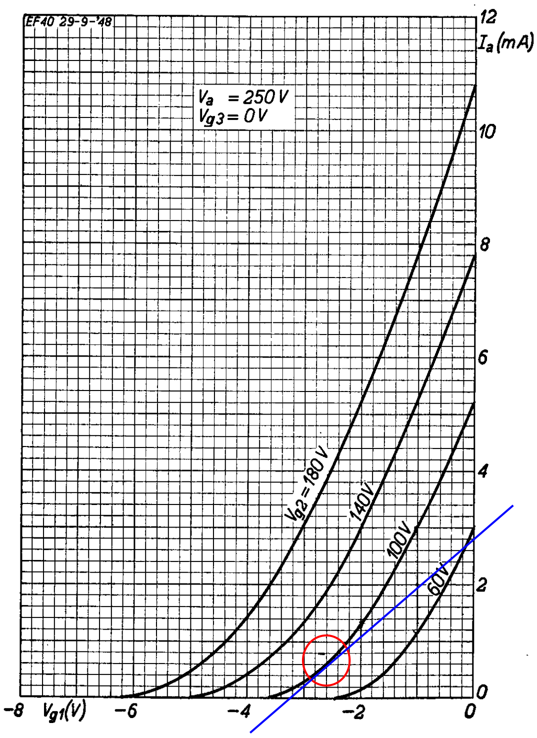
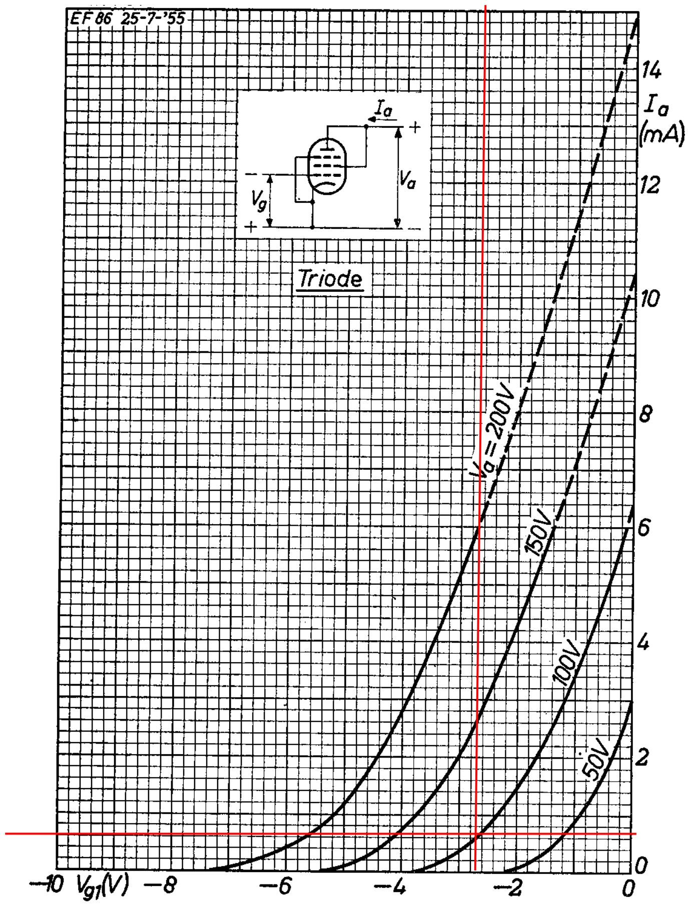
2. Design Info

Input Gain Stage

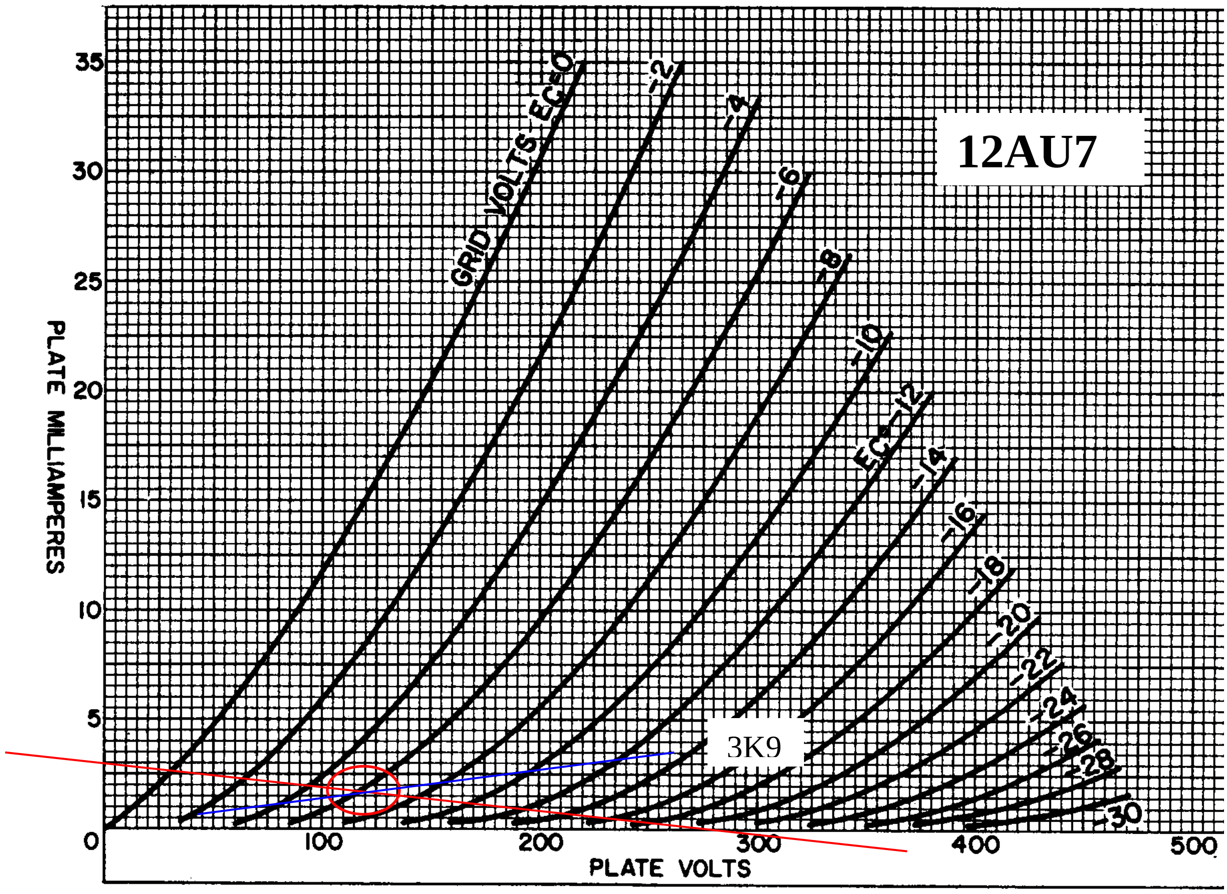
EF86, V5; VS6 = 250V; Rk=3k9; RLdc=220k.
Philips datasheet gives Ia=0.7mA for above conditions when triode connected, and a gain of 30.
Assume anode and screen voltage = 250 – (0.7*220)= 95V. Assume screen current is 22% of anode current (screen resistance 1MΩ), and assume anode current is 0.59mA and screen current is 0.11mA, then effective VS6 is 95+130=225V. Vk= 2.7V. Stage will cope with a bit over 1Vrms before overdrive.





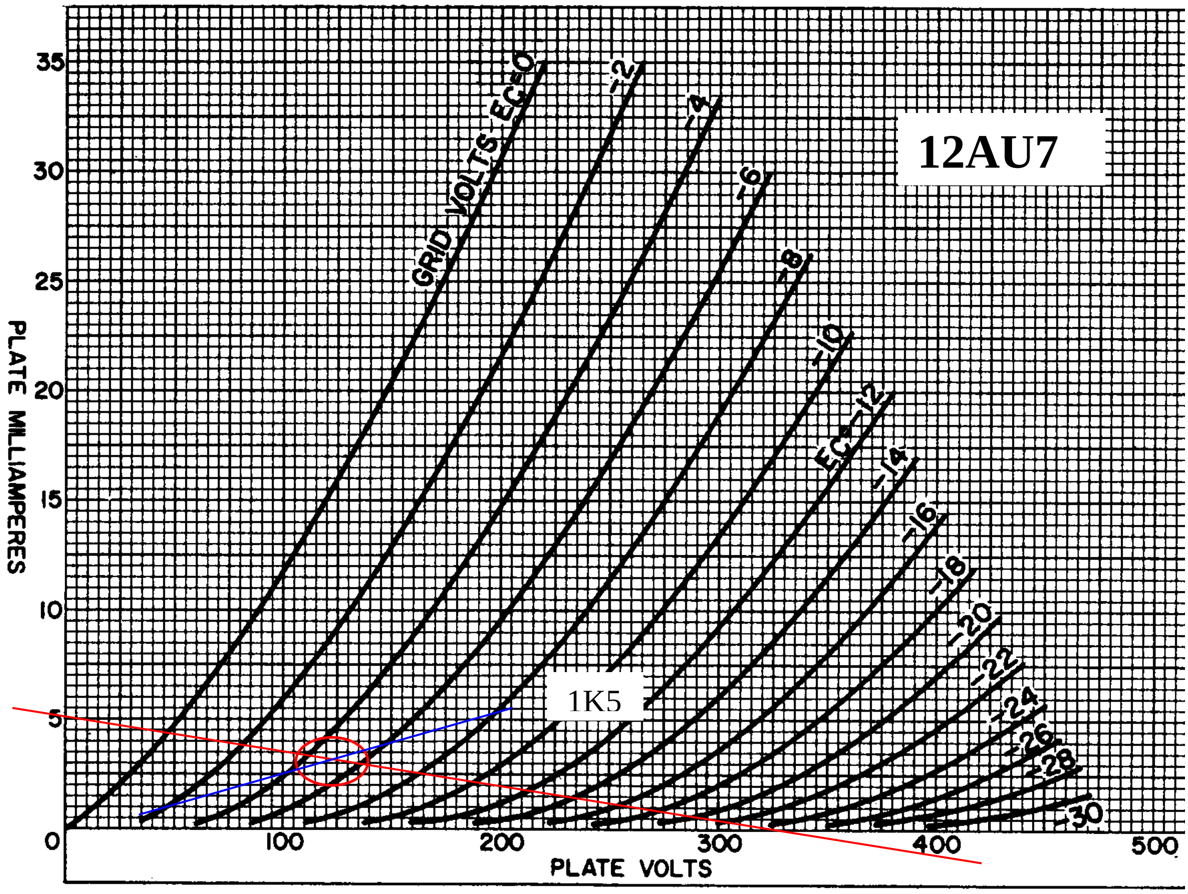
Mixer Gain Stage

12AU7, V4A; VS5 = 270V; Va=120V; Rk=3k9; Vk=6V; Ia=1.5mA; RLdc=100k.



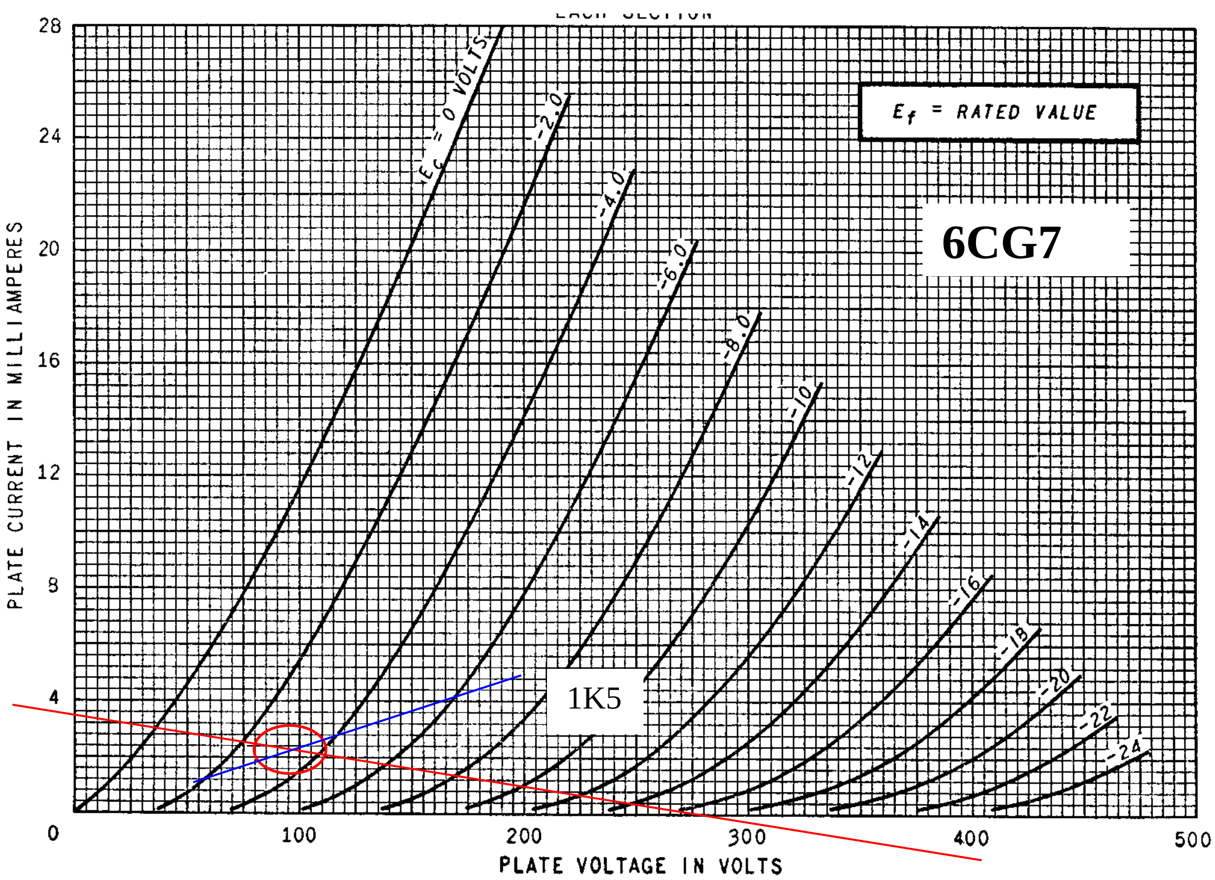
PI splitter stage

Cathodyne PI; 12AU7, V4B; VS4 = 320V; Va-c=120V; Rk=1k5; Vk=5V; Ia=3mA; RLdc=33+33k. Cathode voltage sits at about 100V at idle, which is about max level allowed if heater not elevated. The swings appears to be about 70Vpk.



Wouldn't use a 12AY7 due to low cathode-heater voltage rating.

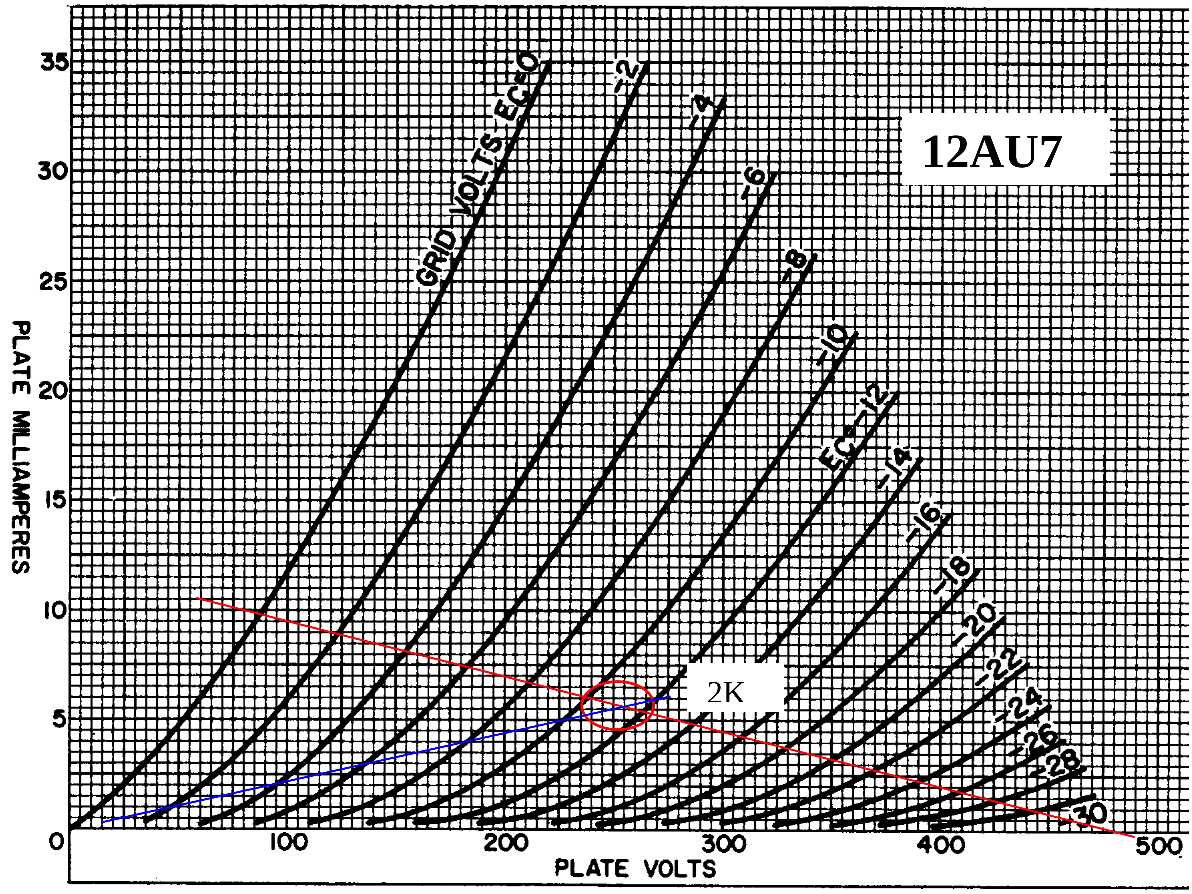
The original 6CG7 design operated the cathode at a bit above 100V, and the available swing of about 60Vpk appears to be lower.

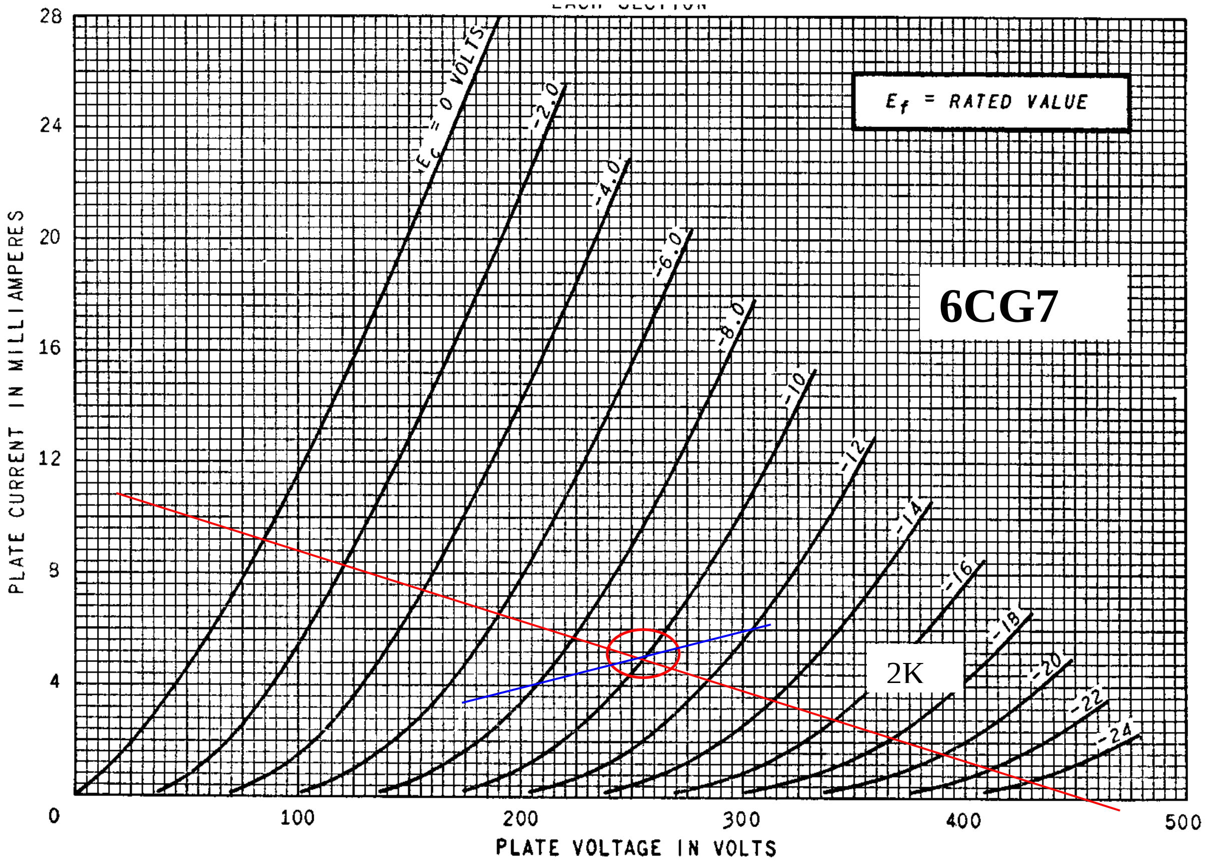


EACH SECTION
E_f = RATED VALUE
6CG7
E_c = 0 VOLTS
-2.0
-4.0
-6.0
-8.0
-10
-12
-14
-16
-18
-20
-22
-24
1K5
PLATE CURRENT IN MILLIAMPERES
28
24
20
16
12
8
4
0
100
200
300
400
500
PLATE VOLTAGE IN VOLTS

Driver Stage

Push-pull common cathode; 12AU7, V3; VS3 = 485V; Va=250V; Rk=1k; Vk=11V; Ia=5.5mA; RLdc=40k. Coupling low frequency corner is 5Hz (56nF and 560k), below output stage corner.





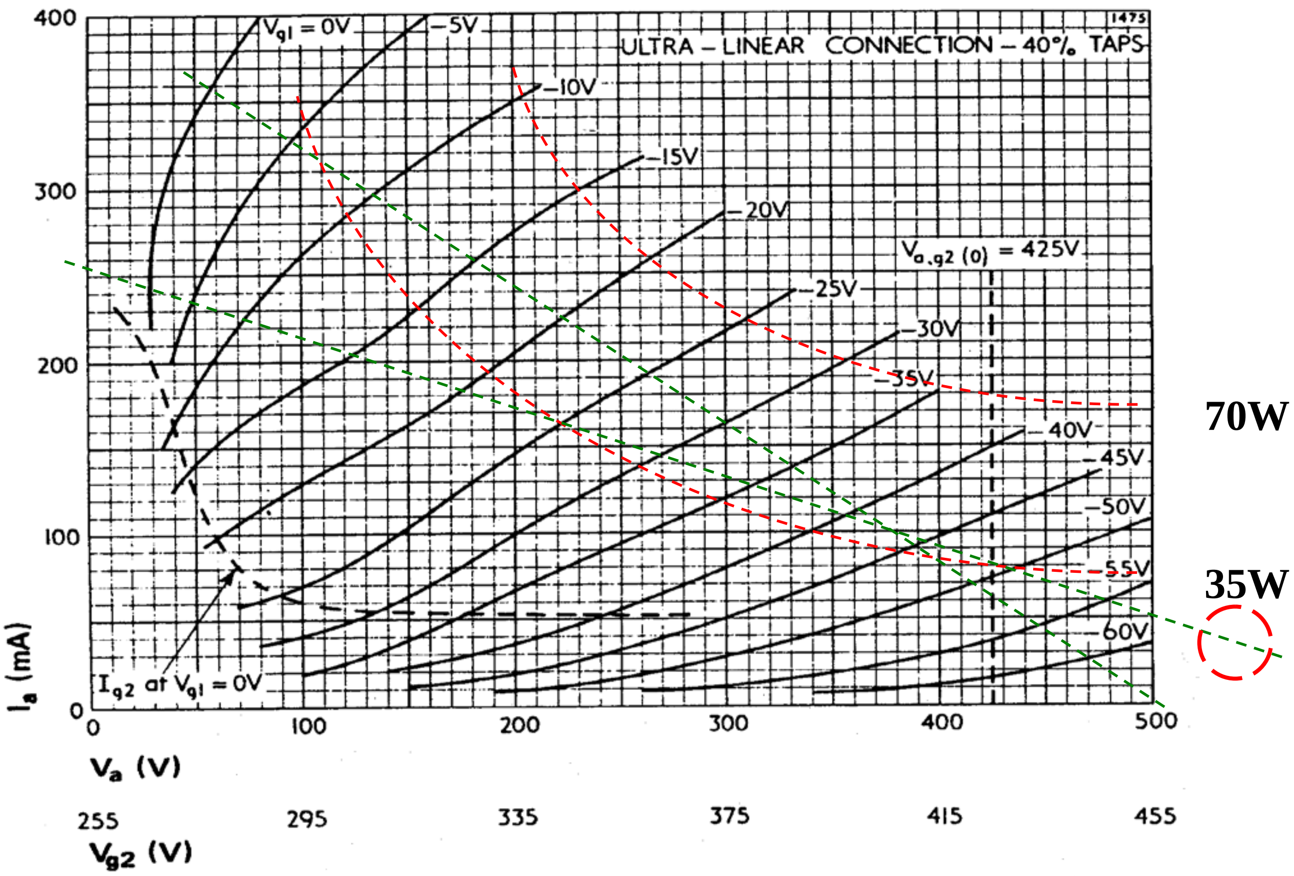
Output Stage

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 where both tubes conduct equivalent levels of current. The cathodes are grounded, and each tube operates in a fixed bias mode with a negative gate voltage. A 5KΩ impedance plate-to-plate OPT, presents each tube with a 2500Ω load impedance around cross-over, moving to a 1250Ω load impedance (Class B) at high signal levels - with a resistance matched secondary load.

As the output loading increases, the supply voltage VS2 to the output valve plates sags from about 550V to well below 500V. Effective plate voltage will be lower than VS2 by an amount up to V due to OPT half resistance of about Ω with a peak current of up to about 0.3A.

The recommended output valve bias current for the KT88 is Ibias = Pd / Vb = 25W / 550V = 45mA. The gate bias voltage required for this current is significantly influenced by the mode of operation - UL, and screen voltage in pentode mode.

The first loadline graph shows the characteristic curves for KT88 with a UL screen voltage. The initial loadline trajectory is along a 2500Ω loadline for small signals where both tubes are conducting – the loadline going through the bias point. The final loadline trajectory for heavy loading (high plate current) is along a 1250Ω loadline – this loadline is aligned with an unsagged effective plate voltage of about 550V, and extends out to the 0V gate level. This 1250Ω loadline indicates a peak plate current of ~300mA would be needed for input grid voltage reaching 0V.



For a peak plate current of 300mA, then the nominal output power of the amplifier would be: $(Ipk)^2$ x Rpp / 8 = 0.35 x 0.35 x 5k / 8 = 77W. For this maximum signal condition, the rms OPT current draw is likely about 0.23A (64% of peak), and the average VS2 power consumed is about 550V x

0.23Arms =126W, and the OPT loss is about $(0.23)^2$ x Ω = W, so the tube plates dissipate 126 – 76W - W = 50W, or about 25W each, which is about max design level.

During dynamic conditions, the plate dissipation mostly exceeds the 35W power contour curve shown on the graph as VS2 hasn't sagged. 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.

In UL, the screen voltage will sag and the output compress during grid swing from about -5V to 0V when a screen stopper is used - a 100R stopper will increase drop by about 10V.

The input coupling cap and grid has a low frequency corner of 20Hz for 110kΩ and 68nF, which aligns with total response.

The RC network from screen to plate has a corner at 160kHz, with 1kΩ loading above that.

Front Panel Meter

1mA FSD meter with 100Ω DCR has a 1MΩ series resistor for 1kVdc FSD. Original shunt resistors were each 0.5Ω for 200mA FSD provided by 100mV across 100Ω DCR. Shunt resistors changed to 1.0Ω for 100mA FSD.

Meter wafer switch includes one spare contact CCW of 'OFF' – added 1MΩ MF50 to display VS3.

Power Supplies

240V HT secondary generates nearly 700VDC unloaded on VS0. Peak diode current suppressed by 5.5R effective secondary resistance, and 10R added series resistance. OA210 diodes stressed by peak current during mains turn-on, so each OA210 bypassed by 2x 1N4007 in parallel. 470uF 400V caps in series used in series to support up to 700VDC on VS0. 220uF 450V caps in series used to support up to 700VDC on VS1.

Choke introduces ~8Hz damped resonant response to step load change. No indication of 100Hz sidebands on high power tone signal

Bleed loads from VS0 is 240k, and VS1 is 200k, so about 110k.

Idle loading:

VS6, 0.5mA, 33kΩ, 20V	250V	
VS5, 0.5+1.5=2mA, 22kΩ, 50V	270V	
VS4, 2+3=5mA, 33kΩ, 165V	320V	
VS3, 5+11=16mA, 5kΩ, 80V	485V	
VS2, 16+2x45=106mA, 60Ω, 6V	565V	
VS1, 106mA	570V	60W

360V zener with 34+5=39k dropper to 600V. (700-360)/39 = 8.7mA (3.2W) max (ie. cold heaters). Zener = 11 x 33V 1W. Series connection of zeners provides poor heatsinking, so need to limit operation when heaters are cold.

Mains on surge from transformer magnetising current, cold heater load, and bias supply surge. A 16Ω NTC (NTH13D160LA) was inserted in series with primary to alleviate initial in-rush. The

NTC has a 1.7A max 55C rating, and mains idle reaches about 0.62A, or 36%, so series resistance should fall from about 16Ω to < 1Ω at steady-state idle, and max current rating is well in excess of amp draw when cranked.

When power is initially turned-on, VS0 is suppressed by inserting 4k7 5W series HT secondary resistance (bypassed by K1 relay NO contact from delay circuit). Initial loading from capacitor discharge resistors is about 3.3mA at 360V. Turn-on delay relay coil (220R 12V G2R-1A-E) powered from half-wave rectifier via IRFR220 FET switch. Fet gate voltage rises slowly via 1.5/3.7=0.4 resistive divider with gate capacitor, and pulled down quickly by 1N4148 to FET low DC supply when AC turned off. A 2M2/1M5 divider should raise gate to about 6V, and a 2M2/33uF tant provides a gate voltage time constant of 70 sec, with a turn-on time of about 12 secs, and instant power cycle reset. VS2 rises to about 280Vdc during relay delay. KT88 cathode current starts at about 20mA when relay contact closes, and takes bout 30-60 secs to reach 40mA.

Total heater load: 2x1.6 + 2x0.6 + 0.2 = 4.6A plus mixer/radio unit (not used for this amp). Changing 6CG7 to 12A*7 reduces heater current to 4.0A. The 12V CT heater rating is 4A, so all valve heaters can connect to one half of 12V winding. The PI cathode-heater is operating at max rating, and so an elevated heater with humdinger pot is appropriate.

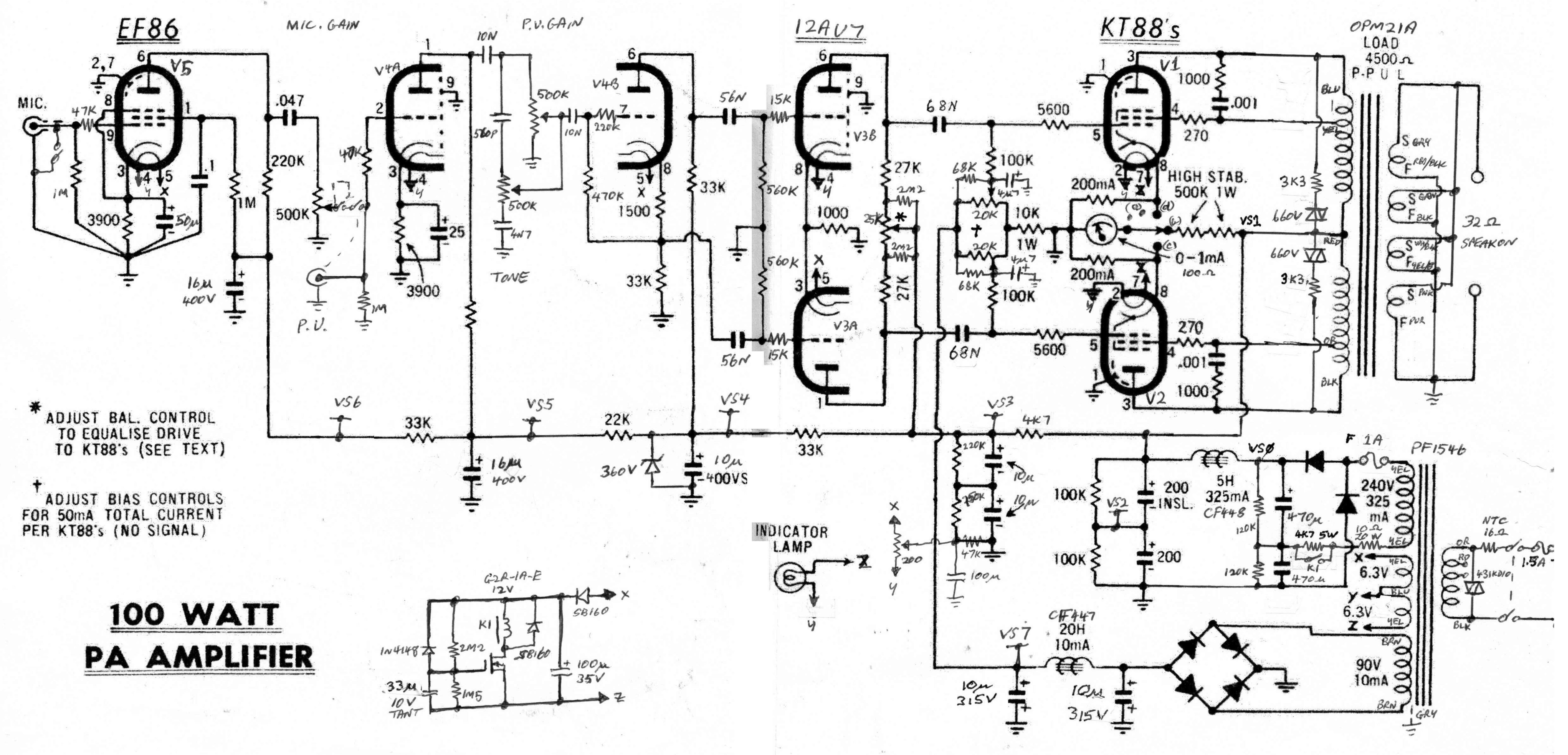
For a hot turn-on with 100mA load, the following data indicates a 1.25A T 3AG is ok. However, with the soft-start relay operating appropriately, the fuse rating could be reduced to circa 0.63A F.

Simulate period in PSUD2	**10ms**	**20ms**	**50ms**	**150ms**	**600ms**	**continuous**
Simulated RMS current		9.6A		4.8A	2.7A	0.48A
Multiplier (for 1A fuse rating)		9.6		4.8	2.7	0.48
IEC 60127-2 **T** min limit multiplier		10		4.0	2.75	1

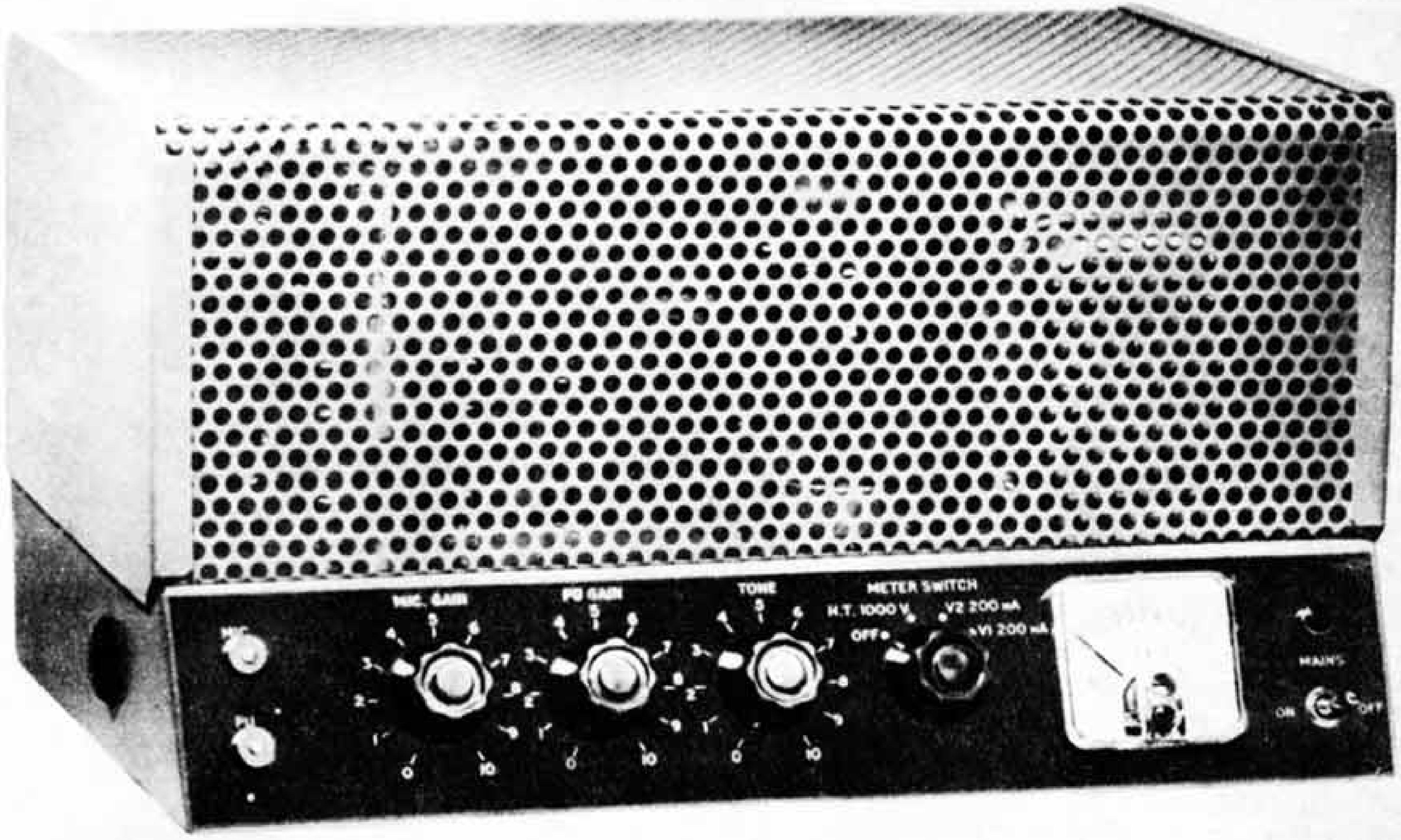
Simulate period in PSUD2	**10ms**	**20ms**	**50ms**	**150ms**	**600ms**	**continuous**
Simulated RMS current		9.6A		4.8A	2.7A	0.48A
Multiplier (for 1.25A fuse rating)		7.7		3.8	2.2	0.39
IEC 60127-2 **T** min limit multiplier		10		4.0	2.75	1

Grid bias supply with 86Vac through SL775 full bridge to 10uF 315V with 117Vdc and 1.3Vrms. LC filtered through 24H 980Ω to 110Vdc and 28mVrms. Bias load ~ 9+10=19k, so 5.8mA and 6V drop across choke. The KT88 grid bias resistors are a bit over 100k, which is the datasheet max for high dissipation applications.

Added a MOV (2x 2502 red 7mm type; 330VDC each) and 3k3 2W resistor across each primary, to act as a high voltage damped clamp in case the speaker load goes open circuit.



100 WATT PA AMPLIFIER



The finished amplifier, complete with cover and engraved front panel. Its facilities and power output make it suitable for almost any P.A. requirement.

A 100 Watt Public Address Amplifier

Here is the most powerful public address amplifier ever to be described in these columns, capable of delivering 100 audio watts. It is ideal for handling the really big jobs in large halls, fair grounds and such like. Its general design is right up to the minute.

By Neville Williams and Brian Cleaves

THOUGH we have had requests in the past for some such design the difficulties of producing it and making it a marketable proposition have outweighed the limited demand. Our higher-powered designs in the public address field have, therefore, been limited to around the 40 watts, which was easily attainable with 807 type valves.

SPECIAL JOB

Just recently, however, the opportunity to tackle something larger occurred when a division of our parent company wanted a big amplifier for pageing in a new large building. An examination of the proposition showed the possibility of building the amplifier required for the particular job as well as deriving from it an interesting article.

But why 100 watts? Is it because it's 10 times louder than 10 watts? Is it the largest anyone is ever likely to want? Is it the largest practical design?

The answer is no, no, and again no! Under practical listening conditions a 10 times increase in power does not produce a sensation of sound level being increased by that amount, because of the "AVC action" of the ears, as indicated by operation of the decibel scale.

However, what is often more to the point, a 100-watt amplifier will operate 10 times as many speakers at a given sound level as a 10-watt amplifier.

Again, while almost any audio power can be obtained, given components of adequate capacity, 100 watts represents a very substantial "round figure" which can now be achieved using components and techniques which are within the orbit of servicemen and advanced hobbyists.

What a 100-watt amplifier will achieve in terms of coverage depends a great deal on the speakers used to disseminate the sound. Different types vary enormously in acoustic efficiency and directivity, as well as in frequency response, distortion and unit cost.

The choice of speakers is a question which is really best resolved with those who supply them but, in any case, cannot be further pursued here.

Coming back to the amplifier, its power is delivered, in the ultimate, from a pair of the relatively new KT88 valves. These are used in this circuit, in class B1 ultra-linear conditions, the actual circuit being closely akin to one featured recently in the valve manufacturers' journal "Radiotronics."

Several points about this method of operation are worthy of explanation. Firstly, there is the matter of "class B1."

The traditional class B method of operation is, of course, well known. It involves applying a fixed bias to the output valves so that they operate from very close to cut-off. Each works into a relatively low value of load, as presented by the output transformer ratio half primary to full secondary.

Each is driven by the input signal well into the grid positive region, in order to secure high conduction through the valve and low voltage drop across it. Since the input grids are driven positive and draw current, the operating condition should rightly be referred to as class B2; the drive has to be supplied from a low-impedance push-pull source, normally involving a "power" driver stage and a special driver transformer of critical design.

NO GRID CURRENT

With valves like the KT88, it is possible to achieve the necessary conduction and low voltage drop without resorting to positive grid operation. Therefore, by operating the valves at near cut-off and carrying the grids to zero on signal peaks, a verv large excursion of plate current is initiated through the load, which adds up to substantial power output.

And since the grids do not swing positive, the mode of operation is defined as class B1, and the need for a special low impedance signal source is eliminated.

Then there is the matter of ultra-linear (or divided load) operation.

It is debatable whether adequate conduction could be obtained through valves of simple triode structure, since the "incentive" to large electron flow disappears as the plate voltage falls during plate current peaks.

The field provided by the screen of a tetrode or pentode is necessary to sustain current flow with low plate voltage. Therefore, class B1 operation relates more naturally to tetrode or pentode rather than to triode operation.

DISTORTION PROBLEM

But this gives rise to the further difficulty that uncompensated pentodes or tetrodes, operating into reactive loads (viz. loudspeakers) are likely to produce excessive peak voltages on high-frequency signal components, as well as generating more than their share of distortion.

Negative feedback is not the complete answer to this problem since it is not very effective during those portions of the input cycle where the two output valves are each close to cut-off.

Neither is it completely satisfactory to connect an R/C filter across the load. The diversion of power into the filter can mean loss of treble response from the speakers, as well as presenting dissipative problems.

From published figures, and from our own results, it would appear that the ultra-linear arrangement provides a neat solution to the problem. While the screen "swings" with signal sufficiently to simulate triode behaviour, it does not digress sufficiently from the HT line to prevent it (in the DC sense) from sustaining high conduction at the minimum plate voltage swing.

As a result, the requisite high power is obtained at a modest distortion level and in keeping with the results normally expected of a public address system.

For the conditions under consideration, the KT88 valves require a power supply of 560 volts at current figures ranging to 325 mA., depending on the output signal level. As with all class-B amplifier systems, the real problem is to obtain adequate voltage regulation.

Much to our surprise, investigation showed that the voltage-doubling silicon rectifier type of supply, currently being used for television receivers, had better potential regulation than the traditional choke input filter, full-wave rectifier.

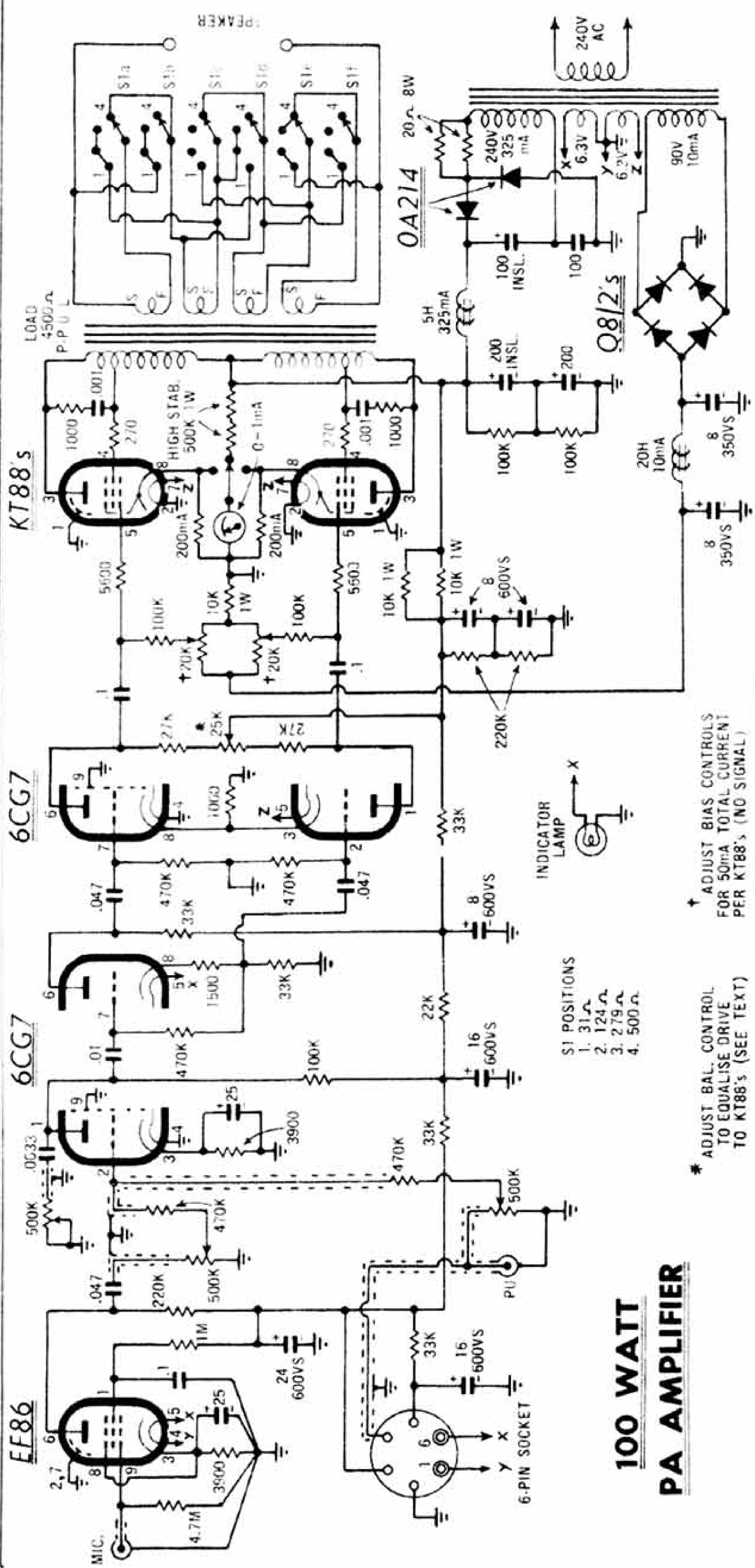
SPECIAL COMPONENTS

Before we could specify it, however, we had to be sure of the supply of silicon diodes with a specially high peak inverse rating. The ordinary 400-volt types will not do.

Then, also, we had to await the development of high voltage, high capacitance electrolytics for the doubler input position. These need to be special types, designed to operate with high ripple current. Again, ordinary types should not be used, even though their voltage ratings may appear to be adequate. One needs to have an insulating and protective type of mounting.

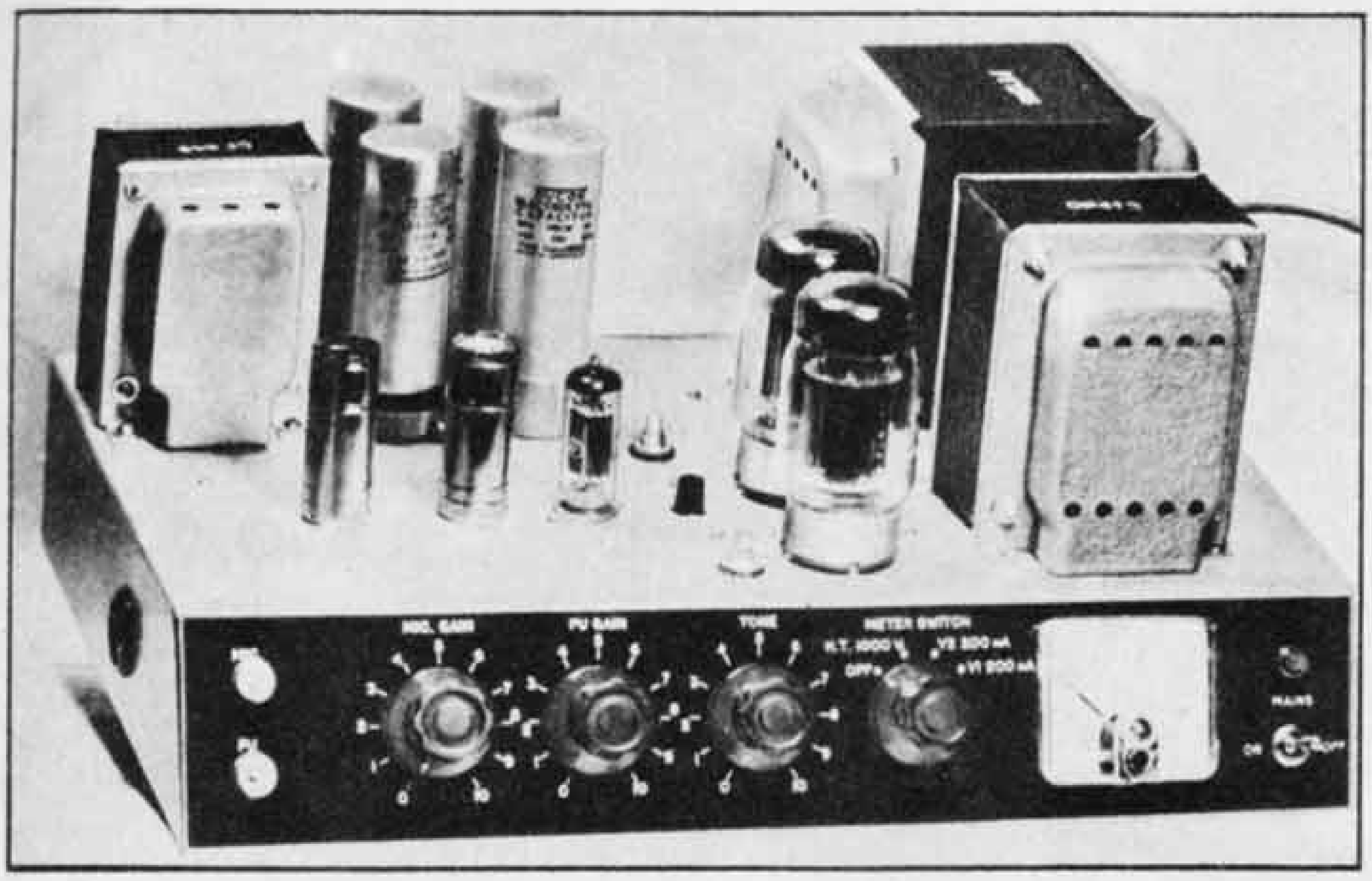
The H.T. filter is completed by a choke and two series-connected electrolytics, with 100K resistors across each to equalise the applied voltages. One of these needs also to be insulated and protected from accidental contact.

100W FROM KT88s CLASS B U/L



The circuit provides microphone and pickup inputs, with mixing facilities. In addition, it may be used with a separate mixer unit giving additional inputs and facilities. Note the special switching arrangement used to select the required output impedance.

LAYOUT OF MAJOR COMPONENTS



The two shielded valves on the left are the EF86 and 1st 6CG7 in that order, followed by the 2nd 6CG7 and the two KT88s. At left rear is the main filter choke, right rear the power transformer, and right front the output transformer. Note the meter used to monitor operating conditions.

A 10 ohm series resistor in the rectifier circuit is intended to minimise peak currents through the rectifiers, and the input filter capacitors. The series resistor is made up from two 20-ohm 8-watt resistors, connected in parallel.

A supplementary circuit in the power supply provides a fixed bias for the two grids. The supply is nominally rated at 90v. 5mA, but the actual bias used is subject to adjustment.

As indicated by the circuit, grid and screen "stoppers" are included to ensure stability, as well as a network between the plate and screen tappings on the output transformer.

Provision has also been included for setting up and metering the conditions for the output stage. Thus, separate 200 mA. shunts are provided in each cathode circuit, across which the meter can be switched as desired. By means of the bias adjustments, the cathode currents of each valve should be maintained at 50 mA. with no signal input.

VOLTAGE RANGE

A further position of the switch connects the meter in series with a 1-meg. resistor across the HT supply, so that it reads the HT voltage on a 1,000-volt scale. The resistor should be a 1-watt high-stability type, with a voltage co-efficient rating comfortably in excess of the 560 volts which it will need to withstand.

If there is any doubt on this point, it would be preferable to use two series-connected 0.5 meg. high stability resistors.

In any case, close tolerance resistors should be used to ensure an accurate reading of voltage.

Although the metering allows the no-signal plate currents of the output valves to be balanced, it does not ensure balance on output peaks, which is a function of drive and of valve transconductance.

In this case, optimum balance can be achieved by varying the setting of a 25K pot. in the plate circuit of one driver valve.

Balance can be checked by comparing the output on a CRO developed across each of the cathode shunts. A better method is to set up the amplifier with an optimum resistive load, turn up the input to the point where clipping just begins and adjust the drive pot. for equal clipping on both peaks.

Both methods assume, of course, that the input waveform is itself pure.

It is a good idea to insulate the balance potentiometer from chassis to obviate any risk of a HT short. Similar precautions should be taken with the bias pot., not in this case because of the voltage, but because failure of the bias supply to the output valves would be quite tragic.

Special consideration had to be given to the matter of the output transformer secondary, with a view to obtaining a reasonable range of impedances without sacrificing efficiency.

FOUR WINDINGS

The arrangement finally adopted was to provide four separate secondary windings, each for a nominal impedance of 31 ohms. The requirement is that all windings be used simultaneously, in order to avoid "idle" copper and window space.

Thus the four windings may be connected in parallel to provide for a 31-ohm load. The four in series match to a 500-ohm load.

The four in series-parallel match to 124 ohms, while two in parallel, connecting in series with the other two, provide for 279 ohms.

Naturally, in effecting these connections, correct phasing is vital, for which reason the coding relating to the start

(Continued on Page 35)

PARTS LIST

- 1 Chassis to suit, see text.
- 1 Power transformer 240v. 325 mA. 6.3V 4A, 6.3V 4A. 90V. 10mA. PF1546 or similar.
- 1 Output transformer Prim. U L 4.5K plate-plate Sec. 500 ohms tapped. Op413 or similar.
- 1 Filter choke 5H 325 mA. CF448 or similar.
- 1 Filter choke 20H 10mA. CF447 or similar.
- 1 Switch 6 pole 4 pos. 250V 10A. (See text).
- 1 Switch 2 pole 4 pos.
- 1 Meter 1mA. (small).
- 2 Silicon diodes OA214.
- 4 Selenium rectifiers type Q8/2 or similar.

VALVES

- 2 KT88
- 2 6CG7
- 1 EF86

SOCKETS

- 2 Octal mica filled
- 2 Miniature 9 pin with shield, one to be tinplate, Philips type B8700/55. (See text).
- 1 Miniature 9 pin plain.
- 1 3 pin recessed plug and socket
- 1 6 pin
- 2 Single contact mic. plugs and sockets C/1/02m or similar.

CAPACITORS

- 1 100mfd 350VW electrolytic voltage doub. EMG1584
- 1 100mfd 350VW electrolytic insul. voltage doub. EMG1585S
- 1 200mfd 350VW electrolytic EMG2035.
- 1 200mfd. 350VW electrolytic EMG2035 (Insulated type)
- 3 8mfd. 600VS electrolytics.
- 2 8mfd. 350VW electrolytcs.
- 2 16mfd. 600VS electrolytics.
- 1 24mfd. 600VS electrolytic.
- 2 25mfd. 40VP electrolytics
- 3 .1mfd. 600V paper.
- 2 .047mfd 600V paper.
- 1 .047mfd. 400V paper
- 1 .0033mfd. 600V paper
- 1 .01mfd. 600V paper
- 2 .001mfd. mica.

RESISTORS

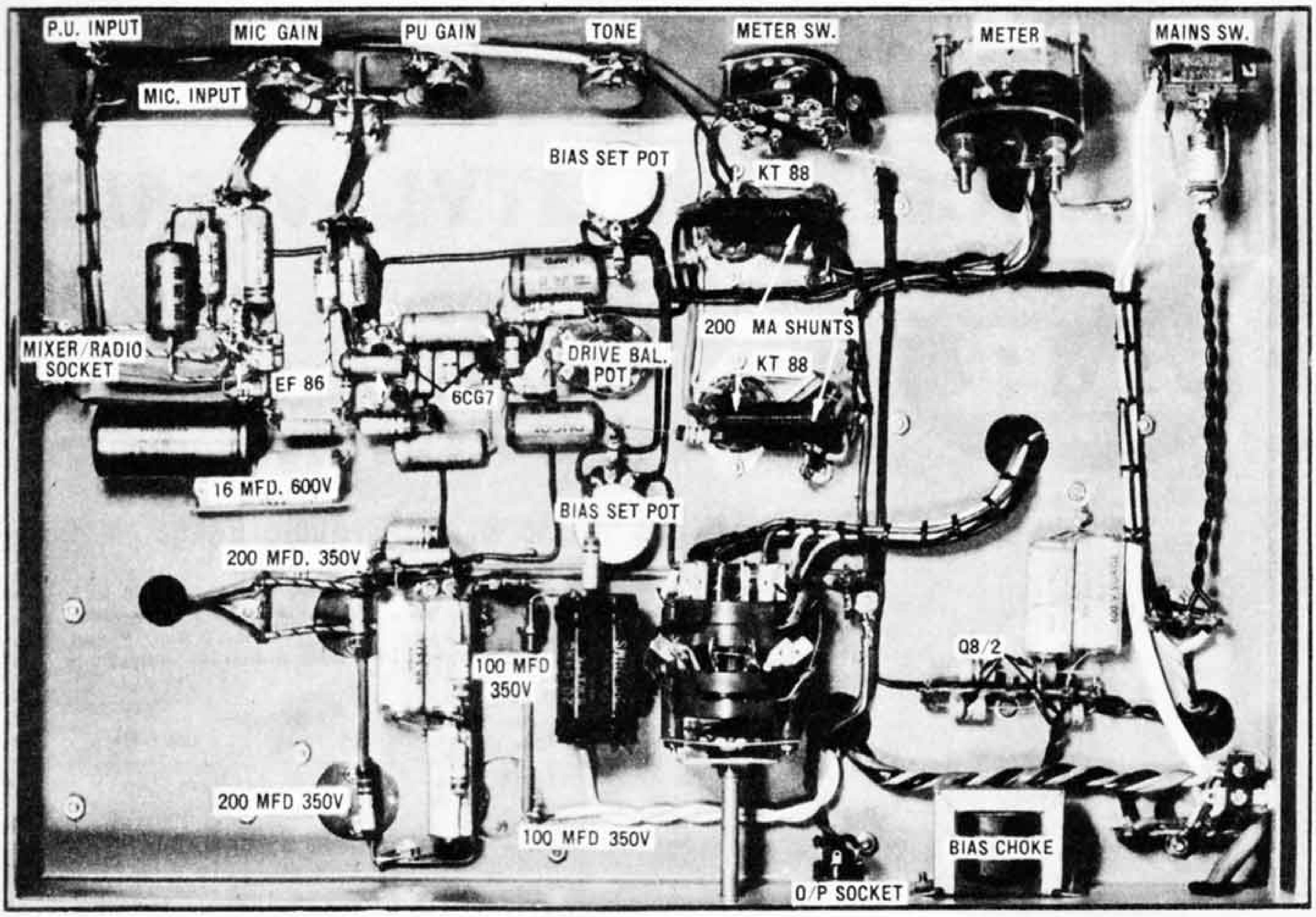
2	270 ohm ½W	2	1K ½W
1	1K 1W	1	1.5K ½W
3	10K 1W	2	27K ½W
1	22K 1W	2	5.6K ½W
2	3.9K 1W	2	100K 1W
3	100K ½W	1	220K ½W
2	220K 1W	1	1meg. ½W
2	500K 1W hi-stab.	5	33K 1W
1	4.7meg ½W	2	20 ohm 8W
5	470K ½W	2	20K potentiometers
3	500K potentiometers	2	200mA. meter shunts.
1	25K potentiometer		

SUNDRIES

- 1 Mains on-off switch
- 1 Pilot lamp assy.
- 7 2 tag terminal strips
- 2 4 tag terminal strips
- 1 7 tag terminal strips
- 2 5 tag terminal strips
- 1 6 tag terminal strips
- 2 stand off ceramic insulators.
- 1 Yd. PT9M Couxial cable
- 4 Clamps for electrolytic capacitors.

Hookup wire, power flex, grommets, nuts and bolts, solder lugs, etc.

UNDER CHASSIS VIEW SHOWS WIRING DETAILS



A good idea of the underchassis wiring and placement of minor components can be obtained from this picture. The two KT88 sockets are towards the top of the picture, almost central, immediately above the impedance selector switch. The EF86 socket is at extreme left of the picture.

and finish of windings should be strictly observed.

In this case we have avoided the use of open connectors for the various secondaries, for two very good reasons. Firstly, they can be confusing and lead to error. Secondly, the voltages produced across the secondary circuit may be every bit as lethal as the power mains.

SPECIAL SWITCH

In our prototype amplifier we installed a special rotary switch, produced by Paton Electric Pty. Ltd. This effects the necessary interconnection as it is rotated and makes the desired impedance available at the turn of a knob.

For a permanent installation, it would probably be sufficient to interconnect the windings as required, without provision for switching.

The remainder of the amplifier ahead of the output valves is fairly straightforward, but the general features are worthy of some comment.

As already explained, the class B1 output valves do not require a specially low impedance input. The grids are, therefore, fed from a pair of conventional triodes, operating in push-pull, and with fairly low values of plate load.

A 6CG7 twin triode makes an excellent pair of drivers and, in the circuit shown, provides ample swing for the KT88 grids.

Ahead of this is another 6CG7, one triode serving as a conventional phase splitter, and the other half as a voltage amplifier feeding the phase splitter.

The phase splitter uses 33K resistors in the anode and cathode circuits, and it is suggested that these be matched to within five per cent to ensure balanced output to the push-pull driver stage. The triode amplifier has a voltage gain of about 16, which brings the sensitivity to a level appropriate for volume control, and to receive the input from a crystal pickup, radio tuner or microphone preamplifier.

A simple top-cut tone control is provided in the anode circuit of this same triode amplifier, the constants chosen giving an adequate degree of control.

In practice, such a control is often handy to "round off" unpleasant voices or unduly shrill music, while it can also minimise feedback where this involves peaks in the treble register.

SIMPLE MIXER

A simple mixer network is incorporated in the triode grid circuit, using two volume controls and two isolating resistors. One section connects to the pickup input, and the other to the output of the microphone pre-amplifier stage.

Something under 400 mV of signal is required at the pickup terminals to drive the amplifier to full output. There should be no difficulty in obtaining this from a standard mono crystal pickup.

To have provided for a magnetic pickup would have involved at least one extra valve giving the requisite compensation and gain.

The pre-amplifier is a pentode-connected EF86 or Z729. The low noise and rigid construction of such valves shows to good advantage in this application. There is no problem with noise or microphony, and no need to resort to shock mounting of the socket.

HUM

However, it is necessary to take all the usual precautions to avoid hum pickup. As implied by the circuit, the entire input network should follow the now well-established practice of single point earthing. A solder lug firmly secured under a socket mounting bolt, and making good contact with a cleaned area of the chassis will make a good earth point.

To this is returned the 4.7M grid resistor, the cathode bias network, the screen by-pass, the central shield of the socket, and the shielding braid of the co-ax cable running to the microphone input socket. This latter should be insulated from the chassis by means of the insulating washers supplied, the braid connecting to the "earthy" side of socket, but not to the chassis.

Another precaution concerns the heater line. This is shown earthed on one side, rather than centre tapped, and this seems to be quite satisfactory in itself. However, while a single heater line

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100W. AMPLIFIER

(Continued from Page 35)

and a chassis return is quite satisfactory (and a good deal easier) for the remainder of the valves, this is not advisable for the first stage.

The best arrangement appears to be a twisted pair running from the transformer terminals to the heater pins, the chassis connection being made near the power transformer, rather than at the EF86 socket.

The only remaining source of hum is a small amount of magnetic coupling between the power transformer and the EF86; always a possibility where we seek the convenience of a high gain amplifier on a single chassis. The amount of hum thus introduced is quite small, and is unlikely to be a problem except where low output microphones are used. In any case the cure is relatively simple.

The magnetic field is so weak that it may be effectively "shielded" by nothing more pretentious than a steel (tinplate) valve shield. This is available in at least one brand, the Philips type B8700/55 combined socket and shield. The "55" indicates the tinplate shield, but this point can be checked with a magnet. We suggest that this type of shield be fitted as a matter of course.

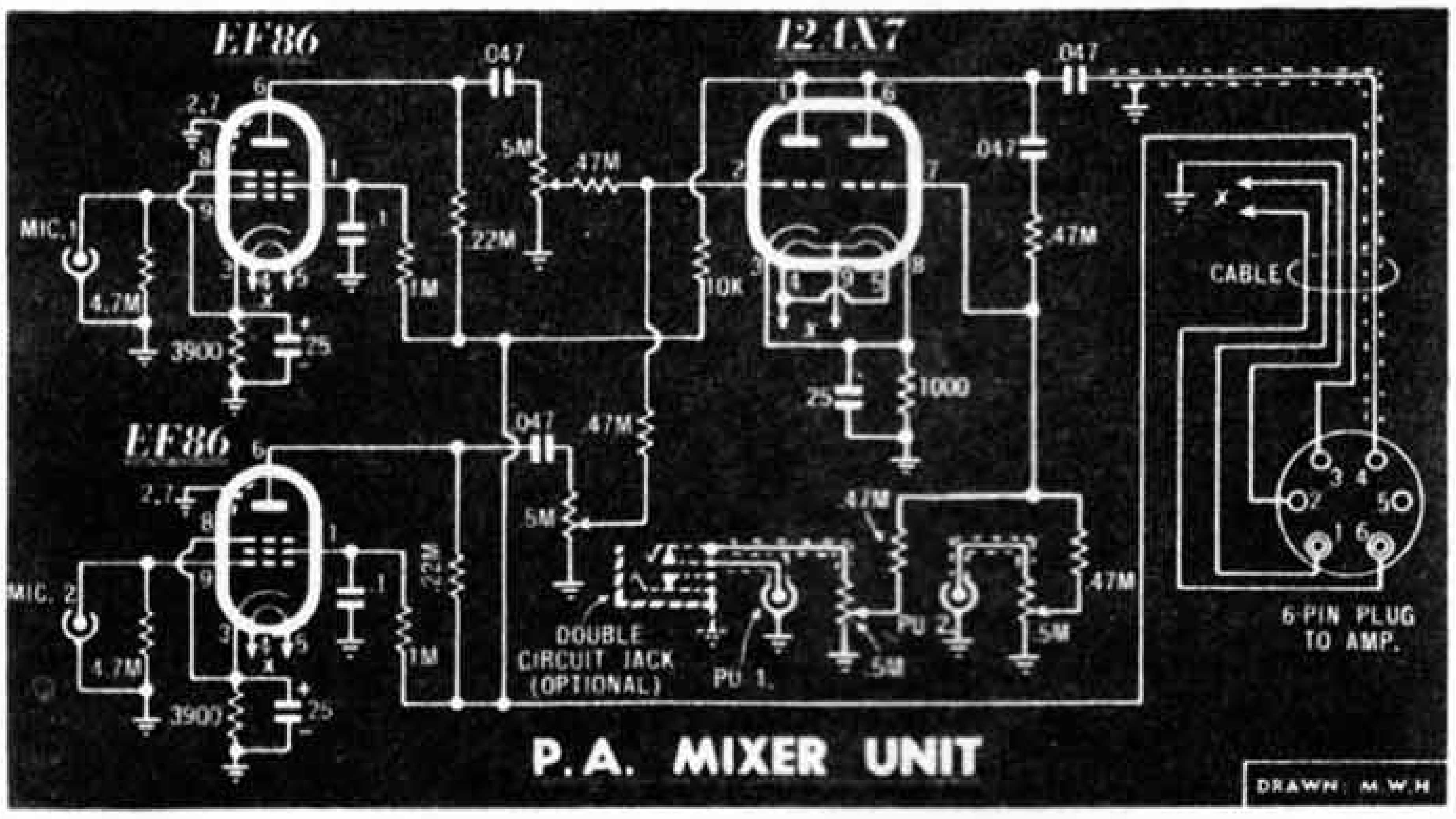
Input to the microphone channel for full output is of the order of 5mV, so that a fairly wide choice of microphone is possible. The better it is, in terms of frequency response, the less will be the troubles experienced with acoustic feedback.

In considering the mixing facilities which should be provided in an amplifier of this kind we decided to repeat the arrangement used in the 35 watt P.A. amplifier of April 1958. This provides for one microphone and one pickup input circuit, at appropriate levels, and a simple mixer network, whereby these may be adjusted separately for any desired balance.

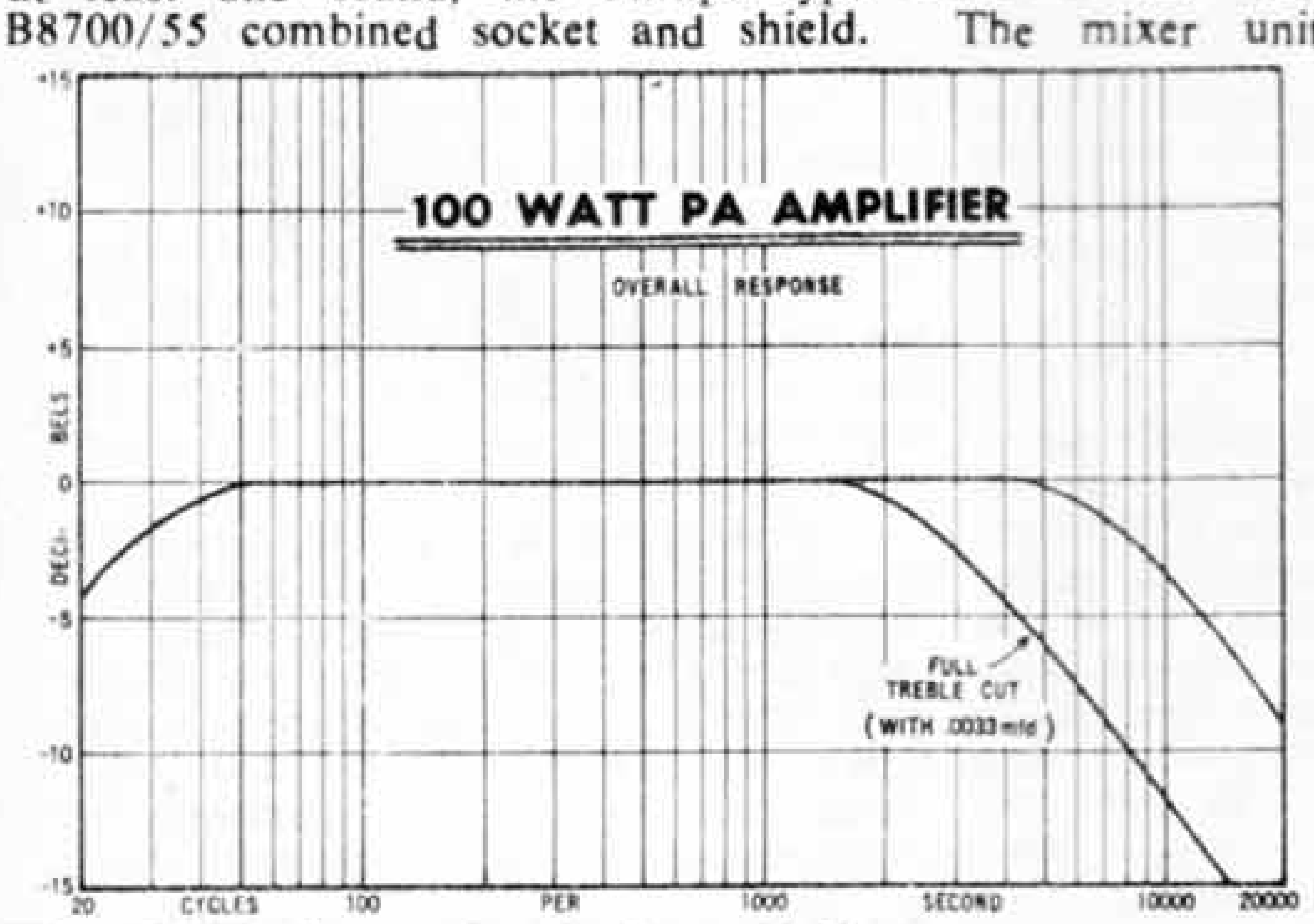
Such an arrangement has the advantage of simplicity, both as regards the circuit and the number and function of controls (P.A. systems often have to be operated by relatively unskilled personnel), yet is adequate for almost all the normal jobs where a P.A. system is required. Thus, in most cases, the amplifier may be used as a completely self-contained unit.

However, for those occasions when something more elaborate is required, as when the local amateur dramatic society needs a system with "everything that opens and shuts," provision is made to fit a separate mixer unit which, with the mixing facilities already in the amplifier makes a very versatile combination.

The mixer unit provides for two microphone and two pickup channels, all independently controlled. The output of the mixer unit feeds into the pickup circuit of the main amplifier, the associated control now becoming a master control, which is a useful feature in itself. In addition, the original microphone channel in the main amplifier may still be used, making three microphone channels in all.



Circuit of the P.A. Mixer Unit, which may be used if required to provide more elaborate mixing facilities than available in the main amplifier. By its use, three microphones and two pickup channels are provided.



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Frequency response is dependent mainly on the output transformer. That shown should be more than adequate for any P.A. requirement.

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(Continued on Page 109)

100W. AMPLIFIER

(Continued from Page 71)

Our prototype amplifier was produced on a 16-gauge steel chassis, measuring 17in long by 10½in wide by 3in deep. A front panel is provided by sloping the front side of the chassis, and this can be embellished, if desired, by the addition of a lettered panel.

In the normal way, a chassis blueprint will be made available showing the details of holes and cutouts.

In service, a plate covers the complete underneath of the chassis while a cover fashioned from perforated metal goes over the valves and transformers.

The layout of major components is quite straightforward, and is shown clearly in the photograph on page 31.

The placement of minor components and general wiring details can be seen in the under chassis picture on page 35. When mounting the valve sockets it is advisable to follow our orientation, in order to duplicate the original layout.

The KT88s have the spigot keys facing the front of the chassis, while the 6CG7 driver has the space between pins 1 and 9 facing toward the microphone and pickup sockets. Both the first 6CG7 and the EF86 face the rear of the chassis.

Otherwise the construction should be perfectly straightforward, and well within the scope of any serviceman or reasonably experienced home builder.

However, it is suggested that care be exercised in bringing the amplifier into operation for the first time. There is a lot of power available both in the power supply, and as audio power in the output stages. A fault due to careless wiring or checking could cause a lot of damage.

Check all wiring most carefully beforehand, and monitor the HT voltage carefully for the first few minutes of operation. Since it is unlikely that speakers will be available immediately to take the full output, the power should be fed into a dummy load, and the power output measured by means of an accurate AC voltmeter and appropriate calculation.

This has been covered in previous articles (see November 1959) and we cannot deal with it here in detail. However, using a suitable load across the output transformer primary, it should be possible to measure the full 100 watts, using a 1,000 cps sine wave input.

And that's a lot of audio power in any application.

100 WATT

PA AMPLIFIER

* ADJUST BAL. CONTROL TO EQUALISE DRIVE TO KT88's (SEE TEXT)

† ADJUST BIAS CONTROLS FOR 50mA TOTAL CURRENT PER KT88's (NO SIGNAL)