

1. Summary

Playmaster No.11 Amplifier & Control Unit No.6 Preamplifier.

Commercial project kits – unknown provider. Preamp joins to amp with 6-pin cable assembly.

1.1 Original Amplifier

Appears to be a kit based on Playmaster No. 11 (crystal pickup) amplifier project in Radio Television and Hobbies August 1955, but with input connector replacing tone and volume controls prior to EF86, and coupling to Control Unit No.6 preamp (RTV&H Nov 1954). 16Wrms nominal rating. Spot-welded aluminium chassis. EF86 input amplifier, then 12AX7 long-tailed ac phase splitter, feeding EL84/6BQ5 cathode biased push-pull.

Components

Output Transformer	Ferguson OP308/15/3.75 8000 & 6000 PP primary 12W rated “HiFi for Mullard 5-10 Amplifier”
Power Transformer	Ferguson PF169 220/240/250V Prim; 325-0-325V 80mA SEC; 6.3V-2A; 6.3V-2A; 5V-2A.
Choke	IRONCORE 1256 (12H at 56mA)
CAPs	Ducon 24uF 525V (x4)
Tubes	5Y3GT fitted (original spec was 5V4-G) 6BQ5/EL84 x2 Miniwatt both with code rX2 and X5G (rX=EL84; X=Philips; 5G=1955 July) 12AX7 Miniwatt code ▲7B EF86 Miniwatt code 9r1 B6F (9r=EF86; B=Mullard; 6F=1956 June)

Issues:

No protective earth or fuse or power switch. Waxed paper caps leaky. EL84's mismatched.



1.2 Original Preamplifier

Playmaster project, CONTROL UNIT No 6 (RTV&H Nov 1954). Using 2 x EF86's, high gain unit for any PU switched tone controls. Radio and Hobbies November 1954, page 46. Umbilical cable connection to Amplifier.

Preamp

POTs	IRC marked. x1 Volume
Tubes	EF36 Miniwatt EF36 Miniwatt
Selector	RIAA, EMI, DEC, 78, RAD

1.3 Playmaster amplifier information

Radio and Hobbies November 1954.

Original kit of parts from Electronics Parts P/L (Sydney) cost about £45 for the Amplifier No.11 and the AG2002 record player, and £54 built and tested (R&H advert).

The amplifier kit is even more exactly the same as the Mullard 5-10, for which the Playmaster variation was based on. The Mullard design was well documented in 1954.



1.4 Restoration aim

The 1958-60 Vox AC15 used a normal channel with the same valve config and quite close in design, including 8k Ω PP OT. The 2007 Heritage AC15H1TV remake included switched pentode/triode modes for EF86 and EL84 PP stages, along with Bass Shift switch and Brilliance switch. Use 5Y3GT in to 2u2 then choke to lower B+, even though 5Y3 is directly heated cathode - use 450V caps after the choke and preferably use standby switch.

Fit amp into a combo plywood enclosure with 16 Ω Celestion Vintage 30, in similar layout as 2007 Heritage. Traffolyte front panel with similar layout, and including bass shift; brilliance 3-pos; top cut pot; pentode and triode mode switches; standby-off-on switch. Remove feedback. Include a Send/Return socket beside the input socket. Possibly have tremolo 2nd channel input coming from a reconfigured Control Unit 6.

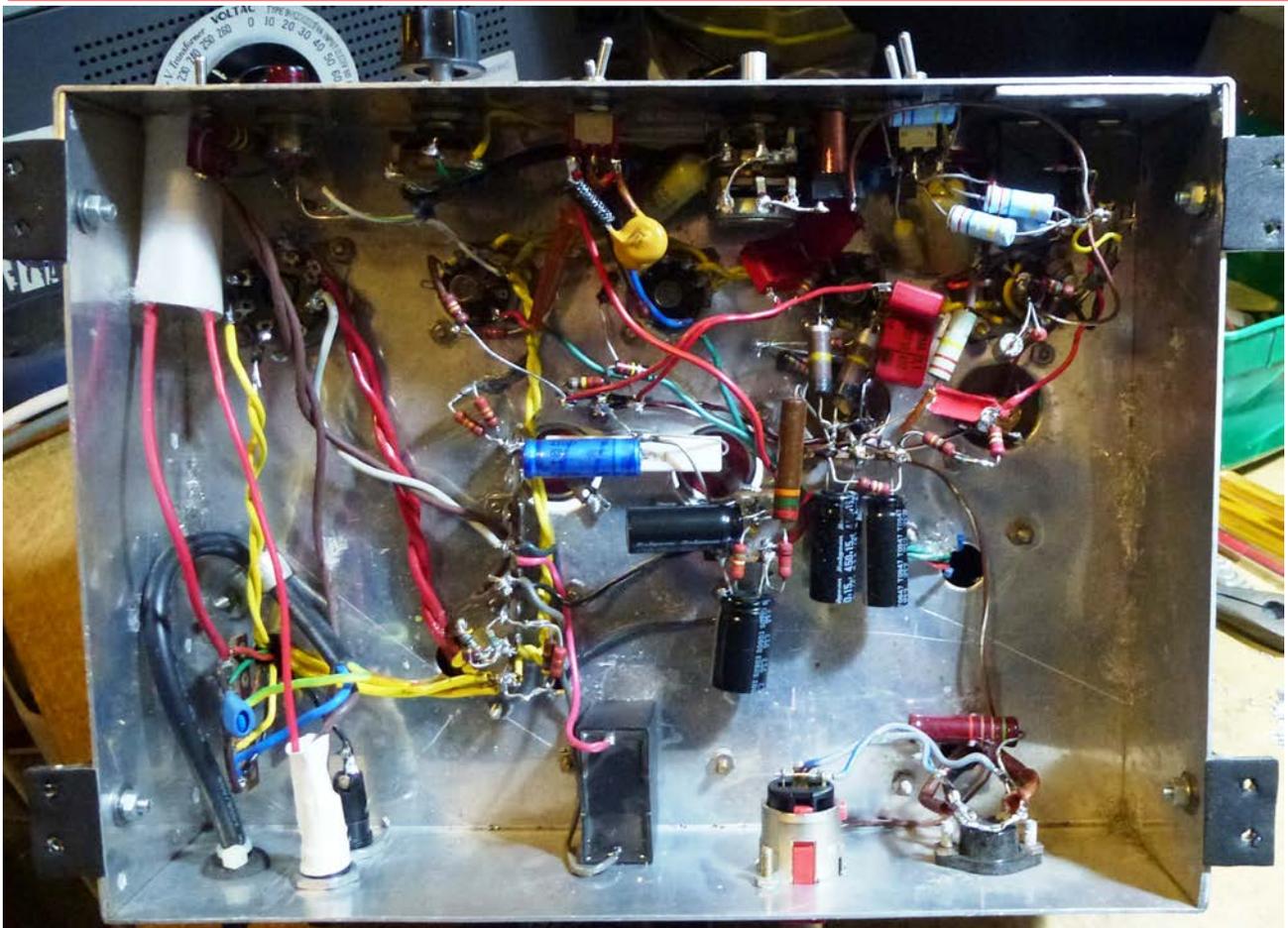
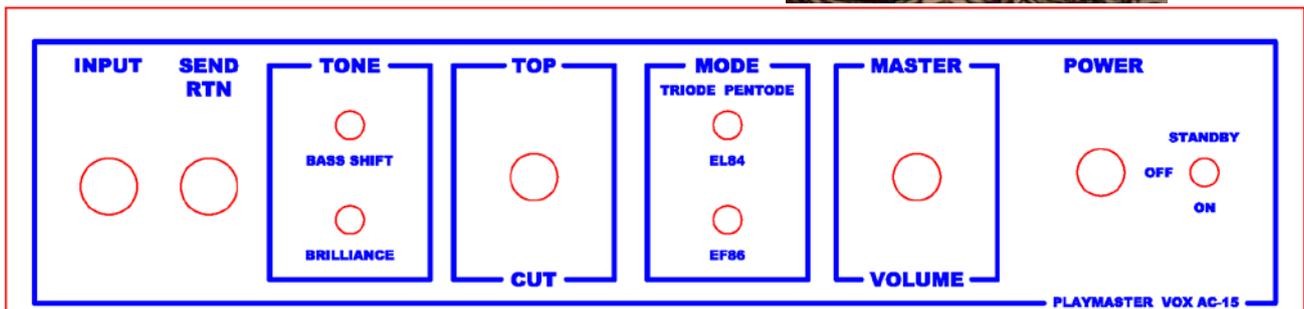
2. Modifications

- Replaced electrolytics and waxed paper caps.
- Replaced EL84s. Added 16V zener to 6BQ5 common cathode.
- Dampened microphonics: high-temp silicon with metal ring to EF86; dampened valve base with neoprene strip; dampened wooden base. Glued up aluminium base (had some rattles).
- Changed EF86 to Vox config, but with 1M2 screen dropper, and removed feedback.
- Added MOV across PT primary.
- Added VE13 0421K (600VDC, 120pF) MOV protection across each OT half-primary.
- Original Playmaster 11 amp design used 285VAC PT with 48uF capacitor input filter for PP stage and 300VDC. This amp has CLC HT filter and 325VAC PT (360V measured) and gives about 400V. The HT is reduced to 335V at idle by using 2.2uF input poly cap.
- Added series 1N4007 with each anode of 5Y3GT, and 200mA IEC F fuse in CT.
- EL84 grid stoppers increased from 1k5 to 10k; screen stoppers increased from 47 Ω to 150 Ω ; grid leaks reduced from 820k to 220k; cathode bias now common, with cathode bypass increased from 100uF to 220uF; cathode resistor changed to 220 Ω 10W to give 9W tube dissipation at idle (70% of 12W design max); 1 Ω sense resistors added for each cathode.
- Tone pot changed to 1kHz notch control with series 68nF and 0.2H shunting EF86 anode.
- Added 2007 Heritage Bass Shift and brilliance switches (Bass Shift positions 1 & 2 reversed).

To do:

- Add switch for the 10V zener clippers on the send output.
- Elevate heater to about 40V to reduce stress on 12AX7.

- Lower AC mains fuse to 800mA delay.



3. Measurements

Primary side Megger is ok.

Rail	No Load * 240Vac mains	Idle 240Vac mains
VS1		357 / 51
VS2		335 / 0.32
VS3		323
VS4		278
VS5		269
Heater 1,2	6.33	
Heater 3	5.	
Sec HT	344-0-344	
EL84 cathode		12 (24+29mA) (54mA, 9W)
EF86 screen		87
EF86		1.9V, 111
12AX7		62V, 215/215V

Note: * no 5Y3.

Power transformer primary DC resistance: 0V black; 14.7 Ω , 220V, yellow; 17 Ω , 240V, green; 17.8 Ω , 250V, red.

Power transformer secondary DC resistance: 149 + 156 = 305 Ω , yellow/yellow. 0V, black. Earth screen, tan tubing.

IRONCORE 1256 (12H at 56mA)

16.6H @ 26mAdc; 14.4H @ 45mAdc; 9.5H @ 93mAdc; DCR = 366 Ω .

Ferguson OP308/15/3.75. Secondary as two windings.

12VAC 50Hz nominal applied to output transformer series connected secondary

Winding	Voltage rms	Turns ratio;	Pri Impedance;	Spec level; Notes
Pri P-P: BLU to BRN	275	-;	8,000 Ω ;	N/A
Sec: BLK to CT	6.19	44.4;	8,000 Ω ;	4 Ω ;
Sec: BRN to CT	6.19	44.4;	8,000 Ω ;	4 Ω ;
Sec: BLK to BRN	12.38	22.21:	8,000 Ω ;	16.2 Ω ;

Output transformer primary DC resistance: 103+135=238 Ω plate-to-plate.

PP stage cathode cold-biasing at increasing overload. 12W in overload (16 Ω load) – VS2 sags too 280V – VS3 sag to 268V – common cathode increases to 16.2V (74mA).

4. Design Info

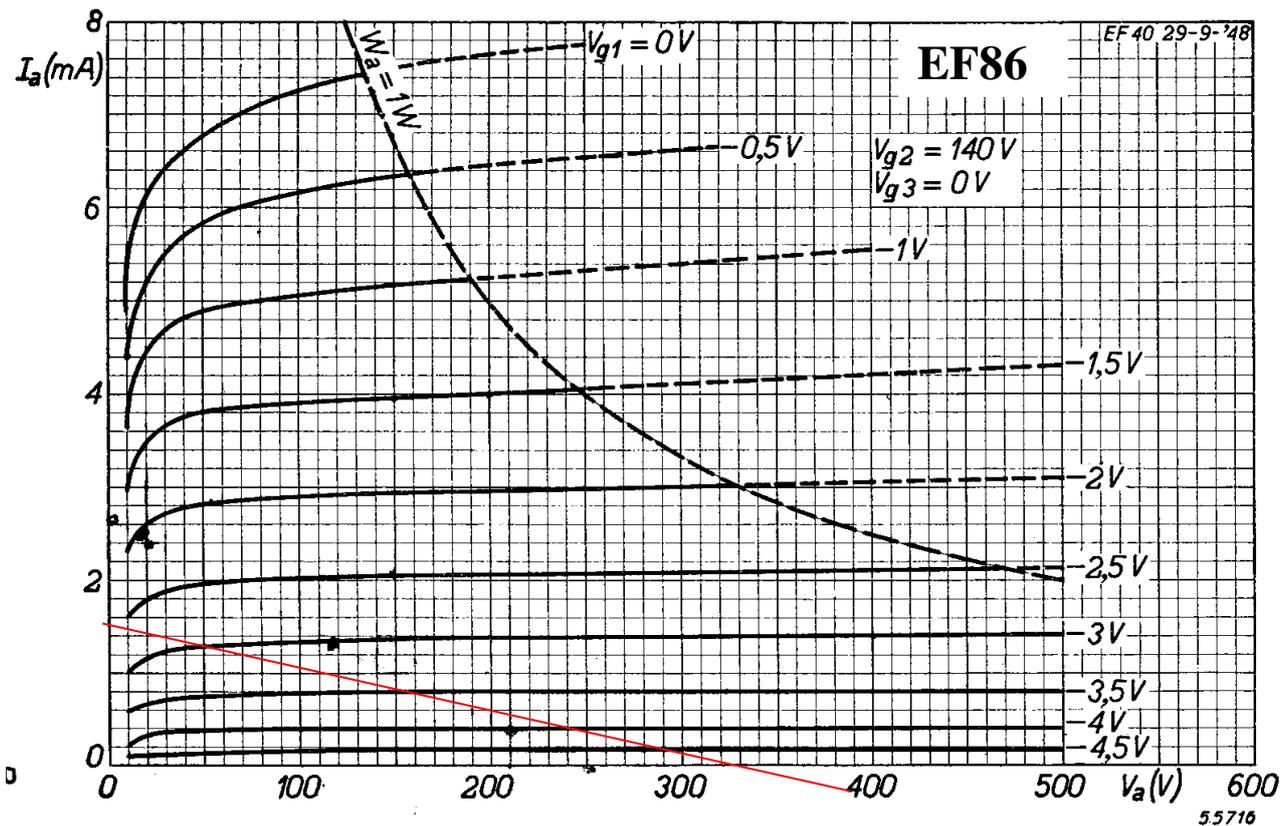
4.1 Input stage – EF86 in Pentode Mode

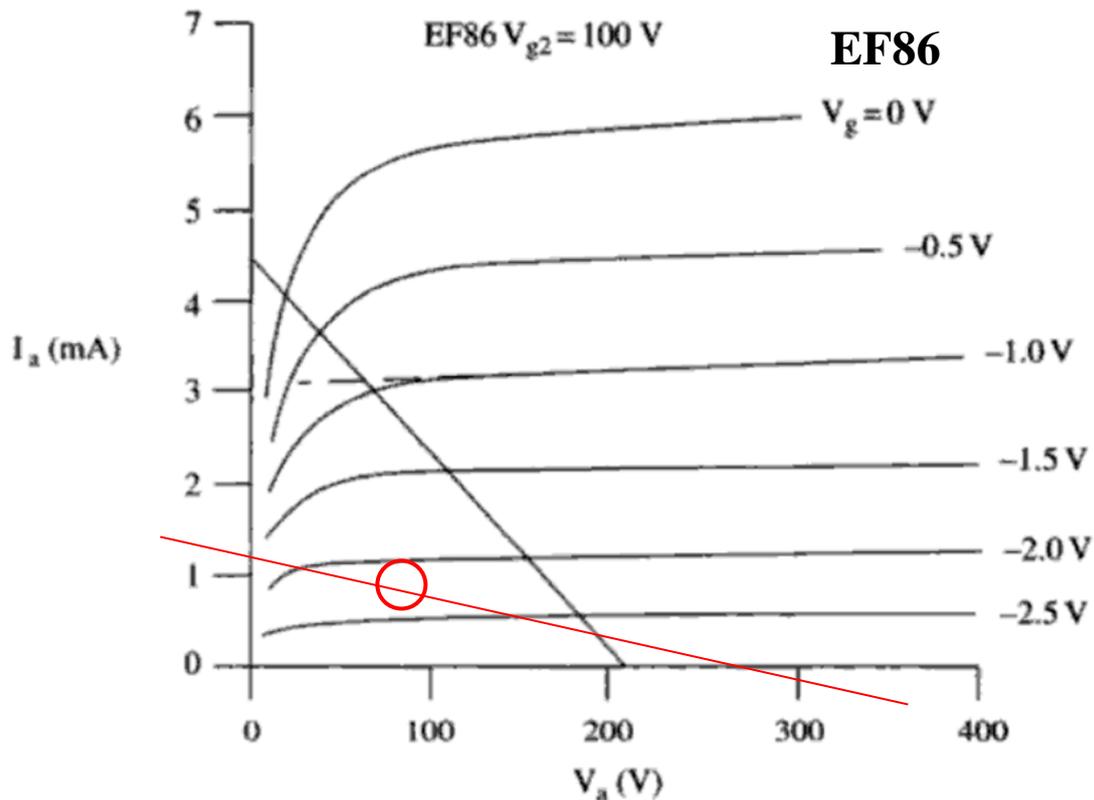
Original circuit measurement: $V_{S4}=202V$; Plate= $113V$; screen= $84V$; cathode= $1.97V$; $100R=92mV$. Cathode current = $0.9mA$. RC across $100k$ plate load same as used by Mullard 5-10 and provided a compensation zero-pole to assist stability (phase advance prior to $0dB$ crossover) using NFB to cathode – not used in R&H circuit.

As an aside, the QUAD 11 runs a $330V$ supply with anodes at $115V$ and screens at $110V$. In the Mullard 5-10, the supply is quite low at $140V$, and the screen and anode are similar around $70V$.

Also screen resistor is typ made about $5x$ anode value to keep screen current at about $20-25%$ of anode. Screen voltage of about $100V$ appears to give similar gate voltage range to that of a $12AX7$ between cut-off and $0V$.

Assume supply voltage is $V_{S4}=330V$; load resistance is $220k$; and cathode resistor is $2K2$. The plate voltage V_p axis intercept is $330V$ for no plate current, and the plate current I_p axis intercept is $330V / 222K\Omega = 1.5mA$. The Philips datasheet indicates a nominal cathode current of $1.1mA$, a gain of $x188$, and distortion rising at a faster rate above about $250mV$ input (ie. output swing $45V$) with a screen resistor of $1M$. Databook pentode curves only for screen $V_{g2}=140V$, but Valve Amplifiers book has curves for $100V$. The AC load line is about $140k$, due mainly to the $500k$ pot and $1M$ gate bleed in parallel with $220k$. Measured levels with $4M4$ screen resistor has operating point around $I_k=0.46mA$, $V_{g1}\sim 1.02V$, $V_s=40V$ and $V_a=225V$ – measured levels with $2M2$ screen resistor has operating point around $I_k=0.7mA$, $V_{g1}\sim 1.54V$, $V_s=65V$, $V_a=164V$, $V_{S4}=310V$ (measurements: $V_{S4}=309V$, $V_a=162V$, $V_{g1}=1.54V$; $V_s=67V$). Measured levels with screen resistor $\sim 1M1$: $V_{S4}=271V$, $V_a=81V$, $V_{g1}=2.1V$; $V_s=96V$ (hence $I_s=0.16mA$, $I_a=0.86mA$).



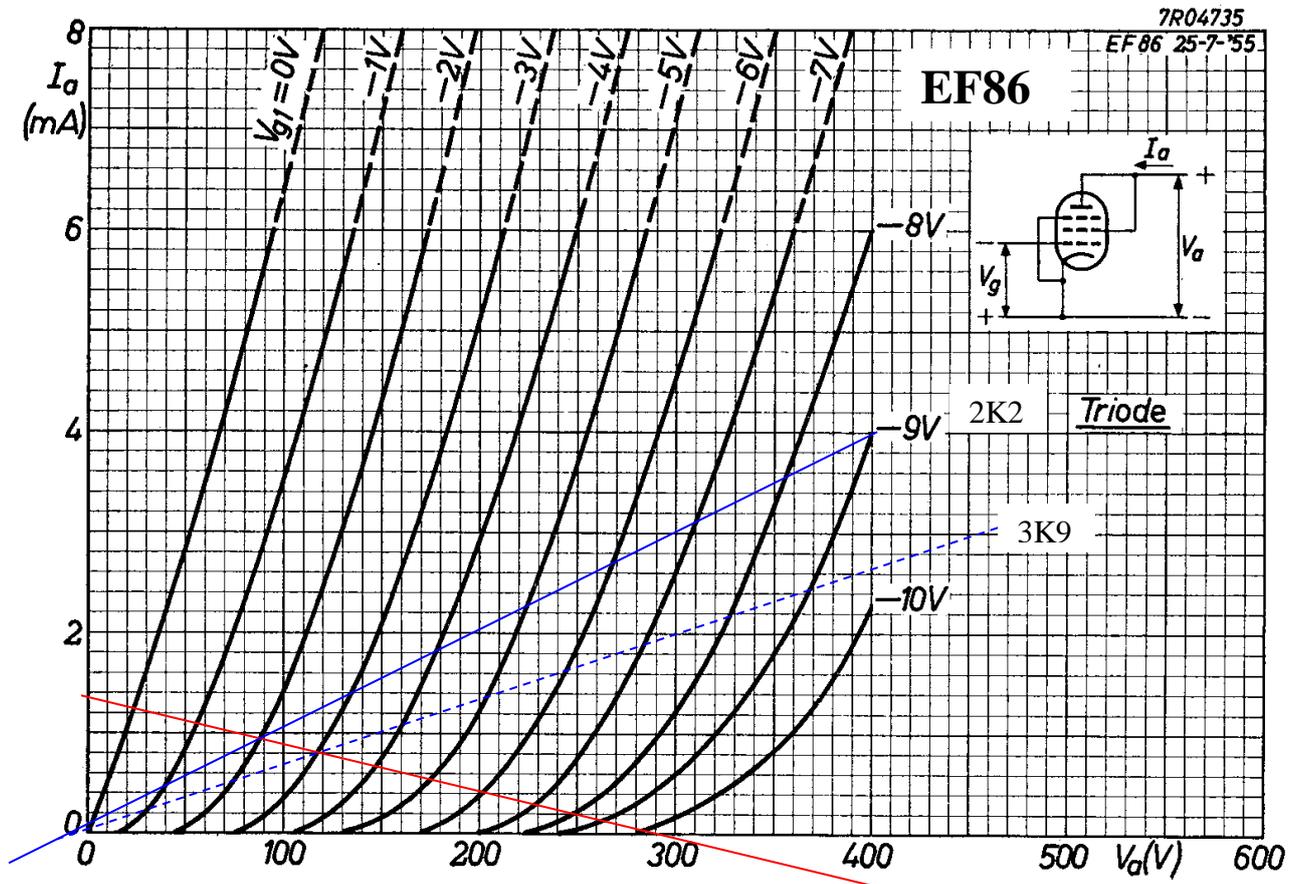


4.2 Input stage – EF86 in Triode Mode

Assume supply voltage is 300V; load resistance is 220k; and cathode resistor is 2K2. The plate voltage V_p axis intercept is 300V for no plate current, and the plate current I_p axis intercept is $300V / 222K\Omega = 1.4mA$. The gate-cathode voltage V_{g1} operating point varies with plate current through the $2k2\Omega$ gate-cathode resistance with the characteristic shown on the graph as a line passing through $I_p=0.5mA$ for $V_{gk}=-1.1V$, and through $I_p=2mA$ for $V_{g1}=-4.4V$. The intersection of the two lines is the nominal biased operating point at $V_{g1}=2.2K \times 0.9mA = 2.0V$.

The input voltage swing limit is from the bias point at $V_{g1}=-2.0V$ to $V_{gk}=0V$, which is about 4.0Vpp or 1.4Vrms. Referring to the loadline, the plate voltage would swing from about 25V to 150V [$150-85=65V$; $85-25=60V$; which is fairly symmetric], for a nominal gain of $125/4 = 31$.

If the cathode resistance is increased to 3k9, then the nominal biased operating point is at $V_{g1}=3.9K \times 0.8mA = 3.1V$, and plate voltage would swing from about 25V to 200V [$200-125=75V$; $125-25=100V$; which is less symmetric], for a nominal gain of $175/6 = 29$.



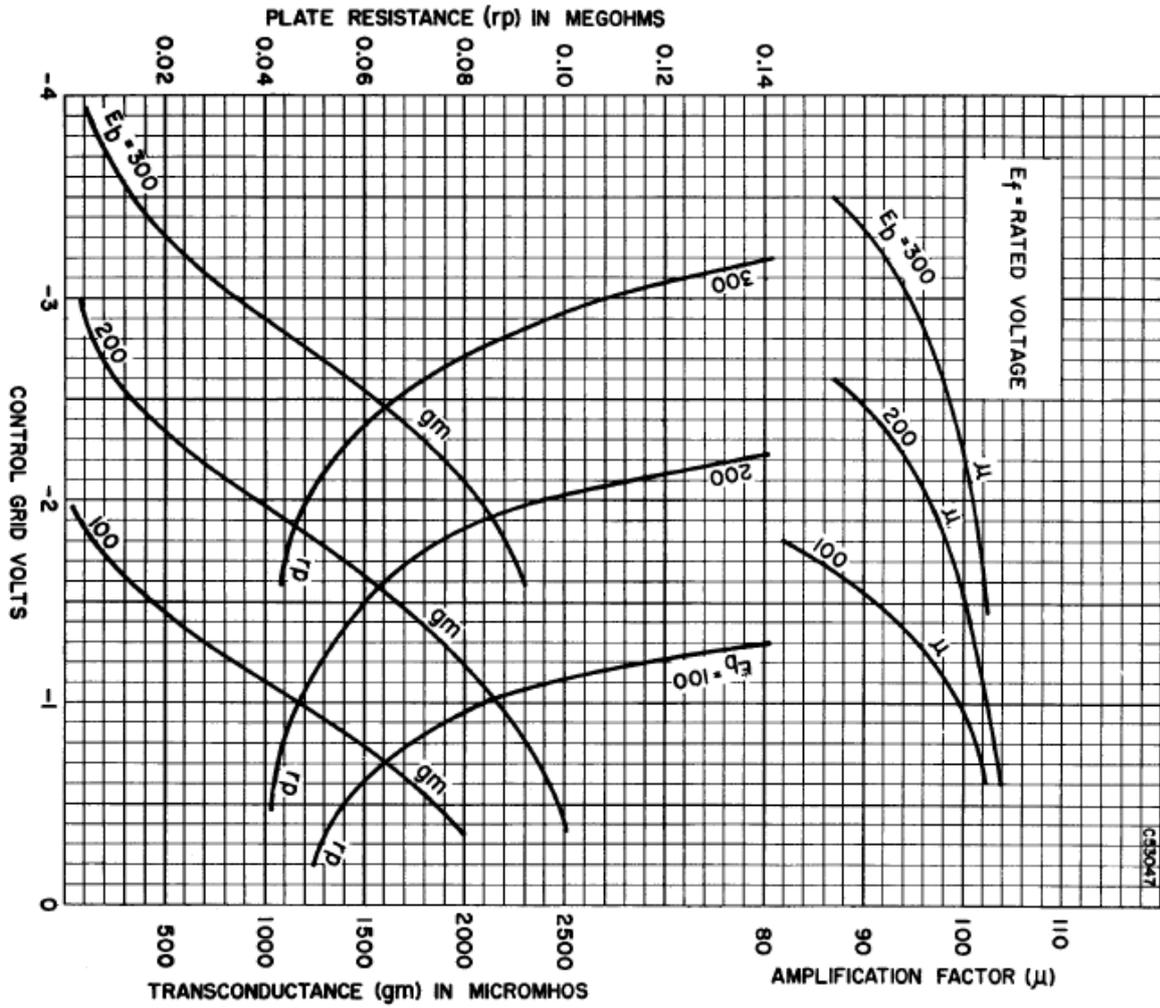
4.3 Splitter stage – 12AX7 in long-tail pair config

Original circuit measurement: VS3=314V; plate 6=166V; plate 1=285V; cathode=113V; common cathode resistor = 80k; common cathode current = 1.4mA, plate resistors ~120k. Possibly leaky cap caused unbalance? Gain is $u \times R_k / 2(R_a + R_L) \sim 110 \times 68k / 2(40k + 100k) \sim 25$. Analysis of this circuit configuration in [Electronic Engineering Feb 1947 by Clare](#).

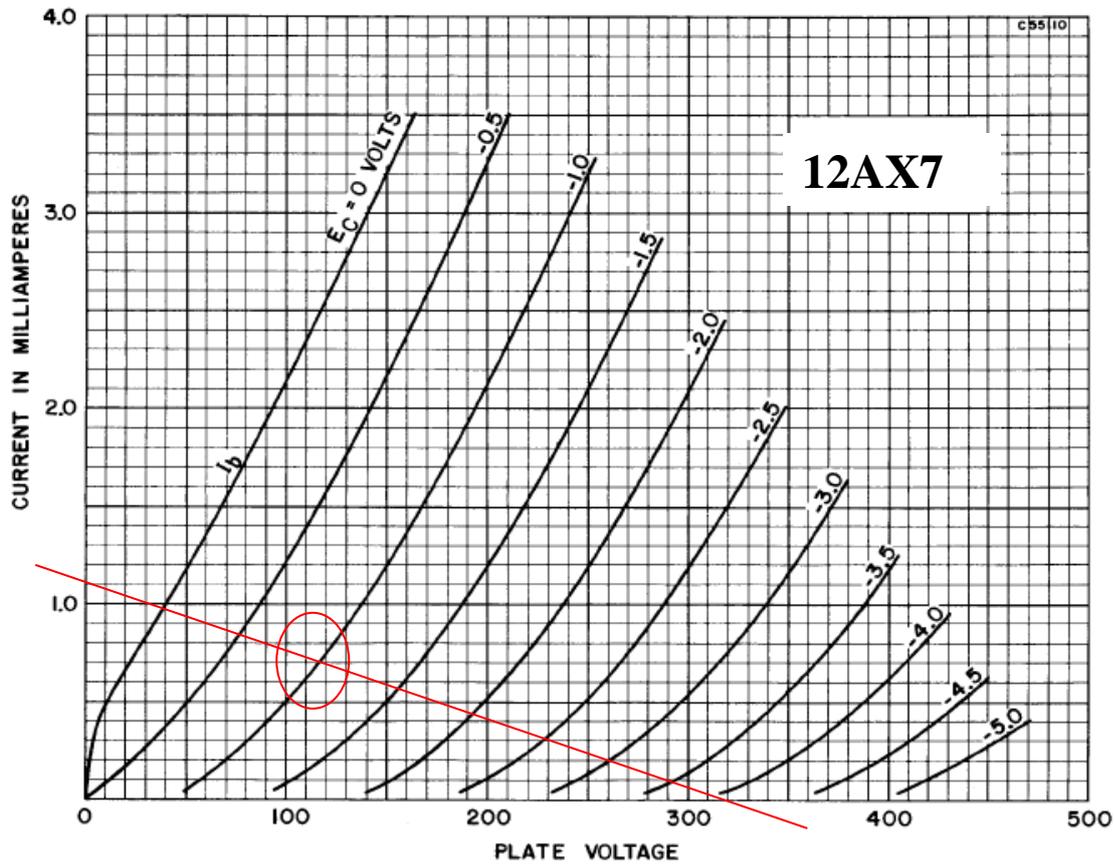
The plate current versus plate voltage load line for each triode is given by the equation:

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

Hence load line resistance of about $100K + 2 \times 80k = 260k$. The plate voltage V_p axis intercept is 315V- for no plate current, and the plate current I_p axis intercept is $315V / 280K\Omega = 1.1mA$. Plate-cathode voltage is about $220 - 110 \sim 110V$.



AVERAGE TRANSFER CHARACTERISTICS
EACH SECTION



AVERAGE PLATE CHARACTERISTICS
EACH SECTION

4.4 Splitter stage – 12AX7 in long tail pair config

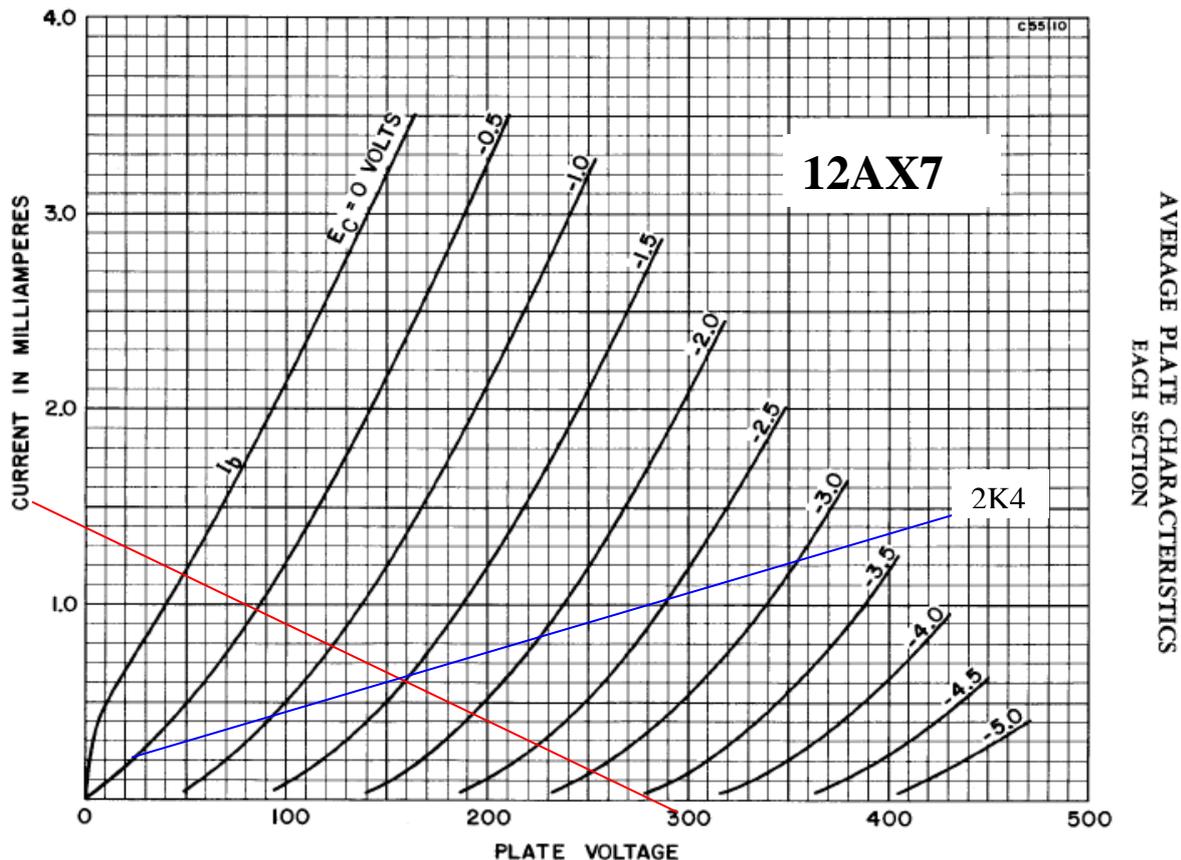
The AC-15 uses an equivalent PI circuit to that starting to be used by Fender in their 5F6 at the time. The ac self-balancing common-cathode PI circuit had been assessed for many years, and was in the 1953 edition of Radiotron Handbook. The plate current versus plate voltage load line for each triode is given by the equation:

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

where $R_k = 1K2\Omega + 47k\Omega = 48k\Omega$. Hence a load line resistance of about $100K + 2 \times 48k = 200k$. With $V_{S4} = 280V$, the plate voltage V_p axis intercept is 280V- for no plate current, and the plate current I_p axis intercept is $280V / 200K\Omega = 1.4mA$. The gate-cathode voltage (E_c on the graph) varies with plate current through the $1K2\Omega$ gate-cathode resistance, but with a $2k4\Omega$ characteristic, and this characteristic is shown on the graph as a line passing through $I_p = 0.5mA$ for $V_{gk} = -1.2V$, and through $I_p = 1mA$ for $V_{gk} = -2.4V$. The intersection of the two lines is the nominal biased operating point of 1.5V and 0.6mA.

Voltage drop across tail $48k$ is $48k \times 1.2mA = 58V$. Hence plate-cathode voltage is about $280 - 58 - 60 = 160V$. Plate load resistance dissipation is about $(160)^2 / 100k = 0.3Wpk$.

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 could be compensated by lowering the load resistor for the out-of-phase output. The input voltage swing limit is from the bias point at $V_{gk} = -1.5V$ to $V_{gk} = 0V$, which is about $3.2Vpp$ or $1.1Vrms$. Referring to the loadline, the plate voltage would swing about 230 V, from about 50V to 280V, with a mid point of 160V [$160-50=110V$; $280-160=120V$] which is quite symmetric.



4.5 Output Stage – EL84/6BQ5 Pentode Push-Pull

In this cathode biased Class AB push-pull output stage the 8k Ω impedance plate-to-plate OPT presents signal currents into each tube with a 4k Ω impedance with both tubes conducting, to 2k Ω load impedance at higher levels.

The recommended design max plate dissipation is 70% x 12W = 8.4W. Idle current at 340V is 25mA/tube. Common cathode bias resistor 220 Ω at 50mA = 11V (0.5W), increasing to 18V in overdrive (82mA, 1.5W).

As the output loading increases, the supply voltage VS2 to the output valve plates sags from about 340V towards 280V. Plate DC voltage will be lower than VS2 by an amount up to ~14Vpk; ie. OPT half resistance of about 120 Ω with a peak current of up to about 0.12Apk. Cathode voltage has an idle bias of 11V and a peak of 18V under sustained signal. So effective plate-cathode voltage sags to about 280-14-18=248V.

Screen supply VS3 will also vary from about 326V towards 270V under steady-state heavy load. Screen voltage will be lower than VS3 by up to about .02A x 150 Ω = 3V due to stoppers, and up to 18V due to cathode bias. STC curves for screen EC2= 300V indicates an 8K P-P (2K line) is quite appropriate, and plate dissipation just extends dynamically into high levels, depending on initial bias level and VS2 sag to about 250V.

Assuming the loadline sags to about 250V plate level and a peak plate current of 120mA is achieved, then the nominal output power of the amplifier (ideal class B2) would be: $(I_{pk})^2 \times R_{pp} / 8 = 0.12 \times 0.12 \times 8k / 8 = 14W$. For this maximum signal condition, the rms OPT current draw is likely about 2 x 77mA (64% of peak), and the average VS2 power consumed is 250x0.154 = 39W, and the OPT loss is $2 \times (0.077)^2 \times 120\Omega = 1.5W$, and the cathode bias loss is 1.5W, so the tube plates dissipate 39 – 14 – 3 = 22W, or about 11W each – which is fine. 1R sense resistors added to each cathode.

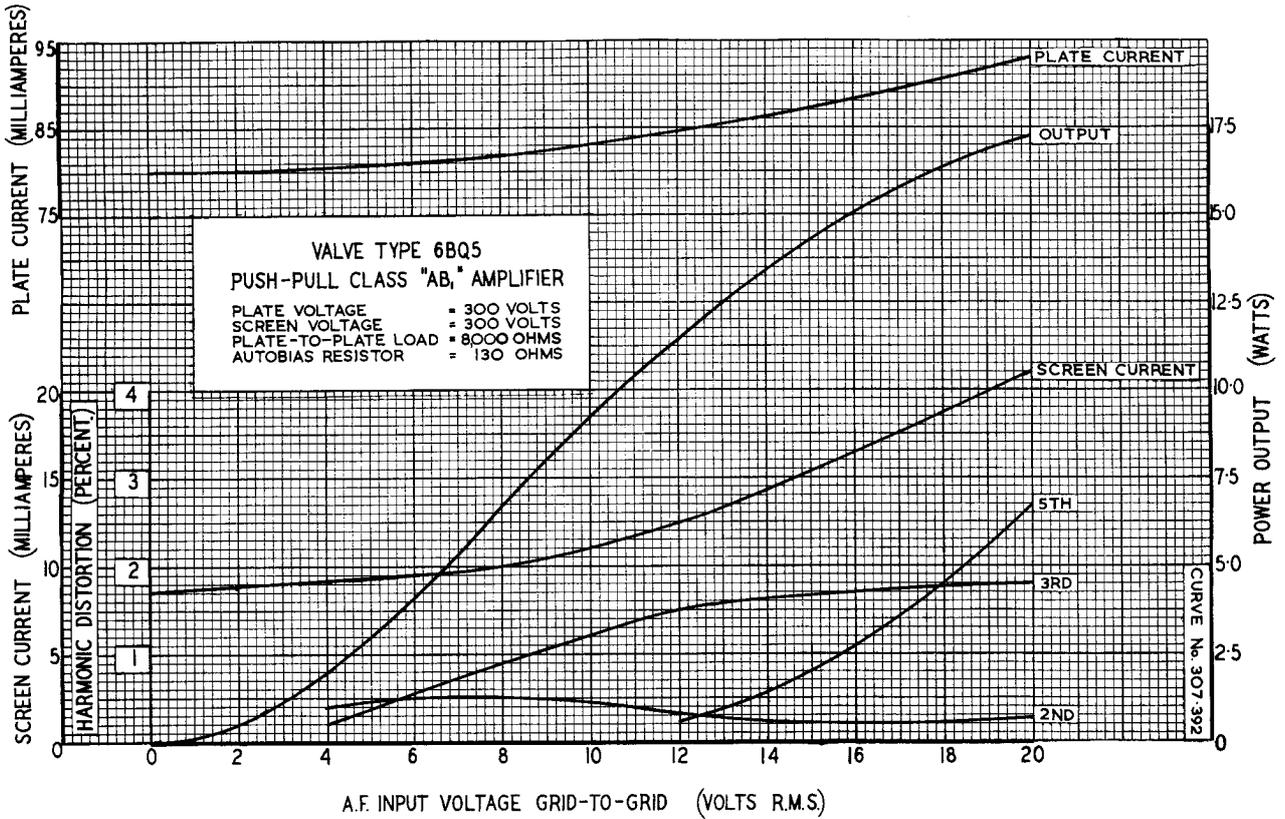
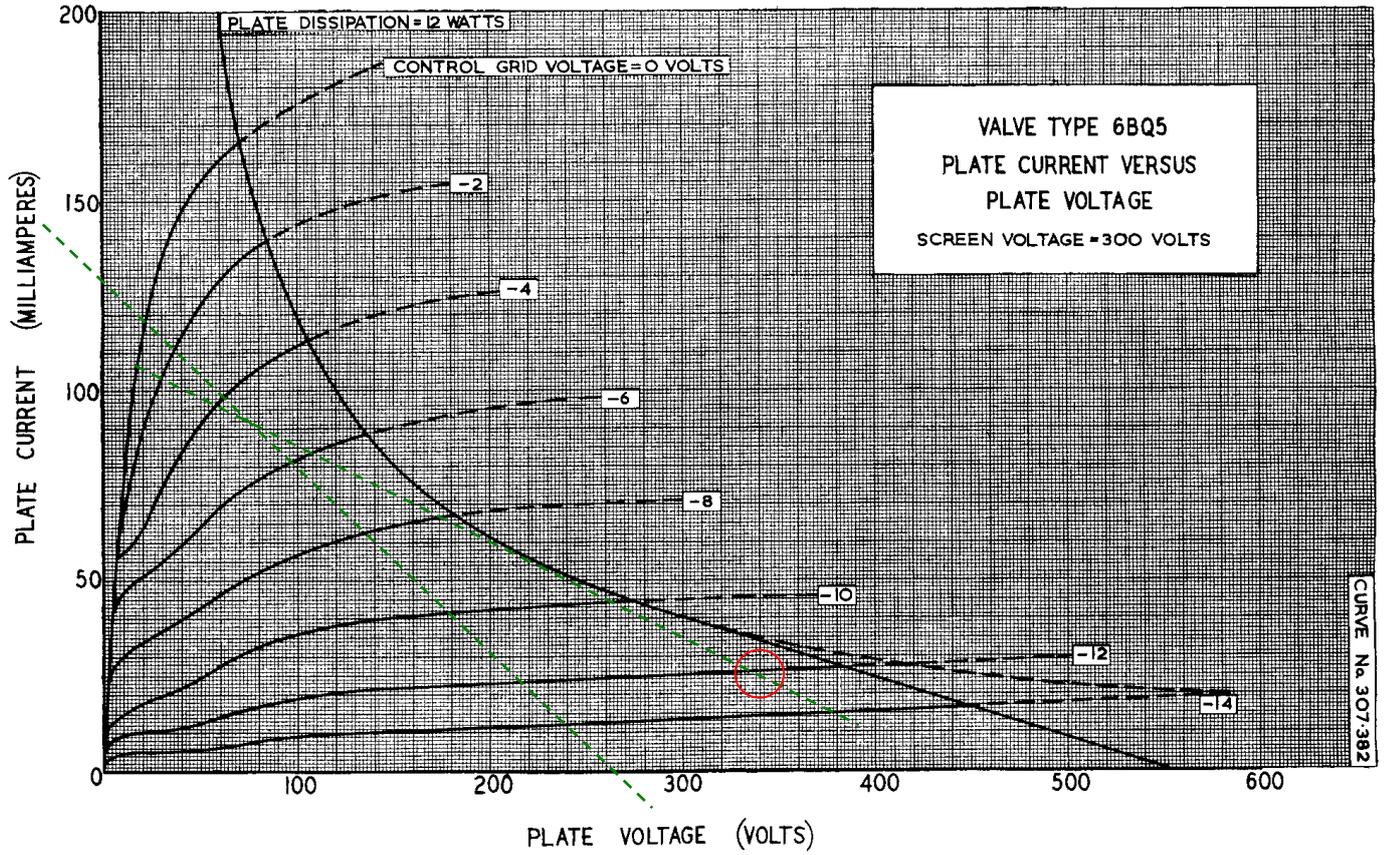
The STC performance characteristics for pentode push-pull class AB1 with 130 Ω common cathode resistor and 40mA idle current, and 300V supply and 8k OPT indicate a grid-to-grid drive voltage level of 20Vrms is needed (28Vpk-pk), and that screen current can reach 20mA.

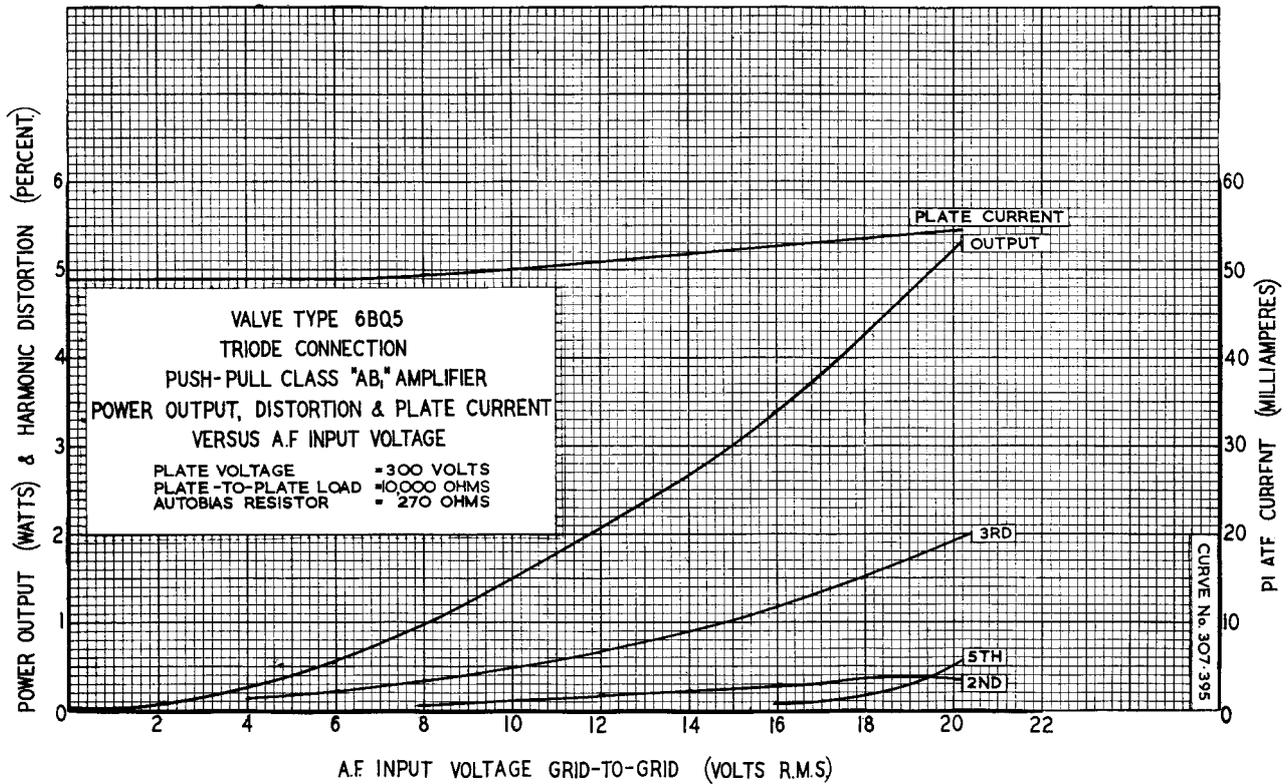
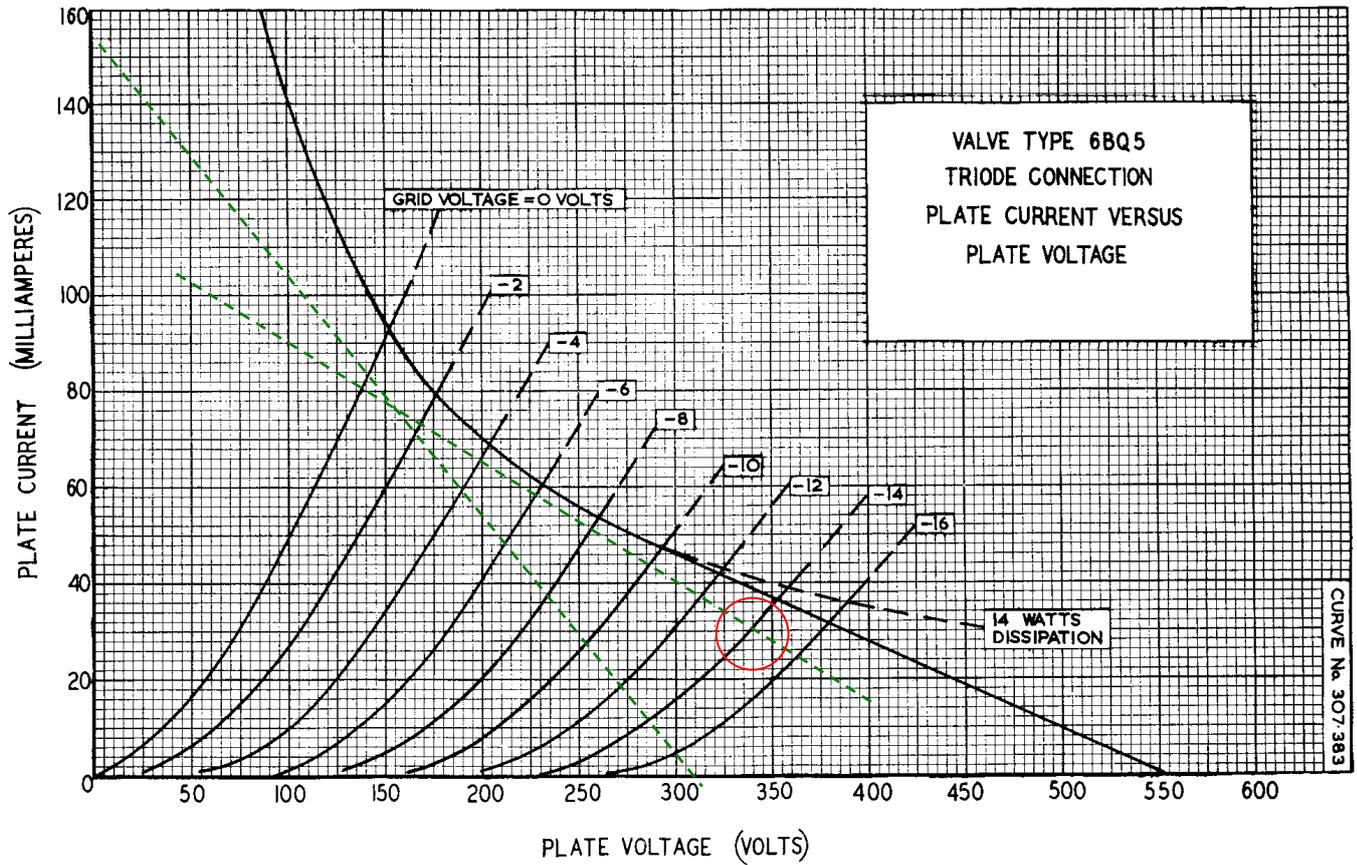
4.6 Output Stage – EL84/6BQ5 Triode Push-Pull

Using triode configuration of EL84/6BQ5 limits the peak output current capability to about 80mA, based on curves, and hence the output power is reduced to about: $(I_{pk})^2 \times R_{pp} / 8 = 0.08 \times 0.08 \times 8k / 8 = 6W$. In this mode, the off valve is not pushed deeply into cut-off, and so most operation is effectively in class A.

The STC performance characteristics for triode push-pull class AB1 and 300V supply and 10k OPT indicate a grid-to-grid drive of 20Vrms is still needed for max output capability. As distortion is much lower, the curves are based on a lower 25mA idle with 220 Ω common cathode resistor.

The Vox Heritage AC15 series common cathode resistor is 150 Ω , which is about 11V bias at 36-40mA in both modes at 300V.





4.7 Power Supplies

A standard full-wave rectifier circuit is used with 344V secondary HT windings with centre-tap to 0V, and a 5V diode heater winding. A CLC filter is used with 12H 56mA rated choke to generate

VS2 and ripple on VS2 is quite low. VS3, 4 and 5 obtained by further RC filtering using 1k, 25k and 10k Ω droppers.

The 5V4G can feed directly into 24 μ F C1 as secondary winding resistance is $>100\Omega$. Effective series resistance is $17\Omega \times (325/240)^2 + 150\Omega = 180\Omega$. The 5V4 is rated to 175mA max, which exceeds the nominal requirement for the output stage plate and 20mA for screen, and a few mA for the other valves. With 100mA rms loading the 5V4 plate drop is about 16V.

The 5Y3GT has equivalent performance to the 5V4G for this application, although it is slightly lower ratings and is directly heated cathode, and so preferable to use standby switch at power on. Diode power on and continuous peak are well below max ratings. The EZ81 in the Heritage is 6.3V heater but otherwise quite close performance.

The ripple voltage across C1 is mainly 100Hz, at a measured level of 51V rms at idle with a choke current of about 56mA DC, with a DC drop of about 22V (DCR=366 Ω).

5. Protection

5.1 Output open circuit

A 510R 3W resistor is added to the 15 Ω output tap, to act as a high resistance limit in case the speaker load goes open circuit.

5.2 Secondary side fuse

CT current has a low level of in-rush due to the choke, with about 115mA rms continuous with an idle B+ supply current of 60mA. Given cranked supply current is unlikely to exceed 90mA, where CT current is about 150mA, then use a quick-acting F 200mA IEC fuse.

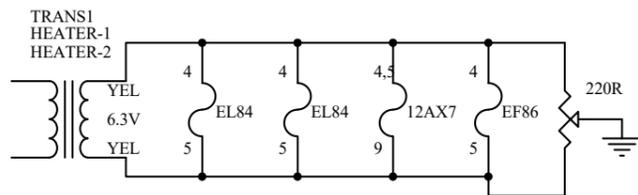
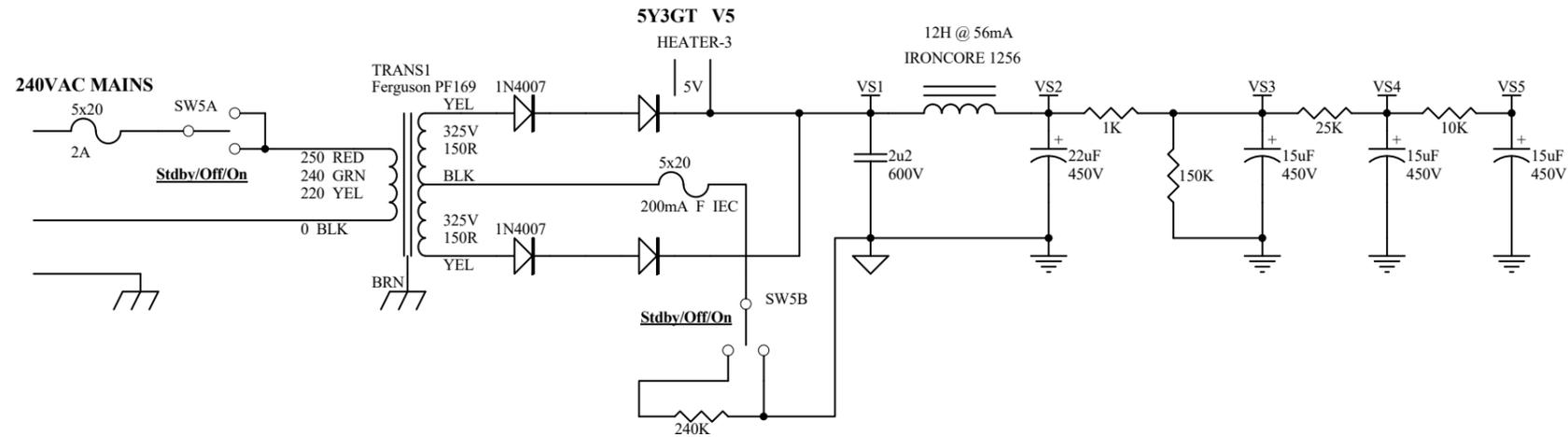
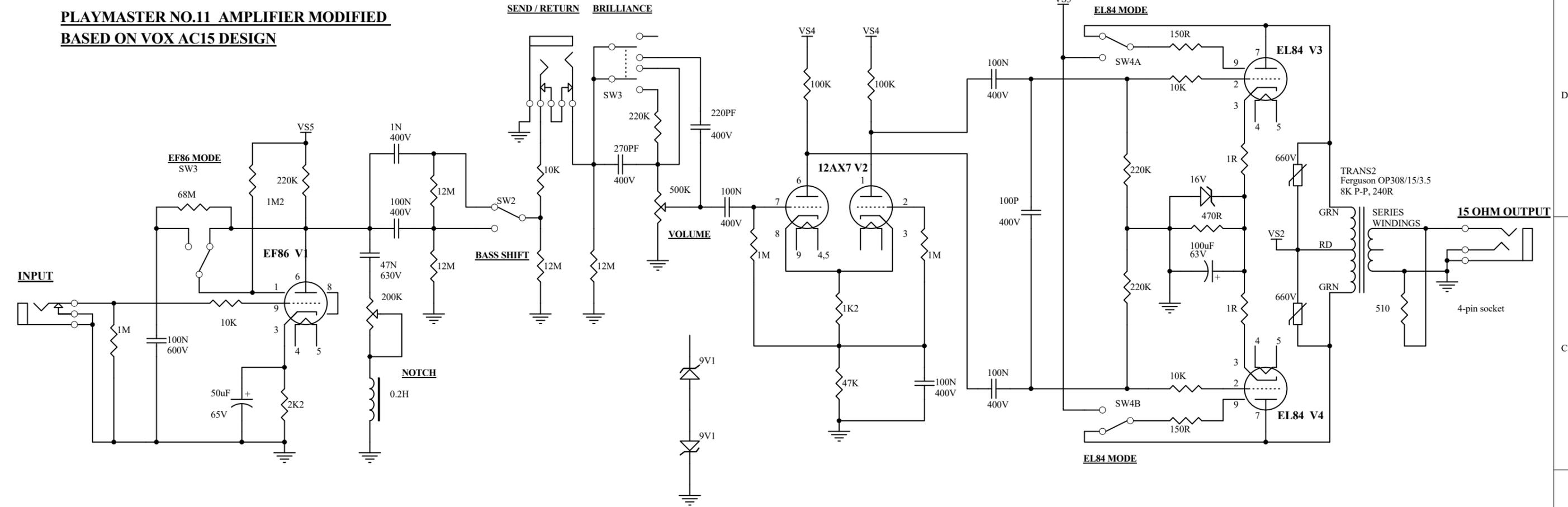
6. Operation

Turn on using Standby first for about 10-15 secs, then switch over to On – this will avoid stressing the filter capacitors whilst the EL84 warm up.

Only switch between triode and pentode modes for EL84 when in standby mode.

EF86 is damped for microphonics but this will still happen.

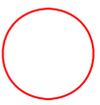
PLAYMASTER NO.11 AMPLIFIER MODIFIED
BASED ON VOX AC15 DESIGN



VOLTAGE RAILS		VALVE	
RAIL	IDLE	EF86	1
VS1	340V	12AX7	1
VS2	310	EL84	2
VS3	300V	5Y3GT	1
VS4	290V		
HEATER-1,2	6.3V		
HEATER-3	5V		



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INPUT



**SEND
RTN**

TONE

BASS SHIFT

BRILLIANCE

TOP

CUT

MODE

TRIODE PENTODE

EL84

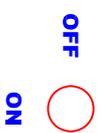
EF86

MASTER

VOLUME



POWER

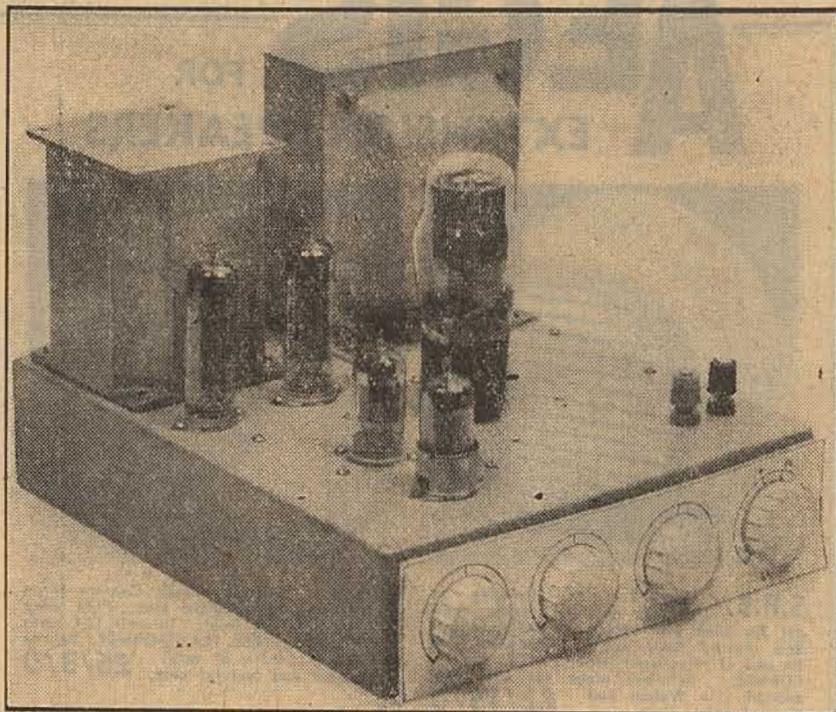


STANDBY

OFF

ON

PLAYMASTER VOX AC-15



Here is the amplifier, pentode version. The EF86 is nearest the camera, then the 12AX7, and behind it the two EL84's. There is no filter choke in this circuit. Controls, left to right, are—Volume, Bass, Treble and Change-over Switch from pick-up to radio.

CRYSTAL PICK-UP AMPLIFIERS

A new Playmaster design intended for crystal pick-ups which features both pentode and Ultra-linear output stages, single-chassis layout, continuously variable tone compensation, high output and low distortion. It does not completely replace Playmaster No. 6, but is to be preferred when crystal pick-ups are to be used.

THE amazing popularity of good quality amplifiers is such that valve applications engineers have been turning their attention to the production of suggested circuits, with particular stress on the selection of valve types and operating conditions for them.

In England, both Mullard and Osram, to mention only two, have evolved designs which they have publicised in considerable detail, and which have achieved great success.

In Australia, the AWA Valve Co. has been carrying out some exhaustive work on amplifiers, with emphasis on the moment on the Ultra-linear circuit and its effects on amplifier performance.

DIFFERENT ANSWERS

One of the most interesting and stimulating things about all this is that, although some very competent men have been engaged in working out these circuits, their conclusions are by no means the same.

This must not be taken to indicate that one person has all the answers, and that all other ideas are wrong. The same pattern can be found in amplifiers made and sold under commercial labels. There are many good ones, but rarely two exactly alike.

From our own point of view, we also look over these designs, and in all humility find that we have our own reactions to them. These reactions are governed primarily by our own particular function of interpreting and providing for our readers what we think is the best course for them to take, bearing in mind that they will have to use components which can be bought over the counter, and assemble them without the benefit of special test equipment.

Apart from actual circuitry, these amplifier designs, which originate from valve specialists are particularly valuable in that they give with considerable accuracy vital information on how valves should be used.

Their advice in this matter is really an extension of the valve characteristics themselves, to which all users must refer when deciding how they can best be incorporated in equipment.

It was only natural, therefore, when considering a new layout for

by *John Moyle*

a special amplifier for crystal pick-ups, that the Mullard circuit should catch our eye.

Not only did it contain much interesting information about the use of the new EL84 output valve, but it also solved very neatly the problem of variable tone controls for use with crystal pick-ups.

It also included an equally neat amplifier-phase-changer combination using a direct-coupled circuit which looked most promising.

These features were eventually incorporated in the amplifiers to be described in this article.

In general form, however, the amplifiers have been laid out to conform to the Playmaster technique, and the design carried forward to include an ultra-linear output stage.

The desire for a "crystal" amplifier of new design was largely inspired by the release of the EL84, and the possibility of using it to push the output up to the higher level we generally expect from a pair of beam power valves.

It will also answer in one swoop all those readers who have written asking about larger valves in the existing No. 6 circuit which, with its 6BV7's, supplied about eight watts.

We felt, too, that here was a circuit which could be used successfully in a number of ways with no major changes.

Firstly, if no tuning unit is required, it can be built purely as an amplifier, with a power supply giving between 250 and 300 volts, and a low rating power transformer.

A heavier power transformer is all that is necessary to convert to a radiogram with one of the standard Playmaster tuners.

Finally, if you want to go for the best, an ultra-linear output stage is the logical answer, with the addition of a filter choke to give the best possible filtering.

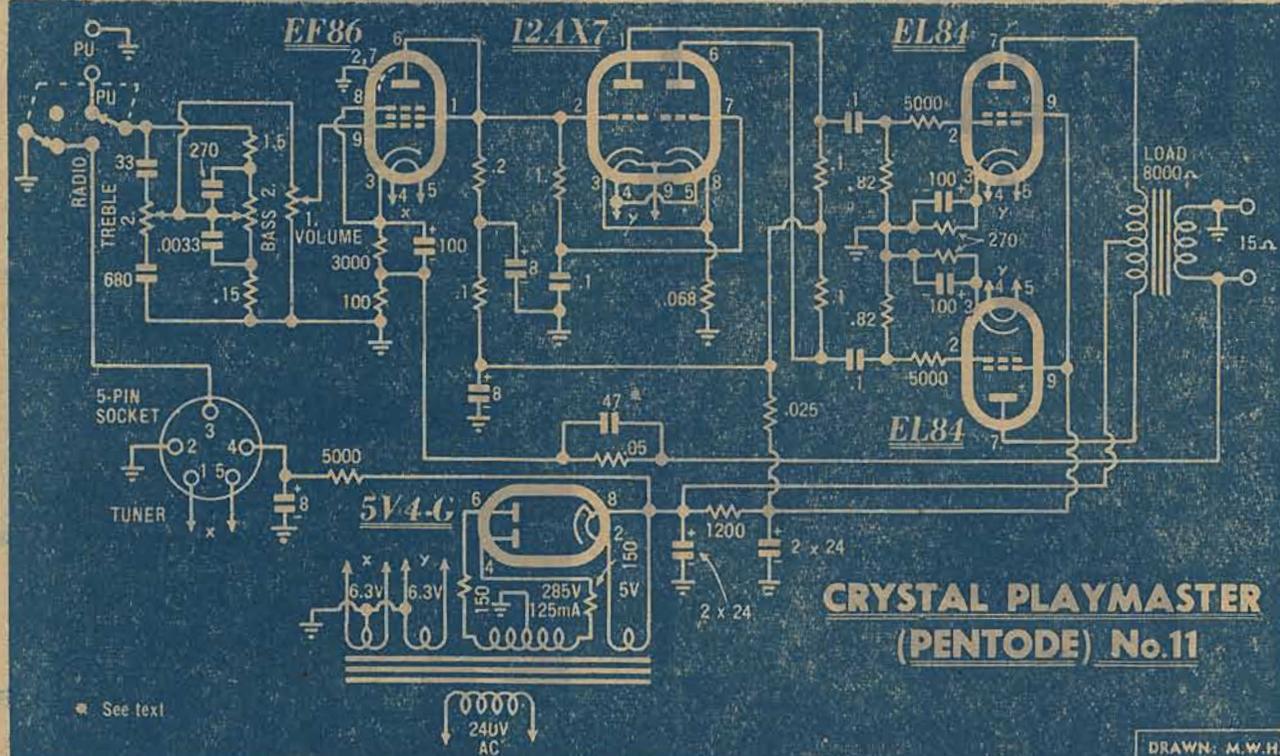
This version is capable of extremely high performance, limited only by the quality of the output transformer.

PICKUP DIFFICULTIES

In the past, we have published a number of articles about standard crystal pick-ups, and how to use compensation with them to flatten out the response. The crystal pick-up is quite the most popular for general use, but unfortunately design makes it almost impossible to avoid peaks and bumps in the output, with the possible exception of some special types.

If trouble is taken to hand-tailor suitable circuits, things can be improved, but our experience has been that there is no single method of

PENTODE VERSION OF THE CRYSTAL AMPLIFIER



This is the amplifier circuit wired with a pentode connected output stage. This version will give almost 17-watt output with full plate voltage. The filter choke may be omitted and the power supply wired as shown above. The phase correction capacitor marked with an asterisk was chosen for the transformer used, but this value should be OK for almost any other type.

compensation which can be used successfully with all types.

The best idea seems to be to buy the highest quality pick-up you can afford, and to use it with an amplifier having a wide range of bass and treble adjustments, which can be set until the music sounds best.

This isn't an acceptable idea to the seeker after the highest fidelity, but this amplifier, although its response as such is extremely good, isn't designed for these people.

It is intended primarily to give you, on one chassis, something which will work from practically any type crystal pickup and sound well.

The man who is interested in this kind of amplifier seems to prefer continuously variable tone compensation controls to the stepped type.

If these controls are to be used to supply all the compensation, there is much virtue in the idea. It allows the utmost flexibility, whereas a stepped control would probably limit the range of adjustment far too much.

RANGE OF CONTROL

This amplifier has quite a wide range of control. The treble cut is quite severe in the maximum condition, but LP records frequently call for this because of their initial pre-emphasis.

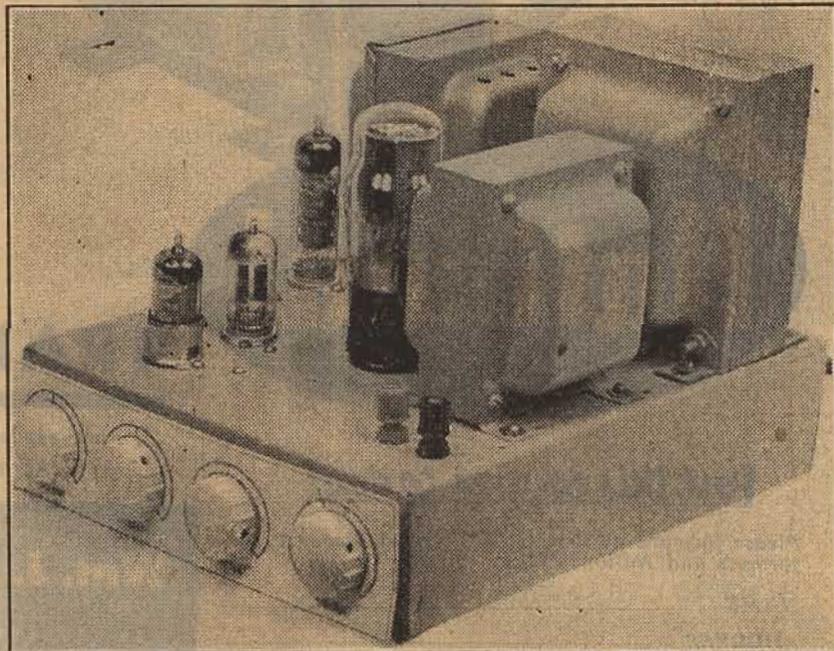
The bass response of a crystal generally has a rising characteristic, which helps to compensate for the bass cut in the recording. Consequently special networks designed to level the response are not generally recommended with the ampli-

fier. Best results seem to be obtained by running into a load somewhere between .25 to 1 meg, wired across the pick-up terminals, and then using the controls to do the rest.

The input sensitivity for full output is about .45 volts with the pentode connection, and about .7

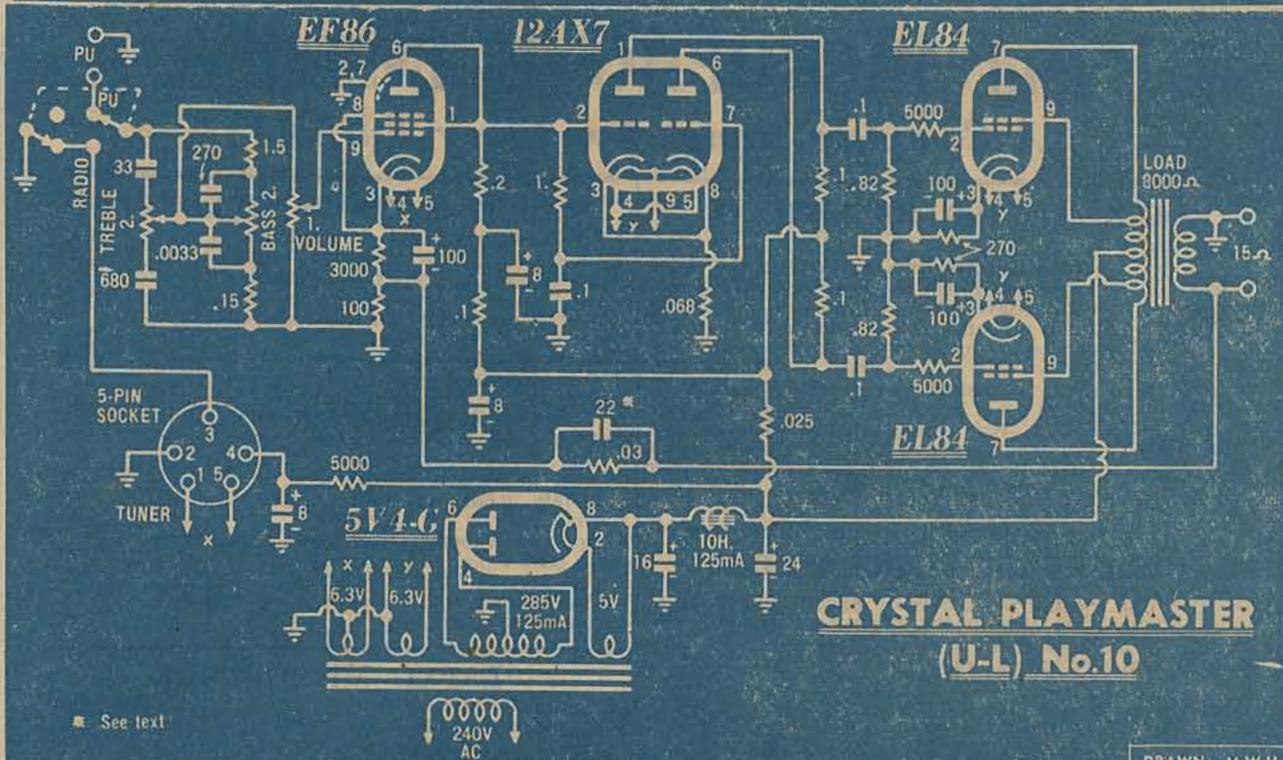
volts for ultra-linear. As full output will be between 13 and 17 watts, this means that even pick-ups with moderate output will give all the volume you can stand.

The sensitivity is ultimately determined by the amount of feedback. Both circuits are set for about 15 db of feedback. A little more or



Here is the amplifier wired for an Ultra-linear circuit and with a standard power supply using a filter choke. Make sure that the cores of the power and output transformers are at right angles to their centres. Controls, etc. are the same as for the pentode version.

U-LINEAR VERSION OF THE CRYSTAL AMPLIFIER



CRYSTAL PLAYMASTER (U-L) No. 10

DRAWN: M.W.H.

The Ultra-linear circuit is similar to the pentode version except for the output stage and power supply. Once again the phase correction condenser was chosen for the transformer used. Limiting resistors in the high-tension leads are not necessary.

less would give a corresponding variation in sensitivity.

Note that feedback is placed right around the amplifier, from the output transformer secondary to the cathode of the first amplifier. In the No. 6 Playmaster it will be remembered that this valve was not included in the feedback loop.

The range of compensation is from 10db of treble boost to 10 db of treble cut, and from 11 db of bass boost to 5 db of bass cut. The "flat" position will occur somewhere near the centre position of each control, but there is some interlocking between them which is difficult to avoid with this type of circuit.

The compensation circuit is placed immediately after the pickup and has a gain reduction of about 12 times. This means that the amplifier itself has an actual sensitivity of around 50 millivolts or less, which, associated with high impedance circuits, is very prone to pick up hum.

INPUT SHIELDING

To avoid this, the controls are grouped along the front edge of the chassis, and a right-angled shield, not shown in the pictures, is provided to completely box in these controls and their associated wiring, as well as the first valve socket and all its associated components.

The filament, power, and output leads to this part of the circuit run through small grooves cut into the edge of the shield, which is held to the chassis by three turnover feet bolted to the underside of the chassis top, and by two small brackets bolted or soldered to the two front corners.

This shielding is effective in completely avoiding any stray pick-up.

The input to the amplifier is via a switch which allows input either from the pick-up terminals or from the 5-pin socket which connects to the tuner. A shielded lead runs from the switch to the socket. Note that a second switch section short-circuits the input from the tuner to prevent "play-through" when using the pick-up.

Incidentally, the voltage divider usually employed in the Playmaster tuners to reduce output need not be so severe in its reduction of voltage. Experiment will be

best, but we suggest using resistors of equal value to reduce the available output by one-half.

Construction of the front section is made easy by the earth wire which runs along in front of the potentiometers and connects to the earthed pickup terminal. All components associated with the front end are earthed to this wire, which in turn is connected to the chassis at one point near the 12AX7.

The idea is to provide a single earthing point for this part of the circuit, thus avoiding any possible

PARTS LIST

PENTODE VERSION

- 1 chassis, 10 x 8½ x 2½ in.
- 1 shield 5½ x 8½ in. (See article)
- 1 power transformer 285V/125 mA. (See article).
- 1 Output transformer 8000 ohms P-P to suit speaker. (See article)
- 3 Noval sockets (ST29G, mica filled.)
- 1 Noval socket with skirt (Ceramic or mica filled.)
- 1 Octal socket.
- 1 5-pin socket.
- 1 min 4-pin speaker socket and plug.
- 5 valves, EF86, 12AX7, 2 x EL84, 5V4.

CAPACITORS

- 4 24 mfd 525 V electros, 3 8 mfd 525 V electros, 2 100 mfd 40 V electros, 1 100 mfd 12 V electro, 3 .1 mfd 400 V paper, 1 .0033 mfd mica, 1 680 pf mica, 1 270 pf mica, 1 47 pf ceramic, 1 33 pf ceramic.

RESISTORS

- 2 2 meg potentiometers, 1 1 meg potentiometer, 1 1.5 meg, 1 1. meg,

- 2 .82 meg, 1 .2 meg, 2 .1 meg 5%, 1 .1 meg, 1 1.5 meg, 1 .068 meg, 1 .033 meg, 1 .03 meg 2 5000 ohms, 1 3000 ohms 1 100 ohms. (All ½ watt.)
- 2 270 ohms 3 W, 1 5000 ohm 3 W, 1 1200 ohm 1 W.

SUNDRIES

- 2 8 point tag strips 1 2 pole 2-pos. Oak switch, 3 3 point tag strip, 4 knobs, nuts, bolts, solder lugs hook-up wire, tinned copper wire, 2 terminals, power flex and plug.

ULTRA-LINEAR VERSION

In the ultra-linear version the high voltage electrolytics needed are: 1 24 mfd 525 V, 1 16 mfd 525 V and 3 8 mfd 525 V, which replace those shown in the pentode list. The output transformer should be an 8000 ohm plate to plate U/L type, to suit the speaker used. An additional item required is a 10 Hy 125 mA choke.

UNDER-CHASSIS OF AMPLIFIER

earth loops which might occur, with resulting hum pickup, if earth points are indiscriminately made.

This technique is only important in the first stage where the gain is highest.

The EF86 plate and screen resistors, cathode resistors, and condensers may be supported on a couple of 3-tag terminal strips bolted to the chassis near the EF86 valve socket. There is plenty of room to fit them in under the shield.

The EF86 is triode-connected and direct-coupled to the cathode-coupled phase-changer, which we have used in several of the latest circuits.

The original Mullard amplifier used a pentode connection in order to obtain higher gain to support a large amount of feedback. But experience has shown us that high feedback generally means individual adjustment and careful phase correction if instability is avoided—a big price for the home constructor to pay for slightly reduced distortion.

The triode connection gives lower gain, but the use of less feedback brings the initial sensitivity up to about the same figure.

The EF86 bias is adjusted to give about the same plate current as with pentode connection, so that the values for the direct-coupled circuit may remain almost unaltered.

The main objection to direct coupling is that, if either valve should vary in emission, circuit conditions may be upset. However there is a certain amount of automatic compensation which reduces this risk to a reasonable level.

Absence of a coupling condenser reduces the phase shift in this portion of the amplifier, and adds to stability.

AMPLIFIER IS STABLE

In practice we found it impossible to make the circuit oscillate, even with feedback well over 20 db and with grossly incorrect phase correction values across the feedback resistor.

This inherent stability is a valuable feature where a wide choice of output transformers is involved.

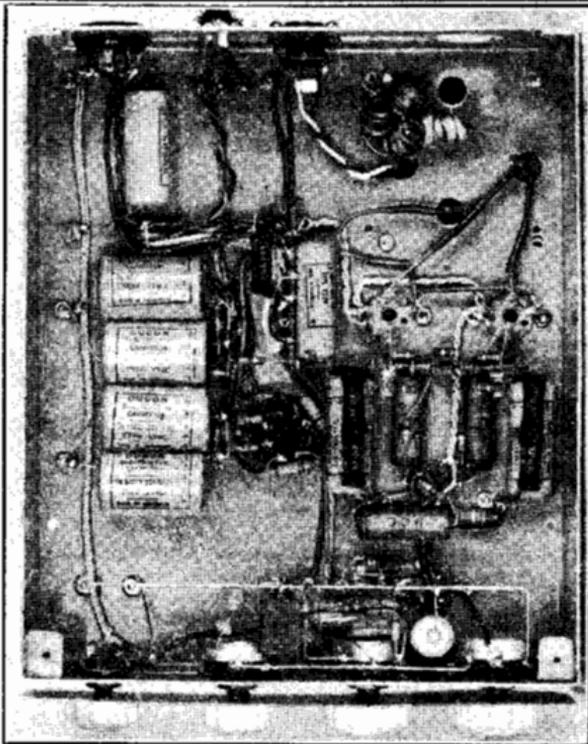
The phase-inverter and output stage are laid out to provide exact symmetry in the push-pull connection. The two plate connections for the 12AX7 have their axis parallel with the front edge of the chassis so that the coupling condensers fall naturally into place. A terminal strip placed just ahead of the output sockets carry the grid resistors and suppressors, and also anchor the cathode resistors and condensers. A glance at the underchassis photograph will tell you all you need to know to put you on the right track.

We have not used screen suppressors because at no time were they found necessary. Even the grid suppressors are there merely as a precaution.

The output bias resistors may need to be 250 and 20 ohms in series if the odd value is hard to get.

The output transformer must be mounted with its core exactly at right angles to that of the power transformer to avoid mutual coupling. If this is done there will be no hum pickup despite their proximity.

If you are very fussy you can pick the exact position by test in



This picture is referred to in the article and shows clearly almost every component. It is the pentode amplifier—the U-L version has only two main filter condensers, shown at the left. Note the corner brackets which help to mount the shield over the front end. Symmetrical layout has been aimed at.

a manner described several times in past issues, removing the rectifier but leaving the mains connected to the power transformer.

For the pentode version a straight output transformer of 8000 ohms output impedance is used. It must be of reasonably good quality which rules out the PA type. Several good multi-section transformers are obtainable, and it is good practice to buy the best you can afford.

NO FILTER CHOKE

With the pentode connection it is possible to eliminate the filter choke to save on cost, using instead a resistance-capacity filter for the output screens and the remainder of the circuit, and feeding the plates directly from the rectifier. With beam power valves and pentodes, having a high plate resistance, this is quite satisfactory.

It calls for extra filter condensers which offset the saving of a choke, but of course you can use a choke in the normal way if you have one.

We have included this type of resistance-capacity filter in the pentode circuit to illustrate the point.

Note the small 1-watt resistors connected in series with the high voltage leads to the transformer. These limit the peak current demanded from the rectifier by the high first capacitor value, and avoid damaging it. The exact value should be calculated after measuring the resistance of the windings, but the value given should be adequate in most cases. The underchassis picture was taken with this circuit.

The filter condensers are supported at the "hot" end with a resistor strip, which also supports a decoupling condenser and the dropping resistor for the tuner.

There is plenty of room to support these odd components in almost any manner you choose, but we have shown you our amplifier as a guide.

In the ultra-linear circuit, the screens cannot easily be isolated from the plate circuit, and we strongly advise the use of a filter choke and a normal connection as shown. The first filter condenser should not be higher than 16 mfd with this circuit.

In all cases, a 285 volt transformer will supply about 300 volts between

the output plates and cathodes. If the tuner is used, a 100 mill rating will be enough. But as the tuner might well run to another 20 mills, the rating should be increased by this amount if you want the radio as well.

The 5000 ohm resistor will drop the tuner voltage to about 230 volts, and an extra 8 mfd decoupler is added for safety.

The only difference in the output connections for UL work is to connect the screen tapping to the correct sides of the circuit, as indicated by the manufacturer. If you get them crossed, the circuit will oscillate.

Separate bias resistors are used for the output valves. With valves having a high mutual conductance, this is often a good idea to allow the automatic bias to compensate for current variations. It makes little difference to distortion unless the valves are appreciably unbalanced.

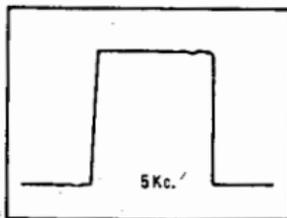
CATHODE BYPASS

High value cathode bypasses are used to hold up the bass response and avoid phase shift at low frequencies.

The feedback resistors are different for each circuit because the gain is greater with the pentode connection. The exact value of the phase correction condenser marked with an asterisk will depend on the output transformer, and we have given the value used with the transformers shown. If you are in doubt, 47 pf should be about right. The values given were chosen for

least ringing and best square-wave performance.

We built our amplifier on an aluminum chassis which is easier to work than steel, but there should be little difference between the two, particularly if care is taken with the single-point earthing of the first stage.



This is a square-wave tracing of the U.L. amplifier at a frequency of 5 Kc. It shows almost complete absence of overshoot and ringing, and illustrates the good over-all frequency response.

Blue-prints will be supplied to the chassis makers so that you can order your chassis in the normal way.

We do not intend to indicate mounting holes for either the power supply or the output transformer, because there are a number of makes available, and unfortunately their mounting arrangements are not standardised.

But it is usually not a matter of great difficulty to drill suitable holes

on the chassis and we have taken care to leave enough room for any of the well-known makes.

The same point applies to output transformers. Some require rectangular cut-outs and some need only holes to allow the leads to pass through.

A cut-out can be made quite easily by drilling an outline with holes which almost overlap, knocking out the section, and cleaning up the ragged edges with a file.

FRONT END SHIELD

The shield for the front section is simply a right-angled metal section fitting closely inside the width of the chassis. The vertical edge fits down just in front of the 1 mfd condenser wired to the 12AX7 valve socket, and clearly visible in the picture. If you look closely you will see the three holes in the chassis by which the three little feet are bolted to it, one at each end and one in the middle.

Clearly visible, too, are the two corner brackets, supporting the top fold of the shield. These are mounted below the chassis edge by an amount equal to the thickness of the shield metal, so that when in place the shield is flush with the bottom of the chassis. The brackets are tapped for 1-8in bolts, using countersunk heads set flush in the metal.

The underchassis photograph shows also the lead to the tuner at the right, and the filament and feedback leads running back near the centre of the chassis. A third set of leads run between the first

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two sockets—they are the plate-grid coupling connection and the single-point earth lead. Thus you will need three little nicks cut in the edge of the shield to give them free passage.

The feedback resistor and its condenser are mounted on the two unnumbered pins of the 4-pin speaker socket.

The white circle seen near the EF86 valve socket is the plate decoupling condenser standing on its end, so that it is earthed to the common earth wire, also clearly visible.

The controls are fitted with medium-sized knobs, and details of the escutcheon plate will be supplied to advertisers so that one may be ordered in the usual way.

The feedback resistor values are given for 15 ohm speakers which are generally characteristic of the better types.

For 8 ohm speakers the resistance value should be reduced to two-thirds the value given, and for 2-ohm speakers to one third. The phase-correcting condenser should be increased by a similar amount.

CIRCUIT BALANCE

For accurate balance in the phase changer circuit, the two plate resistors, specified as .1 meg (5 pc tolerance), should be of different values. In most cases it will not be essential to worry about it as the unbalance is unlikely to exceed a few per cent.

If you are keen to compensate for this point, it should be noted that the plate resistor of the section which has the grid grounded through the .1 mfd condenser, has the larger value.

With a valve such as the 12AX7, the difference in value is estimated as 3 pc, which means that a 3000 ohm resistor should be included in series with the .1 meg plate load to achieve perfect balance.

It is a good plan to measure your two resistors on an ohm-meter. Select the one which has the larger value for use in this position, if it is possible to detect any difference at all with 5 pc resistors.

FILAMENTS

If you have reason to believe the difference is equal to something like 5000 ohms, no extra resistor need be used, as there is no point in having the .1 values accurate to microscopic limits. It is the small difference in value which is important.

Note that the tapped 6.3V winding of the transformer is the one to use for the EF86, as a balanced earth connection is valuable in reducing the danger of hum in high gain audio circuits.

This winding is also used for the tuner to balance the strain between the filament windings, and it is therefore important to see that the filament circuit in the tuner is not connected to its chassis. To do this would be to short-circuit one-half of the winding.

The Playmaster tuners were all designed without a filament earth, but if you use a different type of tuner you should watch this point.

There is no advantage to be gained by centre-tapping the second fila-

ment winding, which feeds the last three valves.

Nor is there any improvement to be noticed by returning the centre-tapped filament to a positive voltage, as was done with many of the Playmasters. Some of these designs ran with a sensitivity much higher than that of the two described here.

THE PICK-UP

The selection of a pick-up must be a matter of individual choice, and it is an obvious remark to say that the best pick-ups sound best. They generally have a lower output than the standard twin-stylus cartridges, but we have used the amplifier with a number of types, and they all provide ample volume on standard discs.

It is quite worth while to buy a good speaker for use with these amplifiers, as their performance will show that they both merit it. Here again cost and personal preference comes into it.

Adequate baffling is quite essential for any such speaker, and the makers often provide designs for suitable enclosures for use with their speakers.

If you are in any doubt about the value of feedback resistor required for any given speaker, it should be of such a value as to give a gain reduction of between five and six times when connected into circuit.

If you find you have more volume than you can use, it is quite in order to use a higher reduction factor which will, of course, give more feedback.

It should rarely be necessary to push this factor higher than 10, which represents 20 db of feedback, although both amplifiers will be quite stable with this amount.

PERFORMANCE

A few figures about the amplifiers tested without the compensation circuit will be of interest. With each amplifier the square wave shape was extremely good. We have given a tracing of the wave-form of one UL version taken at 5 Kc, showing an almost perfect pattern. The pentode circuit was quite comparable, although we would expect better linearity and lower distortion with the UL connection.

A typical response curve for one of the transformers tested showed a flat response to 90 Kc, 1 db down at 125, 2 db at 140, 3 db at 175 and 6 db at 210 Kc. Some transformers did better than this. This performance is only bettered by our best amplifiers using the highest quality parts, and in any case compares very well with the best commercial standards.

Power output of the pentode amplifier was 16 watts at 1 Kc. Output of the UL version was 13 watts at 1 Kc, and 9 watts at both 20 cycles and 10 Kc. Input sensitivity at the grid of the first valve was 50 milliwatts, and the effective plate voltage 300 volts. The feedback was 15 db to which must be added the feedback provided around the output stage by the UL connection. This is enough to reduce distortion to a negligible amount.

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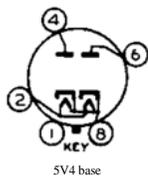
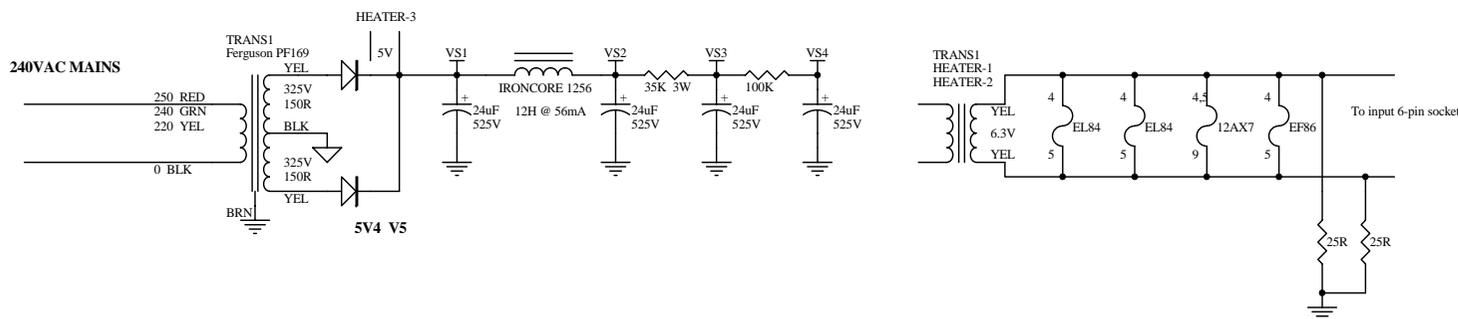
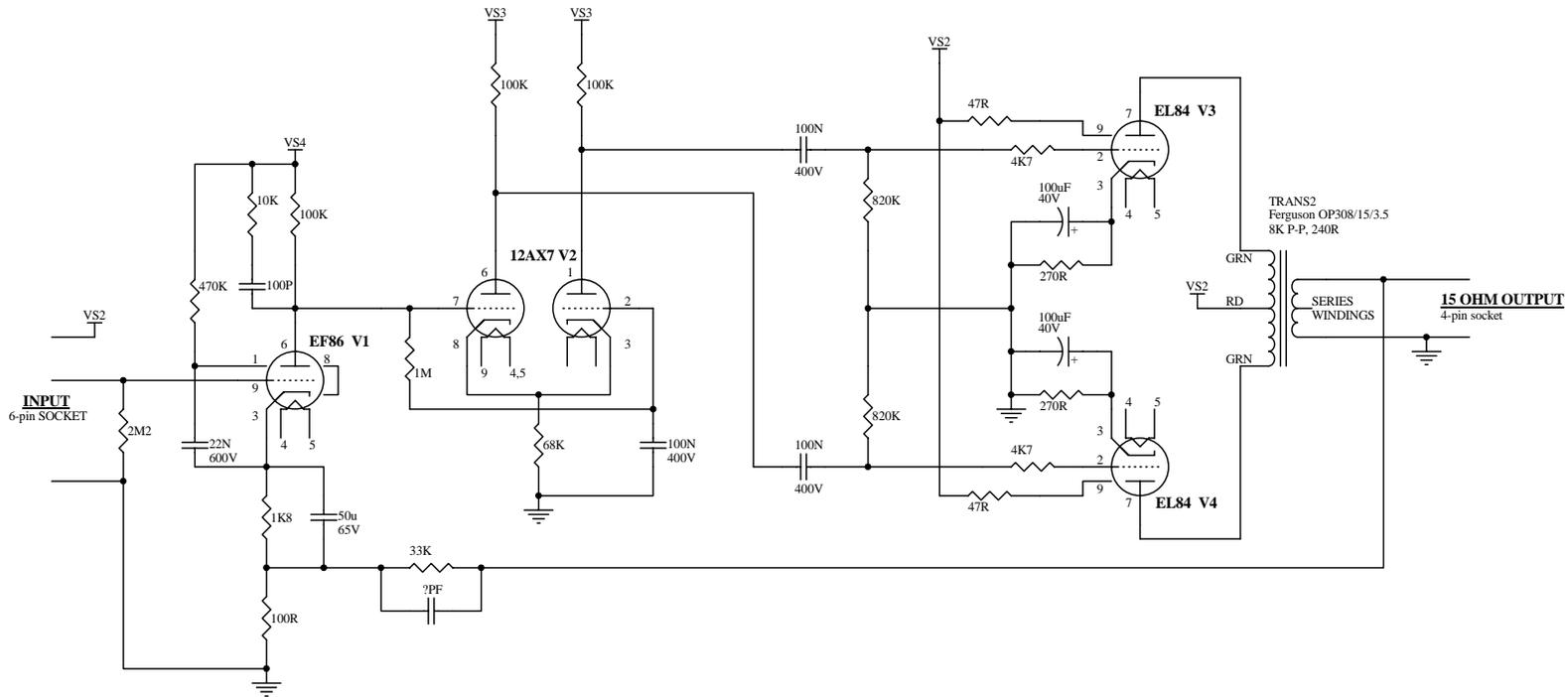
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VS2	425V	EL84	1	1
VS3	314V	12AX7	1	1
VS4	202V	5V4	1	1
HEATER-1.2	6.6V			
HEATER-3	5.4V			



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