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 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. 16Wrms nominal rating. Spot-welded aluminium chassis. EF86 input amplifier, then 12AX7 long-tailed 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 230/240 Prim;
	325-0-325V 80mA SEC; 6.3V-2ACT; 6.3V-2A; 6.3Vtapped5V-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 [1]
	12AX7 Miniwatt code ◢7B
	EF86 Miniwatt code 9r1 B6F

Issues:
No protective earth or fuse or power switch. Waxed paper caps leaky.

1.2 Original Preamplifier

Playmaster project, CONTROL UNIT No 6. 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] Appears to be Philips Canada from the 'r' code. And the date code indicates possibly original 1955 parts.

1.3 Playmaster amplifier information

Radio and Hobbies August 1954, page 70.
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).
Still to check July 1958 and October 1958 issues: Radio, Television and Hobbies.
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 Target Amplifier

In comparison, the 1958-60 Vox AC15 used a normal channel with the same valve config and quite close in design. The 2007 Heritage remake also included ability to switch the EF86 and the EL84 PP stage between pentode and triode modes. Fit amp into a combo plywood enclosure with 16Ω Celestion Vintage 30, in similar layout as 2007 Heritage. Traffolite front panel with similar layout, and including bass shift; brilliance 3-pos; top cut pot; pentode and triode mode switches; standby-off-on switch. Include a Send/Return socket beside the input socket. Possibly have tremolo 2nd channel input coming from a reconfigured Control Unit 6.

2. Modifications so far

Original electrolytics reformed with simple current limited circuit. ESR of 24uF 550V cap after reforming 45mVrms/360uArms = 120Ω, based on 100Hz rectified ripple from supply through 1k resistor. Datasheet replacement ESR appears to be circa 14Ω, so could add a new smaller valued bypass capacitor across each old capacitor if needed. Primary side Megger is ok. Replaced waxed paper caps. Using new EL84s, as original pair were too mismatched in bias. Glued parts and wires down where appropriate. Added high-temp silicon with metal ring to EF86 for dampening microphonics – also dampened valve base, and amp wooden base. Glued up aluminium base which had some rattles. Tried higher EF86 screen resistance, but overdrive distortion too significant, so reduced to 1M1. Still to cover enclosure and add traffolite fascia.

3. Measurements

Voltage rail regulation.

Rail	No Load * (humdinger)	VS2 load ** 10K5	VS2 load ** 3K65	VS2 load *** 10K5	Final config Idle (pentode mode)
VS1		440V	387V		413V
VS2		425V 40mA	352V 96mA		396V
VS3		373V	312V	314V	361V
VS4		311V	263V	202V	271V
Heater 1,2	6.9				6.51
Heater 3	5.8				
Sec HT	366-0-366		360-0-360		351-0-351
Ripple C1		3.4	7.2		3.4
Ripple C2		0.03	0.08		0.05
Ripple C3					0.01
Ripple C4					0.005

Note: * no valves. ** No signal valves. ***No EL84's.
Power transformer primary DC resistance: 0V black; 14.7Ω, 220V, yellow; 17Ω, 240V, green; 17.8Ω, 250V, red.
Power transformer secondary DC resistance: 149 + 156 = 305Ω, yellow/yellow. 0V, black. Earth screen, tan tubing.

IRONCORE 1256 (12H at 56mA)
16.6H @ 26mAdc: 14.4H @ 45mAdc; 9.5H @ 93mAdc; DCR = 366Ω.

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	-;	8,000Ω;	N/A
Sec: BLK to CT	6.19	44.4;	8,000 Ω;	4Ω;
Sec: BRN to CT	6.19	44.4;	8,000Ω;	4Ω;
Sec: BLK to BRN	12.38	22.21:	8,000 Ω;	16.2Ω;

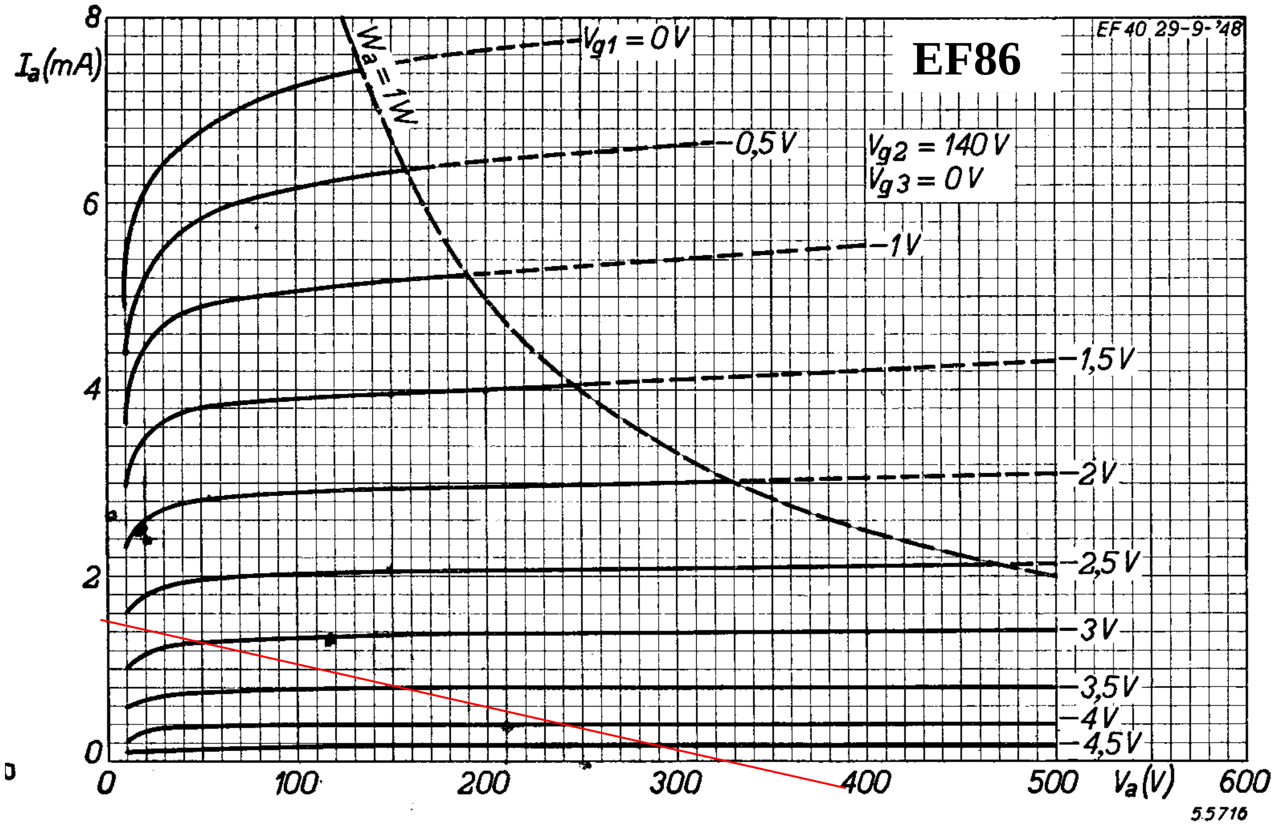
Output transformer primary DC resistance: 103+135=238Ω plate-to-plate.

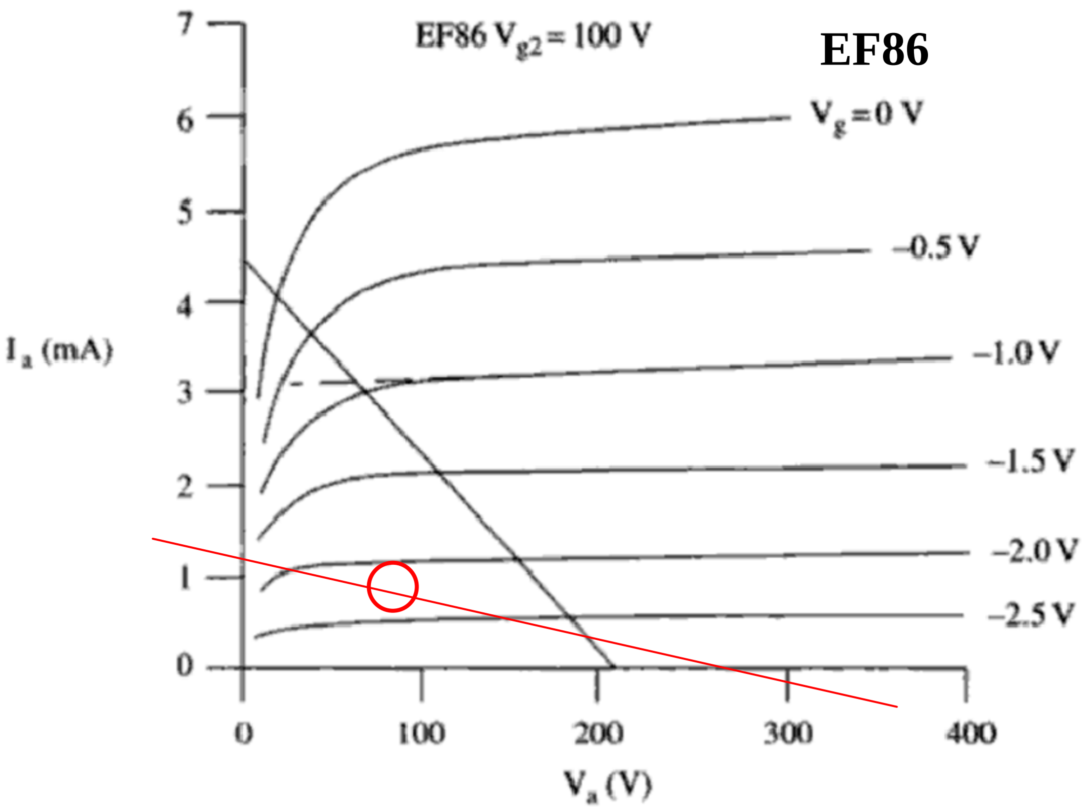
4. Design Info

4.1 Input stage – EF86 in Pentode Mode

Original circuit measurement: VS4=202V; Plate=113V; screen=84V; cathode=1.97V; 100R=92mV. Cathode current = 0.9mA. RC across 100k plate load sam as used by Mullard 5-10 and provide a compensation zero-pole to assist stability (phase advance prior to 0dB crossover) using NFB to cathode – not used in R&H circuit.

Assume supply voltage is VS4=330V; load resistance is 220k; and cathode resistor is 2K2. The plate voltage Vp axis intercept is 330V for no plate current, and the plate current Ip axis intercept is 330V / 222KΩ = 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 Vg2=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 Ik=0.46mA, Vg1~=1.02V, Vs =40V, – measured levels with 4M4 screen resistor has operating point around Ik=0.46mA, Vg1~=1.02V, Vs=40V and Va =225V – measured levels with 2M2 screen resistor has operating point around Ik=0.7mA, Vg1~=1.54V, Vs=65V, Va =164V, VS4=310V (measurements: VS4=309V, Va=162V, Vg1=1.54V; Vs=67V). Measured levels with screen resistor ~1M1: VS4=271V, Va=81V, Vg1=2.1V; Vs=96V.



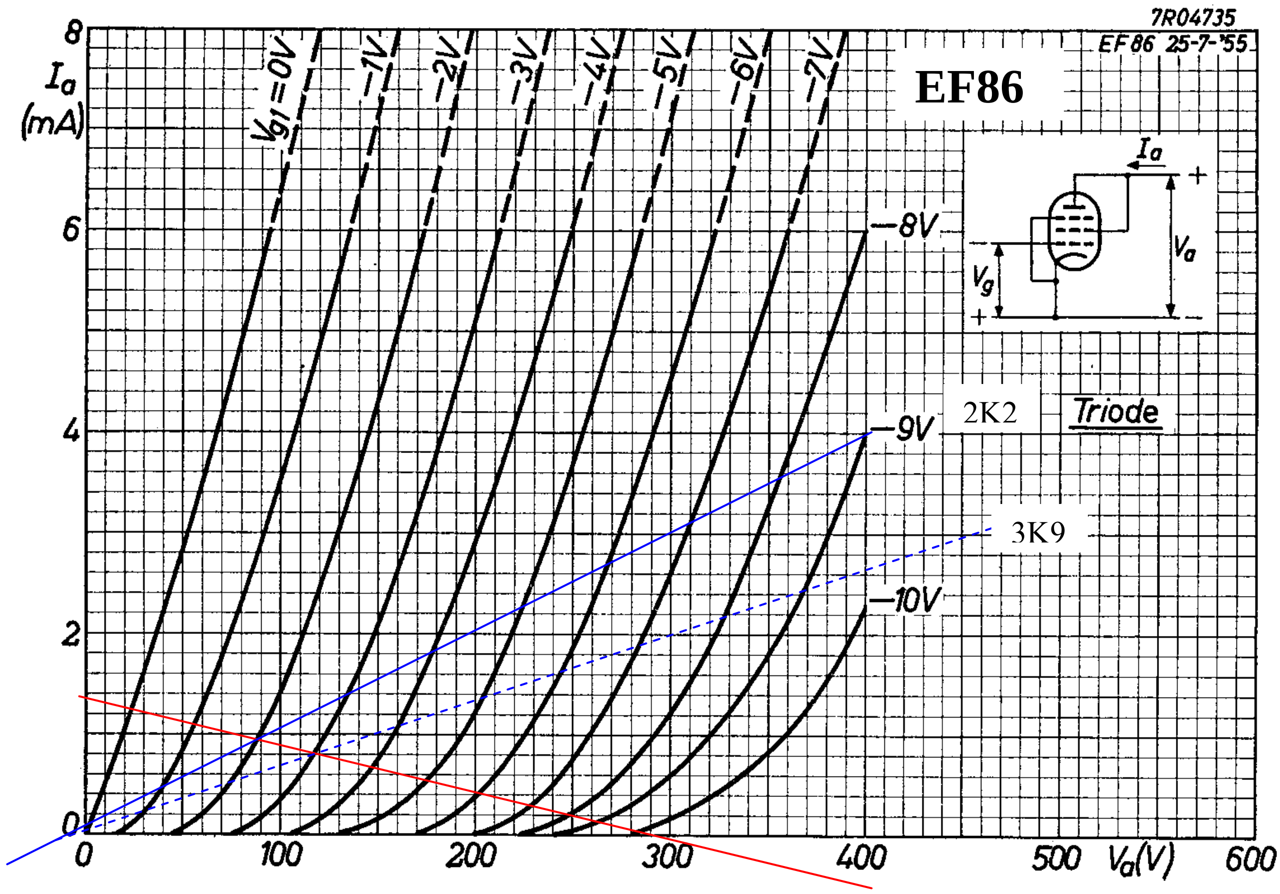


4.2 Input stage – EF86 in Triode Mode

Assume supply voltage is 300V; load resistance is 220k; and cathode resistor is 2K2. The plate voltage Vp axis intercept is 300V for no plate current, and the plate current Ip axis intercept is 300V / 222KΩ = 1.4mA. The gate-cathode voltage Vg1 operating point varies with plate current through the 2k2Ω gate-cathode resistance with the characteristic shown on the graph as a line passing through Ip=0.5mA for Vgk=-1.1V, and through Ip=2mA for Vg1=-4.4V. The intersection of the two lines is the nominal biased operating point at Vg1=2.2Kx0.9mA = 2.0V.

The input voltage swing limit is from the bias point at Vg1=-2.0V to Vgk=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 Vg1=3.9Kx0.8mA = 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 x Rk / 2(Ra + RL) ~ 110 x 68k / 2(40k + 100k) ~ 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:

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

Hence load line resistance of about 100K + 2x80k = 260k. The plate voltage Vp axis intercept is 315V- for no plate current, and the plate current Ip axis intercept is 315V / 280KΩ = 1.1mA. Plate-cathode voltage is about 220 – 110 ~ 110V.

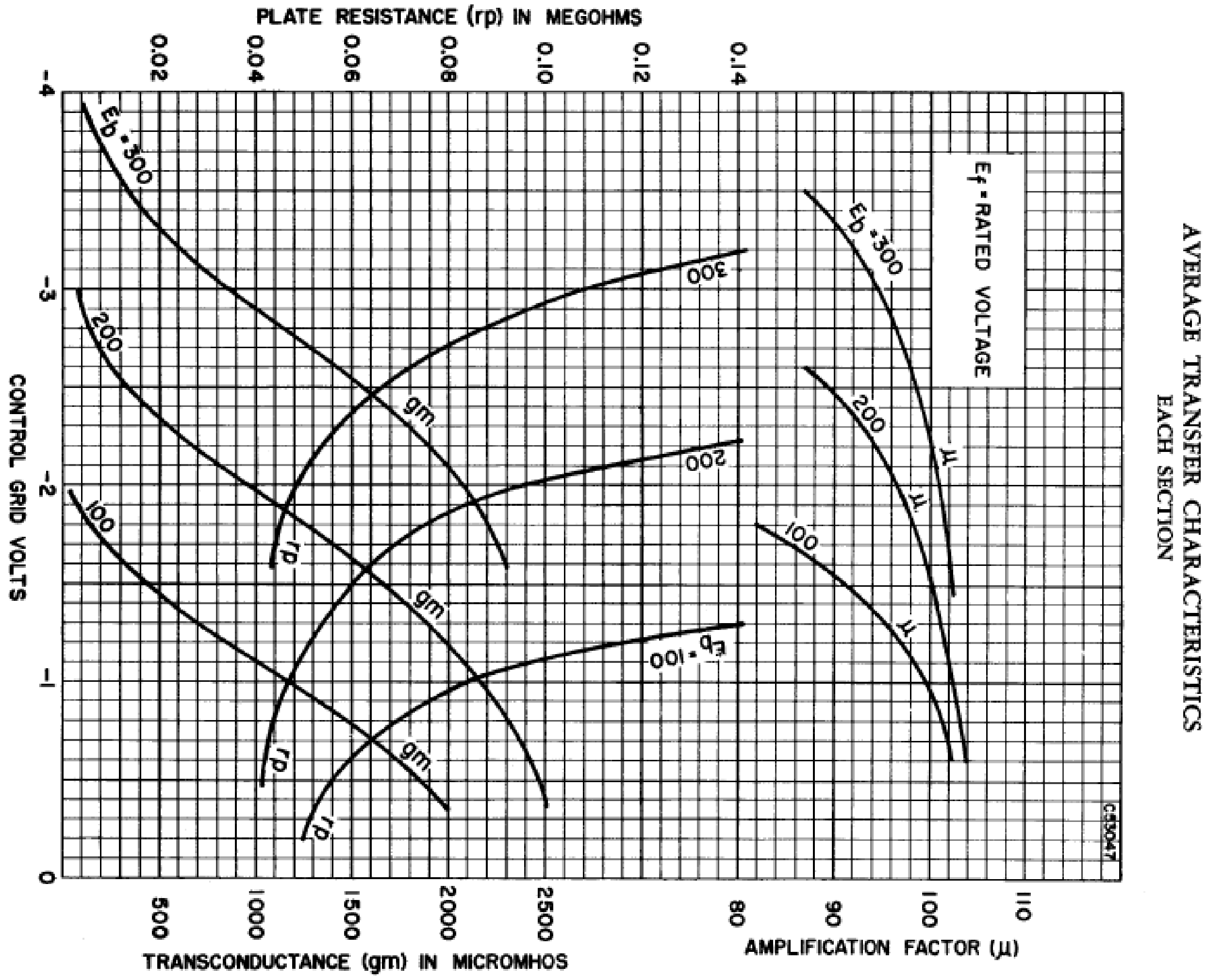
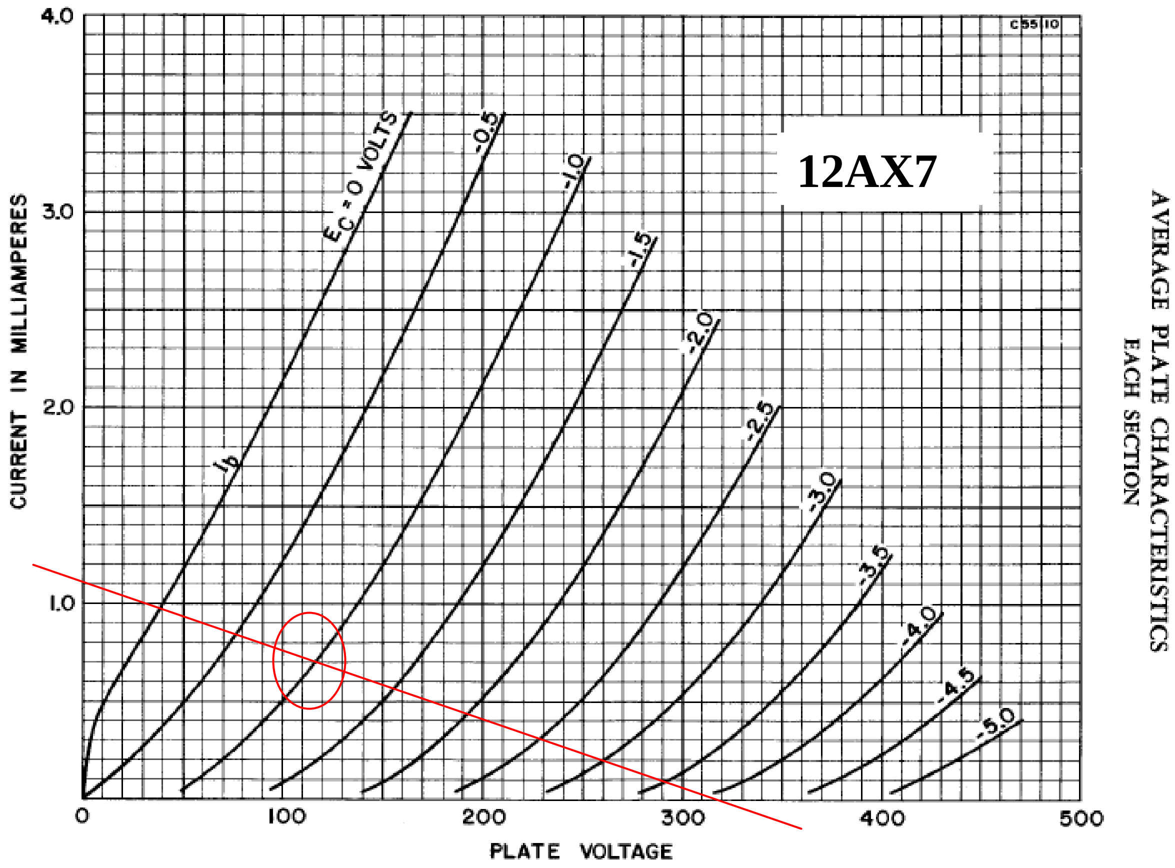


PLATE RESISTANCE (rp) IN MEGOHMS
CONTROL GRID VOLTS
TRANSCONDUCTANCE (gm) IN MICROMHOS
AMPLIFICATION FACTOR (µ)
Ef = RATED VOLTAGE
AVERAGE TRANSFER CHARACTERISTICS
EACH SECTION


12AX7
CURRENT IN MILLIAMPERES
PLATE VOLTAGE
EC = 0 VOLTS
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 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:

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

where R_k = 1K2Ω + 47kΩ = 48kΩ. Hence a load line resistance of about 100K + 2x48k = 200k. With VS3=360V, the plate voltage Vp axis intercept is 360V- for no plate current, and the plate current Ip axis intercept is 360V / 200KΩ = 1.8mA. The gate-cathode voltage (Ec on the graph) varies with plate current through the 1K2Ω gate-cathode resistance, but with a 2k4Ω characteristic, and this characteristic is shown on the graph as a line passing through Ip=0.5mA for Vgk=-1.2V, and through Ip=1mA for Vgk=-2.4V. The intersection of the two lines is the nominal biased operating point of 1.8V and 0.75mA.

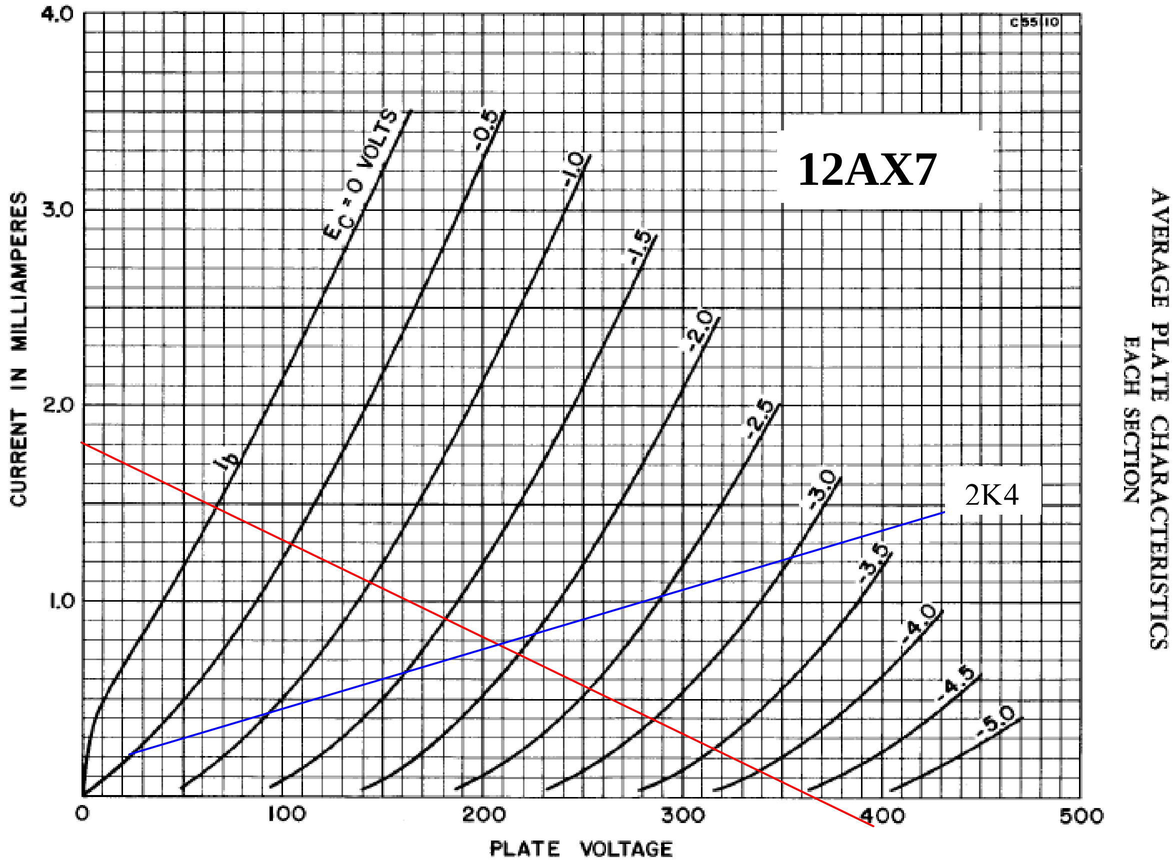
Voltage drop across tail 48k is 48k x 1.5mA = 72V. Hence plate-cathode voltage is about 360 – 75 – 2 – 72 = 210V. Plate load resistance dissipation is about $(360\text{-}70\text{-}72)^2$ / 100k = 0.5Wpk. Plate dissipation at idle is about 210V x 0.75mA = 0.16W. [Measured Va=291V & 285V; Vtail=74V]

The nominal operating point levels of Vgk=-1.6V and Vp=170V are used to determine the parameter values of r_p and gm and μ from the 12AX7 average transfer characteristics graph (note that Eb is Vp).

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 Vgk=-1.6V to Vgk=0V, which is about 3.2Vpp or 1.1Vrms. Referring to the loadline, the plate voltage would swing about 245V, from about 55V to 300V, with a mid point of 170V [170-55=115V; 300-170=130V] which is quite symmetric. This gives a nominal gain of 245/3.2 = 75, but the small signal gain is about x13 with a good headroom.

Parameter	**No signal**	**Notes**
R_L	100k	
Vsupply	300V	= V_{RLoad} + V_P + Vk
I_P	0.65mA	From bias position
V_{gk}	-1.6V	From bias position, = I_P x 2 x 1K2Ω
Vk	62V	= 48KΩ x 2 x I_P
V_P	170V	= 300V – 62V - (100KΩ x I_P)
r_p	190kΩ	= ΔVpk / ΔIp
Gm	0.41mS	= ΔIp / ΔVgk
μ	? [78]	Graph [= gm x r_p]
G	~13	= (u/2) x R_L / (R_L + r_p)
Headroom	14Vpp(rto)	= 2x((G x Vgk) – 14Vpk)

Table 1. Phase Splitter Analysis Results for 12AX7



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

In this Class AB push-pull output stage, one tube is pushed into conduction and the other tube is pulled into cutoff (class B), and there is a region of Class A overlap where both tubes conduct equivalent levels of current. The cathodes are raised above ground by a common bypassed cathode resistor. The 8KΩ impedance plate-to-plate OPT presents signal currents into each tube with a 4KΩ impedance with both tubes conducting, to 2KΩ load impedance at higher levels.

Determining a suitable bias current level is not an empirical design approach, rather it is based on the following recommendations:

- Start with the lowest bias current possible (ie. most negative grid bias voltage), and based on listening tests, increase the bias current until the sound character is acceptable, but:
- use the lowest possible bias current level, as this generally increases the life of the tubes, and decreases the chance of operating at excessive plate dissipation; and
- keep the bias current level below 70% of the recommended design max plate dissipation (ie. <0.7x12=8.4W); and
- assess the dynamic loadline to see if it moves into region of increased plate dissipation.

As the output loading increases, the supply voltage VS2 to the output valve plates sags from about 400V towards 330V at about 130mA average [tbd]. Plate DC voltage will be lower than VS2 by an amount up to ~16Vpk; ie. OPT half resistance of about 120Ω with a peak current of up to about 0.13Apk. Cathode voltage has an idle bias of 19V and a peak of 61V under sustained signal, with an average of $V = \sqrt{(3.2W \times 470\Omega)} = 39V$ where $I^2R = (0.083)^2 \times 470\Omega = 3.2W$. So effective plate-cathode voltage sags to about 330-39-8=283V.

Screen voltage will also vary from about 400V towards 310V under steady-state heavy load. Screen voltage will be lower than VS2 by up to about .02A x 100Ω = 2V. STC curves for screen

E_{C2}= 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.

The maximum output valve bias current allowed is dependant on the maximum recommended plate dissipation of 12W for the EL84/6BQ5: Ibias(max) = Pd / Vb = 12W / 400V = 30mA. With a common cathode resistance of 130Ω, and gate-cathode voltage of 11V, the plate idle current is 42mA, and so needs to be modified for this amps higher supply level. Increasing the common cathode resistance to 230Ω, increases gate-cathode voltage to about 14V, for plate idle current of 30mA.

The gate bias voltage required for this current is significantly influenced by the screen voltage. During dynamic conditions, the plate dissipation must continue to remain below 12W, and so the load line must on average remain in a region below the constant power curve for 12W shown on the plate current/voltage graph. Each valve has an 'off' period for 50% of time, where the average plate dissipation is relatively low and expected to be in the range between the upper limit of the bias level power dissipation, down to a few watts when most of the period is spent in deep cutoff due to very negative grid voltage levels. As such, the average dissipation during the 'on' period can extend dynamically above the 12W curve.

The general textbook design process involves choosing a suitable OPT plate-plate impedance to position the Vg=0 and maximum plate current point at the 'knee' of the Vg=0 curve on the plate current-voltage graph. This knee position has a net minimum level of 2^{nd} and 3^{rd} harmonic levels, where moving away –down from the knee - by increasing the load impedance will increase the 3^{rd} harmonic level, and decreasing the load impedance – moving above the knee - will increase the 2^{nd} and lower the 5^{th} – which is generally perceived as the preferred outcome. From the plate characteristics with screen voltage = 300V, the knee region will drop at heavy loading as screen voltage falls below 300V, and so the loadline match should be good.

Assuming the loadline sags to about 300V plate level (from 400V) and a peak plate current of 130mA is achieved, then the nominal output power of the amplifier (ideal class B2) would be: $(Ipk)^2$ x Rpp / 8 = 0.13 x 0.13 x 8k / 8 = 16.9W. For this maximum signal condition, the rms OPT current draw is likely about 2 x 83mA (64% of peak), and the average VS2 power consumed is 300x0.166 =50W, and the OPT loss is $2x(0.083)^2$ x 120Ω = 1.7W, and the cathode bias loss is 3.2W, so the tube plates dissipate 50 – 17 – 2 -3 = 28W, or about 14W each – which is a tad hot. The achieved dissipation may be a tad lower than above assessment, but aim to keep idle bias a bit lower at about 9W which gives 22mA nominal. . [16.6 and 20.2mA cathode currents; 18.4V cathode bias; Pdiss=(404-18)*.02=7.7W]

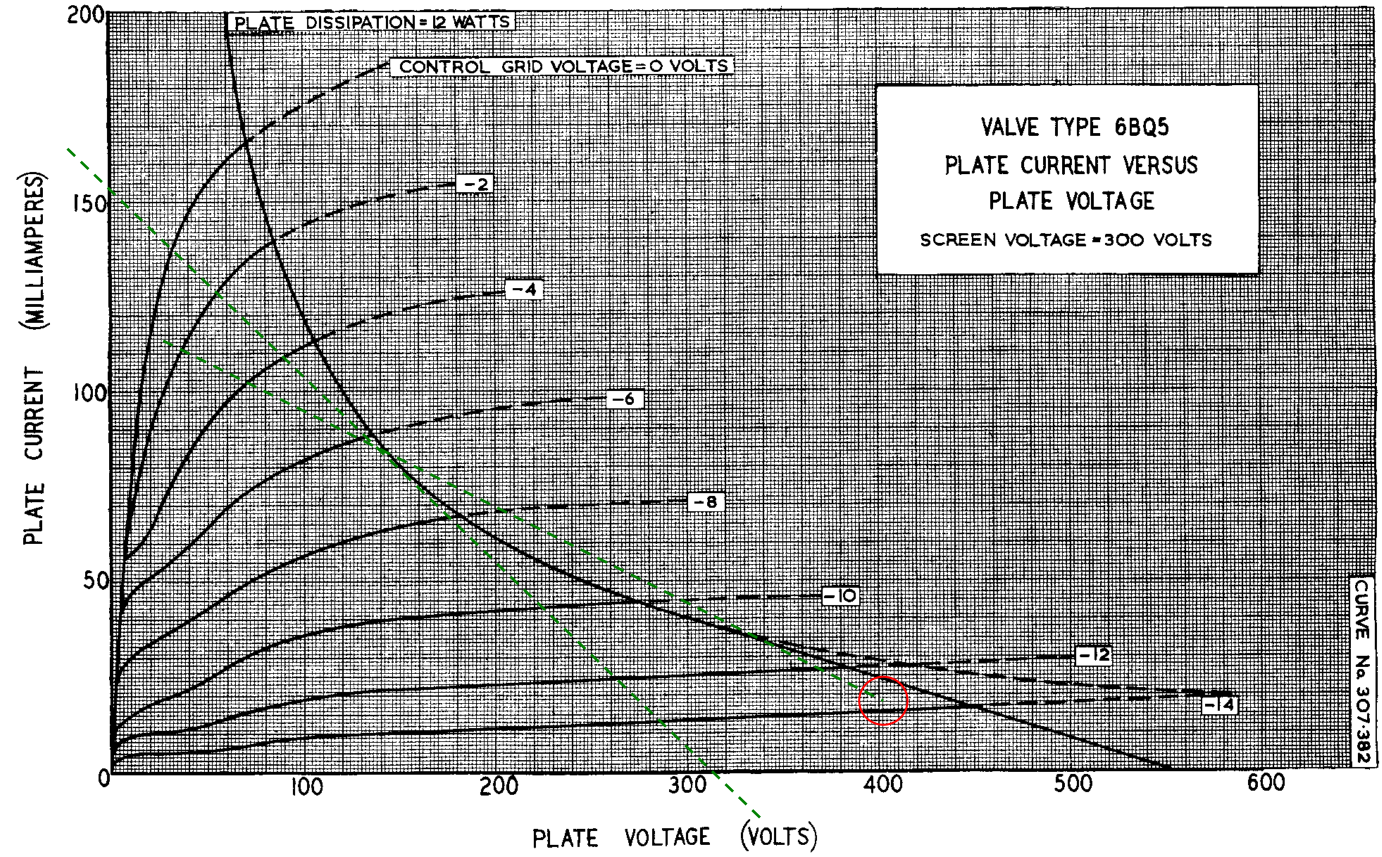
The STC performance characteristics for pentode push-pull class AB1 with 130Ω common cathode resistor and 40mA idle current, and 300V supply and 8k OPT indicate a grid-to-grid drive voltage level of 20Vrms is needed (28Vpk-pk), and that screen current can reach 20mA. However cathode bias voltage is about 10.4V, so a 14Vpk grid swing would take grid into positive region??

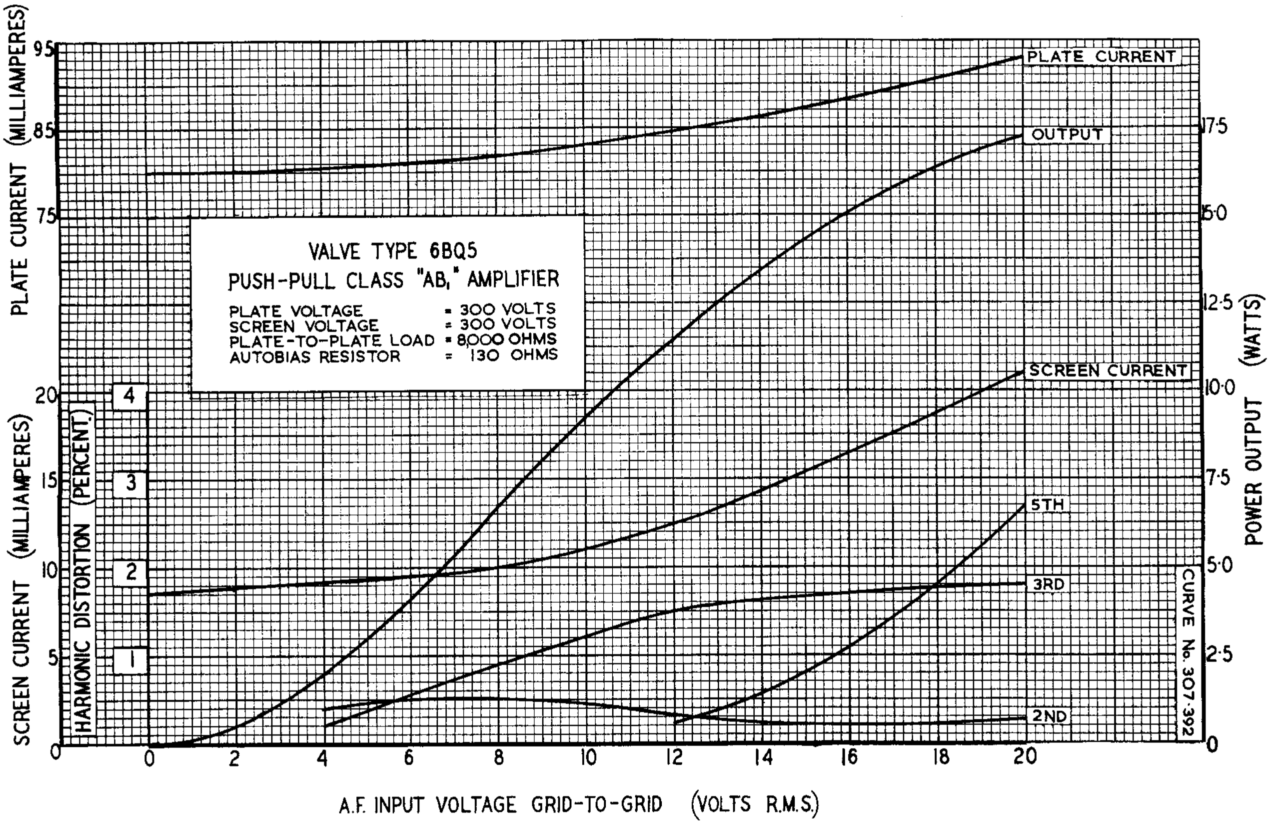
4.6 Output Stage – EL84/6BQ5 Triode Push-Pull

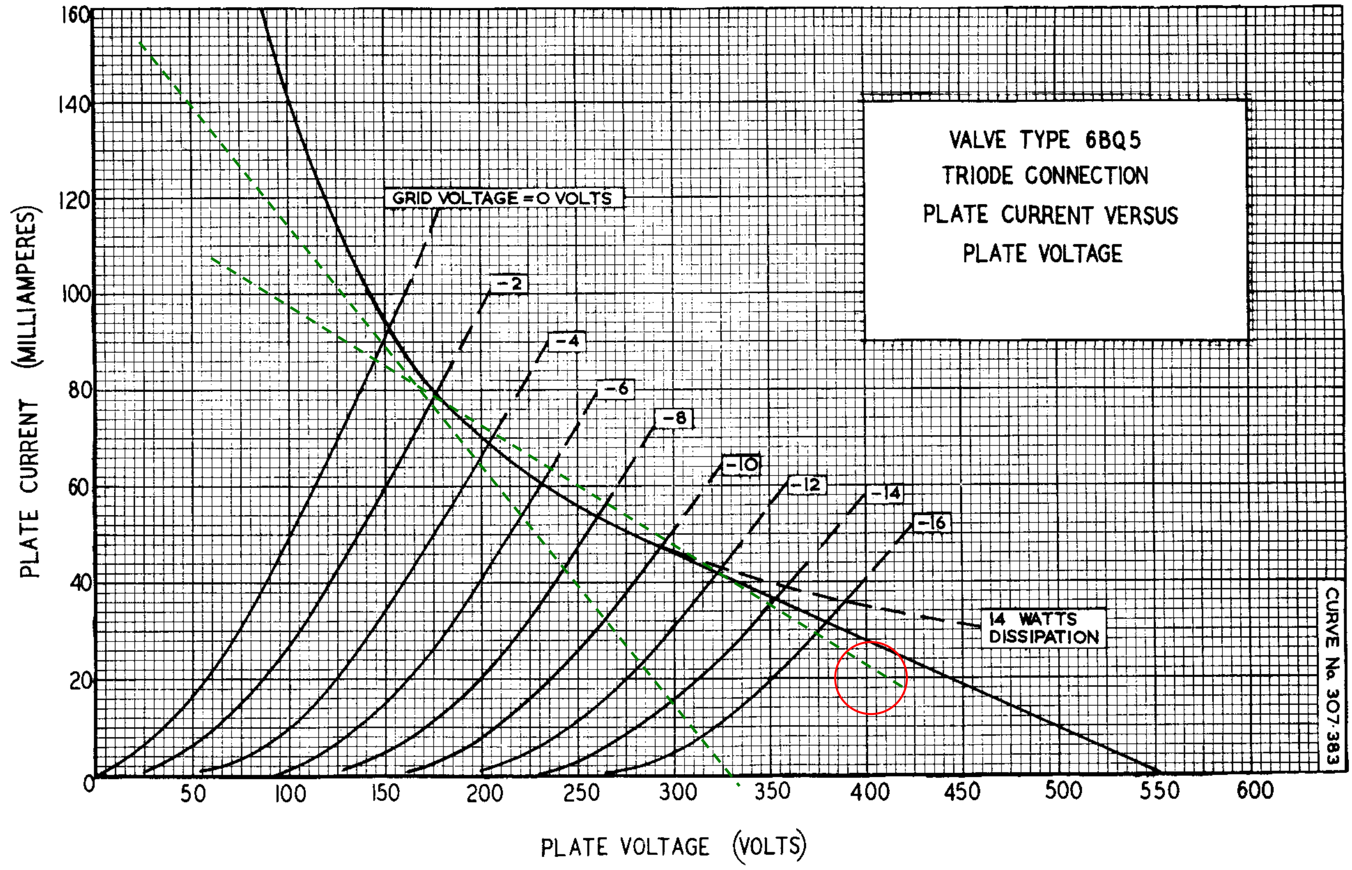
Using triode configuration of EL84/6BQ5 limits the peak output current capability to about 90mA, based on curves, and hence the output power is reduced to about: $(Ipk)^2$ x Rpp / 8 = 0.09 x 0.09 x 8k / 8 = 8W. In this mode, the off valve is not pushed deeply into cut-off, and so most operation is effectively in class A.

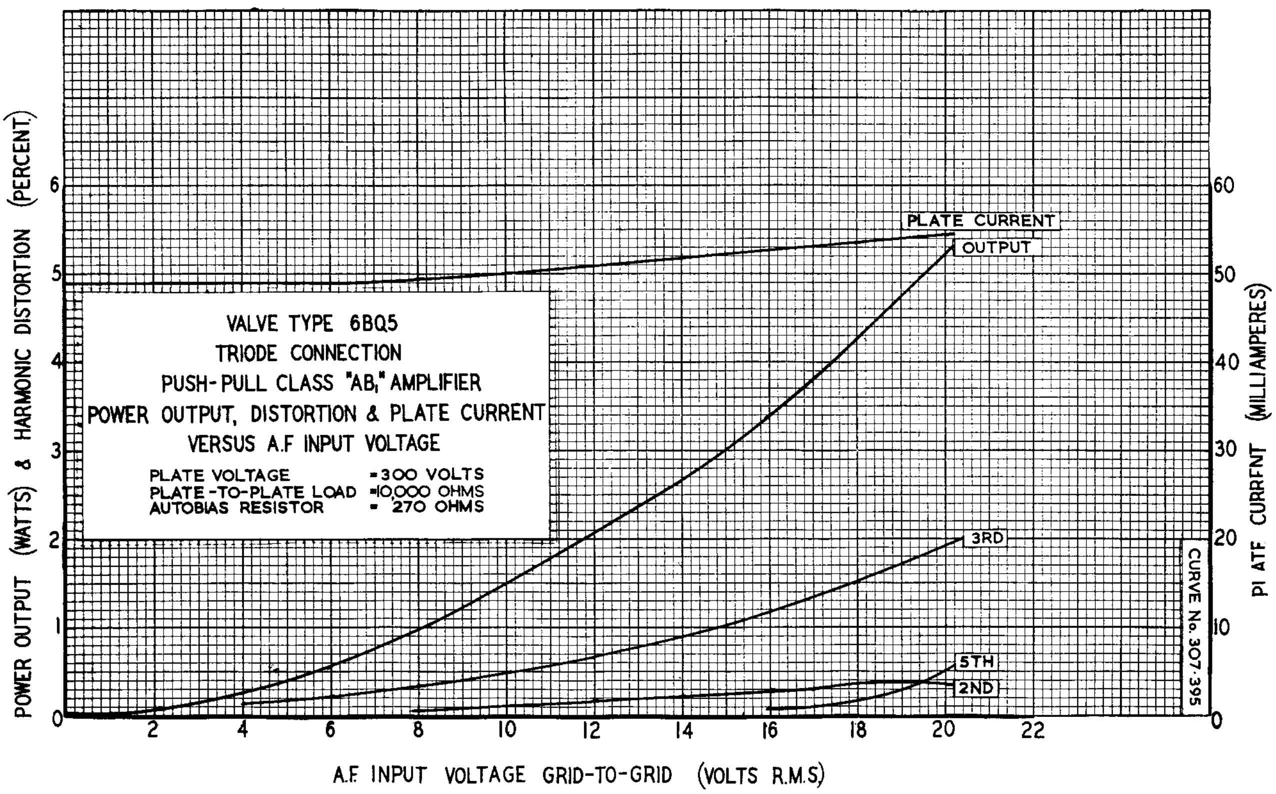
The STC performance characteristics for triode push-pull class AB1 and 300V supply and 10k OPT indicate a grid-to-grid drive of 20Vrms is still needed for max output capability. As distortion is much lower, the curves are based on a lower 25mA idle with 270Ω common cathode resistor.

The Vox Heritage AC15 series common cathode resistor is 150Ω, which is about 11V bias at 36-40mA in both modes at 300V. This amp needs to increase common cathode resistor to about 19V/.04 = 470Ω (from triode curves), with peak power dissipation of ~ $(0.13)^2$ x 470Ω = 8W, but an average about 3-4W.






VALVE TYPE 6BQ5
TRIODE CONNECTION
PLATE CURRENT VERSUS
PLATE VOLTAGE
GRID VOLTAGE = 0 VOLTS
-2
-4
-6
-8
-10
-12
-14
-16
14 WATTS DISSIPATION
PLATE CURRENT (MILLIAMPERES)
PLATE VOLTAGE (VOLTS)
CURVE No. 307-383
0
20
40
60
80
100
120
140
160
50
100
150
200
250
300
350
400
450
500
550
600


VALVE TYPE 6BQ5
TRIODE CONNECTION
PUSH-PULL CLASS "AB1" AMPLIFIER
POWER OUTPUT, DISTORTION & PLATE CURRENT
VERSUS A.F INPUT VOLTAGE
PLATE VOLTAGE = 300 VOLTS
PLATE-TO-PLATE LOAD = 10,000 OHMS
AUTOBIAS RESISTOR = 270 OHMS
PLATE CURRENT
OUTPUT
3RD
5TH
2ND
POWER OUTPUT (WATTS) & HARMONIC DISTORTION (PERCENT)
PLATE CURRENT (MILLIAMPERES)
A.F. INPUT VOLTAGE GRID-TO-GRID (VOLTS R.M.S)
CURVE No. 307-395
0
1
2
3
4
5
6
10
20
30
40
50
60
2
4
6
8
10
12
14
16
18
20
22

4.7 Power Supplies

A standard full-wave rectifier circuit is used with 360V 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 and VS4 ares obtained by further RC filtering using 22kΩ dropper.
The 5V4G can feed directly into 24uF C1 as secondary winding resistance is >100Ω. The 5V4 is rated to 175mA max, which is equivalent to the nominal requirement for the output stage plate and 20mA for screen, and a few mA for the other valves. With 100mArms 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. The EZ81 in the Heritage is 6.3V heater but otherwise quite close performance.

The ripple voltage across C1 and C2 is mainly 100Hz, at a measured level of 7.2Vrms with a load current through the choke of 96mADC. DC drop across the choke is 37V at 100mA. Observed sag in VS2 is about 80V, indicating transformer regulation and capacitor ESR are significant [tbd].

5. Protection

5.1 HV breakdown

A 0.5A secondary fuse is added to protect for a short-circuit on VS1 or VS2, as the prospective current could reach ~ 360V / (150Ω + 100Ω) = 1.4Arms.

5.2 Output open circuit

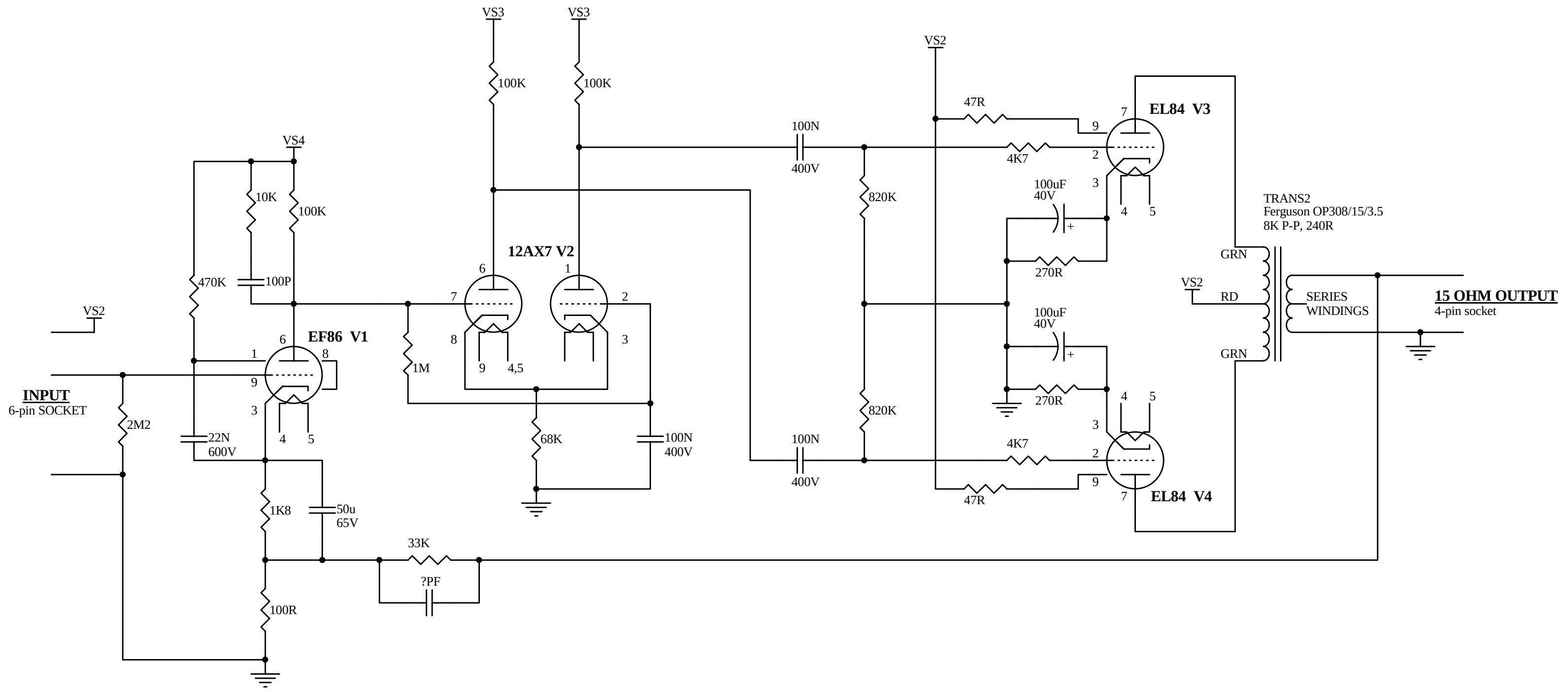
A 470R 3W resistor is added to the 15Ω output tap, to act as a high resistance limit in case the speaker load goes open circuit.

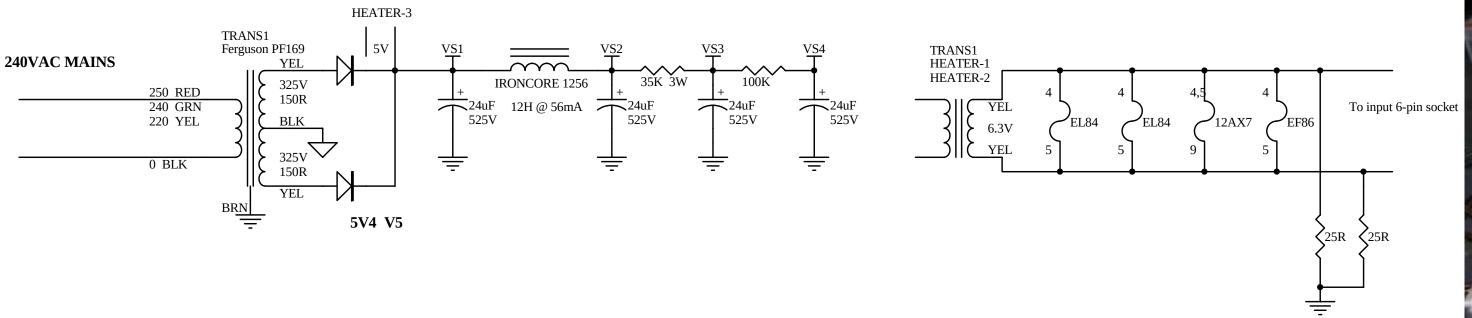
6. Other changes

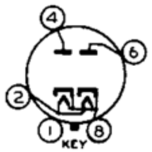
6.1 Hum reduction

Humdinger tuned for lowest hum.

PLAYMASTER NO.11 AMPLIFIER
Unknown Kit Supplier
COUPLED WITH CONTROL UNIT 6







EF86 base　12AX7 base　EL84 base　5V4 base

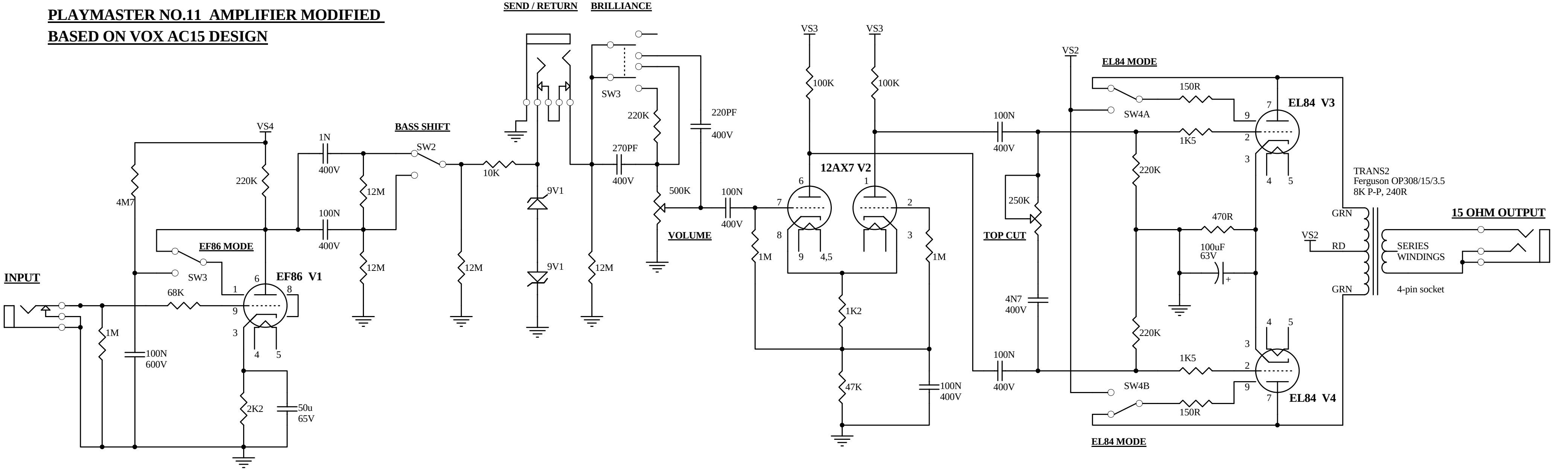
VOLTAGE RAILS

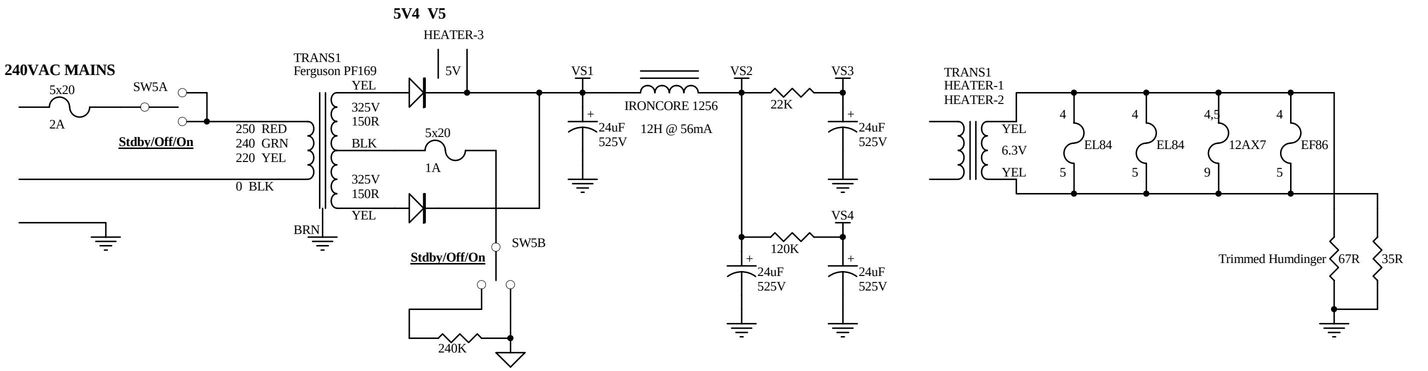
RAIL	NO LOAD
VS1	440V
VS2	425V
VS3	314V
VS4	202V
HEATER-1.2	6.6V
HEATER-3	5.4V

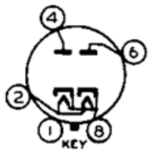
VALVE	QTY
EF86	1
12AX7	1
EL84	2
5V4	1

Title		
Size B	Number	Revision
Date: 12-Oct-2009	Sheet of	
File: C:\Program Files\Design Explorer 99 SE\Projects\Tube amps\Amplifier Modules.ddb	Drawn By:	

PLAYMASTER NO.11 AMPLIFIER MODIFIED
BASED ON VOX AC15 DESIGN





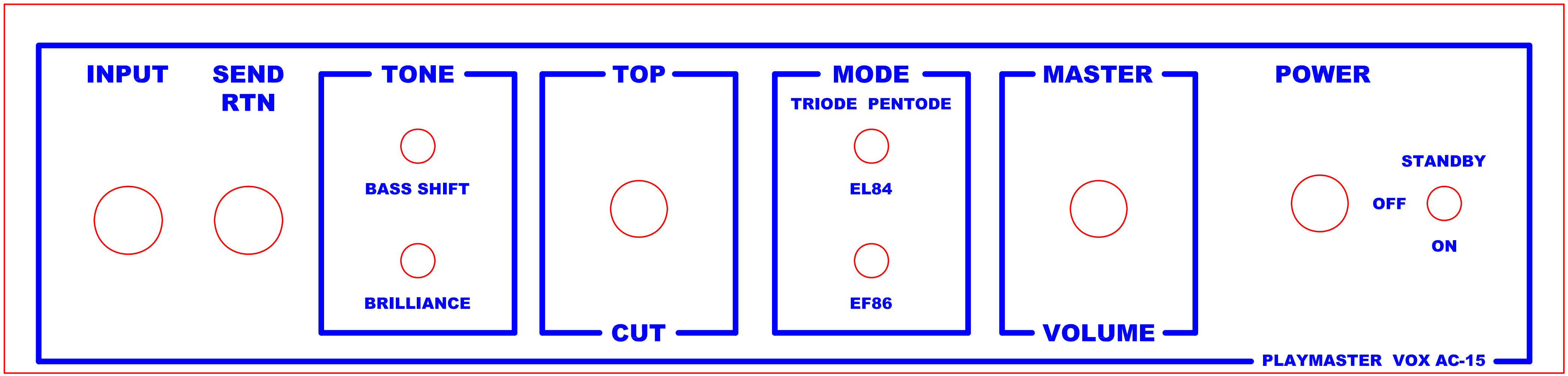


EF86 base   12AX7 base   EL84 base   5V4 base

VOLTAGE RAILS	
RAIL	IDLE
VS1	419V
VS2	404V
VS3	367V
VS4	306V
HEATER-1.2	6.5V
HEATER-3	5V

VALVE	QTY
EF86	1
12AX7	1
EL84	2
5V4	1

Title		
Size B	Number	Revision
Date: 25-Oct-2009		Sheet of
File: C:\Program Files\Design Explorer 99 SE\Projects\Toys amps\Amplifier Modules.ddb		Drawn By:


INPUT
SEND
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TRIODE PENTODE
EL84
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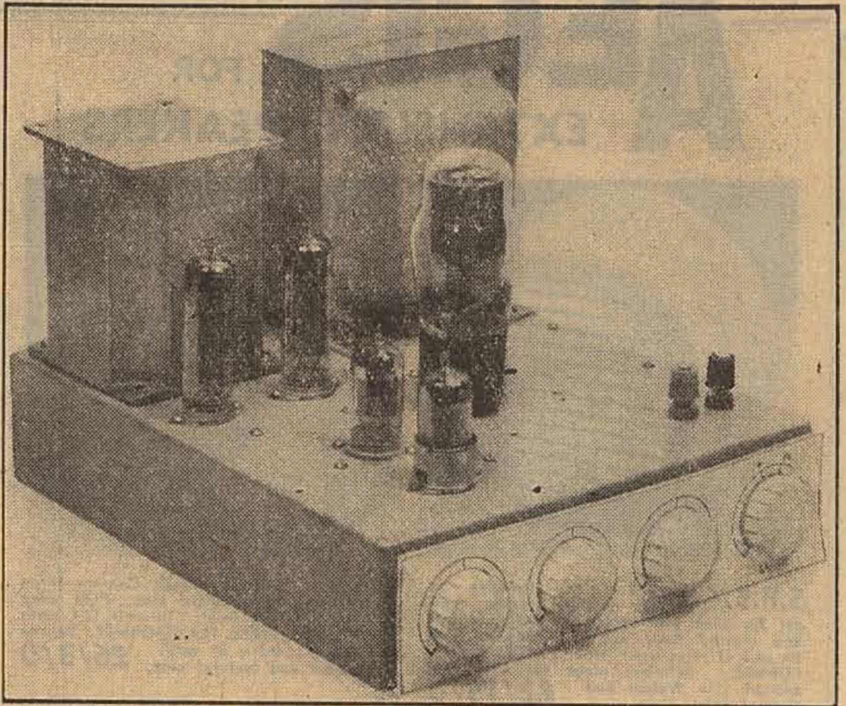
PLAYMASTER VOX AC-15



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.

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.

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

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.

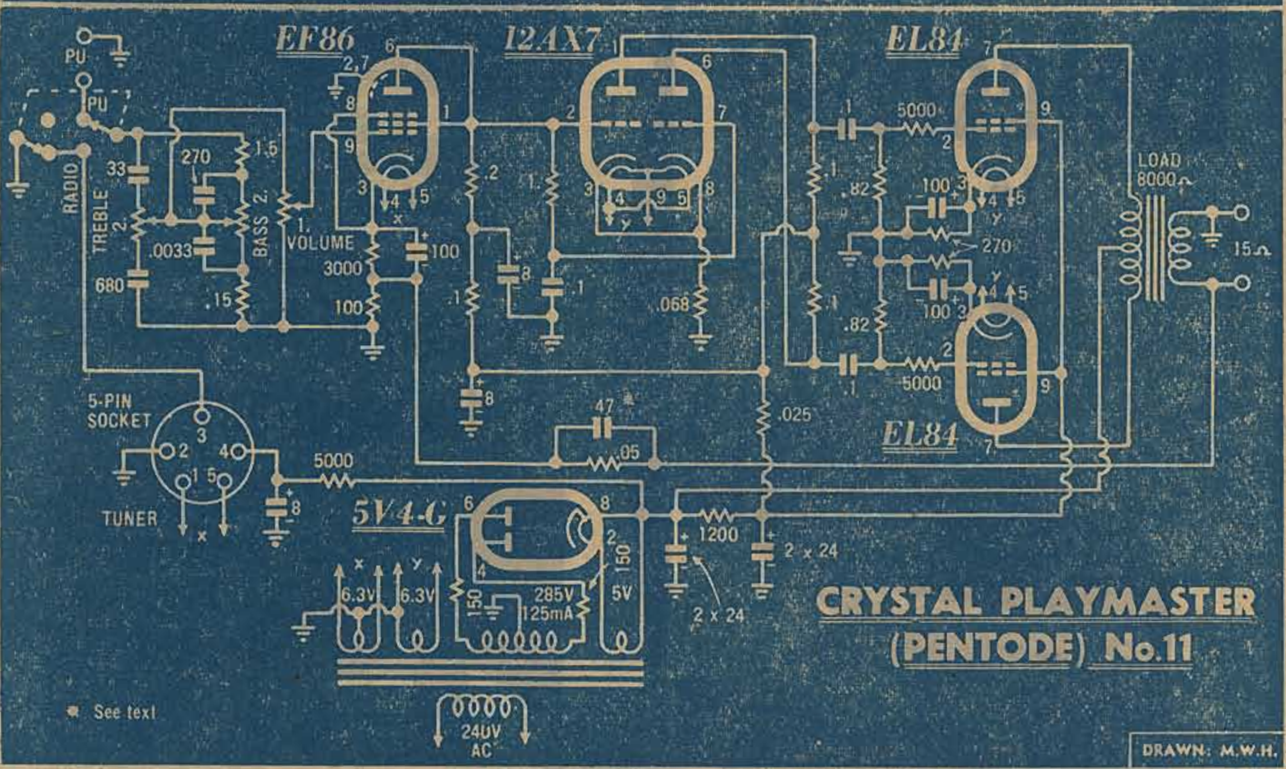
This version is capable of extremely high performance, limited only by the quality of the output transformer.

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 unfortunatelyy 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.

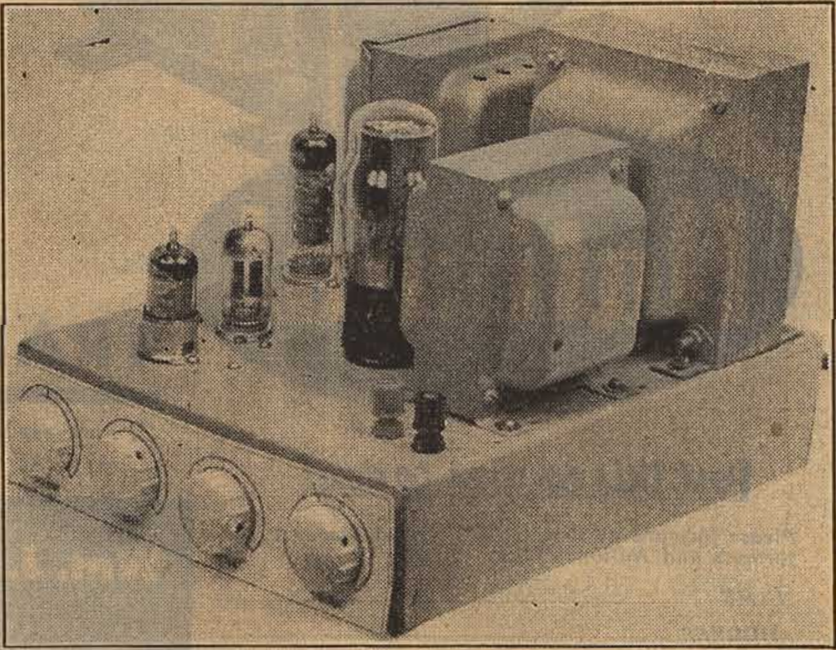
RANGE OF CONTROL

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 amplifier. 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.

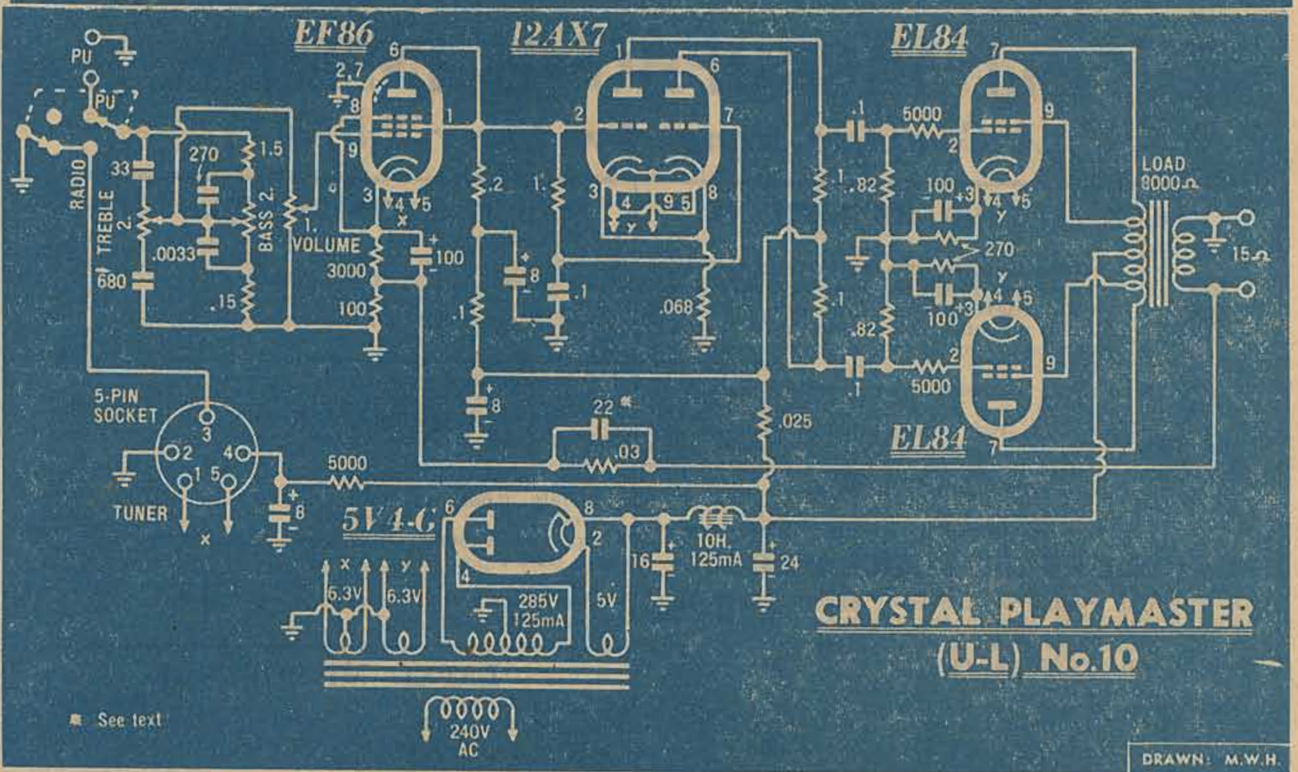
The input sensitivity for full output is about .45 volts with the pentode connection, and about .7 volts for ultra-linear. As full output will be between 13 and 17 watts, this means that even pick-ups with moderate output will give all the volume you can stand.

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



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 2¼in.
1 shield 5½ x 8⅜in. (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 ½watt.) 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.

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 conneetion gives lower gain, but the use of less feedback brings the tntal 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-coopled 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 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 6000 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 cunnection it is possible to elimioate 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 eourse 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 conneeted in series with the high voltage leads to the transformer. These limit the peak current demanded from the rectifier by the high first capaeitor 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.

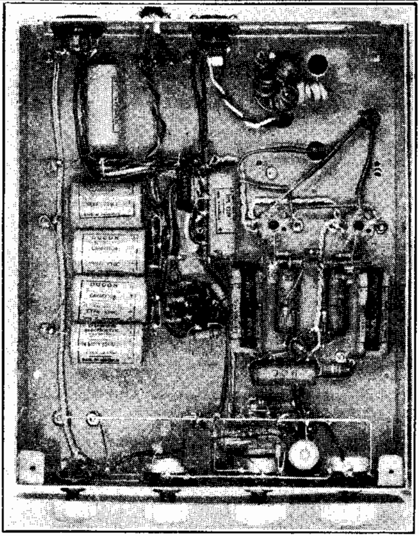
The filter condensers are supported at the "hot" end with a resistor strip, which also supports a decoupling condenser and the dropping resistor for the tuner.

There is plenty of room to support these odd eomponents 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 eircuit, 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 mfds with this circuit.

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

UNDER-CHASSIS OF AMPLIFIER



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.

the output plates and cathodes. If no 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 mfds decoupler is added for safety.

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

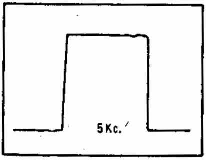
Separate bias resistors are used for the output values. With valves having a high mutual conductance, this is often a good idea to allow the automatic bias to compensate for current variations. It makes little difference to distortion unless the valves are appreciably unbalanced.

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 aluminium 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 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 unused 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-correctinn condenser should be increased by a similar amount.

CIRCUIT BALANCE

For accurate balanee 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, whieh 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 differenee is equal to something like 3000 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 eonnection is valuable in reducing the danger of hum in high gain audio circuita.

This winding is also used for the tuner to balance the drain 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 filament 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 that 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 drop 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.

Hum level is so low that, even with an ear at the speaker, it can barely be heard.