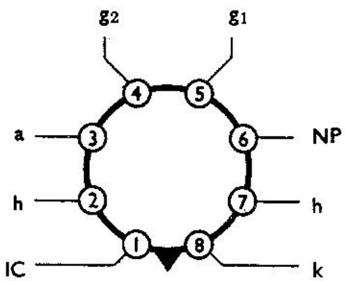
G.E.C. VALVES	BEAM TETRODE 6·3V INDIRECTLY HEATED	KT66 ISSUE 4

A beam tetrode with an absolute maximum anode dissipation rating of 30W. It is designed for use in the output stage of an a.f. amplifier, or as a series valve in a stabilized power supply.

The KT66 is a commercial version of the CV1075.

BASE CONNECTIONS AND VALVE DIMENSIONS



View from underside of base.

Base: International Octal (B8-0)
Bulb: Dome top tubular

Max. overall length :	135	mm
Max. seated length :	121	mm
Max. diameter :	53	mm

HEATER

V_h	6·3	V
I_h	1·3 (approx)	A

MAXIMUM RATINGS

	Design Max.	*Absolute Max.*	
V_a	500	550	V
V_{g2}	500	550	V
$-V_{g1}$	200	200	V
I_k	200	200	mA
p_a	25	30	W
p_{g2}	3·5	4·5	W
*p_{a+g2}	27	32	W
V_{h-k}	150	150	V
T_{bulb}	250	250	°C
R_{g1-k} (cathode bias) :			
$p_{a+g2} \leqslant 27W$	1·0		MΩ
$p_{a+g2} > 27W$	500		kΩ
R_{g1-k} (fixed bias) :			
$p_{a+g2} \leqslant 27W$	250		kΩ
$p_{a+g2} > 27W$	100		kΩ

*Triode or ultra-linear operation.

CAPACITANCES (Measured on a cold unscreened valve)

$c_{g1-all, less\ a}$: 14·5 pF $c_{a-all, less\ g1}$: 10·0 pF c_{a-g1} : 1·1 pF

CHARACTERISTICS

Tetrode Connection

V_a	250	V
V_{g2}	250	V
$-V_{g1}$	15	V
g_m	7	mA/V
r_a	22·5	kΩ

KT66

Triode Connection

V_a	250	V
$-V_{g1}$	15	V
g_m	7·3	mA/V
r_a	1·3	kΩ

TYPICAL OPERATION

Triode Connection. Class A. Single Valve. Cathode Bias.

$V_{a,g2(b)}$	270	440	V
$V_{a,g2}$	250	400	V
$-V_{g1}$ (approx)	20	38	V
$v_{in(pk)}$	20	38	V
R_k	330	600	Ω
$I_{a+g2(o)}$	60	63	mA
$p_{a+g2(o)}$	15	25	W
R_L	2·75	4·5	kΩ
P_{out}	2·2	5·8	W
D_{tot}	6	7	%

Triode Connection. Class AB1. Push-Pull. Cathode Bias.

$V_{a,g2(b)}$	270	440	V
$V_{a,g2}$	250	400	V
$-V_{g1}$ (approx)	19	38	V
$v_{in(g1-g1)(pk)}$	38	76	V
*R_k	2×345	2×615	Ω
$I_{a+g2(o)}$	2×55	2×62	mA
$p_{a+g2(o)}$	2×14	2×25	W
$R_{L(a-a)}$	2·5	4·0	kΩ
P_{out}	4·5	14·5	W
D_{tot}	2·0	3·5	%
†IM	3·0	3·0	%
z_{out}	3·5	3·5	kΩ

*It is essential to use two separate cathode bias resistors.

†Intermodulation distortion ; measured using two input signals at 50 and 6000c/s (ratio of amplitudes 4:1).

Tetrode Connection. Class AB1. Push-Pull. Cathode Bias.

$V_{a(b)(o)}$	450	V
$V_{a(b)(max\ sig)}$	425	V
$V_{a(o)}$	415	V
$V_{a(max\ sig)}$	390	V
$V_{g2(o)}$	300	V
$V_{g2(max\ sig)}$	275	V
$-V_{g1}$ (approx)	27	V
$I_{a(o)}$	2×52	mA
$I_{a(max\ sig)}$	2×62	mA
$I_{g2(o)}$	2×2·5	mA
$I_{g2(max\ sig)}$	2×9	mA
$p_{a(o)}$	2×21	W
$p_{a(max\ sig)}$	2×9·0	W
$p_{g2(o)}$	2×0·75	W
$p_{g2(max\ sig)}$	2×2·5	W
*R_k	2×500	Ω
$R_{L(a-a)}$	8	kΩ
$v_{in(g1-g1)(pk)}$	70	V
P_{out}	30	W
D_{tot}	6	%

*It is essential to use two separate cathode bias resistors.

Ultra-linear Connection. Push-Pull. 40% Taps. Class AB1. Cathode Bias.

$V_{a(b)}$	450	V
$V_{a,g2(o)}$	425	V
$V_{a,g2(max\ sig)}$	400	V
$I_{a+g2(o)}$	2×62·5	mA
$I_{a+g2(max\ sig)}$	2×72·5	mA

$p_{a+g2(o)}$	2×26·5	W
$p_{a+g2(max\ sig)}$	2×13·0	W
*R_k	2×560	Ω
$-V_g$ (approx)	35	V
P_{out}	32	W
$R_{L(a-a)}$	7	kΩ
z_{out}	9	kΩ
D_{tot}	2	%
†IM	4	%

*It is essential to use two separate cathode bias resistors.

†Intermodulation distortion ; measured using two input signals at 50 and 6000c/s (ratio of amplitudes 4:1).

Ultra-linear Connection. Class AB1. Push-Pull. 40% Taps. Fixed Bias.

$V_{a,g2(o)}$	525	V
$V_{a,g2(max\ sig)}$	500	V
$I_{a+g2(o)}$	2×35	mA
$I_{a+g2(max\ sig)}$	2×80	mA
$p_{a+g2(o)}$	2×18	W
$p_{a+g2(max\ sig)}$	2×15	W
*$-V_{g1}$ (approx)	67	V
$R_{L(a-a)}$	8	kΩ
$v_{in(g1-g1)(pk)}$	127	V
P_{out}	50	W
D_{tot}	3	%
†IM	15	%
z_{out}	10	kΩ

*A negative bias range of ±25% of this value should be available for each valve.

†Intermodulation distortion ; measured using two input signals at 50 and 6000c/s (ratio of amplitudes 4:1).

LIFE PERFORMANCE

The average life expectancy of the KT66 when operated at absolute maximum ratings (see page 1) is at least 8000 hours. At a reduced absolute rating of p_{a+g2}=21W a life of at least 10000 hours should be obtained. The environment must be a static one and the valve should be switched not more than 12 times in each 24 hours. Attention should also be paid to the recommendations of the British Standard Code of Practice CP1005 *The Use of Electronic Valves.*

A valve is considered to have reached the end of life when it is either inoperative or one or more of its characteristics have reached the following values:

P_{out}	50% of initial value	
*g_m	<5·5	mA/V
*Measured at:		
V_a	250	V
V_{g2}	250	V
I_a	85	mA

INSTALLATION

The valve may be mounted in any position but when horizontal it should be orientated as shown in fig. 1. No retaining device or external screening is normally necessary.

Adequate ventilation should be provided. A pair of valves working at maximum ratings should be mounted at not less than 3·5 in. (9 cm) between centres.

For the prevention of parasitic oscillation, a series resistor of 100—300Ω should be connected close to the screen tag of the valve socket. When the valve is triode connected, this resistor should be connected between screen and anode. A control grid series resistor of 10-50kΩ is also recommended. In push-pull applications having a large change in anode current between the quiescent and full output conditions, an inductance input filter circuit of good regulation should be used. A badly regulated supply will cause a fall in power output and/or excessive quiescent anode dissipation.

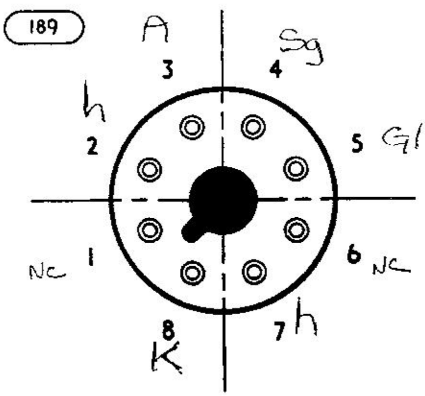


Fig. 1. Correct orientation of the valve socket for horizontally mounting the KT66.

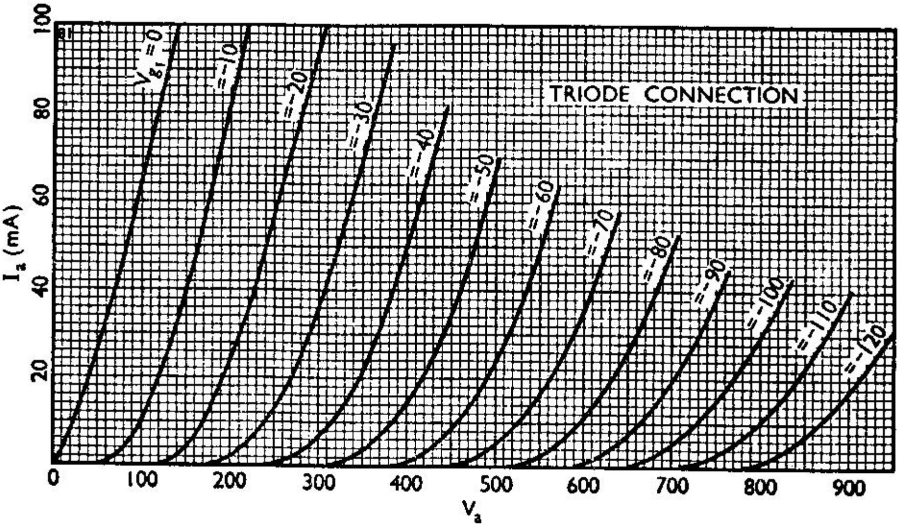

TRIODE CONNECTION
$V_{g1}=0$
=-10
=-20
=-30
=-40
=-50
=-60
=-70
=-80
=-90
=-100
=-110
=-120
I_a (mA)
V_a
0
20
40
60
80
100
0
100
200
300
400
500
600
700
800
900

Fig. 2.

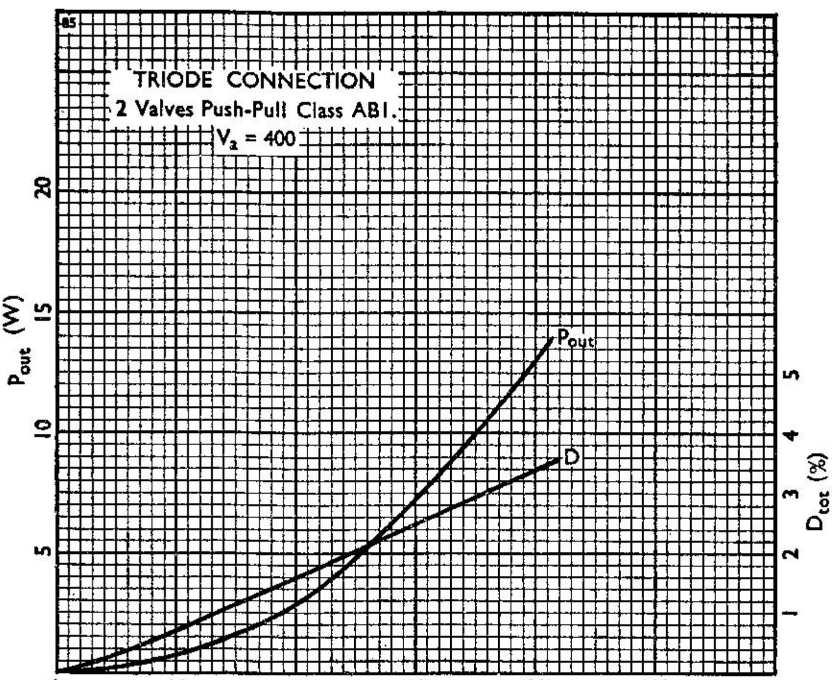

TRIODE CONNECTION
2 Valves Push-Pull Class AB1.
V_a = 400
P_{out} (W)
P_{out}
D
D_{tot} (%)
Vin (pk) (g1-g1)
0
20
40
60
80
100
5
10
15
20
1
2
3
4
5

Fig. 3.

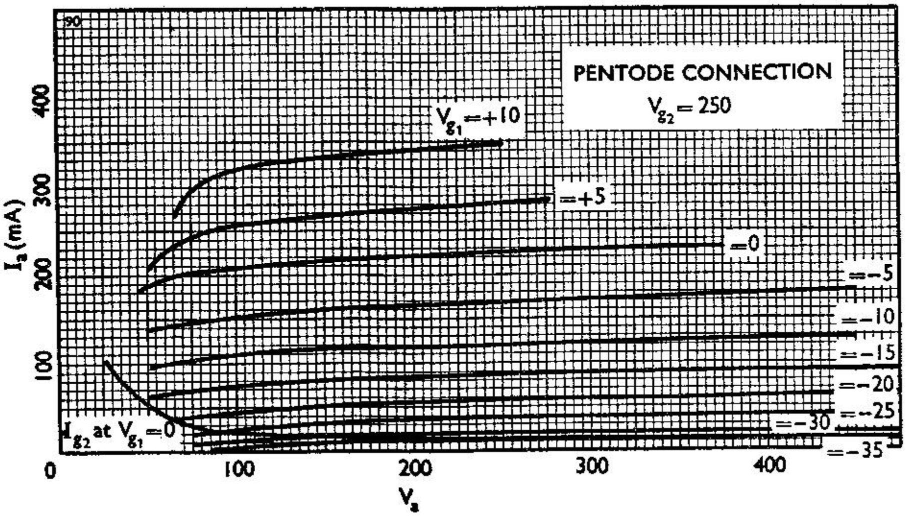

90
PENTODE CONNECTION
V_{g_2} = 250
V_{g_1} = +10
= +5
= 0
= −5
= −10
= −15
= −20
= −25
= −30
= −35
I_{g_2} at V_{g_1} = 0
I_a (mA)
400
300
200
100
0
100
200
300
400
V_a

Fig. 4.

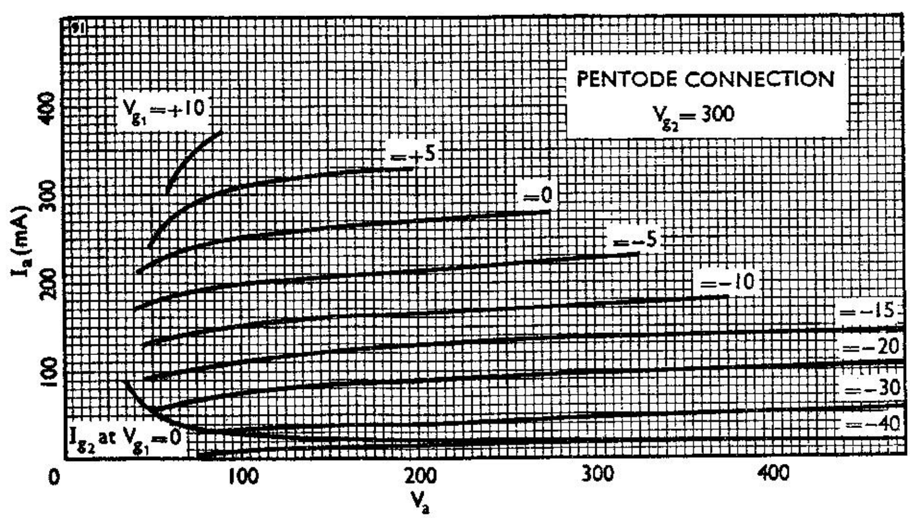

91
PENTODE CONNECTION
V_{g_2} = 300
V_{g_1} = +10
= +5
= 0
= −5
= −10
= −15
= −20
= −30
= −40
I_{g_2} at V_{g_1} = 0
I_a (mA)
400
300
200
100
0
100
200
300
400
V_a

Fig. 5.

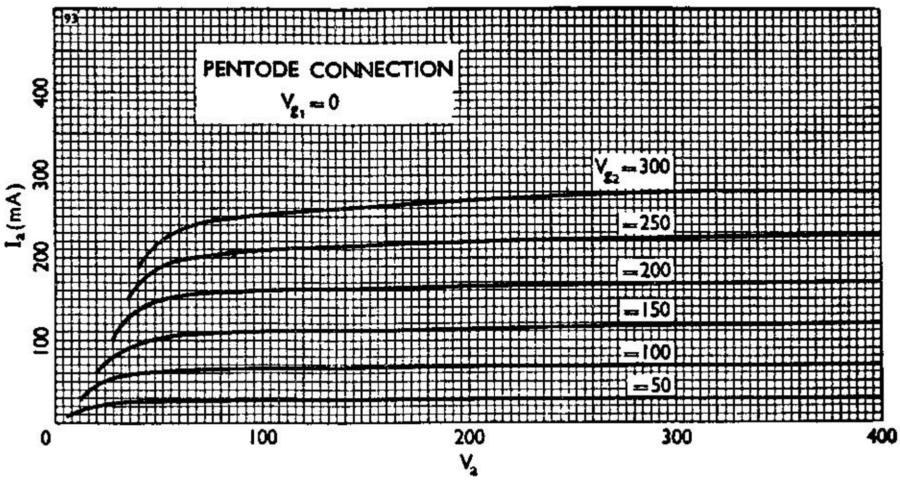

PENTODE CONNECTION
$V_{g1} = 0$
$V_{g2} = 300$
=250
=200
=150
=100
=50
I_a (mA)
100
200
300
400
0
100
200
300
400
V_a

Fig. 6.

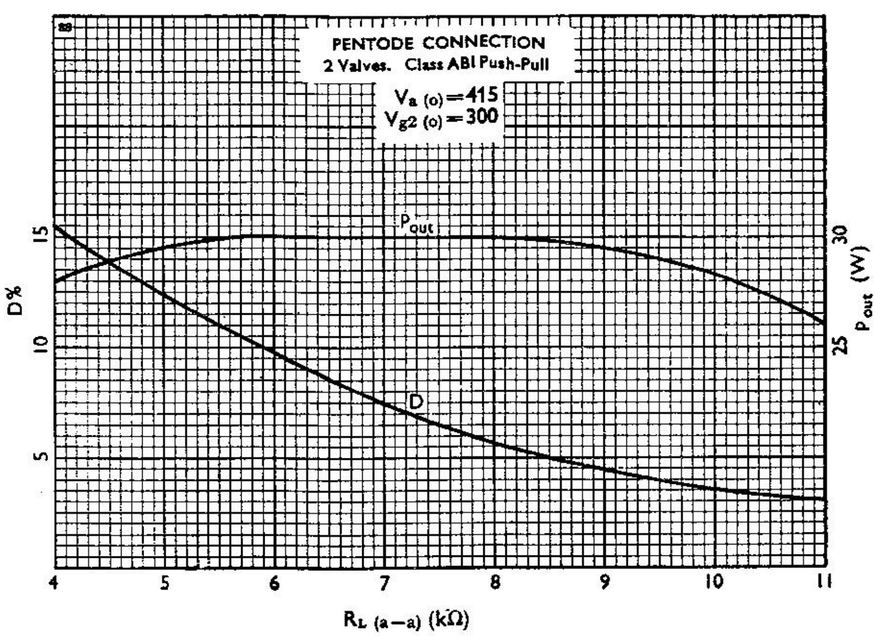

PENTODE CONNECTION
2 Valves. Class ABI Push-Pull
V_a (o) = 415
V_{g2} (o) = 300
P_{out}
D
D%
5
10
15
P_{out} (W)
25
30
4
5
6
7
8
9
10
11
R_L (a—a) (kΩ)

Fig. 7.

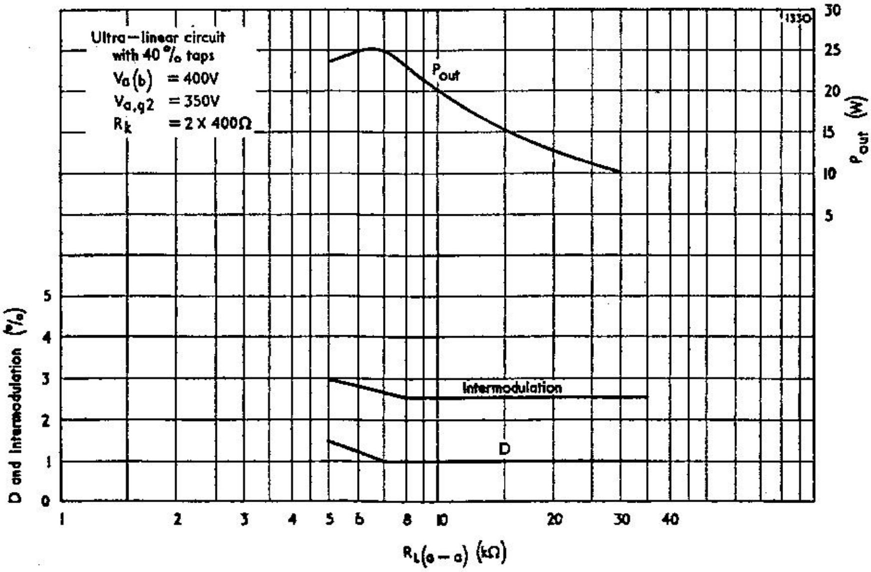


Fig. 8.

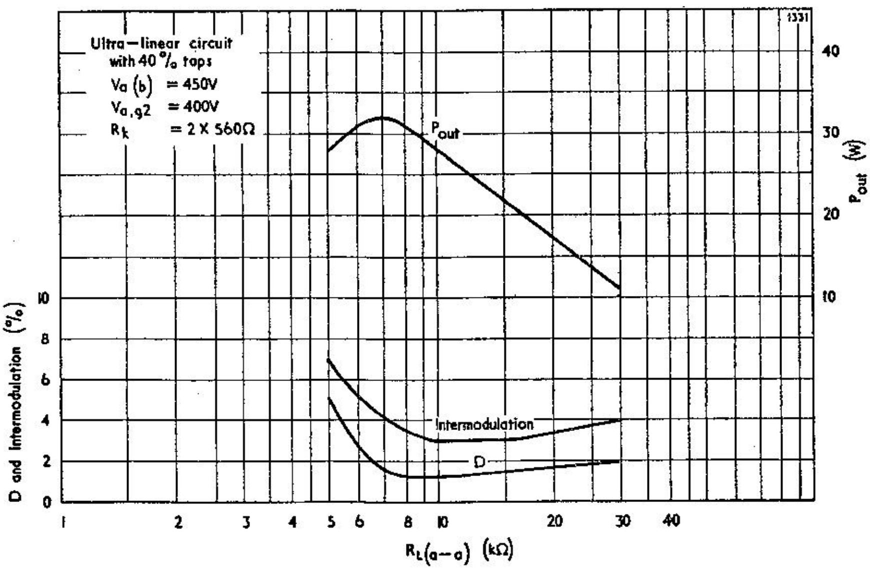


Fig. 9.

The above curves show power output, harmonic distortion and intermodulation plotted against load impedance. Ultra-linear operation at two values of $V_{a(b)}$.

This supplement contains comparisons of the performance of the KT66 under the three different operating conditions of triode, pentode and ultra linear connections. Design details of 30W and 50W ultra linear amplifiers are also given.

The data on normal triode or pentode operation of the KT66 is well-known and is not given here.* In ultra linear operation, the screen grid of each KT66 is returned to a tapping point on the output transformer primary. These tapping points include 20% of the total turns of each half primary, counting from the centre. The voltage during the operating cycle is not held constant, as with pentode operation, nor does it take up the instantaneous anode voltage as in the triode condition. It combines the advantages of both systems in that the high power output of the pentode is still obtainable but with the low distortion of the triode arrangement.

Considerable publicity has been given to this arrangement in the British and American press and in general the claims made are substantiated.

CIRCUIT

The circuit is shown in fig. 1. The two KT66 valves are preceded by a pair of B65 double triode valves, one of which is used as a self-balancing phase inverter and the other as a push-pull voltage amplifier. Full output is given for an input of about 150mV rms.

In ultra linear operation the KT66 valves have their screen grids returned to tapping points on each half primary. When measurements are made under triode conditions, each screen is connected to its anode, and for pentode operation, the screens are connected to the 450V line.

It has been found desirable to connect capacitors C13, C14 of 2000pF across part of the output transformer in the interests of stability. Screen grid and control grid resistors R15, R16, R17 and R18 are included for the same reason.

Independent cathode bias resistors R11, R12 of 560 Ω are used, a value satisfactory for all three classes of operation.

The small capacitors C5, C6 serve to neutralise stray capacitances in the phase inverter stage and ensure that a balanced output is obtained at the higher frequencies. Their value is not critical but they should be both the same.

In order to obtain the full advantages of the ultra linear circuit, an output transformer of high quality is required. That used in the design of this amplifier was made by Partridge Transformers Ltd., Ref. No. C1732. It has two equal secondaries in order to provide either a 4 Ω or 15 Ω output. Other details are :—

Leakage inductance :	15mH
Primary inductance :	80H
Ratio	22:1

**See the KT66 data sheet*

PERFORMANCE

The curves in figs. 2 and 3 show the performance of the three classes of operation at varying anode loads. Fig. 2 shows the ultra linear circuit at three different levels of distortion compared with the triode performance at full output. Fig. 3 shows the pentode condition together with a comparative triode curve.

It will be seen that the ultra linear circuit behaves quite differently from the pentode. With the latter, full output is obtainable with a distortion which varies between 4% and 6% according to anode load. Except at the lower load impedances, the output for 1% and 2% distortion is only a small proportion of the maximum output.

In the ultra linear arrangement, almost full output is obtained at 2% distortion and very little increase is obtained if this is permitted to rise to 3%. The output for 1% distortion is about 50% of the maximum.

It will be seen that, for most values of anode load impedance, the ultra linear circuit produces only one half the distortion of the triode for equivalent outputs and is capable also of giving double the output for the same order of distortion.

The output impedance of the ultra linear circuit is considerably lower than the pentode arrangement, though higher than the triode. Measurements made at 20W output with the optimum anode load of 7kΩ show that the ultra linear and pentode circuits have impedances of 9kΩ and 35kΩ respectively. A comparable measurement on the triode circuit gave 3·5kΩ. The ultra linear circuit has, therefore, an impedance similar to the anode-anode load impedance of 7kΩ, whereas the pentode impedance is very much higher. The ultra linear circuit can exert a considerable damping factor, a valuable asset if the load is a loudspeaker.

The frequency response of the complete amplifier of fig. 1 shows a loss of 1·5db at 20c/s and 25kc/s.

OPERATING CONDITIONS

In all three classes of operation discussed, the anode and screen voltages were equal and maintained at 400 relative to the cathode. The KT66 is not normally used, as a pentode, with an equal anode and screen voltage of 400 due to the high screen current of 12mA per valve at maximum output. Under a sustained output the screen dissipation rating would be exceeded, although this method of operation is satisfactory for normal speech and music. Under these conditions, the current consumption is high but a saving is effected by the elimination of the stabiliser valve normally required in the pentode screen circuit. With the ultra linear circuit, the objection to the high current is removed since this does not exceed 7mA at maximum output. The screen current under the triode condition is, of course, lower still, at about 4mA per valve.

The data given in fig. 3 does not correspond with that previously published due to the use of a higher screen voltage. However, a closer comparison between the three operating conditions is obtained with constant voltages.

At full output, a voltage of 475 rms is present across the primary of the output transformer. The KT66 anodes therefore swing 400±340V, i.e. 60 to 740V. The two screen grids have the same d.c. potential but the a.c. voltage is one-fifth of the anode swing. They therefore operate between 335 and 465V.

COMPARISON OF OPERATING CONDITIONS

	Triode	*Pentode**	*Ultra Linear*	
$V_{a(b)}$	450	450	450	V
V_a	400	400	400	V
V_{g2}	400	400*	400	V
I_{a+g2}	125	125	125	mA
$I_{g2\ (o)}$	5	5	5	mA
$I_{a+g2\ (max\ sig)}$	135	155	145	mA
$I_{g2\ (max\ sig)}$	8	24*	15	mA
R_k (per valve)	560	560	560	Ω
V_k (app)	36	36	36	V
$p_{in\ (o)}$	50	50	50	W
$p_{in\ (max\ sig)}$	54	62	58	W
P_{out}	15	32	32	W
η	28	52	55	%
D (max sig)	2	$\not>$6	2	%
$R_{L(a-a)}$	6	7	7	kΩ
z_{out}	3·5	35	9	kΩ
$V_{in(g1-g1)(rms)}$	52	42	56	V
Relative P_{out} for given V_{in}	×1	×5	×2·5	
	0	+7	+4	db

*Suitable for intermittent operation only, due to excessive screen dissipation at full output. When continuous full output is required, use the operating condition : $V_a = 400$, $V_{g2} = 300$.

ADDITION OF NEGATIVE FEEDBACK

Negative feedback may be added to the circuit of fig. 1 when an improved performance is required. It is suggested that 14db feedback is adequate for all normal purposes, although this may be increased if necessary. The application of 14db feedback will reduce the output impedance, distortion and overall sensitivity by a factor of five. This will provide an amplifier having the following characteristics :

Input for full output :	600mV rms.
Output impedance :	1·8kΩ
Distortion :	0·5%
Damping factor :	4

The method is shown in fig. 4, the feedback voltage being introduced into the cathode circuit of the first valve. The bias resistor R22 (shown as R2 in fig. 1) is connected in the cathode circuit of one triode only. A further bias resistor and capacitor, R23, C23, are provided and feedback is applied across R24 from the secondary of the output transformer via R25.

Since the basic sensitivity of the amplifier is approximately 120mV for full output, a feedback voltage of about 500mV is required for 14db negative feedback. The output voltage is 21·5 for $Z_o = 15\,\Omega$ and 11 for $Z_o = 4\,\Omega$; therefore, the two resistors R24, R25 are chosen so that 500mV will exist at their junction at full output.

Assuming that R24 has a value of 22Ω, the value of R25 is given by $225\sqrt{Z_o}$ and the nearest standard values may be used. For $Z_o = 15$ or $4\,\Omega$, resistors of 1kΩ or 470Ω are satisfactory.

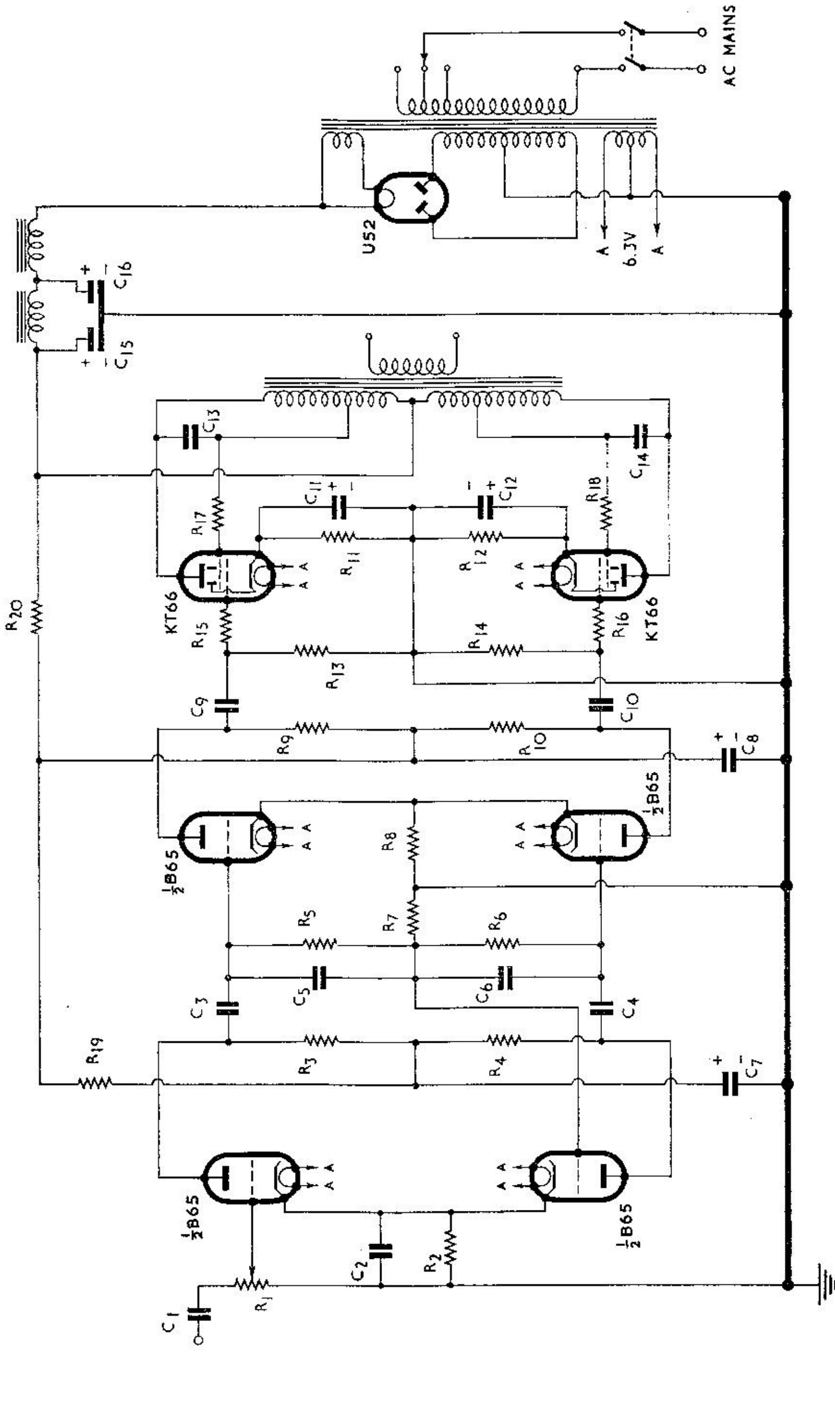


Fig. 1. A 30W ultra linear amplifier.
Component values are given on pages 8 and 9.

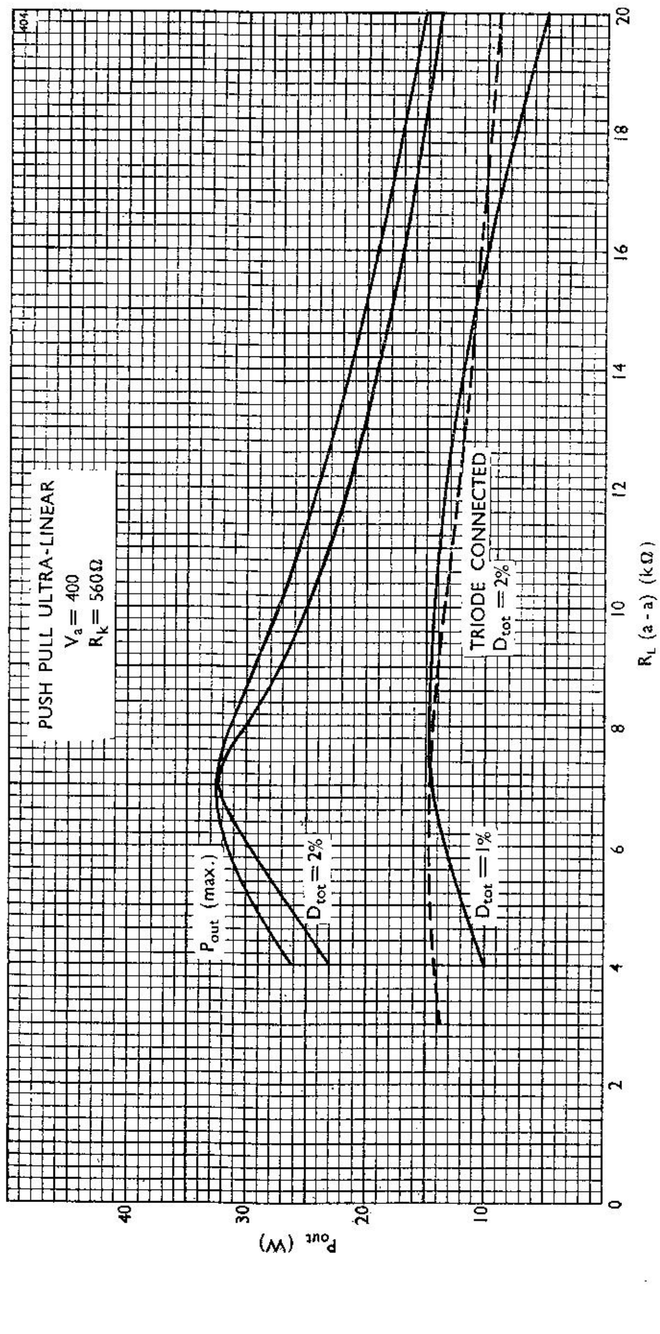


Fig. 2. A comparison of ultra linear with triode operation.

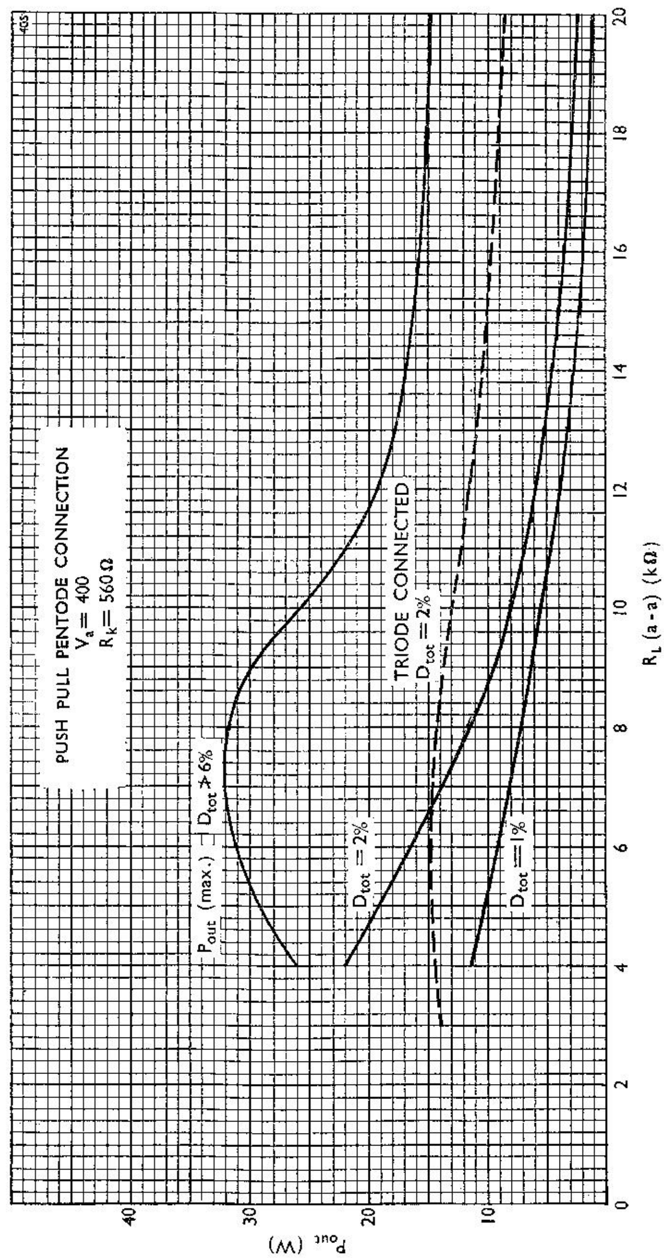


Fig. 3. A comparison of pentode with triode operation.

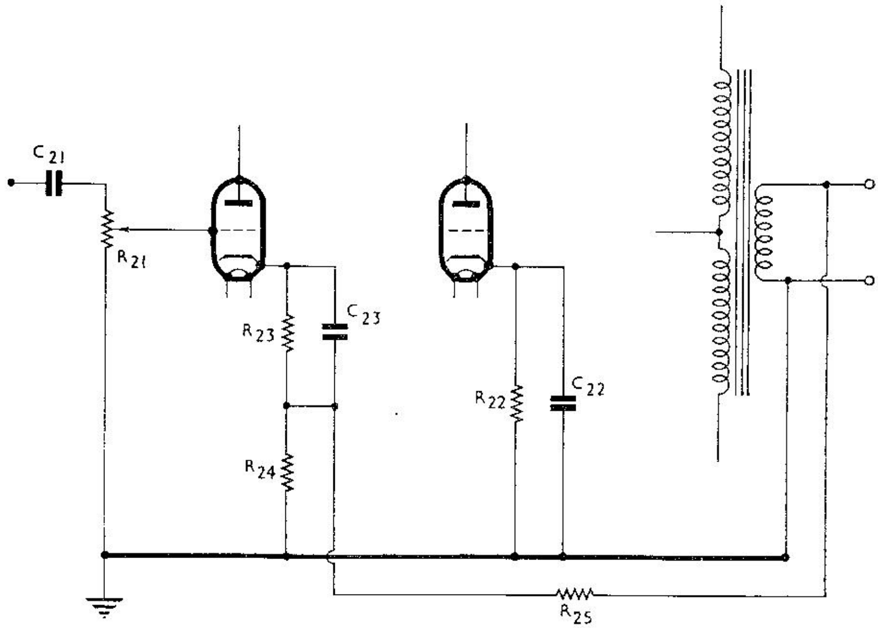


Fig. 4. The addition of negative feedback to the amplifier of fig. 1. See pages 8 and 9 for component values.

A 50W ULTRA LINEAR AMPLIFIER

When the maximum output is required from a pair of KT66 valves they may be used with fixed bias in the ultra-linear circuit. The operating conditions are given below and the recommended circuit is shown in fig. 5.

Per Pair of Valves	*Quiescent*	*Max. Signal*	
$V_{a,g2}$	525	500	V
I_{a+g2}	70	160	mA
V_{g1}	−50/−65	−50/−65	V
†$R_{L(a-a)}$	—	8	kΩ
P_{out}	—	50	W
*D	—	2	%
P_{a+g2} (per valve)	18	15	W
Z_{out}	—	6	kΩ
$V_{in(g1-g1)}$ (rms)	—	90	V
V_{in} (to amplifier in fig. 5)	—	2·5	V

†An output transformer having a ratio of 6 : 1 would be suitable for 105V output, 225 Ω.

*The distortion will vary from 1% to 3% with different valves. The performance is displayed graphically in figs. 7 and 8.

Circuit Notes.

The two KT66 valves are set to a similar quiescent current, which may be between 30 and 40mA, using the meter M and the meter shunts R46, R47. A negative bias voltage range of 50 to 65 is provided by the controls R53, R54. A quiescent current below 30mA will increase the distortion.

The bias voltage is derived from a U50 connected to the 600-0-600V transformer via the capacitors C42, C43. The resistors R55, R56, R57, R58, not only smooth the supply in conjunction with C44 but also reduce the voltage to the appropriate value. The resistors R52 to R58, associated with the bias supply, are generously rated to maintain a stable voltage.

R64 is adjusted, at about 90% of full output, to give equal cathode currents in the two output valves. It is capable of compensating for inequality of output from the driver stage and also for variations between the two output valves. When the two cathode currents are equal the distortion is at a minimum.

The anode supply is provided with an inductance filter L1, C31, C32. Due to the large variation in current with input signal the effective capacitance of C31, C32 has been made 80μF. The working voltage is excessive for a single electrolytic and C31, C32 are, therefore, connected in series to give a rated voltage of 900. This single section filter provides a ripple-free anode current. If a lower capacitance were used in place of C31, C32, an additional filter section would be required to reduce the ripple to a reasonable value, and the lower capacitance would be incapable of supplying the peak current required by a transient input signal.

At lower anode voltages the following results are obtainable. No circuit modifications are needed, the bias supply being a function of the anode voltage.

DC voltage	350	425	V
Quiescent current	25+25	30+30	mA
Max. signal current	55+55	65+65	mA
Power output	20	30	W
Anode to anode load	8	8	kΩ

The value of the components C40, C41, C45 and R59 will depend to some extent on the output transformer. R59 and C45 are optional and are used to suppress ringing. The most satisfactory method of selecting the value of these four components is by the use of a square wave generator, but an audio oscillator extending to, say, 50kc/s may be used to detect a peak in the supersonic region. C40 and C41 may be unnecessary with some types of transformer.

With the transformer used, the values shown gave a fall in output of 3db at 18-20kc/s with a load resistance of 15Ω.

Protection Against Bias Failure.

In common with other amplifiers which derive the bias potential from a separate supply instead of a cathode resistor, the 50W amplifier is rendered inoperative should the bias supply fail. Furthermore, the KT66 anode current would rise to an excessive value. The U50 is run at a very low anode current, a few milliamperes, and will, of course, have a long life.

A simple device which permits the amplifier to function with cathode bias in case of failure of the bias supply is shown in fig. 6. A triode, which could be one half of a B65 substituted for the L63 in the first stage, is connected in series with a relay across the 500V supply. The grid is taken to the bias supply. Normally the anode current is cut off and the relay short-circuits the resistor R60 connected in the cathode circuit of the KT66 valves. Should the bias fail, the relay will be energised, the relay contacts will open and the bias resistor R60 will allow the amplifier to function at about half maximum output.

COMPONENT VALUES

RESISTORS

(0·25W, 20% unless otherwise shown)

R1	500kΩ		
R2	750Ω		
R3	33kΩ	1W	10%
R4	33kΩ	1W	10%
R5	270kΩ } matched to 5%		
R6	270kΩ }		
R7	270kΩ		10%
R8	750Ω		10%
R9	33kΩ	1W	10%
R10	33kΩ	1W	10%
R11	560Ω	5W w.w.	5%
R12	560Ω	5W w.w.	5%
R13	270kΩ		10%
R14	270kΩ		10%
R15	10kΩ		
R16	10kΩ		
R17	220Ω		
R18	220Ω		
R19	10kΩ	0·5W	
R20	5·6kΩ	1W	
R21	500kΩ		
R22	750Ω		
R23	750Ω		

R24 }	see p. 3		
R25 }			
R31	1MΩ		
R32	33kΩ	0·5W } matched to	5%
R33	33kΩ	0·5W }	
R34	1·5kΩ		
R35	1kΩ		
R36	22kΩ	0·5W	
R37	1MΩ		
R38	1MΩ		
R39	47kΩ	1W	10%
R40	47kΩ	1W	10%
R41	150kΩ		10%
R42	150kΩ		10%
R43	10kΩ	1W	10%
R44	10kΩ		
R45	10kΩ		
R46 } Mèter	10Ω		
R47 } shunts	10Ω		
R48	100Ω		
R49	100Ω		
R50	100kΩ	1W	10%
R51	100kΩ	1W	10%
R52 (see fig. 6)	22kΩ	1W	10%
R53	20kΩ	w.w.	
R54	20kΩ	w.w.	
R55	220kΩ	1W	10%
R56	220kΩ	1W	10%
R57	220kΩ	1W	10%
R58	220kΩ	1W	10%
R59	220kΩ	1W	10%
R60 (see fig. 6)	330Ω	5W w.w.	10%
R61 (see fig. 6)	6·6 kΩ	0·5W	10%
R62	15kΩ	0·5W	10%
R63	0·65Ω	5W	
R64	20kΩ		

CAPACITORS

C1	0·01µF	350V	
C2	50µF	12V	Electrolytic
C3	0·1µF	500V	
C4	0·1µF	500V	
C5	100pF	250V	
C6	100pF	250V	
C7	8µF	450V	Electrolytic
C8	8µF	450V	Electrolytic
C9	0·02µF	500V	
C10	0·02µF	500V	
C11	50µF	50V	Electrolytic
C12	50µF	50V	Electrolytic
C13	2000pF	500V	
C14	2000pF	500V	
C15	8µF	450V	Electrolytic
C16	8µF	450V	Electrolytic
C21	0·01µF	350V	
C22	50µF	12V	Electrolytic
C23	50µF	12V	Electrolytic
C31	160µF	450V	Electrolytic
C32	160µF	450V	
C33	8µF	450V	
C34	8µF	450V	
C35	0·01µF	350V	
C36	0·01µF	500V	
C37	0·01µF	500V	
C38	0·05µF	750V	
C39	0·05µF	750V	
C40	0·001µF	300V AC	
C41	0·001µF	300V AC	
C42	0·025µF	600V AC	
C43	0·025µF	600V AC	
C44	4µF	200V	
C45	0·001µF	440V AC	

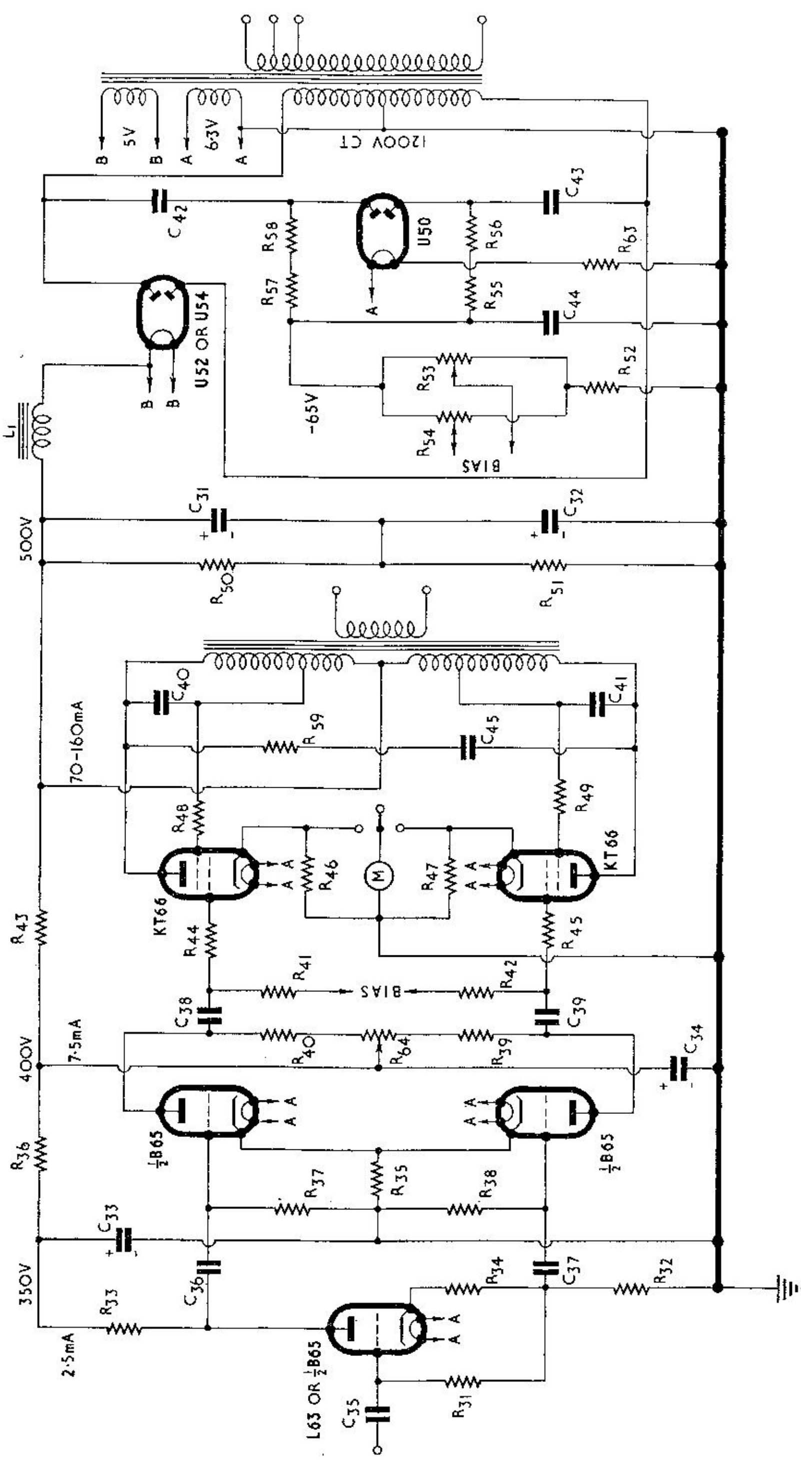


Fig. 5. A 50W ultra linear amplifier. See pages 8 and 9 for component values.

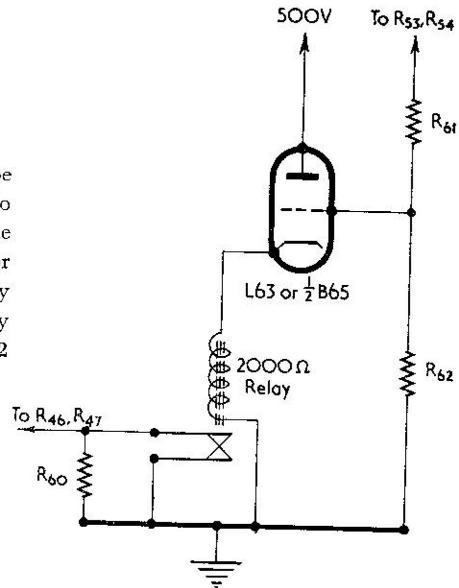


Fig. 6. This circuit may be added to the 50W amplifier to protect the KT66 valves in the event of bias failure. The resistor R60, normally short-circuited by the relay, provides an emergency cathode bias. R61 and R62 replace R52.

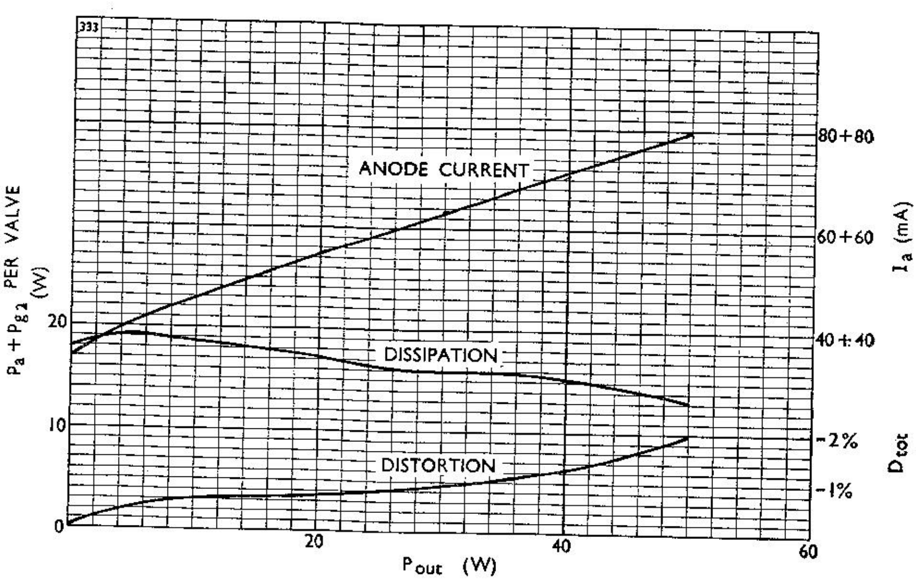


Fig. 7.

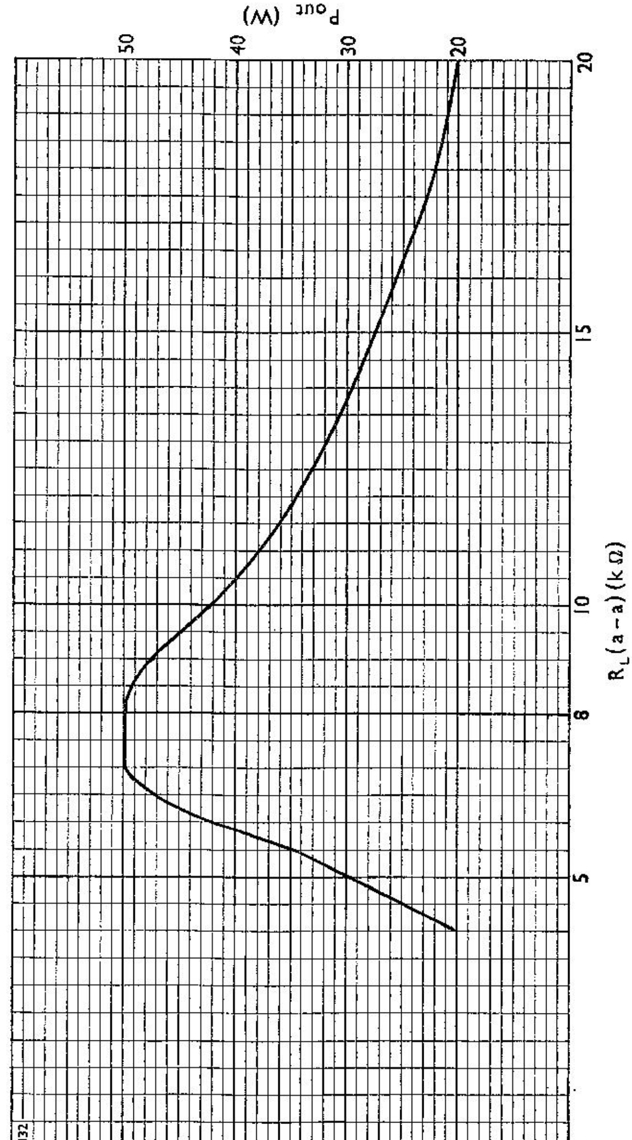


Fig. 8.

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