THE M-O VALVE
COMPANY LIMITED

APPLICATION
REPORT No. 14

AMPLIFIER CIRCUITS FOR KT77

The KT77 may be used in pairs in either triode, tetrode or ultra-linear push-pull circuits and this report gives circuits and operating data for amplifiers giving outputs of 25 W and 60 W in ultra-linear push-pull operation.

Either cathode bias or fixed bias may be used and the circuits show both types of operation. The former has the advantage of simplicity whereas the latter provides greater output and higher efficiency.

The output power of the ultra-linear circuit is not less than that of the tetrode at any given supply voltage and has the advantage that a low impedance screen supply is not required. The ultra-linear circuit does, in fact, show a rather higher efficiency in that a lower current is required from the power supply.

Owing to the high mutual conductance of the KT77 some precautions have to be taken against parasitic oscillation whatever the circuit arrangement. Grid and screen series resistors of about 10 kΩ and 33 Ω respectively, are recommended.

A 25 W ULTRA-LINEAR AMPLIFIER USING CATHODE BIAS

This amplifier provides an output of 25 W with an ht supply of 400 V. The distortion due to the output stage is only 2 %, but the application of 20 dB negative feedback reduces the overall distortion of 0.2 %. The amplifier features low hum and noise, high sensitivity, high damping factor, wide frequency range and fast transient response.

The output stage consists of two KT77 tetrodes operating in Class AB1 with separate cathode resistors. This is preceded by a conventional double triode amplifier which is fed by a triode phase-splitter. The input stage voltage amplifier is directly coupled to the phase-splitter in order to minimise low frequency phase shift. The circuit diagram is shown in fig. 1.

Depending upon the particular characteristics of the output transformer, it may be necessary to prevent instability by connecting capacitors and resistors in series between the screen tap and the anode connection of each half-primary of the output transformer. Typical values are 1000 pF and 470 Ω. The curves of fig. 2 show the distortion and intermodulation performance of the amplifier with and without feedback. The frequency response is shown in fig. 3.

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TABLE 1 Component Values for Fig.1

Valves

V1	ECC83/B339
V2	ECC83/B339
V3	KT77
V4	KT77
V5	U77/GZ34

Resistors

(± 20 % 0.25 W unless otherwise stated)

R1	1 MΩ		0.5 W
R2	68 kΩ		
R3	470 Ω		
R4	47 Ω		
R5	47 kΩ		0.5 W
R6	15 kΩ		1 W
R7	33 kΩ	1 W	matched to 5 %
R8	33 kΩ	1 W	
R9	1 MΩ		matched to 5 %
R10	1 MΩ		
R11	390 Ω		0.5 W
R12	47 kΩ	1 W	matched to 5 %
R13	47 kΩ	1 W	
R14	10 kΩ		1 W
R15	680 kΩ		matched to 5 %
R16	680 kΩ		
R17	10 kΩ		
R18	10 kΩ		
R19	33 Ω		
R20	33 Ω		
R21	470 Ω	5 W	matched to 5 %
R22	470 Ω	5 W	
*R23	250 Ω		12 W / 2000 √(speech coil impedance)
R24	2000 √(speech coil impedance)		
R25	4.7 kΩ		

*R23 Adjust to give ht line voltage of 400 V. This value, together with the resistance of half the secondary of T2 plus the reflected primary resistance of T2 must not be less than 250 Ω.

Capacitors

C1	8 μF	350 V	C7	0.05 μF	500 V
C2	32 + 32 μF	500 V	C8	50 μF	50 V
C3			C9	50 μF	50 V
C4	0.05 μF	350 V	C10	16 + 16 μF	500 V (600 V surge)
C5	0.05 μF	350 V	C11		
C6	0.05 μF	500 V	C12	133 pF	
			C13	220 pF	

Miscellaneous Components

L1 Smoothing Choke
- Inductance: . . . . . 10 H at 200 mA
- Resistance: . . . . . 150 Ω

T1 Ultralinear Output Transformer with 43 % Taps
- Anode-anode impedance: . . . . . 6.6 kΩ
- Primary inductance: . . . . . 200 H
- Leakage inductance: . . . . . P – S: 4 mH
  ½P – screen tap: 4 mH
- Primary dc resistance: . . . . . 70 + 70 Ω

T2 Mains Transformer
- Secondaries: . . . . . 410 – 0 – 410 V, 180 mA
  6.3 V, 5 A
  5 V, 3 A

TABLE 2 DC Voltages Measured at the Points Shown in Fig. 1 (Under quiescent 'no signal' conditions)

Point of Measurement	Voltage	DC Range of Avo Model 8 (50 μA fsd) (V)
1	400	1000
2	340	1000
3	242	1000
4	172	250
5	72	100
6	0.79	2.5
7	74	100
8	167	250
9	175	250
10	2.1	2.5
11	397	1000
12	30	100

TABLE 3 Operating Conditions for Output Stage

V_b	400	V
$V_{a,g2}$	397	V
$I_{a+g2(o)}$	2 x 60	mA
$I_{a+g2(max\ sig)}$	2 x 65	mA
$P_{a+g2(o)}$	2 x 24	W
$P_{a+g2(max\ sig)}$	2 x 13.5	W
R_k	2 x 470	Ω
$-V_{g(approx)}$	30	V
P_L	25	W
$R_{L(a-a)}$	6.6	kΩ

Performance of the Complete Amplifier

Feedback	20	dB
Rated output	25	W
Input for rated output	120	mV rms
Total harmonic distortion (25 W)	0.2	%
Intermodulation distortion (25 W)	0.6	%
Damping factor (15 Ω load)	16.5	—
3 dB frequency response (at 25 W = 0 dB)	25 – 25000	Hz
Hum (amplifier input open-circuit)	65	dB below 25 W
Noise (amplifier input open-circuit)	72	dB below 25 W
Hum (amplifier input short-circuit)	76	dB below 25 W
Noise (amplifier input short-circuit)	> 80	dB below 25 W
Transient response rise time (approx)	7.4	μs

A 60 W ULTRA-LINEAR AMPLIFIER USING FIXED BIAS

This amplifier provides an output of 60 W with an ht supply of 550 V. The distortion due to the output stage is 3 % but this is reduced to 0.3 % when feedback is applied. The wide frequency response, fast transient response and low hum and noise are features of this amplifier.

The output stage consists of two KT77 tetrodes operating in Class AB1 with separate fixed bias adjustment for each valve. The bias is obtained from a separate rectifier supplied by a tap on the ht transformer. The driver stage is a double triode amplifier which is fed by a triode phase-splitter. The circuit diagram is shown in fig. 4.

As in the 25 W amplifier it may be necessary to prevent instability by connecting capacitors and resistors in series between the screen tap and the anode connection of each half-primary of the output transformer. Typical values are 1000 pF and 470 Ω. The curves of figs. 5 and 6 show the distortion and intermodulation performance of the amplifier with and without feedback. Fig. 7 shows the frequency response characteristics.

TABLE 4 Component Values for Fig. 4

Valves

V1	ECC82/B329
V2	ECC82/B329
V3	KT77
V4	KT77
V5	U19 or GXU50
V6	U19 or GXU50
V7	S102/2K or alternative device

Resistors

(± 20 % 0.25 W unless otherwise stated)

R1	1 MΩ		R15	10 kΩ	5 W
R2	4.7 kΩ		R16	220 kΩ	
R3	470 Ω	10 %	R17	220 kΩ	
R4	33 kΩ	1 W	R18	10 kΩ	
R5	47 kΩ	1 W	R19	10 kΩ	
R6	47 Ω		R20	33 Ω	
R7	22 kΩ	1 W	R21	33 Ω	
R8	22 kΩ 1 W } matched to 5 %		R22	250	$\sqrt{\text{speaker impedance}}$
R9	22 kΩ 1 W }		R23	3.9 kΩ	1 W
R10	470 kΩ		R24	20 kΩ	W/W
R11	470 kΩ		R25	20 kΩ	W/W
R12	680 Ω		R26	100 kΩ	1 W
R13	47 kΩ 1 W } matched to 5 %		R27	100 kΩ	1 W
R14	47 kΩ 1 W }				

Capacitors

C1	8 μF	350 V	C7	0.25 μF	350 V
C2	220 pF		C8	0.25 μF	350 V
C3	0.05 μF	350 V	C9	64 μF	450 V (525 V surge)
C4	0.05 μF	350 V	C10	64 μF	450 V (525 V surge)
C5	16 μF	500 V	C11	440 pF	
C6	16 μF	500 V	C12	50 μF	200 V
			C13	50 μF	200 V

Miscellaneous Components

L1 Smoothing Choke
- Inductance : 10 H at 200 mA
- dc resistance : 150 Ω

T1 Ultra-linear Output Transformer with 43 % Taps
- Anode-anode impedance : 5.5 kΩ
- Primary inductance : ⩽ 28 H
- Leakage inductance : P – S ⩾ 6 mH
- ½P – screen tap ⩾ 6 mH
- Primary dc resistance : 70 + 70 Ω

T2 Mains Transformer
- Primary : 0 – 200 – 220 – 240 V
- Secondary : 640 – 0 – 100 – 640 V 250 mA

T3 Filament Transformer
- Secondaries : 6.3 V 5 A CT
  4.0 V 3.5 A

MR1 Sentercell contact rectifier Type C.2 H D.59 or silicone diode BYX10 etc.

F1 Mains Fuse 2 A

F2 HT Fuse 250 mA

TABLE 5 DC Voltages Measured at the Points Shown on Fig. 4 (Under quiescent 'no signal' conditions)

Point of Measurement (Fig. 4)	Voltage (V)	DC Range of Avo Model 8 (50 μA fsd) (V)
1	553	1000
2	389	1000
3	300	1000
4	263	1000
5	84	100
6	209	250
7	1.93	2.5
8	88	100
9	182	250
10	182	250
11	6.7	10
12	550	1000
13	550	1000

TABLE 6 Operating Conditions for Output Stage (Continuous Signal 1 kHz)

V_b	553	V
$V_{a,g2(o)}$	550	V
$V_{a,g2(max\ sig)}$	500	V
$I_{a+g2(o)}$	45	mA
$I_{a+g2(max\ sig)}$	110	mA
$P_{a+g2(o)}$	25	W
$P_{a+g2(max\ sig)}$	25	W
$-V_g$ (approx)	48	V
P_L	60	W
$R_{L(a-a)}$	5.5	kΩ
D_{tot}	0.3	%
Z_{out}	1.5	kΩ
*IM	1.4	%
Damping factor	14.5	–

If negative feedback is omitted, the following changes in values occur:-

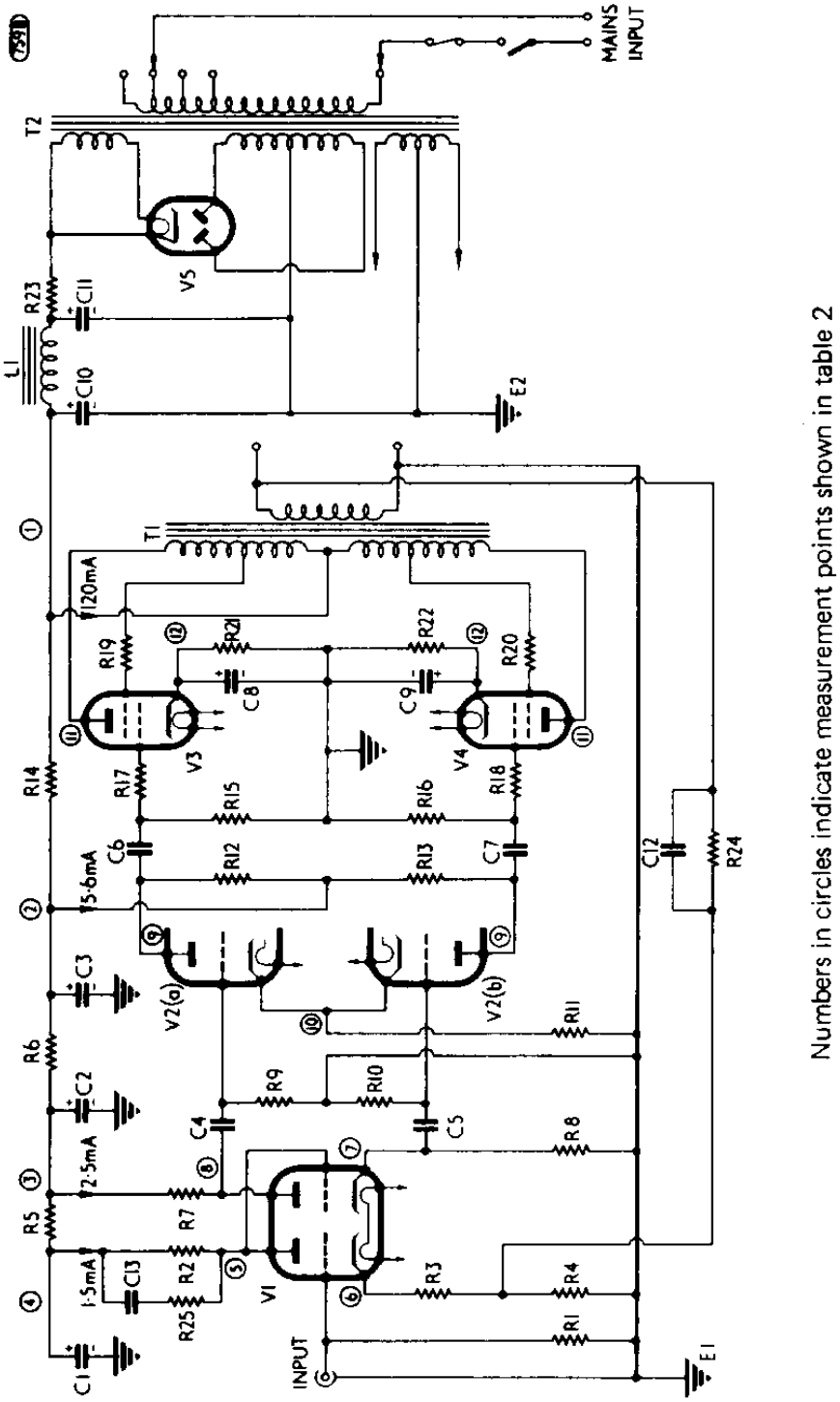
D_{tot}	3.0	%
Z_{out}	20	kΩ
*IM	11	%

*Intermodulation distortion: measured using two input signals at 50 and 6000 Hz (ratio of amplitudes 4:1).

Performance of the Complete Amplifier

Feedback	20	dB
Rated output	60	W
Input for rated output	1.65	V rms
Total harmonic distortion	0.3	%
Intermodulation distortion	1.4	%
3 dB frequency response (at 60 W = 0 dB)	< 20 – 45	kHz
Hum and noise (source resistance 47 kΩ)	74	dB below 60 W
Transient response rise time	1.5	μs

Fig. 1 CIRCUIT DIAGRAM OF 25 W ULTRA-LINEAR AMPLIFIER



Numbers in circles indicate measurement points shown in table 2

Fig. 2 INTERMODULATION AND TOTAL DISTORTION CURVES FOR 25 W AMPLIFIER

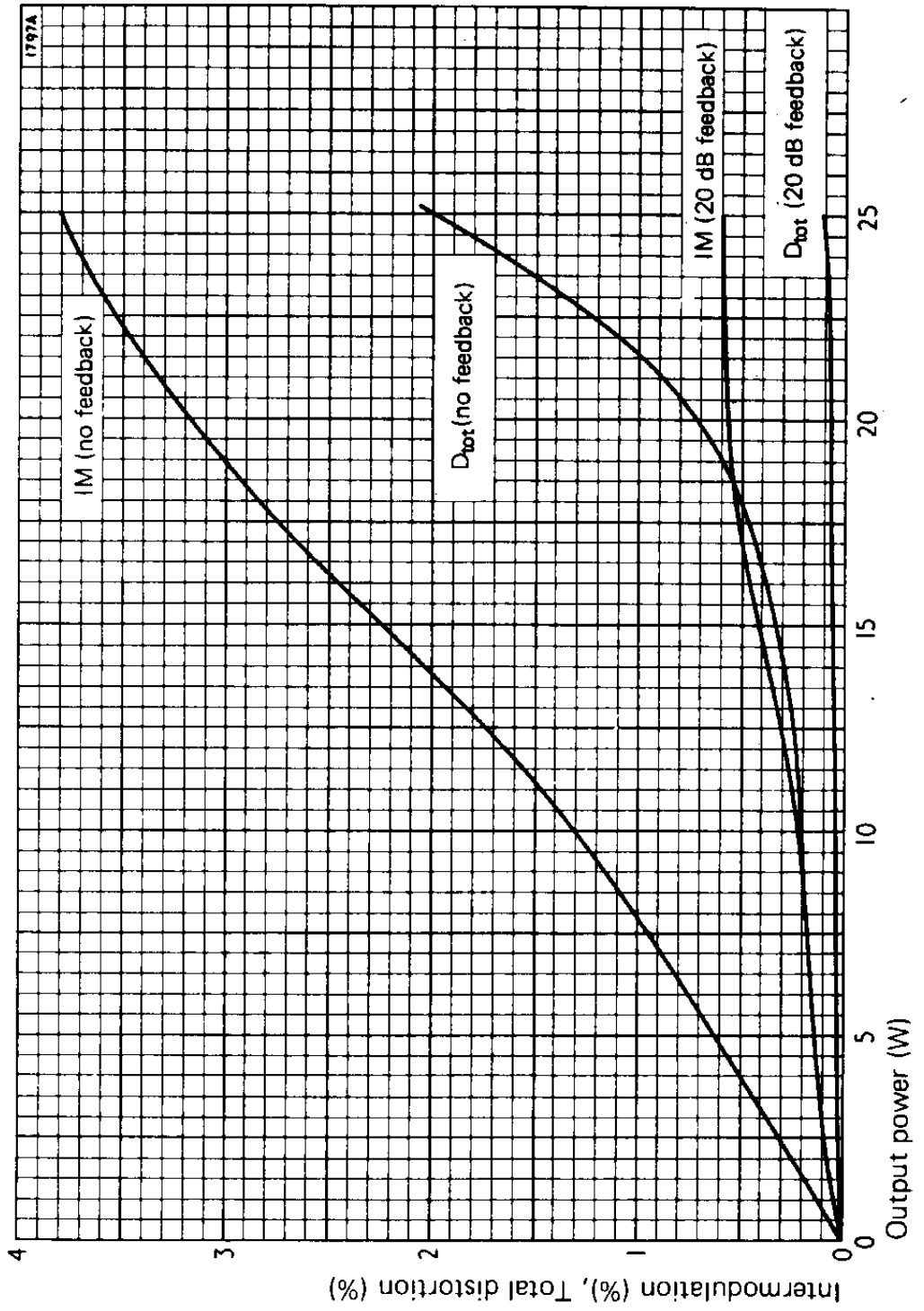


Fig. 3 FREQUENCY RESPONSE OF 25 W AMPLIFIER (20 dB FEEDBACK)

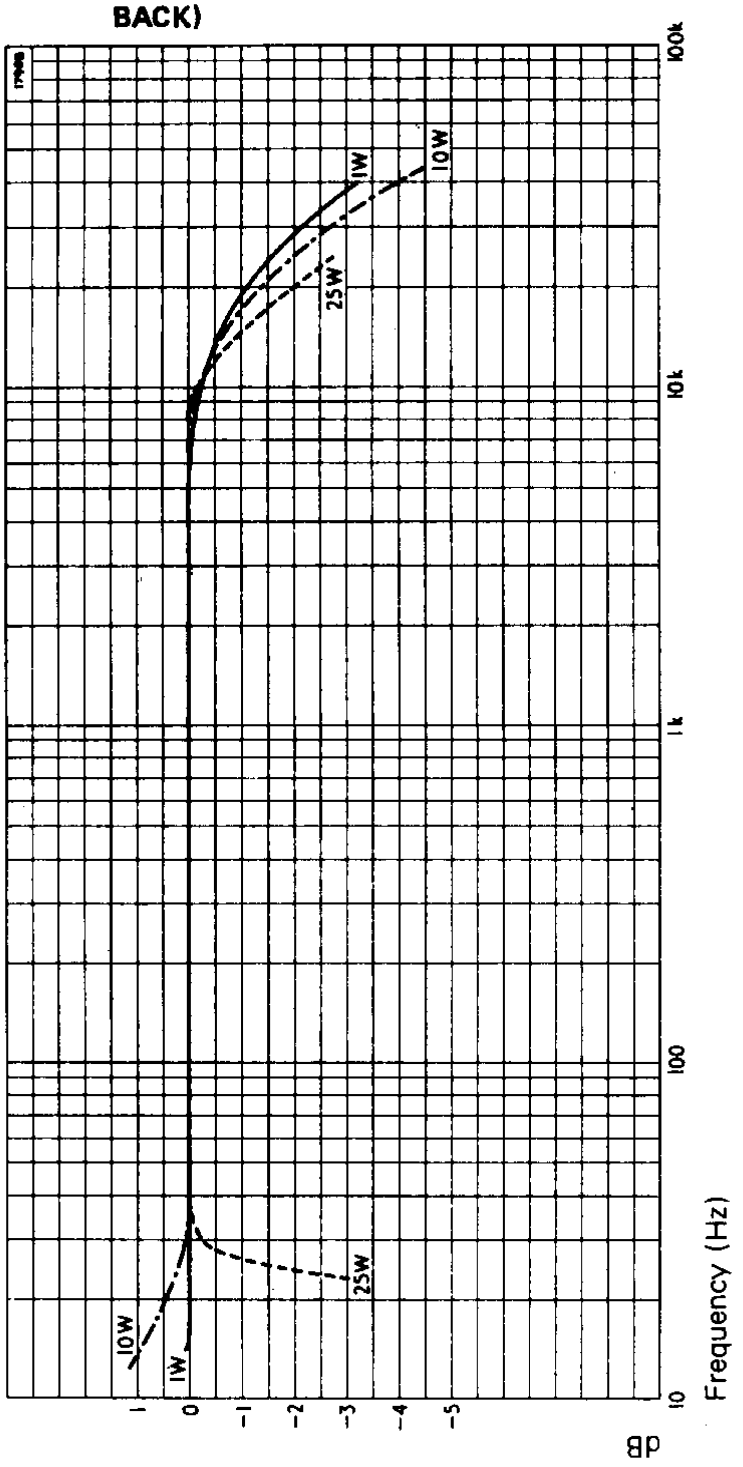
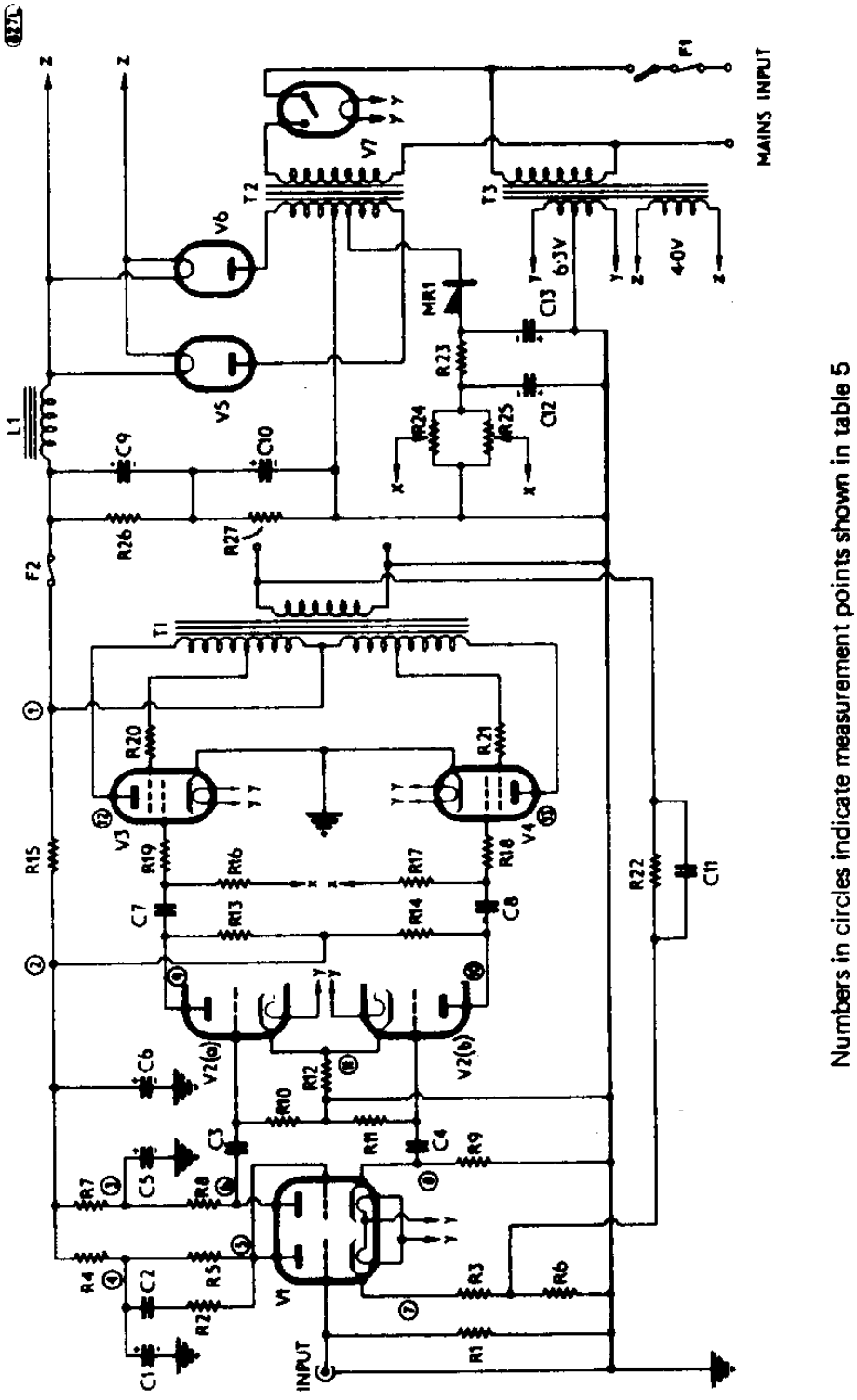


Fig. 4 CIRCUIT DIAGRAM OF 60 W ULTRA-LINEAR AMPLIFIER



Numbers in circles indicate measurement points shown in table 5

Fig. 5 TOTAL DISTORTION CURVES FOR 60 W AMPLIFIER

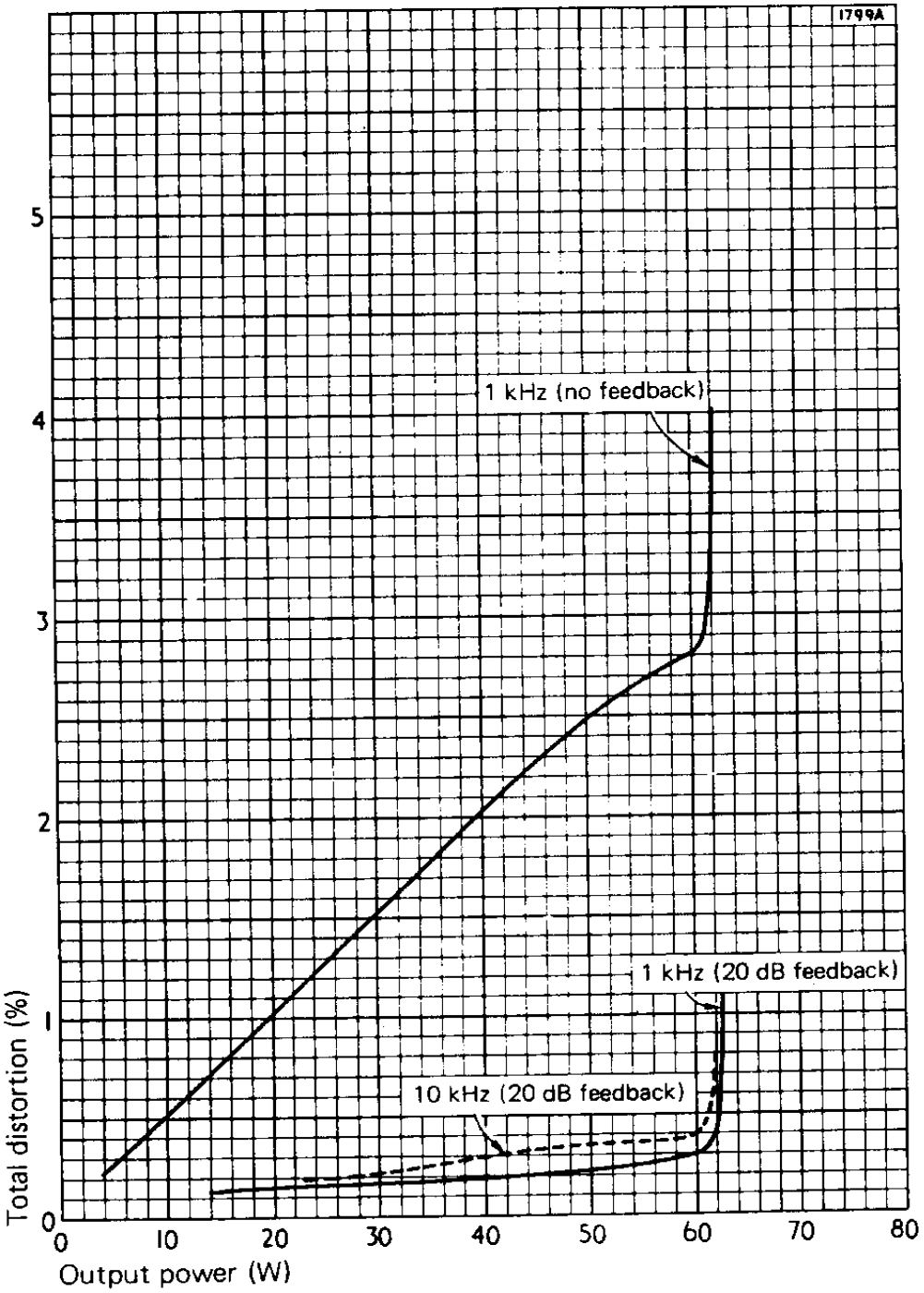


Fig. 6 INTERMODULATION DISTORTION CURVES FOR 60 W AMPLIFIER

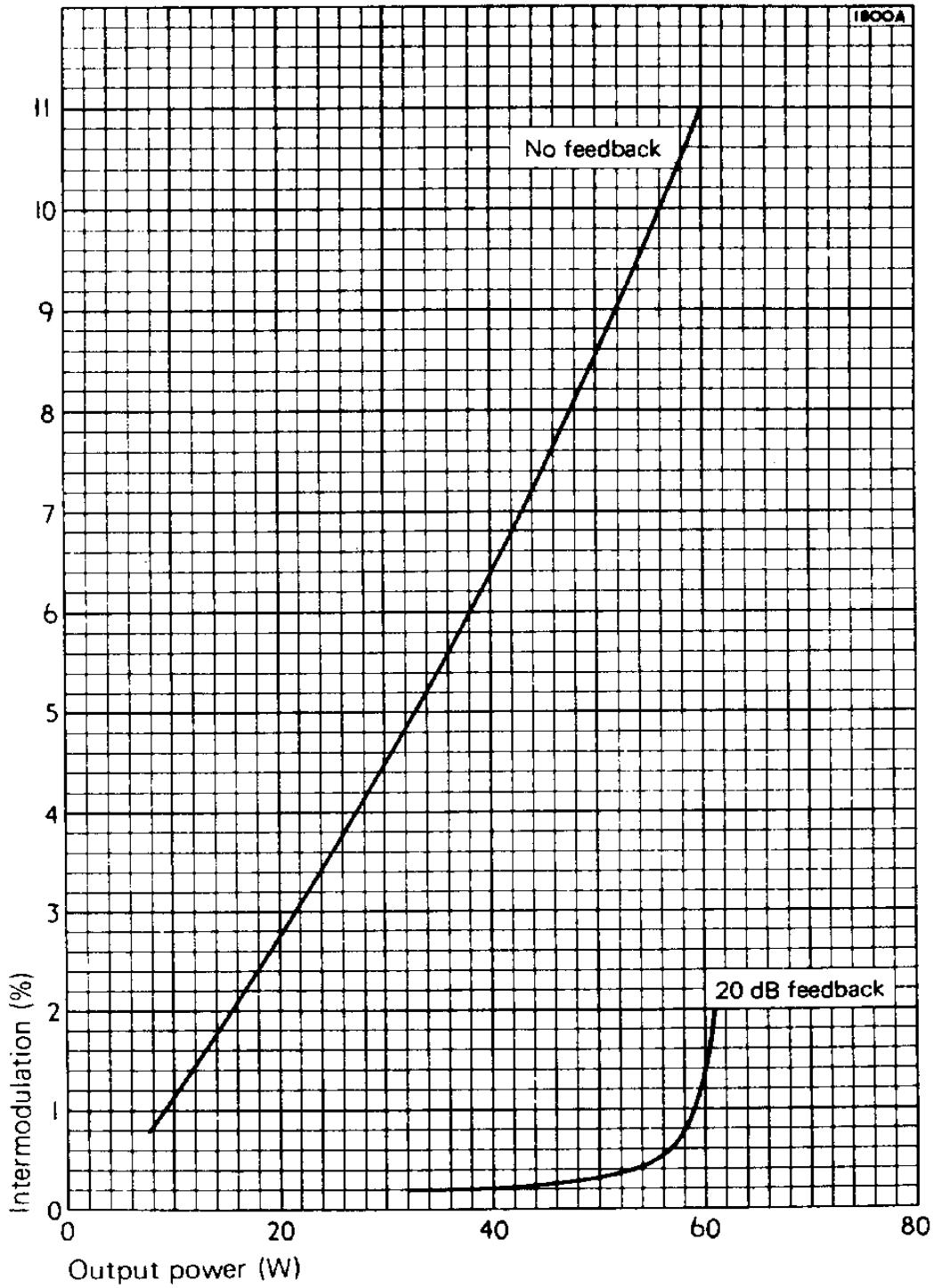


Fig. 7 FULL OUTPUT FREQUENCY RESPONSE OF 60 W AMPLIFIER (20 dB FEEDBACK)