Darlington Power Transistors in Audio Amplifiers

EB 103

Price 20p

SUMMARY

A description is given of three amplifiers with the following output powers:

a) 75W from 2 x 32V rails into 4Ω
b) 50W from 2 x 26V rails into 4Ω
and c) 25W from 2 x 20V rails into 4Ω

These audio circuits are designed primarily for mains powered home equipment.

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DARLINGTON POWER TRANSISTORS IN AUDIO AMPLIFIERS

INTRODUCTION

The use of Darlington transistors in audio amplifiers gives the advantage of a lower component cost and thus mounting cost, both by reducing the number of actual devices required and, through their high gains, the number of conventional driver stages. Also by using complementary Darlington output stages the problem of providing inversion stages is removed.

CIRCUIT DESCRIPTION

A circuit diagram of the 25 and 50W amplifier is given in Figure 1 and of the 75W amplifier in Figure 2. These amplifiers use direct coupling at the output and consequently a differential stage is used at the input to ensure low offset voltages. Otherwise, excessive offset could lead to de-centring of the loudspeaker cone or, in the extreme case, its destruction. Negative feedback is also provided to the

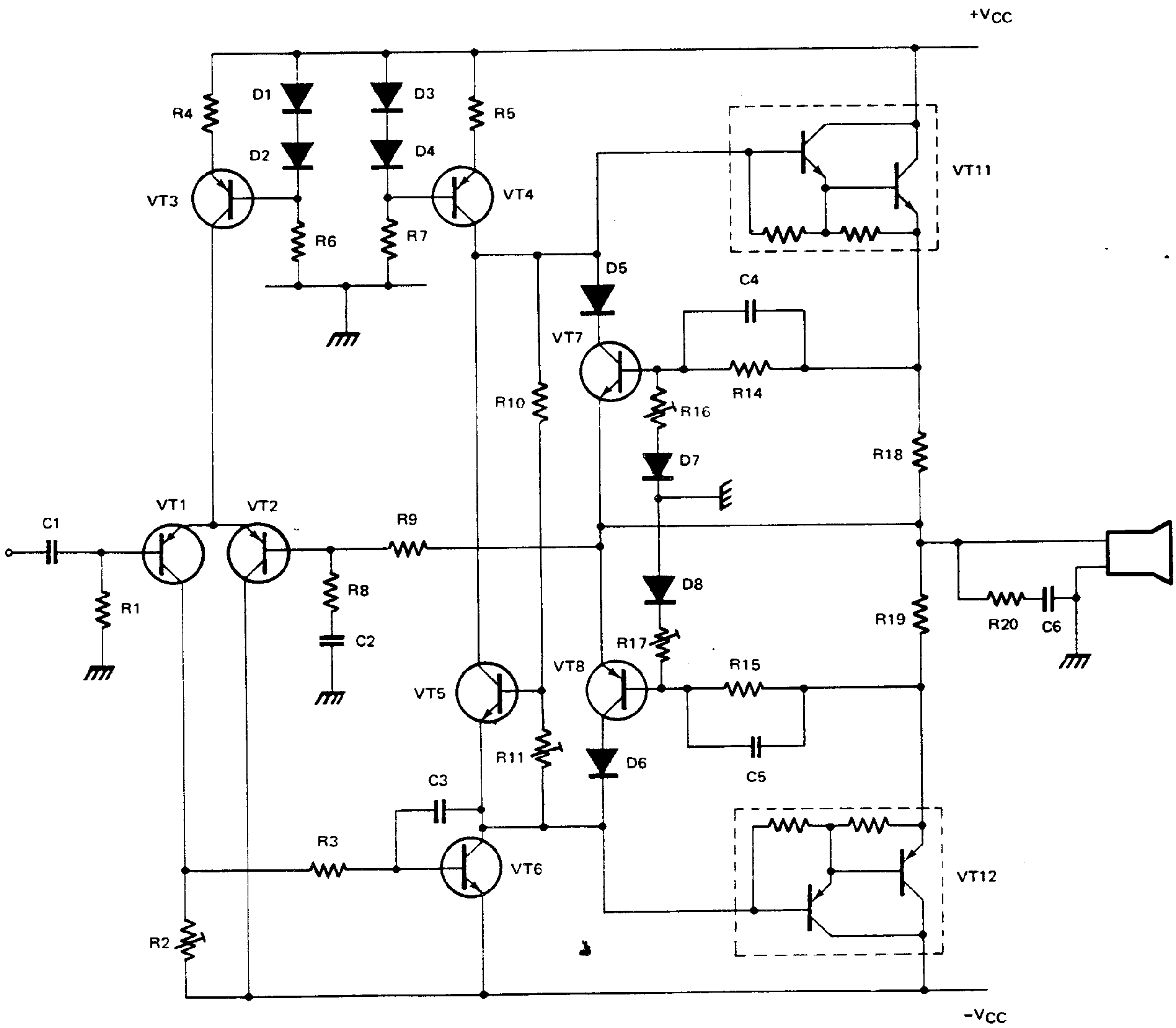

FIGURE 1. Circuit Diagram of 25 and 50W Amplifiers

differential stage, defined by resistors R8 and R9. Transistor VT1 of the pair also drives the class A driver stage comprising of transistor VT6. The latter has, between collector and base, a Miller capacitor in order to improve the high frequency stability. The use of a constant current supply (transistor VT4) gives a high mains supply ripple voltage rejection. It also means that a 'bootstrap' capacitor is not required and thus gives some space saving. The quiescent current is adjusted to 50mA by means of the trim potentiometer R11 in a V_{BE} multiplier stage, transistor VT5. (Positioning the trim potentiometer here rather than in the resistor R10 position, means that should it go open circuit the output will be turned off rather than the catastrophic fully on). The use of Darlington power transistors as the output devices allows the design to deliver 50W without additional driver devices.

Temperature Compensation of the Quiescent Current

The first evaluation of a 25W audio amplifier, with TIP120/125 Darlington transistors, employing a BC183 silect transistor in the V_{BE} multiplier position, VT5, showed the quiescent current to be heavily temperature dependent. At an ambient temperature of approximately 60°C thermal instability of the Darlington output stage starts to occur. Thus the poor thermal contact of the silect transistor means that it is necessary to use an SOT-32 transistor type in the V_{BE} multiplier stage. To additionally reduce the thermal resistance it is suggested that a proprietary silicon grease is also used. With this, the temperature change of the quiescent current is completely compensated.

Construction

Due to the high current gains oscillation problems could occur in the amplifier if care is not taken with the construction. Through careful wiring and layout, oscillations can be avoided. Practice has shown that twisting the short leads to the output transistor, use of the V_{BE} multiplier (with transistor VT5 attached to the heat sink) and adding a high frequency stabilising network (R20 and C6) across the load are all helpful. Also it is good practice to bring the ground lines to a star point near the supply source.

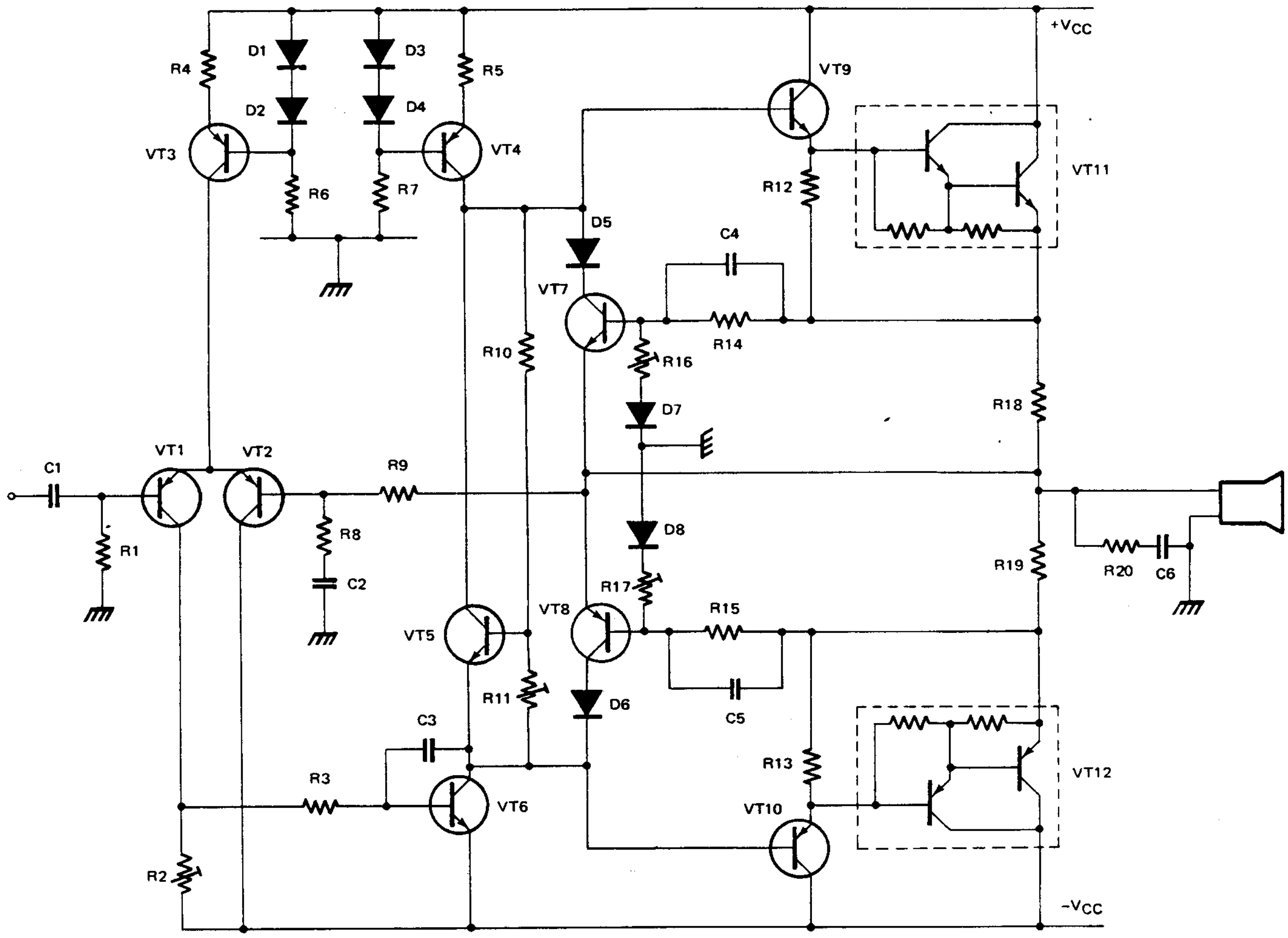

FIGURE 2. Circuit Diagram of 75W Amplifier

Components List

	25W	50W	75W
R1	120kΩ	120kΩ	120kΩ
R2	2k5	2k5	2k5
R3	1k	1k	1k
R4	560	560	560
R5	56	47	180
R6	3k3	3k3	3k3
R7	3k3	3k3	3k3
R8	1k2	1k2	1k2
R9	110k	110k	110k
R10	1k8	1k8	3k3
R11	1k	1k	1k
R12, R13	–	–	470
R14, R15	270	270	270
R16, R17	5k	5k	5k
R18, R19	0·27	0·27	0·27
R20	2Ω7	2Ω7	2Ω7
C1	680nF	680nF	680nF
C2	47μF	47μF	47μF
C3	27pF	27pF	27pF
C4, C5	10nF	10nF	10nF
C6	100nF	100nF	100nF
D1-D6	1N914	1N914	1N914
VT1-VT4	BC212	BC212	BC212
VT5	BC429	BC429	BC429
VT6-VT7	BC182	BC182	BC182
VT8	BC212	BC212	BC212
VT9	–	–	BC182
VT10	–	–	BC212
VT11	TIP120	TIP130	TIP141
VT12	TIP125	TIP135	TIP146

CALCULATIONS

For the 25W into 4Ω Amplifier

Specification P_{out} = 25W

R_L = 4Ω

Input Impedance $R_{in} \geqslant 100k\Omega$

Voltage gain $\triangleq$ 40dB

V_{in} for full output 110mV

Supply voltage $V_S = (P_{out} \times 8 \times [R_L + R_{in}])^{1/2} + 2 \times V_{CE(sat)}$

$P_{out} = 1.2 \times P_{out} = 30W$

R_E is chosen to be 0.27Ω where $R_E = R18 = R19$

R_L = 4Ω

$V_{CE(sat)} = 2V$

$\therefore V_S = (60 \times 8 [4 + 0.27])^{1/2} \times 2 \times 2$

$= 36V$

2 x 20V supplies would be quite adequate.

The peak collector current of the output transistors VT11 and VT12

$\hat{I}_C = (V_S - 2 \times V_{CE(sat)})/2 \times R_L + R_{in})$

where $R_L = 0.8 \times R_L = 3.2\Omega$

$\hat{I}_C = (40 - 2 \times 2)/2 \times (3.2 + 0.27) = 5.2A$

In order to meet these requirements (V_{CEO} = 60V and I_C = 5A) the correct Darlington transistors for the output devices are the TIP120 and TIP125.

$I_B = I_C/h_{FE}$ where $h_{FE} = 1600$

$I_B = 5/1600 = 3.12mA$

With a resistor value of 56Ω for R5, the constant current value

$I_q = 0.7/56 = 12.5mA$

and an output driving ratio

$V = I_B/I_q = 3.12/12.5 = 0.25$

Graphs of total harmonic distortion (t.h.d.) versus output power and versus frequency for this amplifier are given in Figures 3 and 4, and the frequency response is shown in Figure 5.

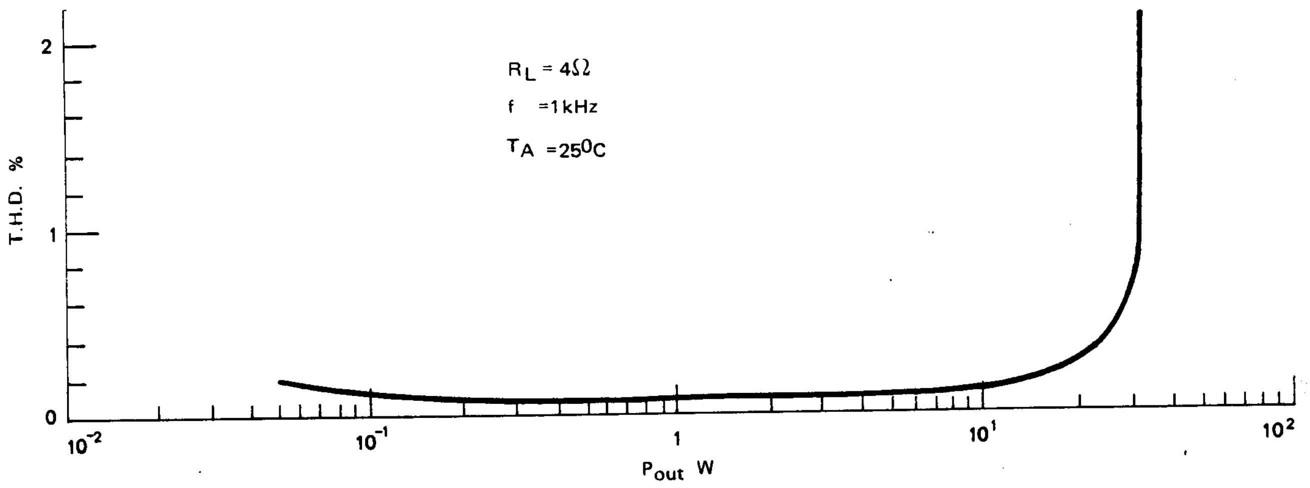

FIGURE 3. T.H.D. vs Output Power of 25W Amplifier

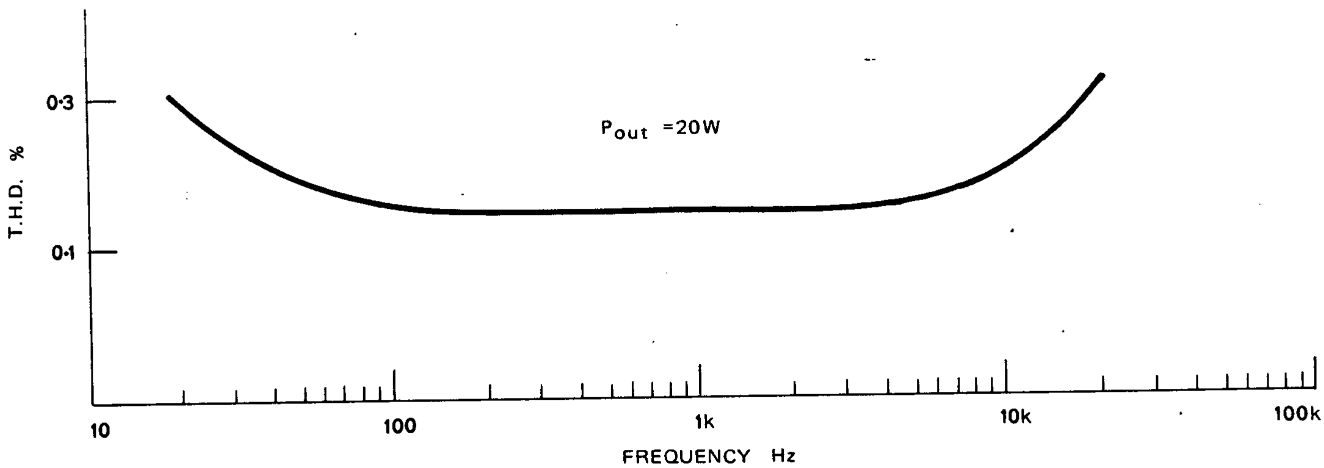

FIGURE 4. T.H.D vs Frequency of 25W Amplifier

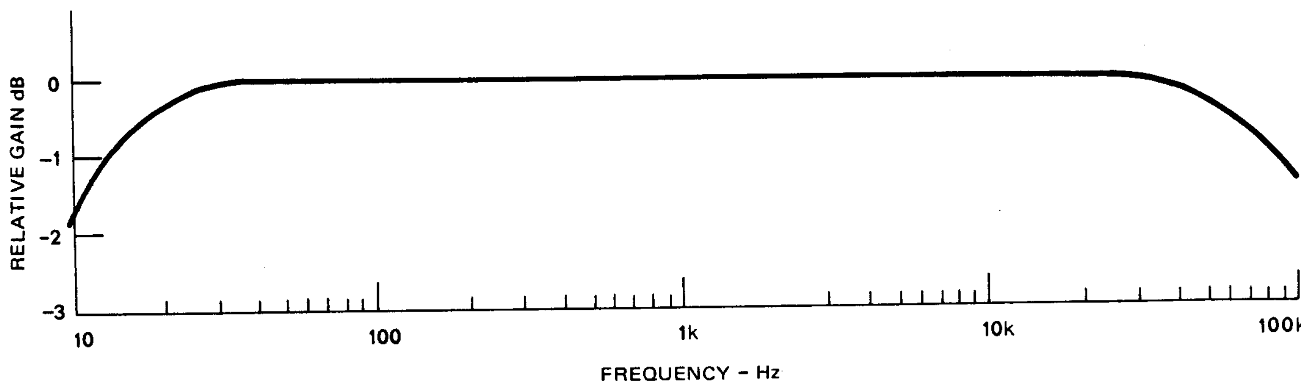

FIGURE 5. Frequency Response of 25W Amplifier

50W into 4Ω Amplifier

Rest of Specification

Input Impedance R_{in} = 100kΩ

V_{in} for full output = 157mV

Suitable supply voltages are ±26V and Darlington Transistors to supply the required 6.8A are the TIP130 and TIP135.

Graphs of t.h.d. versus output power and frequency, and frequency response for this amplifier are given in Figures 6, 7 and 8 respectively.

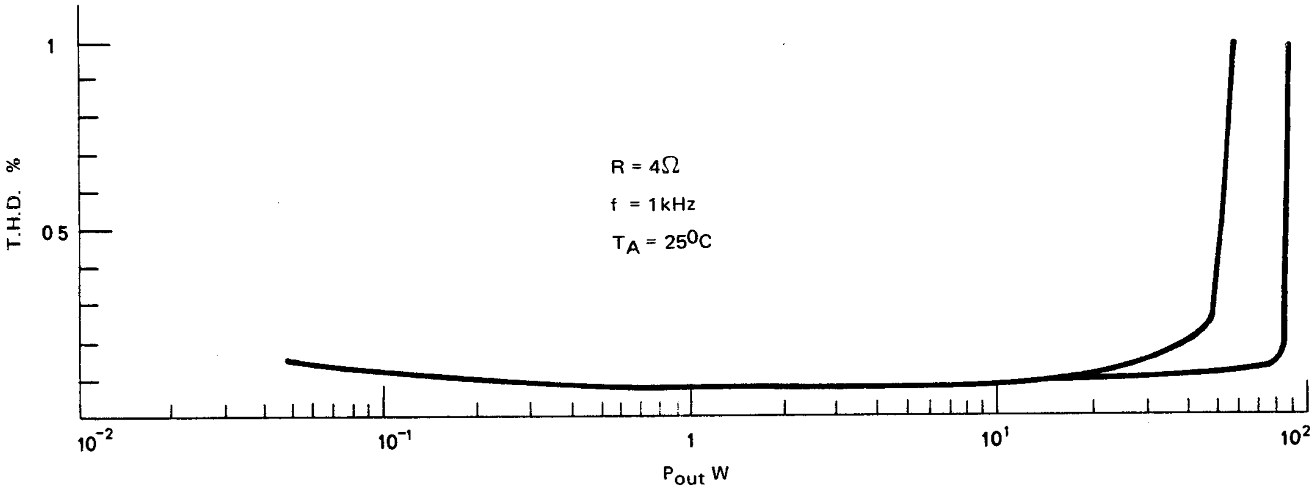

FIGURE 6. T.H.D. vs Output Power of 50W and 75W Amplifiers

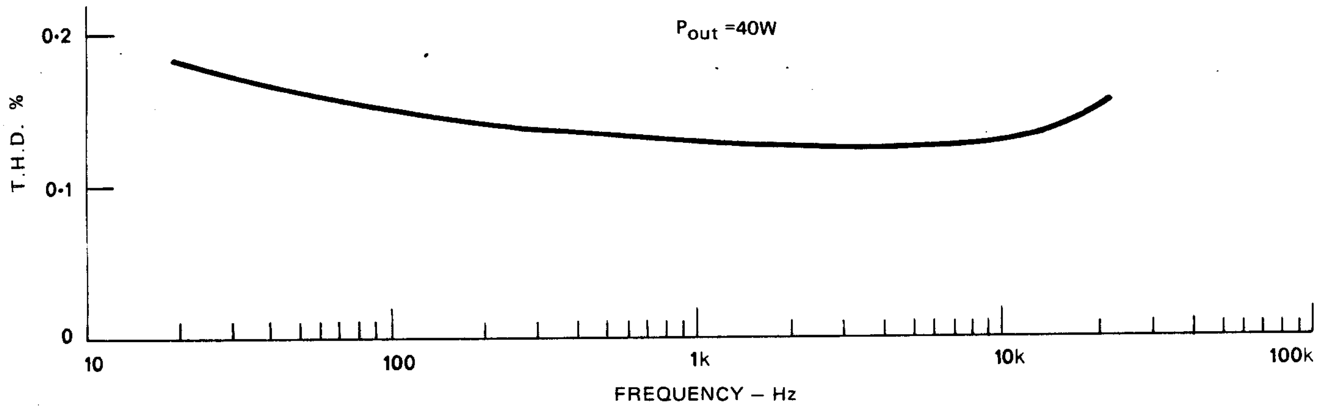

FIGURE 7. T.H.D. vs Frequency of 50W Amplifier

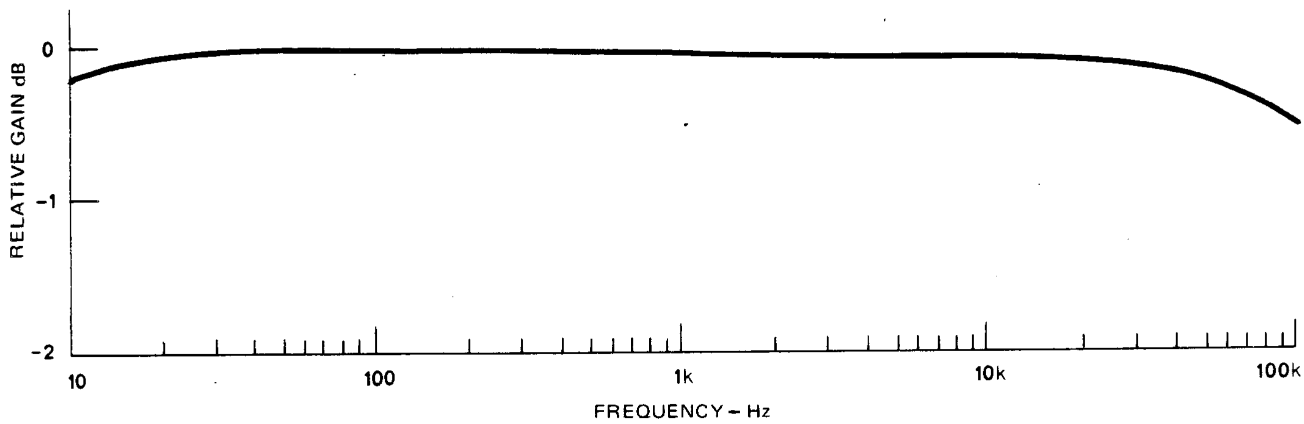

FIGURE 8. Frequency Response of 50W Amplifier

75W into 4Ω Amplifier

Rest of Specification

Input Impedance R_{in} = 100kΩ

V_{in} for full output = 192mV

Suitable supply voltages are ±31V and Darlington transistors to supply the required 8.2A are the TIP141 and TIP146.

The use of a constant current source giving approximately 20mA is not possible due to the high power requirements for transistors VT4 and VT5. Therefore in order to have relatively small currents and minimum power dissipation in the class A driver and the constant current supply device, small signal driver transistors are employed.

Graphs of t.h.d. versus output power and frequency, and frequency response are given in Figures 6, 9 and 10 respectively.

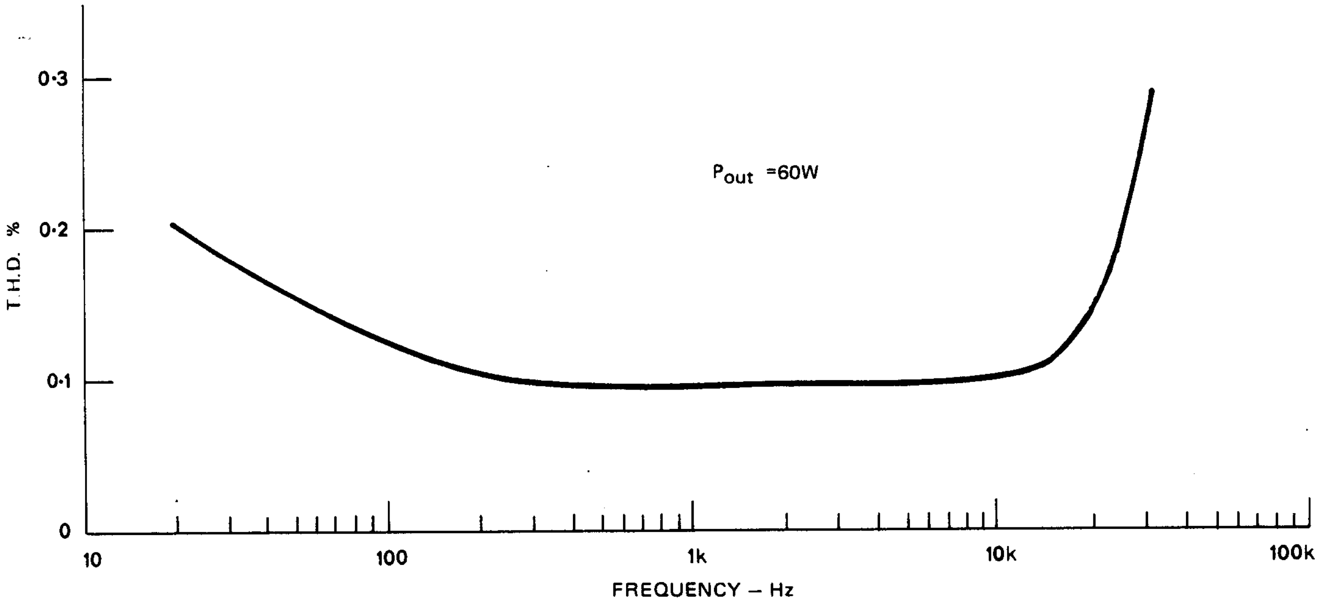

FIGURE 9. T.H.D. vs Frequency of 75W Amplifier

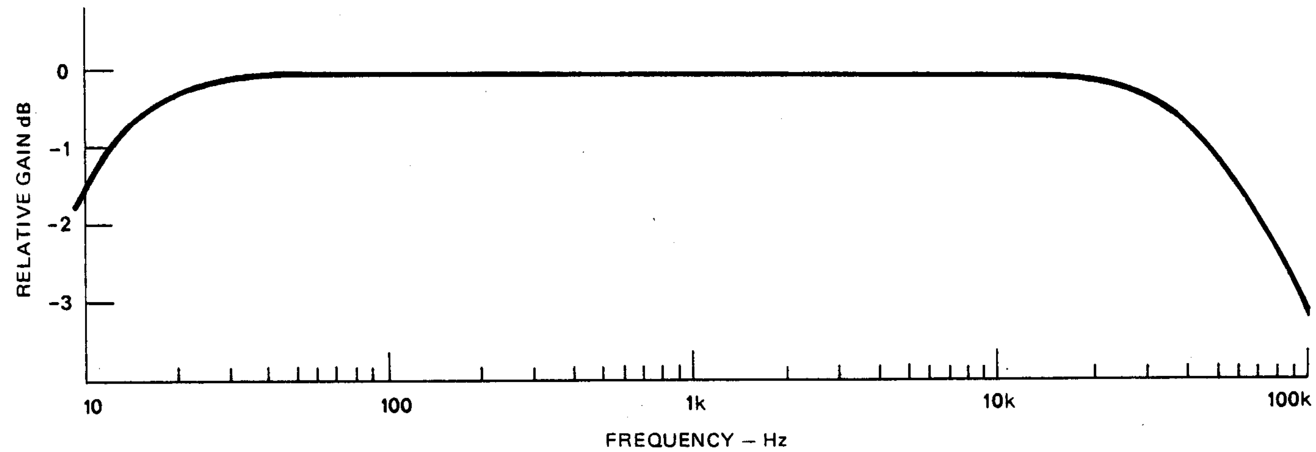

FIGURE 10. Frequency Response of 75W Amplifier