25-WATT AUDIO AMPLIFIER WITH SHORT-CIRCUIT PROTECTION

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INTRODUCTION

A high performance audio amplifier, suitable for the consumer market, must be able to operate efficiently, have low distortion and flat frequency response over the audio range. Other important design considerations are thermal stability, abitily to operate from an unregulated power supply, and provision for short-circuit protection. The component count as well as the cost must be kept as low as possible.

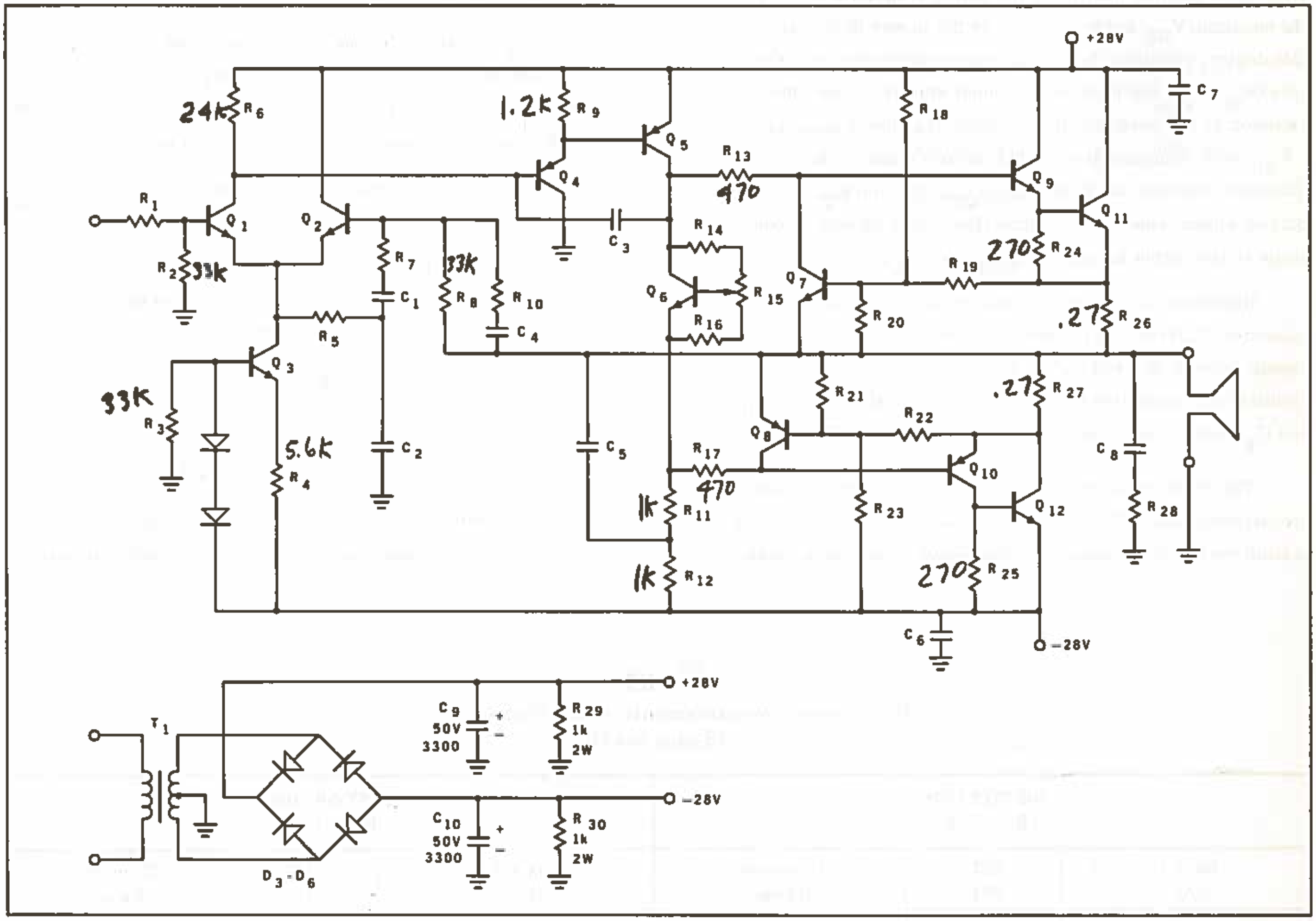

Fig. 1. Schematic of 25-watt, audio amplifier with short circuit protection.

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CIRCUIT DESCRIPTION AND OPERATION

The amplifier described in this bulletin is a class AB type with quasi-complementary direct-coupled output. Circuit schematic and performance measurements are given in Fig. 1 and Table I, respectively. A parts list and a component placement diagram are given in Table II and Fig. 2 at the end of this paper.

Cross-over distortion in the output devices (Q_{11}, Q_{12}) is reduced by maintaining a small quiescent current. The voltage V_{CE} of Q_6 is adjusted by R_{15} to match the total V_{BE} of Q_9, Q_{10}, and Q_{11} and set the quiescent current in the output transistors, Q_{11} and Q_{12}. Due to ambient temperature changes, the V_{BE} variations in Q_9, Q_{10}, and Q_{11} are compensated by the amplified V_{BE} variation in Q_6, thus stabilizing quiescent current for ambient temperature changes. However, junction heating in the output transistor Q_{11}, and the resultant V_{BE} change caused by the power dissipation in this device, requires the use of emitter degeneration resistors (R_{26}, R_{27}) for complete thermal stability. An emitter resistor is not needed with the output transistor Q_{12}, since V_{BE} with temperature in this device does not affect the quiescent current as it does in Q_{11}. R_{26} and R_{27} are replaced either side of the output line, thus providing equal loads to the output transistors, Q_{11} and Q_{12}.

High frequency stability is accomplished with a feedback capacitor (C_3) from (Q_5) collector-to-base of Q_4 and a power supply bypass (C_6 and C_7). The RC network (R_{28} and C_8) stabilizes the amplifier with an inductive speaker load. R_{10} and C_4 control the frequency response above 20 Kilohertz.

The most important feature of the amplifier is short-circuit protection. The function of this type of protection is to limit the power dissipated in the output transistors rather than to completely cut off or latch up these devices. The protection circuit requires six resistors and two transistors.

R_{18}, R_{19}, R_{20}, and Q_7 sense an overload in the output transistor Q_{11} by continuously and simultaneously monitoring I_E and V_{CE} of Q_{11}. When an overload or short occurs, the protection transistor (Q_7) conducts shunting base drive current away from the output transistor (Q_{11}), thus limiting the power dissipated in Q_{11}. Power is limited in the output transistor, Q_{12}, as in Q_{11} by the transistor-resistor network (R_{21}, R_{22}, R_{23} and Q_8) .

The short-circuit protection is very reliable for short circuits, as well as for overloads, when an adequate heat dissipator is provided.

The differential amplifier Q_1, Q_2, (with Q_3 as a constant current source for Q_1, Q_2) in conjunction with 100 percent dc negative feedback to the base of Q_2 ensures stability of the output operating point.

Q_3 is biased by the two diodes in the base to provide a constant current source and to thus reduce transients during switch-on. The capacitors C_1 and C_2 are prebiased by R_5, which is connected to the emitters of Q_1 and Q_2.

C_5, R_{12}, the "bootstrap" circuit to the base of Q_{10} ensures maximum overall open loop gain.

The overall amplifier gain is determined by the ratio of R_8 to R_7. The values used in this case were:

$$R_7 = 1.2\ K, \quad R_8 = 33\ K$$

$$\therefore AV = \frac{R_8}{R_7} = \frac{33\ K}{1.2\ K} = 27.5$$

The actual measured gain was AV equal to 30 as shown in the performance measurements in Table I.

The gain can be increased by reducing R_7. Table I compares performance of both high and low gain circuits.

TABLE I.
Performance Measurements of 25-Watt Amplifier
(8-ohm load)

DISTORTION R_7 120			DISTORTION R_7 1.2 k		
IM 4:1 (%)	HD (%)	Sinewave Power	IM 4:1 (%)	HD (%)	Sinewave Power
1.5	1.6	250 mW	0.06	0.28	250 mW
1.3	0.68	2.5 W	0.07	0.18	2.5 W
3.2	0.45	25.0 W	0.28	0.3	25.0 W
Voltage Gain 270 Frequency Response (-3 dB) 110 Hz - 15 kHz Input Z 30 k Hum and Noise 60 dB below 40 W Music Power 40 W			Voltage Gain 30 Frequency Response (-3 dB) 12 Hz - 25 kHz Input Z 30 k Hum and Noise 80 dB below 40 W Music Power 40 W		

TABLE II.

Material List.

CIRCUIT PART NO.	COMPONENT VALUE	MANUFACTURER	TYPE
Q_1, Q_2, Q_3	SE6002		
Q_4, Q_5, Q_{10}	SE8520		
Q_6	SE2001		
Q_7	2N3641		
Q_8	2N3638		
Q_9	2N2891		
Q_{11}, Q_{12}	SE9040		
D_1, D_2	FD111		
C_1, C_2	25 Hmfd at 3V Electrolytic	Sprague	Te-Lyttic
C_3	27 pF Mica		
C_4	120 pF Mica		
C_5	25 mfd 25V	Sprague	Te-Lyttic
C_8	0.22 mfd 100V	Goodall	Mylar
C_6, C_7	100 µfd 35V Electrolytic	Mallory MTA	100F35
R_1, R_{11}, R_{12}	1 k Ω 1/2 W 5%	Composition	
R_2, R_3, R_8	33 k Ω 1/2 W 5%	Composition	
R_4	5.6 k Ω 1/2 W 5%	Composition	
R_5	470 k Ω 1/2 W 5%	Composition	
R_6	24 k Ω 1/2 W 5%	Composition	
R_7, R_9	1.2 k Ω 1/2 W 5%	Composition	
R_{10}	15 k Ω 1/2 W 5%	Composition	
R_{13}, R_{17}	470 Ω 1/2 W 5%	Composition	
R_{14}	560 Ω 1/2 W 5%	Composition	
R_{16}	360 Ω 1/2 W 5%	Composition	
R_{18}, R_{23}	4.3 k Ω 1/2 W 5%	Composition	
R_{19}, R_{22}, R_{24}, R_{25}	270 Ω 1/2 W 5%	Composition	
R_{20}, R_{21}	100 1/2 W 5%	Composition	
R_{26}, R_{27}	0.47 2W 5%	Wirewound	
R_{28}	15 2W 5%	Composition	
R_{15}	100 Pot 5%	CTS	
Heat Sink	Astro Dynamics 2506	117.2 sq.in.	
Pwr.Xstr.Mtg.	Socket Motorola MK-15	2 each	
Heat Sink	Wakefield Eng. NF207		
POWER SUPPLY			
T_1	40 VCT at 1 A	TRIAD F92A	
C_9, C_{10}	3300 mfd 50 V	Mallory CG332U50k1	
R_{29}, R_{30}	1 k 2 W	Composition	
D_3, D_4, D_5, D_6	1N4002		

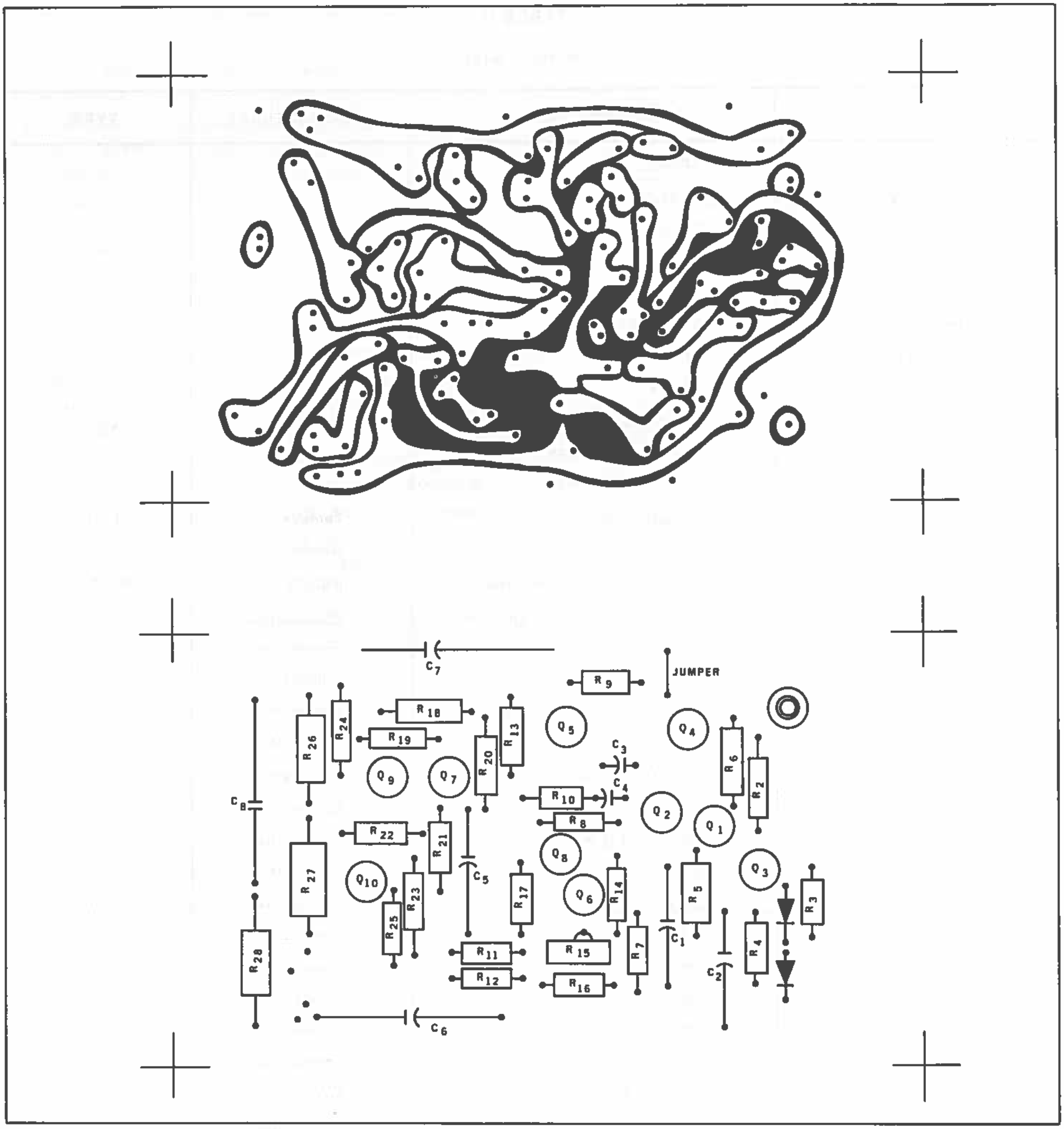

Fig. 2. Component placement diagram.

The amplifier maintains excellent phase and bias stability even with this high overall gain. The bandwidth curve can be extended on the upper end by reducing the value of C_4 from 120 pf to 86 pf.

SUMMARY

The circuit described in this bulletin represents a high performance audio amplifier with the unique feature of electronic protection against any output load condition. Major uses of the circuit would be for high power "Hi-Fi" audio system, where the ultimate in performance and foolproof operation is required.

ACKNOWLEDGEMENTS

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