APPLICATION NOTE

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DELCO RADIO

SEMICONDUCTORS

# 100 WATT AUDIO POWER AMPLIFIER DESIGN

## INTRODUCTION

Delco Radio's DTG-110B, H.K. Nu-Base Power transistor has been introduced to answer the need for a reliable, high voltage, high power audio transistor. This design memorandum demonstrates an exploitation of this capability in practical class AB push-pull output circuits.

## CIRCUIT DESCRIPTION

The circuit shown represents a basic design which will deliver up to 100 watts RMS to an 8 ohm load. It is a practical, functional aproach intended to achieve maximum utilization of a minimum number of circuit components.

The general form of the suggested circuit is that of a 2 stage driver, transformer coupled to a half-bridge push-pull output circuit which is direct coupled to a nominal 8 ohm load. This arrangement was chosen in lieu of the direct coupled quasi-complementary symmetry approach because it allows more design latitude in achieving high sensitivity and high feedback with the fewest number of active components. In addition, it allows for a more thermally stable bias circuit for the output power transistors. The use of the driver transformer presented no limitations on the design because a wide band transformer could be easily fabricated with proper winding techniques on common core material.

**The output circuit** is of the standard half-bridge configuration which drives the load directly from a balanced $\pm$ 50 volt supply. Because of this balanced supply, there is only a negligible d.c. component across the load caused by bias tolerances. This d.c. component and the a.c. ripple accompanying it are easily nulled out by small bias pots as desired. The bias network itself is a stable voltage divider which presents a fixed voltage to the base of each power transistor to allow an idling current determined by the inherent transconductance characteristics of the devices. The modest 0.47 ohm emitter degeneration enhances this stiff voltage bias to provide a thermally stable circuit and offers a small amount of local a.c. feedback. The output circuit of this design uses the transformer secondary resistance as part of the bias network since that resistance can often be held to a tighter tolerance than a separate resistor. This arrangement minimizes the total drive voltage required from the transformer secondary such that the emitter diode of the power transistor is not avalanched too far.

It should be noted that this shunt bias network is practicable only when the output transistors are driven from a low impedance source (as reflected through the transformer) so as to minimize the effects of the shunt negative voltage feedback loop thereby developed, viz., degradation of input impedance and increase in required drive power. Extensive testing has indicated that this voltage drive optimizes the basic linearity of the amplifier throughout the audio bandwidth and extends the frequency response of the output circuit. The low source impedance provides a constant drive voltage to the power devices as their input impedance changes with load and/or frequency. It thus allows a low distortion gain through the exceptionally linear transconductance characteristic.

**The driver section** of this basic amplifier consists of 2 common emitter stages, direct coupled and feedback biased for maximum circuit simplicity and stability. The d.c. feedback bias is derived from the emitter of Q2 and applied back to the input of Q1. The arrangement provides excellent thermal stability and compensates for d.c. parameter variations between the two transistors. About 16 db of negative a.c. feedback is derived from the collector of Q2 to reduce the output impedance of the driver section thereby providing the desired low impedance (voltage) source to drive the output transistors.

The driver transformer is a split primary design using common silicon steel core material. The split primary construction gives a coupling coefficient between primary and secondary which provides flat response in the audio spectrum and rolls off in a frequency range most beneficial to the total gain-phase behavior of the composite amplifier. The magnetization characteristics of the silicon steel allow direct current to be used in the primary without adversely affecting the transformer behavior. This favors maximum driver circuit efficiency. The transformer is constructed with a 1 mil air gap between the E and I member for optimum signal linearity, especially at the high induction levels related to low frequency operation. The 6:1:1 turns ratio was chosen so that a large drive voltage swing from a low current, signal device would drive the DTG-110B's to full output. The 2N3405 was found to be very satisfactory for the requirement.

This particular combination of 2 drivers and 2 output devices provides exceptional sensitivity for the rated output even with the 45 db of total negative feedback used in the design. This was achieved by properly staggering the frequency response characteristics of the silicon planar drivers Q1 and Q2, the driver transformer and the DTG-110B's.

**The power supply** is a basic capacitor filtered design which provides sufficient regulation for full continuous output. A simple feedback regulator provides the desired driver bias supply at very low ripple content for optimum noise and power supply feedback rejection.

## PERFORMANCE

The amplifier delivers up to 100 watts RMS continuous output on an 8 ohm load from an input of 0.1 volt into 10 K. The input may be stepped down by an additional input resistance for a sensitivity of 1.0 volt into 100 K if desired.

An amplifier built from the circuit design shown generated the following performance data: (Similar amplifiers may differ according to parts tolerances but should approach these test figures.)

*Output Power:* 100 watts RMS into 8 ohms.
*Bandwidth:* flat ± 1 db from 20 $H_Z$ to 20 $KH_Z$ at up to full output.
*Total Harmonic Distortion:* less than 0.25% at 1 $KH_Z$ up to full output.
*Intermodulation Distortion:* less than 1.0% at up to full outpct (60 $H_Z$ & 6 $KH_Z$ mixed 4: 1/ IHFM).
*Sensitivity:* 0.1 volt RMS into 10 K or 1.0 volt RMS into 100 K.
*Signal to Noise Ratio:* 80 db below rated output (thermal noise).
*Output Impedance:* less than 0.5 ohm.
*Rise Time:* 10$\mu$Sec to full output.

The principal shortcoming of the amplifier, its harmonic content at high frequencies, is attributed to transit time in the power devices. The quoted figures

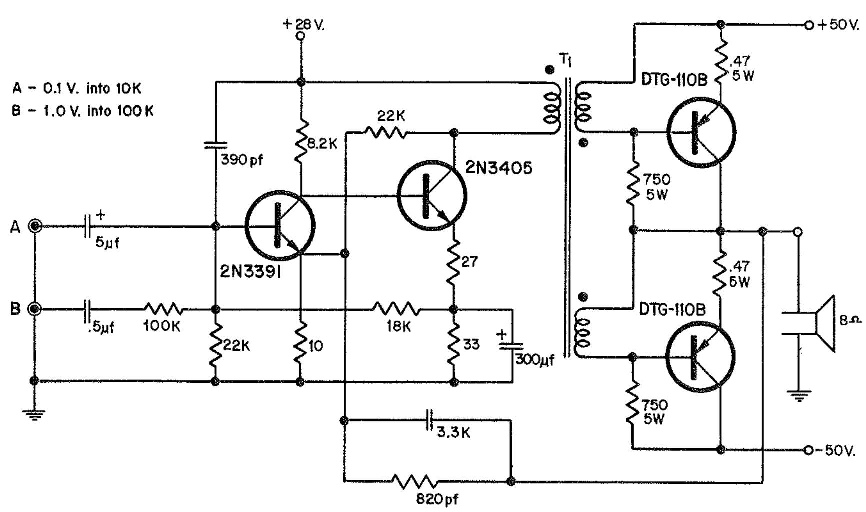



FIGURE 1
AUDIO POWER AMPLIFIER

**T-1 DRIVER TRANSFORMER***

RATINGS
$I_{pri}$ = 50 mA DC
$L_{pri}$ = 4 h at 10 mA DC

SPECIFICATIONS
Core: EI-75, fabricated with laminations of M-19 grade silicon steel. Use 1 mil air gap.
Winding: Design is split primary sandwiching bifilar secondaries.
Details: On nylon bobbin, wind 600 turns of #30 enameled wire. Next, simultaneously wind 2 wires of #27 enameled wire for 200 turns (each). Finally, resume winding the primary for another 600 turns. Bring ends of wire out as desired, observing starts for proper connections as shown in circuit schematic.
Test measurements:
$R_{pri} \simeq$ 45 ohms
$R_{sec} \simeq$ 3.3 ohms
N = 6:1:1

*Triad Transformer Corp. P/N assigned: No. TY-160X.

can be improved with additional drive capability from a low impedance source and trimming the finished response to roll off just beyond the desired bandwidth (e.g., 10 $KH_Z$) so as to attenuate the harmonic response to a desired high frequency signal.

## SUPPLEMENTARY NOTES

For amplifier applications requiring continuous power operation, the output transistors should be mounted individually on Delco type 7281366 or 7281361 heat sinks with a mica washer (for electrical insulation) and silicone oil (e.g., Dow Corning 200). If heat sinks can be caged (to prevent shock hazard), it is preferable to mount the transistors directly to the heat sinks with the same silicone oil, avoiding the thermal resistance of the mica insulator. The Delco type 7269634 insulating spacer will isolate the sinks from a chassis. Reactive loads should be monitored carefully since the phase angle introduced by this load will cause a significant increase in output transistor dissipation.

Because of the high sensitivity of this design, lead dress should be kept as short as possible. Care must be practiced to avoid the generation of ground feedback loops. Printed circuit board construction of the driver is recommended to minimize stray pickup. Individual construction layouts affect the very high frequency (high ultrasonic) behavior of high gain designs such as this and may require adjustments to correct for stray feedback and coupling paths. In particular, the input (390 pf) and feedback (820 pf) trimmer capacitors may have to be changed slightly to allow proper square wave response and open circuit input and/or output stability margins. The values shown are typical and may be used as a starting point for exact adjustment if necessary. The sample amplifier constructed for the curves shown had complete open circuit load and/or input stability and showed excellent square wave response.

The DTG-110B transistors are designed to survive shorted output overload conditions because of their sustaining capability. The overload period for test or other conditions must be limited by proper power supply fusing to prevent ultimate thermal runaway of the power devices during the overload.

The circuit may be scaled directly to lower power levels by changing the raw supply voltages and output transistor bias resistors. The remainder of the circuit—the driver section and driver transformer—may be used as shown.

| RMS Output per Channel | Raw Supply | Bias Resistor |
|---|---|---|
| 100 watts | ± 50 v | 750 ohm, 5 W |
| 75 watts | ± 45 v | 650 ohm, 5 W |
| 50 watts | ± 35 v | 550 ohm, 5 W |
| 35 watts | ± 30 v | 450 ohm, 5 W |

For optimum performance, the Delco DTG-110B's may be selected for use in the 100 watt amplifier circuit. This consists of using devices exhibiting an emitter diode of 3 volts or greater to insure maximum linearity at full output. The gradual avalanching of lesser devices reflects as a non-linear load to the driver and may cause premature wave clipping.

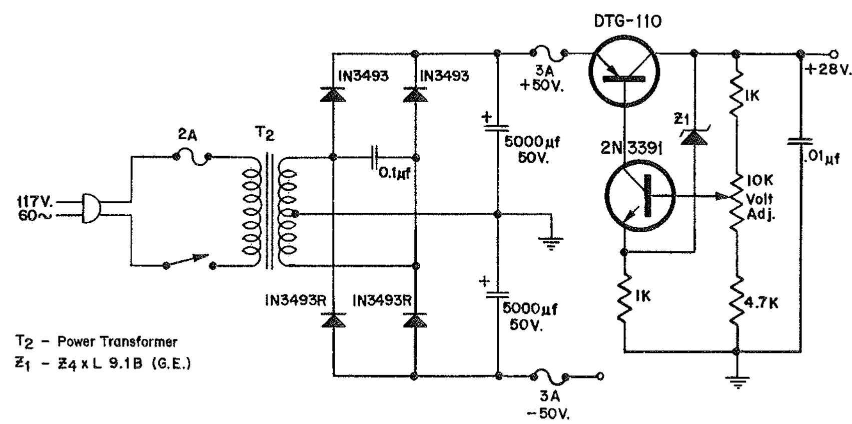



FIGURE 2
POWER SUPPLY

**T-2 POWER TRANSFORMER***

RATINGS

117 v to 70 v c.t.; f = 60 Hz
Secondary load current: 5A rms max.

SPECIFICATIONS

Core: EI-15 (1½"), fabricated with laminations of M-19 grade silicon steel interleaved 2 × 2.
Winding: Standard design on paper layers.
Primary consists of 294 turns of #19 enameled wire.
Secondary consists of 186 turns of #17 enameled wire, tapped halfway.
Test Measurements:
$R_{pri} \approx 1.4$ ohms
$R_{sec} \approx 0.7$ ohms

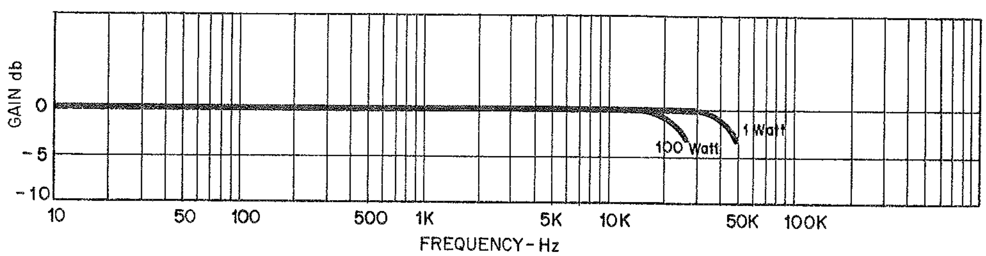
*Triad Transformer Corp. P/N assigned: No. R-82B

The semiconductor applications and circuits shown or described herein are furnished without prejudice to any patent rights of General Motors Corporation and no responsibility is assumed for any infringement of rights of others which may result from the use of this information.

## SEMICONDUCTORS

# 100 WATT AUDIO AMPLIFIER
# BASIC PERFORMANCE CHARACTERISTICS

FREQUENCY RESPONSE




TOTAL HARMONIC DISTORTION

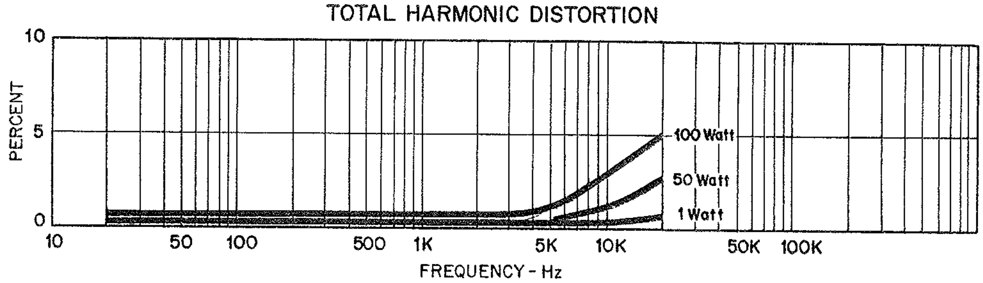
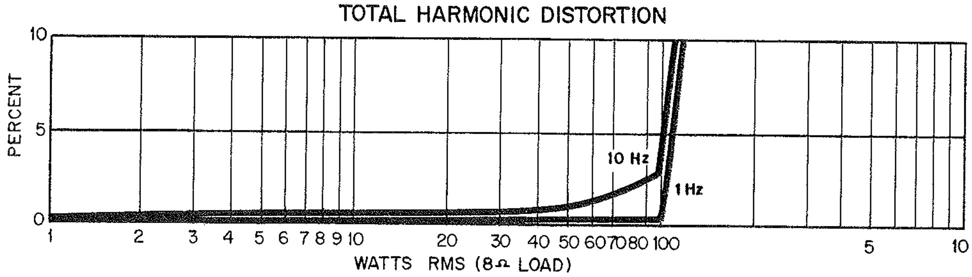



FIGURE 3

# 100 WATT AUDIO AMPLIFIER
# LINEARITY AND CLIPPING CHARACTERISTICS

TOTAL HARMONIC DISTORTION




INTERMODULATION DISTORTION
(60 Hz & 6 KHz Mixed 4:1 - 1 HFM)

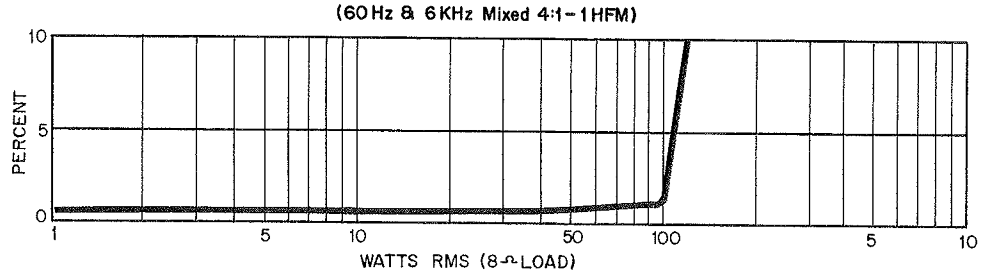



FIGURE 4