



# Stereo 3W Audio Power Amplifiers with Headphone Drive and Input Mux

## General Description

The MAX9777/MAX9778 combine a stereo 3W bridged-load (BTL) audio power amplifier, stereo single-ended (SE) headphone amplifier, headphone sensing, and a 2:1 input multiplexer all in a tiny 28-pin thin QFN package. These devices operate from a single 4.5V to 5.5V supply and feature an industry-leading 100dB PSRR, allowing these devices to operate from noisy supplies without the addition of a linear regulator. An ultra-low 0.002% THD+N ensures clean, low-distortion amplification of the audio signal. Click-and-pop suppression minimizes audible transients on power and shutdown cycles. Power-saving features include low 4mV  $V_{OS}$  (minimizes DC current drain through the speakers), low 13mA supply current, and a 10 $\mu$ A shutdown mode. A MUTE function allows the outputs to be quickly enabled or disabled.

A headphone sense input detects the presence of a headphone jack and automatically configures the amplifiers for either speaker or headphone mode. In speaker mode, the amplifiers can deliver up to 3W of continuous average power into a 3 $\Omega$  load. In headphone mode, the amplifier can deliver up to 200mW of continuous average power into a 16 $\Omega$  load. The gain of the amplifiers is externally set, allowing maximum flexibility in optimizing output levels for a given load. The amplifiers also feature a 2:1 input multiplexer, allowing multiple audio sources to be selected. The multiplexer can also be used to compensate for limitations in the frequency response of the loud speakers by selecting an external equalizer network. The various functions are controlled by either an I<sup>2</sup>C-compatible (MAX9777) or simple parallel control interface (MAX9778).

The MAX9777/MAX9778 are available in a thermally efficient 28-pin thin QFN package (5mm x 5mm x 0.8mm). These devices have thermal-overload protection (OVP) and are specified over the extended -40°C to +85°C temperature range.

## Applications

|                      |                      |
|----------------------|----------------------|
| Notebooks            | PC Audio Peripherals |
| Portable DVD Players | Camcorders           |
| Tablet PCs           | Multimedia Monitor   |

## Features

- ◆ Industry-Leading, Ultra-High 100dB PSRR
- ◆ 3W BTL Stereo Speaker Amplifier
- ◆ 200mW Stereo Headphone Amplifier
- ◆ Low 0.002% THD+N
- ◆ Click-and-Pop Suppression
- ◆ ESD-Protected Outputs
- ◆ Low Quiescent Current: 13mA
- ◆ Low-Power Shutdown Mode: 10 $\mu$ A
- ◆ MUTE Function
- ◆ Headphone Sense Input
- ◆ Stereo 2:1 Input Multiplexer
- ◆ Optional 2-Wire, I<sup>2</sup>C-Compatible or Parallel Interface
- ◆ Tiny 28-Pin Thin QFN (5mm x 5mm x 0.8mm) Package

## Ordering Information

| PART        | CONTROL INTERFACE           | PIN-PACKAGE     | PKG CODE |
|-------------|-----------------------------|-----------------|----------|
| MAX9777ETI+ | I <sup>2</sup> C Compatible | 28 Thin QFN-EP* | T2855-6  |
| MAX9778ETI+ | Parallel                    | 28 Thin QFN-EP* | T2855-6  |

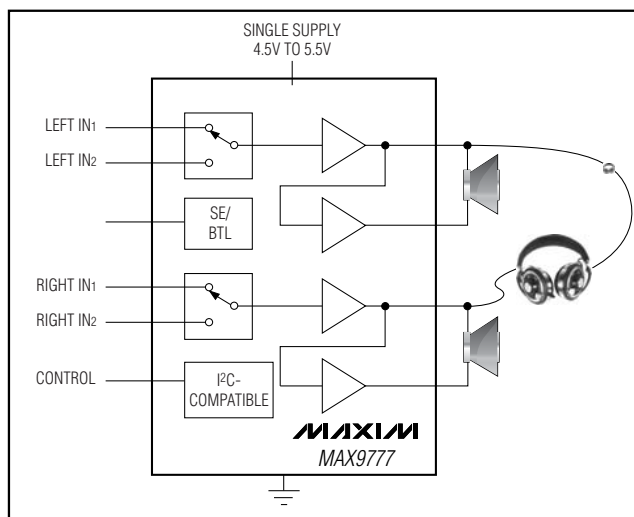
Note: All devices are specified over the -40°C to +85°C operating temperature range.

+Denotes lead-free package.

\*EP = Exposed paddle.

Pin Configurations and Functional Diagrams appear at end of data sheet.

## Simplified Block Diagram



# Stereo 3W Audio Power Amplifiers with Headphone Drive and Input Mux

## ABSOLUTE MAXIMUM RATINGS

V<sub>DD</sub> to GND .....+6V  
 PV<sub>DD</sub> to V<sub>DD</sub> .....±0.3V  
 PGND to GND .....±0.3V  
 All Other Pins to GND .....-0.3V to (V<sub>DD</sub> + 0.3V)  
 Continuous Input Current (into any pin except power-supply and output pins) .....±20mA  
 OUT\_ Short Circuit to GND, V<sub>DD</sub> .....10s  
 Short Circuit Between OUT\_+ and OUT\_- .....Continuous

Continuous Power Dissipation (T<sub>A</sub> = +70°C)  
 28-Pin TQFN, Multilayer Board  
 (derate 34.5mW/°C above +70°C) .....2758.6mW  
 Operating Temperature Range .....-40°C to +85°C  
 Storage Temperature Range .....-65°C to +150°C  
 Junction Temperature .....+150°C  
 Lead Temperature (soldering, 10s) .....+300°C

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## ELECTRICAL CHARACTERISTICS

(V<sub>DD</sub> = PV<sub>DD</sub> = 5.0V, GND = PGND = 0V, V<sub>SHDN</sub> = 5V, C<sub>BIAS</sub> = 1μF, R<sub>IN</sub> = R<sub>F</sub> = 15kΩ, R<sub>L</sub> = ∞. T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>, unless otherwise noted. Typical values are at T<sub>A</sub> = +25°C.) (Note 1)

| PARAMETER                                                        | SYMBOL                            | CONDITIONS                                                                             | MIN | TYP   | MAX | UNITS |
|------------------------------------------------------------------|-----------------------------------|----------------------------------------------------------------------------------------|-----|-------|-----|-------|
| Supply Voltage Range                                             | V <sub>DD</sub> /PV <sub>DD</sub> | Inferred from PSRR test                                                                | 4.5 |       | 5.5 | V     |
| Quiescent Supply Current (I <sub>VDD</sub> + I <sub>PVDD</sub> ) | I <sub>DD</sub>                   | BTL mode, HPS = 0V, MAX9777/MAX9778                                                    |     | 13    | 32  | mA    |
|                                                                  |                                   | Single-ended mode, HPS = V <sub>DD</sub>                                               |     | 7     | 18  |       |
| Shutdown Current                                                 | I <sub>SHDN</sub>                 | SHDN = GND                                                                             |     | 10    | 50  | μA    |
| Switching Time                                                   | t <sub>SW</sub>                   | Gain or input switching                                                                |     | 10    |     | μs    |
| Turn-On Time                                                     | t <sub>ON</sub>                   | C <sub>BIAS</sub> = 1μF                                                                |     | 300   |     | ms    |
|                                                                  |                                   | C <sub>BIAS</sub> = 0.1μF                                                              |     | 30    |     |       |
| Thermal Shutdown Threshold                                       |                                   |                                                                                        |     | +160  |     | °C    |
| Thermal Shutdown Hysteresis                                      |                                   |                                                                                        |     | 15    |     | °C    |
| <b>OUTPUT AMPLIFIERS (SPEAKER MODE, HPS = GND)</b>               |                                   |                                                                                        |     |       |     |       |
| Output Offset Voltage                                            | V <sub>OS</sub>                   | OUT_+ - OUT_-, A <sub>V</sub> = 1V/V                                                   |     | ±4    | ±32 | mV    |
| Power-Supply Rejection Ratio (Note 2)                            | PSRR                              | V <sub>DD</sub> = 4.5V to 5.5V                                                         | 75  | 100   |     | dB    |
|                                                                  |                                   | f = 1kHz, V <sub>RIPPLE</sub> = 200mV <sub>P-P</sub>                                   |     | 82    |     |       |
|                                                                  |                                   | f = 20kHz, V <sub>RIPPLE</sub> = 200mV <sub>P-P</sub>                                  |     | 70    |     |       |
| Output Power                                                     | P <sub>OUT</sub>                  | f <sub>IN</sub> = 1kHz, THD+N < 1%, T <sub>A</sub> = +25°C, R <sub>L</sub> = 8Ω        |     | 1.4   |     | W     |
|                                                                  |                                   | R <sub>L</sub> = 4Ω                                                                    |     | 2.6   |     |       |
|                                                                  |                                   | R <sub>L</sub> = 3Ω                                                                    |     | 3     |     |       |
| Total Harmonic Distortion Plus Noise                             | THD+N                             | f <sub>IN</sub> = 1kHz, BW = 22Hz to 22kHz, P <sub>OUT</sub> = 1W, R <sub>L</sub> = 8Ω |     | 0.005 |     | %     |
|                                                                  |                                   | P <sub>OUT</sub> = 2W, R <sub>L</sub> = 4Ω                                             |     | 0.01  |     |       |
| Signal-to-Noise Ratio                                            | SNR                               | R <sub>L</sub> = 8Ω, P <sub>OUT</sub> = 1W, BW = 22Hz to 22kHz                         |     | 95    |     | dB    |
| Slew Rate                                                        | SR                                |                                                                                        |     | 1.6   |     | V/μs  |
| Maximum Capacitive Load Drive                                    | C <sub>L</sub>                    | No sustained oscillations                                                              |     | 1     |     | nF    |
| Crosstalk                                                        |                                   | f <sub>IN</sub> = 10kHz                                                                |     | 73    |     | dB    |
| Click/Pop Level                                                  | K <sub>CP</sub>                   | Peak voltage, A-weighted, 32 samples per second (Notes 2, 6), Into shutdown            |     | -50   |     | dBV   |
|                                                                  |                                   | Out of shutdown                                                                        |     | -65   |     |       |

# Stereo 3W Audio Power Amplifiers with Headphone Drive and Input Mux

MAX9777/MAX9778

## ELECTRICAL CHARACTERISTICS (continued)

( $V_{DD} = PV_{DD} = 5.0V$ ,  $GND = PGND = 0V$ ,  $V_{SHDN} = 5V$ ,  $C_{BIAS} = 1\mu F$ ,  $R_{IN} = R_F = 15k\Omega$ ,  $R_L = \infty$ .  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ C$ .) (Note 1)

| PARAMETER                                                                          | SYMBOL     | CONDITIONS                                                       | MIN                                  | TYP                 | MAX     | UNITS     |
|------------------------------------------------------------------------------------|------------|------------------------------------------------------------------|--------------------------------------|---------------------|---------|-----------|
| <b>OUTPUT AMPLIFIERS (HEADPHONE MODE, HPS = <math>V_{DD}</math>)</b>               |            |                                                                  |                                      |                     |         |           |
| Power-Supply Rejection Ratio (Note 2)                                              | PSRR       | $V_{DD} = 4.5V$ to $5.5V$                                        | 75                                   | 106                 |         | dB        |
|                                                                                    |            | $f = 1kHz$ , $V_{RIPPLE} = 200mV_{P-P}$                          |                                      | 88                  |         |           |
|                                                                                    |            | $f = 20kHz$ , $V_{RIPPLE} = 200mV_{P-P}$                         |                                      | 76                  |         |           |
| Output Power                                                                       | $P_{OUT}$  | $f_{IN} = 1kHz$ , $THD+N < 1\%$ , $T_A = +25^\circ C$            | $R_L = 32\Omega$                     | 88                  |         | mW        |
|                                                                                    |            |                                                                  | $R_L = 16\Omega$                     | 200                 |         |           |
| Total Harmonic Distortion Plus Noise                                               | THD+N      | $f_{IN} = 1kHz$ , $BW = 22Hz$ to $22kHz$                         | $P_{OUT} = 60mW$ , $R_L = 32\Omega$  | 0.002               |         | %         |
|                                                                                    |            |                                                                  | $P_{OUT} = 125mW$ , $R_L = 16\Omega$ | 0.002               |         |           |
| Signal-to-Noise Ratio                                                              | SNR        | $R_L = 32\Omega$ , $BW = 22Hz$ to $22kHz$ , $V_{OUT} = 1V_{RMS}$ |                                      | 92                  |         | dB        |
| Slew Rate                                                                          | SR         |                                                                  |                                      | 1.8                 |         | $V/\mu s$ |
| Maximum Capacitive Load Drive                                                      | $C_L$      | No sustained oscillations                                        |                                      | 2                   |         | nF        |
| Crosstalk                                                                          |            | $f_{IN} = 10kHz$                                                 |                                      | 78                  |         | dB        |
| <b>BIAS VOLTAGE (BIAS)</b>                                                         |            |                                                                  |                                      |                     |         |           |
| BIAS Voltage                                                                       | $V_{BIAS}$ |                                                                  | 2.35                                 | 2.5                 | 2.65    | V         |
| Output Resistance                                                                  | $R_{BIAS}$ |                                                                  |                                      | 50                  |         | $k\Omega$ |
| <b>DIGITAL INPUTS (MUTE, <math>\overline{SHDN}</math>, HPS_EN, GAINA/B, IN1/2)</b> |            |                                                                  |                                      |                     |         |           |
| Input-Voltage High                                                                 | $V_{IH}$   |                                                                  | 2                                    |                     |         | V         |
| Input-Voltage Low                                                                  | $V_{IL}$   |                                                                  |                                      |                     | 0.8     | V         |
| Input Leakage Current                                                              | $I_{IN}$   |                                                                  |                                      |                     | $\pm 1$ | $\mu A$   |
| <b>HEADPHONE SENSE INPUT (HPS)</b>                                                 |            |                                                                  |                                      |                     |         |           |
| Input-Voltage High                                                                 | $V_{IH}$   |                                                                  | $0.9 \times V_{DD}$                  |                     |         | V         |
| Input-Voltage Low                                                                  | $V_{IL}$   |                                                                  |                                      | $0.7 \times V_{DD}$ |         | V         |
| Input Leakage Current                                                              | $I_{IN}$   |                                                                  |                                      | $\pm 1$             |         | $\mu A$   |
| Click/Pop Level                                                                    | $K_{CP}$   | Peak voltage, A-weighted, 32 samples per second (Notes 2, 4)     | Into shutdown                        | -70                 |         | dBV       |
|                                                                                    |            |                                                                  | Out of shutdown                      | -52                 |         |           |

# Stereo 3W Audio Power Amplifiers with Headphone Drive and Input Mux

## ELECTRICAL CHARACTERISTICS (continued)

( $V_{DD} = PV_{DD} = 5.0V$ ,  $GND = PGND = 0V$ ,  $V_{SHDN} = 5V$ ,  $C_{BIAS} = 1\mu F$ ,  $R_{IN} = R_F = 15k\Omega$ ,  $R_L = \infty$ .  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ C$ .) (Note 1)

| PARAMETER                                                     | SYMBOL       | CONDITIONS     | MIN           | TYP | MAX     | UNITS   |
|---------------------------------------------------------------|--------------|----------------|---------------|-----|---------|---------|
| <b>2-WIRE SERIAL INTERFACE (SCL, SDA, ADD, INT) (MAX9777)</b> |              |                |               |     |         |         |
| Input-Voltage High                                            | $V_{IH}$     |                | 2.6           |     |         | V       |
| Input-Voltage Low                                             | $V_{IL}$     |                |               |     | 0.8     | V       |
| Input Hysteresis                                              |              |                |               | 0.2 |         | V       |
| Input High Leakage Current                                    | $I_{IH}$     | $V_{IN} = 5V$  |               |     | $\pm 1$ | $\mu A$ |
| Input Low Leakage Current                                     | $I_{IL}$     | $V_{IN} = 0V$  |               |     | $\pm 1$ | $\mu A$ |
| Input Capacitance                                             | $C_{IN}$     |                |               | 10  |         | pF      |
| Output-Voltage Low                                            | $V_{OL}$     | $I_{OL} = 3mA$ |               |     | 0.4     | V       |
| Output Current High                                           | $I_{OH}$     | $V_{OH} = 5V$  |               |     | 1       | $\mu A$ |
| <b>TIMING CHARACTERISTICS (MAX9777)</b>                       |              |                |               |     |         |         |
| Serial Clock Frequency                                        | $f_{SCL}$    |                |               |     | 400     | kHz     |
| Bus Free Time Between STOP and START Conditions               | $t_{BUF}$    |                | 1.3           |     |         | $\mu s$ |
| START Condition Hold Time                                     | $t_{HD:STA}$ |                | 0.6           |     |         | $\mu s$ |
| START Condition Setup Time                                    | $t_{SU:STA}$ |                | 0.6           |     |         | $\mu s$ |
| Clock Period Low                                              | $t_{LOW}$    |                | 1.3           |     |         | $\mu s$ |
| Clock Period High                                             | $t_{HIGH}$   |                | 0.6           |     |         | $\mu s$ |
| Data Setup Time                                               | $t_{SU:DAT}$ |                | 100           |     |         | ns      |
| Data Hold Time                                                | $t_{HD:DAT}$ | (Note 3)       | 0             |     | 0.9     | $\mu s$ |
| Receive SCL/SDA Rise Time                                     | $t_r$        | (Note 4)       | 20 + $0.1C_B$ |     | 300     | ns      |
| Receive SCL/SDA Fall Time                                     | $t_f$        | (Note 4)       | 20 + $0.1C_B$ |     | 300     | ns      |
| Transmit SDA Fall Time                                        | $t_f$        | (Note 4)       | 20 + $0.1C_B$ |     | 250     | ns      |
| Pulse Width of Suppressed Spike                               | $t_{SP}$     | (Note 5)       |               | 50  |         | ns      |

**Note 1:** All devices are 100% production tested at  $+25^\circ C$ . All temperature limits are guaranteed by design.

**Note 2:** Inputs AC-coupled to GND.

**Note 3:** A master device must provide a hold time of at least 300ns for the SDA signal to bridge the undefined region of SCL's falling edge.

**Note 4:**  $C_B$  = total capacitance of one of the bus lines in picofarads. Device tested with  $C_B = 400pF$ .  $1k\Omega$  pullup resistors connected from SDA/SCL to  $V_{DD}$ .

**Note 5:** Input filters on SDA, SCL, and ADD suppress noise spikes of less than 50ns.

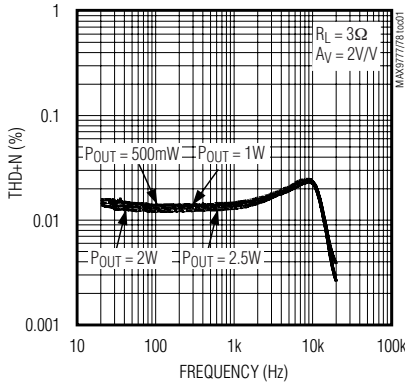
**Note 6:** Headphone mode testing performed with  $32\Omega$  resistive load connected to GND. Speaker mode testing performed with  $8\Omega$  resistive load connected to GND. Mode transitions are controlled by  $\overline{SHDN}$ . KCP level is calculated as  $20\log[(\text{peak voltage during mode transition, no input signal})/1V_{RMS}]$ . Units are expressed in dBV.

# Stereo 3W Audio Power Amplifiers with Headphone Drive and Input Mux

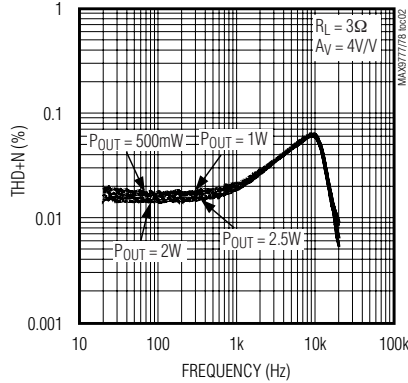
## Typical Operating Characteristics

( $V_{DD} = PV_{DD} = 5V$ ,  $GND = PGND = 0V$ ,  $V_{SHDN} = 5V$ ,  $C_{BIAS} = 1\mu F$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

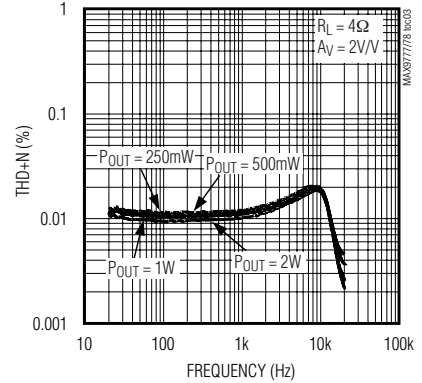
**TOTAL HARMONIC DISTORTION PLUS NOISE vs. FREQUENCY (SPEAKER MODE)**



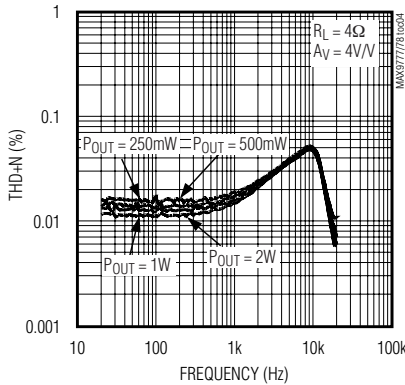
**TOTAL HARMONIC DISTORTION PLUS NOISE vs. FREQUENCY (SPEAKER MODE)**



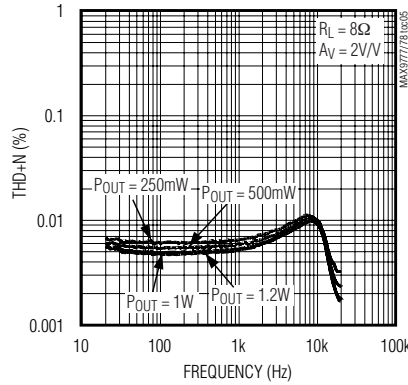
**TOTAL HARMONIC DISTORTION PLUS NOISE vs. FREQUENCY (SPEAKER MODE)**



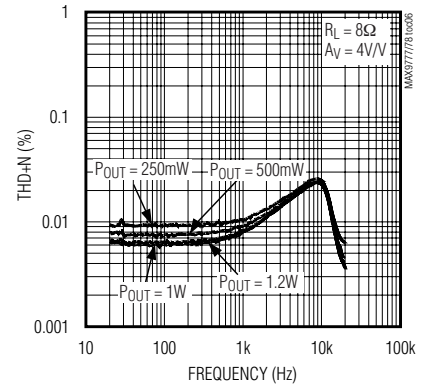
**TOTAL HARMONIC DISTORTION PLUS NOISE vs. FREQUENCY (SPEAKER MODE)**



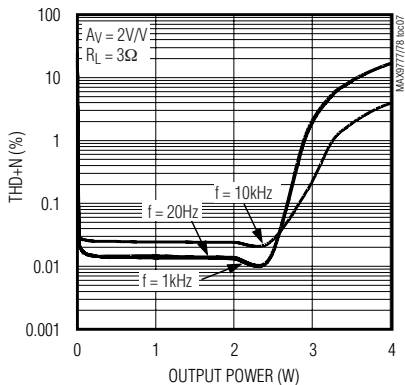
**TOTAL HARMONIC DISTORTION PLUS NOISE vs. FREQUENCY (SPEAKER MODE)**



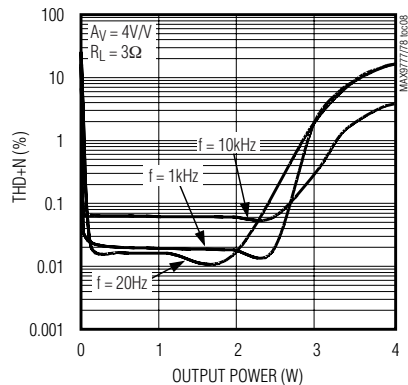
**TOTAL HARMONIC DISTORTION PLUS NOISE vs. FREQUENCY (SPEAKER MODE)**



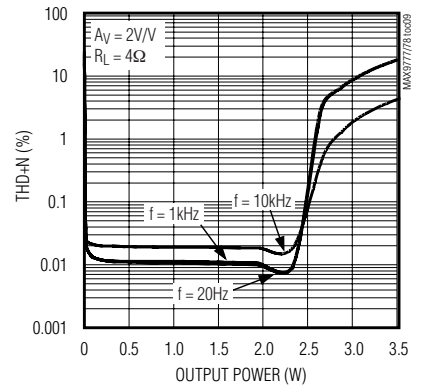
**TOTAL HARMONIC DISTORTION PLUS NOISE vs. OUTPUT POWER (SPEAKER MODE)**



**TOTAL HARMONIC DISTORTION PLUS NOISE vs. OUTPUT POWER (SPEAKER MODE)**



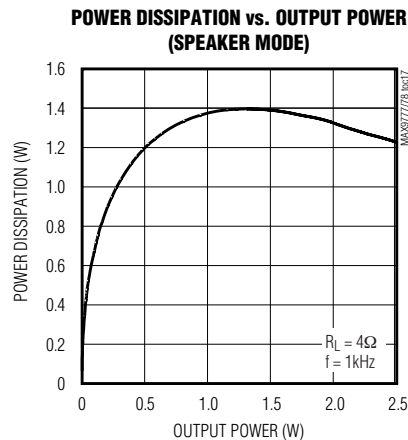
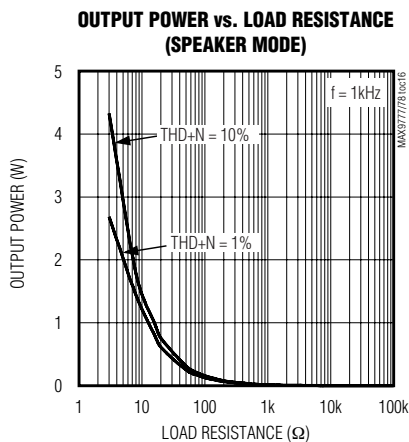
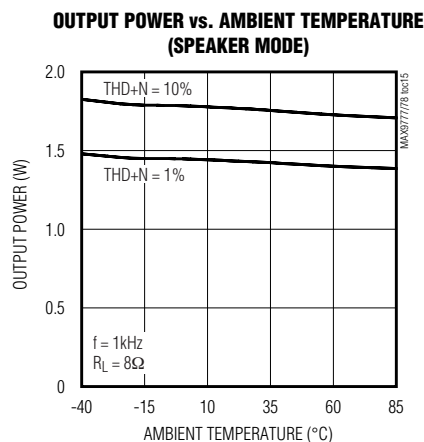
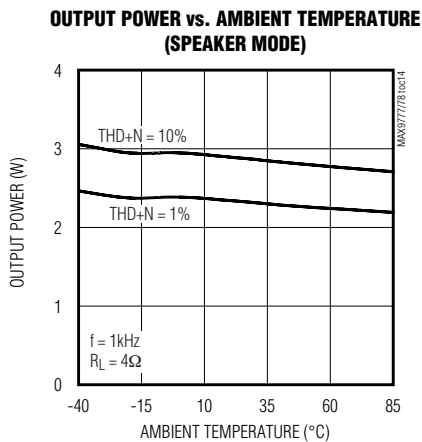
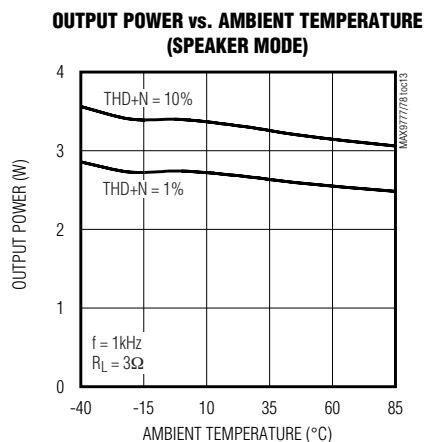
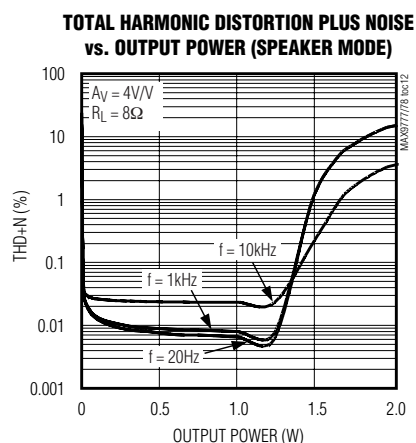
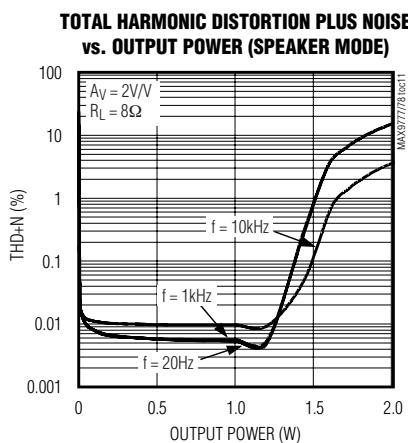
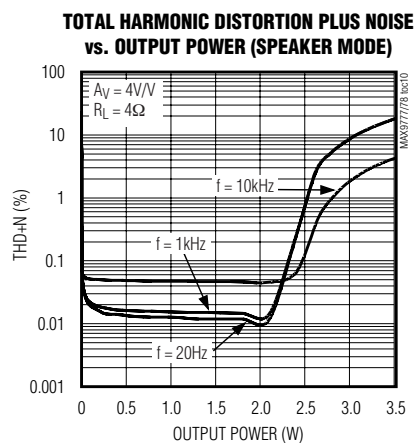
**TOTAL HARMONIC DISTORTION PLUS NOISE vs. OUTPUT POWER (SPEAKER MODE)**



# Stereo 3W Audio Power Amplifiers with Headphone Drive and Input Mux

## Typical Operating Characteristics (continued)

( $V_{DD} = PV_{DD} = 5V$ ,  $GND = PGND = 0V$ ,  $V_{SHDN} = 5V$ ,  $C_{BIAS} = 1\mu F$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

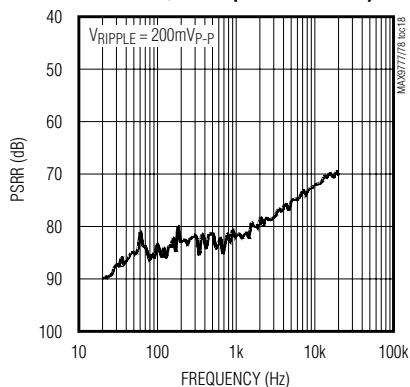


# Stereo 3W Audio Power Amplifiers with Headphone Drive and Input Mux

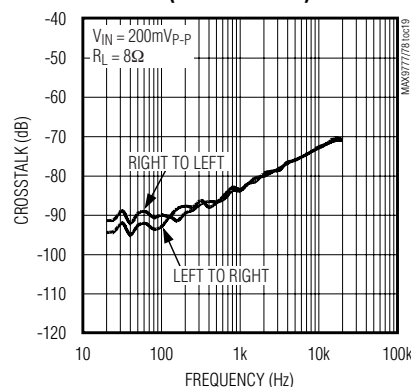
## Typical Operating Characteristics (continued)

( $V_{DD} = PV_{DD} = 5V$ ,  $GND = PGND = 0V$ ,  $V_{SHDN} = 5V$ ,  $C_{BIAS} = 1\mu F$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

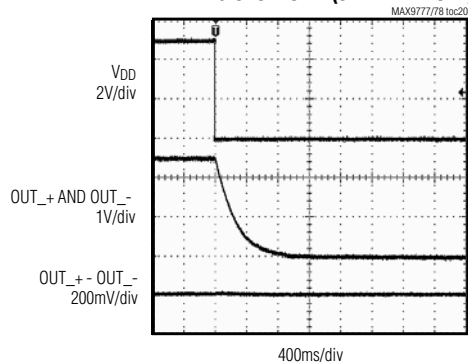
**POWER-SUPPLY REJECTION RATIO  
vs. FREQUENCY (SPEAKER MODE)**



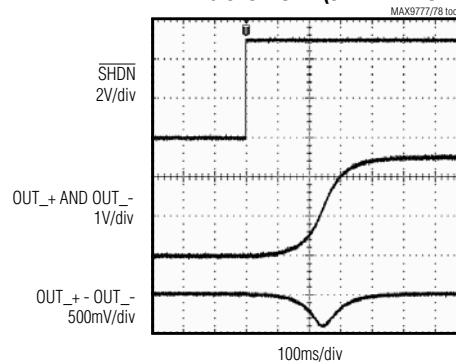
**CROSSTALK vs. FREQUENCY  
(SPEAKER MODE)**



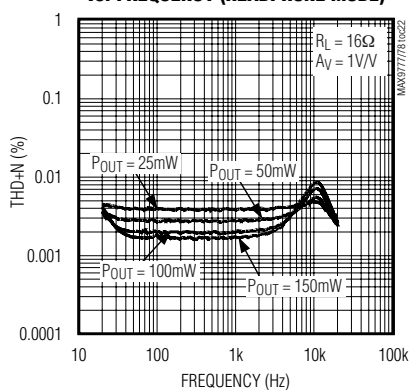
**ENTERING SHUTDOWN (SPEAKER MODE)**



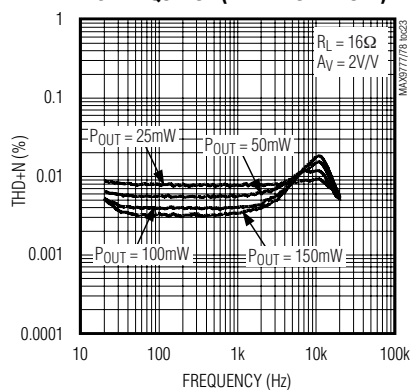
**EXITING SHUTDOWN (SPEAKER MODE)**



**TOTAL HARMONIC DISTORTION PLUS NOISE  
vs. FREQUENCY (HEADPHONE MODE)**



**TOTAL HARMONIC DISTORTION PLUS NOISE  
vs. FREQUENCY (HEADPHONE MODE)**

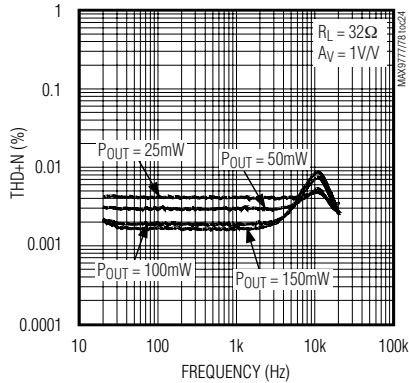


# Stereo 3W Audio Power Amplifiers with Headphone Drive and Input Mux

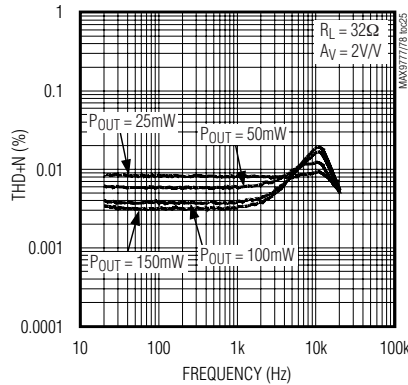
## Typical Operating Characteristics (continued)

( $V_{DD} = PV_{DD} = 5V$ ,  $GND = PGND = 0V$ ,  $V_{SHDN} = 5V$ ,  $C_{BIAS} = 1\mu F$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

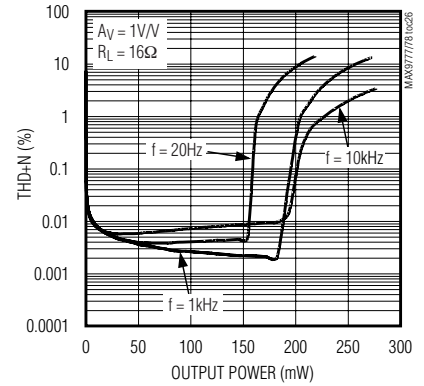
**TOTAL HARMONIC DISTORTION PLUS NOISE vs. FREQUENCY (HEADPHONE MODE)**



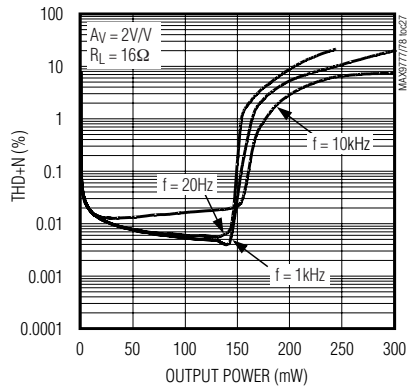
**TOTAL HARMONIC DISTORTION PLUS NOISE vs. FREQUENCY (HEADPHONE MODE)**



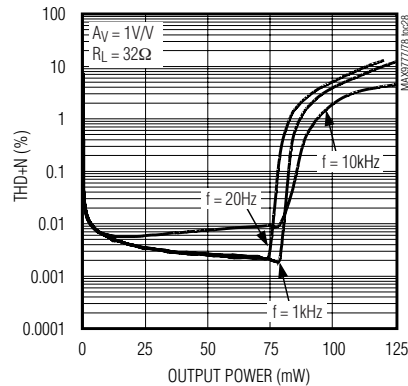
**TOTAL HARMONIC DISTORTION PLUS NOISE vs. OUTPUT POWER (HEADPHONE MODE)**



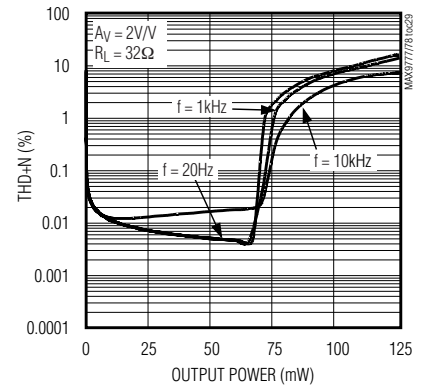
**TOTAL HARMONIC DISTORTION PLUS NOISE vs. OUTPUT POWER (HEADPHONE MODE)**



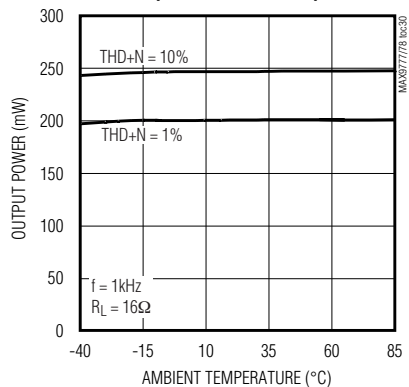
**TOTAL HARMONIC DISTORTION PLUS NOISE vs. OUTPUT POWER (HEADPHONE MODE)**



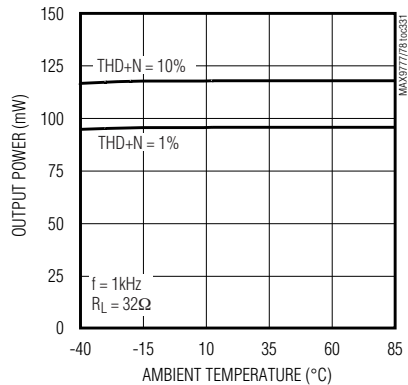
**TOTAL HARMONIC DISTORTION PLUS NOISE vs. OUTPUT POWER (HEADPHONE MODE)**



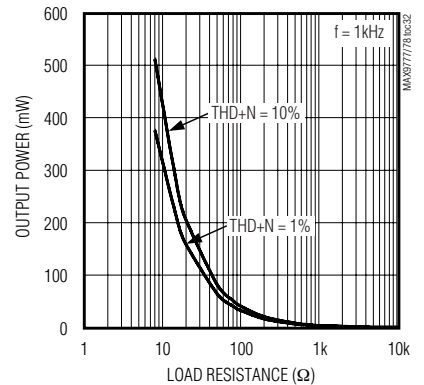
**OUTPUT POWER vs. AMBIENT TEMPERATURE (HEADPHONE MODE)**



**OUTPUT POWER vs. AMBIENT TEMPERATURE (HEADPHONE MODE)**



**OUTPUT POWER vs. LOAD RESISTANCE (HEADPHONE MODE)**

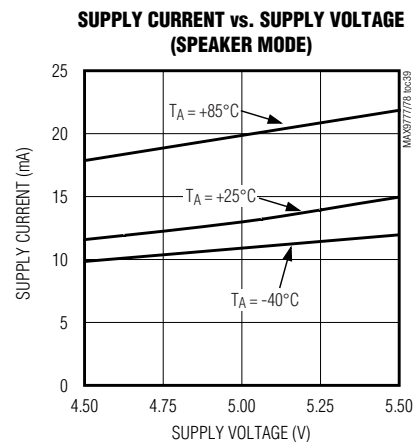
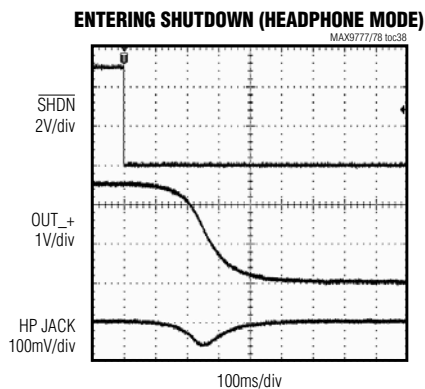
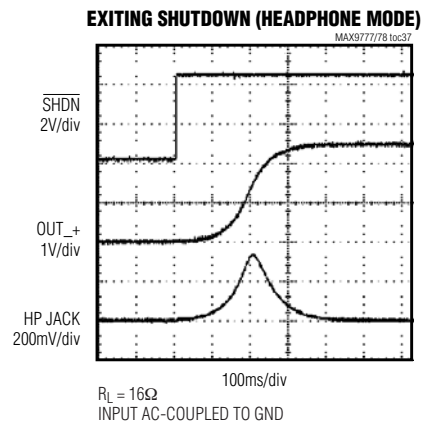
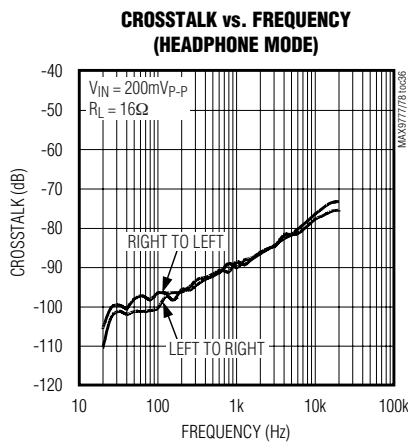
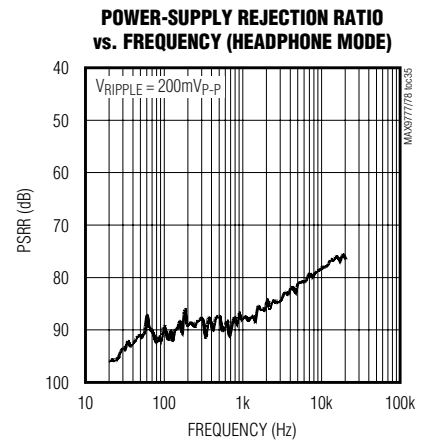
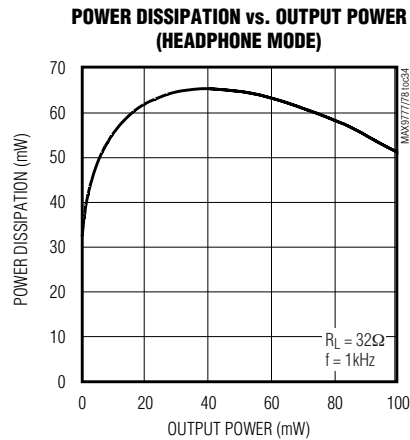
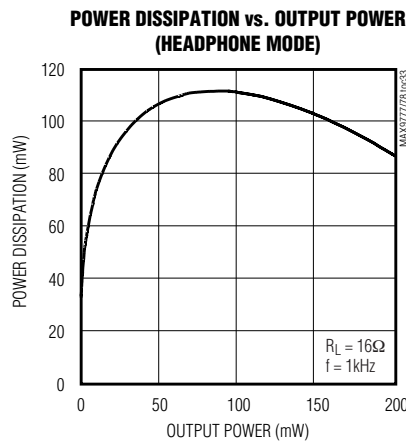




# Stereo 3W Audio Power Amplifiers with Headphone Drive and Input Mux

## Typical Operating Characteristics (continued)

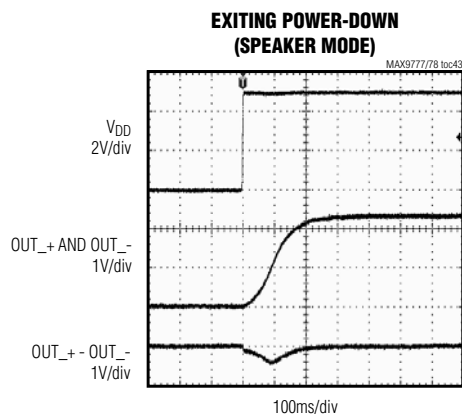
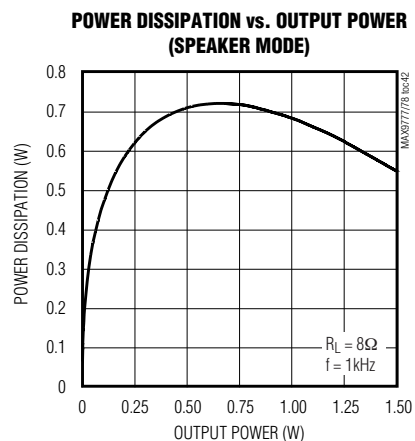
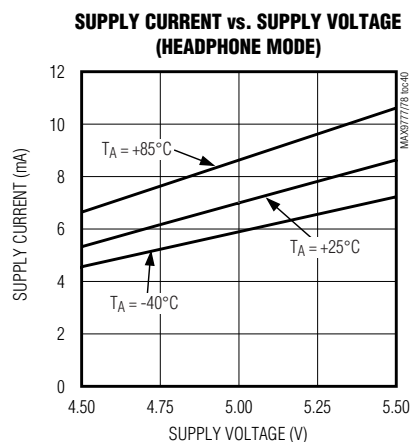
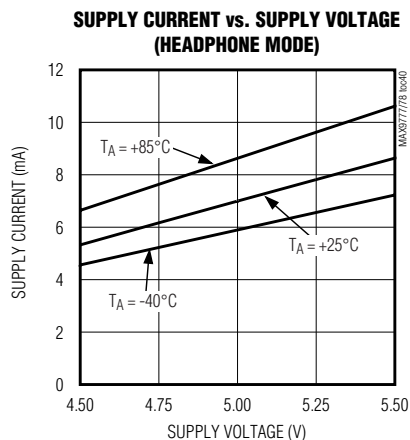
( $V_{DD} = PV_{DD} = 5V$ ,  $GND = PGND = 0V$ ,  $V_{SHDN} = 5V$ ,  $C_{BIAS} = 1\mu F$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



# Stereo 3W Audio Power Amplifiers with Headphone Drive and Input Mux

## Typical Operating Characteristics (continued)

( $V_{DD} = PV_{DD} = 5V$ ,  $GND = PGND = 0V$ ,  $V_{SHDN} = 5V$ ,  $C_{BIAS} = 1\mu F$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



# Stereo 3W Audio Power Amplifiers with Headphone Drive and Input Mux

## Pin Description

| PIN           |               | NAME                          | FUNCTION                                                                                                                                           |
|---------------|---------------|-------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|
| MAX9777       | MAX9778       |                               |                                                                                                                                                    |
| 1             | —             | SDA                           | Serial Data I/O                                                                                                                                    |
| 2             | —             | $\overline{\text{INT}}$       | Interrupt Output                                                                                                                                   |
| 3, 4          | 3, 4          | V <sub>DD</sub>               | Power-Supply Input                                                                                                                                 |
| 5             | 5             | INL1                          | Left-Channel Input 1                                                                                                                               |
| 6             | 6             | INL2                          | Left-Channel Input 2                                                                                                                               |
| 7             | 7             | GAINLA                        | Left-Channel Gain Set A                                                                                                                            |
| 8             | 8             | GAINLB                        | Left-Channel Gain Set B                                                                                                                            |
| 9, 13, 23, 27 | 9, 13, 23, 27 | PGND                          | Power Ground. Connect to GND.                                                                                                                      |
| 10            | 10            | OUTL+                         | Left-Channel Bridged Amplifier Positive Output. OUTL+ also serves as the left-channel headphone amplifier output.                                  |
| 11, 25        | 11, 25        | PV <sub>DD</sub>              | Output Amplifier Power Supply                                                                                                                      |
| 12            | 12            | OUTL-                         | Left-Channel Bridged Amplifier Negative Output                                                                                                     |
| 14            | 14            | $\overline{\text{SHDN}}$      | Active-Low Shutdown Input. Connect $\overline{\text{SHDN}}$ to V <sub>DD</sub> for normal operation.                                               |
| 15            | —             | ADD                           | Address Select. A logic-high sets the address LSB to 1, a logic-low sets the address LSB to zero.                                                  |
| 16            | 16            | HPS                           | Headphone Sense Input. A logic-high configures the device as a single-ended headphone amp. A logic-low configures the device as a BTL speaker amp. |
| 17            | 17            | BIAS                          | DC Bias Bypass Terminal. See the <i>BIAS Capacitor</i> section for capacitor selection. Connect C <sub>BIAS</sub> from BIAS to GND.                |
| 18            | 18            | GND                           | Ground. Connect to PGND.                                                                                                                           |
| 19            | 19            | INR1                          | Right-Channel Input 1                                                                                                                              |
| 20            | 20            | INR2                          | Right-Channel Input 2                                                                                                                              |
| 21            | 21            | GAINRA                        | Right-Channel Gain Set A                                                                                                                           |
| 22            | 22            | GAINRB                        | Right-Channel Gain Set B                                                                                                                           |
| 24            | 24            | OUTR+                         | Right-Channel Bridged Amplifier Positive Output. OUTR+ also serves as the right-channel headphone amplifier output.                                |
| 26            | 26            | OUTR-                         | Right-Channel Bridged Amplifier Negative Output                                                                                                    |
| 28            | —             | SCL                           | Serial Clock Line                                                                                                                                  |
| —             | 1             | MUTE                          | Active-High Mute Input                                                                                                                             |
| —             | 2             | HPS_EN                        | Headphone Enable. A logic-high enables HPS. A logic-low disables HPS and the device is always configured as a BTL speaker amplifier.               |
| —             | 15            | GAIN $\overline{\text{A}}$ /B | Gain Select. A logic-low selects the gain set by GAIN_A. A logic-high selects the gain set by GAIN_B.                                              |
| —             | 28            | IN $\overline{\text{T}}$ /2   | Input Select. A logic-low selects amplifier input 1. A logic-high selects amplifier input 2.                                                       |
| EP            | EP            | EP                            | Exposed Paddle. Connect to GND.                                                                                                                    |

MAX9777/MAX9778

# Stereo 3W Audio Power Amplifiers with Headphone Drive and Input Mux

## Detailed Description

The MAX9777/MAX9778 feature 3W BTL speaker amplifiers, 200mW headphone amplifiers, input multiplexers, headphone sensing, and comprehensive click-and-pop suppression. The MAX9777/MAX9778 are stereo BTL/headphone amplifiers. The MAX9777 is controlled through an I<sup>2</sup>C-compatible, 2-wire serial interface. The MAX9778 is controlled through five logic inputs: MUTE, SHDN, HPS\_EN, GAINA/B, and IN1/2 (see the *Selector Guide*). The MAX9777/MAX9778 feature exceptional PSRR (100dB at 1kHz), allowing these devices to operate from noisy digital supplies without the need for a linear regulator.

The speaker amplifiers use a BTL configuration. The signal path is composed of an input amplifier and an output amplifier. Resistor  $R_{IN}$  sets the input amplifier's gain, and resistor  $R_F$  sets the output amplifier's gain. The output of these two amplifiers serves as the input to a slave amplifier configured as an inverting unity-gain follower. This results in two outputs, identical in magnitude, but 180° out of phase. The overall gain of the speaker amplifiers is twice the product of the two amplifier gains (see the *Gain-Setting Resistors* section). A feature of this architecture is that there is no phase inversion from input to output.

When configured as a headphone (single-ended) amplifier, the slave amplifier is disabled, muting the speaker and the main amplifier drives the headphone. The MAX9777/MAX9778 can deliver 3W of continuous power into a 3Ω load with less than 1% THD+N in speaker mode, and 200mW of continuous average power into a 16Ω load with less than 1% THD+N in headphone mode. These devices also feature thermal-overload protection.

## BIAS

These devices operate from a single 5V supply, and feature an internally generated, power-supply independent, common-mode bias voltage of 2.5V referenced to GND. BIAS provides both click-and-pop suppression and sets the DC bias level for the audio outputs. BIAS is internally connected to the noninverting input of each speaker amplifier (see the *Typical Application Circuits* and *Functional Diagrams*). Choose the value of the bypass capacitor as described in the *BIAS Capacitor* section. No external load should be applied to BIAS. Any load lowers the BIAS voltage, affecting the overall performance of the device.

## Input Multiplexer

Each amplifier features a 2:1 input multiplexer, allowing input selection between two stereo sources. Both multiplexers are controlled by bit 1 in the control register (MAX9777) or by the IN1/2 pin (MAX9778). A logic-low selects input IN\_1 and a logic-high selects input IN\_2.

The input multiplexer can also be used to further expand the number of gain options available from the MAX9777/MAX9778 family. Connecting the audio source to the device through two different input resistors (Figure 1) increases the number of gain options from two to four. Additionally, the input multiplexer allows a speaker equalization network to be switched into the speaker signal path. This is typically useful in optimizing acoustic response from speakers with small physical dimensions.

## Headphone Sense Enable

The HPS input is enabled by HPS\_EN (MAX9778) or the HPS\_D bit (MAX9777). HPS\_D or HPS\_EN determines whether the device is in automatic detection mode or fixed-mode operation (see Tables 1a and 1b).

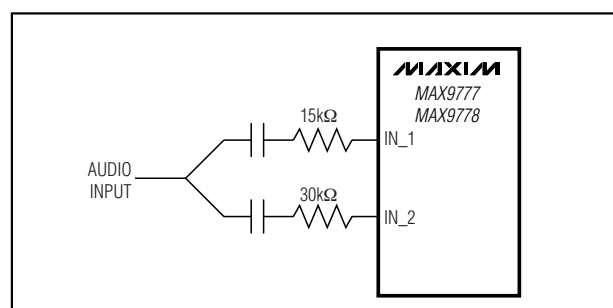


Figure 1. Using the Input Multiplexer for Gain Setting

Table 1a. MAX9777 HPS Setting

| INPUTS    |     |             | MODE | GAIN PATH* |
|-----------|-----|-------------|------|------------|
| HPS_D BIT | HPS | SPKR/HP BIT |      |            |
| 0         | 0   | X           | BTL  | A          |
| 0         | 1   | X           | SE   | B          |
| 1         | X   | 0           | BTL  | A or B     |
| 1         | X   | 1           | SE   | A or B     |

### \*Note:

A—GAINA path selected

B—GAINB path selected

A or B—Gain path selected by GAINAB control bit in register 02h

# Stereo 3W Audio Power Amplifiers with Headphone Drive and Input Mux

**Table 1b. MAX9778 HPS Setting**

| INPUTS |     | MODE | GAIN PATH* |
|--------|-----|------|------------|
| HPS_EN | HPS |      |            |
| 0      | X   | BTL  | A or B     |
| 1      | 0   | BTL  | A or B     |
| 1      | 1   | SE   | A or B     |

**\*Note:**

A or B—Gain path selected by external GAINAB

## Headphone Sense Input (HPS)

With headphone sense enabled, a voltage on HPS less than  $0.7 \times V_{DD}$  sets the device to speaker mode. A voltage greater than  $0.9 \times V_{DD}$  disables the inverting bridge amplifier (OUT<sub>-</sub>), which mutes the speaker amplifier and sets the device into headphone mode.

For automatic headphone detection, enable headphone sense and connect HPS to the control pin of a 3-wire headphone jack as shown in Figure 2. With no headphone present, the resistive voltage-divider created by R1 and R2 sets the voltage on HPS to be less than  $0.7 \times V_{DD}$ , setting the device to speaker mode and the gain setting defaults to GAINA (MAX9777). When a headphone plug is inserted into the jack, the control pin is disconnected from the tip contact, and HPS is pulled to  $V_{DD}$  through R1, setting the device into headphone mode and the gain-setting defaults to GAINB (MAX9777) (see the *Gain Select* section). Place a resistor in series with the control pin and HPS (R3) to prevent any audio signal from coupling into HPS when the device is in speaker mode.

## Shutdown

The MAX9777/MAX9778 feature a 10μA, low-power shutdown mode that reduces quiescent current consumption and extends battery life. The drive amplifiers and bias circuitry are disabled, the amplifier outputs (OUT<sub>-</sub>) go high impedance, and BIAS is driven to GND. Driving  $\overline{\text{SHDN}}$  low places the devices into shutdown mode, disables the interface, and resets the I<sup>2</sup>C registers to a default state. A logic-high on  $\overline{\text{SHDN}}$  enables the devices.

## MAX9777 Software Shutdown

A logic-high on bit 0 of the SHDN register places the MAX9777 in shutdown mode. A logic-low enables the

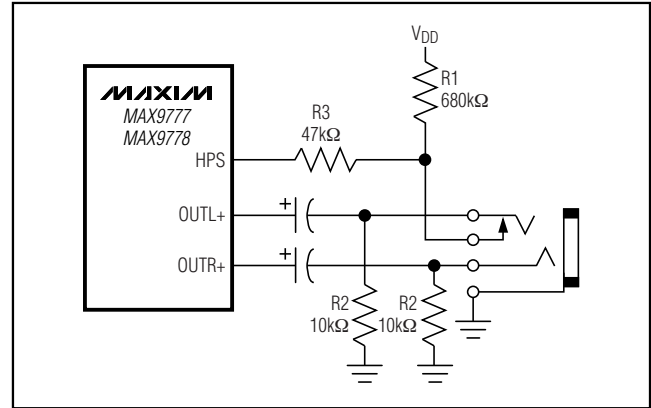


Figure 2. HPS Configuration Circuit

device. The digital section of the MAX9777 remains active when the device is shut down through the interface. All devices feature a logic-low on the  $\overline{\text{SHDN}}$  input.

## MUTE

The MAX9777/MAX9778 feature a mute mode. When the device is muted, the input is disconnected from the amplifiers. MUTE does not shut down the device.

## MAX9777 MUTE

The MAX9777 MUTE mode is selected by writing to the MUTE register (see the *Mute Register* section). The left and right channels can be independently muted.

## MAX9778 MUTE

The MAX9778 features an active-high MUTE input that mutes all channels.

## Click-and-Pop Suppression

The MAX9777/MAX9778 feature Maxim's comprehensive click-and-pop suppression. When entering or exiting shutdown, the common-mode bias voltage of the amplifiers is slowly ramped to and from the DC bias point using an S-shaped waveform. In headphone mode, this waveform shapes the frequency spectrum, minimizing the amount of audible components present at the headphone. In speaker mode, the BTL amplifiers start up in the same fashion as in headphone mode. When entering shutdown, both amplifier outputs ramp to GND quickly and simultaneously. To maximize click-and-pop suppression, drive  $\overline{\text{SHDN}}$  to 0V before power-up or power-down transitions.

# Stereo 3W Audio Power Amplifiers with Headphone Drive and Input Mux

## Digital Interface

The MAX9777 features an I<sup>2</sup>C/SMBus™-compatible 2-wire serial interface consisting of a serial data line (SDA) and a serial clock line (SCL). SDA and SCL facilitate bidirectional communication between the MAX9777 and the master at clock rates up to 400kHz. Figure 3 shows the 2-wire interface timing diagram. The MAX9777 is a transmit/receive slave-only device, relying upon a master to generate a clock signal. The master (typically a microcontroller) initiates data transfer on the bus and generates SCL to permit that transfer.

A master device communicates to the MAX9777 by transmitting the proper address followed by a command and/or data words. Each transmit sequence is framed by a START (S) or REPEATED START (S<sub>r</sub>) condition and a STOP (P) condition. Each word transmitted over the bus is 8 bits long and is always followed by an acknowledge clock pulse.

SDA and SCL are open-drain outputs requiring a pullup resistor (500Ω or greater) to generate a logic-high voltage. Series resistors in line with SDA and SCL are optional. These series resistors protect the input stages of the

SMBus is a trademark of Intel Corp.

devices from high-voltage spikes on the bus lines, and minimize crosstalk and undershoot of the bus signals.

## Bit Transfer

One data bit is transferred during each SCL clock cycle. The data on SDA must remain stable during the high period of the SCL clock pulse. Changes in SDA while SCL is high are control signals (see the *START and STOP Conditions* section). SDA and SCL idle high when the I<sup>2</sup>C bus is not busy.

## START and STOP Conditions

When the serial interface is inactive, SDA and SCL idle high. A master device initiates communication by issuing a START condition. A START condition is a high-to-low transition on SDA with SCL high. A STOP condition is a low-to-high transition on SDA while SCL is high (Figure 4). A START condition from the master signals the beginning of a transmission to the MAX9777. The master terminates transmission by issuing the STOP condition; this frees the bus. If a REPEATED START condition is generated instead of a STOP condition, the bus remains active.

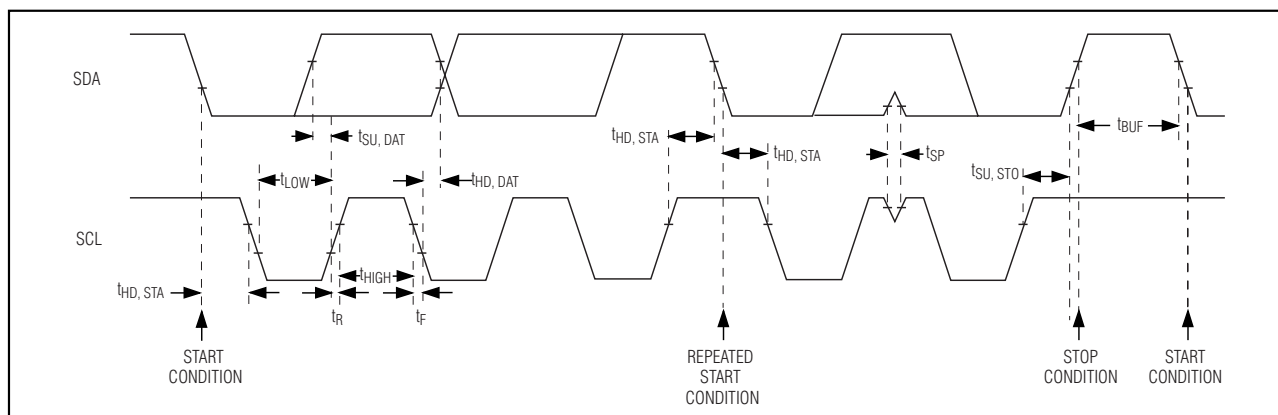


Figure 3. 2-Wire Serial-Interface Timing Diagram

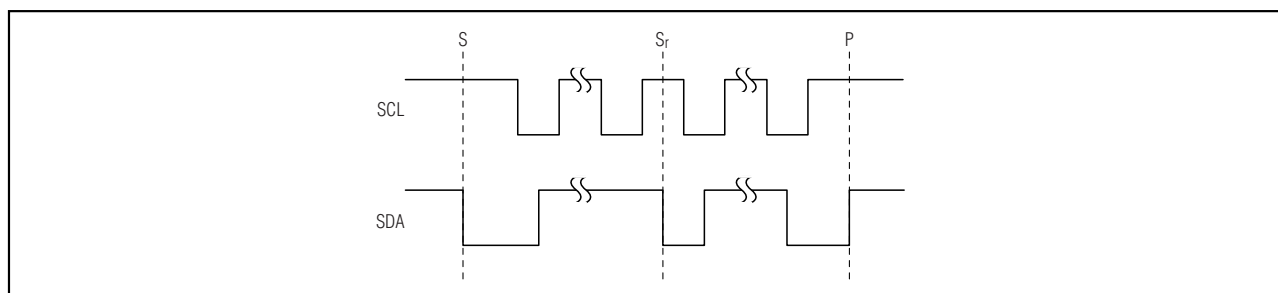


Figure 4. START/STOP Conditions

## Stereo 3W Audio Power Amplifiers with Headphone Drive and Input Mux

### Early STOP Conditions

The MAX9777 recognizes a STOP condition at any point during the transmission except if a STOP condition occurs in the same high pulse as a START condition (Figure 5). This condition is not a legal I<sup>2</sup>C format; at least one clock pulse must separate any START and STOP condition.

### REPEATED START Conditions

A REPEATED START ( $S_r$ ) condition may indicate a change of data direction on the bus. Such a change occurs when a command word is required to initiate a read operation.  $S_r$  may also be used when the bus master is writing to several I<sup>2</sup>C devices and does not want to relinquish control of the bus. The MAX9777 serial interface supports continuous write operations with or without an  $S_r$  condition separating them. Continuous read operations require  $S_r$  conditions because of the change in direction of data flow.

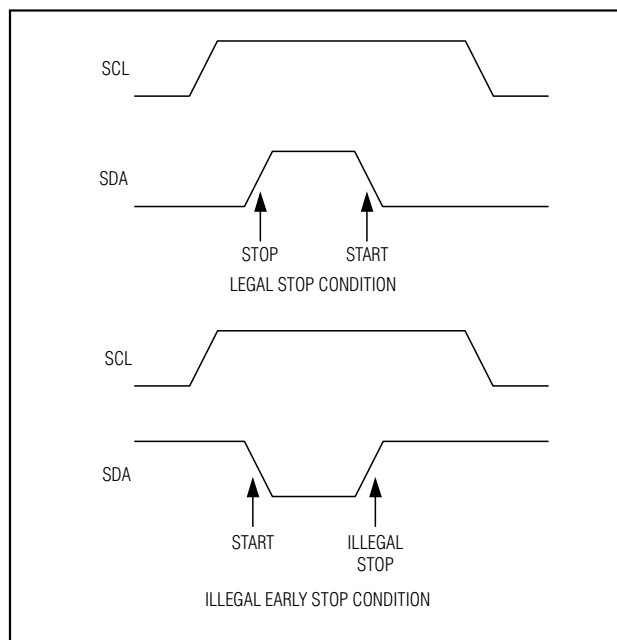


Figure 5. Early STOP Condition

### Acknowledge Bit (ACK)

The acknowledge bit (ACK) is the ninth bit attached to any 8-bit data word. The receiving device always generates ACK. The MAX9777 generates an ACK when receiving an address or data by pulling SDA low during the ninth clock period. When transmitting data, the MAX9777 waits for the receiving device to generate an ACK. Monitoring ACK allows for detection of unsuccessful data transfers. An unsuccessful data transfer occurs if a receiving device is busy or if a system fault has occurred. In the event of an unsuccessful data transfer, the bus master should reattempt communication at a later time.

### Slave Address

The bus master initiates communication with a slave device by issuing a START condition followed by a 7-bit slave address (Figure 6). When idle, the MAX9777 waits for a START condition followed by its slave address. The LSB of the address word is the Read/Write (R/W) bit. R/W indicates whether the master is writing to or reading from the MAX9777 (R/W = 0 selects the write condition, R/W = 1 selects the read condition). After receiving the proper address, the MAX9777 issues an ACK by pulling SDA low for one clock cycle.

The MAX9777 has a factory-/user-programmed address. Address bits A6–A2 are preset, while A0 and A1 is set by ADD. Connect ADD to either V<sub>DD</sub>, GND, SCL, or SDA to change the last 2 bits of the slave address (Table 2).

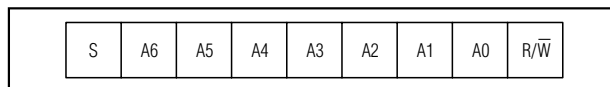


Figure 6. Slave Address Byte Definition

Table 2. MAX9777 I<sup>2</sup>C Slave Addresses

| ADD CONNECTION  | I <sup>2</sup> C ADDRESS |
|-----------------|--------------------------|
| GND             | 100 1000                 |
| V <sub>DD</sub> | 100 1001                 |
| SDA             | 100 1010                 |
| SCL             | 100 1011                 |

# Stereo 3W Audio Power Amplifiers with Headphone Drive and Input Mux

## Write Data Format

There are three registers that configure the MAX9777: the MUTE register, SHDN register, and control register. In write data mode ( $R/\bar{W} = 0$ ), the register address and data byte follow the device address (Figure 7).

## MUTE Register

The MUTE register (01hex) is a read/write register that sets the MUTE status of the device. Bit 3 (MUTEL) of the MUTE register controls the left channel; bit 4 (MUTER) controls the right channel. A logic-high mutes the respective channel; a logic-low brings the channel out of mute.

## SHDN Register

The SHDN register (02hex) is a read/write register that controls the power-up state of the device. A logic-high

in bit 0 of the SHDN register shuts down the device; a logic-low turns on the device. A logic-high is required in bits 2 to 7 to reset all registers to their default settings.

## Control Register

The control register (03hex) is a read/write register that determines the device configuration. Bit 1 (IN1/IN2) controls the input multiplexer, a logic-high selects input 1; a logic-low selects input 2. Bit 2 (HPS\_D) controls the headphone sensing. A logic-low configures the device in automatic headphone detection mode. A logic-high disables the HPS input. Bit 3 (GAINA/B) controls the gain-select multiplexer. A logic-low selects GAINA. A logic-high selects GAINB. GAINA/B is ignored when HPS\_D = 0. Bit 4 (SPKR/HP) selects the amplifier operating mode when HPS\_D = 1. A logic-high selects speaker mode, and a logic-low selects headphone mode.

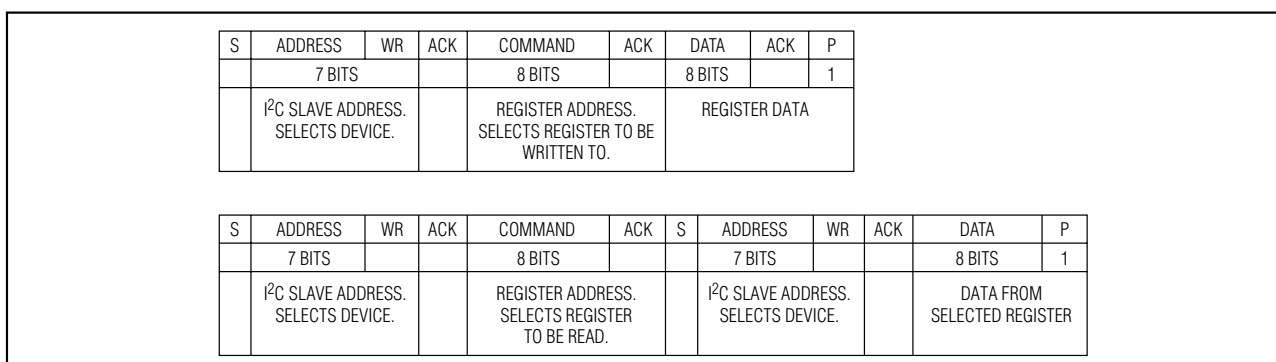


Figure 7. Write/Read Data Format Example

Table 3. MAX9777 MUTE Register Format

| REGISTER ADDRESS |       | 0000 0001  |                      |
|------------------|-------|------------|----------------------|
| BIT              | NAME  | VALUE      | DESCRIPTION          |
| 7                | X     | Don't Care | —                    |
| 6                | X     | Don't Care | —                    |
| 5                | X     | Don't Care | —                    |
| 4                | MUTER | 0*         | Unmute right channel |
|                  |       | 1          | Mute right channel   |
| 3                | MUTEL | 0*         | Unmute left channel  |
|                  |       | 1          | Mute left channel    |
| 2                | X     | Don't Care | —                    |
| 1                | X     | Don't Care | —                    |
| 0                | X     | Don't Care | —                    |

\*Default state.

Table 4. MAX9777 SHDN Register Format

| REGISTER ADDRESS |       | 0000 0010  |                  |
|------------------|-------|------------|------------------|
| BIT              | NAME  | VALUE      | DESCRIPTION      |
| 7                | RESET | 0*         | —                |
|                  |       | 1          | Reset device     |
| 6                | RESET | 0*         | —                |
|                  |       | 1          | Reset device     |
| 5                | RESET | 0*         | —                |
|                  |       | 1          | Reset device     |
| 4                | RESET | 0*         | —                |
|                  |       | 1          | Reset device     |
| 3                | RESET | 0*         | —                |
|                  |       | 1          | Reset device     |
| 2                | RESET | 0*         | —                |
|                  |       | 1          | Reset device     |
| 1                | X     | Don't Care | —                |
| 0                | SHDN  | 0*         | Normal operation |
|                  |       | 1          | Shutdown         |

\*Default state.



# Stereo 3W Audio Power Amplifiers with Headphone Drive and Input Mux

**Table 5. MAX9777 Control Register Format**

| REGISTER ADDRESS |         | 0000 0011  |                                                      |
|------------------|---------|------------|------------------------------------------------------|
| BIT              | NAME    | VALUE      | DESCRIPTION                                          |
| 7                | X       | Don't Care | —                                                    |
| 6                | X       | Don't Care | —                                                    |
| 5                | X       | Don't Care | —                                                    |
| 4                | SPKR/HP | 0*         | Speaker mode selected                                |
|                  |         | 1          | Headphone mode selected                              |
| 3                | GAINA/B | 0*         | Gain-setting A selected                              |
|                  |         | 1          | Gain-setting B selected                              |
| 2                | HPS_D   | 0*         | Automatic headphone detection enabled                |
|                  |         | 1          | Automatic headphone detection disabled (HPS ignored) |
| 1                | IN1/IN2 | 0*         | Input 1 selected                                     |
|                  |         | 1          | Input 2 selected                                     |
| 0                | X       | Don't Care | —                                                    |

\*Default

## Read Data Format

In read mode ( $R/\overline{W} = 1$ ), the MAX9777 writes the contents of the selected register to the bus. The direction of the data flow reverses following the address acknowledge by the MAX9777. The master device reads the contents of all registers, including the read-only status register. Table 6 shows the status register format.

## Interrupt Output ( $\overline{INT}$ )

The MAX9777 includes an interrupt output ( $\overline{INT}$ ) that can indicate to a master device that an event has occurred.  $\overline{INT}$  is triggered when the state of HPS changes. During normal operation,  $\overline{INT}$  idles high. If a headphone is inserted/removed from the jack and that action is detected by HPS,  $\overline{INT}$  pulls the line low.  $\overline{INT}$  remains low until a read data operation is executed.

## I<sup>2</sup>C Compatibility

The MAX9777 is compatible with existing I<sup>2</sup>C systems. SCL and SDA are high-impedance inputs; SDA has an open drain that pulls the data line low during the ninth clock pulse. The communication protocol supports the standard I<sup>2</sup>C 8-bit communications. The general call address is ignored. The MAX9777 slave addresses are compatible with the 7-bit I<sup>2</sup>C addressing protocol only.

**Table 6. MAX9777 Status Register Format**

| REGISTER ADDRESS |       | 0000 0000  |                                            |
|------------------|-------|------------|--------------------------------------------|
| BIT              | NAME  | VALUE      | DESCRIPTION                                |
| 7                | THRM  | 0          | Device temperature below thermal limit     |
|                  |       | 1          | Device temperature exceeding thermal limit |
| 6                | AMPR- | 0          | OUTR- current below current limit          |
|                  |       | 1          | OUTR- current exceeding current limit      |
| 5                | AMPR+ | 0          | OUTR+ current below current limit          |
|                  |       | 1          | OUTR+ current exceeding current limit      |
| 4                | AMPL- | 0          | OUTL- current below current limit          |
|                  |       | 1          | OUTL- current exceeding current limit      |
| 3                | AMPL+ | 0          | OUTL+ current below current limit          |
|                  |       | 1          | OUTL+ current exceeding current limit      |
| 2                | HPSTS | 0          | Device in speaker mode                     |
|                  |       | 1          | Device in headphone mode                   |
| 1                | X     | Don't Care | —                                          |
| 0                | X     | Don't Care | —                                          |

# Stereo 3W Audio Power Amplifiers with Headphone Drive and Input Mux

## Applications Information

### BTL Speaker Amplifiers

The MAX9777/MAX9778 feature speaker amplifiers designed to drive a load differentially, a configuration referred to as bridge-tied load (BTL). The BTL configuration (Figure 8) offers advantages over the single-ended configuration, where one side of the load is connected to ground. Driving the load differentially doubles the output voltage compared to a single-ended amplifier under similar conditions. Thus, the devices' differential gain is twice the closed-loop gain of the input amplifier. The effective gain is given by:

$$A_{VD} = 2 \times \frac{R_F}{R_{IN}}$$

Substituting  $2 \times V_{OUT(P-P)}$  for  $V_{OUT(P-P)}$  into the following equations yields four times the output power due to doubling of the output voltage:

$$V_{RMS} = \frac{V_{OUT(P-P)}}{2\sqrt{2}}$$

$$P_{OUT} = \frac{V_{RMS}^2}{R_L}$$

Since the differential outputs are biased at midsupply, there is no net DC voltage across the load. This eliminates the need for DC-blocking capacitors required for single-ended amplifiers. These capacitors can be large and expensive, consume board space, and degrade low-frequency performance.

When the MAX9777 is configured to automatically detect the presence of a headphone jack, the device defaults to gain setting A when the device is in speaker mode.

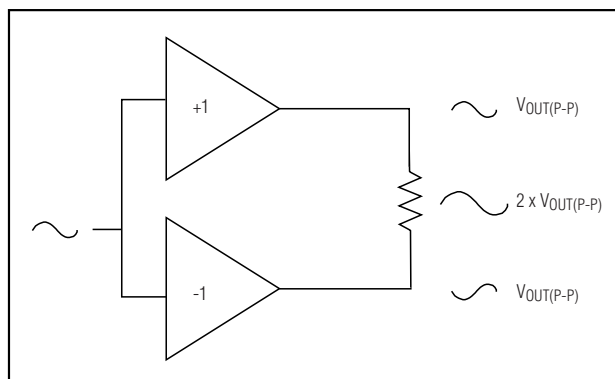


Figure 8. Bridge-Tied Load Configuration

### Single-Ended Headphone Amplifier

The MAX9777/MAX9778 can be configured as single-ended headphone amplifiers through software or by sensing the presence of a headphone plug (HPS). In headphone mode, the inverting output of the BTL amplifier is disabled, muting the speaker. The gain is 1/2 that of the device in speaker mode, and the output power is reduced by a factor of 4.

In headphone mode, the load must be capacitively coupled to the device, blocking the DC bias voltage from the load (see the *Typical Application Circuits*).

### Power Dissipation and Heat Sinking

Under normal operating conditions, the MAX9777/MAX9778 can dissipate a significant amount of power. The maximum power dissipation for each package is given in the *Absolute Maximum Ratings* section under Continuous Power Dissipation or can be calculated by the following equation:

$$P_{DISSPKG(MAX)} = \frac{T_{J(MAX)} - T_A}{\theta_{JA}}$$

where  $T_{J(MAX)}$  is  $+150^{\circ}\text{C}$ ,  $T_A$  is the ambient temperature, and  $\theta_{JA}$  is the reciprocal of the derating factor in  $^{\circ}\text{C/W}$  as specified in the *Absolute Maximum Ratings* section. For example,  $\theta_{JA}$  of the TQFN package is  $+29^{\circ}\text{C/W}$ .

The increase in power delivered by the BTL configuration directly results in an increase in internal power dissipation over the single-ended configuration. The maximum power dissipation for a given  $V_{DD}$  and load is given by the following equation:

$$P_{DISS(MAX)} = \frac{2V_{DD}^2}{\pi^2 R_L}$$

If the power dissipation for a given application exceeds the maximum allowed for a given package, either reduce  $V_{DD}$ , increase load impedance, decrease the ambient temperature, or add heatsinking to the device. Large output, supply, and ground PC board traces improve the maximum power dissipation in the package.

Thermal-overload protection limits total power dissipation in these devices. When the junction temperature exceeds  $+160^{\circ}\text{C}$ , the thermal-protection circuitry disables the amplifier output stage. The amplifiers are enabled once the junction temperature cools by  $15^{\circ}\text{C}$ . This results in a pulsing output under continuous thermal-overload conditions as the device heats and cools.

# Stereo 3W Audio Power Amplifiers with Headphone Drive and Input Mux

## Component Selection

### Gain-Setting Resistors

External feedback components set the gain of the MAX9777/MAX9778. Resistor  $R_{IN}$  sets the gain of the input amplifier ( $A_{VIN}$ ), and resistor  $R_F$  sets the gain of the second stage amplifier ( $A_{VOUT}$ ):

$$A_{VIN} = -\left(\frac{10k\Omega}{R_{IN}}\right), A_{VOUT} = -\left(\frac{R_F}{10k\Omega}\right)$$

Combining  $A_{VIN}$  and  $A_{VOUT}$ ,  $R_{IN}$  and  $R_F$  set the single-ended gain of the device as follows:

$$A_V = A_{VIN} \times A_{VOUT} = -\left(\frac{10k\Omega}{R_{IN}}\right) \times -\left(\frac{R_F}{10k\Omega}\right) = +\left(\frac{R_F}{R_{IN}}\right)$$

As shown, the two-stage amplifier architecture results in a noninverting gain configuration, preserving absolute phase through the MAX9777/MAX9778. The gain of the device in BTL mode is twice that of the single-ended mode. Choose  $R_{IN}$  between  $10k\Omega$  and  $15k\Omega$  and  $R_F$  between  $15k\Omega$  and  $100k\Omega$ .

### Input Filter

The input capacitor ( $C_{IN}$ ), in conjunction with  $R_{IN}$ , forms a highpass filter that removes the DC bias from an incoming signal. The AC-coupling capacitor allows the amplifier to bias the signal to an optimum DC level. Assuming zero-source impedance, the -3dB point of the highpass filter is given by:

$$f_{-3dB} = \frac{1}{2\pi R_{IN} C_{IN}}$$

Choose  $R_{IN}$  according to the *Gain-Setting Resistors* section. Choose the  $C_{IN}$  such that  $f_{-3dB}$  is well below the lowest frequency of interest. Setting  $f_{-3dB}$  too high affects the amplifier's low-frequency response. Use capacitors whose dielectrics have low-voltage coefficients, such as tantalum or aluminum electrolytic. Capacitors with high-voltage coefficients, such as ceramics, may result in an increased distortion at low frequencies.

Other considerations when designing the input filter include the constraints of the overall system, the actual frequency band of interest, and click-and-pop suppression.

### Output-Coupling Capacitor

The MAX9777/MAX9778 require output-coupling capacitors to operate in single-ended (headphone) mode. The output-coupling capacitor blocks the DC component of the amplifier output, preventing DC current from flowing to the load. The output capacitor and

the load impedance form a highpass filter with a -3dB point determined by:

$$f_{-3dB} = \frac{1}{2\pi R_L C_{OUT}}$$

As with the input capacitor, choose  $C_{OUT}$  such that  $f_{-3dB}$  is well below the lowest frequency of interest. Setting  $f_{-3dB}$  too high affects the amplifier's low-frequency response.

Load impedance is a concern when choosing  $C_{OUT}$ . Load impedance can vary, changing the -3dB point of the output filter. A lower impedance increases the corner frequency, degrading low-frequency response. Select  $C_{OUT}$  such that the worst-case load/ $C_{OUT}$  combination yields an adequate response. Select capacitors with low ESR to minimize resistive losses and optimize power transfer to the load.

If layout constraints require a physically smaller output-coupling capacitor, decrease the value of  $C_{OUT}$  and add series resistance to the output of the MAX9777/MAX9778 (see Figure 9). With the added series resistance at the output, the cutoff frequency of the highpass filter is:

$$f_{-3dB} = \frac{1}{2\pi(R_L + R_{SERIES})C_{OUT}}$$

Since the cutoff frequency of the output highpass filter is inversely proportional to the product of the total load resistance seen by the outputs ( $R_L + R_{SERIES}$ ) and  $C_{OUT}$ , increase the total resistance seen by the MAX9777/MAX9778 outputs by the same amount  $C_{OUT}$  is decreased to maintain low-frequency performance. Since the added series resistance forms a voltage-divider with the headphone speaker resistance for frequencies within the passband of the highpass filter, there is a loss in voltage gain. To compensate for this loss, increase the voltage gain setting by an amount equal to the attenuation due to the added series resistance. Use the following equation to approximate the required voltage gain compensation:

$$A_{V\_COMP} = 20\log\left(\frac{R_L + R_{SERIES}}{R_L}\right)$$

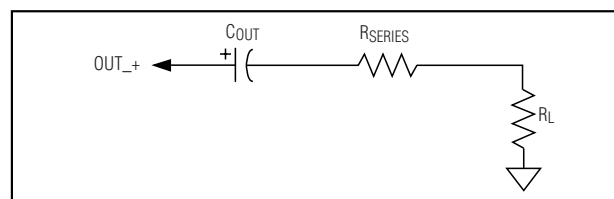


Figure 9. Reducing  $C_{OUT}$  by Adding  $R_{SERIES}$

# Stereo 3W Audio Power Amplifiers with Headphone Drive and Input Mux

## BIAS Capacitor

BIAS is the output of the internally generated 2.5VDC bias voltage. The BIAS bypass capacitor,  $C_{BIAS}$ , improves PSRR and THD+N by reducing power supply and other noise sources at the common-mode bias node, and also generates the clickless/popless, start-up/shutdown DC bias waveforms for the speaker amplifiers. Bypass BIAS with a 1 $\mu$ F capacitor to GND.

## Supply Bypassing

Proper power-supply bypassing ensures low-noise, low-distortion performance. Place a 0.1 $\mu$ F ceramic capacitor from  $V_{DD}$  to GND. Add additional bulk capacitance as required by the application, typically 100 $\mu$ F. Bypass  $V_{DD}$  with a 100 $\mu$ F capacitor to GND. Locate bypass capacitors as close to the device as possible.

## Gain Select

The MAX9777/MAX9778 feature multiple gain settings on each channel, making available different gain and feedback configurations. The gain-setting resistor ( $R_F$ ) is connected between the amplifier output ( $OUT_+$ ) and the gain set point ( $GAIN_-$ ). An internal multiplexer switches between the different feedback resistors depending on the status of the gain control input. The stereo MAX9777/MAX9778 feature two gain options per channel. See Tables 1a and 1b for the gain-setting options.

## Bass Boost Circuit

Headphones typically have a poor low-frequency response due to speaker and enclosure size limitations. A bass boost circuit compensates the poor low-frequency response (Figure 10). At low frequencies, the capacitor  $C_F$  is an open circuit, and the effective impedance in the feedback loop ( $R_{F(EFF)}$ ) is  $R_{F(EFF)} = R_{F1}$ .

At the frequency:

$$\frac{1}{2\pi R_{F2} C_F}$$

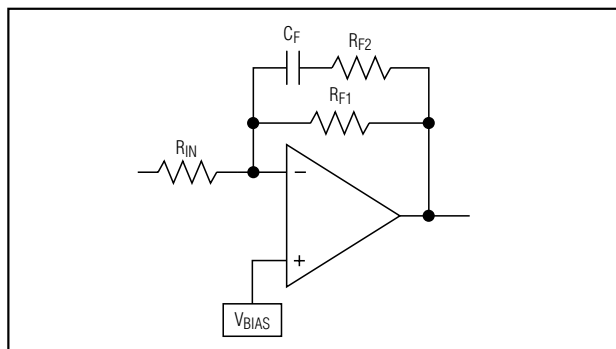


Figure 10. Bass Boost Circuit

where the impedance,  $C_F$ , begins to decrease, and at high frequencies, the  $C_F$  is a short circuit. Here the impedance of the feedback loop is:

$$R_{F(EFF)} = \frac{R_{F1} \times R_{F2}}{R_{F1} + R_{F2}}$$

Assuming  $R_{F1} = R_{F2}$ , then  $R_{F(EFF)}$  at low frequencies is twice that of  $R_{F(EFF)}$  at high frequencies (Figure 11). Thus, the amplifier has more gain at lower frequencies, boosting the system's bass response. Set the gain roll-off frequency based upon the response of the speaker and enclosure.

To minimize distortion at low frequencies, use capacitors with low-voltage coefficient dielectrics when selecting  $C_F$ . Film or COG dielectric capacitors are good choices for  $C_F$ . Capacitors with high-voltage coefficients, such as ceramics (non-COG dielectrics), can result in increased distortion at low frequencies.

## Layout and Grounding

Good PC board layout is essential for optimizing performance. Use large traces for the power-supply inputs and amplifier outputs to minimize losses due to parasitic trace resistance, as well as route heat away from the device. Good grounding improves audio performance, minimizes crosstalk between channels, and prevents any digital switching noise from coupling into the audio signal. If digital signal lines must cross over or under audio signal lines, ensure that they cross perpendicular to each other.

The MAX9777/MAX9778 TQFN package features an exposed thermal pad. This pad lowers the package's thermal resistance by providing a direct heat conduction path from the die to the PC board. Connect the pad to signal ground (0V) by using a large pad or multiple vias to the ground plane.

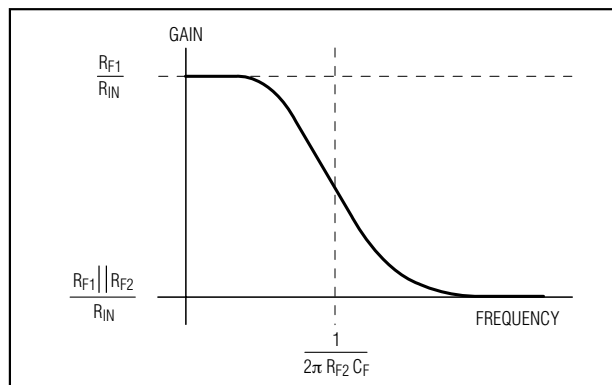
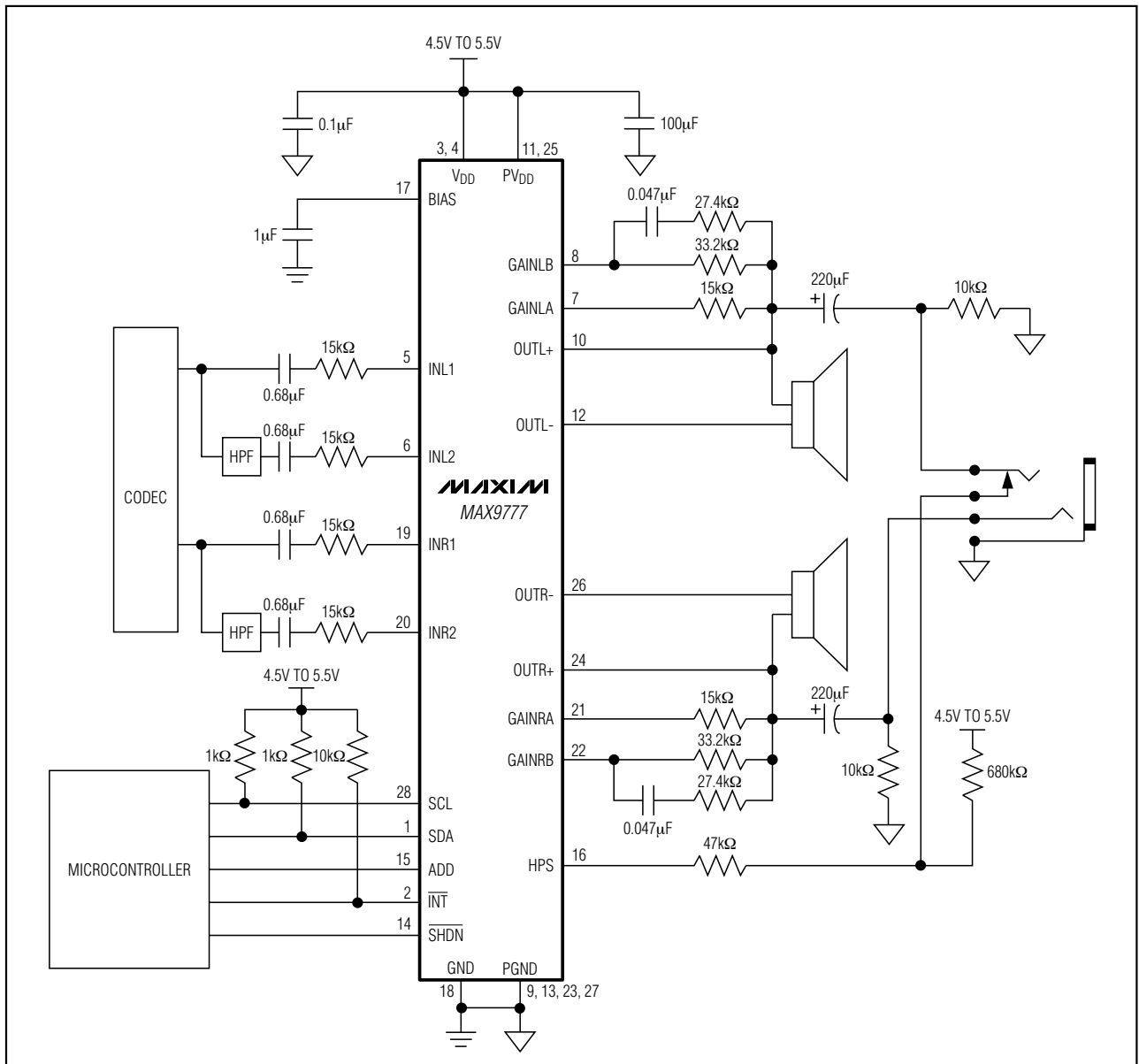


Figure 11. Bass Boost Response

# Stereo 3W Audio Power Amplifiers with Headphone Drive and Input Mux

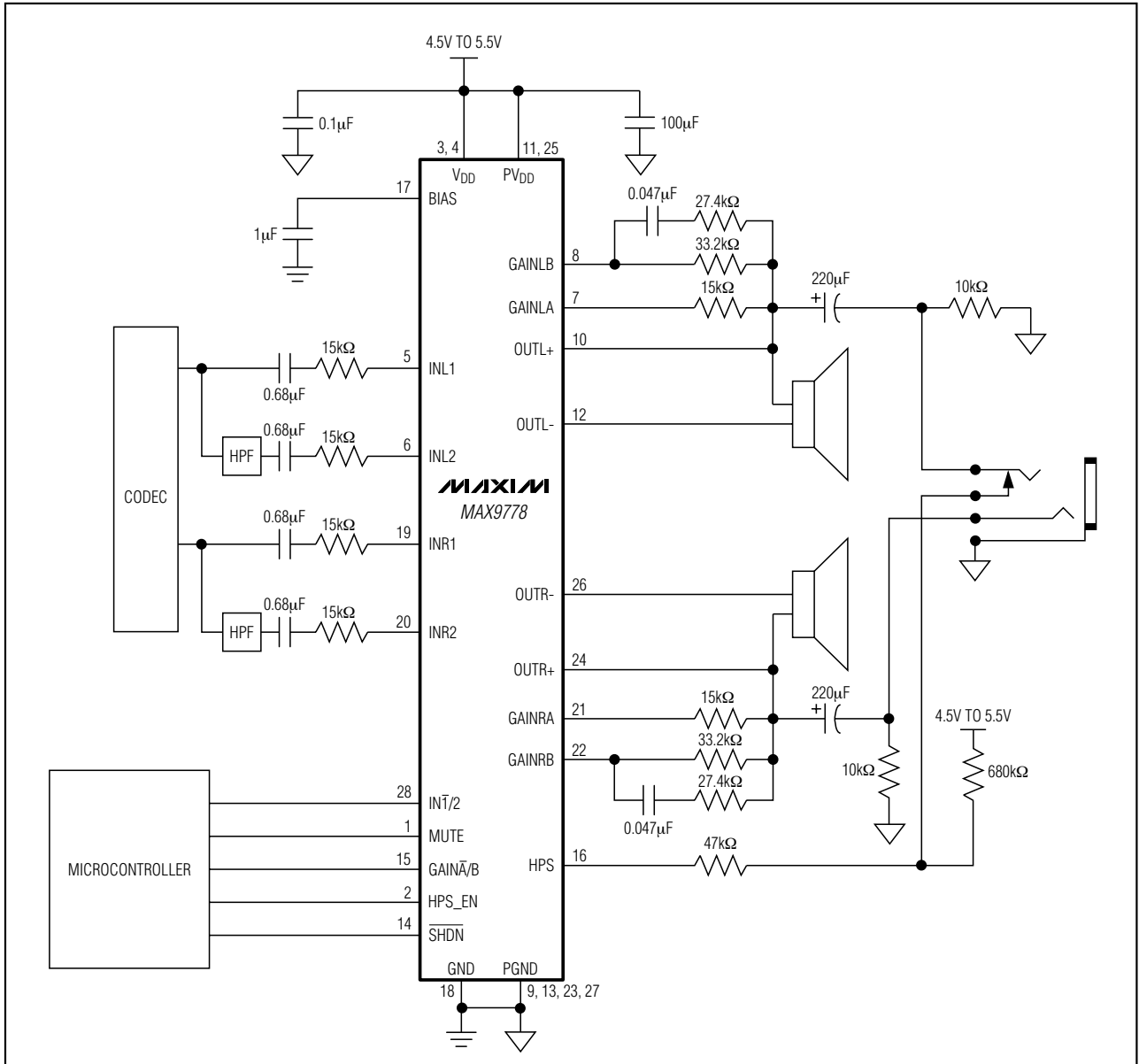
## Typical Application Circuits

MAX9777/MAX9778



# Stereo 3W Audio Power Amplifiers with Headphone Drive and Input Mux

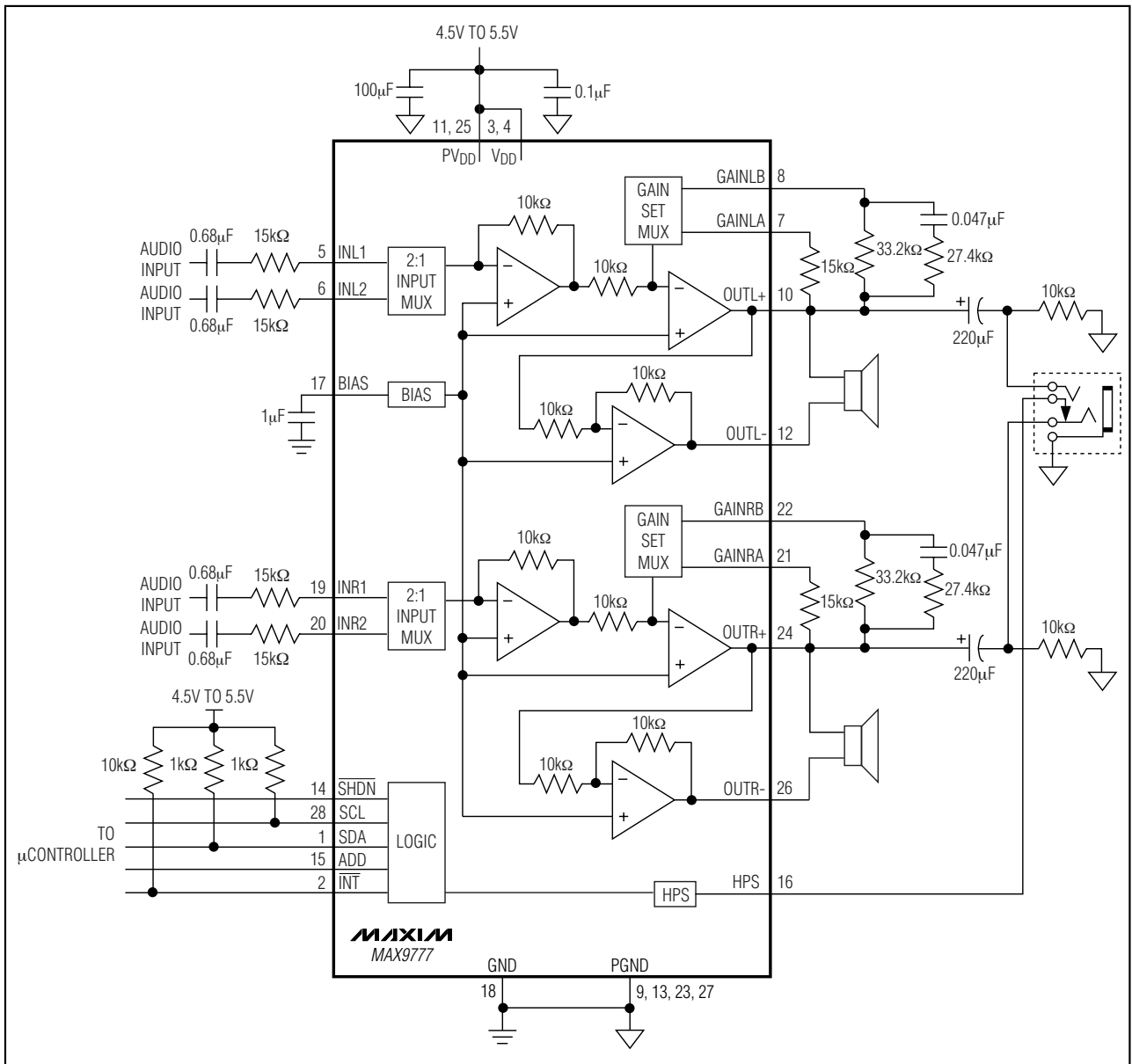
## Typical Application Circuits (continued)



# Stereo 3W Audio Power Amplifiers with Headphone Drive and Input Mux

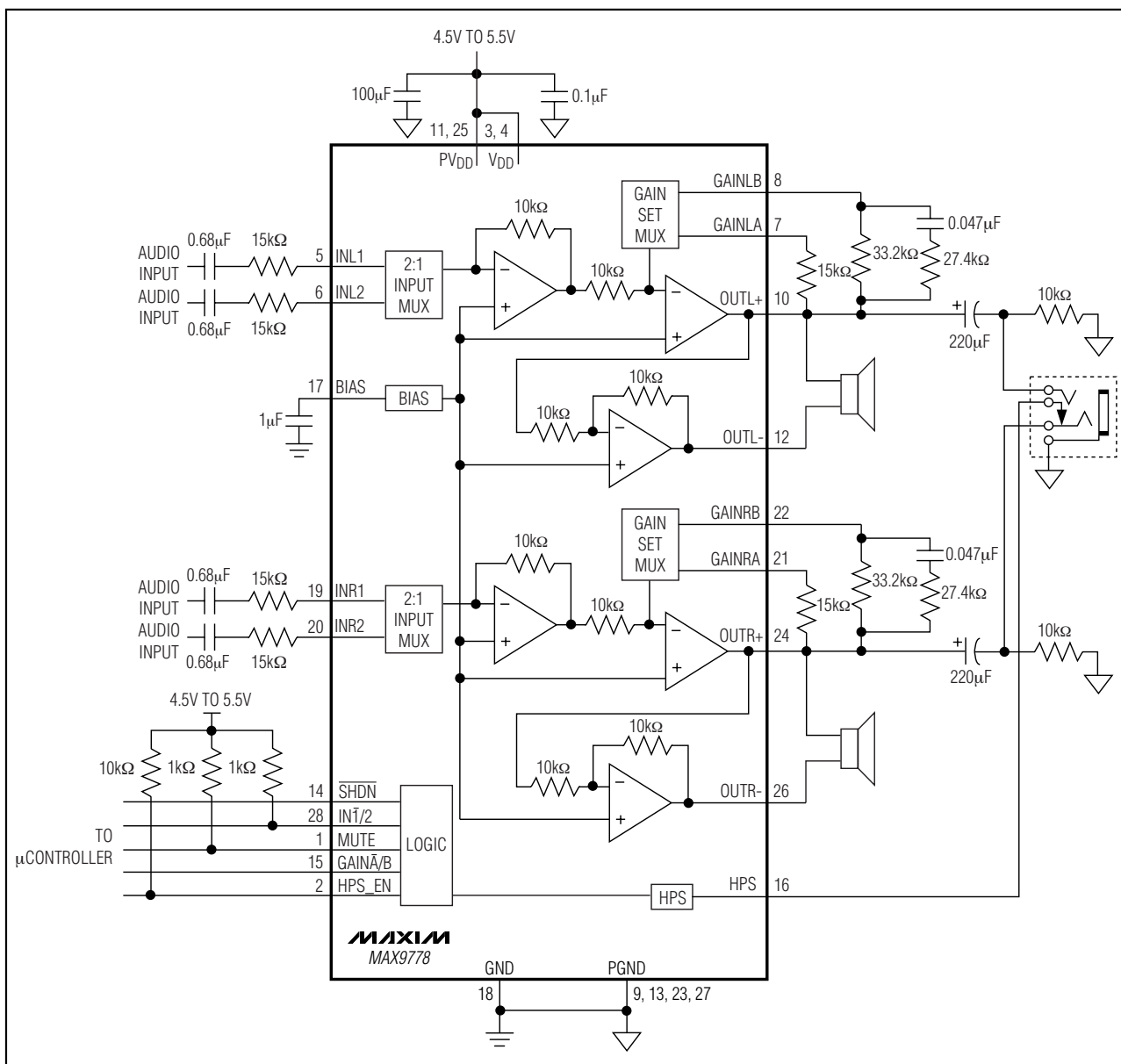
## Functional Diagrams

MAX9777/MAX9778



# Stereo 3W Audio Power Amplifiers with Headphone Drive and Input Mux

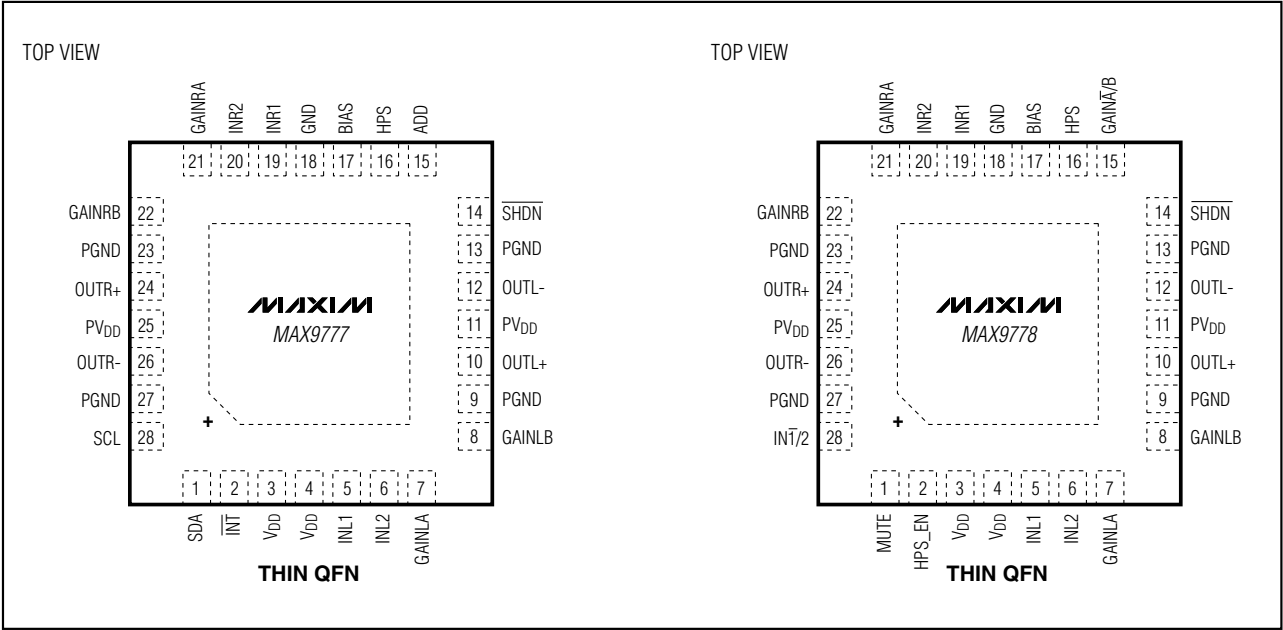
## Functional Diagrams (continued)





# Stereo 3W Audio Power Amplifiers with Headphone Drive and Input Mux

## Pin Configurations

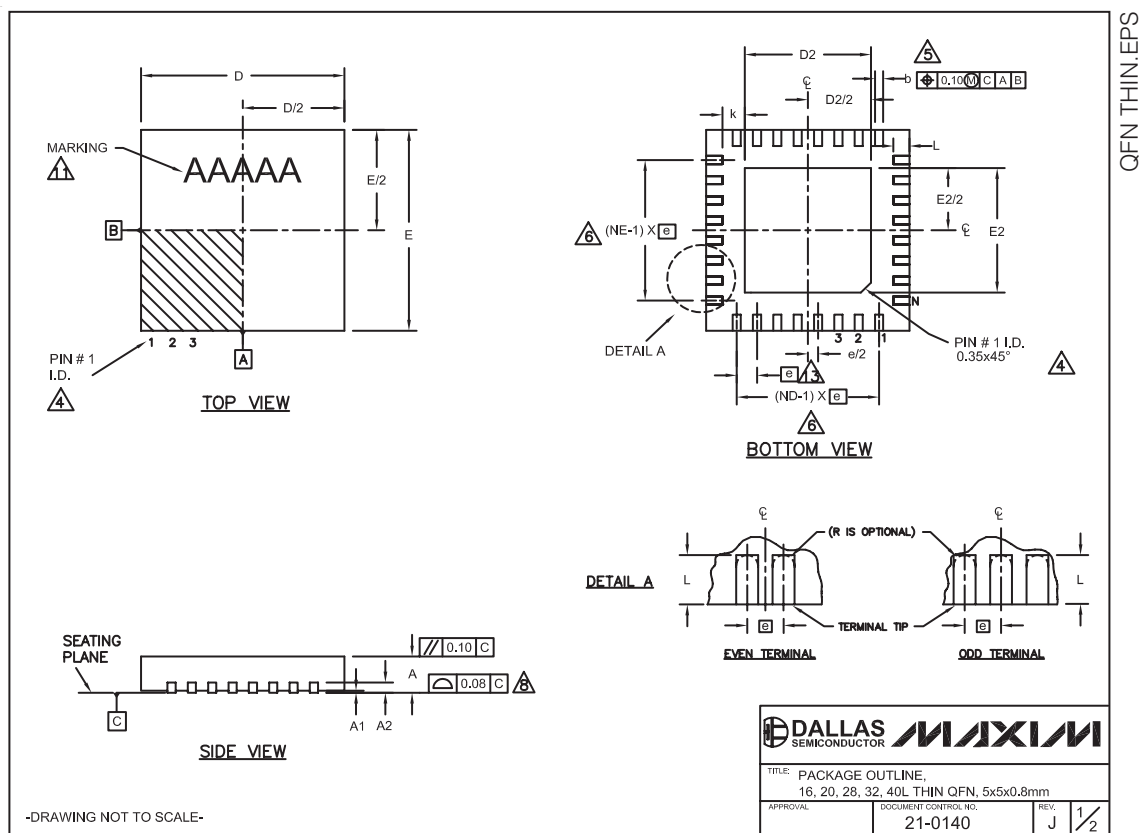


MAX9777/MAX9778

# Stereo 3W Audio Power Amplifiers with Headphone Drive and Input Mux

## Package Information

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages).)



# Stereo 3W Audio Power Amplifiers with Headphone Drive and Input Mux

## Package Information (continued)

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages).)

| COMMON DIMENSIONS |           |      |      |           |      |      |           |      |      |           |      |      |           |      |      |
|-------------------|-----------|------|------|-----------|------|------|-----------|------|------|-----------|------|------|-----------|------|------|
| PKG.              | 16L 5x5   |      |      | 20L 5x5   |      |      | 28L 5x5   |      |      | 32L 5x5   |      |      | 40L 5x5   |      |      |
| SYMBOL            | MIN.      | NOM. | MAX. | MIN.      | NOM. | MAX. | MIN.      | NOM. | MAX. | MIN.      | NOM. | MAX. | MIN.      | NOM. | MAX. |
| A                 | 0.70      | 0.75 | 0.80 | 0.70      | 0.75 | 0.80 | 0.70      | 0.75 | 0.80 | 0.70      | 0.75 | 0.80 | 0.70      | 0.75 | 0.80 |
| A1                | 0         | 0.02 | 0.05 | 0         | 0.02 | 0.05 | 0         | 0.02 | 0.05 | 0         | 0.02 | 0.05 | 0         | 0.02 | 0.05 |
| A2                | 0.20 REF. |      |      | 0.20 REF. |      |      | 0.20 REF. |      |      | 0.20 REF. |      |      | 0.20 REF. |      |      |
| b                 | 0.25      | 0.30 | 0.35 | 0.25      | 0.30 | 0.35 | 0.20      | 0.25 | 0.30 | 0.20      | 0.25 | 0.30 | 0.15      | 0.20 | 0.25 |
| D                 | 4.90      | 5.00 | 5.10 | 4.90      | 5.00 | 5.10 | 4.90      | 5.00 | 5.10 | 4.90      | 5.00 | 5.10 | 4.90      | 5.00 | 5.10 |
| E                 | 4.90      | 5.00 | 5.10 | 4.90      | 5.00 | 5.10 | 4.90      | 5.00 | 5.10 | 4.90      | 5.00 | 5.10 | 4.90      | 5.00 | 5.10 |
| e                 | 0.80 BSC. |      |      | 0.65 BSC. |      |      | 0.50 BSC. |      |      | 0.50 BSC. |      |      | 0.40 BSC. |      |      |
| k                 | 0.25      | -    | -    | 0.25      | -    | -    | 0.25      | -    | -    | 0.25      | -    | -    | 0.25      | -    | -    |
| L                 | 0.30      | 0.40 | 0.50 | 0.45      | 0.55 | 0.65 | 0.45      | 0.55 | 0.65 | 0.30      | 0.40 | 0.50 | 0.30      | 0.40 | 0.50 |
| N                 | 16        |      |      | 20        |      |      | 28        |      |      | 32        |      |      | 40        |      |      |
| ND                | 4         |      |      | 5         |      |      | 7         |      |      | 8         |      |      | 10        |      |      |
| NE                | 4         |      |      | 5         |      |      | 7         |      |      | 8         |      |      | 10        |      |      |
| JEDEC             | WHHB      |      |      | WHHC      |      |      | WHHD-1    |      |      | WHHD-2    |      |      | ---       |      |      |

### NOTES:

1. DIMENSIONING & TOLERANCING CONFORM TO ASME Y14.5M-1994.
  2. ALL DIMENSIONS ARE IN MILLIMETERS, ANGLES ARE IN DEGREES.
  3. N IS THE TOTAL NUMBER OF TERMINALS.
- ⚠ THE TERMINAL #1 IDENTIFIER AND TERMINAL NUMBERING CONVENTION SHALL CONFORM TO JEDEC 95-1 SPP-012. DETAILS OF TERMINAL #1 IDENTIFIER ARE OPTIONAL, BUT MUST BE LOCATED WITHIN THE ZONE INDICATED. THE TERMINAL #1 IDENTIFIER MAY BE EITHER A MOLD OR MARKED FEATURE.
- ⚠ DIMENSION b APPLIES TO METALLIZED TERMINAL AND IS MEASURED BETWEEN 0.25 mm AND 0.30 mm FROM TERMINAL TIP.
- ⚠ ND AND NE REFER TO THE NUMBER OF TERMINALS ON EACH D AND E SIDE RESPECTIVELY.
7. DEPOPULATION IS POSSIBLE IN A SYMMETRICAL FASHION.
- ⚠ COPLANARITY APPLIES TO THE EXPOSED HEAT SINK SLUG AS WELL AS THE TERMINALS.
9. DRAWING CONFORMS TO JEDEC MO220, EXCEPT EXPOSED PAD DIMENSION FOR T2855-3 AND T2855-6.

⚠ WARPAGE SHALL NOT EXCEED 0.10 mm.

- 11. MARKING IS FOR PACKAGE ORIENTATION REFERENCE ONLY.
- 12. NUMBER OF LEADS SHOWN ARE FOR REFERENCE ONLY.

⚠ LEAD CENTERLINES TO BE AT TRUE POSITION AS DEFINED BY BASIC DIMENSION "e",  $\pm 0.05$ .

-DRAWING NOT TO SCALE-

| EXPOSED PAD VARIATIONS |      |      |      |      |      |      |
|------------------------|------|------|------|------|------|------|
| PKG. CODES             | D2   |      |      | E2   |      |      |
|                        | MIN. | NOM. | MAX. | MIN. | NOM. | MAX. |
| T1655-2                | 3.00 | 3.10 | 3.20 | 3.00 | 3.10 | 3.20 |
| T1655-3                | 3.00 | 3.10 | 3.20 | 3.00 | 3.10 | 3.20 |
| T1655N-1               | 3.00 | 3.10 | 3.20 | 3.00 | 3.10 | 3.20 |
| T2055-3                | 3.00 | 3.10 | 3.20 | 3.00 | 3.10 | 3.20 |
| T2055-4                | 3.00 | 3.10 | 3.20 | 3.00 | 3.10 | 3.20 |
| T2055-5                | 3.15 | 3.25 | 3.35 | 3.15 | 3.25 | 3.35 |
| T2855-3                | 3.15 | 3.25 | 3.35 | 3.15 | 3.25 | 3.35 |
| T2855-4                | 2.60 | 2.70 | 2.80 | 2.60 | 2.70 | 2.80 |
| T2855-5                | 2.60 | 2.70 | 2.80 | 2.60 | 2.70 | 2.80 |
| T2855-6                | 3.15 | 3.25 | 3.35 | 3.15 | 3.25 | 3.35 |
| T2855-7                | 2.60 | 2.70 | 2.80 | 2.60 | 2.70 | 2.80 |
| T2855-8                | 3.15 | 3.25 | 3.35 | 3.15 | 3.25 | 3.35 |
| T2855N-1               | 3.15 | 3.25 | 3.35 | 3.15 | 3.25 | 3.35 |
| T3255-3                | 3.00 | 3.10 | 3.20 | 3.00 | 3.10 | 3.20 |
| T3255-4                | 3.00 | 3.10 | 3.20 | 3.00 | 3.10 | 3.20 |
| T3255-5                | 3.00 | 3.10 | 3.20 | 3.00 | 3.10 | 3.20 |
| T3255N-1               | 3.00 | 3.10 | 3.20 | 3.00 | 3.10 | 3.20 |
| T4055-1                | 3.40 | 3.50 | 3.60 | 3.40 | 3.50 | 3.60 |
| T4055-2                | 3.40 | 3.50 | 3.60 | 3.40 | 3.50 | 3.60 |

\*\*SEE COMMON DIMENSIONS TABLE

|                                                                                                                                                                            |                                 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------|
|   |                                 |
| TITLE: PACKAGE OUTLINE,<br>16, 20, 28, 32, 40L THIN QFN, 5x5x0.8mm                                                                                                         |                                 |
| APPROVAL                                                                                                                                                                   | DOCUMENT CONTROL NO.<br>21-0140 |
| REV. J                                                                                                                                                                     | 2/2                             |

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