

**2W STEREO AUDIO POWER AMPLIFIER WITH SHUTDOWN****AA4003****General Description**

The AA4003 is a Class AB stereo Audio Power Amplifier which can deliver 2.0W into 4Ω speakers with limitation of THD+N less than 1%. The chip is designed specially for Portable DVD player, Portable Media Player, LCD monitor and Digital Photo Frame applications.

AA4003 is available in package of SOIC-16 and TSSOP-20 (EDP).

**Features**

- Output Power,  
BTL: 2.0W/CH (4Ω, THD+N≤1%)  
SE: 160mW/CH (16Ω, THD+N≤1%)
- Supply Voltage Range: 2.7V to 5.5V
- External Feedback Loop for Flexible Gain Set-up
- Low Power Consumption at Shutdown Mode 0.7μA Typical
- SE, BTL Mode Switchable
- Optimized Click/POP Noise Suppression
- Thermal Shutdown Protection

**Applications**

- Portable DVD Player
- Portable Media Player
- LCD Monitor
- Digital Photo Frame

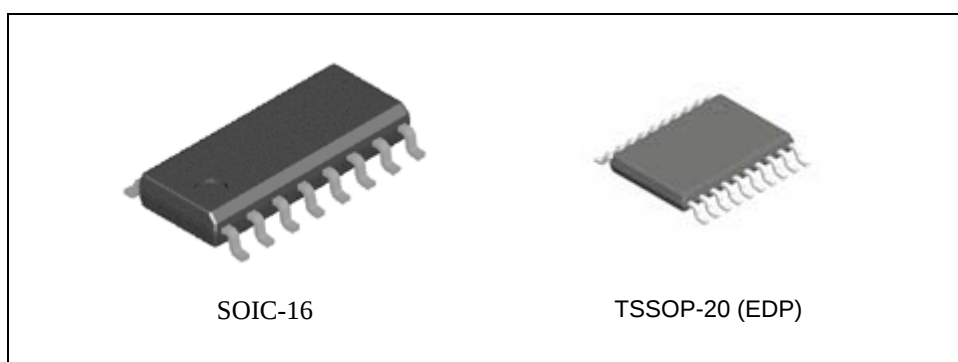


Figure 1. Packages Type of AA4003

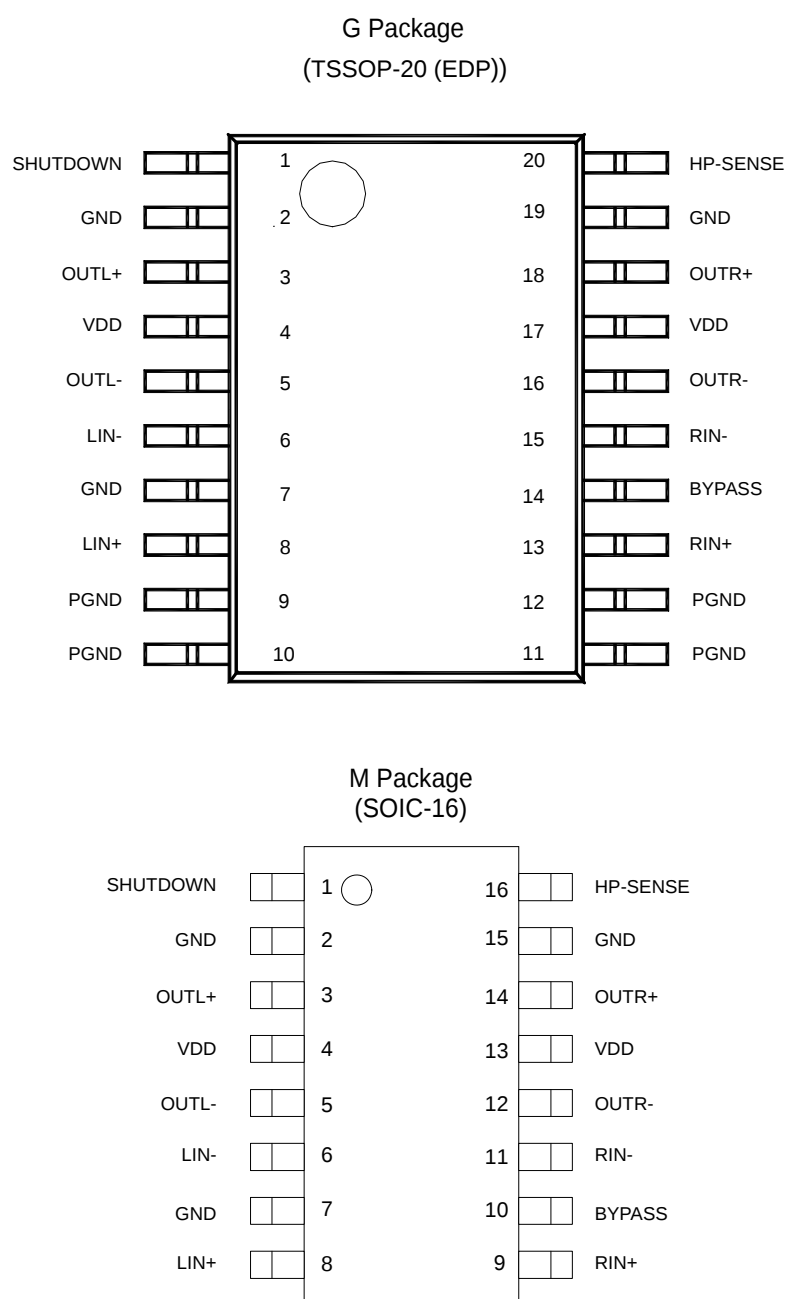
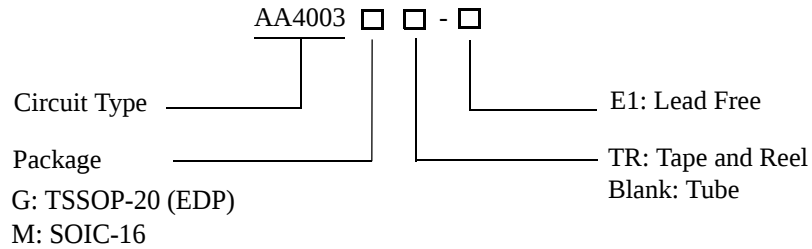
**2W STEREO AUDIO POWER AMPLIFIER WITH SHUTDOWN**
**AA4003**
**Pin Configuration**


Figure 2. Pin Configurations of AA4003 (Top View)

**2W STEREO AUDIO POWER AMPLIFIER WITH SHUTDOWN****AA4003****Pin Description**

| Pin Number    |           | Pin Name | Function                                                               |
|---------------|-----------|----------|------------------------------------------------------------------------|
| G Package     | M Package |          |                                                                        |
| 1             | 1         | SHUTDOWN | Shutdown mode enable pin, active High                                  |
| 2, 7, 19      | 2, 7, 15  | GND      | Signal ground                                                          |
| 3             | 3         | OUTL+    | Left channel positive output                                           |
| 4, 17         | 4, 13     | VDD      | Power supply pin                                                       |
| 5             | 5         | OUTL-    | Left channel negative output                                           |
| 6             | 6         | LIN-     | Left channel negative input                                            |
| 8             | 8         | LIN+     | Left channel positive input                                            |
| 9, 10, 11, 12 |           | PGND     | Power ground, used for thermal release                                 |
| 13            | 9         | RIN+     | Right channel positive input                                           |
| 14            | 10        | BYPASS   | Internal reference voltage pin, connect a 1.0 $\mu$ F capacitor to GND |
| 15            | 11        | RIN-     | Right channel negative input                                           |
| 16            | 12        | OUTR-    | Right channel negative output                                          |
| 18            | 14        | OUTR+    | Right channel positive output                                          |
| 20            | 16        | HP-SENSE | SE, BTL Mode switch pin,<br>L - BTL Mode<br>H - SE Mode                |

**2W STEREO AUDIO POWER AMPLIFIER WITH SHUTDOWN****AA4003****Ordering Information**

| Package        | Temperature Range | Part Number  | Marking ID | Packing Type |
|----------------|-------------------|--------------|------------|--------------|
| TSSOP-20 (EDP) | -40 to 85 °C      | AA4003G-E1   | AA4003G-E1 | Tube         |
|                |                   | AA4003GTR-E1 | AA4003G-E1 | Tape & Reel  |
| SOIC-16        | -40 to 85 °C      | AA4003M-E1   | AA4003M-E1 | Tube         |
|                |                   | AA4003MTR-E1 | AA4003M-E1 | Tape & Reel  |

BCD Semiconductor's Pb-free products, as designated with "E1" suffix in the part number, are RoHS compliant.

**2W STEREO AUDIO POWER AMPLIFIER WITH SHUTDOWN****AA4003****Absolute Maximum Ratings (Note 1)**

| Parameter                                       | Symbol          | Value                  |             | Unit                 |
|-------------------------------------------------|-----------------|------------------------|-------------|----------------------|
| Supply Voltage                                  | $V_{DD}$        | 6                      |             | V                    |
| Input Voltage                                   | $V_{IN}$        | -0.3 to $V_{DD} + 0.3$ |             | V                    |
| Power Dissipation                               | $P_D$           | Internally limited     |             |                      |
| Package Thermal Resistance                      | $R_{\theta JA}$ | M Package              | 90          | $^{\circ}\text{C/W}$ |
|                                                 |                 | G Package              | 50 (Note 2) |                      |
| Operating Junction Temperature                  | $T_J$           | 150                    |             | $^{\circ}\text{C}$   |
| Storage Temperature Range                       | $T_{STG}$       | -65 to 150             |             | $^{\circ}\text{C}$   |
| Lead Temperature 1.6mm from Case for 10 Seconds | $T_{LEAD}$      | 260                    |             | $^{\circ}\text{C}$   |
| ESD (Human Body Model)                          |                 | 2000                   |             | V                    |
| ESD (Machine Model)                             |                 | 300                    |             | V                    |

Note 1: Stresses greater than 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 operation is not implied. Exposure to "Absolute Maximum Ratings" for extended periods may affect device reliability.

Note 2: Chip is soldered to 200mm<sup>2</sup> copper (top side solder mask) of 1oz. on PCB with 8 x 0.5mm vias..

**Recommended Operating Conditions**

| Parameter                     | Symbol   | Min | Max | Unit               |
|-------------------------------|----------|-----|-----|--------------------|
| Supply Voltage                | $V_{DD}$ | 2.7 | 5.5 | V                  |
| Operating Ambient Temperature | $T_A$    | -40 | 85  | $^{\circ}\text{C}$ |

**2W STEREO AUDIO POWER AMPLIFIER WITH SHUTDOWN****AA4003****Electrical Characteristics**

( $V_{DD}=5V$ ,  $T_A=25^{\circ}C$ ,  $C_I=1\mu F$ ,  $C_{OUT}=220\mu F$  and  $R_I=R_F=20k\Omega$  unless otherwise specified. For SE Mode,  $HP\_SENSE=5V$ , for BTL Mode,  $HP\_SENSE=0V$ .)

| Parameter                         | Symbol     | Conditions                                                         | Min | Typ     | Max      | Unit        |
|-----------------------------------|------------|--------------------------------------------------------------------|-----|---------|----------|-------------|
| Quiescent Current                 | $I_{DD}$   | SE Mode, $V_{IN}=0$ , $I_O=0$                                      |     | 3       | 10       | mA          |
|                                   |            | BTL Mode, $V_{IN}=0$ , $I_O=0$                                     |     | 6       | 20       |             |
| Shutdown Current                  | $I_{SD}$   | $V_{SHUTDOWN}=5V$                                                  |     | 0.7     | 2.0      | $\mu A$     |
| HP_SENSE LOGIC                    | $V_{IH}$   |                                                                    | 4   |         |          | V           |
|                                   | $V_{IL}$   |                                                                    |     |         | 0.8      | V           |
| SHUTDOWN LOGIC                    | $V_{IH}$   |                                                                    | 3   |         |          | V           |
|                                   | $V_{IL}$   |                                                                    |     |         | 0.8      | V           |
| Thermal Shutdown Temperature      |            |                                                                    |     | 170     |          | $^{\circ}C$ |
| Hysteresis Temperature Window     |            |                                                                    |     | 25      |          | $^{\circ}C$ |
| <b>SE Mode</b>                    |            |                                                                    |     |         |          |             |
| Output Power                      | $P_O$      | THD+N=1%, $R_L=32\Omega$                                           |     | 80      |          | mW          |
|                                   |            | THD+N=10%, $R_L=32\Omega$                                          |     | 110     |          |             |
|                                   |            | THD+N=1%, $R_L=16\Omega$                                           |     | 160     |          |             |
|                                   |            | THD+N=10%, $R_L=16\Omega$                                          |     | 220     |          |             |
| Total Harmonic Distortion + Noise | THD+N      | $P_O=75mW$ , $R_L=32\Omega$ ,                                      |     | 0.2     |          | %           |
| Signal to Noise Ratio             | SNR        | $P_O=75mW$ , $R_L=32\Omega$ ,                                      |     | 90      |          | dB          |
| Crosstalk                         | $X_{TALK}$ | $P_O=75mW$ , $R_L=32\Omega$ , $f=1kHz$                             |     | -80     |          | dB          |
| Power Supply Rejection Ratio      | PSRR       | $C_b=1\mu F$ , $f=1kHz$ ,<br>$V_{RIPPLE}=0.2VRMS$ , $R_L=16\Omega$ |     | 60      |          | dB          |
| <b>BTL Mode</b>                   |            |                                                                    |     |         |          |             |
| Output Offset Voltage             | $V_{OS}$   | $V_{IN}=0V$ , No load                                              |     | $\pm 5$ | $\pm 50$ | mV          |
| Output Power                      | $P_O$      | THD+N=1%, $R_L=4\Omega$                                            |     | 2       |          | W           |
|                                   |            | THD+N=10%, $R_L=4\Omega$                                           |     | 2.5     |          |             |
|                                   |            | THD+N=1%, $R_L=8\Omega$                                            |     | 1.1     |          |             |
|                                   |            | THD+N=10%, $R_L=8\Omega$                                           |     | 1.5     |          |             |
| Total Harmonic Distortion + Noise | THD+N      | $P_O=1W$ , $R_L=4\Omega$ ,                                         |     | 0.1     |          | %           |
| Signal to Noise Ratio             | SNR        | $P_O=1W$ , $R_L=8\Omega$ ,                                         |     | 95      |          | dB          |
| Crosstalk                         | $X_{TALK}$ | $P_O=1W$ , $R_L=8\Omega$ , $f=1kHz$                                |     | -80     |          | dB          |
| Power Supply Rejection Ratio      | PSRR       | $C_b=1\mu F$ , $f=1kHz$ ,<br>$V_{RIPPLE}=0.2VRMS$ , $R_L=8\Omega$  |     | 67      |          | dB          |

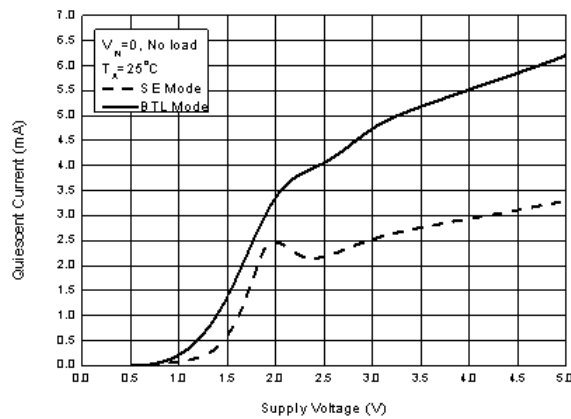
**Typical Performance Characteristics**

Figure 3. Quiescent Current vs. Supply Voltage

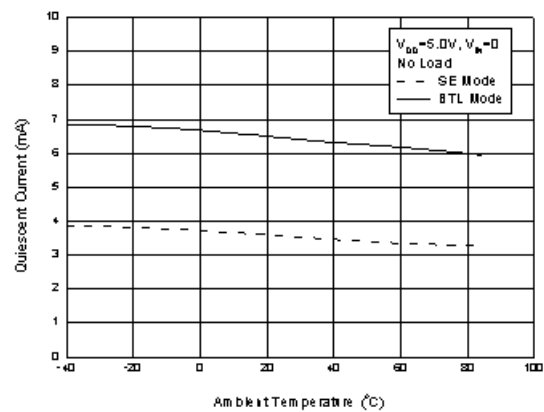
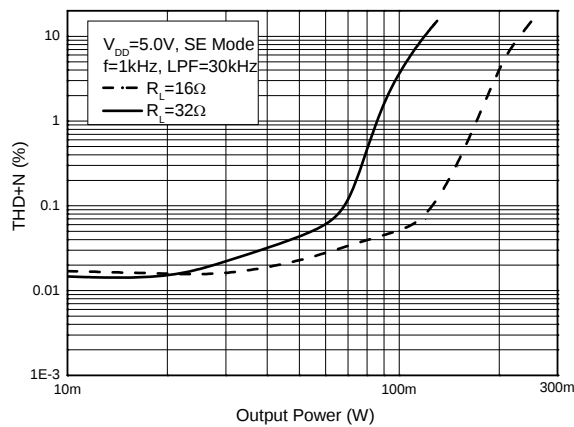
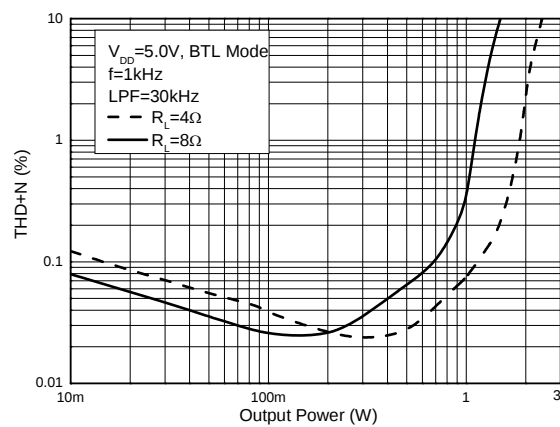
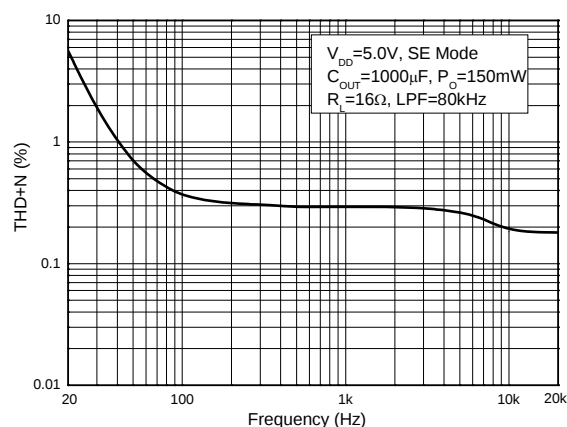
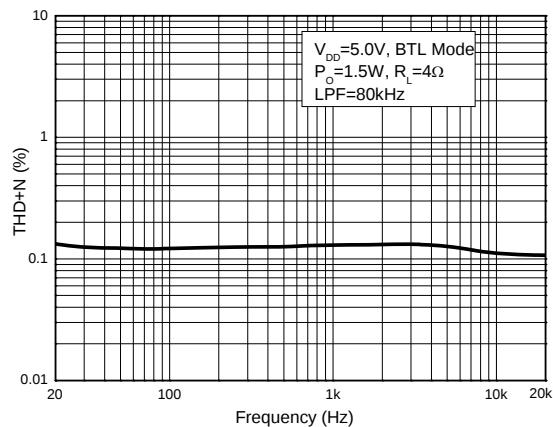
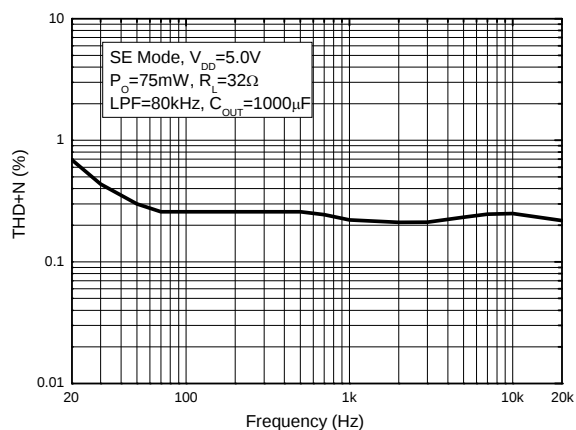
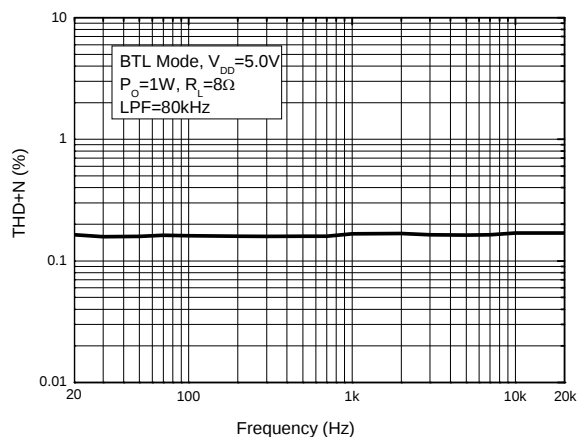
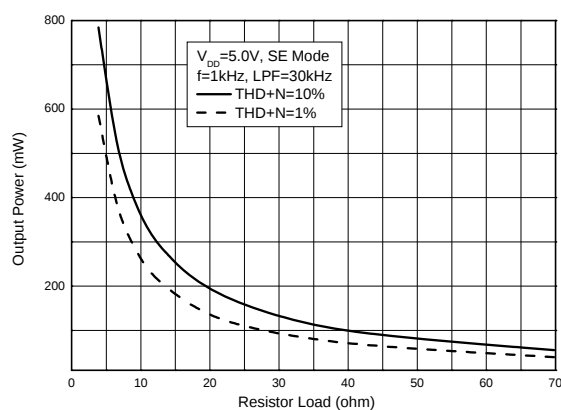
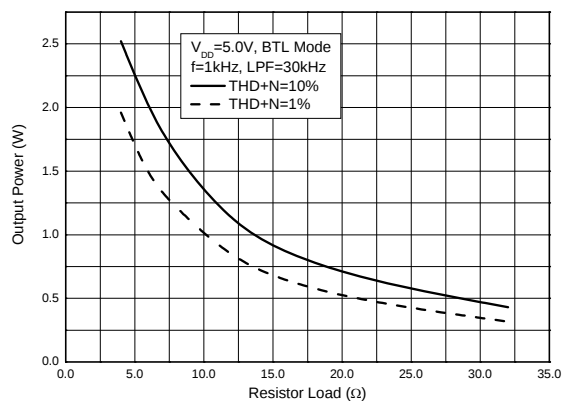
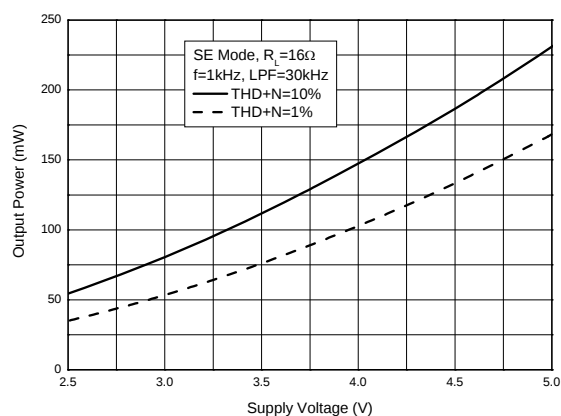
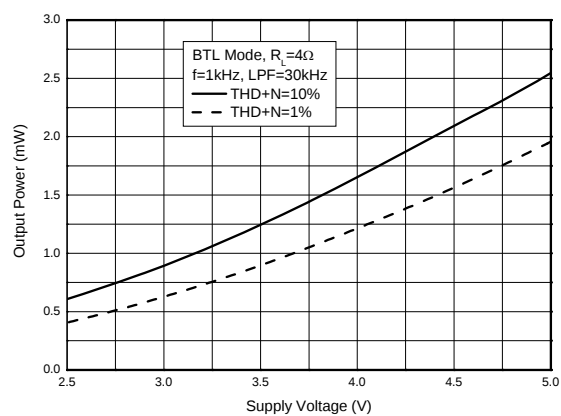


Figure 4. Quiescent Current vs. Ambient Temperature

Figure 5. THD+N vs. Output Power  
@ SE ModeFigure 6. THD+N vs. Output Power  
@ BTL Mode

**2W STEREO AUDIO POWER AMPLIFIER WITH SHUTDOWN****AA4003****Typical Performance Characteristics**Figure 7. THD+N vs. Output Power  
@ SE ModeFigure 8. THD+N vs. Output Power  
@ BTL ModeFigure 9. THD+N vs. Frequency  
@ SE ModeFigure 10. THD+N vs. Frequency  
@ BTL Mode

**2W STEREO AUDIO POWER AMPLIFIER WITH SHUTDOWN****AA4003****Typical Performance Characteristics (Continued)**Figure 11. Output Power vs. Resistor Load  
@ SE ModeFigure 12. Output Power vs. Resistor Load  
@ BTL ModeFigure 13. Output Power vs. Supply Voltage  
@ SE ModeFigure 14. Output Power vs. Supply Voltage  
@ BTL Mode

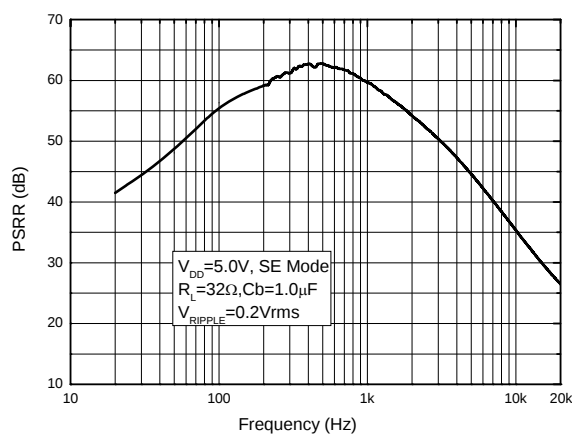
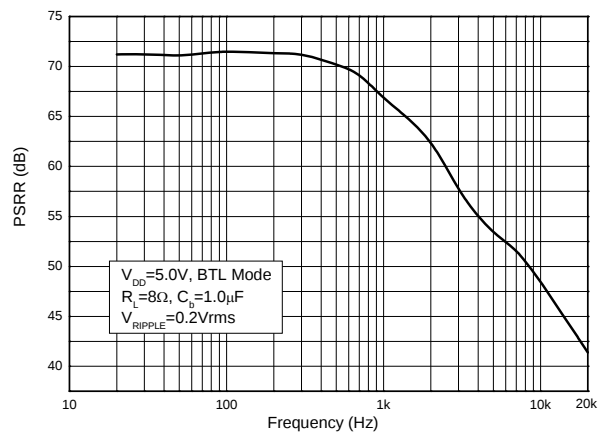
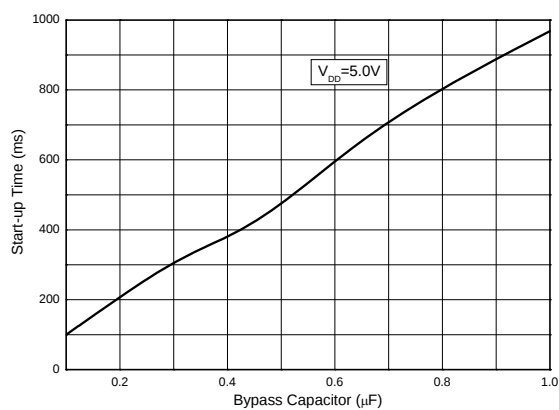
**Typical Performance Characteristics (Continued)**Figure 15. PSRR vs. Frequency  
@ SE ModeFigure 16. PSRR vs. Frequency  
@ BTL Mode

Figure 17. Start-up Time vs. Bypass Capacitor

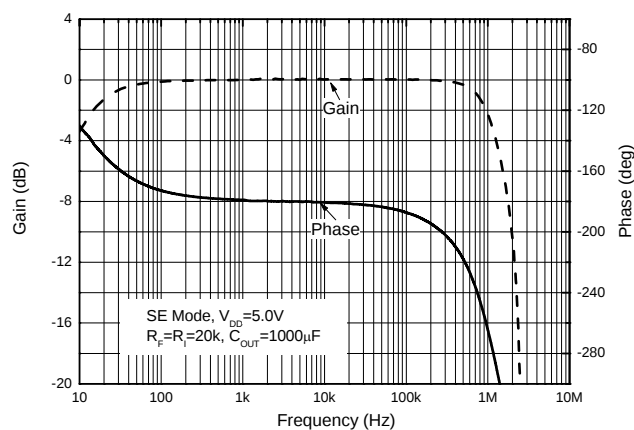


Figure 18. Closed Loop Frequency Response

**2W STEREO AUDIO POWER AMPLIFIER WITH SHUTDOWN****AA4003****Application Information****SE/BTL Mode, HP\_SENSE Pin**

The AA4003 can operate under 2 types of output configuration, BTL (Bridged-Tied-Load) mode and SE (Single-Ended) mode, determined by HP\_SENSE pin's logic level. (Here is the discussion about left channel only, it equally applies to right channel.)

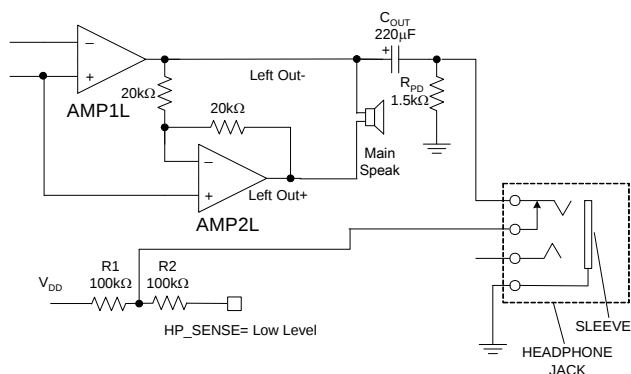


Figure 19. Output Configuration for Left Channel in BTL Mode

When HP\_SENSE pin is held low which sets the chip in BTL mode, the AMP2L unit is turned on. AMP2L has fixed unity gain internally, AC signal at OUT+ is 180 degree phase shifted from OUT-. Because the DC component (Output Bias voltage, approx  $1/2 V_{DD}$ ) between OUT+ and OUT- is canceled, there is no necessity to use DC block capacitors for main speak. In BTL mode, output voltage swing across main speaker is about 2 times that in SE mode, so there is 4 times output power compared to SE mode with same load and input. (see Figure 19)

If applying high level to HP\_SENSE pin which sets the chip in SE mode, the AMP2L unit is in high impedance state. There is no current loop between OUT+ and OUT-, the main speak is naturally disabled without any hardware change. The output audio signal rides on bias voltage at OUT- (Output Bias voltage, approx  $1/2 V_{DD}$ ), so it has to use a capacitor  $C_{OUT}$  to block DC bias and couple AC signal to headphone speak. (See Figure 20)

It is recommended to connect HP\_SENSE to the headphone jack switch pin illustrated in Figure 19.

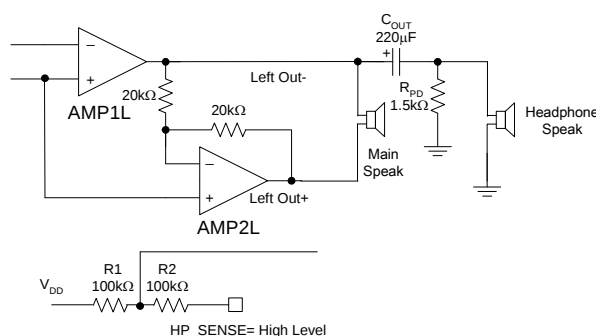


Figure 20. Output Configuration for Left Channel in SE Mode

When headphone plug is not inserted, the voltage of HP\_SENSE pin is determined by voltage divider formed by R1 and  $R_{PD}$ . For given resistor's value in Figure 19,  $R1=100k\Omega$ ,  $R_{PD}=1.5k\Omega$ , DC voltage at HP\_SENSE is about 74mV. AC signal equals output amplitude of OUT- through  $C_{OUT}$ , so signal at HP\_SENSE node is 74mV DC plus AC signal. The maximum peak-to-peak voltage at OUT- is no greater than  $V_{DD}$  (supply voltage 5.0V), so the positive maximum voltage of HP\_SENSE node will be no greater than  $2.5V+75mV \approx 2.575V$ , which is less than HP\_SENSE input high level minimum value (4.0V). That means the chip is in BTL mode and there is no risk of operation mode switch between SE and BTL. When headphone plug is inserted, as the  $R_{PD}$  is disconnected from R1, the voltage of HP\_SENSE pin is pulled up by R1 to  $V_{DD}$  and sets the chip in SE mode.

HP\_SENSE pin can also be connected to MCU I/O port to control the mode switch through MCU.

It is necessary to note that AA4003 still can drive headphone even in BTL mode because OUT- is always active whatever the chip is in SE or BTL mode.

 **$C_{IN}$ ,  $C_{OUT}$ ,  $C_b$  and  $C_s$  (Power Supply) Selection**

For input stages of AA4003, input capacitors  $C_I$  is used to accommodate different DC level between input source and AA4003 bias voltage (about 2.31V). Input capacitors  $C_I$  and input resistors  $R_I$  form a first order High Pass Filter, which determines the lower corner frequency according to the classic equation below,

**2W STEREO AUDIO POWER AMPLIFIER WITH SHUTDOWN****AA4003****Application Information (Continued)**

$$f_{CIL} = \frac{1}{2\pi R_I * C_I} \dots\dots\dots(1)$$

Similarly, for output stage in SE mode, output capacitor ( $C_{OUT}$ ), and headphone load also form a first order High Pass Filters, and its cut-off frequency is determined by equation 2.

$$f_{COL} = \frac{1}{2\pi R_{HP} * C_{OUT}} \dots\dots\dots(2)$$

The purpose of bypass capacitor ( $C_b$ ) is to filter internal noise, reduce harmonic distortion, and improve power supply rejection ratio performance. Tantalum or ceramic capacitor with low ESR is recommended, and it should be placed as close as possible to the chip in PCB layout. The chip will not work until internal DC bias is set up completely. So the size of  $C_b$  will also affect the chip start up time, which is approx linearly proportional to the value of bypass capacitor. For AA4003, here are various start-up times for several typical capacitor values. (see Figure 17)

| <b><math>C_b</math> (<math>\mu F</math>)</b> | <b>Start up Time (ms)</b> |
|----------------------------------------------|---------------------------|
| 0.33                                         | 340                       |
| 0.47                                         | 420                       |
| 1.0                                          | 970                       |

For AA4003 power supply, it is better to use an individual power source generated from voltage regulator split from video, digital circuit units in system. The power supply bypass capacitors,  $C_S$ , is recommended to use one low ESR electrolytic capacitor between 4.7 $\mu F$  to 10 $\mu F$  with a parallel 0.1 $\mu F$  ceramic capacitor which is located close to the chip.

**Setup Proper Gain, Design Example**

The closed loop gain of AA4003 is determined by the ratio of feedback resistor ( $R_F$ ) to input resistor ( $R_I$ ).

$$A_V = \frac{R_F}{R_I} \dots\dots\dots(3)$$

**Example:**

$V_{DD}=5V$ ,  $R_L=8\Omega$ , BTL configuration, Desired output power  $P_O=1.0W$  (each channel),  $THD+N \leq 1\%$ . Input signal,  $V_{IN}=1.0VRMS$  from D-A converter.

**Step 1,**

To check if the chip can deliver 1W to 8 $\Omega$  load with the limitation of  $THD+N \leq 1\%$ ,  $V_{DD}=5V$ . From Figure 6, Figure 12, AA4003 can deliver 1W to 8 $\Omega$  load each channel.

**Step 2,**

If yes, to calculate output voltage,

$$V_{OUT} = \sqrt{P_O * R_L} = \sqrt{1 * 8} = 2.83V_{RMS}$$

So pass-band gain,  $AV=V_{OUT}/V_{IN}=2.83x$ .

**Step 3,**

Assuming input resistor is 20k $\Omega$ , the feedback resistor=20k $\Omega$ \*1.415=28.3k $\Omega$ . Select the closest standard value 28k $\Omega$ .

**Shutdown**

AA4003 has a shutdown feature to reduce power consumption. If apply high level to shutdown pin, output amplifiers will be turned off, bias circuit is also disabled, the maximum current drawn from  $V_{DD}$  is less than 2.0 $\mu A$ . A logic low level will enable the device.

**Optimizing CLICK/POP Noise**

The AA4003 includes optimized circuits to suppress CLICK/POP noise during power up/power down transition.

In BTL mode the AA4003 can effectively reduce most common mode signal including CLICK/POP noise.

In SE mode, optimized ramp for rise/fall edge of BIAS can significantly reduce click/pop noise due to charge and/or discharge output capacitor ( $C_{OUT}$ ). Furthermore, increasing bypass capacitor value ( $C_b$ ) can slower ramp of charging bypass capacitor, prolong start-up time, mask most of transient noises before bias voltage is set up completely. It is recommended to use 1.0 $\mu F$  capacitor with lower ESR.

**2W STEREO AUDIO POWER AMPLIFIER WITH SHUTDOWN****AA4003****Application Information (Continued)****Power Dissipation, Efficiency and Thermal Design Consideration**

For Class AB amplifiers, Formula 4 is the basic equation of efficiency worked in BTL configuration,

$$\eta = \frac{\pi V_P}{4V_{DD}} \dots\dots\dots(4)$$

here  $V_P$  is output peak voltage across the load.

Thermal dissipation becomes major concern when delivering more output power especially in BTL mode. The maximum power dissipation can be calculated by following equation.

$$P_{DMAX} = \frac{T_{JMAX} - T_A}{\theta_{JA}} \dots\dots\dots(5)$$

Here  $T_{JMAX}$  is maximum operating junction temperature, 150°C,  $T_A$  is ambient temperature,  $\theta_{JA}$  is thermal resistance from junction to ambient, which is 50°C/W for TSSOP-20 (EDP), given in datasheet.

Assuming  $T_A$  is 25°C, the maximum power dissipation  $P_{DMAX}$  is about 2.5W according to formula 6.

There is an other formula about power dissipation which is determined by supply voltage and load resistance.

$$P_{DBTLMAX} = \frac{2V_{DD}^2}{\pi^2 R_L} \dots\dots\dots(6)$$

If power dissipation calculated in an application is larger than that package permitted, there will be a need to assemble an additional heat sink, or keep ambient temperature around the chip low, or increase load resistance, or decrease power supply voltage.

Here is an example. Assuming  $V_{DD}=5.0V$ ,  $R_L=4\Omega$ , stereo in BTL mode,

$$P_{DBTLMAX} = \frac{2V_{DD}^2}{\pi^2 R_L} = \frac{2 \times 5^2}{3.14^2 \times 4} = 1.266W$$

per channel, total power dissipation  $P_{DTOTAL}=2*P_{DBTLMAX}=2.53W$ . According to formula 6, maximum ambient temperature is,

$$T_A = T_{JMAX} - \theta_{JA} * P_{DBTLMAX} = 150 - 50 * 2.53 = 23.5 \text{ } ^\circ C$$

That is to say, if user wants AA4003 to delivery 2W power per channel to 4Ω load at  $V_{DD}=5.0V$ , BTL mode, ambient temperature has to hold lower than 23.5°C. When junction temperature exceeds about 170°C, OTSD feature will be enabled, and shutdown the device to limit total power dissipation.

There is an exposed thermal pad on bottom of the chip to provide the direct thermal path from die to heat sink. It is recommended to use copper on the surface of Printed Circuit Board as heat sink. To dig some matrix regular holes under chip, remove mask of this area copper, and make sure to keep them contact well when soldering on PCB are also recommended. (See Figure 21)

**Recommended PCB Layout for AA4003**

Using wide traces for power supply to reduce power losses caused by parasitic resistance in all outputs is useful to help releasing heat away from the chip. It is recommended to place bypass capacitor, power supply bypass capacitors as close as possible to the chip. Figure 21 and Figure 22 show the recommended layout for double layer PCB.

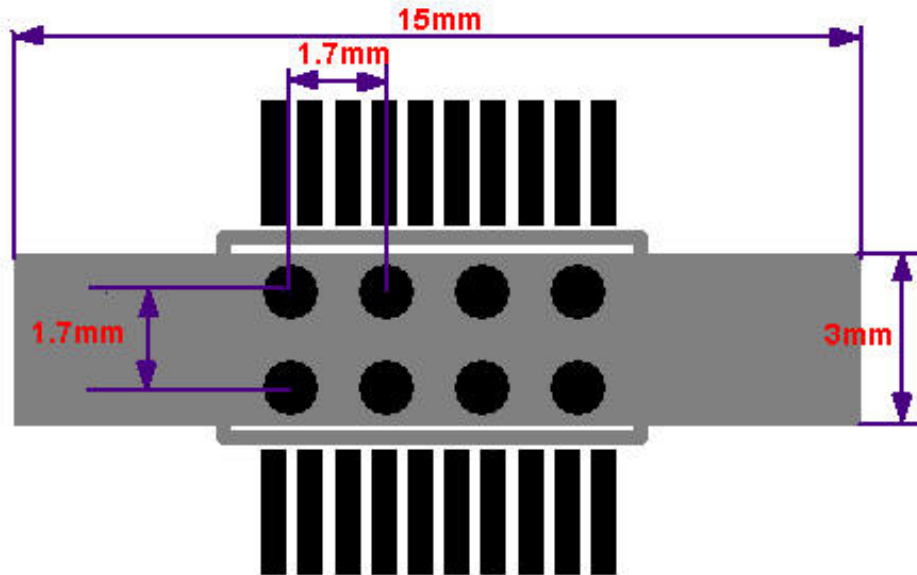
**Application Information (Continued)**


Figure 21. Copper and Holes under Part

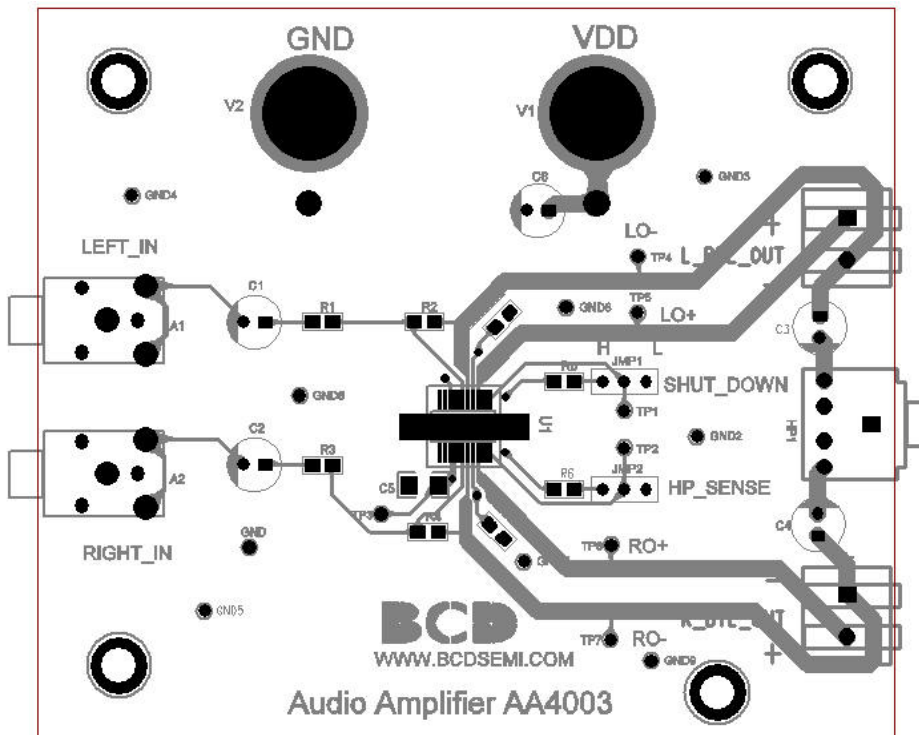


Figure 22. Top Route and Silk Screens

# 2W STEREO AUDIO POWER AMPLIFIER WITH SHUTDOWN

AA4003

## Typical Application

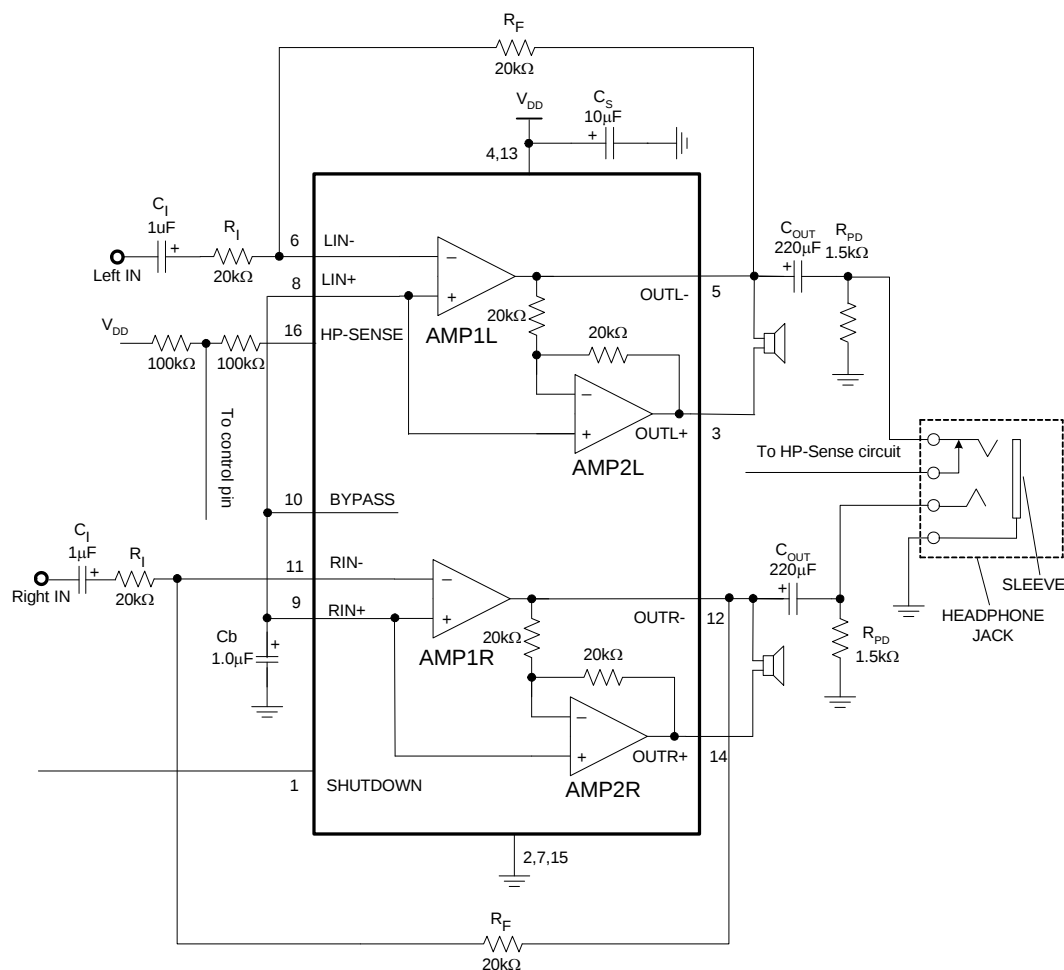
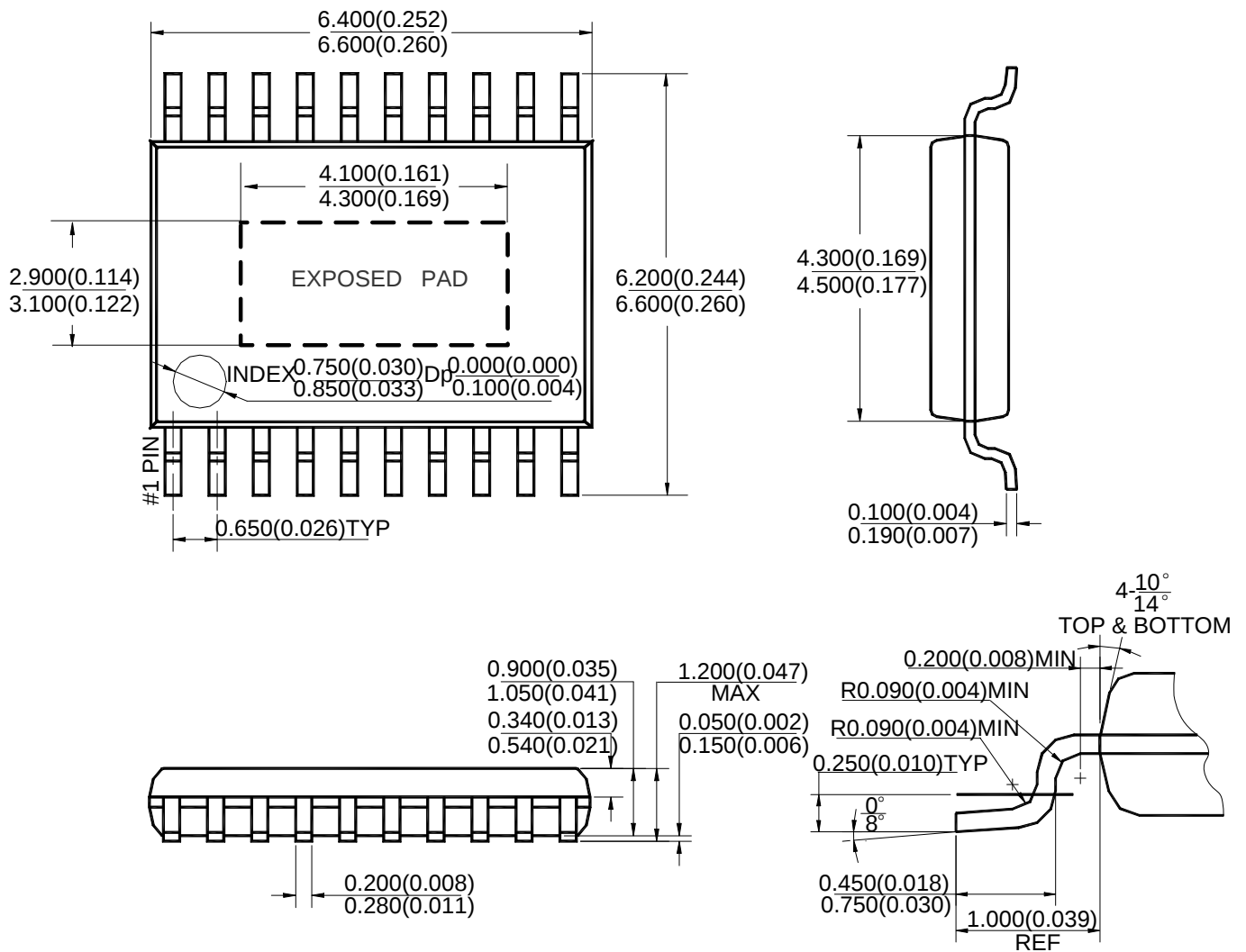


Figure 23. Typical Application Circuit of AA4003 (M Package)

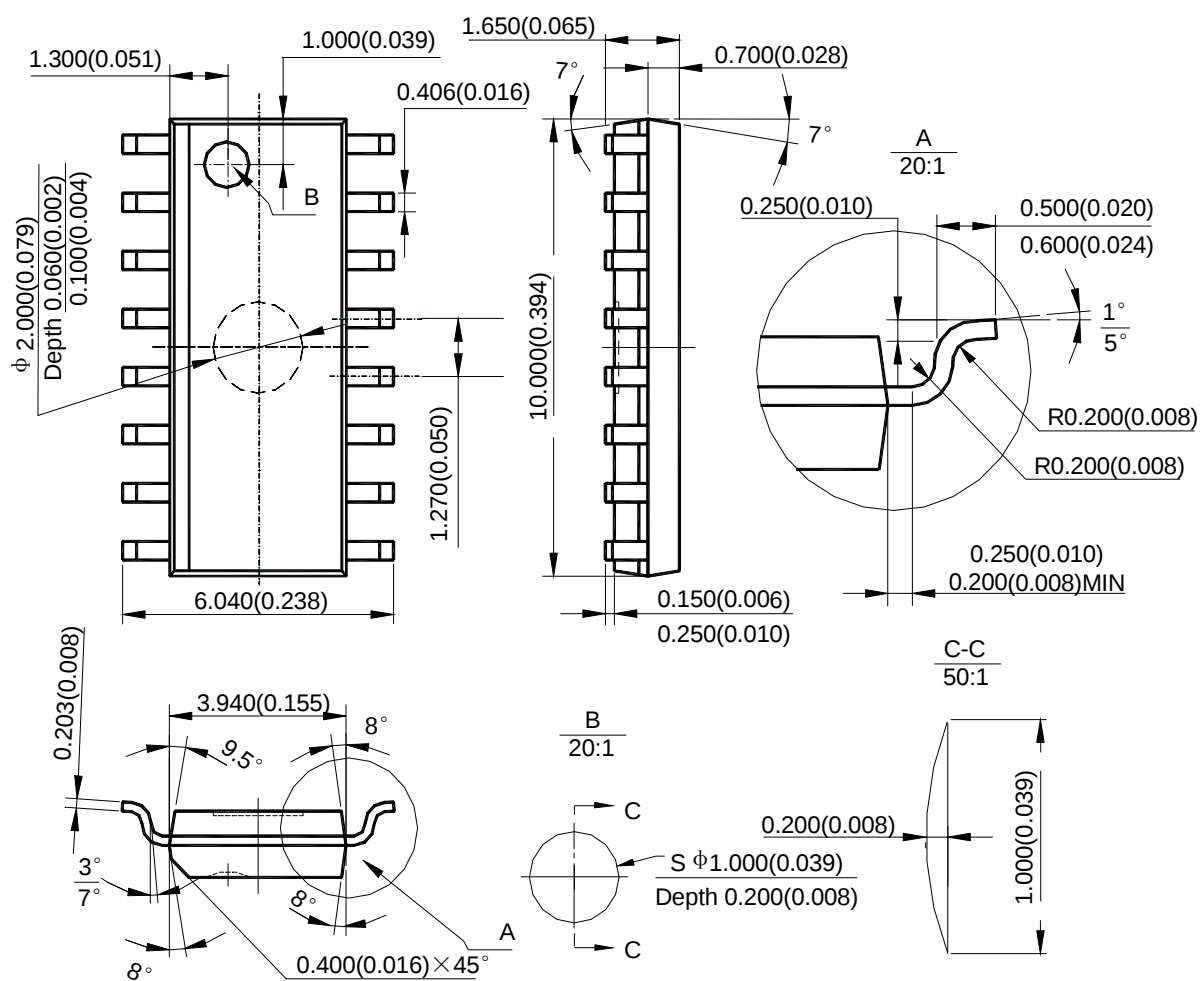
**2W STEREO AUDIO POWER AMPLIFIER WITH SHUTDOWN****AA4003****Mechanical Dimensions****TSSOP-20(EDP)****Unit: mm(inch)**



## AA4003

**SOIC-16**

Unit: mm(inch)





## **BCD Semiconductor Manufacturing Limited**

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