# 2.5W Stereo Class-D Audio Power Amplifier (with DC Volume Control)

## Features

- **Operating Voltage: 3.3V-5.5V**
- **High Efficiency 85% at $P_O$=2.5W, 4Ω Speaker, $V_{DD}$=5V**
- **Filter-Free Class-D Amplifier**
- **Low Shutdown Current**
  **- $I_{DD}$=1μA at $V_{DD}$=5V**
- **64 Steps Volume Adjustable from -80dB to +20dB by DC Voltage with Hysteresis**
- **Output Power at THD+N=1%**
  **- 2.5W at $V_{DD}$=5V, $R_L$=4Ω**
- **Less External Components Required**
- **Internal AGC Function**
- **Input signal and output signal in phase**
- **Thermal and Over-Current Protections with Auto-Recovery**
- **Lead Free and Green Device Available (RoHS Compliant)**
- **Power Enhanced Packages SOP-16 and QFN4x4-20A**

## Applications

- **LCD TVs**
- **DVD Player**
- **Active Speakers**

## General Description

The APA2603B is a stereo, high efficiency, filter-free Class-D audio amplifier available in a SOP-16, QFN4x4-20A package.

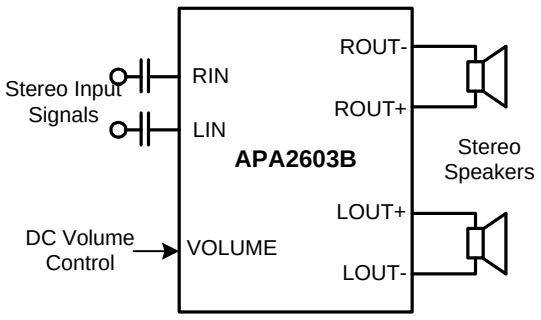
The APA2603B provide the precise DC volume control, the gain range is from -80dB ($V_{VOLUME}$=5V) to +20dB ($V_{VOLUME}$=0V) with 64 steps precise control. It's easy to get the suitable amplifier's gain with the 64 steps gain setting. The filter-free architecture eliminates the output filters compared to the traditional Class-D audio amplifier, and reduces the external component counts and the components high, it could save the PCB space, system cost, simplifies the design and the power loss at filter.

APA2603B provides an internal AGC (Non-Clip) function, and this function can low down the dynamic range for large input signal. APA2603B can provide from 20dB to -80dB with 64 steps gain decrease for non-clipping function, and this function can avoid output signal clipping.

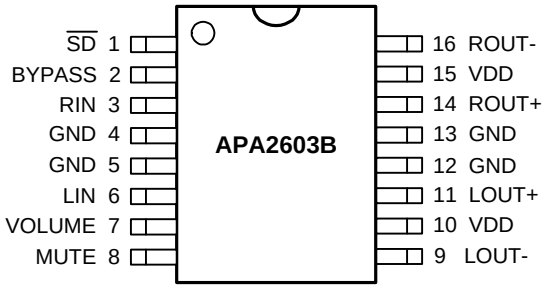
The APA2603B also integrates the de-pop circuitry that reduces the pops and click noises during power on/off or shutdown enable process.

The APA2603B has build-in over-current and thermal protection that prevent the chip being destroyed by short circuit or over temperature situation.

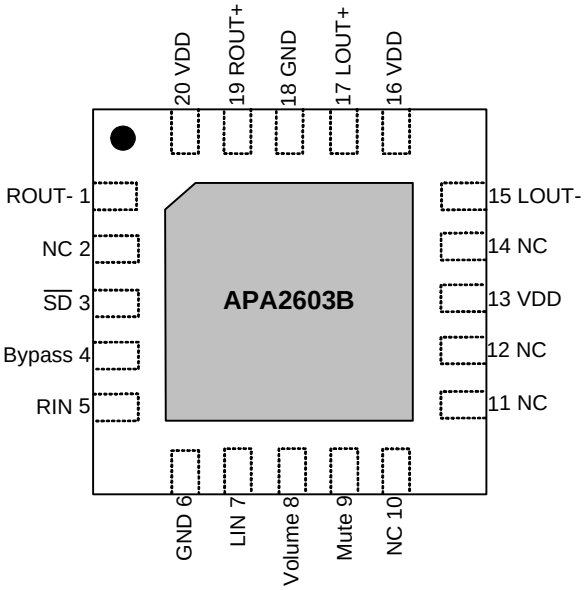
## Simplified Application Circuit



## Pin Configuration




**SOP-16**
**(Top View)**




**QFN4x4-20A**
**(Top View)**

## Ordering and Marking Information

| | |
|---|---|
| APA2603B □□-□□□<br>Lead Free Code<br>Handling Code<br>Temperature Range<br>Package Code | Package Code<br>K : SOP-16 QA : QFN4x4-20A<br>Operating Ambient Temperature Range<br>I : -40 to 85°C<br>Handling Code<br>TR : Tape & Reel<br>Lead Free Code<br>G : Halogen and Lead Free Device |
| APA2603B K :  | XXXXX - Date Code |
| APA2603B QA :  | XXXXX - Date Code |





Note : ANPEC lead-free products contain molding compounds/die attach materials and 100% matte tin plate termination finish; which are fully compliant with RoHS. ANPEC lead-free products meet or exceed the lead-free requirements of IPC/JEDEC J-STD-020D for MSL classification at lead-free peak reflow temperature. ANPEC defines “Green” to mean lead-free (RoHS compliant) and halogen free (Br or Cl does not exceed 900ppm by weight in homogeneous material and total of Br and Cl does not exceed 1500ppm by weight).

## Absolute Maximum Ratings (Note 1)

| Symbol | Parameter | Rating | Unit |
|---|---|---|---|
| $V_{DD}$ | Supply Voltage (VDD to GND) | -0.3 to 6.5 | V |
| | Input Voltage (LINN, RINN to GND) | -0.3 to $V_{DD}$+0.3 | |
| | Input Voltage ($\overline{SD}$, MUTE, VOLUME and BYPASS to GND) | -0.3 to $V_{DD}$+0.3 | |
| $T_J$ | Maximum Junction Temperature | 150 | °C |
| $T_{STG}$ | Storage Temperature Range | -65 to +150 | |
| $T_{SDR}$ | Maximum Soldering Temperature Range, 10 Seconds | 260 | |
| $P_D$ | Power Dissipation | Internally Limited | W |

Note1: 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 under" recommended operating conditions" is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## Thermal Characteristics

| Symbol | Parameter | Typical Value | Unit |
|---|---|---|---|
| $\theta_{JA}$ | Thermal Resistance -Junction to Ambient (Note 2)<br>SOP-16<br>QFN4x4-20A | <br>80<br>45 | °C/W |
| $\theta_{JC}$ | Thermal Resistance -Junction to Case (Note 3)<br>SOP-16<br>QFN4x4-20A | <br>16<br>7 | °C/W |

Note 2: Please refer to " Layout Recommendation", the PGND PIN on the central of the IC should connect to the ground plan, and the PCB is a 2-layer, 5-inch square area with 2oz copper thickness.

Note 3: The case temperature is measured at the center of the PGND PIN on the underside of the SOP-16 package.

## Recommended Operating Conditions

| Symbol | Parameter | | Range | | Unit |
|---|---|---|---|---|---|
| | | | Min | Max | |
| $V_{DD}$ | Supply Voltage | | 3.3 | 5.5 | V |
| $V_{IH}$ | High Level Threshold Voltage | $\overline{SD}$, MUTE | 2 | $V_{DD}$ | |
| $V_{IL}$ | Low Level Threshold Voltage | $\overline{SD}$, MUTE | 0 | 0.8 | |
| $V_{ICM}$ | Common Mode Input Voltage | | 1 | $V_{DD}$-1 | V |
| $T_A$ | Ambient Temperature Range | | -40 | 85 | °C |
| $T_J$ | Junction Temperature Range | | -40 | 125 | |
| $R_L$ | Speaker Resistance | | 3.5 | - | Ω |

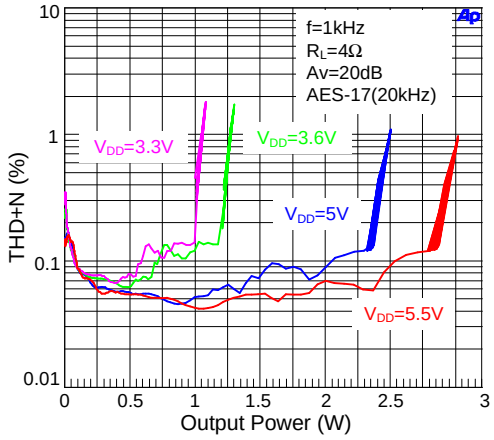
## Electrical Characteristics

$V_{DD}$=5V, $V_{GND}$=0V, $T_A$= 25°C, (unless otherwise noted)

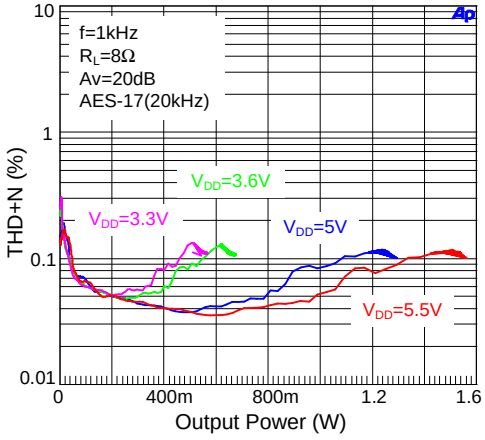
| Symbol | Parameter | Test Conditions | | APA2603B | | | Unit |
|---|---|---|---|---|---|---|---|
| | | | | Min. | Typ. | Max. | |
| $I_{DD}$ | Supply Current | $V_{MUTE}$=0V, $V_{/SD}$=5V, No Load | | - | 8 | 20 | mA |
| $I_{MUTE}$ | Supply Current (Mute Mode) | $V_{MUTE}$=5V, $V_{/SD}$=5V, No Load | | - | 8 | 20 | |
| $I_{SD}$ | Supply Current (SD Mode) | $V_{MUTE}$=0V, $V_{/SD}$=0V, No Load | | - | - | 1 | µA |
| $I_i$ | Input Current | SD, MUTE, VOLUME | | - | - | 1 | |
| $F_{OSC}$ | Oscillator Frequency | | | 400 | 500 | 600 | kHz |
| $R_{DSON}$ | Static Drain-Source On-State Resistance | $V_{DD}$=5.5V, $I_L$=0.8A | P-channel Power MOSFET | 215 | 270 | 325 | mΩ |
| | | | N-channel Power MOSFET | 205 | 260 | 310 | |
| | | $V_{DD}$=4.5V, $I_L$=0.6A | P-channel Power MOSFET | 225 | 285 | 340 | |
| | | | N-channel Power MOSFET | 215 | 270 | 325 | |
| | | $V_{DD}$=3.6V, $I_L$=0.4A | P-channel Power MOSFET | 240 | 300 | 360 | |
| | | | N-channel Power MOSFET | 220 | 280 | 335 | |
| $T_{START-UP}$ | Start-Up Time from Shutdown | Bypass Capacitor, $C_B$=2.2µF. | | - | 1.2 | 2 | s |
| **$V_{DD}$=5V, $T_A$=25°C, GAIN=20dB** | | | | | | | |
| $P_O$ | Output Power | THD+N=1% $f_{in}$=1kHz | $R_L$=4Ω | 2.2 | 2.4 | - | W |
| THD+N | Total Harmonic Distortion Plus Noise | $f_{in}$=1kHz | $R_L$=4Ω, $P_O$=1.7W | - | 0.1 | 0.3 | % |
| | | | $R_L$=8Ω, $P_O$=1W | - | 0.08 | 0.2 | |
| Crosstalk | Channel Separation | $P_O$=0.24W, $R_L$=4Ω, $f_{in}$=1kHz | | - | -90 | -60 | dB |
| PSRR | Power Supply Rejection Ratio | $R_L$=4Ω, Input AC-Ground | $f_{in}$=100Hz | - | -60 | -50 | |
| | | | $f_{in}$=1kHz | - | -70 | -60 | |
| SNR | Signal to Noise Ratio | With A-weighting Filter $V_O$=0.96W, $R_L$=8Ω | | 80 | 85 | - | |
| $Att_{Mute}$ | Mute Attenuation | $f_{in}$=1kHz, $R_L$=8Ω, $V_{in}$=1Vrms | | - | -100 | -80 | |
| $Att_{shutdown}$ | Shutdown Attenuation | $f_{in}$=1kHz, $R_L$=8Ω, $V_{in}$=1Vrms | | - | -120 | -90 | |
| $V_n$ | Output Noise | With A-weighting Filter (Gain=20dB), AC=GND | | - | 75 | 100 | µVrms |
| $V_{OS}$ | Output Offset Voltage | $R_L$=4Ω, Gain=20dB | | - | 10 | 30 | mV |
| **$V_{DD}$=3.6V, $T_A$=25°C, GAIN=20dB** | | | | | | | |
| $P_O$ | Output Power | THD+N=1% $f_{in}$=1kHz | $R_L$=4Ω | - | 1.1 | - | W |
| Crosstalk | Channel Separation | $P_O$=0.12W, $R_L$=4Ω, $f_{in}$=1kHz | | - | -90 | -60 | |
| PSRR | Power Supply Rejection Ratio | $R_L$=4Ω, Input AC-Ground | $f_{in}$=100Hz | - | -60 | -50 | |
| | | | $f_{in}$=1kHz | - | -70 | -60 | |
| SNR | Signal to Noise Ratio | With A-weighting Filter $P_O$ = 0.96W, $R_L$ = 8Ω | | 80 | 85 | - | |
| $Att_{Mute}$ | Mute Attenuation | $f_{in}$=1kHz, $R_L$=8Ω, $V_{in}$=1$V_{rms}$ | | - | -100 | -80 | |
| $Att_{shutdown}$ | Shutdown Attenuation | $f_{in}$=1kHz, $R_L$=8Ω, $V_{in}$=1$V_{rms}$ | | - | -120 | -90 | |
| $V_n$ | Output Noise | With A-weighting Filter (Gain=20dB), AC=GND | | - | 75 | 100 | µVrms |
| $V_{OS}$ | Output Offset Voltage | $R_L$=4Ω, Gain=20dB | | - | 10 | 30 | mV |

## Typical Operating Characteristics

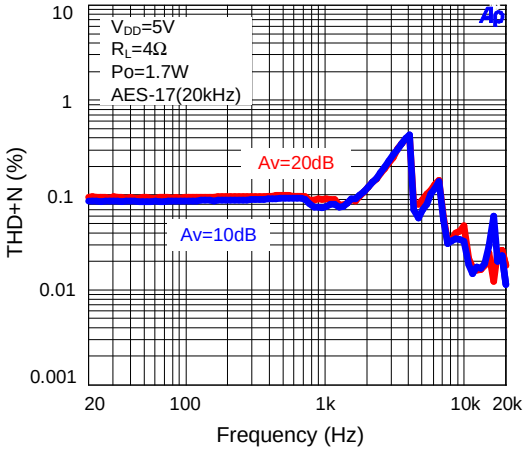
THD+N vs. Output Power



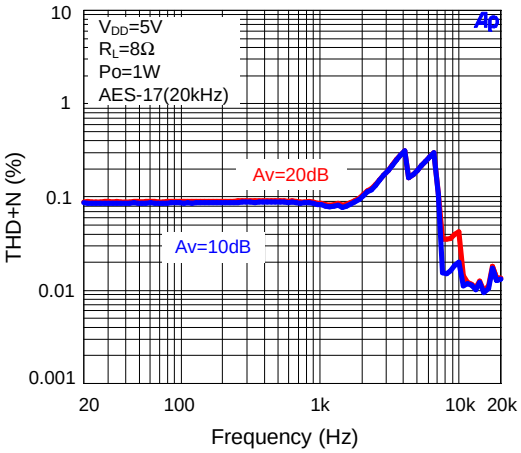

THD+N vs. Output Power



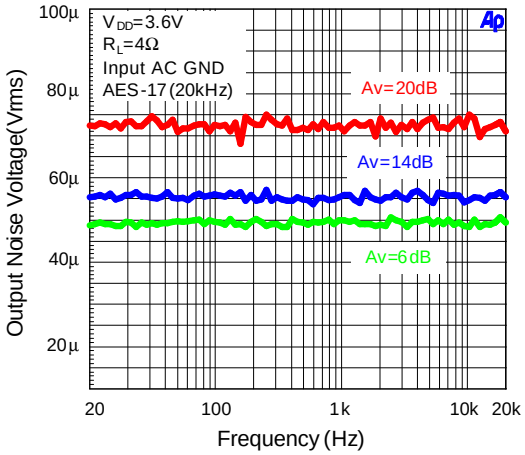

THD+N vs. Frequency



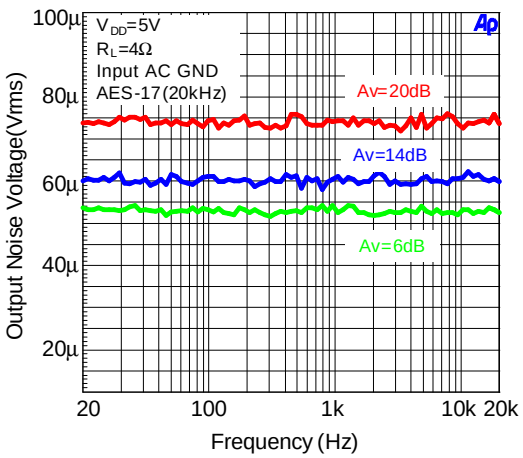

THD+N vs. Frequency




Output Noise Voltage vs. Frequency

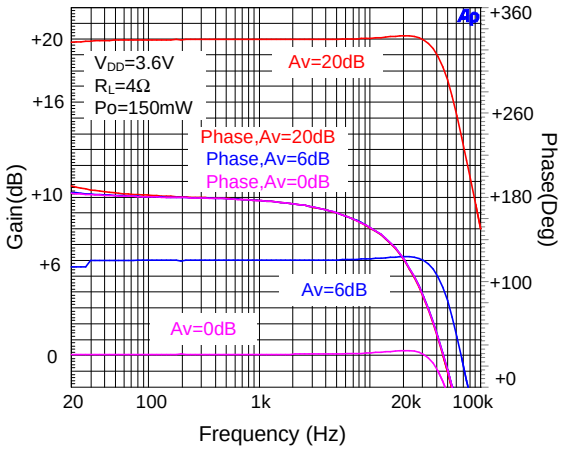



Output Noise Voltage vs. Frequency

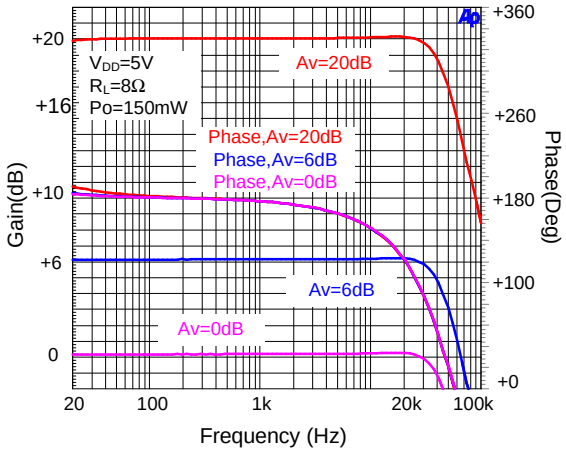


## Typical Operating Characteristics

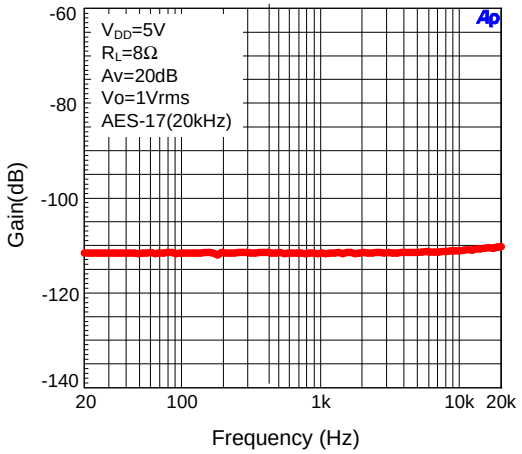
### Frequence Response



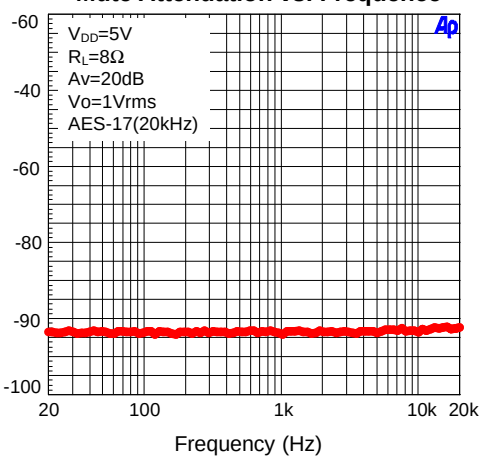

### Frequence Response



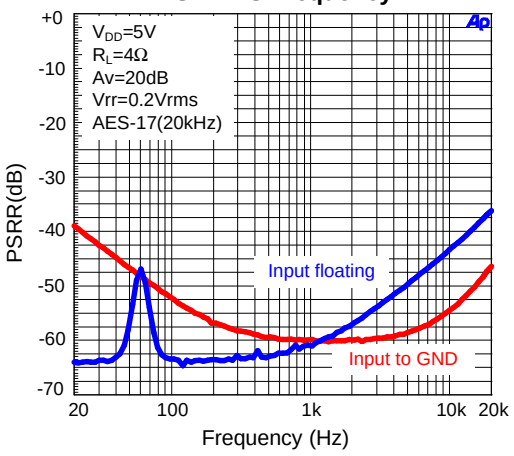

### Shutdown Attenuation vs. Frequence



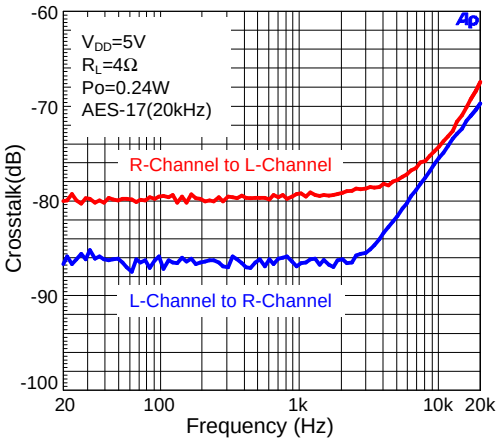

### Mute Attenuation vs. Frequence




### PSRR VS Frequency

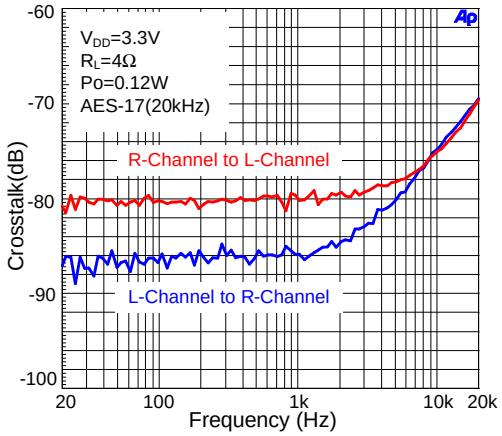



### Crosstalk vs. Frequency

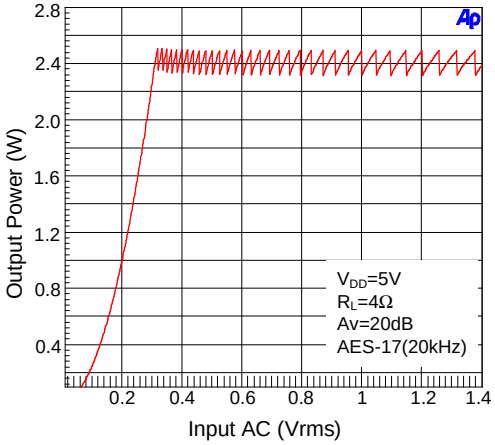


## Typical Operating Characteristics

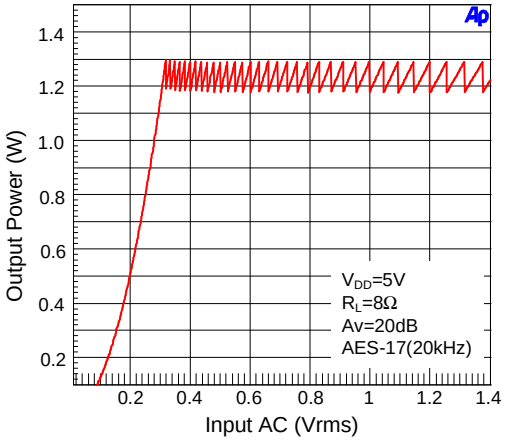
### Crosstalk vs. Frequency



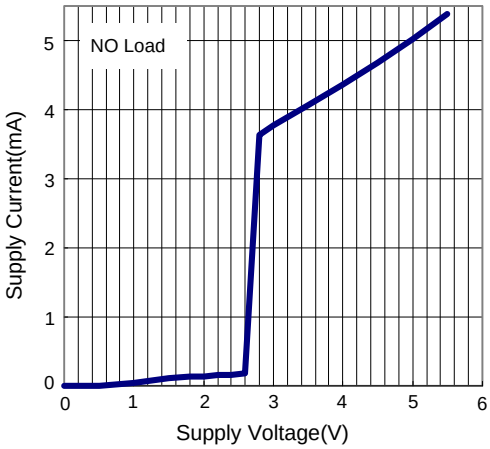

### AGC Function Output Power vs. Input AC



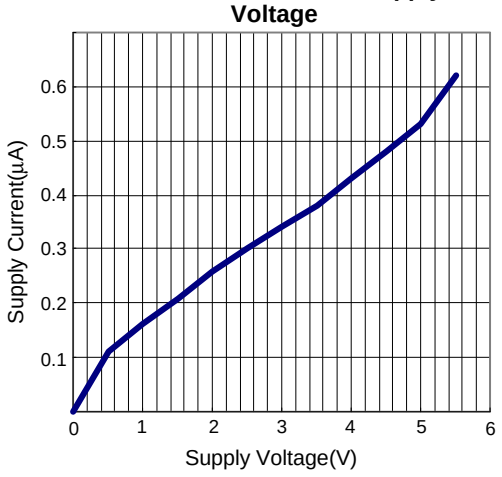

### AGC Function Output Power vs. Input AC



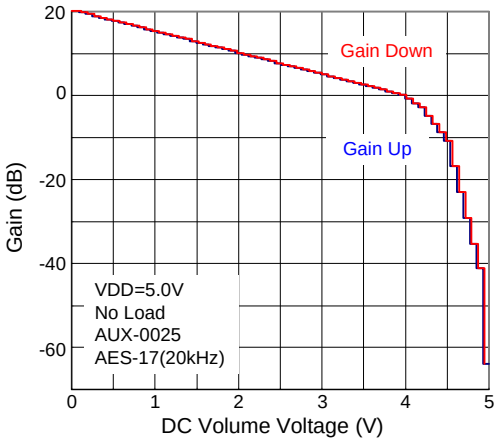

### Supply Current vs. Supply Voltage



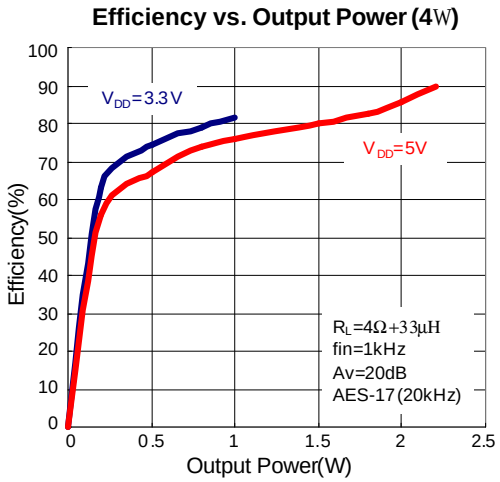

### Shutdown Current vs. Supply Voltage

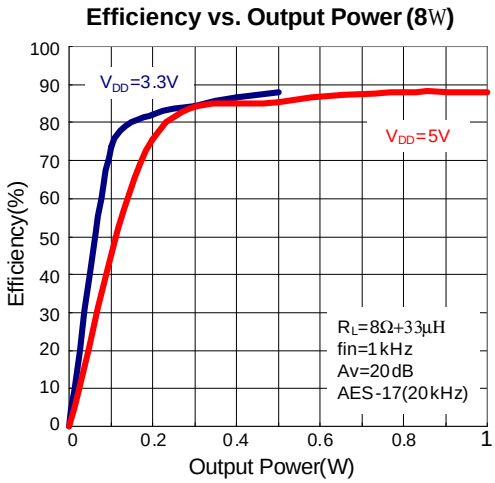



### Gain vs. Volume Voltage



## Typical Operating Characteristics

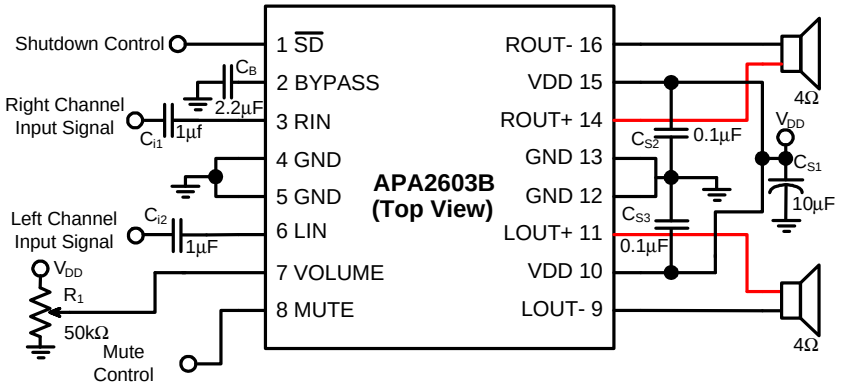


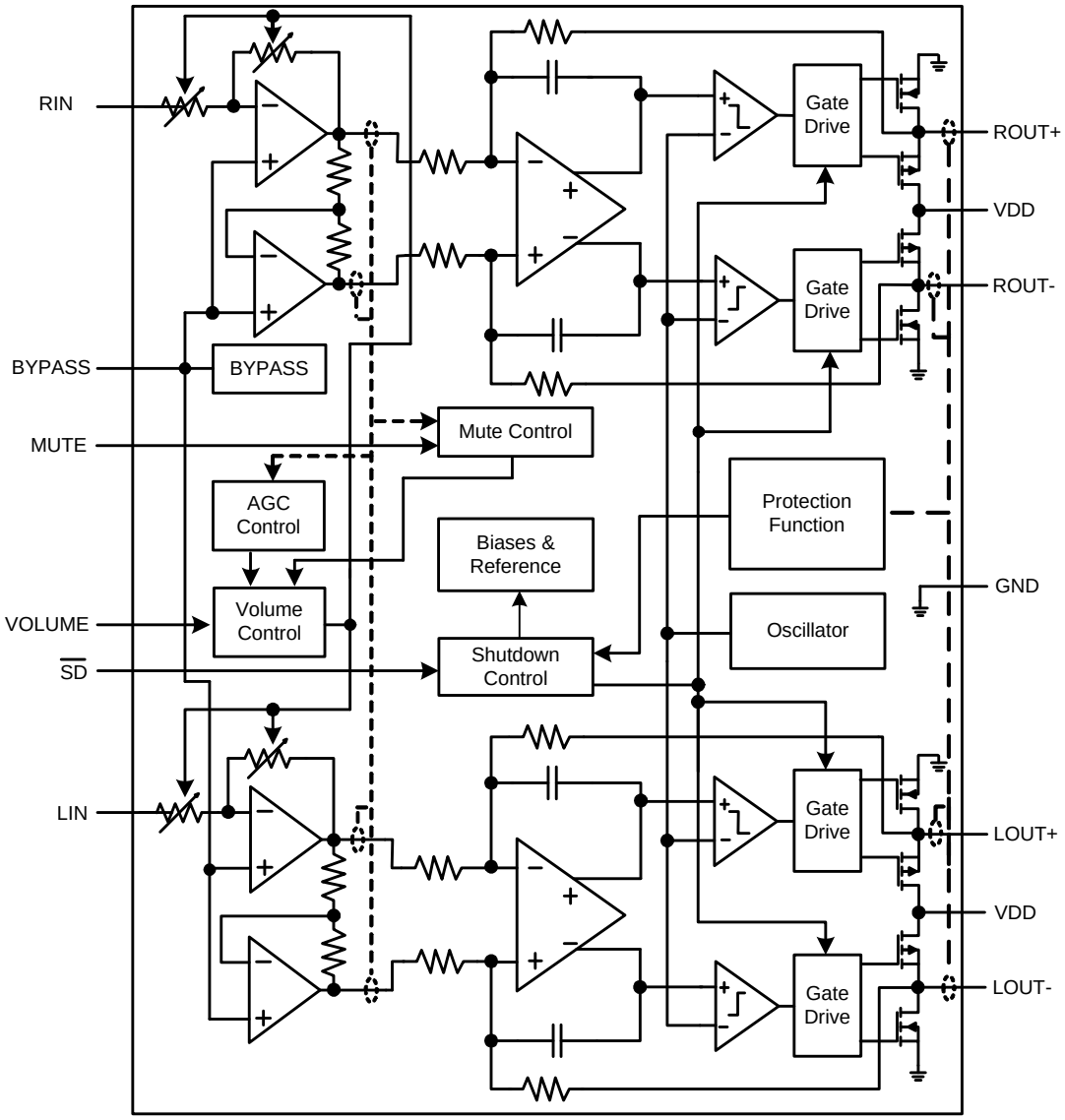
## Pin Description

| PIN | | | I/O/P | FUNCTION |
|---|---|---|---|---|
| NO. | | NAME | | |
| SOP-16 | QFN4x4-20A | | | |
| 1 | 3 | $\overline{SD}$ | I | Shutdown Mode Control Input, Place entire IC in shutdown mode when held low. |
| 2 | 4 | BYPASS | P | Bias Voltage for Power Amplifiers. |
| 3 | 5 | RIN | I | Negative Input of Right Channel Power Amplifier. |
| 4,5,12,13 | 6,18 | GND | P | Ground Connection. |
| 6 | 7 | LIN | I | Negative Input of Left Channel Power Amplifier. |
| 7 | 8 | VOLUME | I | To Set The Amplifier's Gain by Using The DC Voltage. |
| 8 | 9 | MUTE | I | Mute control signal input, hold low for normal operation, hold high to mute. |
| 9 | 15 | LOUT- | O | Negative Output of Left Channel Power Amplifier. |
| 10,15 | 13,16,20 | VDD | P | Power Supply. |
| 11 | 17 | LOUT+ | O | Positive Output of Left Channel Power Amplifier. |
| 14 | 19 | ROUT+ | O | Positive Output of Right Channel Power Amplifier. |
| 16 | 1 | ROUT- | O | Negative Output of Right Channel Power Amplifier. |

## Typical Application Circuit



## Block Diagram



## DC Volume Control Table

$V_{DD}$=5V, $V_{GND}$=0V, $T_A$= 25°C

| Step | Gain (dB) | Down (%) | Down (V) | Up(%) | Up (V) | Recom(%) | Recom(V) |
|---|---|---|---|---|---|---|---|
| | | Volume H to L | | Volume L to H | | | |
| 1 | 20.0 | 1.70 | 0.09 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 19.6 | 3.25 | 0.16 | 2.20 | 0.11 | 2.73 | 0.14 |
| 3 | 19.2 | 4.80 | 0.24 | 3.75 | 0.19 | 4.28 | 0.21 |
| 4 | 18.8 | 6.35 | 0.32 | 5.30 | 0.27 | 5.83 | 0.29 |
| 5 | 18.4 | 7.90 | 0.40 | 6.85 | 0.34 | 7.38 | 0.37 |
| 6 | 18.0 | 9.45 | 0.47 | 8.40 | 0.42 | 8.93 | 0.45 |
| 7 | 17.6 | 11.00 | 0.55 | 9.95 | 0.50 | 10.48 | 0.52 |
| 8 | 17.2 | 12.55 | 0.63 | 11.50 | 0.58 | 12.03 | 0.60 |
| 9 | 16.8 | 14.10 | 0.71 | 13.05 | 0.65 | 13.58 | 0.68 |
| 10 | 16.4 | 15.65 | 0.78 | 14.60 | 0.73 | 15.13 | 0.76 |
| 11 | 16.0 | 17.20 | 0.86 | 16.15 | 0.81 | 16.68 | 0.83 |
| 12 | 15.6 | 18.75 | 0.94 | 17.70 | 0.89 | 18.23 | 0.91 |
| 13 | 15.2 | 20.30 | 1.02 | 19.25 | 0.96 | 19.78 | 0.99 |
| 14 | 14.8 | 21.85 | 1.09 | 20.80 | 1.04 | 21.33 | 1.07 |
| 15 | 14.4 | 23.40 | 1.17 | 22.35 | 1.12 | 22.88 | 1.14 |
| 16 | 14.0 | 24.95 | 1.25 | 23.90 | 1.20 | 24.43 | 1.22 |
| 17 | 13.6 | 26.50 | 1.33 | 25.45 | 1.27 | 25.98 | 1.30 |
| 18 | 13.2 | 28.05 | 1.40 | 27.00 | 1.35 | 27.53 | 1.38 |
| 19 | 12.8 | 29.60 | 1.48 | 28.55 | 1.43 | 29.08 | 1.45 |
| 20 | 12.4 | 31.15 | 1.56 | 30.10 | 1.51 | 30.63 | 1.53 |
| 21 | 12.0 | 32.70 | 1.64 | 31.65 | 1.58 | 32.18 | 1.61 |
| 22 | 11.6 | 34.25 | 1.71 | 33.20 | 1.66 | 33.73 | 1.69 |
| 23 | 11.2 | 35.80 | 1.79 | 34.75 | 1.74 | 35.28 | 1.76 |
| 24 | 10.8 | 37.35 | 1.87 | 36.30 | 1.82 | 36.83 | 1.84 |
| 25 | 10.4 | 38.90 | 1.95 | 37.85 | 1.89 | 38.38 | 1.92 |
| 26 | 10.0 | 40.45 | 2.02 | 39.40 | 1.97 | 39.93 | 2.00 |
| 27 | 9.6 | 42.00 | 2.10 | 40.95 | 2.05 | 41.48 | 2.07 |
| 28 | 9.2 | 43.55 | 2.18 | 42.50 | 2.13 | 43.03 | 2.15 |
| 29 | 8.8 | 45.10 | 2.26 | 44.05 | 2.20 | 44.58 | 2.23 |
| 30 | 8.4 | 46.65 | 2.33 | 45.60 | 2.28 | 46.13 | 2.31 |
| 31 | 8.0 | 48.20 | 2.41 | 47.15 | 2.36 | 47.68 | 2.38 |
| 32 | 7.6 | 49.75 | 2.49 | 48.70 | 2.44 | 49.23 | 2.46 |

## DC Volume Control Table (Cont.)

$V_{DD}$=5V, $V_{GND}$=0V, $T_A$= 25°C

| Step | Gain (dB) | Down (%) | Down (V) | Up(%) | Up (V) | Recom(%) | Recom(V) |
|---|---|---|---|---|---|---|---|
| | | Volume H to L | | Volume L to H | | | |
| 33 | 7.2 | 51.30 | 2.57 | 50.25 | 2.51 | 50.78 | 2.54 |
| 34 | 6.8 | 52.85 | 2.64 | 51.80 | 2.59 | 52.33 | 2.62 |
| 35 | 6.4 | 54.40 | 2.72 | 53.35 | 2.67 | 53.88 | 2.69 |
| 36 | 6.0 | 55.95 | 2.80 | 54.90 | 2.75 | 55.43 | 2.77 |
| 37 | 5.6 | 57.50 | 2.88 | 56.45 | 2.82 | 56.98 | 2.85 |
| 38 | 5.2 | 59.05 | 2.95 | 58.00 | 2.90 | 58.53 | 2.93 |
| 39 | 4.8 | 60.60 | 3.03 | 59.55 | 2.98 | 60.08 | 3.00 |
| 40 | 4.4 | 62.15 | 3.11 | 61.10 | 3.06 | 61.63 | 3.08 |
| 41 | 4.0 | 63.70 | 3.19 | 62.65 | 3.13 | 63.18 | 3.16 |
| 42 | 3.6 | 65.25 | 3.26 | 64.20 | 3.21 | 64.73 | 3.24 |
| 43 | 3.2 | 66.80 | 3.34 | 65.75 | 3.29 | 66.28 | 3.31 |
| 44 | 2.8 | 68.35 | 3.42 | 67.30 | 3.37 | 67.83 | 3.39 |
| 45 | 2.4 | 69.90 | 3.50 | 68.85 | 3.44 | 69.38 | 3.47 |
| 46 | 2.0 | 71.45 | 3.57 | 70.40 | 3.52 | 70.93 | 3.55 |
| 47 | 1.6 | 73.00 | 3.65 | 71.95 | 3.60 | 72.47 | 3.62 |
| 48 | 1.2 | 74.55 | 3.73 | 73.50 | 3.68 | 74.02 | 3.70 |
| 49 | 0.8 | 76.10 | 3.81 | 75.05 | 3.75 | 75.57 | 3.78 |
| 50 | 0.4 | 77.65 | 3.88 | 76.60 | 3.83 | 77.12 | 3.86 |
| 51 | 0.0 | 79.20 | 3.96 | 78.15 | 3.91 | 78.67 | 3.93 |
| 52 | -1.0 | 80.75 | 4.04 | 79.70 | 3.99 | 80.22 | 4.01 |
| 53 | -2.0 | 82.30 | 4.12 | 81.25 | 4.06 | 81.77 | 4.09 |
| 54 | -3.0 | 83.85 | 4.19 | 82.80 | 4.14 | 83.32 | 4.17 |
| 55 | -5.0 | 85.40 | 4.27 | 84.35 | 4.22 | 84.87 | 4.24 |
| 56 | -7.0 | 86.95 | 4.35 | 85.90 | 4.30 | 86.42 | 4.32 |
| 57 | -9.0 | 88.50 | 4.43 | 87.45 | 4.37 | 87.97 | 4.40 |
| 58 | -11.0 | 90.05 | 4.50 | 89.00 | 4.45 | 89.52 | 4.48 |
| 59 | -17.0 | 91.60 | 4.58 | 90.55 | 4.53 | 91.07 | 4.55 |
| 60 | -23.0 | 93.15 | 4.66 | 92.10 | 4.61 | 92.62 | 4.63 |
| 61 | -29.0 | 94.70 | 4.74 | 93.65 | 4.68 | 94.17 | 4.71 |
| 62 | -35.0 | 96.25 | 4.81 | 95.20 | 4.76 | 95.72 | 4.79 |
| 63 | -41.0 | 97.80 | 4.89 | 96.75 | 4.84 | 97.27 | 4.86 |
| 64 | -80.0 | 100.00 | 5.00 | 98.30 | 4.92 | 100.00 | 5.00 |

## Function Description

### Class-D Operation

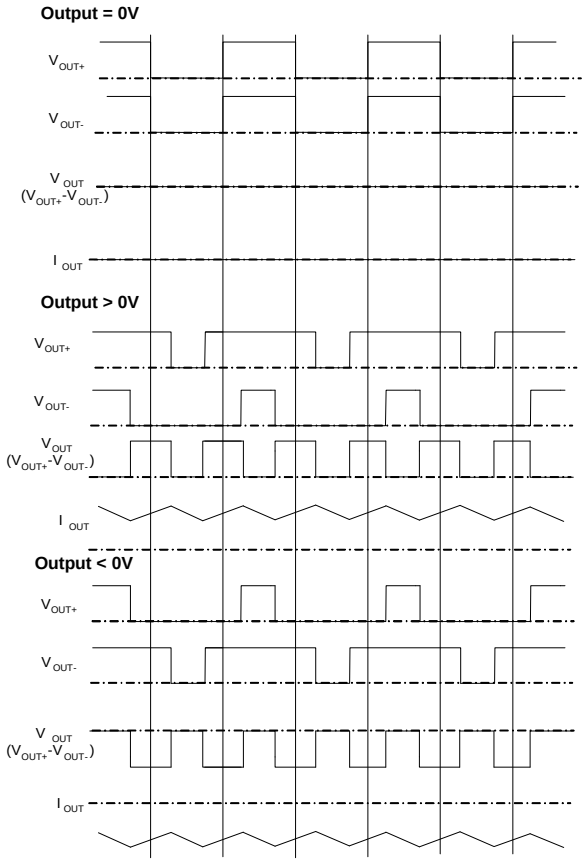



Figure1. The APA2603B Output Waveform (Voltage& Current)

The APA2603B power amplifier modulation scheme is shown in figure 1; the outputs $V_{OUT+}$ and $V_{OUTN}$ are in phase with each other when no input signals. When output > 0V, the duty cycle of $V_{OUT+}$ is greater than 50% and $V_{OUT-}$ is less than 50%; when Output <0V, the duty cycle of $V_{OUT+}$ is less than 50% and $V_{OUT-}$ is greater than 50%. This method reduces the switching current across the load, and reduces the $I^2R$ losses in the load that improve the amplifier's efficiency.

This modulation scheme has very short pulses across the load, this making the small ripple current and very little loss on the load, and the LC filter can be eliminate in most applications. Added the LC filter can increase the efficiency by filter the ripple current.

### Bypass Voltage

The bypass voltage is equal to $V_{DD}/2$, this voltage is for bias the internal preamplifier stages. The external capacitor for this reference ($C_1$) is a critical component and serves several important functions.

### DC Volume Control Function

The APA2603B has an internal stereo volume control whose setting is the function of the DC voltage applied to the VOLUME input pin. The APA2603B volume control consists of 64 steps that are individually selected by a variable DC voltage level on the VOLUME control pin. The range of the steps controlled by the DC voltage, are from +20dB to -80dB. Each gain step corresponds to a specific input voltage range, as shown in the table. To minimize the effect of noise on the volume control pin, which can affect the selected gain level, hysteresis and clock delay are implemented. The amount of hysteresis corresponds to half of the step width, as shown in the "DC Volume Control Graph".

For the highest accuracy, the voltage shown in the "recommended voltage" column of the table is used to select a desired gain. This recommended voltage is exactly halfway between the two nearest transitions. The gains level have are 0.4dB/step from 20dB to 0dB; 1dB/step from 0dB to -3dB; 2dB/step from -3dB to -11dB and 6dB/step from -11dB to -41dB and the last step at -80dB as mute mode.

## Function Description (Cont.)

### AGC (Non-Clipping) Function

The APA2603B provides the 64 steps non-clipping control, and the range is from 20dB to -80dB. When the output reaches the maximum power setting value, the internal Programmable Gain Amplifier (PGA) will decrease the gain for prevent the output waveform clipping. This feature prevents speaker damage from occurring clipping. The AGC pin to set the non-clipping function.

### MUTE Operation

When place the logic high on MUTE pin, the APA2603B's outputs runs at a constant 50% duty cycle, and the APA2603B is at mute state. Place the logic low on MUTE pin enables the outputs, and the output changes the duty cycle with the input signal. This pin could be used as a quick disable/enable of outputs when changing channels on a television or transitioning between different audio sources. The MUTE pin must not be floating.

### Shutdown Operation

In order to reduce power consumption while not in use, the APA2603B contains a shutdown function to externally turn off the amplifier bias circuitry. This shutdown feature turns the amplifier off when logic low is placed on the $\overline{SD}$ pin for APA2603B. The trigger point between a logic high and logic low level is typically 1.5V. It is the best to switch between ground and the supply voltage $V_{DD}$ to provide maximum device performance. By switching the $\overline{SD}$ pin to a low level, the amplifier enters a low-consumption-current state, $I_{DD}$ for APA2603B is in shutdown mode. On normal operating, APA2603B's $\overline{SD}$ pin should pull to a high level to keep the IC out of the shutdown mode. The $\overline{SD}$ pin should be tied to a definite voltage to avoid unwanted state changes.

### Over-Current Protection

The APA2603B monitors the output current, and when the current exceeds the current-limit threshold, the APA2603B turn-off the output stage to prevent the output device from damages in over-current or short-circuit condition. The IC will turn-on the output buffer after 200ms, but if the over-current or short-circuits condition is still remain, it enters the Over-Current protection again. The situation will circulate until the over-current or short-circuits has be removed.

### Thermal Protection

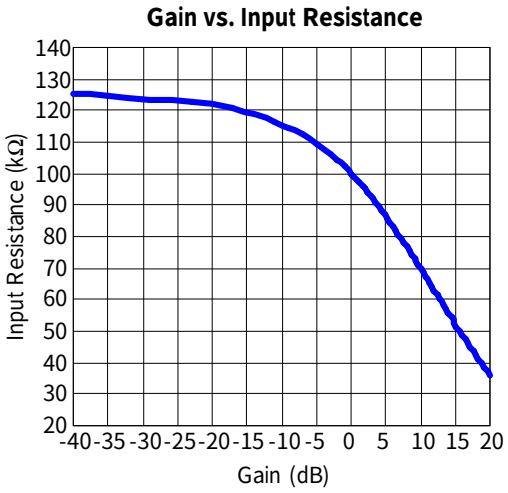
The over-temperature circuit limits the junction temperature of the APA2603B. When the junction temperature exceeds $T_J$=+155°C, a thermal sensor turns off the output buffer, allowing the devices to cool. The thermal sensor allows the amplifier to start-up after the junction temperature down about 125 °C. The thermal protection is designed with a 25 °C hysteresis to lower the average $T_J$ during continuous thermal overload conditions, increasing lifetime of the IC.

## Application Information

**Square Wave into the Speaker**

Apply the square wave into the speaker may cause the voice coil of speaker jumping out the air gap and defacing the voice coil. However, this depends on the amplitude of square wave is high enough and the bandwidth of speaker is higher than the square wave¡¦s frequency. For 500kHz switching frequency, this is not issued for the speaker because the frequency is beyond the audio band and can¡¦t significantly move the voice coil, as cone movement is proportional to $1/f^2$ for frequency out of audio band.

**Input Resistor, $R_i$**




For achieving the 64 steps gain setting, it varies the input resistance network ($R_i$ & $R_f$) of amplifier. The input resistor's range form smallest to maximum is about 3.5 times. Therefore, the input high-pass filter's low cutoff frequency will change 3.5 times from low to high. The cutoff frequency can be calculated by equation 1.

**Input Capacitor, $C_i$**

In the typical application, an input capacitor, $C_i$, is required to allow the amplifier to bias the input signal to the proper DC level for optimum operation. In this case, $C_i$ and the input impedance $R_i$ form a high-pass filter with the corner frequency determined in the following equation:

$$f_{C(highpass)} = \frac{1}{2\pi R_i C_i} \quad (1)$$

The value of $C_i$ must be considered carefully because it directly affects the low frequency performance of the circuit. Where $R_i$ is 36kΩ (minimum) and the specification calls for a flat bass response down to 50Hz. The equation is reconfigured as below:

$$C_i = \frac{1}{2\pi R_i f_c} \quad (2)$$

When the input resistance variation is considered, the $C_i$ is 0.08µF, so a value in the range of 0.01µF to 0.022µF would be chosen. A further consideration for this capacitor is the leakage path from the input source through the input network ($R_i$ + $R_f$, $C_i$) to the load. This leakage current creates a DC offset voltage at the input to the amplifier that reduces useful headroom, especially in high gain applications. For this reason, a low-leakage tantalum or ceramic capacitor is the best choice. When polarized capacitors are used, the positive side of the capacitor should face the amplifiers' input in most applications because the DC level of the amplifiers' inputs are held at $V_{DD}/2$. Please note that it is important to confirm the capacitor polarity in the application.

**Effective Bypass Capacitor, $C_B$**

As with any power amplifier, proper supply bypassing is critical for low noise performance and high power supply rejection.

The bypass capacitance effects the start-up time. It is determined in the following equation:

$$T_{START-UP}=0.5(sec/\mu F)xC1+0.2(sec) \quad (3)$$

The capacitor location on the bypass pin should be as close to the device as possible. The effect of a larger half bypass capacitor is improved PSRR due to increased half-supply stability. The selection of bypass capacitors, especially $C_B$, is thus dependent upon desired PSRR requirements, click and pop performance.

To avoid the start-up pop noise occurred, choose $C_i$ which is not larger than $C_B$.

## Application Information (Cont.)

### Ferrite Bead Selection

If the traces form APA2603B to speaker are short, the ferrite bead filters can reduce the high frequency radiated to meet the FCC & CE required.
A ferrite that has very low impedance at low frequencies and high impedance at high frequencies (above 1 MHz) is recommended.

### Output Low-Pass Filter

If the traces form APA2603B to speaker are short, it doesn't require output filter for FCC & CE standard.
A ferrite bead may be needed if it's failing the test for FCC or CE tested without the LC filter. The figure 2 is the sample for added ferrite bead; the ferrite shows choosing high impedance in high frequency.

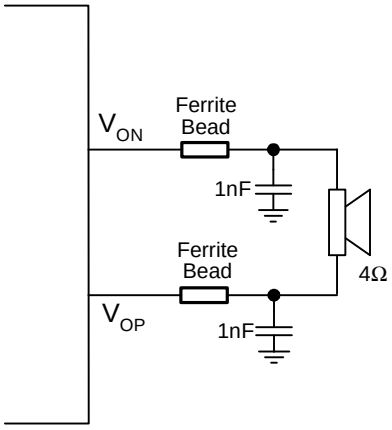



Figure 2. Ferrite bead output filter

Figure 3 and 4 are examples for added the LC filter (Butterworth), it's recommended for the situation that the trace form amplifier to speaker is too long and needs to eliminate the radiated emission or EMI.

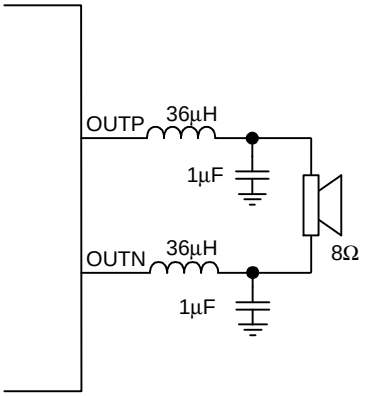



Figure 3. LC output filter for 8Ω speaker

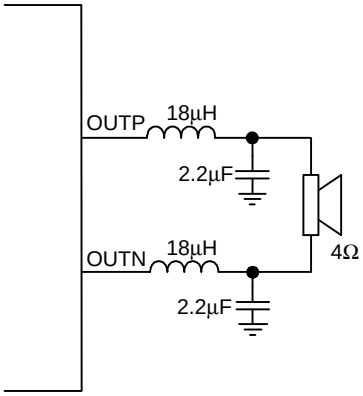



Figure 4. LC output filter for 4Ω speaker

Figure 3 and 4's low pass filter cut-off frequency are 25kHz ($F_C$).

$$f_{C(lowpass)} = \frac{1}{2\pi\sqrt{LC}} \quad (5)$$

### Power-Supply Decoupling Capacitor, $C_S$

The APA2603B is a high-performance CMOS audio amplifier that requires adequate power supply decoupling to ensure the output total harmonic distortion (THD) is as low as possible. Power supply decoupling also prevents the oscillations being caused by long lead length between the amplifier and the speaker.

## Application Information (Cont.)

**Power-Supply Decoupling Capacitor, $C_S$ (Cont.)**

The optimum decoupling is achieved by using two different types of capacitors that target on different types of noise on the power supply leads. For higher frequency transients, spikes, or digital hash on the line, a good low equivalent-series-resistance (ESR) ceramic capacitor, typically 0.1µF placed as close as possible to the device VDD pin for works best. For filtering lower frequency noise signals, a large aluminum electrolytic capacitor of 10µF or greater placed near the audio power amplifier is recommended.

**Layout Recommendation**

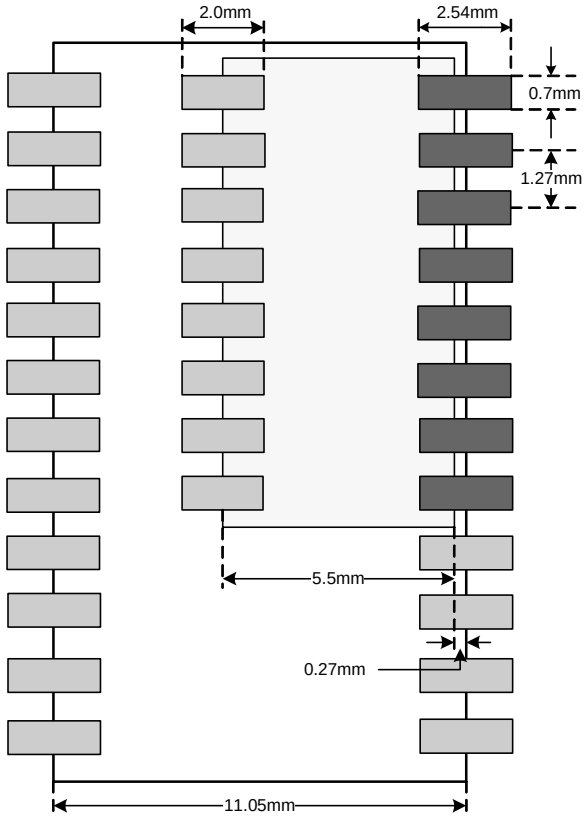



Figure 5.SOP-16P & SOP-24co-layout Land Pattern Recommendation

1. All components should be placed close to the APA2603B. For example, the input capacitor ($C_i$) should be close to APA2603B's input pins to avoid causing noise coupling to APA2603B¡¦s high impedance inputs; the decoupling capacitor ($C_S$) should be placed by the APA2603B's power pin to decouple the power rail noise.
2. The output traces should be short, wide ( >50mil) and symmetric.
3. The input trace should be short and symmetric.
4. The power trace width should greater than 50mil.
5. APA2603B and APA2603A share the pin 9~16 to avoid soldering short. APA2603B's left half pads are connected to APA2603A by lines.

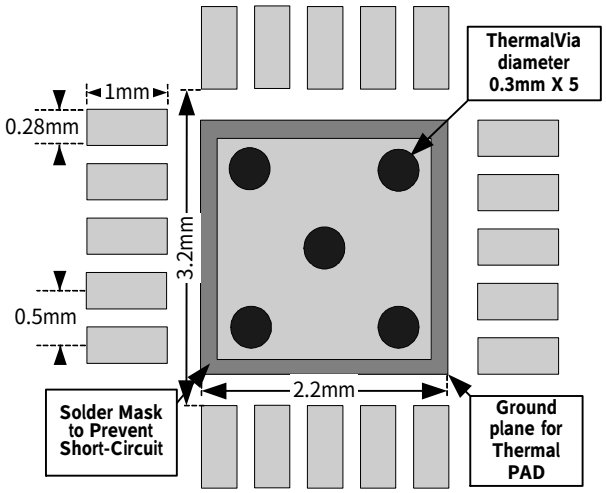
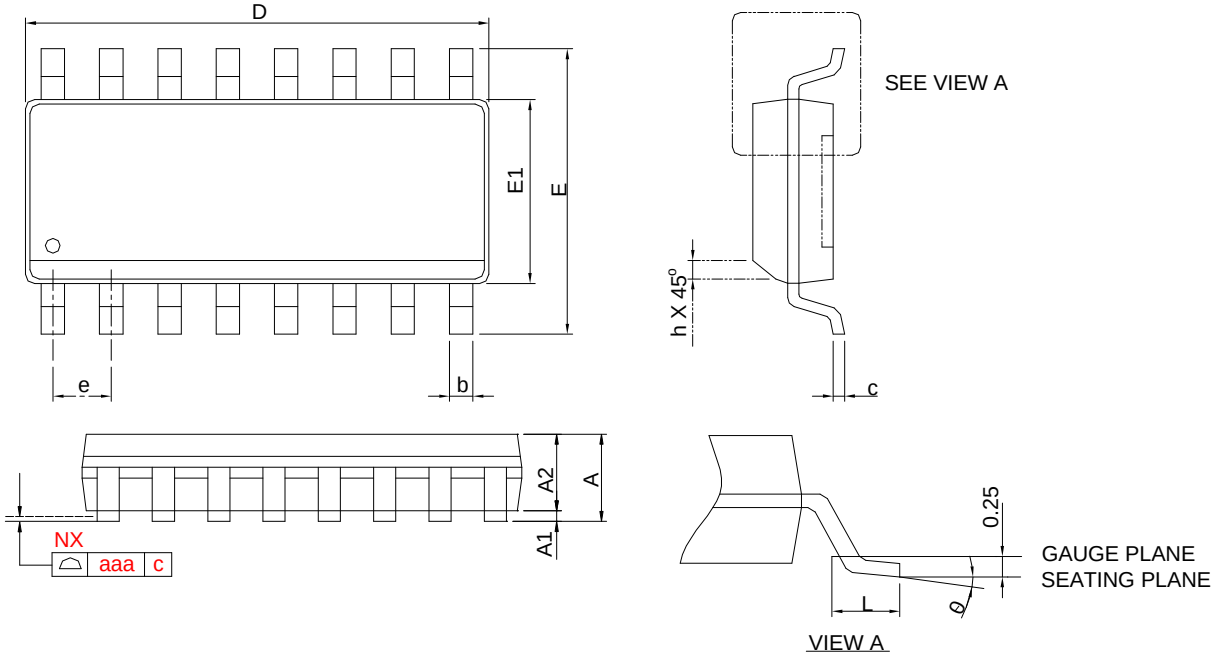



Figure 6. QFN4x4-20A Land Pattern Recommendation

1. All components should be placed close to the APA2603B. For example, the input capacitor ($C_i$) should be close to APA2603B's input pins to avoid causing noise coupling to APA2603B's high impedance inputs; the decoupling capacitor ($C_s$) should be placed by the APA2603B's power pin to decouple the power rail noise.
2. The output traces should be short, wide ( >50mil), and symmetric.
3. The input trace should be short and symmetric.
4. The power trace width should greater than 50mil.
5. The QFN4X4-20A Thermal PAD should be soldered on PCB, and the ground plane needs soldered mask (to avoid short-circuit) except the Thermal PAD area.

## Package Information

**SOP-16**

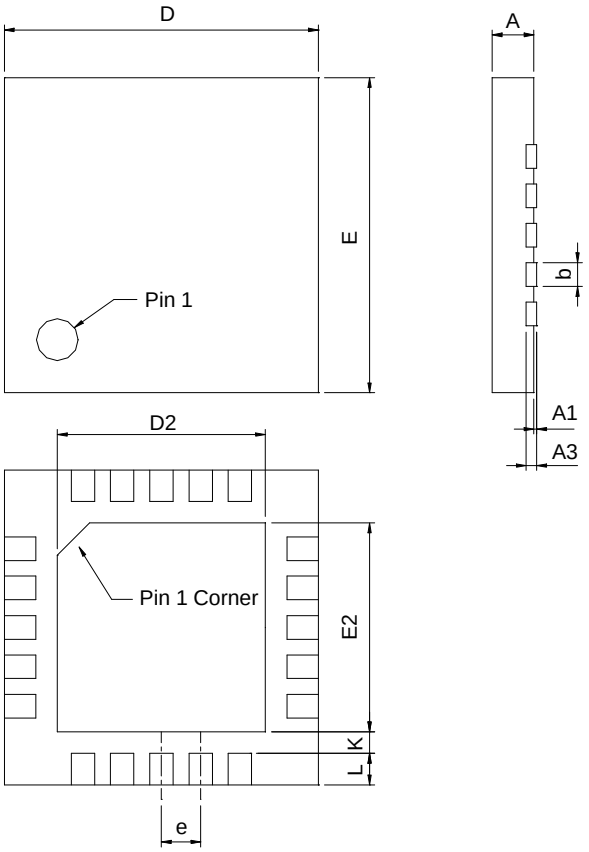



| SYMBOL | SOP-16 | | | |
|---|---|---|---|---|
| | MILLIMETERS | | INCHES | |
| | MIN. | MAX. | MIN. | MAX. |
| A | | 1.75 | | 0.069 |
| A1 | 0.10 | 0.15 | 0.004 | 0.010 |
| A2 | 1.25 | | 0.049 | |
| b | 0.31 | 0.51 | 0.012 | 0.020 |
| c | 0.17 | 0.25 | 0.007 | 0.010 |
| D | 9.80 | 10.00 | 0.374 | 0.394 |
| E | 5.80 | 6.20 | 0.228 | 0.244 |
| E1 | 3.80 | 4.00 | 0.150 | 0.157 |
| e | 1.27 BSC | | 0.050 BSC | |
| h | 0.25 | 0.50 | 0.010 | 0.020 |
| L | 0.40 | 1.27 | 0.016 | 0.050 |
| θ | 0° | 8° | 0° | 8° |
| aaa | 0.10 | | 0.004 | |

Note : 1. Follow from JEDEC MS-012 BC.
2. Dimension "D" does not include mold flash, protrusions or gate burrs. Mold flash, protrusion or gate burrs shall not exceed 6 mil per side.
3. Dimension "E" does not include inter-lead flash or protrusions. Inter-lead flash and protrusions shall not exceed 10 mil per side.

## Package Information

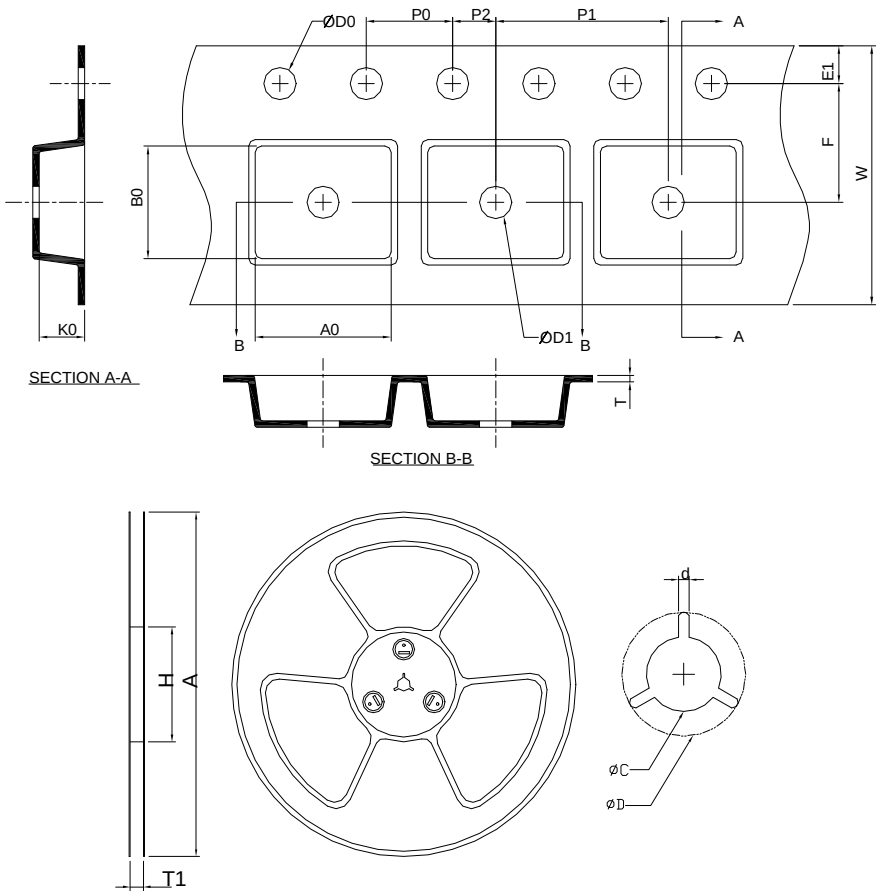
**QFN4x4-20A**




| SYMBOL | QFN4x4-20A | | | |
|---|---|---|---|---|
| | MILLIMETERS | | INCHES | |
| | MIN. | MAX. | MIN. | MAX. |
| A | 0.80 | 1.00 | 0.031 | 0.039 |
| A1 | 0.00 | 0.05 | 0.000 | 0.002 |
| A3 | 0.20 REF | | 0.008 REF | |
| b | 0.18 | 0.30 | 0.008 | 0.012 |
| D | 3.90 | 4.10 | 0.154 | 0.161 |
| D2 | 2.00 | 2.50 | 0.079 | 0.098 |
| E | 3.90 | 4.10 | 0.154 | 0.161 |
| E2 | 2.00 | 2.50 | 0.079 | 0.098 |
| e | 0.50 BSC | | 0.020 BSC | |
| L | 0.35 | 0.45 | 0.014 | 0.018 |
| K | 0.20 | | 0.008 | |

Note : 1. Followed from JEDEC MO-220 VGGD-5.

## Carrier Tape & Reel Dimensions




| Application | A | H | T1 | C | d | D | W | E1 | F |
|---|---|---|---|---|---|---|---|---|---|
| SOP-16 | 330.0±2.00 | 50 MIN. | 16.4+2.00 -0.00 | 13.0+0.50 -0.20 | 1.5 MIN. | 20.2 MIN. | 16.0±0.30 | 1.75±0.10 | 7.5±0.10 |
| | P0 | P1 | P2 | D0 | D1 | T | A0 | B0 | K0 |
| | 4.0±0.10 | 8.0±0.10 | 2.0±0.10 | 1.5+0.10 -0.00 | 1.5 MIN. | 0.6+0.00 -0.40 | 6.40±0.20 | 10.30±0.20 | 2.10±0.20 |
| Application | A | H | T1 | C | d | D | W | E1 | F |
| QFN4x4-20A | 330.0±2.00 | 50 MIN. | 12.4+2.00 -0.00 | 13.0+0.50 -0.20 | 1.5 MIN. | 20.2 MIN. | 12.0±0.30 | 1.75±0.10 | 5.5±0.05 |
| | P0 | P1 | P2 | D0 | D1 | T | A0 | B0 | K0 |
| | 4.0±0.10 | 8.0±0.10 | 2.0±0.05 | 1.5+0.10 -0.00 | 1.5 MIN. | 0.6+0.00 -0.40 | 4.30±0.20 | 4.30±0.20 | 1.30±0.20 |

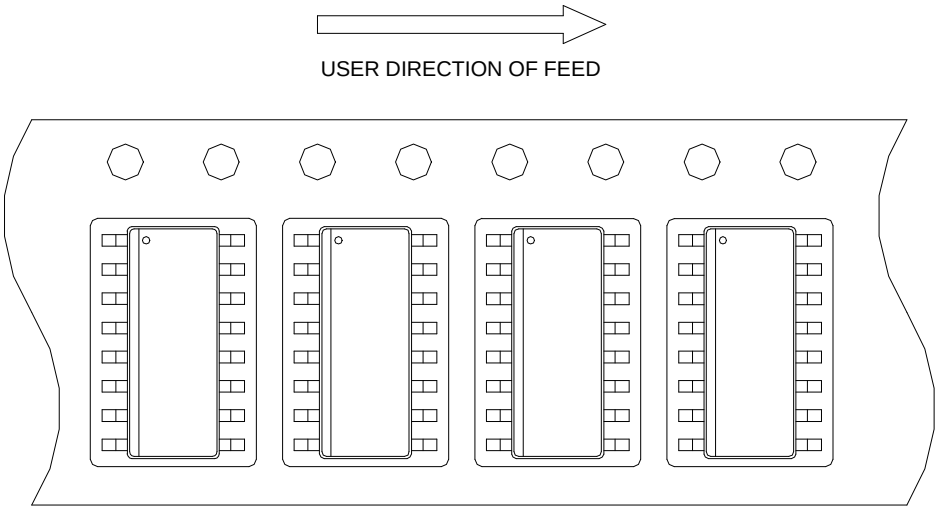
(mm)

## Devices Per Unit

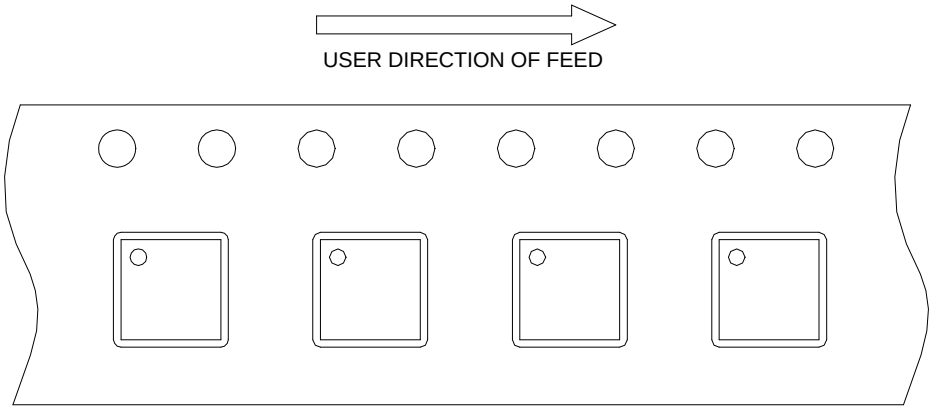
| Package Type | Unit | Quantity |
|---|---|---|
| QFN4x4-20A | Tape & Reel | 3000 |
| SOP-16 | Tape & Reel | 2500 |

## Taping Direction Information

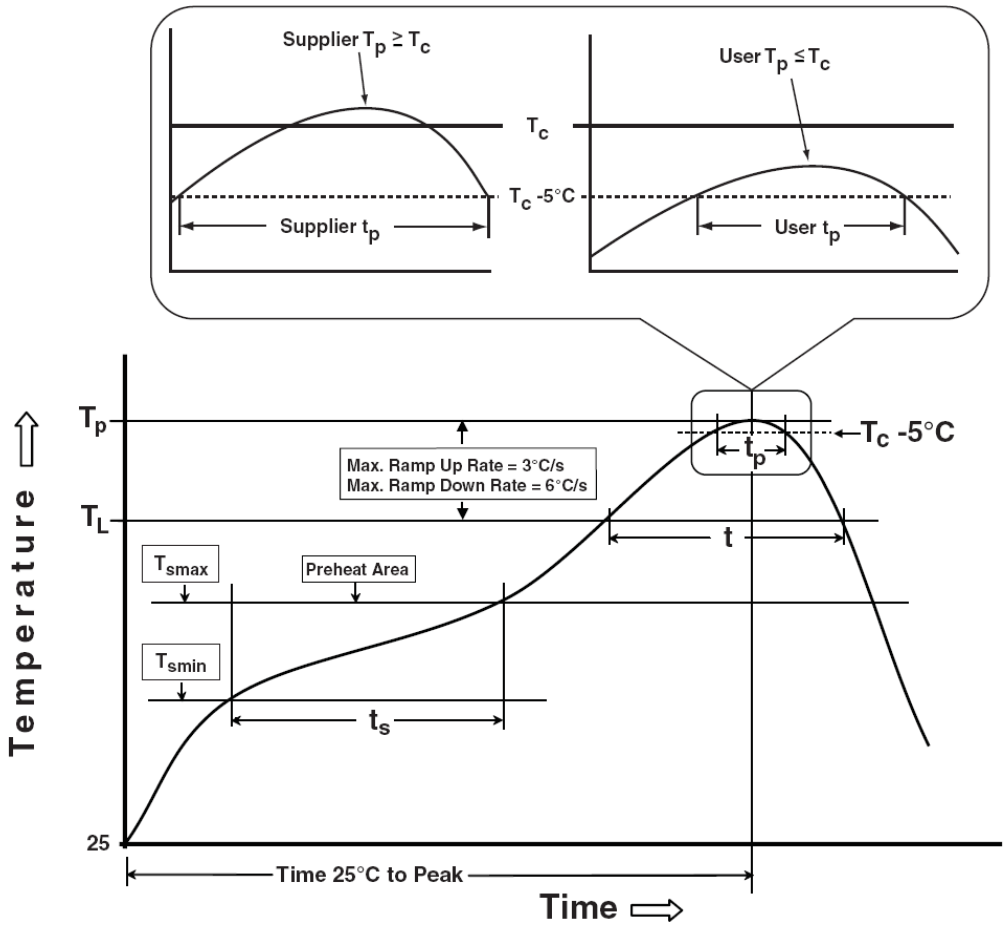
**SOP-16**




**QFN4x4-20A**



## Classification Profile



## Classification Reflow Profiles

| Profile Feature | Sn-Pb Eutectic Assembly | Pb-Free Assembly |
|---|---|---|
| **Preheat & Soak**<br>Temperature min ($T_{smin}$)<br>Temperature max ($T_{smax}$)<br>Time ($T_{smin}$ to $T_{smax}$) ($t_s$) | 100 °C<br>150 °C<br>60-120 seconds | 150 °C<br>200 °C<br>60-120 seconds |
| Average ramp-up rate ($T_{smax}$ to $T_P$) | 3 °C/second max. | 3°C/second max. |
| Liquidous temperature ($T_L$)<br>Time at liquidous ($t_L$) | 183 °C<br>60-150 seconds | 217 °C<br>60-150 seconds |
| Peak package body Temperature ($T_p$)* | See Classification Temp in table 1 | See Classification Temp in table 2 |
| Time ($t_P$)** within 5°C of the specified classification temperature ($T_c$) | 20** seconds | 30** seconds |
| Average ramp-down rate ($T_p$ to $T_{smax}$) | 6 °C/second max. | 6 °C/second max. |
| Time 25°C to peak temperature | 6 minutes max. | 8 minutes max. |
| * Tolerance for peak profile Temperature ($T_p$) is defined as a supplier minimum and a user maximum.<br>** Tolerance for time at peak profile temperature ($t_p$) is defined as a supplier minimum and a user maximum. | | |

Table 1. SnPb Eutectic Process – Classification Temperatures (Tc)

| Package Thickness | Volume $mm^3$ <350 | Volume $mm^3$ ³350 |
|---|---|---|
| <2.5 mm | 235 °C | 220 °C |
| ≥2.5 mm | 220 °C | 220 °C |

Table 2. Pb-free Process – Classification Temperatures (Tc)

| Package Thickness | Volume $mm^3$ <350 | Volume $mm^3$ 350-2000 | Volume $mm^3$ >2000 |
|---|---|---|---|
| <1.6 mm | 260 °C | 260 °C | 260 °C |
| 1.6 mm – 2.5 mm | 260 °C | 250 °C | 245 °C |
| ≥2.5 mm | 250 °C | 245 °C | 245 °C |

## Reliability Test Program

| Test item | Method | Description |
|---|---|---|
| SOLDERABILITY | JESD-22, B102 | 5 Sec, 245°C |
| HOLT | JESD-22, A108 | 1000 Hrs, Bias @ Tj=125°C |
| PCT | JESD-22, A102 | 168 Hrs, 100%RH, 2atm, 121°C |
| TCT | JESD-22, A104 | 500 Cycles, -65°C~150°C |
| HBM | MIL-STD-883-3015.7 | VHBM≧2KV |
| MM | JESD-22, A115 | VMM≧200V |
| Latch-Up | JESD 78 | 10ms, $1_{tr}$≧100mA |

## Customer Service

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