

BiCMOS Linear Integrated Circuit Silicon Monolithic

# TB2909FNG

Maximum Power 5 W SEPP × 1ch Audio Power Amp IC

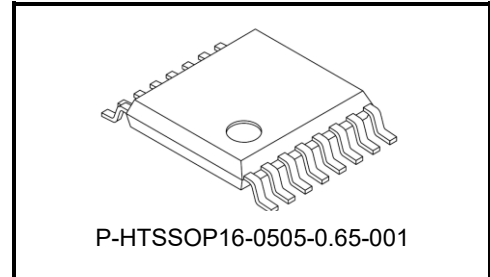
## 1. Description

The TB2909FNG is a power IC with built-in one-channel SEPP amplifier for sound output applications such as audios and vehicle approach warning devices.

It includes a standby switch, mute function, and various protection features for audios.

## 2. Applications

Power IC for sound output applications



P-HTSSOP16-0505-0.65-001

Weight: 0.062 g (typ.)

## 3. Features

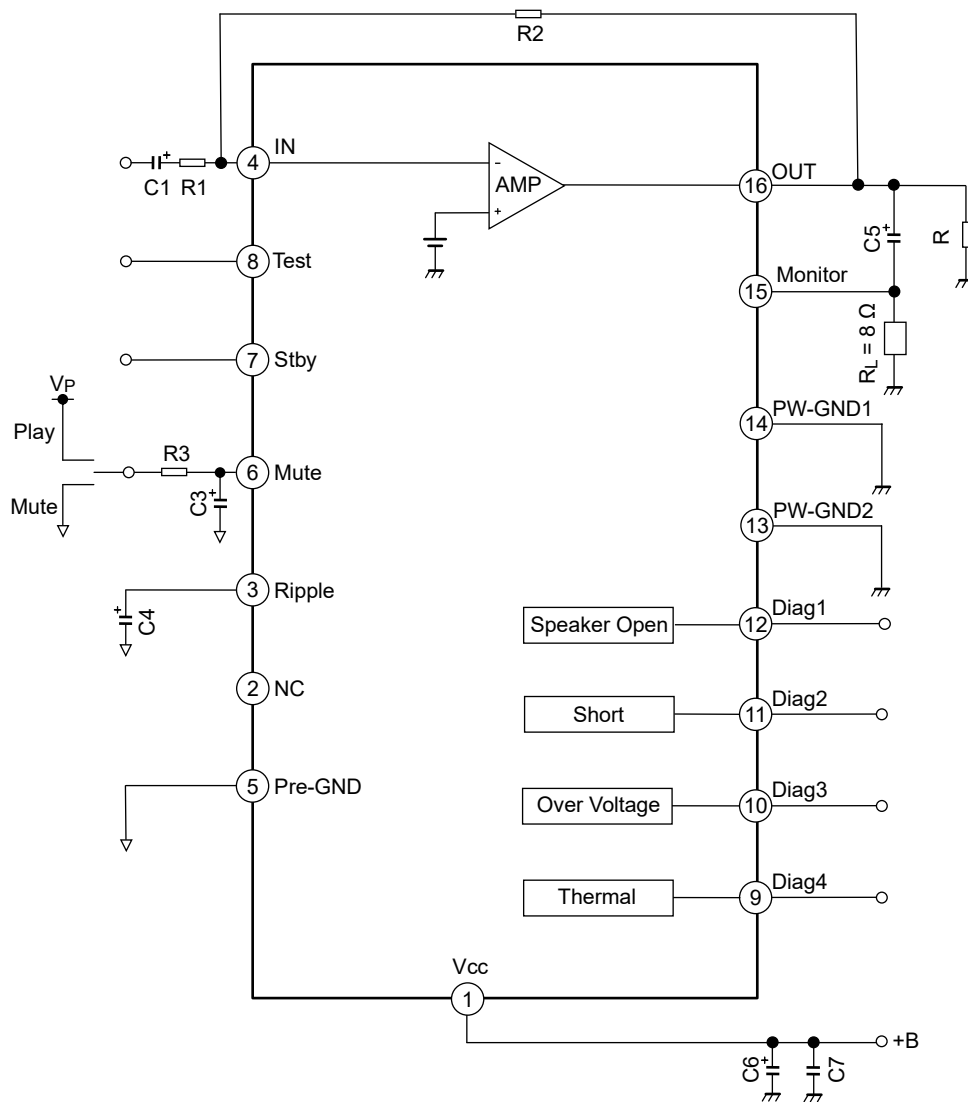
- Built-in various mute functions (for low voltage mute and standby-off mute)
- Built-in standby switch (pin7)
- Built-in mute switch (pin6)
- Built-in various protection circuits(thermal shutdown, over-voltage protection, output short and load short protection)
- Built-in thermal detection (pin9)
- Built-in over-voltage detection (pin10)
- Built-in output short detection (pin11)
- Built-in load short detection (pin11)
- Built-in speaker open detection (pin12)

**Table1 Typical Characteristics (Note1)**

| Condition   | Typ.    | Unit  |
|---|---------|-------|
| <b>Output power (P<sub>OUT MAX</sub>)</b>                 |         |       |
| V <sub>CC</sub> = 16 V Max Power                          | 5       | W     |
| V <sub>CC</sub> = 12 V Max Power                          | 3       | W     |
| THD = 10%   | 2       | W     |
| <b>Total harmonic distortion (THD)</b>                    |         |       |
| P <sub>OUT</sub> = 0.125 W<br>(V <sub>OUT</sub> = 1 Vrms) | 0.08    | %     |
| <b>Output noise voltage (V<sub>NO</sub>)</b>              |         |       |
| DIN_AUDIO, R <sub>g</sub> = 620 Ω                         | 50      | μVrms |
| <b>Operating Supply voltage range (V<sub>CC</sub>)</b>    |         |       |
| R <sub>L</sub> = 8 Ω                                      | 6 to 16 | V     |

Note1: Typical test conditions V<sub>CC</sub> = 12 V, f = 1 kHz, R<sub>L</sub> = 8 Ω, G<sub>V</sub> = 20 dB, T<sub>a</sub> = 25°C; unless otherwise specified  
R<sub>g</sub>: signal source resistance

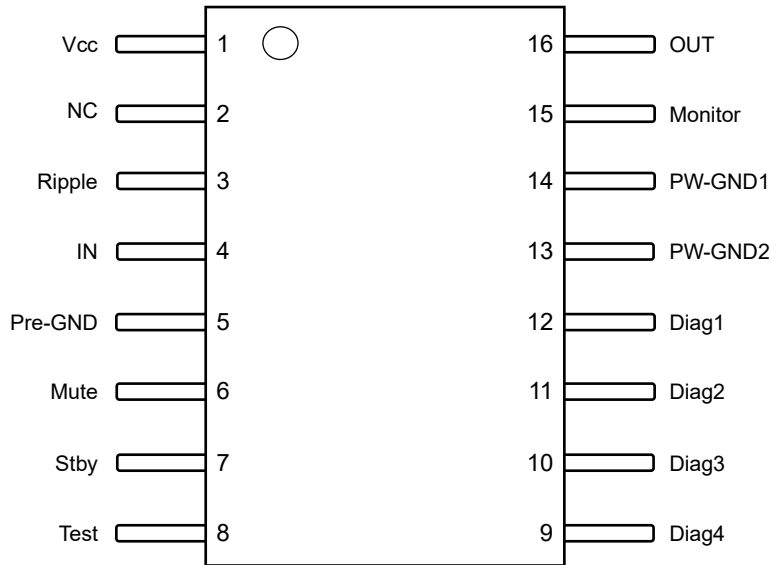
## 4. Block Diagram



Note2: Some of the functional blocks, circuits or constants in the block diagram may have been omitted or simplified for clarity.

## 5. Pin Configuration and Function Descriptions

### 5.1 Pin Configuration (top view)

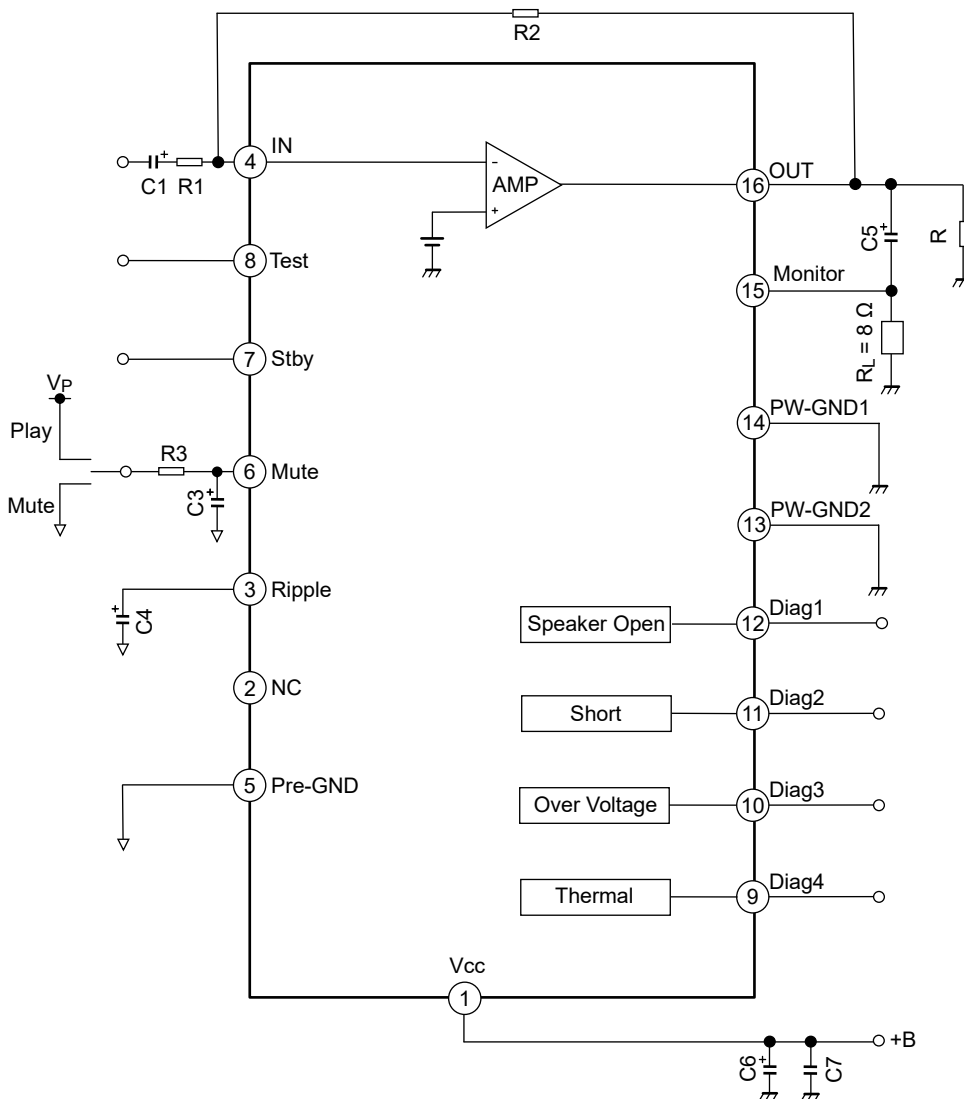


### 5.2 Pin Function Description

| Pin number | Symbol  | I/O                   | Description                               |
|------------|---------|-----------------------|---|
| 1          | Vcc     | V <sub>CC</sub> -IN   | Supply voltage pin                        |
| 2          | NC      | —                     | NC pin                                    |
| 3          | Ripple  | —                     | Ripple voltage pin                        |
| 4          | IN      | IN                    | Input pin                                 |
| 5          | Pre-GND | —                     | Signal ground pin                         |
| 6          | Mute    | V <sub>MUTE</sub> -IN | Mute voltage input pin                    |
| 7          | Stby    | V <sub>SB</sub> -IN   | Standby voltage input pin                 |
| 8          | Test    | IN                    | Test pin                                  |
| 9          | Diag4   | OUT                   | Thermal detection pin                     |
| 10         | Diag3   | OUT                   | Over-voltage detection pin                |
| 11         | Diag2   | OUT                   | Output short and load short detection pin |
| 12         | Diag1   | OUT                   | Speaker open detection pin                |
| 13         | PW-GND2 | —                     | Ground pin 2 for output                   |
| 14         | PW-GND1 | —                     | Ground pin 1 for output                   |
| 15         | Monitor | IN                    | Speaker monitor pin                       |
| 16         | OUT     | OUT                   | Output pin                                |

## 6. Functional Description

### 6.1 External Component Specification (Recommended circuit)



| Component Name | Recommended Value   | Pin     | Purpose                                  | Effect (Note3)   |  |
|----------------|---------------------|---------|--|--|--|
|                |                     |         |  | Lower than Recommended Value   | Higher than Recommended Value  |
| C1             | 4.7 $\mu$ F         | IN      | To eliminate DC                          | Cut-off frequency becomes higher                                       | Cut-off frequency becomes lower                                      |
| C3             | 1 $\mu$ F           | Mute    | To reduce pop noise                      | High pop noise<br>Duration until mute function is turned off is short. | Low pop noise<br>Duration until mute function is turned off is long. |
| C4             | 4.7 $\mu$ F (Note4) | Ripple  | Ripple filter                            | Turn on/off time is short  | Turn on/off time is long   |
| C5             | 1000 $\mu$ F        | OUT     | To eliminate DC                          | Cut-off frequency becomes higher                                       | Cut-off frequency becomes lower                                      |
| C6             | 470 $\mu$ F         | Vcc     | Ripple filter                            | Filter for power supply hum and ripple                                 |  |
| C7             | 0.1 $\mu$ F         | Vcc     | To provide sufficient oscillation margin | Reduces noise and provides sufficient oscillation margin               |  |
| R1             | 2 k $\Omega$        | IN      | Setting of gain                          | —  |  |
| R2             | 20 k $\Omega$       | IN, OUT | Setting of gain                          | —  |  |
| R3             | 47 k $\Omega$       | Mute    | To reduce pop noise                      | High pop noise<br>Duration until mute function is turned off is short. | Low pop noise<br>Duration until mute function is turned off is long. |
| R              | 1 k $\Omega$        | OUT     | To reduce pop noise                      | High pop noise<br>Current consumption becomes larger                   | Low pop noise<br>Current consumption becomes smaller                 |

Note3: When the not recommended value is used, please examine it enough by system evaluation.

Note4: Please examine C4 constants more than 4.7  $\mu$ F in consideration of POP sound.

## 6.2 Setting of Gain

This product can adjust the voltage gain ( $G_V$ ) of built-in amplifier with a setting of  $R_1$  and  $R_2$ . The voltage gain is determined by  $R_1$  and  $R_2$  as below expression. It becomes  $G_V = 20$  dB (typ.) when it is setting the  $R_1 = 2$  k $\Omega$  and  $R_2 = 20$  k $\Omega$ .

$$G_V \text{ (dB)} = 20 \times \log_{10} \frac{R_2}{R_1}$$

## 6.3 Setting of Cut-off frequency

The lower cut-off frequency of this product is determined by  $C_1$ ,  $R_1$  and  $C_5$ ,  $R_L$ . It is calculated by the below expression.

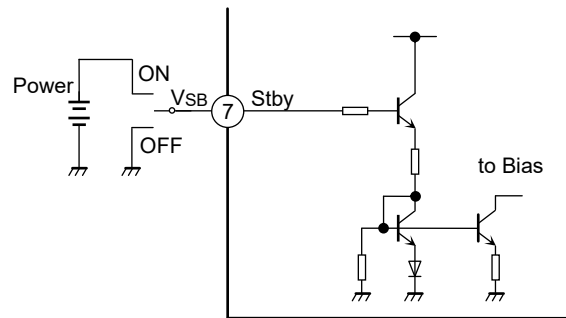
$$\text{Lower cut-off frequency (Hz) } f_{cl} = \frac{1}{2\pi \times C_1 \times R_1} \quad \text{and} \quad f_{cl} = \frac{1}{2\pi \times C_5 \times R_L}$$

## 6.4 Standby Switch (Pin7)

The power supply can be turned on or off via  $Stby$  pin. The power supply current is about 0.01  $\mu$ A (typ.) in the standby state.

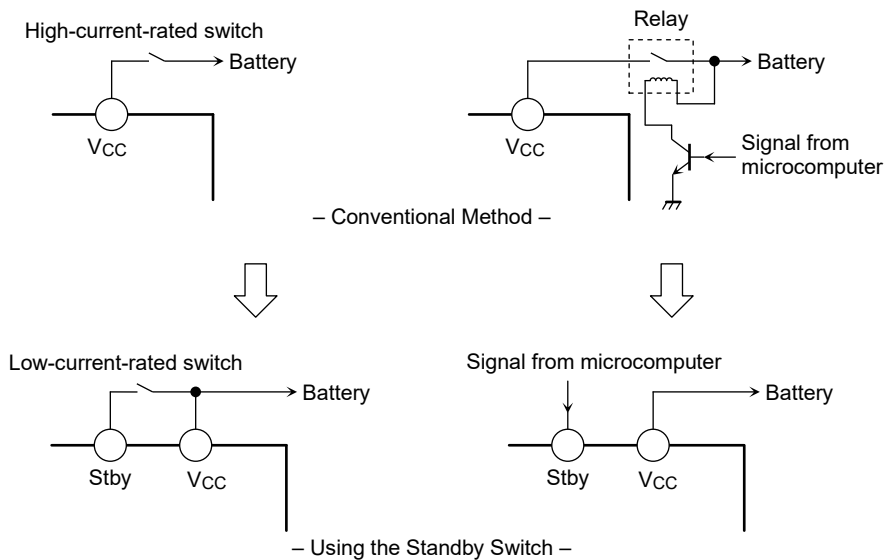
**Table 2 Standby Control voltage ( $V_{SB}$ )**

| Standby | Power | $V_{SB}$ (V)    |
|---------|-------|-----------------|
| ON      | OFF   | 0 to 0.8        |
| OFF     | ON    | 2.4 to $V_{CC}$ |



**Figure 1 Standby Switch Circuit**

As benefit of the standby switch, it is possible that the switch between a battery and  $V_{CC}$  pin changes from a high-current switch to a low-current switch. And  $V_{CC}$  can be directly turned on or off by a microcomputer, and a switching relay can be omitted.



**Figure 2 Standby Switch**

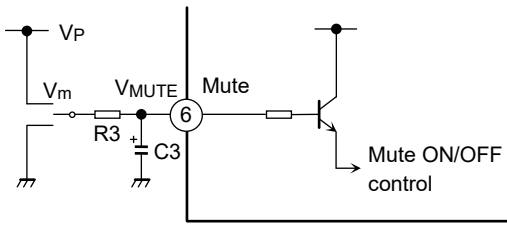
**6.5 Mute Switch (Pin6)**

The mute function is enabled by setting pin 6 (mute voltage input pin) to Low. R3 and C3 connected to the mute pin determine the time constant of the mute function. The time constant affects pop noise generated when power and the mute function are turned on or off. Thus, when the value of R3 and C3 change, they should be determined with an enough consideration.

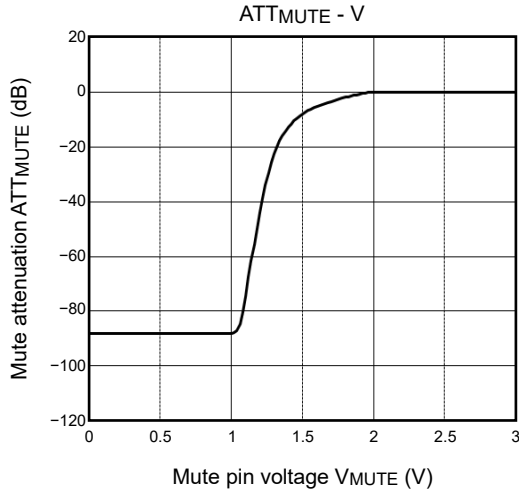
Moreover, this pin is designed on the control voltage of 5 V. If controlling in other voltage, the constant of R3 should be determined as shown below.

For example, when the control voltage ( $V_m$ ) is changed from 5 V to 3.3 V, the value of R3 should be:

$$\frac{3.3 \text{ V}}{5 \text{ V}} \times 47 \text{ k}\Omega = 31 \text{ k}\Omega$$



**Figure 3 Mute Function**



**Figure 4 Mute Attenuation ATTMUTE (dB) - VMUTE (V)**

## 6.6 Speaker Open Detection (Pin12)

Speaker open can be detected with Diag1 pin using Test pin.

At startup, the speaker open detection mode is set by applying the voltage 2.4 V or more to Test pin. Then the Monitor pin connected between the speaker and capacitor C5 sends the measuring current to the speaker. In this time, the speaker open detection is judged by detecting the generated voltage in the IC. (the threshold of  $R_L$  is 80  $\Omega$  (typ.) or more)

In case of speaker open detection, NPN transistor (Q1) is turned on and the Diag1 pin outputs to low.

At the speaker open detection, from applying the voltage 2.4 V or more to Test pin till Diag1 pin outputs to low, it takes 100 ms (typ.). After diagnostics, please set the Test pin to "Low".

In case of diagnostic at the time of the standby-off, please use it in the condition of no inputting or Mute-on. Since the current capability of the collector current of Q1 is about 1 mA, please use the pull-up resistor equal or more than 4.7 k $\Omega$  when Diag1 pin is pulled up at 5 V.

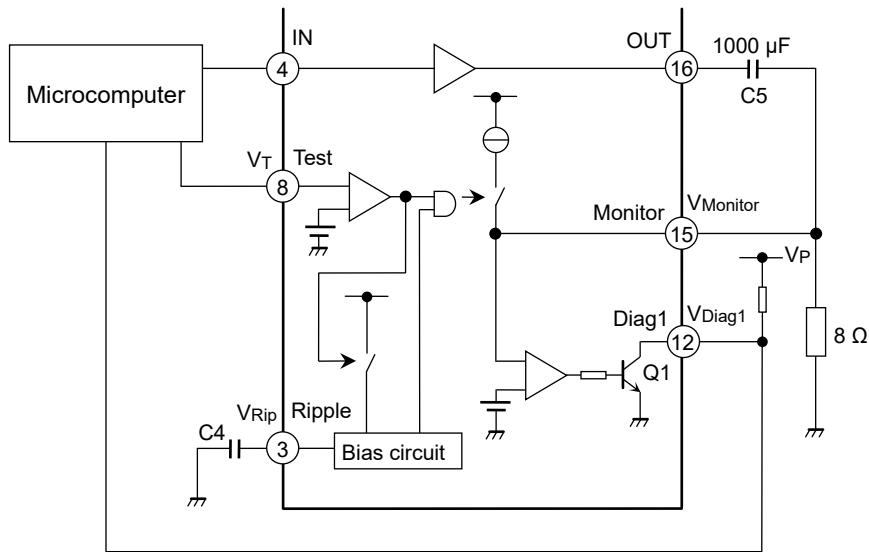
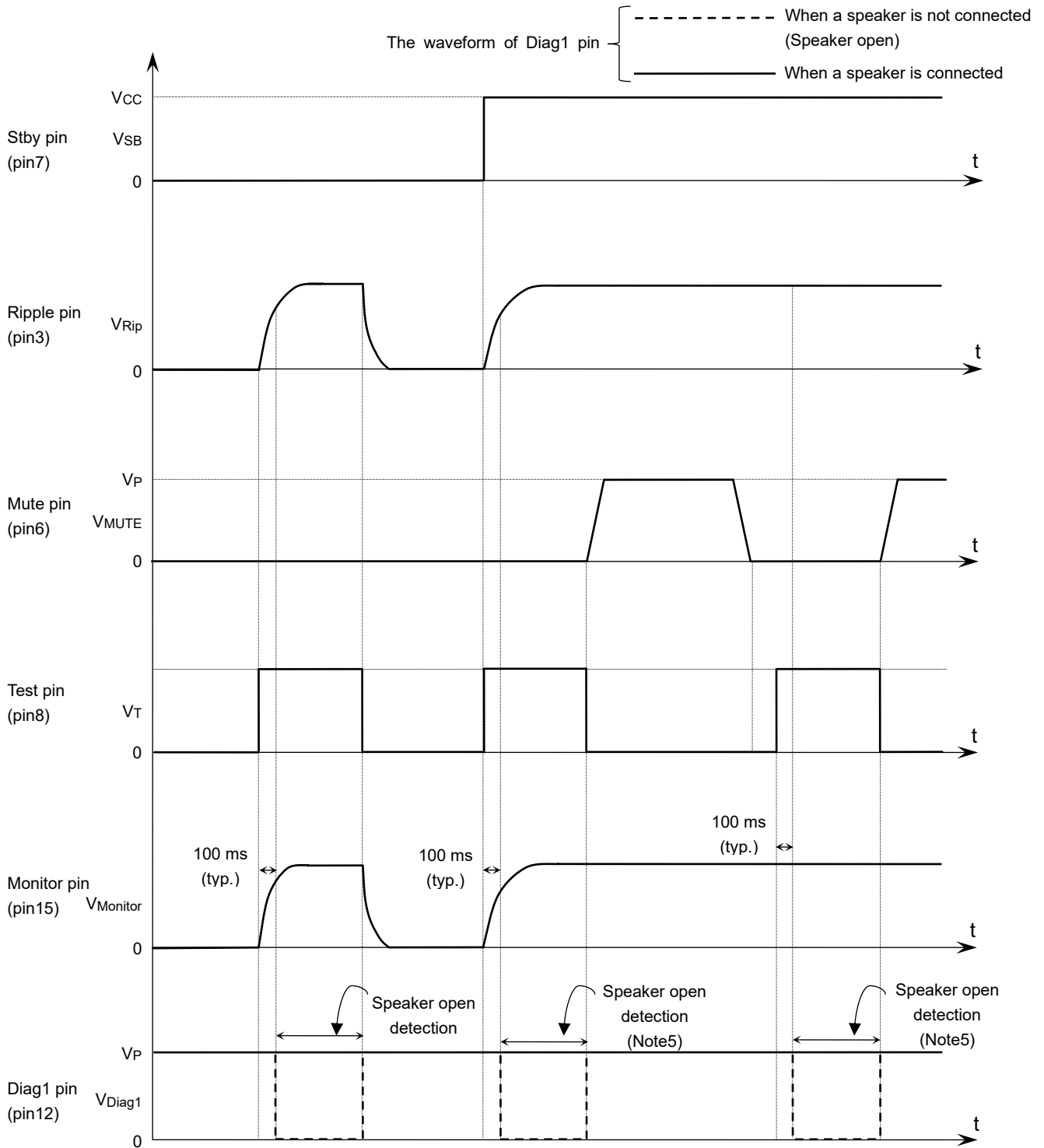


Figure 5 Speaker open detection



**Figure6 Speaker Open Detection Sequence**

| Stby pin | Test pin | Condition                                      |
|----------|----------|--|
| 0        | 0        | Standby on                                     |
| 0        | 1        | Standby on and speaker open detection          |
| 1        | 0        | Standby off                                    |
| 1        | 1        | Standby off and speaker open detection (Note5) |

Note5: In case of diagnostic at standby-off, please use it in the condition of no inputting or mute on state.

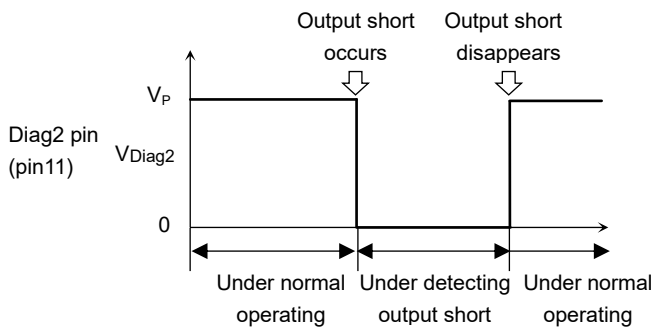
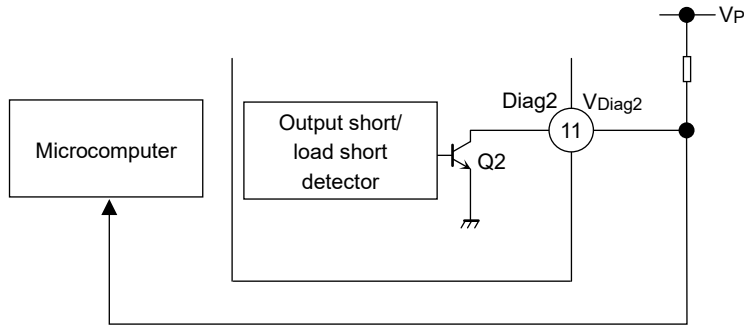
## 6.7 Output Short / Load Short Detection (Pin11)

The Output short and the load short can be detected with Diag2 pin when the protection circuit operates. When the output short is detected, NPN transistor (Q2) is turned on and the Diag2 pin outputs to low. (Refer to figure 7)

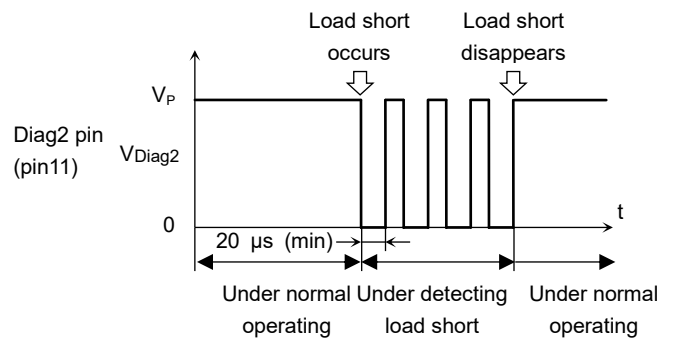
The output short is detected immediately when the decoupling capacitor is shorted.

When the load short is detected, NPN transistor (Q2) repeats turning on and off in response to the output signal. (Refer to Figure 8)

Since the current capability of the collector current of Q2 is set to about 1 mA, please use the pull-up resistor more than 4.7 kΩ when the Diag2 pin is pulled up at 5 V.



**Figure 7 Output Short Detection**



**Figure 8 Load Short Detection**

## 6.8 Over-voltage Detection (Pin10)

The Over-voltage can be detected with Diag3 pin.

When the over-voltage is detected, NPN transistor (Q3) is turned on and the Diag3 pin outputs to low. (Refer to figure 9)

When the power supply voltage is 22 V (typ.) or more, the over-voltage detection is operated. The releasing voltage of the over-voltage detection has hysteresis. After detecting the over-voltage, the over-voltage detection is released when the power supply voltage is 18 V (typ.) or less.

The current capability of the collector current of Q3 is set to about 1 mA, please use the pull-up resistor more than 4.7 kΩ when the Diag3 pin is pulled up at 5 V.

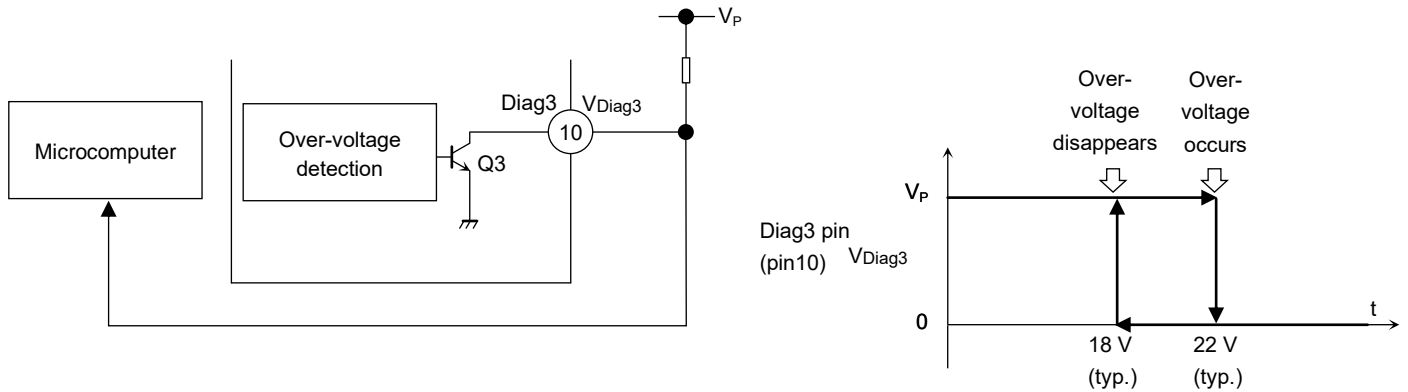


图 9 Over-Voltage Detection

Note6: The over-voltage detection does not recommend that this IC be used above the power supply voltage of absolute maximum ratings (16 V). Please use 16 V or less.

## 6.9 Thermal Detection (Pin9)

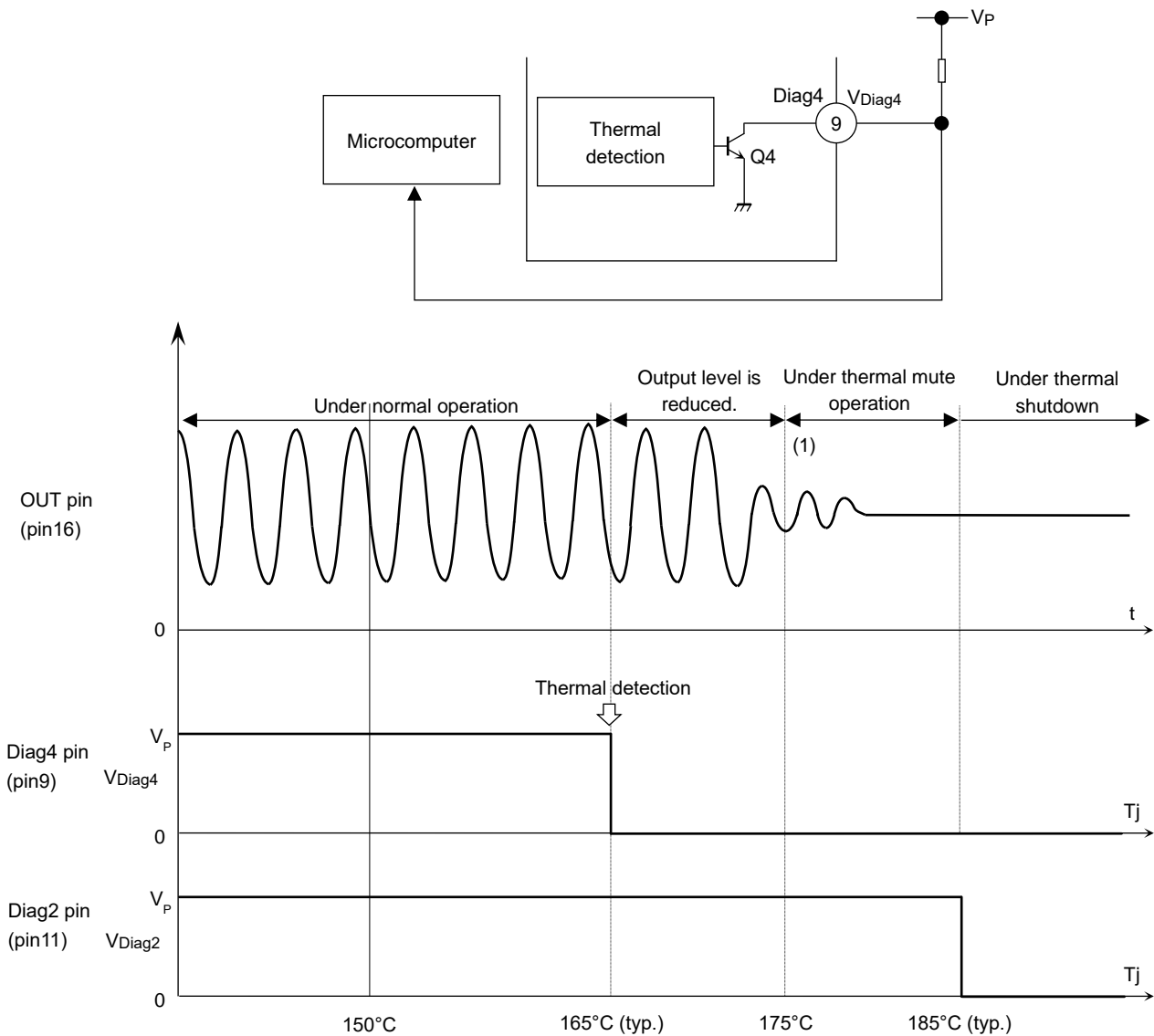
The thermal detection can be detected with Diag4 pin.

When the thermal detection is detected, the output level is reduced. If the junction temperature increased, the output level is more reduced ((1) in Figure 10). Even if the output level is reduced, the junction temperature increased, mute function is enabled (thermal mute). Even if mute function is enabled, the junction temperature increased continuously, the output transistors are OFF (thermal shutdown).

When the junction temperature increases, NPN transistor (Q4) is turned on and the Diag4 pin outputs to low. (Refer to figure 10)

When the junction temperature is 165°C (typ.) or more, the thermal detection is operated.

The current capability of the collector current of Q4 is set to about 1 mA, please use the pull-up resistor 4.7 kΩ or more when the Diag4 pin is pulled up at 5 V.



**Figure 10 Thermal detection**

Note7: The thermal detection does not recommend that this IC be used above the junction temperature of absolute maximum ratings (150°C). Please use 150°C or less.

Note8: If the junction temperature is 185°C (typ.) or more, Diag4 and Daig2 pins become “Low”.

## 6.10 Mute Function

This product has two internal mute functions: low voltage mute, and standby-off mute.

### 6.10.1 Low Voltage Mute

The Low-voltage mute is the function which operates automatically by the internal circuit of IC when the supply voltage ( $V_{CC}$ ) become 5.5 V or lower.

The releasing voltage of the over-voltage detection has hysteresis. After the low voltage mute operates, the low voltage mute is released when the power supply voltage ( $V_{CC}$ ) is 5.7 V (typ.) or more.

### 6.10.2 Standby-off Mute

The standby-off mute is the function which operates automatically by the internal circuit of IC after the standby voltage input pin is set to “High” until the Ripple pin voltage ( $V_{Rip}$ ) becomes about  $V_{CC} / 2 + 1.75$  V. The standby-off mute operates automatically regardless of the state of the mute control voltage.

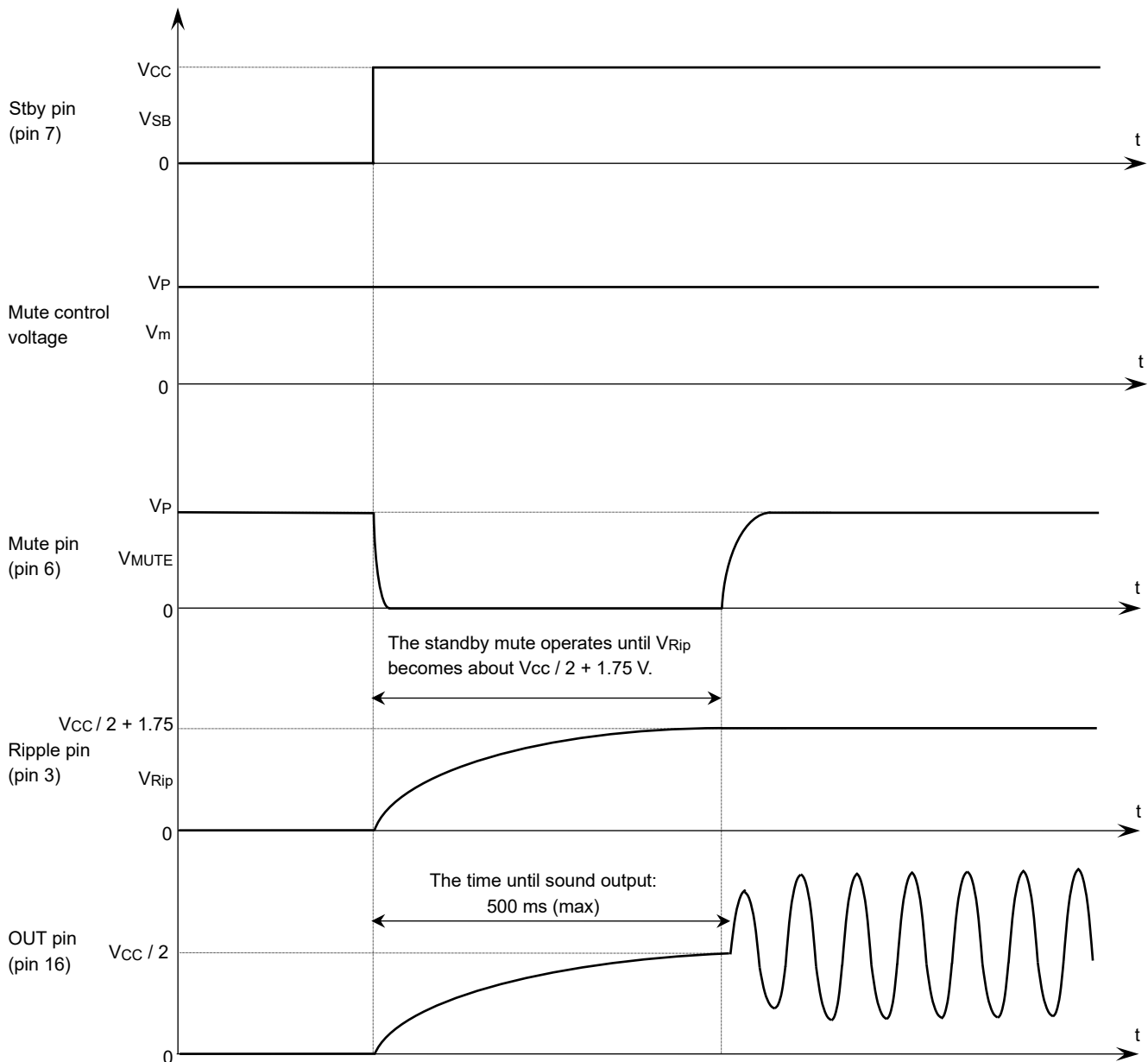


Figure 11 Sequence at Standby-off

### 6.10.3 Mute-off sequence after standby-off

Figure 12 shows the sequence which the mute is turned off by changing the Mute control voltage ( $V_m$ ) from 0 to  $V_P$  after standby-off.

After standby-off, if the mute is turned off before charging  $C_5$  is finished, the pop noise occurs. As a countermeasure of pop noise, please set "Mute-off" with sufficient margin in considering a enough charge time after the output DC bias voltage becomes stable.

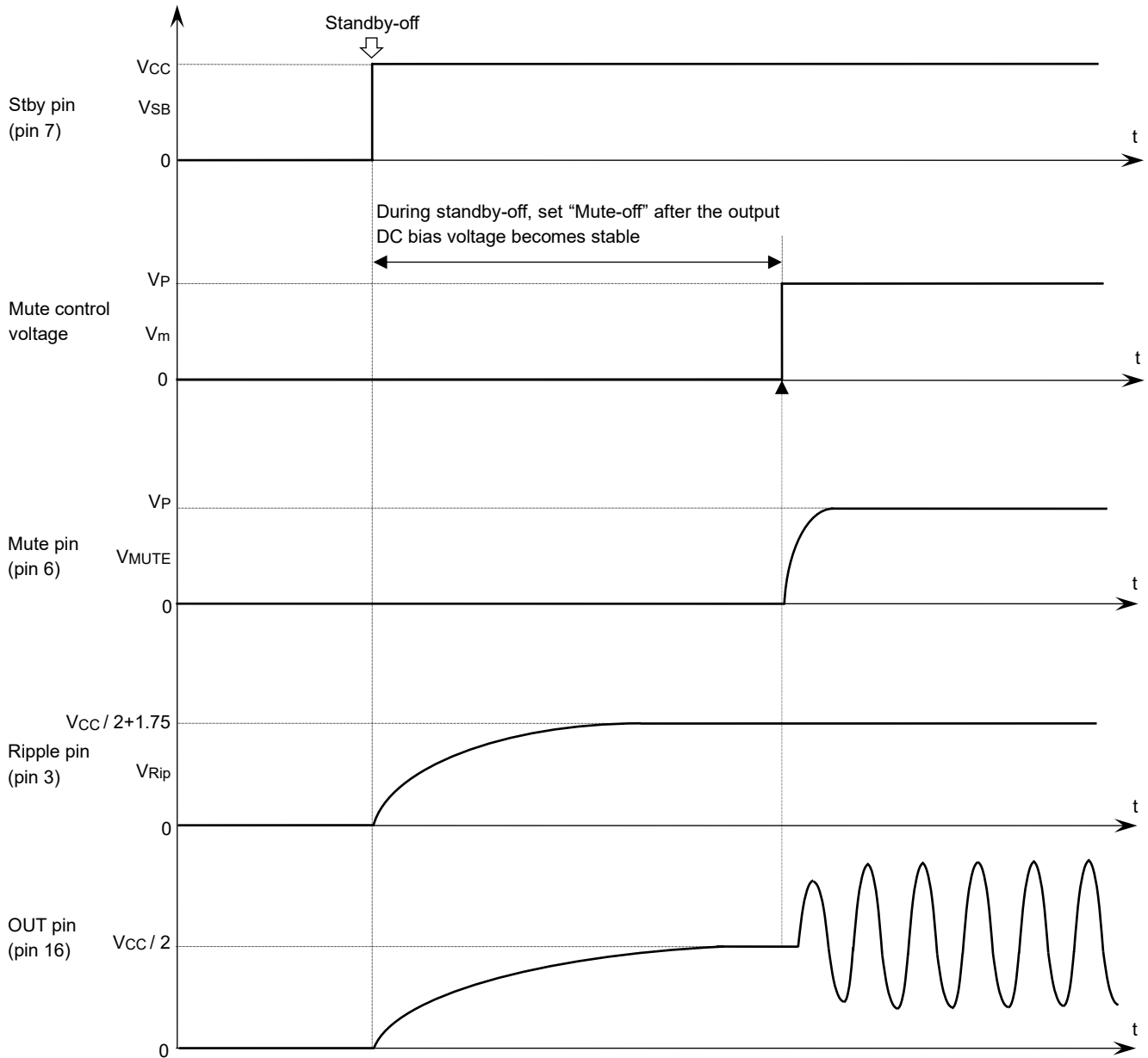


Figure 12 Mute-off Sequence After Standby-off

## 6.11 Protection Functions

This product has internal protection circuits such as thermal shut down, over-voltage protection, output short protection, and load short protection.

### (1) Thermal shut down

It operates when the junction temperature is 165°C or more. (Note9)

If the junction temperature falls, it will return automatically.

When it operates, it is protected in the following order.

1. An attenuation of an output starts first and the amount of attenuation also increases according to a temperature rising.
2. All outputs become in a mute state, when temperature continues rising in spite of output attenuation.
3. Output bias is turned off, when a temperature rise continues in spite of all outputs in a mute state.

### (2) Over-voltage (Note10) (Note11)

It operates when a power supply voltage is operating range (22 V) or more to VCC pin.

If voltage falls, it will return automatically.

When it operates, output bias is turned off.

### (3) Output short, and load short

It operates when each output pin is irregular connection.

If irregular connection is canceled, it will return automatically.

When it operates, output bias is turned off.

Note9: This function does not recommend that this IC be used above the junction temperature of absolute maximum ratings (150°C). Please use 150°C or less.

Note10: This function does not recommend that this IC be used above the power supply voltage of absolute maximum ratings (16 V). Please use 16 V or less.

Note11: This function operates in Standby-on.

## 7. Absolute Maximum Ratings

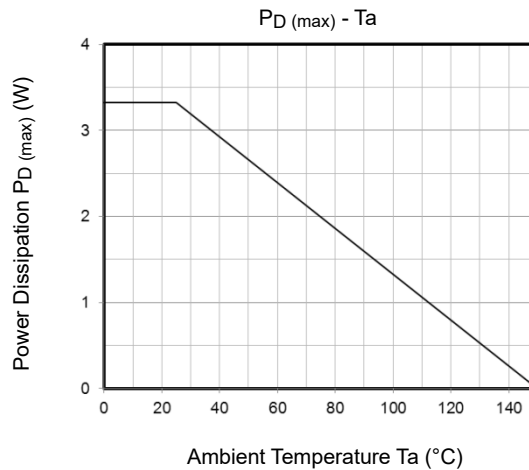
(Ta = 25°C unless otherwise specified)

| Characteristics             | Condition | Symbol          | Rating     | Unit |
|-----------------------------|-----------|-----------------|------------|------|
| Supply voltage (surge)      | max 0.2 s | $V_{CC(surge)}$ | 40         | V    |
| Supply voltage (DC)         | —         | $V_{CC(DC)}$    | 25         | V    |
| Supply voltage (operation)  | —         | $V_{CC(opr)}$   | 16         | V    |
| Output current (peak)       | —         | $I_{O(peak)}$   | 2.5        | A    |
| Power dissipation           | (Note12)  | $P_D$           | 3.3        | W    |
| Operating temperature range | —         | $T_{opr}$       | -40 to 110 | °C   |
| Storage temperature         | —         | $T_{stg}$       | -55 to 150 | °C   |
| Junction temperature        | —         | $T_j$           | 150        | °C   |

Note12: Ta = 25°C, Package thermal resistance  $\theta_{j-a} = 37.6^\circ\text{C/W}$

The maximum rating is the rating that should never be exceeded, even for a shortest of moments. If the maximum rating is exceeded, it could result in damage and/or deterioration of the IC as well as other devices beside the IC. Regardless of the operating conditions, please design so that the maximum rating is never exceeded. Please use within the specified operating range.

### 7.1 Power Dissipation



- Package thermal resistance  $\theta_{j-a} = 37.6^\circ\text{C/W}$
- Condition board material: FR-4  
 Board area: 114.3 × 76.2 mm, t = 1.6 mm  
 1-layer (surface layer) Cu-area: 45 × 70 mm, Cu-surface: 12%, Cu-thickness: 70 μm  
 2-layer (inner layer) Cu-area: 74 × 74 mm, Cu-surface: 100%, Cu-thickness: 35 μm  
 16-Thermal via connected to 1-layer and 2-layer.  
 Connect to the back of package e-pad and Cu of 1-layer by solder.

This package thermal resistance is the evaluation result at board included in chip, package and substrate, the power dissipation is calculated from thermal resistance. Regarding to using this product, please use the low resistance board and give a margin to the power dissipation.

## 8. Operating Ranges

| Characteristics | Symbol   | Condition        | Min | Typ. | Max | Unit |
|-----------------|----------|------------------|-----|------|-----|------|
| Supply voltage  | $V_{CC}$ | $R_L = 8 \Omega$ | 6   | —    | 16  | V    |

## 9. Electrical Characteristics

$V_{CC} = 12 \text{ V}$ ,  $f = 1 \text{ kHz}$ ,  $R_L = 8 \Omega$ ,  $G_V = 20 \text{ dB}$ ,  $T_a = 25^\circ\text{C}$  unless otherwise specified

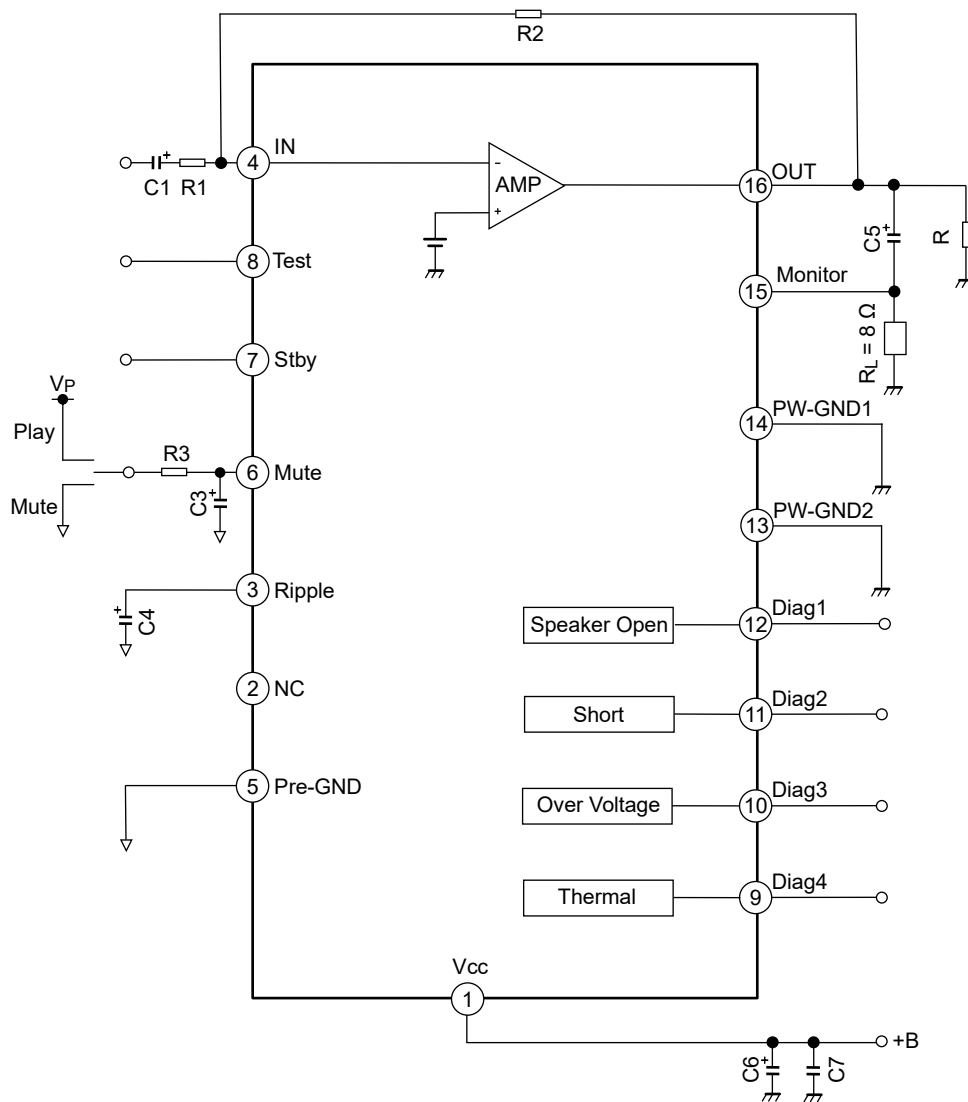
| Characteristics  | Symbol                  | Test Circuit | Test Condition   | Min | Typ. | Max      | Unit             |
|--|-------------------------|--------------|--|-----|------|----------|------------------|
| Quiescent supply current   | $I_{CCQ}$               | —            | $V_{IN} = 0 \text{ V}$   | —   | 7    | —        | mA               |
| Output power   | $P_{OUT \text{ MAX1}}$  | —            | max POWER  | —   | 3    | —        | W                |
|  | $P_{OUT}$               | —            | THD = 10%  | —   | 2    | —        |                  |
|  | $P_{OUT \text{ MAX2}}$  | —            | $V_{CC} = 16 \text{ V}$ , max POWER  | —   | 5    | —        |                  |
| Total harmonic distortion  | THD                     | —            | $P_{out} = 0.125 \text{ W}$ ( $V_{OUT} = 1 \text{ Vrms}$ )<br>Filter = 400 Hz to 30 kHz    | —   | 0.08 | —        | %                |
| Voltage gain   | $G_V$                   | —            | $V_{OUT} = 0.775 \text{ Vrms}$<br>Setting input resistance ( $\pm 1\%$ )                   | 19  | 20   | 21       | dB               |
| Output noise voltage   | $V_{NO}$                | —            | $R_g = 0 \Omega$ , DIN_AUDIO   | —   | 50   | —        | $\mu\text{Vrms}$ |
| Ripple rejection ration  | R.R.                    | —            | $f_{RIP} = 100 \text{ Hz}$ , $R_g = 620 \Omega$<br>$V_{RIP} = 0.775 \text{ Vrms}$ (Note13) | —   | 50   | —        | dB               |
| Standby current  | $I_{SB}$                | —            | Standby-on   | —   | 0.01 | 9        | $\mu\text{A}$    |
| Standby control voltage  | $V_{SB \text{ H}}$      | —            | Standby: OFF(Note14)   | 2.4 | —    | $V_{CC}$ | V                |
|  | $V_{SB \text{ L}}$      | —            | Standby: ON  | 0   | —    | 0.8      |                  |
| Mute pin voltage   | $V_{MUTE \text{ H}}$    | —            | MUTE: OFF(Note14)  | 2.4 | —    | $V_{CC}$ |                  |
|  | $V_{MUTE \text{ L}}$    | —            | MUTE: ON   | 0   | —    | 0.8      |                  |
| Test control voltage   | $V_T \text{ H}$         | —            | Test: ON(Note14)   | 2.4 | —    | $V_{CC}$ |                  |
|  | $V_T \text{ L}$         | —            | Test: OFF  | 0   | —    | 0.8      |                  |
| Mute attenuation   | $ATT_{MUTE}$            | —            | $V_{OUT} = 0.775 \text{ Vrms} \rightarrow$ Mute: ON<br>DIN_AUDIO                           | —   | 85   | —        | dB               |
| Diag1 to Diag4 pin<br>Saturation voltage in operation of<br>each detection | Px-Sat<br>(x = 9 to 12) | —            | $R_{pull-up} = 10 \text{ k}\Omega$ , $+V_{SB} = 5.0 \text{ V}$<br>When detect (pin Low)    | —   | 100  | 500      | mV               |

Note13:  $f_{RIP}$ : Ripple frequency

$V_{RIP}$ : Ripple signal voltage (AC fluctuations in the power supply)

Note14:  $V_{SB \text{ H}}$ ,  $V_{MUTE \text{ H}}$ , and  $V_T \text{ H}$  should be used 16 V or less.

## 10. Test Circuit



Components in the test circuits are only used to obtain and confirm the device characteristics.

## 11. Characteristic Chart

### 11.1 Total Harmonic Distortion vs. Output Power

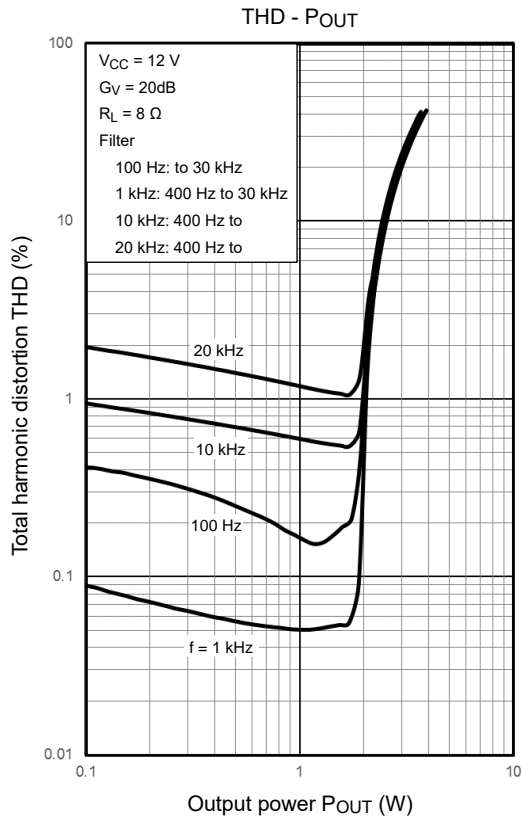


Figure 8 Total Harmonic Distortion of Each Frequency

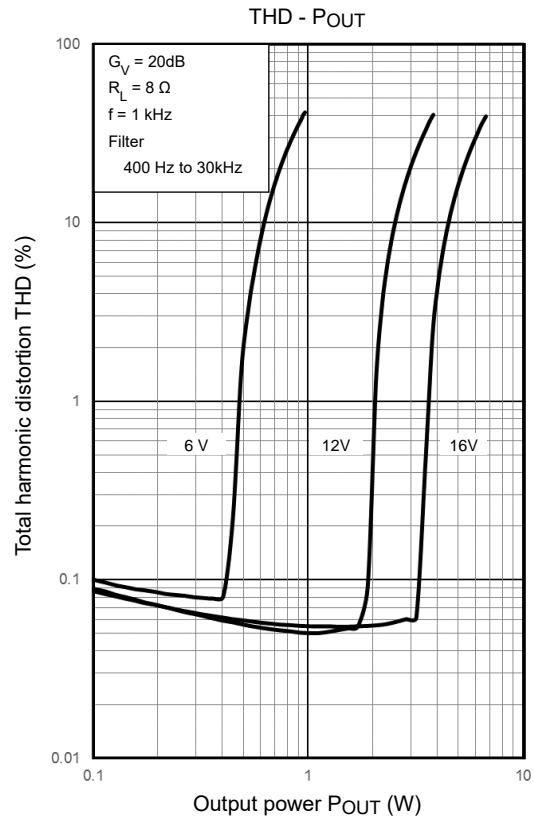


Figure 9 Total Harmonic Distortion by Power Supply Voltage

### 11.2 Various Frequency Characteristics

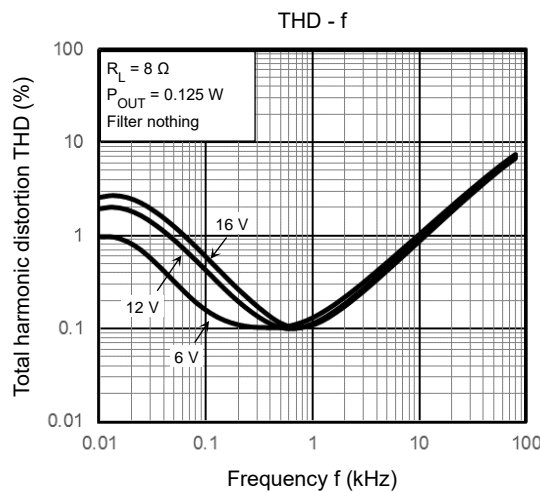
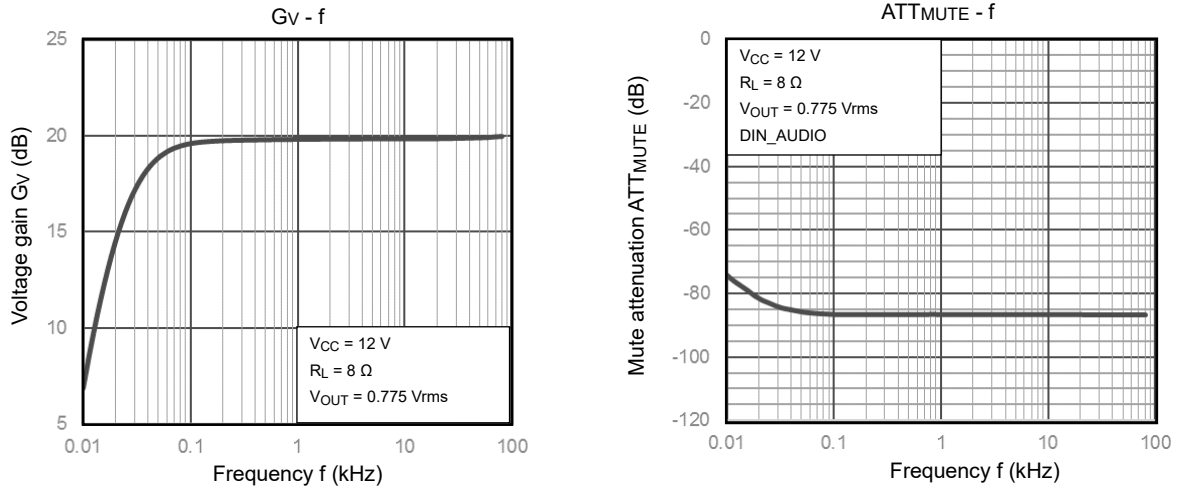
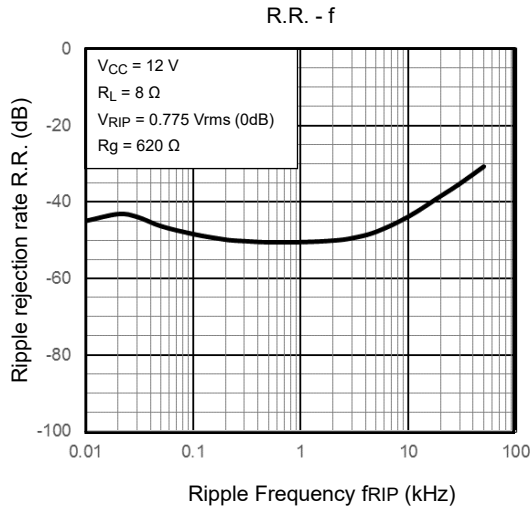


Figure 10 Frequency Characteristics of Total Harmonic Distortion

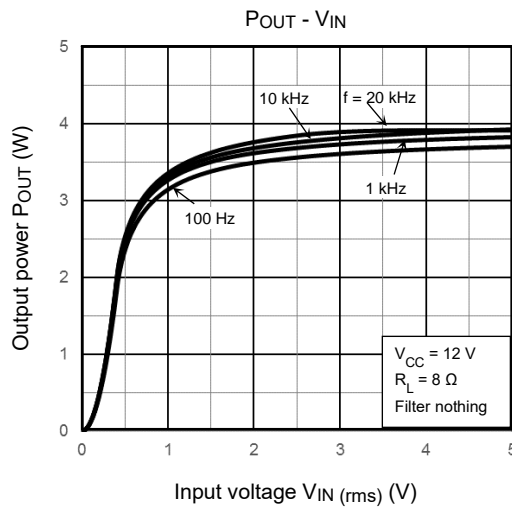


**Figure 11 Frequency Characteristics of Voltage Gain**

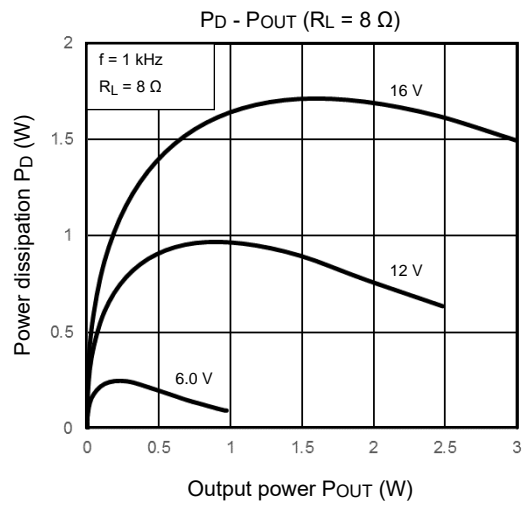


**Figure 12 Frequency Characteristics of**

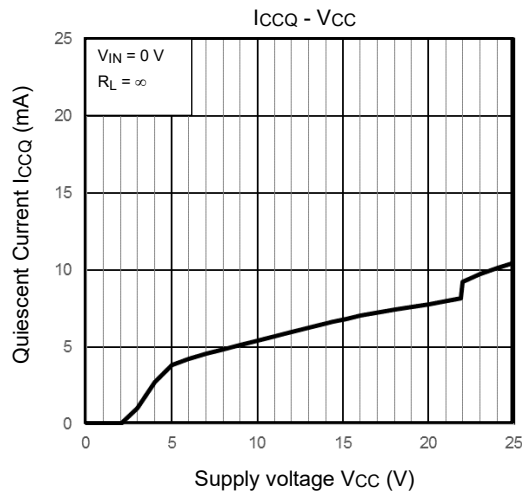
**11.3 Output Power Characteristics to Input Voltage**



## 11.4 Power Dissipation vs. Output Power



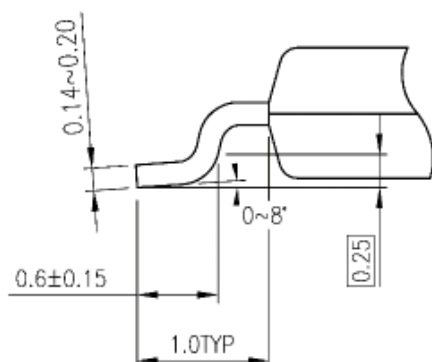
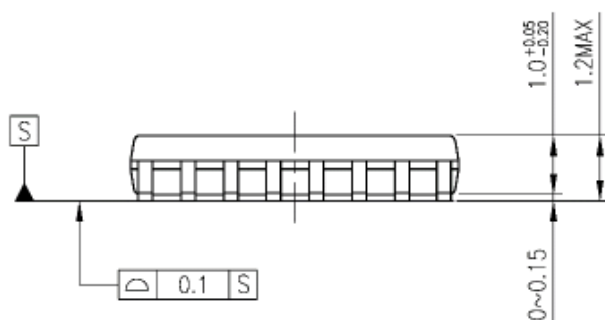
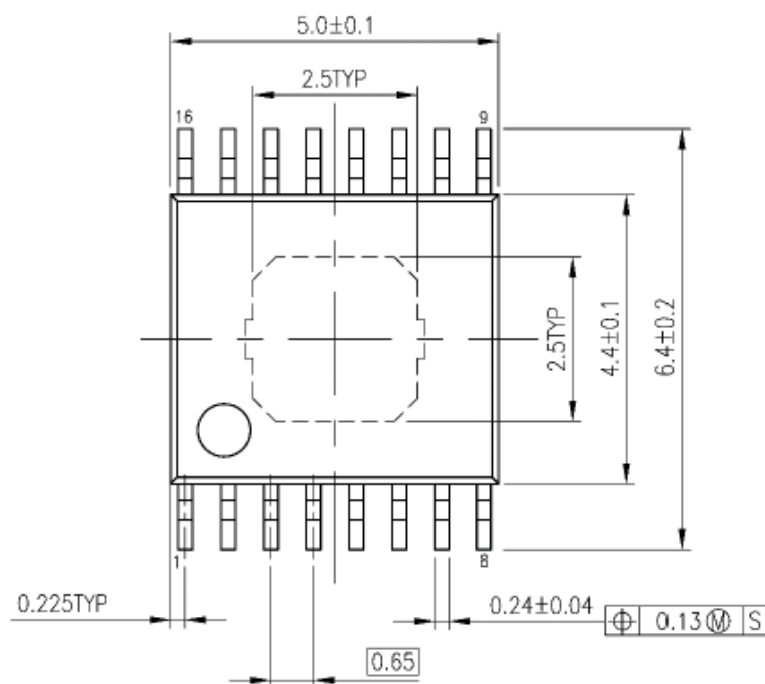
## 11.5 Other Characteristic



## 12. Package Dimensions

Package: P-HTSSOP16-0505-0.65-001

Unit: mm



Weight: 0.062 g (typ.)

## 13. 1ch Power Amp IC Evaluation Board Diagram

This dimension is the pattern layer “RP-2024Z” for 1ch power IC evaluation board using P-HTSSOP16-0505-0.65-001. This product evaluates below board.

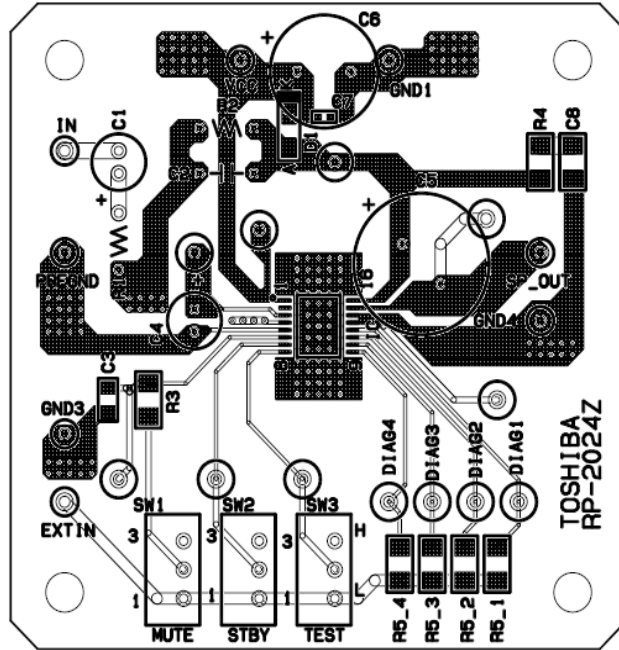
1-layer: (surface layer) Cu-area: 57 × 57 mm, Cu-surface: about 20%, Cu-thickness: 35 μm

2-layer: (inner layer) Cu-area: 57 × 57 mm, Cu-surface: about 80%, Cu-thickness: 70 μm

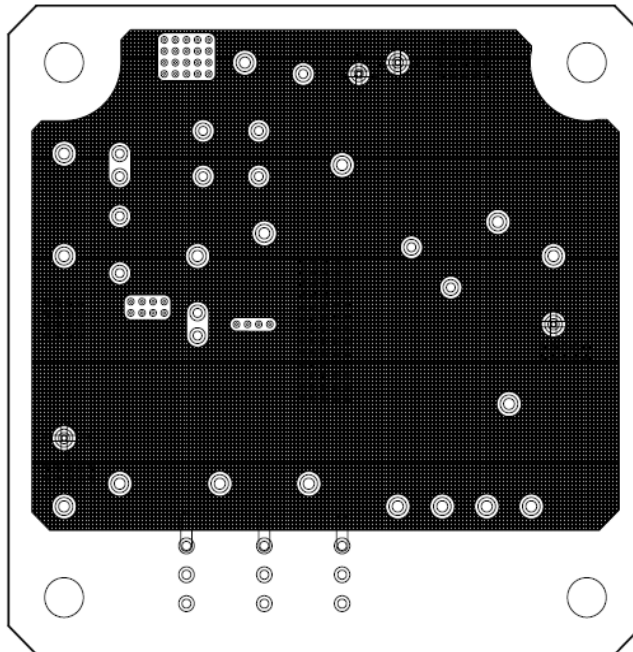
3-layer: (inner layer) Cu-area: 57 × 57 mm, Cu-surface: about 80%, Cu-thickness: 70 μm

4-layer: (solder layer) Cu-area: 57 × 57 mm, Cu-surface: about 20%, Cu-thickness: 35 μm

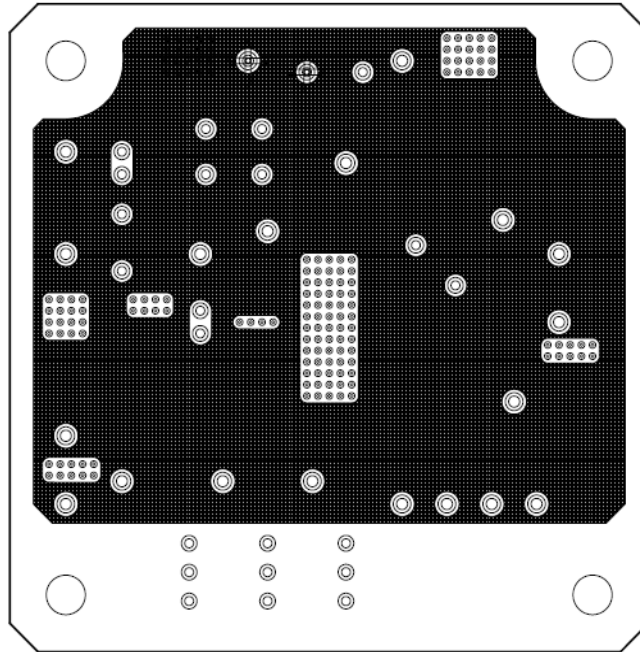
- Component side (1-layer)



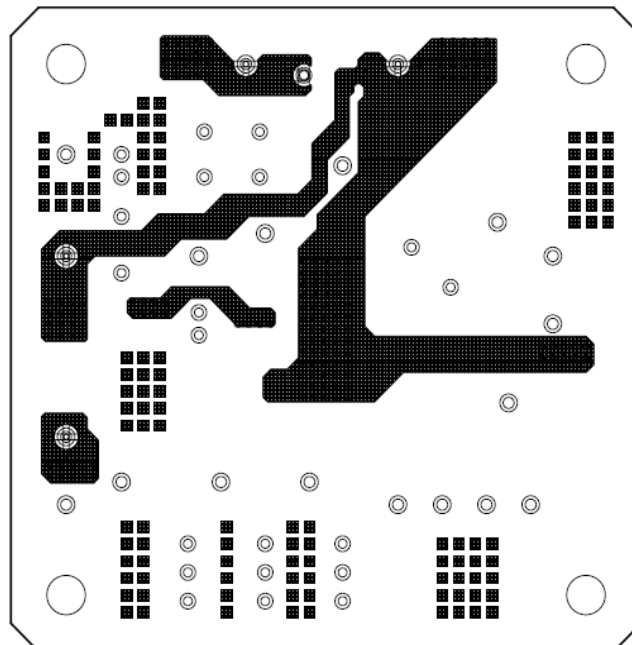
- GND layer (2-layer)



- Vcc layer (3-layer)



- Solder side (4-layer)



## Notes on Contents

- (1) Block Diagrams  
Some of the functional blocks, circuits, or constants in the block diagram may be omitted or simplified for explanatory purposes.
- (2) Equivalent Circuits  
The equivalent circuit diagrams may be simplified or some parts of them may be omitted for explanatory purposes.
- (3) Timing Charts  
Timing charts may be simplified for explanatory purposes.
- (4) Application Circuits  
The application circuits shown in this document are provided for reference purposes only.  
Thorough evaluation is required, especially at the mass production design stage.  
Providing these application circuit examples does not grant a license for industrial property rights.
- (5) Test Circuits  
Components in the test circuits are used only to obtain and confirm the device characteristics. These components and circuits are not guaranteed to prevent malfunction or failure from occurring in the application equipment.
- (6) Characteristic Chart  
This data is provided for reference only. Thorough evaluation and testing should be implemented when designing your application's mass production design.

## IC Usage Considerations

### Notes on handling of ICs

- [1] The absolute maximum ratings of a semiconductor device are a set of ratings that must not be exceeded, even for a moment. Do not exceed any of these ratings.  
Exceeding the rating(s) may cause the device breakdown, damage or deterioration, and may result injury by explosion or combustion.
- [2] Use an appropriate power supply fuse to ensure that a large current does not continuously flow in case of over current and/or IC failure. The IC will fully break down when used under conditions that exceed its absolute maximum ratings, when the wiring is routed improperly or when an abnormal pulse noise occurs from the wiring or load, causing a large current to continuously flow and the breakdown can lead smoke or ignition. To minimize the effects of the flow of a large current in case of breakdown, appropriate settings, such as fuse capacity, fusing time and insertion circuit location, are required.
- [3] If your design includes an inductive load such as a motor coil, incorporate a protection circuit into the design to prevent device malfunction or breakdown caused by the current resulting from the inrush current at power ON or the negative current resulting from the back electromotive force at power OFF. IC breakdown may cause injury, smoke or ignition.  
Use a stable power supply with ICs with built-in protection functions. If the power supply is unstable, the protection function may not operate, causing IC breakdown. IC breakdown may cause injury, smoke or ignition.
- [4] Do not insert devices in the wrong orientation or incorrectly.  
Make sure that the positive and negative terminals of power supplies are connected properly.  
Otherwise, the current or power consumption may exceed the absolute maximum rating, and exceeding the rating(s) may cause the device breakdown, damage or deterioration, and may result injury by explosion or combustion.  
In addition, do not use any device that is applied the current with inserting in the wrong orientation or incorrectly even just one time.

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## Points to remember on handling of ICs

### (1) Over current Protection Circuit

Over current protection circuits (referred to as current limiter circuits) do not necessarily protect ICs under all circumstances. If the over current protection circuits operate against the over current, clear the over current status immediately.

Depending on the method of use and usage conditions, such as exceeding absolute maximum ratings can cause the over current protection circuit to not operate properly or IC breakdown before operation. In addition, depending on the method of use and usage conditions, if over current continues to flow for a long time after operation, the IC may generate heat resulting in breakdown.

### (2) Thermal Shutdown Circuit

Thermal shutdown circuits do not necessarily protect ICs under all circumstances. If the thermal shutdown circuits operate against the over temperature, clear the heat generation status immediately.

Depending on the method of use and usage conditions, such as exceeding absolute maximum ratings can cause the thermal shutdown circuit to not operate properly or IC breakdown before operation.

### (3) Heat Radiation Design

In using an IC with large current flow such as power amp, regulator or driver, please design the device so that heat is appropriately radiated, not to exceed the specified junction temperature ( $T_j$ ) at any time and condition. These ICs generate heat even during normal use. An inadequate IC heat radiation design can lead to decrease in IC life, deterioration of IC characteristics or IC breakdown. In addition, please design the device taking into consideration the effect of IC heat radiation with peripheral components.

### (4) Back-EMF

When a motor rotates in the reverse direction, stops or slows down abruptly, a current flow back to the motor's power supply due to the effect of back-EMF. If the current sink capability of the power supply is small, the device's motor power supply and output pins might be exposed to conditions beyond absolute maximum ratings. To avoid this problem, take the effect of back-EMF into consideration in system design.

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