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
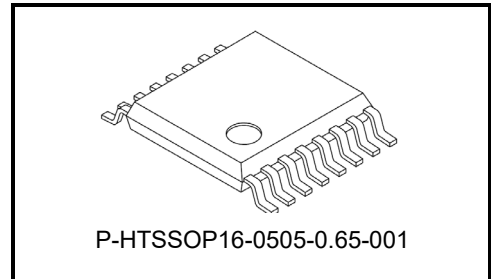
Weight: 0.062 g (typ.)

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
Output power ($P_{OUT\ MAX}$)		
V_{CC} = 16 V Max Power	5	W
V_{CC} = 12 V Max Power	3	W
THD = 10%	2	W
Total harmonic distortion (THD)		
P_{OUT} = 0.125 W (V_{OUT} = 1 Vrms)	0.08	%
Output noise voltage (V_{NO})		
DIN_AUDIO, Rg = 620 Ω	50	µVrms
Operating Supply voltage range (V_{CC})		
R_L = 8 Ω	6 to 16	V

Note1: Typical test conditions V_{CC} = 12 V, f = 1 kHz, R_L = 8 Ω, G_V = 20 dB, Ta = 25°C; unless otherwise specified
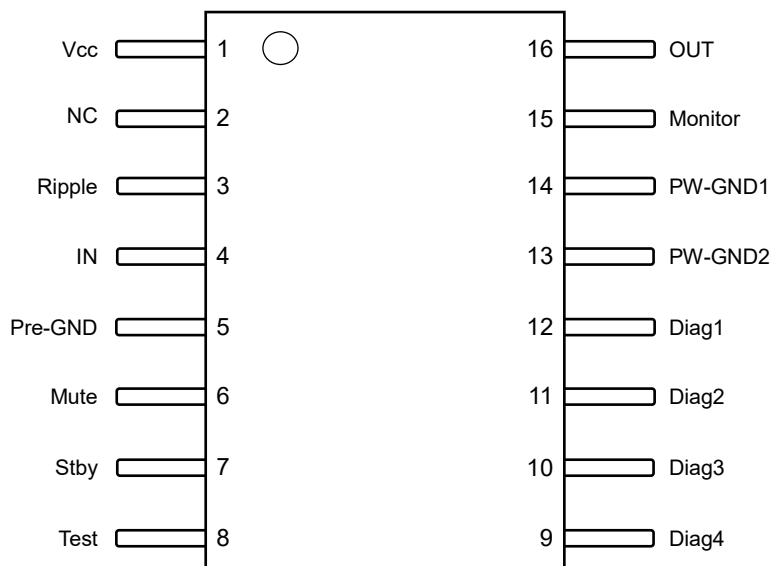
Rg: signal source resistance
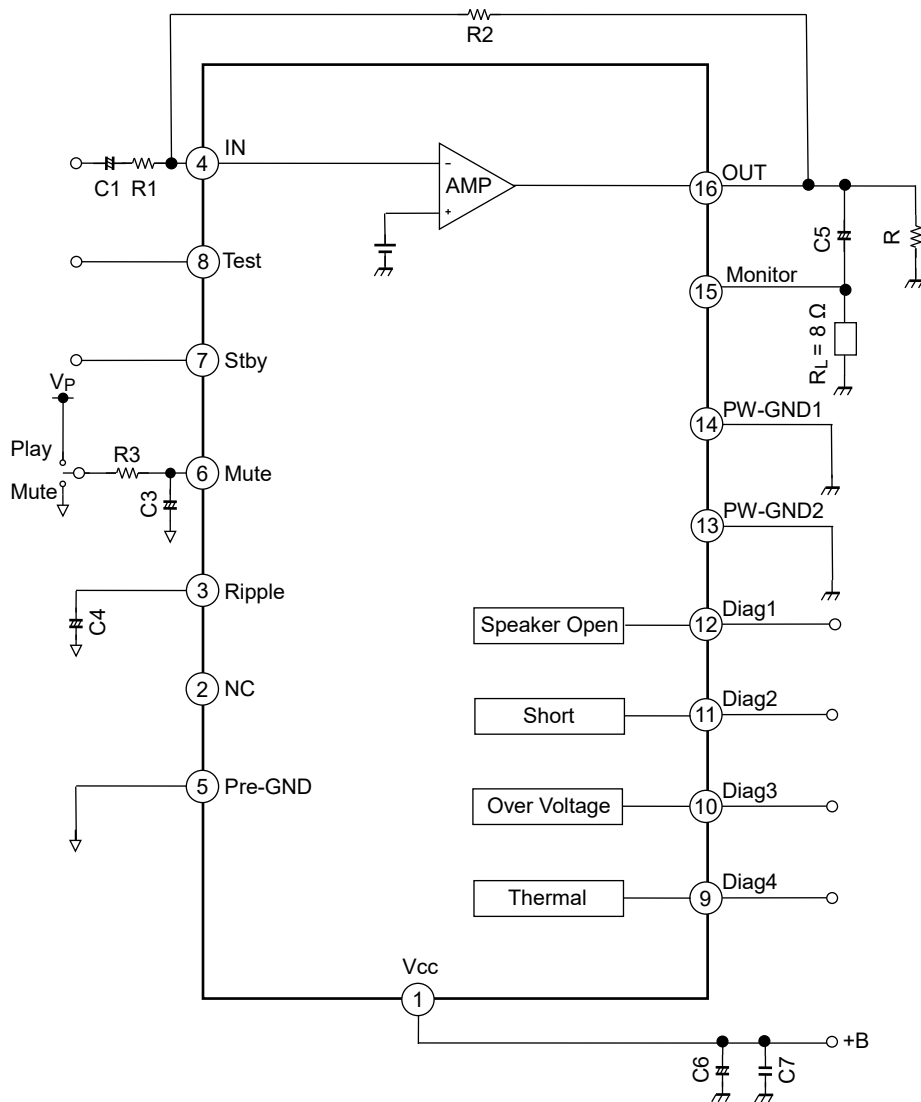
4. Block Diagram

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)

```
          ┌─────────────────────┐
Vcc ──────┤ 1   ◯          16  ├────── OUT
          │                     │
NC ───────┤ 2             15  ├────── Monitor
          │                     │
Ripple ───┤ 3             14  ├────── PW-GND1
          │                     │
IN ───────┤ 4             13  ├────── PW-GND2
          │                     │
Pre-GND ──┤ 5             12  ├────── Diag1
          │                     │
Mute ─────┤ 6             11  ├────── Diag2
          │                     │
Stby ─────┤ 7             10  ├────── Diag3
          │                     │
Test ─────┤ 8              9  ├────── Diag4
          └─────────────────────┘
```

5.2 Pin Function Description

Pin number	Symbol	I/O	Description
1	Vcc	V_{CC}-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_{MUTE}-IN	Mute voltage input pin
7	Stby	V_{SB}-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
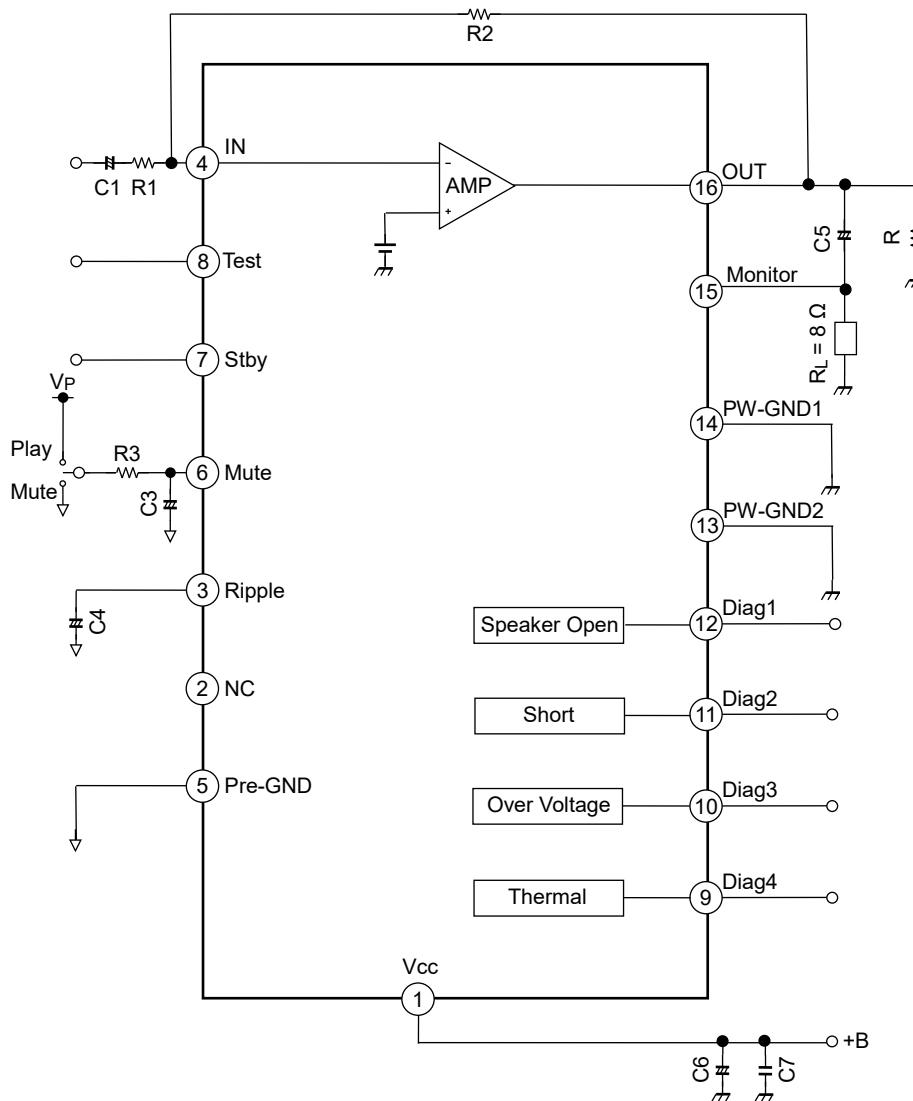
6.1 External Component Specification (Recommended circuit)

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

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

2021-02-05

Note4: Please examine C4 constants more than 4.7 μF in consideration of POP sound.

6.2 Setting of Gain

This product can adjust the voltage gain (Gv) of built-in amplifier with a setting of R1 and R2.
The voltage gain is determined by R1 and R2 as below expression.
It becomes Gv = 20 dB (typ.) when it is setting the R1 = 2 kΩ and R2 = 20 kΩ.

$$G_V \text{ (dB)} = 20 \times \log_{10} \frac{R2}{R1}$$

6.3 Setting of Cut-off frequency

The lower cut-off frequency of this product is determined by C1, R1 and C5, RL.
It is calculated by the below expression.

$$\text{Lower cut-off frequency (Hz) fcl} \quad fcl = \frac{1}{2\pi \times C1 \times R1} \quad \text{and} \quad fcl = \frac{1}{2\pi \times C5 \times R_L}$$

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 μA (typ.) in the standby state.
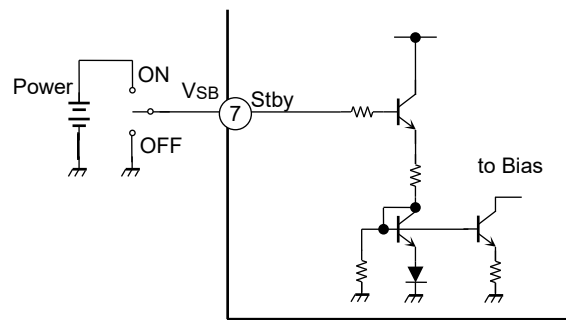
Table 2 Standby Control voltage (V$_{SB}$)

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 Vcc 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.
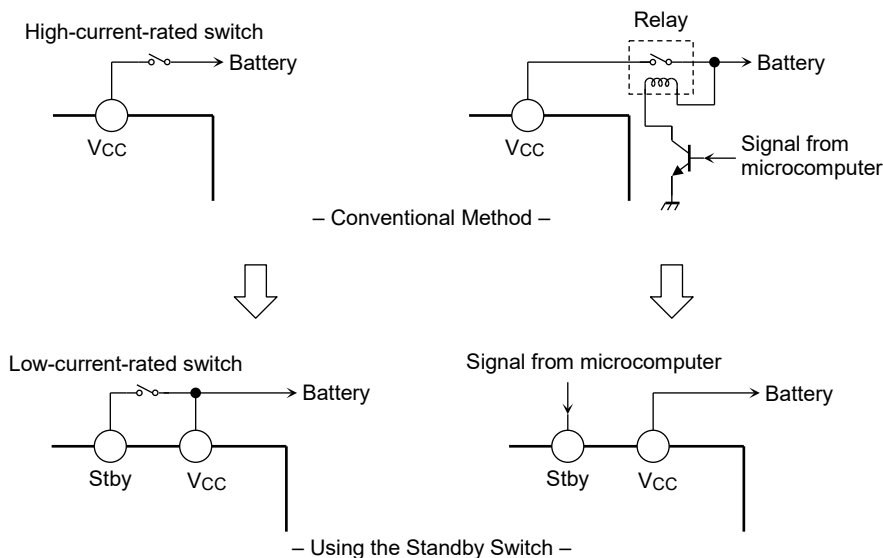

Figure 2 Standby Switch

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:

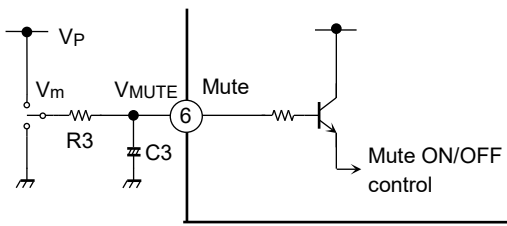$$\frac{3.3 \text{ V}}{5 \text{ V}} \times 47 \text{ k}\Omega = 31 \text{ k}\Omega$$
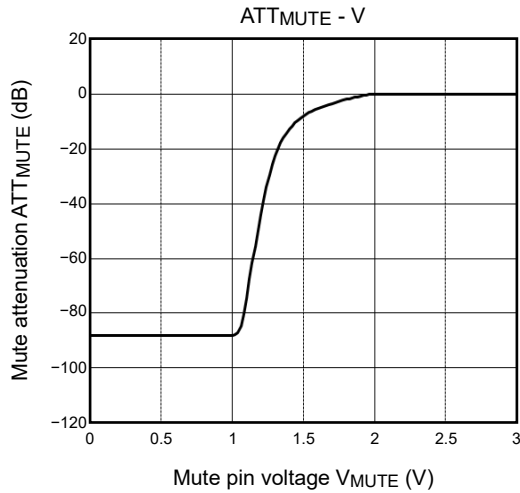
Figure 3 Mute Function

Figure 4 Mute Attenuation ATT$_{MUTE}$ (dB) - V$_{MUTE}$ (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 Ω (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 diagnostication, 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 kΩ when Diag1 pin is pulled up at 5 V.
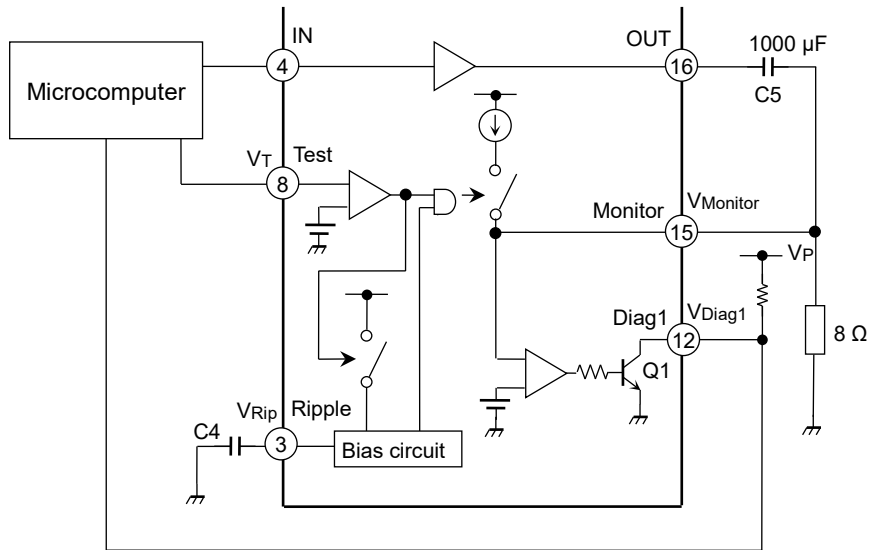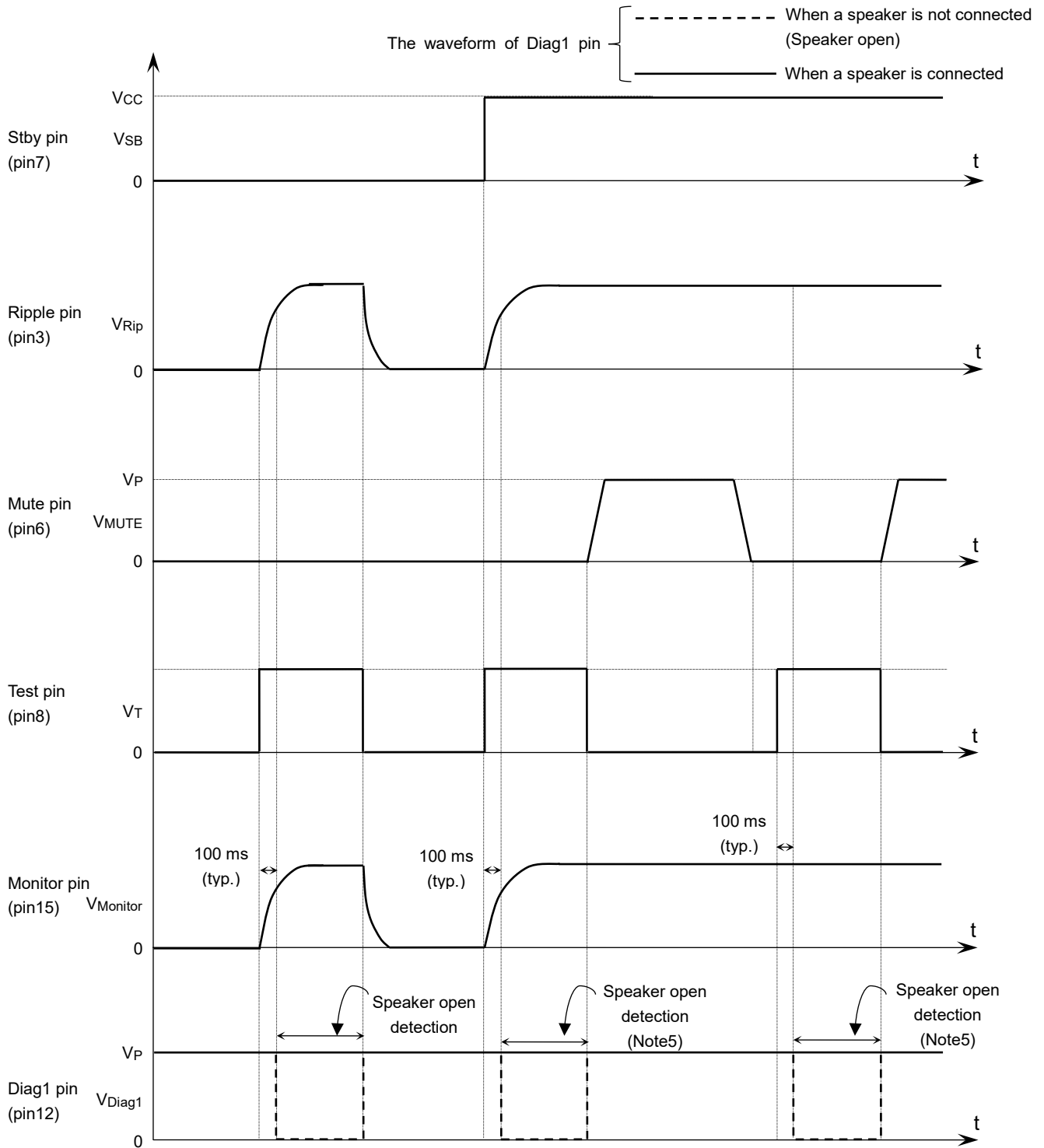
Figure 5 Speaker open detection

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.

Table 3 Control list

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.
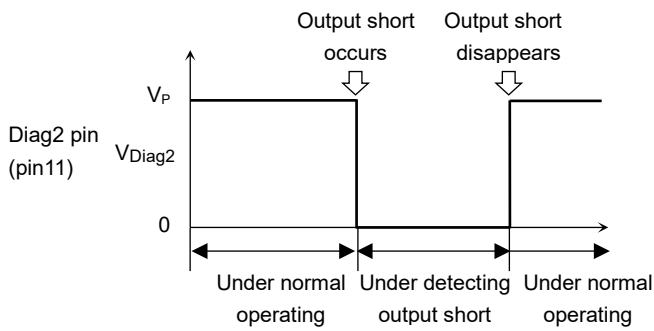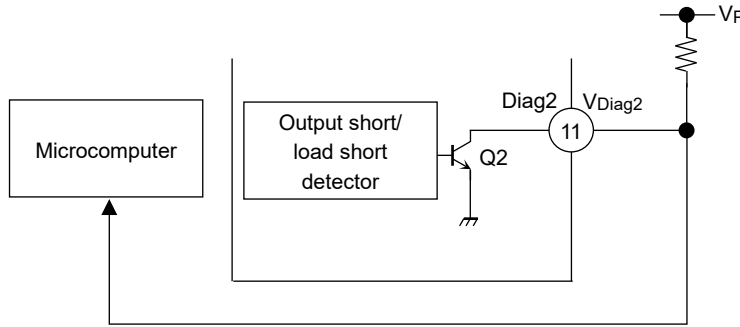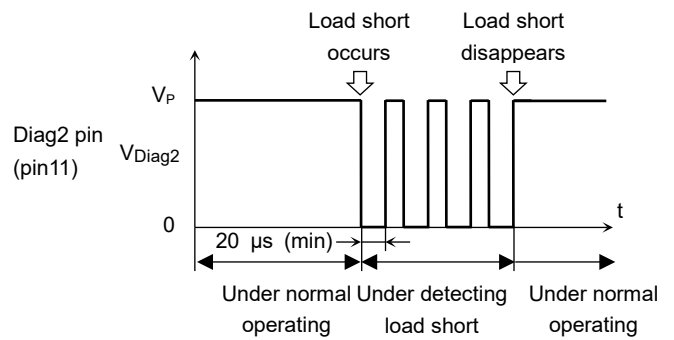

Figure 7 Output Short Detection

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.
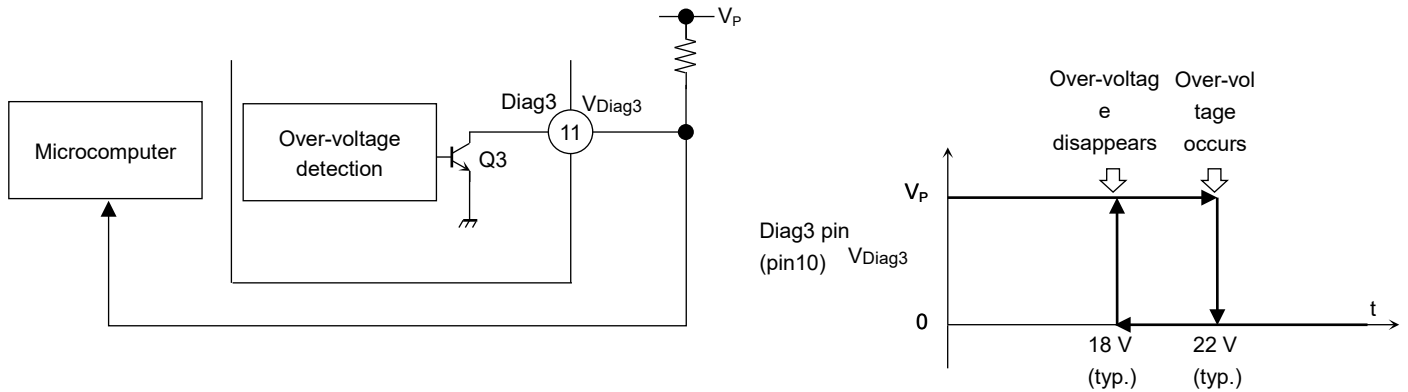
図 9 Over-Voltage Detection

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.
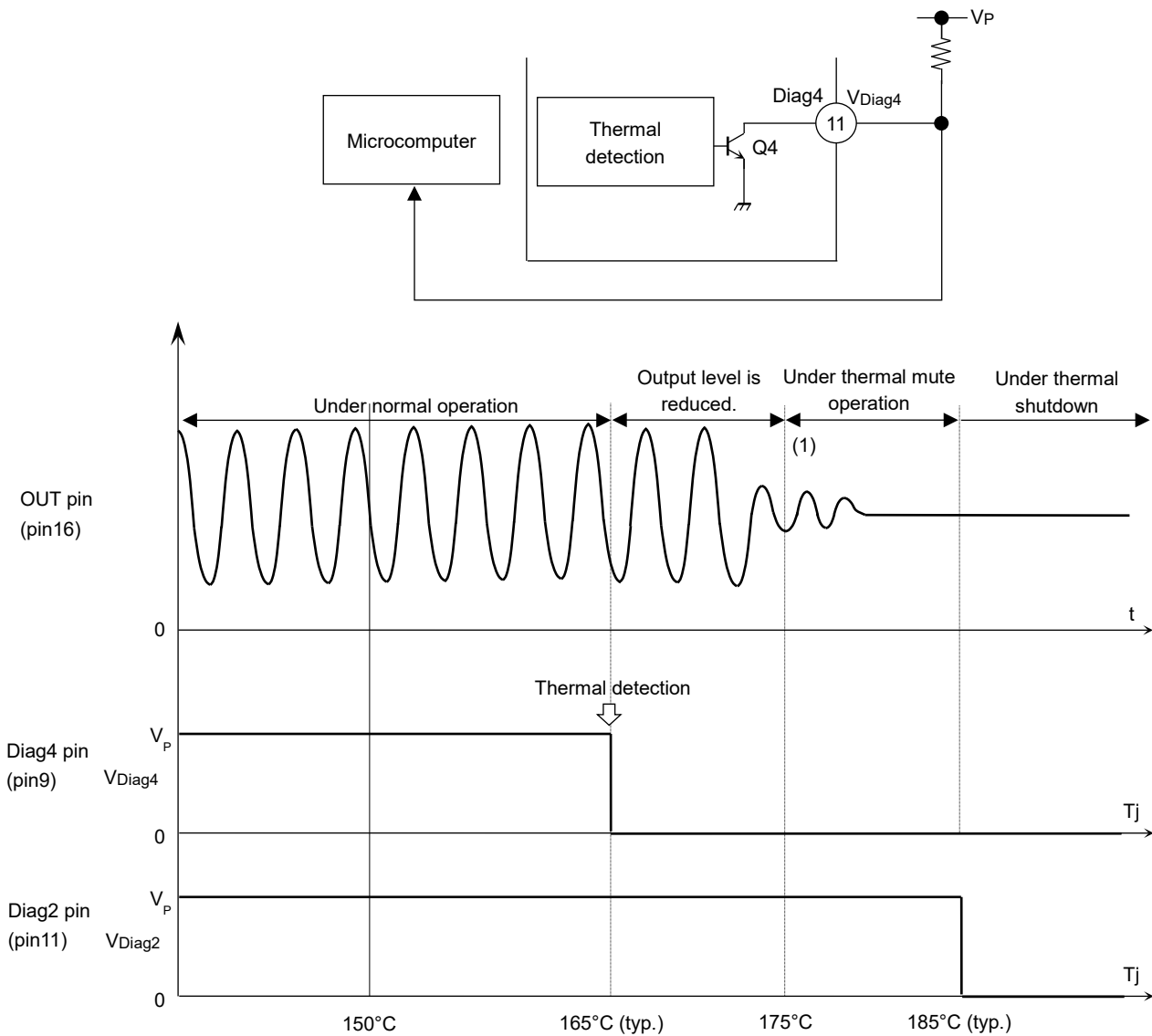

Figure 10 Thermal detection

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.
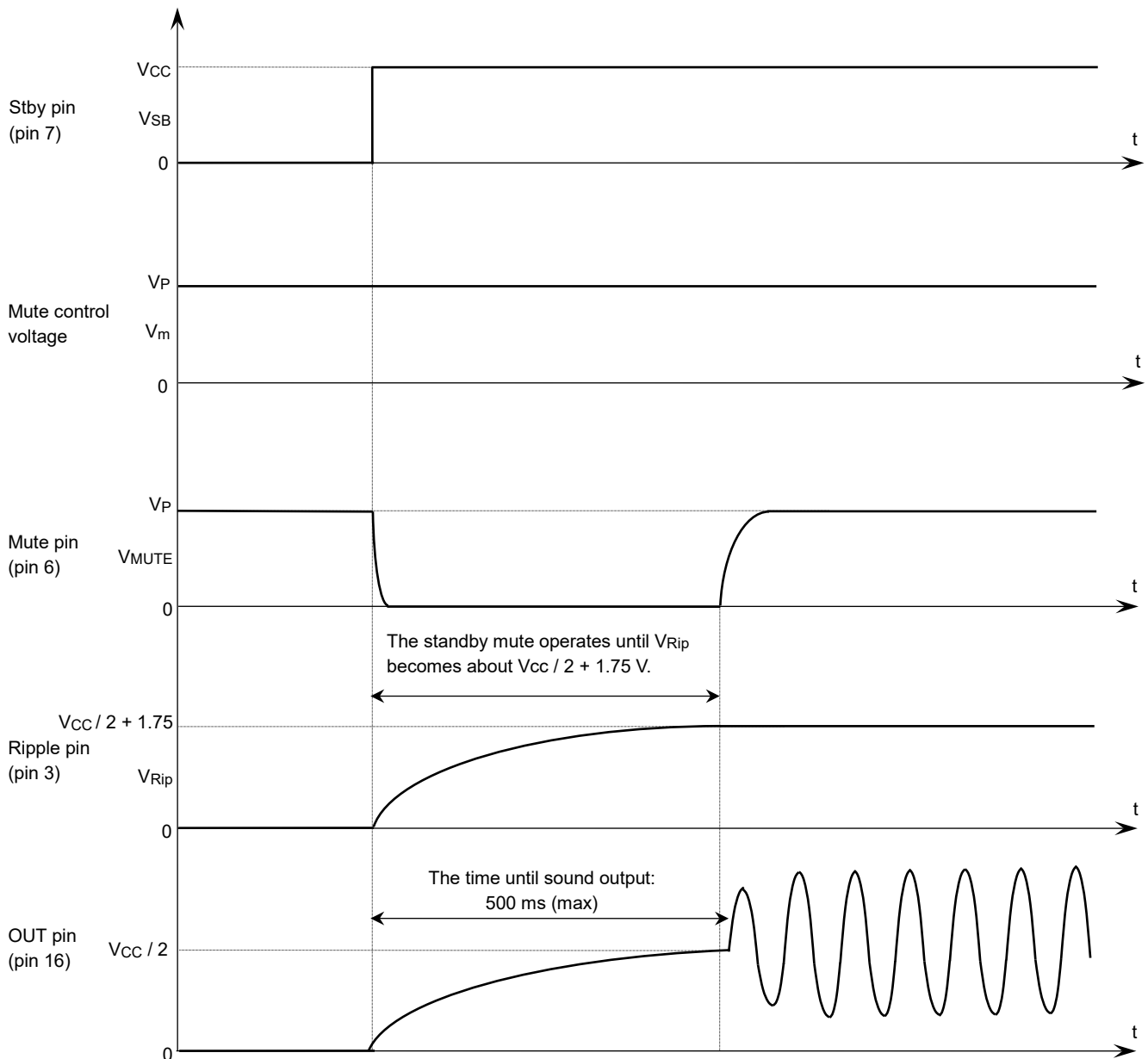

Figure 11 Sequence at Standby-off

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 C5 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.
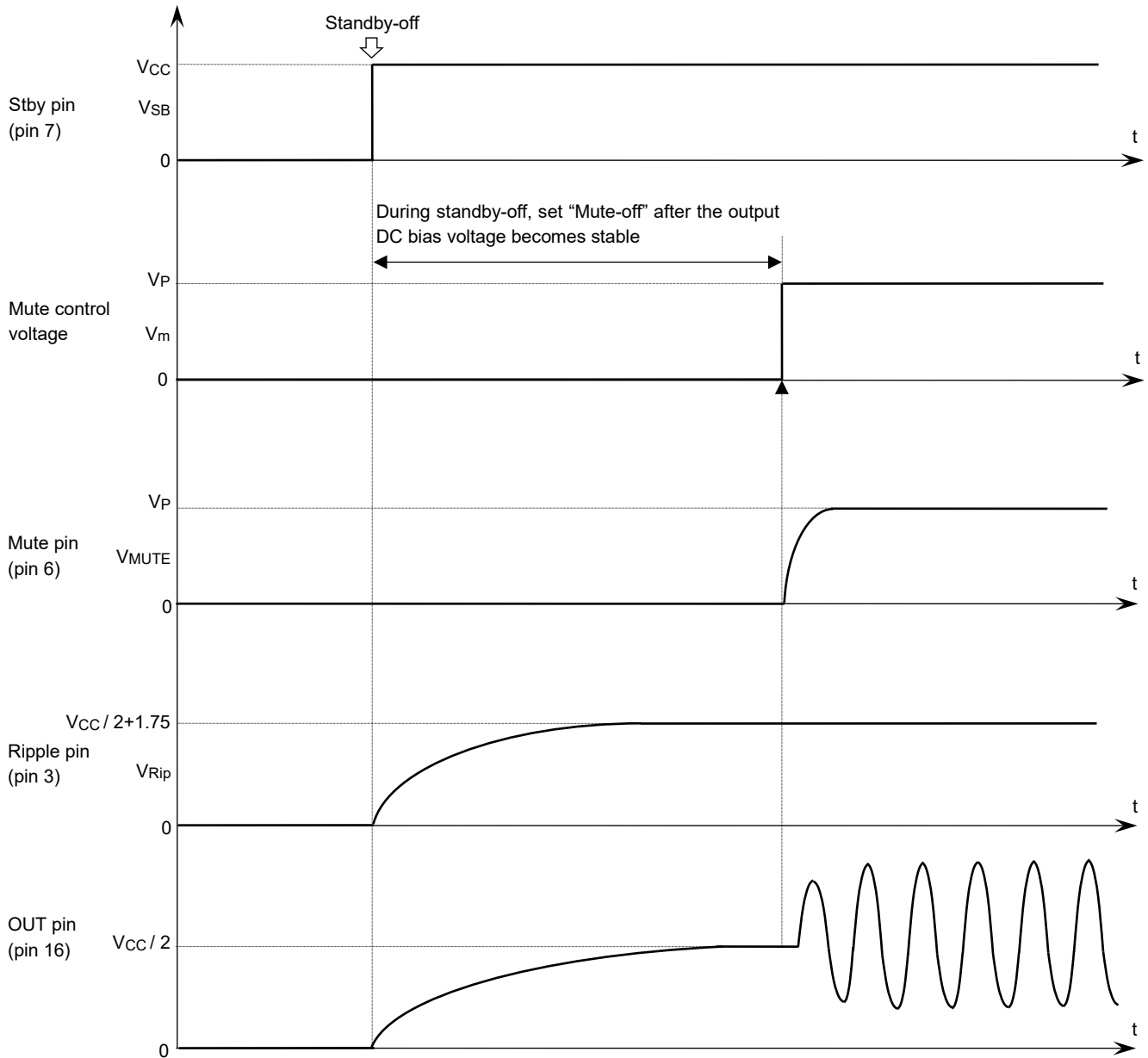

Figure 12 Mute-off Sequence After Standby-off

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)

It operates when a power supply voltage is operating range (22 V) or more to V_{CC} 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 standy-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 $\theta_{j\text{-}a}$ = 37.6°C/W

Note13: 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.

Note14: Please use within the specified operating range.

7.1 Power Dissipation

$P_{D\,(max)}$ - Ta
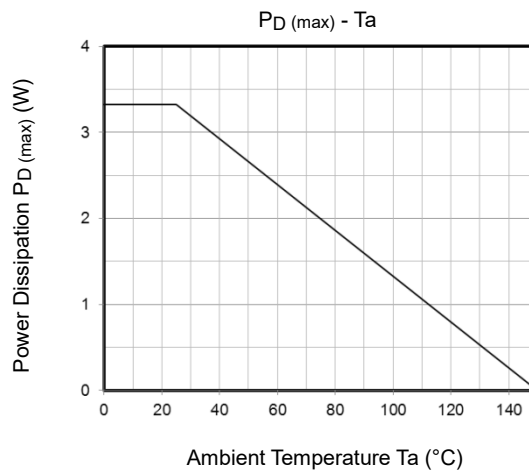
- Package thermal resistance $\theta_{j\text{-}a}$ = 37.6°C/W
- Condition   board material: FR-4

    Board area: 114.3 × 76.2 mm, t = 1.6 mm

    1-layer (surface layer) Cu-are: 45 × 70 mm, Cu-surface: 12%, Cu-thickness: 70 μm

    2-layer (inner layer) Cu-are: 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.

Note15: This package thermal resistance is the evaluation result at board included in chip, package and substrate, the power dissipation is calculated from thermal resistance. Regarning 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

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

Characteristics	Symbol	Test Circuit	Test Condition	Min	Typ.	Max	Unite
Quiescent supply current	I_{CCQ}	—	$V_{IN} = 0$ V	—	7	—	mA
Output power	P_{OUT} MAX1	—	max POWER	—	3	—	W
	P_{OUT}	—	THD = 10%	—	2	—	
	P_{OUT} MAX2	—	$V_{CC} = 16$ V, max POWER	—	5	—	
Total harmonic distortion	THD	—	Pout = 0.125 W (V_{OUT} = 1 Vrms) Filter = 400 Hz to 30 kHz	—	0.08	—	%
Voltage gain	G_V	—	V_{OUT} = 0.775 Vrms Setting input resistance (±1%)	19	20	21	dB
Output noise voltage	V_{NO}	—	Rg = 0 Ω, DIN_AUDIO	—	50	—	µVrms
Ripple rejection ration	R.R.	—	f_{RIP} = 100 Hz, Rg = 620 Ω V_{RIP} = 0.775 Vrms (Note16)	—	50	—	dB
Standby current	I_{SB}	—	Standby-on	—	0.01	9	µA
Standby control voltage	V_{SB} H	—	Standby: OFF(Note17)	2.4	—	V_{CC}	V
	V_{SB} L	—	Standby: ON	0	—	0.8	
Mute pin voltage	V_{MUTE} H	—	MUTE: OFF(Note17)	2.4	—	V_{CC}	
	V_{MUTE} L	—	MUTE: ON	0	—	0.8	
Test control voltage	V_T H	—	Test: ON(Note17)	2.4	—	V_{CC}	
	V_T L	—	Test: OFF	0	—	0.8	
Mute attenuation	ATT_{MUTE}	—	V_{OUT} = 0.775 Vrms → Mute: ON DIN_AUDIO	—	85	—	dB
Diag1 to Diag4 pin Saturation voltage in operation of each detection	Px-Sat (x = 9 to 12)	—	Rpull-up = 10 kΩ, +V_{SB}= 5.0 V When detect (pin Low)	—	100	500	mV

Note16: f_{RIP}: Ripple frequency
V_{RIP}: Ripple signal voltage (AC fluctuations in the power supply)
Note17: V_{SB} H, V_{MUTE} H, and V_T H should be used 16 V or less.

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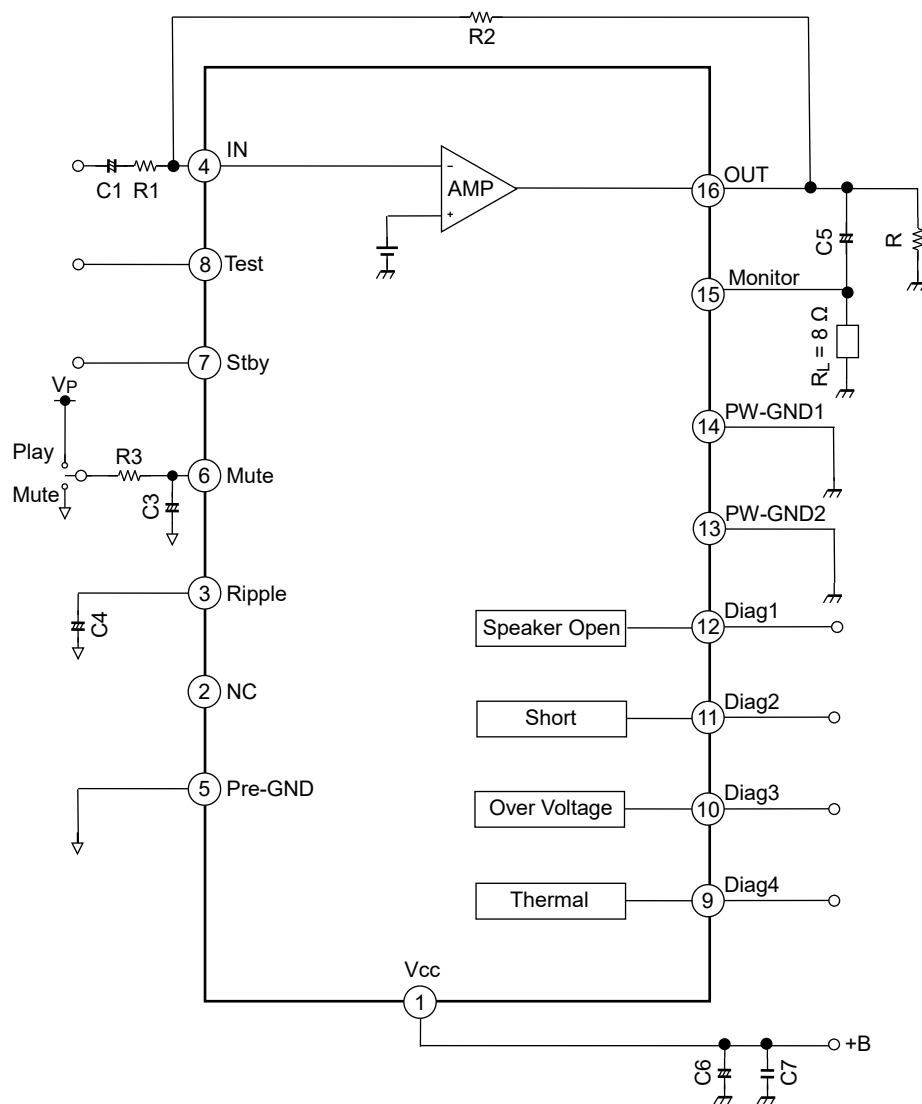
Components in the test circuits are only used to obtain and confirm the device characteristics.

11. Characteristic Chart
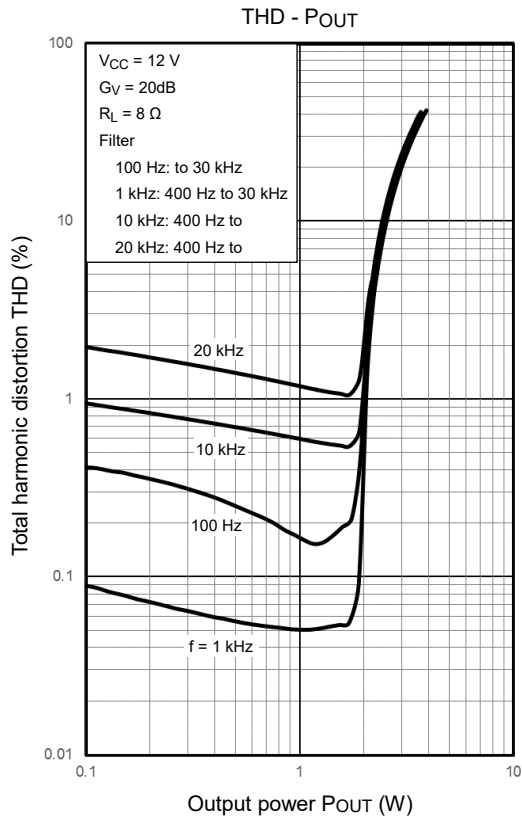
11.1 Total Harmonic Distortion vs. Output Power

THD - P_OUT

V_CC = 12 V
G_V = 20dB
R_L = 8 Ω
Filter
  100 Hz: to 30 kHz
  1 kHz: 400 Hz to 30 kHz
  10 kHz: 400 Hz to
  20 kHz: 400 Hz to

20 kHz
10 kHz
100 Hz
f = 1 kHz

Total harmonic distortion THD (%)
Output power P_OUT (W)

Figure 8 Total Harmonic Distortion of Each Frequency

THD - P_OUT

G_V = 20dB
R_L = 8 Ω
f = 1 kHz
Filter
  400 Hz to 30kHz

6 V   12V   16V

Total harmonic distortion THD (%)
Output power P_OUT (W)
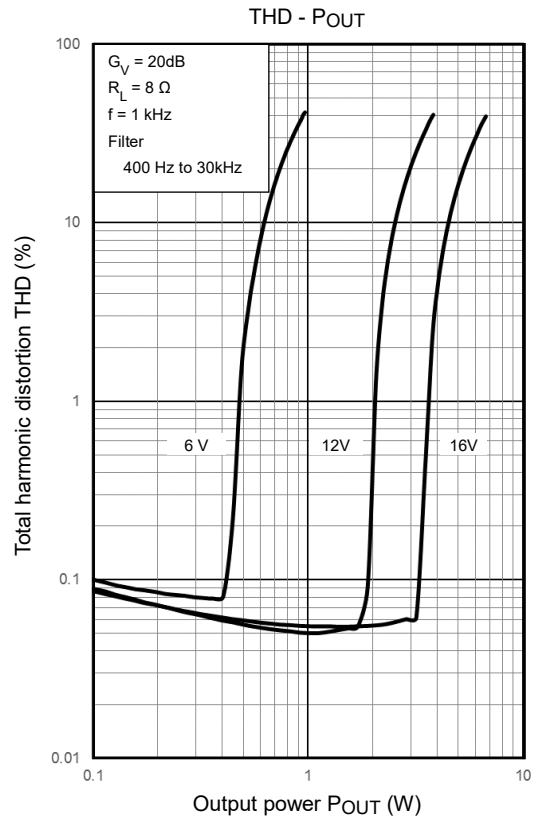
Figure 9 Total Harmonic Distortion by Power Supply Voltage

11.2 Various Frequency Characteristics

THD - f

R_L = 8 Ω
P_OUT = 0.125 W
Filter nothing

16 V
12 V
6 V

Total harmonic distortion THD (%)
Frequency f (kHz)
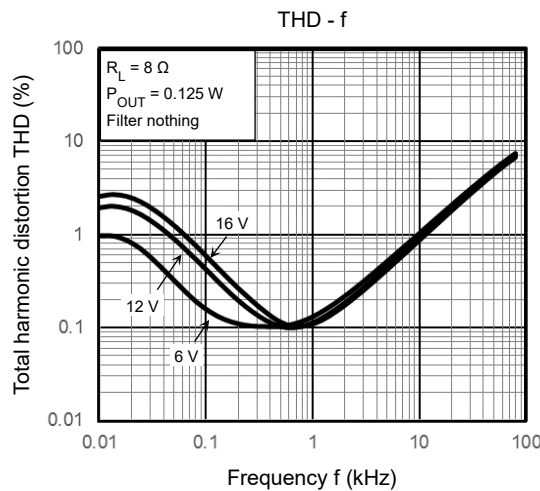
Figure 10 Frequency Characteristics of Total Harmonic Distortion

2021-02-05

G$_V$ - f

Voltage gain G$_V$ (dB) vs Frequency f (kHz)

V$_{CC}$ = 12 V
R$_L$ = 8 Ω
V$_{OUT}$ = 0.775 Vrms

ATT$_{MUTE}$ - f

Mute attenuation ATT$_{MUTE}$ (dB) vs Frequency f (kHz)

V$_{CC}$ = 12 V
R$_L$ = 8 Ω
V$_{OUT}$ = 0.775 Vrms
DIN_AUDIO
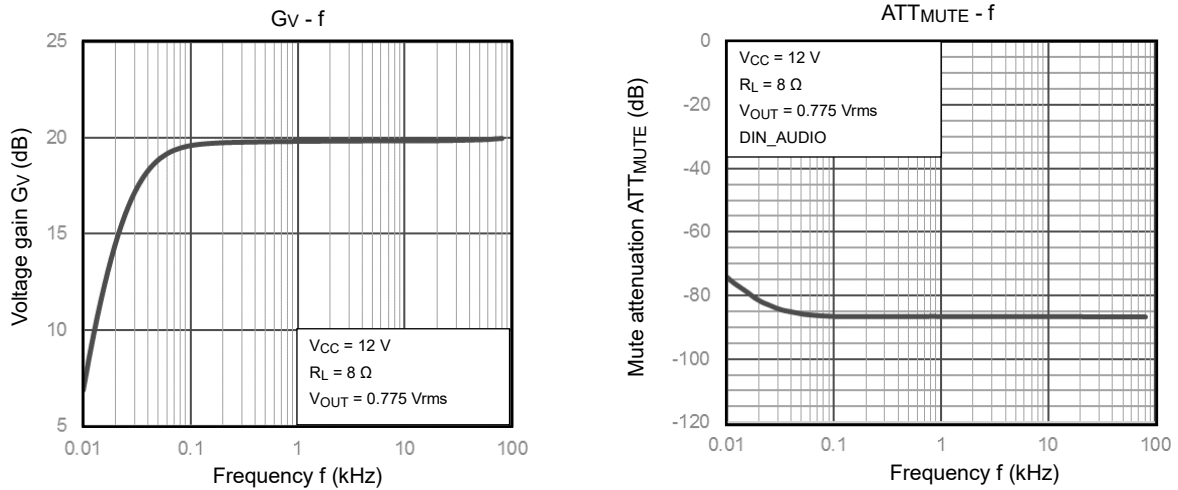
Figure 11 Frequency Characteristics of Voltage Gain

R.R. - f

Ripple rejection rate R.R. (dB) vs Ripple Frequency f$_{RIP}$ (kHz)

V$_{CC}$ = 12 V
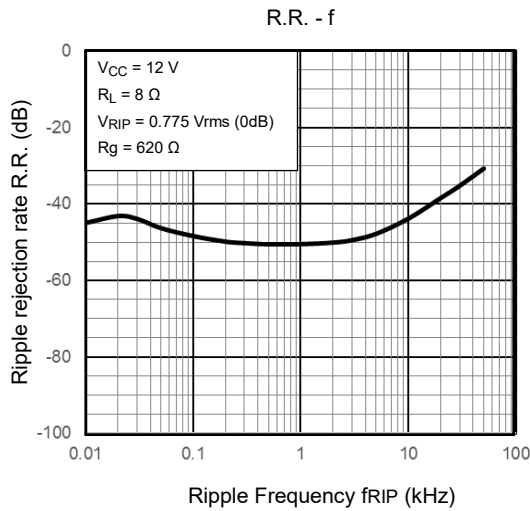R$_L$ = 8 Ω
V$_{RIP}$ = 0.775 Vrms (0dB)
Rg = 620 Ω

Figure 12 Frequency Characteristics of

11.3 Output Power Characteristics to Input Voltage

P$_{OUT}$ - V$_{IN}$

Output power P$_{OUT}$ (W) vs Input voltage V$_{IN\ (rms)}$ (V)

10 kHz
f = 20 kHz
1 kHz
100 Hz

V$_{CC}$ = 12 V
R$_L$ = 8 Ω
Filter nothing
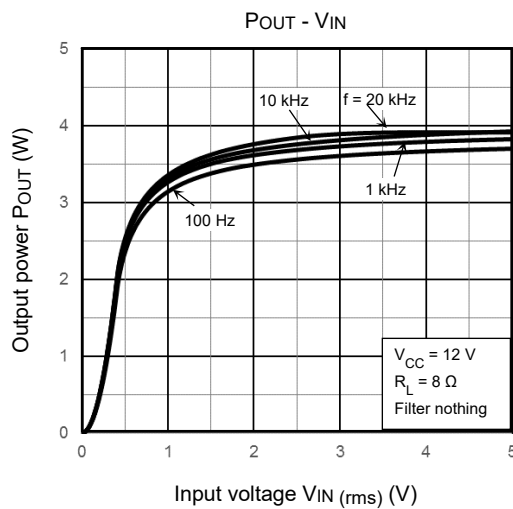
11.4 **Power Dissipation vs. Output Power**

P_D - P_{OUT} (R_L = 8 Ω)

f = 1 kHz
R_L = 8 Ω

16 V

12 V

6.0 V

Power dissipation P_D (W)

Output power P_{OUT} (W)
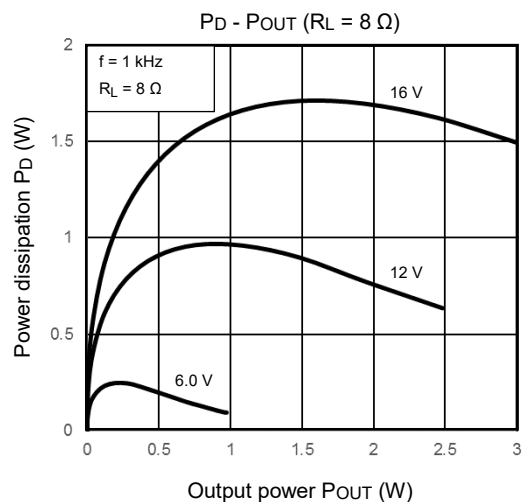
11.5 **Other Characteristic**

I_{CCQ} - V_{CC}

V_{IN} = 0 V
R_L = ∞

Quiescent Current I_{CCQ} (mA)

Supply voltage V_{CC} (V)

2021-02-05
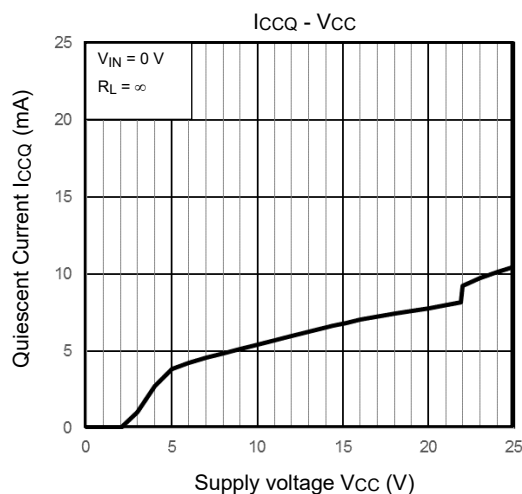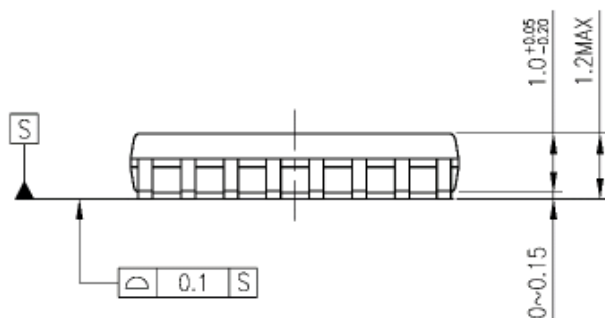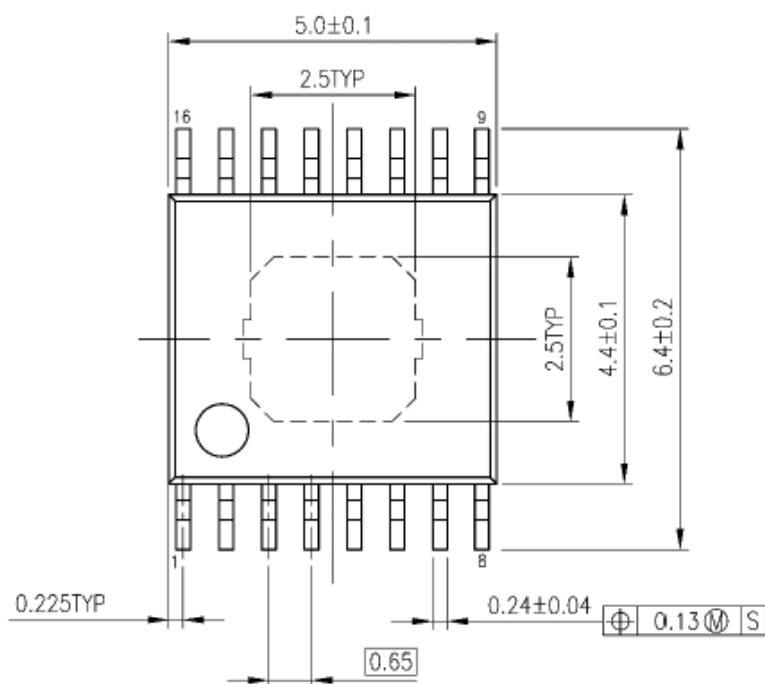
12. Package Dimensions

Package: P-HTSSOP16-0505-0.65-001

Unit: mm
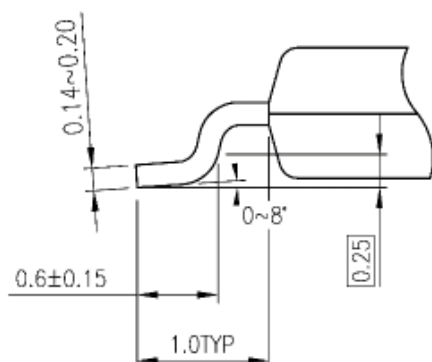
Weight: 0.062 g (typ.)

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)
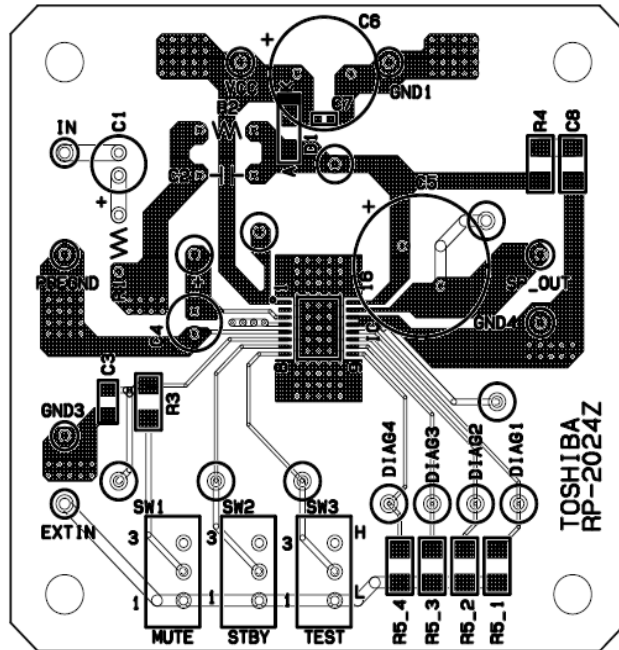
- GND layer (2-layer)
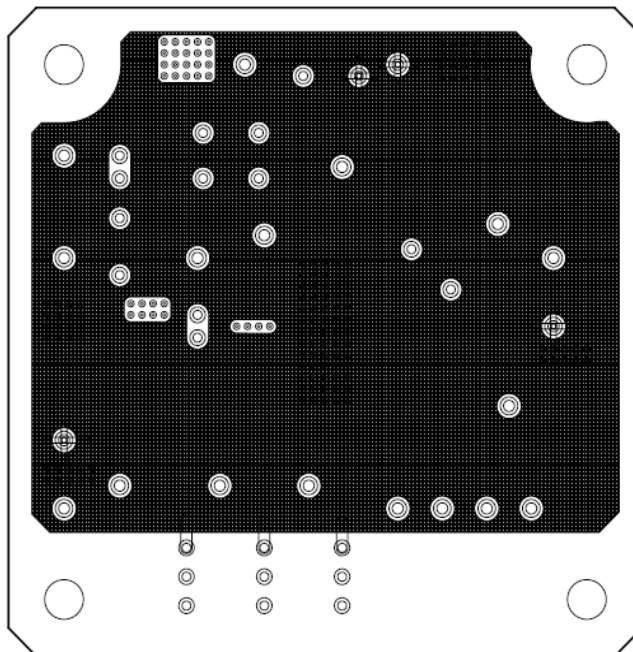
- V_{CC} layer (3-layer)

- 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.
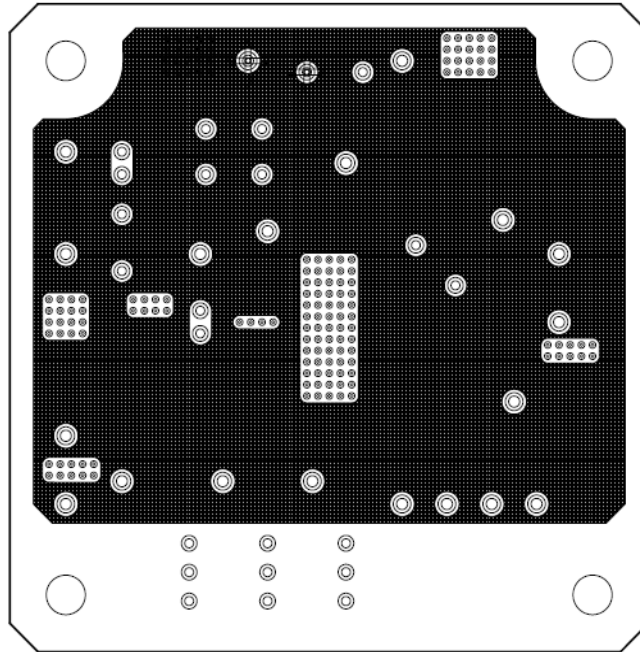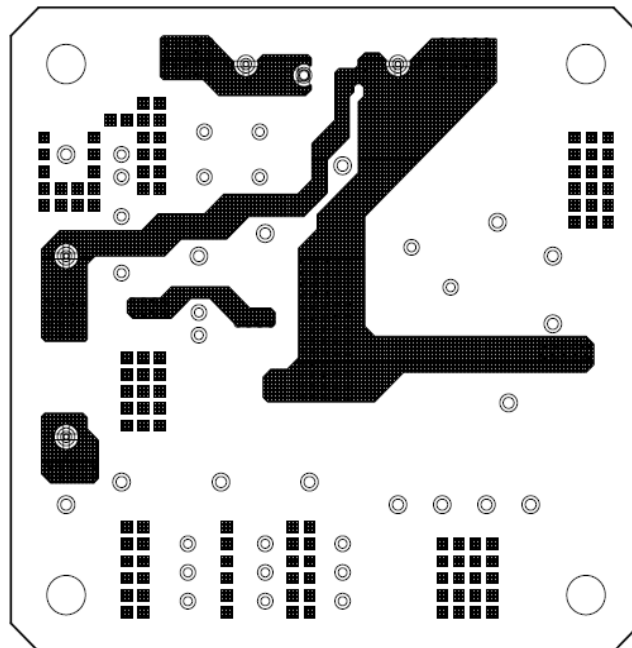
(2) Equivalent Circuits
   The equivalent circuit diagrams may be simplified or some parts of them may be omitted for explanatory purposes.

(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.

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 considerate 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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