

Bi-CMOS Linear Integrated Circuit Silicon Monolithic

# TB2941HQ

Maximum Power 49 W BTL × 4ch Audio Power Amp IC

## 1. Description

The TB2941HQ is a power IC with built-in four-channel BTL amplifier developed for car audio application. The maximum output power  $P_{OUT}$  is 49 W using a pure complementary P-ch and N-ch DMOS output stage.

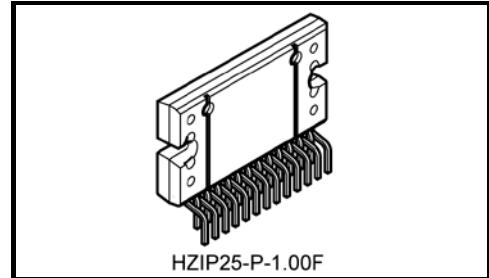
In addition, a standby switch function, a mute function, an output offset voltage detection function, a high-side switch function and various protection features are included.

## 2. Applications

Power Amp IC developed for car audio applications.

## 3. Features

- High output power, low distortion, and low noise property (for details, refer to the Table 1 Typical Characteristics)
- Built-in high-side switch function (Pin 25) (Note2)
- Built-in output DC offset voltage detection function (Pin 1, Pin 25) (Note2)
- Built-in mute function. (Pin 22)
- Built-in auto mute functions (for low  $V_{CC}$  and standby-Off)
- Built-in standby switch function (Pin 4)
- Built-in various protection circuits (thermal shut down, over-voltage, short to GND, short to  $V_{CC}$ , and output to output short)



Weight: 7.7 g (typ.)

**Table 1 Typical Characteristics (Note1)**

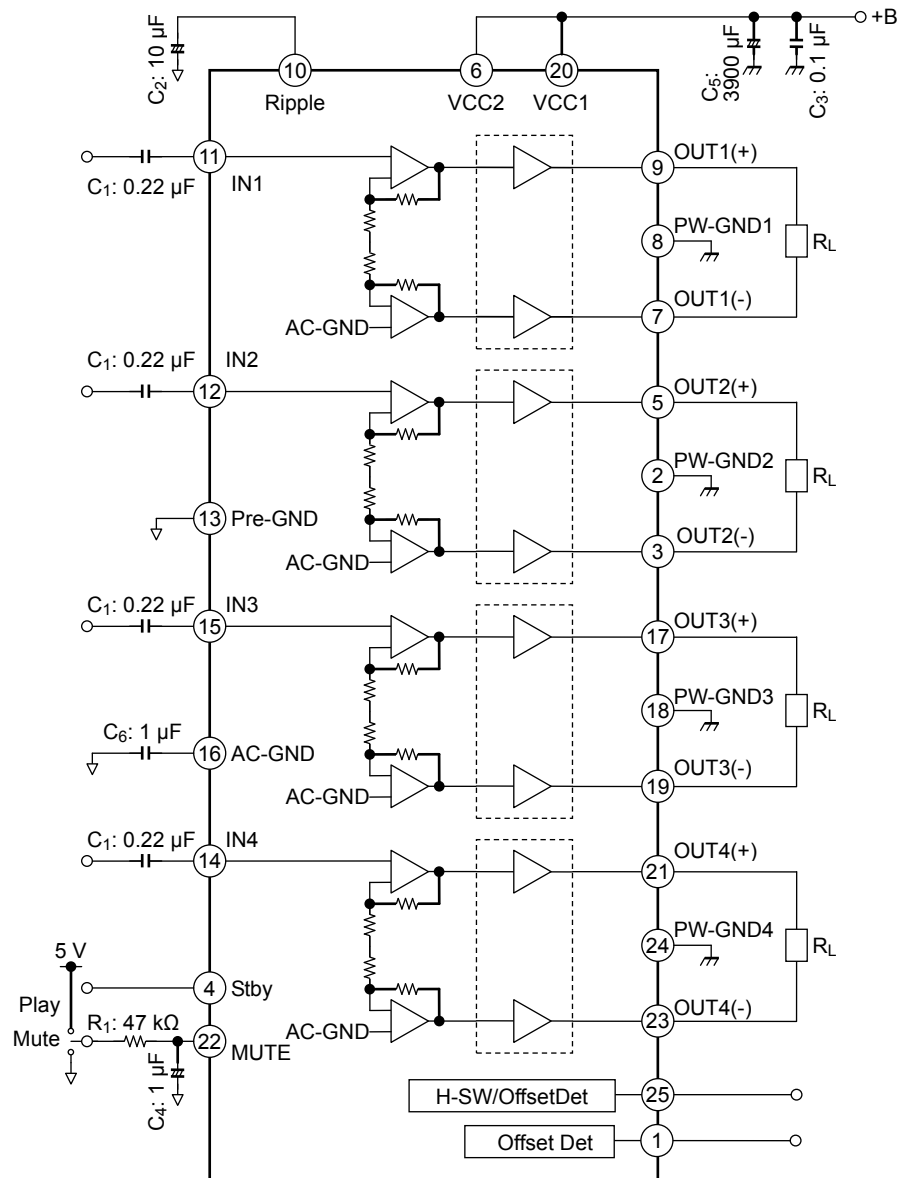
Test condition	Typ.	Unit
<b>Output power (<math>P_{OUT}</math>)</b>		
$V_{CC} = 15.2$ V, JEITA max	49	W
$V_{CC} = 13.7$ V, JEITA max	40	
THD = 10%	24	
<b>Output power (<math>P_{OUT}</math>) (<math>R_L = 2 \Omega</math>)</b>		
$V_{CC} = 13.7$ V, JEITA max	73	W
THD = 10%	45	
<b>Total harmonic distortion (THD)</b>		
$P_{OUT} = 4$ W	0.006	%
<b>Output noise voltage (<math>V_{NO}</math>) (<math>R_g = 0 \Omega</math>)</b>		
Filter: DIN AUDIO	65	$\mu$ Vrms
<b>Operating Supply voltage range (<math>V_{CC}</math>)</b>		
$R_L = 4 \Omega$	6 to 18	V
$R_L = 2 \Omega$	6 to 16	

Note1: Typical test conditions:  $V_{CC} = 13.2$  V,  $f = 1$  kHz,  $R_L = 4 \Omega$ ,  $T_a = 25^\circ\text{C}$ ; unless otherwise specified.

$R_g$ : signal source resistance

Note2: A built-in high-side switch or a built-in output DC offset voltage detection function can be selected for pin 25 by the voltage into MUTE pin (pin 22).

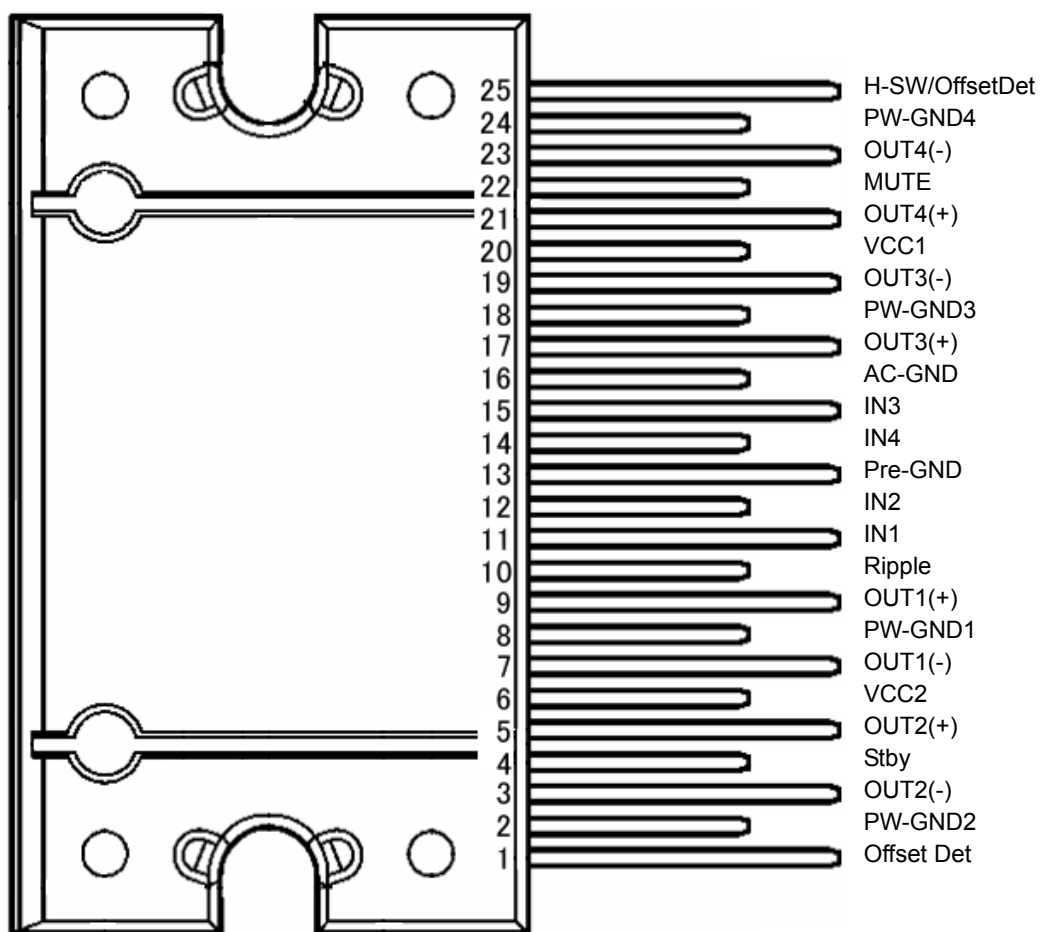
**4. Block Diagram**



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**

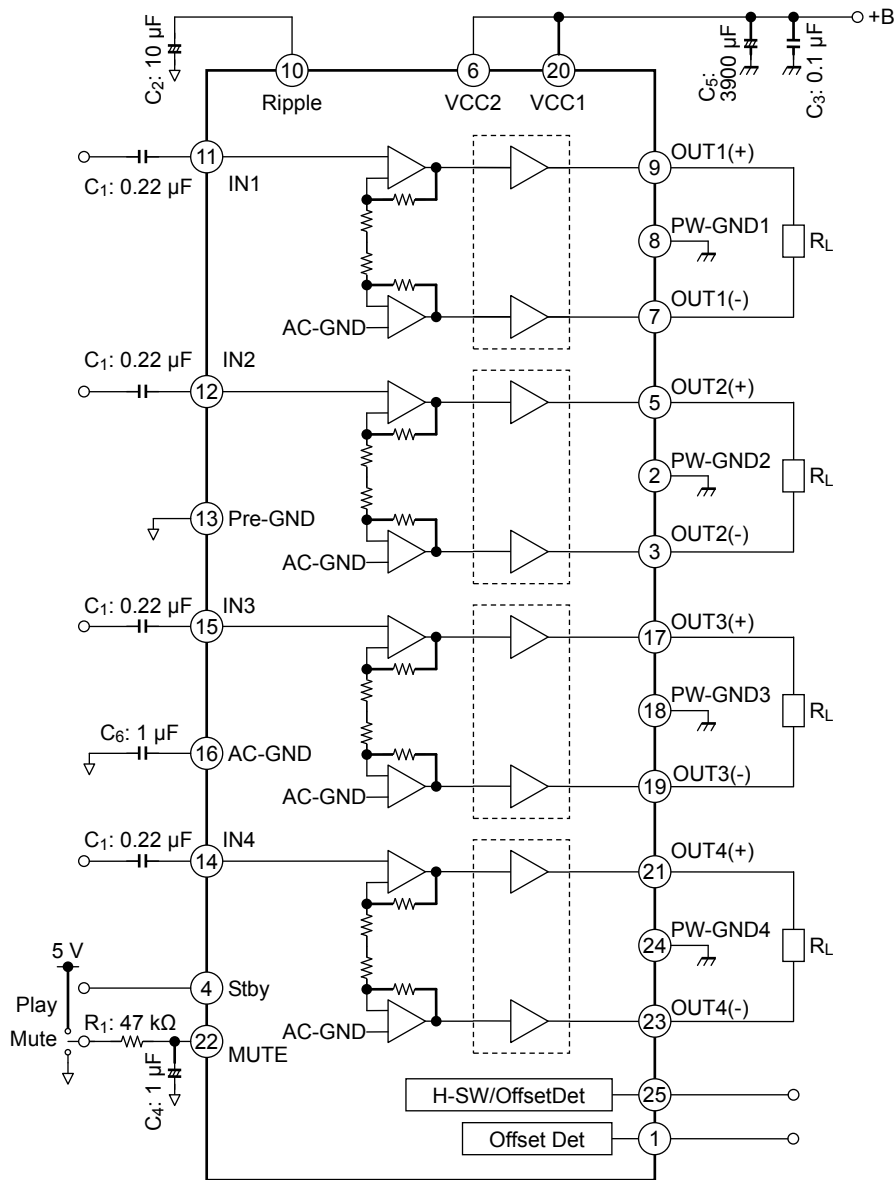
**5.1 Pin Configuration (top view)**



## 5.2 Pin Function Descriptions

Pin	Symbol	I/O	Description
1	Offset Det	V <sub>od</sub> -OUT	Output offset voltage detector output
2	PW-GND2	—	Ground for OUT2
3	OUT2(-)	OUT	OUT2(-) output
4	Stby	V <sub>ST</sub> -IN	Standby voltage input
5	OUT2(+)	OUT	OUT2(+) output
6	VCC2	V <sub>CC</sub> -IN	Supply voltage 2
7	OUT1(-)	OUT	OUT1(-) output
8	PW-GND1	—	Ground for OUT1
9	OUT1(+)	OUT	OUT1(+) output
10	Ripple	—	Ripple voltage
11	IN1	IN	OUT1 input
12	IN2	IN	OUT2 input
13	Pre-GND	—	Signal ground
14	IN4	IN	OUT4 input
15	IN3	IN	OUT3 input
16	AC-GND	—	Common reference voltage for all input
17	OUT3(+)	OUT	OUT3(+) output
18	PW-GND3	—	Ground for OUT3
19	OUT3(-)	OUT	OUT3(-) output
20	VCC1	V <sub>CC</sub> -IN	Supply voltage 1
21	OUT4(+)	OUT	OUT4(+) output
22	MUTE	V <sub>MUTE</sub> -IN	MUTE voltage input
23	OUT4(-)	OUT	OUT4(-) output
24	PW-GND4	—	Ground for OUT4
25	H-SW/OffsetDet	HSW/V <sub>od</sub> -OUT	High-side switch / Offset detector output

6. Functional Description



Component Name	Recommended Value	Pin	Purpose	Effect (Note1)	
				Lower than Recommended Value	Higher than Recommended Value
C <sub>1</sub> (Note3)	0.22 μF	INx (x:1 to 4)	To eliminate DC	Cut-off frequency becomes higher	Cut-off frequency becomes lower
C <sub>2</sub>	10 μF	Ripple	To reduce ripple	Turn on time shorter	Turn on time longer
C <sub>3</sub>	0.1 μF	VCC1 VCC2	To provide sufficient oscillation margin	Reduces noise and provides sufficient oscillation margin	
C <sub>6</sub> (Note3)	1 μF	AC-GND	Common reference voltage for all input	Pop noise is suppressed when C <sub>1</sub> : C <sub>6</sub> = 1:4. (Note2)	
C <sub>5</sub>	3900 μF	VCC1 VCC2	Ripple filter	Filter for power supply ripple and hum	
R <sub>1</sub> / C <sub>4</sub>	47 kΩ / 1 μF	MUTE	Mute ON/OFF Smooth switching	Pop noise becomes larger	Switching time becomes longer

Note1: When the unrecommended value is used, please examine it enough by system evaluation.

Note2: Since "AC-GND" pin is a common reference voltage for all input, this product needs to set the ratio of an input capacitance (C<sub>1</sub>) and the AC-GND capacitance (C<sub>6</sub>) to 1:4

Note3: Use the low leak current capacitor for C<sub>1</sub> and C<sub>6</sub>.

## 7. Standby Switch Function (Pin 4)

The power supply can be turned on or off via pin 4 (Standby voltage input).  
 The threshold voltage of pin 4 is below table.  
 The power supply current is about 0.01  $\mu\text{A}$  (typ.) in the standby state.

### Pin 4 Control Voltage: $V_{SB}$

Stby	Power	$V_{SB}$ (V)
ON	OFF	0 to 0.9
OFF	ON	2.2 to $V_{CC}$

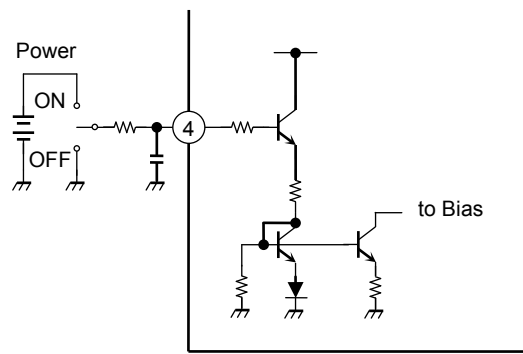


Figure 1 Standby Switch Circuit

### <Benefits of the Standby Switch>

- (1)  $V_{CC}$  can be directly turned on or off by a microcontroller, eliminating the need for a switching relay.
- (2) Since the control current is minuscule, a low-current-rated switching relay can be used.

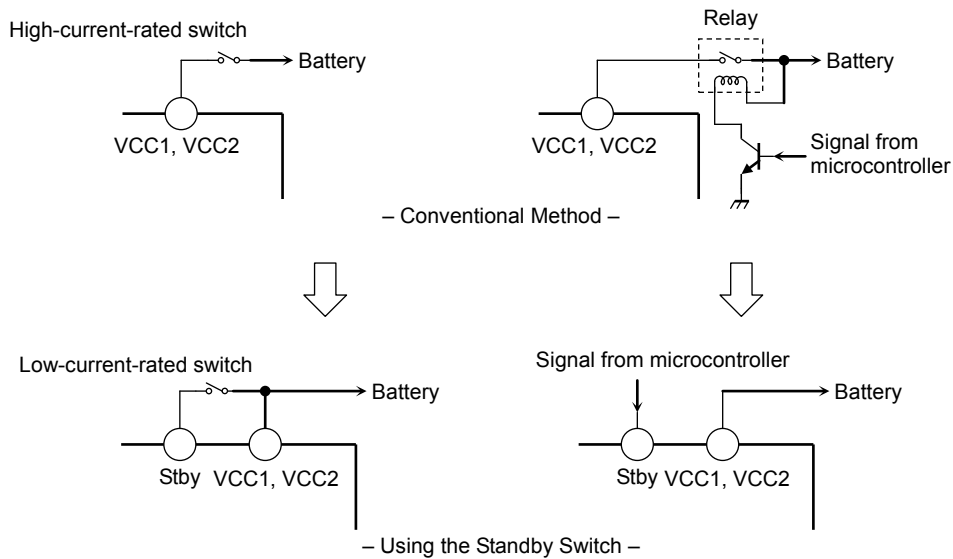


Figure 2 Standby Switch

**8. Mute Function (Pin 22)**

The audio mute function is enabled by setting pin 22 to Low.

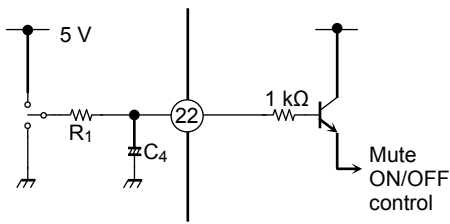
R<sub>1</sub> and C<sub>4</sub> determine the time constant of the mute function. The time constant affects pop noise generated when power or the mute function is turned on or off; thus, it must be determined on a per-application basis. (Refer to Figures 3 and 4.)

The constant value (R<sub>1</sub> and C<sub>4</sub>) is determined in basing on controlling in 5 V. If controlling in other voltage, the value of a pull-up register determined as shown below.

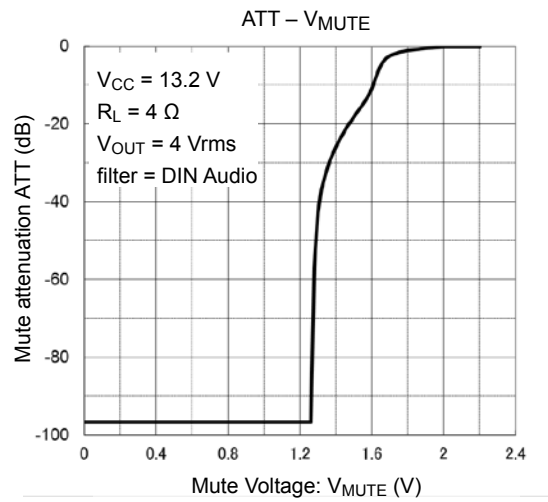
For example:

When the control voltage is changed from 5 V to 3.3 V:  $3.3 \text{ V} / 5 \text{ V} \times 47 \text{ k}\Omega = 31 \text{ k}\Omega$

When the control voltage is changed from 5 V to 8.5 V:  $8.5 \text{ V} / 5 \text{ V} \times 47 \text{ k}\Omega = 80 \text{ k}\Omega$



**Figure 3 Mute Function**



**Figure 4 Mute Attenuation ATT (dB) - V<sub>MUTE</sub> (V)**

**9. Auto Mute Functions**

The TB2941HQ has two auto mute functions.

- a) Low VCC mute function (Auto mute)
- b) Standby-Off mute function

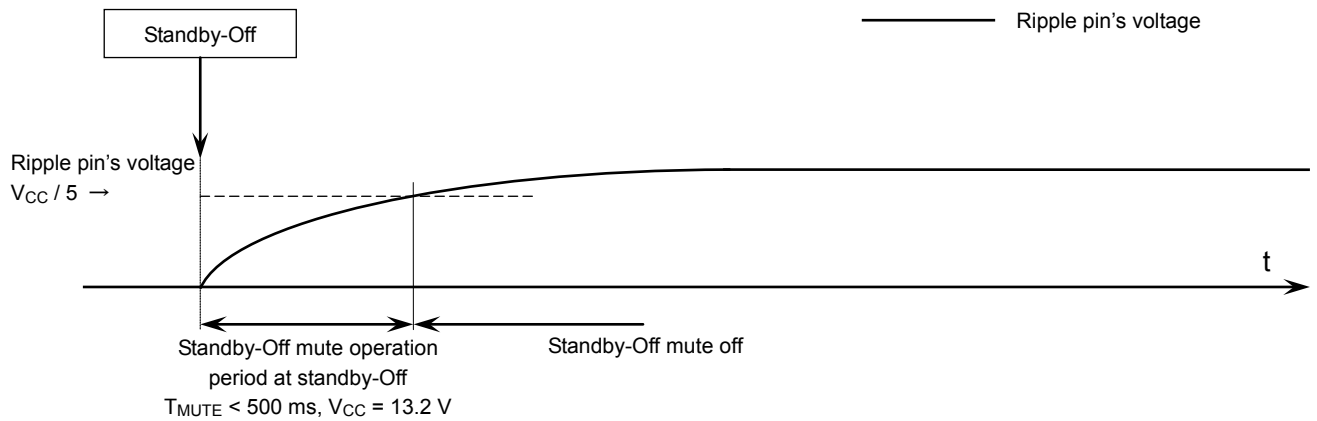
**9.1 Low VCC Mute Function**

When the supply voltage became equal or lower than 5.5 V (Typ.), Low VCC mute function operates automatically. This function prevents the large audible transient noise which is generated by lower VCC.

**9.2 Standby-Off Mute Function**

Standby-Off mute function operates during the particular standby-Off transition. When the Ripple pin's voltage exceeds  $V_{CC} / 5$ , the standby-Off mute is terminated.

It is recommendable that the external mute has to be turned on in the standby-Off sequence (power on) and it is released after releasing the internal mute.



**Figure 5 Standby-Off Mute Function**

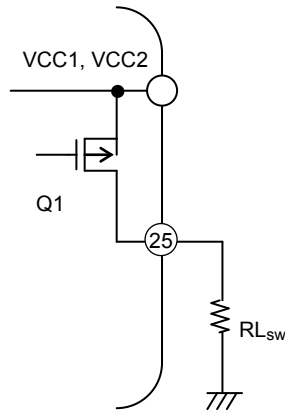


## 10. High-side Switch Function (Pin 25)

When the TB2941HQ is in operation (in releasing standby), the high-side switch makes Q1 turns-on and supplies current to a load circuit

It can be used for many application circuits such as the supplying current or control signal to external application circuit.

When it is enabled, set the voltage of MUTE pin (Pin 22) to equal or less than 6 V.

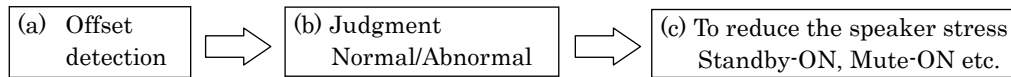


**Figure 6 High-side Switch Function**

## 11. Output DC Offset Detection Function

This function can detect that the offset voltage between amplifier outputs is more than the specified threshold and show it to 1 pin or 25 pin.

When the offset voltage appeared by the leak of coupling capacitor and etc., this function can report it to an application circuit. When the safety process shown as below are executed, this function can be used as part (a).



The detection occurs when the offset voltage exceeds to the threshold level specified in spite of an abnormal voltage.

### 11.1 Description of Operation output DC offset pin

The 25 pin's function is changed from high-side switch function to output DC offset detection function by setting the voltage of MUTE pin (Pin 22) equal or more than 7 V.

The built-in high-side switch in 25 pin is turned-on or off depend on the state of DC offset detection by the offset detection function.

The built-in open drain MOS transistor in 1 pin is turned-on or off depend on the state of DC offset detection by the offset detection function.

The 1 pin's function always operates as the output DC offset detection function. It is not necessary to change.

If it is not used, 1 pin is opened or connected to GND.

An amplifier output waveform and detection results of 1 pin and 25 pin which is changed to output DC offset detection function are shown in Figure 8.

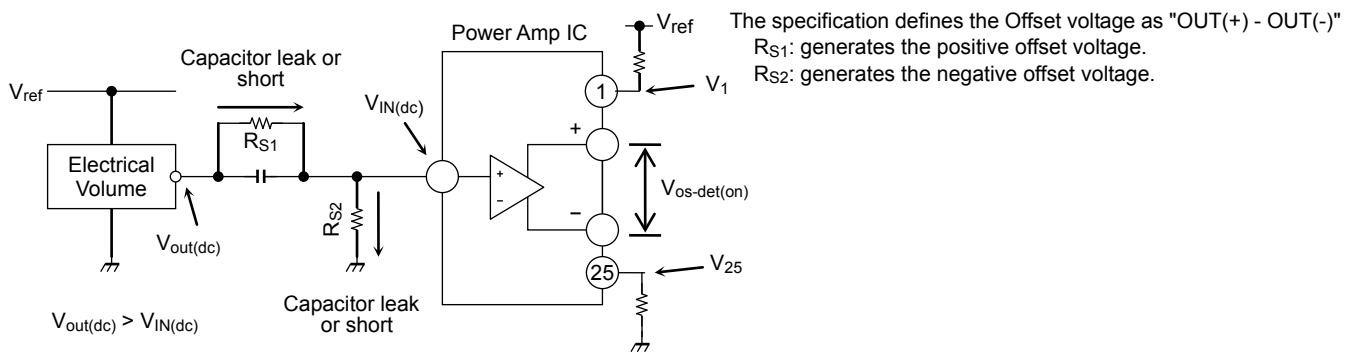
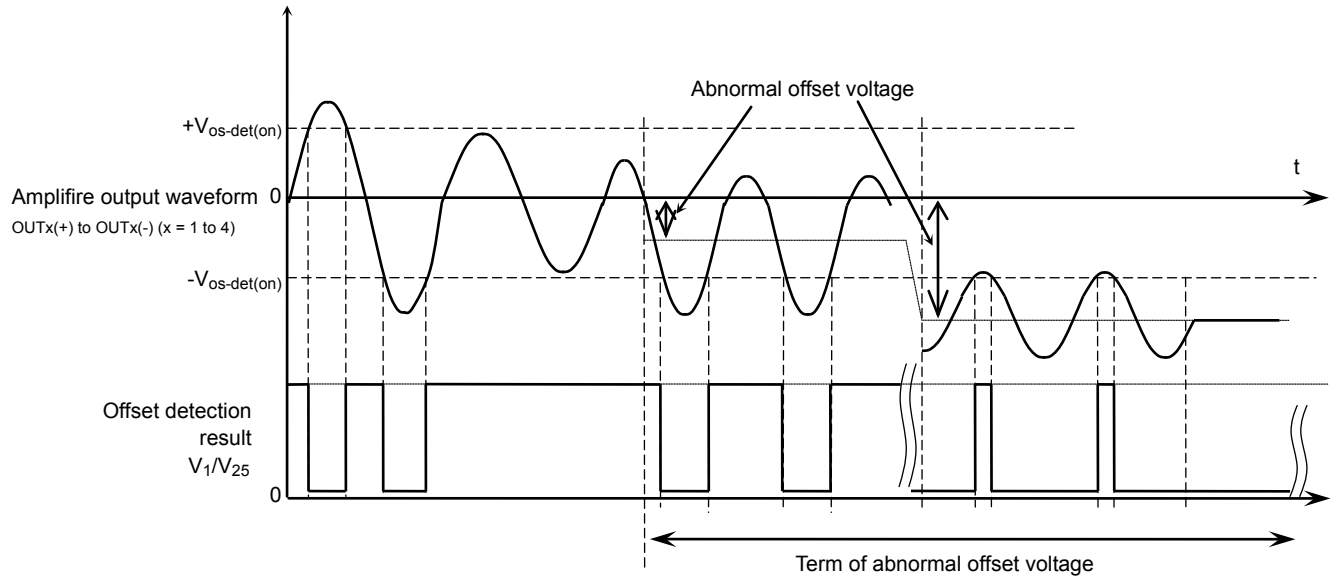


Figure 7 Generation Mechanism of Abnormal output offset voltage



**Figure 8 Output Waveform of Amplifier and Output Waveform on pin 1 ( $V_1$ ) and pin 25 ( $V_{25}$ )**

## 12. Reducing Audible Pop Noise and Sound Cutting Function in Low $V_{CC}$ Voltage

The TB2941HQ has amplifier circuit to reduce the audible pop noise and sound cutting due to low  $V_{CC}$  voltage.

### 12.1 Description

When the supply voltage goes down to low instantaneously, the TB2941HQ switches midpoint potential to  $V_{CC} / 4$  to reduce the audible pop noise and the sound cutting.

The TB2941HQ can reduce the distortion which is generated by low  $V_{CC}$ , because this amplifier circuit keeps the voltage gain of BTL outputs. In other words, if one side output of BTL has the voltage margin, its output can make up for clipped waveform of other side output.

### 13. Protection Functions

This product has internal protection circuits such as thermal shut down, over-voltage, short to GND, short to VCC, and output to output short circuit protections.

(1) Thermal shut down

It operates when junction temperature exceeds 150°C (typ.).

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. Shutdown function starts, when a temperature rise continues in spite of all outputs in a mute state.

In any case if temperature falls, it will return automatically.

(2) Over-voltage

It operates when voltage exceeding operating range is supplied to VCC pin. If voltage falls, it will return automatically. When it operates, all outputs bias and high-side switch are turned off and all outputs are intercepted. Threshold voltage is 23 V (typ.).

(3) Short to GND, Short to VCC, Output to output short

It operates when each output pin is in irregular connection (short to GND, short to VCC, output to output short) and the load line goes over the SOA of power transistor.

When it operates, all outputs are intercepted to turn off all outputs bias circuits. If irregular connection is canceled, it will return automatically.

## 14. Absolute Maximum Ratings

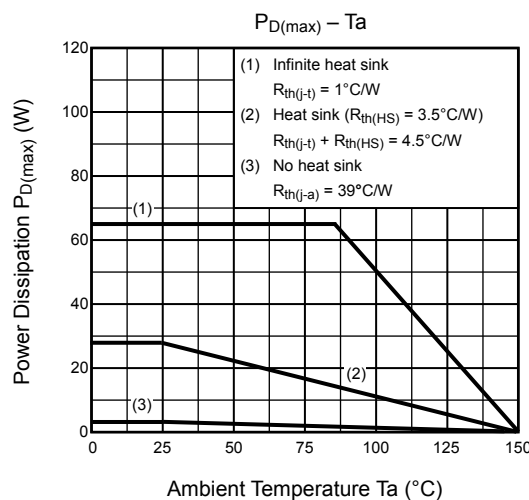
(Ta = 25°C unless otherwise specified)

Characteristics	Condition	Symbol	Rating	Unit
Supply voltage (surge)	Equal or less than 0.2 s	V <sub>CC(surge)</sub>	50	V
Supply voltage (DC)	—	V <sub>CC(DC)</sub>	25	V
Supply voltage (operation)	—	V <sub>CC(opr)</sub>	18	V
Output current (peak)	—	I <sub>O(peak)</sub>	9	A
Power dissipation	(Note)	P <sub>D</sub>	125	W
Operating temperature range	—	T <sub>opr</sub>	-40 to 85	°C
Storage temperature	—	T <sub>stg</sub>	-55 to 150	°C
Junction temperature	—	T <sub>j(max)</sub>	150	°C

Note: Ta = 25°C, Package thermal resistance R<sub>th(j-t)</sub> = 1°C/W (typ.) with infinite heat sink

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.

### 14.1 Power Dissipation



## 15. Operating Ranges

Characteristics	Symbol	Condition	Min	Typ.	Max	Unit
Supply voltage	V <sub>CC</sub>	R <sub>L</sub> = 4 Ω	6	—	18	V
		R <sub>L</sub> = 2 Ω	6	—	16	V

## 16. Electrical Characteristics

### 16.1 Amplifier, Common part

( $V_{CC} = 13.2\text{ V}$ ,  $f = 1\text{ kHz}$ ,  $R_L = 4\ \Omega$ ,  $T_a = 25^\circ\text{C}$  unless otherwise specified)

Characteristics	Symbol	Test Condition	Min	Typ.	Max	Unit
Quiescent supply current	$I_{CCQ}$	$V_{IN} = 0\text{ V}$	100	180	300	mA
Output power	$P_{OUT(max)(1)}$	$V_{CC} = 15.2\text{ V}$ , max POWER	—	49	—	W
	$P_{OUT(max)(2)}$	$V_{CC} = 13.7\text{ V}$ , max POWER	—	40	—	
	$P_{OUT(1)}$	THD = 10%	23	24	—	
Output power( $R_L = 2\ \Omega$ )	$P_{OUT(max)(3)}$	$V_{CC} = 13.7\text{ V}$ , max POWER	—	73	—	W
	$P_{OUT(2)}$	THD = 10%	—	45	—	
Total harmonic distortion	THD(1)	$P_{OUT} = 4\text{ W}$	—	0.006	0.07	%
	THD(2)	$P_{OUT} = 4\text{ W}$ , $R_L = 2\ \Omega$	—	0.015	—	
Voltage gain	$G_V(1)$	$V_{OUT} = 0.775\text{ Vrms}$	25	26	27	dB
Channel-to-channel voltage gain	$\Delta G_V$	$V_{OUT} = 0.775\text{ Vrms}$	-1.0	0	1.0	dB
Output noise voltage	$V_{NO(1)}$	$R_g = 0\ \Omega$ , DIN AUDIO	—	65	80	$\mu\text{Vrms}$
Ripple rejection ratio	R.R.	$f_{RIP} = 100\text{ Hz}$ , $R_g = 620\ \Omega$ (Note) $V_{RIP} = 1\text{ Vrms}$	50	65	—	dB
Crosstalk	C.T.	$P_{OUT} = 4\text{ W}$ , $R_g = 620\ \Omega$ ,	—	80	—	dB
Output offset voltage	$V_{OFFSET}$	—	-90	0	90	mV
Input resistance	$R_{IN}$	—	—	90	—	k $\Omega$
Standby current	$I_{STBY}$	$V_{SB} = 0\text{ V}$	—	0.01	1	$\mu\text{A}$
Mute attenuation	$ATT_{MUTE}$	Mute: ON $V_{OUT} = 7.75\text{ Vrms} \rightarrow$ Mute: OFF	85	100	—	dB
Standby control voltage	$V_{SBH}$	POWER: ON	2.2	—	$V_{CC}$	V
	$V_{SBL}$	POWER: OFF	0	—	0.9	
Mute control voltage	$V_{MH}$	Mute: OFF	2.2	—	$V_{CC}$	V
	$V_{ML}$	Mute: ON	0	—	0.9	

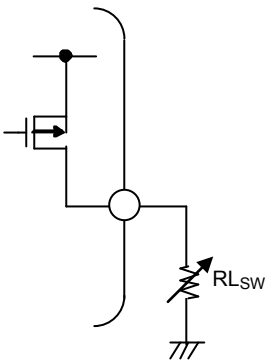
Note:  $f_{RIP}$ : Ripple frequency

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

## 16.2 Pin 25 High-side switch and Output DC offset detection

( $V_{CC} = 13.2\text{ V}$ ,  $f = 1\text{ kHz}$ ,  $R_L = 4\ \Omega$ ,  $I_{O-HSW} = 400\text{ mA}$ ,  $T_a = 25^\circ\text{C}$  unless otherwise specified)

Characteristics	Symbol	Test Condition	Min	Typ.	Max	Unit
HSW maximum current	$I_{O-HSW (MAX)}$	$V_{O-HSW} = 12.6\text{ V}$	400	—	—	mA
HSW I/O voltage ratio	$\Delta V_O$	—	—	0.2	0.6	V
Function switching control voltage	$V_M(HSW)$	Enables High-side switch function	2.2	—	6.0	V
	$V_M(DET)$	Enables output DC offset detection function	7.0	—	$V_{CC}$	
DC offset threshold voltage	$V_{os-det(on)}$	$V_M = 8\text{ V}$ , $OUTx(+)$ to $OUTx(-)$ ( $x = 1$ to $4$ )	$\pm 2.5$	$\pm 3$	$\pm 3.5$	V



High-side switch test circuit 1

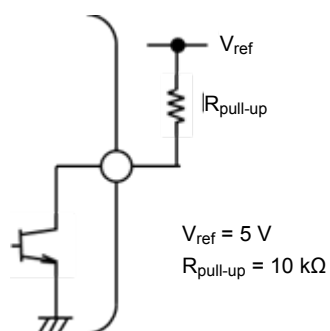


## 16.3 Pin 1 Output DC offset detection

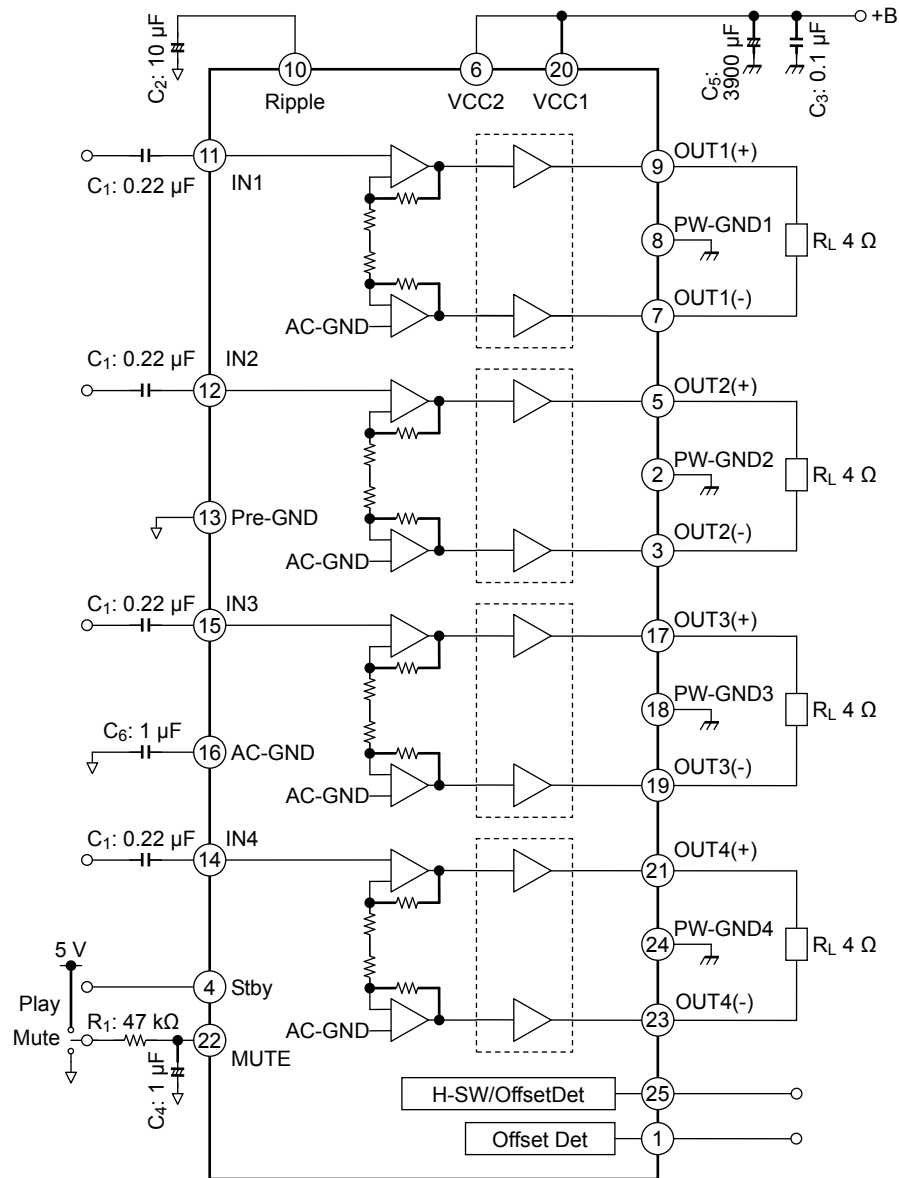
( $V_{CC} = 13.2\text{ V}$ ,  $f = 1\text{ kHz}$ ,  $R_L = 4\ \Omega$ ,  $R_{\text{pull-up}} = 10\text{ k}\Omega$ ,  $V_{\text{SB}} = V_{\text{ref}} = 5\text{ V}$ ,  $T_a = 25^\circ\text{C}$  unless otherwise specified)

Characteristics	Symbol	Test circuit	Test Condition	Min	Typ.	Max	Unit
DC offset threshold voltage	$V_{\text{os-det(on)}}$	(5)	$V_{\text{SB}} = 5\text{ V}$ , $\text{OUT}_x(+)$ to $\text{OUT}_x(-)$ ( $x = 1$ to $4$ )	$\pm 2.5$	$\pm 3.0$	$\pm 3.5$	V
Saturation voltage in offset detection	P1-sat	(5)	$R_{\text{pull-up}} = 10\text{ k}\Omega$ , $V_{\text{ref}} = 5.0\text{ V}$ Active low	—	100	500	mV

Test circuit (5)

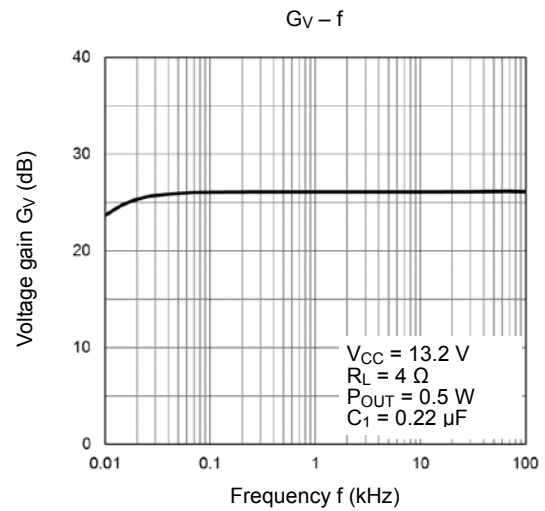
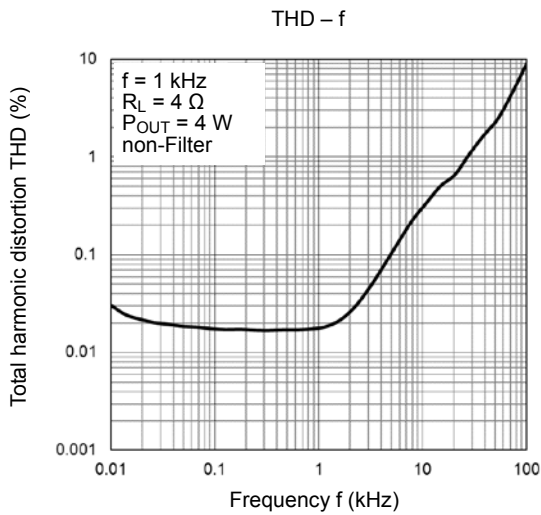
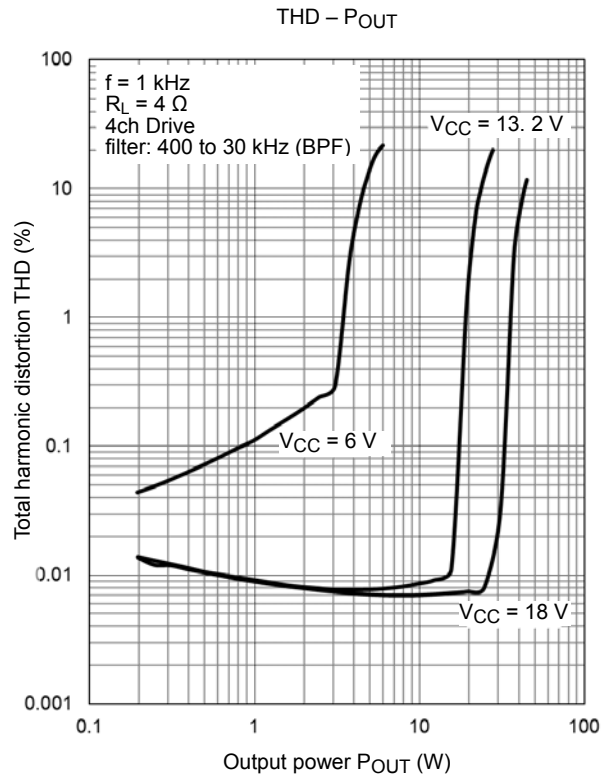
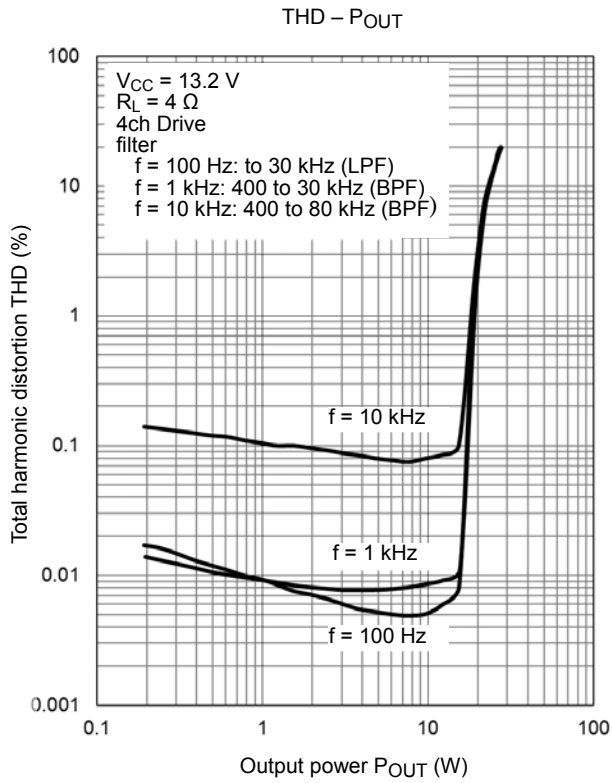


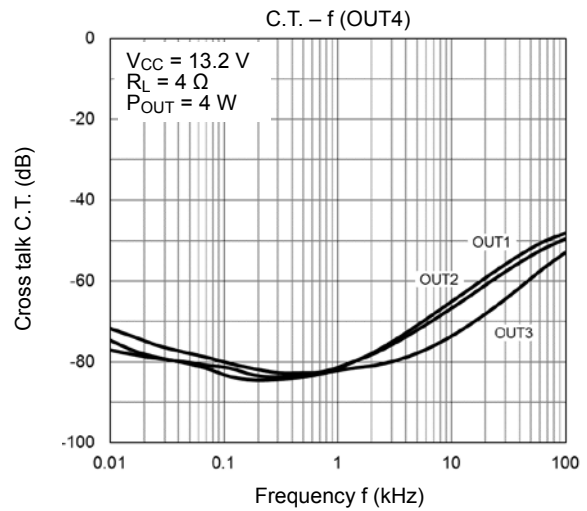
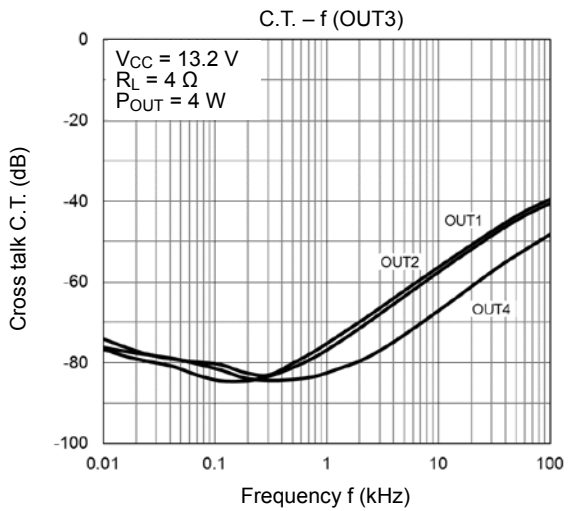
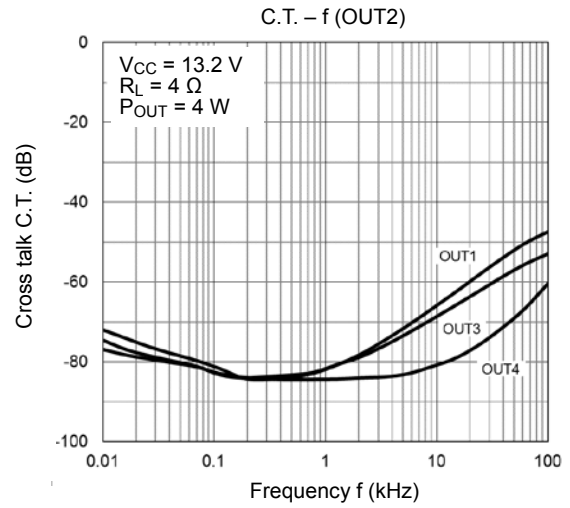
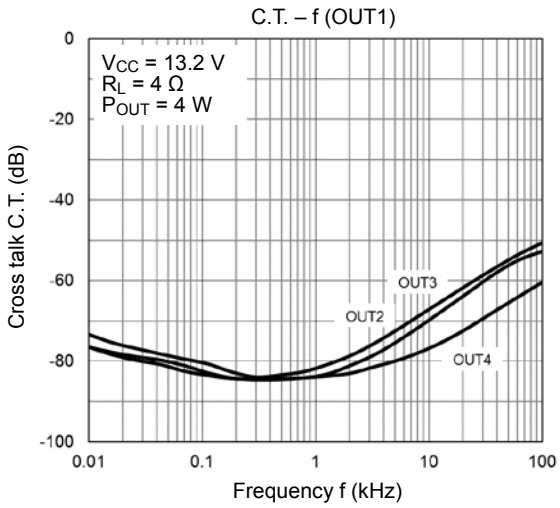
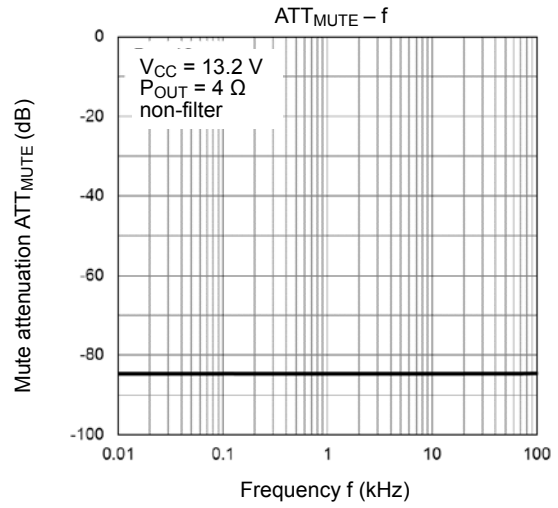
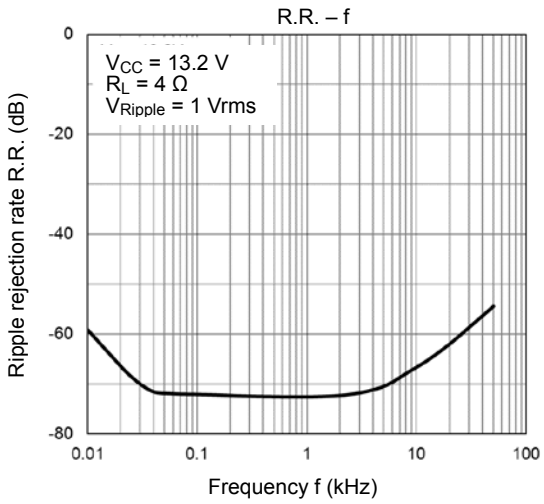
## 17. Test Circuit

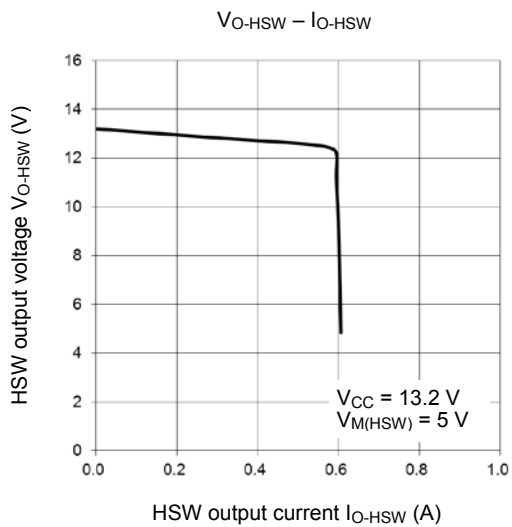
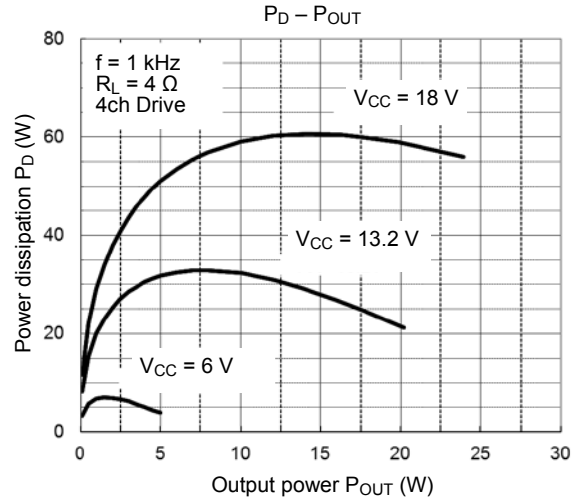
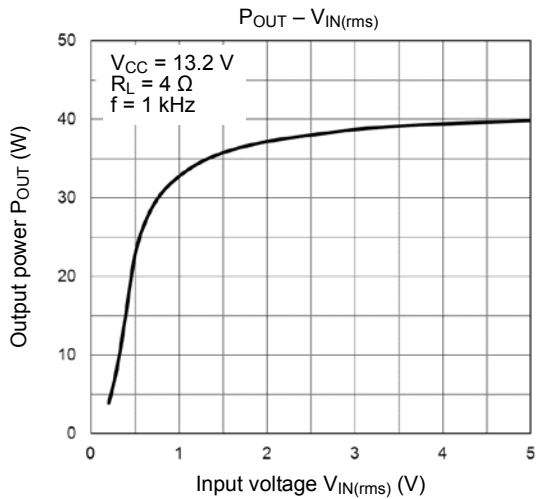
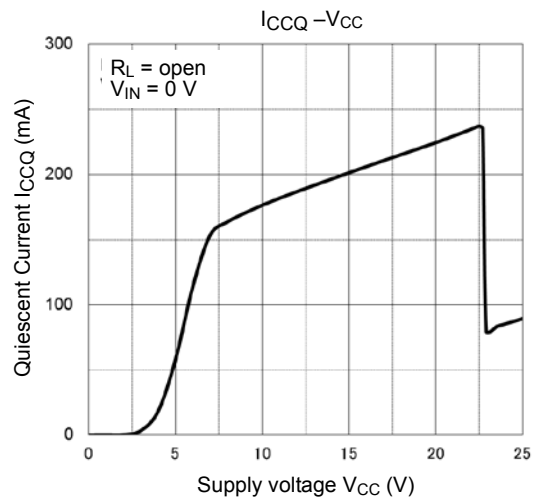
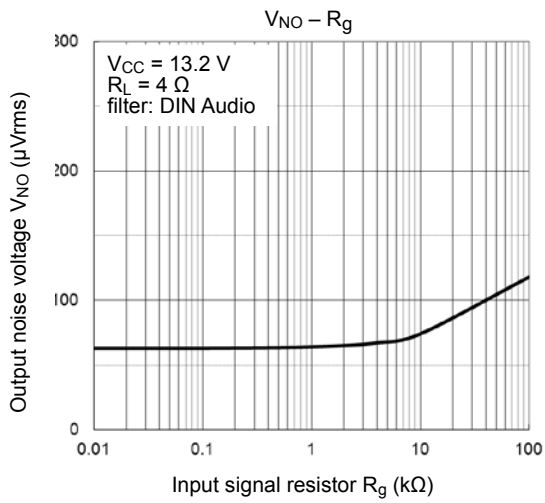


Components in the test circuit are only used to determine the device characteristics.

## 18. Characteristics Curve data



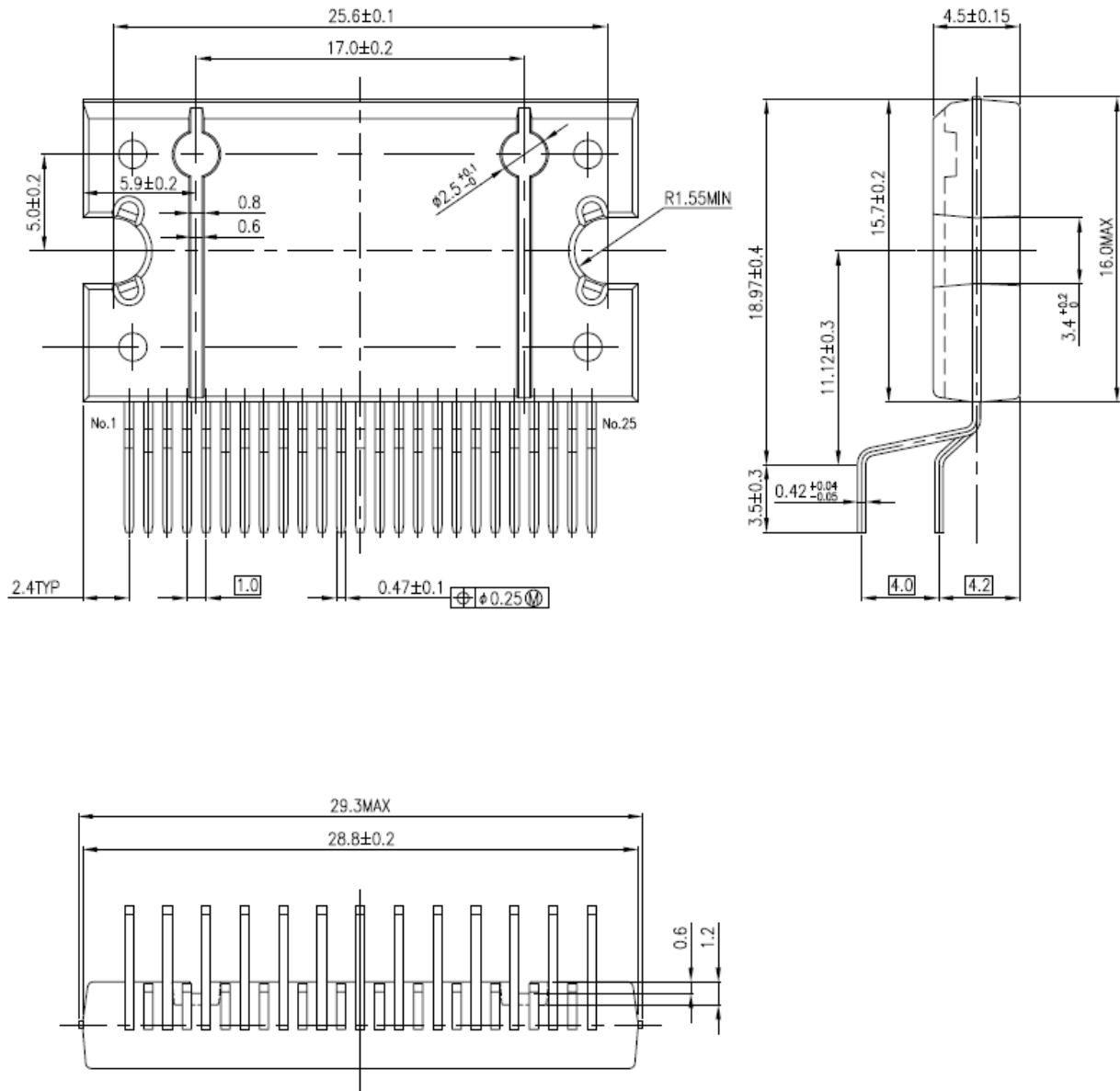




## 19. Package Dimensions

HZIP25-P-1.00F

Unit: mm



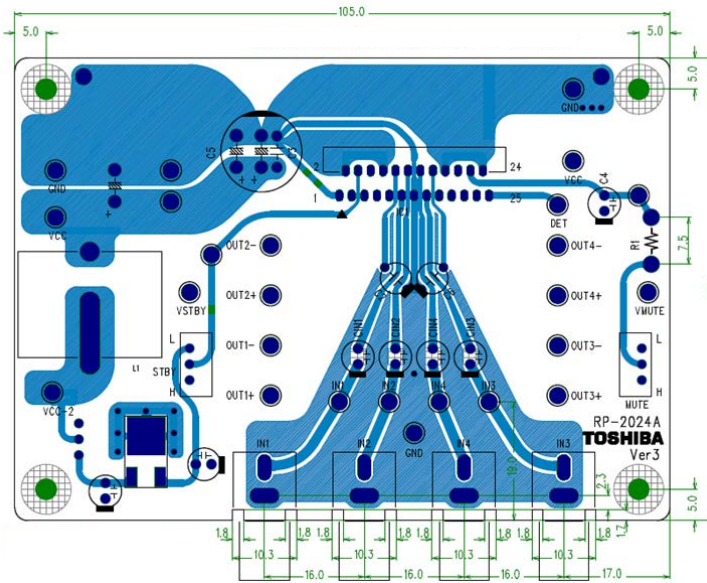
Weight: 7.7 g (typ.)

**20. 4ch Power IC Evaluation Board Diagram**

These figures show a component side and solder side of evaluation board “RP-2024A” for a power IC with built-in four-channel BTL amplifier using HZIP25-P-1.00F (SPP25).

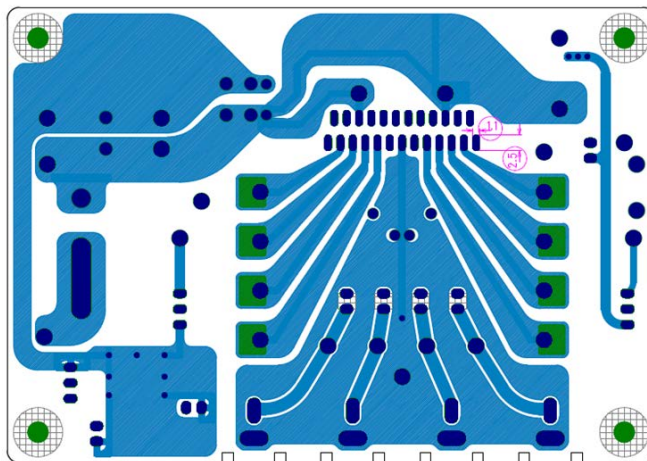
Note: This board can be shared with some other products. Please confirm external parts of the evaluated product and pattern of evaluation board beforehand when you unite the evaluation board.

- Component side



**Figure 9 Pattern of Evaluation Board (component side)**

- Solder side



**Figure 10 Pattern of Evaluation Board (solder side)**

## 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.

## 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.



[5] Carefully select external components (such as inputs and negative feedback capacitors) and load components (such as speakers), for example, power amp and regulator.

If there is a large amount of leakage current such as input or negative feedback condenser, the IC output DC voltage will increase. If this output voltage is connected to a speaker with low input withstand voltage, overcurrent or IC failure can cause smoke or ignition. (The over current can cause smoke or ignition from the IC itself.) In particular, please pay attention when using a Bridge Tied Load (BTL) connection type IC that inputs output DC voltage to a speaker directly.

## 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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