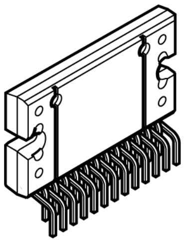
CDMOS Linear Integrated Circuit Silicon Monolithic

TCB503HQ

Maximum Power 50 W BTL × 4ch Audio Power Amplifier IC

1. Description

The TCB503HQ is a power IC with built-in four-channel BTL amplifier developed for car audio application. The maximum output power P_{OUT} is 50 W using a pure complementary P-ch and N-ch DMOS output stage.
In addition, a standby switch, a mute function, output DC offset voltage detection, various protection features are included.



HZIP25-P-1.00F

Weight: 7.7 g (typ.)

2. Applications

Power Amplifier IC developed for car audio applications.

3. Features

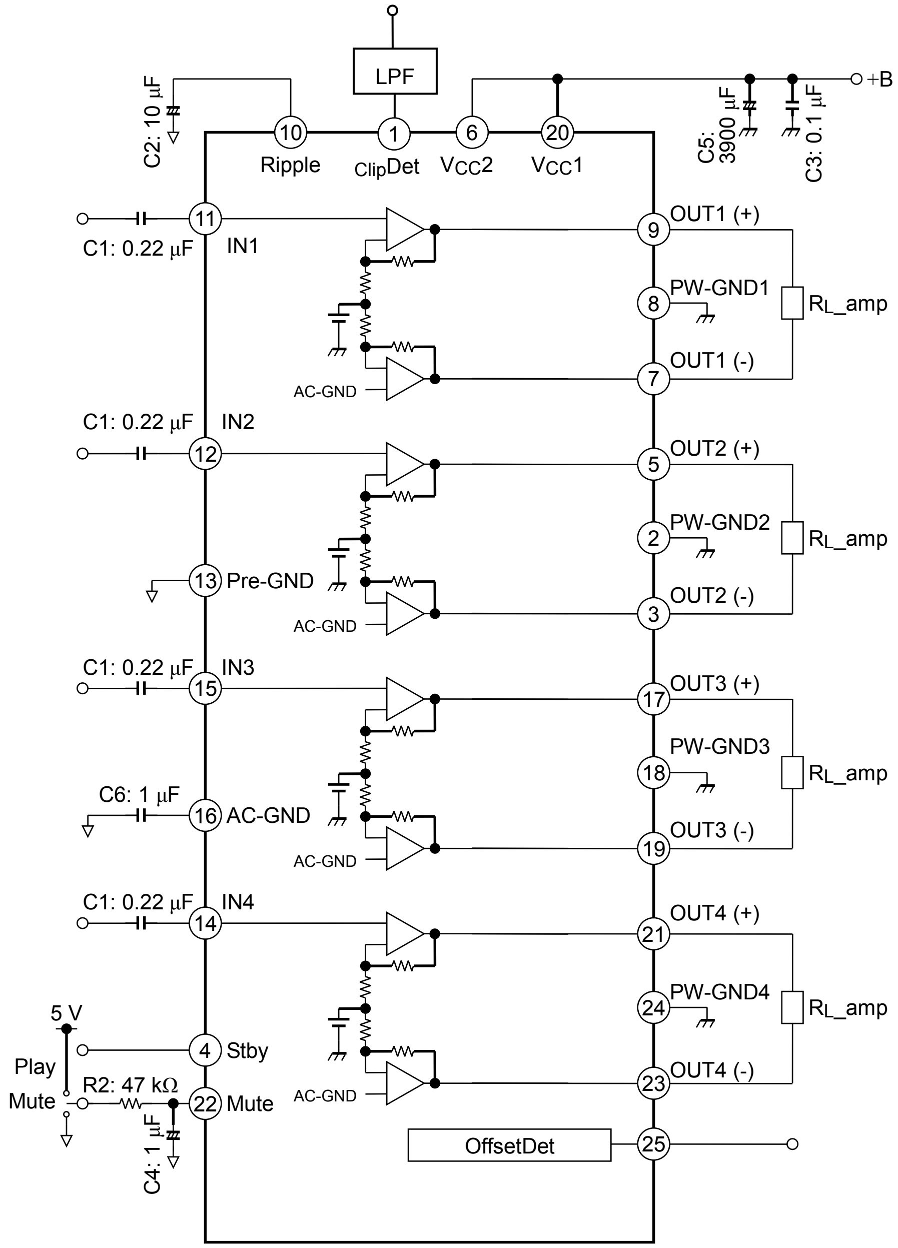
- High output power, low distortion, and low noise property (for details, refer to the Table 1 Typical Characteristics).
- Built-in output DC offset detection. (Pin25)
- Built-in output clip detection. (Pin1)
- Built-in muting function. (Pin 22)
- Built-in auto muting functions (for low V_{CC} and standby sequence)
- Built-in standby switch. (Pin4)
- Built-in various protection circuits (thermal shut down, over-voltage, short to GND, short to V_{CC}, and output to output short)
- Start stop Cruising corresponded to V_{CC} = 6V (Engine idle reduction capability)

Table 1 Typical characteristics (Note 1)

Test condition	Typ.	Unit
Output power (P_{OUT})		
V_{CC} = 15.2 V, max power	50	W
V_{CC} = 14.4 V, max power	45	
V_{CC} = 14.4 V, THD = 10%	29	
Total harmonic distortion (THD)		
P_{OUT} = 4 W	0.01	%
Output noise voltage (V_{NO}) (Rg = 0 Ω)		
Filter: A weighted	45	μV
Operating Supply voltage range (V_{CC})		
RL_amp = 4 Ω	6 to 18	V

Note 1: Typical test conditions:
Unless otherwise specified, V_{CC} = 14.4 V, f = 1 kHz, RL_amp = 4 Ω, and Ta = 25°C
Rg: Signal source resistance

4. Block Digaram

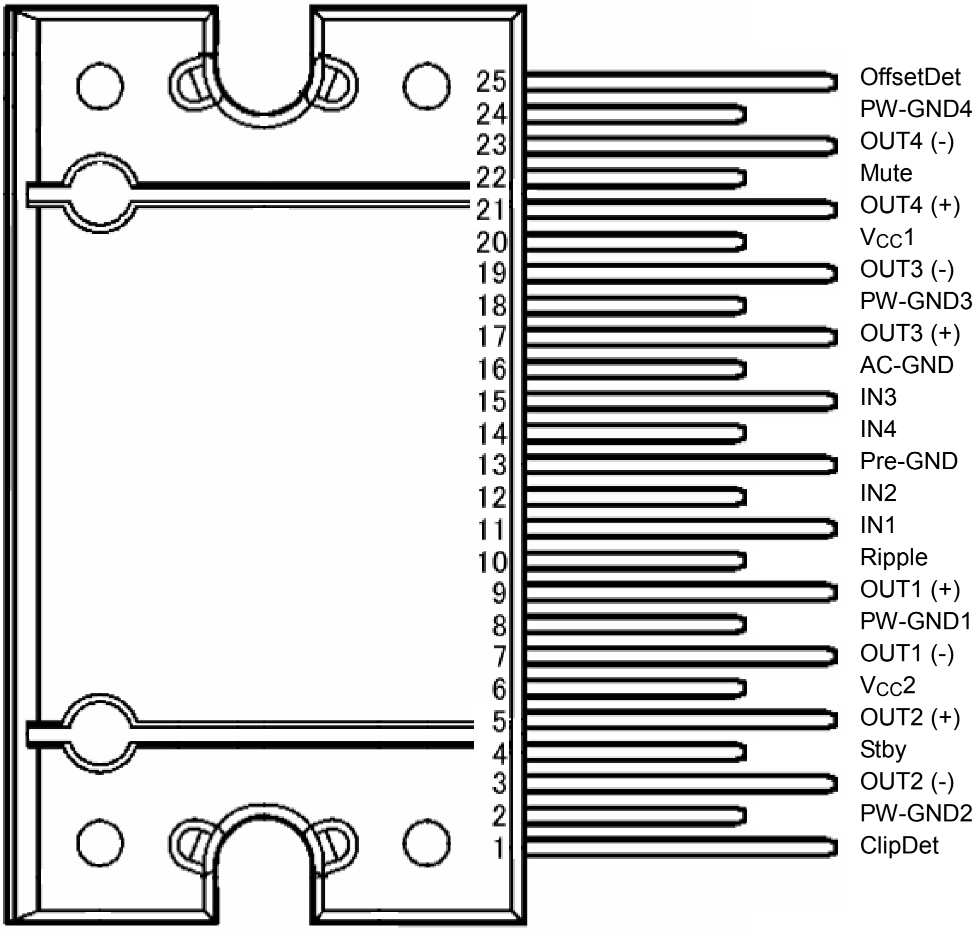


Some of the functional blocks, circuits or constants labels in the block diagram may have been omitted or simplified for clarity.

Note: A "channel" is a circuit which consists of INx, OUTx (+), OUTx (-), and PW-GNDx. (x: 1 to 4)

5. Pin Configuration

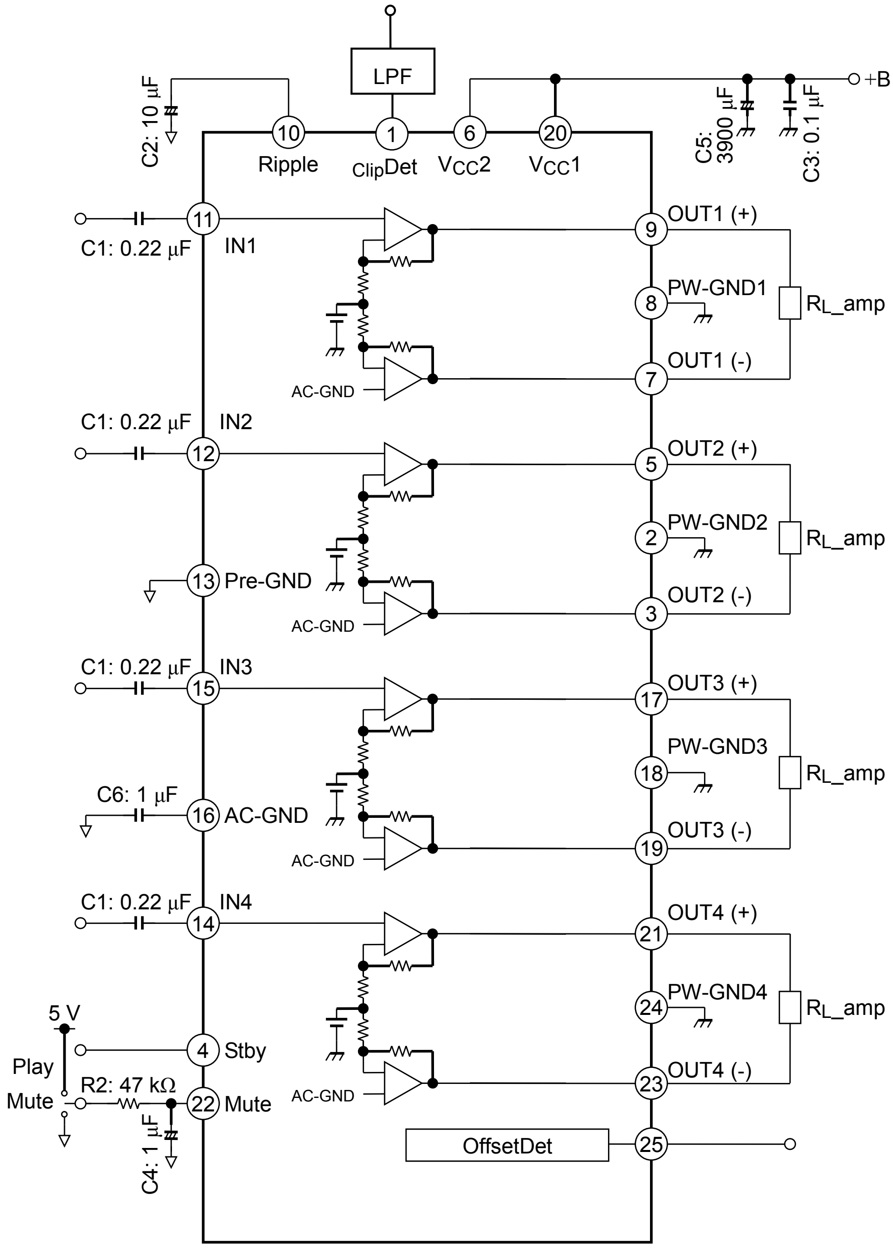
5.1 Pin Configuration (Top View)



5.2 Pin Description

Pin	Symbol	I/O	Description
1	ClipDet	V_{clip}-OUT	Output for output clip detection
2	PW-GND2	—	Ground for OUT2
3	OUT2 (-)	OUT	OUT2(-) output
4	Stby	V_{ST}-IN	Standby voltage input
5	OUT2 (+)	OUT	OUT2(+) output
6	$V_{CC}2$	V_{CC}-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	$V_{CC}1$	V_{CC}-IN	Supply voltage 1
21	OUT4 (+)	OUT	OUT4(+) output
22	Mute	V_{mute}IN	Mute voltage input
23	OUT4(-)	OUT	OUT4(-) output
24	PW-GND4	—	Ground for OUT4
25	OffsetDet	V_{od}-OUT	Output for output DC offset/output short voltage detection

6. Specification of External Parts



Component Name	Recommended Value	Pin	Purpose	Effect (Note1)	
				Lower than Recommended Value	Higher than Recommended Value
C1	0.22 µF	INx(x:1 to 4)	To eliminate DC	Cut-off frequency becomes higher	Cut-off frequency becomes lower
C2	10 µF	Ripple	To reduce ripple	Turn on/off time shorter	Turn on/off time longer
C3	0.1 µF	VCC1, VCC2	To provide sufficient oscillation margin	Reduces noise and provides sufficient oscillation margin	
C6	1 µF	AC-GND	Common reference voltage for all input	Pop noise is suppressed when C1: C6 = 1:4. (Note2)	
C5	3900 µF	VCC1, VCC2	Ripple filter	For power supply hum and ripple filtering	
R2	47 kΩ	Mute	Mute ON/OFF Smooth switching	Pop noise becomes larger	Switching time becomes longer
C4	1 µF				

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 (C1) and the AC-GND capacitance (C6) to 1:4

Note3: Use the low leak current capacitor for C1 and C6.

7. Standby Switch Function (Pin 4)

The power supply can be turned on or off via pin 4 (Stby). The threshold voltage of pin 4 is below table. The power supply current is 0.01 µA (typ.) in the standby state.

Table 1 Standby Control Voltage (V_{SB}): Pin 4

Standby	Power	V_{SB} (V)
ON	OFF	0 to 0.8
OFF	ON	2.2 to V_{CC}

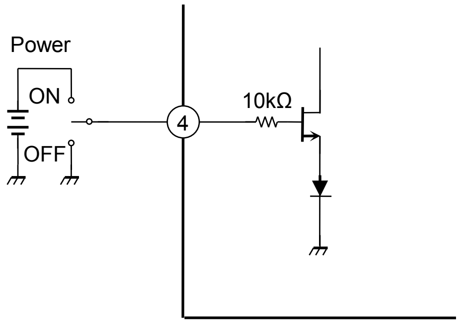


Figure 1 Internal circuit for standby

<ON/OFF of the Standby Switch>

(1) Standby ON state
When the Stby pin (Pin 4) is set to 0.8 V or less, the IC enters to the standby ON state. At that time, Power OFF state, the current which flows to the IC becomes 0.01 µA (typ.).

(2) Standby OFF state
When the voltage of 2.2 V or more is supplied to the Stby pin (Pin 4), the IC enters to the standby OFF state. At that time, Power ON state.

8. Mute Function (Pin 22)

The audio mute function is enabled by setting pin 22 Low. R2 and C4 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 2 and 3.)
The value of the external pull-up resistor is determined, based on pop noise value. In case that it is controlled by other than 5 V, please reexamine the value of the external pull-up resistor as follows;

For example:
When the control voltage is changed from 5 V to 3.3 V, the pull-up resistor should be: 3.3 V/5 V×47 kΩ=31 kΩ

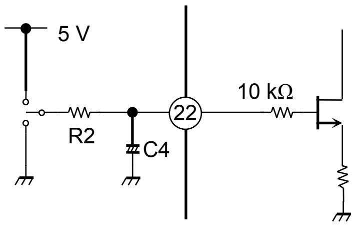


Figure 2 Mute Function

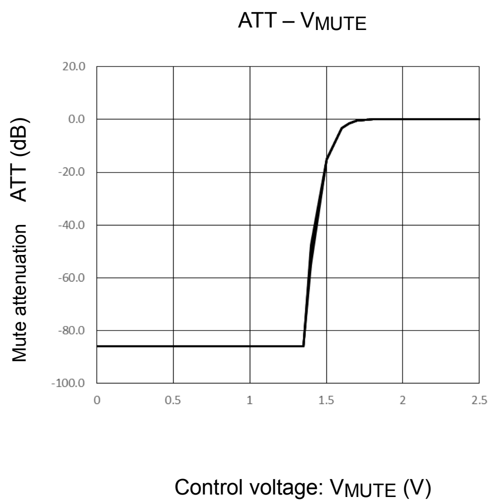


Figure 3 Mute attenuation - V_{MUTE} (V)

9. Auto Muting Functions

The TCB503HQ has two automatic mute functions.

a) Low V_{CC} Mute (Automatic mute function)
b) Standby-Off Mute.

9.1 Low V_{CC} Mute

When the supply voltage became 5.5 V (typ.) or less, The TCB503HQ operates the mute circuit automatically. This function prevents the large audible transient noise which is generated by low V_{CC}.

9.2 Standby-Off Mute

The TCB503HQ operates the mute circuit during the standby-off transition. When the ripple is charged and the voltage reaches $V_{CC}/5$, the standby-off mute is terminated. Additionally, the external mute should be ON in the standby off (power on) sequence, and the timing of external mute OFF should be set after the internal mute OFF.

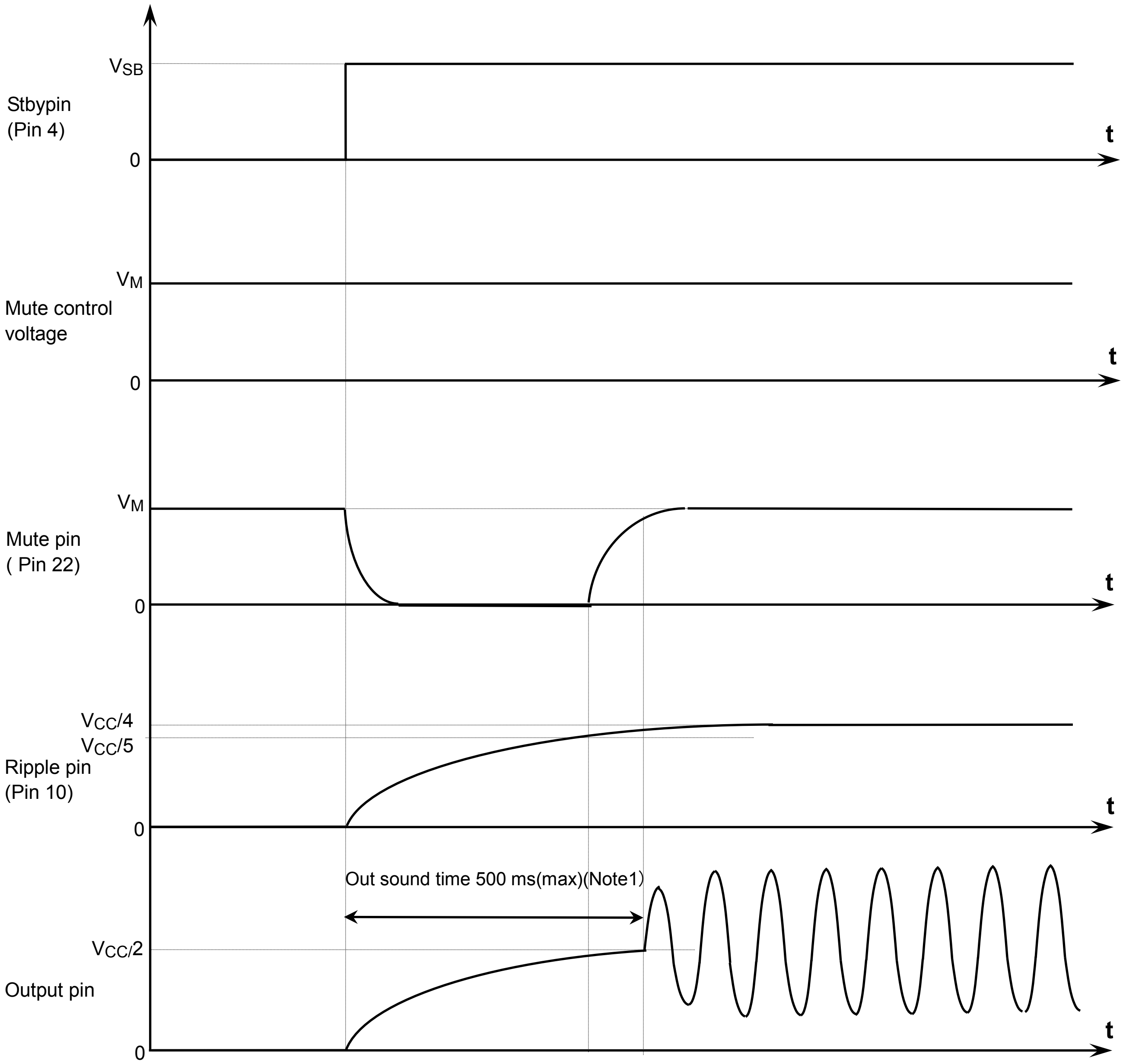


Figure 4 Timing chart when standby-off

Note1: Out sound time is changed due to capacity of the C2 capacitor.

9.3 Mute Off after Standby Off

It affects pop noise generated when capacitor of ripple, input and AC-GND is finished to charge; thus, it must be determined on a per-application basis.
Please set "Mute-off" that it is sufficient margin in considering an enough charge time after the output DC voltage.

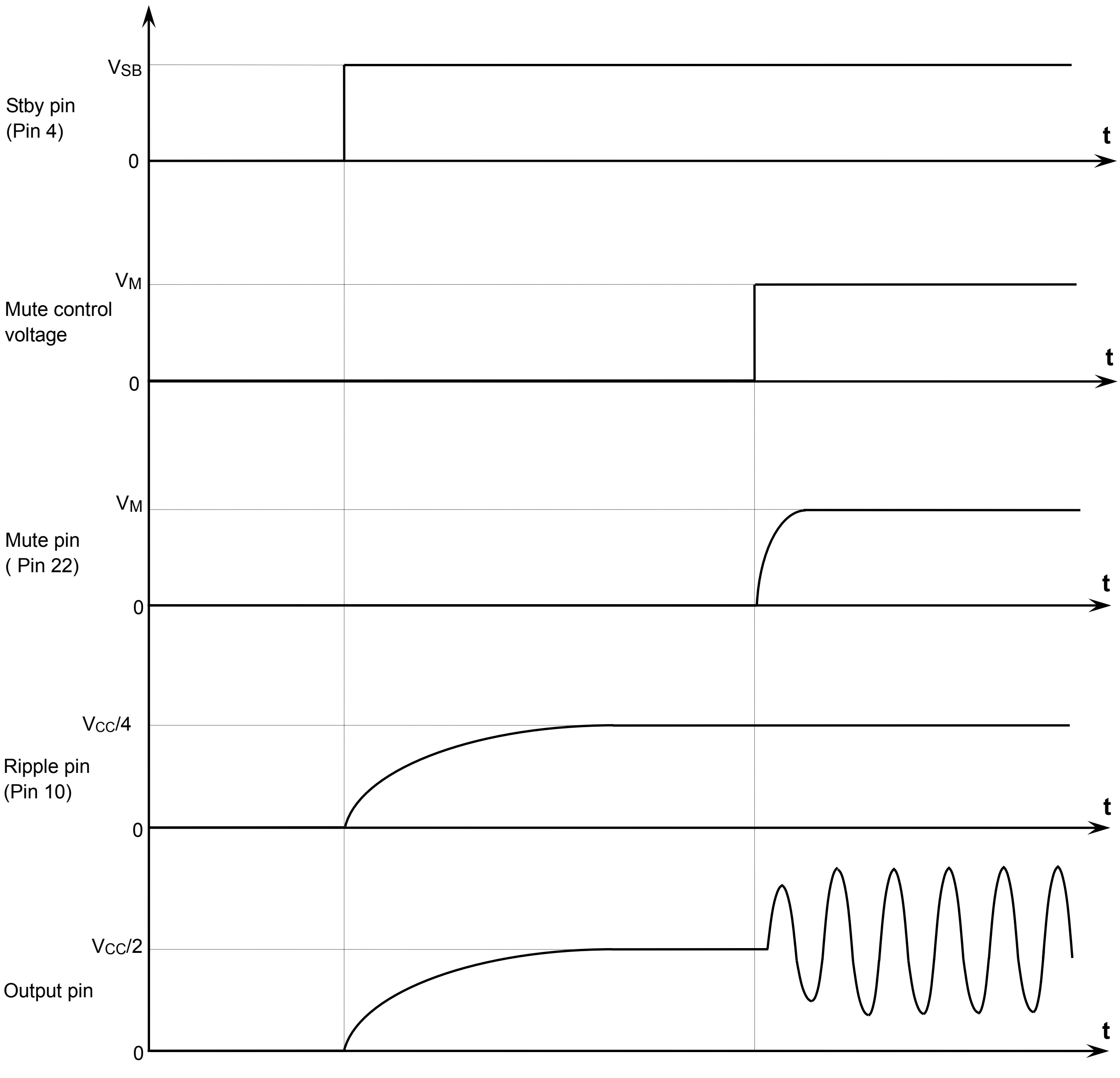


Figure 5 Mute off sequence after standby-off

10. Output DC Offset Detection

This function detects the offset voltage between OUT (+) and OUT (-). The detection result is gotten by pin25. If an abnormal offset voltage is generated in the output by input capacitor leakage, this function can be used as a part (a) of the following to feed back the abnormal state to the application circuit, and to perform the safety measure.

(a) Offset detection → (b) Judgment Normal / Abnormal → (c) Safety measure(Standby-ON, Mute-ON etc.)

The result of detection does not judge the abnormal offset or not. This function detects only the offset voltage which is decided by specification.

10.1 Operation description of Output DC Offset Pin

The result of output offset voltage detection of Pin25 is gotten by the internal open-drain transistor which synchronizes with offset voltage. This function is always available. If this pin does not be used, connect to GND or open.

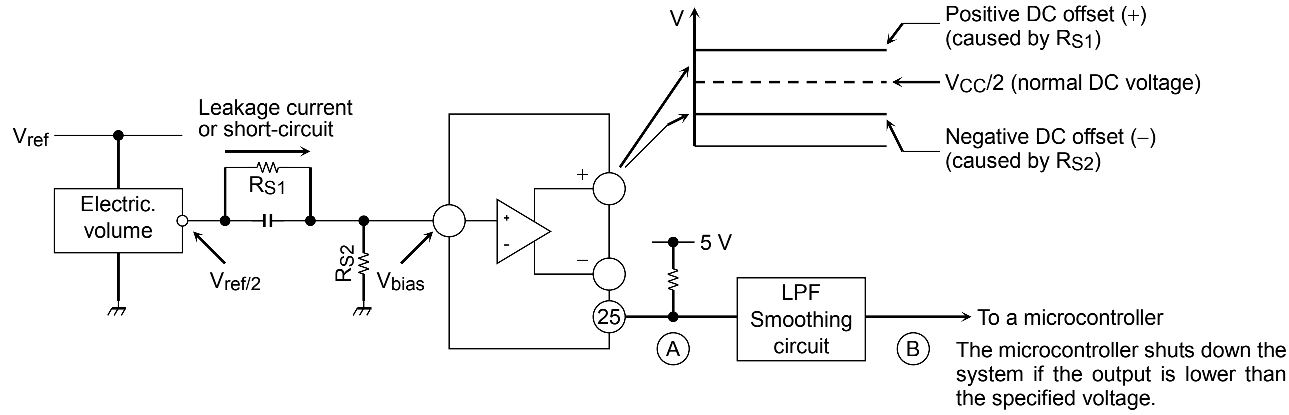


Figure 6 Generation of abnormal output offset voltage

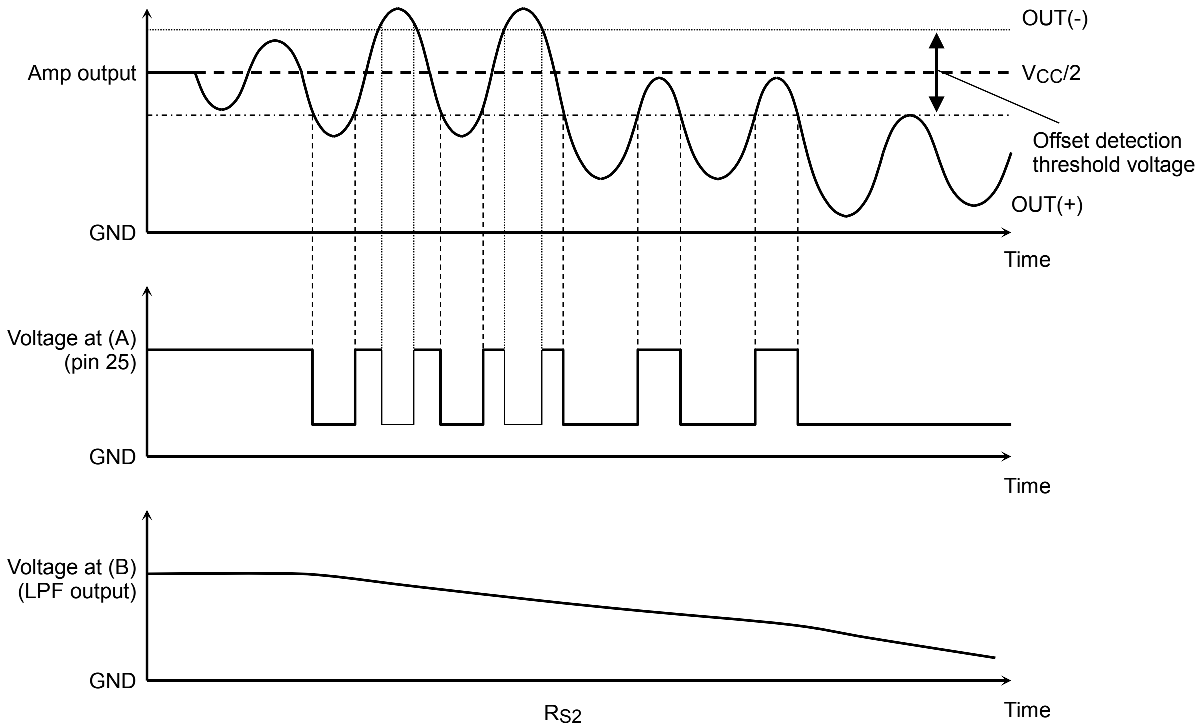
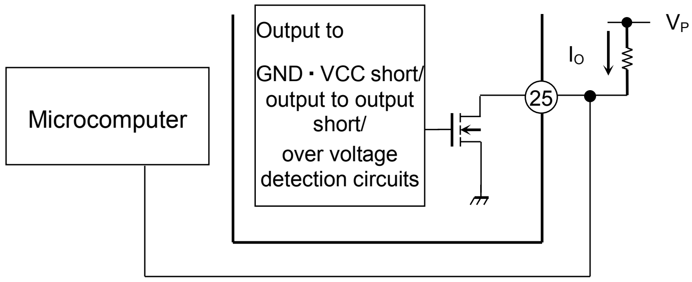


Figure 7 Output waveform of amplifier and pin25

10.2 Each Output Short Detection

In case of shorting output to V_{CC}/GND or over power supplied is turned on the MOS transistor and can be detected.(Reference: Figure 8) Threshold of over voltage protection: V_{CC}=23 V(typ.).
And in the case of output to output short is turned on the MOS transistor and can be detected. (Reference: Figure9) Please use under Io=500 µA at the time of a pull-up.



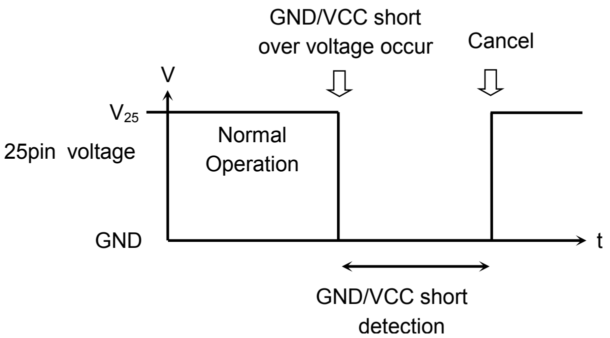


Figure 8 Output waveform of output short detection

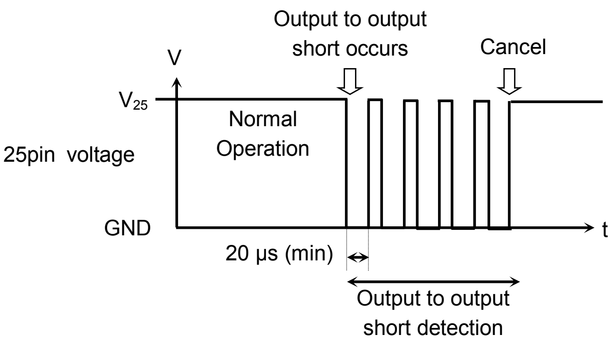
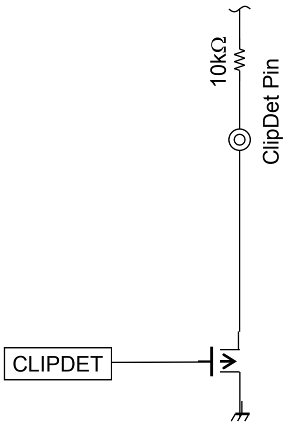


Figure9 Output waveform of output to output short detection

10.3 Output Clip Detection

Output clip detection pin is an open-drain output (active-low) as shown in Figure 10.
When the output voltage waveform is clipped, the internal clip detection is activated so that transistor is enabled.
The sound quality can be improved by controlling the volume and tone control circuitry using this output signal.
Pin 1 should be left open when this feature is not required.



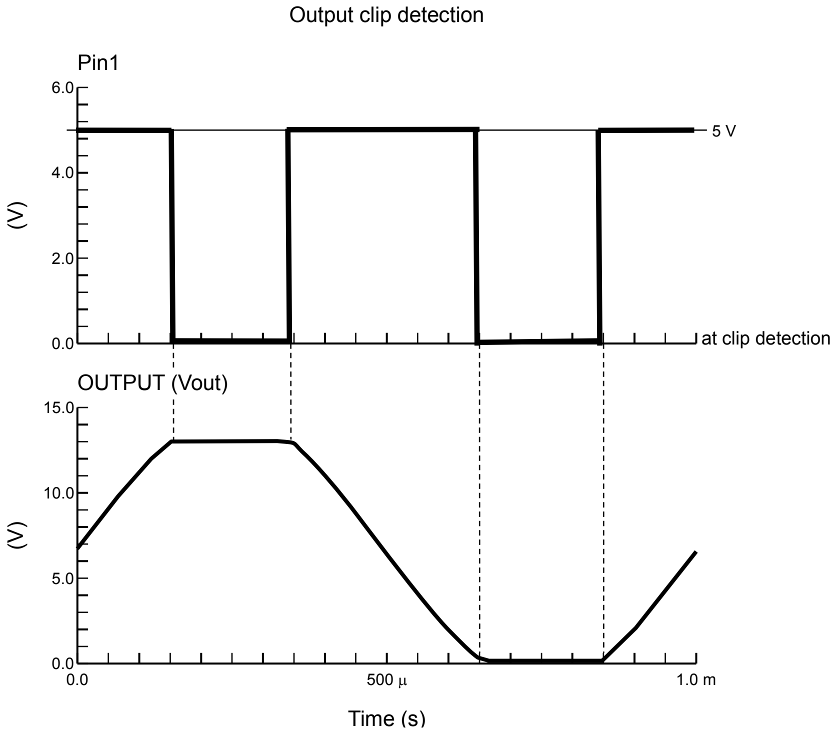


Figure 10 Open-Drain Output of Pin 1

Figure 11 Waveform of Pin 1 Clip Detection

11. Pop Noise and Sound Cutting Reduction with Lowering Supply Voltage

The TCB503HQ applies the amplifier circuit to reduce the audible pop noise and sound cutting due to low V_{CC} voltage.

11.1 Operation Description at Cruising

When the headroom voltage is suppressed by the low V_{CC}, the TCB503HQ switches outputs voltage from $V_{CC}/2$ to $V_{CC}/4$ and reduces the audible pop noise and the sound cutting. The behavior of outputs (Vout) and ripple (Vrip) is shown in Figure 12.

(A) V_{CC} > Vth1 Normal operation
(B) $V_{CC} \leq$ Vth1 Switch outputs voltage from $V_{CC}/2$ to Vrip to keep the headroom voltage.
(C) V_{CC} < Vth2 The C2 (ripple) is discharged with muting, and amplifier is off.

Each of threshold voltage is below.

Vrip = 3 V (Ripple pin voltage)
Vhr1 = 2.2 V (typ.), Vhr2 = 1.7V (typ.)
Vth1 = Vout + Vhr1 = 2Vrip + Vhr1, Vth2 = Vrip + Vhr2

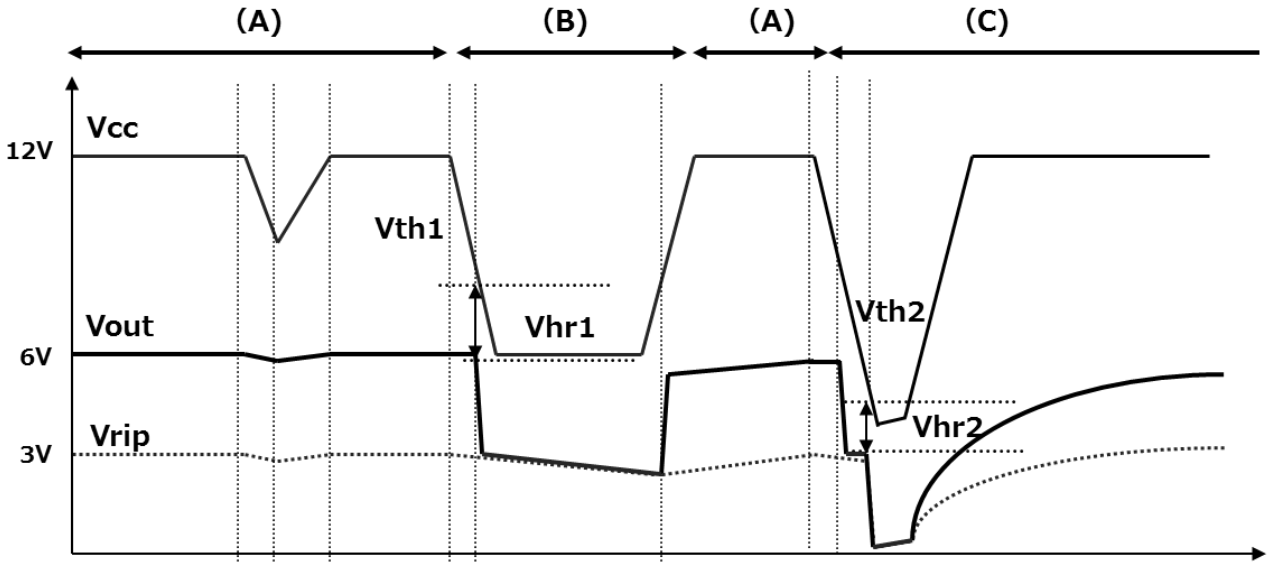


Figure 12 Output DC voltage in lowering V_{CC}

12. Protection Functions

This product has internal protection circuits such as thermal shut down, over-voltage protection, short to V_{CC} protection, short to GND protection, and load short 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 though all outputs are 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 V_{CC} 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 21.5 V(typ.)

(3) Short to V_{CC}, Short to GND, Output to output short
It operates when each output pin is in irregular connection and the load line goes over the SOA of power transistor (DMOS). When it operates, all outputs bias circuits are turned off and all outputs are intercepted. If irregular connection is canceled, it will return automatically.

13. Absolute Maximum Ratings

(Ta = 25°C unless otherwise specified)

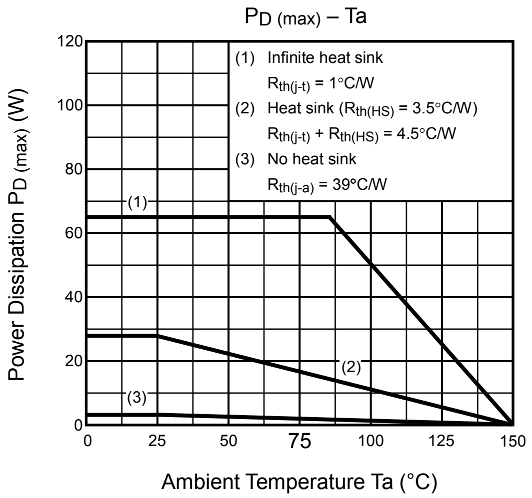
Characteristics		Symbol	Rating	Unit	Condition
Supply voltage (surge)		$V_{CC\ (surge)}$	50	V	Max 0.2 s
Supply voltage (DC)		$V_{CC\ (DC)}$	25	V	Max voltage applied for 1 min
Output current of amplifier (surge)		Io(peak)	9	A	—
Power dissipation		P_D	125	W	(Note 1)
Junction temperature		Tj	150	°C	(Note 2)
Operating temperature range		Topr	-40 to 85	°C	—
Storage temperature		Tstg	-55 to 150	°C	—
Voltage difference between pins	$V_{CC}1$ to $V_{CC}2$	dV1-2	±0.3	V	Permissive voltage difference between $V_{CC}1$ and $V_{CC}2$
	Pre-GND to PW-GND	dV_Gnd	±0.3	V	Permissive voltage difference between Pre-GND and PW-GND
Voltage of input pin	V_{CC}	$V_{CC}1,2$	6 to 18	V	R_L=4Ω
	Stby	Stby	GND-0.3 to V_{CC}+0.3	V	—
	Mute	Mute	GND-0.3 to V_{CC}+0.3	V	—
	IN	In1 to 4	GND-0.3 to 5.3	V	—
	ACGND	ACG	GND-0.3 to 5.3	V	—
	Ripple	Rip	GND-0.3 to 5.3	V	—
	1pin/25pin	Diag	GND-0.3 to V_{CC}+0.3	V	—

The absolute maximum ratings of a semiconductor device are a set of specified parameter values, which must not be exceeded during operation, even for an instant.
If any of these rating would be exceeded during operation, the device electrical characteristics may be irreparably altered and the reliability and lifetime of the device can no longer be guaranteed. Moreover, these operations with exceeded ratings may cause break down, damage, and/or degradation to any other equipment. Applications using the device should be designed such that each maximum rating will never be exceeded in any operating conditions.
Before using, creating, and/or producing designs, refer to and comply with the precautions and conditions set forth in this document.

Note 1: Package thermal resistance $R_{th(j-t)}$ = 1°C/W (Ta = 25°C, with infinite heat sink)

Note 2: When the TAB temperature is more than absolute maximum ratings, the thermal shut down system (mute) operates. The threshold TAB temperature is 160°C(typ.). The threshold TAB temperature is defined as the highest temperature point of the metal side surface. Regarding heat radiation design, please design the device so that heat is appropriately radiated, not to exceed the specified junction temperature (Tj) at any time and condition.

14. Power Dissipation



15. Operating Range

Characteristics	Symbol	Min	Typ.	Max	Unit
Supply voltage	V_{CC}	6	—	18	V

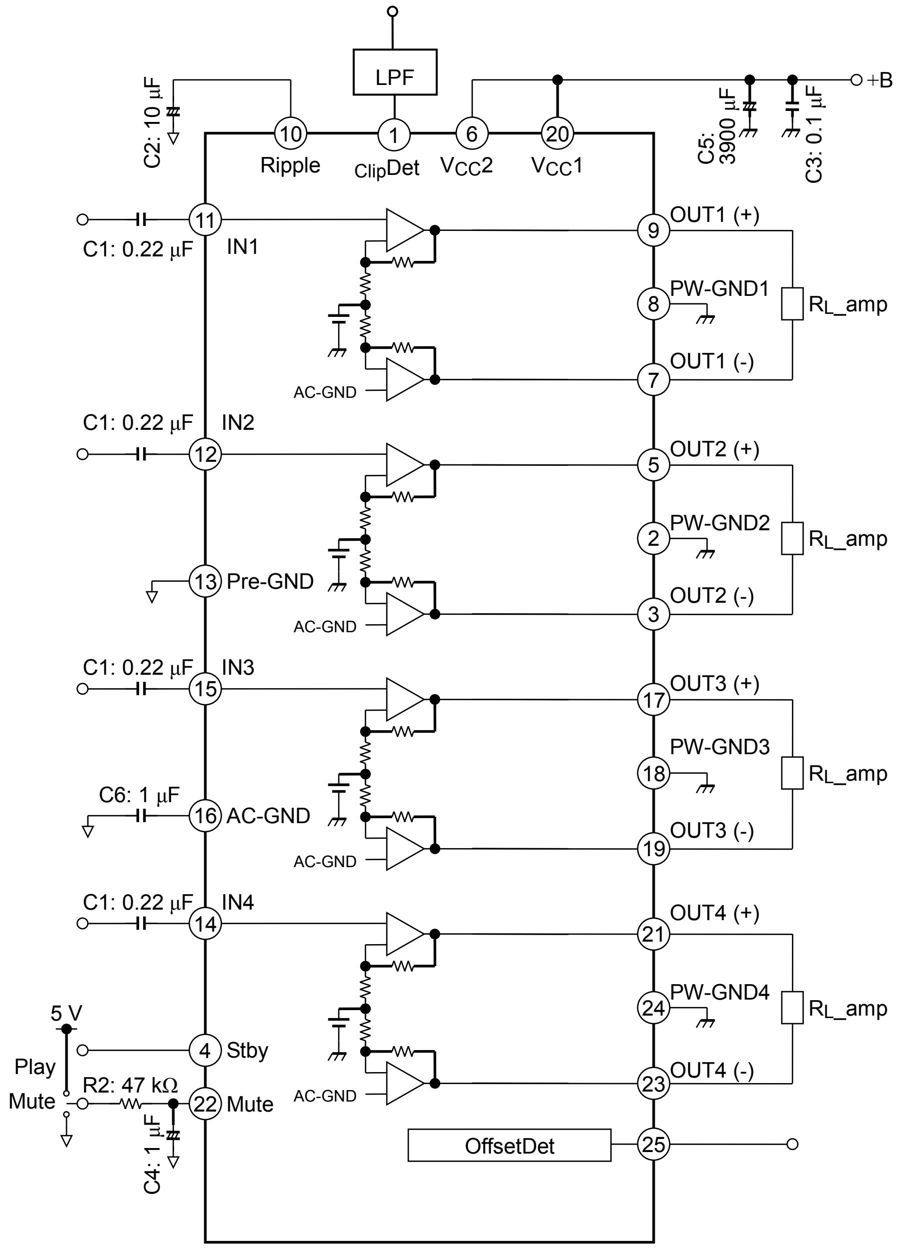
16. Electrical Characteristics

16.1 Amplifier

(Unless otherwise specified, V_{CC}=14.4V, f=1kHz, R_L_amp=4Ω, Vsb/Vm=5V, Ta=25°C)
The value in () is for a design value.

Characteristics	Symbol	Test Condition	Min	Typ.	Max	Unit
Quiescent supply current	I_{CCQ}	V_{IN} = 0Vrms	100	170	300	mA
Output power	P_{OUT} MAX (1)	V_{CC} = 15.2 V, max power	—	50	—	W
	P_{OUT} MAX (2)	V_{CC} = 14.4 V, max power	—	45	—	
	P_{OUT} (1)	V_{CC} = 14.4 V, THD = 10%	—	29	—	
Output power(R_L = 2 Ω)	P_{OUT} MAX (3)	V_{CC} = 14.4 V, max power	—	80	—	
	P_{OUT} (2)	V_{CC} = 14.4 V, THD = 10%	—	50	—	
Total harmonic distortion	THD	P_{OUT} = 4 W	—	0.01	(0.1)	%
Voltage gain	G_V	Vout = 0.775 Vrms	25	26	27	dB
Channel-to-channel voltage gain	ΔG_V	Vout = 0.775 Vrms	(-1.0)	0	(1.0)	dB
Output noise voltage	V_{NO}	Rg = 0 Ω, DIN Audio	—	45	(70)	μVrms
Ripple rejection ratio	R.R.	f_{rip} = 100 Hz, Rg = 620 Ω V_{rip} = 0.775 Vrms	(50)	70	—	dB
Crosstalk	CT.	Rg = 620 Ω P_{OUT} = 4 W	—	80	—	dB
Output DC offset voltage	V_{OFFSET}	—	-70	0	70	mV
Input resistance	R_{IN}	—	—	90	—	kΩ
Standby current	I_{SB}	Standby state, V4= 0, V22= 0	—	0.01	1	μA
Standby control voltage	V_{SB} H	Power: ON	2.2	—	V_{CC}	V
	V_{SB} L	Power: OFF	0	—	0.8	
Mute control voltage	V_M H	Mute: OFF	2.2	—	V_{CC}	V
	V_M L	Mute: ON, R2 = 47 kΩ	0	—	0.8	
Mute attenuation	ATT M	Mute: ON, DIN Audio Vout = 7.75 Vrms → Mute: OFF	(85)	100	—	dB
Voltage of output DC offset voltage detection	Vos25-det	—	±1.0	±1.5	±2.0	V
Threshold of output clip detection	Vclip1-det	—	—	(0.1)	—	%
Saturated voltage in detection	PDET-sat	Rpull-up=10 kΩ, Vref=5.0 V In detection (Pin: Low) 1pin/25pin	—	150	500	mV

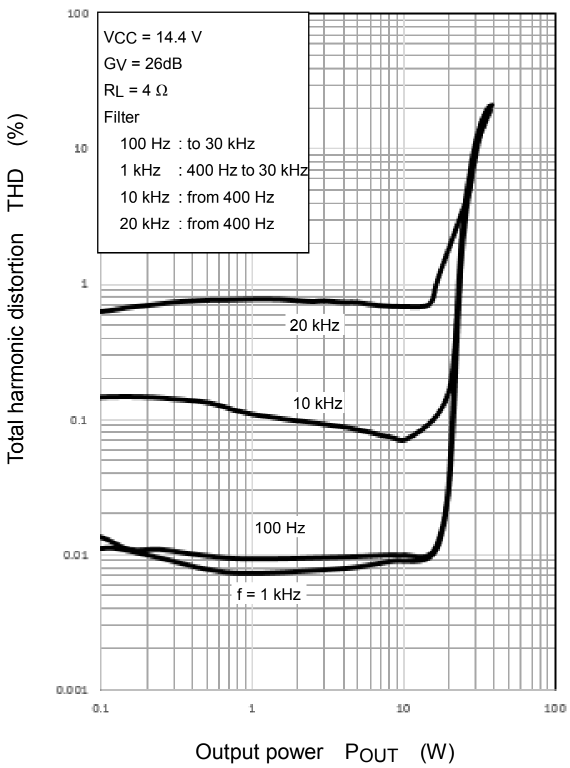
17. Test Circuit



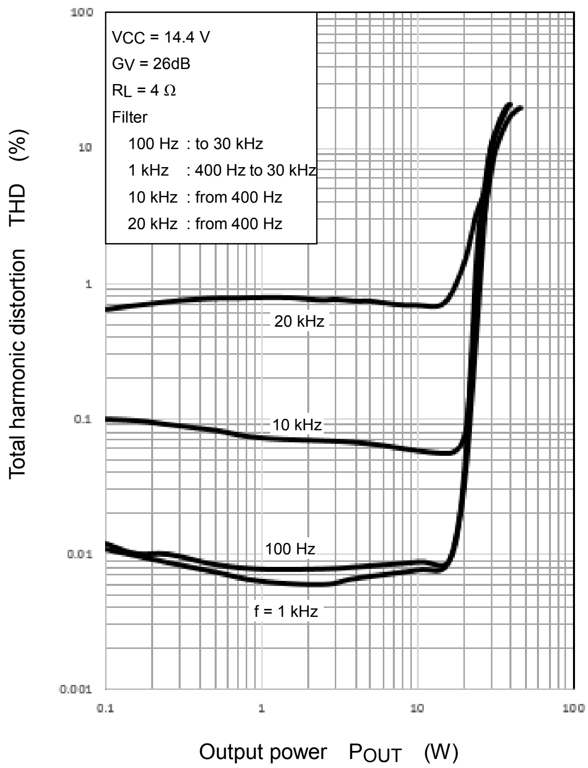
18. Characteristics Curves(Note)

18.1 Total Harmonic Distortion vs Output Power

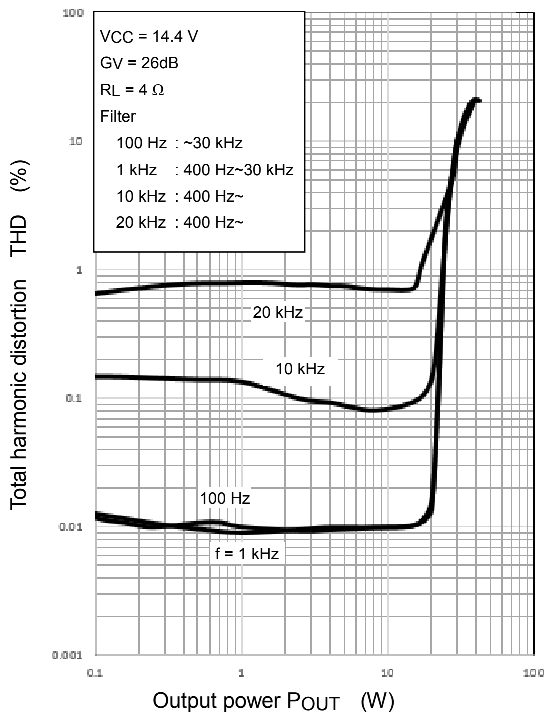
THD – POUT (ch1)



THD – POUT (ch2)



THD – POUT (ch3)



THD – POUT (ch4)

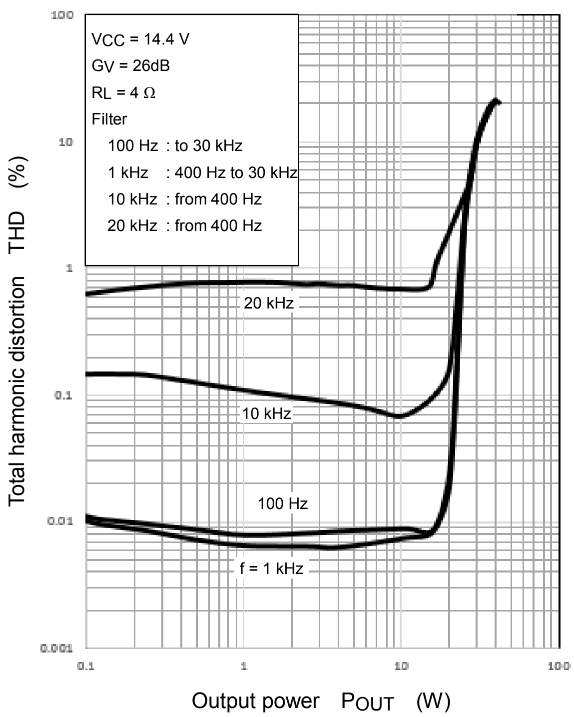
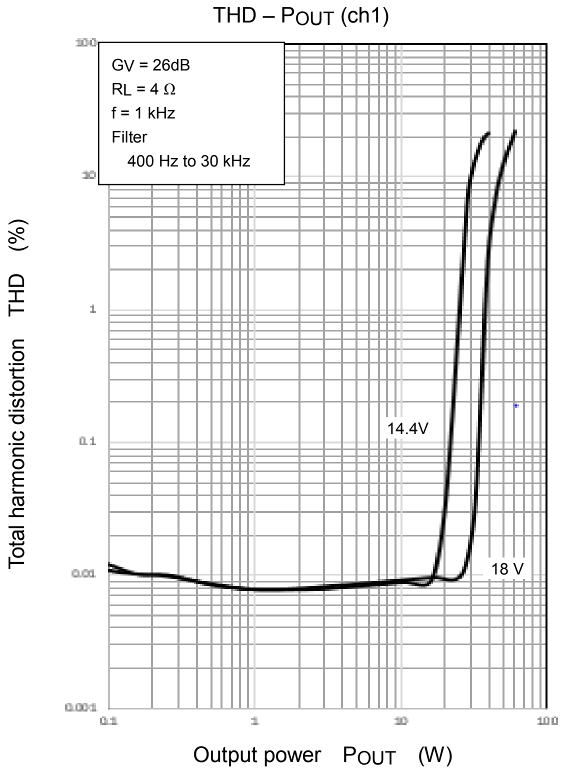
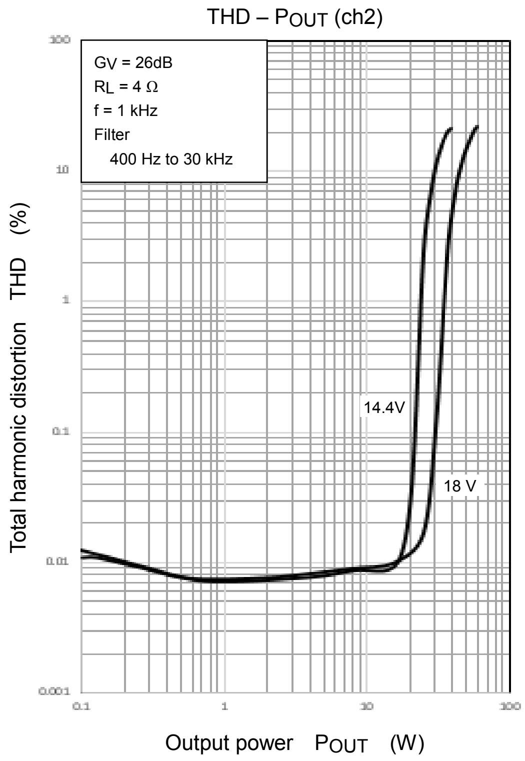
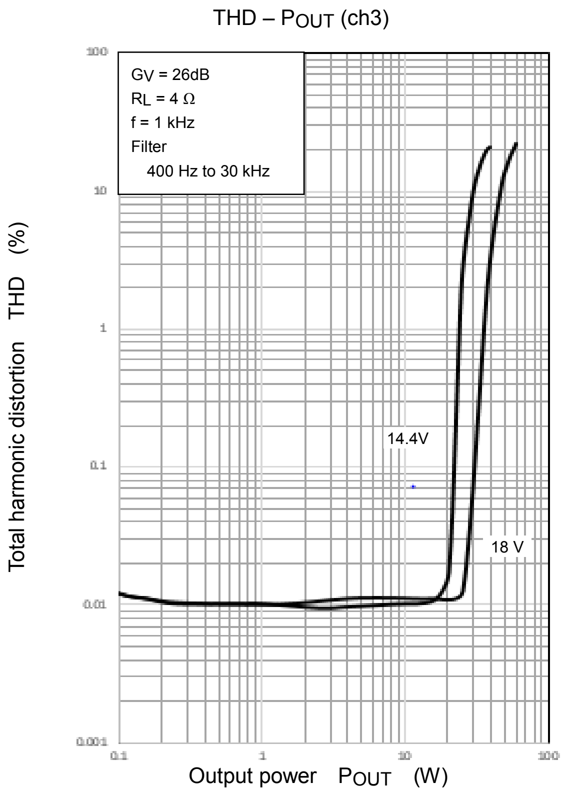


Figure 18-1 Total Harmonic Distortion of Each Frequency (R_L = 4 Ω)







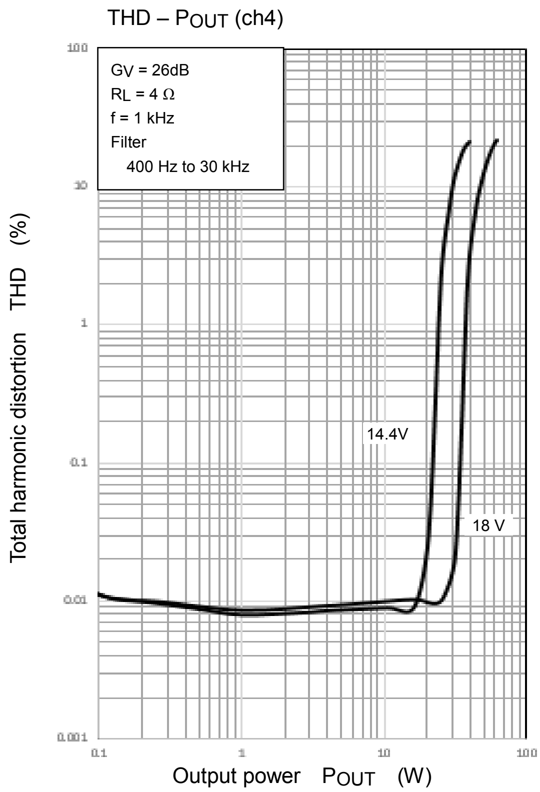


Figure 18-2 Total Harmonic Distortion by Power-supply Voltage (R_L = 4 Ω)

18.2 Various Frequency Characteristics

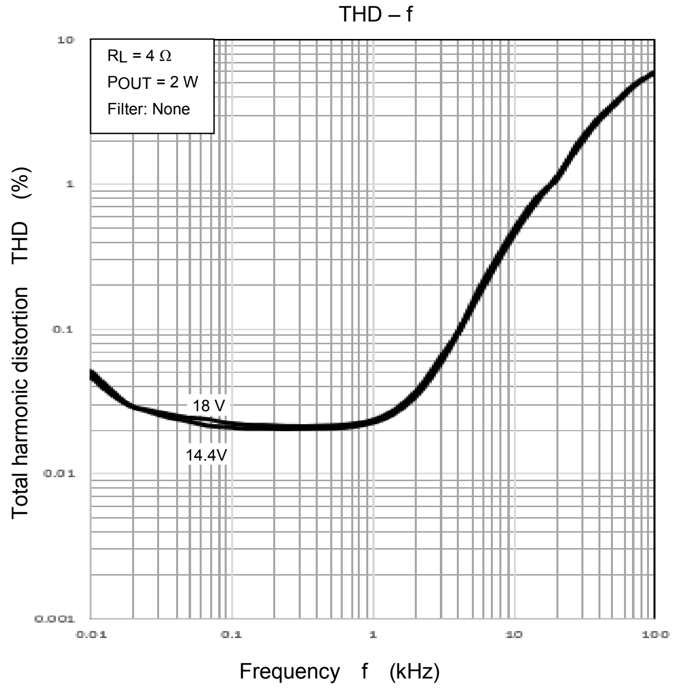


Figure 188-3 Frequency Characteristics of Total Harmonic Distortion

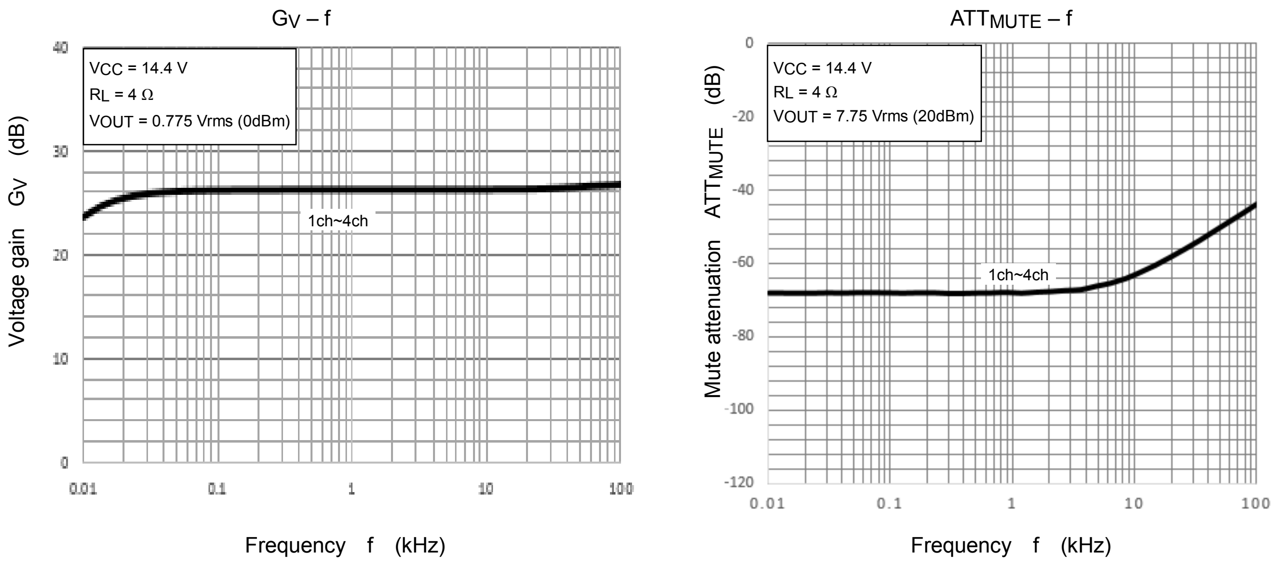


Figure 18-4 Frequency Characteristics of Voltage Gain and Mute Attenuation

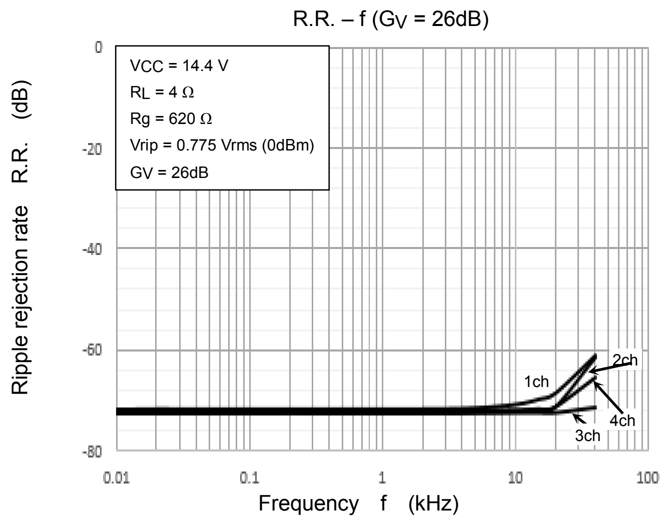


Figure 18-5 Frequency Characteristics of Ripple Rejection Rate

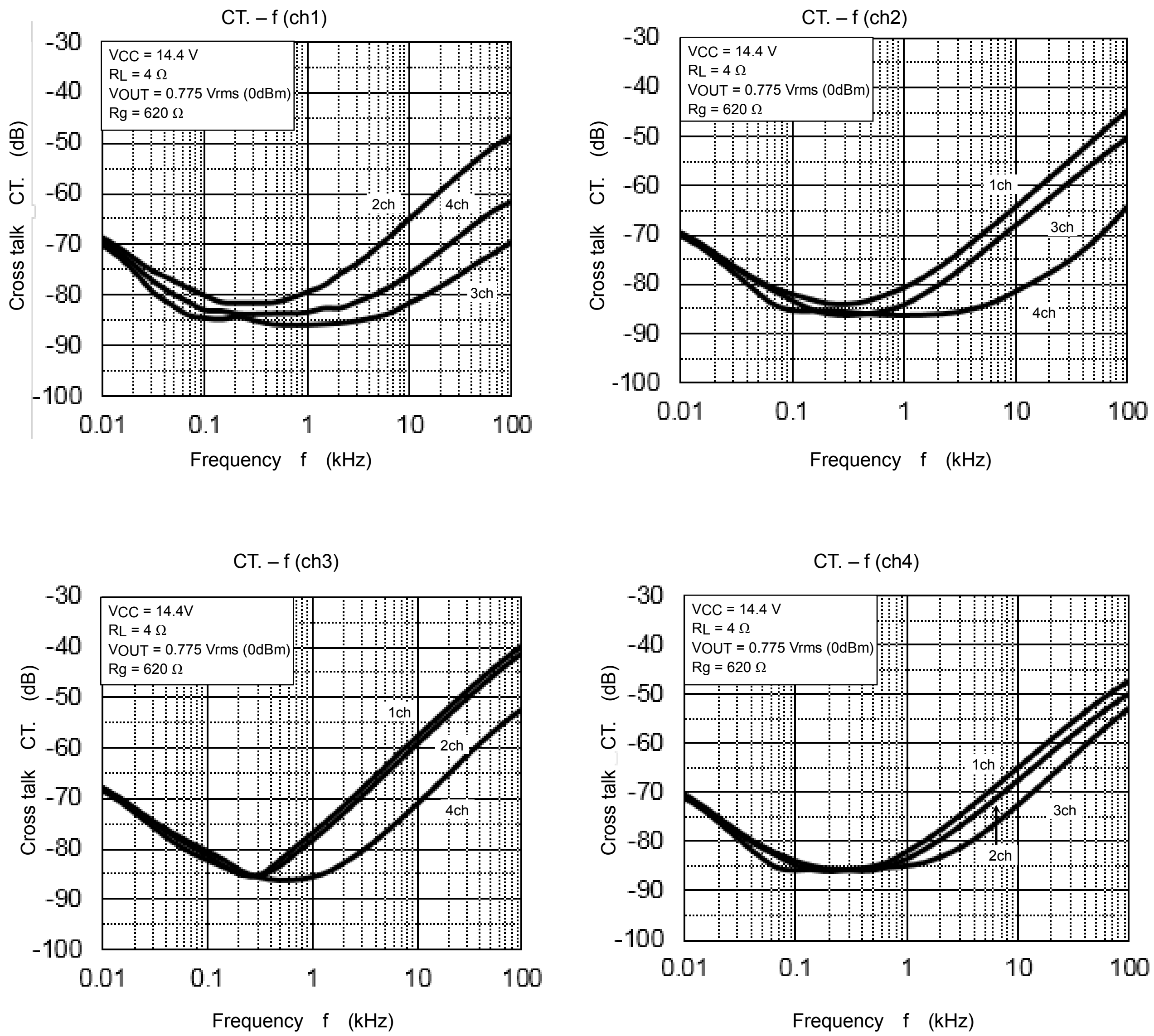
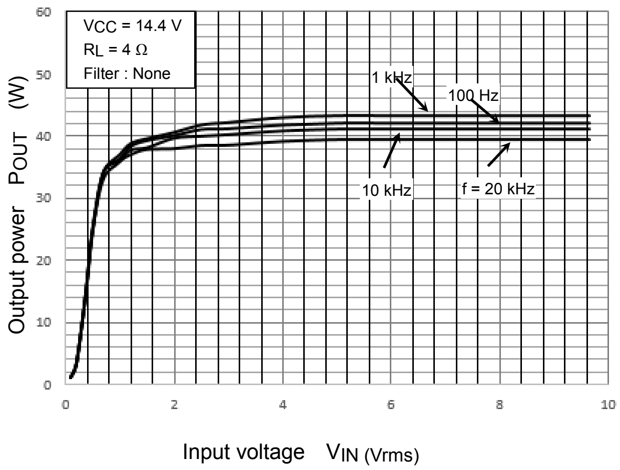


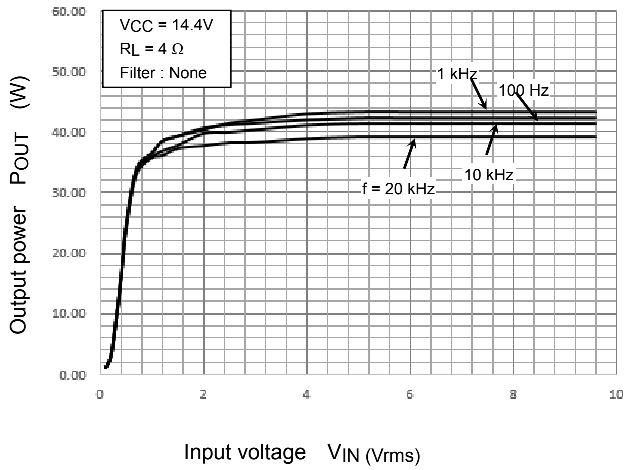
Figure 18-6 Frequency Characteristics of Cross Talk

18.3 Output Power Characteristics to Input Voltage

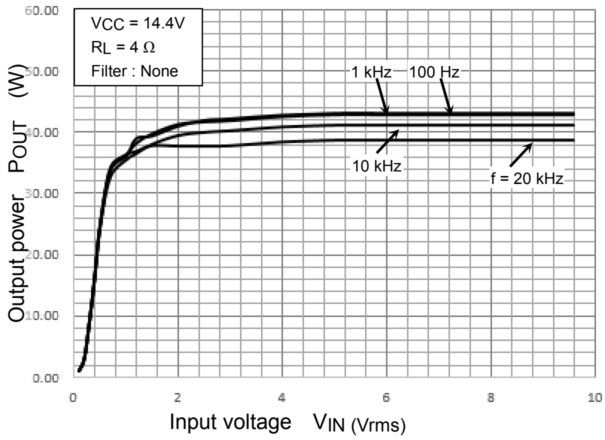
P_{OUT} (ch1) – V_{IN}



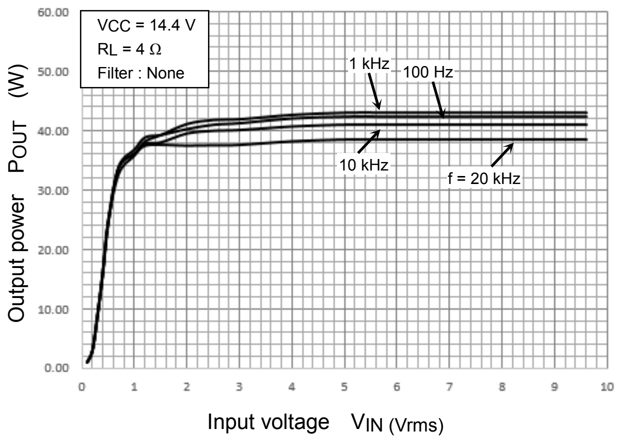
P_{OUT} (ch2) – V_{IN}



P_{OUT} (ch3) – V_{IN}

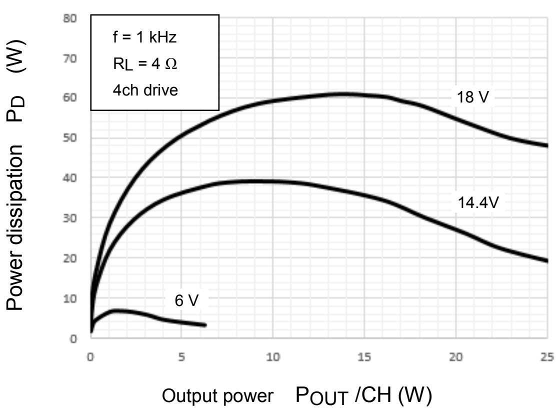


P_{OUT} (ch4) – V_{IN}

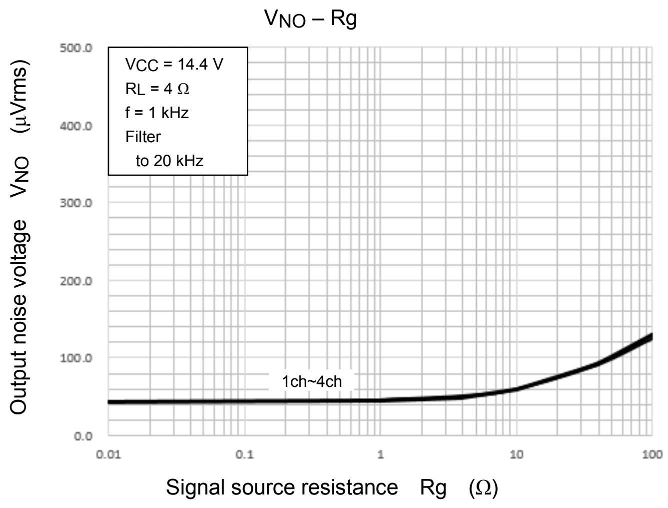


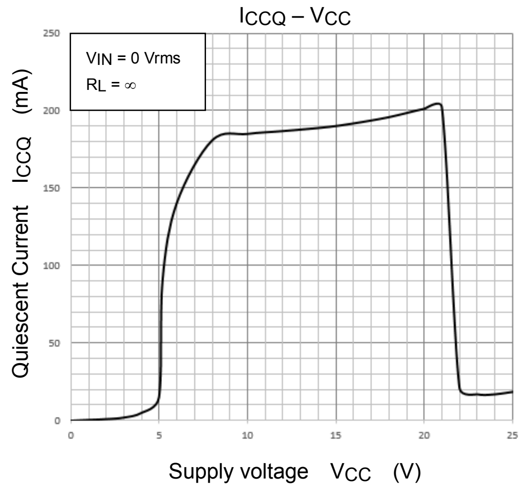
18.4 Power Dissipation vs. Output Power

P_D – P_{OUT} (R_L = 4 Ω)



18.5 Other Characteristics



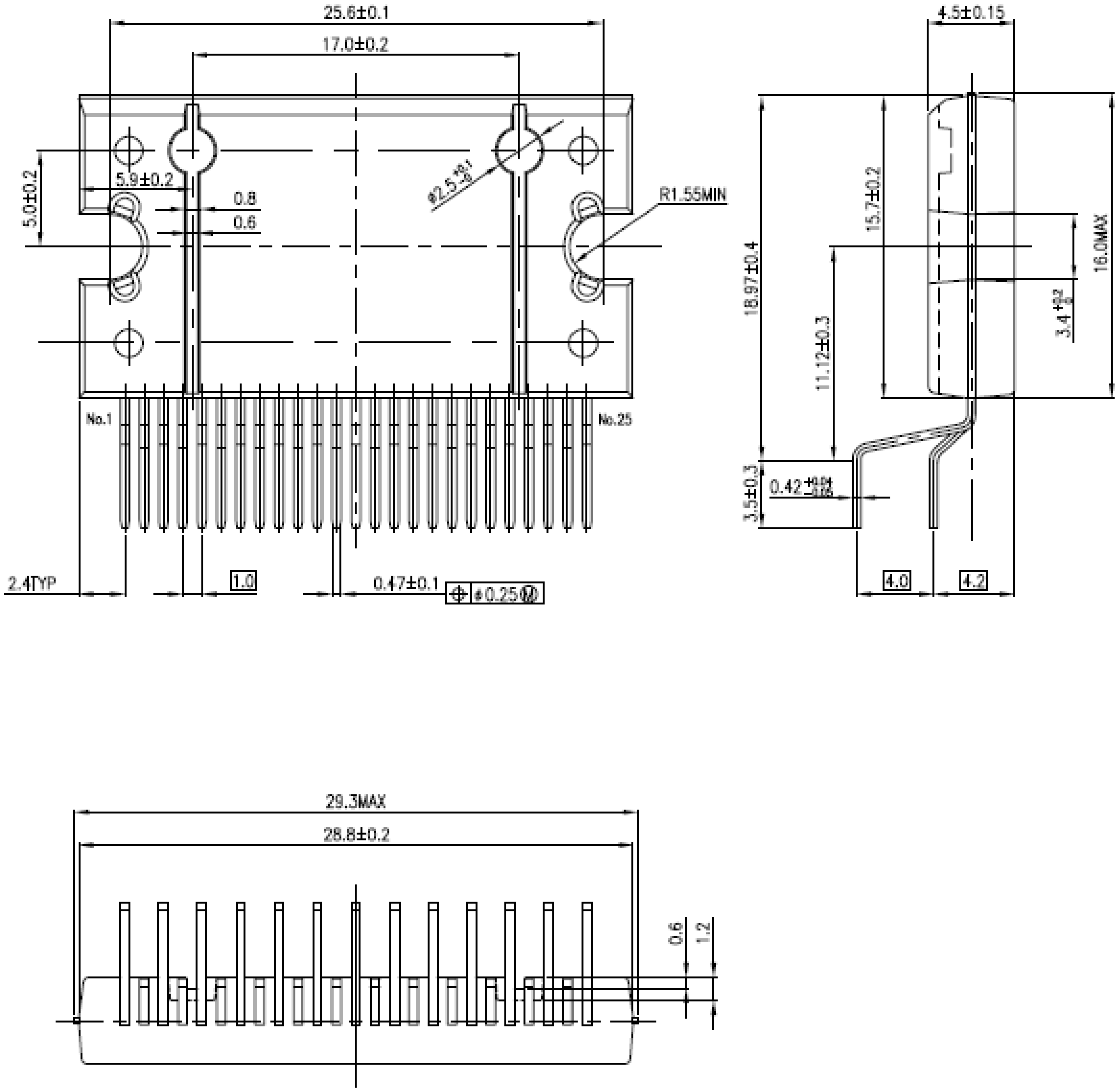


Note: The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.

19. Package Dimension

Unit: mm

HZIP25-P-1.00F



Weight: 7.7 g (typ.)

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 amplifier 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 amplifier, regulator or driver, please design the device so that heat is appropriately radiated, not to exceed the specified junction temperature (Tj) 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 reverses the rotation 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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