CDMOS Linear Integrated Circuit Silicon Monolithic

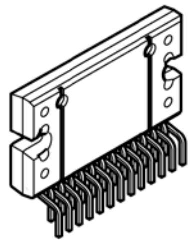
TCB501HQ

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

1. Description

The TCB501HQ is a power IC with built-in four-channel BTL amplifier developed for car audio application. The maximum output power POUT is 49 W using a pure complementary P-ch and N-ch DMOS output stage.

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



HZIP25-P-1.00F

Weight: 7.7g (typ.)

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 switches. (Pin 25)
- Built-in output offset detection for full time (Pin 1)
- Built-in muting function. (Pin 22)
- Built-in auto muting functions (for low V_{DD} and standby sequence)
- Built-in standby switch. (Pin4)
- Built-in various protection circuits (thermal shut down, over-voltage, short to GND, short to V_{DD}, and output to output short)
- Start stop Cruising corresponded to V_{DD}=6V (Engine idle reduction capability)

Table 1 Typical characteristics (Note 1)

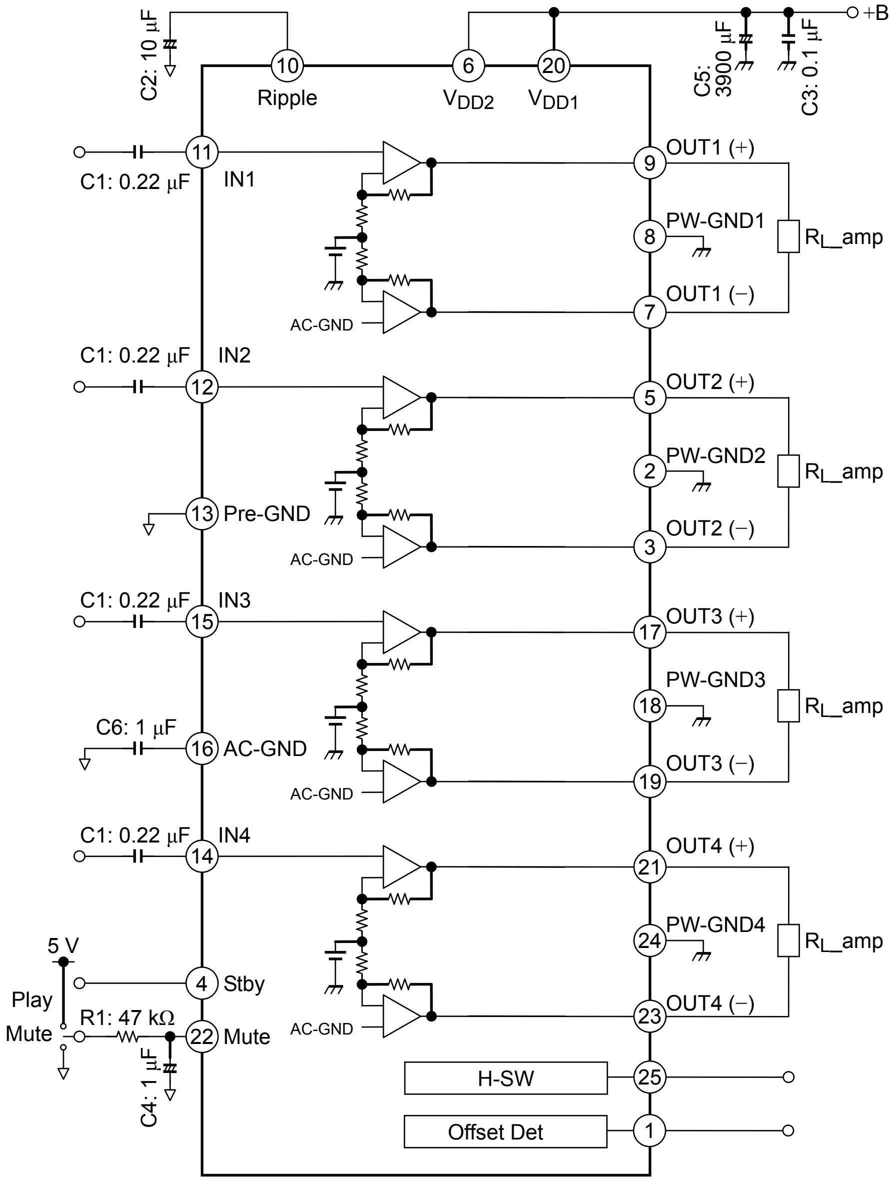
Test condition	Typ.	Unit
Output power (P_{OUT})		
V_{DD} = 15.2 V, max power	49	W
V_{DD} = 14.4 V, max power	44	W
V_{DD} = 14.4V, THD = 10%	29	W
THD =10%	24	W
Total harmonic distortion (THD)		
P_{OUT} = 4 W	0.006	%
Output noise voltage (V_{NO}) (Rg = 0 Ω)		
Filter: A weighted	45	μV
Operating Supply voltage range (V_{DD})		
R_{L_amp} = 4 Ω	6 to 18	V
R_{L_amp} = 2 Ω	6 to 16	V

Note 1:

Typical test conditions: Unless otherwise specified, V_{DD} = 13.2 V, f = 1 kHz, R_{L_amp} = 4 Ω, and Ta = 25°C

Rg: Signal source resistance

4. Block Digaram



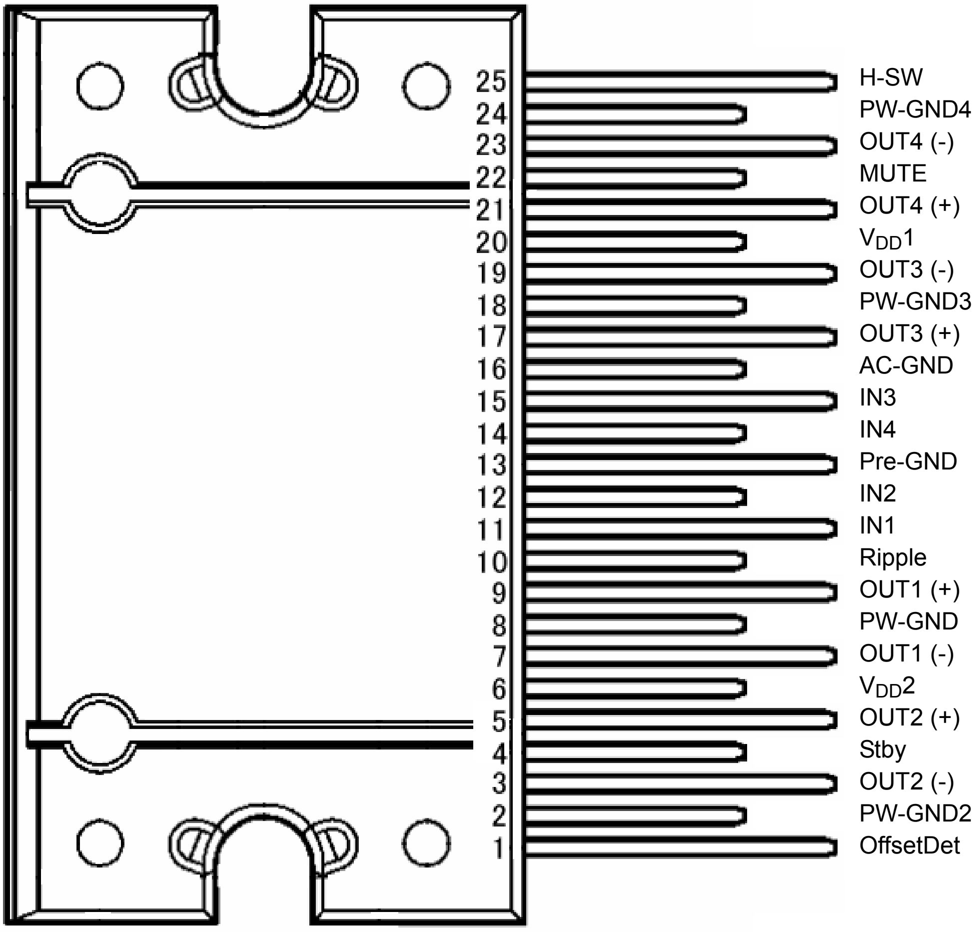
Some of the functional blocks, circuits or constants labels in the block diagram may have been omitted or simplified for clarity.

In the following explanation, a "channel" is a circuit which consists of INx, OUTx (+), OUTx (-),

and PW-GNDx. (x: 1 to 4)

5. Pin Configuration

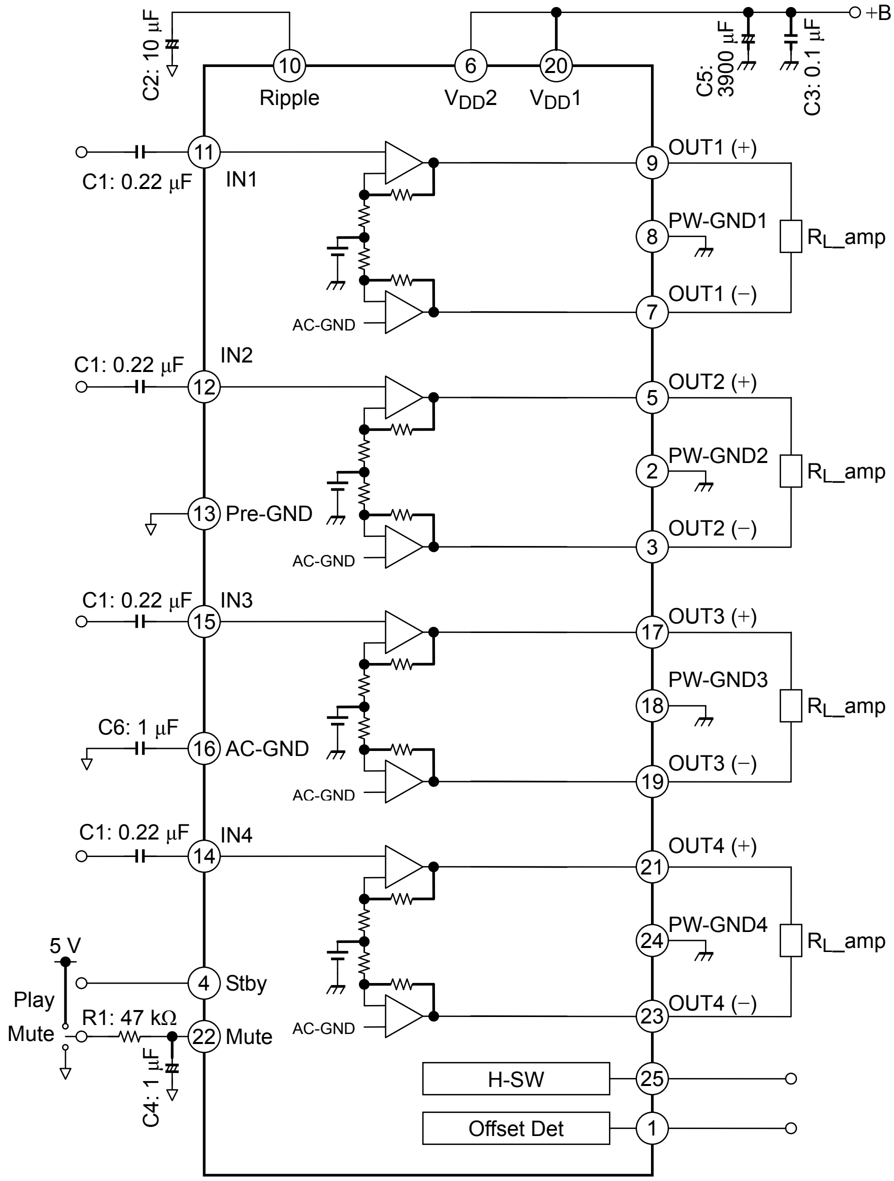
5.1 Pin configuration (top view)



5.2 Pin Description

Pin	Symbol	I/O	Description
1	Offset Det	V_{od}-OUT	Output offset/short voltage detector output
2	PW-GND2	—	Ground for OUT2
3	OUT2(-)	OUT	OUT2(-) output
4	Stby	V_{ST}-IN	Stand-by voltage input
5	OUT2(+)	OUT	OUT2(+) output
6	V_{DD}2	V_{DD}-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_{DD}1	V_{DD}-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	H-SW	HSW	High-side switch output

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	V_{DD1}, V_{DD2}	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	V_{DD1}, V_{DD2}	Ripple filter	Filter for power supply humming and ripple	
R1	47kΩ	Mute	Mute ON/OFF Smooth switching	Pop noise becomes larger	Switching time becomes longer
C4	1μF				

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 about 0.01 μA (typ.) in the standby state.

Table 2 Standby Control Voltage (V_{SB}): Pin 4

Stand-by	Power	V_{SB} (V)
ON	OFF	0 to 0.8
OFF	ON	2.2 to V_{DD}

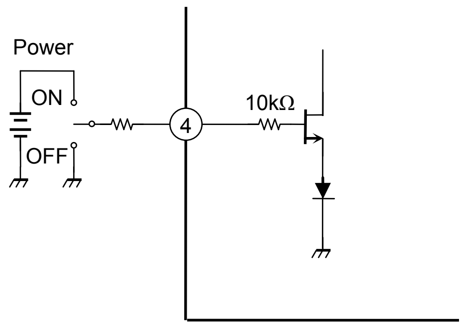


Figure 1 Internal circuit for standby

Benefits of the Standby Switch

(1) V_{DD} 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.

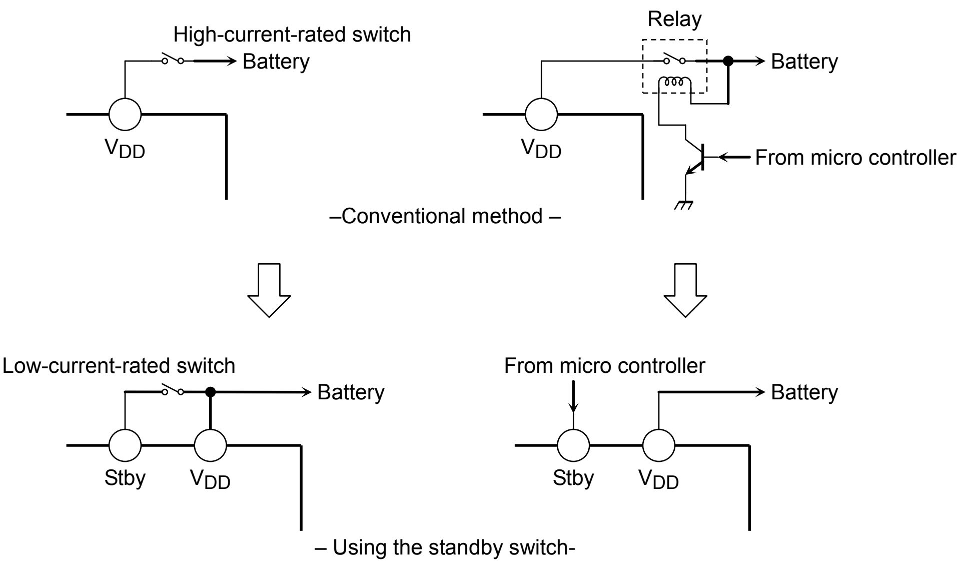


Figure 2 Standby switch

8. Mute Function (Pin 22)

The audio mute function is enabled by setting pin 22 Low. R1 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 3 and 4.)

The values of external elements (R1, C4) of this pin have decided them based on 5V control. In case that it is controlled by other than 5V, please reexamine the value of the external pull-up resistor as follows;

For example:

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

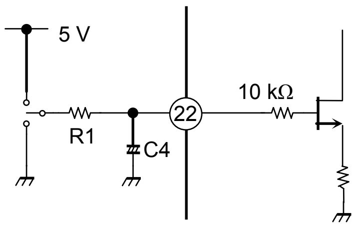


Figure 3 Mute Function

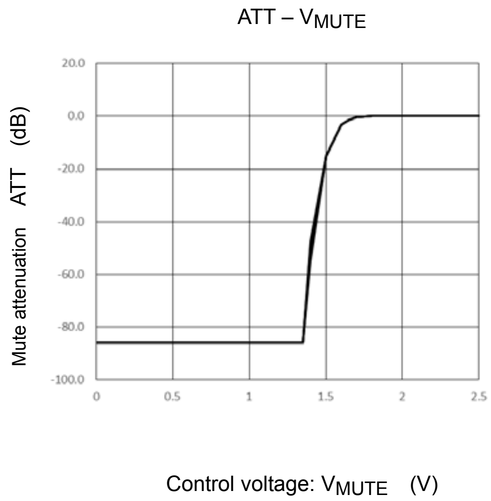


Figure 4 Mute attenuation − V_{MUTE} (V)

9. Auto Muting Functions

The TCB501HQ has two automatic mute functions.

a) Low V_{DD} Mute (Automatic mute function)

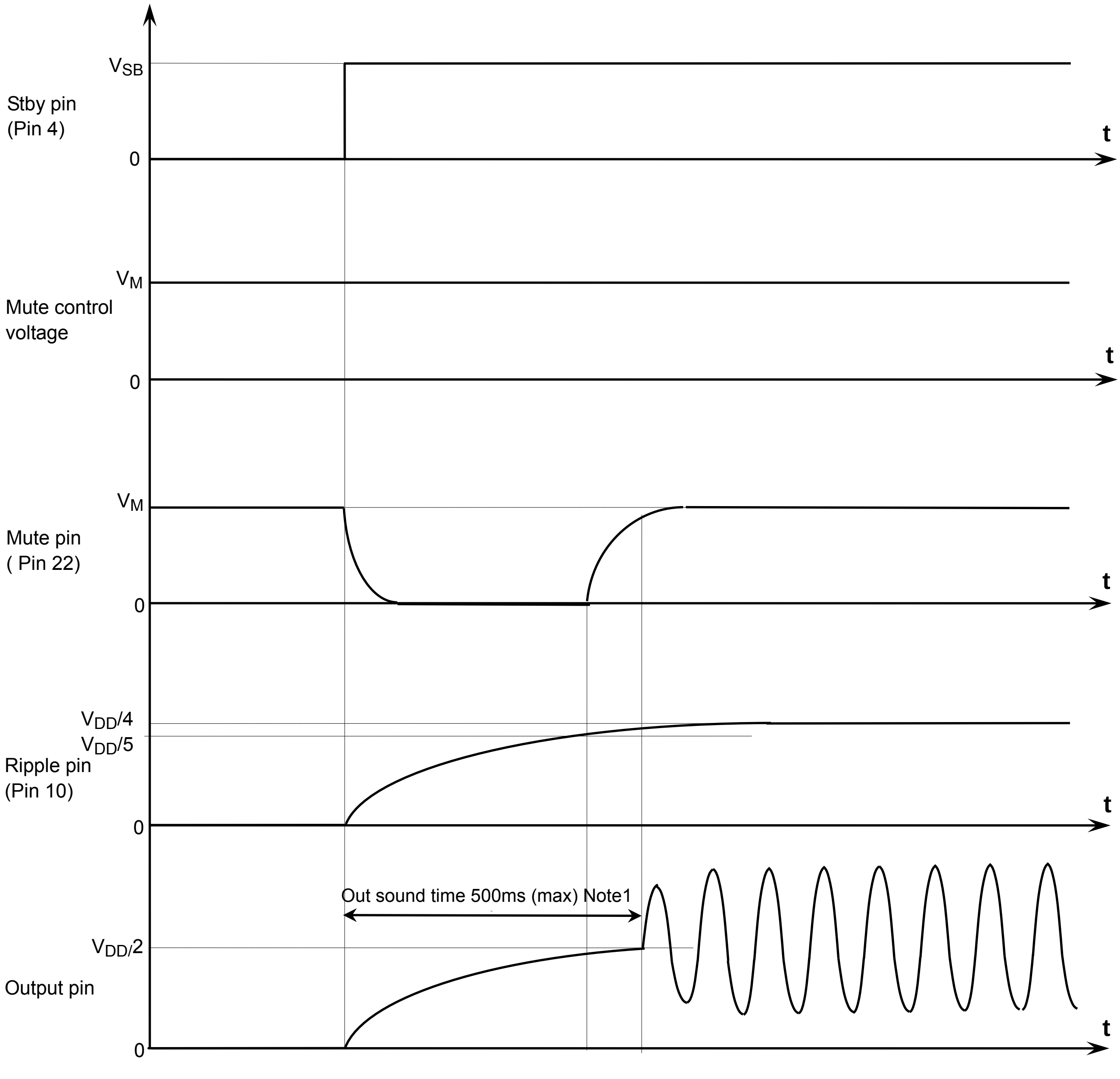
b) Standby Off Mute.

9.1 Low V_{DD} Mute

When the supply voltage became lower than 5.5V (typ.), The TCB501HQ operates the mute circuit automatically. This function prevents the large audible transient noise which is generated by low V_{DD}.

9.2 Standby-Off Mute

The TCB501HQ operates the mute circuit during the standby-off transition. When the ripple voltage reached $V_{DD}/5$, the standby-off mute is terminated. Additionally, in the standby-off transition, it is recommended that the external mute has to be ON till the internal mute-OFF, and that the timing of the external mute-OFF has to be set after the internal mute-OFF.



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

9.3 Mute-off after standby-off

The pop noise is generated when the capacitor of ripple, input, and ACGND has not finished to charge fully.
Please set "Mute-off" that it is sufficient margin in considering an enough charge time after the middle point potential stable.

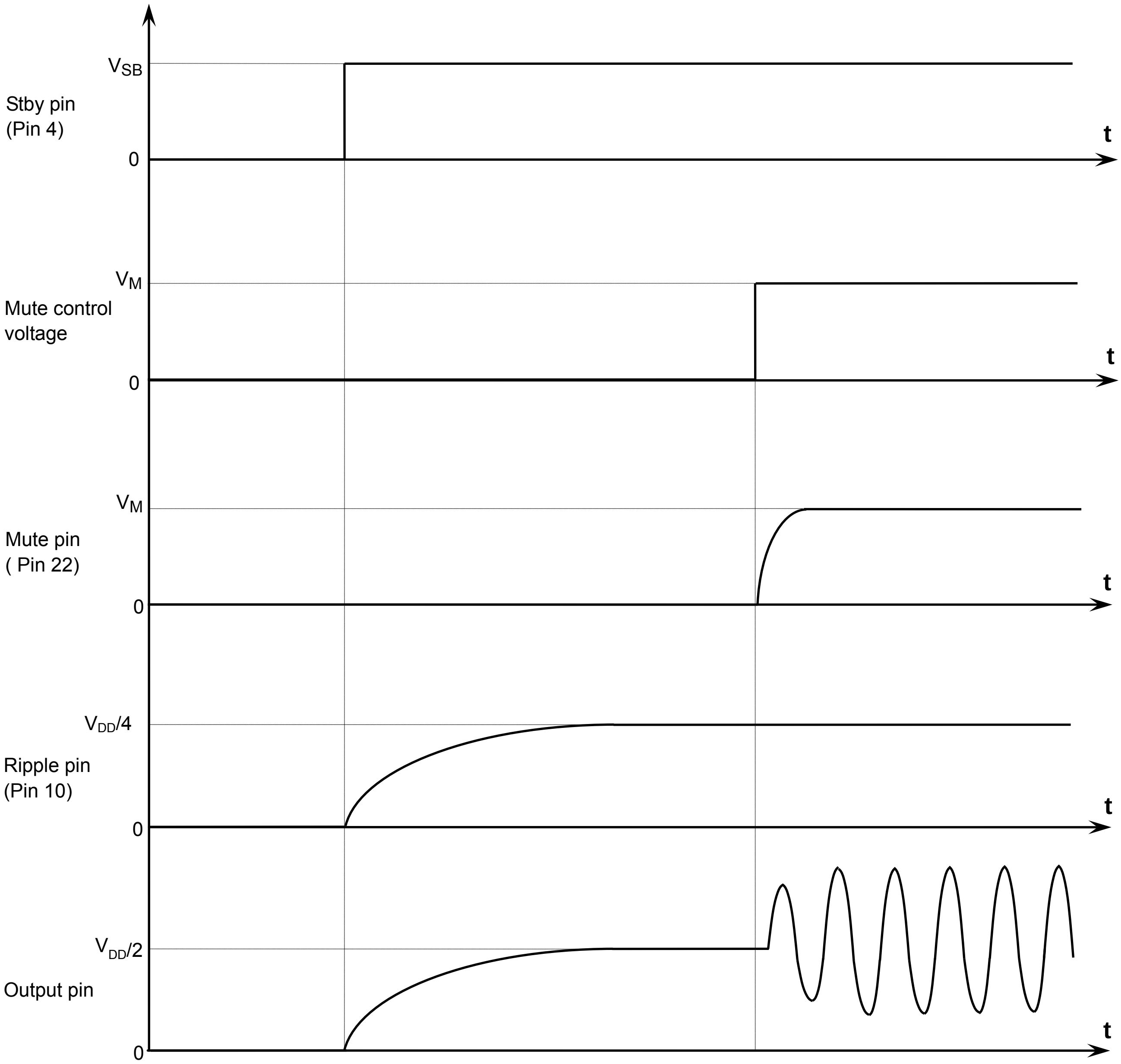


Figure 5 Mute-off transition after standby-off

10. High-side Switch

The Q1 (high-side switch) is always turned on during Power-ON.

The high-side switch can be used for many application circuits related to Power-ON. This output incorporates the backflow prevention structure.

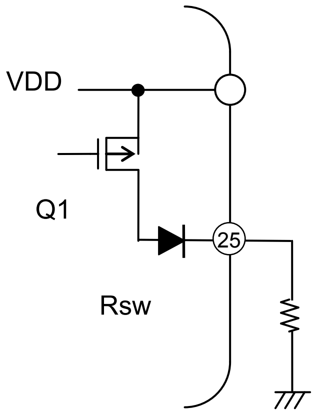


Figure 6 High-side switch

11. Output DC Offset Detection

This function detects the offset voltage between OUT (+) and OUT (-). The detection result is gotten by pin1. When the offset voltage appeared by the external parts accident, for example the leak of coupling capacitor, this function can contribute to a part of safety system to prevent the speaker damage.

The example flowchart: The safety system to prevent damaging to speakers by abnormal offset.

(a) Offset detection ⇨ (b) Judgment Normal / Abnormal ⇨ (c) To reduce the speaker stress 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.

11.1 Operation description of output offset pin

The result of output offset voltage detection of Pin1 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.

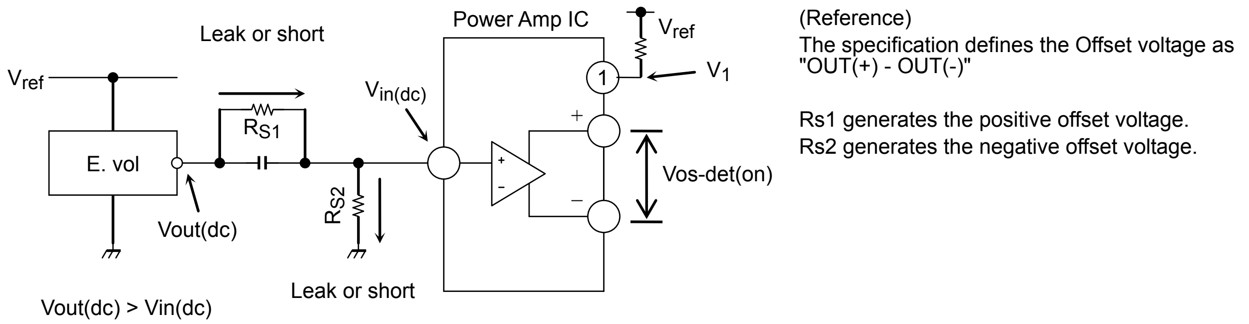


Figure 7 Generating example of abnormal output offset voltage

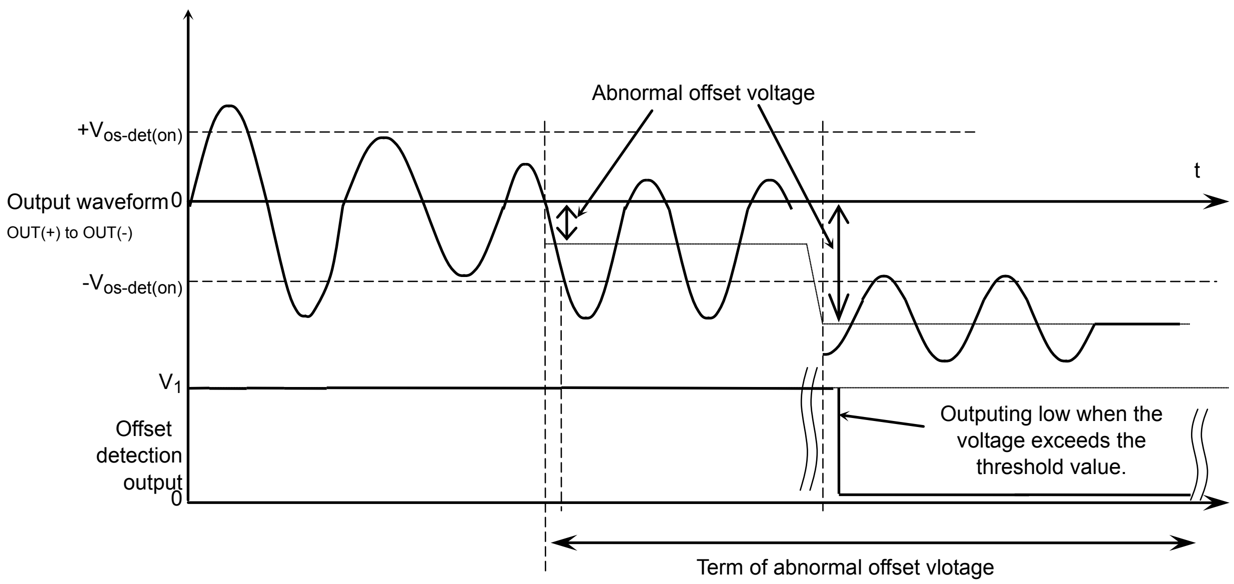


Figure 8 Output waveform of amplifier and pin 1

12. Low voltage operation

The TCB501HQ applies the amplifier circuit to reduce the audible pop noise and sound cutting due to low V_{DD} voltage.

12.1 Operation description

When the headroom voltage is suppressed by the low V_{DD}, the TCB501HQ switches output middle point potential from $V_{DD}/2$ to $V_{DD}/4$ and reduces the audible pop noise and the sound cutting. The behavior of outputs (Vout) and ripple (Vrip) is showed the figure 9 below.

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

Each of threshold voltage is below.

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

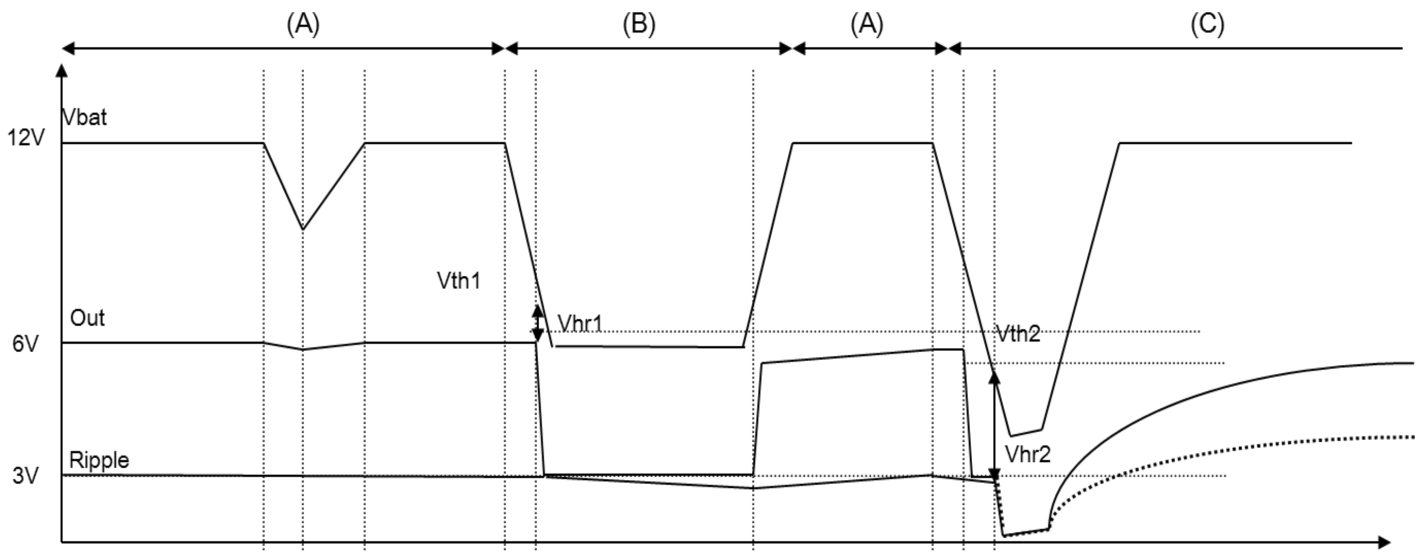


Figure 9 Output $V_{DD}/2$ voltage in lowering V_{DD}

13. Protection Functions

This product has internal protection circuits such as thermal shut down, over-voltage, short to V_{DD}, short to GND, and out to out 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 though all outputs are in a mute state.

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

(2) Over-voltage

It operates when voltage exceeding operating range is supplied to V_{DD} pin. If voltage falls, it will return to normal operation automatically. When it operates, all outputs bias and high-side switch are turned off and all outputs are shut-off. Threshold voltage is 21.5 V(typ.)

(3) Short to V_{DD}, 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 (Safe Operation Area) of power transistor (DMOS). When it operates, all outputs bias circuits are turned off and all outputs are shut-off. If irregular connection is canceled, it will return to normal operation automatically.

14. Absolute Maximum Ratings

(Ta = 25°C unless otherwise specified)

Characteristics		Symbol	Rating	Unit	Condition
Supply voltage (surge)		$V_{DD\ (surge)}$	50	V	Max 0.2 s.
Supply voltage (DC)		$V_{DD\ (DC)}$	25	V	Max voltage applied for 1 min.
Output current of amplifier (surge)		Io(Peak)	9	A	
Power dissipation		P_D	125	W	Note 4
Junction temperature		Tj	150	°C	Note 5
Operating temperature range		Topr	-40 to 85	°C	
Storage temperature		Tstg	-55 to 150	°C	
Voltage difference between pins	$V_{DD}1$ to $V_{DD}2$	dV1-2	±0.3	V	Permissive voltage difference between $V_{DD}1$ and $V_{DD}2$
	Pre-GND to PW-GND	dV_Gnd	±0.3	V	Permissive voltage difference between Pre-GND and PW-GND
Voltage of input pin	V_{DD}	$V_{DD}1,2$	6 to 18	V	RL=4Ω
	Stby	Stby	GND-0.3 to V_{DD}+0.3	V	
	Mute	Mute	GND-0.3 to V_{DD}+0.3	V	
	IN	In1,2,3,4	GND-0.3 to V_{DD}+0.3	V	
	ACGND	ACG	GND-0.3 to V_{DD}+0.3	V	
	Ripple	Rip	GND-0.3 to V_{DD}+0.3	V	
	Diag	Diag	GND-0.3 to V_{DD}+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.

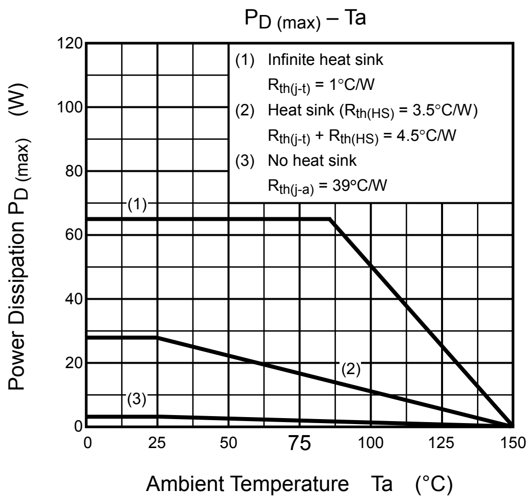
If any of these rating would be exceeded during operation, the device electrical characteristics may be irreparably altered and the reliability and lifetime of the device can no longer be guaranteed. Moreover, these operations with exceeded ratings may cause break down, damage, and/or degradation to 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 4: Package thermal resistance $R_{th(j-t)}$ = 1°C/W (typ.) (Ta = 25°C, with infinite heat sink)

Note 5: 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.

15. Power dissipation



16. Operating Range

Characteristics	Symbol	Condition	Min	Typ.	Max	Unit
Supply voltage	V_{DD}	R_L=4Ω	6	—	18	V
		R_L=2Ω	6	—	16	V

17. Electrical Characteristics

17.1 Amplifier

(Unless otherwise specified, V_{DD}=13.2V, f=1kHz, , RL_amp=4Ω, RL_sw=39Ω, Vsb/Vm=5V, Ta=25°C)

( ): The guaranteed value by design

Characteristics	Symbol	Test Condition	Min	Typ.	Max	Unit
Quiescent supply current	I_Q	V_{IN} = 0V	100	180	320	mA
Output power	P_{OUT} MAX (1)	V_{DD} = 15.2 V, max POWER	―	49	―	W
	P_{OUT} MAX (2)	V_{DD} = 14.4 V, max POWER	―	44	―	
	P_{OUT} (1)	V_{DD} = 14.4 V, THD = 10%	27	29	―	
	P_{OUT} (2)	THD = 10%	21	24	―	
Output power(R_L=2Ω)	P_{OUT} MAX (3)	V_{DD} = 14.4 V, max POWER	―	80	―	W
	P_{OUT} (3)	V_{DD} = 14.4 V, THD = 10%	―	46	―	
	P_{OUT} (4)	THD = 10%	―	45	―	
Total harmonic distortion	THD	P_{OUT} = 5 W	―	0.006	0.07	%
Voltage gain	G_V	V_{OUT} = 0.775 Vrms	25	26	27	dB
Channel-to-channel voltage gain	ΔG_V	V_{OUT} = 0.775 Vrms	−1.0	0	1.0	dB
Output noise voltage	V_{NO}	Rg = 0 Ω, DIN Audio	―	45	80	μV
Ripple rejection ratio	R.R.	f_{rip} = 100 Hz, R_g = 620 Ω V_{rip} = 0.775 Vrms	50	70	―	dB
Crosstalk	C.T.	R_g = 620 Ω P_{OUT} = 4 W	―	80	―	dB
Output offset voltage	V_{OFFSET}	―	−70	0	70	mV
Input resistance	R_{IN}	―	―	100	―	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_{DD}	V
	V_{SB} L	POWER: OFF	0	―	0.8	
Mute control voltage	V_M H	MUTE: OFF	2.2	―	V_{DD}	V
	V_M L	MUTE: ON, R_1 = 47 kΩ	0	―	0.8	
Mute attenuation	ATT M	MUTE: ON, DIN Audio V_{OUT} = 7.75 Vrms → Mute: OFF	85	100	―	dB

17.2 High-side switch

(Unless otherwise specified, V_{DD}=13.2V, f=1kHz, RL_amp=4Ω, RL_sw=39Ω, Vsb/Vm=5V, Ta=25°C)

( ): The guaranteed value by design

Characteristics	Symbol	Test condition	Min	Typ.	Max	Unit
Over Current limits	Iprot	Vo = 12.6V	400	600	800	mA
I/O voltage diffirence	dVo	Vsb=5V	—	0.45	(0.8)	V
Delay time (ON)	Tdon	Vo_sw ≥V_{DD}×0.95	—	0.01	(1)	ms
Delay time (OFF)	Tdoff	Vo_sw ≤V_{DD}×0.05	—	0.2	(1)	ms
Switch off voltage	Vo_sw(L)	Vsb=0V, RL_sw=10kΩ	0	0.01	0.1	V
Peak protection current	Ihsw	V_{DD}=0V, (HSW=VDD-Δvo)	—	—	200	μA
Lower limit of output	VHSWL	V_{DD}=4.5V, IOUT=0 to 100mA	3	—	—	V

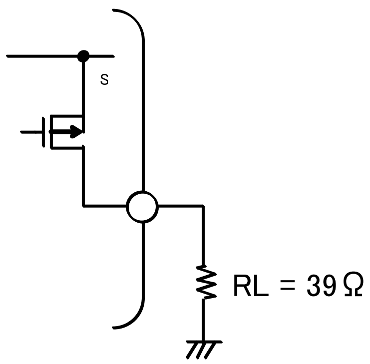


Figure 10 High-side switch measurement circuit

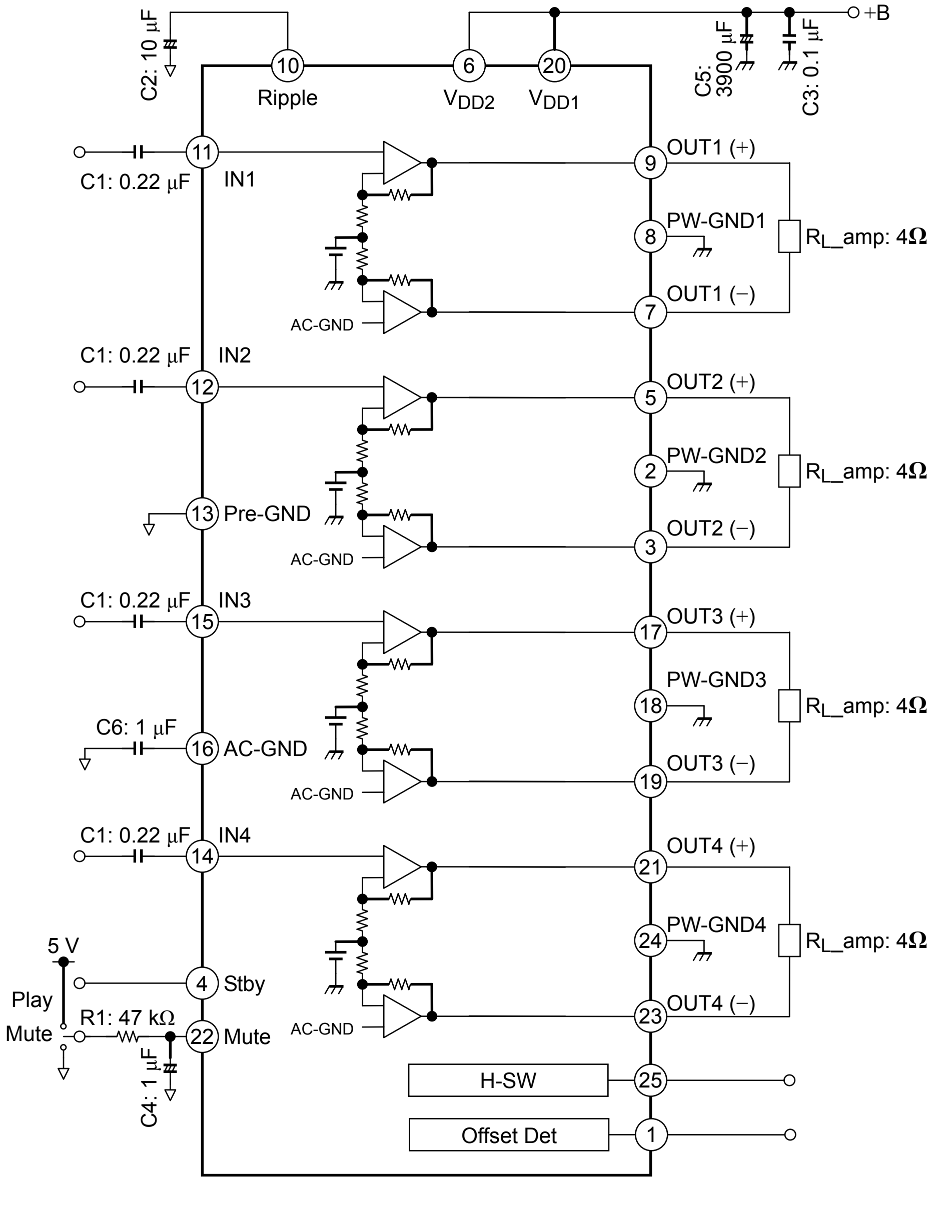
17.3 Output offset voltage detection

(Unless otherwise specified, V_{DD}=13.2V, f=1kHz, RL_amp=4Ω, Rpull-up=10kΩ, Vsb/Vref=5V, and Ta=25°C)

( ): The guaranteed value by design

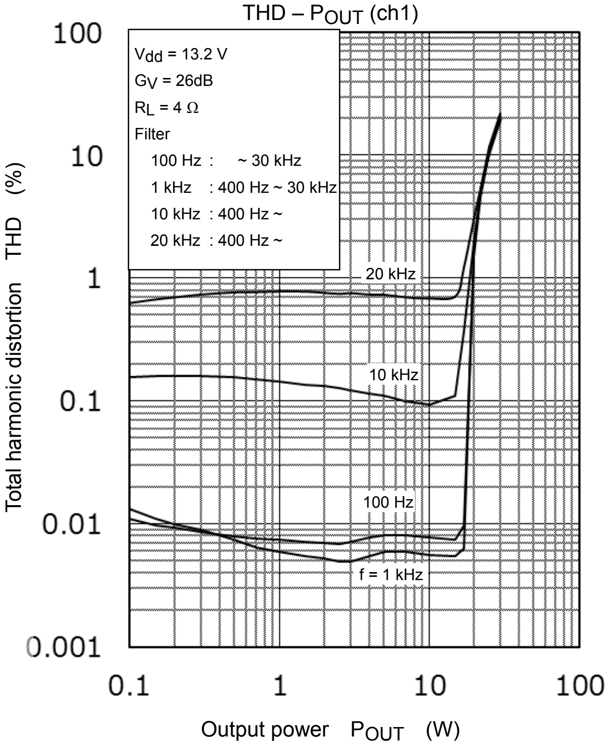
Characteristics	Symbol	Test condition	Min	Typ.	Max	Unit
Supply voltage for detection of output offset	V_{DD}_offset1	Vsb=5V, Vref=5V	6	—	18	V
Detection voltage for output offset	Vos1-det(on)	Vsb=5V, Vo(+)-Vo(-)	±1.0	±1.5	±2.0	V
Saturated voltage in detection	P1-sat	Rpull-up=10kΩ, Vref=5.0V In detection (Pin: Low)	—	100	500	mV
Detection time for output offset	Dtime	Quiescent	—	300	500	ms

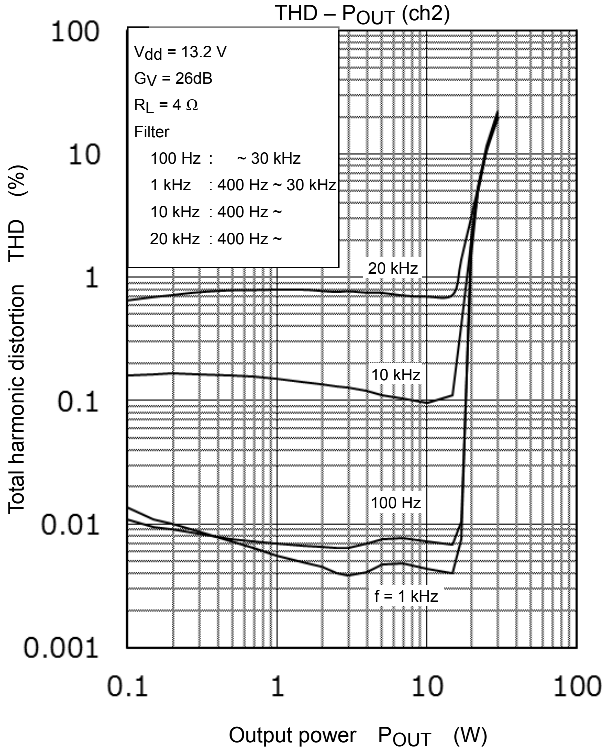
18. Test circuit

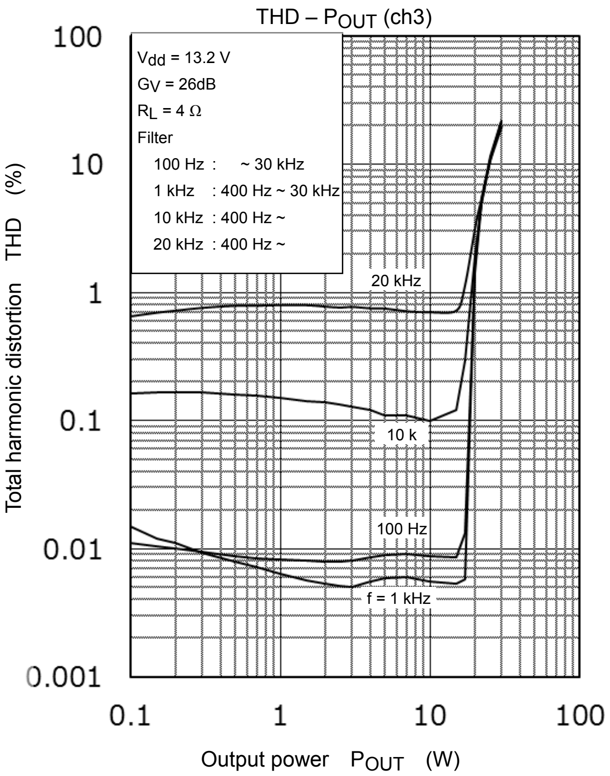


19. Characteristic Chart

19.1 Total Harmonic Distortion vs. Output Power







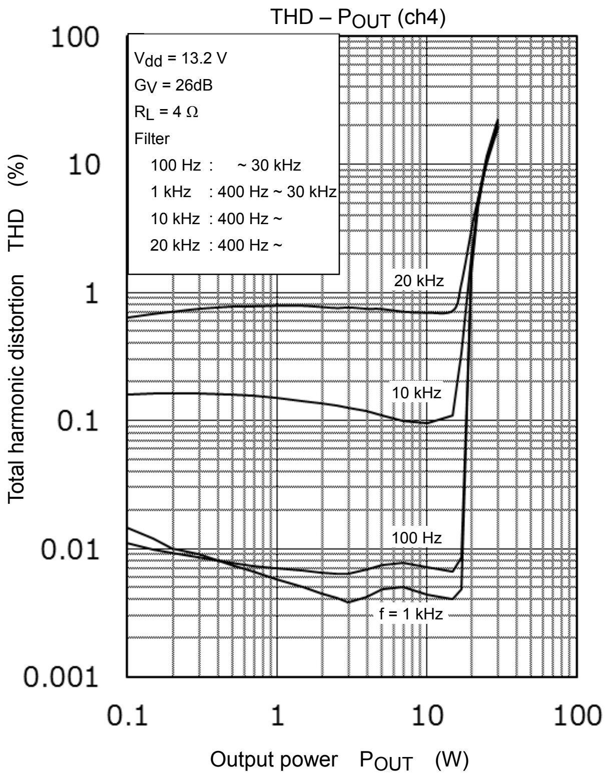


Fig. 11-1 Total Harmonic Distortion of Each Frequency (R_L=4Ω)

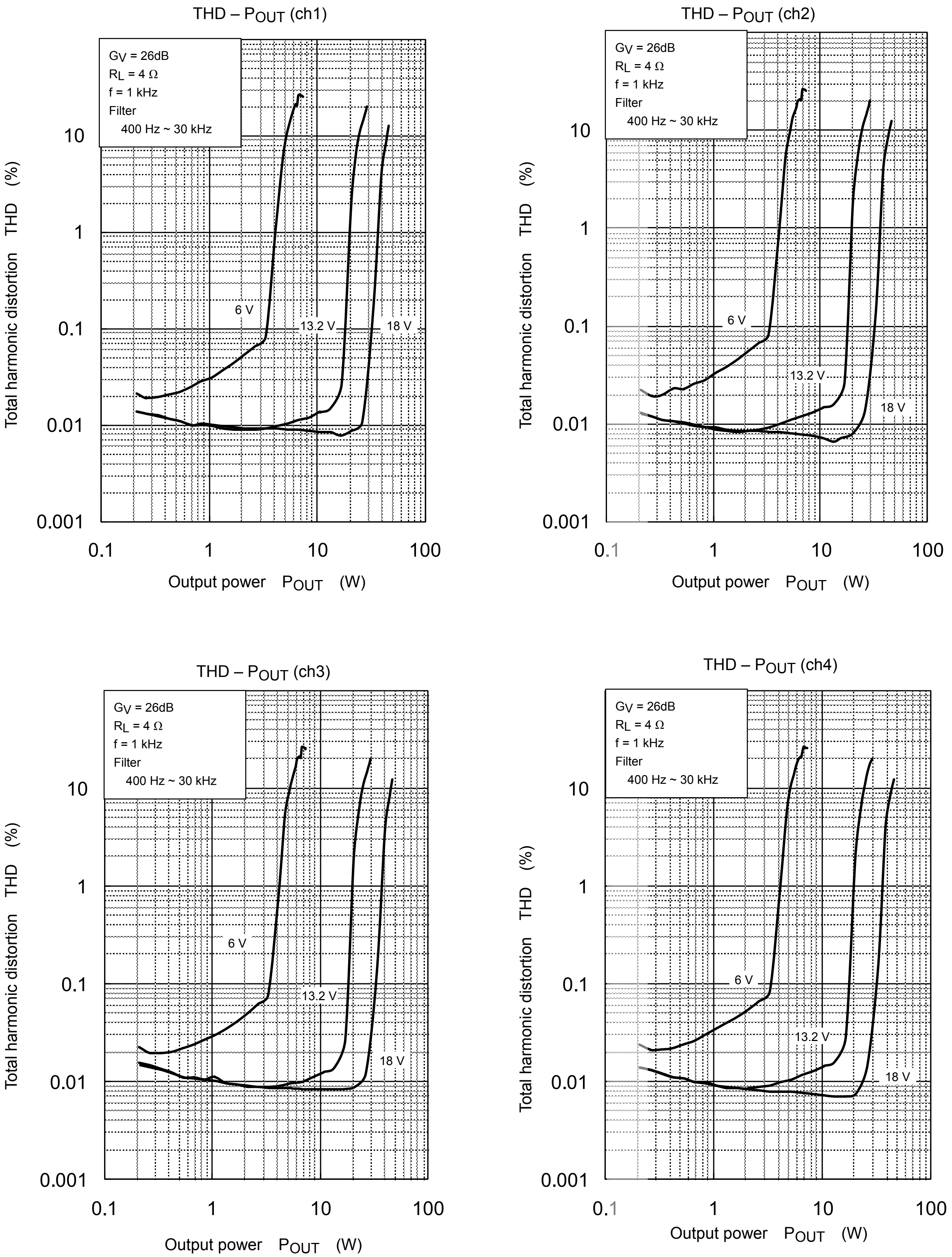


Fig.11-2 Total Harmonic Distortion by Power-supply Voltage (R_L=4Ω)

19.2 Various Frequency Characteristics

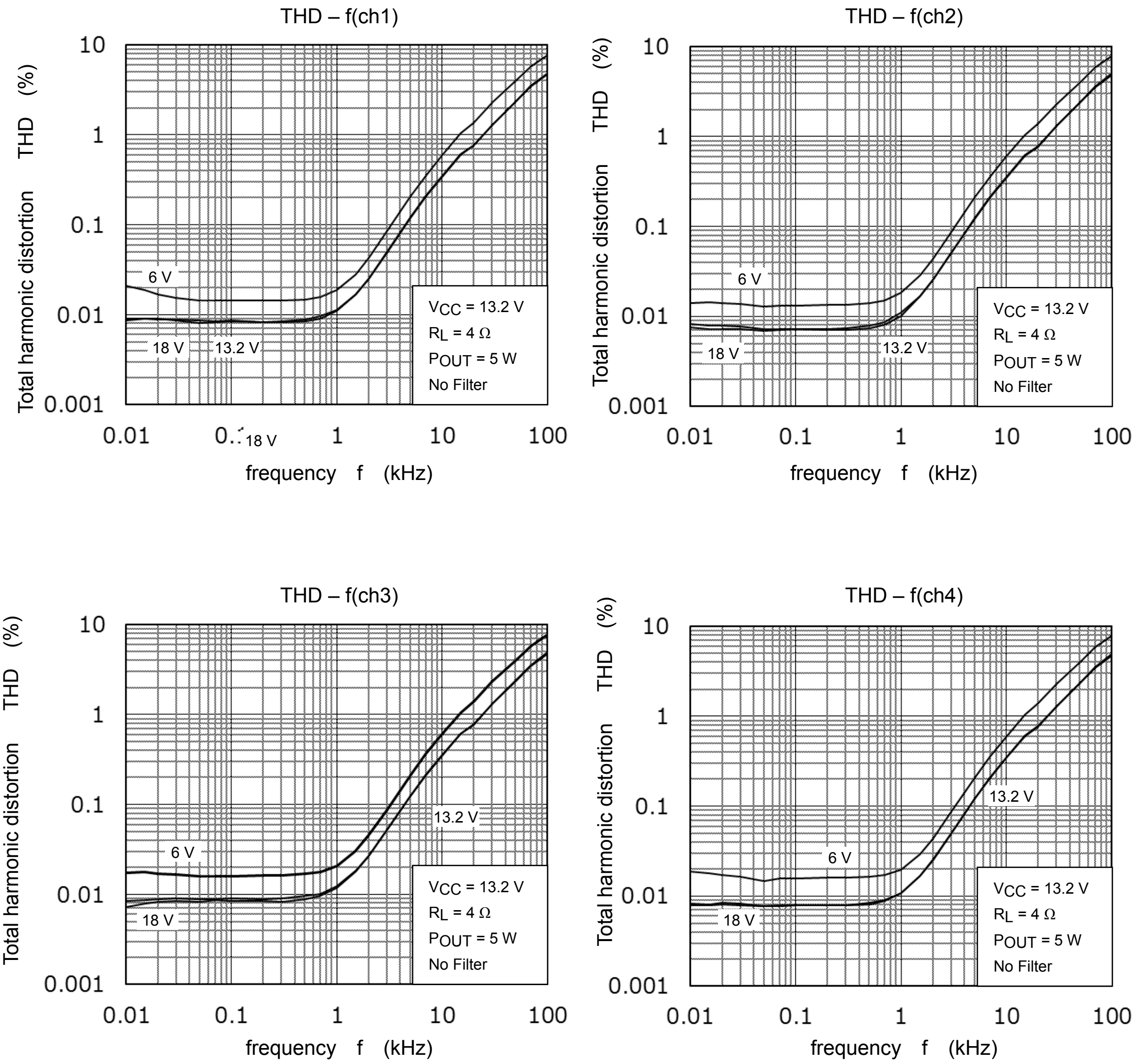
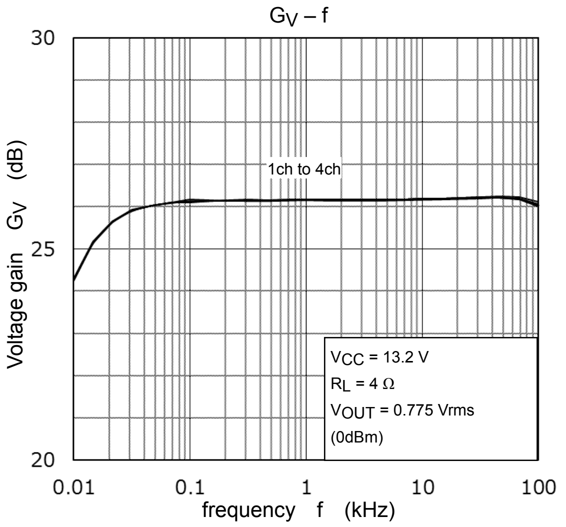


Fig.11-3 Frequency Characteristics of Total Harmonic Distortion



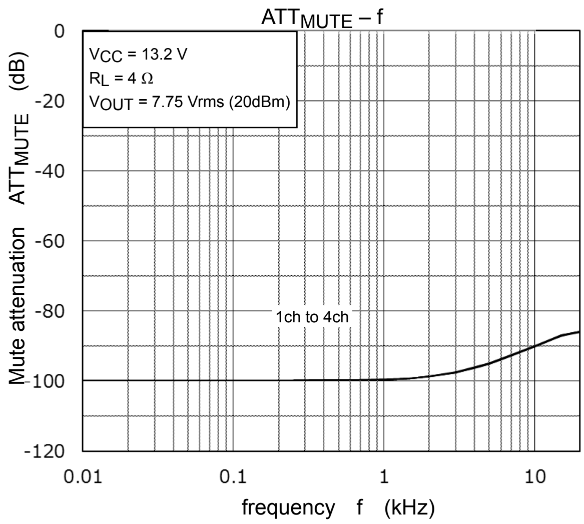


Fig. 11-4 Frequency Characteristics of Voltage Gain and Mute Attenuation

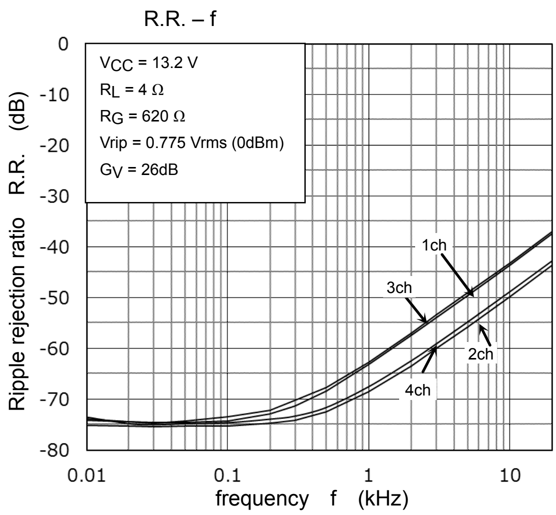


Fig. 11-5 Frequency Characteristics of Ripple Rejection Rate

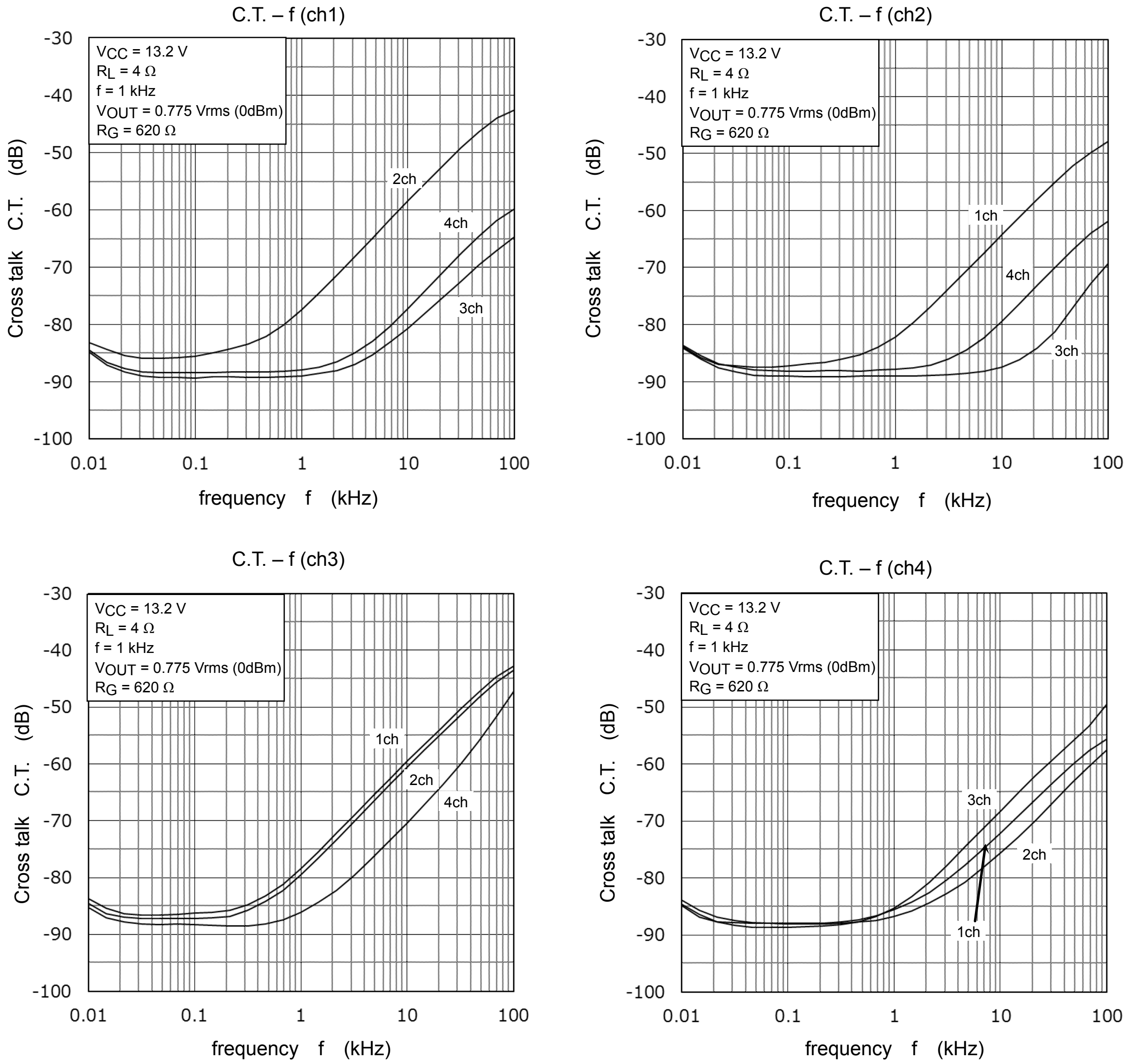
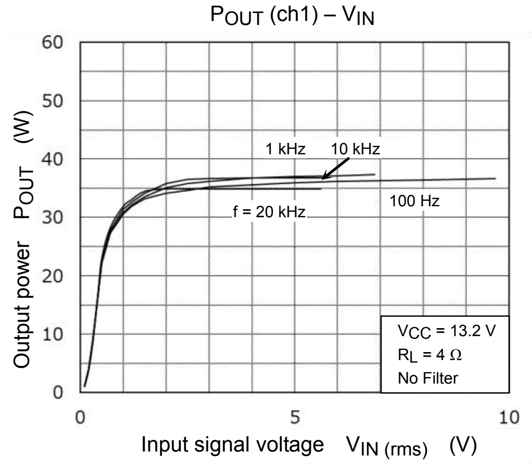
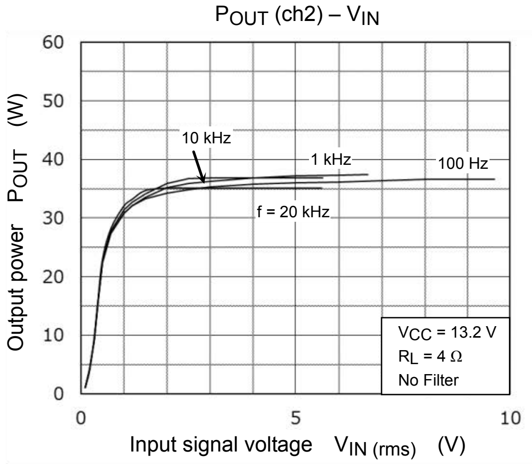
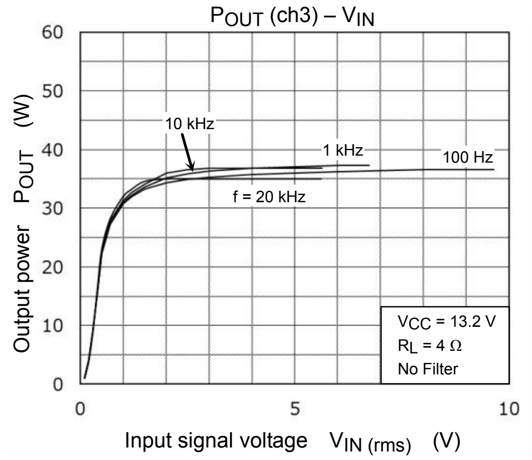


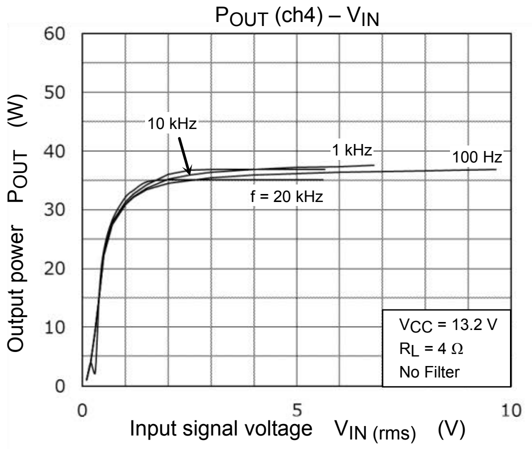
Fig. 11-6 Frequency Characteristics of Cross Talk

19.3 Output Power Characteristics to Input Voltage

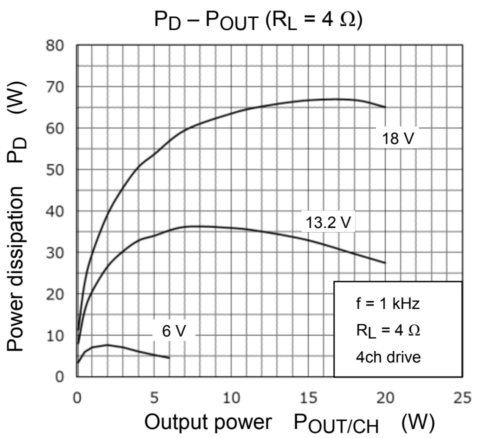




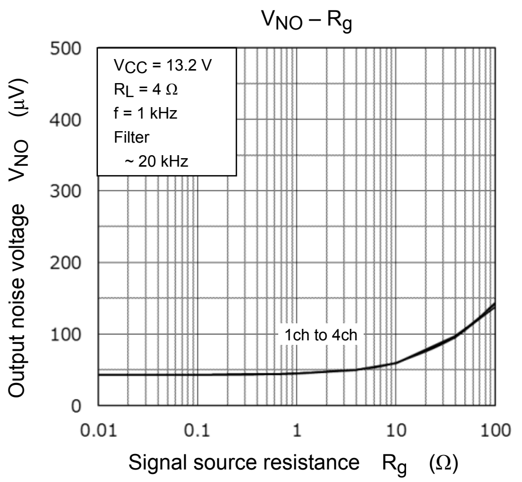


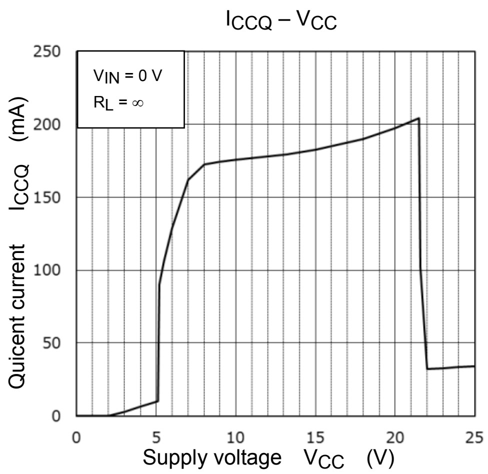


19.4 Power Dissipation vs. Output Power



19.5 Other characteristics

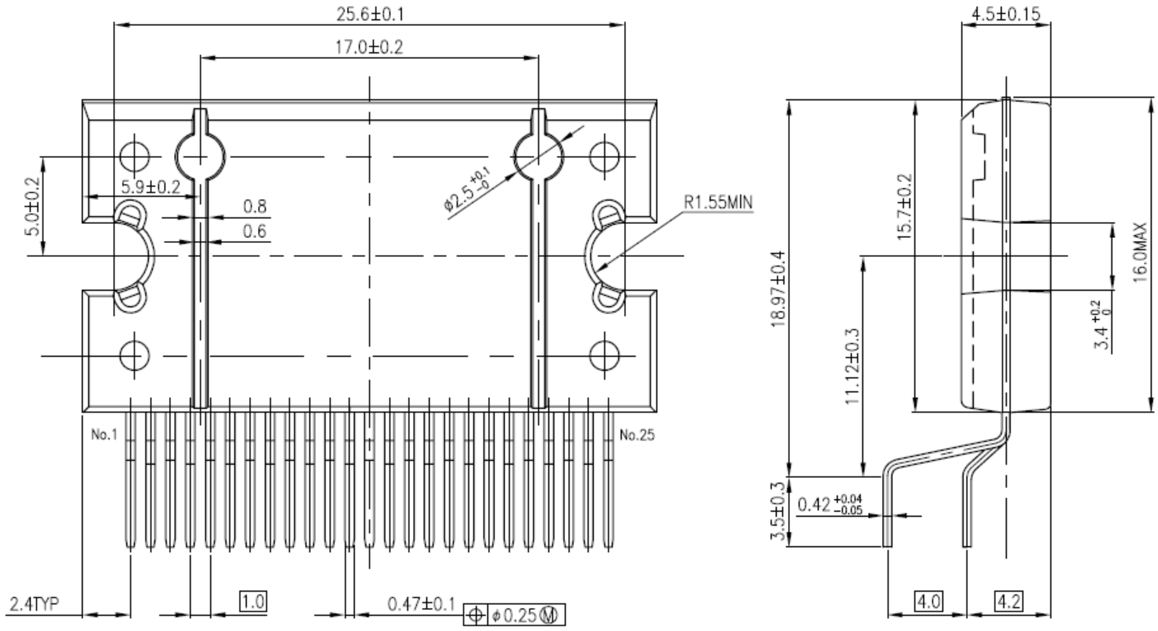


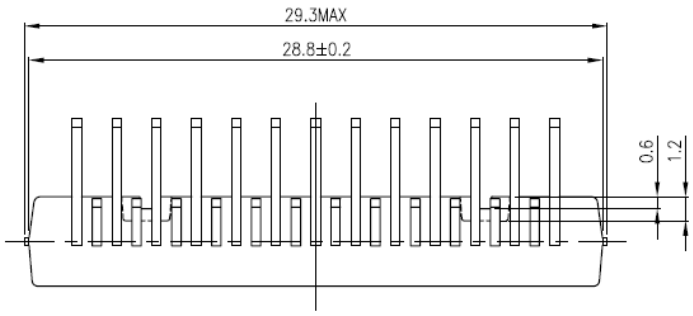


20. Package Dimensions

HZIP25-P-1.00F

Unit: mm





Weight: 7.7 g (typ.)

21. Attention in Use

- 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.
- 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. For details on how to connect a protection circuit such as a current limiting resistor or back electromotive force adsorption diode, refer to individual IC datasheets or the IC databook. 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.
- 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.
- 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.
- 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.
- Heat Radiation Design
  When 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 (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.
- Installation to Heat Sink
  Please install the power IC to the heat sink not to apply excessive mechanical stress to the IC. Excessive mechanical stress can lead to package cracks, resulting in a reduction in reliability or breakdown of internal IC chip. In addition, depending on the IC, the use of silicon rubber may be prohibited. Check whether the use of silicon rubber is prohibited for the IC you intend to use, or not. For details of power IC heat radiation design and heat sink installation, refer to individual technical datasheets or IC databooks.

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