Small-sized Class-D Speaker Amplifiers

Analog Input Monaural Class-D Speaker Amplifier

BD5467GUL

No.10101EAT07

●Description

BD5467GUL is a monaural Class-D speaker amplifier that contained ALC function for mobile phone, portable type electronic devices etc. LC filter of speaker output is not needed, can form monaural speaker amplifier with 3 external parts. ALC, short for Automatic Level Control, is a function that automatically adjusts up to the level of suppression of distortion (clip) of output wave form during excessive input. The time until the limit release operation of output level is called the release time (or recovery time). This IC adopts release time (262ms/1dB Typ.) and suits the applications which play music. Through Class-D operation, efficiency is high low power consumption that is why it's suitable for battery drive application. The current consumption during shutdown when lowered to 0.01μA(Typ.), from the shutdown to the operation time is early and at the same time pop sound is few that is why its also suitable in repeating active and shutdown.

●Feature

1) Contains Digital ALC (Automatic Level Control) Function
2) External Parts : 3points
3) Ultra slim type package : 9pin WL-CSP(1.7×1.7×0.55mmMax.)
4) BD5460/61GUL (No ALC Function, Gain Fixed Goods) Pin Compatible Specs
   BD5465/66/68GUL (ALC Function, Gain Fixed Goods) Pin Compatible Specs
5) Maximum Gain : 13dB(Typ.) [during ALC operation, 13～-2dB@1dB Step]
6) ALC release(recovery) time : 262ms/1dB(Typ.)
7) Limit output power : 0.7W (Typ.) [VDD=4.2V, RL=8Ω, THD+N≦1%]
   : 0.5W (Typ.) [VDD=3.6V, RL=8Ω, THD+N≦1%]
8) Audio Analog Input (corresponds to single-end input / differential input)
9) Output LC filter free
10) Pop noise suppression circuit
11) Shutdown Function (use as mute at the same time) [low shutdown current = 0.01μA (Typ.)]
12) Contains protection circuit: output short, thermal shutdown, under voltage lockout (UVLO)

●Applications

Mobile phone, Portable audio device, PND, DSC, Note-PC etc.

●Absolute Maximum Rating (Ta=+25℃)

Parameter	Symbol	Ratings	Unit
Power Supply Voltage	VDDmax PVDDmax	7.0	V
Power Dissipation	Pd	690※	mW
Storage Temperature Range	Tstg	-55 ～ +150	℃
SDNB Pin Input Range	V_{SDNB}	-0.3～VDD+0.3	V
IN+, IN- Pin Input Range	V_{IN}	-0.3～VDD+0.3	V

※ In case Ta=+25℃ or more, 5.52 mW decrease per 1℃
When mounting Rohm Typical Board 50.0mm×58.0mm (Material : Glass Epoxy)

●Operation Range

Parameter	Symbol	Range	Unit
Temperature	Topr	-40 ～ +85	℃
Power Supply Voltage	VDD PVDD	+2.5 ～ +5.5	V
Common Mode Input Voltage Range	V_{IC}	+0.5 ～ VDD-0.8	V

◎ This product is not designed for protection against radio active rays.

●Electrical Characteristic(Ta=+25℃, VDD=+3.6V, Unless specified otherwise)

Parameter		Symbol	Limits			Unit	Conditions
			Min.	Typ.	Max.		
＜All Device＞							
Circuit current (no signal)		I_{CC}	—	3	6	mA	IC Active, No Load V_{SDNB} =VDD
Circuit current (shutdown)		I_{SDN}	—	0.01	2	μA	IC Shutdown V_{SDNB} =GND
＜Audio Feature＞							
Limit output power		P_O	0.035 ×VDD^2	0.044 ×VDD^2	0.055 ×VDD^2	W	BTL, f=1kHz, R_L=8Ω THD+N≦1% , ∗1
Total harmonic distortion		T_{HD+N}	—	0.2	1	%	BTL, fin=1kHz, R_L=8Ω P_O =0.3W, ∗1
Maximum Gain		G_{MAX}	12	13	14	dB	BTL, ∗1
ALC Limit level		V_{LIM}	1.5 ×VDD	1.68 ×VDD	1.89 ×VDD	Vpp	BTL, ∗1
ALC Release level		V_{REL}	1.19 ×VDD	1.34 ×VDD	1.5 ×VDD	Vpp	BTL, ∗1
Switching frequency		f_{OSC}	150	250	350	kHz	
Start-up time		T_{ON}	0.73	1.02	1.71	msec	
Audio input resistance		Ri	36	55	74	kΩ	Gain=13dB
＜Control Terminal＞							
SDNB terminal Threshold voltage	H	V_{SDNBH}	1.4	—	VDD	V	IC Active
	L	V_{SDNBL}	0	—	0.4	V	IC Shutdown
SDNB terminal Inflow Current	H	I_{SDBNH}	12	24	36	μA	V_{SDNB} =3.6V
	L	I_{SDNBL}	-5	—	5	μA	V_{SDNB} =0V

∗1 Filter bandwidth for measurement：400～30kHz, LC filter for AC measurement：L=22μH / C=1μF, BTL：Voltage between A3,C3

● Shutdown control

Control terminal	Conditions
SDNB	
H	IC operation (active)
L	IC stop (shutdown)

● ALC Parameter

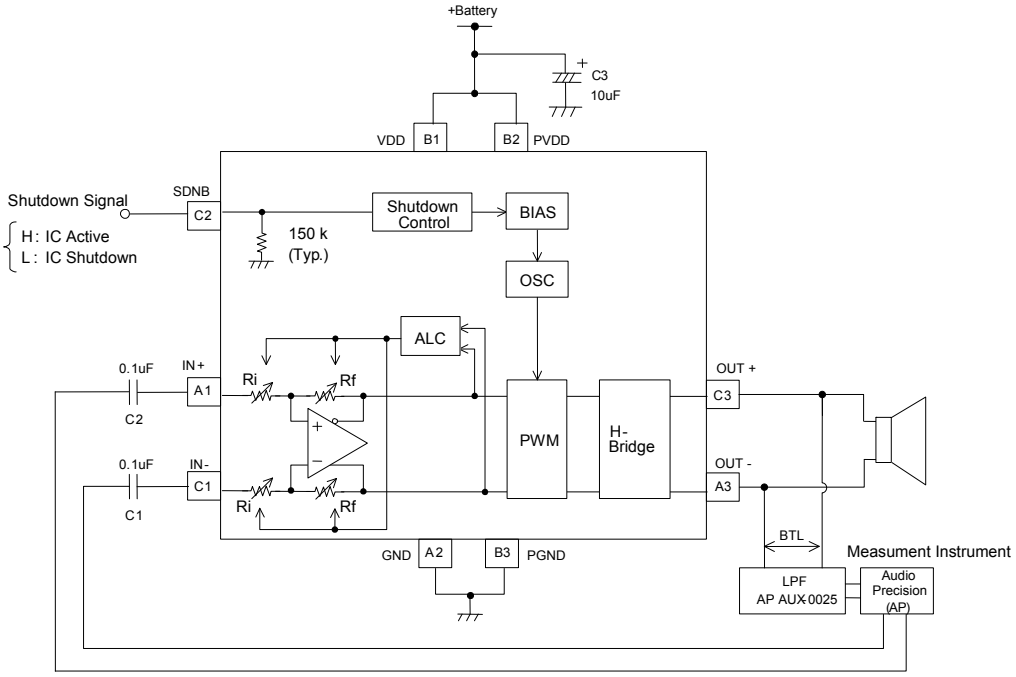
ALC Parameter		
Attack Time (Typ.)	Release Time(Typ.)	Gain Switch Step (Typ.)
～1ms/1dB @ fin=100Hz ～0.5ms/1dB @ fin=1kHz ～0.05ms/1dB @ fin=10kHz	262ms/1dB @ fin=100～10kHz	±1dB

The gain switch timing during ALC operation occurs at zero cross point of audio output voltage.
For that, attack time, release time will change at input frequency “fin”.
ALC Parameter is fixed. ALC operation doesn’t correspond to noise of impulse.

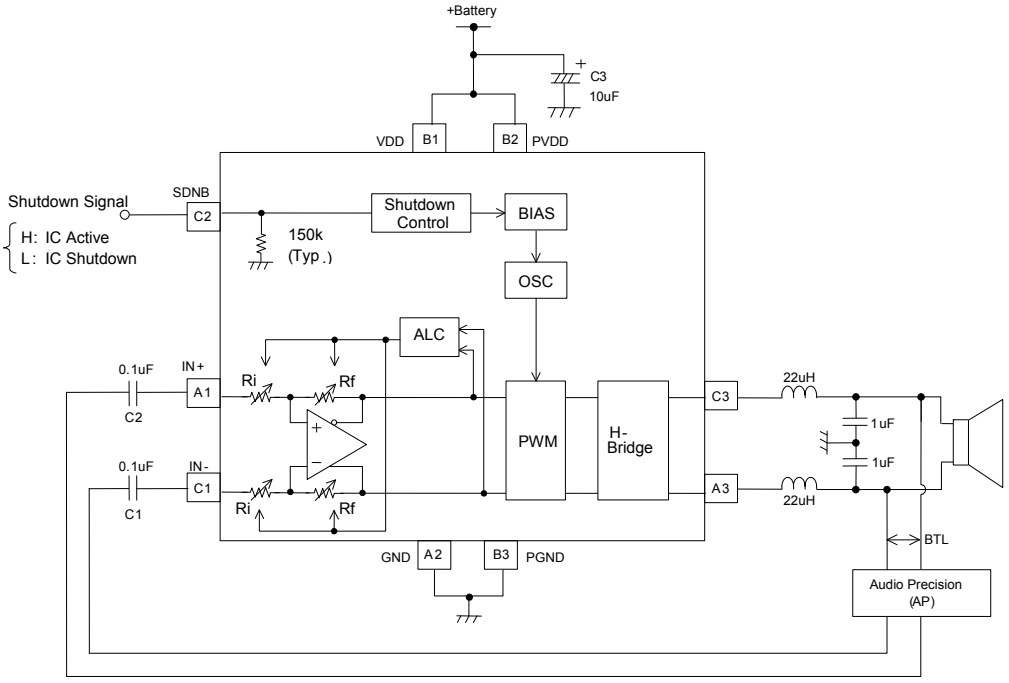
●Measurement Circuit Diagram

<Audio Characteristics Method of Evaluation >

■In case LC filter is not used



■In case LC filter is used



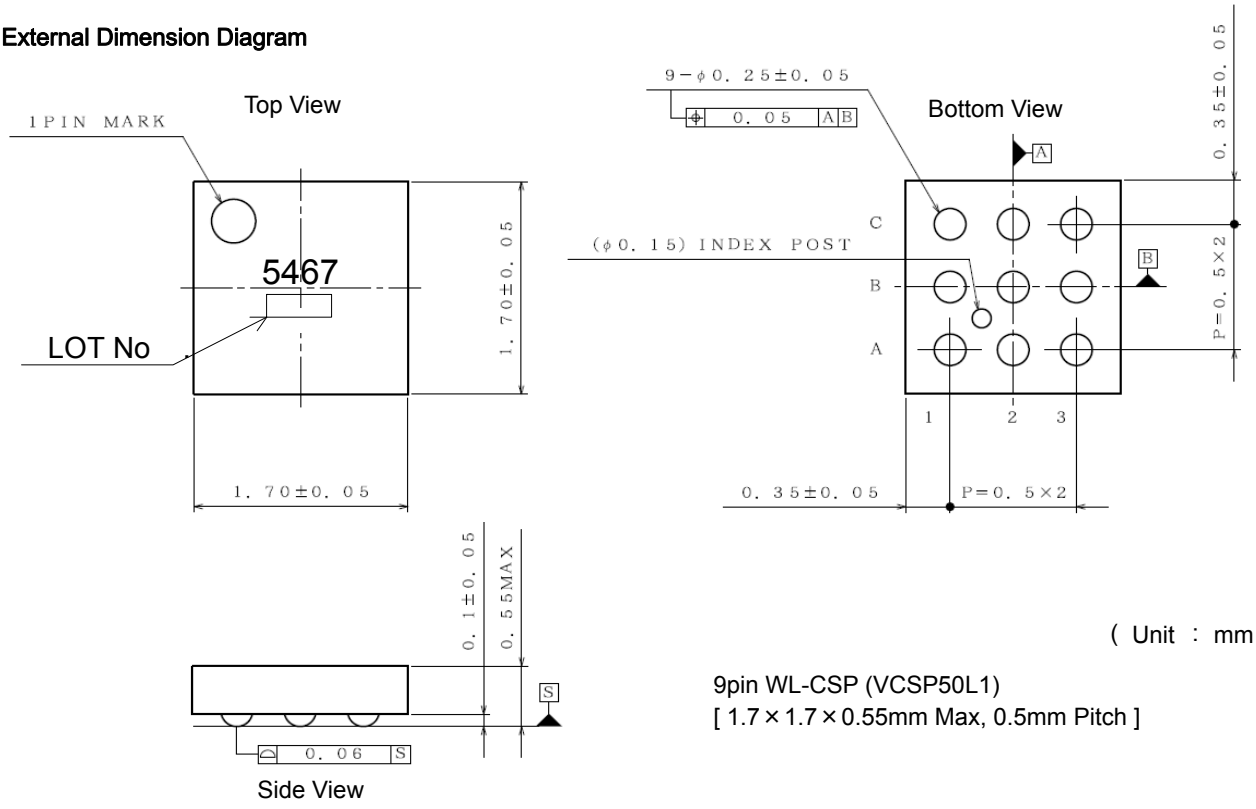
Audio characteristics can be measured to insert LC filter between output pin and speaker load, if you don't have measurement equipment for switching amplifier, like AUX-0025, Audio Precision.
Arrange the LC filter directly close to output pin.

In case of L=22μH, C=1μF, cut off frequency becomes:

$$fc = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{22\mu H \times 1\mu F}} \cong 34kHz$$

For Inductor L, please use huge current type. (Reference)TDK: SLF12575T-220M4R0

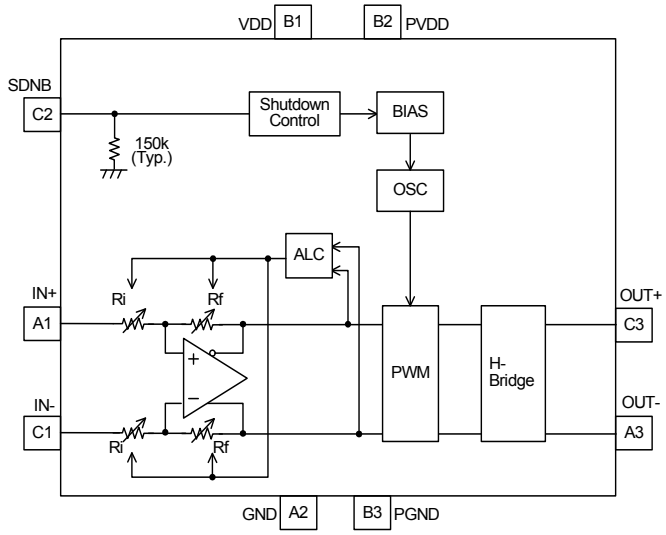
●External Dimension Diagram



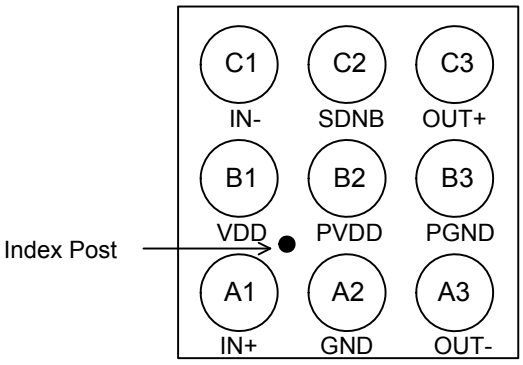
(Unit : mm)

9pin WL-CSP (VCSP50L1)
[1.7 × 1.7 × 0.55mm Max, 0.5mm Pitch]

●Block Diagram



●Pin Arrangement (Bottom View)



●Pin Explanation

Pin No.	Pin Name	Explanation
A1	IN+	Audio differential input+ terminal
A2	GND	GND terminal (signal)
A3	OUT-	Class-D BTL output - terminal
B1	VDD	VDD terminal (signal)
B2	PVDD	VDD terminal (power)
B3	PGND	GND terminal (power)
C1	IN-	Audio differential input - terminal
C2	SDNB	Shutdown control terminal
C3	OUT+	Class-D BTL output+ terminal

●Application circuit example

SHORT the power supply pin VDD (B1), PVDD (B2) at board pattern, then use singleness power supply.

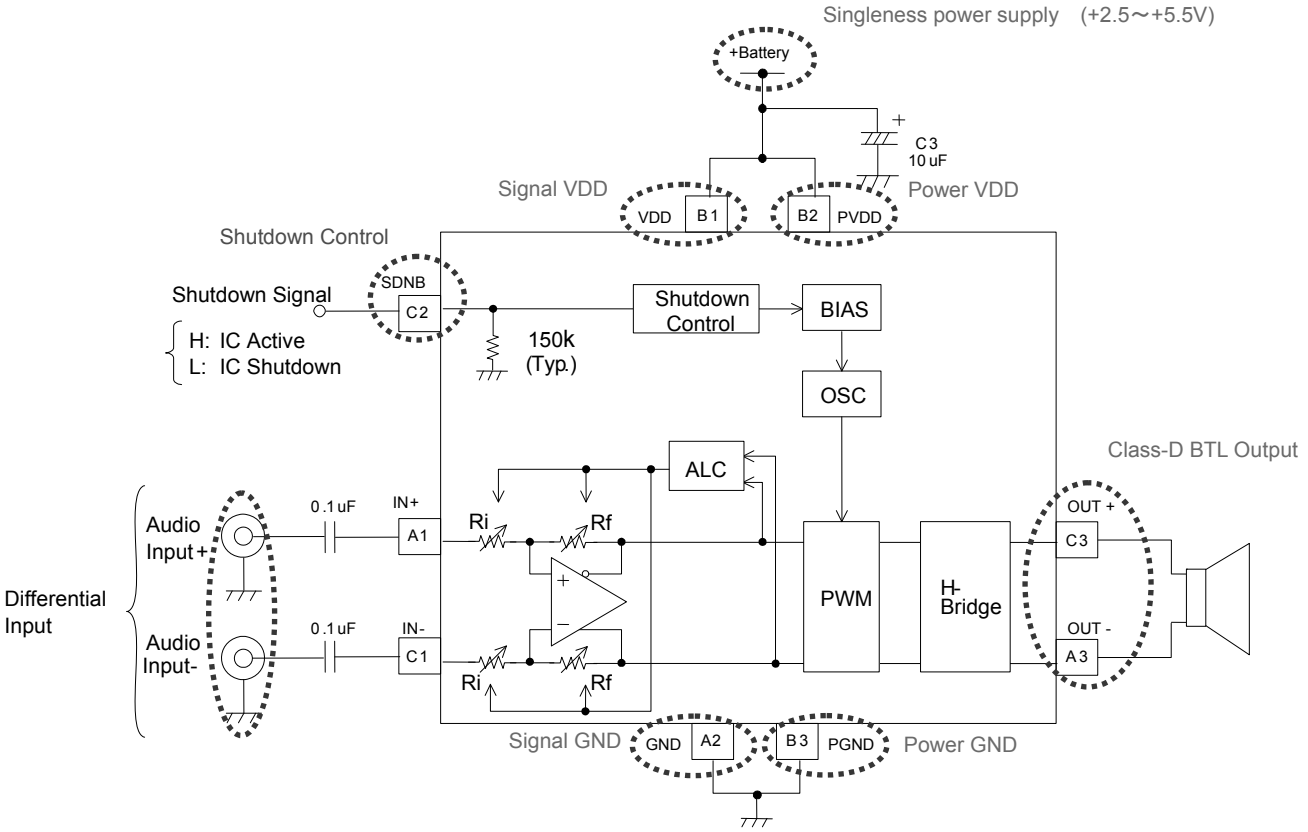


Fig1. Differential Input(With Input Coupling Capacitor)

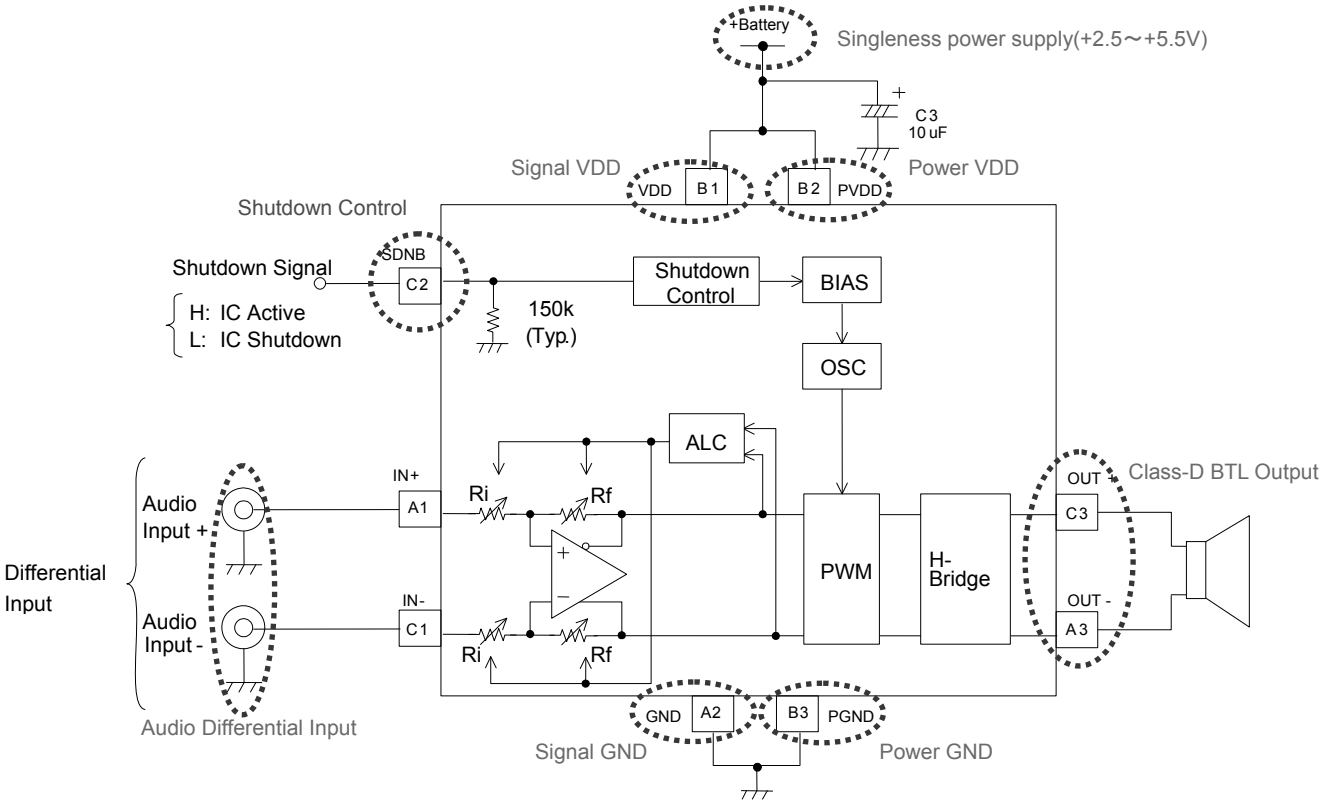


Fig2. Differential Input(Without Input Coupling Capacitor)

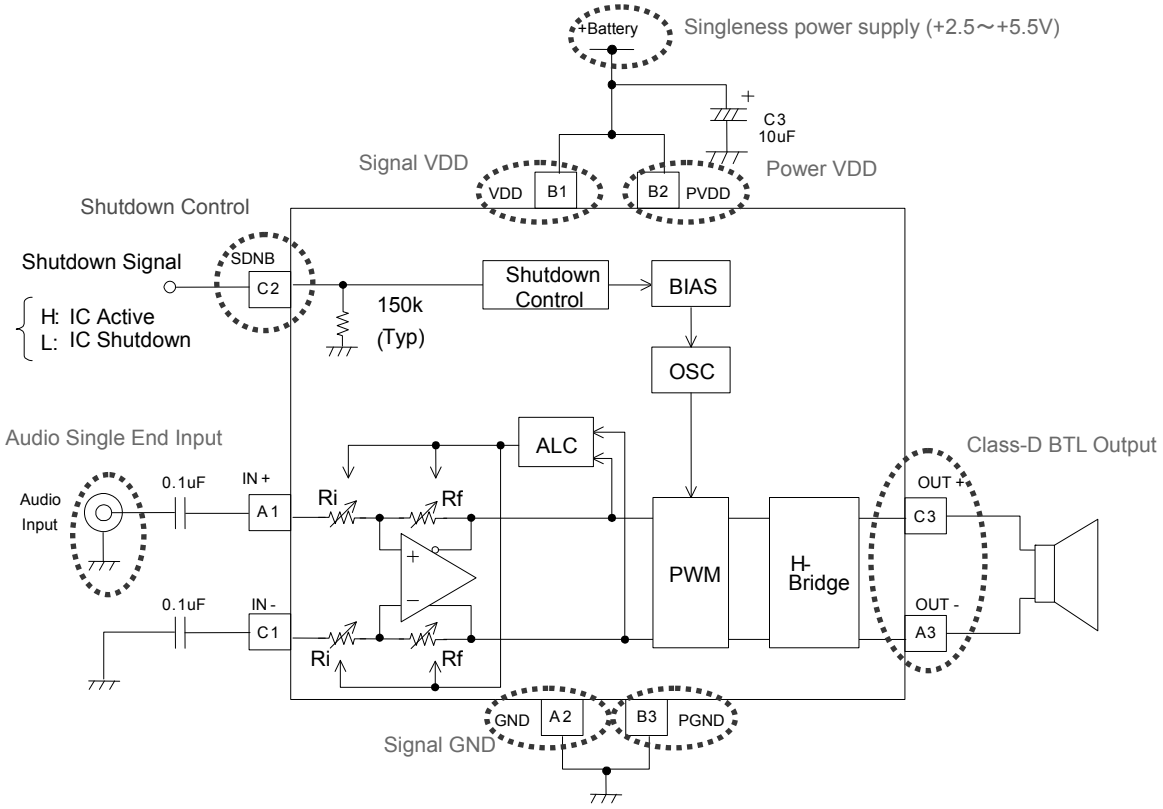


Fig3. Single end input (during IN+ input)

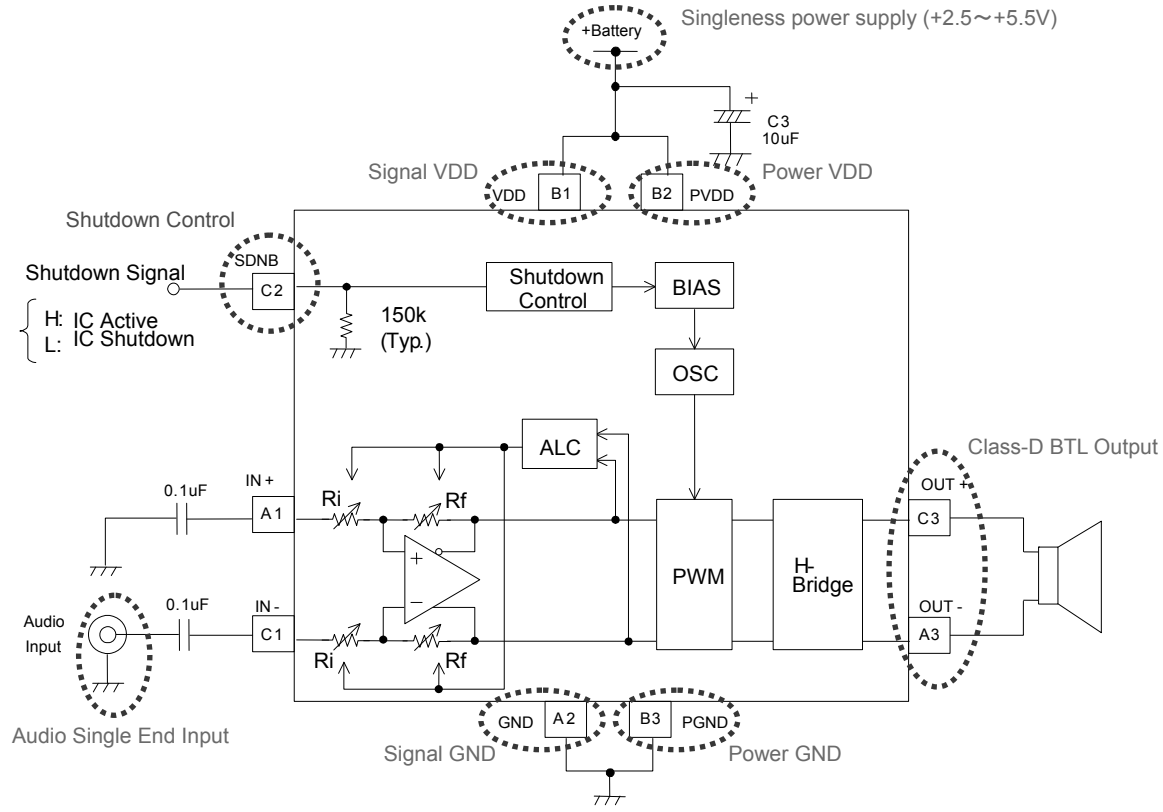


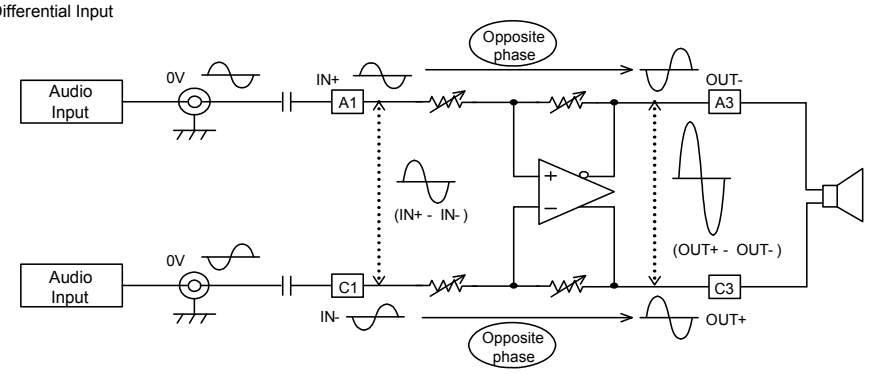
Fig4. Single end input (during IN- Input)

●About the difference of differential input and single end input

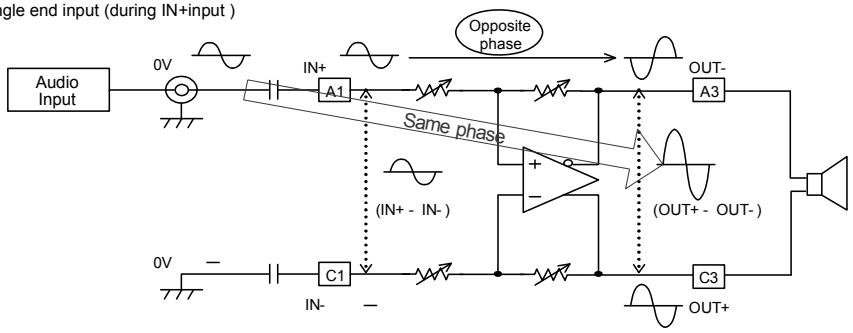
・BD5467GUL uses full differential amplifier.
BD5467GUL is a Class-D but, in relation to Audio Input and Output, is same with the conventional Class-AB Amplifier.
For simplicity purposes of the diagram, the Class-D amplifier output stage is omitted in the following explanation.

About the resistor, signal  on the diagram
Gives meaning to changes of gain setting by means of ALC Control.

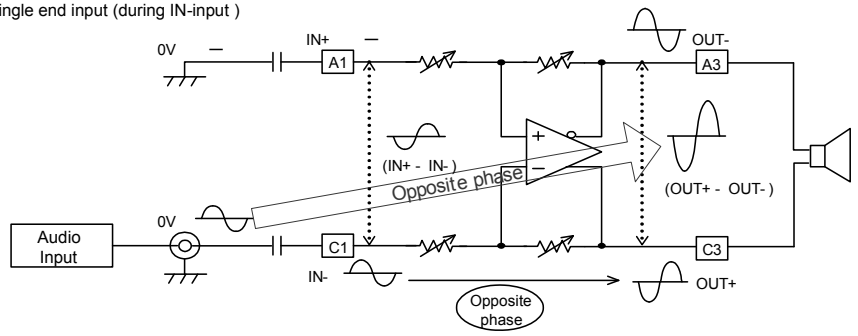
1) Differential Input



2) Single end input (during IN+input)



3) Single end input (during IN-input)



○About single end input

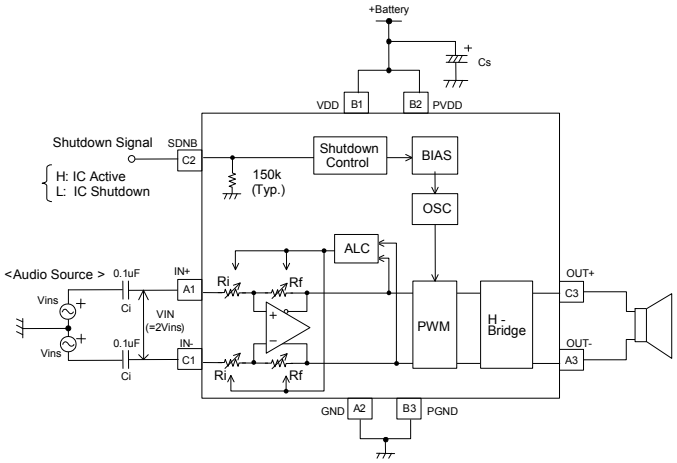
・Input is possible whether IN+ or IN- Pin.
Don't make input pin open, through the input coupling capacitor, please connect to GND as seen on the example above. Audio input pin should make "mute" condition, not "open" condition when you don't input any signal.

・During single end input IN+ and IN-, there is a difference with the phase relation of input and output.
Because of differential amplifier, if input (IN+ - IN-), output (OUT+ - OUT-), the audio input and output phase relation will become:

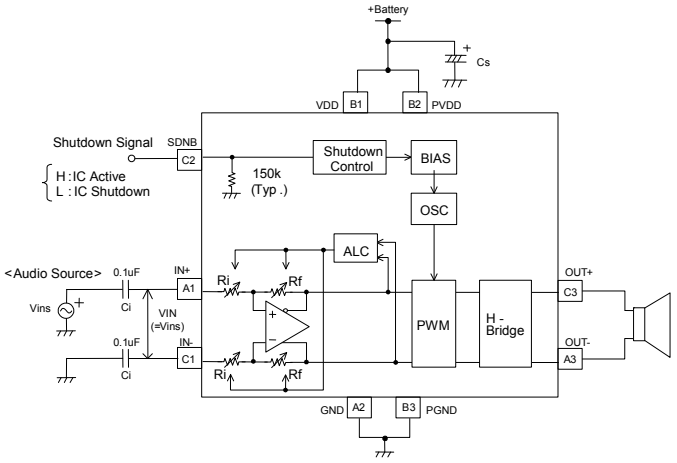
Phase	IN+ Input	IN- Input
Audio Input ⇒ output (OUT+ - OUT-)	Same phase	Opposite phase

○Gain calculation

【Differential Input】



【single end input】



When Input Level is calculated at IC typical and audio source typical, when input coupling capacitor (Ci) value is large enough, every gain during the differential input and single end input will become:

Typical Input Level	Differential Output	Single End Output
IC	Formula①	
Audio Source	Formula②	Formula①

1. IC reference(Difference Input, Single End Input) : Formula ①
   VIN means the Input Voltage between IC Input Pin (IN+, IN-), VOUT means the output voltage between IC Output Pin (OUT+, OUT-). During differential input and single end input, the gain calculation formula at IC reference which includes ALC operation is written below:

   Gain = 20×log | VOUT/VIN | =+13～-2 (Typ.) [dB] ・・・ Formula①

2. Audio Source reference(Differential Input) : Formula ②
   When the input level of audio source is Vins, the relation with the input voltage VIN between IC input pin is written below:

   Vins = VIN / 2

   During differential input, at audio source referece that includes ALC operation, gain calculation formula will become:

   Gain = 20×log | VOUT / Vins | = 20×log | 2×VOUT / VIN | = +19～+4 (Typ.) [dB] ・・・Formula②

3. Audio Source reference (Single End Input) : Formula ①
   When the Input level of audio source is Vins, the relation with input voltage VIN between IC input pin (IN+,IN-) becomes:

   Vins = VIN

   During single end input, at the audio source that includes ALC operation, gain calculation formula becomes:

   Gain = 20×log | VOUT / Vins | = 20×log | VOUT / VIN | = +13～-2 (Typ.) [dB] ・・・ Formula①

●Audio Input Pin External LPF connection example

■External LPF connection example

The connection example of 1st -order LPF which is formed at Resistor R_{LPF} and Capacitor C_{LPF} , to the Audio Input Pin IN+/- (A1, C1 Pin) is shown below. The cut frequency of input LPF, together with the single end input and differential input is written below:

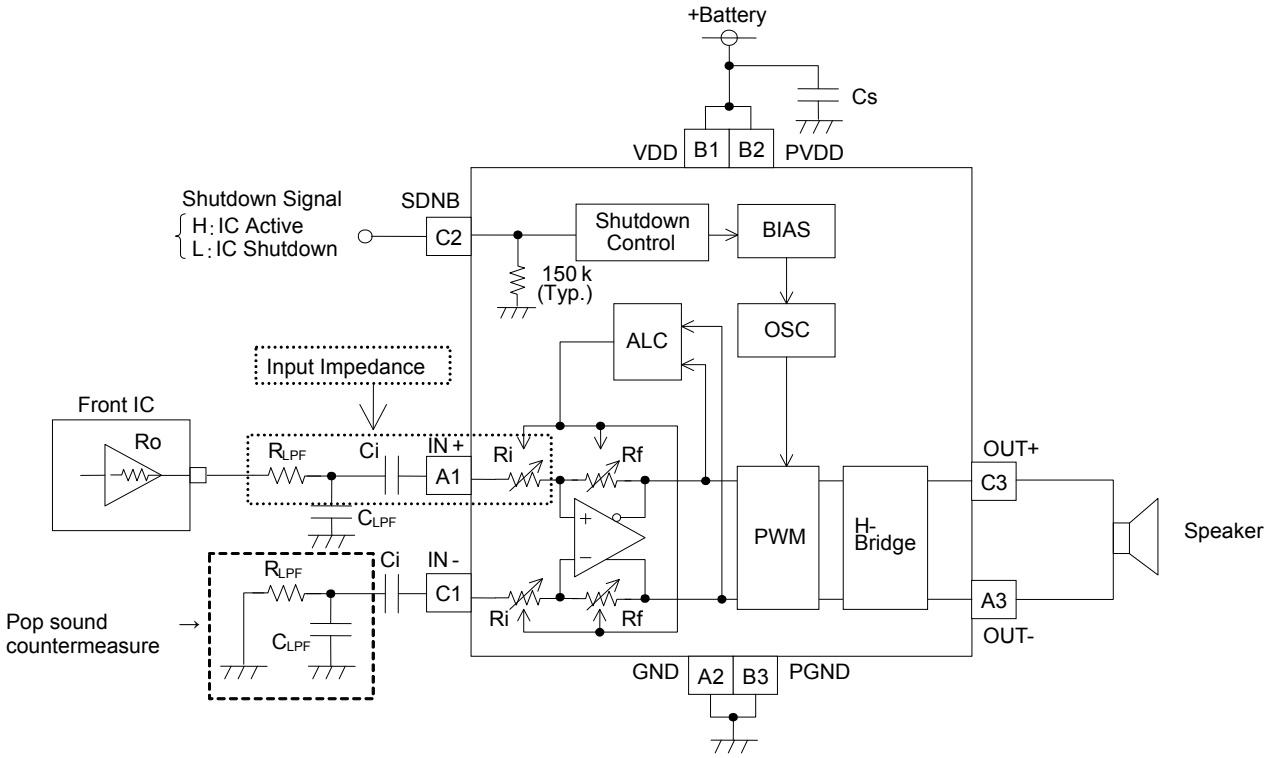
$fc_{LPF} = 1 / (2 \times \pi \times R_{LPF} \times C_{LPF})$ [Hz]

Ex) fc_{LPF}=10kHz ⇒ C_{LPF} =0.01μF, R_{LPF}=1.59kΩ

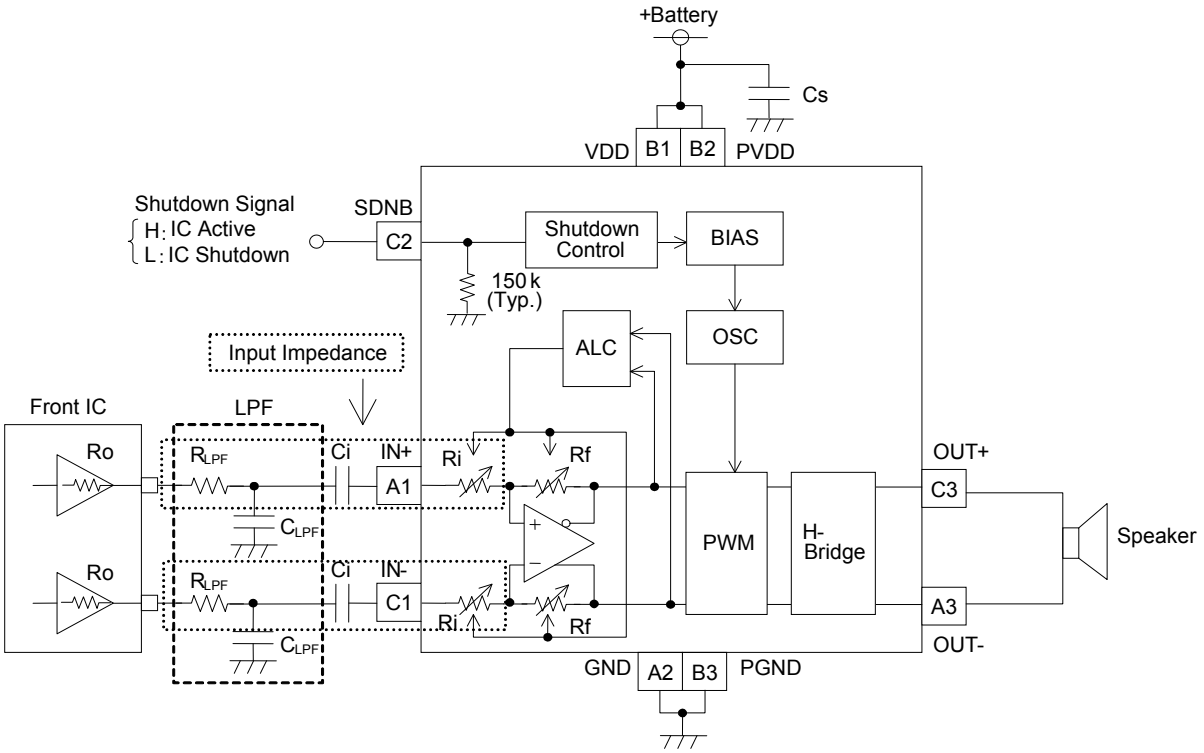
1) During single end input

When LPF is connected to audio input pin at single end input setting, at start-up characteristics of audio input pin IN+/-, during start-up with unbalance (power supply ON/OFF, or shutdown ON/OFF), there is a risk that POP sound will occur so please be careful.

When no audio input, and in order to prevent output noise, please make previous IC “mute” condition, not “open” condition. Please refer at the same time to POP Sound countermeasure example.



2) Differential Input



■Caution during External LPF Setting

External LPF Resistor R_{LPF} which is composed of IC input resistor Ri, forms input impedance.
The bigger the resistor value of LPF resistor $R_{LPF,}$ the more it will decrease the gain.

When the input capacitor Ci has enough large capacity value, the relation among external LPF resistor R_{LPF} and IC input resistor Ri and Gain will become:

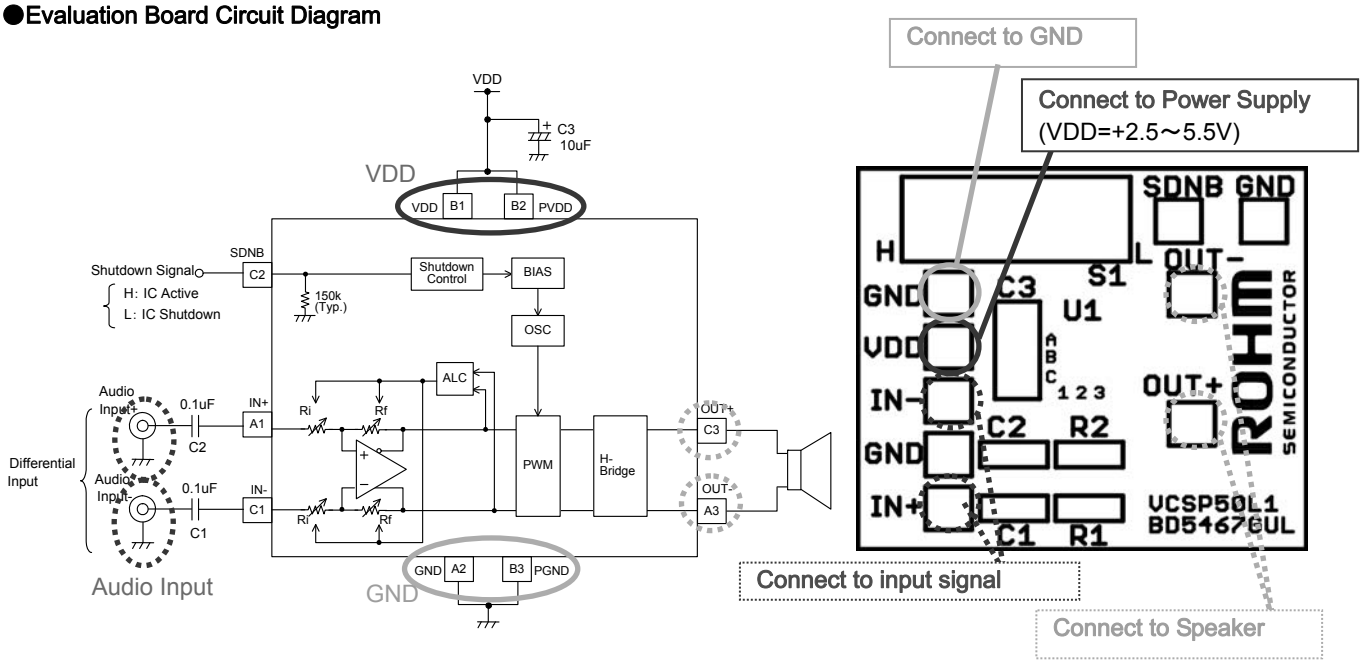
$$Gain = 20 \times \log | Rf / (Ri + R_{LPF}) | \quad [dB]$$

Input resistor Ri of BD5467GUL and resistor value of feedback resistor Rf will become the following below, during ALC operation, changes at ±1dB step, and becomes 16 stages switch specs.

#1. Ri=55kΩ(Typ.), Rf=245kΩ(Typ.)@Gain=13dB
#2. Ri=60kΩ(Typ.), Rf=240kΩ(Typ.)@Gain=12dB
#3. Ri=66kΩ(Typ.), Rf=234kΩ(Typ.)@Gain=11dB
↓
#15. Ri=159kΩ(Typ.), Rf=141kΩ(Typ.)@Gain=-1dB
#16. Ri=167kΩ(Typ.), Rf=132kΩ(Typ.)@Gain=-2dB

Also with the driver ability of previous IC step, after checking, constant setting of external LPF and Resistor $R_{LPF.}$

●Evaluation Board Circuit Diagram



※Power Supply terminals VDD(B1), PVDD(B2) are SHORT in the board pattern and use a single power.

●Evaluation Board Parts List

Qty.	Item	Description	SMD Size	Manufacturer/ Part Number
2	C1, C2	Capacitor, 0.1μF	0603	Murata GRM188R71C104KA01D
1	C3	Capacitor, 10μF	A (3216)	ROHM TCFGA1A106M8R
1	S1	Slide Switch	4mm X 10.2mm	NKK SS-12SDP2
1	U1	IC, BD5467GUL, Mono Class-D Audio Amplifier	1.7mm X 1.7mm WLCSP Package	ROHM BD5467GUL
1	PCB1	Printed-Circuit Board, BD5467GUL EVM	—	—

●About the external part

①Input coupling capacitor (C1, C2)

Input coupling capacitor is 0.1μF.

Input impedance during maximum gain 13dB is 55kΩ (Typ.). A high-pass filter is composed by the input coupling capacitor and the input impedance.

Cut-off frequency"fc" by the formula below, through input coupling capacitor C1(=C2) and input impedance Ri.

$$fc = \frac{1}{2\pi \times Ri \times C1}$$

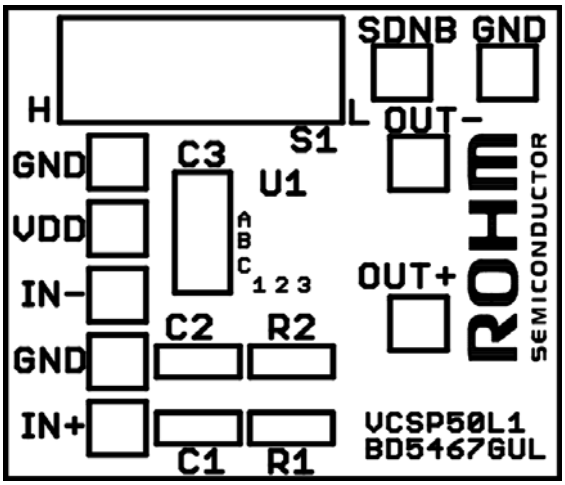
In case of Ri=55kΩ, C1(=C2)=0.1μF, cut-off frequency is about 29Hz

②Power Supply Decoupling Capacitor (C3)

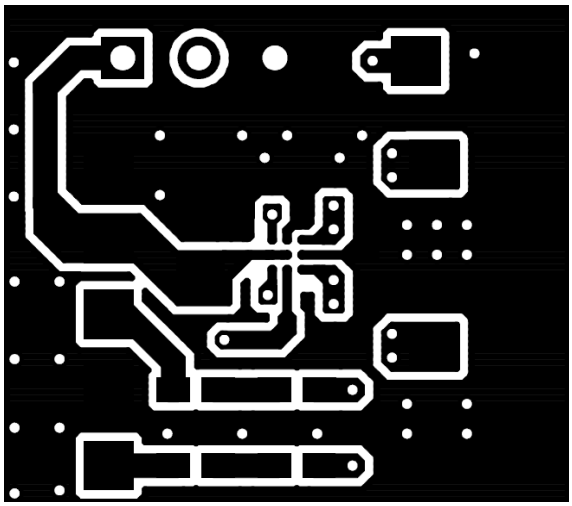
Power Supply Decoupling Capacitor is 10uF. When the capacity value of Power Supply Decoupling Capacitor is made small, it will have an influence to the audio characteristics. When making it small, be careful with the audio characteristics at actual application. ESR (equivalent series resistor) is low enough; please use capacitor with capacity value of 1μF or more.

●Evaluation Board PCB Layer

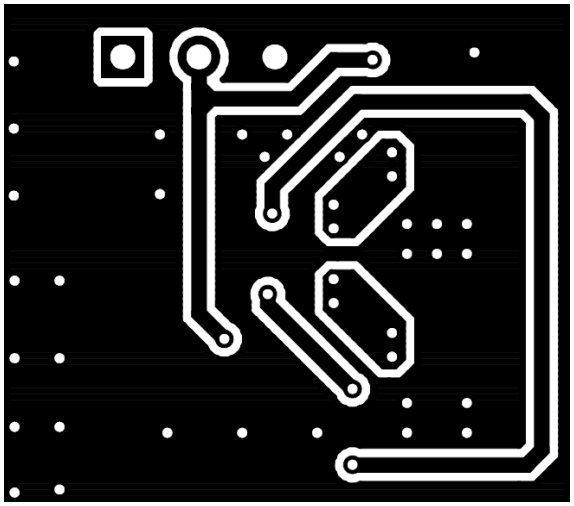
TOP Layer Silk Pattern



TOP Layer



Bottom Layer



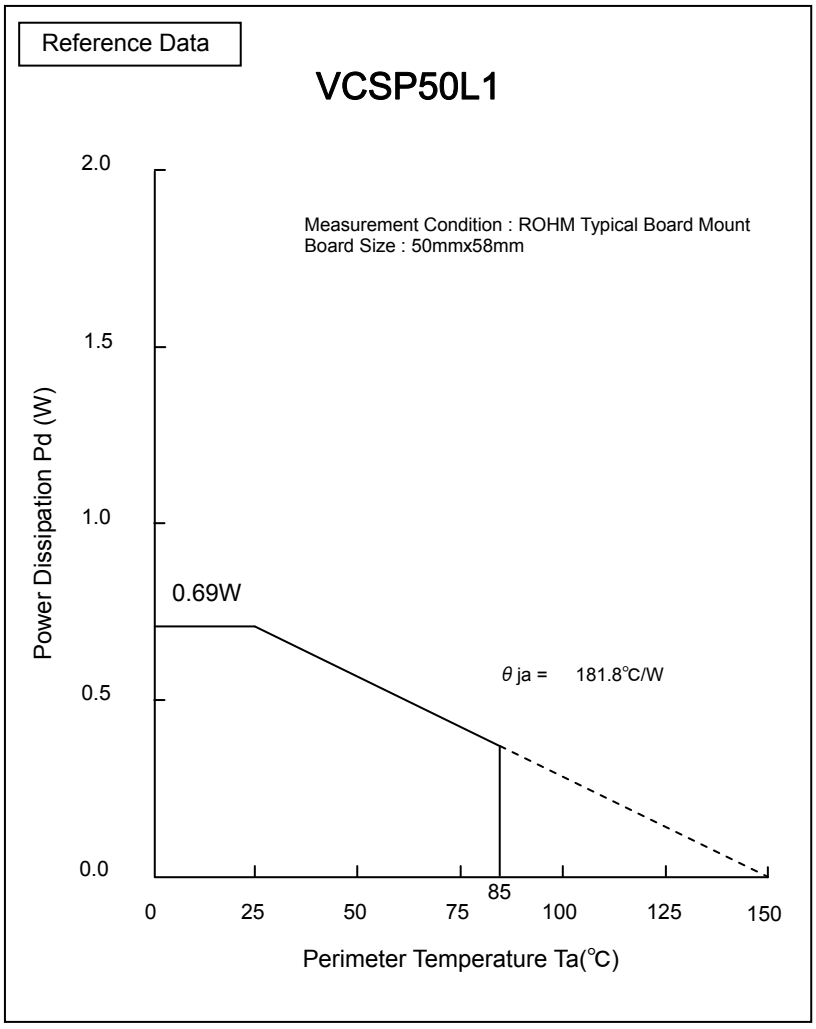
●About IC Thermal Design

The IC Characteristics has a big relation with the temperature that will be used, to exceed the maximum tolerance junction temperature, can deteriorate and destroy it. Instant destruction and long-time operation, from these 2 standpoints, there is a need to be careful with regards to IC thermal. Please be careful with the next points.

The absolute maximum rating of IC shows the maximum junction temperature ($Tj_{MAX.}$) or the operation temperature range (Topr), so refer to this value, use Pd-Ta characteristics (Thermal reduction ratio curve). If input signal is excessive at a state where heat radiation is not sufficient, there will be TSD (Thermal Shutdown)

For TSD, the chip temperature operates at around 180℃, releases if its around 120℃ or less. Since the aim is to prevent damage on the chip, please be careful because the long use time at the vicinity where TSD operates can deteriorate the dependency of the IC.

Thermal Reduction Ratio Curve



Note: This value is the real measurement, but not the guaranteed value.

The value of power dissipation changes based on the board that will be mounted.
The power dissipation of main IC during the heat dissipation design of many mounted boards, will become bigger than the value of the above graph.

●Evaluation data – Typical characteristics (1/4)

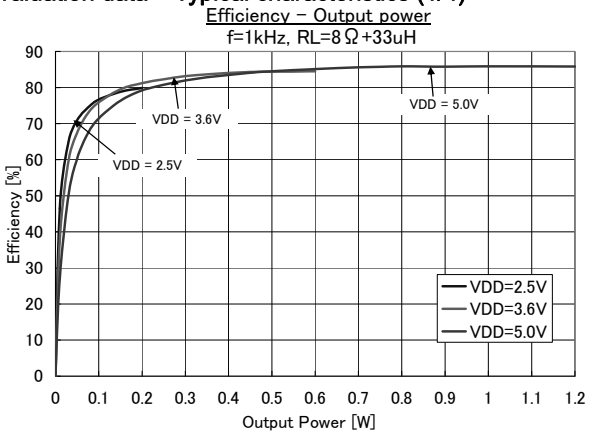


Fig.5

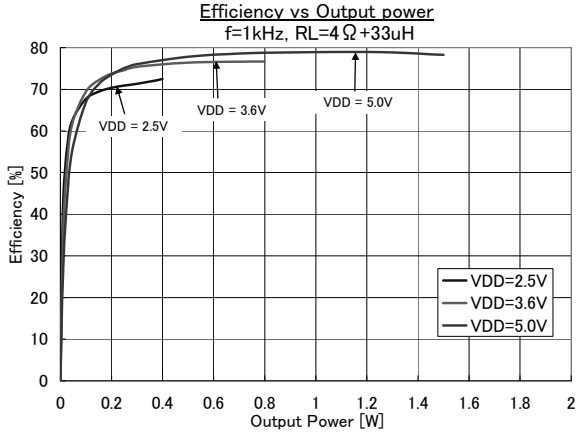


Fig.6

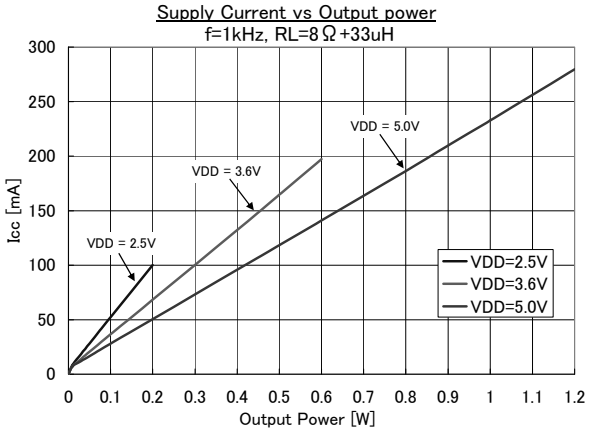


Fig.7

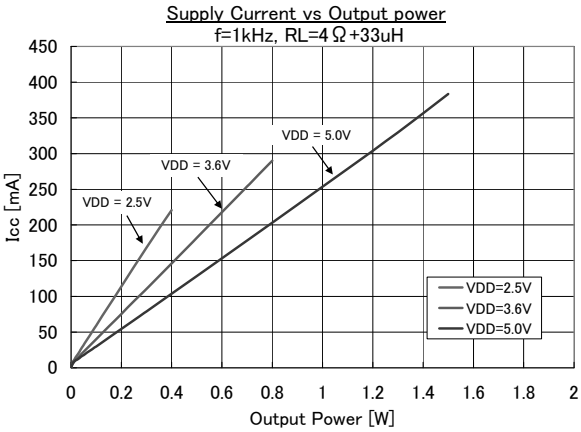


Fig.8

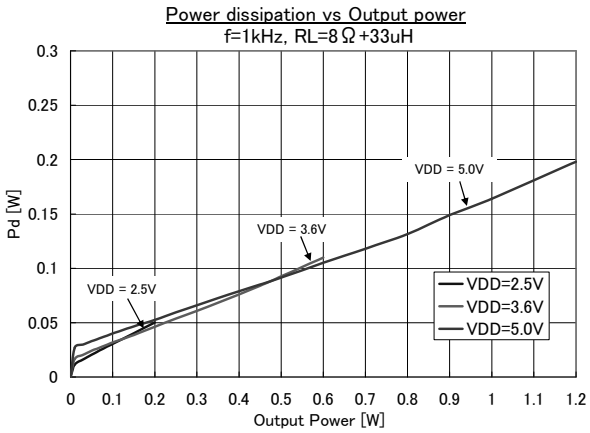


Fig.9

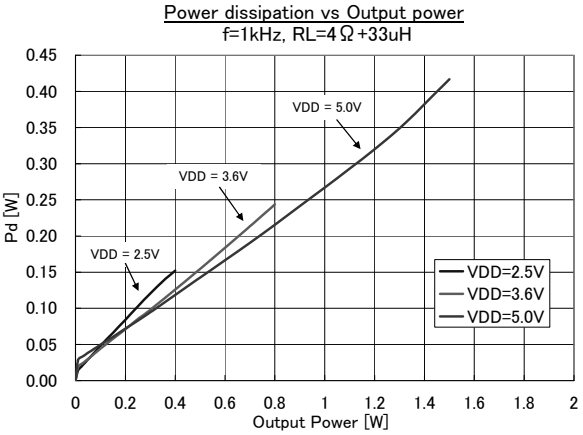


Fig.10

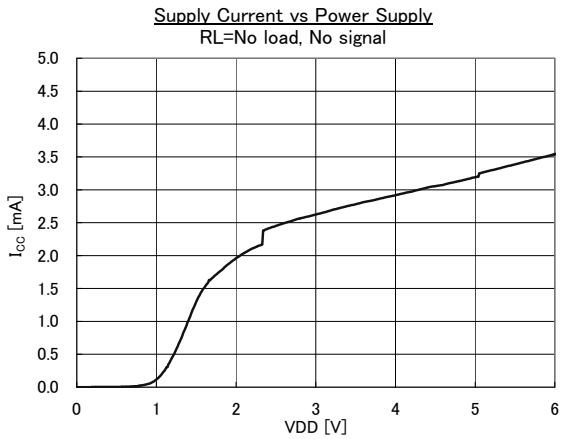


Fig.11

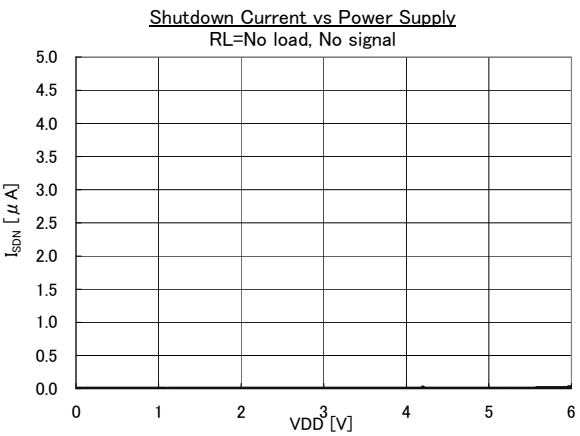


Fig.12

●Evaluation data – Typical characteristics (2/4)

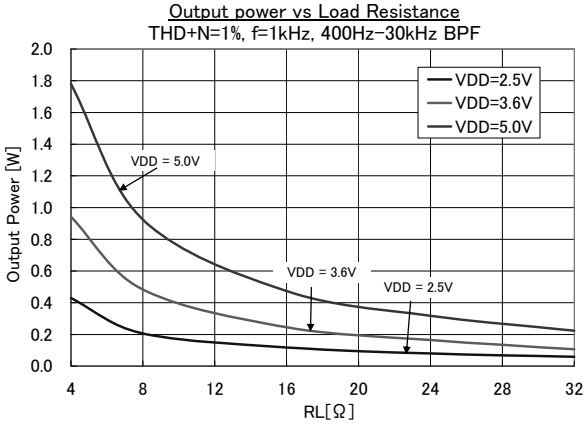


Fig.13

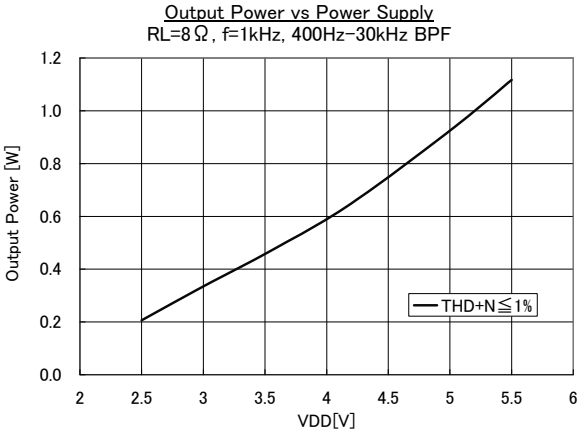


Fig.14

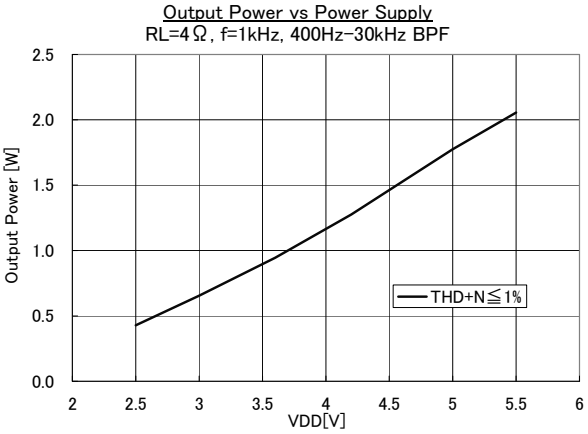


Fig.15

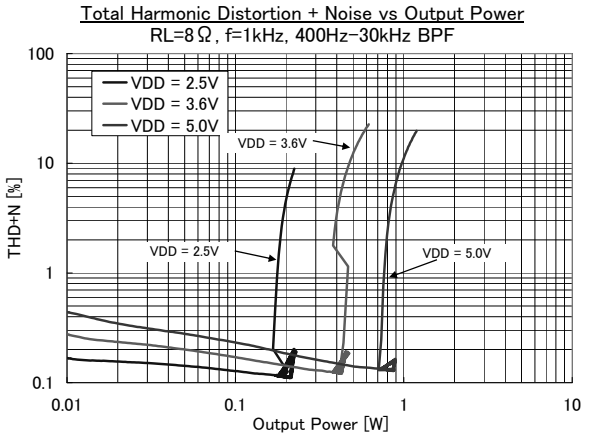


Fig.16

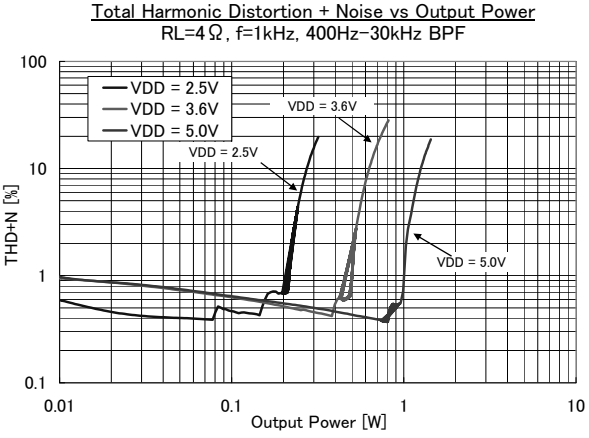


Fig.17

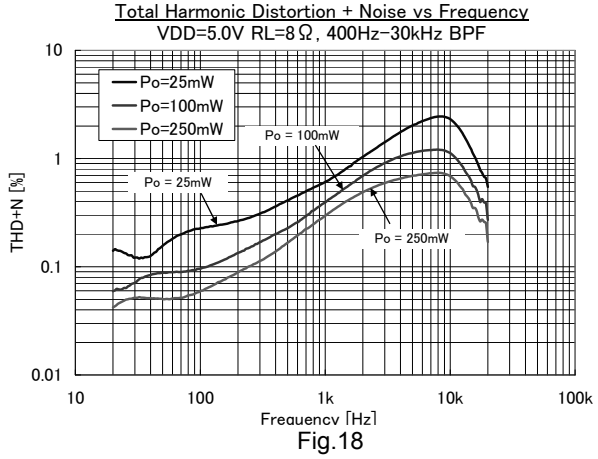


Fig.18

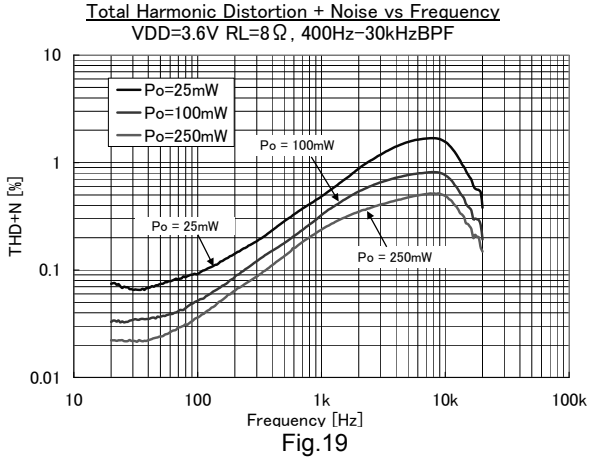


Fig.19

●Evaluation data – Typical characteristics (3/4)

Total Harmonic Distortion + Noise vs Frequency
VDD=2.5V, RL=8Ω, 400Hz-30kHz BPF

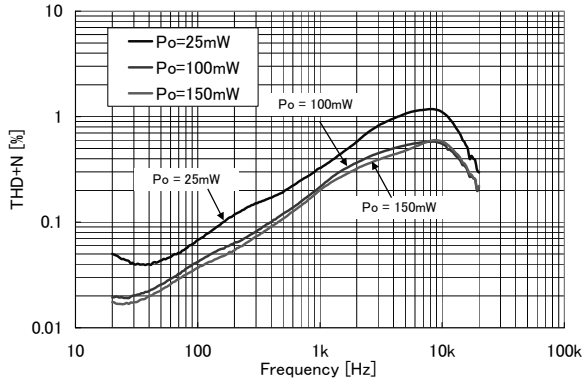


Fig.20

Total Harmonic Distortion + Noise vs Frequency
RL=8Ω, Po=125mW, 400Hz-30kHz BPF

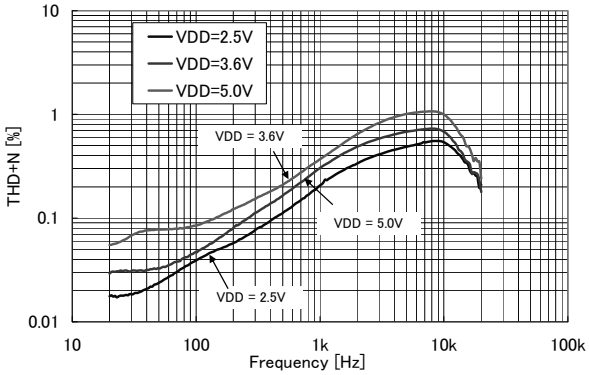


Fig.21

Gain vs Frequency
RL=8Ω, Vin=0.5Vpp, 400Hz-30kHz BPF

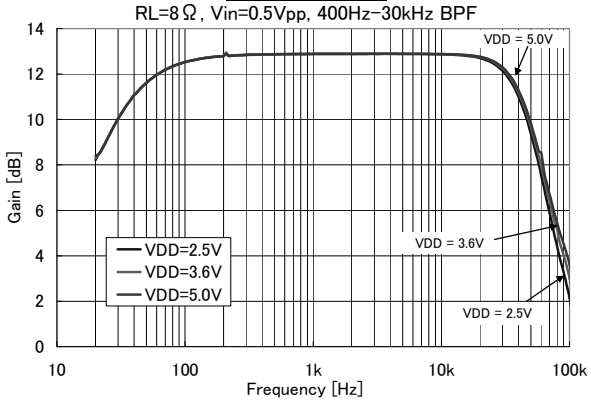


Fig.22

Gain vs Frequency
RL=4Ω, Vin=0.5Vpp, 400Hz-30kHz BPF

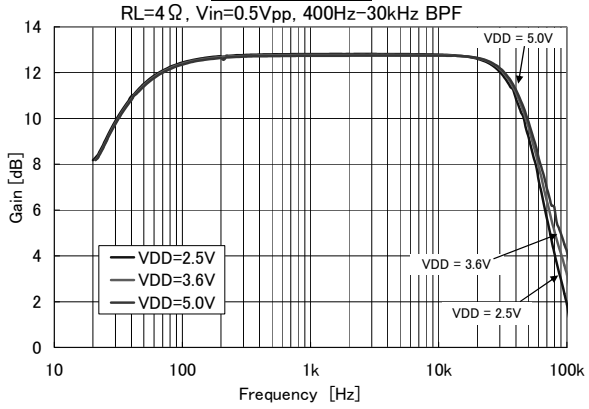


Fig.23

Output Power vs Input Level @ sweep up
RL=8Ω, f=1kHz, 400Hz-30kHz BPF

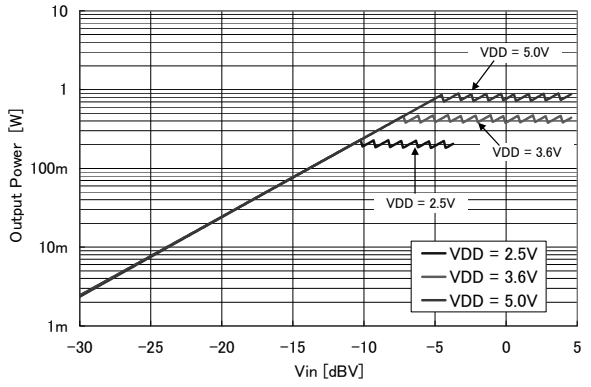


Fig.24

Output Power vs Input Level @ sweep up
RL=4Ω,f=1kHz, 400Hz-30kHz BPF

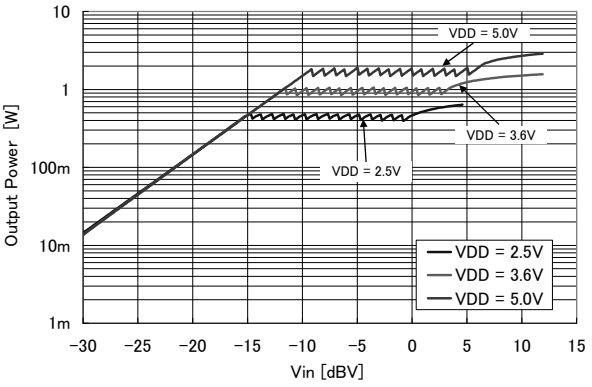


Fig.25

Total Harmonic Distortion + Noise vs Input Level @ sweep up
RL=8Ω,f=1kHz, 400Hz-30kHz BPF

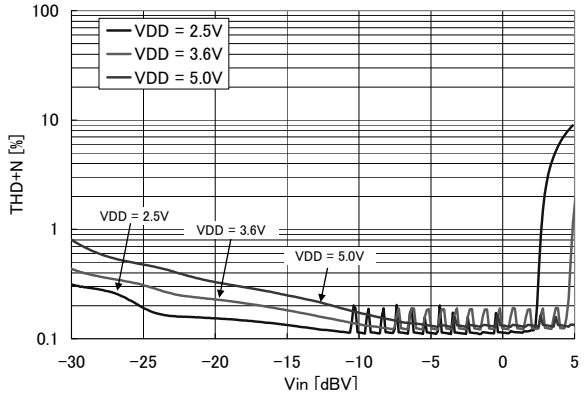


Fig.26

Total Harmonic Distortion + Noise vs Input Level @ sweep up
RL=4Ω,f=1kHz, 400Hz-30kHz BPF

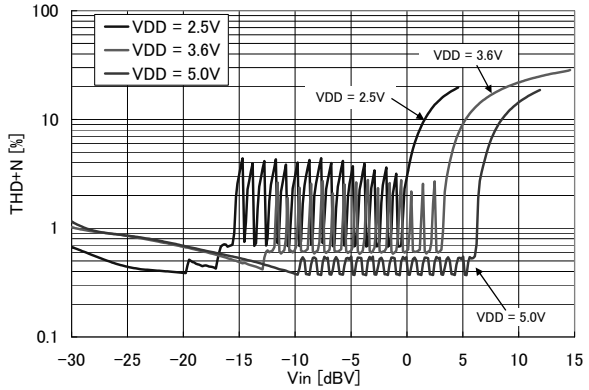


Fig.27

●Evaluation data – Typical characteristics (4/4)

ALC Limit Operation Waveform
f=1kHz

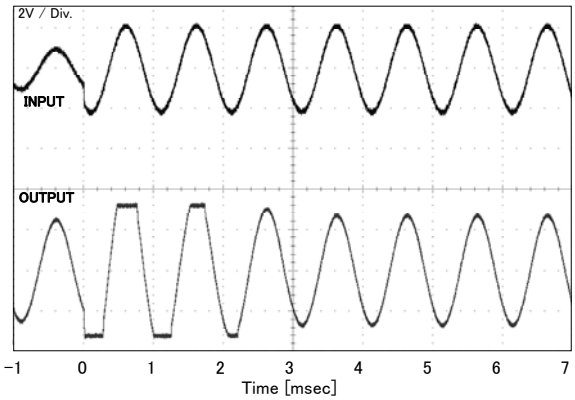


Fig.28

ALC Release Operation Waveform
f=1kHz

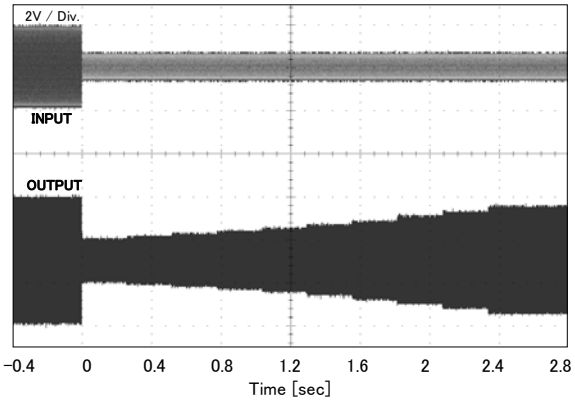


Fig.29

Waveform during Start-up

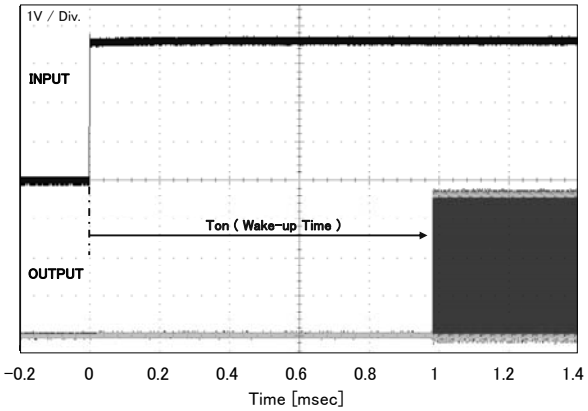


Fig.30

Waveform during Shutdown

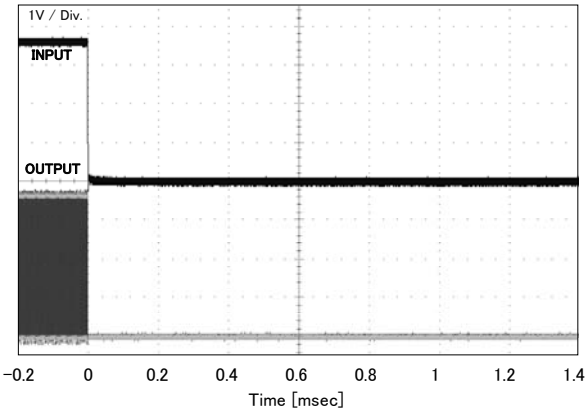


Fig.31

●Notes for use

(1) The numerical value and the data of the mention are a design representative value and are not the one which guarantees the value.

(2) It is convinced that it should recommend application circuit example but in case of use, we request the confirmation of the characteristic more sufficiently. When changing an external part fixed number and becoming use, it considers sprawl of the external part and our company's LSI including the transition characteristic in addition to the stillness characteristic and so on, see and fix an enough margin.

(3) Absolute maximum ratings
This IC may be damaged if the absolute maximum ratings for the applied voltage, temperature range, or other parameters are exceeded. Therefore, avoid using a voltage or temperature that exceeds the absolute maximum ratings. If it is possible that absolute maximum ratings will be exceeded, use fuses or other physical safety measures and determine ways to avoid exceeding the IC's absolute maximum ratings.

(4) GND terminal's potential
Try to set the minimum voltage for GND terminal's potential, regardless of the operation mode.

(5) Shorting between pins and mounting errors
When mounting the IC chip on a board, be very careful to set the chip's orientation and position precisely. When the power is turned on, the IC may be damaged if it is not mounted correctly. The IC may also be damaged if a short occurs (due to a foreign object, etc.) between two pins, between a pin and the power supply, or between a pin and the GND.

(6) Operation in strong magnetic fields
Note with caution that operation faults may occur when this IC operates in a strong magnetic field.

(7) Thermal design
Ensure sufficient margins to the thermal design by taking in to account the allowable power dissipation during actual use modes, because this IC is power amplifier. When excessive signal inputs which the heat dissipation is insufficient condition, it is possible that thermal shutdown circuit is active.

(8) Thermal shutdown circuit
This product is provided with a built-in thermal shutdown circuit. When the thermal shutdown circuit operates, the output transistors are placed under open status. The thermal shutdown circuit is primarily intended to shut down the IC avoiding thermal runaway under abnormal conditions with a chip temperature exceeding T_{jmax}=+150℃, and is not intended to protect and secure an electrical appliance.

(9) Load of the output terminal
This IC corresponds to dynamic speaker load, and doesn't correspond to the load except for dynamic speakers. When using speaker load 8Ω or less (especially 4Ω), there will be a risk of generating distortion at the speaker output wave form during ALC limit operation.

(10) The short protection of the output terminal
This IC is built in the short protection for a protection of output transistors. When the short protection is operated, output terminal become Hi-Z condition and is stopped with latch. Once output is stopped with latch, output does not recover automatically by canceling the short-circuiting condition. The condition of stopping with latch is cancelled, when power supply or mute signal is turned off and turned on again.

(11) Operation Range
The rated operating power supply voltage range (VDD=+2.5V～+5.5V) and the rated operating temperature range (Ta=-40℃～+85℃) are the range by which basic circuit functions is operated. Characteristics and rated output power are not guaranteed in all power supply voltage ranges or temperature ranges.

(12) Electrical Characteristics
Every audio characteristics list of the limit output power, total harmonic distortion, maximum gain, ALC limit level, ALC release level etc. shows the typical characteristics of the device, highly dependent to the board lay-out, parts to be used, power supply. The value when the device and each component are directly mounted to the board of Rohm.

(13) Power Supply
Since the Power Supply Pin for signal (VDD) and power supply for Power (PVDD) is SHORT at internal, short the board pattern, then use a single power supply. Also, the power supply line of class-D speaker amplifier flows big peak energy. It will influence the audio characteristics based on the capacity value of power supply decoupling capacitor, arrangement. For the power supply decoupling capacitor, please arrange appropriately the low capacity (1μF or more) of ESR (equivalent series resistor) directly near to IC Pin.

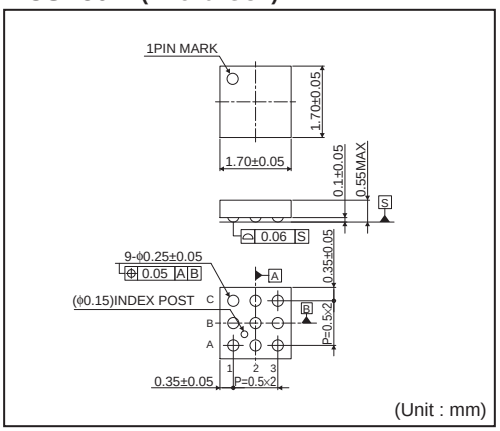
(14) ALC (Automatic Level Control) Function
The ALC automatically adjusts the audio output level, and a function that prevents the over output to the speaker. When ALC function is working, gain switches at zero-cross point of audio output normally. If the time that audio output reaches to zero-cross point is long, gain switches at about 1msec later (attack time), at about 25msec later (release time). So, attack time and release time will change at audio input frequency. ALC parameter is fixed. ALC operation doesn't correspond to noise of impulse.
Also, ALC limit control will become a power supply tracking type, limit output power is dependent to power supply voltage. The ALC characteristics of limit output power, ALC limit and release limit will be influenced by the shaking so please be careful.

●Ordering part number

B	D	5	4	6	7	G	U	L	-	E	2

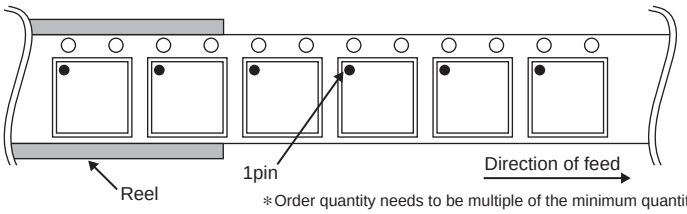
Part No. Part No. Package GUL : VCSP50L1 Packaging and forming specification E2: Embossed tape and reel

VCSP50L1(BD5467GUL)



<Tape and Reel information>

Tape	Embossed carrier tape
Quantity	3000pcs
Direction of feed	E2 (The direction is the 1pin of product is at the upper left when you hold reel on the left hand and you pull out the tape on the right hand)



∗Order quantity needs to be multiple of the minimum quantity.

Notes

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