YDA168B

D-4H3B

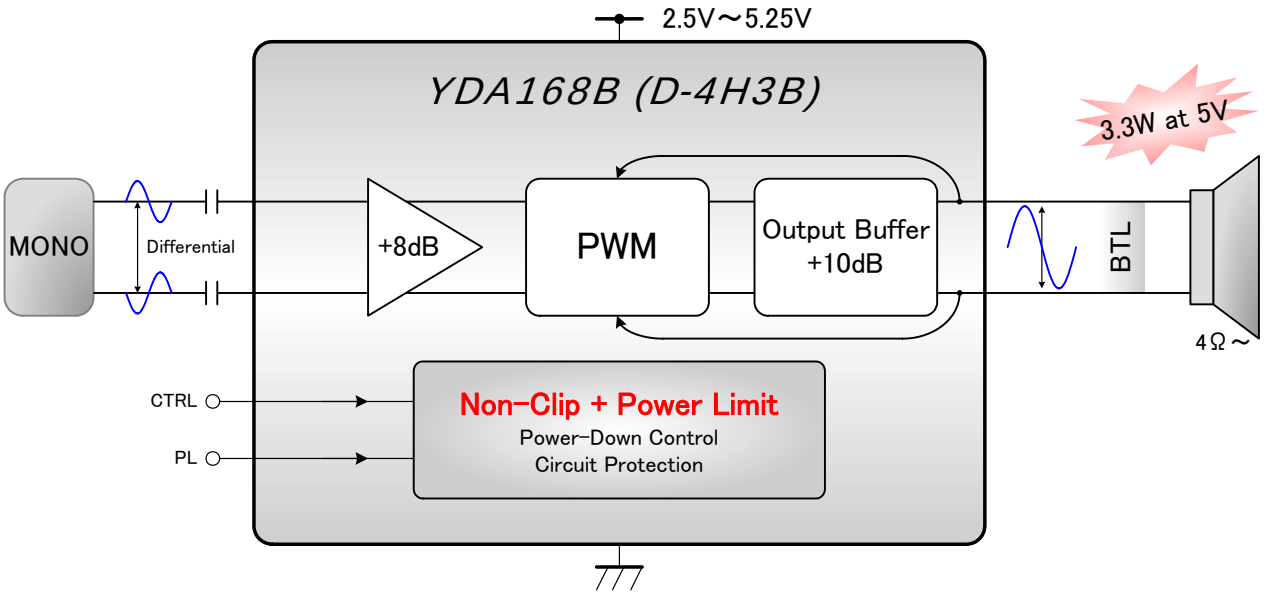
MONO 3.3W Non-Clip DIGITAL AUDIO POWER AMPLIFIER

■ General Description

YDA168B (D-4H3B) is an integrated circuit with Max.3.3W (R_L=4Ω)×1ch Class-D speaker amplifier. This speaker amplifier uses the filter-less method allowing a speaker to be directly connected to the output and features low-level distortion and noise characteristics.

The speaker amplifier, having Yamaha original Power Limit Interlock Non-Clip function, controls Gain automatically and prevents output signals from being clipped at the supply voltage. In addition, this power limit function permits the maximum output to be arbitrarily specified to 100mW to 1000mW according to a speaker to use.

Furthermore, this amplifier has the following functions: overcurrent and overtemperature protection functions, DC output protection function, under-voltage malfunction prevention function, as well as EMI noise and the pop noise reduction functions and High PSRR function.



YDA168B Simplified Diagram

■ Features

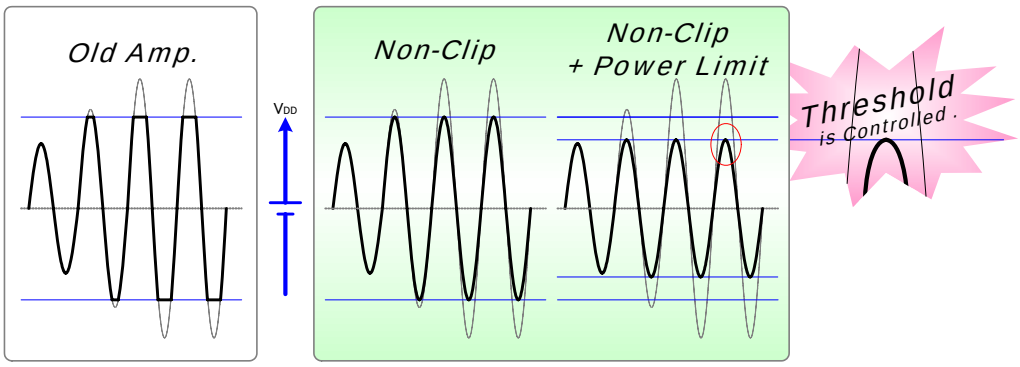
- Supply Voltage V_{DD} 2.5V to 5.25V
- Input Mono (Differential)×1
- Output Speaker (Class-D, BTL)

・Maximum Output	3.3 W×1ch	(V_{DD} = 5.0 V, R_L = 4 Ω, THD+N = 10 %, T_A = 25 °C)
	0.93 W×1ch	(V_{DD} = 3.6 V, R_L = 8 Ω, THD+N = 10 %, T_A = 25 °C)
	1.00 W×1ch	(V_{DD} = 4.2 V, R_L = 8 Ω, THD+N = 1 %, T_A = 25 °C)
	0.75 W×1ch	(V_{DD} = 3.6 V, R_L = 8 Ω, THD+N = 1 %, T_A = 25 °C)
・Maximum Output (Non-Clip)	2.4 W×1ch	(V_{DD} = 5.0 V, R_L = 4 Ω, THD+N = 1 %, T_A = 25 °C)
	0.70W×1ch	(V_{DD} = 3.6 V, R_L = 8 Ω, THD+N = 1 %, T_A = 25 °C)
・Distortion (THD+N)	0.045 %	(V_{DD} = 3.6 V, R_L = 8 Ω, P_O = 0.40 W, 1kHz)
・Residual Noise	50 μVrms	(V_{DD} = 3.6 V, R_L = 8 Ω)
・S/N Ratio	97.2 dB	(V_{DD} = 5.0 V, R_L = 4 Ω)
・PSRR	75 dB	(V_{DD} = 3.6 V, R_L = 8 Ω, f = 217 Hz)
・Efficiency	90 %	(V_{DD} = 3.6 V, R_L = 8 Ω, P_O = 0.8 W)

- NCPL (Power Limit interlock Non-Clip function)
- Protection Function
  - Overcurrent Protection Function (OCP)
  - Overtemperature Protection Function (OTP)
  - DC Output Protection Function (DCOP)
  - Under-voltage Malfunction Prevention Function (UVL)
- Power-down Function
- High Speed Startup
- Pop Noise Reduction
- EMI Noise Reduction
- Lead-free Package 9-ball WLCSP (YDA168B-PZ)

■ NCPL (Power Limit Interlock Non-Clip) Function

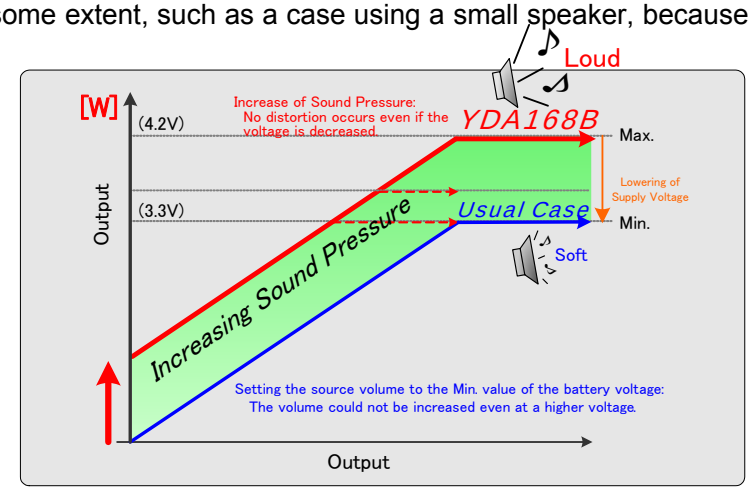
NCPL function allows Non-Clip function to be enabled even though the power limit setting is performed. Non-Clip function automatically controls the PWM amplifier gain so as not to clip the output signals even if the speaker output is clipped at the supply voltage. This control, following the supply-voltage fluctuation, has an effect also on the case that a supply voltage fluctuates, such as a battery etc. And, Power Limit function, allowing a limiting level (Max. Output) to be arbitrarily set, is available for speaker overload protection etc.



NCPL (Power Limit Interlock Non-Clip) Conceptual Diagram

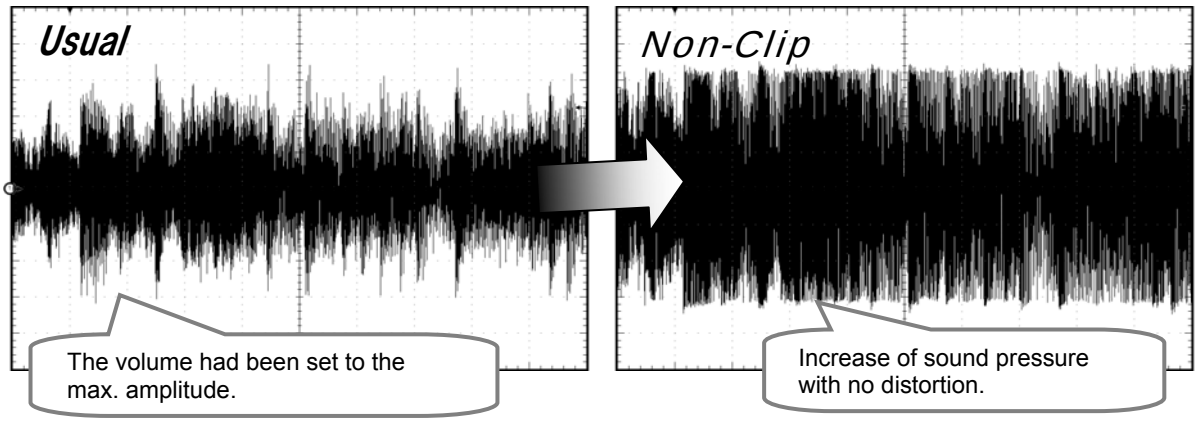
■ Examples of Effects of using Non-Clip Function

Previously, when using a device in an application where the supply voltage may fluctuate, the source volume had been set so as not to distort the sound even at the minimum voltage.
But, Non-Clip function allows source volume to be set based on the maximum voltage without regard for distortion. This function automatically controls the gain according to the variation of a supply voltage; therefore, this is an optimum function for an application that needs a sound pressure level to some extent, such as a case using a small speaker, because the sound pressure is increased.



Increase of Sound Pressure using Non-Clip Function – Conceptual Diagram

Example of Sound Pressure Increase: Music Source

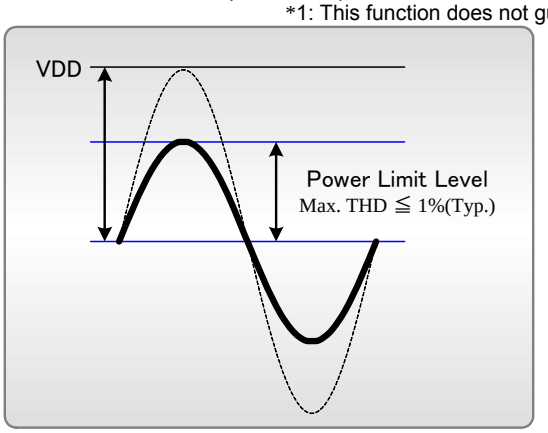


Actually Measured Sound Power Limit Function

■ Examples of Effects of using Power Limit Function

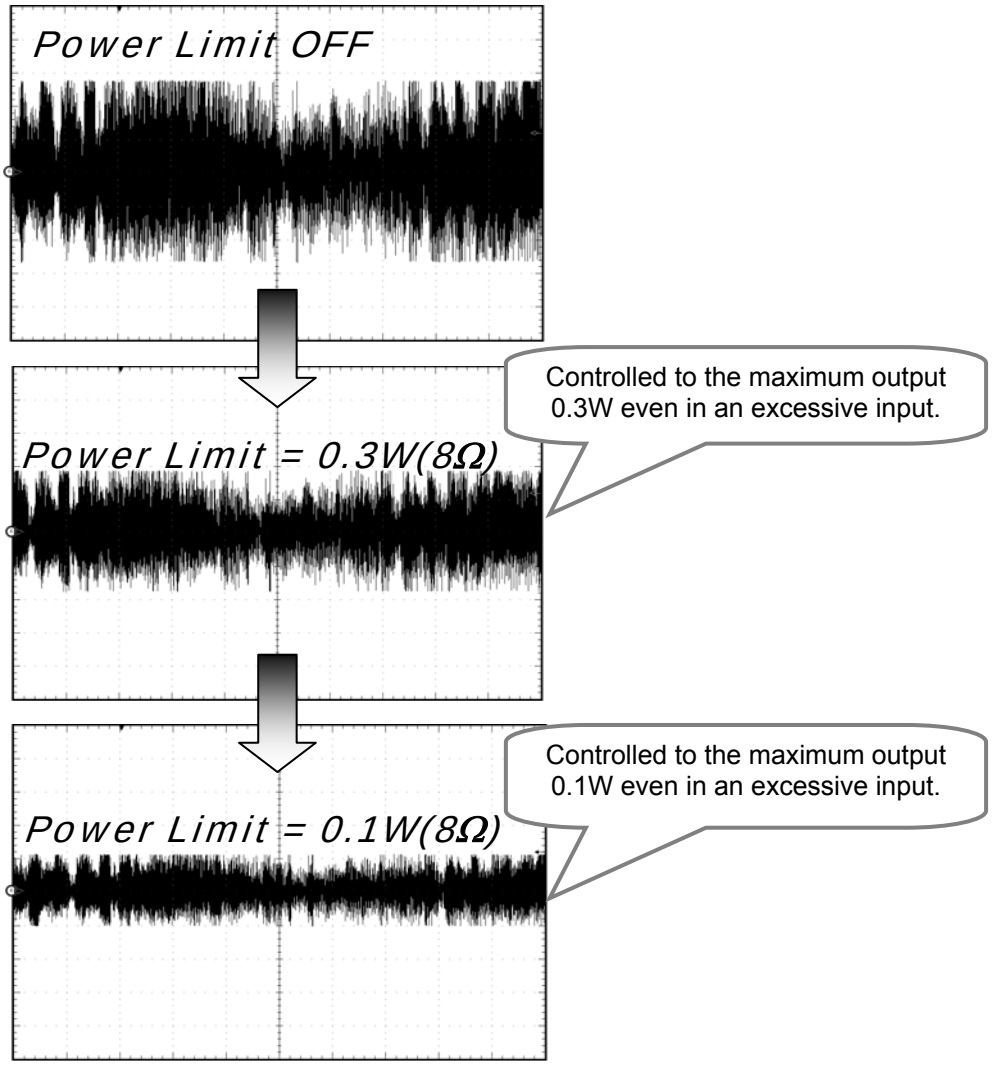
Power Limit function is a function provided for the purpose of reducing the overload on a speaker and limits the output power *1. Any power limit level, ranging from 100mW to 1000mW, can be freely set. Even if an excessive signal is input, Non-Clip function automatically controls PWM amplifier gain to keep the maximum output power to a constant level. And, when PL pin is connected to GND, the output is set to 0.60W (R_L = 8 Ω).

*1: This function does not guarantee 100% speaker protection.



Power Limit – Conceptual Diagram

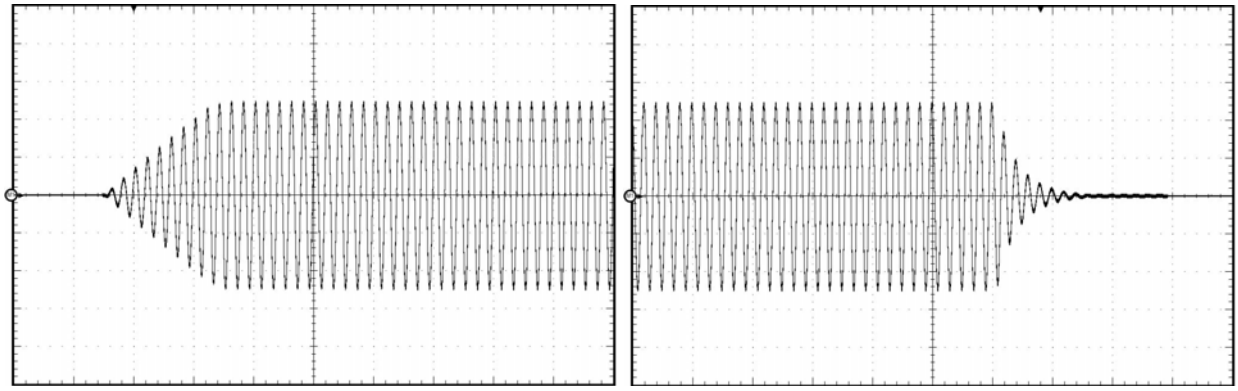
Power Limit Example: Music Source



Actually-measured output power for each power limit value

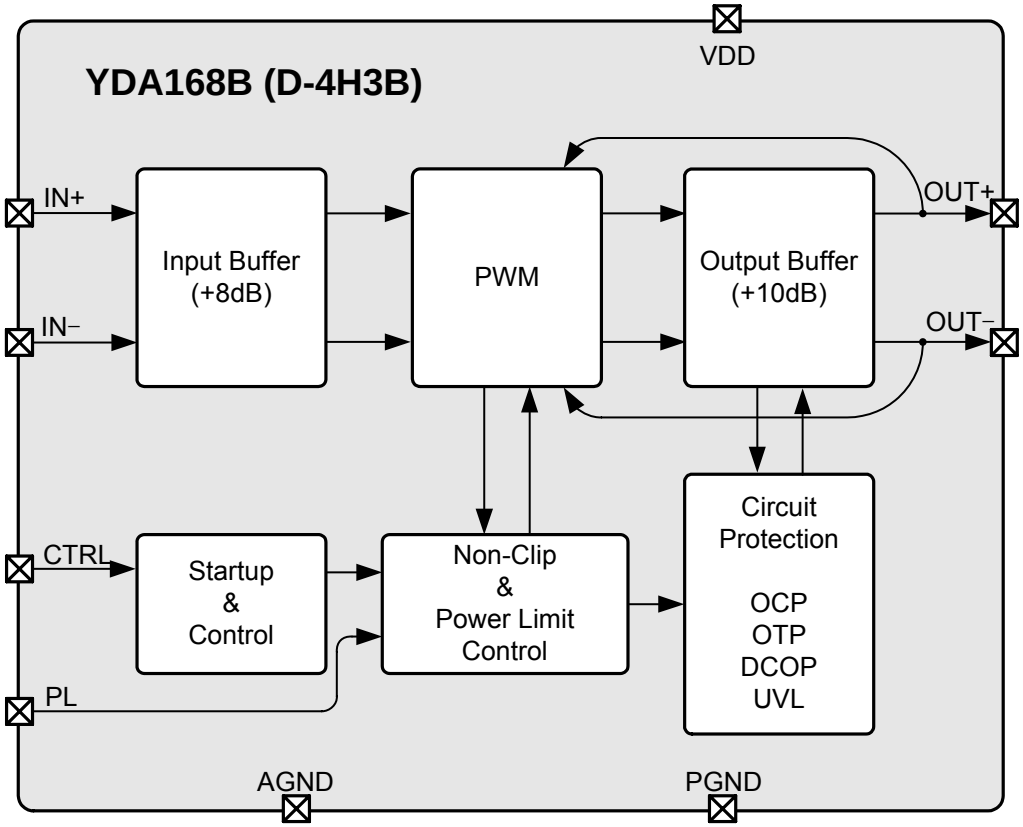
■ Quick Start/Quick Mute Function

Pop noise reduction circuit (Quick Start/Quick Mute) operates at startup or shutdown of the speaker amplifier.
This is a function to vary ON/OFF envelopes at a slow rate. Even a high-speed ON/OFF operation, this reduces intermittent sound considerably and eliminates uncomfortable feeling.
That is, Quick Start/Quick Mute is a pop noise reduction function with Non-Clip technique applied.



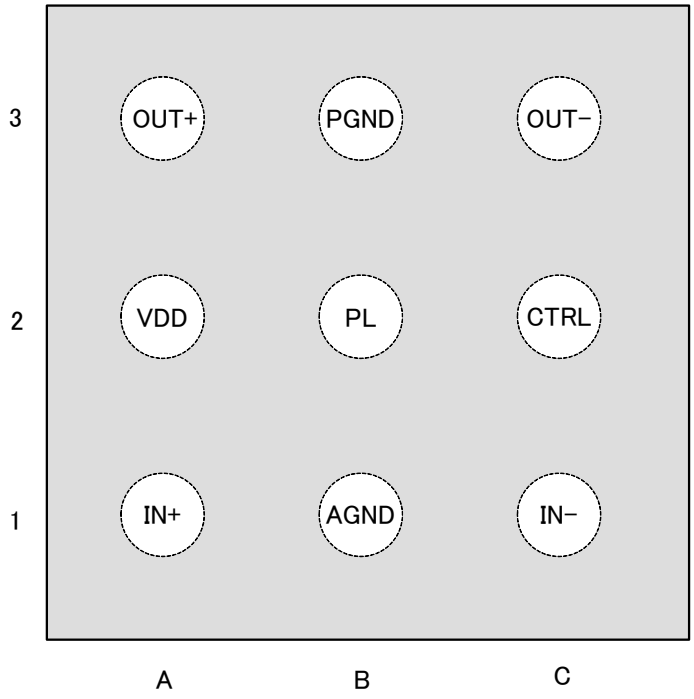
5msec/div 5msec/div

■ Block Diagram



YDA168B Block Diagram

■ Pin Arrangement



Pin Assignment (Top View)

■ Pin Function

No.	Name	I/O	Function
A1	IN+	IA	Differential Input Pin (positive) (Note1, 2)
A2	VDD	Power	Power Supply Pin
A3	OUT+	O	Speaker Output Pin (positive)
B1	AGND	GND	Ground for Analog Circuits
B2	PL	IA	Power Limit Setting Pin (Note1)
B3	PGND	GND	Ground for Output Circuits
C1	IN−	IA	Differential Input Pin (negative) (Note1, 2)
C2	CTRL	IA	Power-down and Non-Clip setting pin
C3	OUT−	O	Speaker Output Pin (negative)

I: Input Pin, O: Output Pin, A : Analog Pin

Note 1: Note that leakage current flows through the protection circuit (PMOS Tr.) when applying a voltage higher than VDD to this pin.

Note 2: When using a D/A Converter output with Noise-Shaping in the former stage, input a signal whose signal components outside the audible frequency have been sufficiently attenuated (e.g. 90dBV at the frequency ranging from 150 kHz to 320 kHz). Otherwise, Beat Noise (i.e. noise caused by interference between two frequencies) may occur because of signal components in the same band as internal clocks used for PWM modulation.

■ Electrical Characteristics

Absolute Maximum Ratings Note)

Item	Symbol	Condition	Min.	Max.	Unit
Supply Voltage Range	V_{DD}	-	– 0.3	6.0	V
Input Pin Voltage Range	V_{IN}	IN +, IN –	V_{GND} – 0.6	V_{DD} + 0.6	V
		Other input pins	V_{GND} – 0.3	V_{DD} + 0.3	
Power Dissipation	P_{D25}	T_A=25 °C *1)	-	1.66	W
	P_{D70}	T_A=70 °C *1)		0.91	
	P_{D85}	T_A=85 °C *1)		0.66	
Junction Temperature	T_{jmax}	-	-	125	ºC
Storage Temperature	T_{STG}	-	– 50	125	ºC
Speaker Impedance	R_{LS}	-	3.2	-	Ω

Note) Absolute Maximum Ratings are values which must not be exceeded to guarantee device reliability and life, and when using a device in excess of the ratings for even a moment, it may immediately cause damage to the device or may significantly deteriorate its reliability. In the system where the voltage at an input pin may exceed the supply voltage (V_{DD} / GND), use an external diode etc. to limit it to the value lower than absolute maximum rating.

* 1: θja = 60 °C/W

(4-layer board, No wind, Copper Foil Thickness 35 µm, Wiring Density 326 %, Board Size 100 mm × 80 mm)

Recommended Operating Conditions

Item	Symbol	Condition	Min.	Typ.	Max.	Unit
Supply Voltage	V_{DD}	-	2.5	3.6	5.25	V
Operating Ambient Temperature	T_A	-	– 40	25	85	ºC

Note) Be sure to use the device within the recommended operating conditions.
Be sure to connect all AGND and PGND pins on a board.
The slew rate should be less than 1V/µsec when turning on the power.

Consumption Current

(V_{DD} = 3.6V, V_{GND} = 0V, T_A = 25 °C, CTRL = V_{MOD3}, PL = V_{DD}, R_L = 8Ω, unless otherwise specified)

Item	Symbol	Condition	Min.	Typ.	Max.	Unit
Consumption Current	I_{DD}	No input, No load	-	5.3	-	mA
Power-down Mode Consumption Current	I_{PD}	CTRL=V_{MOD4}	-	0.5	-	µA

Note) In the measurement conditions with R_L = 8Ω, 8Ω (pure resistor) + 30µH is used.

DC Characteristics

(V_{DD} = 2.5V to 5.25V, V_{GND} = 0V, T_A = – 40 °C to 85 °C, PL = V_{DD}, unless otherwise specified)

Item		Symbol	Condition	Min.	Typ.	Max.	Unit
Startup Threshold Voltage		V_{UVLH}	-	-	2.2	-	V
Startup Threshold Voltage		V_{UVLL}	-	-	2.0	-	V
CTRL Control Pin Input Threshold Voltage	Non-Clip A	V_{MOD1}	-	1.5	1.6	V_{DD}	V
	Non-Clip B	V_{MOD2}	-	1.0	1.18	1.35	V
	Non-Clip OFF	V_{MOD3}	-	0.65	0.75	0.85	V
	Power-down	V_{MOD4}	-	V_{GND}	-	0.1	V
PL Pin Input Threshold Voltage	Power Limit OFF	V_{PDIS}	-	0.8×V_{DD}	-	V_{DD}	V
	Power Limit Enable Mode	V_{PENA}	-	0.45	-	0.7×V_{DD}	V
	Power Limit Fix Mode	V_{PFIX}	-	0	-	0.1	V
High Temperature Protection Function Activated Temperature		T_{OTPH}	-	-	150	-	ºC
High Temperature Protection Function Released Temperature		T_{OTPL}	-	-	120	-	ºC
Input leakage Current		I_{CTRL}	CTRL pin	– 1.0	-	-	µA

AC Characteristics

(V_{DD} = 2.5V to 5.25V, V_{GND} = 0V, T_A = – 40 °C to 85 °C, CTRL = V_{MOD3}, PL = V_{DD}, unless otherwise specified)

Item		Symbol	Condition	Min.	Typ.	Max.	Unit
Startup Time (Power-down Cancel)		T_{STUP}	-	-	20	-	msec
Power-down Setting Time		T_{PDWL}	-	25	-	-	msec
Active Setting Time		T_{PDWH}	-	45	-	-	msec
DC Error Detection Voltage		V_{DCDET}	V_{DD} = 3.6V	-	0.3	-	V
DC Error Detection Time		T_{DCDET}	-	-	1.0	-	sec
Input Cut-off Frequency		fc	C_{IN} = 1.0µF, R_{IN} = 0[*1]	-	16	-	Hz
Non-Clip A	Attack Time	T_{ATA}	CTRL = V_{MOD1}	-	0.5	-	msec/dB
	Release Time	T_{RLA}		-	380	-	
Non-Clip B	Attack Time	T_{ATB}	CTRL = V_{MOD2}	-	0.1	-	msec/dB
	Release Time	T_{RLB}		-	380	-	
Carrier Clock Frequency		F_{PWM}	-	-	500	-	kHz

*1: C_{IN} : DC-cut capacitor at the input stage, R_{IN} : External resistor for setting Gain

Analog Characteristics

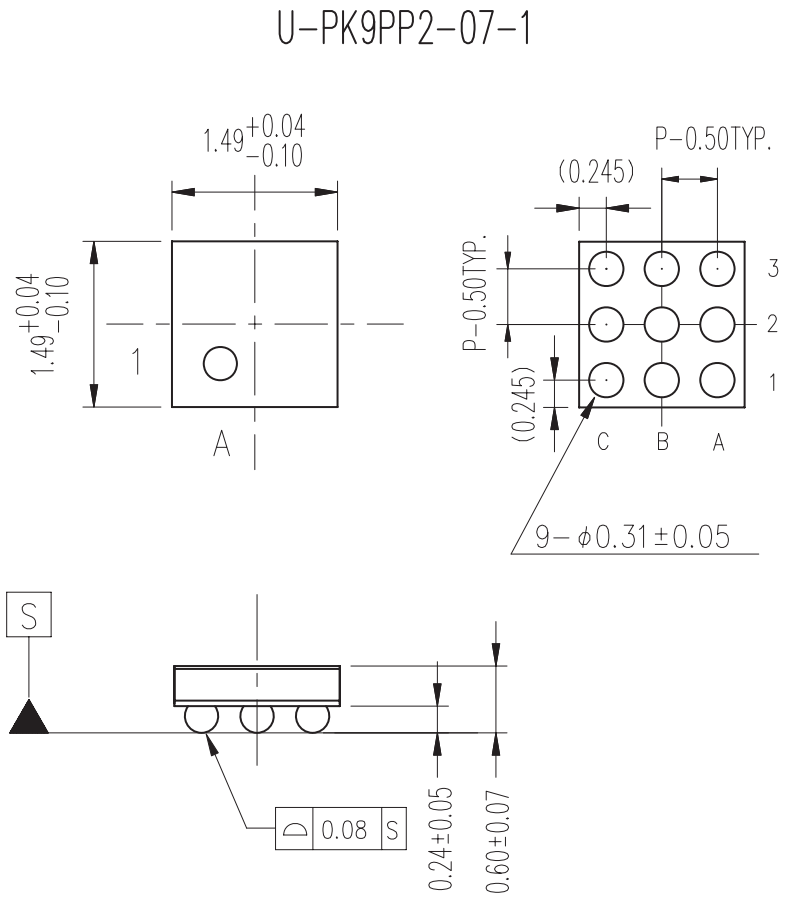
(V_{DD} = 3.6V, V_{GND} = 0V, T_A = 25 °C, CTRL = V_{MOD3}, PL = V_{DD}, A_V = 18dB, R_L = 8Ω, 1kHz, sine wave, unless otherwise specified)

Item	Symbol	Condition	Min.	Typ.	Max.	Unit
Maximum Output	P_O	V_{DD} = 5.0V, R_L = 4Ω, THD = 10%	-	3.3	-	W
		V_{DD} = 3.6V, R_L = 8Ω, THD = 10%	-	0.93	-	
		V_{DD} = 4.2V, R_L = 8Ω, THD = 1%	-	1.00	-	
		V_{DD} = 3.6V, R_L = 8Ω, THD = 1%	-	0.75	-	
Non-Clip Maximum Output	P_{ONC}	V_{DD} = 5.0V, R_L = 4Ω CTRL = V_{MOD1}	-	2.4	-	W
		V_{DD} = 3.6V, R_L = 8Ω CTRL = V_{MOD1}	-	0.70	-	
Power Limit Output	P_{OPL}	PL = 0V (Fix Mode)	-	600	-	mW
Voltage Gain	A_V	-	-	18	-	dB
Total Harmonic Distortion	THD+N	P_O = 0.40W, 1kHz BW : 20kHz	-	0.045	-	%
Residual Noise	N	BW : 20kHz, A-Filter	-	50	-	μVrms
S/N Ratio	SNR	V_{DD} = 5.0V, R_L = 4Ω BW : 20kHz, A-Filter	-	97.2	-	dB
PSRR	PSRR	f = 217Hz, Vripple = 0.1Vpp	-	75	-	dB
Efficiency	η	P_O = 0.8W	-	90	-	%
Output Offset Voltage	V_O	-	-	±3	-	mV
Frequency Characteristics	Fres	C_{IN} = 1.0 μF[*1] 100Hz to 20kHz	– 0.4	-	0.4	dB

*1: C_{IN} : DC-cut capacitor at the input stage

Note) All analog characteristics were obtained by using Yamaha evaluation board. Depending upon pattern layout etc., its characteristics may vary.
In the measurement conditions with R_L = 8Ω, 8Ω (pure resistor) + 30μH is used.

■ Package Dimensions



カッコ内の寸法値は参考値とする。
The value parenthesized is not specified.

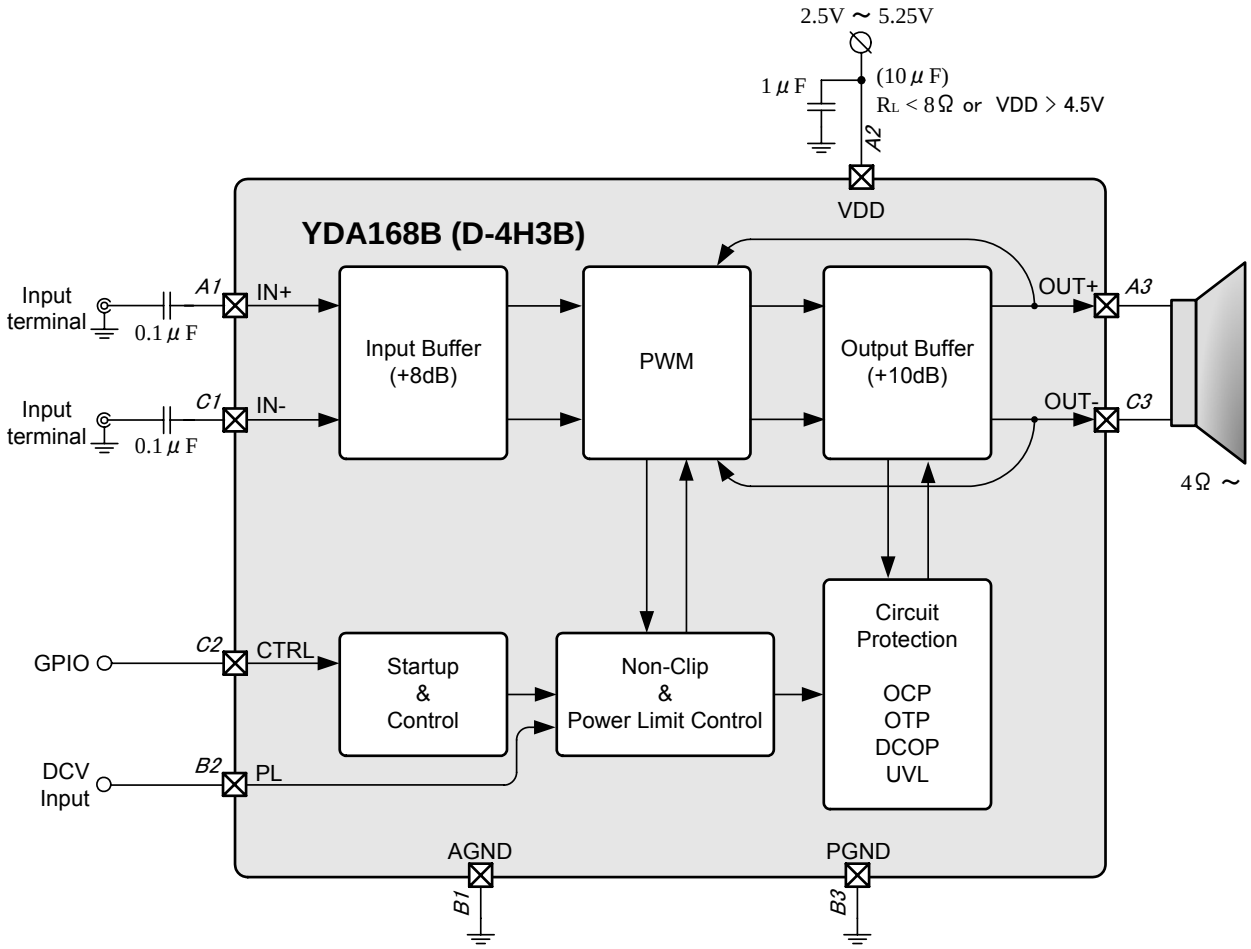
外形寸法はバリを含みます。
Dimensions include burr.

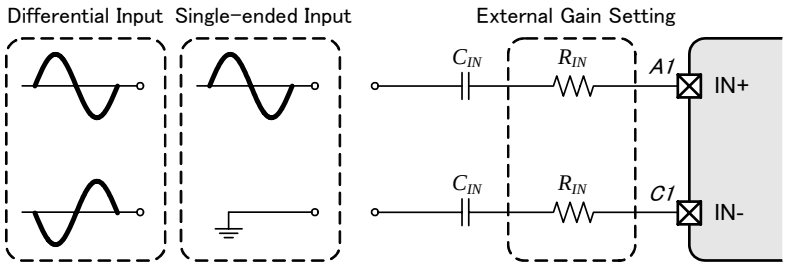
UNIT: mm

注） 1. 表面実装LSIは、保管条件、および、半田付けについての特別な配慮が必要です。
2. 組立工場により、寸法や形状などが異なる場合があります。
詳しくはヤマハ代理店までお問い合わせください。

Note: 1. Special attention needs to be paid to the storage conditions and soldering method of the surface mount IC.
2. Dimension, form, etc. may differ depending on assembly plants.
For details, please contact your local Yamaha agent.

■ Application Example





IMPORTANT NOTICE

1. YAMAHA RESERVES THE RIGHT TO MAKE CHANGES TO ITS PRODUCTS AND TO THIS DOCUMENT WITHOUT NOTICE. THE INFORMATION CONTAINED IN THIS DOCUMENT HAS BEEN CAREFULLY CHECKED AND IS BELIEVED. HOWEVER, YAMAHA SHALL ASSUME NO RESPONSIBILITIES FOR INACCURACIES AND MAKE NO COMMITMENT TO UPDATE OR TO KEEP CURRENT THE INFORMATION CONTAINED IN THIS DOCUMENT.

2. THESE YAMAHA PRODUCTS ARE DESIGNED ONLY FOR COMMERCIAL AND NORMAL INDUSTRIAL APPLICATIONS, AND ARE NOT SUITABLE FOR OTHER USES, SUCH AS MEDICAL LIFE SUPPORT EQUIPMENT, NUCLEAR FACILITIES, CRITICAL CARE EQUIPMENT OR ANY OTHER APPLICATION THE FAILURE OF WHICH COULD LEAD TO DEATH, PERSONAL INJURY OR ENVIRONMENTAL OR PROPERTY DAMAGE. USE OF THE PRODUCTS IN ANY SUCH APPLICATION IS AT THE CUSTOMER'S OWN RISK AND EXPENSE.

3. YAMAHA SHALL ASSUME NO LIABILITY FOR INCIDENTAL, CONSEQUENTIAL OR SPECIAL DAMAGES OR INJURY THAT MAY RESULT FROM MISAPPLICATION OR IMPROPER USE OR OPERATION OF THE PRODUCT.

4. YAMAHA MAKES NO WARRANTY OR REPRESENTATION THAT THE PRODUCTS ARE SUBJECT TO INTELLECTUAL PROPERTY LICENSE FROM YAMAHA OR ANY THIRD PARTY, AND YAMAHA MAKES NO WARRANTY OR REPRESENTATION OF NON-INFRINGEMENT WITH RESPECT TO THE PRODUCTS. YAMAHA SPECIFICALLY EXCLUDES ANY LIABILITY TO THE CUSTOMER OR ANY THIRD PARTY ARISING FROM OR RELATED TO THE PRODUCTS INFRINGEMENT OF ANY THIRD PARTY'S INTELLECTUAL PROPERTY RIGHTS, INCLUDING THE PATENT, COPYRIGHT, TRADEMARK OR TRADE SECRET RIGHTS OF ANY THIRD PARTY.

5. EXAMPLES OF USE DESCRIBED HEREIN ARE MERELY TO INDICATE THE CHARACTERISTICS AND PERFORMANCE OF PRODUCTS. YAMAHA SHALL ASSUME NO RESPONSIBILITY FOR ANY INTELLECTUAL PROPERTY CLAIMES OR OTHER PROBLEMS THAT MAY RESULT FROM APPLICATIONS BASED ON THE EXAMPLES DESCRIBED HEREIN. YAMAHA MAKES NO WARRANTY WITH RESPECT TO THE PRODUCTS, EXPRESS OR IMPLIED, INCLUDING, BUT NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR USE AND TITLE.

6. YAMAHA MAKES EVERY EFFORT TO IMPROVE THE QUALITY AND RELIABILITY OF ITS PRODUCTS. HOWEVER, ALL SEMICONDUCTOR PRODUCTS FAIL WITH SOME PROBABILITY. THEREFORE, YAMAHA REQUIRES THAT SUFFICIENT CARE BE GIVEN TO ENSURING SAFE DESIGN IN CUSTOMER PRODUCTS SUCH AS REDUNDANT DESIGN, ANTI-CONFLAGRATION DESIGN, AND DESIGN FOR PREVENTING MALFUNCTION IN ORDER TO PREVENT ACCIDENTS RESULTING IN INJURY OR DEATH, FIRE OR OTHER SOCIAL DAMAGE FROM OCCURRING AS A RESULT OF PRODUCT FAILURE.

7. INFORMATION DESCRIBED IN THIS DOCUMENT: APPLICATION CIRCUITS AND ITS CONSTANTS AND CALCULATION FORMULAS, PROGRAMS AND CONTROL PROCEDURES ARE PROVIDED FOR THE PURPOSE OF EXPLAINING TYPICAL OPERATION AND USAGE. THEREFORE, PLEASE EVALUATE THE DESIGN SUFFICIENTLY AS WHOLE SYSTEM UNDER THE CONSIDERATION OF VARIOUS EXTERNAL OR ENVIRONMENTAL CONDITIONS AND DETERMINE THEIR APPLICATION AT THE CUSTOMER'S OWN RISK. YAMAHA SHALL ASSUME NO RESPONSIBILITY FOR CLAIMS, DAMAGES, COSTS AND EXPENSES CAUSED BY THE CUSTOMER OR ANY THIRD PARTY, OWING TO THE USE OF THE ABOVE INFORMATION.

PRECAUTIONS AND INSTRUCTIONS FOR SAFETY

⚠ WARNING

Prohibited	Do not use the device under stresses beyond those listed in Absolute Maximum Ratings (current, voltages, safety operation ranges, temperature, etc.). Such stresses may become causes of breakdown, damages, or deterioration, causing explosion or ignition, and this may lead to fire or personal injury.
Prohibited	Do not mount the device reversely or improperly and also do not connect a supply voltage in wrong polarity. Otherwise, this may cause current and/or power-consumption to exceed the absolute maximum ratings, causing personal injury due to explosion or ignition as well as causes of breakdown, damages, or deterioration. And, do not use the device again that has been improperly mounted and powered once.
Prohibited	Do not short between pins. In particular, when different power supply pins, such as between high-voltage and low-voltage pins, are shorted, smoke, fire, or explosion may take place.
Instructions	As to devices capable of generating sound from its speaker outputs, please design with safety of your products and system in mind, in case of the occurrence of unusual speaker output due to a malfunction or failure. A speaker radiates heat in a voice-coil by air flow accompanying vibration of a diaphragm. When a DC signal (several Hz or less) is input due to device failure, heat radiation characteristics degrade rapidly, thereby leading to voice-coil burnout, smoke, or ignition of a speaker even if it is used within the rated input value.

⚠ CAUTION

Prohibited	Do not use Yamaha products in a position close to burning materials, combustible substances, or inflammable materials, in order to prevent the spread of the fire caused by Yamaha products, and to prevent the smoke or fire of Yamaha products due to peripheral components.
Instructions	Generally, semiconductor products may malfunction and break down due to aging, degradation, etc. It is the responsibility of user to take actions such as safety design of products and the entire system and also fail-safe design according to applications, so as not to cause property damage and/or bodily injury due to malfunction and/or failure of semiconductor products.
Instructions	The built-in DSP may output the maximum amplitude waveform suddenly due to malfunction from disturbances etc. and this may cause damage to headphones, external amplifiers, and human body (ear). Please pay attention to safety measures for device malfunction and failure both in product and system design.
Instructions	As semiconductor devices are not nonflammable, overcurrent or failure may cause smoke or fire. Therefore, products should be designed with safety in mind such as overcurrent protection circuit etc. so that it does not keep on flowing during operation or failure.
Instructions	Products should be designed with fail safe in mind in case of malfunction of the built-in protection circuits. Note that the built-in protection circuits such as overcurrent protection circuit and high temperature protection circuit do not always protect the internal circuits. In some cases, depending on usage or situations, such protection circuit may not work properly or the device itself may break down before the start of the protection circuit.
Instructions	Use a stable power supply. The use of unstable power supply may lead to malfunctions of the protection circuit, causing device breakdown, personal injury due to explosion, or smoke or fire.
Instructions	Product's housing should be designed with the possibility of short-circuiting between pins of the mounted device due to foreign conductive substances (such as metal pins etc.). Moreover, the housing should be designed with spatter prevention etc. due to explosion or burning. Otherwise, the spattered substance may cause bodily injury.
Instructions	The device may be heated to a high temperature due to internal heat generation during operation. Therefore, please take care not to touch an operating device directly.

Notice The specifications of this product are subject to improvement changes without prior notice.

CONTACT

YAMAHA CORPORATION

Semiconductor Division

■ **Head Office**
203 Matsunokijima, Iwata, Shizuoka 438-0192 JAPAN
Tel. +81-539-62-4918 Fax. +81-539-62-5054

■ **Tokyo Office**
2-17-11 Takanawa, Minato-ku, Tokyo 108-8568 JAPAN
Tel. +81-3-5488-5431 Fax. +81-3-5488-5088

■ **Osaka Office**
3-12-12 Minami Senba, Chuo-ku, Osaka 542-0081 JAPAN
Tel. +81-6-6252-6221 Fax. +81-6-6252-6229

Printed in Japan