VA2228

Low EMI Stereo Class D Audio Amplifier

General Description

The VA2228 is a cost-effective filter-less Class D stereo audio power amplifier that operates in wide range of various power supplies. VA2228 provides two selectable gain settings (26dB, 36dB). VA2228 can output 15W per channel into 8Ω load with lower supply current and fewer external components for driving bridged-tied stereo speaker directly with excellent EMI performance. With the function of power limit, the speakers could be operated safely and the input signal would be also normalized.

VA2228 operates with high efficiency energy conversion up to 88% (8Ω Load) so that the external heat sink can be eliminated while playing music.

VA2228 also integrates Anti-Pop, Output Short & Over-Heat Protection Circuitry to ensure device reliability. This device also provides the DC detect and protection scheme to prevent the damage of speaker voice coils.

The VA2228 is available in small TSSOP-28 green package with exposed pad.

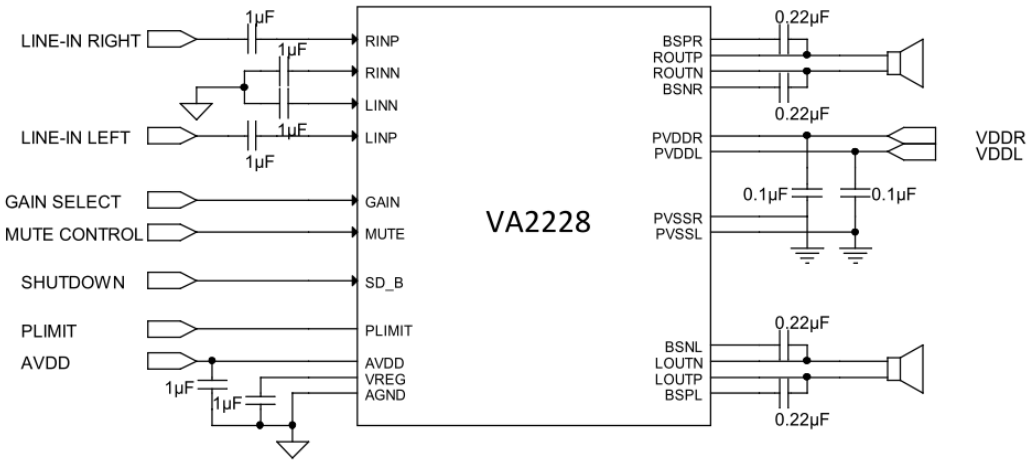
Features

- Operation voltage from 6V to 26V
- Excellent EMI performance
- Maximum 88% efficiency with an 8Ω speaker
  - 12W@4Ω load at 12V
  - 20W@8Ω load at 18V
- 26dB or 36dB selectable gain settings
- Mute control for eliminating pop noise
- Scalable power limit function
- Speaker DC detection and protection
- Thermal protection with Auto-recovery
- Short circuit and thermal protection
- RoHS 2.0 compliant TSSOP-28 green package with exposed pad

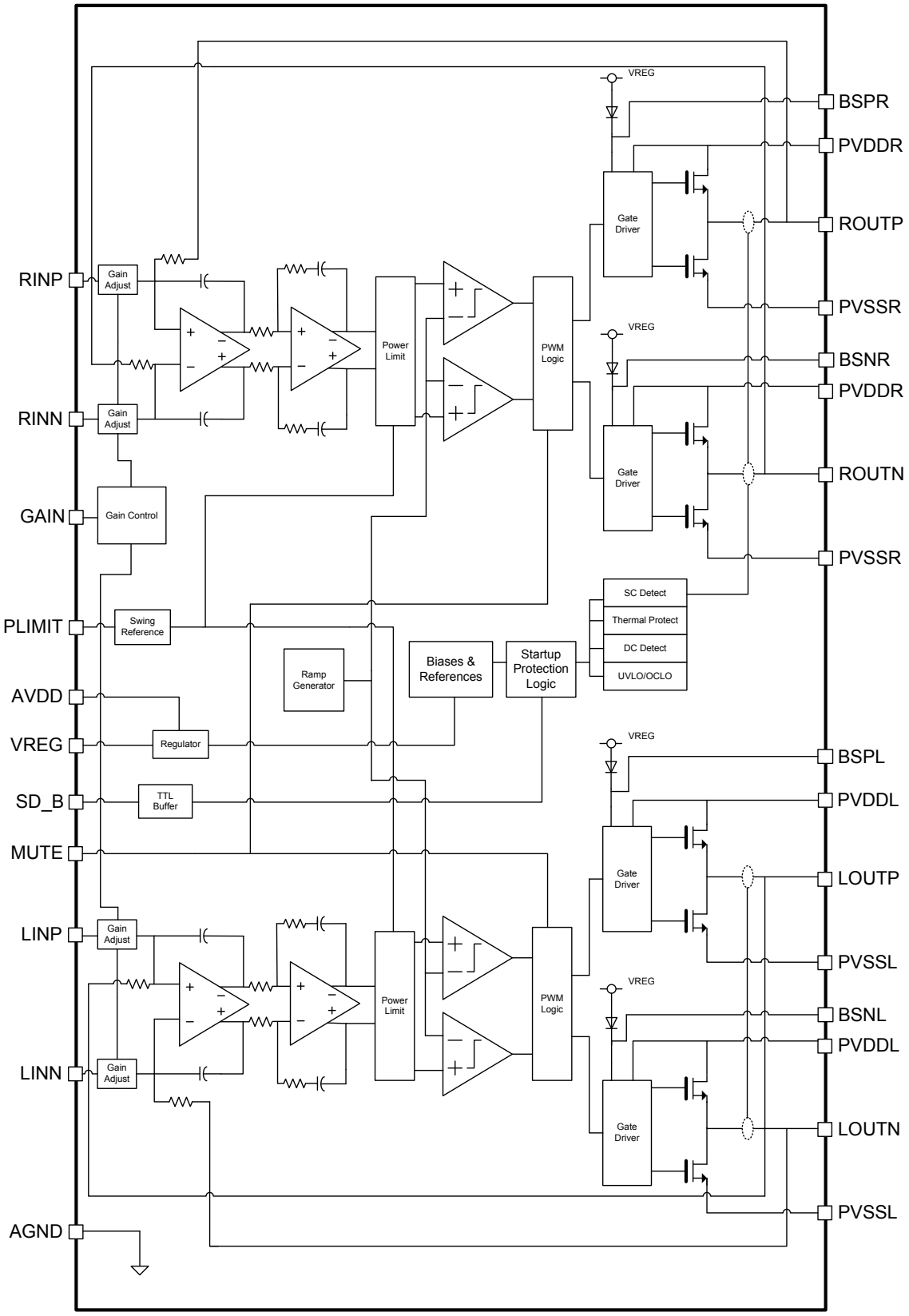
Applications

- LCD TV
- Multimedia Speakers
- Sound Bar

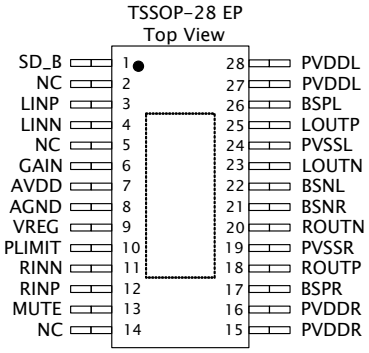
Typical Application



Functional Block Diagram



Pin Assignments And Descriptions



Pin No.	Pin	I/O/P	Function Description
1	SD_B	I	Shutdown control terminal. Low active. TTL Logic levels with compliance to AVDD.
2	NC	-	No internal connection.
3	LINP	I	Left channel positive audio signal input.
4	LINN	I	Left channel negative audio signal input.
5	NC	-	No internal connection.
6	GAIN	I	Gain selection bit.
7	AVDD	P	Analog Power Supply.
8	AGND	P	Analog Ground.
9	VREG	O	Regulated Voltage. Nominal voltage is 5.75V.
10	PLIMIT	I	Power Limit Level Adjust. Connect a resistor divider from VREG to GND to set power limit. Connect to VREG directly for no power limit.
11	RINN	I	Right channel negative audio signal input.
12	RINP	I	Right channel positive audio signal input.
13	MUTE	I	Mute signal for fast disable/enable of outputs (HIGH = outputs Hi-Z, LOW = outputs enabled). Low voltage level compliance to VREG.
14	NC	-	No internal connection.
15,16	PVDDR	P	Right channel power supply.
17	BSPR	I	Bootstrap I/O for right channel positive high-side switch.
18	ROUTP	O	Right channel positive output.
19	PVSSR	P	Right channel power ground.
20	ROUTN	O	Right channel negative output.
21	BSNR	I	Bootstrap I/O for right channel negative high-side switch.
22	BSNL	I	Bootstrap I/O for left channel negative high-side switch.
23	LOUTN	O	Left channel negative output.
24	PVSSL	P	Left channel power ground.
25	LOUTP	O	Left channel positive output.
26	BSPL	O	Bootstrap I/O for left channel positive high-side switch.
27,28	PVDDL	P	Left channel power supply.

Absolutely Maximum Ratings

Over operating free-air temperature range, unless otherwise specified (* 1)

Symbol	Parameter	Limit	Unit
V_{DD}(PVDDR, PVDDL, AVDD)	Supply voltage	-0.3 to 30	V
V_I (GAIN, SD_B)	Input voltage	-0.3 to V_{DD}+0.3	V
V_I (PLIMIT)	Input voltage	-0.3 to V_{REG}+0.3	V
V_I (LINN, RINN, LINP, RINP,MUTE)	Input voltage	-0.3 to 6.5	V
T_A	Operating free-air temperature range	-40 ~ +85	°C
T_J	Operating junction temperature range(* 2)	-40 to +150	°C
T_{STG}	Storage temperature range	-65 to 150	°C
$R_{(LOAD)}$	Minimum load resistance	8 (V_{DD}>12V) 4 (V_{DD}≤12V)	Ω
θ_{JC}	Thermal Resistance (Junction to Case)	16	°C/W
θ_{JA}	Thermal Resistance (Junction to Air)	37	°C/W
Electrostatic discharge	Human body model	±2	kV
Electrostatic discharge	Machine model	±200	V

(*1): Stress beyond those listed at "absolute maximum rating" table may cause permanent damage to the device. These are stress rating ONLY. For functional operation are strongly recommend follow up "recommended operation conditions" table.

Recommended Operating Conditions

Over operating free-air temperature range, unless otherwise specified.

Symbol	Parameter	Test Condition	Specification		Unit
			Min	Max	
V_{DD}	Supply voltage	PVDDL, PVDDR, AVDD	6	26	V
V_{IH}	High level input voltage (GAIN, SD_B, MUTE)	V_{DD}=24V	2		V
V_{IL}	Low level input voltage (GAIN, SD_B, MUTE)	V_{DD}=24V		0.8	V
T_A	Operating free-air temperature		-40	85	°C

Electrical Characteristics

T_A = 25℃, V_{DD} = 12V, R_L=8Ω, GAIN=26dB, unless otherwise noted.

Symbol	Parameter	Test Condition		Specification			Unit
				Min	Typ.	Max	
$\|V_{OS}\|$	Output offset voltage (measured differentially)	V_I=0V			1.5	15	mV
I_Q	Quiescent current	SD_B=2V, No load			30	50	mA
I_{SD}	Shutdown current	SD_B=0.8V, No load			300	500	μA
t_{ON}	Shutdown turn-on time	SD_B=2V			20		ms
t_{OFF}	Shutdown turn-off time	SD_B=0.8V			2		μs
f_{OSC}	Internal oscillation frequency				300		kHz
A	Amplifier gain	GAIN=0.8V			26		dB
		GAIN=2V			36		
$R_{DS(ON)}$	Drain-Source ON resistance[1]	V_{DD}=12V, I_{OUT}=500mA	High Side		240		mΩ
			Low Side		240		
V_{REG}	Regulator output	I_{VREG} = 100μA, V_{DD}=6~26V		5.55	5.75	5.95	V
t_{DC-DET}	DC detect time				450		ms

(1) Design center value.

Operating Characteristics

V_{DD}=12V, A_V=26dB, T_A = 25℃ unless otherwise noted.

Symbol	Parameter	Test Condition		Specification			Unit
				Min	Typ.	Max	
P_O	Output power	THD+N=10%, f=1kHz, R_L=8Ω	V_{DD} = 18V[1]		16.5		W
			V_{DD} = 12V		9.3		
		THD+N=1%, f=1kHz, R_L=8Ω	V_{DD} = 18V[1]		12.8		W
			V_{DD} = 12V		7.4		
THD+N	Total harmonic distortion plus noise	V_{DD}=15V, P_O=7.5W, R_L=8Ω, f=1kHz			0.15		%
$\|V_{OS}\|$	Offset voltage				20		mV
$\|K_{SVR}\|$	Supply ripple rejection ration	Input AC-Grounded, C_i=1μF, f=1kHz			68		dB
|SNR|	Signal-to-Noise ratio	A-weighted, THD+N=1%, R_L=8Ω			96		dB
V_n	Output voltage noise	C_i=1μF, f=20Hz to 20kHz, A-weighted, Input AC-Grounded			160		μV_{RMS}
|CMRR|	Common mode rejection ratio	V_{DD}=12V, V_{IC}=1V_{PP}	f=120Hz		66		dB
Z_I	Input impedance				60		kΩ
Crosstalk	Channel separation	V_O=1W, f=1kHz			96		dB

(1) Heat-sink is required.

Functional Descriptions

Gain Settings

The gain of the VA2228 can be set by GAIN pin. The gain ratios listed in Table 1 are implemented by changing the taps on the feedback resistors in the preamplifier stage.

The input resistance is depended on the gain setting. Since the gain setting is determined by the ratio of the internal feedback resistive network, the variation of the gain is small. But the absolute value of the input resistance may shift by ±20% at the same gain. In actual design cases, 80% of nominal value should be assumed as the input resistance of VA2228 in the input network of whole amplifier.

Gain	Gain Ratio	Resistance	Range
1	36dB	9kΩ	7.2kΩ~10.8kΩ
0	26dB	30kΩ	24kΩ~36kΩ

Table 1. Gain Setting

Amplifier Input Impedance

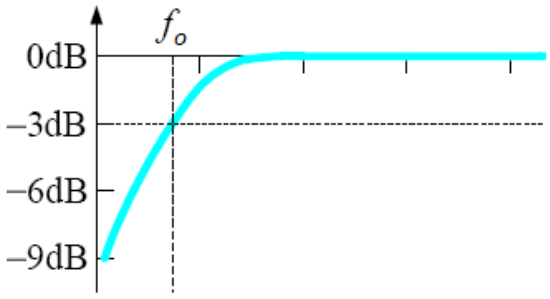


Figure 1. Cut-off point of high-pass filter

In most cases, no extra resistor needs to be added on the input of VA2228. The actual input resistor is already determined while selecting the gain. If a single capacitor is used in the input high-pass filter, the cut-off frequency fo may vary with the change of gain setting. The -3dB point of the cut-off frequency can be calculated by the following equation,

$$fo = \frac{1}{2\pi \times R_I \times C_I} \quad \text{(Hz)} \quad \text{Equation (2)}$$

,where the R_I values is given in Table 1.

Shutdown Operation

The VA2228 employs a state of shutdown mode to reduce supply current to the absolute minimum level during periods of nonuse for power conservation. This terminal should be held high during normal operation when the amplifier is in normal operating. Pulling low causes the output drivers shutdown and the amplifier to enter a low-current state. Do not leave it unconnected, because there is no weakly pulling resistor inside the amplifier.

Remember that to place the amplifier in the shutdown state prior to removing the power supply voltage so that power-off pop noise can be eliminated.

VREG Supply

The V_{REG} Supply is used to bias the gates of the output full-bridge upper half MOSFETs. It could be used to supply the PLIMIT pin and related voltage divider circuit. Add at least 1μF capacitor to ground at this pin.

Speaker Protection

Due to the nature of Class D amplifiers, the speakers may have DC current if the audio inputs get DC voltage in any case. An output DC fault will shut down the audio amplifier and change the state of output into high impedance and the amplifier

Functional Descriptions (cont.)

will be auto recovery again.

To resolve the case of DC input, it is good to treat it as very low frequency sine wave much lower than audio band such as 2Hz. Based on this criteria, a DC detect fault shall be issued when the output differential duty-cycle of either channel exceeds 14% for more than 500ms at the same polarity. This feature protects the speakers away from large currents.

The minimum differential input DC voltages required to trigger the DC detection fault are listed in Table 2.

A_V (dB)	V_{IN} (mV, Differential)
36	17
26	56

Table 2. DC detect fault threshold

To resume the normal operation, it is necessary to power off the amplifier and then power on, cycling SD_B can not resume normal operation.

Short Circuit Protection

VA2228 has protection from over-current conditions caused by a short circuit on the output stage. The amplifier outputs are switched to a high impedance state when the short circuit protection latch is engaged. The VA2228 will attempt to power-on again and the fault will be auto recovery if the short issue has been resolved.

Thermal Protection

Thermal protection on the VA2228 prevents damage to the device when the internal die temperature exceeds 170°C. There is a ±30°C tolerance on this trip point from device to device. Once the die temperature exceeds the thermal set point, the device enters into the shutdown state and the outputs are disabled. This is not a latched fault. The thermal fault is cleared once the temperature of the die is reduced by 30°C. VA2228 will be back to normal operation at this point with no external system interaction.

Power Limit Operation

The voltage at PLIMIT terminal (pin 10) can be used to limit the power to levels below that which is possible based on the supply rail. Add a resistor divider from VREG to ground to set the voltage at the PLIMIT terminal. An external reference may also be used if precise limitation is required. Also add a 1μF capacitor from this pin to ground.

The PLIMIT circuit sets a limit on the output peak-to-peak voltage. The limiting is done by limiting the duty cycle to fixed maximum value. This limit can be thought of as a "virtual" voltage rail which is lower than the supply connected to power rail. This "virtual" rail is 5 times the voltage at the PLIMIT pin. This output voltage can be used to calculate the maximum output power for a given maximum input voltage and speaker impedance.

$$P_{OUT} = \frac{\left(\left(\frac{R_L}{R_L + 2 \times R_S}\right) \times V_P\right)^2}{2 \times R_L}$$

V_P=5 x PLIMIT voltage if PLIMIT<5 x V_P

P_{OUT} (with 10% THD) = 1.25 x P_{OUT}

where R_S is the total series resistance including $R_{DS(ON)}$ and any resistance in the output filter. R_L is the load resistance. V_P is the peak amplifier of the output possible within the supply rail.

Mute Operation

Functional Descriptions (cont.)

The MUTE pin is an input for controlling the output state of the VA2228. A logic high on this terminal disables the outputs. A logic low on this pin enables the outputs. This terminal may be used as a quick disable/enable of outputs when transitioning between different audio sources, or turning off output stage to eliminate the charging noise from upstream CODEC capacitor. The MUTE terminal is recommended not to be left floating. For power conservation, the SD_B terminal should be used to reduce the quiescent current to the absolute minimum level.

Application Information

Output Filter

Many applications require a ferrite bead filter at least. The ferrite filter reduces EMI above 30MHz. When selecting a ferrite bead, choose one with high impedance at high frequencies, but low impedance at low frequencies, be aware of its maximum current limitation. The VA2228 has built-in adapted modulation scheme for better EMI performance.

Use an LC output filter if there are low frequency (<1 MHz) EMI sensitive circuits and there are long wires from the amplifier to the speaker.

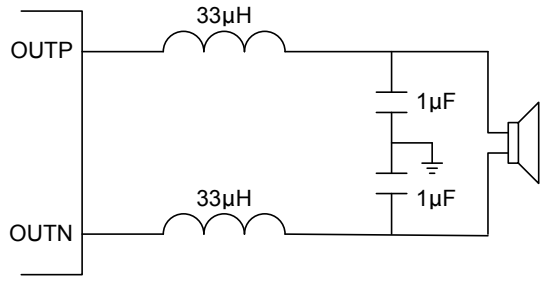


Figure 2. Typical LC Output Filter, Speaker Impedance=8Ω

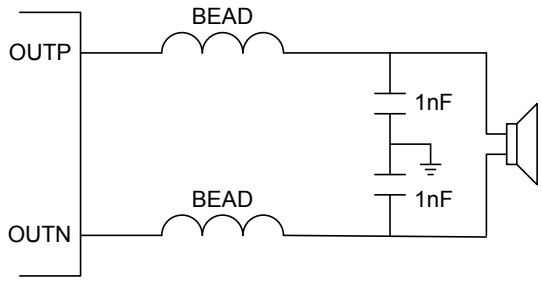


Figure 3. Typical Ferrite Chip Bead Output Filter

Inductors used in LC filters must be selected carefully. A significant change in inductance at the peak output current of the VA2228 will cause increased distortion. The change of inductance at currents up to the peak output current must be less than 0.1μH per amp to avoid this. Also note that smaller inductors than 33μH may cause an increase in distortion above what is shown in preceding graphs of THD versus frequency and output power. In all cases, avoid using inductors which value are less than 22μH.

Like the selection of the inductor in LC filters, the capacitor must be selected carefully, too. A significant change in capacitance at the peak output voltage of the VA2228 will cause increased distortion. LC filter capacitors should be double of DC voltage ratings of the peak application voltage (the power supply voltage) at least. In general, it is strongly recommended using capacitors with good temperature performance like X5R series.

Output Snubbers

In Figure 4, the 330pF capacitors in series with 10Ω resistors connected with the outputs of the VA2228 are snubber circuits. They smooth switching transitions and reduce overshoot and ringing. With these networks, THD+N can be improved at lower power levels and EMC can be reduced 2~4 dB at middle frequencies. They increase quiescent current by 3mA~11mA depending on supply voltage.

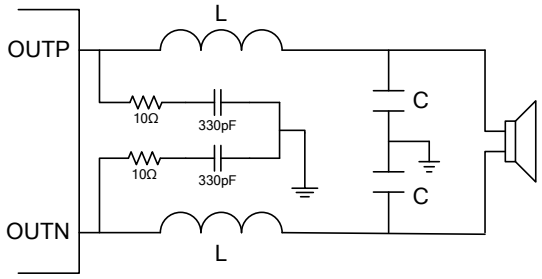


Figure 4. Output Snubber Circuits

Low ESR Capacitors

Low ESR capacitors are high recommended for this

Application Information (cont.)

application. In general, a practical capacitor can be modeled simply as a resistor in series with an ideal capacitor. The voltage drop across this unwanted resistor can eliminate the effects of the ideal capacitor. Place low ESR capacitors on supply circuitry can improve THD+N performance.

Boot-Strap Capacitors

The full H-bridge output stages use only MOS transistors. Therefore, they require bootstrap capacitors for the high side of each output to turn on correctly. A 0.22μF ceramic capacitor, rated for at least 25V, must be connected from each output to its corresponding boot-strap input. Specifically, one 0.22μF capacitor must be connected from OUTP to BSP, and one 0.22μF capacitor must be connected from OUTN to BSN.

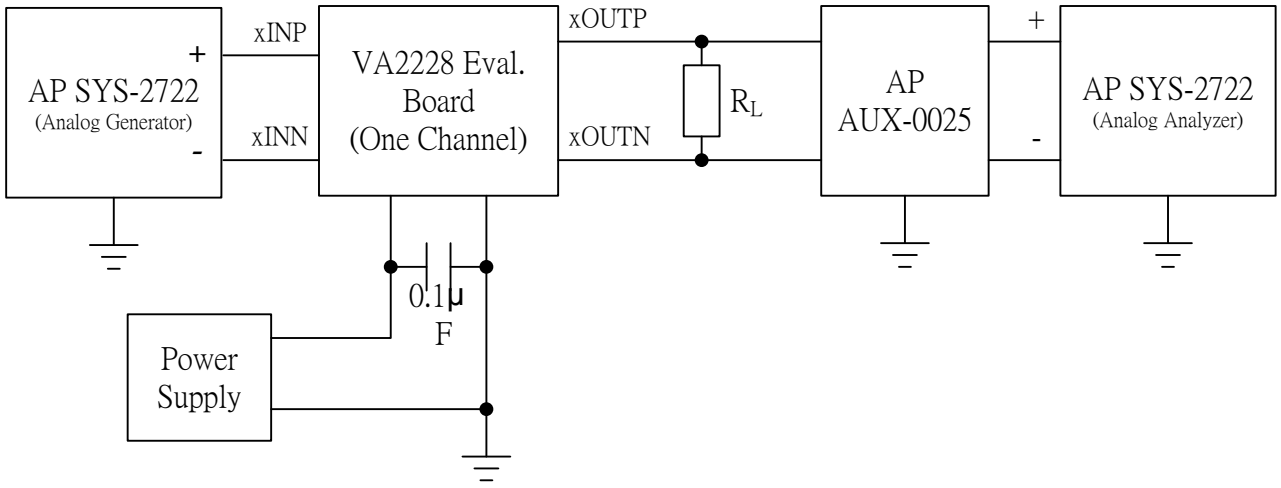
The bootstrap capacitors connected between the BSP or BSN pins and corresponding output function as a floating power supply for the high side N-channel power MOSFET gate drive circuitry. During each high side switching cycle, the bootstrap capacitors hold the gate-to-source voltage high enough to keep the high-side MOSFETs turned on.

Decoupling Capacitors

VA2228 requires appropriate power decoupling to minimize the output total harmonic distortion (THD) and improves EMC performance. Power supply decoupling also prevents intrinsic oscillations for long lead lengths between the amplifier and the speaker. The optimum decoupling can be achieved by using two different types of capacitors which target different types of noise on the power supply lines. For higher frequency spikes, or digital hash on the rail, a good low ESR ceramic capacitor, for example 0.1μF to 10μF, placed as close as possible to PVDDR and PVDDL pins works best. For filtering lower frequency noise, a larger low ESR aluminum electrolytic capacitor of 470μF or greater placed near the audio power amplifier is suggested. The 470μF capacitor also serves as local storage capacitor for supplying current during heavy power output on the amplifier outputs. The PVDDR and PVDDL terminals provide the power to the output transistors, so a 470μF or larger capacitor should be placed by PVDDR and PVDDL terminals as near as possible. A 10μF ceramic capacitor on each PVDDR/PVDDL terminal is also recommended.

Typical Characteristic

Test Setup Connection Diagram

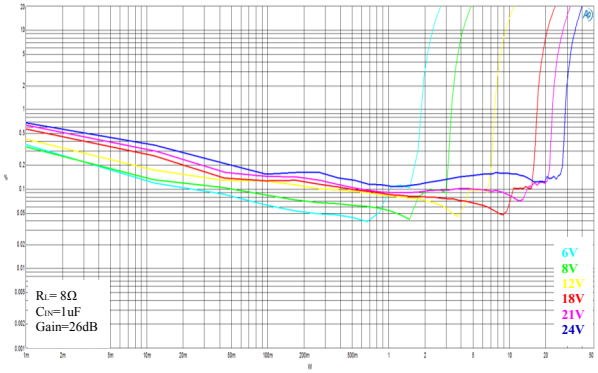


* Remove all L/C (BEAD) filter components on board before performing all measurements.

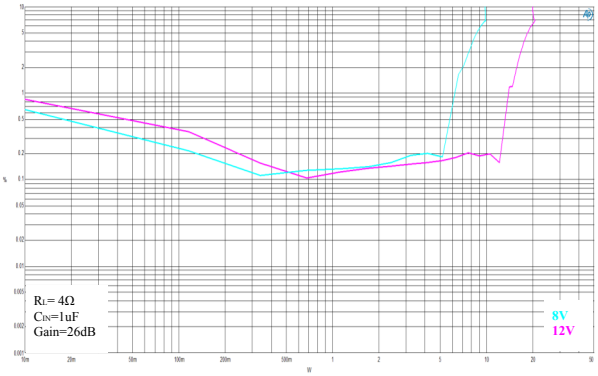
** Connection diagram is for one-channel configuration.

Typical Characteristic (cont.)

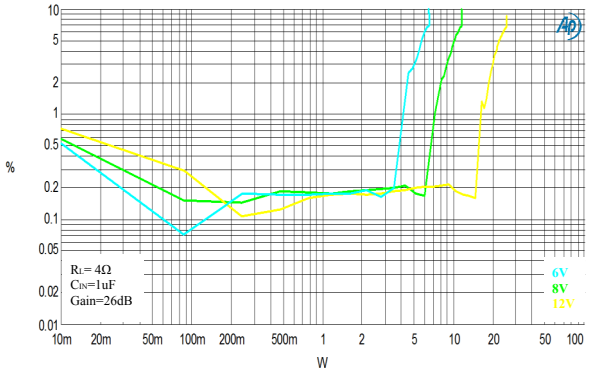
THD+N vs. Output Power, 8Ω load (BTL)



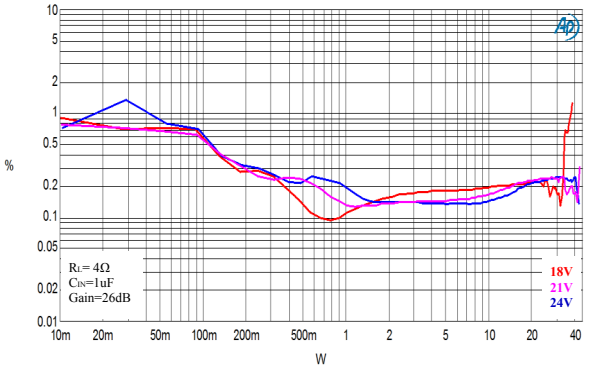
THD+N vs. Output Power, 4Ω load (BTL)



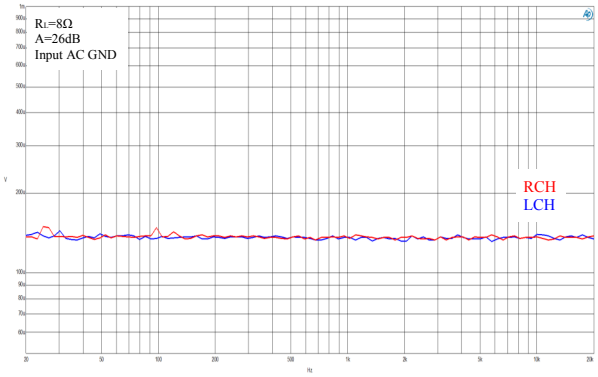
THD+N vs. Output Power, 4Ω load A (PBTL)



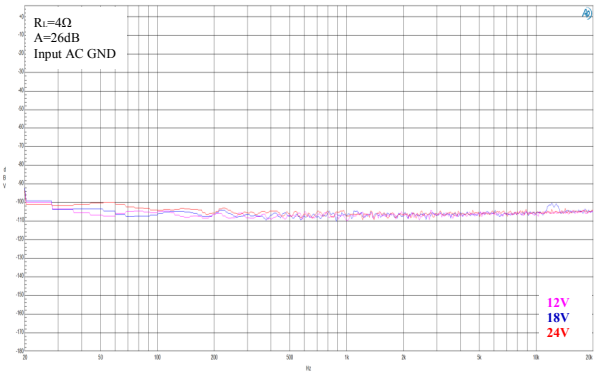
THD+N vs. Output Power, 4Ω load B (PBTL)



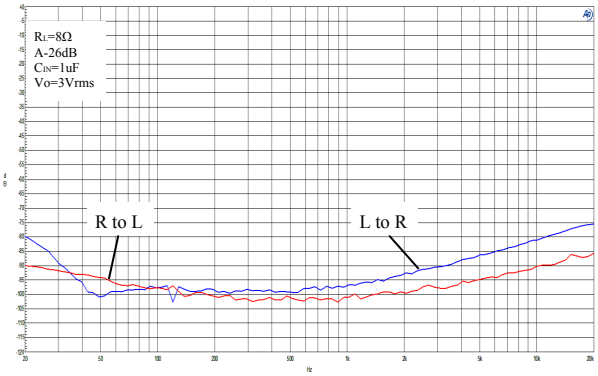
Noise, 12V, 8Ω load (BTL)



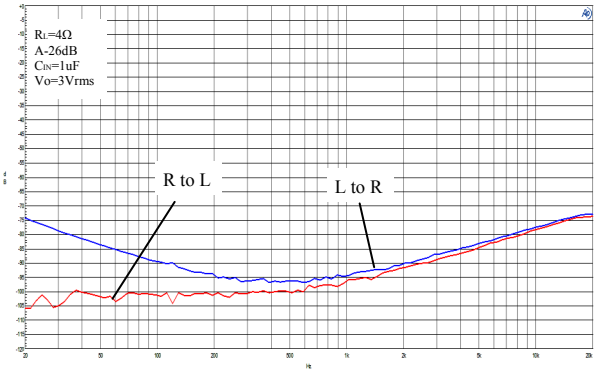
Noise FFT, 4Ω load (BTL)



Cross-Talk, 24V, 8Ω load (BTL)

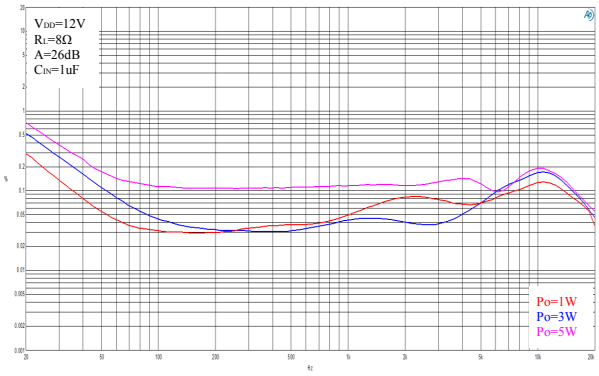


Cross-Talk, 12V, 4Ω load (BTL)

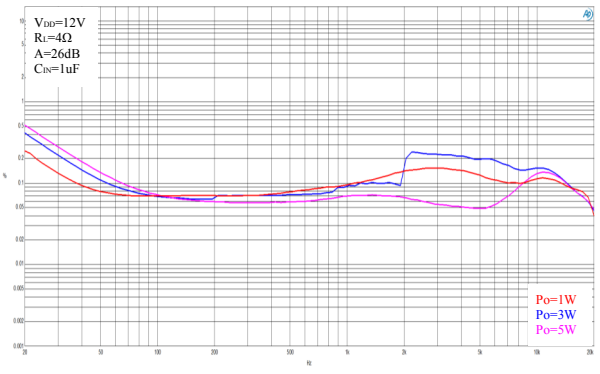


Typical Characteristic (cont.)

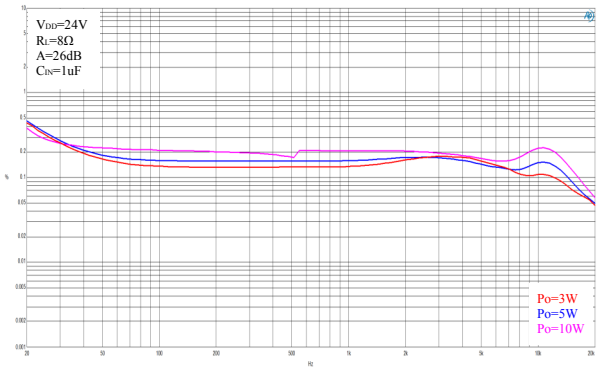
THD + N (%) vs. Frequency, 12V, 8Ω load (BTL)



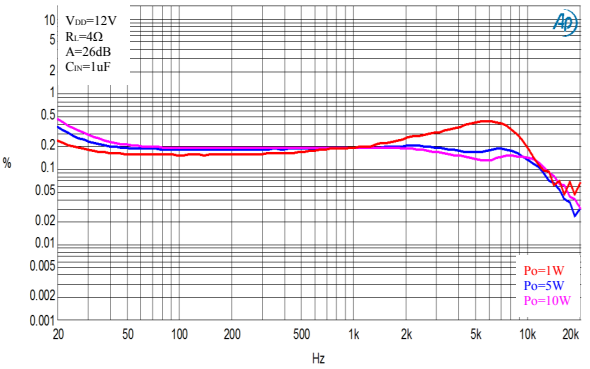
THD + N (%) vs. Frequency, 12V, 4Ω load (BTL)



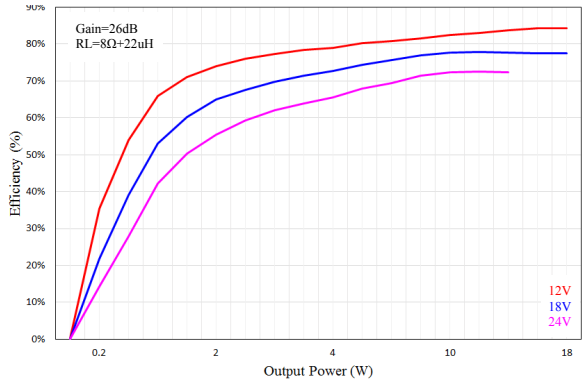
THD + N (%) vs. Frequency, 24V, 8Ω load (BTL)



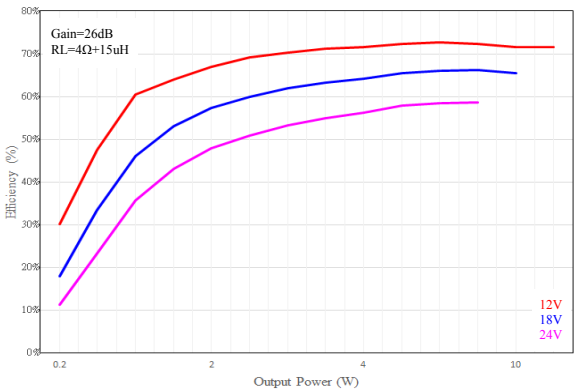
THD + N (%) vs. Frequency, 24V, 4Ω load (PBTL)



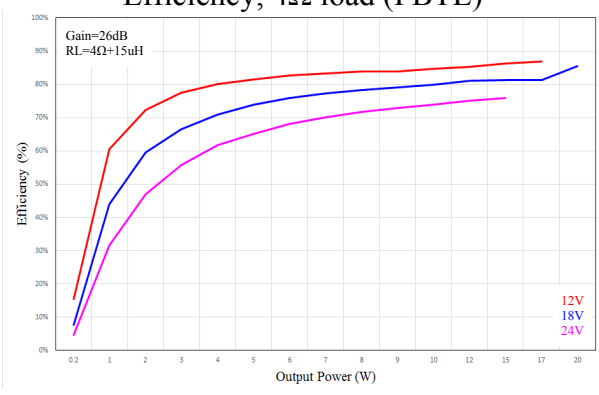
Efficiency, 8Ω load / 2ch (BTL)



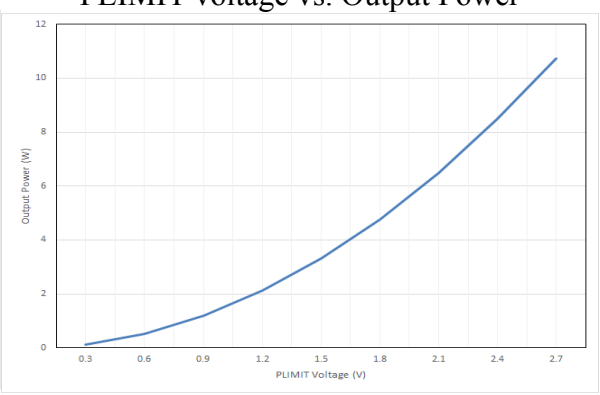
Efficiency, 4Ω load / 2ch (BTL)



Efficiency, 4Ω load (PBTL)

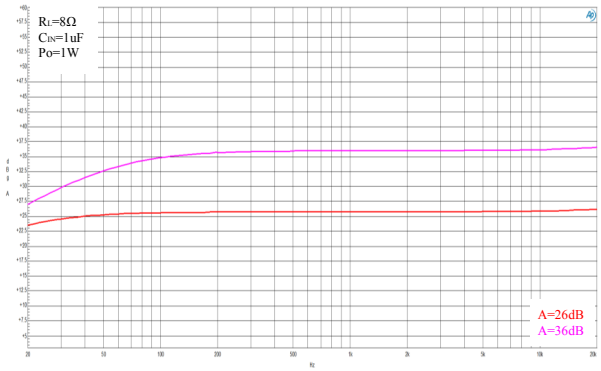


PLIMIT voltage vs. Output Power

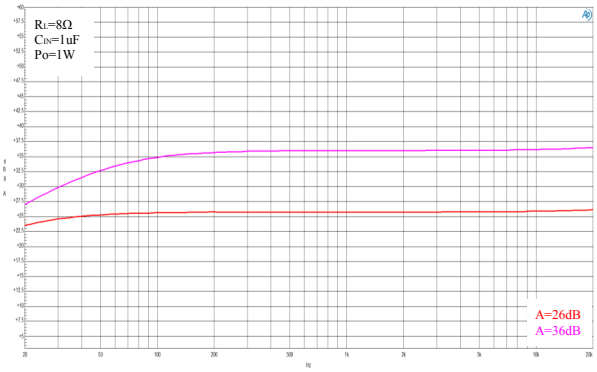


Typical Characteristic (cont.)

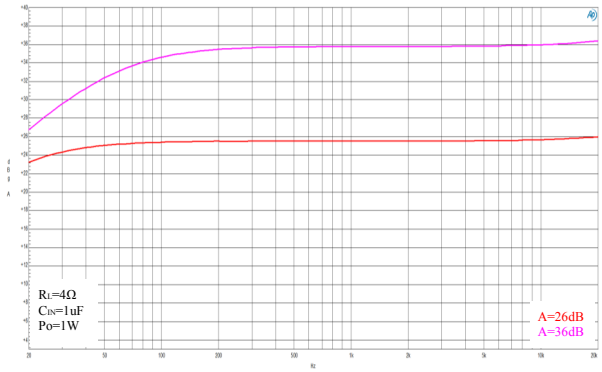
Frequency Response, 12V, 8Ω load (BTL)



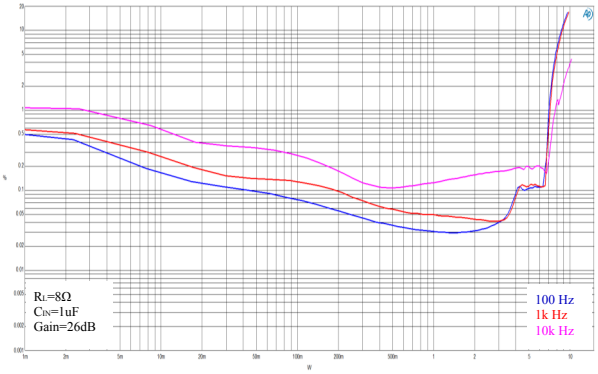
Frequency Response, 24V, 8Ω load (BTL)



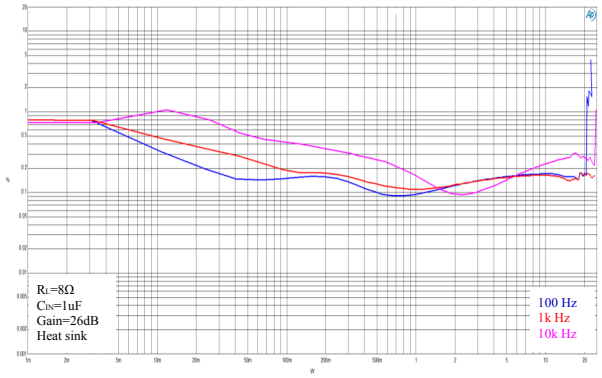
Frequency Response, 12V, 4Ω load (BTL)



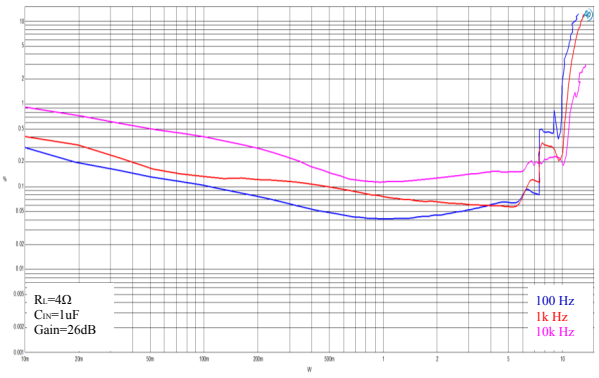
THD+N vs. Freq. vs. Po, 12V, 8Ω load (BTL)



THD+N vs. Freq. vs. Po, 24V, 8Ω load (BTL)



THD+N vs. Freq. vs. Po, 12V, 4Ω load (BTL)



Application Circuit

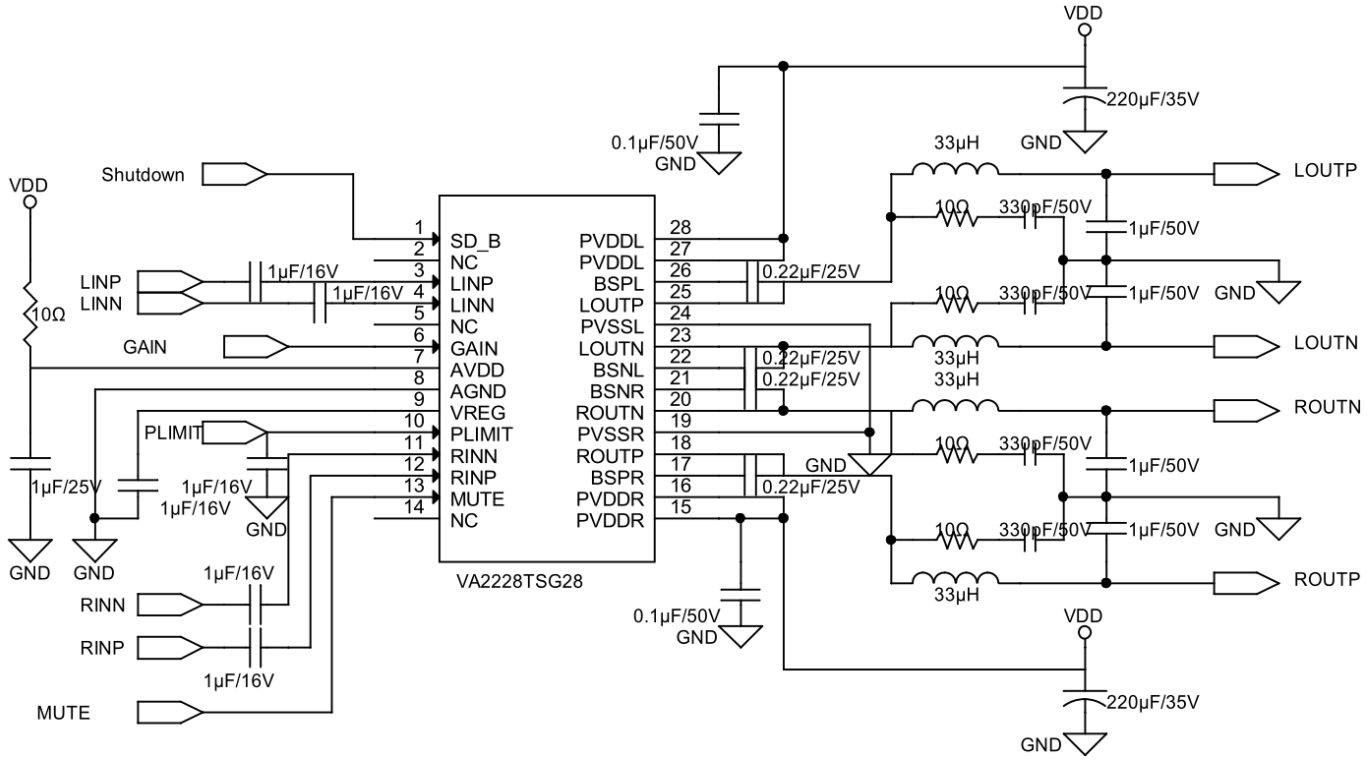


Figure 5. VA2228 Stereo Reference Application with LC Filter

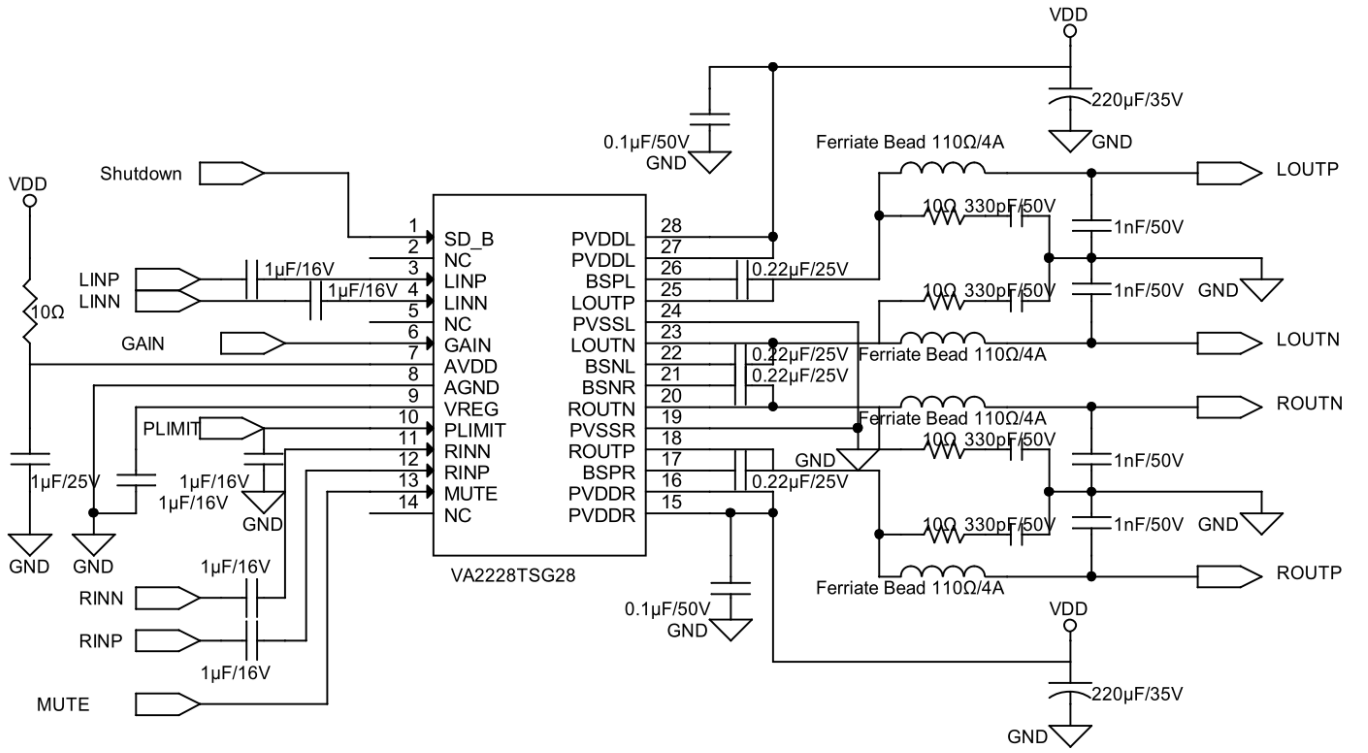
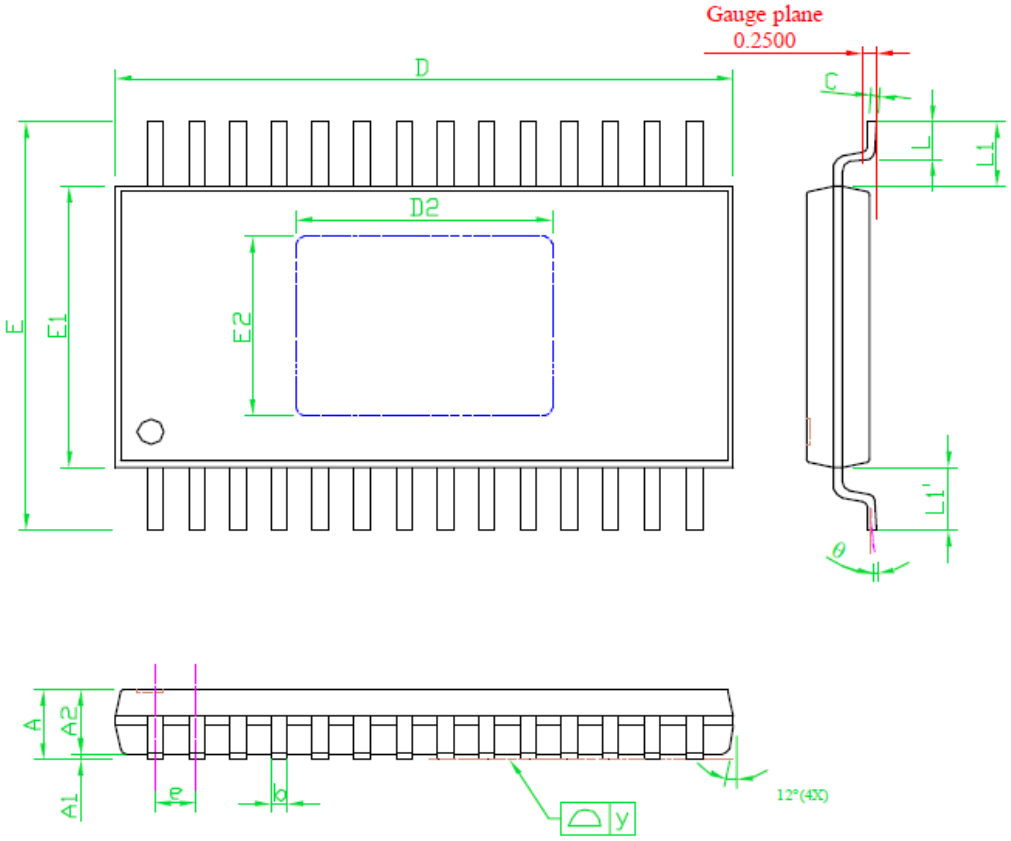


Figure 6. VA2228 Stereo Reference Application with Ferrite Bead

Package Information

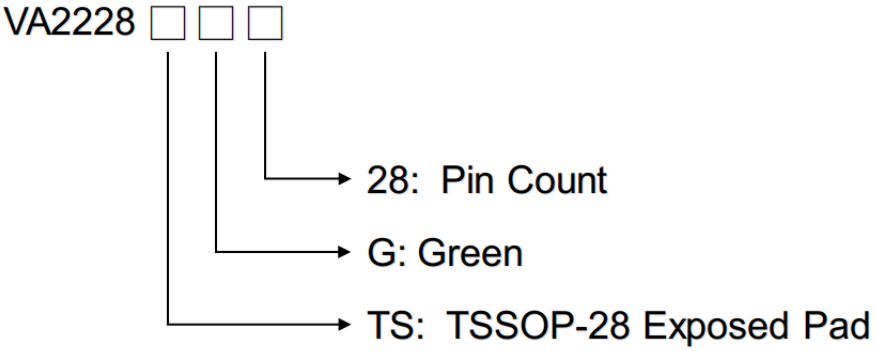
TSSOP-28



NOTE
1. PACKAGE BODY SIZES EXCLUDE MOLD FLASH PROTRUSIONS OR GATE BURRS
2. TOLERANCE ±0.1 mm UNLESS OTHERWISE SPECIFIED
3. COPLANARITY : 0.1 mm
4. REFER TO JEDEC MO-153

SYMBOLS	DIMENSIONS IN MILLIMETER			DIMENSIONS IN INCH		
	MIN	NOM	MAX	MIN	NOM	MAX
A	—	—	1.15	—	—	0.045
A1	0.00	—	0.10	0.000	—	0.004
A2	0.80	1.00	1.05	0.031	0.039	0.041
b	0.19	—	0.30	0.007	—	0.012
C	0.09	—	0.20	0.004	—	0.008
D	9.60	9.70	9.80	0.378	0.382	0.386
D2	3.70	3.80	3.90	0.146	0.150	0.154
E	6.20	6.40	6.60	0.244	0.252	0.260
E1	4.30	4.40	4.50	0.169	0.173	0.177
E2	2.70	2.80	2.90	0.106	0.110	0.114
e	—	0.65	—	—	0.026	—
L	0.45	0.60	0.75	0.018	0.024	0.030
y	—	—	0.10	—	—	0.004
θ	0°	—	8°	0°	—	8°
⚠ |L1-L1'|	—	—	0.12	—	—	0.005
⚠ L1	1.00REF			0.039REF		

Ordering Information



Part No.	Q`ty/Reel
VA2228TSG28	4,000

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