3-W Stereo Class-D Audio Amplifier with 32-Step DC Volume Control

DESCRIPTION

The EUA2008 is a high efficiency, 2 channel bridged-tied load (BTL), class-D audio power amplifier. Operating from a 5V power supply, EUA2008 is capable of delivering 3W/ channel of continuous output power to a 3Ω load with 10% THD+N. The EUA2008 features a differential input architecture offering improved noise immunity over a single-ended (SE) input amplifier. Stereo speaker volume is controlled with a dc voltage applied to the volume control terminal offering a range of gain from -38dB to20 dB.

The EUA2008 also features short-circuit and thermal protection preventing the device from being damaged during a fault condition. The EUA2008 is available in thermally efficient 24-pin TSSOP package.

FEATURES

- Unique Modulation Scheme Reduces EMI Emission
- Efficient 5V Class-D Technology
  - 3W Per Channel into 3Ω Load (THD+N=10%)
  - Low Supply Current, 7mA
  - Low Shutdown Control, 1μA
  - 0.33% THD at 1.5W, 1kHz
  - Low Noise Floor, 62μV
  - Maximum Efficiency into 3Ω, 85%
  - Maximum Efficiency into 8Ω, 90%
  - PSRR, -70dB
- No Large, Expensive LC Output Filter Required
- 32-Step DC Volume Control with 2dB Steps from -38dB to 20dB
- Thermal and Short-Circuit Protection
- Integrated Click and Pop Suppression
- 24-pin TSSOP Package with Thermal Pad
- RoHS Compliant and 100% Lead(Pb)-Free Halogen-Free

APPLICATIONS

- LCD Monitors/TVs
- All-in- One PCs
- Powered Speakers

Typical Application Circuit

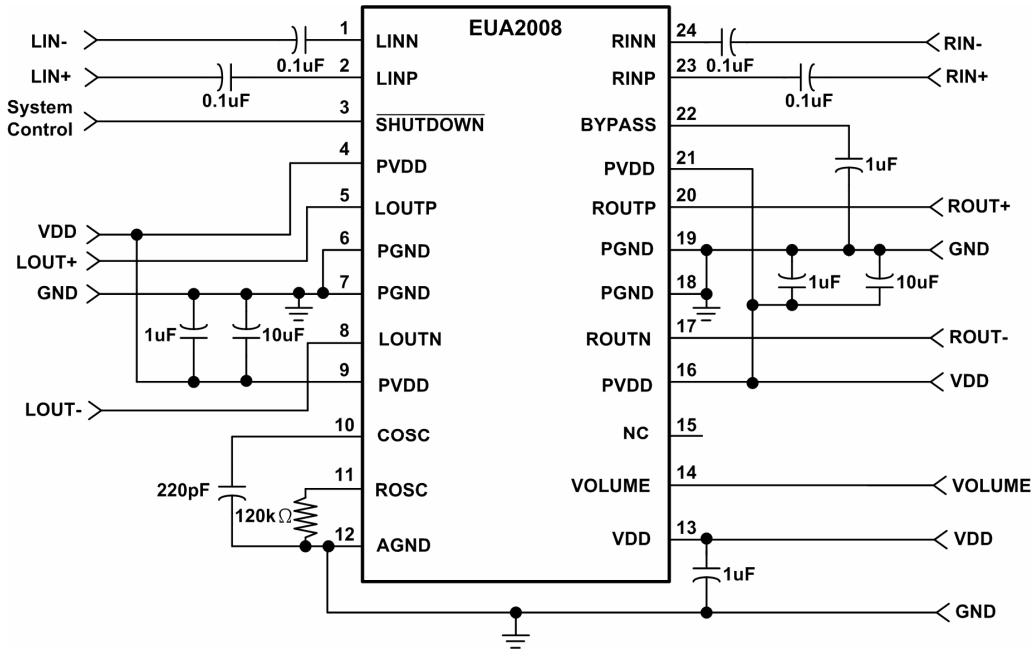
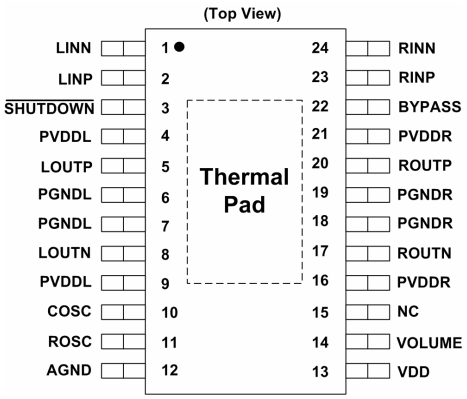


Figure1.

Pin Configurations

Package Type	Pin Configurations
TSSOP-24	

Pin Description

PIN	NAME	I/O	DESCRIPTION
1	LINN	I	Negative differential audio input for left channel
2	LINP	I	Positive differential audio input for left channel
3	$\overline{\text{SHUTDOWN}}$	I	Places the amplifier in shutdown mode if a TTL logic low is placed on this terminal; normal operation if a TTL logic high is placed on this terminal.
4,9	PVDDL		Power supply for left channel H-bridge
5	LOUTP	O	Positive audio output for left channel
6,7	PGNDL	-	Power ground for left channel H-bridge
8	LOUTN	O	Negative audio output for left channel
10	COSC	I	A capacitor connected to this terminal sets the oscillation frequency in conjunction with ROSC. For proper operation, connect a 220-pF capacitor from COSC to ground.
11	ROSC	I	A resistor connected to the ROSC terminal sets the oscillation frequency in conjunction with COSC. For proper operation, connect a 120-kΩ resistor from ROSC to ground.
12	AGND	-	Analog ground
13	VDD	-	Analog power supply
14	VOLUME	I	DC volume control for setting the gain on the internal amplifiers. The dc voltage range is 0 to VDD.
15	NC	I	No connection
16,21	PVDDR		Power supply for right channel H-bridge
17	ROUTN	O	Negative output for right channel
18,19	PGNDR	-	Power ground for right channel H-bridge
20	ROUTP	O	Positive output for right channel
22	BYPASS	I	Tap to voltage divider for internal mid-supply bias generator used for internal analog reference.
23	RINP	I	Positive differential audio input for right channel
24	RINN	I	Negative differential audio input for right channel

Ordering Information

Order Number	Package Type	Marking	Operating Temperature Range
EUA2008QIR1	TSSOP-24	xxxxx EUA2008	-40 °C to +85°C

EUA2008 □ □ □ □

- Lead Free Code
  1: Lead Free 0: Lead
- Packing
  R: Tape & Reel
- Operating temperature range
  I: Industry Standard
- Package Type
  Q: TSSOP

Block Diagram

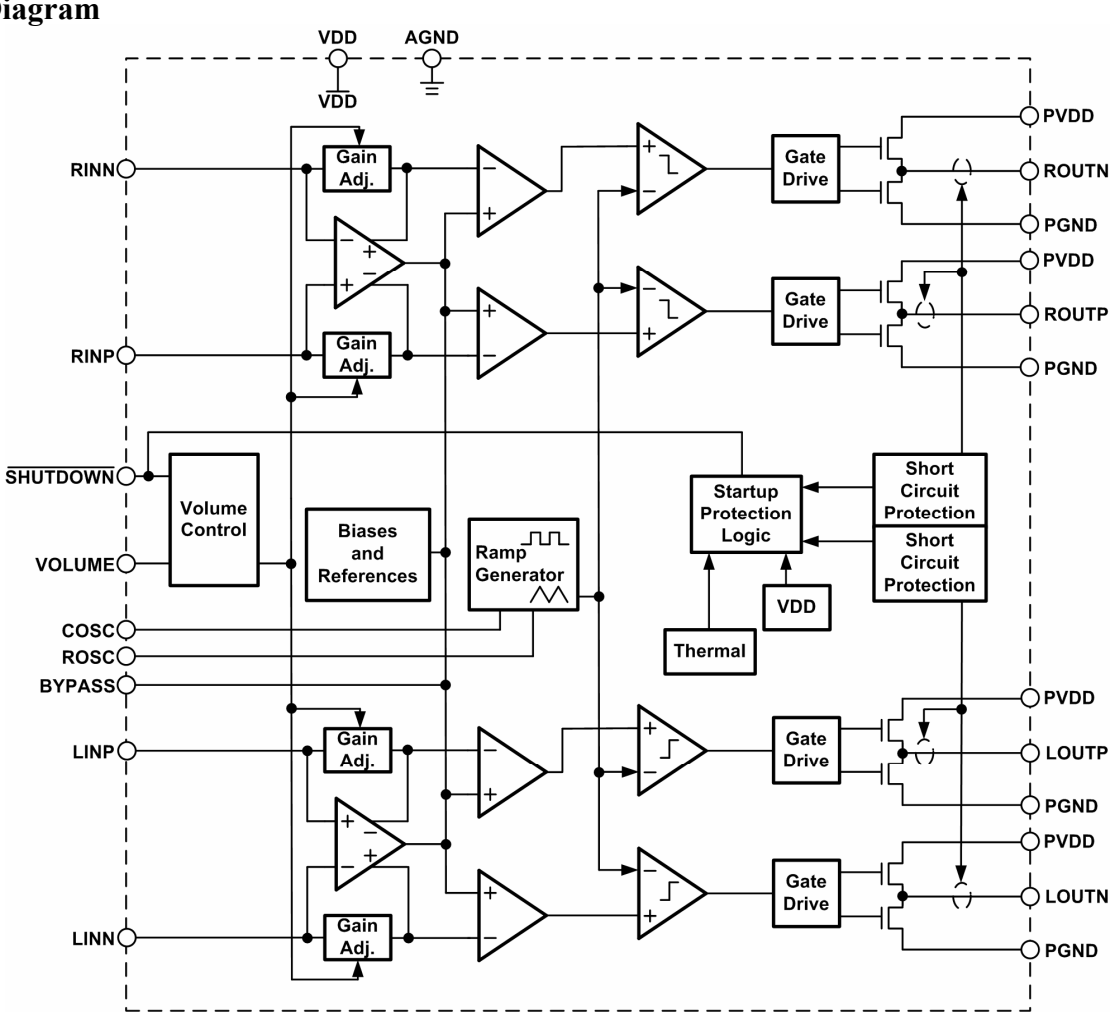


Figure 2.

Absolute Maximum Ratings (1)

- Supply Voltage, V_{DD}, PV_{DD} ---------- -0.3 V to 6V
- Input Voltage, V_I (RINN, RINP, LINN, LINP, VOLUME) ---------- 0V to V_{DD}
- Junction Temperature, T_J ---------- -40°C to 150°C
- Storage Temperature Rang, T_{stg} ---------- -65°C to 85°C
- ESD Susceptibility ---------- 2kV
- Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds ---------- 260°C
- Thermal Resistance

  θ_{JA} (TSSOP) ---------- 35°C/W

Recommended Operating Conditions (2)

	Min	Max	Unit
Supply voltage, V_{DD}	4.5	5.5	V
Volume terminal voltage	0	V_{DD}	V
High-level input voltage, $\overline{SHUTDOWN}$	2		V
Low-level input voltage, $\overline{SHUTDOWN}$		0.3	V
PWM frequency	200	300	kHz
Operating free-air temperature, T_A	-40	85	°C

Note (1): Stress beyond those listed under "Absolute Maximum Ratings" may damage the device.

Note (2): The device is not guaranteed to function outside the recommended operating conditions.

Electrical Characteristics T_A = +25°C, V_{DD}=PV_{DD}=5V (Unless otherwise noted)

Symbol	Parameter	Conditions		EUA2008			Unit
				Min	Typ	Max.	
$\lvert V_{OS} \rvert$	Output offset voltage (measured differentially)	V_I=0V, $A_{V=}$20dB,R_L=8Ω			5	25	mV
PSRR	Power supply rejection ratio	V_{DD}=PV_{DD}= 4.5V to 5.5V			-70		dB
$\lvert I_{IH} \rvert$	High-level input current	V_{DD}=PV_{DD} = 5.5V, V_I= V_{DD} = PV_{DD}				1	µA
$\lvert I_{IL} \rvert$	Low-level input current	V_{DD}=PV_{DD} = 5.5V, V_I= 0V				1	µA
I_{DD}	Supply current	No filter (no load)			7	15	mA
$I_{DD(max)}$	RMS supply current at max power	R_L=3Ω, P_O=2.5W/channel (stereo)			1.3		A
$I_{DD(SD)}$	Supply current in shutdown mode	$\overline{SHUTDOWN}$ =0V			50	1000	nA
$r_{DS(on)}$	Drain-source on-state resistance	V_{DD}= 5V, I_O=500mA, T_J=25°C	High side		450	600	mΩ
			Low side		450	600	
	Resistance from shutdown to GND				300		kΩ

Electrical Characteristics T_A **= +25°C,** V_{DD}**=**PV_{DD}**=5V,** R_L**=3Ω, Gain=0dB** (Unless otherwise noted)

Symbol	Parameter	Conditions		EUA2008			Unit
				Min	Typ	Max.	
P_O	Output power	f=1kHz,RL=3Ω,Stereo operation	THD=1%		2.6		W
			THD=10%		3		
THD+N	Total harmonic distortion plus noise	P_O=2.2W,f=20Hz to 20kHz			0.56%		%
		P_O=1.5W,f=1kHz			0.33%		
BOM	Maximum output power bandwidth	THD=5%			20		kHz
SNR	Signal-to-noise ratio	Volume=20dB, Po=1.5W			83		dB
	Thermal trip point				150		°C
	Thermal hysteresis				20		°C
Vn	Integrated noise floor	20Hz to 20kHz, inputs ac grounded	Volume=0dB		62		μVrms
			Volume=20dB		146		

Table 1. TYPICAL DC VOLUME CONTROL (V_{DD}=PV_{DD}=5.5V)

VOLTAGE ON VOLUME PIN (V) (INCREASING OR FIXED GAIN)	VOLTAGE ON VOLUME PIN(V) (DECREASING GAIN)	TYPICAL GAIN OF AMPLIFIER (dB)
0 -0.37	0.27-0	-38.0
0.37-0.50	0.40-0.27	-36.0
0.50-0.62	0.52-0.40	-33.9
0.62-0.74	0.65-0.52	-31.9
0.74-0.87	0.77-0.65	-29.7
0.87-1.00	0.90-0.77	-27.8
1.00-1.13	1.02-0.90	-25.9
1.13-1.25	1.15-1.02	-23.8
1.25-1.37	1.27-1.15	-22.0
1.37-1.50	1.40-1.27	-20.0
1.50-1.62	1.52-1.40	-18.0
1.62-1.75	1.65-1.52	-16.1
1.75-1.87	1.77-1.65	-14.1
1.87-1.99	1.90-1.77	-12.1
1.99-2.12	2.02-1.90	-11.2
2.12-2.24	2.15-2.02	-9.2
2.24-2.36	2.27-2.15	-7.3
2.36-2.50	2.39-2.27	-5.3
2.50-2.62	2.52-2.39	-3.3
2.62-2.74	2.64-2.52	-1.4
2.74-2.87	2.77-2.64	0.5
2.87-2.99	2.90-2.77	2.5
2.99-3.11	3.02-2.90	4.5
3.11-3.24	3.14-3.02	6.5
3.24-3.36	3.27-3.14	8.5
3.36-3.49	3.40-3.27	10.5
3.49-3.60	3.52-3.40	12.5
3.60-3.73	3.64-3.52	14.5
3.73-3.85	3.76-3.64	16.5
3.85-3.98	3.87-3.76	18.5
3.98-V_{DD}	V_{DD}-3.87	20.5

The volume control circuitry of the EUA2008 is internally referenced to the VDD and AGND terminals. Any common-mode noise between the VOLUME terminal and these terminals will be sensed by the volume control circuitry. If the noise exceeds the step size voltage, the gain will change. In order to minimize this effect, care must be taken to ensure the signal driving the VOLUME terminal is referenced to the VDD and AGND terminals of the EUA2008.

Typical Operating Characteristics

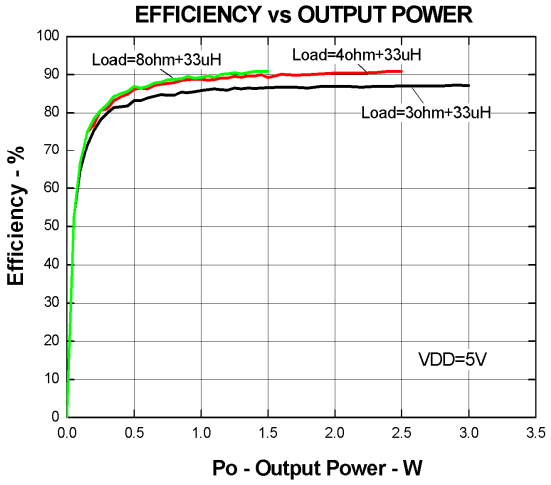


Figure3.

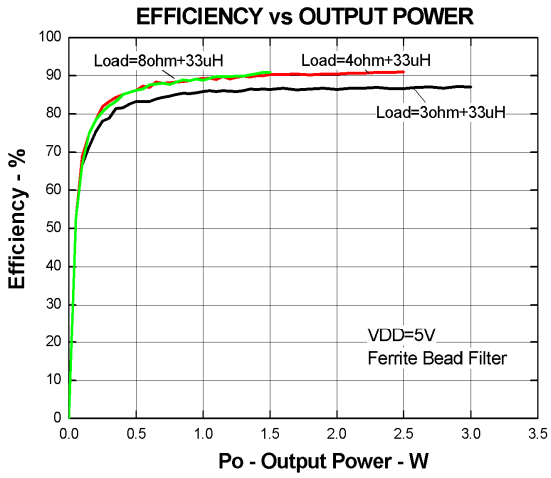


Figure4.

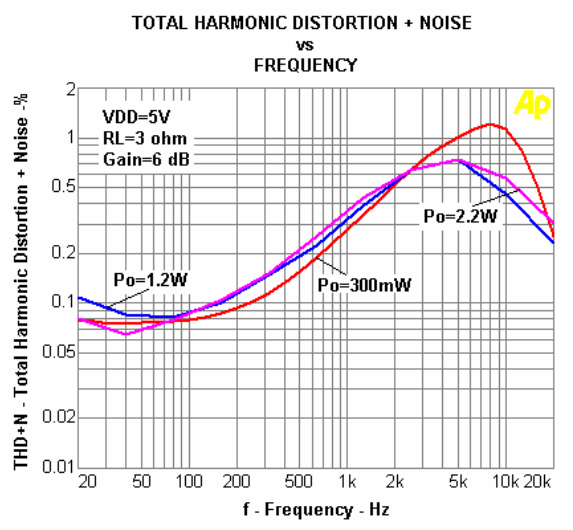


Figure5.

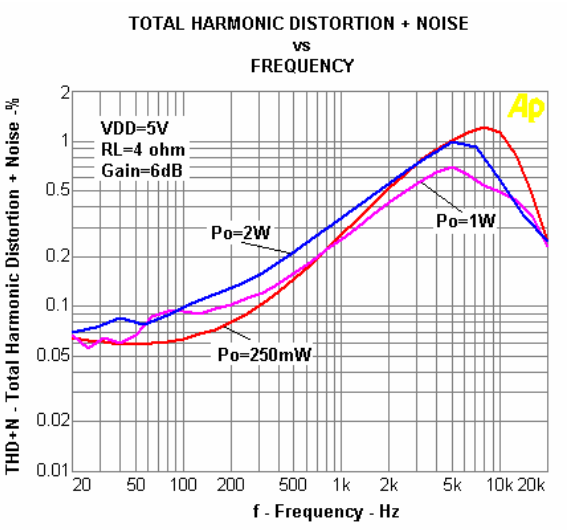
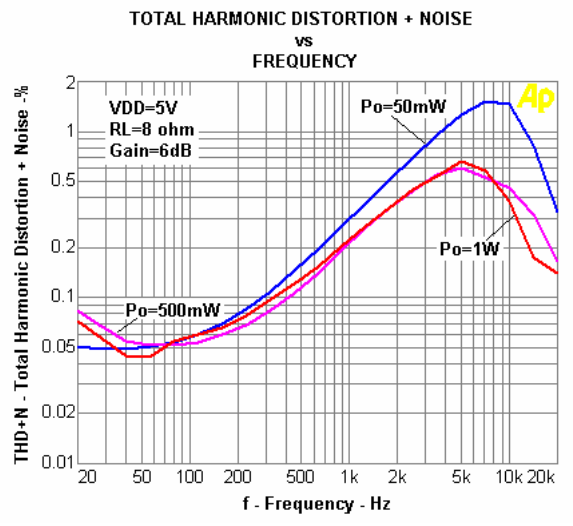


Figure6.



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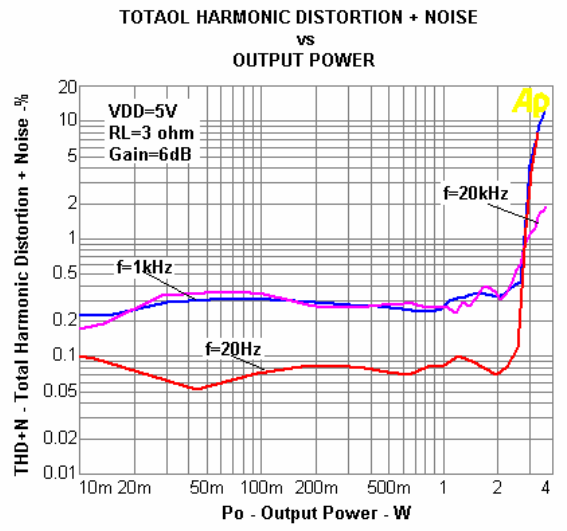


Figure8.

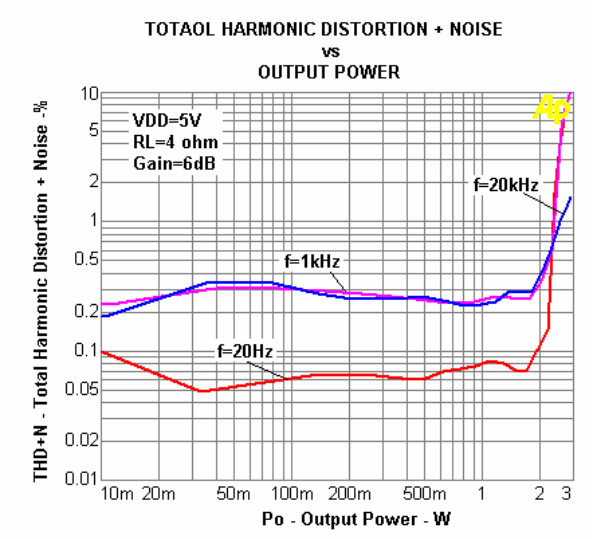


Figure9.

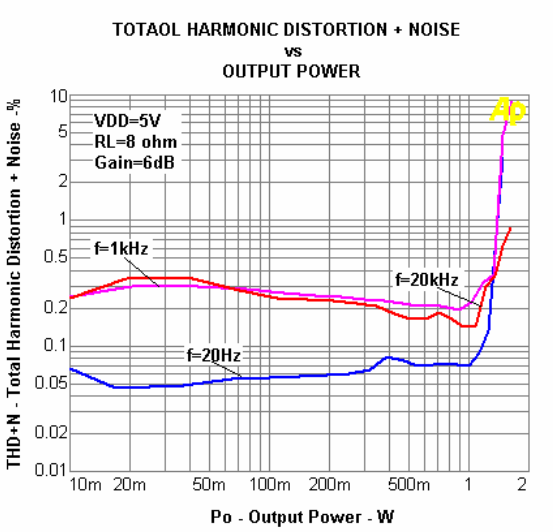


Figure10.

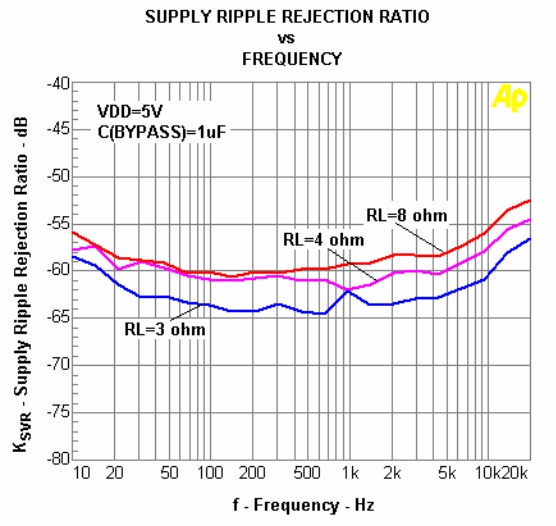


Figure11.

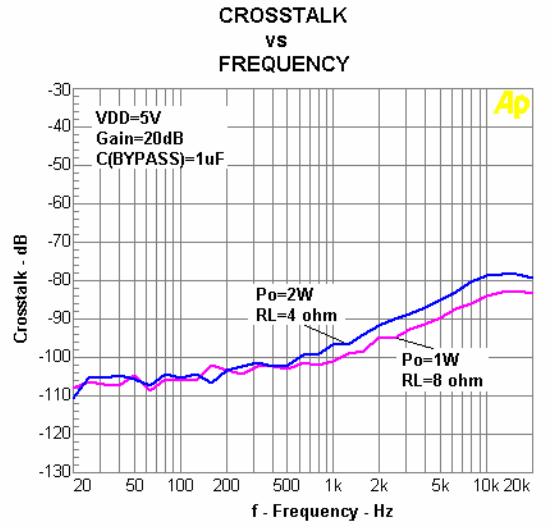


Figure12.

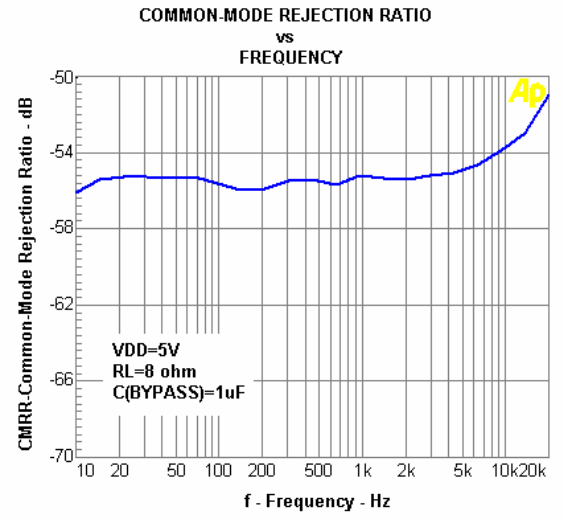


Figure13.

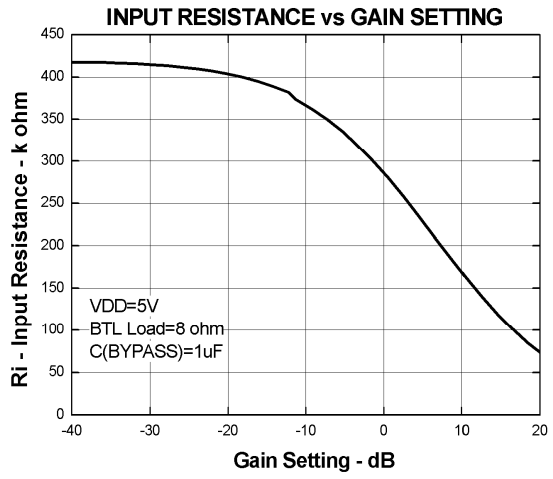


Figure14.

Application Information

Volume Control Operation

The VOLUME pin controls the volume of the EUA2008. It is controlled with a dc voltage, which should not exceed VDD. Table 1 lists the voltage on the VOLUME pin and the corresponding gain.

The trip point, where the gain actually changes, is different depending on whether the voltage on the VOLUME terminal is increasing or decreasing as a result of hysteresis about each trip point. The hysteresis ensures that the gain control is monotonic and does not oscillate from one gain step to another. A pictorial representation of the volume control can be found in Figure 15. The graph focuses on three gain steps with the trip points defined in the first and second columns of Table 1. The dotted lines represent the hysteresis about each gain step.

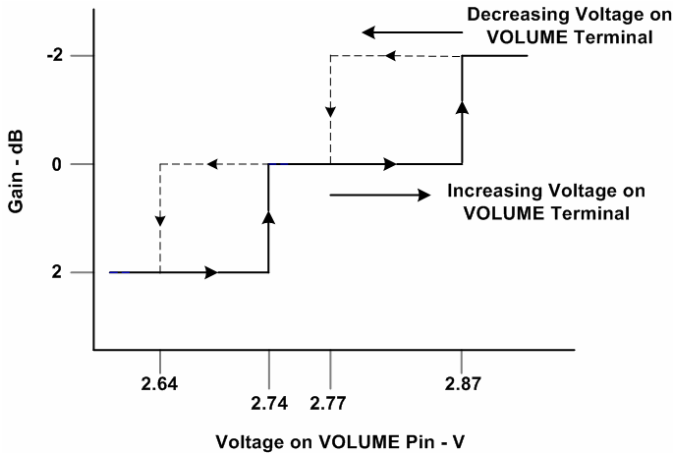


Figure15. DC Volume Control Opetation

$\overline{\text{SHUTDOWN}}$ Operation

The EUA2008 employs a shutdown mode of operation designed to reduce supply current (I_{CC}) to the absolute minimum level during periods of nonuse for power conservation. The $\overline{\text{SHUTDOWN}}$ input terminal should be held high (see specification table for trip point) during normal operation when the amplifier is in use. Pulling $\overline{\text{SHUTDOWN}}$ low causes the outputs to mute and the amplifier to enter a low-current state. $\overline{\text{SHUTDOWN}}$ should never be left unconnected, because amplifier operation would be unpredictable. For the best power-off pop performance, the amplifier should be placed in the shutdown mode prior to removing the power supply voltage.

Short-Circuit Protection

The EUA2008 has short-circuit protection circuitry on the outputs that prevents damage to the device during output-to-output shorts, output-to-GND shorts, and output-to-VCC shorts. When a short circuit event happens, the EUA2008 goes to shutdown mode and tries to reactivate itself after 4ms. This auto-recovery will continue until the short circuit events is removed.

Thermal Protection

Thermal protection on the EUA2008 prevents damage to the device when the internal die temperature exceeds 150°C. 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 15°C. The device begins normal operation at this point with no external system interaction.

Selection of COSC and ROSC

The switching frequency is determined using the values of the components connected to ROSC (pin 11) and COSC (pin 10) and may be calculated with the following equation:

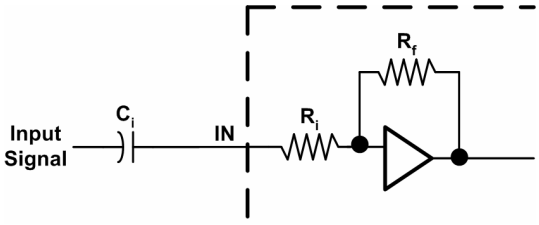
$$f_{OSC} = 6.6/(R_{OSC} \times C_{OSC}) \quad (1)$$

The frequency may be varied from 200 kHz to 300 kHz by adjusting the values chosen for R_{OSC} and C_{OSC}. The recommended values are C_{OSC} = 220 pF, R_{OSC}= 120 kΩ for a switching frequency of 250 kHz.

Input Resistance

Each gain setting is achieved by varying the input resistance of the amplifier, which can range from its smallest value to over five times that value. As a result, if a single capacitor is used in the input high-pass filter, the -3 dB or cutoff frequency also changes by over five times.

The -3-dB frequency can be calculated using equation Equation 2. See Figure 14. Note that due to process variation, the input resistance, Ri, can change by up to 20%.

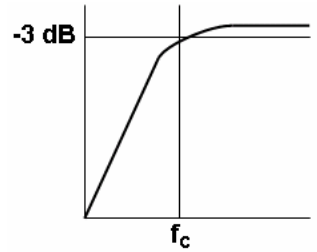


$$f_{-3dB} = \frac{1}{2\pi C_i R_i} \quad (2)$$

Input Capacitors (Ci)

In a typical application, an input capacitor (Ci) is required to allow the amplifier to bias the input signal to the proper dc level for optimum operation. In this case, Ci and the input resistance of the amplifier (Ri) form a high-pass filter with the corner frequency determined in equation Equation 3.

$$f_c = \frac{1}{2\pi R_i C_i} \quad (3)$$



The value of Ci is important, as it directly affects the bass (low frequency) performance of the circuit. Consider the example where Ri is 50 kΩ and the specification calls for a flat bass response down to 30 Hz. Equation Equation 1 is reconfigured as equation Equation 4.

$$C_i = \frac{1}{2\pi R_i f_c} \quad (4)$$

In this example, Ci is 0.1µF, so one would likely choose a value in the range of 0.1µF to 1µF. Figure 14 can be used to determine the input impedance for a given gain and can serve to aid in the calculation of Ci.

Power Supply Decoupling (C_S)

The EUA2008 is a high-performance CMOS audio amplifier that requires adequate power supply decoupling to ensure the output total harmonic distortion (THD) is as low as possible. Power supply decoupling also prevents oscillations for long lead lengths between the amplifier and the speaker. Optimum decoupling is achieved by using two capacitors of different types that target different types of noise on the power supply leads. For higher frequency transients, spikes, or digital hash on the line, a good low equivalent-series-resistance (ESR) ceramic capacitor, typically 0.1µF, placed as close as possible to the device V_{DD} terminal works best. For filtering lower-frequency noise signals, a larger aluminum electrolytic capacitor of 10 µF or greater placed near the audio power amplifier is recommended.

Midrail Bypass (C_{BYP})

The midrail bypass capacitor (C_{BYP}) is the most critical capacitor and serves several important functions. During start-up or recovery from shutdown mode, C_{BYP} determines the rate at which the amplifier starts up. The second function is to reduce noise produced by the power supply caused by coupling into the output drive signal. This noise is from the midrail generation circuit internal to the amplifier, which appears as degraded PSRR and THD+N. Bypass capacitor (C_{BYP}) values of 0.47µF to 1µF ceramic or tantalum low-ESR capacitors are recommended for the best THD and noise performance.

Output Filter

Design the EUA2008 without the filter if the traces from amplifier to speaker are short (< 1 inch). Powered speakers, where the speaker is in the same enclosure as the amplifier, is a typical application for class-D without a filter.

Many applications require a ferrite bead filter. The ferrite filter reduces EMI around 1 MHz and higher (FCC and CE only test radiated emissions greater than 30 MHz). When selecting a ferrite bead, choose one with high impedance at high frequencies, but low impedance at low frequencies.

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

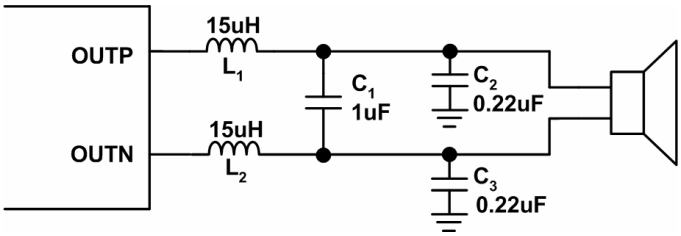


Figure16. Typical LC Output Filter, Cutoff Frequency of 41kHz, Speaker Impedance=4Ω

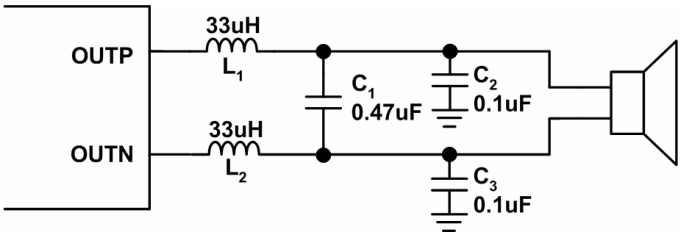


Figure17. Typical LC Output Filter, Cutoff Frequency of 41kHz, Speaker Impedance=8Ω

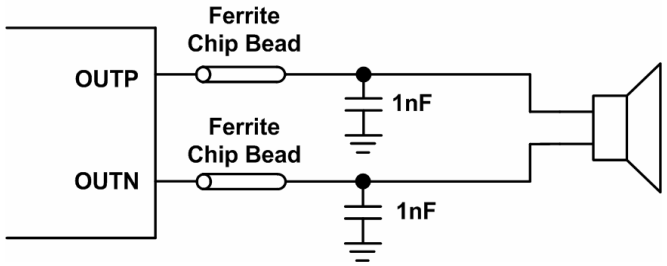
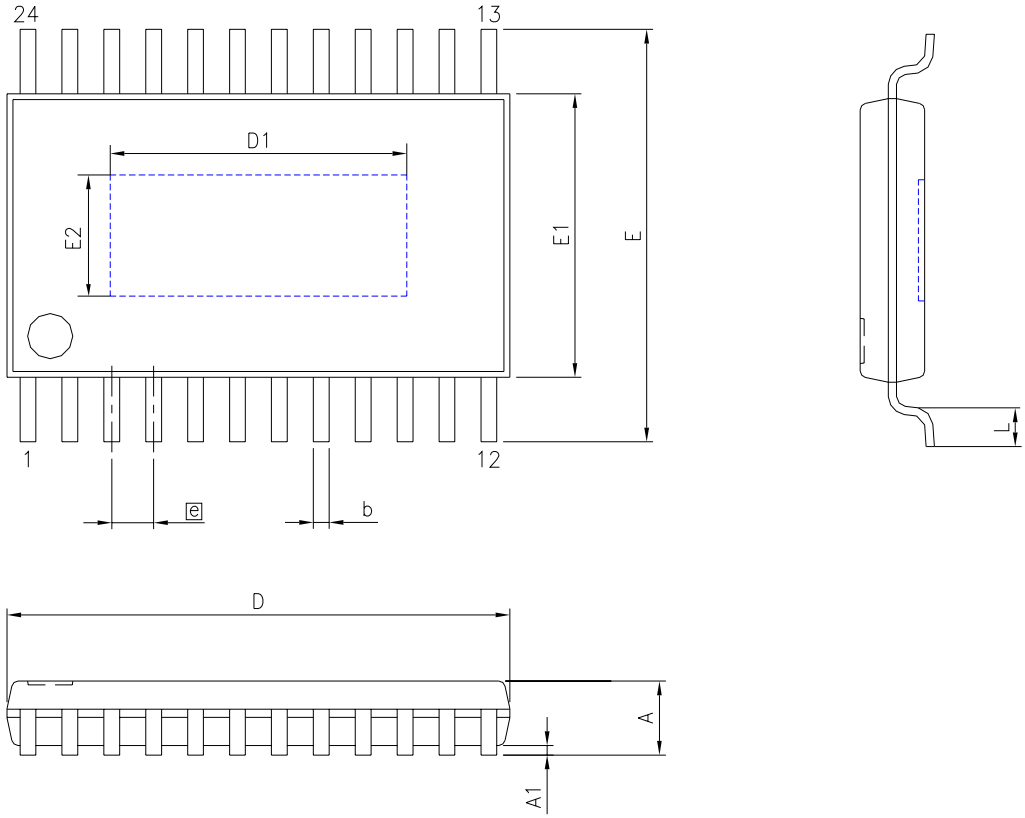


Figure18. Typical Ferrite Chip Bead Filter

Packaging Information

TSSOP-24



SYMBOLS	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	-	1.20	-	0.047
A1	0.00	0.15	0.000	0.006
b	0.19	0.30	0.007	0.012
E1	4.40		0.173	
D	7.80		0.307	
D1	4.60		0.181	
E	6.20	6.60	0.244	0.260
E2	1.88		0.074	
e	0.65		0.026	
L	0.45	0.75	0.018	0.030