EUTECH MICROELECTRONICS

EUA6288

14V$_{P\text{-}P}$, Mono, Class G Ceramic Speaker Driver

DESCRIPTION

The EUA6288 is a mono Class G power amplifier with an integrated inverting charge-pump power supply. The charge pump can supply up to 500mA of peak out-put current over at 5V, guaranteeing an output of 14V$_{P\text{-}P}$.

The EUA6288 offers good performance through the class G output stage, which provides efficiency levels greater than Class AB devices without the EMI penalties commonly associated with Class D amplifiers. The EUA6288 is ideally designed to deliver the high output voltage swing for ceramic/piezoelectric speakers. The device utilizes fully differential inputs and outputs, comprehensive click-and-pop suppression, shutdown control, and soft-start circuitry. The EUA6288 is available in 28-pin TQFN (4mm×4mm) package.

FEATURES

- 2.7V-5.0V Operation
- Integrated Charge-Pump Power Supply
- 14V$_{P\text{-}P}$ Voltage Swing into Piezoelectric Speaker
- Click-and-Pop Suppression
- Available in TQFN-28 Package
- RoHS Compliant and 100% Lead(Pb)-Free Halogen-Free

APPLICATIONS

- Mobile Phones/ Smartphones
- Personal Media Players
- Tablet PC
- Handheld Gaming
- Notebook Computers

Typical Application Circuit

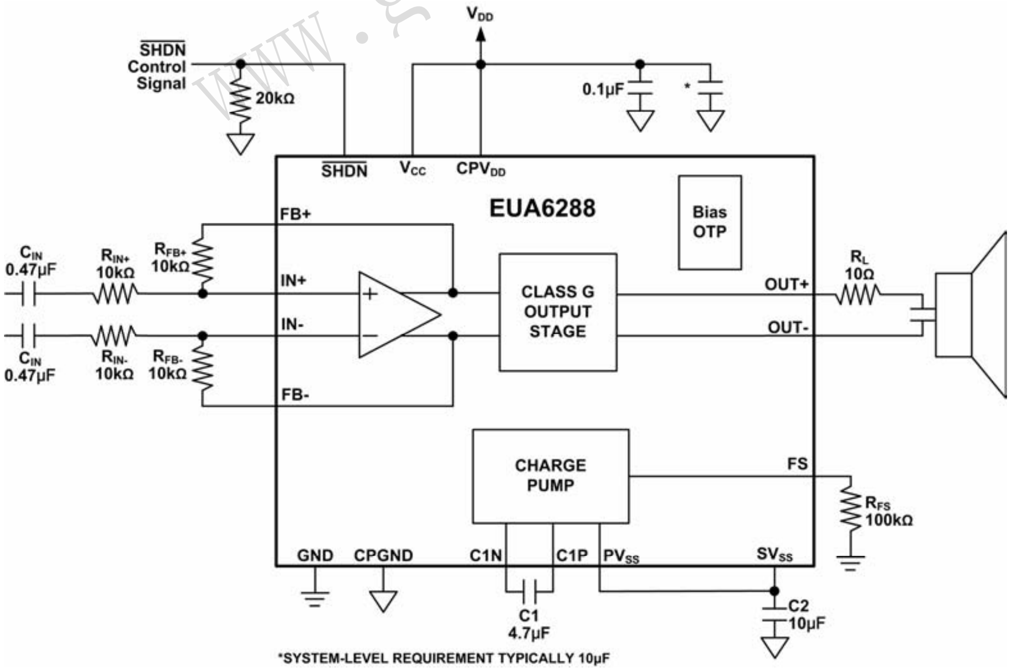
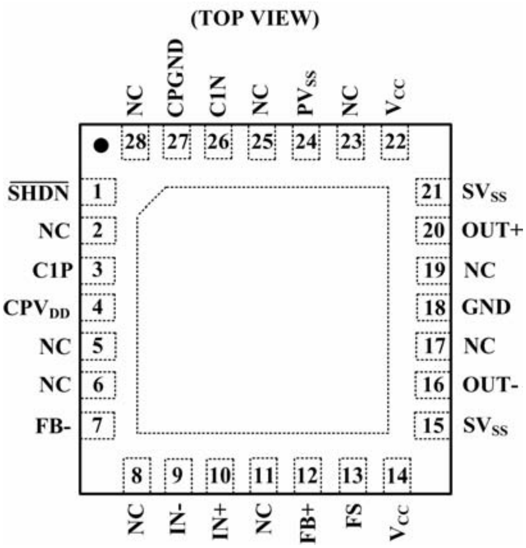


Figure1.

EUTECH

Pin Configurations

Package Type	Pin Configurations
TQFN-28	

Pin Description

PIN	TQFN-28	DESCRIPTION
$\overline{\text{SHDN}}$	1	Shutdown. “High Voltage” enable IC, “Low Voltage” disable IC, $\overline{\text{SHDN}}$ pin can not be floating.
NC	2,5,6,8,11,17, 19,23,25,28	No Connection. No internal connection.
C1P	3	Charge-Pump Flying Capacitor, Positive Terminal. Connect a 4.7µF capacitor between C1P and C1N.
CPV_{DD}	4	Charge-Pump Positive Supply
FB-	7	Negative Amplifier Feedback
IN-	9	Negative Amplifier Input
IN+	10	Positive Amplifier Input
FB+	12	Positive Amplifier Feedback
FS	13	Charge-Pump Frequency Set. Connect a 100kΩ resistor from FS to GND to set the charge-pump switching frequency.
V_{CC}	14,22	Supply Voltage. Bypass with a 10µF capacitor to GND.
SV_{SS}	15,21	Amplifier Negative Power Supply. Connect to PV_{SS}.
OUT-	16	Negative Amplifier Output
GND	18	Ground
OUT+	20	Positive Amplifier Output
PV_{SS}	24	Charge-Pump Output. Connect a 10µF capacitor between PV_{SS} and CPGND.
C1N	26	Charge-Pump Flying Capacitor, Negative Terminal. Connect a 4.7µFcapacitor between C1N and C1P.
CPGND	27	Charge-Pump Ground. Connect to GND.

Ordering Information

Order Number	Package Type	Marking	Operating Temperature Range
EUA6288JIR1	TQFN-28	xxxxx A6288	-40 °C to 85°C

EUA6288 □ □ □ □

- Lead Free Code
  1: Lead Free, Halogen Free 0: Lead
- Packing
  R: Tape & Reel
- Operating temperature range
  I: Industry Standard
- Package Type
  J: TQFN

Simple Block Diagram

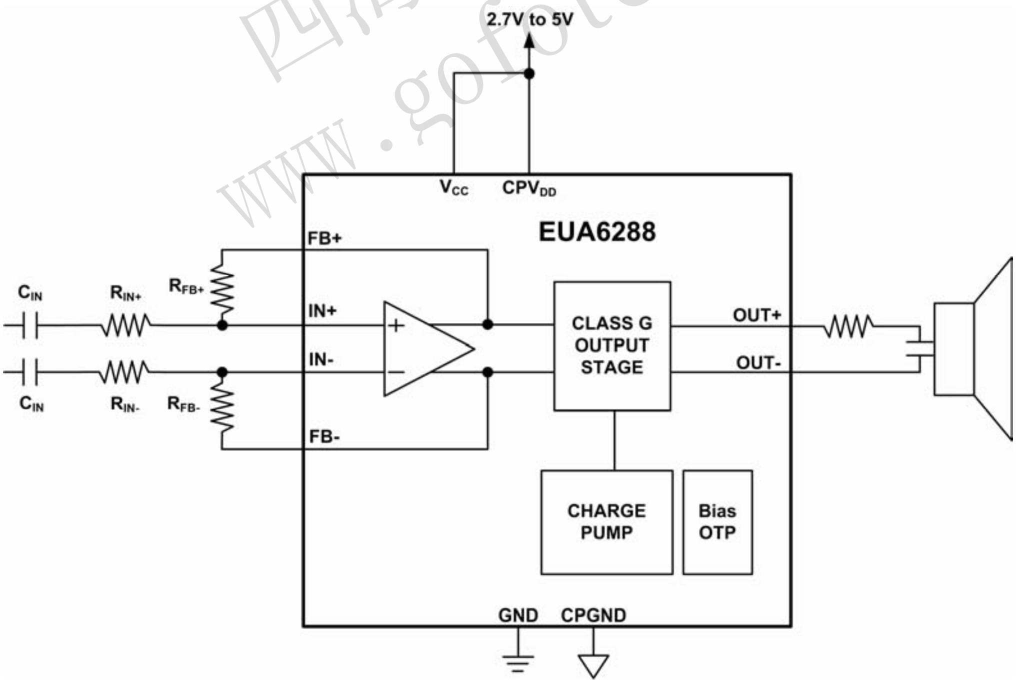


Figure2.

Absolute Maximum Ratings

- V_{CC}, CPV_{DD} ---------- -0.3 V to 5.3V
- PV_{SS}, SV_{SS} ---------- -5.3V to +0.3V
- CPGND ---------- -0.3V to +0.3V
- OUT+, OUT- ---------- (SV_{SS}-0.3V) to (V_{CC}+0.3V)
- IN+,IN-, FB+, FB- ---------- -0.3V to (V_{CC}+0.3V)
- C1N ---------- (PV_{SS}-0.3V) to (CPGND+0.3V)
- C1P ---------- (CPGND-0.3V) to (CPV_{DD}+0.3V)
- FS, $\overline{SHDN}$ ---------- -0.3V to (V_{CC}+0.3V)
- Storage temperature ---------- -65°C to 150°C
- Junction Temperature ---------- 150°C
- Lead Temperature (soldering, 10s) ---------- 260°C
- Thermal Resistance
  - θ_{JA} (TQFN-28) ---------- 40°C/W

Electrical Characteristics

(V_{CC}=CPV_{DD}=$\overline{SHDN}$ =3.6V,GND=CPGND=0V,R_{IN+}=R_{IN-}=10kΩ, R_{FB+}=R_{FB-}=10kΩ, R_{FS}=100kΩ,C1=4.7µF, C2=10µF; speaker load resistors (R_L) are terminated between OUT+ and OUT-, unless otherwise stated; T_A=T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A=25°C.)(Notes 1,2)

Symbol	Parameter	Conditions		EUA6288 Min.	Typ.	Max.	Unit
GENERAL							
V_{CC}	Supply Voltage Range	Inferred from PSRR test		2.7		5	V
I_{CC}	Quiescent Current				4.6	12	mA
$I_{\overline{SHDN}}$	Shutdown Current	$\overline{SHDN}$ =GND			0.1	5	µA
t_{ON}	Turn-On Time	Time from shutdown or power-on to full operation			55		ms
V_{BIAS}	Input DC Bias Voltage	IN_inputs		1.1	1.24	1.4	V
f_{OSC}	Charge-Pump Oscillator Frequency	I_{LOAD}=0mA (slow mode)		55	83	110	kHz
		I_{LOAD}>100mA (normal mode)		230	330	430	kHz
	$\overline{SHDN}$ Input Threshold	V_{IH}		1.4			V
		V_{IL}				0.4	V
	$\overline{SHDN}$ Input Leakage Current					±1	µA
SPEAKER AMPLIFIER							
V_{OS}	Output Offset Voltage	T_A=25°C			±3	±40	mV
A_V	Voltage Gain			11.5	12	12.5	dB
V_{OUT}	Output Voltage	f=1kHz, 1% THD+N	V_{CC}=5V		7.1		V_{RMS}
			V_{CC}=4.2V		5.9		
			V_{CC}=3.6V		5.1		
			V_{CC}=3.0V		4.2		
		f=10kHz, 1% THD+N, Z_L=1µF+10Ω	V_{CC}=5V		6.1		V_{RMS}
			V_{CC}=4.2V		4.9		
			V_{CC}=3.6V		4.3		
			V_{CC}=3.0V		3.4		

Electrical Characteristics (continued)

(V_{CC}=CPV_{DD}=$\overline{SHDN}$ =3.6V,GND=CPGND=0V,R_{IN+}=R_{IN-}=10kΩ, R_{FB+}=R_{FB-}=10kΩ, R_{FS}=100kΩ,C1=4.7µF, C2=10µF; speaker load resistors (R_L) are terminated between OUT+ and OUT-, unless otherwise stated; T_A=T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A=25°C.)(Notes 1,2)

Symbol	Parameter	Conditions		EUA6288 Min.	Typ.	Max.	Unit
SPEAKER AMPLIFIER							
P_{OUT}	Continuous Output Power (Note 3)	1% THD+N, f=1kHz, R_L=8Ω	V_{CC}=5V		2.4		W
			V_{CC}=4.2V		1.67		
			V_{CC}=3.6V		1.25		
			V_{CC}=3.0V		0.8		
PSRR	Power-Supply Rejection Ratio	V_{CC}=2.7V to 5.0V			69		dB
		f=217Hz, 200mV_{P-P} ripple			64		
		f=1kHz, 200mV_{P-P} ripple			60		
THD+N	Total Harmonic Distortion Plus Noise	Z_L=1µF+10Ω,V_{OUT}=1kHz/1.9V_{RMS}			0.01		%
		Z_L=1µF+10Ω,V_{OUT}=1kHz/4.0V_{RMS}			0.09		
SNR	Signal-to-Noise Ratio	V_{OUT}=5.1V_{RMS}, A-Weighted			94		dB

Note 1:All devices are 100% production tested at room temperature. All temperature limits are guaranteed by design.

Note 2:Testing performed with resistive and capacitive loads to simulate an actual ceramic/piezoelectric speaker load, Z_L= 1µF+10Ω.

Note 3:Testing performed with resistive and inductive loads to simulate an actual speaker load. For dynamic speakers, R_L= 8Ω, 68µH.

Typical Operating Characteristics

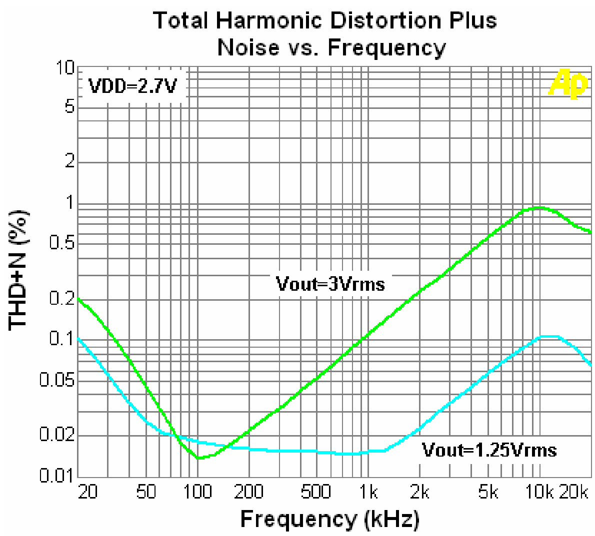


Figure3.

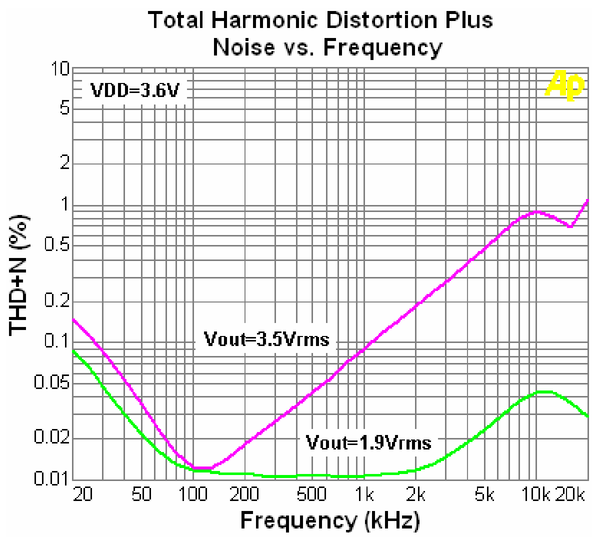


Figure4.

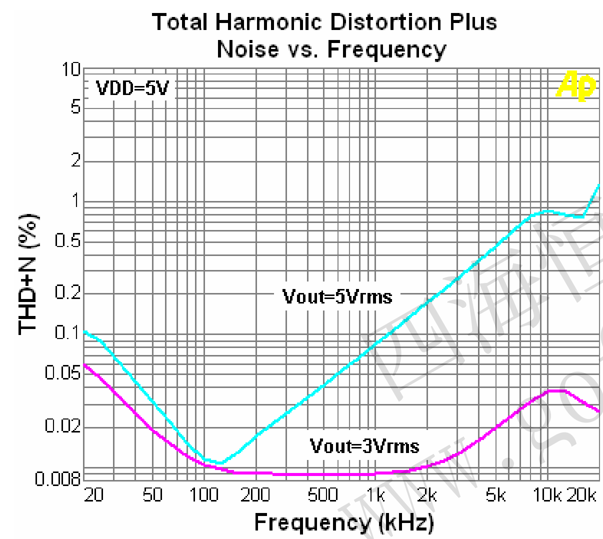
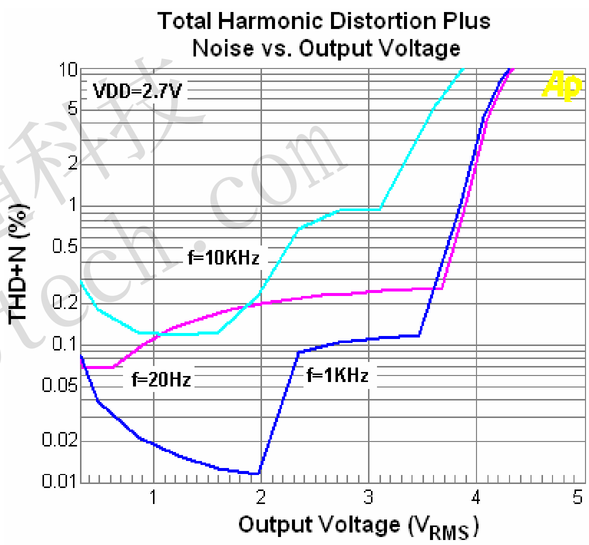


Figure5.



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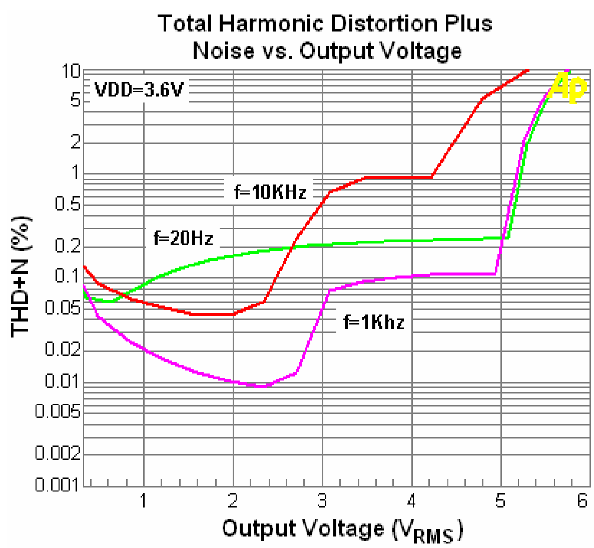

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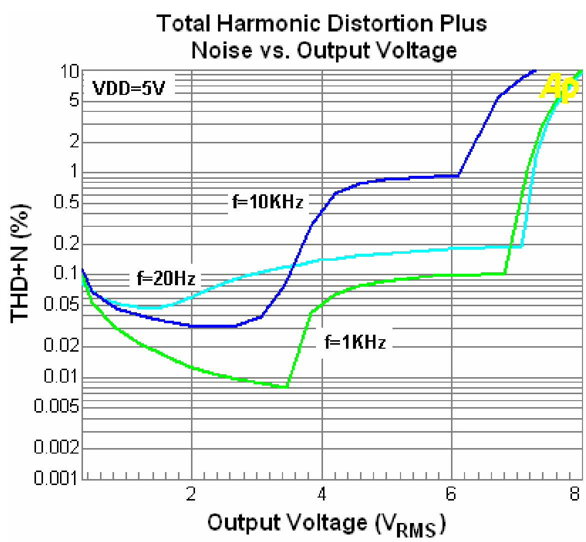


Figure8.

Typical Operating Characteristics (continued)

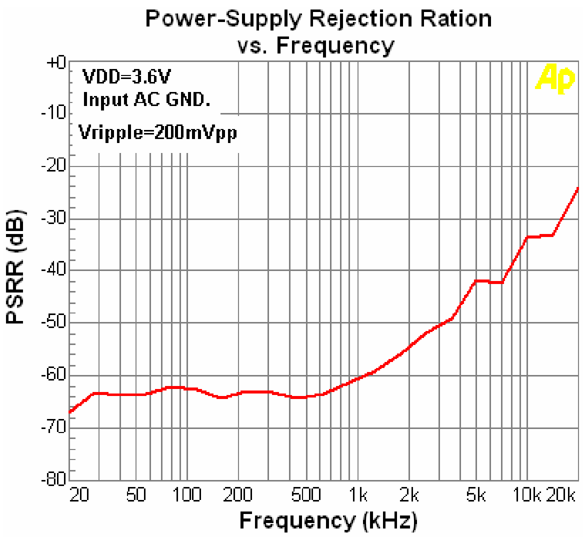


Figure9.

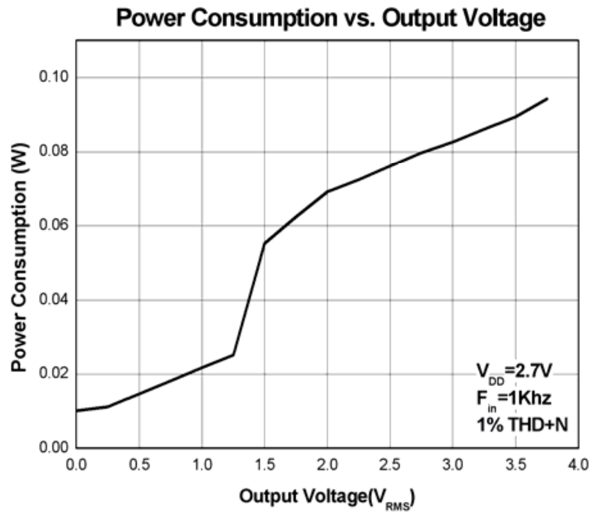


Figure10.

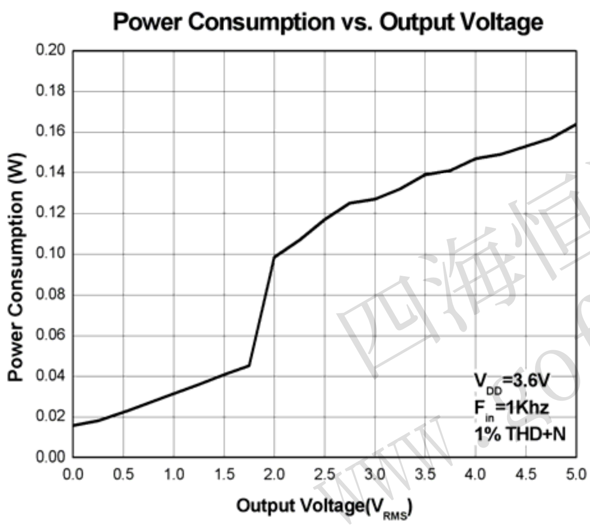


Figure11.

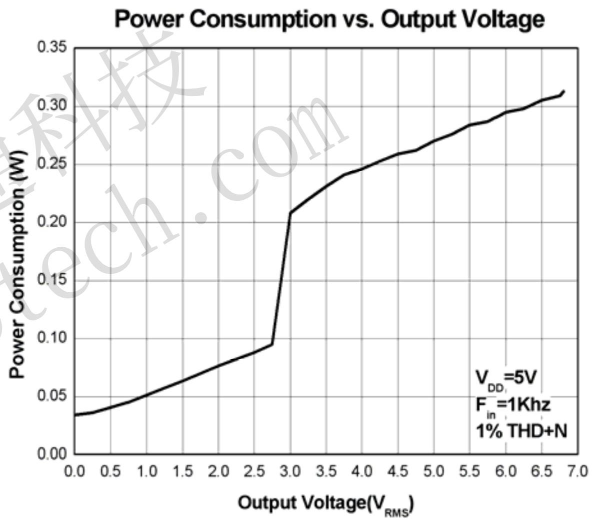
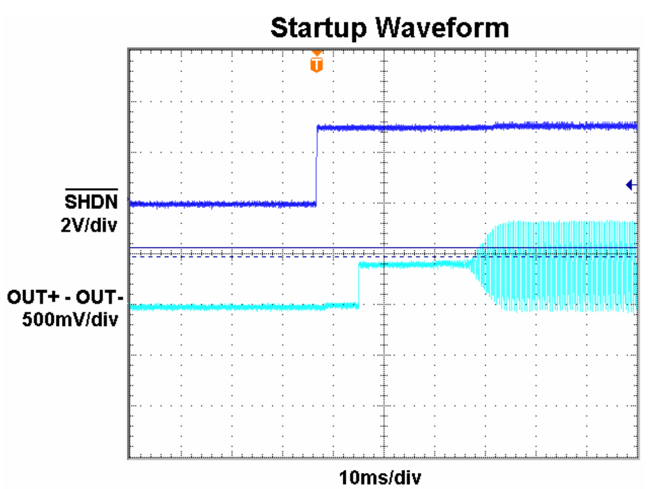


Figure12.



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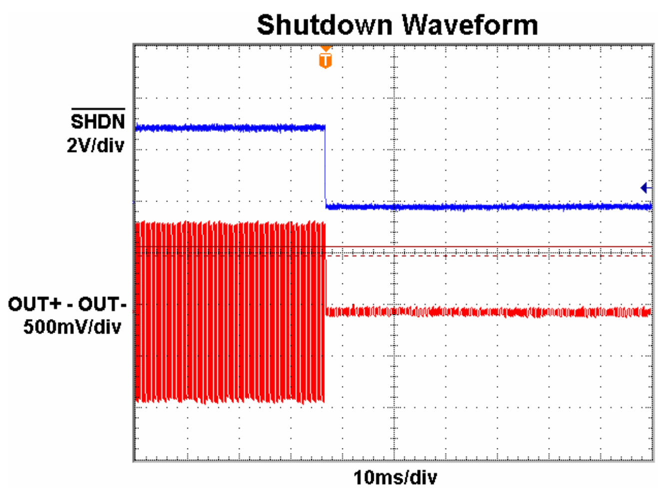


Figure14.

Typical Operating Characteristics (continued)

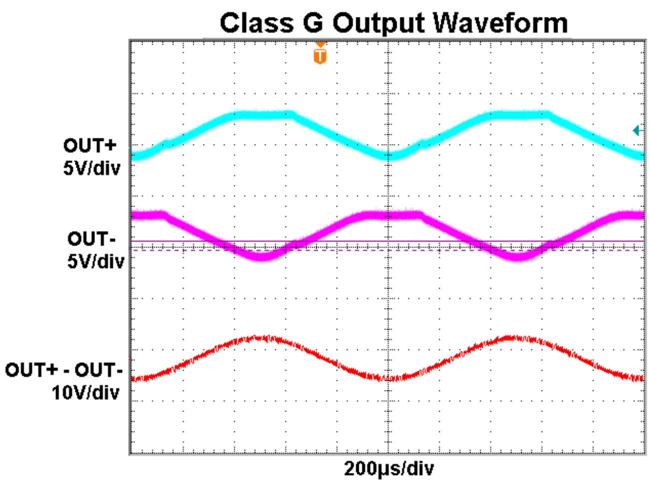


Figure15.

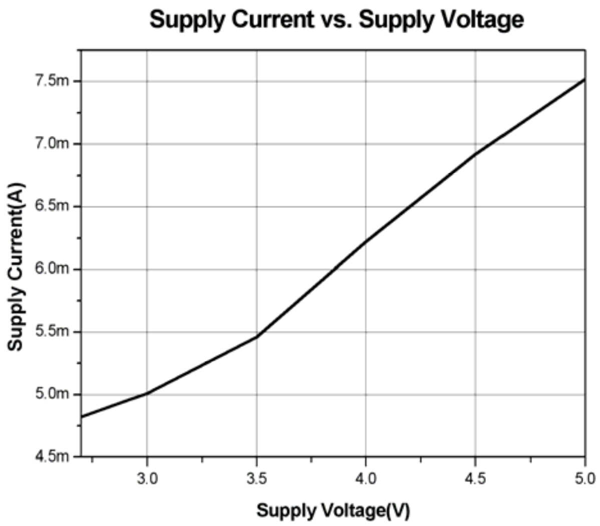


Figure16.

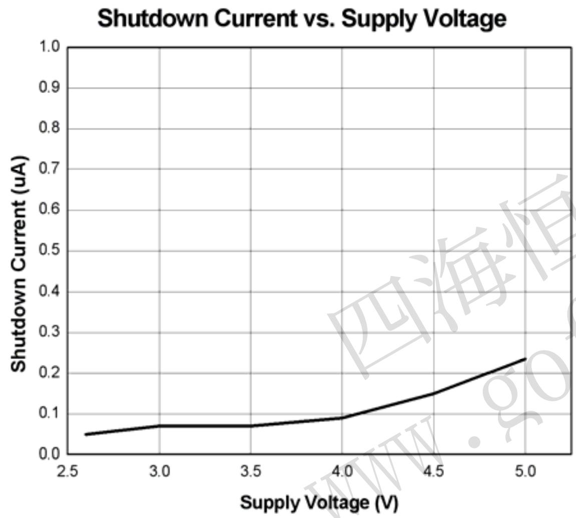


Figure17.

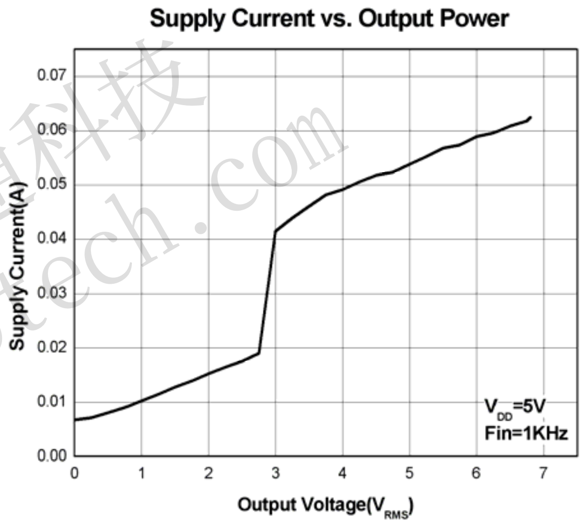


Figure18.

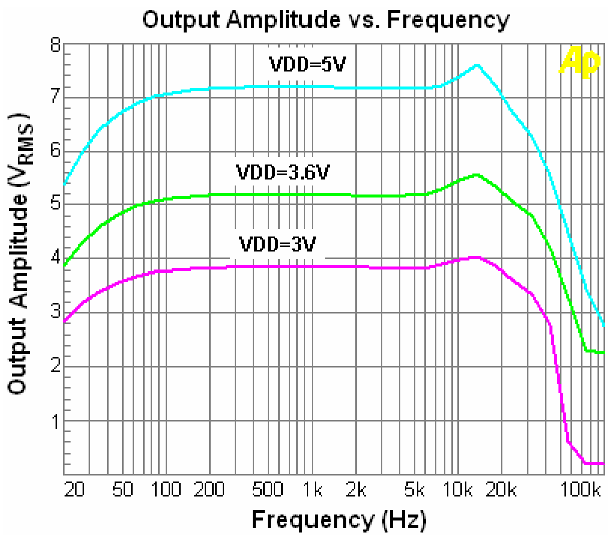


Figure19.

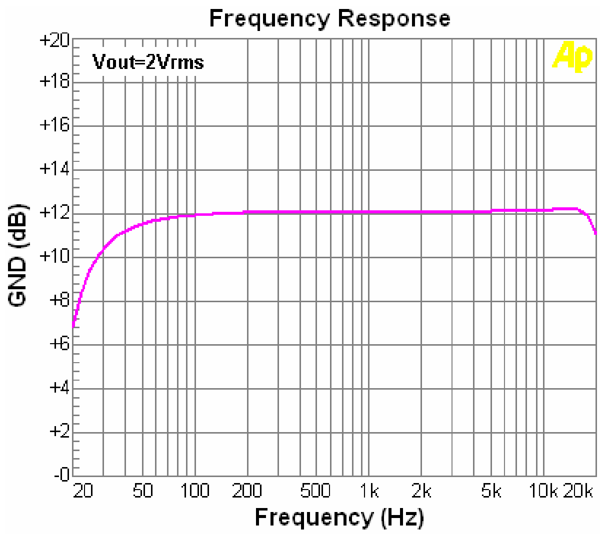


Figure20.

Detail Description

The EUA6288 Class G power amplifier with inverting charge pump is the latest in linear amplifier technology. The Class G output stage offers the performance of a Class AB amplifier while increasing efficiency to extend battery life. The integrated inverting charge pump generates a negative supply capable of delivering up to 500mA.

The Class G output stage and the inverting charge pump allow the EUA6288 to deliver a $14V_{P-P}$ voltage swing, up to two times greater than a traditional single-supply linear amplifier.

Class G Operation

The EUA6288 Class G amplifier is a linear amplifier that operates within a low (V_{CC} to GND) and high (V_{CC} to SV_{SS}) supply range.

During operation, the output common-mode voltage of the EUA6288 adjusts dynamically as the device transitions between supply ranges.

Utilizing a Class G output stage with an inverting charge pump allows the EUA6288 to realize a $20V_{P-P}$ output swing with a 5V supply.

Inverting Charge Pump

The EUA6288 features an integrated charge pump with an inverted supply rail that can supply greater than 500mA over the positive 2.7V to 5.0V supply range. In the case of the EUA6288, the charge pump generates the negative supply rail (PV_{SS}) needed to create the higher supply range, which allows the output of the device to operate over a greater dynamic range as the battery supply collapses over time.

Shutdown Mode

The EUA6288 has a shutdown mode that reduces power consumption and extends battery life. Driving $\overline{SHDN}$ low places the EUA6288 in a low-power (0.3µA) shutdown mode. Connect $\overline{SHDN}$ to V_{CC} for normal operation. $\overline{SHDN}$ pin can't be floating.

Click-and-Pop Suppression

During startup and shutdown, the click-and-pop suppression circuitry eliminates audible pop noise to the output.

Application Information

Differential Input Amplifier

The EUA6288 features a differential input configuration, making the device compatible with many CODECs, and offering improved noise immunity over a single-ended input amplifier. In devices such as PCs, noisy digital signals can be picked up by the amplifier's input traces. The signals appear at the amplifiers' inputs as common-mode noise. A differential input amplifier amplifies the difference of the two inputs, and signals common to both inputs are canceled out. When configured for differential inputs, the voltage gain of the EUA6288 is set by:

$$A_V = 20\log\left[4\times\left(\frac{R_{FB\_}}{R_{IN\_}}\right)\right](dB)$$

where A_V is the desired voltage gain in dB. R_{IN+} should be equal to R_{IN-} and R_{FB+} should be equal to R_{FB-}. The Class G output stage has a fixed gain of 4V/V (12dB). Any gain or attenuation set by the external input stage resistors will add to or subtract from this fixed gain. See Figure 21.

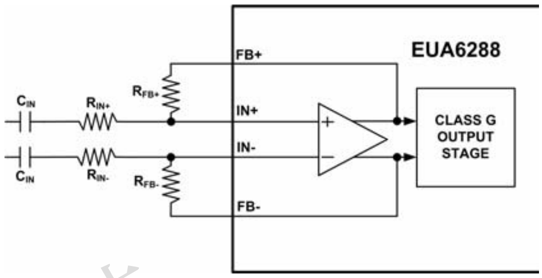


Figure.21

In differential input configurations, the common-mode rejection ratio (CMRR) is primarily limited by the external resistor and capacitor matching. Ideally, to achieve the highest possible CMRR, the following external components should be selected where:

$$\frac{R_{FB+}}{R_{IN+}} = \frac{R_{FB-}}{R_{IN-}}$$

and

$$C_{IN+} = C_{IN-}$$

Driving a Ceramic Speaker

Applications that require thin cases, such as today's mobile phones, demand that external components have a small form factor. Dynamic loudspeakers that use a cone and voice coil typically cannot conform to the height requirements. The option for these applications is to use a ceramic/piezoelectric loud speaker.

Ceramic speakers are much more capacitive than a conventional loudspeaker. Typical capacitance values for such a speaker can be greater than 1µF. High peak-to-peak voltage drive is required to achieve acceptable sound pressure levels. The high output voltage requirement coupled with the capacitive nature of the speaker demand that the amplifier supply much more current at high frequencies than at lower frequencies. Above 10kHz, the typical speaker impedance can be less than 16Ω.

The EUA6288 is ideal for driving a capacitive ceramic speaker. The high charge-pump current limit allows for a flat frequency response out to 20kHz while maintaining high output voltage swings. See the Frequency Response graph in the Typical Operating Characteristics. Figure22 shows a typical circuit for driving a ceramic speaker.

A 10Ωseries resistance is recommended between the amplifier output and the ceramic speaker load to ensure the output of the amplifier sees some fixed resistance at high frequencies when the speaker is essentially an electrical short.

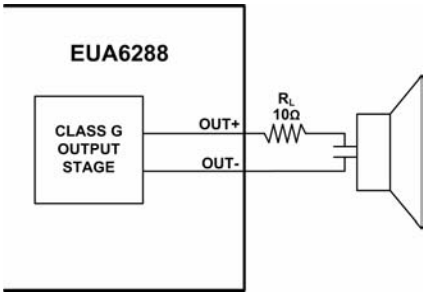


Figure.22

Component Selection

Input-Coupling Capacitor

The AC-coupling capacitors ($C_{IN\_}$) and input resistors ($R_{IN\_}$) form highpass filters that remove any DC bias from an input signal (see the Typical Application Circuit/Functional Diagram). $C_{IN\_}$ blocks DC voltages from the amplifier. The -3dB point of the high pass filter, assuming zero source impedance due to the input signal source, is given by:

$$f_{-3dB} = \frac{1}{2\pi \times R_{IN\_} \times C_{IN\_}} (Hz)$$

Choose C_{IN} so that f_{-3dB} is well below the lowest frequency of interest. Setting f_{-3dB} too high affects the amplifier's low frequency response. Use capacitors with low-voltage coefficient dielectrics. Aluminum electrolytic, tantalum, or film dielectric capacitors are good choices for AC-coupling capacitors. Capacitors with high-voltage coefficients, such as ceramics, can result in increased distortion at low frequencies.

Charge-Pump Capacitor Selection

Use capacitors with an ESR less than 50mΩ for optimum performance. Low-ESR ceramic capacitors minimize the output resistance of the charge pump. For best performance over the extended temperature range, select capacitors with an X7R dielectric.

Flying Capacitor (C1)

The value of the flying capacitor (C1) affects the load regulation and output resistance of the charge pump. A C1 value that is too small degrades the device's ability to provide sufficient current drive. Increasing the value of C1 improves load regulation and reduces the charge-pump output resistance to an extent. Above 1µF, the on-resistance of the switches and the ESR of C1 and C2 dominate. A 4.7µF capacitor is recommended.

Hold Capacitor (C2)

The output capacitor value and ESR directly affect the ripple at PVSS. Increasing C2 reduces output ripple. Likewise, decreasing the ESR of C2 reduces both ripple and output resistance. A 10µF capacitor is recommended.

Charge-Pump Frequency Set Resistor (R_{FS})

The charge pump operates in two modes. When the charge pump is loaded below 100mA, it operates in as low mode where the oscillation frequency is reduced to 1/4 of its normal operating frequency. Once loaded, the charge-pump oscillation frequency returns to normal operation. In applications where the design may be sensitive to the operating charge-pump oscillation frequency, the value of the external resistor R_{FS} can be changed to adjust the charge-pump oscillation frequency.

Ceramic Speaker Impedance Characteristics

A 1µF capacitor is a good model for the ceramic speaker as it best approximates the impedance of a ceramic speaker over the audio band. When selecting a capacitor to simulate a ceramic speaker, the voltage rating or the capacitor must be equal to or higher than the expected output voltage swing.

Series Load Resistor

The capacitive nature of the ceramic speaker results in very low impedances at high frequencies. To prevent the ceramic speaker from shorting the EUA6288 output at high frequencies, a series load resistor must be used. The output load resistor and the ceramic speaker create a low pass filter. To set the roll off frequency of the output filter, the approximate capacitance of the speaker must be known. This information can be obtained from bench testing or from the ceramic speaker manufacturer. A series load resistor greater than 10Ω is recommended. Set the low pass filter cut off frequency with the following equation:

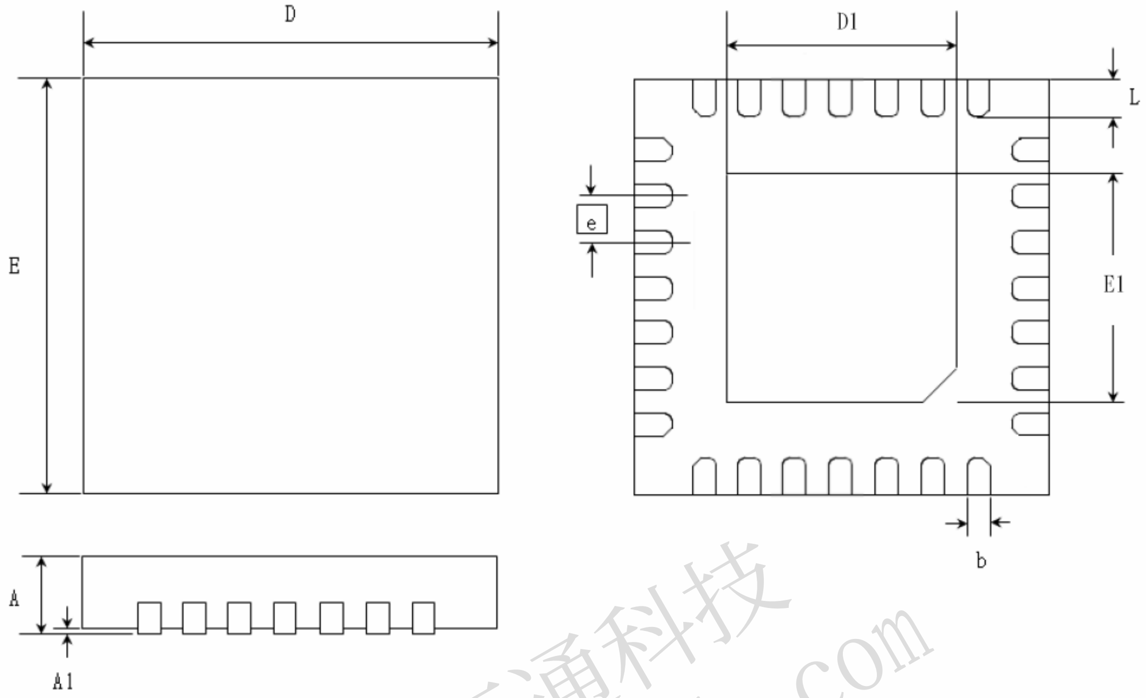
$$f_{LP} = \frac{1}{2\pi \times R_L \times C_{SPEAKER}} (Hz)$$

Thermal Considerations

Class G amplifiers provide much better efficiency and thermal performance than a comparable Class AB amplifier. However, the system's thermal performance must be considered with realistic expectations and include consideration of many parameters. This section examines Class G amplifiers using general examples to illustrate good design practices.

Packaging Information

TQFN-28



SYMBOLS	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	0.70	0.80	0.028	0.031
A1	0.00	0.05	0.000	0.002
b	0.15	0.25	0.006	0.010
E	3.90	4.10	0.154	0.162
D	3.90	4.10	0.154	0.162
D1	1.90	2.65	0.075	0.104
E1	1.90	2.65	0.075	0.104
e	0.40 BSC		0.016 BSC	
L	0.30	0.50	0.012	0.020