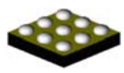
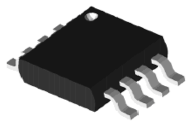
3.1 Watt Fully Differential Audio Power Amplifier with Internal Feedback Resistors

FEATURES

- Fully differential amplifier
- Improved PSRR at 217Hz -86dB (typ)
- Power output at 5.0V, 10% THD, 3 Ω (DFN8 only) 3.1W (typ)
- Power output at 5.0V, 1% THD, 8 Ω 1.36W (typ)
- Ultra low shutdown current 0.01μA (typ)
- Improved pop & click circuitry eliminates noises during turn-on and turn-off transitions
- Thermal overload protection circuitry
- Unity-gain stable
- External gain configuration capability
- Available in space-saving packages: CSP9, MSOP8 and DFN8
- RoHS compliant and 100% lead(Pb)-free



CSP9 Package
1.5mm x 1.5mm
-40℃～85℃



MSOP8 封装
-40℃～85℃

DFN8 封装
3mm x 3mm
-40℃～85℃

DFN8 封装
2mm x 2mm
-40℃～85℃

APPLICATIONS

- Wireless handsets
- Portable audio devices
- PDAs
- Notebook computers

DESCRIPTION

The CP2296 is a fully differential audio power amplifier designed for demanding audio applications. It is capable of delivering 3.1 watt of continuous average power to a 3Ω BTL load with less than 10% distortion (THD+N) from a 5V battery voltage. It operates from 2.2V to 5.5V.

Features like -86dB PSRR at 217Hz, improved RF-rectification immunity, the space-saving CSP9, DFN8 and MSOP8 packages, the advanced pop & click circuitry, a minimal count of external components and low-power shutdown mode make CP2296 ideal for wireless handsets.

The CP2296 is unity-gain stable, and the gain can be configured by external input resistors and internal feedback resistors.

Pin Configuration

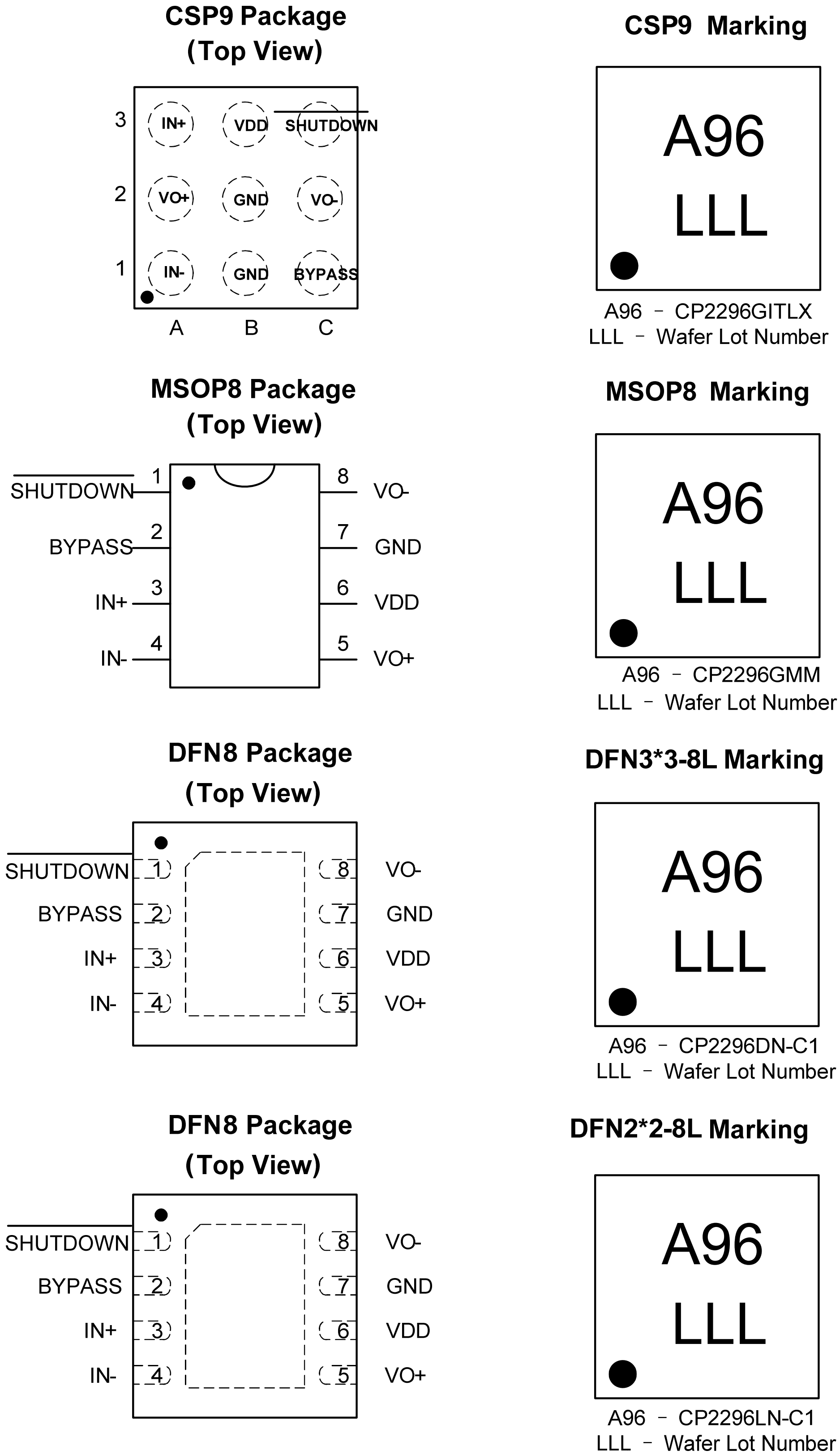


Figure 1 Pin Configuration of CP2296

TYPICAL APPLICATION

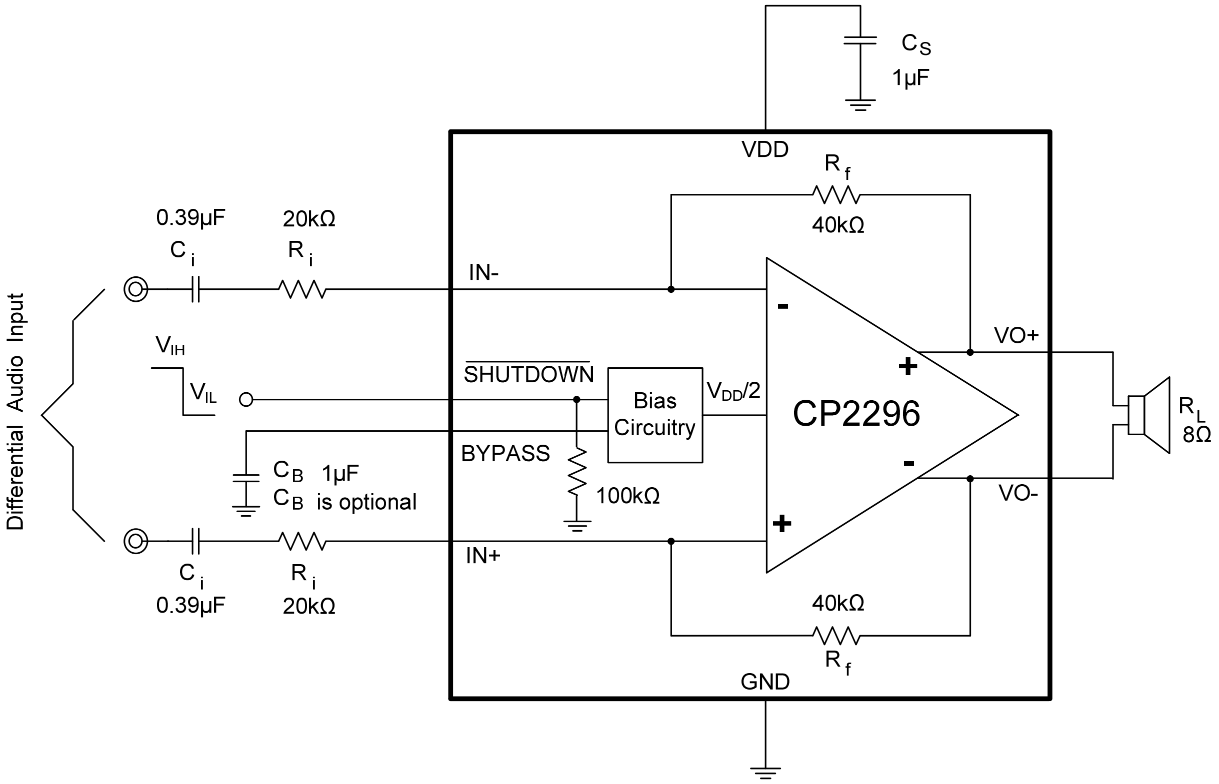


Figure 2 CP2296 Typical application Circuit

ORDERING INFORMATION

Order Number	Temperature Range	Package	RoHS	Marking	Shipping Type
CP2296GITLX	-40℃～85℃	CSP9	Y	A96 LLL	3000 pcs / Tape & Reel
CP2296GMM	-40℃～85℃	MSOP8	Y	A96 LLL	3000 pcs / Tape & Reel
CP2296DN-C1	-40℃～85℃	DFN 3*3-8L	Y	A96 LLL	3000 pcs / Tape & Reel
CP2296LN-C1	-40℃～85℃	DFN 2*2-8L	Y	A96 LLL	3000 pcs / Tape & Reel

CP2296 □□□–□□

Chip Version
C1

Package Type
G: Green Product
MM: MSOP8 , (GITLX: CSP9)
DN: DFN3*3-8L, LN: DFN2*2-8L

ABSOLUTE MAXIMUM RATINGS[1]

Parameter	Unit
Supply voltage (VDD)	-0.3V to 6.0V
Input voltage	-0.3V to VDD+0.3V
Power dissipation [2]	Internally Limited
Package Thermal Resistance θ_{JA} (CSP9)	220℃/W
Package Thermal Resistance θ_{JA} (MSOP8)	190℃/W
Package Thermal Resistance θ_{JC} (MSOP8)	56℃/W
Package Thermal Resistance θ_{JA} (DFN8)	63℃/W
Package Thermal Resistance θ_{JC} (DFN8)	12℃/W
Maximum Junction Temperature	150℃
Storage Temperature Range	-65℃ to 150℃
Lead Temperature（Soldering 10 Seconds）	260℃
ESD Rating [3]	
Human Body Model	8000V
Machine Model	200V
Latch-up Immunity	200mA

(1) Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

(2) The maximum power dissipation must be derated at elevated temperatures and is dictated by T_{JMAX}, θ_{JA}, and the ambient temperature T_A. The maximum allowable power dissipation is $P_{DMAX}=(T_{JMAX}-T_A)/\theta_{JA}$ or the number given in Absolute Maximum Ratings, whichever is lower.

(3) The human body model is a 100pF capacitor discharged through a 1.5kΩ resistor into each pin. The machine model is a 200pF capacitor discharged directly into each pin.

RECOMMENDED OPERATING CONDITIONS

Parameter	Unit
Supply voltage (VDD)	2.2V to 5.5V
Operating temperature range (T_A)	-40℃ to 85℃

ELECTRICAL CHARACTERISTICS

Test Condition: V_{DD}=5.0V,T_A=25℃, A_V=1V/V, The following specifications apply for 8Ω load (unless otherwise specified)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
I_{DD}	Quiescent Power Supply Current	VIN=0V, no load		3	8	mA
		VIN=0V, R_L=8Ω		4	10	
I_{SD}	Shutdown Current	$V_{SHUTDOWN}$=GND		0.01	1	μA
P_O	Output Power	THD=1%(max); f=1kHz R_L=3Ω R_L=4Ω R_L=8Ω		 2.45 2.22 1.36		W
		THD=10%(max); f=1kHz R_L=3Ω R_L=4Ω R_L=8Ω		 3.1 2.6 1.7		W
THD+N	Total Harmonic Distortion + Noise	P_O=1Wrms; f=1kHz		0.02		%
PSRR	Power Supply Rejection Ratio	V_{ripple}=200mV sine p-p				dB
		f=217Hz (Note1)		-86		
		f=1KHz (Note1)		-83		
SNR	Signal to Noise Ratio	P_O=1Wrms; f=1kHz		105		dB
CMRR	Common Mode Rejection Ratio	f=217Hz V_{CM}=200mV_{PP}		-65		dB
V_{OS}	Output Offset	VIN=0V		1	10	mV
V_{SDIH}	Shutdown Voltage Input High		1.5			V
V_{SDIL}	Shutdown Voltage Input Low				0.5	V
A_V	Closed Loop Gain		$\frac{36k\Omega}{R_i}$	$\frac{40k\Omega}{R_i}$	$\frac{44k\Omega}{R_i}$	V/V
R_{SD}	Resistance from shutdown to GND			100		kΩ

Note1: 10Ω terminated input

Test Condition: V_{DD}=3.6V,T_A=25℃, A_V=1V/V, The following specifications apply for 8Ω load (unless otherwise specified)

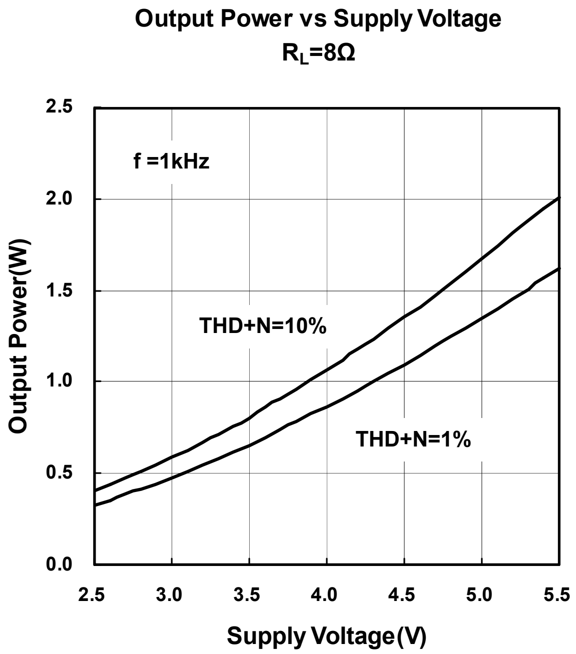
Symbol	Parameter	Conditions	Min	Typ	Max	Unit
I_{DD}	Quiescent Power Supply Current	VIN=0V, no load		2.5	7	mA
		VIN=0V, R_L=8Ω		3.5	9	
I_{SD}	Shutdown Current	$V_{SHUTDOWN}$=GND		0.01	1	μA
P_O	Output Power	THD=1%(max); f=1kHz R_L=3Ω R_L=4Ω R_L=8Ω		 1.22 1.1 0.72		W
THD+N	Total Harmonic Distortion + Noise	P_O=0.5Wrms; f=1kHz		0.02		%
PSRR	Power Supply Rejection Ratio	V_{ripple}=200mV sine p-p				dB
		f=217Hz (Note1)		-83		
		f=1KHz (Note1)		-80		
SNR	Signal to Noise Ratio	P_O=0.5Wrms; f=1kHz		100		dB
CMRR	Common Mode Rejection Ratio	f=217Hz V_{CM}=200mV_{PP}		-63		dB
V_{OS}	Output Offset	VIN=0V		1	10	mV
V_{SDIH}	Shutdown Voltage Input High		1.5			V
V_{SDIL}	Shutdown Voltage Input Low				0.5	V
A_V	Closed Loop Gain		$\frac{36k\Omega}{R_i}$	$\frac{40k\Omega}{R_i}$	$\frac{44k\Omega}{R_i}$	V/V
R_{SD}	Resistance from shutdown to GND			100		kΩ

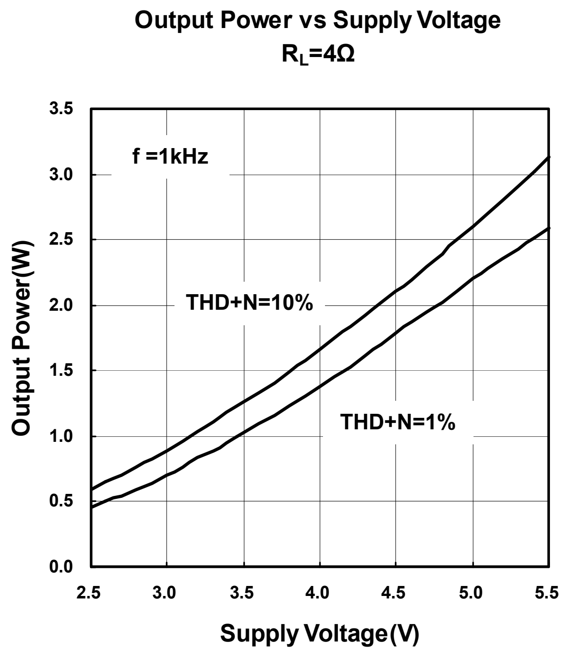
Note1: 10Ω terminated input

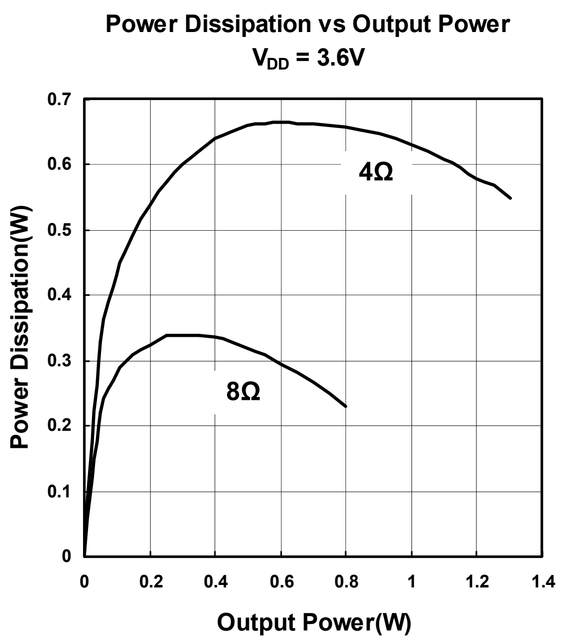
PIN DEFINITION

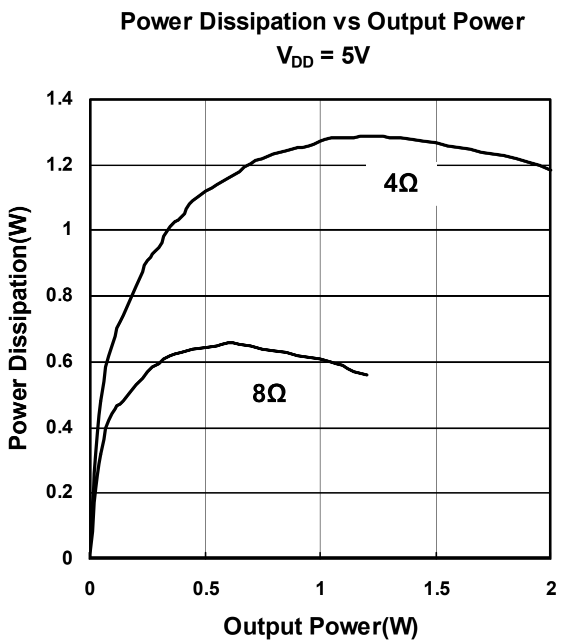
CSP9	DFN8	MSOP8	Symbol	Description
C3	1	1	SHUTDOWN	Shutdown Pin, active low.
C1	2	2	BYPASS	Common mode voltage. Connect a bypass capacitor to GND for common mode voltage filtering. The bypass capacitor is optional.
A3	3	3	IN+	Positive differential input.
A1	4	4	IN-	Negative differential input.
A2	5	5	VO+	Positive differential output.
B3	6	6	VDD	Power supply.
B1,B2	7	7	GND	Ground.
C2	8	8	VO-	Negative differential output.

TYPICAL OPERATING CHARACTERISTICS

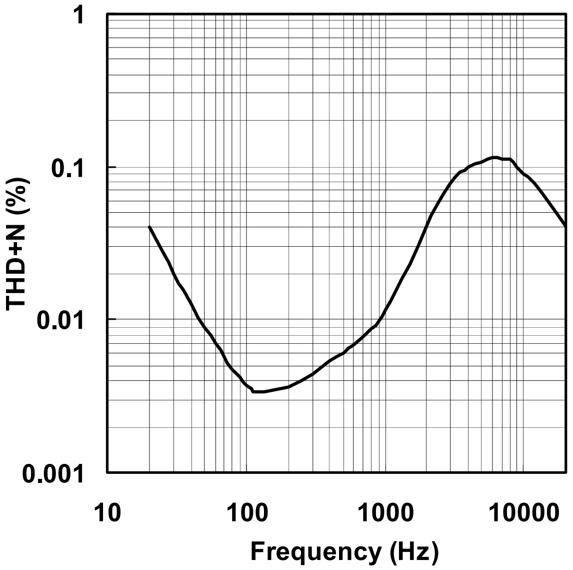




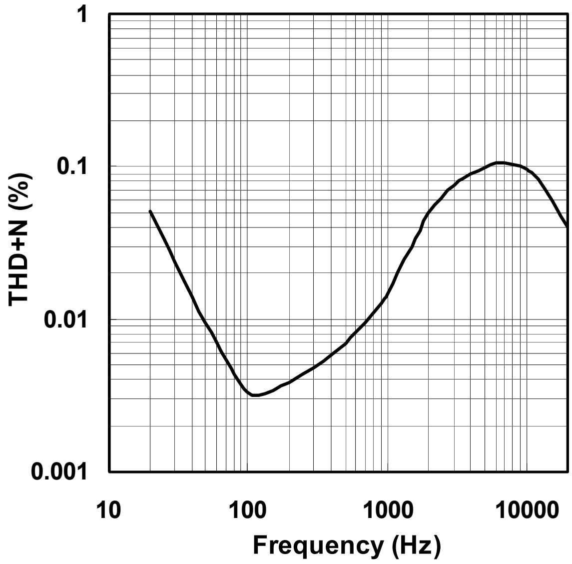




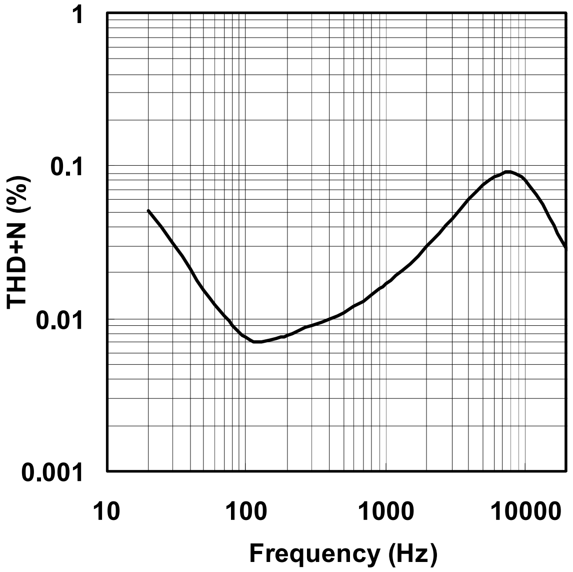
THD+N vs Frequency
V_{DD} = 5V , R_L = 8Ω , P_O = 0.6W



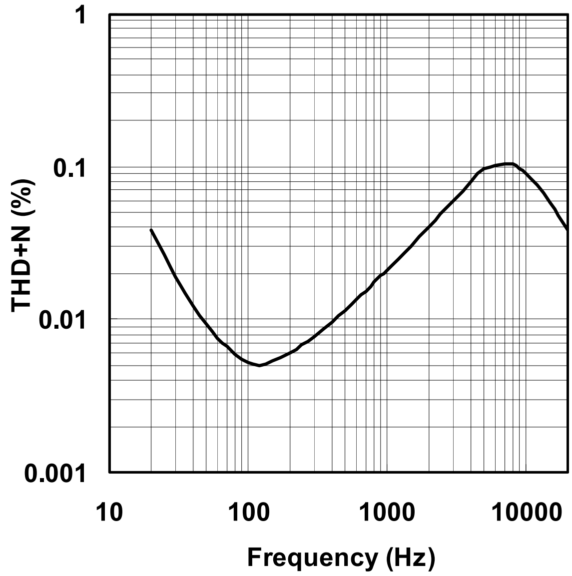
THD+N vs Frequency
V_{DD} = 3.6V , R_L = 8Ω , P_O = 0.4W



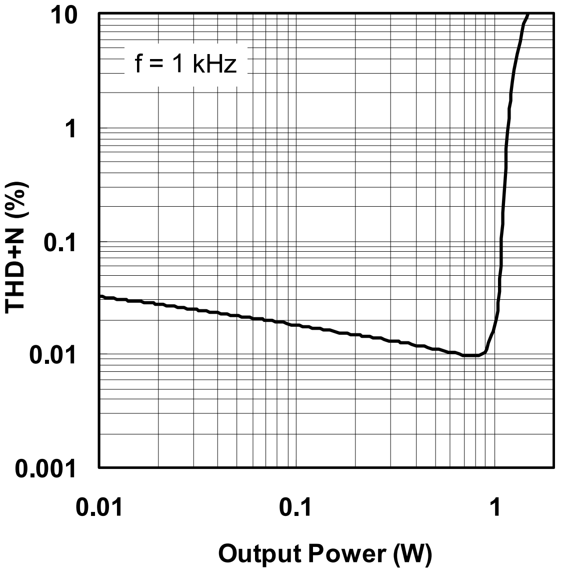
THD+N vs Frequency
V_{DD} = 5V , R_L = 4Ω , P_O =1W



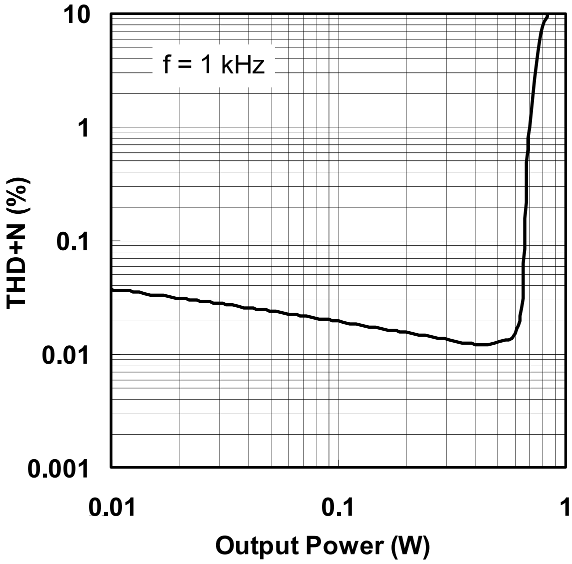
THD+N vs Frequency
V_{DD} = 3.6V , R_L = 4Ω , P_O = 0.6W



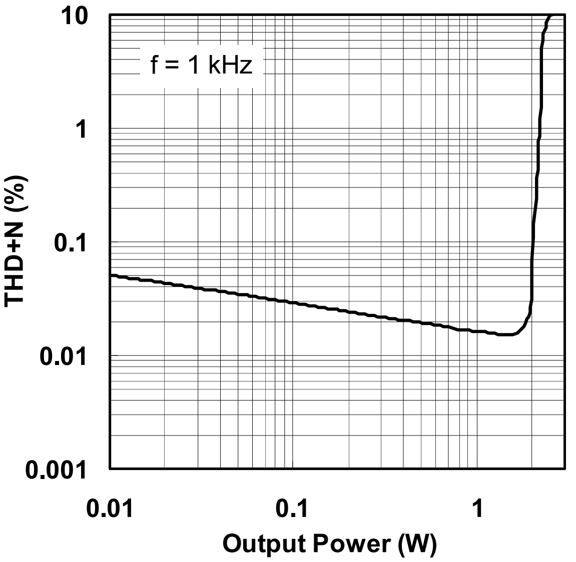
THD+N vs Output Power
V_{DD} = 5V , R_L = 8Ω



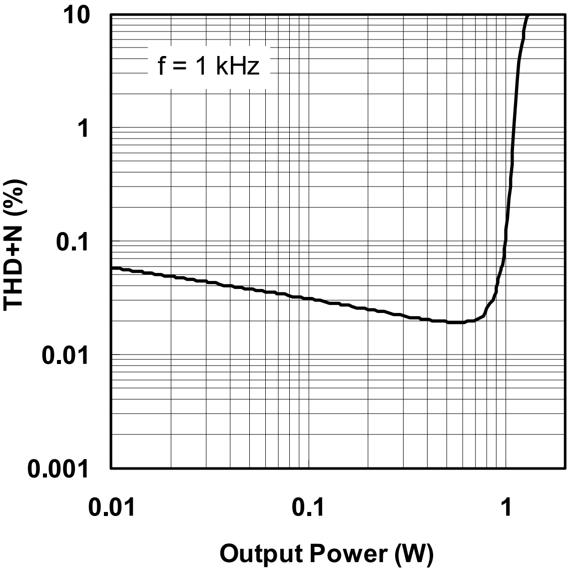
THD+N vs Output Power
V_{DD} =3.6V , R_L = 8Ω

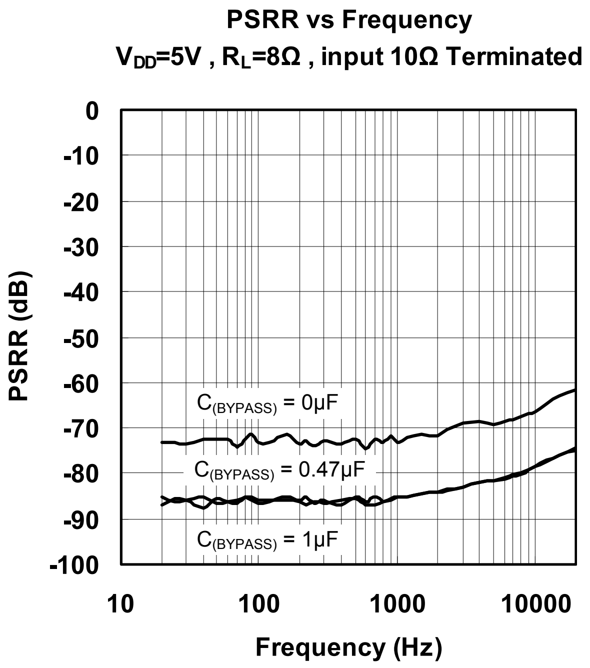


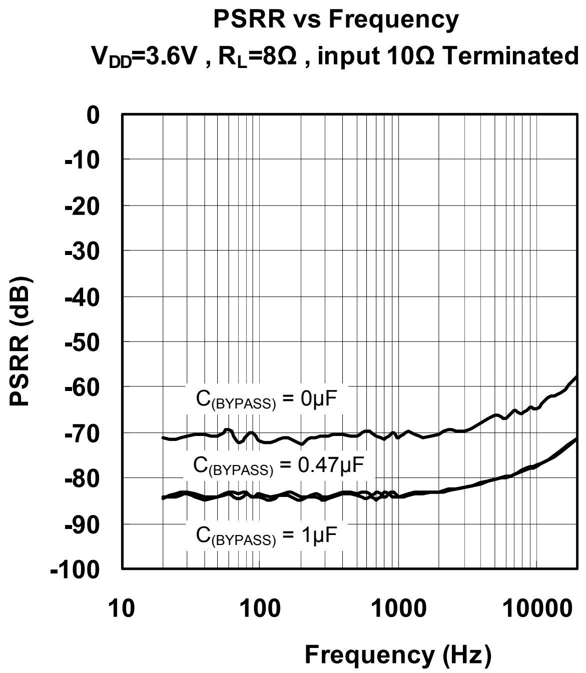
THD+N vs Output Power
V_{DD} =5V , R_L = 4Ω

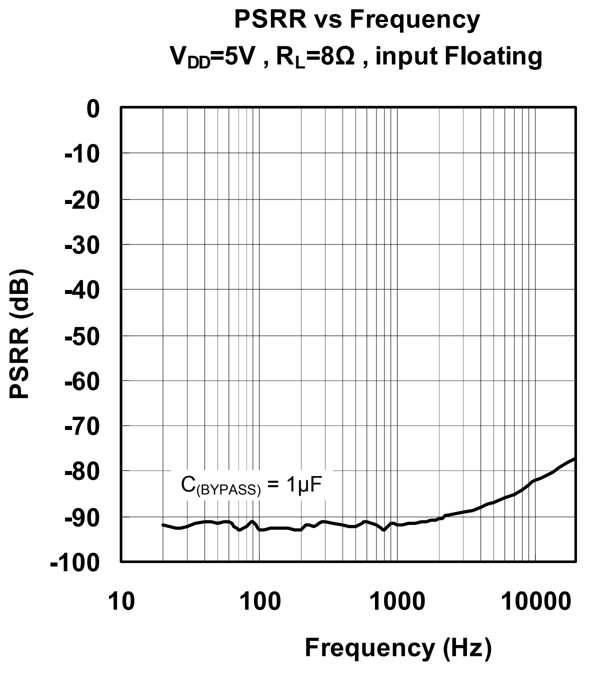


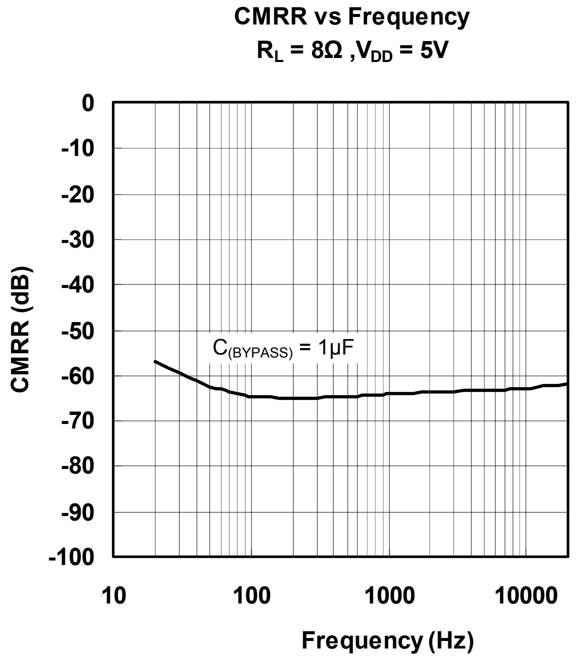
THD+N vs Output Power
V_{DD} =3.6V , R_L = 4Ω

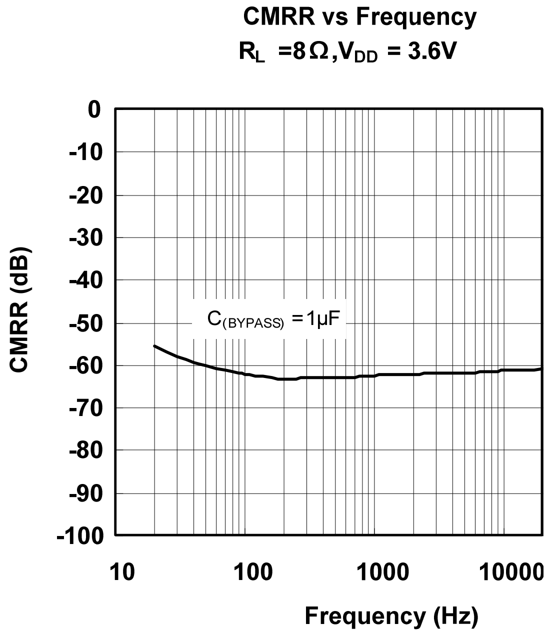


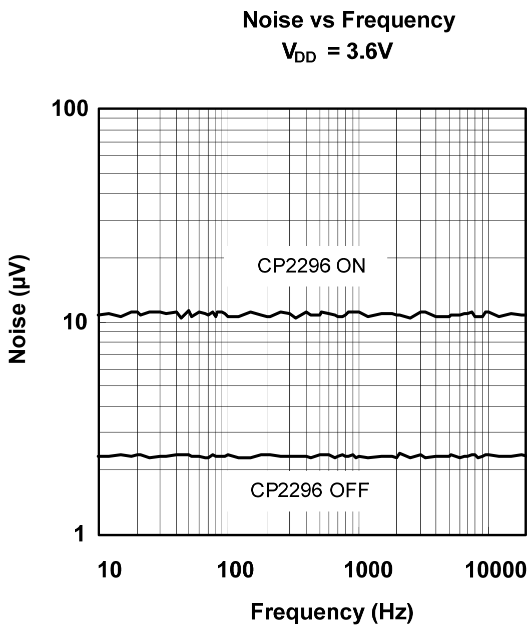

PSRR vs Frequency
VDD=5V , RL=8Ω , input 10Ω Terminated
C(BYPASS) = 0µF
C(BYPASS) = 0.47µF
C(BYPASS) = 1µF
PSRR (dB)
Frequency (Hz)


PSRR vs Frequency
VDD=3.6V , RL=8Ω , input 10Ω Terminated
C(BYPASS) = 0µF
C(BYPASS) = 0.47µF
C(BYPASS) = 1µF
PSRR (dB)
Frequency (Hz)


PSRR vs Frequency
VDD=5V , RL=8Ω , input Floating
C(BYPASS) = 1µF
PSRR (dB)
Frequency (Hz)


CMRR vs Frequency
RL = 8Ω ,VDD = 5V
C(BYPASS) = 1µF
CMRR (dB)
Frequency (Hz)


CMRR vs Frequency
RL =8Ω,VDD = 3.6V
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
CMRR (dB)
C(BYPASS) =1μF
10
100
1000
10000
Frequency (Hz)


Noise vs Frequency
VDD = 3.6V
100
10
1
Noise (μV)
CP2296 ON
CP2296 OFF
10
100
1000
10000
Frequency (Hz)

APPLICATION INFORMATION

Fully Differential Amplifier Description

The CP2296 is a fully differential amplifier with differential inputs and outputs. The fully differential amplifier consists of a differential amplifier and a common mode feedback amplifier. The differential amplifier ensures that the amplifier outputs a differential voltage that is equal to the differential input times the gain. The common mode feedback ensures that the common-mode voltage at the output is biased around VDD/2 regardless of the common-mode voltage at the input.

The CP2296 provides a "bridged mode" output configuration (bridge-tied-load, BTL). This means the output signals at Vo+ and Vo− that are 180° out of phase with respect to each other. Bridged mode operation is different from the single-ended output configuration that connects the load between the amplifier output and ground. A bridged amplifier design has distinct advantages over the single-ended output configuration: it provides differential drive to the load, thus doubling maximum possible output swing for a specific supply voltage. Four times the output power is possible compared with a single-ended output configuration under the same conditions. This increase in attainable output power assumes that the amplifier is not current limited or clipped.

Advantages of Fully Differential Amplifier

Input and output coupling capacitor not required: A fully differential amplifier with good CMRR, the CP2296 allows the input signal to be biased at voltage other than mid-supply of the CP2296, the common-mode feedback circuit adjusts for it, and the outputs are still biased at mid-supply of the CP2296.

Mid-supply bypass capacitor, C_{BYPASS} not required: The fully differential amplifier does not require a bypass capacitor. It is because any shift in the mid-supply affects both positive and negative channels equally and cancels at the differential output. However, removing the bypass capacitor slightly worsens power supply rejection ration, but a slightly decrease of PSRR may be acceptable when an additional component can be eliminated.

Better RF-immunity: GSM handsets save power by turning on and shutting off the RF transmitter at a rate of 217Hz. The transmitted signal is picked-up on input and output traces. The fully differential amplifier reduces the RF rectification much better than the typical audio amplifier.

Applications

From Figure 3 to Figure 5 show application schematics for differential and single-ended inputs.

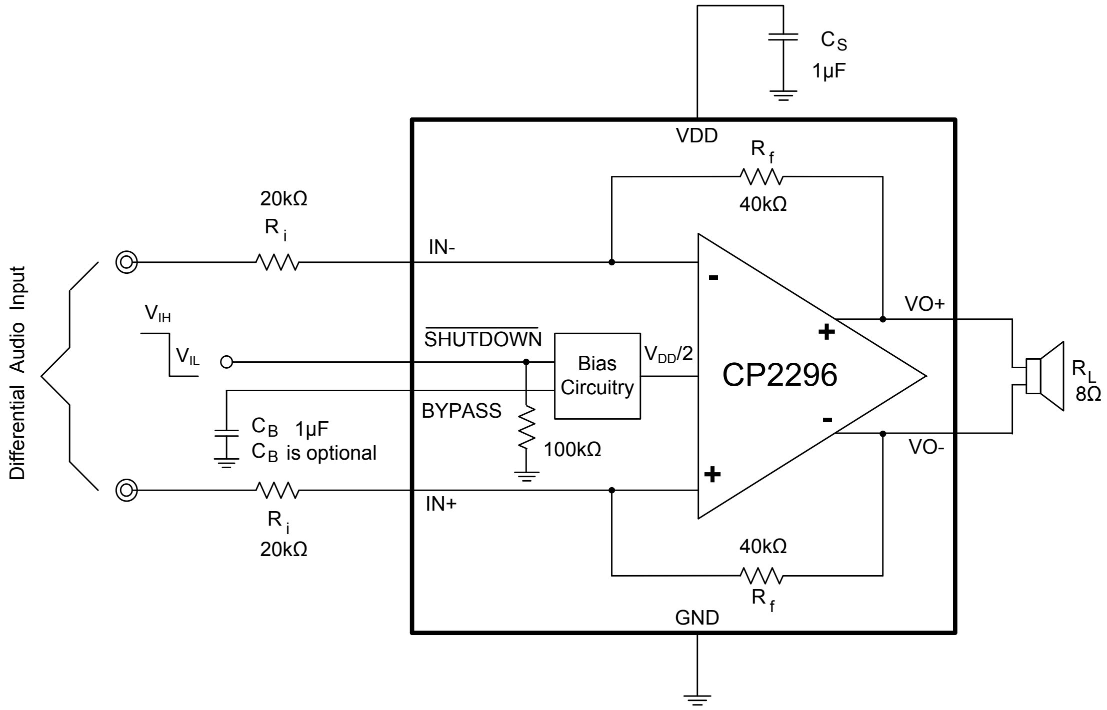


Figure 3 Typical Differential Input Application

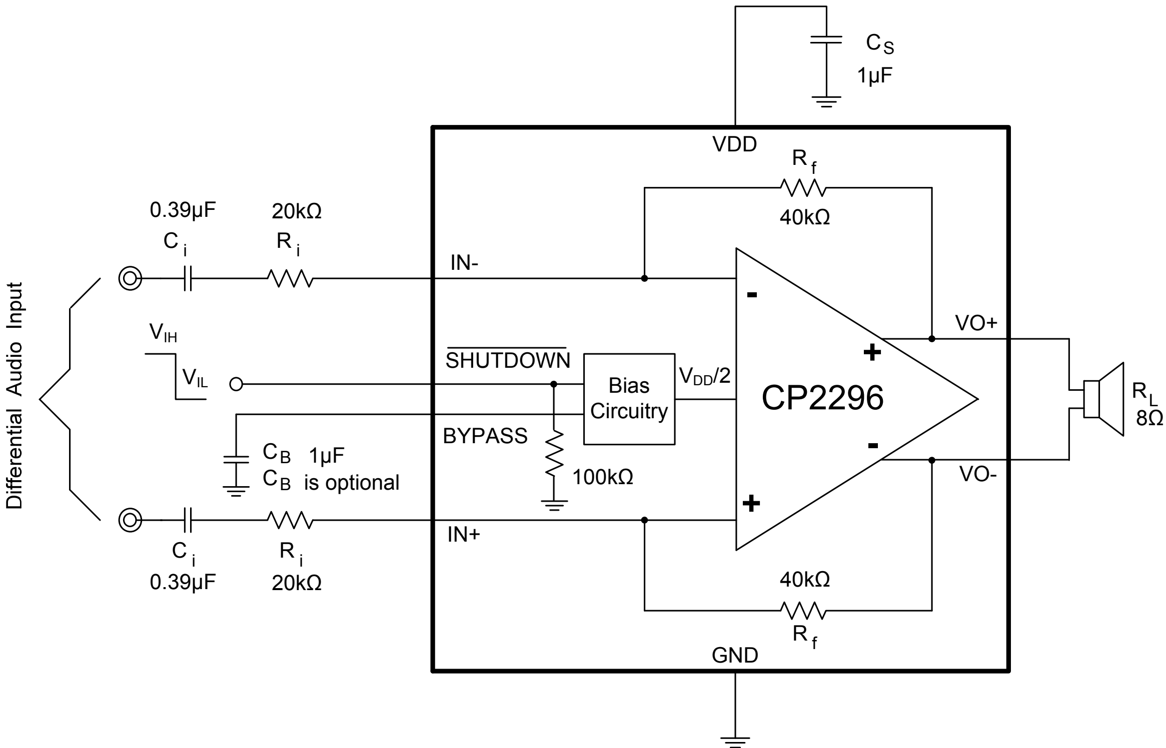


Figure 4 Differential Input Application With Input Capacitors

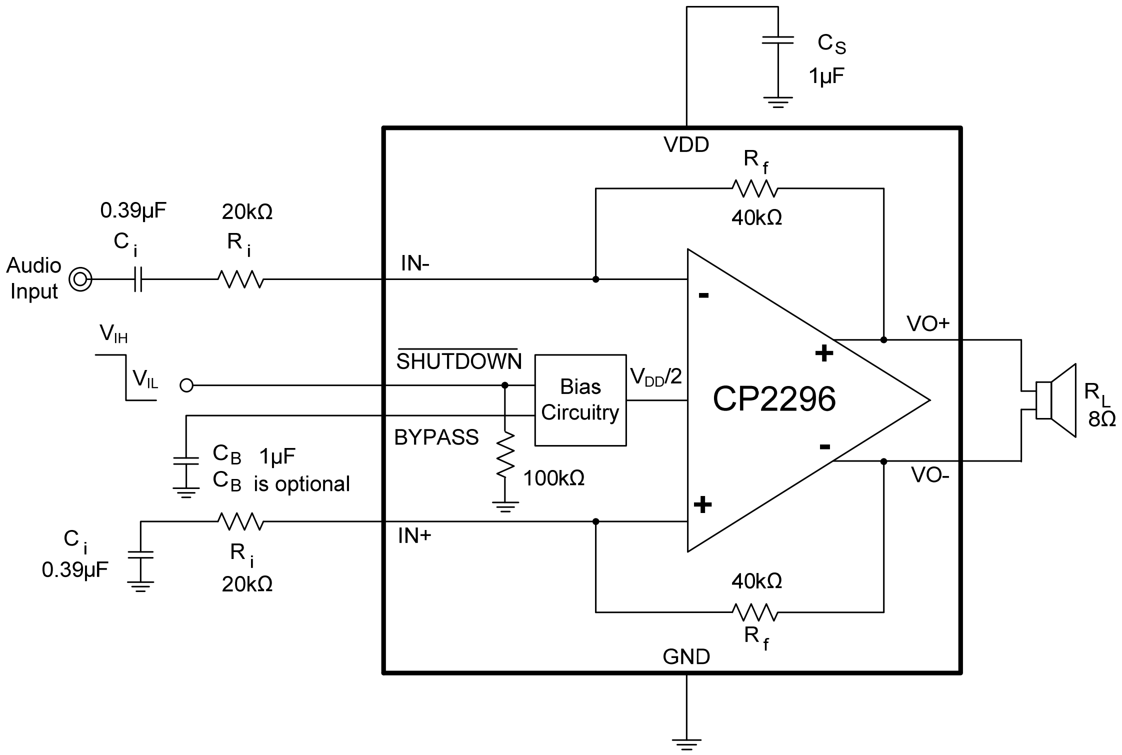


Figure 5 Single-Ended Input Application

Proper Selection of external Components

Input Resistor (R_i)

The input (R_i) and internal feedback resistors, R_f=40kΩ, set the gain of the amplifier according to Equation 1:

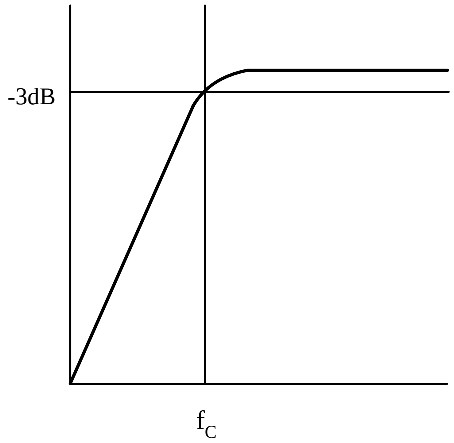
$$\text{Gain} = 40k\Omega / R_i \qquad (1)$$

In order to optimize the THD+N and SNR performance, The CP2296 should be used in low closed-loop gain configuration. R_i should be in range from 1kΩ to 100kΩ. Resistor matching is very important for fully differential amplifiers. The balance of the output on the common mode voltage depends on matched ratios of the resistors. CMRR, PSRR, and the second harmonic distortion is increased if resistor is not matched. Therefore, it is recommended to use 1% tolerance resistors or better to keep the performance optimized.

Input Capacitor (C_i)

The input coupling capacitor blocks the input DC voltage. The CP2296 does not require input coupling capacitors if using a differential input source that is biased from 0.5V to VDD-0.8V. Use 1% tolerance or better resistors if not using input coupling capacitors. In the single-ended input application an input coupling capacitor, C_i, is required to allow the amplifier to bias the input signal to the proper dc level.
The C_i and R_i form a high-pass filter with the corner frequency determined in Equation 2:

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



Special care should be taken to the value of C_i because it directly affects the low frequency performance of the system. For example, assuming R_i is 20kΩ and the specification calls for a flat response down to 100Hz. From Equation 2, C_i is 0.08uF, so C_i would likely choose a value in the range of 0.068μF to 0.47μF. A further consideration for C_i is the leakage path from the input source through the input network (R_i, C_i) and the feedback resistor (R_f) to the load. This leakage current creates a DC offset voltage that reduces useful headroom, especially in high gain applications. For this reason, a ceramic capacitor is the best choice.

Bypass Capacitor (C_{BYPASS}) and Start-Up Time

Connecting a capacitor to BYPASS pin filters any noise into this pin and increases the PSRR performance. C_{BYPASS} also determines the rise time of VO+ and VO-, the larger the capacitor, the slower the rise time, the CP2296 start to work after the C_{BYPASS} voltage reaches the mid-supply voltage. This capacitor can also minimize the pop & click noise during turn-on and turn-off transitions, the larger the capacitor, the smaller the pop & click noise, 1μF capacitor is recommended for C_{BYPASS}.

Decoupling Capacitor (C_S)

Power supply decoupling is critical for low THD+N and high PSRR performance. A low equivalent-series-resistance (ESR) ceramic capacitor, typically 0.1μF to 1μF, placed as close as possible to VDD pin makes the device work better. For filtering lower frequency noise signals, a 10μF or greater capacitor placed near the audio power amplifier also helps, but it is not required in most applications because of the high PSRR of this device.

Using Low-ESR Capacitors

Low-ESR capacitors are recommended. A real capacitor can be modeled simply as a resistor in series with an ideal capacitor. The voltage drop across this resistor minimizes the beneficial effects of the capacitor in the circuit. The lower the equivalent value of this resistance the more the real capacitor behaves like an ideal capacitor.

Power Dissipation

Power dissipation is a major concern when designing a successful amplifier, whether the amplifier is bridged or single-ended. Equation 3 states the maximum power dissipation point for a single-ended amplifier operating at a given supply voltage and driving a specified output load.

$$P_{DMAX} = \frac{V_{DD}^{\ 2}}{2\pi^2 R_L} \qquad \text{Single-Ended} \qquad (3)$$

However, a direct consequence of the increased power delivered to the load by a bridge amplifier is an increase in internal power dissipation versus a single-ended amplifier operating at the same conditions.

$$P_{DMAX} = 4 * \frac{V_{DD}^{\ 2}}{2\pi^2 R_L} \qquad \text{Bridge-Ended} \qquad (4)$$

Since the CP2296 has bridged outputs, the maximum internal power dissipation is 4 times that of a single-ended amplifier. Even with this substantial increasing in power dissipation, the CP2296 does not require additional heat-sinking under most operating conditions and output loading. From Equation 4, assuming a 5V power supply and an 8Ω load, the maximum power dissipation point is 625mW. The maximum power dissipation point obtained from Equation 4 must not be greater than the power dissipation results from Equation 5:

$$P_{DMAX} = (T_{JMAX} - T_A) / \theta_{JA} \quad (5)$$

Depending on the ambient temperature, TA, of the system surroundings, Equation 5 can be used to find the maximum internal power dissipation supported by the IC packaging. If the result of Equation 4 is greater than that of Equation 5, then either the supply voltage must be decreased, the load impedance increased, the ambient temperature reduced, or the θ_{JA} reduced with heat-sinking. In many cases, larger traces near the output, VDD, and GND pins can be used to lower the θ_{JA}. The larger areas of copper provide a form of heat-sinking allowing higher power dissipation. Recall that internal power dissipation is a function of output power. If the typical operation is not around the maximum power dissipation point, the CP2296 can operate at higher ambient temperatures.

Shutdown Function

In order to reduce power consumption while not in use, the CP2296 contains shutdown circuitry that is used to turn off the amplifier's bias circuitry. The shutdown pin should be tied to a definite voltage to avoid unwanted state changes. In many applications, a microcontroller or microprocessor output is used to control the shutdown circuitry, which provides a quick, smooth transition to shutdown.

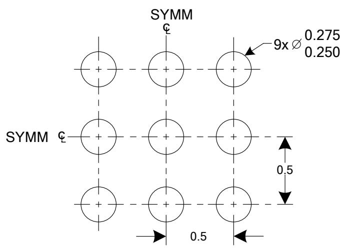
Board Layout Consideration

The residual resistance of the PCB trace between the amplifier output pins and the speaker causes a voltage drop, which results in power dissipated in the PCB trace and not in the speaker as desired. Therefore, to maintain the highest speaker power dissipation and widest output voltage swing, PCB trace that connects the amplifier output pins to the speaker must be as wide as possible.

Poor power supply regulation adversely affects maximum output power. A poorly regulated supply's output voltage decreases with increasing load current. Reduced supply voltage causes decreased headroom, output signal clipping, and reduced output power. Even with tightly regulated supplies, power supply trace resistance creates the same effects as poor supply regulation. Therefore, making the power supply trace as wide as possible helps to maintain full output voltage swing.

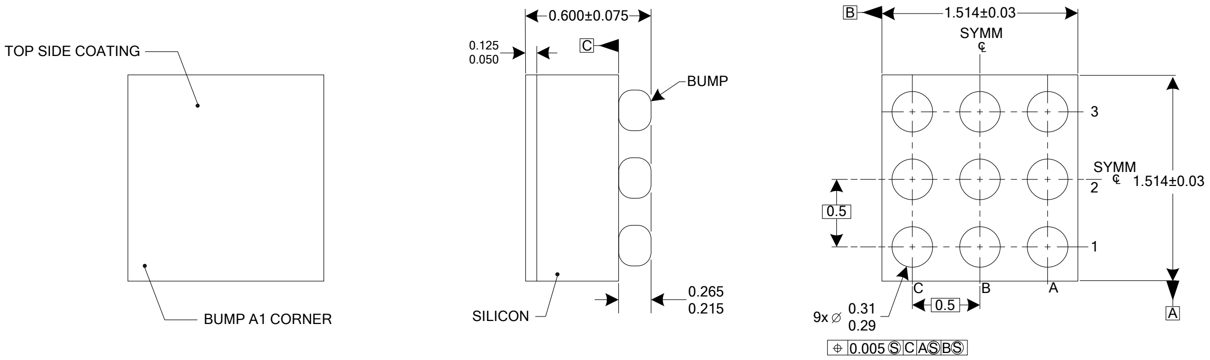
It is very important to keep the CP2296 external components very close to the CP2296 to limit noise pickup.

PACKAGE DESCRIPTION



DIMENSIONS ARE IN MILLIMETERS

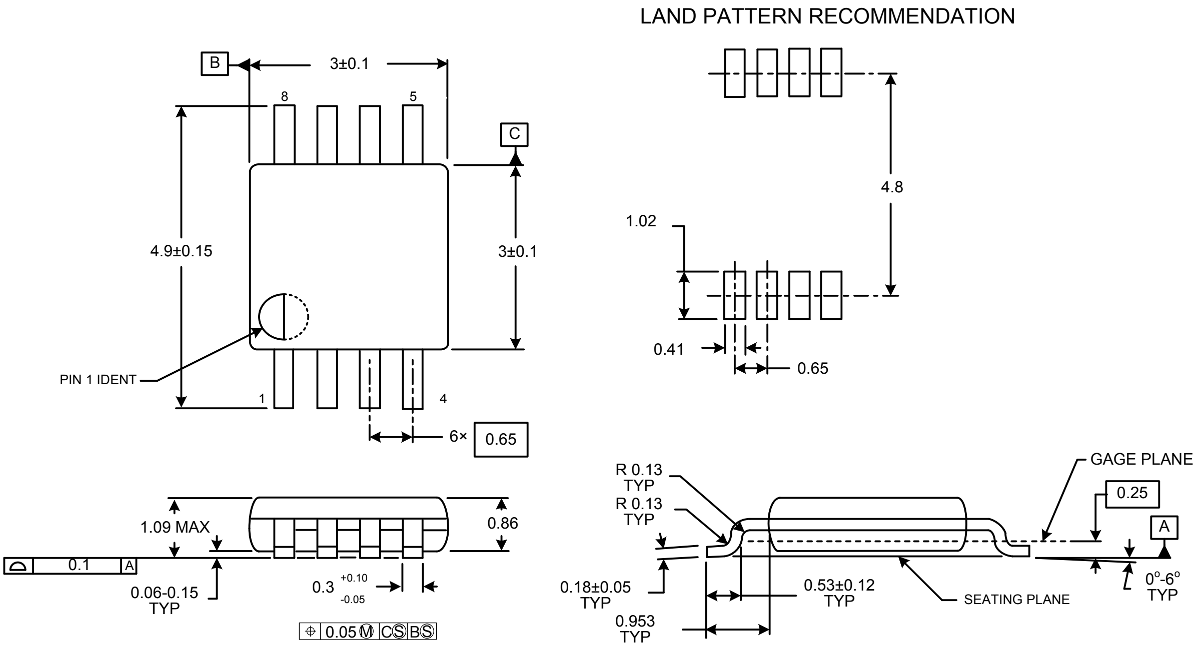
LAND PATTERN RECOMMENDATION



CSP9 Package
Part Number CP2296GITLX

Package Description (continued)

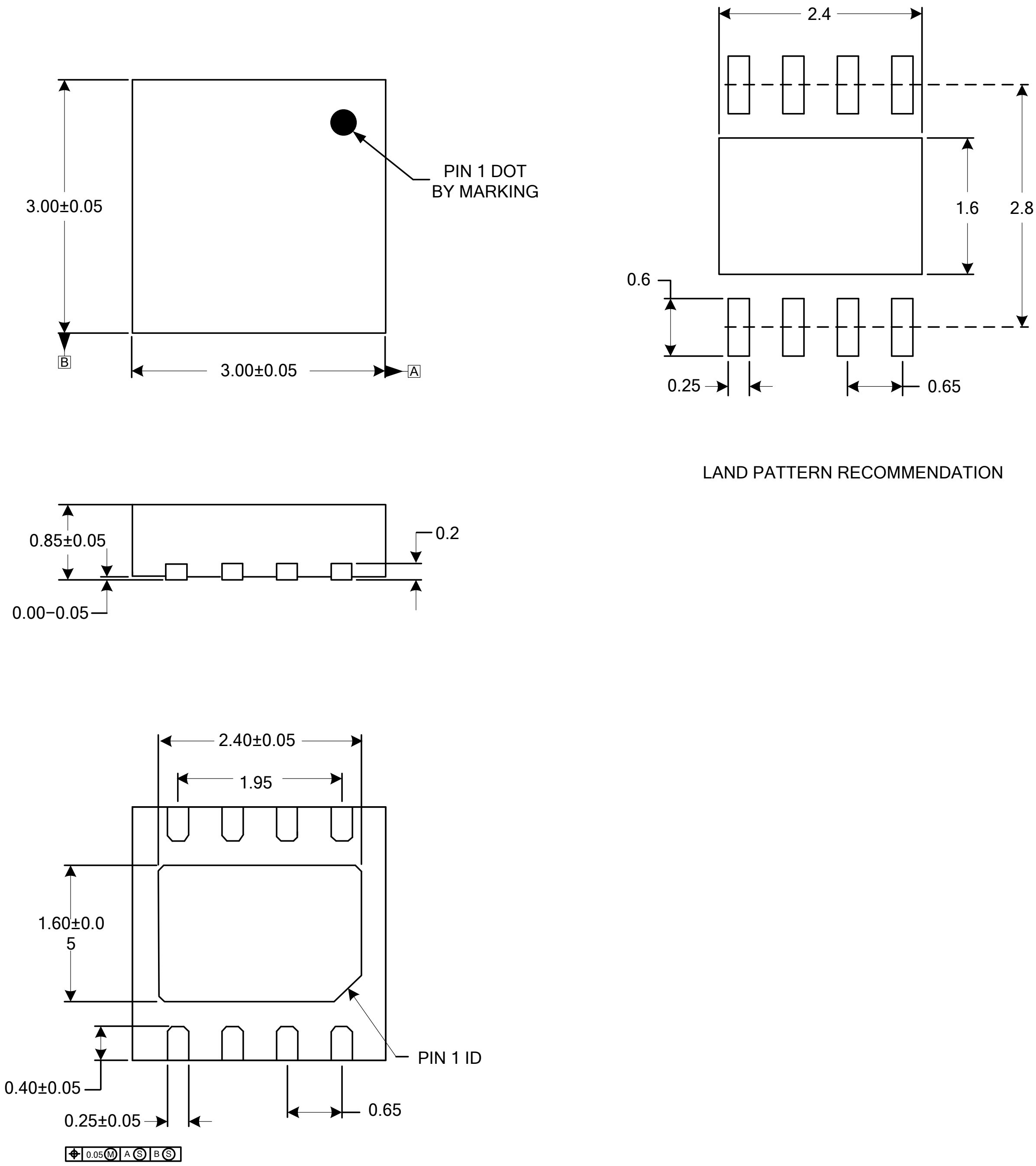
DIMENSIONS ARE IN MILLIMETERS



MSOP8 Package
Part Number CP2296GMM

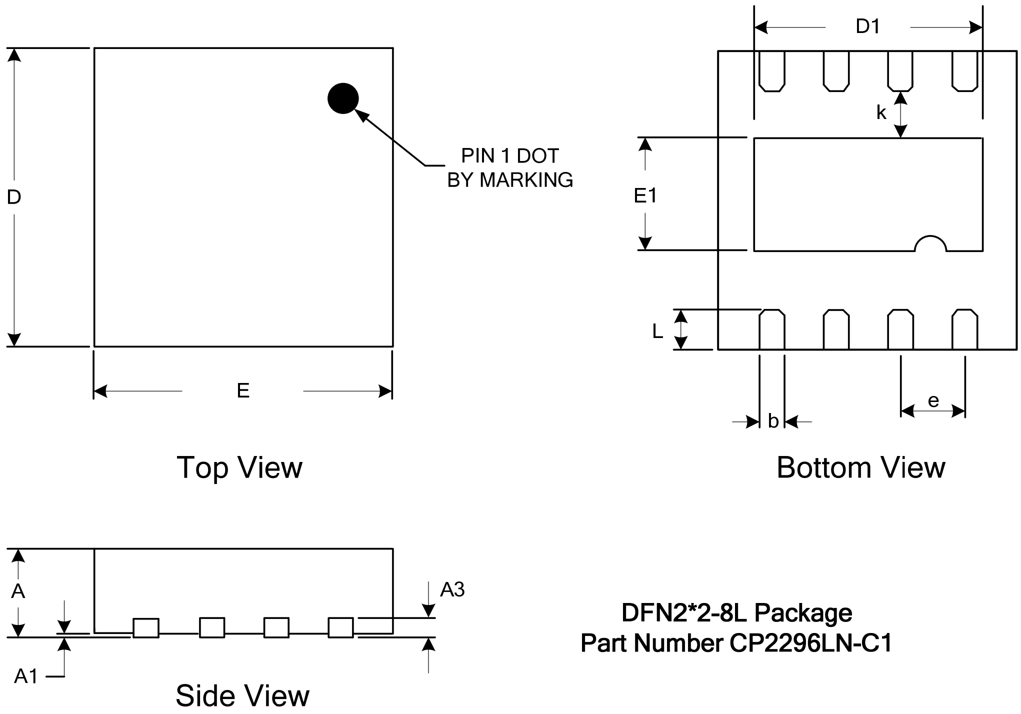
Package Description (continued)

DIMENSIONS ARE IN MILLIMETERS



DFN3*3-8L Package
Part Number CP2296DN-C1

Package Description (continued)



DFN2*2-8L Package
Part Number CP2296LN-C1

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.700/0.800	0.800/0.900	0.028/0.031	0.031/0.035
A1	0.000	0.050	0.000	0.002
A3	0.203REF		0.008REF	
D	1.900	2.100	0.075	0.083
E	1.900	2.100	0.075	0.083
D1	1.100	1.300	0.043	0.051
E1	0.500	0.700	0.020	0.028
k	0.200MIN		0.008MIN	
b	0.180	0.300	0.007	0.012
e	0.500TYP		0.020TYP	
L	0.250	0.450	0.010	0.018

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