Low Distortion 1.5 Watt Audio Power Amplifier

SSM2211

FEATURES

1.5 W output[1]
Differential (BTL[2]) output
Single-supply operation: 2.7 V to 5.5 V
Functions down to 1.75 V
Wide bandwidth: 4 MHz
Highly stable, phase margin: >80 degrees
Low distortion: 0.2% THD @ 1 W output
Excellent power-supply rejection

APPLICATIONS

Portable computers
Personal wireless communicators
Hands-free telephones
Speaker phones
Intercoms
Musical toys and talking games

FUNCTIONAL BLOCK DIAGRAM

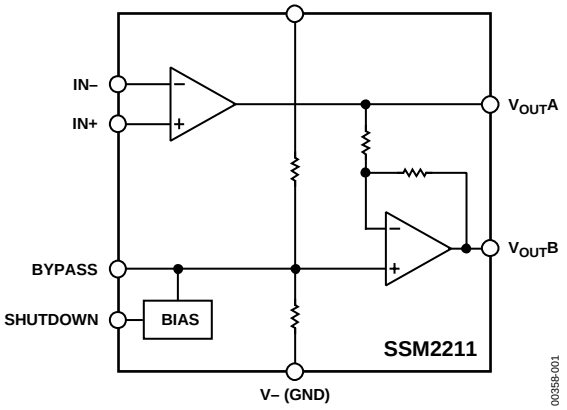

Figure 1.

GENERAL DESCRIPTION

The SSM2211[3] is a high performance audio amplifier that delivers 1 W rms of low distortion audio power into a bridge-connected 8 Ω speaker load (or 1.5 W rms into 4 Ω load). It operates over a wide temperature range and is specified for single-supply voltages between 2.7 V and 5.5 V. When operating from batteries, it continues to operate down to 1.75 V. This makes the SSM2211 the best choice for unregulated applications, such as toys and games. Featuring a 4 MHz bandwidth and distortion below 0.2% THD @ 1 W, superior performance is delivered at higher power or lower speaker load impedance than competitive units.

The low differential dc output voltage results in negligible losses in the speaker winding, and makes high value dc blocking capacitors unnecessary. Battery life is extended by using shutdown mode, which typically reduces quiescent current drain to 100 nA.

The SSM2211 is designed to operate over the −20°C to +85°C temperature range. The SSM2211 is available in SOIC-8 and LFCSP (lead frame chip scale) surface mount packages. The advanced mechanical packaging of the SSM2211CP ensures lower chip temperature and enhanced performance relative to standard packaging options.

Applications include personal portable computers, hands-free telephones and transceivers, talking toys, intercom systems, and other low voltage audio systems requiring 1 W output power.

[1] 1.5 W @ 4 Ω 25°C ambient, < 1% THD, 5 V supply, 4-layer PCB.
[2] Bridge-tied load.
[3] Protected by U.S. Patent No. 5,519,576.

Rev. C
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TABLE OF CONTENTS

Electrical Characteristics 3
Absolute Maximum Ratings 4
Pin Configurations 5
Typical Performance Characteristics 6
Product Overview 13
Thermal Performance—LFCSP 13
Typical Application 14
Bridged Output vs. Single-Ended Output Configurations 14
Speaker Efficiency and Loudness 14
Power Dissipation 15
Output Voltage Headroom 16
Automatic Shutdown-Sensing Circuit 16
Shutdown-Circuit Design Example 17
Start-Up Popping Noise 17
SSM2211 Amplifier Design Example 17
Single-Ended Applications 18
Driving Two Speakers Single Endedly 18
Evaluation Board 19
LFCSP Printed Circuit Board Layout Considerations 19
Outline Dimensions 20
Ordering Guide 20

REVISION HISTORY

10/04—Data Sheet Changed from Rev. B to Rev. C

Updated Format ..... Universal
Changes to General Description 1
Changes to Table 5 4
Deleted Thermal Performance—SOIC Section 8
Changes to Figure 31 10
Changes to Figure 40 12
Changes to Thermal Performance—LFCSP Section 13
Deleted Figure 52, Renumbered Successive Figures 14
Deleted Printed Circuit Board Layout —SOIC Section 14
Changes to Output Voltage Headroom Section 16
Changes to Start-Up Popping Noise Section 17
Changes to Ordering Guide 20

10/02–Data Sheet Changed from Rev. A to Rev. B

Deleted 8-Lead PDIP ..... Universal
Updated OUTLINE DIMENSIONS 15

5/02–Data Sheet Changed from Rev. 0 to Rev. A

Edits to GENERAL DESCRIPTION 1
Edits to PACKAGE TYPE 3
Edits to ORDERING GUIDE 3

Edits to PRODUCT OVERVIEW 8
Edits to PRINTED CIRCUIT BOARD LAYOUT CONSIDERATION 13
Added section PRINTED CIRCUIT BOARD LAYOUT CONSIDERATION—LFCSP 14

ELECTRICAL CHARACTERISTICS

Table 1. V_S = 5.0 V, T_A = 25°C, R_L = 8 Ω, C_B = 0.1 µF, V_{CM} = V_D/2, unless otherwise noted.

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
GENERAL CHARACTERISTICS						
Differential Output Offset Voltage	V_{OOS}	A_{VD} = 2		4	50	mV
Output Impedance	Z_{OUT}			0.1		Ω
SHUTDOWN CONTROL						
Input Voltage High	V_{IH}	I_{SY} = < 100 mA	3.0			V
Input Voltage Low	V_{IL}	I_{SY} = normal			1.3	V
POWER SUPPLY						
Power-Supply Rejection Ratio	PSRR	V_S = 4.75 V to 5.25 V		66		dB
Supply Current	I_{SY}	V_{O1} = V_{O2} = 2.5 V		9.5		mA
Supply Current, Shutdown Mode	I_{SD}	Pin 1 = V_{DD}; see Figure 32		100		nA
DYNAMIC PERFORMANCE						
Gain Bandwidth	GBP			4		MHz
Phase Margin	Ø⁰			86		Degrees
AUDIO PERFORMANCE						
Total Harmonic Distortion	THD + N	P = 0.5 W into 8 Ω, f = 1 kHz		0.15		%
Total Harmonic Distortion	THD + N	P = 1.0 W into 8 Ω, f = 1 kHz		0.2		%
Voltage Noise Density	e_n	f = 1 kHz		85		nV√Hz

Table 2. V_S = 3.3 V, T_A = 25°C, R_L = 8 Ω, C_B = 0.1 µF, V_{CM} = V_D/2, unless otherwise noted.

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
GENERAL CHARACTERISTICS						
Differential Output Offset Voltage	V_{OOS}	A_{VD} = 2		5	50	mV
Output Impedance	Z_{OUT}			0.1		Ω
SHUTDOWN INPUT						
Input Voltage High	V_{IH}	I_{SY} = < 100 µA	1.7			V
Input Voltage Low	V_{IL}				1	V
POWER SUPPLY						
Supply Current	I_{SY}	V_{O1} = V_{O2} = 1.65 V		5.2		mA
Supply Current, Shutdown Mode	I_{SD}	Pin 1 = V_{DD}; see Figure 32		100		nA
AUDIO PERFORMANCE						
Total Harmonic Distortion	THD + N	P = 0.35 W into 8 Ω, f = 1 kHz		0.1		%

Table 3. V_S = 2.7 V, T_A = 25°C, R_L = 8 Ω, C_B = 0.1 µF, V_{CM} = V_S/2, unless otherwise noted.

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
GENERAL CHARACTERISTICS						
Differential Output Offset Voltage	V_{OOS}	A_{VD} = 2		5	50	mV
Output Impedance	Z_{OUT}			0.1		Ω
SHUTDOWN CONTROL						
Input Voltage High	V_{IH}	I_{SY} = < 100 mA	1.5			V
Input Voltage Low	V_{IL}	I_{SY} = normal			0.8	V
POWER SUPPLY						
Supply Current	I_{SY}	V_{O1} = V_{O2} = 1.35 V		4.2		mA
Supply Current, Shutdown Mode	I_{SD}	Pin 1 = V_{DD}; see Figure 32		100		nA
AUDIO PERFORMANCE						
Total Harmonic Distortion	THD + N	P = 0.25 W into 8 Ω, f = 1 kHz		0.1		%

ABSOLUTE MAXIMUM RATINGS

Absolute maximum ratings apply at 25°C, unless otherwise noted.

Table 4.

Parameter	Value
Supply Voltage	6 V
Input Voltage	V_{DD}
Common-Mode Input Voltage	V_{DD}
ESD Susceptibility	2000 V
Storage Temperature Range	−65°C to +150°C
Operating Temperature Range	−20°C to +85°C
Junction Temperature Range	−65°C to +165°C
Lead Temperature Range (Soldering, 60 sec)	300°C

Table 5.

Package Type	θ_{JA}	Units
8-Lead LFCSP (CP)[1]	50	°C/W
8-Lead SOIC (S)[2]	121	°C/W

[1] For the LFCSP, θ_{JA} is measured with exposed lead frame soldered to the printed circuit board.
[2] For the SOIC, θ_{JA} is measured with the device soldered to a 4-layer printed circuit board.

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; the functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ESD CAUTION

ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although this product features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.

PIN CONFIGURATIONS

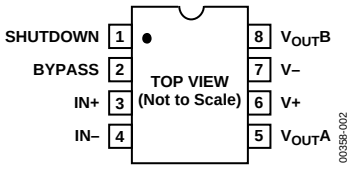


Figure 2. 8-Lead SOIC (SO-8)

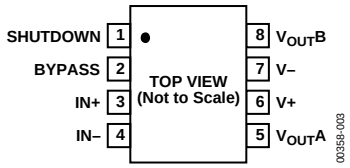


Figure 3. 8-Lead LFCSP (CP-8)

TYPICAL PERFORMANCE CHARACTERISTICS

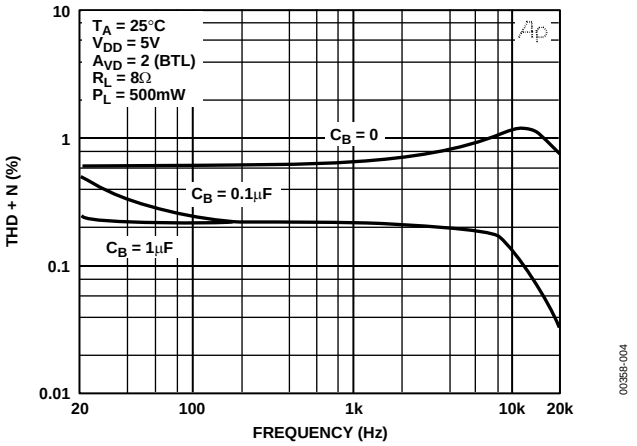


Figure 4. THD + N vs. Frequency

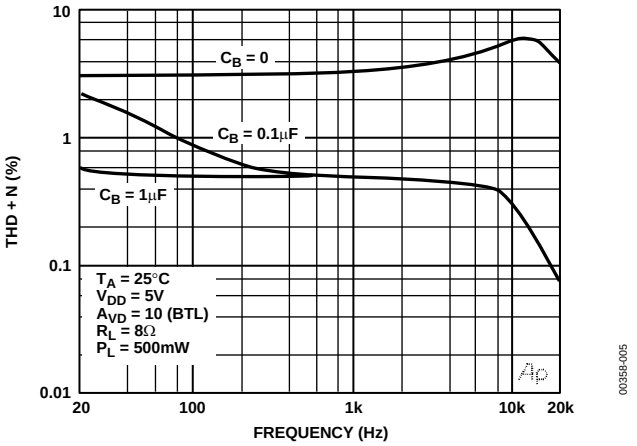


Figure 5. THD + N vs. Frequency

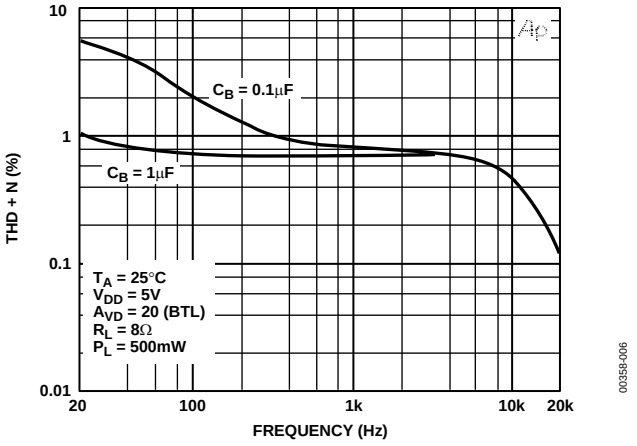
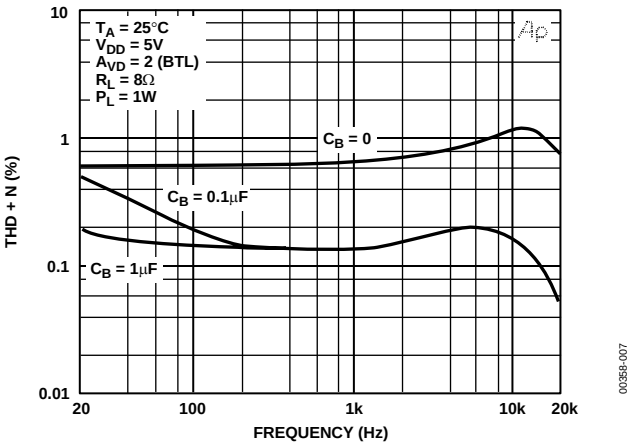


Figure 6. THD + N vs. Frequency



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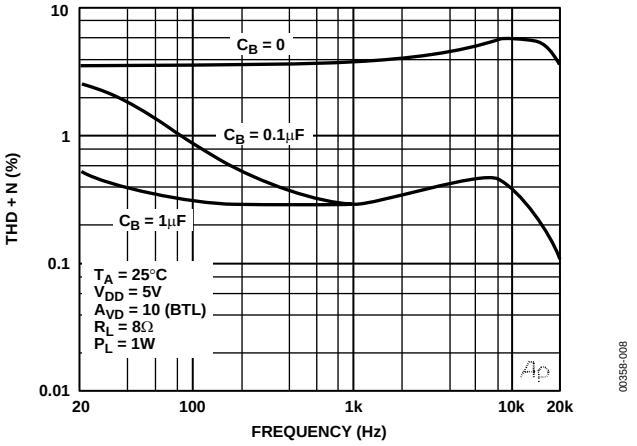


Figure 8. THD + N vs. Frequency

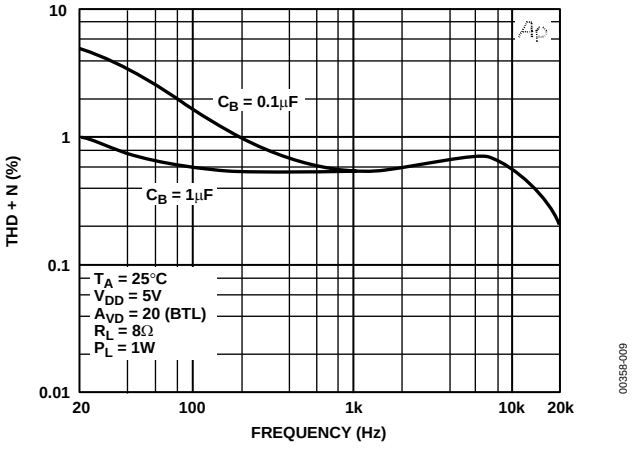


Figure 9. THD + N vs. Frequency

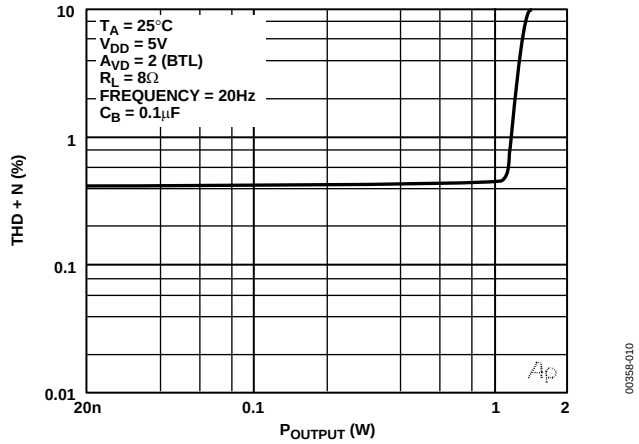


Figure 10. THD + N vs. P_{OUTPUT}

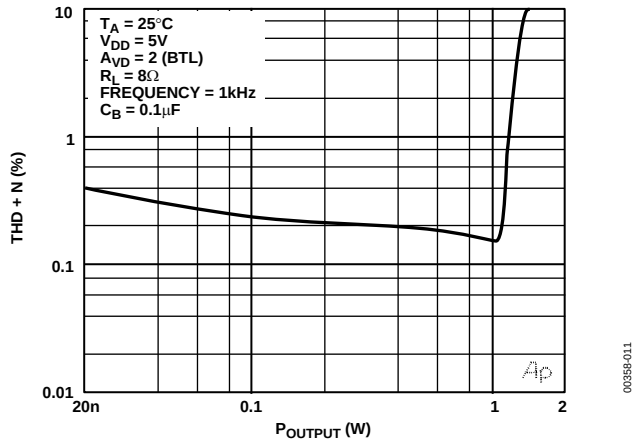


Figure 11. THD + N vs. P_{OUTPUT}

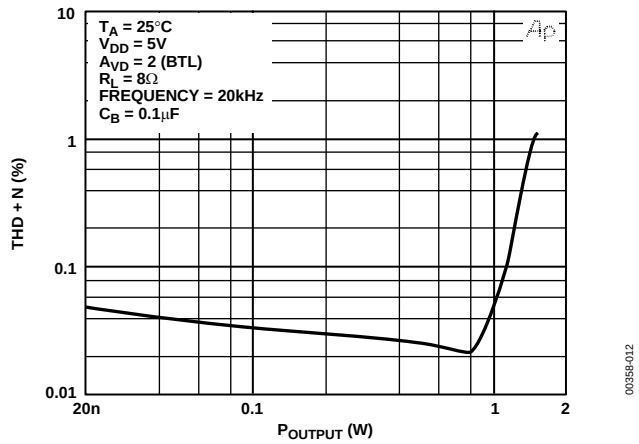


Figure 12. THD + N vs. P_{OUTPUT}

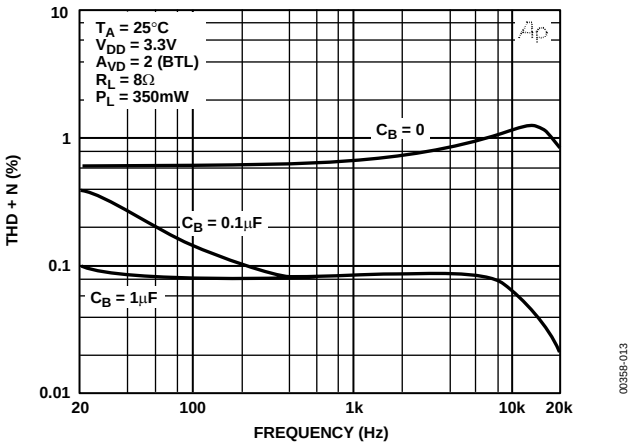
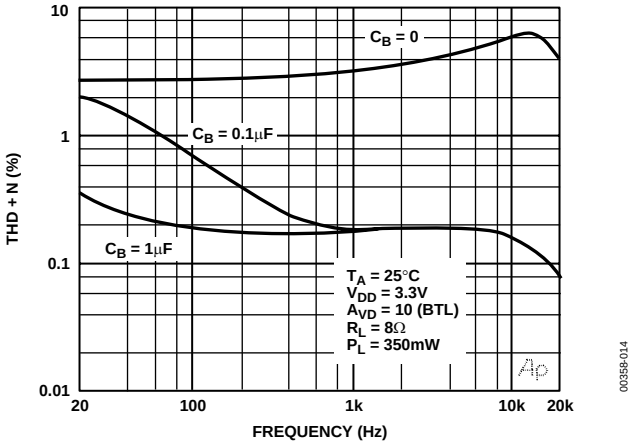


Figure 13. THD + N vs. Frequency



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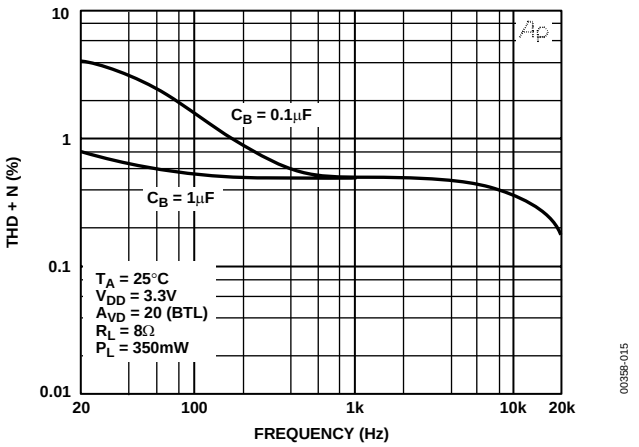

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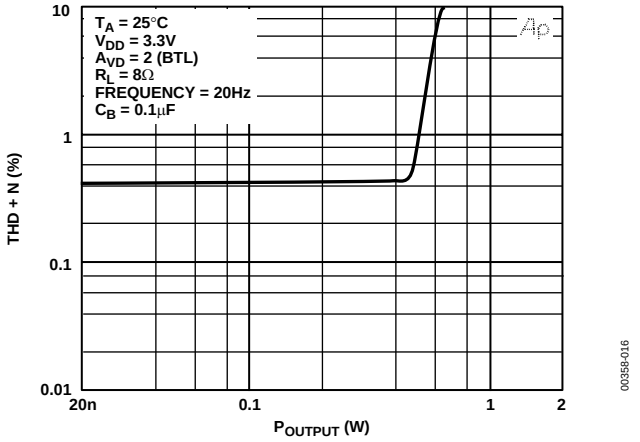


Figure 16. THD + N vs. P_{OUTPUT}

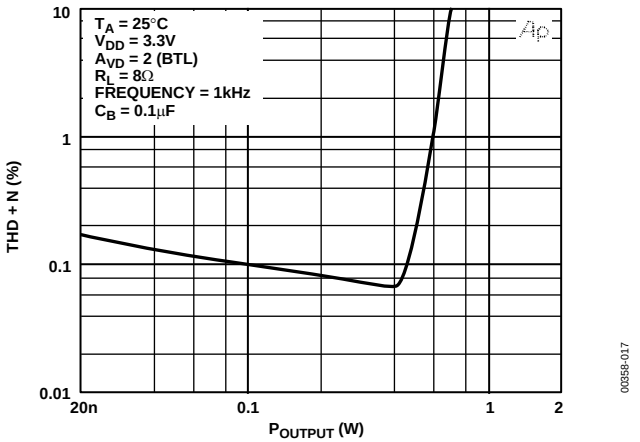


Figure 17. THD + N vs. P_{OUTPUT}

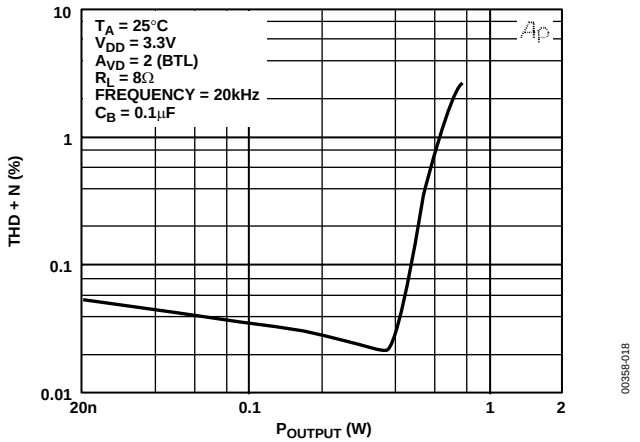


Figure 18. THD + N vs. Frequency

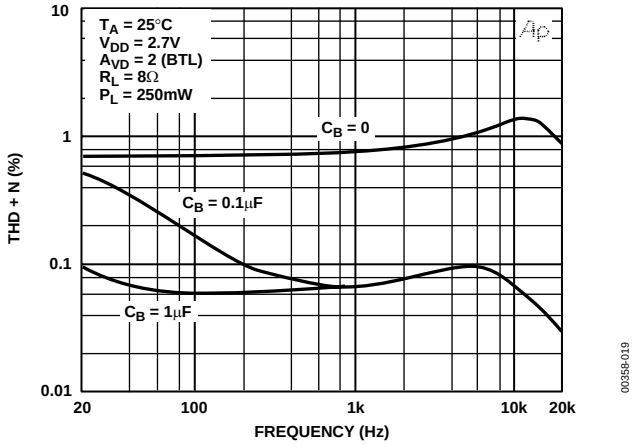


Figure 19. THD + N vs. Frequency

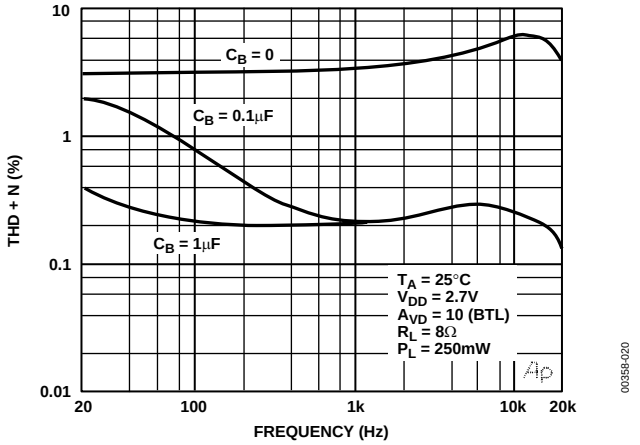
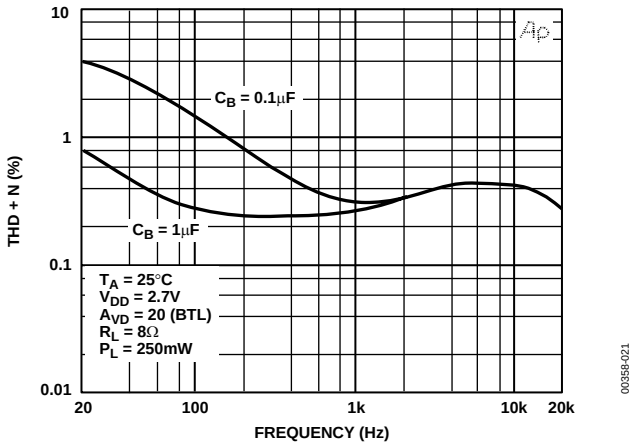


Figure 20. THD + N vs. Frequency



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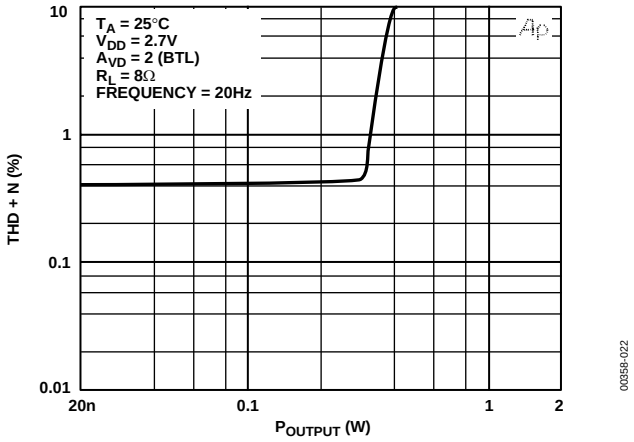


Figure 22. THD + N vs. P_{OUTPUT}

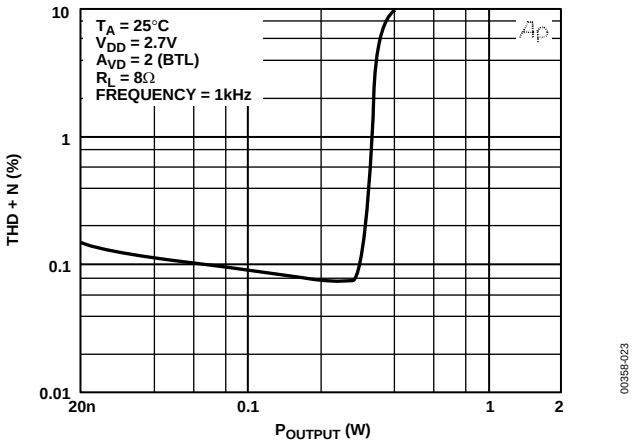


Figure 23. THD + N vs. P_{OUTPUT}

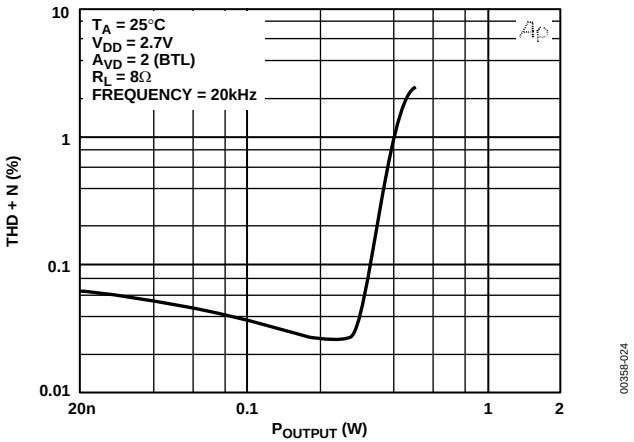


Figure 24. THD + N vs. P_{OUTPUT}

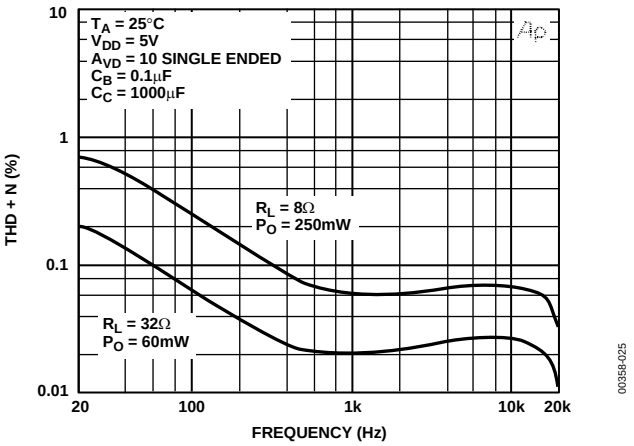


Figure 25. THD + N vs. Frequency

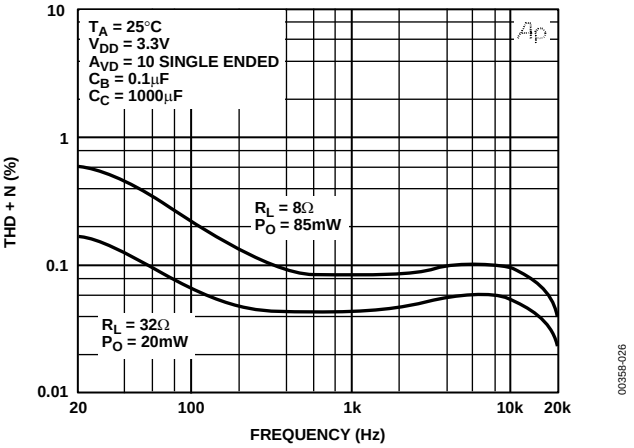


Figure 26. THD + N vs. Frequency

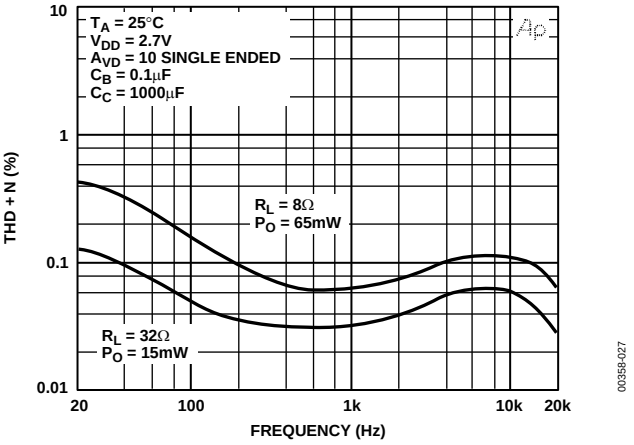


Figure 27. THD + N vs. Frequency

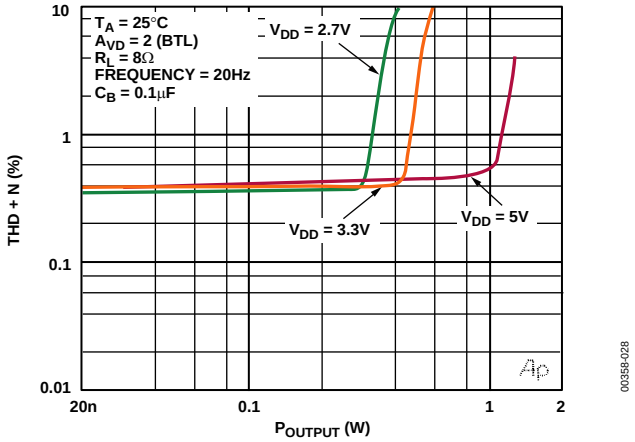


Figure 28. THD + N vs. P_{OUTPUT}

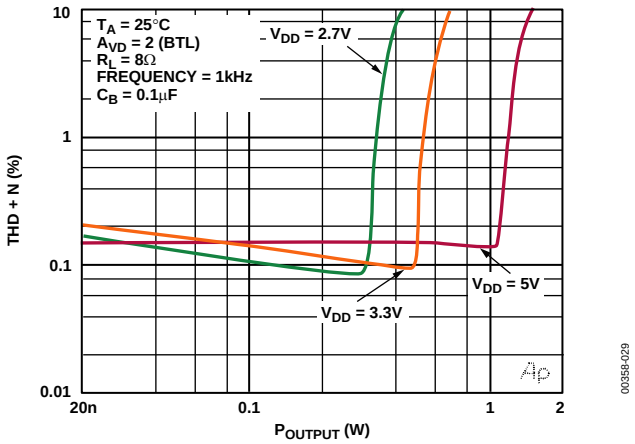


Figure 29. THD + N vs. P_{OUTPUT}

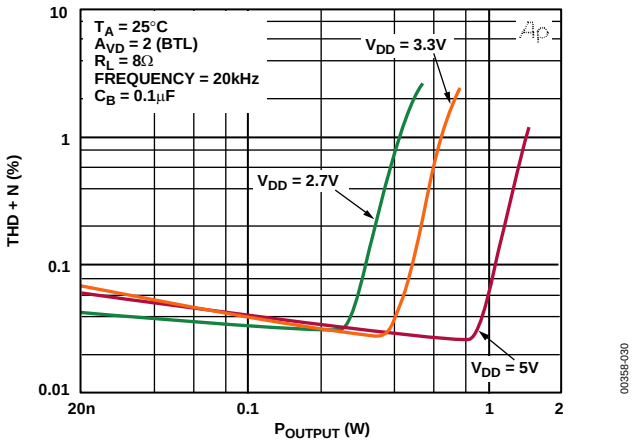


Figure 30. THD + N vs. P_{OUTPUT}

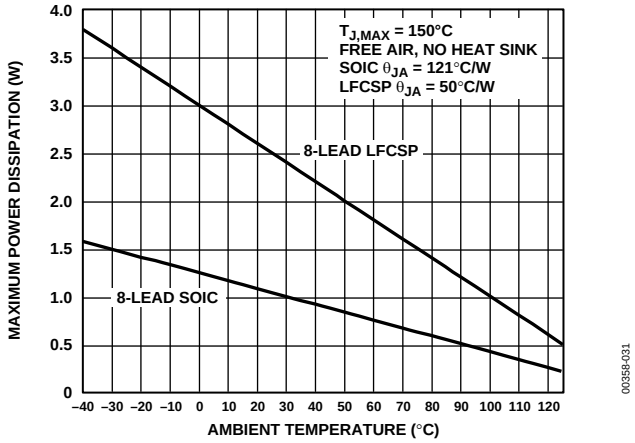


Figure 31. Maximum Power Dissipation vs. Ambient Temperature

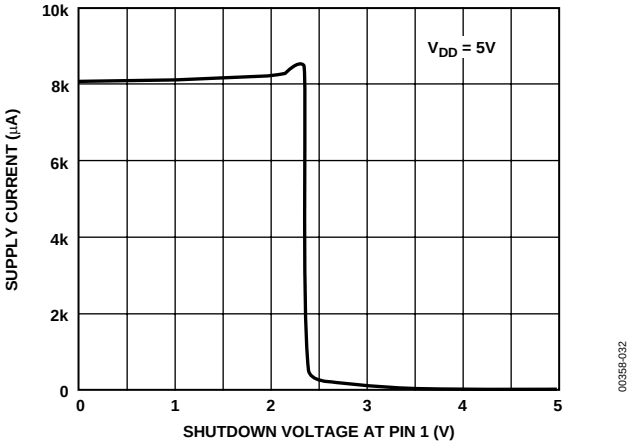


Figure 32. Supply Current vs. Shutdown Voltage

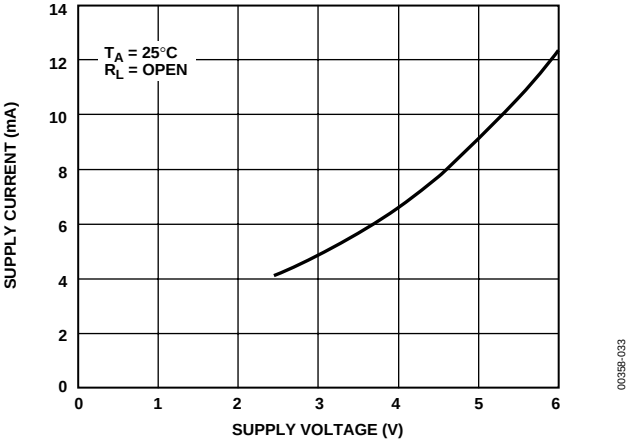


Figure 33. Supply Current vs. Supply Voltage

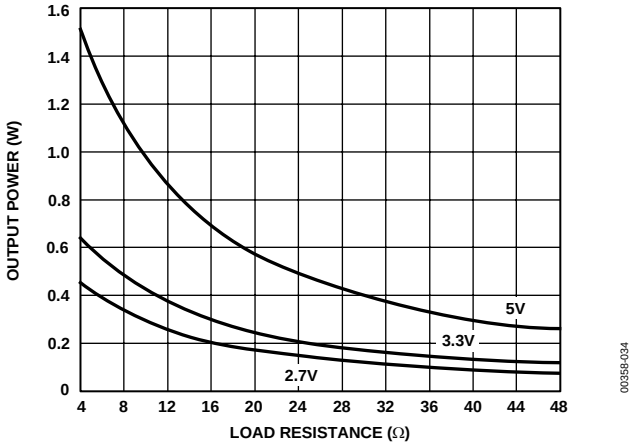


Figure 34. P_{OUTPUT} vs. Load Resistance

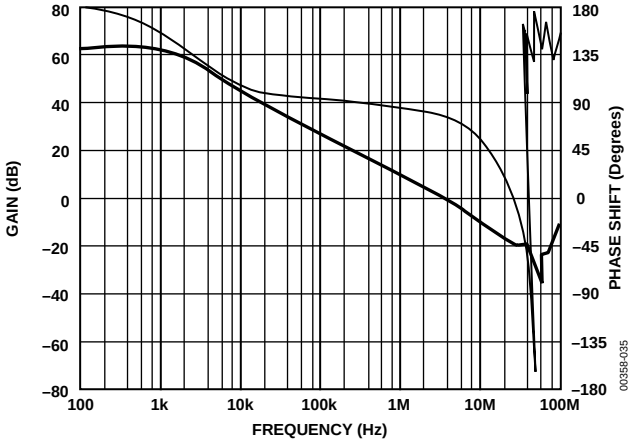


Figure 35. Gain, Phase vs. Frequency (Single Amplifier)

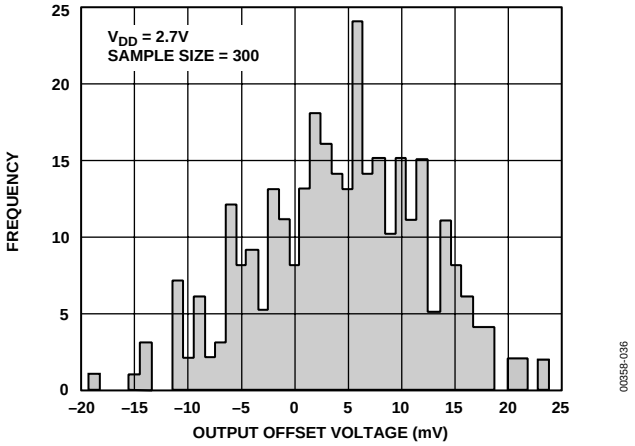


Figure 36. Output Offset Voltage Distribution

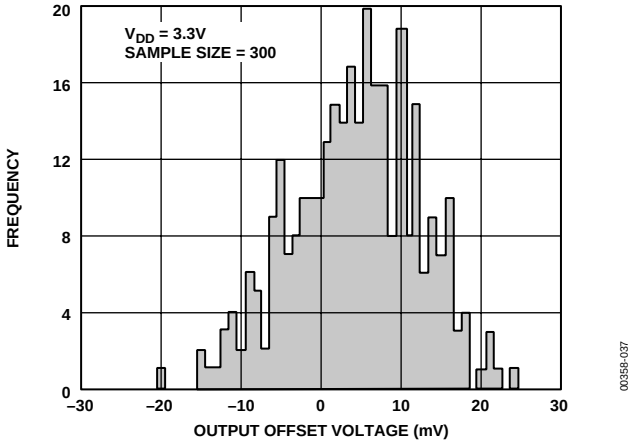


Figure 37. Output Offset Voltage Distribution

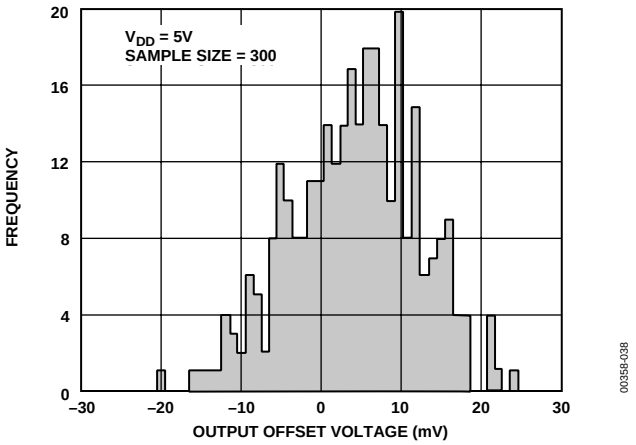


Figure 38. Output Offset Voltage Distribution

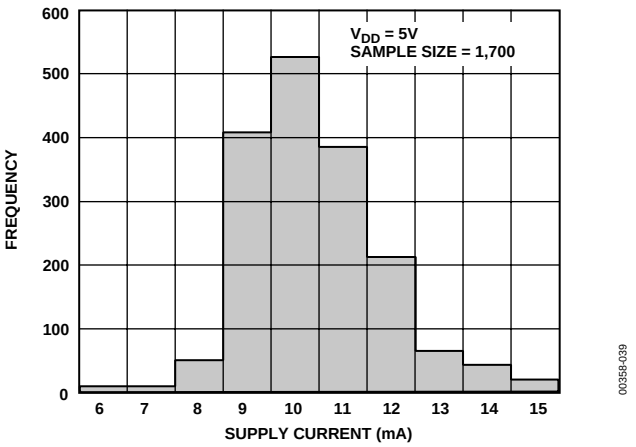


Figure 39. Supply Current Distribution

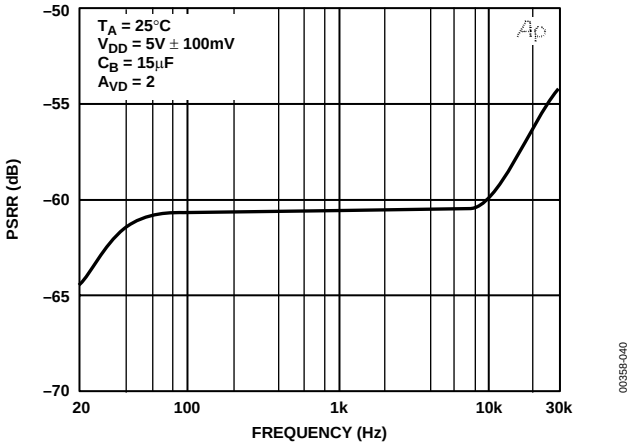


Figure 40. PSRR vs. Frequency

PRODUCT OVERVIEW

The SSM2211 is a low distortion speaker amplifier that can run from a 1.7 V to 5.5 V supply. It consists of a rail-to-rail input and a differential output that can be driven within 400 mV of either supply rail while supplying a sustained output current of 350 mA. The SSM2211 is unity-gain stable, requiring no external compensation capacitors, and can be configured for gains of up to 40 dB. Figure 41 shows the simplified schematic.

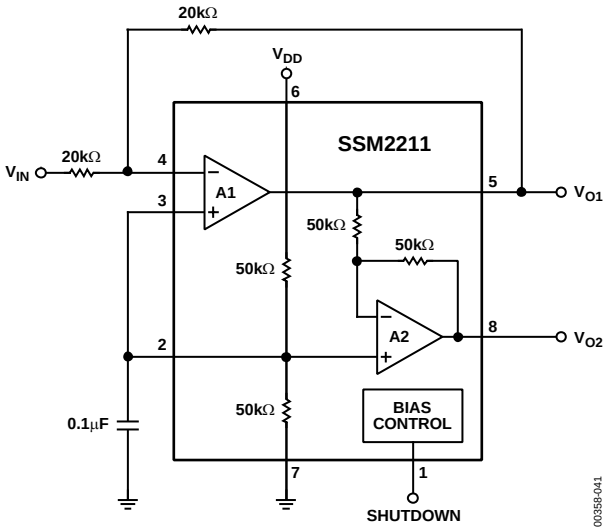


Figure 41. Simplified Schematic

Pin 4 and Pin 3 are the inverting and noninverting terminals to A1. An offset voltage is provided at Pin 2, which should be connected to Pin 3 for use in single-supply applications. The output of A1 appears at Pin 5. A second op amp, A2, is configured with a fixed gain of $A_V = -1$ and produces an inverted replica of Pin 5 at Pin 8. The SSM2211 outputs at Pins 5 and 8 produce a bridged configuration output to which a speaker can be connected. This bridge configuration offers the advantage of a more efficient power transfer from the input to the speaker. Because both outputs are symmetric, the dc bias at Pins 5 and 8 are exactly equal, resulting in zero dc differential voltage across the outputs. This eliminates the need for a coupling capacitor at the output.

THERMAL PERFORMANCE—LFCSP

The addition of the LFCSP to the Analog Devices package portfolio offers the SSM2211 user even greater choice when considering thermal performance criteria. For the 8-lead, 3 mm × 3 mm LFCSP, the θ_{JA} is 50°C/W. This is a significant performance improvement over most other packaging options.

TYPICAL APPLICATION

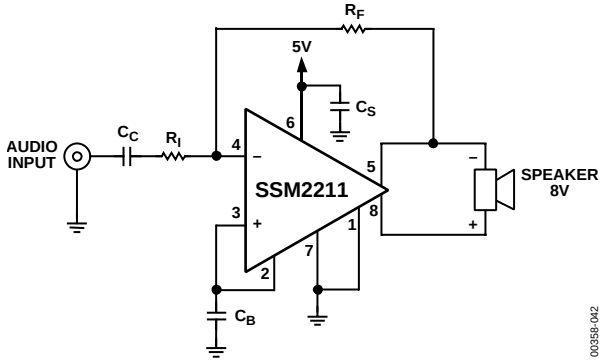


Figure 42. Typical Configuration

Figure 42 shows how the SSM2211 is connected in a typical application. The SSM2211 can be configured for gain much like a standard op amp. The gain from the audio input to the speaker is

$$A_V = 2 \times \frac{R_F}{R_I} \quad (1)$$

The 2 × factor comes from the fact that Pin 8 has the opposite polarity from Pin 5, providing twice the voltage swing to the speaker from the bridged output configuration.

C_S is a supply bypass capacitor to provide power supply filtering. Pin 2 is connected to Pin 3 to provide an offset voltage for single-supply use, with C_B providing a low ac impedance to ground to help power-supply rejection. Because Pin 4 is a virtual ac ground, the input impedance is equal to R_I. C_C is the input coupling capacitor which also creates a high-pass filter with a corner frequency of

$$f_{HP} = \frac{1}{2\pi R_I \times C_C} \quad (2)$$

Because the SSM2211 has an excellent phase margin, a feedback capacitor in parallel with R_F to band limit the amplifier is not required, as it is in some competitor's products.

BRIDGED OUTPUT VS. SINGLE-ENDED OUTPUT CONFIGURATIONS

The power delivered to a load with a sinusoidal signal can be expressed in terms of the signal's peak voltage and the resistance of the load as

$$P_L = \frac{V_{PK}{}^2}{2R_L} \quad (3)$$

By driving a load from a bridged output configuration, the voltage swing across the load doubles. Thus, an advantage in using a bridged output configuration becomes apparent from Equation 3, as doubling the peak voltage results in four times the power delivered to the load. In a typical application operating from a 5 V supply, the maximum power that can be delivered by the SSM2211 to an 8 Ω speaker in a single-ended configuration is 250 mW. By driving this speaker with a bridged output, 1 W of power can be delivered. This translates to a 12 dB increase in sound-pressure level from the speaker.

Driving a speaker differentially from a bridged output offers another advantage in that it eliminates the need for an output coupling capacitor to the load. In a single-supply application, the quiescent voltage at the output is half of the supply voltage. If a speaker is connected in a single-ended configuration, a coupling capacitor is needed to prevent dc current from flowing through the speaker. This capacitor also needs to be large enough to prevent low frequency roll-off. The corner frequency is given by

$$f_{-3\,\mathrm{dB}} = \frac{1}{2\pi R_L C_C} \quad (4)$$

where R_L is the speaker resistance and C_C is the coupling capacitance.

For an 8 Ω speaker and a corner frequency of 20 Hz, a 1000 µF capacitor would be needed, which is physically large and costly. By connecting a speaker in a bridged output configuration, the quiescent differential voltage across the speaker becomes nearly zero, eliminating the need for the coupling capacitor.

SPEAKER EFFICIENCY AND LOUDNESS

The effective loudness of 1 W of power delivered into an 8 Ω speaker is a function of the speaker's efficiency. The efficiency is typically rated as the sound pressure level (SPL) at 1 meter in front of the speaker with 1 W of power applied to the speaker. Most speakers are between 85 dB and 95 dB SPL at 1 meter at 1 W. Table 6 shows a comparison of the relative loudness of different sounds.

Table 6. Typical Sound Pressure Levels

Source of Sound	dB SPL
Threshold of pain	120
Heavy street traffic	95
Cabin of jet aircraft	80
Average conversation	65
Average home at night	50
Quiet recording studio	30
Threshold of hearing	0

It can easily be seen that 1 W of power into a speaker can produce quite a bit of acoustic energy.

POWER DISSIPATION

Another important advantage in using a bridged output configuration is the fact that bridged output amplifiers are more efficient than single-ended amplifiers in delivering power to a load. Efficiency is defined as the ratio of power from the power supply to the power delivered to the load:

$$\eta = \frac{P_L}{P_{SY}}$$

An amplifier with a higher efficiency has less internal power dissipation, which results in a lower die-to-case junction temperature, as compared to an amplifier that is less efficient. This is important when considering the amplifier's maximum power dissipation rating vs. ambient temperature. An internal power dissipation vs. output power equation can be derived to fully understand this.

The internal power dissipation of the amplifier is the internal voltage drop multiplied by the average value of the supply current. An easier way to find internal power dissipation is to measure the difference between the power delivered by the supply voltage source and the power delivered into the load. The waveform of the supply current for a bridged output amplifier is shown in Figure 43.

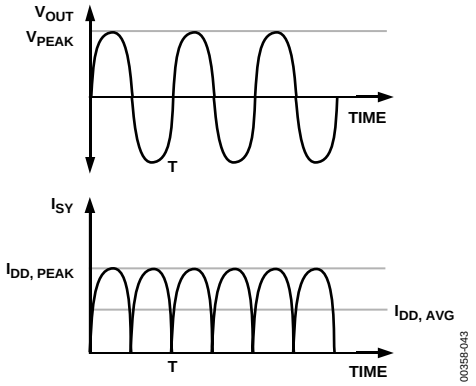


Figure 43. Bridged Amplifier Output Voltage and Supply Current vs. Time

By integrating the supply current over a period T, then dividing the result by T, $I_{DD,AVG}$ can be found. Expressed in terms of peak output voltage and load resistance

$$I_{DD,AVG} = \frac{2V_{PEAK}}{\pi R_L} \quad (5)$$

Therefore power delivered by the supply, neglecting the bias current for the device is

$$P_{SY} = \frac{2\,V_{DD}V_{PEAK}}{\pi R_L} \quad (6)$$

The power dissipated by the amplifier internally is simply the difference between Equation 6 and Equation 3. The equation for internal power dissipated, P_{DISS}, expressed in terms of power delivered to the load and load resistance is

$$P_{DISS} = \frac{2\sqrt{2 \times V_{DD}V_{PEAK}}}{\pi R_L} \quad (7)$$

The graph of this equation is shown in Figure 44.

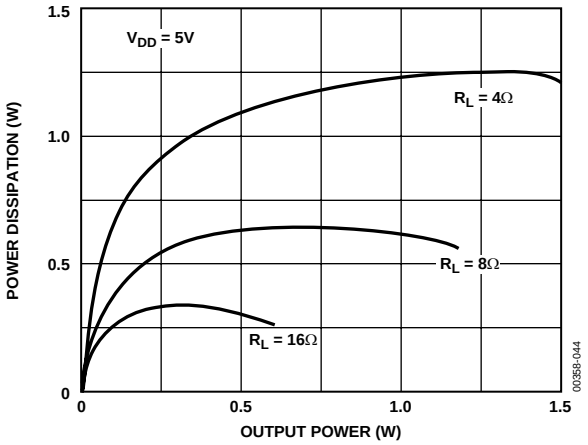


Figure 44. Power Dissipation vs. Output Power with V_{DD} = 5 V

Because the efficiency of a bridged output amplifier (Equation 3 divided by Equation 6) increases with the square root of P_L, the power dissipated internally by the device stays relatively flat, and actually decreases with higher output power. The maximum power dissipation of the device can be found by differentiating Equation 7 with respect to load power, and setting the derivative equal to zero. This yields

$$\frac{\partial P_{DISS}}{\partial P_L} = \frac{\sqrt{2}\times V_{DD}}{\pi R_L} P_L^{-1/2} - 1 = 0 \quad (8)$$

And occurs when

$$P_{DISS,MAX} = \frac{2\,V_{DD}{}^2}{\pi^2 R_L} \quad (9)$$

Using Equation 9 and the power derating curve in Figure 31, the maximum ambient temperature can be found easily. This ensures that the SSM2211 does not exceed its maximum junction temperature of 150°C.

The power dissipation for a single-ended output application where the load is capacitively coupled is given by

$$\partial P_{DISS} = \frac{2\sqrt{2}\times V_{DD}}{\pi\sqrt{R_L}}\sqrt{P_L - P_L} \quad (10)$$

The graph of Equation 10 is shown in Figure 45.

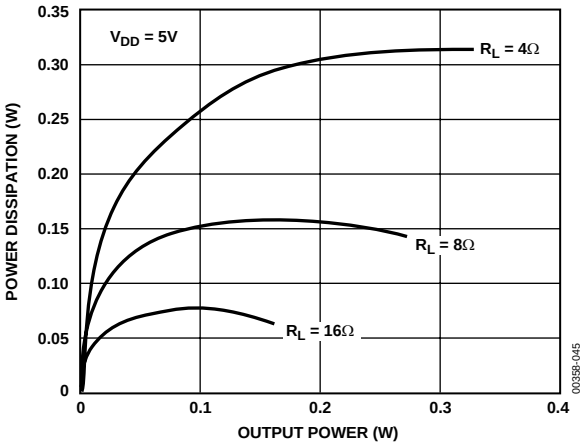


Figure 45. Power Dissipation vs. Single-Ended Output Power with V_{DD} = 5 V

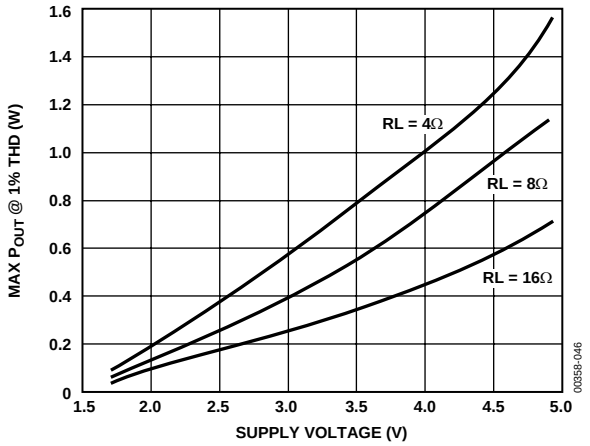


Figure 46. Maximum Output Power vs. V_{SY} Shutdown Feature

The maximum power dissipation for a single-ended output is

$$P_{DISS,MAX} = \frac{V_{DD}^2}{2\pi^2 R_L} \quad (11)$$

OUTPUT VOLTAGE HEADROOM

The outputs of both amplifiers in the SSM2211 can come to within 400 mV of either supply rail while driving an 8 Ω load. As compared to other competitors' equivalent products, the SSM2211 has a higher output voltage headroom. This means that the SSM2211 can deliver an equivalent maximum output power while running from a lower supply voltage. By running at a lower supply voltage, the internal power dissipation of the device is reduced, as can be seen in Equation 9. This extended output headroom, along with the LFCSP package, allows the SSM2211 to operate in higher ambient temperatures than other competitors' devices.

The SSM2211 is also capable of providing amplification even at supply voltages as low as 1.7 V. The maximum power available at the output is a function of the supply voltage. Therefore, as the supply voltage decreases, so does the maximum power output from the device. The maximum output power vs. supply voltage at various bridged-tied load resistances is shown in Figure 46 The maximum output power is defined as the point at which the output has 1% total harmonic distortion (THD).

To find the minimum supply voltage needed to achieve a specified maximum undistorted output power, use Figure 46.

For example, an application requires only 500 mW to be output for an 8 Ω speaker. With the speaker connected in a bridged output configuration, the minimum supply voltage required is 3.3 V.

The SSM2211 can be put into a low power consumption shutdown mode by connecting Pin 1 to 5 V. In shutdown mode, the SSM2211 has an extremely low supply current of less than 10 nA. This makes the SSM2211 ideal for battery-powered applications.

Pin 1 should be connected to ground for normal operation. Connecting Pin 1 to V_{DD} mutes the outputs and puts the device into shutdown mode. A pull-up or pull-down resistor is not required. Pin 1 should always be connected to a fixed potential, either V_{DD} or ground, and never be left floating. Leaving Pin 1 unconnected could produce unpredictable results.

AUTOMATIC SHUTDOWN-SENSING CIRCUIT

Figure 47 shows a circuit that can be used to take the SSM2211 in and out of shutdown mode automatically. This circuit can be set to turn the SSM2211 on when an input signal of a certain amplitude is detected. The circuit also puts the device into low power shutdown mode if an input signal is not sensed within a certain amount of time. This can be useful in a variety of portable radio applications where power conservation is critical.

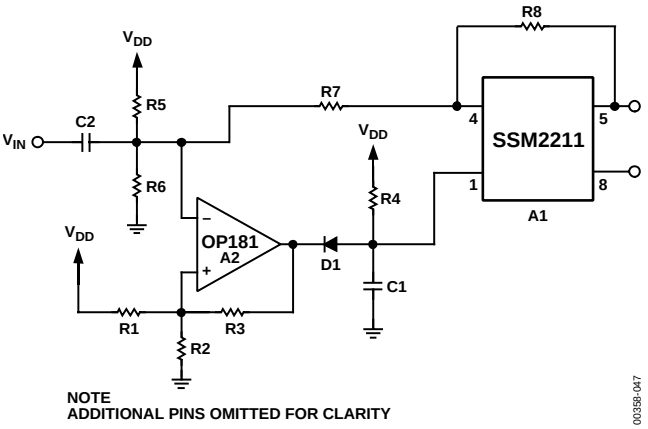


Figure 47. Automatic Shutdown Circuit

The input signal to the SSM2211 is also connected to the non-inverting terminal of A2. R1, R2, and R3 set the threshold voltage for when the SSM2211 is to be taken out of shutdown mode. D1 half-wave rectifies the output of A2, discharging C1 to ground when an input signal greater than the set threshold voltage is detected. R4 controls the charge time of C1, which sets the time until the SSM2211 is put back into shutdown mode after the input signal is no longer detected.

R5 and R6 are used to establish a voltage reference point equal to half of the supply voltage. R7 and R8 set the gain of the SSM2211. D1 should be a 1N914 or equivalent diode and A2 should be a rail-to-rail output amplifier, such as an OP181 or equivalent. This ensures that C1 discharges sufficiently to bring the SSM2211 out of shutdown mode.

To find the appropriate component values, first the gain of A2 must be determined by

$$A_{V,MIN} = \frac{V_{SY}}{V_{THS}} \tag{12}$$

where:
V_{SY} is the single supply voltage.
V_{THS} is the threshold voltage.
A_V should be set to a minimum of 2 for the circuit to work properly.

Next choose *R1* and set *R2* to

$$R2 = R1\left(1 - \frac{2}{A_V}\right) \tag{13}$$

Find *R3* as:

$$R3 = \frac{R1 \times R2}{R2 + R2}\left(A_V - 1\right) \tag{14}$$

C1 can be arbitrarily set but should be small enough to keep A2 from becoming capacitively overloaded. R4 and C1 control the shutdown rate. To prevent intermittent shutdown with low frequency input signals, the minimum time constant should be

$$R4 \times C1 \geq \frac{10}{f_{LOW}} \tag{15}$$

where f_{LOW} is the lowest input frequency expected.

SHUTDOWN-CIRCUIT DESIGN EXAMPLE

In this example, a portable radio application requires the SSM2211 to be turned on when an input signal greater than 50 mV is detected. The device should return to shutdown mode within 500 ms after the input signal is no longer detected. The lowest frequency of interest is 200 Hz, and a 5 V supply is used.

The minimum gain of the shutdown circuit from Equation 12 is A_V = 100. R1 is set to 100 kΩ. Using Equation 13 and Equation 14, R2 = 98 kΩ and R3 = 4.9 MΩ. C1 is set to 0.01 µF, and based on Equation 15, R4 is set to 10 MΩ . To minimize power supply current, R5 and R6 are set to 10 MΩ. The previous procedure provides an adequate starting point for the shutdown circuit. Some component values may need to be adjusted empirically to optimize performance.

START-UP POPPING NOISE

During power-up or release from shutdown mode, the midrail bypass capacitor, C_B, determines the rate at which the SSM2211 starts up. By adjusting the charging time constant of C_B, the start-up pop noise can be pushed into the subaudible range, greatly reducing start-up popping noise. On power-up, the midrail bypass capacitor is charged through an effective resistance of 25 kΩ. To minimize start-up popping, the charging time constant for C_B should be greater than the charging time constant for the input coupling capacitor, C_C.

$$C_B \times 25\ \text{k}\Omega > C_C R_1 \tag{16}$$

For an application where R1 = 10 kΩ and C_C = 0.22 µF, the midrail bypass capacitor, C_B, should be at least 0.1 µF to minimize start-up popping noise.

SSM2211 Amplifier Design Example

Maximum Output Power	1 W
Input Impedance	20 kΩ
Load Impedance	8 Ω
Input Level	1 V rms
Bandwidth	20 Hz − 20 kHz ± 0.25 dB

The configuration shown in Figure 42 is used. The first thing to determine is the minimum supply rail necessary to obtain the specified maximum output power. From Figure 46, for 1 W of output power into an 8 Ω load, the supply voltage must be at least 4.6 V. A supply rail of 5 V can be easily obtained from a voltage reference. The extra supply voltage also allows the SSM2211 to reproduce peaks in excess of 1 W without clipping the signal. With V_{DD} = 5 V and R_L = 8 Ω, Equation 9 shows that the maximum power dissipation for the SSM2211 is 633 mW. From the power derating curve in Figure 31, the ambient temperature must be less than 73°C for the SOIC and 118°C for the LFCSP.

The required gain of the amplifier can be determined from Equation 17 as

$$A_V = \frac{\sqrt{P_L R_L}}{V_{IN,rms}} = 2.8 \tag{17}$$

From Equation 1

$$\frac{R_F}{RI} = \frac{A_V}{2}$$

or $R_F = 1.4 \times RI$. Because the desired input impedance is 20 kΩ, RI = 20 kΩ and R2 = 28 kΩ.

The final design step is to select the input capacitor. When adding an input capacitor, C_C, high-pass filter, the corner frequency needs to be far enough away for the design to meet the bandwidth criteria. For a first-order filter to achieve a pass-band response within 0.25 dB, the corner frequency should be at least 4.14 × away from the pass-band frequency. So, $(4.14 \times f_{HP}) < 20$ Hz. Using Equation 2, the minimum size of input capacitor can be found:

$$C_C > \frac{1}{2\pi(20\ \text{k}\Omega)\left(\frac{20\ \text{Hz}}{4.14}\right)} \quad (18)$$

So $C_C > 1.65$ µF. Using a 2.2 µF is a practical choice for C_C.

The gain bandwidth product for each internal amplifier in the SSM2211 is 4 MHz. Because 4 MHz is much greater than 4.14 × 20 kHz, the design meets the upper frequency bandwidth criteria. The SSM2211 could also be configured for higher differential gains without running into bandwidth limitations. Equation 16 shows an appropriate value for C_B to reduce start-up popping noise:

$$C_B > \frac{(2.2\ \mu\text{F})(20\ \text{k}\Omega)}{25\ \text{k}\Omega} = 1.76\ \mu\text{F} \quad (19)$$

Selecting C_B to be 2.2 µF for a practical value of capacitor minimizes start-up popping noise.

To summarize the final design:

V_{DD}	5 V
R1	20 kΩ
R_F	28 kΩ
C_C	2.2 µF
C_B	2.2 µF
Max. T_A	85°C

SINGLE-ENDED APPLICATIONS

There are applications in which driving a speaker differentially is not practical. An example would be a pair of stereo speakers where the minus terminal of both speakers is connected to ground. Figure 48 shows how this can be accomplished.

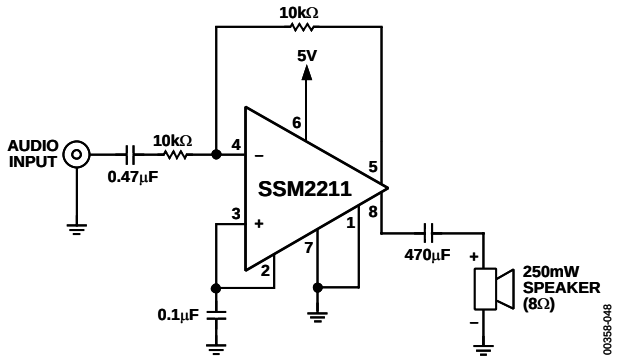


Figure 48. A Single-Ended Output Application

It is not necessary to connect a dummy load to the unused output to help stabilize the output. The 470 µF coupling capacitor creates a high-pass frequency cutoff, as given in Equation 4, of 42 Hz, which is acceptable for most computer speaker applications. The overall gain for a single-ended output configuration is $A_V = R_F/R_1$, which for this example is equal to 1.

DRIVING TWO SPEAKERS SINGLE ENDEDLY

It is possible to drive two speakers single endedly with both outputs of the SSM2211.

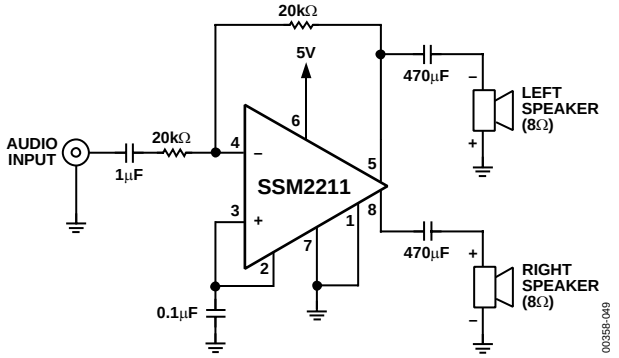


Figure 49. SSM2211 Used as a Dual-Speaker Amplifier

Each speaker is driven by a single ended output. The trade-off is that only 250 mW of sustained power can be put into each speaker. Also, a coupling capacitor must be connected in series with each of the speakers to prevent large dc currents from flowing through the 8 Ω speakers. These coupling capacitors produce a high-pass filter with a corner frequency given by Equation 4. For a speaker load of 8 Ω and a coupling capacitor of 470 µF, this results in a −3 dB frequency of 42 Hz.

Because the power of a single-ended output is one quarter that of a bridged output, both speakers together are still half as loud (−6 dB SPL) as a single speaker driven with a bridged output.

The polarity of the speakers is important, as each output is 180° out of phase with the other. By connecting the minus terminal of Speaker 1 to Pin 5, and the plus terminal of Speaker 2 to Pin 8, proper speaker phase can be established.

The maximum power dissipation of the device can be found by doubling Equation 11, assuming both loads are equal. If the loads are different, use Equation 11 to find the power dissipation caused by each load, then take the sum to find the total power dissipated by the SSM2211.

EVALUATION BOARD

An evaluation board for the SSM2211 is available. For more information, call 1-800-ANALOGD.

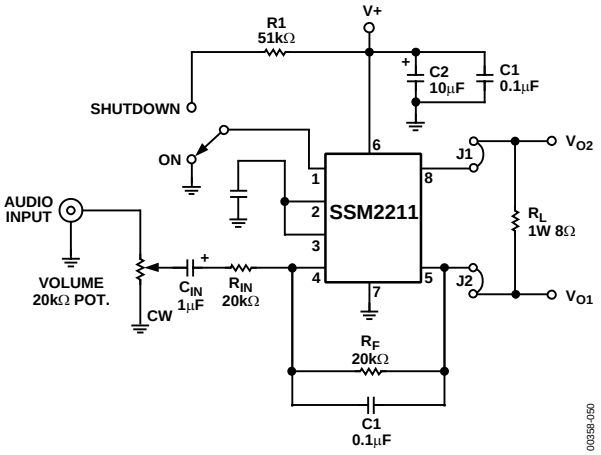


Figure 50. Evaluation Board Schematic

The voltage gain of the SSM2211 is given by Equation 20

$$A_V = 2 \times \frac{R_F}{R_{IN}} \quad (20)$$

If desired, the input signal may be attenuated by turning the 10 kΩ potentiometer in the CW direction. C_{IN} isolates the input common-mode voltage ($V_D/2$) present at Pin 2 and 3. With V+ = 5 V, there is 2.5 V common-mode voltage present at both output terminals, V_{O1} and V_{O2}, as well.

CAUTION: The ground lead of the oscilloscope probe, or any other instrument used to measure the output signal, must not be connected to either output, as this would short out one of the amplifier's outputs and possibly damage the device.

A safe method of displaying the differential output signal using a grounded scope is shown in Figure 51. Connect Channel A's probe to the V_{O2} terminal post, connect Channel B's probe to the V_{O1} post, invert Channel B and add the two channels together. Most multichannel oscilloscopes have this feature built in. If you must connect the ground lead of the test instrument to either output signal pins, a power-line isolation transformer must be used to isolate the instrument ground from the power supply ground.

Recall that $V = \sqrt{P \times R}$, so then for P_O = 1 W and R_L = 8 Ω, V = 2.8 V rms, or 8 V p-p. If the available input signal is 1.4 V rms or more, use the board as is, with $R_F = R_I$ = 20 kΩ. If more gain is needed, increase the value of R_F.

When you have determined the closed-loop gain required by your source level, and can develop 1 W across the 8 Ω load resistor with the normal input signal level, replace the resistor with your speaker. Your speaker may be connected across the V_{O1} and V_{O2} posts for bridged mode operation only after the 8 Ω load resistor is removed. For no phase inversion, V_{O2} should be connected to the (+) terminal of the speaker.

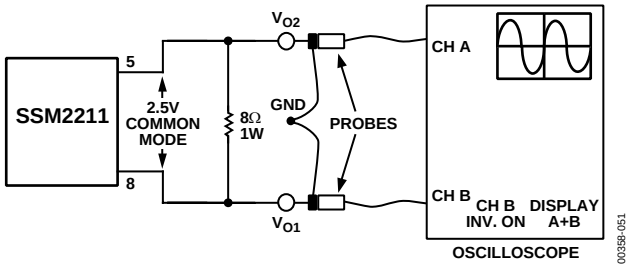


Figure 51. Using an Oscilloscope to Display the Bridged Output Voltage

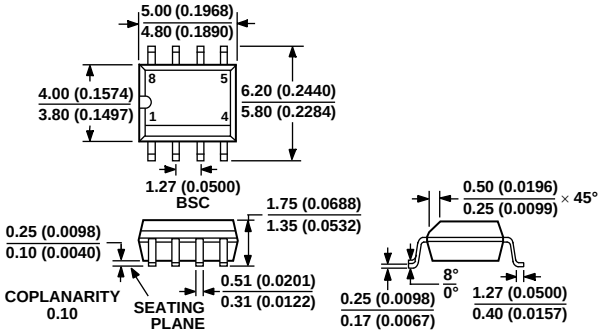
To use the SSM2211 in a single-ended output configuration, replace J1 and J2 jumpers with electrolytic capacitors of a suitable value, with the negative terminals to the output terminals V_{O1} and V_{O2}. The single-ended loads may then be returned to ground. Note that the maximum output power is reduced to 250 mW, one-quarter of the rated maximum, due to the maximum swing in the nonbridged mode being one-half, and power being proportional to the square of the voltage. For frequency response down 3 dB at 100 Hz, a 200 µF capacitor is required with 8 Ω speakers.

The SSM2211 evaluation board also comes with a shutdown switch, which allows the user to switch between on (normal operation) and the power-conserving shutdown mode.

LFCSP PRINTED CIRCUIT BOARD LAYOUT CONSIDERATIONS

The LFCSP is a plastic encapsulated package with a copper lead frame substrate. This is a leadless package with solder lands on the bottom surface of the package instead of conventional formed perimeter leads. A key feature that allows the user to reach the quoted θ_{JA} performance is the exposed die attach paddle (DAP) on the bottom surface of the package. When soldered to the PCB, the DAP can provide efficient conduction of heat from the die to the PCB. For the user to achieve optimum package performance, consideration should be given to the PCB pad design for both the solder lands and the DAP. For further information the user is directed to the Amkor Technology document, "Application Notes for Surface Mount Assembly of Amkor's MicroLead Frame (MLF) Packages." This can be downloaded from the Amkor Technology website, www.amkor.com, as a product application note.

OUTLINE DIMENSIONS



COMPLIANT TO JEDEC STANDARDS MS-012AA
CONTROLLING DIMENSIONS ARE IN MILLIMETERS; INCH DIMENSIONS (IN PARENTHESES) ARE ROUNDED-OFF MILLIMETER EQUIVALENTS FOR REFERENCE ONLY AND ARE NOT APPROPRIATE FOR USE IN DESIGN

Figure 52. 8-Lead Standard Small Outline Package [SOIC]
Narrow Body (R-8), S-Suffix
Dimensions shown in millimeters and (inches)

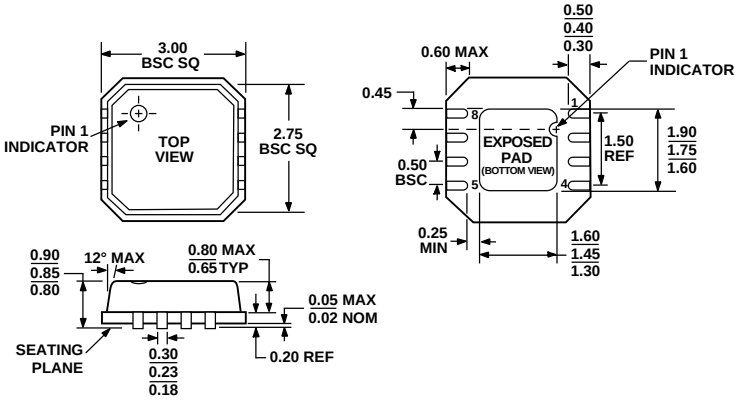


Figure 53. 8-Lead Frame Chip Scale Package [LFCSP]
3 mm × 3 mm Body (CP-8-2)
Dimensions shown in millimeters

ORDERING GUIDE

Model	Temperature Range	Package Description	Package Options	Brand
SSM2211CP-R2	−20°C to +85°C	8-Lead LFCSP	CP-8-2	B5A
SSM2211CP-Reel	−20°C to +85°C	8-Lead LFCSP	CP-8-2	B5A
SSM2211CP-Reel7	−20°C to +85°C	8-Lead LFCSP	CP-8-2	B5A
SSM2211CPZ-Reel[1]	−20°C to +85°C	8-Lead LFCSP	CP-8-2	B5A
SSM2211CPZ-Reel7[1]	−20°C to +85°C	8-Lead LFCSP	CP-8-2	B5A
SSM2211S	−20°C to +85°C	8-Lead SOIC	R-8 (S-Suffix)	
SSM2211S-Reel	−20°C to +85°C	8-Lead SOIC	R-8 (S-Suffix)	
SSM2211S-Reel7	−20°C to +85°C	8-Lead SOIC	R-8 (S-Suffix)	
SSM2211SZ[1]	−20°C to +85°C	8-Lead SOIC	R-8 (S-Suffix)	
SSM2211SZ-Reel[1]	−20°C to +85°C	8-Lead SOIC	R-8 (S-Suffix)	
SSM2211SZ-Reel7[1]	−20°C to +85°C	8-Lead SOIC	R-8 (S-Suffix)	

[1] Z=Pb-free part.

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