



Headphone Amplifier with Digital Volume Control and Shutdown Mode

CM2811

General Description

The CM2811 is a dual audio power amplifier capable of delivering 105mW per channel of continuous average power into a 16Ω load with 0.1%(THD+N) from a 5V power-supply. Boomer audio power amplifier were designed specifically to provide high quality output power with a minimal amount of external components.

Since CM2811 does not require bootstrap capacitors or snubber networks, it is optimally suited for low power portable systems.

The CM2811 features a digital volume control that sets the amplifier's gain from +12dB to -33dB in 16 discrete steps using a two wire interface.

The unity-gain stable CM2811 also feature an externally controlled, active-high, micro-power consumption shutdown mode. It also has an internal thermal shutdown protection mechanism.

Feature

Digital volume control range from +12dB to -33dB

"Click and Pop" suppression circuitry

No bootstrap capacitors required

Low shutdown current

Applications

Electronic Information Organizers

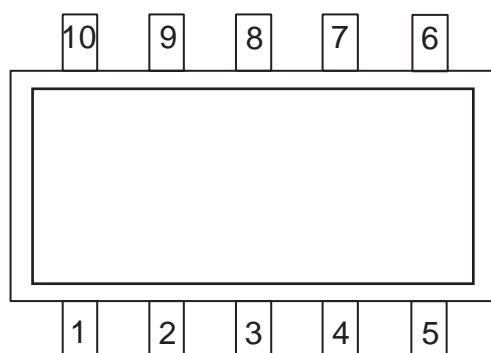
Palmtops

Cellular and portable phones

Portable Audio Systems

DVD,MP3

Pin Assignment



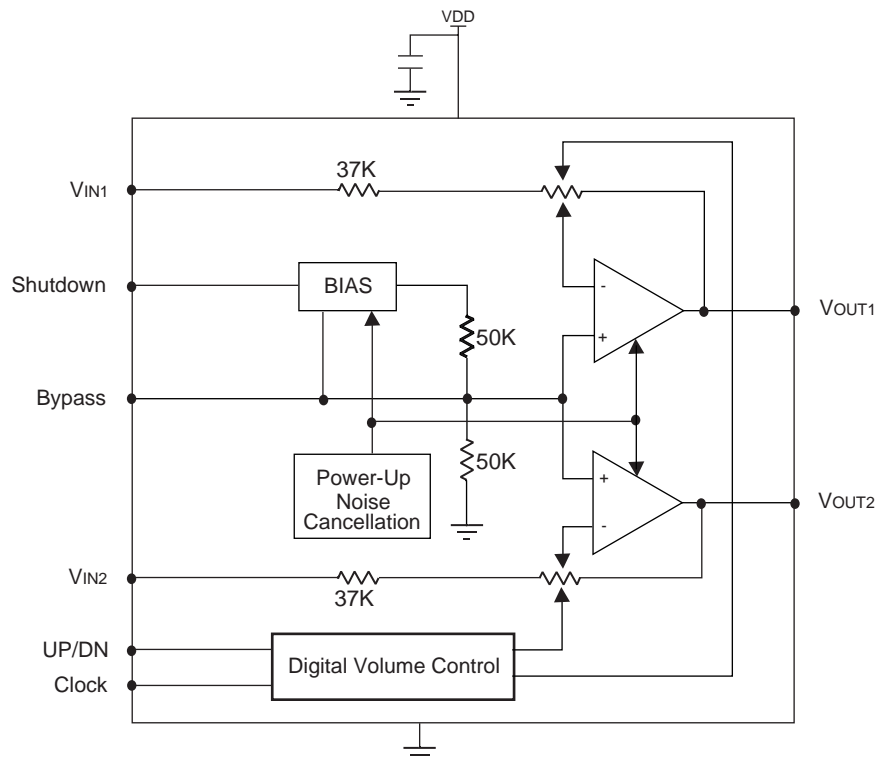
Pin No.	Pin Name
1	VOUT1
2	VIN1
3	Bypass
4	Clock
5	GND
6	UP/DN
7	Shutdown
8	VIN2
9	VOUT2
10	VDD



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Block Diagram



Electrical Characteristics (VDD = 5V)

Symbol	Parameter	Conditions	Typical	Limit	Units	
V _{DD}	Supply Voltage			2.0	V (min)	
				5.5	V (max)	
I _{DD}	Supply Current	V _{IN} = 0V, I _o = 0A	1.3	3.0	mA	
I _{SD}	Shutdown Current	V _{IN} = 0V	0.3		uA	
V _{OS}	Output Offset Voltage	V _{IN} = 0V	4.0	50	mV	
P _O	Output Power	0.1% THD+N: f = 1kHz R _L = 16Ω				
			R _L = 32Ω	105		mW
				70		mW
THD+N	Total Harmonic Distortion	P _O = 50mW, R _L = 32Ω f = 20Hz to 20kHz	0.3		%	
Crosstalk	Channel Separation	R _L = 32Ω; f = 1kHz; P _O = 70mW	100		dB	
PSRR	Power Supply Rejection Ratio	C _B = 1.0 F, V _{RIPPLE} = 100mV _{pp} f = 217Hz	72		dB	
V _{IH}	(CLOCK, UP/DN, SHUTDOWN) Input Voltage High			1.5	V (min)	
V _{IL}	(CLOCK, UP/DN, SHUTDOWN) Input Voltage Low			0.4	V (max)	
	Digital Volume Range	Input referred minimum gain	-33		dB	
		Input referred maximum gain	+12		dB	
	Digital Volume Stepsize	All 16 discrete steps	3.0		dB	
	Stepsize Error	All 16 discrete steps	±0.3		dB	
	Channel to Channel Volume Tracking Error	All gain settings from -33dB to +12 dB	0.15		dB	
	Shutdown Attenuation	Shutdown mode active	-100		dB	



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Electrical Characteristics (VDD = 3.3V)

Symbol	Parameter	Conditions	Typical	Limit	Units
I _{DD}	Supply Current	V _{IN} = 0V, I _O = 0A	1.1		mA
I _{SD}	Shutdown Current	V _{IN} = 0V	0.3		uA
V _{OS}	Output Offset Voltage	V _{IN} = 0V	4.0		mV
P _O	Output Power	0.1% THD+N: f = 1kHz			
		R _L = 16Ω	40		mW
		R _L = 32Ω	28		mW
THD+N	Total Harmonic Distortion	P _O = 50mW, R _L = 32Ω f = 20Hz to 20kHz	0.5		%
PSRR	Power Supply Rejection Ratio	C _B = 1.0uF, V _{RIPPLE} = 100mV _{pp} f = 217Hz	72		dB
V _{IH}	(CLOCK, UP/DN, SHUTDOWN) Input Voltage High		1.5		V (min)
V _{IL}	(CLOCK, UP/DN, SHUTDOWN) Input Voltage Low		0.4		V (max)
	Digital Volume Range	Input referred minimum gain	-33		dB
		Input referred maximum gain	+12		dB
	Digital Volume Stepsize	All 16 discrete steps	3.0		dB
	Stepsize Error	All 16 discrete steps	± 0.3		dB
	Channel ρ to ρ Channel Volume Tracking Error	All gain settings from -33dB to +12 dB	0.15		dB
	Shutdown Attenuation	Shutdown mode active	-100		dB

Electrical Characteristics (VDD = 2.6V)

Symbol	Parameter	Conditions	Typical	Limit	Units
I _{DD}	Supply Current	V _{IN} = 0V, I _O = 0A	1.0		mA
I _{SD}	Shutdown Current	V _{IN} = 0V	0.3		uA
V _{OS}	Output Offset Voltage	V _{IN} = 0V	4.0		mV
P _O	Output Power	0.1% THD+N: f = 1kHz			
		R _L = 16Ω	20		mW
		R _L = 32Ω	16		mW
THD+N	Total Harmonic Distortion	P _O = 50mW, R _L = 32Ω f = 20Hz to 20kHz	0.6		%
PSRR	Power Supply Rejection Ratio	C _B = 1.0uF, V _{RIPPLE} = 100mV _{pp} f = 217Hz	72		dB
V _{IH}	(CLOCK, UP/DN, SHUTDOWN) Input Voltage High		1.5		V (min)
V _{IL}	(CLOCK, UP/DN, SHUTDOWN) Input Voltage Low		0.4		V (max)
	Digital Volume Range	Input referred minimum gain	-33		dB
		Input referred maximum gain	+12		dB
	Digital Volume Stepsize	All 16 discrete steps	3.0		dB
	Stepsize Error	All 16 discrete steps	± 0.3		dB
	Channel ρ to ρ Channel Volume Tracking Error	All gain settings from -33dB to +12 dB	0.15		dB
	Shutdown Attenuation	Shutdown mode active	-75		dB



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Application Notes

DIGITAL VOLUME CONTROL

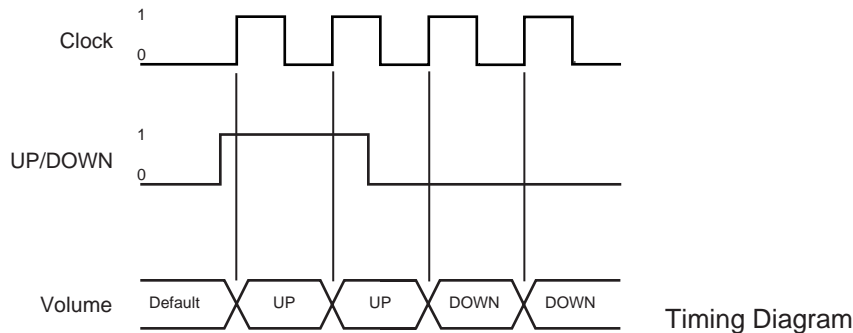
The CM2811 its gain is controlled by the signals applied to the CLOCK and UP/DN inputs. An external clock is required to drive the CLOCK pin.

At each rising edge of the clock signal,the gain will either increase or decrease by a 3dB stepdepending on the logic voltage level applied to the UP/DN pin. A logic high voltage level applied to the UP/DN pin causes the gain to increase by 3dB at each rising edge of the clock signal. Conversely, a logic low voltage level applied to the UP/DN pin causes the gain to decrease 3dB at each rising edge of the clock signal.

For both the CLOCK and UP/DN inputs, the trigger point is 1.4V minimum for a logic high level, and 0.4V maximum for a logic low level.

There are 16 discrete gain settings ranging from +12dB maximum to -33dB minimum. Upon device power on, the amplifier's gain is set to a default value of 0dB. However, when coming out of shutdown mode, the CM2811 will revert back to its previous gain setting.

The CM2811 its CLOCK and UP/DN pins should be debounced in order to avoid unwanted state changes during transitions between VIL and VIH. This will ensure correct operation of the digital volume control. A microcontroller or microprocessor output is recommended to drive the CLOCK and UP/DN pins.



POWER DISSIPATION

Power dissipation is a major concern when using any power amplifier and must be thoroughly understood to ensure a successful design. Equation 1 states the maximum power dissipation point for a single-ended amplifier operating at a given supply voltage and driving a specified output load.

$$P_{D_{MAX}} = (V_{DD})^2 / (2\pi^2 R_L) \dots\dots\dots(1)$$

CM2811 has two operational amplifiers in one package, the maximum internal power dissipation point is twice that of the number which results from Equation 1. Even with the large internal power dissipation, the CM2811 does not require heat sinking over a large range of ambient temperature.

From Equation 1, assuming a 5V power supply and a 32Ω load, the maximum power dissipation point is 40mW per amplifier. Thus the maximum package dissipation point is 80mW. The maximum power dissipation point obtained must not be greater than the power dissipation predicted by Equation 2:

$$P_{D_{MAX}} = (T_{J_{MAX}} - T_A) / \theta_{JA} \dots\dots\dots(2)$$

For the MSOP package, $\theta_{JA} = 194^\circ\text{C/W}$, and for the LD package, $\theta_{JA} = 63^\circ\text{C/W}$. $T_{J_{MAX}} = 150^\circ\text{C}$ for the CM2811. For a given ambient temperature, T_A , of the system surroundings, Equation 2 can be used to find the maximum internal power dissipation supported by the IC packaging. If the result of Equation 1 is greater than that of Equation 2, then either the supply voltage must be decreased, the load impedance increased, or T_A reduced. For the MSOP package in a typical application of a 5V power supply and a 32Ω load, the maximum ambient temperature possible without violating

the maximum junction temperature is approximately 134.5°C. This assumes the device operates at maximum power dissipation and uses surface mount packaging. Internal power dissipation is a function of output power. If typical operation is not around the maximum power dissipation point, operation at higher ambient temperatures is possible. Refer to the Typical Performance Characteristics curves for power dissipation information for lower output power levels.

POWER SUPPLY BYPASSING

As with any power amplifier, proper supply bypassing is critical for low noise performance and high power supply rejection. The capacitor location on both the bypass and power supply pins should be as close to the device as possible. The value of the bypass capacitor directly affects the CM2811 its half-supply voltage stability and PSRR. The stability and supply rejection increase as the bypass capacitors value increases. Typical applications employ a 5V regulator with 10uF and a 0.1uF bypass capacitors which aid in supply stability, but do not eliminate the need for bypassing the supply nodes of the CM2811.

The selection of bypass capacitors, especially C_B , is thus dependent upon desired low frequency PSRR, click and pop performance, (explained in the section, Proper Selection of External Components), system cost, and size constraints.



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Application Notes

SHUTDOWN FUNCTION

In order to reduce power consumption while not in use, the CM2811 features amplifier bias circuitry shutdown. This shutdown function is activated by applying a logic high to the SHUTDOWN pin. The trigger point is 1.4V minimum for a logic high level, and 0.4V maximum for a logic low level. It is best to switch between ground and VDD to ensure optimal shutdown operation. By switching the SHUTDOWN pin to VDD, the CM2811 supply current draw will be minimized in idle mode. Whereas the device will be disabled with shutdown voltages less than VDD, the idle current may be greater than the typical value of 0.3uA. In either case, the SHUTDOWN pin should be tied to a fixed voltage to avoid unwanted state changes.

In many applications, a microcontroller or microprocessor output is used to control the shutdown circuitry.

This provides a quick, smooth shutdown transition. Another solution is to use a single-pole, single-throw switch in conjunction with an external pull-up resistor. When the switch is closed, the SHUTDOWN pin is connected to ground and enables the amplifier.

If the switch is open, the external pull-up resistor, R_{PU}, will disable the CM2811. This scheme guarantees that the SHUTDOWN pin will not float, thus preventing unwanted state changes.

PROPER SELECTION OF EXTERNAL COMPONENTS

Selection of external components when using integrated power amplifiers is critical for optimum device and system performance. While the CM2811 is tolerant of external component combinations, consideration must be given to the external component values that maximize overall system quality.

The CM2811 its unity-gain stability allows a designer to maximize system performance. Low gain settings maximize signal-to-noise performance and minimize THD+N. Low gain configurations require large input signals to obtain a given output power. Input signals equal to or greater than 1 V_{rms} are available from sources such as audio codecs. Please refer to the section, Audio Power Amplifier Design, for a more complete explanation of proper gain selection.

Selection of Input and Output Capacitor Size

Besides gain, one of the major considerations is the closed loop bandwidth of the amplifier. To a large extent, the bandwidth is dictated by the choice of external components shown in Figure 1. Both the input coupling capacitor, C_i, and the output coupling capacitor, C_o, form first order high pass filters which limit low frequency response. These values should be based on the desired frequency response weighed against the following:

Large value input and output capacitors are both expensive and space consuming for portable designs. Clearly a certain sized capacitor is needed to couple in low frequencies without severe attenuation. But in many cases the speakers used in portable systems, whether internal or external, have little ability to reproduce signals below 150Hz. Thus large input and output capacitors may not increase system performance. In addition to system cost and size, click and pop performance is affected by the size of the input coupling capacitor, C_i. A larger input coupling capacitor requires more charge to reach its quiescent DC voltage (nominally 1/2 VDD). This charge comes from the output via the feedback and is apt to create pops upon device enable. Turn on pops can be minimized by reducing C_i value based on necessary low frequency response. Besides minimizing the input and output capacitor values, careful consideration should be paid to the bypass capacitor value. Bypass capacitor C_b is the most critical component to minimize turn on pops since it determines how fast the CM2811 turns on. The slower the CM2811 its outputs ramp to their quiescent DC voltage (nominally 1/2 VDD), the smaller the turn on pop. While the device will function properly, (no oscillations or motorboating), with C_b equal to 1uF, the device will be much more susceptible to turn on clicks and pops. Thus, a value of C_b equal to 1uF or larger is recommended in all but the most cost sensitive designs.

Also, careful consideration must be taken in selecting a certain type of capacitor to be used in the system. Different types of capacitors (tantalum, electrolytic, ceramic) have unique performance characteristics and may affect overall system performance.

AUDIO POWER AMPLIFIER DESIGN

Design a Dual 70mW/32Ω Audio Amplifier

Given:

Power Output 70mW

Load Impedance 32Ω

Input Level 1V_{rms} (max)

Input Impedance 60kΩ (min)

Bandwidth 100 Hz - 20 kHz ± 0.50dB

A designer must first determine the minimum supply rail to obtain the specified output power. By extrapolating from the Output Power vs Supply Voltage graphs in the Typical Performance Characteristics section, the supply rail can be easily found.

A second way to determine the minimum supply rail is to calculate the required V_{OPEAK} using Equation (3) and add the dropout voltage. For a single-ended application, the minimum supply voltage can be approximated by (2V_{OPEAK} + (V_{ODTOP} + V_{ODBOT})), where V_{ODBOT} and V_{ODTOP} are extrapolated from the Dropout Voltage vs Supply Voltage curve in the Typical Performance Characteristics section.

$$V_{\text{opeak}} = \sqrt{(2RLP_0)} \dots\dots\dots(3)$$



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Using the Output Power vs Supply Voltage graph for a 32Ω load, the minimum supply rail is 4.8V. Since 5V is a standard supply voltage in most applications, it is chosen for the supply rail. Extra supply voltage creates headroom that allows the CM2811 to reproduce peaks in excess of 70mW without clipping the signal. At this time, the designer must make sure that the power supply choice along with the output impedance does not violate the conditions explained in the Power Dissipation section.

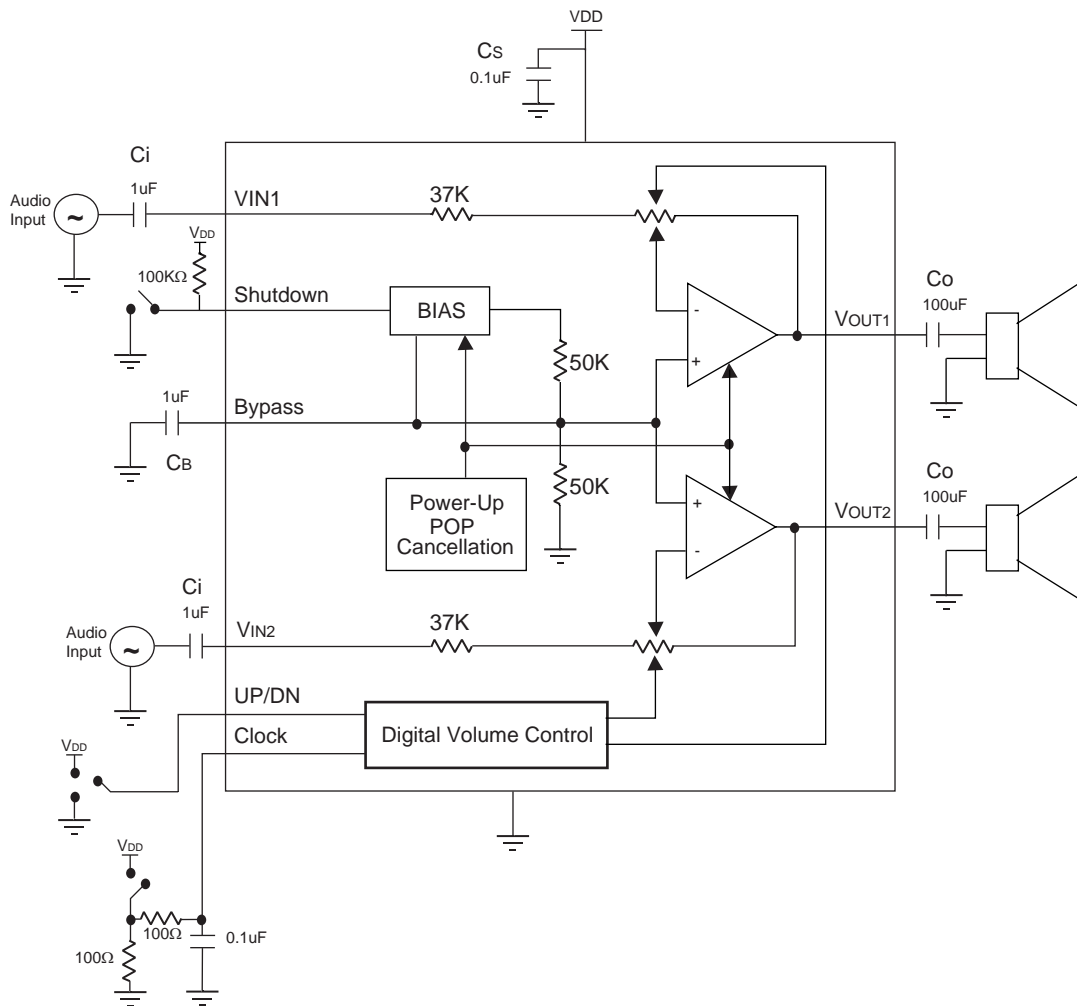
Remember that the maximum power dissipation point from Equation 1 must be multiplied by two since there are two independent amplifiers inside the package.

The final design step is to address the bandwidth requirements which must be stated as a pair of -3dB frequency points. Five times away from a -3dB point is 0.17dB down from passband response assuming a single pole roll-off. As stated in the External Components section, Ci and Co create first order highpass filters. Thus to obtain the desired frequency low response of 100Hz within ±0.5dB, both poles must be taken into consideration. The combination of two single order filters at the same frequency forms a second order response. This results in a signal which is down 0.34dB at five times away from the single order filter -3dB point. Thus, a frequency of 20Hz is used in the following equations to ensure that the response is better than 0.5dB down at 100Hz.

$$C_i \geq 1 / (2\pi * 60k\Omega * 20 \text{ Hz}) = 0.133\mu\text{F}; \text{ use } 0.22\mu\text{F} \dots\dots\dots (4)$$

$$C_o \geq 1 / (2\pi * 32\Omega * 20 \text{ Hz}) = 249\mu\text{F}; \text{ use } 330\mu\text{F} \dots\dots\dots (5)$$

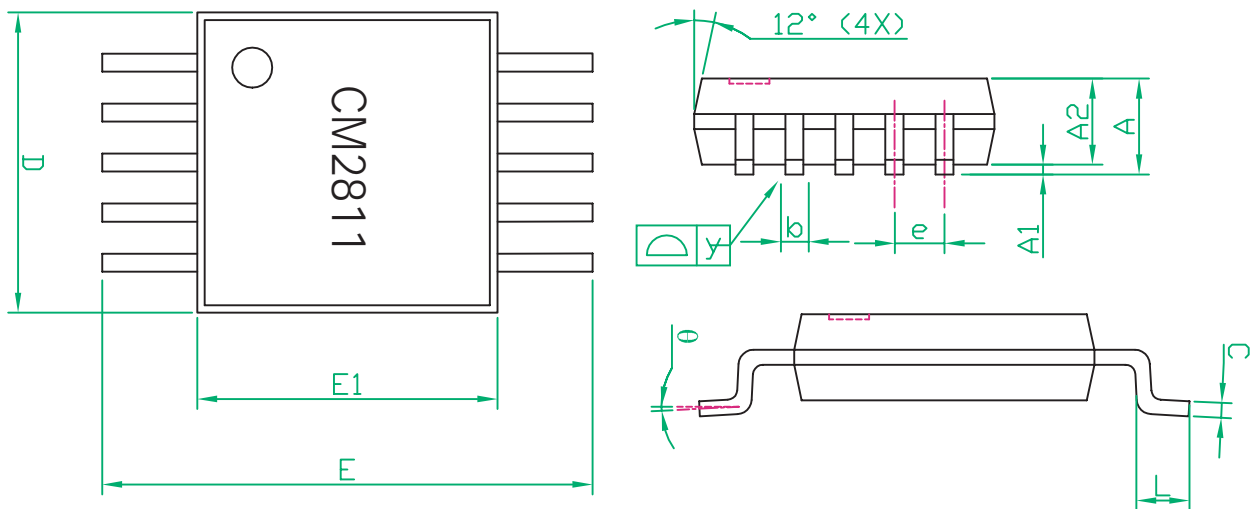
Example Circuit



External Components Description

Components	Functional Description
1. Ci	This is the input coupling capacitor. It blocks the DC voltage at, and couples the input signal to, the amplifier's input terminals. Ci also creates a highpass filter with the internal input resistor, Ri, at $f_c = 1/(2\pi R_i C_i)$. The minimum value of Ri is 60kΩ. Refer to the section, Proper Selection of External Components, for an explanation of how to determine the value of Ci.
2. Cs	This is the supply bypass capacitor. It provides power supply filtering. Refer to the Application Information section for proper placement and selection of the supply bypass capacitor.
3. C _B	This is the BYPASS pin capacitor. It provides half-supply filtering. Refer to the section, Proper Selection of External Components, for information concerning proper placement and selection of C _B .
4. Co	This is the output coupling capacitor. It blocks the DC voltage at the amplifier's output and it forms a high pass filter with R _L at $F_o = 1/(2\pi R_L C_o)$

Package Dimensions



SYMBOLS	DIMENSIONS IN MILLIMETERS			DIMENSIONS IN INCHES		
	MIN	NOM	MAX	MIN	NOM	MAX
A	0.81	1.02	1.12	0.032	0.040	0.044
A1	0.05	—	0.15	0.002	—	0.006
A2	0.76	0.86	0.97	0.030	0.034	0.038
b	0.15	0.20	0.30	0.006	0.008	0.012
C	0.13	0.15	0.23	0.005	0.006	0.009
D	2.90	3.00	3.10	0.114	0.118	0.122
E	4.70	4.90	5.10	0.185	0.193	0.201
E1	2.90	3.00	3.10	0.114	0.118	0.122
e	—	0.50	—	—	0.0197	—
L	0.40	0.53	0.66	0.016	0.021	0.026
y	—	—	0.10	—	—	0.004
θ	0°	—	6°	0°	—	6°

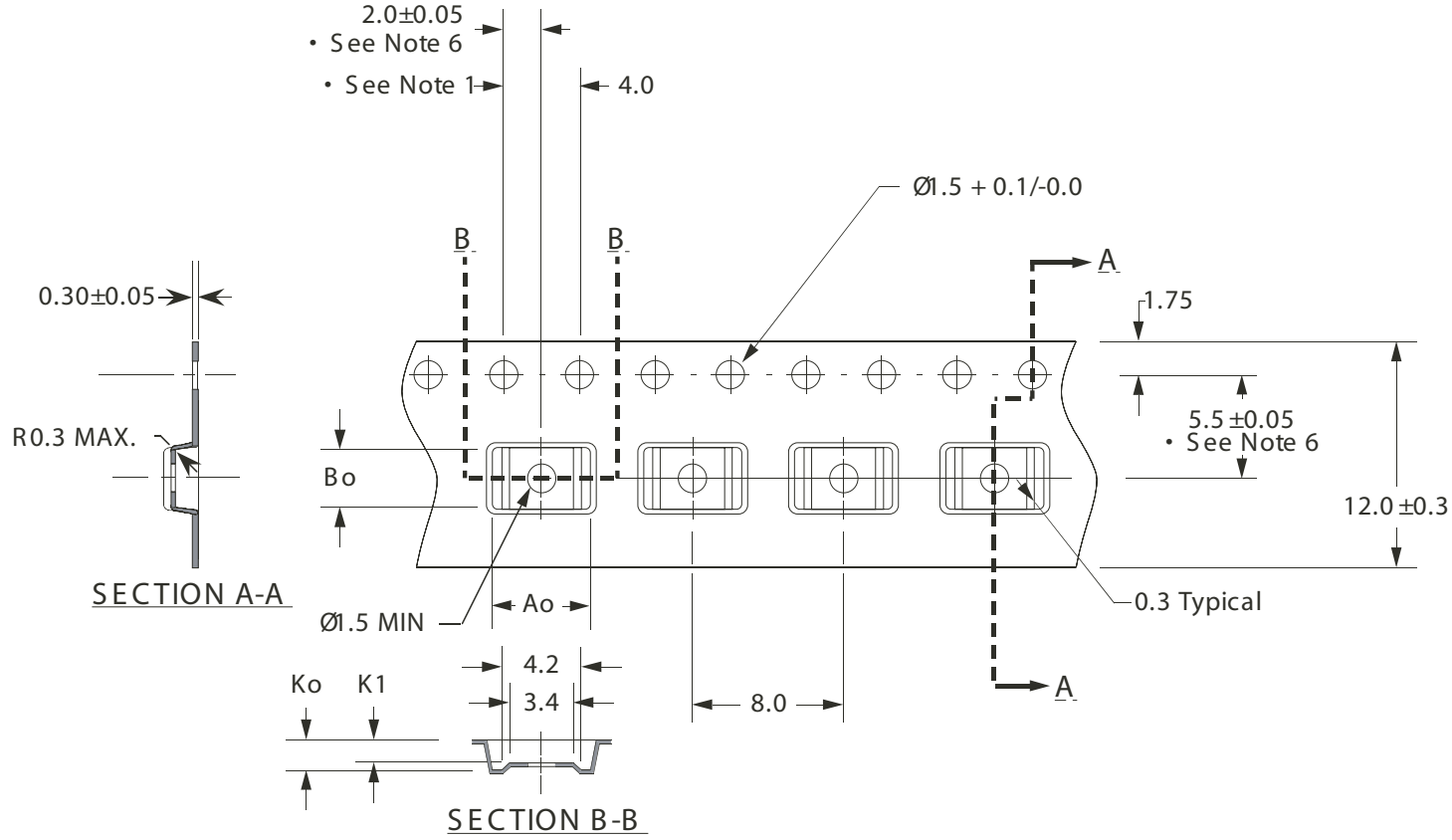


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Package Dimensions

MINI-MSOP-10 Carrier Tape
All Dimensions in Millimeters



Notes:

- 10 sprocket hole pitch cumulative tolerance ± 0.2
- Camber not to exceed 1mm in 100mm
- Material: Black Conductive Advantek Polystyrene .
- Ao and Bo measured on a plane 0.3mm above the bottom of the pocket
- Ko measured from a plane on the inside bottom of the pocket to the top surface of the carrier.
- Pocket position relative to sprocket hole measured as true position of pocket, not pocket hole.

$\text{Ao} = 5.2 \text{ mm}$

$\text{Bo} = 3.3 \text{ mm}$

$\text{Ko} = 1.6 \text{ mm}$

$\text{K1} = 1.2 \text{ mm}$