3W Low EMI Class-D Audio Power Amplifier with Auto-Recovering Short-circuit Protection

GENERAL DESCRIPTION

The HM2010 is a high efficiency, low EMI, filterless Class-D audio amplifier with auto-recovering short-circuit protection. It operates from 2.7V to 5.5V supply. When powered with 5V voltage, the HM2010 can deliver up to 3W into a 4Ω load or 1.8W into an 8Ω load at 10% THD+N.

As a Class-D audio amplifier, the HM2010 features 90% high efficiency and 75dB PSRR at 217Hz which make the device ideal for battery-powered high quality audio applications.

One of the key benefits of the HM2010 over traditional Class-D audio amplifiers is it generates much lower EMI emissions, thus greatly simplifying the system design for use in portable applications. Also included is the over-current or short-circuit protection with auto-recovery, which ensures the device be operated safely and reliably without the need for system interruption.

The HM2010 is available in 1.5mmx1.5mm COL-9L, MSOP-8L, and DFN2x2-8L package.

APPLICATIONS

- Mobile Phones
- Portable Digital Assistant (PDA)
- MP3/MP4 Player

FEATURES

- Filterless Class-D operation
- High efficiency up to 90%
- Output power at 5V supply
  - 3.0W (4Ω load, 10% THD+N)
  - 1.8W (8Ω load, 10% THD+N)
  - 2.4W (4Ω load, 1% THD+N)
  - 1.4W (8Ω load, 1% THD+N)
- Low THD+N: 0.05% (typical) @ 1kHz (VDD=3.6V, RL=8Ω, P_O=0.5W)
- Low quiescent current: 2mA at 3.6V (8Ω load)
- Extremely low shutdown current: 0.1μA (typical)
- High PSRR: 75dB (typical) at 217Hz
- No bypass capacitor required for the common-mode bias
- Under-voltage lockout
- Auto recovering short-circuit protection
- Over-current & thermal overload protection
- Low EMI design
- Available in 1.5mmx1.5mm COL-9L, MSOP-8L, and DFN2x2-8L packages

APPLICATION CIRCUIT

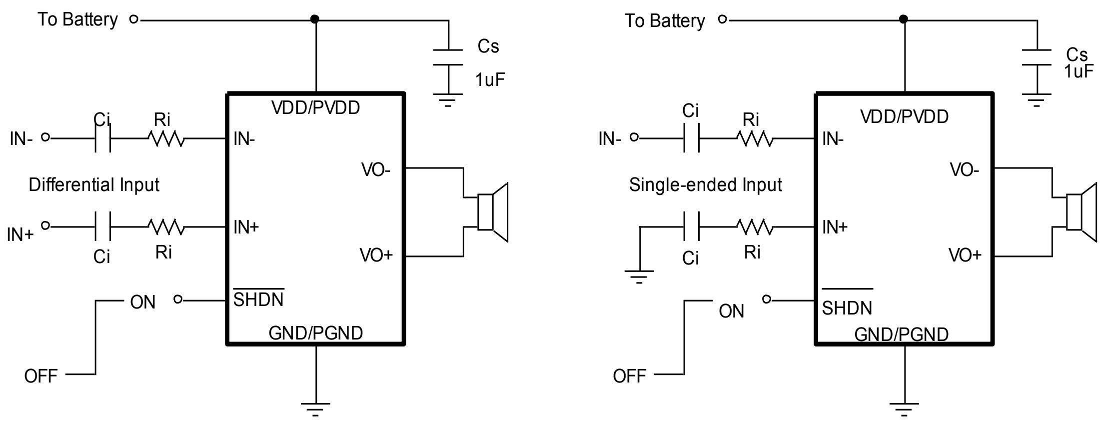
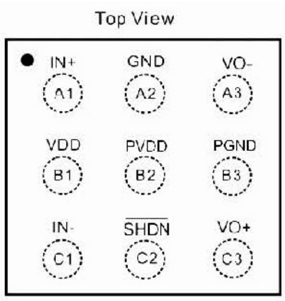
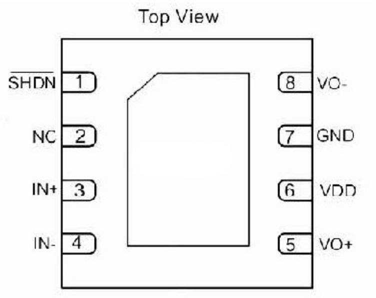


Figure 1: Typical Audio Amplifier Application Circuit

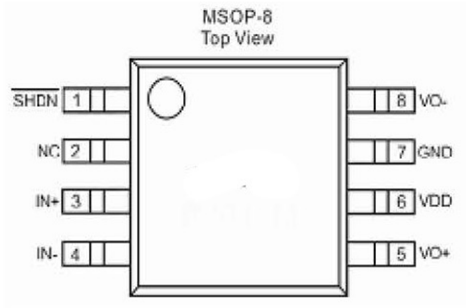
PIN CONFIGURATION AND DESCRIPTION



HM2010A
(TOP VIEW)



HM2010D
(TOP VIEW)



HM2010M
(TOP VIEW)

PIN NUMBER			SYMBOL	DESCRIPTION
HM2010A	HM2010D	HM2010M		
A1	3	3	IN+	Positive differential input
A2	7	7	GND	Signal ground
A3	8	8	VO-	Negative BTL output
B1	6	6	VDD	Power supply
B2			PVDD	Power supply for the output stage. It is internally shorted to VDD pin for MSOP-8L and DFN-8L packages.
B3			PGND	Power ground for the output stage. It is internally shorted to GND pin for MSOP-8L and DFN-8L packages.
C1	4	4	IN-	Negative differential input
C2	1	1	$\overline{SHDN}$	Active low shutdown control
C3	5	5	VO+	Positive BTL output

FUNCTIONAL BLOCK DIAGRAM

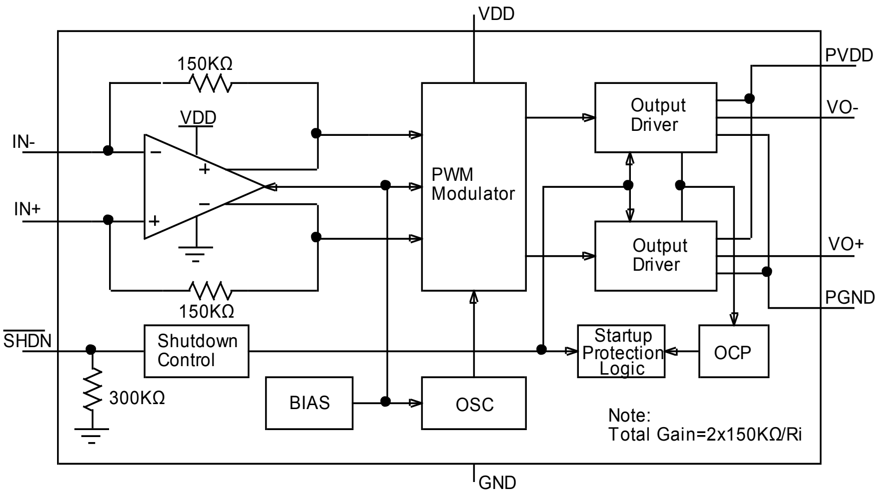


Figure 2: Function Block Diagram

ORDERING INFORMATION

PART NUMBER	TEMPERATURE RANGE	PACKAGE
HM2010A	-40°C to +85°C	COL1.5x1.5-9L
HM2010D	-40°C to +85°C	DFN2x2-8L
HM2010M	-40°C to +85°C	MSOP-8L

ABSOLUTE MAXIMUM RATINGS

PARAMETER	UNIT
Supply Voltage	-0.3V to 6.5V
Storage Temperature	-45°C to 150℃
Input Voltage	-0.3V to VDD+0.3V
Power Dissipation	Internally Limited
ESD Rating (HBM)	4000V
Junction Temperature	150°C
Soldering Information	
Vapor Phase (60 sec.)	215℃
Infrared (15 sec.)	220℃

Note: Stresses beyond those listed under absolute maximun 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.

PACKAGE DISSIPATION RATINGS

PACKAGE	θ_{JA}	UNIT
COL1.5x1.5-9L	90 ~ 220	°C/W
MSOP-8L	180	°C/W
DFN2x2-8L	148	°C/W

RECOMMENDED OPERATING CONDITIONS

PARAMETER	MIN	TYP	MAX	UNIT
Operating Voltage, V_{DD}	2.7		5.5	V
Operating Temperature, T_A	-40		+85	℃
Load Impedance, Z_L	3.2			Ω

ELECTRICAL CHARACTERISTICS

Note: The following electrical characteristics state DC and AC electrical specifications under particular test conditions which guarantee specific performance limits. But note that specifications are not guaranteed for parameters where no limit is given. The typical value however, is a good indication of device performance. All voltages in the following tables are specified at 25°C which is generally taken as parametric norm.

T_A=25°C, V_{DD} = 3.6V, R_L=8Ω, Gain = 2V/V, R_I=150kΩ, C_I=0.1μF, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNIT
V_{DD}	Supply Voltage		2.7		5.5	V
V_{UVLU}	Power Up Threshold Voltage	VDD from Low to High		2.2		V
V_{UVLD}	Power Down Threshold Voltage	VDD from High to Low		2.0		V
I_{DD}	Quiescent Current	VDD=5V, V_{IN}=0V, No Load		2.2	5	mA
		VDD=3.6V, V_{IN}=0V, No Load		2.0	4	mA
I_{SD}	Shutdown Current	$\overline{SHDN}$ =0V		0.1		μA
V_{SDIH}	$\overline{SHDN}$ Input High		1.3			V
V_{SDIL}	$\overline{SHDN}$ Input Low				0.4	V
P_O	Output Power, Load=8Ω, VDD=5V	THD+N=10%; f=1kHz		1.8		W
		THD+N=1%; f=1kHz		1.4		
P_O	Output Power, Load=4Ω, VDD=5V	THD+N=10%; f=1kHz		3.0		W
		THD+N=1%; f=1kHz		2.4		
A_V	Gain			300kΩ / Ri		V/V
R_O	Output Resistance in Shutdown Mode	$\overline{SHDN}$ =0V		2		kΩ
$R_{\overline{SHDN}}$	$\overline{SHDN}$ Input Resistance			300		kΩ
V_{REF}	VREF Voltage			VDD/2		V
THD+N	Total Harmonic Distortion + Noise, Load=8Ω	VDD=3.6V, P_O=0.5W, f=1kHz		0.05		%
		VDD=5V, P_O=1W, f=1kHz		0.08		
THD+N	Total Harmonic Distortion + Noise, Load=4Ω	VDD=3.6V, P_O=1W, f=1kHz		0.06		
		VDD=5V, P_O=2W, f=1kHz		0.09		
V_N	Output Voltage Noise	f_{NOISE}=20Hz ~ 20kHz with Inputs AC-Grounded		45		μV_{RMS}
V_{OS}	Output Offset Voltage	Inputs AC-Grounded		10		mV
η	Efficiency	VDD=5V，P_O=1W, RL=8Ω+33μH，f=1kHz		90		%
PSRR	Power Supply Rejection Ratio	f=217Hz		75		dB
CMRR	Common Mode Rejection Ratio	f=1kHz		70		dB
T_{STUP}	Startup Time			35		ms
f_{PWM}	PWM Switching Frequency			800		kHz
f_{JITTER}	PWM Frequency Jittering Range			±24		kHz
I_{LIMIT}	Over-Current Protection Threshold	VDD=3.6V		1.6		A
T_{OTP}	Over-Temperature Threshold			160		°C
T_{HYS}	Over-Temperature Hysteresis			30		°C

TEST SETUP FOR PERFORMANCE TESTING

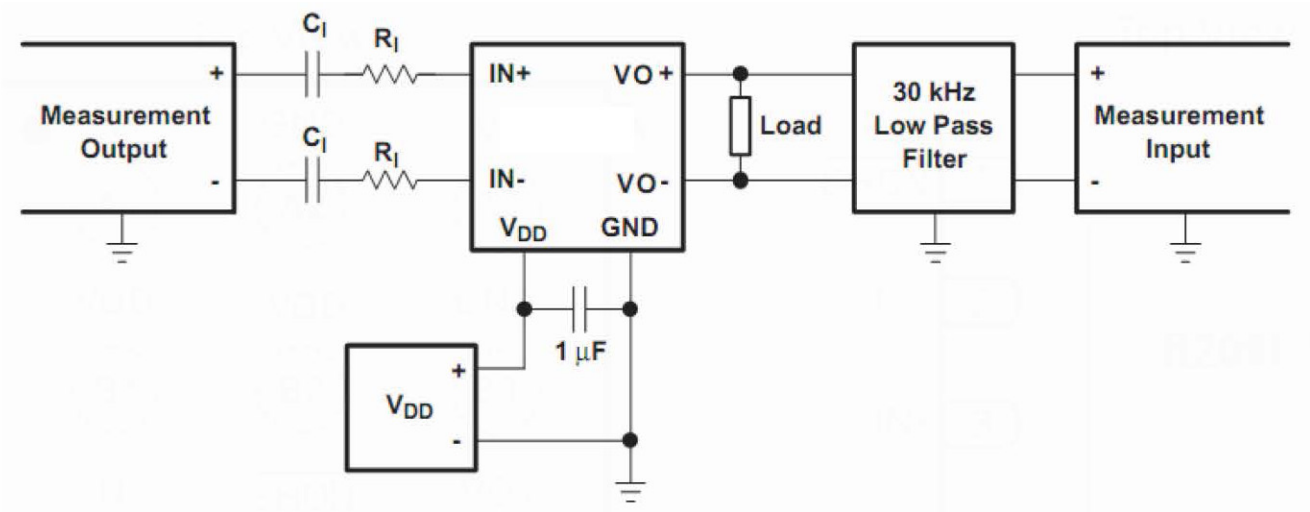


Figure 3: Test Block Diagram

Notes: 1) A 33-μH inductor was placed in series with the load resistor to emulate a small speaker for efficiency measurements; 2) The 30-kHz low-pass filter is required even if the analyzer has an internal low-pass filter. An RC low pass filter (100Ω, 47nF) issued on each output for the data sheet graphs.

TYPICAL PERFORMANCE CHARACTERISTICS

T_A=25°C, VDD = 3.6V, Gain = 2V/V, R_I=150kΩ, C_I=0.1μF, unless otherwise noted.

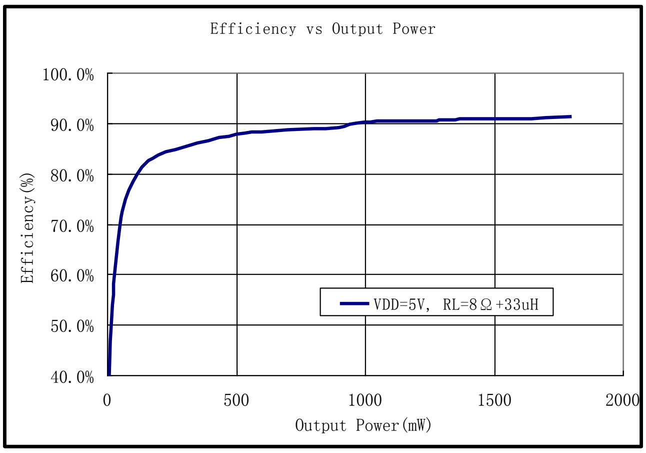


Figure 4: Efficiency vs. Output Power

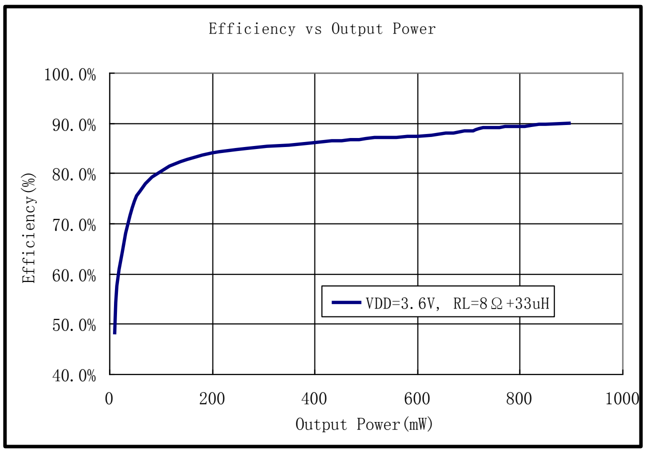


Figure 5: Efficiency vs. Output Power

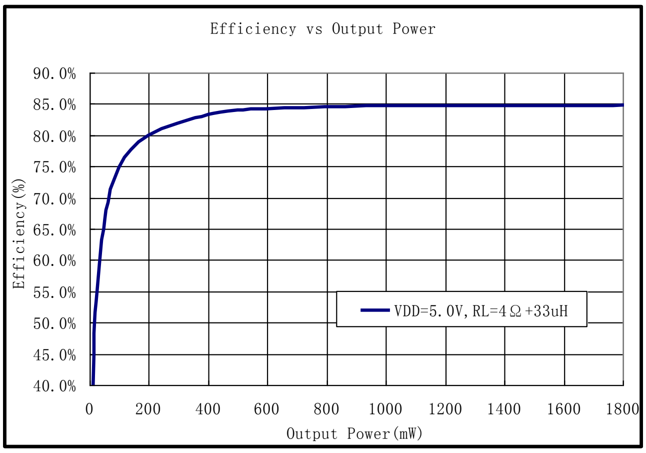


Figure 6: Efficiency vs. Output Power

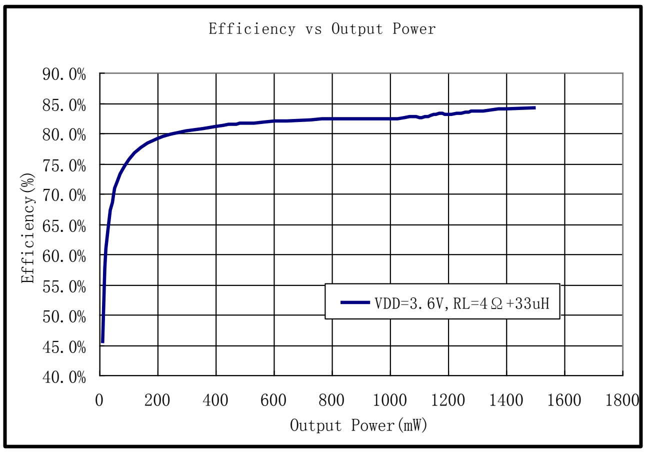


Figure 7: Efficiency vs. Output Power

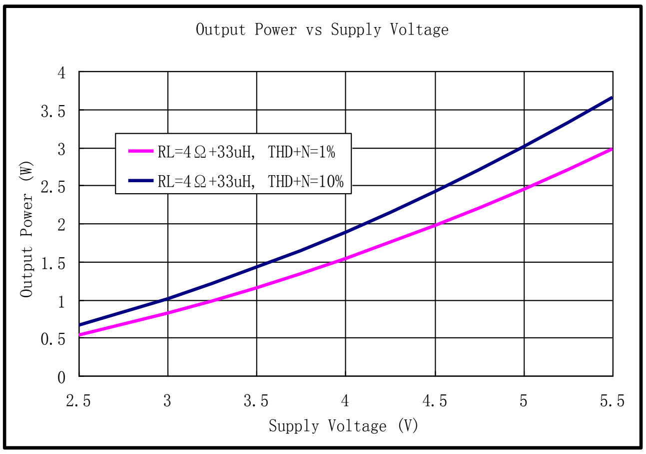


Figure 8: Output Power vs. Supply Voltage

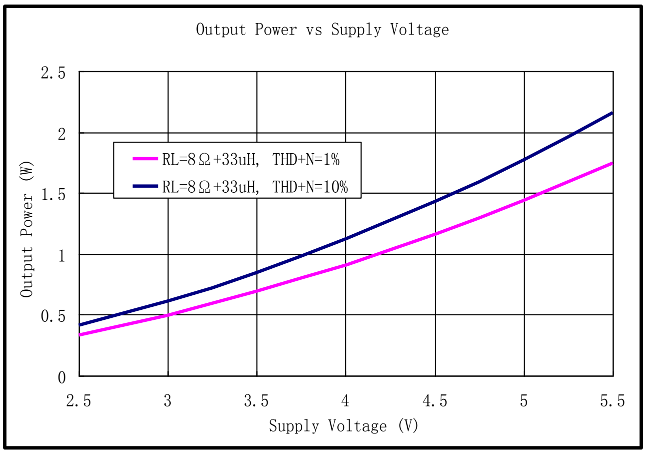


Figure 9: Output Power vs. Supply Voltage

TYPICAL PERFORMANCE CHARACTERISTICS (Cont.)

TA=25°C, VDD = 3.6V, Gain = 2V/V, RI=150kΩ, CI=0.1μF, unless otherwise noted.

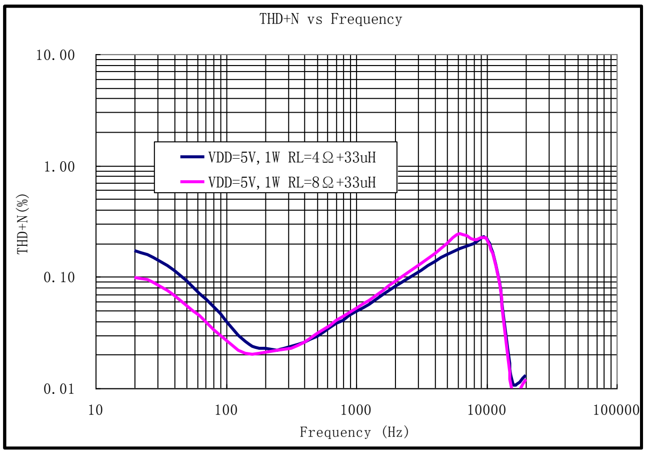


Figure 10: THD+N vs. Frequency

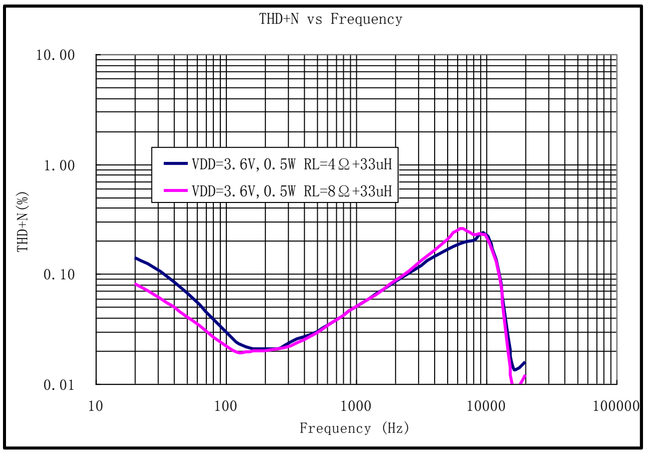


Figure 11: THD+N vs. Frequency

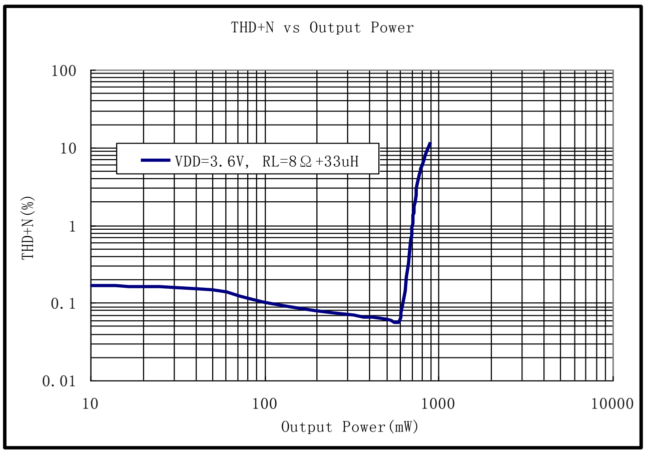


Figure 12: THD+N vs. Output Power

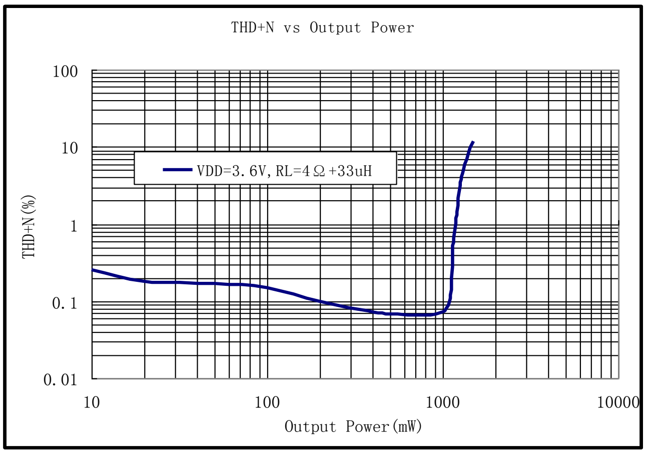


Figure 13: THD+N vs. Output Power

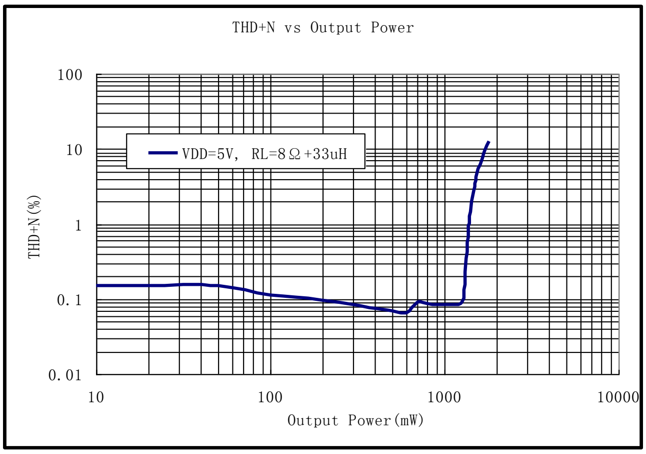


Figure 14: THD+N vs. Output Power

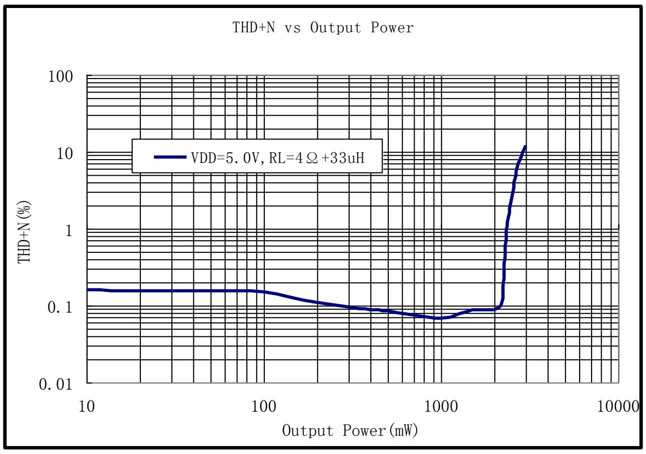


Figure 15: THD+N vs. Output Power

TYPICAL PERFORMANCE CHARACTERISTICS (Cont.)

T_A=25°C, VDD = 3.6V, Gain = 2V/V, R_I=150kΩ, C_I=0.1μF, unless otherwise noted.

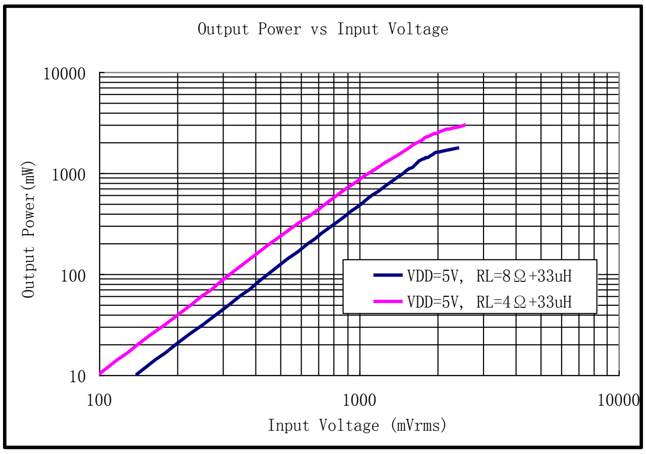


Figure 16: Output Power vs. Input Voltage

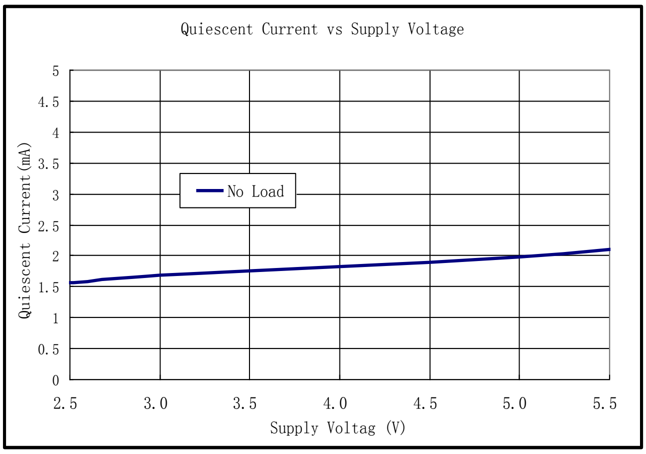


Figure 17: Quiescent Current vs. Supply Voltage

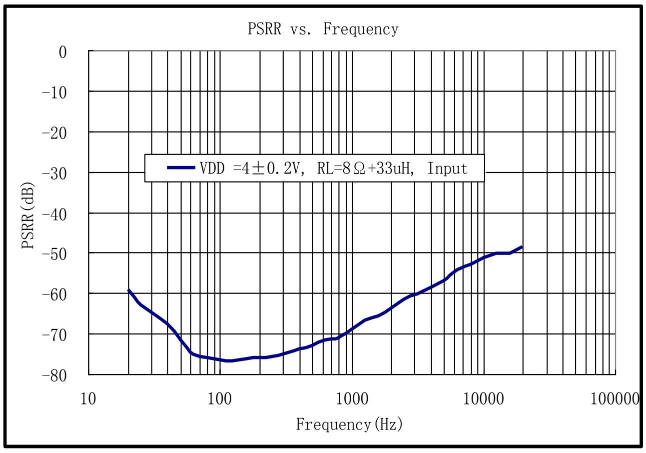


Figure 18: PSRR vs. Frequency

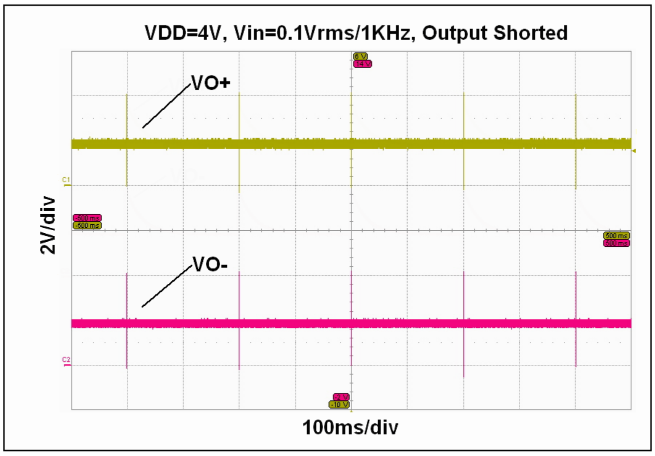


Figure 19: Short-Circuit Auto Recovering

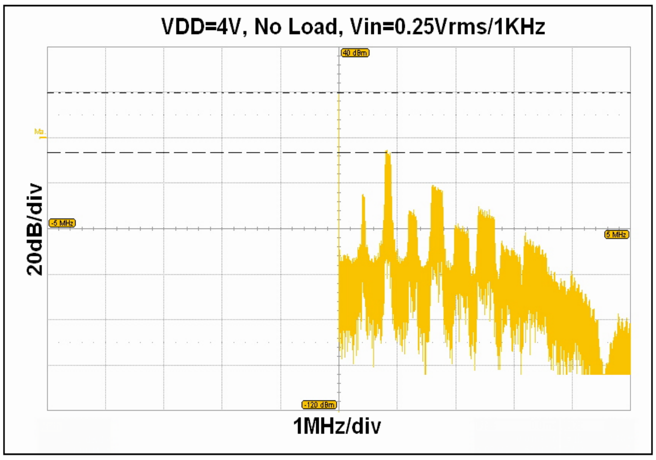


Figure 20: Output Spectrum (Broad Band)

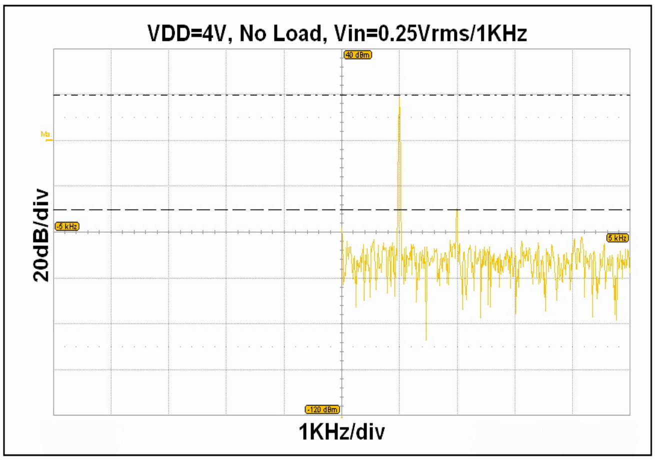


Figure 21: Output Spectrum (Audio Band)

APPLICATION INFORMATION

The HM2010 is a high efficiency, low EMI, filterless Class-D audio power amplifier with auto-recovering short-circuit protection. The HM2010 can operate from 2.7 to 5.5V supply. When powered with 5V voltage, the HM2010 can deliver up to 3W into a 4Ω load or 1.8W into an 8Ω load at 10% THD+N.

As a Class-D audio amplifier, the HM2010 features 90% high efficiency and 75dB PSRR at 217Hz which make the device ideal for battery-supplied, high quality audio applications. One of the key benefits of the HM2010 over conventional Class-D audio amplifiers is it generates much lower EMI emissions, thus greatly simplifying the system design for use in portable device applications, thanks to a proprietary output stage. Also included are the short-circuit protection with auto-recovery and the circuitry to minimize turn-on and turn-off transients or “click and pops”.

Furthermore, it includes under-voltage lockout to ensure proper operation when the device is first powered up; and over-temperature shutdown to safeguard the die temperature in operation.

Full Differential Amplifier

The HM2010 is configured in a fully differential topology. The fully differential topology ensures that the amplifier outputs a differential voltage on the output 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. Although the fully differential topology of the HM2010 can still be used with a single-ended input, it is highly recommended that the HM2010 be used with differential inputs in a noisy environment, like a wireless handset, to ensure maximum noise rejection.

Filterless Design

Traditional Class-D amplifiers require an output filter. The filter adds cost, size, and decreases efficiency and THD+N performance. The HM2010’s filterless modulation scheme does not require an output filter. Because the switching frequency of the HM2010 is well beyond the bandwidth of most speakers, voice coil movement due to the switching frequency is very small. Use a speaker with a series inductance larger than 10μH. Typical 8Ω speakers exhibit series inductances in the 20μH to 100μH range.

However, LC filter is required when the trace between the HM2010 and the speaker exceeds 100mm. Long trace acts like tiny antenna and causes EMI emissions which may result in FCC and CE certification failure.

Low EMI Design

Traditional Class-D amplifiers require the use of external LC filters, or shielding, to reduce electromagnetic-interference (EMI). The HM2010 employs a proprietary output stage and frequency jittering technique to minimize EMI emissions while maintaining high efficiency.

How to Reduce EMI

Most applications require a ferrite bead filter for EMI elimination. The ferrite filter reduces EMI around 1MHz and higher. When selecting a ferrite bead, choose one with high-impedance at high frequencies, but low impedance at low frequencies.

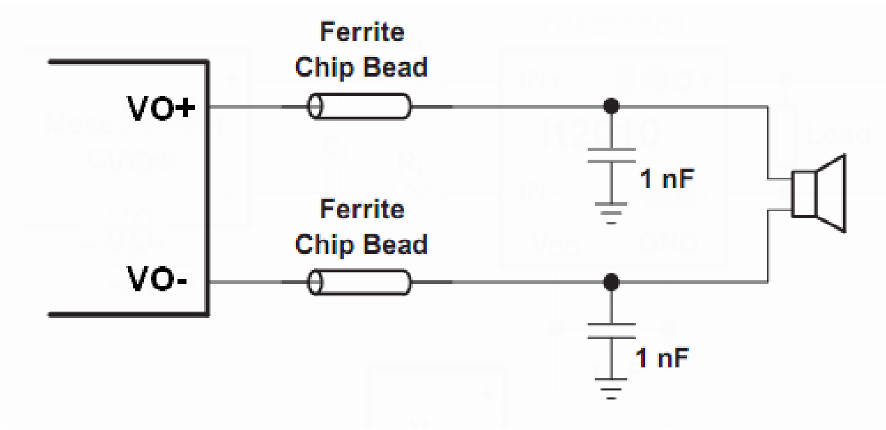


Figure 22: Ferrite Bead Filter to Reduce EMI

Shutdown Operation

In order to reduce power consumption while the device is not in use, the HM2010 includes shutdown circuitry to de-bias all the internal circuitry when the $\overline{\text{SHDN}}$ pin is pulled low. During shutdown, the supply current of the HM2010 is reduced less than 0.1μA, typically.

Under Voltage Lockout (UVLO)

The HM2010 incorporates circuitry designed to detect a low supply voltage. When the supply voltage drops below 2.0V (typical), the HM2010 goes into shutdown mode. The device will emerge out of the shutdown mode and resume its normal operation only when the supply voltage is restored to above 2.2V (typical) and the SHDN pin pulled high.

Short-circuit Auto-Recovery

When an over-current or short-circuit event occurs, the HM2010 goes into shutdown mode. During shutdown, the HM2010 activates auto-recovery process whose aim is to return the device to normal operation once the fault condition is removed. This process repeatedly examines whether the fault condition persists, and returns the device to normal operation immediately after the fault condition is removed. This feature helps protect the device from large currents and maintain long-term reliability while removing the need for external system interaction to resume normal operation.

Over Temperature Protection

Thermal protection on the HM2010 prevents the device from being damaged when the internal die temperature exceeds 160°C. Once the die temperature exceeds the prescribed value, the device will enter into shutdown state and the outputs are disabled. This is not a latched fault. The thermal fault cleared once the temperature of the die decreased by 30°C. This large hysteresis will prevent it from generating motor boating sound and allow the device resume normal operation without the need for external system interaction.

POP and Click Circuitry

The HM2010 contains circuitry to minimize turn-on and turn-off transients or “click and pops”, where turn-on refers to either power supply turn-on or device recover from shutdown mode. When the device is turned on, the amplifiers are internally muted. An internal current source ramps up the internal reference voltage. The device will remain in mute mode until the reference voltage reach half supply voltage, 1/2 VDD. As soon as the reference voltage is stable, the device will begin full operation. For the best power-off pop performance, the amplifier should be set in shutdown mode prior to removing the power supply voltage.

Components Selection

Input Resistors (R_I)

The input resistors (R_I) set the gain of the amplifier according to equation (1).

$$\text{Gain} = \frac{2 \times 150\text{k}\Omega}{R_I}\left(\frac{V}{V}\right) \qquad (1)$$

Resistor matching is very important in full differential amplifiers. The balance of the output on the reference voltage depends on matched ratios of the resistors. CMRR, PSRR, and cancellation of the even-order harmonic distortion diminish if resistor mismatch occurs. Therefore, it is recommended to use 1% tolerance resistors or better to keep the performance optimized. Matching is more important than overall tolerance. Resistor arrays with 1% matching can be used with a tolerance greater than 1%.

Place the input resistors very close to the HM2010 to limit noise injection on the high-impedance nodes. For optimal performance the gain should be set to 2 times of R_I (R_I =150kΩ) or so. Lower gain allows the HM2010 to operate at its best, and keeps a high voltage at the input making the inputs less susceptible to noise. In addition to these features, higher value of R_I minimizes pop noise.

Decoupling Capacitor (C_S)

Decoupling capacitor helps to stabilize voltage of power supply and thus reduce the total harmonic distortion (THD). It can also be applied to prevent oscillation over long leads. A Low Equivalent-series-resistance (ESR) capacitor of 1μF is required for decoupling and should be placed close to the HM2010 to reduce the resistance and inductance on the trace between the amplifier and the capacitor. For filtering lower-frequency noise signals, a 10μF capacitor could be placed near the audio power amplifier.

Input Capacitors (C_I)

The input capacitor and input resistor determine the corner frequency of the high pass filter. The corner frequency (fc) is calculated with the Equation (2) below.

$$f_c = \frac{1}{(2\pi R_I C_I)} \qquad (2)$$

The corner frequency directly influences the low frequency signals and consequently determines output bass quality.

PCB Layout

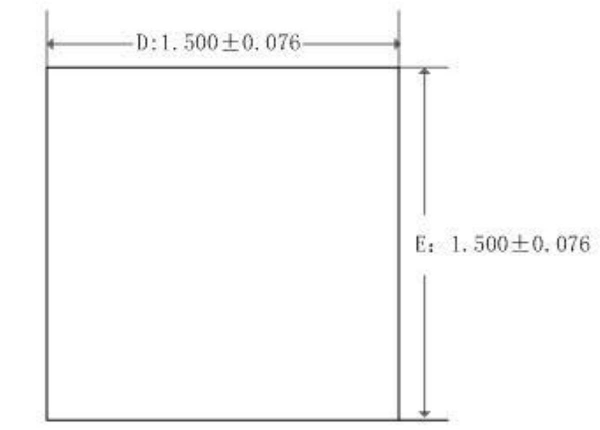
As output power increases, interconnect resistance (PCB traces and wires) among the audio amplifier, load and power supply create a voltage drop. The voltage loss on the traces between the HM2010 and the load results is lower output power and decreased efficiency. Higher trace resistance between the supply and the HM2010 has the same effect as a poorly regulated supply, increase ripple on the supply line also reducing the peak output power. The effects of residual trace resistance increases as output current increases due to higher output power, decreased load impedance or both. To maintain the highest output voltage swing and corresponding peak output power, the PCB traces that connect the output pins to the load and the supply pins to the power supply should be as wide as possible to minimize trace resistance.
The use of power and ground planes will give the best THD+N performance. While reducing trace resistance, the use of power planes also creates parasite capacitors that help to filter the power supply line.

The inductive nature of the transducer load can also result in overshoot on one or both edges, clamped by the parasitic diodes to ground and VDD in each case. From an EMI standpoint, this is an aggressive waveform that can radiate or conduct to other components in the system and cause interference. It is essential to keep the power and output traces short and well shielded if possible. Use of ground planes, beads, and micro-strip layout techniques are all useful in preventing unwanted interference.

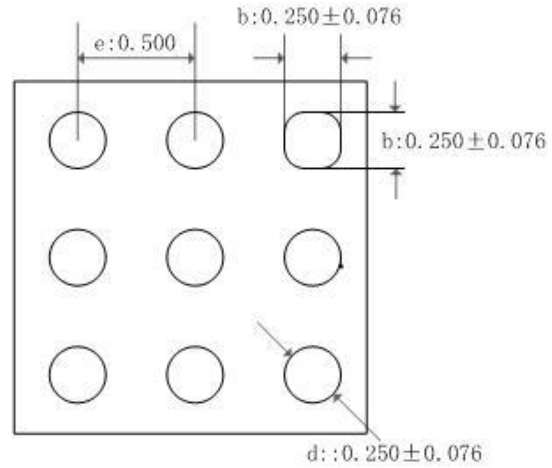
As the distance from the HM2010 and the speaker increase, the amount of EMI radiation will increase since the output wires or traces acting as antenna become more efficient with length. What is acceptable EMI is highly application specific. Ferrite chip inductors placed close to the HM2010 may be needed to reduce EMI radiation. The value of the ferrite chip is very application specific.

PHYSICAL DIMENSIONS

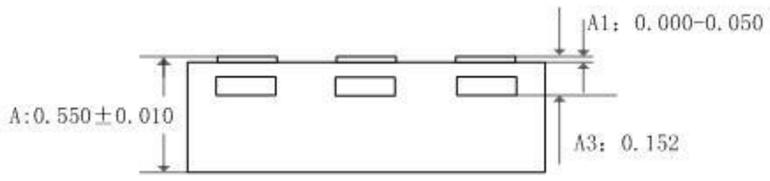
COL1. 5X1. 5-9L PACKAGE OUTLINE DIMENSIONS



Top View



Bottom View



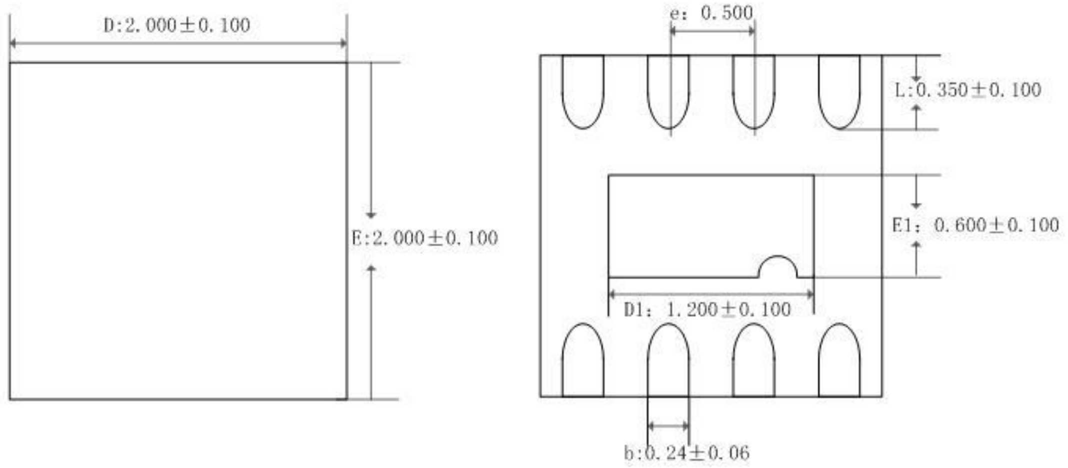
Side View

All dimensions are in millimeters

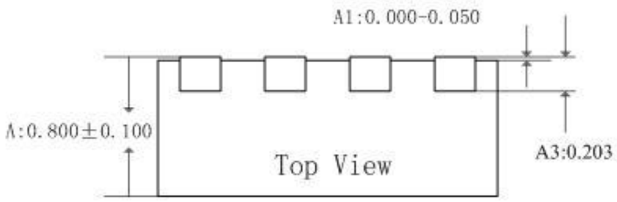
Symbol	Dimensions in Millmeters		Dimensions in Inches	
	Min.	Max.	Min.	Max.
A	0. 450/0. 550	0. 550/0. 650	0. 018/0. 022	0. 022/0. 026
A1	0. 000	0. 050	0. 000	0. 002
A3	0. 152REF.		0. 006REF.	
D	1. 424	1. 576	0. 056	0. 062
E	1. 424	1. 576	0. 056	0. 062
D1	—	—	—	—
E1	—	—	—	—
k	—		—	
b	0. 174	0. 326	0. 007	0. 013
e	0. 500TYP		0. 020TRP.	
L	—	—	—	—
d	0. 174	0. 326	0. 007	0. 013

Unit: millimeters.

DFN2X2-8L PACKAGE OUTLINE DIMENSIONS



Top View   Bottom View



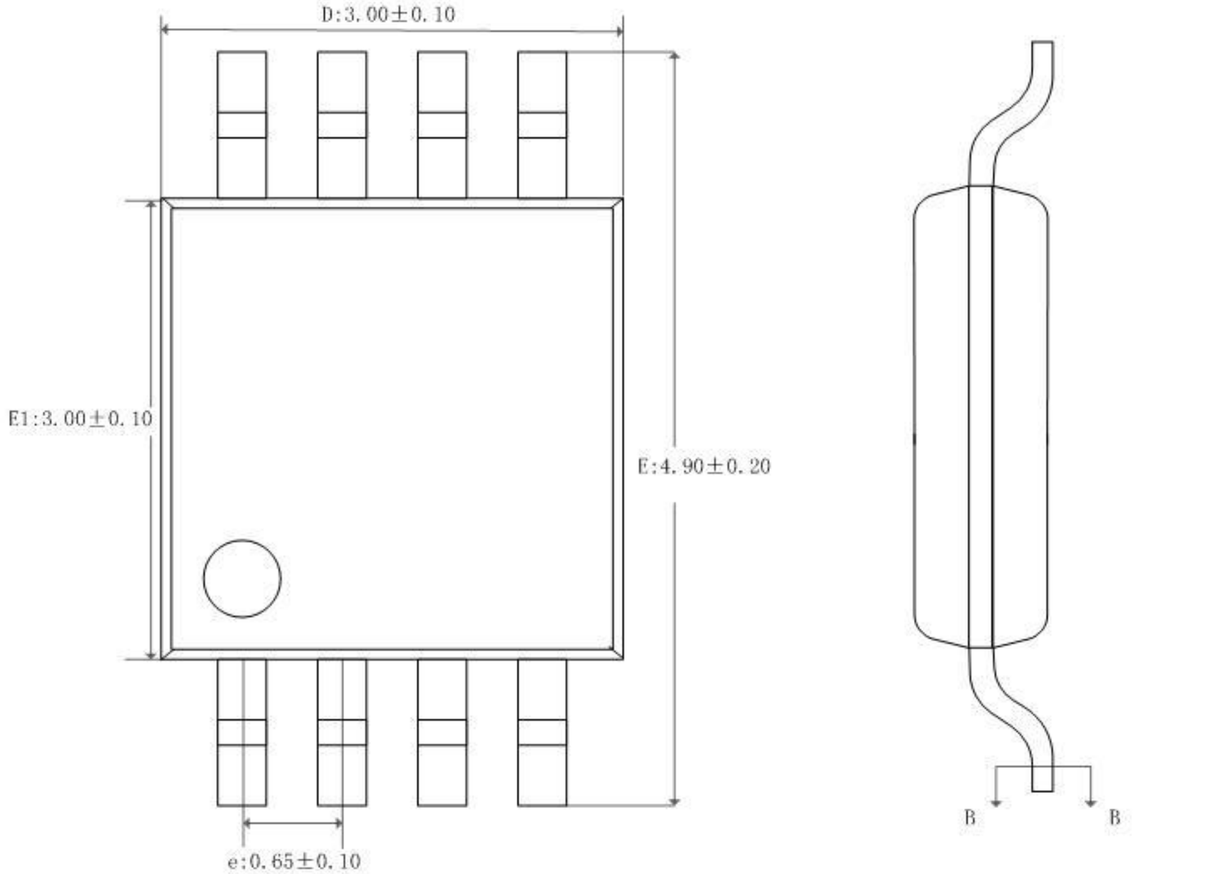
Side View

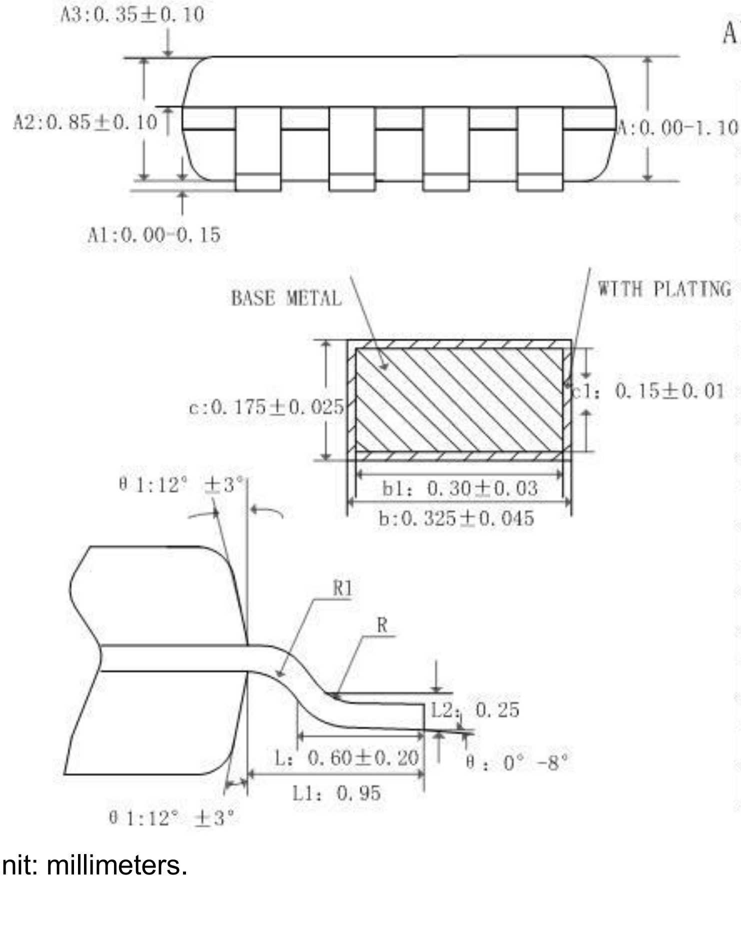
All dimensions are in millimeters

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

Unit: millimeters.

MSOP-8 PACKAGE OUTLINE DIMENSIONS





All dimensions are in millimeters

Symbol	Dimensions in Millimeters	
	Min.	Max.
A	—	1.10
A1	0	0.15
A2	0.75	0.95
A3	0.25	0.39
b	0.28	0.37
b1	0.27	0.33
c	0.15	0.20
c1	0.14	0.16
D	2.90	3.10
E	4.70	5.10
E1	2.90	3.10
e	0.55	0.75
L	0.40	0.80
L1	0.95REF.	
L2	0.25BSC.	
R	0.07	—
R1	0.07	—
θ	0°	8°
θ1	9°	15°

Unit: millimeters.

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