3W Audio Power Amplifier with Shutdown Mode

General Description

The EMA2001 is a mono bridged audio power amplifier capable of delivering 3W of continuous average power into a 3Ω load with less than 10% THD when powered by a 5V power supply. It does not require output coupling capacitors or bootstrap capacitors, and is ideal for mobile phone and other low voltage applications where minimal power consumption is a primary requirement.

The EMA2001 features a low-power consumption shutdown mode, and an internal thermal shutdown protection mechanism. Advanced pop & click circuitry is built in to eliminate noises that would otherwise occur during turn-on and turn-off transitions. The EMA2001 is unity-gain stable and can be configured by external gain-setting resistors.

EMP products are RoHS and Halogen free compliant.

Key Specifications

- BTL mode P_O at THD+N=1%, f=1kHz, V_{DD} =5V
  2.45 W (typ) into 3Ω
  2.1 W (typ) into 4Ω
  1.2 W (typ) into 8Ω
- BTL mode P_O at THD+N=10%, f=1kHz, V_{DD} =5V
  3W (typ) into 3Ω
- Shutdown current 0.1μA (typ)

Features

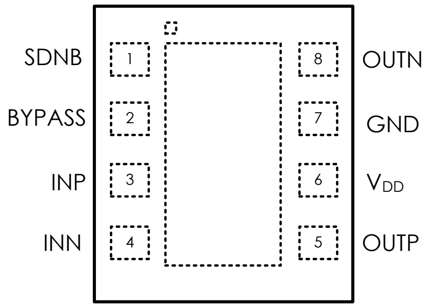
- No output coupling capacitors, bootstrap capacitors, or snubber circuits required
- Unity-gain stable
- MSOP-8, TDFN-8
- External gain configuration capability

Applications

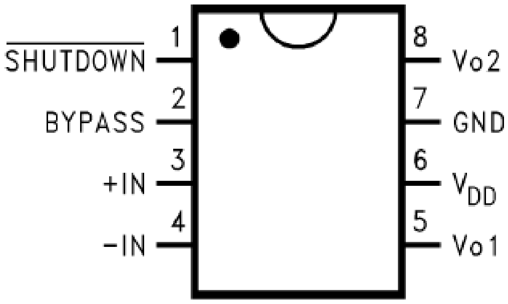
- Portable Computers
- Desktop computers

Connection Diagram

TDFN-8 Package



MSOP-8 Package



Order information

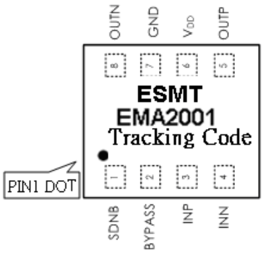
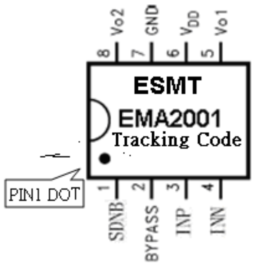
EMA2001-50FF08NRR

50	5.0V Operation
FF08	TDFN-8 Package
NRR	RoHS & Halogen Free Commercial Grade Temperature Rating: -40 to 85°C Package in Tape & Reel

EMA2001-50MA08GRR

50	5.0V Operation
MA08	MSOP-8 Package
GRR	RoHS & Halogen free Rating: -40 to 85°C Package in Tape & Reel

Order, Mark & Packing Information

Package	Product ID	Marking	Packing
TDFN-8	EMA2001-50FF08NRR		5K units Tape & Reel
MSOP-8	EMA2001-50MA08GRR		3K units Tape & Reel

Pin Functions

Pin #	Pin Name	Function
1	$\overline{\text{SDNB}}$ (SHUTDOWN)	Low Level Shutdown
2	BYPASS	Mid-supply Voltage biasing, Adding a Bypass Capacitor to Improves PSRR and Noise Immunity / Turn-on Time Define
3	INP (+IN)	Biased by Mid-supply Voltage / One-side Audio Input for Differential Signal
4	INN (-IN)	Negative Feedback for Audio Input
5	OUTP(Vo1)	Positive(Relative to INN) Audio Output to Load
6	VDD	Power Supply
7	GND	Ground
8	OUTN(Vo2)	Negative(Relative to INN) Audio Output to Load

Typical Application

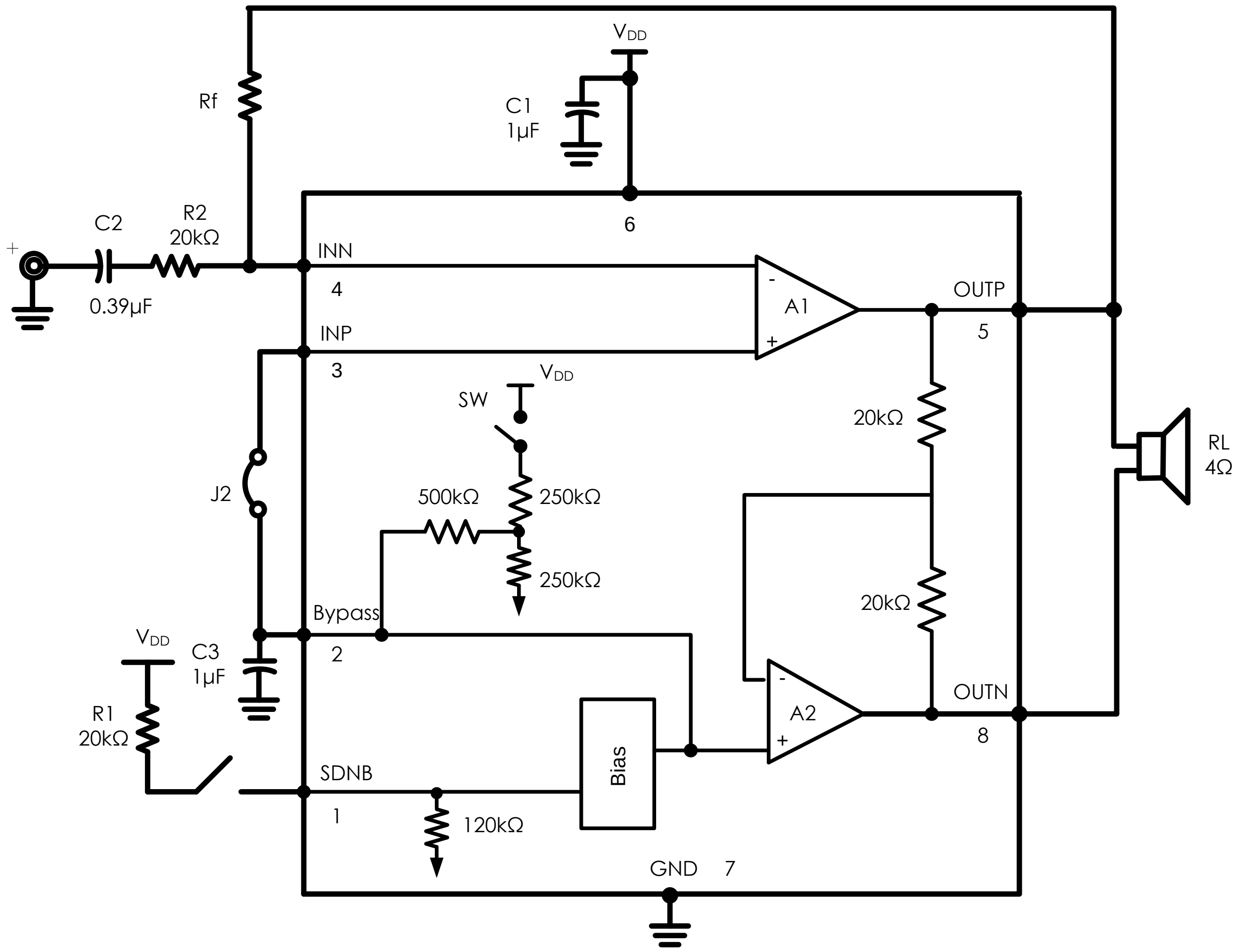


FIGURE 1. Typical Audio Amplifier Application Circuit with single-ended input

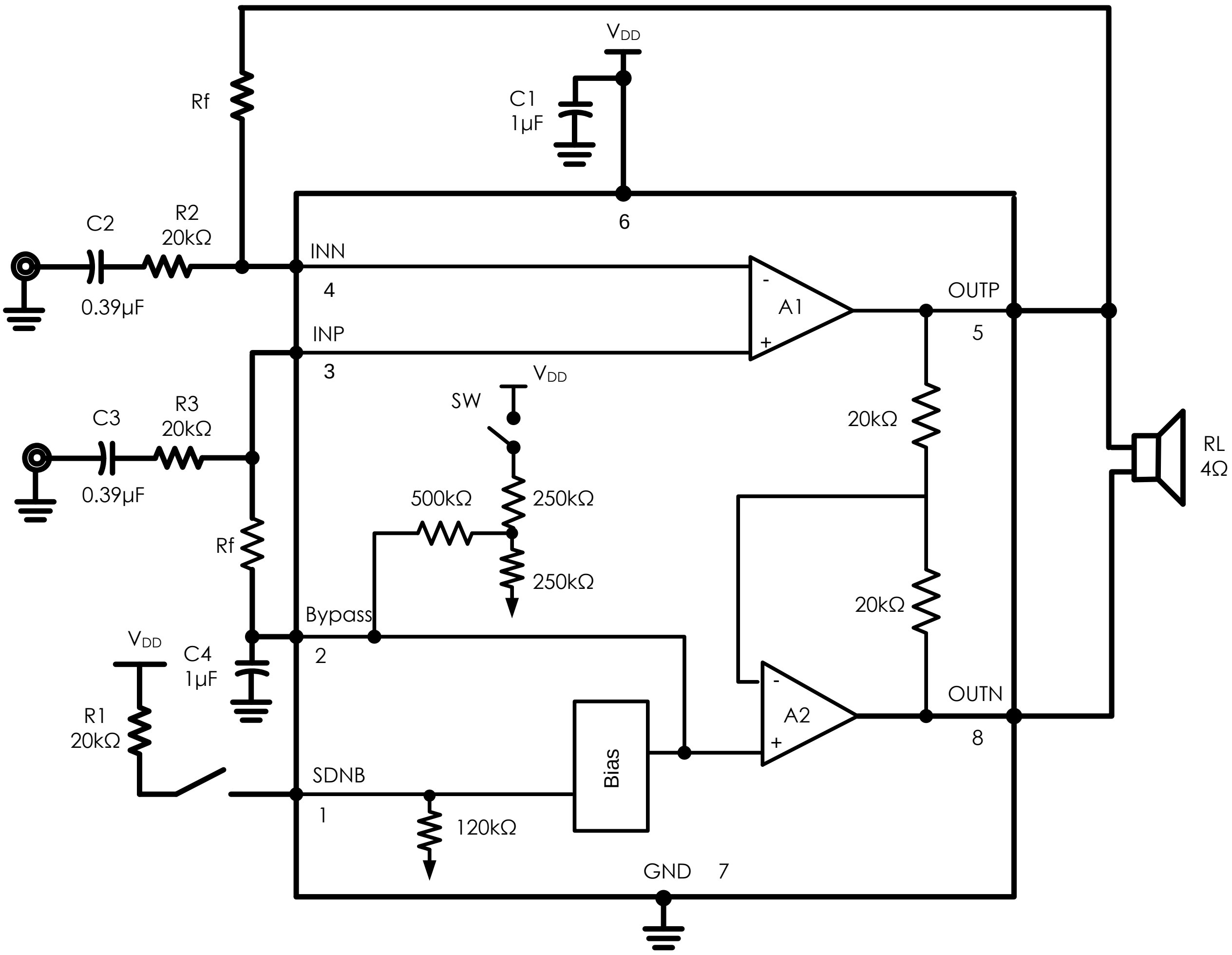


FIGURE 2. Typical Audio Amplifier Application Circuit with differential input

Absolute Maximum Ratings

Supply Voltage	6.0V	Junction Temperature	150°C
Storage Temperature	-65°C to +150°C	Thermal Resistance	
Input Voltage	-0.3V to VDD +0.3V	θ_{JA} (TDFN)	180°C/W
Power Dissipation	Internally Limited	θ_{JA} (MSOP)	190°C/W
ESD Susceptibility	HBM 2kV MM 200V		

Operating Ratings

Supply Voltage	2.0V ≦ VDD ≦ 5.5V
Temperature Range	-40°C ≦ TA ≦ 85°C

Electrical Characteristics

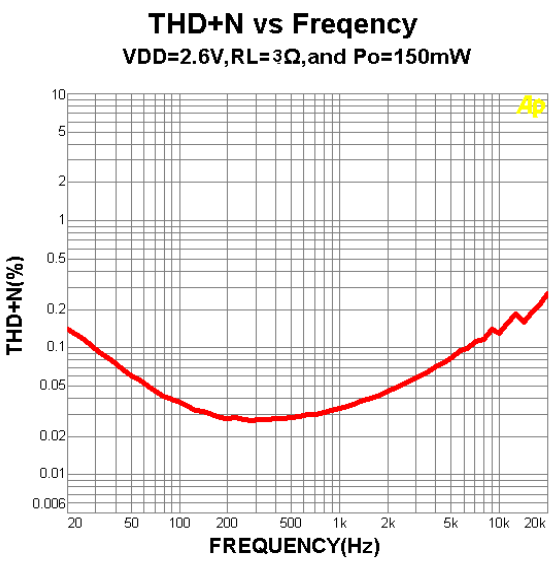
The following specifications apply for V_{DD} = 5V and R_L = 4Ω unless otherwise specified. Limits apply for T_A = 25°C.

Symbol	Parameter	Conditions	Conditions			Units (Limits)
			Min	Typical	Limit	
I_{DD}	Quiescent Power Supply Current	V_{IN} = 0V, Io = 0A		5.0	10.0	mA
I_{SD}	Shutdown Current	V_{SDNB} = GND		0.1	1.0	µA
V_{OS}	Output Offset Voltage	V_{IN} = 0V		5.0	50	mV
P_O	Output Power	THD + N = 1 %, f = 1kHz R_L = 3Ω R_L = 4Ω R_L = 8Ω		2.45 2.1 1.2		W
		THD + N = 10 %, f = 1kHz R_L = 3Ω R_L = 4Ω R_L = 8Ω		3 2.5 1.5		W
THD+N	Total Harmonic Distortion + Noise	f = 1kHz, AV=2, P_O=1W R_L = 3Ω R_L = 4Ω R_L = 8Ω		0.05 0.02 0.013		%
PSRR	Power Supply Rejection Ratio	V_{RIPPLE}=200mV, sine p-p at 217Hz, input 10Ω to GND		60	55	dB

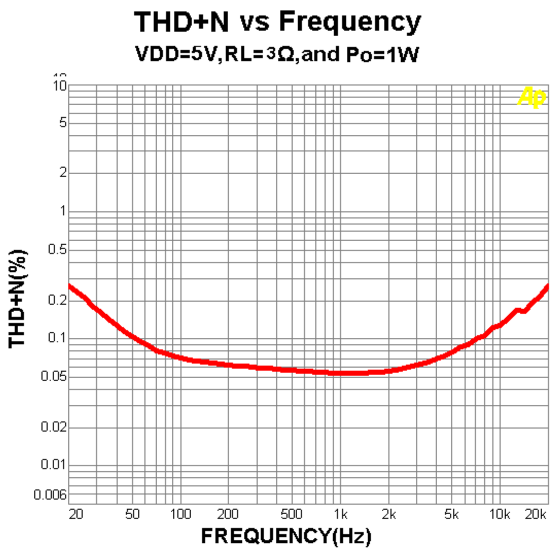
The following specifications apply for V_{DD} = 2.6V and R_L = 4Ω unless otherwise specified. Limits apply for T_A = 25°C.

Symbol	Parameter	Conditions	Conditions			Units (Limits)
			Min	Typical	Limit	
I_{DD}	Quiescent Power Supply Current	V_{IN} = 0V, Io = 0A		4.0	10.0	mA
I_{SD}	Shutdown Current	V_{SDNB} = GND		0.1	1.0	µA
V_{OS}	Output Offset Voltage	V_{IN} = 0V		5.0	50	mV
P_O	Output Power	THD + N = 1 %, f = 1kHz R_L = 3Ω R_L = 4Ω R_L = 8Ω		0.7 0.5 0.32		W
		THD + N = 10 %, f = 1kHz R_L = 3Ω R_L = 4Ω R_L = 8Ω		0.85 0.62 0.52		W
THD+N	Total Harmonic Distortion + Noise	f = 1kHz, AV=2, P_O=150mW R_L = 3Ω R_L = 4Ω R_L = 8Ω		0.03 0.035 0.02		%
PSRR	Power Supply Rejection Ratio	V_{RIPPLE}=200mV, sine p-p at 217Hz, input 10Ω to GND		60	55	dB

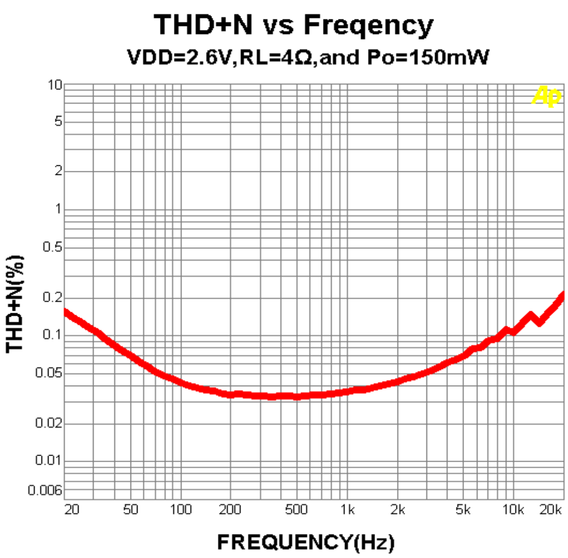
Typical Performance Characteristics



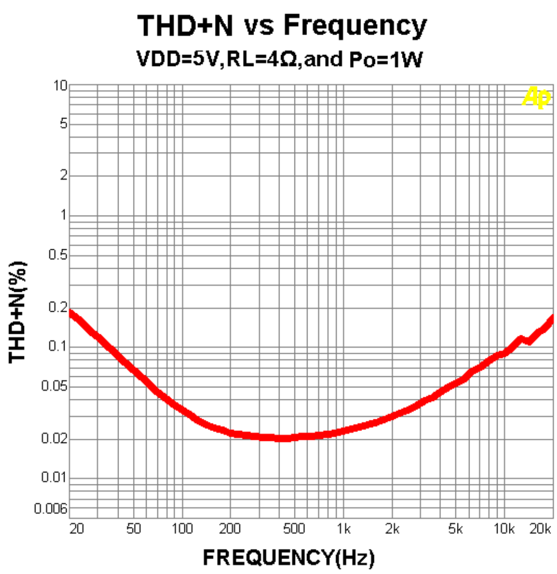
THD + Noise vs Frequency
@ V_{DD} = 2.6V, R_L = 3Ω , Po = 150mW, A_V = 2



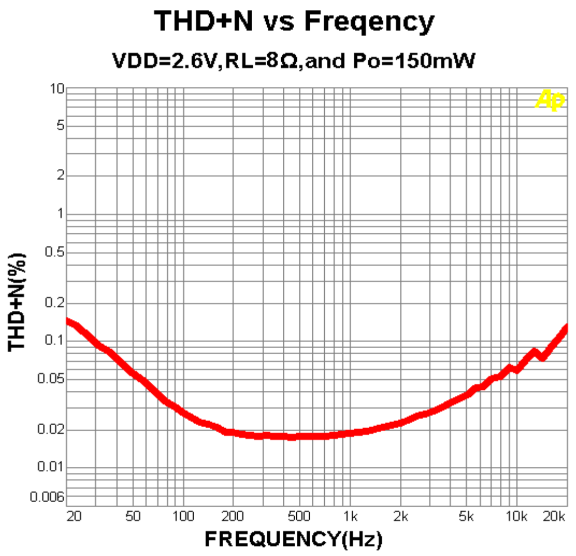
THD + Noise vs Frequency
@ V_{DD} =5V, R_L = 3Ω , Po =1W, A_V = 2



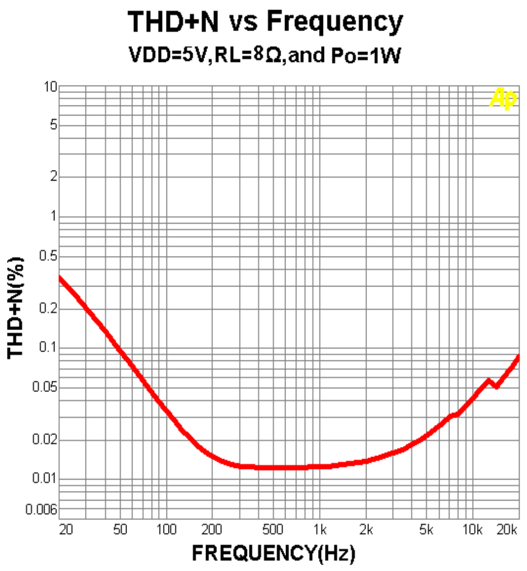
THD + Noise vs Frequency
@ V_{DD} = 2.6V, R_L = 4Ω , Po = 150mW, A_V = 2



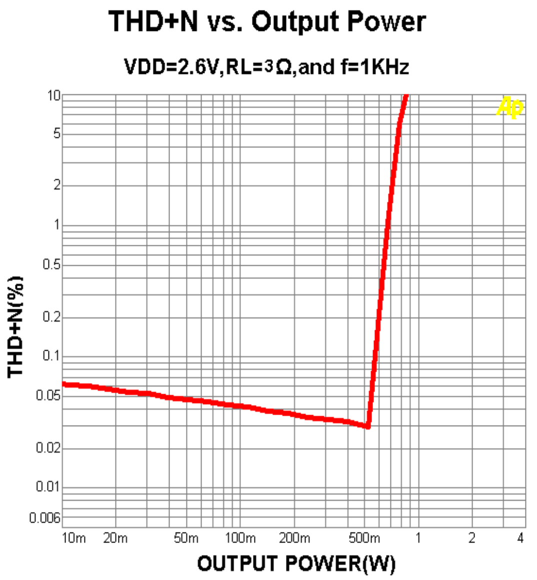
THD + Noise vs Frequency
@ V_{DD} =5V, R_L = 4Ω , Po =1W, A_V = 2



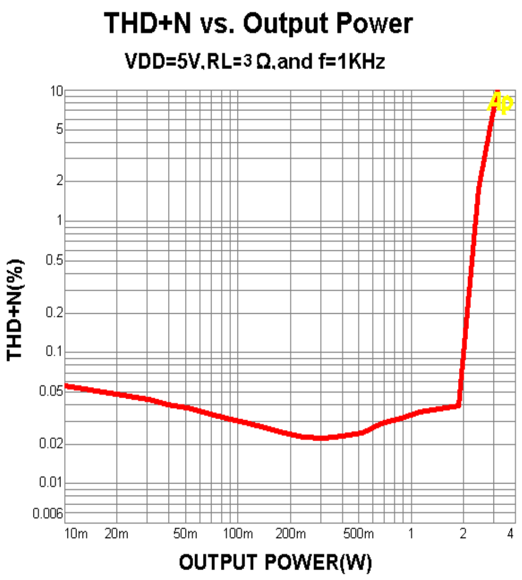
THD + Noise vs Frequency
@ V_{DD} = 2.6V, R_L = 8Ω , Po = 150mW, A_V = 2



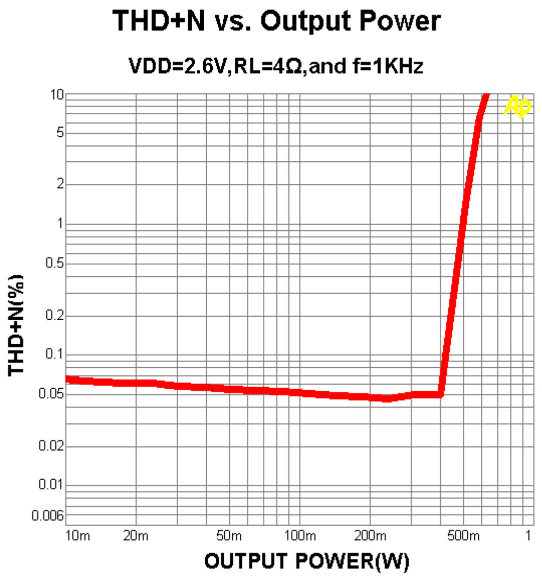
THD + Noise vs Frequency
@ V_{DD} =5V, R_L = 8Ω , Po =1W, A_V = 2



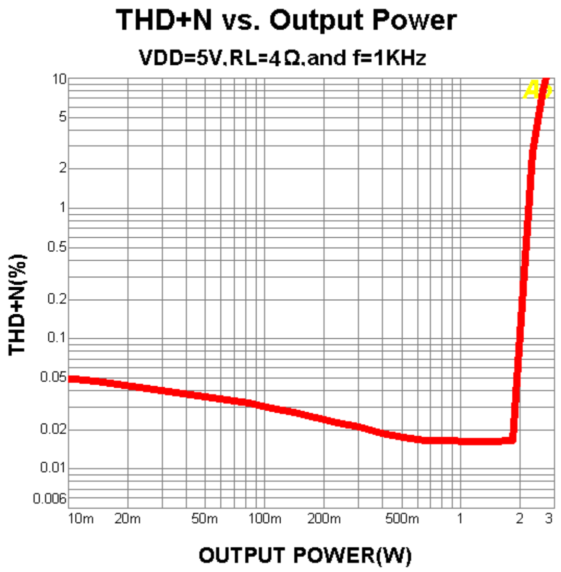
THD + Noise vs Output Power
@ V_{DD} =2.6V, R_L = 3Ω , 1kHz, BW=60kHz, A_V = 2



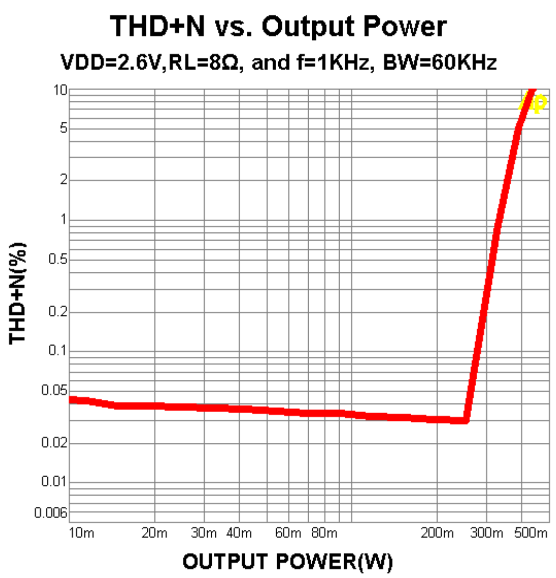
THD + Noise vs Output Power
@ V_{DD} =5V, R_L = 3Ω , 1kHz, BW=60kHz, A_V = 2



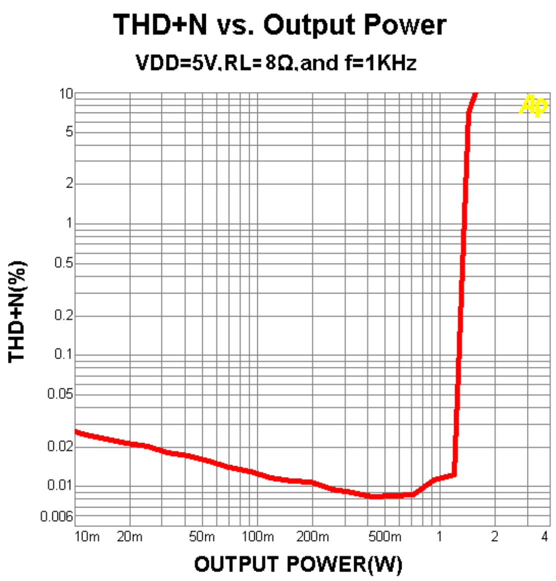
THD + Noise vs Output Power
@ V_{DD} =2.6V, R_L = 4Ω , 1kHz, BW=60kHz, A_V = 2



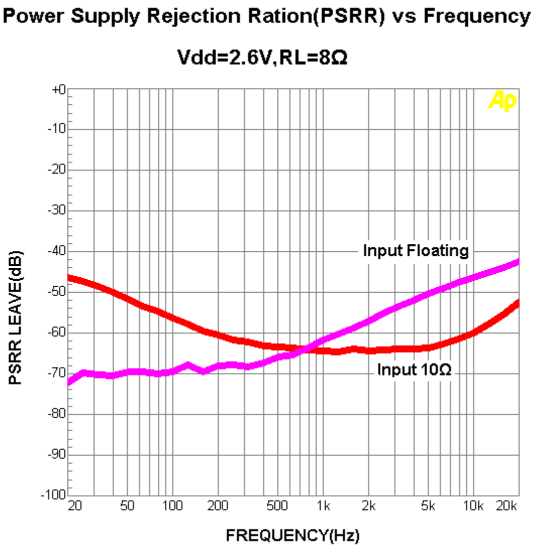
THD + Noise vs Output Power
@ V_{DD} =5V, R_L = 4Ω , 1kHz, BW=60kHz, A_V = 2



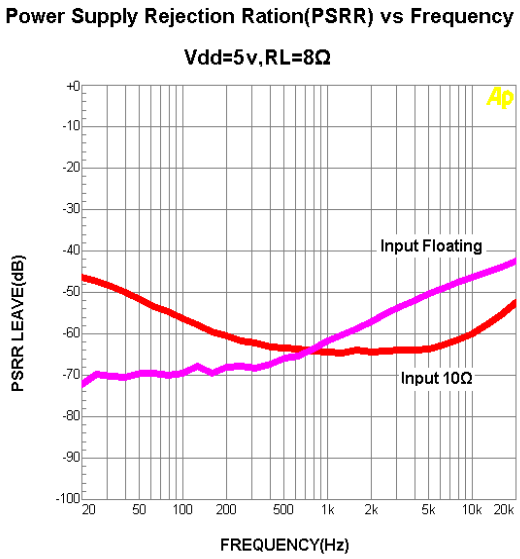
THD + Noise vs Output Power
@ V_{DD} =2.6V, R_L = 8Ω , 1kHz, BW=60kHz, A_V = 2



THD + Noise vs Output Power
@ V_{DD} =5V, R_L = 8Ω , 1kHz, BW=60kHz, A_V = 2



PSRR @ V_{DD} =2.6V, R_L = 8Ω , A_V = 2



PSRR @ V_{DD} =2.6V, R_L = 8Ω , A_V = 2

Application Information

BRIDGED CONFIGURATION EXPLANATION

As shown in *Figure 1*, the EMA2001 has two operational amplifiers internally, A1 and A2, allowing for a few different amplifier configurations. A1's gain is externally configurable, while A2 is internally fixed in a unity-gain, inverting configuration. The closed-loop gain of A1 is set by selecting the ratio of R_f to R_2, while A2's gain is fixed by the two internal 20kΩ resistors. *Figure 1* shows that the output of A1 serves as the input to A2, which results in both amplifiers producing signals identical in magnitude, but out of phase by 180°. Hence, the differential gain for the IC is

$$A_{VD} = 2 * (R_f / R_2)$$

By driving the load differentially through outputs V_{O1} and V_{O2}, a bridged mode amplifier configuration is established. Bridged mode operation is different from the single-ended amplifier configuration where one side of the load is connected to ground. A bridge amplifier design has a few distinct advantages over the single-ended configuration, as it provides differential drive to the load, thus doubling output swing for a specified supply voltage. Four times the output power is possible as compared to a single-ended amplifier under the same conditions. This increase in attainable output power assumes that the amplifier is not current limited or clipped. In order to choose an amplifier's closed-loop gain without causing excessive clipping, please refer to the **Audio Power Amplifier Design** section. A bridge configuration, such as the one used in the EMA2001, also creates a second advantage over single-ended amplifiers. Since the differential outputs, V_{O1} and V_{O2}, are biased at half-supply, no net DC voltage exists across the load. This eliminates the need for an output coupling capacitor, which is required in a single supply, single-ended amplifier configuration. Without an output coupling capacitor, the half-supply bias across the load would result in both increased internal IC power dissipation and also possible loudspeaker damage.

POWER DISSIPATION

Power dissipation is one of the major concerns in designing a quality amplifier -- the higher the power delivered to the load by a bridge amplifier, the higher the increase in internal power dissipation. Since the EMA2001 has two operational amplifiers in one package, the maximum internal power dissipation is 4 times that of a single-ended amplifier. The maximum power dissipation for a given application can be derived from the power dissipation graphs or from Equation 1.

$$P_{DMAX} = 4 * (V_{DD})^2 / (2\pi^2 R_L) \quad (1)$$

It is critical to maintain the maximum junction temperature T_{JMAX} below 150°C. T_{JMAX} can be determined from the power derating curves by using P_{DMAX} and the PC board foil area. By adding additional copper foil, the thermal resistance of the application can be reduced, resulting in higher P_{DMAX}. Additional copper foil can be added to any of the leads connected to the EMA2001. Refer to the **APPLICATION INFORMATION** on the EMA2001 reference design board for an example of good heat sinking. If T_{JMAX} still exceeds 150°C, then additional changes must be made. These changes can include reduced supply voltage, higher load impedance, or reduced ambient temperature. Internal power dissipation is a function of output power. Refer to the **Typical Performance Characteristics** curves for power dissipation information for different output powers and output loading.

POWER SUPPLY BYPASSING

As with any 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. Typical applications employ a 5V regulator with 10μF tantalum or electrolytic capacitor and a ceramic bypass capacitor, which aids in supply stability. This does not eliminate the need for bypassing the supply nodes of the EMA2001. The selection of a bypass capacitor, especially C_3, is dependent upon PSRR requirements, click and pop performance (as in the section, **Proper Selection of External Components**), system cost, and size constraints.

SHUTDOWN FUNCTION

The EMA2001 contains a shutdown pin to externally turn off the amplifier's bias circuitry. When a logic low is placed on the shutdown pin, this shutdown feature turns the amplifier off. By switching the shutdown pin to ground, the EMA2001 supply current draw will be minimized in idle mode. The idle current may be greater than the typical value of 0.1μA while the device is disabled with shutdown pin voltages less than 0.5VDC. Idle current is measured with the shutdown pin grounded. In many applications, a microcontroller or microprocessor output is used to control the shutdown circuitry. They provide a quick, smooth transition into shutdown. 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 disables the amplifier. If the switch is open, then the external pull-up resistor will enable the EMA2001. This scheme guarantees that the shutdown pin will not float thus preventing unwanted state changes.

PROPER SELECTION OF EXTERNAL COMPONENTS

To optimize device and system performance, proper selection of external components is critical. While the EMA2001 can support a wide range of external component combinations, careful selection of component values can maximize overall system quality. The EMA2001 is unity-gain stable, which gives the designer maximum system flexibility. The EMA2001 should be used in low gain configurations to minimize THD+N values, and maximize the signal to noise ratio. Low gain configurations require large input signals to obtain a given output power. Input signals equal to or greater than 1Vrms 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. Besides gain, one of the major considerations is the closed loop bandwidth of the amplifier. The bandwidth is primarily determined by the choice of external components shown in *Figure 1*. The input coupling capacitor, C_2, forms a first order high pass filter, which limits low frequency response. This value should be chosen based on needed frequency response for a few distinct reasons.

SELECTION OF INPUT CAPACITOR SIZE

For portable designs, large input capacitors are prohibited because they are both expensive and space hungry. To couple in low frequencies without severe attenuation, a certain sized capacitor is needed. But in many cases the speakers used in portable systems, whether internal or external, have little ability to reproduce signals below 100Hz to 150Hz. Thus, using a large input capacitor may not increase actual system performance. In addition to system cost and size, click and pop performance is affected by the size of the input coupling capacitor, C_2. A larger input coupling capacitor requires more charge to reach its quiescent DC voltage (nominally 1/2 V_{DD}). This charge comes from the output via the feedback and is apt to create pops upon device enable. Thus, by minimizing the capacitor size based on necessary low frequency response, turn-on pops can be minimized. Besides minimizing the input capacitor size, careful consideration should be paid to the bypass capacitor value. Bypass capacitor, C_3, is the most critical component to minimize turn-on pops since it determines how fast the EMA2001 turns on. The slower the EMA2001's outputs ramp to their quiescent DC voltage (nominally 1/2V_{DD}), the smaller the turn-on pop. Choosing C_3 equal to 1.0μF along with a small value of C_2, (in the range of 0.1μF to 0.39μF), should produce a virtually clickless and popless shutdown function. While the device will function properly, (no oscillations or motor-boating), with C_3 equal to 0.1μF, the device will be much more susceptible to turn-on clicks and pops. Thus, a value of C_3 equal to 1.0μF is recommended in all but the most cost sensitive designs.

AUDIO POWER AMPLIFIER DESIGN

A 1W/8Ω Audio Amplifier

Given:

Power Output	1 Wrms
Load Impedance	8Ω
Input Level	1 Vrms
Input Impedance	20 kΩ
Bandwidth	100 Hz–20 kHz ± 0.25 dB

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. In more applications, 5V is chosen as a standard voltage for the supply rail. Extra supply voltage creates headroom, which allows the EMA2001 to reproduce peaks in excess of 1W without producing audible distortion. At this stage, the designer must make sure that the power supply choice along with the output impedance does not violate the conditions described in the **Power Dissipation** section.

Once the power dissipation equations are addressed, the required differential gain can be determined from Equation 3.

$A_{VD} \geqq (P_O R_L)^{1/2}/Vin = Vorms/Vinrms$ (3)

$R_f/R_2 = A_{VD}/2$

From Equation 3, the minimum A_{VD} is 2.83; use $A_{VD} = 3$. Since the desired input impedance is 20 kΩ , and with an A_{VD} gain of 3, a ratio of 1.5:1 of R_f to R_2 results in an allocation of $R_2 = 20$ kΩ and $R_f = 30$ kΩ . The final design step is to address the bandwidth requirements, which must be stated as a pair of -3 dB frequency points. Five times away from a -3 dB point is 0.17 dB down from passband response, which is better than the required ±0.25 dB specified.

$f_L = 100Hz/5 = 20Hz$

$f_H = 20kHz * 5 = 100kHz$

As stated in the **External Components** section, R_2 and C_2 create a high-pass filter.

$C_2 \geq 1/(2\pi*20\ k\Omega*20Hz) = 0.397\mu F$; use 0.39μF.

The high frequency pole is the product of the desired frequency pole, f_H, and the differential gain, A_{VD}. With a AVD = 3 and f_H = 100kHz, the resulting GBWP = 300kHz which is much smaller than the EMA2001 GBWP of 2.5MHz. This calculation shows that if a designer has a need to design an amplifier with a higher differential gain, the EMA2001 can still be used without running into bandwidth limitations.

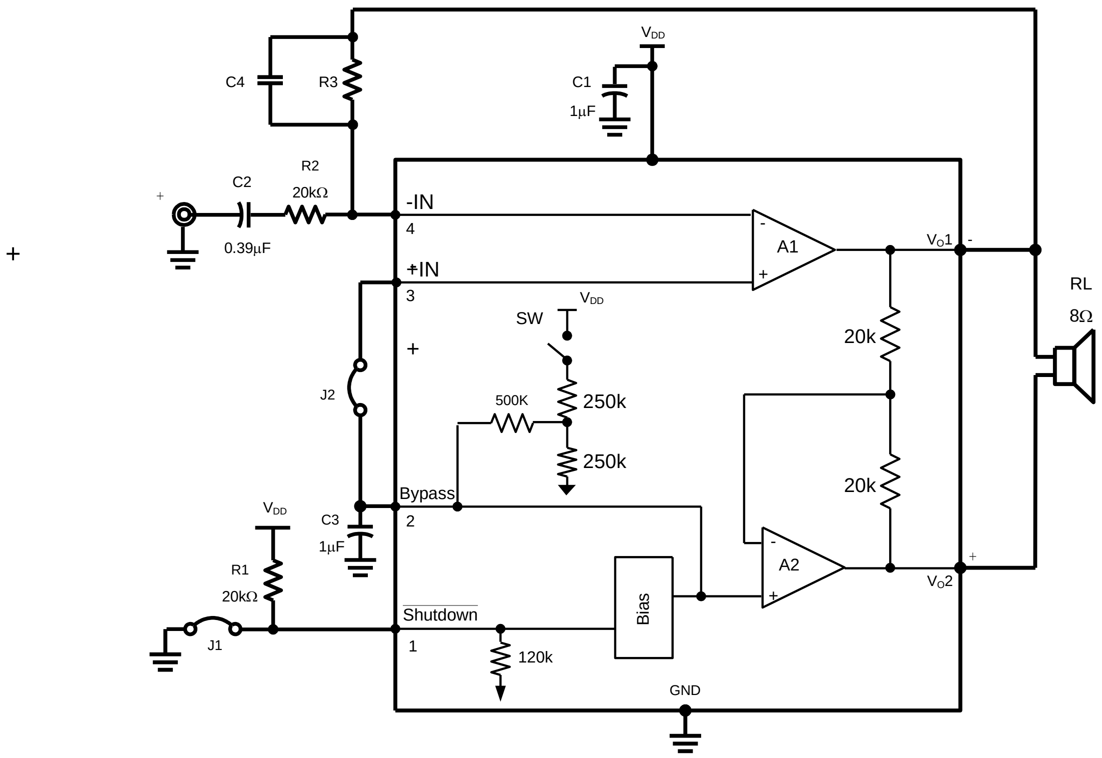


FIGURE 2. HIGHER GAIN AUDIO AMPLIFIER

The EMA2001 is unity-gain stable and requires only gain-setting resistors, an input coupling capacitor, and proper supply bypassing in the typical application. For a closed-loop differential gain of greater than 10, a feedback capacitor (C4) may be needed as shown in **Figure 2** to bandwidth limit the amplifier. This feedback capacitor creates a low pass filter that eliminates possible high frequency oscillations. Care should be taken when calculating the -3dB frequency in that an incorrect combination of R3 and C4 will cause rolloff before 20kHz. A typical combination of feedback resistor and capacitor that will not produce audio band high frequency rolloff is R3 = 20kΩ and C4 = 25pf. These components result in a -3dB point of approximately 320 kHz.

PCB LAYOUT GUIDELINES

This section provides practical guidelines for mixed signal PCB layout that involves various digital/analog power and ground traces. Designers should note that these are only "rule-of-thumb" recommendations and the actual results will depend heavily on the final layout.

GENERAL MIXED SIGNAL LAYOUT RECOMMENDATIONS

Power and Ground Circuits

For 2 layer mixed signal design, it is important to isolate the digital power and ground trace paths from the analog power and ground trace paths. Star trace routing techniques (bringing individual traces back to a central point rather than daisy chaining traces together in a serial manner) can have a major impact on low level signal performance. Star trace routing refers to using individual traces to feed power and ground to each circuit or even device. This technique will require a greater amount of design time but will not increase the final price of the board. The only extra parts required will be some jumpers.

Single-Point Power / Ground Connections

The analog power traces should be connected to the digital traces through a single point (link). A "Pi-filter" can be helpful in minimizing High Frequency noise coupling between the analog and digital sections. It is further recommended to put digital and analog power traces over the corresponding digital and analog ground traces to minimize noise coupling.

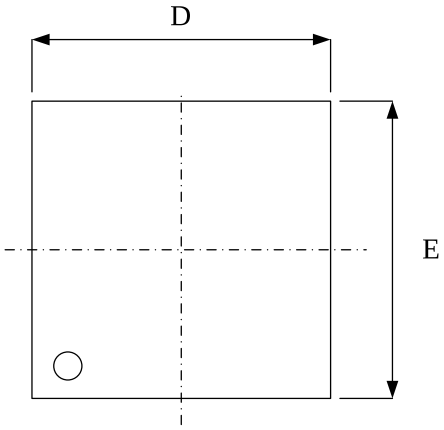
Placement of Digital and Analog Components

All digital components and high-speed digital signals traces should be located as far away as possible from analog components and circuit traces.

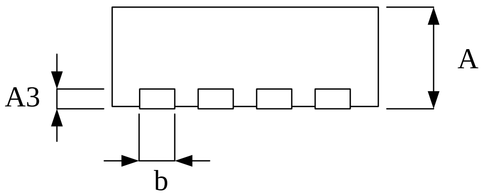
Avoiding Typical Design / Layout Problems

Avoid ground loops or running digital and analog traces parallel to each other (side-by-side) on the same PCB layer. When traces must cross over each other do it at 90 degrees. Running digital and analog traces at 90 degrees to each other from the top to the bottom side as much as possible will minimize capacitive noise coupling and cross talk.

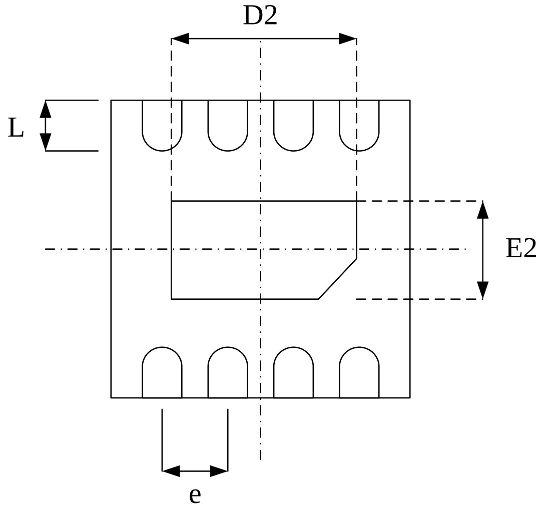
Package Outline Drawing
TDFN-8L (3x3 mm)



TOP VIEW



SIDE VIEW



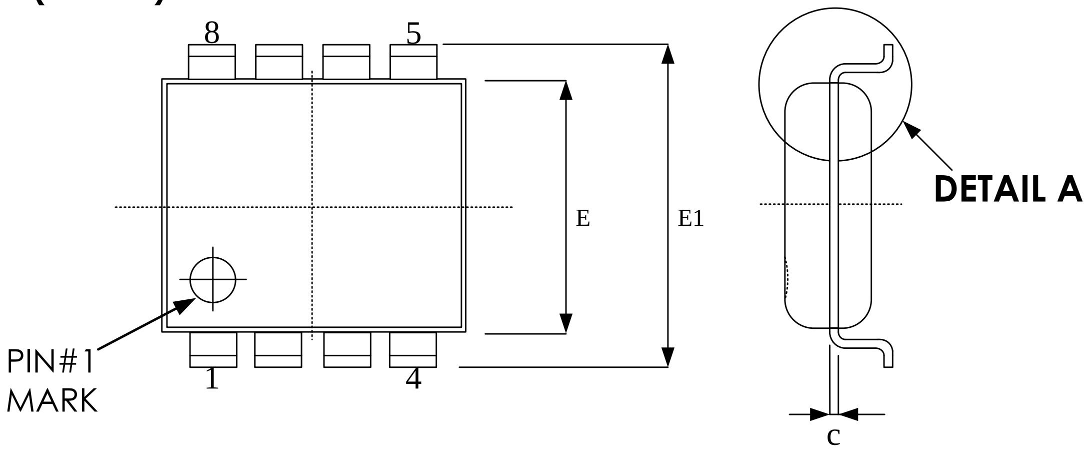
BOTTOM VIEW

Symbol	Dimension in mm	
	Min	Max
A	0.7	0.8
A3	0.20 REF.	
b	0.25	0.35
D	3.00 BSC	
E	3.00 BSC	
e	0.65 BSC	
L	0.3	0.5

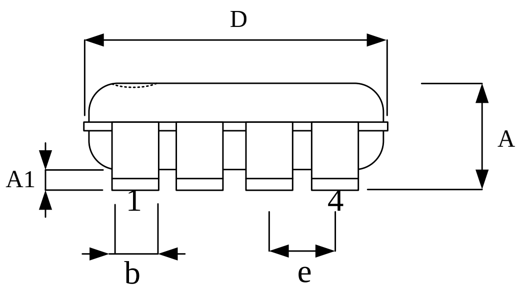
Exposed pad

	Dimension in mm	
	Min	Max
D2	1.95	2.05
E2	1.6	1.75

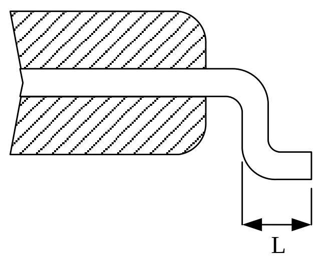
Package Outline Drawing
MSOP-8 (118 mil)



TOP VIEW



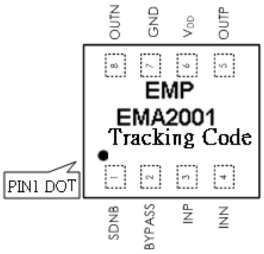
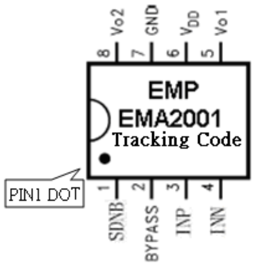
SIDE VIEW



DETAIL A

Symbol	Dimension in mm	
	Min	Max
A	0.81	1.10
A1	0.00	0.15
b	0.22	0.38
c	0.13	0.23
D	2.90	3.10
E	2.90	3.10
E1	4.80	5.00
e	0.65 BSC	
L	0.40	0.80

Old order, Mark & Packing Information

Package	Product ID	Marking	Packing
TDFN-8	EMA2001-50FF08NRR		5K units Tape & Reel
MSOP-8	EMA2001-50MA08GRR		3K units Tape & Reel

Revision History

Revision	Date	Description
3.0	2009.05.08	EMP transferred from version 2.1
3.1	2013.10.16	Marking logo change to ESMT POD format change
3.2	2016.02.26	Modify Package Outline Drawing TDFN-8L(2*2) -> TDFN-8L(3*3)
3.3	2016.08.16	Modify the range of Supply Voltage in Operating Ratings Modify the Description of Features Modify the Description of Order Information
3.4	2016.09.08	Added Application Information

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