

# LM2787

## Low Noise Regulated Switched Capacitor Voltage Inverter in micro SMD

### General Description

The LM2787 CMOS Negative Regulated Switched Capacitor Voltage Inverter delivers a very low noise adjustable output for an input voltage in the range of +2.7V to +5.5V. Four low cost capacitors are used in this circuit to provide up to 10mA of output current. The regulated output for the LM2787 is adjustable between -1.5V and -5.2V. The LM2787 operates at 260 kHz (typical) switching frequency to reduce output resistance and voltage ripple. With an operating current of only 400  $\mu$ A (charge pump power efficiency greater than 90% with most loads) and 0.05  $\mu$ A typical shutdown current, the LM2787 provides ideal performance for cellular phone power amplifier bias and other low current, low noise negative voltage needs. The device comes in small 8-Bump micro SMD and thin micro SMD packages.

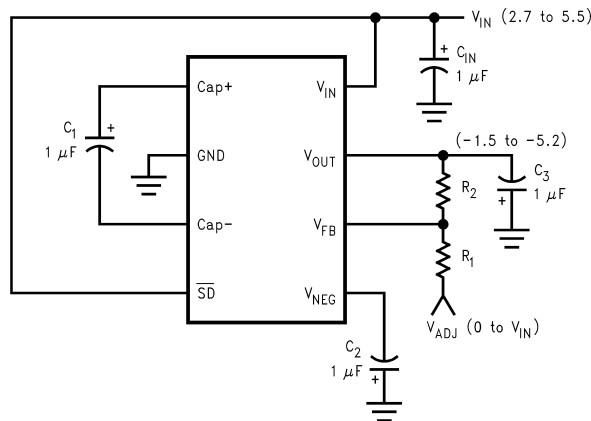
### Features

- Inverts and regulates the input supply voltage
- Small 8-Bump micro SMD and thin micro SMD packages
- 91% typical charge pump power efficiency at 10mA
- Low output ripple
- Shutdown lowers Quiescent current to 0.05  $\mu$ A (typical)

### Applications

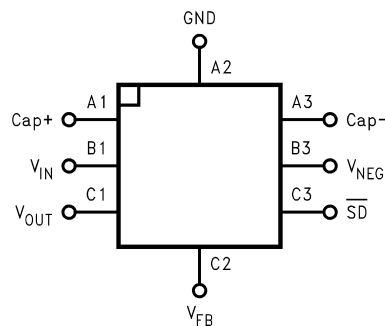
- Wireless Communication Systems
- Cellular Phone Power Amplifier Biasing
- Interface Power Supplies
- Handheld Instrumentation
- Laptop Computers and PDA's

### Typical Application Circuit and Connection Diagram



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### 8-Bump micro SMD (Top View)



10131302

## Ordering Information micro SMD

Device Order Number	Package Number	Package Marking*	Supplies As
LM2787BP	BPA08CCB	S8	Tape and Reel (250 units/reel)
LM2787BPX	BPA08CCB	S8	Tape and Reel (3000 units/reel)

## Thin micro SMD

Device Order Number	Package Number	Package Marking*	Supplies As
LM2787TP	TPA08CCA	S8	Tape and Reel (250 units/reel)
LM2787TPX	TPA08CCA	S8	Tape and Reel (3000 units/reel)

**Note:** \* The small physical size of the micro SMD package does not allow for the full part number marking. Devices will be marked with the designation shown in the column Package Marking.

## Pin Descriptions

Pin No.	Name	Function
A1	Cap+	Positive terminal for $C_1$ .
B1	$V_{IN}$	Positive power supply input.
C1	$V_{OUT}$	Regulated negative output voltage.
C2	$V_{FB}$	Feedback input. Connect $V_{FB}$ to an external resistor divider between $V_{OUT}$ and a positive adjust voltage $V_{ADJ}$ ( $0 \leq V_{ADJ} \leq V_{IN}$ ). <b>DO NOT</b> leave unconnected.
C3	$\overline{SD}$	Active low, logic-level shutdown input.
B3	$V_{NEG}$	Negative unregulated output voltage.
A3	Cap-	Negative terminal for $C_1$ .
A2	GND	Ground.

## Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Supply Voltage ( $V_{IN}$ to GND or GND to OUT)	+ 5.8V
$\overline{SD}$	(GND – 0.3V) to ( $V_{IN} + 0.3V$ )
$V_{NEG}$ and $V_{OUT}$ Continuous Output Current	10mA
$V_{OUT}$ Short-Circuit Duration to GND (Note 2)	1 sec.
Continuous Power Dissipation ( $T_A = 25^\circ\text{C}$ ) (Note 3)	600mW

$T_{JMAX}$ (Note 3)	150°C
$\theta_{JA}$ (Note 3)	220°C/W
Operating Input Voltage Range	2.7V to 5.5V
Operating Output Current Range	0mA to 10mA
Operating Ambient Temp. Range	–40°C to 85°C
Operating Junction Temp. Range	–40°C to 110°C
Storage Temperature	–65°C to 150°C
Lead Temp. (Soldering, 10 sec.)	300°C
ESD Rating (Note 4)	2kV

## Electrical Characteristics

Limits with standard typeface apply for  $T_J = 25^\circ\text{C}$ , and limits in **boldface type** apply over the full temperature range. Unless otherwise specified  $V_{IN} = 3.6V$ ,  $C_1 = C_2 = C_3 = 1\mu\text{F}$ .

Symbol	Parameter	Conditions	Min	Typ	Max	Units
$I_Q$	Supply Current	Open Circuit, No Load		400	<b>950</b>	$\mu\text{A}$
$I_{SD}$	Shutdown Supply Current			0.05	1	$\mu\text{A}$
$F_{SW}$	Switching Frequency (Note 5)	$V_{IN} = 3.6V$	<b>140</b>	260	<b>450</b>	kHz
$\eta_{POWER}$	Power Efficiency at $V_{NEG}$	$I_L = 3.6mA$ $I_L = 10mA$		94 91		%
$T_{START}$	Start Up time			120	600	$\mu\text{s}$
$R_{NEG}$	Output Resistance to $V_{NEG}$	(Note 6)		30		$\Omega$
$V_R$	Output Voltage Ripple (Note 7)	$I_L = 2.5mA$ , $V_{OUT} = -2.7V$ $I_L = 10mA$ , $V_{OUT} = -3.8V$		1		mV
$V_{FB}$	Feedback Pin Reference Voltage	$I_L = 2.5mA$ (Note 8)	<b>–1.25</b>	–1.20	<b>–1.15</b>	V
$V_{OUT}$	Adjustable Output Voltage	$5.5V \geq V_{IN} \geq 2.7V$ , $2.5mA \geq I_L$ $5.5V \geq V_{IN} \geq 3.0V$ , $10mA \geq I_L \geq 0mA$	<b>– (<math>V_{IN} - 0.3V</math>)</b> <b>– (<math>V_{IN} - 1.2V</math>)</b>			V
	Load Regulation	0 to 10mA, $V_{OUT} = -2.4V$		5		mV/mA
	Line Regulation	$5.5V \geq V_{IN} \geq 2.7V$ , $I_L = 2.5mA$		1		mV/V
$V_{IH}$	Shutdown Pin Input Voltage High	$5.5V \geq V_{IN} \geq 2.7V$	<b>2.4</b>			V
$V_{IL}$	Shutdown Pin Input Voltage Low	$5.5V \geq V_{IN} \geq 2.7V$			<b>0.8</b>	V

**Note 1:** Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Electrical specifications do not apply when operating the device beyond its rated operating conditions.

**Note 2:** OUT may be shorted to GND for one second without damage. However, shorting OUT to  $V_{IN}$  may damage the device and must be avoided. Also, for temperatures above  $T_A = 85^\circ\text{C}$ , OUT must not be shorted to GND or  $V_{IN}$  or device may be damaged.

**Note 3:** The maximum power dissipation must be de-rated at elevated temperatures and is limited by  $T_{JMAX}$  (maximum junction temperature),  $T_A$  (ambient temperature) and  $\theta_{JA}$  (junction-to-ambient thermal resistance). The maximum power dissipation at any temperature is:

$$PD_{Diss\_MAX} = (T_{JMAX} - T_A)/\theta_{JA} \text{ up to the value listed in the Absolute Maximum Ratings.}$$

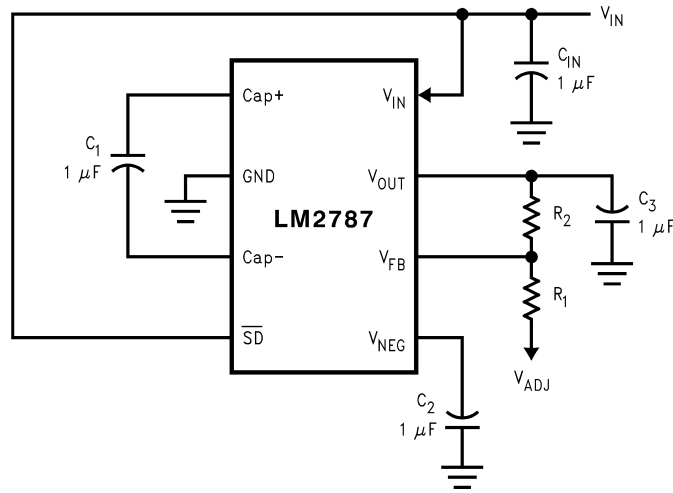
**Note 4:** Rating is for the human body model, a 100pF capacitor discharged through a 1.5 k $\Omega$  resistor into each pin.

**Note 5:** The output switches operate at one half the oscillator frequency,  $f_{OSC} = 2f_{SW}$ .

**Note 6:** Current drawn from  $V_{NEG}$  pin decreases power efficiency and will increase output voltage ripple.

**Note 7:** In the test circuit, capacitors  $C_1$ ,  $C_2$ , and  $C_3$  are 1 $\mu\text{F}$ , 0.30 $\Omega$  maximum ESR capacitors. Capacitors with higher ESR will increase output resistance, increase output voltage ripple, and reduce efficiency.

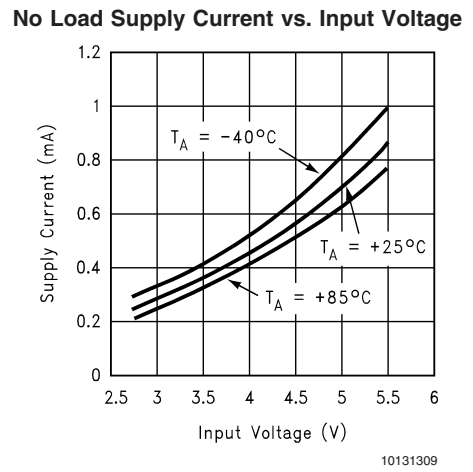
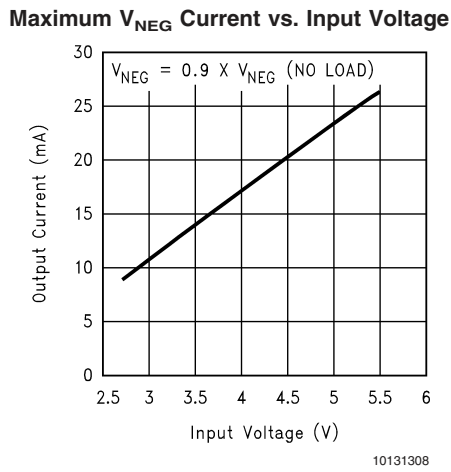
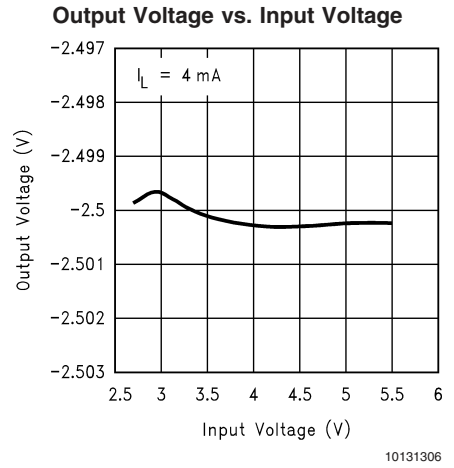
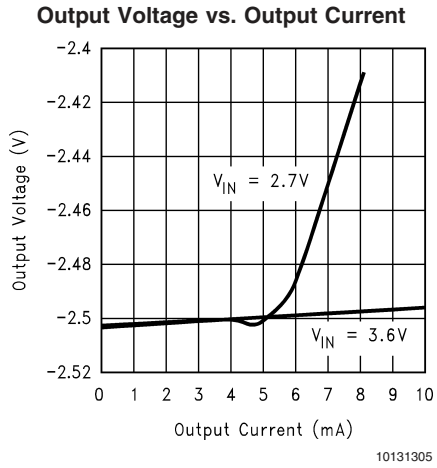
**Note 8:** The feedback resistors R1 and R2 are 200k $\Omega$  resistors.



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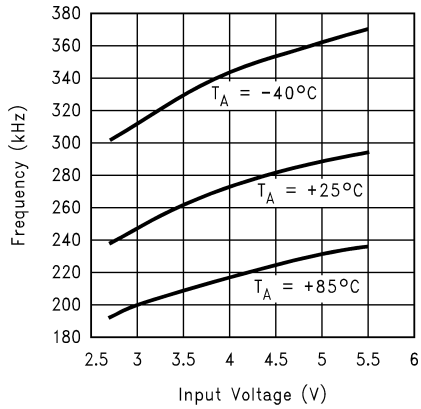
FIGURE 1. Standard Application Circuit

**Typical Performance Characteristics** Unless otherwise specified,  $T_A = 25^\circ\text{C}$ ,  $V_{OUT} = -2.5\text{V}$ .



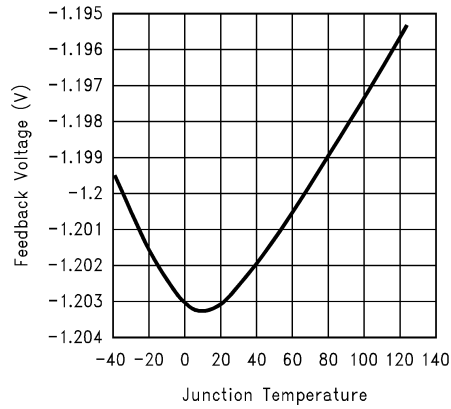
**Typical Performance Characteristics** Unless otherwise specified,  $T_A = 25^\circ\text{C}$ ,  $V_{\text{OUT}} = -2.5\text{V}$ . (Continued)

**Switching Frequency vs. Input Voltage**



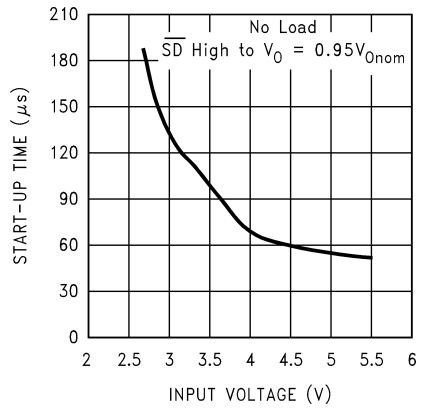
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**$V_{\text{FB}}$  vs. Temperature**



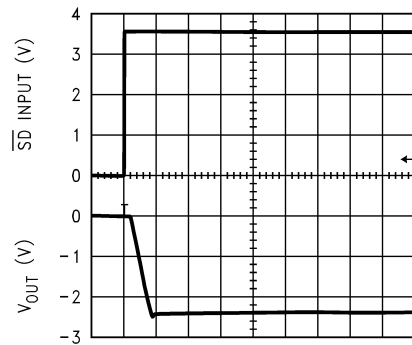
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**Start-up Time vs. Input Voltage**



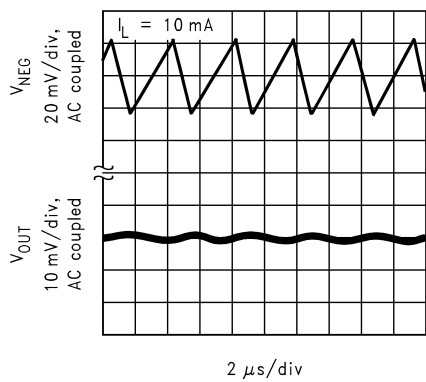
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**Start-up from Shutdown (no load)**



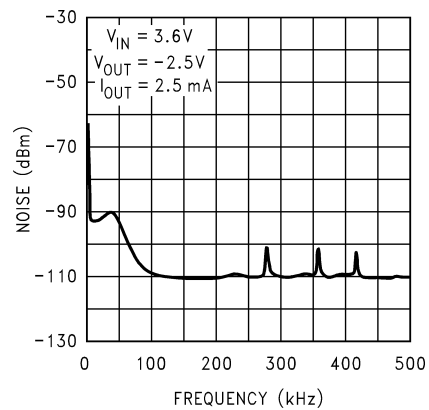
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**Output Ripple**



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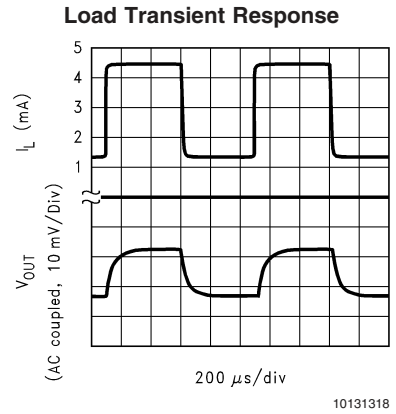
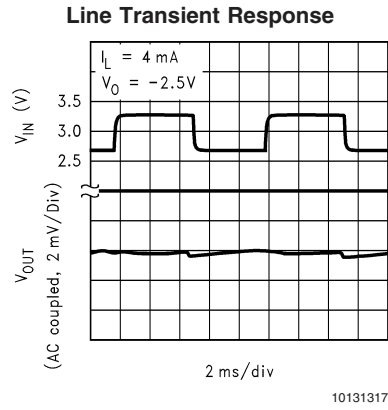
**Output Noise Spectrum**



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## Typical Performance Characteristics

Unless otherwise specified,  $T_A = 25^\circ\text{C}$ ,  $V_{\text{OUT}} = -2.5\text{V}$ . (Continued)



## Functional Block Diagram

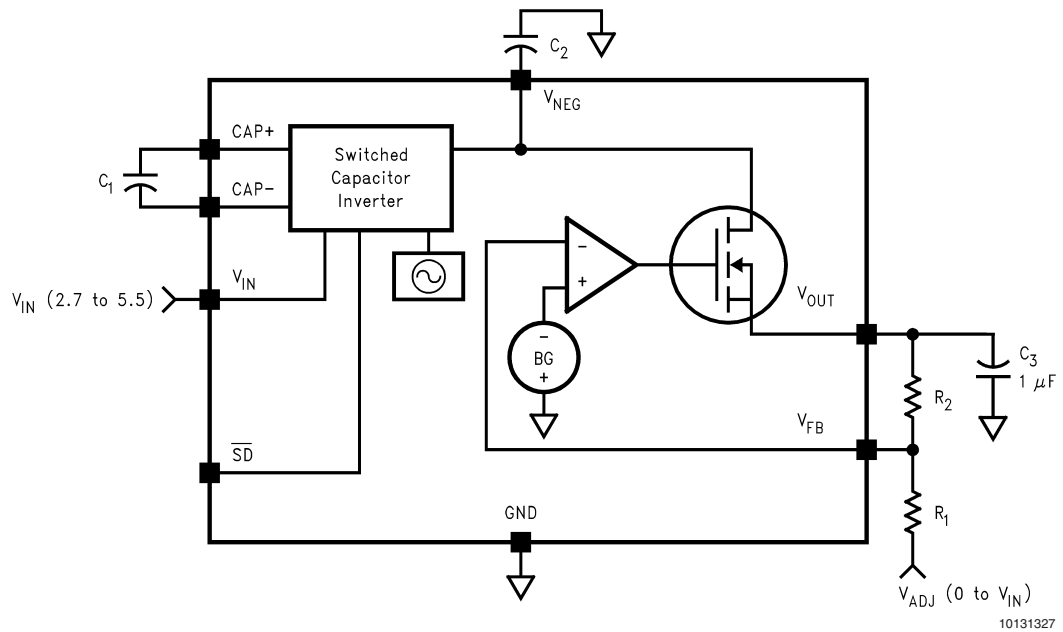


FIGURE 2. Functional Block Diagram

## Device Description

The LM2787 is an inverting, regulated charge-pump power converter. It features low noise, small physical size, and is simple to use. It is an ideal solution for biasing GaAsFET devices such as power amplifier modules found in portable devices and cellular phones.

A switched capacitor charge-pump circuit is used to invert the input voltage  $V_{IN}$  to its corresponding negative value which is seen at  $V_{NEG}$ . This voltage is regulated by a low dropout linear regulator at  $V_{OUT}$  (Figure 2). The output voltage can be regulated anywhere from  $-1.5V$  to  $-5.2V$  and is determined by a pair of feedback resistors (see Setting the Output Voltage). The PSRR of the linear regulator reduces the output voltage ripple produced by the charge-pump inverter at the output  $V_{OUT}$ . The regulator also attenuates noise from the incoming supply due to its high PSRR.

## Shutdown

The LM2787 features a logic-level shutdown feature. The function is active-low and will reduce the supply current to  $0.05\mu A$  (typical) when engaged. When shutdown is active  $V_{OUT}$  and  $V_{NEG}$  are switched to ground.

## Application Information

### SETTING THE OUTPUT VOLTAGE

The output voltage on the LM2787 is set by using a resistor divider between the output, the feedback pin, and an arbitrary voltage  $V_{ADJ}$  (Figure 2).  $V_{ADJ}$  can range from GND to any positive voltage up to  $V_{IN}$ .  $V_{ADJ}$  is usually chosen to be GND and should not be connected to a different voltage unless it is well regulated so the output will stay constant. The feedback pin is held at a constant voltage  $V_{FB}$  which equals  $-1.2V$ . The output voltage can be selected using the equation:

$$V_{OUT} = \frac{R_2}{R_1} (V_{FB} - V_{ADJ}) + V_{FB}$$

The current into the feedback pin  $I_{FB}$  is in the range of  $10nA$  to  $100nA$ . Therefore using a value of  $500k\Omega$  or smaller for  $R_1$  should make this current of little concern when setting the output voltage. For best accuracy, use resistors with 1% or better tolerance.

### CAPACITOR SELECTION

Selecting the right capacitors for your circuit is important. The capacitors affect the output resistance of the charge-pump, the output voltage ripple, and the overall dropout voltage ( $V_{IN}-|V_{OUT}|$ ) of the circuit. The output resistance of the charge-pump inverter is:

$$R_{NEG} = R_{SW} + 4ESR_{C1} + ESR_{C2} + \frac{1}{f_{SW} \times C1}$$

The switching frequency is fixed at  $260kHz$  and  $R_{SW}$  (the combined resistance of the internal switches) is typically

$10\Omega$ . It is clear from this equation that low ESR capacitors are desirable and that larger values of  $C_1$  will further reduce the output resistance. The output resistance of the entire circuit (in dropout) is:

$$R_{OUT} = R_{NEG} + R_{regulator}$$

$R_{regulator}$  (the output impedance of the linear regulator) is approximately  $10\Omega$ . When the circuit is in regulation, the overall output resistance is equal to the linear regulator load regulation ( $5mV/mA$ ). The dropout voltage is therefore affected by the capacitors used since it is simply defined as  $I_{OUT} \times R_{OUT}$ .

A larger value of capacitor and lower ESR for  $C_2$  will lower the output voltage ripple of the charge-pump. This ripple will then be subject to the PSRR of the linear regulator and reduced at  $V_{OUT}$ .

In summation, larger value capacitors with lower ESR will give the lowest output noise and ripple.  $C_1$ ,  $C_2$ , and  $C_3$  should be  $1.0\mu F$  minimum with less than  $0.3\Omega$  ESR. Larger values may be used for any or all capacitors. All capacitors should be either ceramic, surface-mount chip tantalum, or polymer electrolytic.

### OUTPUT NOISE AND RIPPLE

Low output noise and output voltage ripple are two of the attractive features of the LM2787. Because they are small, the noise and ripple can be hard to measure accurately. Ground loop error between the circuit and the oscilloscope caused by the switching of the charge-pump produces ground currents in the probe wires. This causes sharp voltage spikes on the oscilloscope waveform. To reduce this error, measure the output directly at the output capacitor ( $C_3$ ) and use the shortest wires possible. Also, do not use the ground lead on the probe. Take the tip cover off of the probe and touch the grounding ring of the probe directly to the output ground. This should give the most accurate reading of the actual output waveform.

### MICRO SMD MOUNTING

The micro SMD package requires specific mounting techniques which are detailed in National Semiconductor Application Note # 1112. Referring to the section **Surface Mount Technology (SMT) Assembly Considerations**, it should be noted that the pad style which must be used with the 8-pin package is the NSMD (non-solder mask defined) type.

For best results during assembly, alignment ordinals on the PC board may be used to facilitate placement of the micro SMD device.

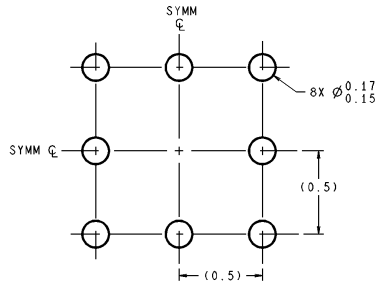
### MICRO SMD LIGHT SENSITIVITY

Exposing the micro SMD device to direct sunlight may cause misoperation of the device. Light sources such as Halogen lamps can also affect electrical performance if brought near the device.

The wavelengths which have the most detrimental effect are reds and infra-reds. The fluorescent lighting used inside of most buildings has very little effect on performance.

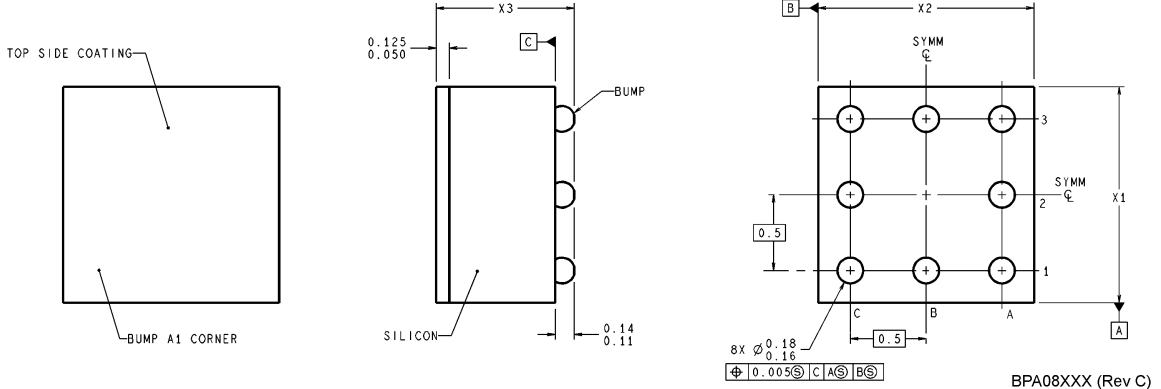
# Physical Dimensions inches (millimeters)

unless otherwise noted



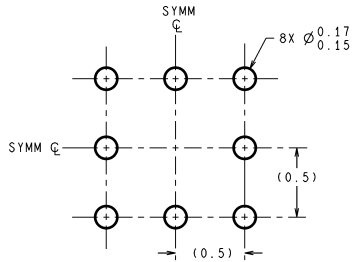
DIMENSIONS ARE IN MILLIMETERS

## LAND PATTERN RECOMMENDATION

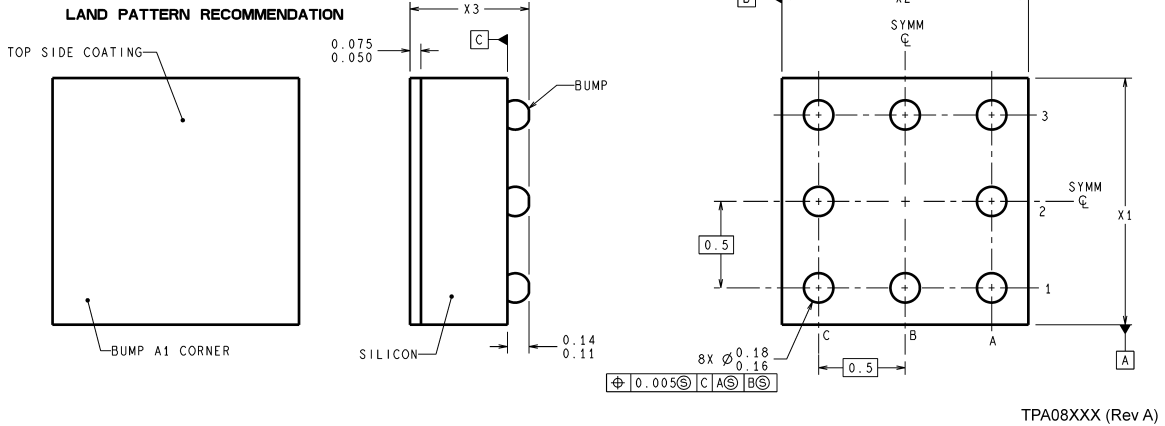


BPA08XXX (Rev C)

**8-Bump micro SMD**  
**NS Package Number BPA08CCB**  
**For Ordering, Refer to Ordering Information Table**  
 $X_1 = 1.346$   $X_2 = 1.346$   $X_3 = 0.850$



DIMENSIONS ARE IN MILLIMETERS



TPA08XXX (Rev A)

**8-Bump thin micro SMD**  
**NS Package Number TPA08CCA**  
**For Ordering, Refer to Ordering Information Table**  
 $X_1 = 1.346$   $X_2 = 1.346$   $X_3 = 0.500$



## Notes

### **LIFE SUPPORT POLICY**

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2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.



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