

## LMP8277

# High Common Mode, Gain of 14, Precision Voltage Difference Amplifier

### General Description

The LMP8277 is a fixed gain differential amplifier with a  $-2\text{V}$  to  $27\text{V}$  input common mode voltage range and a supply voltage range of  $4.75\text{V}$  to  $5.5\text{V}$ . The LMP8277 is part of the LMP™ precision amplifier family which will detect, amplify and filter small differential signals in the presence of high common mode voltages. The gain is fixed at 14 and is adequate to drive an ADC to full scale in most cases. This fixed gain is achieved in two separate stages, a pre-amplifier with gain of +7 and a second stage amplifier with a gain of +2. The internal signal path between these two stages is brought out on two pins that provide a connection for a filter network.

The LMP8277 will operate with reduced specifications over the extended common mode input voltage range of  $-2$  to  $36$  Volts. This feature makes the device suitable for applications with load dump in automotive systems.

### Features

Typical Values,  $T_A = 25^\circ\text{C}$

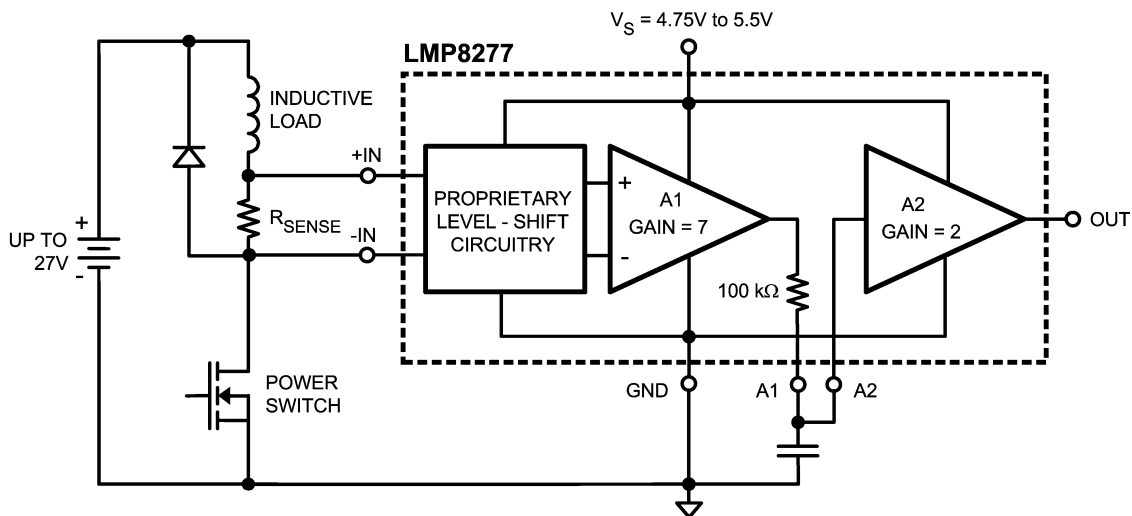
■ Input Offset Voltage	$\pm 2\text{ mV max}$
■ TCVo's	$\pm 30\text{ }\mu\text{V}/^\circ\text{C max}$
■ CMRR	$80\text{ dB Min}$
■ Extended CMVR	$-2\text{V to } 36\text{V}$
■ Output Voltage Swing	Rail-to-Rail
■ Bandwidth	$80\text{ kHz}$
■ Operating Temperature Range (Ambient)	$-40^\circ\text{C to } 125^\circ\text{C}$
■ Supply Voltage	$4.75\text{V to } 5.5\text{V}$
■ Supply Current	$1\text{ mA}$

### Applications

- Fuel Injection Control
- High and Low Side Driver Configuration Current Sensing
- Power Management Systems

### Typical Application

Typical Application: Low side Current Sensing



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**Absolute Maximum Ratings** (Note 1)

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

ESD Tolerance (Note 2)

Human Body Model

For input pins only

±4000V

For All other pins

±2000V

Machine Model

200V

Supply Voltage ( $V_S$  – GND)

5.75V

Voltage on +IN and -IN

–5 to 42 Volts

Transient (400 ms)

–7 to 45 Volts

Storage Temperature Range

–65°C to +150°C

Junction Temperature (Note 3)

+150°C max

Soldering Information

Infrared or Convection (20 sec)

235°C

Wave Soldering Lead Temp. (10 sec)

260°C

**Operating Ratings** (Note 1)

Temperature Range

Packaged Devices (Note 3)

–40°C to +125°C

Supply Voltage ( $V_S$  – GND)

4.75V to 5.5V

Package Thermal Resistance ( $\theta_{JA}$  (Note 3))

8-Pin SOIC

190°C/W

8-Pin MSOP

235°C/W

**5V Electrical Characteristics** (Note 4)

Unless otherwise specified, all limits guaranteed for  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{V}$ , GND = 0,  $-2\text{V} \leq V_{CM} \leq 27\text{V}$ ,  $R_L = \text{OPEN}$ . **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions		Min	Typ (Note 5)	Max	Units
$V_{OS}$	Input Offset Voltage	$V_{CM} = V_S/2$			±0.25	±2.0	mV
TC $V_{OS}$	Input Offset Voltage Drift	$V_{CM} = V_S/2$	$25^\circ\text{C} \leq T_A \leq 125^\circ\text{C}$		±20	<b>±30</b>	$\mu\text{V}/^\circ\text{C}$
			$-40^\circ\text{C} \leq T_A \leq 25^\circ\text{C}$		±20	<b>±35</b>	
A2 $I_B$	Input Bias Current of A2	(Note 6)			–20		pA
						<b>±20</b>	nA
$I_S$	Supply Current				1.0	1.2 1.4	mA
$R_{CM}$	Input impedance Common Mode			<b>160</b>	200	<b>240</b>	k $\Omega$
$R_{DM}$	Input impedance Differential Mode			<b>320</b>	400	<b>480</b>	k $\Omega$
CMVR	Input Common-Mode Voltage Range			<b>–2</b>		<b>+27</b>	V
ECMVR	Extended Common-Mode Voltage Range			–2		36	V
DC CMRR	DC Common Mode Rejection Ratio	$0^\circ\text{C} \leq T_A \leq 125^\circ\text{C}$	$-2\text{V} \leq V_{CM} \leq 27\text{V}$ $-2\text{V} \leq V_{CM} \leq 36\text{V}$	<b>80</b> <b>60</b>	97		dB
		$-40^\circ\text{C} \leq T_A \leq 0^\circ\text{C}$	$-2\text{V} \leq V_{CM} \leq 27\text{V}$ $-2\text{V} \leq V_{CM} \leq 36\text{V}$	<b>77</b> <b>60</b>			
AC CMRR	AC Common Mode Rejection Ratio (Note 7)	$-2\text{V} \leq V_{CM} \leq 27\text{V}$	$f = 1\text{ kHz}$	80	95		dB
			$f = 10\text{ kHz}$		78		
PSRR	Power Supply Rejection Ratio	$4.75\text{V} \leq V_S \leq 5.5\text{V}$		<b>70</b>	80		dB
$R_{F-INT}$	Filter Resistor			<b>97</b>	100	<b>103</b>	k $\Omega$
$TCR_{F-INT}$	Filter Resistor Drift				20		ppm/ $^\circ\text{C}$
$A_V$	Total Gain			13.86	14	14.14	V/V
	Gain Drift				±2	<b>±25</b>	ppm/ $^\circ\text{C}$
$A_{V1}$	A1 Gain			6.93	7	7.07	V/V
$A_{V2}$	A2 Gain			1.98	2	2.02	V/V
A1 $V_{OUT}$	A1 Output Voltage Swing		VOL		0.004	0.01	V
			VOH	4.80	4.95		
A2 $V_{OUT}$	A2 Output Voltage Swing (Notes 8, 9)	$R_L = 100\text{ k}\Omega$ on Output	VOL		0.007	0.02	V
			VOH	4.80	4.99		
		$R_L = 10\text{ k}\Omega$ on Output	VOL		0.03		V
			VOH		4.95		

## 5V Electrical Characteristics (Note 4) (Continued)

Unless otherwise specified, all limits guaranteed for  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{V}$ ,  $\text{GND} = 0$ ,  $-2\text{V} \leq V_{\text{CM}} \leq 27\text{V}$ ,  $R_L = \text{OPEN}$ . **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min	Typ (Note 5)	Max	Units
SR	Slew Rate (Note 10)			0.7		V/ $\mu\text{s}$
BW	Bandwidth			80		kHz
Noise	0.1 Hz to 10 Hz			3.82		$\mu\text{Vpp}$
	Spectral Density	$f = 1\text{ kHz}$		486		nV/ $\sqrt{\text{Hz}}$

**Note 1:** Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but specific performance is not guaranteed. For guaranteed specifications and the test conditions, see the Electrical Characteristics Tables.

**Note 2:** Human Body Model, 1.5 k $\Omega$  in series with 100 pF. Machine Model: 0 $\Omega$  in series with 200 pF.

**Note 3:** The maximum power dissipation is a function of  $T_{\text{J(MAX)}}$ ,  $\theta_{\text{JA}}$ , and  $T_A$ . The maximum allowable power dissipation at any ambient temperature is  $P_D = (T_{\text{J(MAX)}} - T_A) / \theta_{\text{JA}}$ . All numbers apply for packages soldered directly onto a PC board.

**Note 4:** Electrical table values apply only for factory testing conditions at the temperature indicated. Factory testing conditions result in very limited self-heating of the device.

**Note 5:** Typical values represent the parametric norm at the time of characterization.

**Note 6:** Positive current corresponds to current flowing into the device.

**Note 7:** AC Common Mode Signal is a 24 V<sub>PP</sub> sine-wave (0V to 24V) at the given frequency

**Note 8:** For VOL,  $R_L$  is connected to  $V_S$  and for VOH,  $R_L$  is connected to GND.

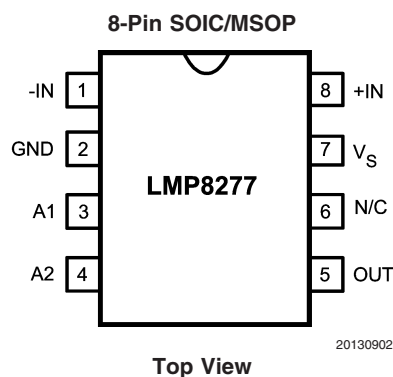
**Note 9:** For this test input is driven from A1 stage.

**Note 10:** Slew rate is the average of the rising and falling slew rates.

## Ordering Information

Package	Part Number	Package Marking	Transport Media	NSC Drawing
8-Pin SOIC	LMP8277MA	LMP8277MA	95 Units/Rail	M08A
	LMP8277MAX		2.5K Units Tape and Reel	
8-Pin MSOP	LMP8277MM	LMP8277MM	95 Units/Rail	MUA08A
	LMP8277MMX		2.5K Units Tape and Reel	

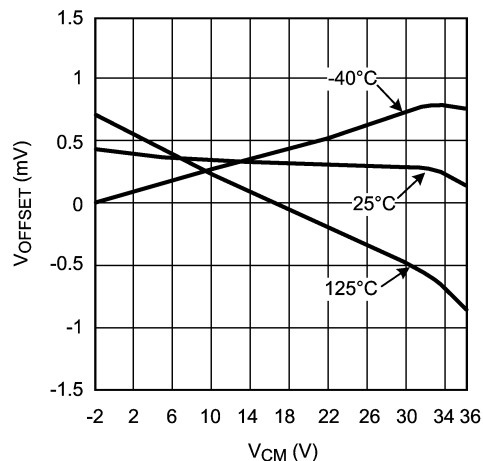
## Connection Diagram



# Typical Performance Characteristics

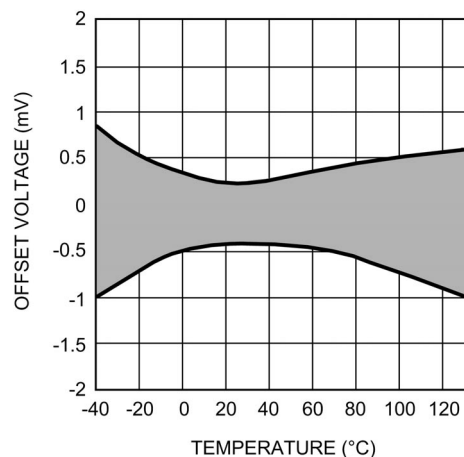
Unless otherwise specified:  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{V}$ ,  $V_{CM} = V_S/2$

## $V_{OS}$ vs. $V_{CM}$ Over Temperature



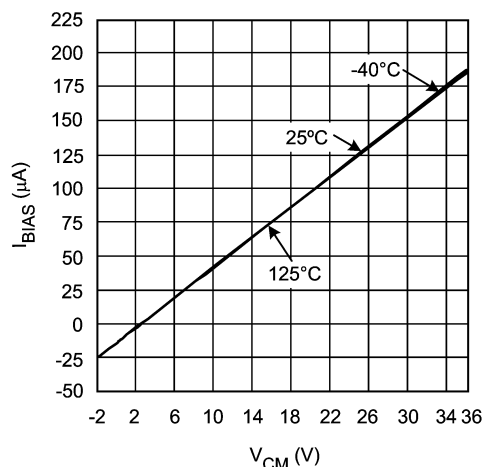
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## Typical $V_{OS}$ vs. Temperature



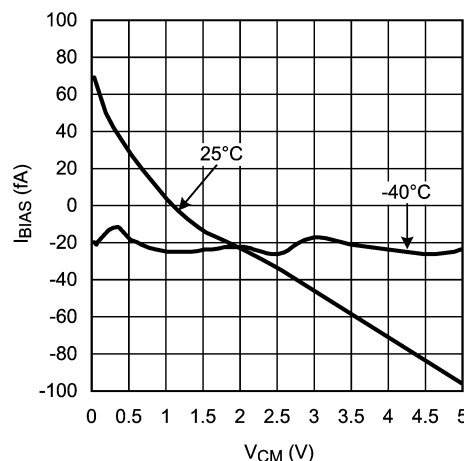
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## Input Bias Current Over Temperature (A1 Inputs)



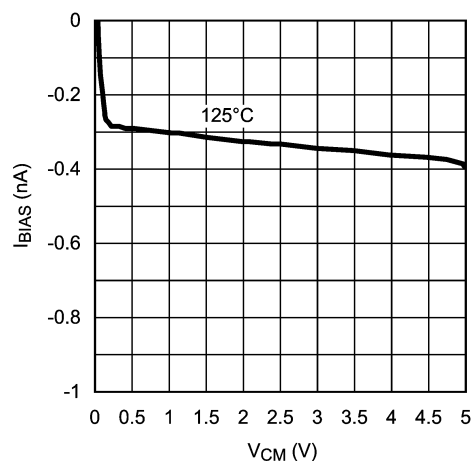
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## Input Bias Current Over Temperature (A2 Inputs)



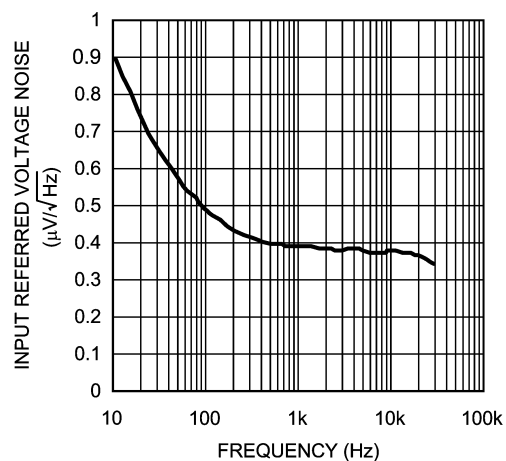
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## Input Bias Current Over Temperature (A2 Inputs)



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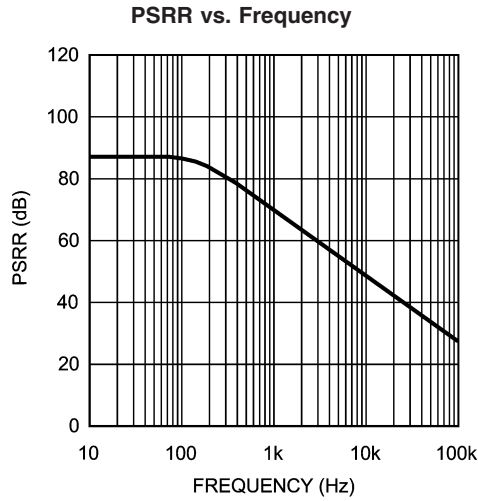
## Input Referred Voltage Noise vs. Frequency



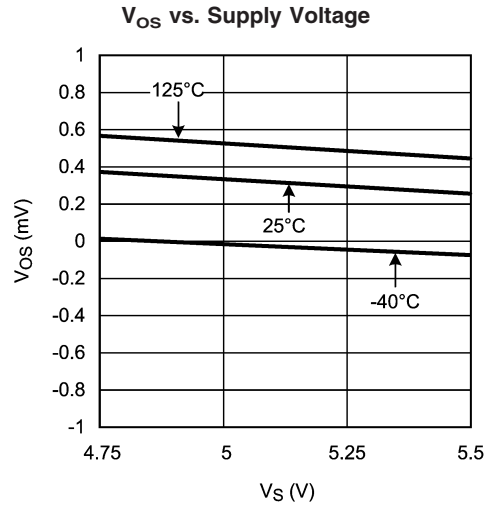
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# Typical Performance Characteristics

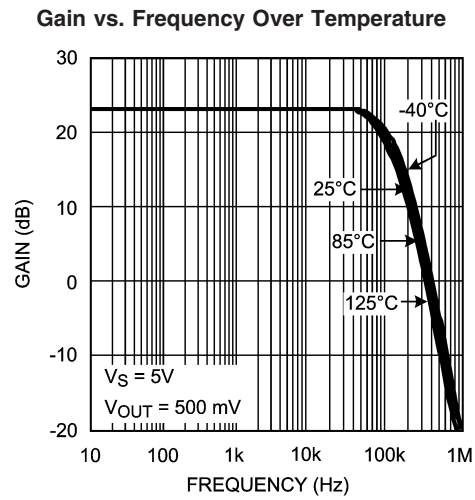
Unless otherwise specified:  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{V}$ ,  $V_{CM} = V_S/2$   
(Continued)



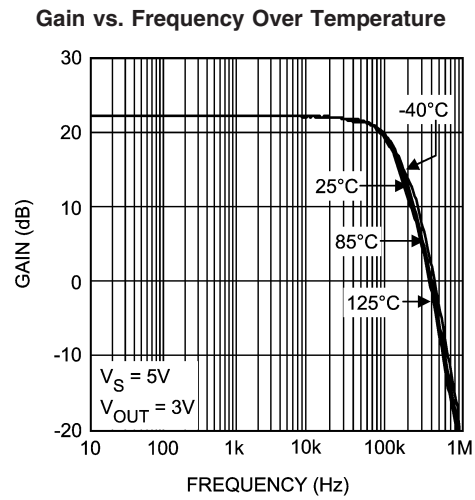
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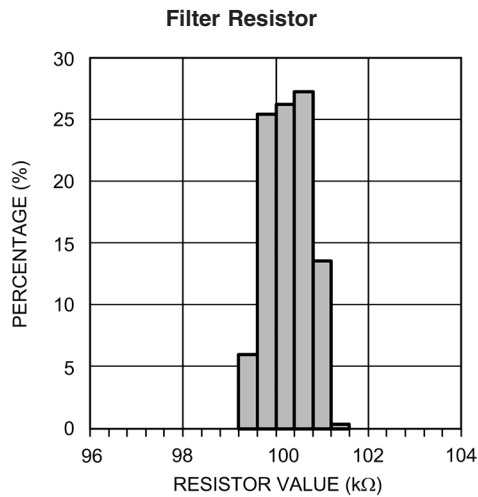
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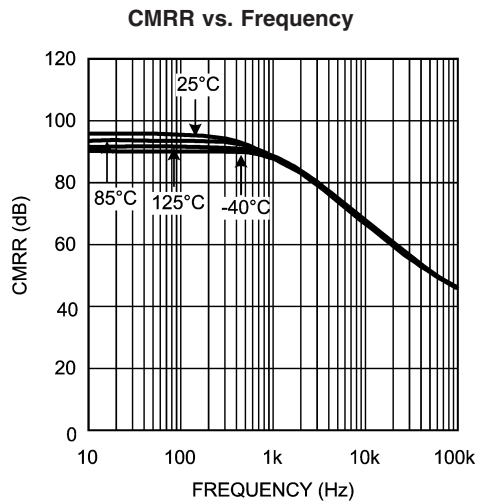
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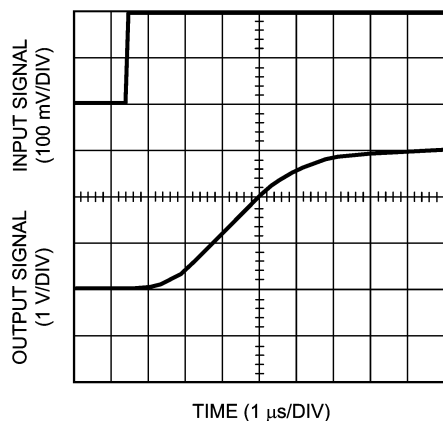


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# Typical Performance Characteristics

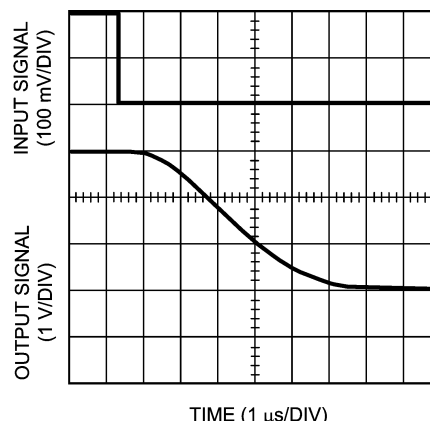
Unless otherwise specified:  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{V}$ ,  $V_{CM} = V_S/2$   
(Continued)

Settling Time (Rising Edge)

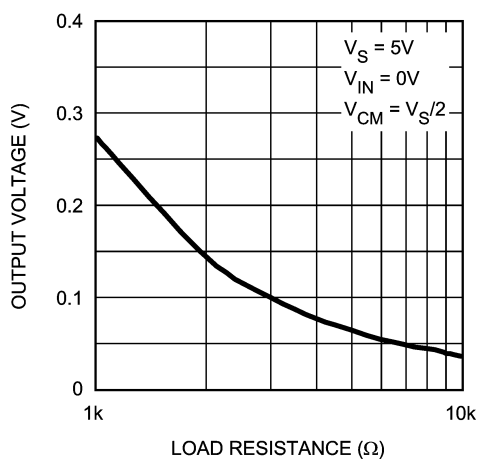


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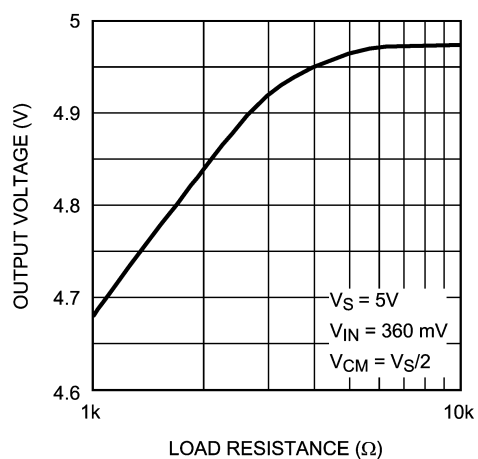
Settling Time (Falling Edge)



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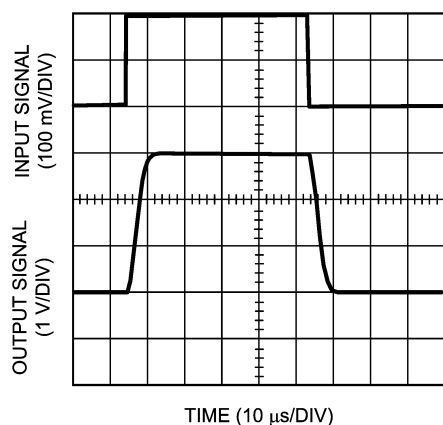
Output Voltage vs.  $R_L$  to  $V_S$ 

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Output Voltage vs.  $R_L$  to GND

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Step Response



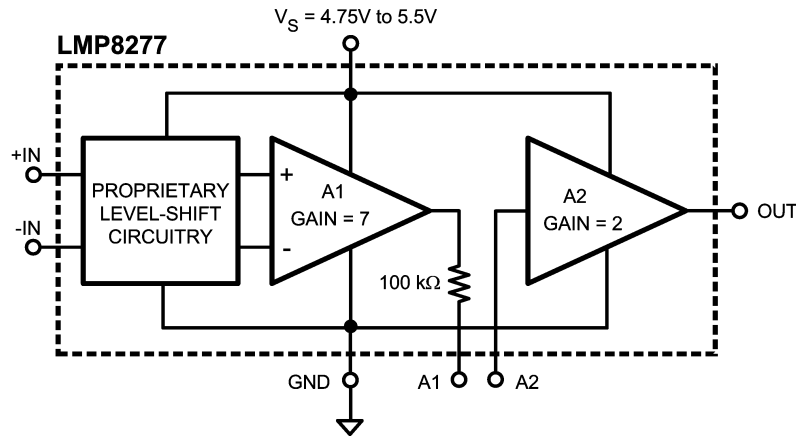
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## Application Note

### LMP8277

The LMP8277 is a single supply amplifier with a fixed gain of 14 and an extended common mode voltage range of  $-2V$  to

$36V$ . The fixed gain is achieved in two separate stages, a preamplifier with gain of  $+7$  and a second stage amplifier with gain of  $+2$ . A block diagram of the LMP8277 is shown in Figure 1.



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FIGURE 1.

The overall offset of the LMP8277 is minimized by trimming amplifier A1. This is done so that the output referred offset of A1 cancels the input referred offset of A2 or  $7V_{OS1} = -V_{OS2}$ . Because of this offset voltage relationship, the offset of each individual amplifier stage may be more than the limit specified for the overall system in the datasheet tables. Care must be given when pin 3 and 4, A1 and A2, are connected to each other. If the signal going from A1 to A2 is amplified or attenuated (by use of amplifiers and resistors), the overall LMP8277 offset will be affected as a result. Filtering the signal between A1 and A2 or simply connecting the two pins will not change the offset of the LMP8277.

Referencing the input referred offset voltages of each stage, the following relationship holds:

$$\frac{(7V_{OS1}) + (V_{OS2})}{7} = V_{OS}(\text{LMP8277})$$

If the signal on pin 3 is scaled, attenuated or amplified, by a factor  $X$ , then the offset of the overall system will become:

$$\frac{(7V_{OS1}) \cdot (X) + (V_{OS2})}{7(X)} = V_{OS}(\text{LMP8277})$$

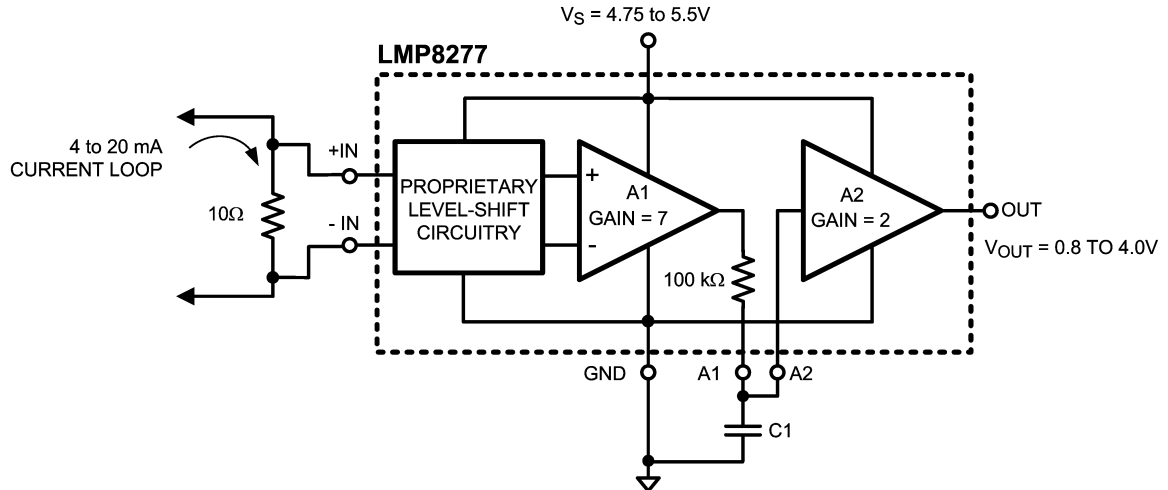
### POWER SUPPLY DECOUPLING

In order to decouple the LMP8277 from AC noise on the power supply, it is recommended to use a  $0.1 \mu F$  on the supply pin. It is best to use a  $0.1 \mu F$  capacitor in parallel with a  $10 \mu F$  capacitor. This will generate an AC path to ground for most frequency ranges and will almost greatly reduce the noise introduced by the power supply.

### CURRENT LOOP RECEIVER

Many types of process control instrumentation use 4 to 20 mA transmitters to transmit the sensor's analog value to a central control room. The LMP8272 can be used as a current loop receiver as shown in Figure 2.

## Application Note (Continued)



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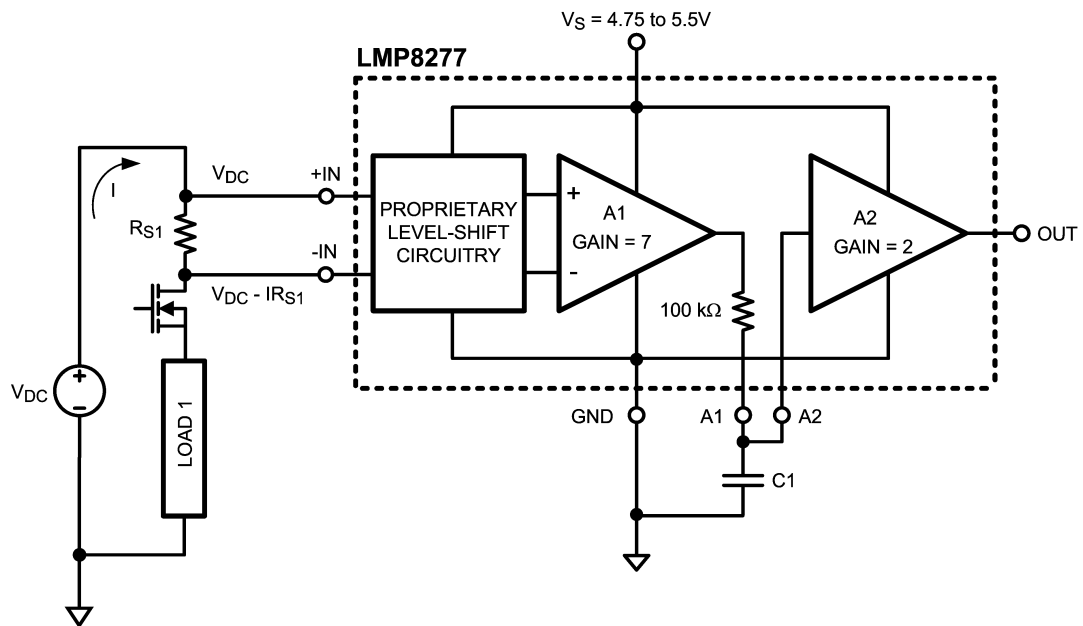
FIGURE 2.

### HIGH SIDE CURRENT SENSING

High side current measurement requires a differential amplifier with gain. Here the DC voltage source represent a common mode voltage with the +IN input at the supply voltage and the -IN input very close to the supply voltage. The LMP8277 can be used with a common mode voltage,  $V_{DC}$  in this case, of up to of 36 volts.

The LMP8277 can be used for high side current sensing. The large common mode voltage range of this device allows

it to sense signals outside of its supply voltage range. Also, the LMP8277 has very high CMRR, which enables it to sense very small signals in presence of larger common mode signals. The system in *Figure 3* couples these two characteristics of the LMP8277 in an automotive application. The signal through  $R_{S1}$  is detected and amplified by LMP8277 in the presence of a common mode signal of up to 27 Volts with highest accuracy.



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FIGURE 3.

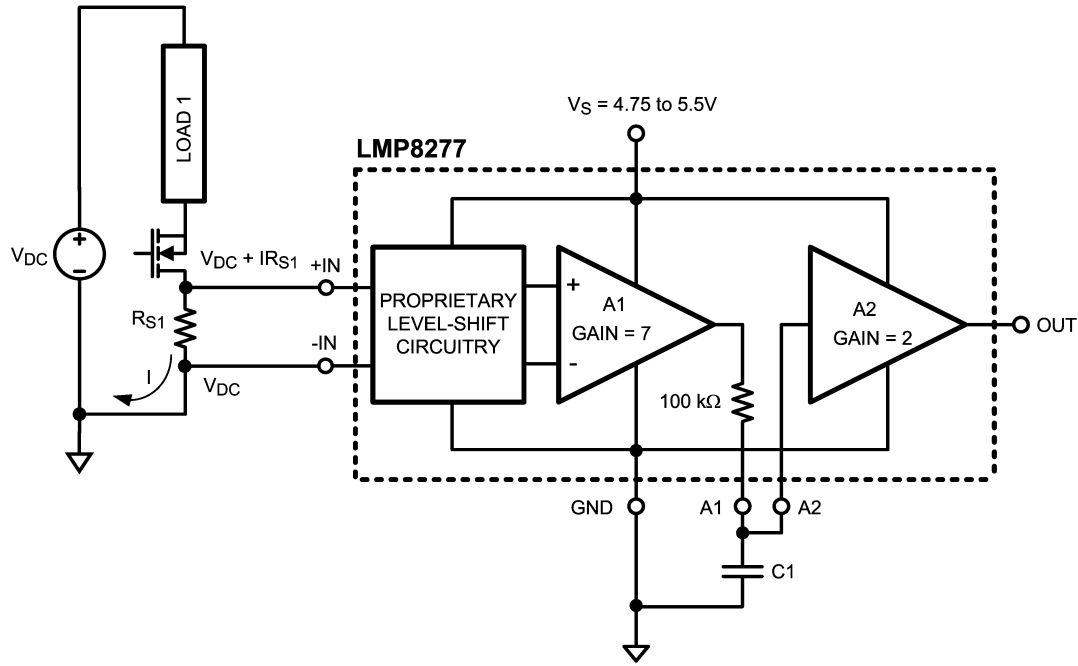


## Application Note (Continued)

### LOW SIDE CURRENT SENSING

Low side current measurements can cause a problem for operational amplifiers by exceeding the negative common mode voltage limit of the device. In *Figure 4*, the load current is returning to the power source through a common connection that has a parasitic resistance. The voltage drop across

the parasitic resistances can cause the ground connection of the circuits being at a positive voltage with respect to the common side of the sense resistor. This will result in one or both of the inputs to be negative with respect to the measurement circuit's ground. The LMP8277 has a wide common mode voltage range of -2 to 36 volts and will function in this condition.

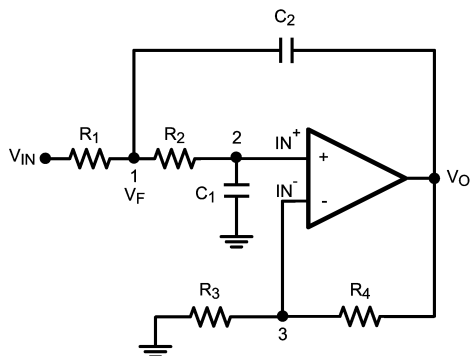


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FIGURE 4.

### SECOND ORDER LOW PASS FILTER

The LMP8277 can be effectively used to build a second order Sallen-Key low pass filter. The general filter is shown in *Figure 5*:



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FIGURE 5.

With the general transfer function:

$$\frac{V_O}{V_{IN}} = \frac{K}{M - KN} \quad (1)$$

Where:

$$M = s^2 C_1 C_2 R_1 R_2 + s(R_1 C_1 + R_1 C_2 + C_1 R_2) + 1$$

$$N = s C_2 R_1$$

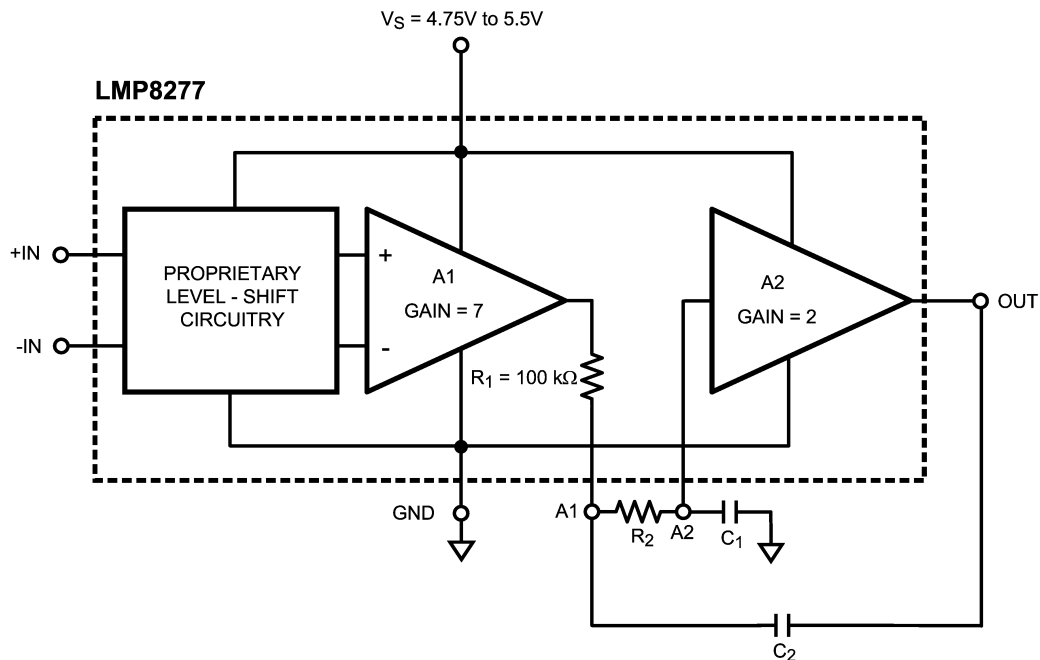
and

$$\frac{1}{K} = \frac{1}{A_{VOL}} + \frac{R_3}{R_3 + R_4}$$

K represents the sum of DC closed loop gain and the non-ideal behavior of the operational amplifier.

The LMP8277 can be used to realize this configuration as shown in *Figure 6*:

## Application Note (Continued)



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FIGURE 6.

Assuming ideal behavior, the equation for K simply reduces to the DC gain, which is set to +2 for the LMP8277.

Using *Equation (1)*, the filter parameters can be calculated as follows:

$$\omega_o = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}}$$

$$f_c = \frac{1}{2\pi \sqrt{R_1 R_2 C_1 C_2}}$$

$$Q = \frac{\sqrt{R_1 R_2 C_1 C_2}}{R_1 C_1 + R_2 C_1 + (1-K) R_1 C_2}$$

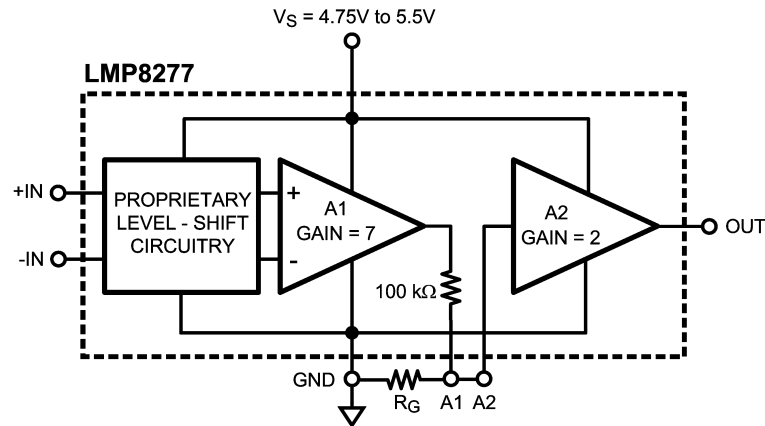
for the LMP8277,  $R_1 = 100\text{K}\Omega$ . Setting  $R_1 = R_2$  and  $C_1 = C_2$  results in a low pass filter with  $Q=1$ . Since the values of resistors are predetermined, the corner frequency of this implementation of the filter depends on the capacitor values.

### GAINS OTHER THAN 14

The LMP8277 has an internal gain of +14; however this gain can be modified. The signal path between the two amplifiers is available as external pins.

### GAINS LESS THAN 14

shows the configuration used to reduce the LMP8277 gain.



**FIGURE 7.**

Where:

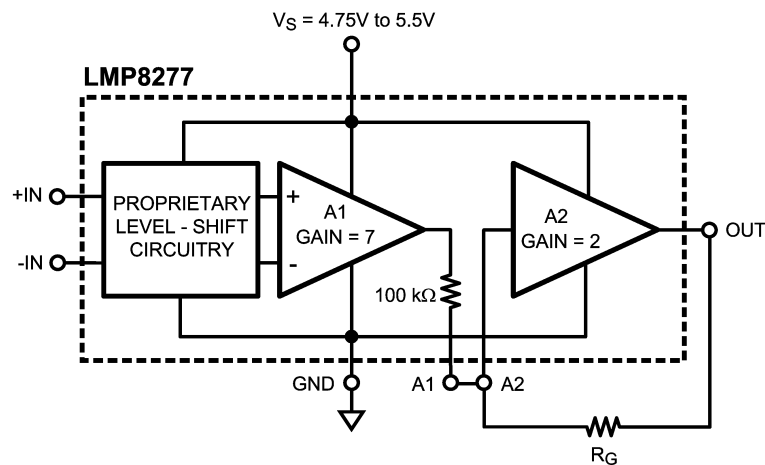
$$\text{GAIN (NEW)} = \frac{14 R_G}{R_G + 100 \text{ k}\Omega}$$

and

$$R_G = (100 \text{ k}\Omega) \frac{\text{GAIN (NEW)}}{14 - \text{GAIN (NEW)}}$$

### GAINS GREATER THAN 14

A higher gain can be achieved by using positive feedback on the second stage amplifier, A2, of the LMP8277. *Figure 8* shows the configuration:



**FIGURE 8.**

The total gain is given by:

$$\text{GAIN (NEW)} = \frac{14 R_G}{R_G - 100 \text{ k}\Omega}$$

Which can be rearranged to calculate  $R_G$ :

$$R_G = (100 \text{ k}\Omega) \frac{\text{GAIN (NEW)}}{\text{GAIN (NEW)} - 14}$$

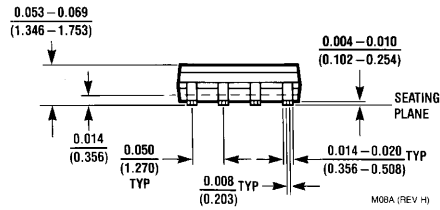
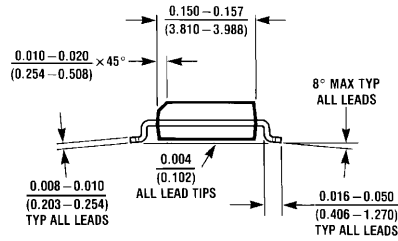
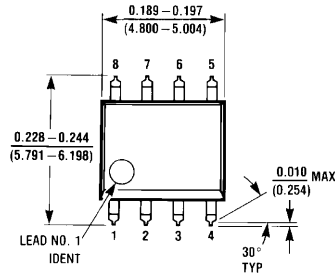
The inverting gain of the second amplifier is set at 2, giving a total system gain of 14. The non-inverting gain which is achieved through positive feedback can be less than or equal to this gain without any issues. This implies a total

**Application Note** (Continued)

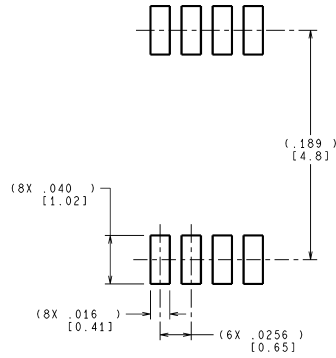
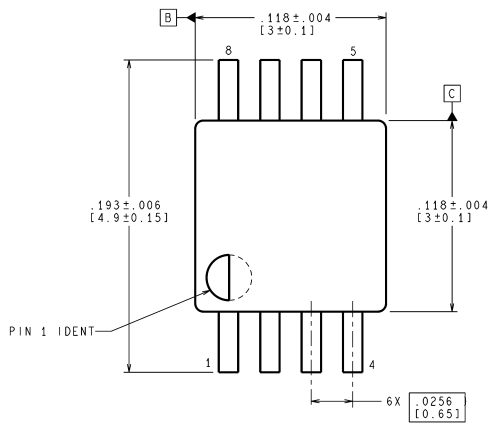
system gain of 28 or less is easily achievable. Once the

positive gain surpasses the negative gain, the system might oscillate.

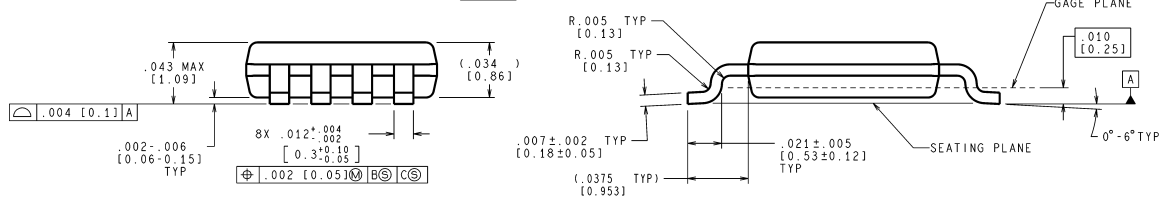
# Physical Dimensions inches (millimeters) unless otherwise noted



**8-Pin SOIC**  
**NS Package Number M08A**



**LAND PATTERN RECOMMENDATION**



CONTROLLING DIMENSION IS INCH  
VALUES IN [ ] ARE MILLIMETERS

MUA08A (Rev E)

**8-Pin MSOP**  
**NS Package Number MUA08A**

## Notes

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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.

### BANNED SUBSTANCE COMPLIANCE

National Semiconductor manufactures products and uses packing materials that meet the provisions of the Customer Products Stewardship Specification (CSP-9-111C2) and the Banned Substances and Materials of Interest Specification (CSP-9-111S2) and contain no "Banned Substances" as defined in CSP-9-111S2.

Leadfree products are RoHS compliant.



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