

## Low Noise, Low Power Op Amp

### Features

- Low Noise: 5.4 nV/ $\sqrt{\text{Hz}}$  (typical)
- Low Quiescent Current: 520  $\mu\text{A}$  (typical)
- Rail-to-Rail Output
- Wide Supply Voltage Range: 2.2V to 5.5V
- Gain Bandwidth Product: 3.5 MHz (typical)
- Unity Gain Stable
- Extended Temperature Range:  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$
- No Phase Reversal
- Small Package

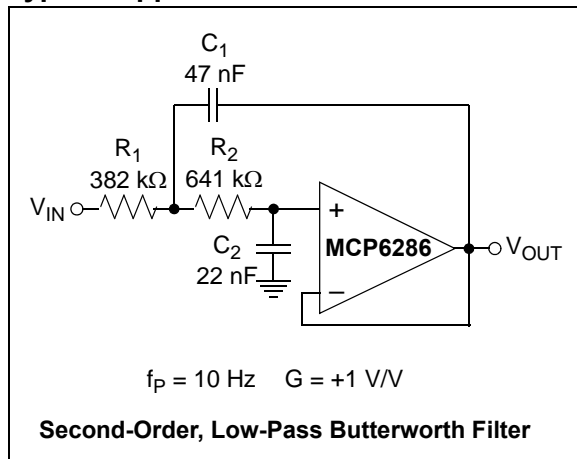
### Applications

- Noise Cancellation Headphones
- Cellular Phones
- Analog Filters
- Sensor Conditioning
- Portable Instrumentation
- Medical Instrumentation
- Battery Powered Systems

### Design Aids

- SPICE Macro Models
- FilterLab<sup>®</sup> Software
- Mindi<sup>™</sup> Circuit Designer & Simulator
- MAPS (Microchip Advanced Part Selector)
- Analog Demonstration and Evaluation Boards
- Application Notes

### Typical Application

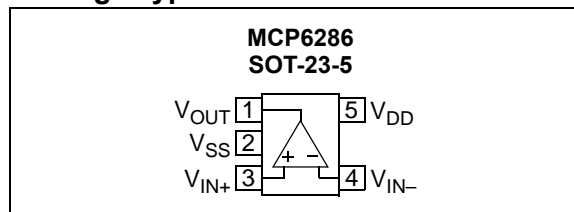


### Description

The Microchip Technology Inc. MCP6286 operational amplifier (op amp) has low noise (5.4 nV/ $\sqrt{\text{Hz}}$ , typical), low power (520  $\mu\text{A}$ , typical) and rail-to-rail output operation. It is unity gain stable and has a gain bandwidth product of 3.5 MHz (typical). This device operates with a single supply voltage as low as 2.2V, while drawing low quiescent current. These features make the product well suited for single-supply, low noise, battery-powered applications.

The MCP6286 op amp is offered in a space saving SOT-23-5 package. It is designed with Microchip's advanced CMOS process and available in the extended temperature range, with a power supply range of 2.2V to 5.5V.

### Package Types



# MCP6286

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NOTES:

## 1.0 ELECTRICAL CHARACTERISTICS

### 1.1 Absolute Maximum Ratings †

$V_{DD} - V_{SS}$ .....	7.0V
Current at Input Pins .....	$\pm 2$ mA
Analog Inputs ( $V_{IN+}$ , $V_{IN-}$ )†† .....	$V_{SS} - 1.0V$ to $V_{DD} + 1.0V$
All Other Inputs and Outputs .....	$V_{SS} - 0.3V$ to $V_{DD} + 0.3V$
Difference Input Voltage .....	$ V_{DD} - V_{SS} $
Output Short-Circuit Current .....	continuous
Current at Output and Supply Pins .....	$\pm 30$ mA
Storage Temperature .....	$-65^{\circ}C$ to $+150^{\circ}C$
Maximum Junction Temperature ( $T_J$ ) .....	$+150^{\circ}C$
ESD protection on all pins (HBM; MM) .....	$\geq 4$ kV; 400V

† **Notice:** Stresses above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

†† See 4.1.2 “Input Voltage And Current Limits”

## DC ELECTRICAL SPECIFICATIONS

**Electrical Characteristics:** Unless otherwise indicated,  $V_{DD} = +2.2V$  to  $+5.5V$ ,  $V_{SS} = GND$ ,  $T_A = +25^{\circ}C$ ,  $V_{CM} = V_{DD}/3$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$  and  $R_L = 10$  k $\Omega$  to  $V_L$ . (Refer to Figure 1-1).

Parameters	Sym	Min	Typ	Max	Units	Conditions
<b>Input Offset</b>						
Input Offset Voltage	$V_{OS}$	-1.5	—	+1.5	mV	
Input Offset Drift with Temperature	$\Delta V_{OS}/\Delta T_A$	—	$\pm 1$	—	$\mu V/^{\circ}C$	$T_A = -40^{\circ}C$ to $+125^{\circ}C$
Power Supply Rejection Ratio	PSRR	80	100	—	dB	
<b>Input Bias Current and Impedance</b>						
Input Bias Current	$I_B$	—	$\pm 1$	—	pA	$T_A = +85^{\circ}C$ $T_A = +125^{\circ}C$
		—	50	150	pA	
		—	1500	3000	pA	
Input Offset Current	$I_{OS}$	—	$\pm 1$	—	pA	
Common Mode Input Impedance	$Z_{CM}$	—	$10^{13}    20$	—	$\Omega    pF$	
Differential Input Impedance	$Z_{DIFF}$	—	$10^{13}    20$	—	$\Omega    pF$	
<b>Common Mode</b>						
Common Mode Input Voltage Range	$V_{CMR}$	$V_{SS} - 0.3$	—	$V_{DD} - 1.2$	V	<b>Note 1</b>
Common Mode Rejection Ratio	CMRR	76	95	—	dB	$V_{CM} = -0.3V$ to $1.0V$ , $V_{DD} = 2.2V$
		80	100	—	dB	$V_{CM} = -0.3V$ to $4.3V$ , $V_{DD} = 5.5V$
<b>Open-Loop Gain</b>						
DC Open-Loop Gain (Large Signal)	$A_{OL}$	100	120	—	dB	$0.2V < V_{OUT} < (V_{DD} - 0.2V)$
<b>Output</b>						
Maximum Output Voltage Swing	$V_{OL}, V_{OH}$	$V_{SS} + 15$	—	$V_{DD} - 15$	mV	0.5V Input overdrive
		$V_{SS} + 75$	—	$V_{DD} - 75$	mV	0.5V Input overdrive $R_L = 2$ k $\Omega$
Output Short-Circuit Current	$I_{SC}$	—	$\pm 20$	—	mA	

**Note 1:** Figure 2-12 shows how  $V_{CMR}$  changes across temperature.

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## DC ELECTRICAL SPECIFICATIONS (CONTINUED)

**Electrical Characteristics:** Unless otherwise indicated,  $V_{DD} = +2.2V$  to  $+5.5V$ ,  $V_{SS} = GND$ ,  $T_A = +25^\circ C$ ,  $V_{CM} = V_{DD}/3$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$  and  $R_L = 10\text{ k}\Omega$  to  $V_L$ . (Refer to [Figure 1-1](#)).

Parameters	Sym	Min	Typ	Max	Units	Conditions
<b>Power Supply</b>						
Supply Voltage	$V_{DD}$	2.2	—	5.5	V	
Quiescent Current per Amplifier	$I_Q$	300	520	700	$\mu A$	$I_O = 0$ , $V_{DD} = 2.2V$
		320	540	720	$\mu A$	$I_O = 0$ , $V_{DD} = 5.5V$

**Note 1:** [Figure 2-12](#) shows how  $V_{CMR}$  changes across temperature.

## AC ELECTRICAL SPECIFICATIONS

**Electrical Characteristics:** Unless otherwise indicated,  $T_A = +25^\circ C$ ,  $V_{DD} = +2.2$  to  $+5.5V$ ,  $V_{SS} = GND$ ,  $V_{CM} = V_{DD}/3$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_L$  and  $C_L = 60\text{ pF}$ . (Refer to [Figure 1-1](#)).

Parameters	Sym	Min	Typ	Max	Units	Conditions
<b>AC Response</b>						
Gain Bandwidth Product	GBWP	—	3.5	—	MHz	
Phase Margin	PM	—	60	—	$^\circ$	$G = +1\text{ V/V}$
Slew Rate	SR	—	2	—	$V/\mu s$	
<b>Noise</b>						
Input Noise Voltage	$E_{ni}$	—	1.0	—	$\mu V_{P-P}$	$f = 0.1\text{ Hz to }10\text{ Hz}$
Input Noise Voltage Density	$e_{ni}$	—	22	—	$nV/\sqrt{Hz}$	$f = 10\text{ Hz}$
		—	5.4	—	$nV/\sqrt{Hz}$	$f = 10\text{ kHz}$
Input Noise Current Density	$i_{ni}$	—	0.6	—	$fA/\sqrt{Hz}$	$f = 1\text{ kHz}$

## TEMPERATURE SPECIFICATIONS

<b>Electrical Characteristics:</b> Unless otherwise indicated, $V_{DD} = +2.2V$ to $+5.5V$ and $V_{SS} = GND$ .						
Parameters	Sym	Min	Typ	Max	Units	Conditions
<b>Temperature Ranges</b>						
Operating Temperature Range	$T_A$	-40	—	+125	$^\circ C$	<b>Note 1</b>
Storage Temperature Range	$T_A$	-65	—	+150	$^\circ C$	
<b>Thermal Package Resistances</b>						
Thermal Resistance, 5L-SOT-23	$\theta_{JA}$	—	256	—	$^\circ C/W$	

**Note 1:** The internal junction temperature ( $T_J$ ) must not exceed the absolute maximum specification of  $+150^\circ C$ .

## 1.2 Test Circuits

The circuit used for most DC and AC tests is shown in Figure 1-1. It independently sets  $V_{CM}$  and  $V_{OUT}$ ; see Equation 1-1. The circuit's common mode voltage is  $(V_P + V_M)/2$ , not  $V_{CM}$ .  $V_{OST}$  includes  $V_{OS}$  plus the effects of temperature, CMRR, PSRR and  $A_{OL}$ .

### EQUATION 1-1:

$$G_{DM} = R_F/R_G$$

$$G_N = 1 + G_{DM}$$

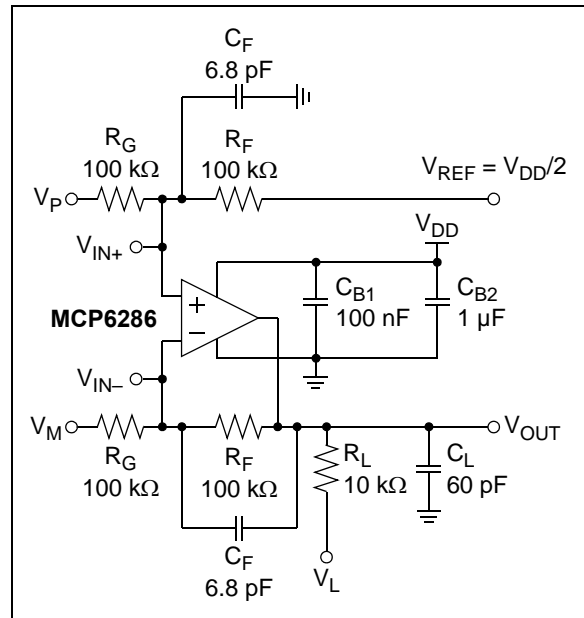
$$V_{CM} = V_P(1 - 1/G_N) + V_{REF}(1/G_N)$$

$$V_{OST} = V_{IN-} - V_{IN+}$$

$$V_{OUT} = V_{REF} + (V_P - V_M)G_{DM} + V_{OST}G_N$$

Where:

$G_{DM}$ = Differential Mode Gain	(V/V)
$G_N$ = Noise Gain	(V/V)
$V_{CM}$ = Op Amp's Common Mode Input Voltage	(V)
$V_{OST}$ = Op Amp's Total Input Offset Voltage	(mV)



**FIGURE 1-1:** AC and DC Test Circuit for Most Specifications.

# MCP6286

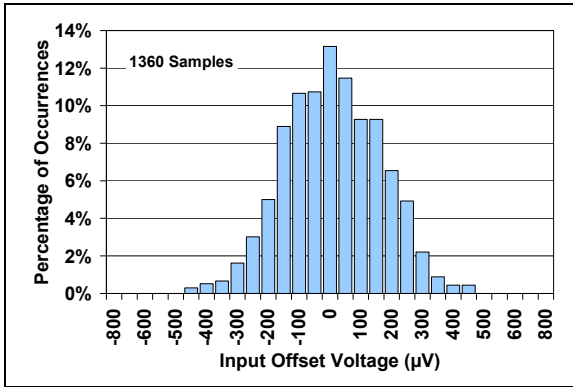
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NOTES:

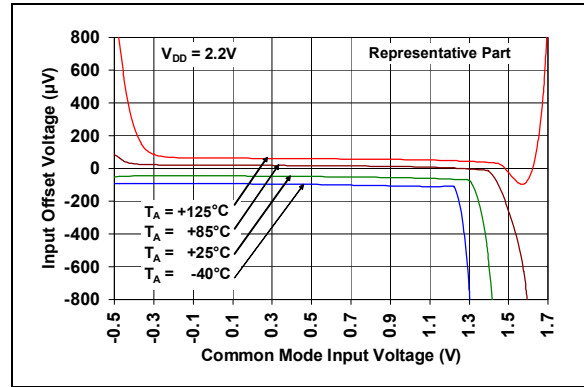
## 2.0 TYPICAL PERFORMANCE CURVES

**Note:** The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

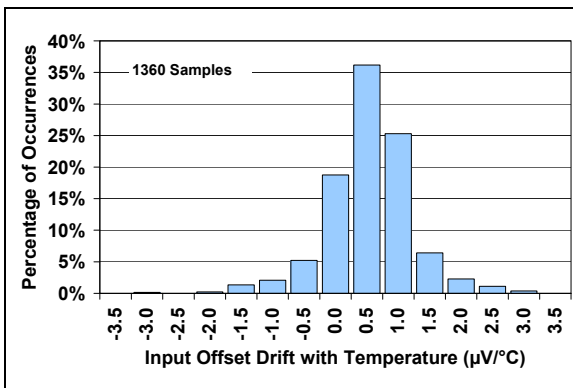
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +2.2\text{V}$  to  $+5.5\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/3$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_L$  and  $C_L = 60\text{ pF}$ .



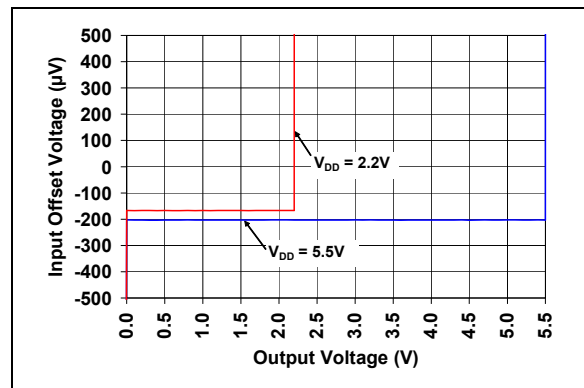
**FIGURE 2-1:** Input Offset Voltage.



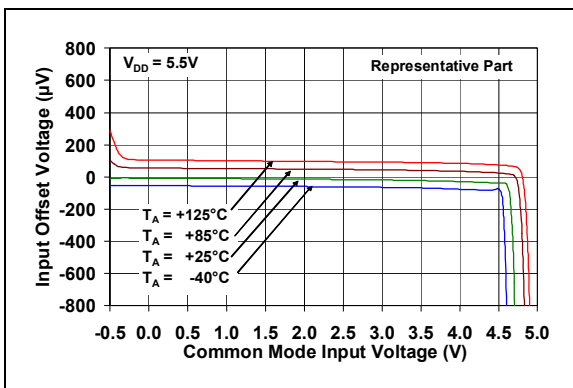
**FIGURE 2-4:** Input Offset Voltage vs. Common Mode Input Voltage with  $V_{DD} = 2.2\text{V}$ .



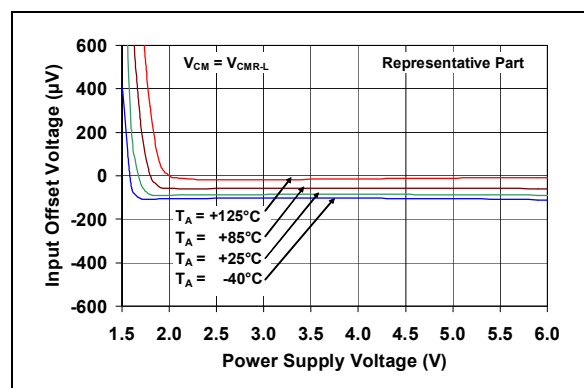
**FIGURE 2-2:** Input Offset Voltage Drift.



**FIGURE 2-5:** Input Offset Voltage vs. Output Voltage.



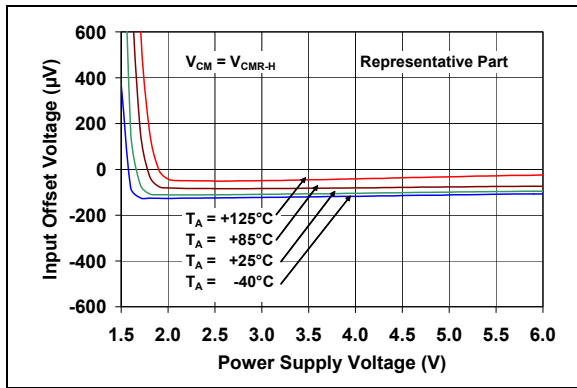
**FIGURE 2-3:** Input Offset Voltage vs. Common Mode Input Voltage with  $V_{DD} = 5.5\text{V}$ .



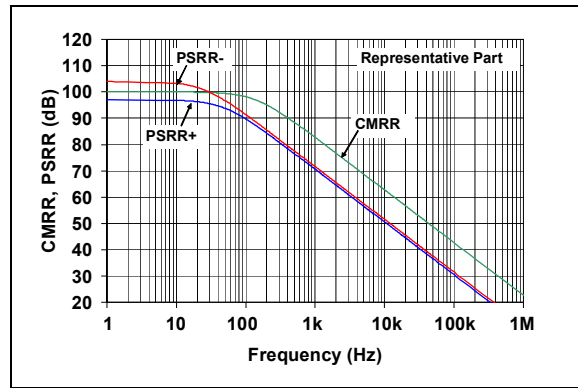
**FIGURE 2-6:** Input Offset Voltage vs. Power Supply Voltage with  $V_{CM} = V_{CMR\_L}$ .

# MCP6286

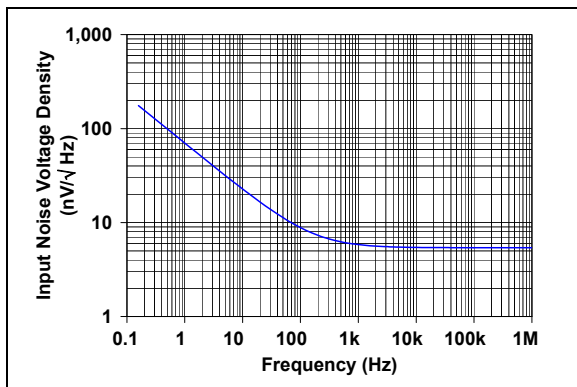
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +2.2\text{V}$  to  $+5.5\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/3$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_L$  and  $C_L = 60\text{ pF}$ .



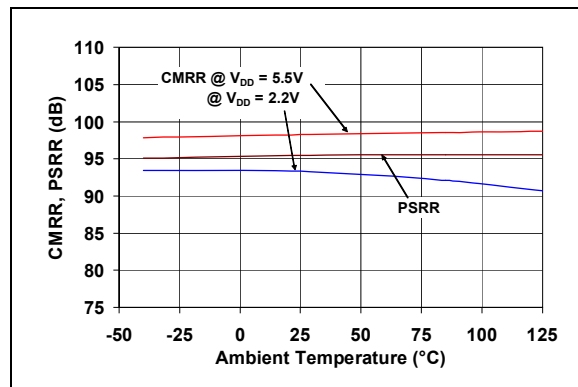
**FIGURE 2-7:** Input Offset Voltage vs. Power Supply Voltage with  $V_{CM} = V_{CM,H}$



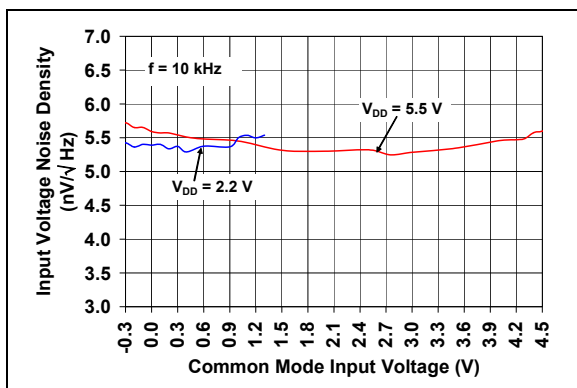
**FIGURE 2-10:** CMRR, PSRR vs. Frequency.



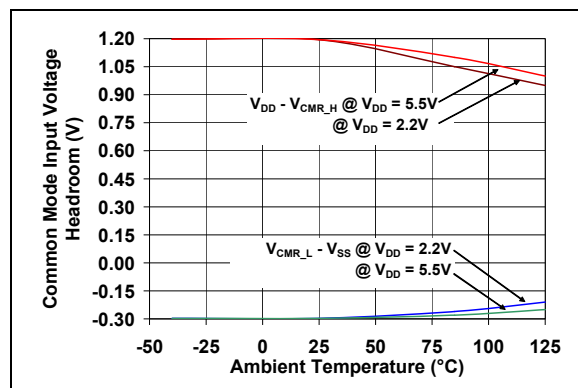
**FIGURE 2-8:** Input Noise Voltage Density vs. Frequency.



**FIGURE 2-11:** CMRR, PSRR vs. Ambient Temperature.



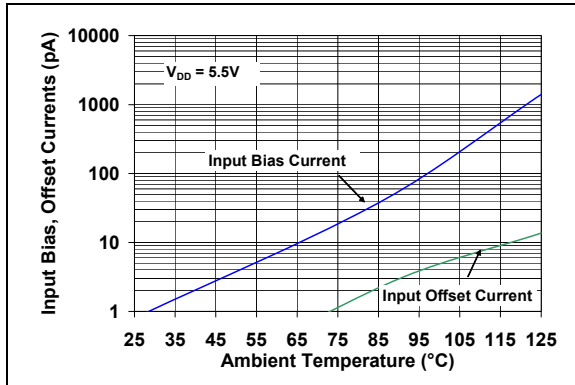
**FIGURE 2-9:** Input Noise Voltage Density vs. Common Mode Input Voltage.



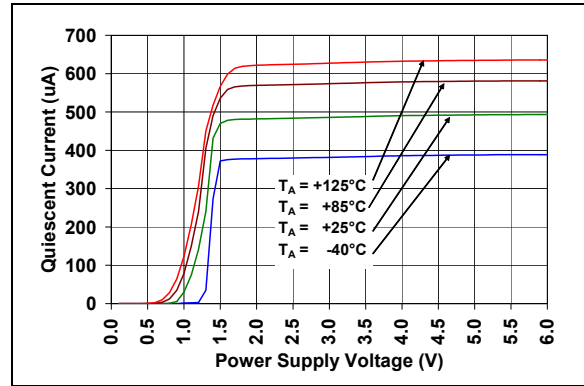
**FIGURE 2-12:** Common Mode Input Voltage Headroom vs. Ambient Temperature.



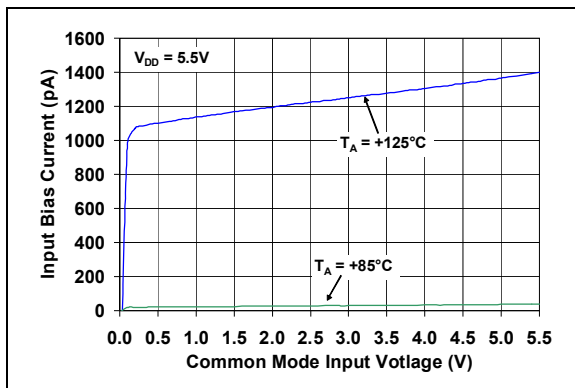
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +2.2\text{V}$  to  $+5.5\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/3$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_L$  and  $C_L = 60\text{ pF}$ .



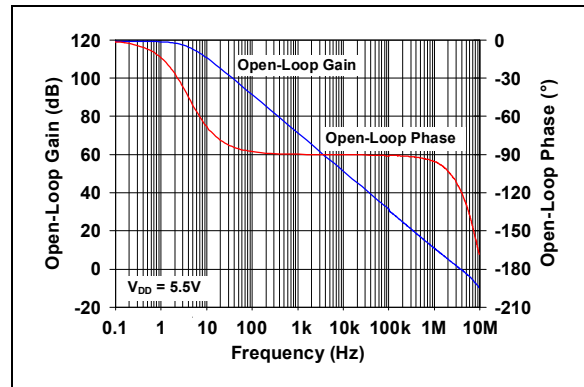
**FIGURE 2-13:** Input Bias, Offset Currents vs. Ambient Temperature.



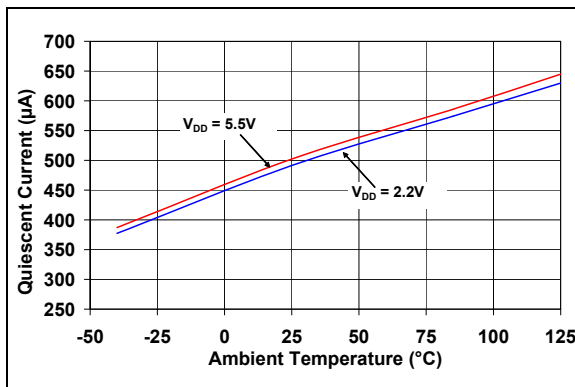
**FIGURE 2-16:** Quiescent Current vs. Power Supply Voltage.



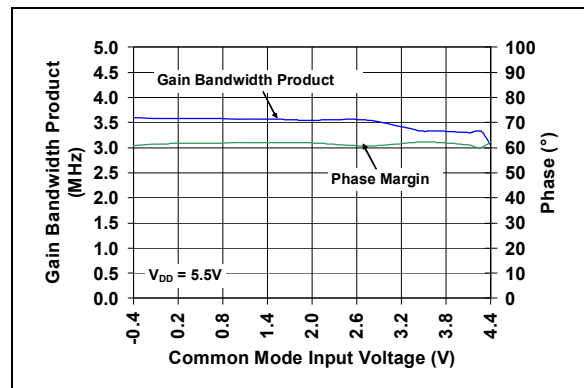
**FIGURE 2-14:** Input Bias Current vs. Common Mode Input Voltage.



**FIGURE 2-17:** Open-Loop Gain, Phase vs. Frequency.



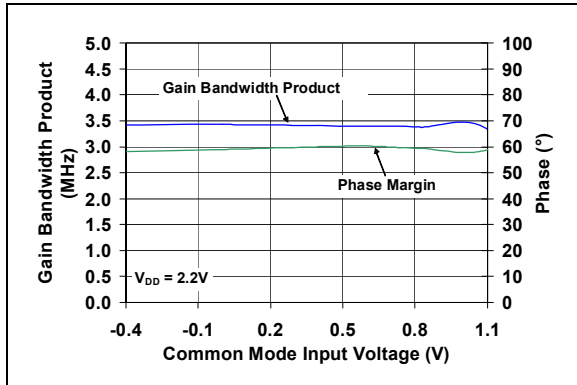
**FIGURE 2-15:** Quiescent Current vs. Ambient Temperature.



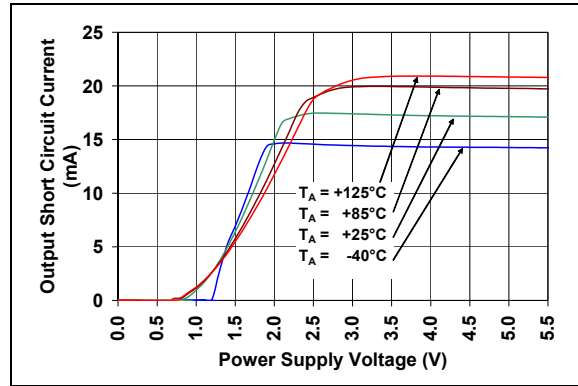
**FIGURE 2-18:** Gain Bandwidth Product, Phase Margin vs. Common Mode Input Voltage with  $V_{DD} = 5.5\text{V}$ .

# MCP6286

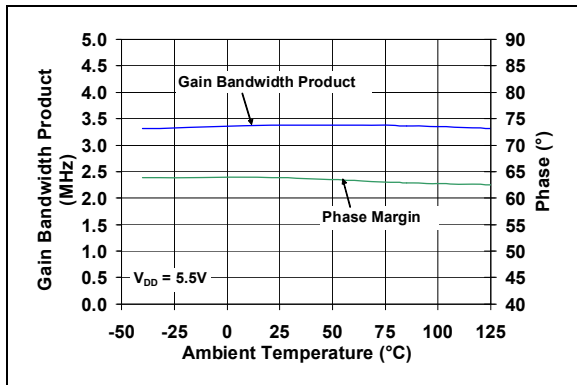
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +2.2\text{V}$  to  $+5.5\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/3$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_L$  and  $C_L = 60\text{ pF}$



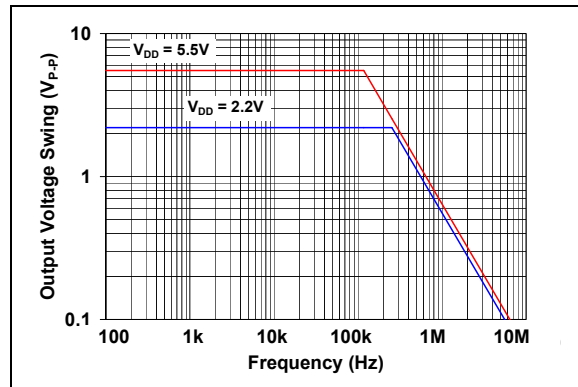
**FIGURE 2-19:** Gain Bandwidth Product, Phase Margin vs. Common Mode Input Voltage with  $V_{DD} = 2.2\text{V}$ .



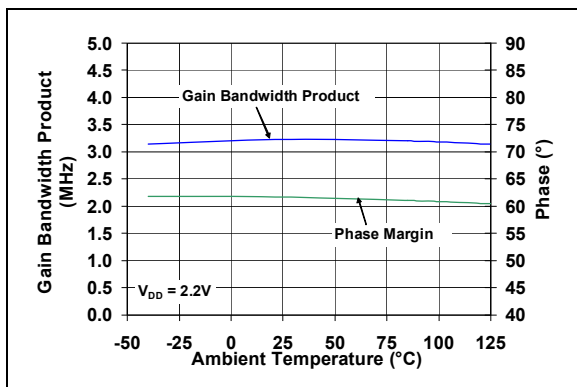
**FIGURE 2-22:** Output Short Circuit Current vs. Power Supply Voltage.



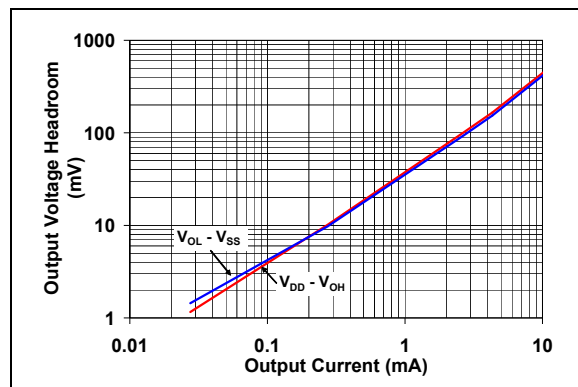
**FIGURE 2-20:** Gain Bandwidth Product, Phase Margin vs. Ambient Temperature with  $V_{DD} = 5.5\text{V}$ .



**FIGURE 2-23:** Output Voltage Swing vs. Frequency.

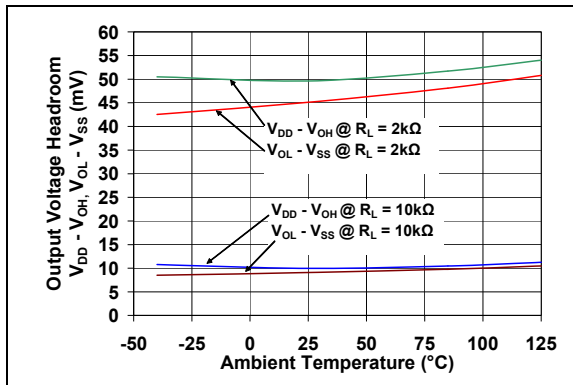


**FIGURE 2-21:** Gain Bandwidth Product, Phase Margin vs. Ambient Temperature with  $V_{DD} = 2.2\text{V}$ .

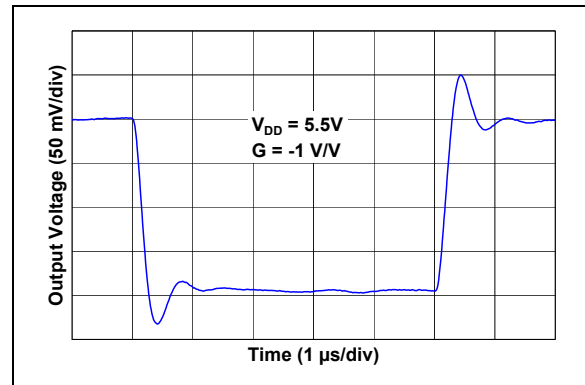


**FIGURE 2-24:** Output Voltage Headroom vs. Output Current.

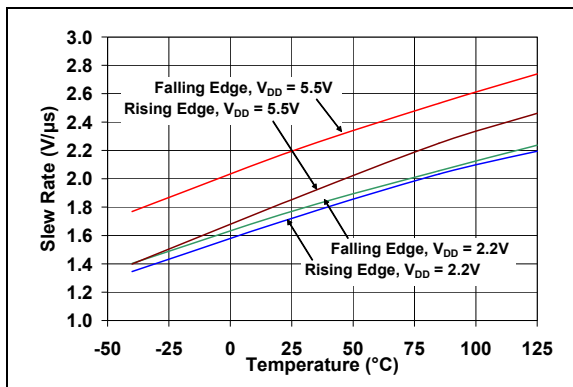
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +2.2\text{V}$  to  $+5.5\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/3$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_L$  and  $C_L = 60\text{ pF}$ .



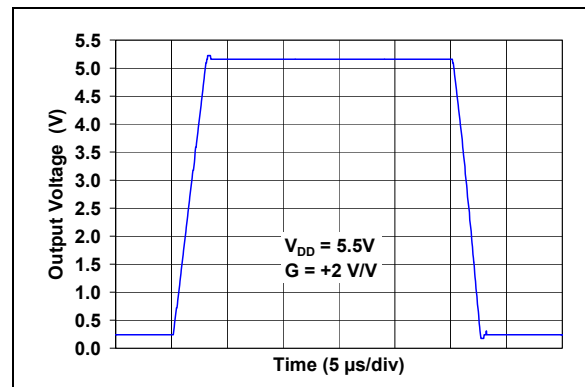
**FIGURE 2-25:** Output Voltage Headroom vs. Ambient Temperature.



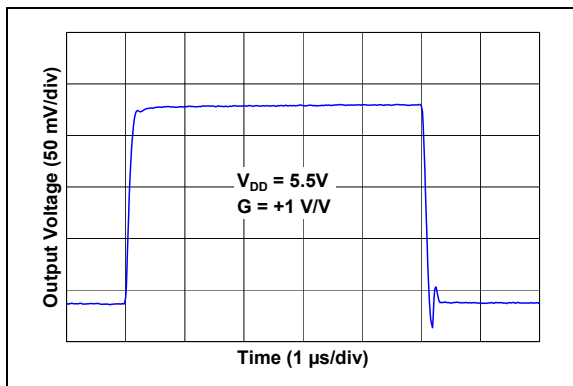
**FIGURE 2-28:** Small Signal Inverting Pulse Response.



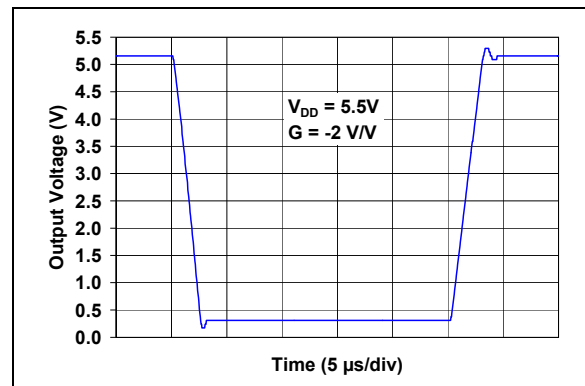
**FIGURE 2-26:** Slew Rate vs. Ambient Temperature.



**FIGURE 2-29:** Large Signal Non-Inverting Pulse Response.



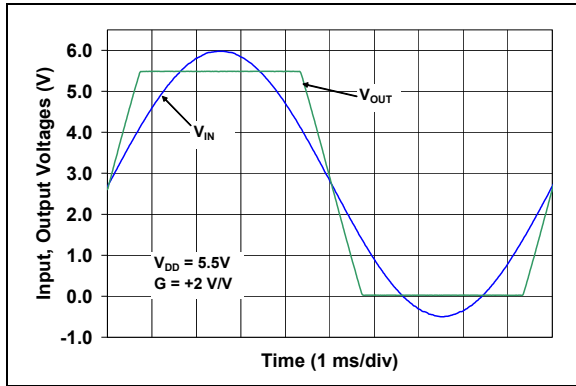
**FIGURE 2-27:** Small Signal Non-Inverting Pulse Response.



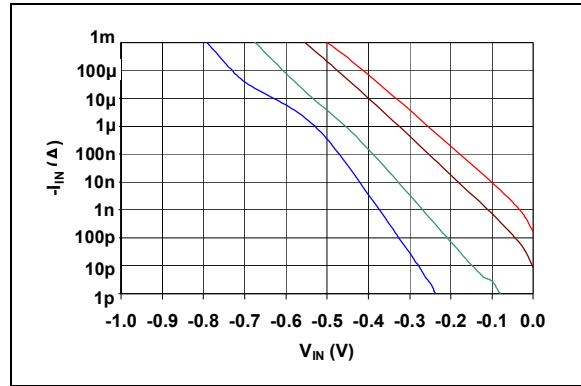
**FIGURE 2-30:** Large Signal Inverting Pulse Response.

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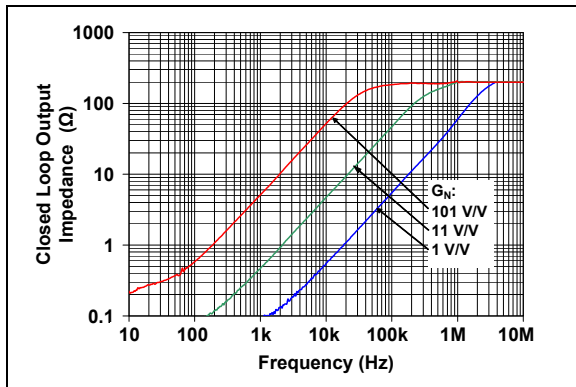
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.8\text{V}$  to  $+6.0\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/3$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_L$  and  $C_L = 60\text{ pF}$ .



**FIGURE 2-31:** The MCP6286 Shows No Phase Reversal.



**FIGURE 2-33:** Measured Input Current vs. Input Voltage (below  $V_{SS}$ ).



**FIGURE 2-32:** Closed Loop Output Impedance vs. Frequency.

## 3.0 PIN DESCRIPTIONS

Descriptions of the pins are listed in [Table 3-1](#).

**TABLE 3-1: PIN FUNCTION TABLE**

MCP6286 SOT-23-5	Symbol	Description
1	$V_{OUT}$	Analog Output
2	$V_{SS}$	Negative Power Supply
3	$V_{IN+}$	Non-inverting Input
4	$V_{IN-}$	Inverting Input
5	$V_{DD}$	Positive Power Supply

### 3.1 Analog Output

The output pin is low-impedance voltage source.

### 3.2 Analog Inputs

The non-inverting and inverting inputs are high-impedance CMOS inputs with low bias currents.

### 3.3 Power Supply Pins

The positive power supply ( $V_{DD}$ ) is 2.2V to 5.5V higher than the negative power supply ( $V_{SS}$ ). For normal operation, the other pins are at voltages between  $V_{SS}$  and  $V_{DD}$ .

Typically, these parts are used in a single (positive) supply configuration. In this case,  $V_{SS}$  is connected to ground and  $V_{DD}$  is connected to the supply.  $V_{DD}$  will need bypass capacitors.

# MCP6286

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NOTES:

## 4.0 APPLICATION INFORMATION

The MCP6286 op amp is manufactured using Microchip's state-of-the-art CMOS process and is specifically designed for low-power, low-noise applications.

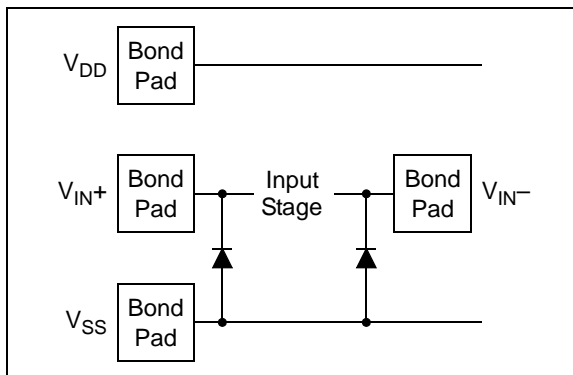
### 4.1 Input

#### 4.1.1 PHASE REVERSAL

The MCP6286 op amp is designed to prevent phase reversal when the input pins exceed the supply voltages. [Figure 2-31](#) shows the input voltage exceeding the supply voltage without any phase reversal.

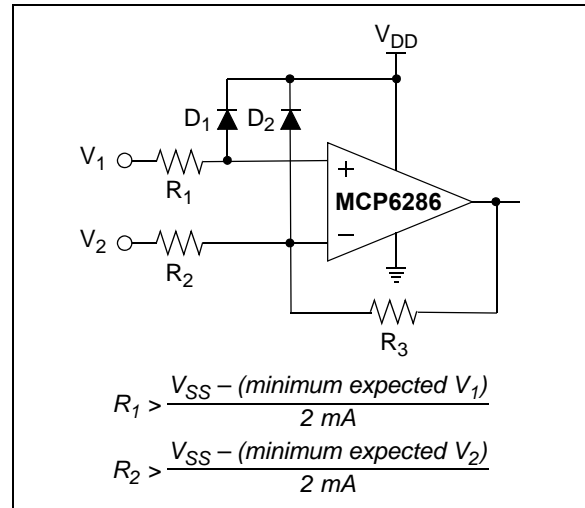
#### 4.1.2 INPUT VOLTAGE AND CURRENT LIMITS

The ESD protection on the inputs can be depicted as shown in [Figure 4-1](#). This structure was chosen to protect the input transistors and to minimize input bias current ( $I_B$ ). The input ESD diodes clamp the inputs when they try to go more than one diode drop below  $V_{SS}$ . They also clamp any voltage that goes too far above  $V_{DD}$ ; their breakdown voltage is high enough to allow normal operation and low enough to bypass ESD events within the specified limits.



**FIGURE 4-1:** Simplified Analog Input ESD Structures.

In order to prevent damage and/or improper operation of these op amps, the circuit they are in must limit the voltages and currents at the  $V_{IN+}$  and  $V_{IN-}$  pins (see **Absolute Maximum Ratings** at the beginning of [Section 1.0 "Electrical Characteristics"](#)). [Figure 4-2](#) shows the recommended approach to protecting these inputs. The internal ESD diodes prevent the input pins ( $V_{IN+}$  and  $V_{IN-}$ ) from going too far below ground, and the resistors  $R_1$  and  $R_2$  limit the possible current drawn out of the input pins. Diodes  $D_1$  and  $D_2$  prevent the input pins ( $V_{IN+}$  and  $V_{IN-}$ ) from going too far above  $V_{DD}$ . When implemented as shown, resistors  $R_1$  and  $R_2$  also limit the current through  $D_1$  and  $D_2$ .



**FIGURE 4-2:** Protecting the Analog Inputs.

It is also possible to connect the diodes to the left of the resistors  $R_1$  and  $R_2$ . In this case, the currents through the diodes  $D_1$  and  $D_2$  need to be limited by some other mechanism. The resistors then serve as in-rush current limiters; the DC currents into the input pins ( $V_{IN+}$  and  $V_{IN-}$ ) should be very small. A significant amount of current can flow out of the inputs when the common mode voltage ( $V_{CM}$ ) is below ground ( $V_{SS}$ ). (See [Figure 2-33](#)).

#### 4.1.3 NORMAL OPERATION

The input stage of the MCP6286 op amp uses a PMOS input stage. It operates at low common mode input voltage ( $V_{CM}$ ), including ground. With this topology, the device operates with a  $V_{CM}$  up to  $V_{DD} - 1.2V$  and  $0.3V$  below  $V_{SS}$ . (See [Figure 2-12](#)). The input offset voltage is measured at  $V_{CM} = V_{SS} - 0.3V$  and  $V_{DD} - 1.2V$  to ensure proper operation.

For a unity gain buffer, since  $V_{OUT}$  is the same voltage as the inverting input,  $V_{OUT}$  must be maintained below  $V_{DD} - 1.2V$  for correct operation.

## 4.2 Rail-to-Rail Output

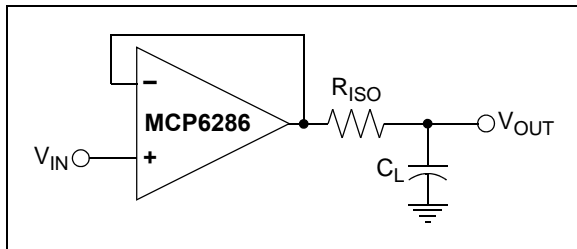
The output voltage range of the MCP6286 op amp is  $V_{SS} + 15 \text{ mV}$  (minimum) and  $V_{DD} - 15 \text{ mV}$  (maximum) when  $R_L = 10 \text{ k}\Omega$  is connected to  $V_{DD}/2$  and  $V_{DD} = 5.5V$ . Refer to [Figure 2-24](#) and [Figure 2-25](#) for more information.

# MCP6286

## 4.3 Capacitive Loads

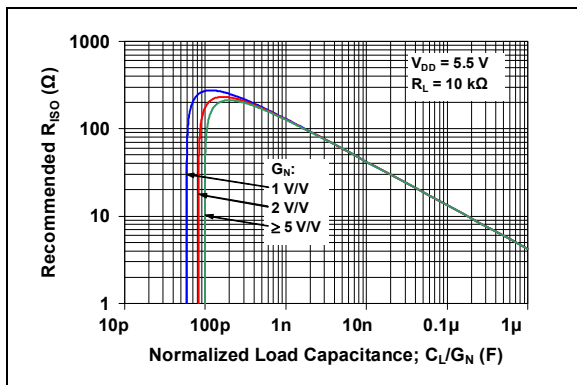
Driving large capacitive loads can cause stability problems for voltage feedback op amps. As the load capacitance increases, the feedback loop's phase margin decreases and the closed-loop bandwidth is reduced. This produces gain peaking in the frequency response, with overshoot and ringing in the step response. While a unity-gain buffer ( $G = +1$  V/V) is the most sensitive to capacitive loads, all gains show the same general behavior.

When driving large capacitive loads with these op amps (e.g.,  $> 100$  pF when  $G = +1$  V/V), a small series resistor at the output ( $R_{ISO}$  in Figure 4-3) improves the feedback loop's phase margin (stability) by making the output load resistive at higher frequencies. The bandwidth will be generally lower than the bandwidth with no capacitance load.



**FIGURE 4-3:** Output Resistor,  $R_{ISO}$  Stabilizes Large Capacitive Loads.

Figure 4-4 gives recommended  $R_{ISO}$  values for different capacitive loads and gains. The x-axis is the normalized load capacitance ( $C_L/G_N$ ), where  $G_N$  is the circuit's noise gain. For non-inverting gains,  $G_N$  and the Signal Gain are equal. For inverting gains,  $G_N$  is  $1+|\text{Signal Gain}|$  (e.g.,  $-1$  V/V gives  $G_N = +2$  V/V).



**FIGURE 4-4:** Recommended  $R_{ISO}$  Values for Capacitive Loads.

After selecting  $R_{ISO}$  for your circuit, double check the resulting frequency response peaking and step response overshoot. Modify  $R_{ISO}$ 's value until the response is reasonable. Bench evaluation and simulations with the MCP6286 SPICE macro model are very helpful.

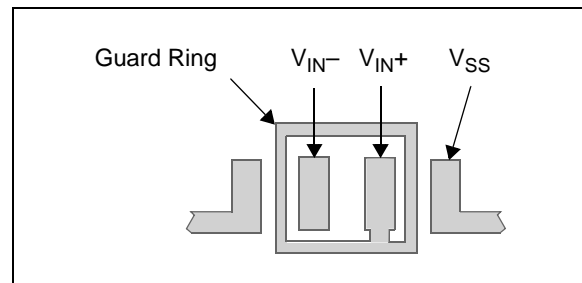
## 4.4 Supply Bypass

MCP6286 op amp's power supply pin ( $V_{DD}$  for single-supply) should have a local bypass capacitor (i.e.,  $0.01$   $\mu$ F to  $0.1$   $\mu$ F) within 2 mm for good high frequency performance. It can use a bulk capacitor (i.e.,  $1$   $\mu$ F or larger) within 100 mm to provide large, slow currents. This bulk capacitor can be shared with other analog parts.

## 4.5 PCB Surface Leakage

In applications where low input bias current is critical, Printed Circuit Board (PCB) surface leakage effects need to be considered. Surface leakage is caused by humidity, dust or other contamination on the board. Under low humidity conditions, a typical resistance between nearby traces is  $10^{12}$   $\Omega$ . A 5V difference would cause 5 pA of current to flow; which is greater than the MCP6286 op amp's bias current at  $+25^\circ\text{C}$  ( $\pm 1$  pA, typical).

The easiest way to reduce surface leakage is to use a guard ring around sensitive pins (or traces). The guard ring is biased at the same voltage as the sensitive pin. An example of this type of layout is shown in Figure 4-5.



**FIGURE 4-5:** Example Guard Ring Layout for Inverting Gain.

1. Non-inverting Gain and Unity-Gain Buffer:
  - a. Connect the non-inverting pin ( $V_{IN+}$ ) to the input with a wire that does not touch the PCB surface.
  - b. Connect the guard ring to the inverting input pin ( $V_{IN-}$ ). This biases the guard ring to the common mode input voltage.
2. Inverting Gain and Transimpedance Gain Amplifiers (convert current to voltage, such as photo detectors):
  - a. Connect the guard ring to the non-inverting input pin ( $V_{IN+}$ ). This biases the guard ring to the same reference voltage as the op amp (e.g.,  $V_{DD}/2$  or ground).
  - b. Connect the inverting pin ( $V_{IN-}$ ) to the input with a wire that does not touch the PCB surface.

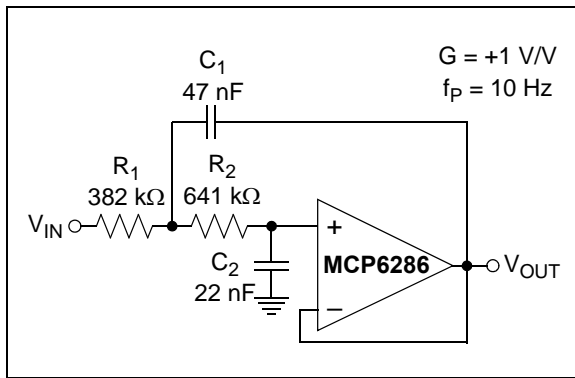


## 4.6 Application Circuits

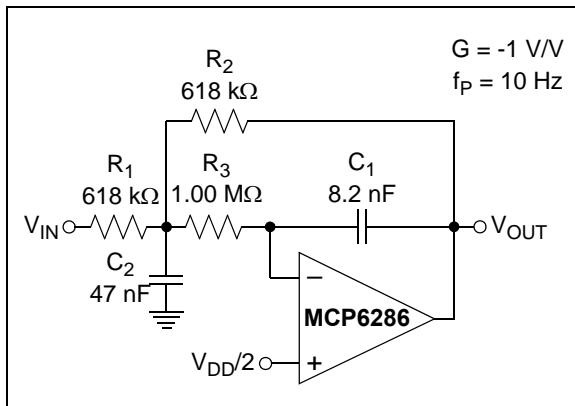
### 4.6.1 ACTIVE LOW-PASS FILTER

The MCP6286 op amp's low input bias current makes it possible for the designer to use larger resistors and smaller capacitors for active low-pass filter applications. However, as the resistance increases, the noise generated also increases. Parasitic capacitances and the large value resistors could also modify the frequency response. These trade-offs need to be considered when selecting circuit elements.

Figure 4-6 and Figure 4-7 show low-pass, second-order, Butterworth filters with a cut-off frequency of 10 Hz. The filter in Figure 4-6 has a non-inverting gain of +1 V/V, and the filter in Figure 4-7 has an inverting gain of -1 V/V.



**FIGURE 4-6:** Second-Order, Low-Pass Butterworth Filter with Sallen-Key Topology.

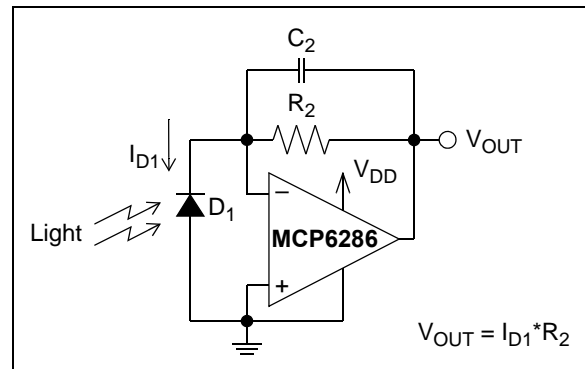


**FIGURE 4-7:** Second-Order, Low-Pass Butterworth Filter with Multiple-Feedback Topology.

### 4.6.2 PHOTO DETECTION

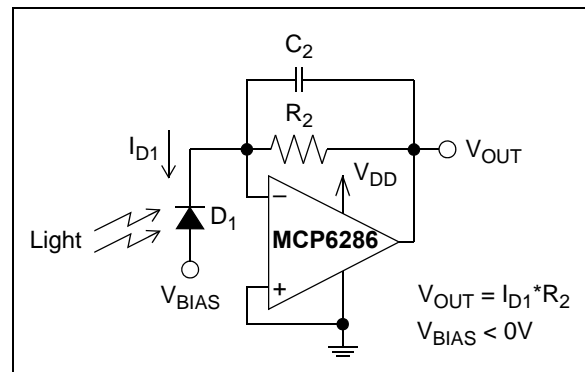
The MCP6286 op amps can be used to easily convert the signal from a sensor that produces an output current (such as a photo diode) into a voltage (a transimpedance amplifier). This is implemented with a single resistor ( $R_2$ ) in the feedback loop of the amplifiers shown in Figure 4-8 and Figure 4-9. The optional capacitor ( $C_2$ ) sometimes provides stability for these circuits.

A photodiode configured in the Photovoltaic mode has zero voltage potential placed across it (Figure 4-8). In this mode, the light sensitivity and linearity is maximized, making it best suited for precision applications. The key amplifier specifications for this application are: low input bias current, low noise, common mode input voltage range (including ground), and rail-to-rail output.



**FIGURE 4-8:** Photovoltaic Mode Detector.

In contrast, a photodiode that is configured in the Photoconductive mode has a reverse bias voltage across the photo-sensing element (Figure 4-9). This decreases the diode capacitance, which facilitates high-speed operation (e.g., high-speed digital communications). The design trade-off is increased diode leakage current and linearity errors. The op amp needs to have a wide Gain Bandwidth Product (GBWP).



**FIGURE 4-9:** Photoconductive Mode Detector.

# MCP6286

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NOTES:

## 5.0 DESIGN AIDS

Microchip provides the basic design tools needed for the MCP6286 op amp.

### 5.1 SPICE Macro Model

The latest SPICE macro model for the MCP6286 op amp is available on the Microchip web site at [www.microchip.com](http://www.microchip.com). The model was written and tested in official Orcad (Cadence) owned PSPICE. For the other simulators, it may require translation.

The model covers a wide aspect of the op amp's electrical specifications. Not only does the model cover voltage, current, and resistance of the op amp, but it also covers the temperature and noise effects on the behavior of the op amp. The model has not been verified outside of the specification range listed in the op amp data sheet. The model behaviors under these conditions can not be guaranteed that it will match the actual op amp performance.

Moreover, the model is intended to be an initial design tool. Bench testing is a very important part of any design and cannot be replaced with simulations. Also, simulation results using this macro model need to be validated by comparing them to the data sheet specifications and characteristic curves.

### 5.2 FilterLab® Software

Microchip's FilterLab® software is an innovative software tool that simplifies analog active filter (using op amps) design. Available at no cost from the Microchip web site at [www.microchip.com/filterlab](http://www.microchip.com/filterlab), the FilterLab design tool provides full schematic diagrams of the filter circuit with component values. It also outputs the filter circuit in SPICE format, which can be used with the macro model to simulate actual filter performance.

### 5.3 Mindi™ Circuit Designer & Simulator

Microchip's Mindi™ Circuit Designer & Simulator aids in the design of various circuits useful for active filter, amplifier and power-management applications. It is a free online circuit designer & simulator available from the Microchip web site at [www.microchip.com/mindi](http://www.microchip.com/mindi). This interactive circuit designer & simulator enables designers to quickly generate circuit diagrams, simulate circuits. Circuits developed using the Mindi Circuit Designer & Simulator can be downloaded to a personal computer or workstation.

### 5.4 Microchip Advanced Part Selector (MAPS)

MAPS is a software tool that helps semiconductor professionals efficiently identify Microchip devices that fit a particular design requirement. Available at no cost from the Microchip website at [www.microchip.com/maps](http://www.microchip.com/maps), the MAPS is an overall selection tool for Microchip's product portfolio that includes Analog, Memory, MCUs and DSCs. Using this tool you can define a filter to sort features for a parametric search of devices and export side-by-side technical comparison reports. Helpful links are also provided for Datasheets, Purchase, and Sampling of Microchip parts.

### 5.5 Analog Demonstration and Evaluation Boards

Microchip offers a broad spectrum of Analog Demonstration and Evaluation Boards that are designed to help you achieve faster time to market. For a complete listing of these boards and their corresponding user's guides and technical information, visit the Microchip web site at [www.microchip.com/analogtools](http://www.microchip.com/analogtools).

Some boards that are especially useful are:

- MCP6XXX Amplifier Evaluation Board 1
- MCP6XXX Amplifier Evaluation Board 2
- MCP6XXX Amplifier Evaluation Board 3
- MCP6XXX Amplifier Evaluation Board 4
- Active Filter Demo Board Kit
- 5/6-Pin SOT-23 Evaluation Board, P/N VSUPEV2

### 5.6 Application Notes

The following Microchip Analog Design Note and Application Notes are available on the Microchip web site at [www.microchip.com/appnotes](http://www.microchip.com/appnotes) and are recommended as supplemental reference resources.

- **ADN003:** "Select the Right Operational Amplifier for your Filtering Circuits", DS21821
- **AN722:** "Operational Amplifier Topologies and DC Specifications", DS00722
- **AN723:** "Operational Amplifier AC Specifications and Applications", DS00723
- **AN884:** "Driving Capacitive Loads With Op Amps", DS00884
- **AN990:** "Analog Sensor Conditioning Circuits – An Overview", DS00990
- **AN1177:** "Op Amp Precision Design: DC Errors", DS01177
- **AN1228:** "Op Amp Precision Design: Random Noise", DS01228

These application notes and others are listed in the design guide:

- "Signal Chain Design Guide", DS21825

# MCP6286

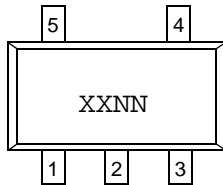
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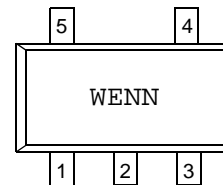
## 6.0 PACKAGING INFORMATION

### 6.1 Package Marking Information

5-Lead SOT-23



Example:



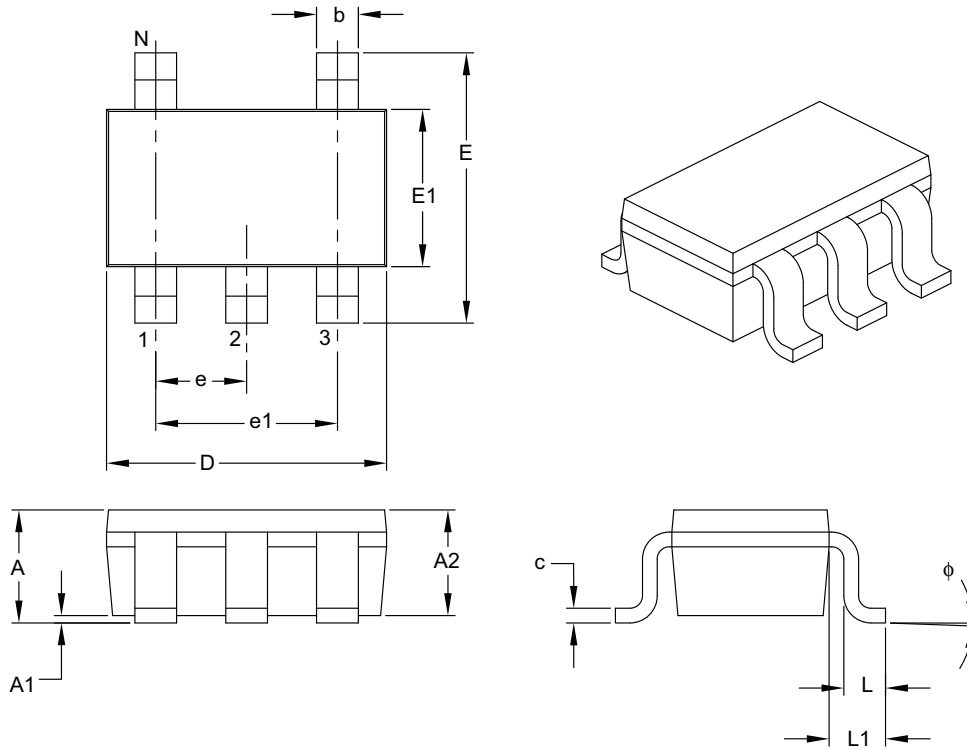
<b>Legend:</b>	XX...X	Customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week '01')
	NNN	Alphanumeric traceability code
	(e3)	Pb-free JEDEC designator for Matte Tin (Sn)
	*	This package is Pb-free. The Pb-free JEDEC designator (e3) can be found on the outer packaging for this package.

**Note:** In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information.

# MCP6286

## 5-Lead Plastic Small Outline Transistor (OT) [SOT-23]

**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



Dimension Limits	Units	MILLIMETERS		
		MIN	NOM	MAX
Number of Pins	N	5		
Lead Pitch	e	0.95 BSC		
Outside Lead Pitch	e1	1.90 BSC		
Overall Height	A	0.90	–	1.45
Molded Package Thickness	A2	0.89	–	1.30
Standoff	A1	0.00	–	0.15
Overall Width	E	2.20	–	3.20
Molded Package Width	E1	1.30	–	1.80
Overall Length	D	2.70	–	3.10
Foot Length	L	0.10	–	0.60
Footprint	L1	0.35	–	0.80
Foot Angle	$\phi$	0°	–	30°
Lead Thickness	c	0.08	–	0.26
Lead Width	b	0.20	–	0.51

**Notes:**

- Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.127 mm per side.
- Dimensioning and tolerancing per ASME Y14.5M.

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing C04-091B

## APPENDIX A: REVISION HISTORY

### Revision A (August 2009)

- Original Release of this Document.

# MCP6286

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NOTES:



## PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.

<u>PART NO.</u>	<u>X</u>	<u>/XX</u>
Device	Temperature Range	Package
Device:	MCP6286T:	Single Op Amp (Tape and Reel)
Temperature Range:	E	= -40°C to +125°C
Package:	OT	= Plastic Small Outline Transistor, 5-lead

**Examples:**

a) MCP6286T-E/OT: Tape and Reel, 5-LD SOT-23 package

# MCP6286

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NOTES:

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- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
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