

## 1 MHz, Low-Power Op Amp

### Features

- Available in SC-70-5 and SOT-23-5 packages
- Gain Bandwidth Product: 1 MHz (typ.)
- Rail-to-Rail Input/Output
- Supply Voltage: 1.8V to 5.5V
- Supply Current:  $I_Q = 100 \mu\text{A}$  (typ.)
- Phase Margin: 90° (typ.)
- Temperature Range:
  - Industrial: -40°C to +85°C
  - Extended: -40°C to +125°C
- Available in Single, Dual and Quad Packages

### Applications

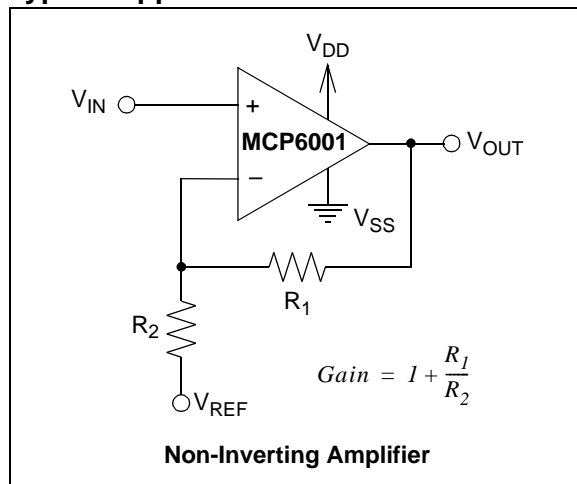
- Automotive
- Portable Equipment
- Photodiode Amplifier
- Analog Filters
- Notebooks and PDAs
- Battery-Powered Systems

### Available Tools

SPICE Macro Models (at [www.microchip.com](http://www.microchip.com))

FilterLab® Software (at [www.microchip.com](http://www.microchip.com))

### Typical Application

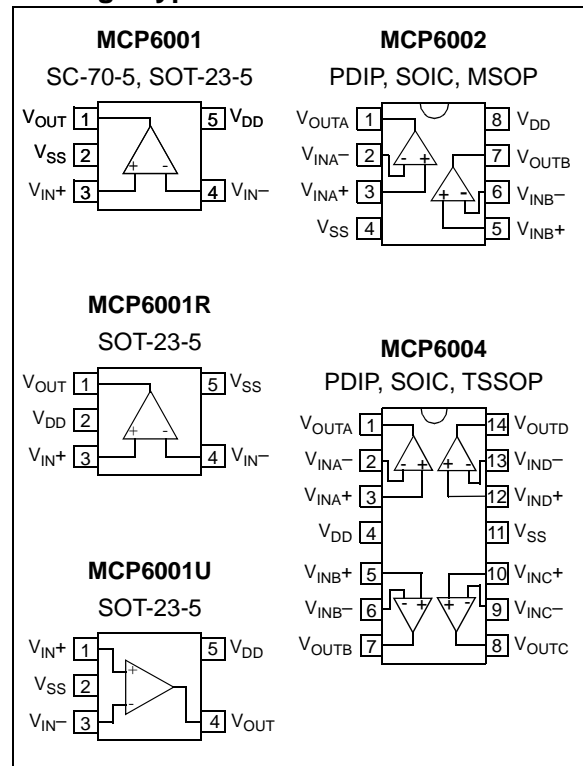


### Description

The Microchip Technology Inc. MCP6001/2/4 family of operational amplifiers (op amps) is specifically designed for general-purpose applications. This family has a 1 MHz Gain Bandwidth Product (GBWP) and 90° phase margin (typ.). It also maintains 45° phase margin (typ.) with a 500 pF capacitive load. This family operates from a single supply voltage as low as 1.8V, while drawing 100  $\mu\text{A}$  (typ.) quiescent current. Additionally, the MCP6001/2/4 supports rail-to-rail input and output swing, with a common mode input voltage range of  $V_{DD} + 300 \text{ mV}$  to  $V_{SS} - 300 \text{ mV}$ . This family of op amps is designed with Microchip's advanced CMOS process.

The MCP6001/2/4 family is available in the industrial and extended temperature ranges, with a power supply range of 1.8V to 5.5V.

### Package Types



# MCP6001/2/4

## 1.0 ELECTRICAL CHARACTERISTICS

### Absolute Maximum Ratings †

$V_{DD} - V_{SS}$ .....	7.0V
All 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 Input Pins .....	$\pm 2$ mA
Current at Output and Supply Pins .....	$\pm 30$ mA
Storage Temperature.....	$-65^{\circ}\text{C}$ to $+150^{\circ}\text{C}$
Maximum Junction Temperature ( $T_J$ ).....	$+150^{\circ}\text{C}$
ESD Protection On All Pins (HBM;MM) .....	$\geq 4$ kV; 200V

† **Notice:** Stresses above those listed under “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.

### DC ELECTRICAL SPECIFICATIONS

**Electrical Characteristics:** Unless otherwise indicated,  $T_A = +25^{\circ}\text{C}$ ,  $V_{DD} = +1.8\text{V}$  to  $+5.5\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $R_L = 10$  k $\Omega$  to  $V_{DD}/2$  and  $V_{OUT} \approx V_{DD}/2$ .

Parameters	Sym	Min	Typ	Max	Units	Conditions
<b>Input Offset</b>						
Input Offset Voltage	$V_{OS}$	-4.5	—	+4.5	mV	$V_{CM} = V_{SS}$ ( <b>Note 1</b> )
Input Offset Drift with Temperature	$\Delta V_{OS}/\Delta T_A$	—	$\pm 2.0$	—	$\mu\text{V}/^{\circ}\text{C}$	$T_A = -40^{\circ}\text{C}$ to $+125^{\circ}\text{C}$ , $V_{CM} = V_{SS}$
Power Supply Rejection Ratio	PSRR	—	86	—	dB	$V_{CM} = V_{SS}$
<b>Input Bias Current and Impedance</b>						
Input Bias Current:	$I_B$	—	$\pm 1.0$	—	pA	
Industrial Temperature	$I_B$	—	19	—	pA	$T_A = +85^{\circ}\text{C}$
Extended Temperature	$I_B$	—	1100	—	pA	$T_A = +125^{\circ}\text{C}$
Input Offset Current	$I_{OS}$	—	$\pm 1.0$	—	pA	
Common Mode Input Impedance	$Z_{CM}$	—	$10^{13}  6$	—	$\Omega  \text{pF}$	
Differential Input Impedance	$Z_{DIFF}$	—	$10^{13}  3$	—	$\Omega  \text{pF}$	
<b>Common Mode</b>						
Common Mode Input Range	$V_{CMR}$	$V_{SS} - 0.3$	—	$V_{DD} + 0.3$	V	
Common Mode Rejection Ratio	CMRR	60	76	—	dB	$V_{CM} = -0.3\text{V}$ to $5.3\text{V}$ , $V_{DD} = 5\text{V}$
<b>Open-Loop Gain</b>						
DC Open-Loop Gain (Large Signal)	$A_{OL}$	88	112	—	dB	$V_{OUT} = 0.3\text{V}$ to $V_{DD} - 0.3\text{V}$ , $V_{CM} = V_{SS}$
<b>Output</b>						
Maximum Output Voltage Swing	$V_{OL}, V_{OH}$	$V_{SS} + 25$	—	$V_{DD} - 25$	mV	$V_{DD} = 5.5\text{V}$
Output Short-Circuit Current	$I_{SC}$	—	$\pm 6$	—	mA	$V_{DD} = 1.8\text{V}$
		—	$\pm 23$	—	mA	$V_{DD} = 5.5\text{V}$
<b>Power Supply</b>						
Supply Voltage	$V_{DD}$	1.8	—	5.5	V	
Quiescent Current per Amplifier	$I_Q$	50	100	170	$\mu\text{A}$	$I_O = 0$ , $V_{DD} = 5.5\text{V}$ , $V_{CM} = 5\text{V}$

**Note 1:** MCP6001/2/4 parts with date codes prior to December 2004 (week code 49) were tested to  $\pm 7$  mV minimum/maximum limits.

## AC ELECTRICAL SPECIFICATIONS

**Electrical Characteristics:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.8$  to  $5.5\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_{DD}/2$  and  $C_L = 60\text{ pF}$ .

Parameters	Sym	Min	Typ	Max	Units	Conditions
<b>AC Response</b>						
Gain Bandwidth Product	GBWP	—	1.0	—	MHz	
Phase Margin	PM	—	90	—	°	G = +1
Slew Rate	SR	—	0.6	—	V/ $\mu\text{s}$	
<b>Noise</b>						
Input Noise Voltage	$E_{ni}$	—	6.1	—	$\mu\text{Vp-p}$	f = 0.1 Hz to 10 Hz
Input Noise Voltage Density	$e_{ni}$	—	28	—	nV/ $\sqrt{\text{Hz}}$	f = 1 kHz
Input Noise Current Density	$i_{ni}$	—	0.6	—	fA/ $\sqrt{\text{Hz}}$	f = 1 kHz

## TEMPERATURE SPECIFICATIONS

**Electrical Characteristics:** Unless otherwise indicated,  $V_{DD} = +1.8\text{V}$  to  $+5.5\text{V}$  and  $V_{SS} = \text{GND}$ .

Parameters	Sym	Min	Typ	Max	Units	Conditions
<b>Temperature Ranges</b>						
Industrial Temperature Range	$T_A$	-40	—	+85	°C	
Extended Temperature Range	$T_A$	-40	—	+125	°C	
Operating Temperature Range	$T_A$	-40	—	+125	°C	<b>Note</b>
Storage Temperature Range	$T_A$	-65	—	+150	°C	
<b>Thermal Package Resistances</b>						
Thermal Resistance, 5L-SC70	$\theta_{JA}$	—	331	—	°C/W	
Thermal Resistance, 5L-SOT-23	$\theta_{JA}$	—	256	—	°C/W	
Thermal Resistance, 8L-PDIP	$\theta_{JA}$	—	85	—	°C/W	
Thermal Resistance, 8L-SOIC (150 mil)	$\theta_{JA}$	—	163	—	°C/W	
Thermal Resistance, 8L-MSOP	$\theta_{JA}$	—	206	—	°C/W	
Thermal Resistance, 14L-PDIP	$\theta_{JA}$	—	70	—	°C/W	
Thermal Resistance, 14L-SOIC	$\theta_{JA}$	—	120	—	°C/W	
Thermal Resistance, 14L-TSSOP	$\theta_{JA}$	—	100	—	°C/W	

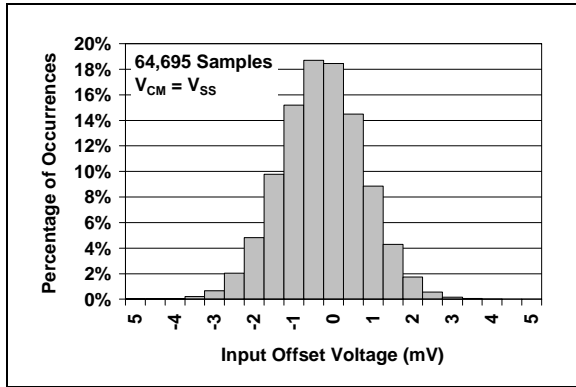
**Note:** The industrial temperature devices operate over this extended temperature range, but with reduced performance. In any case, the internal Junction Temperature ( $T_J$ ) must not exceed the Absolute Maximum specification of  $+150^\circ\text{C}$ .

# MCP6001/2/4

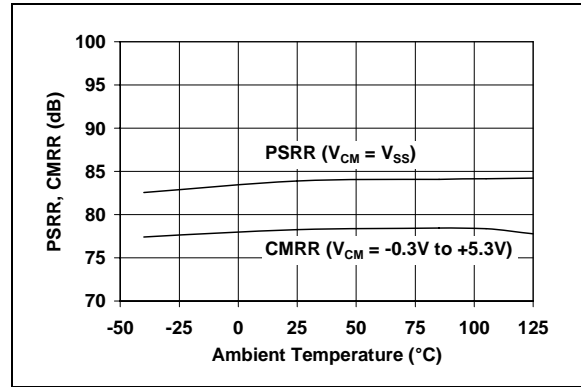
## 2.0 TYPICAL PERFORMANCE CURVES

**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.

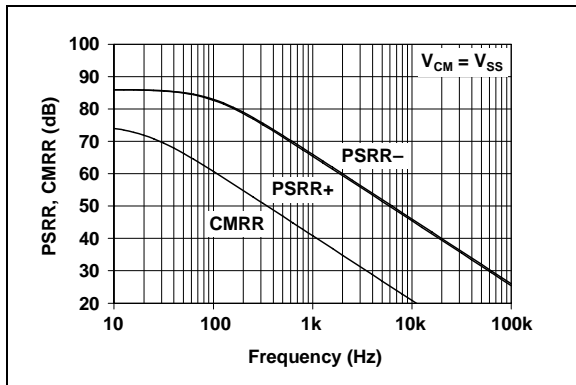
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.8\text{V to } +5.5\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_{DD}/2$  and  $C_L = 60\text{ pF}$ .



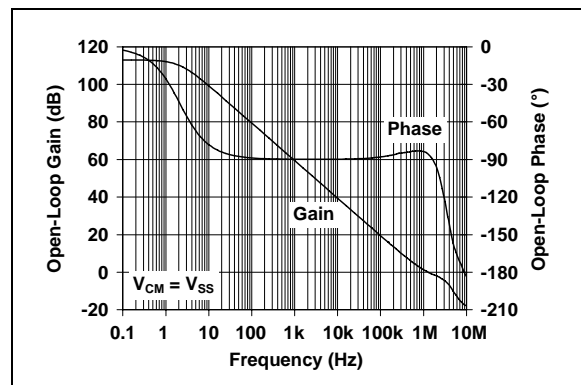
**FIGURE 2-1:** Input Offset Voltage.



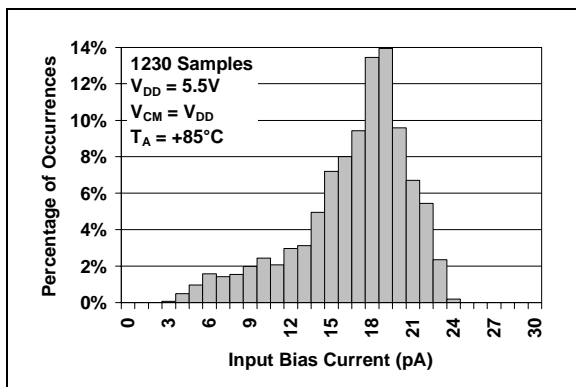
**FIGURE 2-4:** CMRR, PSRR vs. Ambient Temperature.



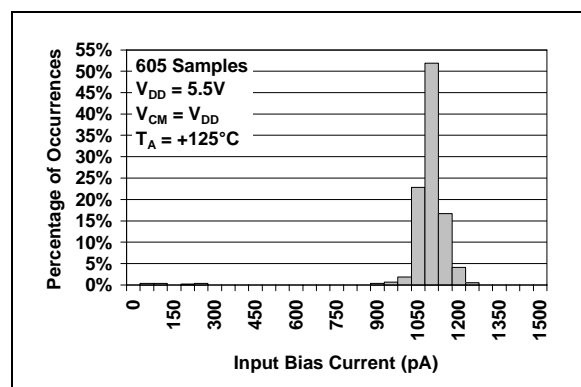
**FIGURE 2-2:** PSRR, CMRR vs. Frequency.



**FIGURE 2-5:** Open-Loop Gain, Phase vs. Frequency.

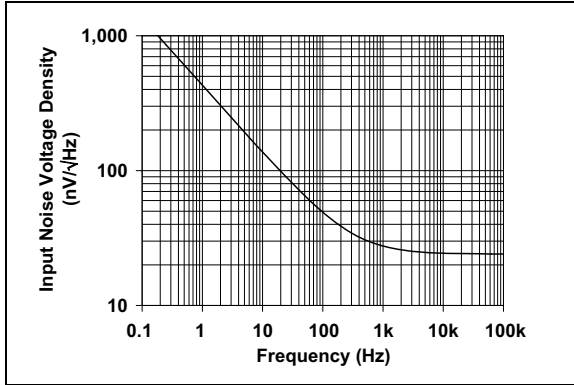


**FIGURE 2-3:** Input Bias Current at  $+85^\circ\text{C}$ .

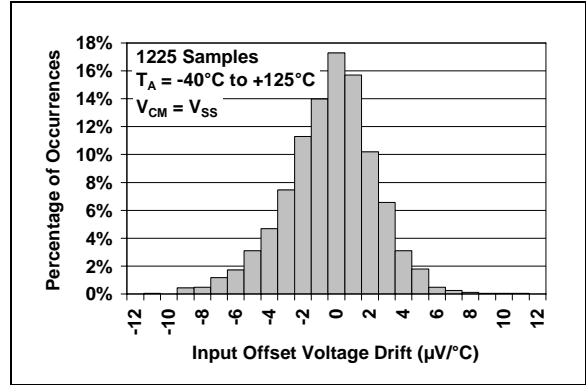


**FIGURE 2-6:** Input Bias Current at  $+125^\circ\text{C}$ .

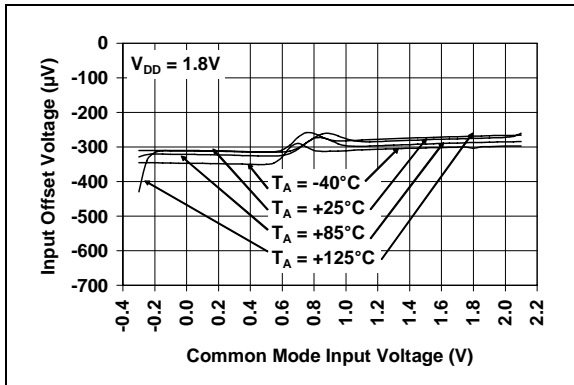
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.8\text{V}$  to  $+5.5\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_{DD}/2$  and  $C_L = 60\text{ pF}$ .



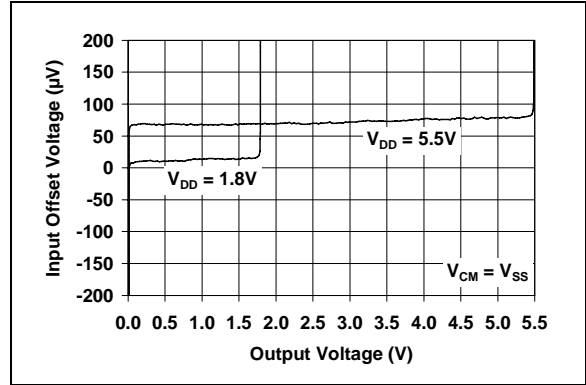
**FIGURE 2-7:** Input Noise Voltage Density vs. Frequency.



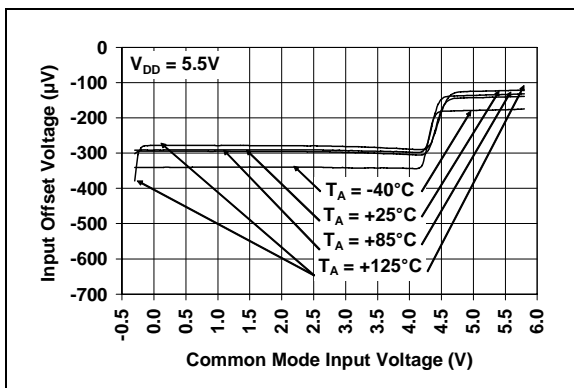
**FIGURE 2-10:** Input Offset Voltage Drift.



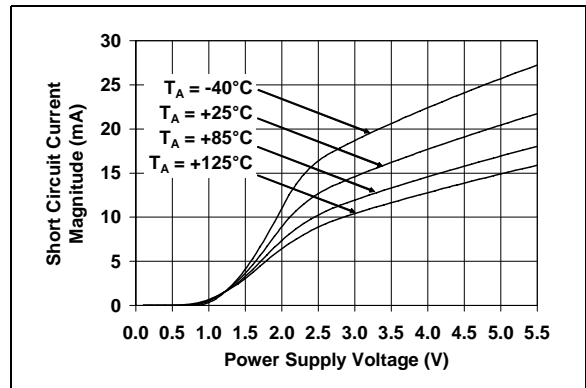
**FIGURE 2-8:** Input Offset Voltage vs. Common Mode Input Voltage at  $V_{DD} = 1.8\text{V}$ .



**FIGURE 2-11:** Input Offset Voltage vs. Output Voltage.



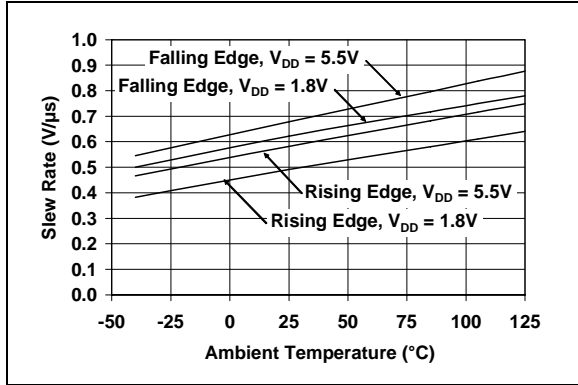
**FIGURE 2-9:** Input Offset Voltage vs. Common Mode Input Voltage at  $V_{DD} = 5.5\text{V}$ .



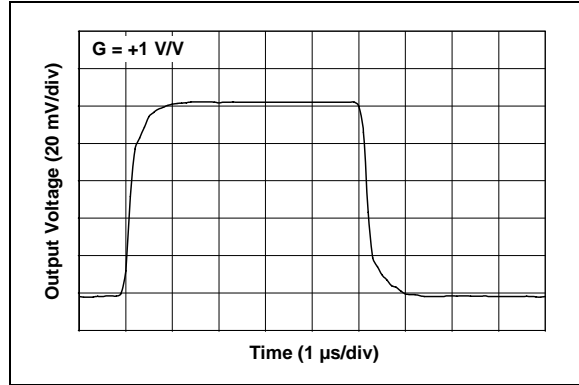
**FIGURE 2-12:** Output Short-Circuit Current vs. Power Supply Voltage.

# MCP6001/2/4

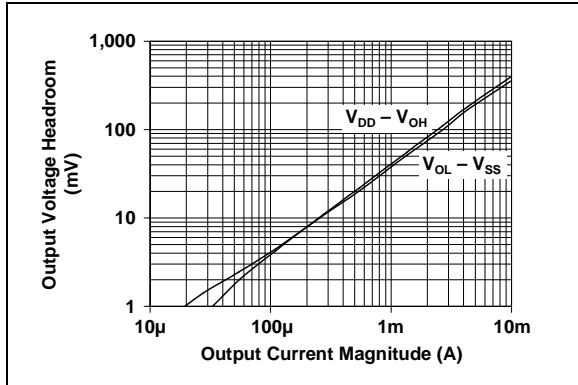
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.8\text{V}$  to  $+5.5\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_{DD}/2$  and  $C_L = 60\text{ pF}$ .



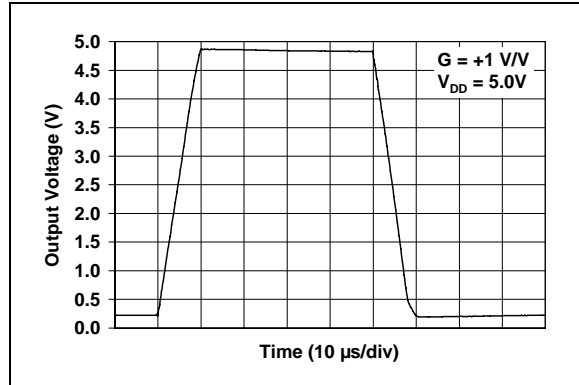
**FIGURE 2-13:** Slew Rate vs. Ambient Temperature.



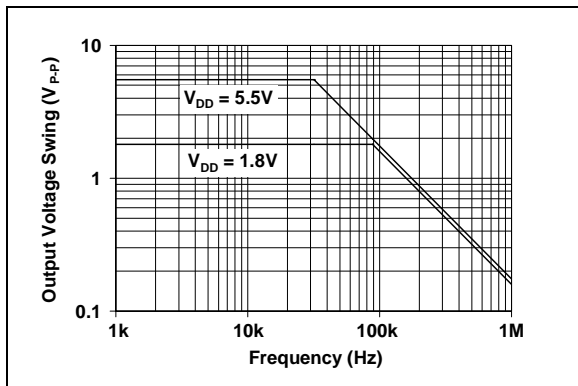
**FIGURE 2-16:** Small-Signal, Non-Inverting Pulse Response.



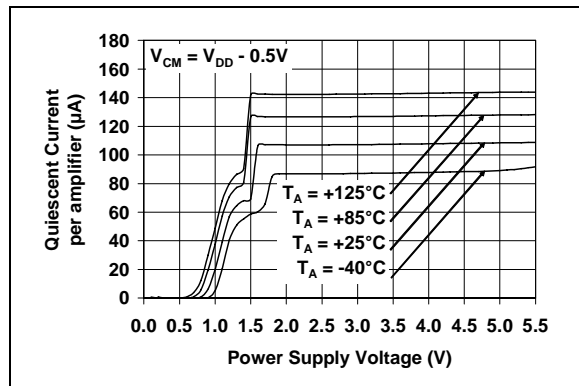
**FIGURE 2-14:** Output Voltage Headroom vs. Output Current Magnitude.



**FIGURE 2-17:** Large-Signal, Non-Inverting Pulse Response.



**FIGURE 2-15:** Output Voltage Swing vs. Frequency.



**FIGURE 2-18:** Quiescent Current vs. Power Supply Voltage.

## 3.0 PIN DESCRIPTIONS

Descriptions of the pins are listed in Table 3-1.

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

MCP6001	MCP6001R	MCP6001U	MCP6002	MCP6004	Symbol	Description
1	1	4	1	1	$V_{OUT}, V_{OUTA}$	Analog Output (op amp A)
4	4	3	2	2	$V_{IN}^-, V_{INA}^-$	Inverting Input (op amp A)
3	3	1	3	3	$V_{IN}^+, V_{INA}^+$	Non-inverting Input (op amp A)
5	2	5	8	4	$V_{DD}$	Positive Power Supply
—	—	—	5	5	$V_{INB}^+$	Non-inverting Input (op amp B)
—	—	—	6	6	$V_{INB}^-$	Inverting Input (op amp B)
—	—	—	7	7	$V_{OUTB}$	Analog Output (op amp B)
—	—	—	—	8	$V_{OUTC}$	Analog Output (op amp C)
—	—	—	—	9	$V_{INC}^-$	Inverting Input (op amp C)
—	—	—	—	10	$V_{INC}^+$	Non-inverting Input (op amp C)
2	5	2	4	11	$V_{SS}$	Negative Power Supply
—	—	—	—	12	$V_{IND}^+$	Non-inverting Input (op amp D)
—	—	—	—	13	$V_{IND}^-$	Inverting Input (op amp D)
—	—	—	—	14	$V_{OUTD}$	Analog Output (op amp D)

### 3.1 Analog Outputs

The output pins are low-impedance voltage sources.

### 3.2 Analog Inputs

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

### 3.3 Power Supply ( $V_{SS}$ and $V_{DD}$ )

The positive power supply ( $V_{DD}$ ) is 1.8V 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 a local bypass capacitor (typically 0.01  $\mu$ F to 0.1  $\mu$ F) within 2 mm of the  $V_{DD}$  pin. These parts can share a bulk capacitor with analog parts (typically 2.2  $\mu$ F to 10  $\mu$ F) within 100 mm of the  $V_{DD}$  pin.

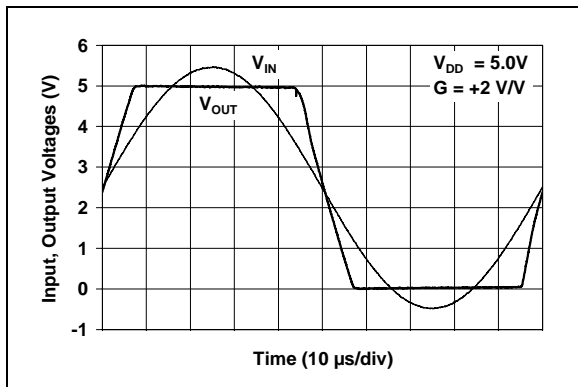
# MCP6001/2/4

## 4.0 APPLICATION INFORMATION

The MCP6001/2/4 family of op amps is manufactured using Microchip's state-of-the-art CMOS process and is specifically designed for low-cost, low-power and general-purpose applications. The low supply voltage, low quiescent current and wide bandwidth makes the MCP6001/2/4 ideal for battery-powered applications. This device has high phase margin, which makes it stable for larger capacitive load applications.

### 4.1 Rail-to-Rail Input

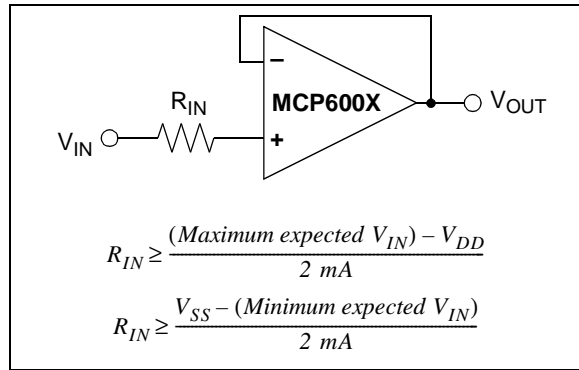
The MCP6001/2/4 op amps are designed to prevent phase reversal when the input pins exceed the supply voltages. Figure 4-1 shows the input voltage exceeding the supply voltage without any phase reversal.



**FIGURE 4-1:** The MCP6001/2/4 Show No Phase Reversal.

The input stage of the MCP6001/2/4 op amps use two differential input stages in parallel. One operates at a low common mode input voltage ( $V_{CM}$ ), while the other operates at a high  $V_{CM}$ . With this topology, the device operates with a  $V_{CM}$  up to 300 mV above  $V_{DD}$  and 300 mV below  $V_{SS}$ . The input offset voltage is measured at  $V_{CM} = V_{SS} - 300$  mV and  $V_{DD} + 300$  mV to ensure proper operation.

Input voltages that exceed the input voltage range ( $V_{SS} - 0.3$ V to  $V_{DD} + 0.3$ V at 25°C) can cause excessive current to flow into or out of the input pins, while current beyond  $\pm 2$  mA can cause reliability problems. Applications that exceed this rating must be externally limited with a resistor, as shown in Figure 4-2.



**FIGURE 4-2:** Input Current Limiting Resistor ( $R_{IN}$ ).

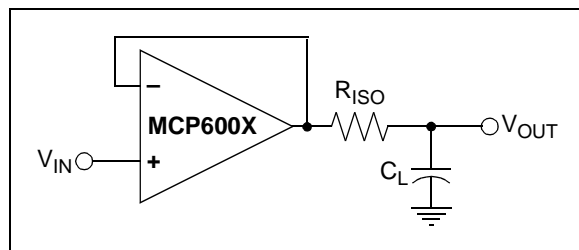
### 4.2 Rail-to-Rail Output

The output voltage range of the MCP6001/2/4 op amps is  $V_{DD} - 25$  mV (min.) and  $V_{SS} + 25$  mV (max.) when  $R_L = 10$  kΩ is connected to  $V_{DD}/2$  and  $V_{DD} = 5.5$ V. Refer to Figure 2-14 for more information.

### 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 ( $G = +1$ ) is the most sensitive to capacitive loads, all gains show the same general behavior.

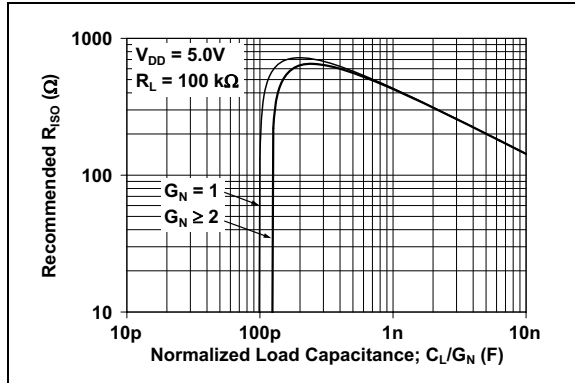
When driving large capacitive loads with these op amps (e.g.,  $> 100$  pF when  $G = +1$ ), a small series resistor at the output ( $R_{ISO}$  in Figure 4-3) improves the feedback loop's phase margin (stability) by making the output load resistive at higher frequencies. The bandwidth will be generally 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.,  $-1 \text{ V/V}$  gives  $G_N = +2 \text{ V/V}$ ).



**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 MCP6001/2/4 SPICE macro model are very helpful.

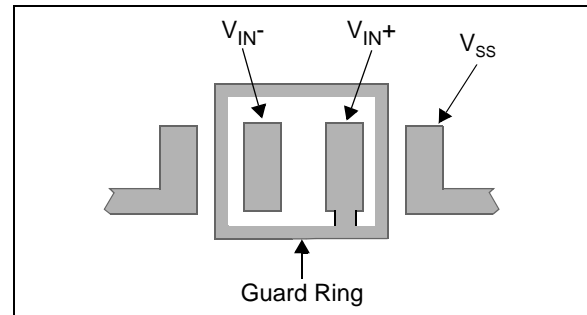
## 4.4 Supply Bypass

With this family of operational amplifiers, the power supply pin ( $V_{DD}$  for single-supply) should have a local bypass capacitor (i.e.,  $0.01 \mu\text{F}$  to  $0.1 \mu\text{F}$ ) within 2 mm for good high-frequency performance. It also needs a bulk capacitor (i.e.,  $1 \mu\text{F}$  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 MCP6001/2/4 family's bias current at  $25^\circ\text{C}$  (1 pA, typ.).

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.

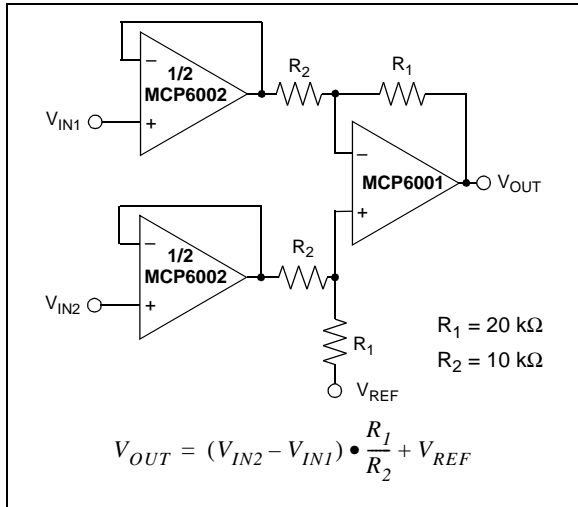
1. Non-inverting Gain and Unity-Gain Buffer:
  - a. Connect the non-inverting pin ( $V_{IN+}$ ) to the input with a wire that does not touch the PCB surface.
  - b. Connect the guard ring to the inverting input pin ( $V_{IN-}$ ). This biases the guard ring to the common mode input voltage.
2. Inverting 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.

# MCP6001/2/4

## 4.6 Application Circuits

### 4.6.1 UNITY-GAIN BUFFER

The rail-to-rail input and output capability of the MCP6001/2/4 op amp is ideal for unity-gain buffer applications. The low quiescent current and wide bandwidth makes the device suitable for a buffer configuration in an instrumentation amplifier circuit, as shown in Figure 4-6.



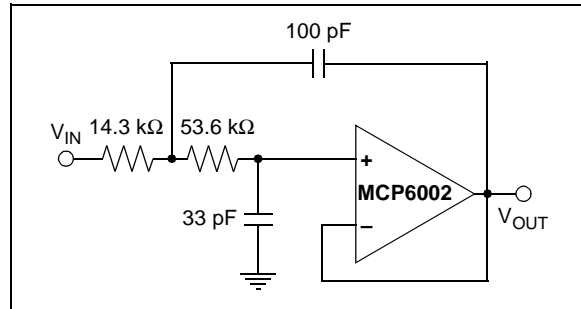
**FIGURE 4-6:** Instrumentation Amplifier with Unity-Gain Buffer Inputs.

### 4.6.2 ACTIVE LOW-PASS FILTER

The MCP6001/2/4 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.

Usually, the op amp bandwidth is 100X the filter cutoff frequency (or higher) for good performance. It is possible to have the op amp bandwidth 10X higher than the cutoff frequency, thus having a design that is more sensitive to component tolerances.

Figure 4-7 shows a second-order Butterworth filter with 100 kHz cutoff frequency and a gain of +1 V/V; the op amp bandwidth is only 10X higher than the cutoff frequency. The component values were selected using Microchip's FilterLab<sup>®</sup> software.



**FIGURE 4-7:** Active Second-Order Low-Pass Filter.

### 4.6.3 PEAK DETECTOR

The MCP6001/2/4 op amp has a high input impedance, rail-to-rail input/output and low input bias current, which makes this device suitable for peak detector applications. Figure 4-8 shows a peak detector circuit with clear and sample switches. The peak-detection cycle uses a clock (CLK), as shown in Figure 4-8.

At the rising edge of CLK, Sample Switch closes to begin sampling. The peak voltage stored on  $C_1$  is sampled to  $C_2$  for a sample time defined by  $t_{SAMP}$ . At the end of the sample time (falling edge of Sample Signal), Clear Signal goes high and closes the Clear Switch. When the Clear Switch closes,  $C_1$  discharges through  $R_1$  for a time defined by  $t_{CLEAR}$ . At the end of the clear time (falling edge of Clear Signal), op amp A begins to store the peak value of  $V_{IN}$  on  $C_1$  for a time defined by  $t_{DETECT}$ .

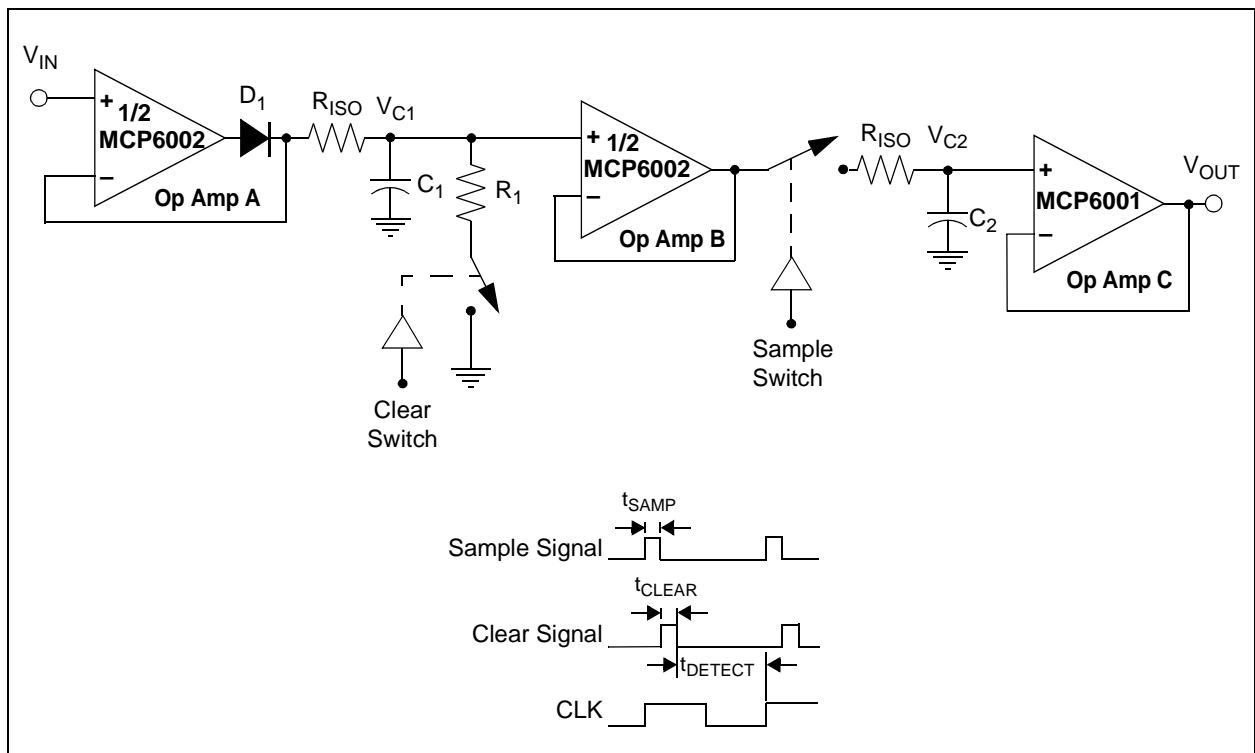
In order to define  $t_{SAMP}$  and  $t_{CLEAR}$ , it is necessary to determine the capacitor charging and discharging period. The capacitor charging time is limited by the amplifier source current, while the discharging time ( $\tau$ ) is defined using  $R_1$  ( $\tau = R_1 C_1$ ).  $t_{DETECT}$  is the time that the input signal is sampled on  $C_1$  and is dependent on the input voltage change frequency.

The op amp output current limit, and the size of the storage capacitors (both  $C_1$  and  $C_2$ ), could create slewing limitations as the input voltage ( $V_{IN}$ ) increases. Current through a capacitor is dependent on the size of the capacitor and the rate of voltage change. From this relationship, the rate of voltage change or the slew rate can be determined. For example, with an op amp short-circuit current of  $I_{SC} = 25 \text{ mA}$  and a load capacitor of  $C_1 = 0.1 \mu\text{F}$ , then:

#### EQUATION 4-1:

$$\begin{aligned}
 I_{SC} &= C_1 \frac{dV_{C1}}{dt} \\
 \frac{dV_{C1}}{dt} &= \frac{I_{SC}}{C_1} \\
 &= \frac{25 \text{ mA}}{0.1 \mu\text{F}} \\
 \frac{dV_{C1}}{dt} &= 250 \text{ mV}/\mu\text{s}
 \end{aligned}$$

This voltage rate of change is less than the MCP6001/2/4 slew rate of  $0.6 \text{ V}/\mu\text{s}$ . When the input voltage swings below the voltage across  $C_1$ ,  $D_1$  becomes reverse-biased. This opens the feedback loop and rails the amplifier. When the input voltage increases, the amplifier recovers at its slew rate. Based on the rate of voltage change shown in the above equation, it takes an extended period of time to charge a  $0.1 \mu\text{F}$  capacitor. The capacitors need to be selected so that the circuit is not limited by the amplifier slew rate. Therefore, the capacitors should be less than  $40 \mu\text{F}$  and a stabilizing resistor ( $R_{\text{ISO}}$ ) needs to be properly selected. (Refer to **Section 4.3 “Capacitive Loads”**).



**FIGURE 4-8:** Peak Detector with Clear and Sample CMOS Analog Switches.

# MCP6001/2/4

---

## 5.0 DESIGN TOOLS

Microchip provides the basic design tools needed for the MCP6001/2/4 family of op amps.

### 5.1 SPICE Macro Model

The latest SPICE macro model for the MCP6001/2/4 op amps is available on our web site at [www.microchip.com](http://www.microchip.com). This model is intended to be an initial design tool that works well in the op amp's linear region of operation at room temperature. See the model file for information on its capabilities.

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.

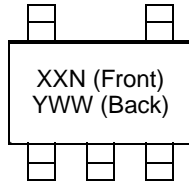
### 5.2 FilterLab<sup>®</sup> Software

Microchip's FilterLab<sup>®</sup> software is an innovative software tool that simplifies analog active filter (using op amps) design. Available at no cost from our web site at [www.microchip.com](http://www.microchip.com), 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.

## 6.0 PACKAGING INFORMATION

### 6.1 Package Marking Information

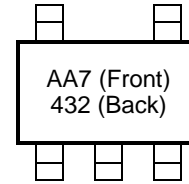
5-Lead SC-70 (MCP6001)



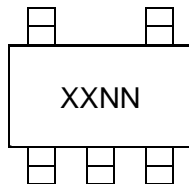
Device	I-Temp Code	E-Temp Code
MCP6001	AAN	CDN

**Note:** Applies to 5-Lead SC-70.

Example: (I-Temp)



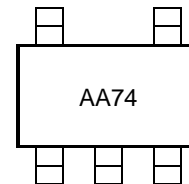
OR



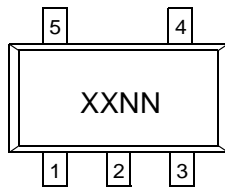
Device	I-Temp Code	E-Temp Code
MCP6001	AANN	CDNN

**Note:** Applies to 5-Lead SC-70.

OR



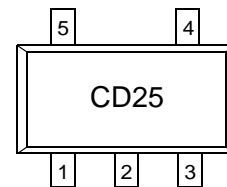
5-Lead SOT-23 (MCP6001/1R/1U)



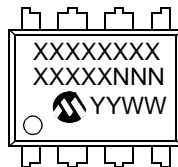
Device	I-Temp Code	E-Temp Code
MCP6001	AANN	CDNN
MCP6001R	ADNN	CENN
MCP6001U	AFNN	CFNN

**Note:** Applies to 5-Lead SOT-23.

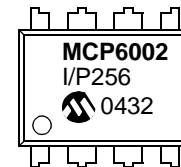
Example: (E-Temp)



8-Lead PDIP (300 mil)



Example:



<b>Legend:</b>	XX...X	Customer specific information*
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week '01')
	NNN	Alphanumeric traceability code

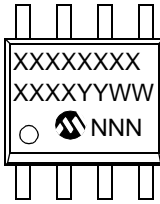
**Note:** In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line thus limiting the number of available characters for customer specific information.

\* Standard marking consists of Microchip part number, year code, week code, traceability code (facility code, mask rev#, and assembly code). For marking beyond this, certain price adders apply. Please check with your Microchip Sales Office.

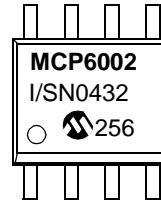
# MCP6001/2/4

## Package Marking Information (Continued)

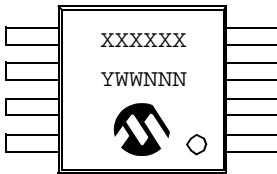
8-Lead SOIC (150 mil)



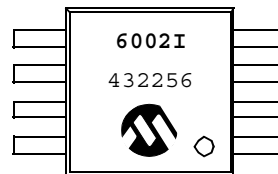
Example:



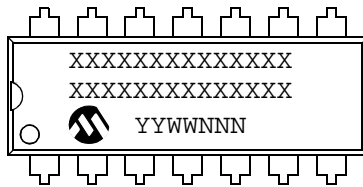
8-Lead MSOP



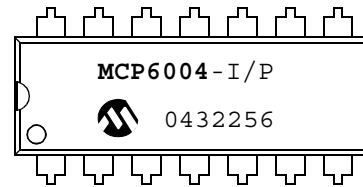
Example:



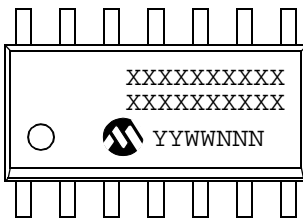
14-Lead PDIP (300 mil) (MCP6004)



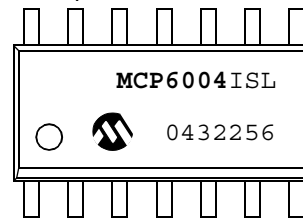
Example:



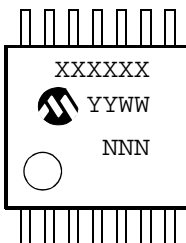
14-Lead SOIC (150 mil) (MCP6004)



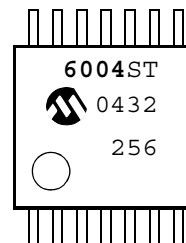
Example:



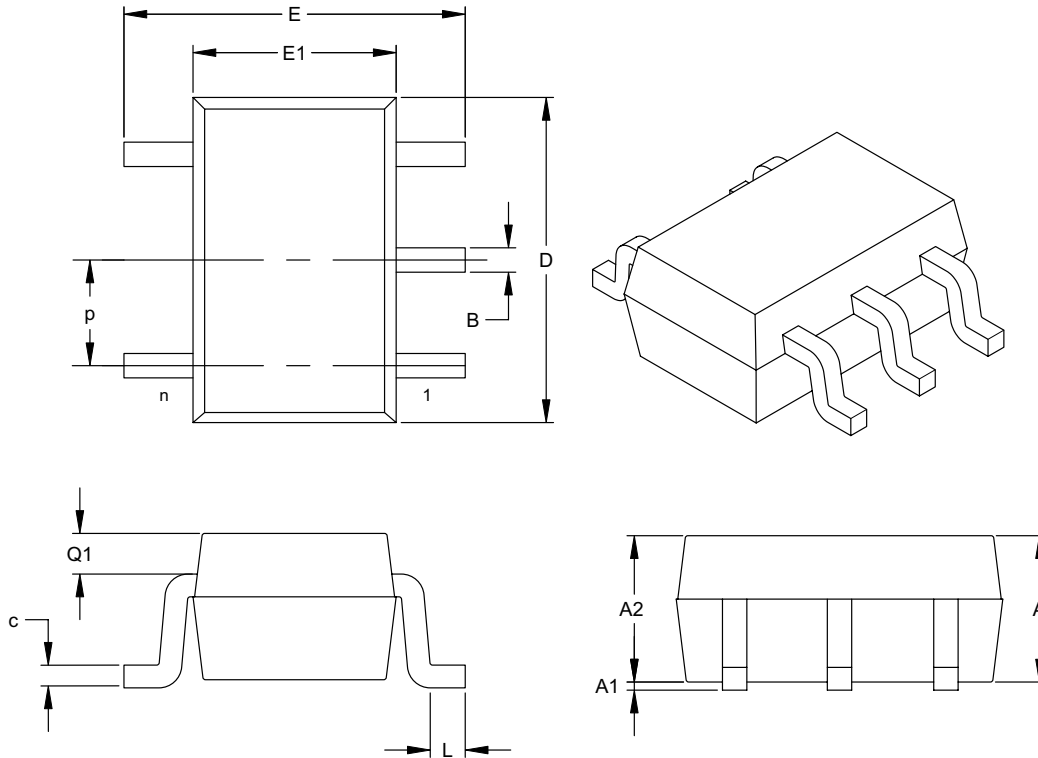
14-Lead TSSOP (MCP6004)



Example:



## 5-Lead Plastic Package (SC-70)



Dimension Limits	Units	INCHES			MILLIMETERS*		
		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n	5			5		
Pitch	p	.026 (BSC)			0.65 (BSC)		
Overall Height	A	.031		.043	0.80		1.10
Molded Package Thickness	A2	.031		.039	0.80		1.00
Standoff	A1	.000		.004	0.00		0.10
Overall Width	E	.071		.094	1.80		2.40
Molded Package Width	E1	.045		.053	1.15		1.35
Overall Length	D	.071		.087	1.80		2.20
Foot Length	L	.004		.012	0.10		0.30
Top of Molded Pkg to Lead Shoulder	Q1	.004		.016	0.10		0.40
Lead Thickness	c	.004		.007	0.10		0.18
Lead Width	B	.006		.012	0.15		0.30

\*Controlling Parameter

Notes:

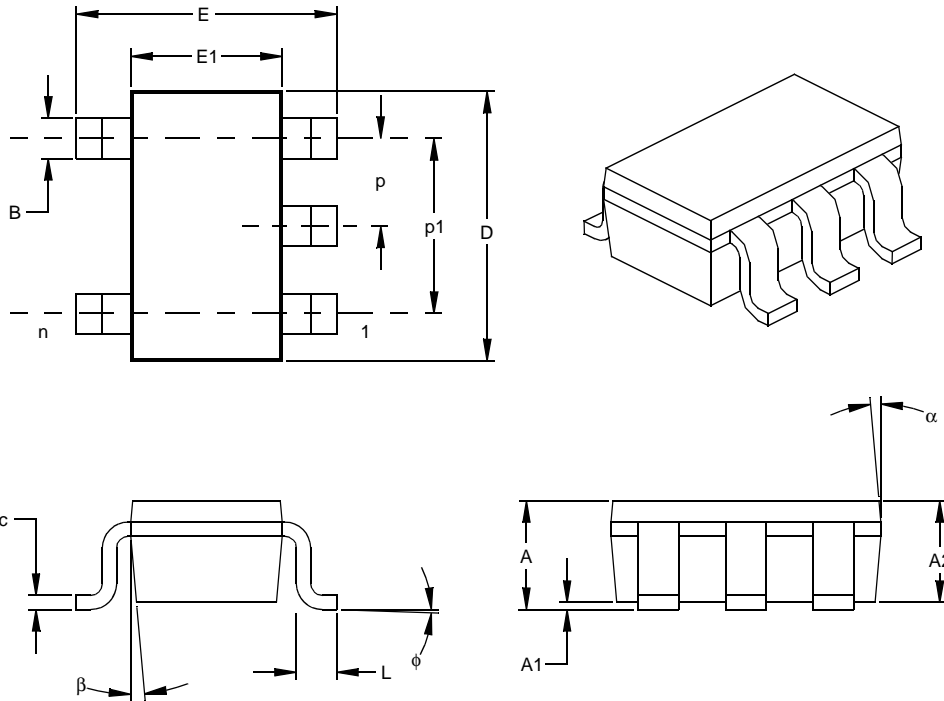
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .005" (0.127mm) per side.

JEITA (EIAJ) Standard: SC-70

Drawing No. C04-061

# MCP6001/2/4

## 5-Lead Plastic Small Outline Transistor (OT) (SOT23)



Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		5			5	
Pitch	p		.038			0.95	
Outside lead pitch (basic)	p1		.075			1.90	
Overall Height	A	.035	.046	.057	0.90	1.18	1.45
Molded Package Thickness	A2	.035	.043	.051	0.90	1.10	1.30
Standoff §	A1	.000	.003	.006	0.00	0.08	0.15
Overall Width	E	.102	.110	.118	2.60	2.80	3.00
Molded Package Width	E1	.059	.064	.069	1.50	1.63	1.75
Overall Length	D	.110	.116	.122	2.80	2.95	3.10
Foot Length	L	.014	.018	.022	0.35	0.45	0.55
Foot Angle	φ	0	5	10	0	5	10
Lead Thickness	c	.004	.006	.008	0.09	0.15	0.20
Lead Width	B	.014	.017	.020	0.35	0.43	0.50
Mold Draft Angle Top	α	0	5	10	0	5	10
Mold Draft Angle Bottom	β	0	5	10	0	5	10

\* Controlling Parameter

§ Significant Characteristic

Notes:

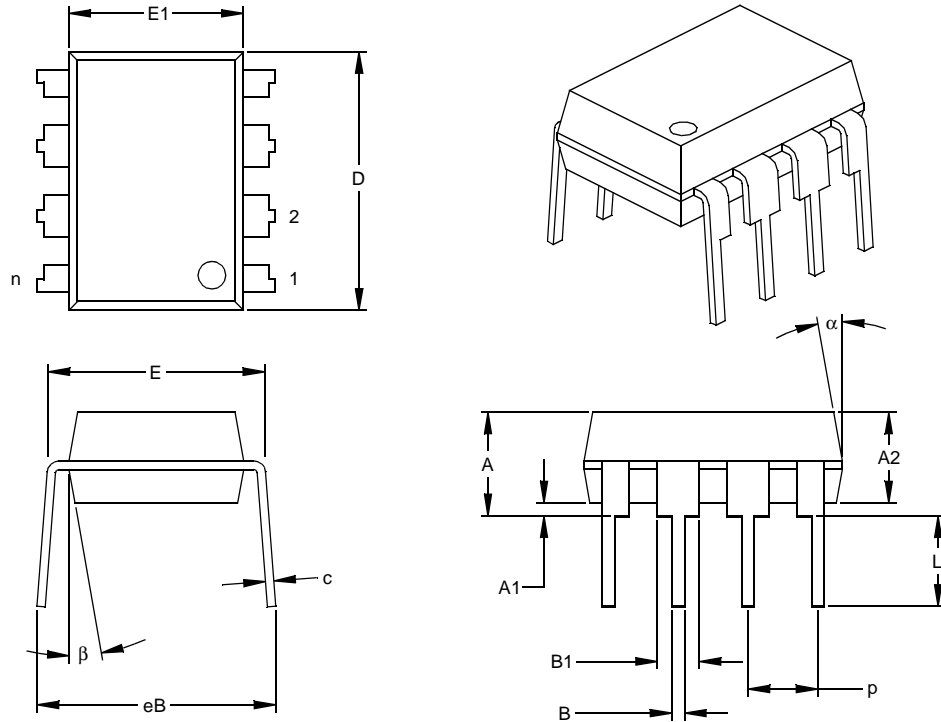
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.

JEDEC Equivalent: MO-178

Drawing No. C04-091



## 8-Lead Plastic Dual In-line (P) – 300 mil (PDIP)



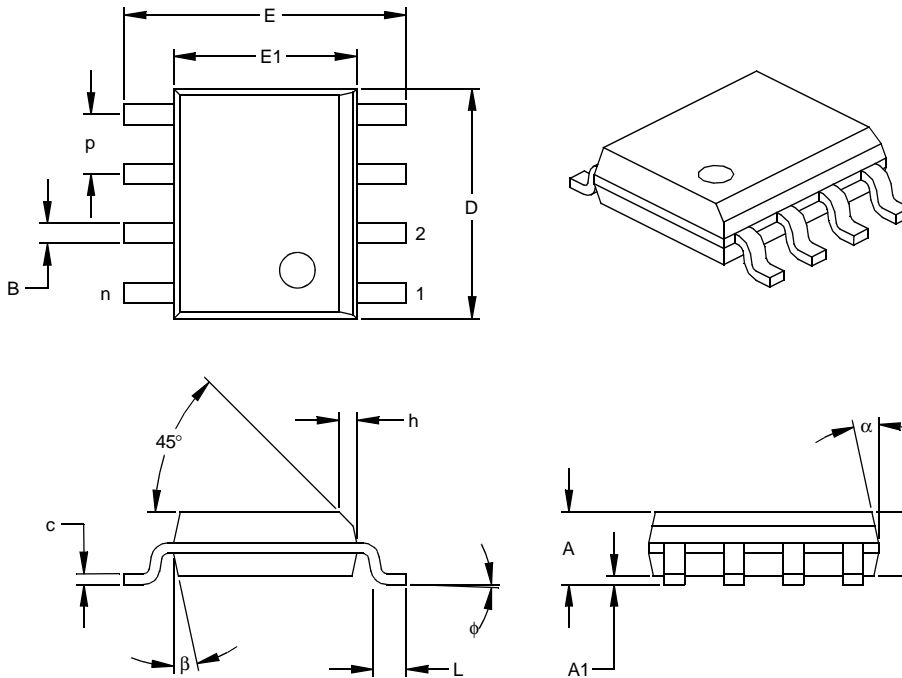
Dimension Limits	Units	INCHES*			MILLIMETERS		
		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		8			8	
Pitch	p		.100			2.54	
Top to Seating Plane	A	.140	.155	.170	3.56	3.94	4.32
Molded Package Thickness	A2	.115	.130	.145	2.92	3.30	3.68
Base to Seating Plane	A1	.015			0.38		
Shoulder to Shoulder Width	E	.300	.313	.325	7.62	7.94	8.26
Molded Package Width	E1	.240	.250	.260	6.10	6.35	6.60
Overall Length	D	.360	.373	.385	9.14	9.46	9.78
Tip to Seating Plane	L	.125	.130	.135	3.18	3.30	3.43
Lead Thickness	c	.008	.012	.015	0.20	0.29	0.38
Upper Lead Width	B1	.045	.058	.070	1.14	1.46	1.78
Lower Lead Width	B	.014	.018	.022	0.36	0.46	0.56
Overall Row Spacing	§ eB	.310	.370	.430	7.87	9.40	10.92
Mold Draft Angle Top	α	5	10	15	5	10	15
Mold Draft Angle Bottom	β	5	10	15	5	10	15

\* Controlling Parameter  
 § Significant Characteristic

Notes:  
 Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.  
 JEDEC Equivalent: MS-001  
 Drawing No. C04-018

# MCP6001/2/4

## 8-Lead Plastic Small Outline (SN) – Narrow, 150 mil (SOIC)



Dimension Limits	Units	INCHES*			MILLIMETERS		
		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		8			8	
Pitch	p		.050			1.27	
Overall Height	A	.053	.061	.069	1.35	1.55	1.75
Molded Package Thickness	A2	.052	.056	.061	1.32	1.42	1.55
Standoff §	A1	.004	.007	.010	0.10	0.18	0.25
Overall Width	E	.228	.237	.244	5.79	6.02	6.20
Molded Package Width	E1	.146	.154	.157	3.71	3.91	3.99
Overall Length	D	.189	.193	.197	4.80	4.90	5.00
Chamfer Distance	h	.010	.015	.020	0.25	0.38	0.51
Foot Length	L	.019	.025	.030	0.48	0.62	0.76
Foot Angle	φ	0	4	8	0	4	8
Lead Thickness	c	.008	.009	.010	0.20	0.23	0.25
Lead Width	B	.013	.017	.020	0.33	0.42	0.51
Mold Draft Angle Top	α	0	12	15	0	12	15
Mold Draft Angle Bottom	β	0	12	15	0	12	15

\* Controlling Parameter

§ Significant Characteristic

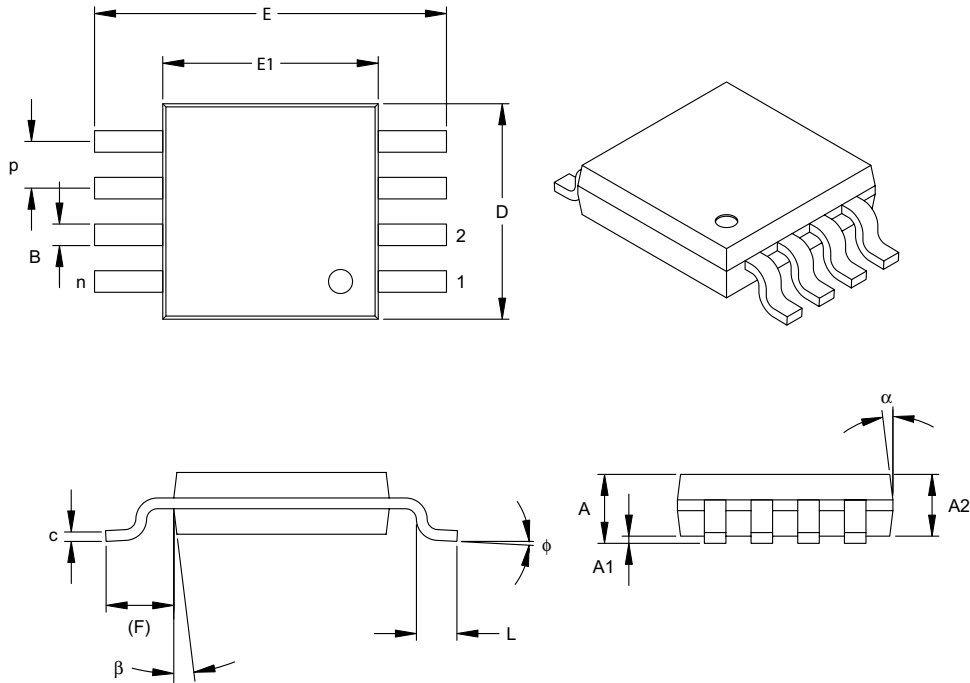
Notes:

Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.

JEDEC Equivalent: MS-012

Drawing No. C04-057

## 8-Lead Plastic Micro Small Outline Package (MS) (MSOP)



Units		INCHES			MILLIMETERS*		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n	8			8		
Pitch	P	.026 BSC			0.65 BSC		
Overall Height	A	-	-	.043	-	-	1.10
Molded Package Thickness	A2	.030	.033	.037	0.75	0.85	0.95
Standoff	A1	.000	-	.006	0.00	-	0.15
Overall Width	E	.193 TYP.			4.90 BSC		
Molded Package Width	E1	.118 BSC			3.00 BSC		
Overall Length	D	.118 BSC			3.00 BSC		
Foot Length	L	.016	.024	.031	0.40	0.60	0.80
Footprint (Reference)	F	.037 REF			0.95 REF		
Foot Angle	$\phi$	0°	-	8°	0°	-	8°
Lead Thickness	c	.003	.006	.009	0.08	-	0.23
Lead Width	B	.009	.012	.016	0.22	-	0.40
Mold Draft Angle Top	$\alpha$	5°	-	15°	5°	-	15°
Mold Draft Angle Bottom	$\beta$	5°	-	15°	5°	-	15°

\*Controlling Parameter

Notes:

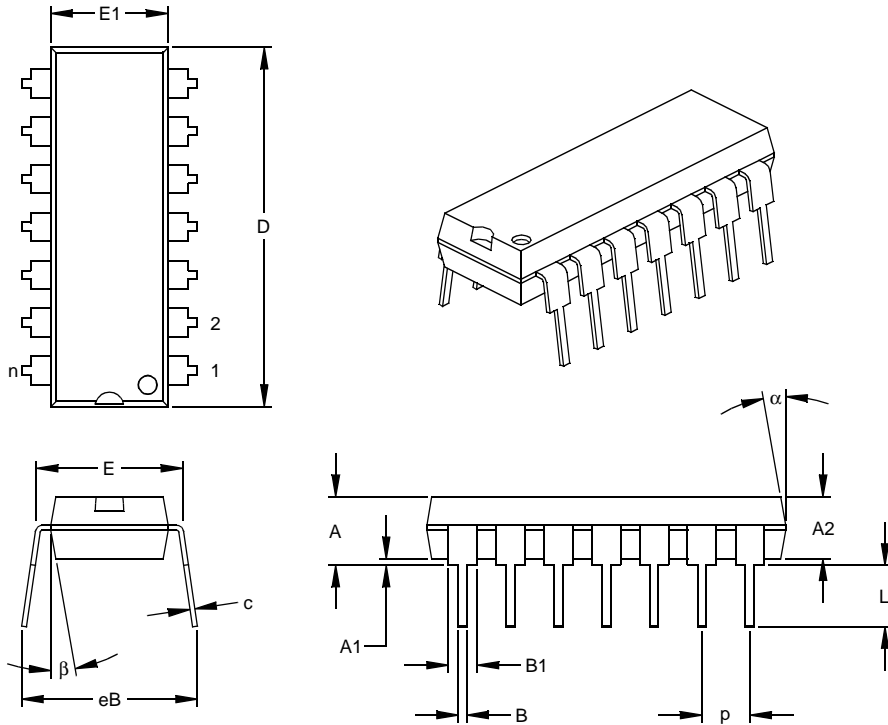
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.

JEDEC Equivalent: MO-187

Drawing No. C04-111

# MCP6001/2/4

## 14-Lead Plastic Dual In-line (P) – 300 mil (PDIP)



Dimension Limits	Units	INCHES*			MILLIMETERS		
		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		14			14	
Pitch	p		.100			2.54	
Top to Seating Plane	A	.140	.155	.170	3.56	3.94	4.32
Molded Package Thickness	A2	.115	.130	.145	2.92	3.30	3.68
Base to Seating Plane	A1	.015			0.38		
Shoulder to Shoulder Width	E	.300	.313	.325	7.62	7.94	8.26
Molded Package Width	E1	.240	.250	.260	6.10	6.35	6.60
Overall Length	D	.740	.750	.760	18.80	19.05	19.30
Tip to Seating Plane	L	.125	.130	.135	3.18	3.30	3.43
Lead Thickness	c	.008	.012	.015	0.20	0.29	0.38
Upper Lead Width	B1	.045	.058	.070	1.14	1.46	1.78
Lower Lead Width	B	.014	.018	.022	0.36	0.46	0.56
Overall Row Spacing	§ eB	.310	.370	.430	7.87	9.40	10.92
Mold Draft Angle Top	α	5	10	15	5	10	15
Mold Draft Angle Bottom	β	5	10	15	5	10	15

\* Controlling Parameter

§ Significant Characteristic

Notes:

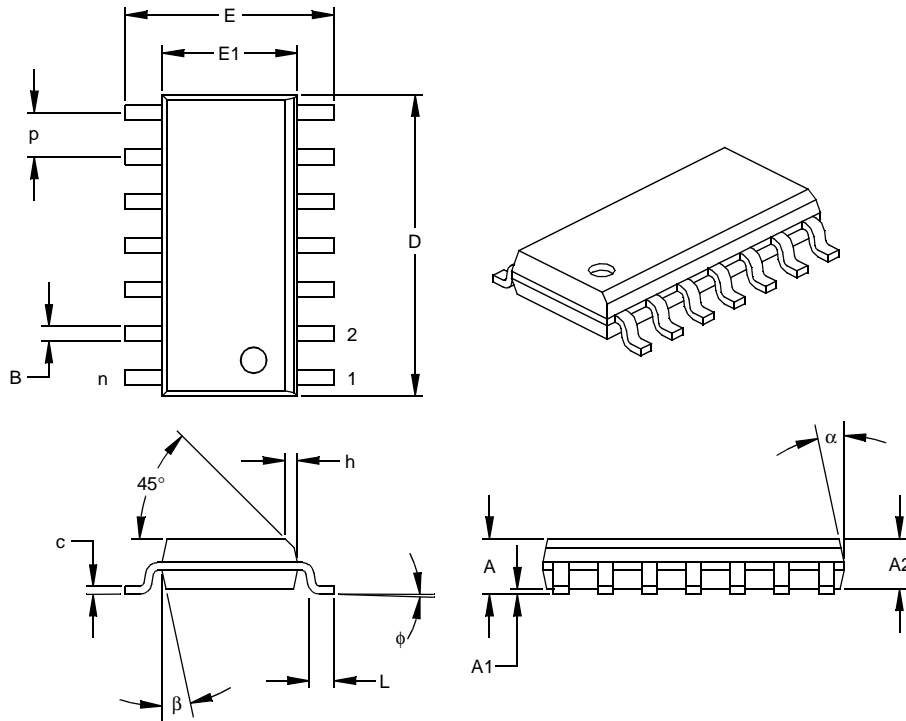
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed

.010" (0.254mm) per side.

JEDEC Equivalent: MS-001

Drawing No. C04-005

## 14-Lead Plastic Small Outline (SL) – Narrow, 150 mil (SOIC)



Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		14			14	
Pitch	p		.050			1.27	
Overall Height	A	.053	.061	.069	1.35	1.55	1.75
Molded Package Thickness	A2	.052	.056	.061	1.32	1.42	1.55
Standoff §	A1	.004	.007	.010	0.10	0.18	0.25
Overall Width	E	.228	.236	.244	5.79	5.99	6.20
Molded Package Width	E1	.150	.154	.157	3.81	3.90	3.99
Overall Length	D	.337	.342	.347	8.56	8.69	8.81
Chamfer Distance	h	.010	.015	.020	0.25	0.38	0.51
Foot Length	L	.016	.033	.050	0.41	0.84	1.27
Foot Angle	φ	0	4	8	0	4	8
Lead Thickness	c	.008	.009	.010	0.20	0.23	0.25
Lead Width	B	.014	.017	.020	0.36	0.42	0.51
Mold Draft Angle Top	α	0	12	15	0	12	15
Mold Draft Angle Bottom	β	0	12	15	0	12	15

\* Controlling Parameter  
 § Significant Characteristic

Notes:

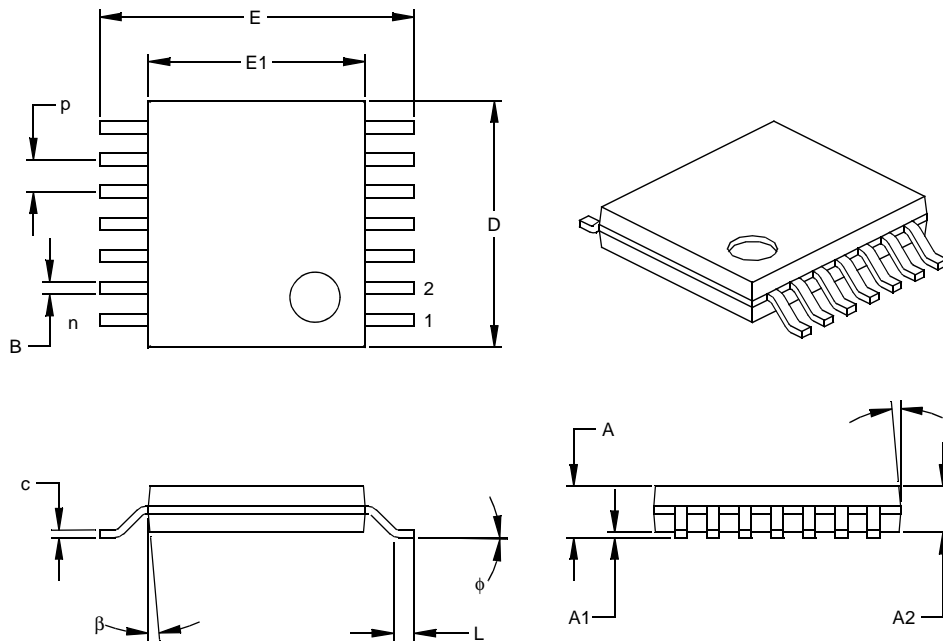
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.

JEDEC Equivalent: MS-012

Drawing No. C04-065

# MCP6001/2/4

## 14-Lead Plastic Thin Shrink Small Outline (ST) – 4.4 mm (TSSOP)



Dimension Limits	Units	INCHES			MILLIMETERS*		
		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		14			14	
Pitch	p		.026			0.65	
Overall Height	A			.043			1.10
Molded Package Thickness	A2	.033	.035	.037	0.85	0.90	0.95
Standoff §	A1	.002	.004	.006	0.05	0.10	0.15
Overall Width	E	.246	.251	.256	6.25	6.38	6.50
Molded Package Width	E1	.169	.173	.177	4.30	4.40	4.50
Molded Package Length	D	.193	.197	.201	4.90	5.00	5.10
Foot Length	L	.020	.024	.028	0.50	0.60	0.70
Foot Angle	φ	0	4	8	0	4	8
Lead Thickness	c	.004	.006	.008	0.09	0.15	0.20
Lead Width	B1	.007	.010	.012	0.19	0.25	0.30
Mold Draft Angle Top	α	0	5	10	0	5	10
Mold Draft Angle Bottom	β	0	5	10	0	5	10

\* Controlling Parameter  
 § Significant Characteristic

Notes:  
 Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .005" (0.127mm) per side.  
 JEDEC Equivalent: MO-153  
 Drawing No. C04-087

## APPENDIX A: REVISION HISTORY

### Revision F (March 2005)

Updated **6.0 “Packaging Information”** to include old and new packaging examples.

### Revision E (December 2004)

The following is the list of modifications:

1.  $V_{OS}$  specification reduced to  $\pm 4.5$  mV from  $\pm 7.0$  mV for parts starting with date code YYWW = 0449
2. Corrected package markings in **Section 6.0 “Packaging Information”**
3. Added Appendix A: Revision History.

### Revision D (May 2003)

### Revision C (December 2002)

### Revision B (October 2002)

### Revision A (June 2002)

Original data sheet release.

# MCP6001/2/4

---

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>	<b>Examples:</b>
<b>Device</b>	<b>Temperature Range</b>	<b>Package</b>	
<b>Device:</b> MCP6001T: Single Op Amp (Tape and Reel) (SC-70, SOT-23) MCP6001RT: Single Op Amp (Tape and Reel) (SOT-23) MCP6001UT: Single Op Amp (Tape and Reel) (SOT-23) MCP6002: Dual Op Amp MCP6002T: Dual Op Amp (Tape and Reel) (SOIC, MSOP) MCP6004: Quad Op Amp MCP6004T: Quad Op Amp (Tape and Reel) (SOIC, MSOP)	<b>Temperature Range:</b> I = -40°C to +85°C E = -40°C to +125°C	<b>Package:</b> LT = Plastic Package (SC-70), 5-lead (MCP6001 only) OT = Plastic Small Outline Transistor (SOT-23), 5-lead (MCP6001, MCP6001R, MCP6001U) MS = Plastic MSOP, 8-lead P = Plastic DIP (300 mil Body), 8-lead, 14-lead SN = Plastic SOIC, (150 mil Body), 8-lead SL = Plastic SOIC (150 mil Body), 14-lead ST = Plastic TSSOP (4.4mm Body), 14-lead	a) MCP6001T-I/LT: Tape and Reel, Industrial Temperature, 5LD SC-70 package. b) MCP6001T-I/OT: Tape and Reel, Industrial Temperature, 5LD SOT-23 package. c) MCP6001RT-I/OT: Tape and Reel, Industrial Temperature, 5LD SOT-23 package. d) MCP6001UT-E/OT: Tape and Reel, Extended Temperature, 5LD SOT-23 package. a) MCP6002-I/MS: Industrial Temperature, 8LD MSOP package. b) MCP6002-I/P: Industrial Temperature, 8LD PDIP package. c) MCP6002-E/P: Extended Temperature, 8LD PDIP package. d) MCP6002-I/SN: Industrial Temperature, 8LD SOIC package. e) MCP6002T-I/MS: Tape and Reel, Industrial Temperature, 8LD MSOP package. a) MCP6004-I/P: Industrial Temperature, 14LD PDIP package. b) MCP6004-I/SL: Industrial Temperature, 14LD SOIC package. c) MCP6004-E/SL: Extended Temperature, 14LD SOIC package. d) MCP6004-I/ST: Industrial Temperature, 14LD TSSOP package. e) MCP6004T-I/SL: Tape and Reel, Industrial Temperature, 14LD SOIC package. f) MCP6004T-I/ST: Tape and Reel, Industrial Temperature, 14LD TSSOP package.

## Sales and Support

### Data Sheets

Products supported by a preliminary Data Sheet may have an errata sheet describing minor operational differences and recommended workarounds. To determine if an errata sheet exists for a particular device, please contact one of the following:

1. Your local Microchip sales office
2. The Microchip Worldwide Site ([www.microchip.com](http://www.microchip.com))

Please specify which device, revision of silicon and Data Sheet (include Literature #) you are using.

### Customer Notification System

Register on our web site ([www.microchip.com](http://www.microchip.com)) to receive the most current information on our products.

# MCP6001/2/4

---

NOTES:

---

---

**Note the following details of the code protection feature on Microchip devices:**

- 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.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as "unbreakable."

Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

---

Information contained in this publication regarding device applications and the like is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION, INCLUDING BUT NOT LIMITED TO ITS CONDITION, QUALITY, PERFORMANCE, MERCHANTABILITY OR FITNESS FOR PURPOSE. Microchip disclaims all liability arising from this information and its use. Use of Microchip's products as critical components in life support systems is not authorized except with express written approval by Microchip. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights.

**Trademarks**

The Microchip name and logo, the Microchip logo, Accuron, dsPIC, KEELoQ, microID, MPLAB, PIC, PICmicro, PICSTART, PRO MATE, PowerSmart, rfPIC, and SmartShunt are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.


AmpLab, FilterLab, MXDEV, MXLAB, PICMASTER, SEEVAL, SmartSensor and The Embedded Control Solutions Company are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Analog-for-the-Digital Age, Application Maestro, dsPICDEM, dsPICDEM.net, dsPICworks, ECAN, ECONOMONITOR, FanSense, FlexROM, fuzzyLAB, In-Circuit Serial Programming, ICSP, ICEPIC, Migratable Memory, MPASM, MPLIB, MPLINK, MPSIM, PICkit, PICDEM, PICDEM.net, PICLAB, PICtail, PowerCal, PowerInfo, PowerMate, PowerTool, rLAB, rfPICDEM, Select Mode, Smart Serial, SmartTel and Total Endurance are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

All other trademarks mentioned herein are property of their respective companies.

© 2005, Microchip Technology Incorporated, Printed in the U.S.A., All Rights Reserved.

 Printed on recycled paper.

**QUALITY MANAGEMENT SYSTEM**  
**CERTIFIED BY DNV**  
**== ISO/TS 16949:2002 ==**

*Microchip received ISO/TS-16949:2002 quality system certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona and Mountain View, California in October 2003. The Company's quality system processes and procedures are for its PICmicro® 8-bit MCUs, KEELoQ® code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001:2000 certified.*



---

---

## WORLDWIDE SALES AND SERVICE

---

---

### AMERICAS

**Corporate Office**  
2355 West Chandler Blvd.  
Chandler, AZ 85224-6199  
Tel: 480-792-7200  
Fax: 480-792-7277  
Technical Support:  
<http://support.microchip.com>  
Web Address:  
[www.microchip.com](http://www.microchip.com)

**Atlanta**  
Alpharetta, GA  
Tel: 770-640-0034  
Fax: 770-640-0307

**Boston**  
Westford, MA  
Tel: 978-692-3848  
Fax: 978-692-3821

**Chicago**  
Itasca, IL  
Tel: 630-285-0071  
Fax: 630-285-0075

**Dallas**  
Addison, TX  
Tel: 972-818-7423  
Fax: 972-818-2924

**Detroit**  
Farmington Hills, MI  
Tel: 248-538-2250  
Fax: 248-538-2260

**Kokomo**  
Kokomo, IN  
Tel: 765-864-8360  
Fax: 765-864-8387

**Los Angeles**  
Mission Viejo, CA  
Tel: 949-462-9523  
Fax: 949-462-9608

**San Jose**  
Mountain View, CA  
Tel: 650-215-1444  
Fax: 650-961-0286

**Toronto**  
Mississauga, Ontario,  
Canada  
Tel: 905-673-0699  
Fax: 905-673-6509

### ASIA/PACIFIC

**Australia - Sydney**  
Tel: 61-2-9868-6733  
Fax: 61-2-9868-6755

**China - Beijing**  
Tel: 86-10-8528-2100  
Fax: 86-10-8528-2104

**China - Chengdu**  
Tel: 86-28-8676-6200  
Fax: 86-28-8676-6599

**China - Fuzhou**  
Tel: 86-591-8750-3506  
Fax: 86-591-8750-3521

**China - Hong Kong SAR**  
Tel: 852-2401-1200  
Fax: 852-2401-3431

**China - Shanghai**  
Tel: 86-21-5407-5533  
Fax: 86-21-5407-5066

**China - Shenyang**  
Tel: 86-24-2334-2829  
Fax: 86-24-2334-2393

**China - Shenzhen**  
Tel: 86-755-8203-2660  
Fax: 86-755-8203-1760

**China - Shunde**  
Tel: 86-757-2839-5507  
Fax: 86-757-2839-5571

**China - Qingdao**  
Tel: 86-532-502-7355  
Fax: 86-532-502-7205

### ASIA/PACIFIC

**India - Bangalore**  
Tel: 91-80-2229-0061  
Fax: 91-80-2229-0062

**India - New Delhi**  
Tel: 91-11-5160-8631  
Fax: 91-11-5160-8632

**Japan - Kanagawa**  
Tel: 81-45-471- 6166  
Fax: 81-45-471-6122

**Korea - Seoul**  
Tel: 82-2-554-7200  
Fax: 82-2-558-5932 or  
82-2-558-5934

**Singapore**  
Tel: 65-6334-8870  
Fax: 65-6334-8850

**Taiwan - Kaohsiung**  
Tel: 886-7-536-4818  
Fax: 886-7-536-4803

**Taiwan - Taipei**  
Tel: 886-2-2500-6610  
Fax: 886-2-2508-0102

**Taiwan - Hsinchu**  
Tel: 886-3-572-9526  
Fax: 886-3-572-6459

### EUROPE

**Austria - Weis**  
Tel: 43-7242-2244-399  
Fax: 43-7242-2244-393

**Denmark - Ballerup**  
Tel: 45-4450-2828  
Fax: 45-4485-2829

**France - Massy**  
Tel: 33-1-69-53-63-20  
Fax: 33-1-69-30-90-79

**Germany - Ismaning**  
Tel: 49-89-627-144-0  
Fax: 49-89-627-144-44

**Italy - Milan**  
Tel: 39-0331-742611  
Fax: 39-0331-466781

**Netherlands - Drunen**  
Tel: 31-416-690399  
Fax: 31-416-690340

**England - Berkshire**  
Tel: 44-118-921-5869  
Fax: 44-118-921-5820