

## 20 $\mu$ A, 300 kHz Rail-to-Rail Op Amp

### Features

- Gain Bandwidth Product: 300 kHz (typ.)
- Supply Current:  $I_Q = 20 \mu\text{A}$  (typ.)
- Supply Voltage: 1.8V to 5.5V
- Rail-to-Rail Input/Output
- Extended Temperature Range:  $-40^\circ\text{C}$  to  $+125^\circ\text{C}$
- Available in 5-Pin SC-70 and SOT-23 packages

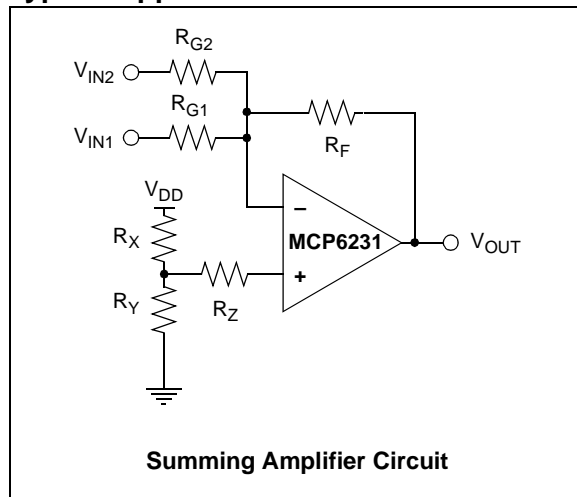
### Applications

- Automotive
- Portable Equipment
- Transimpedance amplifiers
- Analog Filters
- Notebooks and PDAs
- Battery-Powered Systems

### Available Tools

- SPICE Macro Models (at [www.microchip.com](http://www.microchip.com))
- FilterLab<sup>®</sup> Software (at [www.microchip.com](http://www.microchip.com))

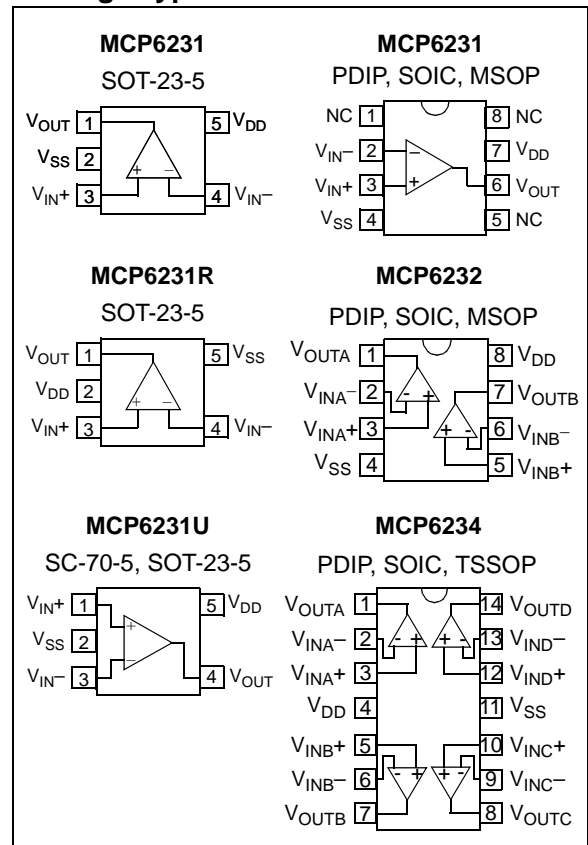
### Typical Application



### Description

The Microchip Technology Inc. MCP6231/2/4 operational amplifiers (op amps) provide wide bandwidth for the quiescent current. The MCP6231/2/4 family has a 300 kHz Gain Bandwidth Product (GBWP) and  $65^\circ$  (typ.) phase margin. This family operates from a single supply voltage as low as 1.8V, while drawing 20  $\mu\text{A}$  (typ.) quiescent current. In addition, the MCP6231/2/4 family supports rail-to-rail input and output swing, with a common mode input voltage range of  $V_{DD} + 300 \text{ mV}$  to  $V_{SS} - 300 \text{ mV}$ . These op amps are designed in one of Microchip's advanced CMOS processes.

### Package Types



# MCP6231/2/4

## 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 $+150^{\circ}\text{C}$
Junction Temperature ( $T_J$ ).....	$+150^{\circ}\text{C}$
ESD Protection On All Pins (HBM;MM) .....	$\geq 4$ kV; 300V

† **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.

### DC ELECTRICAL CHARACTERISTICS

Electrical Characteristics: Unless otherwise indicated, $T_A = +25^{\circ}\text{C}$ , $V_{DD} = +1.8\text{V}$ to $+5.5\text{V}$ , $V_{SS} = \text{GND}$ , $V_{CM} = V_{DD}/2$ , $R_L = 100\text{ k}\Omega$ 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	$V_{OS}$	-5.0	—	+5.0	mV	$V_{CM} = V_{SS}$
Extended Temperature	$V_{OS}$	-7.0	—	+7.0	mV	$T_A = -40^{\circ}\text{C}$ to $+125^{\circ}\text{C}$ , $V_{CM} = V_{SS}$ ( <b>Note</b> )
Input Offset Drift with Temperature	$\Delta V_{OS}/\Delta T_A$	—	$\pm 3.0$	—	$\mu\text{V}/^{\circ}\text{C}$	$T_A = -40^{\circ}\text{C}$ to $+125^{\circ}\text{C}$ , $V_{CM} = V_{SS}$
Power Supply Rejection Ratio	PSRR	—	83	—	dB	$V_{CM} = V_{SS}$
<b>Input Bias Current and Impedance</b>						
Input Bias Current:	$I_B$	—	$\pm 1.0$	—	pA	
At Temperature	$I_B$	—	20	—	pA	$T_A = +85^{\circ}\text{C}$
At 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	61	75	—	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)	$A_{OL}$	90	110	—	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	$V_{OL}, V_{OH}$	$V_{SS} + 35$	—	$V_{DD} - 35$	mV	$R_L = 10\text{ k}\Omega$ , 0.5V Output Overdrive
Output Short-Circuit Current	$I_{SC}$	—	$\pm 6$	—	mA	$V_{DD} = 1.8\text{V}$
	$I_{SC}$	—	$\pm 23$	—	mA	$V_{DD} = 5.5\text{V}$
<b>Power Supply</b>						
Supply Voltage	$V_{DD}$	1.8	—	5.5	V	
Quiescent Current per Amplifier	$I_Q$	10	20	30	$\mu\text{A}$	$I_O = 0$ , $V_{CM} = V_{DD} - 0.5\text{V}$

**Note:** The SC-70 package is only tested at  $+25^{\circ}\text{C}$ .

## AC ELECTRICAL CHARACTERISTICS

**Electrical Characteristics:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.8$  to  $5.5\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $R_L = 100\text{ k}\Omega$  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	—	300	—	kHz	
Phase Margin	PM	—	65	—	°	G = +1
Slew Rate	SR	—	0.15	—	V/ $\mu\text{s}$	
<b>Noise</b>						
Input Noise Voltage	$E_{ni}$	—	6.0	—	$\mu\text{V}_{P-P}$	f = 0.1 Hz to 10 Hz
Input Noise Voltage Density	$e_{ni}$	—	52	—	nV/ $\sqrt{\text{Hz}}$	f = 1 kHz
Input Noise Current Density	$i_{ni}$	—	0.6	—	fA/ $\sqrt{\text{Hz}}$	f = 1 kHz

## TEMPERATURE CHARACTERISTICS

**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>						
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-MSOP	$\theta_{JA}$	—	206	—	°C/W	
Thermal Resistance, 8L-PDIP	$\theta_{JA}$	—	85	—	°C/W	
Thermal Resistance, 8L-SOIC	$\theta_{JA}$	—	163	—	°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	

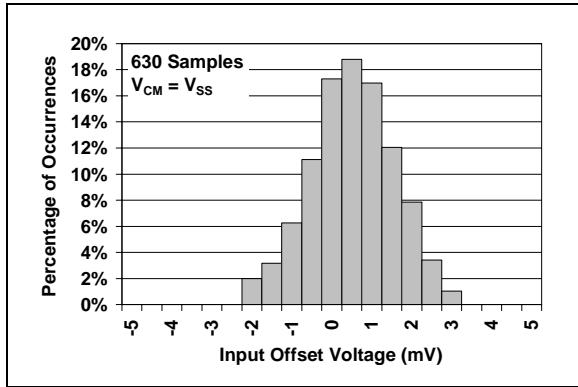
**Note:** The internal Junction Temperature ( $T_J$ ) must not exceed the Absolute Maximum specification of  $+150^\circ\text{C}$ .

# MCP6231/2/4

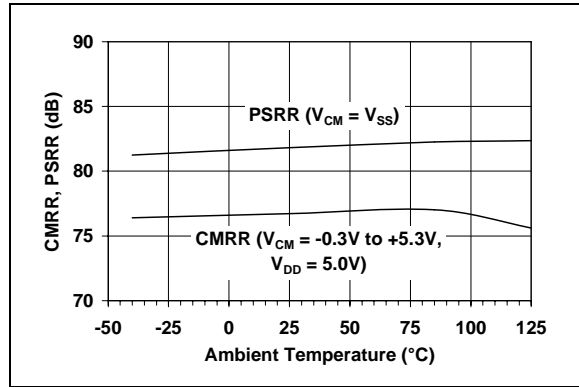
## 2.0 TYPICAL PERFORMANCE CURVES

**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.

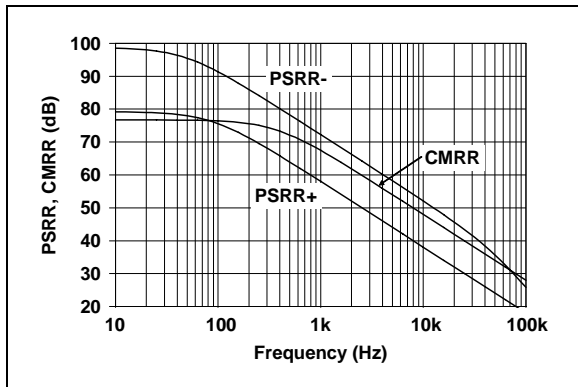
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.8\text{V}$  to  $+5.5\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $R_L = 100\text{ k}\Omega$  to  $V_{DD}/2$  and  $C_L = 60\text{ pF}$ .



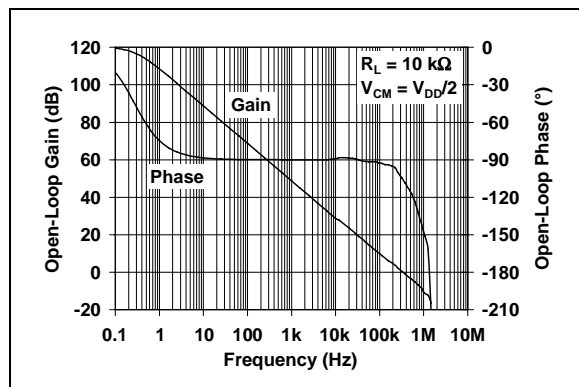
**FIGURE 2-1:** Input Offset Voltage.



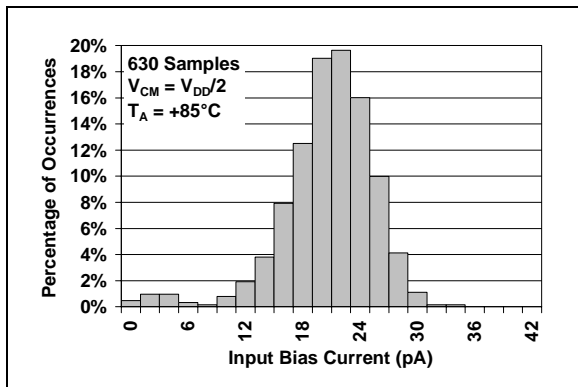
**FIGURE 2-4:** CMRR, PSRR vs. Ambient Temperature.



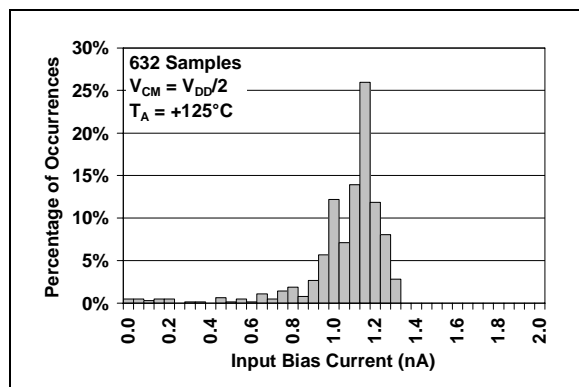
**FIGURE 2-2:** PSRR, CMRR vs. Frequency.



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

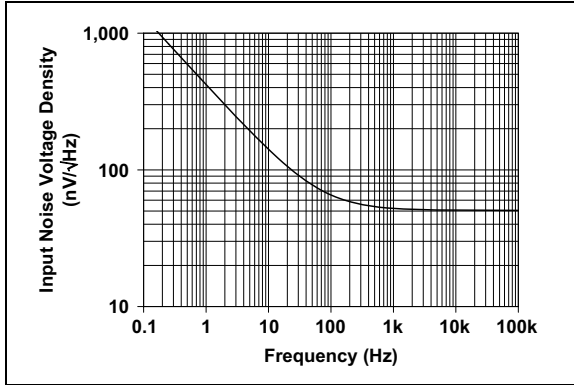


**FIGURE 2-3:** Input Bias Current at  $+85^\circ\text{C}$ .

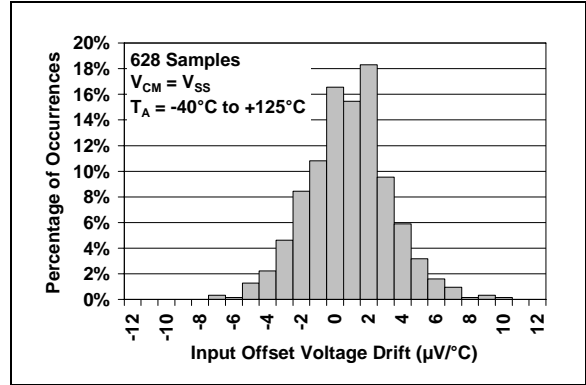


**FIGURE 2-6:** Input Bias Current at  $+125^\circ\text{C}$ .

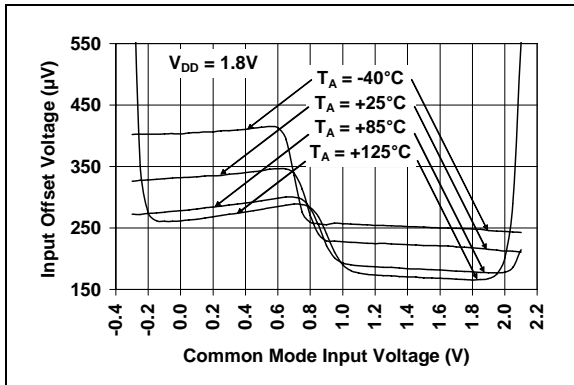
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.8\text{V}$  to  $+5.5\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $R_L = 100\text{ k}\Omega$  to  $V_{DD}/2$  and  $C_L = 60\text{ pF}$ .



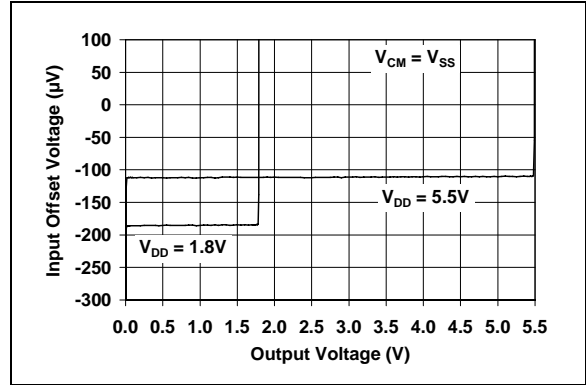
**FIGURE 2-7:** Input Noise Voltage Density vs. Frequency.



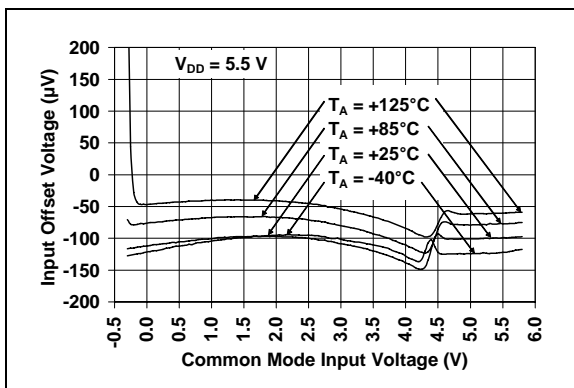
**FIGURE 2-10:** Input Offset Voltage Drift.



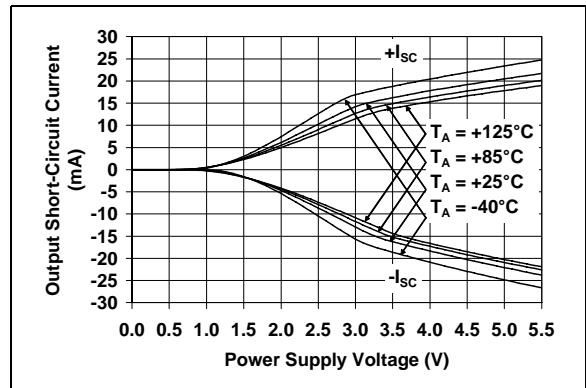
**FIGURE 2-8:** Input Offset Voltage vs. Common Mode Input Voltage at  $V_{DD} = 1.8\text{V}$ .



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



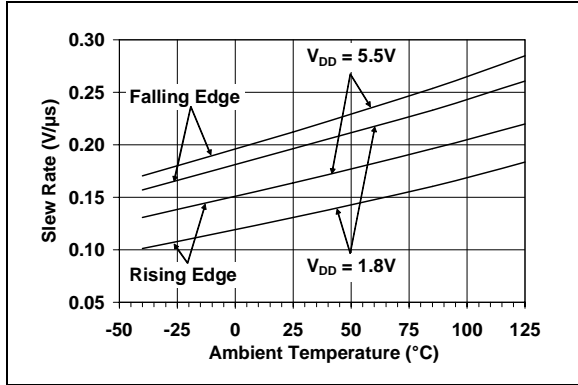
**FIGURE 2-9:** Input Offset Voltage vs. Common Mode Input Voltage at  $V_{DD} = 5.5\text{V}$ .



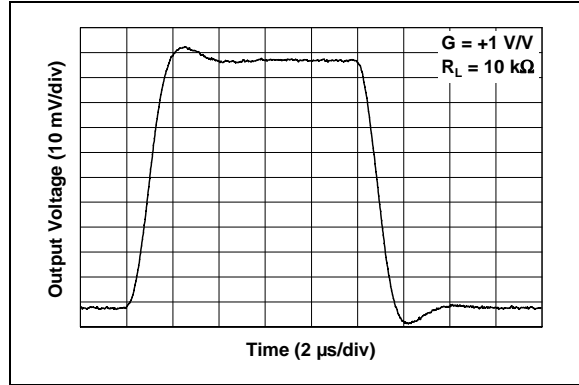
**FIGURE 2-12:** Output Short-Circuit Current vs. Ambient Temperature.

# MCP6231/2/4

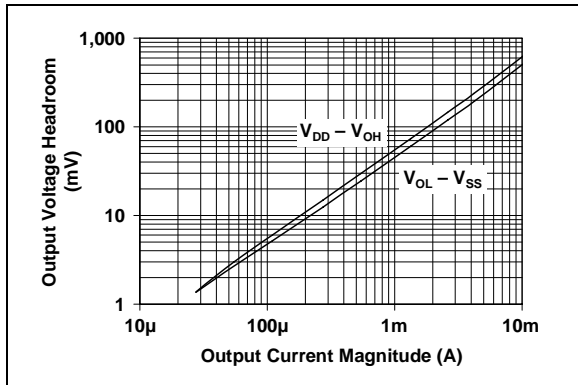
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.8\text{V}$  to  $+5.5\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $R_L = 100\text{ k}\Omega$  to  $V_{DD}/2$  and  $C_L = 60\text{ pF}$ .



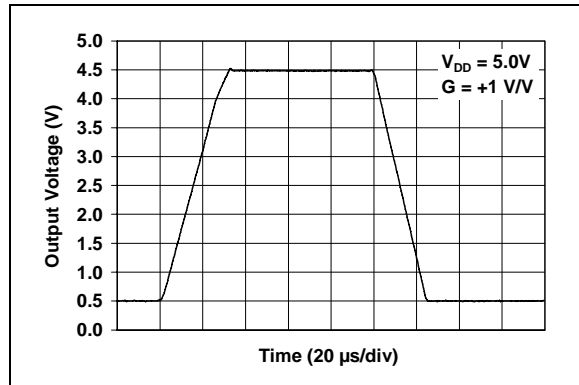
**FIGURE 2-13:** Slew Rate vs. Ambient Temperature.



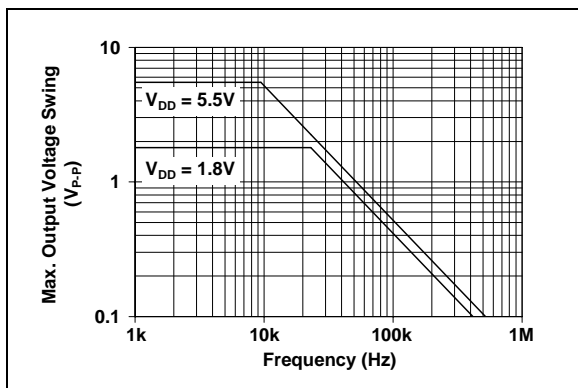
**FIGURE 2-16:** Small-Signal, Non-Inverting Pulse Response.



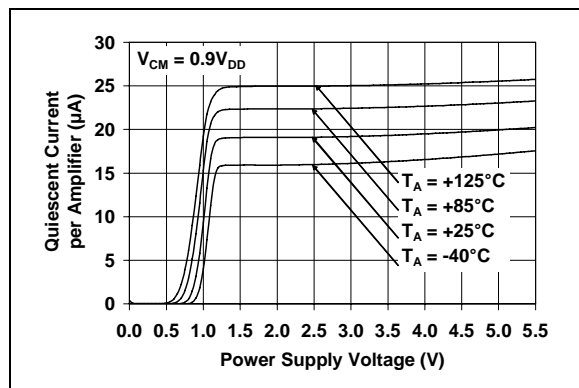
**FIGURE 2-14:** Output Voltage Headroom vs. Output Current Magnitude.



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



**FIGURE 2-15:** Maximum 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 (single op amps) and Table 3-2 (dual and quad op amps).

**TABLE 3-1: PIN FUNCTION TABLE FOR SINGLE OP AMPS**

MCP6231 (PDIP, SOIC, MSOP)	MCP6231 (SOT-23-5)	MCP6231R (SOT-23-5)	MCP6231U (SOT-23-5)	Symbol	Description
6	1	1	4	$V_{OUT}$	Analog Output
2	4	4	3	$V_{IN-}$	Inverting Input
3	3	3	1	$V_{IN+}$	Non-inverting Input
7	5	2	5	$V_{DD}$	Positive Power Supply
4	2	5	2	$V_{SS}$	Negative Power Supply
1, 5, 8	—	—	—	NC	No Internal Connection

**TABLE 3-2: PIN FUNCTION TABLE FOR DUAL AND QUAD OP AMPS**

MCP6232	MCP6234	Symbol	Description
1	1	$V_{OUTA}$	Analog Output (op amp A)
2	2	$V_{INA-}$	Inverting Input (op amp A)
3	3	$V_{INA+}$	Non-inverting Input (op amp A)
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)
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 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 (typically 1  $\mu$ F to 100  $\mu$ F) with other nearby analog parts; it needs to be within 100 mm of the  $V_{DD}$  pin.

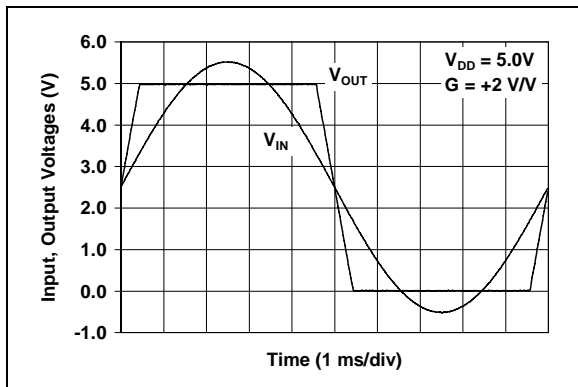
# MCP6231/2/4

## 4.0 APPLICATION INFORMATION

The MCP6231/2/4 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 MCP6231/2/4 ideal for battery-powered applications.

### 4.1 Rail-to-Rail Inputs

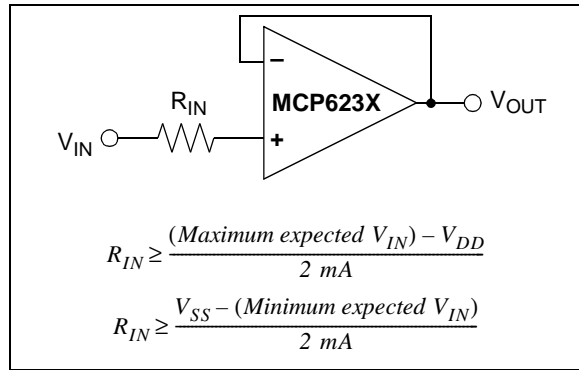
The MCP6231/2/4 op amps are designed to prevent phase reversal when the input pins exceed the supply voltages. Figure 4-1 shows the input voltage exceeding the supply voltage without any phase reversal.



**FIGURE 4-1:** The MCP6231/2/4 Show No Phase Reversal.

The input stage of the MCP6231/2/4 op amps use two differential input stages in parallel. One operates at low common mode input voltage ( $V_{CM}$ ) and the other at high  $V_{CM}$ . With this topology, the device operates with  $V_{CM}$  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. 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 ( $R_{IN}$ ).

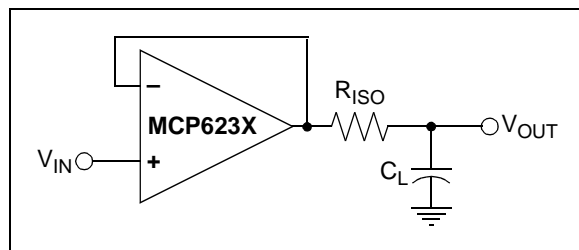
### 4.2 Rail-to-Rail Output

The output voltage range of the MCP6231/2/4 op amps is  $V_{DD} - 35$  mV (max.) and  $V_{SS} + 35$  mV (min.) when  $R_L = 10$  k $\Omega$  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. A unity-gain buffer ( $G = +1$ ) is the most sensitive to capacitive loads, but all gains show the same general behavior.

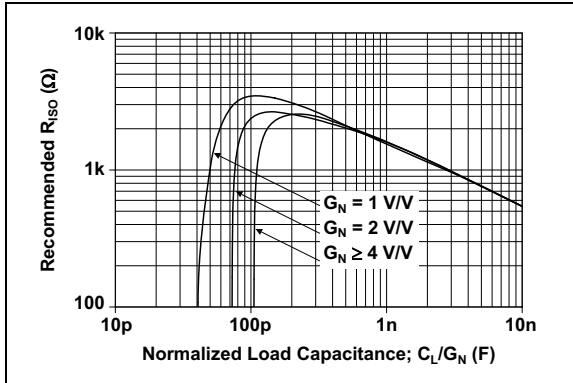
When driving large capacitive loads with these op amps (e.g.,  $> 60$  pF when  $G = +1$ ), a small series resistor at the output ( $R_{ISO}$  in Figure 4-3) improves the feedback loop's phase margin (stability) by making the output load resistive at higher frequencies. The bandwidth will be generally lower than the bandwidth with no capacitive 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.

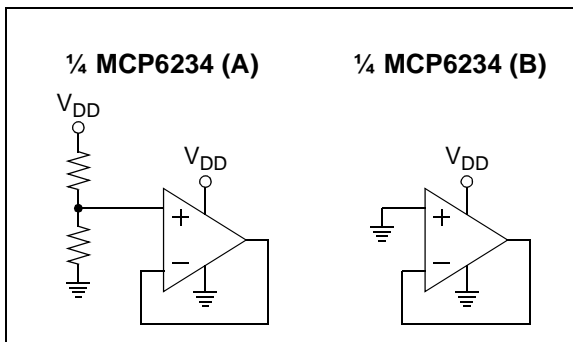
After selecting  $R_{ISO}$  for your circuit, double-check the resulting frequency response peaking and step response overshoot. Evaluation on the bench and simulations with the MCP6231/2/4 SPICE macro model are very helpful. Modify  $R_{ISO}$ 's value until the response is reasonable.

#### 4.4 Supply Bypass

With this op amp, 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 can use 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 nearby analog parts.

#### 4.5 Unused Op Amps

An unused op amp in a quad package (MCP6234) should be configured as shown in Figure 4-5. Both circuits prevent the output from toggling and causing crosstalk. Circuit A can use any reference voltage between the supplies, provides a buffered DC voltage and minimizes the supply current draw of the unused op amp. Circuit B minimizes the number of components, but may draw a little more supply current for the unused op amp.

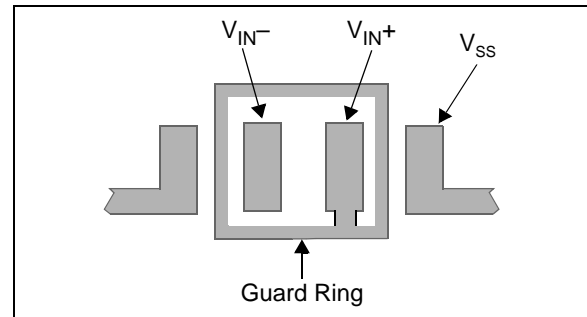


**FIGURE 4-5:** Unused Op Amps.

#### 4.6 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 MCP6231/2/4 family's bias current at 25°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 4-6.



**FIGURE 4-6:** Example Guard Ring Layout for Inverting Gain.

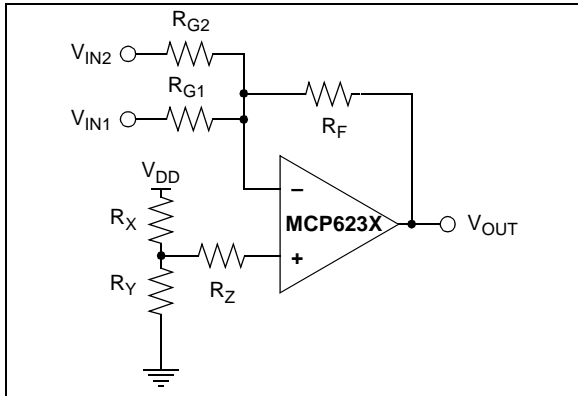
1. Non-inverting Gain and Unity-Gain Buffer:
  - a. Connect the non-inverting pin ( $V_{IN+}$ ) to the input with a wire that does not touch the PCB surface.
  - b. Connect the guard ring to the inverting input pin ( $V_{IN-}$ ). This biases the guard ring to the common mode input voltage.
2. Inverting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

# MCP6231/2/4

## 4.7 Application Circuits

### 4.7.1 MATCHING THE IMPEDANCE AT THE INPUTS

To minimize the effect of input bias current in an amplifier circuit (this is important for very high source-impedance applications, such as pH meters and transimpedance amplifiers), the impedances at the inverting and non-inverting inputs need to be matched. This is done by choosing the circuit resistor values so that the total resistance at each input is the same. Figure 4-7 shows a summing amplifier circuit.



**FIGURE 4-7:** Summing Amplifier Circuit.

To match the inputs, set all voltage sources to ground and calculate the total resistance at the input nodes. In this summing amplifier circuit, the resistance at the inverting input is calculated by setting  $V_{IN1}$ ,  $V_{IN2}$  and  $V_{OUT}$  to ground. In this case,  $R_{G1}$ ,  $R_{G2}$  and  $R_F$  are in parallel. The total resistance at the inverting input is:

$$R_{IN}^- = \frac{1}{\left(\frac{1}{R_{G1}} + \frac{1}{R_{G2}} + \frac{1}{R_F}\right)}$$

Where:  
 $R_{VIN}^-$  = total resistance at the inverting input

At the non-inverting input,  $V_{DD}$  is the only voltage source. When  $V_{DD}$  is set to ground, both  $R_X$  and  $R_Y$  are in parallel. The total resistance at the non-inverting input is:

$$R_{VIN}^+ = \frac{1}{\left(\frac{1}{R_X} + \frac{1}{R_Y}\right)} + R_Z$$

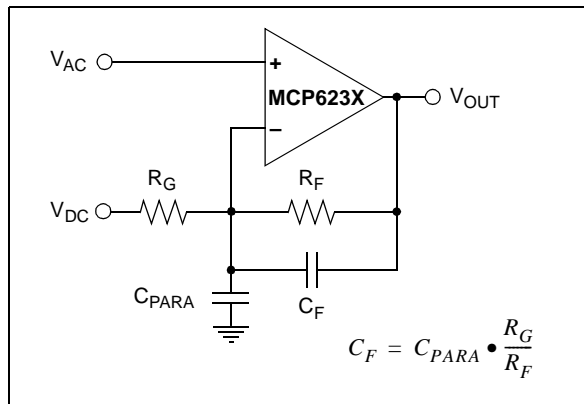
Where:  
 $R_{VIN}^+$  = total resistance at the inverting input

To minimize output offset voltage and increase circuit accuracy, the resistor values need to meet the conditions:

$$R_{VIN}^+ = R_{IN}^-$$

### 4.7.2 COMPENSATING FOR THE PARASITIC CAPACITANCE

In analog circuit design, the PCB parasitic capacitance can compromise the circuit behavior; Figure 4-8 shows a typical scenario. If the input of an amplifier sees parasitic capacitance of several picofarad ( $C_{PARA}$ , which includes the common mode capacitance of 6 pF, typ.), and large  $R_F$  and  $R_G$ , the frequency response of the circuit will include a zero. This parasitic zero introduces gain-peaking and can cause circuit instability.



**FIGURE 4-8:** Effect of Parasitic Capacitance at the Input.

One solution is to use smaller resistor values to push the zero to a higher frequency. Another solution is to compensate by introducing a pole at the point at which the zero occurs. This can be done by adding  $C_F$  in parallel with the feedback resistor ( $R_F$ ).  $C_F$  needs to be selected so that the ratio  $C_{PARA}:C_F$  is equal to the ratio of  $R_F:R_G$ .

## 5.0 DESIGN TOOLS

Microchip provides the basic design tools needed for the MCP6231/2/4 family of op amps.

### 5.1 SPICE Macro Model

The latest SPICE macro model for the MCP6231/2/4 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 macro 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

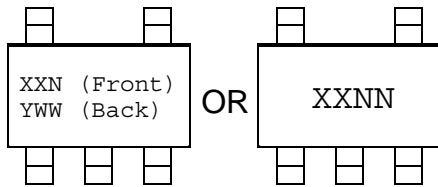
Microchip's FilterLab software is an innovative tool that simplifies analog active-filter (using op amps) design. Available at no cost from our web site at [www.microchip.com](http://www.microchip.com), the FilterLab design tool provides full schematic diagrams of the filter circuit with component values.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

# MCP6231/2/4

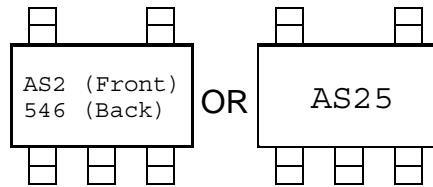
## 6.0 PACKAGING INFORMATION

### 6.1 Package Marking Information

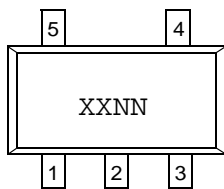
5-Lead SC-70 (MCP6231U Only)



Example:



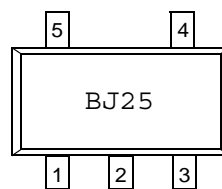
5-Lead SOT-23



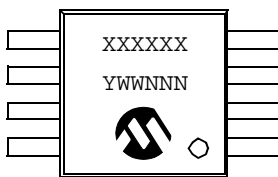
Device	Code
MCP6231	BJNN
MCP6231R	BKNN
MCP6231U	BLNN

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

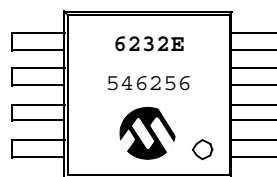
Example:



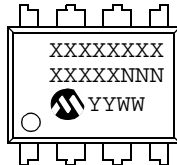
8-Lead MSOP



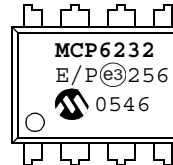
Example:



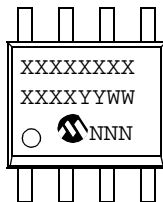
8-Lead PDIP (300 mil)



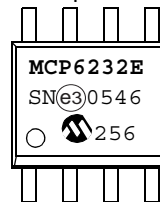
Example:



8-Lead SOIC (150 mil)



Example:

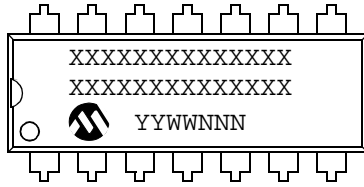


<b>Legend:</b>	XX...X	Customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week '01')
	NNN	Alphanumeric traceability code
	(e3)	Pb-free JEDEC designator for Matte Tin (Sn)
	*	This package is Pb-free.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

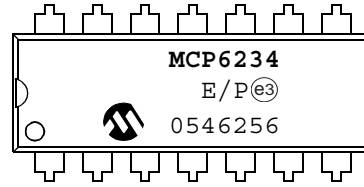
**Note:** In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information.

## Package Marking Information (Continued)

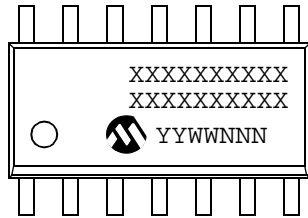
14-Lead PDIP (300 mil) (MCP6234)



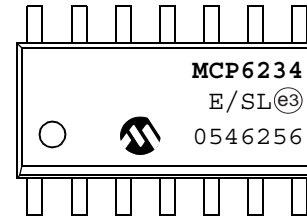
Example:



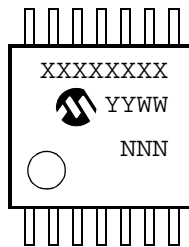
14-Lead SOIC (150 mil) (MCP6234)



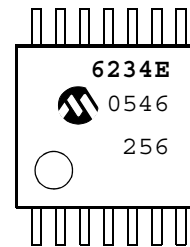
Example:



14-Lead TSSOP (MCP6234)

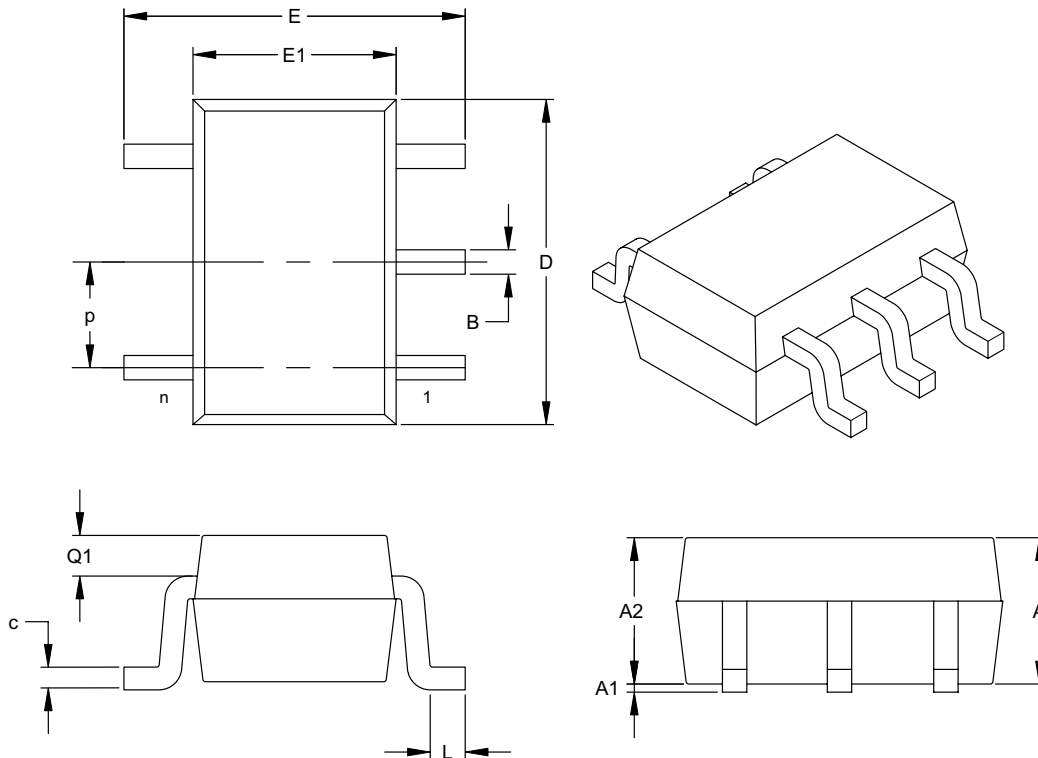


Example:



# MCP6231/2/4

## 5-Lead Small Outline Transistor 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

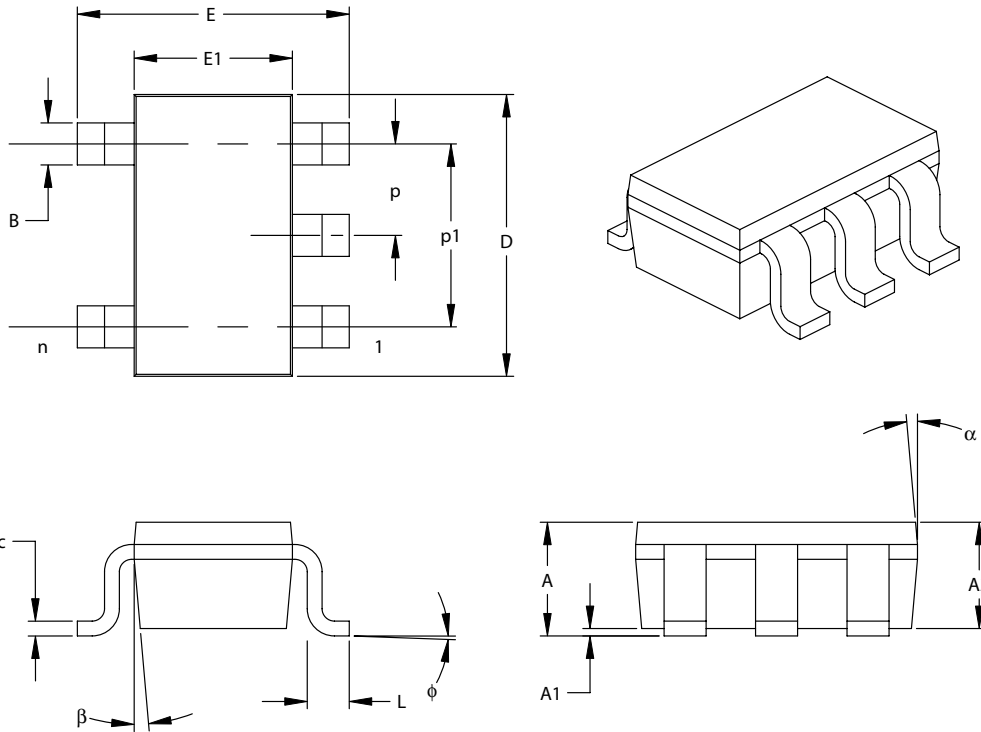
Notes:

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

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



Dimension Limits	Units	INCHES*			MILLIMETERS		
		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

Notes:

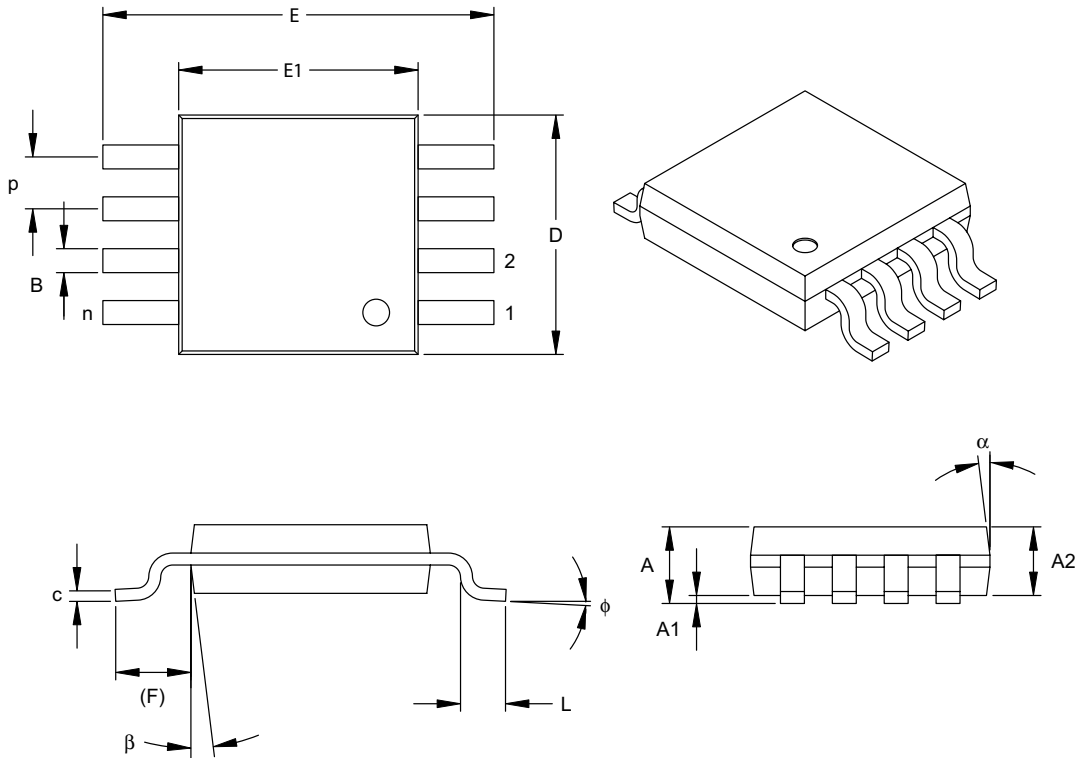
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .005" (0.127mm) per side.

EIAJ Equivalent: SC-74A

Drawing No. C04-091

# MCP6231/2/4

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



Dimension Limits	Units	INCHES			MILLIMETERS*		
		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	φ	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	α	5°	-	15°	5°	-	15°
Mold Draft Angle Bottom	β	5°	-	15°	5°	-	15°

\*Controlling Parameter

Notes:

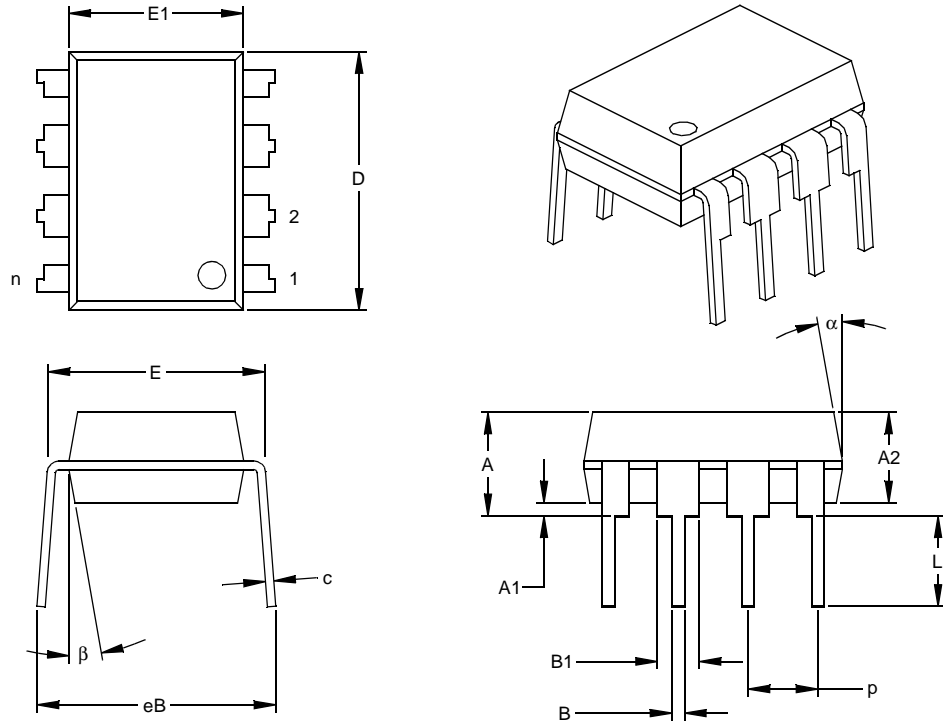
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.

JEDEC Equivalent: MO-187

Drawing No. C04-111



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



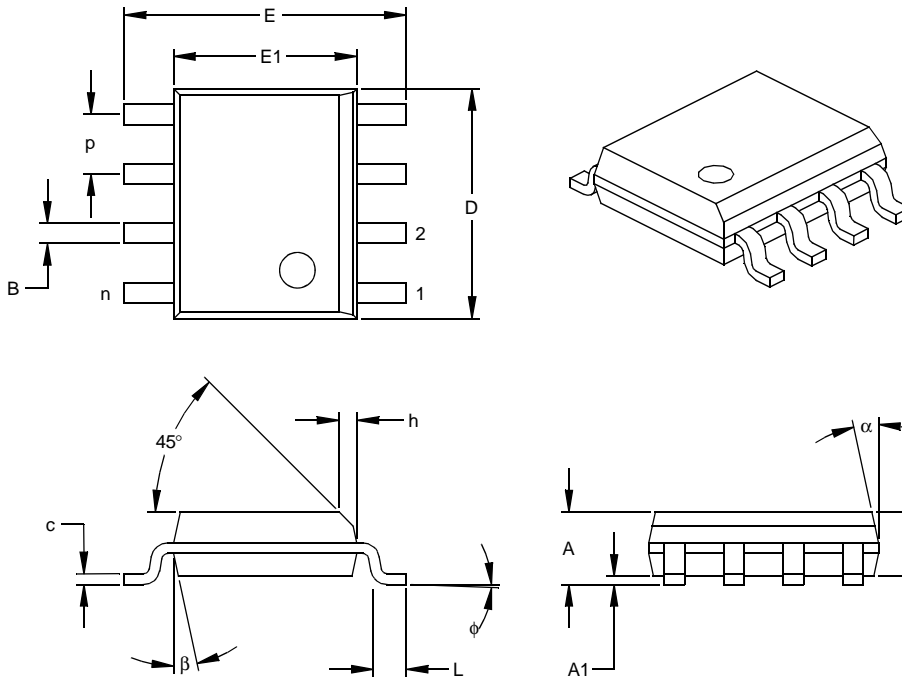
Dimension Limits	Units	INCHES*			MILLIMETERS		
		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		8			8	
Pitch	p		.100			2.54	
Top to Seating Plane	A	.140	.155	.170	3.56	3.94	4.32
Molded Package Thickness	A2	.115	.130	.145	2.92	3.30	3.68
Base to Seating Plane	A1	.015			0.38		
Shoulder to Shoulder Width	E	.300	.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

# MCP6231/2/4

## 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

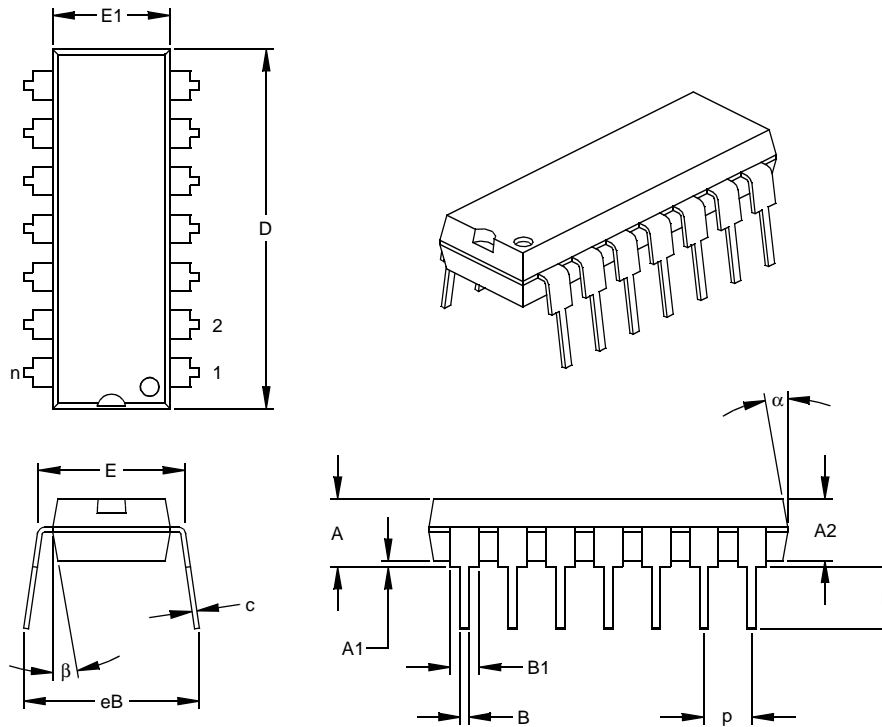
Notes:

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

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



Units		INCHES*			MILLIMETERS		
Dimension Limits		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:

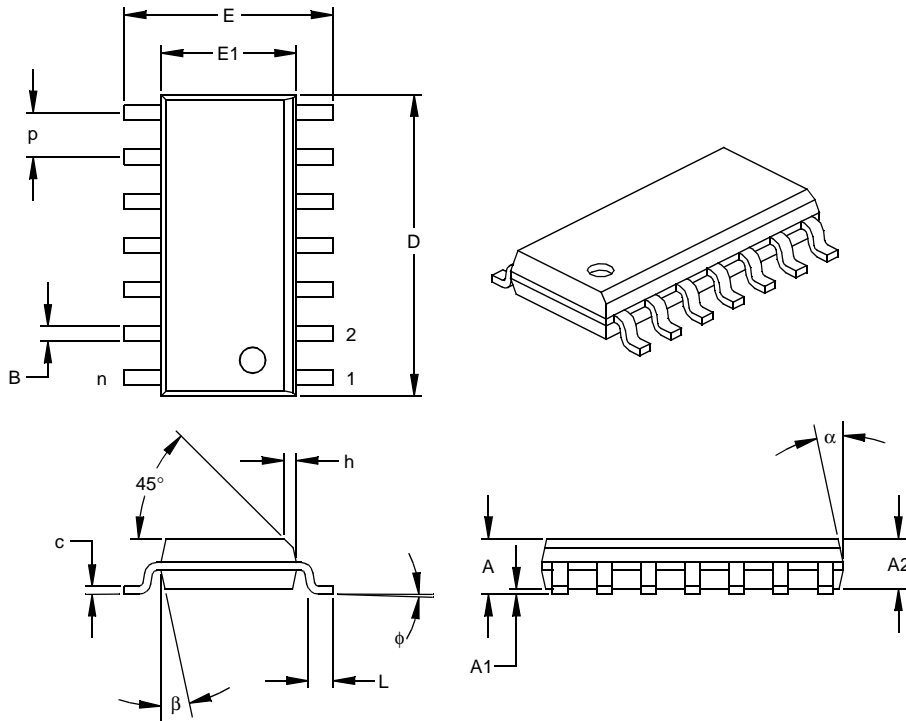
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.

JEDEC Equivalent: MS-001

Drawing No. C04-005

# MCP6231/2/4

## 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

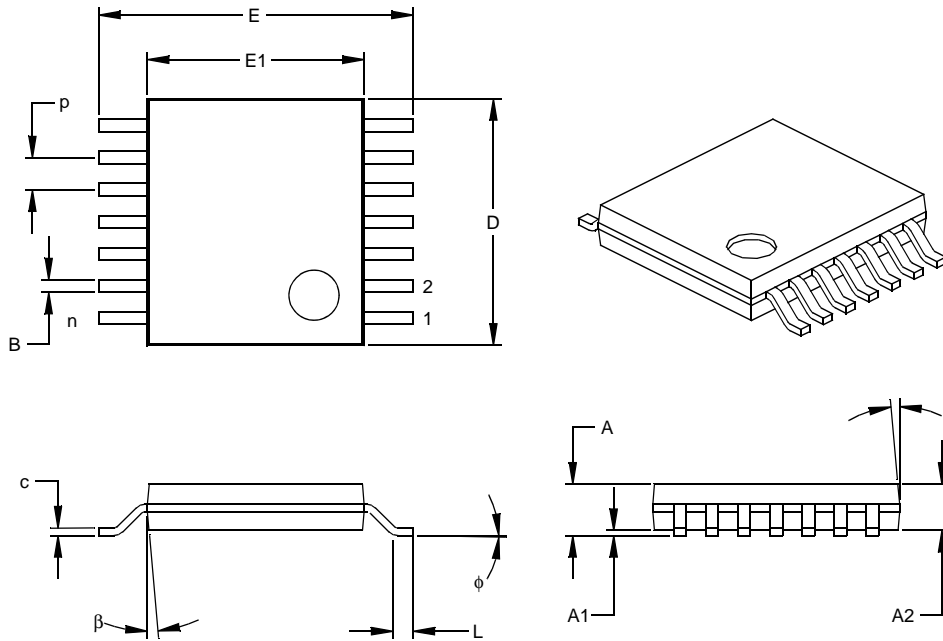
Notes:

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

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



Units		INCHES			MILLIMETERS*		
Dimension	Limits	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

# MCP6231/2/4

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NOTES:

## APPENDIX A: REVISION HISTORY

### Revision C (March 2005)

The following is the list of modifications:

1. Added the MCP6234 quad op amp.
2. Corrected plots in **Section 2.0 “Typical Performance Curves”**.
3. Added **Section 3.0 “Pin Descriptions”**.
4. Added new SC-70 package markings. Added PDIP-14, SOIC-14, and TSSOP-14 packages and corrected package marking information (**Section 6.0 “Packaging Information”**).
5. Added **Appendix A: “Revision History”**.

### Revision B (August 2004)

### Revision A (March 2004)

- Original Release of this Document.

# MCP6231/2/4

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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>-X</u>	<u>/XX</u>
Device	Tape and Reel and/or Alternate Pinout	Temperature Range	Package
Device:	MCP6231: MCP6231T:	Single Op Amp (MSOP, PDIP, SOIC) Single Op Amp (Tape and Reel) (MSOP, SOIC, SOT-23)	
	MCP6231RT:	Single Op Amp (Tape and Reel) (SOT-23)	
	MCP6231UT:	Single Op Amp (Tape and Reel) (SC-70, SOT-23)	
	MCP6232: MCP6232T:	Dual Op Amp Dual Op Amp (Tape and Reel) (MSOP, SOIC)	
	MCP6234: MCP6234T:	Quad Op Amp Quad Op Amp (Tape and Reel) (TSSOP, SOIC)	
Temperature Range:	E	= -40°C to +125°C	
Package:	LT	= Plastic Package (SC-70), 5-lead (MCP6231U only)	
	MS	= Plastic Micro Small Outline (MSOP), 8-lead	
	P	= Plastic DIP (300 mil Body), 8-lead, 14-lead	
	OT	= Plastic Small Outline Transistor (SOT-23), 5-lead (MCP6231, MCP6231R, MCP6231U)	
	SN	= Plastic SOIC (150 mil Body), 8-lead	
	SL	= Plastic SOIC (150 mil Body), 14-lead	
	ST	= Plastic TSSOP (4.4 mil Body), 14-lead	
<b>Examples:</b>			
a)	MCP6231-E/SN:	Extended Temp., 8LD SOIC package.	
b)	MCP6231-E/MS:	Extended Temp., 8LD MSOP package.	
c)	MCP6231-E/P:	Extended Temp., 8LD PDIP package.	
d)	MCP6231RT-E/OT:	Tape and Reel, Extended Temp., 5LD SOT-23 package	
e)	MCP6231UT-E/OT:	Tape and Reel, Extended Temp., 5LD SOT-23 package.	
f)	MCP6231UT-E/LT:	Tape and Reel, Extended Temp., 5LD SC-70 package.	
a)	MCP6232-E/SN:	Extended Temp., 8LD SOIC package.	
b)	MCP6232-E/MS:	Extended Temp., 8LD MSOP package.	
c)	MCP6232-E/P:	Extended Temp., 8LD PDIP package.	
d)	MCP6232T-E/SN:	Tape and Reel, Extended Temp., 8LD SOIC package.	
a)	MCP6234-E/P:	Extended Temp., 14LD PDIP package.	
b)	MCP6234-E/SL:	Extended Temp., 14LD SOIC package.	
c)	MCP6234-E/ST:	Extended Temp., 14LD TSSOP package.	
d)	MCP6234T-E/SL:	Tape and Reel, Extended Temp., 14LD SOIC package.	
e)	MCP6234T-E/ST:	Tape and Reel, Extended Temp., 14LD TSSOP package.	

# MCP6231/2/4

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NOTES:

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- Microchip products meet the specification contained in their particular Microchip Data Sheet.
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