

# MICROCHIP MCP6L01/1R/1U/2/4

## 1 MHz, 85 $\mu$ A Op Amps

### Features

- Available in SC-70-5 and SOT-23-5 packages
- Gain Bandwidth Product: 1 MHz (typical)
- Rail-to-Rail Input/Output
- Supply Voltage: 1.8V to 6.0V
- Supply Current:  $I_Q = 85 \mu\text{A}/\text{amplifier}$  (typical)
- Extended Temperature Range:  $-40^\circ\text{C}$  to  $+125^\circ\text{C}$
- Available in Single, Dual and Quad Packages

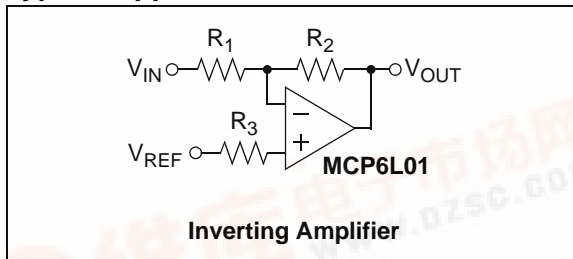
### Typical Applications

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

### Design Aids

- FilterLab<sup>®</sup> Software
- Microchip Advanced Part Selector (MAPS)
- Analog Demonstration and Evaluation Boards
- Application Notes

### Typical Application

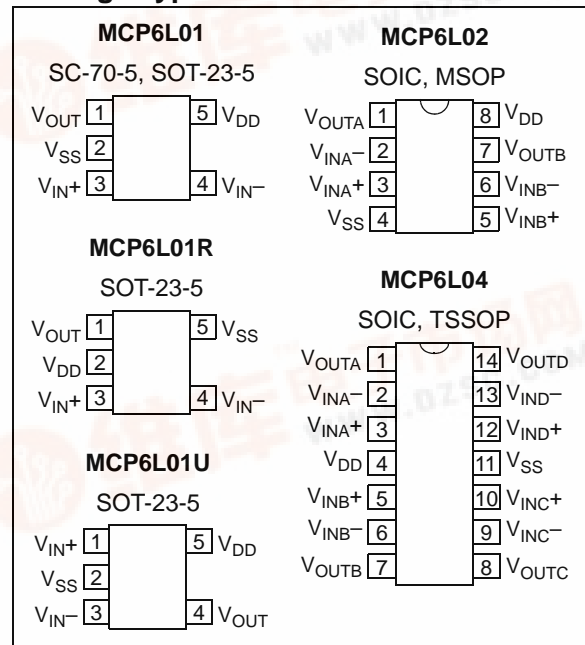


### Description

The Microchip Technology Inc. MCP6L01/1R/1U/2/4 family of operational amplifiers (op amps) supports general-purpose applications. The combination of rail-to-rail input and output, low quiescent current and bandwidth fit into many applications.

This family has a 1 MHz Gain Bandwidth Product (GBWP) and a low 85  $\mu\text{A}$  per amplifier quiescent current. These op amps operate on supply voltages between 1.8V and 6.0V, with rail-to-rail input and output swing. They are available in the extended temperature range.

### Package Types



# MCP6L01/1R/1U/2/4

---

[查询MCP6L02供应商](#)

**NOTES:**

## 1.0 ELECTRICAL CHARACTERISTICS

### 1.1 Absolute Maximum Ratings †

$V_{DD} - V_{SS}$ .....	7.0V
Current at Input Pins .....	$\pm 2$ mA
Analog Inputs ( $V_{IN+}$ , $V_{IN-}$ ) †† .....	$V_{SS} - 1.0V$ to $V_{DD} + 1.0V$
All Inputs and Outputs .....	$V_{SS} - 0.3V$ to $V_{DD} + 0.3V$
Difference Input voltage .....	$ V_{DD} - V_{SS} $
Output Short Circuit Current .....	Continuous
Current at Output and Supply Pins .....	$\pm 150$ mA
Storage Temperature .....	$-65^{\circ}C$ to $+150^{\circ}C$
Max. Junction Temperature .....	$+150^{\circ}C$
ESD protection on all pins (HBM, MM) .....	$\geq 4$ kV, 200V

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

†† See **Section 4.1.2 “Input Voltage and Current Limits”**.

### 1.2 Specifications

**TABLE 1-1: DC ELECTRICAL SPECIFICATIONS**

Electrical Characteristics: Unless otherwise indicated, $T_A = +25^{\circ}C$ , $V_{DD} = 5.0V$ , $V_{SS} = GND$ , $V_{CM} = V_{SS}$ , $V_{OUT} \approx V_{DD}/2$ , $V_L = V_{DD}/2$ , and $R_L = 10$ k $\Omega$ to $V_L$ (refer to <a href="#">Figure 1-1</a> ).						
Parameters	Sym	Min (Note 1)	Typ	Max (Note 1)	Units	Conditions
<b>Input Offset</b>						
Input Offset Voltage	$V_{OS}$	-5	$\pm 1$	+5	mV	
Input Offset Voltage Drift	$\Delta V_{OS}/\Delta T_A$	—	$\pm 2$	—	$\mu V/^{\circ}C$	$T_A = -40^{\circ}C$ to $+125^{\circ}C$
Power Supply Rejection Ratio	PSRR	—	83	—	dB	
<b>Input Current and Impedance</b>						
Input Bias Current Across Temperature Across Temperature	$I_B$	—	2	—	pA	
	$I_B$	—	80	—	pA	$T_A = +85^{\circ}C$
	$I_B$	—	2,000	—	pA	$T_A = +125^{\circ}C$
Input Offset Current	$I_{OS}$	—	$\pm 1$	—	pA	
Common Mode Input Impedance	$Z_{CM}$	—	$10^{13}  5$	—	$\Omega  pF$	
Differential Input Impedance	$Z_{DIFF}$	—	$10^{13}  2$	—	$\Omega  pF$	
<b>Common Mode</b>						
Common-Mode Input Voltage Range	$V_{CMR}$	-0.3	—	5.3	V	
Common-Mode Rejection Ratio	CMRR	—	78	—	dB	$V_{CM} = -0.3V$ to $5.3V$
<b>Open Loop Gain</b>						
DC Open Loop Gain (large signal)	$A_{OL}$	—	105	—	dB	$V_{OUT} = 0.2V$ to $4.8V$
<b>Output</b>						
Maximum Output Voltage Swing	$V_{OL}$	—	—	0.035	V	$G = +2$ , 0.5V Input Overdrive
	$V_{OH}$	4.965	—	—	V	$G = +2$ , 0.5V Input Overdrive
Output Short Circuit Current	$I_{SC}$	—	$\pm 20$	—	mA	
<b>Power Supply</b>						
Supply Voltage	$V_{DD}$	1.8	—	6.0	V	
Quiescent Current per Amplifier	$I_Q$	30	85	170	$\mu A$	$I_O = 0$

**Note 1:** For design guidance only; not tested.

# MCP6L01/1R/1U/2/4

[查询MCP6L02供应商](#)

**TABLE 1-2: AC ELECTRICAL SPECIFICATIONS**

**Electrical Characteristics:** Unless otherwise indicated,  $T_A = 25^\circ\text{C}$ ,  $V_{DD} = +5.0\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{SS}$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_L$  and  $C_L = 60\text{ pF}$  (refer to [Figure 1-1](#)).

Parameters	Sym	Min	Typ	Max	Units	Conditions
<b>AC Response</b>						
Gain Bandwidth Product	GBWP	—	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	—	$\mu\text{V}_{P-P}$	f = 0.1 Hz to 10 Hz
Input Noise Voltage Density	$e_{ni}$	—	24	—	nV/ $\sqrt{\text{Hz}}$	f = 10 kHz
Input Noise Current Density	$i_{ni}$	—	4	—	fA/ $\sqrt{\text{Hz}}$	f = 1 kHz

**TABLE 1-3: TEMPERATURE SPECIFICATIONS**

**Electrical Characteristics:** Unless otherwise indicated, all limits are specified for:  $V_{DD} = +1.8\text{V}$  to  $+6.0\text{V}$ ,  $V_{SS} = \text{GND}$ .

Parameters	Sym	Min	Typ	Max	Units	Conditions
<b>Temperature Ranges</b>						
Specified Temperature Range	$T_A$	-40	—	+125	°C	
Operating Temperature Range	$T_A$	-40	—	+125	°C	(Note 1)
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-SOIC (150 mil)	$\theta_{JA}$	—	163	—	°C/W	
Thermal Resistance, 8L-MSOP	$\theta_{JA}$	—	206	—	°C/W	
Thermal Resistance, 14L-SOIC	$\theta_{JA}$	—	120	—	°C/W	
Thermal Resistance, 14L-TSSOP	$\theta_{JA}$	—	100	—	°C/W	

**Note 1:** Operation must not cause  $T_J$  to exceed Maximum Junction Temperature specification (150°C).

## 1.3 Test Circuit

The circuit used for most DC and AC tests is shown in [Figure 1-1](#). This circuit can independently set  $V_{CM}$  and  $V_{OUT}$ ; see [Equation 1-1](#). Note that  $V_{CM}$  is not the circuit's common mode voltage ( $(V_P + V_M)/2$ ), and that  $V_{OST}$  includes  $V_{OS}$  plus the effects (on the input offset error,  $V_{OST}$ ) of temperature, CMRR, PSRR and  $A_{OL}$ .

**EQUATION 1-1:**

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

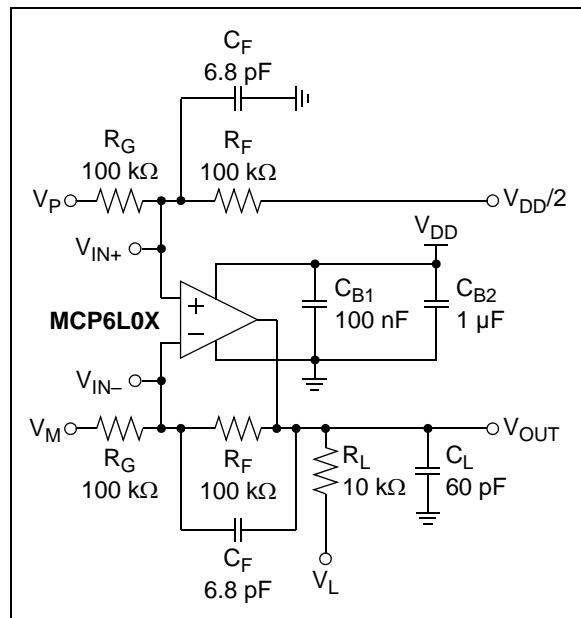
$$V_{CM} = (V_P + V_{DD}/2)/2$$

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

$$V_{OUT} = (V_{DD}/2) + (V_P - V_M) + V_{OST}(1 + G_{DM})$$

Where:

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

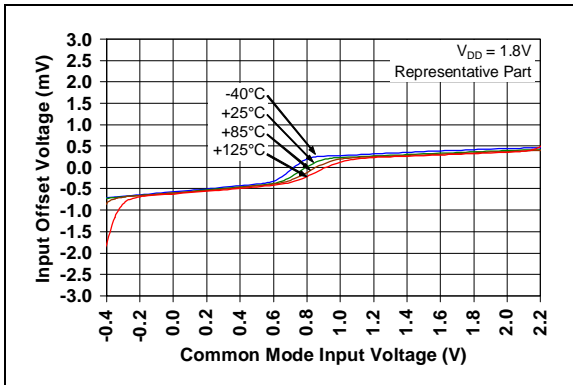


**FIGURE 1-1:** AC and DC Test Circuit for Most Specifications.

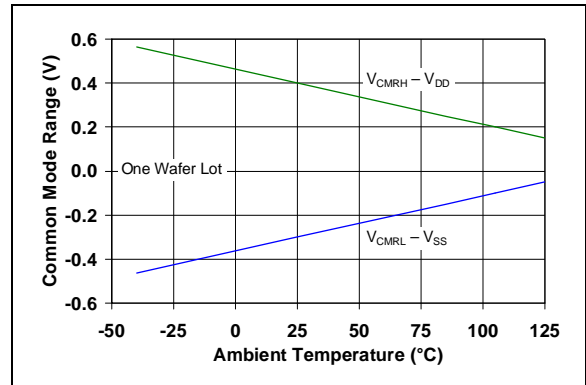
## 2.0 TYPICAL PERFORMANCE CURVES

**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.

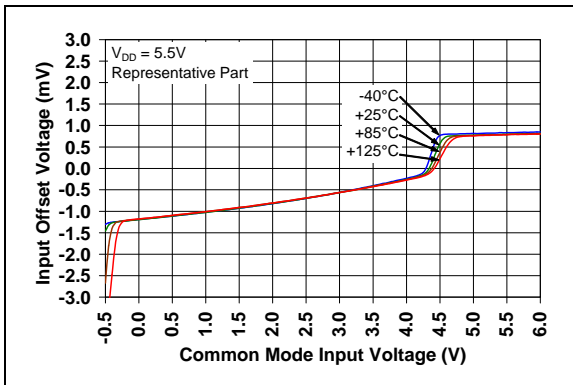
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = 5.0\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{SS}$ ,  $V_{OUT} = V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_L$  and  $C_L = 60\text{ pF}$ .



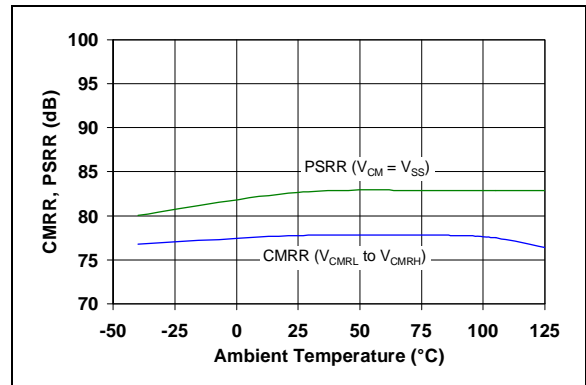
**FIGURE 2-1:** Input Offset Voltage vs. Common Mode Input Voltage at  $V_{DD} = 1.8\text{V}$ .



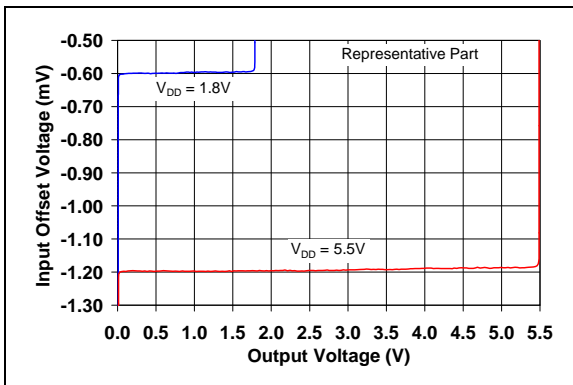
**FIGURE 2-4:** Input Common Mode Range Voltage vs. Ambient Temperature.



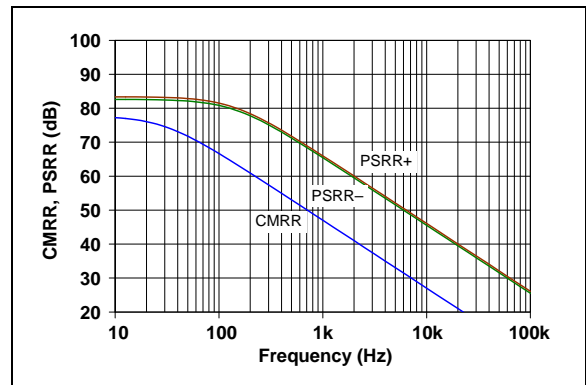
**FIGURE 2-2:** Input Offset Voltage vs. Common Mode Input Voltage at  $V_{DD} = 5.5\text{V}$ .



**FIGURE 2-5:** CMRR, PSRR vs. Ambient Temperature.



**FIGURE 2-3:** Input Offset Voltage vs. Output Voltage.

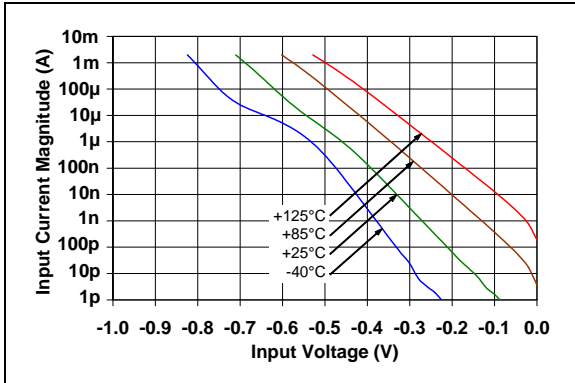


**FIGURE 2-6:** CMRR, PSRR vs. Frequency.

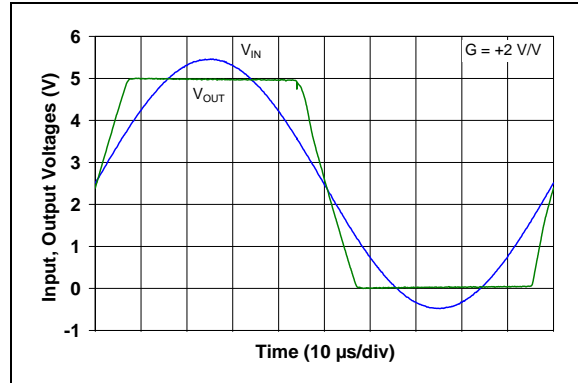
# MCP6L01/1R/1U/2/4

[查询MCP6L02供应商](#)

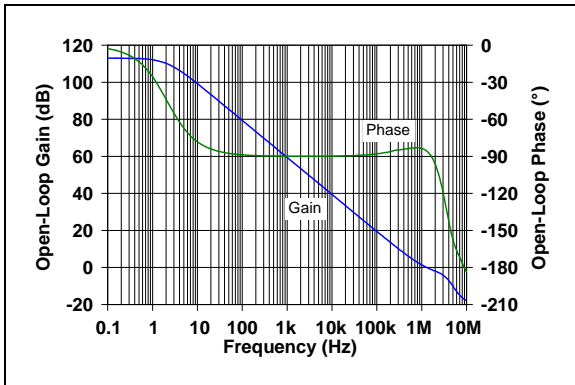
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +5.0\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{SS}$ ,  $V_{OUT} = V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_L$  and  $C_L = 60\text{ pF}$ .



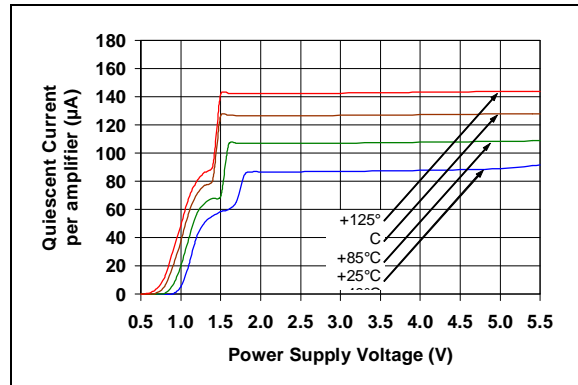
**FIGURE 2-7:** Measured Input Current vs. Input Voltage (below  $V_{SS}$ ).



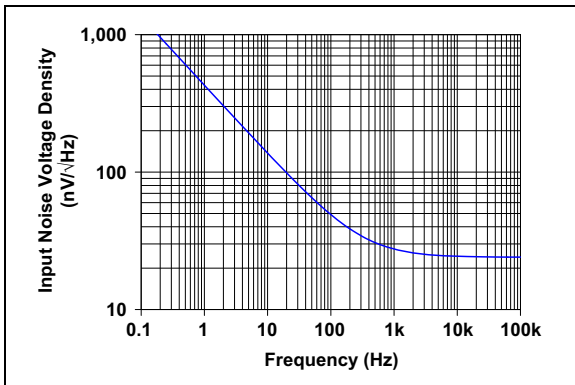
**FIGURE 2-10:** The MCP6L01/1R/1U/2/4 Show No Phase Reversal.



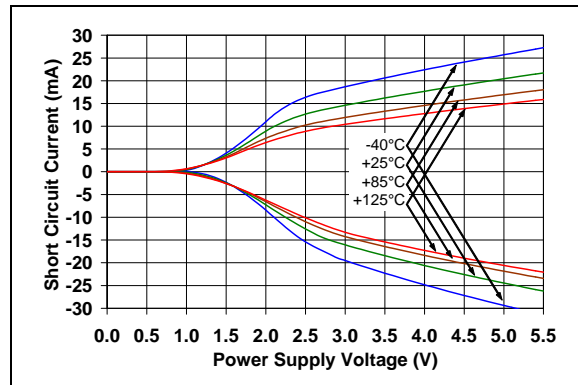
**FIGURE 2-8:** Open-Loop Gain, Phase vs. Frequency.



**FIGURE 2-11:** Quiescent Current vs. Power Supply Voltage.



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

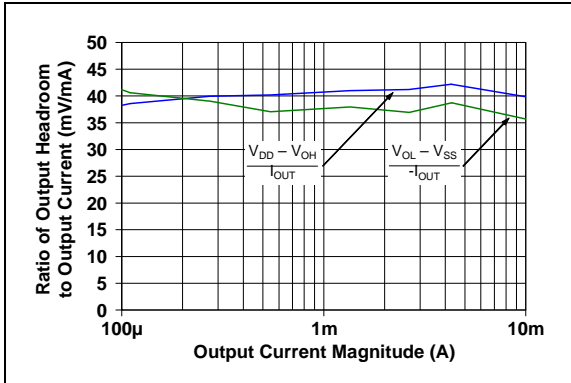


**FIGURE 2-12:** Output Short Circuit Current vs. Power Supply Voltage.

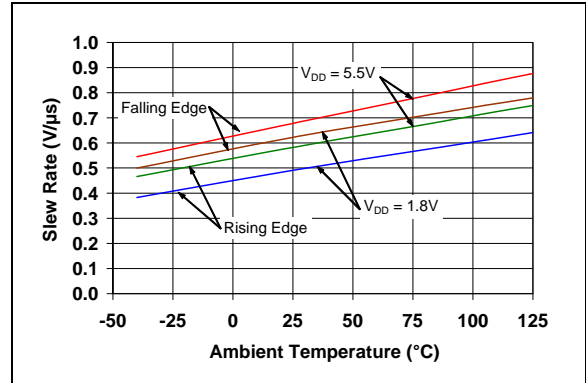
# MCP6L01/1R/1U/2/4

[查询MCP6L02供应商](#)

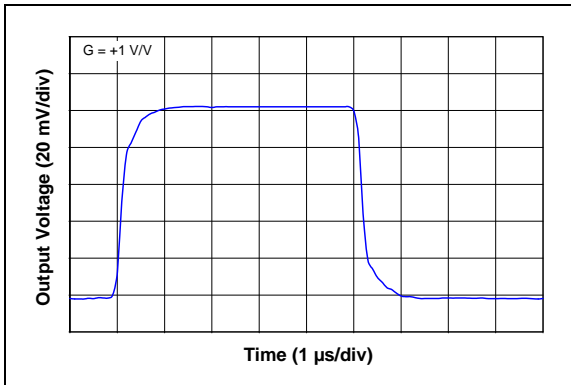
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +5.0\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{SS}$ ,  $V_{OUT} = V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_L$  and  $C_L = 60\text{ pF}$ .



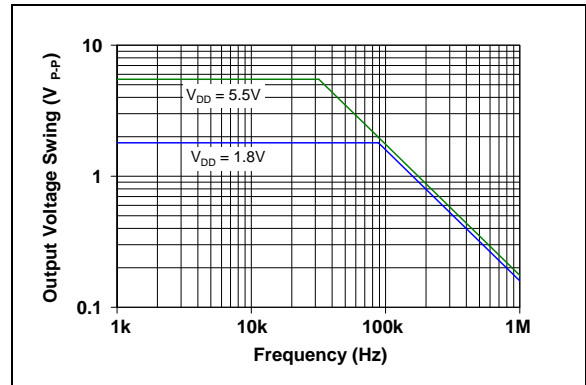
**FIGURE 2-13:** Ratio of Output Voltage Headroom to Output Current vs. Output Current.



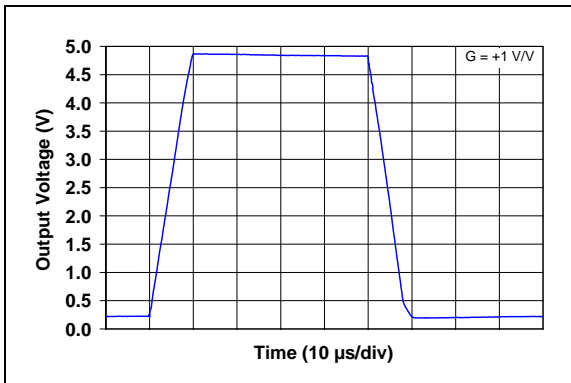
**FIGURE 2-16:** Slew Rate vs. Ambient Temperature.



**FIGURE 2-14:** Small Signal, Non-Inverting Pulse Response.



**FIGURE 2-17:** Output Voltage Swing vs. Frequency.



**FIGURE 2-15:** Large Signal, Non-Inverting Pulse Response.

# MCP6L01/1R/1U/2/4

---

[查询MCP6L02供应商](#)

**NOTES:**



## 3.0 PIN DESCRIPTIONS

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

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

MCP6L01	MCP6L01R	MCP6L01U	MCP6L02	MCP6L04	Symbol	Description
SC-70-5, SOT-23-5	SOT-23-5	SOT-23-5	SOIC-8, MSOP-8	SOIC-14, TSSOP-14		
1	1	4	1	1	$V_{OUT}, V_{OUTA}$	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	$V_{OUTB}$	Output (op amp B)
—	—	—	—	8	$V_{OUTC}$	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	$V_{OUTD}$	Output (op amp D)
—	—	—	—	—	NC	No Internal Connection

### 3.1 Analog Outputs

The analog output pins ( $V_{OUT}$ ) are low-impedance voltage sources.

### 3.2 Analog Inputs

The non-inverting and inverting inputs ( $V_{IN+}, V_{IN-}, \dots$ ) are high-impedance CMOS inputs with low bias currents.

### 3.3 Power Supply Pins

The positive power supply ( $V_{DD}$ ) is 1.8V to 6.0V 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 bypass capacitors.

# MCP6L01/1R/1U/2/4

---

[查询MCP6L02供应商](#)

**NOTES:**

## 4.0 APPLICATION INFORMATION

The MCP6L01/1R/1U/2/4 family of op amps is manufactured using Microchip's state of the art CMOS process. It is designed for low cost, low power and general purpose applications. The low supply voltage, low quiescent current and wide bandwidth makes the MCP6L01/1R/1U/2/4 ideal for battery-powered applications. This device has high phase margin, which makes it stable for larger capacitive load applications.

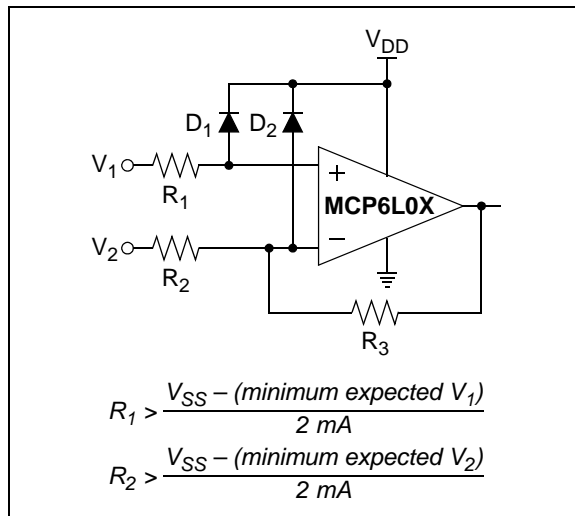
### 4.1 Rail-to-Rail Inputs

#### 4.1.1 PHASE REVERSAL

The MCP6L01/1R/1U/2/4 op amps are designed to prevent phase inversion when the input pins exceed the supply voltages. Figure 2-10 shows an input voltage exceeding both supplies without any phase reversal.

#### 4.1.2 INPUT VOLTAGE AND CURRENT LIMITS

In order to prevent damage and/or improper operation of these amplifiers, the circuit they are in must limit the currents (and voltages) at the input pins (see Section 1.1 "Absolute Maximum Ratings †"). Figure 4-1 shows the recommended approach to protecting these inputs. The internal ESD diodes prevent the input pins ( $V_{IN+}$  and  $V_{IN-}$ ) from going too far below ground, and the resistors  $R_1$  and  $R_2$  limit the possible current drawn out of the input pins. Diodes  $D_1$  and  $D_2$  prevent the input pins ( $V_{IN+}$  and  $V_{IN-}$ ) from going too far above  $V_{DD}$ , and dump any currents onto  $V_{DD}$ .



**FIGURE 4-1:** Protecting the Analog Inputs.

A significant amount of current can flow out of the inputs (through the ESD diodes) when the common mode voltage ( $V_{CM}$ ) is below ground ( $V_{SS}$ ); see Figure 2-7. Applications that are high impedance may need to limit the usable voltage range.

#### 4.1.3 NORMAL OPERATION

The input stage of the MCP6L01/1R/1U/2/4 op amps use two differential CMOS input stages in parallel. One operates at low common mode input voltage ( $V_{CM}$ ), while the other operates at high  $V_{CM}$ . With this topology, and at room temperature, the device operates with  $V_{CM}$  up to 0.3V above  $V_{DD}$  and 0.3V below  $V_{SS}$  (typically at +25°C).

The transition between the two input stages occurs when  $V_{CM} = V_{DD} - 1.1V$ . For the best distortion and gain linearity, with non-inverting gains, avoid this region of operation.

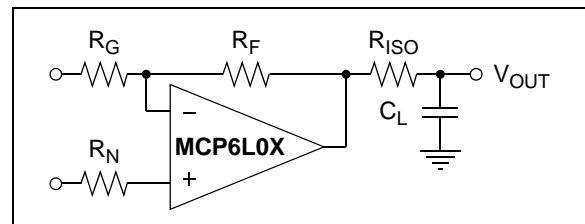
### 4.2 Rail-to-Rail Output

The output voltage range of the MCP6L01/1R/1U/2/4 op amps is  $V_{DD} - 35 \text{ mV}$  (minimum) and  $V_{SS} + 35 \text{ mV}$  (maximum) when  $R_L = 10 \text{ k}\Omega$  is connected to  $V_{DD}/2$  and  $V_{DD} = 5.0V$ . Refer to Figure 2-13 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.

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 4-2) improves the feedback loop's stability by making the output load resistive at higher frequencies; the bandwidth will usually be decreased.



**FIGURE 4-2:** Output Resistor,  $R_{ISO}$  stabilizes large capacitive loads.

Bench measurements are helpful in choosing  $R_{ISO}$ . Adjust  $R_{ISO}$  so that a small signal step response (see Figure 2-14) has reasonable overshoot (e.g., 4%).

# MCP6L01/1R/1U/2/4

[查询MCP6L02供应商](#)

## 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 nearby analog parts.

## 4.5 Unused Op Amps

An unused op amp in a quad package (e.g., MCP6L04) should be configured as shown in Figure 4-3. These circuits prevent the output from toggling and causing crosstalk. Circuit A sets the op amp at its minimum noise gain. The resistor divider produces any desired reference voltage within the output voltage range of the op amp; the op amp buffers that reference voltage. Circuit B uses the minimum number of components and operates as a comparator, but it may draw more current.

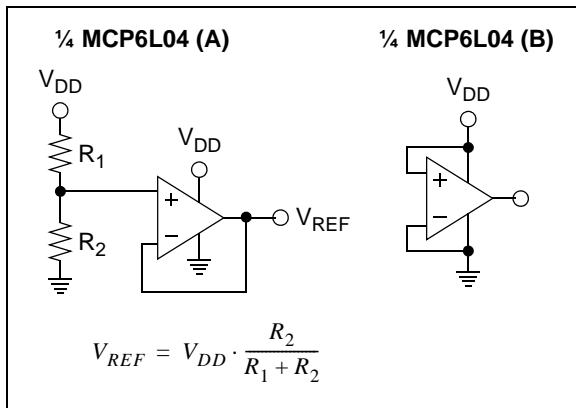


FIGURE 4-3: Unused Op Amps.

## 4.6 PCB Surface Leakage

In applications where low input bias current is critical, PCB (printed circuit board) 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; this is greater than this family's bias current at +25°C (1 pA, typical).

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

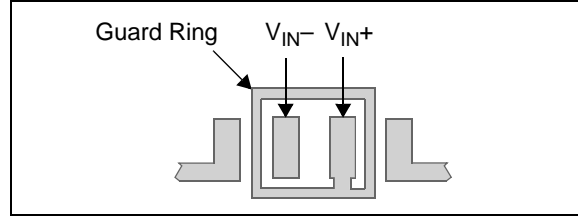


FIGURE 4-4: Example Guard Ring Layout.

1. Inverting Amplifiers (Figure 4-4) 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's input (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.
2. Non-inverting Gain and Unity-Gain Buffer.
  - a) Connect the guard ring to the inverting input pin ( $V_{IN-}$ ); this biases the guard ring to the common mode input voltage.
  - b) Connect the non-inverting pin ( $V_{IN+}$ ) to the input with a wire that does not touch the PCB surface.

## 4.7 Application Circuit

### 4.7.1 ACTIVE LOW-PASS FILTER

The MCP6L01/1R/1U/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.

Figure 4-5 shows a second-order Bessel filter with 100 Hz cutoff frequency and a gain of +1 V/V. The component values were selected using Microchip's FilterLab® software; the capacitor values were reduced to a more common range.

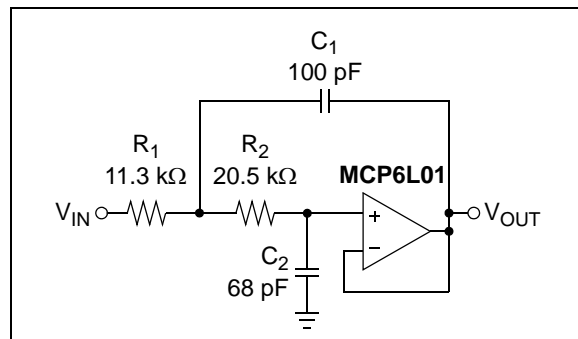


FIGURE 4-5: Bessel Filter.

## 5.0 DESIGN AIDS

Microchip provides the basic design aids needed for the MCP6L01/1R/1U/2/4 family of op amps.

### 5.1 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 the Microchip web site at [www.microchip.com/filterlab](http://www.microchip.com/filterlab), the FilterLab design tool provides full schematic diagrams of the filter circuit with component values. It also outputs the filter circuit in SPICE format, which can be used with the macro model to simulate actual filter performance.

### 5.2 Microchip Advanced Part Selector (MAPS)

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

### 5.3 Analog Demonstration and Evaluation Boards

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

Some boards that are especially useful are:

- MCP6XXX Amplifier Evaluation Board 1
- MCP6XXX Amplifier Evaluation Board 2
- MCP6XXX Amplifier Evaluation Board 3
- MCP6XXX Amplifier Evaluation Board 4
- Active Filter Demo Board Kit
- 5/6-Pin SOT-23 Evaluation Board, P/N VSUPEV2
- 8-Pin SOIC/MSOP/TSSOP/DIP Evaluation Board, P/N SOIC8EV
- 14-Pin SOIC/TSSOP/DIP Evaluation Board, P/N SOIC14EV

## 5.4 Application Notes

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

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

# MCP6L01/1R/1U/2/4

---

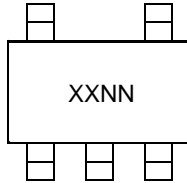
[查询MCP6L02供应商](#)

**NOTES:**

## 6.0 PACKAGING INFORMATION

### 6.1 Package Marking Information

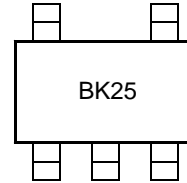
5-Lead SC-70 (MCP6L01)



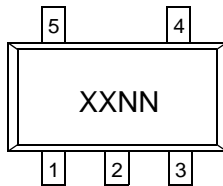
Device	Code
MCP6L01	BKNN

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

Example:



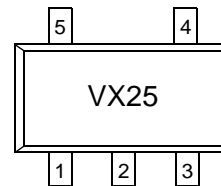
5-Lead SOT-23 (MCP6L01/1R/1U)



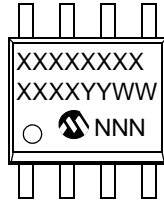
Device	Code
MCP6L01	VXNN
MCP6L01R	VYNN
MCP6L01U	VZNN

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

Example:



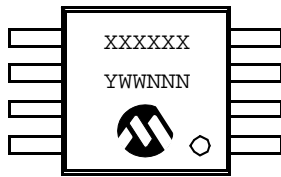
8-Lead SOIC (150 mil) (MCP6L02)



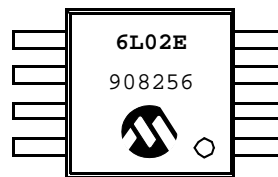
Example:



8-Lead MSOP (MCP6L02)



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
	<sup>e3</sup>	Pb-free JEDEC designator for Matte Tin (Sn)
	*	This package is Pb-free. The Pb-free JEDEC designator ( <sup>e3</sup> ) can be found on the outer packaging for this package.

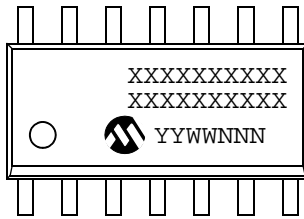
**Note:** In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information.

# MCP6L01/1R/1U/2/4

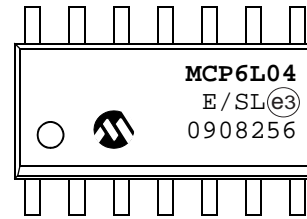
[查询MCP6L02供应商](#)

## Package Marking Information

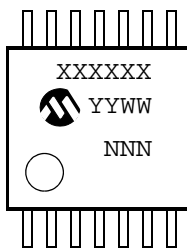
14-Lead SOIC (150 mil) (MCP6L04)



Example:



14-Lead TSSOP (MCP6L04)



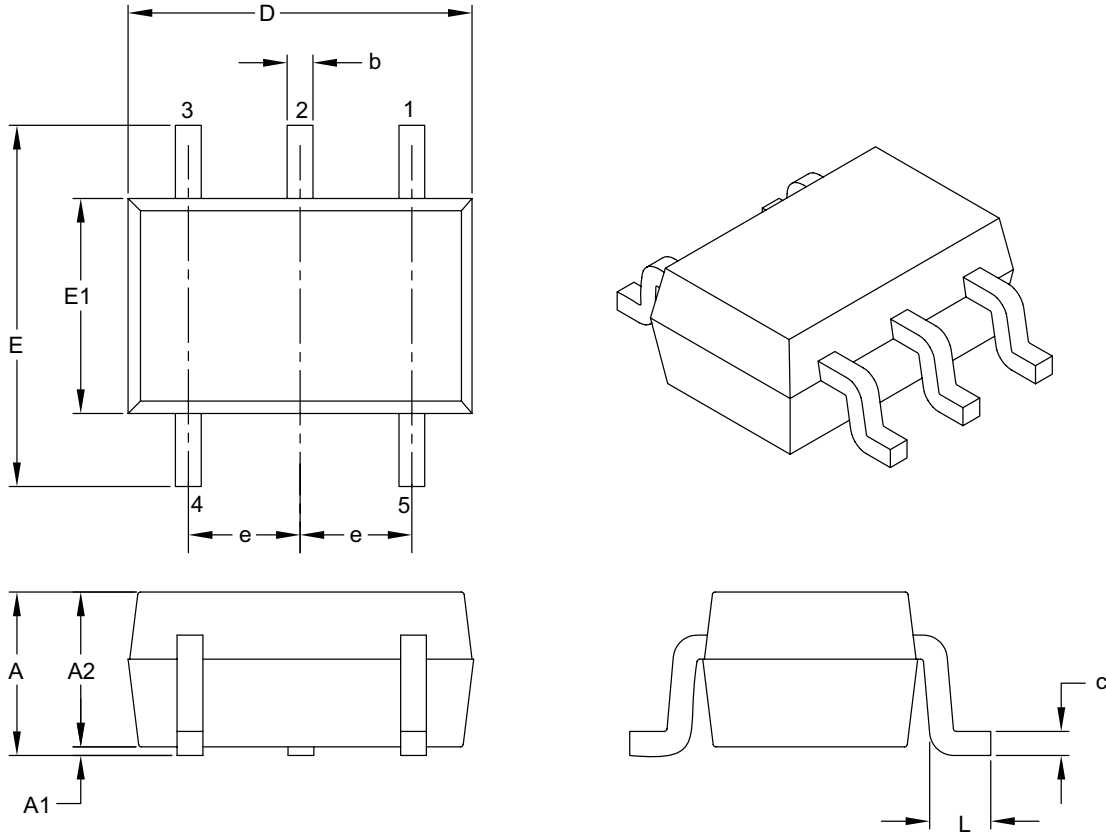
Example:





## 5-Lead Plastic Small Outline Transistor (LT) [SC70]

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



Dimension Limits	Units	MILLIMETERS		
		MIN	NOM	MAX
Number of Pins	N	5		
Pitch	e	0.65 BSC		
Overall Height	A	0.80	-	1.10
Molded Package Thickness	A2	0.80	-	1.00
Standoff	A1	0.00	-	0.10
Overall Width	E	1.80	2.10	2.40
Molded Package Width	E1	1.15	1.25	1.35
Overall Length	D	1.80	2.00	2.25
Foot Length	L	0.10	0.20	0.46
Lead Thickness	c	0.08	-	0.26
Lead Width	b	0.15	-	0.40

**Notes:**

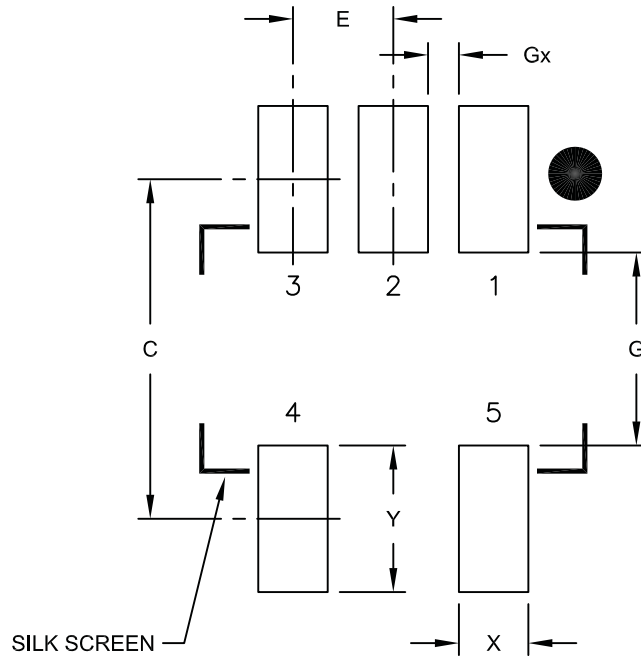
- Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.127 mm per side.
- Dimensioning and tolerancing per ASME Y14.5M.  
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

# MCP6L01/1R/1U/2/4

[查询MCP6L02供应商](#)

## 5-Lead Plastic Small Outline Transistor (LT) [SC70]

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



RECOMMENDED LAND PATTERN

Dimension Limits	Units	MILLIMETERS		
		MIN	NOM	MAX
Contact Pitch	E	0.65 BSC		
Contact Pad Spacing	C		2.20	
Contact Pad Width	X			0.45
Contact Pad Length	Y			0.95
Distance Between Pads	G	1.25		
Distance Between Pads	Gx	0.20		

**Notes:**

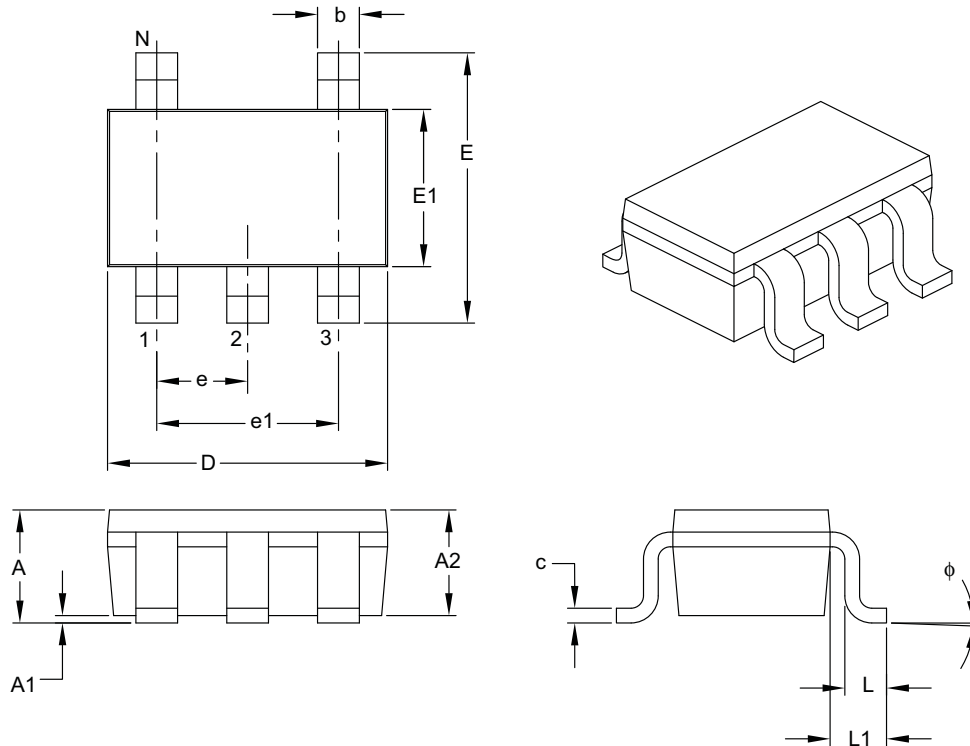
1. Dimensioning and tolerancing per ASME Y14.5M

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

Microchip Technology Drawing No. C04-2061A

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

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



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

**Notes:**

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

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

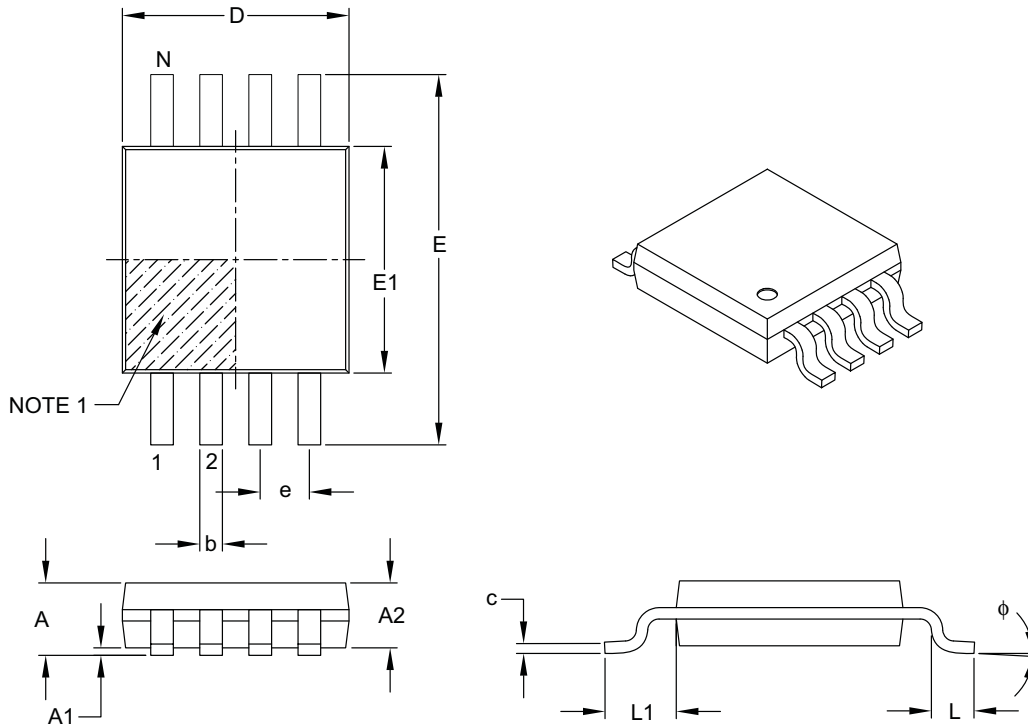
Microchip Technology Drawing C04-091B

# MCP6L01/1R/1U/2/4

[查询MCP6L02供应商](#)

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

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



Dimension Limits	Units	MILLIMETERS		
		MIN	NOM	MAX
Number of Pins	N	8		
Pitch	e	0.65 BSC		
Overall Height	A	–	–	1.10
Molded Package Thickness	A2	0.75	0.85	0.95
Standoff	A1	0.00	–	0.15
Overall Width	E	4.90 BSC		
Molded Package Width	E1	3.00 BSC		
Overall Length	D	3.00 BSC		
Foot Length	L	0.40	0.60	0.80
Footprint	L1	0.95 REF		
Foot Angle	$\phi$	0°	–	8°
Lead Thickness	c	0.08	–	0.23
Lead Width	b	0.22	–	0.40

**Notes:**

- Pin 1 visual index feature may vary, but must be located within the hatched area.
- Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15 mm per side.
- Dimensioning and tolerancing per ASME Y14.5M.

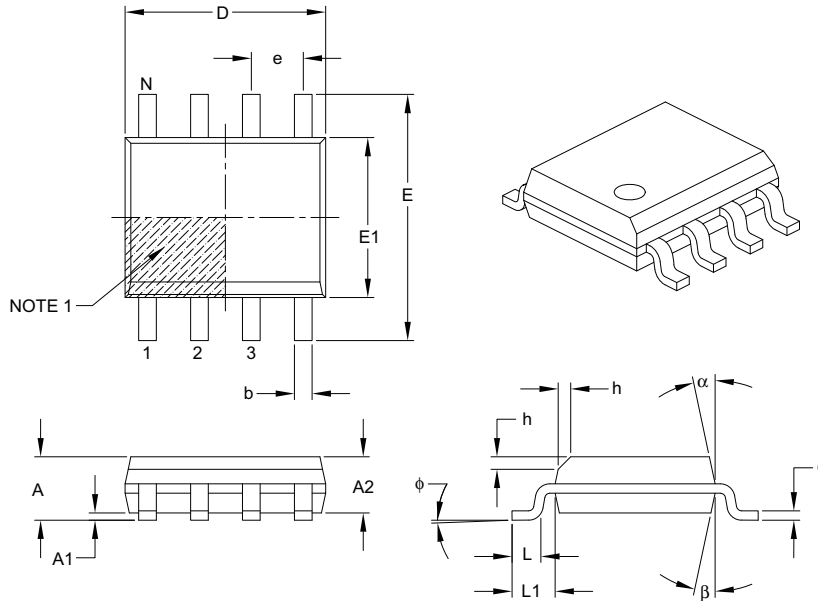
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-111B

## 8-Lead Plastic Small Outline (SN) – Narrow, 3.90 mm Body [SOIC]

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



Dimension Limits	Units	MILLIMETERS		
		MIN	NOM	MAX
Number of Pins	N	8		
Pitch	e	1.27 BSC		
Overall Height	A	–	–	1.75
Molded Package Thickness	A2	1.25	–	–
Standoff §	A1	0.10	–	0.25
Overall Width	E	6.00 BSC		
Molded Package Width	E1	3.90 BSC		
Overall Length	D	4.90 BSC		
Chamfer (optional)	h	0.25	–	0.50
Foot Length	L	0.40	–	1.27
Footprint	L1	1.04 REF		
Foot Angle	$\phi$	0°	–	8°
Lead Thickness	c	0.17	–	0.25
Lead Width	b	0.31	–	0.51
Mold Draft Angle Top	$\alpha$	5°	–	15°
Mold Draft Angle Bottom	$\beta$	5°	–	15°

**Notes:**

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. § Significant Characteristic.
3. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15 mm per side.
4. Dimensioning and tolerancing per ASME Y14.5M.

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

REF: Reference Dimension, usually without tolerance, for information purposes only.

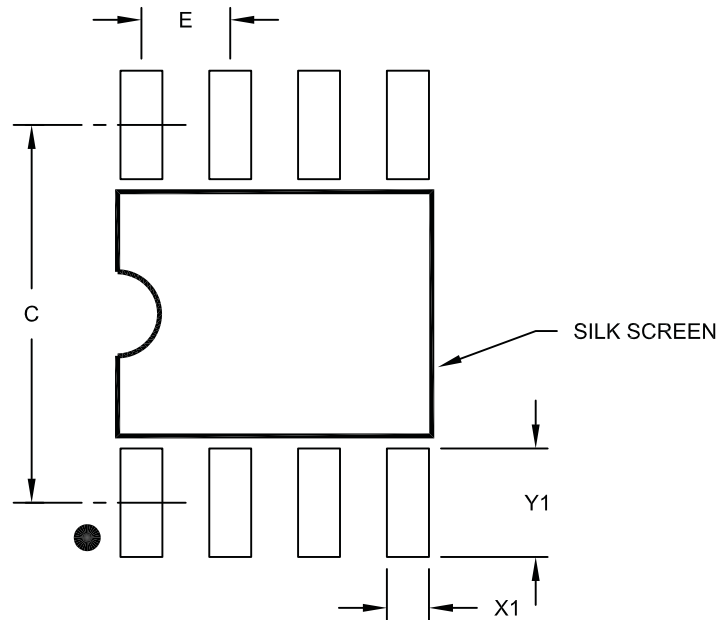
Microchip Technology Drawing C04-057B

# MCP6L01/1R/1U/2/4

[查询MCP6L02供应商](#)

## 8-Lead Plastic Small Outline (SN) – Narrow, 3.90 mm Body [SOIC]

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



RECOMMENDED LAND PATTERN

Dimension Limits	Units	MILLIMETERS		
		MIN	NOM	MAX
Contact Pitch	E	1.27 BSC		
Contact Pad Spacing	C		5.40	
Contact Pad Width (X8)	X1			0.60
Contact Pad Length (X8)	Y1			1.55

Notes:

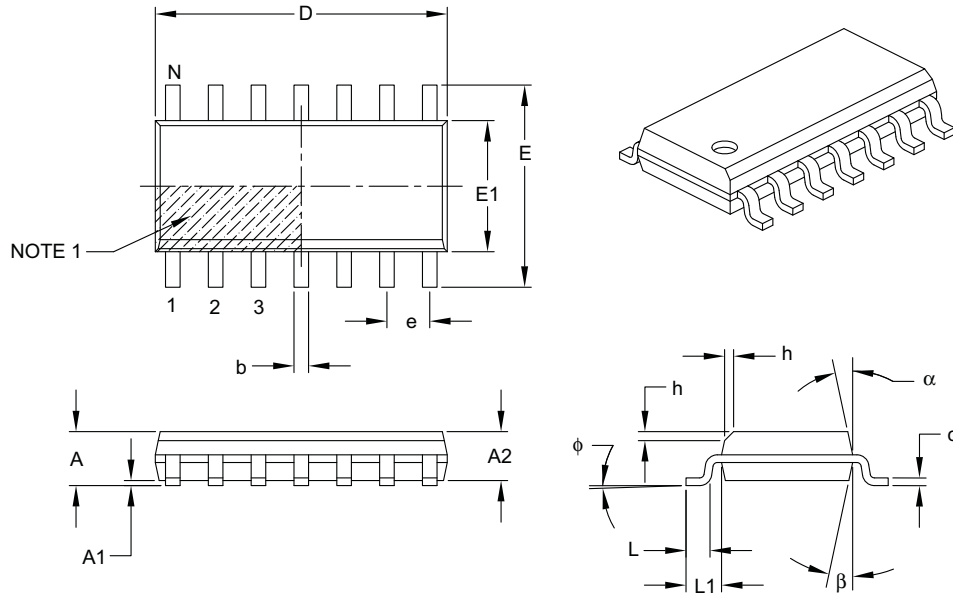
1. Dimensioning and tolerancing per ASME Y14.5M

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

Microchip Technology Drawing No. C04-2057A

## 14-Lead Plastic Small Outline (SL) – Narrow, 3.90 mm Body [SOIC]

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



Dimension Limits	Units	MILLIMETERS		
		MIN	NOM	MAX
Number of Pins	N	14		
Pitch	e	1.27 BSC		
Overall Height	A	–	–	1.75
Molded Package Thickness	A2	1.25	–	–
Standoff §	A1	0.10	–	0.25
Overall Width	E	6.00 BSC		
Molded Package Width	E1	3.90 BSC		
Overall Length	D	8.65 BSC		
Chamfer (optional)	h	0.25	–	0.50
Foot Length	L	0.40	–	1.27
Footprint	L1	1.04 REF		
Foot Angle	φ	0°	–	8°
Lead Thickness	c	0.17	–	0.25
Lead Width	b	0.31	–	0.51
Mold Draft Angle Top	α	5°	–	15°
Mold Draft Angle Bottom	β	5°	–	15°

**Notes:**

- Pin 1 visual index feature may vary, but must be located within the hatched area.
- § Significant Characteristic.
- Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15 mm per side.
- Dimensioning and tolerancing per ASME Y14.5M.

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

REF: Reference Dimension, usually without tolerance, for information purposes only.

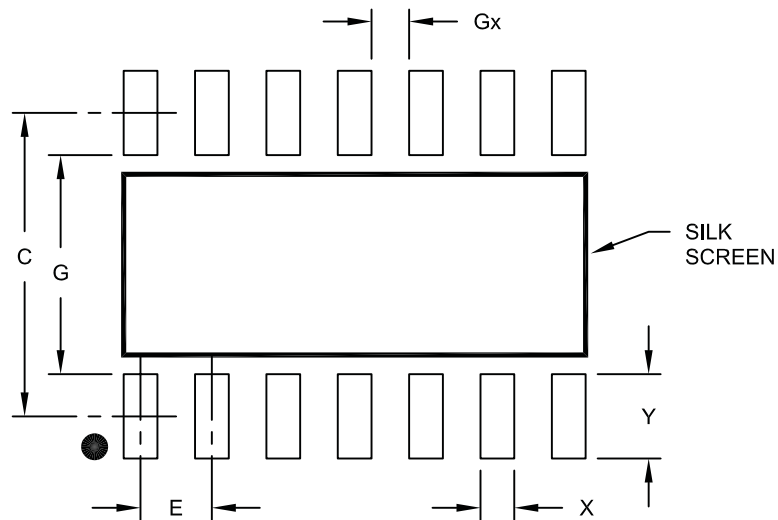
Microchip Technology Drawing C04-065B

# MCP6L01/1R/1U/2/4

[查询MCP6L02供应商](#)

14-Lead Plastic Small Outline (SL) - Narrow, 3.90 mm Body [SOIC]

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



RECOMMENDED LAND PATTERN

		MILLIMETERS		
		MIN	NOM	MAX
Contact Pitch	E	1.27 BSC		
Contact Pad Spacing	C		5.40	
Contact Pad Width	X			0.60
Contact Pad Length	Y			1.50
Distance Between Pads	Gx	0.67		
Distance Between Pads	G	3.90		

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

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

Microchip Technology Drawing No. C04-2065A

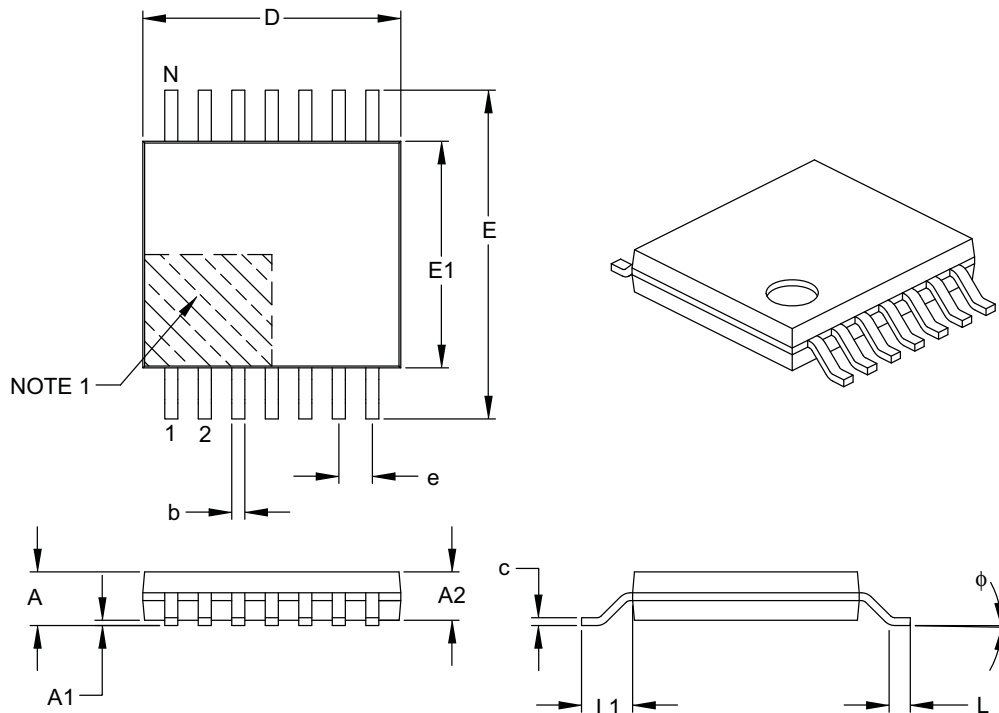


# MCP6L01/1R/1U/2/4

[查询MCP6L02供应商](#)

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

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



		Units	MILLIMETERS		
Dimension Limits			MIN	NOM	MAX
Number of Pins	N		14		
Pitch	e		0.65 BSC		
Overall Height	A	–	–	–	1.20
Molded Package Thickness	A2		0.80	1.00	1.05
Standoff	A1		0.05	–	0.15
Overall Width	E		6.40 BSC		
Molded Package Width	E1		4.30	4.40	4.50
Molded Package Length	D		4.90	5.00	5.10
Foot Length	L		0.45	0.60	0.75
Footprint	L1		1.00 REF		
Foot Angle	$\phi$		0°	–	8°
Lead Thickness	c		0.09	–	0.20
Lead Width	b		0.19	–	0.30

**Notes:**

- Pin 1 visual index feature may vary, but must be located within the hatched area.
- Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15 mm per side.
- Dimensioning and tolerancing per ASME Y14.5M.

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

REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-087B

# MCP6L01/1R/1U/2/4

---

[查询MCP6L02供应商](#)

**NOTES:**

[查询MCP6L02供应商](#)

## APPENDIX A: REVISION HISTORY

### Revision A (March 2009)

- Original Release of this Document.

# MCP6L01/1R/1U/2/4

---

[查询MCP6L02供应商](#)

**NOTES:**

# MCP6L01/1R/1U/2/4

[查询MCP6L02供应商](#)

## PRODUCT IDENTIFICATION SYSTEM

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

<b>PART NO.</b>	<b>X</b>	<b>XX</b>		
Device	Temperature Range	Package		
Device:	MCP6L01T:	Single Op Amp (Tape and Reel) (SC-70, SOT-23)		
	MCP6L01RT:	Single Op Amp (Tape and Reel) (SOT-23)		
	MCP6L01UT:	Single Op Amp (Tape and Reel) (SOT-23)		
	MCP6L02T:	Dual Op Amp (Tape and Reel) (SOIC, MSOP)		
	MCP6L04T:	Quad Op Amp (Tape and Reel) (SOIC, TSSOP)		
Temperature Range:	E	= -40°C to +125°C		
Package:	LT	= Plastic Package (SC-70), 5-lead (MCP6L01 only)		
	OT	= Plastic Small Outline Transistor (SOT-23), 5-lead		
	MS	= Plastic MSOP, 8-lead		
	SN	= Plastic SOIC, (3.99 mm body), 8-lead		
	SL	= Plastic SOIC (3.99 mm body), 14-lead		
	ST	= Plastic TSSOP (4.4mm body), 14-lead		
			<b>Examples:</b>	
			a)	MCP6L01T-E/LT: Tape and Reel, Extended Temperature, 5LD SC-70 package
			b)	MCP6L01T-E/OT: Tape and Reel, Extended Temperature, 5LD SOT-23 package
			a)	MCP6L01RT-E/OT: Tape and Reel, Extended Temperature, 5LD SOT-23 package.
			a)	MCP6L01UT-E/OT: Tape and Reel, Extended Temperature, 5LD SOT-23 package.
			a)	MCP6L02T-E/MS: Tape and Reel, Extended Temperature, 8LD MSOP package.
			b)	MCP6L02T-E/SN: Tape and Reel, Extended Temperature, 8LD SOIC package.
			a)	MCP6L04T-E/SL: Tape and Reel, Extended Temperature, 14LD SOIC package.
			b)	MCP6L04T-E/ST: Tape and Reel, Extended Temperature, 14LD TSSOP package.

# MCP6L01/1R/1U/2/4

---

[查询MCP6L02供应商](#)

**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 devices in life support and/or safety applications is entirely at the buyer's risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. 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, KEELOQ logo, MPLAB, PIC, PICmicro, PICSTART, rfPIC, SmartShunt and UNI/O are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.


FilterLab, Linear Active Thermistor, MXDEV, MXLAB, 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, CodeGuard, dsPICDEM, dsPICDEM.net, dsPICworks, dsSPEAK, ECAN, ECONOMONITOR, FanSense, In-Circuit Serial Programming, ICSP, ICEPIC, Mindi, MiWi, MPASM, MPLAB Certified logo, MPLIB, MPLINK, mTouch, nanoWatt XLP, PICkit, PICDEM, PICDEM.net, PICtail, PIC<sup>32</sup> logo, PowerCal, PowerInfo, PowerMate, PowerTool, REAL ICE, rfLAB, Select Mode, Total Endurance, TSHARC, WiperLock and ZENA 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.

© 2009, 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 certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona; Gresham, Oregon and design centers in California and India. The Company's quality system processes and procedures are for its PIC® MCUs and dsPIC® DSCs, 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**  
Duluth, GA  
Tel: 678-957-9614  
Fax: 678-957-1455

**Boston**  
Westborough, MA  
Tel: 774-760-0087  
Fax: 774-760-0088

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

**Cleveland**  
Independence, OH  
Tel: 216-447-0464  
Fax: 216-447-0643

**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

**Santa Clara**  
Santa Clara, CA  
Tel: 408-961-6444  
Fax: 408-961-6445

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

### ASIA/PACIFIC

**Asia Pacific Office**  
Suites 3707-14, 37th Floor  
Tower 6, The Gateway  
Harbour City, Kowloon  
Hong Kong  
Tel: 852-2401-1200  
Fax: 852-2401-3431

**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: 86-28-8665-5511  
Fax: 86-28-8665-7889

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

**China - Nanjing**  
Tel: 86-25-8473-2460  
Fax: 86-25-8473-2470

**China - Qingdao**  
Tel: 86-532-8502-7355  
Fax: 86-532-8502-7205

**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 - Wuhan**  
Tel: 86-27-5980-5300  
Fax: 86-27-5980-5118

**China - Xiamen**  
Tel: 86-592-2388138  
Fax: 86-592-2388130

**China - Xian**  
Tel: 86-29-8833-7252  
Fax: 86-29-8833-7256

**China - Zhuhai**  
Tel: 86-756-3210040  
Fax: 86-756-3210049

### ASIA/PACIFIC

**India - Bangalore**  
Tel: 91-80-3090-4444  
Fax: 91-80-3090-4080

**India - New Delhi**  
Tel: 91-11-4160-8631  
Fax: 91-11-4160-8632

**India - Pune**  
Tel: 91-20-2566-1512  
Fax: 91-20-2566-1513

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

**Korea - Daegu**  
Tel: 82-53-744-4301  
Fax: 82-53-744-4302

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

**Malaysia - Kuala Lumpur**  
Tel: 60-3-6201-9857  
Fax: 60-3-6201-9859

**Malaysia - Penang**  
Tel: 60-4-227-8870  
Fax: 60-4-227-4068

**Philippines - Manila**  
Tel: 63-2-634-9065  
Fax: 63-2-634-9069

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

**Taiwan - Hsin Chu**  
Tel: 886-3-572-9526  
Fax: 886-3-572-6459

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

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

**Thailand - Bangkok**  
Tel: 66-2-694-1351  
Fax: 66-2-694-1350

### EUROPE

**Austria - Wels**  
Tel: 43-7242-2244-39  
Fax: 43-7242-2244-393

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

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

**Germany - Munich**  
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

**Spain - Madrid**  
Tel: 34-91-708-08-90  
Fax: 34-91-708-08-91

**UK - Wokingham**  
Tel: 44-118-921-5869  
Fax: 44-118-921-5820