

## 1 MHz, 45 $\mu$ A Op Amps

### Features

- Low Quiescent Current: 45  $\mu$ A (typical)
- Gain Bandwidth Product: 1 MHz (typical)
- Rail-to-Rail Input and Output
- Supply Voltage Range: 1.8V to 6.0V
- Unity Gain Stable
- Extended Temperature Ranges:
  - -40°C to +125°C (E temp)
  - -40°C to +150°C (H temp)
- No Phase Reversal

### Applications

- Portable Equipment
- Battery Powered System
- Medical Instrumentation
- Automotive Electronics
- Data Acquisition Equipment
- Sensor Conditioning
- Analog Active Filters

### Design Aids

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

### Typical Application



### Description

The Microchip Technology Inc. MCP6401/1R/1U/2/4/6/7/9 family of operational amplifiers (op amps) has low quiescent current (45  $\mu$ A, typical) and rail-to-rail input and output operation. This family is unity gain stable and has a gain bandwidth product of 1 MHz (typical). These devices operate with a power supply voltage of 1.8V to 6.0V. These features make the family of op amps well suited for single-supply, battery-powered applications.

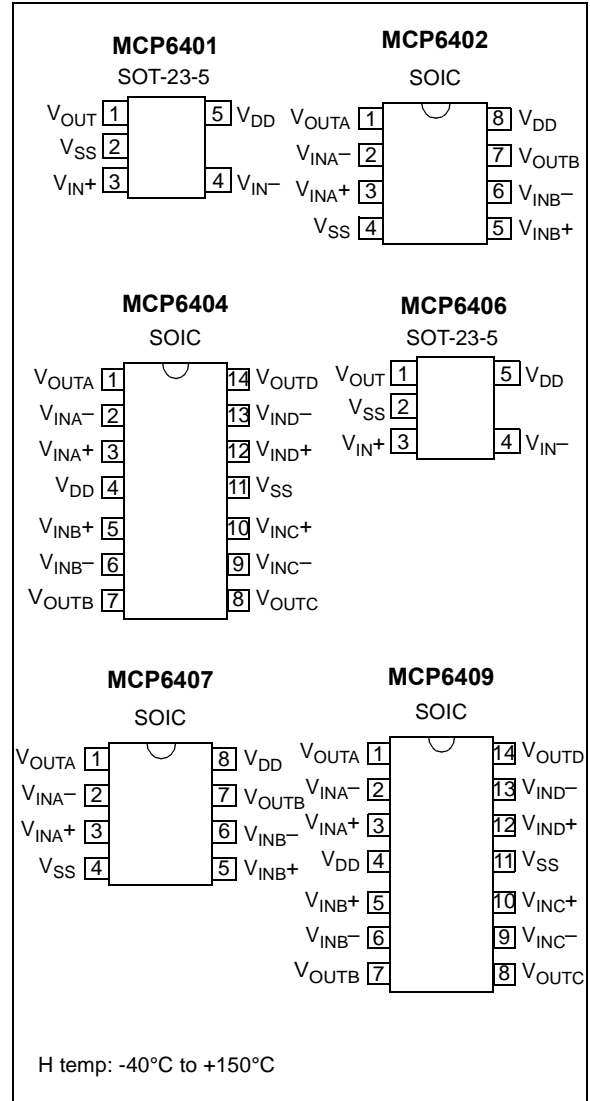
The MCP6401/1R/1U/2/4/6/7/9 family is designed with Microchip's advanced CMOS process and offered in single, dual and quad packages. The devices are available in two extended temperature ranges (E temp and H temp) with different package types, which makes them well-suited for automotive and industrial applications.

# MCP6401/1R/1U/2/4/6/7/9

## E Temp Package Types



## H Temp Package Types



# MCP6401/1R/1U/2/4/6/7/9

## 1.0 ELECTRICAL CHARACTERISTICS

### 1.1 Absolute Maximum Ratings †

|   |                                    |
|---|------------------------------------|
| $V_{DD} - V_{SS}$ .....                         | 7.0V                               |
| Current at Input Pins .....                     | ±2 mA                              |
| Analog Inputs ( $V_{IN+}$ , $V_{IN-}$ )†† ..... | $V_{SS} - 1.0V$ to $V_{DD} + 1.0V$ |
| All Other Inputs and Outputs .....              | $V_{SS} - 0.3V$ to $V_{DD} + 0.3V$ |
| Difference Input Voltage .....                  | $ V_{DD} - V_{SS} $                |
| Output Short-Circuit Current .....              | Continuous                         |
| Current at Output and Supply Pins .....         | ±30 mA                             |
| Storage Temperature .....                       | -65°C to +150°C                    |
| Maximum Junction Temperature ( $T_J$ ) .....    | +155°C                             |
| ESD Protection on All Pins (HBM; MM; CDM) ..... | ≥ 4 kV; 300V, 1500V                |

† **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 Limits”](#).

### 1.2 MCP6401/1R/1U/2/4 Electrical Specifications

#### DC ELECTRICAL SPECIFICATIONS

**Electrical Characteristics:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.8\text{v}$  to  $+6.0\text{v}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$  and  $R_L = 100\text{ k}\Omega$  to  $V_L$  (Refer to [Figure 1-1](#)).

| Parameters                              | Sym                        | Min  | Typ  | Max  | Units                        | Temp            | Parts (Note 1) | Conditions        |
|---|----------------------------|------|------|------|------------------------------|-----------------|----------------|-------------------|
| <b>Input Offset</b>                     |                            |      |      |      |                              |                 |                |                   |
| Input Offset Voltage                    | $V_{OS}$                   | -4.5 | ±0.8 | +4.5 | mV                           |                 | E, H           | $V_{CM} = V_{SS}$ |
|   |                            | —    | ±1.0 | —    | mV                           | +125°C          | E              |                   |
|   |                            | —    | ±1.5 | —    | mV                           | +150°C          | H              |                   |
| Input Offset Drift with Temperature     | $\Delta V_{OS}/\Delta T_A$ | —    | ±2.0 | —    | $\mu\text{V}/^\circ\text{C}$ | -40°C to +125°C | E              | $V_{CM} = V_{SS}$ |
|   |                            | —    | ±2.5 | —    | $\mu\text{V}/^\circ\text{C}$ | -40°C to +150°C | H              |                   |
| Power Supply Rejection Ratio            | PSRR                       | 63   | 78   | —    | dB                           |                 | E, H           | $V_{CM} = V_{SS}$ |
|   |                            | —    | 75   | —    | dB                           | +125°C          | E              |                   |
|   |                            | —    | 73   | —    | dB                           | +150°C          | H              |                   |
| <b>Input Bias Current and Impedance</b> |                            |      |      |      |                              |                 |                |                   |
| Input Bias Current                      | $I_B$                      | —    | 1    | 100  | pA                           |                 | E, H           |                   |
|   |                            | —    | 30   | —    | pA                           | +85°C           | E, H           |                   |
|   |                            | —    | 800  | —    | pA                           | +125°C          | E              |                   |
|   |                            | —    | 7    | —    | nA                           | +150°C          | H              |                   |
| Input Offset Current                    | $I_{OS}$                   | —    | 1    | —    | pA                           |                 | E, H           |                   |
|   |                            | —    | 5    | —    | pA                           | +85°C           | E, H           |                   |
|   |                            | —    | 20   | —    | pA                           | +125°C          | E              |                   |
|   |                            | —    | 45   | —    | pA                           | +150°C          | H              |                   |

**Note 1:** E part stands for the one whose operating temperature range is from -40°C to +125°C and H part stands for the one whose operating temperature range is from -40°C to +150°C.

**2:** [Figure 2-14](#) shows how  $V_{CMR}$  changes across temperature.

# MCP6401/1R/1U/2/4/6/7/9

## DC ELECTRICAL SPECIFICATIONS (CONTINUED)

**Electrical Characteristics:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.8\text{V}$  to  $+6.0\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$  and  $R_L = 100\text{ k}\Omega$  to  $V_L$  (Refer to [Figure 1-1](#)).

| Parameters                               | Sym        | Min           | Typ          | Max           | Units               | Temp                 | Parts (Note 1) | Conditions  |
|--|------------|---------------|--------------|---------------|---------------------|----------------------|----------------|---|
| Common Mode Input Impedance              | $Z_{CM}$   | —             | $10^{13}  6$ | —             | $\Omega  \text{pF}$ |                      | E, H           |   |
| Differential Input Impedance             | $Z_{DIFF}$ | —             | $10^{13}  6$ | —             | $\Omega  \text{pF}$ |                      | E, H           |   |
| <b>Common Mode</b>                       |            |               |              |               |                     |                      |                |   |
| Common Mode Input Voltage Range (Note 2) | $V_{CMR}$  | $V_{SS}-0.20$ | —            | $V_{DD}+0.20$ | V                   |                      | E, H           | $V_{DD} = 1.8\text{V}$  |
|  |            | $V_{SS}-0.05$ | —            | $V_{DD}+0.05$ | V                   | $+125^\circ\text{C}$ | E              |   |
|  |            | $V_{SS}$      | —            | $V_{DD}$      | V                   | $+150^\circ\text{C}$ | H              |   |
|  |            | $V_{SS}-0.30$ | —            | $V_{DD}+0.30$ | V                   |                      | E, H           | $V_{DD} = 6.0\text{V}$  |
|  |            | $V_{SS}-0.15$ | —            | $V_{DD}+0.15$ | V                   | $+125^\circ\text{C}$ | E              |   |
|  |            | $V_{SS}-0.10$ | —            | $V_{DD}+0.10$ | V                   | $+150^\circ\text{C}$ | H              |   |
| Common Mode Rejection Ratio              | CMRR       | 56            | 71           | —             | dB                  |                      | E, H           | $V_{CM} = -0.2\text{V}$ to $2.0\text{V}$ ,<br>$V_{DD} = 1.8\text{V}$        |
|  |            | —             | 68           | —             | dB                  | $+125^\circ\text{C}$ | E              | $V_{CM} = -0.05\text{V}$ to $1.85\text{V}$ ,<br>$V_{DD} = 1.8\text{V}$      |
|  |            | —             | 65           | —             | dB                  | $+150^\circ\text{C}$ | H              | $V_{CM} = 0\text{V}$ to $1.8\text{V}$ ,<br>$V_{DD} = 1.8\text{V}$           |
|  |            | 63            | 78           | —             | dB                  |                      | E, H           | $V_{CM} = -0.3\text{V}$ to $6.3\text{V}$ ,<br>$V_{DD} = 6.0\text{V}$        |
|  |            | —             | 76           | —             | dB                  | $+125^\circ\text{C}$ | E              | $V_{CM} = -0.15\text{V}$ to $6.15\text{V}$ ,<br>$V_{DD} = 6.0\text{V}$      |
|  |            | —             | 75           | —             | dB                  | $+150^\circ\text{C}$ | H              | $V_{CM} = -0.1\text{V}$ to $6.1\text{V}$ ,<br>$V_{DD} = 6.0\text{V}$        |
| <b>Open-Loop Gain</b>                    |            |               |              |               |                     |                      |                |   |
| DC Open-Loop Gain (Large Signal)         | $A_{OL}$   | 90            | 110          | —             | dB                  |                      | E, H           | $V_{OUT} = 0.3\text{V}$ to $V_{DD}-0.3\text{V}$ ,<br>$V_{CM} = V_{SS}$      |
|  |            | —             | 105          | —             | dB                  | $+125^\circ\text{C}$ | E              |   |
|  |            | —             | 100          | —             | dB                  | $+150^\circ\text{C}$ | H              |   |
| <b>Output</b>                            |            |               |              |               |                     |                      |                |   |
| High-Level Output Voltage                | $V_{OH}$   | 1.790         | 1.792        | —             | V                   |                      | E, H           | $V_{DD} = 1.8\text{V}$<br>$R_L = 10\text{ k}\Omega$<br>0.5V input overdrive |
|  |            | —             | 1.788        | —             | V                   | $+125^\circ\text{C}$ | E              |   |
|  |            | —             | 1.785        | —             | V                   | $+150^\circ\text{C}$ | H              |   |
|  |            | 5.980         | 5.985        | —             | V                   |                      | E, H           |   |
|  |            | —             | 5.980        | —             | V                   | $+125^\circ\text{C}$ | E              |   |
|  |            | —             | 5.975        | —             | V                   | $+150^\circ\text{C}$ | H              |   |
| Low-Level Output Voltage                 | $V_{OL}$   | —             | 0.008        | 0.010         | V                   |                      | E, H           | $V_{DD} = 1.8\text{V}$<br>$R_L = 10\text{ k}\Omega$<br>0.5V input overdrive |
|  |            | —             | 0.012        | —             | V                   | $+125^\circ\text{C}$ | E              |   |
|  |            | —             | 0.015        | —             | V                   | $+150^\circ\text{C}$ | H              |   |
|  |            | —             | 0.015        | 0.020         | V                   |                      | E, H           |   |
|  |            | —             | 0.020        | —             | V                   | $+125^\circ\text{C}$ | E              |   |
|  |            | —             | 0.025        | —             | V                   | $+150^\circ\text{C}$ | H              |   |

**Note 1:** E part stands for the one whose operating temperature range is from  $-40^\circ\text{C}$  to  $+125^\circ\text{C}$  and H part stands for the one whose operating temperature range is from  $-40^\circ\text{C}$  to  $+150^\circ\text{C}$ .

**2:** [Figure 2-14](#) shows how  $V_{CMR}$  changes across temperature.

# MCP6401/1R/1U/2/4/6/7/9

## DC ELECTRICAL SPECIFICATIONS (CONTINUED)

**Electrical Characteristics:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.8\text{V}$  to  $+6.0\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$  and  $R_L = 100\text{ k}\Omega$  to  $V_L$  (Refer to [Figure 1-1](#)).

| Parameters                      | Sym      | Min | Typ      | Max | Units         | Temp                 | Parts (Note 1) | Conditions   |
|---------------------------------|----------|-----|----------|-----|---------------|----------------------|----------------|--|
| Output Short-Circuit Current    | $I_{SC}$ | —   | $\pm 5$  | —   | mA            |                      | E, H           | $V_{DD} = 1.8\text{V}$                                     |
|                                 |          | —   | $\pm 15$ | —   | mA            |                      | E, H           | $V_{DD} = 6.0\text{V}$                                     |
| <b>Power Supply</b>             |          |     |          |     |               |                      |                |  |
| Supply Voltage                  | $V_{DD}$ | 1.8 | —        | 6.0 | V             |                      | E, H           |  |
| Quiescent Current per Amplifier | $I_Q$    | 20  | 45       | 70  | $\mu\text{A}$ |                      | E, H           | $I_O = 0$ , $V_{DD} = 5.0\text{V}$<br>$V_{CM} = 0.2V_{DD}$ |
|                                 |          | —   | 55       | —   | $\mu\text{A}$ | $+125^\circ\text{C}$ | E              |  |
|                                 |          | —   | 60       | —   | $\mu\text{A}$ | $+150^\circ\text{C}$ | H              |  |

**Note 1:** E part stands for the one whose operating temperature range is from  $-40^\circ\text{C}$  to  $+125^\circ\text{C}$  and H part stands for the one whose operating temperature range is from  $-40^\circ\text{C}$  to  $+150^\circ\text{C}$ .

**2:** [Figure 2-14](#) shows how  $V_{CMR}$  changes across temperature.

## AC ELECTRICAL SPECIFICATIONS

**Electrical Characteristics:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.8$  to  $+6.0\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 100\text{ k}\Omega$  to  $V_L$  and  $C_L = 60\text{ pF}$  (Refer to [Figure 1-1](#)).

| Parameters                  | Sym      | Min | Typ | Max | Units                        | Parts | Conditions                            |
|-----------------------------|----------|-----|-----|-----|------------------------------|-------|---------------------------------------|
| <b>AC Response</b>          |          |     |     |     |                              |       |                                       |
| Gain Bandwidth Product      | GBWP     | —   | 1   | —   | MHz                          | E, H  |                                       |
| Phase Margin                | PM       | —   | 65  | —   | $^\circ$                     | E, H  | $G = +1\text{ V/V}$                   |
| Slew Rate                   | SR       | —   | 0.5 | —   | $\text{V}/\mu\text{s}$       | E, H  |                                       |
| <b>Noise</b>                |          |     |     |     |                              |       |                                       |
| Input Noise Voltage         | $E_{ni}$ | —   | 3.6 | —   | $\mu\text{Vp-p}$             | E, H  | $f = 0.1\text{ Hz}$ to $10\text{ Hz}$ |
| Input Noise Voltage Density | $e_{ni}$ | —   | 28  | —   | $\text{nV}/\sqrt{\text{Hz}}$ | E, H  | $f = 1\text{ kHz}$                    |
| Input Noise Current Density | $i_{ni}$ | —   | 0.6 | —   | $\text{fA}/\sqrt{\text{Hz}}$ | E, H  | $f = 1\text{ kHz}$                    |

## TEMPERATURE SPECIFICATIONS

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

| Parameters                         | Sym           | Min | Typ   | Max  | Units                     | Conditions                              |
|------------------------------------|---------------|-----|-------|------|---------------------------|---|
| <b>Temperature Ranges</b>          |               |     |       |      |                           |   |
| Operating Temperature Range        | $T_A$         | -40 | —     | +125 | $^\circ\text{C}$          | E temp parts ( <a href="#">Note 1</a> ) |
|                                    | $T_A$         | -40 | —     | +150 | $^\circ\text{C}$          | H temp parts ( <a href="#">Note 1</a> ) |
| Storage Temperature Range          | $T_A$         | -65 | —     | +155 | $^\circ\text{C}$          |   |
| <b>Thermal Package Resistances</b> |               |     |       |      |                           |   |
| Thermal Resistance, 5L-SC70        | $\theta_{JA}$ | —   | 331   | —    | $^\circ\text{C}/\text{W}$ |   |
| Thermal Resistance, 5L-SOT-23      | $\theta_{JA}$ | —   | 220.7 | —    | $^\circ\text{C}/\text{W}$ |   |
| Thermal Resistance, 8L-SOIC        | $\theta_{JA}$ | —   | 149.5 | —    | $^\circ\text{C}/\text{W}$ |   |
| Thermal Resistance, 8L-2x3 TDFN    | $\theta_{JA}$ | —   | 52.5  | —    | $^\circ\text{C}/\text{W}$ |   |
| Thermal Resistance, 14L-SOIC       | $\theta_{JA}$ | —   | 95.3  | —    | $^\circ\text{C}/\text{W}$ |   |
| Thermal Resistance, 14L-TSSOP      | $\theta_{JA}$ | —   | 100   | —    | $^\circ\text{C}/\text{W}$ |   |

**Note 1:** The internal junction temperature ( $T_J$ ) must not exceed the absolute maximum specification of  $+155^\circ\text{C}$ .

# MCP6401/1R/1U/2/4/6/7/9

## 1.3 MCP6406/7/9 Electrical Specifications

### DC ELECTRICAL SPECIFICATIONS

| Electrical Characteristics: Unless otherwise indicated, $T_A = +25^\circ\text{C}$ , $V_{DD} = +1.8\text{V}$ to $+6.0\text{V}$ , $V_{SS} = \text{GND}$ , $V_{CM} = V_{DD}/2$ , $V_{OUT} \gg V_{DD}/2$ , $V_L = V_{DD}/2$ and $R_L = 100\text{ k}\Omega$ to $V_L$ (Refer to <a href="#">Figure 1-1</a> ). |                      |               |              |               |                              |                 |                |                        |
|---|----------------------|---------------|--------------|---------------|------------------------------|-----------------|----------------|------------------------|
| Parameters  | Sym                  | Min           | Typ          | Max           | Units                        | Temp            | Parts (Note 1) | Conditions             |
| <b>Input Offset</b>   |                      |               |              |               |                              |                 |                |                        |
| Input Offset Voltage  | $V_{OS}$             | -4.5          | —            | +4.5          | mV                           |                 | E, H           | $V_{CM} = V_{SS}$      |
|   |                      | -5.0          | $\pm 1.0$    | +5.0          | mV                           | +125°C          | E              |                        |
|   |                      | -5.5          | $\pm 1.5$    | +5.5          | mV                           | +150°C          | H              |                        |
| Input Offset Drift with Temperature   | $\Delta V_{OS}/DT_A$ | —             | $\pm 2.0$    | —             | $\mu\text{V}/^\circ\text{C}$ | -40°C to +125°C | E              | $V_{CM} = V_{SS}$      |
|   |                      | —             | $\pm 2.5$    | —             | $\mu\text{V}/^\circ\text{C}$ | -40°C to +150°C | H              |                        |
| Power Supply Rejection Ratio  | PSRR                 | 63            | 78           | —             | dB                           |                 | E, H           | $V_{CM} = V_{SS}$      |
|   |                      | 60            | 75           | —             | dB                           | +125°C          | E              |                        |
|   |                      | 58            | 73           | —             | dB                           | +150°C          | H              |                        |
| <b>Input Bias Current and Impedance</b>   |                      |               |              |               |                              |                 |                |                        |
| Input Bias Current  | $I_B$                | —             | $\pm 1$      | 100           | pA                           |                 | E, H           |                        |
|   |                      | —             | 30           | —             | pA                           | +85°C           | E, H           |                        |
|   |                      | —             | 800          | 2000          | pA                           | +125°C          | E              |                        |
|   |                      | —             | 7            | 12            | nA                           | +150°C          | H              |                        |
| Input Offset Current  | $I_{OS}$             | —             | 1            | —             | pA                           |                 | E, H           |                        |
|   |                      | —             | 5            | —             | pA                           | +85°C           | E, H           |                        |
|   |                      | —             | 20           | —             | pA                           | +125°C          | E              |                        |
|   |                      | —             | 45           | —             | pA                           | +150°C          | H              |                        |
| Common Mode Input Impedance   | $Z_{CM}$             | —             | $10^{13}  6$ | —             | $\Omega  \text{pF}$          |                 | E, H           |                        |
| Differential Input Impedance  | $Z_{DIFF}$           | —             | $10^{13}  6$ | —             | $\Omega  \text{pF}$          |                 | E, H           |                        |
| <b>Common Mode</b>  |                      |               |              |               |                              |                 |                |                        |
| Common Mode Input Voltage Range (Note 2)  | $V_{CMR}$            | $V_{SS}-0.20$ | —            | $V_{DD}+0.20$ | V                            |                 | E, H           | $V_{DD} = 1.8\text{V}$ |
|   |                      | $V_{SS}-0.05$ | —            | $V_{DD}+0.05$ | V                            | +125°C          | E              |                        |
|   |                      | $V_{SS}$      | —            | $V_{DD}$      | V                            | +150°C          | H              |                        |
|   |                      | $V_{SS}-0.30$ | —            | $V_{DD}+0.30$ | V                            |                 | E, H           | $V_{DD} = 6.0\text{V}$ |
|   |                      | $V_{SS}-0.15$ | —            | $V_{DD}+0.15$ | V                            | +125°C          | E              |                        |
|   |                      | $V_{SS}-0.10$ | —            | $V_{DD}+0.10$ | V                            | +150°C          | H              |                        |

**Note 1:** E part stands for the one whose operating temperature range is from -40°C to +125°C and H part stands for the one whose operating temperature range is from -40°C to +150°C.

**2:** [Figure 2-14](#) shows how  $V_{CMR}$  changes across temperature.

# MCP6401/1R/1U/2/4/6/7/9

## DC ELECTRICAL SPECIFICATIONS (CONTINUED)

**Electrical Characteristics:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.8\text{V}$  to  $+6.0\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \gg V_{DD}/2$ ,  $V_L = V_{DD}/2$  and  $R_L = 100\text{ k}\Omega$  to  $V_L$  (Refer to [Figure 1-1](#)).

| Parameters                       | Sym      | Min   | Typ      | Max   | Units         | Temp                 | Parts (Note 1) | Conditions  |
|----------------------------------|----------|-------|----------|-------|---------------|----------------------|----------------|---|
| Common Mode Rejection Ratio      | CMRR     | 56    | 71       | —     | dB            |                      | E, H           | $V_{CM} = -0.2\text{V}$ to $2.0\text{V}$ , $V_{DD} = 1.8\text{V}$           |
|                                  |          | 53    | 68       | —     | dB            | $+125^\circ\text{C}$ | E              | $V_{CM} = -0.05\text{V}$ to $1.85\text{V}$ , $V_{DD} = 1.8\text{V}$         |
|                                  |          | 50    | 65       | —     | dB            | $+150^\circ\text{C}$ | H              | $V_{CM} = 0\text{V}$ to $1.8\text{V}$ , $V_{DD} = 1.8\text{V}$              |
|                                  |          | 63    | 78       | —     | dB            |                      | E, H           | $V_{CM} = -0.3\text{V}$ to $6.3\text{V}$ , $V_{DD} = 6.0\text{V}$           |
|                                  |          | 61    | 76       | —     | dB            | $+125^\circ\text{C}$ | E              | $V_{CM} = -0.15\text{V}$ to $6.15\text{V}$ , $V_{DD} = 6.0\text{V}$         |
|                                  |          | 60    | 75       | —     | dB            | $+150^\circ\text{C}$ | H              | $V_{CM} = -0.1\text{V}$ to $6.1\text{V}$ , $V_{DD} = 6.0\text{V}$           |
| <b>Open-Loop Gain</b>            |          |       |          |       |               |                      |                |   |
| DC Open-Loop Gain (Large Signal) | $A_{OL}$ | 90    | 110      | —     | dB            |                      | E, H           | $V_{OUT} = 0.3\text{V}$ to $V_{DD}-0.3\text{V}$ , $V_{CM} = V_{SS}$         |
|                                  |          | 88    | 105      | —     | dB            | $+125^\circ\text{C}$ | E              |   |
|                                  |          | 85    | 100      | —     | dB            | $+150^\circ\text{C}$ | H              |   |
| <b>Output</b>                    |          |       |          |       |               |                      |                |   |
| High-Level Output Voltage        | $V_{OH}$ | 1.790 | 1.792    | —     | V             |                      | E, H           | $V_{DD} = 1.8\text{V}$<br>$R_L = 10\text{ k}\Omega$<br>0.5V input overdrive |
|                                  |          | 1.785 | 1.788    | —     | V             | $+125^\circ\text{C}$ | E              |   |
|                                  |          | 1.782 | 1.785    | —     | V             | $+150^\circ\text{C}$ | H              |   |
|                                  |          | 5.980 | 5.985    | —     | V             |                      | E, H           |   |
|                                  |          | 5.970 | 5.980    | —     | V             | $+125^\circ\text{C}$ | E              |   |
| Low-Level Output Voltage         | $V_{OL}$ | —     | 0.008    | 0.010 | V             |                      | E, H           | $V_{DD} = 1.8\text{V}$<br>$R_L = 10\text{ k}\Omega$<br>0.5V input overdrive |
|                                  |          | —     | 0.012    | 0.015 | V             | $+125^\circ\text{C}$ | E              |   |
|                                  |          | —     | 0.015    | 0.018 | V             | $+150^\circ\text{C}$ | H              |   |
|                                  |          | —     | 0.015    | 0.020 | V             |                      | E, H           |   |
|                                  |          | —     | 0.020    | 0.030 | V             | $+125^\circ\text{C}$ | E              |   |
| Output Short-Circuit Current     | $I_{SC}$ | —     | $\pm 5$  | —     | mA            |                      | E, H           | $V_{DD} = 1.8\text{V}$  |
|                                  |          | —     | $\pm 15$ | —     | mA            |                      | E, H           | $V_{DD} = 6.0\text{V}$  |
| <b>Power Supply</b>              |          |       |          |       |               |                      |                |   |
| Supply Voltage                   | $V_{DD}$ | 1.8   | —        | 6.0   | V             |                      | E, H           |   |
| Quiescent Current per Amplifier  | $I_Q$    | 20    | 45       | 70    | $\mu\text{A}$ |                      | E, H           | $I_O = 0$ , $V_{DD} = 5.0\text{V}$<br>$V_{CM} = 0.2V_{DD}$                  |
|                                  |          | 30    | 55       | 80    | $\mu\text{A}$ | $+125^\circ\text{C}$ | E              |   |
|                                  |          | 35    | 60       | 90    | $\mu\text{A}$ | $+150^\circ\text{C}$ | H              |   |

**Note 1:** E part stands for the one whose operating temperature range is from  $-40^\circ\text{C}$  to  $+125^\circ\text{C}$  and H part stands for the one whose operating temperature range is from  $-40^\circ\text{C}$  to  $+150^\circ\text{C}$ .

**2:** [Figure 2-14](#) shows how  $V_{CMR}$  changes across temperature.

# MCP6401/1R/1U/2/4/6/7/9

## AC ELECTRICAL SPECIFICATIONS

**Electrical Characteristics:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.8$  to  $+6.0\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 100\text{ k}\Omega$  to  $V_L$  and  $C_L = 60\text{ pF}$  (Refer to [Figure 1-1](#)).

| Parameters                  | Sym      | Min | Typ | Max | Units                        | Part | Conditions                          |
|-----------------------------|----------|-----|-----|-----|------------------------------|------|-------------------------------------|
| <b>AC Response</b>          |          |     |     |     |                              |      |                                     |
| Gain Bandwidth Product      | GBWP     | —   | 1   | —   | MHz                          | E, H |                                     |
| Phase Margin                | PM       | —   | 65  | —   | °                            | E, H | $G = +1\text{ V/V}$                 |
| Slew Rate                   | SR       | —   | 0.5 | —   | V/ $\mu\text{s}$             | E, H |                                     |
| <b>Noise</b>                |          |     |     |     |                              |      |                                     |
| Input Noise Voltage         | $E_{ni}$ | —   | 3.6 | —   | $\mu\text{Vp-p}$             | E, H | $f = 0.1\text{ Hz to }10\text{ Hz}$ |
| Input Noise Voltage Density | $e_{ni}$ | —   | 28  | —   | $\text{nV}/\sqrt{\text{Hz}}$ | E, H | $f = 1\text{ kHz}$                  |
| Input Noise Current Density | $i_{ni}$ | —   | 0.6 | —   | $\text{fA}/\sqrt{\text{Hz}}$ | E, H | $f = 1\text{ kHz}$                  |

## TEMPERATURE SPECIFICATIONS

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

| Parameters                         | Sym           | Min | Typ   | Max  | Units | Conditions                              |
|------------------------------------|---------------|-----|-------|------|-------|---|
| <b>Temperature Ranges</b>          |               |     |       |      |       |   |
| Operating Temperature Range        | $T_A$         | -40 | —     | +125 | °C    | E temp parts ( <a href="#">Note 1</a> ) |
|                                    | $T_A$         | -40 | —     | +150 | °C    | H temp parts ( <a href="#">Note 1</a> ) |
| Storage Temperature Range          | $T_A$         | -65 | —     | +155 | °C    |   |
| <b>Thermal Package Resistances</b> |               |     |       |      |       |   |
| Thermal Resistance, 5L-SOT-23      | $\theta_{JA}$ | —   | 220.7 | —    | °C/W  |   |
| Thermal Resistance, 8L-SOIC        | $\theta_{JA}$ | —   | 149.5 | —    | °C/W  |   |
| Thermal Resistance, 14L-SOIC       | $\theta_{JA}$ | —   | 95.3  | —    | °C/W  |   |

**Note 1:** The internal junction temperature ( $T_J$ ) must not exceed the absolute maximum specification of  $+155^\circ\text{C}$ .

### 1.4 Test Circuits

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:

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

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

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

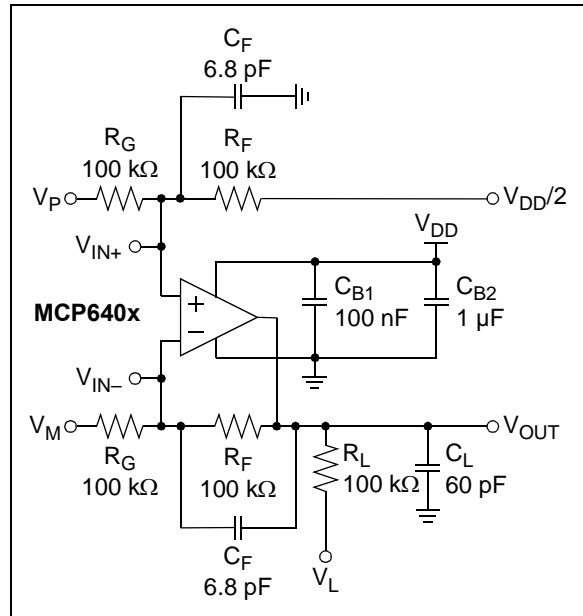
$$V_{OUT} = (V_{DD}/2) + (V_P - V_M) + V_{OST}(1 + G_{DM})$$

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,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.8\text{V}$  to  $+6.0\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 100\text{ k}\Omega$  to  $V_L$  and  $C_L = 60\text{ pF}$ .

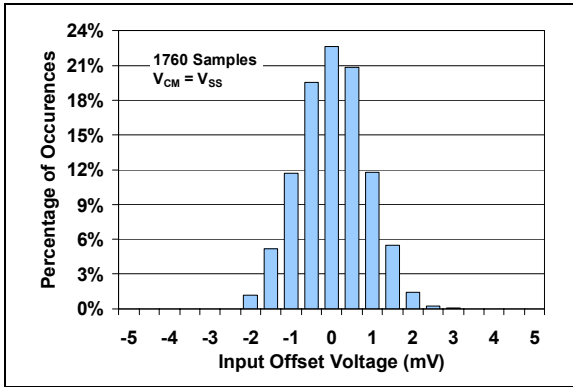


FIGURE 2-1: Input Offset Voltage.

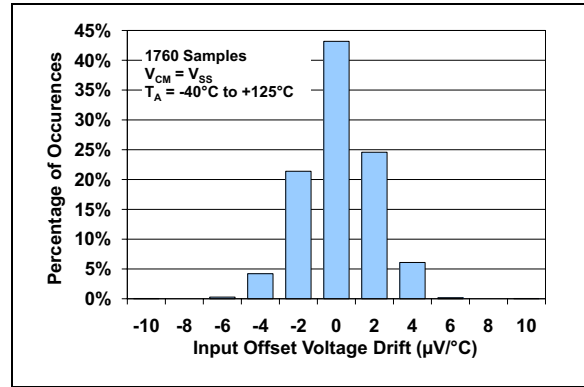


FIGURE 2-4: Input Offset Voltage Drift.

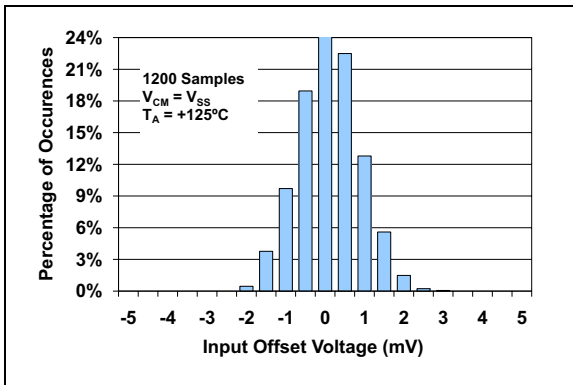


FIGURE 2-2: Input Offset Voltage.

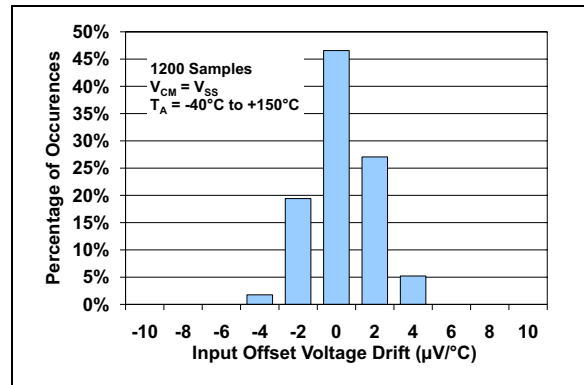


FIGURE 2-5: Input Offset Voltage Drift.

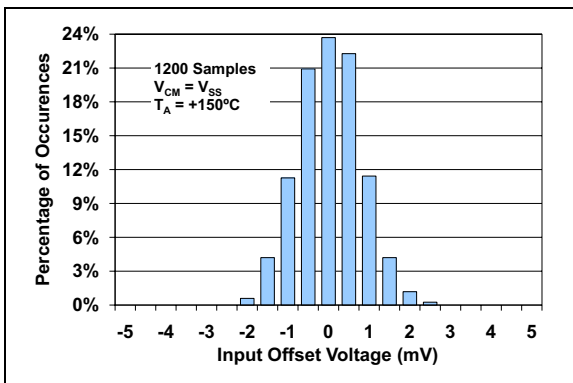


FIGURE 2-3: Input Offset Voltage.

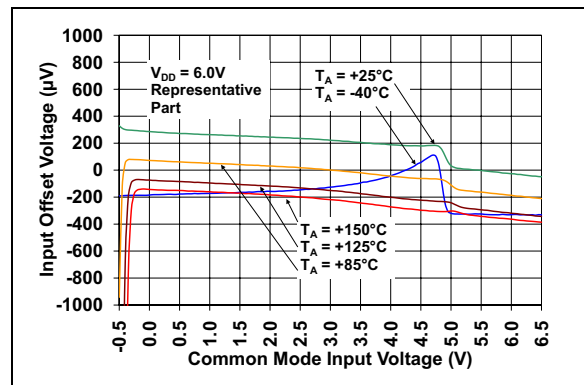
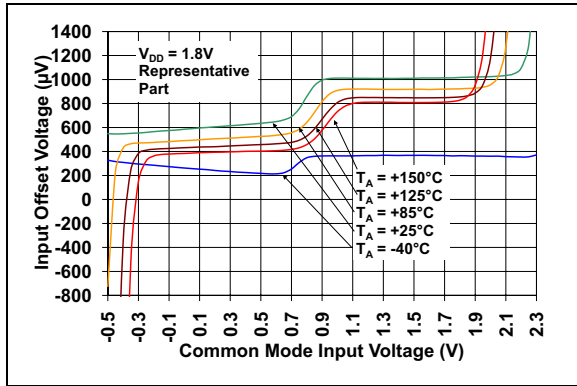


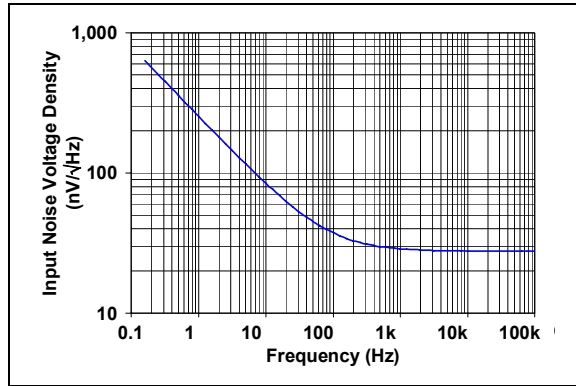
FIGURE 2-6: Input Offset Voltage vs. Common Mode Input Voltage with  $V_{DD} = 6.0\text{V}$ .

# MCP6401/1R/1U/2/4/6/7/9

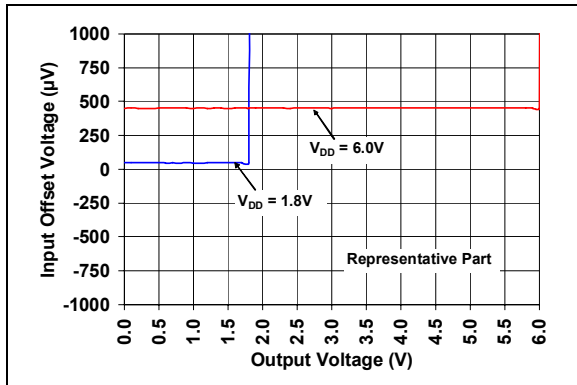
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.8\text{V}$  to  $+6.0\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 100\text{ k}\Omega$  to  $V_L$  and  $C_L = 60\text{ pF}$ .



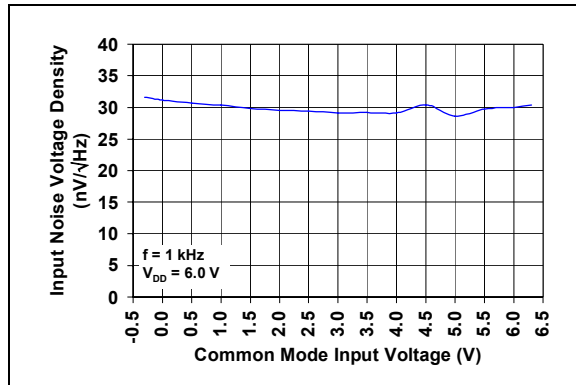
**FIGURE 2-7:** Input Offset Voltage vs. Common Mode Input Voltage with  $V_{DD} = 1.8\text{V}$ .



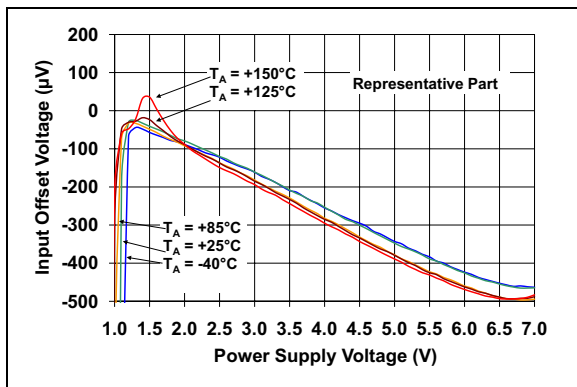
**FIGURE 2-10:** Input Noise Voltage Density vs. Frequency.



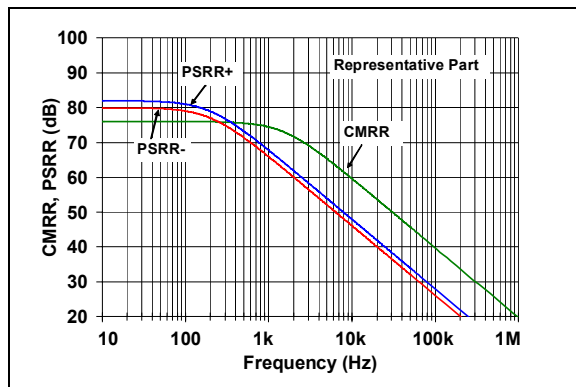
**FIGURE 2-8:** Input Offset Voltage vs. Output Voltage.



**FIGURE 2-11:** Input Noise Voltage Density vs. Common Mode Input Voltage.



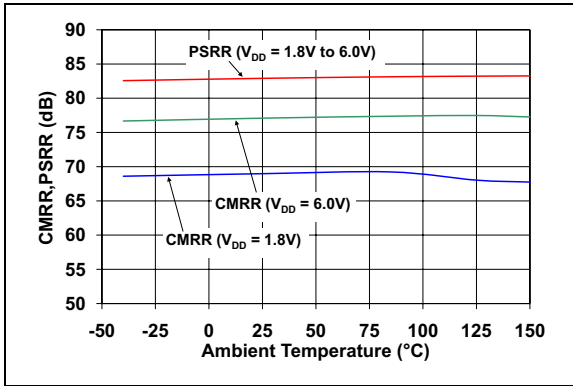
**FIGURE 2-9:** Input Offset Voltage vs. Power Supply Voltage.



**FIGURE 2-12:** CMRR, PSRR vs. Frequency.

# MCP6401/1R/1U/2/4/6/7/9

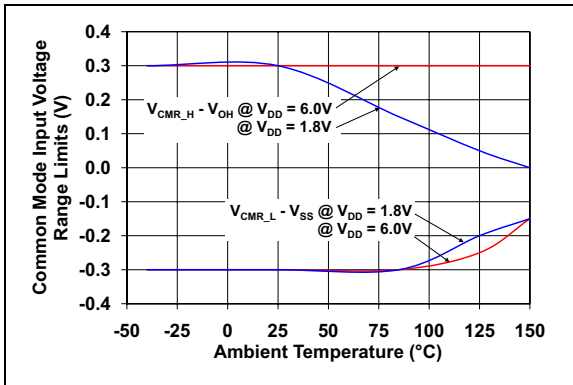
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.8\text{V to }+6.0\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 100\text{ k}\Omega$  to  $V_L$  and  $C_L = 60\text{ pF}$ .



**FIGURE 2-13:** CMRR, PSRR vs. Ambient Temperature.



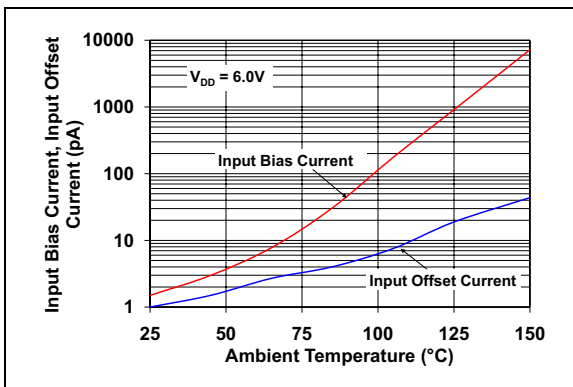
**FIGURE 2-16:** Input Bias Current vs. Common Mode Input Voltage.



**FIGURE 2-14:** Common Mode Input Voltage Range Limits vs. Ambient Temperature.



**FIGURE 2-17:** Quiescent Current vs. Ambient Temperature.



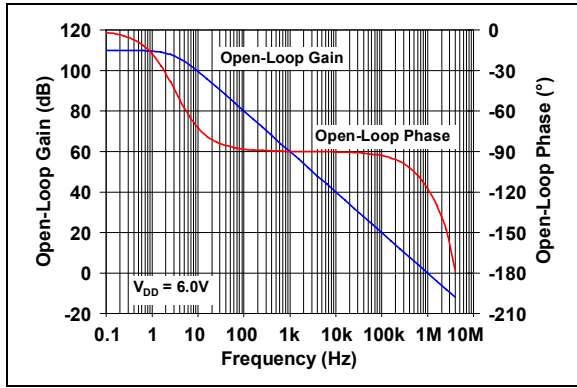
**FIGURE 2-15:** Input Bias, Offset Current vs. Ambient Temperature.



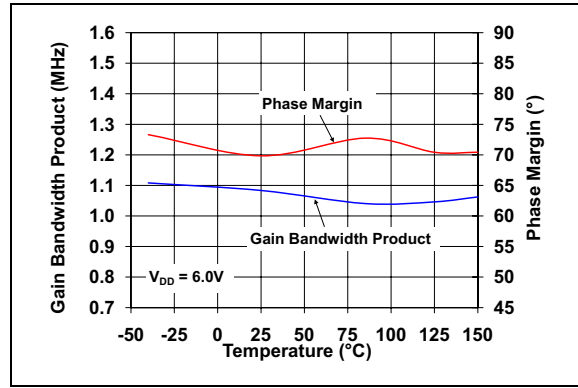
**FIGURE 2-18:** Quiescent Current vs. Power Supply Voltage.

# MCP6401/1R/1U/2/4/6/7/9

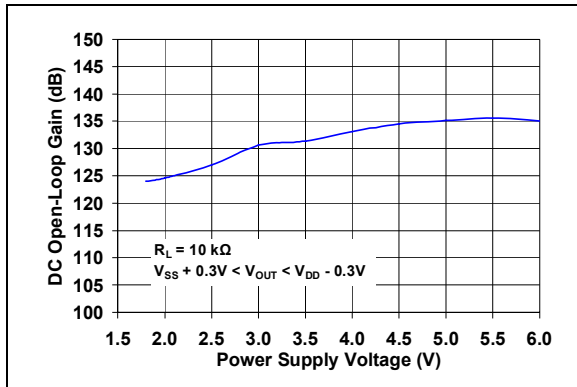
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.8\text{V}$  to  $+6.0\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 100\text{ k}\Omega$  to  $V_L$  and  $C_L = 60\text{ pF}$ .



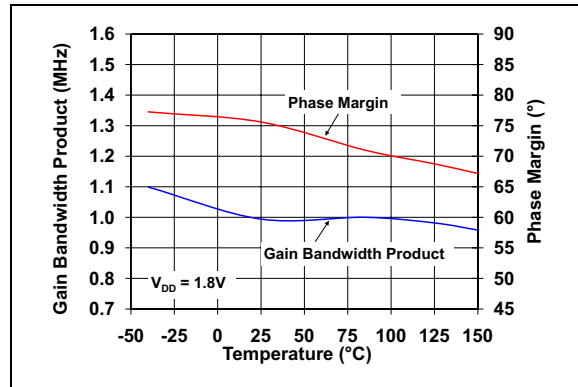
**FIGURE 2-19:** Open-Loop Gain, Phase vs. Frequency.



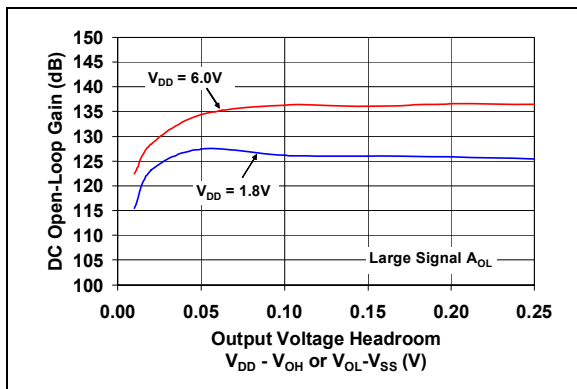
**FIGURE 2-22:** Gain Bandwidth Product, Phase Margin vs. Ambient Temperature.



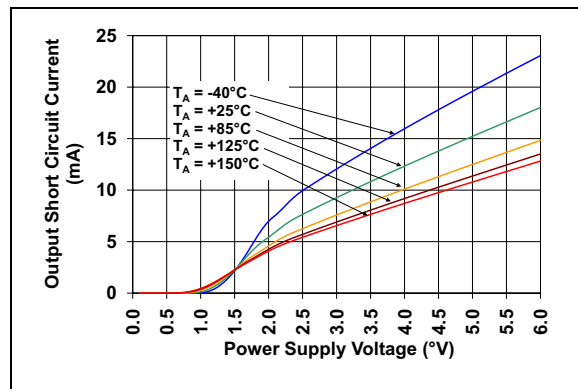
**FIGURE 2-20:** DC Open-Loop Gain vs. Power Supply Voltage.



**FIGURE 2-23:** Gain Bandwidth Product, Phase Margin vs. Ambient Temperature.



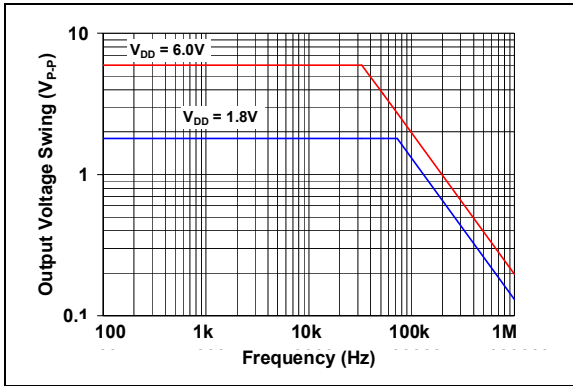
**FIGURE 2-21:** DC Open-Loop Gain vs. Output Voltage Headroom.



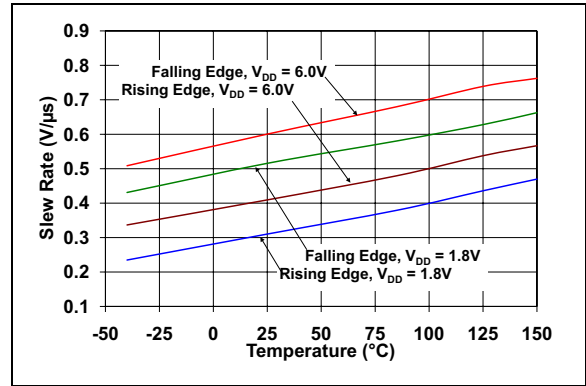
**FIGURE 2-24:** Output Short Circuit Current vs. Power Supply Voltage.

# MCP6401/1R/1U/2/4/6/7/9

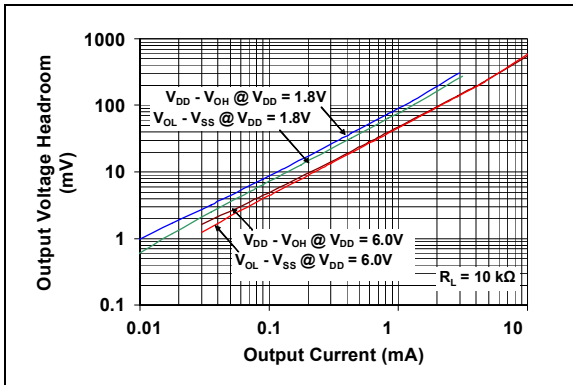
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.8\text{V}$  to  $+6.0\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 100\text{ k}\Omega$  to  $V_L$  and  $C_L = 60\text{ pF}$ .



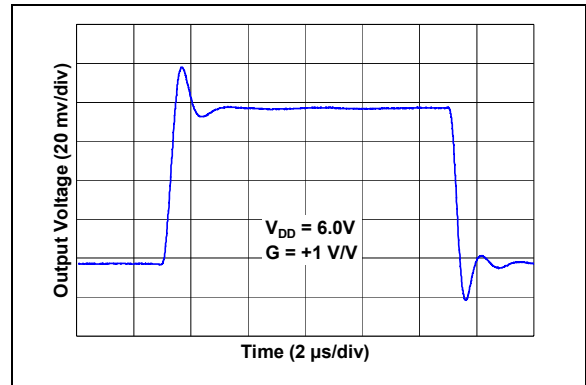
**FIGURE 2-25:** Output Voltage Swing vs. Frequency.



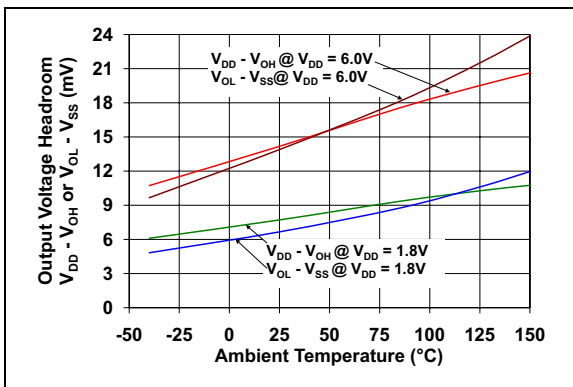
**FIGURE 2-28:** Slew Rate vs. Ambient Temperature.



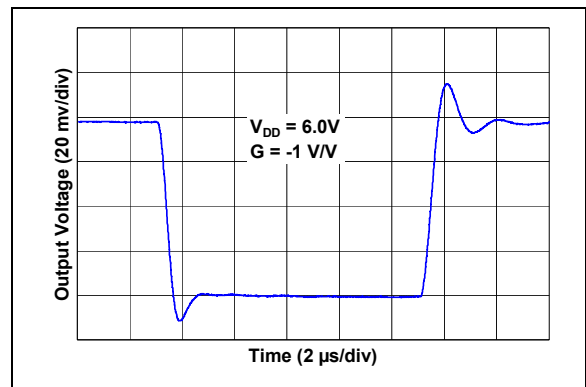
**FIGURE 2-26:** Output Voltage Headroom vs. Output Current.



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



**FIGURE 2-27:** Output Voltage Headroom vs. Ambient Temperature.



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

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**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.8\text{V}$  to  $+6.0\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 100\text{ k}\Omega$  to  $V_L$  and  $C_L = 60\text{ pF}$ .



**FIGURE 2-31:** Large Signal Non-Inverting Pulse Response.



**FIGURE 2-34:** Closed Loop Output Impedance vs. Frequency.



**FIGURE 2-32:** Large Signal Inverting Pulse Response.



**FIGURE 2-35:** Measured Input Current vs. Input Voltage (below  $V_{SS}$ ).



**FIGURE 2-33:** The MCP6401/1R/1U/2/4/6/7/9 Shows No Phase Reversal.



**FIGURE 2-36:** Channel-to-Channel Separation vs. Frequency (MCP6402/4/7/9 only).

### 3.0 PIN DESCRIPTIONS

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

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

| MCP6401             | MCP6401R | MCP6401U | MCP6402 |             | MCP6404        | MCP6406  | MCP6407 | MCP6409 | Symbol              | Description   |
|---------------------|----------|----------|---------|-------------|----------------|----------|---------|---------|---------------------|---|
| SC70-5,<br>SOT-23-5 | SOT-23-5 | SOT-23-5 | SOIC    | 2x3<br>TDFN | SOIC,<br>TSSOP | SOT-23-5 | SOIC    | SOIC    |                     |   |
| 1                   | 1        | 4        | 1       | 1           | 1              | 1        | 1       | 1       | $V_{OUT}, V_{OUTA}$ | Analog Output (op amp A)                                  |
| 4                   | 4        | 3        | 2       | 2           | 2              | 4        | 2       | 2       | $V_{IN-}, V_{INA-}$ | Inverting Input (op amp A)                                |
| 3                   | 3        | 1        | 3       | 3           | 3              | 3        | 3       | 3       | $V_{IN+}, V_{INA+}$ | Non-inverting Input (op amp A)                            |
| 5                   | 2        | 5        | 8       | 8           | 4              | 5        | 8       | 4       | $V_{DD}$            | Positive Power Supply                                     |
| —                   | —        | —        | 5       | 5           | 5              | —        | 5       | 5       | $V_{INB+}$          | Non-inverting Input (op amp B)                            |
| —                   | —        | —        | 6       | 6           | 6              | —        | 6       | 6       | $V_{INB-}$          | Inverting Input (op amp B)                                |
| —                   | —        | —        | 7       | 7           | 7              | —        | 7       | 7       | $V_{OUTB}$          | Analog Output (op amp B)                                  |
| —                   | —        | —        | —       | —           | 8              | —        | —       | 8       | $V_{OUTC}$          | Analog Output (op amp C)                                  |
| —                   | —        | —        | —       | —           | 9              | —        | —       | 9       | $V_{INC-}$          | Inverting Input (op amp C)                                |
| —                   | —        | —        | —       | —           | 10             | —        | —       | 10      | $V_{INC+}$          | Non-inverting Input (op amp C)                            |
| 2                   | 5        | 2        | 4       | 4           | 11             | 2        | 4       | 11      | $V_{SS}$            | Negative Power Supply                                     |
| —                   | —        | —        | —       | —           | 12             | —        | —       | 12      | $V_{IND+}$          | Non-inverting Input (op amp D)                            |
| —                   | —        | —        | —       | —           | 13             | —        | —       | 13      | $V_{IND-}$          | Inverting Input (op amp D)                                |
| —                   | —        | —        | —       | —           | 14             | —        | —       | 14      | $V_{OUTD}$          | Analog Output (op amp D)                                  |
| —                   | —        | —        | —       | 9           | —              | —        | —       | —       | EP                  | Exposed Thermal Pad (EP); must be connected to $V_{SS}$ . |

# MCP6401/1R/1U/2/4/6/7/9

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## 3.1 Analog Output ( $V_{OUT}$ )

The output pin is low-impedance voltage source.

## 3.2 Analog Inputs ( $V_{IN+}$ , $V_{IN-}$ )

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

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

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 at voltages between  $V_{SS}$  and  $V_{DD}$ .

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



## 4.0 APPLICATION INFORMATION

The MCP6401/1R/1U/2/4/6/7/9 family of op amps is manufactured using Microchip's state-of-the-art CMOS process and is specifically designed for low-power, high-precision applications.

### 4.1 Rail-to-Rail Input

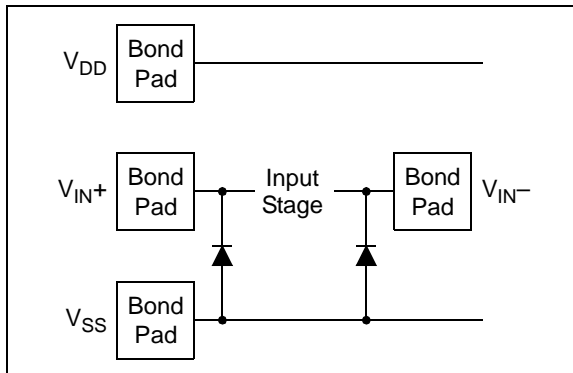
#### 4.1.1 PHASE REVERSAL

The MCP6401/1R/1U/2/4/6/7/9 op amps are designed to prevent phase reversal when the input pins exceed the supply voltages. Figure 2-33 shows the input voltage exceeding the supply voltage with no phase reversal.

#### 4.1.2 INPUT VOLTAGE LIMITS

In order to prevent damage and/or improper operation of these amplifiers, the circuit must limit the voltages at the input pins (see Section 1.1 "Absolute Maximum Ratings †").

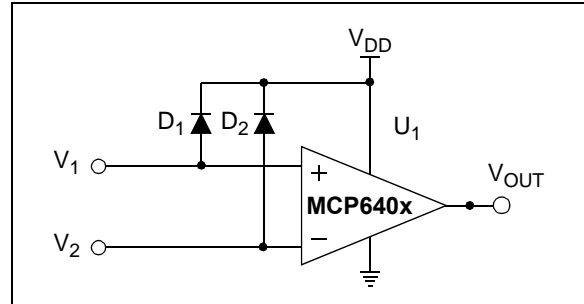
The ESD protection on the inputs can be depicted as shown in Figure 4-1. This structure was chosen to protect the input transistors against many (but not all) over-voltage conditions, and to minimize the input bias current ( $I_B$ ).



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

The input ESD diodes clamp the inputs when they try to go more than one diode drop below  $V_{SS}$ . They also clamp any voltages that go well above  $V_{DD}$ ; their breakdown voltage is high enough to allow normal operation, but not low enough to protect against slow over-voltage (beyond  $V_{DD}$ ) events. Very fast ESD events (that meet the spec) are limited so that damage does not occur.

In some applications, it may be necessary to prevent excessive voltages from reaching the op amp inputs; Figure 4-2 shows one approach to protecting these inputs.



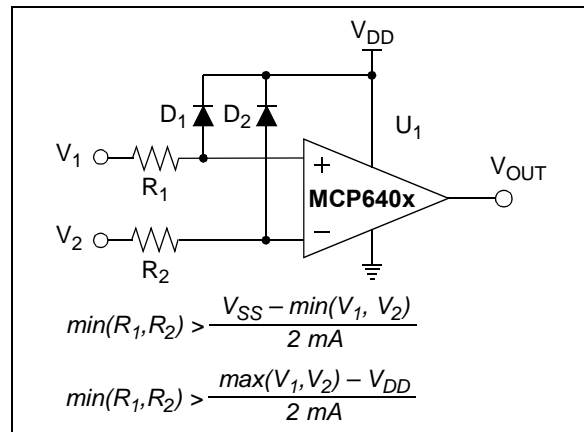
**FIGURE 4-2:** Protecting the Analog Inputs.

A significant amount of current can flow out of the inputs when the Common Mode voltage ( $V_{CM}$ ) is below ground ( $V_{SS}$ ); See Figure 2-35.

#### 4.1.3 INPUT CURRENT LIMITS

In order to prevent damage and/or improper operation of these amplifiers, the circuit must limit the currents into the input pins (see Section 1.1 "Absolute Maximum Ratings †").

Figure 4-3 shows one approach to protecting these inputs. The resistors  $R_1$  and  $R_2$  limit the possible currents in or out of the input pins (and the ESD diodes,  $D_1$  and  $D_2$ ). The diode currents will go through either  $V_{DD}$  or  $V_{SS}$ .



**FIGURE 4-3:** Protecting the Analog Inputs.

#### 4.1.4 NORMAL OPERATION

The input stage of the MCP6401/1R/1U/2/4/6/7/9 op amps use two differential input stages in parallel. One operates at a low Common Mode input voltage ( $V_{CM}$ ), while the other operates at a high  $V_{CM}$ . With this topology, the device operates with a  $V_{CM}$  up to 300 mV above  $V_{DD}$  and 300 mV below  $V_{SS}$  (see Figure 2-14). The input offset voltage is measured at  $V_{CM} = V_{SS} - 0.3V$  and  $V_{DD} + 0.3V$  to ensure proper operation.

The transition between the input stages occurs when  $V_{CM}$  is near  $V_{DD} - 1.1V$  (see Figures 2-6 and 2-7). For the best distortion performance and gain linearity, with non-inverting gains, avoid this region of operation.

# MCP6401/1R/1U/2/4/6/7/9

## 4.2 Rail-to-Rail Output

The output voltage range of the MCP6401/1R/1U/2/4/6/7/9 op amps is  $V_{SS} + 20\text{ mV}$  (minimum) and  $V_{DD} - 20\text{ mV}$  (maximum) when  $R_L = 10\text{ k}\Omega$  is connected to  $V_{DD}/2$  and  $V_{DD} = 6.0\text{V}$ . Refer to Figures 2-26 and 2-27 for more information.

## 4.3 Capacitive Loads

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

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



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

Figure 4-5 gives recommended  $R_{ISO}$  values for different capacitive loads and gains. The x-axis is the normalized load capacitance ( $C_L/G_N$ ), where  $G_N$  is the circuit's noise gain. For non-inverting gains,  $G_N$  and the Signal Gain are equal. For inverting gains,  $G_N$  is  $1+|\text{Signal Gain}|$  (e.g.,  $-1\text{ V/V}$  gives  $G_N = +2\text{ V/V}$ ).



**FIGURE 4-5:** Recommended  $R_{ISO}$  Values for Capacitive Loads.

After selecting  $R_{ISO}$  for your circuit, double-check the resulting frequency response peaking and step response overshoot. Modify  $R_{ISO}$ 's value until the response is reasonable. Bench evaluation and simulations with the MCP6401/1R/1U/2/4/6/7/9 SPICE macro model are very helpful.

## 4.4 Supply Bypass

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

## 4.5 Unused Op Amps

An unused op amp in quad packages (MCP6404 or MCP6409) should be configured as shown in Figure 4-6. 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, which buffers that reference voltage. Circuit B uses the minimum number of components and operates as a comparator, but it may draw more current.

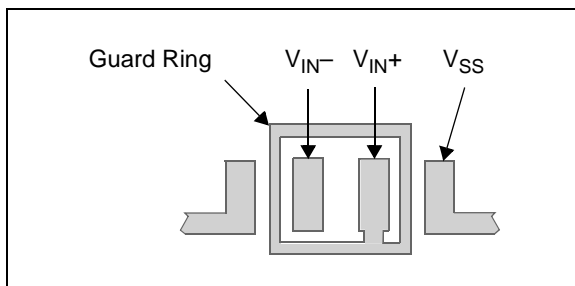


**FIGURE 4-6:** Unused Op Amps.

## 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 MCP6401/1R/1U/2/4/6/7/9 family's bias current at +25°C ( $\pm 1.0$  pA, typical).

The easiest way to reduce surface leakage is to use a guard ring around sensitive pins (or traces). The guard ring is biased at the same voltage as the sensitive pin. An example of this type of layout is shown in Figure 4-7.



**FIGURE 4-7:** Example Guard Ring Layout for Inverting Gain.

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

## 4.7 Application Circuits

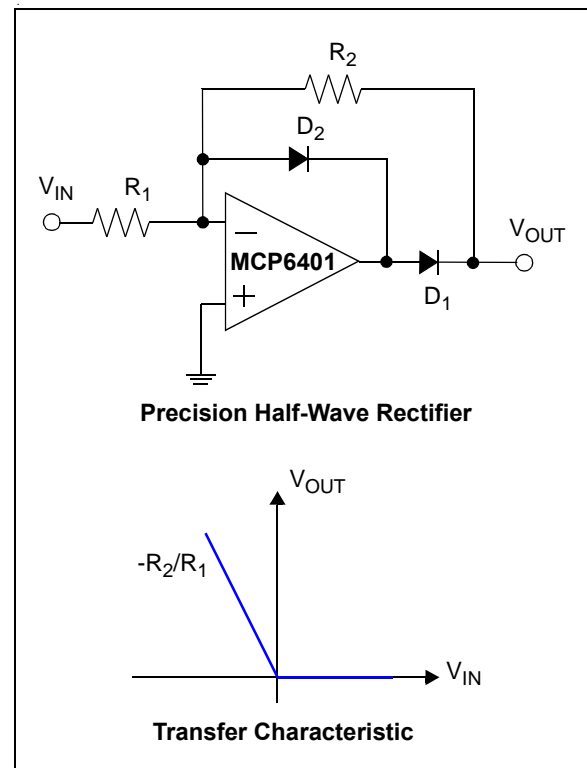
### 4.7.1 PRECISION HALF-WAVE RECTIFIER

The precision half-wave rectifier, which is also known as a super diode, is a configuration obtained with an operational amplifier in order to have a circuit behave like an ideal diode and rectifier. It effectively cancels the forward voltage drop of the diode so that very low level signals can still be rectified with minimal error. This can be useful for high-precision signal processing. The MCP6401/1R/1U/2/4/6/7/9 op amps have high input impedance, low input bias current and rail-to-rail input/output, which makes this device suitable for precision rectifier applications.

Figure 4-8 shows a precision half-wave rectifier and its transfer characteristic. The rectifier's input impedance is determined by the input resistor  $R_1$ . To avoid loading effect, it must be driven from a low-impedance source.

When  $V_{IN}$  is greater than zero,  $D_1$  is OFF,  $D_2$  is ON, and  $V_{OUT}$  is zero. When  $V_{IN}$  is less than zero,  $D_1$  is ON,  $D_2$  is OFF, and  $V_{OUT}$  is the  $V_{IN}$  with an amplification of  $-R_2/R_1$ .

The rectifier circuit shown in Figure 4-8 has the benefit that the op amp never goes in saturation, so the only thing affecting its frequency response is the amplification and the gain bandwidth product.



**FIGURE 4-8:** Precision Half-Wave Rectifier.

# MCP6401/1R/1U/2/4/6/7/9

## 4.7.2 BATTERY CURRENT SENSING

The MCP6401/1R/1U/2/4/6/7/9 op amps' Common Mode Input Range, which goes 0.3V beyond both supply rails, supports their use in high-side and low-side battery current sensing applications. The low quiescent current (45  $\mu$ A, typical) helps prolong battery life, and the rail-to-rail output supports detection of low currents.

Figure 4-9 shows a high-side battery current sensor circuit. The 10 $\Omega$  resistor is sized to minimize power losses. The battery current ( $I_{DD}$ ) through the 10 $\Omega$  resistor causes its top terminal to be more negative than the bottom terminal. This keeps the Common Mode input voltage of the op amp below  $V_{DD}$ , which is within its allowed range. The output of the op amp will also be below  $V_{DD}$ , which is within its Maximum Output Voltage Swing specification.



**FIGURE 4-9:** Supply Current Sensing.

## 4.7.3 INSTRUMENTATION AMPLIFIER

The MCP6401/1R/1U/2/4/6/7/9 op amps are well suited for conditioning sensor signals in battery-powered applications. Figure 4-10 shows a two op amp instrumentation amplifier, using the MCP6402, that works well for applications requiring rejection of Common Mode noise at higher gains. The reference voltage ( $V_{REF}$ ) is supplied by a low impedance source. In single supply applications,  $V_{REF}$  is typically  $V_{DD}/2$ .



**FIGURE 4-10:** Two Op Amp Instrumentation Amplifier.

## 5.0 DESIGN AIDS

Microchip provides the basic design tools needed for the MCP6401/1R/1U/2/4/6/7/9 family of op amps.

### 5.1 SPICE Macro Model

The latest SPICE macro model for the MCP6401/1R/1U/2/4/6/7/9 op amp is available on the Microchip web site at [www.microchip.com](http://www.microchip.com). The model was written and tested in official Orcad (Cadence) owned PSPICE. For other simulators, translation may be required.

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

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

### 5.2 FilterLab<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.

### 5.3 Microchip Advanced Part Selector (MAPS)

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

## 5.4 Analog Demonstration and Evaluation Boards

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

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

## 5.5 Application Notes

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

- **ADN003:** "Select the Right Operational Amplifier for your Filtering Circuits", DS21821
- **AN722:** "Operational Amplifier Topologies and DC Specifications", DS00722
- **AN723:** "Operational Amplifier AC Specifications and Applications", DS00723
- **AN884:** "Driving Capacitive Loads With Op Amps", DS00884
- **AN990:** "Analog Sensor Conditioning Circuits – An Overview", DS00990
- **AN1177:** "Op Amp Precision Design: DC Errors", DS01177
- **AN1228:** "Op Amp Precision Design: Random Noise", DS01228
- **AN1297:** "Microchip's Op Amp SPICE Macro Models", DS01297
- **AN1332:** "Current Sensing Circuit Concepts and Fundamentals", DS01332

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

- "Signal Chain Design Guide", DS21825

# MCP6401/1R/1U/2/4/6/7/9

## 6.0 PACKAGING INFORMATION

### 6.1 Package Marking Information

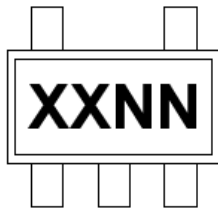
5-Lead SC70 (MCP6401 only)

Example:



5-Lead SOT-23  
(MCP6401/1R/1U, MCP6406)

Example:



| Part Number    | Code |
|----------------|------|
| MCP6401T-E/OT  | NLNN |
| MCP6401T-H/OT  | U8NN |
| MCP6401RT-E/OT | NMNN |
| MCP6401RT-H/OT | U9NN |
| MCP6401UT-E/OT | NPNN |
| MCP6401UT-H/OT | V8NN |
| MCP6406T-E/OT  | ZXNN |
| MCP6406T-H/OT  | ZYNN |

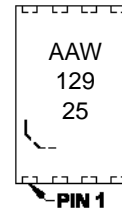


8-Lead TDFN (2 x 3)(MCP6402 only)

Example:

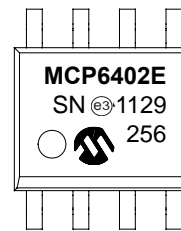
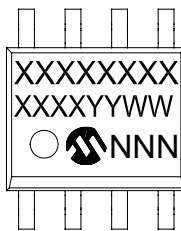


| Part Number    | Code |
|----------------|------|
| MCP6402T-E/MNY | AAW  |



8-Lead SOIC (150 mil)(MCP6401, MCP6402, MCP6407)

Example:



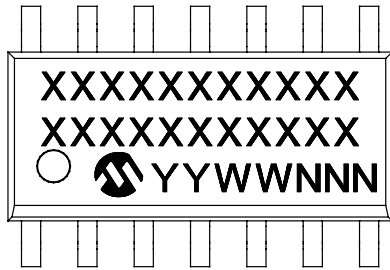
|                |        |  |
|----------------|--------|--|
| <b>Legend:</b> | XX...X | Customer-specific information  |
|                | Y      | Year code (last digit of calendar year)  |
|                | YY     | Year code (last 2 digits of calendar year)   |
|                | WW     | Week 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.

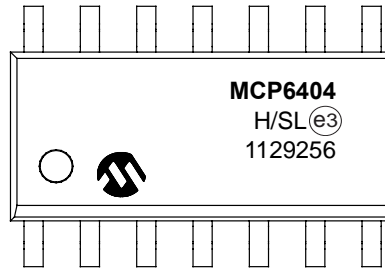
# MCP6401/1R/1U/2/4/6/7/9

## Package Marking Information (Continued)

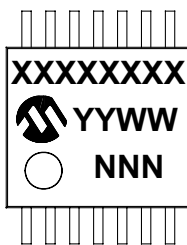
14-Lead SOIC (150 mil) (MCP6404, MCP6409)



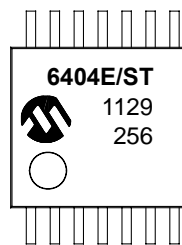
Example:



14-Lead TSSOP (MCP6404 only)



Example:



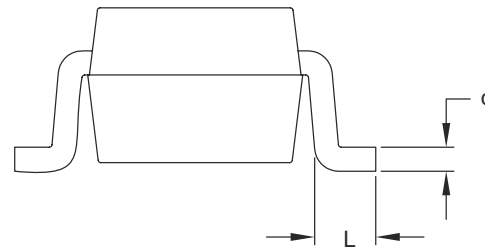
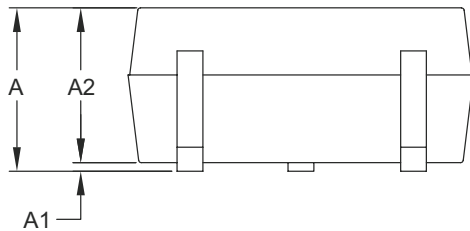
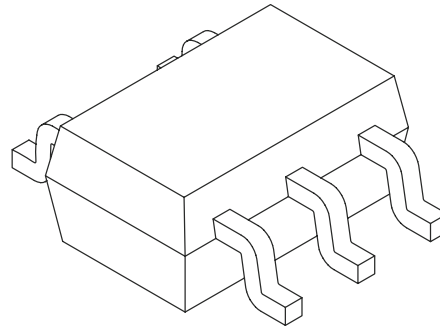
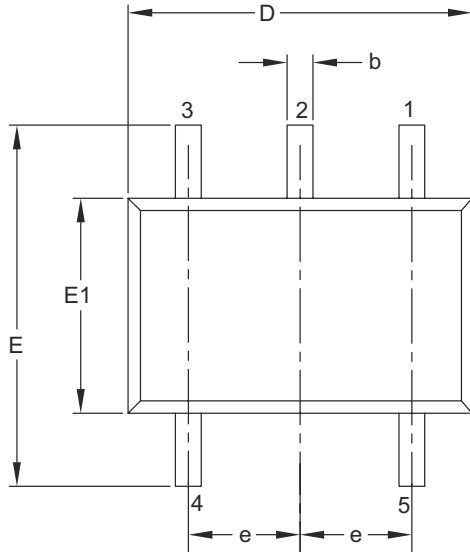
|                |        |  |
|----------------|--------|--|
| <b>Legend:</b> | XX...X | Customer-specific information  |
|                | Y      | Year code (last digit of calendar year)  |
|                | YY     | Year code (last 2 digits of calendar year)   |
|                | WW     | Week 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.

# MCP6401/1R/1U/2/4/6/7/9

## 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.

Microchip Technology Drawing C04-061B



# MCP6401/1R/1U/2/4/6/7/9

## 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

# MCP6401/1R/1U/2/4/6/7/9

## 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.

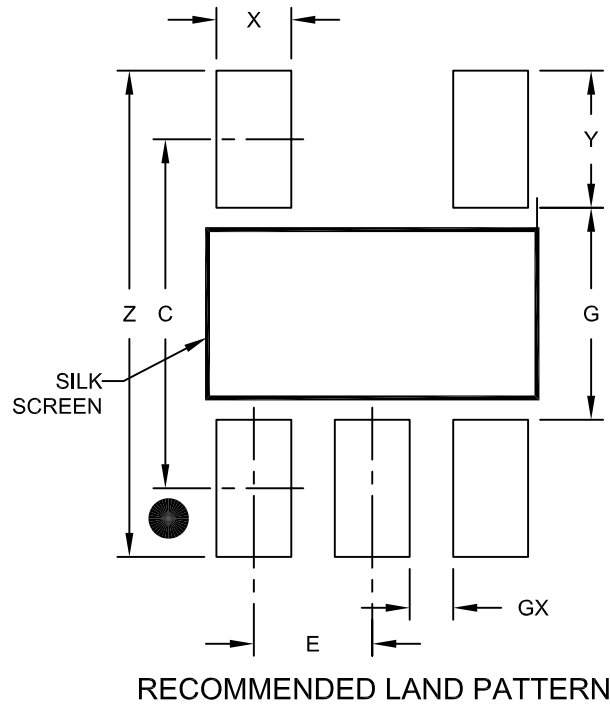
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing C04-091B

# MCP6401/1R/1U/2/4/6/7/9

## 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  |
| Contact Pitch           | E     | 0.95 BSC    |      |      |
| Contact Pad Spacing     | C     |             | 2.80 |      |
| Contact Pad Width (X5)  | X     |             |      | 0.60 |
| Contact Pad Length (X5) | Y     |             |      | 1.10 |
| Distance Between Pads   | G     | 1.70        |      |      |
| Distance Between Pads   | GX    | 0.35        |      |      |
| Overall Width           | Z     |             |      | 3.90 |

**Notes:**

1. Dimensioning and tolerancing per ASME Y14.5M

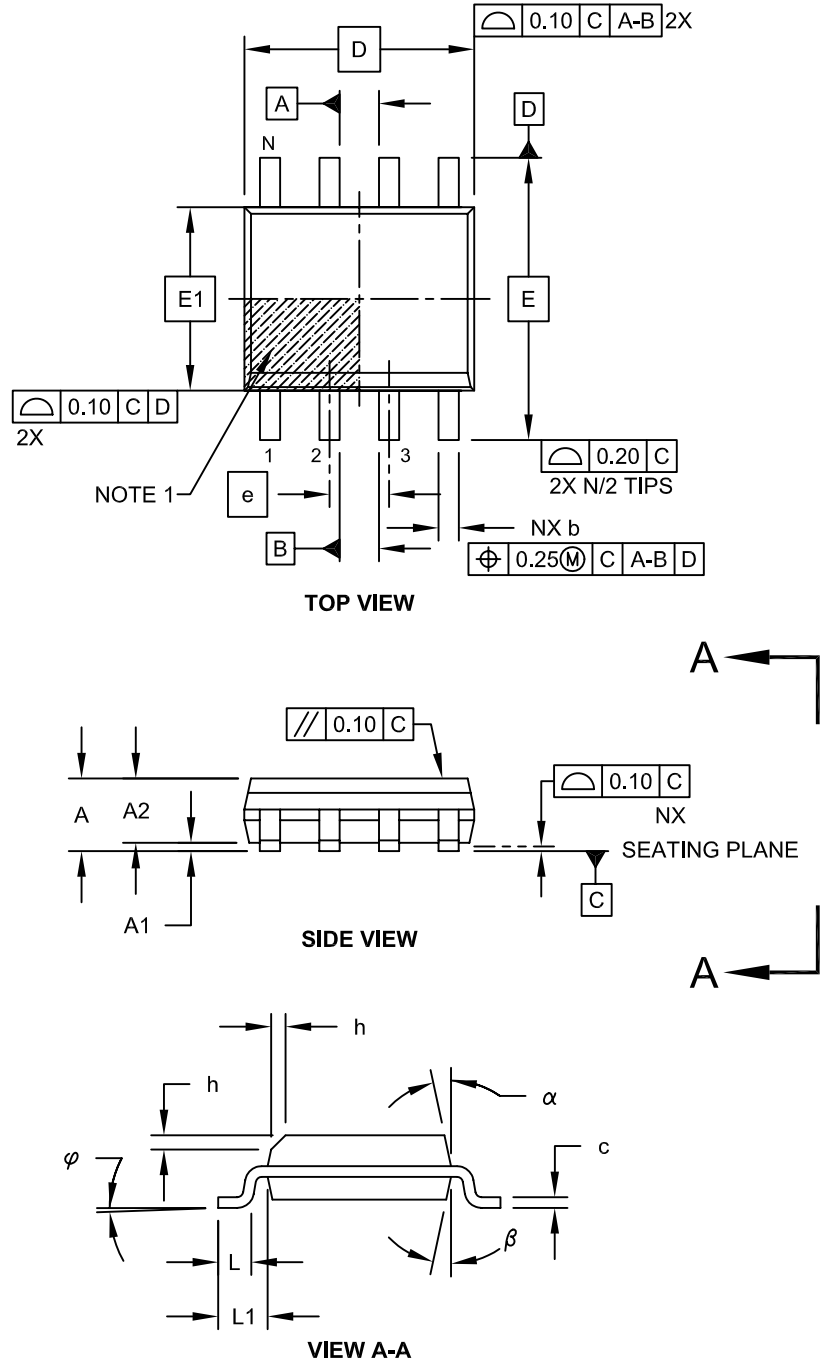
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing No. C04-2091A

# MCP6401/1R/1U/2/4/6/7/9

## 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>



Microchip Technology Drawing No. C04-057C Sheet 1 of 2

# MCP6401/1R/1U/2/4/6/7/9

## 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               | 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:

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 0.15mm per side.
4. Dimensioning and tolerancing per ASME Y14.5M

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

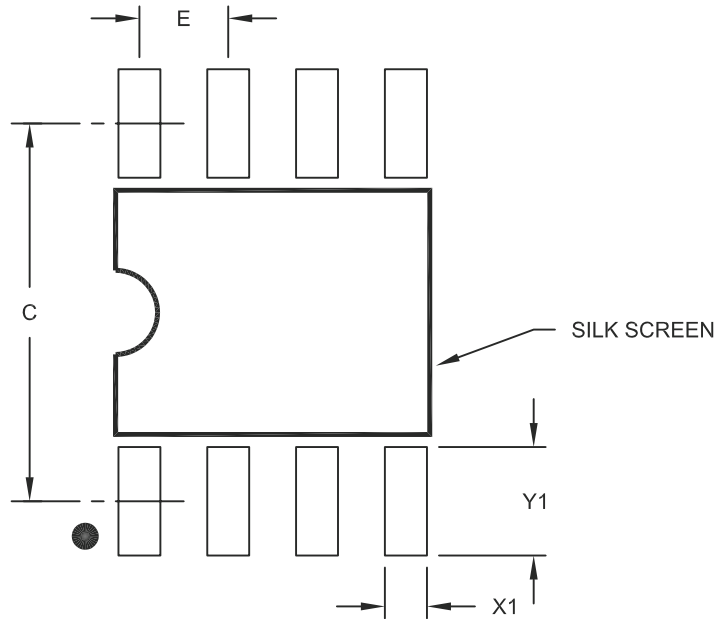
REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing No. C04-057C Sheet 2 of 2

# MCP6401/1R/1U/2/4/6/7/9

## 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

|                         |    | Units | MILLIMETERS |      |      |
|-------------------------|----|-------|-------------|------|------|
| Dimension Limits        |    |       | 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

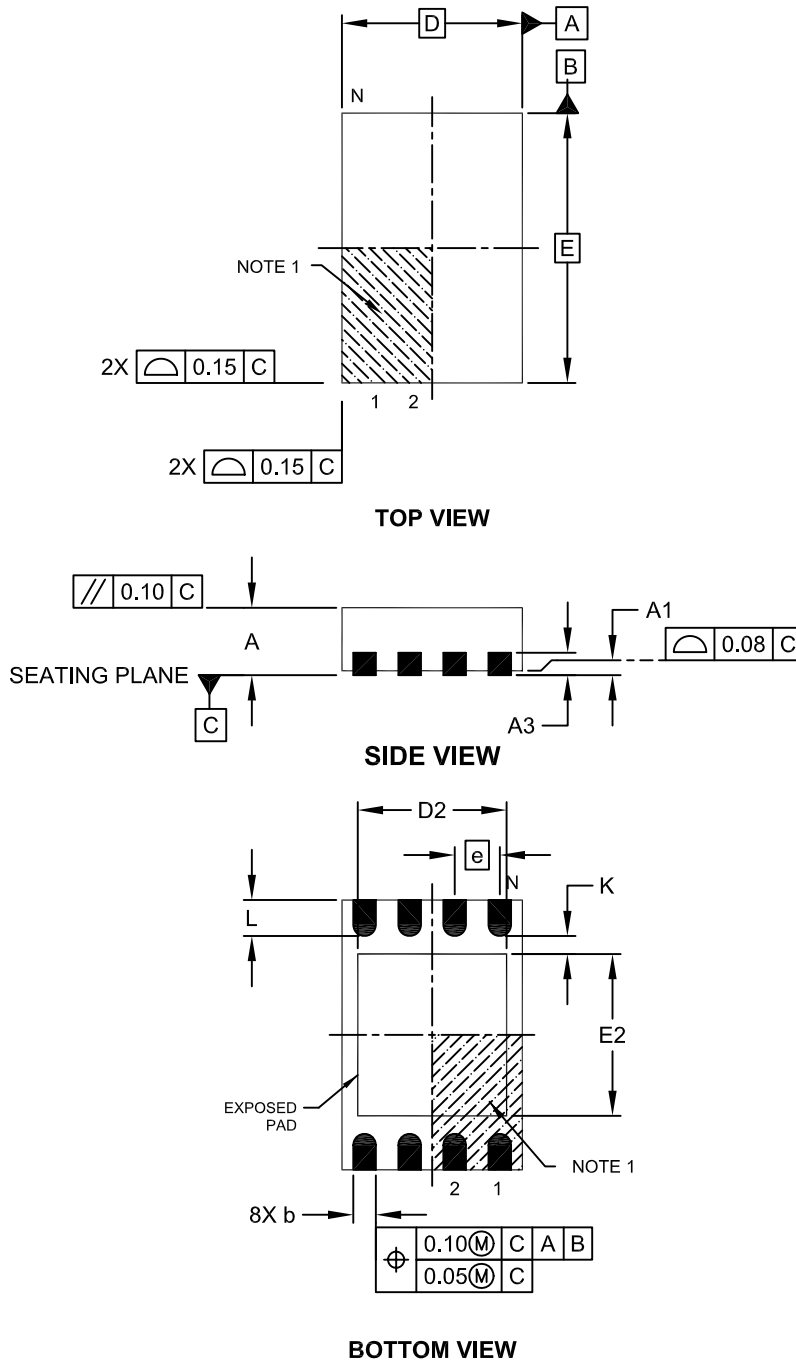
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing No. C04-2057A

# MCP6401/1R/1U/2/4/6/7/9

## 8-Lead Plastic Dual Flat, No Lead Package (MN) – 2x3x0.75mm Body [TDFN]

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



Microchip Technology Drawing No. C04-129C Sheet 1 of 2

# MCP6401/1R/1U/2/4/6/7/9

## 8-Lead Plastic Dual Flat, No Lead Package (MN) – 2x3x0.75mm Body [TDFN]

**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     | 0.50 BSC    |      |      |
| Overall Height         | A     | 0.70        | 0.75 | 0.80 |
| Standoff               | A1    | 0.00        | 0.02 | 0.05 |
| Contact Thickness      | A3    | 0.20 REF    |      |      |
| Overall Length         | D     | 2.00 BSC    |      |      |
| Overall Width          | E     | 3.00 BSC    |      |      |
| Exposed Pad Length     | D2    | 1.20        | -    | 1.60 |
| Exposed Pad Width      | E2    | 1.20        | -    | 1.60 |
| Contact Width          | b     | 0.20        | 0.25 | 0.30 |
| Contact Length         | L     | 0.25        | 0.30 | 0.45 |
| Contact-to-Exposed Pad | K     | 0.20        | -    | -    |

### Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Package may have one or more exposed tie bars at ends.
3. Package is saw singulated
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.

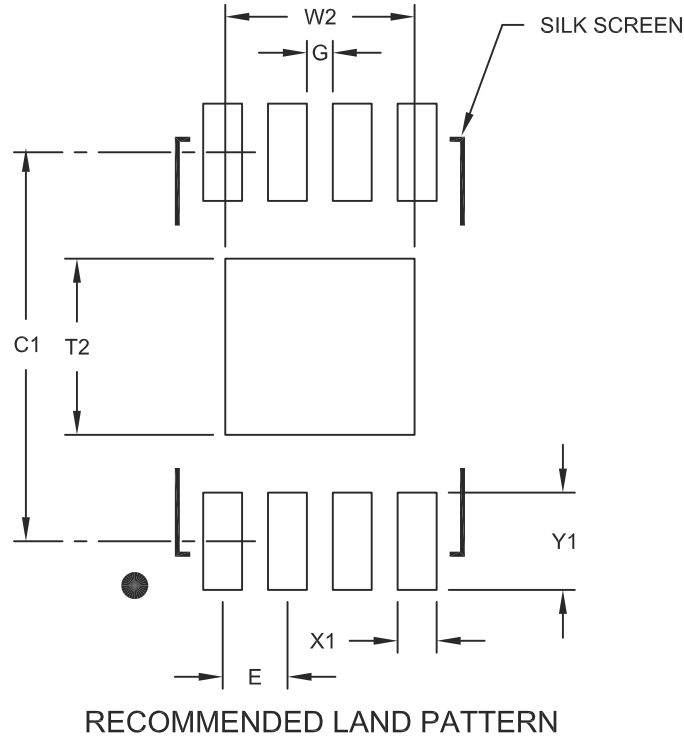
Microchip Technology Drawing No. C04-129C



# MCP6401/1R/1U/2/4/6/7/9

## 8-Lead Plastic Dual Flat, No Lead Package (MN) – 2x3x0.75 mm Body [TDFN]

**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  |
| Contact Pitch              | E     | 0.50 BSC    |      |      |
| Optional Center Pad Width  | W2    |             |      | 1.46 |
| Optional Center Pad Length | T2    |             |      | 1.36 |
| Contact Pad Spacing        | C1    |             | 3.00 |      |
| Contact Pad Width (X8)     | X1    |             |      | 0.30 |
| Contact Pad Length (X8)    | Y1    |             |      | 0.75 |
| Distance Between Pads      | G     | 0.20        |      |      |

**Notes:**

1. Dimensioning and tolerancing per ASME Y14.5M

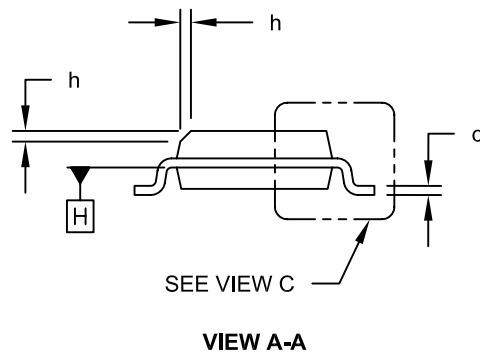
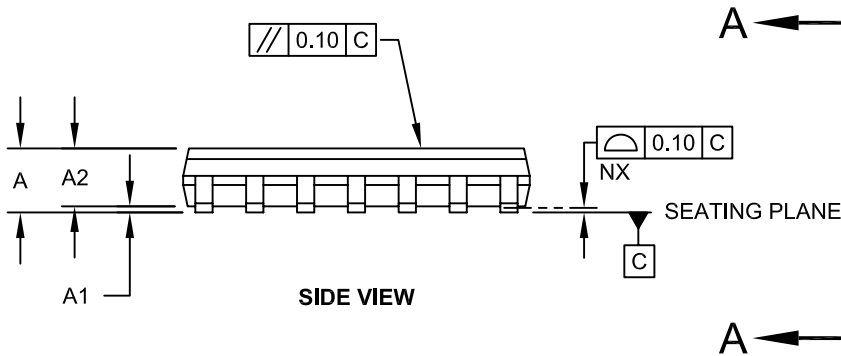
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing No. C04-2129A

# MCP6401/1R/1U/2/4/6/7/9

## 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>

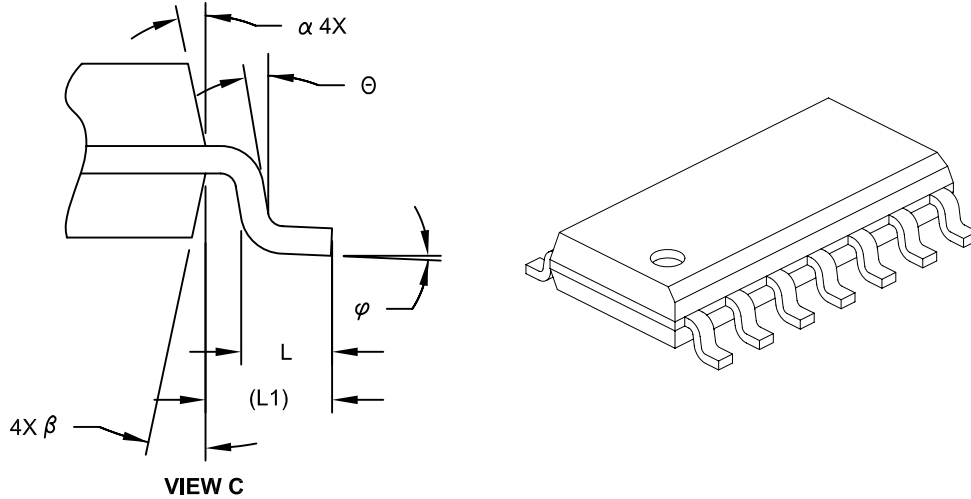


Microchip Technology Drawing No. C04-065C Sheet 1 of 2

# MCP6401/1R/1U/2/4/6/7/9

## 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    |     |      |
| Lead Angle               | Θ     | 0°          | -   | -    |
| Foot Angle               | φ     | 0°          | -   | 8°   |
| Lead Thickness           | c     | 0.10        | -   | 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
- Dimension D does not include mold flash, protrusions or gate burrs, which shall not exceed 0.15 mm per end. Dimension E1 does not include interlead flash or protrusion, which shall not exceed 0.25 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.
- Datums A & B to be determined at Datum H.

Microchip Technology Drawing No. C04-065C Sheet 2 of 2

# MCP6401/1R/1U/2/4/6/7/9

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

| Units                 |    | MILLIMETERS |      |      |
|-----------------------|----|-------------|------|------|
| Dimension Limits      |    | 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

# MCP6401/1R/1U/2/4/6/7/9

## 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>

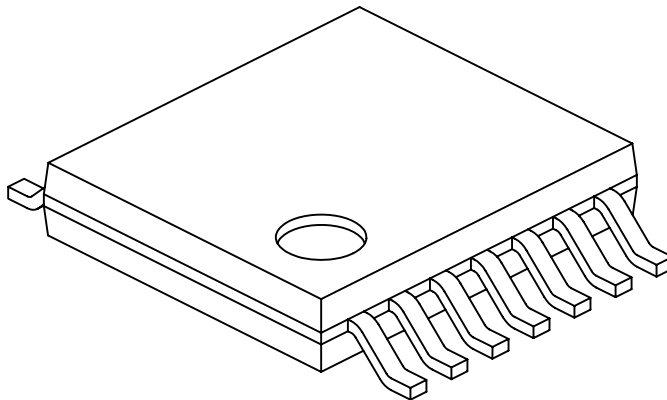


Microchip Technology Drawing C04-087C Sheet 1 of 2

# MCP6401/1R/1U/2/4/6/7/9

## 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>



| Dimension Limits         | Units     | MILLIMETERS |      |      |
|--------------------------|-----------|-------------|------|------|
|                          |           | 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               | $\varphi$ | 0°          | -    | 8°   |
| Lead Thickness           | c         | 0.09        | -    | 0.20 |
| Lead Width               | b         | 0.19        | -    | 0.30 |

**Notes:**

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15mm per side.
3. 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 No. C04-087C Sheet 2 of 2

# MCP6401/1R/1U/2/4/6/7/9

## 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>



### RECOMMENDED LAND PATTERN

| Dimension Limits         | Units | MILLIMETERS |      |      |
|--------------------------|-------|-------------|------|------|
|                          |       | MIN         | NOM  | MAX  |
| Contact Pitch            | E     | 0.65 BSC    |      |      |
| Contact Pad Spacing      | C1    |             | 5.90 |      |
| Contact Pad Width (X14)  | X1    |             |      | 0.45 |
| Contact Pad Length (X14) | Y1    |             |      | 1.45 |
| Distance Between Pads    | G     | 0.20        |      |      |

**Notes:**

1. Dimensioning and tolerancing per ASME Y14.5M

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

Microchip Technology Drawing No. C04-2087A

# MCP6401/1R/1U/2/4/6/7/9

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## APPENDIX A: REVISION HISTORY

### Revision D (September 2011)

The following is the list of modifications:

1. **Section 1.0 “Electrical Characteristics”**: Updated minor typographical corrections in both **“DC Electrical Specifications”** tables to show the correct unit for  $R_L$  ( $k\Omega$  instead of kW).

### Revision C (August 2011)

The following is the list of modifications:

1. Added new MCP6406, MCP6407 and MCP6409 devices and the related information throughout the document.
2. Created two package type drawings based on the temperature characterization (see **E Temp Package Types** and **H Temp Package Types**).
3. Added MCP6406/7/9 specification tables in **Section 1.3 “MCP6406/7/9 Electrical Specifications”**.
4. Updated characterization graphics in **Section 2.0 “Typical Performance Curves”**.
5. Updated **Table 3-1** in **Section 3.0 “Pin Descriptions”** to show all the devices.
6. Updated markings examples in **Section 6.1 “Package Marking Information”**.
7. Updated the package markings information to show all drawings available for each type of package.
8. Updated the **Product Identification System** page with the new devices and temperature specifications.

### Revision B (June 2010)

The following is the list of modifications:

1. Added the MCP6402 and MCP6404 package information.
2. Updated the ESD protection value on all pins in **Section 1.1 “Absolute Maximum Ratings †”**.
3. Added **Figure 2-36**.
4. Updated **Table 3-1**.
5. Updated **Section 4.1.2 “Input Voltage Limits”**.
6. Added **Section 4.1.3 “Input Current Limits”**.
7. Added **Section 4.5 “Unused Op Amps”**.
8. Updated **Section 5.4 “Analog Demonstration and Evaluation Boards”**.
9. Updated the package markings information and drawings.
10. Updated the **Product Identification System** page.

### Revision A (December 2009)

Original data sheet for the MCP6401/1R/1U/2/4/6/7/9 family of devices.



# MCP6401/1R/1U/2/4/6/7/9

## PRODUCT IDENTIFICATION SYSTEM

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

| <u>PART NO.</u>    | <u>-X</u>         | <u>/XX</u>  | <b>Examples:</b>   |
|--------------------|-------------------|---|--|
| Device             | Temperature Range | Package   |  |
| Device:            | MCP6401T:         | Single Op Amp (Tape and Reel) (SC70, SOT-23)  | a) MCP6401T-E/LT: Tape and Reel, Extended Temperature, 5LD SC70 pkg      |
|                    | MCP6401RT:        | Single Op Amp (Tape and Reel) (SOT-23)  | b) MCP6401T-E/OT: Tape and Reel, Extended Temperature, 5LD SOT-23 pkg    |
|                    | MCP6401UT:        | Single Op Amp (Tape and Reel) (SOT-23)  | c) MCP6401RT-E/OT: Tape and Reel, 5LD SOT-23 pkg                         |
|                    | MCP6402:          | Dual Op Amp   | d) MCP6401UT-E/OT: Tape and Reel, Extended Temperature, 5LD SOT-23 pkg   |
|                    | MCP6402T:         | Dual Op Amp (Tape and Reel) (SOIC, 2x3 TDFN)  | e) MCP6402-E/SN: Extended Temperature, 8LD SOIC pkg                      |
|                    | MCP6404:          | Quad Op Amp   | f) MCP6402T-E/SN: Tape and Reel, Extended Temperature, 8LD SOIC pkg      |
|                    | MCP6404T:         | Quad Op Amp (Tape and Reel) (SOIC, TSSOP)   | g) MCP6402T-E/MNY: Tape and Reel, Extended Temperature, 8LD 2x3 TDFN pkg |
|                    | MCP6406T:         | Single Op Amp (Tape and Reel) (SOT-23)  | h) MCP6404-E/SL: Extended Temperature, 14LD SOIC pkg                     |
|                    | MCP6407:          | Dual Op Amp   | i) MCP6404T-E/SL: Tape and Reel, Extended Temperature, 14LD SOIC pkg     |
|                    | MCP6407T:         | Dual Op Amp (Tape and Reel) (SOIC)  | j) MCP6404-E/ST: Extended Temperature, 14LD TSSOP pkg                    |
|                    | MCP6409:          | Quad Op Amp   | k) MCP6404T-E/ST: Tape and Reel, Extended Temperature, 14LD TSSOP pkg.   |
|                    | MCP6409T:         | Quad Op Amp (Tape and Reel) (SOIC)  | a) MCP6401T-H/OT: Tape and Reel, High Temperature, 5LD SOT-23 pkg        |
| Temperature Range: | E                 | = -40°C to +125°C (Extended Temperature)  | b) MCP6402-H/SN: High Temperature, 8LD SOIC pkg                          |
|                    | H                 | = -40°C to +150°C (High Temperature)  | c) MCP6402T-H/SN: Tape and Reel, High Temperature, 8LD SOIC pkg          |
| Package:           | LT                | = Plastic Package (SC70), 5-lead  | d) MCP6404-H/SL: High Temperature, 14LD SOIC pkg                         |
|                    | OT                | = Plastic Small Outline Transistor (SOT-23), 5-lead                                   | e) MCP6404T-H/SL: Tape and Reel, High Temperature, 14LD SOIC pkg         |
|                    | SN                | = Plastic SOIC, (3.90 mm body), 8-lead  | f) MCP6406T-H/OT: Tape and Reel, High Temperature, 5LD SOT-23 pkg        |
|                    | MNY*              | = Plastic Dual Flat, No Lead, (2x3 TDFN), 8-lead                                      | g) MCP6407-H/SN: High Temperature, 8LD SOIC pkg                          |
|                    | SL                | = Plastic SOIC (3.90 mm body), 14-lead  | h) MCP6407T-H/SN: Tape and Reel, High Temperature, 8LD SOIC pkg          |
|                    | ST                | = Plastic TSSOP (4.4mm body), 14-lead   | i) MCP6409-H/SL: High Temperature, 14LD SOIC pkg                         |
|                    | * Y               | = Nickel palladium gold manufacturing designator. Only available on the TDFN package. | j) MCP6409T-H/SL: Tape and Reel, High Temperature, 14LD SOIC pkg         |

# MCP6401/1R/1U/2/4/6/7/9

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NOTES:

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**Korea - Seoul**  
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**Malaysia - Penang**  
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**Philippines - Manila**  
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**Singapore**  
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**Taiwan - Hsin Chu**  
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**Taiwan - Kaohsiung**  
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08/02/11

Компания «Океан Электроники» предлагает заключение долгосрочных отношений при поставках импортных электронных компонентов на взаимовыгодных условиях!

Наши преимущества:

- Поставка оригинальных импортных электронных компонентов напрямую с производств Америки, Европы и Азии, а так же с крупнейших складов мира;
- Широкая линейка поставок активных и пассивных импортных электронных компонентов (более 30 млн. наименований);
- Поставка сложных, дефицитных, либо снятых с производства позиций;
- Оперативные сроки поставки под заказ (от 5 рабочих дней);
- Экспресс доставка в любую точку России;
- Помощь Конструкторского Отдела и консультации квалифицированных инженеров;
- Техническая поддержка проекта, помощь в подборе аналогов, поставка прототипов;
- Поставка электронных компонентов под контролем ВП;
- Система менеджмента качества сертифицирована по Международному стандарту ISO 9001;
- При необходимости вся продукция военного и аэрокосмического назначения проходит испытания и сертификацию в лаборатории (по согласованию с заказчиком);
- Поставка специализированных компонентов военного и аэрокосмического уровня качества (Xilinx, Altera, Analog Devices, Intersil, Interpoint, Microsemi, Actel, Aeroflex, Peregrine, VPT, Syfer, Eurofarad, Texas Instruments, MS Kennedy, Miteq, Cobham, E2V, MA-COM, Hittite, Mini-Circuits, General Dynamics и др.);

Компания «Океан Электроники» является официальным дистрибьютором и эксклюзивным представителем в России одного из крупнейших производителей разъемов военного и аэрокосмического назначения «JONHON», а так же официальным дистрибьютором и эксклюзивным представителем в России производителя высокотехнологичных и надежных решений для передачи СВЧ сигналов «FORSTAR».



## JONHON

«JONHON» (основан в 1970 г.)

Разъемы специального, военного и аэрокосмического назначения:

(Применяются в военной, авиационной, аэрокосмической, морской, железнодорожной, горно- и нефтедобывающей отраслях промышленности)

«FORSTAR» (основан в 1998 г.)

ВЧ соединители, коаксиальные кабели, кабельные сборки и микроволновые компоненты:

(Применяются в телекоммуникациях гражданского и специального назначения, в средствах связи, РЛС, а так же военной, авиационной и аэрокосмической отраслях промышленности).



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