

## Rail-to-Rail Input/Output, 10 MHz Op Amps

### Features

- Rail-to-Rail Input/Output
- Wide Bandwidth: 10 MHz (typical)
- Low Noise: 8.7 nV/√Hz, at 10 kHz (typical)
- Low Offset Voltage:
  - Industrial Temperature: ±500 μV (maximum)
  - Extended Temperature: ±250 μV (maximum)
- Mid-Supply  $V_{REF}$ : MCP6021 and MCP6023
- Low Supply Current: 1 mA (typical)
- Total Harmonic Distortion:
  - 0.00053% (typical,  $G = 1$  V/V)
- Unity Gain Stable
- Power Supply Range: 2.5V to 5.5V
- Temperature Range:
  - Industrial: -40°C to +85°C
  - Extended: -40°C to +125°C

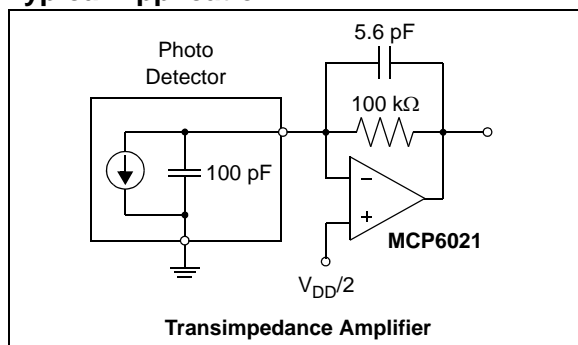
### Applications

- Automotive
- Multi-Pole Active Filters
- Audio Processing
- DAC Buffer
- Test Equipment
- Medical Instrumentation

### Design Aids

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

### Typical Application



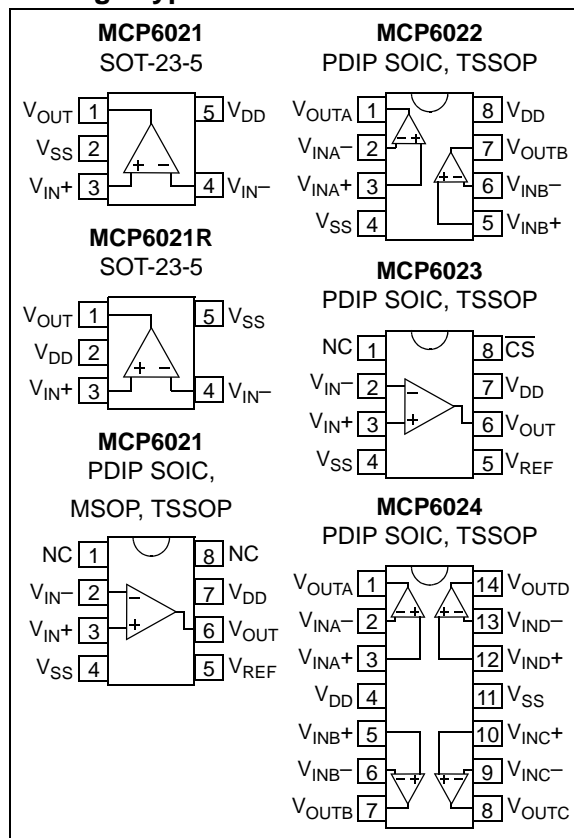
### Description

The MCP6021, MCP6021R, MCP6022, MCP6023 and MCP6024 from Microchip Technology Inc. are rail-to-rail input and output op amps with high performance. Key specifications include: wide bandwidth (10 MHz), low noise (8.7 nV/√Hz), low input offset voltage and low distortion (0.00053% THD+N). The MCP6023 also offers a Chip Select pin (CS) that gives power savings when the part is not in use.

The single MCP6021 and MCP6021R are available in SOT-23-5. The single MCP6021, single MCP6023 and dual MCP6022 are available in 8-lead PDIP, SOIC and TSSOP. The Extended Temperature single MCP6021 is available in 8-lead MSOP. The quad MCP6024 is offered in 14-lead PDIP, SOIC and TSSOP packages.

The MCP6021/1R/2/3/4 family is available in Industrial and Extended temperature ranges. It has a power supply range of 2.5V to 5.5V.

### Package Types



# MCP6021/1R/2/3/4

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NOTES:

## 1.0 ELECTRICAL CHARACTERISTICS

### Absolute Maximum Ratings †

|                                                              |                                     |
|--------------------------------------------------------------|-------------------------------------|
| $V_{DD} - V_{SS}$ .....                                      | 7.0V                                |
| Current at Analog Input Pins ( $V_{IN+}$ , $V_{IN-}$ ) ..... | $\pm 2$ mA                          |
| Analog Inputs ( $V_{IN+}$ , $V_{IN-}$ ) †† .....             | $V_{SS} - 1.0V$ to $V_{DD} + 1.0V$  |
| All Other Inputs and Outputs .....                           | $V_{SS} - 0.3V$ to $V_{DD} + 0.3V$  |
| Difference Input Voltage .....                               | $ V_{DD} - V_{SS} $                 |
| Output Short Circuit Current .....                           | Continuous                          |
| Current at Output and Supply Pins .....                      | $\pm 30$ mA                         |
| Storage Temperature .....                                    | $-65^{\circ}$ C to $+150^{\circ}$ C |
| Maximum Junction Temperature ( $T_J$ ) .....                 | $+150^{\circ}$ C                    |
| ESD Protection On All Pins (HBM; MM) .....                   | $\geq 2$ kV; 200V                   |

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

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

### DC ELECTRICAL CHARACTERISTICS

| Electrical Specifications: Unless otherwise indicated, $T_A = +25^{\circ}$ C, $V_{DD} = +2.5V$ to $+5.5V$ , $V_{SS} = GND$ , $V_{CM} = V_{DD}/2$ , $V_{OUT} \approx V_{DD}/2$ and $R_L = 10$ k $\Omega$ to $V_{DD}/2$ . |                             |              |              |              |                       |                                                                              |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|--------------|--------------|--------------|-----------------------|------------------------------------------------------------------------------|
| Parameters                                                                                                                                                                                                              | Sym                         | Min          | Typ          | Max          | Units                 | Conditions                                                                   |
| <b>Input Offset</b>                                                                                                                                                                                                     |                             |              |              |              |                       |                                                                              |
| Input Offset Voltage:                                                                                                                                                                                                   |                             |              |              |              |                       |                                                                              |
| Industrial Temperature Parts                                                                                                                                                                                            | $V_{OS}$                    | -500         | —            | +500         | $\mu$ V               | $V_{CM} = 0V$                                                                |
| Extended Temperature Parts                                                                                                                                                                                              | $V_{OS}$                    | -250         | —            | +250         | $\mu$ V               | $V_{CM} = 0V$ , $V_{DD} = 5.0V$                                              |
| Extended Temperature Parts                                                                                                                                                                                              | $V_{OS}$                    | -2.5         | —            | +2.5         | mV                    | $V_{CM} = 0V$ , $V_{DD} = 5.0V$<br>$T_A = -40^{\circ}$ C to $+125^{\circ}$ C |
| Input Offset Voltage Temperature Drift                                                                                                                                                                                  | $\Delta V_{OS}/\Delta T_A$  | —            | $\pm 3.5$    | —            | $\mu$ V/ $^{\circ}$ C | $T_A = -40^{\circ}$ C to $+125^{\circ}$ C                                    |
| Power Supply Rejection Ratio                                                                                                                                                                                            | PSRR                        | 74           | 90           | —            | dB                    | $V_{CM} = 0V$                                                                |
| <b>Input Current and Impedance</b>                                                                                                                                                                                      |                             |              |              |              |                       |                                                                              |
| Input Bias Current                                                                                                                                                                                                      | $I_B$                       | —            | 1            | —            | pA                    |                                                                              |
| Industrial Temperature Parts                                                                                                                                                                                            | $I_B$                       | —            | 30           | 150          | pA                    | $T_A = +85^{\circ}$ C                                                        |
| Extended Temperature Parts                                                                                                                                                                                              | $I_B$                       | —            | 640          | 5,000        | pA                    | $T_A = +125^{\circ}$ C                                                       |
| Input Offset Current                                                                                                                                                                                                    | $I_{OS}$                    | —            | $\pm 1$      | —            | pA                    |                                                                              |
| Common-Mode Input Impedance                                                                                                                                                                                             | $Z_{CM}$                    | —            | $10^{13}  6$ | —            | $\Omega  pF$          |                                                                              |
| Differential Input Impedance                                                                                                                                                                                            | $Z_{DIFF}$                  | —            | $10^{13}  3$ | —            | $\Omega  pF$          |                                                                              |
| <b>Common-Mode</b>                                                                                                                                                                                                      |                             |              |              |              |                       |                                                                              |
| Common-Mode Input Range                                                                                                                                                                                                 | $V_{CMR}$                   | $V_{SS}-0.3$ | —            | $V_{DD}+0.3$ | V                     |                                                                              |
| Common-Mode Rejection Ratio                                                                                                                                                                                             | CMRR                        | 74           | 90           | —            | dB                    | $V_{DD} = 5V$ , $V_{CM} = -0.3V$ to $5.3V$                                   |
|                                                                                                                                                                                                                         | CMRR                        | 70           | 85           | —            | dB                    | $V_{DD} = 5V$ , $V_{CM} = 3.0V$ to $5.3V$                                    |
|                                                                                                                                                                                                                         | CMRR                        | 74           | 90           | —            | dB                    | $V_{DD} = 5V$ , $V_{CM} = -0.3V$ to $3.0V$                                   |
| <b>Voltage Reference (MCP6021 and MCP6023 only)</b>                                                                                                                                                                     |                             |              |              |              |                       |                                                                              |
| $V_{REF}$ Accuracy ( $V_{REF} - V_{DD}/2$ )                                                                                                                                                                             | $V_{REF\_ACC}$              | -50          | —            | +50          | mV                    |                                                                              |
| $V_{REF}$ Temperature Drift                                                                                                                                                                                             | $\Delta V_{REF}/\Delta T_A$ | —            | $\pm 100$    | —            | $\mu$ V/ $^{\circ}$ C | $T_A = -40^{\circ}$ C to $+125^{\circ}$ C                                    |
| <b>Open-Loop Gain</b>                                                                                                                                                                                                   |                             |              |              |              |                       |                                                                              |
| DC Open-Loop Gain (Large Signal)                                                                                                                                                                                        | $A_{OL}$                    | 90           | 110          | —            | dB                    | $V_{CM} = 0V$ ,<br>$V_{OUT} = V_{SS}+0.3V$ to $V_{DD}-0.3V$                  |
| <b>Output</b>                                                                                                                                                                                                           |                             |              |              |              |                       |                                                                              |
| Maximum Output Voltage Swing                                                                                                                                                                                            | $V_{OL}$ , $V_{OH}$         | $V_{SS}+15$  | —            | $V_{DD}-20$  | mV                    | 0.5V input overdrive                                                         |
| Output Short Circuit Current                                                                                                                                                                                            | $I_{SC}$                    | —            | $\pm 30$     | —            | mA                    | $V_{DD} = 2.5V$                                                              |
|                                                                                                                                                                                                                         | $I_{SC}$                    | —            | $\pm 22$     | —            | mA                    | $V_{DD} = 5.5V$                                                              |

# MCP6021/1R/2/3/4

## AC ELECTRICAL CHARACTERISTICS

| <b>Electrical Specifications:</b> Unless otherwise indicated, $T_A = +25^\circ\text{C}$ , $V_{DD} = +2.5\text{V}$ to $+5.5\text{V}$ , $V_{SS} = \text{GND}$ , $V_{CM} = V_{DD}/2$ , $V_{OUT} \approx V_{DD}/2$ , $R_L = 10\text{ k}\Omega$ to $V_{DD}/2$ and $C_L = 60\text{ pF}$ . |              |     |         |      |                              |                                                                                                                                    |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|-----|---------|------|------------------------------|------------------------------------------------------------------------------------------------------------------------------------|
| Parameters                                                                                                                                                                                                                                                                          | Sym          | Min | Typ     | Max  | Units                        | Conditions                                                                                                                         |
| <b>Power Supply</b>                                                                                                                                                                                                                                                                 |              |     |         |      |                              |                                                                                                                                    |
| Supply Voltage                                                                                                                                                                                                                                                                      | $V_{DD}$     | 2.5 | —       | 5.5  | V                            |                                                                                                                                    |
| Quiescent Current per Amplifier                                                                                                                                                                                                                                                     | $I_Q$        | 0.5 | 1.0     | 1.35 | mA                           | $I_O = 0$                                                                                                                          |
| <b>AC Response</b>                                                                                                                                                                                                                                                                  |              |     |         |      |                              |                                                                                                                                    |
| Gain Bandwidth Product                                                                                                                                                                                                                                                              | GBWP         | —   | 10      | —    | MHz                          |                                                                                                                                    |
| Phase Margin                                                                                                                                                                                                                                                                        | PM           | —   | 65      | —    | °                            | $G = +1\text{ V/V}$                                                                                                                |
| Settling Time, 0.2%                                                                                                                                                                                                                                                                 | $t_{SETTLE}$ | —   | 250     | —    | ns                           | $G = +1\text{ V/V}$ , $V_{OUT} = 100\text{ mV}_{P-P}$                                                                              |
| Slew Rate                                                                                                                                                                                                                                                                           | SR           | —   | 7.0     | —    | V/ $\mu\text{s}$             |                                                                                                                                    |
| <b>Total Harmonic Distortion Plus Noise</b>                                                                                                                                                                                                                                         |              |     |         |      |                              |                                                                                                                                    |
| $f = 1\text{ kHz}$ , $G = +1\text{ V/V}$                                                                                                                                                                                                                                            | THD+N        | —   | 0.00053 | —    | %                            | $V_{OUT} = 0.25\text{V}$ to $3.25\text{V}$ ( $1.75\text{V} \pm 1.50\text{V}_{PK}$ ), $V_{DD} = 5.0\text{V}$ , $BW = 22\text{ kHz}$ |
| $f = 1\text{ kHz}$ , $G = +1\text{ V/V}$ , $R_L = 600\Omega$                                                                                                                                                                                                                        | THD+N        | —   | 0.00064 | —    | %                            | $V_{OUT} = 0.25\text{V}$ to $3.25\text{V}$ ( $1.75\text{V} \pm 1.50\text{V}_{PK}$ ), $V_{DD} = 5.0\text{V}$ , $BW = 22\text{ kHz}$ |
| $f = 1\text{ kHz}$ , $G = +1\text{ V/V}$                                                                                                                                                                                                                                            | THD+N        | —   | 0.0014  | —    | %                            | $V_{OUT} = 4\text{V}_{P-P}$ , $V_{DD} = 5.0\text{V}$ , $BW = 22\text{ kHz}$                                                        |
| $f = 1\text{ kHz}$ , $G = +10\text{ V/V}$                                                                                                                                                                                                                                           | THD+N        | —   | 0.0009  | —    | %                            | $V_{OUT} = 4\text{V}_{P-P}$ , $V_{DD} = 5.0\text{V}$ , $BW = 22\text{ kHz}$                                                        |
| $f = 1\text{ kHz}$ , $G = +100\text{ V/V}$                                                                                                                                                                                                                                          | THD+N        | —   | 0.005   | —    | %                            | $V_{OUT} = 4\text{V}_{P-P}$ , $V_{DD} = 5.0\text{V}$ , $BW = 22\text{ kHz}$                                                        |
| <b>Noise</b>                                                                                                                                                                                                                                                                        |              |     |         |      |                              |                                                                                                                                    |
| Input Noise Voltage                                                                                                                                                                                                                                                                 | $E_{ni}$     | —   | 2.9     | —    | $\mu\text{V}_{p-p}$          | $f = 0.1\text{ Hz}$ to $10\text{ Hz}$                                                                                              |
| Input Noise Voltage Density                                                                                                                                                                                                                                                         | $e_{ni}$     | —   | 8.7     | —    | $\text{nV}/\sqrt{\text{Hz}}$ | $f = 10\text{ kHz}$                                                                                                                |
| Input Noise Current Density                                                                                                                                                                                                                                                         | $i_{ni}$     | —   | 3       | —    | $\text{fA}/\sqrt{\text{Hz}}$ | $f = 1\text{ kHz}$                                                                                                                 |

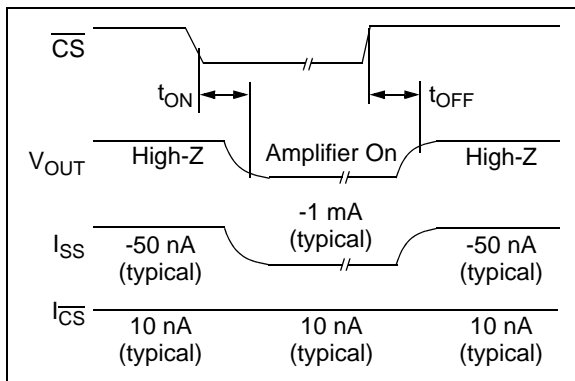
## MCP6023 CHIP SELECT ( $\overline{\text{CS}}$ ) ELECTRICAL CHARACTERISTICS

| <b>Electrical Specifications:</b> Unless otherwise indicated, $T_A = +25^\circ\text{C}$ , $V_{DD} = +2.5\text{V}$ to $+5.5\text{V}$ , $V_{SS} = \text{GND}$ , $V_{CM} = V_{DD}/2$ , $V_{OUT} \approx V_{DD}/2$ , $R_L = 10\text{ k}\Omega$ to $V_{DD}/2$ and $C_L = 60\text{ pF}$ . |               |              |       |              |               |                                                                                                  |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|--------------|-------|--------------|---------------|--------------------------------------------------------------------------------------------------|
| Parameters                                                                                                                                                                                                                                                                          | Sym           | Min          | Typ   | Max          | Units         | Conditions                                                                                       |
| <b><math>\overline{\text{CS}}</math> Low Specifications</b>                                                                                                                                                                                                                         |               |              |       |              |               |                                                                                                  |
| $\overline{\text{CS}}$ Logic Threshold, Low                                                                                                                                                                                                                                         | $V_{IL}$      | $V_{SS}$     | —     | $0.2 V_{DD}$ | V             |                                                                                                  |
| $\overline{\text{CS}}$ Input Current, Low                                                                                                                                                                                                                                           | $I_{CSL}$     | -1.0         | 0.01  | —            | $\mu\text{A}$ | $\overline{\text{CS}} = V_{SS}$                                                                  |
| <b><math>\overline{\text{CS}}</math> High Specifications</b>                                                                                                                                                                                                                        |               |              |       |              |               |                                                                                                  |
| $\overline{\text{CS}}$ Logic Threshold, High                                                                                                                                                                                                                                        | $V_{IH}$      | $0.8 V_{DD}$ | —     | $V_{DD}$     | V             |                                                                                                  |
| $\overline{\text{CS}}$ Input Current, High                                                                                                                                                                                                                                          | $I_{CSH}$     | —            | 0.01  | 2.0          | $\mu\text{A}$ | $\overline{\text{CS}} = V_{DD}$                                                                  |
| GND Current                                                                                                                                                                                                                                                                         | $I_{SS}$      | -2           | -0.05 | —            | $\mu\text{A}$ | $\overline{\text{CS}} = V_{DD}$                                                                  |
| Amplifier Output Leakage                                                                                                                                                                                                                                                            | $I_{O(LEAK)}$ | —            | 0.01  | —            | $\mu\text{A}$ | $\overline{\text{CS}} = V_{DD}$                                                                  |
| <b><math>\overline{\text{CS}}</math> Dynamic Specifications</b>                                                                                                                                                                                                                     |               |              |       |              |               |                                                                                                  |
| $\overline{\text{CS}}$ Low to Amplifier Output Turn-on Time                                                                                                                                                                                                                         | $t_{ON}$      | —            | 2     | 10           | $\mu\text{s}$ | $G = +1$ , $V_{IN} = V_{SS}$ , $\overline{\text{CS}} = 0.2V_{DD}$ to $V_{OUT} = 0.45V_{DD}$ time |
| $\overline{\text{CS}}$ High to Amplifier Output High-Z Time                                                                                                                                                                                                                         | $t_{OFF}$     | —            | 0.01  | —            | $\mu\text{s}$ | $G = +1$ , $V_{IN} = V_{SS}$ , $\overline{\text{CS}} = 0.8V_{DD}$ to $V_{OUT} = 0.05V_{DD}$ time |
| Hysteresis                                                                                                                                                                                                                                                                          | $V_{HYST}$    | —            | 0.6   | —            | V             | $V_{DD} = 5.0\text{V}$ , Internal Switch                                                         |

## TEMPERATURE CHARACTERISTICS

| Electrical Specifications: Unless otherwise indicated, $V_{DD} = +2.5V$ to $+5.5V$ and $V_{SS} = GND$ . |               |     |     |      |               |               |
|---------------------------------------------------------------------------------------------------------|---------------|-----|-----|------|---------------|---------------|
| Parameters                                                                                              | Sym           | Min | Typ | Max  | Units         | Conditions    |
| <b>Temperature Ranges</b>                                                                               |               |     |     |      |               |               |
| Industrial Temperature Range                                                                            | $T_A$         | -40 | —   | +85  | $^{\circ}C$   |               |
| Extended Temperature Range                                                                              | $T_A$         | -40 | —   | +125 | $^{\circ}C$   |               |
| Operating Temperature Range                                                                             | $T_A$         | -40 | —   | +125 | $^{\circ}C$   | <b>Note 1</b> |
| Storage Temperature Range                                                                               | $T_A$         | -65 | —   | +150 | $^{\circ}C$   |               |
| <b>Thermal Package Resistances</b>                                                                      |               |     |     |      |               |               |
| Thermal Resistance, 5L-SOT-23                                                                           | $\theta_{JA}$ | —   | 256 | —    | $^{\circ}C/W$ |               |
| Thermal Resistance, 8L-PDIP                                                                             | $\theta_{JA}$ | —   | 85  | —    | $^{\circ}C/W$ |               |
| Thermal Resistance, 8L-SOIC                                                                             | $\theta_{JA}$ | —   | 163 | —    | $^{\circ}C/W$ |               |
| Thermal Resistance, 8L-MSOP                                                                             | $\theta_{JA}$ | —   | 206 | —    | $^{\circ}C/W$ |               |
| Thermal Resistance, 8L-TSSOP                                                                            | $\theta_{JA}$ | —   | 124 | —    | $^{\circ}C/W$ |               |
| Thermal Resistance, 14L-PDIP                                                                            | $\theta_{JA}$ | —   | 70  | —    | $^{\circ}C/W$ |               |
| Thermal Resistance, 14L-SOIC                                                                            | $\theta_{JA}$ | —   | 120 | —    | $^{\circ}C/W$ |               |
| Thermal Resistance, 14L-TSSOP                                                                           | $\theta_{JA}$ | —   | 100 | —    | $^{\circ}C/W$ |               |

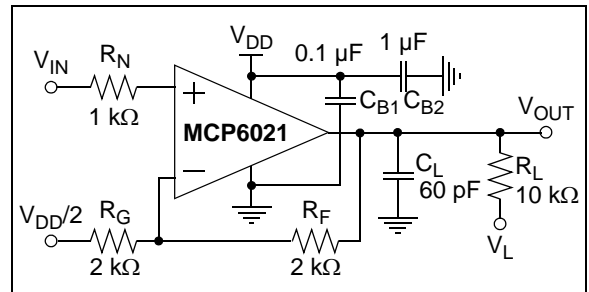
**Note 1:** The industrial temperature devices operate over this extended temperature range, but with reduced performance. In any case, the internal junction temperature ( $T_J$ ) must not exceed the absolute maximum specification of  $150^{\circ}C$ .



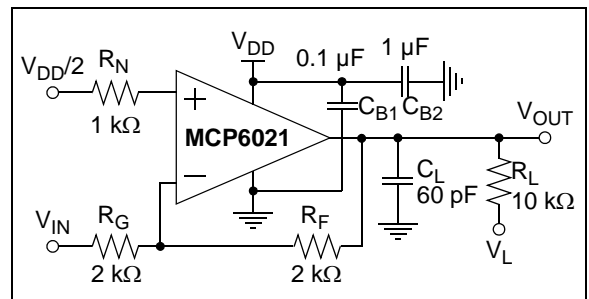
**FIGURE 1-1:** Timing diagram for the  $\overline{CS}$  pin on the MCP6023.

### 1.1 Test Circuits

The test circuits used for the DC and AC tests are shown in [Figure 1-2](#) and [Figure 1-3](#). The bypass capacitors are laid out according to the rules discussed in [Section 4.7 “Supply Bypass”](#).



**FIGURE 1-2:** AC and DC Test Circuit for Most Non-Inverting Gain Conditions.



**FIGURE 1-3:** AC and DC Test Circuit for Most Inverting Gain Conditions.

# MCP6021/1R/2/3/4

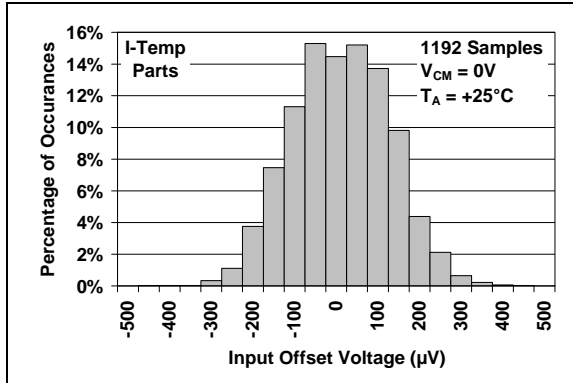
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NOTES:

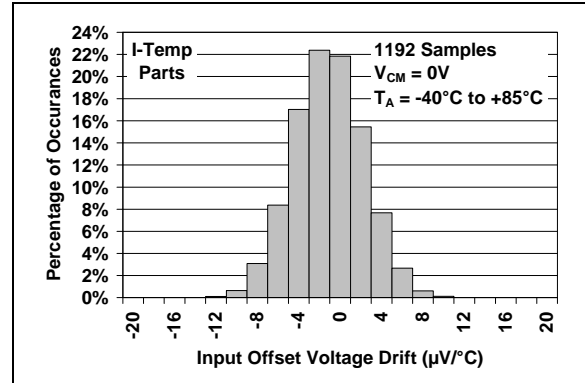
## 2.0 TYPICAL PERFORMANCE CURVES

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

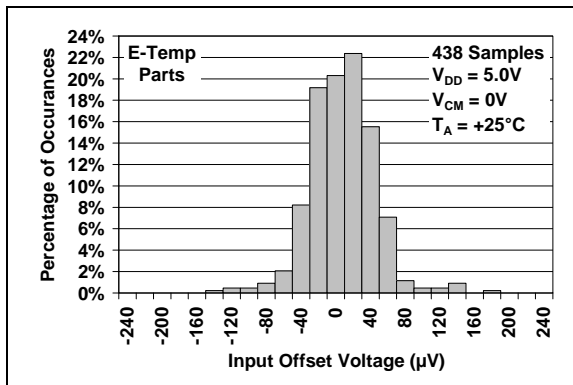
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +2.5\text{V}$  to  $+5.5\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_{DD}/2$  and  $C_L = 60\text{ pF}$ .



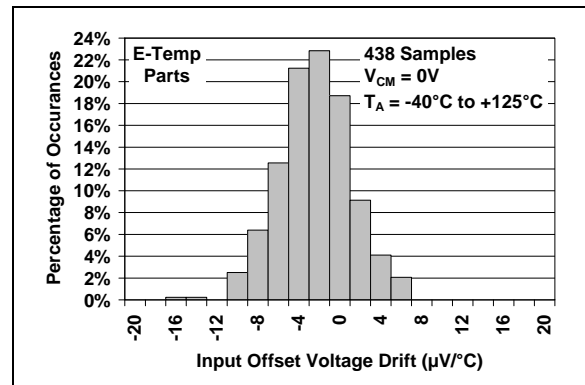
**FIGURE 2-1:** Input Offset Voltage, (Industrial Temperature Parts).



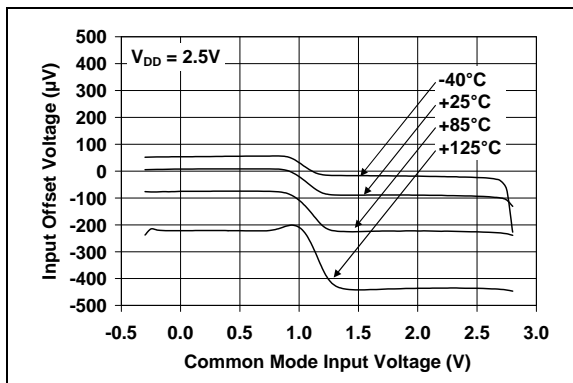
**FIGURE 2-4:** Input Offset Voltage Drift, (Industrial Temperature Parts).



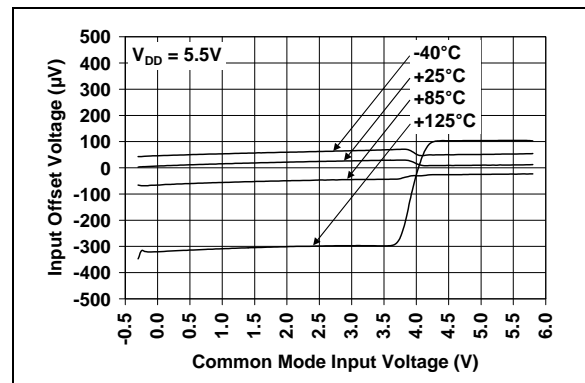
**FIGURE 2-2:** Input Offset Voltage, (Extended Temperature Parts).



**FIGURE 2-5:** Input Offset Voltage Drift, (Extended Temperature Parts).



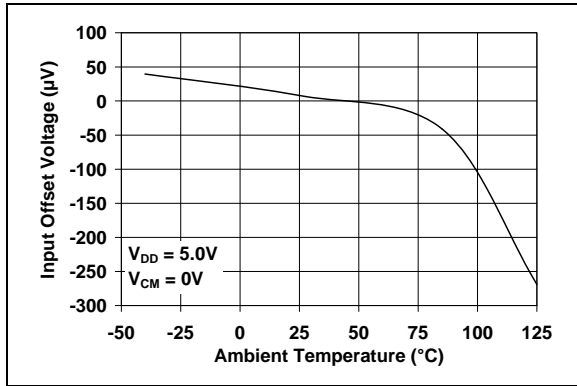
**FIGURE 2-3:** Input Offset Voltage vs. Common Mode Input Voltage with  $V_{DD} = 2.5\text{V}$ .



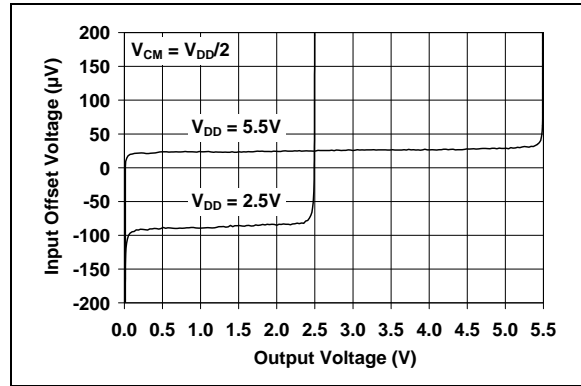
**FIGURE 2-6:** Input Offset Voltage vs. Common Mode Input Voltage with  $V_{DD} = 5.5\text{V}$ .

# MCP6021/1R/2/3/4

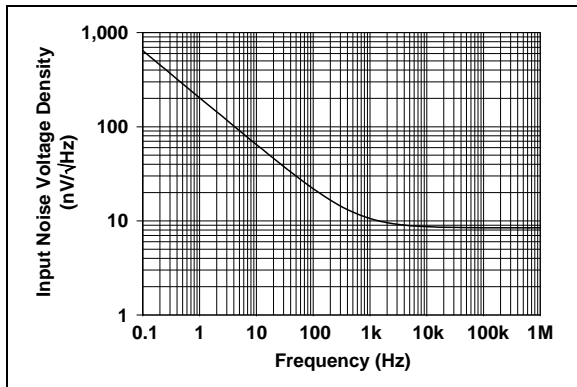
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +2.5\text{V}$  to  $+5.5\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_{DD}/2$  and  $C_L = 60\text{ pF}$ .



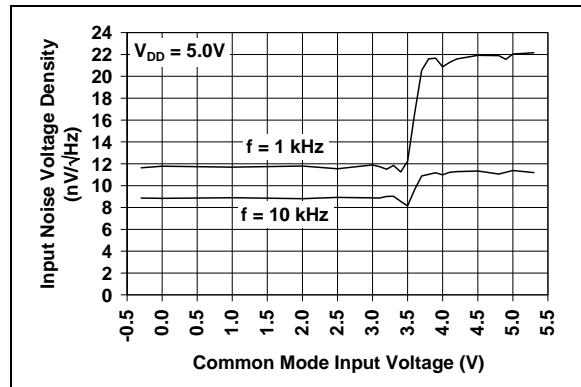
**FIGURE 2-7:** Input Offset Voltage vs. Temperature.



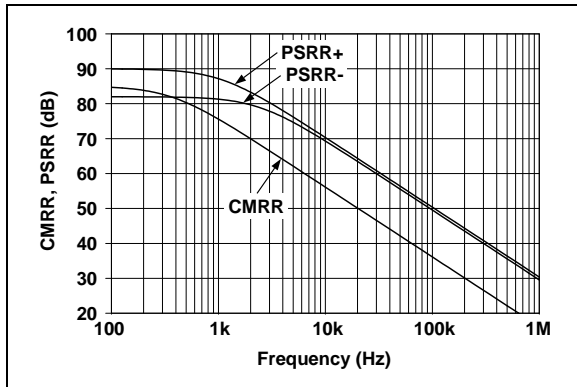
**FIGURE 2-10:** Input Offset Voltage vs. Output Voltage.



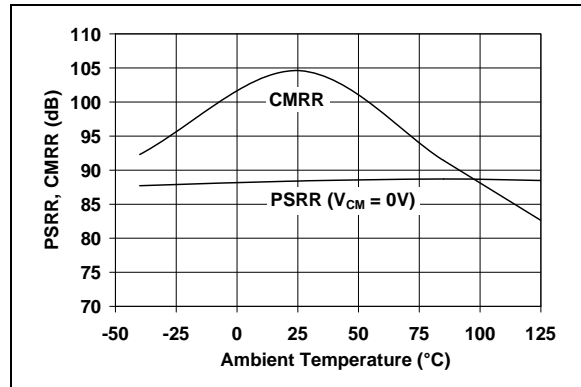
**FIGURE 2-8:** Input Noise Voltage Density vs. Frequency.



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



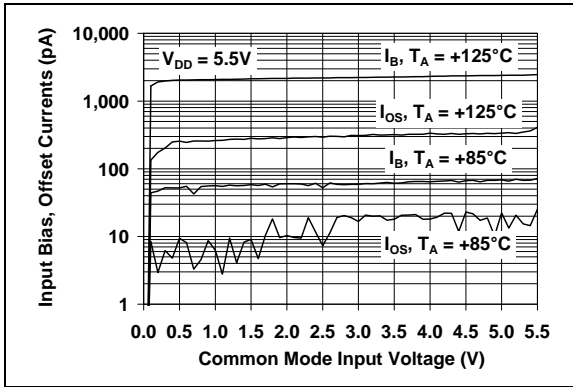
**FIGURE 2-9:** CMRR, PSRR vs. Frequency.



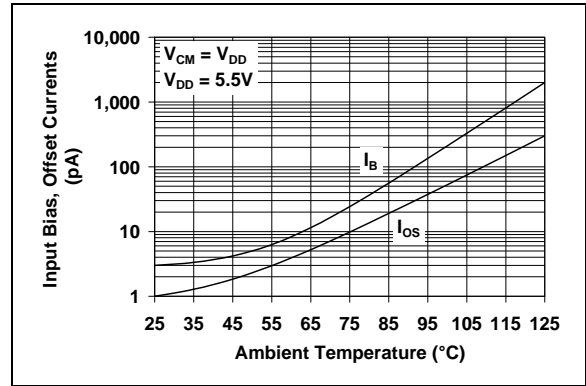
**FIGURE 2-12:** CMRR, PSRR vs. Temperature.



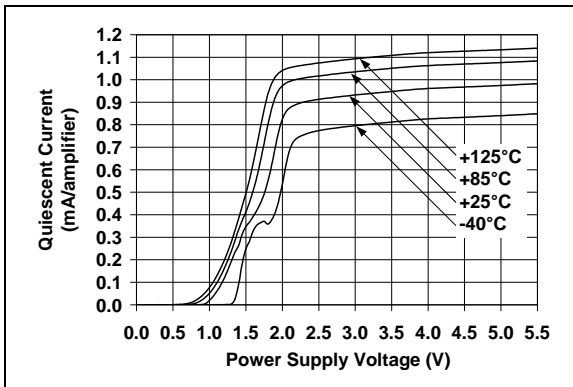
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +2.5\text{V}$  to  $+5.5\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_{DD}/2$  and  $C_L = 60\text{ pF}$ .



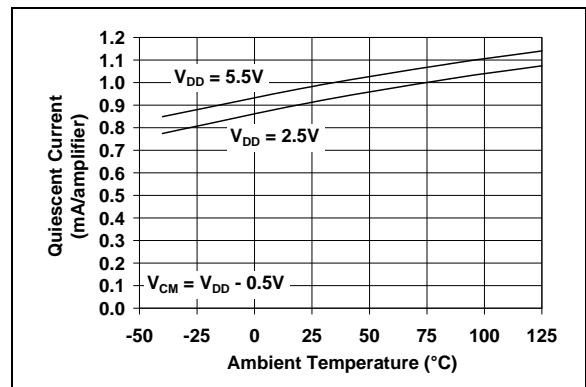
**FIGURE 2-13:** Input Bias, Offset Currents vs. Common Mode Input Voltage.



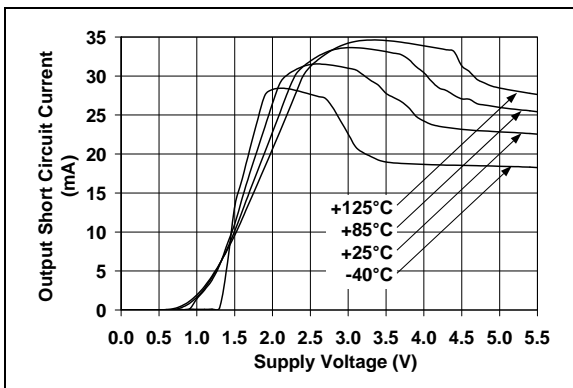
**FIGURE 2-16:** Input Bias, Offset Currents vs. Temperature.



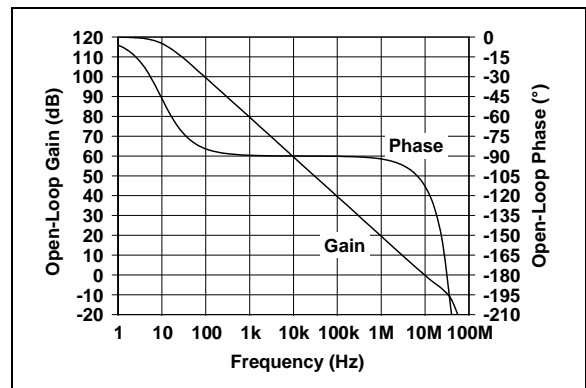
**FIGURE 2-14:** Quiescent Current vs. Supply Voltage.



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



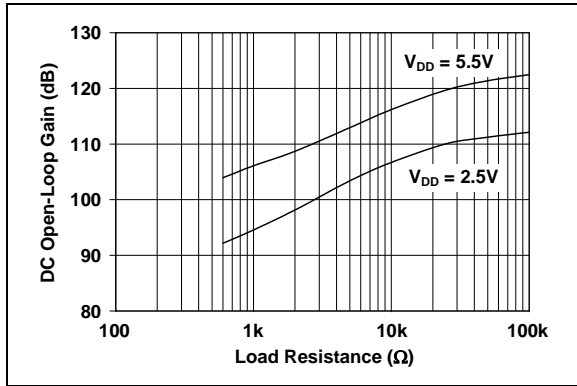
**FIGURE 2-15:** Output Short-Circuit Current vs. Supply Voltage.



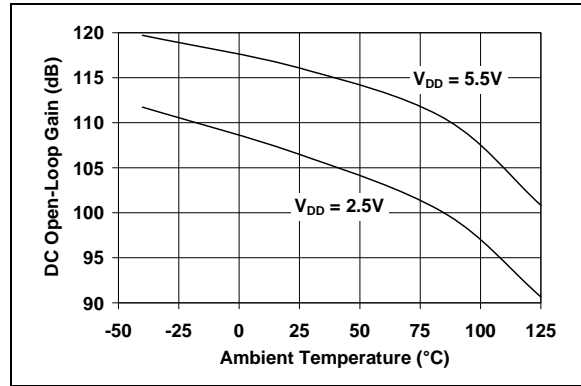
**FIGURE 2-18:** Open-Loop Gain, Phase vs. Frequency.

# MCP6021/1R/2/3/4

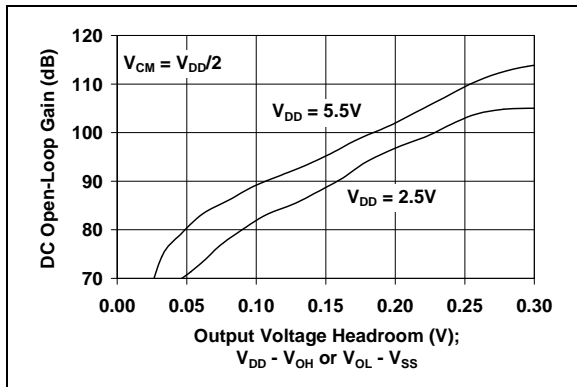
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +2.5\text{V}$  to  $+5.5\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_{DD}/2$  and  $C_L = 60\text{ pF}$ .



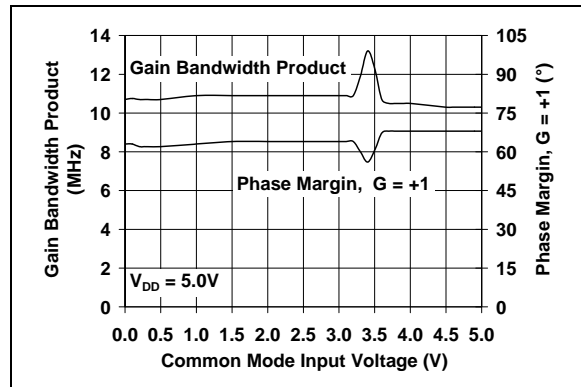
**FIGURE 2-19:** DC Open-Loop Gain vs. Load Resistance.



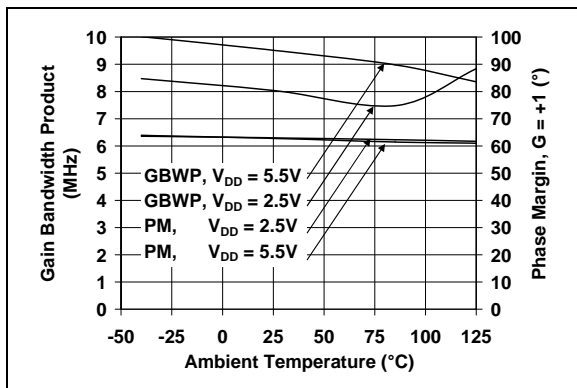
**FIGURE 2-22:** DC Open-Loop Gain vs. Temperature.



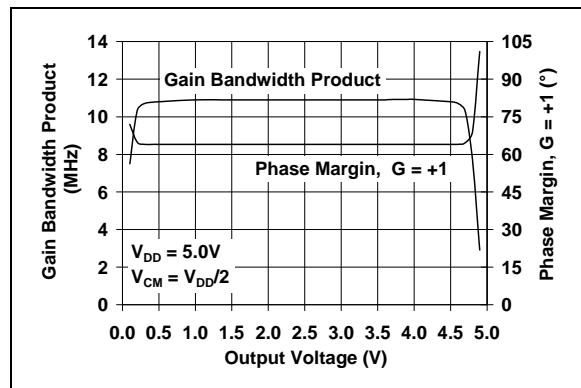
**FIGURE 2-20:** Small Signal DC Open-Loop Gain vs. Output Voltage Headroom.



**FIGURE 2-23:** Gain Bandwidth Product, Phase Margin vs. Common Mode Input Voltage.



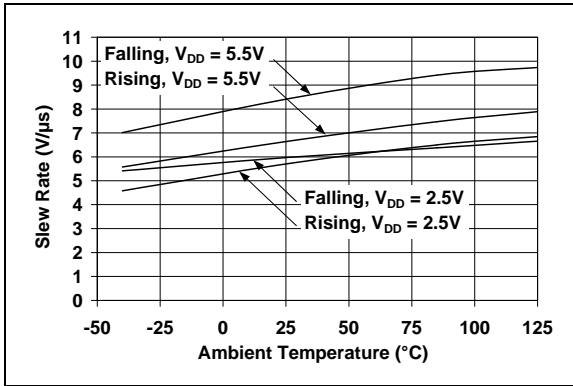
**FIGURE 2-21:** Gain Bandwidth Product, Phase Margin vs. Temperature.



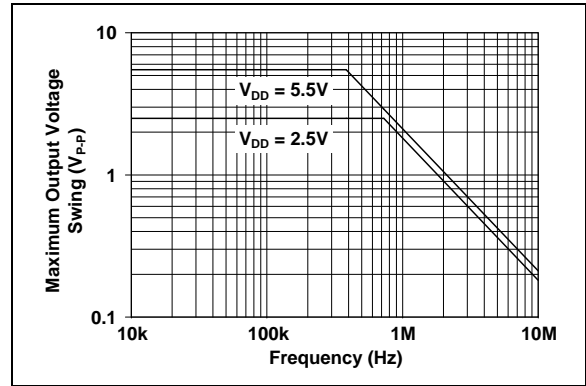
**FIGURE 2-24:** Gain Bandwidth Product, Phase Margin vs. Output Voltage.

# MCP6021/1R/2/3/4

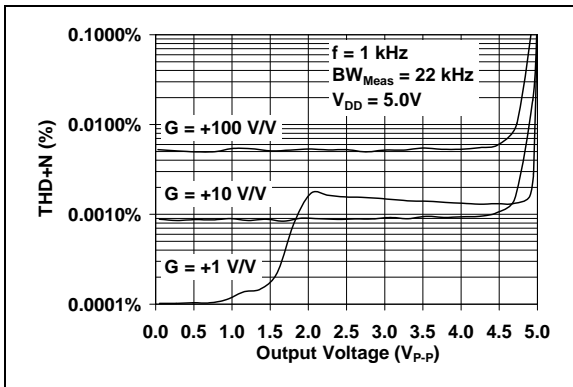
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +2.5\text{V}$  to  $+5.5\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_{DD}/2$  and  $C_L = 60\text{ pF}$ .



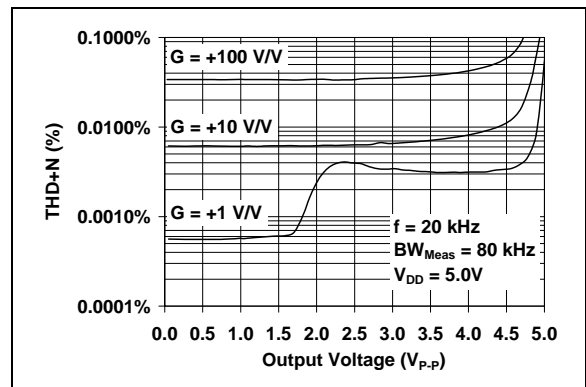
**FIGURE 2-25:** Slew Rate vs. Temperature.



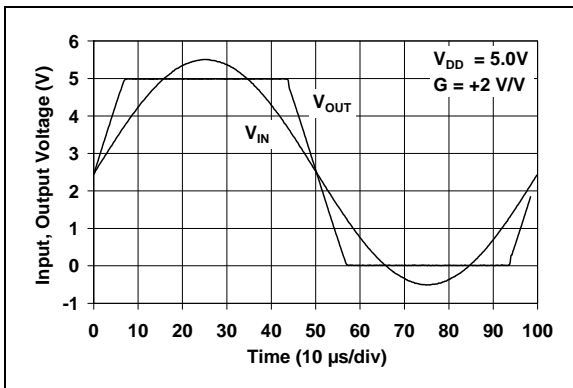
**FIGURE 2-28:** Maximum Output Voltage Swing vs. Frequency.



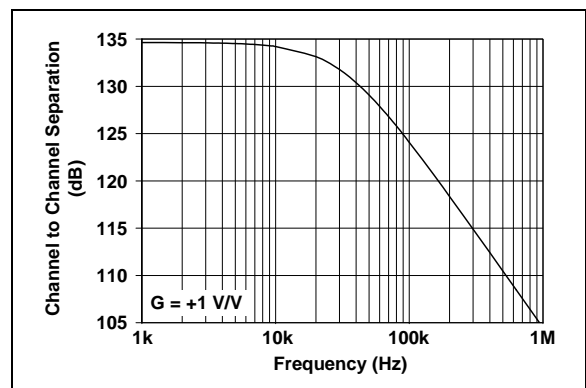
**FIGURE 2-26:** Total Harmonic Distortion plus Noise vs. Output Voltage with  $f = 1\text{ kHz}$ .



**FIGURE 2-29:** Total Harmonic Distortion plus Noise vs. Output Voltage with  $f = 20\text{ kHz}$ .



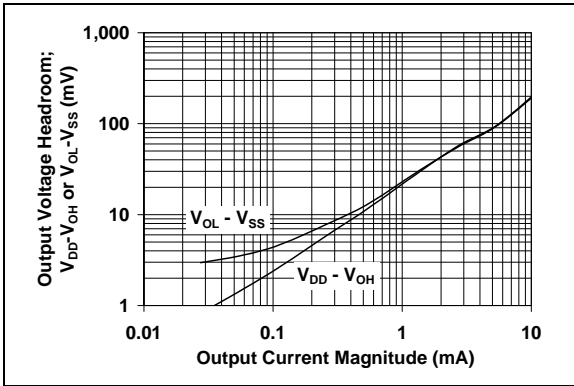
**FIGURE 2-27:** The MCP6021/1R/2/3/4 family shows no phase reversal under overdrive.



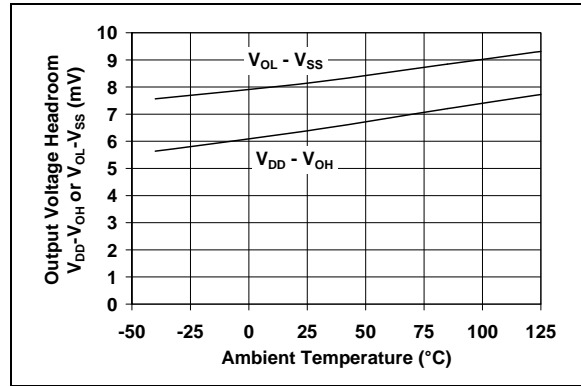
**FIGURE 2-30:** Channel-to-Channel Separation vs. Frequency (MCP6022 and MCP6024 only).

# MCP6021/1R/2/3/4

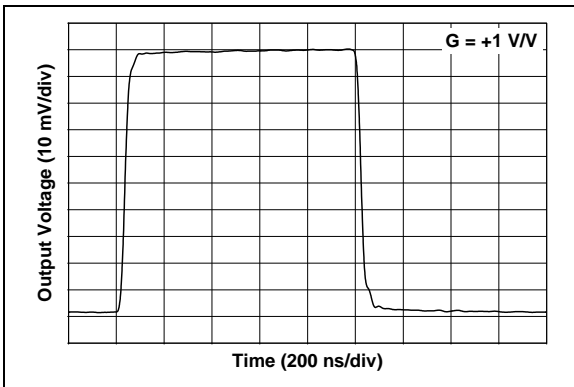
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +2.5\text{V to } +5.5\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_{DD}/2$  and  $C_L = 60\text{ pF}$ .



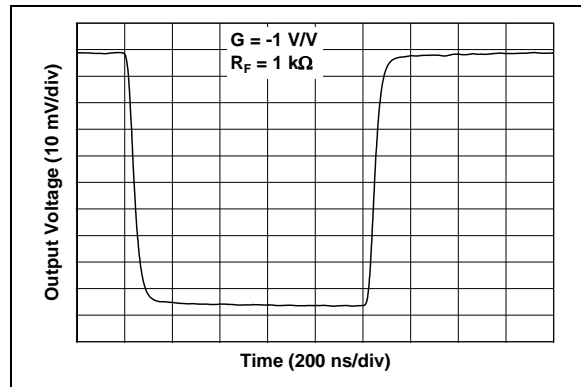
**FIGURE 2-31:** Output Voltage Headroom vs. Output Current.



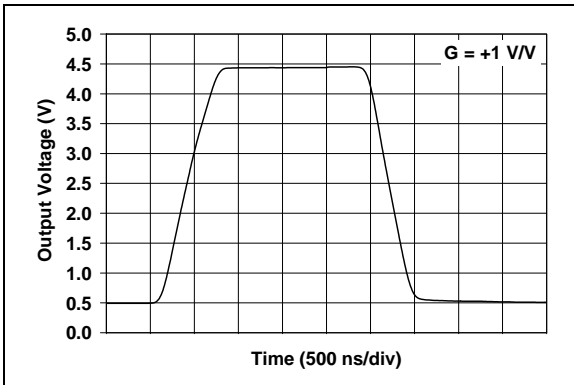
**FIGURE 2-34:** Output Voltage Headroom vs. Temperature.



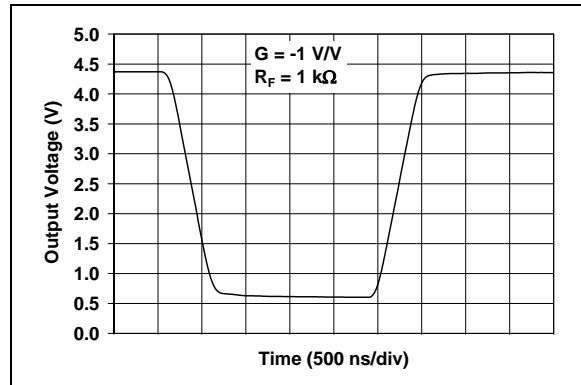
**FIGURE 2-32:** Small-Signal Non-inverting Pulse Response.



**FIGURE 2-35:** Small-Signal Inverting Pulse Response.

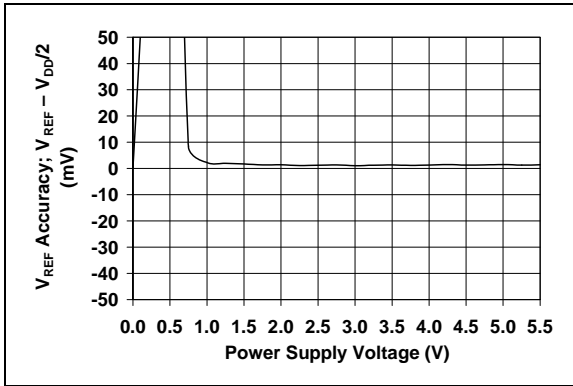


**FIGURE 2-33:** Large-Signal Non-inverting Pulse Response.

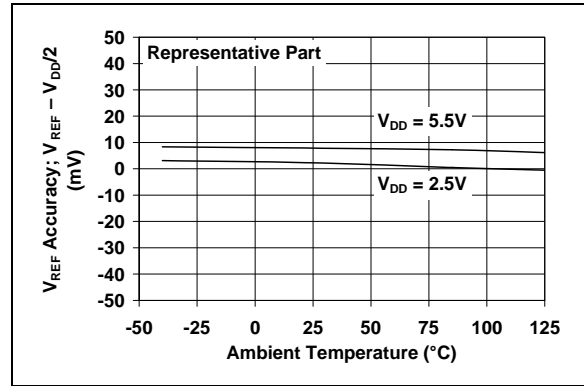


**FIGURE 2-36:** Large-Signal Inverting Pulse Response.

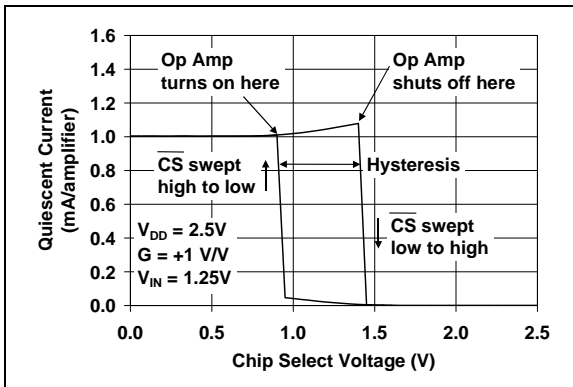
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +2.5\text{V}$  to  $+5.5\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_{DD}/2$  and  $C_L = 60\text{ pF}$ .



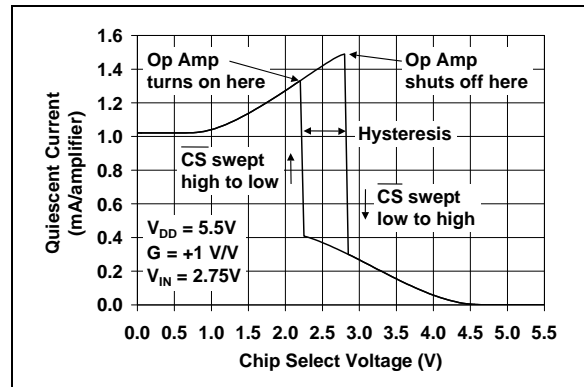
**FIGURE 2-37:**  $V_{REF}$  Accuracy vs. Supply Voltage (MCP6021 and MCP6023 only).



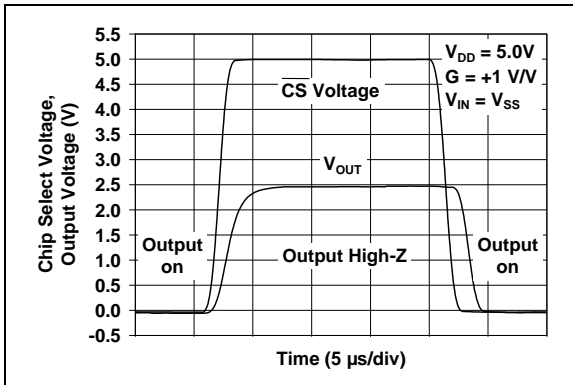
**FIGURE 2-40:**  $V_{REF}$  Accuracy vs. Temperature (MCP6021 and MCP6023 only).



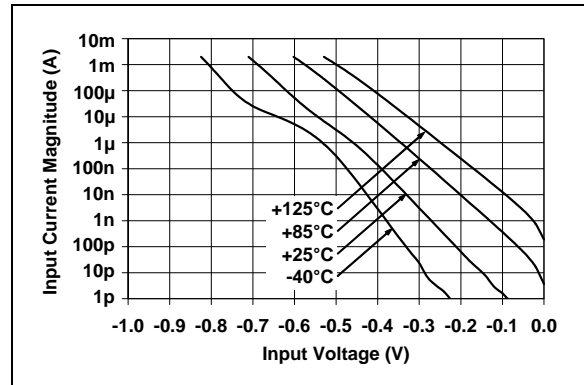
**FIGURE 2-38:** Chip Select ( $\overline{\text{CS}}$ ) Hysteresis (MCP6023 only) with  $V_{DD} = 2.5\text{V}$ .



**FIGURE 2-41:** Chip Select ( $\overline{\text{CS}}$ ) Hysteresis (MCP6023 only) with  $V_{DD} = 5.5\text{V}$ .



**FIGURE 2-39:** Chip Select ( $\overline{\text{CS}}$ ) to Amplifier Output Response Time (MCP6023 only).



**FIGURE 2-42:** Measured Input Current vs. Input Voltage (below  $V_{SS}$ ).

# MCP6021/1R/2/3/4

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NOTES:

## 3.0 PIN DESCRIPTIONS

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

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

| MCP6021                                      |          | MCP6021R             | MCP6022                 | MCP6023                 | MCP6024                 | Symbol              | Description                    |
|----------------------------------------------|----------|----------------------|-------------------------|-------------------------|-------------------------|---------------------|--------------------------------|
| PDIP,<br>SOIC,<br>MSOP,<br>TSSOP<br>(Note 1) | SOT-23-5 | SOT-23-5<br>(Note 2) | PDIP,<br>SOIC,<br>TSSOP | PDIP,<br>SOIC,<br>TSSOP | PDIP,<br>SOIC,<br>TSSOP |                     |                                |
| 6                                            | 1        | 1                    | 1                       | 6                       | 1                       | $V_{OUT}, V_{OUTA}$ | Analog Output (op amp A)       |
| 2                                            | 4        | 4                    | 2                       | 2                       | 2                       | $V_{IN-}, V_{INA-}$ | Inverting Input (op amp A)     |
| 3                                            | 3        | 3                    | 3                       | 3                       | 3                       | $V_{IN+}, V_{INA+}$ | Non-inverting Input (op amp A) |
| 7                                            | 5        | 2                    | 8                       | 7                       | 4                       | $V_{DD}$            | Positive Power Supply          |
| —                                            | —        | —                    | 5                       | —                       | 5                       | $V_{INB+}$          | Non-inverting Input (op amp B) |
| —                                            | —        | —                    | 6                       | —                       | 6                       | $V_{INB-}$          | Inverting Input (op amp B)     |
| —                                            | —        | —                    | 7                       | —                       | 7                       | $V_{OUTB}$          | Analog Output (op amp B)       |
| —                                            | —        | —                    | —                       | —                       | 8                       | $V_{OUTC}$          | Analog Output (op amp C)       |
| —                                            | —        | —                    | —                       | —                       | 9                       | $V_{INC-}$          | Inverting Input (op amp C)     |
| —                                            | —        | —                    | —                       | —                       | 10                      | $V_{INC+}$          | Non-inverting Input (op amp C) |
| 4                                            | 2        | 5                    | 4                       | 4                       | 11                      | $V_{SS}$            | Negative Power Supply          |
| —                                            | —        | —                    | —                       | —                       | 12                      | $V_{IND+}$          | Non-inverting Input (op amp D) |
| —                                            | —        | —                    | —                       | —                       | 13                      | $V_{IND-}$          | Inverting Input (op amp D)     |
| —                                            | —        | —                    | —                       | —                       | 14                      | $V_{OUTD}$          | Analog Output (op amp D)       |
| 5                                            | —        | —                    | —                       | 5                       | —                       | $V_{REF}$           | Reference Voltage              |
| —                                            | —        | —                    | —                       | 8                       | —                       | $\overline{CS}$     | Chip Select                    |
| 1, 8                                         | —        | —                    | —                       | 1                       | —                       | NC                  | No Internal Connection         |

**Note 1:** The MCP6021 in the 8-pin TSSOP package is only available for I-temp (Industrial Temperature) parts.

**Note 2:** The MCP6021R is only available in the 5-pin SOT-23 package, and for E-temp (Extended Temperature) parts.

### 3.1 Analog Outputs

The op amp output pins are low-impedance voltage sources.

### 3.2 Analog Inputs

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

### 3.3 Reference Voltage ( $V_{REF}$ ) MCP6021 and MCP6023

Mid-supply reference voltage provided by the single op amps (except in SOT-23-5 package). This is an unbuffered, resistor voltage divider internal to the part.

### 3.4 Chip Select Digital Input ( $\overline{CS}$ )

This is a CMOS, Schmitt-triggered input that places the part into a low power mode of operation.

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

The positive power supply pin ( $V_{DD}$ ) is 2.5V to 6.0V higher than the negative power supply pin ( $V_{SS}$ ). For normal operation, the other pins are at voltages between  $V_{SS}$  and  $V_{DD}$ .

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

# MCP6021/1R/2/3/4

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NOTES:



## 4.0 APPLICATIONS INFORMATION

The MCP6021/1R/2/3/4 family of operational amplifiers are fabricated on Microchip's state-of-the-art CMOS process. They are unity-gain stable and suitable for a wide range of general-purpose applications.

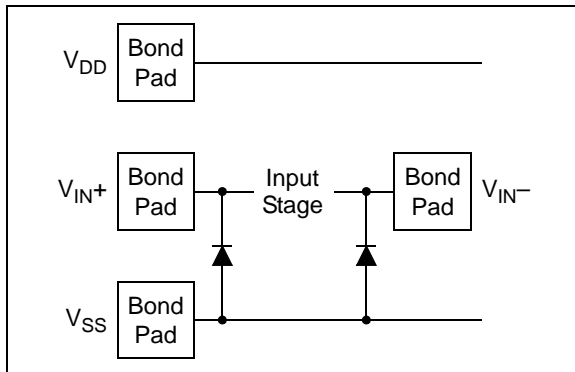
### 4.1 Rail-to-Rail Input

#### 4.1.1 PHASE REVERSAL

The MCP6021/1R/2/3/4 op amp is designed to prevent phase reversal when the input pins exceed the supply voltages. Figure 2-42 shows the input voltage exceeding the supply voltage without any phase reversal.

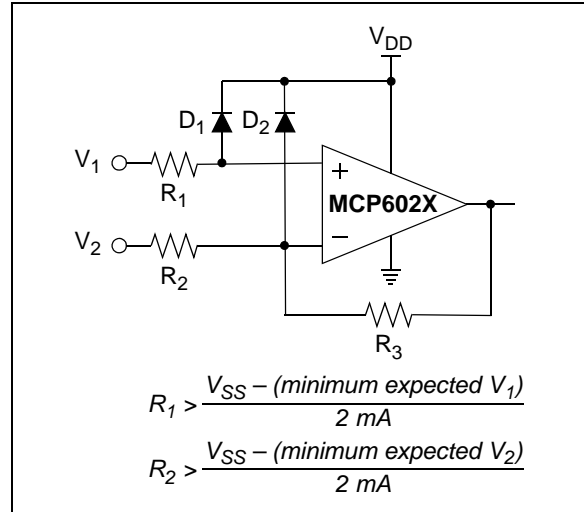
#### 4.1.2 INPUT VOLTAGE AND CURRENT LIMITS

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



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

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



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

It is also possible to connect the diodes to the left of resistors  $R_1$  and  $R_2$ . In this case, current through the diodes  $D_1$  and  $D_2$  needs to be limited by some other mechanism. The resistors then serve as in-rush current limiters; the DC current into the input pins ( $V_{IN+}$  and  $V_{IN-}$ ) should be very small.

A significant amount of current can flow out of the inputs when the common mode voltage ( $V_{CM}$ ) is below ground ( $V_{SS}$ ); see Figure 2-42. Applications that are high impedance may need to limit the useable voltage range.

#### 4.1.3 NORMAL OPERATION

The input stage of the MCP6021/1R/2/3/4 op amps use two differential CMOS input stages in parallel. One operates at low common mode input voltage ( $V_{CM}$ ), while the other operates at high  $V_{CM}$ . With this topology, the device operates with  $V_{cm}$  up to 0.3V above  $V_{DD}$  and 0.3V below  $V_{SS}$ .

### 4.2 Rail-to-Rail Output

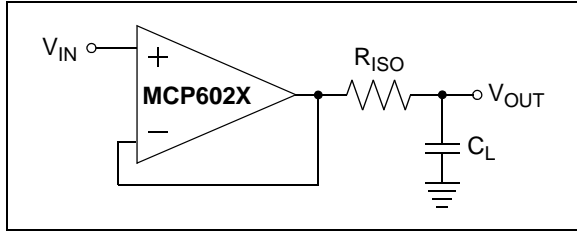
The Maximum Output Voltage Swing is the maximum swing possible under a particular output load. According to the specification table, the output can reach within 20 mV of either supply rail when  $R_L = 10 \text{ k}\Omega$ . See Figure 2-31 and Figure 2-34 for more information concerning typical performance.

### 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.

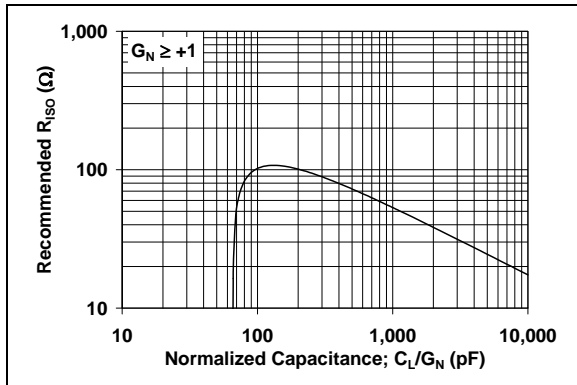
# MCP6021/1R/2/3/4

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



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

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



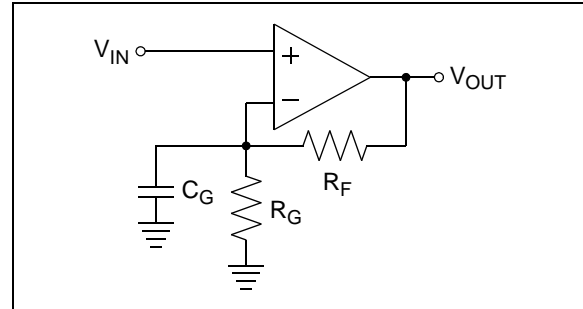
**FIGURE 4-4:** Recommended  $R_{ISO}$  values for capacitive loads.

After selecting  $R_{ISO}$  for your circuit, double-check the resulting frequency response peaking and step response overshoot. Modify  $R_{ISO}$ 's value until the response is reasonable. Evaluation on the bench and simulations with the MCP6021/1R/2/3/4 Spice macro model are helpful.

## 4.4 Gain Peaking

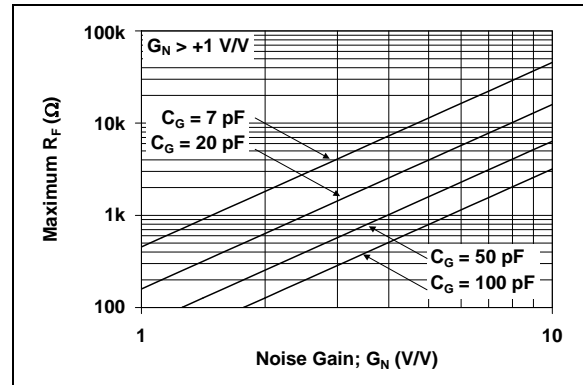
Figure 2-35 and Figure 2-36 use  $R_F = 1$  k $\Omega$  to avoid (frequency response) gain peaking and (step response) overshoot. The capacitance to ground at the inverting input ( $C_G$ ) is the op amp's common mode input capacitance plus board parasitic capacitance.  $C_G$  is in parallel with  $R_G$ , which causes an increase in gain at high frequencies for non-inverting gains greater than

1 V/V (unity gain).  $C_G$  also reduces the phase margin of the feedback loop for both non-inverting and inverting gains.



**FIGURE 4-5:** Non-inverting Gain Circuit with Parasitic Capacitance.

The largest value of  $R_F$  in Figure 4-5 that should be used is a function of noise gain (see  $G_N$  in Section 4.3 "Capacitive Loads") and  $C_G$ . Figure 4-6 shows results for various conditions. Other compensation techniques may be used, but they tend to be more complicated to the design.



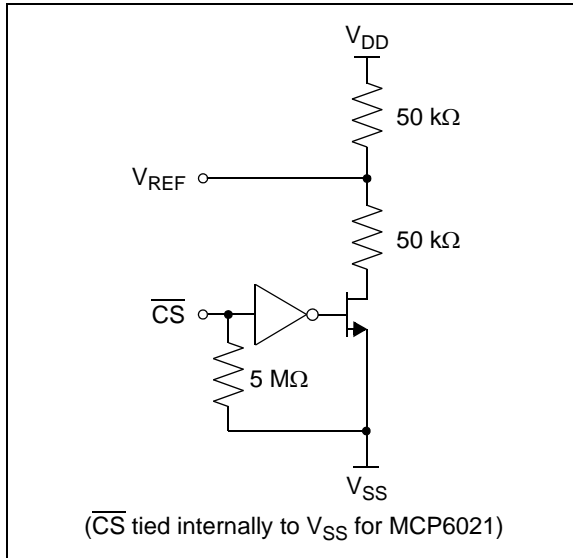
**FIGURE 4-6:** Non-inverting gain circuit with parasitic capacitance.

## 4.5 MCP6023 Chip Select ( $\overline{CS}$ )

The MCP6023 is a single amplifier with chip select ( $\overline{CS}$ ). When  $\overline{CS}$  is pulled high, the supply current drops to 10 nA (typical) and flows through the  $\overline{CS}$  pin to  $V_{SS}$ . When this happens, the amplifier output is put into a high-impedance state. By pulling  $\overline{CS}$  low, the amplifier is enabled. The  $\overline{CS}$  pin has an internal 5 M $\Omega$  (typical) pulldown resistor connected to  $V_{SS}$ , so it will go low if the  $\overline{CS}$  pin is left floating. Figure 1-1 and Figure 2-39 show the output voltage and supply current response to a  $\overline{CS}$  pulse.

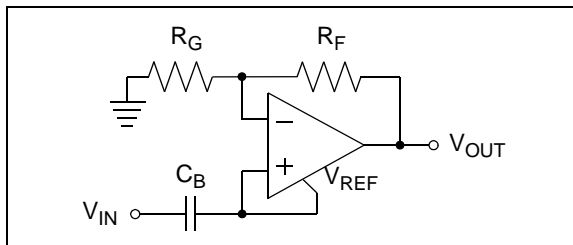
## 4.6 MCP6021 and MCP6023 Reference Voltage

The single op amps (MCP6021 and MCP6023), not in the SOT-23-5 package, have an internal mid-supply reference voltage connected to the  $V_{REF}$  pin (see Figure 4-7). The MCP6021 has  $\overline{CS}$  internally tied to  $V_{SS}$ , which always keeps the op amp on and always provides a mid-supply reference. With the MCP6023, taking the  $\overline{CS}$  pin high conserves power by shutting down both the op amp and the  $V_{REF}$  circuitry. Taking the  $\overline{CS}$  pin low turns on the op amp and  $V_{REF}$  circuitry.



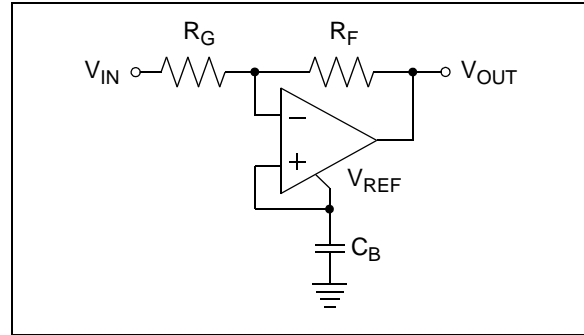
**FIGURE 4-7:** Simplified internal  $V_{REF}$  circuit (MCP6021 and MCP6023 only).

See Figure 4-8 for a non-inverting gain circuit using the internal mid-supply reference. The DC-blocking capacitor ( $C_B$ ) also reduces noise by coupling the op amp input to the source.



**FIGURE 4-8:** Non-inverting gain circuit using  $V_{REF}$  (MCP6021 and MCP6023 only).

To use the internal mid-supply reference for an inverting gain circuit, connect the  $V_{REF}$  pin to the non-inverting input, as shown in Figure 4-9. The capacitor  $C_B$  helps reduce power supply noise on the output.



**FIGURE 4-9:** Inverting gain circuit using  $V_{REF}$  (MCP6021 and MCP6023 only).

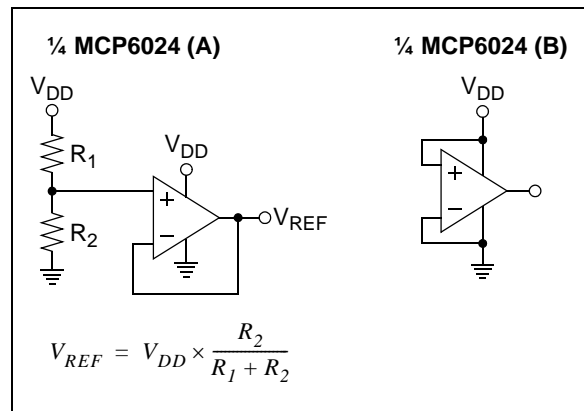
If you don't need the mid-supply reference, leave the  $V_{REF}$  pin open.

## 4.7 Supply Bypass

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

## 4.8 Unused Op Amps

An unused op amp in a quad package (MCP6024) should be configured as shown in Figure 4-10. These circuits prevent the output from toggling and causing crosstalk. Circuit A sets the op amp at its minimum noise gain. The resistor divider produces any desired reference voltage within the output voltage range of the op amp; the op amp buffers that reference voltage. Circuit B uses the minimum number of components and operates as a comparator, but it may draw more current.



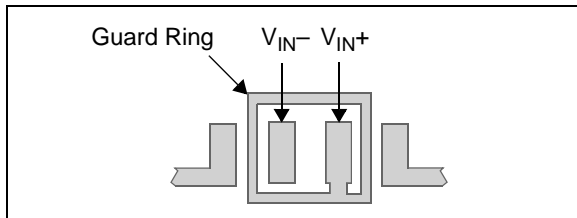
**FIGURE 4-10:** Unused Op Amps.

# MCP6021/1R/2/3/4

## 4.9 PCB Surface Leakage

In applications where low input bias current is critical, PCB (printed circuit board) surface-leakage effects need to be considered. Surface leakage is caused by humidity, dust or other contamination on the board. Under low humidity conditions, a typical resistance between nearby traces is  $10^{12}\Omega$ . A 5V difference would cause 5 pA of current to flow, which is greater than the MCP6021/1R/2/3/4 family's bias current at +25°C (1 pA, typical).

The easiest way to reduce surface leakage is to use a guard ring around sensitive pins (or traces). The guard ring is biased at the same voltage as the sensitive pin. [Figure 4-11](#) shows an example of this type of layout.



**FIGURE 4-11:** Example Guard Ring Layout.

1. Non-inverting Gain and Unity-Gain Buffer.
  - a) Connect the guard ring to the inverting input pin ( $V_{IN-}$ ); this biases the guard ring to the common mode input voltage.
  - b) Connect the non-inverting pin ( $V_{IN+}$ ) to the input with a wire that does not touch the PCB surface.
2. Inverting ([Figure 4-11](#)) and Transimpedance Gain Amplifiers (convert current to voltage, such as photo detectors).
  - a) Connect the guard ring to the non-inverting input pin ( $V_{IN+}$ ). This biases the guard ring to the same reference voltage as the op amp's input (e.g.,  $V_{DD}/2$  or ground).
  - b) Connect the inverting pin ( $V_{IN-}$ ) to the input with a wire that does not touch the PCB surface.

## 4.10 High Speed PCB Layout

Due to their speed capabilities, a little extra care in the PCB (Printed Circuit Board) layout can make a significant difference in the performance of these op amps. Good PCB board layout techniques will help you achieve the performance shown in [Section 1.0 "Electrical Characteristics"](#) and [Section 2.0 "Typical Performance Curves"](#), while also helping you minimize EMC (Electro-Magnetic Compatibility) issues.

Use a solid ground plane and connect the bypass local capacitor(s) to this plane with minimal length traces. This cuts down inductive and capacitive crosstalk.

Separate digital from analog, low speed from high speed and low power from high power. This will reduce interference.

Keep sensitive traces short and straight. Separating them from interfering components and traces. This is especially important for high-frequency (low rise-time) signals.

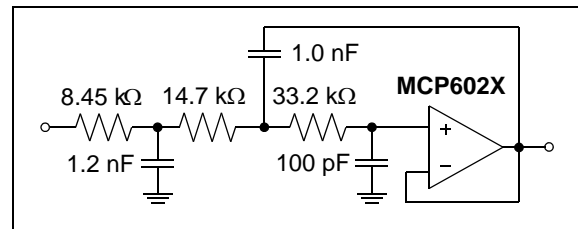
Sometimes it helps to place guard traces next to victim traces. They should be on both sides of the victim trace, and as close as possible. Connect the guard trace to ground plane at both ends, and in the middle for long traces.

Use coax cables (or low inductance wiring) to route signal and power to and from the PCB.

## 4.11 Typical Applications

### 4.11.1 A/D CONVERTER DRIVER AND ANTI-ALIASING FILTER

[Figure 4-12](#) shows a third-order Butterworth filter that can be used as an A/D converter driver. It has a bandwidth of 20 kHz and a reasonable step response. It will work well for conversion rates of 80 ksp/s and greater (it has 29 dB attenuation at 60 kHz).

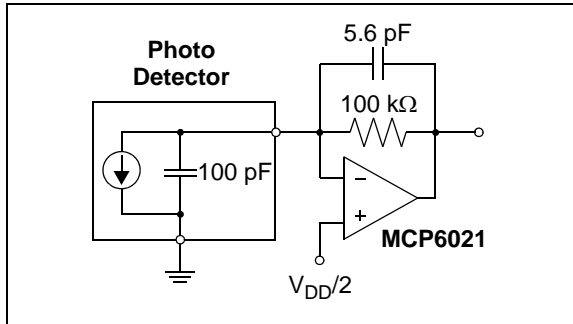


**FIGURE 4-12:** A/D Converter Driver and Anti-aliasing Filter with a 20 kHz Cutoff Frequency.

This filter can easily be adjusted to another bandwidth by multiplying all capacitors by the same factor. Alternatively, the resistors can all be scaled by another common factor to adjust the bandwidth.

## 4.11.2 OPTICAL DETECTOR AMPLIFIER

Figure 4-13 shows the MCP6021 op amp used as a transimpedance amplifier in a photo detector circuit. The photo detector looks like a capacitive current source, so the 100 k $\Omega$  resistor gains the input signal to a reasonable level. The 5.6 pF capacitor stabilizes this circuit and produces a flat frequency response with a bandwidth of 370 kHz.



**FIGURE 4-13:** *Transimpedance Amplifier for an Optical Detector.*

# MCP6021/1R/2/3/4

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NOTES:

## 5.0 DESIGN AIDS

Microchip provides the basic design tools needed for the MCP6021/1R/2/3/4 family of op amps.

### 5.1 SPICE Macro Model

The latest SPICE macro model available for the MCP6021/1R/2/3/4 op amps is on Microchip's web site at [www.microchip.com](http://www.microchip.com). This model is intended as an initial design tool that works well in the op amp's linear region of operation at room temperature. Within the macro model file is information on its capabilities.

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

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

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

### 5.3 Mindi<sup>™</sup> Circuit Designer & Simulator

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

### 5.4 Microchip Advanced Part Selector (MAPS)

MAPS is a software tool that helps semiconductor professionals efficiently identify Microchip devices that fit a particular design requirement. Available at no cost from the Microchip web site 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 Data sheets, Purchase, and Sampling of Microchip parts.

## 5.5 Analog Demonstration and Evaluation Boards

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

Some boards that are especially useful are:

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

## 5.6 Application Notes

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

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

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

"Signal Chain Design Guide", DS21825

# MCP6021/1R/2/3/4

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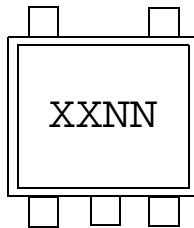
NOTES:



## 6.0 PACKAGING INFORMATION

### 6.1 Package Marking Information

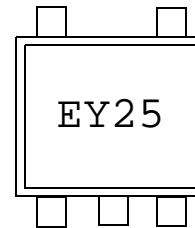
5-Lead SOT-23 (MCP6021/MCP6021R)



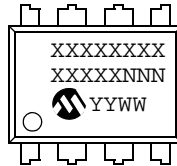
| Device   | E-Temp Code |
|----------|-------------|
| MCP6021  | EYNN        |
| MCP6021R | EZNN        |

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

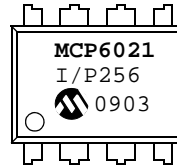
Example: (E-temp)



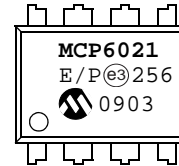
8-Lead PDIP (300 mil)



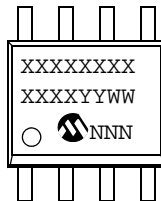
Example:



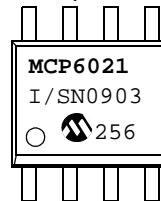
OR



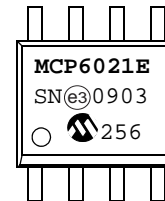
8-Lead SOIC (150 mil)



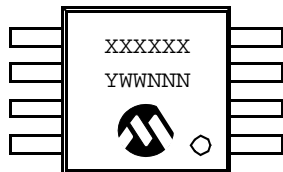
Example:



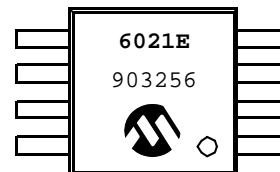
OR



8-Lead MSOP



Example:



8-Lead TSSOP



Example:



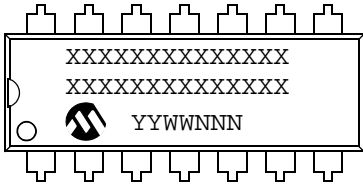
|                |        |                                                                                                                  |
|----------------|--------|------------------------------------------------------------------------------------------------------------------|
| <b>Legend:</b> | 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.

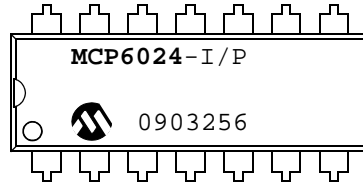
# MCP6021/1R/2/3/4

## Package Marking Information (Continued)

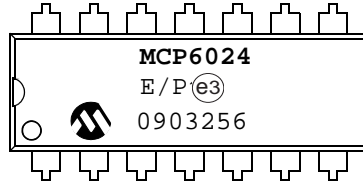
14-Lead PDIP (300 mil) (MCP6024)



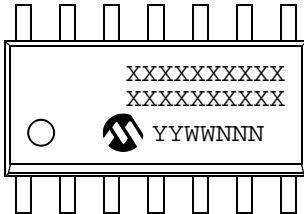
Example:



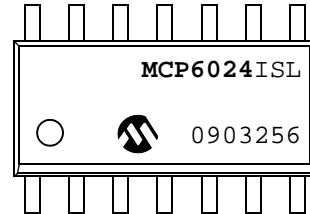
OR



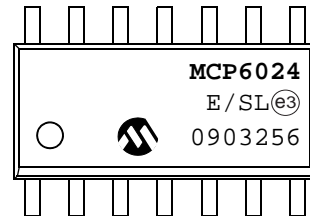
14-Lead SOIC (150 mil) (MCP6024)



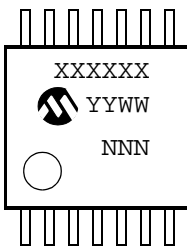
Example:



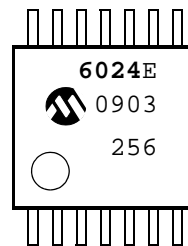
OR



14-Lead TSSOP (MCP6024)



Example:



## 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.

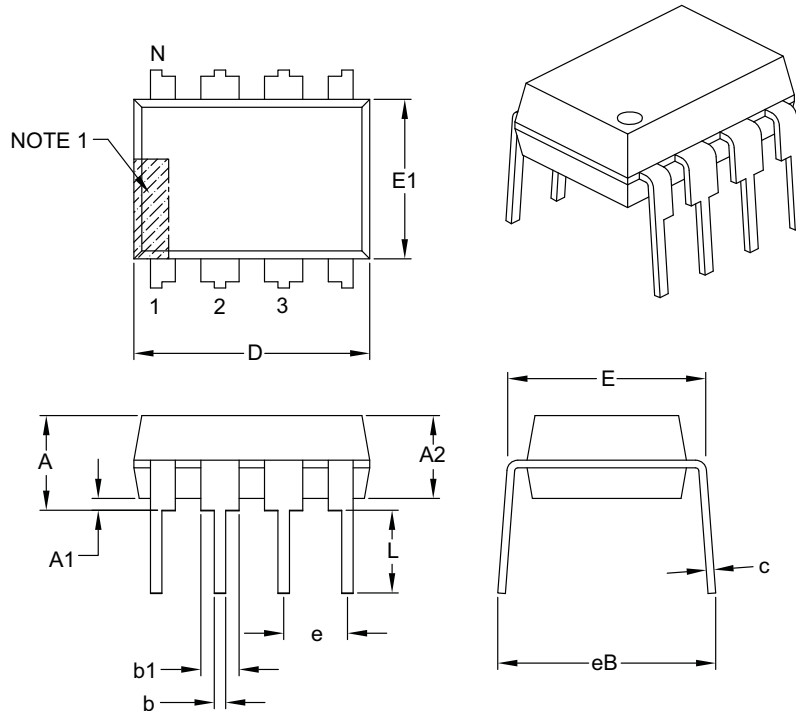
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing C04-091B

# MCP6021/1R/2/3/4

## 8-Lead Plastic Dual In-Line (P) – 300 mil Body [PDIP]

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



| Dimension Limits           | Units | INCHES   |      |      |
|----------------------------|-------|----------|------|------|
|                            |       | MIN      | NOM  | MAX  |
| Number of Pins             | N     | 8        |      |      |
| Pitch                      | e     | .100 BSC |      |      |
| Top to Seating Plane       | A     | –        | –    | .210 |
| Molded Package Thickness   | A2    | .115     | .130 | .195 |
| Base to Seating Plane      | A1    | .015     | –    | –    |
| Shoulder to Shoulder Width | E     | .290     | .310 | .325 |
| Molded Package Width       | E1    | .240     | .250 | .280 |
| Overall Length             | D     | .348     | .365 | .400 |
| Tip to Seating Plane       | L     | .115     | .130 | .150 |
| Lead Thickness             | c     | .008     | .010 | .015 |
| Upper Lead Width           | b1    | .040     | .060 | .070 |
| Lower Lead Width           | b     | .014     | .018 | .022 |
| Overall Row Spacing §      | eB    | –        | –    | .430 |

**Notes:**

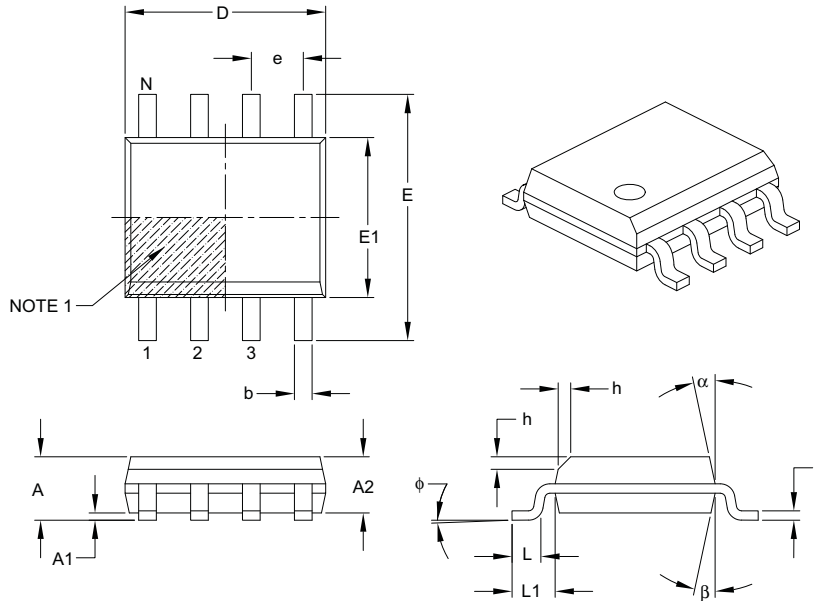
- Pin 1 visual index feature may vary, but must be located with the hatched area.
- § Significant Characteristic.
- Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" per side.
- Dimensioning and tolerancing per ASME Y14.5M.

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

Microchip Technology Drawing C04-018B

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

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



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

**Notes:**

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

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

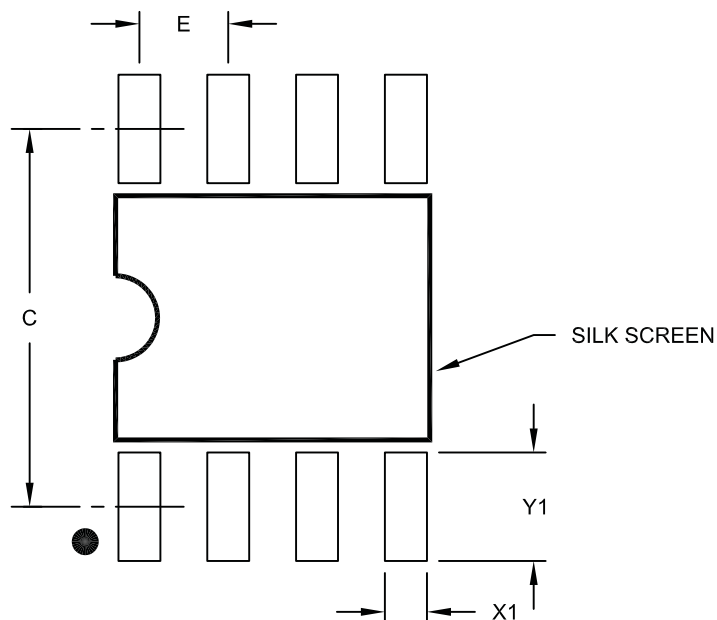
REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-057B

# MCP6021/1R/2/3/4

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

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



RECOMMENDED LAND PATTERN

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

Notes:

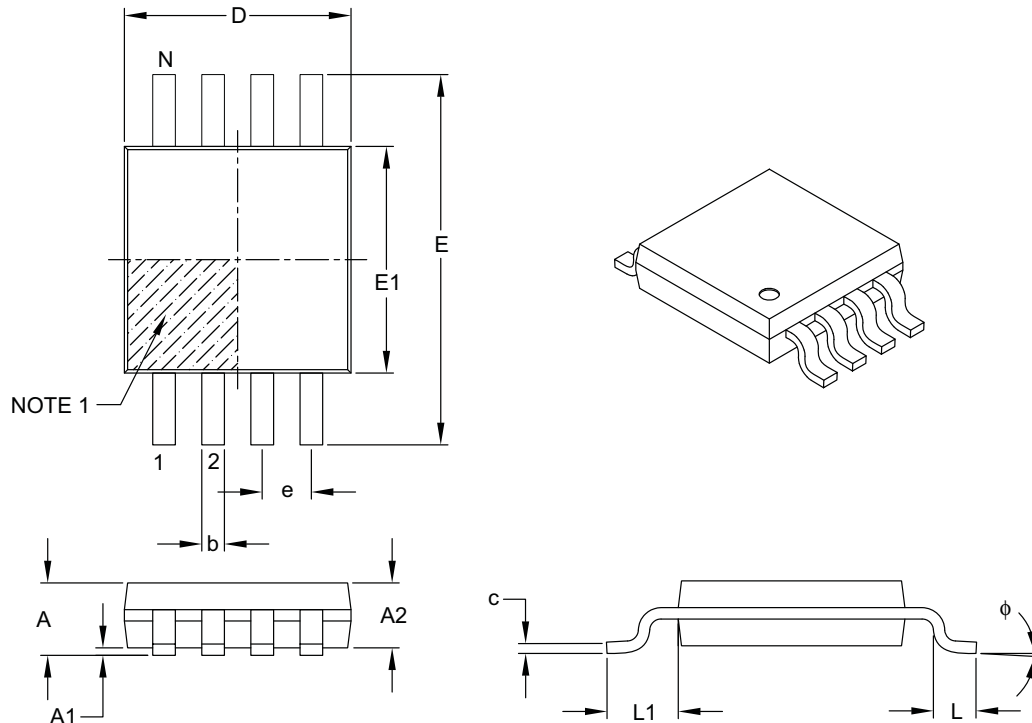
1. Dimensioning and tolerancing per ASME Y14.5M

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

Microchip Technology Drawing No. C04-2057A

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

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



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

**Notes:**

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

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

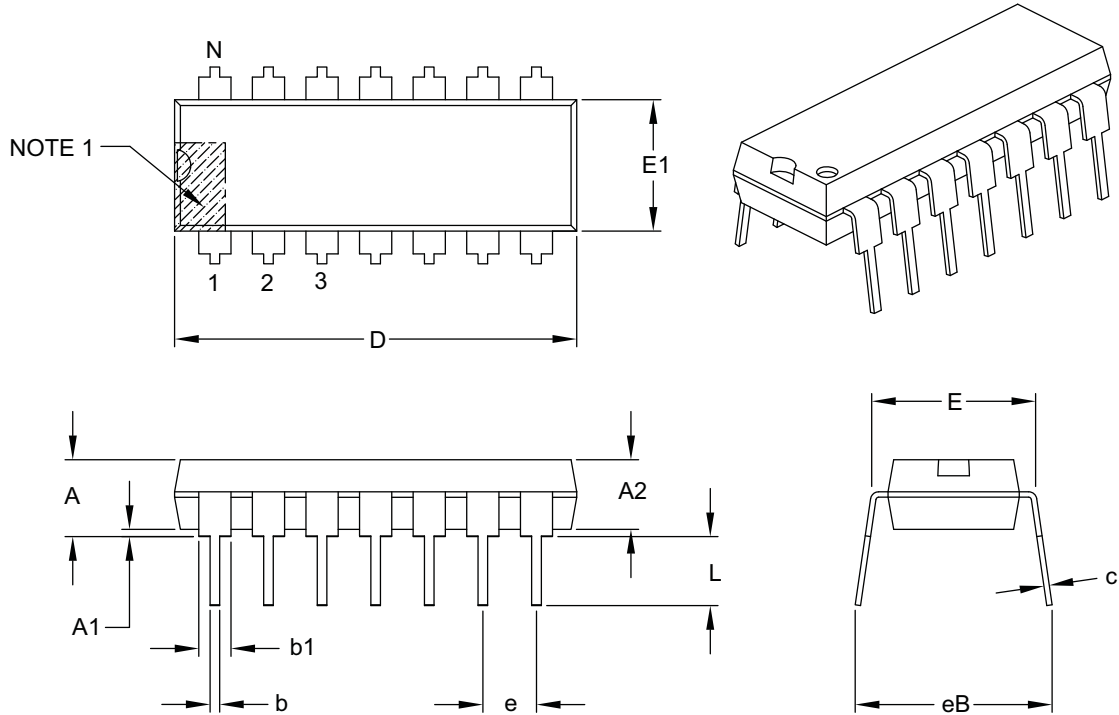
REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-111B

# MCP6021/1R/2/3/4

## 14-Lead Plastic Dual In-Line (P) – 300 mil Body [PDIP]

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



| Dimension Limits           | Units | INCHES   |      |      |
|----------------------------|-------|----------|------|------|
|                            |       | MIN      | NOM  | MAX  |
| Number of Pins             | N     | 14       |      |      |
| Pitch                      | e     | .100 BSC |      |      |
| Top to Seating Plane       | A     | –        | –    | .210 |
| Molded Package Thickness   | A2    | .115     | .130 | .195 |
| Base to Seating Plane      | A1    | .015     | –    | –    |
| Shoulder to Shoulder Width | E     | .290     | .310 | .325 |
| Molded Package Width       | E1    | .240     | .250 | .280 |
| Overall Length             | D     | .735     | .750 | .775 |
| Tip to Seating Plane       | L     | .115     | .130 | .150 |
| Lead Thickness             | c     | .008     | .010 | .015 |
| Upper Lead Width           | b1    | .045     | .060 | .070 |
| Lower Lead Width           | b     | .014     | .018 | .022 |
| Overall Row Spacing §      | eB    | –        | –    | .430 |

**Notes:**

- Pin 1 visual index feature may vary, but must be located with the hatched area.
- § Significant Characteristic.
- Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" per side.
- Dimensioning and tolerancing per ASME Y14.5M.

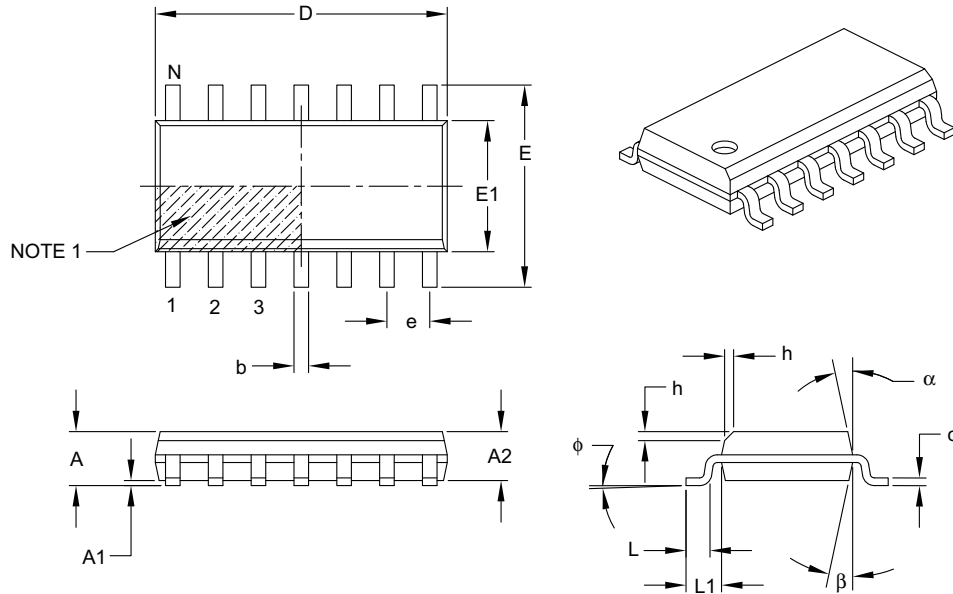
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing C04-005B



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

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



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

**Notes:**

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

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

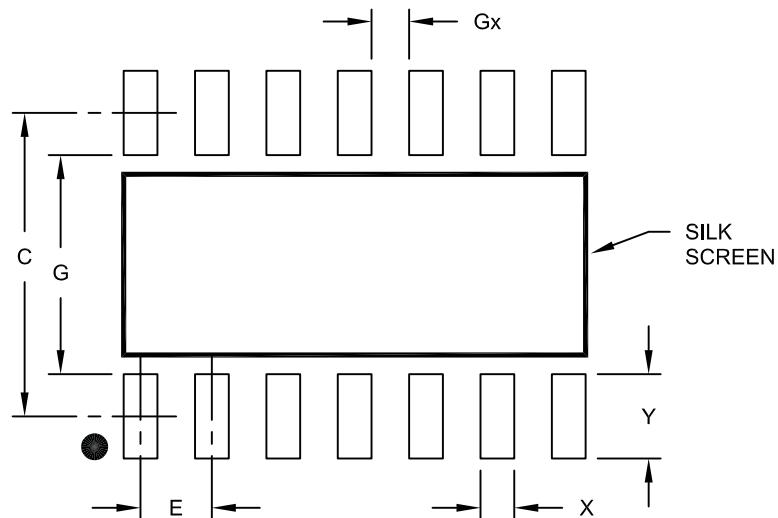
REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-065B

# MCP6021/1R/2/3/4

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:

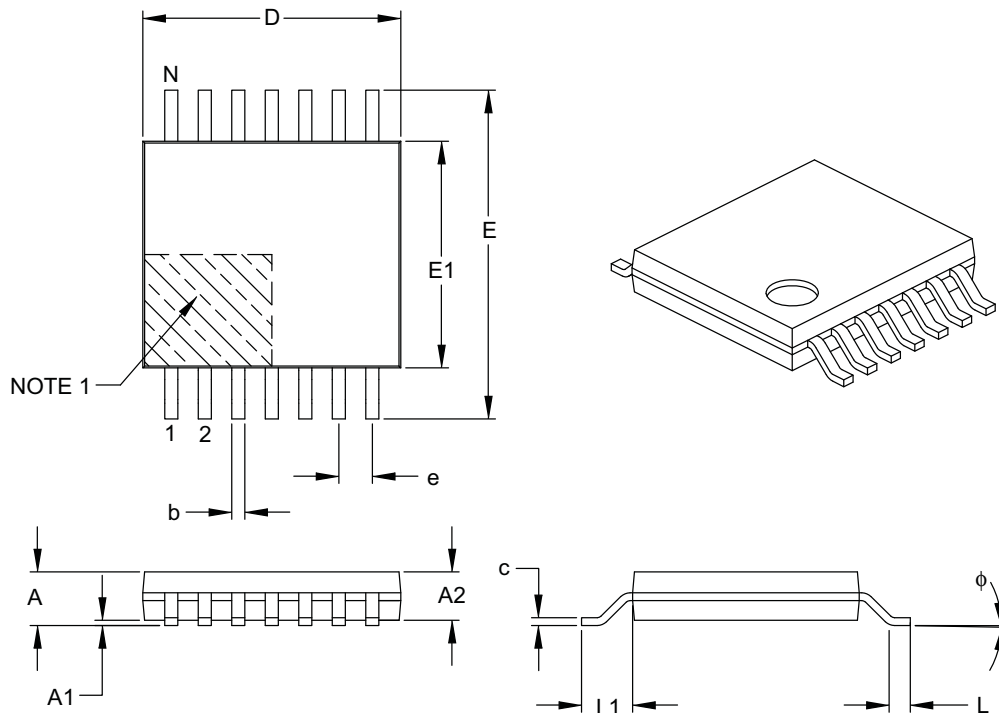
1. Dimensioning and tolerancing per ASME Y14.5M

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

Microchip Technology Drawing No. C04-2065A

## 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               | $\phi$ | 0°          | –    | 8°   |
| Lead Thickness           | c      | 0.09        | –    | 0.20 |
| Lead Width               | b      | 0.19        | –    | 0.30 |

**Notes:**

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

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

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

Microchip Technology Drawing C04-087B

# MCP6021/1R/2/3/4

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NOTES:

## APPENDIX A: REVISION HISTORY

### Revision D (February 2009)

The following is the list of modifications:

1. Changed all references to 6.0V back to 5.5V throughout document.
2. **Design Aids:** Name change for Mindi Simulation Tool.
3. **Section 1.0 “Electrical Characteristics”, DC Electrical Specifications:** Corrected “Maximum Output Voltage Swing” condition from 0.9V Input Overdrive to 0.5V Input Overdrive.
4. **Section 1.0 “Electrical Characteristics”, AC Electrical Specifications:** Changed Phase Margin condition from  $G = +1$  to  $G = +1 V/V$ .
5. **Section 1.0 “Electrical Characteristics”, AC Electrical Specifications:** Changed Settling Time, 0.2% condition from  $G = +1$  to  $G = +1 V/V$ .
6. **Section 1.0 “Electrical Characteristics”:** Added Section 1.1 Test Circuits.
7. **Section 5.0 “Design AIDS”:** Name change for Mindi Simulation Tool. Added new boards to **Section 5.5 “Analog Demonstration and Evaluation Boards”** and new application notes to **Section 5.6 “Application Notes”**.
8. Updates **Appendix A: “Revision History”**

### Revision C (March 2006)

The following is the list of modifications:

1. Added SOT-23-5 package option for single op amps MCP6021 and MCP6021R (E-temp only).
2. Added MSOP-8 package option for E-temp single op amp (MCP6021).
3. Corrected package drawing on front page for dual op amp (MCP6022).
4. Clarified spec conditions ( $I_{SC}$ , PM and THD+N) in **Section 2.0 “Typical Performance Curves”**.
5. Added **Section 3.0 “Pin Descriptions”**.
6. Updated **Section 4.0 “Applications information”** for THD+N, unused op amps, and gain peaking discussions.
7. Corrected and updated package marking information in **Section 6.0 “Packaging Information”**.
8. Added **Appendix A: “Revision History”**.

### Revision B (November 2003)

- Second Release of this Document

### Revision A (November 2001)

- Original Release of this Document.

# MCP6021/1R/2/3/4

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NOTES:

## PRODUCT IDENTIFICATION SYSTEM

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

| <u>PART NO.</u>    | <u>X</u>          | <u>/XX</u>                                                                                         |  |
|--------------------|-------------------|----------------------------------------------------------------------------------------------------|--|
| Device             | Temperature Range | Package                                                                                            |  |
| Device:            | MCP6021           | Single Op Amp                                                                                      |  |
|                    | MCP6021T          | Single Op Amp<br>(Tape and Reel for SOT-23, SOIC, TSSOP, MSOP)                                     |  |
|                    | MCP6021R          | Single Op Amp                                                                                      |  |
|                    | MCP6021RT         | Single Op Amp<br>(Tape and Reel for SOT-23)                                                        |  |
|                    | MCP6022           | Dual Op Amp                                                                                        |  |
|                    | MCP6022T          | Dual Op Amp<br>(Tape and Reel for SOIC and TSSOP)                                                  |  |
|                    | MCP6023           | Single Op Amp w/ $\overline{CS}$                                                                   |  |
|                    | MCP6023T          | Single Op Amp w/ $\overline{CS}$<br>(Tape and Reel for SOIC and TSSOP)                             |  |
|                    | MCP6024           | Quad Op Amp                                                                                        |  |
|                    | MCP6024T          | Quad Op Amp<br>(Tape and Reel for SOIC and TSSOP)                                                  |  |
| Temperature Range: | I                 | = -40°C to +85°C                                                                                   |  |
|                    | E                 | = -40°C to +125°C                                                                                  |  |
| Package:           | OT                | = Plastic Small Outline Transistor (SOT-23), 5-lead<br>(MCP6021, E-Temp; MCP6021R, E-Temp)         |  |
|                    | MS                | = Plastic MSOP, 8-lead<br>(MCP6021, E-Temp)                                                        |  |
|                    | P                 | = Plastic DIP (300 mil Body), 8-lead, 14-lead                                                      |  |
|                    | SN                | = Plastic SOIC (150mil Body), 8-lead                                                               |  |
|                    | SL                | = Plastic SOIC (150 mil Body), 14-lead                                                             |  |
|                    | ST                | = Plastic TSSOP, 8-lead<br>(MCP6021, I-Temp; MCP6022, I-Temp, E-Temp;<br>MCP6023, I-Temp, E-Temp;) |  |
|                    | ST                | = Plastic TSSOP, 14-lead                                                                           |  |

### Examples:

- a) MCP6021T-E/OT: Tape and Reel, Extended temperature, 5LD SOT-23.
- b) MCP6021-E/P: Extended temperature, 8LD PDIP.
- c) MCP6021-E/SN: Extended temperature, 8LD SOIC.
- a) MCP6021RT-E/OT: Tape and Reel, Extended temperature, 5LD SOT-23.
- a) MCP6022-I/P: Industrial temperature, 8LD PDIP.
- b) MCP6022-E/P: Extended temperature, 8LD PDIP.
- c) MCP6022T-E/ST: Tape and Reel, Extended temperature, 8LD TSSOP.
- a) MCP6023-I/P: Industrial temperature, 8LD PDIP.
- b) MCP6023-E/P: Extended temperature, 8LD PDIP.
- c) MCP6023-E/SN: Extended temperature, 8LD SOIC.
- a) MCP6024-I/SL: Industrial temperature, 14LD SOIC.
- b) MCP6024-E/SL: Extended temperature, 14LD SOIC.
- c) MCP6024T-E/ST: Tape and Reel, Extended temperature, 14LD TSSOP.

# MCP6021/1R/2/3/4

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NOTES:



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