



MCP601/2/3/4

2.7V to 5.5V Single Supply CMOS Op Amps

FEATURES

- Single Supply: 2.7V to 5.5V
- Rail-to-Rail Output
- Input Range Includes Ground
- Gain Bandwidth Product: 2.8 MHz (typ.)
- Unity Gain Stable
- Low Quiescent Current: 230 μ A/amplifier (typ.)
- Chip Select: MCP603
- Temperature Ranges:
 - Industrial: -40°C to +85°C
 - Extended: -40°C to +125°C
- Available in Single, Dual and Quad

TYPICAL APPLICATIONS

- Portable Equipment
- A/D Converter Driver
- Photo Diode Pre-amp
- Analog Filters
- Data Acquisition
- Notebooks and PDAs
- Sensor Interface

AVAILABLE TOOLS

- SPICE Macro Models at www.microchip.com
- FilterLab[®] Software at www.microchip.com

DESCRIPTION

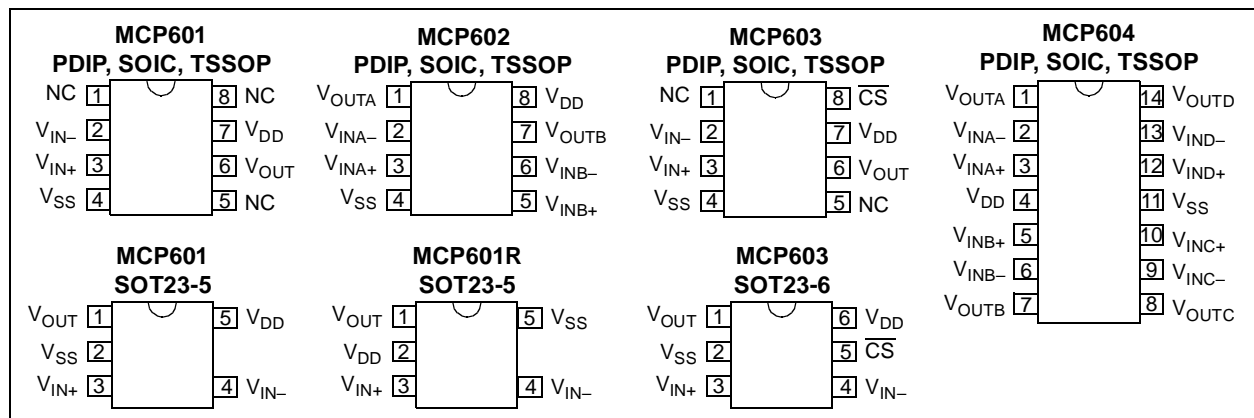
The Microchip Technology Inc. MCP601/2/3/4 family of low-power op amps (operational amplifiers) are offered in single (MCP601), single with Chip Select (MCP603), dual (MCP602) and quad (MCP604) configurations. These op amps utilize an advanced CMOS technology, which provides low bias current, high-speed operation, high open-loop gain, and rail-to-rail output swing. This product offering operates with a single supply voltage that can be as low as 2.7V, while drawing 230 μ A (typ.) of quiescent current per amplifier. In addition, the common mode input voltage range goes 0.3V below ground, making these amplifiers ideal for single supply operation.

These devices are appropriate for low-power, battery-operated circuits due to the low quiescent current, for A/D convert driver amplifiers because of their wide bandwidth or for anti-aliasing filters by virtue of their low input bias current.

The MCP601, MCP602 and MCP603 are available in standard 8-lead PDIP, SOIC and TSSOP packages. The MCP601 and MCP601R are also available in a standard 5-lead SOT23 package and the MCP603 in a standard 6-lead SOT23 package. The MCP604 is offered in standard 14-lead PDIP, SOIC and TSSOP packages.

The MCP601/2/3/4 family is available in the Industrial and Extended temperature ranges and also has a power supply range of 2.7V to 5.5V.

PACKAGE TYPES



MCP601/2/3/4

1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

| | |
|--|------------------------------------|
| $V_{DD} - V_{SS}$ | 7.0V |
| All inputs and outputs | $V_{SS} - 0.3V$ to $V_{DD} + 0.3V$ |
| Difference Input voltage | $ V_{DD} - V_{SS} $ |
| Output Short Circuit Current | continuous |
| Current at Input Pin | ± 2 mA |
| Current at Output and Supply Pins | ± 30 mA |
| Storage temperature | $-65^{\circ}C$ to $+150^{\circ}C$ |
| Junction temperature | $+150^{\circ}C$ |
| ESD protection on all pins (HBM; MM) | ≥ 3 kV; 200V |

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

DC CHARACTERISTICS

| Electrical Specifications: Unless otherwise specified, $T_A = +25^{\circ}C$, $V_{DD} = +2.7V$ to $+5.5V$, $V_{SS} = GND$, $V_{CM} = V_{DD}/2$, $V_{OUT} \approx V_{DD}/2$, and $R_L = 100$ k Ω to $V_{DD}/2$. | | | | | | |
|--|----------------------------|--------------|--------------|--------------|-------------------|---|
| Parameters | Sym | Min | Typ | Max | Units | Conditions |
| Input Offset | | | | | | |
| Input Offset Voltage | V_{OS} | -2 | ± 0.7 | +2 | mV | |
| Industrial Temperature | V_{OS} | -3 | ± 1 | +3 | mV | $T_A = -40^{\circ}C$ to $+85^{\circ}C$ (Note 1) |
| Extended Temperature | V_{OS} | -4.5 | ± 1 | +4.5 | mV | $T_A = -40^{\circ}C$ to $+125^{\circ}C$ (Note 1) |
| Input Offset Temperature Drift | $\Delta V_{OS}/\Delta T_A$ | — | ± 2.5 | — | $\mu V/^{\circ}C$ | $T_A = -40^{\circ}C$ to $+125^{\circ}C$ |
| Power Supply Rejection | PSRR | 80 | 88 | — | dB | $V_{DD} = 2.7V$ to $5.5V$ |
| Input Current and Impedance | | | | | | |
| Input Bias Current | I_B | — | 1 | — | pA | |
| Industrial Temperature | I_B | — | 20 | 60 | pA | $T_A = +85^{\circ}C$ (Note 2) |
| Extended Temperature | I_B | — | 450 | 5000 | pA | $T_A = +125^{\circ}C$ (Note 2) |
| Input Offset Current | I_{OS} | — | ± 1 | — | pA | |
| Common Mode Input Impedance | Z_{CM} | — | $10^{13} 6$ | — | ΩpF | |
| Differential Input Impedance | Z_{DIFF} | — | $10^{13} 3$ | — | ΩpF | |
| Common Mode | | | | | | |
| Common Mode Input Range | V_{CMR} | $V_{SS}-0.3$ | — | $V_{DD}-1.2$ | V | |
| Common Mode Rejection Ratio | CMRR | 75 | 90 | — | dB | $V_{DD} = 5.0V$, $V_{CM} = -0.3V$ to $3.8V$ |
| Open-loop Gain | | | | | | |
| DC Open-loop Gain (large signal) | A_{OL} | 100 | 115 | — | dB | $R_L = 25$ k Ω to $V_{DD}/2$, $V_{OUT} = 100$ mV to $V_{DD} - 100$ mV |
| | A_{OL} | 95 | 110 | — | dB | $R_L = 5$ k Ω to $V_{DD}/2$, $V_{OUT} = 100$ mV to $V_{DD} - 100$ mV |
| Output | | | | | | |
| Maximum Output Voltage Swing | V_{OL}, V_{OH} | $V_{SS}+15$ | — | $V_{DD}-20$ | mV | $R_L = 25$ k Ω to $V_{DD}/2$, Output overdrive = 0.5V |
| | V_{OL}, V_{OH} | $V_{SS}+45$ | — | $V_{DD}-60$ | mV | $R_L = 5$ k Ω to $V_{DD}/2$, Output overdrive = 0.5V |
| Linear Output Voltage Swing | V_{OUT} | $V_{SS}+100$ | — | $V_{DD}-100$ | mV | $R_L = 25$ k Ω to $V_{DD}/2$, $A_{OL} \geq 100$ dB |
| | V_{OUT} | $V_{SS}+100$ | — | $V_{DD}-100$ | mV | $R_L = 5$ k Ω to $V_{DD}/2$, $A_{OL} \geq 95$ dB |
| Output Short Circuit Current | I_{SC} | — | ± 22 | — | mA | $V_{DD} = 5.5V$ |
| | I_{SC} | — | ± 12 | — | mA | $V_{DD} = 2.7V$ |
| Power Supply | | | | | | |
| Supply Voltage | V_{DD} | 2.7 | — | 5.5 | V | |
| Quiescent Current per Amplifier | I_Q | — | 230 | 325 | μA | $I_O = 0$ |

Note 1: Maximum and minimum specified for PDIP and SOIC packages only. Typical specs refer to all packages.

Note 2: Maximum and minimum specified for PDIP, SOIC and TSSOP packages only. Typical specs refer to all packages.

PIN FUNCTION TABLE

| Name | Function |
|---|------------------------|
| $V_{IN+}, V_{INA+}, V_{INB+}, V_{INC+}, V_{IND+}$ | Non-inverting Inputs |
| $V_{IN-}, V_{INA-}, V_{INB-}, V_{INC-}, V_{IND-}$ | Inverting Inputs |
| V_{DD} | Positive Power Supply |
| V_{SS} | Negative Power Supply |
| $V_{OUT}, V_{OUTA}, V_{OUTB}, V_{OUTC}, V_{OUTD}$ | Outputs |
| \overline{CS} | Chip Select |
| NC | No Internal Connection |

AC CHARACTERISTICS

Electrical Specifications: Unless otherwise indicated, $T_A = +25^\circ\text{C}$, $V_{DD} = +2.7\text{V}$ to $+5.5\text{V}$, $V_{SS} = \text{GND}$, $V_{CM} = V_{DD}/2$, $V_{OUT} \approx V_{DD}/2$, $R_L = 100\text{ k}\Omega$ to $V_{DD}/2$, and $C_L = 50\text{ pF}$.

| Parameters | Sym | Min | Typ | Max | Units | Conditions |
|-----------------------------|---------------------|-----|-----|-----|----------------------------|---------------------------------------|
| Frequency Response | | | | | | |
| Gain Bandwidth Product | GBWP | — | 2.8 | — | MHz | |
| Phase Margin | PM | — | 50 | — | ° | $G = +1\text{ V/V}$ |
| Step Response | | | | | | |
| Slew Rate | SR | — | 2.3 | — | V/ μs | $G = +1\text{ V/V}$ |
| Settling Time (0.01%) | t_{settle} | — | 4.5 | — | μs | $G = +1\text{ V/V}$, 3.8V step |
| Noise | | | | | | |
| Input Noise Voltage | E_{ni} | — | 7 | — | $\mu\text{V}_{\text{P-P}}$ | $f = 0.1\text{ Hz}$ to 10 Hz |
| Input Noise Voltage Density | e_{ni} | — | 29 | — | nV/ $\sqrt{\text{Hz}}$ | $f = 1\text{ kHz}$ |
| | e_{ni} | — | 21 | — | nV/ $\sqrt{\text{Hz}}$ | $f = 10\text{ kHz}$ |
| Input Noise Current Density | i_{ni} | — | 0.6 | — | fA/ $\sqrt{\text{Hz}}$ | $f = 1\text{ kHz}$ |

MCP603 CHIP SELECT CHARACTERISTICS

Electrical Specifications: Unless otherwise indicated, $T_A = +25^\circ\text{C}$, $V_{DD} = +2.7\text{V}$ to $+5.5\text{V}$, $V_{SS} = \text{GND}$, $V_{CM} = V_{DD}/2$, $V_{OUT} \approx V_{DD}/2$, $R_L = 100\text{ k}\Omega$ to $V_{DD}/2$, and $C_L = 50\text{ pF}$.

| Parameters | Sym | Min | Typ | Max | Units | Conditions |
|---|---------------|--------------|------|--------------|---------------|---|
| DC Characteristics | | | | | | |
| $\overline{\text{CS}}$ Logic Threshold, Low | V_{IL} | V_{SS} | — | $0.2 V_{DD}$ | V | |
| $\overline{\text{CS}}$ Input Current, Low | I_{CSL} | -1.0 | — | — | μA | $\overline{\text{CS}} = 0.2V_{DD}$ |
| $\overline{\text{CS}}$ Logic Threshold, High | V_{IH} | $0.8 V_{DD}$ | — | V_{DD} | V | |
| $\overline{\text{CS}}$ Input Current, High | I_{CSH} | — | 0.7 | 2.0 | μA | $\overline{\text{CS}} = V_{DD}$ |
| Shutdown V_{SS} current | I_{Q_SHDN} | -2.0 | -0.7 | — | μA | $\overline{\text{CS}} = V_{DD}$ |
| Amplifier Output Leakage in Shutdown | I_{O_SHDN} | — | 1 | — | nA | |
| $\overline{\text{CS}}$ Threshold Hysteresis | HYST | — | 0.3 | — | V | Internal switch |
| Timing | | | | | | |
| $\overline{\text{CS}}$ Low to Amplifier Output Turn-on Time | t_{ON} | — | 3.1 | 10 | μs | $\overline{\text{CS}} \leq 0.2V_{DD}$, $G = +1\text{ V/V}$ |
| $\overline{\text{CS}}$ High to Amplifier Output High-Z Time | t_{OFF} | — | 100 | — | ns | $\overline{\text{CS}} \geq 0.8V_{DD}$, $G = +1\text{ V/V}$, No Load |

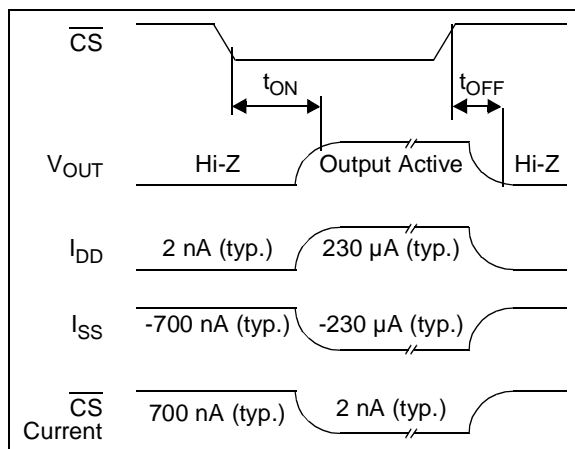


FIGURE 1-1: MCP603 Chip Select ($\overline{\text{CS}}$) timing diagram.

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TEMPERATURE CHARACTERISTICS

| Electrical Specifications: Unless otherwise indicated, $V_{DD} = +2.7V$ to $+5.5V$ and $V_{SS} = GND$. | | | | | | |
|---|---------------|-----|-----|------|-------|------------------------------|
| Parameters | Sym | Min | Typ | Max | Units | Conditions |
| Temperature Ranges | | | | | | |
| Specified Temperature Range | T_A | -40 | — | +85 | °C | Industrial temperature parts |
| | T_A | -40 | — | +125 | °C | Extended temperature parts |
| Operating Temperature Range | T_A | -40 | — | +125 | °C | Note |
| Storage Temperature Range | T_A | -65 | — | +150 | °C | |
| Thermal Package Resistances | | | | | | |
| Thermal Resistance, 5L-SOT23 | θ_{JA} | — | 256 | — | °C/W | |
| Thermal Resistance, 6L-SOT23 | θ_{JA} | — | 230 | — | °C/W | |
| Thermal Resistance, 8L-PDIP | θ_{JA} | — | 85 | — | °C/W | |
| Thermal Resistance, 8L-SOIC | θ_{JA} | — | 163 | — | °C/W | |
| Thermal Resistance, 8L-TSSOP | θ_{JA} | — | 124 | — | °C/W | |
| Thermal Resistance, 14L-PDIP | θ_{JA} | — | 70 | — | °C/W | |
| Thermal Resistance, 14L-SOIC | θ_{JA} | — | 120 | — | °C/W | |
| Thermal Resistance, 14L-TSSOP | θ_{JA} | — | 100 | — | °C/W | |

Note: The Industrial temperature parts operate over this extended range, but with reduced performance. The Extended temperature specs do not apply to Industrial temperature parts. In any case, the internal Junction temperature (T_J) must not exceed the absolute maximum specification of 150°C.

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, $T_A = +25^\circ\text{C}$, $V_{DD} = +2.7\text{V}$ to $+5.5\text{V}$, $V_{SS} = \text{GND}$, $V_{CM} = V_{DD}/2$, $R_L = 100\text{ k}\Omega$ to $V_{DD}/2$, $V_{OUT} \approx V_{DD}/2$, and $C_L = 50\text{ pF}$.

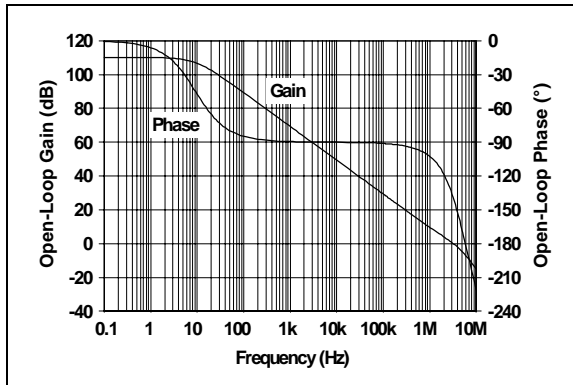


FIGURE 2-1: Open-Loop Gain, Phase vs. Frequency.

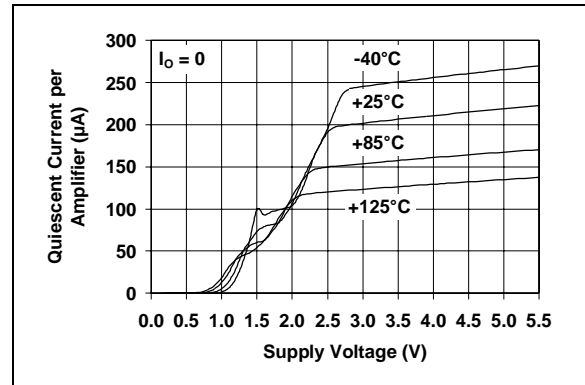


FIGURE 2-4: Quiescent Current vs. Supply Voltage.

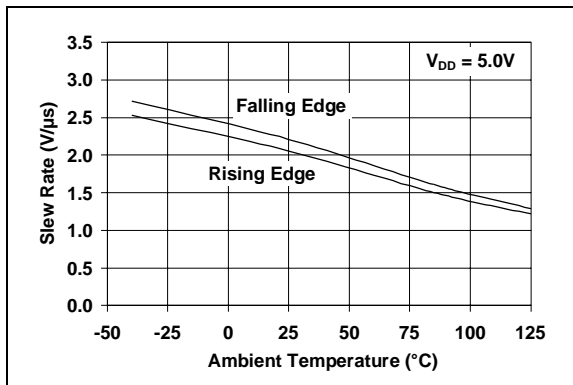


FIGURE 2-2: Slew Rate vs. Temperature.

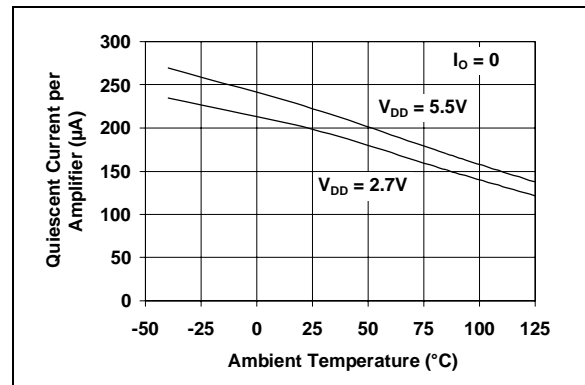


FIGURE 2-5: Quiescent Current vs. Temperature.

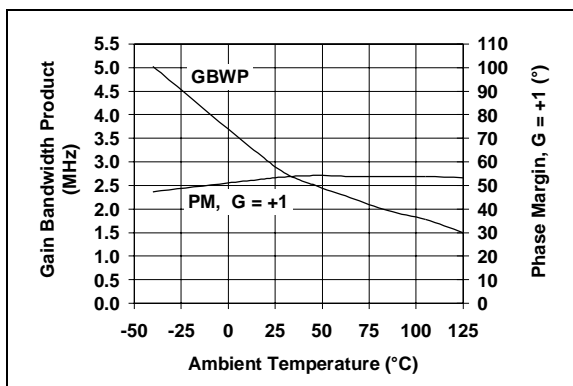


FIGURE 2-3: Gain Bandwidth Product, Phase Margin vs. Temperature.

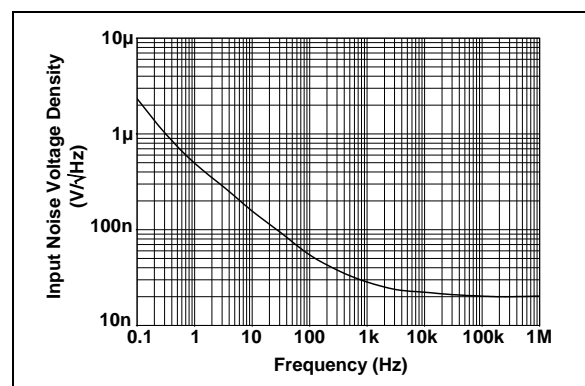


FIGURE 2-6: Input Noise Voltage Density vs. Frequency.

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Note: Unless otherwise indicated, $T_A = +25^\circ\text{C}$, $V_{DD} = +2.7\text{V}$ to $+5.5\text{V}$, $V_{SS} = \text{GND}$, $V_{CM} = V_{DD}/2$, $R_L = 100\text{ k}\Omega$ to $V_{DD}/2$, $V_{OUT} \approx V_{DD}/2$, and $C_L = 50\text{ pF}$.

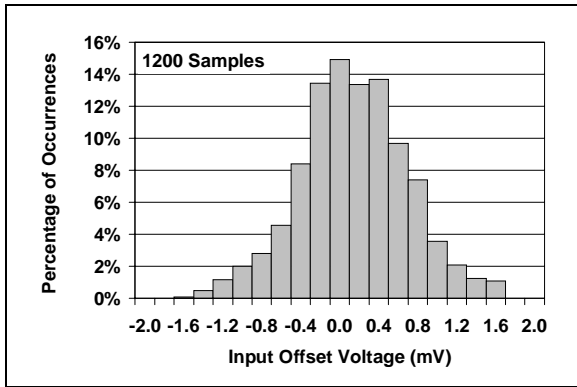


FIGURE 2-7: *Input Offset Voltage.*

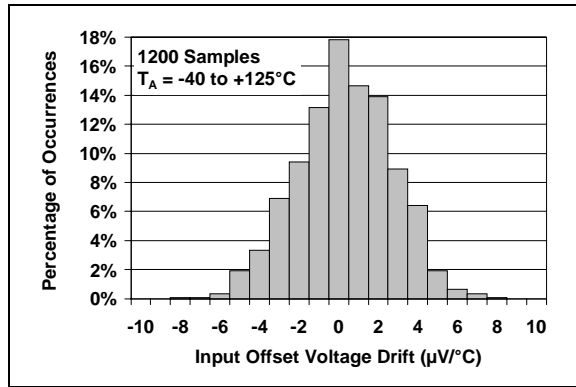


FIGURE 2-10: *Input Offset Voltage Drift.*

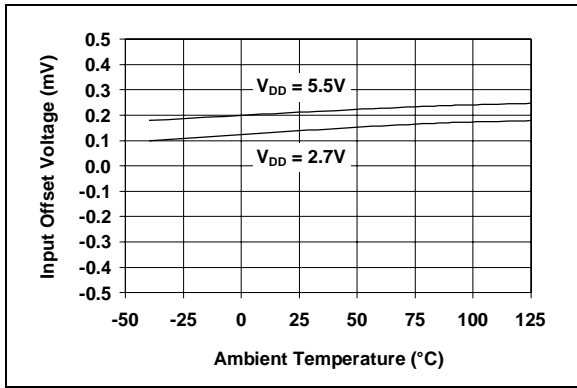


FIGURE 2-8: *Input Offset Voltage vs. Temperature.*

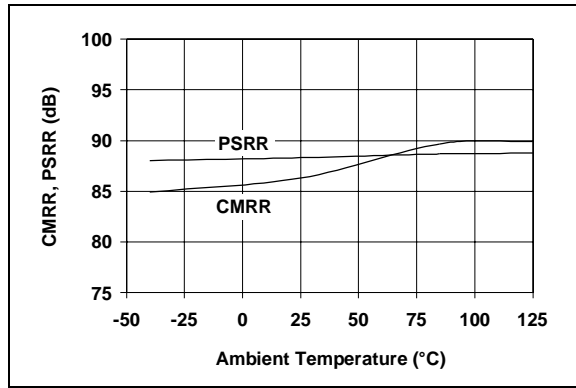


FIGURE 2-11: *CMRR, PSRR vs. Temperature.*

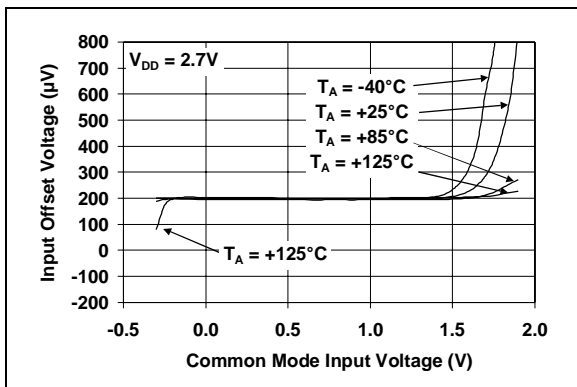


FIGURE 2-9: *Input Offset Voltage vs. Common Mode Input Voltage with $V_{DD} = 2.7\text{V}$.*

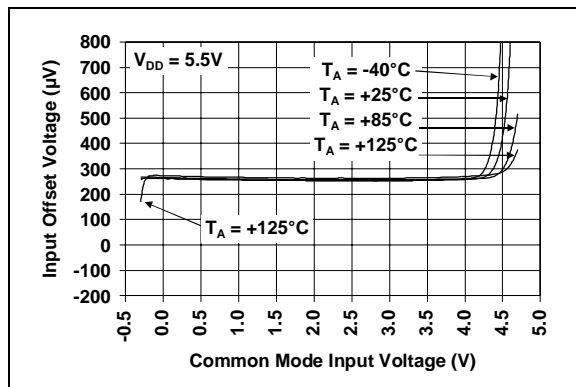


FIGURE 2-12: *Input Offset Voltage vs. Common Mode Input Voltage with $V_{DD} = 5.5\text{V}$.*

Note: Unless otherwise indicated, $T_A = +25^\circ\text{C}$, $V_{DD} = +2.7\text{V}$ to $+5.5\text{V}$, $V_{SS} = \text{GND}$, $V_{CM} = V_{DD}/2$, $R_L = 100\text{ k}\Omega$ to $V_{DD}/2$, $V_{OUT} \approx V_{DD}/2$, and $C_L = 50\text{ pF}$.

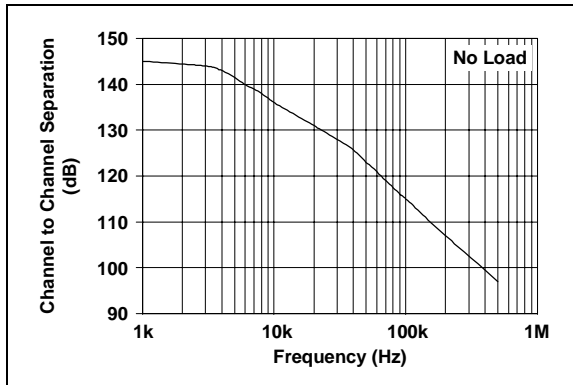


FIGURE 2-13: Channel-to-Channel Separation vs. Frequency.

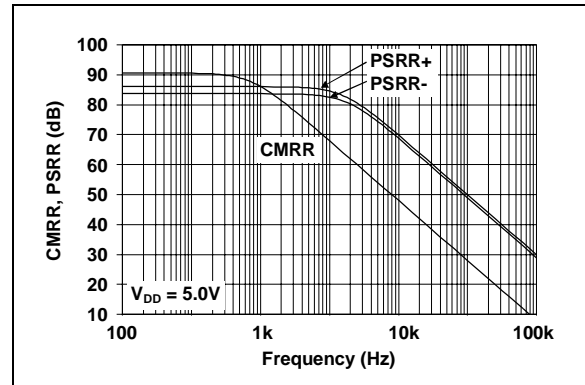


FIGURE 2-16: CMRR, PSRR vs. Frequency.

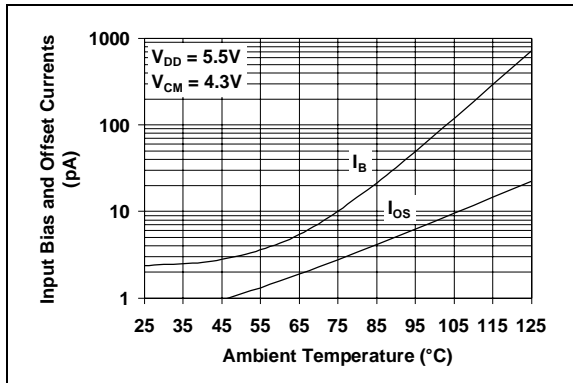


FIGURE 2-14: Input Bias Current, Input Offset Current vs. Ambient Temperature.

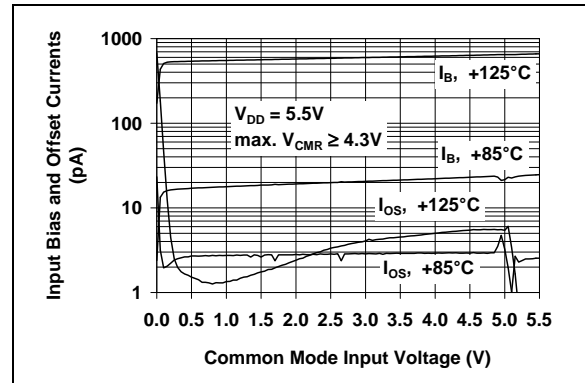


FIGURE 2-17: Input Bias Current, Input Offset Current vs. Common Mode Input Voltage.

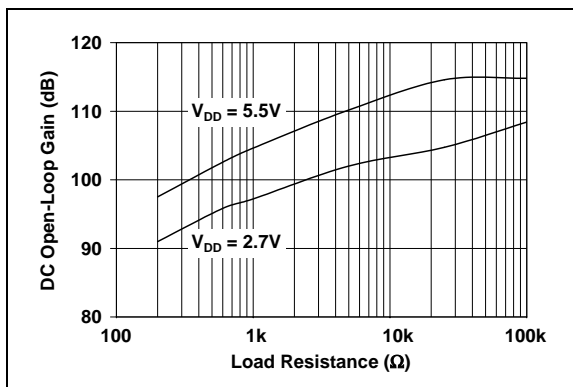


FIGURE 2-15: DC Open-Loop Gain vs. Load Resistance.

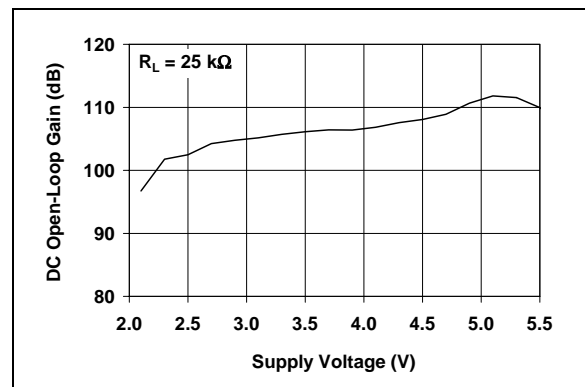


FIGURE 2-18: DC Open-Loop Gain vs. Supply Voltage.

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Note: Unless otherwise indicated, $T_A = +25^\circ\text{C}$, $V_{DD} = +2.7\text{V}$ to $+5.5\text{V}$, $V_{SS} = \text{GND}$, $V_{CM} = V_{DD}/2$, $R_L = 100\text{ k}\Omega$ to $V_{DD}/2$, $V_{OUT} \approx V_{DD}/2$, and $C_L = 50\text{ pF}$.

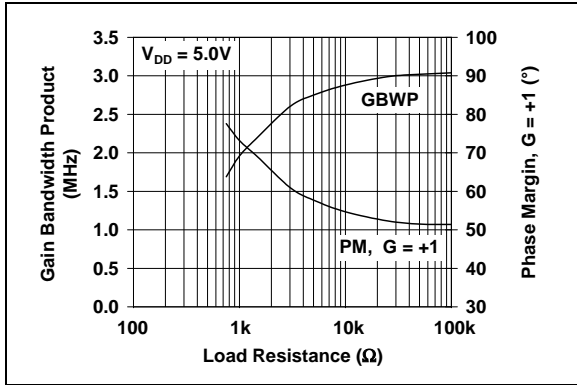


FIGURE 2-19: Gain Bandwidth Product, Phase Margin vs. Load Resistance.

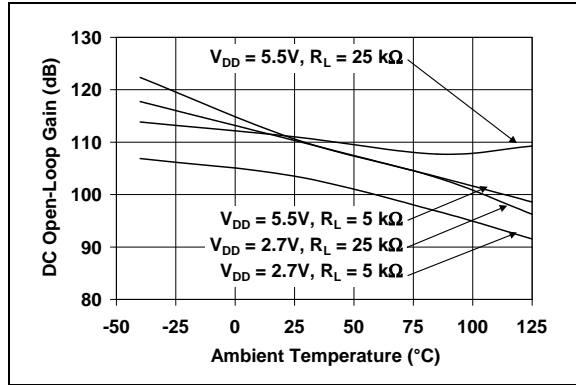


FIGURE 2-22: DC Open-Loop Gain vs. Temperature.

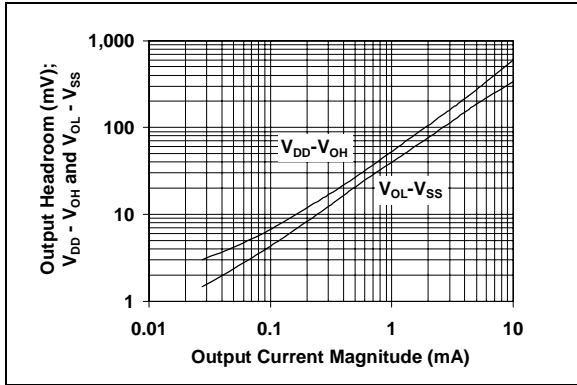


FIGURE 2-20: Output Voltage Headroom vs. Output Current.

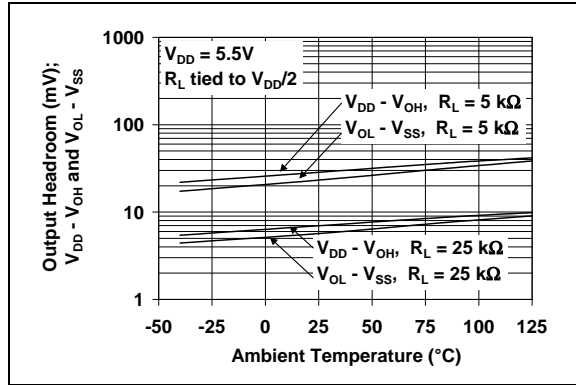


FIGURE 2-23: Output Voltage Headroom vs. Temperature.

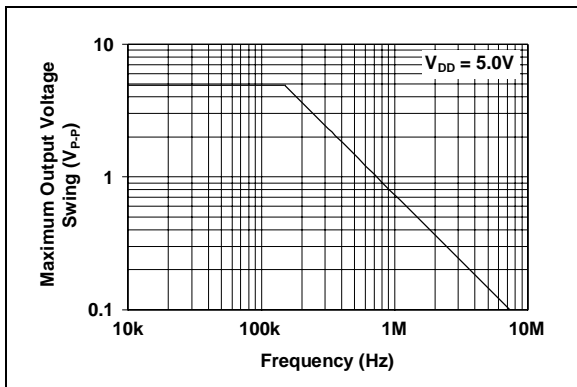


FIGURE 2-21: Maximum Output Voltage Swing vs. Frequency.

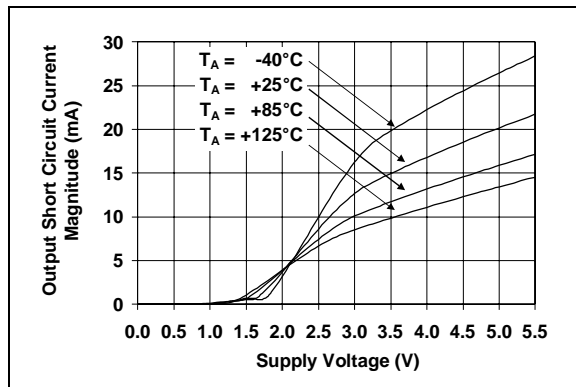


FIGURE 2-24: Output Short-Circuit Current vs. Supply Voltage.

Note: Unless otherwise indicated, $T_A = +25^\circ\text{C}$, $V_{DD} = +2.7\text{V to } +5.5\text{V}$, $V_{SS} = \text{GND}$, $V_{CM} = V_{DD}/2$, $R_L = 100\text{ k}\Omega$ to $V_{DD}/2$, $V_{OUT} \approx V_{DD}/2$, and $C_L = 50\text{ pF}$.

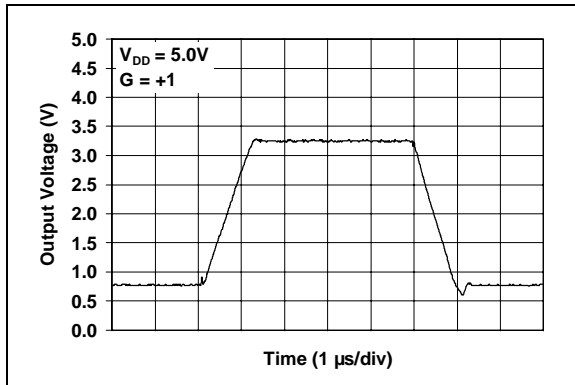


FIGURE 2-25: Large Signal Non-Inverting Pulse Response.

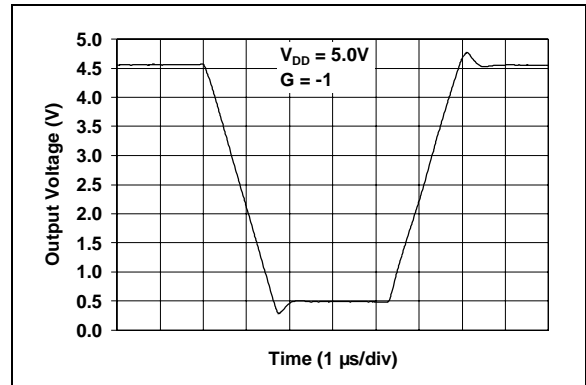


FIGURE 2-28: Large Signal Inverting Pulse Response.

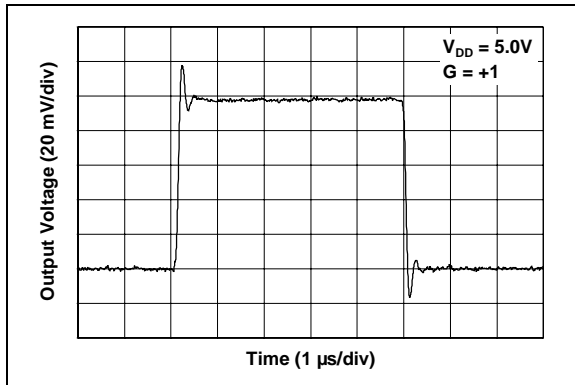


FIGURE 2-26: Small Signal Non-Inverting Pulse Response.

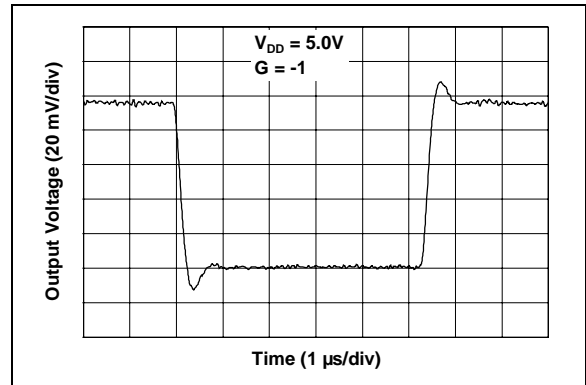


FIGURE 2-29: Small Signal Inverting Pulse Response.

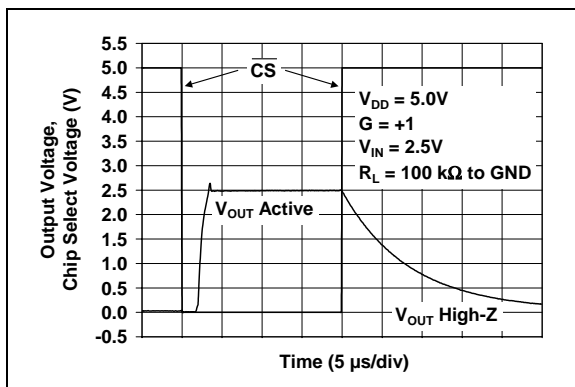


FIGURE 2-27: Chip Select Timing (MCP603).

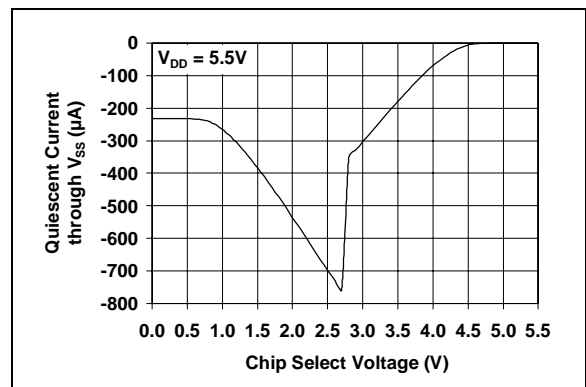


FIGURE 2-30: Quiescent Current Through V_{SS} vs. Chip Select Voltage (MCP603).

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Note: Unless otherwise indicated, $T_A = +25^\circ\text{C}$, $V_{DD} = +2.7\text{V}$ to $+5.5\text{V}$, $V_{SS} = \text{GND}$, $V_{CM} = V_{DD}/2$, $R_L = 100\text{ k}\Omega$ to $V_{DD}/2$, $V_{OUT} \approx V_{DD}/2$, and $C_L = 50\text{ pF}$.

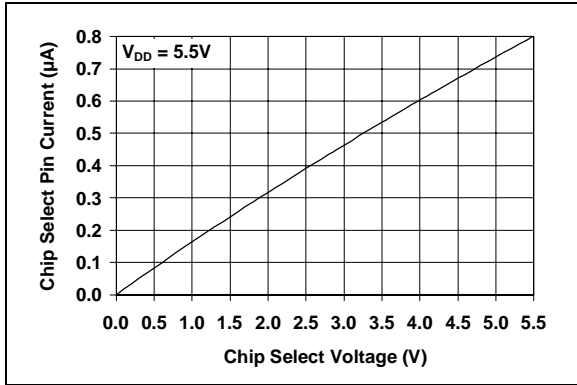


FIGURE 2-31: Chip Select Pin Input Current vs. Chip Select Voltage.

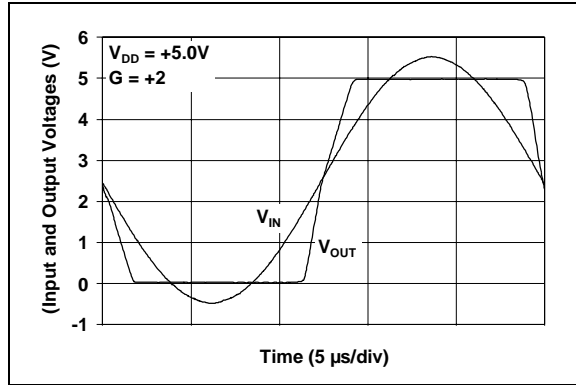


FIGURE 2-33: The MCP601/2/3/4 family of op amps shows no phase reversal under input overdrive.

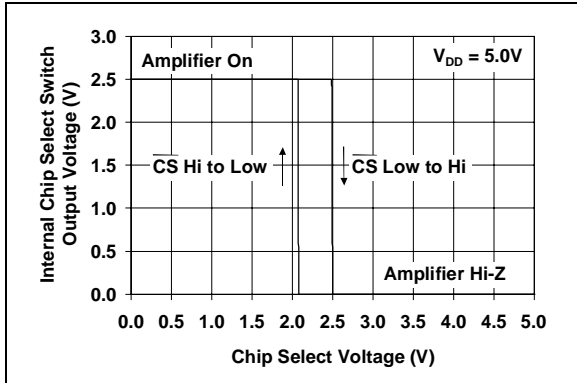


FIGURE 2-32: Hysteresis of Chip Select's Internal Switch.

3.0 APPLICATIONS INFORMATION

The MCP601/2/3/4 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.

3.1 Input

The MCP601/2/3/4 amplifier family is designed to not exhibit phase reversal when the input pins exceed the supply rails. Figure 2-33 shows an input voltage that exceeds both supplies with no resulting phase inversion.

The Common Mode Input Voltage Range (V_{CMR}) includes ground in single supply systems (V_{SS}), but does not include V_{DD} . This means that the amplifier input behaves linearly as long as the Common Mode Input Voltage (V_{CM}) is kept within the specified V_{CMR} limits ($V_{SS}-0.3V$ to $V_{DD}-1.2V$ at $+25^{\circ}C$).

Input voltages that exceed the input voltage range ($V_{SS}-0.3V$ to $V_{DD}-1.2V$ at $+25^{\circ}C$) can cause excessive current to flow into, or out of, the input pins. Current beyond ± 2 mA may cause reliability problems. Applications that exceed this rating must externally limit the input current with a resistor (R_{IN}), as shown in Figure 3-1.

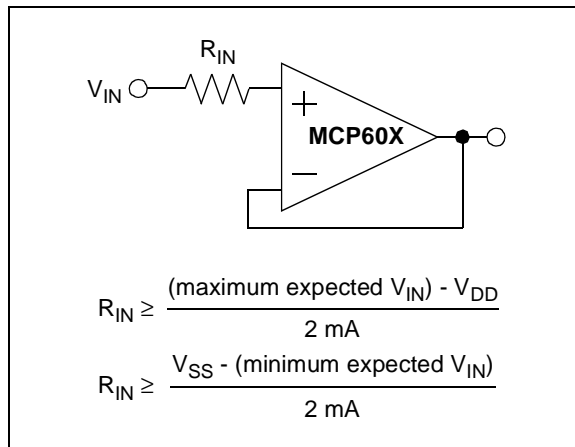


FIGURE 3-1: R_{IN} limits the current flow into an input pin.

3.2 Rail-to-Rail Output

There are two specifications that describe the output swing capability of the MCP601/2/3/4 family of operational amplifiers. The first specification, Maximum Output Voltage Swing, defines the absolute maximum swing that can be achieved under the specified load conditions. For instance, the output voltage swings to within 15 mV of the negative rail with a 25 k Ω load to $V_{DD}/2$. Figure 2-33 shows how the output voltage is limited when the input goes beyond the linear region of operation.

The second specification that describes the output swing capability of these amplifiers is the Linear Output Voltage Swing. This specification defines the maximum output swing that can be achieved while the amplifier is still operating in its linear region. To verify linear operation in this range, the large signal, DC Open-Loop Gain (A_{OL}), is measured at points 100 mV inside the supply rails. The measurement must exceed the specified gains in the spec table.

3.3 MCP603 Chip Select

The MCP603 is a single amplifier with Chip Select (\overline{CS}). When \overline{CS} is pulled high, the supply current drops to -0.7 μA (typ.), which is pulled through the \overline{CS} pin to V_{SS} . When this happens, the amplifier output is put into a high impedance state. Pulling \overline{CS} low enables the amplifier. If the \overline{CS} pin is left floating, the amplifier may not operate properly. Figure 1-1 is the Chip Select timing diagram and shows the output voltage, supply currents and \overline{CS} current in response to a \overline{CS} pulse. Figure 2-27 shows the measured output voltage response to a \overline{CS} pulse.

3.4 Capacitive Loads

Driving large capacitive loads can cause stability problems for voltage feedback op amps. As the load capacitance increases, the feedback loop's phase margin decreases and the closed-loop bandwidth is reduced. This produces gain peaking in the frequency response with overshoot and ringing in the step response.

When driving large capacitive loads with these op amps (e.g., > 40 pF when $G = +1$), a small series resistor at the output (R_{ISO} in Figure 3-2) improves the feedback loop's phase margin (stability) by making the output load resistive at higher frequencies. The bandwidth will be generally lower than the bandwidth with no capacitive load.

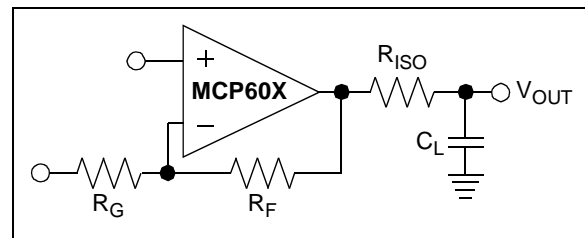


FIGURE 3-2: Output resistor R_{ISO} stabilizes large capacitive loads.

Figure 3-3 gives recommended R_{ISO} values for different capacitive loads and gains. The x-axis is the normalized load capacitance (C_L/G_N) to make it easier to interpret the plot for arbitrary gains. G_N is the circuit's noise gain. For non-inverting gains, G_N and the gain are equal. For inverting gains, G_N is $1+|\text{Gain}|$ (e.g., -1 V/V gives $G_N = +2$ V/V).

MCP601/2/3/4

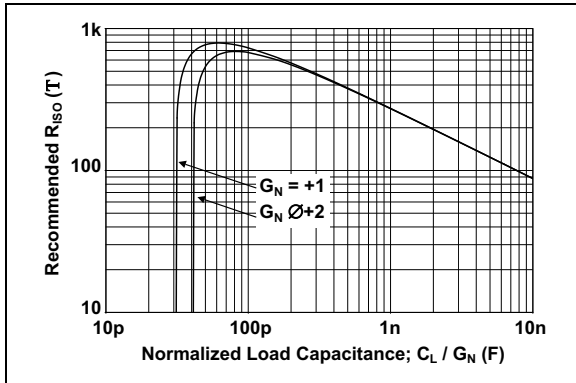


FIGURE 3-3: Recommended R_{ISO} values for capacitive loads.

After selecting R_{ISO} for your circuit, double-check the resulting frequency response peaking and step response overshoot in your circuit. Evaluation on the bench and simulations with the MCP601/2/3/4 SPICE macro model are very helpful. Modify R_{ISO} 's value until the response is reasonable.

3.5 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 μF to 0.1 μF) within 2 mm for good high-frequency performance. It also needs a bulk capacitor (i.e., 1 μF or larger) within 100 mm to provide large, slow currents. This bulk capacitor can be shared with other parts.

3.6 PCB Surface Leakage

In applications where low input bias current is critical, PCB (printed circuit board) surface leakage effects need to be considered. Surface leakage is caused by humidity, dust or other contamination on the board. Under low humidity conditions, a typical resistance between nearby traces is $10^{12}\Omega$. A 5V difference would cause 5 pA of current to flow. This is greater than the MCP601/2/3/4 family's bias current at +25°C (1 pA, typ.).

The easiest way to reduce surface leakage is to use a guard ring around sensitive pins (or traces). The guard ring is biased at the same voltage as the sensitive pin. An example of this type of layout is shown in Figure 3-4.

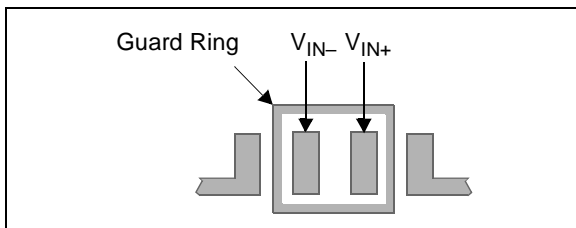


FIGURE 3-4: Example guard ring layout.

1. Connect the guard ring to the inverting input pin (V_{IN-}) for non-inverting gain amplifiers, including unity-gain buffers. This biases the guard ring to the common mode input voltage.
2. Connect the guard ring to the non-inverting input pin (V_{IN+}) for inverting gain amplifiers and transimpedance amplifiers (convert current to voltage, such as photo detectors). This biases the guard ring to the same reference voltage as the op amp (e.g., $V_{DD}/2$ or ground).

3.7 Typical Applications

3.7.1 ANALOG FILTERS

Figure 3-5 and Figure 3-6 show low-pass, second-order, Butterworth filters with a cutoff frequency of 10 Hz. The filter in Figure 3-5 has a non-inverting gain of +1 V/V, and the filter in Figure 3-6 has an inverting gain of -1 V/V.

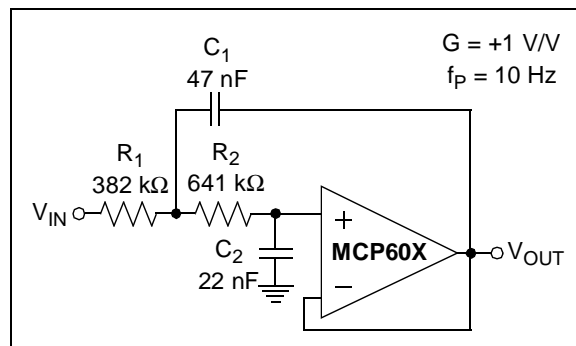


FIGURE 3-5: 2nd order, low-pass Sallen-Key filter.

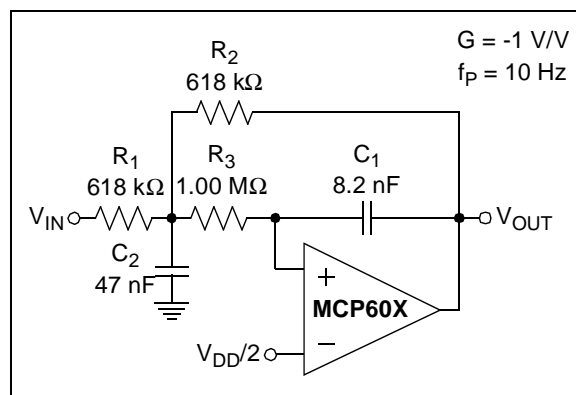


FIGURE 3-6: 2nd order, low-pass Multiple-Feedback filter.

The MCP601/2/3/4 family of operational amplifiers have low input bias current, which allows the designer to select larger resistor values and smaller capacitor values for these filters. This helps produce a compact PCB layout. These filters, and others, can be designed using Microchip's FilterLab[®] software.

3.7.2 INSTRUMENTATION AMPLIFIER CIRCUITS

Instrumentation amplifiers have a differential input, which subtracts one input voltage from another and rejects common mode signals. These amplifiers also provide a single-ended output voltage.

The three op amp instrumentation amplifier is illustrated in Figure 3-7. One advantage of this approach is unity-gain operation. A disadvantage is that the common mode input range is reduced as R_2/R_G gets larger.

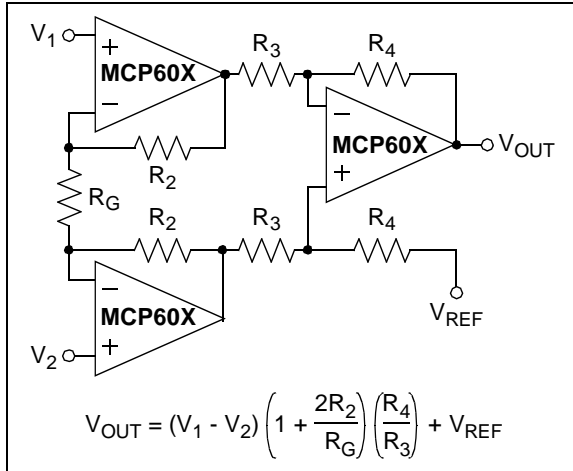


FIGURE 3-7: Three op amp instrumentation amplifier.

The two op amp instrumentation amplifier is shown in Figure 3-8. Its power consumption is lower than the three op amp version. Its main drawbacks are that the common mode range is reduced with higher gains and it must be configured in gains of two or higher.

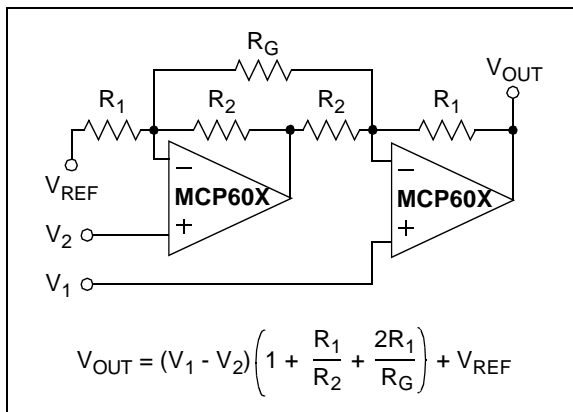


FIGURE 3-8: Two op amp instrumentation amplifier.

Both instrumentation amplifiers should use a bulk bypass capacitor of at least 1 μ F. The CMRR of these amplifiers will be set by the op amp CMRR and by resistor matching.

3.7.3 PHOTO DETECTION

The MCP601/2/3/4 op amps can be used to easily convert the signal from a sensor that produces an output current (such as a photo diode) into a voltage (a transimpedance amplifier). This is implemented with a single resistor (R_2) in the feedback loop of the amplifiers shown in Figure 3-9 and Figure 3-10. The optional capacitor (C_2) sometimes provides stability for these circuits.

A photodiode configured in the photovoltaic mode has zero voltage potential placed across it (Figure 3-9). In this mode, the light sensitivity and linearity is maximized, making it best suited for precision applications. The key amplifier specifications for this application are: low input bias current, low noise, common mode input voltage range (including ground) and rail-to-rail output.

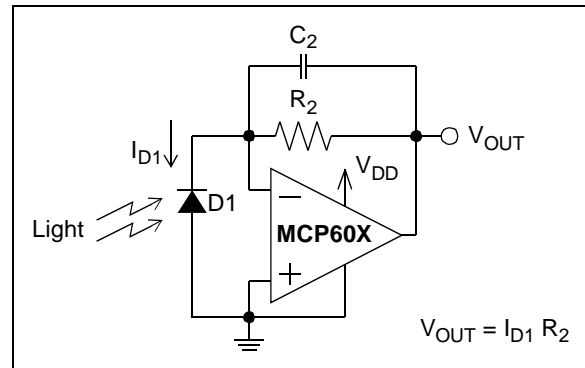


FIGURE 3-9: Photovoltaic mode detector.

In contrast, a photodiode that is configured in the photoconductive mode has a reverse bias voltage across the photo sensing element (Figure 3-10). This decreases the diode capacitance, which facilitates high-speed operation (e.g., high-speed digital communications). The design trade off is increased diode leakage current and linearity errors. The op amp needs to have a wide Gain Bandwidth Product.

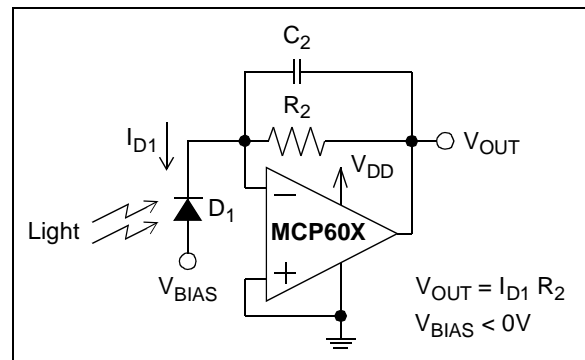


FIGURE 3-10: Photoconductive Mode Detector.

MCP601/2/3/4

4.0 DESIGN TOOLS

Microchip provides the basic design tools needed for the MCP601/2/3/4 family of op amps.

4.1 SPICE Macro Model

The latest SPICE macro model of the MCP601/2/3/4 operational amplifiers is available on our website (at 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. See the SPICE model file for information on its capabilities.

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

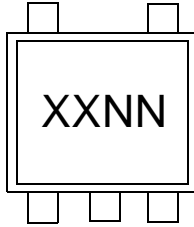
4.2 FilterLab[®] 2.0

FilterLab[®] 2.0 is an innovative software tool that simplifies analog active filter (using op amps) design. Available at no cost from our web site (at www.microchip.com), the FilterLab active filter software 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.

5.0 PACKAGING INFORMATION

5.1 Package Marking Information

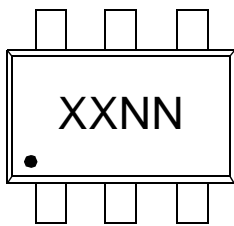
5-Lead SOT-23 (MCP601 and MCP601R Only)



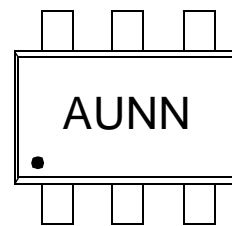
Example:



6-Lead SOT-23A (MCP603 Only)



Example:



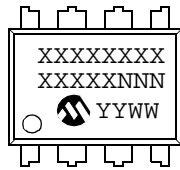
| | | |
|----------------|--|--|
| Legend: | XX...X | Customer specific information* |
| | YY | Year code (last 2 digits of calendar year) |
| | WW | Week code (week of January 1 is week '01') |
| | NNN | Alphanumeric traceability code |
| Note: | In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line thus limiting the number of available characters for customer specific information. | |

* Standard OTP marking consists of Microchip part number, year code, week code, and traceability code.

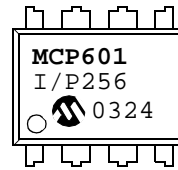
MCP601/2/3/4

Package Marking Information

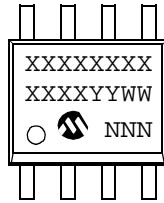
8-Lead PDIP (300 mil)



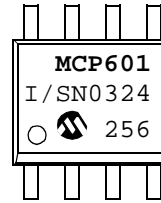
Example:



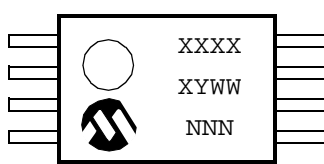
8-Lead SOIC (150 mil)



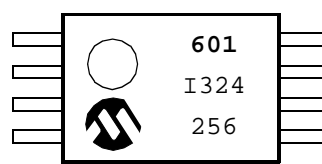
Example:



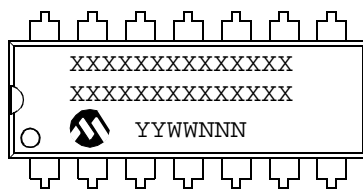
8-Lead TSSOP



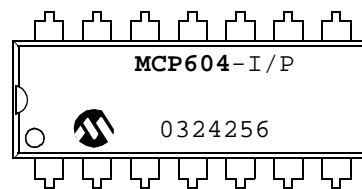
Example:



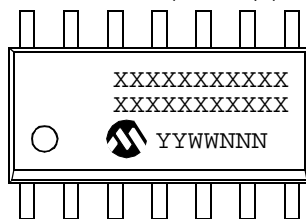
14-Lead PDIP (300 mil) (MCP604 Only)



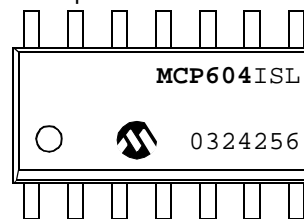
Example:



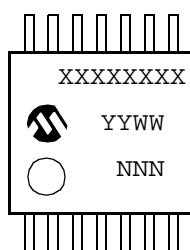
14-Lead SOIC (150 mil) (MCP604 Only)



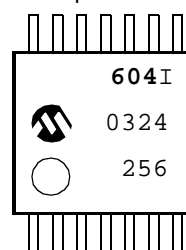
Example:



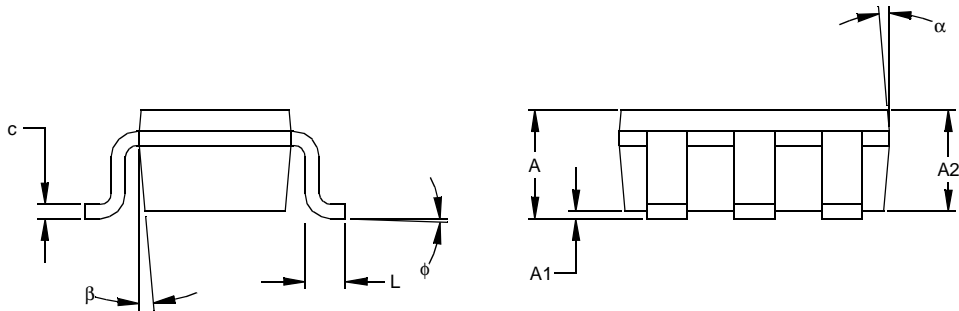
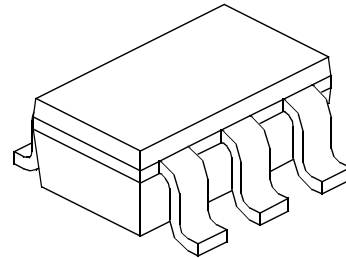
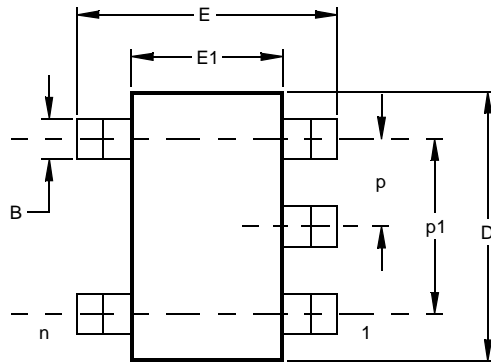
14-Lead TSSOP (4.4mm) (MCP604 Only)



Example:



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



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

* Controlling Parameter
 § Significant Characteristic

Notes:

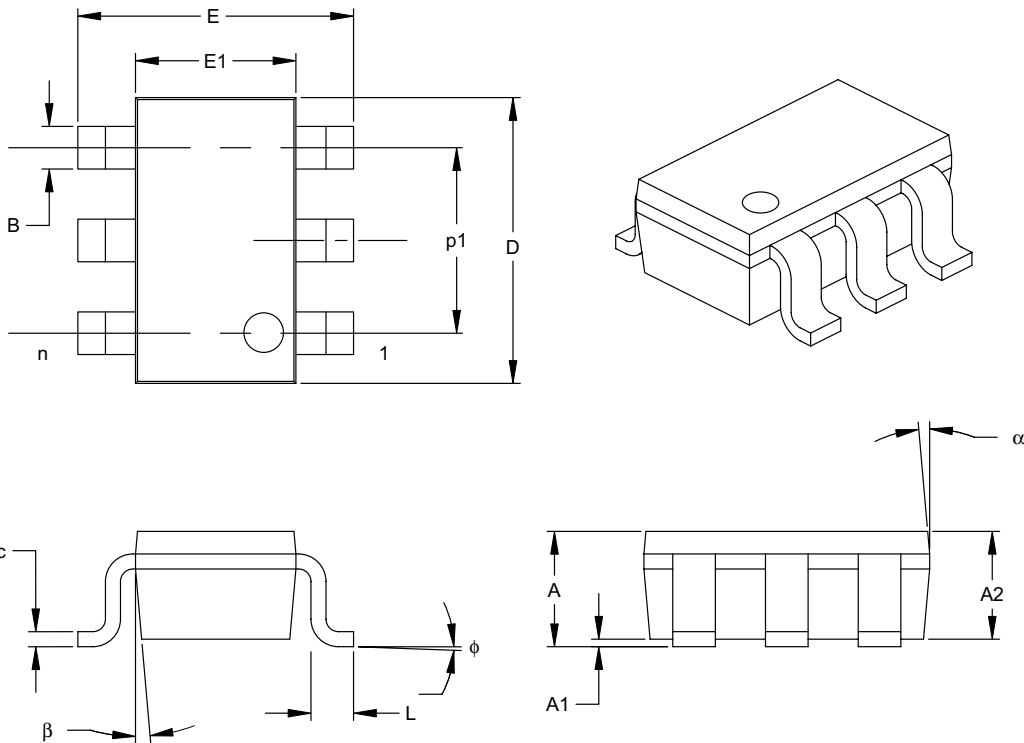
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.

JEDEC Equivalent: MO-178

Drawing No. C04-091

MCP601/2/3/4

6-Lead Plastic Small Outline Transistor (CH) (SOT-23)



| Dimension Limits | Units | INCHES* | | | MILLIMETERS | | |
|----------------------------|-------|---------|------|------|-------------|------|------|
| | | MIN | NOM | MAX | MIN | NOM | MAX |
| Number of Pins | n | | 6 | | | 6 | |
| Pitch | p | | .038 | | | 0.95 | |
| Outside lead pitch (basic) | p1 | | .075 | | | 1.90 | |
| Overall Height | A | .035 | .046 | .057 | 0.90 | 1.18 | 1.45 |
| Molded Package Thickness | A2 | .035 | .043 | .051 | 0.90 | 1.10 | 1.30 |
| Standoff | A1 | .000 | .003 | .006 | 0.00 | 0.08 | 0.15 |
| Overall Width | E | .102 | .110 | .118 | 2.60 | 2.80 | 3.00 |
| Molded Package Width | E1 | .059 | .064 | .069 | 1.50 | 1.63 | 1.75 |
| Overall Length | D | .110 | .116 | .122 | 2.80 | 2.95 | 3.10 |
| Foot Length | L | .014 | .018 | .022 | 0.35 | 0.45 | 0.55 |
| Foot Angle | φ | 0 | 5 | 10 | 0 | 5 | 10 |
| Lead Thickness | c | .004 | .006 | .008 | 0.09 | 0.15 | 0.20 |
| Lead Width | B | .014 | .017 | .020 | 0.35 | 0.43 | 0.50 |
| Mold Draft Angle Top | α | 0 | 5 | 10 | 0 | 5 | 10 |
| Mold Draft Angle Bottom | β | 0 | 5 | 10 | 0 | 5 | 10 |

*Controlling Parameter

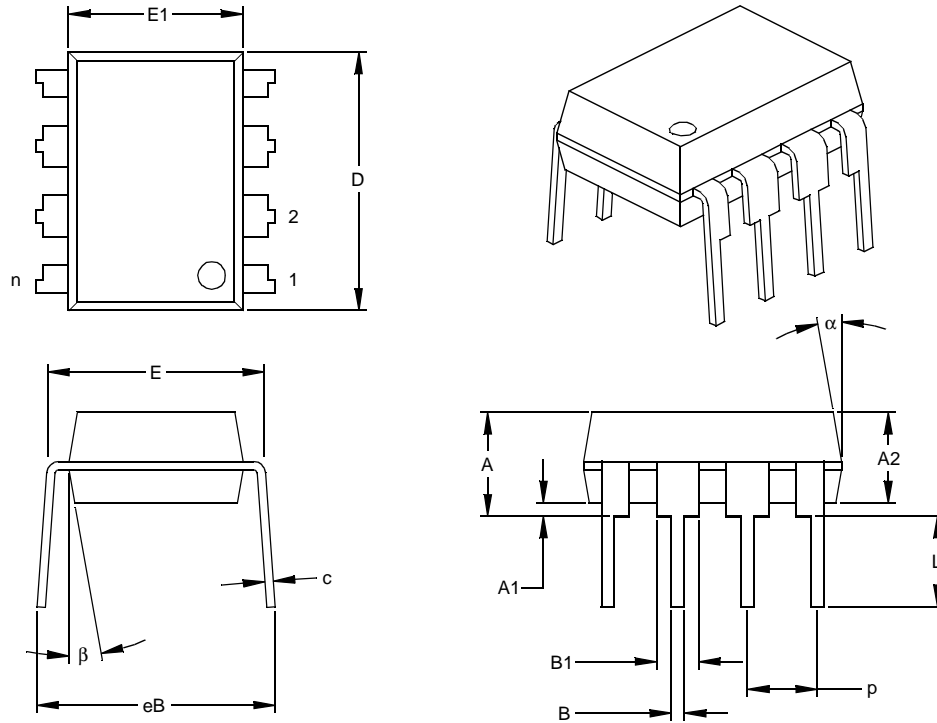
Notes:

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

JEITA (formerly EIAJ) equivalent: SC-74A

Drawing No. C04-120

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



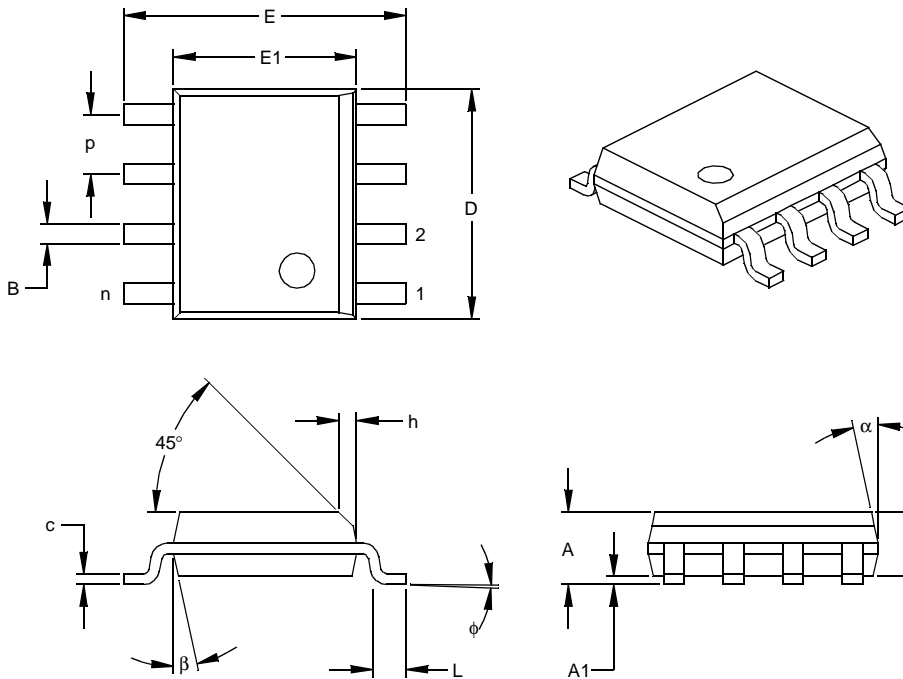
| Units | | INCHES* | | | MILLIMETERS | | |
|----------------------------|------|---------|------|------|-------------|------|-------|
| Dimension Limits | | MIN | NOM | MAX | MIN | NOM | MAX |
| Number of Pins | n | | 8 | | | 8 | |
| Pitch | p | | .100 | | | 2.54 | |
| Top to Seating Plane | A | .140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

* Controlling Parameter
 § Significant Characteristic

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

MCP601/2/3/4

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

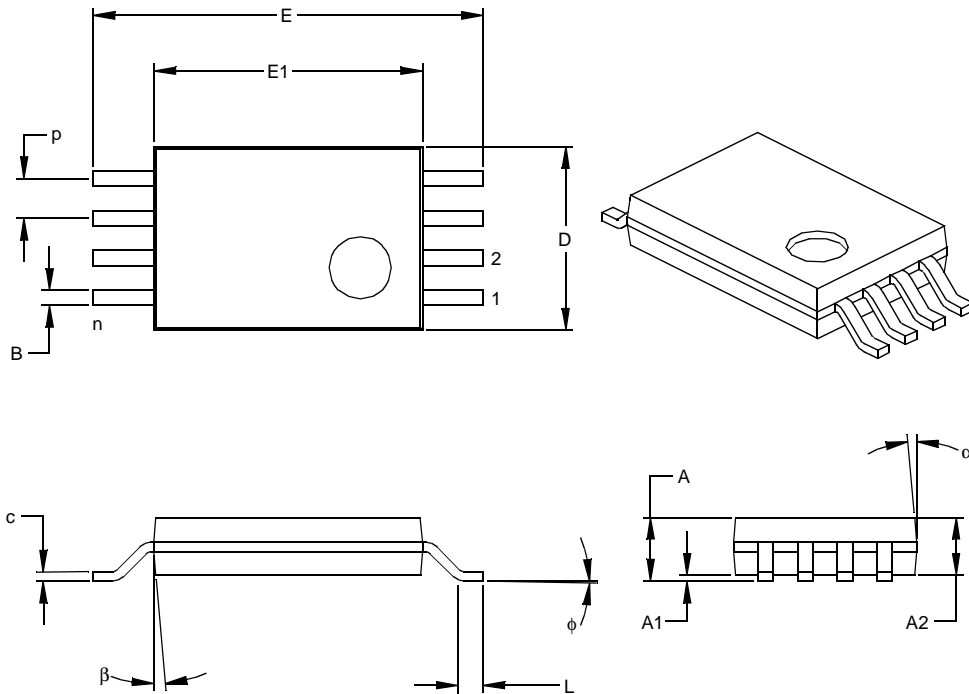


| Dimension Limits | Units | INCHES* | | | MILLIMETERS | | |
|--------------------------|-------|---------|------|------|-------------|------|------|
| | | MIN | NOM | MAX | MIN | NOM | MAX |
| Number of Pins | n | | 8 | | | 8 | |
| Pitch | p | | .050 | | | 1.27 | |
| Overall Height | A | .053 | .061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

* Controlling Parameter
 § Significant Characteristic

Notes:
 Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.
 JEDEC Equivalent: MS-012
 Drawing No. C04-057

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



| Units | | INCHES | | | MILLIMETERS* | | |
|--------------------------|----|--------|------|------|--------------|------|------|
| Dimension Limits | | MIN | NOM | MAX | MIN | NOM | MAX |
| Number of Pins | n | | 8 | | | 8 | |
| Pitch | p | | .026 | | | 0.65 | |
| Overall Height | A | | | .043 | | | 1.10 |
| Molded Package Thickness | A2 | .033 | .035 | .037 | 0.85 | 0.90 | 0.95 |
| Standoff § | A1 | .002 | .004 | .006 | 0.05 | 0.10 | 0.15 |
| Overall Width | E | .246 | .251 | .256 | 6.25 | 6.38 | 6.50 |
| Molded Package Width | E1 | .169 | .173 | .177 | 4.30 | 4.40 | 4.50 |
| Molded Package Length | D | .114 | .118 | .122 | 2.90 | 3.00 | 3.10 |
| Foot Length | L | .020 | .024 | .028 | 0.50 | 0.60 | 0.70 |
| Foot Angle | φ | 0 | 4 | 8 | 0 | 4 | 8 |
| Lead Thickness | c | .004 | .006 | .008 | 0.09 | 0.15 | 0.20 |
| Lead Width | B | .007 | .010 | .012 | 0.19 | 0.25 | 0.30 |
| Mold Draft Angle Top | α | 0 | 5 | 10 | 0 | 5 | 10 |
| Mold Draft Angle Bottom | β | 0 | 5 | 10 | 0 | 5 | 10 |

* Controlling Parameter

§ Significant Characteristic

Notes:

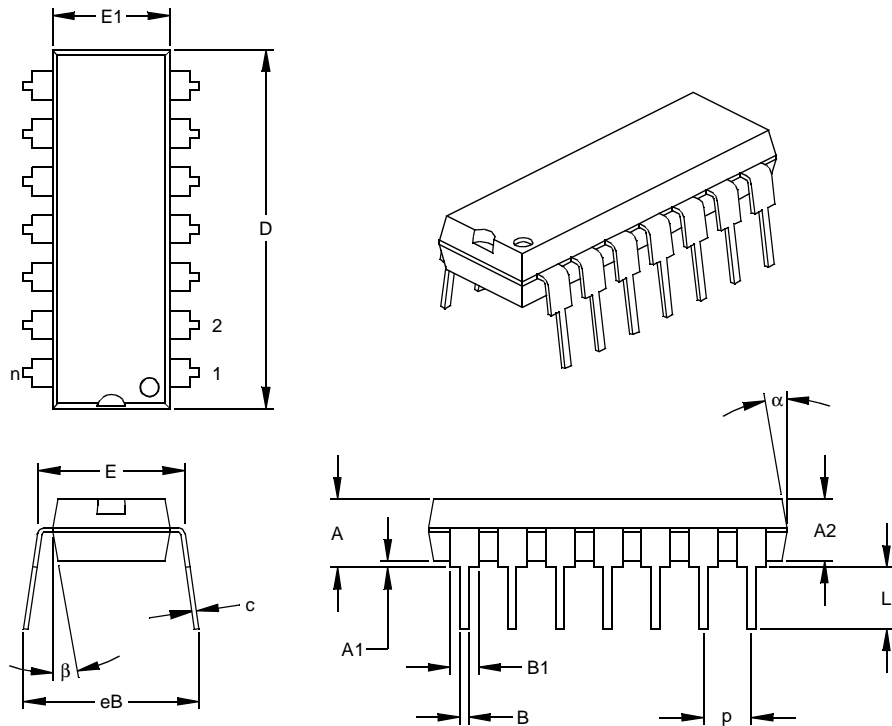
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .005" (0.127mm) per side.

JEDEC Equivalent: MO-153

Drawing No. C04-086

MCP601/2/3/4

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



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

* Controlling Parameter

§ Significant Characteristic

Notes:

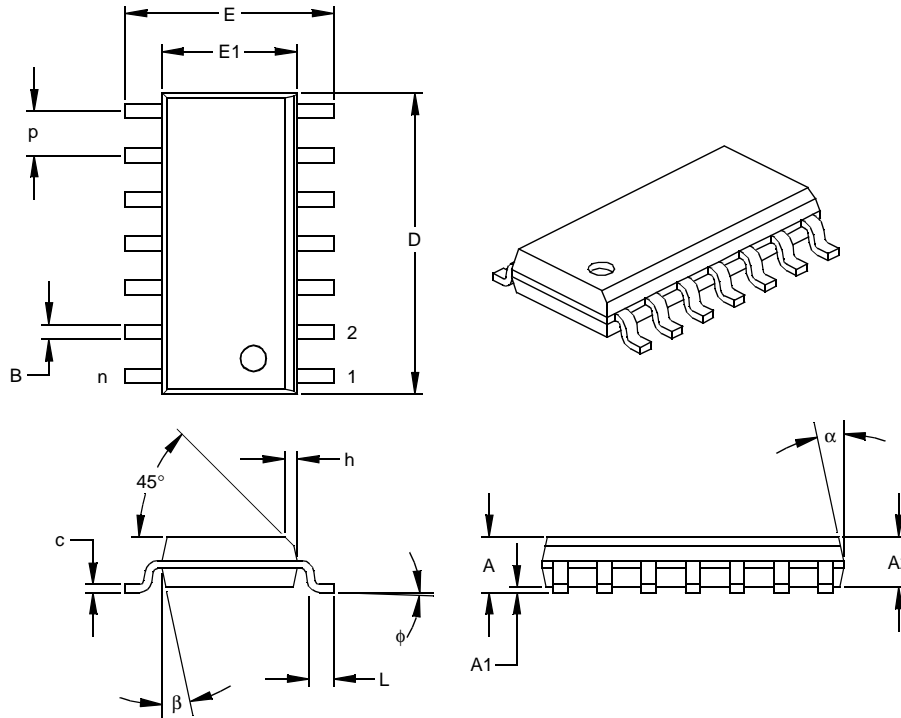
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed

.010" (0.254mm) per side.

JEDEC Equivalent: MS-001

Drawing No. C04-005

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



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

* Controlling Parameter
 § Significant Characteristic

Notes:

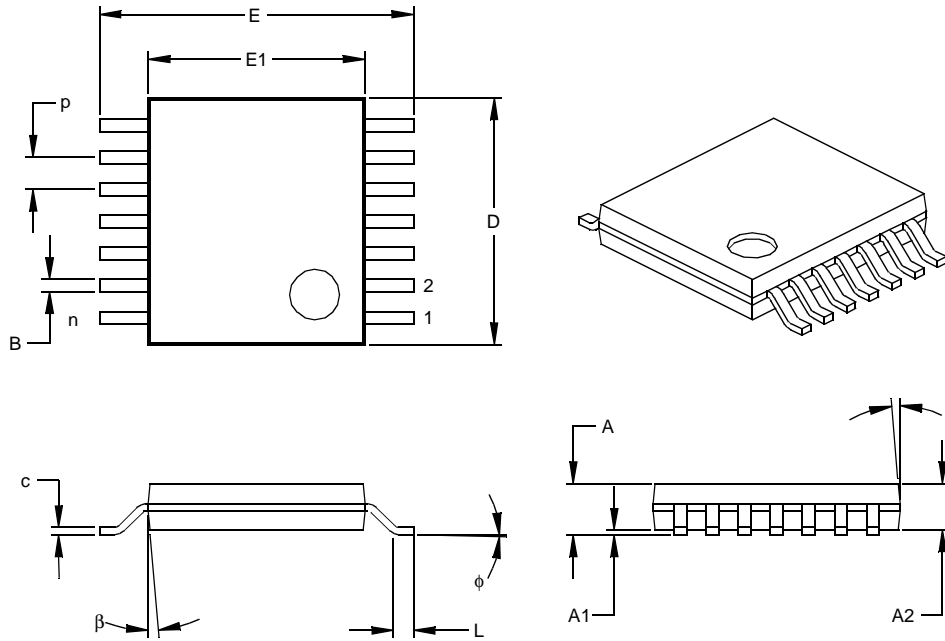
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.

JEDEC Equivalent: MS-012

Drawing No. C04-065

MCP601/2/3/4

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



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

* Controlling Parameter
 § Significant Characteristic

Notes:

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

JEDEC Equivalent: MO-153

Drawing No. C04-087

PRODUCT IDENTIFICATION SYSTEM

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

| PART NO. | X | /XX | |
|-------------------|-------------------|--|--|
| Device | Temperature Range | Package | |
| Device | MCP601 | Single Op Amp | |
| | MCP601T | Single Op Amp (Tape and Reel for SOT23, SOIC and TSSOP) | |
| | MCP601RT | Single Op Amp (Tape and Reel for SOT23-5) | |
| | MCP602 | Dual Op Amp | |
| | MCP602T | Dual Op Amp (Tape and Reel for SOIC and TSSOP) | |
| | MCP603 | Single Op Amp with Chip Select | |
| | MCP603T | Single Op Amp with Chip Select (Tape and Reel for SOT23, SOIC and TSSOP) | |
| | MCP604 | Quad Op Amp | |
| | MCP604T | Quad Op Amp (Tape and Reel for SOIC and TSSOP) | |
| Temperature Range | I | = -40°C to +85°C | |
| | E | = -40°C to +125°C | |
| Package | OT | = Plastic SOT23, 5-lead (MCP601 only) | |
| | CH | = Plastic SOT23, 6-lead (MCP603 only) | |
| | P | = Plastic DIP (300 mil Body), 8, 14-lead | |
| | SN | = Plastic SOIC (150 mil Body), 8-lead | |
| | SL | = Plastic SOIC (150 mil Body), 14-lead | |
| | ST | = Plastic TSSOP (4.4mm Body), 8, 14-lead | |
| Examples: | | | |
| a) | MCP601-I/P: | Single Op Amp, Industrial Temp., 8LD PDIP package. | |
| b) | MCP601-E/SN: | Single Op Amp, Extended Temp., 8LD SOIC package. | |
| c) | MCP601T-I/OT: | Tape and Reel, Industrial Temp., Single Op Amp, 5-LD SOT23 package. | |
| d) | MCP601T-E/ST: | Tape and Reel, Extended Temp., Single Op Amp, 8LD TSSOP package | |
| e) | MCP601RT-E/OT: | Tape and Reel, Extended Temp., Single Op Amp, Rotated, 5-LD SOT23 package. | |
| a) | MCP602-I/SN: | Dual Op Amp, Industrial Temp., 8LD SOIC package. | |
| b) | MCP602-E/P: | Dual Op Amp, Extended Temp., 8LD PDIP package. | |
| c) | MCP602T-E/ST: | Tape and Reel, Extended Temp., Dual Op Amp, 8LD TSSOP package. | |
| a) | MCP603-I/SN: | Industrial Temp., Single Op Amp with Chip Select, 8LD SOIC package. | |
| b) | MCP603-E/P: | Extended Temp., Single Op Amp with Chip Select, 8LD PDIP package. | |
| c) | MCP603T-E/ST: | Tape and Reel, Extended Temp., Single Op Amp with Chip Select, 8LD TSSOP package. | |
| d) | MCP603T-I/SN: | Tape and Reel, Industrial Temp., Single Op Amp with Chip Select, 8LD SOIC package. | |
| a) | MCP604-I/P: | Industrial Temp., Quad Op Amp, 14LD PDIP package. | |
| b) | MCP604-E/SL: | Extended Temp., Quad Op Amp, 14LD SOIC package. | |
| c) | MCP604T-I/ST: | Tape and Reel, Industrial Temp., Quad Op Amp, 14LD TSSOP package. | |

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MCP601/2/3/4

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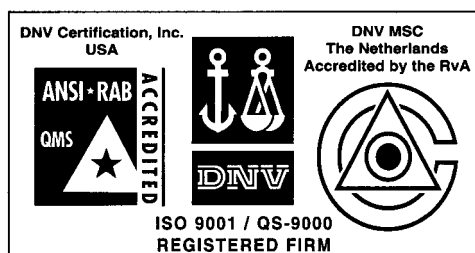
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