300 µA, Auto-Zeroed Op Amps

Features

- High DC Precision:
  - $V_{OS}$ Drift: ±50 nV/°C (maximum)
  - $V_{OS}$: ±2 µV (maximum)
  - $A_{OL}$: 130 dB (minimum)
  - PSRR: 130 dB (minimum)
  - CMRR: 130 dB (minimum)
  - $E_{n}$: 2.5 µVp-p (typical), $f = 0.1$ Hz to 10 Hz
  - $E_{n}$: 0.79 µVp-p (typical), $f = 0.01$ Hz to 1 Hz
- Low Power and Supply Voltages:
  - $I_{Q}$: 300 µA/amplifier (typical)
  - Wide Supply Voltage Range: 1.8V to 5.5V
- Easy to Use:
  - Rail-to-Rail Input/Output
  - Gain Bandwidth Product: 1.3 MHz (typical)
  - Unity Gain Stable
  - Available in Single and Dual
  - Single with Chip Select (CS): MCP6V03
- Extended Temperature Range: -40°C to +125°C

Typical Applications

- Portable Instrumentation
- Sensor Conditioning
- Temperature Measurement
- DC Offset Correction
- Medical Instrumentation

Design Aids

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

Related Parts

- MCP6V06/7/8: Non-spread clock, lower noise

Description

The Microchip Technology Inc. MCP6V01/2/3 family of operational amplifiers has input offset voltage correction for very low offset and offset drift. These devices have a wide gain bandwidth product (1.3 MHz, typical) and strongly reject switching noise. They are unity gain stable, have no 1/f noise, and have good PSRR and CMRR. These products operate with a single supply voltage as low as 1.8V, while drawing 300 µA/amplifier (typical) of quiescent current.

The Microchip Technology Inc. MCP6V01/2/3 op amps are offered in single (MCP6V01), single with Chip Select (CS) (MCP6V03), and dual (MCP6V02). They are designed in an advanced CMOS process.

Package Types (top view)

<table>
<thead>
<tr>
<th>MCP6V01</th>
<th>MCP6V01</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOIC</td>
<td>2x3 TDFN *</td>
</tr>
<tr>
<td>NC</td>
<td>NC</td>
</tr>
<tr>
<td>$V_{IN-}$</td>
<td>$V_{IN-}$</td>
</tr>
<tr>
<td>$V_{IN+}$</td>
<td>$V_{IN+}$</td>
</tr>
<tr>
<td>$V_{SS}$</td>
<td>$V_{SS}$</td>
</tr>
<tr>
<td>$V_{OUT}$</td>
<td>$V_{OUT}$</td>
</tr>
<tr>
<td>$V_{DD}$</td>
<td>$V_{DD}$</td>
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<table>
<thead>
<tr>
<th>MCP6V02</th>
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</tr>
</thead>
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<tr>
<td>SOIC</td>
<td>4x4 DFN *</td>
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<tr>
<td>VOUTA</td>
<td>VOUTB</td>
</tr>
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<td>VOUTA</td>
<td>VOUTB</td>
</tr>
<tr>
<td>$V_{IN-}$</td>
<td>$V_{IN-}$</td>
</tr>
<tr>
<td>$V_{IN+}$</td>
<td>$V_{IN+}$</td>
</tr>
<tr>
<td>$V_{SS}$</td>
<td>$V_{SS}$</td>
</tr>
<tr>
<td>$V_{DD}$</td>
<td>$V_{DD}$</td>
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<tr>
<td>$V_{OUT}$</td>
<td>$V_{OUT}$</td>
</tr>
<tr>
<td>$V_{DD}$</td>
<td>$V_{DD}$</td>
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</table>

<table>
<thead>
<tr>
<th>MCP6V03</th>
<th>MCP6V03</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>NC</td>
<td>NC</td>
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<tr>
<td>$V_{IN-}$</td>
<td>$V_{IN-}$</td>
</tr>
<tr>
<td>$V_{IN+}$</td>
<td>$V_{IN+}$</td>
</tr>
<tr>
<td>$V_{SS}$</td>
<td>$V_{SS}$</td>
</tr>
<tr>
<td>$V_{OUT}$</td>
<td>$V_{OUT}$</td>
</tr>
<tr>
<td>$V_{OUT}$</td>
<td>$V_{OUT}$</td>
</tr>
<tr>
<td>$V_{DD}$</td>
<td>$V_{DD}$</td>
</tr>
</tbody>
</table>

* Includes Exposed Thermal Pad (EP); see Table 3-1.
Typical Application Circuit

Offset Voltage Correction for Power Driver
1.0 ELECTRICAL CHARACTERISTICS

1.1 Absolute Maximum Ratings †

VDD – VSS ................................................................. 6.5V
Current at Input Pins .................................................. ±2 mA
Analog Inputs (VIN+ and VIN–) †† ... VSS – 1.0V to VDD+1.0V
All other Inputs and Outputs .......................... VSS – 0.3V to VDD+0.3V
Difference Input voltage ...................................... |V DD – V SS|
Output Short Circuit Current ................................Continuous
Current at Output and Supply Pins ............................ ±30 mA
Storage Temperature ...................................-65°C to +150°C
Max. Junction Temperature ........................................ +150°C
ESD protection on all pins (HBM, MM) .............. ≥ 4 kV, 300V

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

†† See Section 4.2.1 “Rail-to-Rail Inputs”.

1.2 Specifications

TABLE 1-1: DC ELECTRICAL SPECIFICATIONS

Electrical Characteristics: Unless otherwise indicated, TA = +25°C, VDD = +1.8V to +5.5V, VSS = GND, VCM = VDD/3, VOUT = VDD/2, VIL = VDD/2, RL = 20 kΩ to VIL, and CS = GND (refer to Figure 1-5 and Figure 1-6).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sym</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Offset Voltage</td>
<td>VOS</td>
<td>-2.0</td>
<td>—</td>
<td>+2.0</td>
<td>μV</td>
<td>(Note 1)</td>
</tr>
<tr>
<td>Input Offset Voltage Drift with Temperature (linear Temp. Co.)</td>
<td>TC1</td>
<td>-50</td>
<td>—</td>
<td>+50</td>
<td>nV/°C</td>
<td>(Note 1)</td>
</tr>
<tr>
<td>Input Offset Voltage Quadratic Temp. Co.</td>
<td>TC2</td>
<td>—</td>
<td>±0.1</td>
<td>—</td>
<td>nV/°C²</td>
<td>(Note 1)</td>
</tr>
<tr>
<td>Power Supply Rejection</td>
<td>PSRR</td>
<td>130</td>
<td>143</td>
<td>—</td>
<td>dB</td>
<td>(Note 1)</td>
</tr>
<tr>
<td>Input Bias Current and Impedance</td>
<td>IÎÎ</td>
<td>—</td>
<td>±1</td>
<td>—</td>
<td>pA</td>
<td></td>
</tr>
<tr>
<td>Input Bias Current</td>
<td>IB</td>
<td>—</td>
<td>60</td>
<td>—</td>
<td>pA</td>
<td>(Note 12)</td>
</tr>
<tr>
<td>Input Bias Current across Temperature</td>
<td>IB</td>
<td>—</td>
<td>600</td>
<td>5000</td>
<td>pA</td>
<td>TA = +125°C</td>
</tr>
<tr>
<td>Input Offset Current</td>
<td>IOS</td>
<td>—</td>
<td>-30</td>
<td>—</td>
<td>pA</td>
<td></td>
</tr>
<tr>
<td>Input Offset Current across Temperature</td>
<td>IOS</td>
<td>—</td>
<td>-50</td>
<td>—</td>
<td>pA</td>
<td>TA = +125°C</td>
</tr>
<tr>
<td>Common Mode Input Impedance</td>
<td>ZCM</td>
<td>—</td>
<td>10¹³</td>
<td>6</td>
<td>Ω/pF</td>
<td></td>
</tr>
<tr>
<td>Differential Input Impedance</td>
<td>ZDIFF</td>
<td>—</td>
<td>10¹³</td>
<td>6</td>
<td>Ω/pF</td>
<td></td>
</tr>
</tbody>
</table>

Common Mode

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sym</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common-Mode Input Voltage Range</td>
<td>VCMR</td>
<td>VSS – 0.20</td>
<td>—</td>
<td>VDD + 0.20</td>
<td>V</td>
<td>(Note 2)</td>
</tr>
<tr>
<td>Common-Mode Rejection</td>
<td>CMRR</td>
<td>130</td>
<td>142</td>
<td>—</td>
<td>dB</td>
<td>VDD = 1.8V, VCM = -0.2V to 2.0V</td>
</tr>
<tr>
<td></td>
<td>CMRR</td>
<td>140</td>
<td>152</td>
<td>—</td>
<td>dB</td>
<td>VDD = 5.5V, VCM = -0.2V to 5.7V</td>
</tr>
</tbody>
</table>

Open-Loop Gain

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sym</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC Open-Loop Gain (large signal)</td>
<td>AOL</td>
<td>130</td>
<td>145</td>
<td>—</td>
<td>dB</td>
<td>VDD = 1.8V, VOUT = 0.2V to 1.6V</td>
</tr>
<tr>
<td></td>
<td>AOL</td>
<td>140</td>
<td>156</td>
<td>—</td>
<td>dB</td>
<td>VDD = 5.5V, VOUT = 0.2V to 5.3V</td>
</tr>
</tbody>
</table>

Note 1: Set by design and characterization. Due to thermal junction and other effects in the production environment, these parts can only be screened in production (except TC2; see Appendix B: “Offset Related Test Screens”).

2: Figure 2-18 shows how VCMR changed across temperature for the first three production lots.
### TABLE 1-1: DC ELECTRICAL SPECIFICATIONS (CONTINUED)

**Electrical Characteristics:** Unless otherwise indicated, $T_A = +25^\circ C$, $V_{DD} = +1.8$V to $+5.5$V, $V_{SS} = GND$, $V_{CM} = V_{DD}/3$, $V_{OUT} = V_{DD}/2$, $V_{L} = V_{DD}/2$, $R_L = 20$ k$\Omega$ to $V_{L}$, and $CS = GND$ (refer to Figure 1-5 and Figure 1-6).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sym</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum Output Voltage Swing $V_{OL}$, $V_{OH}$</td>
<td>$V_{SS} + 15$</td>
<td>—</td>
<td>—</td>
<td>$V_{DD} - 15$</td>
<td>mV</td>
<td>$G = +2$, 0.5V input overdrive</td>
</tr>
<tr>
<td>Output Short Circuit Current $I_{SC}$</td>
<td>—</td>
<td>±7</td>
<td>—</td>
<td>—</td>
<td>mA</td>
<td>$V_{DD} = 1.8$V</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Power Supply</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply Voltage $V_{DD}$</td>
<td>1.8</td>
<td>—</td>
<td>5.5</td>
<td></td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Quiescent Current per amplifier $I_{Q}$</td>
<td>200</td>
<td>300</td>
<td>400</td>
<td></td>
<td>$\mu$A</td>
<td>$I_{O} = 0$</td>
</tr>
<tr>
<td>POR Trip Voltage $V_{POR}$</td>
<td>1.15</td>
<td>—</td>
<td>1.65</td>
<td></td>
<td>V</td>
<td></td>
</tr>
</tbody>
</table>

**Note 1:** Set by design and characterization. Due to thermal junction and other effects in the production environment, these parts can only be screened in production (except TC1; see Appendix B: “Offset Related Test Screens”).

**Note 2:** Figure 2-18 shows how $V_{CMR}$ changed across temperature for the first three production lots.

### TABLE 1-2: AC ELECTRICAL SPECIFICATIONS

**Electrical Characteristics:** Unless otherwise indicated, $T_A = +25^\circ C$, $V_{DD} = +1.8$V to $+5.5$V, $V_{SS} = GND$, $V_{CM} = V_{DD}/3$, $V_{OUT} = V_{DD}/2$, $V_{L} = V_{DD}/2$, $R_L = 20$ k$\Omega$ to $V_{L}$, $C_L = 60$ pF, and $CS = GND$ (refer to Figure 1-5 and Figure 1-6).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sym</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amplifier AC Response</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gain Bandwidth Product</td>
<td>GBWP</td>
<td>—</td>
<td>1.3</td>
<td>—</td>
<td>MHz</td>
<td></td>
</tr>
<tr>
<td>Slew Rate</td>
<td>SR</td>
<td>—</td>
<td>0.5</td>
<td>—</td>
<td>V/\mu s</td>
<td>$G = +1$</td>
</tr>
<tr>
<td>Phase Margin</td>
<td>PM</td>
<td>65</td>
<td>—</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amplifier Noise Response</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input Noise Voltage</td>
<td>E_{ni}</td>
<td>—</td>
<td>0.79</td>
<td>—</td>
<td>$\mu$V_{PP} $f = 0.01$ Hz to 1 Hz</td>
<td></td>
</tr>
<tr>
<td></td>
<td>E_{ni}</td>
<td>—</td>
<td>2.5</td>
<td>—</td>
<td>$\mu$V_{PP} $f = 0.1$ Hz to 10 Hz</td>
<td></td>
</tr>
<tr>
<td>Input Noise Voltage Density</td>
<td>e_{ni}</td>
<td>—</td>
<td>120</td>
<td>—</td>
<td>nV/\sqrt{Hz} $f &lt; 2.5$ kHz</td>
<td></td>
</tr>
<tr>
<td></td>
<td>e_{ni}</td>
<td>—</td>
<td>45</td>
<td>—</td>
<td>nV/\sqrt{Hz} $f = 100$ kHz</td>
<td></td>
</tr>
<tr>
<td>Input Noise Current Density</td>
<td>i_{ni}</td>
<td>—</td>
<td>0.6</td>
<td>—</td>
<td>fA/\sqrt{Hz}</td>
<td></td>
</tr>
<tr>
<td>Amplifier Distortion (Note 1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermodulation Distortion (AC)</td>
<td>IMD</td>
<td>—</td>
<td>&lt;1</td>
<td>—</td>
<td>$\mu$V_{PK} $V_{CM}$ tone = 50 mV_{PK} at 1 kHz, $G_N = 1, V_{DD} = 1.8$V</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IMD</td>
<td>—</td>
<td>&lt;1</td>
<td>—</td>
<td>$\mu$V_{PK} $V_{CM}$ tone = 50 mV_{PK} at 1 kHz, $G_N = 1, V_{DD} = 5.5$V</td>
<td></td>
</tr>
<tr>
<td>Amplifier Step Response</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start Up Time</td>
<td>t_{STR}</td>
<td>—</td>
<td>500</td>
<td>—</td>
<td>$\mu$s</td>
<td>$V_{OS}$ within 50 $\mu$V of its final value</td>
</tr>
<tr>
<td>Offset Correction Settling Time</td>
<td>t_{STL}</td>
<td>—</td>
<td>300</td>
<td>—</td>
<td>$\mu$s</td>
<td>$G = +1, V_{IN}$ step of 2V, $V_{OS}$ within 50 $\mu$V of its final value</td>
</tr>
<tr>
<td>Output Overdrive Recovery Time</td>
<td>t_{ODR}</td>
<td>—</td>
<td>100</td>
<td>—</td>
<td>$\mu$s</td>
<td>$G = -100, \pm 0.5$V input overdrive to $V_{DD}/2$, $V_{IN}$ 50% point to $V_{OUT}$ 90% point (Note 2)</td>
</tr>
</tbody>
</table>

**Note 1:** These parameters were characterized using the circuit in Figure 1-7. Figure 2-37 and Figure 2-38 show both an IMD tone at DC and a residual tone at 1 kHz; all other IMD and clock tones are spread by the randomization circuitry.

**Note 2:** $t_{ODR}$ includes some uncertainty due to clock edge timing.
### TABLE 1-3: DIGITAL ELECTRICAL SPECIFICATIONS

**Electrical Characteristics:** Unless otherwise indicated, $T_A = +25^\circ C$, $V_{DD} = +1.8V$ to $+5.5V$, $V_{SS} = GND$, $V_{CM} = V_{DD}/3$, $V_{OUT} = V_{DD}/2$, $V_L = V_{DD}/2$, $R_L = 20\ k\Omega$ to $V_L$, $C_L = 60\ pF$, and $CS = GND$ (refer to Figure 1-5 and Figure 1-6).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sym</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS Pull-Down Resistor (MCP6V03)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R_{PD}$</td>
<td></td>
<td>3</td>
<td>5</td>
<td></td>
<td>$M\Omega$</td>
<td></td>
</tr>
<tr>
<td>CS Low Specifications (MCP6V03)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CS Logic Threshold, Low</td>
<td>$V_{IL}$</td>
<td>$V_{SS}$</td>
<td></td>
<td>$0.3\ V_{DD}$</td>
<td>V</td>
<td>$CS = V_{SS}$</td>
</tr>
<tr>
<td>CS Input Current, Low</td>
<td>$I_{CSL}$</td>
<td></td>
<td>5</td>
<td></td>
<td>pA</td>
<td>$CS = V_{SS}$</td>
</tr>
<tr>
<td>CS High Specifications (MCP6V03)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CS Logic Threshold, High</td>
<td>$V_{IH}$</td>
<td>$0.7\ V_{DD}$</td>
<td></td>
<td>$V_{DD}$</td>
<td>V</td>
<td>$CS = V_{DD}$</td>
</tr>
<tr>
<td>CS Input Current, High</td>
<td>$I_{CSH}$</td>
<td></td>
<td>$V_{DD}/R_{PD}$</td>
<td></td>
<td>pA</td>
<td>$CS = V_{DD}$</td>
</tr>
<tr>
<td>CS Input High, GND Current per amplifier</td>
<td>$I_{SS}$</td>
<td></td>
<td>-0.7</td>
<td></td>
<td>$\mu$A</td>
<td>$CS = V_{DD}$, $V_{DD} = 1.8V$</td>
</tr>
<tr>
<td></td>
<td>$I_{SS}$</td>
<td></td>
<td>-2.3</td>
<td></td>
<td>$\mu$A</td>
<td>$CS = V_{DD}$, $V_{DD} = 5.5V$</td>
</tr>
<tr>
<td>Amplifier Output Leakage, CS High</td>
<td>$I_{O_LEAK}$</td>
<td></td>
<td>20</td>
<td></td>
<td>pA</td>
<td>$CS = V_{DD}$</td>
</tr>
<tr>
<td>CS Dynamic Specifications (MCP6V03)</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>CS Low to Amplifier Output On Turn-on Time</td>
<td>$I_{ON}$</td>
<td></td>
<td>11</td>
<td></td>
<td>100 $\mu$s</td>
<td>$CS = V_{SS}+0.3\ V$, $G = +1\ V/V$, $V_{OUT} = 0.9\ V_{DD}/2$</td>
</tr>
<tr>
<td>CS High to Amplifier Output High-Z</td>
<td>$I_{OFF}$</td>
<td></td>
<td>10</td>
<td></td>
<td></td>
<td>$CS = V_{DD} - 0.3\ V$, $G = +1\ V/V$, $V_{OUT} = 0.1\ V_{DD}/2$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sym</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal Hysteresis</td>
<td>$V_{HYST}$</td>
<td></td>
<td>0.25</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 1-4: TEMPERATURE SPECIFICATIONS

**Electrical Characteristics:** Unless otherwise indicated, all limits are specified for: $V_{DD} = +1.8V$ to $+5.5V$, $V_{SS} = GND$.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sym</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature Ranges</td>
<td></td>
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</tr>
<tr>
<td>Specified Temperature Range</td>
<td>$T_{A}$</td>
<td>-40</td>
<td></td>
<td>+125</td>
<td>$^\circ C$</td>
<td></td>
</tr>
<tr>
<td>Operating Temperature Range</td>
<td>$T_{A}$</td>
<td>-40</td>
<td></td>
<td>+125</td>
<td>$^\circ C$</td>
<td>(Note 1)</td>
</tr>
<tr>
<td>Storage Temperature Range</td>
<td>$T_{A}$</td>
<td>-65</td>
<td></td>
<td>+150</td>
<td>$^\circ C$</td>
<td></td>
</tr>
<tr>
<td>Thermal Package Resistances</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal Resistance, 8L-2x3 TDFN</td>
<td>$\theta_{JA}$</td>
<td></td>
<td>41</td>
<td></td>
<td>$^\circ C/W$</td>
<td></td>
</tr>
<tr>
<td>Thermal Resistance, 8L-4x4 DFN</td>
<td>$\theta_{JA}$</td>
<td></td>
<td>44</td>
<td></td>
<td>$^\circ C/W$</td>
<td>(Note 2)</td>
</tr>
<tr>
<td>Thermal Resistance, 8L-SOIC</td>
<td>$\theta_{JA}$</td>
<td></td>
<td>150</td>
<td></td>
<td>$^\circ C/W$</td>
<td></td>
</tr>
</tbody>
</table>

**Note:**
1. Operation must not cause $T_J$ to exceed Maximum Junction Temperature specification (150°C).
2. Measured on a standard JC51-7, four layer printed circuit board with ground plane and vias.
1.3 Timing Diagrams

**FIGURE 1-1:** Amplifier Start Up.

**FIGURE 1-2:** Offset Correction Settling Time.

**FIGURE 1-3:** Output Overdrive Recovery.

**FIGURE 1-4:** Chip Select (MCP6V03).

1.4 Test Circuits

The circuits used for the DC and AC tests are shown in Figure 1-5 and Figure 1-6. Lay the bypass capacitors out as discussed in Section 4.3.8 “Supply Bypassing and Filtering”. $R_N$ is equal to the parallel combination of $R_F$ and $R_G$ to minimize bias current effects.

**FIGURE 1-5:** AC and DC Test Circuit for Most Non-Inverting Gain Conditions.

**FIGURE 1-6:** AC and DC Test Circuit for Most Inverting Gain Conditions.

The circuit in Figure 1-7 tests the op amp input's dynamic behavior (i.e., IMD, $t_{STR}$, $t_{STL}$ and $t_{ODR}$). The potentiometer balances the resistor network ($V_{OUT}$ should equal $V_{REF}$ at DC). The op amp's common mode input voltage is $V_{CM} = \frac{V_{IN}}{2}$. The error at the input ($V_{ERR}$) appears at $V_{OUT}$ with a noise gain of 10 V/V.

**FIGURE 1-7:** Test Circuit for Dynamic Input Behavior.
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, $T_A = +25^\circ C$, $V_{DD} = +1.8$V to 5.5V, $V_{SS} = GND$, $V_{CM} = V_{DD}/3$, $V_{OUT} = V_{DD}/2$, $V_L = V_{DD}/2$, $R_L = 20$ k$\Omega$ to $V_L$, $C_L = 60$ pF, and $C_S = GND$.

2.1 DC Input Precision

![Input Offset Voltage](image1)

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

![Input Offset Voltage Drift](image2)

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

![Input Offset Voltage Quadratic Temp Co.](image3)

**FIGURE 2-3:** Input Offset Voltage Quadratic Temp Co.

![Input Offset Voltage vs. Power Supply Voltage with $V_{CM} = V_{CMR_L}$](image4)

**FIGURE 2-4:** Input Offset Voltage vs. Power Supply Voltage with $V_{CM} = V_{CMR_L}$.

![Input Offset Voltage vs. Power Supply Voltage with $V_{CM} = V_{CMR_H}$](image5)

**FIGURE 2-5:** Input Offset Voltage vs. Power Supply Voltage with $V_{CM} = V_{CMR_H}$.

![Input Offset Voltage vs. Output Voltage](image6)

**FIGURE 2-6:** Input Offset Voltage vs. Output Voltage.
Note: Unless otherwise indicated, $T_A = +25^\circ C$, $V_{DD} = +1.8V$ to $5.5V$, $V_{SS} = GND$, $V_{CM} = V_{DD}/3$, $V_{OUT} = V_{DD}/2$, $V_L = V_{DD}/2$, $R_L = 20 k\Omega$ to $V_L$, $C_L = 60 pF$, and $C_S = GND$.

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

**FIGURE 2-8:** Input Offset Voltage vs. Common Mode Voltage with $V_{DD} = 5.5V$.

**FIGURE 2-9:** CMRR.

**FIGURE 2-10:** PSRR.

**FIGURE 2-11:** DC Open-Loop Gain.

**FIGURE 2-12:** CMRR and PSRR vs. Ambient Temperature.
Note: Unless otherwise indicated, $T_A = +25^\circ C$, $V_{DD} = +1.8V$ to 5.5V, $V_{SS} = GND$, $V_{CM} = V_{DD}/3$, $V_{OUT} = V_{DD}/2$, $V_L = V_{DD}/2$, $R_L = 20 \, k\Omega$ to $V_L$, $C_L = 60 \, pF$, and $CS = GND$.

**FIGURE 2-13:** DC Open-Loop Gain vs. Ambient Temperature.

**FIGURE 2-14:** Input Bias and Offset Currents vs. Common Mode Input Voltage with $T_A = +85^\circ C$.

**FIGURE 2-15:** Input Bias and Offset Currents vs. Common Mode Input Voltage with $T_A = +125^\circ C$.

**FIGURE 2-16:** Input Bias and Offset Currents vs. Ambient Temperature with $V_{DD} = +5.5V$.

**FIGURE 2-17:** Input Bias Current vs. Input Voltage (below $V_{SS}$).
Note: Unless otherwise indicated, $T_A = +25^\circ C$, $V_{DD} = +1.8V$ to 5.5V, $V_{SS} = GND$, $V_{CM} = V_{DD}/3$, $V_{OUT} = V_{DD}/2$, $V_L = V_{DD}/2$, $R_L = 20\, k\Omega$ to $V_L$, $C_L = 60\, pF$, and $CS = GND$.

2.2 Other DC Voltages and Currents

FIGURE 2-18: Input Common Mode Voltage Headroom (Range) vs. Ambient Temperature.

FIGURE 2-19: Output Voltage Headroom vs. Output Current.

FIGURE 2-20: Output Voltage Headroom vs. Ambient Temperature.

FIGURE 2-21: Output Short Circuit Current vs. Power Supply Voltage.


FIGURE 2-23: Power On Reset Trip Voltage.
Note: Unless otherwise indicated, $T_A = +25\,^\circ C$, $V_{DD} = +1.8\,V$ to $5.5\,V$, $V_{SS} = GND$, $V_{CM} = V_{DD}/3$, $V_{OUT} = V_{DD}/2$, $V_L = V_{DD}/2$, $R_L = 20\,k\Omega$ to $V_L$, $C_L = 60\,pF$, and $CS = GND$. 

**FIGURE 2-24:** Power On Reset Voltage vs. Ambient Temperature.
Note: Unless otherwise indicated, $T_A = +25^\circ C$, $V_{DD} = +1.8V$ to $5.5V$, $V_{SS} = GND$, $V_{CM} = V_{DD}/3$, $V_{OUT} = V_{DD}/2$, $V_L = V_{DD}/2$, $R_L = 20 \, k\Omega$ to $V_L$, $C_L = 60 \, pF$, and $CS = GND$.

2.3 Frequency Response

**FIGURE 2-25:** CMRR and PSRR vs. Frequency.

**FIGURE 2-26:** Open-Loop Gain vs. Frequency with $V_{DD} = 1.8V$.

**FIGURE 2-27:** Open-Loop Gain vs. Frequency with $V_{DD} = 5.5V$.

**FIGURE 2-28:** Gain Bandwidth Product and Phase Margin vs. Ambient Temperature.

**FIGURE 2-29:** Gain Bandwidth Product and Phase Margin vs. Common Mode Input Voltage.

**FIGURE 2-30:** Gain Bandwidth Product and Phase Margin vs. Output Voltage.
**Note:** Unless otherwise indicated, $T_A = +25^\circ C$, $V_{DD} = +1.8V$ to $5.5V$, $V_{SS} = GND$, $V_{CM} = V_{DD}/3$, $V_{OUT} = V_{DD}/2$, $V_L = V_{DD}/2$, $R_L = 20 \text{k}\Omega$ to $V_L$, $C_L = 60 \text{pF}$, and $C_S = GND$.

**FIGURE 2-31:** Closed-Loop Output Impedance vs. Frequency with $V_{DD} = 1.8V$.

**FIGURE 2-32:** Closed-Loop Output Impedance vs. Frequency with $V_{DD} = 5.5V$.

**FIGURE 2-33:** Channel-to-Channel Separation vs. Frequency.

**FIGURE 2-34:** Maximum Output Voltage Swing vs. Frequency.
Note: Unless otherwise indicated, $T_A = +25^\circ\text{C}$, $V_{DD} = +1.8\text{V}$ to 5.5V, $V_{SS} = \text{GND}$, $V_{CM} = V_{DD}/3$, $V_{OUT} = V_{DD}/2$, $V_L = V_{DD}/2$, $R_L = 20\ \text{k}\Omega$ to $V_L$, $C_L = 60\ \text{pF}$, and $CS = \text{GND}$.

2.4 Input Noise and Distortion

**FIGURE 2-35:** Input Noise Voltage Density vs. Frequency.

**FIGURE 2-36:** Input Noise Voltage Density vs. Input Common Mode Voltage.

**FIGURE 2-37:** Inter-Modulation Distortion vs. Frequency with $V_{CM}$ Disturbance (see Figure 1-7).

**FIGURE 2-38:** Inter-Modulation Distortion vs. Frequency with $V_{DD}$ Disturbance (see Figure 1-7).

**FIGURE 2-39:** Input Noise vs. Time with 1 Hz and 10 Hz Filters and $V_{DD} = 1.8\text{V}$.

**FIGURE 2-40:** Input Noise vs. Time with 1 Hz and 10 Hz Filters and $V_{DD} = 5.5\text{V}$.
Note: Unless otherwise indicated, \( T_A = +25^\circ C \), \( V_{DD} = +1.8V \) to 5.5V, \( V_{SS} = GND \), \( V_{CM} = V_{DD}/3 \), \( V_{OUT} = V_{DD}/2 \), \( V_L = V_{DD}/2 \), \( R_L = 20 \, k\Omega \) to \( V_L \), \( C_L = 60 \, pF \), and \( C_S = GND \).

2.5 Time Response

**FIGURE 2-41:** Input Offset Voltage vs. Time with Temperature Change.

**FIGURE 2-42:** Input Offset Voltage vs. Time at Power Up.

**FIGURE 2-43:** The MCP6V01/2/3 family shows no input phase reversal with overdrive.

**FIGURE 2-44:** Non-inverting Small Signal Step Response.

**FIGURE 2-45:** Non-inverting Large Signal Step Response.

**FIGURE 2-46:** Inverting Small Signal Step Response.
Note: Unless otherwise indicated, \( T_A = +25^\circ C \), \( V_{DD} = +1.8V \) to 5.5V, \( V_{SS} = \text{GND} \), \( V_{CM} = V_{DD}/3 \), \( V_{OUT} = V_{DD}/2 \), \( V_L = V_{DD}/2 \), \( R_L = 20 \, k\Omega \) to \( V_L \), \( C_L = 60 \, pF \), and \( C_S = \text{GND} \).

**FIGURE 2-47:** Inverting Large Signal Step Response.

**FIGURE 2-48:** Slew Rate vs. Ambient Temperature.

**FIGURE 2-49:** Output Overdrive Recovery vs. Time with \( G = -100 \, V/V \).

**FIGURE 2-50:** Output Overdrive Recovery Time vs. Inverting Gain.
Note: Unless otherwise indicated, $T_A = +25^\circ C$, $V_{DD} = +1.8V$ to 5.5V, $V_{SS} = GND$, $V_{CM} = V_{DD}/3$, $V_{OUT} = V_{DD}/2$, $V_L = V_{DD}/2$, $R_L = 20 \, k\Omega$ to $V_L$, $C_L = 60 \, pF$, and $CS = GND$.

2.6 Chip Select Response (MCP6V03 only)

**FIGURE 2-51:** Chip Select Current vs. Power Supply Voltage.

**FIGURE 2-52:** Power Supply Current vs. Chip Select Voltage with $V_{DD} = 1.8V$.

**FIGURE 2-53:** Power Supply Current vs. Chip Select Voltage with $V_{DD} = 5.5V$.

**FIGURE 2-54:** Chip Select Current vs. Chip Select Voltage.

**FIGURE 2-55:** Chip Select Voltage, Output Voltage vs. Time with $V_{DD} = 1.8V$.

**FIGURE 2-56:** Chip Select Voltage, Output Voltage vs. Time with $V_{DD} = 5.5V$. 
MCP6V01/2/3

Note: Unless otherwise indicated, $T_A = +25^\circ C$, $V_{DD} = +1.8V$ to $5.5V$, $V_{SS} = GND$, $V_{CM} = V_{DD}/3$, $V_{OUT} = V_{DD}/2$, $V_L = V_{DD}/2$, $R_L = 20 \, k\Omega$ to $V_L$, $C_L = 60 \, pF$, and $CS = GND$.

**FIGURE 2-57:** Chip Select Relative Logic Thresholds vs. Ambient Temperature.

**FIGURE 2-58:** Chip Select Hysteresis.

**FIGURE 2-59:** Chip Select Turn On Time vs. Ambient Temperature.

**FIGURE 2-60:** Chip Select’s Pull-down Resistor ($R_{PD}$) vs. Ambient Temperature.

**FIGURE 2-61:** Quiescent Current in Shutdown vs. Power Supply Voltage.
3.0  PIN DESCRIPTIONS

Descriptions of the pins are listed in Table 3-1.

TABLE 3-1:  PIN FUNCTION TABLE

<table>
<thead>
<tr>
<th>MCP6V01</th>
<th>MCP6V02</th>
<th>MCP6V03</th>
<th>Symbol Description</th>
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<tr>
<td>DFN</td>
<td>DFN</td>
<td>DFN</td>
<td>V_{OUT}, V_{OUTA}</td>
</tr>
<tr>
<td>TDFN</td>
<td>SOIC</td>
<td>TDFN</td>
<td>Output (op amp A)</td>
</tr>
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<td>6</td>
<td>6</td>
<td>V_{IN}, V_{INA}</td>
</tr>
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<td>2</td>
<td>2</td>
<td>2</td>
<td>Inverting Input (op amp A)</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>3</td>
<td>Non-inverting Input (op amp A)</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>4</td>
<td>V_{SS} Negative Power Supply</td>
</tr>
<tr>
<td>—</td>
<td>5</td>
<td>5</td>
<td>V_{INB} Non-inverting Input (op amp B)</td>
</tr>
<tr>
<td>—</td>
<td>6</td>
<td>6</td>
<td>V_{INB} Inverting Input (op amp B)</td>
</tr>
<tr>
<td>—</td>
<td>7</td>
<td>7</td>
<td>V_{OUTB} Output (op amp B)</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
<td>7</td>
<td>V_{DD} Positive Power Supply</td>
</tr>
<tr>
<td>—</td>
<td>—</td>
<td>8</td>
<td>CS Chip Select (op amp A)</td>
</tr>
<tr>
<td>1, 5, 8</td>
<td>1, 5, 8</td>
<td>1, 5</td>
<td>EP Exposed Thermal Pad (EP); must be connected to V_{SS}</td>
</tr>
</tbody>
</table>

3.1  Analog Outputs

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

3.2  Analog Inputs

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

3.3  Power Supply Pins

The positive power supply (\(V_{DD}\)) is 1.8V to 5.5V higher than the negative power supply (\(V_{SS}\)). For normal operation, the other pins are between \(V_{SS}\) and \(V_{DD}\).

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

3.4  Chip Select (CS) Digital Input

This pin (\(\overline{CS}\)) is a CMOS, Schmitt-triggered input that places the MCP6V03 op amps into a low power mode of operation.

3.5  Exposed Thermal Pad (EP)

There is an internal connection between the Exposed Thermal Pad (EP) and the \(V_{SS}\) pin; they must be connected to the same potential on the Printed Circuit Board (PCB).

This pad can be connected to a PCB ground plane to provide a larger heat sink. This improves the package thermal resistance (\(\theta_{JA}\)).
4.0 APPLICATIONS

The MCP6V01/2/3 family of auto-zeroed op amps is manufactured using Microchip’s state of the art CMOS process. It is designed for low cost, low power and high precision applications. Its low supply voltage, low quiescent current and wide bandwidth makes the MCP6V01/2/3 ideal for battery-powered applications.

4.1 Overview of Auto-zeroing Operation

Figure 4-1 shows a simplified diagram of the MCP6V01/2/3 auto-zeroed op amps. This will be used to explain how the DC voltage errors are reduced in this architecture.

**FIGURE 4-1: Simplified Auto-zeroed Op Amp Functional Diagram.**

### 4.1.1 BUILDING BLOCKS

The Null Amp. and Main Amp. are designed for high gain and accuracy using a differential topology. They have an auxiliary input (bottom left) used for correcting the offset voltages. Both inputs are added together internally. The capacitors at the auxiliary inputs ($C_{FW}$ and $C_H$) hold the corrected values during normal operation.

The Output Buffer is designed to drive external loads at the $V_{OUT}$ pin. It also produces a single ended output voltage ($V_{REF}$ is an internal reference voltage).

All of these switches are make-before-break in order to minimize glitch-induced errors. They are driven by two clock phases ($\phi_1$ and $\phi_2$) that select between normal mode and auto-zeroing mode.

The clock is derived from an internal R-C oscillator running at a rate of $f_{OSC1} = 300$ kHz. The oscillator’s output is divided down to the desired rate. It is also randomized to minimize (spread) undesired clock tones in the output.

The internal POR ensures the part starts up in a known good state. It also provides protection against power supply brown out events.

The Chip Select input places the op amp in a low power state when it is high. When it goes low, it powers the op amp at its normal level and starts operation properly.

The Digital Control circuitry takes care of all of the housekeeping details of the switching operation. It also takes care of Chip Select and POR events.
4.1.2 AUTO-ZEROING ACTION

Figure 4-2 shows the connections between amplifiers during the Normal Mode of operation ($\phi_1$). The hold capacitor ($C_H$) corrects the Null Amplifier’s input offset. Since the Null Amplifier has very high gain, it dominates the signal seen by the Main Amplifier. This greatly reduces the impact of the Main Amplifier’s input offset voltage on overall performance. Essentially, the Null Amplifier and Main Amplifier behave as a regular op amp with very high gain ($A_{OL}$) and very low offset voltage ($V_{OS}$).

![Figure 4-2: Normal Mode of Operation ($\phi_1$); Equivalent Amplifier Diagram.](image)

Since these corrections happen every 100 $\mu$s, or so, we also minimize slow errors, including offset drift with temperature ($\Delta V_{OS}/\Delta T_A$), $1/f$ noise, and input offset aging.

![FIGURE 4-3: Auto-zeroing Mode of Operation ($\phi_2$); Equivalent Diagram.](image)

4.1.3 INTERMODULATION DISTORTION (IMD)

The MCP6V01/2/3 op amps will show intermodulation distortion (IMD), products when an AC signal is present.

The signal and clock can be decomposed into sine wave tones (Fourier series components). These tones interact with the auto-zeroing circuitry’s non-linear response to produce IMD tones at sum and difference frequencies. IMD distortion tones are generated about all of the square wave clock’s harmonics.

Clock randomization spreads the IMD tones across the frequency spectrum, but cannot eliminate them. The spread energy is low and is not correlated with the signal of interest, so it is not of concern for most precision applications. See Figure 2-37 and Figure 2-38.

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DS22058C-page 22 © 2008 Microchip Technology Inc.
4.2 Other Functional Blocks

4.2.1 RAIL-TO-RAIL INPUTS
The input stage of the MCP6V01/2/3 op amps uses two differential CMOS input stages in parallel. One operates at low common mode input voltage ($V_{CM}$, which is approximately equal to $V_{IN^+}$ and $V_{IN^-}$ in normal operation) and the other at high $V_{CM}$. With this topology, the input operates with $V_{CM}$ up to 0.2V past either supply rail at +25°C (see Figure 2-18). The input offset voltage ($V_{OS}$) is measured at $V_{CM} = V_{SS} - 0.2V$ and $V_{DD} + 0.2V$ to ensure proper operation.

The transition between the input stages occurs when $V_{CM} \approx V_{DD} - 0.9V$ (see Figure 2-7 and Figure 2-8). For the best distortion and gain linearity, with non-inverting gains, avoid this region of operation.

4.2.1.1 Phase Reversal
The input devices are designed to not exhibit phase inversion when the input pins exceed the supply voltages. Figure 2-43 shows an input voltage exceeding both supplies with no phase inversion.

4.2.1.2 Input Voltage and Current Limits
The ESD protection on the inputs can be depicted as shown in Figure 4-4. 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.

![Simplified Analog Input ESD Structures](image)

In order to prevent damage and/or improper operation of these amplifiers, the circuit must limit the currents (and voltages) at the input pins (see Section 1.1 “Absolute Maximum Ratings†”). Figure 4-5 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 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 $D_2$.

![Protecting the Analog Inputs](image)

It is also possible to connect the diodes to the left of the resistor $R_1$ and $R_2$. In this case, the currents through the diodes $D_1$ and $D_2$ need 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 (through the ESD diodes) when the common mode voltage ($V_{CM}$) is below ground ($V_{SS}$); see Figure 2-17. Applications that are high impedance may need to limit the usable voltage range.

4.2.2 RAIL-TO-RAIL OUTPUT
The output voltage range of the MCP6V01/2/3 auto-zeroed op amps is $V_{DD} - 15 mV$ (minimum) and $V_{SS} + 15 mV$ (maximum) when $R_L = 20k\Omega$ is connected to $V_{DD}/2$ and $V_{DD} = 5.5V$. Refer to Figure 2-19 and Figure 2-20 for more information.

These op amps are designed to drive light loads; use another amplifier to buffer the output from heavy loads.

4.2.3 CHIP SELECT (CS)
The single MCP6V03 has a Chip Select (CS) pin. When CS is pulled high, the supply current for the corresponding op amp drops to about 1 µA (typical), and is pulled through the CS pin to $V_{SS}$. When this happens, the amplifier is put into a high impedance state. By pulling CS low, the amplifier is enabled. If the CS pin is left floating, the internal pull-down resistor (about 5 MΩ) will keep the part on. Figure 1-4 shows the output voltage and supply current response to a CS pulse.
4.3 Application Tips

4.3.1 INPUT OFFSET VOLTAGE OVER TEMPERATURE

Table 1-1 gives both the linear and quadratic temperature coefficients (TC₁ and TC₂) of input offset voltage. The input offset voltage, at any temperature in the specified range, can be calculated as follows:

**EQUATION 4-1:**

\[ V_{OS}(T_A) = V_{OS} + TC_1 \Delta T + TC_2 \Delta T^2 \]

Where:
- \( \Delta T \) = \( T_A - 25°C \)
- \( V_{OS}(T_A) \) = input offset voltage at \( T_A \)
- \( V_{OS} \) = input offset voltage at +25°C
- \( TC_1 \) = linear temperature coefficient
- \( TC_2 \) = quadratic temperature coefficient

4.3.2 DC GAIN PLOTS

Figure 2-9, Figure 2-10 and Figure 2-11 are histograms of the reciprocals (in units of µV/V) of CMRR, PSRR and A_OLD respectively. They represent the change in input offset voltage (V_OS) with a change in common mode input voltage (V_CM), power supply voltage (V_DD) and output voltage (V_OUT).

The 1/A_OLD histogram is centered near 0 µV/V because the measurements are dominated by the op amp’s input noise. The negative values shown represent noise, not unstable behavior. We validate the op amps’ stability by making multiple measurements of V_OS: instability would manifest itself as a greater unexplained variability in V_OS or as the railing of the output.

4.3.3 SOURCE RESISTANCES

The input bias currents have two significant components; switching glitches that dominate at room temperature and below, and input ESD diode leakage currents that dominate at +85°C and above.

Make the resistances seen by the inputs small and equal. This minimizes the output offset caused by the input bias currents.

The inputs should see a resistance on the order of 10Ω to 1 kΩ at high frequencies (i.e., above 1 MHz). This helps minimize the impact of switching glitches, which are very fast, on overall performance. In some cases, it may be necessary to add resistors in series with the inputs to achieve this improvement in performance.

4.3.4 SOURCE CAPACITANCE

The capacitances seen by the two inputs should be small and matched. The internal switches connected to the inputs dump charges on these capacitors; an offset can be created if the capacitances do not match.

4.3.5 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. These auto-zeroed op amps have a different output impedance than most op amps, due to their unique topology.

When driving a capacitive load with these op amps, a series resistor at the output (R_ISO in Figure 4-6) improves the feedback loop’s phase margin (stability) by making the output load resistive at higher frequencies. The bandwidth will be generally lower than the bandwidth with no capacitive load.

**FIGURE 4-6:** Output Resistor, R_ISO, Stabilizes Capacitive Loads.

Figure 4-7 gives recommended R_ISO values for different capacitive loads and is independent of the gain.

**FIGURE 4-7:** Recommended R_ISO values for Capacitive Loads.
After selecting $R_{ISO}$ for your circuit, double check the resulting frequency response peaking and step response overshoot. Modify $R_{ISO}$'s value until the response is reasonable. Bench evaluation and simulations with the MCP6V01 SPICE macro model (good for all of the MCP6V01/2/3 op amps) are helpful.

4.3.6 STABILIZING OUTPUT LOADS

This family of auto-zeroed op amps has an output impedance (Figure 2-31 and Figure 2-32) that has a double zero when the gain is low. This can cause a large phase shift in feedback networks that have low resistance near the part’s bandwidth. This large phase shift can cause stability problems.

Figure 4-8 shows one circuit example that has low resistance near the part’s bandwidth. $R_F$ and $C_F$ set a pole at 0.16 kHz, so the noise gain ($G_N$) is 1 V/V at the circuit’s bandwidth (roughly 1.3 MHz). The load seen by the op amp’s output at 1.3 MHz is $R_O || R_L$ (99 $\Omega$). This is low enough to be a real concern.

**FIGURE 4-8:** Output Load Issue.

To solve this problem, increase the resistive load to at least 3 k$\Omega$. Methods to accomplish this task include:
- Increase $R_O$
- Remove $C_F$ (relocate the filter)
- Add a 3 k$\Omega$ resistor at the op amp’s output that is not in the signal path; see Figure 4-9

4.3.7 REDUCING UNDESIRED NOISE AND SIGNALS

Reduce undesired noise and signals with:
- Low bandwidth signal filters:
  - Minimizes random analog noise
  - Reduces interfering signals
- Good PCB layout techniques:
  - Minimizes crosstalk
  - Minimizes parasitic capacitances and inductances that interact with fast switching edges
- Good power supply design:
  - Isolation from other parts
  - Filtering of interference on supply line(s)

4.3.8 SUPPLY BYPASSING AND FILTERING

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 $\mu$F to 0.1 $\mu$F) within 2 mm of the pin for good high-frequency performance.

These parts also need a bulk capacitor (i.e., 1 $\mu$F or larger) within 100 mm to provide large, slow currents. This bulk capacitor can be shared with other low noise, analog parts.

Additional filtering of high frequency power supply noise (e.g., switched mode power supplies) can be achieved using resistors. The resistors need to be small enough to prevent a large drop in $V_{DD}$ for the op amp, which would cause a reduced output range and possible load-induced power supply noise. The resistors also need to be large enough to dissipate little power when $V_{DD}$ is turned on and off quickly. The circuit in Figure 4-10 gives good rejection out to 1 MHz for switched mode power supplies. Smaller resistors and capacitors are a better choice for designs where the power supply is reasonably quiet.

**FIGURE 4-10:** Additional Supply Filtering.
4.3.9 PCB DESIGN FOR DC PRECISION

In order to achieve DC precision on the order of ±1 µV, many physical errors need to be minimized. The design of the Printed Circuit Board (PCB), the wiring, and the thermal environment has a strong impact on the precision achieved. A poor PCB design can easily be more than 100 times worse than the MCP6V01/2/3 op amps minimum and maximum specifications.

4.3.9.1 Thermo-junctions

Any time two dissimilar metals are joined together, a temperature dependent voltage appears across the junction (the Seebeck or thermo-junction effect). This effect is used in thermocouples to measure temperature. The following are examples of thermo-junctions on a PCB:

- Components (resistors, op amps, …) soldered to a copper pad
- Wires mechanically attached to the PCB
- Jumpers
- Solder joints
- PCB vias

Typical thermo-junctions have temperature to voltage conversion coefficients of 10 to 100 µV/°C (sometimes higher).

There are three basic approaches to minimizing thermo-junction effects:

- Minimize thermal gradients
- Cancel thermo-junction voltages
- Minimize difference in thermal potential between metals

4.3.9.2 Non-inverting and Inverting Amplifier Layout for Thermo-junctions

Figure 4-11 shows the recommended non-inverting and inverting gain amplifier circuits on one schematic. Usually, to minimize the input bias current related offset, $R_1$ is chosen to be $R_2||R_3$.

The guard traces (with ground vias at the ends) help minimize the thermal gradients. The resistor layout cancels the resistor thermal voltages, assuming the temperature gradient is constant near the resistors:

**EQUATION 4-2:**

$$V_{OUT} \approx V_{PG}, \quad V_M = GND \quad \approx -V_{MG}, \quad V_P = GND$$

Where:

- $G_M = \frac{R_3}{R_2}$, inverting gain magnitude
- $G_P = 1 + G_M$, non-inverting gain magnitude
- $V_{OS}$ is neglected

**FIGURE 4-11:** PCB Layout and Schematic for Single Non-inverting and Inverting Amplifiers.

Note: Changing the orientation of the resistors will usually cause a significant decrease in the cancellation of the thermal voltages.
4.3.9.3 Difference Amplifier Layout for Thermo-junctions

Figure 4-12 shows the recommended difference amplifier circuit. Usually, we choose \( R_1 = R_2 \) and \( R_3 = R_4 \). The guard traces (with ground vias at the ends) help minimize the thermal gradients. The resistor layout cancels the resistor thermal voltages, assuming the temperature gradient is constant near the resistors:

**EQUATION 4-3:**

\[
V_{\text{OUT}} = V_{\text{REF}} + (V_P - V_M)G_{DM}
\]

Where:
- Thermal voltages are approximately equal
- \( G_{DM} = \frac{R_3}{R_1} = \frac{R_4}{R_2} \), difference gain
- \( V_{OS} \) is neglected

**FIGURE 4-12:** PCB Layout and Schematic for Single Difference Amplifier.

Note: Changing the orientation of the resistors will usually cause a significant decrease in the cancellation of the thermal voltages.

4.3.9.4 Dual Non-inverting Amplifier Layout for Thermo-junctions

The dual op amp amplifiers shown in Figure 4-16 and Figure 4-17 produce a non-inverting difference gain greater than 1, and a common mode gain of 1. They can use the layout shown in Figure 4-13. The gain setting resistors \( (R_2) \) between the two sides are not combined so that the thermal voltages can be canceled.

The guard traces (with ground vias at the ends) help minimize the thermal gradients. The resistor layout cancels the resistor thermal voltages, assuming the temperature gradient is constant near the resistors:

**EQUATION 4-4:**

\[
\begin{align*}
(V_{OA} - V_{OB}) &\approx (V_{IA} - V_{IB})G_{DM} \\
(V_{OA} + V_{OB})/2 &\approx (V_{IA} + V_{IB})/2
\end{align*}
\]

Where:
- Thermal voltages are approximately equal
- \( G_{DM} = 1 + \frac{R_3}{R_2} \), differential mode gain
- \( G_{CM} = 1 \), common mode gain
- \( V_{OS} \) is neglected

**FIGURE 4-13:** PCB Layout and Schematic for Dual Non-inverting Amplifier.

Note: Changing the orientation of the resistors will usually cause a significant decrease in the cancellation of the thermal voltages.
4.3.9.5 Other PCB Thermal Design Tips

In cases where an individual resistor needs to have its thermo-junction voltage cancelled, it can be split into two equal resistors as shown in Figure 4-14. To keep the thermal gradients near the resistors as small as possible, the layouts are symmetrical with a ring of metal around the outside. Make \( R_{1A} = R_{1B} = R_1/2 \) and \( R_{2A} = R_{2B} = 2R_2 \).

![Figure 4-14: PCB Layout for Individual Resistors.](image)

**Note:** Changing the orientation of the resistors will usually cause a significant decrease in the cancellation of the thermal voltages.

Minimize temperature gradients at critical components (resistors, op amps, heat sources, etc.):

- Minimize exposure to gradients
  - Small components
  - Tight spacing
  - Shield from air currents
- Align with constant temperature (contour) lines
  - Place on PCB center line
- Minimize magnitude of gradients
  - Select parts with lower power dissipation
  - Use same metal junctions on thermo-junctions that need to match
  - Use metal junctions with low temperature to voltage coefficients
  - Large distance from heat sources
  - Ground plane underneath (large area)
  - FR4 gaps (no copper for thermal insulation)
  - Series resistors inserted into traces (adds thermal and electrical resistance)
  - Use heat sinks

Make the temperature gradient point in one direction:

- Add guard traces
  - Constant temperature curves follow the traces
  - Connect to ground plane
- Shape any FR4 gaps
  - Constant temperature curves follow the edges

4.3.9.6 Crosstalk

DC crosstalk causes offsets that appear as a larger input offset voltage. Common causes include:

- Common mode noise (remote sensors)
- Ground loops (current return paths)
- Power supply coupling

Interference from the mains (usually 50 Hz or 60 Hz), and other AC sources, can also affect the DC performance. Non-linear distortion can convert these signals to multiple tones, included a DC shift in voltage. When the signal is sampled by an ADC, these AC signals can also be aliased to DC, causing an apparent shift in offset.

To reduce interference:

- Keep traces and wires as short as possible
- Use shielding (e.g., encapsulant)
- Use ground plane (at least a star ground)
- Place the input signal source near to the DUT
- Use good PCB layout techniques
- Use a separate power supply filter (bypass capacitors) for these auto-zeroed op amps

4.3.9.7 Miscellaneous Effects

Keep the resistances seen by the input pins as small and as near to equal as possible to minimize bias current related offsets.

Make the (trace) capacitances seen by the input pins small and equal. This is helpful in minimizing switching glitch-induced offset voltages.

Bending a coax cable with a radius that is too small causes a small voltage drop to appear on the center conductor (the tribo-electric effect). Make sure the bending radius is large enough to keep the conductors and insulation in full contact.

Mechanical stresses can make some capacitor types (such as ceramic) to output small voltages. Use more appropriate capacitor types in the signal path and minimize mechanical stresses and vibration.

Humidity can cause electro-chemical potential voltages to appear in a circuit. Proper PCB cleaning helps, as does the use of encapsulants.
4.4 Typical Applications

4.4.1 WHEATSTONE BRIDGE

Many sensors are configured as Wheatstone bridges. Strain gauges and pressure sensors are two common examples. These signals can be small and the common mode noise large. Amplifier designs with high differential gain are desirable.

Figure 4-15 shows how to interface to a Wheatstone bridge with a minimum of components. Because the circuit is not symmetric, the ADC input is single ended, and there is a minimum of filtering, the CMRR is good enough for moderate common mode noise.

![Figure 4-15: Simple Design.](image)

4.4.2 RTD SENSOR

The ratiometric circuit in Figure 4-17 conditions a three wire RTD. It corrects for the sensor's wiring resistance by subtracting the voltage across the middle $R_W$. The top $R_1$ does not change the output voltage; it balances the op amp inputs. Failure (open) of the RTD is detected by an out of range voltage.

![Figure 4-17: RTD Sensor.](image)

The voltages at the input of the ADC can be calculated with the following:

$$
G_{RTD} = l + 2 \cdot R_3/R_2 \\
G_w = G_{RTD} - R_3/R_1 \\
V_{DM} = G_{RTD}(V_T - V_B) + G_w V_W \\
V_{CM} = V_T + V_B + (G_{RTD} + 1 - G_w)V_W/2
$$

Where:

- $V_T$ = Voltage at the top of $R_{RTD}$
- $V_B$ = Voltage at the bottom of $R_{RTD}$
- $V_W$ = Voltage across top and middle $R_W$'s
- $V_{CM}$ = ADC's common mode input
- $V_{DM}$ = ADC's differential mode input
4.4.3 THERMOCOUPLE SENSOR

Figure 4-18 shows a simplified diagram of an amplifier and temperature sensor used in a thermocouple application. The type K thermocouple senses the temperature at the hot junction (T\textsubscript{HJ}), and produces a voltage at V\textsubscript{1} proportional to T\textsubscript{HJ} (in °C). The amplifier’s gain is set so that \( \frac{V_4}{T_{HJ}} = 10 \text{ mV/°C} \). V\textsubscript{3} represents the output of a temperature sensor, which produces a voltage proportional to the temperature (in °C) at the cold junction (T\textsubscript{CJ}), and with a 0.50V offset. V\textsubscript{2} is set so that V\textsubscript{4} is 0.50V when T\textsubscript{HJ} – T\textsubscript{CJ} is 0°C.

**EQUATION 4-5:**

\[
V_1 \approx T_{HJ}(40 \mu V/°C) \\
V_2 = (1.00V) \\
V_3 = T_{CJ}(10 \text{ mV/°C}) + (0.50V) \\
V_4 = 250V_1 + (V_2 - V_3) \\
\approx (10 \text{ mV/°C}) (T_{HJ} - T_{CJ}) + (0.50V)
\]

**FIGURE 4-18:** Thermocouple Sensor; Simplified Circuit.

Figure 4-19 shows a more complete implementation of this circuit. The dashed red arrow indicates a thermally conductive connection between the thermocouple and the MCP9700A; it needs to be very short and have low thermal resistance.

The MCP9700A senses the temperature at its physical location. It needs to be at the same temperature as the cold junction (T\textsubscript{CJ}), and produces V\textsubscript{3} (Figure 4-16).

The MCP1541 produces a 4.10V output, assuming V\textsubscript{DD} is at 5.0V. This voltage, tied to a resistor ladder of 4.100(R\textsubscript{TH}) and 1.3224(R\textsubscript{TH}), would produce a Thevenin equivalent of 1.00V and 250(R\textsubscript{TH}). The 1.3224(R\textsubscript{TH}) resistor is combined in parallel with the top right R\textsubscript{TH} resistor (in Figure 4-18), producing the 0.5696(R\textsubscript{TH}) resistor.

V\textsubscript{4} should be converted to digital, then corrected for the thermocouple’s non-linearity. The ADC can use the MCP1541 as its voltage reference. Alternatively, an absolute reference inside a PICmicro\textsuperscript{®} can be used instead of the MCP1541.

4.4.4 OFFSET VOLTAGE CORRECTION

Figure 4-20 shows a MCP6V01 correcting the input offset voltage of another op amp. R\textsubscript{2} and C\textsubscript{2} integrate the offset error seen at the other op amp’s input; the integration needs to be slow enough to be stable (with the feedback provided by R\textsubscript{1} and R\textsubscript{3}).

**FIGURE 4-20:** Offset Correction.

4.4.5 PRECISION COMPARATOR

Use high gain before a comparator to improve the latter’s performance. Do not use MCP6V01/2/3 as a comparator by itself; the V\textsubscript{OS} correction circuitry does not operate properly without a feedback loop.

**FIGURE 4-21:** Precision Comparator.
5.0 DESIGN AIDS
Microchip provides the basic design aids needed for the MCP6V01/2/3 family of op amps.

5.1 SPICE Macro Model
The latest SPICE macro model for the MCP6V01/2/3 op amps is available on the Microchip web site at www.microchip.com. This model is intended to be an initial design tool that works well in the op amp's linear region of operation over the temperature range. See the model file for information on its capabilities.

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

5.2 FilterLab® Software
Microchip's FilterLab® 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, the Filter-Lab 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™ Circuit Designer & Simulator
Microchip's Mindi™ 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. This interactive circuit designer & simulator enables designers to quickly generate circuit diagrams, and 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 efficiently identify Microchip devices that fit a particular design requirement. Available at no cost from the Microchip website at www.microchip.com/maps, the MAPS is an overall selection tool for Microchip's product portfolio that includes Analog, Memory, MCUs and DSCs. Using this tool, a customer can define a filter to sort features for a parametric search of devices and export side-by-side technical comparison reports. Helpful links are also provided for Data sheets, Purchase and Sampling of Microchip parts.

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

Some boards that are especially useful are:
- MCP6V01 Thermocouple Auto-Zeroed Reference Design
- 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
- P/N SOIC8EV: 8-Pin SOIC/MSOP/TSSOP/DIP Evaluation Board
- P/N SOIC14EV: 14-Pin SOIC/TSSOP/DIP Evaluation Board

5.6 Application Notes
The following Microchip Application Notes are available on the Microchip web site at 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

These application notes and others are listed in the design guide:
“Signal Chain Design Guide”, DS21825
6.0 PACKAGING INFORMATION

6.1 Package Marking Information

**8-Lead DFN (4x4) (MCP6V02)**

Example:

```
XXXXXXXX
XXXXXXX
YYWW
NNN

6V02
E/MD e3
0750
256
```

**8-Lead SOIC (150 mil)**

```
XXXXXXXXXX
XXXXXXYYWW
NNN

MCP6V01E
SN 0750
256
```

**8-Lead TDFN (2x3) (MCP6V01, MCP6V03)**

```
XXX
YWW
NN

AAA
838
25
```

**Device** | **Code**
---|---
MCP6V01 | AAA
MCP6V03 | AAB

**Note:** Applies to 8-Lead 2x3 TDFN

**Legend:**

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<td>NNN</td>
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<td>e3</td>
<td>Pb-free JEDEC designator for Matte Tin (Sn)</td>
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<td>*</td>
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**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.
8-Lead Plastic Dual Flat, No Lead Package (MD) – 4x4x0.9 mm Body [DFN]

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

**Top View**

**Bottom View**

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**Notes:**

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Package may have one or more exposed tie bars at ends.
3. Package is saw singulated.
4. Dimensioning and tolerancing per ASME Y14.5M.

BSC: Basic Dimension. Theoretically exact value shown without tolerances.
REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-131C
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](http://www.microchip.com/packaging)

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**Notes:**
1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. § Significant Characteristic.
3. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15 mm per side.
4. Dimensioning and tolerancing per ASME Y14.5M.
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
   REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-057B
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

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

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

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<td>Contact Length</td>
<td>L</td>
</tr>
<tr>
<td>Contact-to-Exposed Pad</td>
<td>K</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dimension Limits</th>
<th>MIN</th>
<th>NOM</th>
<th>MAX</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>e</td>
<td></td>
<td>0.50 BSC</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>0.70</td>
<td>0.75</td>
<td>0.80</td>
</tr>
<tr>
<td>A1</td>
<td>0.00</td>
<td>0.02</td>
<td>0.05</td>
</tr>
<tr>
<td>A3</td>
<td></td>
<td>0.20 REF</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>2.00 BSC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td></td>
<td>3.00 BSC</td>
<td></td>
</tr>
<tr>
<td>D2</td>
<td>1.20</td>
<td>-</td>
<td>1.60</td>
</tr>
<tr>
<td>E2</td>
<td>1.20</td>
<td>-</td>
<td>1.60</td>
</tr>
<tr>
<td>b</td>
<td>0.20</td>
<td>0.25</td>
<td>0.30</td>
</tr>
<tr>
<td>L</td>
<td>0.25</td>
<td>0.30</td>
<td>0.45</td>
</tr>
<tr>
<td>K</td>
<td>0.20</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Notes:
1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Package may have one or more exposed tie bars at ends.
3. Package is saw singulated.
4. Dimensioning and tolerancing per ASME Y14.5M
   
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
   
   REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing No. C04-129B
8-Lead Plastic Dual Flat, No Lead Package (MN) – 2x3x0.75 mm Body [TDFN]

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

<table>
<thead>
<tr>
<th>Units</th>
<th>MILLIMETERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimension Limits</td>
<td>MIN</td>
</tr>
<tr>
<td>Contact Pitch</td>
<td>E</td>
</tr>
<tr>
<td>Optional Center Pad Width</td>
<td>W2</td>
</tr>
<tr>
<td>Optional Center Pad Length</td>
<td>T2</td>
</tr>
<tr>
<td>Contact Pad Spacing</td>
<td>C1</td>
</tr>
<tr>
<td>Contact Pad Width (X8)</td>
<td>X1</td>
</tr>
<tr>
<td>Contact Pad Length (X8)</td>
<td>Y1</td>
</tr>
<tr>
<td>Distance Between Pads</td>
<td>G</td>
</tr>
</tbody>
</table>

Notes:
1. Dimensioning and tolerancing per ASME Y14.5M
   
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.

   Microchip Technology Drawing No. C04-2129A
APPENDIX A: REVISION HISTORY

Revision C (December 2008)
The following is the list of modifications:
1. Added the 8-lead, 2x3 TDFN package for the MCP6V01 and MCP6V03 devices.
2. Corrected the IMD specification in Table 1-2.
3. Added 8-lead, 2x3 TDFN package information to Thermal Characteristic table.
4. Added information on the Exposed Thermal Pad (EP) for the 8-lead, 2x3 TDFN and 8-lead, 4x4 DFN packages.
5. Added Section 4.3.6 “Stabilizing Output Loads”
6. Other minor typographical corrections.

Revision B (June 2008)
The following is the list of modifications:
1. Updated the specifications and their conditions.
2. Corrected the Timing Diagrams.
3. Added to the Test Circuits.
4. Added $R_{ISO}$ (see Figure 4-6) to all circuit diagrams.
5. Added the Typical Performance Curves.
6. Corrected and expanded Applications Information.
7. Minor edits due to change in production status.
8. Added Appendix B, Offset Related Test Screens.

Revision A (September 2007)
• Original Release of this Document.
APPENDIX B:  OFFSET RELATED TEST SCREENS

We use production screens to ensure the quality of our outgoing products. These screens are set at wider limits to eliminate any fliers; see Table B-1.

Input offset voltage related specifications in the DC spec table (Table 1-1) are based on bench measurements (see Section 2.1 “DC Input Precision”). These measurements are much more accurate because:

- More compact circuit
- Soldered parts on the PCB
- More time spent averaging (reduces noise)
- Better temperature control
  - Reduced temperature gradients
  - Greater accuracy

TABLE B-1:  OFFSET RELATED TEST SCREENS

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sym</th>
<th>Min</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Offset Voltage</td>
<td>V_{OS}</td>
<td>-10</td>
<td>10</td>
<td>µV</td>
<td>T_{A} = +25°C (Note 1, Note 2)</td>
</tr>
<tr>
<td>Input Offset Voltage Drift with Temperature</td>
<td>TC_{1}</td>
<td>—</td>
<td>—</td>
<td>nV/°C</td>
<td>T_{A} = -40 to +125°C (Note 3)</td>
</tr>
<tr>
<td>Power Supply Rejection</td>
<td>PSRR</td>
<td>115</td>
<td>—</td>
<td>dB</td>
<td>(Note 1)</td>
</tr>
<tr>
<td>Common Mode Rejection</td>
<td>CMRR</td>
<td>106</td>
<td>—</td>
<td>dB</td>
<td>V_{DD} = 1.8V, V_{CM} = -0.2V to 2.0V (Note 1)</td>
</tr>
<tr>
<td>Common Mode Rejection</td>
<td>CMRR</td>
<td>116</td>
<td>—</td>
<td>dB</td>
<td>V_{DD} = 5.5V, V_{CM} = -0.2V to 5.7V (Note 1)</td>
</tr>
<tr>
<td>DC Open-Loop Gain (large signal)</td>
<td>A_{OL}</td>
<td>114</td>
<td>—</td>
<td>dB</td>
<td>V_{DD} = 1.8V, V_{OUT} = 0.2V to 1.6V (Note 1)</td>
</tr>
<tr>
<td>DC Open-Loop Gain (large signal)</td>
<td>A_{OL}</td>
<td>122</td>
<td>—</td>
<td>dB</td>
<td>V_{DD} = 5.5V, V_{OUT} = 0.2V to 5.3V (Note 1)</td>
</tr>
</tbody>
</table>

Note 1:  Due to thermal junctions and other errors in the production environment, these specifications are only screened in production.
2:  V_{OS} is also sample screened at +125°C.
3:  TC_{1} is not measured in production.
**PRODUCT IDENTIFICATION SYSTEM**

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

<table>
<thead>
<tr>
<th>PART NO.</th>
<th>-X</th>
<th>/XXX</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Device</strong></td>
<td><strong>Temperature Range</strong></td>
<td><strong>Package</strong></td>
</tr>
<tr>
<td>MCP6V01</td>
<td>Single Op Amp</td>
<td>MD = Plastic Dual Flat, No-Lead (4×4x0.9 mm), 8-lead</td>
</tr>
<tr>
<td>MCP6V01T</td>
<td>Single Op Amp (Tape and Reel for 2x3 TDFN and SOIC)</td>
<td>MNY = Plastic Dual Flat No Lead (2x3x0.75 mm), 8-lead (MCP6V01, MCP6V03)</td>
</tr>
<tr>
<td>MCP6V02</td>
<td>Dual Op Amp</td>
<td>SN = Plastic SOIC (150mil Body), 8-lead</td>
</tr>
<tr>
<td>MCP6V02T</td>
<td>Dual Op Amp (Tape and Reel for 4×4 DFN and SOIC)</td>
<td>* Y = nickel palladium gold manufacturing designator. Only available on the TDFN package.</td>
</tr>
<tr>
<td>MCP6V03</td>
<td>Single Op Amp with Chip Select</td>
<td></td>
</tr>
<tr>
<td>MCP6V03T</td>
<td>Single Op Amp with Chip Select (Tape and Reel for SOIC)</td>
<td></td>
</tr>
</tbody>
</table>

**Temperature Range:** E = -40°C to +125°C

**Examples:**

- a) MCP6V01T-E/SN: Extended temperature, 8LD SOIC package.
- b) MCP6V01-E/MNY: Extended temperature, 8LD 2x3 TDFN package.
- a) MCP6V02-E/MD: Extended temperature, 8LD 4x4 DFN package.
- b) MCP6V02T-E/SN: Tape and Reel, Extended temperature, 8LD SOIC package.
- a) MCP6V03-E/SN: Extended temperature, 8LD SOIC package.
- b) MCP6V03-E/MNY: Extended temperature, 8LD 2x3 TDFN package.
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