

## 300 $\mu$ A, Auto-Zeroed Op Amps

### Features

- High DC Precision:
  - $V_{OS}$  Drift:  $\pm 50$  nV/ $^{\circ}$ C (maximum)
  - $V_{OS}$ :  $\pm 3$   $\mu$ V (maximum)
  - $A_{OL}$ : 125 dB (minimum)
  - PSRR: 125 dB (minimum)
  - CMRR: 120 dB (minimum)
  - $E_{ni}$ : 1.7  $\mu$ V<sub>p-p</sub> (typical),  $f = 0.1$  Hz to 10 Hz
  - $E_{ni}$ : 0.54  $\mu$ V<sub>p-p</sub> (typical),  $f = 0.01$  Hz to 1 Hz
- Low Power and Supply Voltages:
  - $I_Q$ : 300  $\mu$ A/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 ( $\overline{CS}$ ): MCP6V08
- Extended Temperature Range:  $-40^{\circ}$ C to  $+125^{\circ}$ C

### Typical Applications

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

### Design Aids

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

### Related Parts

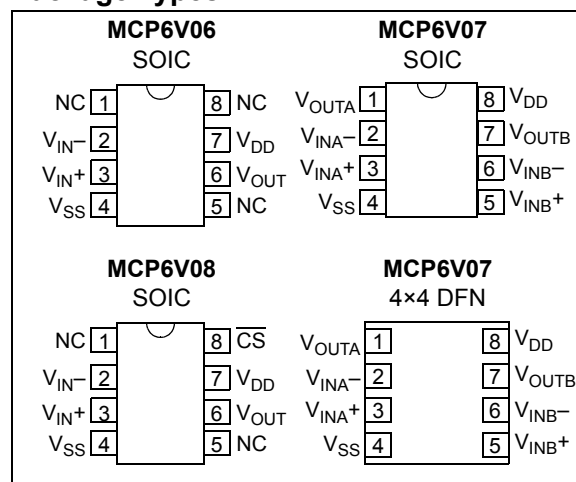
- MCP6V01/2/3: Spread clock, lower offset

### Description

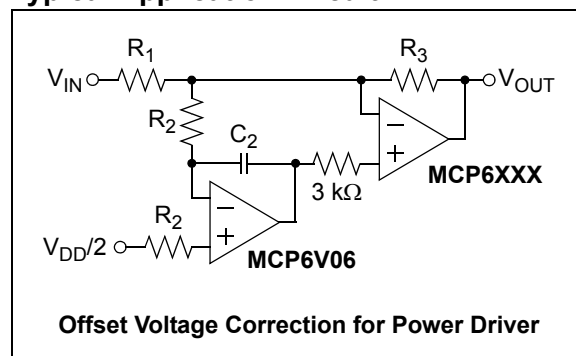
The Microchip Technology Inc. MCP6V06/7/8 family of operational amplifiers has input offset voltage correction for very low offset and offset drift. These devices have a wide gain bandwidth product (1.3 MHz, typical) and strongly reject switching noise. They are unity gain stable, have no 1/f noise, and have good PSRR and CMRR. These products operate with a single supply voltage as low as 1.8V, while drawing 300  $\mu$ A/amplifier (typical) of quiescent current.

The Microchip Technology Inc. MCP6V06/7/8 op amps are offered in single (MCP6V06), single with Chip Select ( $\overline{CS}$ ) (MCP6V08), and dual (MCP6V07). They are designed in an advanced CMOS process.

### Package Types



### Typical Application Circuit



# MCP6V06/7/8

## 1.0 ELECTRICAL CHARACTERISTICS

### 1.1 Absolute Maximum Ratings †

$V_{DD} - V_{SS}$ .....	6.5V
Current at Input Pins .....	$\pm 2$ mA
Analog Inputs ( $V_{IN+}$ and $V_{IN-}$ ) †† ... $V_{SS} - 1.0V$ to $V_{DD} + 1.0V$	
All other Inputs and Outputs .....	$V_{SS} - 0.3V$ to $V_{DD} + 0.3V$
Difference Input voltage .....	$ V_{DD} - V_{SS} $
Output Short Circuit Current .....	Continuous
Current at Output and Supply Pins .....	$\pm 30$ mA
Storage Temperature .....	$-65^{\circ}C$ to $+150^{\circ}C$
Max. Junction Temperature .....	$+150^{\circ}C$
ESD protection on all pins (HBM, MM) .....	$\geq 4$ 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, $T_A = +25^{\circ}C$ , $V_{DD} = +1.8V$ 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 $V_L$ , and $\overline{CS} = GND$ (refer to Figure 1-5 and Figure 1-6).						
Parameters	Sym	Min	Typ	Max	Units	Conditions
<b>Input Offset</b>						
Input Offset Voltage	$V_{OS}$	-3	—	+3	$\mu V$	$T_A = +25^{\circ}C$ (Note 1)
Input Offset Voltage Drift with Temperature (linear Temp. Co.)	$TC_1$	-50	—	+50	nV/ $^{\circ}C$	$T_A = -40$ to $+125^{\circ}C$ (Note 1)
Input Offset Voltage Quadratic Temp. Co.	$TC_2$	—	$\pm 0.15$	—	nV/ $^{\circ}C^2$	$T_A = -40$ to $+125^{\circ}C$
Power Supply Rejection	PSRR	125	142	—	dB	(Note 1)
<b>Input Bias Current and Impedance</b>						
Input Bias Current	$I_B$	—	+6	—	pA	
Input Bias Current across Temperature	$I_B$	—	+140	—	pA	$T_A = +85^{\circ}C$
	$I_B$	—	+1500	+5000	pA	$T_A = +125^{\circ}C$
Input Offset Current	$I_{OS}$	—	-85	—	pA	
Input Offset Current across Temperature	$I_{OS}$	—	-85	—	pA	$T_A = +85^{\circ}C$
	$I_{OS}$	-1000	-190	1000	pA	$T_A = +125^{\circ}C$
Common Mode Input Impedance	$Z_{CM}$	—	$10^{13}  6$	—	$\Omega  pF$	
Differential Input Impedance	$Z_{DIFF}$	—	$10^{13}  6$	—	$\Omega  pF$	
<b>Common Mode</b>						
Common-Mode Input Voltage Range	$V_{CMR}$	$V_{SS} - 0.20$	—	$V_{DD} + 0.20$	V	(Note 2)
Common-Mode Rejection	CMRR	120	136	—	dB	$V_{DD} = 1.8V$ , $V_{CM} = -0.2V$ to $2.0V$ (Note 1, Note 2)
	CMRR	130	147	—	dB	$V_{DD} = 5.5V$ , $V_{CM} = -0.2V$ to $5.7V$ (Note 1, Note 2)
<b>Open-Loop Gain</b>						
DC Open-Loop Gain (large signal)	$A_{OL}$	125	147	—	dB	$V_{DD} = 1.8V$ , $V_{OUT} = 0.2V$ to $1.6V$ (Note 1)
	$A_{OL}$	135	158	—	dB	$V_{DD} = 5.5V$ , $V_{OUT} = 0.2V$ to $5.3V$ (Note 1)

**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  $TC_1$ ; see Appendix B: “Offset Related Test Screens”).

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

**TABLE 1-1: DC ELECTRICAL SPECIFICATIONS (CONTINUED)**

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

Parameters	Sym	Min	Typ	Max	Units	Conditions
<b>Output</b>						
Maximum Output Voltage Swing	$V_{OL}, V_{OH}$	$V_{SS} + 15$	—	$V_{DD} - 15$	mV	$G = +2$ , 0.5V input overdrive
Output Short Circuit Current	$I_{SC}$	—	$\pm 7$	—	mA	$V_{DD} = 1.8\text{V}$
	$I_{SC}$	—	$\pm 22$	—	mA	$V_{DD} = 5.5\text{V}$
<b>Power Supply</b>						
Supply Voltage	$V_{DD}$	1.8	—	5.5	V	
Quiescent Current per amplifier	$I_Q$	200	300	400	$\mu\text{A}$	$I_O = 0$
POR Trip Voltage	$V_{POR}$	1.15	—	1.65	V	

**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  $TC_1$ ; see **Appendix B: “Offset Related Test Screens”**).

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

Parameters	Sym	Min	Typ	Max	Units	Conditions
<b>Amplifier AC Response</b>						
Gain Bandwidth Product	GBWP	—	1.3	—	MHz	
Slew Rate	SR	—	0.5	—	$\text{V}/\mu\text{s}$	
Phase Margin	PM	—	65	—	$^\circ$	$G = +1$
<b>Amplifier Noise Response</b>						
Input Noise Voltage	$E_{ni}$	—	0.54	—	$\mu\text{V}_{P-P}$	$f = 0.01\text{ Hz}$ to $1\text{ Hz}$
	$E_{ni}$	—	1.7	—	$\mu\text{V}_{P-P}$	$f = 0.1\text{ Hz}$ to $10\text{ Hz}$
Input Noise Voltage Density	$e_{ni}$	—	82	—	$\text{nV}/\sqrt{\text{Hz}}$	$f < 2.5\text{ kHz}$
	$e_{ni}$	—	52	—	$\text{nV}/\sqrt{\text{Hz}}$	$f = 100\text{ kHz}$
Input Noise Current Density	$i_{ni}$	—	0.6	—	$\text{fA}/\sqrt{\text{Hz}}$	
<b>Amplifier Distortion (Note 1)</b>						
Intermodulation Distortion (Not DC)	IMD	—	32	—	$\mu\text{V}_{PK}$	$V_{CM}$ tone = $50\text{ mV}_{PK}$ at $1\text{ kHz}$ , $G_N = 1$ , $V_{DD} = 5.5\text{V}$
	IMD	—	25	—	$\mu\text{V}_{PK}$	$V_{CM}$ tone = $50\text{ mV}_{PK}$ at $1\text{ kHz}$ , $G_N = 1$ , $V_{DD} = 5.5\text{V}$
<b>Amplifier Step Response</b>						
Start Up Time	$t_{STR}$	—	500	—	$\mu\text{s}$	$V_{OS}$ within $50\text{ }\mu\text{V}$ of its final value
Offset Correction Settling Time	$t_{STL}$	—	300	—	$\mu\text{s}$	$G = +1$ , $V_{IN}$ step of $2\text{V}$ , $V_{OS}$ within $50\text{ }\mu\text{V}$ of its final value
Output Overdrive Recovery Time	$t_{ODR}$	—	100	—	$\mu\text{s}$	$G = -100$ , $\pm 0.5\text{V}$ input overdrive to $V_{DD}/2$ , $V_{IN}$ 50% point to $V_{OUT}$ 90% point ( <b>Note 2</b> )

**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  $1\text{ kHz}$ ; all other IMD and clock tones are spread by the randomization circuitry.

**2:**  $t_{ODR}$  includes some uncertainty due to clock edge timing.

# MCP6V06/7/8

**TABLE 1-3: DIGITAL ELECTRICAL SPECIFICATIONS**

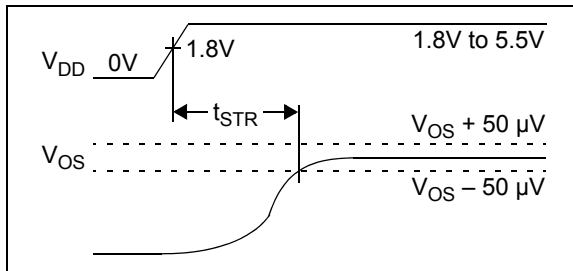
<b>Electrical Characteristics:</b> Unless otherwise indicated, $T_A = +25^\circ\text{C}$ , $V_{DD} = +1.8\text{V to } +5.5\text{V}$ , $V_{SS} = \text{GND}$ , $V_{CM} = V_{DD}/3$ , $V_{OUT} = V_{DD}/2$ , $V_L = V_{DD}/2$ , $R_L = 20\text{ k}\Omega$ to $V_L$ , $C_L = 60\text{ pF}$ , and $\overline{\text{CS}} = \text{GND}$ (refer to <a href="#">Figure 1-5</a> and <a href="#">Figure 1-6</a> ).						
Parameters	Sym	Min	Typ	Max	Units	Conditions
<b><math>\overline{\text{CS}}</math> Pull-Down Resistor (MCP6V08)</b>						
$\overline{\text{CS}}$ Pull-Down Resistor	$R_{PD}$	3	5	—	M $\Omega$	
<b><math>\overline{\text{CS}}</math> Low Specifications (MCP6V08)</b>						
$\overline{\text{CS}}$ Logic Threshold, Low	$V_{IL}$	$V_{SS}$	—	$0.3V_{DD}$	V	
$\overline{\text{CS}}$ Input Current, Low	$I_{CSL}$	—	5	—	$\mu\text{A}$	$\overline{\text{CS}} = V_{SS}$
<b><math>\overline{\text{CS}}</math> High Specifications (MCP6V08)</b>						
$\overline{\text{CS}}$ Logic Threshold, High	$V_{IH}$	$0.7V_{DD}$	—	$V_{DD}$	V	
$\overline{\text{CS}}$ Input Current, High	$I_{CSH}$	—	$V_{DD}/R_{PD}$	—	$\mu\text{A}$	$\overline{\text{CS}} = V_{DD}$
$\overline{\text{CS}}$ Input High, GND Current per amplifier	$I_{SS}$	—	-0.7	—	$\mu\text{A}$	$\overline{\text{CS}} = V_{DD}$ , $V_{DD} = 1.8\text{V}$
	$I_{SS}$	—	-2.3	—	$\mu\text{A}$	$\overline{\text{CS}} = V_{DD}$ , $V_{DD} = 5.5\text{V}$
Amplifier Output Leakage, $\overline{\text{CS}}$ High	$I_{O\_LEAK}$	—	20	—	$\mu\text{A}$	$\overline{\text{CS}} = V_{DD}$
<b><math>\overline{\text{CS}}</math> Dynamic Specifications (MCP6V08)</b>						
$\overline{\text{CS}}$ Low to Amplifier Output On Turn-on Time	$t_{ON}$	—	11	100	$\mu\text{s}$	$\overline{\text{CS}}$ Low = $V_{SS} + 0.3\text{ V}$ , $G = +1\text{ V/V}$ , $V_{OUT} = 0.9\text{ }V_{DD}/2$
$\overline{\text{CS}}$ High to Amplifier Output High-Z	$t_{OFF}$	—	10	—	$\mu\text{s}$	$\overline{\text{CS}}$ High = $V_{DD} - 0.3\text{ V}$ , $G = +1\text{ V/V}$ , $V_{OUT} = 0.1\text{ }V_{DD}/2$
Internal Hysteresis	$V_{HYST}$	—	0.25	—	V	

**TABLE 1-4: TEMPERATURE SPECIFICATIONS**

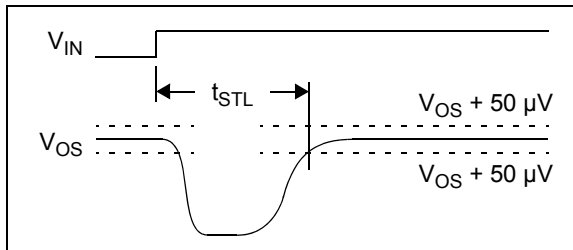
<b>Electrical Characteristics:</b> Unless otherwise indicated, all limits are specified for: $V_{DD} = +1.8\text{V to } +5.5\text{V}$ , $V_{SS} = \text{GND}$ .						
Parameters	Sym	Min	Typ	Max	Units	Conditions
<b>Temperature Ranges</b>						
Specified Temperature Range	$T_A$	-40	—	+125	$^\circ\text{C}$	
Operating Temperature Range	$T_A$	-40	—	+125	$^\circ\text{C}$	<b>(Note 1)</b>
Storage Temperature Range	$T_A$	-65	—	+150	$^\circ\text{C}$	
<b>Thermal Package Resistances</b>						
Thermal Resistance, 8L-4x4 DFN	$\theta_{JA}$	—	44	—	$^\circ\text{C/W}$	<b>(Note 2)</b>
Thermal Resistance, 8L-SOIC	$\theta_{JA}$	—	150	—	$^\circ\text{C/W}$	

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

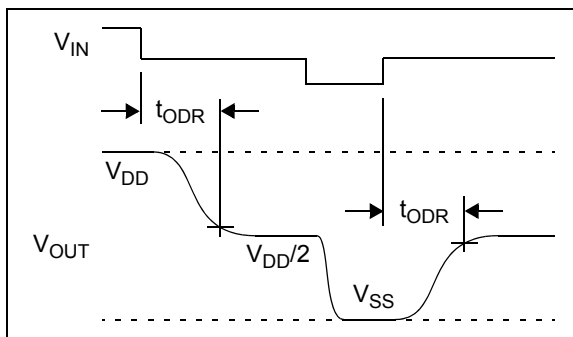
## 1.3 Timing Diagrams



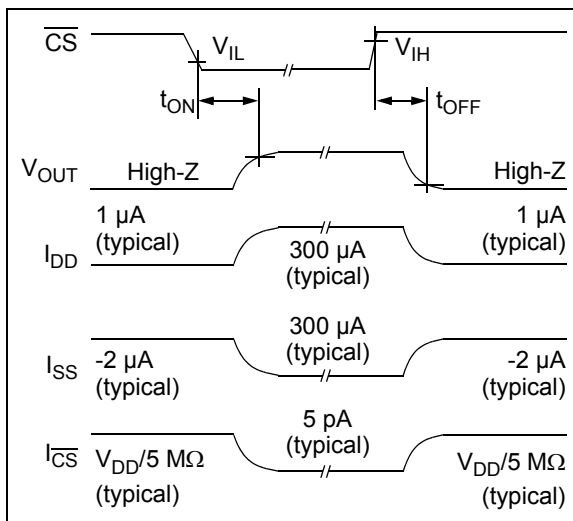
**FIGURE 1-1:** Amplifier Start Up.



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



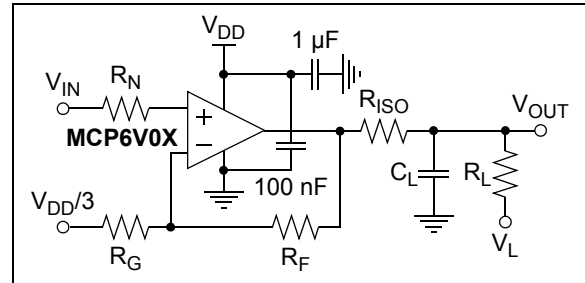
**FIGURE 1-3:** Output Overdrive Recovery.



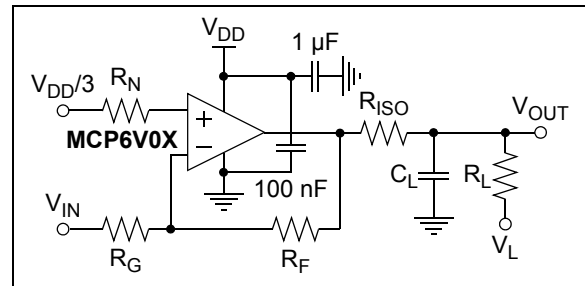
**FIGURE 1-4:** Chip Select (MCP6V08).

## 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 4.3.7 “Supply Bypassing and Filtering”](#).  $R_N$  is equal to the parallel combination of  $R_F$  and  $R_G$  to minimize bias current effects.

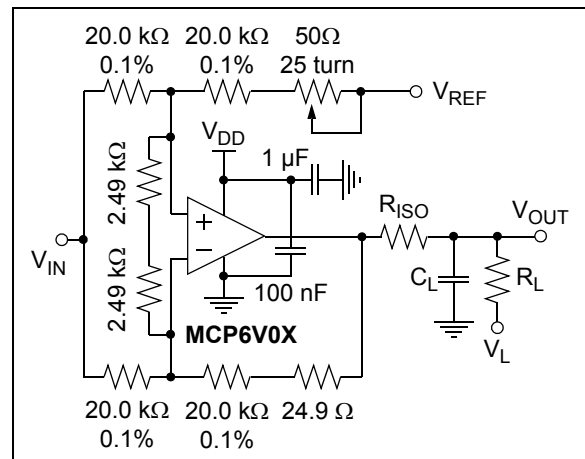


**FIGURE 1-5:** AC and DC Test Circuit for Most Non-Inverting Gain Conditions.



**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  $V_{CM} = V_{IN}/2$ . 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.

# MCP6V06/7/8

## 2.0 TYPICAL PERFORMANCE CURVES

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

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

### 2.1 DC Input Precision

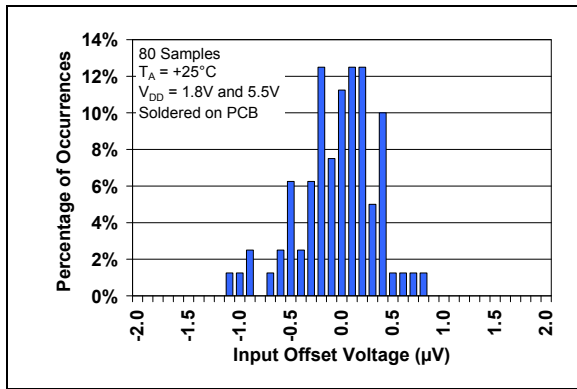


FIGURE 2-1: Input Offset Voltage.

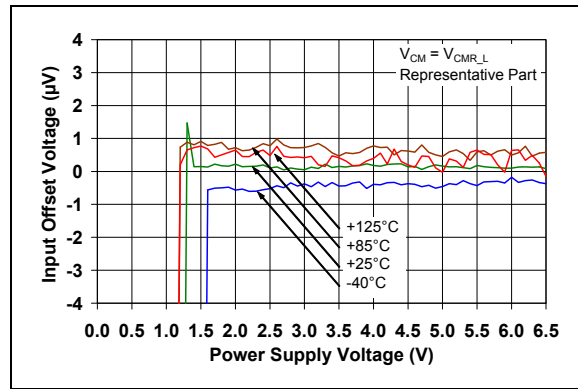


FIGURE 2-4: Input Offset Voltage vs. Power Supply Voltage with  $V_{CM} = V_{CMR\_L}$ .

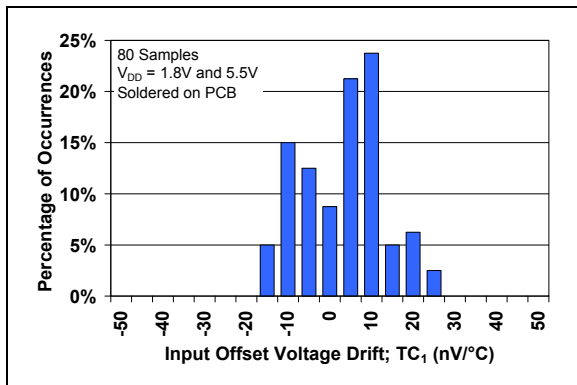


FIGURE 2-2: Input Offset Voltage Drift.

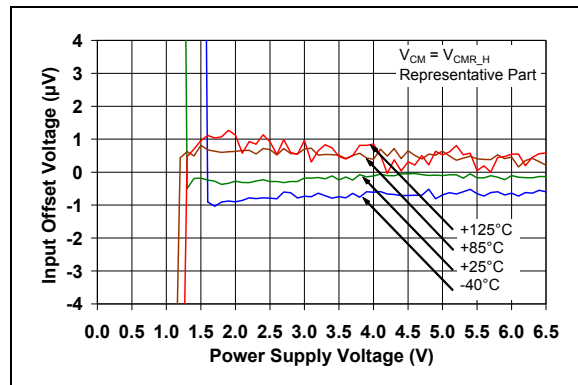


FIGURE 2-5: Input Offset Voltage vs. Power Supply Voltage with  $V_{CM} = V_{CMR\_H}$ .

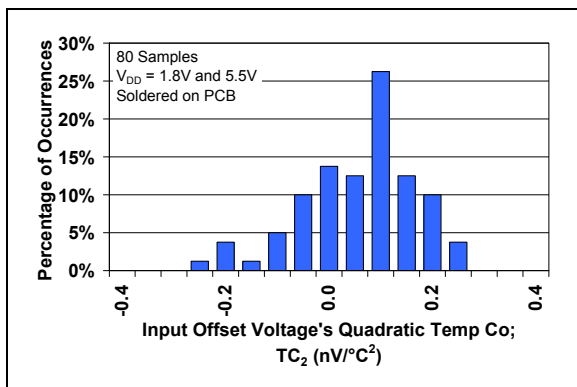


FIGURE 2-3: Input Offset Voltage Quadratic Temp Co.

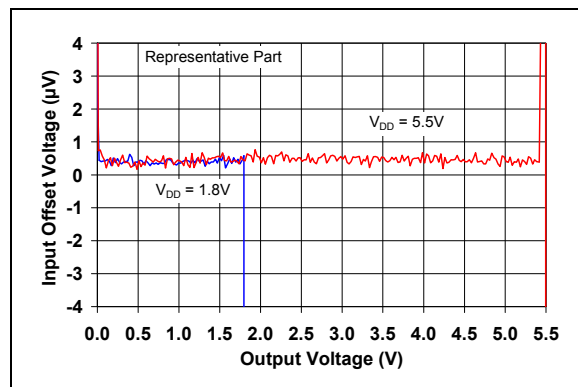
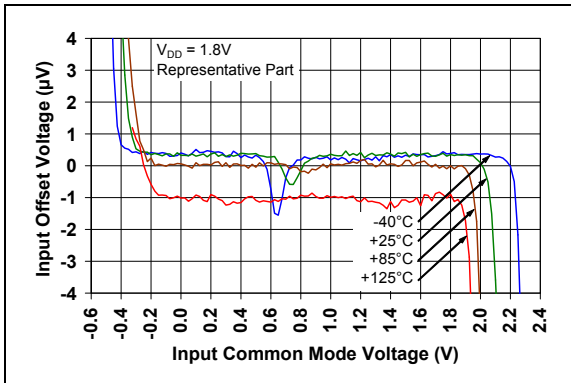
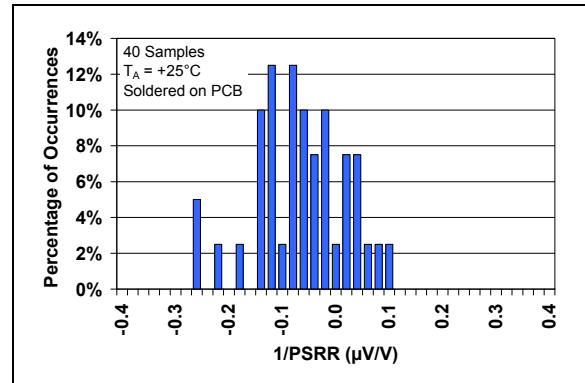


FIGURE 2-6: Input Offset Voltage vs. Output Voltage.

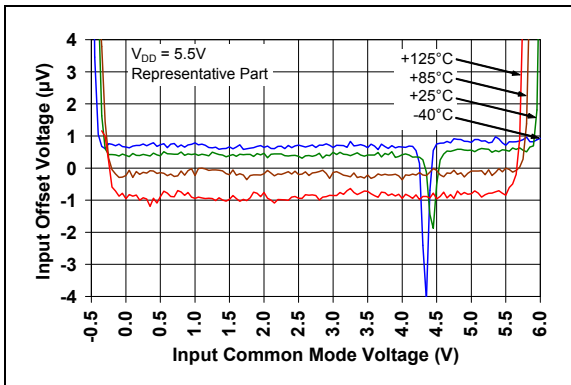
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.8\text{V}$  to  $5.5\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/3$ ,  $V_{OUT} = V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 20\text{ k}\Omega$  to  $V_L$ ,  $C_L = 60\text{ pF}$ , and  $\overline{\text{CS}} = \text{GND}$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



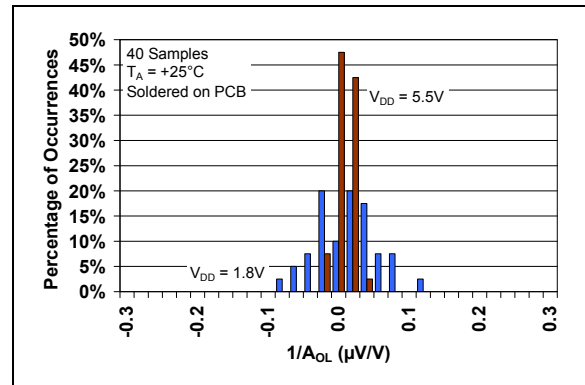
**FIGURE 2-7:** Input Offset Voltage vs. Common Mode Voltage with  $V_{DD} = 1.8\text{V}$ .



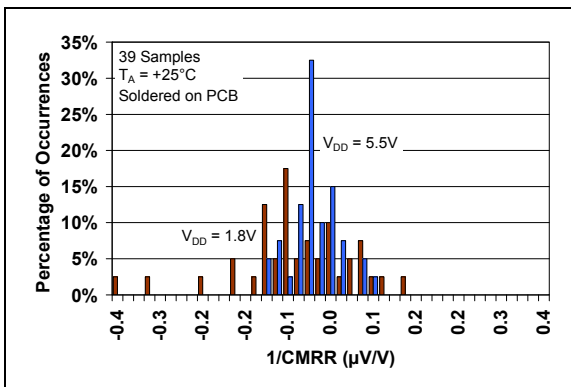
**FIGURE 2-10:** PSRR.



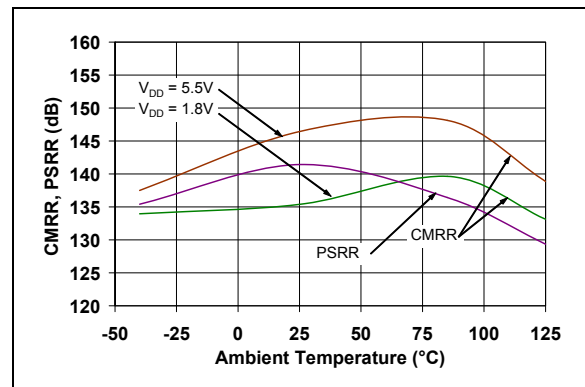
**FIGURE 2-8:** Input Offset Voltage vs. Common Mode Voltage with  $V_{DD} = 5.5\text{V}$ .



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



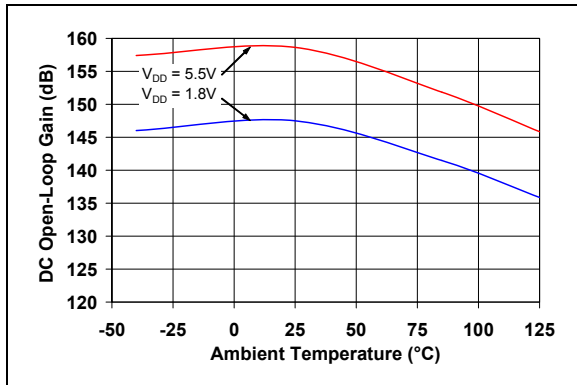
**FIGURE 2-9:** CMRR.



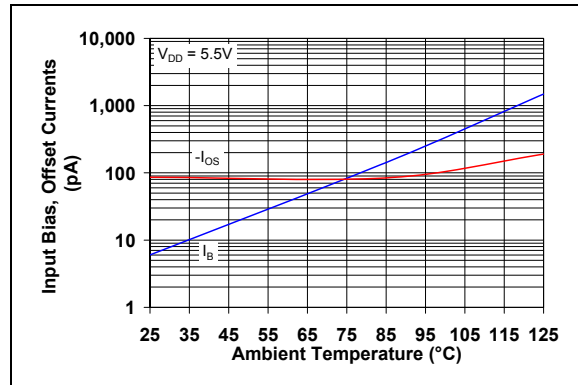
**FIGURE 2-12:** CMRR and PSRR vs. Ambient Temperature.

# MCP6V06/7/8

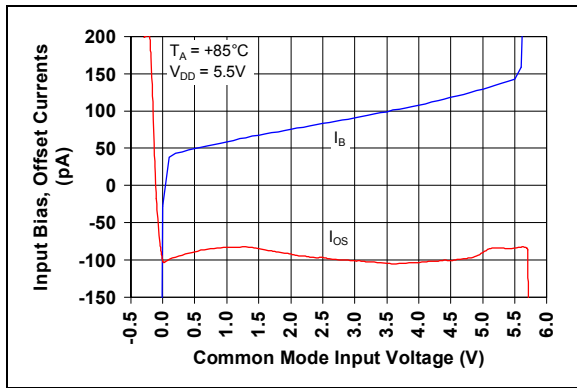
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.8\text{V}$  to  $5.5\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/3$ ,  $V_{OUT} = V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 20\text{ k}\Omega$  to  $V_L$ ,  $C_L = 60\text{ pF}$ , and  $\overline{CS} = \text{GND}$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



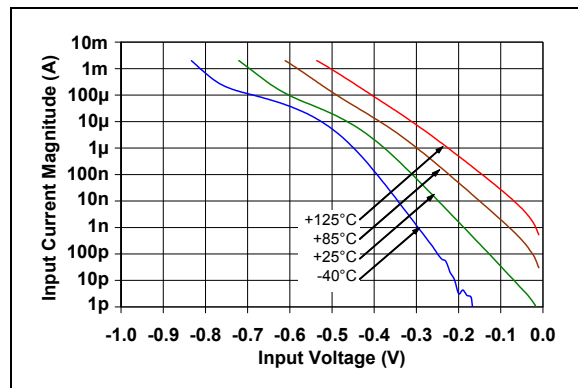
**FIGURE 2-13:** DC Open-Loop Gain vs. Ambient Temperature.



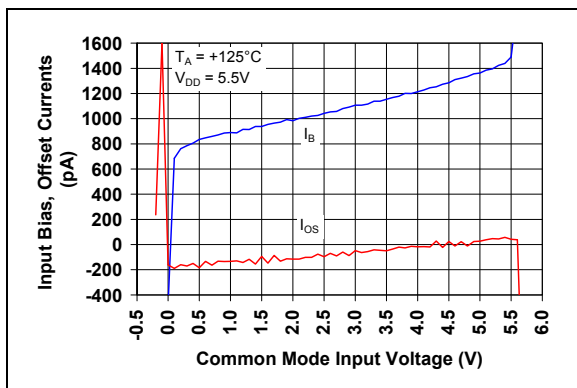
**FIGURE 2-16:** Input Bias and Offset Currents vs. Ambient Temperature with  $V_{DD} = +5.5\text{V}$ .



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



**FIGURE 2-17:** Input Bias Current vs. Input Voltage (below  $V_{SS}$ ).

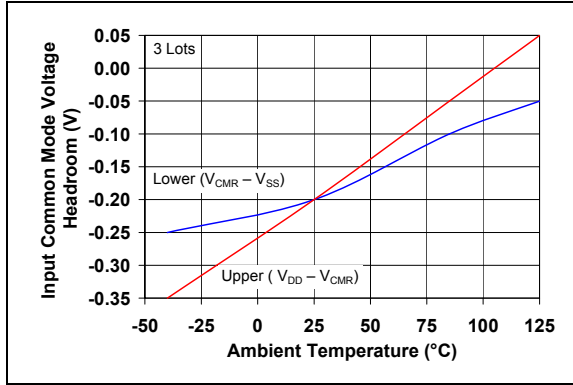


**FIGURE 2-15:** Input Bias and Offset Currents vs. Common Mode Input Voltage with  $T_A = +125^\circ\text{C}$ .

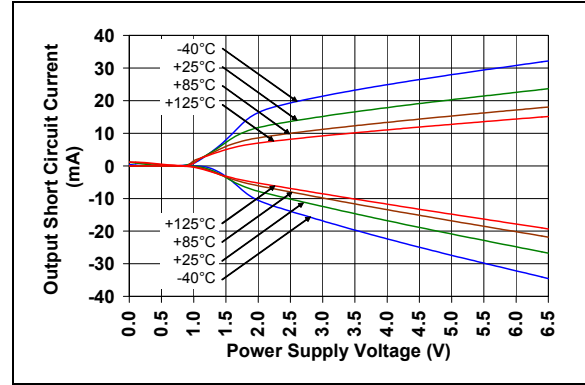


**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.8\text{V}$  to  $5.5\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/3$ ,  $V_{OUT} = V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 20\text{ k}\Omega$  to  $V_L$ ,  $C_L = 60\text{ pF}$ , and  $\overline{\text{CS}} = \text{GND}$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

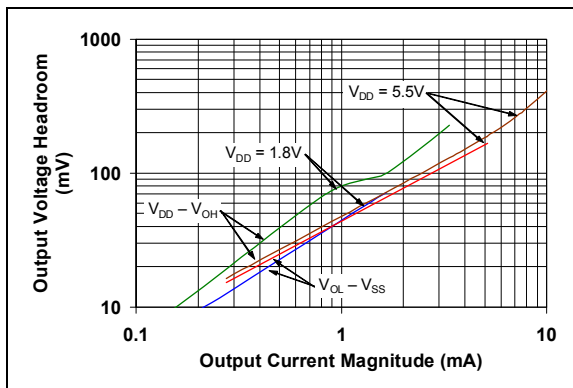
## 2.2 Other DC Voltages and Currents



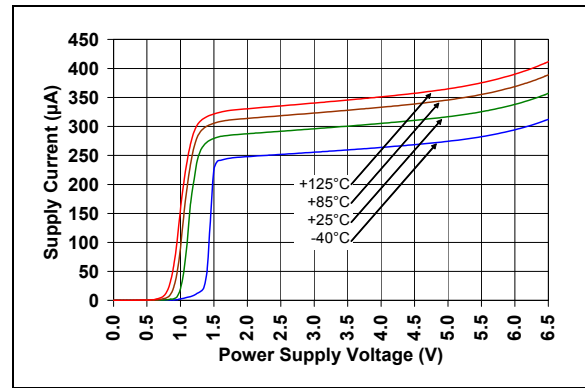
**FIGURE 2-18:** Input Common Mode Voltage Headroom (Range) vs. Ambient Temperature.



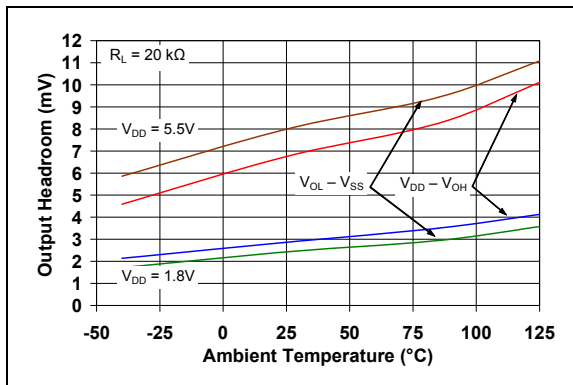
**FIGURE 2-21:** Output Short Circuit Current vs. Power Supply Voltage.



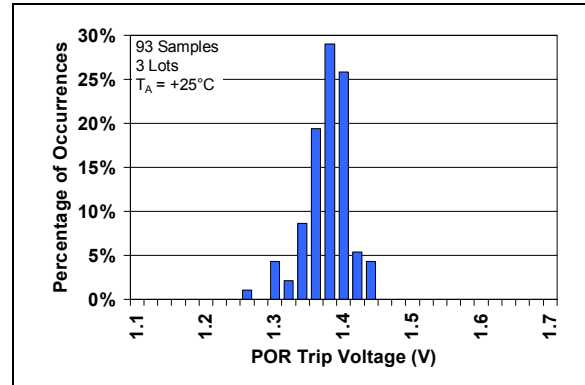
**FIGURE 2-19:** Output Voltage Headroom vs. Output Current.



**FIGURE 2-22:** Supply Current vs. Power Supply Voltage.



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

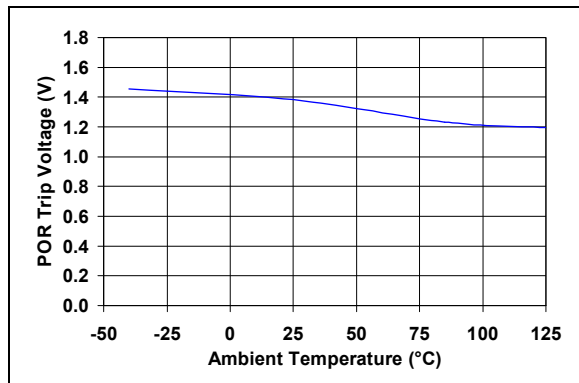


**FIGURE 2-23:** Power On Reset Trip Voltage.

# MCP6V06/7/8

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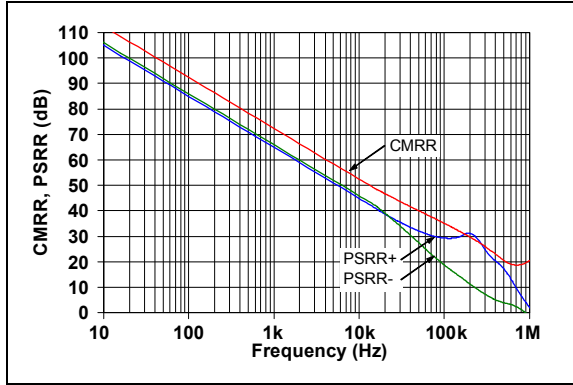
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.8\text{V}$  to  $5.5\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/3$ ,  $V_{OUT} = V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 20\text{ k}\Omega$  to  $V_L$ ,  $C_L = 60\text{ pF}$ , and  $\overline{\text{CS}} = \text{GND}$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



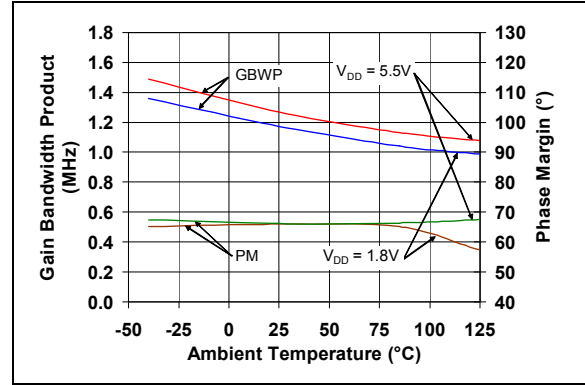
**FIGURE 2-24:** Power On Reset Voltage vs. Ambient Temperature.

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

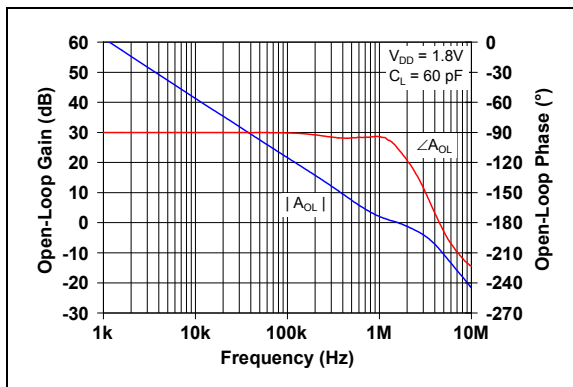
## 2.3 Frequency Response



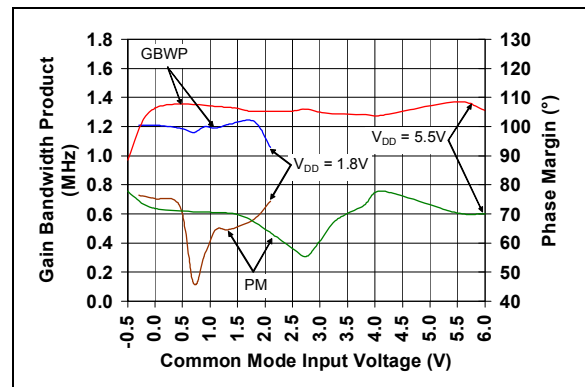
**FIGURE 2-25:** CMRR and PSRR vs. Frequency.



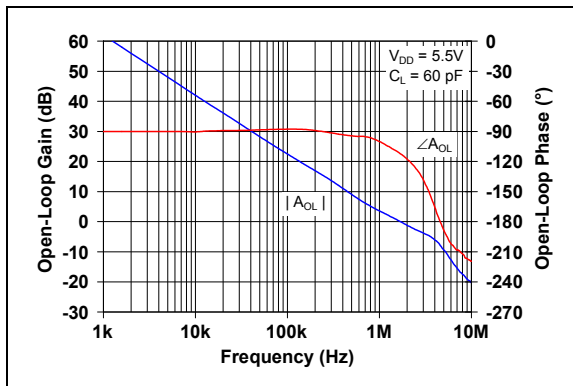
**FIGURE 2-28:** Gain Bandwidth Product and Phase Margin vs. Ambient Temperature.



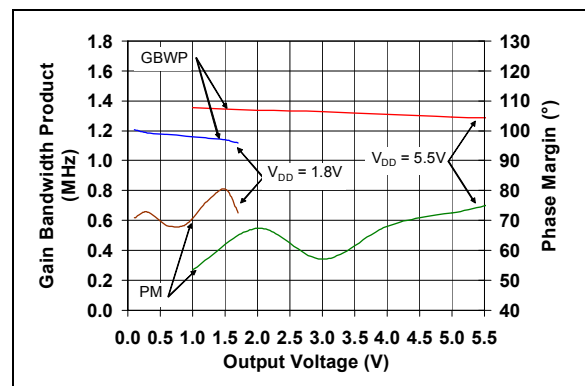
**FIGURE 2-26:** Open-Loop Gain vs. Frequency with  $V_{DD} = 1.8\text{V}$ .



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



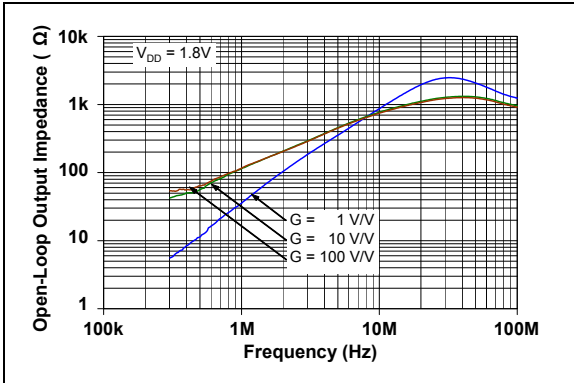
**FIGURE 2-27:** Open-Loop Gain vs. Frequency with  $V_{DD} = 5.5\text{V}$ .



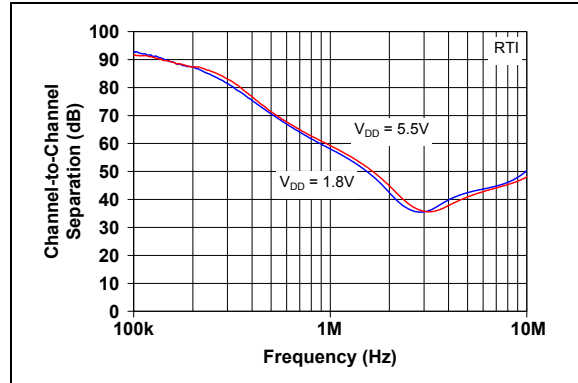
**FIGURE 2-30:** Gain Bandwidth Product and Phase Margin vs. Output Voltage.

# MCP6V06/7/8

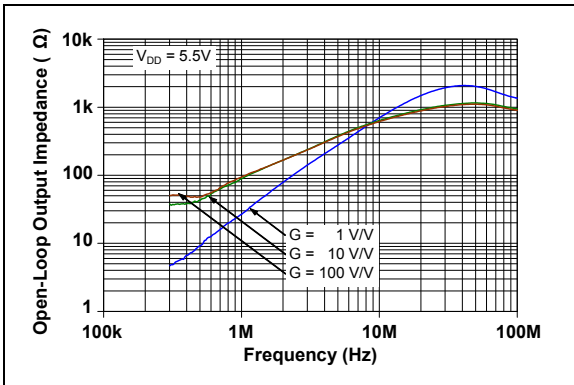
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.8\text{V}$  to  $5.5\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/3$ ,  $V_{OUT} = V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 20\text{ k}\Omega$  to  $V_L$ ,  $C_L = 60\text{ pF}$ , and  $\overline{CS} = \text{GND}$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



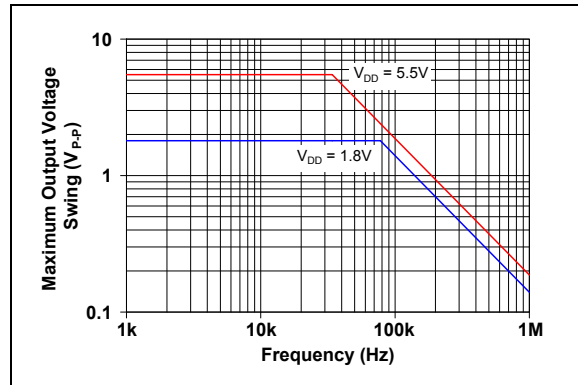
**FIGURE 2-31:** Closed-Loop Output Impedance vs. Frequency with  $V_{DD} = 1.8\text{V}$ .



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



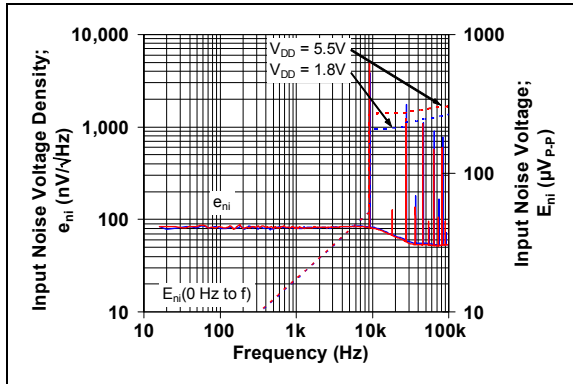
**FIGURE 2-32:** Closed-Loop Output Impedance vs. Frequency with  $V_{DD} = 5.5\text{V}$ .



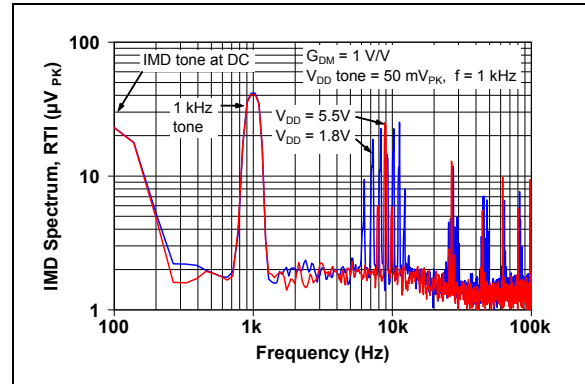
**FIGURE 2-34:** Maximum Output Voltage Swing vs. Frequency.

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

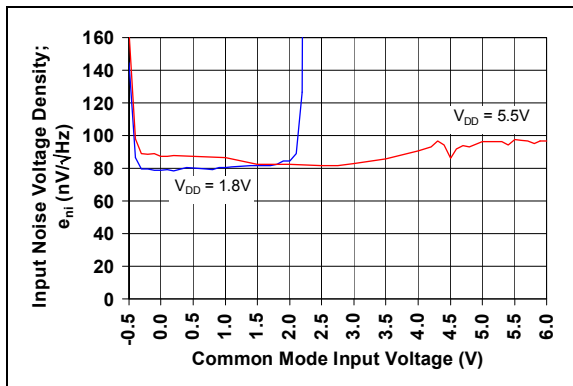
## 2.4 Input Noise and Distortion



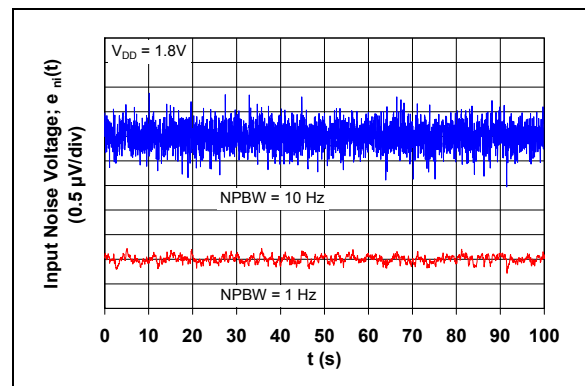
**FIGURE 2-35:** Input Noise Voltage Density vs. Frequency.



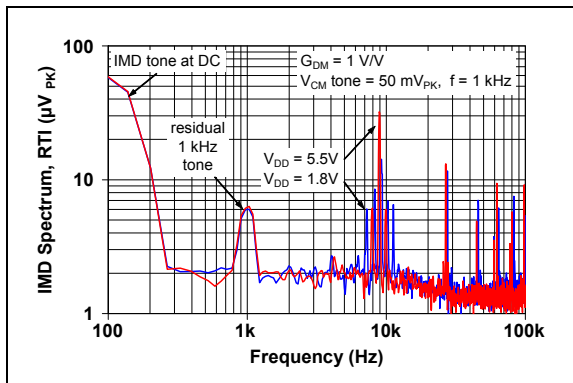
**FIGURE 2-38:** Inter-Modulation Distortion vs. Frequency with  $V_{DD}$  Disturbance (see Figure 1-7).



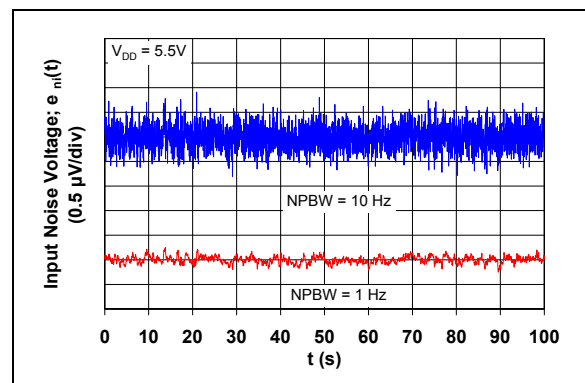
**FIGURE 2-36:** Input Noise Voltage Density vs. Input Common Mode Voltage.



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



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

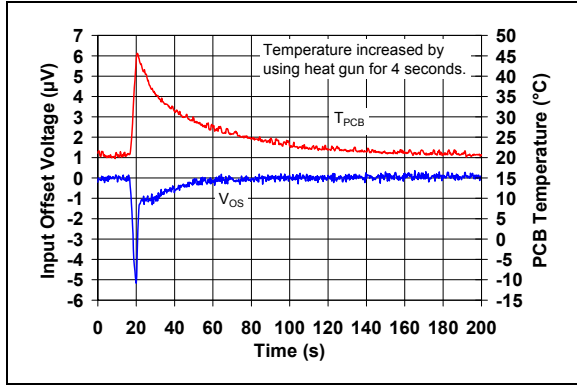


**FIGURE 2-40:** Input Noise vs. Time with 1 Hz and 10 Hz Filters and  $V_{DD} = 5.5\text{V}$ .

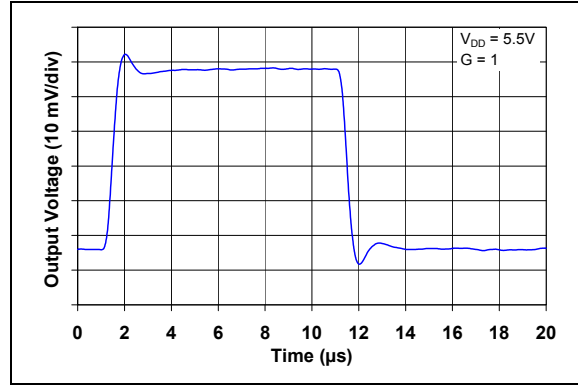
# MCP6V06/7/8

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

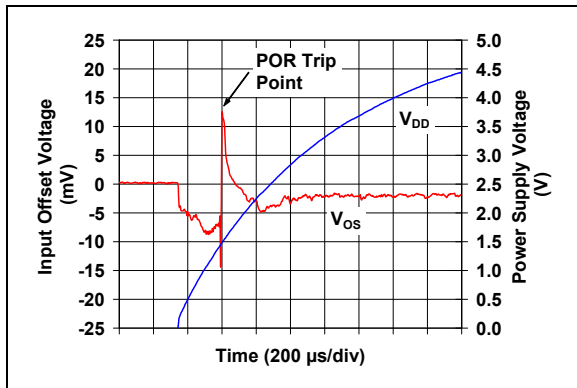
## 2.5 Time Response



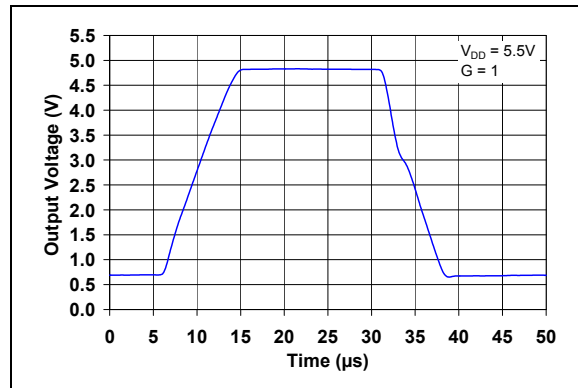
**FIGURE 2-41:** Input Offset Voltage vs. Time with Temperature Change.



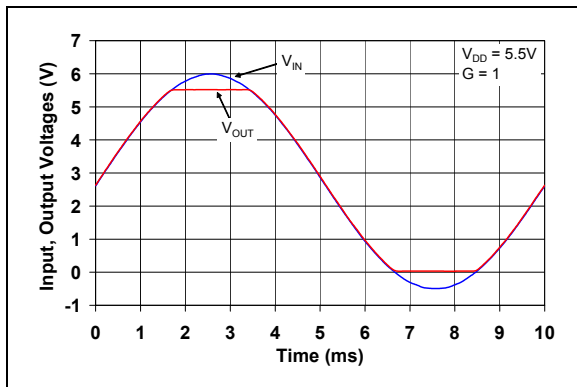
**FIGURE 2-44:** Non-inverting Small Signal Step Response.



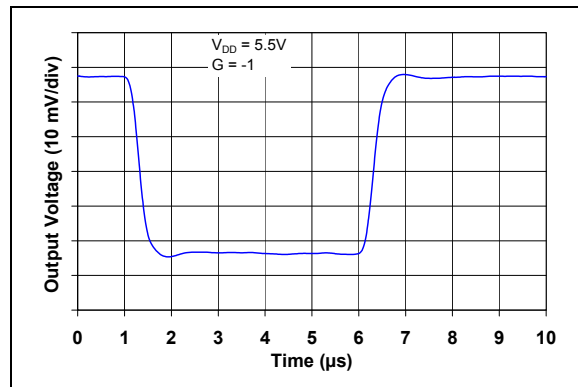
**FIGURE 2-42:** Input Offset Voltage vs. Time at Power Up.



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

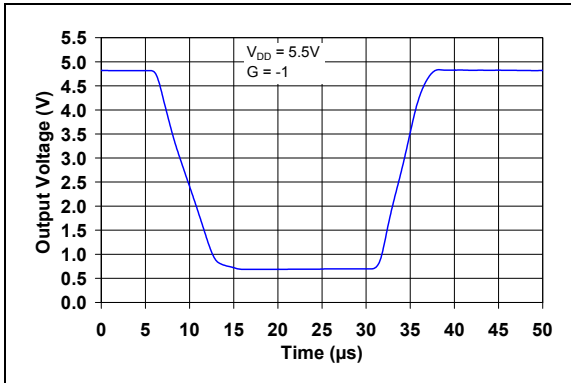


**FIGURE 2-43:** The MCP6V06/7/8 family shows no input phase reversal with overdrive.

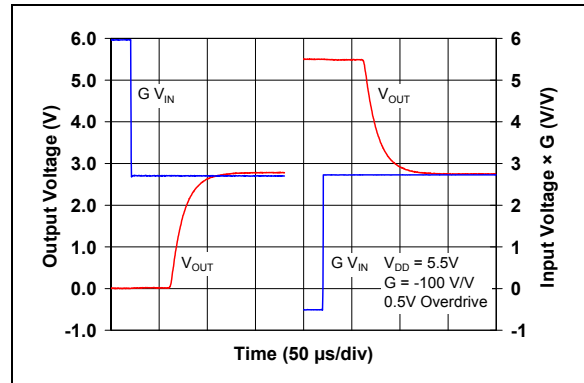


**FIGURE 2-46:** Inverting Small Signal Step Response.

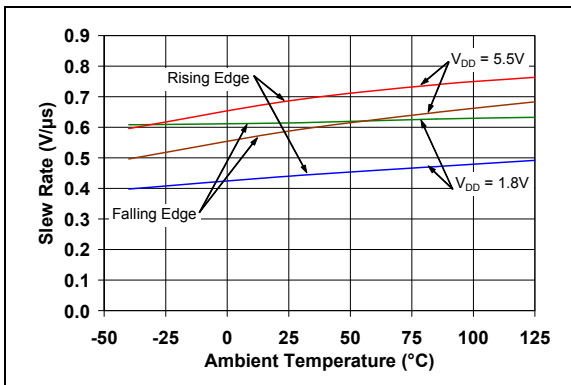
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.8\text{V}$  to  $5.5\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/3$ ,  $V_{OUT} = V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 20\text{ k}\Omega$  to  $V_L$ ,  $C_L = 60\text{ pF}$ , and  $\overline{\text{CS}} = \text{GND}$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



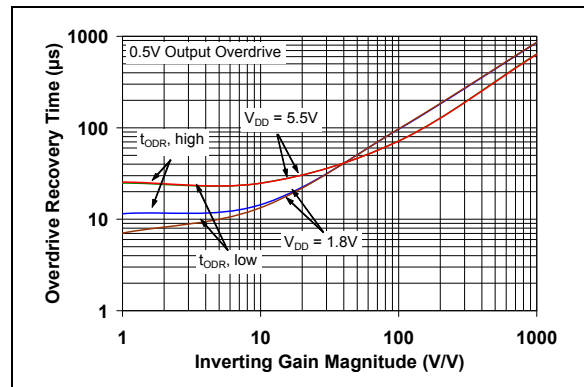
**FIGURE 2-47:** Inverting Large Signal Step Response.



**FIGURE 2-49:** Output Overdrive Recovery vs. Time with  $G = -100\text{ V/V}$ .



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

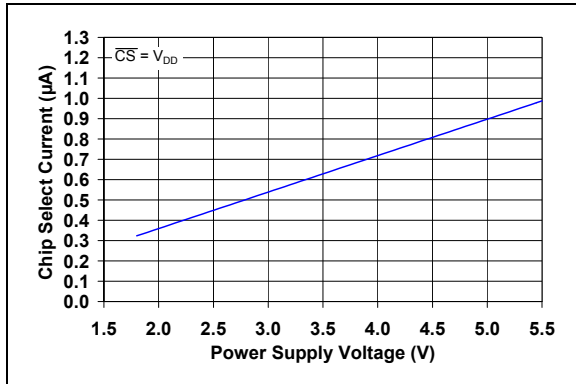


**FIGURE 2-50:** Output Overdrive Recovery Time vs. Inverting Gain.

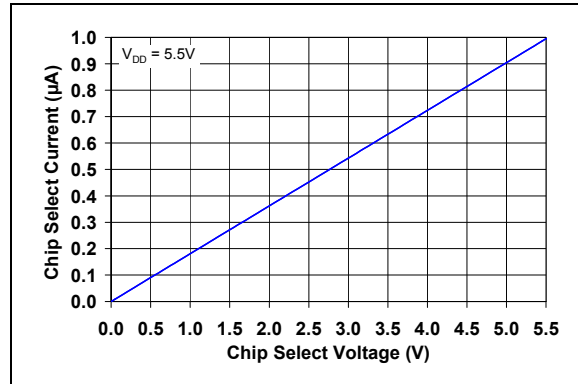
# MCP6V06/7/8

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

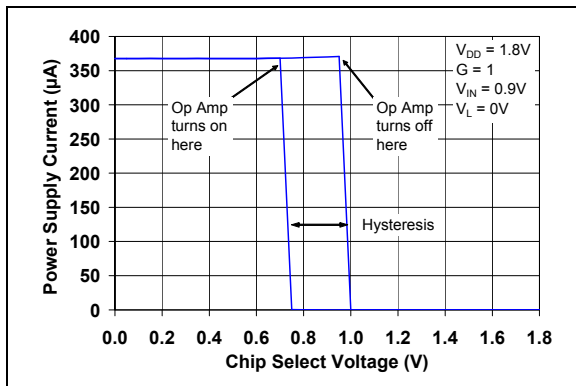
## 2.6 Chip Select Response (MCP6V08 only)



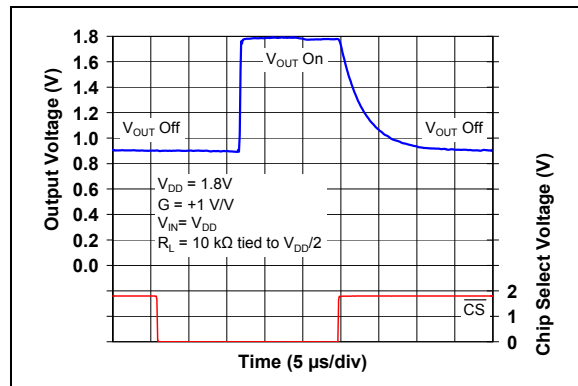
**FIGURE 2-51:** Chip Select Current vs. Power Supply Voltage.



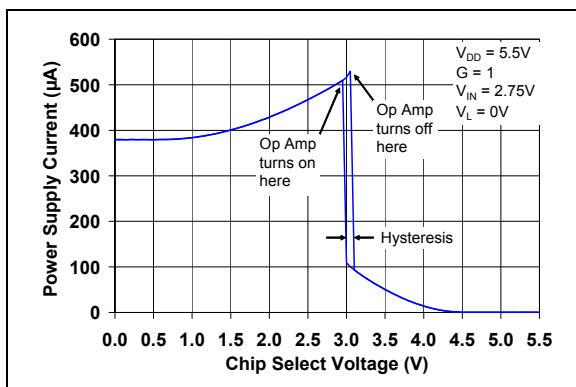
**FIGURE 2-54:** Chip Select Current vs. Chip Select Voltage.



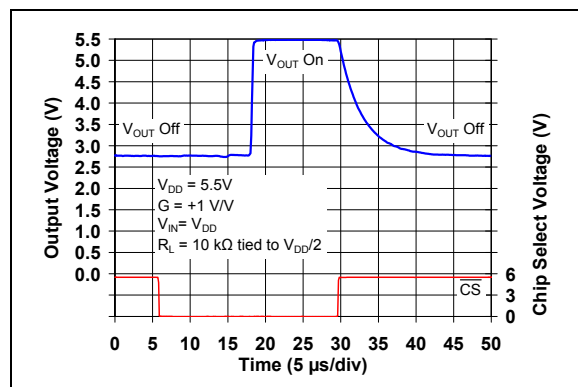
**FIGURE 2-52:** Power Supply Current vs. Chip Select Voltage with  $V_{DD} = 1.8\text{V}$ .



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



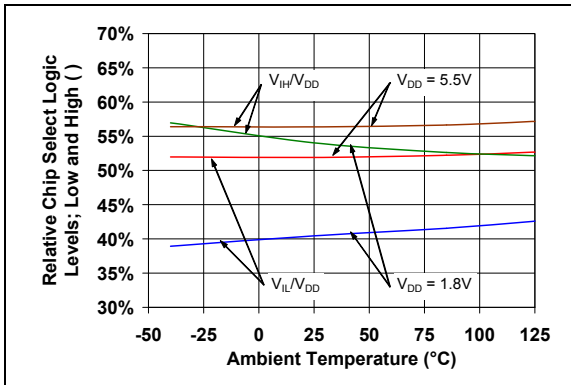
**FIGURE 2-53:** Power Supply Current vs. Chip Select Voltage with  $V_{DD} = 5.5\text{V}$ .



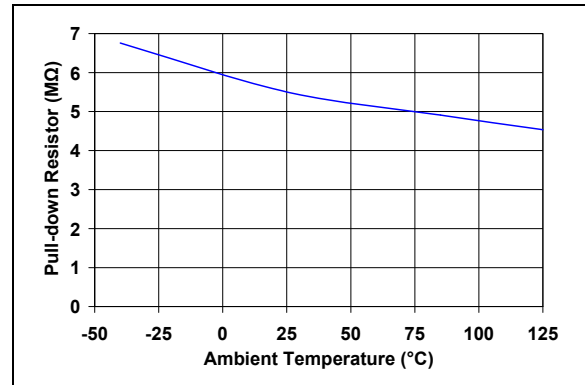
**FIGURE 2-56:** Chip Select Voltage, Output Voltage vs. Time with  $V_{DD} = 5.5\text{V}$ .



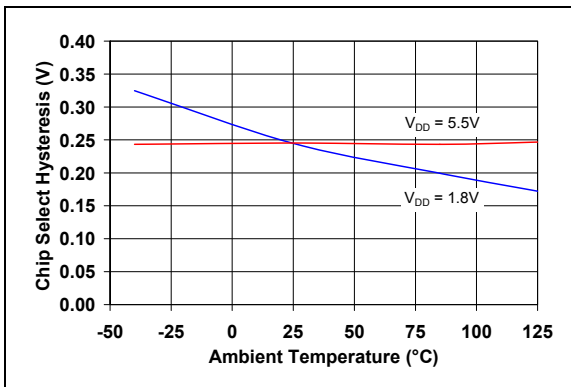
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.8\text{V}$  to  $5.5\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/3$ ,  $V_{OUT} = V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 20\text{ k}\Omega$  to  $V_L$ ,  $C_L = 60\text{ pF}$ , and  $\overline{\text{CS}} = \text{GND}$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



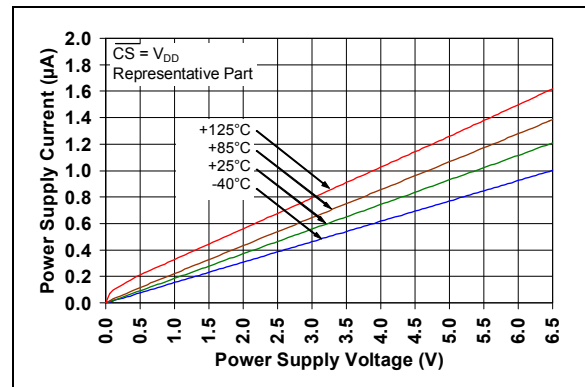
**FIGURE 2-57:** Chip Select Relative Logic Thresholds vs. Ambient Temperature.



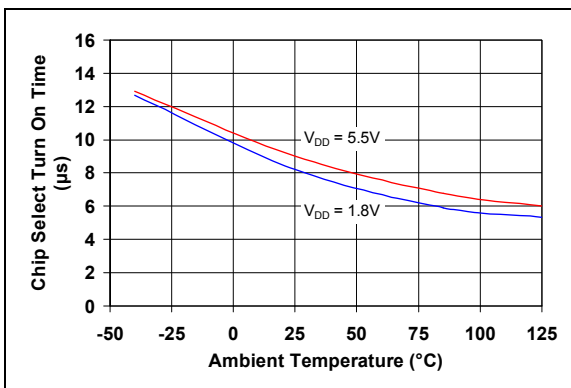
**FIGURE 2-60:** Chip Select's Pull-down Resistor ( $R_{PD}$ ) vs. Ambient Temperature.



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



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



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

# MCP6V06/7/8

## 3.0 PIN DESCRIPTIONS

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

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

MCP6V06	MCP6V07	MCP6V08	Symbol	Description
SOIC	DFN, SOIC	SOIC		
6	1	6	$V_{OUT}, V_{OUTA}$	Output (op amp A)
2	2	2	$V_{IN}^-, V_{INA}^-$	Inverting Input (op amp A)
3	3	3	$V_{IN}^+, V_{INA}^+$	Non-inverting Input (op amp A)
4	4	4	$V_{SS}$	Negative Power Supply
—	5	—	$V_{INB}^+$	Non-inverting Input (op amp B)
—	6	—	$V_{INB}^-$	Inverting Input (op amp B)
—	7	—	$V_{OUTB}$	Output (op amp B)
7	8	7	$V_{DD}$	Positive Power Supply
—	—	8	$\overline{CS}$	Chip Select (op amp A)
1, 5, 8	—	1, 5	NC	No Internal Connection

### 3.1 Analog Outputs

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

### 3.2 Analog Inputs

The non-inverting and inverting inputs ( $V_{IN}^+$ ,  $V_{IN}^-$ , ...) 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 ( $\overline{CS}$ ) Digital Input

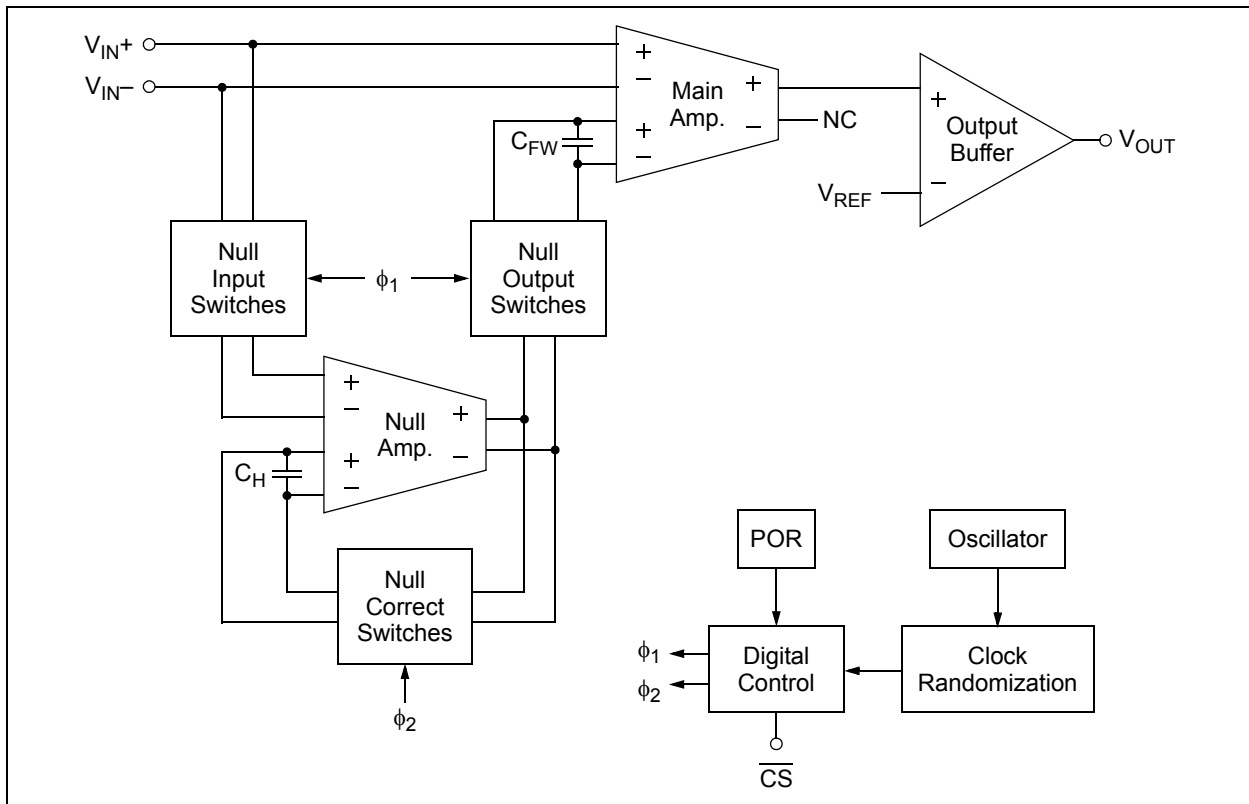
This pin ( $\overline{CS}$ ) is a CMOS, Schmitt-triggered input that places the MCP6V08 op amps into a low power mode of operation.

## 4.0 APPLICATIONS

The MCP6V06/7/8 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 MCP6V06/7/8 ideal for battery-powered applications.

## 4.1 Overview of Auto-zeroing Operation

Figure 4-1 shows a simplified diagram of the MCP6V06/7/8 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  $f_{OSC1} = 650$  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.

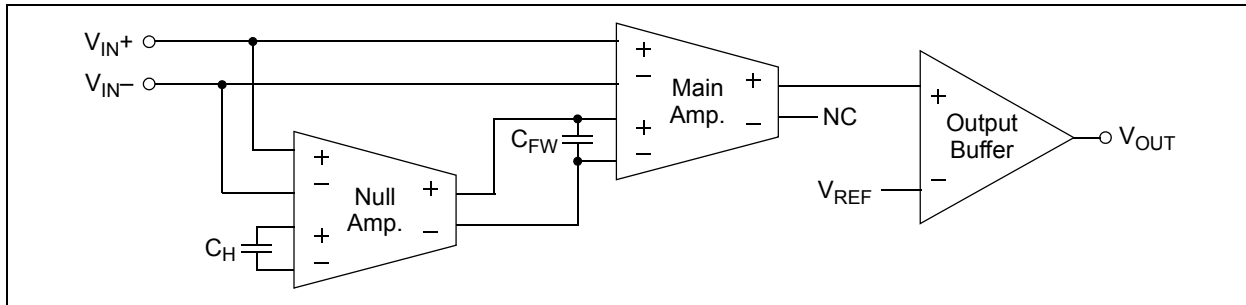
The Digital Control circuitry takes care of all of the housekeeping details of the switching operation. It also takes care of Chip Select and POR events.

# MCP6V06/7/8

## 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 ( $V_{OS}$ ).

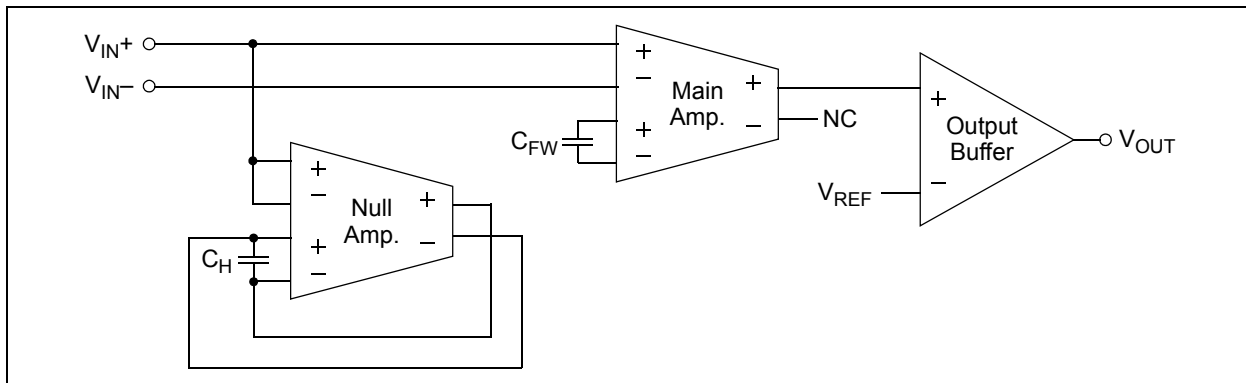


**FIGURE 4-2:** Normal Mode of Operation ( $\phi_1$ ); Equivalent Amplifier Diagram.

Figure 4-3 shows the connections between amplifiers during the Auto-zeroing Mode of operation ( $\phi_2$ ). The signal goes directly through the Main Amplifier, and the flywheel capacitor ( $C_{FW}$ ) maintains a constant correction on the Main Amplifier's offset.

Since these corrections happen every 50  $\mu$ 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.

The Null Amplifier uses its own high open loop gain to drive the voltage across  $C_H$  to the point where its input offset voltage is almost zero. Because the principal input is connected to  $V_{IN+}$ , the auto-zeroing action corrects the offset at the current common mode input voltage ( $V_{CM}$ ) and supply voltage ( $V_{DD}$ ). This makes the DC CMRR and PSRR very high also.



**FIGURE 4-3:** Auto-zeroing Mode of Operation ( $\phi_2$ ); Equivalent Diagram.

## 4.1.3 INTERMODULATION DISTORTION (IMD)

The MCP6V06/7/8 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. See Figure 2-37 and Figure 2-38.

## 4.2 Other Functional Blocks

### 4.2.1 RAIL-TO-RAIL INPUTS

The input stage of the MCP6V06/7/8 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.

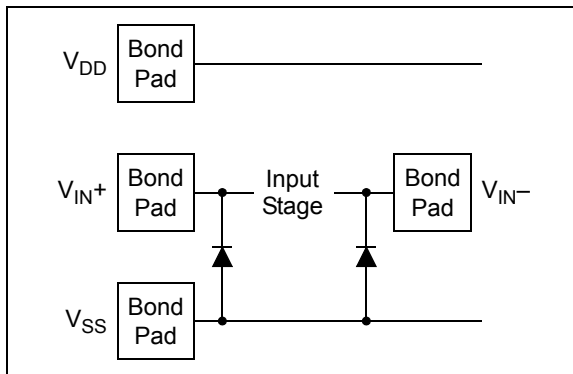
The transition between the input stages occurs when  $V_{CM} \approx V_{DD} - 0.9V$  (see Figure 2-7 and Figure 2-8). For the best distortion and gain linearity, with non-inverting gains, avoid this region of operation.

#### 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

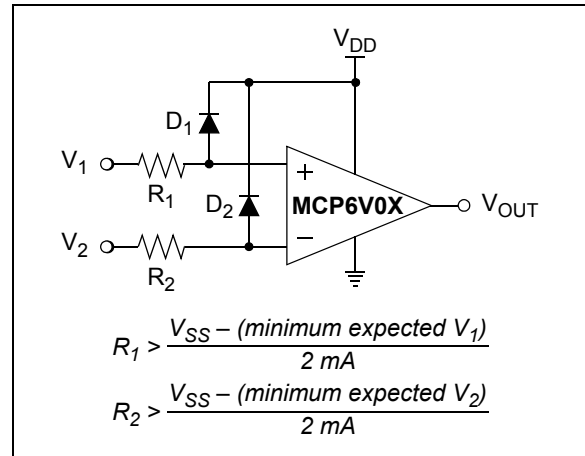
The ESD protection on the inputs can be depicted as shown in Figure 4-4. This structure was chosen to protect the input transistors, and to minimize input bias current ( $I_B$ ). The input ESD diodes clamp the inputs when they try to go more than one diode drop below  $V_{SS}$ . They also clamp any voltages 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.



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

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 below ground, and the resistors  $R_1$  and  $R_2$  limit the possible current drawn out of the input pins. Diodes  $D_1$  and  $D_2$  prevent the input

pins ( $V_{IN+}$  and  $V_{IN-}$ ) from going too far above  $V_{DD}$ , and dump any currents onto  $V_{DD}$ . When implemented as shown, resistors  $R_1$  and  $R_2$  also limit the current through  $D_1$  and  $D_2$ .



**FIGURE 4-5:** Protecting the Analog Inputs.

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 MCP6V06/7/8 auto-zeroed op amps is  $V_{DD} - 15\text{ mV}$  (minimum) and  $V_{SS} + 15\text{ mV}$  (maximum) when  $R_L = 20\text{ k}\Omega$  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 ( $\overline{CS}$ )

The single MCP6V08 has a Chip Select ( $\overline{CS}$ ) pin. When  $\overline{CS}$  is pulled high, the supply current for the corresponding op amp drops to about 1  $\mu\text{A}$  (typical), and is pulled through the  $\overline{CS}$  pin to  $V_{SS}$ . When this happens, the amplifier is put into a high impedance state. By pulling  $\overline{CS}$  low, the amplifier is enabled. If the  $\overline{CS}$  pin is left floating, the internal pull-down resistor (about 5  $M\Omega$ ) will keep the part on. Figure 1-4 shows the output voltage and supply current response to a  $\overline{CS}$  pulse.

# MCP6V06/7/8

## 4.3 Application Tips

### 4.3.1 INPUT OFFSET VOLTAGE OVER TEMPERATURE

Table 1-1 gives both the linear and quadratic temperature coefficients ( $TC_1$  and  $TC_2$ ) 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:

$\Delta T$	=	$T_A - 25^\circ\text{C}$
$V_{OS}(T_A)$	=	input offset voltage at $T_A$
$V_{OS}$	=	input offset voltage at $+25^\circ\text{C}$
$TC_1$	=	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  $\mu\text{V}/\text{V}$ ) of CMRR, PSRR and  $A_{OL}$ , 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  $1/A_{OL}$  histogram is centered near  $0 \mu\text{V}/\text{V}$  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 amp's 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  $+85^\circ\text{C}$  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  $10\Omega$  to  $1 \text{ k}\Omega$  at high frequencies (i.e., above  $1 \text{ MHz}$ ). 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.

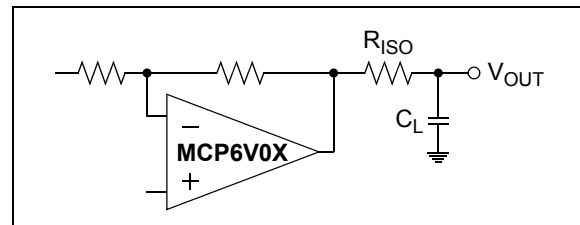


FIGURE 4-6: Output Resistor,  $R_{ISO}$ , Stabilizes Capacitive Loads.

Figure 4-7 gives recommended  $R_{ISO}$  values for different capacitive loads and is independent of the gain.

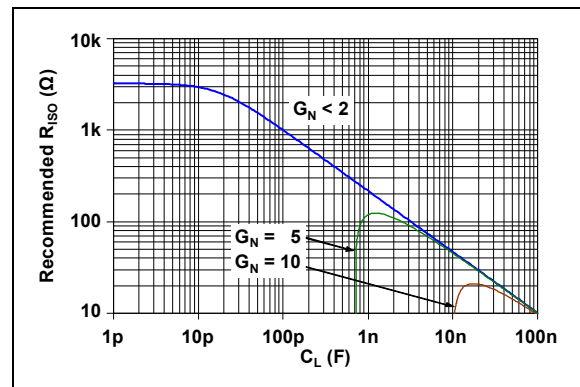


FIGURE 4-7: Recommended  $R_{ISO}$  values for Capacitive Loads.

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 MCP6V06 SPICE macro model (good for all of the MCP6V06/7/8 op amps) are helpful.

## 4.3.6 REDUCING UNDESIRED NOISE AND SIGNALS

Reduce undesired noise and signals with:

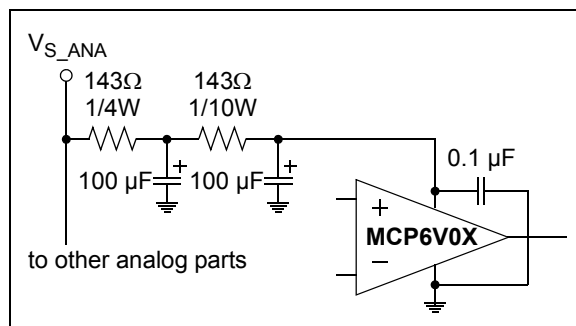
- Low bandwidth signal filters:
  - Minimizes random analog noise
  - Reduces interfering signals
- Good PCB layout techniques:
  - Minimizes crosstalk
  - Minimizes parasitic capacitances and inductances that interact with fast switching edges
- Good power supply design:
  - Isolation from other parts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

## 4.3.7 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.,  $0.01\ \mu\text{F}$  to  $0.1\ \mu\text{F}$ ) within 2 mm of the pin for good high-frequency performance.

These parts also need a bulk capacitor (i.e.,  $1\ \mu\text{F}$  or larger) within 100 mm to provide large, slow currents. This bulk capacitor can be shared with other 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 4-8](#) 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 4-8:** Additional Supply Filtering.

## 4.3.8 PCB DESIGN FOR DC PRECISION

In order to achieve DC precision on the order of  $\pm 1\ \mu\text{V}$ , 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 MCP6V06/7/8 op amps minimum and maximum specifications.

### 4.3.8.1 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  $100\ \mu\text{V}/^\circ\text{C}$  (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



# MCP6V06/7/8

## 4.3.8.2 Non-inverting and Inverting Amplifier Layout for Thermo-junctions

Figure 4-9 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:

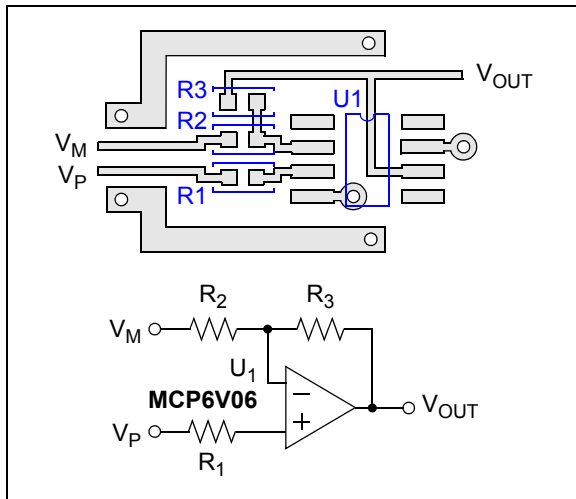
$$V_{OUT} \approx V_P G_P, \quad V_M = GND \\ \approx -V_M G_M, \quad V_P = GND$$

Where:

$$G_M = R_3/R_2, \quad \text{inverting gain magnitude}$$

$$G_P = 1 + G_M, \quad \text{non-inverting gain magnitude}$$

$V_{OS}$  is neglected



**FIGURE 4-9:** 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.

## 4.3.8.3 Difference Amplifier Layout for Thermo-junctions

Figure 4-10 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:

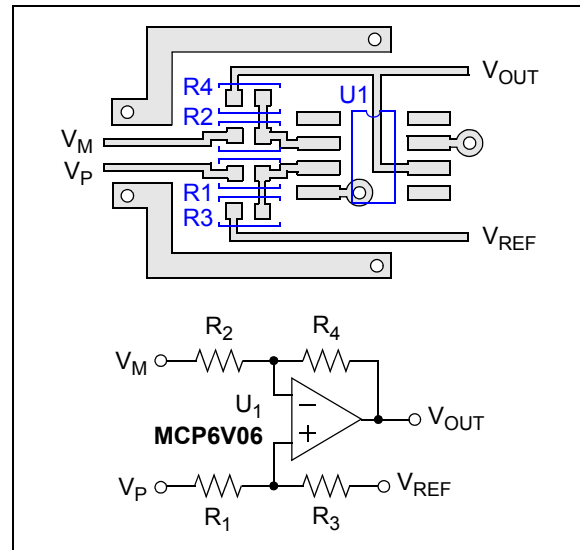
$$V_{OUT} \approx V_{REF} + (V_P - V_M)G_{DM}$$

Where:

Thermal voltages are approximately equal

$$G_{DM} = R_3/R_1 = R_4/R_2, \quad \text{difference gain}$$

$V_{OS}$  is neglected



**FIGURE 4-10:** 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.



## 4.3.8.4 Dual Non-inverting Amplifier Layout for Thermo-junctions

The dual op amp amplifiers shown in Figure 4-14 and Figure 4-15 produce a non-inverting difference gain greater than 1, and a common mode gain of 1. They can use the layout shown in Figure 4-11. 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:

$$(V_{OA} - V_{OB}) \approx (V_{IA} - V_{IB})G_{DM}$$

$$(V_{OA} + V_{OB})/2 \approx (V_{IA} + V_{IB})/2$$

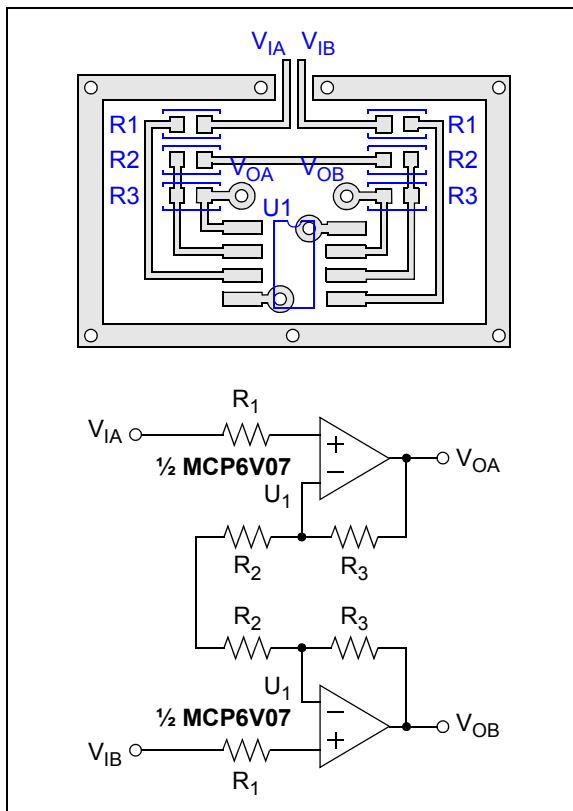
Where:

Thermal voltages are approximately equal

$$G_{DM} = 1 + R_3/R_2, \text{ differential mode gain}$$

$$G_{CM} = 1, \text{ common mode gain}$$

$V_{OS}$  is neglected

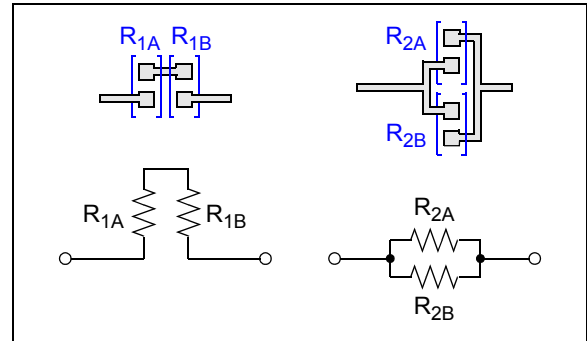


**FIGURE 4-11:** PCB Layout and Schematic for Dual Non-inverting Amplifier.

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

## 4.3.8.5 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 4-12. 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 4-12:** PCB Layout for Individual Resistors.

**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

# MCP6V06/7/8

## 4.3.8.6 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

## 4.3.8.7 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 or (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 4-13 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.

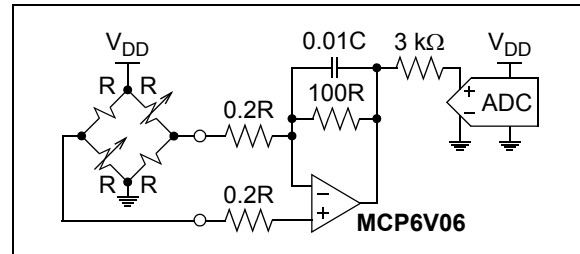


FIGURE 4-13: Simple Design.

Figure 4-14 shows a higher performance circuit for Wheatstone bridges. This circuit is symmetric and has high CMRR. Using a differential input to the ADC helps with the CMRR.

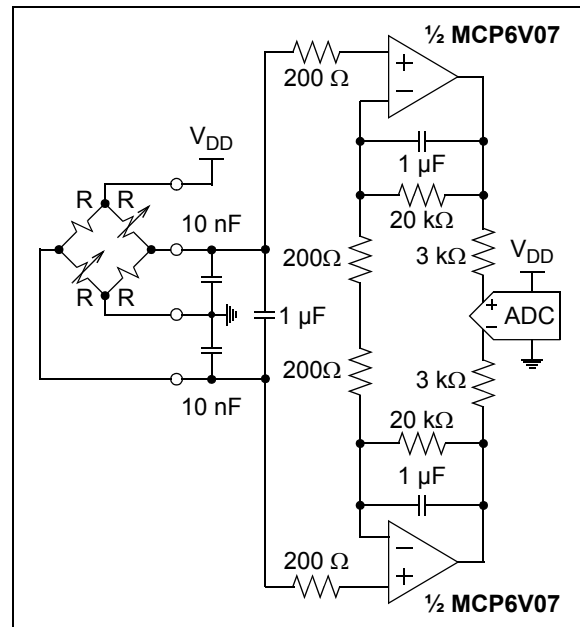
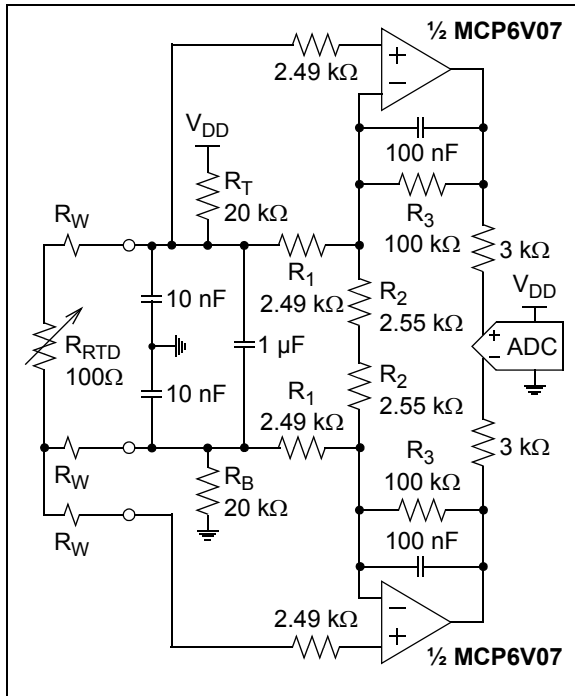


FIGURE 4-14: High Performance Design.

## 4.4.2 RTD SENSOR

The ratiometric circuit in [Figure 4-15](#) 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 4-15:** RTD Sensor.

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

$$G_{RTD} = 1 + 2 \cdot R_3/R_2$$

$$G_W = G_{RTD} - R_3/R_1$$

$$V_{DM} = G_{RTD}(V_T - V_B) + G_W V_W$$

$$V_{CM} = \frac{V_T + V_B + (G_{RTD} + 1 - G_W)V_W}{2}$$

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 4-16](#) 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 ( $T_{HJ}$ ), and produces a voltage at  $V_1$  proportional to  $T_{HJ}$  (in °C). The amplifier's

gain is set so that  $V_4/T_{HJ}$  is 10 mV/°C.  $V_3$  represents the output of a temperature sensor, which produces a voltage proportional to the temperature (in °C) at the cold junction ( $T_{CJ}$ ), and with a 0.50V offset.  $V_2$  is set so that  $V_4$  is 0.50V when  $T_{HJ} - T_{CJ}$  is 0°C.

### EQUATION 4-5:

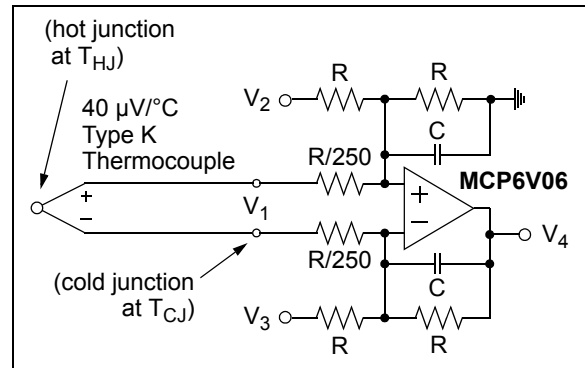
$$V_1 \approx T_{HJ}(40 \mu\text{V}/^\circ\text{C})$$

$$V_2 = (1.00\text{V})$$

$$V_3 = T_{CJ}(10 \text{ mV}/^\circ\text{C}) + (0.50\text{V})$$

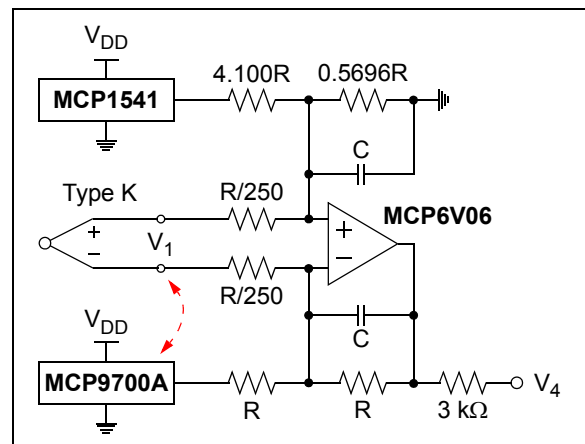
$$V_4 = 250V_1 + (V_2 - V_3)$$

$$\approx (10 \text{ mV}/^\circ\text{C})(T_{HJ} - T_{CJ}) + (0.50\text{V})$$



**FIGURE 4-16:** Thermocouple Sensor; Simplified Circuit.

[Figure 4-17](#) 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.



**FIGURE 4-17:** Thermocouple Sensor.

The MCP9700A senses the temperature at its physical location. It needs to be at the same temperature as the cold junction ( $T_{CJ}$ ), and produces  $V_3$  ([Figure 4-14](#)).

# MCP6V06/7/8

The MCP1541 produces a 4.10V output, assuming  $V_{DD}$  is at 5.0V. This voltage, tied to a resistor ladder of 4.100R and 1.3224R, would produce a Thevenin equivalent of 1.00V and 250R. The 1.3224R resistor is combined in parallel with the top right R resistor (in Figure 4-16), producing the 0.5696R resistor.

$V_4$  should be converted to digital, then corrected for the thermocouple's non-linearity. The ADC can use the MCP1541 as its voltage reference. Alternately, an absolute reference inside a PIC can be used instead of the MCP1541.

## 4.4.4 OFFSET VOLTAGE CORRECTION

Figure 4-18 shows a MCP6V06 correcting the input offset voltage of another op amp.  $R_2$  and  $C_2$  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  $R_1$  and  $R_3$ ).

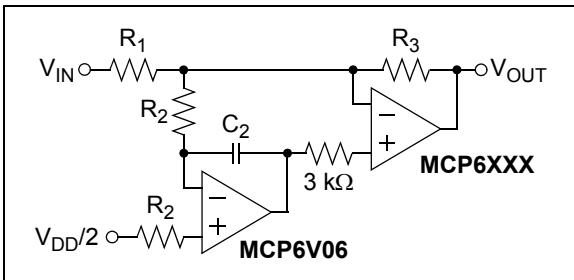


FIGURE 4-18: Offset Correction.

## 4.4.5 PRECISION COMPARATOR

Use high gain before a comparator to improve the latter's performance. Do not use MCP6V06/7/8 as a comparator by itself; the  $V_{OS}$  correction circuitry does not operate properly without a feedback loop.

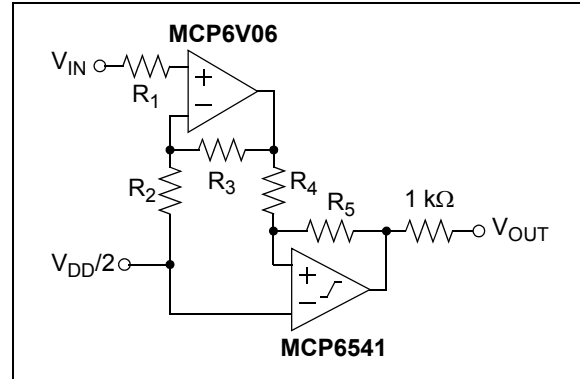


FIGURE 4-19: Precision Comparator.

## 5.0 DESIGN AIDS

Microchip provides the basic design aids needed for the MCP6V06/7/8 family of op amps.

### 5.1 SPICE Macro Model

The latest SPICE macro model for the MCP6V06/7/8 op amps is available on the Microchip web site at [www.microchip.com](http://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<sup>®</sup> Software

Microchip's FilterLab<sup>®</sup> software is an innovative software tool that simplifies analog active filter (using op amps) design. Available at no cost from the Microchip web site at [www.microchip.com/filterlab](http://www.microchip.com/filterlab), the 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<sup>™</sup> Circuit Designer & Simulator

Microchip's Mindi<sup>™</sup> Circuit Designer & Simulator aids in the design of various circuits useful for active filter, amplifier and power management applications. It is a free online circuit designer & simulator available from the Microchip web site at [www.microchip.com/mindi](http://www.microchip.com/mindi). This interactive circuit designer & simulator enables designers to quickly generate circuit diagrams, 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](http://www.microchip.com/maps), the MAPS is an overall selection tool for Microchip's product portfolio that includes Analog, Memory, MCUs and DSCs. Using this tool, a customer can define a filter to sort features for a parametric search of devices and export side-by-side technical comparison reports. Helpful links are also provided for Data sheets, Purchase and Sampling of Microchip parts.

## 5.5 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/analog](http://www.microchip.com/analog) 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](http://www.microchip.com/appnotes) and are recommended as supplemental reference resources.

**ADN003:** "Select the Right Operational Amplifier for your Filtering Circuits", DS21821

**AN722:** "Operational Amplifier Topologies and DC Specifications", DS00722

**AN723:** "Operational Amplifier AC Specifications and Applications", DS00723

**AN884:** "Driving Capacitive Loads With Op Amps", DS00884

**AN990:** "Analog Sensor Conditioning Circuits – An Overview", DS00990

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

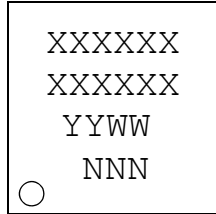
"Signal Chain Design Guide", DS21825

# MCP6V06/7/8

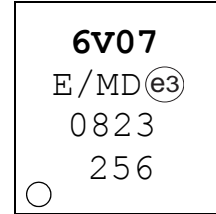
## 6.0 PACKAGING INFORMATION

### 6.1 Package Marking Information

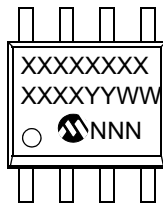
8-Lead DFN (4x4) (MCP6V07)



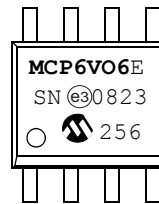
Example



8-Lead SOIC (150 mil)



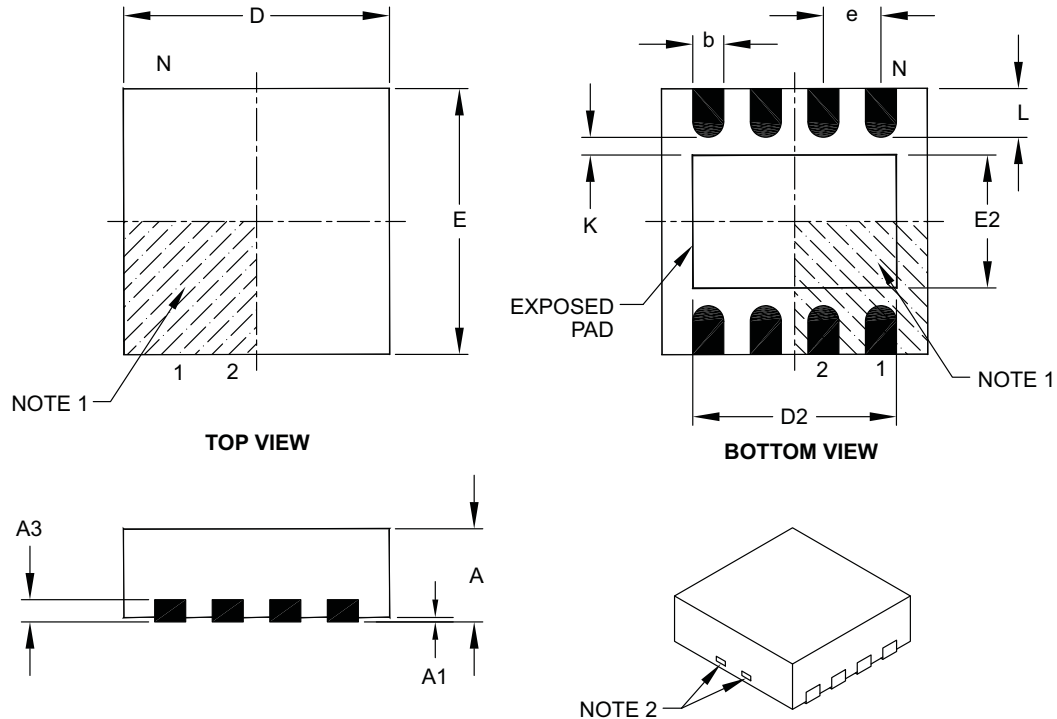
Example:



<b>Legend:</b>	XX...X	Customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week '01')
	NNN	Alphanumeric traceability code
	(e3)	Pb-free JEDEC designator for Matte Tin (Sn)
	*	This package is Pb-free. The Pb-free JEDEC designator (e3) can be found on the outer packaging for this package.
<b>Note:</b>	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>



Dimension Limits	Units	MILLIMETERS		
		MIN	NOM	MAX
Number of Pins	N	8		
Pitch	e	0.80 BSC		
Overall Height	A	0.80	0.90	1.00
Standoff	A1	0.00	0.02	0.05
Contact Thickness	A3	0.20 REF		
Overall Length	D	4.00 BSC		
Exposed Pad Width	E2	0.00	2.20	2.80
Overall Width	E	4.00 BSC		
Exposed Pad Length	D2	0.00	3.00	3.60
Contact Width	b	0.25	0.30	0.35
Contact Length	L	0.30	0.55	0.65
Contact-to-Exposed Pad	K	0.20	–	–

**Notes:**

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

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

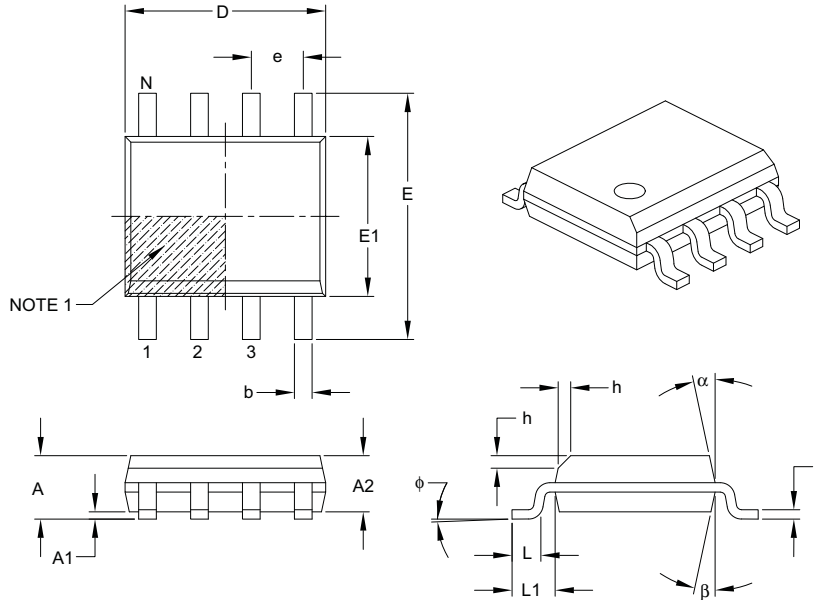
REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-131C

# MCP6V06/7/8

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

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



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

**Notes:**

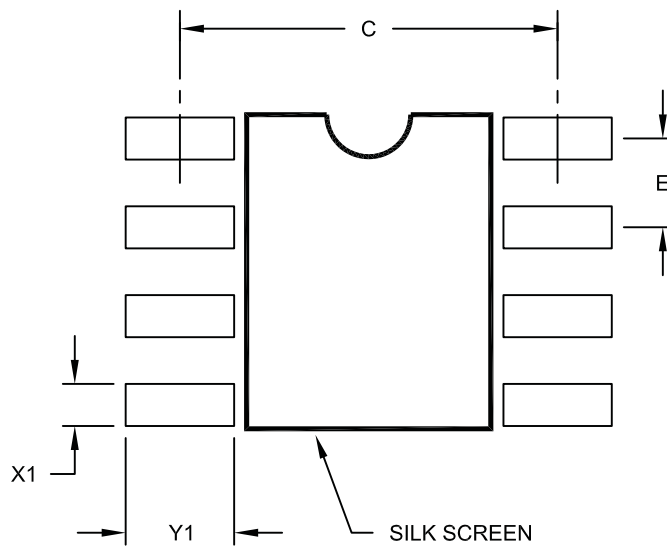
- Pin 1 visual index feature may vary, but must be located within the hatched area.
- § Significant Characteristic.
- Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15 mm per side.
- Dimensioning and tolerancing per ASME Y14.5M.  
 BSC: Basic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

Microchip Technology Drawing C04-057B



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

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



### RECOMMENDED LAND PATTERN

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

**Notes:**

1. Dimensioning and tolerancing per ASME Y14.5M

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

Microchip Technology Drawing No. C04-2057A

# MCP6V06/7/8

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NOTES:

## APPENDIX A: REVISION HISTORY

### Revision A (June 2008)

- Original Release of this Document.

# MCP6V06/7/8

## 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**

<b>Electrical Characteristics:</b> Unless otherwise indicated, $T_A = 25^\circ\text{C}$ , $V_{DD} = +1.8\text{V}$ to $+5.5\text{V}$ , $V_{SS} = \text{GND}$ , $V_{CM} = V_{DD}/3$ , $V_{OUT} = V_{DD}/2$ , $V_L = V_{DD}/2$ , $R_L = 20\text{ k}\Omega$ to $V_L$ , and $\overline{\text{CS}} = \text{GND}$ (refer to <a href="#">Figure 1-5</a> and <a href="#">Figure 1-6</a> ).					
Parameters	Sym	Min	Max	Units	Conditions
<b>Input Offset</b>					
Input Offset Voltage	$V_{OS}$	-10	+10	$\mu\text{V}$	$T_A = +25^\circ\text{C}$ ( <b>Note 1</b> , <b>Note 2</b> )
Input Offset Voltage Drift with Temperature (linear Temp. Co.)	$TC_1$	—	—	$\text{nV}/^\circ\text{C}$	$T_A = -40$ to $+125^\circ\text{C}$ ( <b>Note 3</b> )
Power Supply Rejection	PSRR	115	—	dB	( <b>Note 1</b> )
<b>Common Mode</b>					
Common Mode Rejection	CMRR	106	—	dB	$V_{DD} = 1.8\text{V}$ , $V_{CM} = -0.2\text{V}$ to $2.0\text{V}$ ( <b>Note 1</b> )
	CMRR	116	—	dB	$V_{DD} = 5.5\text{V}$ , $V_{CM} = -0.2\text{V}$ to $5.7\text{V}$ ( <b>Note 1</b> )
<b>Open-Loop Gain</b>					
DC Open-Loop Gain (large signal)	$A_{OL}$	114	—	dB	$V_{DD} = 1.8\text{V}$ , $V_{OUT} = 0.2\text{V}$ to $1.6\text{V}$ ( <b>Note 1</b> )
	$A_{OL}$	122	—	dB	$V_{DD} = 5.5\text{V}$ , $V_{OUT} = 0.2\text{V}$ to $5.3\text{V}$ ( <b>Note 1</b> )

- Note 1:** Due to thermal junctions and other errors in the production environment, these specifications are only screened in production.
- Note 2:**  $V_{OS}$  is also sample screened at  $+125^\circ\text{C}$ .
- Note 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.

<u>PART NO.</u>	<u>-X</u>	<u>XX</u>	
Device	Temperature Range	Package	
Device:	MCP6V06	Single Op Amp	
	MCP6V06T	Single Op Amp (Tape and Reel for SOIC)	
	MCP6V07	Dual Op Amp	
	MCP6V07T	Dual Op Amp (Tape and Reel for 4x4 DFN and SOIC)	
	MCP6V08	Single Op Amp with Chip Select	
	MCP6V08T	Single Op Amp with Chip Select (Tape and Reel for SOIC)	
Temperature Range:	E	= -40°C to +125°C	
Package:	MD	= Plastic Dual Flat, No-Lead (4x4x0.9), 8-lead (MCP6V07 only)	
	SN	= Plastic SOIC (150mil Body), 8-lead	

**Examples:**

- a) MCP6V06T-E/SN: Extended temperature, 8LD SOIC package.
- a) MCP6V07-E/MD: Extended temperature, 8LD 4x4 DFN.
- b) MCP6V07T-E/SN: Tape and Reel, Extended temperature, 8LD SOIC.
- a) MCP6V08-E/SN: Extended temperature, 8LD SOIC.

# MCP6V06/7/8

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NOTES:

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**Note the following details of the code protection feature on Microchip devices:**

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
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