



# MICROCHIP MCP601/602/603/604

## 2.7V to 5.5V Single Supply CMOS Op Amps

### FEATURES

- Specifications rated from 2.7V to 5.5V supplies
- Rail-to-rail swing at output
- Common-mode input swing below ground
- 2.8MHz GBWP
- Unity gain stable
- Low power  $I_{DD} = 325\mu\text{A}$  max
- Chip Select capability with MCP603
- Industrial temperature range (-40°C to 85°C)
- Available in single, dual and quad

### APPLICATIONS

- Portable Equipment
- A/D Converter Driver
- Photodiode Pre-amps
- Analog Filters
- Data Acquisition
- Notebooks and PDAs
- Sensor Interface

### AVAILABLE TOOLS

- Spice Macromodels (at [www.microchip.com](http://www.microchip.com))
  - **FilterLab™** Software (at [www.microchip.com](http://www.microchip.com))
- © 2000 Microchip Technology Inc.

### DESCRIPTION

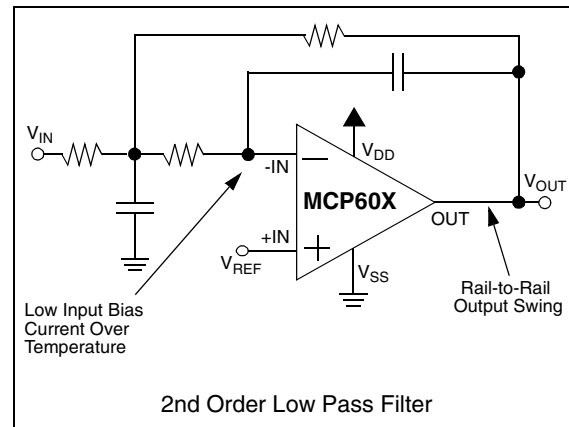
The Microchip Technology Inc. MCP601/602/603/604 family of low power operational amplifiers are offered in single (MCP601), single with a Chip Select pin feature (MCP603), dual (MCP602) and quad (MCP604) configurations. These operational amplifiers (op amps) utilize an advanced CMOS technology, which provides low bias current, high speed operation, high open-loop gain and rail-to-rail output swing. This product offering oper-

ates with a single supply voltage that can be as low as 2.7V, while drawing less than 325 $\mu\text{A}$  of quiescent current. In addition, the common-mode input voltage range goes 0.3V below ground, making these amplifiers ideal for single supply operation.

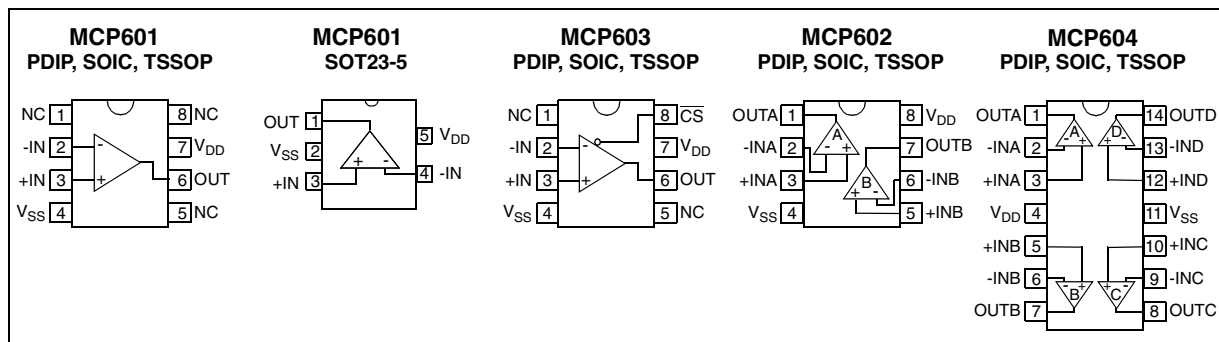
These devices are appropriate for low-power battery operated circuits due to the low quiescent current, for A/D Converter driver amplifiers because of their wide bandwidth, or for anti-aliasing filters by virtue of their low input bias current.

The MCP601, MCP602 and MCP603 are available in standard 8-lead PDIP, SOIC and TSSOP packages. The MCP601 is also available in the SOT23-5 package. The quad MCP604 is offered in 14-lead PDIP, SOIC and TSSOP packages. PDIP and SOIC packages are fully specified from -40°C to +85°C with power supplies from 2.7V to 5.5V.

### TYPICAL APPLICATION



### PACKAGES



# MCP601/602/603/604

## 1.0 ELECTRICAL CHARACTERISTICS

### 1.1 Maximum Ratings\*

$V_{DD}$ .....	7.0V
All inputs and outputs w.r.t. .... $V_{SS}$ -0.3V to $V_{DD}$ +0.3V	
Difference Input voltage .....	$ V_{DD} - V_{SS} $
Output Short Circuit Current .....	continuous
Current at Input Pin .....	$\pm 2$ mA
Current at Output and Supply Pins .....	$\pm 30$ mA
Storage temperature .....	-65°C to +150°C
Ambient temp. with power applied .....	-55°C to +125°C
Soldering temperature of leads (10 seconds) .....	+300°C
ESD Tolerance .....	3KV Human Body Model

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

## PIN FUNCTION TABLE

NAME	FUNCTION
+IN, +INA, +INB, +INC, +IND	Non-inverting Input Terminals
-IN, -INA, -INB, -INC, -IND	Inverting Input Terminals
$V_{DD}$	Positive Power Supply
$V_{SS}$	Negative Power Supply
OUT, OUTA, OUTB, OUTC, OUTD	Output Terminals
CS	Chip Select
NC	No internal connection to IC

## DC CHARACTERISTICS

Unless otherwise indicated, all limits are specified for  $V_{DD} = +2.7$ V to +5.5V,  $V_{SS} = \text{GND}$ ,  $T_A = 25^\circ\text{C}$ ,  $V_{CM} = V_{DD}/2$ ,  $R_L = 100\text{k}\Omega$  to  $V_{DD}/2$ , and  $V_{OUT} \sim V_{DD}/2$

PARAMETERS	SYMBOL	MIN.	TYP.	MAX.	UNITS	CONDITIONS
<b>INPUT OFFSET VOLTAGE</b>						
Input Offset Voltage	$V_{OS}$	-2	—	+2	mV	
Over Temperature <sup>(1)</sup>	$V_{OS}$	-3	—	+3	mV	$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$
Drift with Temperature	$dV_{OS}/dT$	—	$\pm 2.5$	—	$\mu\text{V}/^\circ\text{C}$	$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$
Power Supply Rejection	PSRR	—	40	100	$\mu\text{V}/\text{V}$	for $V_{DD} = 2.7$ V to 5.5V
<b>INPUT CURRENT AND IMPEDANCE</b>						
Input Bias Current	$I_B$	—	1	—	$\mu\text{A}$	
Over Temperature <sup>(2)</sup>	$I_B$	—	20	60	$\mu\text{A}$	$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$
Input Offset Bias Current	$I_{OS}$	—	1	—	$\mu\text{A}$	
Common Mode Input Impedance	$Z_{CM}$	—	$10^{13}  6$	—	$\Omega  \text{pF}$	
Differential Input Impedance	$Z_{DIFF}$	—	$10^{13}  3$	—	$\Omega  \text{pF}$	
<b>COMMON MODE</b>						
Common-Mode Input Range	$V_{CM}$	$V_{SS}-0.3$	—	$V_{DD}-1.2$	V	
Common-Mode Rejection Ratio	CMRR	75	90	—	dB	$V_{DD} = 5$ V, $V_{CM} = -0.3$ to 3.8V
<b>OPEN LOOP GAIN</b>						
DC Open Loop Gain	$A_{OL}$	100	115	—	dB	$R_L = 25\text{k}\Omega$ to $V_{DD}/2$ , $50\text{mV} < V_{OUT} < (V_{DD} - 50\text{mV})$
DC Open Loop Gain	$A_{OL}$	95	110	—	dB	$R_L = 5\text{k}\Omega$ to $V_{DD}/2$ , $100\text{mV} < V_{OUT} < (V_{DD} - 100\text{mV})$
<b>OUTPUT</b>						
Low Level/High Level Output Swing	$V_{OL}, V_{OH}$	$V_{SS} + 0.015$	—	$V_{DD} - 0.020$	V	$R_L = 25\text{k}\Omega$ to $V_{DD}/2$
	$V_{OL}, V_{OH}$	$V_{SS} + 0.045$	—	$V_{DD} - 0.060$	V	$R_L = 5\text{k}\Omega$ to $V_{DD}/2$
Linear Region Maximum Output Voltage Swing	$V_{OUT}$	$V_{SS} + 0.050$	—	$V_{DD} - 0.050$	V	$R_L = 25\text{k}\Omega$ to $V_{DD}/2$ , $A_{OL} \geq 100\text{dB}$
	$V_{OUT}$	$V_{SS} + 0.100$	—	$V_{DD} - 0.100$	V	$R_L = 5\text{k}\Omega$ to $V_{DD}/2$ , $A_{OL} \geq 95\text{dB}$
Output Short Circuit Current	$I_{SC}$	—	20	—	mA	$V_{OUT} = 2.5$ V, $V_{DD} = 5$ V
<b>POWER SUPPLY</b>						
Supply Voltage	$V_{DD}$	2.7	—	5.5	V	
Quiescent Current Per Amp	$I_Q$	—	230	325	$\mu\text{A}$	$I_L = 0$

**Note 1:** Max. and Min. specified for PDIP and SOIC packages only. Typical refers to all other packages

**Note 2:** Max. and Min. specified for PDIP, SOIC, and TSSOP packages only. Typical refers to all packages.

# MCP601/602/603/604

## AC CHARACTERISTICS

Unless otherwise indicated, all limits are specified for  $V_{DD} = +2.7V$  to  $+5.5V$ ,  $V_{SS} = GND$ ,  $T_A = 25^\circ C$ ,  $V_{CM} = V_{DD}/2$ ,  $R_L = 100k\Omega$  to  $V_{DD}/2$ , and  $V_{OUT} \sim V_{DD}/2$

PARAMETERS	SYMBOL	MIN.	TYP.	MAX.	UNITS	CONDITIONS
Gain Bandwidth Product	GBWP	—	2.8	—	MHz	$V_{DD} = 5V$
Phase Margin	$\theta_m$	—	50	—	degrees	$C_L = 50pF$ , $V_{DD} = 5V$
Slew Rate	SR	—	2.3	—	V/ $\mu s$	$G = +1V/V$ , $V_{DD} = 5V$
Setting Time to 0.01%		—	4.5	—	$\mu s$	for $\Delta V_{OUT} = 3.8V_{STEP}$ , $C_L = 50pF$ , $V_{DD} = 5V$ , $G = +1V/V$
<b>NOISE</b>						
Input Voltage Noise	$e_n$	—	7	—	$\mu V_{P-P}$	$f = 0.1Hz$ to $10Hz$
Input Voltage Noise Density	$e_n$	—	29	—	$nV/\sqrt{Hz}$	$f = 1kHz$
Input Current Noise Density	$i_n$	—	0.6	—	$fA/\sqrt{Hz}$	$f = 1kHz$

## SPECIFICATIONS FOR MCP603 CHIP SELECT FEATURE

Unless otherwise indicated, all limits are specified for  $V_{DD} = +2.7V$  to  $+5.5V$ ,  $V_{SS} = GND$ ,  $T_A = 25^\circ C$ ,  $V_{CM} = V_{DD}/2$ ,  $R_L = 100k\Omega$  to  $V_{DD}/2$ , and  $V_{OUT} \sim V_{DD}/2$

PARAMETERS	SYMBOL	MIN.	TYP.	MAX.	UNITS	CONDITIONS
<b>CS LOW SPECIFICATIONS</b>						
$\overline{CS}$ Logic Threshold, Low	$V_{IL}$	$V_{SS}$	$0.42 V_{DD}$	$0.2 V_{DD}$	V	For entire $V_{DD}$ range
$\overline{CS}$ Input Current, Low	$I_{CSL}$	-1.0	—	—	$\mu A$	$\overline{CS} = 0.2V_{DD}$
Amplifier Output Leakage, $\overline{CS}$ High		—	1	—	nA	
<b>CS HIGH SPECIFICATIONS</b>						
$\overline{CS}$ Logic Threshold, High	$V_{IH}$	$0.8 V_{DD}$	$0.51 V_{DD}$	$V_{DD}$	V	For entire $V_{DD}$ range
$\overline{CS}$ Input High, Shutdown $\overline{CS}$ Pin Current	$I_{CSH}$	—	0.7	2.0	$\mu A$	$\overline{CS} = V_{DD}$
$\overline{CS}$ Input High, Shutdown GND Current	$I_Q$	—	0.7	2.0	$\mu A$	$\overline{CS} = V_{DD}$
<b>DYNAMIC SPECIFICATIONS</b>						
$\overline{CS}$ Low to Amplifier Output High Turn-on Time	$t_{ON}$	—	3.1	10	$\mu s$	$\overline{CS}$ low $\leq 0.2V_{DD}$
$\overline{CS}$ High to Amplifier Output High Z	$t_{OFF}$	—	100	—	ns	$\overline{CS}$ high $\geq 0.8V_{DD}$ , No Load
$\overline{CS}$ Threshold Hysteresis		—	0.3	—	V	

## TEMPERATURE SPECIFICATIONS

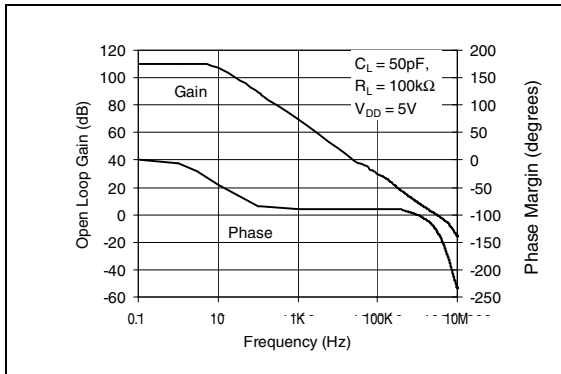
Unless otherwise indicated, all limits are specified for  $V_{DD} = +2.7V$  to  $+5.5V$ ,  $V_{SS} = GND$

PARAMETERS	SYMBOL	MIN.	TYP.	MAX.	UNITS	CONDITIONS
<b>TEMPERATURE RANGE</b>						
Specified Temperature Range	$T_A$	-40	—	+85	$^\circ C$	
Operating Temperature Range	$T_A$	-40	—	+85	$^\circ C$	
Storage Temperature Range	$T_A$	-65	—	+150	$^\circ C$	
<b>THERMAL PACKAGE RESISTANCE</b>						
Thermal Resistance, 5L-SOT23-5	$\theta_{JA}$	—	256	—	$^\circ C/W$	
Thermal Resistance, 8L-PDIP	$\theta_{JA}$	—	85	—	$^\circ C/W$	
Thermal Resistance, 8L-SOIC	$\theta_{JA}$	—	163	—	$^\circ C/W$	
Thermal Resistance, 8L-TSSOP	$\theta_{JA}$	—	124	—	$^\circ C/W$	
Thermal Resistance, 14L-PDIP	$\theta_{JA}$	—	70	—	$^\circ C/W$	
Thermal Resistance, 14L-SOIC	$\theta_{JA}$	—	120	—	$^\circ C/W$	
Thermal Resistance, 14L-TSSOP	$\theta_{JA}$	—	100	—	$^\circ C/W$	

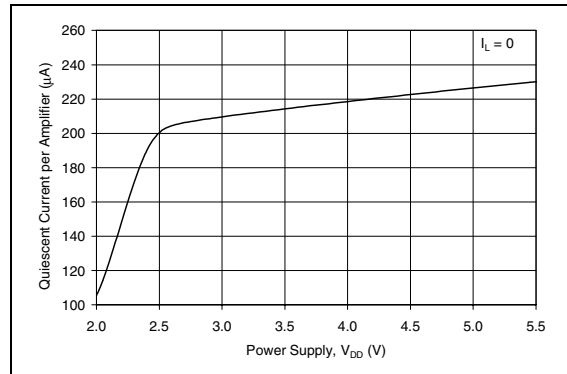
# MCP601/602/603/604

## 2.0 TYPICAL PERFORMANCE CURVES

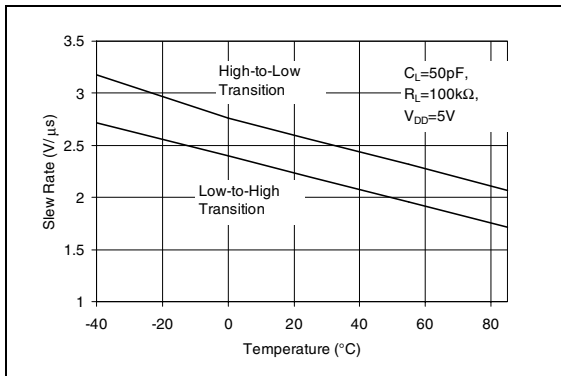
**Note:** Unless otherwise indicated,  $V_{DD} = +2.7V$  to  $+5.5V$ ,  $T_A = 25^\circ C$ ,  $V_{CM} = V_{DD}/2$ ,  $R_L = 25k\Omega$  to  $V_{DD}/2$  and  $V_{OUT} \sim V_{DD}/2$



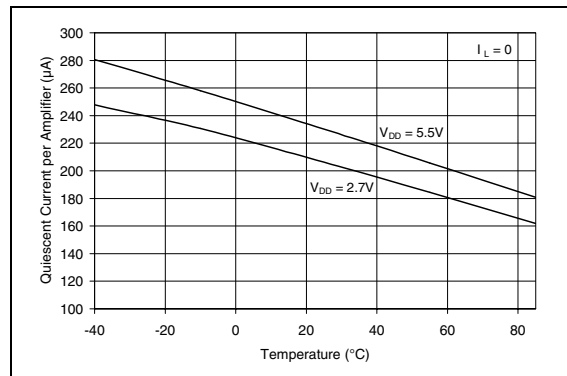
**FIGURE 2-1:** Open Loop Gain, Phase Margin vs. Frequency



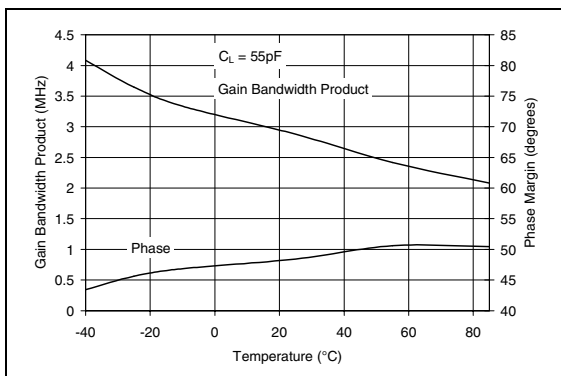
**FIGURE 2-4:** Quiescent Current vs. Power Supply



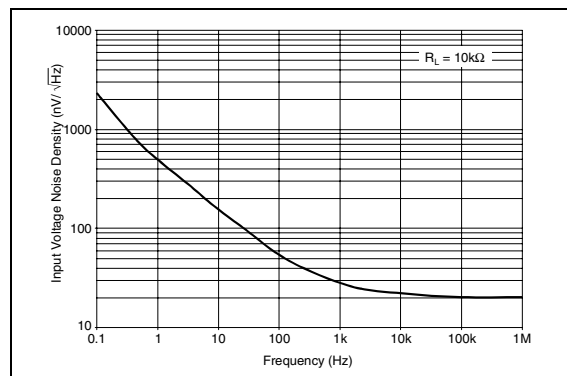
**FIGURE 2-2:** Slew Rate vs. Temperature



**FIGURE 2-5:** Quiescent Current vs. Temperature



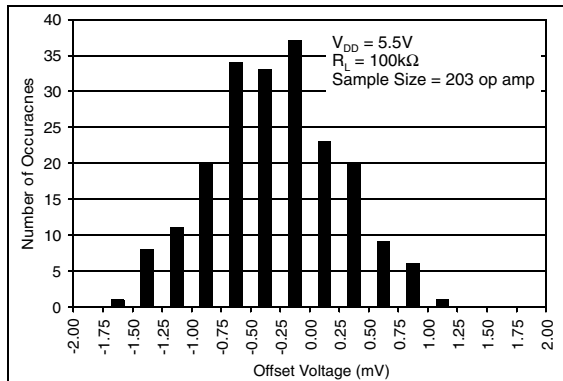
**FIGURE 2-3:** Gain Bandwidth Product vs. Temperature



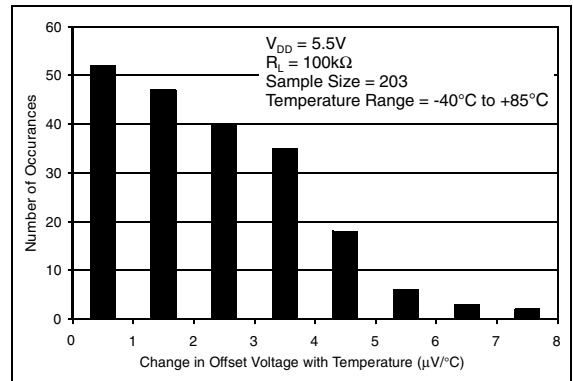
**FIGURE 2-6:** Input Voltage Noise Density vs. Frequency

# MCP601/602/603/604

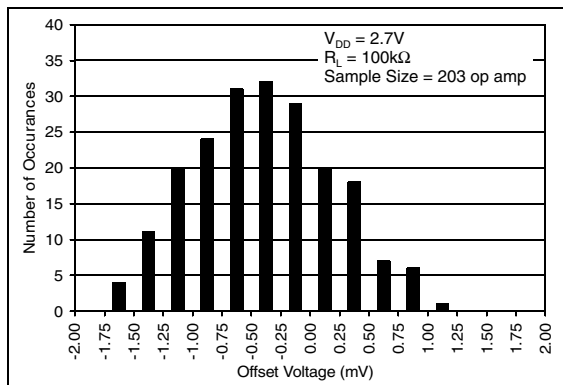
**Note:** Unless otherwise indicated,  $V_{DD} = +2.7V$  to  $+5.5V$ ,  $T_A = 25^\circ C$ ,  $V_{CM} = V_{DD}/2$ ,  $R_L = 25k\Omega$  to  $V_{DD}/2$  and  $V_{OUT} \sim V_{DD}/2$



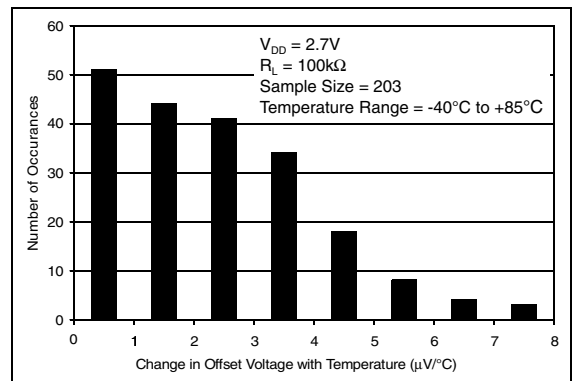
**FIGURE 2-7:** Offset Voltage vs. Number of Occurrences with  $V_{DD} = 5.5V$



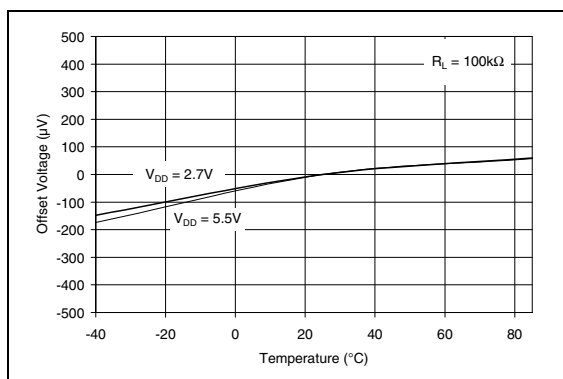
**FIGURE 2-10:** Offset Voltage Drift vs. Number of Occurrences with  $V_{DD} = 5.5V$



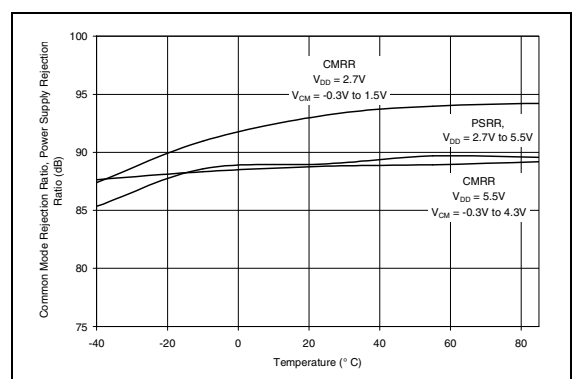
**FIGURE 2-8:** Offset Voltage vs. Number of Occurrences with  $V_{DD} = 2.7V$ .



**FIGURE 2-11:** Offset Voltage Drift vs. Number of Occurrences with  $V_{DD} = 2.7V$



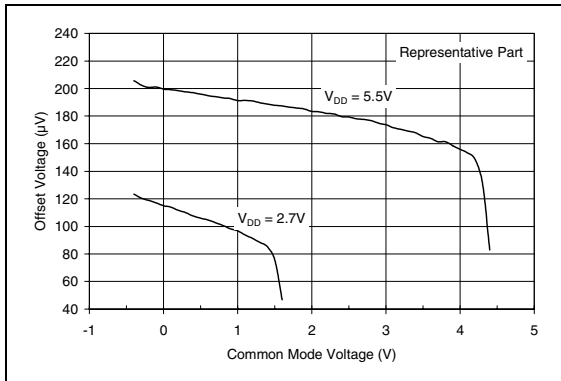
**FIGURE 2-9:** Normalized Offset Voltage vs. Temperature with  $V_{DD} = 2.7V$



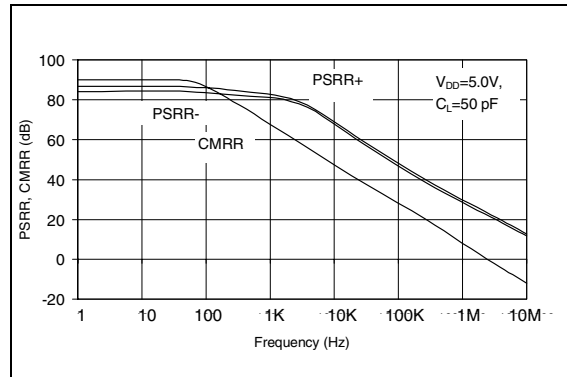
**FIGURE 2-12:** Common-Mode Rejection Ratio, Power Supply Rejection Ratio vs. Temperature

# MCP601/602/603/604

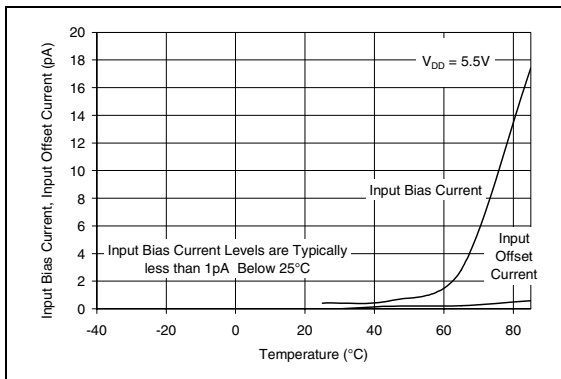
**Note:** Unless otherwise indicated,  $V_{DD} = +2.7V$  to  $+5.5V$ ,  $T_A = 25^\circ C$ ,  $V_{CM} = V_{DD}/2$ ,  $R_L = 25k\Omega$  to  $V_{DD}/2$  and  $V_{OUT} \sim V_{DD}/2$



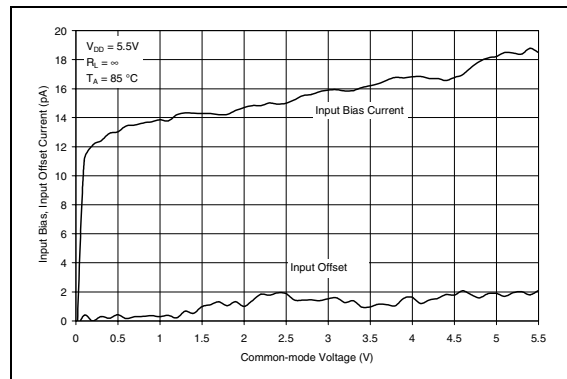
**FIGURE 2-13:** Offset Voltage vs. Common-Mode Voltage



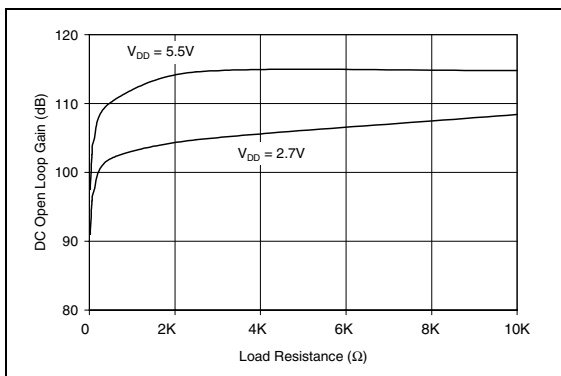
**FIGURE 2-16:** Common-Mode Rejection Ratio, Power Supply Rejection Ratio vs. Frequency



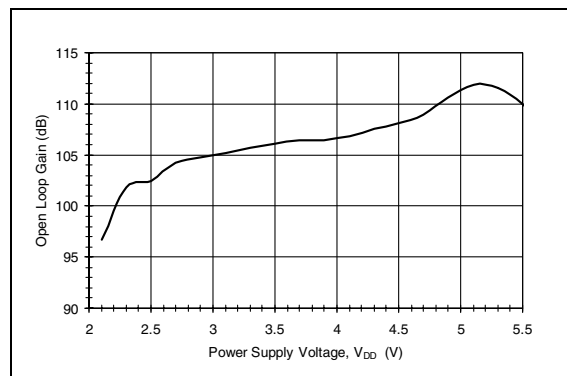
**FIGURE 2-14:** Input Bias Current, Input Offset Current vs. Temperature



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



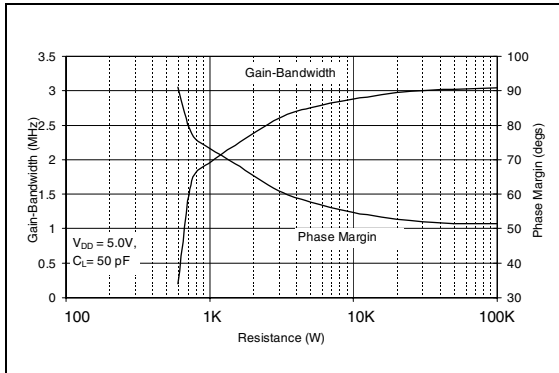
**FIGURE 2-15:** DC Open Loop Gain vs. Output Load



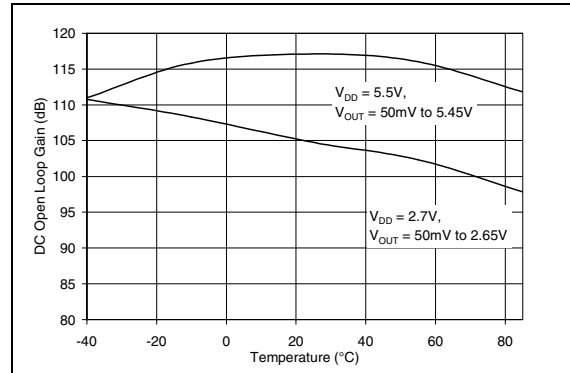
**FIGURE 2-18:** DC Open Loop Gain vs. Power Supply

# MCP601/602/603/604

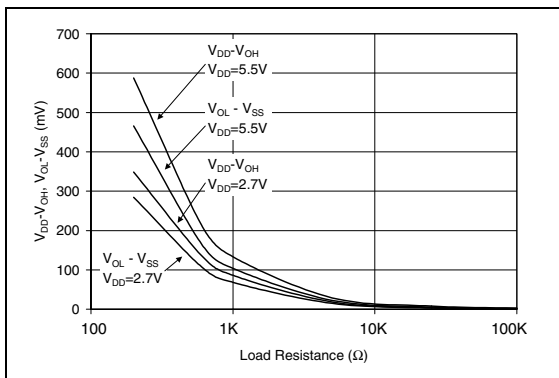
**Note:** Unless otherwise indicated,  $V_{DD} = +2.7V$  to  $+5.5V$ ,  $V_{SS} = GND$ ,  $T_A = 25^\circ C$ ,  $V_{CM} = V_{DD}/2$ ,  $R_L = 25k\Omega$  to  $V_{DD}/2$  and  $V_{OUT} \sim V_{DD}/2$



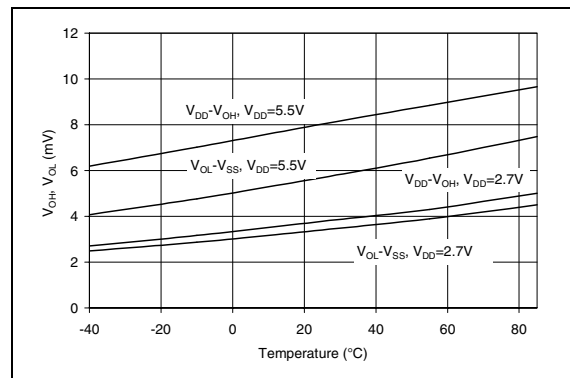
**FIGURE 2-19:** Gain Bandwidth, Phase Margin vs. Load Resistance



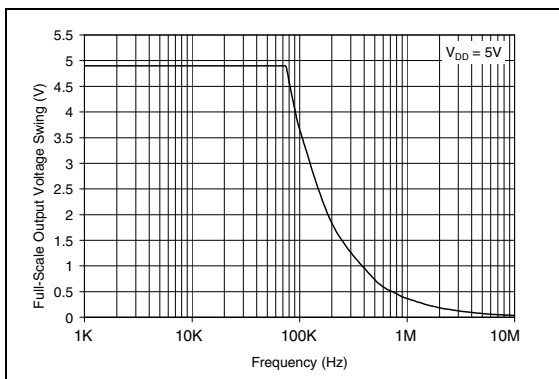
**FIGURE 2-22:** DC Open Loop Gain vs. Temperature



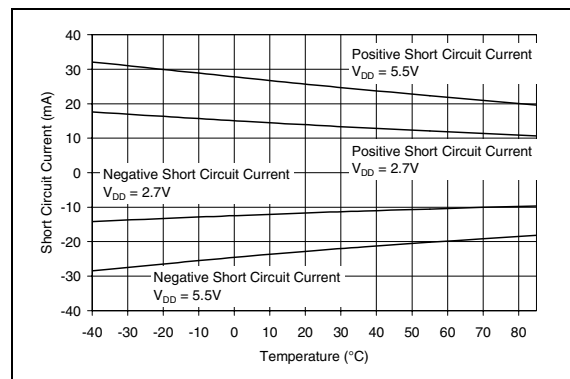
**FIGURE 2-20:** Low Level and High Level Output Swing vs. Resistive Load



**FIGURE 2-23:** Low Level and High Level Output Swing vs. Temperature



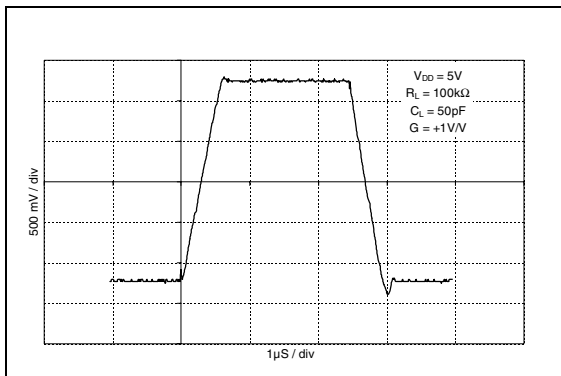
**FIGURE 2-21:** Maximum Full Scale Output Voltage Swing vs. Frequency



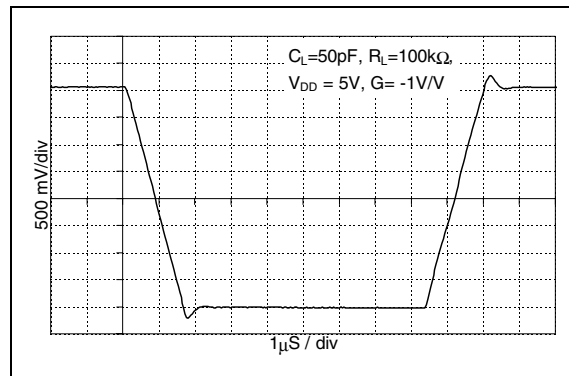
**FIGURE 2-24:** Output Short Circuit Current vs. Temperature

# MCP601/602/603/604

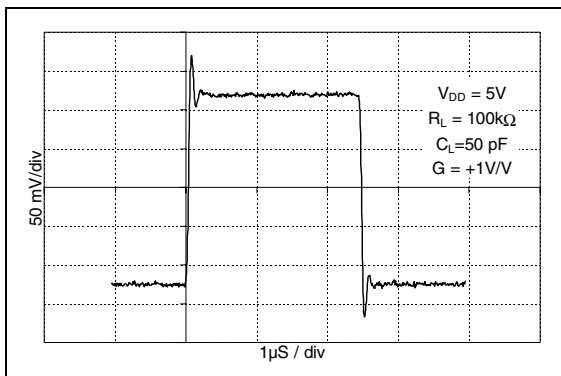
**Note:** Unless otherwise indicated,  $V_{DD} = +2.7V$  to  $+5.5V$ ,  $V_{SS} = GND$ ,  $T_A = 25^\circ C$ ,  $V_{CM} = V_{DD}/2$ ,  $R_L = 25k\Omega$  to  $V_{DD}/2$  and  $V_{OUT} \sim V_{DD}/2$



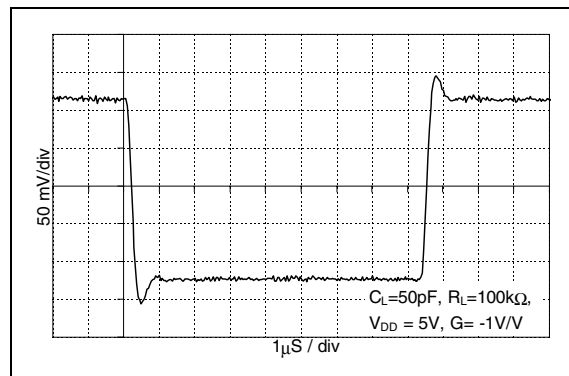
**FIGURE 2-25:** Large Signal Non-Inverting Signal Pulse Response



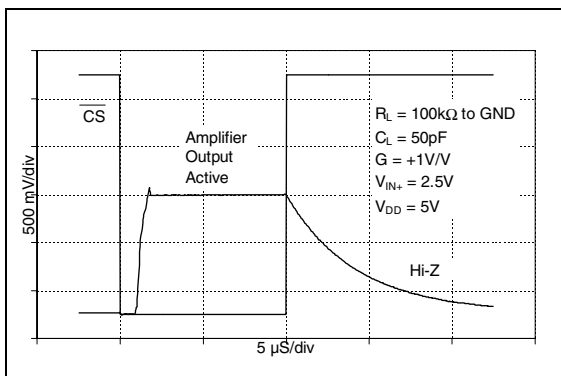
**FIGURE 2-28:** Large Signal Inverting Signal Pulse Response



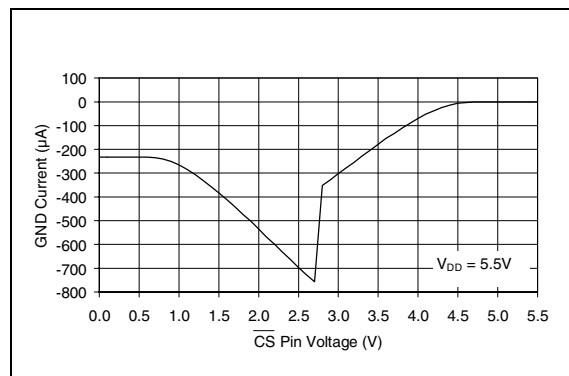
**FIGURE 2-26:** Small Signal Non-inverting Pulse Response



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



**FIGURE 2-27:** Chip Select to Amplifier Output Response Time

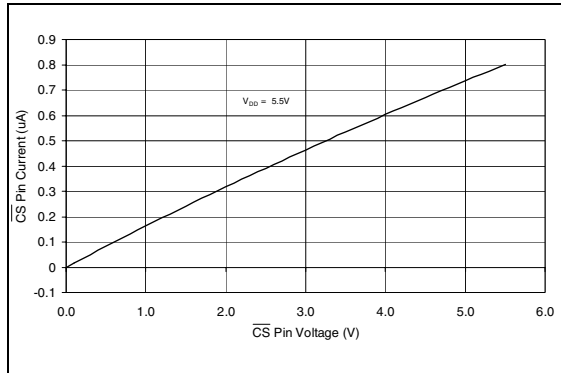


**FIGURE 2-30:** GND Current vs.  $\overline{CS}$  Voltage

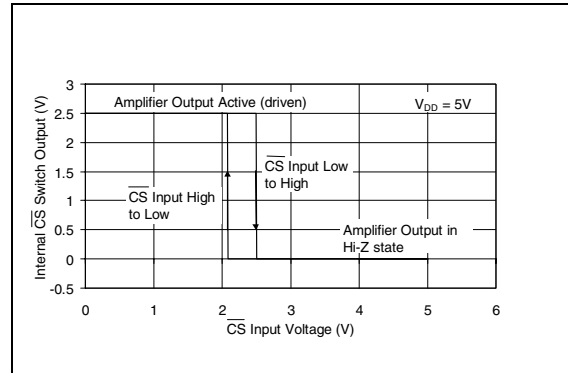


# MCP601/602/603/604

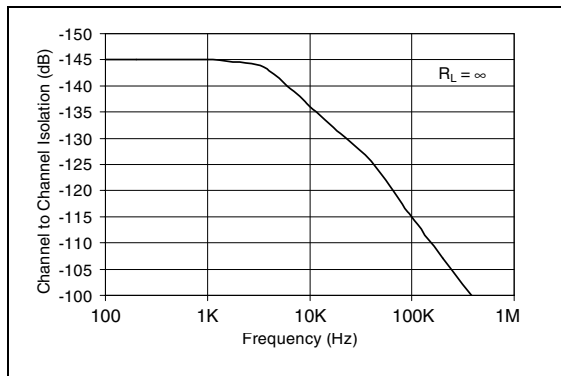
**Note:** Unless otherwise indicated,  $V_{DD} = +2.7V$  to  $+5.5V$ ,  $V_{SS} = GND$ ,  $T_A = 25^\circ C$ ,  $V_{CM} = V_{DD}/2$ ,  $R_L = 25k\Omega$  to  $V_{DD}/2$  and  $V_{OUT} \sim V_{DD}/2$



**FIGURE 2-31:** Input  $\overline{CS}$  Current vs.  $\overline{CS}$  Voltage



**FIGURE 2-33:** CS hysteresis



**FIGURE 2-32:** Channel to Channel Separation

# MCP601/602/603/604

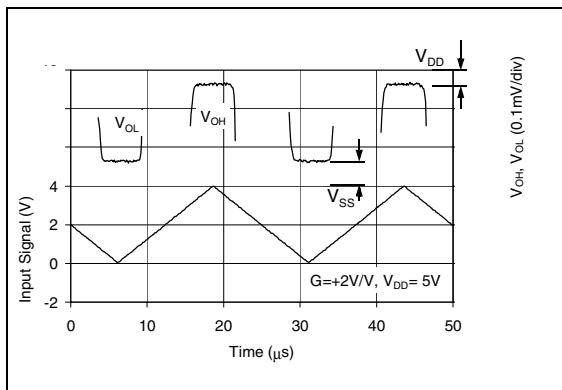
## 3.0 APPLICATIONS INFORMATION

The MCP601/602/603/604 family of operational amplifiers are fabricated on Microchip's state-of-the-art CMOS process. They are unity gain stable and suitable for a wide range of general purpose applications. With this family of operational amplifiers, the power supply pin should be by-passed with a 1 $\mu$ F capacitor.

### 3.1 Rail-to-Rail Output Swing

There are two specifications that describe the output swing capability of the MCP601/602/603/604 family of operational amplifiers. The first specification, Low Level and High Level Output Voltage Swing, defines the absolute maximum swing that can be achieved under specified loaded conditions. For instance, the Low Level Output Voltage Swing of the MCP601/602/603/604 family is specified to be able to swing at least to 15mV from the negative rail with a 25k $\Omega$  load to  $V_{DD}/2$ .

This output swing performance is shown in Figure 3-1, where the output of an MCP601 is configured in a gain of +2V/V and over driven with a 40kHz triangle wave. In this figure, the degradation of the output swing linearity is clearly illustrated. This degradation occurs after the point at which the open loop gain of the amplifier is specified and before the amplifier reaches its maximum and minimum output swing.



**FIGURE 3-1:** Low Level and High Level Output Swing

The second specification that describes the output swing capability of these amplifiers is the Linear Region Maximum Output Voltage Swing. This specification defines the maximum output swing that can be achieved while the amplifier is still operating in its linear region.

The Linear Region Maximum Output Voltage Swing of the MCP601/602/603/604 family is specified within 50mV from the positive and negative rail with a 25k $\Omega$  load and 100mV from the rails with a 5k $\Omega$  load. The overriding condition that defines the linear region of the amplifier is the open loop gain that is specified over that region. In the voltage output region between  $V_{SS} + 50mV$  and  $V_{DD} - 50mV$ , the open loop gain is specified to 100dB (min) with a 25k $\Omega$  load.

The classical definition of the open loop gain of an amplifier is:

$$A_{OL} = \Delta V_{OUT} / \Delta V_{OS}$$

where:

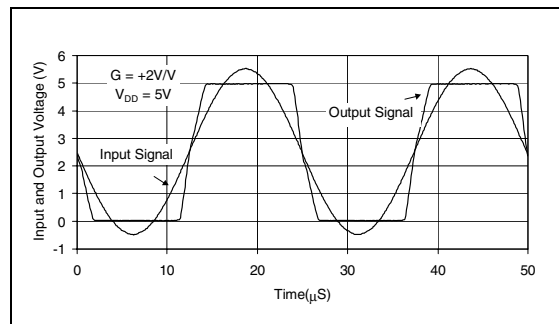
$A_{OL}$  is the DC open loop gain of the amplifier,

$\Delta V_{OUT}$  is equal to  $(V_{DD} - 50mV) - (V_{SS} + 50mV)$  for  $R_L = 25k\Omega$ , and

$\Delta V_{OS}$  is the change in offset voltage with the changing output voltage of the amplifier.

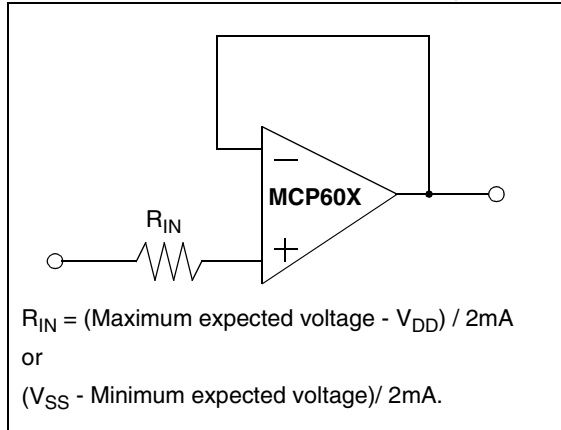
### 3.2 Input Voltage and Phase Reversal

Since the MCP601/602/603/604 amplifier family is designed with CMOS devices, it does not exhibit phase inversion when the input pins exceed the negative supply voltage. Figure 3-2 shows an input voltage exceeding both supplies with no resulting phase inversion.



**FIGURE 3-2:** The MCP601/602/603/604 family of op amps do not have phase reversal issues. For the graph, the amplifier is in a unity gain or buffer configuration.

The maximum operating common-mode voltage that can be applied to the inputs is  $V_{SS} - 0.3V$  to  $V_{DD} - 1.2V$ . In contrast, the absolute maximum input voltage is  $V_{SS} - 0.3V$  and  $V_{DD} + 0.3V$ . Voltages on the input that exceed this absolute maximum rating can cause excessive current to flow in or out of the input pins. Current beyond  $\pm 2mA$  can cause possible reliability problems. Applications that exceed this rating must be externally limited with an input resistor as shown in Figure 3-3.



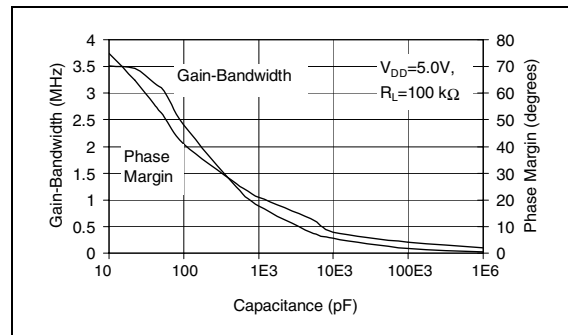
**FIGURE 3-3:** If the inputs of the amplifier exceed the Absolute Maximum Specifications, an input resistor,  $R_{IN}$ , should be used to limit the current flow into that pin.

### 3.3 Capacitive Load and Stability

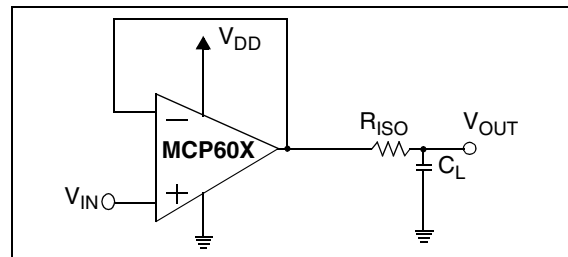
Driving capacitive loads can cause stability problems with many of the higher speed amplifiers.

For any closed loop amplifier circuit, a good rule of thumb is to design for a phase margin that is no less than  $45^\circ$ . This is a conservative theoretical value, however, if the phase margin is lower, layout parasitics can degrade the phase margin further causing a truly unstable circuit. A system phase shift of  $45^\circ$  will have an overshoot in its step response of approximately 25%.

A buffer configuration with a capacitive load is the most difficult configuration for an amplifier to maintain stability. The Phase versus Capacitive Load of the MCP60X amplifier is shown in Figure 3-4. In this figure, it can be seen that the amplifier has a phase margin above  $40^\circ$ , while driving capacitance loads up to 100pF.



**FIGURE 3-4:** Gain Bandwidth, Phase Margin vs. Capacitive Load



**FIGURE 3-5:** Amplifier circuits that can be used when driving heavy capacitive loads.

If the amplifier is required to drive larger capacitive loads, the circuit shown in Figure 3-5 can be used. A small series resistor ( $R_{ISO}$ ) at the output of the amplifier improves the phase margin when driving large capacitive loads. This resistor decouples the capacitive load from the amplifier by introducing a zero in the transfer function.

This zero adjusts the phase margin by approximately:

$$\Delta\theta_m = \tan^{-1} (2\pi \text{ GBWP} \times R_{ISO} \times C_L)$$

where:

$\Delta\theta_m$  is the improvement in phase margin,

$\text{GBWP}$  is the gain bandwidth product of the amplifier,

$R_{ISO}$  is the capacitive decoupling resistor, and

$C_L$  is the load capacitance

# MCP601/602/603/604

## 3.4 The Chip Select Option of the MCP603

The MCP603 is a single amplifier with a  $\overline{\text{CS}}$  Chip Select option. When  $\overline{\text{CS}}$  is pulled high the supply current drops to  $0.7\mu\text{A}$  (typ), which is pulled through the  $\overline{\text{CS}}$  pin to  $V_{\text{SS}}$ . In this state, the amplifier is put into a high impedance state. By pulling  $\overline{\text{CS}}$  low or letting the pin float, the amplifier is enabled. Figure 3-6 shows the output voltage and supply current response to a  $\overline{\text{CS}}$  pulse.

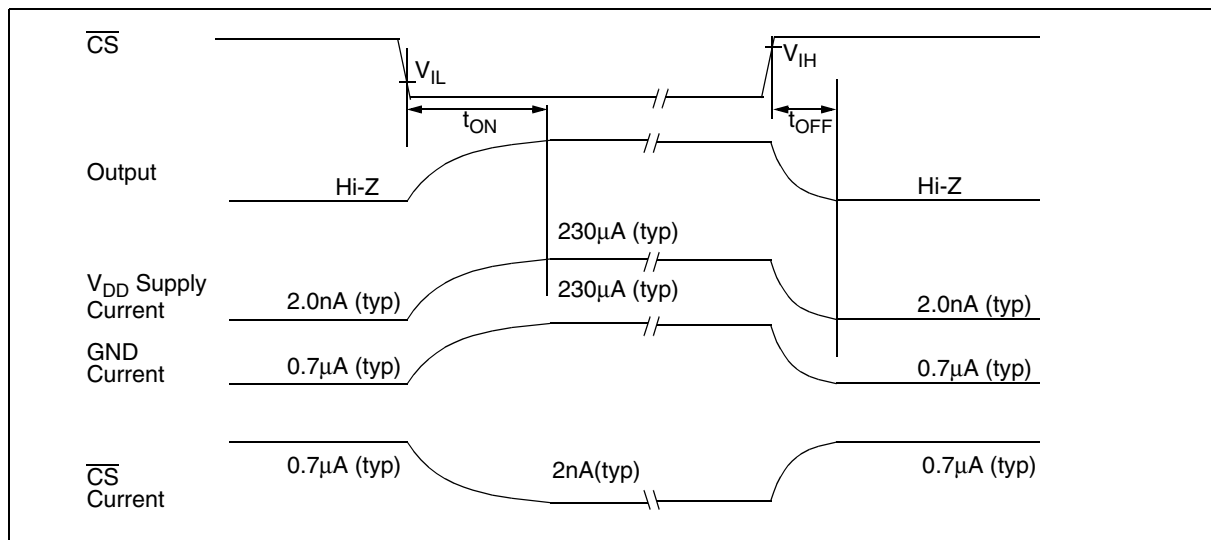


FIGURE 3-6: Timing Diagram for the  $\overline{\text{CS}}$  Function of the MCP603 Amplifier

## 3.5 Layout Considerations

In applications where low input bias current is critical, PC board surface leakage effects and signal coupling from trace to trace need to be taken into consideration.

### 3.5.1 SURFACE LEAKAGE

Surface leakage across a PC board is a consequence of differing DC voltages between two traces combined with high humidity, dust or contamination on the board. For instance, the typical resistance from PC board trace to pad is approximately  $10^{12}\Omega$  under low humidity conditions. If an adjacent trace is biased at or near zero volts, a  $5\text{pA}$  leakage current will appear on the amplifier's input node. This type of PCB leakage is five times the room temperature input bias current ( $1\text{pA}$ , typ) of the MCP601/602/603/604 family of amplifiers.

The simplest technique that can be used to reduce the effects of PC board leakage is to design a ring around sensitive pins and traces. An example of this type of layout is shown in Figure 3-7.

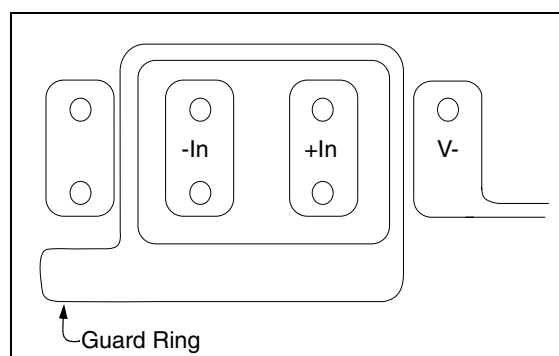
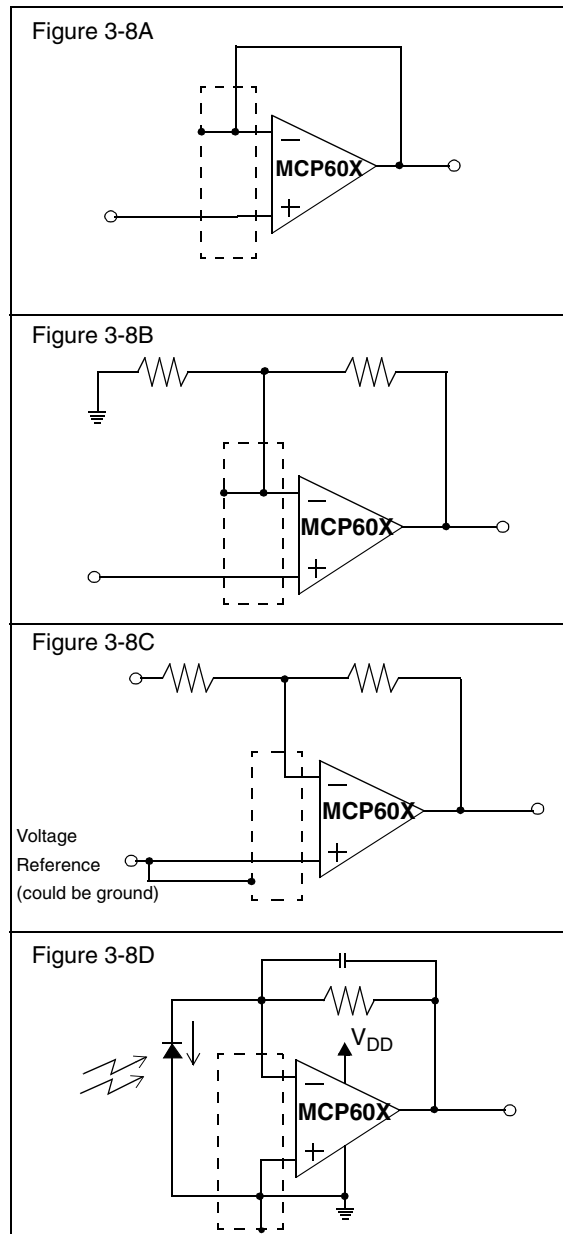


FIGURE 3-7: Example of Guard Ring for the MCP601, the A-amplifier of the MCP602 or the MCP603 in a PC Board Layout

Circuit examples of ring implementations are shown in Figure 3-8. In Figure 3-8A, B and C, the guard ring is biased to the common-mode voltage of the amplifier. This type of guard ring is most effective for applications where the common-mode voltage of the input stage changes, such as buffers, inverting gain amplifiers or instrumentation amplifiers.

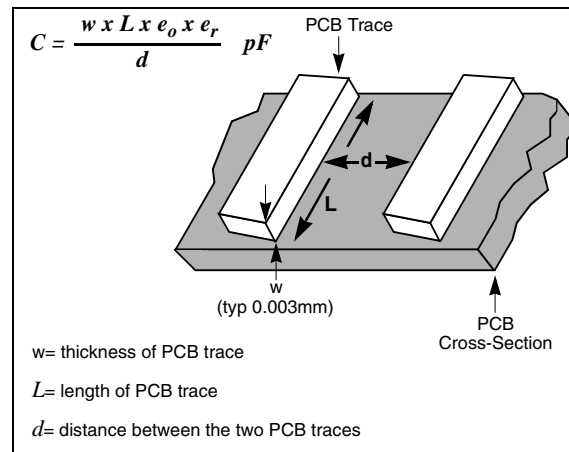
The strategy shown in Figure 3-8D, biases the common-mode voltage and guard ring to ground. This type of guard ring is typically used in precision photo sensing circuits.



**FIGURE 3-8:** Examples of how to design PC Board traces to minimize leakage paths to the high impedance input pins of the MCP601/602/603/604 amplifiers.

## 3.5.2 SIGNAL COUPLING

The input pins of the MCP601/602/603/604 amplifiers have a high impedance providing an opportunity for noise injection, if layout issues are not considered. These high impedance input terminals are sensitive to injected currents. This can occur if the trace from a high impedance input is next to a trace that has fast changing voltages, such as a digital or clock signal. When a high impedance trace is in close proximity to a trace with these types of voltage changes, charge is capacitively coupled into the high impedance trace.



**FIGURE 3-9:** Capacitors can be built with PCB traces allowing for coupling of signals from one trace to another.

As shown in Figure 3-9, the value of the capacitance between two traces is primarily dependent on the distance ( $d$ ) between the traces and the distance that the two traces are in parallel ( $L$ ). From this model, the amount of current generated into the high impedance trace is equal to:

$$I = C \partial V / \partial t$$

where:

- |  $I$  equals the current that appears on the high impedance trace,
- |  $C$  equals the value of capacitance between the two PCB traces,
- |  $\partial V$  equals the change in voltage of the trace that is switching, and
- |  $\partial t$  equals the amount of time that the voltage change took to get from one level to the next.

# MCP601/602/603/604

## 3.6 Typical Applications

### 3.6.1 ANALOG FILTERS

Examples of two second order low pass filters are shown in Figure 3-10 and Figure 3-11. The filter in Figure 3-10 can be configured for gain of +1V/V or greater. The filter in Figure 3-11 can be configured for inverting gains.

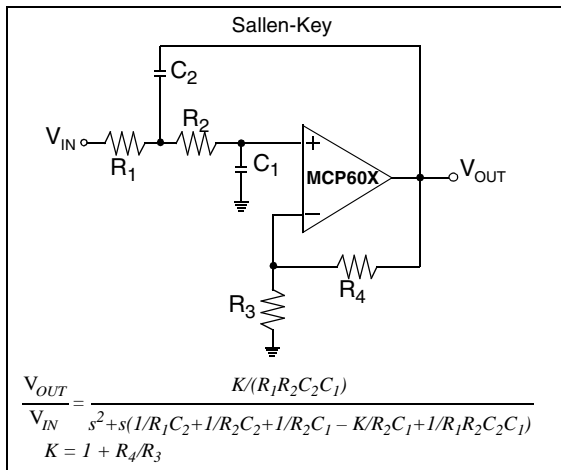


FIGURE 3-10: 2nd Order Low Pass Sallen-Key Filter

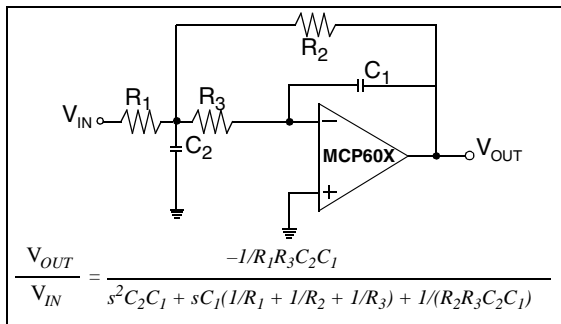


FIGURE 3-11: 2nd Order Low Pass Multiple-Feedback Filter

The MCP601/602/603/604 family of operational amplifiers are particularly well suited for these types of filters. The low input bias current, which is typically 1pA (up to 60pA at temperature), allows the designer to select higher value resistors, which in turn reduces the capacitive values. This allows the designer to select surface mount capacitors, which in turn can produce a compact layout.

The rail-to-rail output operation of the MCP601/602/603/604 family of amplifiers make these circuits well suited for single supply operation. Additionally, the wide bandwidth allows low pass filter design up to 1/10 of the GBWP or 300kHz.

These filters can be designed using the calculations provided in the Figures or with Microchip's interactive **FilterLab** software. **FilterLab** will calculate capacitor and resistor values, as well as, determine the number

of poles that are required for the application. Finally, the program will generate a SPICE macromodel, which can be used for spice simulations.

### 3.6.2 INSTRUMENTATION AMPLIFIER CIRCUITS

The instrumentation amplifier has a differential input, which subtracts one analog signal from another and rejects common mode signals. This amplifier also provides a single ended analog output signal. The three op amp instrumentation amplifier is illustrated in Figure 3-12 and the two op amp instrumentation amplifier is shown in Figure 3-13.

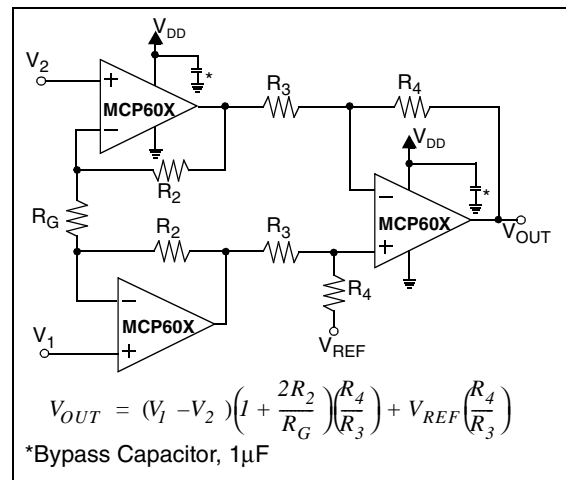


FIGURE 3-12: An instrumentation amplifier can be built using three operational amplifiers and seven resistors.

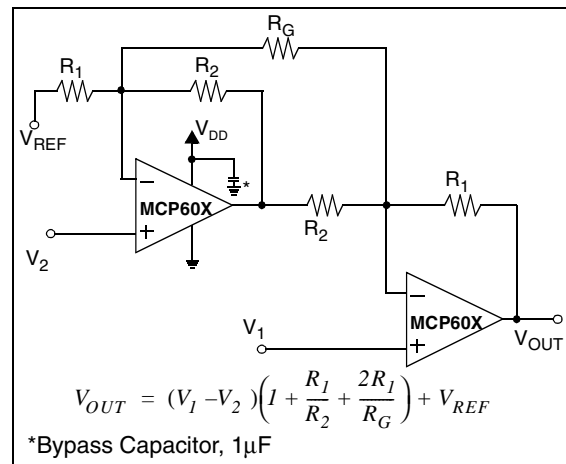


FIGURE 3-13: An instrumentation amplifier can also be built using two operational amplifiers and five resistors.

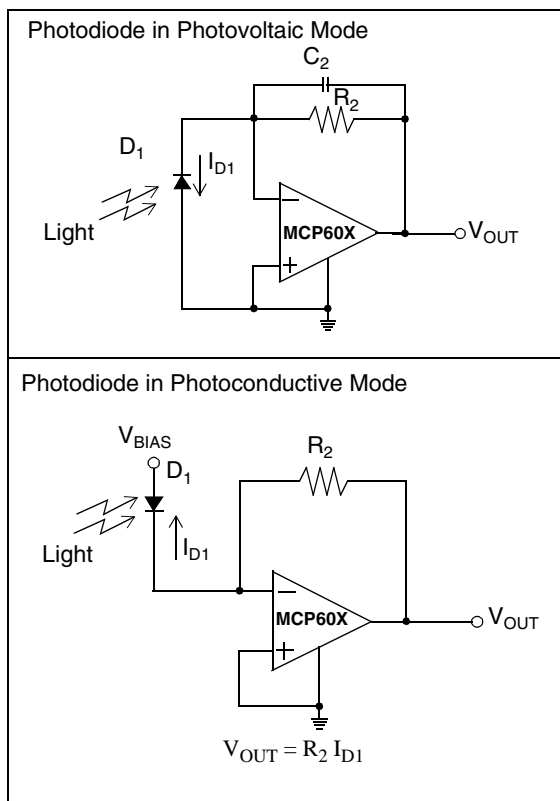
An advantage of the three op amp configuration is that it is capable of unity gain operation. A disadvantage, as compared to the two op amp instrumentation amplifier, is that the common mode range reduces with higher gains.

The two op amp configuration uses fewer op amps, so power consumption is also low. Disadvantages of this configuration are that the common-mode range reduces with gain and it must be configured in gains of two or higher.

### 3.6.3 PHOTO DETECTION

The amplifiers in the MCP601/602/603/604 family of devices can be used to easily convert the signal from a sensor that produces an output current, such as a photodiode, into a voltage. This is implemented with a single resistor and an optional capacitor in the feedback loop of the amplifier as shown in Figure 3-14.

In contrast, a photodiode that is configured in the photoconductive mode has a reverse bias voltage, which is applied across the photo sensing element as shown in Figure 3-14. The width of the depletion region is reduced when this voltage is applied across the photo detector, which reduces the photodiode parasitic capacitance significantly. This reduced parasitic capacitance facilitates high speed operation, however, the linearity and offset errors are not optimized. The design trade off for this action is increased diode leakage current and linearity errors. A key amplifier specification for this application is high speed digital communication. The MCP601/602/603/604 family is well suited for medium speed photoconductive applications with their wide bandwidth and rail-to-rail output swing.



**FIGURE 3-14:** Photo Sensing Circuits Using the MCP60X Amplifier

A photodiode that is configured in the photovoltaic mode has no voltage potential placed across the element or is zero biased (Figure 3-14). In this mode, the light sensitivity and linearity is maximized making it best suited for precision applications. The key amplifier specifications for this application are low input bias current, low noise and rail-to-tail output swing. The MCP601/602/603/604 family is capable of meeting all three of these difficult requirements.

# MCP601/602/603/604

---

## 4.0 SPICE MACROMODEL

The Spice macromodel for the MCP601, MCP602, MCP603 and MCP604 simulates the typical amplifier performance of offset voltage, DC power supply rejection, input capacitance, DC common mode rejection ratio, open loop gain over frequency, phase margin with no capacitive load, output swing, DC power supply current, power supply current change with supply voltage, input common mode range and input voltage noise.

The characteristics of the MCP601, MCP602, MCP603, and MCP604 amplifiers are similar in terms of performance and behavior. This single op amp macromodel supports all four devices with the exception of the chip select function of the MCP603, which is not modeled.

The listing for this macromodel is shown on the next page. The most recent revision of the model can be downloaded from Microchip's web site at [www.microchip.com](http://www.microchip.com).



# MCP601/602/603/604

```
.subckt mcp601 1 2 3 4 5
*
*      | | | |
*      | | | | Output
*      | | | Negative supply
*      | | Positive Supply
*      | Inverting input
*      Non-inverting input
*
* Macromodel for MCP601 (single), MCP602 (dual), MCP603 (single w/CS), and MCP604 (quad)
*
* The characteristics of the MCP601, MCP602, MCP603, and MCP604 have the same fundamental
* performance and behavior. Consequently, this single op amp macromodel supports all four
* devices. However, the chip select function of the MCP603 is not modeled.
*
* Revision History:
* REV A : 6-30-99 created BCB
* REV B : 7-10-99 corrected DC Iq BCB
* REV C : 11-30-99 Placed ".subckt" command as first line, added L, W to Ptype model in
*               : listing BCB
*
* This macromodel models typical amplifier offset voltage, DC power supply rejection, input
* capacitance, DC common mode rejection ratio, open loop gain over frequency, phase margin
* with no capacitive load, output swing, power supply current, input voltage noise.
*
* NOTICE: THE INFORMATION PROVIDED HEREIN IS BELIEVED TO BE RELIABLE,
* HOWEVER, MICROCHIP ASSUMES NO RESPONSIBILITY FOR INACCURACIES OR
* OMISSIONS. MICROCHIP ASSUMES NO RESPONSIBILITY FOR THE USE OF THIS
* INFORMATION, AND ALL USE OF SUCH INFORMATION SHALL BE ENTIRELY AT
* THE USER'S OWN RISK. NO INTELLECTUAL PROPERTY RIGHTS OR LICENSES
* TO ANY OF THE TECHNOLOGY DESCRIBED HEREIN ARE IMPLIED OR GRANTED TO
* ANY THIRD PARTY. MICROCHIP RESERVES THE RIGHT TO CHANGE THIS MODEL
* AT ANY TIME WITHOUT NOTICE.
*
*Input Stage, pole at 5MHz
M1  9  64  7  3  Ptype L=2 W=275
M2  8  2  7  3  Ptype L=2 W=275
CDIFF 1  2  3E-12
CCM1  1  4  6E-12
CCM2  2  4  6E-12
IDD  3  7  30e-6
RA  8  6  1.485e3
RB  9  6  1.485e3
CA  8  9  10.71e-12

*Input Stage Common-Mode Clamping
VCMM  4  6  0.35
ECM  55  4  3 64  1

RCM  57  56  1E3
DCMP 56  55  DX
VCMP 57  4  1.2

RST  58  59  1E3
DST  59  55  DX
VST  58  4  1.6

GCMP2 23  4  POLY(2) 57 56 58 59 0 -0.5E-3 0.5E-3

*Input errors (vos, en, psr, cmr)
ERR  64  1  POLY(3) (67,4) (3, 4) (1,34) 0 1 40e-6 3.2e-6

*Second Stage, pole at 3.3Hz
GS  23  4  8  9  5.7e-3
R1  23  4  0.397e9
C2  23  4  122.8e-12
```

# MCP601/602/603/604

---

---

```
VSOP    3    24    4.784
VSOM    25    4    -3.48
DSOP    23    24    DY
DSOM    25    23    DY
```

```
*HCM    23    3    VCMP
```

```
FS 3 4 POLY(11) VO3 VO5 VO4 VO6 VO1 VO2 VO9 VO10 VMID1 VSOP VSOM
+ 200E-6 -1 -1 -1 1 -1 -1 1 1 -1 -1 -1
```

```
*mid-supply reference, output swing limit
```

```
RMID1    3    35    61.62E3
VMID1    35    34    0
RMID2    4    34    61.62E3
ELEVEL   34    4    23        4    -1
```

```
*output stage
```

```
DO3     34    43    DY
DO4     44    34    DY
DO5     3    45    DY
DO6     3    46    DY
DO7     4    45    DY
DO8     4    46    DY
VO3     43    5    0.1
VO4     5    44    0.1
GO5     3    47    3        34    10E-3
VO5     47    5    0
GO6     4    48    34        4    10E-3
VO6     48    5    0
GO1     49    4    5        34    10E-3
VO1     49    45    0
GO2     50    4    34        5    10E-3
VO2     50    46    0
RO9     3    51    100
VO9     51    5    0
RO10    52    4    100
VO10    52    5    0
```

```
* input voltage noise
```

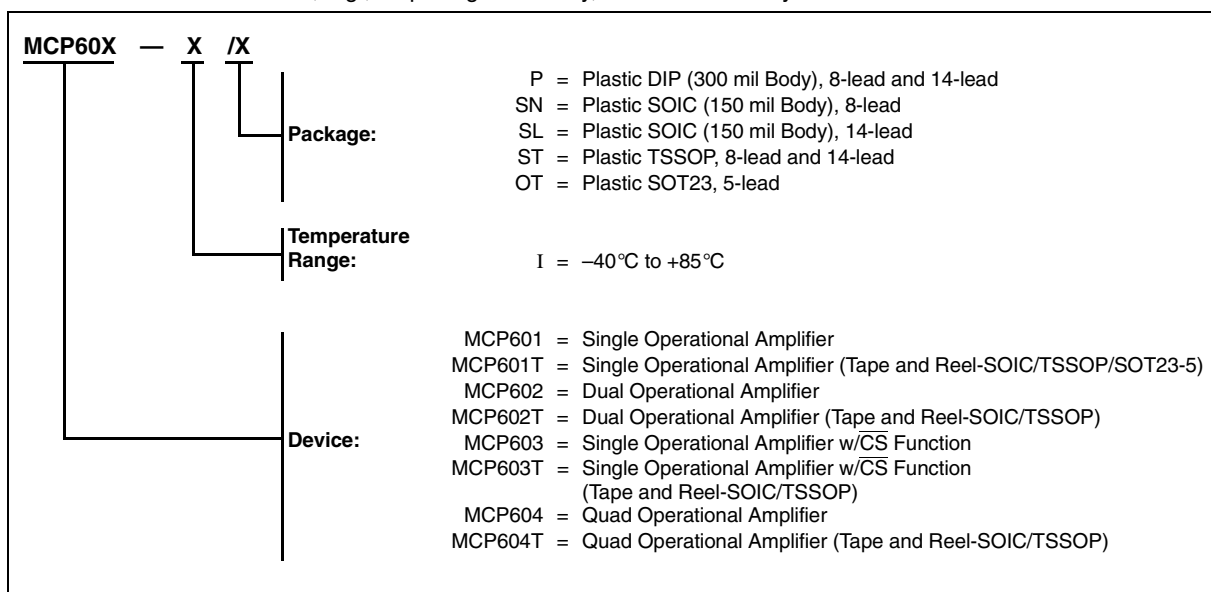
```
VN1     65    4    0.6
DN1     65    67    DX
RN1     67    4    13E3
```

```
.model Ptype PMOS
.model DY D(IS=1e-15 BV =50)
.model DX D(IS=1e-18 AF=0.6 KF=10e-17)
.ENDS
```

# MCP601/602/603/604

## MCP60X PRODUCT IDENTIFICATION SYSTEM

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



## Sales and Support

### Data Sheets

Products supported by a preliminary Data Sheet may have an errata sheet describing minor operational differences and recommended workarounds. To determine if an errata sheet exists for a particular device, please contact one of the following:

1. Your local Microchip sales office
2. The Microchip Corporate Literature Center U.S. FAX: (480) 786-7277
3. The Microchip Worldwide Site ([www.microchip.com](http://www.microchip.com))

Please specify which device, revision of silicon and Data Sheet (include Literature #) you are using.

### New Customer Notification System

Register on our web site ([www.microchip.com/cn](http://www.microchip.com/cn)) to receive the most current information on our products.



# MICROCHIP

## WORLDWIDE SALES AND SERVICE

### AMERICAS

#### Corporate Office

Microchip Technology Inc.  
2355 West Chandler Blvd.  
Chandler, AZ 85224-6199  
Tel: 480-786-7200 Fax: 480-786-7277  
Technical Support: 480-786-7627  
Web Address: <http://www.microchip.com>

#### Atlanta

Microchip Technology Inc.  
500 Sugar Mill Road, Suite 200B  
Atlanta, GA 30350  
Tel: 770-640-0034 Fax: 770-640-0307

#### Boston

Microchip Technology Inc.  
5 Mount Royal Avenue  
Marlborough, MA 01752  
Tel: 508-480-9990 Fax: 508-480-8575

#### Chicago

Microchip Technology Inc.  
333 Pierce Road, Suite 180  
Itasca, IL 60143  
Tel: 630-285-0071 Fax: 630-285-0075

#### Dallas

Microchip Technology Inc.  
4570 Westgrove Drive, Suite 160  
Addison, TX 75248  
Tel: 972-818-7423 Fax: 972-818-2924

#### Dayton

Microchip Technology Inc.  
Two Prestige Place, Suite 150  
Miamisburg, OH 45342  
Tel: 937-291-1654 Fax: 937-291-9175

#### Detroit

Microchip Technology Inc.  
Tri-Atria Office Building  
32255 Northwestern Highway, Suite 190  
Farmington Hills, MI 48334  
Tel: 248-538-2250 Fax: 248-538-2260

#### Los Angeles

Microchip Technology Inc.  
18201 Von Karman, Suite 1090  
Irvine, CA 92612  
Tel: 949-263-1888 Fax: 949-263-1338

#### New York

Microchip Technology Inc.  
150 Motor Parkway, Suite 202  
Hauppauge, NY 11788  
Tel: 631-273-5305 Fax: 631-273-5335

#### San Jose

Microchip Technology Inc.  
2107 North First Street, Suite 590  
San Jose, CA 95131  
Tel: 408-436-7950 Fax: 408-436-7955

### AMERICAS (continued)

#### Toronto

Microchip Technology Inc.  
5925 Airport Road, Suite 200  
Mississauga, Ontario L4V 1W1, Canada  
Tel: 905-405-6279 Fax: 905-405-6253

### ASIA/PACIFIC

#### China - Beijing

Microchip Technology, Beijing  
Unit 915, 6 Chaoyangmen Bei Dajie  
Dong Erhuan Road, Dongcheng District  
New China Hong Kong Manhattan Building  
Beijing, 100027, P.R.C.  
Tel: 86-10-85282100 Fax: 86-10-85282104

#### China - Shanghai

Microchip Technology  
Unit B701, Far East International Plaza,  
No. 317, Xianxia Road  
Shanghai, 200051, P.R.C.  
Tel: 86-21-6275-5700 Fax: 86-21-6275-5060

#### Hong Kong

Microchip Asia Pacific  
Unit 2101, Tower 2  
Metroplaza  
223 Hing Fong Road  
Kwai Fong, N.T., Hong Kong  
Tel: 852-2-401-1200 Fax: 852-2-401-3431

#### India

Microchip Technology Inc.  
India Liaison Office  
No. 6, Legacy, Convent Road  
Bangalore, 560 025, India  
Tel: 91-80-229-0061 Fax: 91-80-229-0062

#### Japan

Microchip Technology Intl. Inc.  
Benex S-1 6F  
3-18-20, Shinyokohama  
Kohoku-Ku, Yokohama-shi  
Kanagawa, 222-0033, Japan  
Tel: 81-45-471-6166 Fax: 81-45-471-6122

#### Korea

Microchip Technology Korea  
168-1, Youngbo Bldg. 3 Floor  
Samsung-Dong, Kangnam-Ku  
Seoul, Korea  
Tel: 82-2-554-7200 Fax: 82-2-558-5934

### ASIA/PACIFIC (continued)

#### Singapore

Microchip Technology Singapore Pte Ltd.  
200 Middle Road  
#07-02 Prime Centre  
Singapore, 188980  
Tel: 65-334-8870 Fax: 65-334-8850

#### Taiwan

Microchip Technology Taiwan  
10F-1C 207  
Tung Hua North Road  
Taipei, Taiwan  
Tel: 886-2-2717-7175 Fax: 886-2-2545-0139

### EUROPE

#### Denmark

Microchip Technology Denmark ApS  
Regus Business Centre  
Lautrup høj 1-3  
Ballerup DK-2750 Denmark  
Tel: 45 4420 9895 Fax: 45 4420 9910

#### France

Arizona Microchip Technology SARL  
Parc d'Activite du Moulin de Massy  
43 Rue du Saule Trapu  
Batiment A - 1er Etage  
91300 Massy, France  
Tel: 33-1-69-53-63-20 Fax: 33-1-69-30-90-79

#### Germany

Arizona Microchip Technology GmbH  
Gustav-Heinemann-Ring 125  
D-81739 München, Germany  
Tel: 49-89-627-144 0 Fax: 49-89-627-144-44

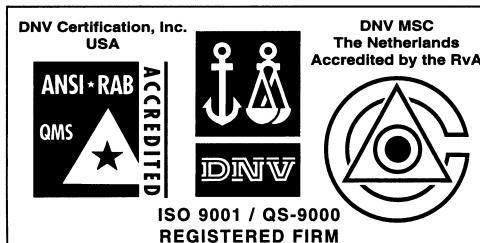
#### Italy

Arizona Microchip Technology SRL  
Centro Direzionale Colleoni  
Palazzo Taurus 1 V. Le Colleoni 1  
20041 Agrate Brianza  
Milan, Italy  
Tel: 39-039-65791-1 Fax: 39-039-6899883

#### United Kingdom

Arizona Microchip Technology Ltd.  
505 Eskdale Road  
Winkersham Triangle  
Wokingham  
Berkshire, England RG41 5TU  
Tel: 44 118 921 5858 Fax: 44-118 921-5835

03/23/00



Microchip received QS-9000 quality system certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona in July 1999. The Company's quality system processes and procedures are QS-9000 compliant for its PICmicro® 8-bit MCUs, KEELOC® code hopping devices, Serial EEPROMs and microperipheral products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001 certified.

All rights reserved. © 2000 Microchip Technology Incorporated. Printed in the USA. 5/00 Printed on recycled paper.

Information contained in this publication regarding device applications and the like is intended through suggestion only and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. No representation or warranty is given and no liability is assumed by Microchip Technology Incorporated with respect to the accuracy or use of such information, or infringement of patents or other intellectual property rights arising from such use or otherwise. Use of Microchip's products as critical components in life support systems is not authorized except with express written approval by Microchip. No licenses are conveyed, implicitly or otherwise, except as maybe explicitly expressed herein, under any intellectual property rights. The Microchip logo and name are registered trademarks of Microchip Technology Inc. in the U.S.A. and other countries. All rights reserved. All other trademarks mentioned herein are the property of their respective companies.