MCP606/607/608/609

2.5V to 5.5V Micropower CMOS Op Amps

FEATURES

- Low Power I_{DD} = 25µA, max
- Low Offset Voltage: 250µV, max
- Rail-to-Rail Swing at Output
- 80pA, Low Input Bias Current over Temperature
- Specifications rated for 2.5V to 5.5V Supplies
- Unity Gain Stable
- $\overline{\text{Chip Select}}$ Capability with MCP608
- Industrial Temperature range supported
- No Phase Reversal
- Available in Single, Dual, and Quad

APPLICATIONS

- Battery Power Instruments
- High Impedance Applications
  - Photodiode Pre-amps
  - pH probe Buffer Amplifier
  - Infrared Detectors
  - Precision Integrators
  - Charge Amplifier for Piezoelectric Transducers
- Strain Gauges
- Medical Instruments
- Test Equipment

AVAILABLE TOOLS

- Spice Macromodels (at www.microchip.com)
- **FilterLab**™ Software (at www.microchip.com)

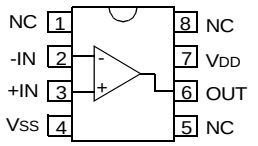
DESCRIPTION

The MCP606, MCP607, MCP608 and MCP609 from Microchip Technology, Inc. are unity gain stable, low offset voltage operational amplifiers capable of precision low power single supply operation. Performance characteristics include ultra low offset voltage (250µV, max), rail-to-rail output swing capability, and low input bias current (80pA@85C). These features make this family of amplifiers well suited for single supply precision, high impedance, battery powered applications.

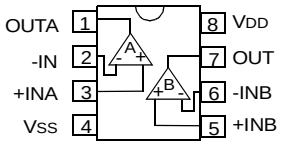
The single MCP606 is available in standard 8-lead PDIP, SOIC, and TSSOP packages. Another version of the single op amp, MCP608 is offered with a $\overline{\text{Chip Select}}$ option in standard 8-lead PDIP, SOIC, and TSSOP packages. The dual MCP607 is offered in standard 8-lead PDIP, SOIC, as well as the TSSOP package. Finally, the quad MCP609 is offered in 14-lead PDIP, SOIC and TSSOP packages. All devices are fully specified from -40 °C to +85 °C with power supplies from 2.5V to 5.5V.

PACKAGES

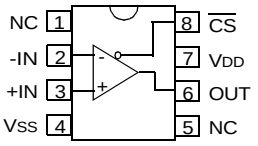
MCP606
PDIP, SOIC,TSSOP



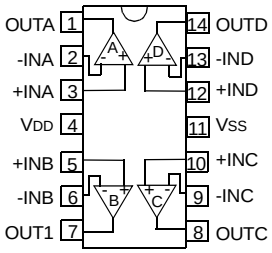
MCP607
PDIP, SOIC,TSSOP



MCP608
PDIP, SOIC,TSSOP



MCP609
PDIP, SOIC,TSSOP



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 ..... +/-2mA
Current at Output and Supply Pins ..... +/-30mA
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 protection on all pins ..... ≥ 2 kV

***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
$\overline{CS}$	$\overline{\text{Chip Select}}$
NC	No internal connection to IC

DC CHARACTERISTICS

Unless otherwise specified, all limits are specified for V_{DD} = +2.5V to +5.5V, V_{SS} = GND, T_A = 25 °C, V_{CM} = V_{DD}/2, R_L = 100kΩ to V_{DD}/2, and V_{OUT} ~ V_{DD}/2

PARAMETERS	SYMBOL	MIN.	TYP.	MAX.	UNITS	CONDITIONS
INPUT OFFSET						
Input Offset Voltage	V_{OS}	-250	—	+250	µV	
Drift with Temperature,	dV_{OS}/dT	—	±1.8	—	µV/°C	T_A= -40°C to+85°C
Power Supply Rejection	PSRR	80	93	—	dB	for V_{DD} = 2.5V to 5.5V
INPUT BIAS CURRENT AND IMPEDANCE						
Input Bias Current	I_B	—	1	—	pA	
Over Temperature	I_B	—	—	80	pA	T_A= -40°C to+85°
Input Offset Bias Current	I_{OS}	—	1	—	pA	
Common Mode Input Impedance	Z_{CM}	—	10^{13}||6	—	Ω||pF	
Differential Input Impedance	Z_{DIFF}	—	10^{13}||6	—	Ω||pF	
COMMON MODE						
Common-Mode Input Range	VCM	V_{SS}–0.3		V_{DD}–1.1	V	CMRR > 75dB
Common-Mode Rejection Ratio	CMRR	75	91	—	dB	V_{DD} = 5V, V_{CM} = -0.3 to 3.9V
OPEN LOOP GAIN						
DC Open Loop Gain	A_{OL}	105	121	—	dB	R_L = 25kΩ to GND, 50mV < V_{OUT} < (V_{DD} – 50mV)
DC Open Loop Gain	A_{OL}	100	118	—	dB	R_L = 5kΩ to GND, 100mV < V_{OUT} < (V_{DD} – 100mV)
OUTPUT						
Low Level/High Level Output Voltage Swing	V_{OL}, V_{OH}	V_{SS} + 0.015	—	V_{DD} – 0.020	V	R_L = 25kΩ to V_{DD}/2
	V_{OL}, V_{OH}	V_{SS} + 0.045	—	V_{DD} – 0.060	V	R_L = 5kΩ to V_{DD}/2
Linear Region Maximum Output Voltage Swing	V_{OUT}	V_{SS} + 0.050	—	V_{DD} – 0.050	V	R_L = 25kΩ to V_{DD}/2, A_{OL} ≥ 105dB
	V_{OUT}	V_{SS} + 0.100	—	V_{DD} – 0.100	V	R_L = 5kΩ to V_{DD}/2, A_{OL} ≥ 100dB
Output Short Circuit Current	I_{SC}		17		mA	V_{OUT} = 2.5V, V_{DD} = 5V
POWER SUPPLY						
Supply Voltage	V_S	2.5	—	5.5	V	
Quiescent Current Per Amp	I_Q	—	18.7	25	µA	I_O = 0

AC CHARACTERISTICS

Unless otherwise specified, all limits are specified for V_{DD} = +2.5V to +5.5V, V_{SS} = GND, T_A = 25 °C, V_{CM} = V_{DD}/2, R_L = 100kΩ to V_{DD}/2, and V_{OUT} ~ V_{DD}/2

PARAMETERS	SYMBOL	MIN.	TYP.	MAX.	UNITS	CONDITIONS
Gain Bandwidth Product	GBWP	—	155	—	kHz	V_{DD} = 5V, C_L = 60 pf
Phase Margin at Unity Crossing	θ	—	62	—	degrees	V_{DD} = 5V, C_L = 60 pf
Slew Rate	SR	—	0.08	—	V/µs	G = 1, V_{DD} = 5V, C_L = 60 pf
Input Voltage Noise	e_n	—	2.8	—	µVp-p	f = 0.1Hz to 10Hz
Noise Density	e_n	—	38	—	nV/√Hz	f = 1kHz
Input Current Noise Density	i_n	—	3	—	fA/√Hz	f = 1kHz

SPECIFICATIONS FOR MCP608 CHIP SELECT FEATURE

Unless otherwise specified, all limits are specified for V_{DD} = +2.5V to +5.5V, V_{SS} = GND, T_A = 25 °C, V_{CM} = V_{DD}/2, R_L = 100kΩ, and V_{OUT} ~ V_{DD}/2

PARAMETERS	SYMBOL	MIN.	TYP.	MAX.	UNITS	CONDITIONS
$\overline{CS}$ LOW SPECIFICATIONS						
$\overline{CS}$ Logic Threshold, Low	V_{IL}	V_{SS}	—	0.2 V_{DD}	V	For entire V_{DD} range
$\overline{CS}$ Input Current, Low	I_{CSL}	-0.1	0.01	—	µA	$\overline{CS}$ = 0.2V_{DD}
$\overline{CS}$ HIGH SPECIFICATIONS						
$\overline{CS}$ Logic Threshold, High	V_{IH}	0.8 V_{DD}	—	V_{DD}	V	For entire V_{DD} range
$\overline{CS}$ Input Current, High	I_{CSH}	—	0.01	0.1	µA	$\overline{CS}$ = V_{DD}
$\overline{CS}$ Input High, GND Current	I_Q	—	0.05	0.1	µA	$\overline{CS}$ = V_{DD}
Amplifier Output Leakage, $\overline{CS}$ High		—	10	—	nA	$\overline{CS}$ = 0.8V_{DD}
DYNAMIC SPECIFICATIONS						
$\overline{CS}$ Low to Amplifier Output High Turn-on Time	t_{ON}	—	9	100	µs	$\overline{CS}$ low = 0.2V_{DD}, V_{OUT} = 0.9 *V_{DD}/2, G = +1V/V
$\overline{CS}$ High to Amplifier Output High Z	t_{OFF}	—	0.1	—	µs	$\overline{CS}$ high = 0.8V_{DD}, V_{OUT} = 0.1 *V_{DD}/2, G = +1V/V
Hysteresis		—	0.6	—	V	V_{DD} = 5V

TEMPERATURE SPECIFICATIONS

Unless otherwise specified, all limits are specified for V_{DD} = +2.5V to +5.5V, V_{SS} = GND

PARAMETERS	SYMBOL	MIN.	TYP.	MAX.	UNITS	CONDITIONS
TEMPERATURE RANGES						
Specified Temperature Range	T_A	-40	—	+85	°C	
Operating Temperature Range	T_A	-40	—	+85	°C	
Storage Temperature Range	T_A	-65	—	+150	°C	
THERMAL PACKAGE RESISTANCE						
Thermal Resistance, 8L-PDIP	$θ_{JA}$	—	85	—	°C/W	
Thermal Resistance, 8L-SOIC	$θ_{JA}$	—	163	—	°C/W	
Thermal Resistance, 8L-TSSOP	$θ_{JA}$	—	124	—	°C/W	
Thermal Resistance, 14L-PDIP	$θ_{JA}$	—	70	—	°C/W	
Thermal Resistance, 14L-SOIC	$θ_{JA}$	—	120	—	°C/W	
Thermal Resistance, 14L-TSSOP	$θ_{JA}$	—	100	—	°C/W	

2.0 TYPICAL PERFORMANCE CURVES

Note: Unless otherwise indicated, $T_A = 25^{\circ}C$, $V_{CM} = V_{DD} / 2$ and $V_{OUT} \sim V_{DD}/2$, V_{SS} = GND

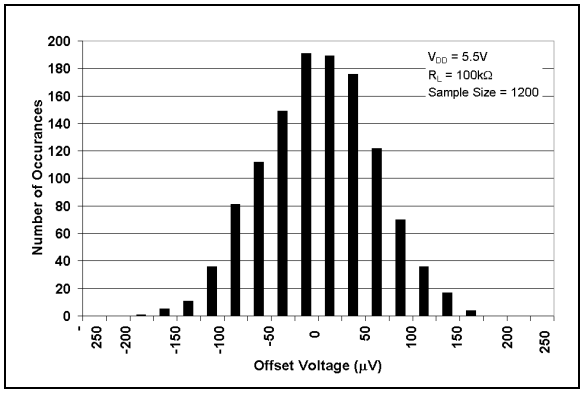


FIGURE 2-1: *Offset Voltage vs. Number of Occurrences with V_{DD} = 5.5V*

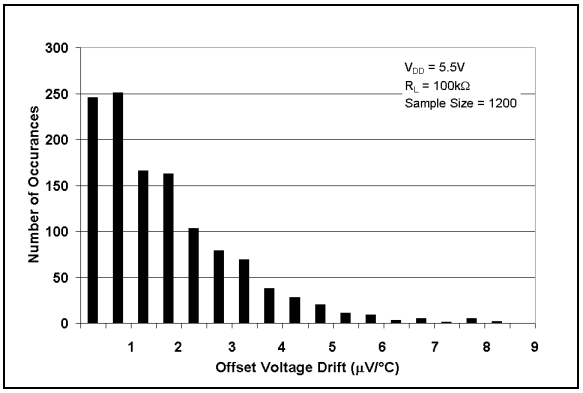


FIGURE 2-4: *Offset Voltage Drift vs. Number of Occurrences with V_{DD} = 5.5V*

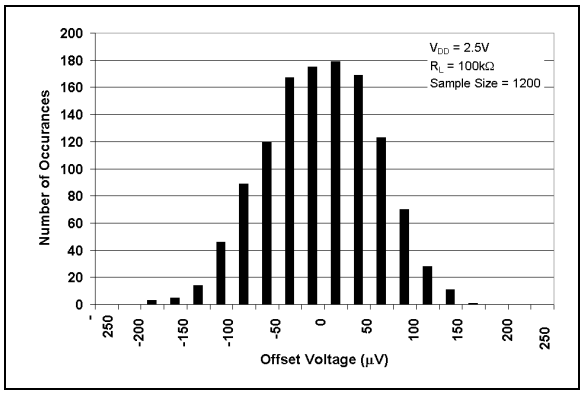


FIGURE 2-2: *Offset Voltage vs. Number of Occurrences with V_{DD} = 2.5V*

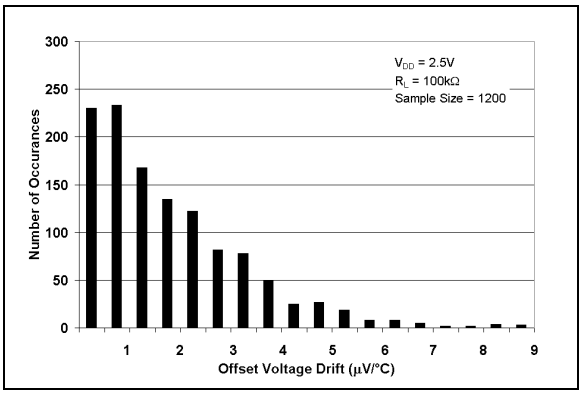


FIGURE 2-5: *Offset Voltage Drift vs. Number of Occurrences with V_{DD} = 2.5V*

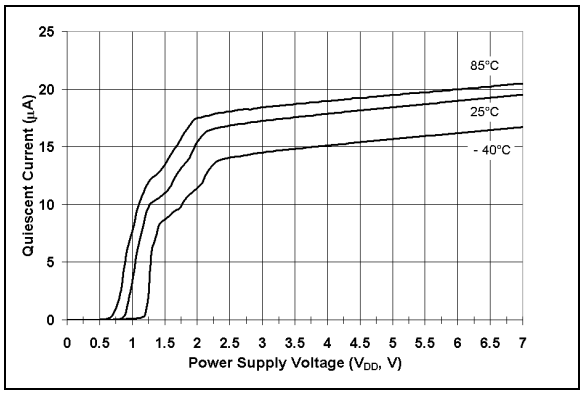


FIGURE 2-3: *Quiescent Current vs. Power Supply Voltage vs. Temperature*

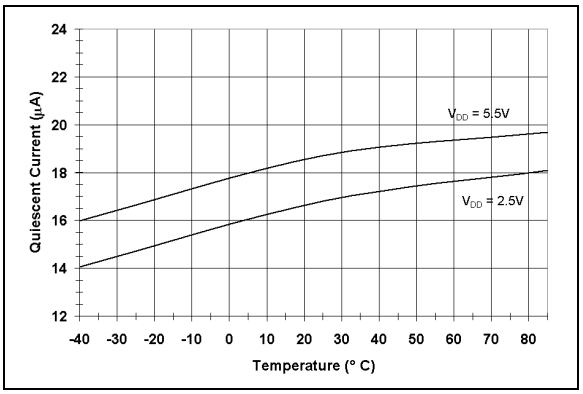


FIGURE 2-6: *Quiescent Current vs. Temperature*

Note: Unless otherwise indicated, $T_A = 25^\circ C$, $V_{CM} = V_{DD} / 2$ and $V_{OUT} \sim V_{DD}/2$, V_{SS} = GND

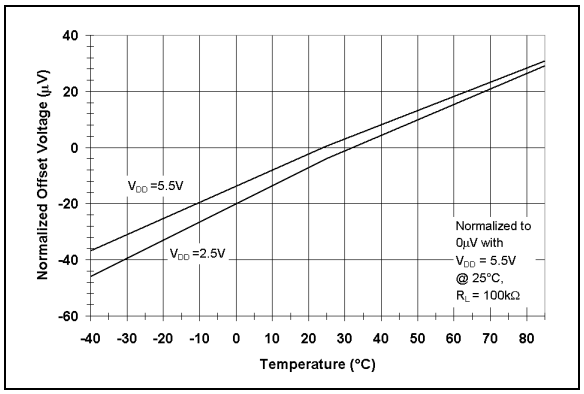


FIGURE 2-7: *Normalized Offset Voltage vs. Temperature*

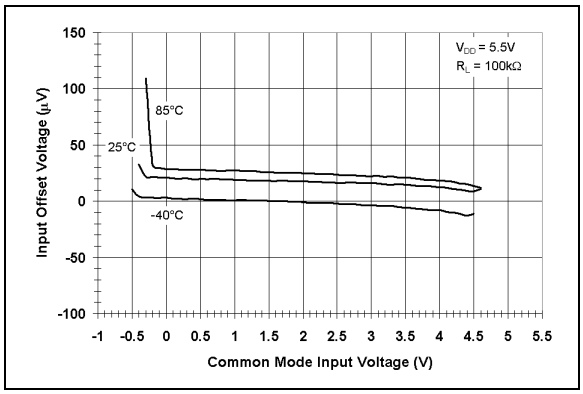


FIGURE 2-10: *Input Offset Voltage vs. Common Mode Voltage*

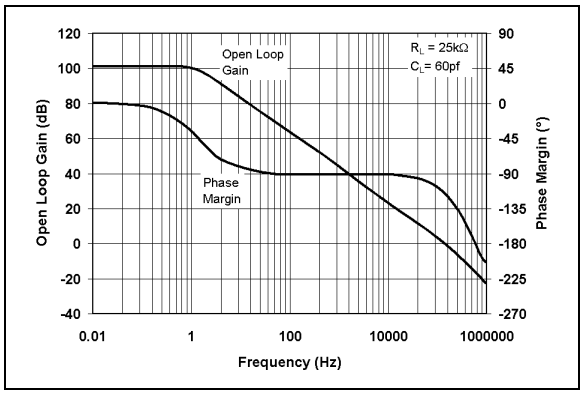


FIGURE 2-8: *Open Loop Gain, Phase Margin vs. Frequency*

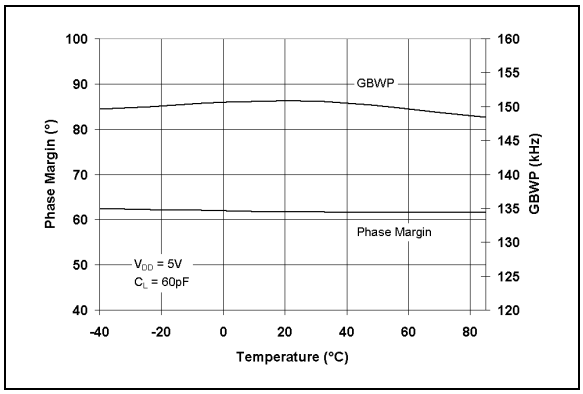


FIGURE 2-11: *Phase Margin, Gain Bandwidth Product vs. Temperature*

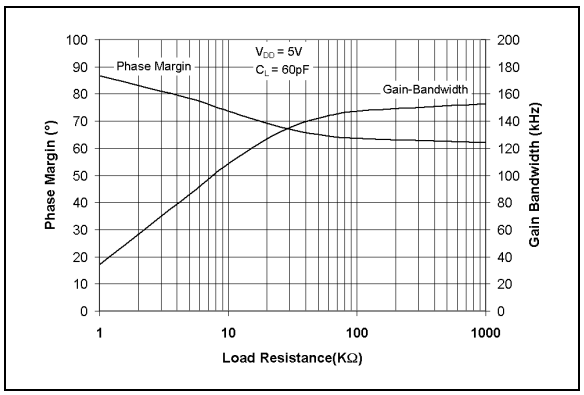


FIGURE 2-9: *Phase Margin, Gain Bandwidth, vs. Load Resistance*

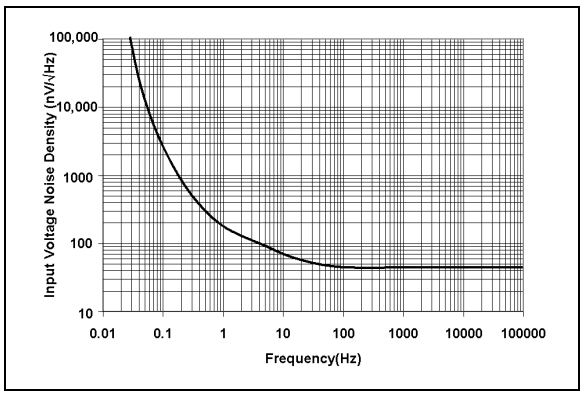


FIGURE 2-12: *Input Voltage Noise Density vs. Frequency*

Note: Unless otherwise indicated, $T_A = 25^\circ C$, $V_{CM} = V_{DD} / 2$ and $V_{OUT} \sim V_{DD}/2$, V_{SS} = GND

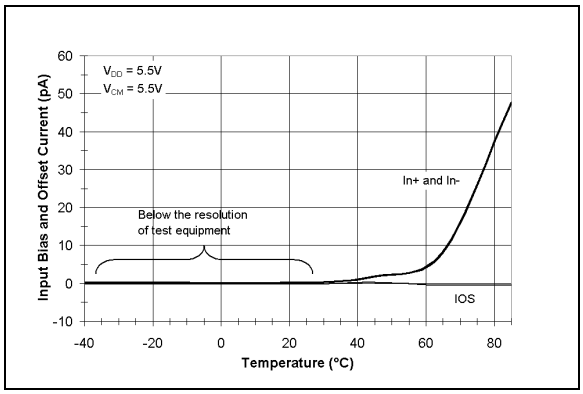


FIGURE 2-13: *Input Bias Current, Input Offset Current vs. Temperature*

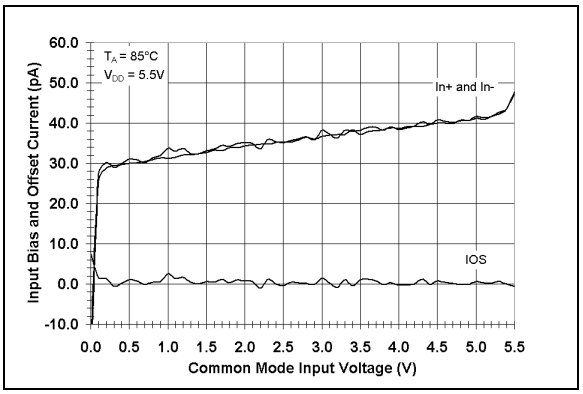


FIGURE 2-16: *Input Bias Current, Input Offset Current vs. Common mode Input Voltage*

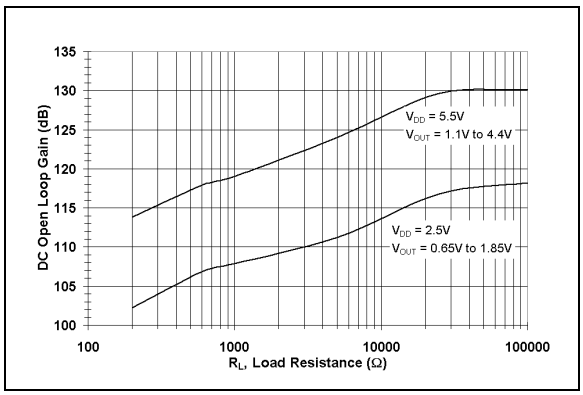


FIGURE 2-14: *DC Open Loop Gain vs. Output Load Resistance*

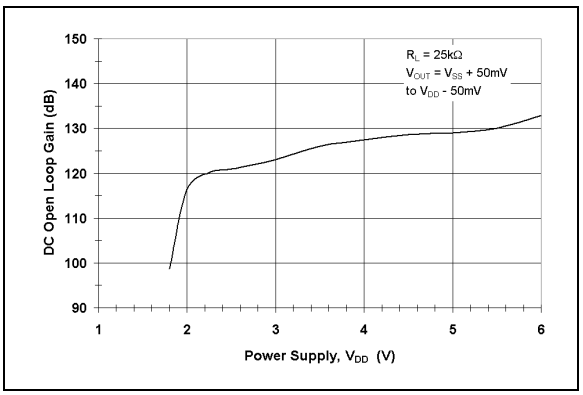


FIGURE 2-17: *DC Open Loop Gain vs. Power Supply Voltage*

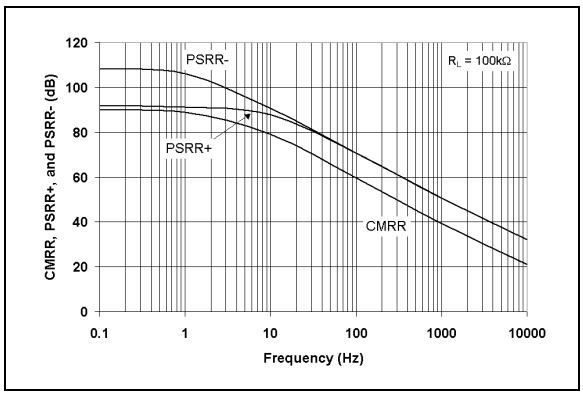


FIGURE 2-15: *Common-Mode Rejection Ratio, Power Supply Rejection Ratio vs. Frequency*

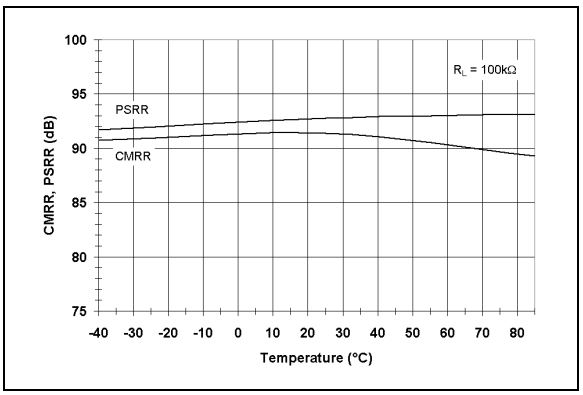


FIGURE 2-18: *Common-Mode Rejection Ratio, Power Supply Rejection Ratio vs. Temperature*

Note: Unless otherwise indicated, $T_A = 25^\circ C$, $V_{CM} = V_{DD} / 2$ and $V_{OUT} \sim V_{DD}/2$, V_{SS} = GND

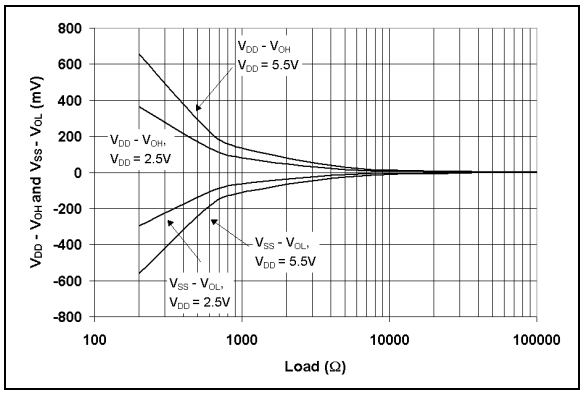


FIGURE 2-19: *Low Level and High Level Output Swing vs. Load Resistance*

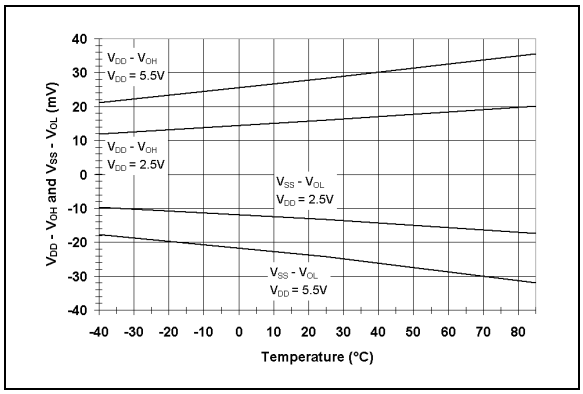


FIGURE 2-22: *Low Level and High Level output Swing vs. Temperature, R_L=5kΩ*

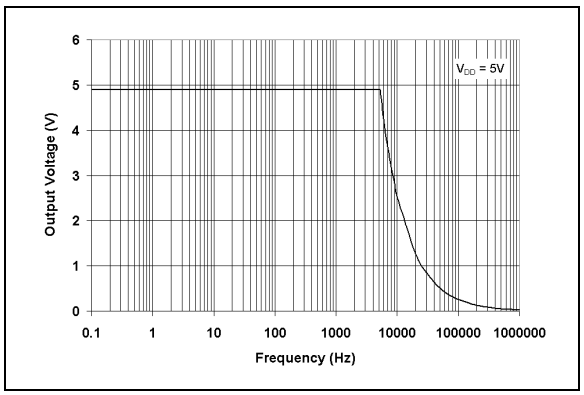


FIGURE 2-20: *Maximum Full Scale Output Voltage Swing vs. Frequency*

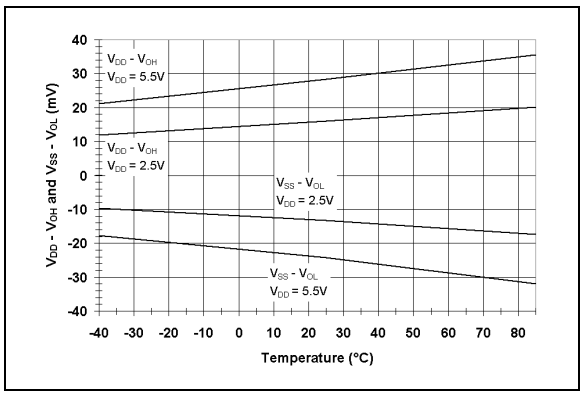


FIGURE 2-23: *Low Level and High level Output Swing vs. Temperature, R_L=25kΩ*

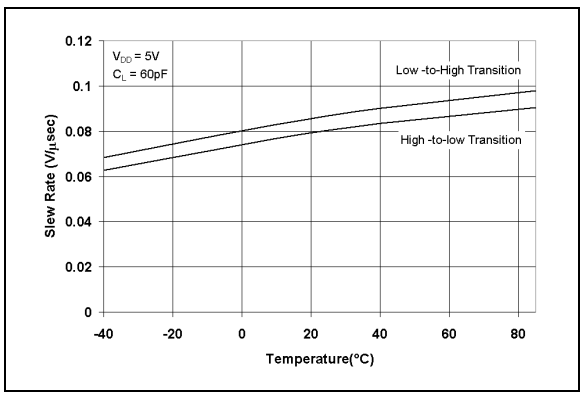


FIGURE 2-21: *Slew Rate vs. Temperature*

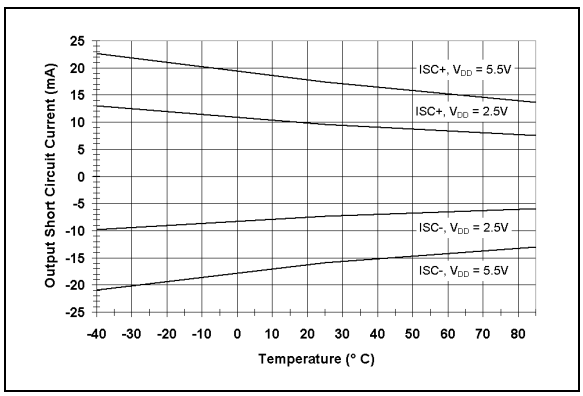


FIGURE 2-24: *Output Short Circuit Current vs. Temperature*

Note: Unless otherwise indicated, $T_A = 25^\circ C$, $V_{CM} = V_{DD} / 2$ and $V_{OUT} \sim V_{DD}/2$, V_{SS} = GND

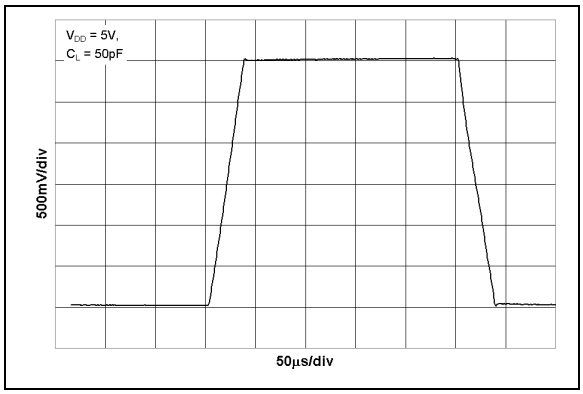


FIGURE 2-25: *Large Signal Non-inverting Signal Pulse Response*

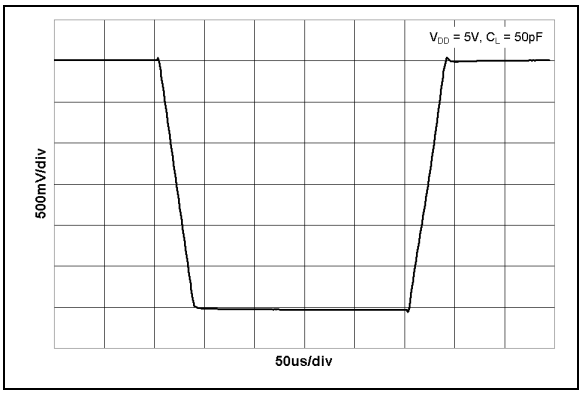


FIGURE 2-28: *Large Signal Inverting Signal Pulse Response*

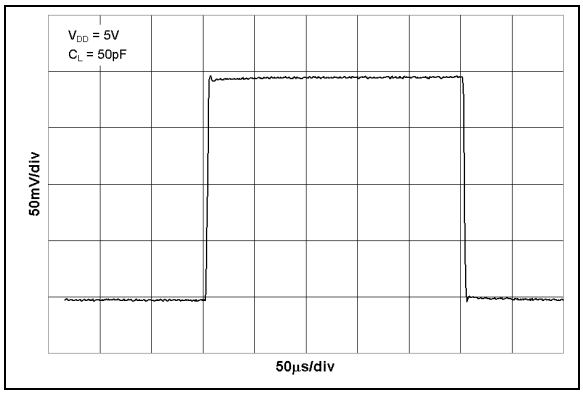


FIGURE 2-26: *Small Signal Non-inverting Pulse Response*

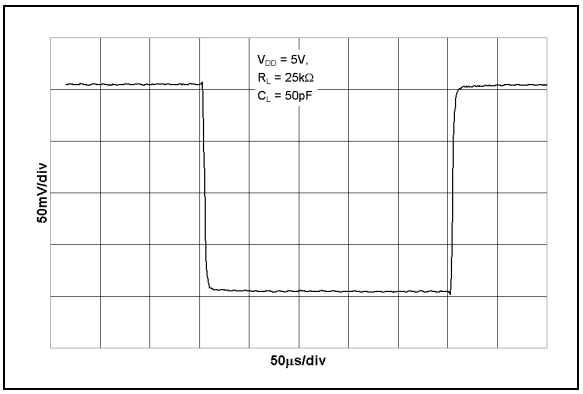


FIGURE 2-29: *Small Signal Inverting Signal Pulse Response*

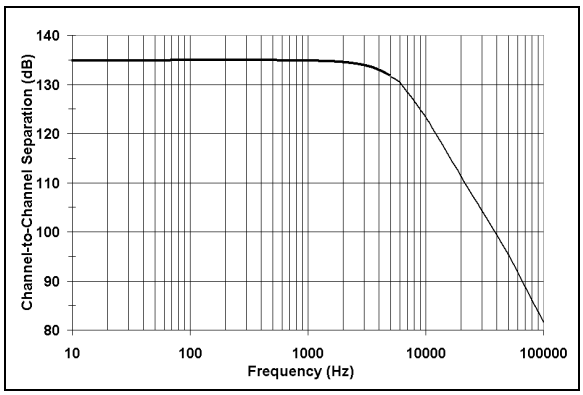


FIGURE 2-27: *Channel to Channel Separation (MCP607 and MCP609 only)*

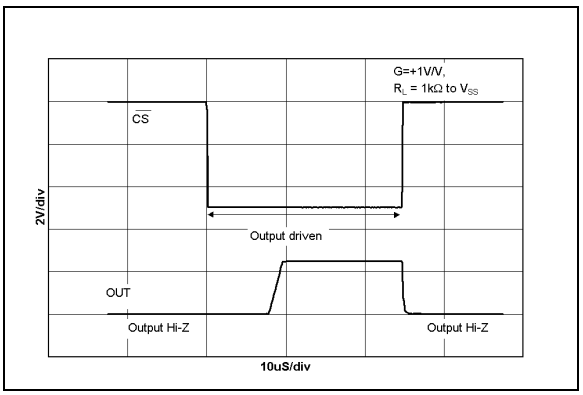


FIGURE 2-30: *$\overline{\text{Chip Select}}$ to Amplifier Output Response Time (MCP608 only)*

Note: Unless otherwise indicated, $T_A = 25^{\circ}C$, $V_{CM} = V_{DD} / 2$ and $V_{OUT} \sim V_{DD}/2$, V_{SS} = GND

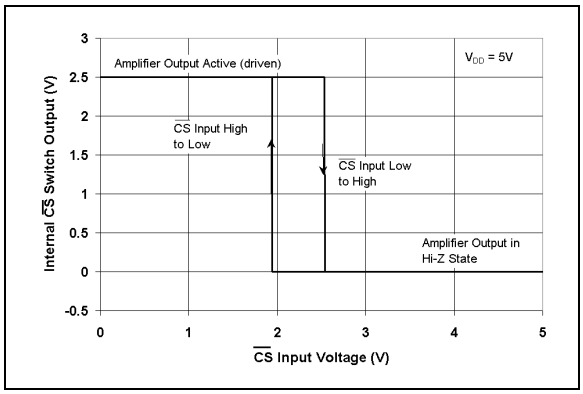


FIGURE 2-31: *$\overline{CS}$ hysteresis (MCP608 only)*

3.0 APPLICATIONS INFORMATION

The MCP606/607/608/609 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 0.1µF capacitor.

3.1 Rail-to-Rail Output Swing

There are two specifications that describe the output swing capability of the MCP606/607/608/609 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 MCP606/607/608/609 family is specified to be able to swing at least to 15mV from the negative rail with a 25kΩ load to V_{DD}/2.

This output swing performance is shown in Figure 3-1, where the output of an MCP606 is configured in a gain of +2V/V and overdriven with a 4kHz 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.

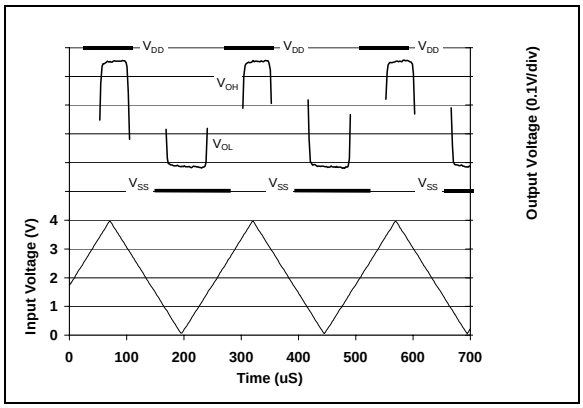


FIGURE 3-1: *Low Level and High Level Output Swing*

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 MCP606/607/608/609 family is specified within 50mV from the positive and negative rail with a 25kΩ load and 100mV from the rails with a 5kΩ 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 105dB (min) with a 25kΩ load.

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

$$A_{OL} = 20\ log_{10}\ \Delta(VOUT / \Delta VOS)$$

where:

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

ΔV_{OUT} is equal to (V_{DD} - 50mV) - (V_{SS}+ 50mV) for R_L= 25kΩ, and

ΔV_{OS} is the change in offset voltage with the changing output voltage of the amplifier.

3.2 Input Voltage and Phase Reversal

Since the MCP606/607/608/609 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.

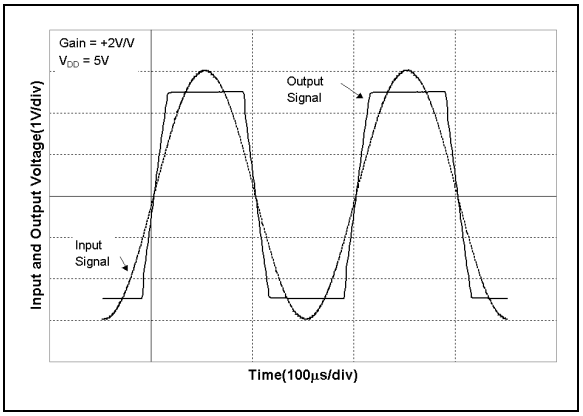


FIGURE 3-2: *The MCP606/607/608/609 family of op amps do not have phase reversal issues. For this graph, the amplifier is in a gain of +2V/V.*

The maximum operating common-mode voltage that can be applied to the inputs is V_{SS} - 0.3V to V_{DD} - 1.1V. 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 ±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.

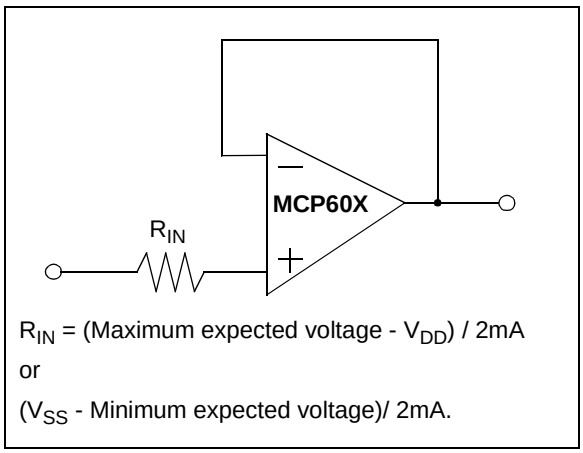


FIGURE 3-3: *If the inputs of the amplifier exceed the Absolute Maximum Specifications, an input resistor, R_{IN}, should be used to limit the current flow into that pin.*

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°. 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° 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°, while driving capacitance loads up to 220pF.

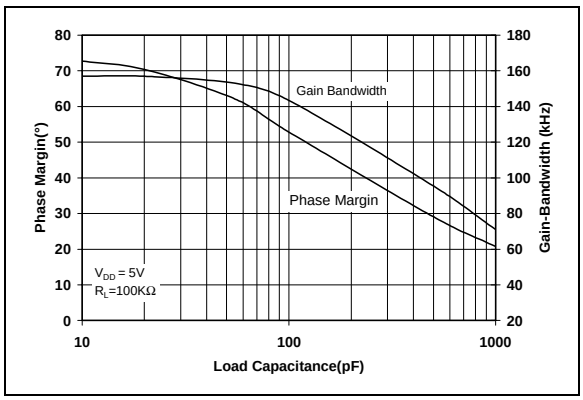


FIGURE 3-4: *Gain Bandwidth, Phase Margin vs. Capacitive Load*

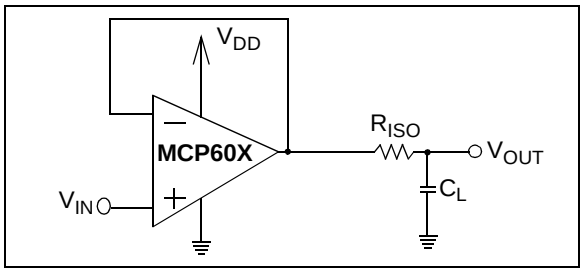


FIGURE 3-5: *Amplifier circuits that can be used when driving heavy capacitive loads.*

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:

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

where:

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

GBWP is the gain bandwidth product of the amplifier,

R_{ISO} is the capacitive decoupling resistor, and

C_L is the load capacitance

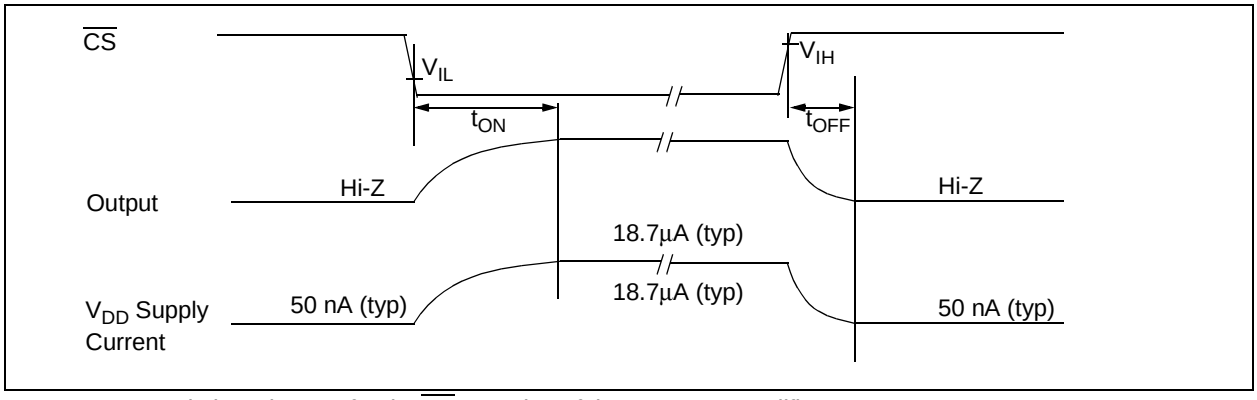


FIGURE 3-6: *Timing Diagram for the $\overline{CS}$ Function of the MCP608 Amplifier*

3.4 The Chip Select Option of the MCP608

The MCP608 is a single amplifier with a Chip Select ($\overline{CS}$) option. When $\overline{CS}$ is pulled high the supply current drops to 50 nA (typ). In this state, 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 amplifier will not operate properly. Figure 3-6 shows the output voltage and supply current response to a $\overline{CS}$ pulse.

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 to 5V and the input pin of the amplifier is biased at or near zero volts, a 5pA leakage current will appear on the amplifier's input node. This type of PCB leakage is five times the room temperature input bias current (1pA, typ) of the MCP606/607/608/609 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.

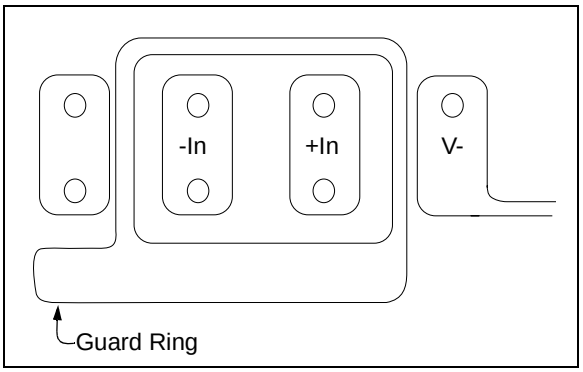


FIGURE 3-7: *Example of Guard Ring for the MCP606, the A-amplifier of the MCP607 or the MCP608 in a PC Board Layout*

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, non-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 3-8A

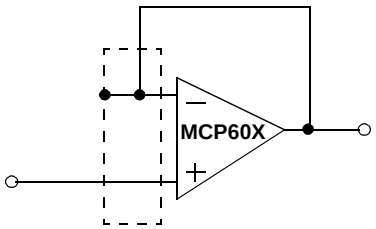


Figure 3-8B

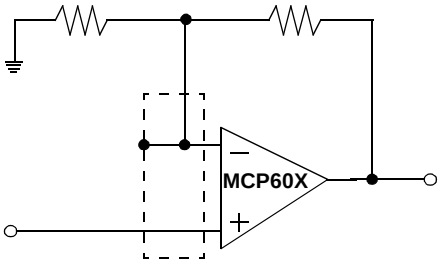


Figure 3-8C

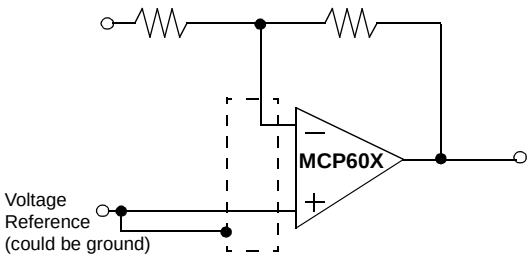


Figure 3-8D

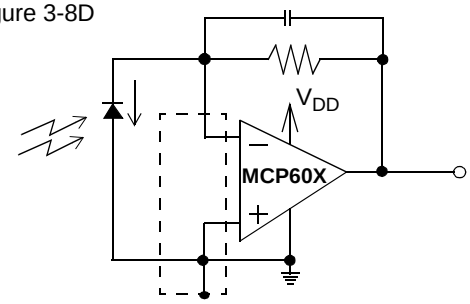


FIGURE 3-8: *Examples of how to design PC Board traces to minimize leakage paths to the high impedance input pins of the MCP606/607/608/609 amplifiers.*

3.5.2 SIGNAL COUPLING

The input pins of the MCP606/607/608/609 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.

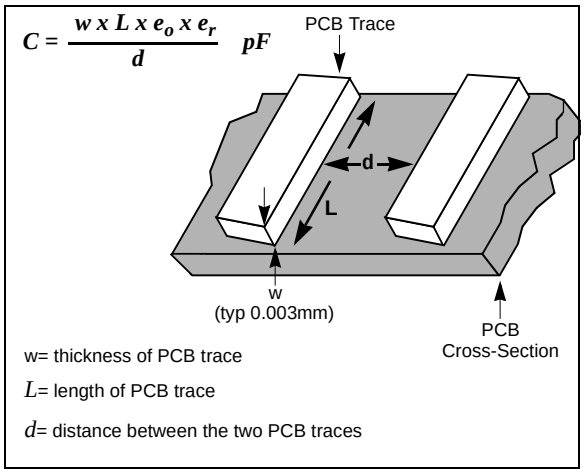


FIGURE 3-9: *Capacitors can be built with PCB traces allowing for coupling of signals from one trace to another.*

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,

∂V equals the change in voltage of the trace that is switching, and

∂t equals the amount of time that the voltage change took to get from one level to the next.

3.6 Typical Applications

3.6.1 LOW SIDE BATTERY CURRENT SENSING

The MCP606/607/608/609 amplifiers can be used to sense the output current on the low side of a battery using the circuit in Figure 3-10. In this circuit, the current from the power supply (minus the current required to power the MCP606) flows through a ten ohm resistor from the rest of the circuit in the system. This current is converted to a voltage through the sense resistor and gained by the resistors around the amplifier. Since the input bias current and offset voltage of the MCP606 is low, there is very little error generated by the amplifier. Additionally, the amplifier is capable of swinging below ground and the quiescent current is very low. These four specifications make this amplifier appropriate for this type of circuit.

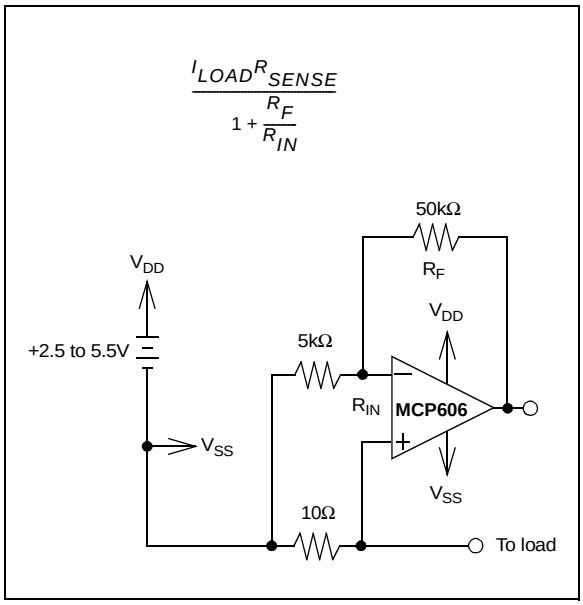


FIGURE 3-10: *Low Side Battery Current Sensing*

3.6.2 PREAMPLIFIER FOR PHOTO DETECTION CIRCUIT

Any amplifier from this family of operational amplifiers can be used to convert an output current signal from a sensor into a voltage. A sensor that fits this description is a photodetector as shown in Figure 3-11. This type of circuit is implemented with a single resistor and an optional capacitor in the feedback loop of the amplifier. As light impinges on the photo diode, charge is generated, causing a current to flow in the reverse bias direction of the photodetector.

Two circuits are shown in Figure 3-11. The top circuit is designed to provide precision sensing from the photodetector. In this circuit the voltage across the detector is nearly zero and equal to the offset voltage of the amplifier. With this configuration, current that appears across the resistor, R_2, is primarily a result of the light excitation on the photodetector. The photosensing circuit on the bottom of Figure 3-11 is designed for higher speed sensing. This is done by reverse biasing the photodetector, which reduces the parasitic capacitance of the diode.

The key specifications that influence the accuracy of these circuits are low offset voltage, low input bias current, high input impedance and an input common mode range below ground. The low input offset voltage and low input bias current provide an environment where there is minimal voltage placed across the photodetector, consequently the linearity of the photodetector is not compromised. Given that the MCP606/607/608/609 amplifiers are specified for a ±250µV(max) offset voltage and input bias currents in the pico ampere region they are ideal for these circuits. Additionally, these two circuits will only work if the common-mode range of the amplifier includes zero, which is the case with the MCP606/607/608/609 amplifiers.

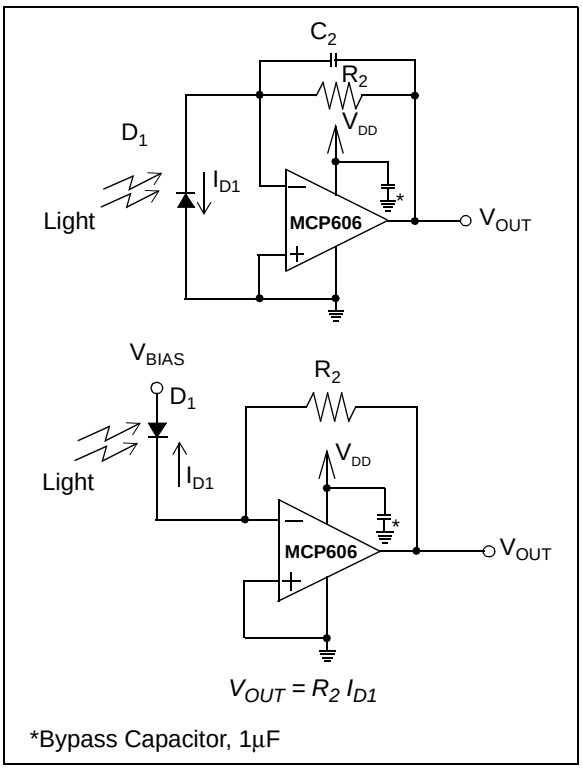
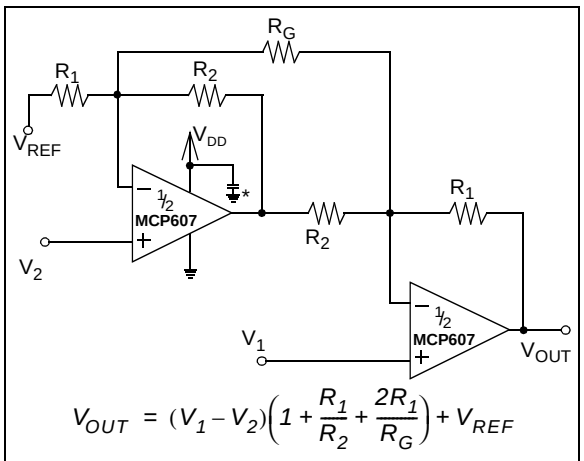


FIGURE 3-11: *Pre-Amplifier for Photo Detection Circuit*

3.6.3 TWO OP-AMP INSTRUMENTATION AMPLIFIER

The two op-amp instrumentation amplifier shown in Figure 3-12 serves the function of taking the difference of two input voltages, level shifting then and providing a single output. This configuration is best suited for higher gains. (gain > 3 V/V) is shown in Figure 3-12. The key specifications that make the MCP606/607/608/609 family appropriate for this application circuit is low input bias current, low offset voltage and high common-mode rejection. The reference voltage of this circuit is supplied to the first op amp in the signal chain. Typically, this voltage is half of the supply voltage in a single supply environment.

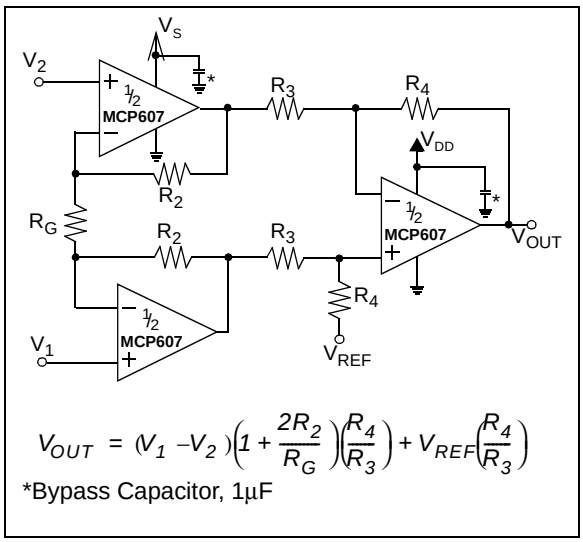


$$V_{OUT} = (V_1 - V_2)\left(1 + \frac{R_1}{R_2} + \frac{2R_1}{R_G}\right) + V_{REF}$$

FIGURE 3-12: *Two Op-Amp Instrumentation Amplifier*

3.6.4 THREE OP-AMP INSTRUMENTATION AMPLIFIER

A classic, three op amp instrumentation amplifier is illustrated in Figure 3-15. The input operational amplifiers in this circuit provide signal gain. The output operational amplifier converts the signal from two inputs to a single ended output with a difference amplifier. The gain of this circuit is simply adjusted with one resistor, R_G. The reference voltage of the difference stage of this instrumentation amplifier is capable of spanning a wide range. Most typically this node is referenced to half of the supply voltage in a signal supply application.



$$V_{OUT} = (V_1 - V_2)\left(1 + \frac{2R_2}{R_G}\right)\left(\frac{R_4}{R_3}\right) + V_{REF}\left(\frac{R_4}{R_3}\right)$$

FIGURE 3-13: *Three Op-Amp Instrumentation Amplifier*

3.6.5 PRECISION GAIN WITH GOOD LOAD ISOLATION

In Figure 3-14, the low input offset voltage of the MCP606 is used to implement a circuit with a high gain. This precision measurement can easily be disrupted by changing the output current drive of the device that is doing the amplification work. Consequently the precision amplifier configuration is followed by a MCP601 amplifier which is capable of driving higher currents. Since the two amplifiers are housed in separate packages, there is minimal change in offset voltage of the MCP606 due to loading effects.

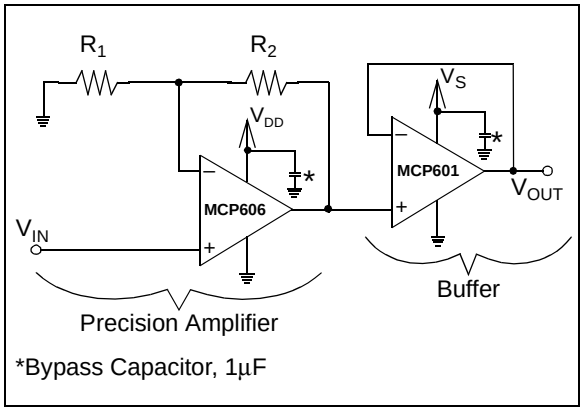


FIGURE 3-14: *Precision Gain with Good Load Isolation*

4.0 SPICE MACROMODEL

The Spice macromodel for the MCP606, MCP607, MCP608 and MCP609 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 MCP606, MCP607, MCP608, and MCP609 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 MCP608, 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.

```
.subckt mcp606 1 2 3 4 5
*               | | | | |
*               | | | | Output
*               | | | Negative supply
*               | | Positive Supply
*               | Inverting input
*              Non-inverting input
*
* Macromodel for MCP606 (single), MCP607 (dual), MCP608 (single w/CS), and MCP609 (quad)
*
* The characteristics of the MCP606, MCP607, MCP608, and MCP609 have the same fundamental
* performance and behavior. Consequently, this single op amp macromodel supports all four
* devices. However, the chip select function of the MCP608 is not modeled.
*
* Revision History:
*   REV A : 6-30-99  created  BCB
*
* This macromodel models typical amplifier offset voltage, DC power supply rejection, input
* capacitance, open loop gain over frequency, phase margin with 60pF load, output swing,
* power supply current, input voltage noise, slew rate.
*
* 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
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* TO ANY OF THE TECNOLOGY 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 300kHz
M1      9       64      7         3     Ptype
M2      8       2       7         3     Ptype
CDIFF   1       2       3E-12
CCM1    1       4       6E-12
CCM2    2       4       6E-12
IDD     3       7       13.33e-6
RA      8       6       1.839e3
RB      9       6       1.839e3
CA      8       9       125e-12
ICOMP   3       4       -194.63e-6

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

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

RST     58      59      1E3
DST     59      55      DX
```
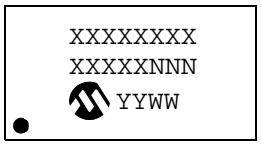

```
VST     58      4       1.6

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

*Input errors (vos, en, psr)

ERR  64   1  poly(2) (67,4) (3, 4) -229.9e-6 1 23e-6

*Second Stage, pole at 0.183Hz
GS      23      4       8       9     543.78e-6
R1      23      4       8.2144e9
C2      23      4       110e-12

VSOM    3       24      4.784
VSOP    25      4       -3.98
DSOM    23      24      DY
DSOP    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
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      0.03

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       10E3

.model Ptype PMOS L=2 W=105
.model DY D (IS=1e-15 BV =50)
.model DX D (IS=1e-18 AF=0.6 KF=10e-17)
.ENDS
```

5.0 PACKAGING INFORMATION

5.1 Package Marking Information

8-Lead PDIP (300 mil)

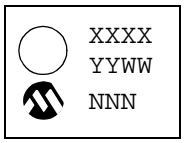


Example

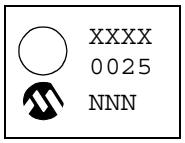
8-Lead SOIC (208 mil)

Example

8-Lead TSSOP



Example



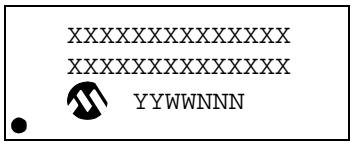
Legend:	XX...X	Customer specific information*
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week ‘01’)
	NNN	Alphanumeric traceability code

Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line thus limiting the number of available characters for customer specific information.

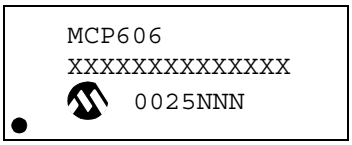
***** Standard OTP marking consists of Microchip part number, year code, week code, facility code, mask rev#, and assembly code. For OTP marking beyond this, certain price adders apply. Please check with your Microchip Sales Office. For QTP devices, any special marking adders are included in QTP price.

Package Marking Information (Continued)

14-Lead PDIP (300 mil)



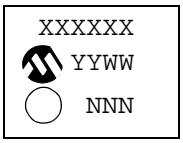
Example



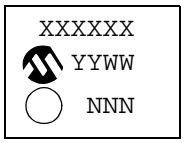
14-Lead SOIC (208 mil)

Example

14-Lead TSSOP



Example



Legend:	XX...X	Customer specific information*
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week ‘01’)
	NNN	Alphanumeric traceability code

Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line thus limiting the number of available characters for customer specific information.

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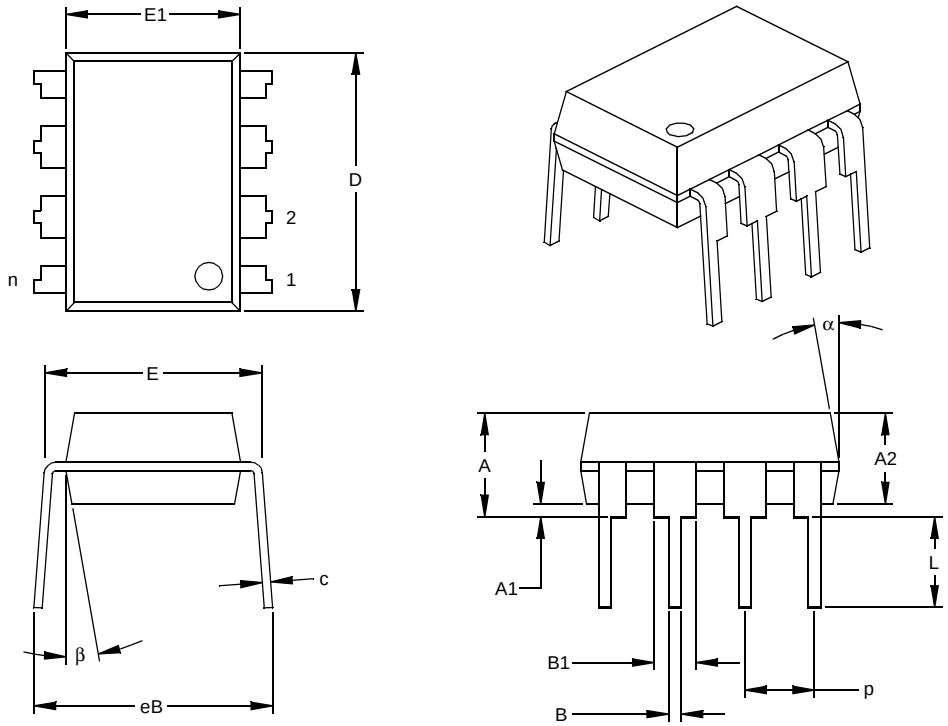
8-Lead Plastic Dual In-line (P) – 300 mil (PDIP)

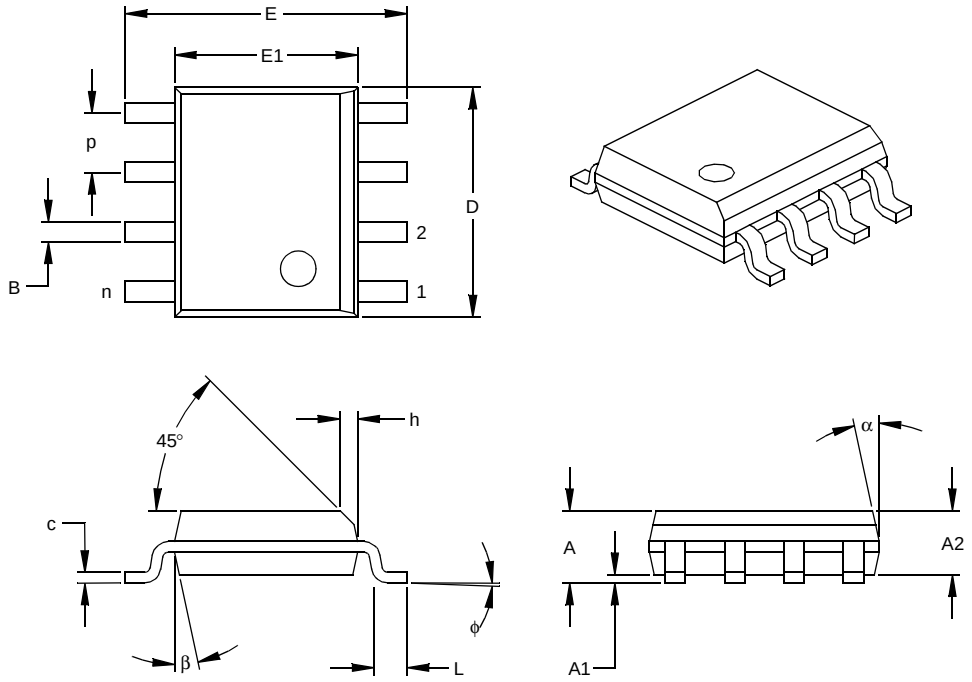


Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		8			8	
Pitch	p		.100			2.54	
Top to Seating Plane	A	.140	.155	.170	3.56	3.94	4.32
Molded Package Thickness	A2	.115	.130	.145	2.92	3.30	3.68
Base to Seating Plane	A1	.015			0.38		
Shoulder to Shoulder Width	E	.300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

* Controlling Parameter
§ Significant Characteristic

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

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

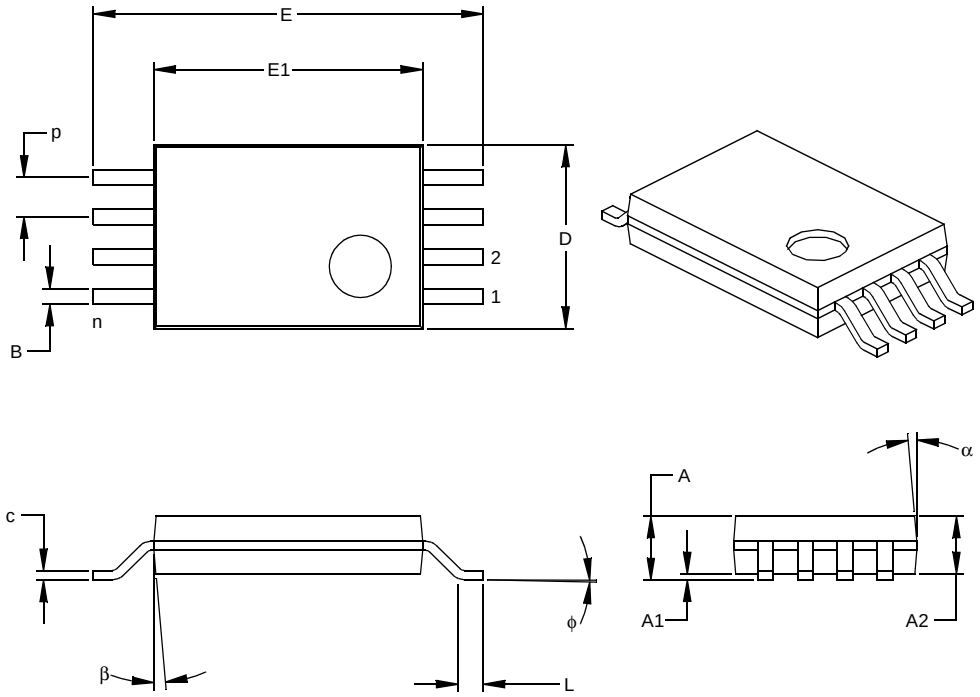


Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		8			8	
Pitch	p		.050			1.27	
Overall Height	A	.053	.061	.069	1.35	1.55	1.75
Molded Package Thickness	A2	.052	.056	.061	1.32	1.42	1.55
Standoff §	A1	.004	.007	.010	0.10	0.18	0.25
Overall Width	E	.228	.237	.244	5.79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

* Controlling Parameter
§ Significant Characteristic

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

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

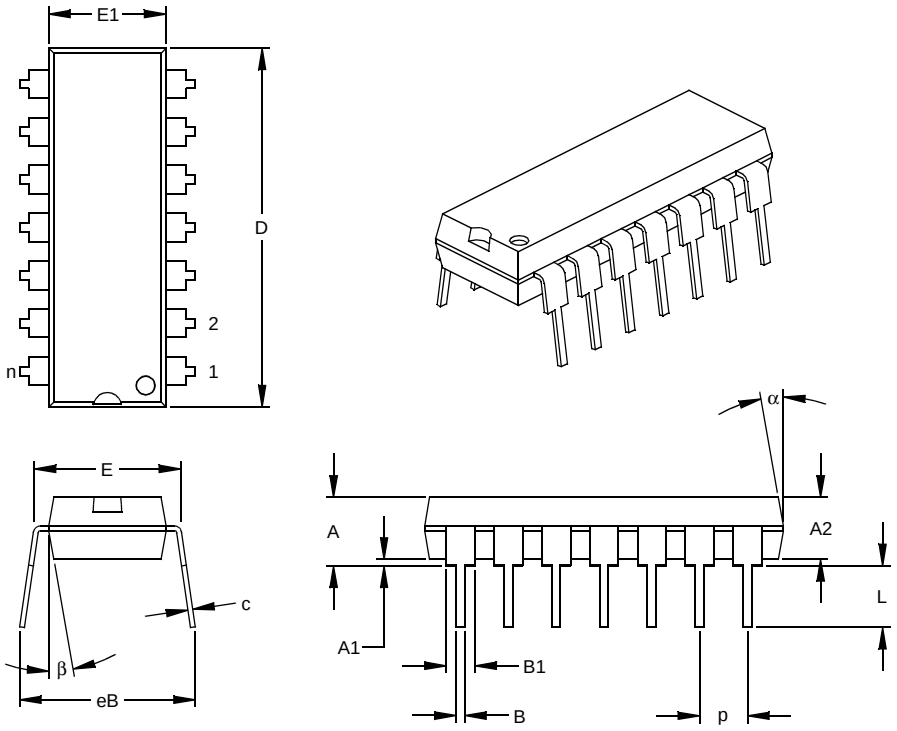


Units		INCHES			MILLIMETERS*		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		8			8	
Pitch	p		.026			0.65	
Overall Height	A			.043			1.10
Molded Package Thickness	A2	.033	.035	.037	0.85	0.90	0.95
Standoff §	A1	.002	.004	.006	0.05	0.10	0.15
Overall Width	E	.246	.251	.256	6.25	6.38	6.50
Molded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

* Controlling Parameter
§ Significant Characteristic

Notes:
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .005” (0.127mm) per side.
JEDEC Equivalent: MO-153
Drawing No. C04-086

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

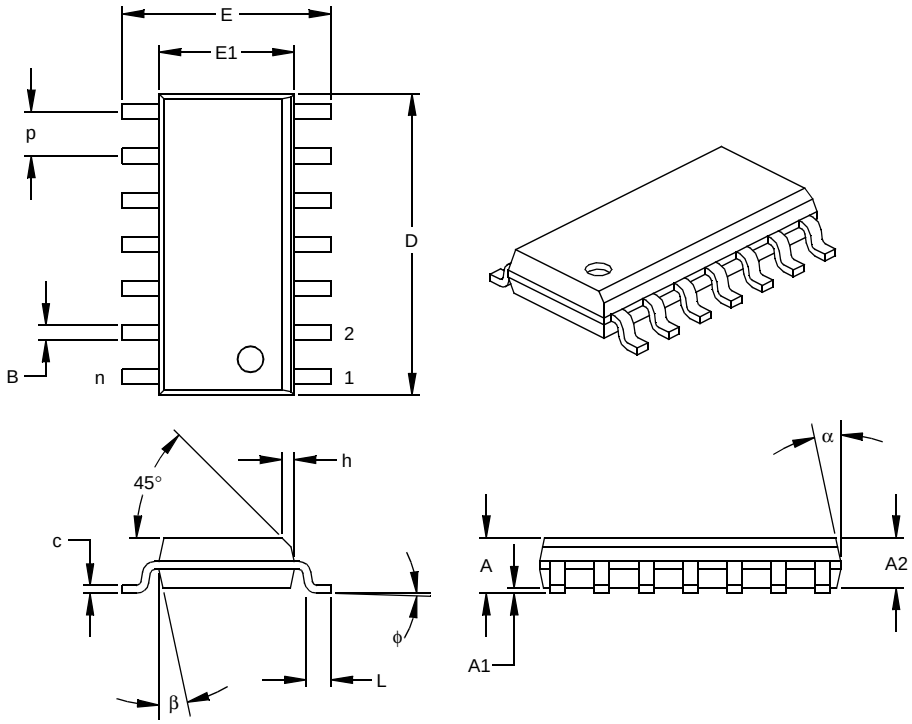


Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		14			14	
Pitch	p		.100			2.54	
Top to Seating Plane	A	.140	.155	.170	3.56	3.94	4.32
Molded Package Thickness	A2	.115	.130	.145	2.92	3.30	3.68
Base to Seating Plane	A1	.015			0.38		
Shoulder to Shoulder Width	E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

* Controlling Parameter
§ Significant Characteristic

Notes:
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010” (0.254mm) per side.
JEDEC Equivalent: MS-001
Drawing No. C04-005

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

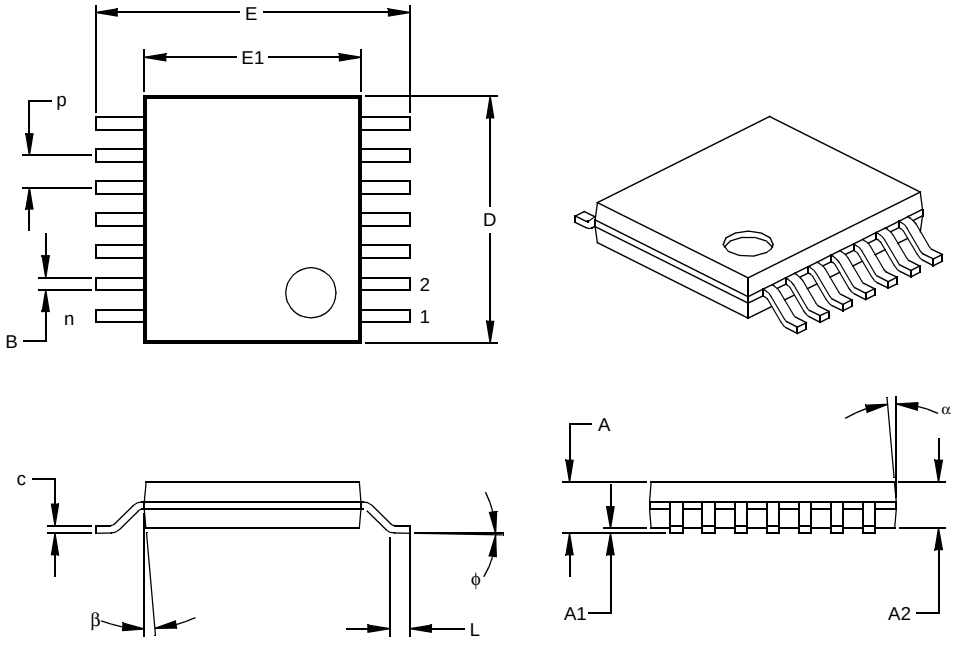


Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		14			14	
Pitch	p		.050			1.27	
Overall Height	A	.053	.061	.069	1.35	1.55	1.75
Molded Package Thickness	A2	.052	.056	.061	1.32	1.42	1.55
Standoff §	A1	.004	.007	.010	0.10	0.18	0.25
Overall Width	E	.228	.236	.244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

* Controlling Parameter
§ Significant Characteristic

Notes:
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010” (0.254mm) per side.
JEDEC Equivalent: MS-012
Drawing No. C04-065

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



Units		INCHES			MILLIMETERS*		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		14			14	
Pitch	p		.026			0.65	
Overall Height	A			.043			1.10
Molded Package Thickness	A2	.033	.035	.037	0.85	0.90	0.95
Standoff §	A1	.002	.004	.006	0.05	0.10	0.15
Overall Width	E	.246	.251	.256	6.25	6.38	6.50
Molded Package Width	E1	.169	.173	.177	4.30	4.40	4.50
Molded Package Length	D	.193	.197	.201	4.90	5.00	5.10
Foot Length	L	.020	.024	.028	0.50	0.60	0.70
Foot Angle	ϕ	0	4	8	0	4	8
Lead Thickness	c	.004	.006	.008	0.09	0.15	0.20
Lead Width	B1	.007	.010	.012	0.19	0.25	0.30
Mold Draft Angle Top	α	0	5	10	0	5	10
Mold Draft Angle Bottom	β	0	5	10	0	5	10

* Controlling Parameter
§ Significant Characteristic

Notes:
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .005” (0.127mm) per side.
JEDEC Equivalent: MO-153
Drawing No. C04-087

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NOTES:

NOTES:

MCP606/607/608/609 PRODUCT IDENTIFICATION SYSTEM

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

Part Number **X** **/X**

Package:

P	=	Plastic DIP (300 mil Body), 8-lead and 14-lead
SN	=	Plastic SOIC (150 mil Body), 8-lead
SL	=	Plastic SOIC (150 mil Body), 14-lead
ST	=	Plastic TSSOP, 8-lead and 14-lead

Temperature Range:

I	=	–40°C to +85°C

Device:

MCP606	=	Single Operational Amplifier
MCP606T	=	Single Operational Amplifier (Tape and Reel-SOIC/TSSOP)
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MCP607T	=	Dual Operational Amplifier (Tape and Reel-SOIC/TSSOP)
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