MCP6291/2/3/4/5

1.0 mA, 10 MHz Bandwidth, Rail-to-Rail Op Amp

Features

- Gain Bandwidth Product: 10 MHz (typ.)
- Supply Current: I_Q = 1.0 mA
- Supply Voltage: 2.4V to 5.5V
- Rail-to-Rail Input/Output
- Extended Temperature Range: -40°C to +125°C
- Available in Single, Dual and Quad Packages
- Single with Chip Select ($\overline{CS}$) (**MCP6293**)
- Dual with Chip Select ($\overline{CS}$) (**MCP6295**)

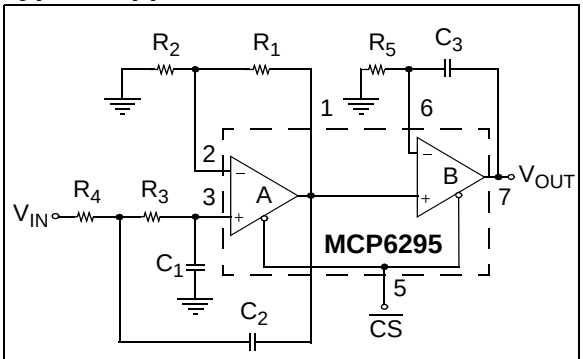
Applications

- Automotive
- Portable Equipment
- Photo Diode Pre-amps
- Analog Filters
- Notebooks and PDAs
- Battery-Powered Systems

Available Tools

- SPICE Macro Model (at www.microchip.com)
- FilterLab® Software (at www.microchip.com)

Typical Application



Second-Order Sallen-Key Low-Pass Filter with an Extra Pole-Zero Pair and a Chip Select.

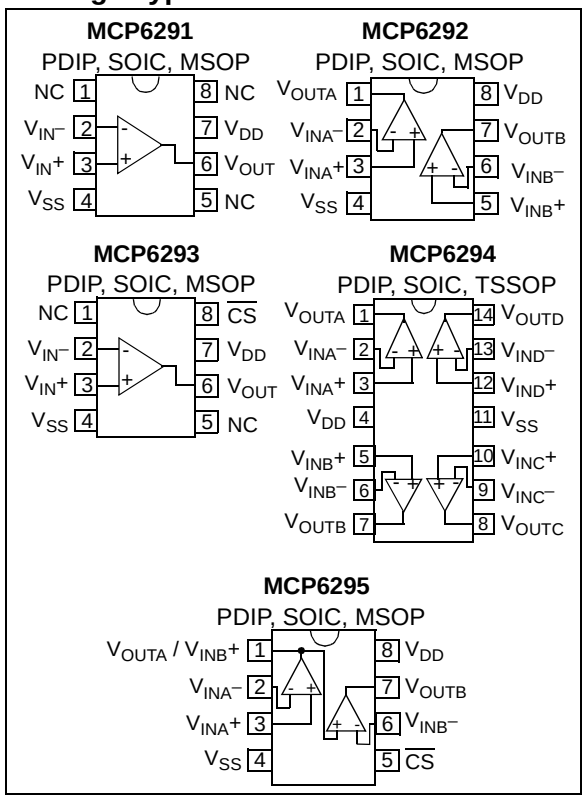
Description

The Microchip Technology Inc. MCP6291/2/3/4/5 family of operational amplifiers (op amps) provide wide bandwidth for the current. This family has a 10 MHz gain bandwidth product (GBWP) and a 65° phase margin. This family also operates from a single supply voltage as low as 2.4V, while drawing 1 mA (typ.) quiescent current. In addition, the MCP6291/2/3/4/5 supports rail-to-rail input and output swing, with a common mode input voltage range of V_{DD} + 300 mV to V_{SS} – 300 mV. This family of operational amplifiers is designed with Microchip's advanced CMOS process.

The MCP6295 has a chip select line ($\overline{CS}$) for dual op amps in an 8-pin package. This device is manufactured by cascading the two op amps, with the output of op amp A being connected to the non-inverting input of op amp B. The chip select line puts the device in a Low Power mode.

The MCP6291/2/3/4/5 family operates in the Extended Temperature Range of -40°C to +125°C. It also has a power supply range of 2.4V to 5.5V.

Package Types



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

V_{DD} - V_{SS} 7.0V
All Inputs and Outputs ..... V_{SS} -0.3V to V_{DD} +0.3V
Difference Input Voltage ..... $|V_{DD} – V_{SS}|$
Output Short Circuit Current .....continuous
Current at Input Pins .....±2 mA
Current at Output and Supply Pins .....±30 mA
Storage Temperature.....-65°C to +150°C
Junction Temperature (T_J) .....+150°C
ESD Protection On All Pins (HBM/MM) ..... ≥ 4 kV/400V

† **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
$V_{IN}+$, $V_{INA}+$, $V_{INB}+$, $V_{INC}+$, $V_{IND}+$	Non-inverting Inputs
$V_{IN}–$, $V_{INA}–$, $V_{INB}–$, $V_{INC}–$, $V_{IND}–$	Inverting Inputs
V_{DD}	Positive Power Supply
V_{SS}	Negative Power Supply
V_{OUT}, V_{OUTA}, V_{OUTB}, V_{OUTC}, V_{OUTD}	Outputs
NC	No Internal Connection
$\overline{CS}$	Chip Select
V_{OUTA} / $V_{INB}+$	Output of op amp A and non-inverting input of op amp B (MCP6295)

DC ELECTRICAL SPECIFICATIONS

Electrical Characteristics: Unless otherwise indicated, T_A = +25°C, V_{DD} = +2.4V to +5.5V, V_{SS} = GND, V_{CM} = V_{DD}/2, R_L = 10 kΩ to V_{DD}/2 and $V_{OUT} \approx V_{DD}$/2.

Parameters	Sym	Min	Typ	Max	Units	Conditions
Input Offset						
Input Offset Voltage	V_{OS}	-3.0	—	+3.0	mV	$V_{CM} = V_{SS}$ **(Note 1)**
Input Offset Voltage (Extended Temperature)	V_{OS}	-5.0	—	+5.0	mV	T_A = -40°C to +125°C, $V_{CM} = V_{SS}$ **(Note 1)**
Input Offset Temperature Drift	$\Delta V_{OS}/\Delta T_A$	—	±1.7	—	µV/°C	T_A = -40°C to +125°C, $V_{CM} = V_{SS}$ **(Note 1)**
Power Supply Rejection	PSRR	70	90	—	dB	$V_{CM} = V_{SS}$ **(Note 1)**
Input Bias, Input Offset Current and Impedance						
Input Bias Current	I_B	—	±1.0	—	pA	**Note 2**
At Temperature	I_B	—	50	200	pA	T_A = +85°C **(Note 2)**
At Temperature	I_B	—	2	5	nA	T_A = +125°C **(Note 2)**
Input Offset Current	I_{OS}	—	±1.0	—	pA	**Note 3**
Common Mode Input Impedance	Z_{CM}	—	10^{13}||6	—	Ω||pF	**Note 3**
Differential Input Impedance	Z_{DIFF}	—	10^{13}||3	—	Ω||pF	**Note 3**
Common Mode (Note 4)						
Common Mode Input Range	V_{CMR}	V_{SS}–0.3	—	V_{DD}+0.3	V	
Common Mode Rejection Ratio	CMRR	70	85	—	dB	V_{CM} = -0.3V to 2.5V, V_{DD} = 5V
Common Mode Rejection Ratio	CMRR	65	80	—	dB	V_{CM} = -0.3V to 5.3V, V_{DD} = 5V
Open-Loop Gain						
DC Open-Loop Gain (large signal)	A_{OL}	90	110	—	dB	V_{OUT} = 0.2V to V_{DD} - 0.2V, $V_{CM} = V_{SS}$ **(Note 1)**

Note 1: V_{CM} for op amp B of the MCP6295 is V_{SS} + 100 mV.
2: The V_{INB}– pin bias current for the MCP6295 is specified by I_B only.
3: This specification does not apply to the V_{OUTA}/V_{INB}+ pin of the MCP6295.
4: The common mode (V_{CM}) range for the MCP6295 is V_{SS} + 100 mV to V_{DD} - 100 mV. And the maximum voltage limit at V_{OUTA}/V_{INB}+ pin is specified by V_{OH} and V_{OL}.

DC ELECTRICAL SPECIFICATIONS (CONTINUED)

Electrical Characteristics: Unless otherwise indicated, T_A = +25°C, V_{DD} = +2.4V to +5.5V, V_{SS} = GND, V_{CM} = V_{DD}/2, R_L = 10 kΩ to V_{DD}/2 and V_{OUT} ≈ V_{DD}/2.

Parameters	Sym	Min	Typ	Max	Units	Conditions
Output						
Maximum Output Voltage Swing	V_{OL}, V_{OH}	V_{SS} + 15	—	V_{DD} – 15	mV	
Output Short-Circuit Current	I_{SC}	—	±25	—	mA	
Power Supply						
Supply Voltage	V_{DD}	2.4	—	5.5	V	T_A = -40°C to +125°C
Quiescent Current per Amplifier	I_Q	0.7	1.0	1.3	mA	I_O = 0

Note 1: V_{CM} for op amp B of the MCP6295 is V_{SS} + 100 mV.

2: The V_{INB}– pin bias current for the MCP6295 is specified by I_B only.

3: This specification does not apply to the V_{OUTA}/V_{INB}+ pin of the MCP6295.

4: The common mode (V_{CM}) range for the MCP6295 is V_{SS} + 100 mV to V_{DD} - 100 mV. And the maximum voltage limit at V_{OUTA}/V_{INB}+ pin is specified by V_{OH} and V_{OL}.

AC ELECTRICAL SPECIFICATIONS

Electrical Characteristics: Unless otherwise indicated, T_A = +25°C, V_{DD} = +2.4V to +5.5V, V_{SS} = GND, V_{CM} = V_{DD}/2, V_{OUT} ≈ V_{DD}/2, R_L = 10 kΩ to V_{DD}/2 and C_L = 60 pF.

Parameters	Sym	Min	Typ	Max	Units	Conditions
AC Response						
Gain Bandwidth Product	GBWP	—	10.0	—	MHz	
Phase Margin at Unity-Gain	PM	—	65	—	°	
Slew Rate	SR	—	7	—	V/µs	
Noise						
Input Noise Voltage	E_{ni}	—	3.5	—	µVp-p	f = 0.1 Hz to 10 Hz
Input Noise Voltage Density	e_{ni}	—	8.7	—	nV/√Hz	f = 10 kHz
Input Noise Current Density	i_{ni}	—	3	—	fA/√Hz	f = 1 kHz

TEMPERATURE SPECIFICATIONS

Electrical Characteristics: Unless otherwise indicated, V_{DD} = +2.4V to +5.5V and V_{SS} = GND.

Parameters	Sym	Min	Typ	Max	Units	Conditions
Temperature Ranges						
Operating Temperature Range	T_A	-40	—	+125	°C	**Note**
Storage Temperature Range	T_A	-65	—	+150	°C	
Thermal Package Resistances						
Thermal Resistance, 8L-PDIP	θ_{JA}	—	85	—	°C/W	
Thermal Resistance, 8L-SOIC	θ_{JA}	—	163	—	°C/W	
Thermal Resistance, 8L-MSOP	θ_{JA}	—	206	—	°C/W	
Thermal Resistance, 14L-PDIP	θ_{JA}	—	70	—	°C/W	
Thermal Resistance, 14L-SOIC	θ_{JA}	—	120	—	°C/W	
Thermal Resistance, 14L-TSSOP	θ_{JA}	—	100	—	°C/W	

Note: The Junction Temperature (T_J) must not exceed the Absolute Maximum specification of +150°C.

MCP6293/MCP6295 CHIP SELECT ($\overline{CS}$) SPECIFICATIONS

Electrical Characteristics: Unless otherwise indicated, T_A = +25°C, V_{DD} = +2.4V to +5.5V, V_{SS} = GND, $V_{CM} = V_{DD}/2$, $V_{OUT} \approx V_{DD}/2$, R_L = 10 kΩ to $V_{DD}/2$ and C_L = 60 pF.

Parameters	Sym	Min	Typ	Max	Units	Conditions
$\overline{CS}$ Low Specifications						
$\overline{CS}$ Logic Threshold, Low	V_{IL}	V_{SS}	—	0.2 V_{DD}	V	
$\overline{CS}$ Input Current, Low	I_{CSL}	—	0.01	—	µA	$\overline{CS} = V_{SS}$
$\overline{CS}$ High Specifications						
$\overline{CS}$ Logic Threshold, High	V_{IH}	0.8 V_{DD}	—	V_{DD}	V	
$\overline{CS}$ Input Current, High	I_{CSH}	—	0.7	2	µA	$\overline{CS} = V_{DD}$
GND Current	I_Q	—	-0.7	—	µA	$\overline{CS} = V_{DD}$
Amplifier Output Leakage	—	—	0.01	—	µA	$\overline{CS} = V_{DD}$
Dynamic Specifications (Note 1)						
$\overline{CS}$ Low to Valid Amplifier Output, Turn-on Time	t_{ON}	—	4	10	µs	$\overline{CS}$ Low ≤ 0.2 V_{DD}, G = +1 V/V, $V_{IN} = V_{DD}/2$, V_{OUT} = 0.9 $V_{DD}/2$, V_{DD} = 5.0V
$\overline{CS}$ High to Amplifier Output High-Z	t_{OFF}	—	0.01	—	µs	$\overline{CS}$ High ≥ 0.8 V_{DD}, G = +1 V/V, $V_{IN} = V_{DD}/2$, V_{OUT} = 0.1 $V_{DD}/2$
Hysteresis	V_{HYST}	—	0.6	—	V	V_{DD} = 5V

Note 1: The input condition (V_{IN}) specified applies to both op amp A and B of the MCP6295. The dynamic specification is tested at the output of op amp B (V_{OUTB}).

2.0 TYPICAL PERFORMANCE CURVES

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

Note: Unless otherwise indicated, T_A = +25°C, V_{DD} = +2.4V to +5.5V, V_{SS} = GND, V_{CM} = V_{DD}/2, V_{OUT} ≈ V_{DD}/2, R_L = 10 kΩ to V_{DD}/2 and C_L = 60 pF.

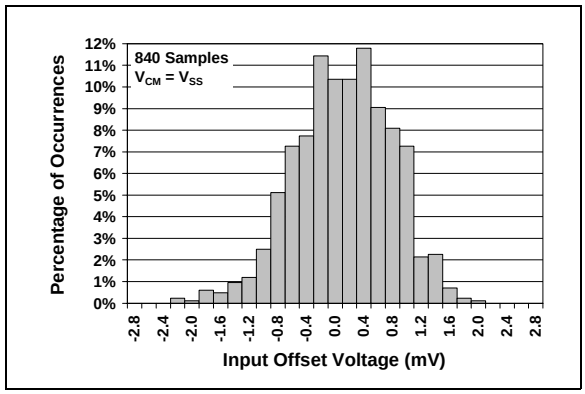


FIGURE 2-1: *Input Offset Voltage.*

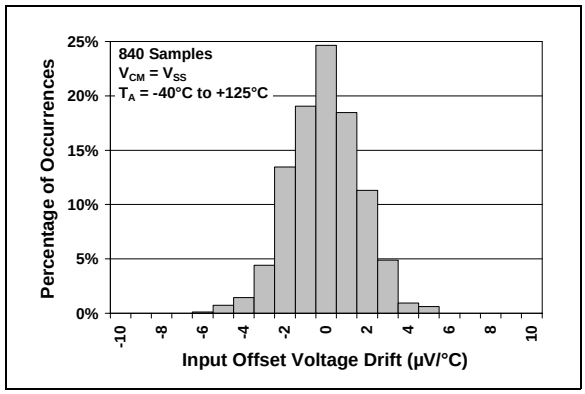


FIGURE 2-4: *Input Offset Voltage Drift.*

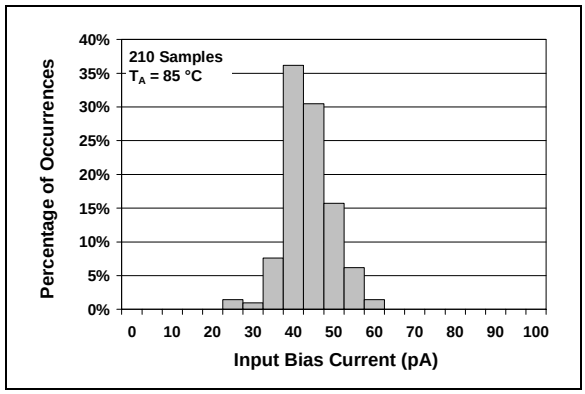


FIGURE 2-2: *Input Bias Current with T_A = +85 °C.*

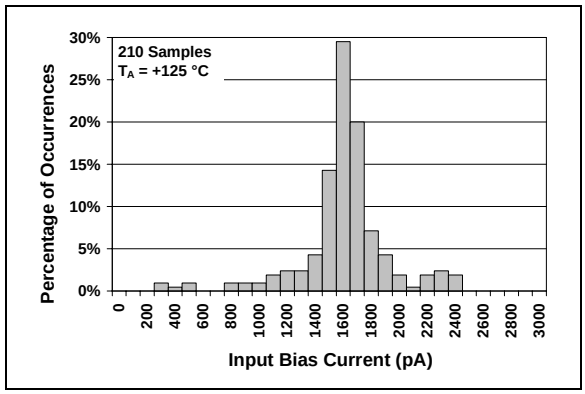


FIGURE 2-5: *Input Bias Current with T_A = +125 °C.*

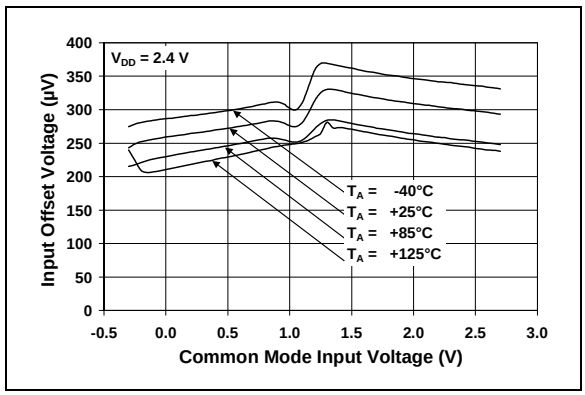


FIGURE 2-3: *Input Offset Voltage vs. Common Mode Input Voltage with V_{DD} = 2.4V.*

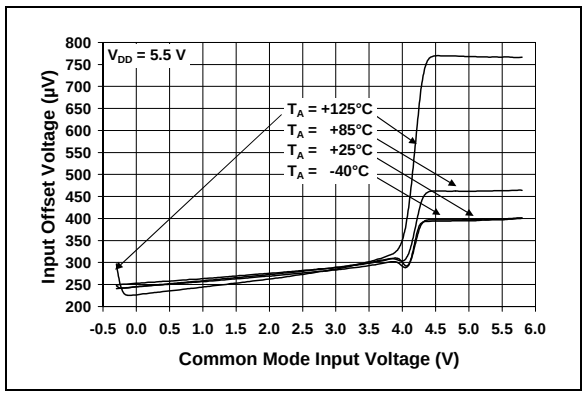


FIGURE 2-6: *Input Offset Voltage vs. Common Mode Input Voltage with V_{DD} = 5.5V.*

Note: Unless otherwise indicated, T_A = +25°C, V_{DD} = +2.4V to +5.5V, V_{SS} = GND, V_{CM} = V_{DD}/2, V_{OUT} ≈ V_{DD}/2, R_L = 10 kΩ to V_{DD}/2 and C_L = 60 pF.

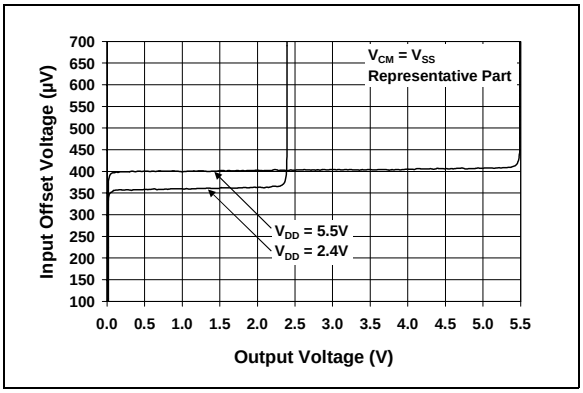


FIGURE 2-7: *Input Offset Voltage vs. Output Voltage.*

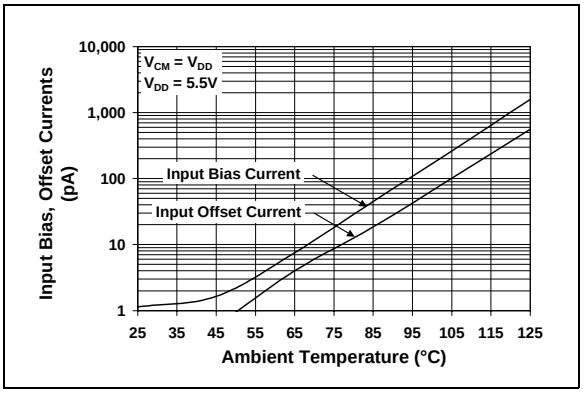


FIGURE 2-10: *Input Bias, Input Offset Currents vs. Ambient Temperature V_{DD} = 5.5V.*

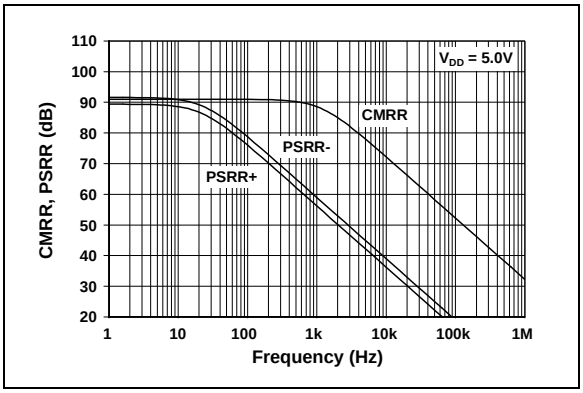


FIGURE 2-8: *CMRR, PSRR vs. Frequency.*

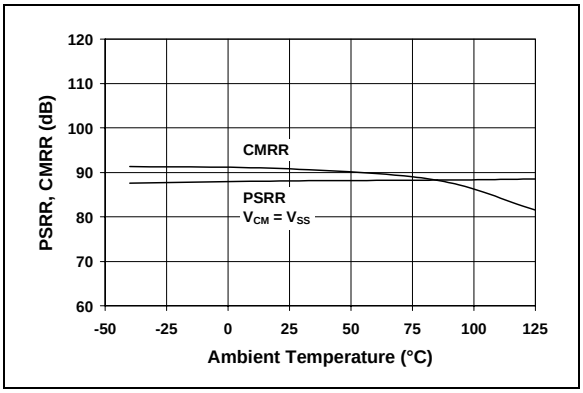


FIGURE 2-11: *CMRR, PSRR vs. Ambient Temperature.*

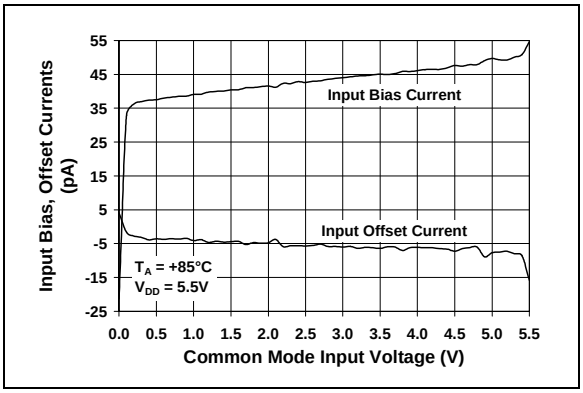


FIGURE 2-9: *Input Bias, Input Offset Currents vs. Common Mode Input Voltage with T_A = +85°C.*

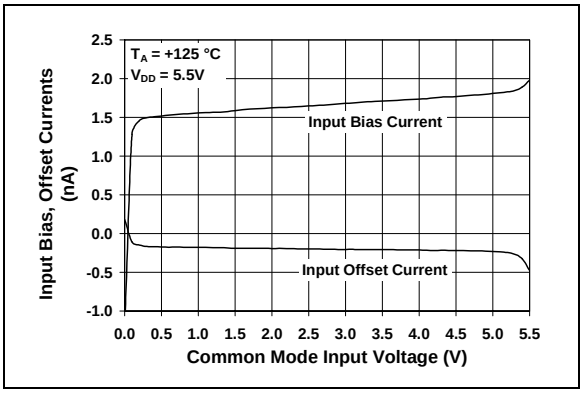


FIGURE 2-12: *Input Bias, Input Offset Currents vs. Common Mode Input Voltage with T_A = +125°C.*

Note: Unless otherwise indicated, T_A = +25°C, V_{DD} = +2.4V to +5.5V, V_{SS} = GND, V_{CM} = V_{DD}/2, V_{OUT} ≈ V_{DD}/2, R_L = 10 kΩ to V_{DD}/2 and C_L = 60 pF.

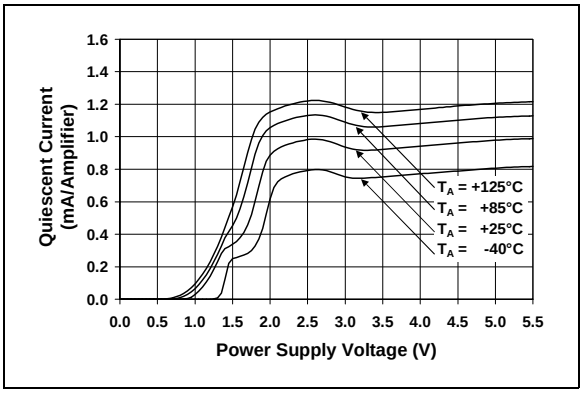


FIGURE 2-13: *Quiescent Current vs. Power Supply Voltage.*

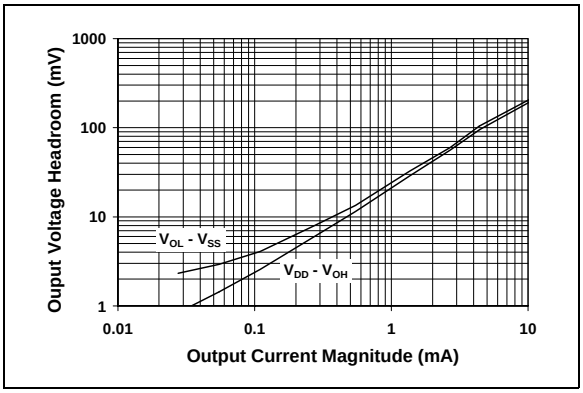


FIGURE 2-16: *Output Voltage Headroom vs. Output Current Magnitude.*

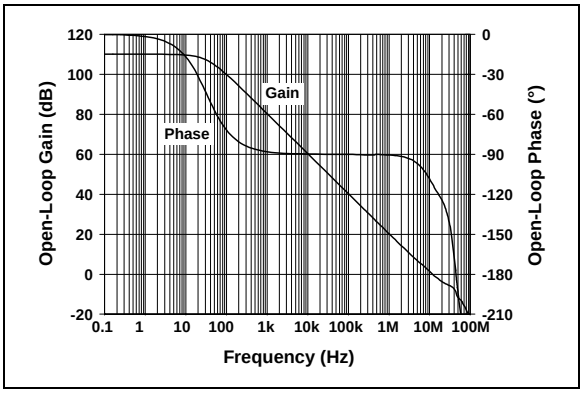


FIGURE 2-14: *Open-Loop Gain, Phase vs. Frequency.*

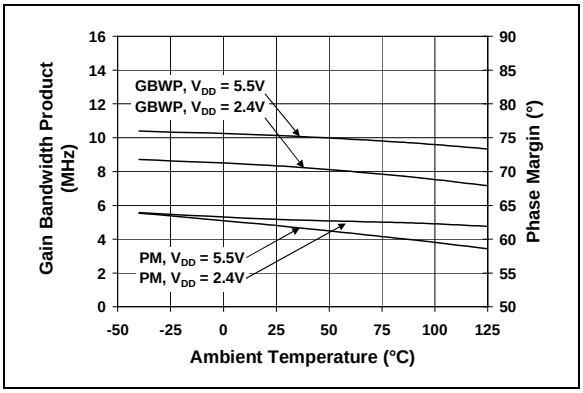


FIGURE 2-17: *Gain Bandwidth Product, Phase Margin vs. Ambient Temperature.*

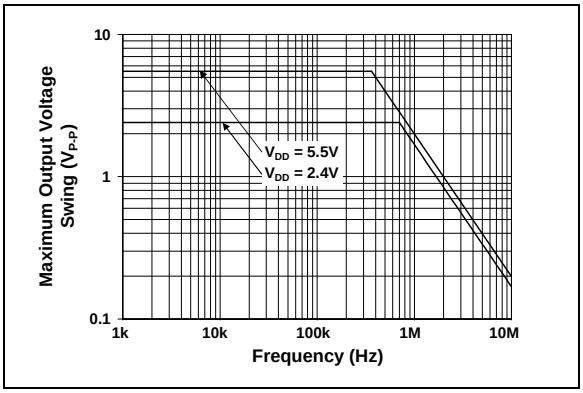


FIGURE 2-15: *Maximum Output Voltage Swing vs. Frequency.*

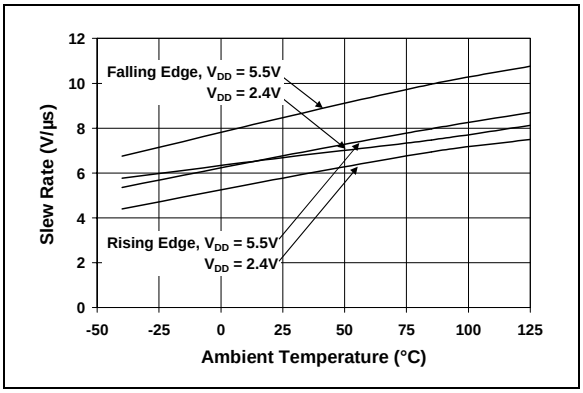


FIGURE 2-18: *Slew Rate vs. Ambient Temperature.*

Note: Unless otherwise indicated, T_A = +25°C, V_{DD} = +2.4V to +5.5V, V_{SS} = GND, V_{CM} = V_{DD}/2, V_{OUT} ≈ V_{DD}/2, R_L = 10 kΩ to V_{DD}/2 and C_L = 60 pF.

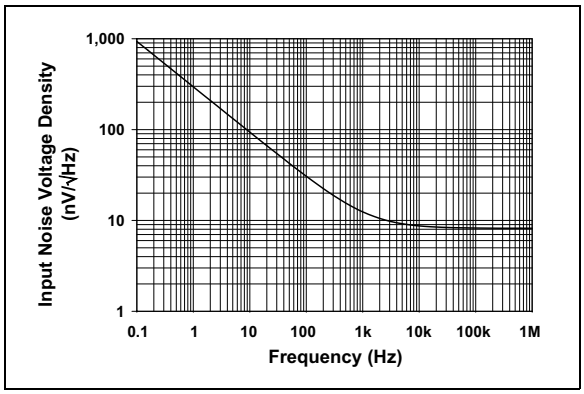


FIGURE 2-19: *Input Noise Voltage Density vs. Frequency.*

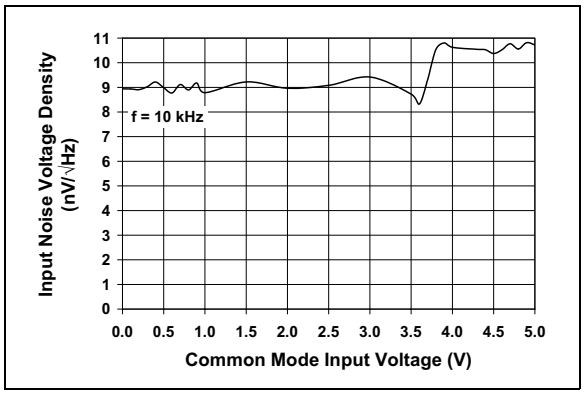


FIGURE 2-22: *Input Noise Voltage Density vs. Common Mode Input Voltage at 10 kHz.*

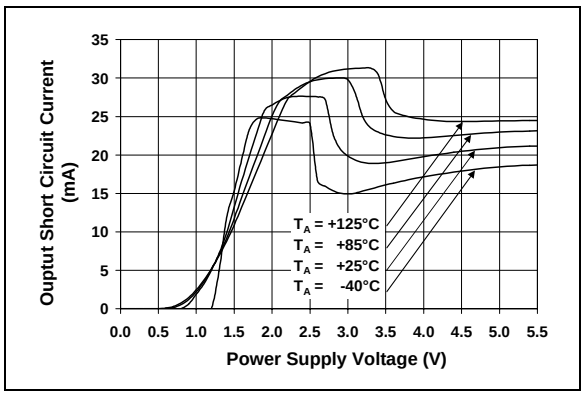


FIGURE 2-20: *Output Short-Circuit Current vs. Power Supply Voltage.*

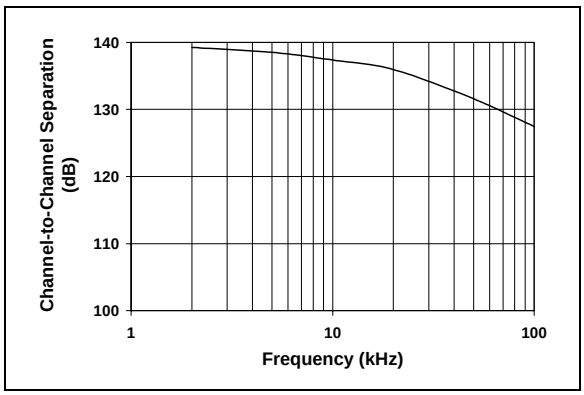


FIGURE 2-23: *Channel-to-Channel Separation vs. Frequency (MCP6292, MCP6294 and MCP6295 only).*

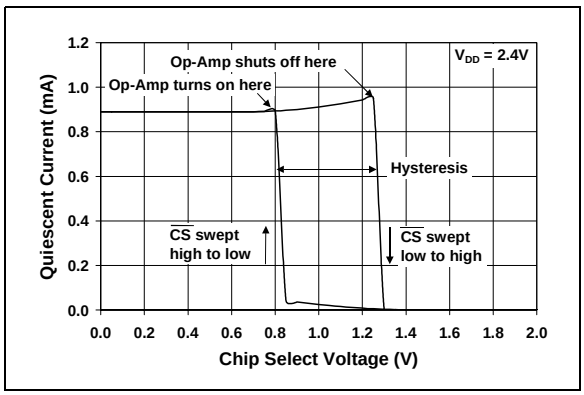


FIGURE 2-21: *Quiescent Current vs. Chip Select (CS) Voltage with V_{DD} = 2.4V (MCP6293 and MCP6295 only).*

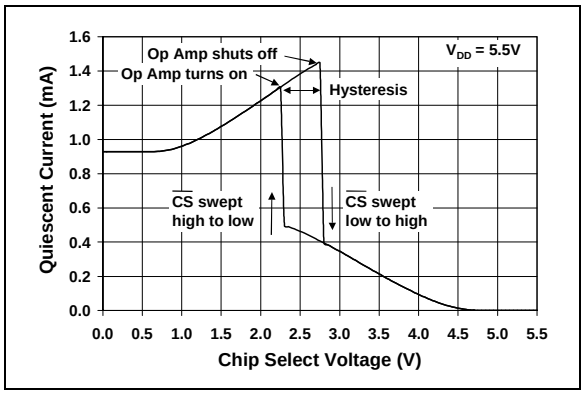


FIGURE 2-24: *Quiescent Current vs. Chip Select (CS) Voltage with V_{DD} = 5.5V (MCP6293 and MCP6295 only).*

Note: Unless otherwise indicated, T_A = +25°C, V_{DD} = +2.4V to +5.5V, V_{SS} = GND, V_{CM} = V_{DD}/2, V_{OUT} ≈ V_{DD}/2, R_L = 10 kΩ to V_{DD}/2 and C_L = 60 pF.

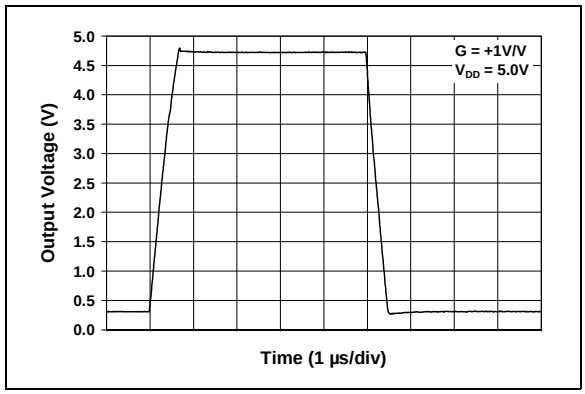


FIGURE 2-25: *Large Signal Non-inverting Pulse Response.*

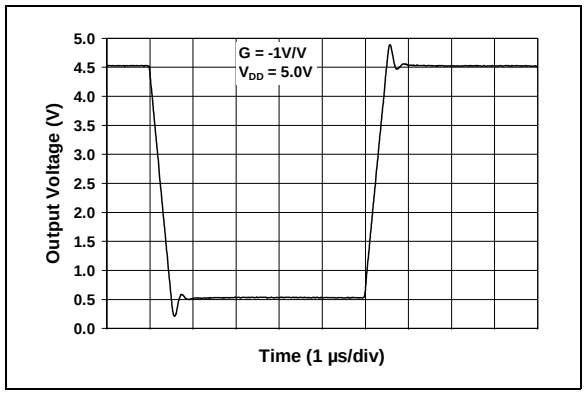


FIGURE 2-28: *Large Signal Inverting Pulse Response.*

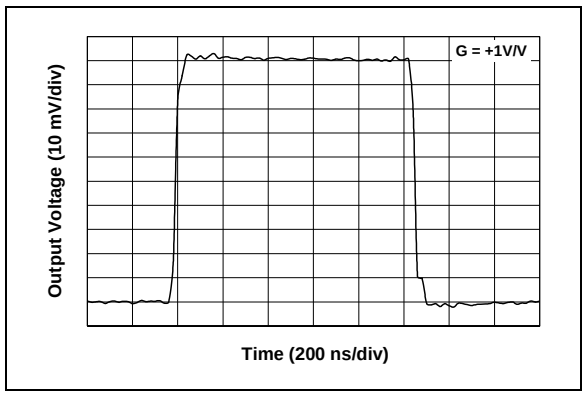


FIGURE 2-26: *Small Signal Non-inverting Pulse Response.*

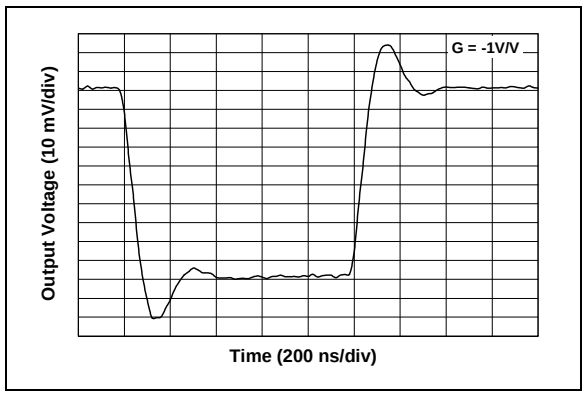


FIGURE 2-29: *Small Signal Inverting Pulse Response.*

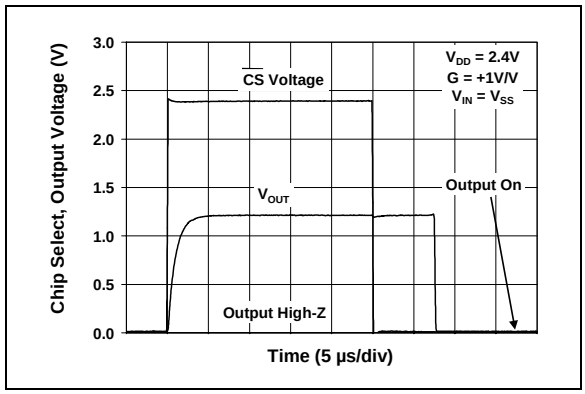


FIGURE 2-27: *Chip Select ($\overline{CS}$) to Amplifier Output Response Time with V_{DD} = 2.4V (MCP6293 and MCP6295 only).*

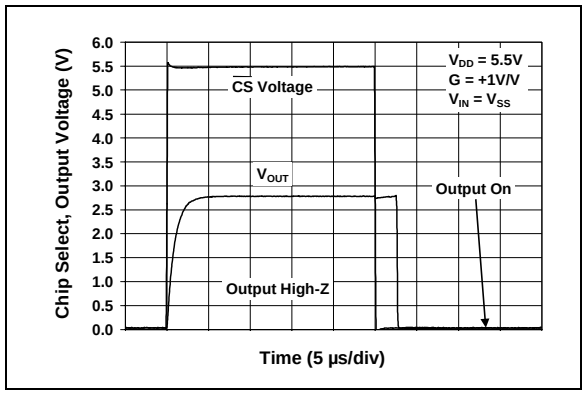


FIGURE 2-30: *Chip Select ($\overline{CS}$) to Amplifier Output Response Time with V_{DD} = 5.5V (MCP6293 and MCP6295 only).*

3.0 APPLICATION INFORMATION

The MCP6291/2/3/4/5 family of op amps is manufactured using Microchip's state-of-the-art CMOS process, specifically designed for low-cost, low-power and general-purpose applications. The low supply voltage, low quiescent current and wide bandwidth makes the MCP6291/2/3/4/5 ideal for battery-powered applications.

3.1 Rail-to-Rail Input

The MCP6291/2/3/4/5 op amps are designed to prevent phase reversal when the input pins exceed the supply voltages. Figure 3-1 shows the input voltage exceeding the supply voltage without any phase reversal.

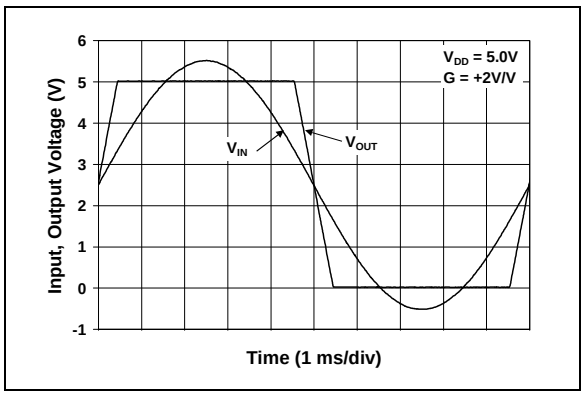


FIGURE 3-1: *The MCP6291/2/3/4/5 Show No Phase Reversal.*

The input stage of the MCP6291/2/3/4/5 op amp uses two differential input stages in parallel. One operates at low common mode input voltage (V_{CM}), while the other operates at high V_{CM}. With this topology, the device operates with V_{CM} up to 300 mV above V_{DD} and 300 mV below V_{SS}. The Input Offset Voltage is measured at $V_{CM} = V_{SS} - 300$ mV and $V_{DD} + 300$ mV to ensure proper operation.

Input voltages that exceed the input voltage range (V_{SS} – 0.3V to V_{DD} + 0.3V at 25°C) can cause excessive current to flow into or out of the input pins. Current beyond ±2 mA can cause reliability problems. Applications that exceed this rating must be externally limited with a resistor, as shown in Figure 3-2.

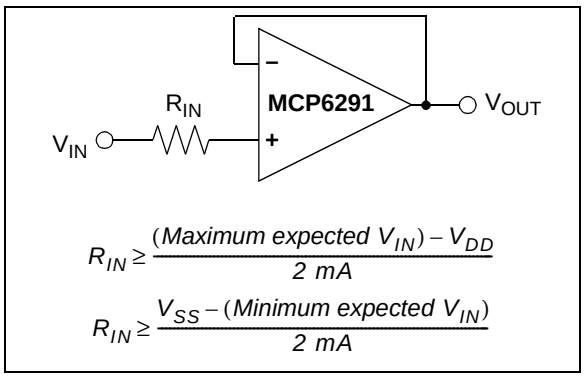


FIGURE 3-2: *Input Current Limiting Resistor (R_{IN}).*

3.2 Rail-to-Rail Output

The output voltage range of the MCP6291/2/3/4/5 op amp is V_{DD} – 15 mV (min.) and V_{SS} + 15 mV (max.) when R_L = 10 kΩ is connected to $V_{DD}/2$ and V_{DD} = 5.5V. Refer to Figure 2-16 for more information.

3.3 MCP6293/5 Chip Select ($\overline{CS}$)

The MCP6293 and MCP6295 are single and dual op amps with chip select ($\overline{CS}$), respectively. When $\overline{CS}$ is pulled high, the supply current drops to 0.7 µA (typ.) and flows through the $\overline{CS}$ pin to V_{SS}. When this happens, the amplifier output 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 may not operate properly. Figure 3-3 shows the output voltage and supply current response to a $\overline{CS}$ pulse.

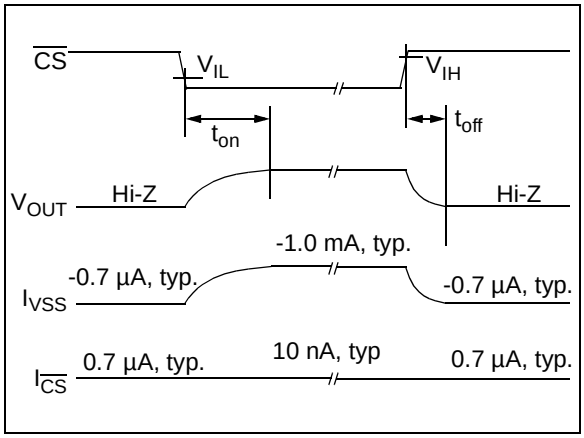


FIGURE 3-3: *Timing Diagram for the Chip Select ($\overline{CS}$) pin on the MCP6293 and MCP6295.*

3.4 Cascaded Dual Op Amps (MCP6295)

The MCP6295 is a dual op amp with chip select ($\overline{CS}$). The chip select line is available on what would be the non-inverting input of a standard dual op amp (pin 5). This feature is provided by connecting the output of op amp A to the non-inverting input of op amp B, as shown in Figure 3-4. The chip select line, which can be connected to a microcontroller I/O line, puts the device in Low Power mode. Refer to **Section 3.3 "MCP6283/5 Chip Select (CS)"**.

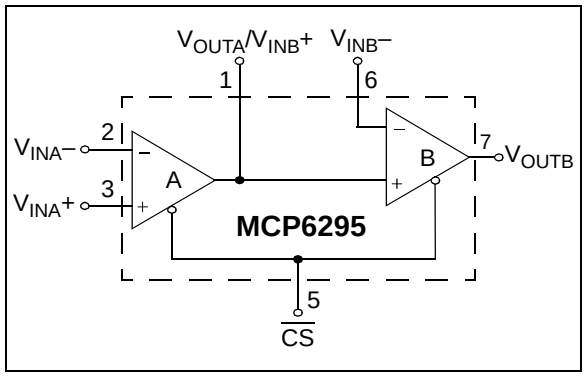


FIGURE 3-4: *Cascaded Gain Amplifier.*

The key issue to note from this configuration is that the output of op amp A is loaded by the input impedance and input offset current (I_{OS}) of op amp B. The input impedance of the op amp is typically $10^{13}\Omega||6$ pF, as specified in the DC specification table (Refer to **Section 3.5 "Capacitive Loads"** for further details regarding capacitive loads). An I_{OS} of 15 pA at +85°C and 500 pA at +125°C (V_{DD} = 5.5V) sinks into the output of op amp A. This is illustrated in Figures 2-5 and 2-12.

The common mode input range of these op amps is specified in the data sheet as V_{SS} – 300 mV and V_{DD} + 300 mV. However, since the output of op amp A is limited to V_{OL} and V_{OH} (20 mV from the rails with a 10 kΩ load), the non-inverting input range of op amp B is limited to the common mode input range of V_{SS} + 20 mV and V_{DD} – 20 mV.

3.5 Capacitive Loads

Driving large capacitive loads can cause stability problems for voltage feedback op amps. As the load capacitance increases, the feedback loop's phase margin decreases and the closed-loop bandwidth is reduced. This produces gain peaking in the frequency response, with overshoot and ringing in the step response. A unity-gain buffer (G = +1) is the most sensitive to capacitive loads, though all gains show the same general behavior.

When driving large capacitive loads with these op amps (e.g., > 100 pF when G = +1), a small series resistor at the output (R_{ISO} in Figure 3-5) improves the feedback loop's phase margin (stability) by making the output load resistive at higher frequencies. The bandwidth will be generally lower than the bandwidth with no capacitive load.

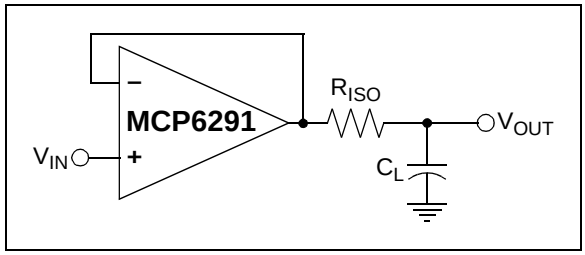


FIGURE 3-5: *Output Resistor, R_{ISO} stabilizes large capacitive loads.*

Figure 3-6 gives recommended R_{ISO} values for different capacitive loads and gains. The x-axis is the normalized load capacitance (C_L/G_N), where G_N is the circuit's noise gain. For non-inverting gains, G_N and the Signal Gain are equal. For inverting gains, G_N is 1+|Signal Gain| (e.g., -1 V/V gives G_N = +2 V/V).

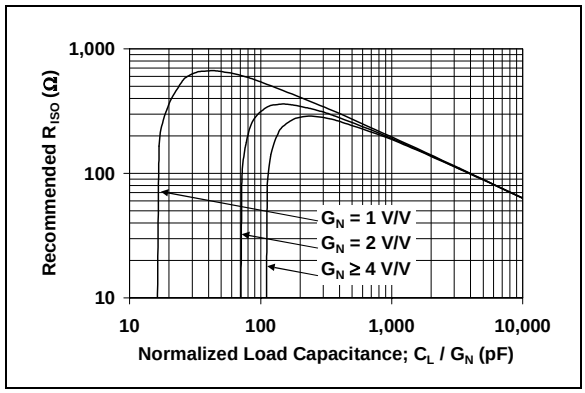


FIGURE 3-6: *Recommended R_{ISO} values for Capacitive Loads.*

After selecting R_{ISO} for your circuit, double-check the resulting frequency response peaking and step response overshoot. Modify R_{ISO}'s value until the response is reasonable. Bench evaluation and simulations with the MCP6291/2/3/4/5 SPICE macro model are very helpful.

3.6 Supply Bypass

With this family of operational amplifiers, the power supply pin (V_{DD} for single supply) should have a local bypass capacitor (i.e., 0.01 µF to 0.1 µF) within 2 mm for good high-frequency performance. It also needs a bulk capacitor (i.e., 1 µF or larger) within 100 mm to provide large, slow currents. This bulk capacitor can be shared with other parts.

3.7 PCB Surface Leakage

In applications where low input bias current is critical, printed circuit board (PCB) surface leakage effects need to be considered. Surface leakage is caused by humidity, dust or other contamination on the board. Under low humidity conditions, a typical resistance between nearby traces is $10^{12}\Omega$. A 5V difference would cause 5 pA, if current-to-flow, which is greater than the MCP6291/2/3/4/5 family's bias current at 25°C (1 pA, typ).

The easiest way to reduce surface leakage is to use a guard ring around sensitive pins (or traces). The guard ring is biased at the same voltage as the sensitive pin. An example of this type of layout is shown in Figure 3-7.

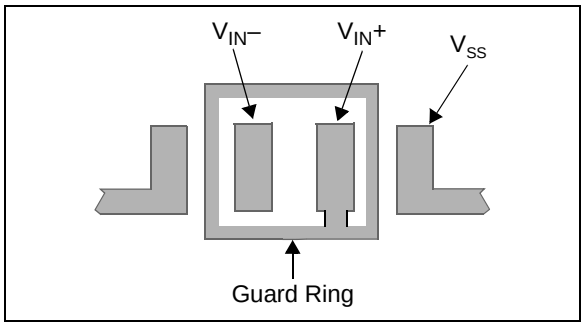


FIGURE 3-7: *Example Guard Ring Layout for Inverting Gain.*

1. For Inverting (Figure 3-7) and Transimpedance Amplifiers (convert current to voltage, such as photo detectors):
   a. Connect the guard ring to the non-inverting input pin (V_{IN}+). This biases the guard ring to the same reference voltage as the op amp (e.g., $V_{DD}/2$ or ground).
   b. Connect the inverting pin (V_{IN}–) to the input with a wire that does not touch the PCB surface.
2. Non-inverting Gain and Unity-Gain Buffer:
   a. Connect the non-inverting pin (V_{IN}+) to the input with a wire that does not touch the PCB surface.
   b. Connect the guard ring to the inverting input pin (V_{IN}–). This biases the guard ring to the common mode input voltage.

3.8 Application Circuits

3.8.1 MULTIPLE FEEDBACK LOW-PASS FILTER

The MCP6291/2/3/4/5 op amp can be used in active-filter applications. Figure 3-8 shows an inverting, third-order, multiple feedback low-pass filter that can be used as an anti-aliasing filter.

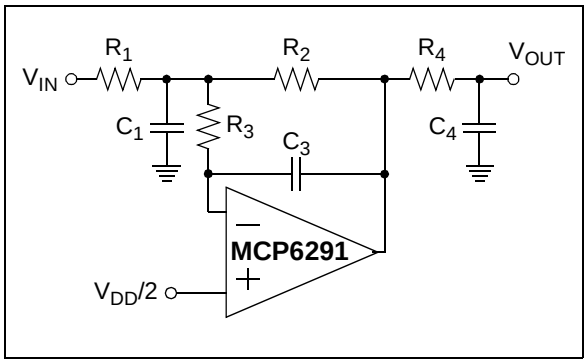


FIGURE 3-8: *Multiple Feedback Low-Pass Filter.*

This filter, and others, can be designed using Microchip's FilterLab® software, which is available on our web site (www.microchip.com).

3.8.2 PHOTO DIODE AMPLIFIER

Figure 3-9 shows a photo diode biased in the photo-voltaic mode for high precision. The resistor R converts the diode current I_D to the voltage V_{OUT}. The capacitor is used to limit the bandwidth or to stabilize the circuit against the diode's capacitance (it is not always needed).

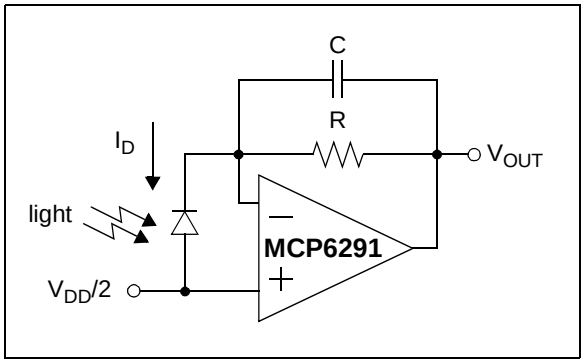


FIGURE 3-9: *Photo Diode Amplifier.*

3.8.3 CASCADED OP AMPS APPLICATIONS

The MCP6295 provides the flexibility of Low Power mode for dual op amps in an 8-pin package. The MCP6295 eliminates the added cost and space in battery-powered applications by using two single op amps with chip select lines or a 10-pin device with chip select line for each op amp. The only inherent limitation to this device is that the two op amps are internally cascaded. Therefore, this device cannot be used in circuits that require active or passive elements between the two op amps. However, there are several applications where this op amp configuration with chip select line becomes suitable. The circuits below show possible applications for this device.

3.8.3.1 Load Isolation

With the cascaded op amp configuration, op amp B can be used to isolate the load from op amp A. In applications where op amp A is driving capacitive or low resistance loads in the feedback loop (such as an integrator circuit or filter circuit) the op amp may not have sufficient source current to drive the load. In this case, op amp B can be used as a buffer.

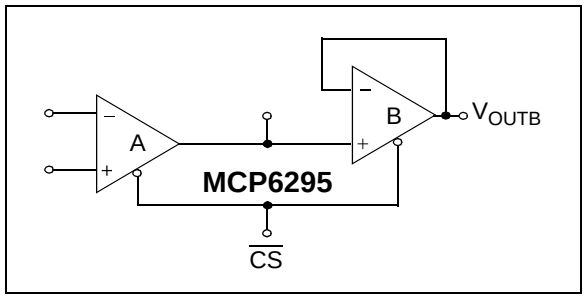


FIGURE 3-10: *Isolating the Load with a Buffer.*

3.8.3.2 Cascaded Gain

Figure 3-11 shows a cascaded gain circuit configuration with chip select. Op amps A and B are configured in a non-inverting amplifier configuration. In this configuration, it is important to note that the input offset voltage of op amp A is amplified by the gain of op amp A and B, as shown below:

$$V_{OUT} = V_{IN}G_AG_B + V_{OSA}G_AG_B + V_{OSB}G_B$$

Where:

G_A = op amp A gain
G_B = op amp B gain
V_{OSA} = op amp A offset voltage
V_{OSB} = op amp B offset voltage

Therefore, it is recommended to set most of the gain with op amp A and use op amp B with relatively small gain, or as a unity-gain buffer.

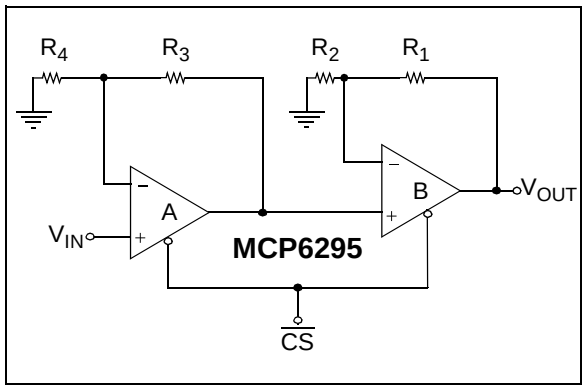


FIGURE 3-11: *Cascaded Gain Circuit Configuration.*

3.8.3.3 Difference Amplifier

Figure 3-12 shows op amp A as a difference amplifier with chip select. In this configuration, it is recommended to use well matched resistors (0.1%) to increase the common mode rejection ratio (CMRR). Op amp B can be used for additional gain or as a unity-gain buffer to isolate the load from the difference amplifier.

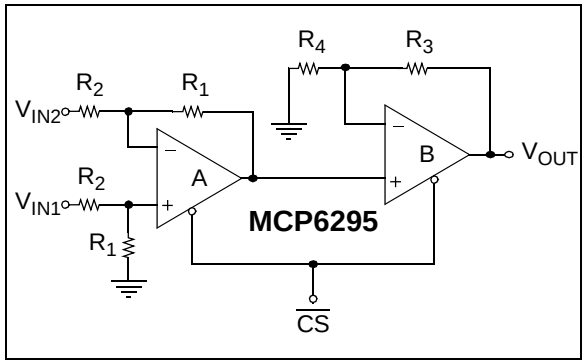


FIGURE 3-12: *Difference Amplifier Circuit.*

3.8.3.4 Buffered Non-inverting Integrator

Figure 3-13 shows a buffered non-inverting integrator with chip select. Op amp A is configured as a non-inverting integrator. In this configuration, matching the impedance at each input is recommended. R_f is used to provide a feedback loop at frequencies << $1/(2\pi RC)$. Op amp B is used to isolate the load from the integrator.

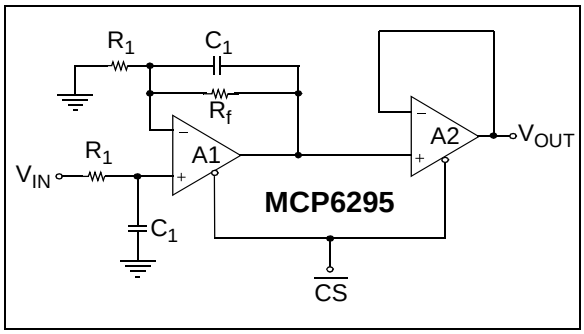


FIGURE 3-13: *Buffered Non-inverting Integrator with Chip Select Circuit.*

3.8.3.5 Integrator with Active Compensation and a Chip Select

Figure 3-14 uses an active compensator (op amp B) to compensate for the non-ideal characteristics introduced at higher frequency integration. The alternative is to use a passive element, such as a resistor, for compensation. However, the quality of compensation would not be constant since the AC characteristics of an amplifier varies over temperature and process. This circuit uses op amp B as a unity-gain buffer to isolate the integration capacitor C_1 from op amp A and drives the capacitor with low impedance source. Since both amplifiers are matched very well, it provides a higher quality of integration.

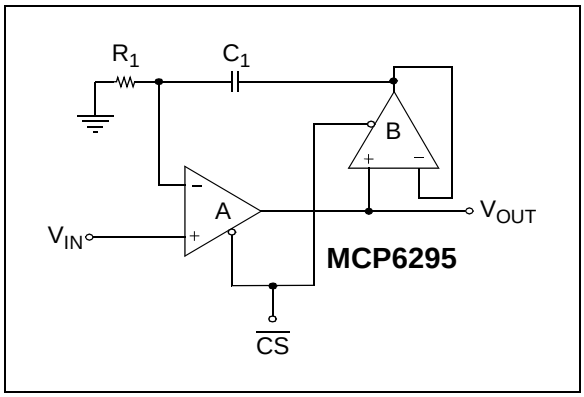


FIGURE 3-14: *Integrator Circuit with Active Compensation.*

3.8.3.6 Second-Order MFB Low-Pass Filter with an Extra Pole-Zero Pair

Figure 3-15 is a second-order multiple feedback low-pass filter with chip select. Use the Filterlab® software from Microchip to determine the R and C values for the op amp A's second-order filter. Op amp B can be used to add a pole-zero pair using C_3 and R_6.

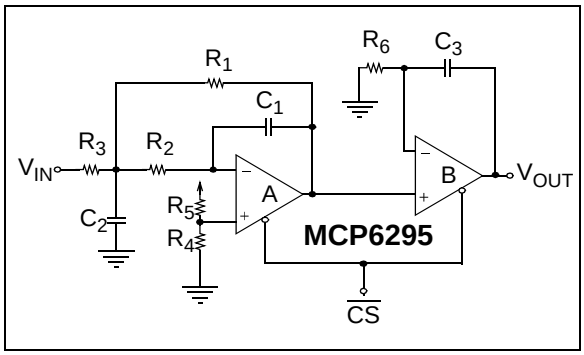


FIGURE 3-15: *Second-Order Multiple Feedback Low-Pass Filter with an Extra Pole-Zero Pair and Chip Select.*

3.8.3.7 Second-Order Sallen-Key Low-Pass Filter with an Extra Pole-Zero Pair

Figure 3-16 is a second-order Sallen-Key low-pass filter with chip select. Use the Filterlab® software from Microchip to determine the R and C values for the op amp A's second-order filter. Op amp B can be used to add a pole-zero pair using C_3 and R_5.

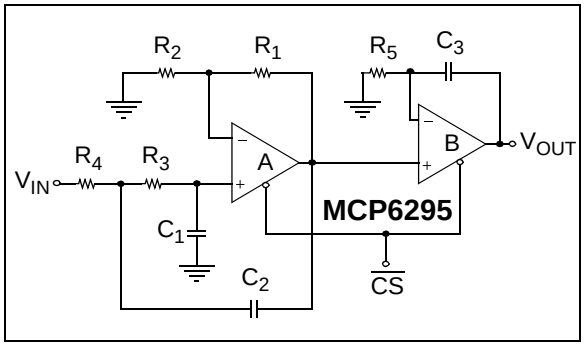


FIGURE 3-16: *Second-Order Sallen-Key Low-Pass Filter with an Extra Pole-Zero Pair and Chip Select.*

3.8.3.8 Capacitorless Second-Order Low-Pass filter with Chip Select

The low-pass filter shown in Figure 3-17 does not require external capacitors. It uses only three external resistors. The op amp's GBWP sets the corner frequency. R_1 and R_2 are used to set the circuit gain and R_3 is used to set the Q. To avoid gain peaking in the frequency response, Q needs to be low (lower values need to be selected for R_3). Note that the amplifier bandwidth varies greatly over temperature and process. However, this configuration provides a low cost solution for applications with high bandwidth.

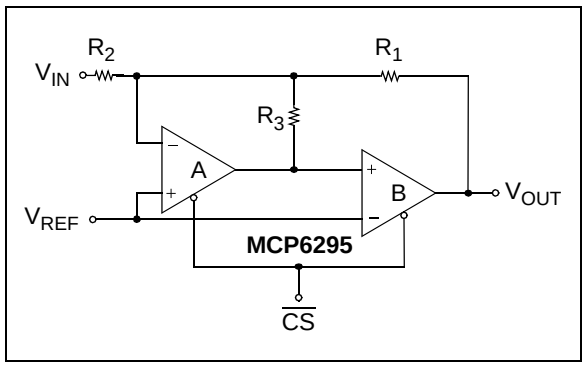


FIGURE 3-17: *Capacitorless Second-Order Low-Pass Filter with Chip Select Circuit.*

4.0 DESIGN TOOLS

Microchip provides the basic design tools needed for the MCP6291/2/3/4/5 family of op amps.

4.1 SPICE Macro Model

The latest version of SPICE Macro Model for the MCP6291/2/3/4/5 op amps is available on our web site at www.microchip.com. This model is intended to be an initial design tool that works well in the op amp's linear region of operation at room temperature. See the model file for information on its capabilities.

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

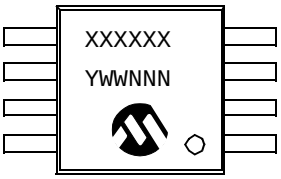
4.2 FilterLab® Software

Microchip's FilterLab software is an innovative tool that simplifies analog active-filter (using op amps) design. Available at no cost from our web site at www.microchip.com, the FilterLab active-filter software design tool provides full schematic diagrams of the filter circuit with component values. It also outputs the filter circuit in SPICE format, which can be used with the macro model to simulate actual filter performance.

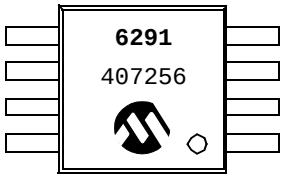
5.0 PACKAGING INFORMATION

5.1 Package Marking Information

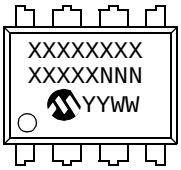
8-Lead MSOP



Example:



8-Lead PDIP (300 mil)



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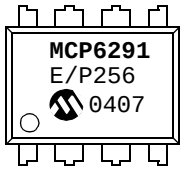
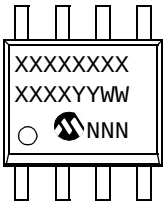


8-Lead SOIC (150 mil)



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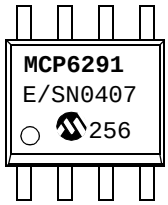


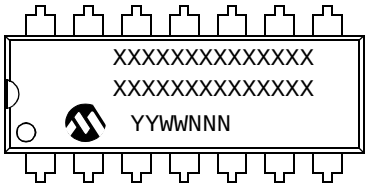
Legend:	XX...X	Customer specific information*
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week ‘01’)
	NNN	Alphanumeric traceability code

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.

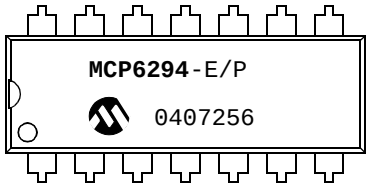
***** Standard marking consists of Microchip part number, year code, week code, traceability code (facility code, mask rev#, and assembly code). For marking beyond this, certain price adders apply. Please check with your Microchip Sales Office.

Package Marking Information (Continued)

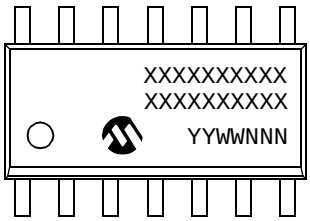
14-Lead PDIP (300 mil) **(MCP6294)**



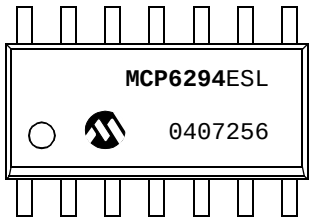
Example:



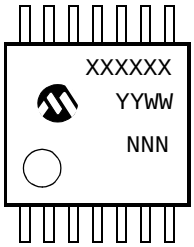
14-Lead SOIC (150 mil) **(MCP6294)**



Example:



14-Lead TSSOP **(MCP6294)**



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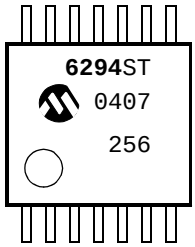
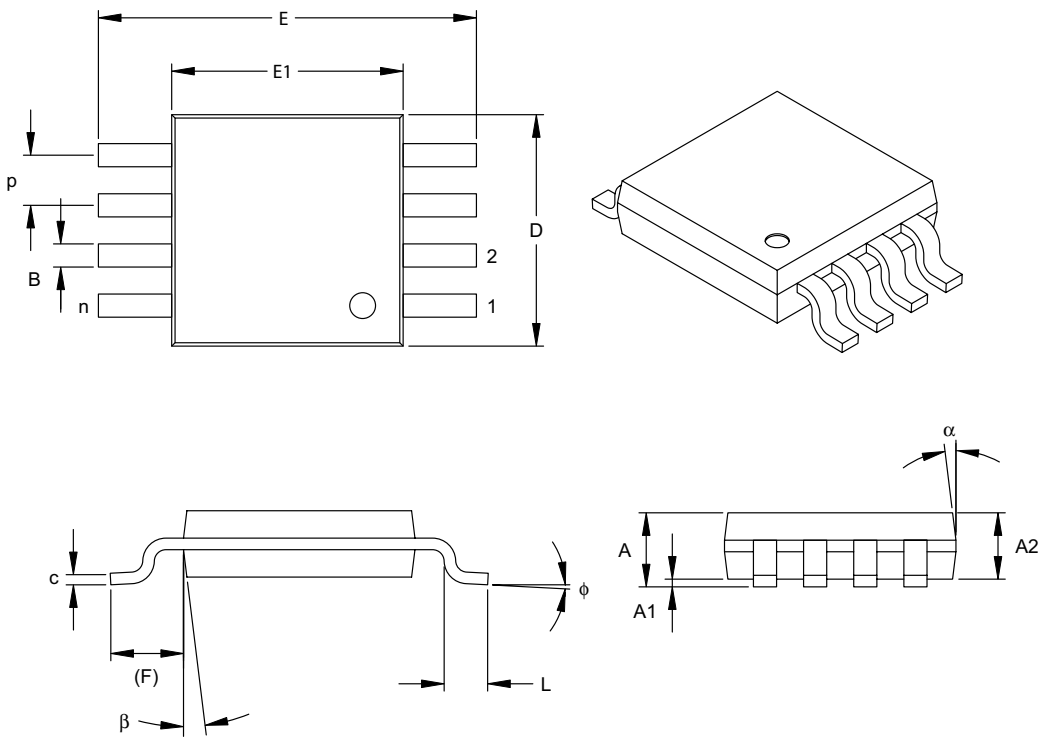


8-Lead Plastic Micro Small Outline Package (MS) (MSOP)



Units		INCHES			MILLIMETERS*		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		8			8	
Pitch	p		.026 BSC			0.65 BSC	
Overall Height	A	-	-	.043	-	-	1.10
Molded Package Thickness	A2	.030	.033	.037	0.75	0.85	0.95
Standoff	A1	.000	-	.006	0.00	-	0.15
Overall Width	E		.193 TYP.			4.90 BSC	
Molded Package Width	E1		.118 BSC			3.00 BSC	
Overall Length	D		.118 BSC			3.00 BSC	
Foot Length	L	.016	.024	.031	0.40	0.60	0.80
Footprint (Reference)	F		.037 REF			0.95 REF	
Foot Angle	φ	0°	-	8°	0°	-	8°
Lead Thickness	c	.003	.006	.009	0.08	-	0.23
Lead Width	B	.009	.012	.016	0.22	-	0.40
Mold Draft Angle Top	α	5°	-	15°	5°	-	15°
Mold Draft Angle Bottom	β	5°	-	15°	5°	-	15°

*Controlling Parameter

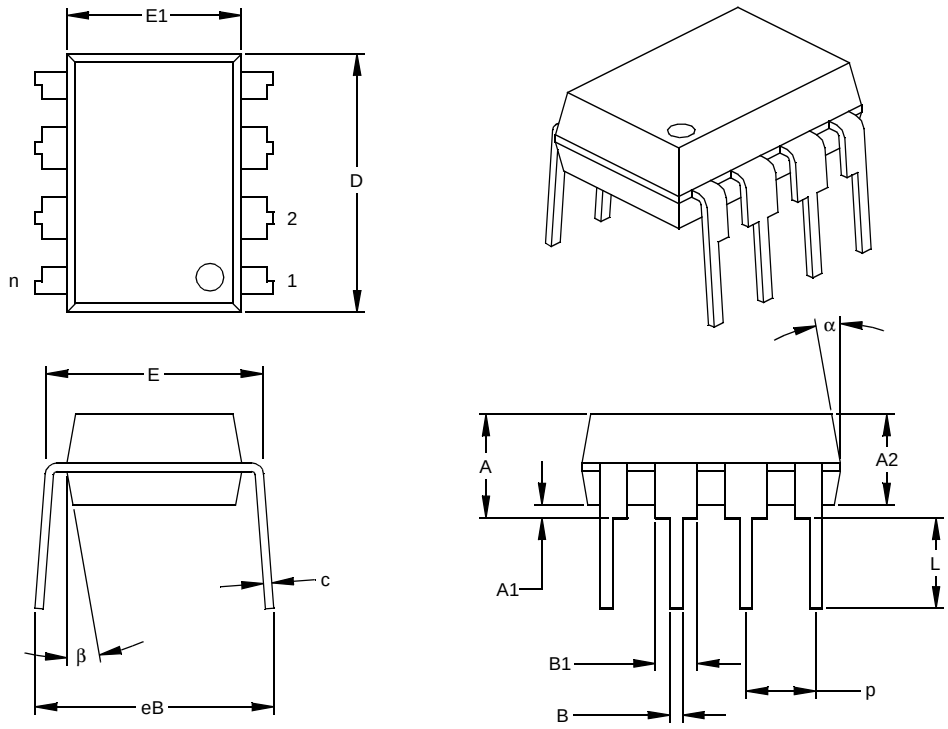
Notes:

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

JEDEC Equivalent: MO-187

Drawing No. C04-111

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

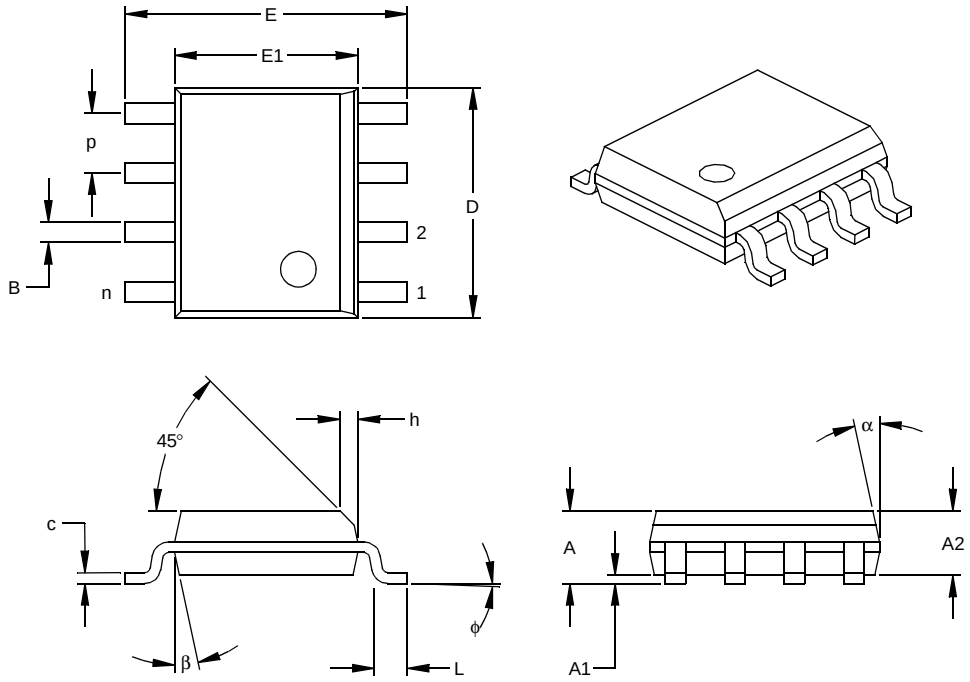


Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		8			8	
Pitch	p		.100			2.54	
Top to Seating Plane	A	.140	.155	.170	3.56	3.94	4.32
Molded Package Thickness	A2	.115	.130	.145	2.92	3.30	3.68
Base to Seating Plane	A1	.015			0.38		
Shoulder to Shoulder Width	E	.300	.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)

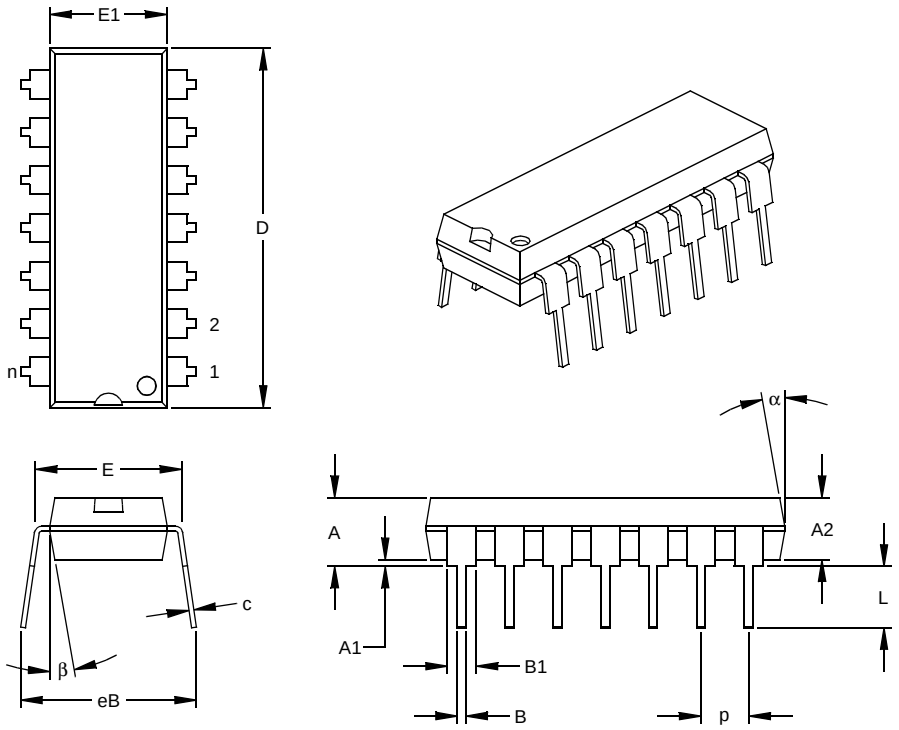


Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		8			8	
Pitch	p		.050			1.27	
Overall Height	A	.053	.061	.069	1.35	1.55	1.75
Molded Package Thickness	A2	.052	.056	.061	1.32	1.42	1.55
Standoff §	A1	.004	.007	.010	0.10	0.18	0.25
Overall Width	E	.228	.237	.244	5.79	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

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

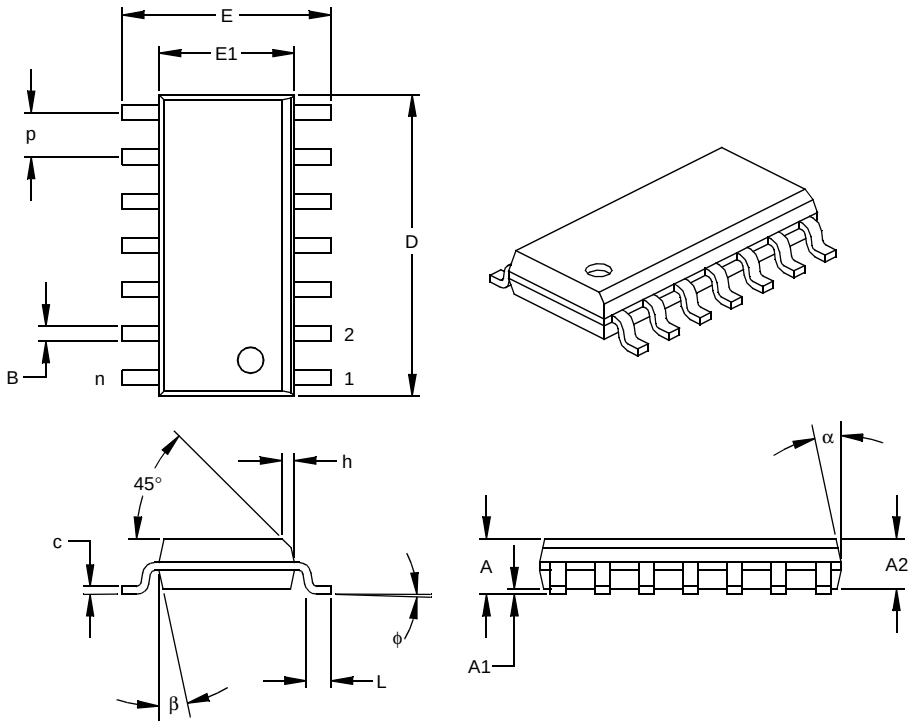


Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		14			14	
Pitch	p		.100			2.54	
Top to Seating Plane	A	.140	.155	.170	3.56	3.94	4.32
Molded Package Thickness	A2	.115	.130	.145	2.92	3.30	3.68
Base to Seating Plane	A1	.015			0.38		
Shoulder to Shoulder Width	E	.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)

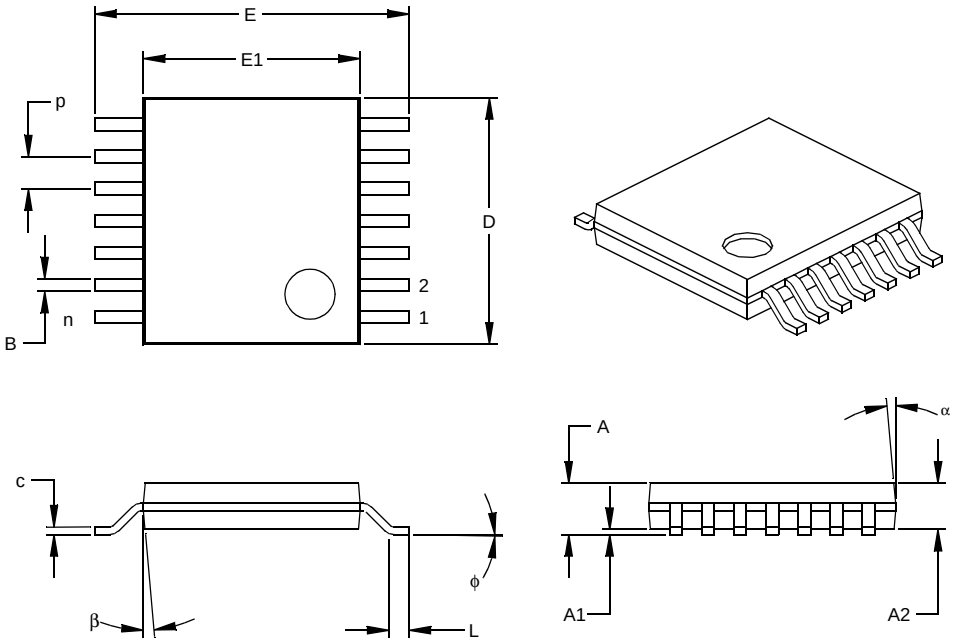


Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		14			14	
Pitch	p		.050			1.27	
Overall Height	A	.053	.061	.069	1.35	1.55	1.75
Molded Package Thickness	A2	.052	.056	.061	1.32	1.42	1.55
Standoff §	A1	.004	.007	.010	0.10	0.18	0.25
Overall Width	E	.228	.236	.244	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

NOTES:

PRODUCT IDENTIFICATION SYSTEM

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

PART NO.	X	/XX
Device	Temperature Range	Package

Device:	MCP6291:	Single Operational Amplifier
	MCP6291T:	Single Operational Amplifier (Tape and Reel) (SOIC, MSOP)
	MCP6292:	Dual Operational Amplifier
	MCP6292T:	Dual Operational Amplifier (Tape and Reel) (SOIC, MSOP)
	MCP6293:	Single Operational Amplifier with Chip Select
	MCP6293T:	Single Operational Amplifier with Chip Select (Tape and Reel) (SOIC, MSOP)
	MCP6294:	Quad Operational Amplifier
	MCP6294T:	Quad Operational Amplifier (Tape and Reel) (SOIC, TSSOP)
	MCP6295:	Dual Operational Amplifier with Chip Select
	MCP6295T:	Dual Operational Amplifier with Chip Select (Tape and Reel) (SOIC, MSOP)
Temperature Range:	E = -40°C to +125°C	
Package:	MS = Plastic MSOP, 8-lead	
	P = Plastic DIP (300 mil Body), 8-lead, 14-lead	
	SN = Plastic SOIC, (150 mil Body), 8-lead	
	SL = Plastic SOIC (150 mil Body), 14-lead	
	ST = Plastic TSSOP (4.4mm Body), 14-lead	

Examples:

a)	MCP6291-E/SN:	Extended Temperature, 8LD SOIC package.
b)	MCP6291-E/MS:	Extended Temperature, 8LD MSOP package.
c)	MCP6291-E/P:	Extended Temperature, 8LD PDIP package.
d)	MCP6291T-E/SN:	Tape and Reel, Extended Temperature, 8LD SOIC package.
a)	MCP6292-E/SN:	Extended Temperature, 8LD SOIC package.
b)	MCP6292-E/MS:	Extended Temperature, 8LD MSOP package.
c)	MCP6292-E/P:	Extended Temperature, 8LD PDIP package.
d)	MCP6292T-E/SN:	Tape and Reel, Extended Temperature, 8LD SOIC package.
a)	MCP6293-E/SN:	Extended Temperature, 8LD SOIC package.
b)	MCP6293-E/MS:	Extended Temperature, 8LD MSOP package.
c)	MCP6293-E/P:	Extended Temperature, 8LD PDIP package.
d)	MCP6293T-E/SN:	Tape and Reel, Extended Temperature, 8LD SOIC package.
a)	MCP6294-E/P:	Extended Temperature, 14LD PDIP package.
b)	MCP6294T-E/SL:	Tape and Reel, Extended Temperature, 14LD SOIC package.
c)	MCP6294-E/SL:	Extended Temperature, 14LD SOIC package.
d)	MCP6294-E/ST:	Extended Temperature, 14LD TSSOP package.
a)	MCP6295-E/SN:	Extended Temperature, 8LD SOIC package.
b)	MCP6295-E/MS:	Extended Temperature, 8LD MSOP package.
c)	MCP6295-E/P:	Extended Temperature, 8LD PDIP package.
d)	MCP6295T-E/SN:	Tape and Reel, Extended Temperature, 8LD SOIC package.

Sales and Support

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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:

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