MCP6V96/6U/7/9

10 MHz, Zero-Drift Op Amps

Features

- High DC Precision:
  - V_{OS} Drift: ±150 nV/°C (maximum)
  - V_{OS}: ±25 µV (maximum)
  - A_{OL}: 111 dB (minimum, V_{DD} = 5.5V)
  - PSRR: 110 dB (minimum, V_{DD} = 5.5V)
  - CMRR: 112 dB (minimum, V_{DD} = 5.5V)
  - E_{ni}: 0.24 μV_{P-P} (typical), f = 0.1 Hz to 10 Hz
  - E_{ni}: 0.08 μV_{P-P} (typical), f = 0.01 Hz to 1 Hz
- Enhanced EMI Protection:
  - Electromagnetic Interference Rejection Ratio (EMIRR) at 1.8 GHz: 93 dB
- Low Power and Supply Voltages:
  - I_Q: 1.1 mA/amplifier (typical)
  - Wide supply voltage range: 2.4V to 5.5V
- Small Packages:
  - Singles in SC70, SOT-23
  - Duals in MSOP-8, 2 x 3 TDFN
  - Quads in TSSOP-14
- Easy to Use:
  - Rail-to-rail input/output
  - Gain bandwidth product: 10 MHz (typical)
  - Unity gain stable
- Extended Temperature Range: -40°C to +125°C

Typical Applications

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

Design Aids

- SPICE Macro Models
- Microchip Advanced Part Selector (MAPS)
- Analog Demonstration and Evaluation Boards
- Application Notes

Related Parts

- MCP6V16/6U/7/9: Zero-Drift, Low Power
- MCP6V36/6U/7/9: Zero-Drift, Low Power
- MCP6V66/6U/7/9: Zero-Drift, 1 MHz
- MCP6V76/6U/7/9: Zero-Drift, 2 MHz
- MCP6V86/6U/7/9: Zero-Drift, 5 MHz

General Description

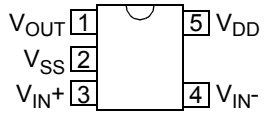
The MCP6V96/6U/7/9 family of operational amplifiers provides input offset voltage correction for very low offset and offset drift. These devices have a gain bandwidth product of 10 MHz (typical). They are unity-gain stable, have virtually no 1/f noise and have good Power Supply Rejection Ratio (PSRR) and Common-Mode Rejection Ratio (CMRR). These products operate with a single supply voltage as low as 2.4V, while drawing 1.1 mA/amplifier (typical) of quiescent current.

The MCP6V96/6U/7/9 family has enhanced EMI protection to minimize any electromagnetic interference from external sources. This feature makes it well-suited for EMI-sensitive applications such as power lines, radio stations and mobile communications, etc.

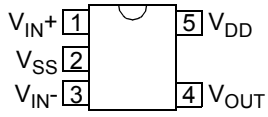
The MCP6V96/6U/7/9 op amps are offered in single (MCP6V96 and MCP6V96U), dual (MCP6V97) and quad (MCP6V99) packages. They were designed using an advanced CMOS process.

Package Types

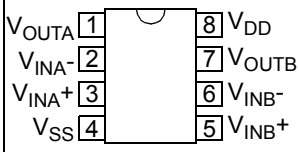
MCP6V96
SOT-23



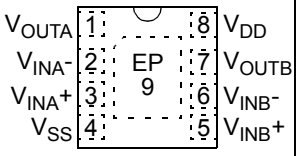
MCP6V96U
SC70, SOT-23



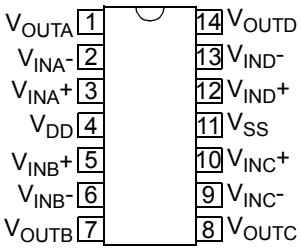
MCP6V97
MSOP



MCP6V97
2×3 TDFN*



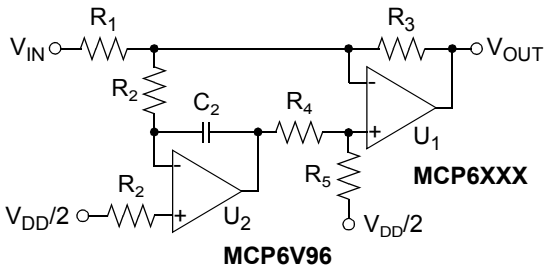
MCP6V99
TSSOP



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

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Typical Application Circuit



Offset Voltage Correction for Power Driver

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1.0 ELECTRICAL CHARACTERISTICS

1.1 Absolute Maximum Ratings †

$V_{DD} - V_{SS}$ 6.5V
Current at Input Pins ..... ±2 mA
Analog Inputs (V_{IN}+ and V_{IN}-)[(1)] ..... V_{SS} – 1.0V to V_{DD} + 1.0V
All Other Inputs and Outputs ..... V_{SS} – 0.3V to V_{DD} + 0.3V
Difference Input Voltage ..... $|V_{DD} - V_{SS}|$
Output Short-Circuit Current ..... Continuous
Current at Output and Supply Pins ..... ±30 mA
Storage Temperature ..... -65°C to +150°C
Maximum Junction Temperature ..... +150°C
ESD Protection on All Pins (HBM, CDM, MM)
MCP6V96/6U ..... ≥ 4 kV, 1.5 kV, 400V
MCP6V97/9 ..... ≥ 4 kV, 1.5 kV, 300V

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

Note 1: See **Section 4.2.1 "Rail-to-Rail Inputs"**.

1.2 Specifications

TABLE 1-1: DC ELECTRICAL CHARACTERISTICS

Electrical Characteristics: Unless otherwise indicated, T_A = +25°C, V_{DD} = +2.4V to +5.5V, V_{SS} = GND, V_{CM} = V_{DD}/3, V_{OUT} = V_{DD}/2, V_L = V_{DD}/2, R_L = 10 kΩ to V_L and C_L = 30 pF (refer to Figures 1-4 and 1-5).

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Input Offset						
Input Offset Voltage	V_{OS}	-25	—	+25	µV	T_A = +25°C
Input Offset Voltage Drift with Temperature (Linear Temperature Coefficient)	TC_1	-150	—	+150	nV/°C	T_A = -40 to +125°C **(Note 1)**
Input Offset Voltage Quadratic Temperature Coefficient	TC_2	—	±74	—	pV/°C^2	T_A = -40 to +125°C
Input Offset Voltage Aging	ΔV_{OS}	—	±0.75	—	µV	408 hours Life Test at +150°, measured at +25°C.
Power Supply Rejection Ratio	PSRR	110	137	—	dB	
Input Bias Current and Impedance						
Input Bias Current	I_B	-50	±2	+50	pA	
Input Bias Current Across Temperature	I_B	—	+10	—	pA	T_A = +85°C
	I_B	0	+0.2	+1	nA	T_A = +125°C
Input Offset Current	I_{OS}	-400	±100	+400	pA	
Input Offset Current Across Temperature	I_{OS}	—	±75	—	pA	T_A = +85°C
	I_{OS}	-500	±100	+500	pA	T_A = +125°C
Common-Mode Input Impedance	Z_{CM}	—	10^{13}||14	—	Ω||pF	
Differential Input Impedance	Z_{DIFF}	—	10^{13}||3	—	Ω||pF	

Note 1: For design guidance only; not tested.

TABLE 1-1: DC ELECTRICAL CHARACTERISTICS (CONTINUED)

Electrical Characteristics: Unless otherwise indicated, T_A = +25°C, V_{DD} = +2.4V to +5.5V, V_{SS} = GND, V_{CM} = V_{DD}/3, V_{OUT} = V_{DD}/2, V_L = V_{DD}/2, R_L = 10 kΩ to V_L and C_L = 30 pF (refer to Figures 1-4 and 1-5).

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Common-Mode						
Common-Mode Input Voltage Range Low	V_{CML}	—	—	V_{SS} – 0.2	V	
Common-Mode Input Voltage Range High	V_{CMH}	V_{DD} + 0.3	—	—	V	
Common-Mode Rejection Ratio	CMRR	104	132	—	dB	V_{DD} = 2.4V, V_{CM} = -0.2V to 2.7V
	CMRR	112	140	—	dB	V_{DD} = 5.5V, V_{CM} = -0.2V to 5.8V
Open-Loop Gain						
DC Open-Loop Gain (Large Signal)	A_{OL}	97	142	—	dB	V_{DD} = 2.4V, V_{OUT} = 0.3V to 2.0V
	A_{OL}	111	158	—	dB	V_{DD} = 5.5V, V_{OUT} = 0.3V to 5.3V
Output						
Minimum Output Voltage Swing	V_{OL}	V_{SS}	V_{SS} + 35	V_{SS} + 120	mV	R_L = 1 kΩ, G = +2, 0.5V input overdrive
	V_{OL}	—	V_{SS} + 7	—	mV	R_L = 10 kΩ, G = +2, 0.5V input overdrive
Maximum Output Voltage Swing	V_{OH}	V_{DD} – 120	V_{DD} – 45	V_{DD}	mV	R_L = 1 kΩ, G = +2, 0.5V input overdrive
	V_{OH}	—	V_{DD} – 9	—	mV	R_L = 10 kΩ, G = +2, 0.5V input overdrive
Output Short-Circuit Current	I_{SC}	—	±15	—	mA	V_{DD} = 2.4V
	I_{SC}	—	±40	—	mA	V_{DD} = 5.5V
Power Supply						
Supply Voltage	V_{DD}	2.4	—	5.5	V	
Quiescent Current per Amplifier	I_Q	0.6	1.1	1.6	mA	I_O = 0
Power-on Reset (POR) Trip Voltage	V_{POR}	1.4	1.85	2.2	V	

Note 1: For design guidance only; not tested.

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TABLE 1-2: AC ELECTRICAL CHARACTERISTICS

Electrical Characteristics: Unless otherwise indicated, T_A = +25°C, V_{DD} = +2.4V to +5.5V, V_{SS} = GND, V_{CM} = V_{DD}/3, V_{OUT} = V_{DD}/2, V_L = V_{DD}/2, R_L = 10 kΩ to V_L and C_L = 30 pF (refer to Figures 1-4 and 1-5).						
Parameters	**Sym.**	**Min.**	**Typ.**	**Max.**	**Units**	**Conditions**
Amplifier AC Response						
Gain Bandwidth Product	GBWP	—	10	—	MHz	
Slew Rate	SR	—	9.5	—	V/µs	
Phase Margin	PM	—	60	—	°	G = +1
Amplifier Noise Response						
Input Noise Voltage	E_{ni}	—	0.08	—	$µV_{P-P}$	f = 0.01 Hz to 1 Hz
	E_{ni}	—	0.24	—	$µV_{P-P}$	f = 0.1 Hz to 10 Hz
Input Noise Voltage Density	e_{ni}	—	11	—	nV/√Hz	f < 2 kHz, V_{DD} = 5.5V
Input Noise Current Density	i_{ni}	—	6	—	fA/√Hz	
Amplifier Distortion(1)						
Intermodulation Distortion (AC)	IMD	—	35	—	$µV_{PK}$	V_{CM} tone = 100 mV_{PK} at 1 kHz, G_N = 11, RTI
Amplifier Step Response						
Start-Up Time	t_{STR}	—	100	—	µs	G = +1, 0.1% V_{OUT} settling (**Note 2**)
Offset Correction Settling Time	t_{STL}	—	60	—	µs	G = +1, V_{IN} step of 2V, V_{OS} within 100 µV of its final value
Output Overdrive Recovery Time	t_{ODR}	—	65	—	µs	G = -10, ±0.5V input overdrive to V_{DD}/2, V_{IN} 50% point to V_{OUT} 90% point (**Note 3**)
EMI Protection						
EMI Rejection Ratio	EMIRR	—	88	—	dB	V_{IN} = 0.1 V_{PK}, f = 400 MHz
		—	95	—		V_{IN} = 0.1 V_{PK}, f = 900 MHz
		—	93	—		V_{IN} = 0.1 V_{PK}, f = 1800 MHz
		—	90	—		V_{IN} = 0.1 V_{PK}, f = 2400 MHz

Note 1: These parameters were characterized using the circuit in Figure 1-6. In Figures 2-36 and 2-37, there is an IMD tone at DC, a residual tone at 1 kHz and other IMD tones and clock tones. IMD is Referred to Input (RTI).

2: High gains behave differently; see **Section 4.3.2 "Offset at Power-Up"**.

3: $t_{STL\ and}$ t_{ODR} include some uncertainty due to clock edge timing.

TABLE 1-3: TEMPERATURE SPECIFICATIONS

Electrical Characteristics: Unless otherwise indicated, all limits are specified for: V_{DD} = +2.4V to +5.5V, V_{SS} = GND.						
Parameters	**Sym.**	**Min.**	**Typ.**	**Max.**	**Units**	**Conditions**
Temperature Ranges						
Specified Temperature Range	T_A	-40	—	+125	°C	
Operating Temperature Range	T_A	-40	—	+125	°C	**Note 1**
Storage Temperature Range	T_A	-65	—	+150	°C	
Thermal Package Resistances						
Thermal Resistance, 5-Lead SC70	$θ_{JA}$	—	209	—	°C/W	
Thermal Resistance, 5-Lead SOT-23	$θ_{JA}$	—	201	—	°C/W	
Thermal Resistance, 8-Lead 2 x 3 TDFN	$θ_{JA}$	—	53	—	°C/W	
Thermal Resistance, 8-Lead MSOP	$θ_{JA}$	—	211	—	°C/W	
Thermal Resistance, 14-Lead TSSOP	$θ_{JA}$	—	100	—	°C/W	

Note 1: Operation must not cause T_J to exceed Maximum Junction Temperature specification (+150°C).

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1.3 Timing Diagrams

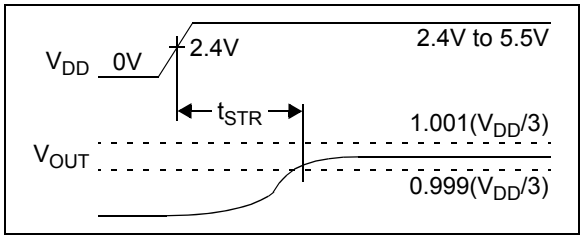


FIGURE 1-1: *Amplifier Start-Up.*

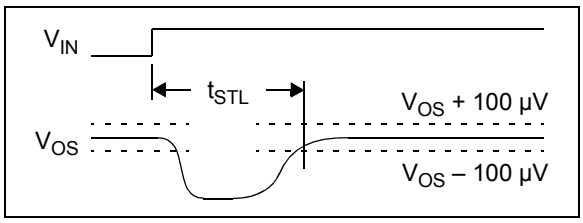


FIGURE 1-2: *Offset Correction Settling Time.*

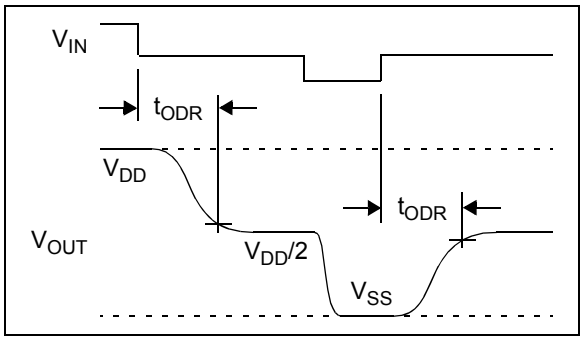


FIGURE 1-3: *Output Overdrive Recovery.*

1.4 Test Circuits

The circuits used for most DC and AC tests are shown in Figures 1-4 and 1-5. Lay the bypass capacitors out as discussed in **Section 4.3.9 "Supply Bypassing and Filtering"**. R_N is equal to the parallel combination of R_F and R_G to minimize bias current effects.

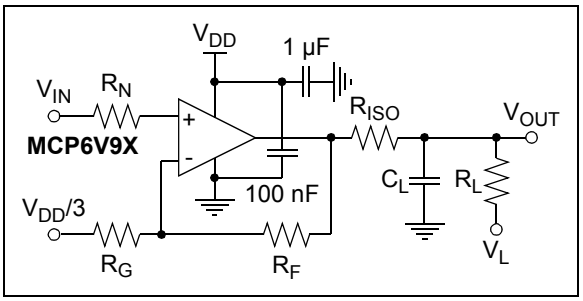


FIGURE 1-4: *AC and DC Test Circuit for Most Noninverting Gain Conditions.*

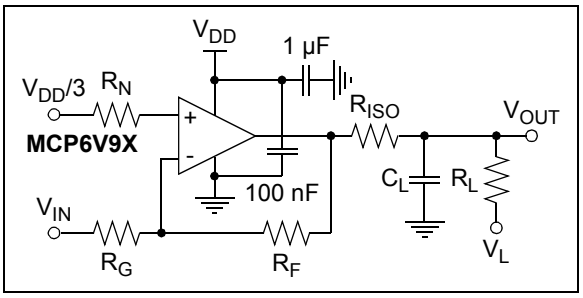


FIGURE 1-5: *AC and DC Test Circuit for Most Inverting Gain Conditions.*

The circuit in Figure 1-6 tests the input's dynamic behavior (i.e., IMD, t_{STR}, t_{STL} and t_{ODR}). The potentiometer balances the resistor network (V_{OUT} should equal V_{REF} at DC). The op amp's Common-mode input voltage is $V_{CM} = V_{IN}/2$. The error at the input (V_{ERR}) appears at V_{OUT} with a noise gain of 10 V/V.

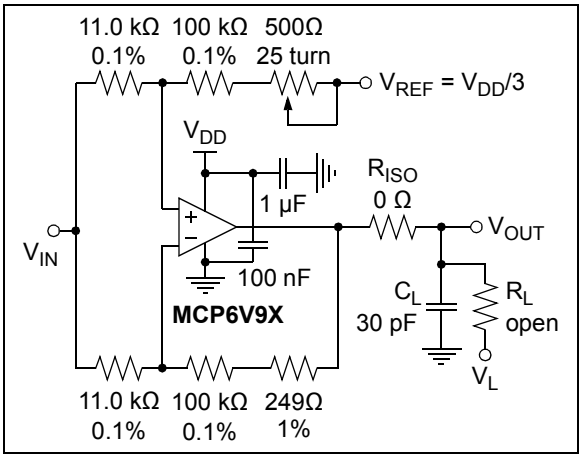


FIGURE 1-6: *Test Circuit for Dynamic Input Behavior.*

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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}/3, V_{OUT} = V_{DD}/2, V_L = V_{DD}/2, R_L = 10 kΩ to V_L and C_L = 30 pF.

2.1 DC Input Precision

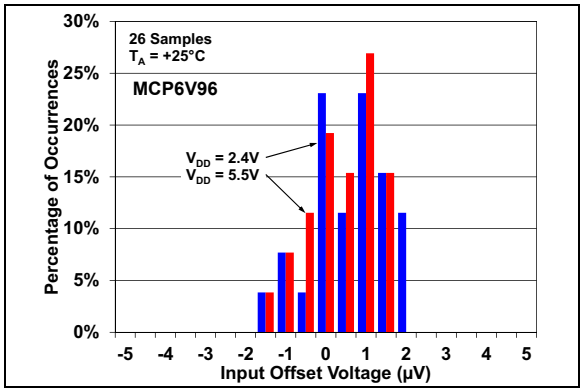


FIGURE 2-1: *Input Offset Voltage.*

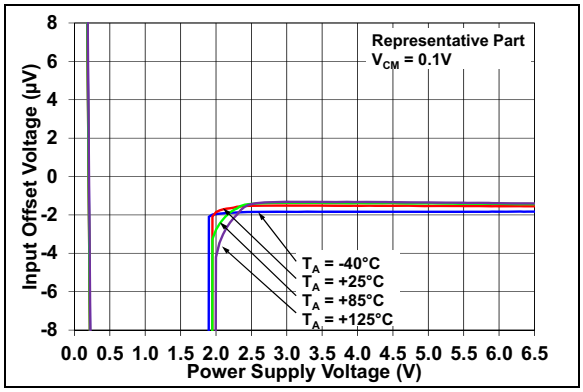


FIGURE 2-4: *Input Offset Voltage vs. Power Supply Voltage with V_{CM} = V_{CML}.*

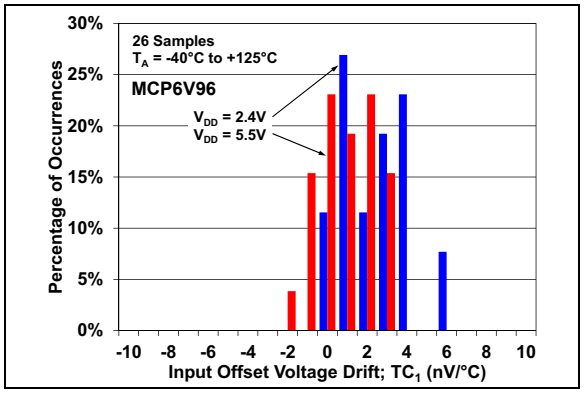


FIGURE 2-2: *Input Offset Voltage Drift.*

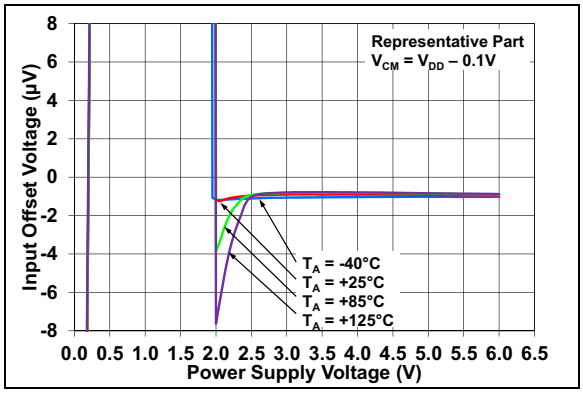


FIGURE 2-5: *Input Offset Voltage vs. Power Supply Voltage with V_{CM} = V_{CMH}.*

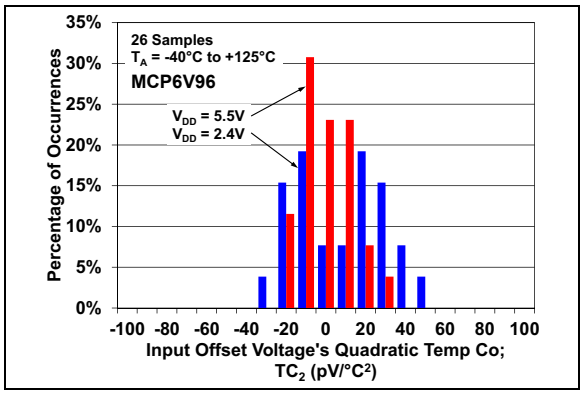


FIGURE 2-3: *Input Offset Voltage Quadratic Temperature Coefficient.*

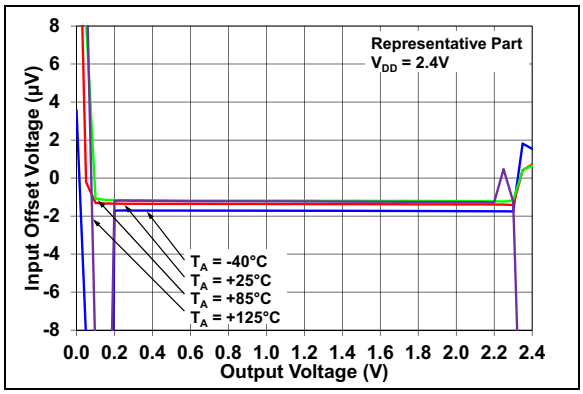


FIGURE 2-6: *Input Offset Voltage vs. Output Voltage with V_{DD} = 2.4V.*

Note: Unless otherwise indicated, T_A = +25°C, V_{DD} = +2.4V to 5.5V, V_{SS} = GND, V_{CM} = V_{DD}/3, V_{OUT} = V_{DD}/2, V_L = V_{DD}/2, R_L = 10 kΩ to V_L and C_L = 30 pF.

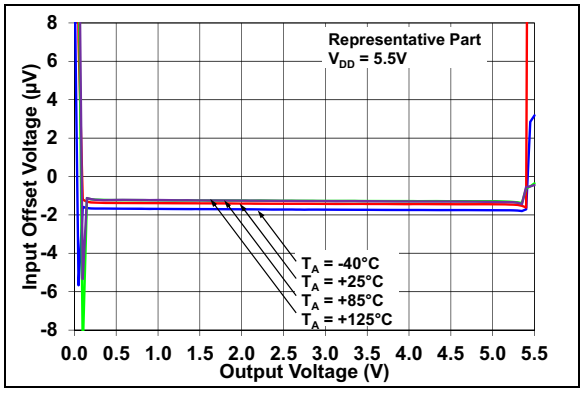


FIGURE 2-7: *Input Offset Voltage vs. Output Voltage with V_{DD} = 5.5V.*

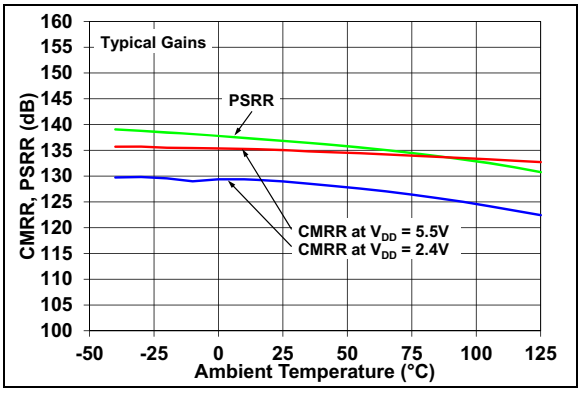


FIGURE 2-10: *CMRR and PSRR vs. Ambient Temperature.*

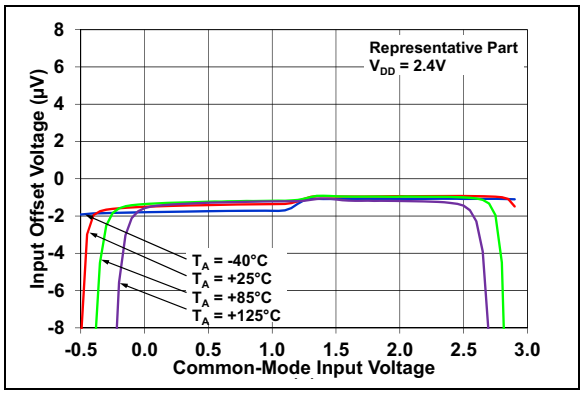


FIGURE 2-8: *Input Offset Voltage vs. Common-Mode Voltage with V_{DD} = 2.4V.*

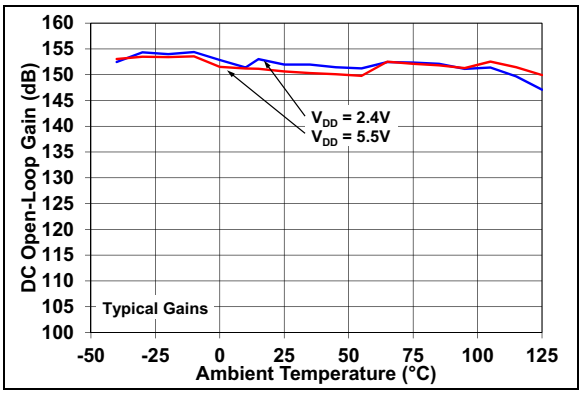


FIGURE 2-11: *DC Open-Loop Gain vs. Ambient Temperature.*

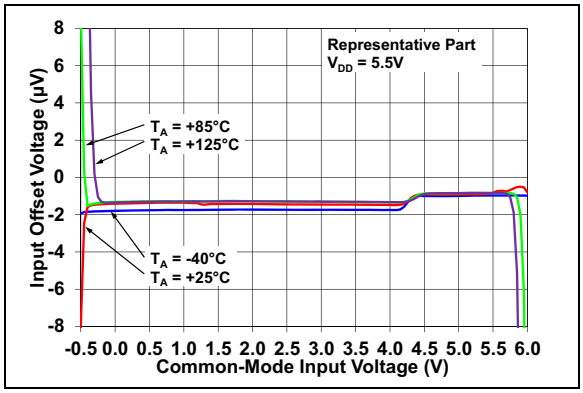


FIGURE 2-9: *Input Offset Voltage vs. Common-Mode Voltage with V_{DD} = 5.5V.*

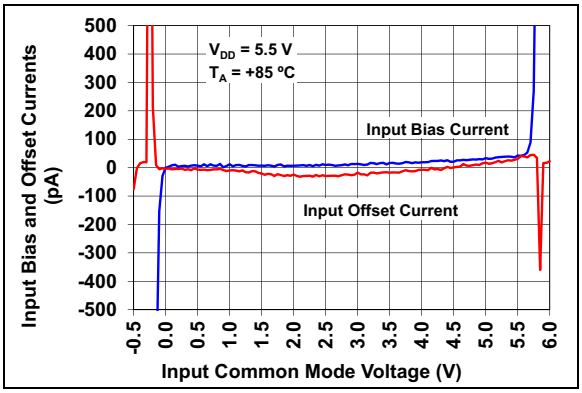


FIGURE 2-12: *Input Bias and Offset Currents vs. Common-Mode Input Voltage with T_A = +85°C.*

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Note: Unless otherwise indicated, T_A = +25°C, V_{DD} = +2.4V to 5.5V, V_{SS} = GND, V_{CM} = V_{DD}/3, V_{OUT} = V_{DD}/2, V_L = V_{DD}/2, R_L = 10 kΩ to V_L and C_L = 30 pF.

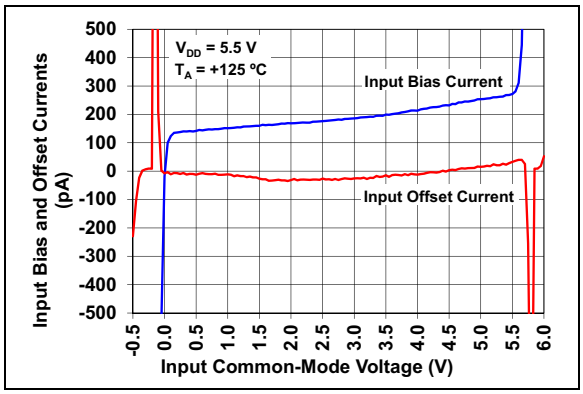


FIGURE 2-13: *Input Bias and Offset Currents vs. Common-Mode Input Voltage with T_A = +125°C.*

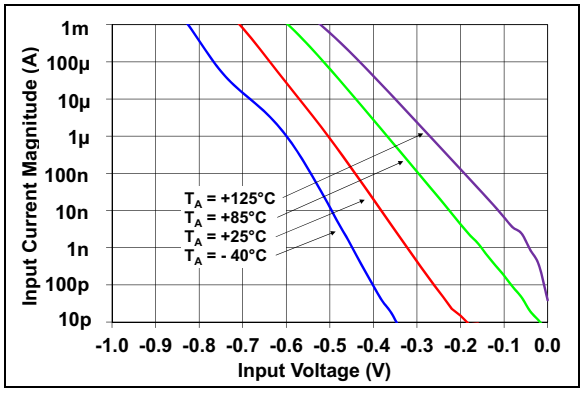


FIGURE 2-15: *Input Bias Current vs. Input Voltage (Below V_{SS}).*

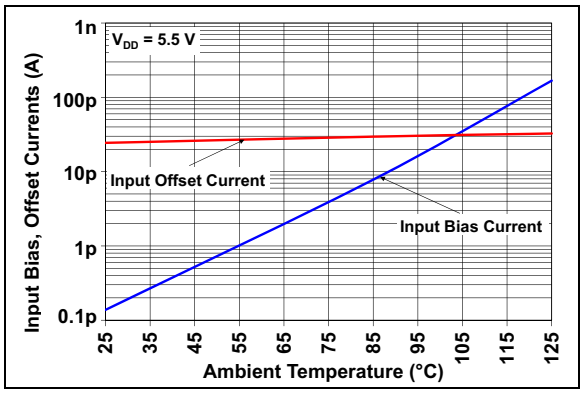


FIGURE 2-14: *Input Bias and Offset Currents vs. Ambient Temperature with V_{DD} = 5.5V.*

Note: Unless otherwise indicated, T_A = +25°C, V_{DD} = +2.4V to 5.5V, V_{SS} = GND, V_{CM} = V_{DD}/3, V_{OUT} = V_{DD}/2, V_L = V_{DD}/2, R_L = 10 kΩ to V_L and C_L = 30 pF.

2.2 Other DC Voltages and Currents

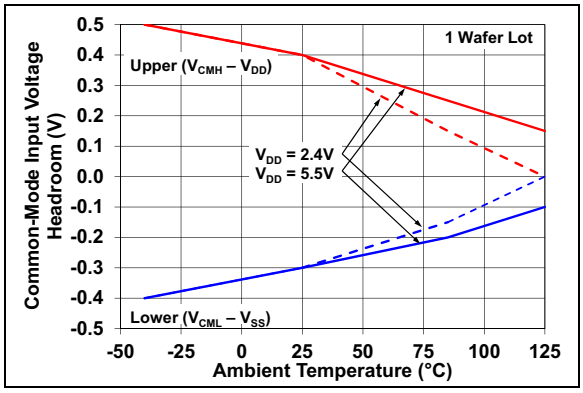


FIGURE 2-16: *Input Common-Mode Voltage Headroom (Range) vs. Ambient Temperature.*

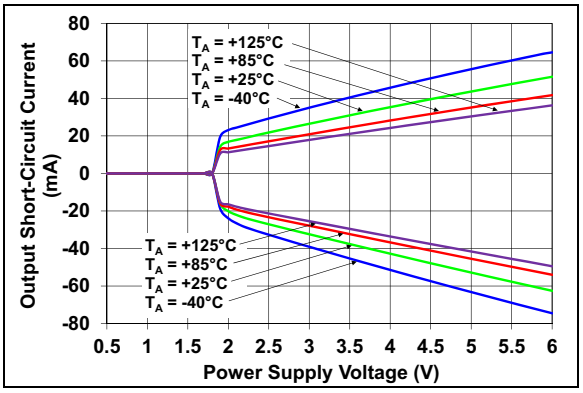


FIGURE 2-19: *Output Short-Circuit Current vs. Power Supply Voltage.*

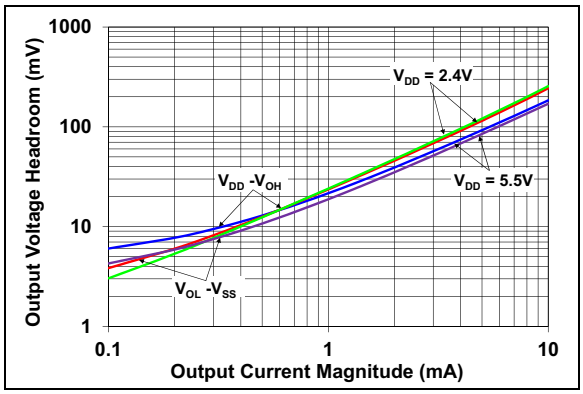


FIGURE 2-17: *Output Voltage Headroom vs. Output Current.*

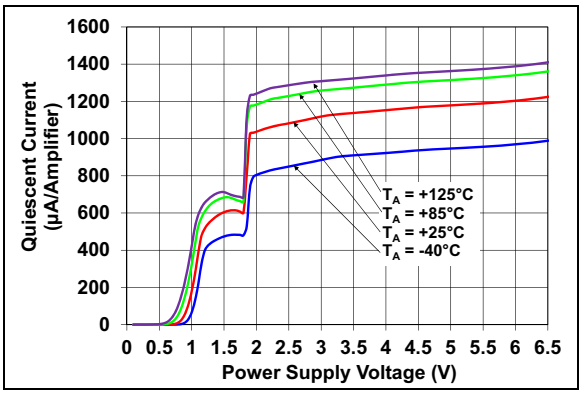


FIGURE 2-20: *Supply Current vs. Power Supply Voltage.*

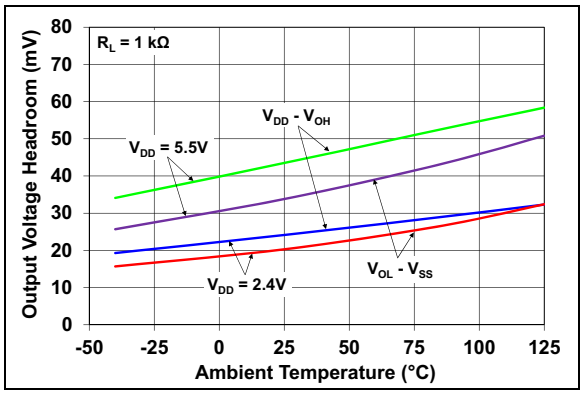


FIGURE 2-18: *Output Voltage Headroom vs. Ambient Temperature.*

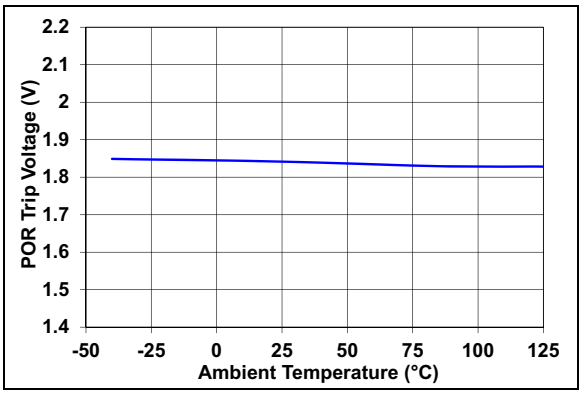


FIGURE 2-21: *Power-On Reset Voltage vs. Ambient Temperature.*

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Note: Unless otherwise indicated, T_A = +25°C, V_{DD} = +2.4V to 5.5V, V_{SS} = GND, V_{CM} = V_{DD}/3, V_{OUT} = V_{DD}/2, V_L = V_{DD}/2, R_L = 10 kΩ to V_L and C_L = 30 pF.

2.3 Frequency Response

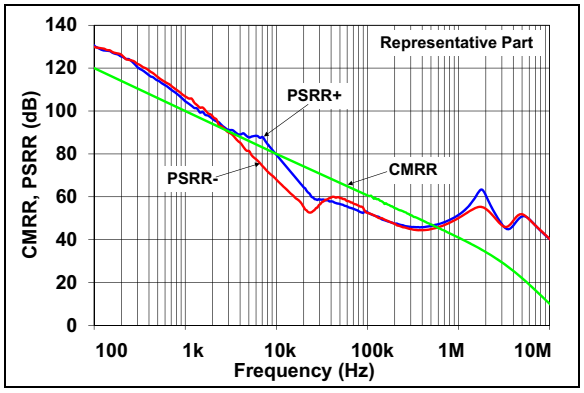


FIGURE 2-22: *CMRR and PSRR vs. Frequency.*

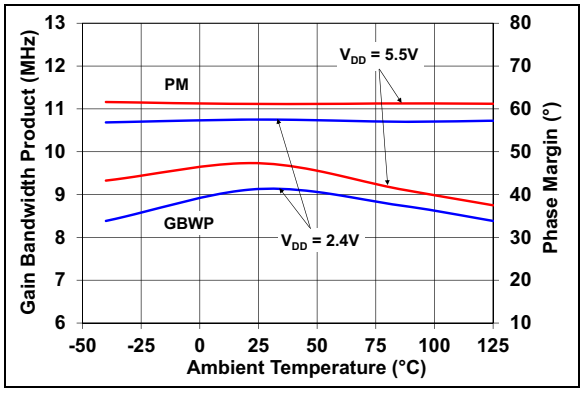


FIGURE 2-25: *Gain Bandwidth Product and Phase Margin vs. Ambient Temperature.*

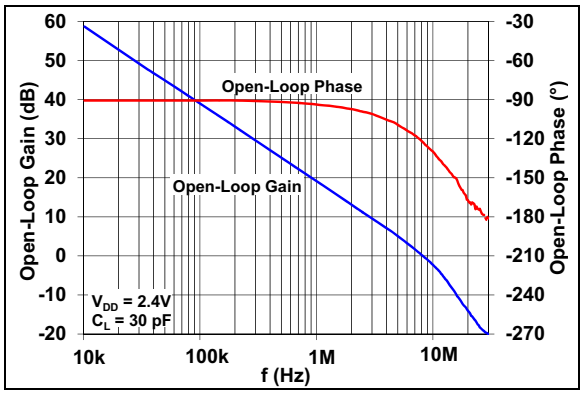


FIGURE 2-23: *Open-Loop Gain vs. Frequency with V_{DD} = 2.4V.*

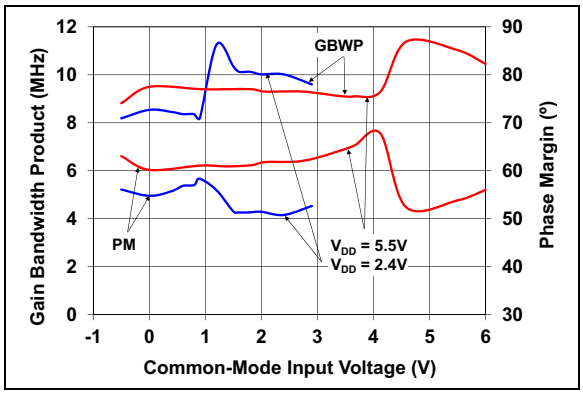


FIGURE 2-26: *Gain Bandwidth Product and Phase Margin vs. Common-Mode Input Voltage.*

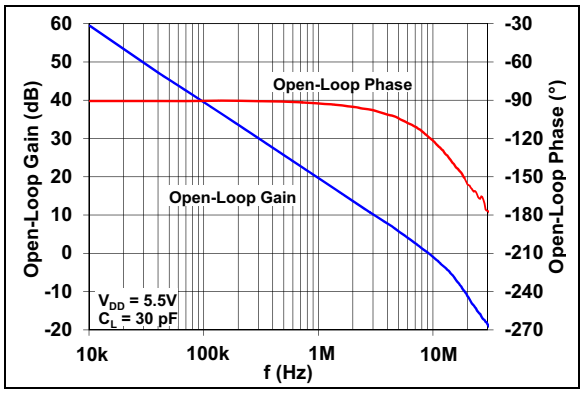


FIGURE 2-24: *Open-Loop Gain vs. Frequency with V_{DD} = 5.5V.*

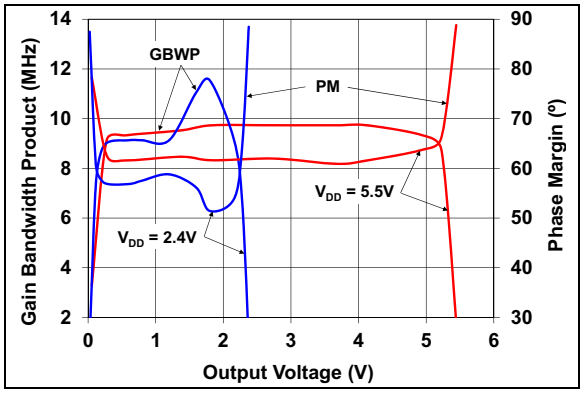


FIGURE 2-27: *Gain Bandwidth Product and Phase Margin vs. Output Voltage.*

Note: Unless otherwise indicated, T_A = +25°C, V_{DD} = +2.4V to 5.5V, V_{SS} = GND, V_{CM} = V_{DD}/3, V_{OUT} = V_{DD}/2, V_L = V_{DD}/2, R_L = 10 kΩ to V_L and C_L = 30 pF.

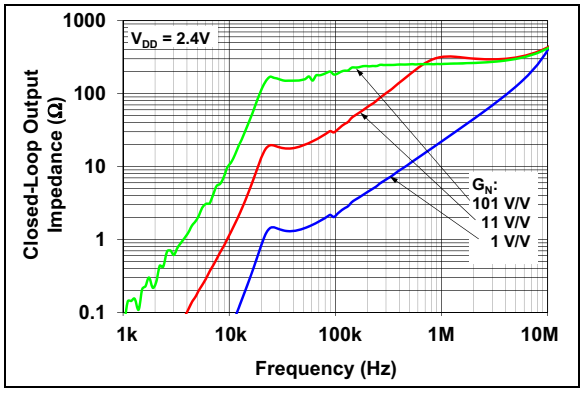


FIGURE 2-28: *Closed-Loop Output Impedance vs. Frequency with V_{DD} = 2.2V.*

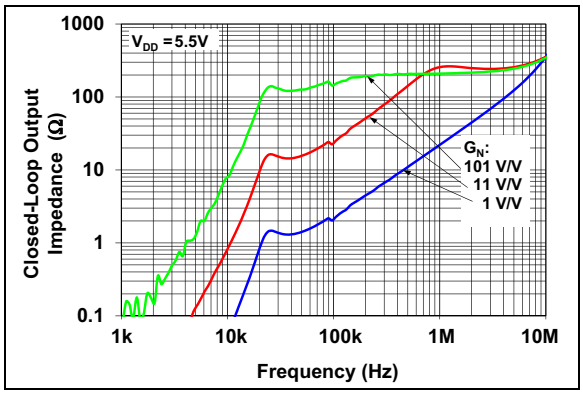


FIGURE 2-29: *Closed-Loop Output Impedance vs. Frequency with V_{DD} = 5.5V.*

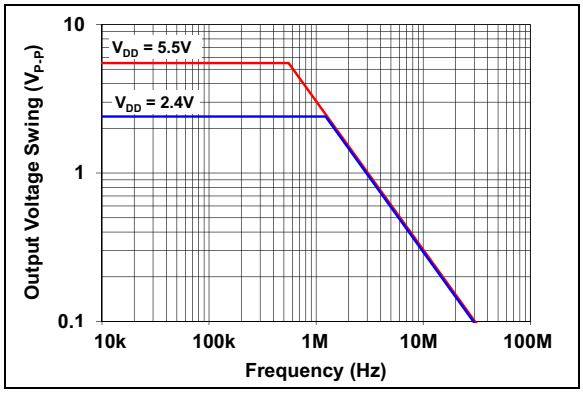


FIGURE 2-30: *Maximum Output Voltage Swing vs. Frequency.*

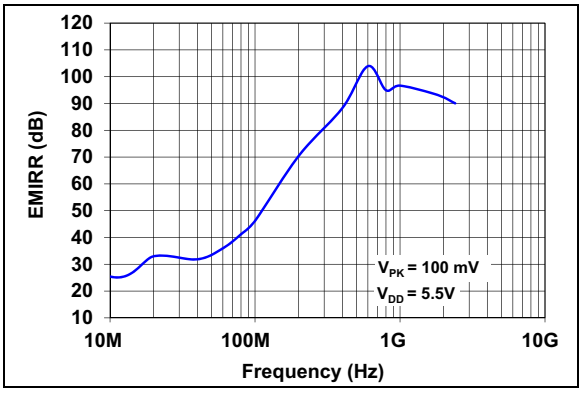


FIGURE 2-31: *EMIRR vs. Frequency.*

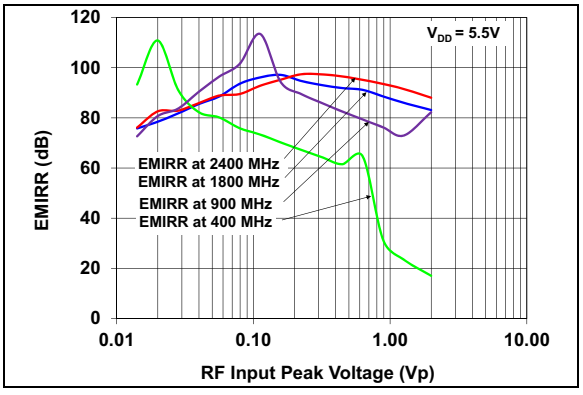


FIGURE 2-32: *EMIRR vs. Input Voltage.*

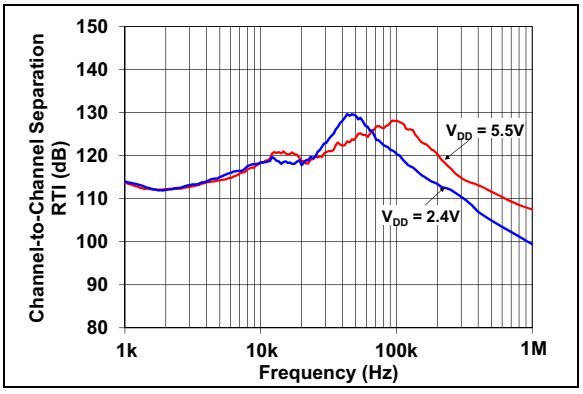


FIGURE 2-33: *Channel-to-Channel Separation vs. Frequency.*

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Note: Unless otherwise indicated, T_A = +25°C, V_{DD} = +2.4V to 5.5V, V_{SS} = GND, V_{CM} = V_{DD}/3, V_{OUT} = V_{DD}/2, V_L = V_{DD}/2, R_L = 10 kΩ to V_L and C_L = 30 pF.

2.4 Input Noise and Distortion

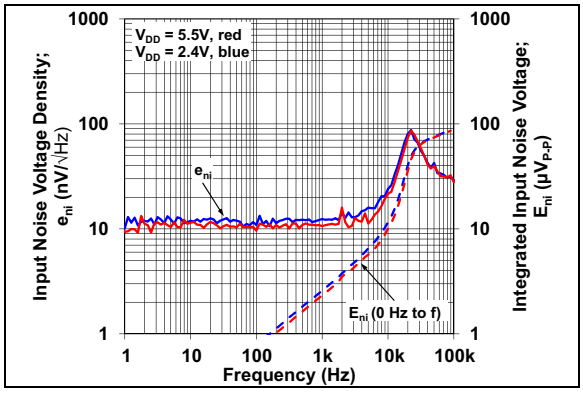


FIGURE 2-34: *Input Noise Voltage Density and Integrated Input Noise Voltage vs. Frequency.*

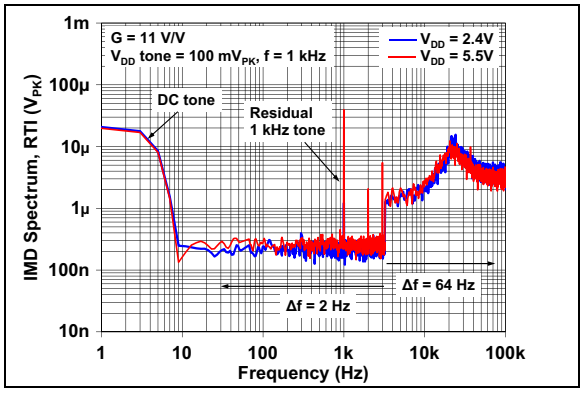


FIGURE 2-37: *Intermodulation Distortion vs. Frequency with V_{DD} Disturbance (see Figure 1-6).*

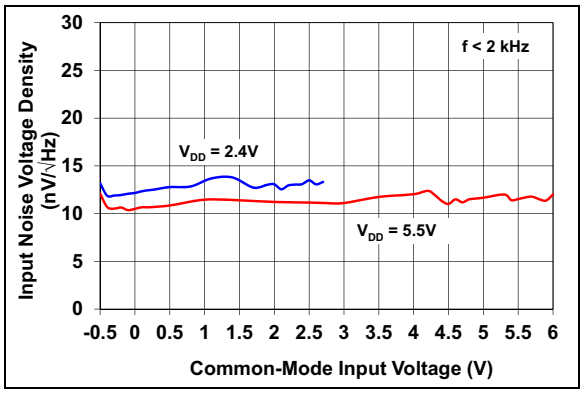


FIGURE 2-35: *Input Noise Voltage Density vs. Input Common-Mode Voltage.*

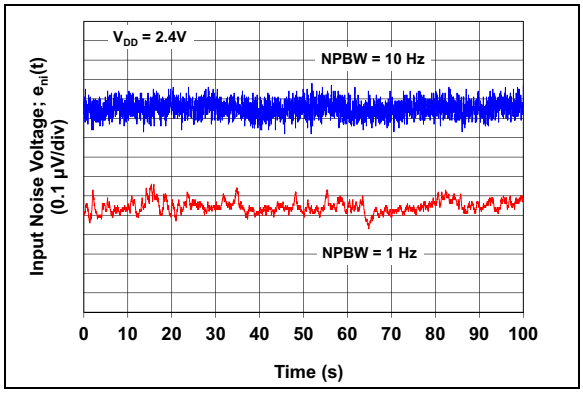


FIGURE 2-38: *Input Noise vs. Time with 1 Hz and 10 Hz Filters and V_{DD} = 2.4V.*

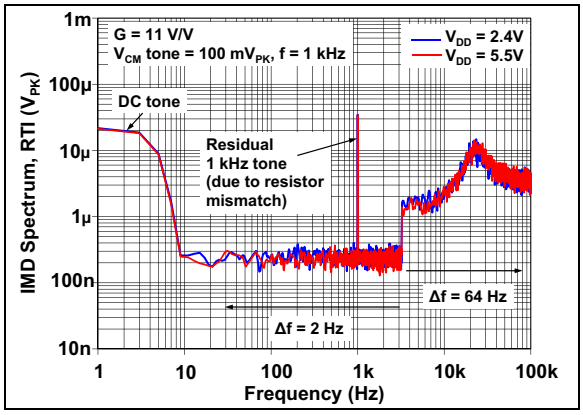


FIGURE 2-36: *Intermodulation Distortion vs. Frequency with V_{CM} Disturbance (see Figure 1-6).*

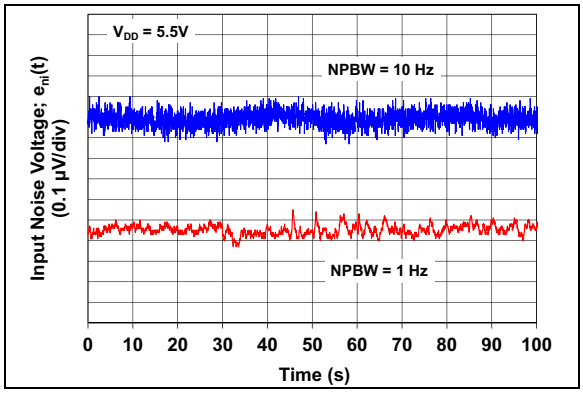


FIGURE 2-39: *Input Noise vs. Time with 1 Hz and 10 Hz Filters and V_{DD} = 5.5V.*

Note: Unless otherwise indicated, T_A = +25°C, V_{DD} = +2.4V to 5.5V, V_{SS} = GND, V_{CM} = V_{DD}/3, V_{OUT} = V_{DD}/2, V_L = V_{DD}/2, R_L = 10 kΩ to V_L and C_L = 30 pF.

2.5 Time Response

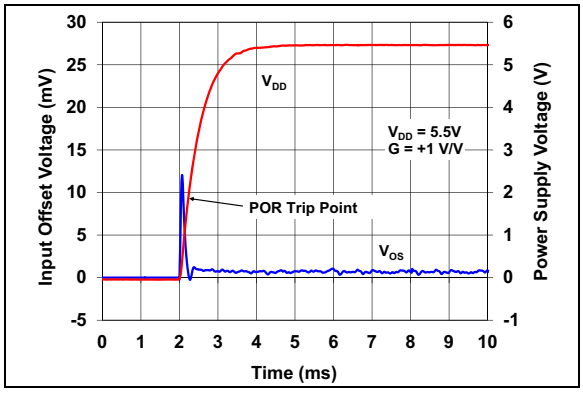


FIGURE 2-40: *Input Offset Voltage vs. Time at Power-Up.*

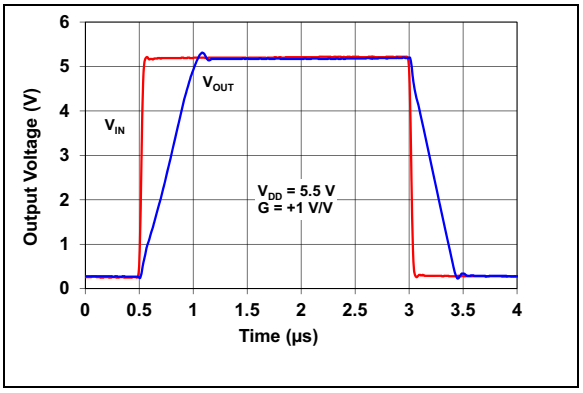


FIGURE 2-43: *Noninverting Large Signal Step Response.*

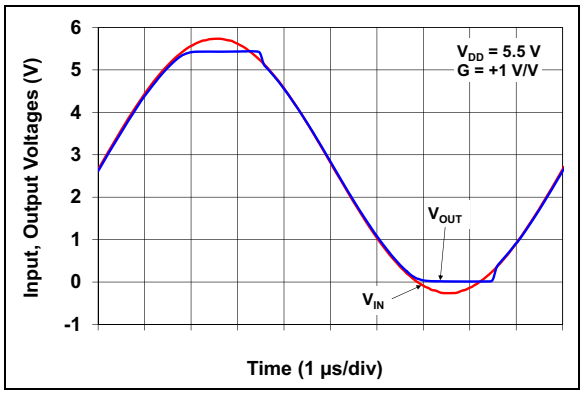


FIGURE 2-41: *The MCP6V96/6U/7/9 Family Shows No Input Phase Reversal with Overdrive.*

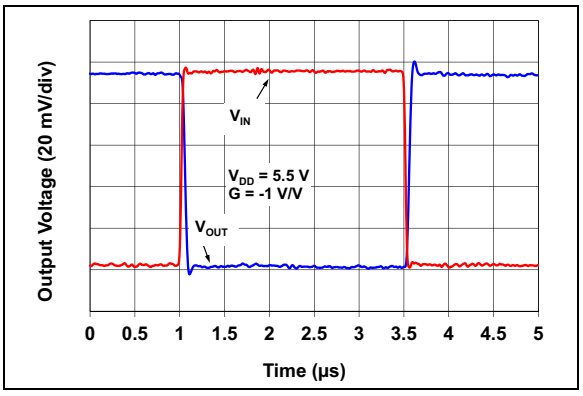


FIGURE 2-44: *Inverting Small Signal Step Response.*

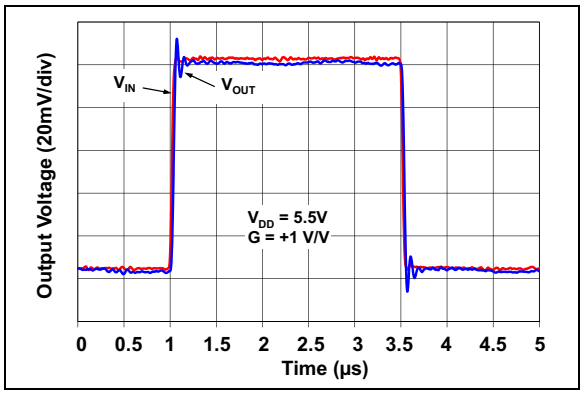


FIGURE 2-42: *Noninverting Small Signal Step Response.*

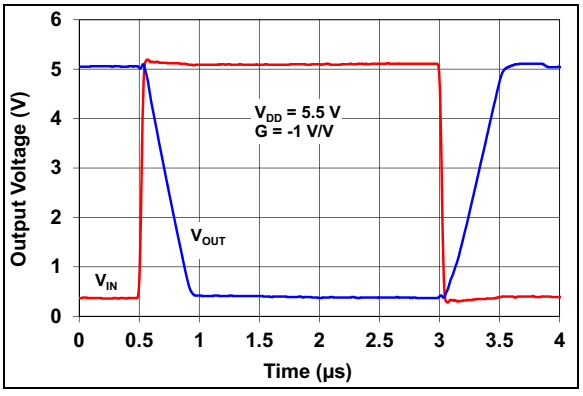


FIGURE 2-45: *Inverting Large Signal Step Response.*

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Note: Unless otherwise indicated, T_A = +25°C, V_{DD} = +2.4V to 5.5V, V_{SS} = GND, V_{CM} = V_{DD}/3, V_{OUT} = V_{DD}/2, V_L = V_{DD}/2, R_L = 10 kΩ to V_L and C_L = 30 pF.

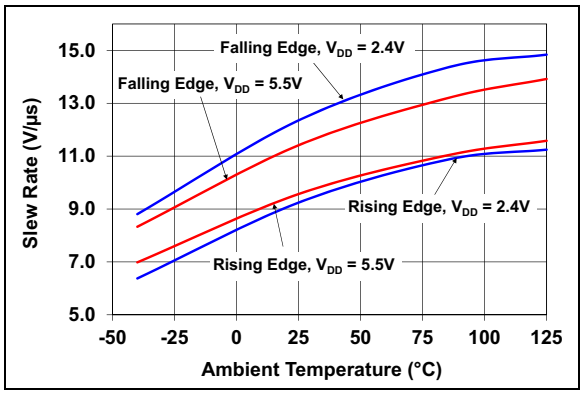


FIGURE 2-46: *Slew Rate vs. Ambient Temperature.*

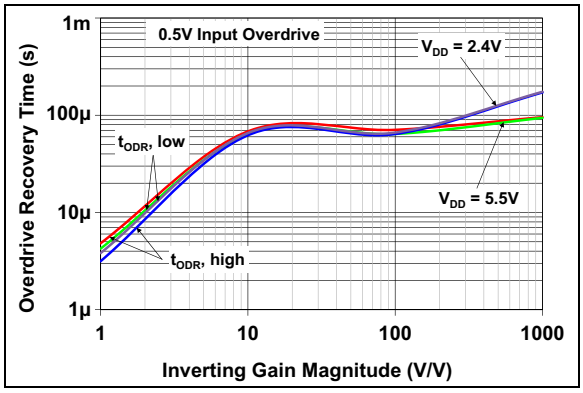


FIGURE 2-48: *Output Overdrive Recovery Time vs. Inverting Gain.*

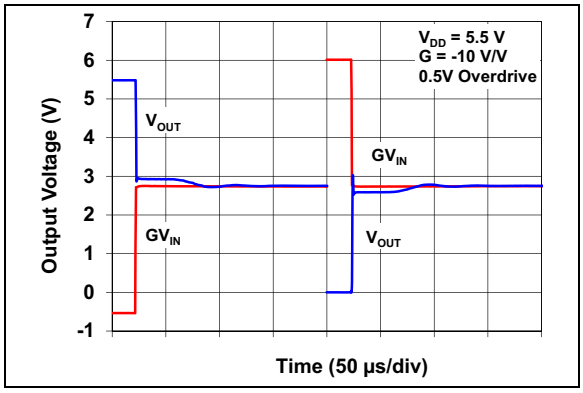


FIGURE 2-47: *Output Overdrive Recovery vs. Time with G = -10 V/V.*

NOTES:

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3.0 PIN DESCRIPTIONS

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

TABLE 3-1: PIN FUNCTION TABLE

MCP6V96	MCP6V96U	MCP6V97		MCP6V99	Symbol	Description
SOT-23	SOT-23, SC70	2 x 3 TDFN	MSOP	TSSOP		
1	4	1	1	1	V_{OUT}	Output
4	3	2	2	2	$V_{IN}-$	Inverting Input
3	1	3	3	3	$V_{IN}+$	Noninverting Input
5	5	8	8	4	V_{DD}	Positive Power Supply
—	—	5	5	5	$V_{INB}+$	Noninverting Input (Op Amp B)
—	—	6	6	6	$V_{INB}-$	Inverting Input (Op Amp B)
—	—	7	7	7	V_{OUTB}	Output (Op Amp B)
—	—	—	—	8	V_{OUTC}	Output (Op Amp C)
—	—	—	—	9	$V_{INC}-$	Inverting Input (Op Amp C)
—	—	—	—	10	$V_{INC}+$	Noninverting Input (Op Amp C)
2	2	4	4	11	V_{SS}	Negative Power Supply
—	—	—	—	12	$V_{IND}+$	Noninverting Input (Op Amp D)
—	—	—	—	13	$V_{IND}-$	Inverting Input (Op Amp D)
—	—	—	—	14	V_{OUTD}	Output (Op Amp D)
—	—	9	—	—	EP	Exposed Thermal Pad (EP); must be connected to V_{SS}

3.1 Analog Outputs (V_{OUT}, V_{OUTA}, V_{OUTB}, V_{OUTC}, V_{OUTD})

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

3.2 Analog Inputs ($V_{IN}+$, $V_{IN}-$, $V_{INB}+$, $V_{INB}-$, $V_{INC}-$, $V_{INC}+$, $V_{IND}-$, $V_{IND}+$)

The noninverting and inverting inputs ($V_{IN}+$, $V_{IN}-$) are high-impedance CMOS inputs with low bias currents.

3.3 Power Supply Pins (V_{DD}, V_{SS})

The positive power supply (V_{DD}) is 2.4V to 5.5V higher than the negative power supply (V_{SS}). For normal operation, the other pins are between V_{SS} and V_{DD}.

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

3.4 Exposed Thermal Pad (EP)

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

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

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NOTES:

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4.0 APPLICATIONS

The MCP6V96/6U/7/9 family of zero-drift op amps is manufactured using Microchip's state-of-the-art CMOS process. It is designed for precision applications with requirements for small packages and low power. Its low supply voltage and low quiescent current make the MCP6V96/6U/7/9 devices ideal for battery-powered applications.

4.1 Overview of Zero-Drift Operation

Figure 4-1 shows a simplified diagram of the MCP6V96/6U/7/9 zero-drift op amp. This diagram will be used to explain how slow voltage errors are reduced in this architecture (much better V_{OS}, $\Delta V_{OS}/\Delta T_A$ (TC_1), CMRR, PSRR, A_{OL} and 1/f noise).

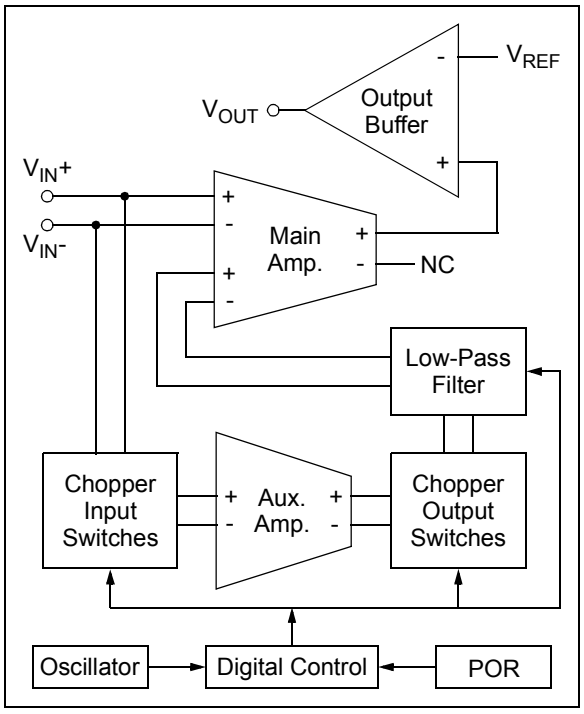


FIGURE 4-1: *Simplified Zero-Drift Op Amp Functional Diagram.*

4.1.1 BUILDING BLOCKS

The main amplifier is designed for high gain and bandwidth, with a differential topology. Its main input pair (+ and - pins at the top left) is used for the higher frequency portion of the input signal. Its auxiliary input pair (+ and - pins at the bottom left) is used for the low-frequency portion of the input signal and corrects the op amp's input offset voltage. Both inputs are added together internally.

The auxiliary amplifier, chopper input switches and chopper output switches provide a high DC gain to the input signal. DC errors are modulated to higher frequencies, while white noise is modulated to a low frequency.

The low-pass filter reduces high-frequency content, including harmonics of the chopping clock.

The output buffer drives external loads at the V_{OUT} pin (V_{REF} is an internal reference voltage).

The oscillator runs at f_{OSC1} = 200 kHz. Its output is divided by two, to produce the chopping clock rate of f_{CHOP} = 100 kHz.

The internal Power-on Reset (POR) starts the part in a known good state, protecting against power supply brown-outs.

The digital control block controls switching and POR events.

4.1.2 CHOPPING ACTION

Figure 4-2 shows the amplifier connections for the first phase of the chopping clock and Figure 4-3 shows the connections for the second phase. Its slow voltage errors alternate in polarity, making the average error small.

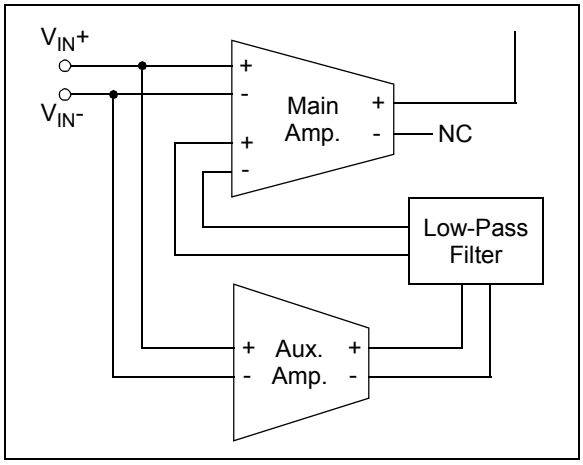


FIGURE 4-2: *First Chopping Clock Phase; Equivalent Amplifier Diagram.*

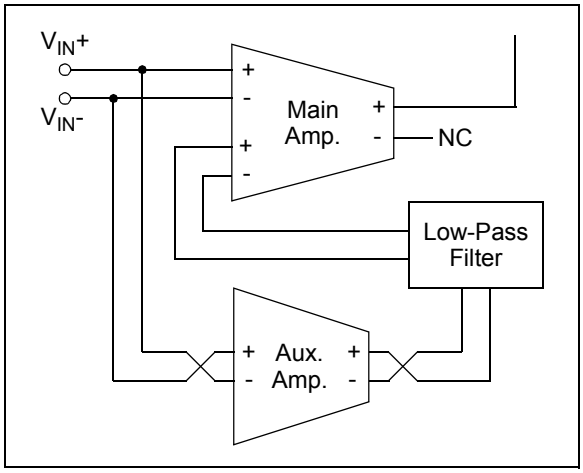


FIGURE 4-3: *Second Chopping Clock Phase; Equivalent Amplifier Diagram.*

4.1.3 INTERMODULATION DISTORTION (IMD)

These op amps will show intermodulation distortion (IMD) products when an AC signal is present.

The signal and clock can be decomposed into sine wave tones (Fourier series components). These tones interact with the zero-drift circuitry's nonlinear response to produce IMD tones at sum and difference frequencies. Each of the square wave clock's harmonics has a series of IMD tones centered on it (see Figures 2-36 and 2-37).

4.2 Other Functional Blocks

4.2.1 RAIL-TO-RAIL INPUTS

The input stage of the MCP6V96/6U/7/9 op amps uses two differential CMOS input stages in parallel. One operates at low Common-mode input voltage (V_{CM}, which is approximately equal to $V_{IN}+$ and $V_{IN}-$ in normal operation) and the other operates at high V_{CM}. With this topology, the input operates with V_{CM} up to V_{DD} + 0.3V and down to V_{SS} – 0.2V, at +25°C (see Figure 2-16). The input offset voltage (V_{OS}) is measured at V_{CM} = V_{SS} – 0.2V and V_{DD} + 0.3V to ensure proper operation.

4.2.1.1 Phase Reversal

The input devices are designed to not exhibit phase inversion when the input pins exceed the supply voltages. Figure 2-41 shows an input voltage exceeding both supplies with no phase inversion.

4.2.1.2 Input Voltage Limits

In order to prevent damage and/or improper operation of these amplifiers, the circuit must limit the voltages at the input pins (see **Section 1.1 "Absolute Maximum Ratings †"**). This requirement is independent of the input current limits discussed later on.

The ESD protection on the inputs can be depicted as shown in Figure 4-4. This structure was chosen to protect the input transistors against many (but not all) overvoltage conditions and to minimize input bias current (I_B).

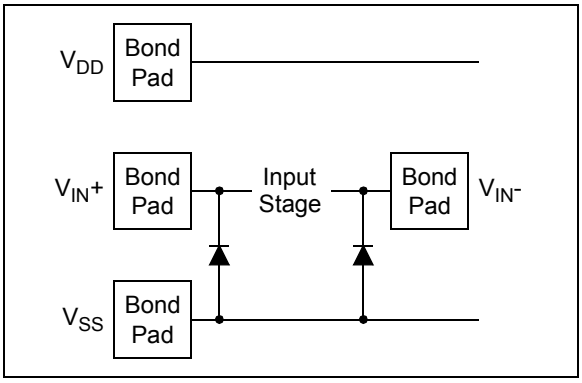


FIGURE 4-4: *Simplified Analog Input ESD Structures.*

The input ESD diodes clamp the inputs when they try to go more than one diode drop below V_{SS}. They also clamp any voltages well above V_{DD}; their breakdown voltage is high enough to allow normal operation but not low enough to protect against slow overvoltage (beyond V_{DD}) events. Very fast ESD events (that meet the specification) are limited so that damage does not occur.

In some applications, it may be necessary to prevent excessive voltages from reaching the op amp inputs; Figure 4-5 shows one approach to protecting these inputs. D_1 and D_2 may be small signal silicon diodes, Schottky diodes for lower clamping voltages or diode-connected FETs for low leakage.

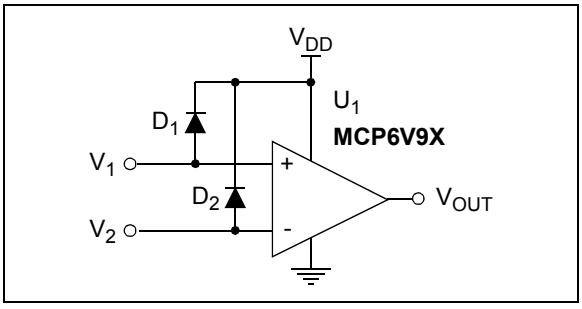


FIGURE 4-5: *Protecting the Analog Inputs Against High Voltages.*

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4.2.1.3 Input Current Limits

In order to prevent damage and/or improper operation of these amplifiers, the circuit must limit the currents into the input pins (see **Section 1.1 "Absolute Maximum Ratings †"**). This requirement is independent of the voltage limits discussed previously.

Figure 4-6 shows one approach to protecting these inputs. The R_1 and R_2 resistors limit the possible current in or out of the input pins (and into D_1 and D_2). The diode currents will dump onto V_{DD}.

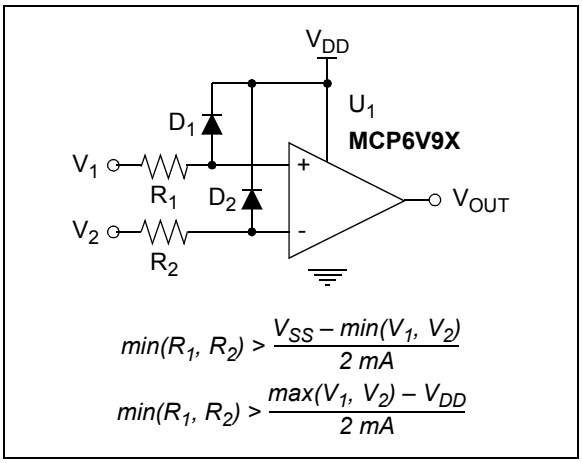


FIGURE 4-6: *Protecting the Analog Inputs Against High Currents.*

It is also possible to connect the diodes to the left of the R_1 and R_2 resistors. In this case, the currents through the D_1 and D_2 diodes need to be limited by some other mechanism. The resistors then serve as inrush current limiters; the DC current into the input pins (V_{IN}+ and V_{IN}-) should be very small.

A significant amount of current can flow out of the inputs (through the ESD diodes) when the Common-mode input voltage (V_{CM}) is below ground (V_{SS}) (see Figure 2-15).

4.2.2 RAIL-TO-RAIL OUTPUT

The output voltage range of the MCP6V96/6U/7/9 zero-drift op amps is V_{DD} – 9 mV (typical) and V_{SS} + 7 mV (typical) when R_L = 10 kΩ is connected to $V_{DD}/2$ and V_{DD} = 5.5V. Refer to Figures 2-17 and 2-18 for more information.

This op amp is designed to drive light loads; use another amplifier to buffer the output from heavy loads.

4.3 Application Tips

4.3.1 INPUT OFFSET VOLTAGE OVER TEMPERATURE

Table 1-1 gives both the linear and quadratic temperature coefficients (TC_1 and TC_2) of the input offset voltage. The input offset voltage, at any temperature in the specified range, can be calculated as follows:

EQUATION 4-1:

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

Where:

ΔT	=	T_A – +25°C
$V_{OS}(T_A)$	=	Input offset voltage at T_A
V_{OS}	=	Input offset voltage at +25°C
TC_1	=	Linear temperature coefficient
TC_2	=	Quadratic temperature coefficient

4.3.2 OFFSET AT POWER-UP

When these parts power up, the input offset (V_{OS}) starts at its uncorrected value. Circuits with high DC gain can cause the output to reach one of the two rails. In this case, the time to a valid output is delayed by an output overdrive time (like t_{ODR}) in addition to the start-up time (like t_{STR}).

It can be simple to avoid this extra start-up time. Reducing the gain is one method. Adding a capacitor across the feedback resistor (R_F) is another method.

4.3.3 SOURCE RESISTANCES

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

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

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

Small input resistances may be needed for high gains. Without them, parasitic capacitances might cause positive feedback and instability.

4.3.4 SOURCE CAPACITANCE

The capacitances seen by the two inputs should be small. Large input capacitances and source resistances, together with high gain, can lead to positive feedback and instability.

4.3.5 CAPACITIVE LOADS

Driving large capacitive loads can cause stability problems for voltage feedback op amps. As the load capacitance increases, the feedback loop's phase margin decreases and the closed-loop bandwidth is reduced. This produces gain peaking in the frequency response, with overshoot and ringing in the step response. These zero-drift op amps have a different output impedance than most op amps, due to their unique topology.

When driving a capacitive load with these op amps, a series resistor at the output (R_{ISO} in Figure 4-7) improves the feedback loop's phase margin (stability) by making the output load resistive at higher frequencies. The bandwidth will be generally lower than the bandwidth with no capacitive load.

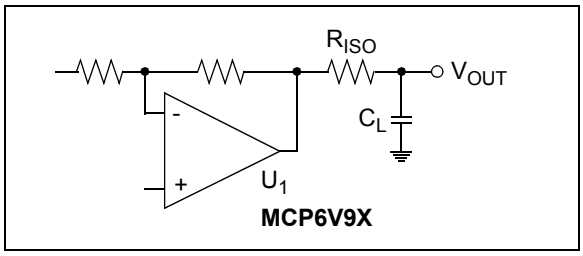


FIGURE 4-7: *Output Resistor, R_{ISO}, Stabilizes Capacitive Loads.*

Figure 4-8 gives recommended R_{ISO} values for different capacitive loads and gains. The x-axis is the load capacitance (C_L). The y-axis is the resistance (R_{ISO}).

G_N is the circuit's noise gain. For noninverting 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).

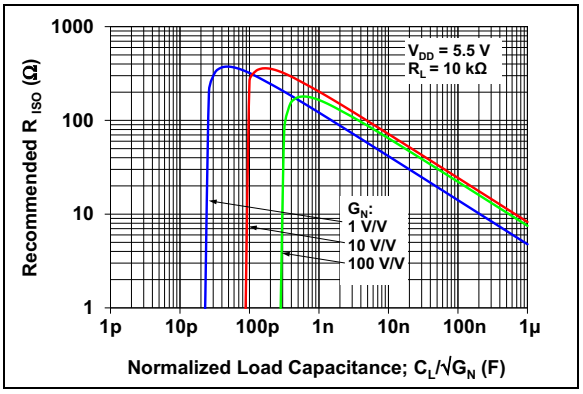


FIGURE 4-8: *Recommended R_{ISO} Values for Capacitive Loads.*

After selecting R_{ISO} for your circuit, double check the resulting frequency response peaking and step response overshoot. Modify the R_{ISO} value until the response is reasonable. Bench evaluation is helpful.

4.3.6 STABILIZING OUTPUT LOADS

This family of zero-drift op amps have an output impedance that has a double zero when the gain is low (see Figures 2-28 and 2-29). This can cause a large phase shift in feedback networks that have low-impedance near the part's bandwidth. This large phase shift can cause stability problems.

Figure 4-9 shows that the load on the output is $(R_L + R_{ISO})||(R_F + R_G)$, where R_{ISO} is before the load (like Figure 4-7). This load needs to be large enough to maintain stability; it should be at least 10 kΩ.

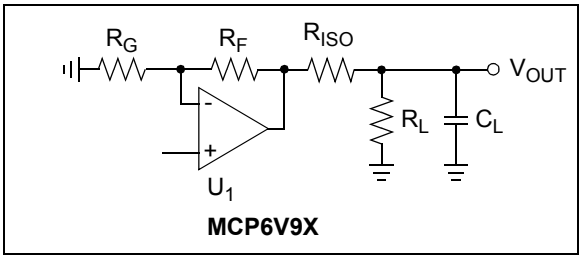


FIGURE 4-9: *Output Load.*

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4.3.7 GAIN PEAKING

Figure 4-10 shows an op amp circuit that represents noninverting amplifiers (V_M is a DC voltage and V_P is the input) or inverting amplifiers (V_P is a DC voltage and V_M is the input). The C_N and C_G capacitances represent the total capacitance at the input pins; they include the op amp's Common-mode input capacitance (C_{CM}), board parasitic capacitance and any capacitor placed in parallel. The C_{FP} capacitance represents the parasitic capacitance coupling the output and noninverting input pins.

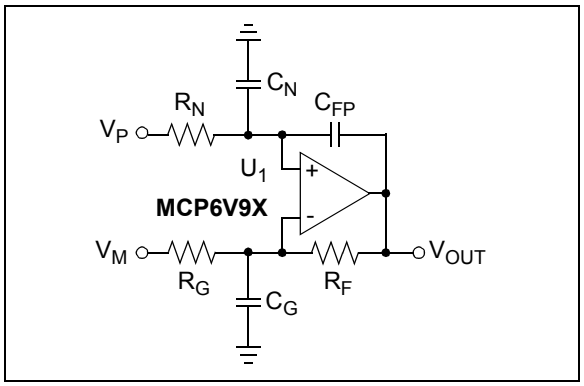


FIGURE 4-10: *Amplifier with Parasitic Capacitance.*

C_G acts in parallel with R_G (except for a gain of +1 V/V), which causes an increase in gain at high frequencies. C_G also reduces the phase margin of the feedback loop, which becomes less stable. This effect can be reduced by reducing either C_G or $R_F||R_G$.

C_N and R_N form a low-pass filter that affects the signal at V_P. This filter has a single real pole at $1/(2\pi R_N C_N)$.

The largest value of R_F that should be used depends on noise gain (see G_N in **Section 4.3.5 "Capacitive Loads"**), C_G and the open-loop gain's phase shift. An approximate limit for R_F is:

EQUATION 4-2:

$$R_F \leq 10\ k\Omega \times \frac{3.5\ pF}{C_G} \times G_N^2$$

Some applications may modify these values to reduce either output loading or gain peaking (step-response overshoot).

At high gains, R_N needs to be small in order to prevent positive feedback and oscillations. Large C_N values can also help.

4.3.8 REDUCING UNDESIRED NOISE AND SIGNALS

Reduce undesired noise and signals with:

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

4.3.9 SUPPLY BYPASSING AND FILTERING

With this family of operational amplifiers, the power supply pin (V_{DD} for single supply) should have a local bypass capacitor (i.e., 0.01 µF to 0.1 µF) within 2 mm of the pin for good high-frequency performance.

These parts also need 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 low-noise analog parts.

In some cases, high-frequency power supply noise (e.g., switched mode power supplies) may cause undue intermodulation distortion with a DC offset shift; this noise needs to be filtered. Adding a small resistor into the supply connection can be helpful.

4.3.10 PCB DESIGN FOR DC PRECISION

In order to achieve DC precision on the order of ±1 µV, many physical errors need to be minimized. The design of the PCB, the wiring and the thermal environment have a strong impact on the precision achieved. A poor PCB design can easily be more than 100 times worse than the MCP6V96/6U/7/9 op amps' minimum and maximum specifications.

4.3.10.1 PCB Layout

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

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

Typical thermojunctions have temperature-to-voltage conversion coefficients of 1 to 100 µV/°C (sometimes higher).

Microchip's AN1258 "*Op Amp Precision Design: PCB Layout Techniques*" (DS01258) contains in-depth information on PCB layout techniques that minimize thermojunction effects. It also discusses other effects, such as crosstalk, impedances, mechanical stresses and humidity.

4.3.10.2 Crosstalk

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

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

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

To reduce interference:

- Keep traces and wires as short as possible
- Use shielding
- Use ground plane (at least a star ground)
- Place the input signal source near the DUT
- Use good PCB layout techniques
- Use a separate power supply filter (bypass capacitors) for these zero-drift op amps

4.3.10.3 Miscellaneous Effects

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

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

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

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

Humidity can cause electrochemical potential voltages to appear in a circuit. Proper PCB cleaning helps, as does the use of encapsulants.

4.4 Typical Applications

4.4.1 WHEATSTONE BRIDGE

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

Figure 4-11 shows how to interface to a Wheatstone bridge with a minimum of components. Because the circuit is not symmetric, the ADC input is single-ended and there is a minimum of filtering; the CMRR is good enough for moderate Common-mode noise.

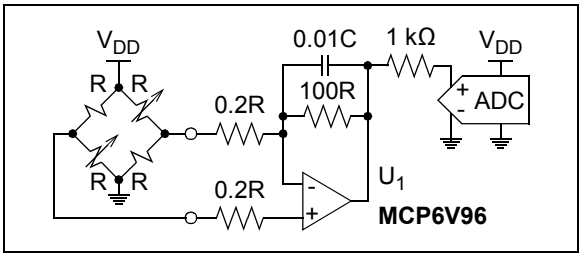


FIGURE 4-11: *Simple Design.*

4.4.2 RESISTANCE TEMPERATURE DETECTOR (RTD) SENSOR

The ratiometric circuit in Figure 4-12 conditions a two-wire RTD for applications with a limited temperature range. U_1 acts as a difference amplifier with a low-frequency pole. The sensor's wiring resistance (R_W) is corrected in firmware. Failure (open) of the RTD is detected by an out-of-range voltage.

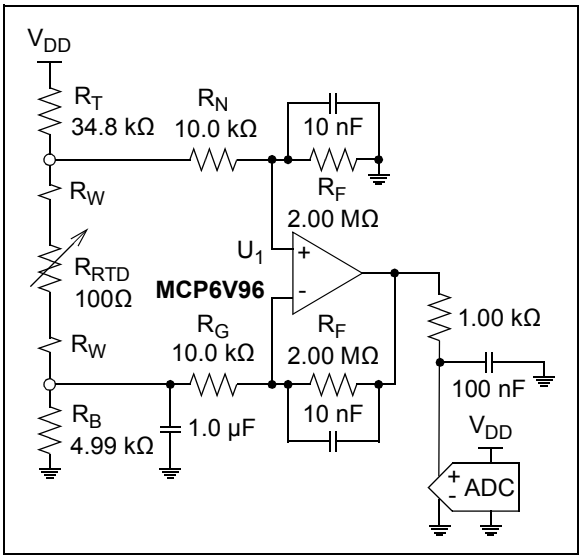


FIGURE 4-12: *RTD Sensor.*

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4.4.3 OFFSET VOLTAGE CORRECTION

Figure 4-13 shows MCP6V96 (U_2) correcting the input offset voltage of another op amp (U_1). R_2 and C_2 integrate the offset error seen at U_1's input. The integration needs to be slow enough to be stable (with the feedback provided by R_1 and R_3). R_4 and R_5 attenuate the integrator's output. This shifts the integrator pole down in frequency.

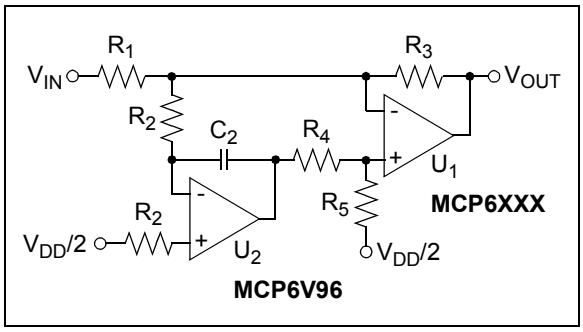


FIGURE 4-13: *Offset Correction.*

4.4.4 PRECISION COMPARATOR

Use high gain before a comparator to improve the latter's performance. Do not use MCP6V96/6U/7/9 as a comparator by itself; the V_{OS} correction circuitry does not operate properly without a feedback loop.

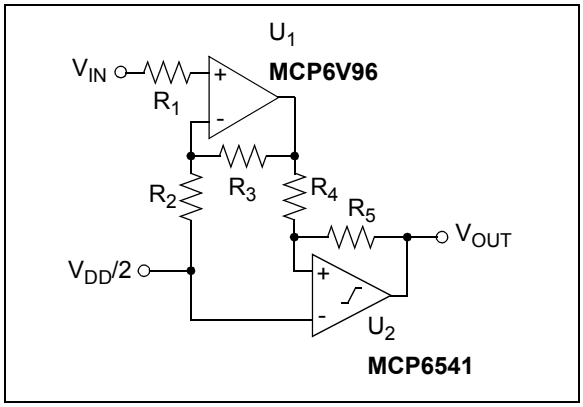


FIGURE 4-14: *Precision Comparator.*

NOTES:

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5.0 DESIGN AIDS

Microchip provides the basic design aids needed for the MCP6V96/6U/7/9 family of op amps.

5.1 Microchip Advanced Part Selector (MAPS)

MAPS is a software tool that helps efficiently identify Microchip devices that fit a particular design requirement. Available at no cost from the Microchip web site at www.microchip.com/maps, MAPS is an overall selection tool for Microchip's product portfolio that includes Analog, Memory, MCUs and DSCs. Using this tool, a customer can define a filter to sort features for a parametric search of devices and export side-by-side technical comparison reports. Helpful links are also provided for data sheets, purchase and sampling of Microchip parts.

5.2 Analog Demonstration and Evaluation Boards

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

Some boards that are especially useful are:

- MCP6V01 Thermocouple Auto-Zeroed Reference Design (MCP6V01RD-TCPL)
- MCP6XXX Amplifier Evaluation Board 2 (DS51668)
- MCP6XXX Amplifier Evaluation Board 3 (DS51673)
- 8-Pin SOIC/MSOP/TSSOP/DIP Evaluation Board (SOIC8EV)
- 14-Pin SOIC/TSSOP/DIP Evaluation Board (SOIC14EV)

5.3 Application Notes

The following Microchip Application Notes are available on the Microchip web site at www.microchip.com/appnotes and are recommended as supplemental reference resources:

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

AN722: *"Operational Amplifier Topologies and DC Specifications"* (DS00722)

AN723: *"Operational Amplifier AC Specifications and Applications"* (DS00723)

AN884: *"Driving Capacitive Loads With Op Amps"* (DS00884)

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

AN1177: *"Op Amp Precision Design: DC Errors"* (DS01177)

AN1228: *"Op Amp Precision Design: Random Noise"* (DS01228)

AN1258: *"Op Amp Precision Design: PCB Layout Techniques"* (DS01258)

AN1767: *"Solutions for Radio Frequency Electromagnetic Interference in Amplifier Circuits"* (DS00001767)

These Application Notes and others are listed in the design guide: *"Signal Chain Design Guide"* (DS21825).

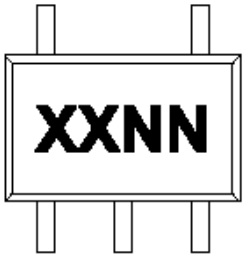
NOTES:

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6.0 PACKAGING INFORMATION

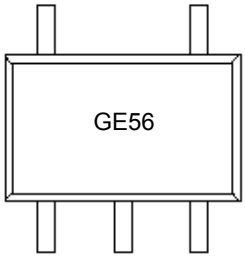
6.1 Package Marking Information

5-Lead SC70 (**MCP6V96U**)

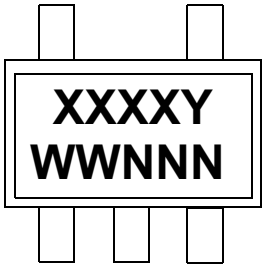


Device	Code
MCP6V96UT-E/LTY	GENN

Example

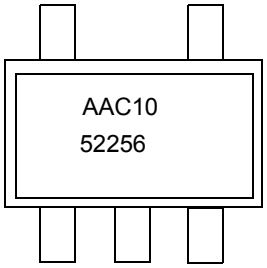


5-Lead SOT-23 **(MCP6V96, MCP6V96U)**

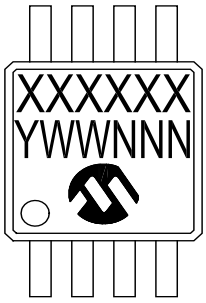


Device	Code
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MCP6V96UT-E/OT	AAC2Y

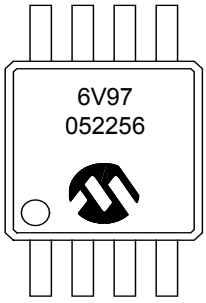
Example



8-Lead MSOP (**MCP6V97**)



Example



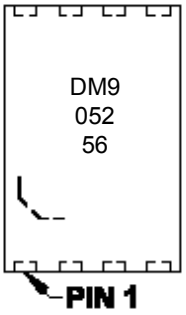
8-Lead TDFN **(MCP6V97)**



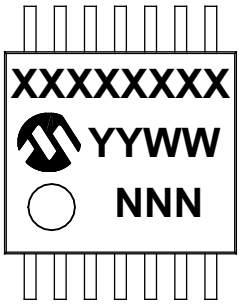
Device	Code
MCP6V97T-E/MNY	DM9

Note: Applies to 8-Lead 2 x 3 TDFN.

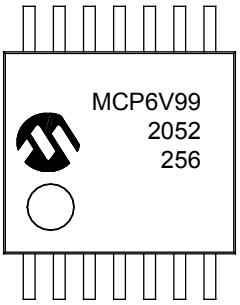
Example



14-Lead TSSOP (**MCP6V99**)



Example



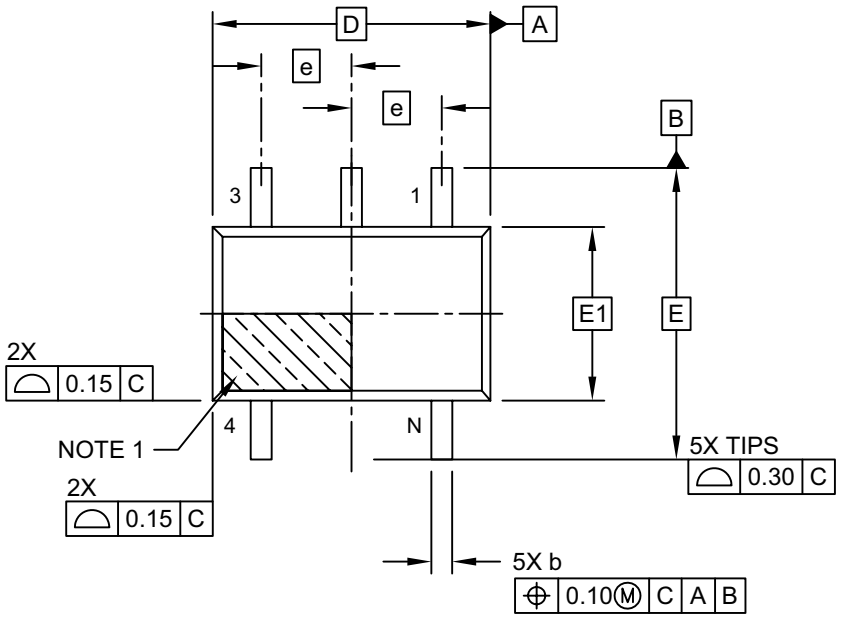
Legend:	XX...X	Customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week ‘01’)
	NNN	Alphanumeric traceability code
	(e3)	Pb-free JEDEC® designator for Matte Tin (Sn)
	*	This package is Pb-free. The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

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.

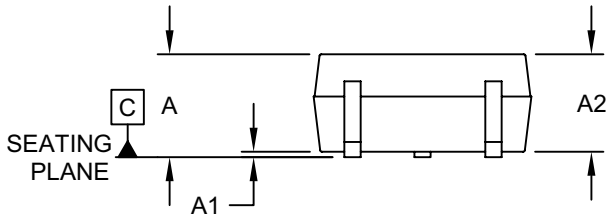
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5-Lead Plastic Small Outline Transistor (LTY) [SC70]

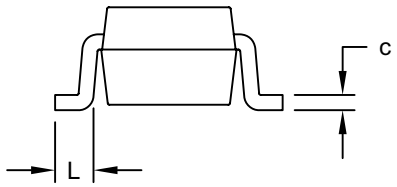
Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



TOP VIEW



SIDE VIEW

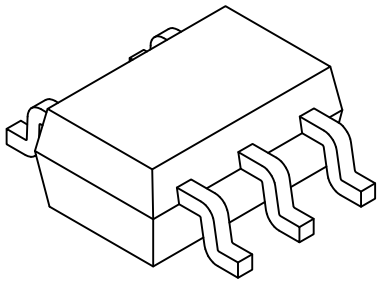


END VIEW

Microchip Technology Drawing C04-061-LTY Rev E Sheet 1 of 2

5-Lead Plastic Small Outline Transistor (LTY) [SC70]

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



Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Pins	N		5	
Pitch	e		0.65 BSC	
Overall Height	A	0.80	-	1.10
Standoff	A1	0.00	-	0.10
Molded Package Thickness	A2	0.80	-	1.00
Overall Length	D		2.00 BSC	
Overall Width	E		2.10 BSC	
Molded Package Width	E1		1.25 BSC	
Terminal Width	b	0.15	-	0.40
Terminal Length	L	0.10	0.20	0.46
Lead Thickness	c	0.08	-	0.26

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15mm per side.
3. Dimensioning and tolerancing per ASME Y14.5M

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

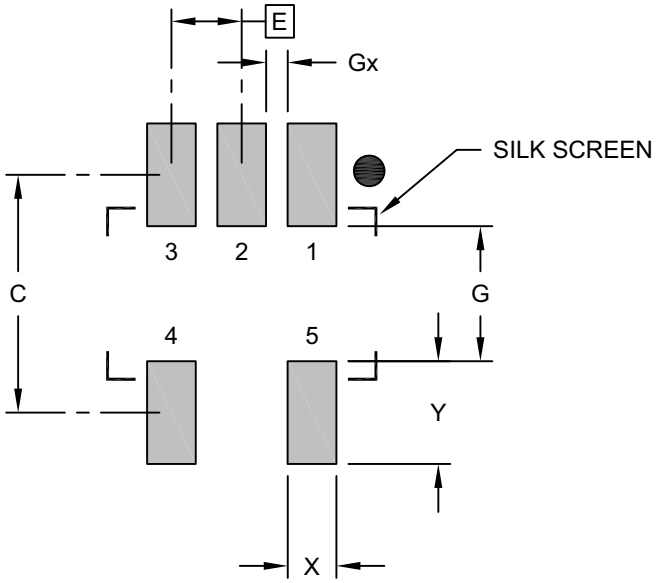
   REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-061-LTY Rev E Sheet 2 of 2

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5-Lead Plastic Small Outline Transistor (LTY) [SC70]

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



RECOMMENDED LAND PATTERN

Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Contact Pitch	E		0.65 BSC	
Contact Pad Spacing	C		2.20	
Contact Pad Width	X			0.45
Contact Pad Length	Y			0.95
Distance Between Pads	G	1.25		
Distance Between Pads	Gx	0.20		

Notes:

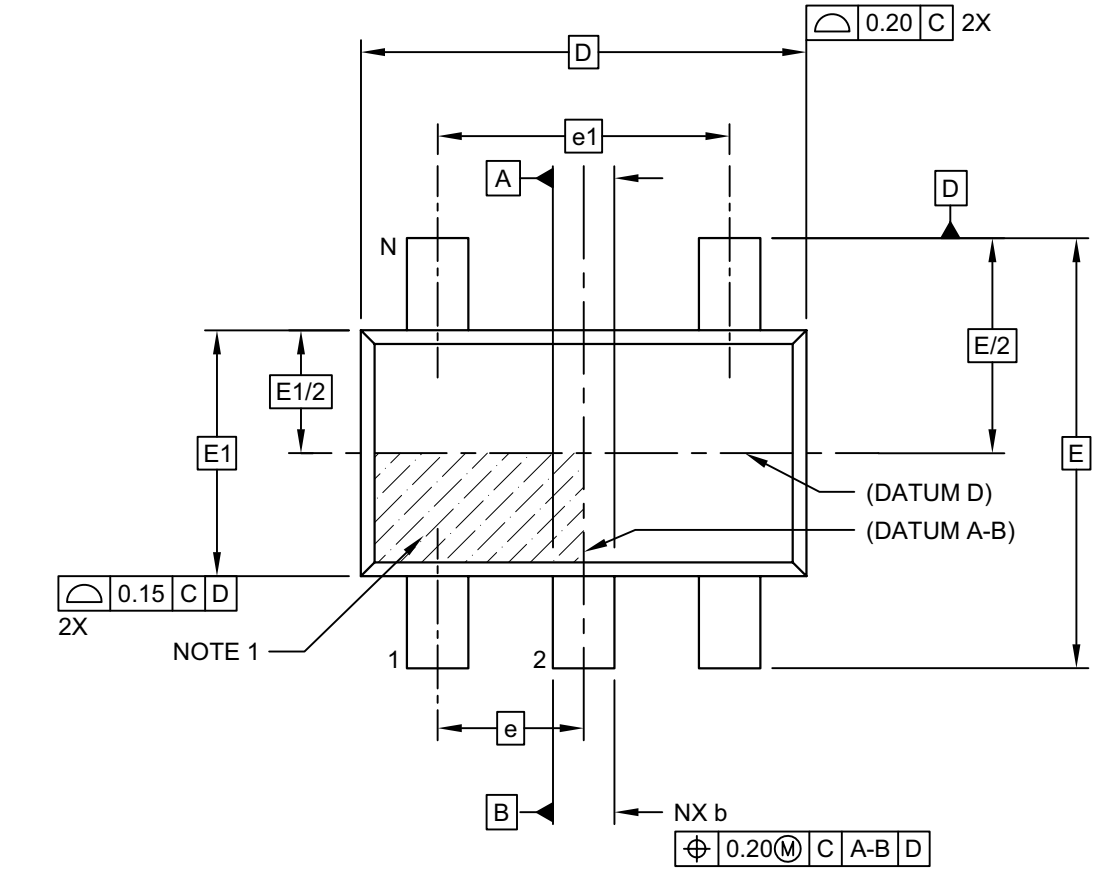
1. Dimensioning and tolerancing per ASME Y14.5M

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

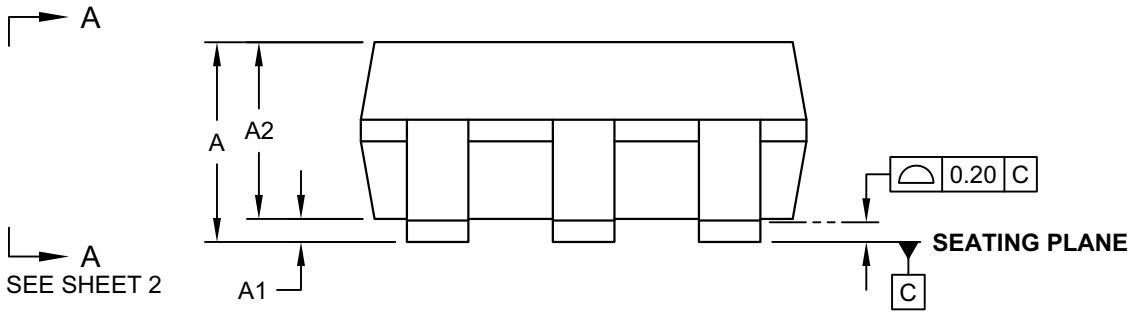
Microchip Technology Drawing No. C04-2061-LTY Rev E

5-Lead Plastic Small Outline Transistor (OT) [SOT23]

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



TOP VIEW



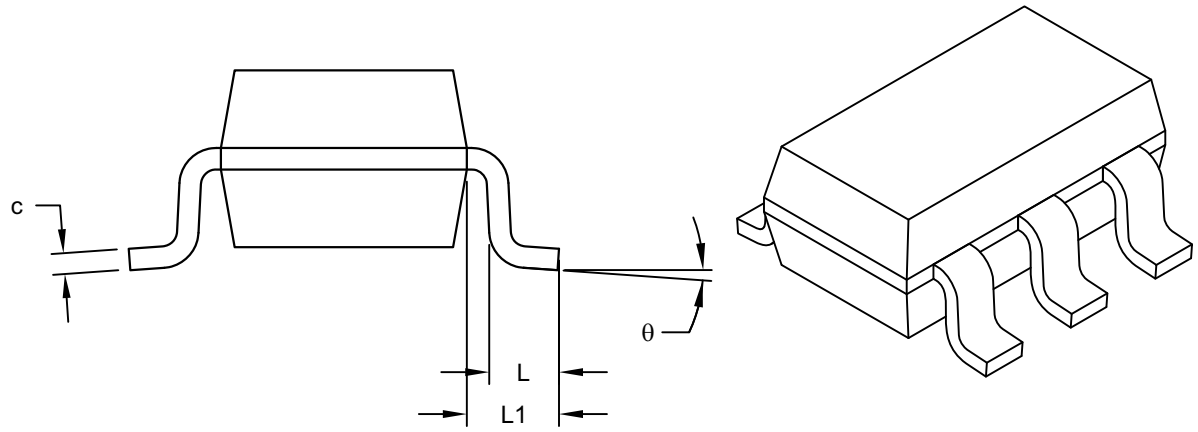
SIDE VIEW

Microchip Technology Drawing C04-091-OT Rev F Sheet 1 of 2

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5-Lead Plastic Small Outline Transistor (OT) [SOT23]

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



VIEW A-A
SHEET 1

Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Pins	N		5	
Pitch	e		0.95 BSC	
Outside lead pitch	e1		1.90 BSC	
Overall Height	A	0.90	-	1.45
Molded Package Thickness	A2	0.89	-	1.30
Standoff	A1	-	-	0.15
Overall Width	E		2.80 BSC	
Molded Package Width	E1		1.60 BSC	
Overall Length	D		2.90 BSC	
Foot Length	L	0.30	-	0.60
Footprint	L1		0.60 REF	
Foot Angle	ϕ	0°	-	10°
Lead Thickness	c	0.08	-	0.26
Lead Width	b	0.20	-	0.51

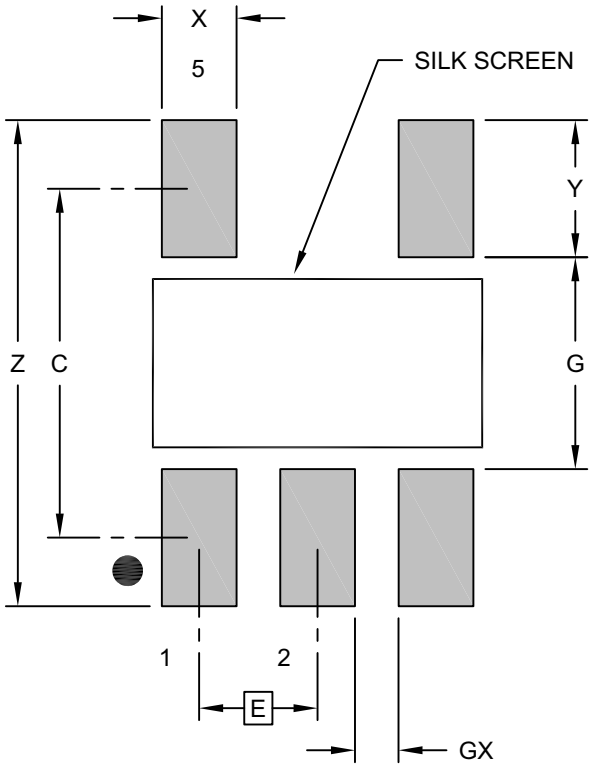
Notes:

1. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.25mm per side.
2. Dimensioning and tolerancing per ASME Y14.5M
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
   REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-091-OT Rev F Sheet 2 of 2

5-Lead Plastic Small Outline Transistor (OT) [SOT23]

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



RECOMMENDED LAND PATTERN

Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Contact Pitch	E	0.95 BSC		
Contact Pad Spacing	C		2.80	
Contact Pad Width (X5)	X			0.60
Contact Pad Length (X5)	Y			1.10
Distance Between Pads	G	1.70		
Distance Between Pads	GX	0.35		
Overall Width	Z			3.90

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

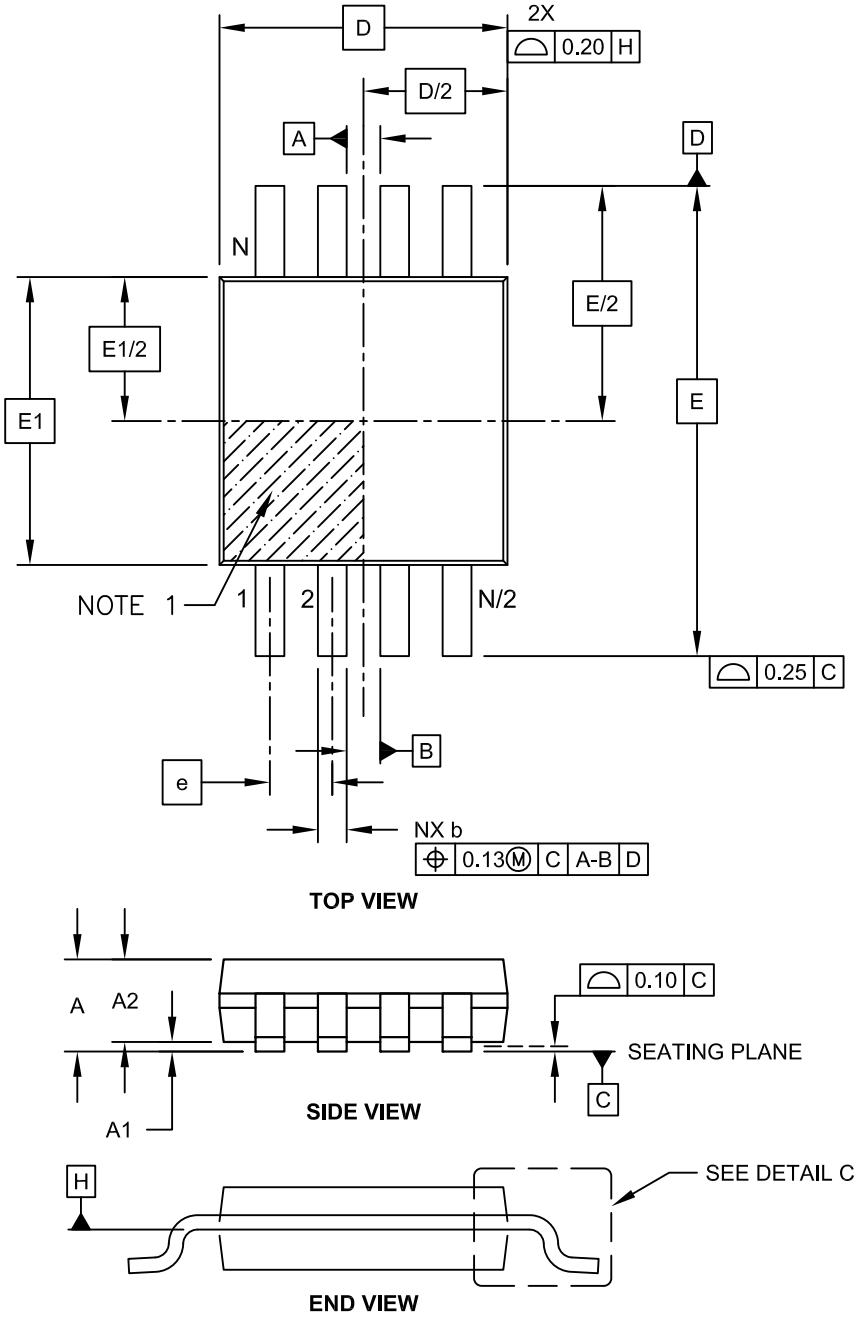
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing No. C04-2091-OT Rev F

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

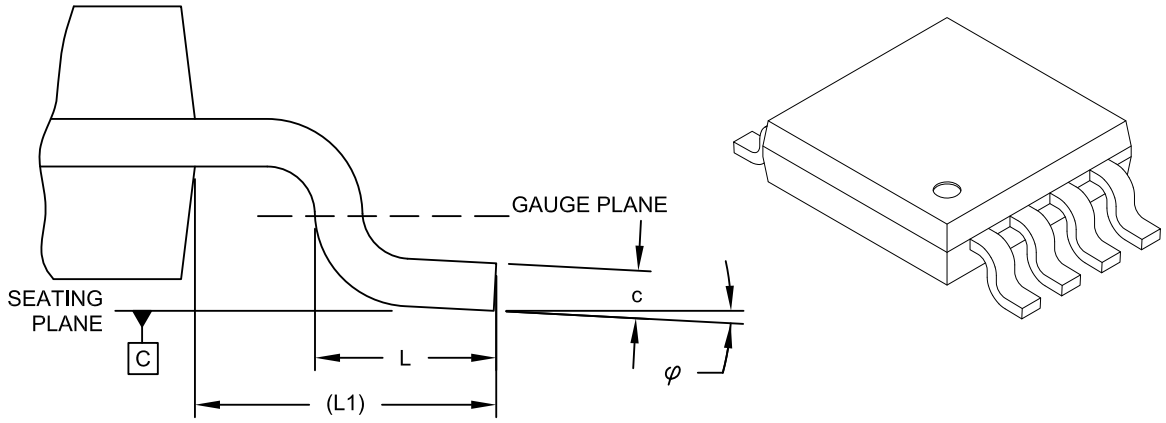
Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Microchip Technology Drawing C04-111C Sheet 1 of 2

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

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



DETAIL C

Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Pins	N		8	
Pitch	e		0.65 BSC	
Overall Height	A	-	-	1.10
Molded Package Thickness	A2	0.75	0.85	0.95
Standoff	A1	0.00	-	0.15
Overall Width	E		4.90 BSC	
Molded Package Width	E1		3.00 BSC	
Overall Length	D		3.00 BSC	
Foot Length	L	0.40	0.60	0.80
Footprint	L1		0.95 REF	
Foot Angle	φ	0°	-	8°
Lead Thickness	c	0.08	-	0.23
Lead Width	b	0.22	-	0.40

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15mm per side.
3. Dimensioning and tolerancing per ASME Y14.5M.

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

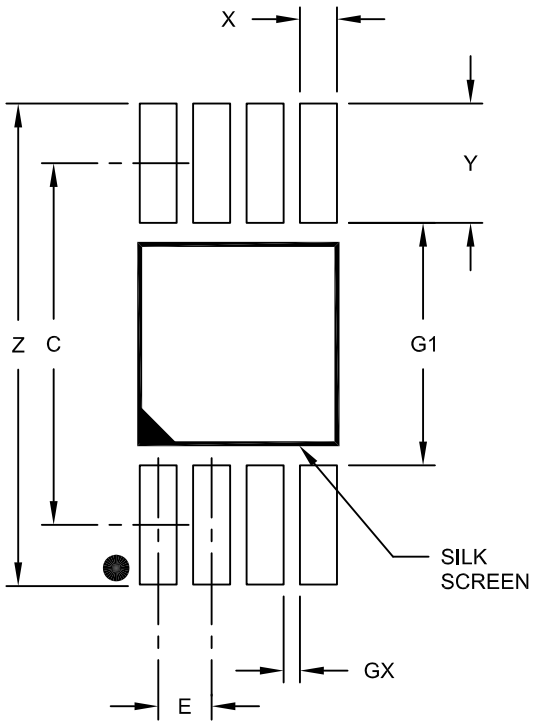
   REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-111C Sheet 2 of 2

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

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



RECOMMENDED LAND PATTERN

Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Contact Pitch	E		0.65 BSC	
Contact Pad Spacing	C		4.40	
Overall Width	Z			5.85
Contact Pad Width (X8)	X1			0.45
Contact Pad Length (X8)	Y1			1.45
Distance Between Pads	G1	2.95		
Distance Between Pads	GX	0.20		

Notes:

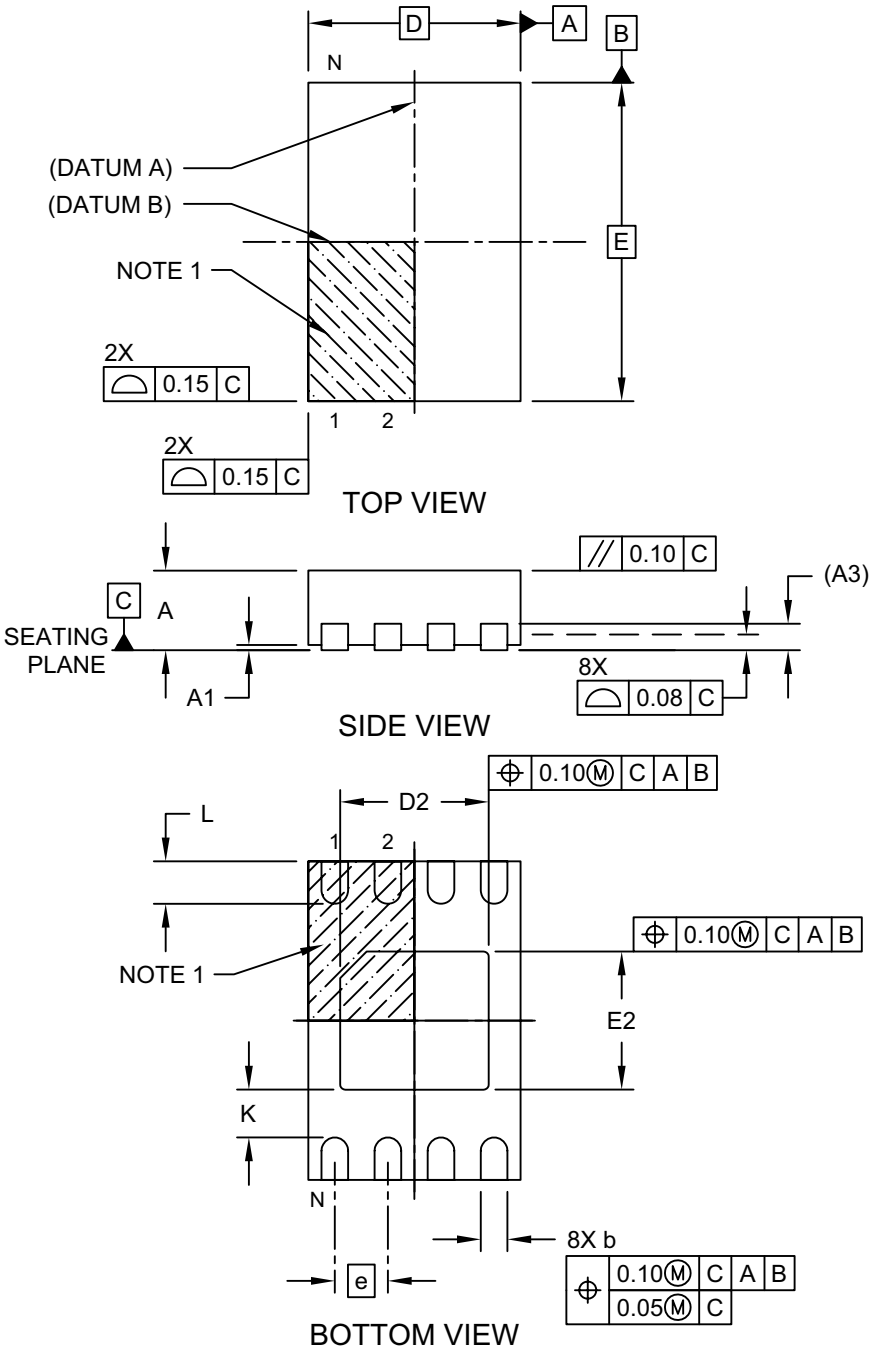
1. Dimensioning and tolerancing per ASME Y14.5M

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

Microchip Technology Drawing No. C04-2111A

8-Lead Plastic Dual Flat, No Lead Package (MNY) – 2x3x0.8 mm Body [TDFN]
With 1.4x1.3 mm Exposed Pad (JEDEC Package type WDFN)

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

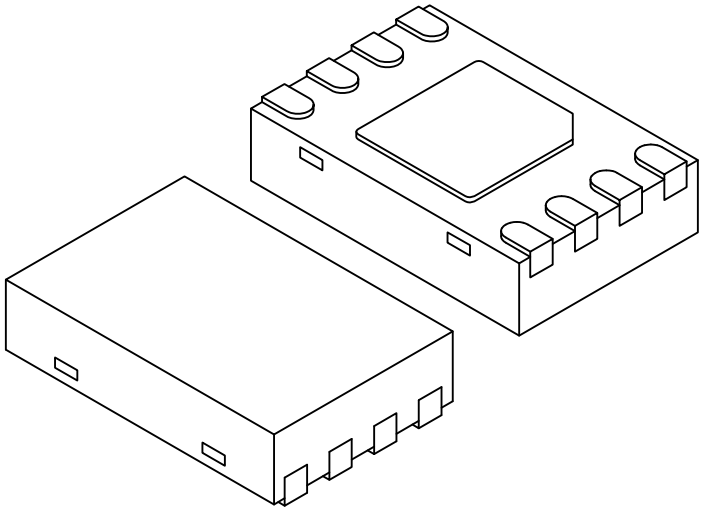


Microchip Technology Drawing No. C04-129-MNY Rev E Sheet 1 of 2

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8-Lead Plastic Dual Flat, No Lead Package (MNY) – 2x3x0.8 mm Body [TDFN] With 1.4x1.3 mm Exposed Pad (JEDEC Package type WDFN)

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



Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Pins	N		8	
Pitch	e		0.50 BSC	
Overall Height	A	0.70	0.75	0.80
Standoff	A1	0.00	0.02	0.05
Contact Thickness	A3		0.20 REF	
Overall Length	D		2.00 BSC	
Overall Width	E		3.00 BSC	
Exposed Pad Length	D2	1.35	1.40	1.45
Exposed Pad Width	E2	1.25	1.30	1.35
Contact Width	b	0.20	0.25	0.30
Contact Length	L	0.25	0.30	0.45
Contact-to-Exposed Pad	K	0.20	-	-

Notes:

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

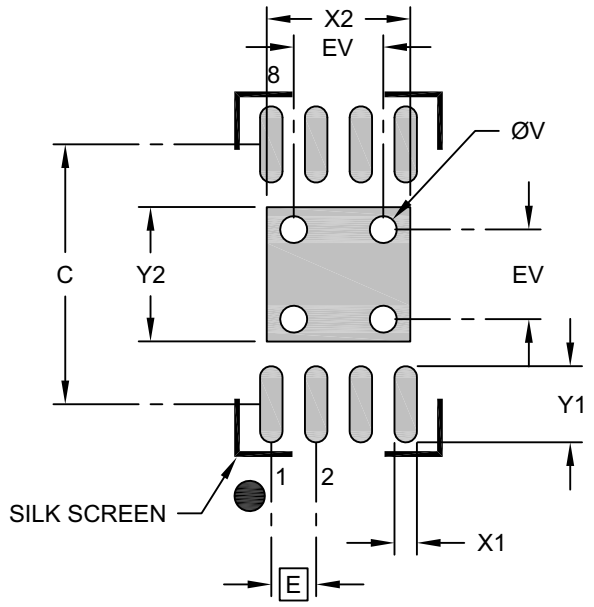
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

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

Microchip Technology Drawing No. C04-129-MNY Rev E Sheet 2 of 2

8-Lead Plastic Dual Flat, No Lead Package (MNY) – 2x3x0.8 mm Body [TDFN] With 1.4x1.3 mm Exposed Pad (JEDEC Package type WDFN)

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



RECOMMENDED LAND PATTERN

Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Contact Pitch	E		0.50 BSC	
Optional Center Pad Width	X2			1.60
Optional Center Pad Length	Y2			1.50
Contact Pad Spacing	C		2.90	
Contact Pad Width (X8)	X1			0.25
Contact Pad Length (X8)	Y1			0.85
Thermal Via Diameter	V		0.30	
Thermal Via Pitch	EV		1.00	

Notes:

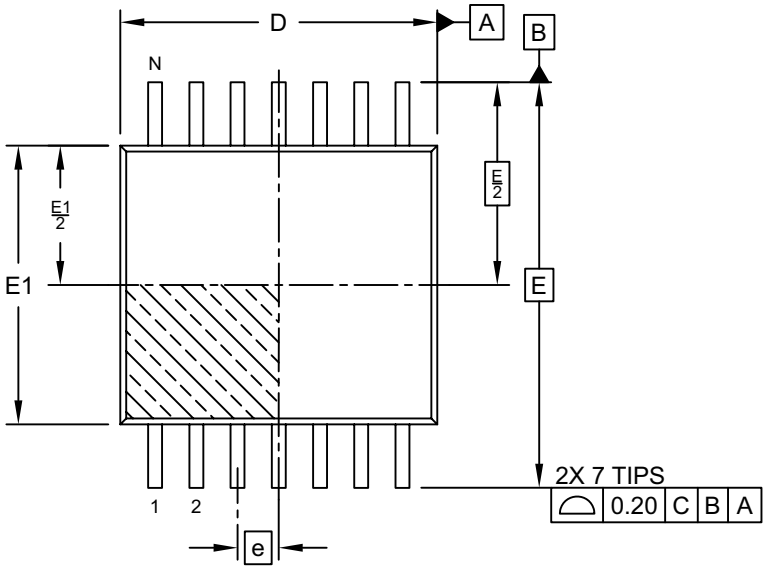
1. Dimensioning and tolerancing per ASME Y14.5M
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
2. For best soldering results, thermal vias, if used, should be filled or tented to avoid solder loss during reflow process

Microchip Technology Drawing No. C04-129-MNY Rev. B

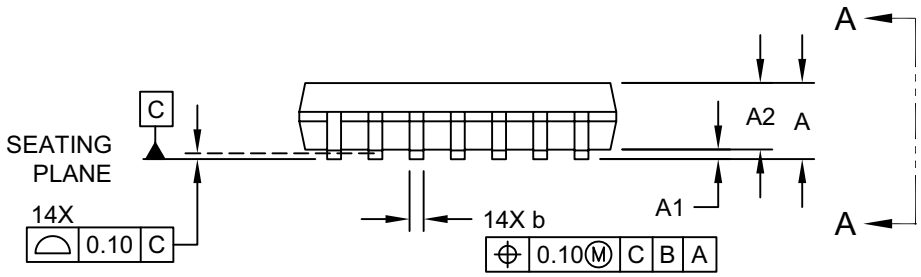
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14-Lead Thin Shrink Small Outline Package [ST] 4.4 mm Body [TSSOP]

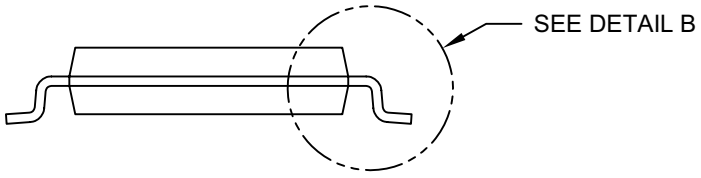
Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



TOP VIEW



SIDE VIEW

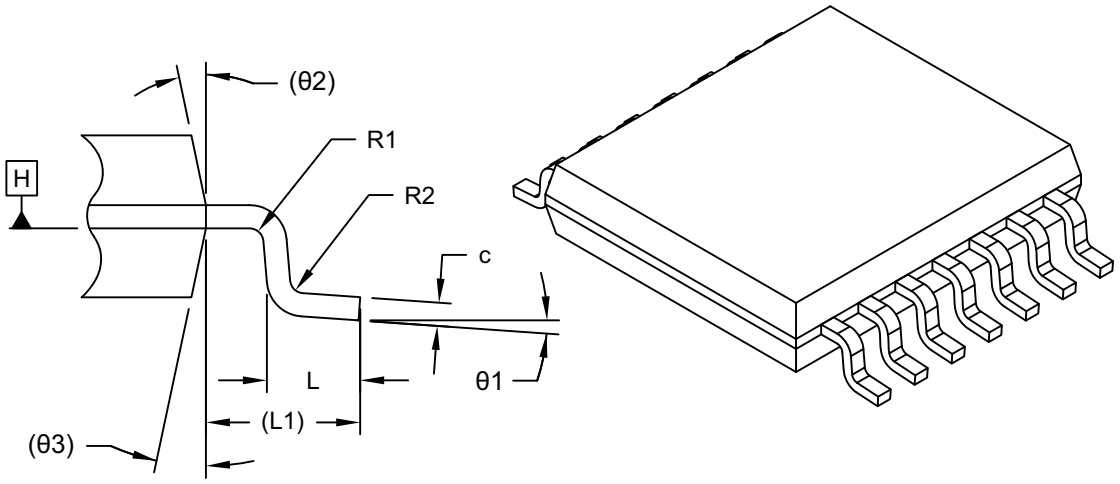


VIEW A–A

Microchip Technology Drawing C04-087 Rev D Sheet 1 of 2

14-Lead Thin Shrink Small Outline Package [ST] 4.4 mm Body [TSSOP]

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



DETAIL B

Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Terminals	N		14	
Pitch	e		0.65 BSC	
Overall Height	A	–	–	1.20
Standoff	A1	0.05	–	0.15
Molded Package Thickness	A2	0.80	1.00	1.05
Overall Length	D	4.90	5.00	5.10
Overall Width	E		6.40 BSC	
Molded Package Width	E1	4.30	4.40	4.50
Terminal Width	b	0.19	–	0.30
Terminal Thickness	c	0.09	–	0.20
Terminal Length	L	0.45	0.60	0.75
Footprint	L1		1.00 REF	
Lead Bend Radius	R1	0.09	–	–
Lead Bend Radius	R2	0.09	–	–
Foot Angle	θ1	0°	–	8°
Mold Draft Angle	θ2	–	12° REF	–
Mold Draft Angle	θ3	–	12° REF	–

Notes:

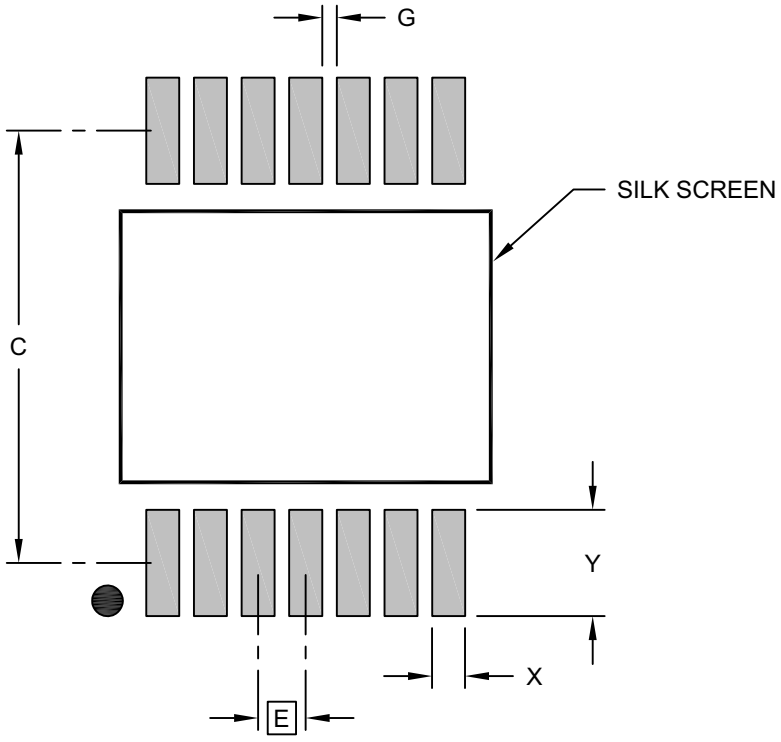
1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Dimensioning and tolerancing per ASME Y14.5M
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
   REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-087 Rev D Sheet 2 of 2

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14-Lead Thin Shrink Small Outline Package [ST] 4.4 mm Body [TSSOP]

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



RECOMMENDED LAND PATTERN

Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Contact Pitch	E	0.65 BSC		
Contact Pad Spacing	C		5.90	
Contact Pad Width (Xnn)	X			0.45
Contact Pad Length (Xnn)	Y			1.45
Contact Pad to Contact Pad (Xnn)	G	0.20		

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

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

Microchip Technology Drawing C04-2087 Rev D

NOTES:

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APPENDIX A: REVISION HISTORY

Revision A (November 2020)

- Original release of this document.

NOTES:

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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](1)	–X	/XX
Device	Tape and Reel	Temperature Range	Package

Device:	MCP6V96:	Single Op Amp (SOT-23 only)
	MCP6V96U:	Single Op Amp (SC-70, SOT-23)
	MCP6V97:	Dual Op Amp (MSOP, 2 x 3 TDFN)
	MCP6V99:	Quad Op Amp (TSSOP)
Tape and Reel Option	T =	Tape and Reel
Temperature Range:	E =	-40°C to +125°C (Extended)
Package:	LTY* =	Plastic Small Outline Transistor, SC-70, 5-lead
	OT =	Plastic Small Outline Transistor, SOT-23, 5-lead
	MNY* =	Plastic Dual Flat, No-Lead, 2 × 3 × 0.8 mm TDFN, 8-lead
	MS =	Plastic Micro Small Outline, MSOP, 8-lead
	ST =	Thin Shrink Small Outline, 4.4 mm TSSOP, 14-lead
	*Y =	Nickel palladium gold manufacturing designator. Only available on the SC70 and TDFN packages.

Examples:

a) MCP6V96T-E/OT: Tape and Reel, Extended temperature, 5LD SOT-23 package

a) MCP6V96UT-E/LTY: Tape and Reel Extended temperature, 5LD SC70 package

b) MCP6V96UT-E/OT: Tape and Reel, Extended temperature, 5LD SOT-23 package

a) MCP6V97-E/MS: Extended temperature, 8LD MSOP package

b) MCP6V97T-E/MS: Tape and Reel, Extended temperature, 8LD MSOP package

c) MCP6V97T-E/MNY: Tape and Reel, Extended temperature, 8LD 2 x 3 TDFN package

a) MCP6V99-E/ST: Extended temperature, 14LD TSSOP package

b) MCP6V99T-E/ST: Tape and Reel, Extended temperature, 14LD TSSOP package

Note 1: Tape and Reel identifier only appears in the catalog part number description. This identifier is used for ordering purposes and is not printed on the device package. Check with your Microchip Sales Office for package availability with the Tape and Reel option.

NOTES:

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- Microchip products meet the specifications contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is secure when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods being used in attempts to breach the code protection features of the Microchip devices. We believe that these methods require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Attempts to breach these code protection features, most likely, cannot be accomplished without violating Microchip's intellectual property rights.
- Microchip is willing to work with any customer who is concerned about the integrity of its code.
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