

## 450 nA, 9 kHz Op Amp

### Features:

- Low Quiescent Current: 450 nA (typical)
- Gain Bandwidth Product: 9 kHz (typical)
- Supply Voltage Range: 1.4V to 6.0V
- Rail-to-Rail Input and Output
- Unity Gain Stable
- Slew Rate: 3V/ms (typical)
- Extended Temperature Range: -40°C to +125°C
- No Phase Reversal
- Small Packages

### Applications:

- Portable Equipment
- Battery Powered System
- Data Acquisition Equipment
- Sensor Conditioning
- Battery Current Sensing
- Analog Active Filters

### Design Aids:

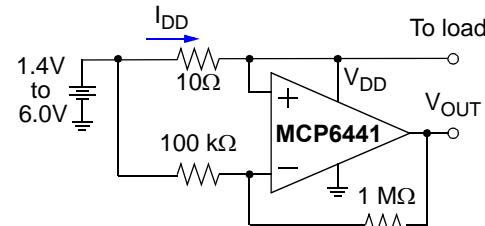
- SPICE Macro Models
- FilterLab® Software
- Microchip Advanced Part Selector (MAPS)
- Analog Demonstration and Evaluation Boards
- Application Notes

### Description:

The MCP6441/2/4 device is a single nanopower operational amplifier (op amp), which has low quiescent current (450 nA, typical) and rail-to-rail input and output operation. This op amp is unity gain stable and has a gain bandwidth product of 9 kHz (typical). These devices operate with a single supply voltage as low as 1.4V. These features make the family of op amps well suited for single-supply, battery-powered applications.

The MCP6441/2/4 op amp is designed with Microchip's advanced CMOS process and offered in single (MCP6441), dual (MCP6442), and quad (MCP6444) configurations. All devices are available in the extended temperature range, with a power supply range of 1.4V to 6.0V.

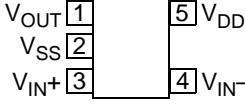
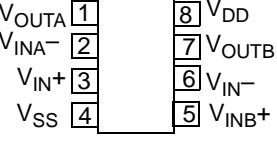
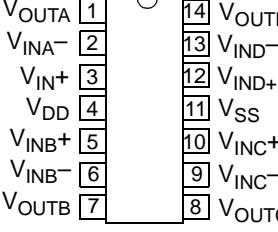
### Typical Application



$$I_{DD} = \frac{V_{DD} - V_{OUT}}{(10 \text{ V/V}) \cdot (10\Omega)}$$

**Battery Current Sensing**

### Package Types

MCP6441	MCP6442	MCP6442	MCP6444
SC70-5, SOT-23-5	SOIC, MSOP	2x3 TDFN *	SOIC, TSSOP
			

\* Includes Exposed Thermal Pad (EP); see [Table 3-1](#).

# MCP6441/2/4

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## NOTES:

## 1.0 ELECTRICAL CHARACTERISTICS

### 1.1 Absolute Maximum Ratings †

$V_{DD} - V_{SS}$ .....	7.0V
Current at Input Pins .....	$\pm 2$ mA
Analog Inputs ( $V_{IN+}, V_{IN-}$ )†† .....	$V_{SS} - 1.0V$ to $V_{DD} + 1.0V$
All Other Inputs and Outputs .....	$V_{SS} - 0.3V$ to $V_{DD} + 0.3V$
Difference Input Voltage .....	$ V_{DD} - V_{SS} $
Output Short-Circuit Current .....	Continuous
Current at Output and Supply Pins .....	$\pm 30$ mA
Storage Temperature .....	-65°C to +150°C
Maximum Junction Temperature ( $T_J$ ) .....	+150°C
ESD Protection on All Pins (HBM; MM) .....	$\geq 4$ kV; 200V

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

†† See [Section 4.1.2 "Input Voltage Limits"](#).

## DC ELECTRICAL SPECIFICATIONS

**Electrical Characteristics:** Unless otherwise indicated,  $V_{DD} = +1.4V$  to  $+6.0V$ ,  $V_{SS} = GND$ ,  $T_A = +25^\circ C$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$  and  $R_L = 1 \text{ M}\Omega$  to  $V_L$ . (Refer to [Figure 1-1](#)).

Parameters	Sym	Min	Typ	Max	Units	Conditions
<b>Input Offset</b>						
Input Offset Voltage	$V_{OS}$	-4.5	—	+4.5	mV	$V_{CM} = V_{SS}$
Input Offset Drift with Temperature	$\Delta V_{OS}/\Delta T_A$	—	$\pm 2.5$	—	$\mu V/^\circ C$	$T_A = -40^\circ C$ to $+125^\circ C$ , $V_{CM} = V_{SS}$
Power Supply Rejection Ratio	PSRR	65	86	—	dB	$V_{CM} = V_{SS}$
<b>Input Bias Current and Impedance</b>						
Input Bias Current	$I_B$	—	$\pm 1$	—	pA	
		—	20	—	pA	$T_A = +85^\circ C$
		—	400	—	pA	$T_A = +125^\circ C$
Input Offset Current	$I_{OS}$	—	$\pm 1$	—	pA	
Common Mode Input Impedance	$Z_{CM}$	—	$10^{13} \parallel 6$	—	$\Omega \parallel pF$	
Differential Input Impedance	$Z_{DIFF}$	—	$10^{13} \parallel 6$	—	$\Omega \parallel pF$	
<b>Common Mode</b>						
Common Mode Input Voltage Range	$V_{CMR}$	$V_{SS} - 0.3$	—	$V_{DD} + 0.3$	V	
Common Mode Rejection Ratio	CMRR	60	76	—	dB	$V_{CM} = -0.3V$ to $6.3V$ , $V_{DD} = 6.0V$
<b>Open-Loop Gain</b>						
DC Open-Loop Gain (Large Signal)	$A_{OL}$	90	110	—	dB	$V_{OUT} = 0.1V$ to $V_{DD} - 0.1V$ , $R_L = 10 \text{ k}\Omega$ to $V_L$
<b>Output</b>						
Maximum Output Voltage Swing	$V_{OL}, V_{OH}$	$V_{SS} + 20$	—	$V_{DD} - 20$	mV	$V_{DD} = 6.0V$ , $R_L = 10 \text{ k}\Omega$ 0.5V input overdrive
Output Short-Circuit Current	$I_{SC}$	—	$\pm 3$	—	mA	$V_{DD} = 1.4V$
		—	$\pm 22$	—	mA	$V_{DD} = 6.0V$
<b>Power Supply</b>						
Supply Voltage	$V_{DD}$	1.4	—	6.0	V	
Quiescent Current per Amplifier	$I_Q$	250	450	650	nA	$I_O = 0$ , $V_{DD} = 5.0V$

# MCP6441/2/4

## AC ELECTRICAL SPECIFICATIONS

**Electrical Characteristics:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.4\text{V}$  to  $+6.0\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 1\text{ M}\Omega$  to  $V_L$  and  $C_L = 60\text{ pF}$ . (Refer to Figure 1-1).

Parameters	Sym	Min	Typ	Max	Units	Conditions
<b>AC Response</b>						
Gain Bandwidth Product	GBWP	—	9	—	kHz	
Phase Margin	PM	—	65	—	°	$G = +1\text{ V/V}$
Slew Rate	SR	—	3	—	V/ms	
<b>Noise</b>						
Input Noise Voltage	$E_{ni}$	—	5	—	$\mu\text{Vp-p}$	$f = 0.1\text{ Hz}$ to $10\text{ Hz}$
Input Noise Voltage Density	$e_{ni}$	—	190	—	$\text{nV}/\sqrt{\text{Hz}}$	$f = 1\text{ kHz}$
Input Noise Current Density	$i_{ni}$	—	0.6	—	$\text{fA}/\sqrt{\text{Hz}}$	$f = 1\text{ kHz}$

## TEMPERATURE SPECIFICATIONS

**Electrical Characteristics:** Unless otherwise indicated,  $V_{DD} = +1.4\text{V}$  to  $+6.0\text{V}$  and  $V_{SS} = \text{GND}$ .

Parameters	Sym	Min	Typ	Max	Units	Conditions
<b>Temperature Ranges</b>						
Operating Temperature Range	$T_A$	-40	—	+125	°C	<a href="#">Note 1</a>
Storage Temperature Range	$T_A$	-65	—	+150	°C	
<b>Thermal Package Resistances</b>						
Thermal Resistance, 5L-SC70	$\theta_{JA}$	—	331	—	°C/W	
Thermal Resistance, 5L-SOT-23	$\theta_{JA}$	—	220.7	—	°C/W	
Thermal Resistance, 8L-MSOP	$\theta_{JA}$	—	211	—	°C/W	
Thermal Resistance, 8L-SOIC	$\theta_{JA}$	—	149.5	—	°C/W	
Thermal Resistance, 8L-2x3 TDFN	$\theta_{JA}$	—	52.5	—	°C/W	
Thermal Resistance, 14L-SOIC	$\theta_{JA}$	—	95.3	—	°C/W	
Thermal Resistance, 14L-TSSOP	$\theta_{JA}$	—	100	—	°C/W	

**Note 1:** The internal junction temperature ( $T_J$ ) must not exceed the absolute maximum specification of  $+150^\circ\text{C}$ .

## 1.2 Test Circuits

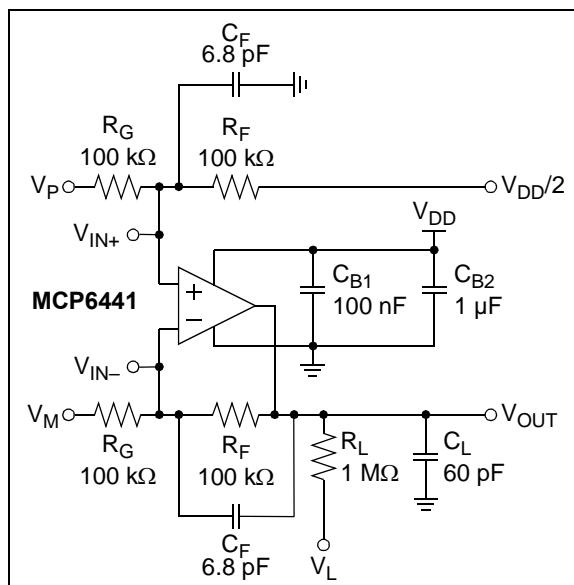
The circuit used for most DC and AC tests is shown in Figure 1-1. This circuit can independently set  $V_{CM}$  and  $V_{OUT}$  (see Equation 1-1). Note that  $V_{CM}$  is not the circuit's Common Mode voltage  $((V_P + V_M)/2)$ , and that  $V_{OST}$  includes  $V_{OS}$  plus the effects (on the input offset error,  $V_{OST}$ ) of the temperature, CMRR, PSRR and  $A_{OL}$ .

### EQUATION 1-1:

$$\begin{aligned}
 G_{DM} &= R_F/R_G \\
 V_{CM} &= (V_P + V_{DD}/2)/2 \\
 V_{OST} &= V_{IN+} - V_{IN-} \\
 V_{OUT} &= (V_{DD}/2) + (V_P - V_M) + V_{OST}(1 + G_{DM})
 \end{aligned}$$

Where:

$$\begin{aligned}
 G_{DM} &= \text{Differential Mode Gain} & (\text{V/V}) \\
 V_{CM} &= \text{Op Amp's Common Mode} & (\text{V}) \\
 &\quad \text{Input Voltage} \\
 V_{OST} &= \text{Op Amp's Total Input Offset Voltage} & (\text{mV})
 \end{aligned}$$

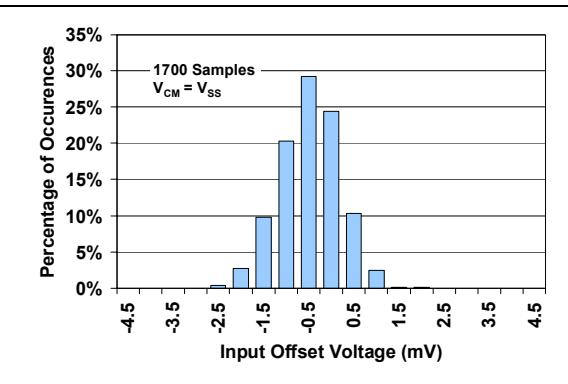


**FIGURE 1-1:** AC and DC Test Circuit for Most Specifications.

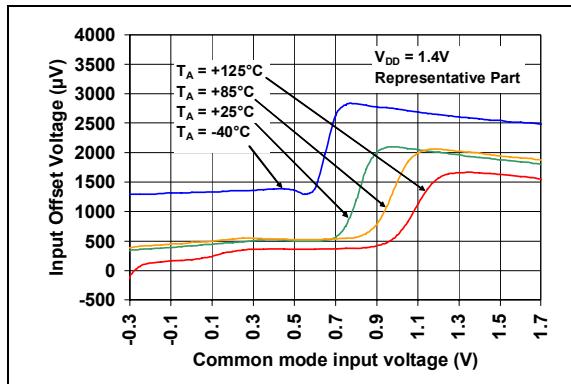
## 2.0 TYPICAL PERFORMANCE CURVES

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

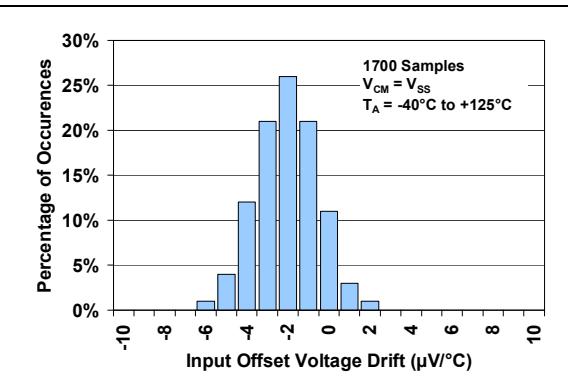
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.4\text{V}$  to  $+6.0\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 1 \text{ M}\Omega$  to  $V_L$  and  $C_L = 60 \text{ pF}$ .



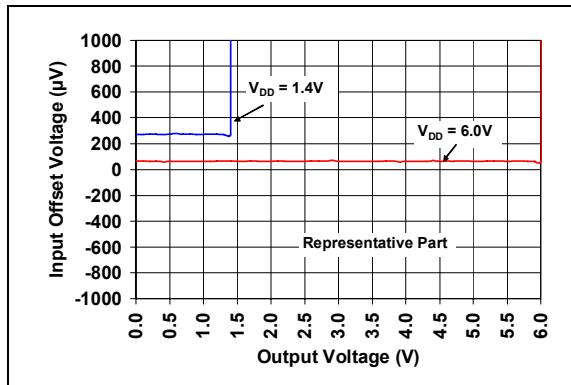
**FIGURE 2-1:** Input Offset Voltage.



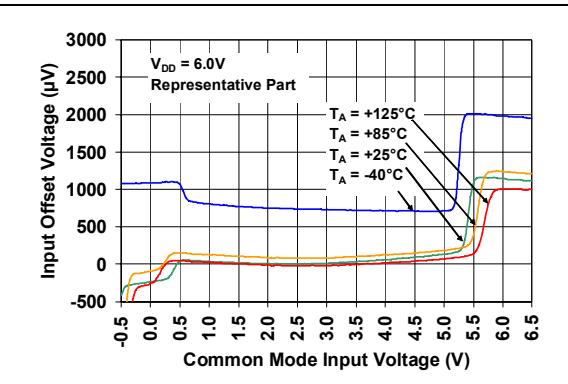
**FIGURE 2-4:** Input Offset Voltage vs. Common Mode Input Voltage with  $V_{DD} = 1.4\text{V}$ .



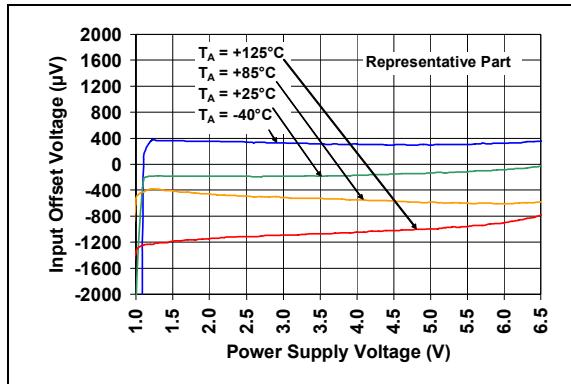
**FIGURE 2-2:** Input Offset Voltage Drift.



**FIGURE 2-5:** Input Offset Voltage vs. Output Voltage.



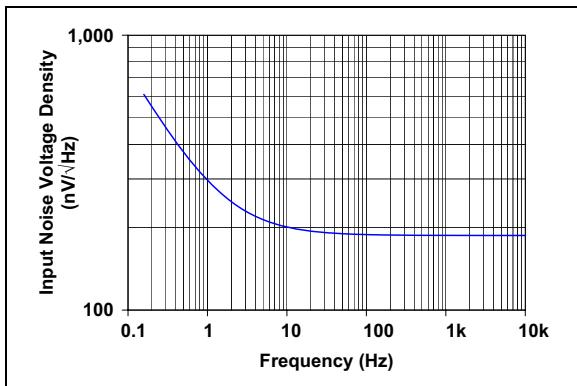
**FIGURE 2-3:** Input Offset Voltage vs. Common Mode Input Voltage with  $V_{DD} = 6.0\text{V}$ .



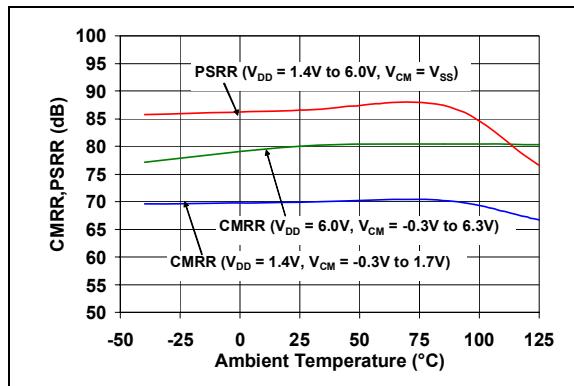
**FIGURE 2-6:** Input Offset Voltage vs. Power Supply Voltage.

# MCP6441/2/4

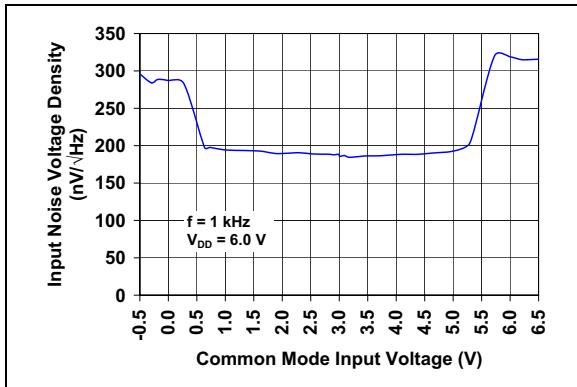
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.4\text{V}$  to  $+6.0\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 1 \text{ M}\Omega$  to  $V_L$  and  $C_L = 60 \text{ pF}$ .



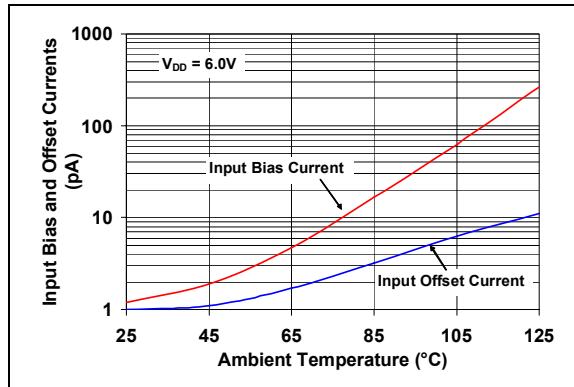
**FIGURE 2-7:** Input Noise Voltage Density vs. Frequency.



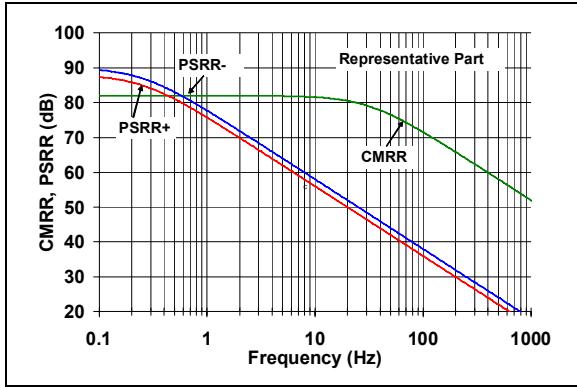
**FIGURE 2-10:** CMRR, PSRR vs. Ambient Temperature.



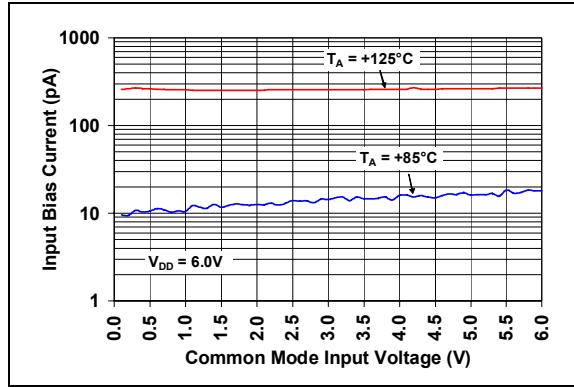
**FIGURE 2-8:** Input Noise Voltage Density vs. Common Mode Input Voltage.



**FIGURE 2-11:** Input Bias, Offset Current vs. Ambient Temperature.

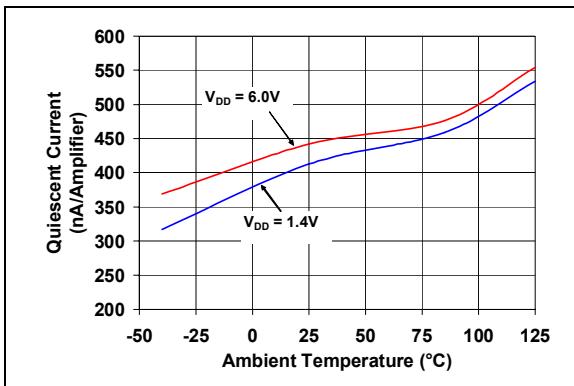


**FIGURE 2-9:** CMRR, PSRR vs. Frequency.

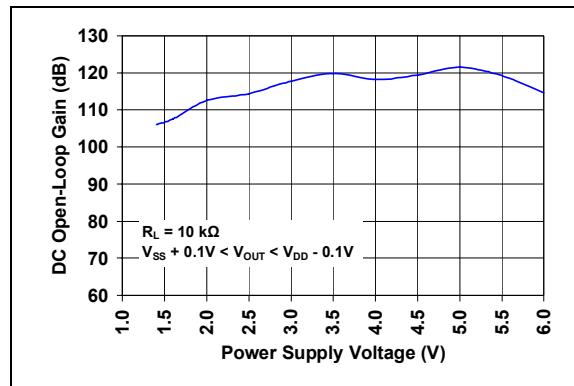


**FIGURE 2-12:** Input Bias Current vs. Common Mode Input Voltage.

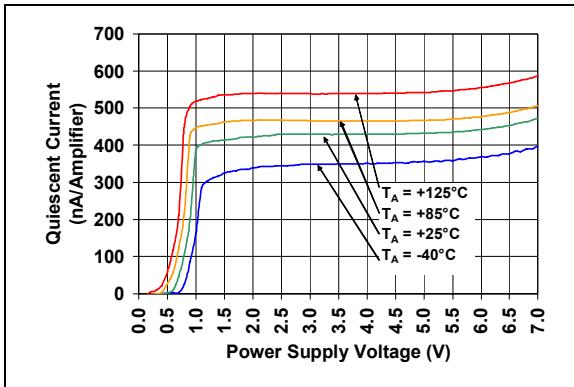
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.4\text{V}$  to  $+6.0\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 1\text{ M}\Omega$  to  $V_L$  and  $C_L = 60\text{ pF}$ .



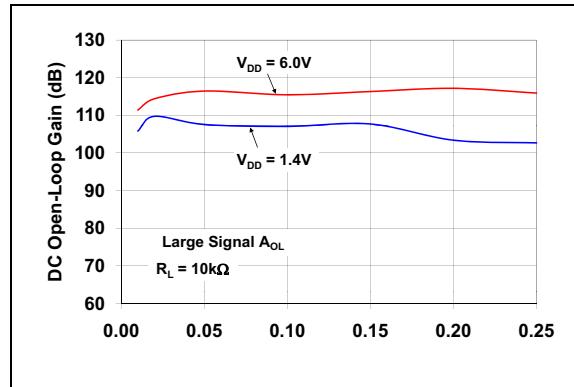
**FIGURE 2-13:** Quiescent Current vs. Ambient Temperature.



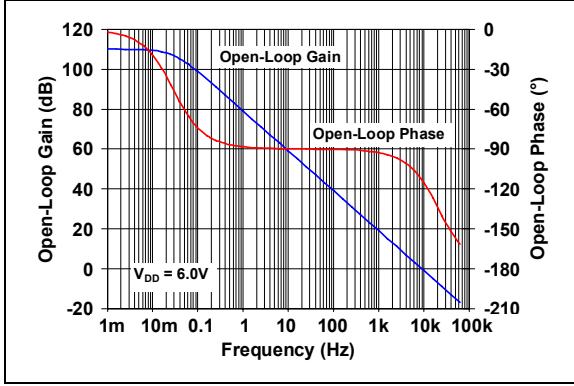
**FIGURE 2-16:** DC Open-Loop Gain vs. Power Supply Voltage.



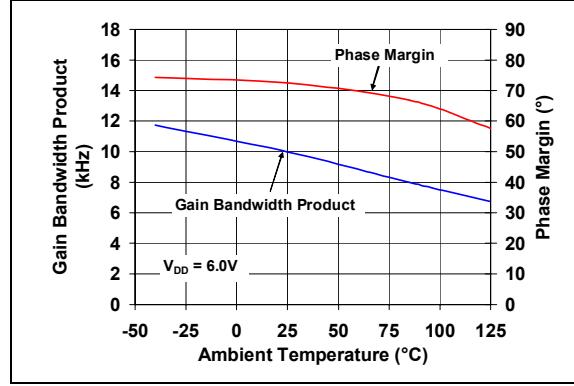
**FIGURE 2-14:** Quiescent Current vs. Power Supply Voltage.



**FIGURE 2-17:** DC Open-Loop Gain vs. Output Voltage Headroom.



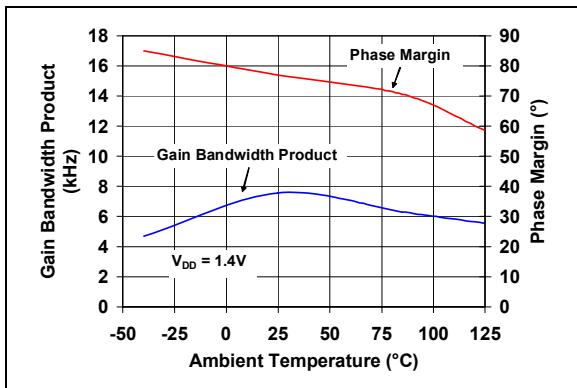
**FIGURE 2-15:** Open-Loop Gain, Phase vs. Frequency.



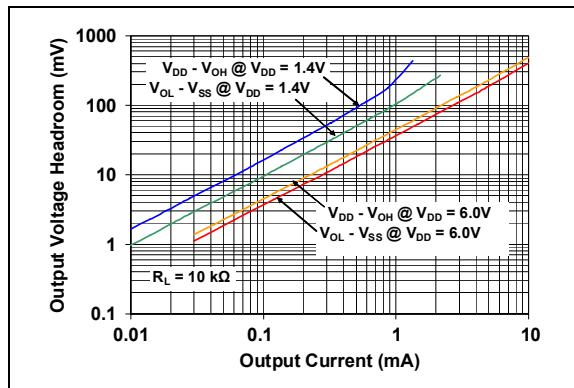
**FIGURE 2-18:** Gain Bandwidth Product, Phase Margin vs. Ambient Temperature.

# MCP6441/2/4

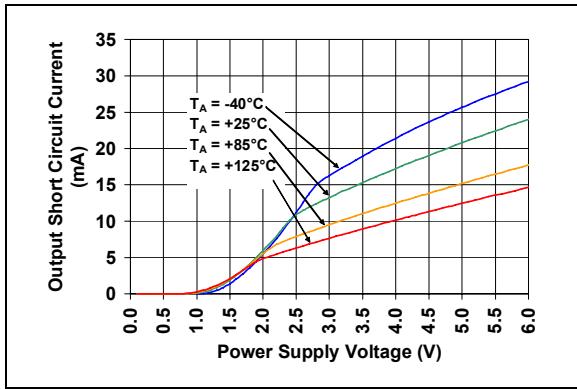
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.4\text{V}$  to  $+6.0\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 1 \text{ M}\Omega$  to  $V_L$  and  $C_L = 60 \text{ pF}$ .



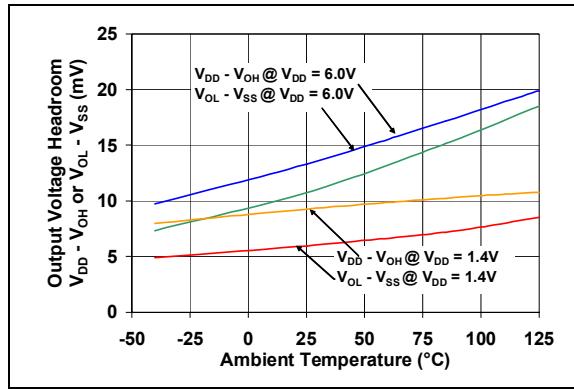
**FIGURE 2-19:** Gain Bandwidth Product, Phase Margin vs. Ambient Temperature.



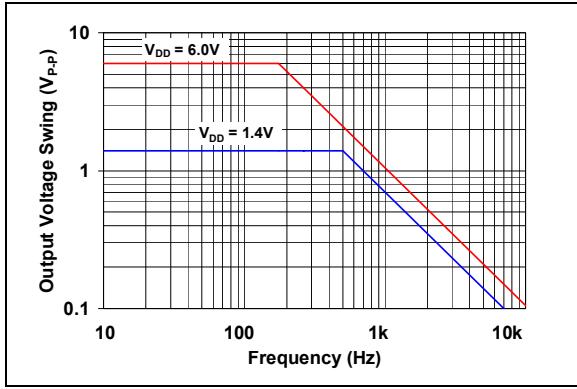
**FIGURE 2-22:** Output Voltage Headroom vs. Output Current.



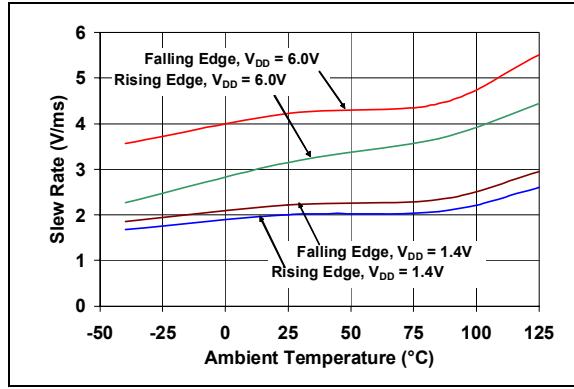
**FIGURE 2-20:** Output Short Circuit Current vs. Power Supply Voltage.



**FIGURE 2-23:** Output Voltage Headroom vs. Ambient Temperature.

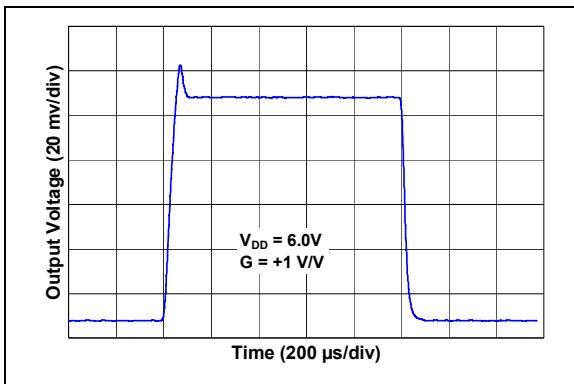


**FIGURE 2-21:** Output Voltage Swing vs. Frequency.

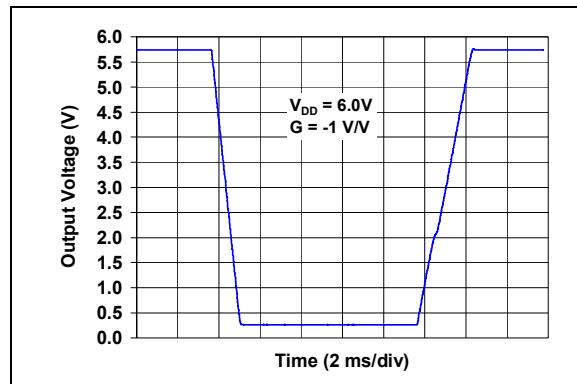


**FIGURE 2-24:** Slew Rate vs. Ambient Temperature.

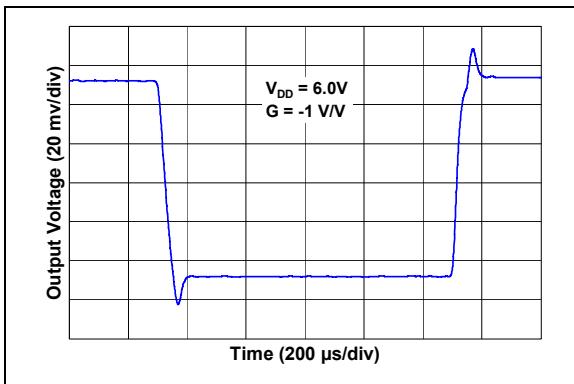
**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.4\text{V}$  to  $+6.0\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 1\text{ M}\Omega$  to  $V_L$  and  $C_L = 60\text{ pF}$ .



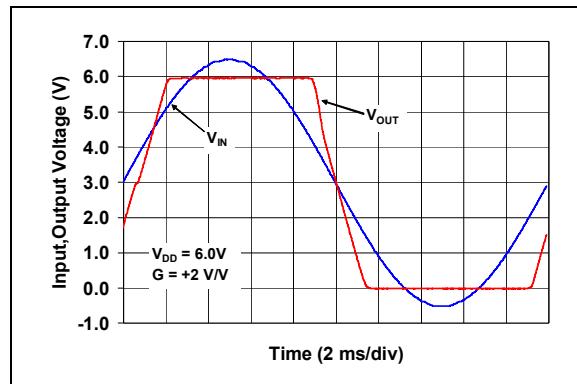
**FIGURE 2-25:** Small Signal Non-Inverting Pulse Response.



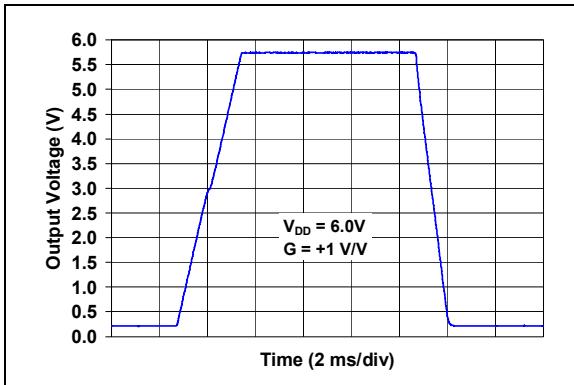
**FIGURE 2-28:** Large Signal Inverting Pulse Response.



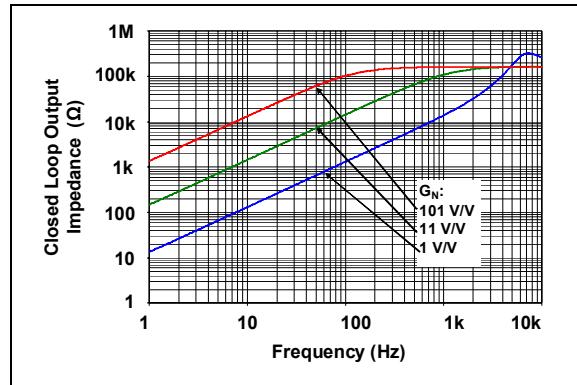
**FIGURE 2-26:** Small Signal Inverting Pulse Response.



**FIGURE 2-29:** The MCP6441/2/4 Device Shows No Phase Reversal.



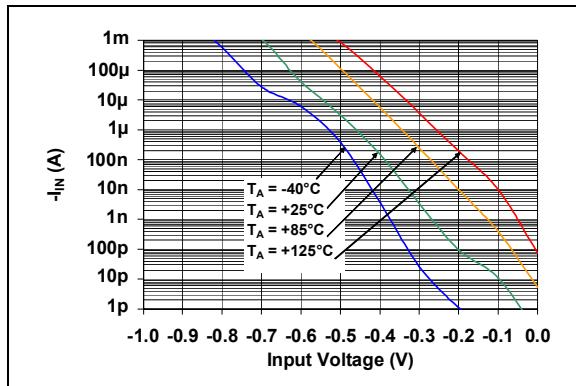
**FIGURE 2-27:** Large Signal Non-Inverting Pulse Response.



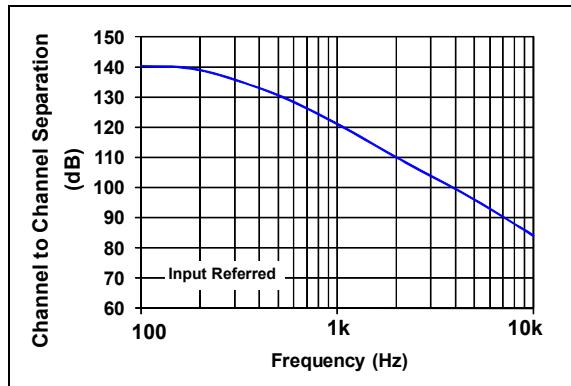
**FIGURE 2-30:** Closed Loop Output Impedance vs. Frequency.

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**Note:** Unless otherwise indicated,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = +1.4\text{V}$  to  $+6.0\text{V}$ ,  $V_{SS} = \text{GND}$ ,  $V_{CM} = V_{DD}/2$ ,  $V_{OUT} \approx V_{DD}/2$ ,  $V_L = V_{DD}/2$ ,  $R_L = 1\text{ M}\Omega$  to  $V_L$  and  $C_L = 60\text{ pF}$ .



**FIGURE 2-31:** Measured Input Current vs. Input Voltage (below  $V_{SS}$ ).



**FIGURE 2-32:** Channel-to-Channel Separation vs. Frequency (MCP6442/4 only).

## 3.0 PIN DESCRIPTIONS

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

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

MCP6441	MCP6442		MCP6444	Symbol	Description
SC70-5, SOT-23-5	SOIC, MSOP	2x3 TDFN	SOIC, TSSOP		
1	1	1	1	$V_{OUT}, V_{OUTA}$	Analog Output (op amp A)
4	2	2	2	$V_{IN^-}, V_{INA^-}$	Inverting Input (op amp A)
3	3	3	3	$V_{IN^+}, V_{INA^+}$	Non-inverting Input (op amp A)
5	8	8	4	$V_{DD}$	Positive Power Supply
—	5	5	5	$V_{INB^+}$	Non-inverting Input (op amp B)
—	6	6	6	$V_{INB^-}$	Inverting Input (op amp B)
—	7	7	7	$V_{OUTB}$	Analog Output (op amp B)
—	—	—	8	$V_{OUTC}$	Analog Output (op amp C)
—	—	—	9	$V_{INC^-}$	Inverting Input (op amp C)
—	—	—	10	$V_{INC^+}$	Non-inverting Input (op amp C)
2	4	4	11	$V_{SS}$	Negative Power Supply
—	—	—	12	$V_{IND^+}$	Non-inverting Input (op amp D)
—	—	—	13	$V_{IND^-}$	Inverting Input (op amp D)
—	—	—	14	$V_{OUTD}$	Analog Output (op amp D)
—	—	9	—	EP	Exposed Thermal Pad (EP); must be connected to $V_{SS}$

### 3.1 Analog Output ( $V_{OUT}$ )

The output pin is a low-impedance voltage source.

### 3.2 Power Supply Pins ( $V_{DD}, V_{SS}$ )

The positive power supply ( $V_{DD}$ ) is 1.4V to 6.0V higher than the negative power supply ( $V_{SS}$ ). For normal operation, the other pins are at voltages 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.

### 3.3 Analog Inputs ( $V_{IN^+}, V_{IN^-}$ )

The non-inverting and inverting inputs are high-impedance CMOS inputs with low bias currents.

### 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 ( $\theta_{JA}$ ).

# MCP6441/2/4

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Notes:

## 4.0 APPLICATION INFORMATION

The MCP6441/2/4 op amp is manufactured using Microchip's state-of-the-art CMOS process, specifically designed for low power applications.

### 4.1 Rail-to-Rail Input

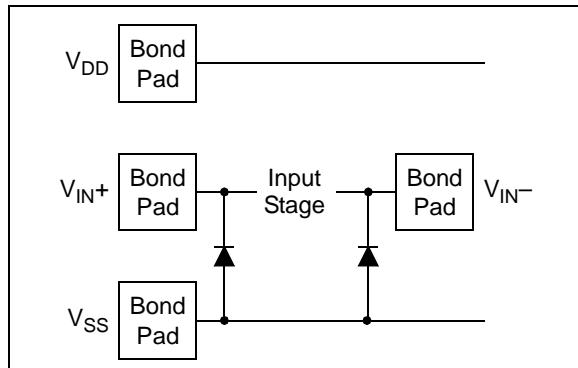
#### 4.1.1 PHASE REVERSAL

The MCP6441/2/4 op amp is designed to prevent phase reversal, when the input pins exceed the supply voltages. [Figure 2-29](#) shows the input voltage exceeding the supply voltage with no phase reversal.

#### 4.1.2 INPUT VOLTAGE LIMITS

In order to prevent damage and/or improper operation of the amplifier, the circuit must limit the voltages at the input pins (see [Section 1.1, Absolute Maximum Ratings](#) †).

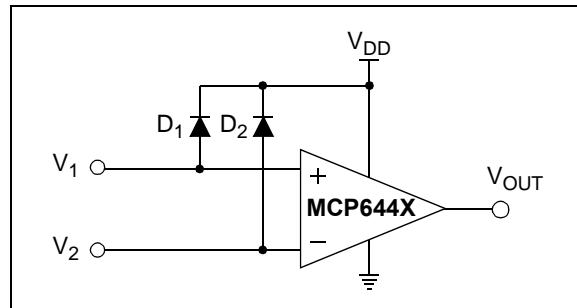
The Electrostatic Discharge (ESD) protection on the inputs can be depicted as shown in [Figure 4-1](#). This structure was chosen to protect the input transistors against many, but not all, over-voltage conditions, and to minimize the input bias current ( $I_B$ ).



**FIGURE 4-1:** 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 that go well above  $V_{DD}$ ; their breakdown voltage is high enough to allow normal operation, but not low enough to protect against slow over-voltage (beyond  $V_{DD}$ ) events. Very fast ESD events that meet the spec 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 4-2](#) shows one approach to protecting these inputs.



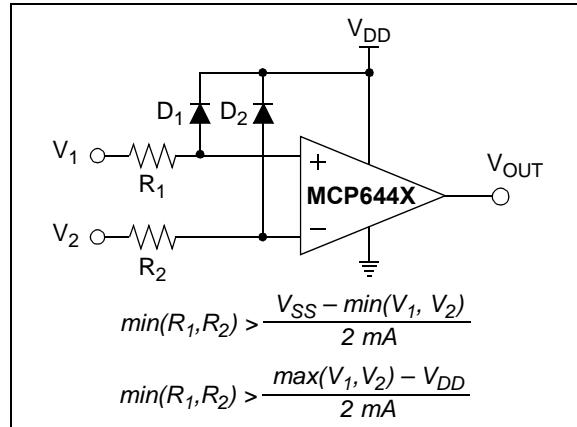
**FIGURE 4-2:** Protecting the Analog Inputs.

A significant amount of current can flow out of the inputs when the Common Mode voltage ( $V_{CM}$ ) is below ground ( $V_{SS}$ ); see [Figure 2-31](#).

#### 4.1.3 INPUT CURRENT LIMITS

In order to prevent damage and/or improper operation of the amplifier, the circuit must limit the currents into the input pins (see [Section 1.1 “Absolute Maximum Ratings](#) †).

[Figure 4-3](#) shows one approach to protecting these inputs. The resistors  $R_1$  and  $R_2$  limit the possible currents in or out of the input pins (and the ESD diodes,  $D_1$  and  $D_2$ ). The diode currents will go through either  $V_{DD}$  or  $V_{SS}$ .



**FIGURE 4-3:** Protecting the Analog Inputs.

# MCP6441/2/4

## 4.1.4 NORMAL OPERATION

The input stage of the MCP6441/2/4 op amp uses two differential input stages in parallel. One operates at a low Common Mode input voltage ( $V_{CM}$ ), while the other operates at a high  $V_{CM}$ . With this topology, the device operates with a  $V_{CM}$  up to 300 mV above  $V_{DD}$  and 300 mV below  $V_{SS}$ . The input offset voltage is measured at  $V_{CM} = V_{SS} - 0.3V$  and  $V_{DD} + 0.3V$ , to ensure proper operation.

The transition between the input stages occurs when  $V_{CM}$  is near  $V_{DD} - 0.6V$  (see Figures 2-3 and 2-4). For the best distortion performance and gain linearity, with non-inverting gains, avoid this region of operation.

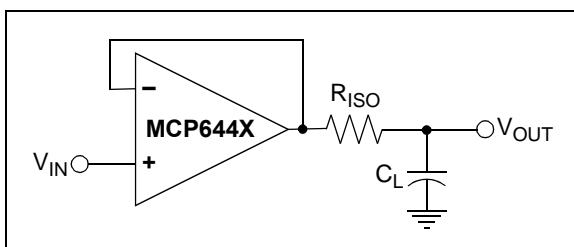
## 4.2 Rail-to-Rail Output

The output voltage range of the MCP6441/2/4 op amp is  $V_{SS} + 20$  mV (minimum) and  $V_{DD} - 20$  mV (maximum) when  $R_L = 10\text{ k}\Omega$  is connected to  $V_{DD}/2$  and  $V_{DD} = 6.0\text{V}$ . Refer to Figures 2-22 and 2-23 for more information.

## 4.3 Capacitive Loads

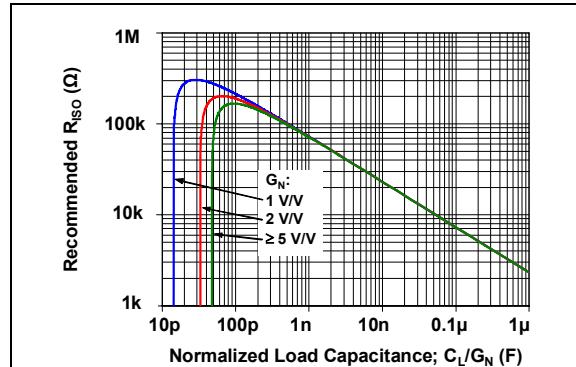
Driving large capacitive loads can cause stability problems for voltage feedback op amps. As the load capacitance increases, the feedback loop's phase margin decreases, and the closed-loop bandwidth is reduced. This produces gain peaking in the frequency response, with overshoot and ringing in the step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

When driving large capacitive loads with the MCP6441/2/4 op amp (e.g.,  $> 100\text{ pF}$  when  $G = +1\text{ V/V}$ ), a small series resistor at the output ( $R_{ISO}$  in Figure 4-4) 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 capacitance load.



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

Figure 4-5 gives the recommended  $R_{ISO}$  values for the 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  $1 + |\text{Signal Gain}|$  (e.g.,  $-1\text{ V/V}$  gives  $G_N = +2\text{ V/V}$ ).



**FIGURE 4-5:** 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 MCP6441/2/4 SPICE macro model are very helpful.

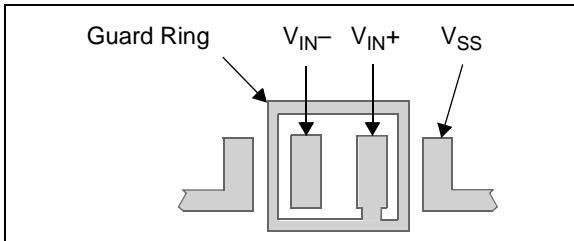
## 4.4 Supply Bypass

The MCP6441/2/4 op amp's power supply pin ( $V_{DD}$  for single-supply) should have a local bypass capacitor (i.e.,  $0.01\text{ }\mu\text{F}$  to  $0.1\text{ }\mu\text{F}$ ) within 2 mm for good high frequency performance. It can use a bulk capacitor (i.e.,  $1\text{ }\mu\text{F}$  or larger) within 100 mm to provide large, slow currents. This bulk capacitor can be shared with other analog parts.

## 4.5 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 of current to flow, which is greater than the MCP6441/2/4 op amp's bias current at  $+25^\circ\text{C}$  ( $\pm 1\text{ pA}$ , typical).

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 4-6.



**FIGURE 4-6:** Example Guard Ring Layout for Inverting Gain.

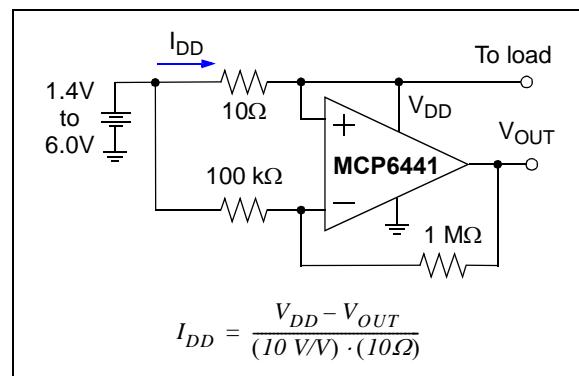
1. Non-inverting Gain and Unity-Gain Buffer:
  - a) Connect the non-inverting pin ( $V_{IN+}$ ) to the input with a wire that does not touch the PCB surface.
  - b) Connect the guard ring to the inverting input pin ( $V_{IN-}$ ). This biases the guard ring to the Common Mode input voltage.
2. Inverting Gain and Transimpedance Gain 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.

## 4.6 Application Circuits

### 4.6.1 BATTERY CURRENT SENSING

The MCP6441/2/4 op amp's Common Mode Input Range, which goes 0.3V beyond both supply rails, supports their use in high-side and low-side battery current sensing applications. The low quiescent current (450 nA, typical) helps prolong battery life, and the rail-to-rail output supports detection of low currents.

Figure 4-7 shows a high side battery current sensor circuit. The  $10\Omega$  resistor is sized to minimize power losses. The battery current ( $I_{DD}$ ) through the  $10\Omega$  resistor causes its top terminal to be more negative than the bottom terminal. This keeps the Common Mode input voltage of the op amp below  $V_{DD}$ , which is within its allowed range. The output of the op amp will also be below  $V_{DD}$ , within its Maximum Output Voltage Swing specification.



**FIGURE 4-7:** Battery Current Sensing.

# MCP6441/2/4

## 4.6.2 PRECISION HALF-WAVE RECTIFIER

The precision half-wave rectifier, which is also known as a super diode, is a configuration obtained with an operational amplifier in order to have a circuit behaving like an ideal diode and rectifier. It effectively cancels the forward voltage drop of the diode in such a way that very low level signals can still be rectified, with minimal error. This can be useful for high-precision signal processing. The MCP6441/2/4 op amp has high input impedance, low input bias current and rail-to-rail input/output, which makes this device suitable for precision rectifier applications.

Figure 4-8 shows a precision half-wave rectifier and its transfer characteristic. The rectifier's input impedance is determined by the input resistor  $R_1$ . To avoid the loading effect, it must be driven from a low-impedance source.

When  $V_{IN}$  is greater than zero,  $D_1$  is OFF,  $D_2$  is ON, and  $V_{OUT}$  is zero. When  $V_{IN}$  is less than zero,  $D_1$  is ON,  $D_2$  is OFF, and  $V_{OUT}$  is the  $V_{IN}$  with an amplification of  $-R_2/R_1$ .

The rectifier circuit shown in Figure 4-8 has the benefit that the op amp never goes to saturation, so the only thing affecting its frequency response is the amplification and the gain bandwidth product.

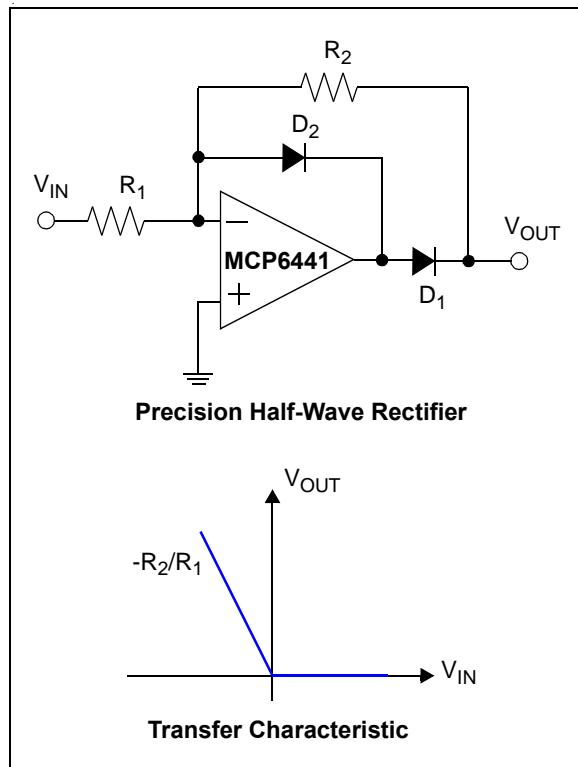


FIGURE 4-8: Precision Half-Wave Rectifier.

## 4.6.3 INSTRUMENTATION AMPLIFIER

The MCP6441/2/4 op amp is well suited for conditioning sensor signals in battery-powered applications. Figure 4-9 shows a two op amp instrumentation amplifier, using the MCP6441/2/4 device, that works well for applications requiring rejection of Common Mode noise at higher gains. The reference voltage ( $V_{REF}$ ) is supplied by a low-impedance source. In single supply applications,  $V_{REF}$  is typically  $V_{DD}/2$ .

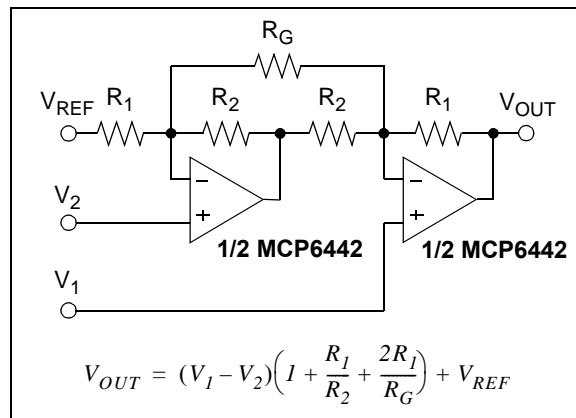


FIGURE 4-9: Two Op Amp Instrumentation Amplifier.

## 5.0 DESIGN AIDS

Microchip provides the basic design tools needed for the MCP6441/2/4 op amp.

### 5.1 SPICE Macro Model

The latest SPICE macro model for the MCP6441/2/4 op amp is available on the Microchip web site at [www.microchip.com](http://www.microchip.com). The model was written and tested in the official OrCAD (Cadence®) owned PSpice®. For the other simulators, translation may be required.

The model covers a wide aspect of the op amp's electrical specifications. Not only does the model cover voltage, current and resistance of the op amp, but it also covers the temperature and the noise effects on the behavior of the op amp. The model has not been verified outside of the specification range listed in the op amp data sheet. The model behaviors under these conditions cannot ensure it will match the actual op amp performance.

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

### 5.2 FilterLab® Software

Microchip's FilterLab software is an innovative software tool that simplifies analog active filter design using op amps. Available at no cost from the Microchip web site at [www.microchip.com/filterlab](http://www.microchip.com/filterlab), the FilterLab 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 the actual filter performance.

### 5.3 Microchip Advanced Part Selector (MAPS)

MAPS is a software tool that helps semiconductor professionals efficiently identify the Microchip devices that fit a particular design requirement. Available at no cost from the Microchip website at [www.microchip.com/maps](http://www.microchip.com/maps), the MAPS is an overall selection tool for Microchip's product portfolio that includes Analog, Memory, MCUs and DSCs. Using this tool, you 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.

### 5.4 Analog Demonstration and Evaluation Boards

Microchip offers a broad spectrum of Analog Demonstration and Evaluation Boards that are designed to help you achieve faster time to market. For a complete listing of these boards and their corresponding user's guides and technical information, visit the Microchip web site at [www.microchip.com/analogtools](http://www.microchip.com/analogtools).

Some boards that are especially useful are:

- MCP6XXX Amplifier Evaluation Board 1
- MCP6XXX Amplifier Evaluation Board 2
- MCP6XXX Amplifier Evaluation Board 3
- MCP6XXX Amplifier Evaluation Board 4
- Active Filter Demo Board Kit
- 5/6-Pin SOT-23 Evaluation Board, P/N VSUPEV2

### 5.5 Application Notes

The following Microchip Analog Design Note and Application Notes are available on the Microchip web site at [www.microchip.com/appnotes](http://www.microchip.com/appnotes), and are recommended as supplemental reference resources.

- **ADN003** – “Select the Right Operational Amplifier for your Filtering Circuits”, DS21821
- **AN722** – “Operational Amplifier Topologies and DC Specifications”, DS00722
- **AN723** – “Operational Amplifier AC Specifications and Applications”, DS00723
- **AN884** – “Driving Capacitive Loads With Op Amps”, DS00884
- **AN990** – “Analog Sensor Conditioning Circuits – An Overview”, DS00990
- **AN1177** – “Op Amp Precision Design: DC Errors”, DS01177
- **AN1228** – “Op Amp Precision Design: Random Noise”, DS01228
- **AN1297** – “Microchip's Op Amp SPICE Macro Models”, DS01297
- **AN1332**: “Current Sensing Circuit Concepts and Fundamentals” DS01332

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

- “Signal Chain Design Guide”, DS21825

# MCP6441/2/4

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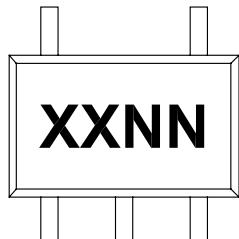
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## NOTES:

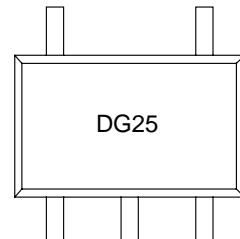
## 6.0 PACKAGING INFORMATION

### 6.1 Package Marking Information

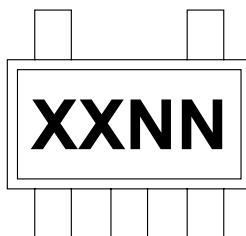
5-Lead SC70 (MCP6441)



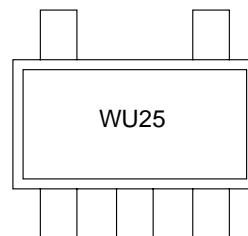
Example:



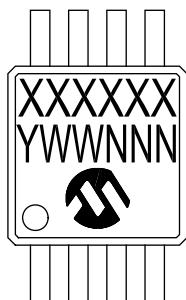
5-Lead SOT-23 (MCP6441)



Example:



8-Lead MSOP (MCP6442)



Example:

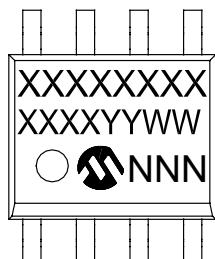


<b>Legend:</b>	XX...X	Customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week '01')
	NNN	Alphanumeric traceability code
	(e3)	Pb-free JEDEC designator for Matte Tin (Sn)
*		This package is Pb-free.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

**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.

# MCP6441/2/4

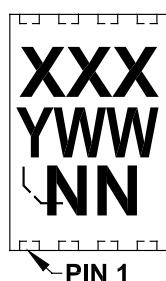
8-Lead SOIC (150 mil) (**MCP6442**)



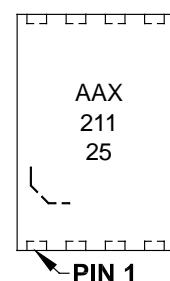
Example:



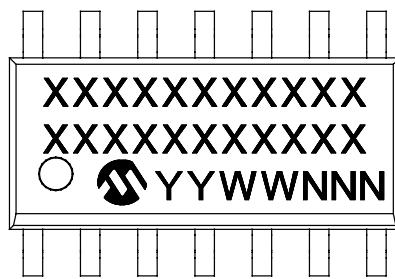
8-Lead TDFN (2x3x0.75 mm) (**MCP6442**)



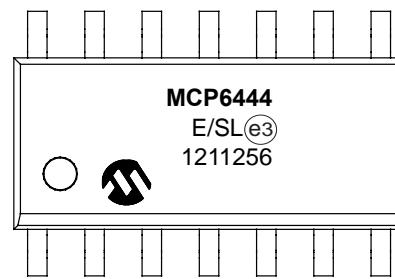
Example:



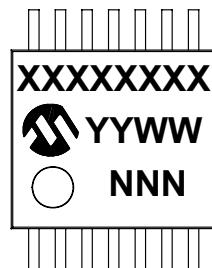
14-Lead SOIC (150 mil) (**MCP6444**)



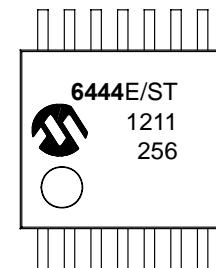
Example:



14-Lead TSSOP (**MCP6444**)



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

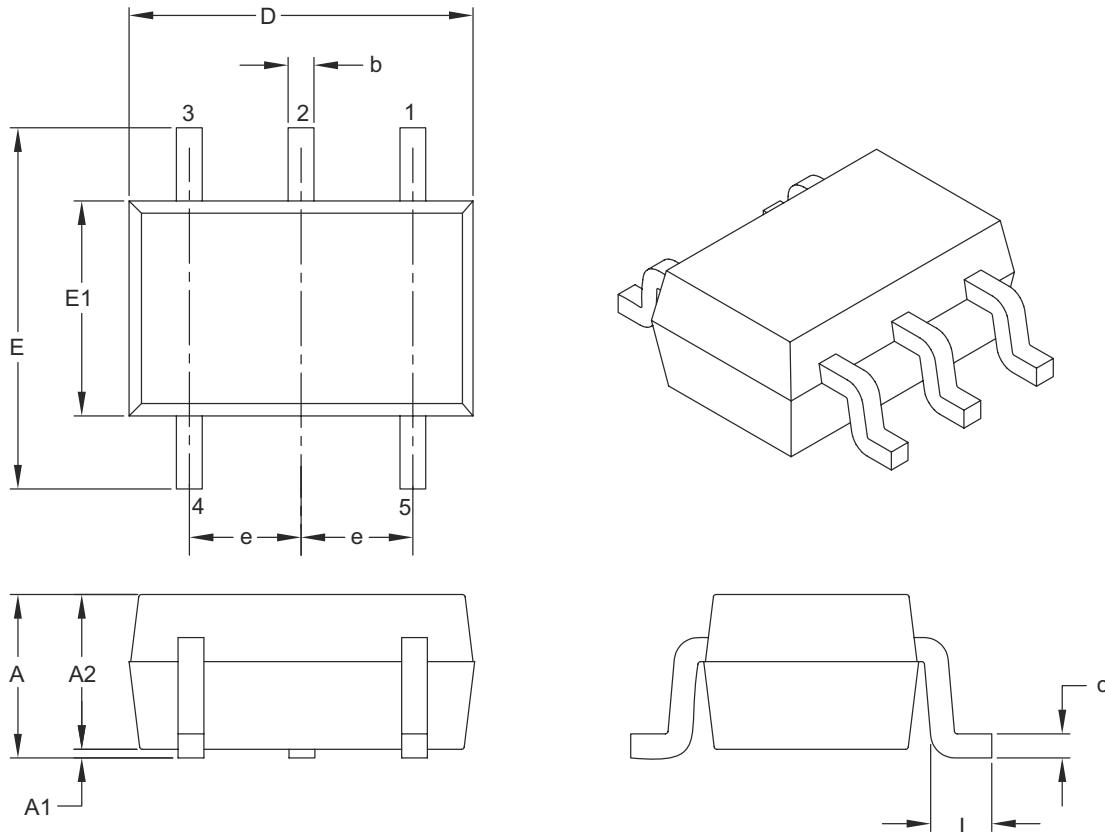
(e3) Pb-free JEDEC designator for Matte Tin (Sn)

\* 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.

## 5-Lead Plastic Small Outline Transistor (LT) [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
Molded Package Thickness	A2	0.80	—	1.00
Standoff	A1	0.00	—	0.10
Overall Width	E	1.80	2.10	2.40
Molded Package Width	E1	1.15	1.25	1.35
Overall Length	D	1.80	2.00	2.25
Foot Length	L	0.10	0.20	0.46
Lead Thickness	c	0.08	—	0.26
Lead Width	b	0.15	—	0.40

### Notes:

1. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.127 mm per side.
2. Dimensioning and tolerancing per ASME Y14.5M.

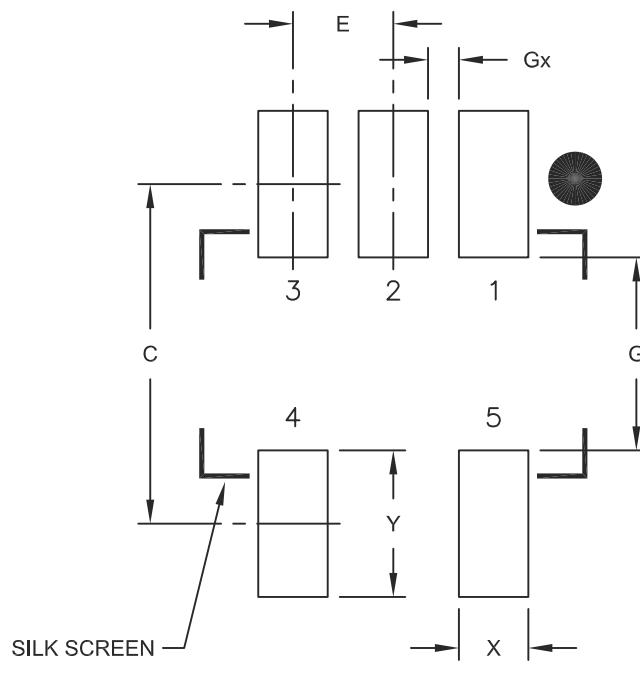
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing C04-061B

# MCP6441/2/4

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

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



RECOMMENDED LAND PATTERN

Dimension Limits		MILLIMETERS		
		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:

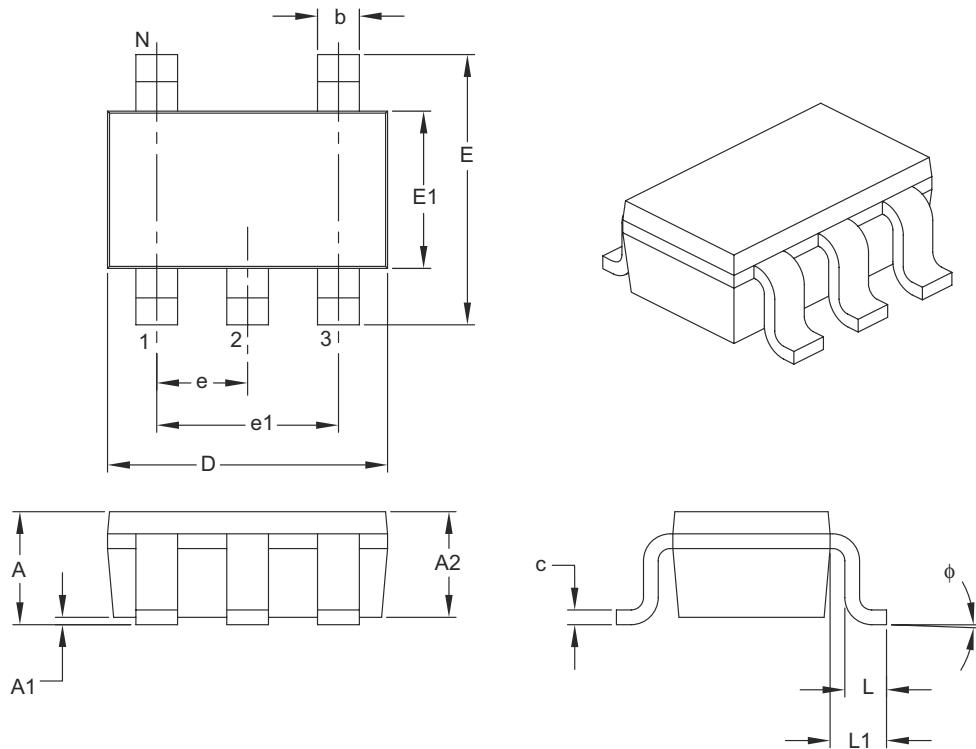
1. Dimensioning and tolerancing per ASME Y14.5M

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

Microchip Technology Drawing No. C04-2061A

## 5-Lead Plastic Small Outline Transistor (OT) [SOT-23]

**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	
Lead 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	0.00	—	0.15
Overall Width	E	2.20	—	3.20
Molded Package Width	E1	1.30	—	1.80
Overall Length	D	2.70	—	3.10
Foot Length	L	0.10	—	0.60
Footprint	L1	0.35	—	0.80
Foot Angle	φ	0°	—	30°
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 0.127 mm per side.
2. Dimensioning and tolerancing per ASME Y14.5M.

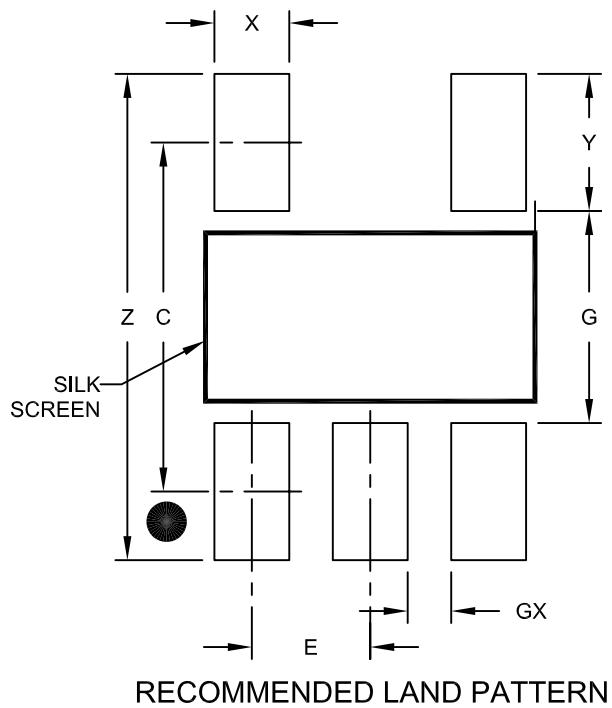
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing C04-091B

# MCP6441/2/4

## 5-Lead Plastic Small Outline Transistor (OT) [SOT-23]

**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:

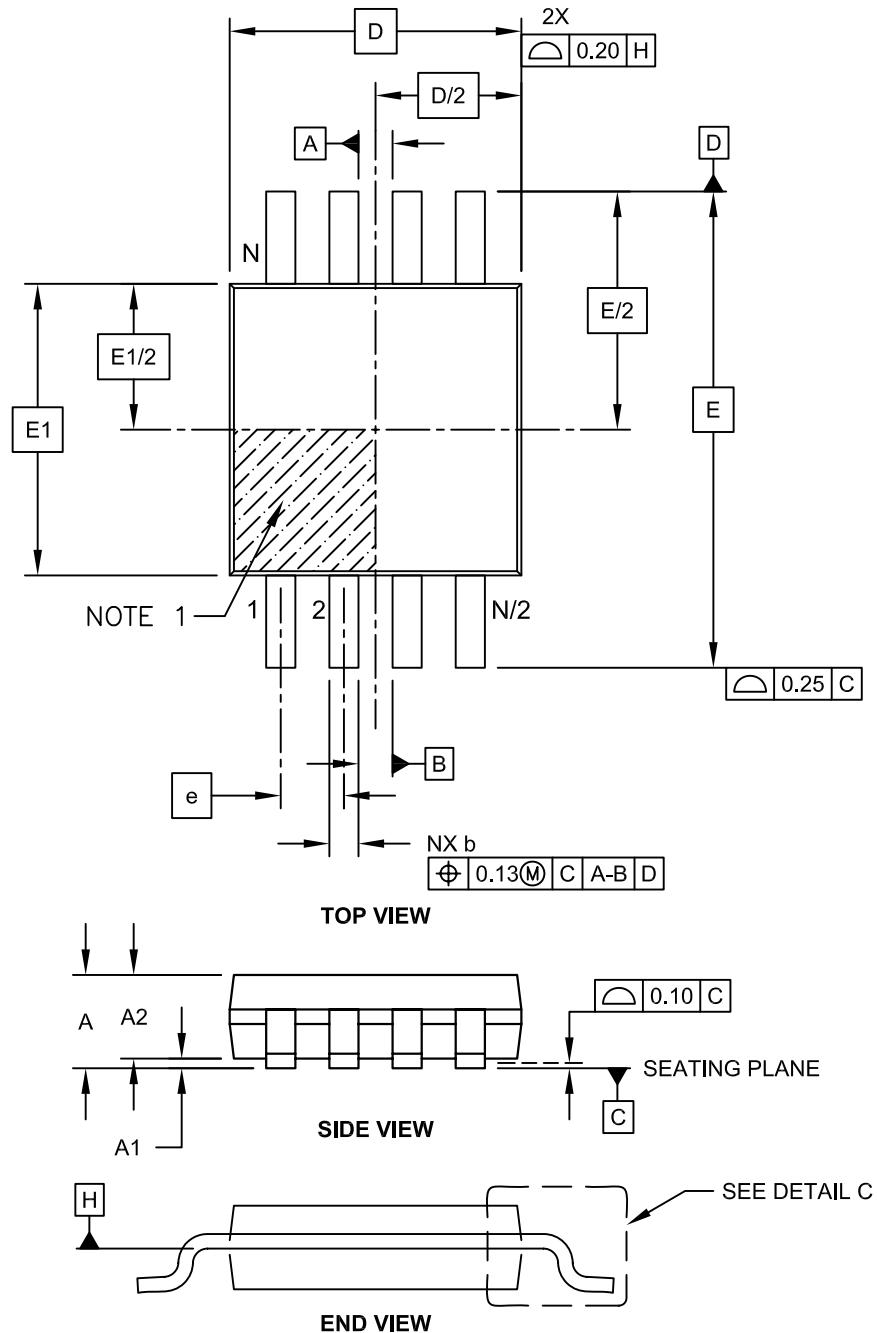
1. Dimensioning and tolerancing per ASME Y14.5M

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

Microchip Technology Drawing No. C04-2091A

## 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>

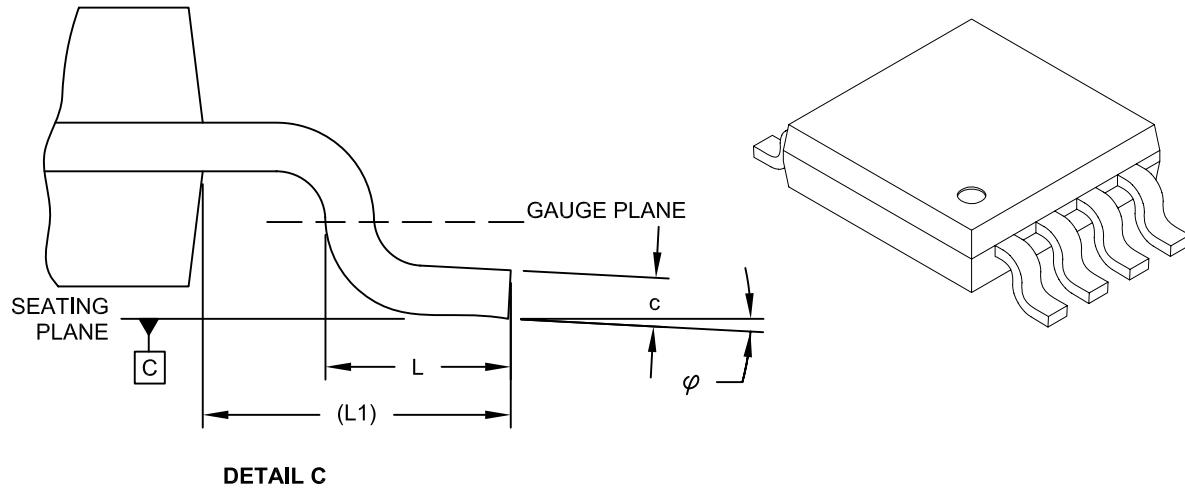


Microchip Technology Drawing C04-111C Sheet 1 of 2

# MCP6441/2/4

## 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>



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.

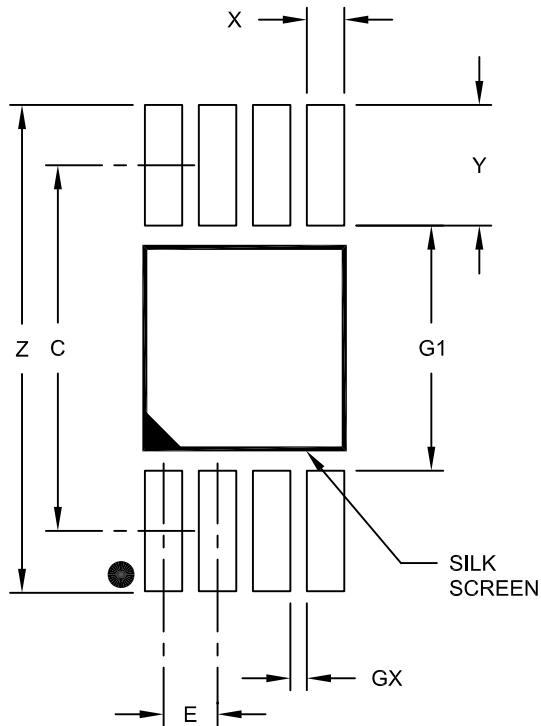
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

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

Microchip Technology Drawing C04-111C Sheet 2 of 2

## 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

Dimension	Limits	MILLIMETERS		
		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

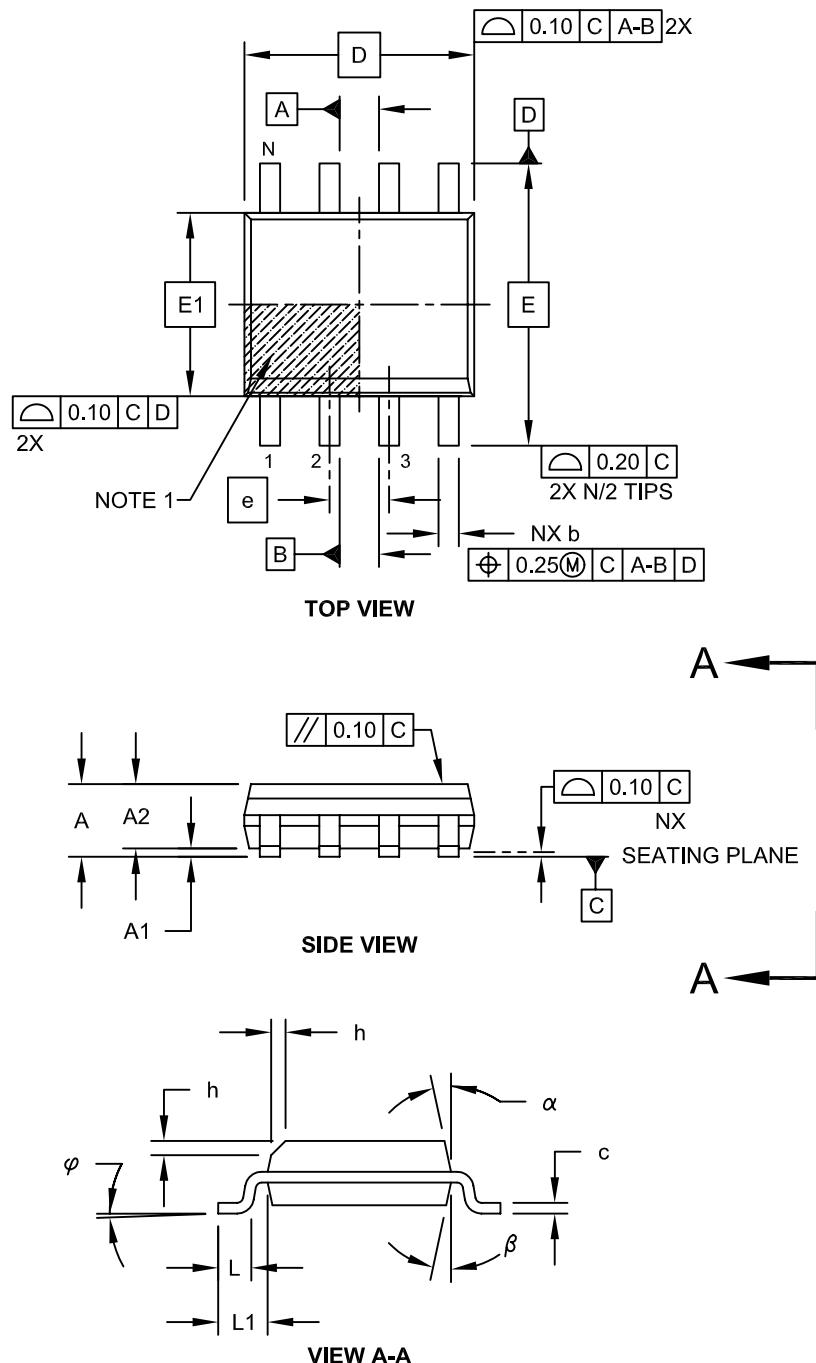
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing No. C04-2111A

# MCP6441/2/4

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

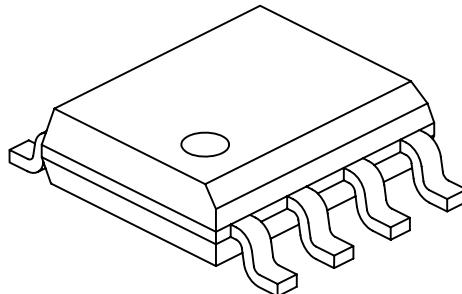
**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



Microchip Technology Drawing No. C04-057C Sheet 1 of 2

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

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



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

**Notes:**

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

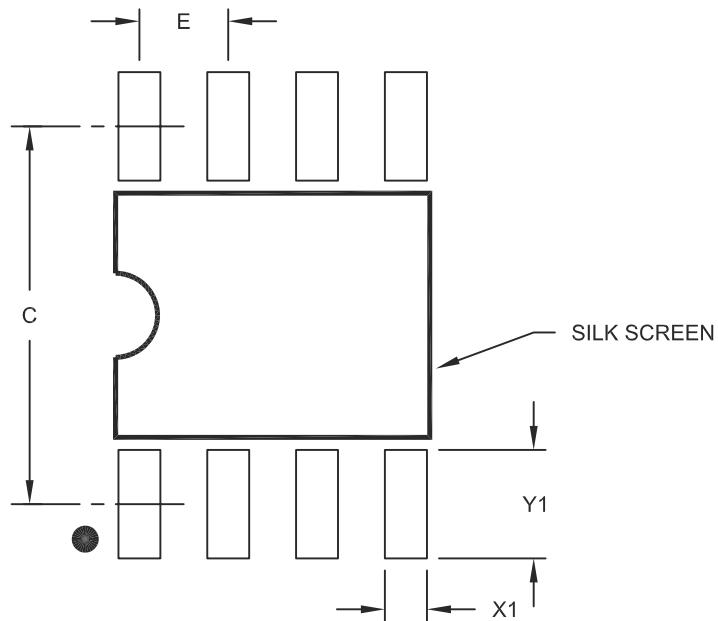
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

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

# MCP6441/2/4

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

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



RECOMMENDED LAND PATTERN

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

Notes:

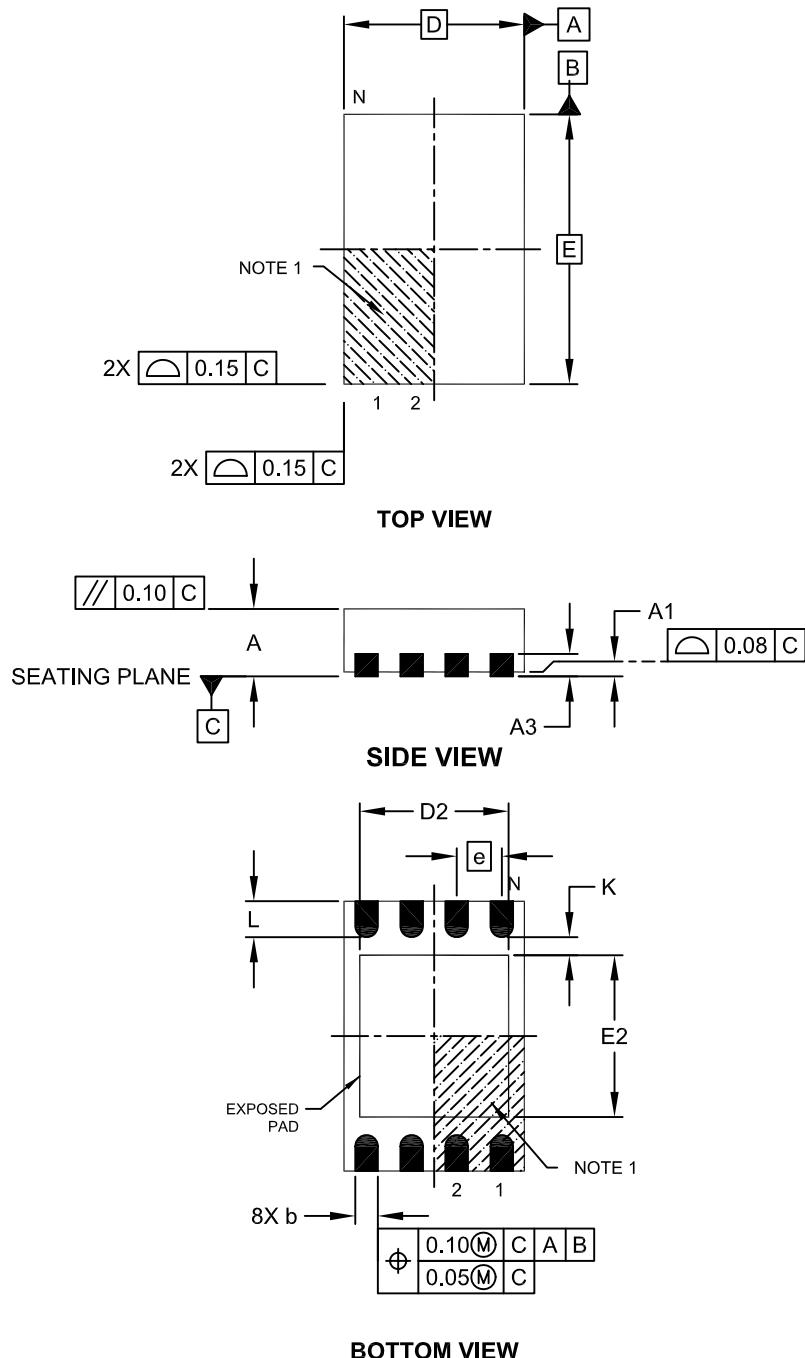
1. Dimensioning and tolerancing per ASME Y14.5M

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

Microchip Technology Drawing No. C04-2057A

## 8-Lead Plastic Dual Flat, No Lead Package (MN) – 2x3x0.75mm Body [TDFN]

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

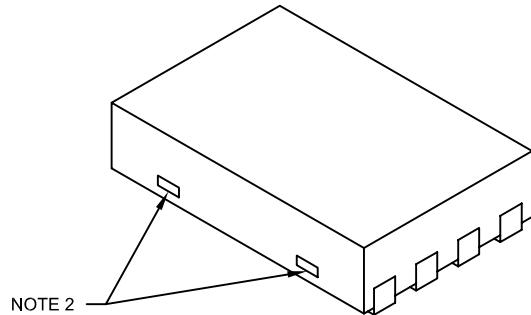


Microchip Technology Drawing No. C04-129C Sheet 1 of 2

# MCP6441/2/4

## 8-Lead Plastic Dual Flat, No Lead Package (MN) – 2x3x0.75mm Body [TDFN]

**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		1.20 - 1.60
Exposed Pad Width		E2		1.20 - 1.60
Contact Width		b		0.20 0.25 0.30
Contact Length		L		0.25 0.30 0.45
Contact-to-Exposed Pad		K		- -

**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

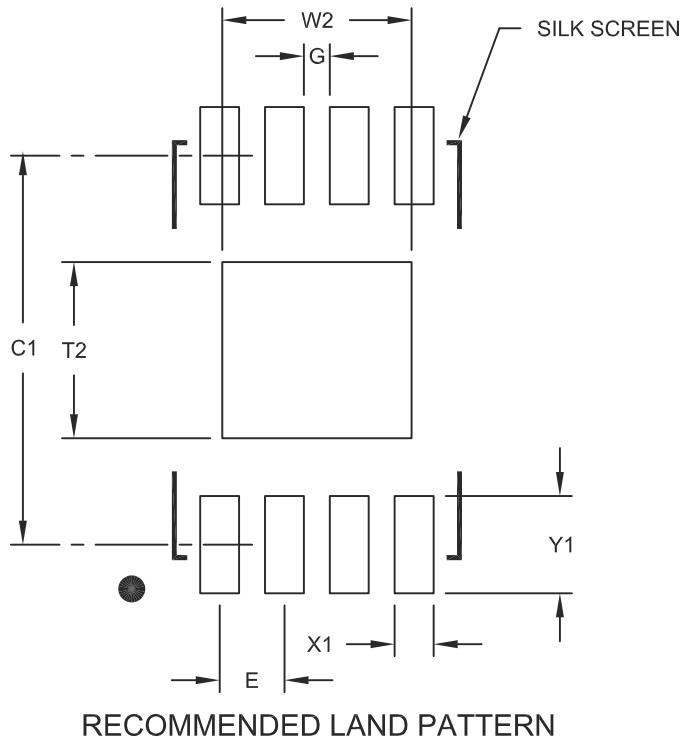
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

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

Microchip Technology Drawing No. C04-129C Sheet 2 of 2

## 8-Lead Plastic Dual Flat, No Lead Package (MN) – 2x3x0.75 mm Body [TDFN]

**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
Contact Pitch		E		0.50 BSC
Optional Center Pad Width	W2			1.46
Optional Center Pad Length	T2			1.36
Contact Pad Spacing	C1		3.00	
Contact Pad Width (X8)	X1			0.30
Contact Pad Length (X8)	Y1			0.75
Distance Between Pads	G	0.20		

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

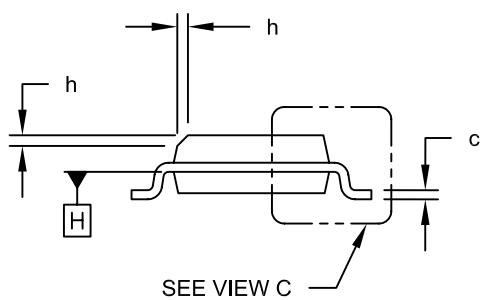
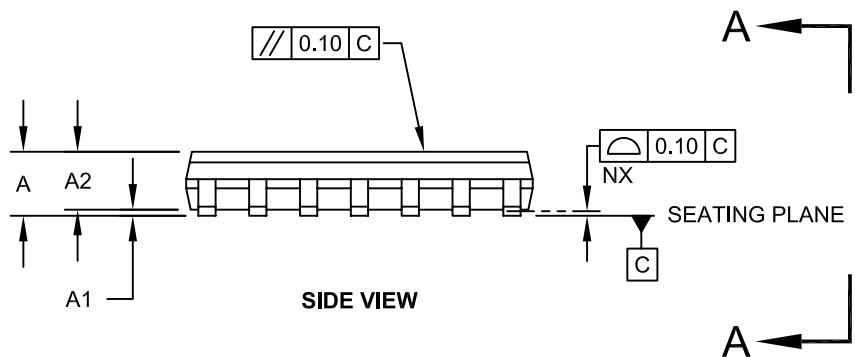
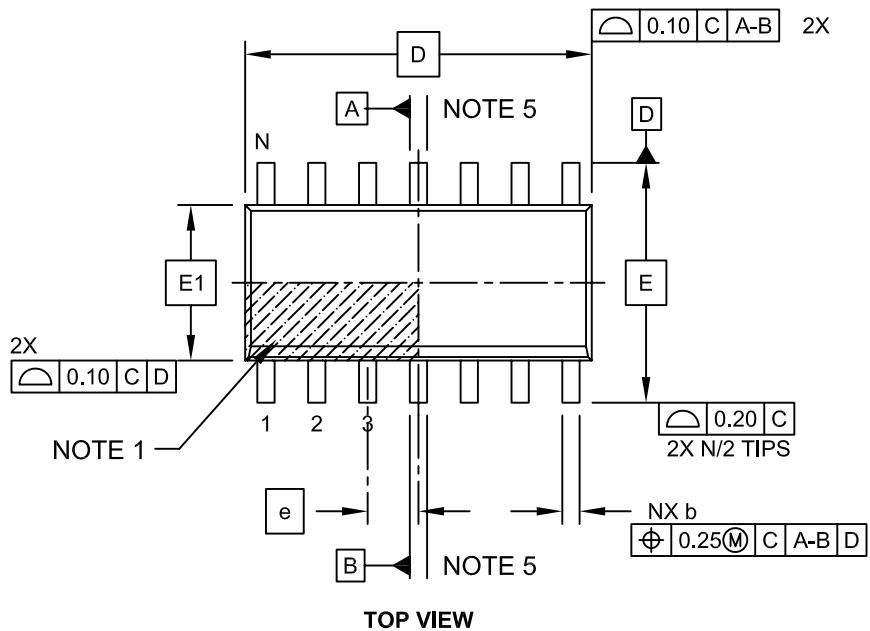
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing No. C04-2129A

# MCP6441/2/4

## 14-Lead Plastic Small Outline (SL) - Narrow, 3.90 mm Body [SOIC]

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

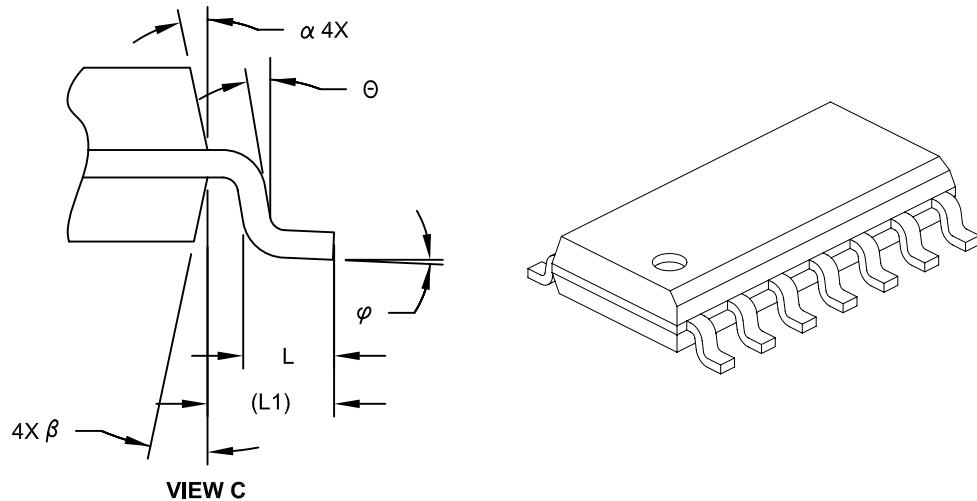


## **VIEW A-A**

Microchip Technology Drawing No. C04-065C Sheet 1 of 2

## 14-Lead Plastic Small Outline (SL) - Narrow, 3.90 mm Body [SOIC]

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



Dimension	Limits	Units			MILLIMETERS		
		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	N		14				
Pitch	e		1.27 BSC				
Overall Height	A	-	-	1.75			
Molded Package Thickness	A2	1.25	-	-			
Standoff	§	A1	0.10	-	0.25		
Overall Width	E		6.00 BSC				
Molded Package Width	E1		3.90 BSC				
Overall Length	D		8.65 BSC				
Chamfer (Optional)	h	0.25	-	0.50			
Foot Length	L	0.40	-	1.27			
Footprint	L1		1.04 REF				
Lead Angle	θ	0°	-	-			
Foot Angle	φ	0°	-	8°			
Lead Thickness	c	0.10	-	0.25			
Lead Width	b	0.31	-	0.51			
Mold Draft Angle Top	α	5°	-	15°			
Mold Draft Angle Bottom	β	5°	-	15°			

### Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.

2. § Significant Characteristic

3. Dimension D does not include mold flash, protrusions or gate burrs, which shall not exceed 0.15 mm per end. Dimension E1 does not include interlead flash or protrusion, which shall not exceed 0.25 mm per side.

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.

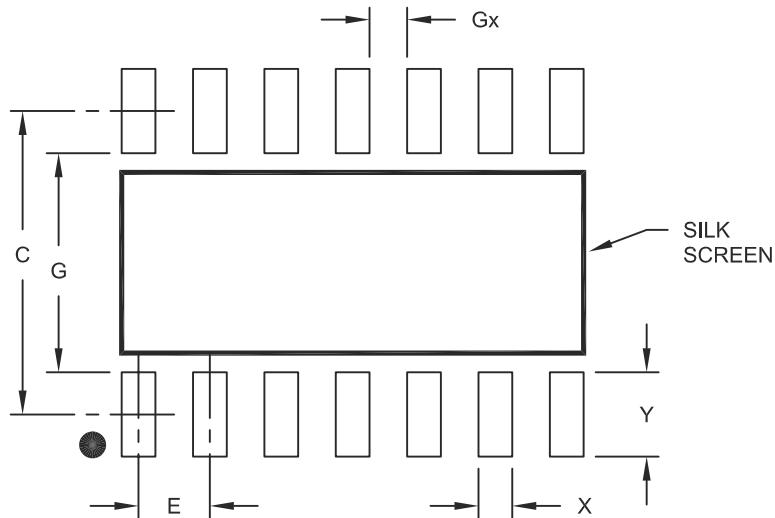
5. Datums A & B to be determined at Datum H.

Microchip Technology Drawing No. C04-065C Sheet 2 of 2

# MCP6441/2/4

14-Lead Plastic Small Outline (SL) - Narrow, 3.90 mm Body [SOIC]

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



## RECOMMENDED LAND PATTERN

Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Contact Pitch		E		1.27 BSC
Contact Pad Spacing		C	5.40	
Contact Pad Width		X		0.60
Contact Pad Length		Y		1.50
Distance Between Pads		Gx	0.67	
Distance Between Pads		G	3.90	

### Notes:

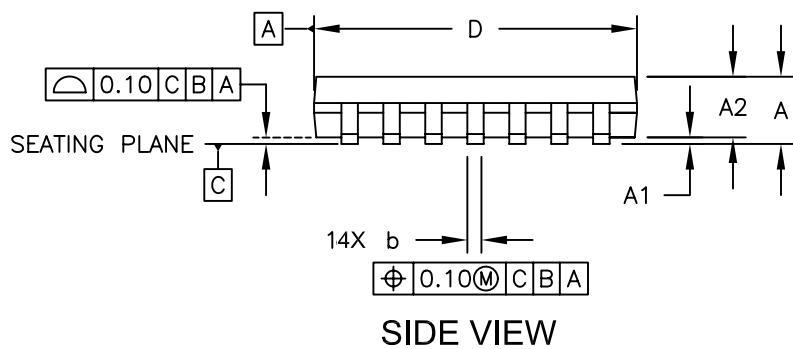
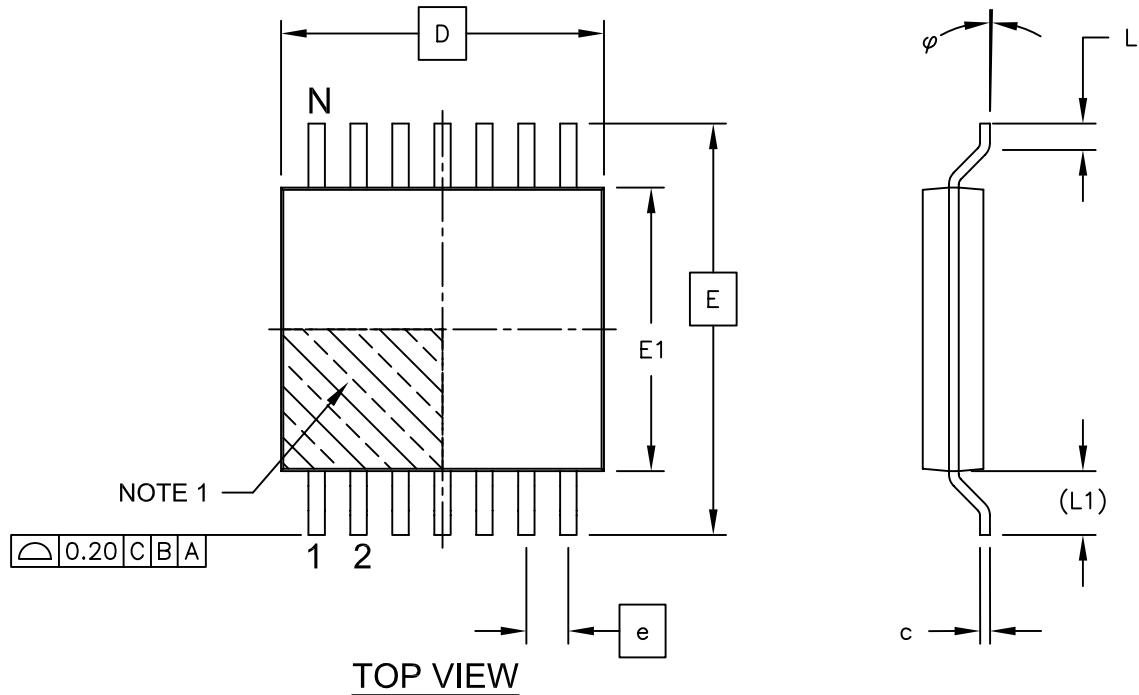
1. Dimensioning and tolerancing per ASME Y14.5M

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

Microchip Technology Drawing No. C04-2065A

## 14-Lead Plastic Thin Shrink Small Outline (ST) - 4.4 mm Body [TSSOP]

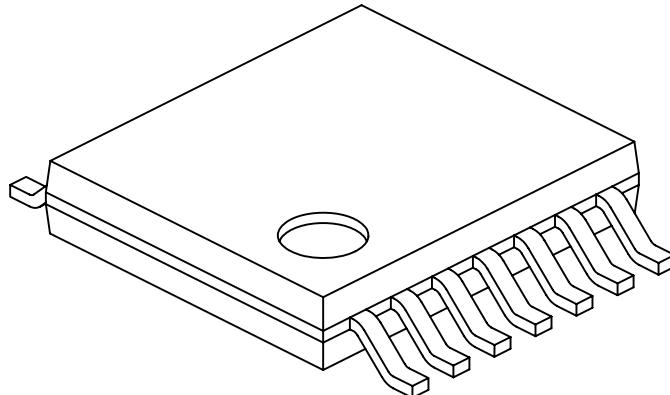
**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



# MCP6441/2/4

## 14-Lead Plastic Thin Shrink Small Outline (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>



Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Pins		N		14
Pitch		e		0.65 BSC
Overall Height		A		1.20
Molded Package Thickness		A2	0.80	1.00
Standoff		A1	0.05	0.15
Overall Width		E	6.40 BSC	
Molded Package Width		E1	4.30	4.40
Molded Package Length		D	4.90	5.00
Foot Length		L	0.45	0.60
Footprint		(L1)	1.00 REF	
Foot Angle		$\varphi$	0°	8°
Lead Thickness		c	0.09	0.20
Lead Width		b	0.19	0.30

### 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

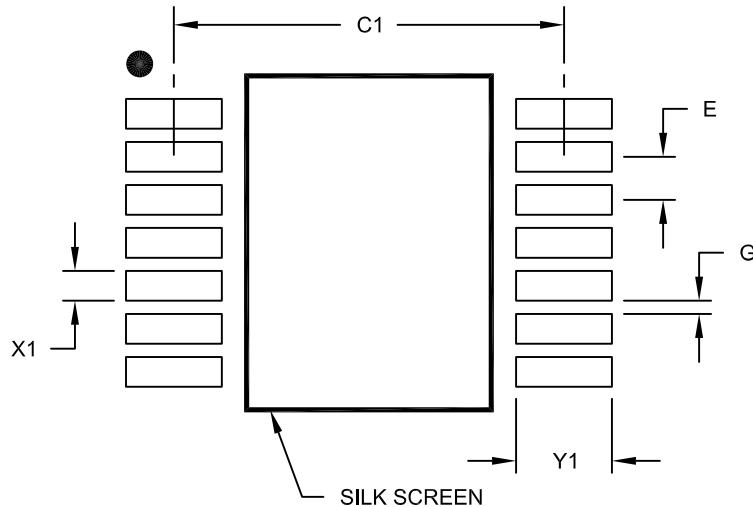
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

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

Microchip Technology Drawing No. C04-087C Sheet 2 of 2

## 14-Lead Plastic Thin Shrink Small Outline (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	C1		5.90	
Contact Pad Width (X14)	X1			0.45
Contact Pad Length (X14)	Y1			1.45
Distance Between Pads	G	0.20		

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

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

Microchip Technology Drawing No. C04-2087A

# MCP6441/2/4

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## NOTES:

## APPENDIX A: REVISION HISTORY

### Revision C (April 2012)

The following is the list of modifications:

1. Added new package type (8-Lead 2x3 TDFN) for MCP6442, and the related information throughout the document.
2. Updated [Table 3-1](#) with TDFN package pinouts.
3. Updated [Section 6.0, Packaging Information](#).
4. Updated the [Product Identification System](#) section.

### Revision B (March 2011)

The following is the list of modifications:

1. Added the MCP6442 and MCP6444 package information.
2. Updated the ESD protection value on all pins in [Section 1.1, Absolute Maximum Ratings](#) †.
3. Added Figure 2-32.
4. Updated [Table 3-1](#).
5. Updated the package markings information and drawings.
6. Updated the [Product Identification System](#) section.

### Revision A (September 2010)

- Original Release of this Document.

# MCP6441/2/4

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## NOTES:

## PRODUCT IDENTIFICATION SYSTEM

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

<u>PART NO.</u>	<u>T</u>	<u>X</u>	<u>XX</u>	<b>Examples:</b>
Device	Tape and Reel	Temperature Range	Package	
Device:	MCP6441T:		Single Op Amp (Tape and Reel) (SC70, SOT-23)	a) MCP6441T-E/LT: Tape and Reel, Extended Temperature 5LD SC70 Package
	MCP6442:		Dual Op Amp (Tube) (SOIC, MSOP)	b) MCP6441T-E/OT: Tape and Reel, Extended Temperature 5LD SOT-23 Package
	MCP6442T:		Dual Op Amp (Tape and Reel) (SOIC, MSOP, 2x3 TDFN)	c) MCP6442T-E/MNY: Tape and Reel, Extended Temperature 8LD 2x3 TDFN Package
	MCP6444:		Quad Op Amp (Tube) (SOIC, TSSOP)	d) MCP6442T-E/MS: Tape and Reel, Extended Temperature 8LD MSOP Package
	MCP6444T:		Quad Op Amp (Tape and Reel) (SOIC, TSSOP)	e) MCP6442-E/MS: Tube, Extended Temperature 8LD MSOP Package
Temperature Range:	E	= -40°C to +125°C (Extended)		f) MCP6442T-E/SN: Tube, Extended Temperature 8LD SOIC Package
Package:	LT	= Plastic Package (SC70), 5-lead		g) MCP6442-E/SN: Tube, Extended Temperature 8LD SOIC Package
	MNY*	= Thin Plastic Dual Flat (2x3 TDFN), 8-lead		h) MCP6444T-E/SL: Tape and Reel, Extended Temperature 14LD SOIC Package
	MS	= Plastic MSOP, 8-lead		i) MCP6444-E/SL: Tube, Extended Temperature 14LD SOIC Package
	OT	= Plastic Small Outline Transistor (SOT-23), 5-lead		j) MCP6444T-E/ST: Tape and Reel, Extended Temperature 14LD TSSOP Package
	SL	= Plastic SOIC, (3.99 mm body), 14-lead		k) MCP6444-E/ST: Tube, Extended Temperature 14LD TSSOP Package
	SN	= Plastic SOIC, (3.99 mm body), 8-lead		
	ST	= Plastic TSSOP (4.4 mm body), 14-lead		
* Y = Nickel palladium gold manufacturing designator. Only available on the TDFN package.				

# MCP6441/2/4

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## NOTES:

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

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
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