

## Push-Pull Output Sub-Microamp Comparators

### Features

- Low Quiescent Current: 600 nA/comparator (typ.)
- Rail-to-Rail Input:  $V_{SS} - 0.3V$  to  $V_{DD} + 0.3V$
- CMOS/TTL-Compatible Output
- Propagation Delay 4  $\mu s$  (typ.)
- Wide Supply Voltage Range: 1.6V to 5.5V
- Available in Single, Dual and Quad
- Single available in SOT-23-5, SC-70-5 packages
- Chip Select (CS) with MCP6543
- Low Switching Current
- Internal Hysteresis: 3.3 mV (typ.)
- Industrial Temperature:  $-40^{\circ}C$  to  $+85^{\circ}C$

### Typical Applications

- Laptop Computers
- Mobile Phones
- Metering Systems
- Hand-held Electronics
- RC Timers
- Alarm and Monitoring Circuits
- Windowed Comparators
- Multi-vibrators

### Related Devices

- Open-Drain Output: MCP6546/7/8/9

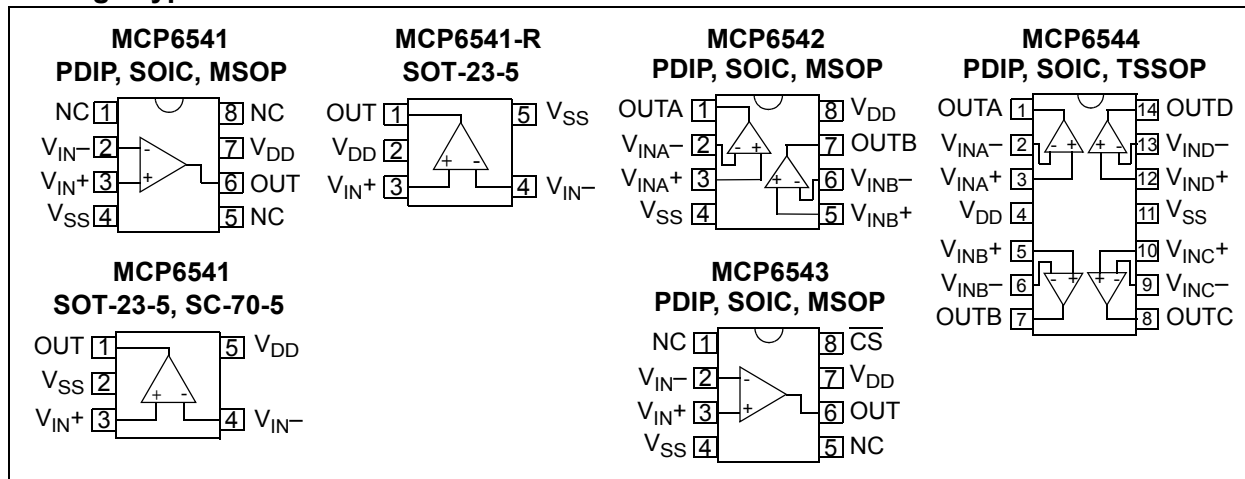
### Description

The Microchip Technology Inc. MCP6541/2/3/4 family of comparators is offered in single (MCP6541), single with chip select (MCP6543), dual (MCP6542) and quad (MCP6544) configurations. The outputs are push-pull (CMOS/TTL-compatible) and are capable of driving heavy DC or capacitive loads.

These comparators are optimized for low power, single-supply operation with greater than rail-to-rail input operation. The push-pull output of the MCP6541/2/3/4 family supports rail-to-rail output swing and interfaces with TTL/CMOS logic. The internal input hysteresis eliminates output switching due to internal input noise voltage, reducing current draw. The output limits supply current surges and dynamic power consumption while switching. This product family operates with a single-supply voltage as low as 1.6V and draws less than 1  $\mu A$ /comparator of quiescent current.

The related MCP6546/7/8/9 family of comparators from Microchip has an open-drain output. Used with a pull-up resistor, these devices can be used as level-shifters for any desired voltage up to 10V and in wired-OR logic.

### Package Types



# MCP6541/2/3/4

## 1.0 ELECTRICAL CHARACTERISTICS

### 1.1 Absolute Maximum Ratings †

$V_{DD} - V_{SS}$ .....	7.0V
All inputs and outputs .....	$V_{SS} - 0.3V$ to $V_{DD} + 0.3V$
Difference Input voltage .....	$ V_{DD} - V_{SS} $
Output Short-Circuit Current .....	continuous
Current at Input Pins .....	$\pm 2$ mA
Current at Output and Supply Pins .....	$\pm 30$ mA
Storage temperature .....	$-65^{\circ}C$ to $+150^{\circ}C$
Maximum Junction Temperature ( $T_J$ ) .....	$+150^{\circ}C$
ESD protection on all pins (HBM;MM) .....	4 kV; 400V

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

### PIN FUNCTION TABLE

NAME	FUNCTION
$V_{IN+}$ , $V_{INA+}$ , $V_{INB+}$ , $V_{INC+}$ , $V_{IND+}$	Non-Inverting Inputs
$V_{IN-}$ , $V_{INA-}$ , $V_{INB-}$ , $V_{INC-}$ , $V_{IND-}$	Inverting Inputs
$V_{DD}$	Positive Power Supply
$V_{SS}$	Negative Power Supply
OUT, OUTA, OUTB, OUTC, OUTD	Outputs
CS	Chip Select
NC	Not Connected

## DC CHARACTERISTICS

**Electrical Specifications:** Unless otherwise indicated,  $V_{DD} = +1.6V$  to  $+5.5V$ ,  $V_{SS} = GND$ ,  $T_A = +25^{\circ}C$ ,  $V_{IN+} = V_{DD}/2$ ,  $V_{IN-} = V_{SS}$ , and  $R_L = 100$  k $\Omega$  to  $V_{DD}/2$  (Refer to Figure 1-3).

Parameters	Sym	Min	Typ	Max	Units	Conditions
<b>Power Supply</b>						
Supply Voltage	$V_{DD}$	1.6	—	5.5	V	
Quiescent Current per comparator	$I_Q$	0.3	0.6	1.0	$\mu A$	$I_{OUT} = 0$
<b>Input</b>						
Input Voltage Range	$V_{CMR}$	$V_{SS} - 0.3$	—	$V_{DD} + 0.3$	V	
Common Mode Rejection Ratio	CMRR	55	70	—	dB	$V_{DD} = 5V$ , $V_{CM} = -0.3V$ to $5.3V$
Common Mode Rejection Ratio	CMRR	50	65	—	dB	$V_{DD} = 5V$ , $V_{CM} = 2.5V$ to $5.3V$
Common Mode Rejection Ratio	CMRR	55	70	—	dB	$V_{DD} = 5V$ , $V_{CM} = -0.3V$ to $2.5V$
Power Supply Rejection Ratio	PSRR	63	80	—	dB	$V_{CM} = V_{SS}$
Input Offset Voltage	$V_{OS}$	-7.0	$\pm 1.5$	+7.0	mV	$V_{CM} = V_{SS}$ ( <b>Note 1</b> )
Drift with Temperature	$\Delta V_{OS}/\Delta T_A$	—	$\pm 3$	—	$\mu V/^{\circ}C$	$T_A = -40^{\circ}C$ to $+85^{\circ}C$ , $V_{CM} = V_{SS}$
Input Hysteresis Voltage	$V_{HYST}$	1.5	3.3	6.5	mV	$V_{CM} = V_{SS}$ ( <b>Note 1</b> )
Drift with Temperature	$\Delta V_{HYST}/\Delta T_A$	—	10	—	$\mu V/^{\circ}C$	$T_A = -40^{\circ}C$ to $+25^{\circ}C$ , $V_{CM} = V_{SS}$
Drift with Temperature	$\Delta V_{HYST}/\Delta T_A$	—	5	—	$\mu V/^{\circ}C$	$T_A = +25^{\circ}C$ to $+85^{\circ}C$ , $V_{CM} = V_{SS}$
Input Bias Current	$I_B$	—	1	—	pA	$V_{CM} = V_{SS}$
Over-Temperature	$I_B$	—	—	100	pA	$T_A = -40^{\circ}C$ to $+85^{\circ}C$ , $V_{CM} = V_{SS}$ ( <b>Note 3</b> )
Input Offset Current	$I_{OS}$	—	$\pm 1$	—	pA	$V_{CM} = V_{SS}$
Common Mode Input Impedance	$Z_{CM}$	—	$10^{13}    4$	—	$\Omega    pF$	
Differential Input Impedance	$Z_{DIFF}$	—	$10^{13}    2$	—	$\Omega    pF$	
<b>Push-Pull Output</b>						
High-Level Output Voltage	$V_{OH}$	$V_{DD} - 0.2$	—	—	V	$I_{OUT} = -2$ mA, $V_{DD} = 5V$
Low-Level Output Voltage	$V_{OL}$	—	—	$V_{SS} + 0.2$	V	$I_{OUT} = 2$ mA, $V_{DD} = 5V$
Short-Circuit Current	$I_{SC}$	—	$\pm 50$	—	mA	( <b>Note 2</b> )

**Note 1:** The input offset voltage is the center (average) of the input-referred trip points. The input hysteresis is the difference between the input-referred trip points.

**2:** Limit the output current to Absolute Maximum Rating of 30 mA.

**3:** Input bias current over temperature is not tested for SC-70-5 package.

## AC CHARACTERISTICS

**Electrical Specifications:** Unless otherwise indicated,  $V_{DD} = +1.6V$  to  $+5.5V$ ,  $V_{SS} = GND$ ,  $T_A = +25^\circ C$ ,  $V_{IN+} = V_{DD}/2$ , Step = 200 mV, Overdrive = 100 mV, and  $C_L = 36$  pF (Refer to Figure 1-2 and Figure 1-3).

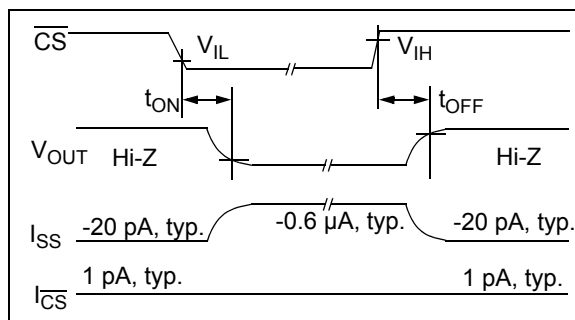
Parameters	Sym	Min	Typ	Max	Units	Conditions
Rise Time	$t_R$	—	0.85	—	$\mu s$	
Fall Time	$t_F$	—	0.85	—	$\mu s$	
Propagation Delay (High-to-Low)	$t_{PHL}$	—	4	8	$\mu s$	
Propagation Delay (Low-to-High)	$t_{PLH}$	—	4	8	$\mu s$	
Propagation Delay Skew	$t_{PDS}$	—	$\pm 0.2$	—	$\mu s$	<b>(Note 1)</b>
Maximum Toggle Frequency	$f_{MAX}$	—	160	—	kHz	$V_{DD} = 1.6V$
	$f_{MAX}$	—	120	—	kHz	$V_{DD} = 5.5V$
Input Noise Voltage	$E_N$	—	200	—	$\mu V_{P-P}$	10 Hz to 100 kHz

**Note 1:** Propagation Delay Skew is defined as:  $t_{PDS} = t_{PLH} - t_{PHL}$ .

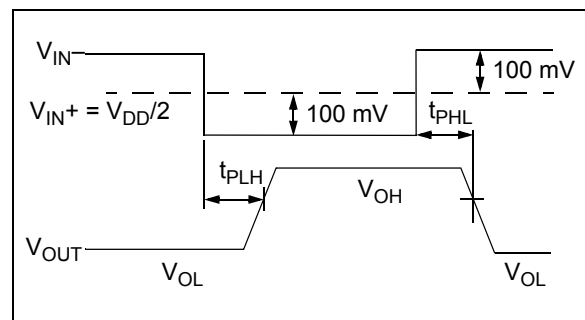
## SPECIFICATIONS FOR MCP6543 CHIP-SELECT

**Electrical Specifications:** Unless otherwise indicated,  $V_{DD} = +1.6V$  to  $+5.5V$ ,  $V_{SS} = GND$ ,  $T_A = +25^\circ C$ ,  $V_{IN+} = V_{DD}/2$ ,  $V_{IN-} = V_{SS}$ , and  $C_L = 36$  pF (Refer to Figures 1-1 and 1-3).

Parameters	Sym	Min	Typ	Max	Units	Conditions
<b><math>\overline{CS}</math> Low Specifications</b>						
$\overline{CS}$ Logic Threshold, Low	$V_{IL}$	$V_{SS}$	—	$0.2V_{DD}$	V	
$\overline{CS}$ Input Current, Low	$I_{CSL}$	—	5.0	—	pA	$\overline{CS} = V_{SS}$
<b><math>\overline{CS}</math> High Specifications</b>						
$\overline{CS}$ Logic Threshold, High	$V_{IH}$	$0.8V_{DD}$	—	$V_{DD}$	V	
$\overline{CS}$ Input Current, High	$I_{CSH}$	—	1	—	pA	$\overline{CS} = V_{DD}$
$\overline{CS}$ Input High, $V_{DD}$ Current	$I_{DD}$	—	18	—	pA	$\overline{CS} = V_{DD}$
$\overline{CS}$ Input High, GND Current	$I_{SS}$	—	-20	—	pA	$\overline{CS} = V_{DD}$
Comparator Output Leakage	$I_{O(LEAK)}$	—	1	—	pA	$V_{OUT} = V_{DD}$
<b><math>\overline{CS}</math> Dynamic Specifications</b>						
$\overline{CS}$ Low to Comparator Output Low Turn-on Time	$t_{ON}$	—	2	50	ms	$\overline{CS} = 0.2 V_{DD}$ to $V_{OUT} = V_{DD}/2$ , $V_{IN-} = V_{DD}$
$\overline{CS}$ High to Comparator Output High Z Turn-off Time	$t_{OFF}$	—	10	—	$\mu s$	$\overline{CS} = 0.8 V_{DD}$ to $V_{OUT} = V_{DD}/2$ , $V_{IN-} = V_{DD}$
$\overline{CS}$ Hysteresis	$V_{CS\_HYST}$	—	0.6	—	V	$V_{DD} = 5V$



**FIGURE 1-1:** Timing Diagram for the  $\overline{CS}$  Pin on the MCP6543.



**FIGURE 1-2:** Propagation Delay Timing Diagram.

# MCP6541/2/3/4

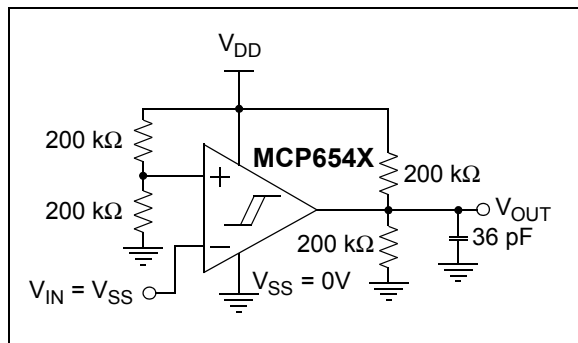
## TEMPERATURE SPECIFICATIONS

Electrical Specifications: Unless otherwise indicated, $V_{DD} = +1.6V$ to $+5.5V$ and $V_{SS} = GND$ .						
Parameters	Sym	Min	Typ	Max	Units	Conditions
<b>Temperature Ranges</b>						
Specified Temperature Range	$T_A$	-40	—	+85	°C	
Operating Temperature Range	$T_A$	-40	—	+125	°C	<b>Note</b>
Storage Temperature Range	$T_A$	-65	—	+150	°C	
<b>Thermal Package Resistances</b>						
Thermal Resistance, 5L-SC-70	$\theta_{JA}$	—	331	—	°C/W	
Thermal Resistance, 5L-SOT-23	$\theta_{JA}$	—	256	—	°C/W	
Thermal Resistance, 8L-PDIP	$\theta_{JA}$	—	85	—	°C/W	
Thermal Resistance, 8L-SOIC	$\theta_{JA}$	—	163	—	°C/W	
Thermal Resistance, 8L-MSOP	$\theta_{JA}$	—	206	—	°C/W	
Thermal Resistance, 14L-PDIP	$\theta_{JA}$	—	70	—	°C/W	
Thermal Resistance, 14L-SOIC	$\theta_{JA}$	—	120	—	°C/W	
Thermal Resistance, 14L-TSSOP	$\theta_{JA}$	—	100	—	°C/W	

**Note:** The MCP6541/2/3/4 operates over this extended temperature range, but with reduced performance. In any case, the Junction Temperature ( $T_J$ ) must not exceed the Absolute Maximum specification of  $+150^\circ\text{C}$ .

## 1.2 Test Circuit Configuration

This test circuit configuration is used to determine the AC and DC specifications.

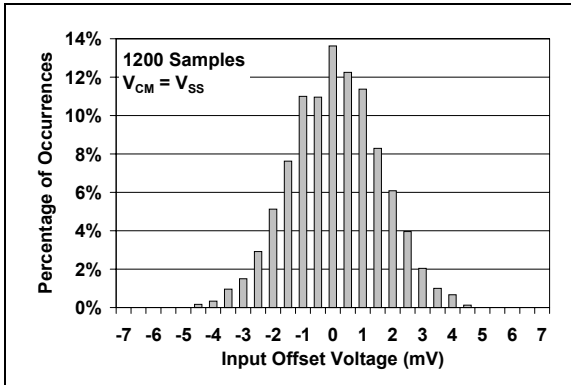


**FIGURE 1-3:** AC and DC Test Circuit for the Push-Pull Output Comparators.

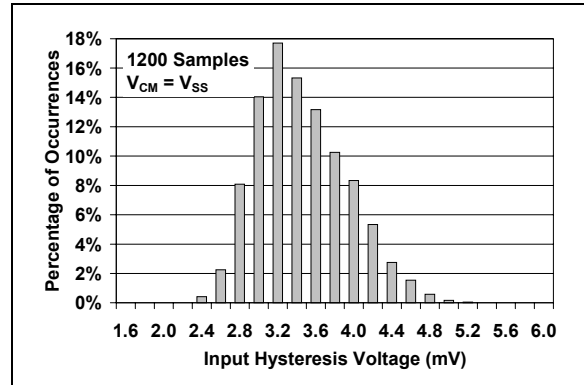
## 2.0 TYPICAL PERFORMANCE CURVES

**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.

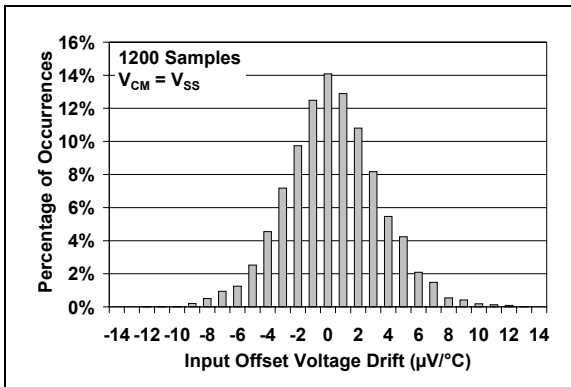
**Note:** Unless otherwise indicated,  $V_{DD} = +1.6V$  to  $+5.5V$ ,  $V_{SS} = GND$ ,  $T_A = +25^\circ C$ ,  $V_{IN+} = V_{DD}/2$ ,  $V_{IN-} = GND$ ,  $R_L = 100\text{ k}\Omega$  to  $V_{DD}/2$ , and  $C_L = 36\text{ pF}$ .



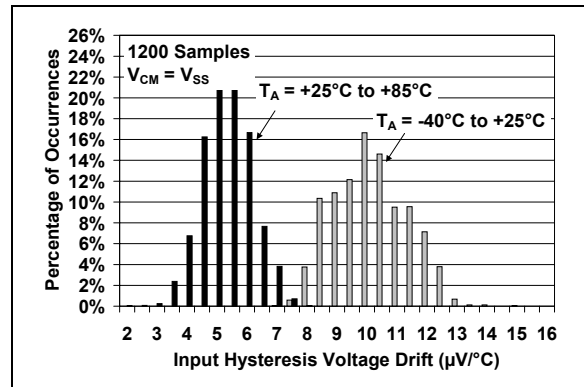
**FIGURE 2-1:** Input Offset Voltage Histogram at  $V_{CM} = V_{SS}$ .



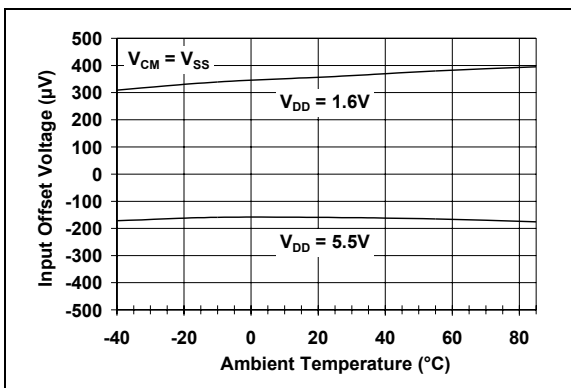
**FIGURE 2-4:** Input Hysteresis Voltage Histogram at  $V_{CM} = V_{SS}$ .



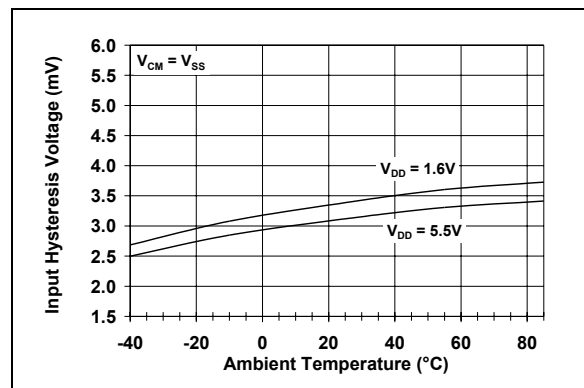
**FIGURE 2-2:** Input Offset Voltage Drift Histogram at  $V_{CM} = V_{SS}$ .



**FIGURE 2-5:** Input Hysteresis Voltage Drift Histogram.



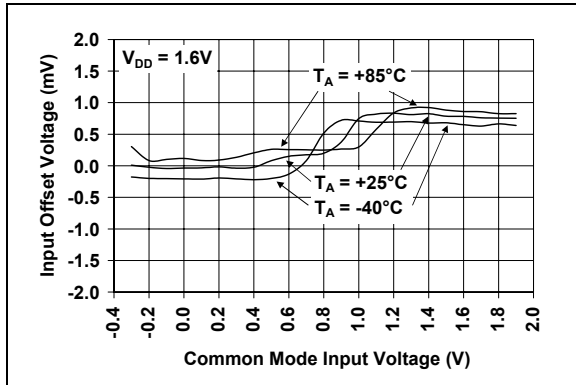
**FIGURE 2-3:** Input Offset Voltage vs. Ambient Temperature at  $V_{CM} = V_{SS}$ .



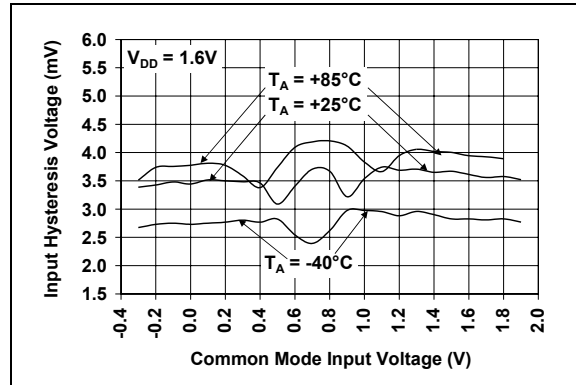
**FIGURE 2-6:** Input Hysteresis Voltage vs. Ambient Temperature at  $V_{CM} = V_{SS}$ .

# MCP6541/2/3/4

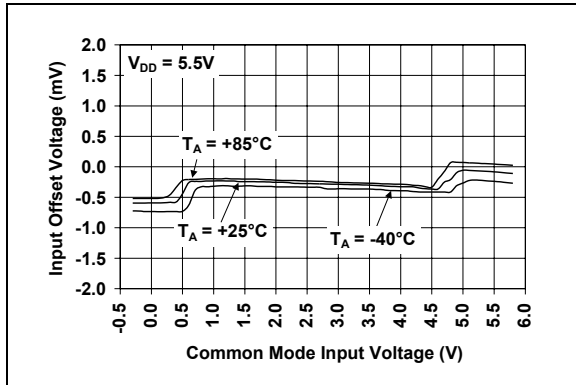
**Note:** Unless otherwise indicated,  $V_{DD} = +1.6V$  to  $+5.5V$ ,  $V_{SS} = GND$ ,  $T_A = +25^\circ C$ ,  $V_{IN+} = V_{DD}/2$ ,  $V_{IN-} = GND$ ,  $R_L = 100\text{ k}\Omega$  to  $V_{DD}/2$ , and  $C_L = 36\text{ pF}$ .



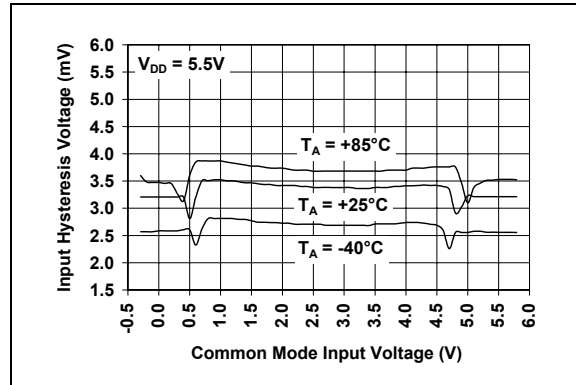
**FIGURE 2-7:** Input Offset Voltage vs. Common Mode Input Voltage at  $V_{DD} = 1.6V$ .



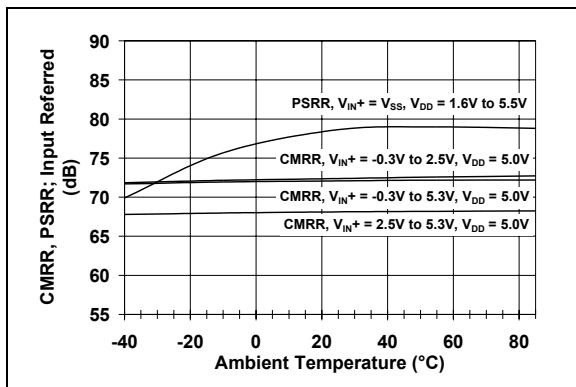
**FIGURE 2-10:** Input Hysteresis Voltage vs. Common Mode Input Voltage at  $V_{DD} = 1.6V$ .



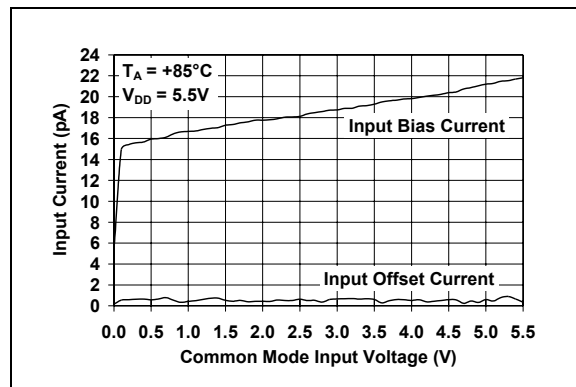
**FIGURE 2-8:** Input Offset Voltage vs. Common Mode Input Voltage at  $V_{DD} = 5.5V$ .



**FIGURE 2-11:** Input Hysteresis Voltage vs. Common Mode Input Voltage at  $V_{DD} = 5.5V$ .

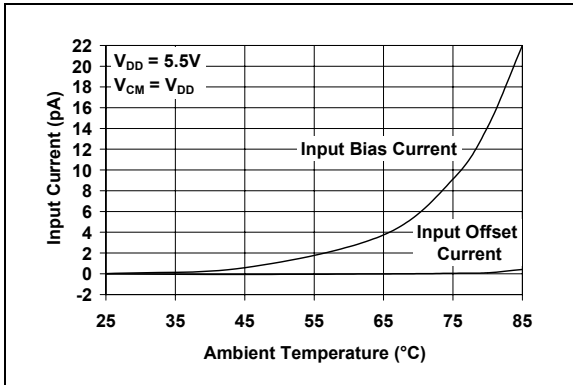


**FIGURE 2-9:** CMRR, PSRR vs. Ambient Temperature at  $V_{CM} = V_{SS}$ .

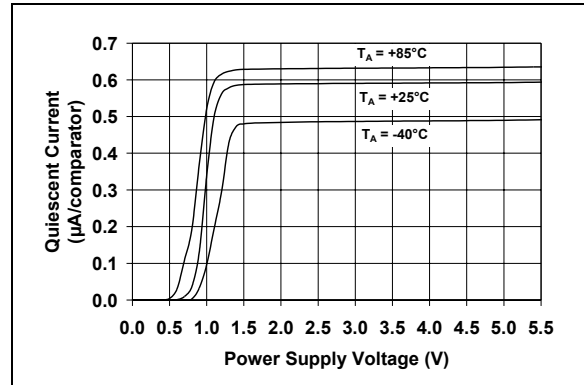


**FIGURE 2-12:** Input Bias Current, Input Offset Current vs. Common Mode Voltage at  $+85^\circ C$ .

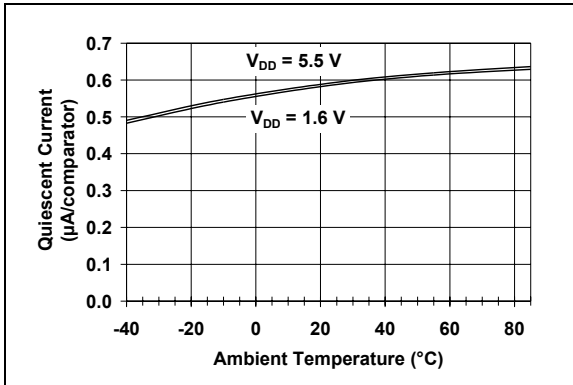
**Note:** Unless otherwise indicated,  $V_{DD} = +1.6V$  to  $+5.5V$ ,  $V_{SS} = GND$ ,  $T_A = +25^\circ C$ ,  $V_{IN+} = V_{DD}/2$ ,  $V_{IN-} = GND$ ,  $R_L = 100\text{ k}\Omega$  to  $V_{DD}/2$ , and  $C_L = 36\text{ pF}$ .



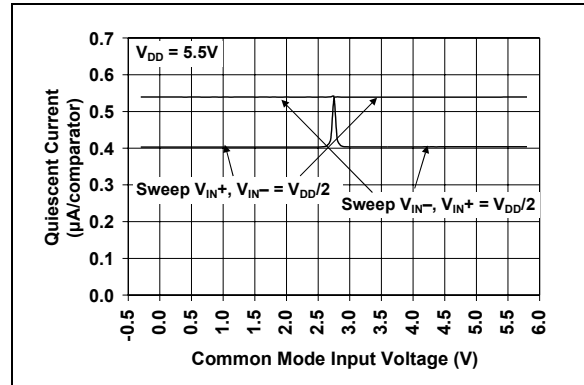
**FIGURE 2-13:** Input Bias Current, Input Offset Current vs. Ambient Temperature.



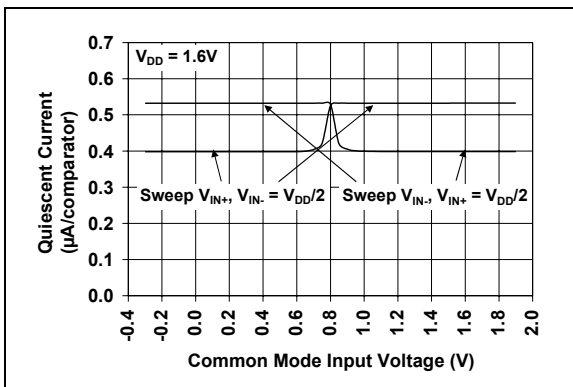
**FIGURE 2-16:** Quiescent Current vs. Power Supply Voltage.



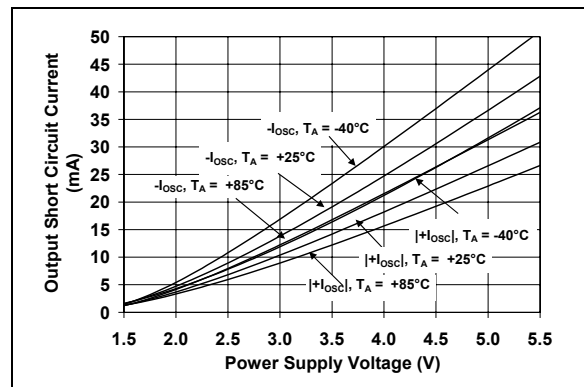
**FIGURE 2-14:** Quiescent Current vs. Ambient Temperature.



**FIGURE 2-17:** Quiescent Current vs. Common Mode Input Voltage at  $V_{DD} = 5V$ .



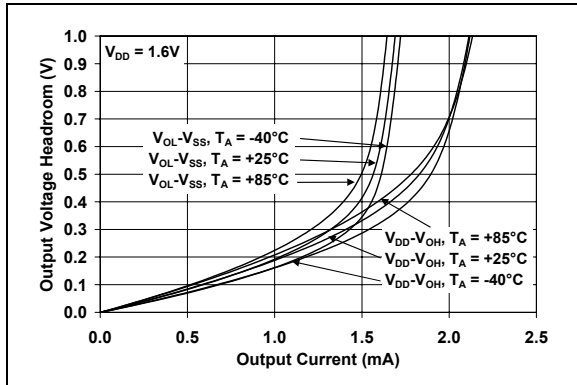
**FIGURE 2-15:** Quiescent Current vs. Common Mode Input Voltage at  $V_{DD} = 1.6V$ .



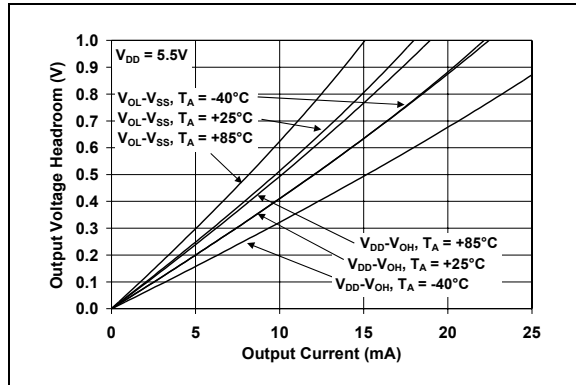
**FIGURE 2-18:** Output Short-Circuit Current vs. Power Supply Voltage.

# MCP6541/2/3/4

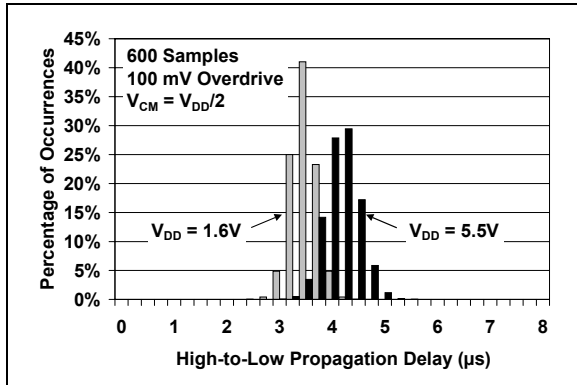
**Note:** Unless otherwise indicated,  $V_{DD} = +1.6V$  to  $+5.5V$ ,  $V_{SS} = GND$ ,  $T_A = +25^\circ C$ ,  $V_{IN+} = V_{DD}/2$ ,  $V_{IN-} = GND$ ,  $R_L = 100\text{ k}\Omega$  to  $V_{DD}/2$ , and  $C_L = 36\text{ pF}$ .



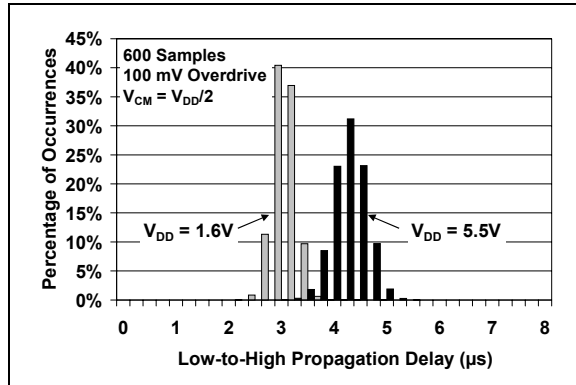
**FIGURE 2-19:** Output Voltage Headroom vs. Output Current at  $V_{DD} = 1.6V$ .



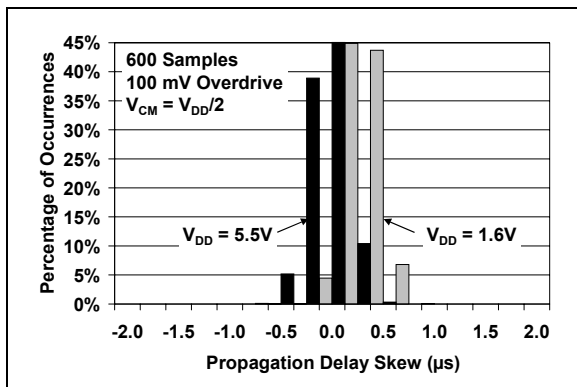
**FIGURE 2-22:** Output Voltage Headroom vs. Output Current at  $V_{DD} = 5.5V$ .



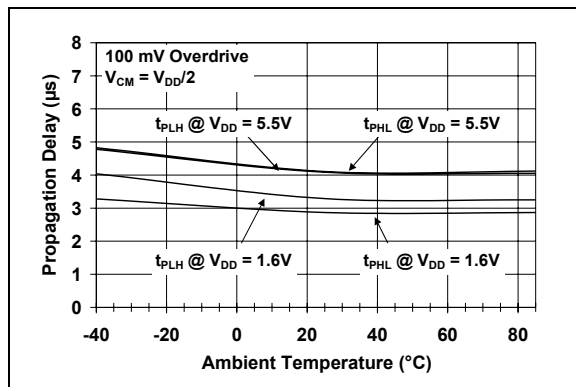
**FIGURE 2-20:** High-to-Low Propagation Delay Histogram.



**FIGURE 2-23:** Low-to-High Propagation Delay Histogram.



**FIGURE 2-21:** Propagation Delay Skew Histogram.

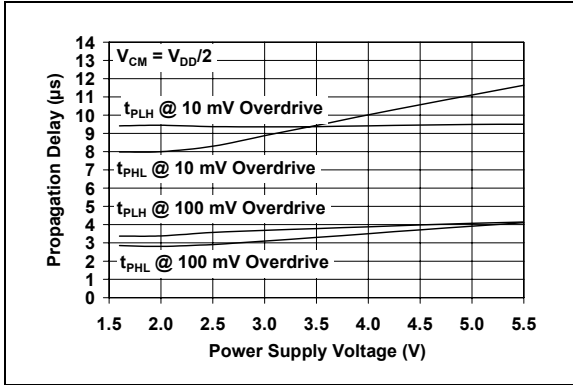


**FIGURE 2-24:** Propagation Delay vs. Ambient Temperature.

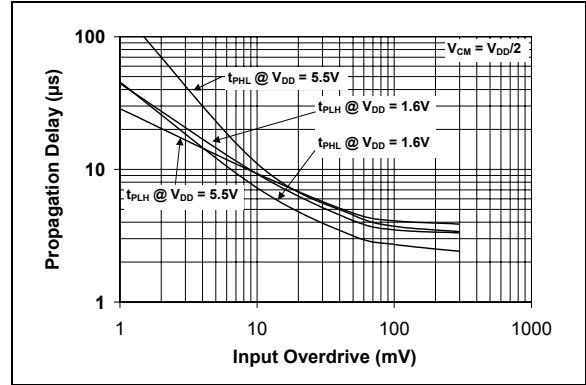


# MCP6541/2/3/4

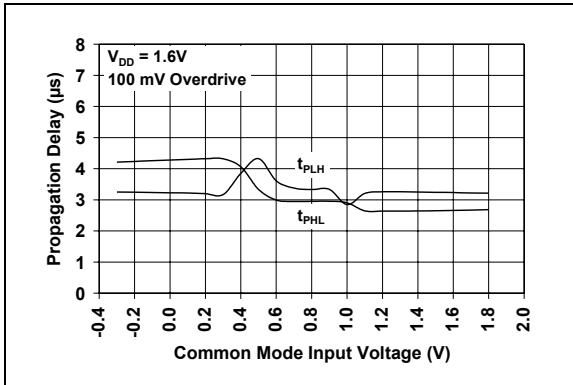
**Note:** Unless otherwise indicated,  $V_{DD} = +1.6V$  to  $+5.5V$ ,  $V_{SS} = GND$ ,  $T_A = +25^\circ C$ ,  $V_{IN+} = V_{DD}/2$ ,  $V_{IN-} = GND$ ,  $R_L = 100\text{ k}\Omega$  to  $V_{DD}/2$ , and  $C_L = 36\text{ pF}$ .



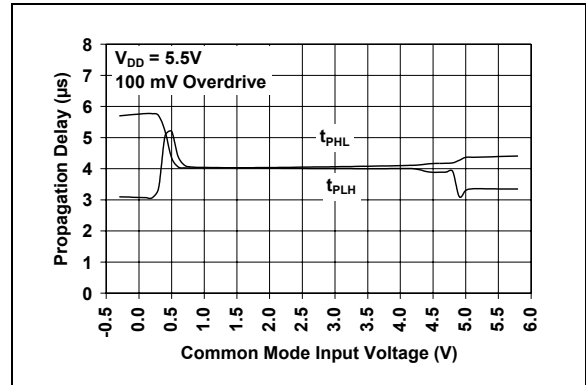
**FIGURE 2-25:** Propagation Delay vs. Power Supply Voltage.



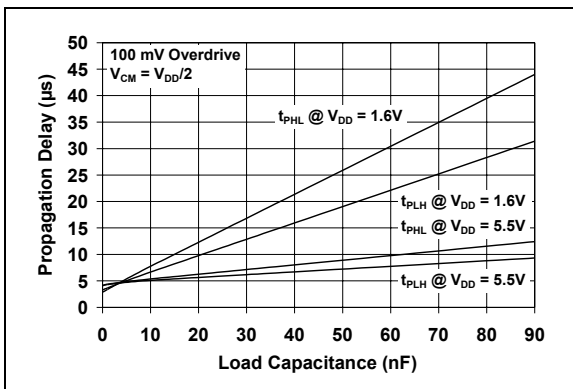
**FIGURE 2-28:** Propagation Delay vs. Input Overdrive.



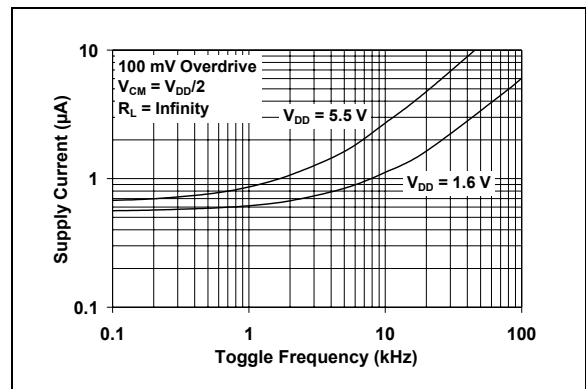
**FIGURE 2-26:** Propagation Delay vs. Common Mode Input Voltage at  $V_{DD} = 1.6V$ .



**FIGURE 2-29:** Propagation Delay vs. Common Mode Input Voltage at  $V_{DD} = 5.5V$ .



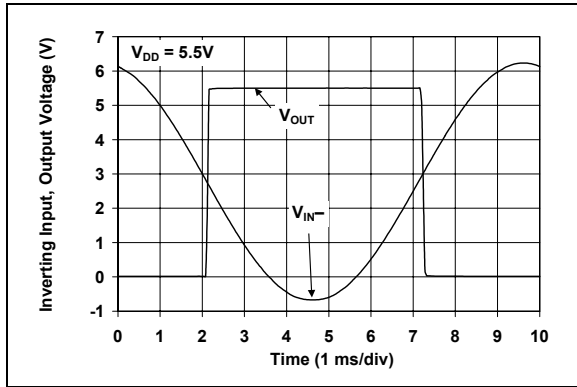
**FIGURE 2-27:** Propagation Delay vs. Load Capacitance.



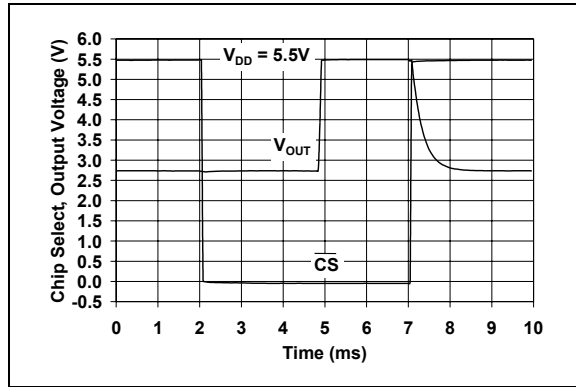
**FIGURE 2-30:** Supply Current vs. Toggle Frequency.

# MCP6541/2/3/4

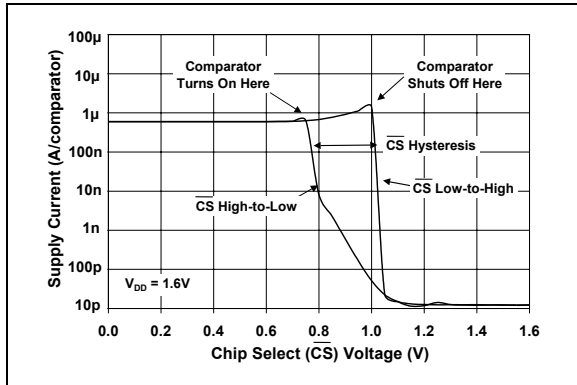
**Note:** Unless otherwise indicated,  $V_{DD} = +1.6V$  to  $+5.5V$ ,  $V_{SS} = GND$ ,  $T_A = +25^\circ C$ ,  $V_{IN+} = V_{DD}/2$ ,  $V_{IN-} = GND$ ,  $R_L = 100\text{ k}\Omega$  to  $V_{DD}/2$ , and  $C_L = 36\text{ pF}$ .



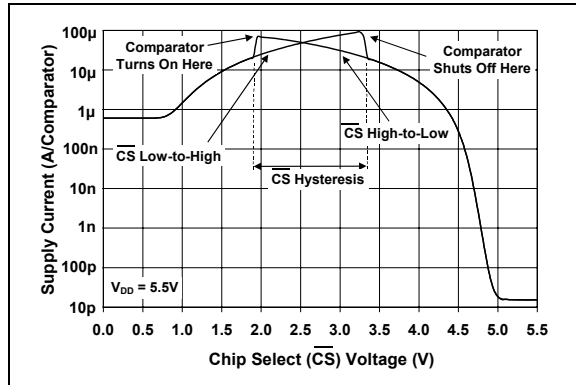
**FIGURE 2-31:** The MCP6541/2/3/4 comparators show no phase reversal.



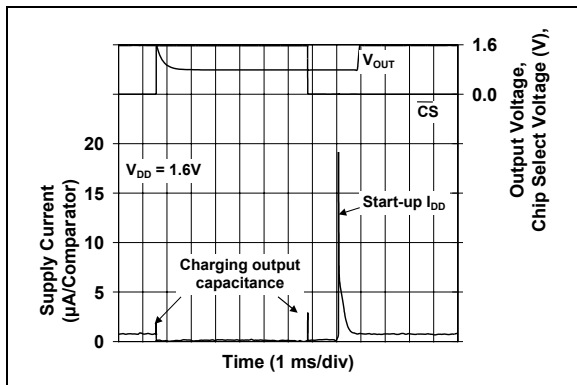
**FIGURE 2-34:** Chip-Select ( $\overline{CS}$ ) Step Response (MCP6543 only).



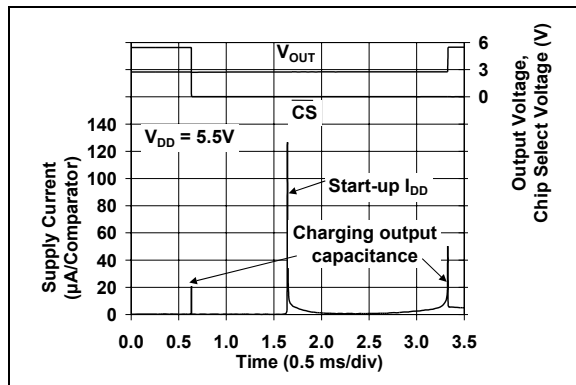
**FIGURE 2-32:** Supply Current (shoot through current) vs. Chip-Select ( $\overline{CS}$ ) Voltage at  $V_{DD} = 1.6V$  (MCP6543 only).



**FIGURE 2-35:** Supply Current (shoot through current) vs. Chip-Select ( $\overline{CS}$ ) Voltage at  $V_{DD} = 5.5V$  (MCP6543 only).



**FIGURE 2-33:** Supply Current (charging current) vs. Chip-Select ( $\overline{CS}$ ) pulse at  $V_{DD} = 1.6V$  (MCP6543 only).



**FIGURE 2-36:** Supply Current (charging current) vs. Chip-Select ( $\overline{CS}$ ) pulse at  $V_{DD} = 5.5V$  (MCP6543 only).

## 3.0 APPLICATIONS INFORMATION

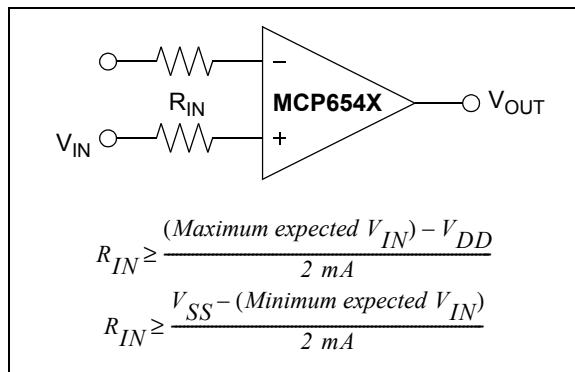
The MCP6541/2/3/4 family of push-pull output comparators are fabricated on Microchip's state-of-the-art CMOS process. They are suitable for a wide range of applications requiring very low power consumption.

### 3.1 Comparator Inputs

The MCP6541/2/3/4 comparator family uses CMOS transistors at the input. They are designed to prevent phase inversion when the input pins exceed the supply voltages. Figure 2-31 shows an input voltage exceeding both supplies with no resulting phase inversion.

The input stage of this family of devices uses two differential input stages in parallel: one operates at low input voltages and the other at high input voltages. With this topology, the input voltage is 0.3V above  $V_{DD}$  and 0.3V below  $V_{SS}$ . Therefore, the input offset voltage is measured at both  $V_{SS} - 0.3V$  and  $V_{DD} + 0.3V$  to ensure proper operation.

The maximum operating input voltages that can be applied are  $V_{SS} - 0.3V$  and  $V_{DD} + 0.3V$ . Voltages on the inputs that exceed this absolute maximum rating can cause excessive current to flow and permanently damage the device. In applications where the input pin exceeds the specified range, external resistors can be used to limit the current below  $\pm 2$  mA, as shown in Figure 3-1.



**FIGURE 3-1:** An input resistor ( $R_{IN}$ ) should be used to limit excessive input current if either of the inputs exceeds the Absolute Maximum specification.

### 3.2 Push-Pull Output

The push-pull output is designed to be compatible with CMOS and TTL logic, while the output transistors are configured to give rail-to-rail output performance. They are driven with circuitry that minimizes any switching current (shoot-through current from supply-to-supply) when the output is transitioned from high-to-low, or from low-to-high (see Figures 2-15, 2-17, 2-32 through 2-36 for more information).

### 3.3 MCP6543 Chip Select ( $\overline{CS}$ )

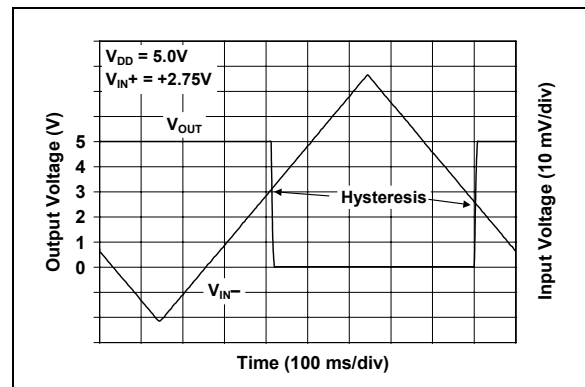
The MCP6543 is a single comparator with chip select ( $\overline{CS}$ ). When  $\overline{CS}$  is pulled high, the total current consumption drops to 20 pA (typ); 1 pA (typ) flows through the  $\overline{CS}$  pin, 1 pA (typ) flows through the output pin and 18 pA (typ) flows through the  $V_{DD}$  pin, as shown in Figure 1-1. When this happens, the comparator output is put into a high-impedance state. By pulling  $\overline{CS}$  low, the comparator is enabled. If the  $\overline{CS}$  pin is left floating, the comparator will not operate properly. Figure 1-1 shows the output voltage and supply current response to a  $\overline{CS}$  pulse.

The internal  $\overline{CS}$  circuitry is designed to minimize glitches when cycling the  $\overline{CS}$  pin. This helps conserve power, which is especially important in battery-powered applications.

### 3.4 Externally-Set Hysteresis

Greater flexibility in selecting hysteresis (or input trip points) is achieved by using external resistors.

Input offset voltage ( $V_{OS}$ ) is the center (average) of the (input-referred) low-high and high-low trip points. Input hysteresis voltage ( $V_{HYST}$ ) is the difference between the same trip points. Hysteresis reduces output chattering when one input is slowly moving past the other and thus reduces dynamic supply current. It also helps in systems where it is best not to cycle between states too frequently (e.g., air conditioner thermostatic control). The MCP6541/2/3/4 family has internally-set hysteresis that is small enough to maintain input offset accuracy ( $< 7$  mV) and large enough to eliminate output chattering caused by the comparator's own input noise voltage (200  $\mu$ Vp-p).

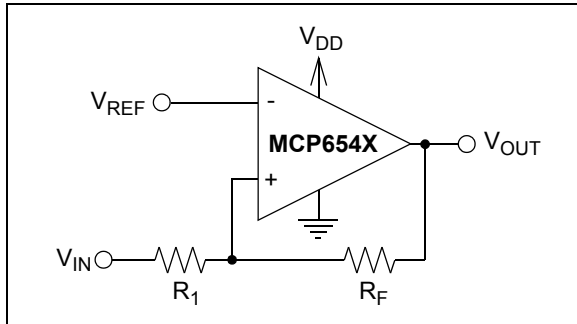


**FIGURE 3-2:** The MCP6541/2/3/4 comparators' internal hysteresis eliminates output chatter caused by input noise voltage.

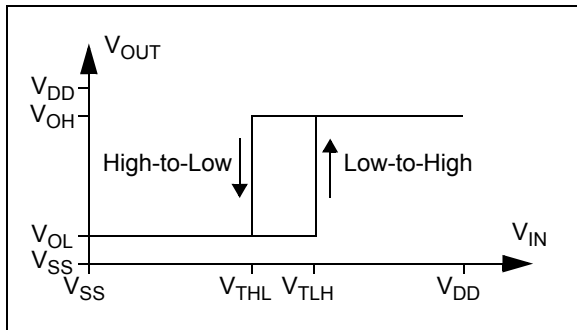
# MCP6541/2/3/4

## 3.4.1 NON-INVERTING CIRCUIT

Figure 3-3 shows a non-inverting circuit for single-supply applications using just two resistors. The resulting hysteresis diagram is shown in Figure 3-4.



**FIGURE 3-3:** Non-inverting circuit with hysteresis for single-supply.



**FIGURE 3-4:** Hysteresis Diagram for the Non-Inverting Circuit.

The trip points for Figures 3-3 and 3-4 are:

### EQUATION

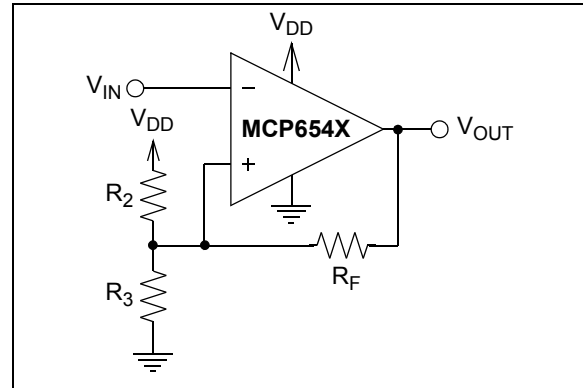
$$V_{TLH} = V_{REF} \left( 1 + \frac{R_1}{R_F} \right) - V_{OL} \left( \frac{R_1}{R_F} \right)$$

$$V_{THL} = V_{REF} \left( 1 + \frac{R_1}{R_F} \right) - V_{OH} \left( \frac{R_1}{R_F} \right)$$

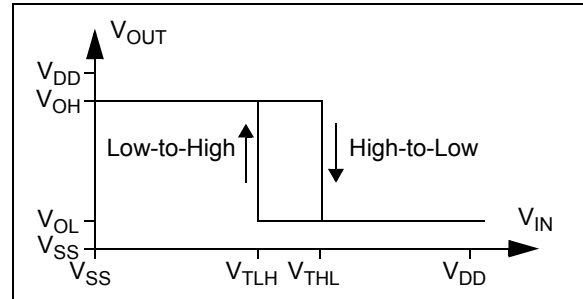
$V_{TLH}$  = trip voltage from low to high  
 $V_{THL}$  = trip voltage from high to low

## 3.4.2 INVERTING CIRCUIT

Figure 3-5 shows an inverting circuit for single-supply using three resistors. The resulting hysteresis diagram is shown in Figure 3-6.

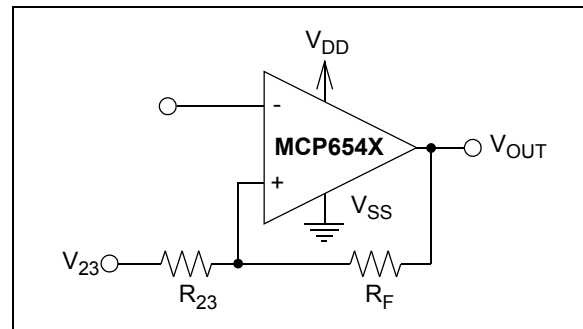


**FIGURE 3-5:** Inverting Circuit With Hysteresis.



**FIGURE 3-6:** Hysteresis Diagram for the Inverting Circuit.

In order to determine the trip voltages ( $V_{THL}$  and  $V_{TLH}$ ) for the circuit shown in Figure 3-5,  $R_2$  and  $R_3$  can be simplified to the Thevenin equivalent circuit with respect to  $V_{DD}$ , as shown in Figure 3-7.



**FIGURE 3-7:** Thevenin Equivalent Circuit.

Where:

$$R_{23} = \frac{R_2 R_3}{R_2 + R_3}$$

$$V_{23} = \frac{R_3}{R_2 + R_3} \times V_{DD}$$

Using this simplified circuit, the trip voltage can be calculated using the following equation:

### EQUATION

$$V_{THL} = V_{OH} \left( \frac{R_{23}}{R_{23} + R_F} \right) + V_{23} \left( \frac{R_F}{R_{23} + R_F} \right)$$

$$V_{TLH} = V_{OL} \left( \frac{R_{23}}{R_{23} + R_F} \right) + V_{23} \left( \frac{R_F}{R_{23} + R_F} \right)$$

$V_{TLH}$  = trip voltage from low to high  
 $V_{THL}$  = trip voltage from high to low

Figure 2-19 and Figure 2-22 can be used to determine typical values for  $V_{OH}$  and  $V_{OL}$ .

### 3.5 Bypass Capacitors

With this family of comparators, the power supply pin ( $V_{DD}$  for single supply) should have a local bypass capacitor (i.e., 0.01  $\mu\text{F}$  to 0.1  $\mu\text{F}$ ) within 2 mm for good edge rate performance.

### 3.6 Capacitive Loads

Reasonable capacitive loads (e.g., logic gates) have little impact on propagation delay (see Figure 2-27). The supply current increases with increasing toggle frequency (Figure 2-30), especially with higher capacitive loads.

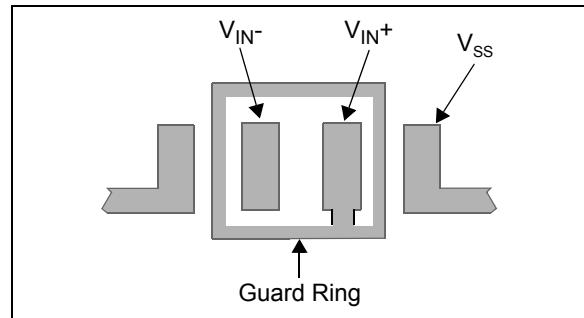
### 3.7 Battery Life

In order to maximize battery life in portable applications, use large resistors and small capacitive loads. Also, avoid toggling the output more than necessary and do not use chip select (CS) to conserve power for short periods of time. Capacitive loads will draw additional power at start-up.

### 3.8 PCB Surface Leakage

In applications where low input bias current is critical, PCB (Printed Circuit Board) surface leakage effects need to be considered. Surface leakage is caused by humidity, dust or other contamination on the board. Under low humidity conditions, a typical resistance between nearby traces is  $10^{12}\Omega$ . A 5V difference would cause 5 pA, if current-to-flow. This is greater than the MCP6541/2/3/4 family's bias current at 25°C (1 pA, typ).

The easiest way to reduce surface leakage is to use a guard ring around sensitive pins (or traces). The guard ring is biased at the same voltage as the sensitive pin. An example of this type of layout is shown in Figure 3-8.



**FIGURE 3-8:** Example Guard Ring Layout for Inverting Circuit.

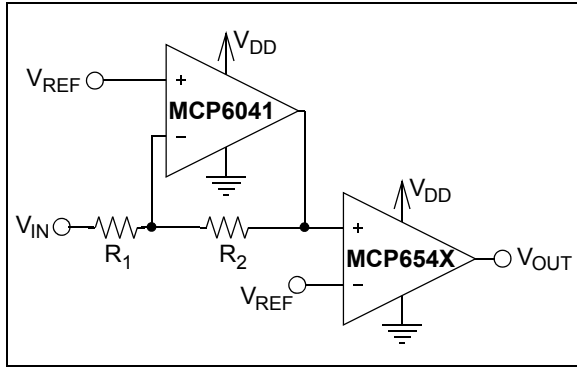
1. Inverting Configuration (Figures 3-5 and 3-8):
  - a. Connect the guard ring to the non-inverting input pin ( $V_{IN+}$ ). This biases the guard ring to the same reference voltage as the comparator (e.g.,  $V_{DD}/2$  or ground).
  - b. Connect the inverting pin ( $V_{IN-}$ ) to the input pad without touching the guard ring.
2. Non-inverting Configuration (Figure 3-3):
  - a. Connect the non-inverting pin ( $V_{IN+}$ ) to the input pad without touching the guard ring.
  - b. Connect the guard ring to the inverting input pin ( $V_{IN-}$ ).

# MCP6541/2/3/4

## 3.9 Typical Applications

### 3.9.1 PRECISE COMPARATOR

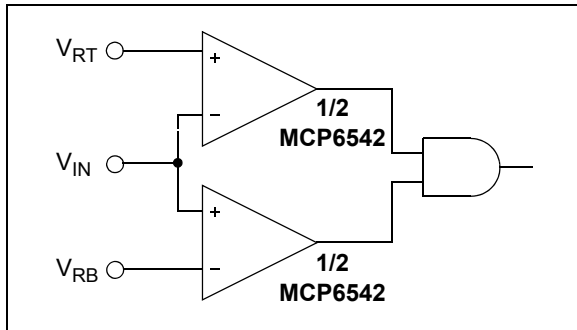
Some applications require higher DC precision. An easy way to solve this problem is to use an amplifier (such as the MCP6041) to gain-up the input signal before it reaches the comparator. Figure 3-9 shows an example of this approach.



**FIGURE 3-9:** *Precise Inverting Comparator.*

### 3.9.2 WINDOWED COMPARATOR

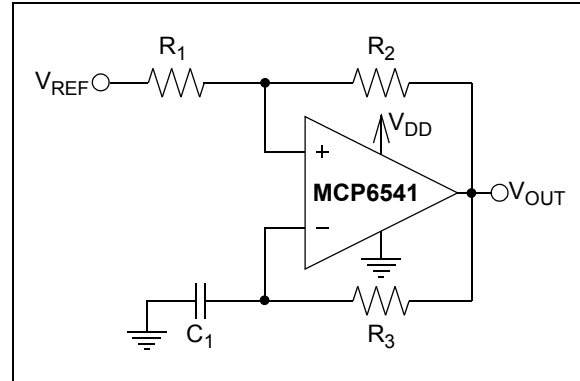
Figure 3-10 shows one approach to designing a windowed comparator. The AND gate produces a logic '1' when the input voltage is between  $V_{RB}$  and  $V_{RT}$  (where  $V_{RT} > V_{RB}$ ).



**FIGURE 3-10:** *Windowed Comparator.*

### 3.9.3 BISTABLE MULTI-VIBRATOR

A simple bistable multi-vibrator design is shown in Figure 3-11.  $V_{REF}$  needs to be between the power supplies ( $V_{SS} = GND$  and  $V_{DD}$ ) to achieve oscillation. The output duty cycle changes with  $V_{REF}$ .

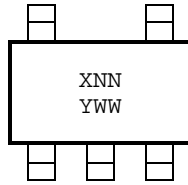


**FIGURE 3-11:** *Bistable Multi-vibrator.*

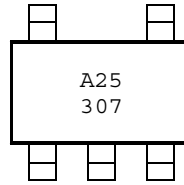
## 4.0 PACKAGING INFORMATION

### 4.1 Package Marking Information

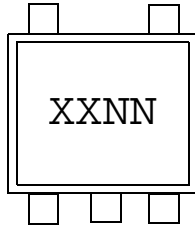
5-Lead SC-70 (MCP6541)



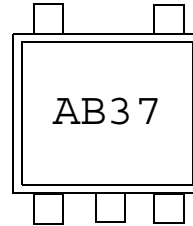
Example:



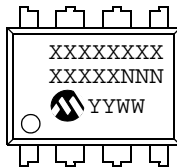
5-Lead SOT-23 (MCP6541)



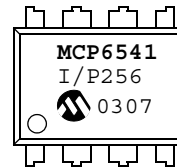
Example:



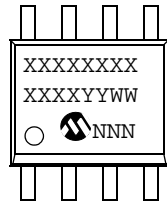
8-Lead PDIP (300 mil)



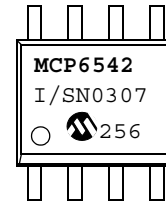
Example:



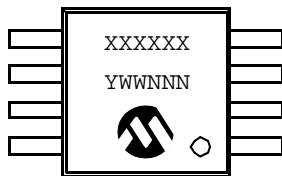
8-Lead SOIC (150 mil)



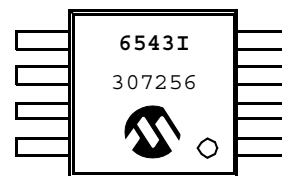
Example:



8-Lead MSOP



Example:



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

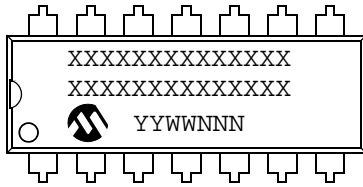
**Note:** In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line thus limiting the number of available characters for customer specific information.

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

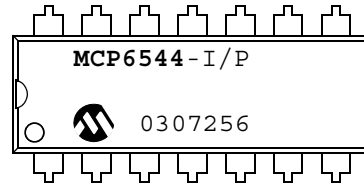
# MCP6541/2/3/4

## Package Marking Information (Continued)

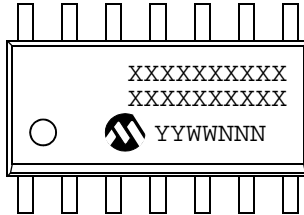
14-Lead PDIP (300 mil) (MCP6544)



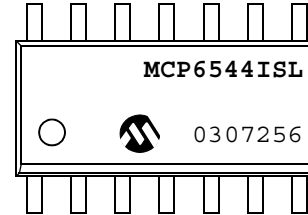
Example:



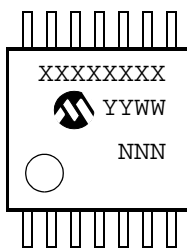
14-Lead SOIC (150 mil) (MCP6544)



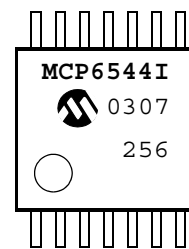
Example:



14-Lead TSSOP (MCP6544)

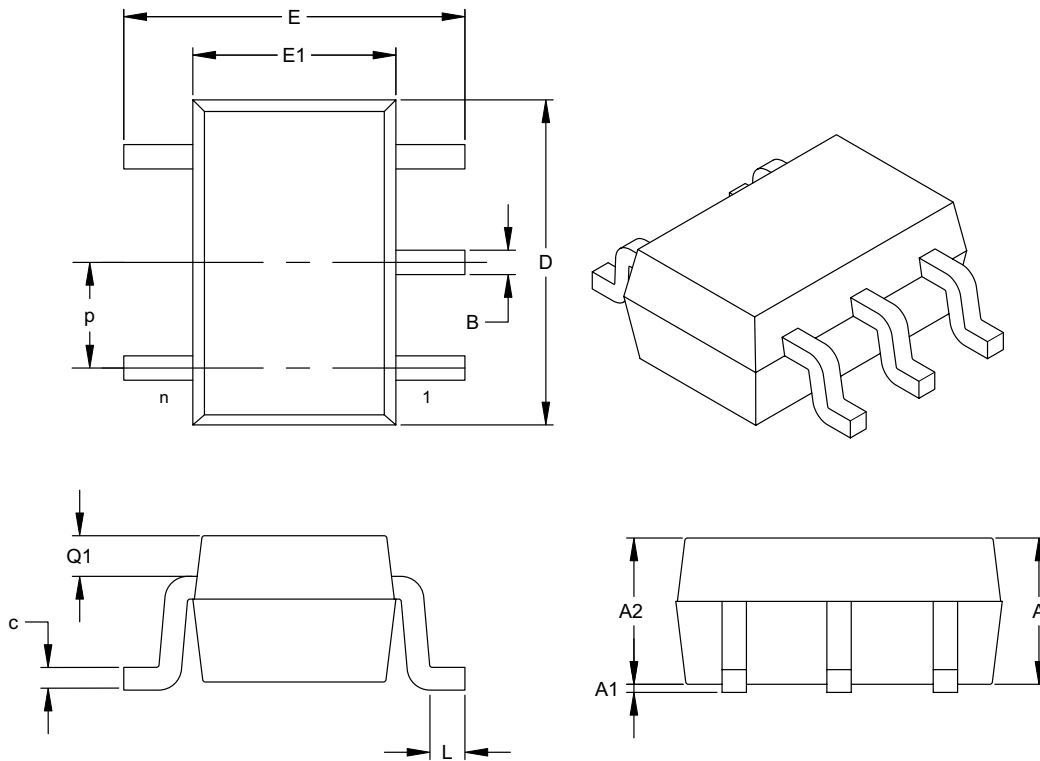


Example:





## 5-Lead Plastic Package (LT) (SC-70)



Dimension	Units	INCHES			MILLIMETERS*		
		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n	5			5		
Pitch	p	.026 (BSC)			0.65 (BSC)		
Overall Height	A	.031		.043	0.80		1.10
Molded Package Thickness	A2	.031		.039	0.80		1.00
Standoff	A1	.000		.004	0.00		0.10
Overall Width	E	.071		.094	1.80		2.40
Molded Package Width	E1	.045		.053	1.15		1.35
Overall Length	D	.071		.087	1.80		2.20
Foot Length	L	.004		.012	0.10		0.30
Top of Molded Pkg to Lead Shoulder	Q1	.004		.016	0.10		0.40
Lead Thickness	c	.004		.007	0.10		0.18
Lead Width	B	.006		.012	0.15		0.30

\*Controlling Parameter

Notes:

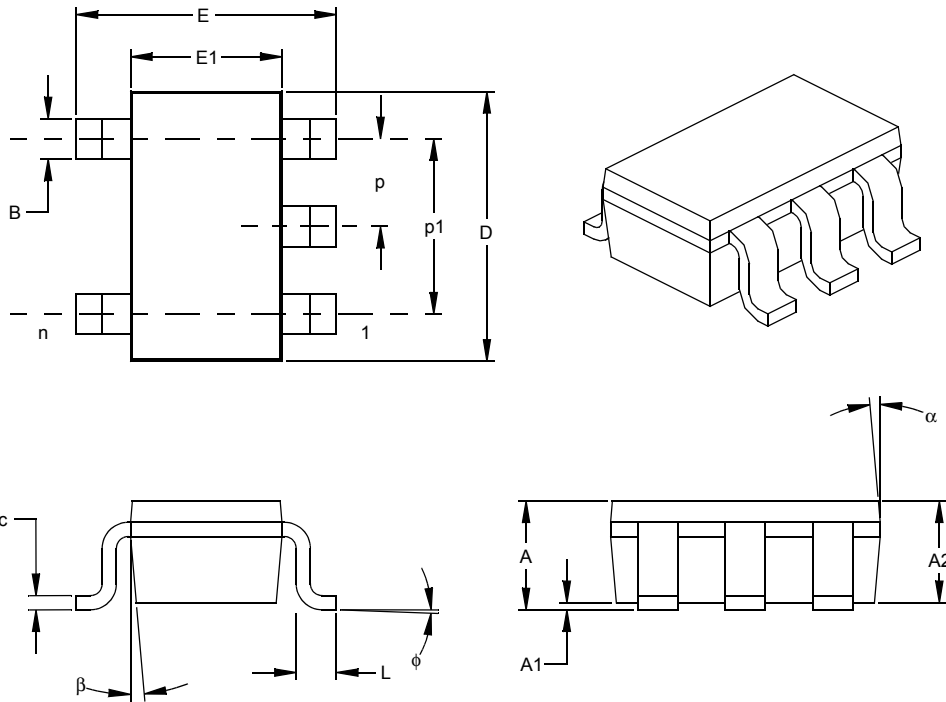
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .005" (0.127mm) per side.

JEITA (EIAJ) Standard: SC-70

Drawing No. C04-061

# MCP6541/2/3/4

## 5-Lead Plastic Small Outline Transistor (OT) (SOT23)



Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		5			5	
Pitch	p		.038			0.95	
Outside lead pitch (basic)	p1		.075			1.90	
Overall Height	A	.035	.046	.057	0.90	1.18	1.45
Molded Package Thickness	A2	.035	.043	.051	0.90	1.10	1.30
Standoff §	A1	.000	.003	.006	0.00	0.08	0.15
Overall Width	E	.102	.110	.118	2.60	2.80	3.00
Molded Package Width	E1	.059	.064	.069	1.50	1.63	1.75
Overall Length	D	.110	.116	.122	2.80	2.95	3.10
Foot Length	L	.014	.018	.022	0.35	0.45	0.55
Foot Angle	φ	0	5	10	0	5	10
Lead Thickness	c	.004	.006	.008	0.09	0.15	0.20
Lead Width	B	.014	.017	.020	0.35	0.43	0.50
Mold Draft Angle Top	α	0	5	10	0	5	10
Mold Draft Angle Bottom	β	0	5	10	0	5	10

\* Controlling Parameter

§ Significant Characteristic

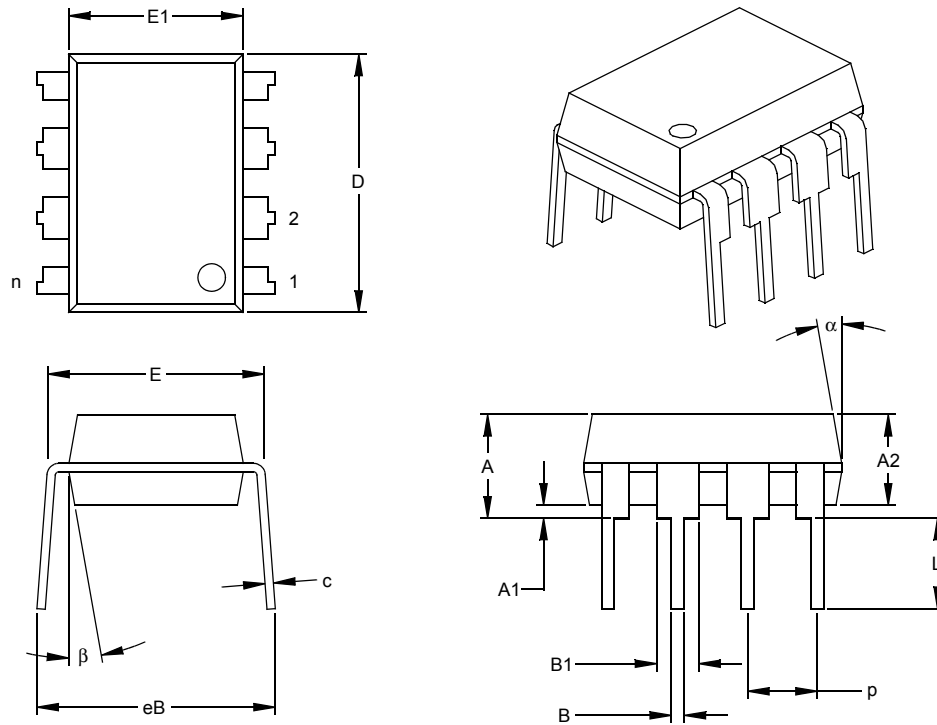
Notes:

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

JEDEC Equivalent: MO-178

Drawing No. C04-091

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



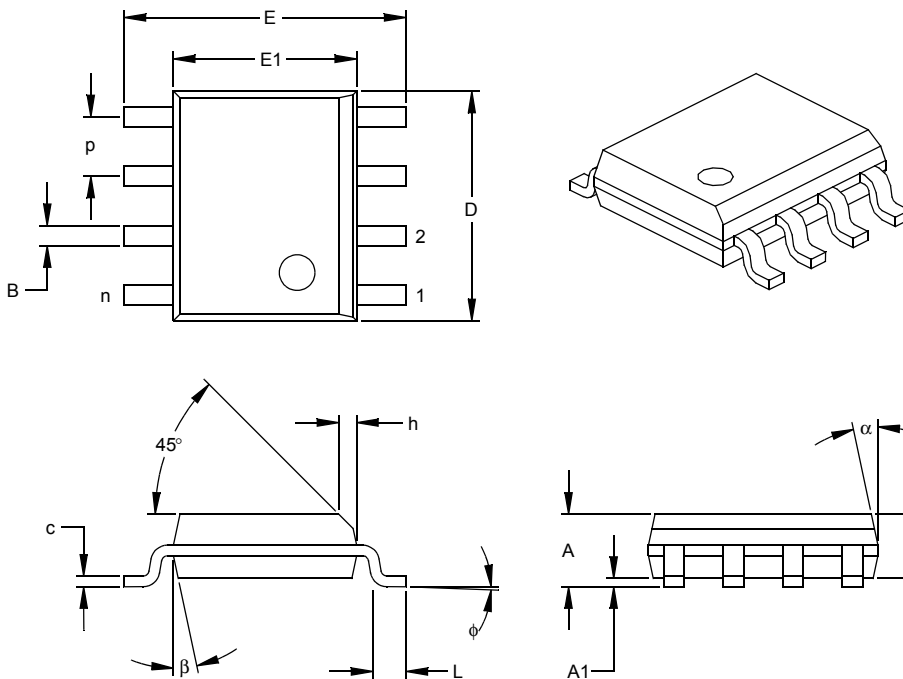
Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		8			8	
Pitch	p		.100			2.54	
Top to Seating Plane	A	.140	.155	.170	3.56	3.94	4.32
Molded Package Thickness	A2	.115	.130	.145	2.92	3.30	3.68
Base to Seating Plane	A1	.015			0.38		
Shoulder to Shoulder Width	E	.300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

\* Controlling Parameter  
 § Significant Characteristic

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

# MCP6541/2/3/4

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



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

\* Controlling Parameter

§ Significant Characteristic

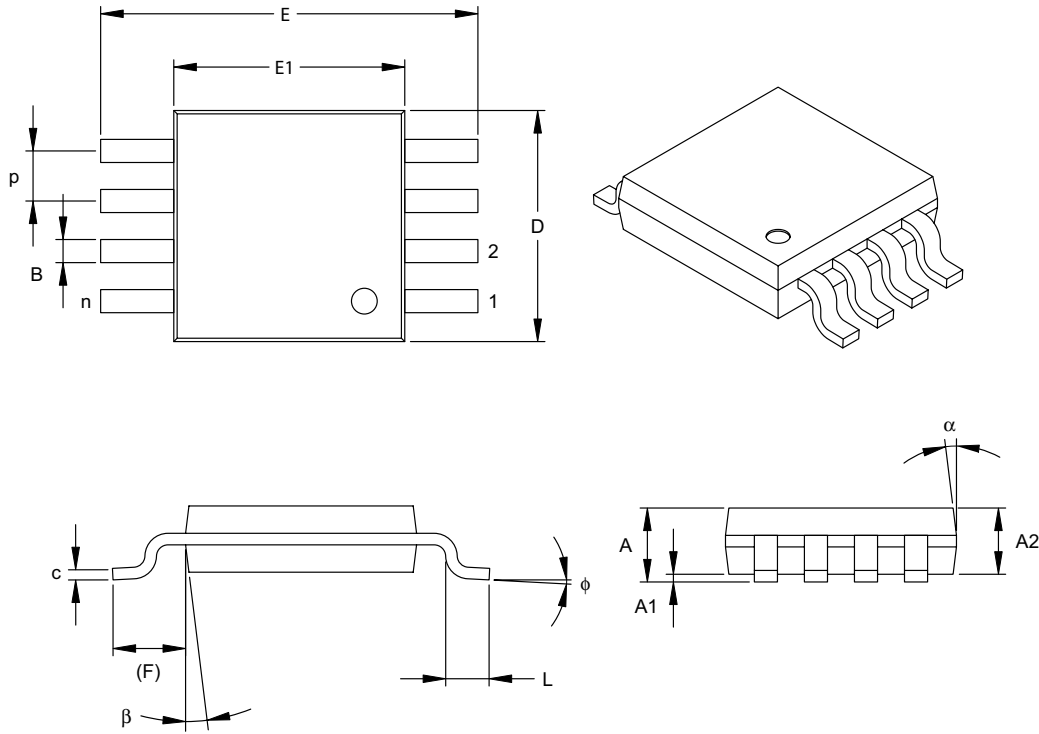
**Notes:**

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

JEDEC Equivalent: MS-012

Drawing No. C04-057

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



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

\*Controlling Parameter

Notes:

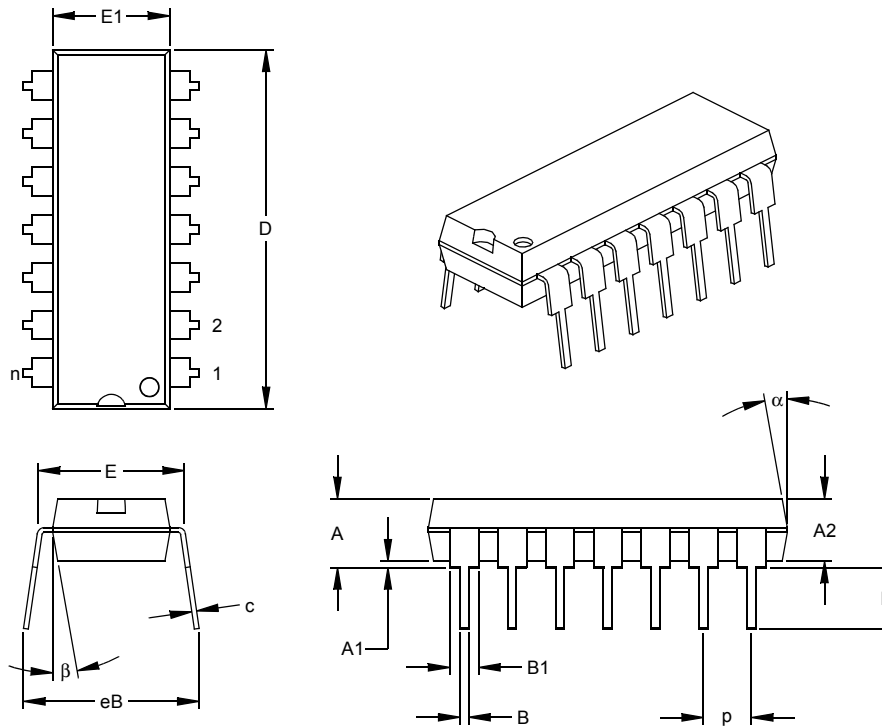
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.

JEDEC Equivalent: MO-187

Drawing No. C04-111

# MCP6541/2/3/4

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



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

\* Controlling Parameter

§ Significant Characteristic

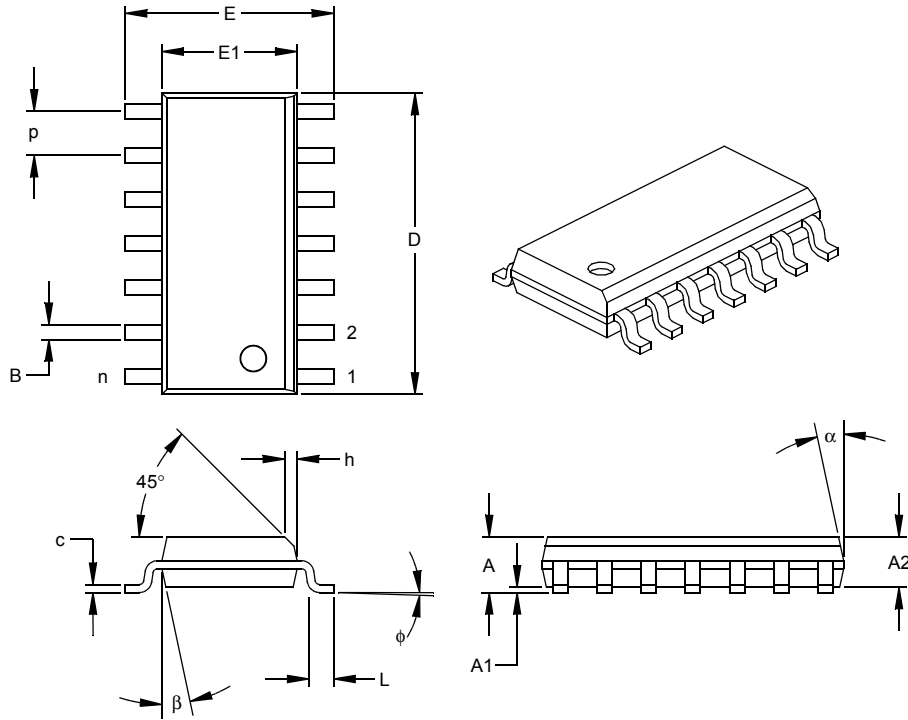
Notes:

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

JEDEC Equivalent: MS-001

Drawing No. C04-005

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



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

\* Controlling Parameter  
 § Significant Characteristic

Notes:

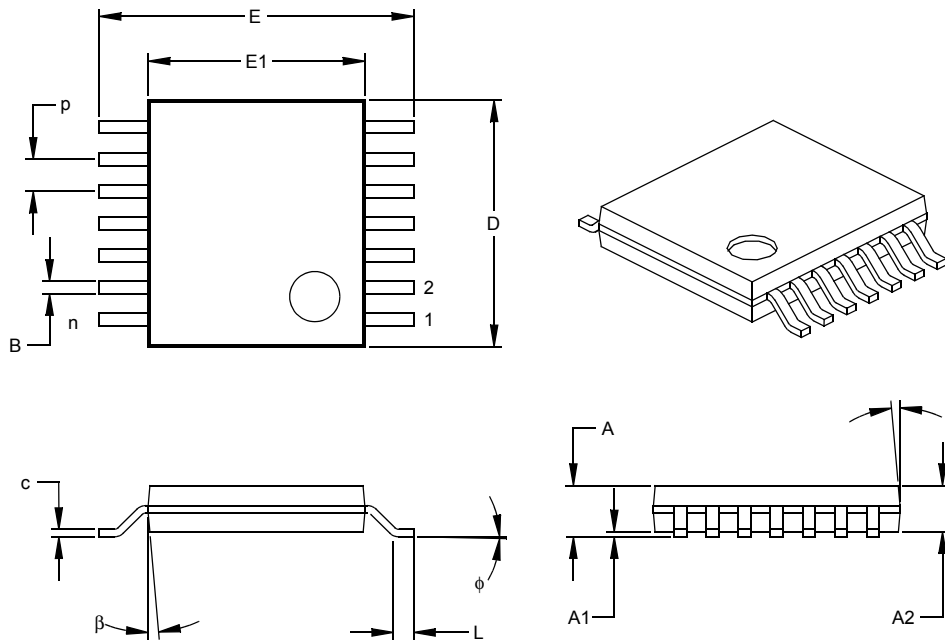
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.

JEDEC Equivalent: MS-012

Drawing No. C04-065

# MCP6541/2/3/4

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



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

\* Controlling Parameter

§ Significant Characteristic

### Notes:

Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .005" (0.127mm) per side.

JEDEC Equivalent: MO-153

Drawing No. C04-087



## 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>X</u>	<u>XX</u>	<b>Examples:</b>
Device	Temperature Range	Package	
<p>Device:</p> <p>MCP6541: Single Comparator  MCP6541T: Single Comparator (Tape and Reel) (SC-70, SOT-23, SOIC, MSOP)  MCP6541RT: Single Comparator (Rotated - Tape and Reel) (SOT-23 only)  MCP6542: Dual Comparator  MCP6542T: Dual Comparator (Tape and Reel for SOIC and MSOP)  MCP6543: Single Comparator with CS  MCP6543T: Single Comparator with CS (Tape and Reel for SOIC and MSOP)  MCP6544: Quad Comparator  MCP6544T: Quad Comparator (Tape and Reel for SOIC and TSSOP)</p> <p>Temperature Range: I = -40°C to +85°C</p> <p>Package:</p> <p>LT = Plastic Package (SC-70), 5-lead  OT = Plastic Small Outline Transistor (SOT-23), 5-lead  MS = Plastic MSOP, 8-lead  P = Plastic DIP (300 mil Body), 8-lead, 14-lead  SN = Plastic SOIC (150 mil Body), 8-lead  SL = Plastic SOIC (150 mil Body), 14-lead (MCP6544)  ST = Plastic TSSOP (4.4mm Body), 14-lead (MCP6544)</p>			<p>a) MCP6541T-I/LT: Tape and Reel, Industrial Temperature, 5LD SC-70.</p> <p>b) MCP6541T-I/OT: Tape and Reel, Industrial Temperature, 5LD SOT-23.</p> <p>c) MCP6541-I/P: Industrial Temperature, 8LD PDIP.</p> <p>d) MCP6541RT-I/OT: Tape and Reel, Industrial Temperature, 5LD SOT23.</p> <p>a) MCP6542-I/MS: Industrial Temperature, 8LD MSOP.</p> <p>b) MCP6542T-I/MS: Tape and Reel, Industrial Temperature, 8LD MSOP.</p> <p>c) MCP6542-I/P: Industrial Temperature, 8LD PDIP.</p> <p>a) MCP6543-I/SN: Industrial Temperature, 8LD SOIC.</p> <p>b) MCP6543T-I/SN: Tape and Reel, Industrial Temperature, 8LD SOIC.</p> <p>c) MCP6543-I/P: Industrial Temperature, 8LD PDIP.</p> <p>a) MCP6544T-I/SL: Tape and Reel, Industrial Temperature, 14LD SOIC.</p> <p>b) MCP6544T-I/SL: Tape and Reel, Industrial Temperature, 14LD SOIC.</p> <p>c) MCP6544-I/P: Industrial Temperature, 14LD PDIP.</p>

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# MCP6541/2/3/4

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NOTES:

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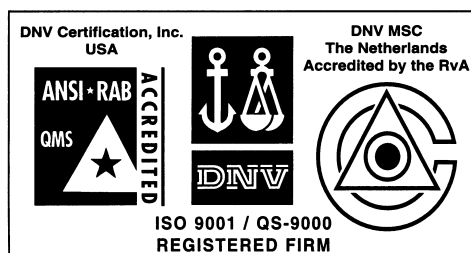
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