Push-Pull Output Sub-Microamp Comparators

Description

The Microchip Technology Inc. HT6541/2/3/4 family of comparators is offered in single (HT6541), single with chip select (HT6543), dual (HT6542) and quad (HT6544) 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 HT6541/2/3/4 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 µA/ comparator of quiescent current.The related HT6546/7/8/9 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.

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 µs (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 HT6543
- Low Switching Current
- Internal Hysteresis: 3.3 mV (typ.)
- Industrial Temperature: -40°C to +85°C

Typical Applications

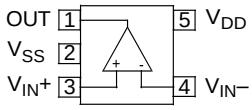
- Laptop Computers
- Mobile Phones
- Metering Systems
- Hand-held Electronics
- RC Timers
- Alarm and Monitoring Circuits
- Windowed Comparators
- Multi-vibrators

Related Devices

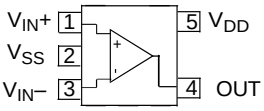
- Open-Drain Output: HT6546/7/8/9

PIN CONFIGURATIONS (Top View)

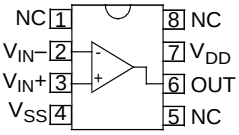
HT6541A
SOT-23-5



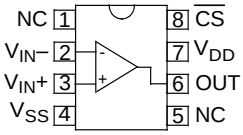
HT6541B
SOT-23-5



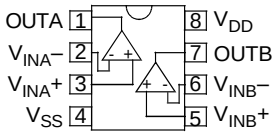
HT6541A
PDIP, SOIC, MSOP



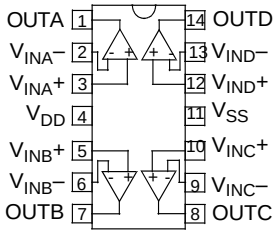
HT6543A
PDIP, SOIC, MSOP



HT6542A
PDIP, SOIC, MSOP



HT6544A
PDIP, SOIC, TSSOP



1.1 ELECTRICAL CHARACTERISTICS

1.2 Absolute Maximum Ratings †

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

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

PIN FUNCTION TABLE

NAME	FUNCTION
V_{IN}+, V_{INA}+, V_{INB}+, V_{INC}+, V_{IND}+	Non-Inverting Inputs
V_{IN}–, V_{INA}–, V_{INB}–, V_{INC}–, V_{IND}–	Inverting Inputs
V_{DD}	Positive Power Supply
V_{SS}	Negative Power Supply
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°C, V_{IN}+ = V_{DD}/2, V_{IN}– = V_{SS}, and R_L = 100 kΩ to V_{DD}/2 (Refer to Figure 1-3).

Parameters	Sym	Min	Typ	Max	Units	Conditions
Power Supply						
Supply Voltage	V_{DD}	1.6	—	5.5	V	
Quiescent Current per comparator	I_Q	0.3	0.6	1.0	µA	I_{OUT} = 0
Input						
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	±1.5	+7.0	mV	V_{CM} = V_{SS} **(Note 1)**
Drift with Temperature	$\Delta V_{OS}/\Delta T_A$	—	±3	—	µV/°C	T_A = -40°C to +85°C, V_{CM} = V_{SS}
Input Hysteresis Voltage	V_{HYST}	1.5	3.3	6.5	mV	V_{CM} = V_{SS} **(Note 1)**
Drift with Temperature	$\Delta V_{HYST}/\Delta T_A$	—	10	—	µV/°C	T_A = -40°C to +25°C, V_{CM} = V_{SS}
Drift with Temperature	$\Delta V_{HYST}/\Delta T_A$	—	5	—	µV/°C	T_A = +25°C to +85°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°C to +85°C, V_{CM} = V_{SS} **(Note 3)**
Input Offset Current	I_{OS}	—	±1	—	pA	V_{CM} = V_{SS}
Common Mode Input Impedance	Z_{CM}	—	10^{13}||4	—	Ω||pF	
Differential Input Impedance	Z_{DIFF}	—	10^{13}||2	—	Ω||pF	
Push-Pull Output						
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}	—	±50	—	mA	(**Note 2**)

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°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	—	µs	
Fall Time	t_F	—	0.85	—	µs	
Propagation Delay (High-to-Low)	t_{PHL}	—	4	8	µs	
Propagation Delay (Low-to-High)	t_{PLH}	—	4	8	µs	
Propagation Delay Skew	t_{PDS}	—	±0.2	—	µs	**(Note 1)**
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	—	μV_{P-P}	10 Hz to 100 kHz

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

SPECIFICATIONS FOR HT6543 CHIP-SELECT

Electrical Specifications: Unless otherwise indicated, V_{DD} = +1.6V to +5.5V, V_{SS} = GND, T_A = +25°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
CS Low Specifications						
$\overline{CS}$ 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}
CS High Specifications						
$\overline{CS}$ 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}
CS Dynamic Specifications						
$\overline{CS}$ 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	—	µs	$\overline{CS}$ = 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

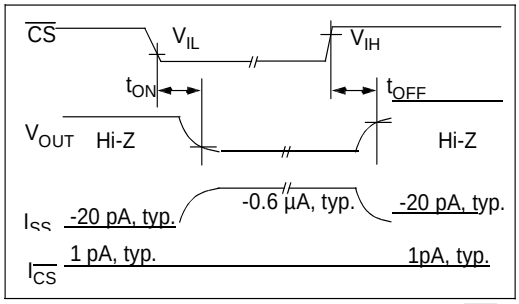


FIGURE 1-1: *Timing Diagram for the $\overline{CS}$ Pin on the HT6543.*

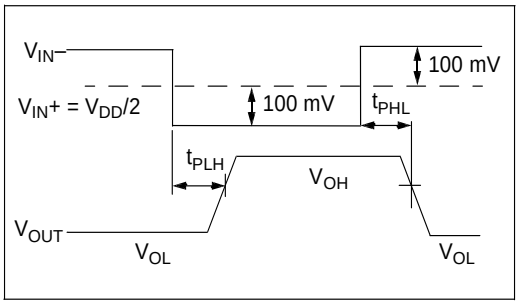


FIGURE 1-2: *Propagation Delay Timing Diagram.*

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**
Temperature Ranges						
Specified Temperature Range	T_A	-40	—	+85	°C	
Operating Temperature Range	T_A	-40	—	+125	°C	**Note**
Storage Temperature Range	T_A	-65	—	+150	°C	
Thermal Package Resistances						
Thermal Resistance, 5L-SC-70	θ_{JA}	—	331	—	°C/W	
Thermal Resistance, 5L-SOT-23	θ_{JA}	—	256	—	°C/W	
Thermal Resistance, 8L-PDIP	θ_{JA}	—	85	—	°C/W	
Thermal Resistance, 8L-SOIC	θ_{JA}	—	163	—	°C/W	
Thermal Resistance, 8L-MSOP	θ_{JA}	—	206	—	°C/W	
Thermal Resistance, 14L-PDIP	θ_{JA}	—	70	—	°C/W	
Thermal Resistance, 14L-SOIC	θ_{JA}	—	120	—	°C/W	
Thermal Resistance, 14L-TSSOP	θ_{JA}	—	100	—	°C/W	

Note: The HT6541/2/3/4 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°C.

1.3 Test Circuit Configuration

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

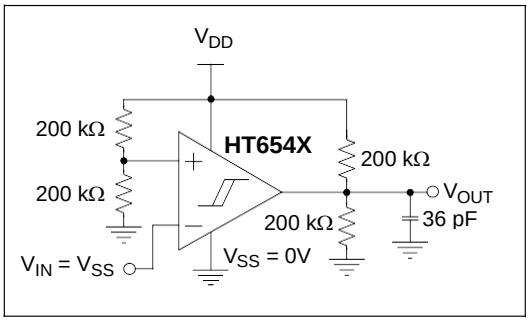


FIGURE 1-3: *AC and DC Test Circuit for the Push-Pull Output Comparators.*

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°C, V_{IN}+ = V_{DD}/2, V_{IN}– = GND, R_L = 100 kΩ to V_{DD}/2, and C_L = 36 pF.

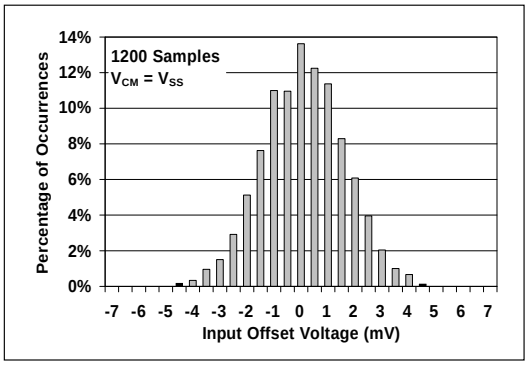


FIGURE 2-1: *Input Offset Voltage Histogram at V_{CM} = V_{SS}.*

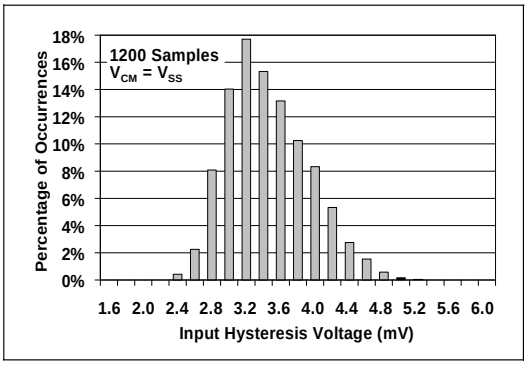


FIGURE 2-4: *Input Hysteresis Voltage Histogram at V_{CM} = V_{SS}.*

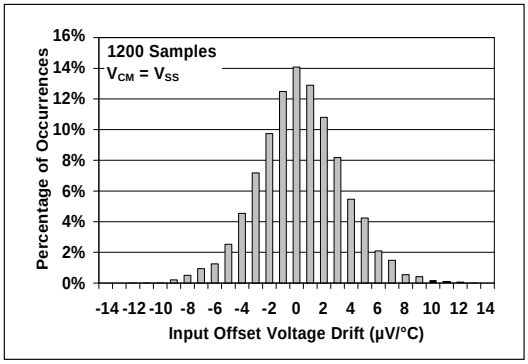


FIGURE 2-2: *Input Offset Voltage Drift Histogram at V_{CM} = V_{SS}.*

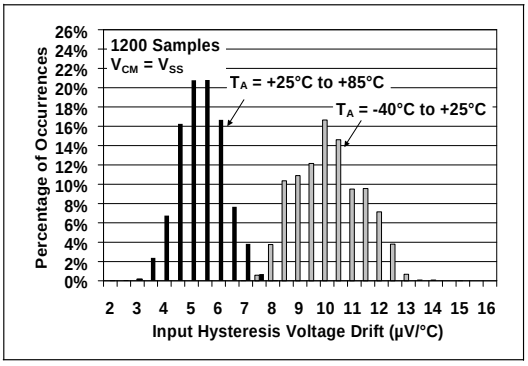


FIGURE 2-5: *Input Hysteresis Voltage Drift Histogram.*

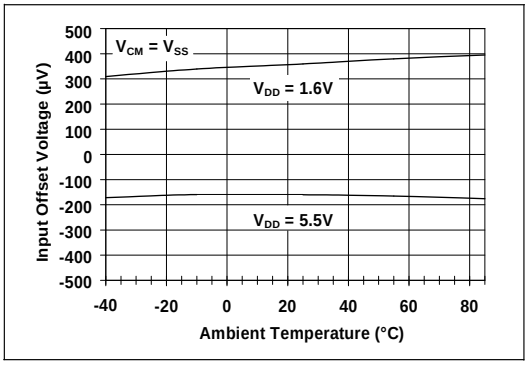


FIGURE 2-3: *Input Offset Voltage vs. Ambient Temperature at V_{CM} = V_{SS}.*

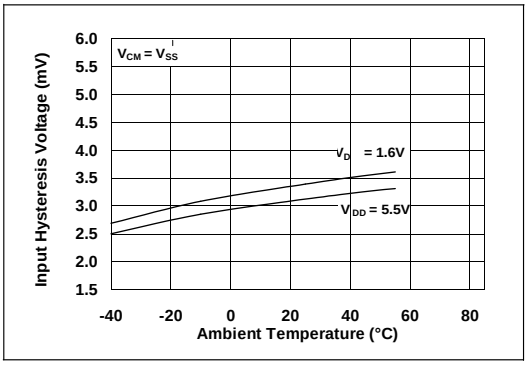


FIGURE 2-6: *Input Hysteresis Voltage vs. Ambient Temperature at V_{CM} = V_{SS}.*

Note: Unless otherwise indicated, V_{DD} = +1.6V to +5.5V, V_{SS} = GND, T_A = +25°C, V_{IN}+ = V_{DD}/2, V_{IN}– = GND, R_L = 100 kΩ to V_{DD}/2, and C_L = 36 pF.

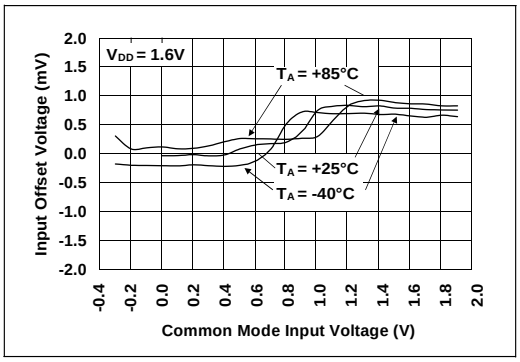


FIGURE 2-7: *Input Offset Voltage vs. Common Mode Input Voltage at V_{DD} = 1.6V.*

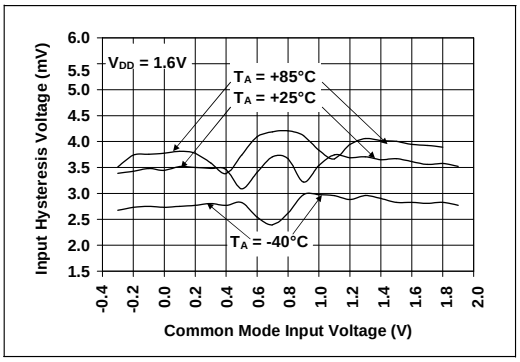


FIGURE 2-10: *Input Hysteresis Voltage vs. Common Mode Input Voltage at V_{DD} = 1.6V.*

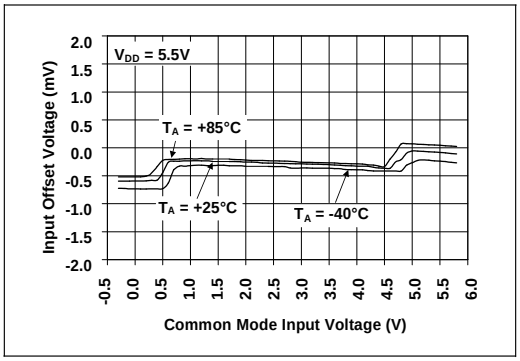


FIGURE 2-8: *Input Offset Voltage vs. Common Mode Input Voltage at V_{DD} = 5.5V.*

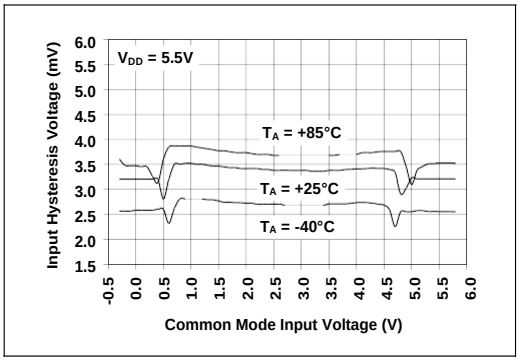


FIGURE 2-11: *Input Hysteresis Voltage vs. Common Mode Input Voltage at V_{DD} = 5.5V.*

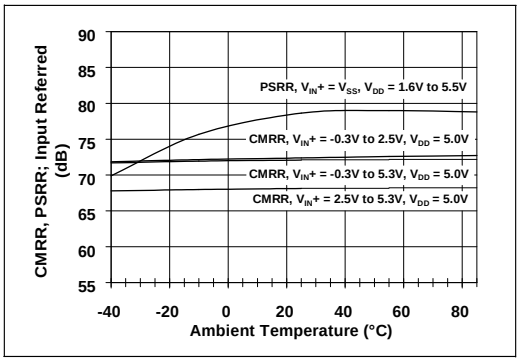


FIGURE 2-9: *CMRR, PSRR vs. Ambient Temperature at V_{CM} = V_{SS}.*

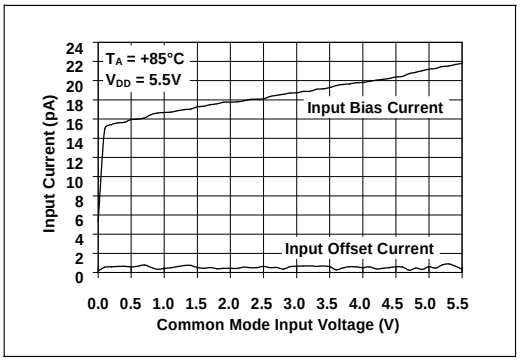


FIGURE 2-12: *Input Bias Current, Input Offset Current vs. Common Mode Voltage at +85°C.*

Note: Unless otherwise indicated, V_{DD} = +1.6V to +5.5V, V_{SS} = GND, T_A = +25°C, V_{IN}+ = V_{DD}/2, V_{IN}– = GND, R_L = 100 kΩ to V_{DD}/2, and C_L = 36 pF.

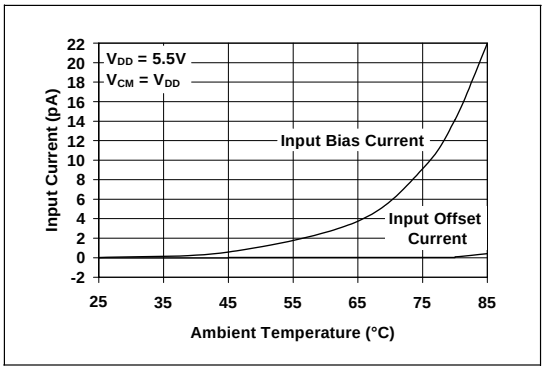


FIGURE 2-13: *Input Bias Current, Input Offset Current vs. Ambient Temperature.*

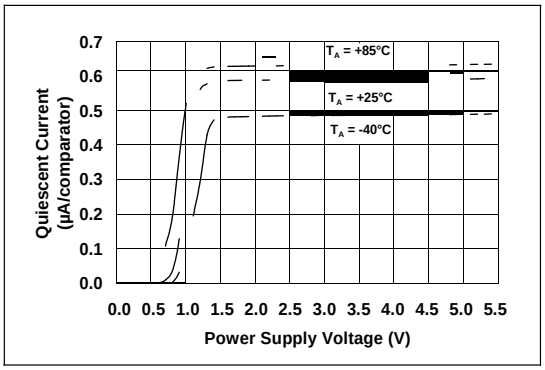


FIGURE 2-16: *Quiescent Current vs. Power Supply Voltage.*

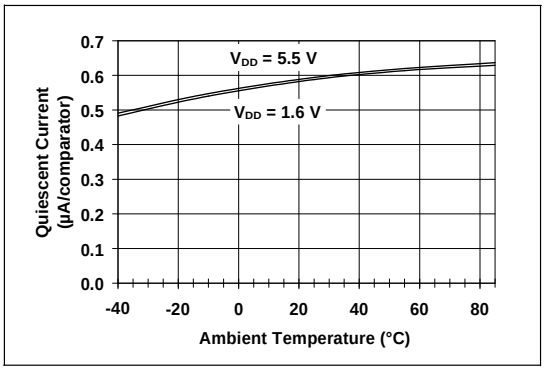


FIGURE 2-14: *Quiescent Current vs. Ambient Temperature.*

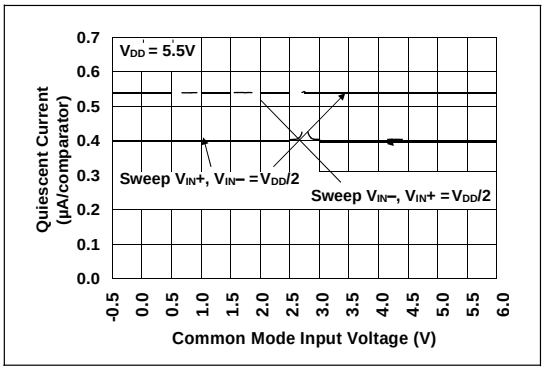


FIGURE 2-17: *Quiescent Current vs. Common Mode Input Voltage at V_{DD} = 5V.*

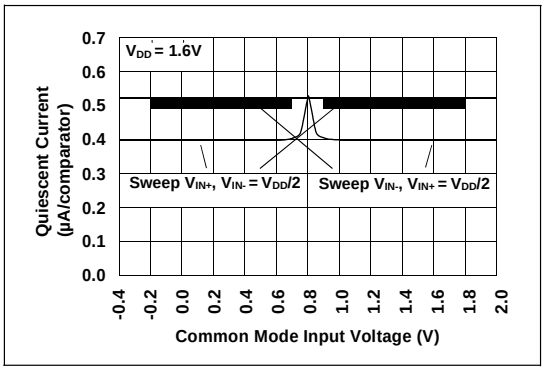


FIGURE 2-15: *Quiescent Current vs. Common Mode Input Voltage at V_{DD} = 1.6V.*

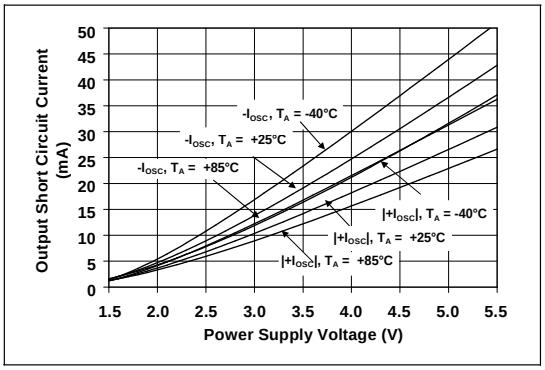


FIGURE 2-18: *Output Short-Circuit Current vs. Power Supply Voltage.*

Note: Unless otherwise indicated, V_{DD} = +1.6V to +5.5V, V_{SS} = GND, T_A = +25°C, V_{IN}+ = V_{DD}/2, V_{IN}– = GND, R_L = 100 kΩ to V_{DD}/2, and C_L = 36 pF.

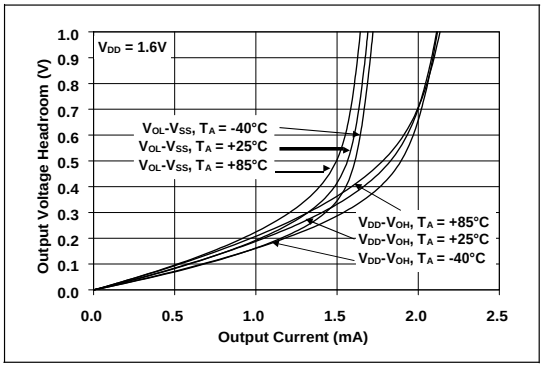


FIGURE 2-19: *Output Voltage Headroom vs. Output Current at V_{DD} = 1.6V.*

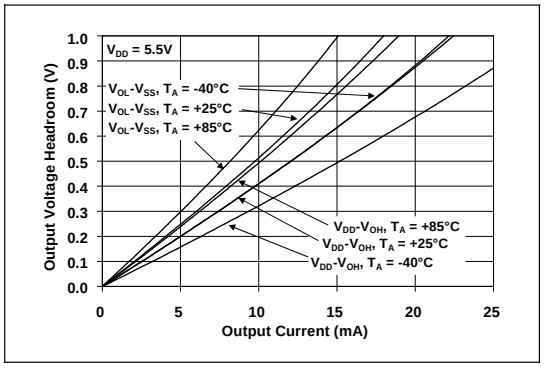


FIGURE 2-22: *Output Voltage Headroom vs. Output Current at V_{DD} = 5.5V.*

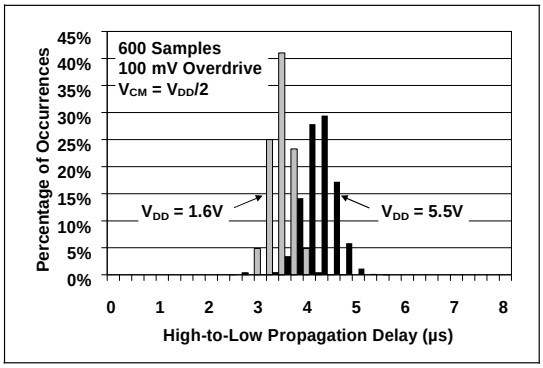


FIGURE 2-20: *High-to-Low Propagation Delay Histogram.*

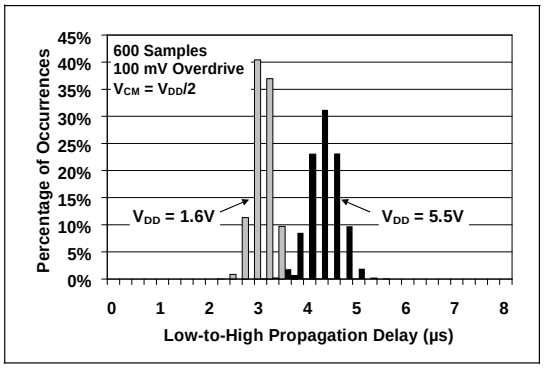


FIGURE 2-23: *Low-to-High Propagation Delay Histogram.*

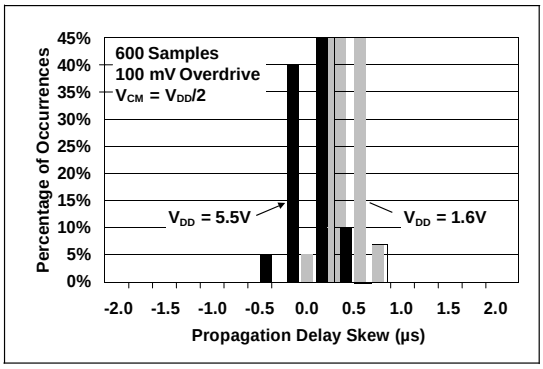


FIGURE 2-21: *Propagation Delay Skew Histogram.*

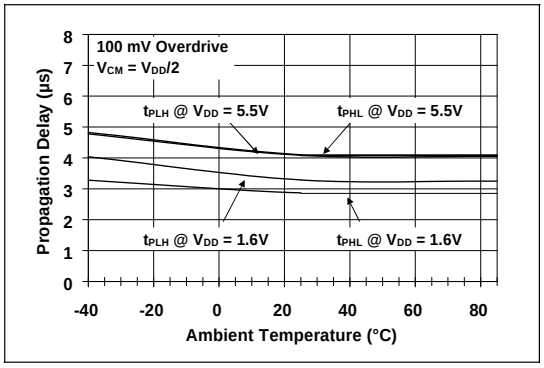


FIGURE 2-24: *Propagation Delay vs. Ambient Temperature.*

Note: Unless otherwise indicated, V_{DD} = +1.6V to +5.5V, V_{SS} = GND, T_A = +25°C, V_{IN}+ = V_{DD}/2, V_{IN}– = GND, R_L = 100 kΩ to V_{DD}/2, and C_L = 36 pF.

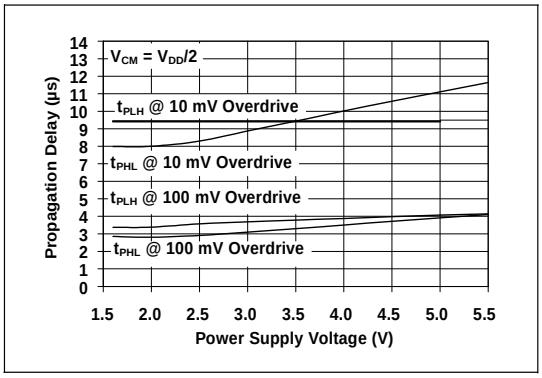


FIGURE 2-25: *Propagation Delay vs. Power Supply Voltage.*

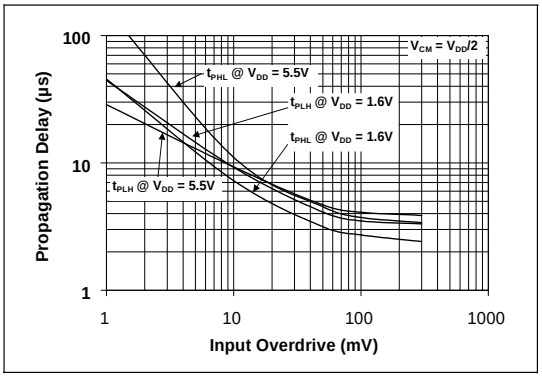


FIGURE 2-28: *Propagation Delay vs. Input Overdrive.*

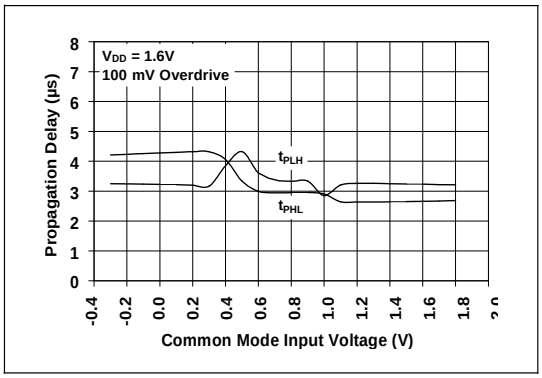


FIGURE 2-26: *Propagation Delay vs. Common Mode Input Voltage at V_{DD} = 1.6V.*

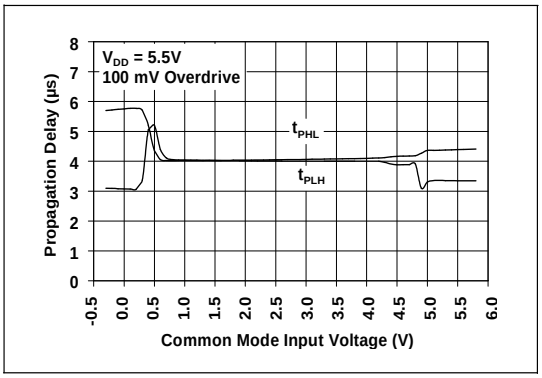


FIGURE 2-29: *Propagation Delay vs. Common Mode Input Voltage at V_{DD} = 5.5V.*

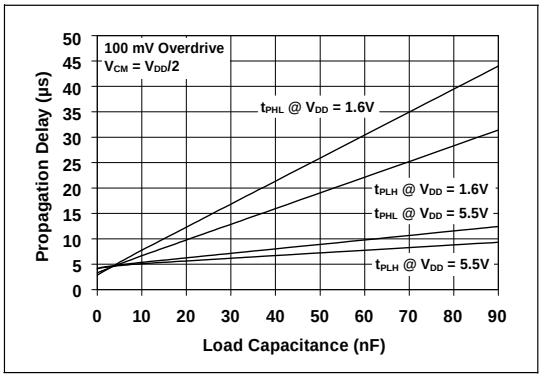


FIGURE 2-27: *Propagation Delay vs. Load Capacitance.*

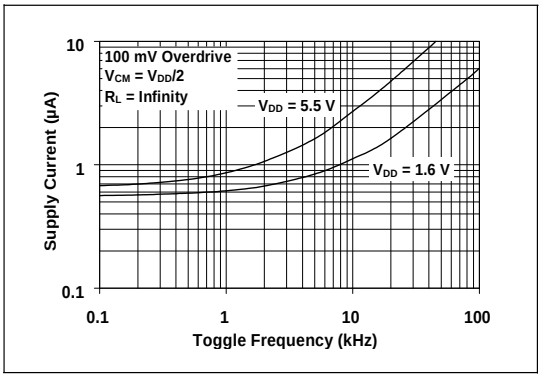


FIGURE 2-30: *Supply Current vs. Toggle Frequency.*

Note: Unless otherwise indicated, V_{DD} = +1.6V to +5.5V, V_{SS} = GND, T_A = +25°C, V_{IN}+ = V_{DD}/2, V_{IN}– = GND, R_L = 100 kΩ to V_{DD}/2, and C_L = 36 pF.

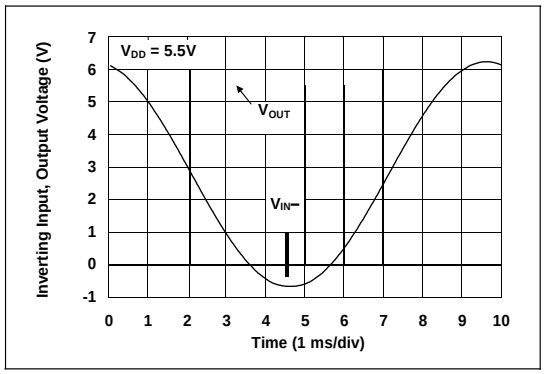


FIGURE 2-31: *The HT6541/2/3/4 comparators show no phase reversal.*

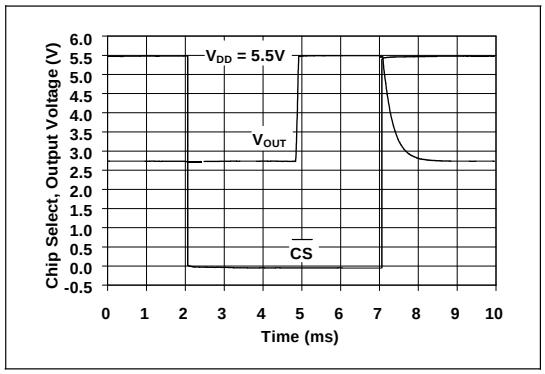


FIGURE 2-34: *Chip-Select ($\overline{CS}$) Step Response (HT6543 only).*

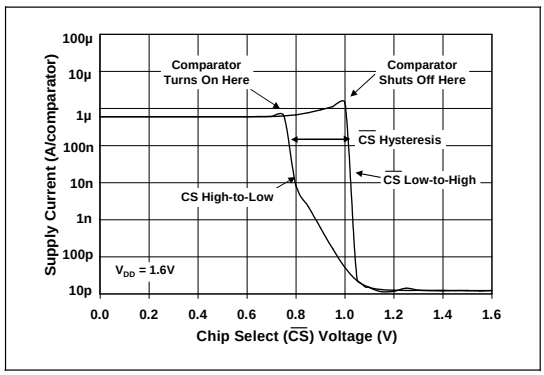


FIGURE 2-32: *Supply Current (shoot through current) vs. Chip-Select (CS) Voltage at V_{DD} = 1.6V (HT6543 only).*

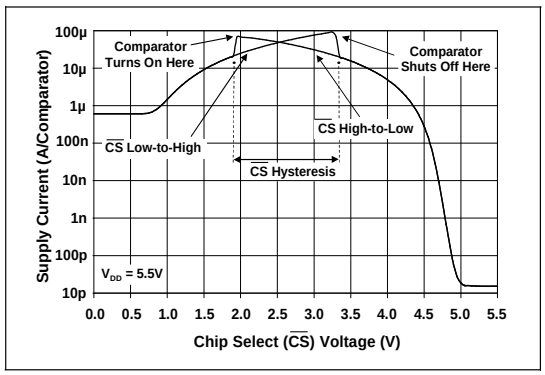


FIGURE 2-35: *Supply Current (shoot through current) vs. Chip-Select (CS) Voltage at V_{DD} = 5.5V (HT6543 only).*

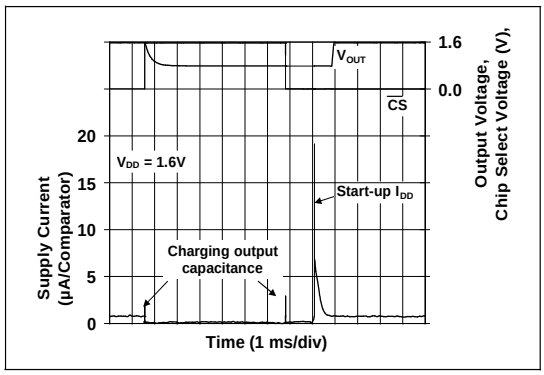


FIGURE 2-33: *Supply Current (charging current) vs. Chip-Select (CS) pulse at V_{DD} = 1.6V (HT6543 only).*

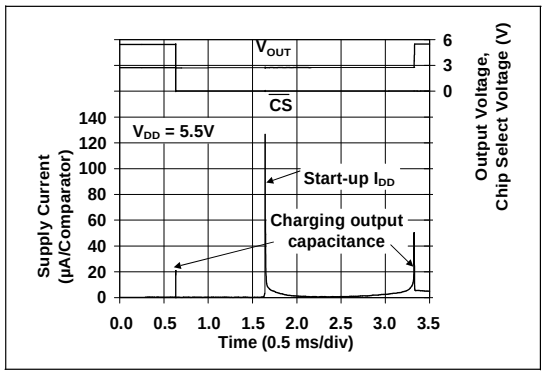


FIGURE 2-36: *Supply Current (charging current) vs. Chip-Select (CS) pulse at V_{DD} = 5.5V (HT6543 only).*

3.1 APPLICATIONS INFORMATION

The HT6541/2/3/4 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.

3.2 Comparator Inputs

The HT6541/2/3/4 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 ±2 mA, as shown in Figure 3-1.

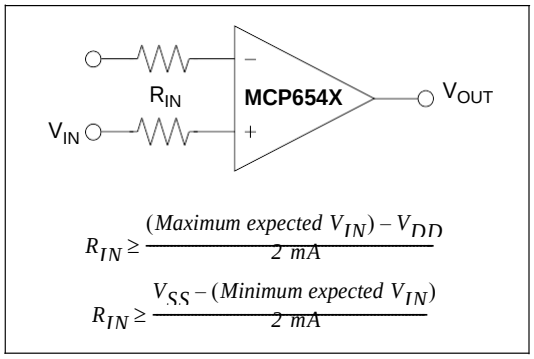


FIGURE 3-1: *An input resistor (R_{IN}) should be used to limit excessive input current if either of the inputs exceeds the Absolute Maximum specification.*

3.3 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).

3.4 HT6543 Chip Select ($\overline{CS}$)

The HT6543 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 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 CS low, the comparator is enabled. If the CS pin is left floating, the comparator will not operate properly. Figure 1-1 shows the output voltage and supply current response to a CS pulse.

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

3.5 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 HT6541/2/3/4 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 µVp-p).

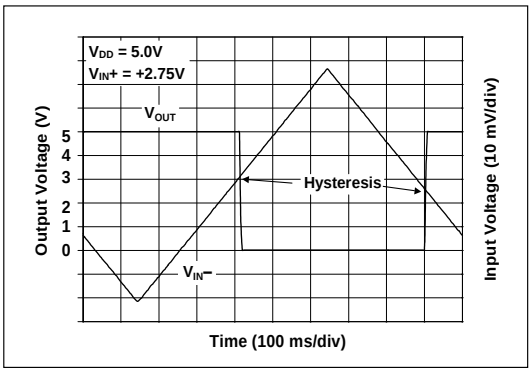


FIGURE 3-2: *The HT6541/2/3/4 comparators' internal hysteresis eliminates output chatter caused by input noise voltage.*

3.5.1 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.

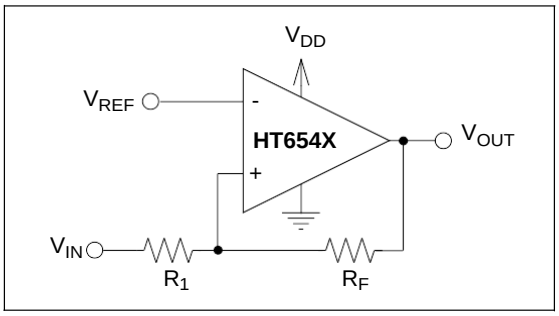


FIGURE 3-3: *Non-inverting circuit with hysteresis for single-supply.*

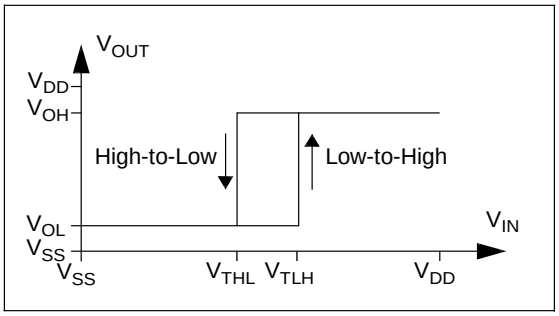


FIGURE 3-4: *Hysteresis Diagram for the Non-Inverting Circuit.*

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

3.5.2 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.

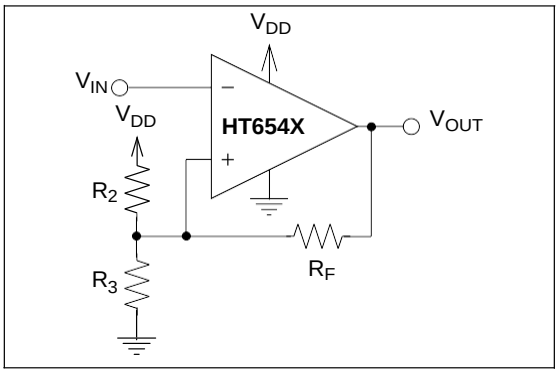


FIGURE 3-5: *Inverting Circuit With Hysteresis.*

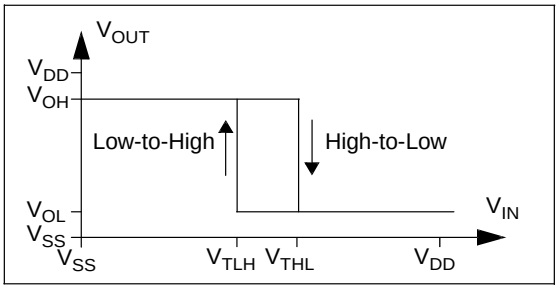


FIGURE 3-6: *Hysteresis Diagram for the Inverting Circuit.*

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.

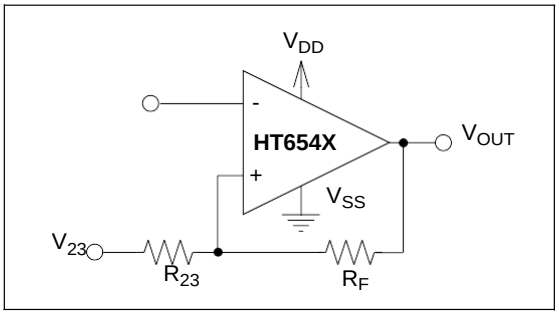


FIGURE 3-7: *Thevenin Equivalent Circuit.*

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 µF to 0.1 µF) 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 HT6541/2/3/4 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.

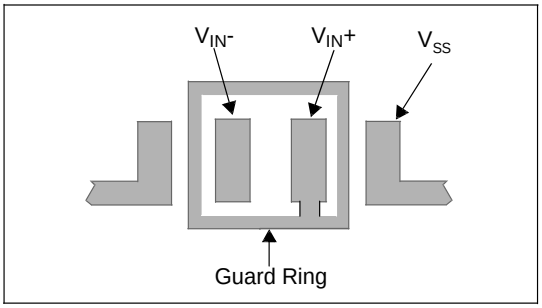


FIGURE 3-8: *Example Guard Ring Layout for Inverting Circuit.*

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}–).

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 HT6041) to gain-up the input signal before it reaches the comparator. Figure 3-9 shows an example of this approach.

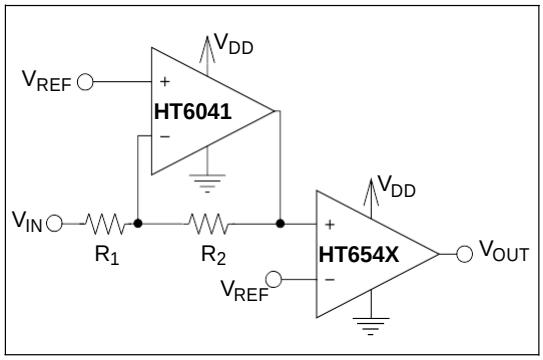


FIGURE 3-9: *Precise Inverting Comparator.*

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 $V_{RT} > V_{RB}$).

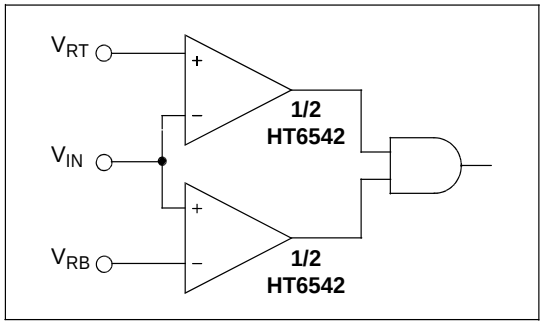


FIGURE 3-10: *Windowed Comparator.*

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}.

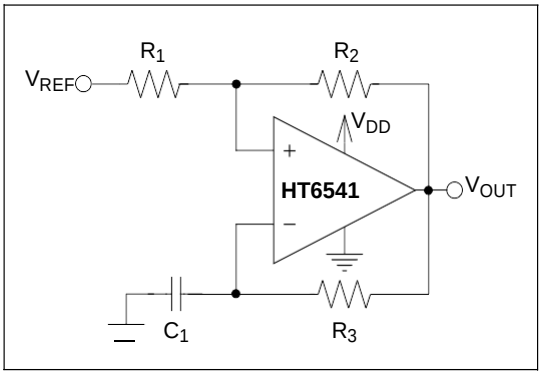
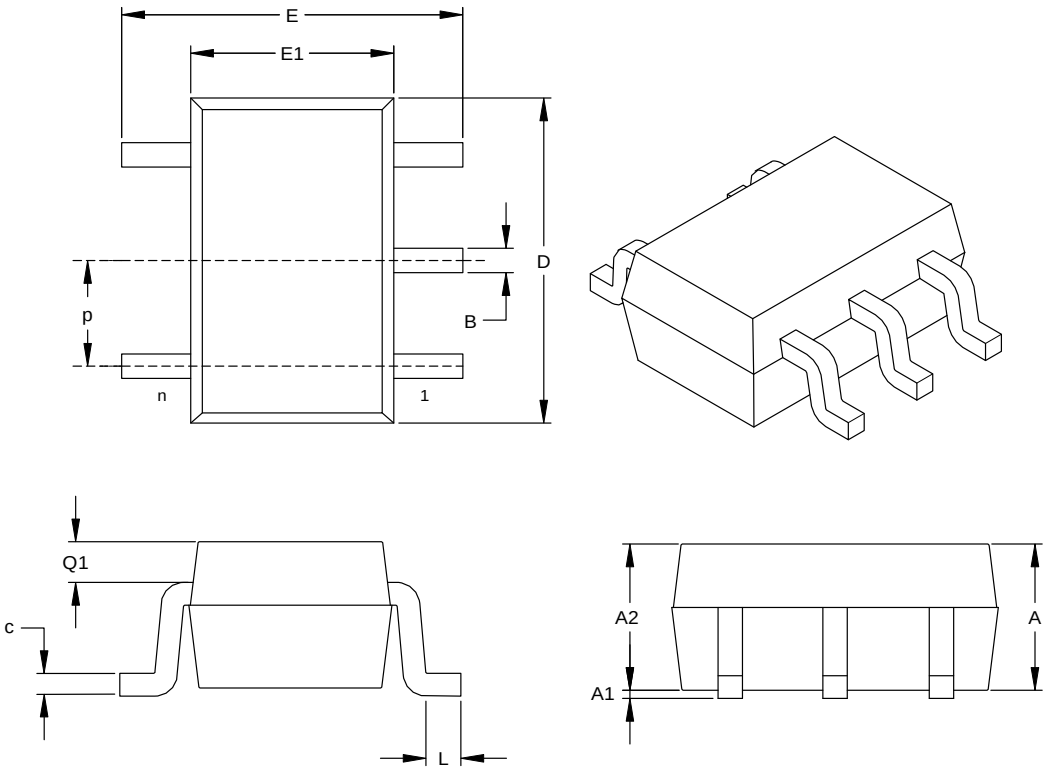


FIGURE 3-11: *Bistable Multi-vibrator.*

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



Units		INCHES			MILLIMETERS*		
Dimension Limits		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

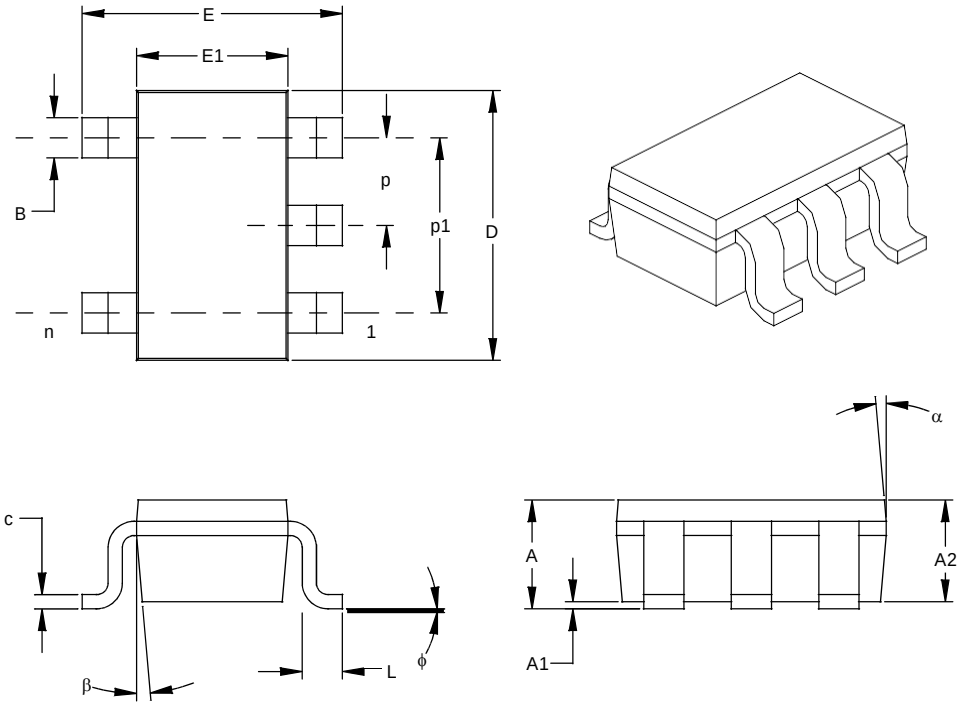
Notes:

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

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

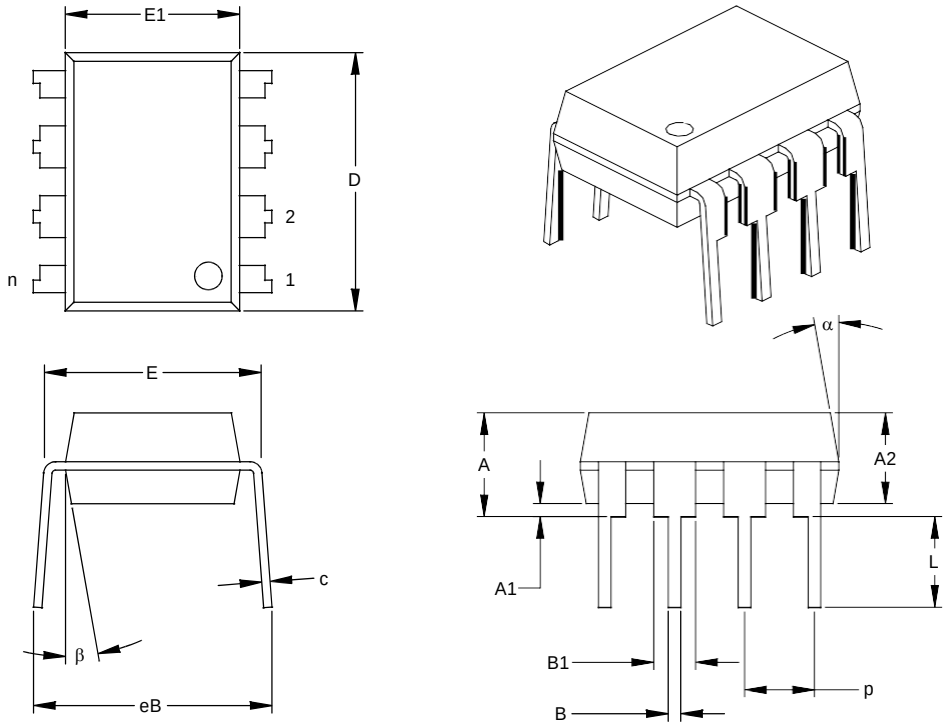


Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		5			5	
Pitch	p		.038			0.95	
Outside lead pitch (basic)	p1		.075			1.90	
Overall Height	A	.035	.046	.057	0.90	1.18	1.45
Molded Package Thickness	A2	.035	.043	.051	0.90	1.10	1.30
Standoff §	A1	.000	.003	.006	0.00	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)

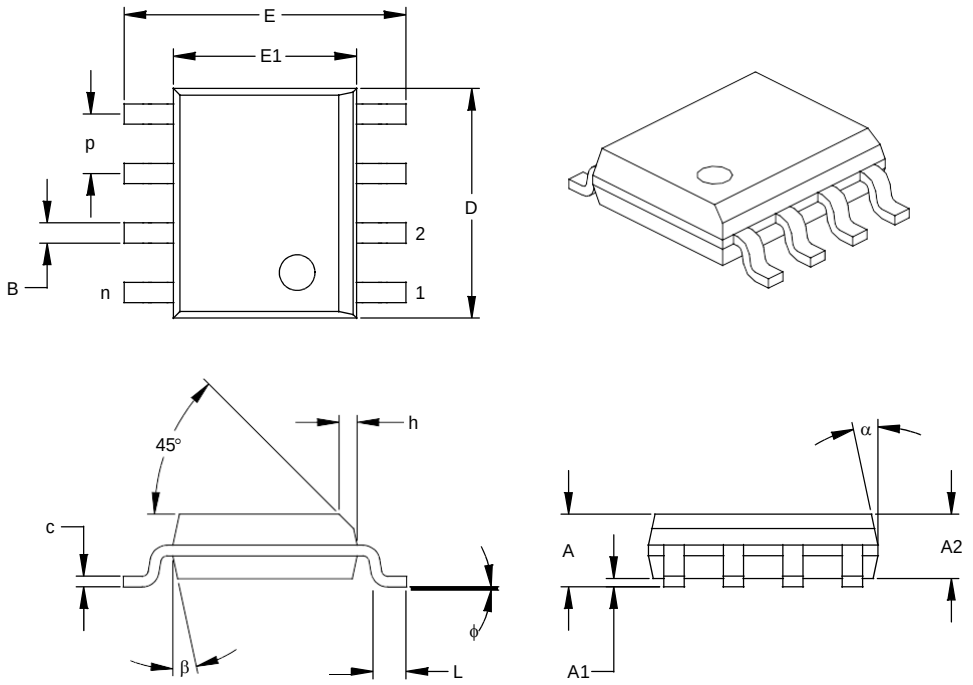


Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		8			8	
Pitch	p		.100			2.54	
Top to Seating Plane	A	.140	.155	.170	3.56	3.94	4.32
Molded Package Thickness	A2	.115	.130	.145	2.92	3.30	3.68
Base to Seating Plane	A1	.015			0.38		
Shoulder to Shoulder Width	E	.300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

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

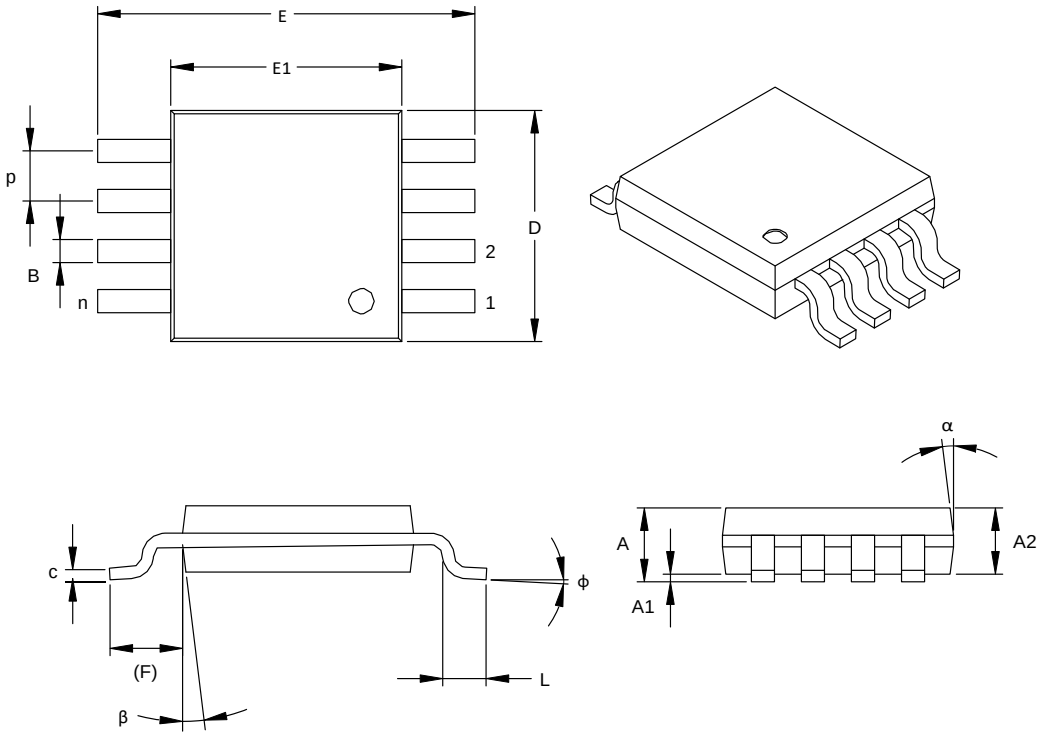


Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		8			8	
Pitch	p		.050			1.27	
Overall Height	A	.053	.061	.069	1.35	1.55	1.75
Molded Package Thickness	A2	.052	.056	.061	1.32	1.42	1.55
Standoff §	A1	.004	.007	.010	0.10	0.18	0.25
Overall Width	E	.228	.237	.244	5.79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

* Controlling Parameter
§ Significant Characteristic

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

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



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

*Controlling Parameter

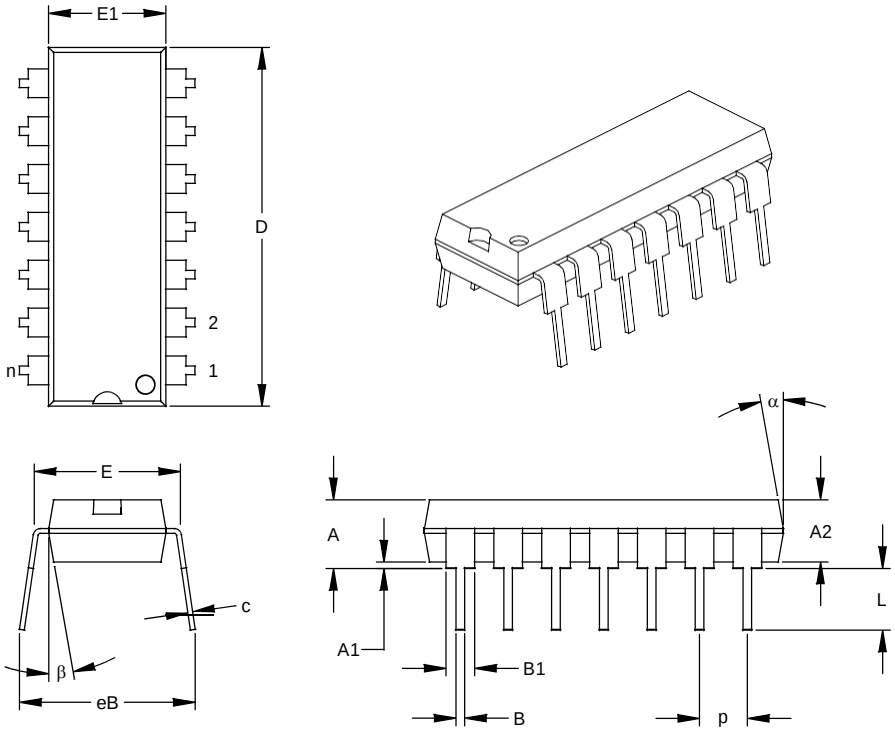
Notes:

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

JEDEC Equivalent: MO-187

Drawing No. C04-111

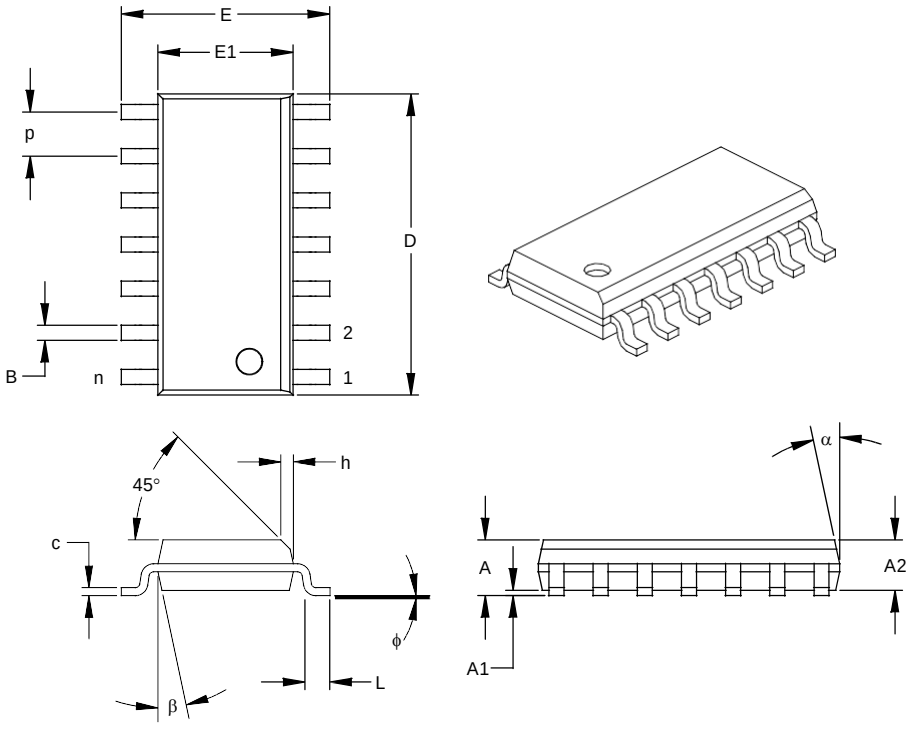
14-Lead Plastic Dual In-line (P) – 300 mil (PDIP)



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

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

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

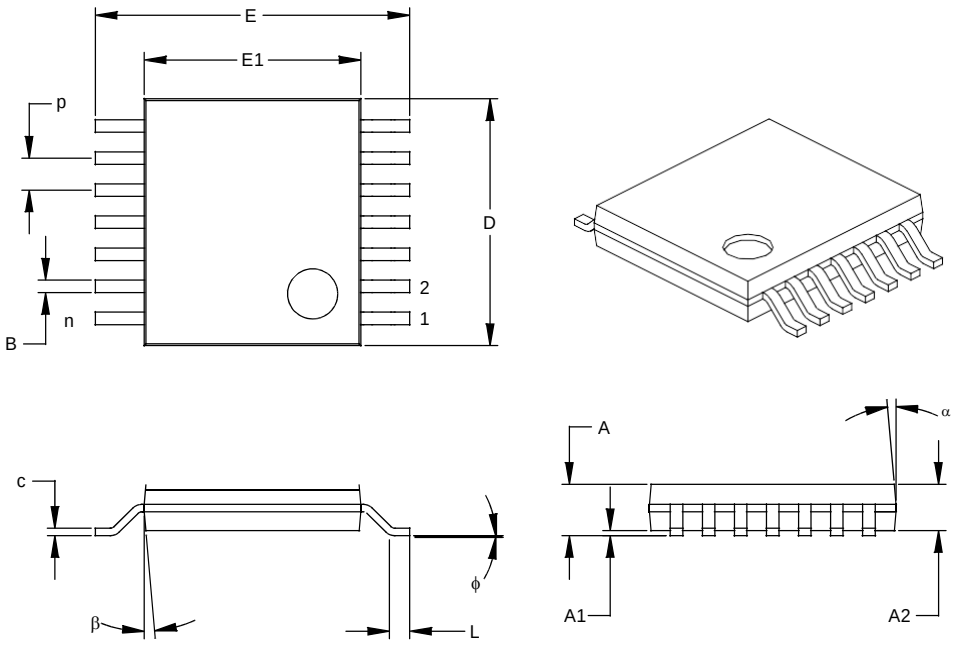


Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		14			14	
Pitch	p		.050			1.27	
Overall Height	A	.053	.061	.069	1.35	1.55	1.75
Molded Package Thickness	A2	.052	.056	.061	1.32	1.42	1.55
Standoff §	A1	.004	.007	.010	0.10	0.18	0.25
Overall Width	E	.228	.236	.244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

* Controlling Parameter
§ Significant Characteristic

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

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



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

* Controlling Parameter
§ Significant Characteristic

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