



# Low-Cost, Ultra-Small, Single/Dual/Quad Single-Supply Comparators

MAX9030/MAX9031/MAX9032/MAX9034

## General Description

The MAX9030/MAX9031/MAX9032/MAX9034 single/dual/quad comparators are optimized for single-supply applications from +2.5V to +5.5V but can also be operated from dual supplies. These comparators have a 188ns propagation delay and consume 35µA of supply current per comparator over the -40°C to +125°C operating temperature range. The combination of low-power, single-supply operation down to +2.5V, and ultra-small footprint makes these devices ideal for portable applications.

The MAX9030 is a low-cost single comparator with shutdown. The MAX9031, MAX9032, and MAX9034 are low-cost single, dual, and quad comparators without shutdown, respectively. The comparators' 4mV of built-in hysteresis provides noise immunity and prevents oscillations even with a slow-moving input signal. The input common-mode range extends from the negative supply to within 1.1V of the positive supply. The design of the comparator output stage substantially reduces switching current during output transitions, virtually eliminating power-supply glitches.

The MAX9030 single comparator with shutdown is available in the space-saving 6-pin SC70 and SOT23 packages. The MAX9031 single comparator is available in tiny 5-pin SC70 and SOT23 packages. The MAX9032 dual comparator is available in 8-pin SOT23 and µMAX packages, and the MAX9034 quad comparator is available in a 14-pin TSSOP package.

## Applications

- |                         |  |
|-------------------------|--|
| Battery-Powered         | Digital Line Receivers                 |
| Portable Systems        | Keyless Entry Systems                  |
| Mobile Communications   | Threshold Detectors/<br>Discriminators |
| Sensor Signal Detection |  |
| Photodiode Preamps      |  |

## Features

- ◆ Low-Cost Solution Available in Space-Saving SC70 Packages (MAX9030/MAX9031)
- ◆ +2.5 to +5.5V Single-Supply Voltage Range
- ◆ Comparator Output Swings Rail-to-Rail®
- ◆ Internal 4mV Comparator Hysteresis
- ◆ 188ns Propagation Delay
- ◆ Low 35µA Supply Current
- ◆ No Phase Reversal for Overdriven Inputs
- ◆ Space-Saving Packages
  - 5-Pin SC70 (MAX9031)
  - 6-Pin SC70 (MAX9030)
  - 8-Pin SOT23 (MAX9032)
  - 14-Pin TSSOP (MAX9034)

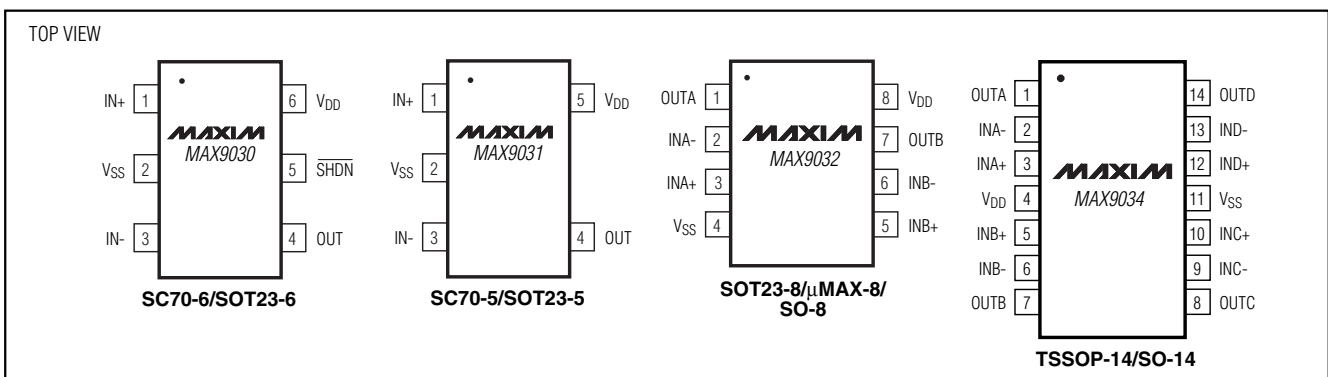
## Ordering Information

| PART         | TEMP. RANGE     | PIN-PACKAGE |
|--------------|-----------------|-------------|
| MAX9030AXT-T | -40°C to +125°C | 6 SC70      |
| MAX9030AUT-T | -40°C to +125°C | 6 SOT23     |
| MAX9031AXK-T | -40°C to +125°C | 5 SC70      |
| MAX9031AUK-T | -40°C to +125°C | 5 SOT23     |
| MAX9032AKA-T | -40°C to +125°C | 8 SOT23     |
| MAX9032AUA*  | -40°C to +125°C | 8 µMAX      |
| MAX9032ASA   | -40°C to +125°C | 8 SO        |
| MAX9034AUD   | -40°C to +125°C | 14 TSSOP    |
| MAX9034ASD   | -40°C to +125°C | 14 SO       |

\*Future product—contact factory for availability.

Typical Application Circuit appears at end of data sheet.

## Pin Configurations



Rail-to-Rail is a registered trademark of Nippon Motorola, Ltd.



For price, delivery, and to place orders, please contact Maxim Distribution at 1-888-629-4642, or visit Maxim's website at [www.maxim-ic.com](http://www.maxim-ic.com).

# Low-Cost, Ultra-Small, Single/Dual/Quad Single-Supply Comparators

## ABSOLUTE MAXIMUM RATINGS

|   |  |   |                      |
|---|--|---|----------------------|
| Supply Voltage ( $V_{DD}$ to $V_{SS}$ )       | .....-0.3V to +6V                      | 8-Pin SOT23 (derate 9.1mW/°C above +70°C)     | .....727mW           |
| Voltage Inputs (IN+, IN- to $V_{SS}$ )        | .....-0.3V to ( $V_{DD}$ + 0.3V)       | 8-Pin $\mu$ MAX (derate 4.5mW/°C above +70°C) | .....362mW           |
| Differential Input Voltage (IN+ to IN-)       | .....+6.6V                             | 8-Pin SO (derate 5.88mW/°C above +70°C)       | .....471mW           |
| Output Short-Circuit                          |  | 14-Pin TSSOP (derate 9.1mW/°C above +70°C)    | .....727mW           |
| Duration                                      | .....2s to Either $V_{DD}$ or $V_{SS}$ | 14-Pin SO (derate 8.33mW/°C above +70°C)      | .....667mW           |
| Current into Any Pin                          | .....20mA                              | Operating Temperature Range                   |                      |
| Continuous Power Dissipation ( $T_A$ = +70°C) | .....                                  | Automotive Application                        | .....-40°C to +125°C |
| 5-Pin SC70 (derate 3.1mW/°C above +70°C)      | .....247mW                             | Junction Temperature                          | .....+150°C          |
| 5-Pin SOT23 (derate 7.1mW/°C above +70°C)     | .....571mW                             | Storage Temperature Range                     | .....-65°C to +150°C |
| 6-Pin SC70 (derate 3.1mW/°C above +70°C)      | .....245mW                             | Lead Temperature (soldering, 10s)             | .....+300°C          |
| 6-Pin SOT23 (derate 8.7mW/°C above +70°C)     | .....696mW                             |   |                      |

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## ELECTRICAL CHARACTERISTICS

( $V_{DD}$  = +5V,  $V_{SS}$  = 0,  $V_{CM}$  = 0,  $V_{SHDN}$  = +5V (Note 1),  $T_A$  = -40°C to +125°C, unless otherwise noted. Typical values are at  $T_A$  = +25°C.) (Note 2)

| PARAMETER                                    | SYMBOL     | CONDITIONS   | MIN                 | TYP     | MAX                 | UNITS      |
|--|------------|--|---------------------|---------|---------------------|------------|
| Operating Voltage Range                      | $V_{DD}$   | Guaranteed by PSRR test                                      | 2.5                 |         | 5.5                 | V          |
| Supply Current per Comparator                | $I_{DD}$   |  |                     | 35      | 55                  | $\mu$ A    |
| Supply Current in Shutdown                   |            | $V_{SHDN} = 0$ (Note 1)                                      |                     | 0.05    | 1                   | $\mu$ A    |
| Shutdown Input Bias Current                  |            | $V_{SHDN} = 0$ to $V_{DD}$ (Note 1)                          |                     | 0.1     | 2.5                 | $\mu$ A    |
| Shutdown Logic High                          |            | (Note 1)   | $0.7 \times V_{DD}$ |         |                     | V          |
| Shutdown Logic Low                           |            | (Note 1)   |                     |         | $0.3 \times V_{DD}$ | V          |
| Input Offset Voltage                         | $V_{OS}$   | (Note 3)   |                     | $\pm 1$ | $\pm 5$             | mV         |
| Input Offset Voltage Temperature Coefficient | $TCV_{OS}$ |  |                     | $\pm 1$ |                     | $\mu$ V/°C |
| Hysteresis                                   |            | (Note 4)   |                     | 4       |                     | mV         |
| Input Bias Current                           | $I_{BIAS}$ |  |                     | 8       | 80                  | nA         |
| Input Offset Current                         | $I_{OS}$   |  |                     | $\pm 2$ | $\pm 60$            | nA         |
| Common-Mode Voltage Range                    | $V_{CM}$   | Guaranteed by CMRR test                                      | $V_{SS}$            |         | $V_{DD} - 1.1$      | V          |
| Common-Mode Rejection Ratio                  | CMRR       | $V_{SS} \leq V_{CM} \leq (V_{DD} - 1.1V)$ , $V_{DD} = +5.5V$ | 72                  | 100     |                     | dB         |
| Power-Supply Rejection Ratio                 | PSRR       | $V_{DD} = +2.5V$ to +5.5V                                    | 72                  | 100     |                     | dB         |

# Low-Cost, Ultra-Small, Single/Dual/Quad Single-Supply Comparators

MAX9030/MAX9031/MAX9032/MAX9034

## ELECTRICAL CHARACTERISTICS (continued)

( $V_{DD} = +5V$ ,  $V_{SS} = 0$ ,  $V_{CM} = 0$ ,  $V_{SHDN} = +5V$  (Note 1),  $T_A = -40^{\circ}C$  to  $+125^{\circ}C$ , unless otherwise noted. Typical values are at  $T_A = +25^{\circ}C$ .) (Note 2)

| PARAMETER                    | SYMBOL             | CONDITIONS  | MIN                    | TYP        | MAX       | UNITS   |
|------------------------------|--------------------|---|------------------------|------------|-----------|---------|
| Output Voltage-Swing         | $V_{OL}, V_{OH}$   | $V_{OH} = V_{DD} - V_{OUT}$ ,<br>$(V_{IN+} - V_{IN-}) \geq 20mV$            | $I_{SOURCE} = 10\mu A$ | 2          |           | mV      |
|                              |                    |   | $I_{SOURCE} = 4mA$     | 165        | 400       |         |
|                              |                    | $V_{OL} = V_{OUT} - V_{SS}$ ,<br>$(V_{IN-} - V_{IN+}) \geq 20mV$            | $I_{SINK} = 10\mu A$   | 2          |           |         |
|                              |                    |   | $I_{SINK} = 4mA$       | 165        | 400       |         |
| Output Short-Circuit Current | $I_{SC}$           |   |                        | 45         |           | mA      |
| Shutdown Mode Output Leakage |                    | $V_{SHDN} \leq (0.3 \times V_{DD})$ , $V_{OUT} = 0$ to $V_{DD}$<br>(Note 1) |                        | $\pm 0.01$ | $\pm 3.5$ | $\mu A$ |
| Propagation Delay            | $t_{PD+}, t_{PD-}$ | $R_L = 10k\Omega$ ,<br>$C_L = 15pF$ (Note 5)                                | $V_{OD} = 10mV$        | 228        |           | ns      |
|                              |                    |   | $V_{OD} = 100mV$       | 188        |           |         |
| Rise/Fall-Time               | $t_R, t_F$         | $V_{DD} = +5V$ , $R_L = 10k\Omega$ , $C_L = 15pF$ (Note 6)                  |                        | 20         |           | ns      |
| Shutdown Delay Time ON/OFF   |                    | (Note 1)  |                        | 40         |           | ns      |
| Shutdown Delay Time OFF/ON   |                    | (Note 1)  |                        | 400        |           | ns      |
| Power-On Time                |                    | $R_L = 10k\Omega$ , $C_L = 15pF$  |                        | 200        |           | ns      |
| Maximum Capacitive Load      | $C_L$              | No sustained oscillations   |                        | 150        |           | pF      |

**Note 1:** MAX9030 only.

**Note 2:** All devices are production tested at  $+25^{\circ}C$ . All temperature limits are guaranteed by design.

**Note 3:** Comparator Input Offset is defined as the center of the hysteresis zone.

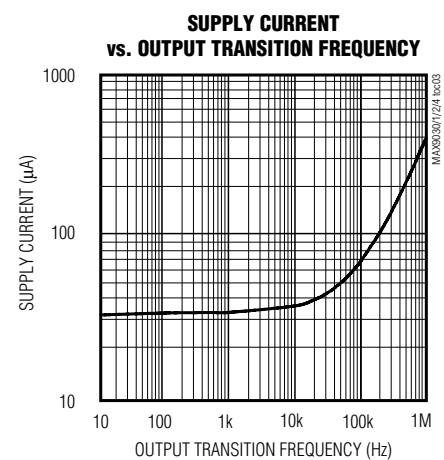
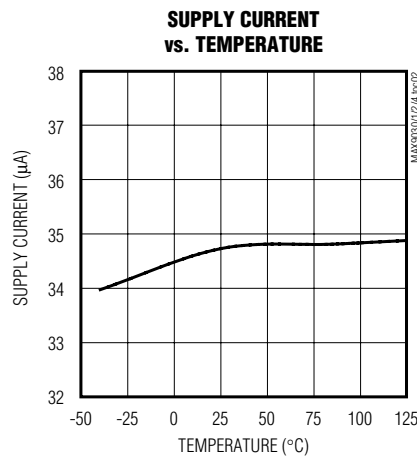
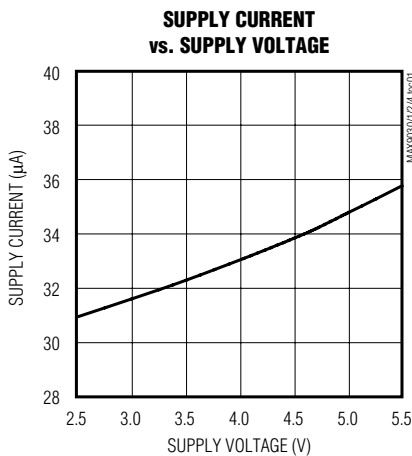
**Note 4:** Hysteresis is defined as the difference of the trip points required to change comparator output states.

**Note 5:**  $V_{OD}$  is the overdrive that is beyond the offset and hysteresis-determined trip points.

**Note 6:** Rise and fall times are measured between 10% and 90% at OUT.

## Typical Operating Characteristics

( $V_{DD} = +5V$ ,  $V_{SS} = 0$ ,  $V_{CM} = 0$ ,  $R_L = 10k\Omega$ ,  $C_L = 15pF$ ,  $V_{OD} = 100mV$ ,  $T_A = +25^{\circ}C$ , unless otherwise noted.)

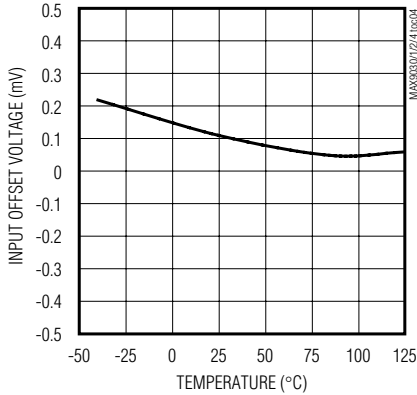


# Low-Cost, Ultra-Small, Single/Dual/Quad Single-Supply Comparators

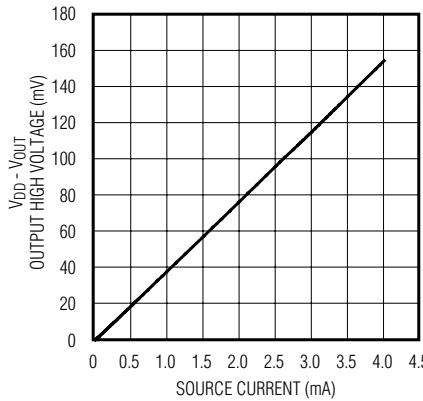
## Typical Operating Characteristics (continued)

( $V_{DD} = +5V$ ,  $V_{SS} = 0$ ,  $V_{CM} = 0$ ,  $R_L = 10k\Omega$ ,  $C_L = 15pF$ ,  $V_{OD} = 100mV$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

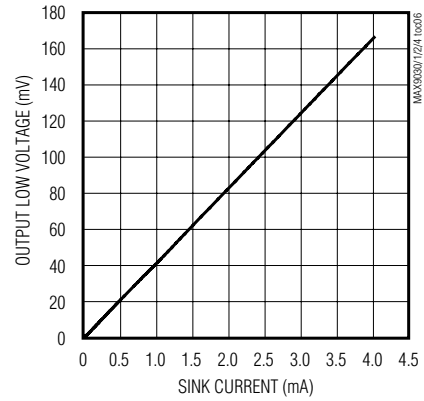
**INPUT OFFSET VOLTAGE vs. TEMPERATURE**



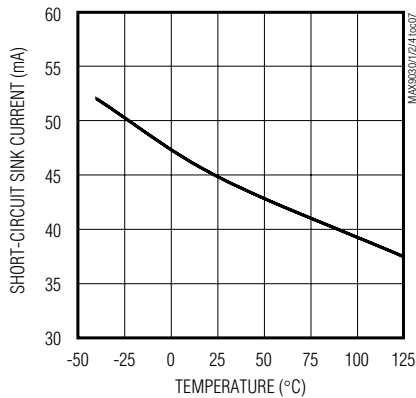
**OUTPUT HIGH VOLTAGE vs. SOURCE CURRENT**



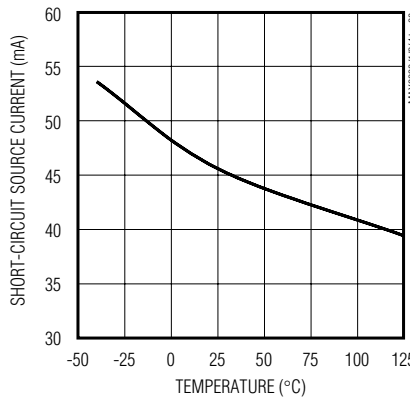
**OUTPUT LOW VOLTAGE vs. SINK CURRENT**



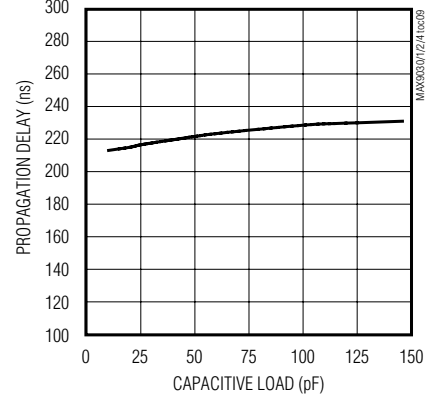
**OUTPUT SHORT-CIRCUIT (SINK) CURRENT vs. TEMPERATURE**



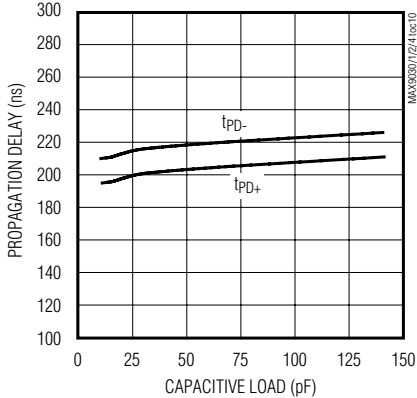
**OUTPUT SHORT-CIRCUIT (SOURCE) CURRENT vs. TEMPERATURE**



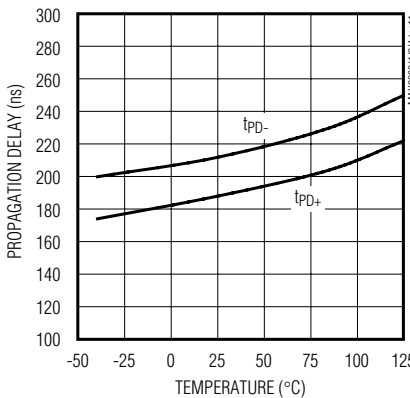
**PROPAGATION DELAY vs. CAPACITIVE LOAD ( $V_{DD} = 2.7V$ )**



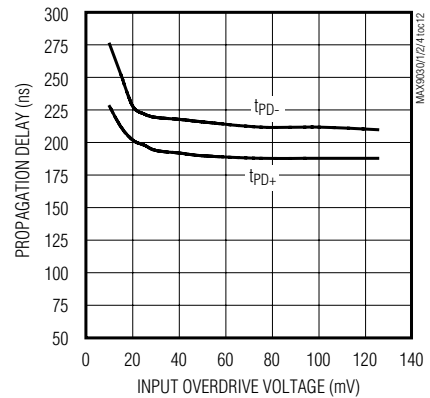
**PROPAGATION DELAY vs. CAPACITIVE LOAD ( $V_{DD} = +5V$ )**



**PROPAGATION DELAY vs. TEMPERATURE**



**PROPAGATION DELAY vs. INPUT OVERDRIVE VOLTAGE**



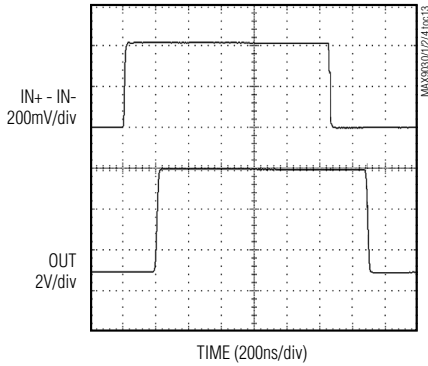
# Low-Cost, Ultra-Small, Single/Dual/Quad Single-Supply Comparators

## Typical Operating Characteristics (continued)

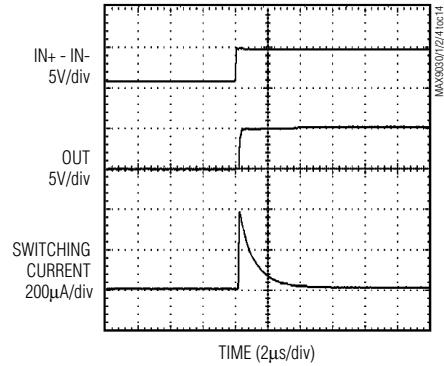
( $V_{DD} = +5V$ ,  $V_{SS} = 0$ ,  $V_{CM} = 0$ ,  $R_L = 10k\Omega$ ,  $C_L = 15pF$ ,  $V_{OD} = 100mV$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

MAX9030/MAX9031/MAX9032/MAX9034

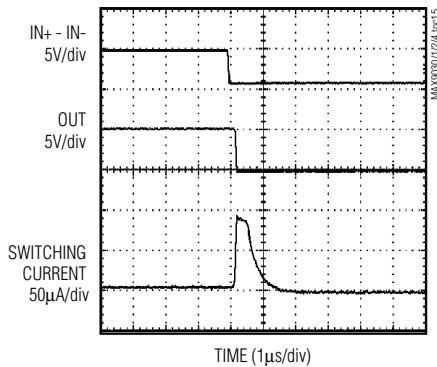
**PROPAGATION DELAY**



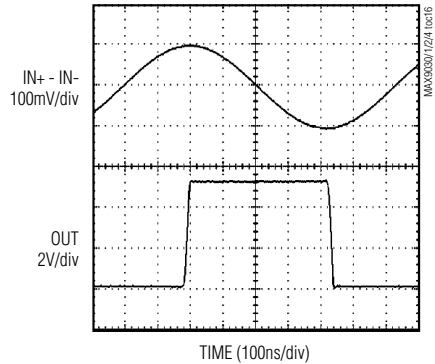
**OUTPUT SWITCHING CURRENT, RISING**



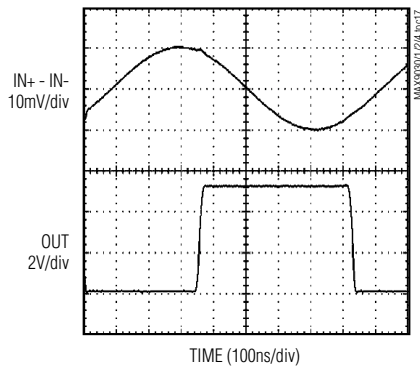
**OUTPUT SWITCHING CURRENT, FALLING**



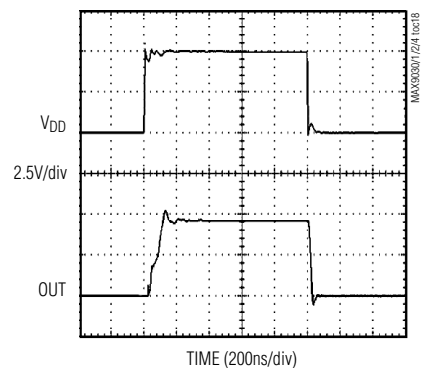
**SINUSOID 1MHz RESPONSE AT 1.25MHz  
 $V_{OD} = 100mV$**



**SINUSOID 1MHz RESPONSE AT 1.25MHz  
 $V_{OD} = 10mV$**



**POWER-UP DELAY**



# Low-Cost, Ultra-Small, Single/Dual/Quad Single-Supply Comparators

## Pin Description

| PIN     |         |         |         | NAME                     | FUNCTION  |
|---------|---------|---------|---------|--------------------------|---|
| MAX9030 | MAX9031 | MAX9032 | MAX9034 |                          |   |
| 1       | 1       | —       | —       | IN+                      | Comparator Noninverting Input                           |
| 2       | 2       | 4       | 11      | V <sub>SS</sub>          | Negative Supply Voltage. Bypass with a 0.1μF capacitor. |
| 3       | 3       | —       | —       | IN-                      | Comparator Inverting Input                              |
| 4       | 4       | —       | —       | OUT                      | Comparator Output                                       |
| 5       | —       | —       | —       | $\overline{\text{SHDN}}$ | Shutdown  |
| 6       | 5       | 8       | 4       | V <sub>DD</sub>          | Positive Supply Voltage. Bypass with a 0.1μF capacitor. |
| —       | —       | 1       | 1       | OUTA                     | Comparator A Output                                     |
| —       | —       | 2       | 2       | INA-                     | Comparator A Inverting Input                            |
| —       | —       | 3       | 3       | INA+                     | Comparator A Noninverting Input                         |
| —       | —       | 5       | 5       | INB+                     | Comparator B Noninverting Input                         |
| —       | —       | 6       | 6       | INB-                     | Comparator B Inverting Input                            |
| —       | —       | 7       | 7       | OUTB                     | Comparator B Output                                     |
| —       | —       | —       | 8       | OUTC                     | Comparator C Output                                     |
| —       | —       | —       | 9       | INC-                     | Comparator C Inverting Input                            |
| —       | —       | —       | 10      | INC+                     | Comparator C Noninverting Input                         |
| —       | —       | —       | 12      | IND+                     | Comparator D Noninverting Input                         |
| —       | —       | —       | 13      | IND-                     | Comparator D Inverting Input                            |
| —       | —       | —       | 14      | OUTD                     | Comparator D Output                                     |

### Detailed Description

The MAX9030/MAX9031/MAX9032/MAX9034 are single/dual/quad low-cost comparators. They have an operating supply voltage from +2.5V to +5.5V when operating from a single supply and from ±1.25V to ±2.75V when operating from dual power supplies, and consume only 35μA. Their common-mode input voltage range extends from the negative supply to within 1.1V of the positive supply. Internal hysteresis ensures clean output switching, even with slow-moving input signals.

#### Shutdown Mode

The MAX9030 comparator comes with a power-saving shutdown mode. When in shutdown, the supply current drops from a typical 35μA to 0.05μA, and the outputs become high impedance.  $\overline{\text{SHDN}}$  has a high input impedance and typically draws 0.1μA when connected to V<sub>SS</sub> or V<sub>DD</sub>. A maximum logic low voltage of  $0.3V \times V_{DD}$

applied to  $\overline{\text{SHDN}}$  places the device in the shutdown mode. A minimum logic high voltage of  $0.7V \times V_{DD}$  applied to  $\overline{\text{SHDN}}$  will enable normal operation. To disable shutdown, connect  $\overline{\text{SHDN}}$  to V<sub>DD</sub>.

### Applications Information

#### Adding Hysteresis

Hysteresis extends the comparator's noise margin by increasing the upper threshold and decreasing the lower threshold. A voltage-divider from the output of the comparator sets the trip voltage. Therefore, the trip voltage is related to the output voltage.

These comparators have 4mV internal hysteresis. Additional hysteresis can be generated with two resistors using positive feedback (Figure 1). Use the following procedure to calculate resistor values:

# Low-Cost, Ultra-Small, Single/Dual/Quad Single-Supply Comparators

MAX9030/MAX9031/MAX9032/MAX9034

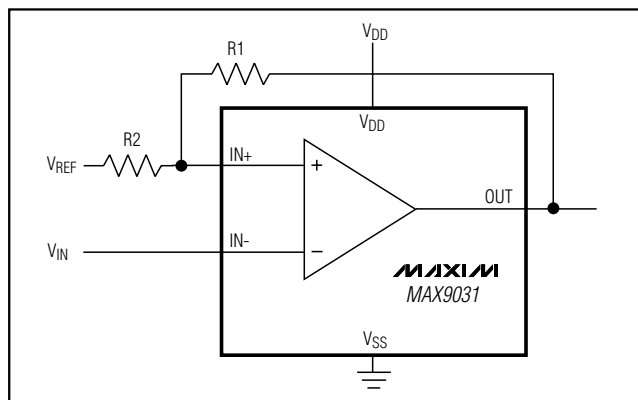


Figure 1. Additional Hysteresis

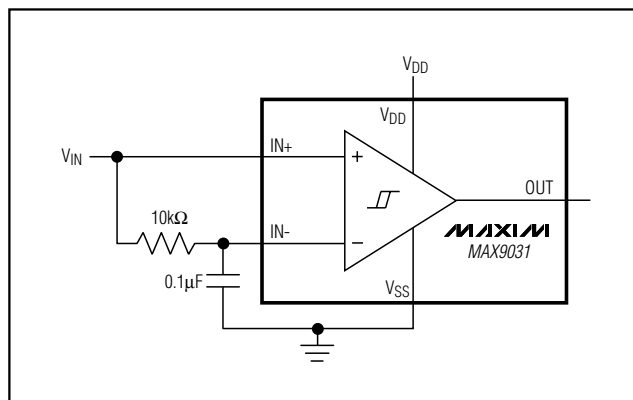


Figure 2. Time Averaging of the Input Signal for Data Recovery

- 1) Find the trip points of the comparator using these formulas:

$$V_{TH} = V_{REF} + [(V_{DD} - V_{REF})R_2] / (R_1 + R_2)$$

$$V_{TL} = V_{REF}(1 - (R_2 / (R_1 + R_2)))$$

where  $V_{TH}$  is the threshold voltage at which the comparator switches its output from high to low as  $V_{IN}$  rises above the trip point.  $V_{TL}$  is the threshold voltage at which the comparator switches its output from low to high as  $V_{IN}$  drops below the trip point.

- 2) The hysteresis band will be:

$$V_{HYS} = V_{TH} - V_{TL} = V_{DD}(R_2 / (R_1 + R_2))$$

- 3) In this example, let  $V_{DD} = +5V$  and  $V_{REF} = +2.5V$ .

$$V_{TH} = 2.5V + 2.5(R_2 / (R_1 + R_2))V$$

and

$$V_{TL} = 2.5[1 - (R_2 / (R_1 + R_2))]$$

- 4) Select  $R_2$ . In this example, we will choose  $1k\Omega$ .
- 5) Select  $V_{HYS}$ . In this example, we will choose  $50mV$ .
- 6) Solve for  $R_1$ .

$$V_{HYS} = V_{DD}(R_2 / (R_1 + R_2))$$

$$0.050V = 5(1000\Omega / (R_1 + 1000\Omega)) V$$

where  $R_1 \approx 100k\Omega$ ,  $V_{TH} = 2.525V$ , and  $V_{TL} = 2.475V$ .

The above-described design procedure assumes rail-to-rail output swing. If the output is significantly loaded, the results should be corrected.

## Board Layout and Bypassing

Use  $100nF$  bypass as a starting point. Minimize signal trace lengths to reduce stray capacitance. Minimize the capacitive coupling between  $IN-$  and  $OUT$ . For slow-moving input signals (rise-time  $> 1ms$ ), use a  $1nF$  capacitor between  $IN+$  and  $IN-$ .

## Biasing for Data Recovery

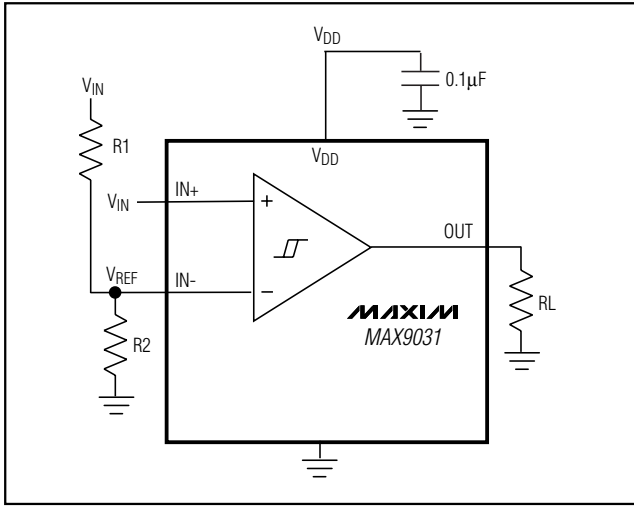
Digital data is often embedded into a bandwidth and amplitude-limited analog path. Recovering the data can be difficult. Figure 2 compares the input signal to a time-averaged version of itself. This self-biases the threshold to the average input voltage for optimal noise margin. Even severe phase distortion is eliminated from the digital output signal. Be sure to choose  $R_1$  and  $C_1$  so that:

$$f_{CAR} \gg 1 / (2\pi R_1 C_1)$$

where  $f_{CAR}$  is the fundamental carrier frequency of the digital data stream.

# Low-Cost, Ultra-Small, Single/Dual/Quad Single-Supply Comparators

## Typical Application Circuit



## Chip Information

TRANSISTOR COUNT/MAX9030/MAX9031: 123

TRANSISTOR COUNT/MAX9032: 184

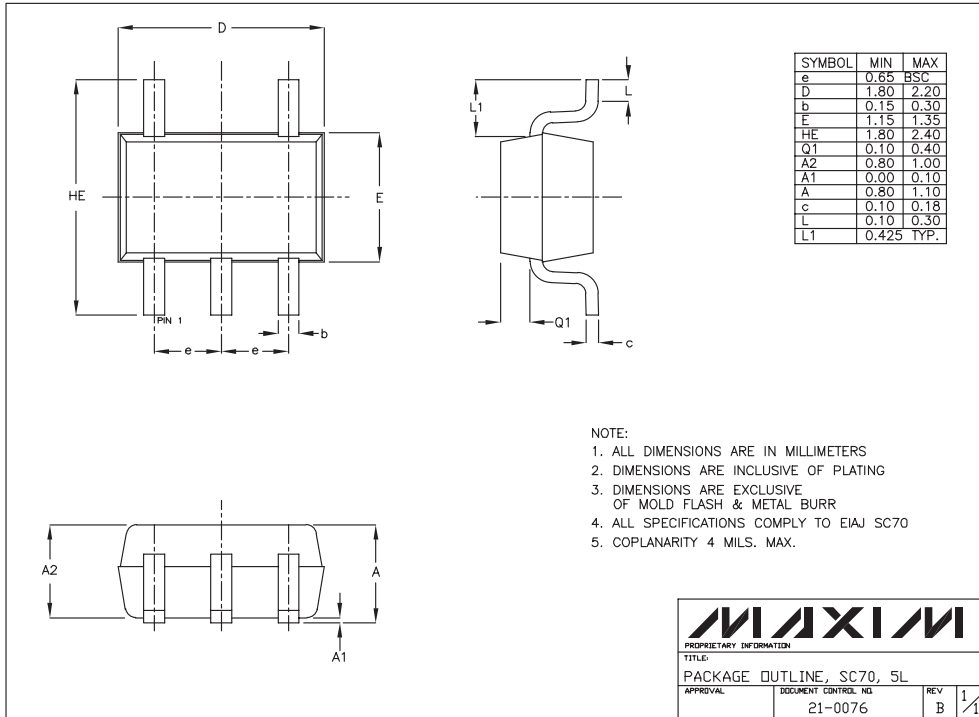
TRANSISTOR COUNT/MAX9034: 368



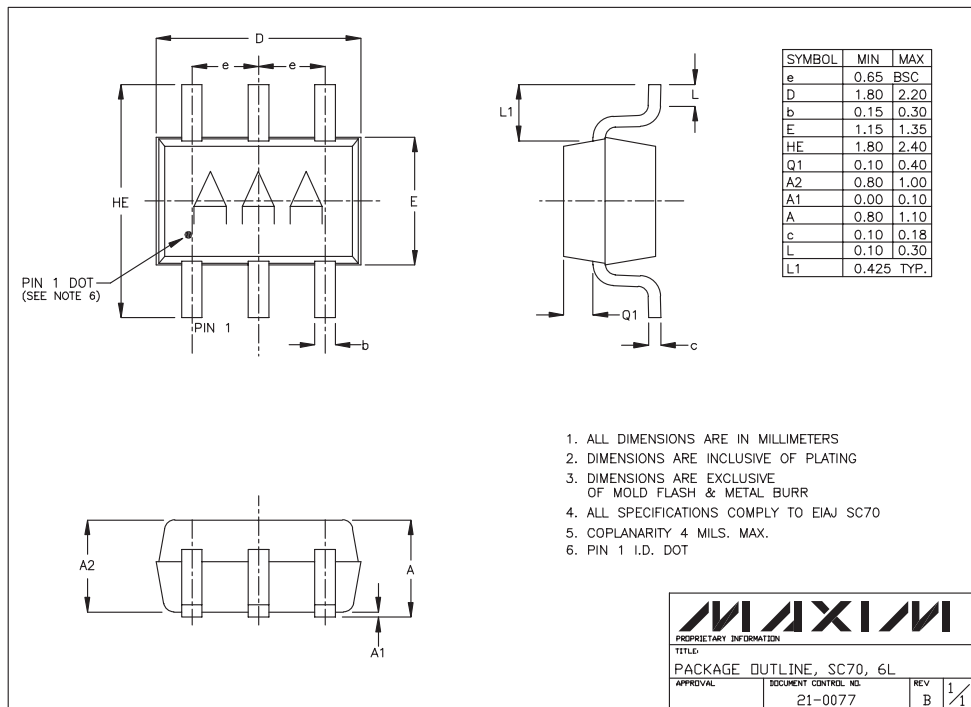
# Low-Cost, Ultra-Small, Single/Dual/Quad Single-Supply Comparators

## Package Information

MAX9030/MAX9031/MAX9032/MAX9034



SC70, 5LEPS



SC70, 6LEPS

# Low-Cost, Ultra-Small, Single/Dual/Quad Single-Supply Comparators

## Package Information (continued)

| SYMBOL   | MIN      | MAX  |
|----------|----------|------|
| A        | 0.90     | 1.45 |
| A1       | 0.00     | 0.15 |
| A2       | 0.90     | 1.30 |
| b        | 0.28     | 0.45 |
| c        | 0.09     | 0.20 |
| D        | 2.80     | 3.00 |
| E        | 2.60     | 3.00 |
| E1       | 1.50     | 1.75 |
| L        | 0.10     | 0.60 |
| e        | 0.65 ref |      |
| e1       | 1.95 ref |      |
| $\alpha$ | 0°       | 10°  |

NOTE:  
 1. ALL DIMENSIONS ARE IN MILLIMETERS.  
 2. FOOT LENGTH MEASURED REFERENCE TO FLAT FOOT SURFACE PARALLEL TO DATUM "A".  
 3. PACKAGE OUTLINE EXCLUSIVE OF MOLD FLASH & METAL BURR.  
 4. PACKAGE OUTLINE INCLUSIVE OF SOLDER PLATING.  
 5. EIAJ REF. NUMBER\* SC-74 (6 LEAD VERSION)  
 6. COPLANARITY 4 MILS. MAX.  
 7. PIN 1 I.D. DOT IS 0.3 MM  $\phi$  MIN. LOCATED ABOVE PIN 1.

PIN 1 I.D. DOT (SEE NOTE 7)

DATUM "A"

PROPRIETARY INFORMATION

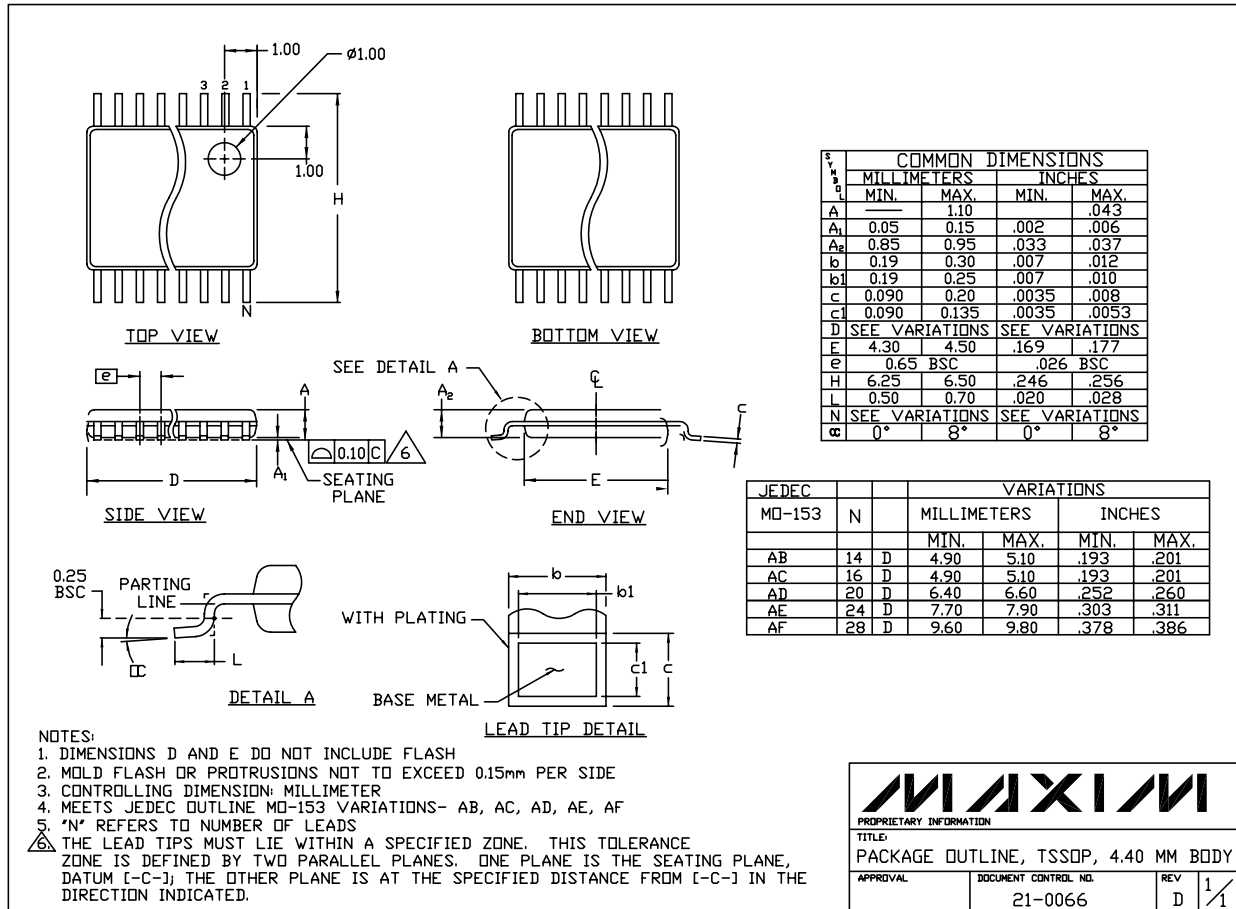
TITLE: PACKAGE OUTLINE, SOT 23, 8L

|          |                                 |          |     |
|----------|---------------------------------|----------|-----|
| APPROVAL | DOCUMENT CONTROL NO.<br>21-0078 | REV<br>B | 1/1 |
|----------|---------------------------------|----------|-----|

SOT23-8LEPS

# Low-Cost, Ultra-Small, Single/Dual/Quad Single-Supply Comparators

## Package Information (continued)



MAX9030/MAX9031/MAX9032/MAX9034

Maxim cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in a Maxim product. No circuit patent licenses are implied. Maxim reserves the right to change the circuitry and specifications without notice at any time.

Maxim Integrated Products, 120 San Gabriel Drive, Sunnyvale, CA 94086 408-737-7600 11