19-0229; Rev 8; 11/08

# High-Speed, Low-Power, 3V/5V, Rail-to-Rail, Single-Supply Comparators



## General Description

The MAX941/MAX942/MAX944 are single/dual/quad high-speed comparators optimized for systems powered from a 3V or 5V supply. These devices combine high speed, low power, and rail-to-rail inputs. Propagation delay is 80ns, while supply current is only 350µA per comparator.

The input common-mode range of the MAX941/MAX942/MAX944 extends beyond both power-supply rails. The outputs pull to within 0.4V of either supply rail without external pullup circuitry, making these devices ideal for interface with both CMOS and TTL logic. All input and output pins can tolerate a continuous short-circuit fault condition to either rail.

Internal hysteresis ensures clean output switching, even with slow-moving input signals. The MAX941 features latch enable and device shutdown.

The single MAX941 and dual MAX942 are offered in a tiny µMAX® package. Both the single and dual MAX942 are available in 8-pin DIP and SO packages. The quad MAX944 comes in 14-pin DIP and narrow SO packages.

## Applications

3V/5V Systems

Battery-Powered Systems

Threshold Detectors/Discriminators

Line Receivers

Zero-Crossing Detectors

Sampling Circuits

## Features

- ♦ **Available in µMAX Package for Automotive Applications**
- ♦ **Optimized for 3V and 5V Applications (Operation Down to 2.7V)**
- ♦ **Fast, 80ns Propagation Delay (5mV Overdrive)**
- ♦ **Rail-to-Rail Input Voltage Range**
- ♦ **Low 350µA Supply Current per Comparator**
- ♦ **Low, 1mV Offset Voltage**
- ♦ **Internal Hysteresis for Clean Switching**
- ♦ **Outputs Swing 200mV of Power Rails**
- ♦ **CMOS/TTL-Compatible Outputs**
- ♦ **Output Latch (MAX941 Only)**
- ♦ **Shutdown Function (MAX941 Only)**

## Ordering Information

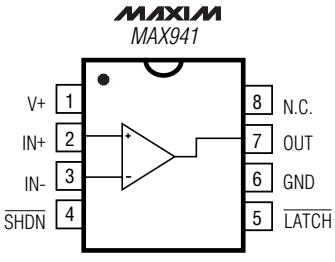
| PART | TEMP RANGE | PIN-PACKAGE |
|---|---|---|
| **MAX941**CPA | 0°C to +70°C | 8 Plastic DIP |
| MAX941CSA | 0°C to +70°C | 8 SO |
| MAX941EPA | -40°C to +85°C | 8 Plastic DIP |
| MAX941ESA | -40°C to +85°C | 8 SO |
| MAX941EUA-T | -40°C to +85°C | 8 µMAX |
| MAX941AUA-T | -40°C to +125°C | 8 µMAX |

***Ordering Information continued at end of data sheet.***

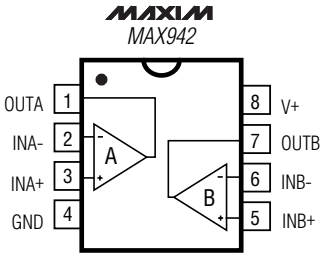
*µMAX is a registered trademark of Maxim Integrated Products, Inc.*

## Pin Configurations

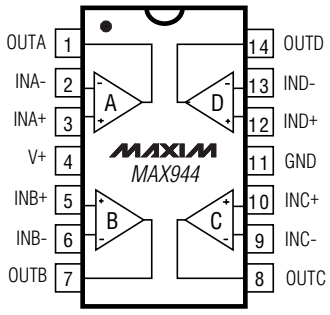
TOP VIEW




DIP/SO/µMAX




DIP/SO/µMAX




DIP/SO

# High-Speed, Low-Power, 3V/5V, Rail-to-Rail, Single-Supply Comparators

## ABSOLUTE MAXIMUM RATINGS

Power-Supply Ranges
- Supply Voltage V+ to GND .....+6.5V
- Differential Input Voltage .....-0.3V to (V+ + 0.3V)
- Common-Mode Input Voltage .....-0.3V to (V+ + 0.3V)
- $\overline{LATCH}$ Input (MAX941 only) .....-0.3V to (V+ + 0.3V)
- $\overline{SHDN}$ Control Input (MAX941 only) .....-0.3V to (V+ + 0.3V)
- Current Into Input Pins .....±20mA

Continuous Power Dissipation ($T_A$ = +70°C)
- 8-Pin Plastic DIP (derate 9.09mW/°C above +70°C) ...727mW
- 8-Pin SO (derate 5.88mW/°C above +70°C).....471mW
- 8-Pin µMAX (derate 4.1mW/°C above +70°C) .....330mW
- 14-Pin Plastic DIP (derate 10.00mW/°C above +70°C)..800mW
- 14-Pin SO (derate 8.33mW/°C above +70°C).....667mW

Operating Temperature Ranges
- MAX94_C_ _ .....0°C to +70°C
- MAX94_E_ _.....-40°C to +85°C
- MAX94_AUA .....-40°C to +125°C
- MAX942MSA.....-55°C to +125°C

Storage Temperature Range .....-65°C to +150°C

Lead Temperature (soldering, 10s) .....+300°C

*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+ = 2.7V to 5.5V, $T_A = T_{MIN}$ to $T_{MAX}$, unless otherwise noted. Typical values are at $T_A$ = +25°C.) (Note 14)

| PARAMETER | SYMBOL | CONDITIONS | | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|---|
| Positive Supply Voltage | V+ | | | | 2.7 | | 5.5 | V |
| Input Voltage Range | $V_{CMR}$ | (Note 1) | | | -0.2 | | V+ + 0.2 | V |
| Input-Referred Trip Points | $V_{TRIP}$ | $V_{CM}$ = 0 or $V_{CM}$ = V+ (Note 2) | $T_A$ = +25°C | MAX94_C_ _, MAX94_EP_, MAX94_ES_, MAX942MSA | | 1 | 3 | mV |
| | | | | MAX941_UA/MAX942_UA | | 1 | 4 | |
| | | | $T_A = T_{MIN}$ to $T_{MAX}$ | MAX94_C_ _, MAX94_EP_, MAX94_ES_, MAX942MSA | | | 4 | mV |
| | | | | MAX941_UA/MAX942_UA | | | 6 | |
| Input Offset Voltage | $V_{OS}$ | $V_{CM}$ = 0 or $V_{CM}$ = V+ (Note 3) | $T_A$ = +25°C | MAX94_C_ _, MAX94_EP_, MAX94_ES_, MAX942MSA | | 1 | 2 | mV |
| | | | | MAX941_UA/MAX942_UA | | 1 | 3 | |
| | | | $T_A = T_{MIN}$ to $T_{MAX}$ | MAX94_C_ _, MAX94_EP_, MAX94_ES_, MAX942MSA | | | 3 | mV |
| | | | | MAX941_UA/MAX942_UA | | | 5.5 | |
| Input Bias Current | $I_B$ | $V_{IN} = V_{OS}$, $V_{CM}$ = 0 or $V_{CM}$ = V+ (Note 4) | | MAX94_C | | 150 | 300 | nA |
| | | | | MAX94_E/A, MAX942MSA | | 150 | 400 | |
| Input Offset Current | $I_{OS}$ | $V_{IN} = V_{OS}$, $V_{CM}$ = 0 or V+ | | | | 10 | 150 | nA |
| Input Differential Clamp Voltage | $V_{CLAMP}$ | Force 100µA into IN+, IN- = GND, measure $V_{IN+}$ - $V_{IN-}$, Figure 3 | | | | 2.2 | | V |
| Common-Mode Rejection Ratio | CMRR | (Note 5) | | MAX94_C_ _, MAX94_EP_, MAX94_ES_, MAX942MSA | | 80 | 300 | µV/V |
| | | | | MAX941_UA/MAX942_UA | | 80 | 800 | |
| Power-Supply Rejection Ratio | PSRR | 2.7V ≤ V+ ≤ 5.5V, $V_{CM}$ = 0V | | MAX94_C_ _, MAX94_EP_, MAX94_ES_, MAX942MSA | | 80 | 300 | µV/V |
| | | | | MAX941_UA/MAX942_UA | | 80 | 350 | |
| Output High Voltage | $V_{OH}$ | $I_{SOURCE}$ = 400µA | | | V+ - 0.4 | V+ - 0.2 | | V |
| | | $I_{SOURCE}$ = 4mA | | | V+ - 0.4 | V+ - 0.3 | | |
| Output Low Voltage | $V_{OL}$ | $I_{SINK}$ = 400µA | | | | 0.2 | 0.4 | V |
| | | $I_{SINK}$ = 4mA | | | | 0.3 | 0.4 | |
| Output Leakage Current | $I_{LEAK}$ | (Note 6) | | | | | 1 | µA |

## ELECTRICAL CHARACTERISTICS (continued)

(V+ = 2.7V to 5.5V, $T_A$ = $T_{MIN}$ to $T_{MAX}$, unless otherwise noted. Typical values are at $T_A$ = +25°C.) (Note 14)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| Supply Current per Comparator | $I_{CC}$ | V+ = 3V | MAX941 | | 380 | 600 | µA |
| | | | MAX942/MAX944 | | 350 | 500 | |
| | | V+ = 5V | MAX941 | | 430 | 700 | |
| | | | MAX942/MAX944 | | 400 | 600 | |
| | | MAX941 only, shutdown mode (V+ = 3V) | | | 12 | 60 | |
| Power Dissipation per Comparator | PD | (Note 7) | MAX941 | | 1.0 | 4.2 | mW |
| | | | MAX942/MAX944 | | 1.0 | 3.6 | |
| Propagation Delay | $t_{PD+}$, $t_{PD-}$ | (Note 8) | MAX94_C | | 80 | 150 | ns |
| | | | MAX94_E/A, MAX942MSA | | 80 | 200 | |
| Differential Propagation Delay | $dt_{PD}$ | (Note 9) | | | 10 | | ns |
| Propagation Delay Skew | | (Note 10) | | | 10 | | ns |
| Logic Input Voltage High | $V_{IH}$ | (Note 11) | | $\frac{V+}{2}$ + 0.4 | $\frac{V+}{2}$ | | V |
| Logic Input Voltage Low | $V_{IL}$ | (Note 11) | | | $\frac{V+}{2}$ | $\frac{V+}{2}$ - 0.4 | V |
| Logic Input Current | $I_{IL}$, $I_{IH}$ | $V_{LOGIC}$ = 0 or V+ (Note 11) | | | 2 | 10 | µA |
| Data-to-Latch Setup Time | $t_S$ | (Note 12) | | | 20 | | ns |
| Latch-to-Data Hold Time | $t_H$ | (Note 12) | | | 30 | | ns |
| Latch Pulse Width | $t_{LPW}$ | MAX941 only | | | 50 | | ns |
| Latch Propagation Delay | $t_{LPD}$ | MAX941 only | | | 70 | | ns |
| Shutdown Time | | (Note 13) | | | 3 | | µs |
| Shutdown Disable Time | | (Note 13) | | | 10 | | µs |

**Note 1:** Inferred from the CMRR test. Note also that either or both inputs can be driven to the absolute maximum limit (0.3V beyond either supply rail) without damage or false output inversion.

**Note 2:** The input-referred trip points are the extremities of the differential input voltage required to make the comparator output change state. The difference between the upper and lower trip points is equal to the width of the input-referred hysteresis zone (see Figure 1).

**Note 3:** $V_{OS}$ is defined as the center of the input-referred hysteresis zone (see Figure 1).

**Note 4:** The polarity of $I_B$ reverses direction as $V_{CM}$ approaches either supply rail. See *Typical Operating Characteristics* for more detail.

**Note 5:** Specified over the full common-mode range ($V_{CMR}$).

**Note 6:** Applies to the MAX941 only when in shutdown mode. Specification is for current flowing into or out of the output pin for $V_{OUT}$ driven to any voltage from V+ to GND.

**Note 7:** Typical power dissipation specified with V+ = 3V; maximum with V+ = 5.5V.

**Note 8:** Parameter is guaranteed by design and specified with $V_{OD}$ = 5mV and $C_{LOAD}$ = 15pF in parallel with 400µA of sink or source current. $V_{OS}$ is added to the overdrive voltage for low values of overdrive (see Figure 2).

**Note 9:** Specified between any two channels in the MAX942/MAX944.

**Note 10:** Specified as the difference between $t_{PD+}$ and $t_{PD-}$ for any one comparator.

**Note 11:** Applies to the MAX941 only for both $\overline{SHDN}$ and $\overline{LATCH}$ pins.

**Note 12:** Applies to the MAX941 only. Comparator is active with $\overline{LATCH}$ pin driven high and is latched with $\overline{LATCH}$ pin driven low (see Figure 2).

**Note 13:** Applicable to the MAX941 only. Comparator is active with $\overline{SHDN}$ pin driven high and is in shutdown with $\overline{SHDN}$ pin driven low. Shutdown disable time is the delay when $\overline{SHDN}$ is driven high to the time the output is valid.

**Note 14:** The MAX941_UA and MAX942_UA are 100% production tested at $T_A$ = +25°C. Specifications over temperature are guaranteed by design.

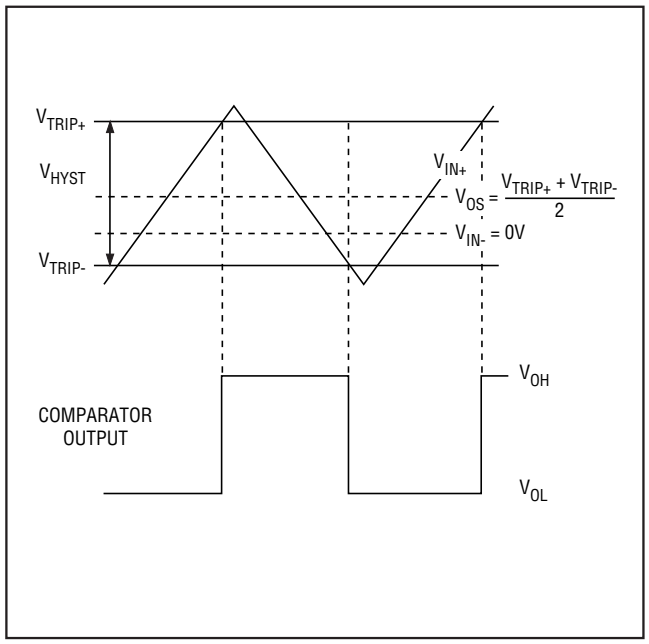



*Figure 1. Input and Output Waveform, Noninverting Input Varied*

## Detailed Description

The MAX941/MAX942/MAX944 single-supply comparators feature internal hysteresis, high speed, and low power. Their outputs are guaranteed to pull within 0.4V of either supply rail without external pullup or pulldown circuitry. Rail-to-rail input voltage range and low-voltage single-supply operation make these devices ideal for portable equipment. The MAX941/MAX942/MAX944 interface directly to CMOS and TTL logic.

### Timing

Most high-speed comparators oscillate in the linear region because of noise or undesired parasitic feedback. This tends to occur when the voltage on one input is at or equal to the voltage on the other input. To counter the parasitic effects and noise, the MAX941/MAX942/MAX944 have internal hysteresis.

The hysteresis in a comparator creates two trip points: one for the rising input voltage and one for the falling input voltage (Figure 1). The difference between the trip points is the hysteresis. When the comparator's input voltages are equal, the hysteresis effectively causes one comparator input voltage to move quickly past the other, thus taking the input out of the region where oscillation occurs. Standard comparators require hysteresis to be added with external resistors. The MAX941/MAX942/MAX944's fixed internal hysteresis eliminates these resistors and the equations needed to determine appropriate values.

Figure 1 illustrates the case where IN- is fixed and IN+ is varied. If the inputs were reversed, the figure would look the same, except the output would be inverted.

The MAX941 includes an internal latch that allows storage of comparison results. The $\overline{LATCH}$ pin has a high input impedance. If $\overline{LATCH}$ is high, the latch is transparent (i.e., the comparator operates as though the latch is not present). The comparator's output state is stored when $\overline{LATCH}$ is pulled low. All timing constraints must be met when using the latch function (Figure 2).

### Shutdown Mode (MAX941 Only)

The MAX941 shuts down when $\overline{SHDN}$ is low. When shut down, the supply current drops to less than 60µA, and the three-state output becomes high impedance. The $\overline{SHDN}$ pin has a high input impedance. Connect $\overline{SHDN}$ to V+ for normal operation. Exit shutdown with $\overline{LATCH}$ high; otherwise, the output will be indeterminate.

### Input Stage Circuitry

The MAX941/MAX942/MAX944 include internal protection circuitry that prevents damage to the precision input stage from large differential input voltages. This protection circuitry consists of two back-to-back diodes between IN+ and IN- as well as two 4.1kΩ resistors (Figure 3). The diodes limit the differential voltage applied to the internal circuitry of the comparators to be no more than $2V_F$, where $V_F$ is the forward voltage drop of the diode (about 0.7V at +25°C).

For a large differential input voltage (exceeding $2V_F$), this protection circuitry increases the input bias current at IN+ (source) and IN- (sink).

$$\text{Input Current} = \frac{(IN+ - IN-) - 2V_F}{2 \times 4.1k\Omega}$$

Input current with large differential input voltages should not be confused with input bias current ($I_B$). As long as the differential input voltage is less than $2V_F$, this input current is equal to $I_B$. The protection circuitry also allows for the input common-mode range of the MAX941/MAX942/MAX944 to extend beyond both power-supply rails. The output is in the correct logic state if one or both inputs are within the common-mode range.

# High-Speed, Low-Power, 3V/5V, Rail-to-Rail, Single-Supply Comparators

## Ordering Information (continued)

| PART | TEMP RANGE | PIN-PACKAGE |
|---|---|---|
| **MAX942**MSA/PR | -55°C to +125°C | 8 SO |
| MAX942CPA | 0°C to +70°C | 8 Plastic DIP |
| MAX942CSA | 0°C to +70°C | 8 SO |
| MAX942EPA | -40°C to +85°C | 8 Plastic DIP |
| MAX942ESA | -40°C to +85°C | 8 SO |
| MAX942EUA-T | -40°C to +85°C | 8 µMAX |
| MAX942AUA-T | -40°C to +125°C | 8 µMAX |
| **MAX944**CPD | 0°C to +70°C | 14 Plastic DIP |
| MAX944CSD | 0°C to +70°C | 14 SO |
| MAX944EPD | -40°C to +85°C | 14 Plastic DIP |
| MAX942ESD | -40°C to +85°C | 14 SO |

## Chip Information

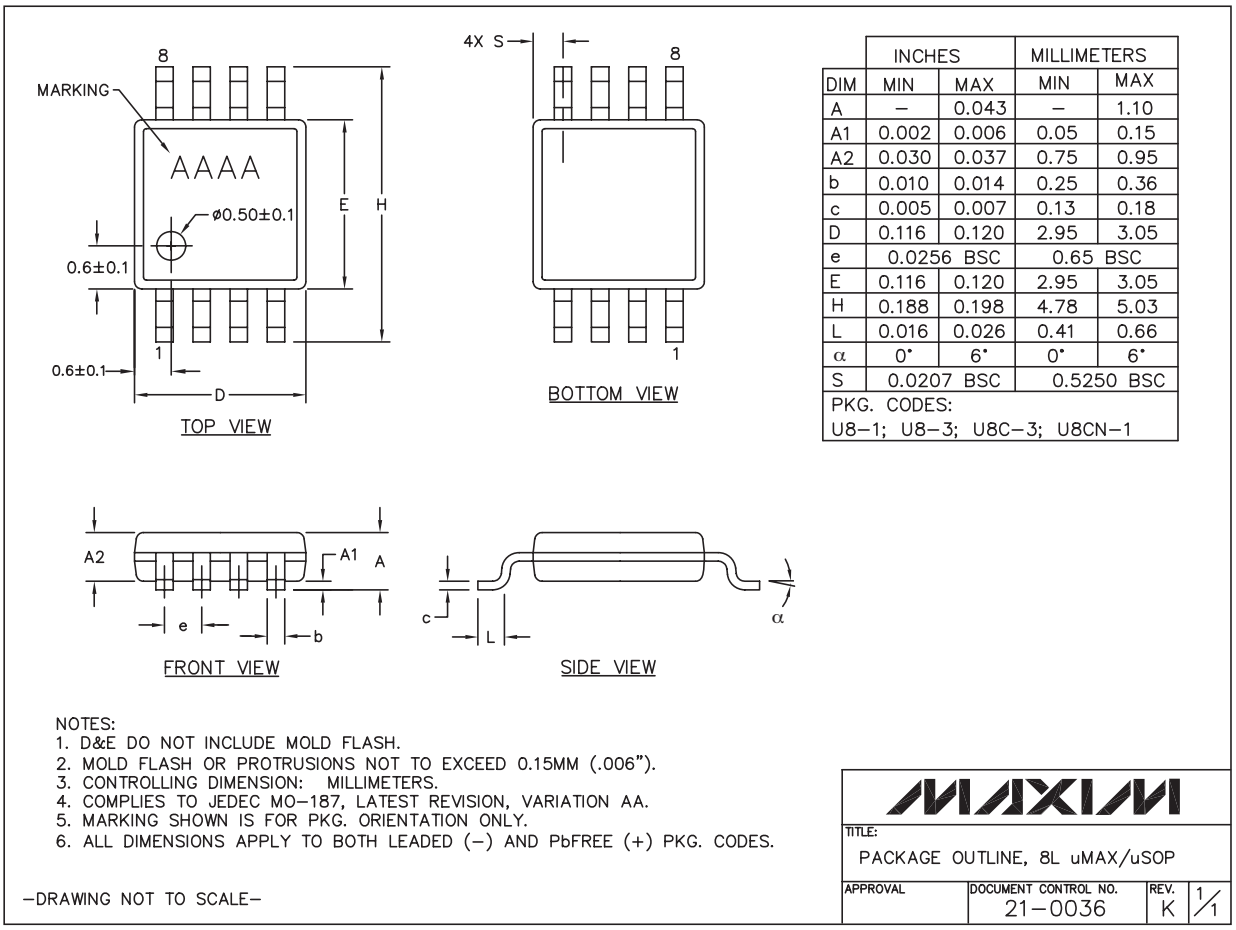
PROCESS: BiPOLAR

# High-Speed, Low-Power, 3V/5V, Rail-to-Rail, Single-Supply Comparators

## Package Information

(For the latest package outline information and land patterns, go to **www.maxim-ic.com/packages**.)

| PACKAGE TYPE | PACKAGE CODE | DOCUMENT NO. |
|---|---|---|
| 8 µMAX | U8-1 | 21-0036 |
| 8 Plastic DIP | P8-1 | 21-0043 |
| 8 SO | S8-2 | 21-0041 |
| 14 Plastic DIP | P14-3 | 21-0043 |
| 14 SO | S14-1 | 21-0041 |




| DIM | INCHES MIN | INCHES MAX | MILLIMETERS MIN | MILLIMETERS MAX |
|---|---|---|---|---|
| A | – | 0.043 | – | 1.10 |
| A1 | 0.002 | 0.006 | 0.05 | 0.15 |
| A2 | 0.030 | 0.037 | 0.75 | 0.95 |
| b | 0.010 | 0.014 | 0.25 | 0.36 |
| c | 0.005 | 0.007 | 0.13 | 0.18 |
| D | 0.116 | 0.120 | 2.95 | 3.05 |
| e | 0.0256 BSC | | 0.65 BSC | |
| E | 0.116 | 0.120 | 2.95 | 3.05 |
| H | 0.188 | 0.198 | 4.78 | 5.03 |
| L | 0.016 | 0.026 | 0.41 | 0.66 |
| α | 0° | 6° | 0° | 6° |
| S | 0.0207 BSC | | 0.5250 BSC | |