



**THE DATASHEET OF  
MAX998ESA+T**



## Single/Dual/Quad, SOT23, Single-Supply, High-Speed, Low-Power Comparators

### General Description

The MAX976/MAX978/MAX998 dual/quad/single, high-speed, low-power comparators are optimized for +3V/+5V single-supply applications. They achieve a 20ns propagation delay while consuming only 225 $\mu$ A supply current per comparator. The MAX998 features a low-power shutdown mode that places the output in a high-impedance state and reduces supply current to 1nA.

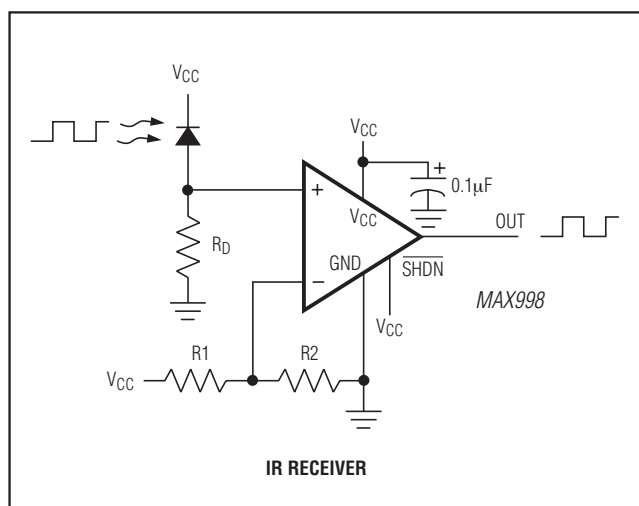
The MAX976/MAX978/MAX998 inputs have a common-mode voltage range that extends 200mV below ground. Their outputs are capable of rail-to-rail operation without external pullup circuitry, making these devices ideal for interface with CMOS/TTL logic. All inputs and outputs can tolerate a continuous short-circuit fault condition to either rail. The comparators' internal hysteresis ensures clean output switching, even with slow-moving input signals.

For space-critical applications, the single MAX998 is available in a 6-pin SOT23 package, the dual MAX976 is available in an 8-pin  $\mu$ MAX® package, and the quad MAX978 is available in a 16-pin QSOP package.

### Applications

- Battery-Powered Systems
- Threshold Detectors/Discriminators
- 3V Systems
- IR Receivers
- Digital Line Receivers

### Typical Operating Circuit



$\mu$ MAX a registered trademark of Maxim Integrated Products, Inc.

### Features

- ◆ Single-Supply Operation Down to 2.7V
- ◆ 20ns Propagation Delay
- ◆ 225 $\mu$ A Supply Current
- ◆ 1nA Shutdown Supply Current
- ◆ Rail-to-Rail Outputs
- ◆ Ground-Sensing Inputs
- ◆ Internal Hysteresis Ensures Clean Switching
- ◆ Available in Space-Saving Packages
  - SOT23 (MAX998)
  - $\mu$ MAX (MAX976)
  - QSOP (MAX978)

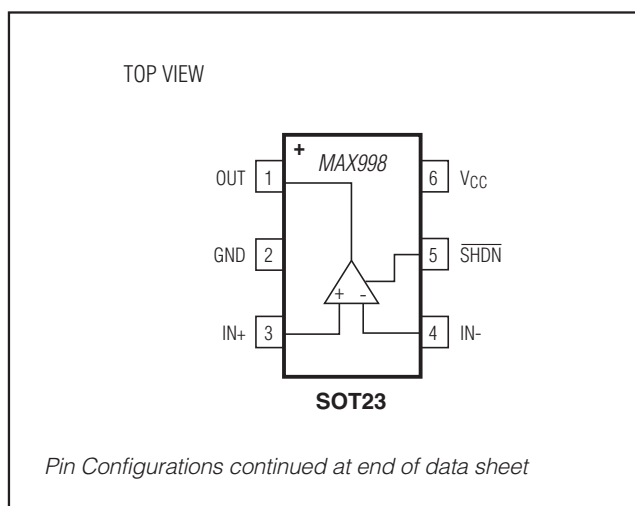
### Ordering Information

PART	PIN-PACKAGE	SOT23 TOP MARK
MAX976ESA+	8 SO	—
MAX976EUA+	8 $\mu$ MAX	—
MAX978ESE+	16 Narrow SO	—
MAX978EEE+	16 QSOP	—
MAX998ESA+	8 SO	—
MAX998EUT+T	6 SOT23	AAA0

**Note:** All devices are specified over the -40°C to +85°C temperature range.

+ Denotes a lead(Pb)-free/RoHS-compliant package.

### Pin Configurations



# MAX976/MAX978/MAX998

## Single/Dual/Quad, SOT23, Single-Supply, High-Speed, Low-Power Comparators

### ABSOLUTE MAXIMUM RATINGS

Supply Voltage ( $V_{CC}$ ).....	+6V	8-Pin SO (derate 5.88mW/°C above +70°C).....	471mW
SHDN (MAX998).....	-0.3V to 6V	16-Pin Narrow SO (derate 8.70mW/°C above +70°C) ..	696mW
All Other Pins.....	-0.3V to ( $V_{CC} + 0.3V$ )	16-Pin QSOP (derate 8.33mW/°C above +70°C).....	667mW
Current into Input Pins.....	±20mA	Operating Temperature Range .....	-40°C to +85°C
Duration of Output Short Circuit to GND or $V_{CC}$ .....	Continuous	Storage Temperature Range .....	-65°C to +160°C
Continuous Power Dissipation ( $T_A = +70^\circ\text{C}$ )		Lead Temperature (soldering, 10s) .....	+300°C
6-Pin SOT23-6 (derate 7.1mW/°C above +70°C) .....	571mW	Soldering Temperature (reflow) .....	+260°C
8-Pin $\mu$ MAX (derate 4.10mW/°C above +70°C) .....	330mW		

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

( $V_{CC} = +2.7V$  to  $+5.5V$ ,  $V_{CM} = 0V$ ,  $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ\text{C}$ .) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	
Supply Voltage Range	$V_{CC}$	Inferred from PSRR test	2.7		5.5	V	
Supply Current per Comparator	$I_{CC}$	$V_{CC} = 5.5V$		300	650	$\mu\text{A}$	
		$V_{CC} = 2.7V$		225			
Shutdown Supply Current	$I_{SD}$	MAX998 only, $\overline{\text{SHDN}} = \text{GND}$		1	500	nA	
Power-Supply Rejection Ratio	PSRR	$2.7V < V_{CC} < 5.5V$	63	100		dB	
Common-Mode Voltage Range	$V_{CMR}$	(Note 2)	-0.2	$V_{CC} - 1.2$		V	
Common-Mode Rejection Ratio	CMRR	$-0.2V \leq V_{CM} \leq (V_{CC} - 1.2V)$	66	95		dB	
Input Offset Voltage	$V_{OS}$	$V_{CC} = 5V$ (Note 3)	$T_A = +25^\circ\text{C}$	0.2	±2	mV	
			$T_A = T_{MIN}$ to $T_{MAX}$				±3
Input-Referred Hysteresis	$V_{HYS}$	$V_{CC} = 5V$ (Note 4)	MAX976EUA, MAX998EUT	0.3	1.5	5.0	mV
			All others	0.5	1.5	4.0	
Input Bias Current	$I_B$			75	300	nA	
Input Offset Current	$I_{OS}$			±5	±100	nA	
OUT Output-Voltage High	$V_{OH}$	$I_{SOURCE} = 2mA$ , $V_{CC} - V_{OH}$		0.1	0.4	V	
OUT Output-Voltage Low	$V_{OL}$	$I_{SINK} = 2mA$		0.1	0.4	V	
OUT Short-Circuit Current	$I_{SH}$	$V_{CC} = 5.5V$	Sinking		74	mA	
			Sourcing		90		
Input Capacitance	$C_{IN}$			3		pF	
SHDN Input-Voltage High	$V_{IH}$	MAX998 only	0.65 x $V_{CC}$			V	
SHDN Input-Voltage Low	$V_{IL}$	MAX998 only			0.2 x $V_{CC}$	V	
OUT Leakage Current	$I_{OUT}$	MAX998 only, $\overline{\text{SHDN}} = \text{GND}$ , $V_{OUT} = 0V$ to $V_{CC}$		1	200	nA	
SHDN Input Current	$I_{SHDN}$	MAX998 only		1	200	nA	
Propagation Delay	$t_{PD}$	$C_{LOAD} = 10pF$ , $V_{CC} = 5V$ (Note 5)	Overdrive = 5mV		28	ns	
			Overdrive = 50mV		20		40
Propagation-Delay Skew	$t_{SKEW}$	$C_{LOAD} = 10pF$ (Note 6)		2		ns	
Propagation-Delay Matching Between Channels	$\Delta t_{PD}$	MAX976/MAX978 only		1		ns	
Output Rise/Fall Time	$t_R/t_F$	$C_{LOAD} = 10pF$		1.6		ns	
Shutdown Delay Time	$t_{SD}$	MAX998 only, $V_{CC} = 5V$ , $I_{CC} = 10\%$ of typical		5		$\mu\text{s}$	

# MAX976/MAX978/MAX998

## Single/Dual/Quad, SOT23, Single-Supply, High-Speed, Low-Power Comparators

### ELECTRICAL CHARACTERISTICS (continued)

( $V_{CC} = +2.7V$  to  $+5.5V$ ,  $V_{CM} = 0V$ ,  $T_A = -40^{\circ}C$  to  $+85^{\circ}C$ , unless otherwise noted. Typical values are at  $T_A = +25^{\circ}C$ .) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Wake-Up from Shutdown	$t_{EN}$	MAX998 only, $V_{CC} = 5V$ , $I_{CC} = 90\%$ of typical (Note 7)		15		$\mu s$
Power-Up Delay	$t_{PU}$	$V_{CC} = 0V$ to $5V$ step, output valid		3		$\mu s$

**Note 1:** The MAX998EUT specifications are 100% tested at  $T_A = +25^{\circ}C$ . Limits over the extended temperature range are guaranteed by design, not production tested.

**Note 2:** Inferred from CMRR test. Either input can be driven to the absolute maximum limit without false output inversion, as long as the other input is within the common-mode voltage range.

**Note 3:**  $V_{OS}$  is defined as the mean of trip points. The trip points are the extremities of the differential input voltage required to make the comparator output change state (Figure 1).

**Note 4:** The difference between the upper and lower trip points is equal to the width of the input-referred hysteresis zone (Figure 1).

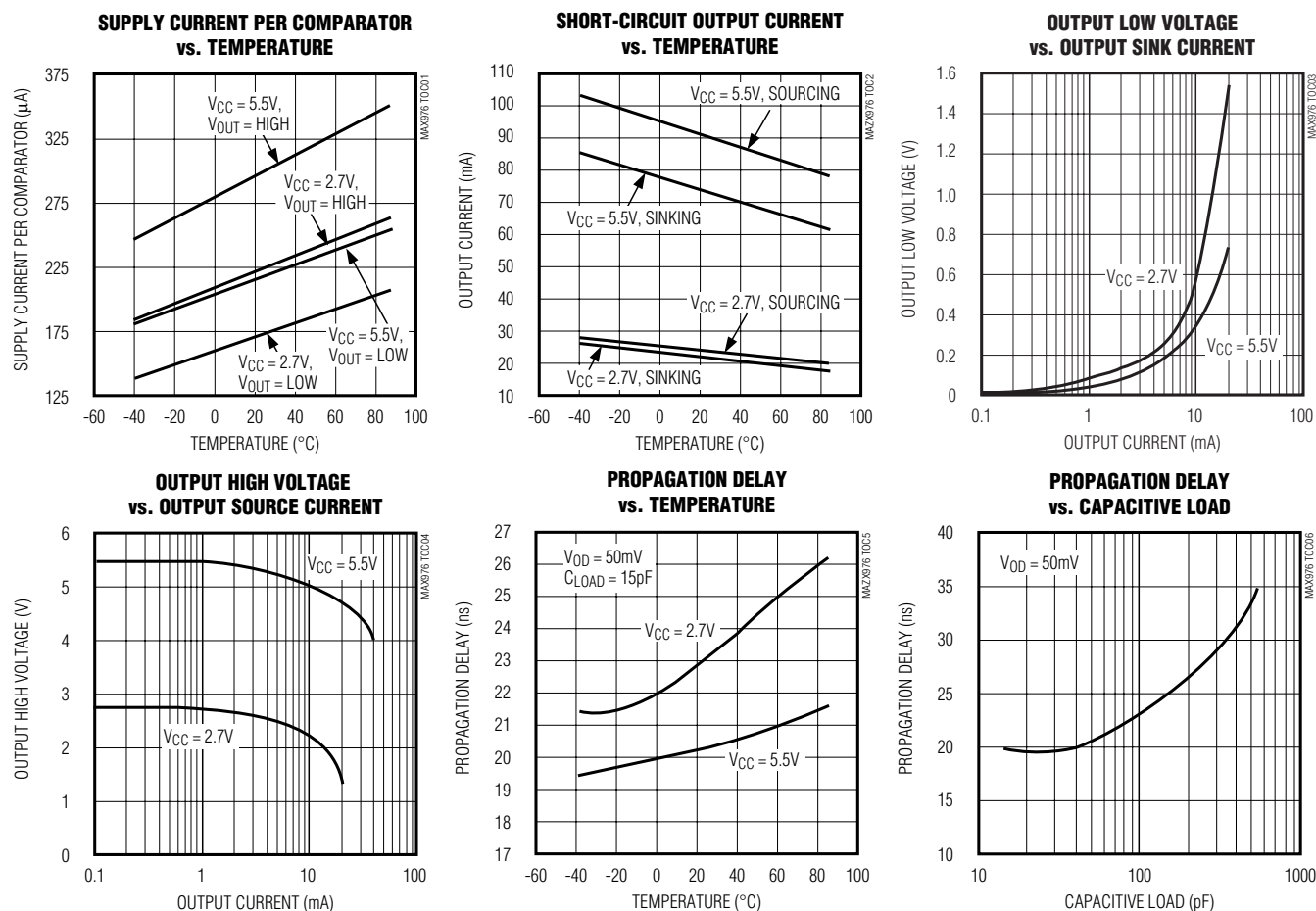
**Note 5:** Propagation Delay is guaranteed by design. For low overdrive conditions,  $V_{TRIP}$  (Figure 1) is added to the overdrive.

**Note 6:** Propagation-Delay Skew is the difference between the positive-going and the negative-going propagation delay.

**Note 7:** For design purposes, the  $t_{EN}$  can be as high as  $60\mu s$ .

### Typical Operating Characteristics

( $V_{CC} = +5V$ ,  $V_{CM} = 0V$ ,  $T_A = +25^{\circ}C$ , unless otherwise noted.)

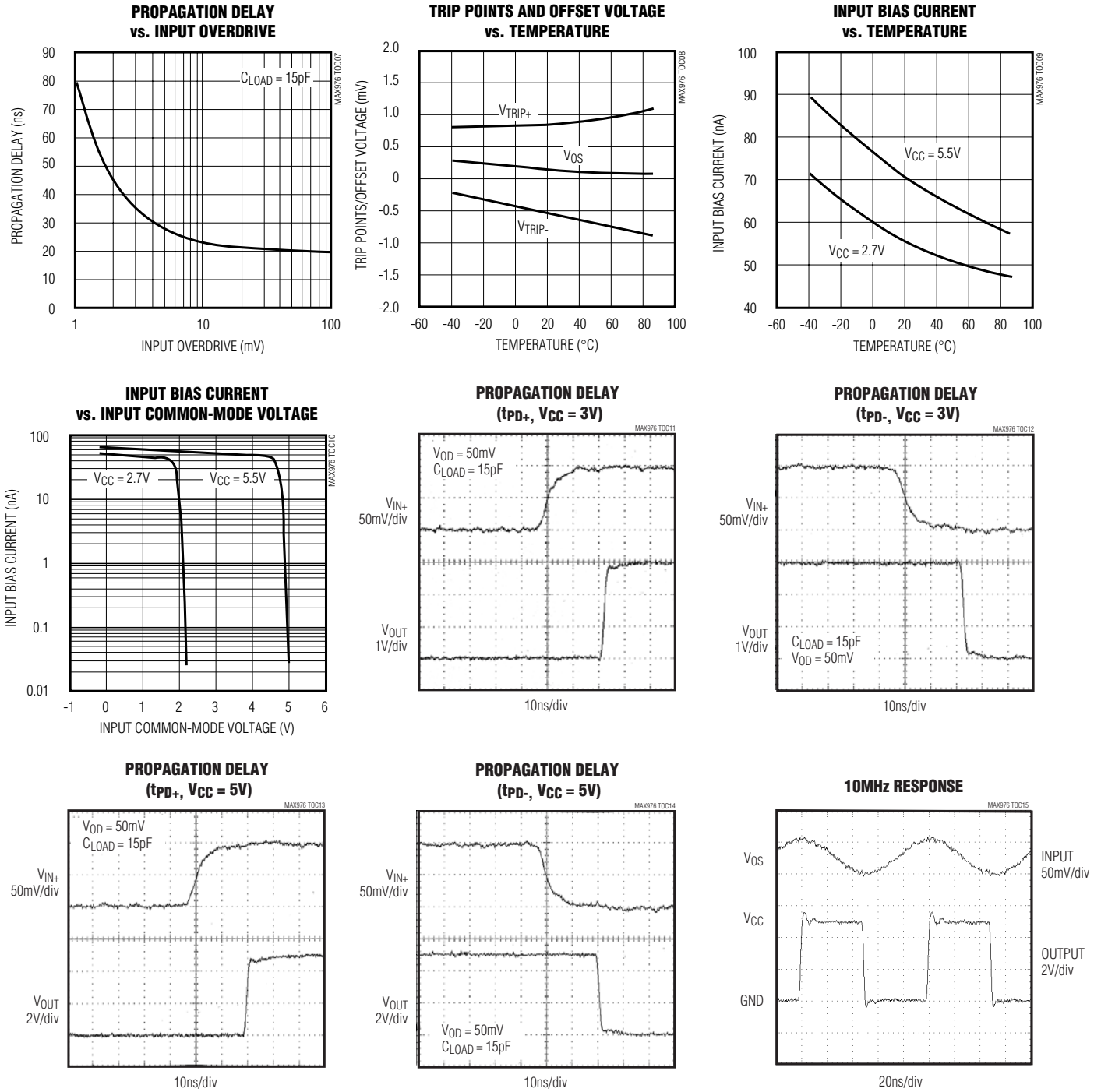


# MAX976/MAX978/MAX998

## Single/Dual/Quad, SOT23, Single-Supply, High-Speed, Low-Power Comparators

### Typical Operating Characteristics (continued)

( $V_{CC} = +5V$ ,  $V_{CM} = 0V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

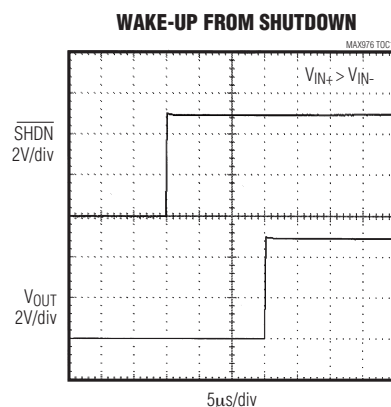
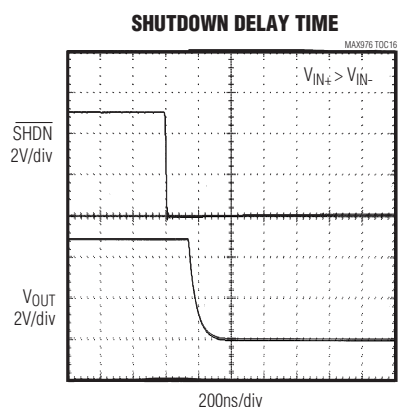


# MAX976/MAX978/MAX998

## Single/Dual/Quad, SOT23, Single-Supply, High-Speed, Low-Power Comparators

### Typical Operating Characteristics (continued)

( $V_{CC} = +5V$ ,  $V_{CM} = 0V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



### Pin Description

PIN				NAME	FUNCTION
MAX976	MAX978	MAX998			
SO/ $\mu$ MAX	SO/QSOP	SOT23-6	SO		
1, 3	1, 3, 5, 7	3	3	IN <sub>+</sub>	Comparator Noninverting Input
2, 4	2, 4, 6, 8	4	2	IN <sub>-</sub>	Comparator Inverting Input
5	9, 13	2	4	GND	Ground
6, 7	10, 11, 14, 15	1	6	OUT <sub>-</sub>	Comparator Output
8	12, 16	6	7	V <sub>CC</sub>	Supply Voltage, +2.7V to +5.5V
—	—	—	1, 5	N.C.	No Connection. Not internally connected.
—	—	5	8	$\overline{\text{SHDN}}$	Shutdown Input. Drive low for shutdown mode. Drive high or connect to V <sub>CC</sub> for normal operation.

### Detailed Description

The MAX976/MAX978/MAX998 dual/quad/single comparators operate from a single +2.7V to +5.5V supply. They achieve a 20ns propagation delay while consuming only 225 $\mu$ A of supply current per comparator. The MAX998 features a low-power shutdown mode that places the output in a high-impedance state and reduces supply current to 1nA. Activate shutdown mode by driving  $\overline{\text{SHDN}}$  low.

The MAX976/MAX978/MAX998 comparator inputs have a common-mode voltage range of -0.2V to ( $V_{CC} - 1.2V$ ).

Either input can be driven to the Absolute Maximum Ratings limit without false output inversion, as long as the other input is within the Common-Mode Voltage Range. Their push/pull output structure is capable of rail-to-rail operation without external pull-up circuitry, making these devices ideal for interfacing with CMOS/TTL logic. All inputs and outputs can tolerate a continuous short-circuit fault condition to either supply. The comparator's internal hysteresis ensures clean output switching, even with slow-moving input signals.



# MAX976/MAX978/MAX998

## Single/Dual/Quad, SOT23, Single-Supply, High-Speed, Low-Power Comparators

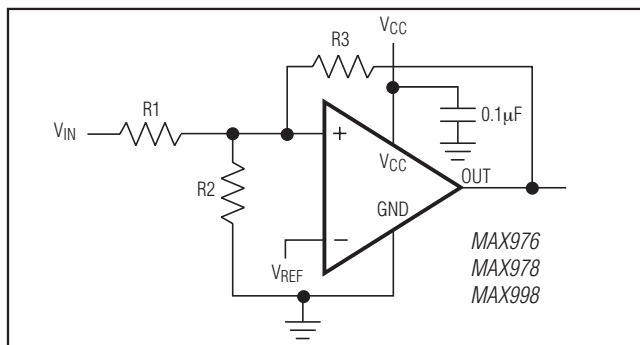


Figure 2. Additional Hysteresis

- 2) Choose the hysteresis band required ( $V_{HB}$ ). For this example, choose 100mV.
- 3) Calculate R1.  $R1 = R3 \times (V_{HB} / V_{CC})$ . Plugging in the values for this example,

$$R1 = 1.2M\Omega \times (100mV / 5.0V) = 24k\Omega$$

- 4) Choose the trip point for  $V_{IN}$  rising. This is the threshold voltage at which the comparator switches from low to high as  $V_{IN}$  rises above the trip point. In this example, choose 3.0V.
- 5) Calculate R2 as follows:

$$R2 = \frac{1}{\left(\frac{V_{THR}}{V_{REF} \times R1}\right) - \frac{1}{R1} - \frac{1}{R3}}$$

$$R2 = \frac{1}{\left(\frac{3.0V}{1.2 \times 24k\Omega}\right) - \frac{1}{24k\Omega} - \frac{1}{1.2M}} = 16.2k\Omega$$

Choose a standard value for R2 of 16k $\Omega$ .

- 6) Verify the trip voltage and hysteresis as follows:

$$V_{IN \text{ rising}}: V_{THR} = V_{REF} \times R1 \times \left(\frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}\right)$$

$$V_{IN \text{ falling}}: V_{THF} = V_{THR} - \left(\frac{R1 \times V_{CC}}{R3}\right)$$

$$\text{Hysteresis} = V_{THR} - V_{THF}$$

### IR Receiver

The *Typical Operating Circuit* shows an application using the MAX998 as an infrared receiver. The infrared photodiode creates a current relative to the amount of infrared light present. This current creates a voltage across  $R_D$ . When this voltage level crosses the voltage applied by the voltage divider to the inverting input, the output transitions.

### Window Comparator

The MAX976 is ideal for making a window detector (undervoltage/overvoltage detector). The schematic shown in Figure 3 uses a MAX6120 reference and component values selected for a 2.0V undervoltage threshold and a 2.5V overvoltage threshold. Choose different thresholds by changing the values of R1, R2, and R3. OUTA provides an active-low undervoltage indication, and OUTB gives an active-low overvoltage indication. ANDing the two outputs provides an active-high, power-good signal. The design procedure is as follows:

- 1) Select R1. The leakage current into INB- is normally 75nA, so the current through R1 should exceed 1.0 $\mu$ A for the thresholds to be accurate. R1 values in the 50k $\Omega$  to 100k $\Omega$  range are typical.
- 2) Choose the overvoltage threshold ( $V_{OTH}$ ) when  $V_{IN}$  is rising, and calculate R2 and R3 with the following formula:

$$R_{SUM} = R2 + R3 = R1 \times [V_{OTH} / (V_{REF} + V_H) - 1]$$

where  $V_H = 1/2V_{HYST}$ .

- 3) Choose the undervoltage threshold ( $V_{UTH}$ ) when  $V_{IN}$  is falling, and calculate R2 with the following formula:

$$R2 = (R1 + R_{SUM}) \times [(V_{REF} - V_H) / V_{UTH}] - R1$$

where  $V_H = 1/2V_{HYST}$ .

- 4) Calculate R3 with the following formula:

$$R3 = (R_{SUM}) - R2$$

- 5) Verify the resistor values. The equations are as follows:

$$V_{OTH} = (V_{REF} + V_H) \times (R1 + R2 + R3) / R1$$

$$V_{UTH} = (V_{REF} - V_H) \times (R1 + R2 + R3) / (R1 + R2)$$

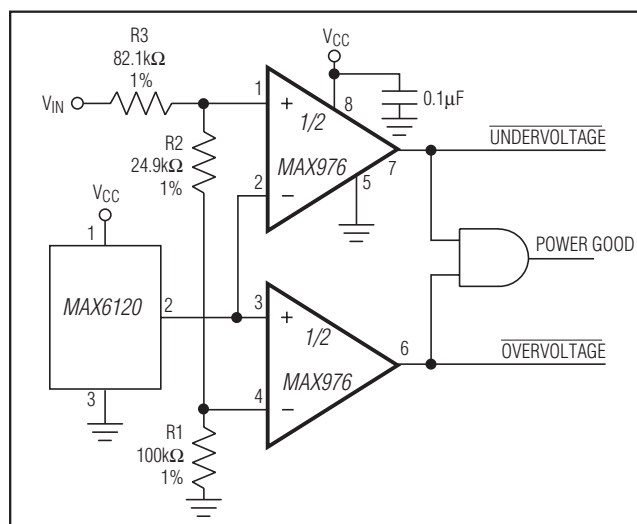
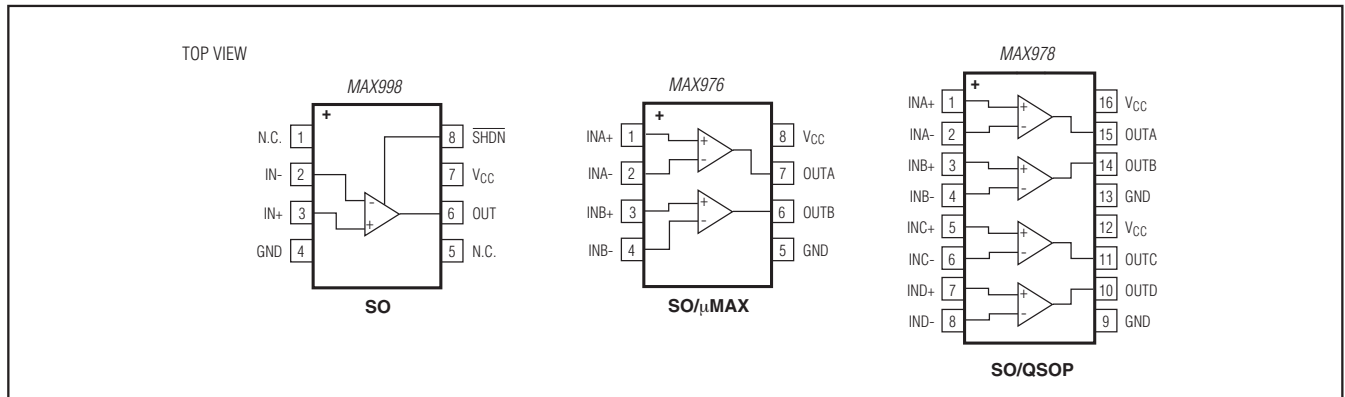


Figure 3. Window Comparator

# MAX976/MAX978/MAX998

## Single/Dual/Quad, SOT23, Single-Supply, High-Speed, Low-Power Comparators

### Pin Configurations (continued)



### Chip Information

PROCESS: CMOS

# **MAX976/MAX978/MAX998**

## **Single/Dual/Quad, SOT23, Single-Supply, High-Speed, Low-Power Comparators**

### **Package Information**

For the latest package outline information and land patterns (footprints), go to [www.maximintegrated.com/packages](http://www.maximintegrated.com/packages). Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

PACKAGE TYPE	PACKAGE CODE	OUTLINE NO.	LAND PATTERN NO.
6 SOT23	U6+2	<a href="#">21-0058</a>	<a href="#">90-0175</a>
8 SO	S8+2	<a href="#">21-0041</a>	<a href="#">90-0096</a>
8 $\mu$ MAX	U8+1	<a href="#">21-0036</a>	<a href="#">90-0092</a>
16 SO	S16M+3	<a href="#">21-0041</a>	<a href="#">90-0097</a>
16 QSOP	E16M+1	<a href="#">21-0055</a>	<a href="#">90-0167</a>

# MAX976/MAX978/MAX998

## Single/Dual/Quad, SOT23, Single-Supply, High-Speed, Low-Power Comparators

### Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	10/97	Initial release	—
1	1/98	Adding specs for MAX998	—
2	1/07	Adding input current ratings to Abs Max	—
3	3/09	Update <i>Chip Information</i> , Package Info, correct unit measurement in TOC 8, style changes	1, 3, 4, 8
4	5/14	Added lead-free information to <i>Ordering Information</i> , revised <i>Absolute Maximum Ratings</i> and <i>Package Information</i>	1, 2, 9



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