19-1299; Rev 0; 10/97

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

MAX976/MAX978/MAX998

General Description

The MAX976/MAX978/MAX998 single/dual/quad, high-speed, low-power comparators are optimized for +3V/+5V single-supply applications. They achieve a 20ns propagation delay while consuming only 300µA supply current per comparator. The MAX998 features a low-power shutdown which, when activated, 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 pull-up 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 SOT23-6 package, the dual MAX976 is available in an 8-pin µMAX 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

Features

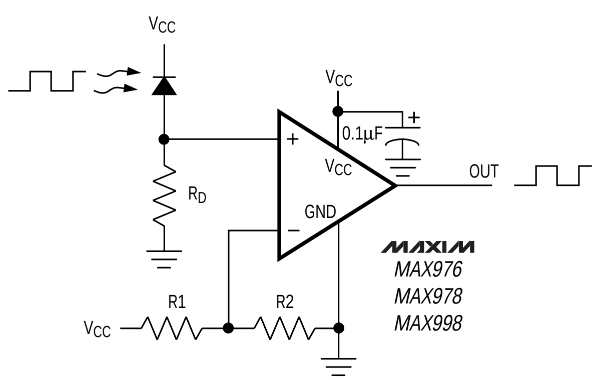
- **20ns Propagation Delay**
- **300µA Supply Current**
- **1nA Shutdown Supply Current**
- **+3V/+5V Single-Supply Operation**
- **Rail-to-Rail Outputs**
- **Ground-Sensing Inputs**
- **Internal Hysteresis Ensures Clean Switching**
- **Available in Space-Saving Packages:**
  SOT23-6 (MAX998)
  µMAX (MAX976)
  QSOP-16 (MAX978)

Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
MAX976ESA	-40°C to +85°C	8 SO
MAX976EUA	-40°C to +85°C	8 µMAX
MAX978ESE	-40°C to +85°C	16 Narrow SO
MAX978EEE	-40°C to +85°C	16 QSOP
MAX998ESA*	-40°C to +85°C	8 SO
MAX998EUT-T*	-40°C to +85°C	6 SOT23-6

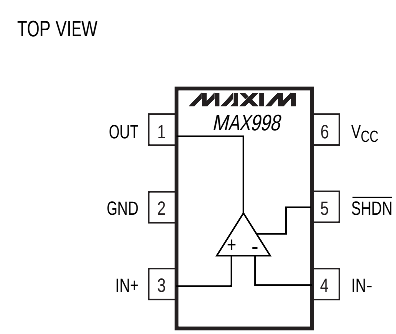
Future product—contact factory for availability.

Typical Operating Circuit



IR RECEIVER

Pin Configurations



SOT23-6

Pin Configurations continued at end of data sheet

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

ABSOLUTE MAXIMUM RATINGS

Supply Voltage (V_{CC})...+6V
$\overline{SHDN}$ (MAX998)..-0.3V to 6V
All Other Pins..-0.3V to (V_{CC} + 0.3V)
Duration of Output Short Circuit to GND or V_{CC} ....Continuous
Continuous Power Dissipation (T_A = +70°C)
6-Pin SOT23-6 (derate 7.1mW/°C above +70°C) 571mW
8-Pin µMAX (derate 4.10mW/°C above +70°C) 330mW
8-Pin SO (derate 5.88mW/°C above +70°C).................471mW
16-Pin Narrow SO (derate 8.70mW/°C above +70°C) ..696mW
16-Pin QSOP (derate 8.33mW/°C above +70°C)..........667mW
Operating Temperature Range ....-40°C to +85°C
Storage Temperature Range ....-65°C to +160°C
Lead Temperature (soldering, 10sec) ....+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_{CC} = +2.7V to +5.5V, V_{CM} = 0V, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Supply Voltage Operating Range	V_{CC}	Inferred from PSRR Test		2.7		5.5	V
Supply Current per Comparator	I_{CC}				300	650	µA
Shutdown Supply Current	I_{SHDN}	MAX998 only, $\overline{SHDN}$ = 0V			1	1000	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 ≤ V_{CM} ≤ (V_{CC} - 1.2V)		66	95		dB
Input Offset Voltage	V_{OS}	V_{CC} = 5V (Note 3)	T_A = +25°C		0.2	±2	mV
			T_A = T_{MIN} to T_{MAX}			±3	
Input-Referred Hysteresis	V_{HYS}	V_{CC} = 5V (Note 4)		0.5	1.5	4	mV
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_{SHORT}	V_{CC} = 5.5V	Sinking		74		mA
			Sourcing		90		
Input Capacitance	C_{IN}				3		pF
$\overline{SHDN}$ Input Voltage High	V_{IH}	MAX998 only		0.8 x V_{CC}			V
$\overline{SHDN}$ Input Voltage Low	V_{IL}	MAX998 only				0.2 x V_{CC}	V
OUT Leakage Current	I_{OUT}	MAX998 only, $\overline{SHDN}$ = GND, V_{OUT} = 0V to Vcc			1	1000	nA
$\overline{SHDN}$ Input Current		MAX998 only			1	1000	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	Δt_{PD}	MAX976, MAX978 only			1		ns

ELECTRICAL CHARACTERISTICS (continued)

(V_{CC} = +2.7V to +5.5V, V_{CM} = 0V, T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

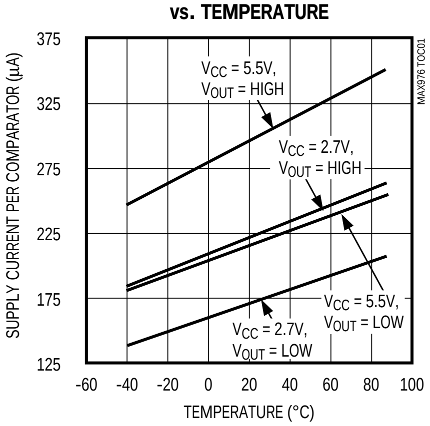
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Output Rise/Fall Time	T_R/T_F	C_{LOAD} =10pF		1.6		ns
Shutdown Delay Time	t_{DIS}	MAX998 only, V_{CC} = 5V, I_{CC} = 10% of typical		5		µs
Wake-Up from Shutdown	t_{EN}	MAX998 only, V_{CC} = 5V, I_{CC} = 90% of typical		60		µs
Power-Up Delay	t_{PU}	V_{CC} = 0V to 5V step, Output valid		2		µs

Note 1: The MAX998EUT specifications are 100% tested at T_A = +25°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} (see 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.

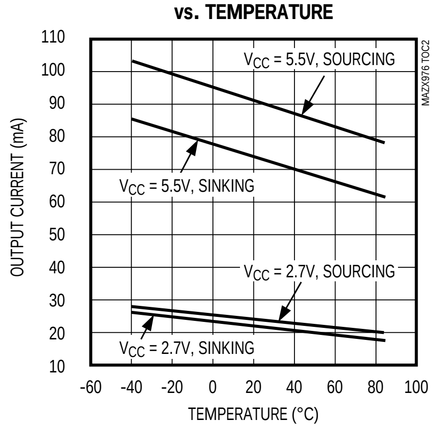
Typical Operating Characteristics

(V_{CC} = +5V, T_A = +25°C, unless otherwise noted.)

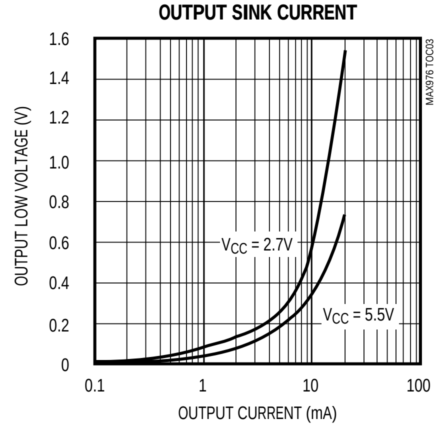
SUPPLY CURRENT PER COMPARATOR vs. TEMPERATURE



SHORT-CIRCUIT OUTPUT CURRENT vs. TEMPERATURE



OUTPUT LOW VOLTAGE vs. OUTPUT SINK CURRENT

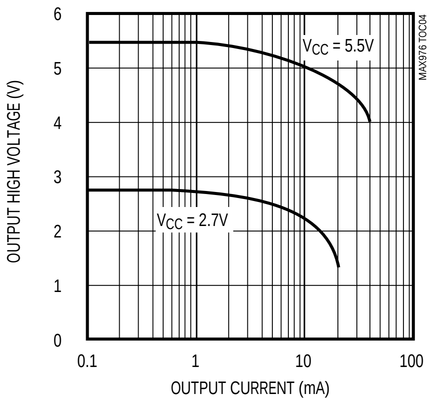


Single/Dual/Quad, SOT23, Single-Supply, High-Speed, Low-Power Comparators

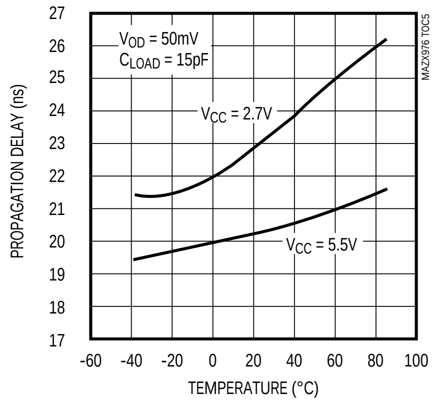
Typical Operating Characteristics (continued)

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

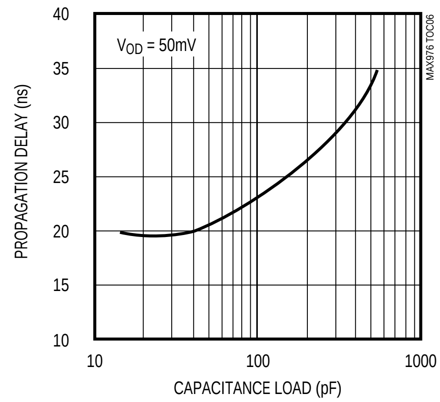
OUTPUT HIGH VOLTAGE vs. OUTPUT SOURCE CURRENT



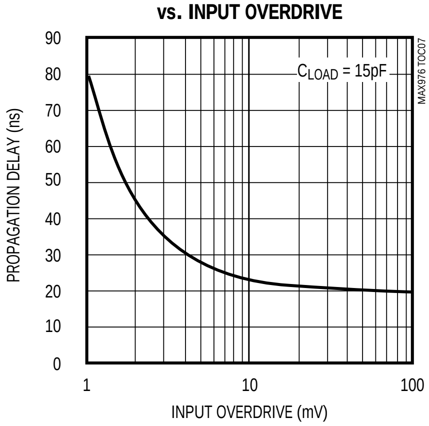
PROPAGATION DELAY vs. TEMPERATURE



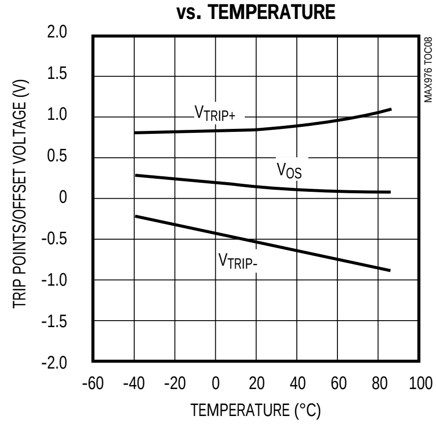
PROPAGATION DELAY vs. CAPACITIVE LOAD



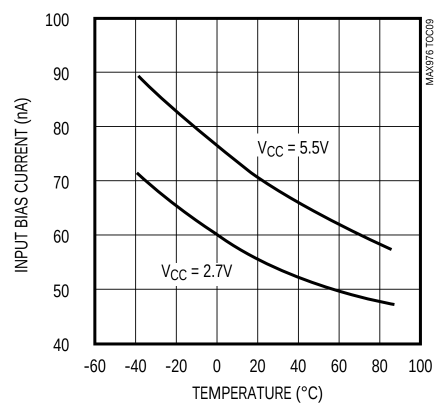
PROPAGATION DELAY vs. INPUT OVERDRIVE



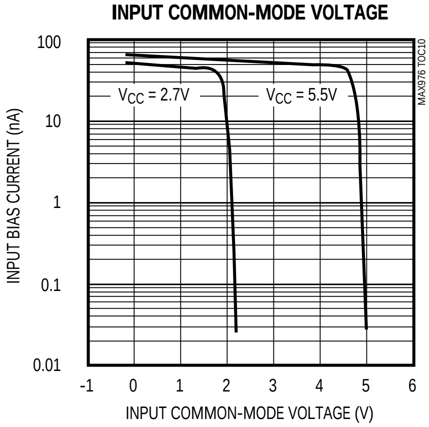
TRIP POINTS AND OFFSET VOLTAGE vs. TEMPERATURE



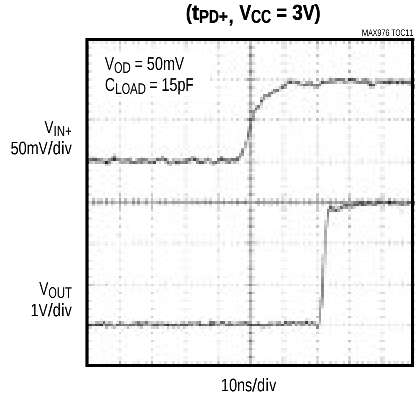
INPUT BIAS CURRENT vs. TEMPERATURE



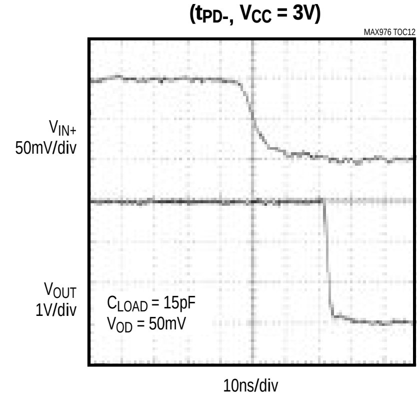
INPUT BIAS CURRENT vs. INPUT COMMON-MODE VOLTAGE



PROPAGATION DELAY (t_{PD+}, V_{CC} = 3V)



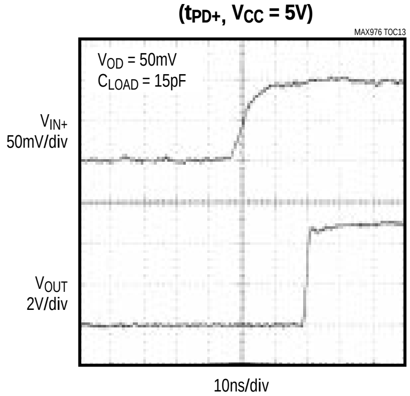
PROPAGATION DELAY (t_{PD-}, V_{CC} = 3V)



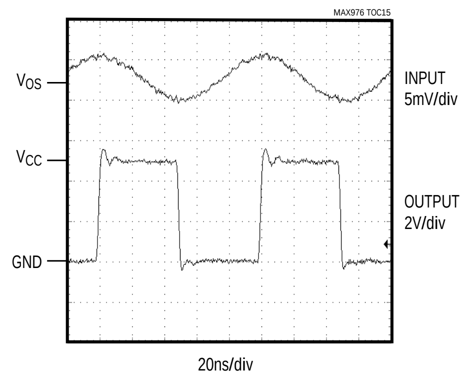
Typical Operating Characteristics (continued)

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

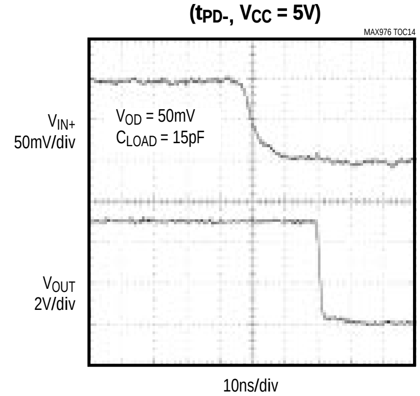
PROPAGATION DELAY (t_{PD+}, V_{CC} = 5V)



10MHz RESPONSE



PROPAGATION DELAY (t_{PD-}, V_{CC} = 5V)



Pin Description

PIN				NAME	FUNCTION
MAX976	MAX978	MAX998			
S0/µMAX	S0/QSOP	SOT23-6	SO		
1, 3	1, 3, 5, 7	3	3	IN_+	Comparator Noninverting Input
2, 4	2, 4, 6, 8	4	2	IN_-	Comparator Inverting Input
5	9, 13	2	4	GND	Ground
6, 7	10, 11, 14, 15	1	6	OUT_	Comparator Output
8	12, 16	6	7	V_{CC}	Supply Voltage, +2.7V to +5.5V
—	—	—	1, 5	N.C.	No Connection. Not internally connected.
—	—	5	8	$\overline{SHDN}$	Shutdown Input. Drive low for shutdown mode. Drive high or connect to V_{CC} for normal operation.

Detailed Description

The MAX976/MAX978/MAX998 single/dual/quad comparators operate from a single +2.7V to +5.5V supply. They achieve a 20ns propagation delay while consuming only 300µA 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 $\overline{SHDN}$ 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 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.

Hysteresis

Most high-speed comparators can oscillate in the linear operating region because of noise or undesired parasitic feedback. This tends to occur when the voltage on one input is equal to or very close to the voltage on the other input. The MAX976/MAX978/MAX998 have internal hysteresis to counter parasitic effects and noise. 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 input voltages are equal, the hysteresis effectively causes one comparator input voltage to move quickly past the other, taking the input out of the region where oscillation occurs.

Figure 1 illustrates the case where IN- has a fixed voltage applied and IN+ is varied. If the inputs were reversed, the figure would be the same, except with an inverted output.

Input-Stage Circuitry

The MAX976/MAX978/MAX998 input common-mode voltage range is from -0.2V to (V_{CC} - 1.2V). The voltage range for each comparator input extends to both V_{CC} and GND rails. The output remains in the correct logic state while one or both of the inputs are within the common-mode range. If both input levels are out of the common-mode range, input-stage current saturation occurs and the output becomes unpredictable.

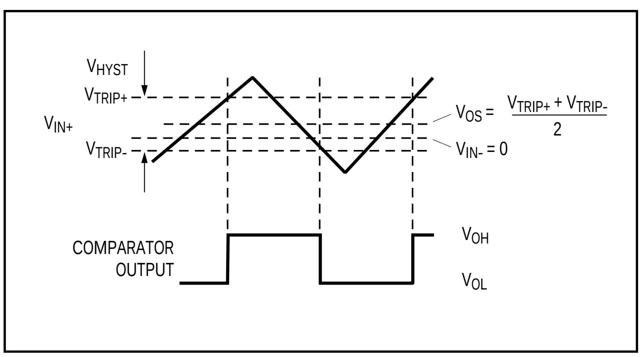


Figure 1. Input and Output Waveforms, Noninverting Input Varied

Shutdown Mode

The MAX998 features a low-power shutdown mode, which is activated by forcing $\overline{SHDN}$ low. Shutdown mode reduces the supply current to 1nA (typical), disables the comparator, and places the output in a high-impedance state. Drive $\overline{SHDN}$ high to enable the comparator. Do not leave $\overline{SHDN}$ unconnected. Since it is a high-impedance input, leaving $\overline{SHDN}$ unconnected could result in indeterminate logic levels, adversely affecting comparator operation. Likewise, do not three-state $\overline{SHDN}$. Due to the output leakage currents of three-state devices and the small internal current for $\overline{SHDN}$, three-stating this pin could also result in indeterminate logic levels.

Applications Information

Circuit Layout and Bypassing

The MAX976/MAX978/MAX998 have a high-gain bandwidth and require careful board layout. We recommend the following design guidelines:

1) Use a printed circuit board with an unbroken, low-inductance ground plane. Surface mount componants are recommended.
2) Place a decoupling capacitor (a 0.1µF ceramic capacitor is a good choice) between V_{CC} and ground as close to the pins as possible.
3) Keep lead lengths short on the inputs and outputs, to avoid unwanted parasitic feedback around the comparators.
4) Solder the devices directly to the printed circuit board instead of using a socket.
5) Minimize input impedance.
6) For slowly varying inputs, use a small capacitor (~1000pF) across the inputs to improve stability.

Additional Hysteresis

Generate additional hysteresis with three resistors using positive feedback, as shown in Figure 2. This positive feedback method slows the hysteresis response time. Calculate resistor values as follows:

1) Select R3. The leakage current of IN+ is under 500nA, so the current through R3 should be at least 50µA to minimize errors caused by leakage current. The current through R3 at the trip point is $(V_{REF} - V_{OUT})/R3$. Consider the two possible output states when solving for R3; the two formulas are

   $R3 = V_{REF}/50µA$
   or
   $R3 = (V_{REF} - V_{CC})/50µA$.

   Use the smaller of the two resulting resistor values. For example, if $V_{REF} = 1.2V$ and $V_{CC} = 5.0V$, the two resistor values are 24kΩ and 76kΩ. Choose a standard value for R3 of 24kΩ.

2) Choose the hysteresis band required (V_{HB}). For this example, choose 50mV.

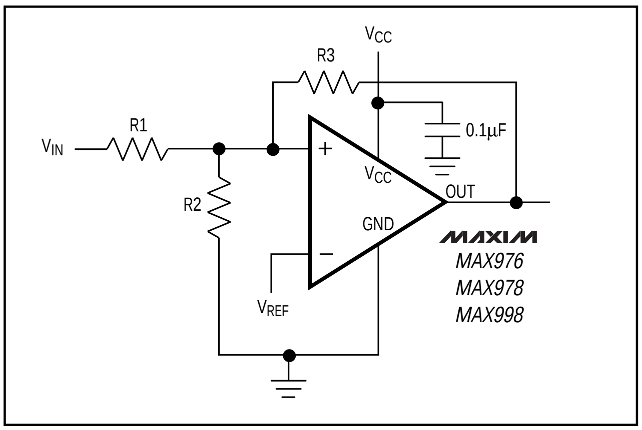


Figure 2. Additional Hysteresis

3) Calculate R1. $R1 = R3 \times (V_{HB}/V_{CC})$. Plugging in the values for this example,

   $R1 = 24kΩ \times (50mV/5.0V) = 240Ω$.

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:

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

$$R2 = \frac{1}{\left(\frac{3.0V}{1.2 \times 240}\right) - \frac{1}{240} - \frac{1}{24k}} = 161W$$

   Choose a standard value for R2 of 150Ω.

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 100nA, so the current through R1 should exceed 10µA for the thresholds to be accurate. R1 values in the 5kΩ to 10kΩ 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 $V_H = 1/2 V_{HYST}$.
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 $V_H = 1/2 V_{HYST}$.
4) Calculate R3 with the following formula:

   $$R3 = (R_{SUM}) - R2$$
5) Verify the resistor values. The equations are as follows:

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

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

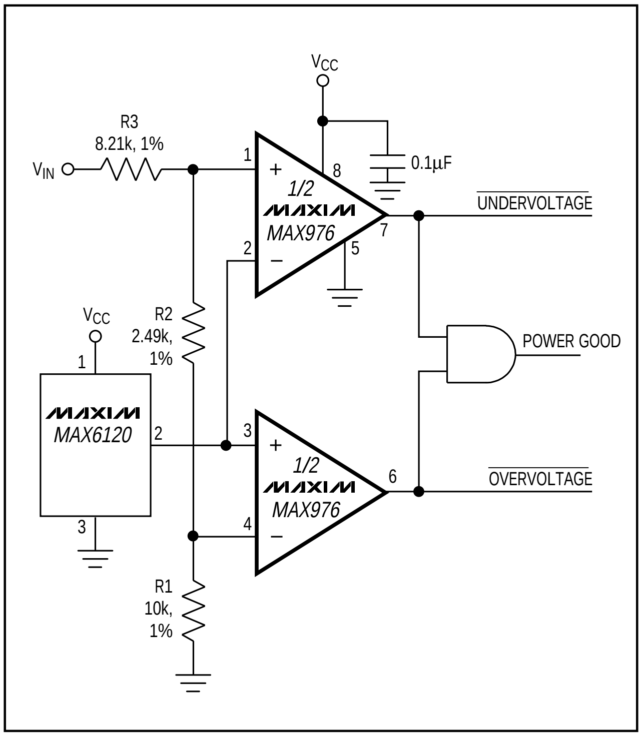
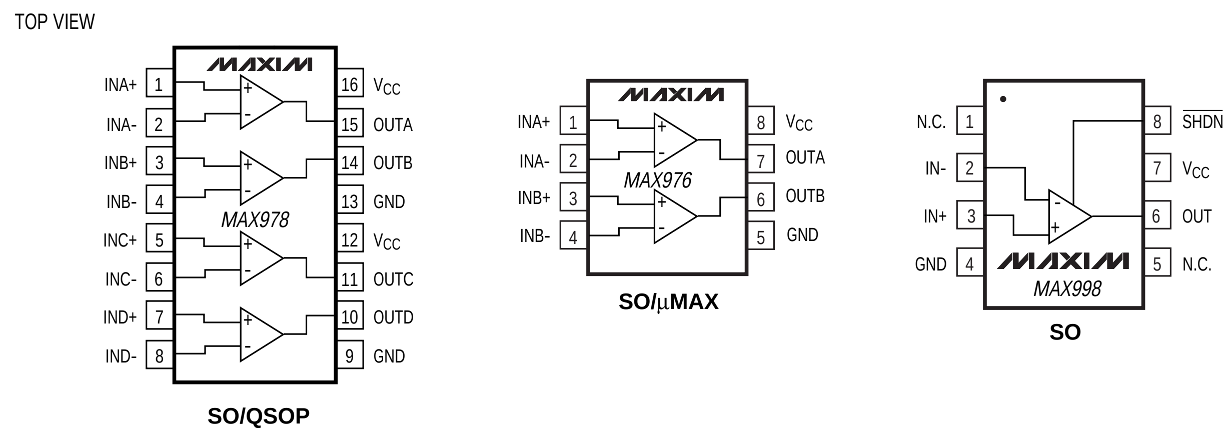


Figure 3. Window Comparator

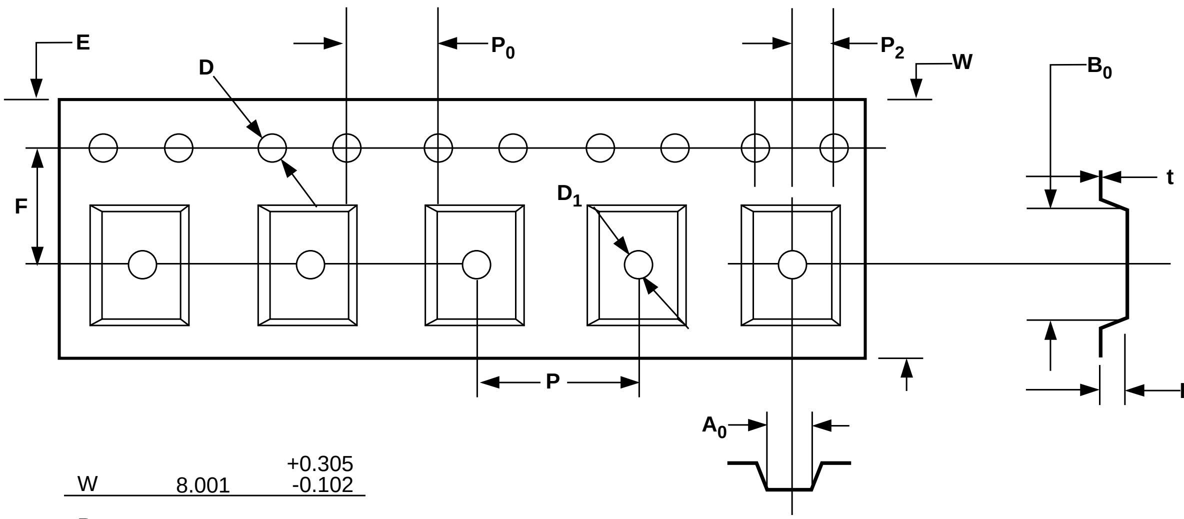
Pin Configurations (continued)



Chip Information

TRANSISTOR COUNT: 415 (MAX976)
830 (MAX978)
300 (MAX998)

Tape-and-Reel Information

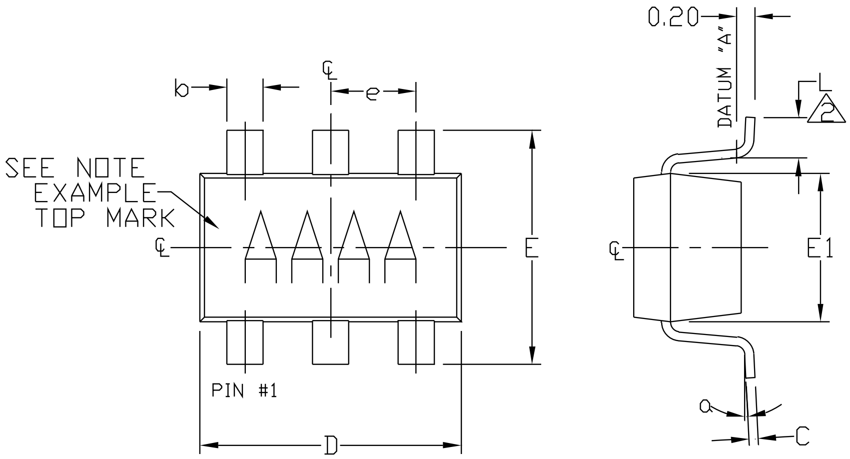


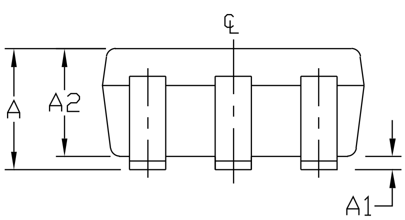
W	8.001	+0.305 -0.102
P	3.988	±0.102
E	1.753	±0.102
F	3.505	±0.051
D	1.499	+0.102 +0.000
D_1	0.991	+0.254 +0.000
P_0	3.988	±0.102
$P_0$10	40.005	±0.203
P_2	2.007	±0.051
A0	3.200	±0.102
B0	3.099	±0.102
K0	1.397	±0.102
t	0.254	±0.127

NOTE: DIMENSIONS ARE IN MM.
AND FOLLOW EIA481-1 STANDARD.

Package Information

6LSOT.EPS





SYMBOL	MIN	MAX
A	0.90	1.45
A1	0.00	0.15
A2	0.90	1.30
b	0.35	0.50
C	0.08	0.20
D	2.80	3.00
E	2.60	3.00
E1	1.50	1.75
L	0.35	0.55
e	0.95 REF	
a	0°	10°

NOTE:

1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. FOOT LENGTH MEASURED AT INTERCEPT POINT BETWEEN DATUM A & LEAD SURFACE.
3. PACKAGE OUTLINE EXCLUSIVE OF MOLD FLASH & METAL BURR.
4. PACKAGE OUTLINE INCLUSIVE OF SOLDER PLATING.
5. PIN 1 IS LOWER LEFT PIN WHEN READING TOP MARK FROM LEFT TO RIGHT. (SEE EXAMPLE TOP MARK)

MAXIM

PROPRIETARY INFORMATION

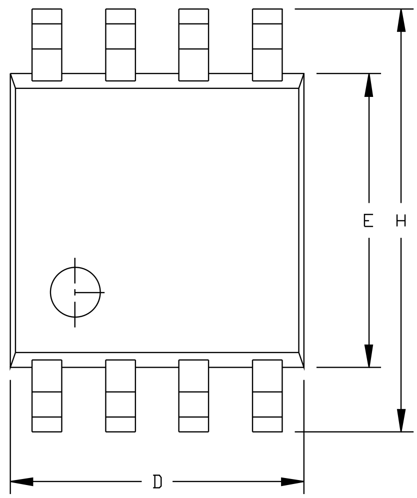
TITLE:

PACKAGE OUTLINE, SOT23, 6L

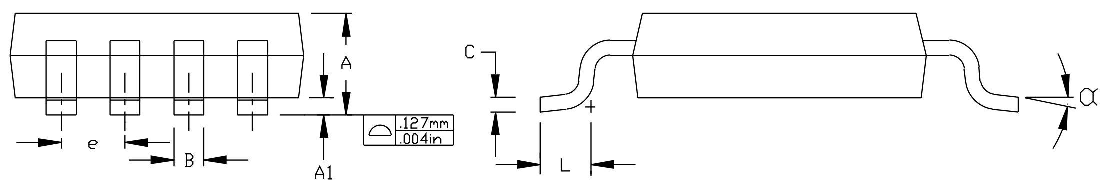
APPROVAL	DOCUMENT CONTROL NO.	REV	
	21-0058	C	1/1

Package Information (continued)

8LUMAXD.EPS



	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.036	0.044	0.91	1.11
A1	0.004	0.008	0.10	0.20
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		0.65	
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°



NOTES:
1. D&E DO NOT INCLUDE MOLD FLASH.
2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED .15mm(.006").
3. CONTROLLING DIMENSION: INCHES

MAXIM
PROPRIETARY INFORMATION
TITLE:
8LD uMAX PACKAGE OUTLINE DWG.

APPROVAL	DOCUMENT CONTROL NO.	REV	
	21-0036	D	1/1