19-1512; Rev 0; 7/99

SOT23, 1.8V, Nanopower, Beyond-the-Rails Comparators With/Without Reference

General Description

The MAX917–MAX920 nanopower comparators in space-saving SOT23 packages feature Beyond-the-Rails™ inputs and are guaranteed to operate down to +1.8V. The MAX917/MAX918 feature an on-board 1.245V ±1.5% reference and draw an ultra-low supply current of only 750nA, while the MAX919/MAX920 (without reference) require just 380nA of supply current. These features make the MAX917–MAX920 family of comparators ideal for all 2-cell battery applications, including monitoring/management.

The unique design of the output stage limits supply-current surges while switching, virtually eliminating the supply glitches typical of many other comparators. This design also minimizes overall power consumption under dynamic conditions. The MAX917/MAX919 have a push/pull output stage that sinks and sources current. Large internal output drivers allow Rail-to-Rail® output swing with loads up to 8mA. The MAX918/MAX920 have an open-drain output stage that makes them suitable for mixed-voltage system design.

Applications

2-Cell Battery Monitoring/Management
Ultra-Low-Power Systems
Mobile Communications
Notebooks and PDAs
Threshold Detectors/Discriminators
Sensing at Ground or Supply Line
Telemetry and Remote Systems
Medical Instruments

Selector Guide

PART	INTERNAL REFERENCE	OUTPUT TYPE	SUPPLY CURRENT (nA)
MAX917	Yes	Push/Pull	750
MAX918	Yes	Open-Drain	750
MAX919	No	Push/Pull	380
MAX920	No	Open-Drain	380

Typical Application Circuit appears at end of data sheet.

Beyond-the-Rails is a trademark of Maxim Integrated Products.
Rail-to-Rail is a registered trademark of Nippon Motorola, Ltd.

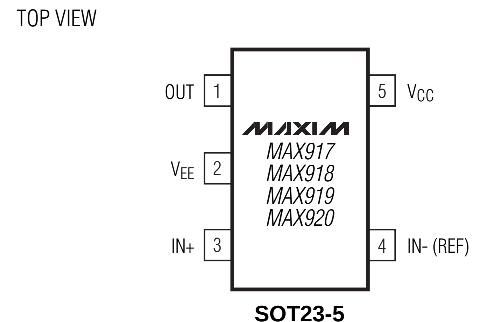
Features

- ♦ **Ultra-Low Supply Current**
  380nA per Comparator (MAX919/MAX920)
  750nA per Comparator with Reference (MAX917/MAX918)
- ♦ **Guaranteed to Operate Down to +1.8V**
- ♦ **Internal 1.245V ±1.5% Reference (MAX917/MAX918)**
- ♦ **Input Voltage Range Extends 200mV Beyond-the-Rails**
- ♦ **CMOS Push/Pull Output with ±8mA Drive Capability (MAX917/MAX919)**
- ♦ **Open-Drain Output Versions Available (MAX918/MAX920)**
- ♦ **Crowbar-Current-Free Switching**
- ♦ **Internal Hysteresis for Clean Switching**
- ♦ **No Phase Reversal for Overdriven Inputs**
- ♦ **Space-Saving SOT23 Package**

Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE	SOT TOP MARK
MAX917EUK-T	-40°C to +85°C	5 SOT23-5	ADIQ
MAX917ESA	-40°C to +85°C	8 SO	—
MAX918EUK-T	-40°C to +85°C	5 SOT23-5	ADIR
MAX918ESA	-40°C to +85°C	8 SO	—
MAX919EUK-T	-40°C to +85°C	5 SOT23-5	ADIS
MAX919ESA	-40°C to +85°C	8 SO	—
MAX920EUK-T	-40°C to +85°C	5 SOT23-5	ADIT
MAX920ESA	-40°C to +85°C	8 SO	—

Pin Configurations



( ) ARE FOR MAX917/MAX918.

Pin Configurations continue at end of data sheet.

ABSOLUTE MAXIMUM RATINGS

Supply Voltage (V_{CC} to V_{EE})	+6V
Voltage Inputs (IN+, IN-, REF)	(V_{EE} - 0.3V) to (V_{CC} + 0.3V)
Output Voltage	
MAX917/MAX919	(V_{EE} - 0.3V) to (V_{CC} + 0.3V)
MAX918/MAX920	(V_{EE} - 0.3V) to +6V
Output Current	±50mA
Output Short-Circuit Duration	10sec
Continuous Power Dissipation (T_A = +70°C)	
5-Pin SOT23 (derate 7.31mW/°C above +70°C)	571mW
8-Pin SO (derate 5.88mW/°C above +70°C)	471mW
Operating Temperature Range	-40°C to +85°C
Storage Temperature Range	-65°C to +150°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—MAX917/MAX918

(V_{CC} = +5V, V_{EE} = 0, V_{IN+} = V_{REF}, 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 Range	V_{CC}	Inferred from the PSRR test		1.8		5.5	V
Supply Current	I_{CC}	V_{CC} = 1.8V			0.75		µA
		V_{CC} = 5V	T_A = +25°C		0.80	1.30	
			T_A = T_{MIN} to T_{MAX}			1.60	
IN+ Voltage Range	V_{IN+}	Inferred from the output swing test		V_{EE} - 0.2		V_{CC} + 0.2	V
Input Offset Voltage	V_{OS}	(Note 2)	T_A = +25°C		1	5	mV
			T_A = T_{MIN} to T_{MAX}			10	
Input-Referred Hysteresis	V_{HB}	(Note 3)			4		mV
Input Bias Current	I_B	T_A = +25°C			0.15	1	nA
		T_A = T_{MIN} to T_{MAX}				2	
Power-Supply Rejection Ratio	PSRR	V_{CC} = 1.8V to 5.5V			0.1	1	mV/V
Output Voltage Swing High	V_{CC} - V_{OH}	MAX917 only, V_{CC} = 5V, I_{SOURCE} = 8mA	T_A = +25°C		190	400	mV
			T_A = T_{MIN} to T_{MAX}			500	
		MAX917 only, V_{CC} = 1.8V, I_{SOURCE} = 1mA	T_A = +25°C		55	200	
			T_A = T_{MIN} to T_{MAX}			300	
Output Voltage Swing Low	V_{OL}	V_{CC} = 5V, I_{SINK} = 8mA	T_A = +25°C		190	400	mV
			T_A = T_{MIN} to T_{MAX}			500	
		V_{CC} = 1.8V, I_{SINK} = 1mA	T_A = +25°C		55	200	
			T_A = T_{MIN} to T_{MAX}			300	
Output Leakage Current	I_{LEAK}	MAX918 only, V_O = 5.5V			0.001	1	µA
Output Short-Circuit Current	I_{SC}	Sourcing, V_O = V_{EE}	V_{CC} = 5V		95		mA
			V_{CC} = 1.8V		8		
		Sinking, V_O = V_{CC}	V_{CC} = 5V		98		
			V_{CC} = 1.8V		10		

ELECTRICAL CHARACTERISTICS—MAX917/MAX918 (continued)

(V_{CC} = +5V, V_{EE} = 0, V_{IN+} = V_{REF}, 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
High-to-Low Propagation Delay (Note 4)	t_{PD-}	V_{CC} = 1.8V			17		µs
		V_{CC} = 5V			22		
Low-to-High Propagation Delay (Note 4)	t_{PD+}	MAX917 only	V_{CC} = 1.8V		30		µs
			V_{CC} = 5V		95		
		MAX918 only	V_{CC} = 1.8V, $R_{PULL-UP}$ = 100kΩ		35		
			V_{CC} = 5V, $R_{PULL-UP}$ = 100kΩ		120		
Rise Time	t_{RISE}	MAX917 only, C_L = 15pF			6		µs
Fall Time	t_{FALL}	C_L = 15pF			4		µs
Power-Up Time	t_{ON}				1.2		ms
Reference Voltage	V_{REF}	T_A = +25°C		1.227	1.245	1.263	V
		T_A = T_{MIN} to T_{MAX}		1.200		1.290	
Reference Voltage Temperature Coefficient	TC_{REF}				95		ppm/°C
Reference Output Voltage Noise	e_n	BW = 10Hz to 100kHz			600		$µV_{RMS}$
		BW = 10Hz to 100kHz, C_{REF} = 1nF			215		
Reference Line Regulation	$\Delta V_{REF}/\Delta V_{CC}$	1.8V ≤ V_{CC} ≤ 5.5V			0.1		mV/V
Reference Load Regulation	$\Delta V_{REF}/\Delta I_{OUT}$	ΔI_{OUT} = 10nA			±0.2		mV/nA

ELECTRICAL CHARACTERISTICS—MAX919/MAX920

(V_{CC} = +5V, V_{EE} = 0, V_{CM} = 0, 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 Range	V_{CC}	Inferred from the PSRR test		1.8		5.5	V
Supply Current	I_{CC}	V_{CC} = 1.8V			0.38		µA
		V_{CC} = 5V	T_A = +25°C		0.45	0.80	
			T_A = T_{MIN} to T_{MAX}			1.2	
Input Common-Mode Voltage Range	V_{CM}	Inferred from the CMRR test		V_{EE} - 0.2		V_{CC} + 0.2	V
Input Offset Voltage	V_{OS}	-0.2V ≤ V_{CM} ≤ (V_{CC} + 0.2V) (Note 2)	T_A = +25°C		1	5	mV
			T_A = T_{MIN} to T_{MAX}			10	
Input-Referred Hysteresis	V_{HB}	-0.2V ≤ V_{CM} ≤ (V_{CC} + 0.2V) (Note 3)			4		mV
Input Bias Current	I_B	T_A = +25°C			0.15	1	nA
		T_A = T_{MIN} to T_{MAX}				2	

ELECTRICAL CHARACTERISTICS—MAX919/MAX920 (continued)

(V_{CC} = +5V, V_{EE} = 0, V_{CM} = 0, 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
Input Offset Current	I_{OS}				10		pA
Power-Supply Rejection Ratio	PSRR	V_{CC} = 1.8V to 5.5V			0.1	1	mV/V
Common-Mode Rejection Ratio	CMRR	(V_{EE} - 0.2V) ≤ V_{CM} ≤ (V_{CC} + 0.2V)			0.5	3	mV/V
Output Voltage Swing High,	V_{CC} - V_{OH}	MAX919 only, V_{CC} = 5V, I_{SOURCE} = 8mA	T_A = +25°C		190	400	mV
			T_A = T_{MIN} to T_{MAX}			500	
		MAX919 only, V_{CC} = 1.8V, I_{SOURCE} = 1mA	T_A = +25°C		55	200	
			T_A = T_{MIN} to T_{MAX}			300	
Output Voltage Swing Low	V_{OL}	V_{CC} = 5V, I_{SINK} = 8mA	T_A = +25°C		190	400	mV
			T_A = T_{MIN} to T_{MAX}			500	
		V_{CC} = 1.8V, I_{SINK} = 1mA	T_A = +25°C		55	200	
			T_A = T_{MIN} to T_{MAX}			300	
Output Leakage Current	I_{LEAK}	MAX920 only, V_O = 5.5V			0.001	1	µA
Output Short-Circuit Current	I_{SC}	Sourcing, V_O = V_{EE}	V_{CC} = 5V		95		mA
			V_{CC} = 1.8V		8		
		Sinking, V_O = V_{CC}	V_{CC} = 5V		98		
			V_{CC} = 1.8V		10		
High-to-Low Propagation Delay (Note 4)	t_{PD-}		V_{CC} = 1.8V		17		µs
			V_{CC} = 5V		22		
Low-to-High Propagation Delay (Note 4)	t_{PD+}	MAX919 only	V_{CC} = 1.8V		30		µs
			V_{CC} = 5V		95		
		MAX920 only	V_{CC} = 1.8V $R_{PULL-UP}$ = 100kΩ		35		
			V_{CC} = 5V $R_{PULL-UP}$ = 100kΩ		120		
Rise Time	t_{RISE}	MAX919 only, C_L = 15pF			6		µs
Fall Time	t_{FALL}	C_L = 15pF			4		µs
Power-Up Time	t_{ON}				1.2		ms

Note 1: All specifications are 100% tested at T_A = +25°C. Specification limits over temperature (T_A = T_{MIN} to T_{MAX}) are guaranteed by design, not production tested.

Note 2: V_{OS} is defined as the center of the hysteresis band at the input.

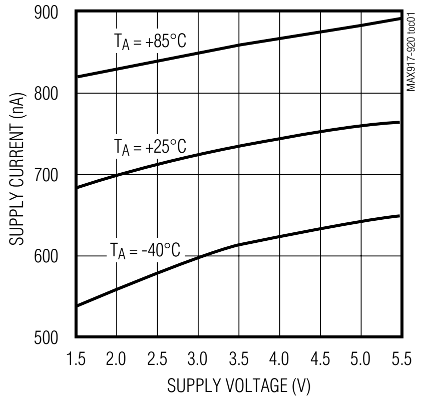
Note 3: The hysteresis-related trip points are defined as the edges of the hysteresis band, measured with respect to the center of the band (i.e., V_{OS}) (Figure 2).

Note 4: Specified with an input overdrive ($V_{OVERDRIVE}$) of 100mV, and load capacitance of C_L = 15pF. $V_{OVERDRIVE}$ is defined above and beyond the offset voltage and hysteresis of the comparator input. For the MAX917/MAX918, reference voltage error should also be added.

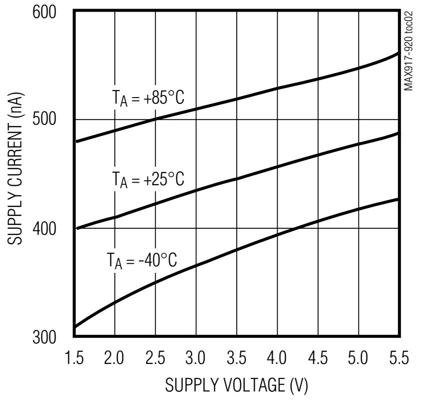
Typical Operating Characteristics

(V_{CC} = +5V, V_{EE} = 0, C_L = 15pF, $V_{OVERDRIVE}$ = 100mV, T_A = +25°C, unless otherwise noted.)

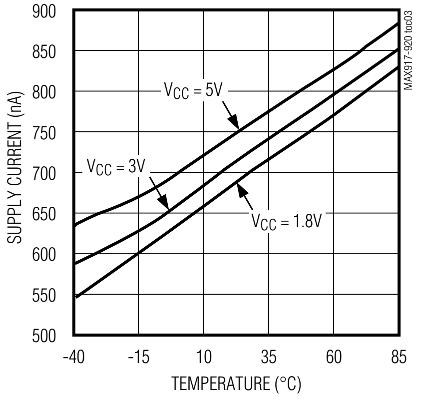
MAX917/MAX918
SUPPLY CURRENT vs.
SUPPLY VOLTAGE AND TEMPERATURE



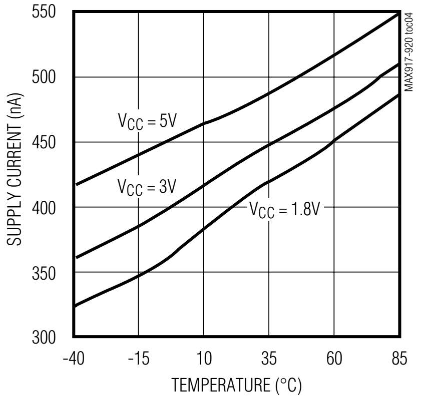
MAX919/MAX920
SUPPLY CURRENT vs.
SUPPLY VOLTAGE AND TEMPERATURE



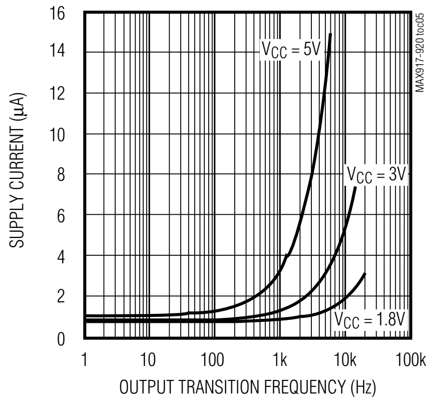
MAX917/MAX918
SUPPLY CURRENT vs. TEMPERATURE



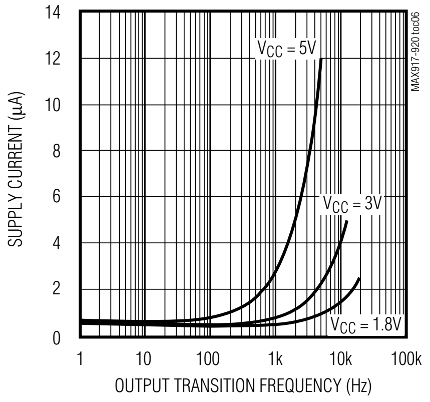
MAX919/MAX920
SUPPLY CURRENT vs. TEMPERATURE



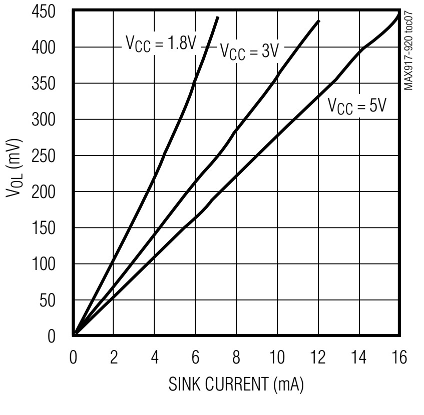
MAX917/MAX918
SUPPLY CURRENT vs.
OUTPUT TRANSITION FREQUENCY



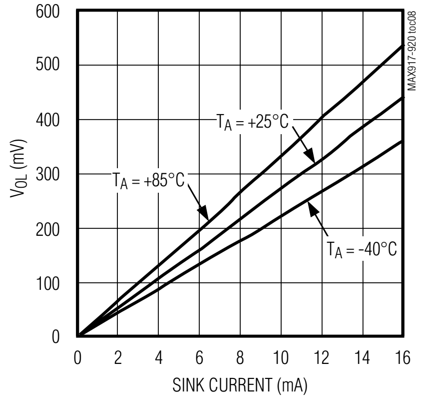
MAX919/MAX920
SUPPLY CURRENT vs.
OUTPUT TRANSITION FREQUENCY



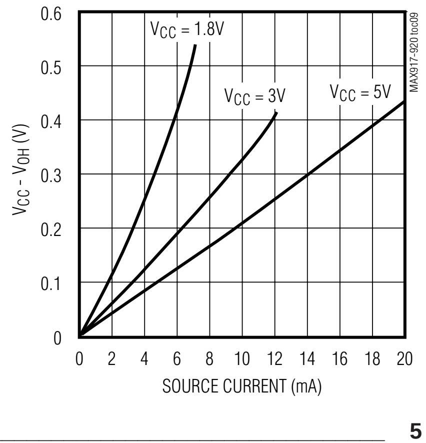
OUTPUT VOLTAGE LOW vs. SINK CURRENT



OUTPUT VOLTAGE LOW vs. SINK CURRENT
AND TEMPERATURE



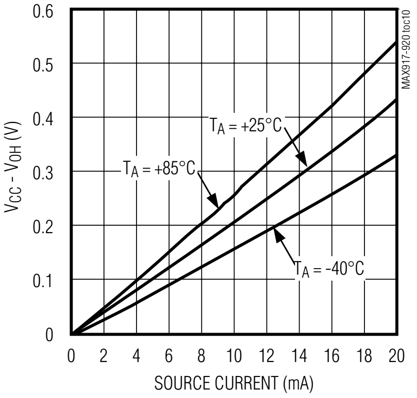
MAX917/MAX919
OUTPUT VOLTAGE HIGH vs. SOURCE CURRENT



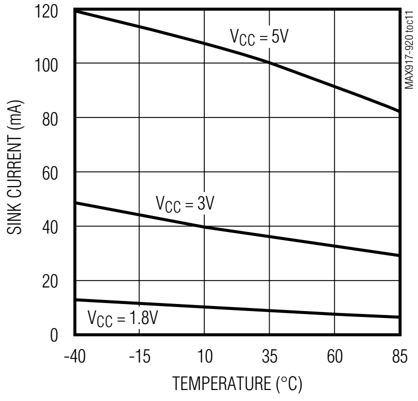
Typical Operating Characteristics (continued)

(V_{CC} = +5V, V_{EE} = 0, C_L = 15pF, $V_{OVERDRIVE}$ = 100mV, T_A = +25°C, unless otherwise noted.)

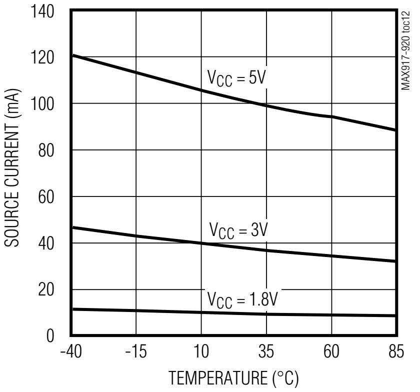
MAX917/MAX919
OUTPUT VOLTAGE HIGH vs.
SOURCE CURRENT AND TEMPERATURE



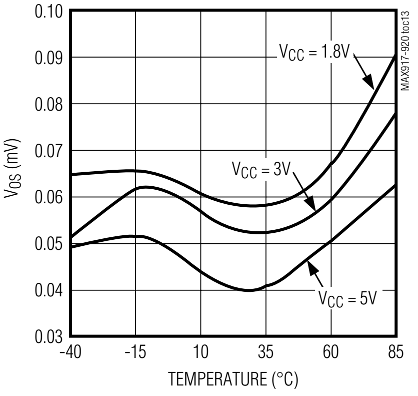
SHORT-CIRCUIT SINK CURRENT
vs. TEMPERATURE



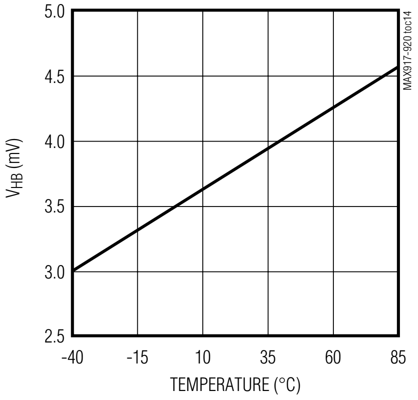
MAX917/MAX919
SHORT-CIRCUIT SOURCE CURRENT
vs. TEMPERATURE



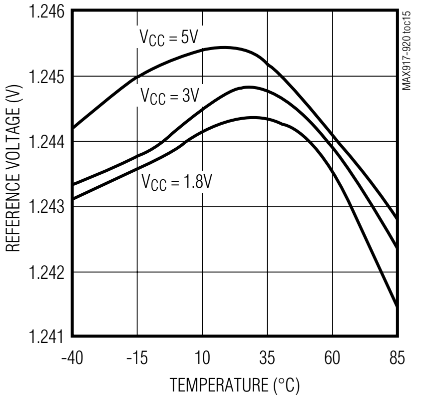
OFFSET VOLTAGE vs. TEMPERATURE



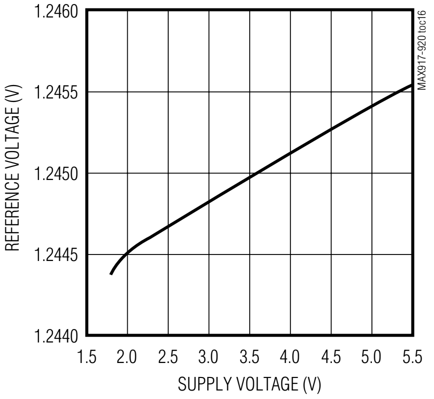
HYSTERESIS VOLTAGE vs. TEMPERATURE



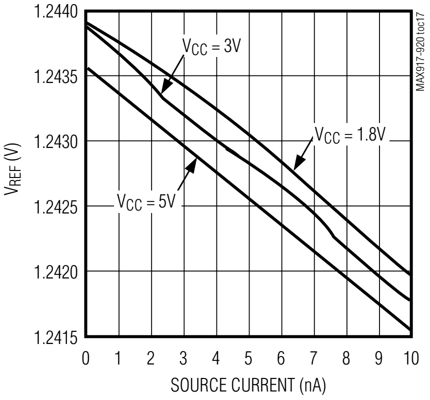
MAX917/MAX918
REFERENCE VOLTAGE vs. TEMPERATURE



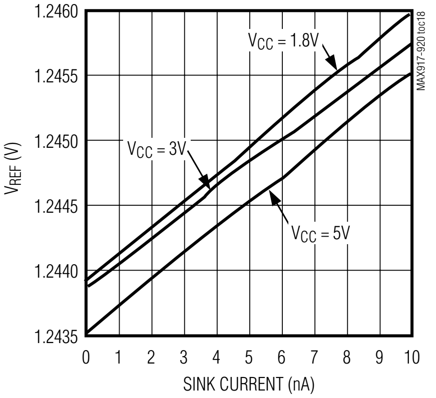
MAX917/MAX918
REFERENCE VOLTAGE vs.
SUPPLY VOLTAGE



MAX917/MAX918
REFERENCE OUTPUT VOLTAGE vs.
REFERENCE SOURCE CURRENT



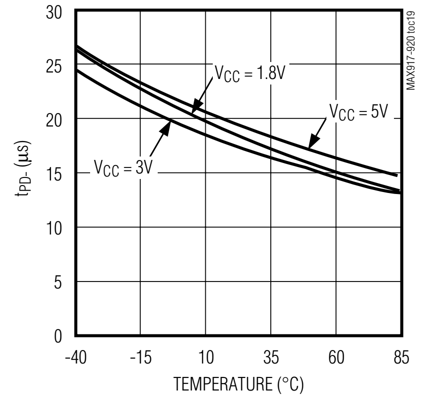
MAX917/MAX918
REFERENCE OUTPUT VOLTAGE vs.
REFERENCE SINK CURRENT



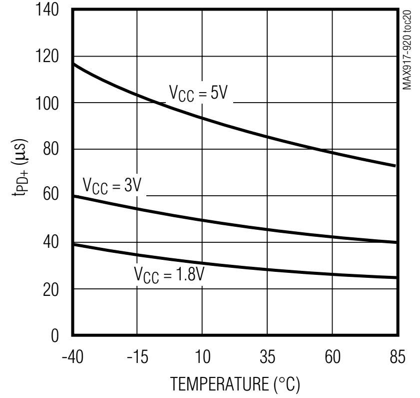
Typical Operating Characteristics (continued)

(V_{CC} = +5V, V_{EE} = 0, C_L = 15pF, $V_{OVERDRIVE}$ = 100mV, T_A = +25°C, unless otherwise noted.)

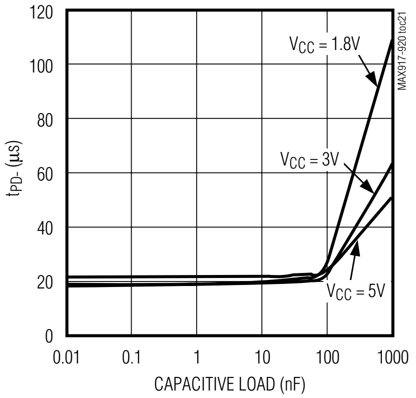
PROPAGATION DELAY (t_{PD-}) vs. TEMPERATURE



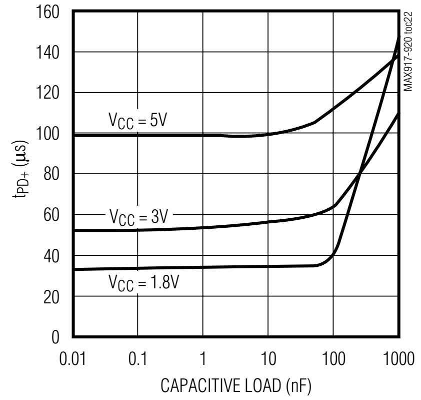
MAX917/MAX919 PROPAGATION DELAY (t_{PD+}) vs. TEMPERATURE



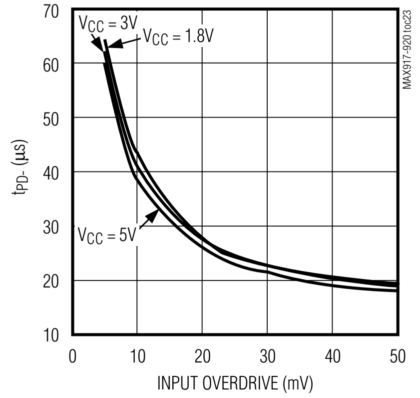
PROPAGATION DELAY (t_{PD-}) vs. CAPACITIVE LOAD



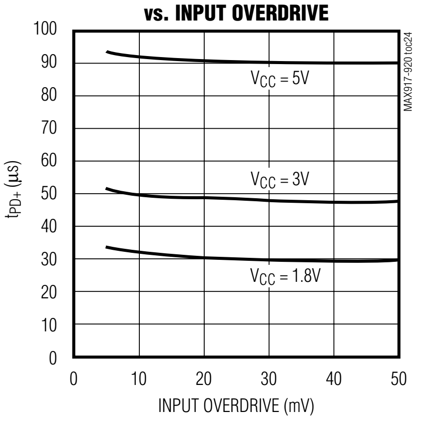
MAX917/MAX919 PROPAGATION DELAY (t_{PD+}) vs. CAPACITIVE LOAD



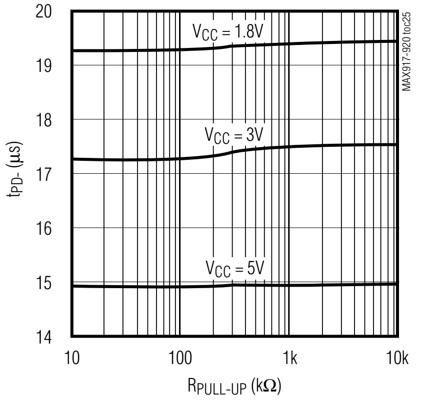
PROPAGATION DELAY (t_{PD-}) vs. INPUT OVERDRIVE



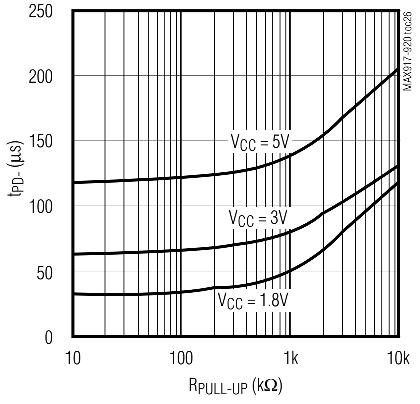
MAX917/MAX919 PROPAGATION DELAY (t_{PD+}) vs. INPUT OVERDRIVE



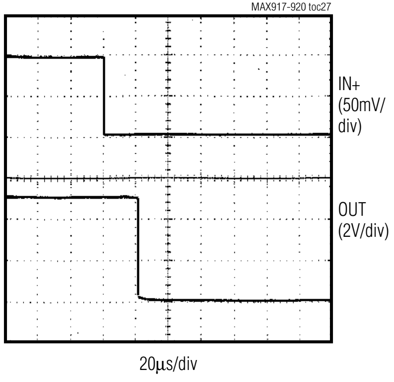
MAX918/MAX920 PROPAGATION DELAY (t_{PD-}) vs. PULL-UP RESISTANCE



MAX918/MAX920 PROPAGATION DELAY (t_{PD+}) vs. PULL-UP RESISTANCE



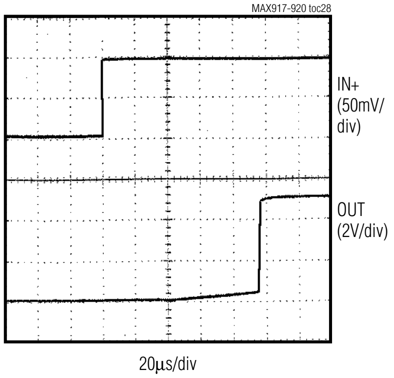
PROPAGATION DELAY (t_{PD-}) (V_{CC} = 5V)



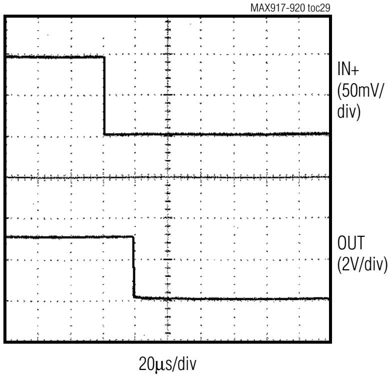
Typical Operating Characteristics (continued)

(V_{CC} = +5V, V_{EE} = 0, C_L = 15pF, $V_{OVERDRIVE}$ = 100mV, T_A = +25°C, unless otherwise noted.)

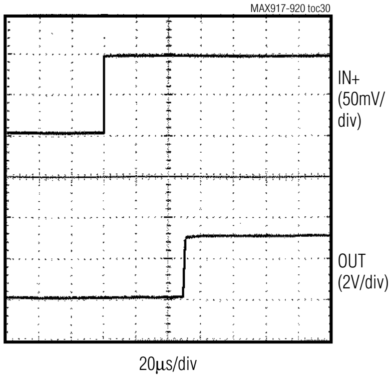
MAX917/MAX919
PROPAGATION DELAY (t_{PD+})
(V_{CC} = 5V)



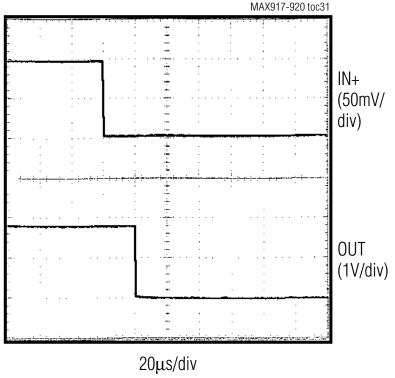
PROPAGATION DELAY (t_{PD-})
(V_{CC} = 3V)



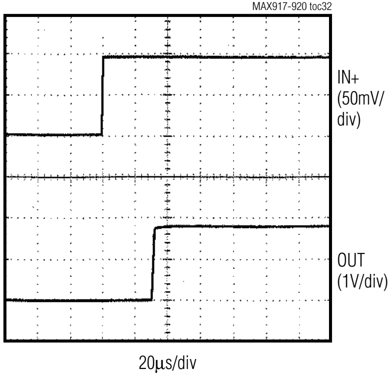
MAX917/MAX919
PROPAGATION DELAY (t_{PD+})
(V_{CC} = 3V)



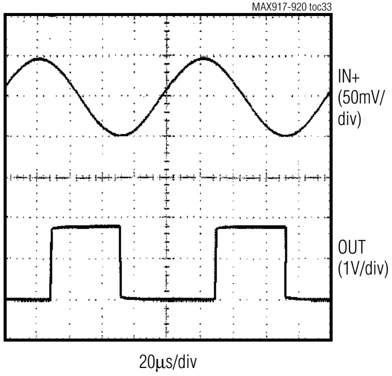
PROPAGATION DELAY (t_{PD-})
(V_{CC} = 1.8V)



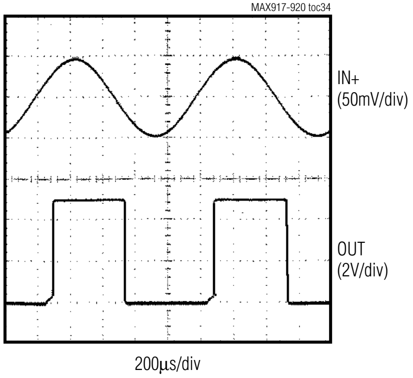
MAX917/MAX919
PROPAGATION DELAY (t_{PD+})
(V_{CC} = 1.8V)



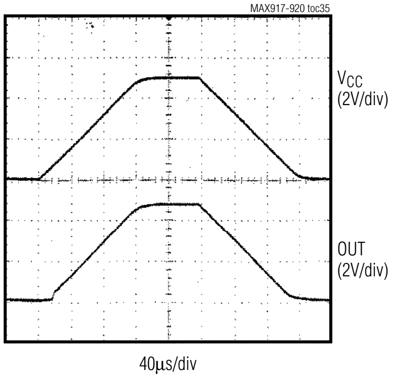
MAX917/MAX919
10kHz RESPONSE (V_{CC} = 1.8V)



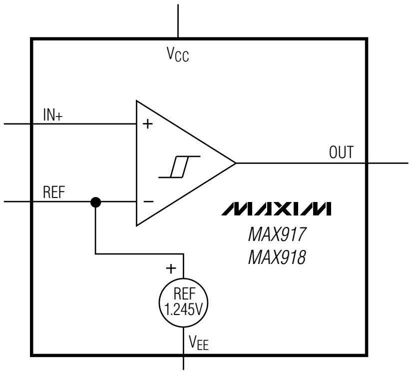
MAX917/MAX919
1kHz RESPONSE (V_{CC} = 5V)

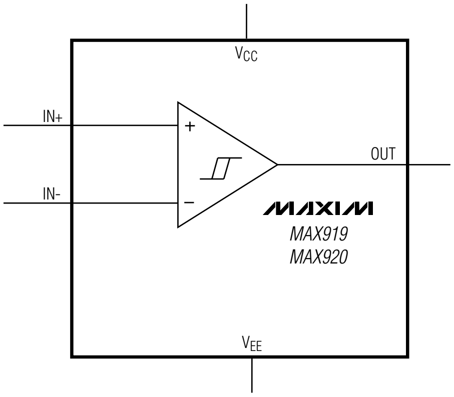


POWER-UP/DOWN RESPONSE



Functional Diagrams





Pin Description

PIN				NAME	FUNCTION
MAX917/MAX918		MAX919/MAX920			
SOT23-5	SO	SOT23-5	SO		
1	6	1	6	OUT	Comparator Output
2	4	2	4	V_{EE}	Negative Supply Voltage
3	3	3	3	IN+	Comparator Noninverting Input
—	—	4	2	IN-	Comparator Inverting Input
4	2	—	—	REF	1.245V Reference Output and Comparator Inverting Input
5	7	5	7	V_{CC}	Positive Supply Voltage
—	1, 5, 8	—	1, 5, 8	N.C.	No Connection. Not internally connected.

Detailed Description

The MAX917/MAX918 feature an on-board 1.245V ±1.5% reference, yet draw an ultra-low supply current of 750nA. The MAX919/MAX920 (without reference) consume just 380nA of supply current. All four devices are guaranteed to operate down to +1.8V. Their common-mode input voltage range extends 200mV beyond-the-rails. Internal hysteresis ensures clean output switching, even with slow-moving input signals. Large internal output drivers allow rail-to-rail output swing with up to ±8mA loads.

The output stage employs a unique design that minimizes supply-current surges while switching, virtually eliminating the supply glitches typical of many other comparators. The MAX917/MAX919 have a push/pull output stage that sinks as well as sources current. The MAX918/MAX920 have an open-drain output stage that can be pulled beyond V_{CC} to an absolute maximum of 6V above V_{EE}. These open-drain versions are ideal for implementing wire-Or output logic functions.

Input Stage Circuitry

The input common-mode voltage range extends from V_{EE} - 0.2V to V_{CC} + 0.2V. These comparators operate at any differential input voltage within these limits. Input bias current is typically ±0.15nA if the input voltage is between the supply rails. Comparator inputs are protected from overvoltage by internal ESD protection diodes connected to the supply rails. As the input voltage exceeds the supply rails, these ESD protection diodes become forward biased and begin to conduct.

Output Stage Circuitry

The MAX917–MAX920 contain a unique break-before-make output stage capable of rail-to-rail operation with up to ±8mA loads. Many comparators consume orders of magnitude more current during switching than during steady-state operation. However, with this family of comparators, the supply-current change during an output transition is extremely small. In the *Typical Operating Characteristics*, the Supply Current vs. Output Transition Frequency graphs show the minimal supply-current increase as the output switching frequency approaches 1kHz. This characteristic reduces the need for power-supply filter capacitors to reduce glitches created by comparator switching currents. In battery-powered applications, this characteristic results in a substantial increase in battery life.

Reference (MAX917/MAX918)

The internal reference in the MAX917/MAX918 has an output voltage of +1.245V with respect to V_{EE}. Its typical temperature coefficient is 95ppm/°C over the full -40°C to +85°C temperature range. The reference is a PNP emitter-follower driven by a 120nA current source (Figure 1). The output impedance of the voltage reference is typically 200kΩ, preventing the reference from driving large loads. The reference can be bypassed with a low-leakage capacitor. The reference is stable for any capacitive load. For applications requiring a lower output impedance, buffer the reference with a low-input-leakage op amp, such as the MAX406.

Applications Information

Low-Voltage, Low-Power Operation

The MAX917–MAX920 are ideally suited for use with most battery-powered systems. Table 1 lists a variety of battery types, capacities, and approximate operating times for the MAX917–MAX920, assuming nominal conditions.

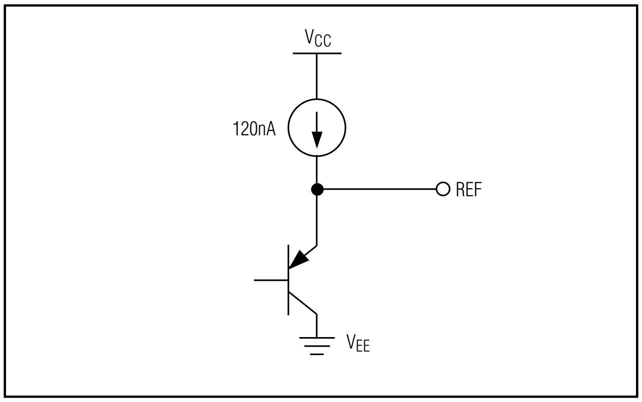


Figure 1. MAX917/MAX918 Voltage Reference Output Equivalent Circuit

Internal Hysteresis

Many comparators oscillate in the linear region of operation because of noise or undesired parasitic feedback. This tends to occur when the voltage on one input is equal or very close to the voltage on the other input. The MAX917–MAX920 have internal hysteresis to counter parasitic effects and noise.

The hysteresis in a comparator creates two trip points: one for the rising input voltage (V_{THR}) and one for the falling input voltage (V_{THF}) (Figure 2). The difference between the trip points is the hysteresis (V_{HB}). When the comparator's input voltages are equal, the hysteresis effectively causes one comparator input to move quickly past the other, thus taking the input out of the region where oscillation occurs. Figure 2 illustrates the case in which 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.

Table 1. Battery Applications Using MAX917–MAX920

BATTERY TYPE	RECHARGEABLE	V_{FRESH} (V)	$V_{END-OF-LIFE}$ (V)	CAPACITY, AA SIZE (mA-h)	MAX917/MAX918 OPERATING TIME (hr)	MAX919/MAX920 OPERATING TIME (hr)
Alkaline (2 Cells)	No	3.0	1.8	2000	2.5×10^6	5×10^6
Nickel-Cadmium (2 Cells)	Yes	2.4	1.8	750	937,500	1.875×10^6
Lithium-Ion (1 Cell)	Yes	3.5	2.7	1000	1.25×10^6	2.5×10^6
Nickel-Metal-Hydride (2 Cells)	Yes	2.4	1.8	1000	1.25×10^6	2.5×10^6

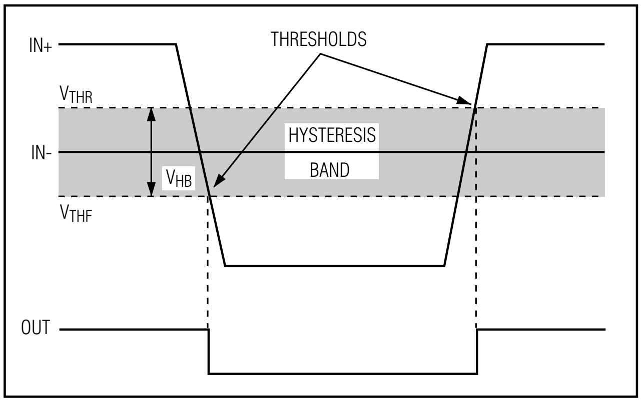


Figure 2. Threshold Hysteresis Band

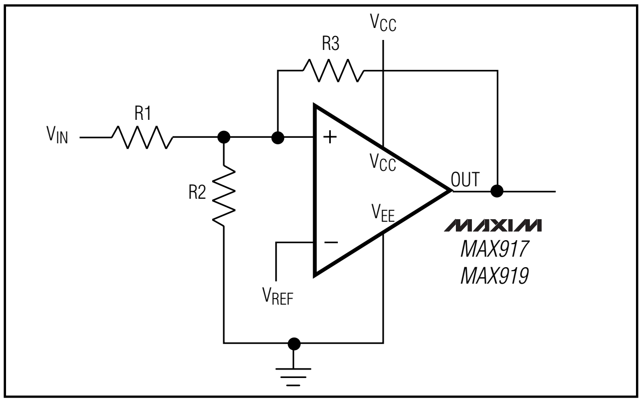


Figure 3. MAX917/MAX919 Additional Hysteresis

Additional Hysteresis (MAX917/MAX919)

The MAX917/MAX919 have a 4mV internal hysteresis band (V_{HB}). Additional hysteresis can be generated with three resistors using positive feedback (Figure 3). Unfortunately, this method also slows hysteresis response time. Use the following procedure to calculate resistor values.

1) Select R3. Leakage current at IN is under 2nA, so the current through R3 should be at least 0.2µA to minimize errors caused by leakage current. The current through R3 at the trip point is $(V_{REF} - V_{OUT})/R3$. Considering the two possible output states in solving for R3 yields two formulas: $R3 = V_{REF}/I_{R3}$ or $R3 = (V_{CC} - V_{REF})/I_{R3}$. Use the smaller of the two resulting resistor values. For example, when using the MAX917 (V_{REF} = 1.245V) and V_{CC} = 5V, and if we choose I_{R3} = 1µA, then the two resistor values are 1.2MΩ and 3.8MΩ. Choose a 1.2MΩ standard value for R3.

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

3) Calculate R1 according to the following equation:

$$R1 = R3\,(V_{HB} / V_{CC})$$

For this example, insert the values

$$R1 = 1.2\text{M}\Omega\,(50\text{mV}/5\text{V}) = 12\text{k}\Omega$$

4) Choose the trip point for V_{IN} rising (V_{THR}) such that $V_{THR} > V_{REF} \cdot (R1 + R3)/R3$ (V_{THF} is the trip point for V_{IN} falling). This is the threshold voltage at which the comparator switches its output from low to high as V_{IN} rises above the trip point. For this example, choose 3V.

5) Calculate R2 as follows:

$$R2 = 1/[V_{THR}/(V_{REF} \cdot R1) - (1 / R1) - (1 / R3)]$$

$$R2 = 1/[3.0\text{V}/(1.2\text{V} \cdot 12\text{k}\Omega) - (1 / 12\text{k}\Omega) - (1/1.2\text{M}\Omega)] = 8.05\text{k}\Omega$$

For this example, choose an 8.2kΩ standard value.

6) Verify the trip voltages and hysteresis as follows:

V_{IN} rising: $V_{THR} = V_{REF} \cdot R1\,[(1 / R1) + (1 / R2) + (1 / R3)]$

V_{IN} falling: $V_{THF} = V_{THR} - (R1 \cdot V_{CC} / R3)$

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

Additional Hysteresis (MAX918/MAX920)

The MAX918/MAX920 have a 4mV internal hysteresis band. They have open-drain outputs and require an external pull-up resistor (Figure 4). Additional hysteresis can be generated using positive feedback, but the formulas differ slightly from those of the MAX917/MAX919. Use the following procedure to calculate resistor values.

1) Select R3 according to the formulas $R3 = V_{REF}$ / 1µA or $R3 = (V_{CC} - V_{REF})$/1µA - R4. Use the smaller of the two resulting resistor values.

2) Choose the hysteresis band required (V_{HB}).

3) Calculate R1 according to the following equation:

$$R1 = (R3 + R4)\,(V_{HB}/V_{CC})$$

4) Choose the trip point for V_{IN} rising (V_{THR}) (V_{THF} is the trip point for V_{IN} falling). This is the threshold voltage at which the comparator switches its output from low to high as V_{IN} rises above the trip point.

5) Calculate R2 as follows:

$$R2 = 1/\left[V_{THR}/\left(V_{REF} \cdot R1\right) - \left(\frac{1}{R1}\right) - \frac{1}{R3}\right]$$

6) Verify the trip voltages and hysteresis as follows:

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

$$V_{IN}\text{ falling}: V_{THF} =$$

$$V_{REF} \cdot R1\left(\frac{1}{R1}+\frac{1}{R2}+\frac{1}{R3+R4}\right)-\frac{R1}{R3+R4} \cdot V_{CC}$$

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

Board Layout and Bypassing

Power-supply bypass capacitors are not typically needed, but use 100nF bypass capacitors close to the device's supply pins when supply impedance is high, supply leads are long, or excessive noise is expected on the supply lines. Minimize signal trace lengths to reduce stray capacitance. A ground plane and surface-mount components are recommended.

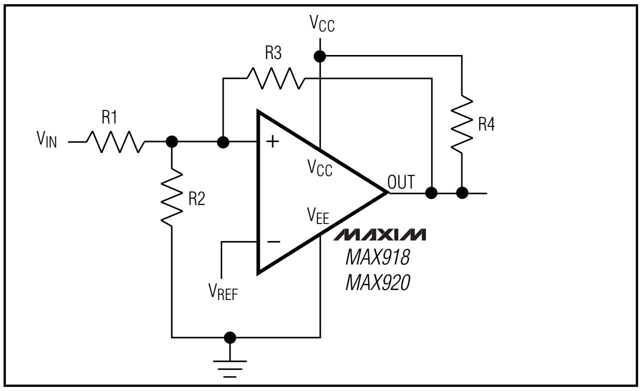
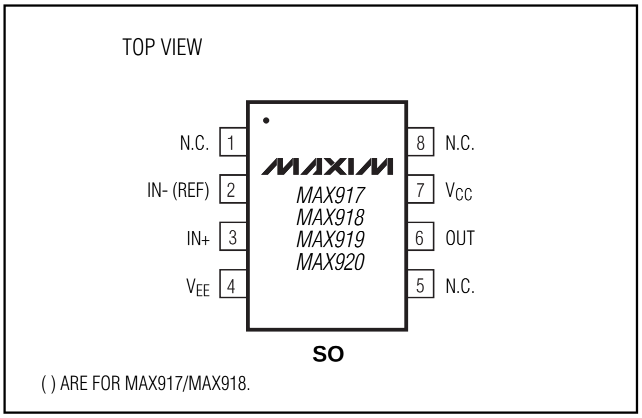


Figure 4. MAX918/MAX920 Additional Hysteresis

Pin Configurations (continued)



Zero-Crossing Detector

Figure 5 shows a zero-crossing detector application. The MAX919's inverting input is connected to ground, and its noninverting input is connected to a 100mVp-p signal source. As the signal at the noninverting input crosses 0V, the comparator's output changes state.

Logic-Level Translator

The *Typical Application Circuit* shows an application that converts 5V logic to 3V logic levels. The MAX920 is powered by the +5V supply voltage, and the pull-up resistor for the MAX920's open-drain output is connected to the +3V supply voltage. This configuration allows the full 5V logic swing without creating overvoltage on the 3V logic inputs. For 3V to 5V logic-level translations, simply connect the +3V supply voltage to V_{CC} and the +5V supply voltage to the pull-up resistor.

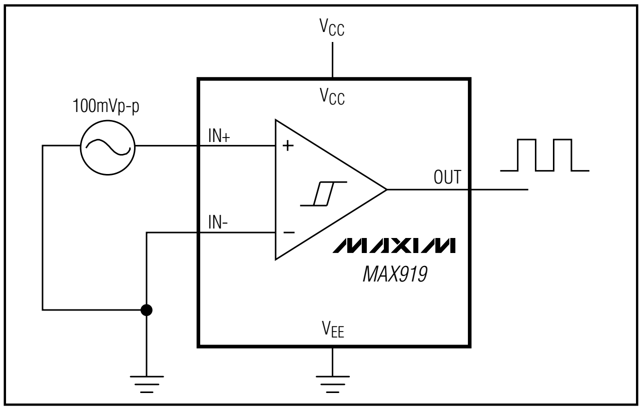


Figure 5. Zero-Crossing Detector

Typical Application Circuit