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## Micropower, Ultra-Small, Single/Dual/Quad, Single-Supply Comparators

## MAX9021/MAX9022/MAX9024

### General Description

The MAX9021/MAX9022/MAX9024 single/dual/quad comparators are optimized for low-power consumption while still providing a fast output response. They are designed for single-supply applications from 2.5V to 5.5V, but can also operate from dual supplies. These comparators have a 3 $\mu$ s propagation delay and consume 2.8 $\mu$ A 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.

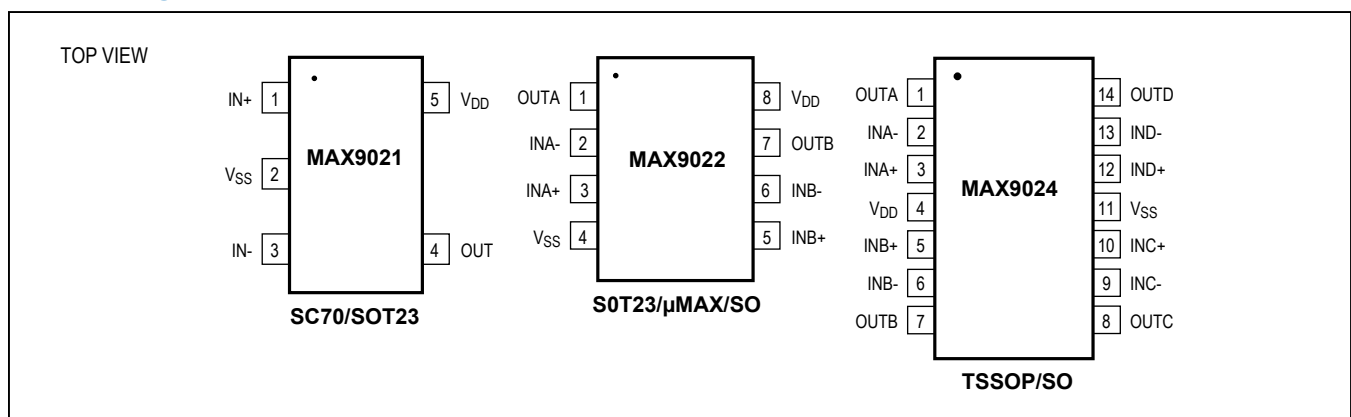
The MAX9021/MAX9022/MAX9024 have 4mV of built-in hysteresis to provide noise immunity and prevent oscillations even with a slow-moving input signal. The input common-mode range extends from the negative supply to within 1.1V of the positive supply. The design of the comparator-output stage substantially reduces switching current during output transitions, eliminating power-supply glitches.

The MAX9021 single comparator is available in tiny 5-pin SC70 and SOT23 packages. The MAX9022 dual comparator is available in 8-pin SOT23,  $\mu$ MAX®, and SO packages, and the MAX9024 quad comparator is available in 14-pin TSSOP and SO packages.

### Applications

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

### Pin Configurations



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

### Features

- Low-Cost Solution Available in Space-Saving SC70 Packages (Half the Size of SOT23)
- Low 2.8 $\mu$ A Supply Current
- 3 $\mu$ s Propagation Delay
- Internal 4mV Comparator Hysteresis
- Comparator Output Swings Rail-to-Rail
- 2.5V to 5.5V Single-Supply Voltage Range
- No Phase Reversal for Overdriven Inputs
- Space-Saving Packages
  - 5-Pin SC70 (MAX9021)
  - 8-Pin SOT23 (MAX9022)
  - 8-Pin  $\mu$ MAX (MAX9022)

### Ordering Information

PART	TEMP RANGE	PIN-PACKAGE	PKG CODE
MAX9021AXK+T	-40°C to +125°C	5 SC70-5	X5+1
MAX9021AUK+T	-40°C to +125°C	5 SOT23-5	U5+1
MAX9022AKA+T	-40°C to +125°C	8 SOT23-8	K8+5
MAX9022AUA+T	-40°C to +125°C	8 $\mu$ MAX	U8+1
MAX9022ASA+T	-40°C to +125°C	8 SO	S8+2
MAX9024AUD+T	-40°C to +125°C	14 TSSOP	U14+1
MAX9024ASD+T	-40°C to +125°C	14 SO	S14+2

+Denotes a lead(Pb)-free/RoHS-compliant package.  
T = Tape and reel.

[Typical Application Circuit](#) appears at end of data sheet.

**Absolute Maximum Ratings**

Supply Voltage (V <sub>DD</sub> to V <sub>SS</sub> ).....	-0.3V to +6V	8-Pin μMAX (derate 4.5mW/°C above +70°C).....	362mW
Voltage Inputs (IN+, IN- to V <sub>SS</sub> ).....	-0.3V to (V <sub>DD</sub> + 0.3V)	8-Pin SO (derate 5.88mW/°C above +70°C).....	471mW
Differential Input Voltage (IN+ to IN-).....	6.6V	14-Pin TSSOP (derate 9.1mW/°C above +70°C).....	727mW
Current into Input Pins .....	±20mA	14-Pin SO (derate 8.3mW/°C above +70.....	667mW
Output Short-Circuit Duration.....	2s to Either V <sub>DD</sub> or V <sub>SS</sub>	Operating Temperature Range	
Current into Any Pin .....	20mA	Automotive Application .....	-40°C to +125°C
Continuous Power Dissipation (T <sub>A</sub> = +70°C)		Junction Temperature.....	+150°C
5-Pin SC70 (derate 3.1mW/°C above +70°C).....	247mW	Storage Temperature Range .....	-65°C to +150°C
5-Pin SOT23 (derate 7.1mW/°C above +70°C) .....	571mW	Lead Temperature (soldering, 10s) .....	+300°C
8-Pin SOT23 (derate 9.1mW/°C above +70°C) .....	727mW		

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**

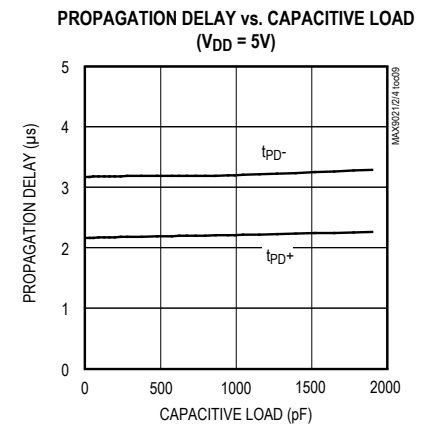
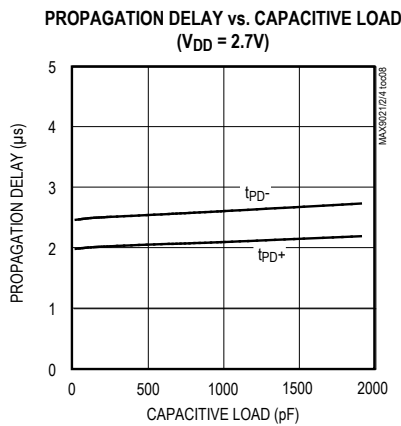
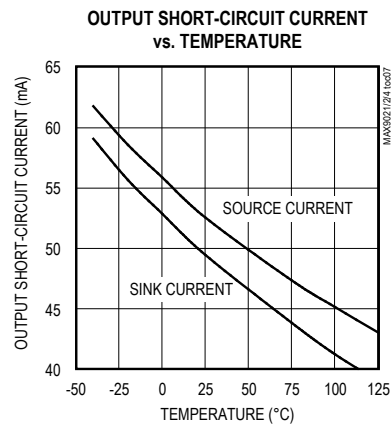
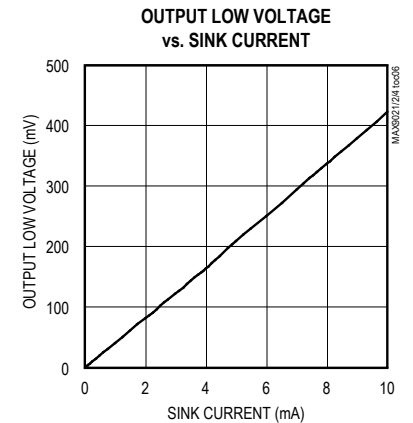
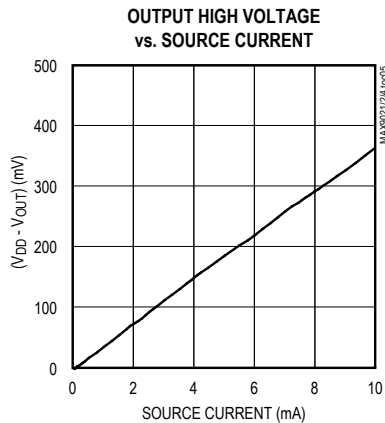
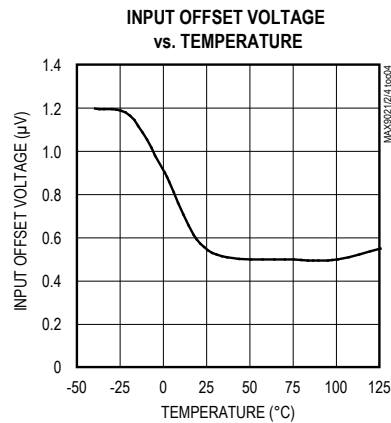
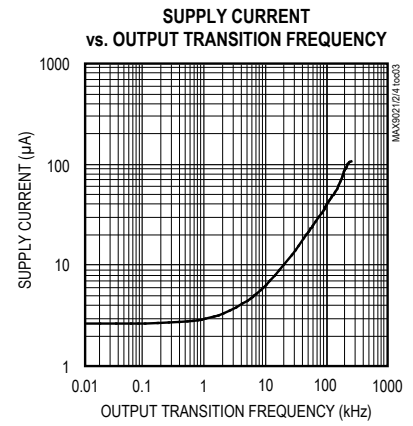
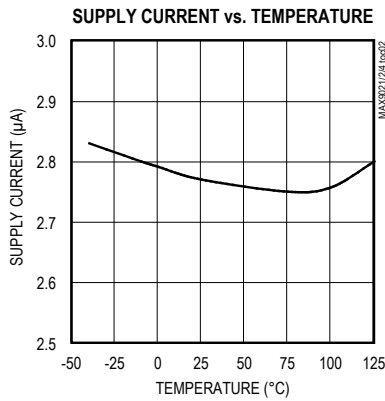
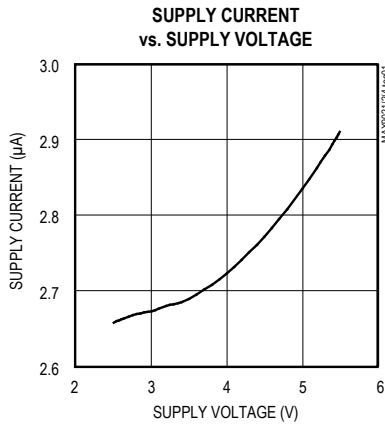
(V<sub>DD</sub> = 5V, V<sub>SS</sub> = 0, V<sub>CM</sub> = 0, T<sub>A</sub> = -40°C to +125°C, unless otherwise noted. Typical values are at T<sub>A</sub> = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Operating Voltage Range	V <sub>DD</sub>	Guaranteed by PSRR test	2.5		5.5	V
Supply Current Per Comparator	I <sub>DD</sub>			2.8	5	μA
Input Offset Voltage	V <sub>OS</sub>	(Note 2)		±1	±8	mV
Input Offset Voltage Temperature Coefficient	TCV <sub>OS</sub>			±1		μV/°C
Hysteresis		(Note 3)		4		mV
Input Bias Current	I <sub>BIAS</sub>			3	80	nA
Input Offset Current	I <sub>OS</sub>			±2	±60	nA
Common-Mode Voltage Range	V <sub>CM</sub>	Guaranteed by CMRR test	V <sub>SS</sub>		V <sub>DD</sub> - 1.1	V
Common-Mode Rejection Ratio	CMRR	V <sub>SS</sub> ≤ V <sub>CM</sub> ≤ (V <sub>DD</sub> - 1.1V), V <sub>DD</sub> = 5.5V	70	100		dB
Power-Supply Rejection Ratio	PSRR	V <sub>DD</sub> = 2.5V to 5.5V	60	80		dB
Output-Voltage Swing	V <sub>OL</sub> , V <sub>OH</sub>	V <sub>OH</sub> = V <sub>DD</sub> - V <sub>OUT</sub> , (V <sub>IN+</sub> - V <sub>IN-</sub> ) ≥ 20mV	I <sub>SOURCE</sub> = 10μA		2	mV
			I <sub>SOURCE</sub> = 4mA		160 400	
		V <sub>OL</sub> = V <sub>OUT</sub> - V <sub>SS</sub> , (V <sub>IN-</sub> - V <sub>IN+</sub> ) ≥ 20mV	I <sub>SINK</sub> = 10μA		2	
			I <sub>SINK</sub> = 4mA		180 400	
Output Short-Circuit Current	I <sub>SC</sub>			50		mA
Propagation Delay	t <sub>pd+</sub> , t <sub>pd-</sub>	R <sub>L</sub> = 10kΩ, C <sub>L</sub> = 15pF (Note 4)	V <sub>OD</sub> = 10mV	8		μs
			V <sub>OD</sub> = 100mV	3		
Rise and Fall Time	t <sub>R</sub> , t <sub>F</sub>	R <sub>L</sub> = 10kΩ, C <sub>L</sub> = 15pF (Note 5)		20		ns
Power-On Time		R <sub>L</sub> = 10kΩ, C <sub>L</sub> = 15pF		150		ns
Maximum Capacitive Load	C <sub>L</sub>	No sustained oscillations		150		pF

- Note 1:** All devices are production tested at 25°C. All temperature limits are guaranteed by design.
- Note 2:** Comparator Input Offset is defined as the center of the hysteresis zone.
- Note 3:** Hysteresis is defined as the difference of the trip points required to change comparator output states.
- Note 4:** V<sub>OD</sub> is the overdrive voltage beyond the offset and hysteresis-determined trip points.
- Note 5:** Rise and fall times are measured between 10% and 90% at OUT.

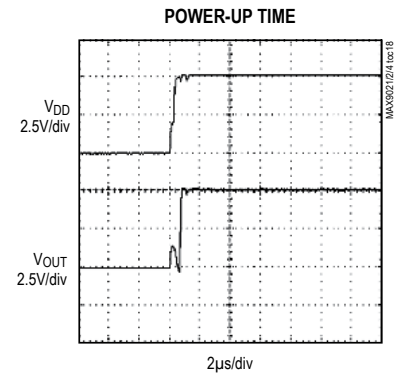
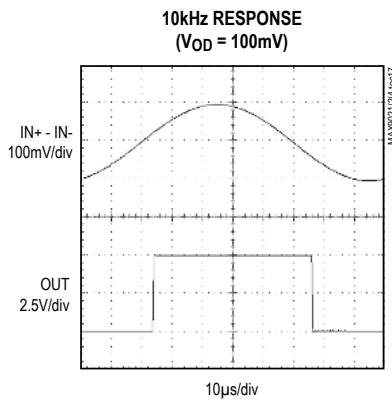
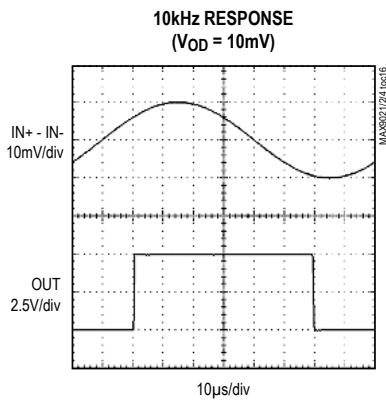
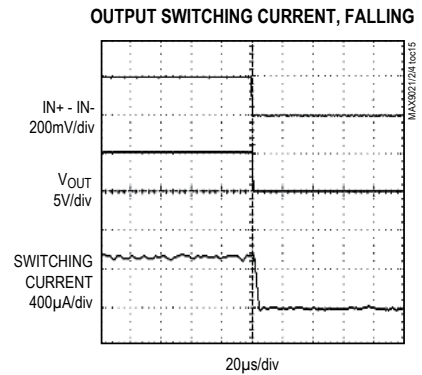
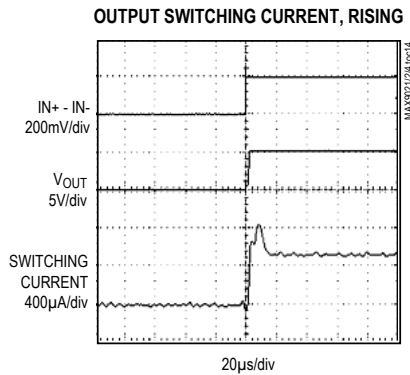
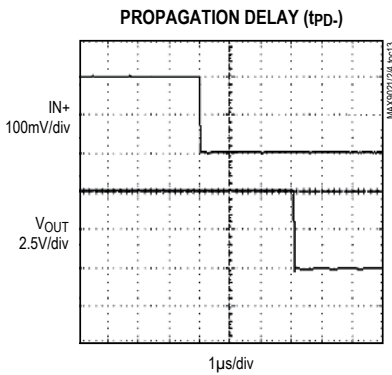
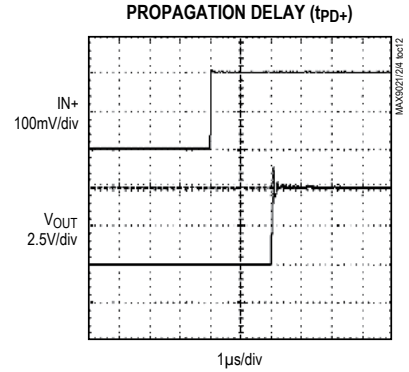
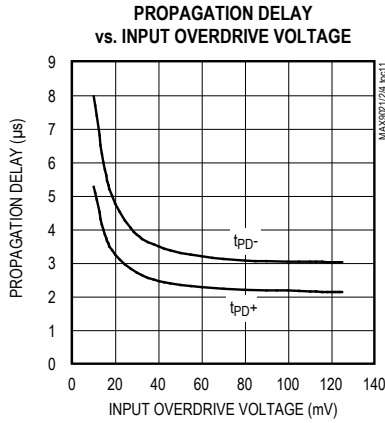
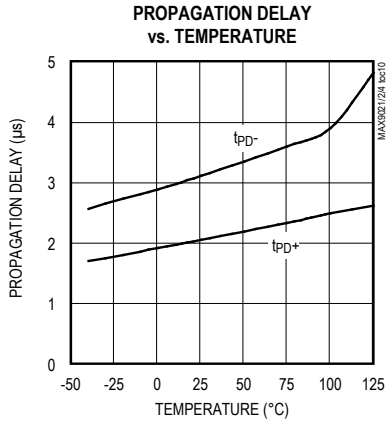
**Typical Operating Characteristics**

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



**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.)



## Pin Description

PIN			NAME	FUNCTION
MAX9021	MAX9022	MAX9024		
1	—	—	IN+	Comparator Noninverting Input
2	4	11	VSS	Negative Supply Voltage
3	—	—	IN-	Comparator Inverting Input
4	—	—	OUT	Comparator Output
5	8	4	VDD	Positive Supply Voltage. Bypass with a 0.1µF capacitor to GND.
—	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 MAX9021/MAX9022/MAX9024 are single/dual/quad, low-cost, low-power comparators that consume only 2.8µA and provide a propagation delay,  $t_{PD}$ , typically 3µs. 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. 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.

## 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 comparator's output 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:

- 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.

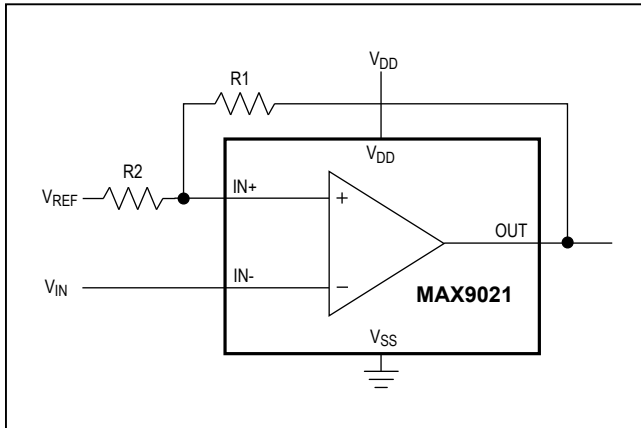


Figure 1. Additional Hysteresis

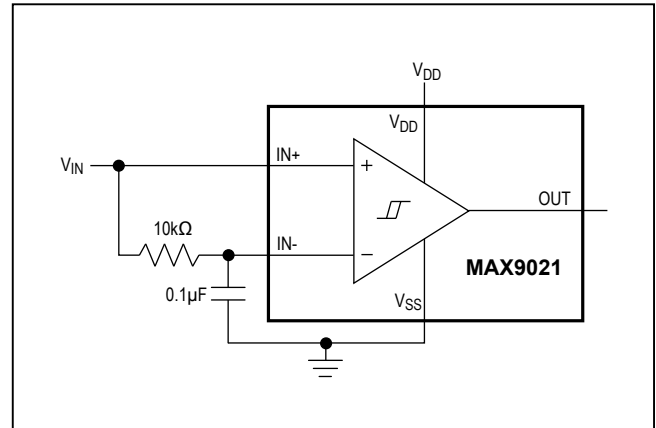


Figure 2. Time Averaging of the Input Signal for Data Recovery

- 2) The hysteresis band will be:

$$V_{HYS} = V_{TH} - V_{TL} = V_{DD}(R2 / (R1 + R2))$$

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

$$V_{TH} = 2.5V + 2.5V(R2 / (R1 + R2))$$

and

$$V_{TL} = 2.5V[(1 - (R2 / (R1 + R2)))]$$

- 4) Select  $R2$ . In this example, we will choose  $1k\Omega$ .  
 5) Select  $V_{HYS}$ . In this example, we will choose  $50mV$ .  
 6) Solve for  $R1$ .

$$V_{HYS} = V_{DD}(R2 / (R1 + R2))$$

$$0.050V = 5(1000\Omega / (R1 + 1000\Omega)) V$$

where  $R1 \approx 100k\Omega$ ,  $V_{TH} = 2.525V$ , 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 slowmoving 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  $R1$  and  $C1$  so that:

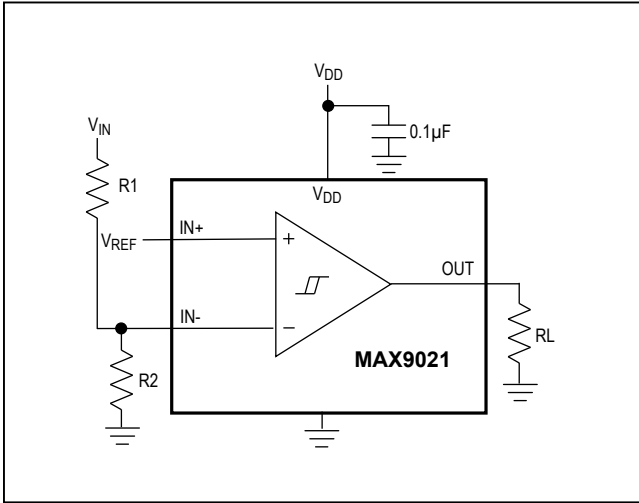
$$f_{CAR} \gg 1 / (2\pi R1C1)$$

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

# MAX9021/MAX9022/ MAX9024

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## Typical Application Circuit



## Chip Information

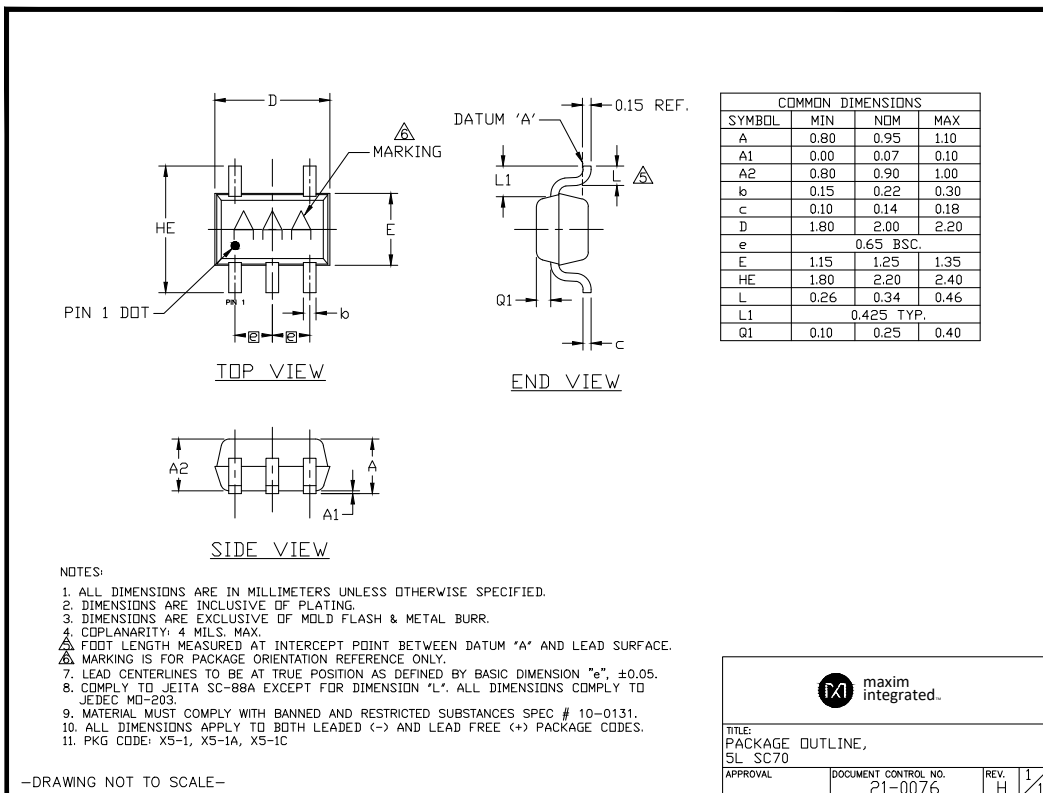
MAX9021 TRANSISTOR COUNT: 106

MAX9022 TRANSISTOR COUNT: 212

MAX9024 TRANSISTOR COUNT: 424

## 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.

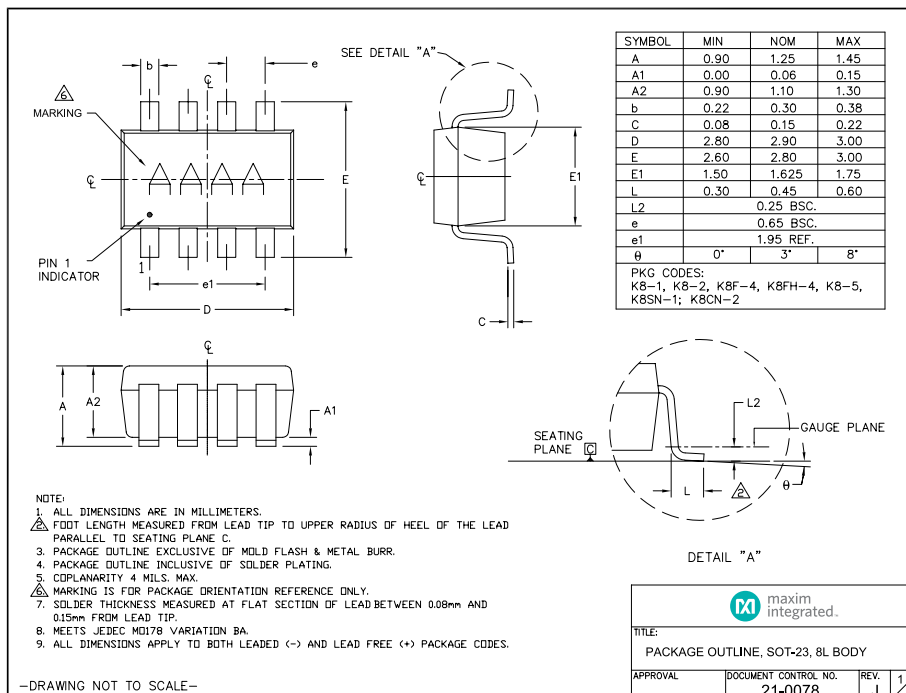
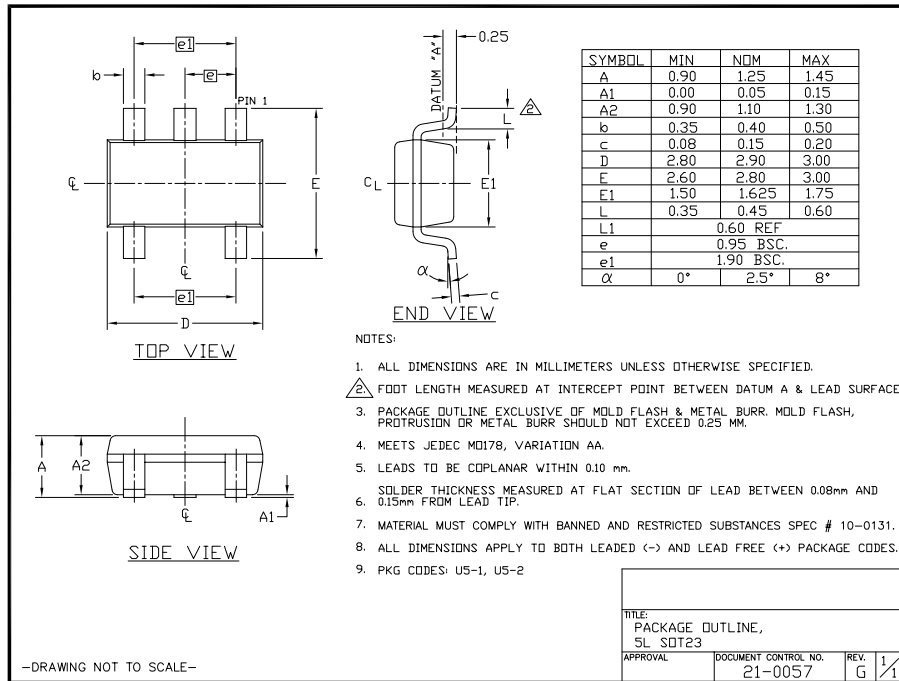


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### Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	10/00	Initial release	—
1	7/01	Updated Ordering Information table	1
2	1/07	Updated Absolute Maximum Ratings	2
3	12/22	Updated Ordering Information table	1



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