ANALOG DEVICES

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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 3µs propagation delay and consume 2.8µA 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, µMAX®, 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

Features

- Low-Cost Solution Available in Space-Saving SC70 Packages (Half the Size of SOT23)
- Low 2.8µA Supply Current
- 3µs 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 µMAX (MAX9022)

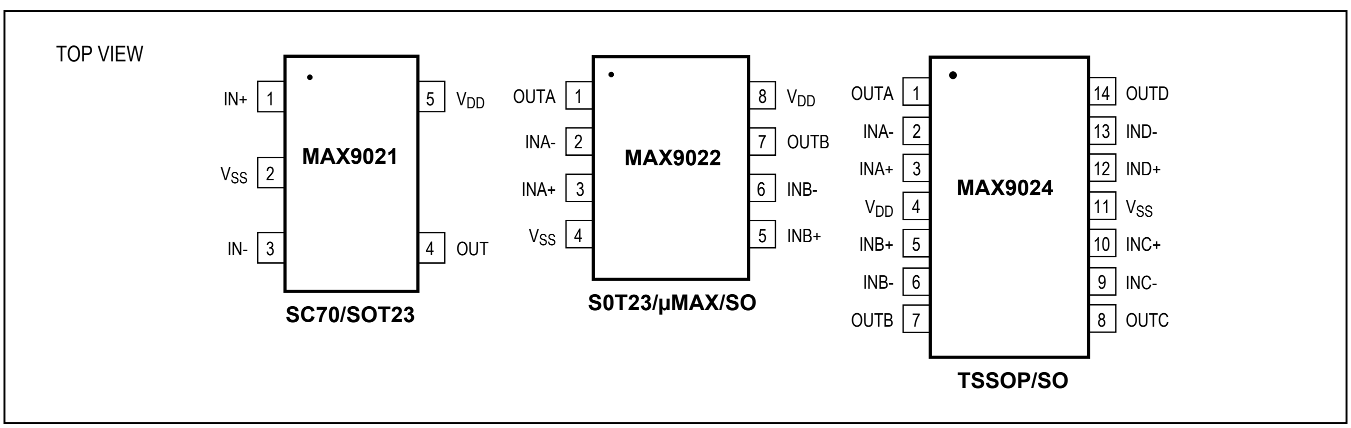
Ordering Information

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 µMAX	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.**

Pin Configurations



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

19-1842; Rev 3; 12/22

Absolute Maximum Ratings

Supply Voltage (V_{DD} to V_{SS}) ....-0.3V to +6V
Voltage Inputs (IN+, IN- to V_{SS}).... -0.3V to (V_{DD} + 0.3V)
Differential Input Voltage (IN+ to IN-)....6.6V
Current into Input Pins ....±20mA
Output Short-Circuit Duration ....2s to Either V_{DD} or V_{SS}
Current into Any Pin 20mA
Continuous Power Dissipation (T_A = +70°C)
5-Pin SC70 (derate 3.1mW/°C above +70°C)....247mW
5-Pin SOT23 (derate 7.1mW/°C above +70°C) 571mW
8-Pin SOT23 (derate 9.1mW/°C above +70°C) 727mW
8-Pin µMAX (derate 4.5mW/°C above +70°C)....362mW
8-Pin SO (derate 5.88mW/°C above +70°C)....471mW
14-Pin TSSOP (derate 9.1mW/°C above +70°C)....727mW
14-Pin SO (derate 8.3mW/°C above +70....667mW
Operating Temperature Range
Automotive Application .... -40°C to +125°C
Junction Temperature ....+150°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_{DD} = 5V, V_{SS} = 0, V_{CM} = 0, T_A = -40°C to +125°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

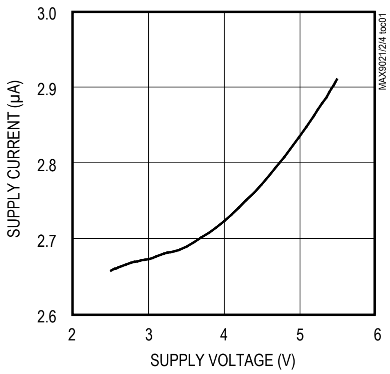
PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Operating Voltage Range	V_{DD}	Guaranteed by PSRR test		2.5		5.5	V
Supply Current Per Comparator	I_{DD}				2.8	5	µA
Input Offset Voltage	V_{OS}	(Note 2)			±1	±8	mV
Input Offset Voltage Temperature Coefficient	TCV_{OS}				±1		µV/°C
Hysteresis		(Note 3)			4		mV
Input Bias Current	I_{BIAS}				3	80	nA
Input Offset Current	I_{OS}				±2	±60	nA
Common-Mode Voltage Range	V_{CM}	Guaranteed by CMRR test		V_{SS}		V_{DD} - 1.1	V
Common-Mode Rejection Ratio	CMRR	$V_{SS} \le V_{CM} \le (V_{DD}$ - 1.1V), V_{DD} = 5.5V		70	100		dB
Power-Supply Rejection Ratio	PSRR	V_{DD} = 2.5V to 5.5V		60	80		dB
Output-Voltage Swing	V_{OL}, V_{OH}	$V_{OH} = V_{DD} - V_{OUT}$, $(V_{IN+} - V_{IN-}) \ge$ 20mV	I_{SOURCE} = 10µA		2		mV
			I_{SOURCE} = 4mA		160	400	
		$V_{OL} = V_{OUT} - V_{SS}$, $(V_{IN-} - V_{IN+}) \ge$ 20mV	I_{SINK} = 10µA		2		
			I_{SINK} = 4mA		180	400	
Output Short-Circuit Current	I_{SC}				50		mA
Propagation Delay	t_{pd+}, t_{pd-}	R_L = 10kΩ, C_L = 15pF (Note 4)	V_{OD} = 10mV		8		µs
			V_{OD} = 100mV		3		
Rise and Fall Time	t_R, t_F	R_L = 10kΩ, C_L = 15pF (Note 5)			20		ns
Power-On Time		R_L = 10kΩ, C_L = 15pF			150		ns
Maximum Capacitive Load	C_L	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_{OD} 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.

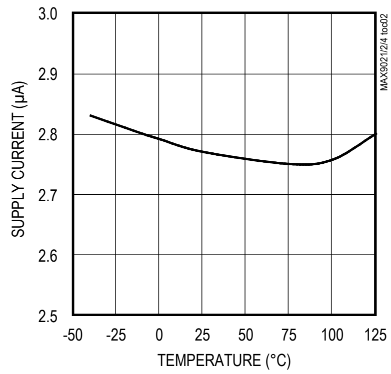
Typical Operating Characteristics

(V_{DD} = 5V, V_{SS} = 0, V_{CM} = 0, R_L = 10kΩ, C_L = 15pF, V_{OD} = 100mV, T_A = +25°C, unless otherwise noted.)

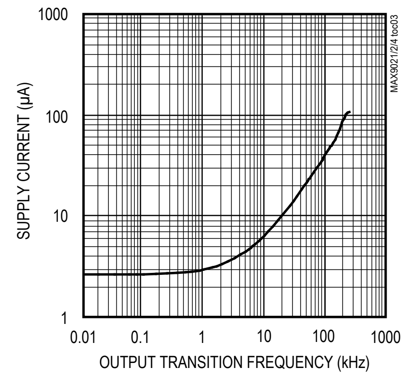
SUPPLY CURRENT vs. SUPPLY VOLTAGE



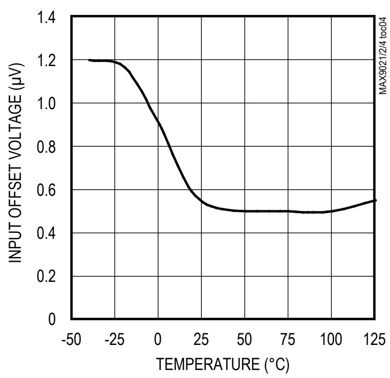
SUPPLY CURRENT vs. TEMPERATURE



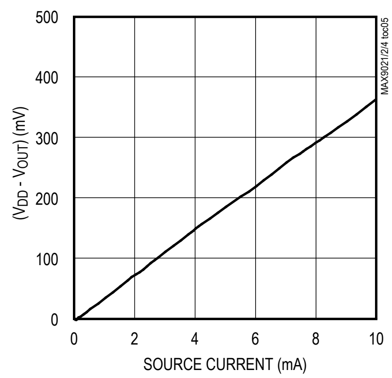
SUPPLY CURRENT vs. OUTPUT TRANSITION FREQUENCY



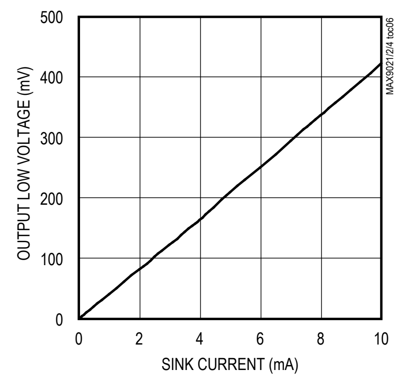
INPUT OFFSET VOLTAGE vs. TEMPERATURE



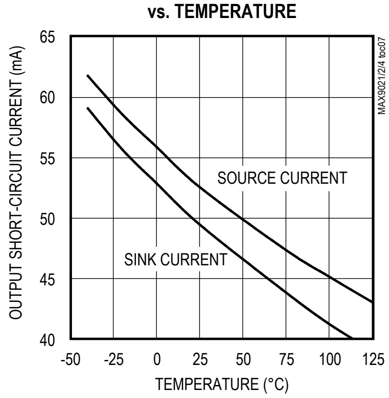
OUTPUT HIGH VOLTAGE vs. SOURCE CURRENT



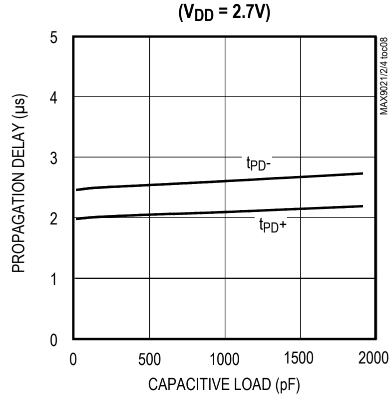
OUTPUT LOW VOLTAGE vs. SINK CURRENT



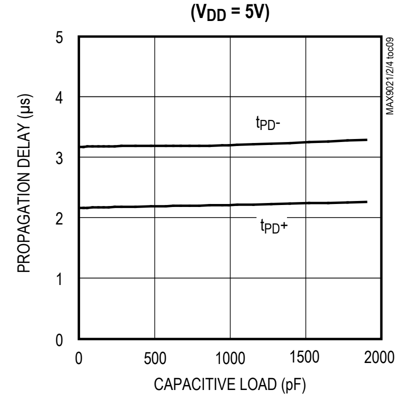
OUTPUT SHORT-CIRCUIT CURRENT vs. TEMPERATURE



PROPAGATION DELAY vs. CAPACITIVE LOAD (V_{DD} = 2.7V)



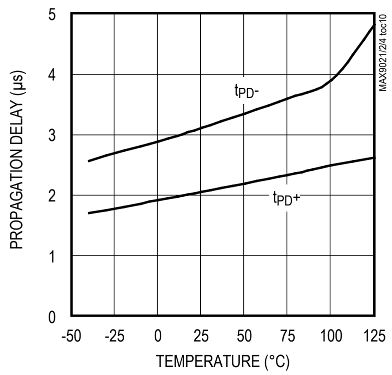
PROPAGATION DELAY vs. CAPACITIVE LOAD (V_{DD} = 5V)



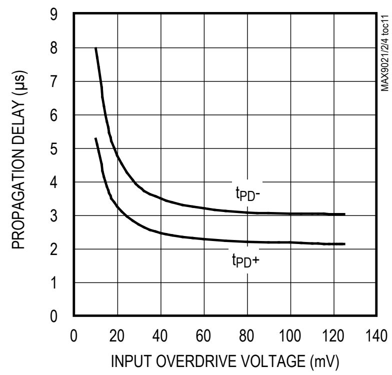
Typical Operating Characteristics (continued)

(V_{DD} = 5V, V_{SS} = 0, V_{CM} = 0, R_L = 10kΩ, C_L = 15pF, V_{OD} = 100mV, T_A = +25°C, unless otherwise noted.)

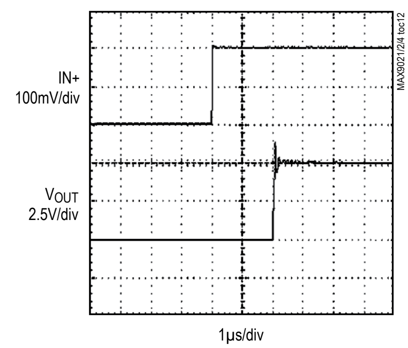
PROPAGATION DELAY vs. TEMPERATURE



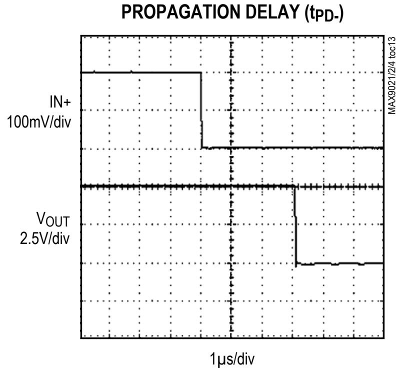
PROPAGATION DELAY vs. INPUT OVERDRIVE VOLTAGE



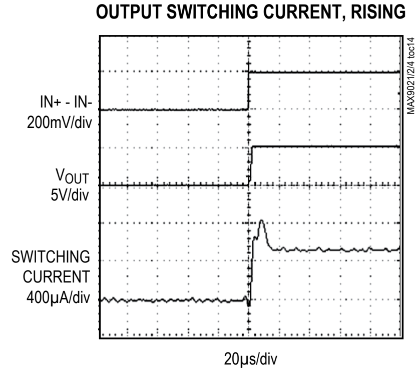
PROPAGATION DELAY (t_{PD+})



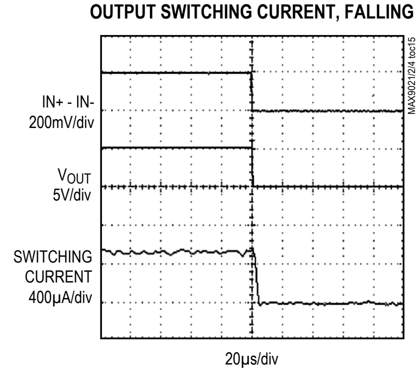
PROPAGATION DELAY (t_{PD-})



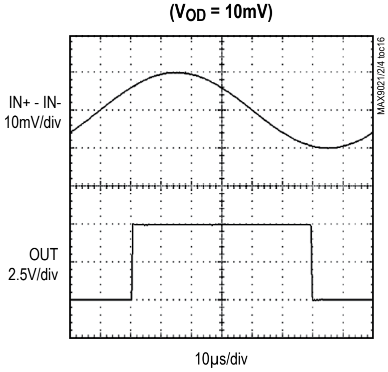
OUTPUT SWITCHING CURRENT, RISING



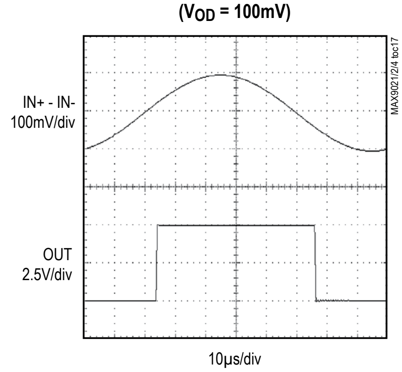
OUTPUT SWITCHING CURRENT, FALLING



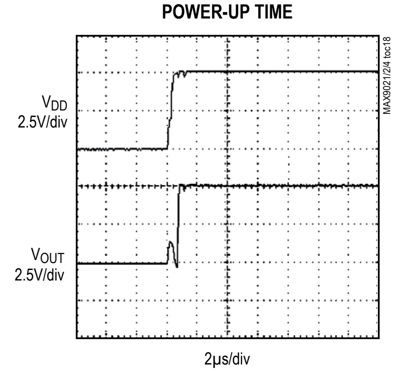
10kHz RESPONSE (V_{OD} = 10mV)



10kHz RESPONSE (V_{OD} = 100mV)



POWER-UP TIME



Pin Description

PIN			NAME	FUNCTION
MAX9021	MAX9022	MAX9024		
1	—	—	IN+	Comparator Noninverting Input
2	4	11	V_{SS}	Negative Supply Voltage
3	—	—	IN-	Comparator Inverting Input
4	—	—	OUT	Comparator Output
5	8	4	V_{DD}	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:

$$V_{TH} = V_{REF} + ((V_{DD} - V_{REF})R2) / (R1 + R2)$$
$$V_{TL} = V_{REF}(1 - (R2 / (R1 + R2))$$

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.

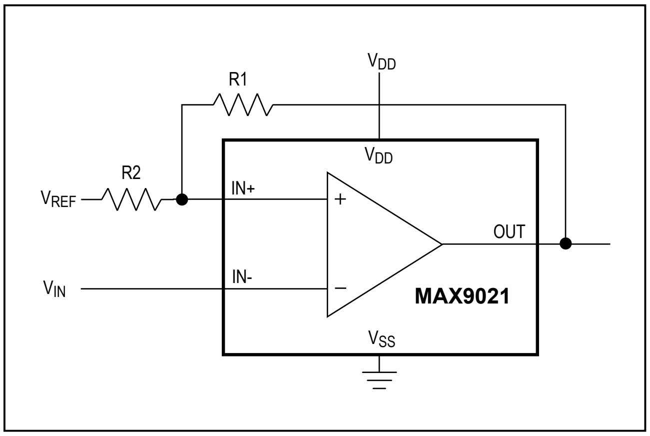


Figure 1. Additional Hysteresis

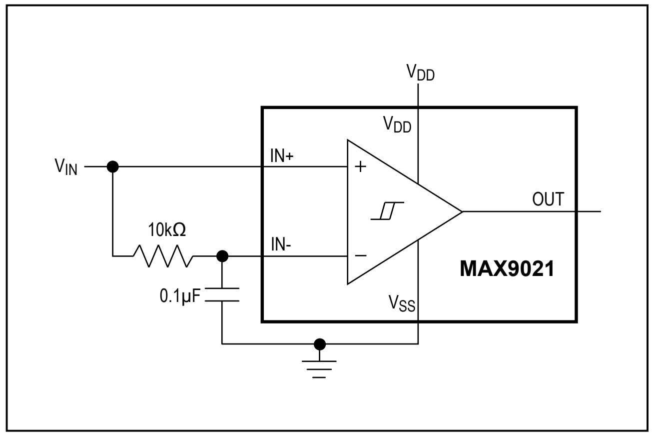


Figure 2. Time Averaging of the Input Signal for Data Recovery

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 1kΩ.

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 ≈ 100kΩ, V_{TH} = 2.525V, and V_{TL} = 2.475V.

The above-described design procedure assumes railto-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-.

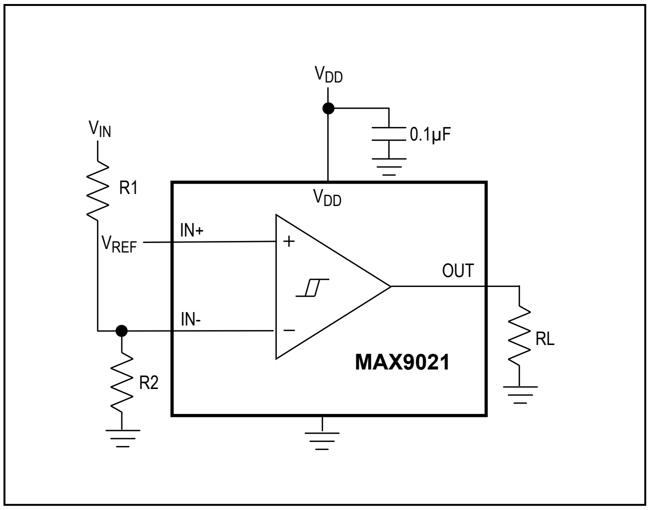
Biasing for Data Recovery

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:

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

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

Typical Application Circuit

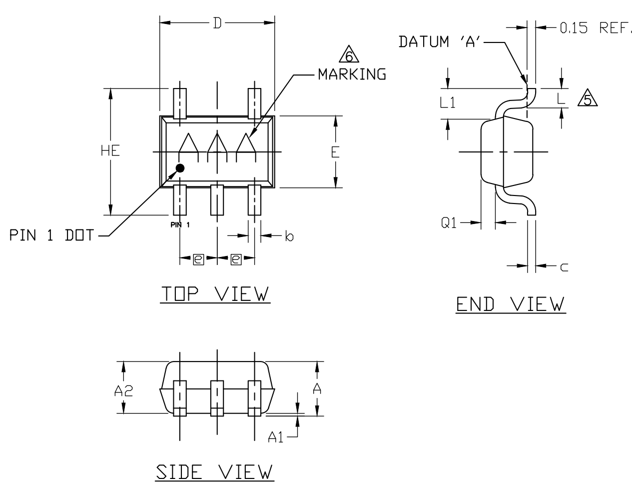


Chip Information

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**. 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.



COMMON DIMENSIONS			
SYMBOL	MIN	NOM	MAX
A	0.80	0.95	1.10
A1	0.00	0.07	0.10
A2	0.80	0.90	1.00
b	0.15	0.22	0.30
c	0.10	0.14	0.18
D	1.80	2.00	2.20
e		0.65 BSC.	
E	1.15	1.25	1.35
HE	1.80	2.20	2.40
L	0.26	0.34	0.46
L1		0.425 TYP.	
Q1	0.10	0.25	0.40

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SPECIFIED.
2. DIMENSIONS ARE INCLUSIVE OF PLATING.
3. DIMENSIONS ARE EXCLUSIVE OF MOLD FLASH & METAL BURR.
4. COPLANARITY: 4 MILS. MAX.
5. FOOT LENGTH MEASURED AT INTERCEPT POINT BETWEEN DATUM 'A' AND LEAD SURFACE.
6. MARKING IS FOR PACKAGE ORIENTATION REFERENCE ONLY.
7. LEAD CENTERLINES TO BE AT TRUE POSITION AS DEFINED BY BASIC DIMENSION "e", ±0.05.
8. COMPLY TO JEITA SC-88A EXCEPT FOR DIMENSION 'L'. ALL DIMENSIONS COMPLY TO JEDEC MO-203.
9. MATERIAL MUST COMPLY WITH BANNED AND RESTRICTED SUBSTANCES SPEC # 10-0131.
10. ALL DIMENSIONS APPLY TO BOTH LEADED (-) AND LEAD FREE (+) PACKAGE CODES.
11. PKG CODE: X5-1, X5-1A, X5-1C

-DRAWING NOT TO SCALE-

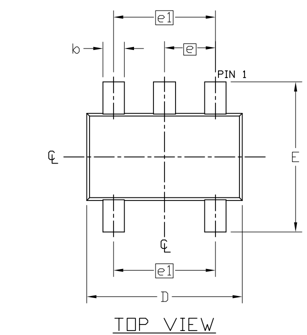
maxim integrated

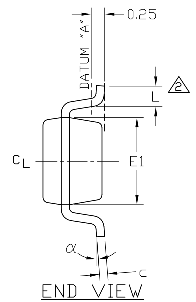
TITLE: PACKAGE OUTLINE, 5L SC70

APPROVAL | DOCUMENT CONTROL NO. 21-0076 | REV. H | 1/1

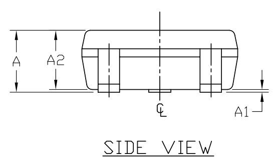
Package Information (continued)

For the latest package outline information and land patterns (footprints), go to **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.





SYMBOL	MIN	NOM	MAX
A	0.90	1.25	1.45
A1	0.00	0.05	0.15
A2	0.90	1.10	1.30
b	0.35	0.40	0.50
c	0.08	0.15	0.20
D	2.80	2.90	3.00
E	2.60	2.80	3.00
E1	1.50	1.625	1.75
L	0.35	0.45	0.60
L1	0.60 REF		
e	0.95 BSC.		
e1	1.90 BSC.		
α	0°	2.5°	8°



NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SPECIFIED.
2. (△) FOOT LENGTH MEASURED AT INTERCEPT POINT BETWEEN DATUM A & LEAD SURFACE.
3. PACKAGE OUTLINE EXCLUSIVE OF MOLD FLASH & METAL BURR. MOLD FLASH, PROTRUSION OR METAL BURR SHOULD NOT EXCEED 0.25 MM.
4. MEETS JEDEC MO178, VARIATION AA.
5. LEADS TO BE COPLANAR WITHIN 0.10 mm.
6. SOLDER THICKNESS MEASURED AT FLAT SECTION OF LEAD BETWEEN 0.08mm AND 0.15mm FROM LEAD TIP.
7. MATERIAL MUST COMPLY WITH BANNED AND RESTRICTED SUBSTANCES SPEC # 10-0131.
8. ALL DIMENSIONS APPLY TO BOTH LEADED (-) AND LEAD FREE (+) PACKAGE CODES.
9. PKG CODES: U5-1, U5-2

TITLE: PACKAGE OUTLINE, 5L SOT23

APPROVAL	DOCUMENT CONTROL NO.	REV.	
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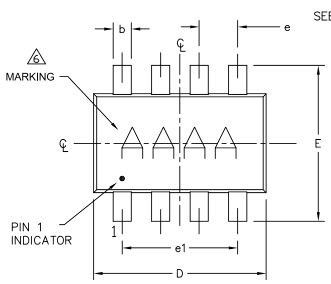
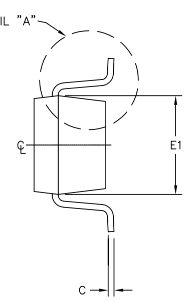
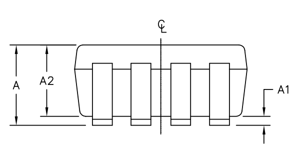
-DRAWING NOT TO SCALE-

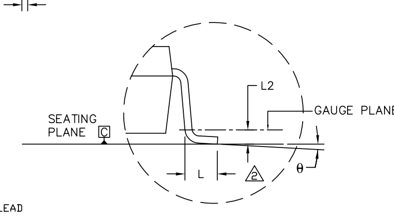




SYMBOL	MIN	NOM	MAX
A	0.90	1.25	1.45
A1	0.00	0.06	0.15
A2	0.90	1.10	1.30
b	0.22	0.30	0.38
C	0.08	0.15	0.22
D	2.80	2.90	3.00
E	2.60	2.80	3.00
E1	1.50	1.625	1.75
L	0.30	0.45	0.60
L2	0.25 BSC.		
e	0.65 BSC.		
e1	1.95 REF.		
θ	0°	3°	8°

PKG CODES: K8-1, K8-2, K8F-4, K8FH-4, K8-5, K8SN-1; K8CN-2





DETAIL "A"

NOTE:

1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. (△) FOOT LENGTH MEASURED FROM LEAD TIP TO UPPER RADIUS OF HEEL OF THE LEAD PARALLEL TO SEATING PLANE C.
3. PACKAGE OUTLINE EXCLUSIVE OF MOLD FLASH & METAL BURR.
4. PACKAGE OUTLINE INCLUSIVE OF SOLDER PLATING.
5. COPLANARITY 4 MILS. MAX.
6. (△) MARKING IS FOR PACKAGE ORIENTATION REFERENCE ONLY.
7. SOLDER THICKNESS MEASURED AT FLAT SECTION OF LEAD BETWEEN 0.08mm AND 0.15mm FROM LEAD TIP.
8. MEETS JEDEC MO178 VARIATION BA.
9. ALL DIMENSIONS APPLY TO BOTH LEADED (-) AND LEAD FREE (+) PACKAGE CODES.

maxim integrated.

TITLE: PACKAGE OUTLINE, SOT-23, 8L BODY

APPROVAL	DOCUMENT CONTROL NO.	REV.	
	21-0078	J	1/1

-DRAWING NOT TO SCALE-

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