



# Low-Power, High-Efficiency, Single/Dual, Rail-to-Rail I/O Op Amps

## General Description

The MAX9613/MAX9615 are low-power precision op amps with rail-to-rail inputs and rail-to-rail outputs. They feature precision MOS inputs powered from an internal charge pump to eliminate crossover distortion that is common to complementary input-pair type amplifier architectures.

These devices are ideal for a large number of signal processing applications such as photodiode transimpedance amplifiers and filtering/amplification of a wide variety of signals in industrial equipment. The devices also feature excellent RF immunity, making them ideal for portable applications.

The MAX9613/MAX9615 feature a self-calibration system (on power-up), eliminating the effects of temperature and power-supply variations.

The MAX9613/MAX9615 are capable of operating from a 1.7V to 5.5V supply voltage over the 0°C to +70°C temperature range, and from 1.8V to 5.5V over the -40°C to +125°C automotive temperature range.

Both singles and duals are available in tiny SC70 packages. The MAX9613 features a high-impedance output while in shutdown.

## Applications

Notebooks, Portable Media Players  
Industrial and Medical Sensors  
General Purpose Signal Processing

## Features

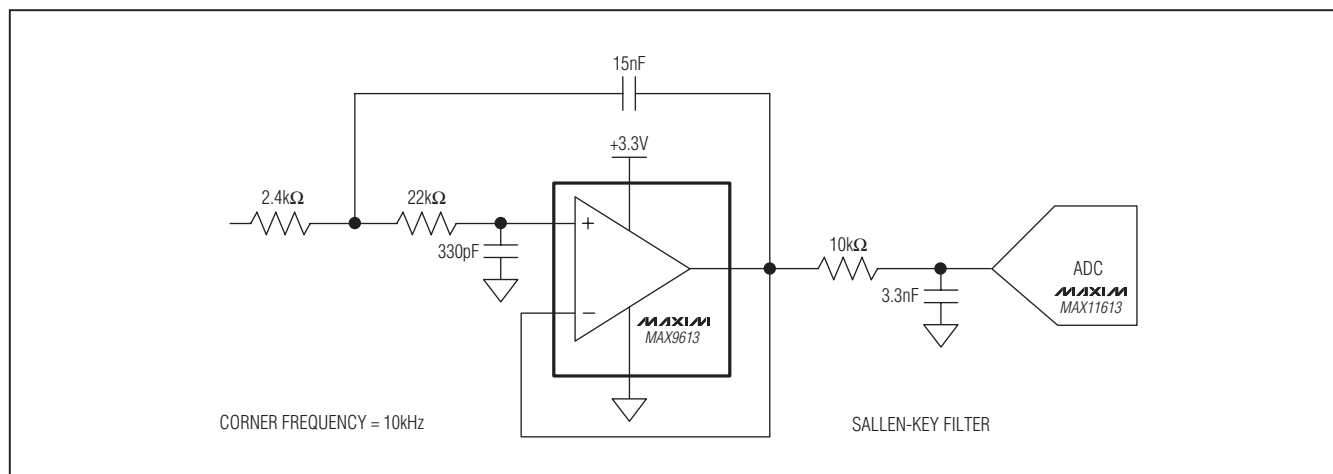
- ◆  $V_{CC} = 1.7V$  to  $5.5V$  (0°C to +70°C)
- ◆  $V_{CC} = 1.8V$  to  $5.5V$  (-40°C to +125°C)
- ◆ Low 100 $\mu V$  (max)  $V_{OS}$
- ◆ Rail-to-Rail Inputs and Outputs
- ◆ Low 220 $\mu A$  Supply Current, 1 $\mu A$  in Shutdown
- ◆ Autotrim Offset Calibration
- ◆ 2.8MHz Bandwidth
- ◆ Excellent RF Immunity

## Ordering Information

PART	TEMP RANGE	PIN-PACKAGE	TOP MARK
MAX9613AXT+T	-40°C to +125°C	6 SC70	+ADK
MAX9615AXA+T	-40°C to +125°C	8 SC70	+AAD

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

## Typical Application Circuit



# Low-Power, High-Efficiency, Single/Dual, Rail-to-Rail I/O Op Amps

## ABSOLUTE MAXIMUM RATINGS

IN+, IN-,  $\overline{\text{SHDN}}$ ,  $V_{CC}$  to GND.....-0.3V to +6V  
 OUT to GND.....-0.3V to ( $V_{CC} + 0.3V$ )  
 Short-Circuit (GND) Duration to Either Supply Rail.....5s  
 Continuous Input Current (any pin)..... $\pm 20\text{mA}$   
 Thermal Limits (Note 1) Multilayer PCB  
 Continuous Power Dissipation ( $T_A = +70^\circ\text{C}$ )  
   6-Pin SC70 (derate 3.1mW/ $^\circ\text{C}$  above  $+70^\circ\text{C}$ ).....245mW  
      $\theta_{JA}$ .....326.5 $^\circ\text{C/W}$   
      $\theta_{JC}$ .....115 $^\circ\text{C/W}$

8-Pin SC70 (derate 3.1mW/ $^\circ\text{C}$  above  $+70^\circ\text{C}$ ).....245mW  
      $\theta_{JA}$ .....326 $^\circ\text{C/W}$   
      $\theta_{JC}$ .....115 $^\circ\text{C/W}$   
 Operating Temperature Range..... $-40^\circ\text{C}$  to  $+125^\circ\text{C}$   
 Storage Temperature Range..... $-65^\circ\text{C}$  to  $+150^\circ\text{C}$   
 Junction Temperature..... $+150^\circ\text{C}$   
 Lead Temperature (soldering, 10s)..... $+300^\circ\text{C}$   
 Soldering Temperature (reflow)..... $+260^\circ\text{C}$

**Note 1:** Package thermal resistances were obtained using the method described in JEDEC specification JESD51-7, using a four-layer board. For detailed information on package thermal considerations, refer to [www.maxim-ic.com/thermal-tutorial](http://www.maxim-ic.com/thermal-tutorial).

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

( $V_{CC} = \overline{\text{VSHDN}} = 3.3\text{V}$ ,  $V_{IN+} = V_{IN-} = V_{CM} = 0\text{V}$ ,  $R_L = 10\text{k}\Omega$  to  $V_{CC}/2$ ,  $T_A = -40^\circ\text{C}$  to  $+125^\circ\text{C}$ . Typical values are at  $T_A = +25^\circ\text{C}$ , unless otherwise noted.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>DC CHARACTERISTICS</b>						
Input Voltage Range	$V_{IN+}, V_{IN-}$	Guaranteed by CMRR test	-0.1		$V_{CC} + 0.1$	V
Input Offset Voltage	$V_{OS}$	$T_A = +25^\circ\text{C}$		23	100	$\mu\text{V}$
		$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$ after power-up auto-calibration			150	
		$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$			750	
Input Offset Voltage Drift	$V_{OS} - TC$			1	7	$\mu\text{V}/^\circ\text{C}$
Input Bias Current (Note 3)	$I_B$	$T_A = +40^\circ\text{C}$ to $+25^\circ\text{C}$		1	1.55	pA
		$T_A = +70^\circ\text{C}$			45	
		$T_A = +85^\circ\text{C}$			135	
		$T_A = +125^\circ\text{C}$			1.55	nA
Common-Mode Rejection Ratio	CMRR	$V_{CM} = -0.1\text{V}$ to $V_{CC} + 0.1\text{V}$ , $T_A = +25^\circ\text{C}$	82	100		dB
		$V_{CM} = -0.1\text{V}$ to $V_{CC} + 0.1\text{V}$ , $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$	80			
Input Offset Current (Note 3)	$I_{OS}$	$T_A = +40^\circ\text{C}$ to $+25^\circ\text{C}$			0.5	pA
		$T_A = +70^\circ\text{C}$			7	
		$T_A = +85^\circ\text{C}$			25	
		$T_A = +125^\circ\text{C}$			400	
Open-Loop Gain	$A_{OL}$	$+0.4\text{V} \leq V_{OUT} \leq V_{CC} - 0.4\text{V}$ , $R_L = 10\text{k}\Omega$	99	120		dB
Output Short-Circuit Current (Note 4)	$I_{SC}$	To $V_{CC}$		275		mA
		To GND		75		
Output Voltage Low	$V_{OL}$	$R_L = 10\text{k}\Omega$			0.011	V
		$R_L = 600\Omega$			0.1	
		$R_L = 32\Omega$		0.170		

# Low-Power, High-Efficiency, Single/Dual, Rail-to-Rail I/O Op Amps

## ELECTRICAL CHARACTERISTICS (continued)

( $V_{CC} = \overline{V_{SHDN}} = 3.3V$ ,  $V_{IN+} = V_{IN-} = V_{CM} = 0V$ ,  $R_L = 10k\Omega$  to  $V_{CC}/2$ ,  $T_A = -40^\circ C$  to  $+125^\circ C$ . Typical values are at  $T_A = +25^\circ C$ , unless otherwise noted.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage High	VOH	RL = 10kΩ	VCC - 0.011		V	
		RL = 600Ω	VCC - 0.1			
		RL = 32Ω	VCC - 0.560			
AC CHARACTERISTICS						
Input Voltage Noise Density	en	f = 10kHz	28		nV/√Hz	
Input Voltage Noise	Total noise	0.1Hz ≤ f ≤ 10Hz	5		μVP-P	
Input Current Noise Density	In	f = 10kHz	0.1		fA/√Hz	
Gain Bandwidth	GBW		2.8		MHz	
Slew Rate	SR		1.3		V/μs	
Capacitive Loading	CLOAD	No sustained oscillation	200		pF	
Total Harmonic Distortion	THD	f = 10kHz, VOUT = 2VP-P, AV = 1V/V	85		dB	
POWER-SUPPLY CHARACTERISTICS						
Power-Supply Range	VCC	Guaranteed by PSRR	1.8	5.5		V
		TA = 0°C to +70°C, guaranteed by PSSR	1.7	5.5		
Power-Supply Rejection Ratio	PSRR	TA = +25°C	85	106		dB
		TA = -40°C to +125°C	83			
Quiescent Current	ICC	Per amplifier, TA = +25°C	220	305		μA
		Per amplifier	420			
Shutdown Supply Current	ISHDN	MAX9613 only	1		μA	
Shutdown Input Low	VIL	MAX9613 only	0.5		V	
Shutdown Input High	VIH	MAX9613 only	1.4		V	
Output Impedance in Shutdown	ROUT_SHDN	MAX9613 only	10		MΩ	
Turn-On Time from SHDN	ton	MAX9613 only	20		μs	
Power-Up Time	tup		10		ms	

**Note 2:** All devices are 100% production tested at  $T_A = +25^\circ C$ . Temperature limits are guaranteed by design.

**Note 3:** Guaranteed by design, not production tested.

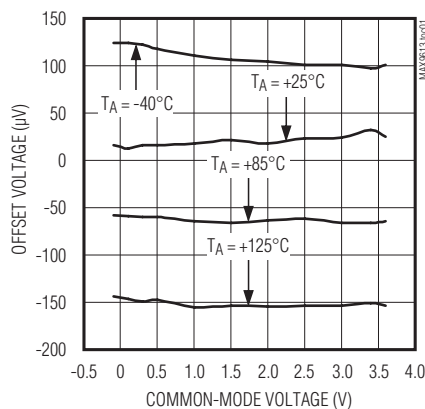
**Note 4:** Do not exceed package thermal dissipation in the *Absolute Maximum Ratings* section.

# Low-Power, High-Efficiency, Single/Dual, Rail-to-Rail I/O Op Amps

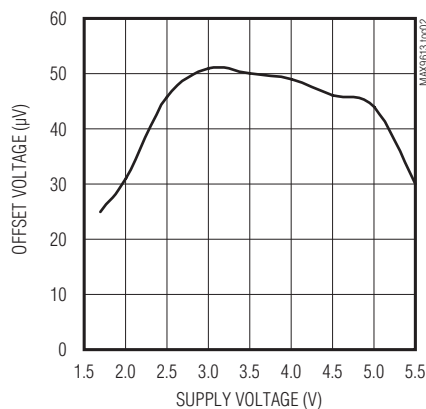
## Typical Operating Characteristics

( $V_{CC} = 3.3V$ ,  $V_{IN+} = V_{IN-} = 0V$ ,  $V_{CM} = V_{CC}/2$ ,  $R_L = 10k\Omega$  to  $V_{CC}/2$ , values are at  $T_A = +25^\circ C$ , unless otherwise noted.)

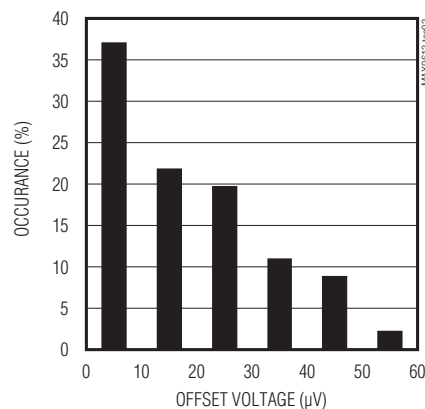
**OFFSET VOLTAGE vs. COMMON-MODE VOLTAGE vs. TEMPERATURE**



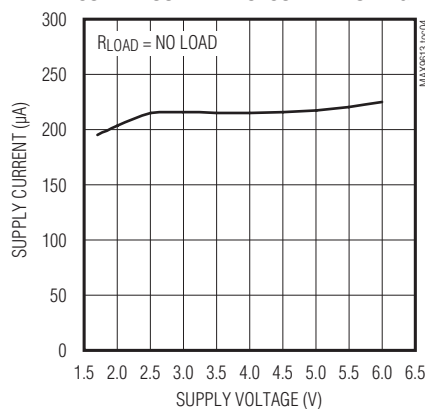
**OFFSET VOLTAGE vs. SUPPLY VOLTAGE**



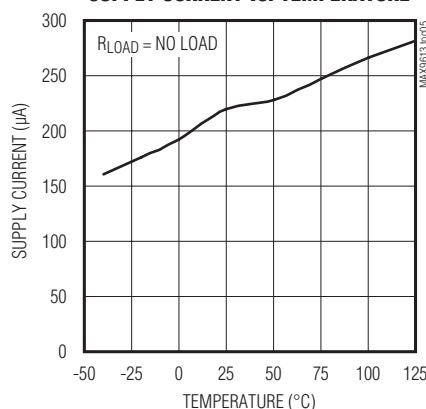
**OFFSET VOLTAGE HISTOGRAM**



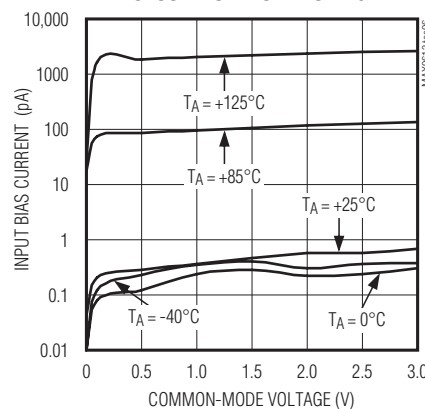
**SUPPLY CURRENT vs. SUPPLY VOLTAGE**



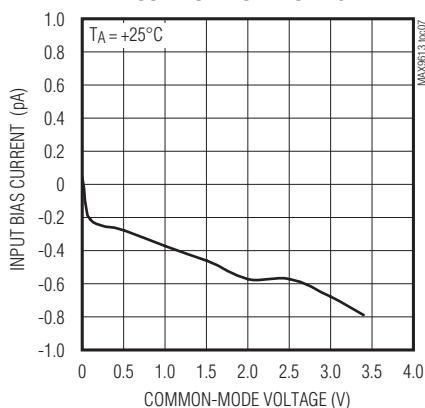
**SUPPLY CURRENT vs. TEMPERATURE**



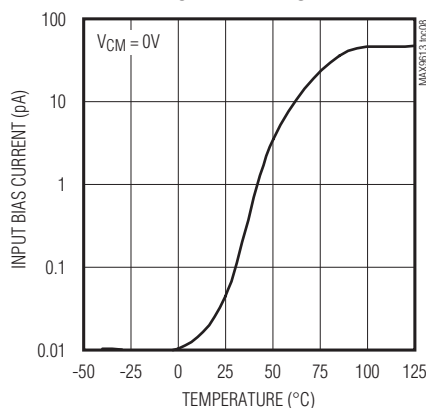
**INPUT BIAS CURRENT vs. COMMON-MODE VOLTAGE**



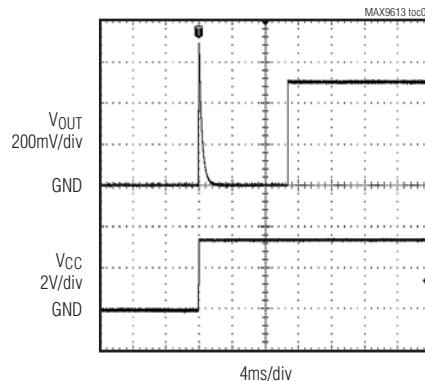
**INPUT BIAS CURRENT vs. COMMON-MODE VOLTAGE**



**INPUT BIAS CURRENT vs. TEMPERATURE**



**POWER-UP TRANSIENT**



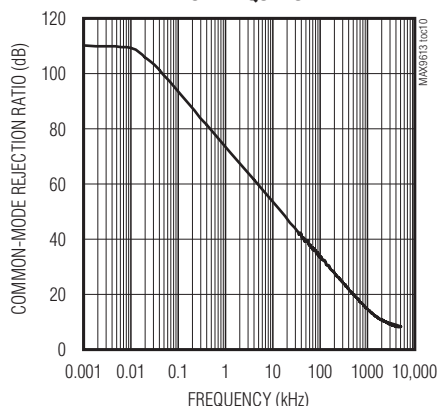
# Low-Power, High-Efficiency, Single/Dual, Rail-to-Rail I/O Op Amps

## Typical Operating Characteristics (continued)

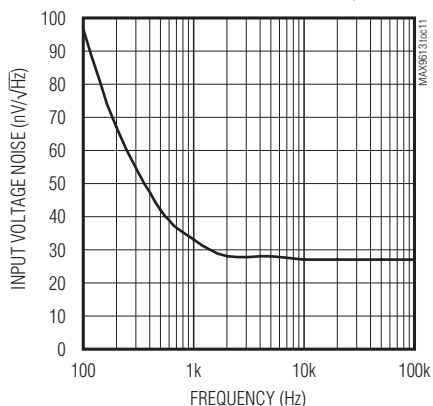
( $V_{CC} = 3.3V$ ,  $V_{IN+} = V_{IN-} = 0V$ ,  $V_{CM} = V_{CC}/2$ ,  $R_L = 10k\Omega$  to  $V_{CC}/2$ , values are at  $T_A = +25^\circ C$ , unless otherwise noted.)

MAX9613/MAX9615

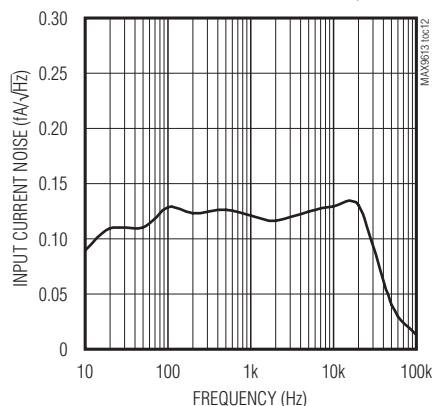
**COMMON-MODE REJECTION RATIO  
vs. FREQUENCY**



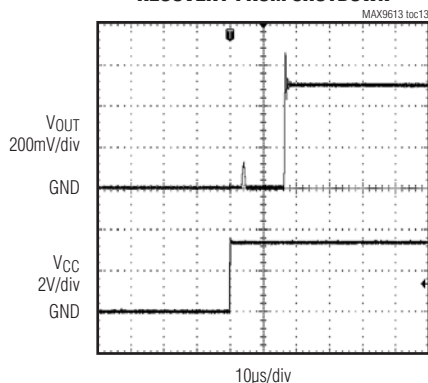
**INPUT VOLTAGE NOISE vs. FREQUENCY**



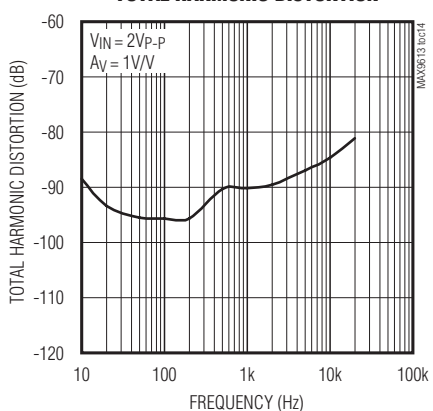
**INPUT CURRENT NOISE vs. FREQUENCY**



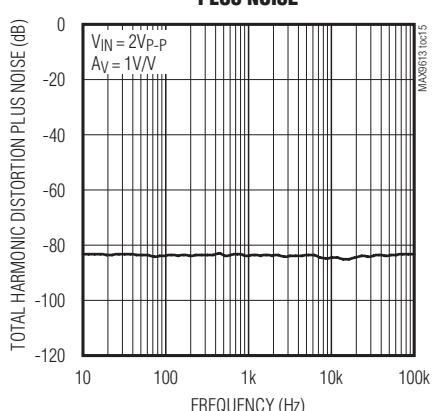
**RECOVERY FROM SHUTDOWN**



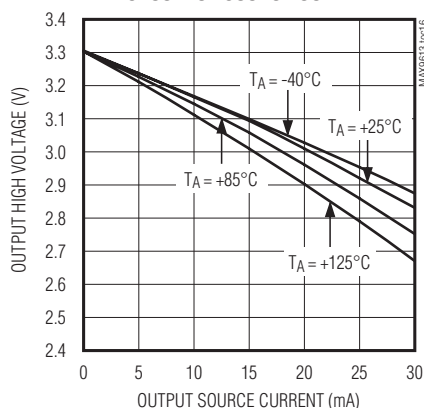
**TOTAL HARMONIC DISTORTION**



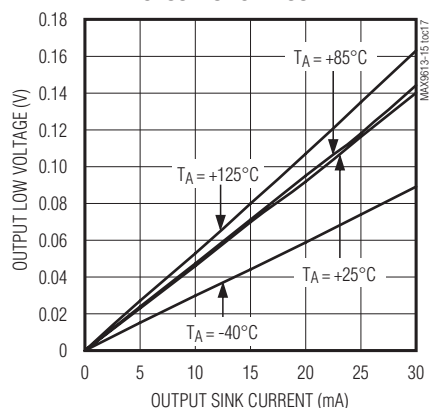
**TOTAL HARMONIC DISTORTION  
PLUS NOISE**



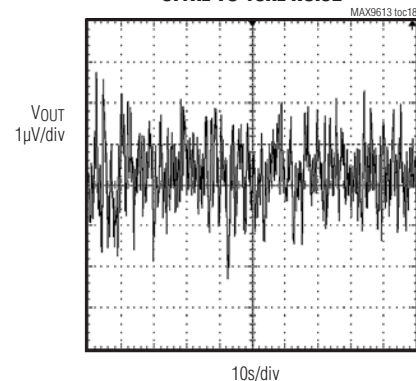
**OUTPUT HIGH VOLTAGE  
vs. OUTPUT SOURCE CURRENT**



**OUTPUT LOW VOLTAGE  
vs. OUTPUT SINK CURRENT**



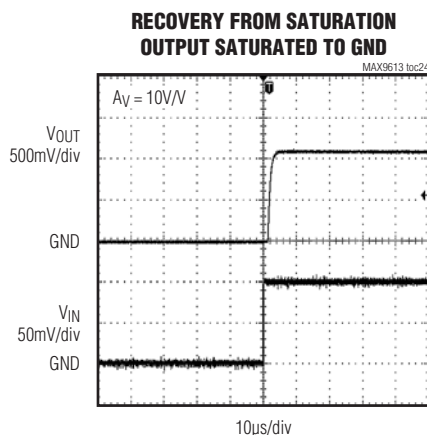
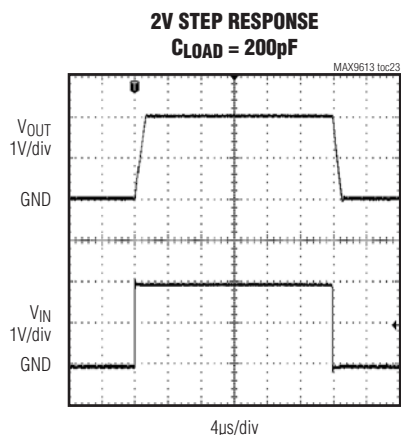
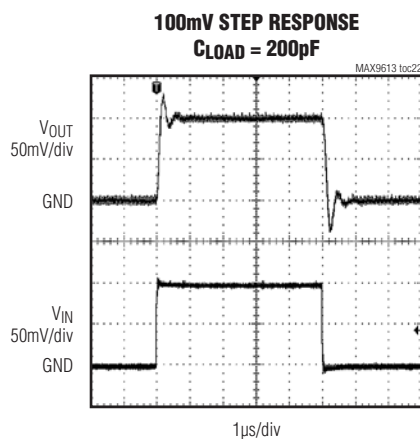
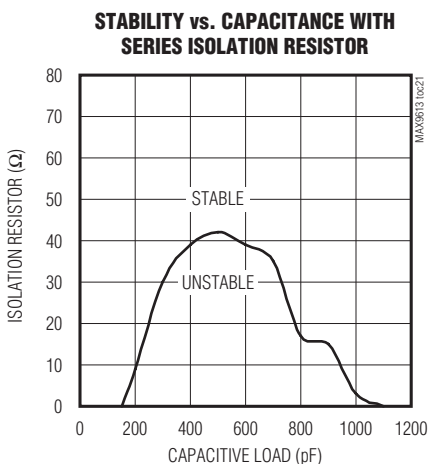
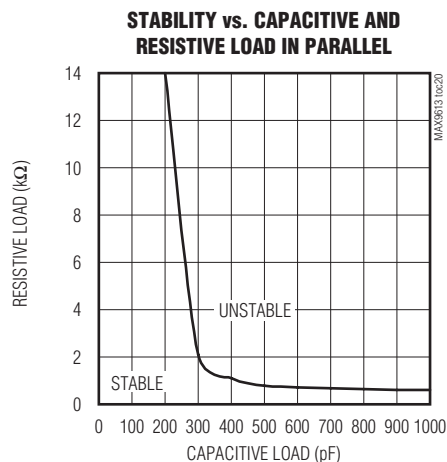
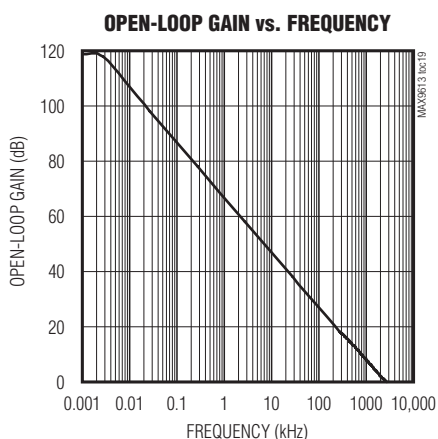
**0.1Hz TO 10Hz NOISE**



# Low-Power, High-Efficiency, Single/Dual, Rail-to-Rail I/O Op Amps

## Typical Operating Characteristics (continued)

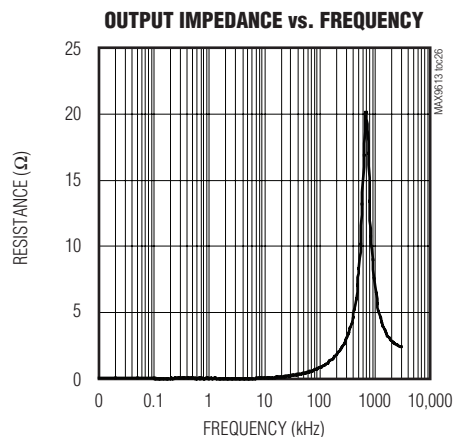
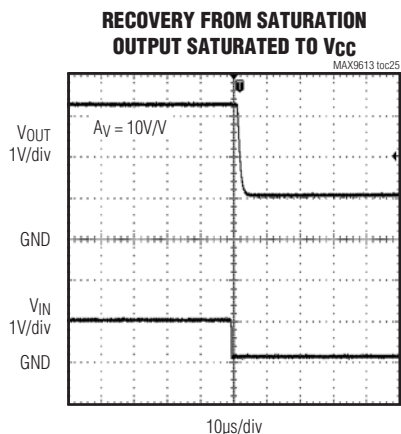
( $V_{CC} = 3.3V$ ,  $V_{IN+} = V_{IN-} = 0V$ ,  $V_{CM} = V_{CC}/2$ ,  $R_L = 10k\Omega$  to  $V_{CC}/2$ , values are at  $T_A = +25^\circ C$ , unless otherwise noted.)



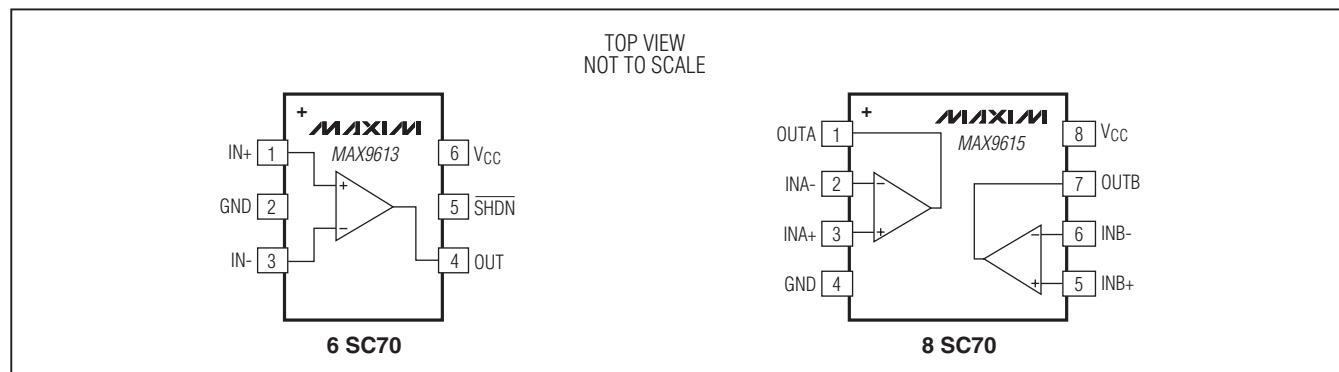
# Low-Power, High-Efficiency, Single/Dual, Rail-to-Rail I/O Op Amps

## Typical Operating Characteristics (continued)

( $V_{CC} = 3.3V$ ,  $V_{IN+} = V_{IN-} = 0V$ ,  $V_{CM} = V_{CC}/2$ ,  $R_L = 10k\Omega$  to  $V_{CC}/2$ , values are at  $T_A = +25^\circ C$ , unless otherwise noted.)



## Pin Configuration



## Pin Description

PIN		NAME	FUNCTION
MAX9613	MAX9615		
1	—	IN+	Positive Input
—	3	INA+	Positive Input A
—	5	INB+	Positive Input B
2	4	GND	Ground
3	—	IN-	Negative Input
—	2	INA-	Negative Input A
—	6	INB-	Negative Input B
4	—	OUT	Output
—	1	OUTA	Output A
—	7	OUTB	Output B
5	—	SHDN	Active-Low Shutdown
6	8	VCC	Positive Power Supply. Bypass with a 0.1µF capacitor to ground.

# Low-Power, High-Efficiency, Single/Dual, Rail-to-Rail I/O Op Amps

## Detailed Description

The MAX9613/MAX9615 are low-power op amps ideal for signal processing applications due to their high precision and CMOS inputs.

The MAX9613 also features a low-power shutdown mode that greatly reduces quiescent current while the device is not operational.

The MAX9613/MAX9615 self-calibrate on power-up to eliminate effects of temperature and power-supply variation.

## Crossover Distortion

These op amps feature an integrated charge pump that creates an internal voltage rail 1V above  $V_{CC}$  that is used to power the input differential pair of pMOS transistors. This unique architecture eliminates crossover distortion common in traditional complementary pair type of input architecture.

In these op amps, an inherent input offset voltage difference between the nMOS pair and pMOS pair of transistors causes signal degradation as shown in Figure 1. By using a single pMOS pair of transistors, this source of input distortion is eliminated, making these parts extremely useful in noninverting configurations such as Sallen-Key filters.

The charge pump requires no external components and is entirely transparent to the user. See Figure 2.

## RF Immunity

The MAX9613/MAX9615 feature robust internal EMI filters that reduce the devices' susceptibility to high-frequency RF signals such as from wireless and mobile devices. This, combined with excellent DC and AC specifications, makes these devices ideal for a wide variety of portable audio and sensitive signal-conditioning applications.

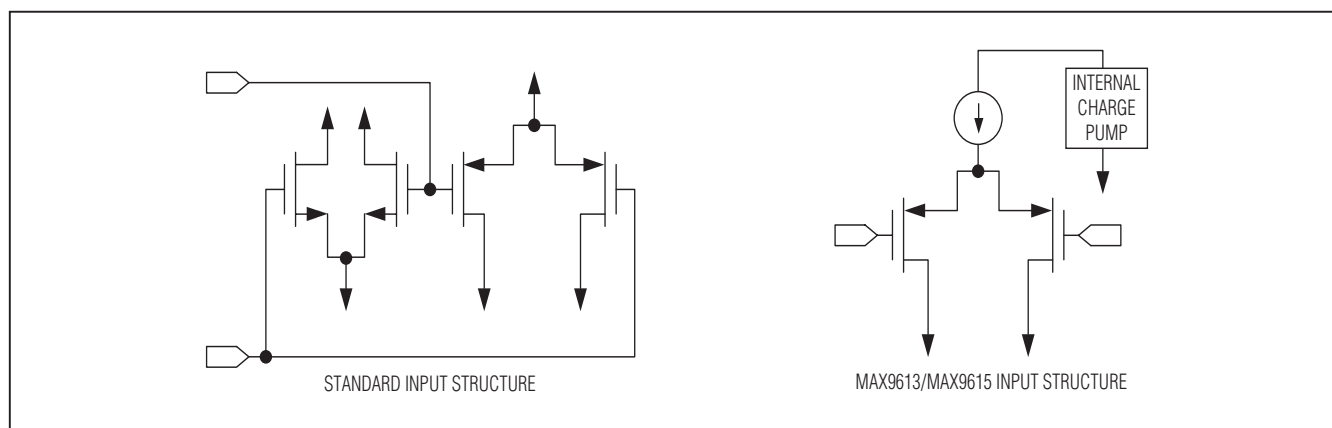


Figure 1. Rail-to-Rail Input Stage Architectures

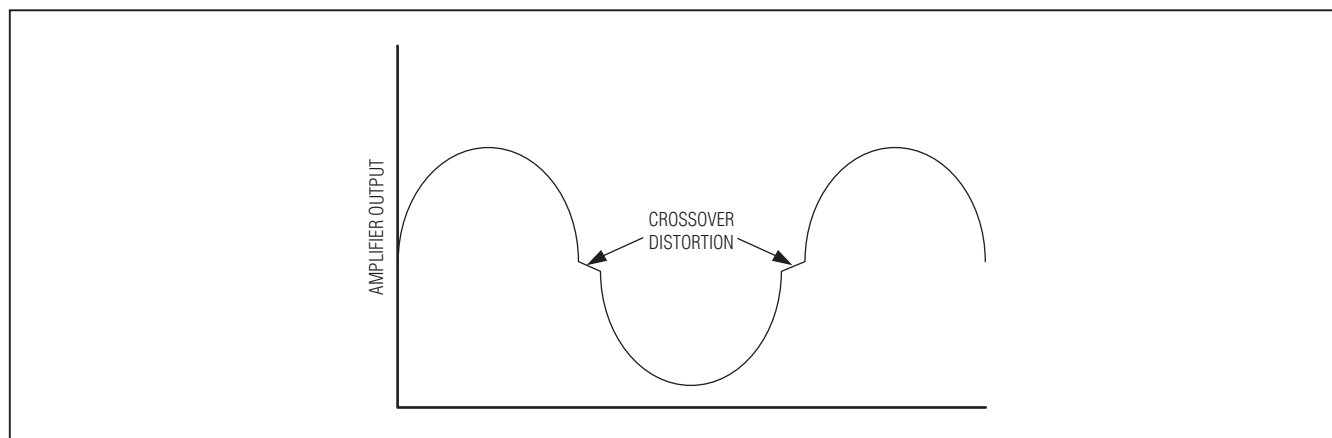


Figure 2. Crossover Distortion When Using Standard Rail-to-Rail Input Stage Architecture. The Input Stage Design Eliminates This Drawback.



# Low-Power, High-Efficiency, Single/Dual, Rail-to-Rail I/O Op Amps

## Applications Information

### Power-Up Autotrim

The MAX9613/MAX9615 feature an automatic autotrim that self-calibrates the  $V_{OS}$  of these devices to less than  $100\mu\text{V}$  of input offset voltage (Figure 3). The autotrim sequence takes approximately 3ms to complete, and is triggered by an internal power-on reset (POR) threshold of 0.5V. During this time, the inputs and outputs are put into high impedance and left unconnected. This self-calibration feature allows the device to eliminate input offset voltage effects due to power supply and operating temperature variation simply by cycling its power.

If the power supply glitches below the 0.5V threshold, the POR circuitry reactivates during next power-up.

### Shutdown Operation

The MAX9613 features an active-low shutdown mode that puts both inputs and outputs into a high-impedance state. In this mode, the quiescent current is less than  $1\mu\text{A}$ . Putting the output in high impedance allows multiple signal outputs to be multiplexed onto a single output line without the additional external buffers. The device does not self-calibrate when exiting shutdown mode, and retains its power-up trim settings. The device also instantly recovers from shutdown.

The shutdown logic levels of the device are independent of supply, allowing the shutdown to be operated by either a 1.8V or 3.3V microcontroller.

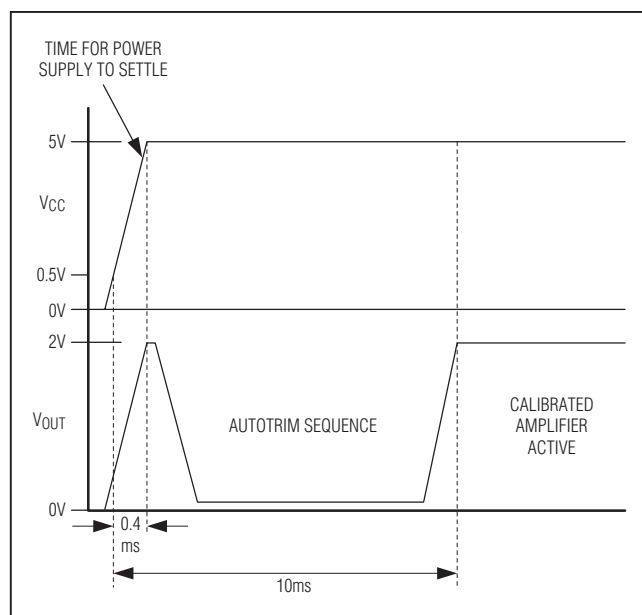


Figure 3. Autotrim Timing Diagram

### Rail-to-Rail Input/Output

The input voltage range of the MAX9613/MAX9615 extends 100mV above  $V_{CC}$  and below ground. The wide input common-mode voltage range allows the op amp to be used as a buffer and as a differential amplifier in a wide variety of signal processing applications. Output voltage low is designed to be especially close to ground—it is only 11mV above ground, allowing maximum dynamic range in single-supply applications. High output current and capacitance drive capability of the part help it to be useful in ADC driver and line driver applications.

### Interfacing with the MAX11613

The MAX9615 dual amplifier's low power and tiny size is ideal for driving multichannel analog-to-digital converters (ADCs) such as the MAX11613. See the *Typical Application Circuit*. The MAX11613 is a low-power, 12-bit I<sup>2</sup>C ADC that measures either four single-ended or two differential channels in an 8-pin  $\mu\text{MAX}^{\text{®}}$  package. Operating from a single 3V or 3.3V supply, the MAX11613 draws a low  $380\mu\text{A}$  supply current when sampling at 10ksps. The MAX11613 family also offers pin-compatible 5V ADCs (MAX11612) and 8-bit (MAX11601) and 10-bit (MAX11607) options.

### Input Bias Current

The MAX9613/MAX9615 feature a high-impedance CMOS input stage and a specialized ESD structure that allows low input bias current operation at low input common-mode voltages. Low input bias current is useful when interfacing with high-ohmic sensors. It is also beneficial for designing transimpedance amplifiers for photodiode sensors. This makes these MAX9613/MAX9615 devices ideal for ground referenced medical and industrial sensor applications.

### Active Filters

The MAX9613/MAX9615 are ideal for a wide variety of active filter circuits that make use of their rail-to-rail input/output stages and high-impedance CMOS inputs. The *Typical Application Circuit* shows an example Sallen-Key active filter circuit with a corner frequency of 10kHz. At low frequencies, the amplifier behaves like a simple low-distortion noninverting buffer, while its high bandwidth gives excellent stopband attenuation above its corner frequency. See the *Typical Application Circuit*.

## Chip Information

PROCESS: BiCMOS

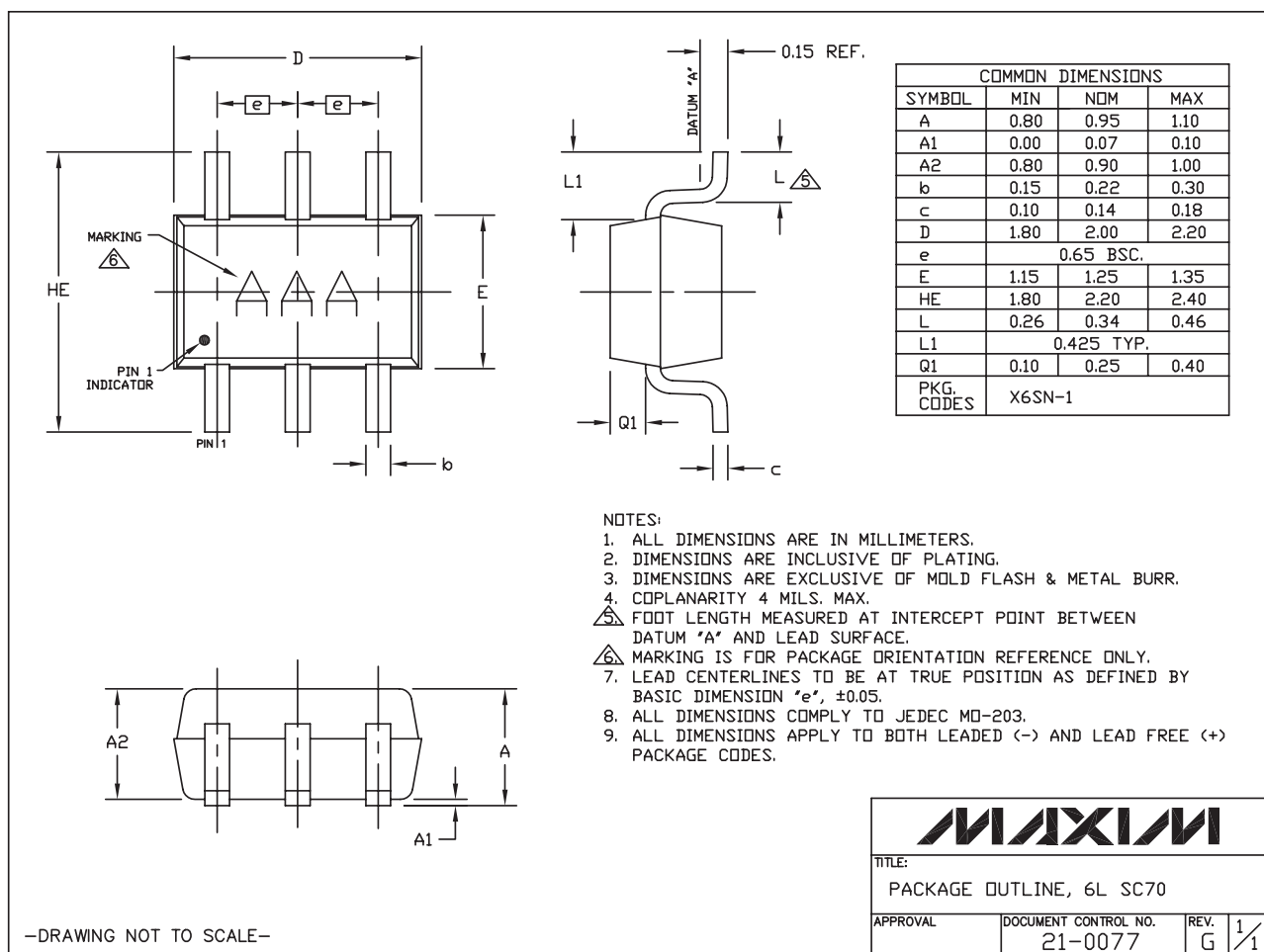
$\mu\text{MAX}$  is a registered trademark of Maxim Integrated Products, Inc.

# Low-Power, High-Efficiency, Single/Dual, Rail-to-Rail I/O Op Amps

## Package Information

For the latest package outline information and land patterns, go to [www.maxim-ic.com/packages](http://www.maxim-ic.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 SC70	X6SN-1	<a href="#">21-0077</a>	<a href="#">90-0189</a>
8 SC70	X8SN-1	<a href="#">21-0460</a>	<a href="#">90-0348</a>



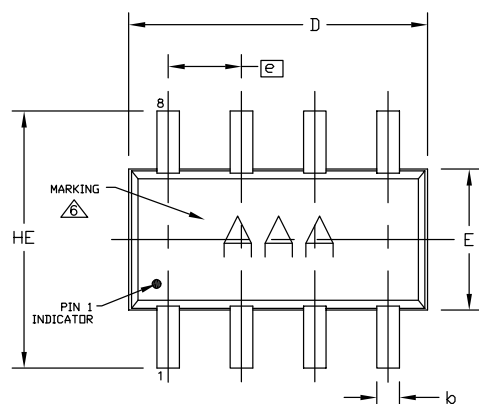
SC70, 6LEPS

# Low-Power, High-Efficiency, Single/Dual, Rail-to-Rail I/O Op Amps

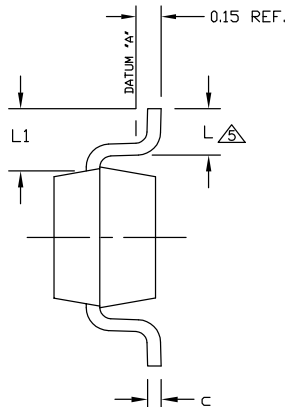
## Package Information (continued)

For the latest package outline information and land patterns, go to [www.maxim-ic.com/packages](http://www.maxim-ic.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.

MAX9613/MAX9615

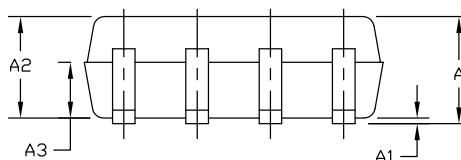


TOP VIEW



SIDE VIEW

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
A3	0.40	0.47	0.55
b	0.15	0.21	0.27
c	0.10	0.14	0.18
D	1.80	2.00	2.20
e	0.50 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.		
PKG. CODE	X8C-1		



SIDE VIEW

### NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETERS.
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. ALL DIMENSIONS COMPLY TO JEDEC MO-203.
9. ALL DIMENSIONS APPLY TO BOTH LEADED (-) AND LEAD FREE (+) PACKAGE CODES.

-DRAWING NOT TO SCALE-

**MAXIM**

TITLE:  
PACKAGE OUTLINE,  
8L SC70, COL PKG.

APPROVAL	DOCUMENT CONTROL NO. 21-0460	REV. A	1/1
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## Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	8/10	Initial release	—

Maxim cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in a Maxim product. No circuit patent licenses are implied. Maxim reserves the right to change the circuitry and specifications without notice at any time.

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