



# 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) VOS
- ◆ 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

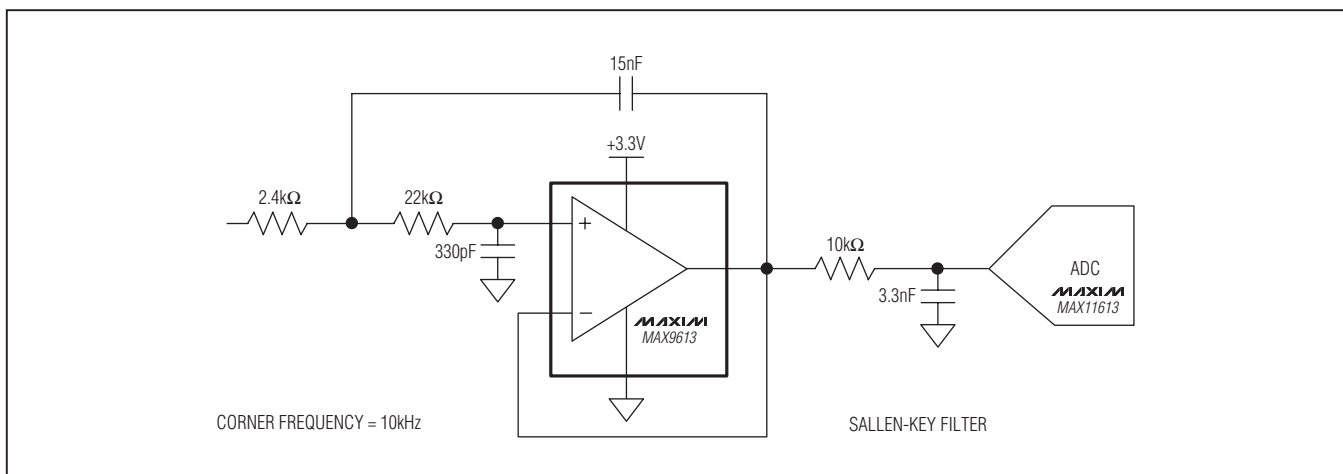
## Ordering Information

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.

MAX9613/MAX9615

## Typical Application Circuit



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## ABSOLUTE MAXIMUM RATINGS

IN+, IN-, $\overline{\text{SHDN}}$ , VCC to GND.....	-0.3V to +6V	8-Pin SC70 (derate 3.1mW/°C above +70°C).....	245mW
OUT to GND .....	-0.3V to (VCC + 0.3V)	$\theta_{JA}$ .....	326°C/W
Short-Circuit (GND) Duration to Either Supply Rail.....	5s	$\theta_{JC}$ .....	115°C/W
Continuous Input Current (any pin).....	±20mA	Operating Temperature Range .....	-40°C to +125°C
Thermal Limits (Note 1) Multilayer PCB		Storage Temperature Range.....	-65°C to +150°C
Continuous Power Dissipation (TA = +70°C)		Junction Temperature .....	+150°C
6-Pin SC70 (derate 3.1mW/°C above +70°C).....	245mW	Lead Temperature (soldering, 10s) .....	+300°C
$\theta_{JA}$ .....	326.5°C/W	Soldering Temperature (reflow) .....	+260°C
$\theta_{JC}$ .....	115°C/W		

**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

(VCC = V $\overline{\text{SHDN}}$  = 3.3V, VIN+ = VIN- = VCM = 0V, RL = 10k $\Omega$  to VCC/2, TA = -40°C to +125°C. Typical values are at TA = +25°C, unless otherwise noted.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>DC CHARACTERISTICS</b>						
Input Voltage Range	VIN+, VIN-	Guaranteed by CMRR test	-0.1		VCC + 0.1	V
Input Offset Voltage	VOS	TA = +25°C		23	100	$\mu$ V
		TA = -40°C to +125°C after power-up auto-calibration			150	
		TA = -40°C to +125°C			750	
Input Offset Voltage Drift	VOS - TC			1	7	$\mu$ V/°C
Input Bias Current (Note 3)	IB	TA = +40°C to +25°C		1	1.55	pA
		TA = +70°C			45	
		TA = +85°C			135	
		TA = +125°C			1.55	nA
Common-Mode Rejection Ratio	CMRR	VCM = -0.1V to VCC + 0.1V, TA = +25°C	82	100		dB
		VCM = -0.1V to VCC + 0.1V, TA = -40°C to +125°C	80			
Input Offset Current (Note 3)	IOS	TA = +40°C to +25°C			0.5	pA
		TA = +70°C			7	
		TA = +85°C			25	
		TA = +125°C			400	
Open-Loop Gain	AOL	+0.4V $\leq$ VOUT $\leq$ VCC - 0.4V, RL = 10k $\Omega$	99	120		dB
Output Short-Circuit Current (Note 4)	ISC	To VCC		275		mA
		To GND		75		
Output Voltage Low	VOL	RL = 10k $\Omega$			0.011	V
		RL = 600 $\Omega$			0.1	
		RL = 32 $\Omega$		0.170		

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## 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	$V_{OH}$	$R_L = 10k\Omega$	$V_{CC} - 0.011$			V
		$R_L = 600\Omega$	$V_{CC} - 0.1$			
		$R_L = 32\Omega$	$V_{CC} - 0.560$			
<b>AC CHARACTERISTICS</b>						
Input Voltage Noise Density	$e_n$	$f = 10kHz$		28		$nV/\sqrt{Hz}$
Input Voltage Noise	Total noise	$0.1Hz \leq f \leq 10Hz$		5		$\mu V_{P-P}$
Input Current Noise Density	$I_n$	$f = 10kHz$		0.1		$fA/\sqrt{Hz}$
Gain Bandwidth	GBW			2.8		MHz
Slew Rate	SR			1.3		$V/\mu s$
Capacitive Loading	$C_{LOAD}$	No sustained oscillation		200		pF
Total Harmonic Distortion	THD	$f = 10kHz$ , $V_{OUT} = 2V_{P-P}$ , $A_V = 1V/V$		85		dB
<b>POWER-SUPPLY CHARACTERISTICS</b>						
Power-Supply Range	$V_{CC}$	Guaranteed by PSRR	1.8		5.5	V
		$T_A = 0^\circ C$ to $+70^\circ C$ , guaranteed by PSSR	1.7		5.5	
Power-Supply Rejection Ratio	PSRR	$T_A = +25^\circ C$	85	106		dB
		$T_A = -40^\circ C$ to $+125^\circ C$	83			
Quiescent Current	$I_{CC}$	Per amplifier, $T_A = +25^\circ C$		220	305	$\mu A$
		Per amplifier			420	
Shutdown Supply Current	$I_{SHDN}$	MAX9613 only			1	$\mu A$
Shutdown Input Low	$V_{IL}$	MAX9613 only			0.5	V
Shutdown Input High	$V_{IH}$	MAX9613 only	1.4			V
Output Impedance in Shutdown	$R_{OUT\_SHDN}$	MAX9613 only		10		$M\Omega$
Turn-On Time from SHDN	$t_{ON}$	MAX9613 only		20		$\mu s$
Power-Up Time	$t_{UP}$			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.

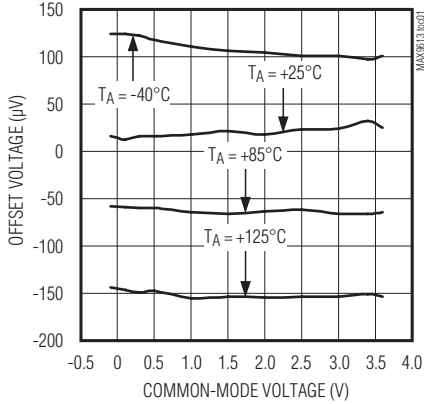
**Note 4:** Do not exceed package thermal dissipation in the *Absolute Maximum Ratings* section.

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

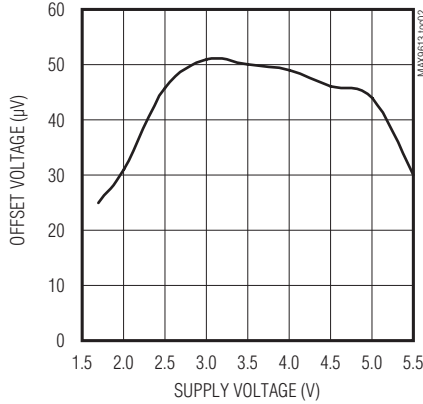
## Typical Operating Characteristics

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

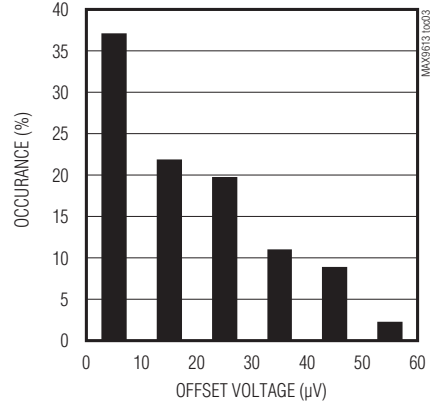
**OFFSET VOLTAGE vs. COMMON-MODE VOLTAGE vs. TEMPERATURE**



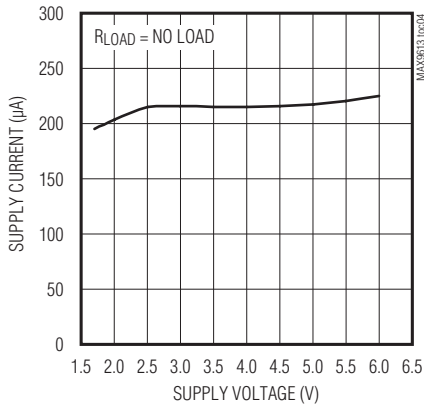
**OFFSET VOLTAGE vs. SUPPLY VOLTAGE**



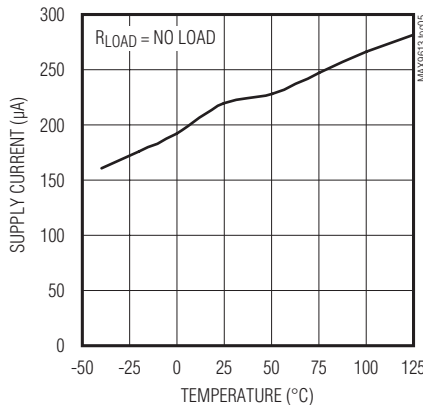
**OFFSET VOLTAGE HISTOGRAM**



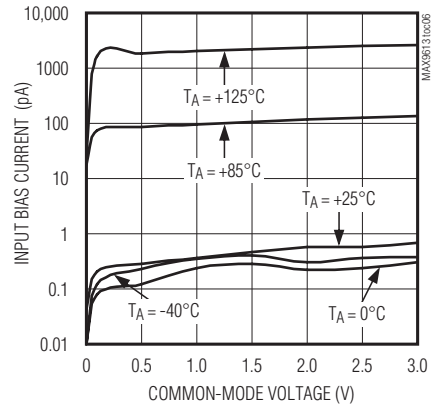
**SUPPLY CURRENT vs. SUPPLY VOLTAGE**



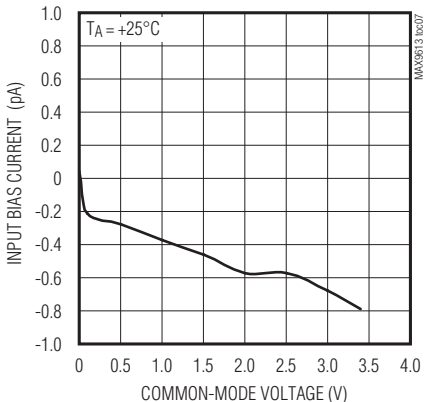
**SUPPLY CURRENT vs. TEMPERATURE**



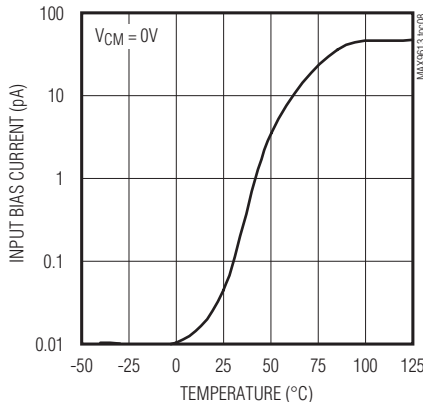
**INPUT BIAS CURRENT vs. COMMON-MODE VOLTAGE**



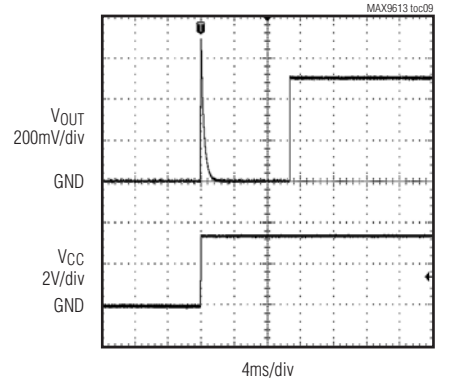
**INPUT BIAS CURRENT vs. COMMON-MODE VOLTAGE**



**INPUT BIAS CURRENT vs. TEMPERATURE**



**POWER-UP TRANSIENT**

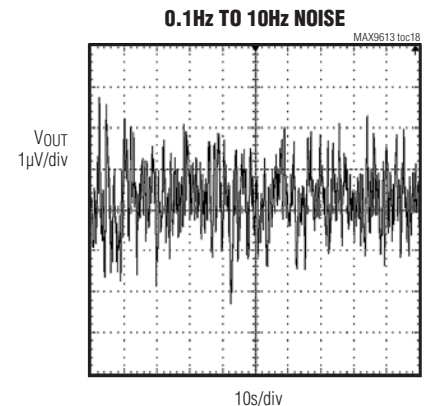
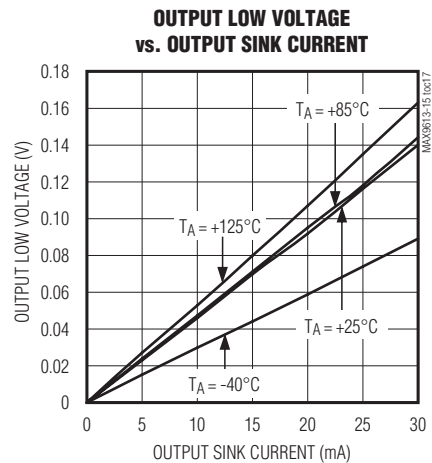
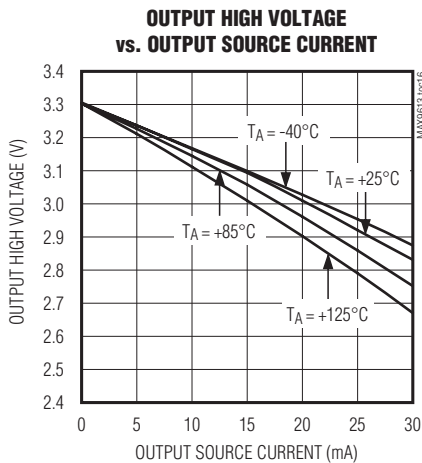
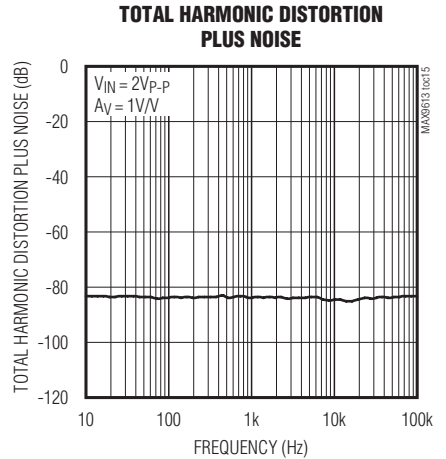
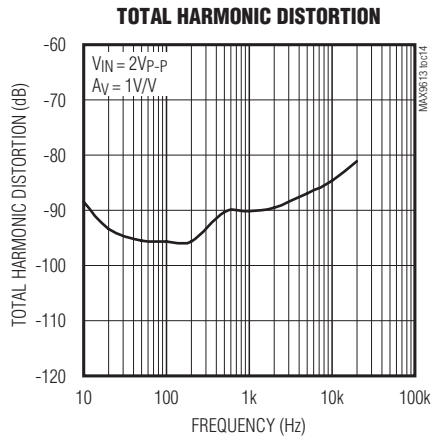
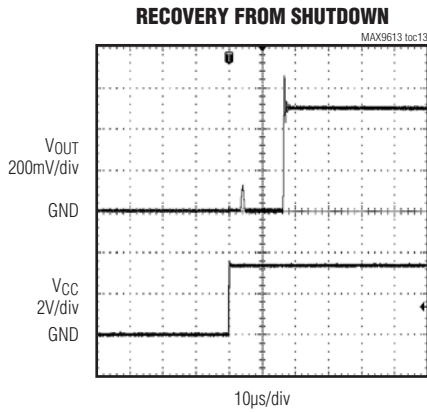
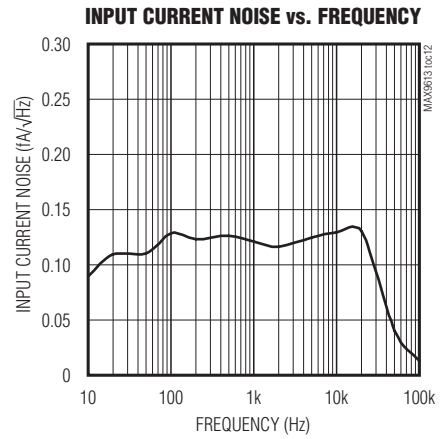
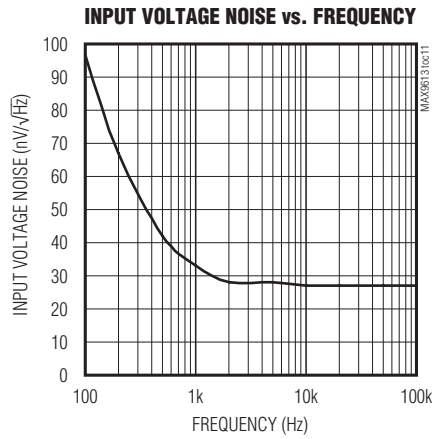
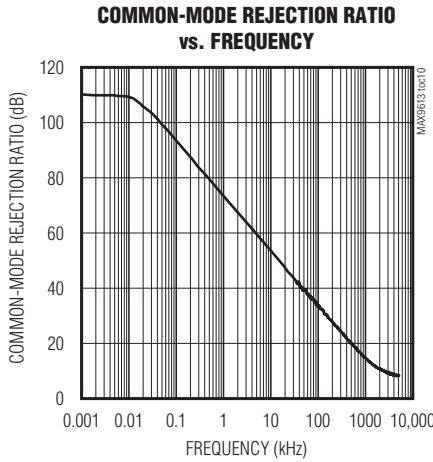


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## Typical Operating Characteristics (continued)

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

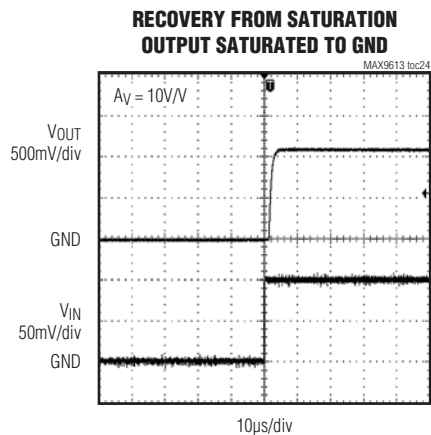
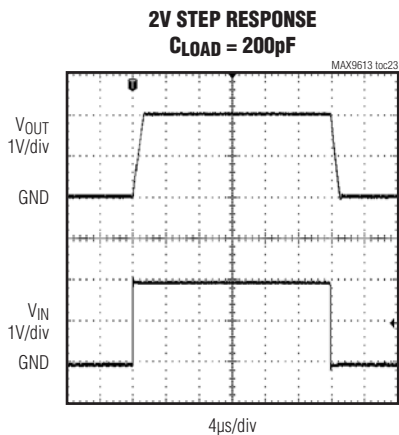
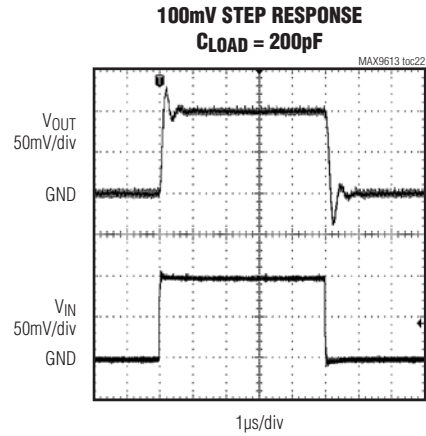
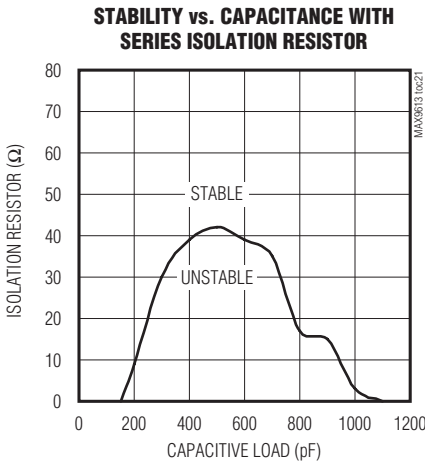
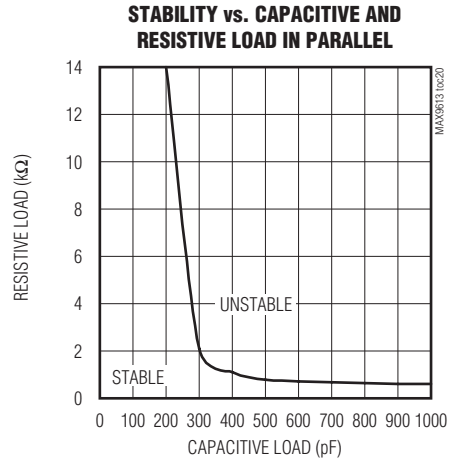
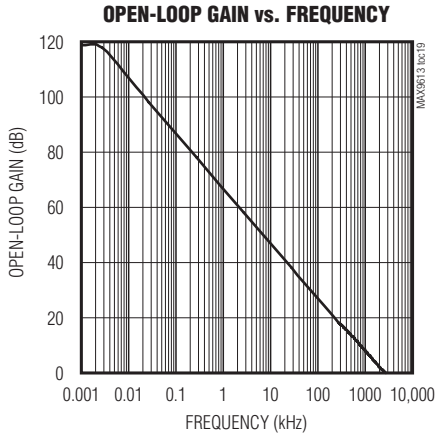
MAX9613/MAX9615



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

## Typical Operating Characteristics (continued)

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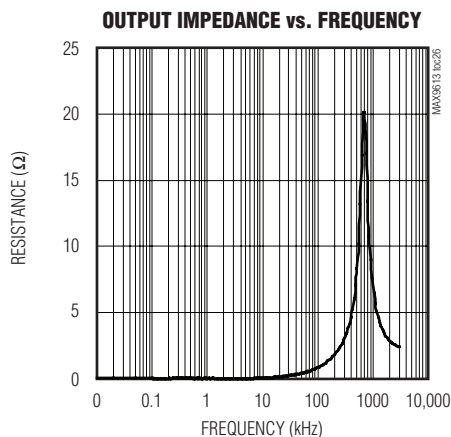
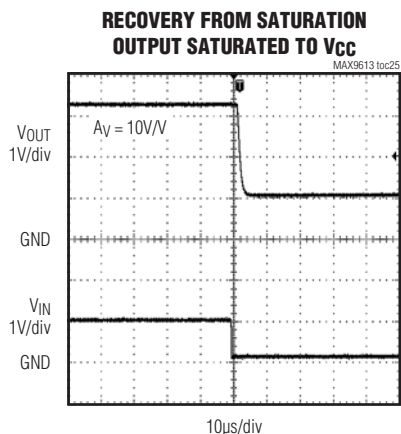


# Low-Power, High-Efficiency, Single/Dual, Rail-to-Rail I/O Op Amps

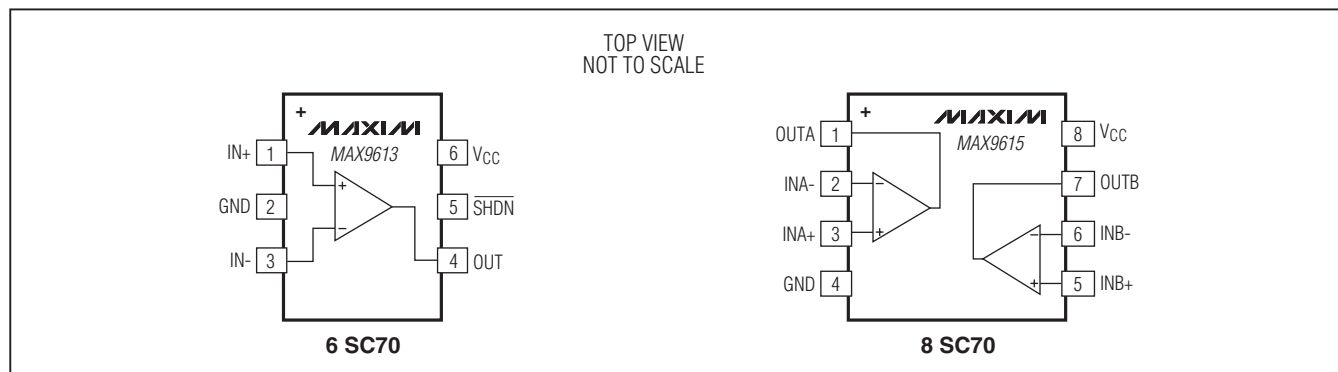
MAX9613/MAX9615

## 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	—	$\overline{\text{SHDN}}$	Active-Low Shutdown
6	8	$V_{CC}$	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.

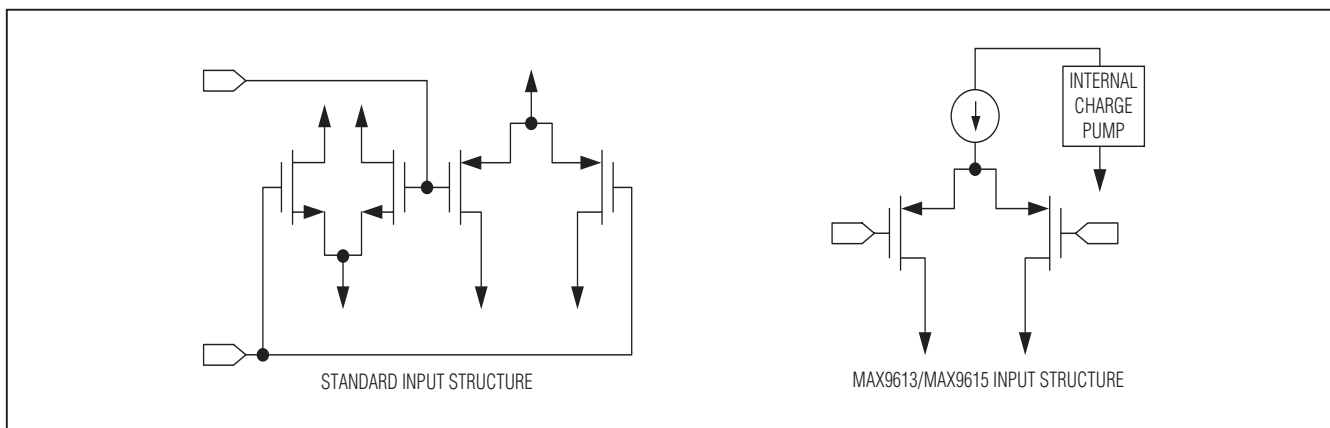


Figure 1. Rail-to-Rail Input Stage Architectures

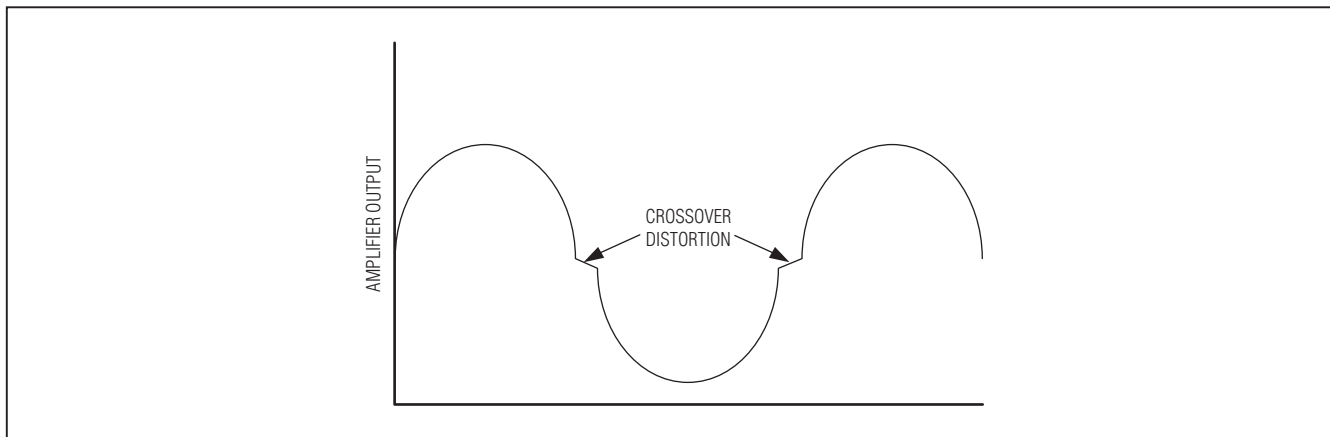


Figure 2. Crossover Distortion When Using Standard Rail-to-Rail Input Stage Architecture. The Input Stage Design Eliminates This Drawback.



# 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.

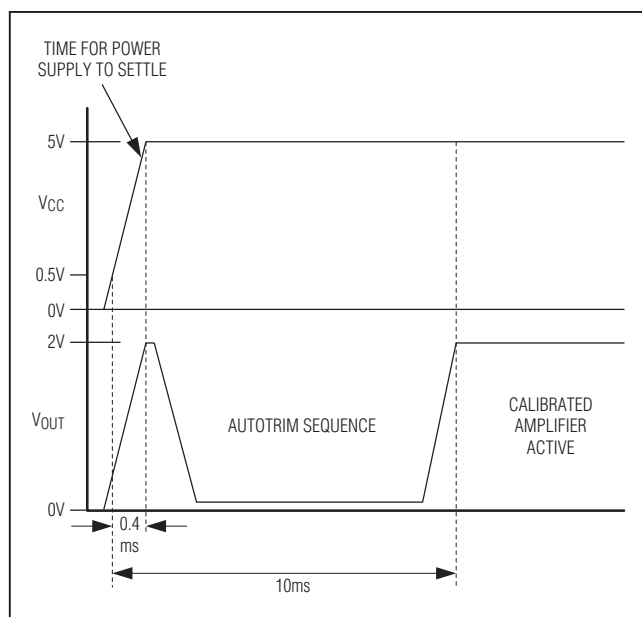


Figure 3. Autotrim Timing Diagram

### 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.

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## 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>

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
PKG. CODES	X6SN-1		

NOTES:

- ALL DIMENSIONS ARE IN MILLIMETERS.
- DIMENSIONS ARE INCLUSIVE OF PLATING.
- DIMENSIONS ARE EXCLUSIVE OF MOLD FLASH & METAL BURR.
- COPLANARITY 4 MILS. MAX.
- FOOT LENGTH MEASURED AT INTERCEPT POINT BETWEEN DATUM 'A' AND LEAD SURFACE.
- MARKING IS FOR PACKAGE ORIENTATION REFERENCE ONLY.
- LEAD CENTERLINES TO BE AT TRUE POSITION AS DEFINED BY BASIC DIMENSION 'e', ±0.05.
- ALL DIMENSIONS COMPLY TO JEDEC MO-203.
- ALL DIMENSIONS APPLY TO BOTH LEADED (-) AND LEAD FREE (+) PACKAGE CODES.

SC70\_6LEPS

MAXIM

TITLE:  
PACKAGE OUTLINE, 6L SC70

APPROVAL	DOCUMENT CONTROL NO. 21-0077	REV. G	1/1
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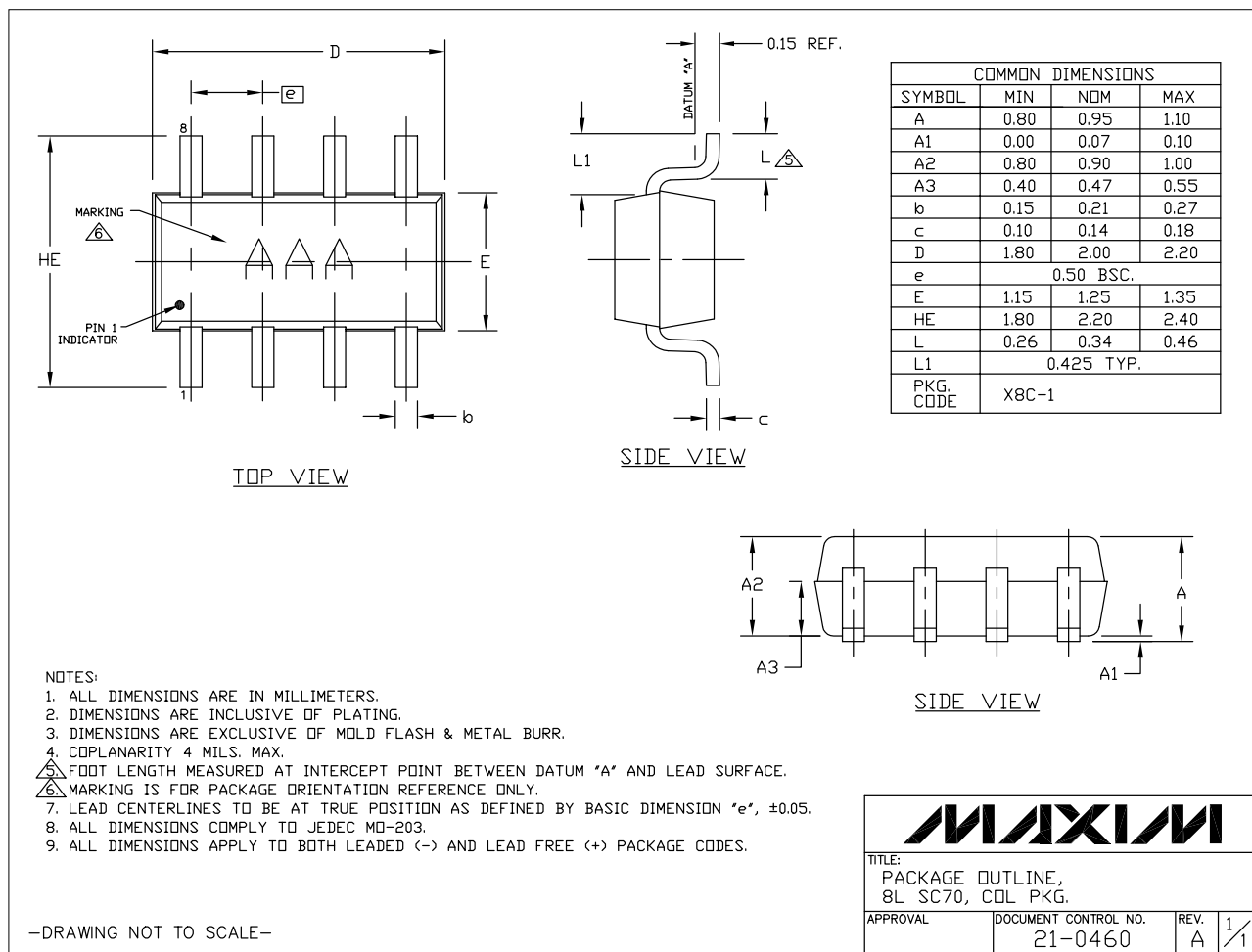
-DRAWING NOT TO SCALE-

# 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



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

## **Revision History**

<b>REVISION NUMBER</b>	<b>REVISION DATE</b>	<b>DESCRIPTION</b>	<b>PAGES CHANGED</b>
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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