19-1195; Rev 3; 1/10

UCSP, Micropower, Single-Supply, 10V, Rail-to-Rail I/O Op Amps

General Description

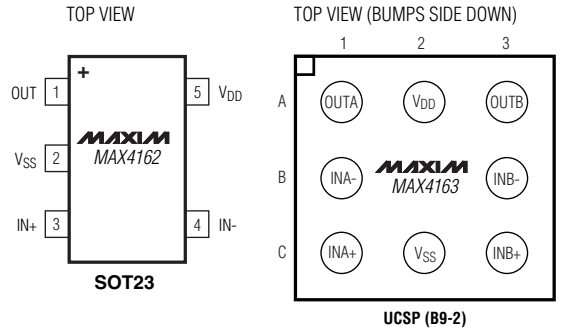
The MAX4162/MAX4163/MAX4164 are single/dual/quad, micropower operational amplifiers that combine an exceptional bandwidth to power consumption ratio with true rail-to-rail inputs and outputs. They consume a mere 25µA quiescent current per amplifier, yet achieve 200kHz gain-bandwidth product and are unity-gain stable while driving any capacitive load. The MAX4162/MAX4163/MAX4164 operate from either a single supply (2.5V to 10V) or dual supplies (±1.25V to ±5V), with an input common-mode voltage range that extends 250mV beyond either supply rail. These amplifiers use a proprietary architecture to achieve a very high input common-mode rejection ratio without the midswing nonlinearities present in other rail-to-rail op amps. This architecture also maintains high open-loop gain and output swing while driving substantial loads.

The combination of excellent bandwidth/power performance, single-supply operation, and miniature footprint makes these op amps ideal for portable equipment and other low-power, single-supply applications. The single MAX4162 is available in 8-pin SO and space-saving 5-pin SOT23 packages. The MAX4163 is available in an 8-pin ultra chip-scale package (UCSP™) and an 8-pin µMAX® or SO package. The MAX4164 is available in a 14-pin SO package.

Applications

Battery-Powered Devices
pH Probes
Portable Equipment
Low-Power, Low-Voltage Equipment
Medical Instruments
Ionization Detectors
Cellular Phones

Pin Configurations



Pin Configurations continued at end of data sheet.

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

Features

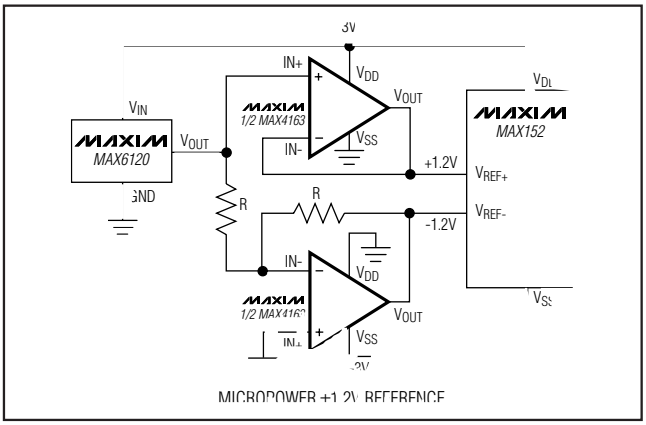
- ♦ **UCSP Package (MAX4163)**
- ♦ **1.0pA Typical Input Bias Current**
- ♦ **Single-Supply Operation from 2.5V to 10V**
- ♦ **Input Common-Mode Voltage Range Extends 250mV Beyond Either Supply Rail**
- ♦ **Rail-to-Rail Output Swing**
- ♦ **200kHz Gain-Bandwidth Product**
- ♦ **25µA Quiescent Current per Amplifier**
- ♦ **Excellent CMRR, PSRR, and Gain Linearity**
- ♦ **No Phase Reversal for Overdriven Inputs**
- ♦ **Unity-Gain Stable**
- ♦ **Stable with Any Capacitive Load**
- ♦ **Internally Short-Circuit Protected to Either Rail**

Ordering Information

PART	TEMP RANGE	PIN-PACKAGE	TOP MARK
MAX4162ESA+	-40°C to +85°C	8 SO	—
MAX4162EUK+	-40°C to +85°C	5 SOT23	AABX
MAX4163EBL+T*	-40°C to +85°C	8 UCSP	AAX
MAX4163ESA+	-40°C to +85°C	8 SO	—
MAX4163EUA+	-40°C to +85°C	8 µMAX	—
MAX4164ESD+	-40°C to +85°C	14 SO	—

+Denotes a lead(Pb)-free/RoHS-compliant package.
T = Tape and reel.
**UCSP reliability is integrally linked to the user's assembly methods, circuit board material, and environment. Refer to the UCSP Reliability Notice in the UCSP Reliability section of this data sheet for more information.*

Typical Application Circuit



For pricing, delivery, and ordering information, please contact Maxim Direct at 1-888-629-4642, or visit Maxim's website at www.maxim-ic.com.

UCSP, Micropower, Single-Supply, 10V, Rail-to-Rail I/O Op Amps

ABSOLUTE MAXIMUM RATINGS

Supply Voltage (V_{DD} to V_{SS}) 11V
IN+, IN-, OUT Voltage ..... (V_{DD} + 0.3V) to (V_{SS} - 0.3V)
Short-Circuit Duration (to either rail) ..... Continuous
Continuous Power Dissipation (T_A = +70°C)
5-Pin SOT23 (derate 3.9mW/°C above +70°C) 312mW
8-Pin SO (derate 7.4mW/°C above +70°C) 588mW
8-Pin UCSP (derate 4.7mW/°C above +70°C) 379mW
8-Pin µMAX (derate 4.8mW/°C above +70°C) 387mW
14-Pin SO (derate 12.3mW/°C above +70°C) 987mW
Operating Temperature Range ..... -40°C to +85°C
Storage Temperature Range ..... -65°C to +150°C
Junction Temperature ..... +150°C
Lead Temperature (soldering, 10s) ..... +300°C
Soldering Temperature (reflow, UCSP) ..... +260°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: 3V Operation

(V_{DD} = 3V, V_{SS} = 0V, V_{CM} = V_{DD}/2, V_{OUT} = V_{DD}/2, R_L connected to V_{DD}/2, 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
Operating Voltage Range	V_{DD}	Inferred from PSRR test		2.5		10.0	V
Supply Current (Per Amplifier)	I_{DD}				25	40	µA
Input Bias Current (Note 2)	I_B				1.0	100	pA
Input Offset Voltage	V_{OS}	MAX4162	T_A = +25°C		±0.5	±3	mV
			T_A = -40°C to +85°C			±4	
		MAX4163	T_A = +25°C		±0.5	±4	
			T_A = -40°C to +85°C			±5	
		MAX4164	T_A = +25°C		±0.5	±5	
			T_A = -40°C to +85°C			±6	
Input Offset Voltage Tempco	TCV_{OS}				2		µV/°C
Differential Input Resistance	R_{IN}				>10		TΩ
Input Common-Mode Voltage Range	V_{CM}	Inferred from CMRR test		V_{SS} - 0.25		V_{DD} + 0.25	V
Common-Mode Rejection Ratio	CMRR	V_{CM} = (V_{SS} - 0.25V) to (V_{DD} + 0.25V)		70	100		dB
Large-Signal Voltage Gain	A_V	R_L = 10kΩ		85	120		dB
Output Voltage Swing	V_{OUT}	R_L = 10kΩ	V_{DD} - V_{OH}		30	180	mV
			V_{OL} - V_{SS}		30	180	
		R_L = 100kΩ	V_{DD} - V_{OH}		3	25	
			V_{OL} - V_{SS}		3	25	
Output Short-Circuit Current	I_{SC}	To either supply rail			15		mA
Closed-Loop Output Resistance	R_{OUT}	A_V = 1V/V			0.1		Ω
Power-Supply Rejection Ratio	PSRR	V_{DD} = 2.5V to 10V		80	110		dB
Gain-Bandwidth Product	GBWP				200		kHz
Phase Margin	φM				60		degrees
Gain Margin	GM				12		dB
Total Harmonic Distortion	THD	f = 1kHz, V_{OUT} = $2V_{P-P}$, R_L = 100kΩ, A_V = 1V/V			0.02		%
Slew Rate	SR				115		V/ms
Settling Time to 0.1%		V_{OUT} = 1V to 2V step			50		µs
Turn-On Time	t_{ON}	V_{DD} = 0 to 3V step, V_{IN} = V_{DD}/2, A_V = 1V/V			20		µs

ELECTRICAL CHARACTERISTICS: 3V Operation (continued)

(V_{DD} = 3V, V_{SS} = 0V, V_{CM} = V_{DD}/2, V_{OUT} = V_{DD}/2, R_L connected to V_{DD}/2, 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 Voltage-Noise Density	e_n	f = 1kHz		80		$nV/\sqrt{Hz}$
Differential Input Capacitance				0.7		pF
Input Common-Mode Capacitance				1.5		pF
Internal Charge-Pump Frequency				700		kHz
Charge-Pump Output Feedthrough				100		μV_{P-P}

ELECTRICAL CHARACTERISTICS: 5V Operation

(V_{DD} = 5V, V_{SS} = 0V, V_{CM} = V_{DD}/2, V_{OUT} = V_{DD}/2, R_L connected to V_{DD}/2, 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
Operating Voltage Range	V_{DD}	Inferred from PSRR test		4.5		10.0	V
Supply Current (Per Amplifier)	I_{DD}				25	45	µA
Input Bias Current (Note 2)	I_B				1.0	100	pA
Input Offset Voltage	V_{OS}	MAX4162	T_A = +25°C		±0.5	±3	mV
			T_A = -40°C to +85°C			±4	
		MAX4163	T_A = +25°C		±0.5	±4	
			T_A = -40°C to +85°C			±5	
		MAX4164	T_A = +25°C		±0.5	±5	
			T_A = -40°C to +85°C			±6	
Input Offset Voltage Tempco					2		µV/°C
Differential Input Resistance					>10		TΩ
Input Common-Mode Voltage Range	V_{CM}	Inferred from CMRR test		V_{SS} - 0.25		V_{DD} + 0.25	V
Common-Mode Rejection Ratio	CMRR	V_{CM} = (V_{SS} - 0.25V) to (V_{DD} + 0.25V)		70	100		dB
Large-Signal Voltage Gain	A_V	R_L = 10kΩ		85	120		dB
Output Voltage Swing	V_{OUT}	R_L = 10kΩ	V_{DD} - V_{OH}		50	300	mV
			V_{OL} - V_{SS}		50	300	
		R_L = 100kΩ	V_{DD} - V_{OH}		5	40	
			V_{OL} - V_{SS}		5	40	
Output Short-Circuit Current	I_{SC}	To either supply rail			15		mA
Closed-Loop Output Resistance	R_{OUT}	A_V = 1V/V			0.1		Ω
Power-Supply Rejection Ratio	PSRR	V_{DD} = 4.5V to 10V		80	110		dB
Gain-Bandwidth Product	GBWP				200		kHz
Phase Margin	ϕM				60		degrees
Gain Margin	GM				12		dB

UCSP, Micropower, Single-Supply, 10V, Rail-to-Rail I/O Op Amps

ELECTRICAL CHARACTERISTICS: 5V Operation (continued)

(V_{DD} = 5V, V_{SS} = 0V, V_{CM} = V_{DD}/2, V_{OUT} = V_{DD}/2, R_L connected to V_{DD}/2, 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
Total Harmonic Distortion	THD	f = 1kHz, V_{OUT} = $2V_{P-P}$, R_L = 100kΩ, A_V = 1V/V		0.02		%
Slew Rate	SR			115		V/ms
Settling Time to 0.1%		V_{OUT} = 1V to 2V step		70		µs
Turn-On Time	t_{ON}	V_{DD} = 0 to 3V step, V_{IN} = V_{DD}/2, A_V = 1V/V		40		µs
Input Voltage-Noise Density	e_n	f = 1kHz		80		$nV/\sqrt{Hz}$
Differential Input Capacitance				0.7		pF
Input Common-Mode Capacitance				1.5		pF
Internal Charge-Pump Frequency				700		kHz
Charge-Pump Output Feedthrough				100		$µV_{P-P}$

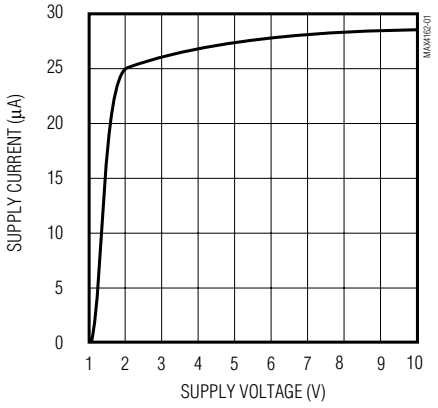
Note 1: All device specifications are 100% tested at T_A = +25°C. Limits over the extended temperature range are guaranteed by design, not production tested.

Note 2: Input bias current guaranteed by design, not production tested.

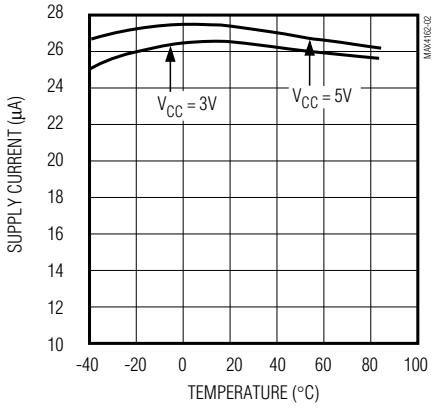
Typical Operating Characteristics

(V_{DD} = 5V, V_{SS} = 0V, V_{CM} = V_{DD}/2, T_A = +25°C, unless otherwise noted.)

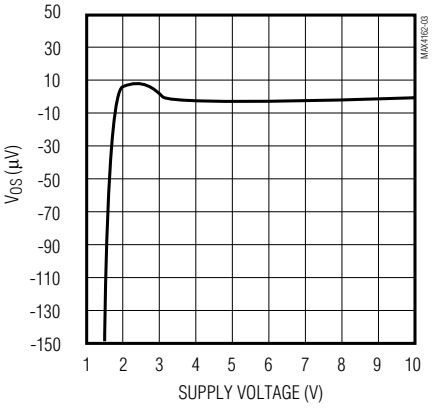
SUPPLY CURRENT vs. SUPPLY VOLTAGE



SUPPLY CURRENT vs. TEMPERATURE



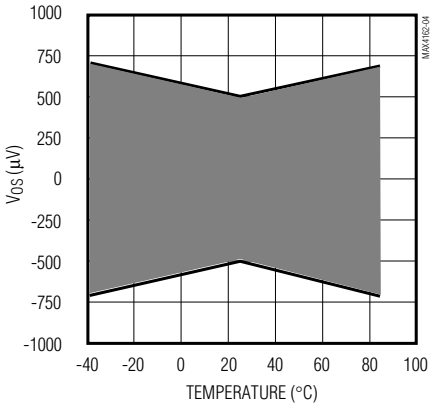
INPUT OFFSET VOLTAGE VARIATION vs. SUPPLY VOLTAGE



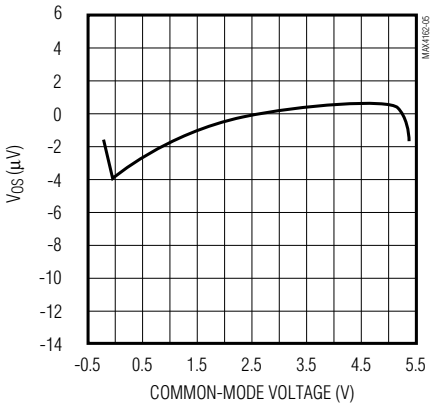
Typical Operating Characteristics (continued)

(V_{DD} = 5V, V_{SS} = 0V, V_{CM} = V_{DD}/2, T_A = +25°C, unless otherwise noted.)

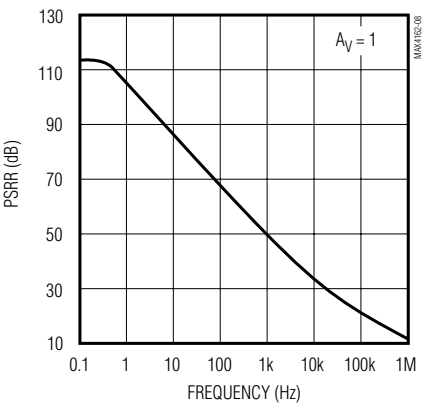
INPUT OFFSET VOLTAGE vs. TEMPERATURE



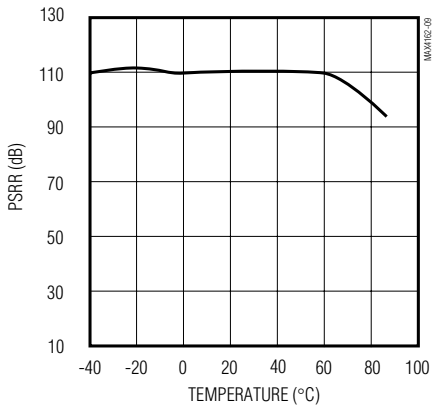
INPUT OFFSET VOLTAGE VARIATION vs. COMMON-MODE VOLTAGE



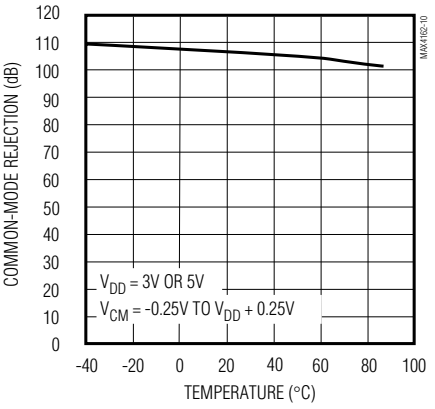
POWER-SUPPLY REJECTION RATIO vs. FREQUENCY



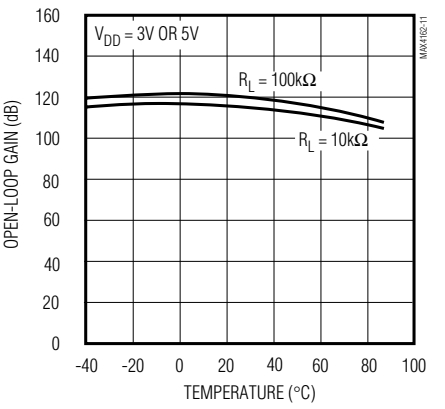
POWER-SUPPLY REJECTION RATIO vs. TEMPERATURE



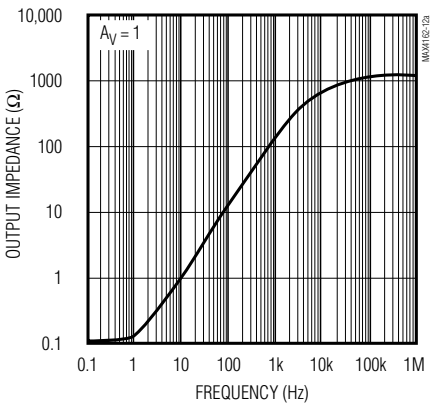
COMMON-MODE REJECTION vs. TEMPERATURE



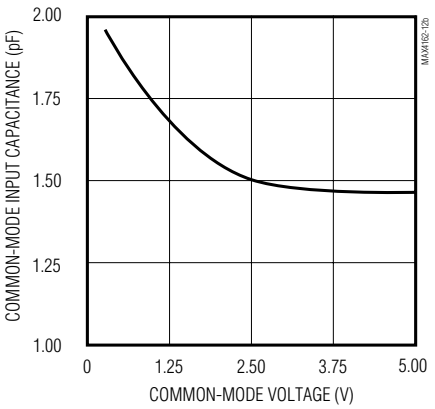
OPEN-LOOP GAIN vs. TEMPERATURE



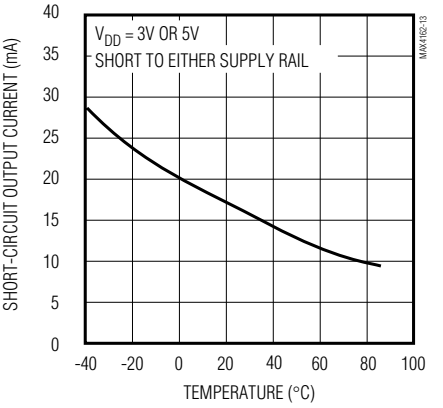
OUTPUT IMPEDANCE vs. FREQUENCY



COMMON-MODE INPUT CAPACITANCE vs. COMMON-MODE VOLTAGE



SHORT-CIRCUIT OUTPUT CURRENT vs. TEMPERATURE

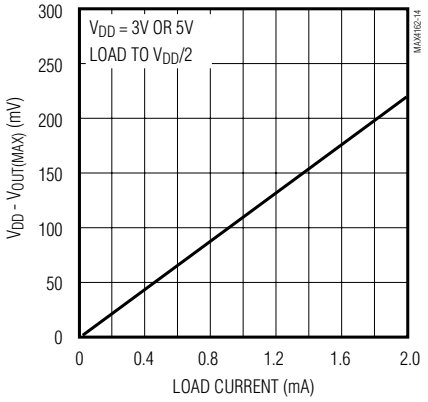


UCSP, Micropower, Single-Supply, 10V, Rail-to-Rail I/O Op Amps

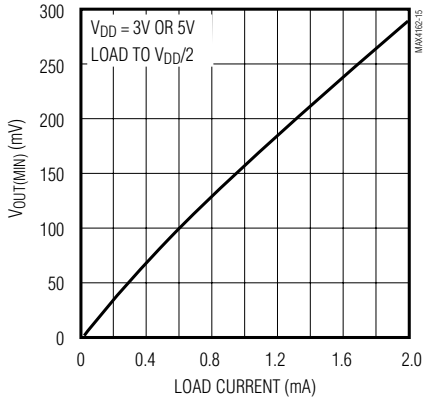
Typical Operating Characteristics (continued)

(V_{DD} = 5V, V_{SS} = 0V, V_{CM} = V_{DD}/2, T_A = +25°C, unless otherwise noted.)

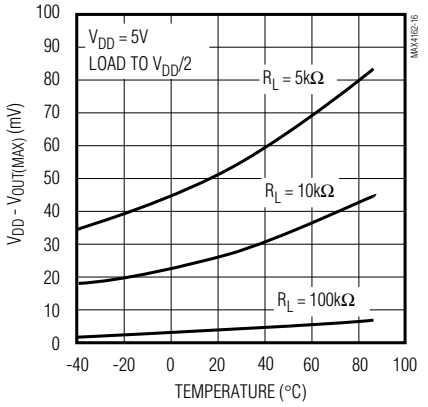
MAXIMUM OUTPUT VOLTAGE vs. LOAD CURRENT



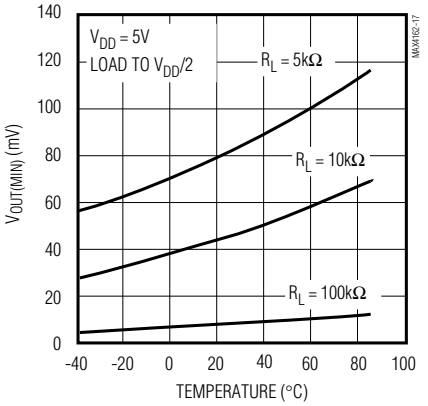
MINIMUM OUTPUT VOLTAGE vs. LOAD CURRENT



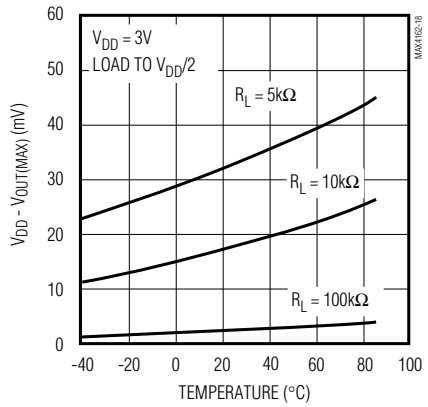
MAXIMUM OUTPUT VOLTAGE vs. TEMPERATURE (V_{DD} = 5V)



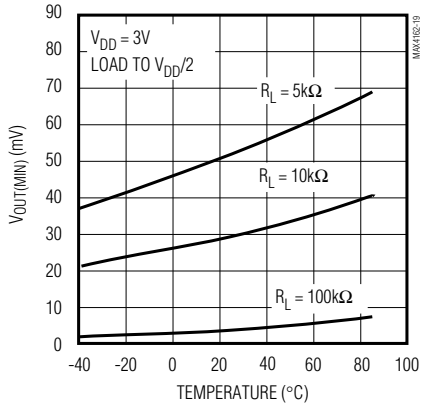
MINIMUM OUTPUT VOLTAGE vs. TEMPERATURE (V_{DD} = 5V)



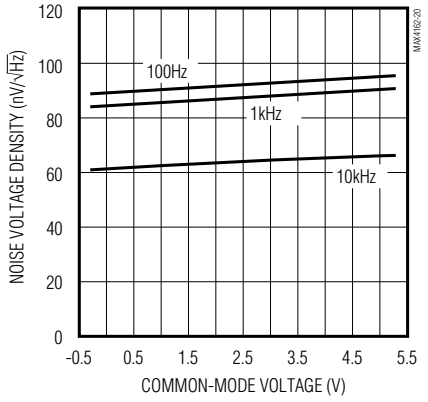
MAXIMUM OUTPUT VOLTAGE vs. TEMPERATURE (V_{DD} = 3V)



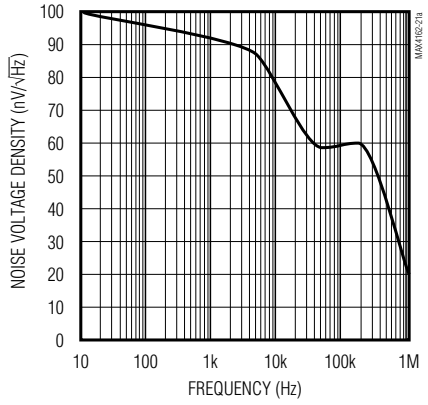
MINIMUM OUTPUT VOLTAGE vs. TEMPERATURE (V_{DD} = 3V)



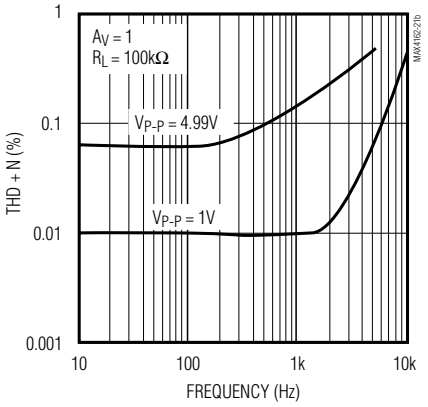
NOISE VOLTAGE DENSITY vs. COMMON-MODE VOLTAGE



NOISE VOLTAGE DENSITY vs. FREQUENCY



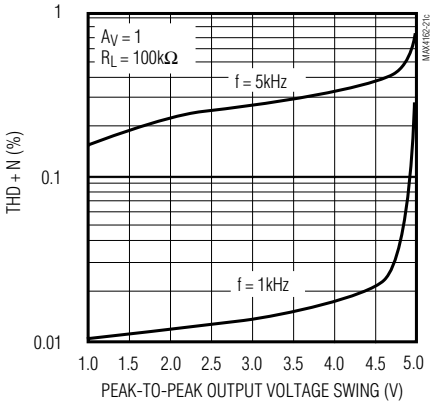
TOTAL HARMONIC DISTORTION PLUS NOISE vs. FREQUENCY



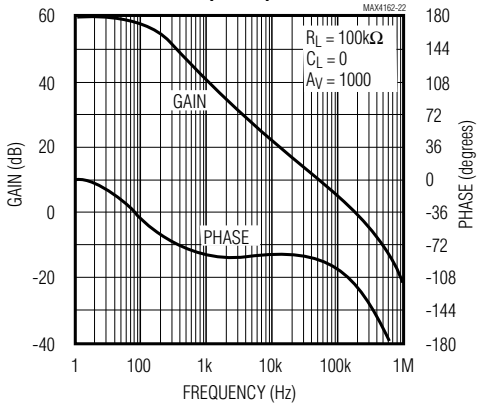
Typical Operating Characteristics (continued)

(V_{DD} = 5V, V_{SS} = 0V, V_{CM} = V_{DD}/2, T_A = +25°C, unless otherwise noted.)

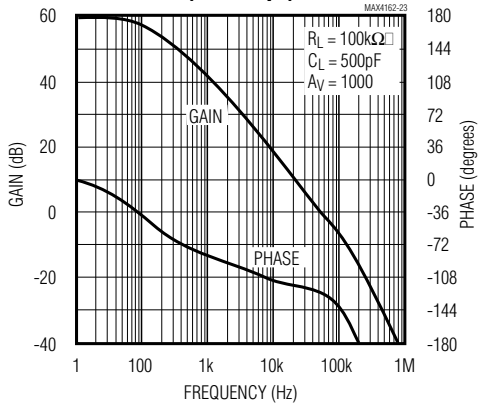
TOTAL HARMONIC DISTORTION PLUS NOISE vs. OUTPUT VOLTAGE SWING



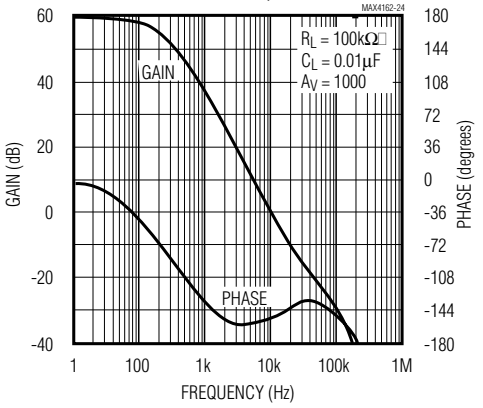
GAIN AND PHASE vs. FREQUENCY (C_L = 0)



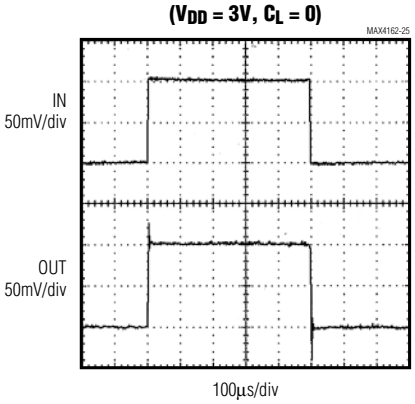
GAIN AND PHASE vs. FREQUENCY (C_L = 500pF)



GAIN AND PHASE vs. FREQUENCY (C_L = 0.01µF)

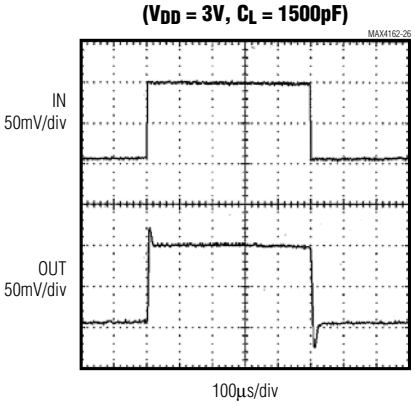


NONINVERTING SMALL-SIGNAL PULSE RESPONSE (V_{DD} = 3V, C_L = 0)



V_{DD} = 3V, V_{IN} = 100mV, R_L = 100kΩ to V_{DD}/2, C_L = 0

NONINVERTING SMALL-SIGNAL PULSE RESPONSE (V_{DD} = 3V, C_L = 1500pF)



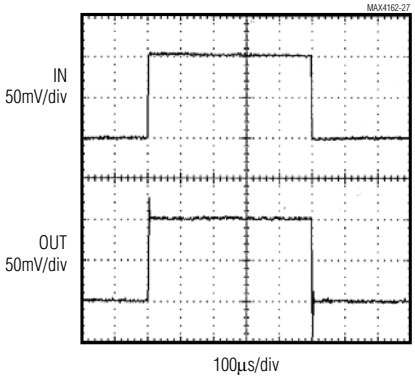
V_{DD} = 3V, V_{IN} = 100mV, R_L = 100kΩ to V_{DD}/2, C_L = 1500pF

UCSP, Micropower, Single-Supply, 10V, Rail-to-Rail I/O Op Amps

Typical Operating Characteristics (continued)

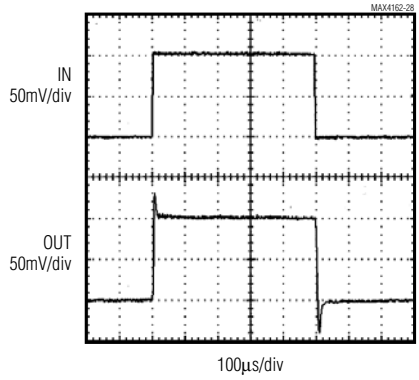
(V_{DD} = 5V, V_{SS} = 0V, V_{CM} = V_{DD}/2, T_A = +25°C, unless otherwise noted.)

NONINVERTING SMALL-SIGNAL PULSE RESPONSE (V_{DD} = 5V, C_L = 0)



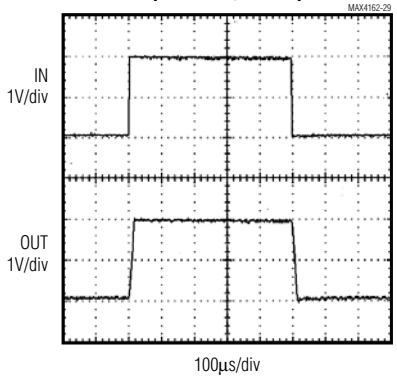
V_{DD} = 5V, V_{IN} = 100mV, R_L = 100kΩ to V_{DD}/2, C_L = 0

NONINVERTING SMALL-SIGNAL PULSE RESPONSE (V_{DD} = 5V, C_L = 1500pF)



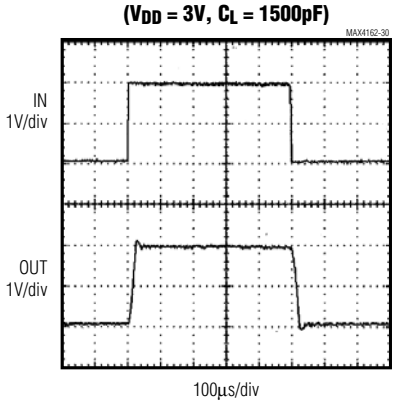
V_{DD} = 5V, V_{IN} = 100mV, R_L = 100kΩ to V_{DD}/2, C_L = 1500pF

NONINVERTING LARGE-SIGNAL PULSE RESPONSE (V_{DD} = 3V, C_L = 0)



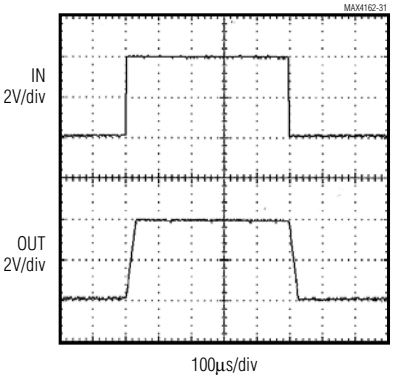
V_{DD} = 3V, V_{IN} = 2V, R_L = 100kΩ to V_{DD}/2, C_L = 0

NONINVERTING LARGE-SIGNAL PULSE RESPONSE (V_{DD} = 3V, C_L = 1500pF)



V_{DD} = 3V, V_{IN} = 2V, R_L = 100kΩ to V_{DD}/2, C_L = 1500pF

NONINVERTING LARGE-SIGNAL PULSE RESPONSE (V_{DD} = 5V, C_L = 0)

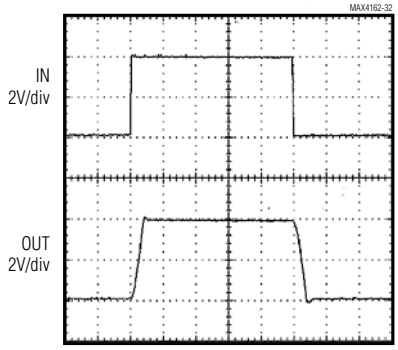


V_{DD} = 5V, V_{IN} = 4V, R_L = 100kΩ to V_{DD}/2, C_L = 0

Typical Operating Characteristics (continued)

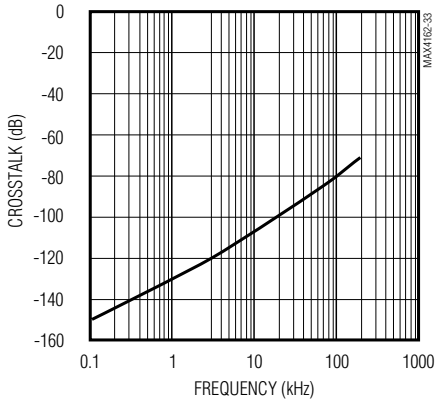
(V_{DD} = 5V, V_{SS} = 0V, V_{CM} = V_{DD}/2, T_A = +25°C, unless otherwise noted.)

NONINVERTING LARGE-SIGNAL PULSE RESPONSE (V_{DD} = 5V, C_L = 1500pF)



V_{DD} = 5V, V_{IN} = 4V, R_L = 100kΩ to V_{DD}/2, C_L = 1500pF

MAX4163/MAX4164 CROSSTALK vs. FREQUENCY



Pin Description

PIN					NAME	FUNCTION
MAX4162		MAX4163		MAX4164		
SO	SOT23	SO/µMAX	UCSP	SO		
1, 5, 8	—	—	—	—	N.C.	No Connection. Not internally connected.
2	4	—	—	—	IN-	Amplifier Inverting Input
3	3	—	—	—	IN+	Amplifier Noninverting Input
4	2	4	C2	11	V_{SS}	Negative Power Supply
6	1	—	—	—	OUT	Amplifier Output
7	5	8	A2	4	V_{DD}	Positive Power Supply
—	—	1	A1	1	OUTA	Amplifier A Output
—	—	2	B1	2	INA-	Amplifier A Inverting Input
—	—	3	C1	3	INA+	Amplifier A Noninverting Input
—	—	5	C3	5	INB+	Amplifier B Noninverting Input
—	—	6	B3	6	INB-	Amplifier B Inverting Input
—	—	7	A3	7	OUTB	Amplifier B Output
—	—	—	—	8	OUTC	Amplifier C Output
—	—	—	—	9	INC-	Amplifier C Inverting Input
—	—	—	—	10	INC+	Amplifier C Noninverting Input
—	—	—	—	12	IND+	Amplifier D Noninverting Input
—	—	—	—	13	IND-	Amplifier D Inverting Input
—	—	—	—	14	OUTD	Amplifier D Output

UCSP, Micropower, Single-Supply, 10V, Rail-to-Rail I/O Op Amps

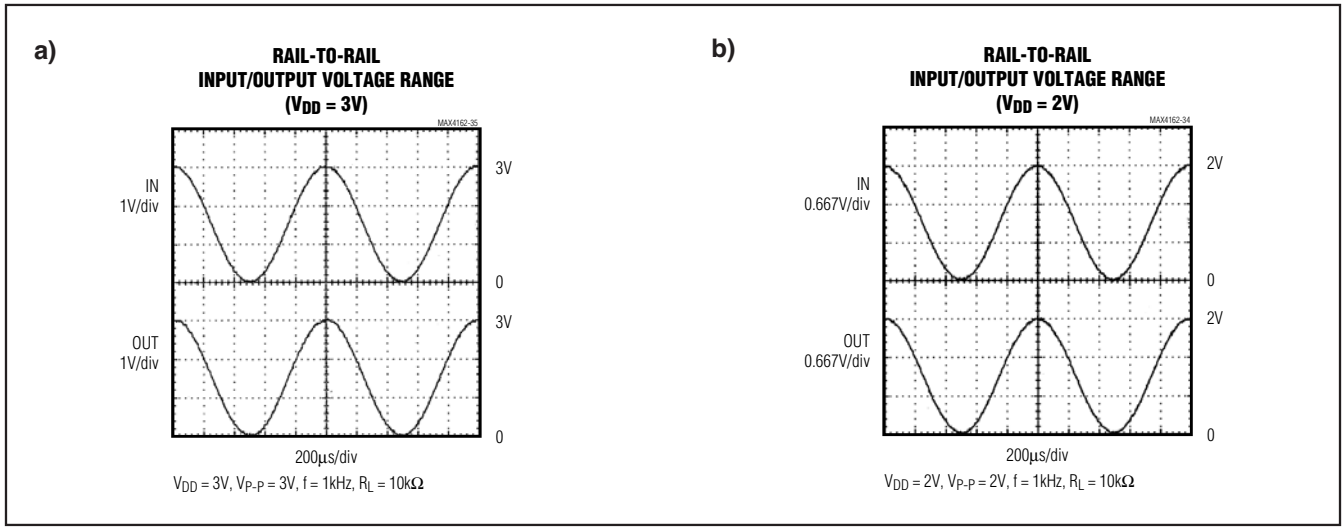


Figure 1. Rail-to-Rail I/O: a) V_{DD} = 3V; b) V_{DD} = 2V

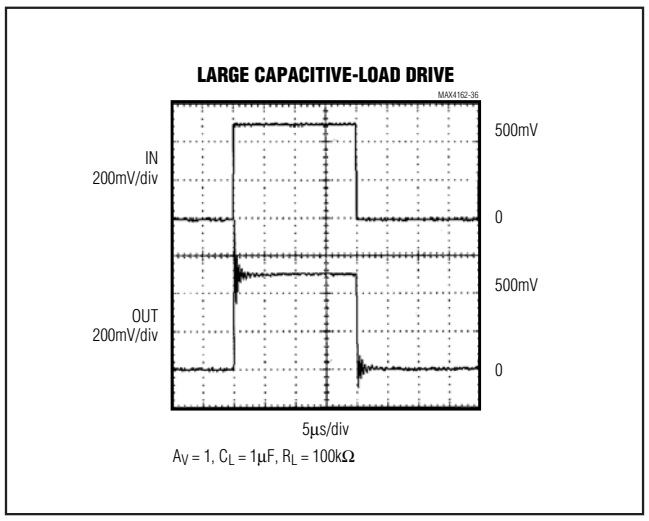


Figure 2. Large Capacitive-Load Drive

Applications Information

Rail-to-Rail Inputs and Outputs

The MAX4162/MAX4163/MAX4164 input common-mode range extends 250mV beyond each of the supply rails, providing a substantial increase in dynamic range over other op amps (even many of those referred to as rail-to-rail). Although the minimum operating voltage is specified at 2.5V, the devices typically provide full rail-to-rail operation below 2.0V (Figure 1). These amplifiers do not suffer from midswing common-mode-rejection degradation or crossover nonlinearity often encountered in other rail-to-rail op amps. Extremely low, 1.0pA input bias current makes these devices ideal for applications such as pH probes, electrometers, and ionization detectors. They are also protected against phase reversal (inferred from CMRR test) and latchup for input signals extending beyond the supply rails. The output stage achieves a lower output impedance than traditional rail-to-rail output stages, providing an output voltage range that typically swings within 150mV of the supply rails for 1mA loads. This architecture also maintains high open-loop gain and output swing while driving substantial loads.

Output Loading and Stability

These devices drive 1mA loads to within 150mV of the supply rails while consuming only 25µA of quiescent current. Internal compensation allows these amplifiers to remain unity-gain stable while driving any capacitive load (Figure 2).

Internal Charge Pump

An internal charge pump provides two internal supplies typically 2V beyond each rail. These internal rails allow the MAX4162/MAX4163/MAX4164 to achieve true rail-to-rail inputs and outputs, while providing excellent common-mode rejection, power-supply rejection ratios, and gain linearity.

These charge pumps require no external components, and in most applications are entirely transparent to the user. Two characteristics may be visible to the user, depending on the application:

1) The on-board charge pumps generate a small amount of 700kHz switching noise at the op amp's output. The amplitude of this noise is typically 100μV$_{P-P}$. The noise is **not** referred to the input, and is independent of amplifier gain. The charge-pump switching frequency is well beyond the amplifier's 200kHz bandwidth, and is therefore unnoticeable in most applications.
2) The charge pumps typically require up to 20μs on power-up to fully energize the internal supply rails (Figure 3).

Power Supplies and Layout

The MAX4162/MAX4163/MAX4164 are guaranteed to operate from a single 2.5V to 10.0V power supply, but full rail-to-rail operation typically extends below 2V. For single-supply operation, bypass the power supply with a 1μF capacitor in parallel with a 0.1μF ceramic capacitor. If operating from dual supplies, bypass each supply to ground.

Good layout improves performance by decreasing the amount of stray capacitance at the op amp's inputs and output. To decrease stray capacitance, minimize both trace and external component lead lengths, and place external components close to the op amp's pins.

UCSP Package Consideration

For general UCSP package information and PC layout considerations, please refer to the Maxim Application Note (Wafer-Level Ultra-Chip-Board-Scale-Package).

UCSP Reliability

The UCSP represents a unique packaging form factor that may not perform equally to a packaged product through traditional mechanical reliability tests. UCSP reliability is integrally linked to the user's assembly methods, circuit board material, and usage environment. The user should closely review these areas when considering use of a UCSP. Performance through operating life test and moisture resistance remains uncompromised as it is primarily determined by the wafer-fabrication process. Mechanical stress performance is a greater consideration for a UCSP package. UCSPs are attached through direct solder contact to the user's PC board, foregoing the inherent stress relief of a packaged product lead frame. Solder joint contact integrity must be considered.

Table 1 shows the testing done to characterize the UCSP reliability performance. In conclusion, the UCSP is capable of performing reliably through environmental stresses as indicated by the results in the table. Additional usage data and recommendations are detailed in the UCSP application note, which can be found on Maxim's website at **www.maxim-ic.com**.

Table 1. Reliability Test Data

TEST	CONDITIONS	DURATION	NO. OF FAILURES PER SAMPLE SIZE
Temperature Cycle	-35°C to +85°C, -40°C to +100°C	150 cycles, 900 cycles	0/10, 0/200
Operating Life	T_A = +70°C	240h	0/10
Moisture Resistance	-20°C to +60°C, 90% RH	240h	0/10
Low-Temperature Storage	-20°C	240h	0/10
Low-Temperature Operational	-10°C	24h	0/10
Solderability	8h steam age	—	0/15
ESD	±2000V, Human Body Model	—	0/5
High-Temperature Operating Life	T_J = +150°C	168h	0/45

UCSP, Micropower, Single-Supply, 10V, Rail-to-Rail I/O Op Amps

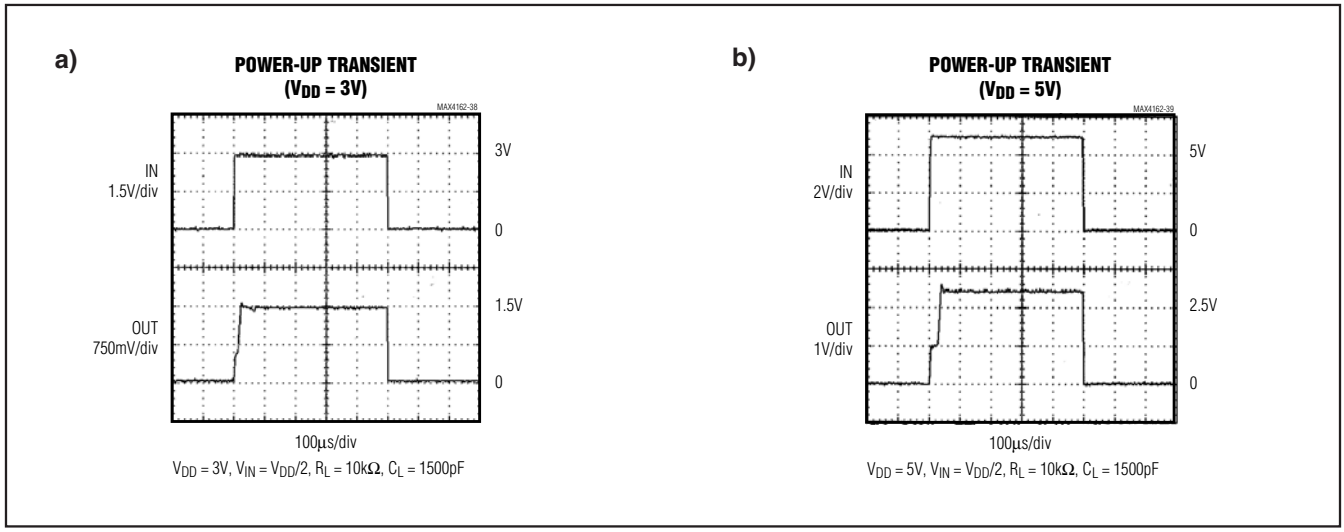
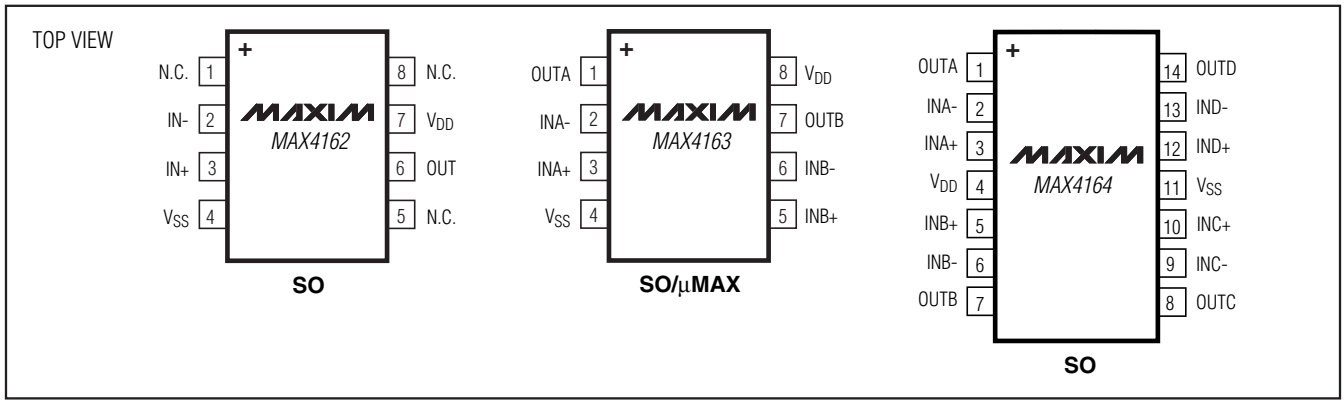


Figure 3. Power-Up Transient: a) V_{DD} = 3V; b) V_{DD} = 5V

Pin Configurations (continued)



Chip Information

PROCESS: BiCMOS

Package Information

For the latest package outline information and land patterns, go to **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	DOCUMENT NO.
8 SO	S8-2, S8-4	21-0041
5 SOT23	U5-1	21-0057
8 UCSP	B9-5	21-0093
8 µMAX	U8-1	21-0036
14 SO	S14M-5	21-0041

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
2	5/09	Changed operating supply voltage from 2.7V to 2.5V	1, 2, 3, 10, 11
3	1/10	Updated PSRR condition for 5V operation, added lead-free designation to *Ordering Information*, and added UCSP soldering temperature	1–9, 12

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