

## MAX40100

## Precision, Low-Power and Low-Noise Op Amp with RRIO

### General Description

The MAX40100 is a low-power, zero-drift operational amplifier available in a space-saving, 6-bump, wafer-level package (WLP).

Designed for use in portable consumer, medical, and industrial applications, the MAX40100 features rail-to-rail CMOS inputs and outputs, a 1.5MHz GBW at just 66µA supply current, and 10µV (max) “zero-drift” input voltage offset over time and temperature.

The zero-drift feature of the MAX40100 reduces the high 1/f noise typically found in CMOS input operational amplifiers, making it useful for a wide variety of low-frequency measurement applications.

The MAX40100 is available in a space-saving, 1.1 x 0.76mm, 6-bump WLP with 0.35mm bump pitch.

The MAX40100 is specified over the -40°C to +125°C extended automotive operating temperature range.

### Benefits and Features

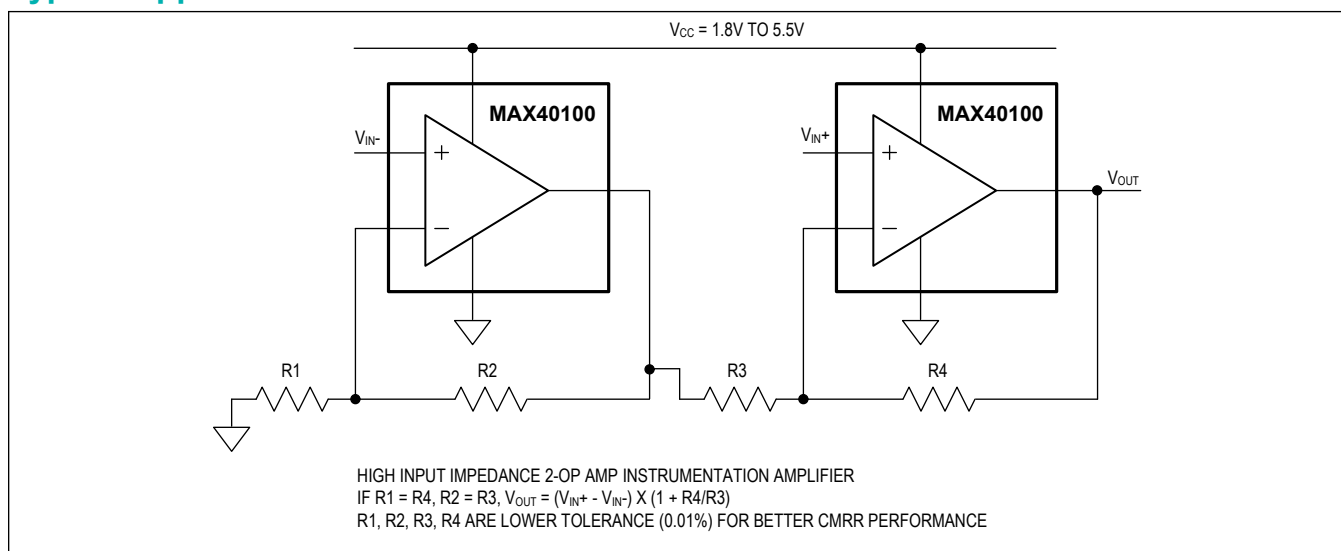
- Low 66µA Quiescent Current
- Low Input Noise:
  - 42nV/√Hz at 1kHz
  - 0.42µV<sub>p-p</sub> from 0.1Hz to 10Hz
- Rail-to-Rail Inputs and Outputs (RRIO)
- 1.5MHz GBW
- Ultra-Low 10pA Input Bias Current
- Single 1.6V to 5.5V Supply Voltage Range
- Unity Gain Stable
- Power-Saving Shutdown Mode
- Tiny, 1.1mm x 0.76mm, 6-bump WLP

**Ordering Information** appears at end of data sheet.

### Applications

- Cell Phones
- Sensor Interfaces
- Loop-Powered Systems
- Portable Medical Devices
- Battery-Powered Devices

### Typical Application Circuit



## Absolute Maximum Ratings

IN+, IN-, Supply Voltage,  $\overline{\text{SHDN}}$  ( $V_{DD}$  to GND) ..... -0.3V to +6V  
 OUT ..... (GND - 0.3V) to ( $V_{DD}$  + 0.3V)  
 Short-Circuit Duration to Either Supply Rail,  
     OUT, OUTA, OUTB ..... 10s  
 Continuous Input Current (Any Pins) .....  $\pm 20\text{mA}$   
 Continuous Power Dissipation ( $T_A = +70^\circ\text{C}$ ) .....  
 6-Bump WLP (Derate 10.19mW/ $^\circ\text{C}$  above  $+70^\circ\text{C}$ ) ..... 816mW

Package Thermal Characteristics (multilayer board)  
     Junction-to-Ambient Thermal Resistance ( $\theta_{JA}$ ) ..... 98.06 $^\circ\text{C}/\text{W}$   
 Operating Temperature Range .....  $-40^\circ\text{C}$  to  $+125^\circ\text{C}$   
 Junction Temperature .....  $+150^\circ\text{C}$   
 Storage Temperature Range .....  $-65^\circ\text{C}$  to  $+150^\circ\text{C}$   
 Lead Temperature (soldering 10s) .....  $+300^\circ\text{C}$

**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.maximintegrated.com/thermal-tutorial](http://www.maximintegrated.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.*

## Package Information

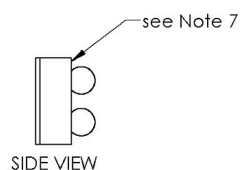
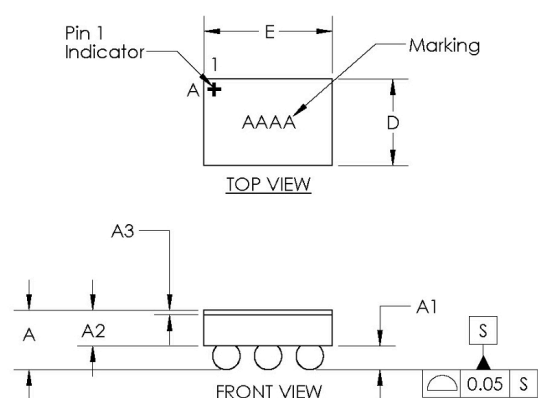
### 6 WLP

Package Code	N60D1+1
Outline Number	<a href="#">21-100086</a>
Land Pattern Number	Refer to <a href="#">Application Note 1891</a>

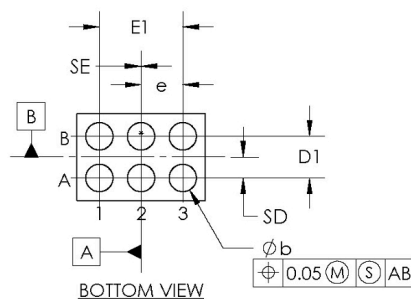
For the latest package outline information and land patterns (footprints), go to [www.maximintegrated.com/packages](http://www.maximintegrated.com/packages). Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

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.maximintegrated.com/thermal-tutorial](http://www.maximintegrated.com/thermal-tutorial).

## Package Outline Drawing



COMMON DIMENSIONS	
A	0.50 MAX
A1	0.17 ±0.03
A2	0.30 REF
A3	0.040 BASIC
b	∅0.23 ±0.03
D	0.727 ±0.025
E	1.077 ±0.025
D1	0.35 BASIC
E1	0.70 BASIC
e	0.35 BASIC
SD	0.175 BASIC
SE	0.00 BASIC
DEPOPULATED BUMPS: NONE	



- NOTES:
1. Terminal pitch is defined by terminal center to center value.
  2. Outer dimension is defined by center lines between scribe lines.
  3. All dimensions in millimeter.
  4. Marking shown is for package orientation reference only.
  5. Tolerance is ±0.02 unless specified otherwise.
  6. All dimensions apply to PbFree (+) package codes only.
  7. Front - side finish can be either Black or Clear.



TITLE		
PACKAGE OUTLINE 6 BUMPS THIN WLP PKG. 0.35 mm PITCH, N60D1+1		
APPROVAL	DOCUMENT CONTROL NO. 21-100086	REV. C

- DRAWING NOT TO SCALE -

## Electrical Characteristics

( $V_{DD} = +3.3V$ ,  $GND = 0$ ,  $A_V = 1V/V$ ,  $V_{OUT} = V_{DD}/2$ ,  $C_L = 20pF$ ,  $R_L = 100k\Omega$  to  $V_{DD}/2$ ,  $V_{SHDN} = V_{DD}$ ,  $T_A = -40^\circ C$  to  $+125^\circ C$  unless otherwise noted. Typical values are at  $+25^\circ C$ ) ([Note 2](#))

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
POWER SUPPLY							
Supply Voltage Range	V <sub>DD</sub>	Guaranteed by PSRR, 0°C ≤ T <sub>A</sub> ≤ +70°C		1.6		5.5	V
		Guaranteed by PSRR, -40°C ≤ T <sub>A</sub> ≤ +125°C		1.8		5.5	
Quiescent Supply Current	I <sub>DD</sub>	T <sub>A</sub> = +25°C			66	92	μA
		-40°C ≤ T <sub>A</sub> ≤ +125°C				124	
Power-Supply Rejection Ratio	PSRR	V <sub>DD</sub> = 1.8V to 5.5V	T <sub>A</sub> = +25°C	116	135		dB
			-40°C ≤ T <sub>A</sub> ≤ +125°C	107			
		0°C ≤ T <sub>A</sub> ≤ +70°C, V <sub>DD</sub> = 1.6V to 5.5V		107			
Power-Up Time	t <sub>ON</sub>	V <sub>DD</sub> = 0 to 3V step, A <sub>V</sub> = 1V/V			20		μs
Shutdown Supply Current	I <sub>SHDN</sub>					300	nA
Turn-On Time from Shutdown	t <sub>OSD</sub>	V <sub>DD</sub> = 3.3V, V <sub>SHDN</sub> = 0 to 3.3V step in < 1μs			50		μs
DC SPECIFICATIONS							
Input Offset Voltage	V <sub>OS</sub>	T <sub>A</sub> = +25°C			0.8	10	μV
		-40°C ≤ T <sub>A</sub> ≤ +125°C				25	
Input Offset Voltage Drift	ΔV <sub>OS</sub>				5		nV/°C
Input Bias Current ( <a href="#">Note 3</a> )	I <sub>B</sub>	T <sub>A</sub> = +25°C			±0.031	±0.160	nA
		-40°C ≤ T <sub>A</sub> ≤ +85°C				±4.6	
		-40°C ≤ T <sub>A</sub> ≤ +125°C				±28	
Input Offset Current	I <sub>OS</sub>				±0.005		nA
Input Common-Mode Range	V <sub>CM</sub>	Guaranteed by CMRR test	T <sub>A</sub> = +25°C	-0.1		V <sub>DD</sub> + 0.1	V
			-40°C ≤ T <sub>A</sub> ≤ +125°C	-0.1		V <sub>DD</sub> + 0.05	
Common-Mode Rejection Ratio	CMRR	-0.1 ≤ V <sub>CM</sub> ≤ V <sub>DD</sub> + 0.1, T <sub>A</sub> = +25°C		122	135		dB
		-0.1 ≤ V <sub>CM</sub> ≤ V <sub>DD</sub> + 0.05, -40°C ≤ T <sub>A</sub> ≤ +125°C		116			
Open-Loop Gain	A <sub>VOL</sub>	20mV ≤ V <sub>OUT</sub> ≤ V <sub>DD</sub> - 20mV, R <sub>L</sub> = 100kΩ to V <sub>DD</sub> /2		120	138		dB
		150mV ≤ V <sub>OUT</sub> ≤ V <sub>DD</sub> - 150mV, R <sub>L</sub> = 5kΩ to V <sub>DD</sub> /2		123	160		
Input Resistance	R <sub>IN</sub>	Differential			50		MΩ
		Common-mode			200		

## Electrical Characteristics (continued)

( $V_{DD} = +3.3V$ ,  $GND = 0$ ,  $A_V = 1V/V$ ,  $V_{OUT} = V_{DD}/2$ ,  $C_L = 20pF$ ,  $R_L = 100k\Omega$  to  $V_{DD}/2$ ,  $V_{SHDN} = V_{DD}$ ,  $T_A = -40^\circ C$  to  $+125^\circ C$  unless otherwise noted. Typical values are at  $+25^\circ C$ ) (*Note 2*)

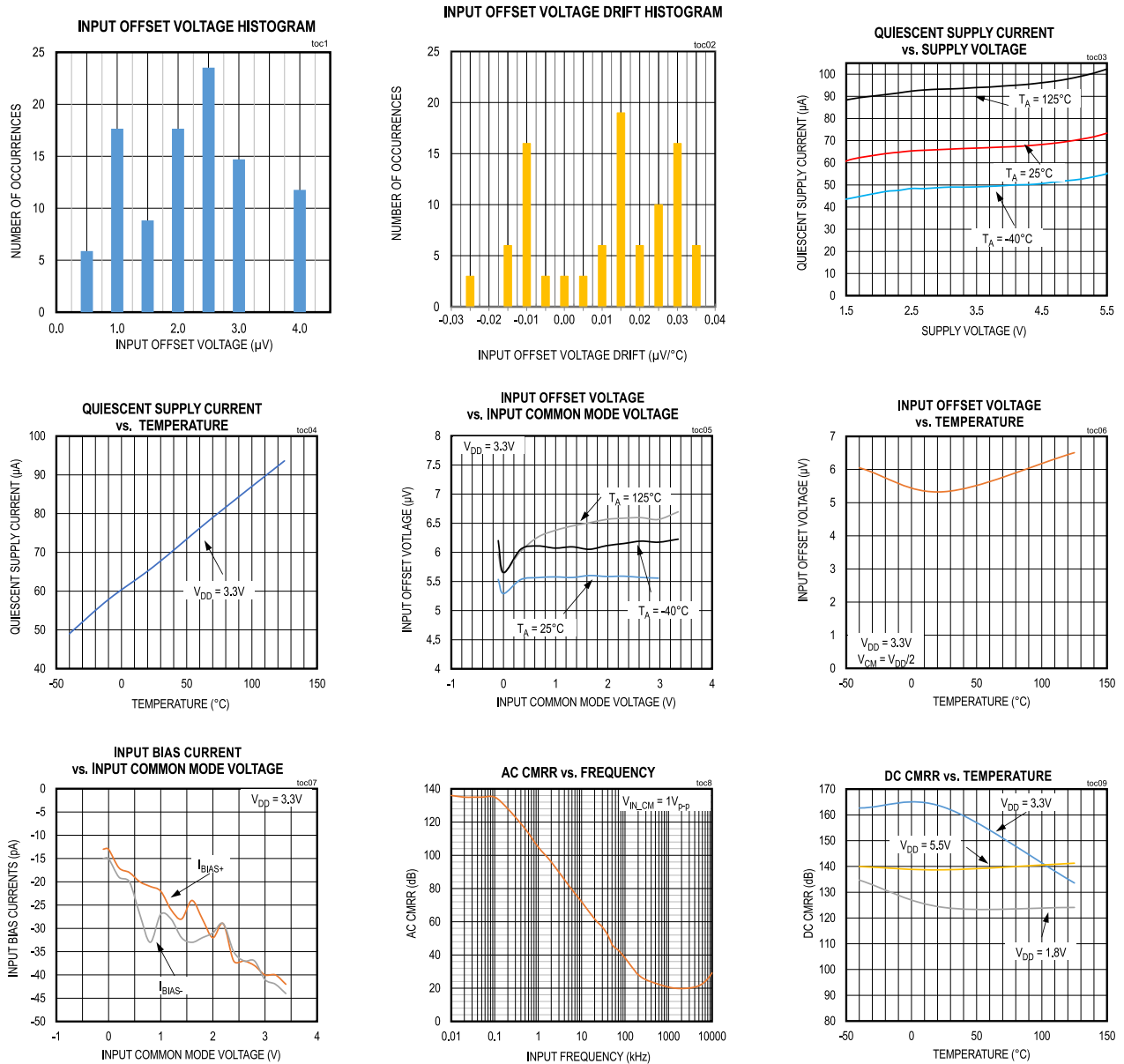
PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Output Voltage Swing	$V_{OH}$	$V_{DD} - V_{OUT}$	$R_L = 100k\Omega$ to $V_{DD}/2$			12	mV
			$R_L = 50k\Omega$ to $V_{DD}/2$			22	
			$R_L = 600\Omega$ to $V_{DD}/2$		50		
	$V_{OL}$	$V_{OUT}$	$R_L = 100k\Omega$ to $V_{DD}/2$			11	
			$R_L = 50k\Omega$ to $V_{DD}/2$			18	
			$R_L = 600\Omega$ to $V_{DD}/2$		50		
Short-Circuit Current	$I_{SC}$				50		mA
<b>AC SPECIFICATIONS</b>							
Gain-Bandwidth Product	GBWP				1.5		MHz
Slew Rate	SR	$0 \leq V_{OUT} \leq 2V$			0.7		V/ $\mu s$
Input Voltage Noise Density	$E_n$	$f_{SW} = 1kHz$			42		nV/ $\sqrt{Hz}$
Input Voltage Noise		$0.1Hz \leq f_{SW} \leq 10Hz$			0.42		$\mu V_{P-P}$
Input Current Noise Density		$f_{SW} = 1kHz$			100		fA/ $\sqrt{Hz}$
Phase Margin		$C_L = 20pF$			60		°
Capacitive Loading	$C_L$	No sustained oscillation, $A_V = 1V/V$			400		pF
<b>LOGIC INPUT</b>							
Shutdown Input Low	$V_{IL}$					0.5	V
Shutdown Input High	$V_{IH}$			1.3			V
Shutdown Input Leakage Current	$I_{IL}/I_{IH}$					100	nA

**Note 2:** Specifications are 100% tested at  $T_A = +25^\circ C$  (exceptions noted). All temperature limits are guaranteed by design.

**Note 3:** Guaranteed by design.

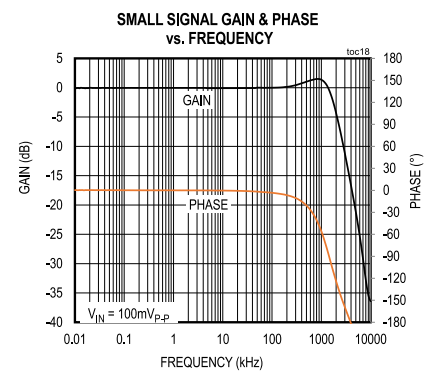
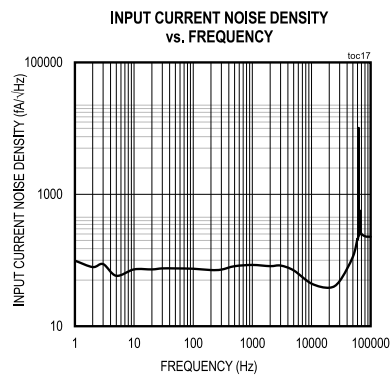
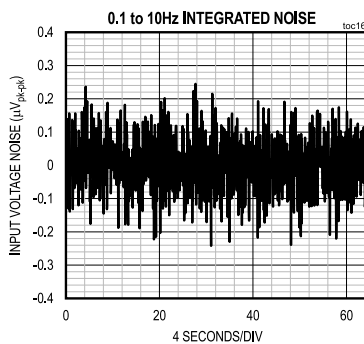
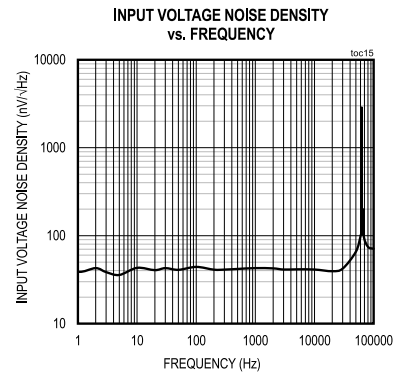
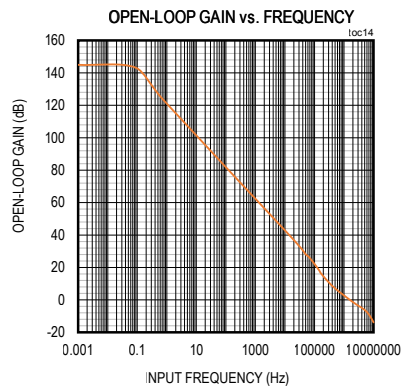
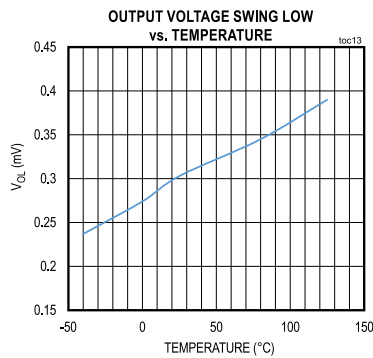
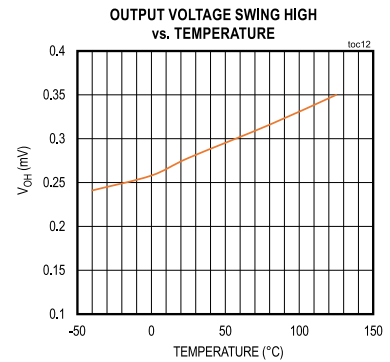
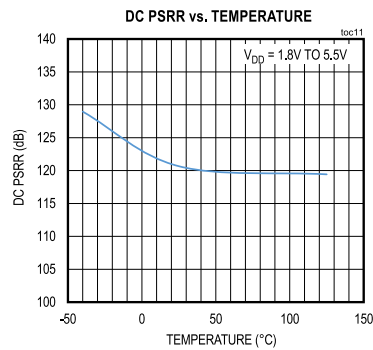
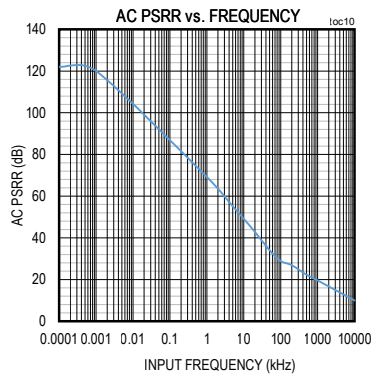
## Typical Operating Characteristics

( $V_{DD} = +3.3V$ ,  $GND = 0$ ,  $A_V = 1V/V$ ,  $V_{OUT} = V_{DD}/2$ ,  $C_L = 20pF$ ,  $R_L = 100k\Omega$  to  $V_{DD}/2$ ,  $\overline{V_{SHDN}} = V_{DD}$ ,  $T_A = -40^\circ C$  to  $+125^\circ C$  unless otherwise noted. Typical values are at  $+25^\circ C$ )



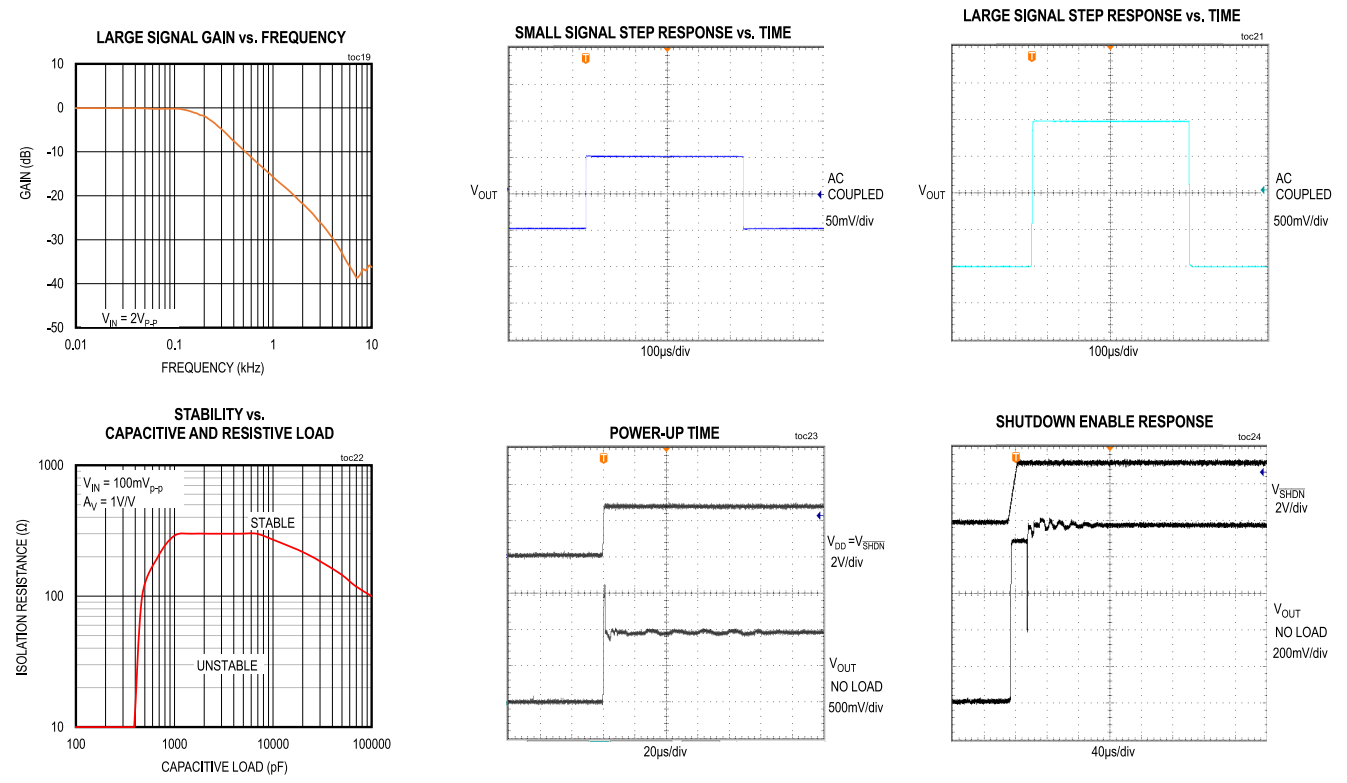
## Typical Operating Characteristics (continued)

( $V_{DD} = +3.3V$ ,  $GND = 0$ ,  $A_V = 1V/V$ ,  $V_{OUT} = V_{DD}/2$ ,  $C_L = 20pF$ ,  $R_L = 100k\Omega$  to  $V_{DD}/2$ ,  $\overline{V_{SHDN}} = V_{DD}$ ,  $T_A = -40^\circ C$  to  $+125^\circ C$  unless otherwise noted. Typical values are at  $+25^\circ C$ )

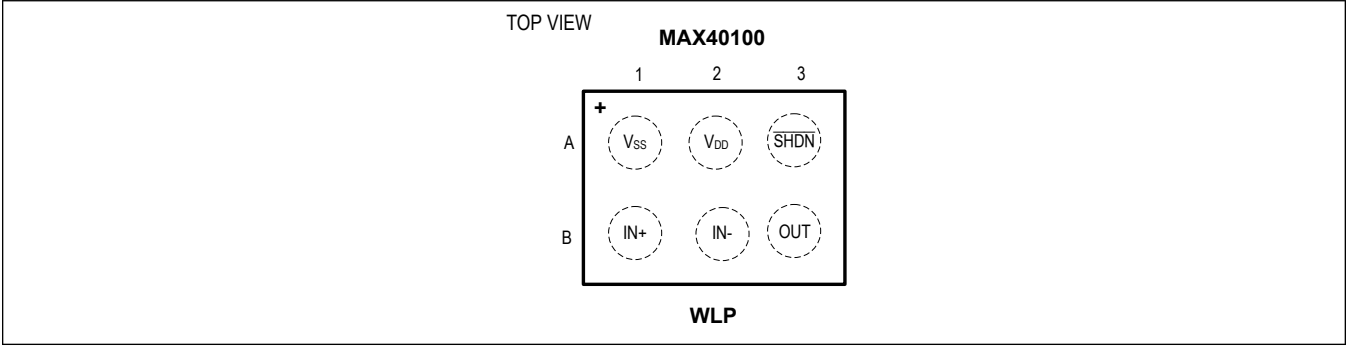


Typical Operating Characteristics (continued)

( $V_{DD} = +3.3V$ ,  $GND = 0$ ,  $A_V = 1V/V$ ,  $V_{OUT} = V_{DD}/2$ ,  $C_L = 20pF$ ,  $R_L = 100k\Omega$  to  $V_{DD}/2$ ,  $V_{SHDN} = V_{DD}$ ,  $T_A = -40^{\circ}C$  to  $+125^{\circ}C$  unless otherwise noted. Typical values are at  $+25^{\circ}C$ )



Bump Configuration



Bump Descriptions

PIN	NAME	FUNCTION
A1	VSS	Negative Supply Voltage
A2	VDD	Positive Supply Voltage. Bypass to GND with a 0.1µF capacitor.
A3	SHDN	Shutdown. Pull to VSS to activate shutdown mode.



**Bump Descriptions (continued)**

<b>PIN</b>	<b>NAME</b>	<b>FUNCTION</b>
B1	IN+	Positive Input
B2	IN-	Negative Input
B3	OUT	Output

## Detailed Description

The MAX40100 is a precision, low-power op-amps ideal for signal processing applications. This device use an innovative auto-zero technique that allows precision and low-noise with a minimum amount of power. The low input offset voltage, CMOS inputs, and the absence of  $1/f$  noise allows for optimization of active-filter designs.

The MAX40100 achieves rail-to-rail performance at the input through the use of a low-noise charge pump. This ensures a glitch-free, common-mode input voltage range extending from the negative supply rail up to the positive supply rail, eliminating cross over distortion common to traditional N-channel/P-channel CMOS pair inputs, reducing harmonic distortion at the output.

The device features a shutdown mode that greatly reduces quiescent current while the device is not operational.

### Auto-Zero

The MAX40100 features an auto-zero circuit that allows the device to achieve less than  $10\mu\text{V}$  of input offset voltage and eliminates the  $1/f$  noise.

### Internal Charge Pump

An internal charge pump provides an internal supply typically 1V beyond the upper rail. This internal rail allows the MAX40100 to achieve true rail-to-rail inputs and outputs, while providing excellent common-mode rejection, power-supply rejection ratios, and gain linearity.

The charge pump requires no external components, and in most applications is entirely transparent to the user. The operating frequency is well beyond the unity-gain frequency of the amplifier, avoiding aliasing or other signal integrity issues in sensitive applications.

### Shutdown Operation

The device features an active-low shutdown mode that lowers the quiescent current to less than  $1\mu\text{A}$ . In shutdown mode the inputs and output are high impedance. This allows multiple devices to be multiplexed onto a single line without the use of external buffers. Pull SHDN high for normal operation.

The shutdown high ( $V_{IH}$ ) and low ( $V_{IL}$ ) threshold voltages are designed for ease of integration with digital controls like microcontroller outputs. These thresholds are independent of supply, eliminating the need for external pulldown circuitry.

Applications Information

The MAX40100 is a low-power, low-noise, precision operational amplifier designed for applications in the portable medical (such as ECG and Pulse Oximetry), portable consumer, and industrial markets.

The MAX40100 is also ideal for loop-powered systems that interface with pressure sensors or strain-gauges.

Capacitive Load Stability

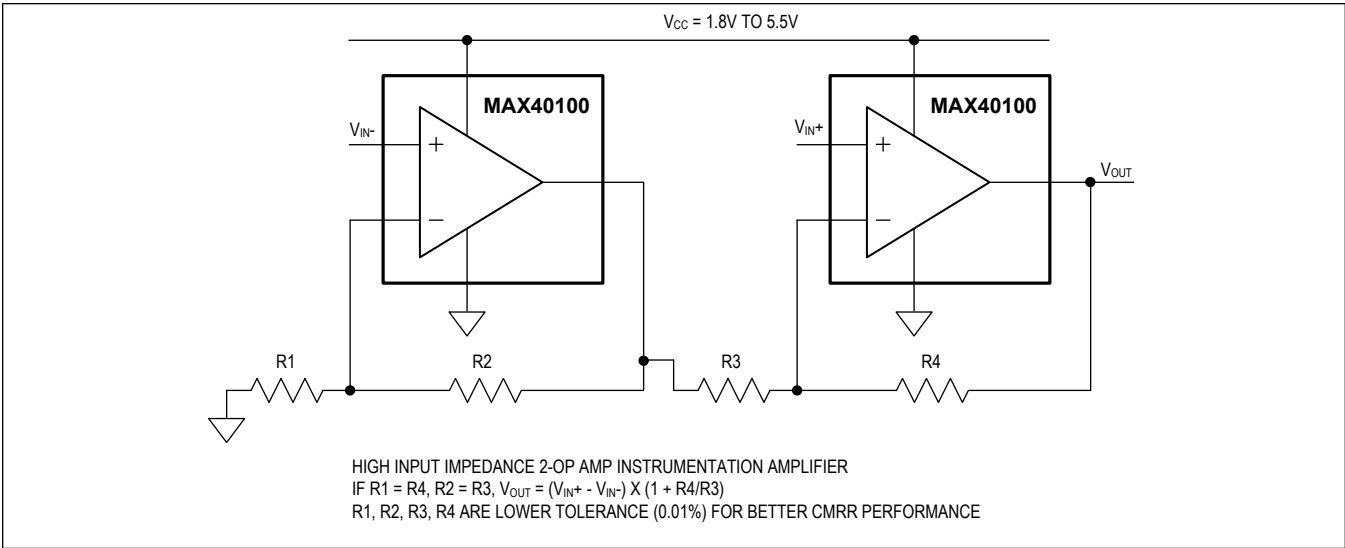
Driving large capacitive loads can cause instability in many op amps. MAX40100 is stable with capacitive loads up to 400pF. Stability with higher capacitive loads can be improved by adding an isolation resistor in series with the op-amp output. This resistor improves the circuit's phase margin by isolating the load capacitor from the amplifier's output. The graph in the [Typical Operating Characteristics](#) gives the stable operation region for capacitive load versus isolation resistors.

Power Supplies and Layout

The MAX40100 operate either with a single supply from +1.6V to +5.5V with respect to ground or with dual supplies from ±0.8V to ±2.75V. When used with dual supplies, bypass both supplies with their own 0.1µF capacitor to ground. When used with a single supply, bypass V<sub>DD</sub> with a 0.1µF capacitor to ground.

Careful layout technique helps optimize performance by decreasing the amount of stray capacitance at the op amp's inputs and outputs. To decrease stray capacitance, minimize trace lengths by placing external components close to the op amp's pins.

Typical Application Circuit



Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
MAX40100ANT+	-40°C to +125°C	6 WLP

+Denotes lead(Pb)-free/RoHS compliant package.

## Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	5/16	Initial release	—
1	6/17	Updated units in <i>Electrical Characteristics</i> table	2, 3
2	3/18	Updated <i>Absolute Maximum Ratings</i> sections	2
3	3/20	Updated TOC02	4
4	1/21	Updated <i>Benefits and Features</i> , added <i>Package Outline Drawing</i>	1, 3
5	2/21	Added <i>Typical Application Circuit</i>	1

For pricing, delivery, and ordering information, please visit Maxim Integrated's online storefront at <https://www.maximintegrated.com/en/storefront/storefront.html>.

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