# MAX40108    1V, Low-Power, Precision Operational Amplifier

## General Description

The MAX40108 is a low-power, high-precision operational amplifier (op amp) that operates with a power supply voltage as low as 0.9V.

Available in a space-saving, 1.22mmx 0.92mm, 6-bump wafer-level package (WLP) with a 0.4mm bump pitch, it is designed for use in portable, consumer, medical, and industrial applications.

The MAX40108 features rail-to-rail CMOS inputs and outputs, a 168kHz GBW consuming only 25.5µA (typ) supply current and 1µV (typ) zero-drift input offset voltage over time and temperature. The zero-drift feature 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 MAX40108 operates from a 0.9V to 3.6V power supply voltage and is specified over the -40°C to +125°C extended operating temperature range.

## Applications

- Wearable Devices
- Home Medical (Blood Glucose,Weight Scale, Blood Pressure, EKG)
- Fitness and Health (Smart Watch, Heart-Rate Monitor)
- Industrial IOT (Pressure, Flow, Level, Temperature, Proximity)

## Benefits and Features

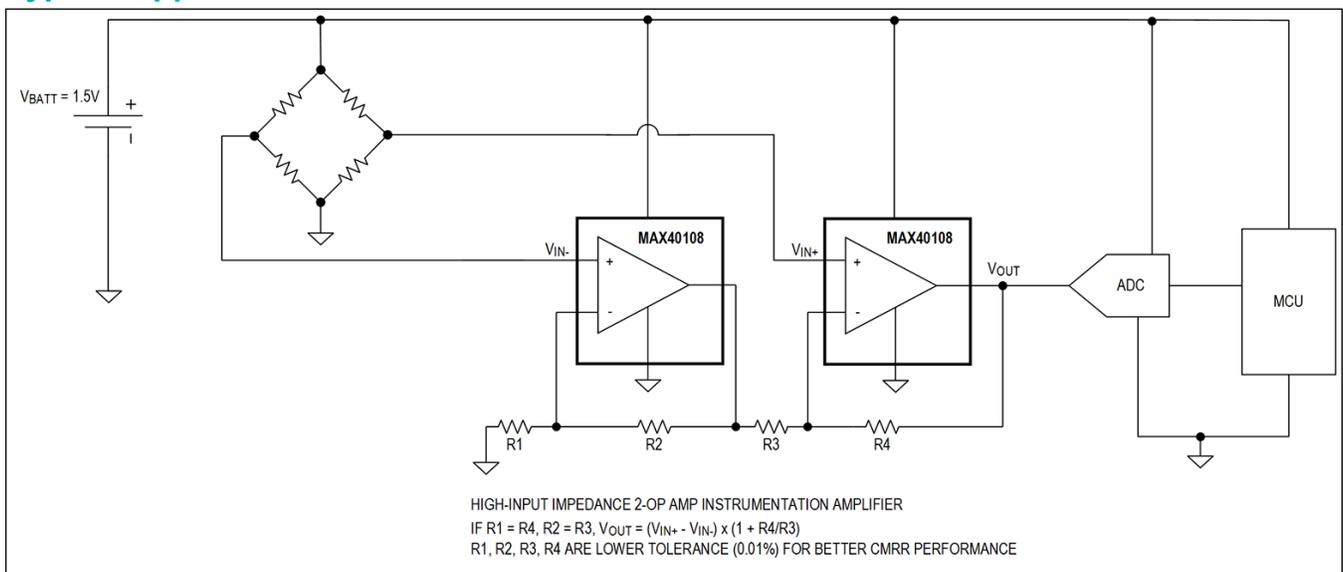- Supply Voltage Range: 0.9V to 3.6V
- Low 25.5µA Quiescent Current
- Very Low 1µV (typ) Input Offset Voltage
- Rail-to-Rail Inputs and Outputs
- Internal EMI Rejection
- 168kHz GBW
- Low Input Bias Current
- Power-Saving Shutdown Mode
- Available in Tiny, 1.22mm x 0.92mm, 6-bump WLP and 8-pin TDFN

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

## Typical Application Circuit



HIGH-INPUT IMPEDANCE 2-OP AMP INSTRUMENTATION AMPLIFIER
IF R1 = R4, R2 = R3, $V_{OUT}$ = ($V_{IN+}$ - $V_{IN-}$) x (1 + R4/R3)
R1, R2, R3, R4 ARE LOWER TOLERANCE (0.01%) FOR BETTER CMRR PERFORMANCE

# TABLE OF CONTENTS

## Absolute Maximum Ratings

$V_{DD}$ to GND.............................................................. -0.3V to +4V
IN+ to IN- ..................................................... -0.3V to $V_{DD}$ + 0.3V
OUT to GND ................................................ -0.3V to $V_{DD}$ + 0.3V
IN+, IN- to GND ......................................... -0.3V to $V_{DD}$ + 0.3V
Continuous Current into Any Input/Output Pin ................... 10mA

Output Short-Circuit Duration to Either $V_{DD}$ or GND ..Continuous
Continuous Power Dissipation (Derate 10.51mW/°C above
+70°C).............................................................................840.78mW
Operating Temperature Range ..........................-40°C to +125°C
Junction Temperature .......................................................+150°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.*

## Package Information

### WLP

| Package Code | N60M1+1 |
|---|---|
| Outline Number | 21-100427 |
| Land Pattern Number | Refer to Application Note 1891 |
| **Thermal Resistance, Four-Layer Board:** | |
| Junction to Ambient ($\theta_{JA}$) | 95.15°C/W |
| Junction to Case ($\theta_{JC}$) | 56°C/W |

### TDFN

| Package Code | T822+3C |
|---|---|
| Outline Number | 21-0168 |
| Land Pattern Number | 90-0065 |
| **Thermal Resistance, Four-Layer Board:** | |
| Junction to Ambient ($\theta_{JA}$) | 85.3°C/W |
| Junction to Case ($\theta_{JC}$) | 8.9°C/W |

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

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*.

## Electrical Characteristics

($V_{DD}$ = +1.5V, GND = 0, $V_{CM}$ = $V_{DD}$/2, $R_{LOAD}$ = 10kΩ to $V_{DD}$/2, $V_{\overline{SHDN}}$ = $V_{DD}$, $T_A$ = -40°C ≤ $T_A$ ≤ +125°C unless otherwise noted. Typical values are at +25°C.(*Note 1*))

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| **DC SPECIFICATIONS** | | | | | | |
| Input Offset Voltage | $V_{OS}$ | 0°C ≤ $T_A$ ≤ +85°C | | 1 | 10 | µV |
| | | -40°C ≤ $T_A$ ≤ +125°C | | | 25 | |
| Input Offset Voltage Drift | $\Delta V_{OS}$ | | | 25 | | nV/°C |
| Input Bias Current | $I_B$ (Note 2) | -40°C ≤ $T_A$ ≤ +85°C | | 55 | 200 | pA |
| | | -40°C ≤ $T_A$ ≤ +125°C | | | 400 | |
| Input Offset Current | $I_{OS}$ | | | 110 | | pA |
| Input Common-Mode Range | $V_{CM}$ | Guaranteed by CMRR test | -0.1 | | $V_{DD}$ + 0.1 | V |

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## Electrical Characteristics (continued)

($V_{DD}$ = +1.5V, GND = 0, $V_{CM}$ = $V_{DD}$/2, $R_{LOAD}$ = 10kΩ to $V_{DD}$/2, $V_{\overline{SHDN}}$ = $V_{DD}$, $T_A$ = -40°C ≤ $T_A$ ≤ +125°C unless otherwise noted. Typical values are at +25°C.(_Note 1_))

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| Common-Mode Rejection Ratio | CMRR | −0.1V ≤ $V_{CM}$ ≤ $V_{DD}$ + 0.1V | | 107 | 135 | | dB |
| Power-Supply Rejection Ratio | PSRR | | | 116 | 140 | | dB |
| Open-Loop Gain | $A_{OL}$ | (150mV - GND) ≤ $V_{OUT}$ ≤ ($V_{DD}$ - 150mV), $R_{LOAD}$ = 10kΩ to $V_{DD}$/2 | | 106 | 130 | | dB |
| Output Voltage Swing High | $V_{OH}$ | $V_{DD}$ - $V_{OUT}$ | $R_{LOAD}$ = 10kΩ to $V_{DD}$/2 | | | 25 | mV |
| | | | No load | | | 15 | |
| Output Voltage Swing Low | $V_{OL}$ | $V_{OUT}$ | $R_{LOAD}$ = 10kΩ to $V_{DD}$/2 | | | 25 | mV |
| | | | No load | | | 5 | |
| Short Circuit Current | $I_{SC}$ | | | | 25 | | mA |
| **AC SPECIFICATIONS** | | | | | | | |
| Gain Bandwidth Product | GBW | | | | 168 | | kHz |
| Slew Rate | SR | | | | 0.08 | | V/µs |
| Input Voltage Noise Density | $V_N$ | f = 1kHz, unity gain | | | 117 | | nV/√Hz |
| Input Voltage Noise Density | $V_N$ | f = 1kHz, gain = 10 | | | 90 | | nV/√Hz |
| Input Voltage Noise | | 0.1Hz to 10Hz | | | 2.5 | | $µV_{P-P}$ |
| Input Current Noise Density | $I_N$ | f = 1kHz | | | 100 | | fA/√Hz |
| Phase Margin | PM | $C_{LOAD}$ = 10pF | | | 60 | | ° |
| Capacitive Loading Stability | | | | | 50 | | pF |
| **POWER SUPPLY** | | | | | | | |
| Supply Voltage | $V_{DD}$ | Guaranteed by PSRR, -40°C < $T_A$ < +125°C | | 0.9 | | 3.6 | V |
| Supply Current | $I_{DD}$ | | | | 25.5 | 42 | µA |
| Power-Up Time | $t_{ON}$ | $V_{DD}$ = 0V to 3V step, AV = 1V/V | | | 250 | | µs |
| Shutdown Supply Current | $I_{\overline{SHDN}}$ | -40ºC ≤ $T_A$ ≤ +85ºC | | | 320 | 1600 | nA |
| | | -40ºC ≤ $T_A$ ≤ +125ºC | | | 320 | 3000 | |
| Turn-On Time | $t_{ONSD}$ | $V_{DD}$ = 3.3V, $V_{\overline{SHDN}}$ = 0V to 3.3V step in <1µs | | | 600 | | µs |
| **LOGIC INPUT DC CHARACTERISTICS** | | | | | | | |
| Input Low Level | $V_{IL}$ | Active level | | | | 0.37 x $V_{DD}$ | V |
| Input High Level | $V_{IH}$ | | | 0.8*$V_{DD}$ | | | V |
| Input Leakage Current | $I_L$ | | | | 60 | 250 | nA |

**Note 1:** Specifications are 100% tested at $T_A$ = +25°C (exceptions noted). All temperature limits are guaranteed by design.
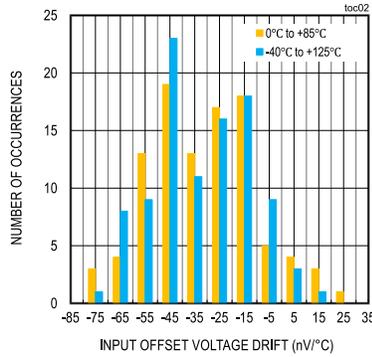**Note 2:** Not production tested, guaranteed by design and bench characterization.

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# Typical Operating Characteristics

($V_{DD}$ = +1.5V, GND = 0, $V_{CM}$ = $V_{DD}$/2, $R_{LOAD}$ = 10kΩ to $V_{DD}$/2, $V_{\overline{SHDN}}$ = $V_{DD}$, $T_A$ = -40°C to +125°C unless otherwise noted. Typical values are at +25°C.)

INPUT OFFSET VOLTAGE HISTOGRAM
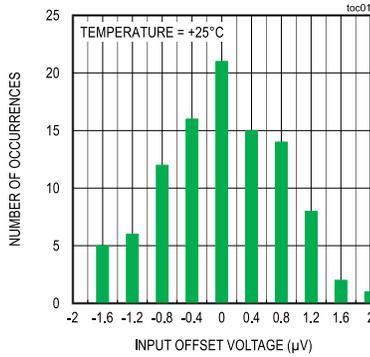
INPUT OFFSET VOLTAGE DRIFT HISTOGRAM

QUIESCENT SUPPLY CURRENT vs. SUPPLY VOLTAGE
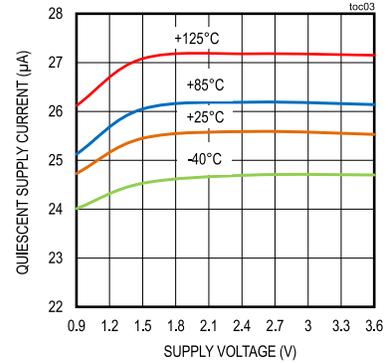
QUIESCENT SUPPLY CURRENT vs. TEMPERATURE
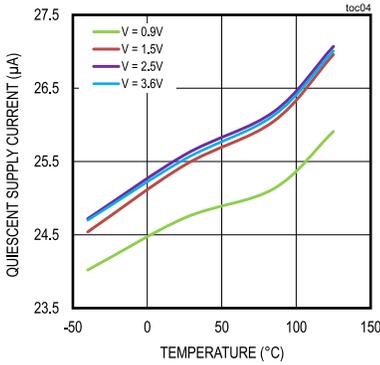
INPUT OFFSET VOLTAGE vs. INPUT COMMON-MODE VOLTAGE
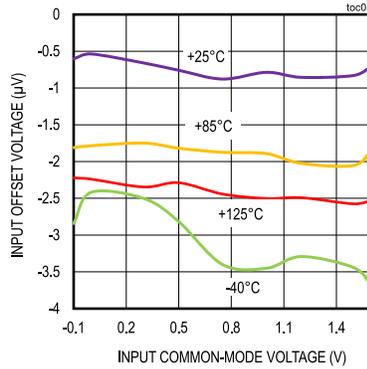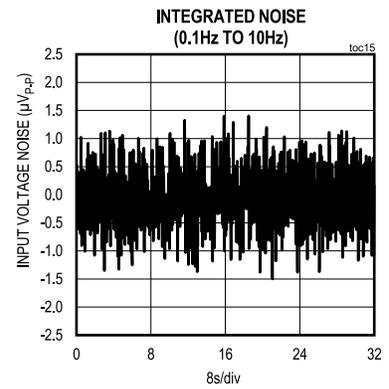
INPUT BIAS CURRENT vs. INPUT COMMON-MODE VOLTAGE
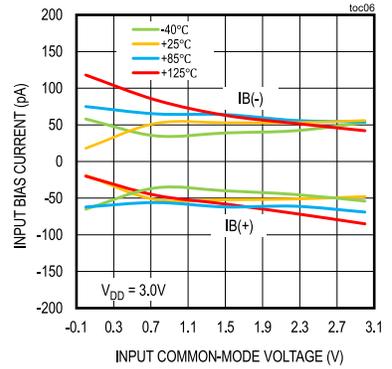
AC CMRR vs. FREQUENCY
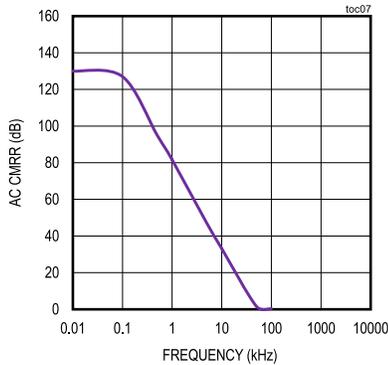
DC CMRR vs. TEMPERATURE
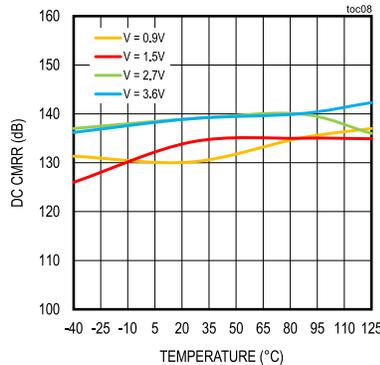
AC PSRR
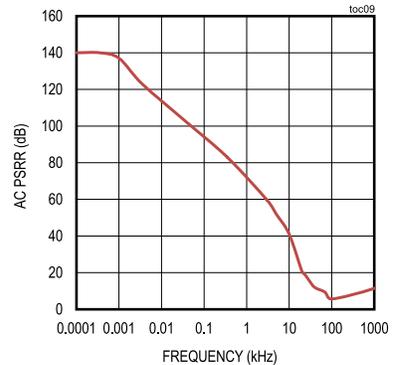
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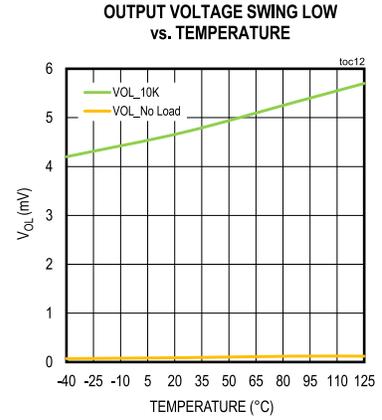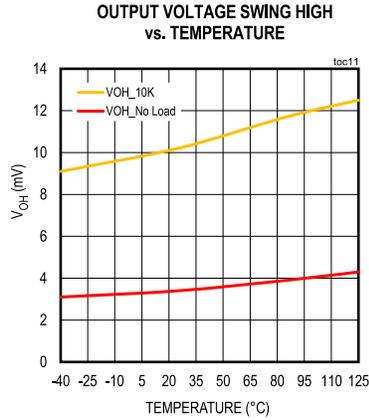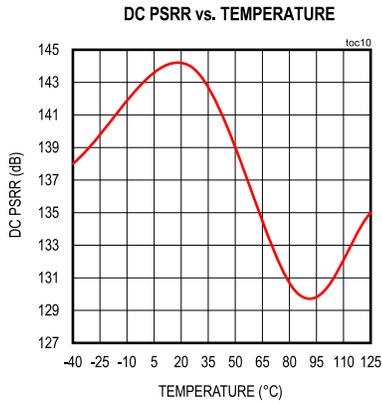
# Typical Operating Characteristics (continued)

($V_{DD}$ = +1.5V, GND = 0, $V_{CM}$ = $V_{DD}$/2, $R_{LOAD}$ = 10kΩ to $V_{DD}$/2,  $V_{\overline{SHDN}}$ = $V_{DD}$, $T_A$ = -40°C to +125°C unless otherwise noted. Typical values are at +25°C.)

DC PSRR vs. TEMPERATURE

toc10

OUTPUT VOLTAGE SWING HIGH
vs. TEMPERATURE

toc11

OUTPUT VOLTAGE SWING LOW
vs. TEMPERATURE

toc12

OPEN-LOOP GAIN vs. FREQUENCY

toc13

INPUT VOLTAGE NOISE
DENSITY vs. FREQUENCY

toc14

INTEGRATED NOISE
(0.1Hz TO 10Hz)

toc15

SMALL SIGNAL GAIN AND PHASE
vs. FREQUENCY

toc16

LARGE SIGNAL GAIN
vs. FREQUENCY

toc17

SMALL SIGNAL STEP RESPONSE
vs. TIME

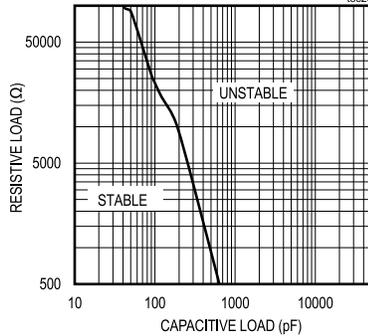toc18

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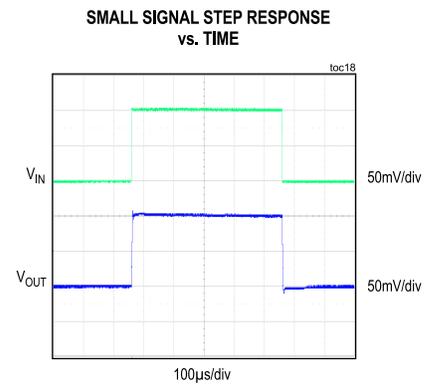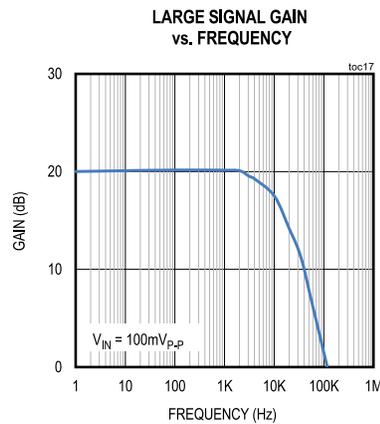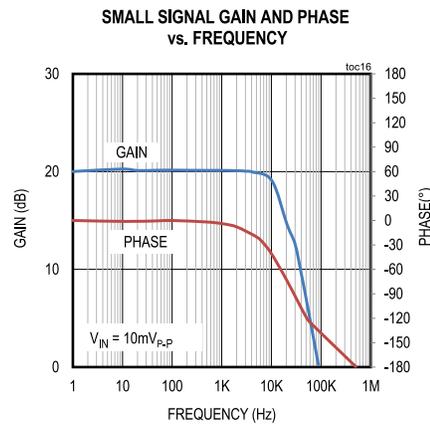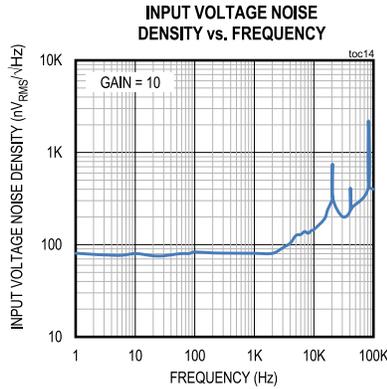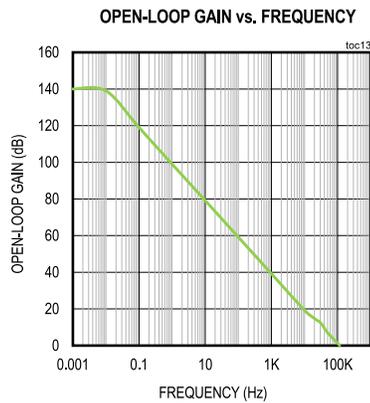
## Typical Operating Characteristics (continued)

($V_{DD}$ = +1.5V, GND = 0, $V_{CM}$ = $V_{DD}$/2, $R_{LOAD}$ = 10kΩ to $V_{DD}$/2, $V_{\overline{SHDN}}$ = $V_{DD}$, $T_A$ = -40°C to +125°C unless otherwise noted. Typical values are at +25°C.)
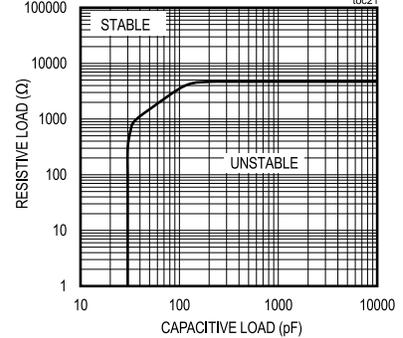


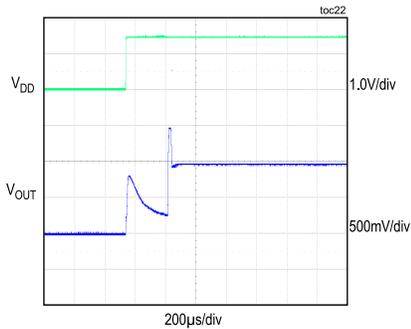LARGE SIGNAL STEP RESPONSE vs. TIME
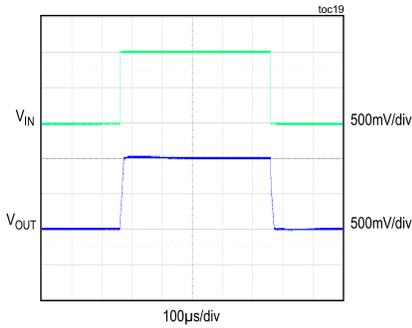


STABILITY vs. CAPACITIVE LOAD AND RESISTIVE LOAD
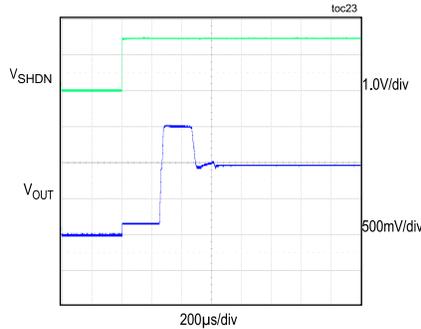


STABILITY vs. CAPACITIVE LOAD AND ISOLATION RESISTOR
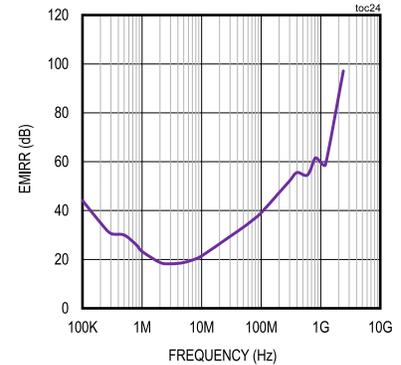


POWER-UP TIME



SHUTDOWN ENABLE RESPONSE



EMIRR vs. FREQUENCY



EMIRR vs. RF INPUT VOLTAGE

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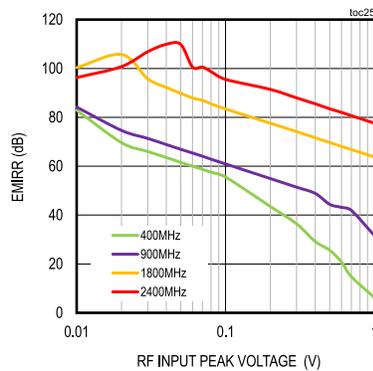
## Pin Configurations

**WLP**
**TOP VIEW (BUMP SIDE DOWN)**



6-BUMP WLP WITH 0.4mm PITCH

**TDFN**



8-PIN TDFN, 2mm x 2mm
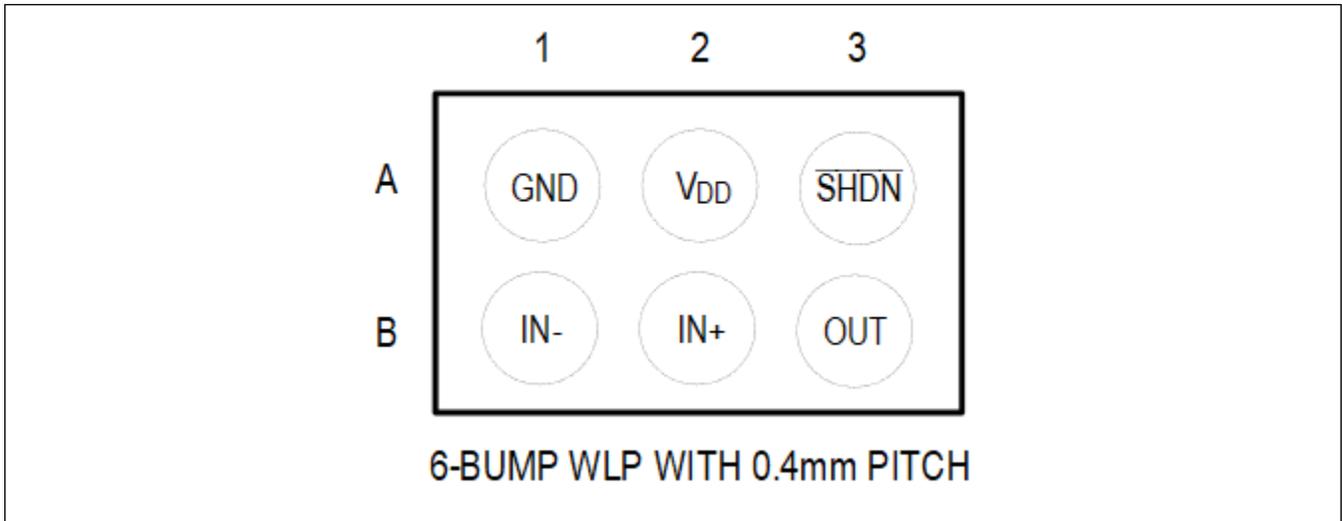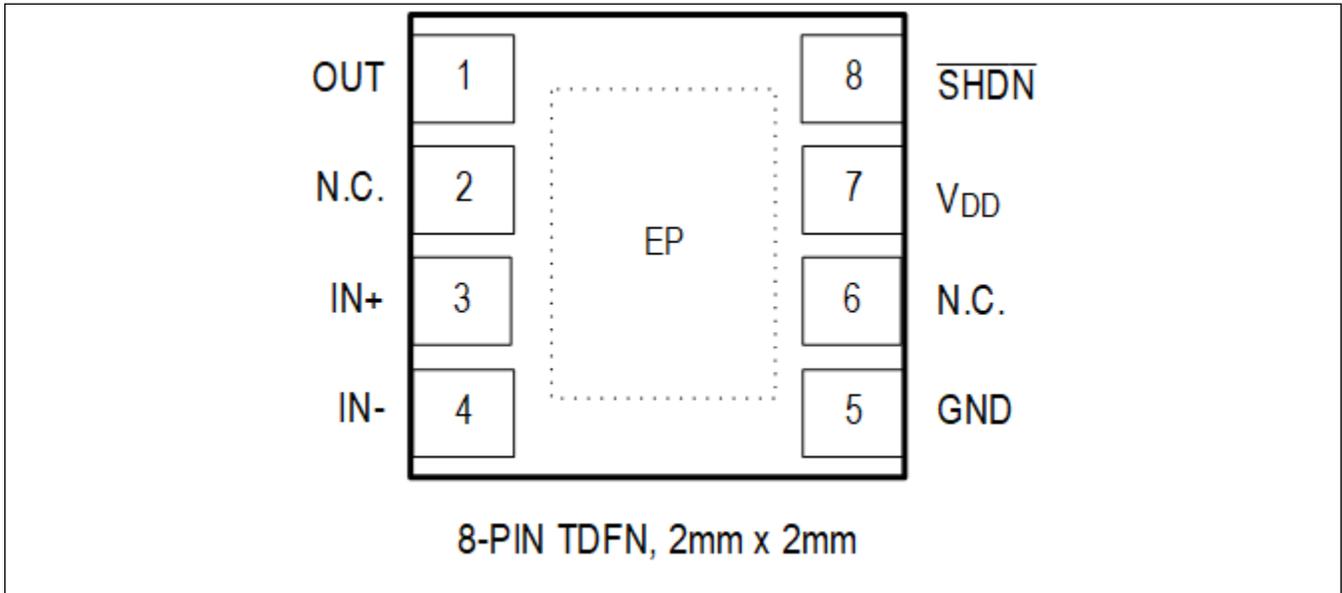
## Pin Description

| PIN | | NAME | FUNCTION |
|---|---|---|---|
| **WLP** | **TDFN** | | |
| B2 | 3 | IN+ | Noninverting Input |

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## Pin Description (continued)

| PIN | | NAME | FUNCTION |
|---|---|---|---|
| WLP | TDFN | | |
| A1 | 5 | GND | Ground |
| B1 | 4 | IN- | Inverting Input |
| A2 | 7 | VDD | Positive Supply |
| B3 | 1 | OUT | Output |
| A3 | 8 | SHDN_ | Shutdown (Active Low) |
| — | 2, 6 | NC | Do Not Connect |

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## Detailed Description

The MAX40108 is a precision, low-power op amp with a power supply as low as 0.9V that is ideal for portable consumer, medical, and industrial applications. The device uses an auto-zero technique that allows precision and low-noise with a minimum amount of power. The MAX40108 features rail-to rail CMOS inputs and outputs at just 25.5µA supply current and 1µV (typ) input-referred offset voltage. The low input offset voltage, CMOS inputs, and the absence of 1/f noise allows for optimization of sensor interfaces, in particular for sensors that operate with low voltage and at low frequency.

The MAX40108 achieves rail-to-rail performance at the input through the use of a low-noise charge pump. The rail-to-rail input maximizes the amplifier input dynamic range when it is operating at its minimum supply voltage of 0.9V. This also ensures a glitch-free, common-mode input-voltage range extending from the negative supply rail up to the positive supply rail, eliminating crossover distortion common to traditional n-channel/p-channel CMOS pair inputs. 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.

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

### Auto-Zero

The MAX40108 features Maxim's patented autochop circuit, which reduces input offset voltage and 1/f noise, while reducing the output ripple typically associated with chopping circuits.

### Shutdown Operation

The device features an active-low shutdown mode that lowers the quiescent current to a typical value of 320nA. 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 $\overline{SHDN}$ 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. See the *Typical Operating Characteristics* for output voltage response to a shutdown disable signal.

## Applications Information

### Overview

The MAX40108 low-power, low-noise, and precision op amp is designed for applications that interface with sensors like the ones found in portable medical, such as ECG and blood glucose meter, as well as industrial equipment. Because the MAX40108 supply voltage can operate as low as 0.9V, the amplifier can be used in applications with single-cell battery (1.5V, nom) by connecting the device directly to the battery voltage.

### Power-Up Settling Time

The MAX40108 typically requires 250µs to power up. During this startup time, the output is indeterminate. The application circuit should allow for this initial delay. See the *Typical Operating Characteristics* for the Power-Up Time curve.

### Capacitive-Load Stability

Driving large capacitive loads can cause instability in many op amps. The MAX40108 is stable with capacitive loads up to 50pF. 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. Note that this solution reduces the gain and output voltage swing because $R_{ISO}$ forms a voltage-divider with the load resistor. The graph in the *Typical Operating Characteristics* gives the stable operation region for capacitive load versus isolation resistors.

### Power Supplies and Layout

The MAX40108 operates either with a single supply from +0.9V to +3.6V with respect to ground or with dual supplies from ±0.45V to ±1.8V. Bypass both supplies with bypass capacitor to ground when used with dual supplies; bypass $V_{DD}$ with bypass capacitor to ground when used with single supply.

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.

## Ordering Information

| PART NUMBER | TEMP RANGE | PIN-PACKAGE | TOP MARK |
|---|---|---|---|
| MAX40108ANT+ | -40°C to +125°C | 6 WLP | +BE |
| MAX40108ANT+T | -40°C to +125°C | 6 WLP | +BE |
| MAX40108ATA* | -40°C to +125°C | 8 TDFN | BTR |
| MAX40108ATA+T* | -40°C to +125°C | 8 TDFN | BTR |

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

*T Denotes tape-and-reel.*

*\*Future product—contact factory for availability.*

## Revision History

| REVISION NUMBER | REVISION DATE | DESCRIPTION | PAGES CHANGED |
|---|---|---|---|
| 0 | 7/20 | Release for intro | — |

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