

## MAX6069

## 1 $\mu$ A Ultra-Tiny Shunt Voltage Reference

### General Description

The MAX6069 ultra-low-power shunt references are ideal for space-critical and low-power applications. They are offered in a 4-bump wafer-level package (WLP), and the minimum operating current is guaranteed to be less than 1 $\mu$ A. These references feature low temperature coefficients of less than 20ppm/ $^{\circ}$ C and initial accuracy of better than 0.2%.

Available with +1.25V, +2.048V, +2.5V, and 3V output voltages, these references can be used as lower-power, higher-precision upgrades to the ICL8069, LM385, LT1004, and LM4040 in much smaller packages. Two grades are available: A and B. The A grade features a temperature coefficient of 25ppm/ $^{\circ}$ C over the extended temperature range of  $-40^{\circ}$ C to  $+85^{\circ}$ C, with an initial accuracy of 0.2%. Grade B features a temperature coefficient of 50ppm/ $^{\circ}$ C over the extended temperature range of  $-40^{\circ}$ C to  $+85^{\circ}$ C, with an initial accuracy of 0.5%. Their tiny wafer-level packages make these references ideal for equipment with very small form factors.

### Applications

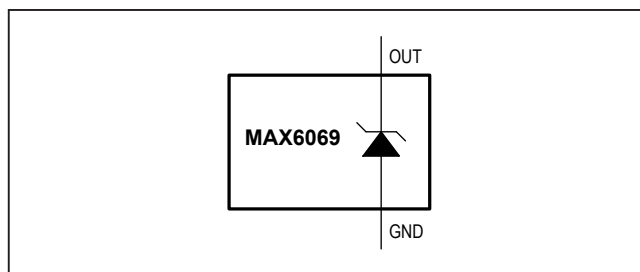
- Portable Sensors
- Portable Meters
- Precision Regulators
- A/D and D/A Converters
- 4mA–20mA Loop-Powered Sensors

### Benefits and Features

- Wide Operating Current Range: 1 $\mu$ A to 2mA
- 0.88mm x 1.16mm, 4-Bump WLP
- Initial Voltage Accuracy: 0.2%
- Temperature Coefficient: 20ppm/ $^{\circ}$ C (max)
- Temperature Range:  $-40^{\circ}$ C to  $+125^{\circ}$ C
- Factory-Trimmed Output Voltages: +1.25V, +2.048V, +2.5V, +3.0V
- Functionally Equivalent to the MAX6006/MAX6007/MAX6008/MAX6009

Ordering Information appears at end of data sheet.

### Simplified Block Diagram



## Absolute Maximum Ratings

Operating Current (OUT to GND) ..... 20mA  
 Forward Current (GND to OUT) ..... 20mA  
 Continuous Power Dissipation (Multilayer Board;  
 derate 9.75mW/°C above +70°C) ..... 780mW

Operating Temperature Range ..... -40°C to +125°C  
 Storage Temperature Range ..... -65°C to +150°C  
 Junction Temperature ..... +150°C  
 Soldering Temperature (reflow) ..... +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.

## Package Information

### WLP

|                                              |                                                |
|----------------------------------------------|------------------------------------------------|
| Package Code                                 | W40D1+1                                        |
| Outline Number                               | <a href="#">21-100139</a>                      |
| Land Pattern Number                          | Refer to <a href="#">Application Note 1891</a> |
| <b>Thermal Resistance, Four-Layer Board:</b> |                                                |
| Junction-to-Ambient ( $\theta_{JA}$ )        | 102.59°C/W                                     |
| Junction-to-Case ( $\theta_{JC}$ )           | N/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).

## Electrical Characteristics

( $T_A$  = -40°C to +125°C, unless otherwise noted., Typical values are at  $T_A$  = +25°C. (Note 1))

| PARAMETER                             | SYMBOL            | CONDITIONS                                                                 |                  | MIN    | TYP    | MAX    | UNITS |
|---------------------------------------|-------------------|----------------------------------------------------------------------------|------------------|--------|--------|--------|-------|
| MAX6069A (1.250V)                     |                   |                                                                            |                  |        |        |        |       |
| Reverse Breakdown Voltage             | V <sub>R</sub>    | T <sub>A</sub> = +25°C,<br>I <sub>R</sub> = 1.2µA                          | MAX6069AA (0.2%) | 1.2475 | 1.2500 | 1.2525 | V     |
|                                       |                   |                                                                            | MAX6069AB (0.5%) | 1.2438 | 1.2500 | 1.2563 |       |
| Minimum Operating Current             | I <sub>RMIN</sub> | V <sub>R</sub> change < 0.2% from V <sub>R</sub> at I <sub>R</sub> = 1.2µA |                  | 0.5    |        | 1.0    | µA    |
| Reverse Breakdown Change with Current |                   | I <sub>R</sub> = 1.2µA to 200µA                                            |                  |        |        | 1      | mV    |
|                                       |                   | I <sub>R</sub> = 200µA to 2mA                                              |                  |        |        | 2.0    |       |
| Reverse Dynamic Impedance             |                   | I <sub>R</sub> = 1.2µA to 2mA (Note 2)                                     |                  |        |        | 1.5    | Ω     |
| Low-Frequency Noise                   |                   | I <sub>R</sub> = 1.2µA, f = 0.1Hz to 10Hz                                  |                  | 30     |        |        | µVp-p |

## Electrical Characteristics (continued)

(T<sub>A</sub> = -40°C to +125°C, unless otherwise noted., Typical values are at T<sub>A</sub> = +25°C. (Note 1))

| PARAMETER                                | SYMBOL            | CONDITIONS                                                                 |                                  | MIN    | TYP    | MAX    | UNITS  |
|------------------------------------------|-------------------|----------------------------------------------------------------------------|----------------------------------|--------|--------|--------|--------|
| Temperature Coefficient<br>(Note 3)      | TC                | I <sub>R</sub> = 1.2μA,<br>MAX6069AA                                       | T <sub>A</sub> = -40°C to +85°C  |        |        | 20     | ppm/°C |
|                                          |                   | I <sub>R</sub> = 1.2μA,<br>MAX6069AA                                       | T <sub>A</sub> = -40°C to +125°C |        |        | 25     |        |
|                                          |                   | I <sub>R</sub> = 1.2μA,<br>MAX6069AB                                       | T <sub>A</sub> = -40°C to +85°C  |        |        | 50     |        |
|                                          |                   | I <sub>R</sub> = 1.2μA,<br>MAX6069AB                                       | T <sub>A</sub> = -40°C to +125°C |        |        | 75     |        |
| Long-Term Drift                          |                   | 1000h at T <sub>A</sub> = +25°C                                            |                                  |        | 150    |        | ppm    |
| Thermal Hysteresis (Note 4)              |                   |                                                                            |                                  |        | 200    |        | ppm    |
| MAX6069B (2.048V)                        |                   |                                                                            |                                  |        |        |        |        |
| Reverse Breakdown Voltage                | V <sub>R</sub>    | T <sub>A</sub> = +25°C,<br>I <sub>R</sub> = 1.2μA                          | MAX6069BA (0.2%)                 | 2.0439 | 2.048  | 2.0521 | V      |
|                                          |                   |                                                                            | MAX6069BB (0.5%)                 | 2.0378 | 2.048  | 2.0582 |        |
| Minimum Operating Current                | I <sub>RMIN</sub> | V <sub>R</sub> change < 0.2% from V <sub>R</sub> at I <sub>R</sub> = 1.2μA |                                  |        | 0.5    | 1.0    | μA     |
| Reverse Breakdown Change<br>with Current |                   | I <sub>R</sub> = 1.2μA to 200μA                                            |                                  |        |        | 1.3    | mV     |
|                                          |                   | I <sub>R</sub> = 200μA to 2mA                                              |                                  |        |        | 2.3    |        |
| Reverse Dynamic<br>Impedance             |                   | I <sub>R</sub> = 1.2μA to 2mA (Note 2)                                     |                                  |        |        | 1.8    | Ω      |
| Low-Frequency Noise                      |                   | I <sub>R</sub> = 1.2μA, f = 0.1Hz to 10Hz                                  |                                  |        | 50     |        | μVp-p  |
| Temperature Coefficient<br>(Note 3)      | TC                | I <sub>R</sub> = 1.2μA,<br>MAX6069BA                                       | T <sub>A</sub> = -40°C to +85°C  |        |        | 20     | ppm/°C |
| Temperature Coefficient<br>(Note 3)      | TC                | I <sub>R</sub> = 1.2μA,<br>MAX6069BA                                       | T <sub>A</sub> = -40°C to +125°C |        |        | 25     | ppm/°C |
| Temperature Coefficient<br>(Note 3)      | TC                | I <sub>R</sub> = 1.2μA,<br>MAX6069BB                                       | T <sub>A</sub> = -40°C to +85°C  |        |        | 50     | ppm/°C |
| Temperature Coefficient<br>(Note 3)      | TC                | I <sub>R</sub> = 1.2μA,<br>MAX6069BB                                       | T <sub>A</sub> = -40°C to +125°C |        |        | 75     | ppm/°C |
| Long-Term Drift                          |                   | 1000h at T <sub>A</sub> = +25°C                                            |                                  |        | 150    |        | ppm    |
| Thermal Hysteresis (Note 4)              |                   |                                                                            |                                  |        | 200    |        | ppm    |
| MAX6069C (2.500V)                        |                   |                                                                            |                                  |        |        |        |        |
| Reverse Breakdown Voltage                | V <sub>R</sub>    | T <sub>A</sub> = +25°C,<br>I <sub>R</sub> = 1.2μA                          | MAX6069CA (0.2%)                 | 2.4950 | 2.5000 | 2.5050 | V      |
|                                          |                   |                                                                            | MAX6069CB (0.5%)                 | 2.4875 | 2.5000 | 2.5125 |        |
| Minimum Operating Current                | I <sub>RMIN</sub> | V <sub>R</sub> change < 0.2% from V <sub>R</sub> at I <sub>R</sub> = 1.2μA |                                  |        | 0.5    | 1.0    | μA     |
| Reverse Breakdown Change<br>with Current |                   | I <sub>R</sub> = 1.2μA to 200μA                                            |                                  |        |        | 1.5    | mV     |
|                                          |                   | I <sub>R</sub> = 200μA to 2mA                                              |                                  |        |        | 2.5    |        |
| Reverse Dynamic<br>Impedance             |                   | I <sub>R</sub> = 1.2μA to 2mA (Note 2)                                     |                                  |        |        | 2      | Ω      |

## Electrical Characteristics (continued)

(T<sub>A</sub> = -40°C to +125°C, unless otherwise noted., Typical values are at T<sub>A</sub> = +25°C. (Note 1))

| PARAMETER                                | SYMBOL            | CONDITIONS                                                                 |                                  | MIN    | TYP    | MAX    | UNITS |
|------------------------------------------|-------------------|----------------------------------------------------------------------------|----------------------------------|--------|--------|--------|-------|
| Low-Frequency Noise                      |                   | I <sub>R</sub> = 1.2μA, f = 0.1Hz to 10Hz                                  |                                  | 60     |        |        | μVp-p |
| Temperature Coefficient<br>(Note 3)      | TC                | I <sub>R</sub> = 1.2μA,<br>MAX6069CA                                       | T <sub>A</sub> = -40°C to +85°C  | 20     |        | ppm/°C |       |
|                                          |                   |                                                                            | T <sub>A</sub> = -40°C to +125°C | 25     |        |        |       |
|                                          |                   | I <sub>R</sub> = 1.2μA,<br>MAX6069CB                                       | T <sub>A</sub> = -40°C to +85°C  | 50     |        |        |       |
|                                          |                   |                                                                            | T <sub>A</sub> = -40°C to +125°C | 75     |        |        |       |
| Long-Term Drift                          |                   | 1000h at T <sub>A</sub> = +25°C                                            |                                  | 150    |        |        | ppm   |
| Thermal Hysteresis (Note 4)              |                   |                                                                            |                                  | 200    |        |        | ppm   |
| MAX6069D (3.00V)                         |                   |                                                                            |                                  |        |        |        |       |
| Reverse Breakdown Voltage                | V <sub>R</sub>    | T <sub>A</sub> = +25°C,<br>I <sub>R</sub> = 1.2μA                          | MAX6069DA (0.2%)                 | 2.9940 | 3.0000 | 3.0060 | V     |
|                                          |                   |                                                                            | MAX6069DB (0.5%)                 | 2.9850 | 3.0000 | 3.0150 |       |
| Minimum Operating Current                | I <sub>RMIN</sub> | V <sub>R</sub> change < 0.2% from V <sub>R</sub> at I <sub>R</sub> = 1.2μA |                                  | 0.5    |        | 1.0    | μA    |
| Reverse Breakdown<br>Change with Current |                   | I <sub>R</sub> = 1.2μA to 200μA                                            |                                  |        |        | 1.7    | mV    |
|                                          |                   | I <sub>R</sub> = 200μA to 2mA                                              |                                  |        |        | 2.7    |       |
| Reverse Dynamic<br>Impedance             |                   | I <sub>R</sub> = 1.2μA to 2mA (Note 2)                                     |                                  |        |        | 2.2    | Ω     |
| Low-Frequency Noise                      |                   | I <sub>R</sub> = 1.2μA, f = 0.1Hz to 10Hz                                  |                                  | 75     |        |        | μVp-p |
| Temperature Coefficient<br>(Note 3)      | TC                | I <sub>R</sub> = 1.2μA,<br>MAX6069DA                                       | T <sub>A</sub> = -40°C to +85°C  | 20     |        | ppm/°C |       |
|                                          |                   | I <sub>R</sub> = 1.2μA,<br>MAX6069DA                                       | T <sub>A</sub> = -40°C to +125°C | 25     |        |        |       |
|                                          |                   | I <sub>R</sub> = 1.2μA,<br>MAX6069DB                                       | T <sub>A</sub> = -40°C to +85°C  | 50     |        |        |       |
|                                          |                   | I <sub>R</sub> = 1.2μA,<br>MAX6069DB                                       | T <sub>A</sub> = -40°C to +125°C | 75     |        |        |       |
| Long-Term Drift                          |                   | 1000h at T <sub>A</sub> = +25°C                                            |                                  | 150    |        |        | ppm   |
| Thermal Hysteresis (Note 4)              |                   |                                                                            |                                  | 200    |        |        | ppm   |

**Note 1:** All units are 100% production tested at T<sub>A</sub> = +25°C and are guaranteed by design and characterization for T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>, as specified.

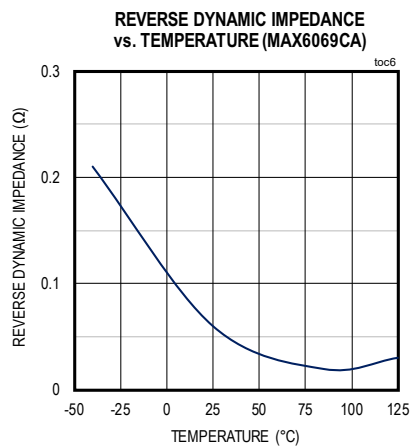
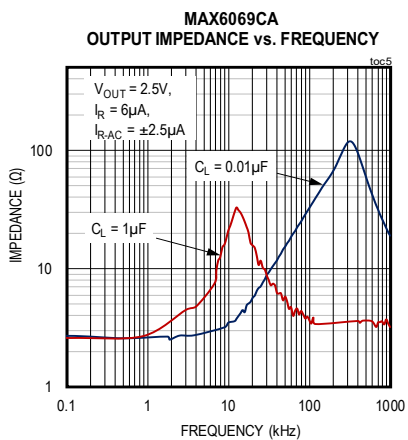
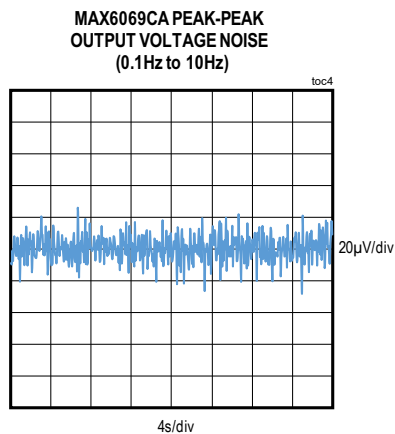
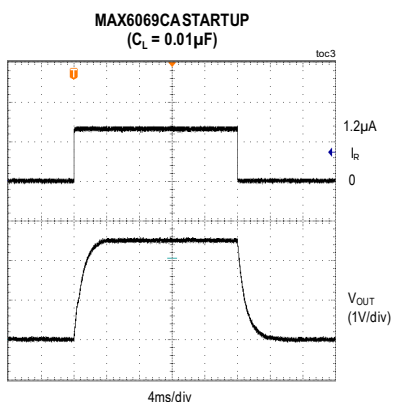
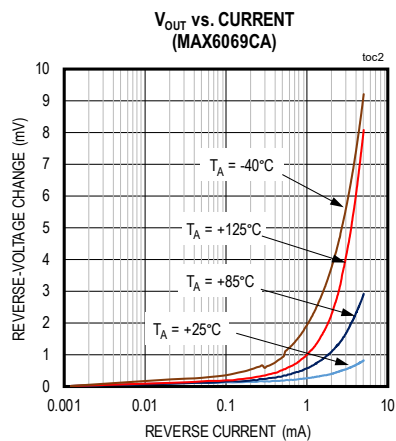
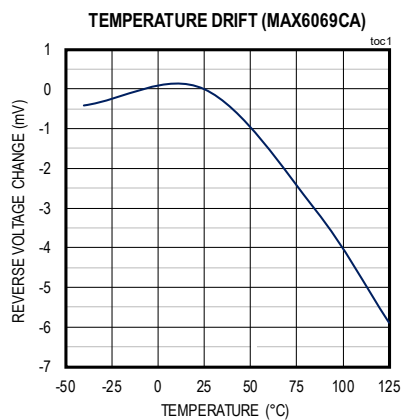
**Note 2:** This parameter is guaranteed by the “reverse breakdown change with current” test.

**Note 3:** TC is measured by the “box” method; i.e., (V<sub>MAX</sub> - V<sub>MIN</sub>)/(T<sub>MAX</sub> - T<sub>MIN</sub>).

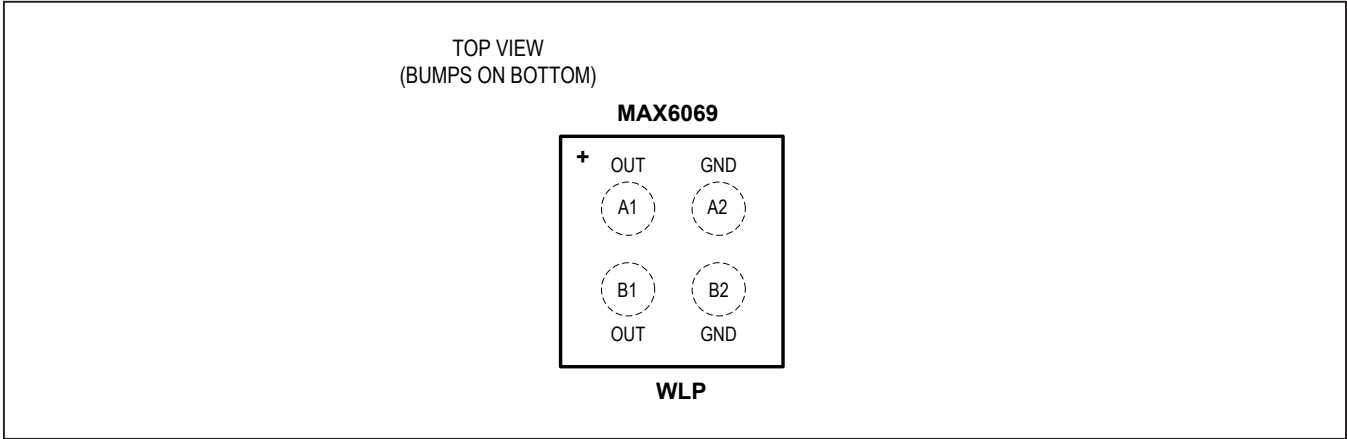
**Note 4:** Thermal hysteresis is defined as the change in the +25°C output voltage after cycling a unit from T<sub>MIN</sub> to T<sub>MAX</sub>.

## Typical Operating Characteristics

( $T_A = +25^\circ\text{C}$ , unless otherwise noted.)



Pin Configuration



Pin Description

| PIN | NAME | FUNCTION                                                                                                                              |
|-----|------|---------------------------------------------------------------------------------------------------------------------------------------|
| A1  | OUT  | Output Voltage. Bias OUT with a pullup resistor to a potential greater than OUT. Bypass OUT to GND with a 0.01μF or larger capacitor. |
| A2  | GND  | Ground                                                                                                                                |
| B1  | OUT  | Output Voltage. B1 is shorted to A1 internally.                                                                                       |
| B2  | GND  | Ground. B2 is shorted to A2 internally.                                                                                               |

Detailed Description

The MAX6069 family consists of precision, two-terminal, shunt bandgap voltage references. On-chip, thin-film resistors are laser-trimmed to provide 0.2% output voltage accuracies. Voltages of +1.25V, +2.048V, +2.5V, and +3.0V are available in a space-saving 4-bump WLP.

Applications Information

Output/Load Capacitance

Bypass OUT to GND with a 0.01μF or larger capacitor. In applications where the load or the supply can experience step changes, additional capacitance will reduce the amount of overshoot (or undershoot) and assist the circuit’s transient response.

Output Voltage Hysteresis

Output voltage hysteresis is the change in the output voltage at  $T_A = +25^{\circ}\text{C}$  before and after the device is cycled over its entire operating temperature range. Hysteresis is caused by differential package stress appearing across the bandgap core transistors. The temperature hysteresis value is typically less than 200ppm.

Turn-On Time

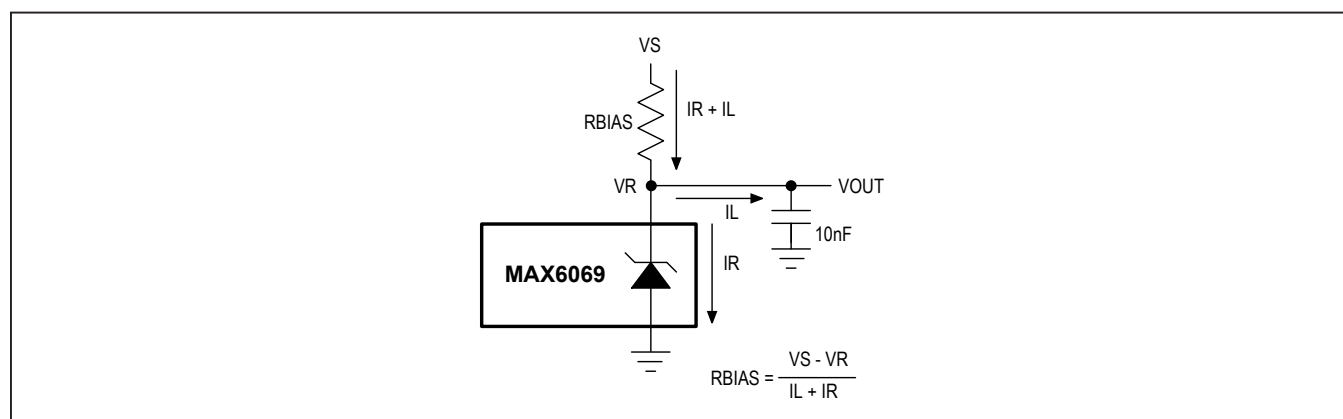
The output capacitance and bias current of the MAX6069 greatly affect turn-on settling time. In the [Typical Operating Characteristics](#), turn-on time is shown with a 10nF output capacitor and a 1.2μA bias current. Under these conditions, the MAX6069 settles in about 4ms. Settling time linearly decreases in proportion to the circuit’s bias current.

## Typical Application Circuits

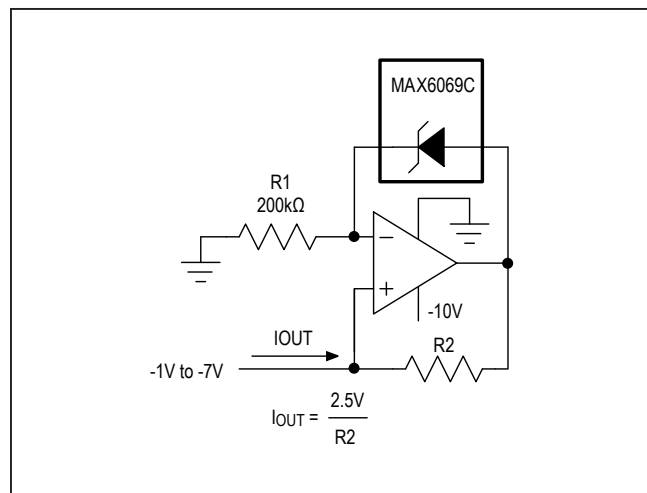
### Shunt Regulator Connection

In the typical shunt regulator connection shown here,  $R_{BIAS}$  sets the current through the load ( $I_L$ ) and the current through the shunt regulator ( $I_R$ ). There are two worst-case situations that  $R_{BIAS}$  needs to be sized for:

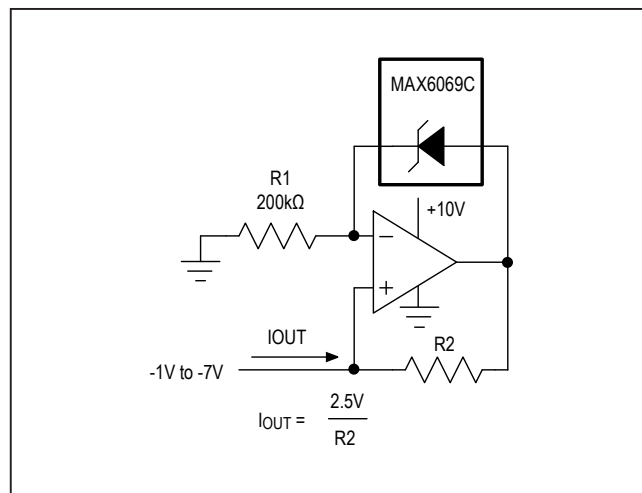
- 1)  $R_{BIAS}$  must be small enough that when  $V_S$  (supply voltage) is at its minimum and  $I_L$  is at its maximum,  $I_R$  is equal to at least the minimum operating current of the shunt regulator.
- 2)  $R_{BIAS}$  must be large enough that when  $V_S$  is at its maximum and  $I_L$  is at its minimum,  $I_R$  is  $< 2\text{mA}$ .



### Precision Current Sink



### Precision Current Sink



## Ordering Information

| PART NUMBER     | OUTPUT VOLTAGE (V) | INITIAL ACCURACY (%) | TEMP COEFFICIENT (PPM/°C) | PIN-PACKAGE | TOP MARK |
|-----------------|--------------------|----------------------|---------------------------|-------------|----------|
| MAX6069AAAWS+*  | 1.250              | 0.2                  | 20                        | 4 WLP       | +AM      |
| MAX6069AAAWS+T* | 1.250              | 0.2                  | 20                        | 4 WLP       | +AM      |
| MAX6069ABAWS+*  | 1.250              | 0.5                  | 50                        | 4 WLP       | +AN      |
| MAX6069ABAWS+T* | 1.250              | 0.5                  | 50                        | 4 WLP       | +AN      |
| MAX6069BAAWS+*  | 2.048              | 0.2                  | 20                        | 4 WLP       | +AO      |
| MAX6069BAAWS+T* | 2.048              | 0.2                  | 20                        | 4 WLP       | +AO      |
| MAX6069BBAWS+*  | 2.048              | 0.5                  | 50                        | 4 WLP       | +AP      |
| MAX6069BBAWS+T* | 2.048              | 0.5                  | 50                        | 4 WLP       | +AP      |
| MAX6069CAAWS+   | 2.500              | 0.2                  | 20                        | 4 WLP       | +AQ      |
| MAX6069CAAWS+T  | 2.500              | 0.2                  | 20                        | 4 WLP       | +AQ      |
| MAX6069CBAWS+   | 2.500              | 0.5                  | 50                        | 4 WLP       | +AR      |
| MAX6069CBAWS+T  | 2.500              | 0.5                  | 50                        | 4 WLP       | +AR      |
| MAX6069DAAWS+*  | 3.000              | 0.2                  | 20                        | 4 WLP       | +AS      |
| MAX6069DAAWS+T* | 3.000              | 0.2                  | 20                        | 4 WLP       | +AS      |
| MAX6069DBAWS+*  | 3.000              | 0.5                  | 50                        | 4 WLP       | +AT      |
| MAX6069DBAWS+T* | 3.000              | 0.5                  | 50                        | 4 WLP       | +AT      |

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

T = Tape and reel.

\*Future product—contact factory for availability.

## Revision History

| REVISION<br>NUMBER | REVISION<br>DATE | DESCRIPTION     | PAGES<br>CHANGED |
|--------------------|------------------|-----------------|------------------|
| 0                  | 6/17             | Initial release | —                |

For pricing, delivery, and ordering information, please contact Maxim Direct at 1-888-629-4642, or visit Maxim Integrated's website at [www.maximintegrated.com](http://www.maximintegrated.com).

*Maxim Integrated cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in a Maxim Integrated product. No circuit patent licenses are implied. Maxim Integrated reserves the right to change the circuitry and specifications without notice at any time. The parametric values (min and max limits) shown in the Electrical Characteristics table are guaranteed. Other parametric values quoted in this data sheet are provided for guidance.*