

# MAX6006–MAX6009

# 1µA SOT23 Precision Shunt Voltage Reference

## General Description

The MAX6006–MAX6009 ultra-low-power shunt references are ideal for space-critical and low-power applications. They are offered in 3-pin SOT23 packages, and the minimum operating current is guaranteed to be <1µA. The devices feature low temperature coefficients of <30ppm/°C and initial accuracy of better than 0.2%.

Available in +1.25V, +2.048V, +2.5V, and 3V output voltages, the MAX6006–MAX6009 have references of +1.25V, +2.048V, +2.5V, and +3.0V, respectively. The devices can be used as lower-power, higher-precision upgrades to the ICL8069, LM385, LT1004, and LM4040 references. The MAX6006–MAX6009 are available in two grades: A and B. The A grade features a temperature coefficient of 30ppm/°C over the extended temperature range of -40°C to +85°C, with an initial accuracy of 0.2%. Grade B features a temperature coefficient of 75ppm/°C with an initial accuracy of 0.5%. MAX6006 in +1.25V and MAX6008 in +2.5V are offered in 8-pin SO packages, as plug in upgrades for LT1004 and LM285.

## Features

- Ultra-Low Operating Current: Guaranteed < 1µA
- Small 3-Pin SOT23 Package
- Initial Voltage Accuracy: 0.2%
- Temperature Coefficient: 30ppm/°C max
- Temperature Range: -40°C to +85°C
- Factory-Trimmed Output Voltages: +1.25V, +2.048V, +2.5V, +3.0V
- Wide Operating Range: 1µA to 2mA
- AEC-Q100 (MAX6008AEUR/V+ Only)

## Applications

- Battery-Powered Equipment
- Portable Meters
- Precision Regulators
- A/D and D/A Converters

## Ordering Information

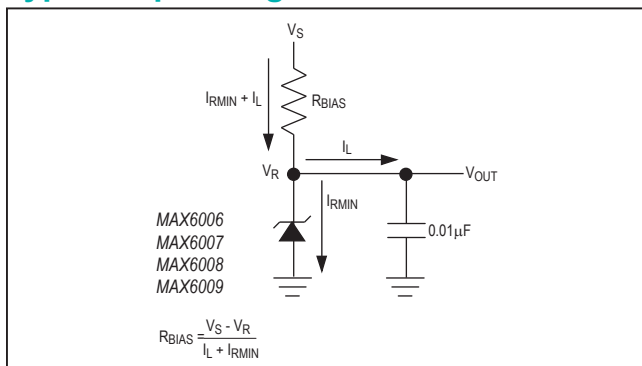
| PART          | OUTPUT VOLTAGE (V) | INITIAL ACCURACY (%) | TEMP COEFFICIENT (ppm/°C) | PIN-PACKAGE | TOP MARK |
|---------------|--------------------|----------------------|---------------------------|-------------|----------|
| MAX6006AEUR+T | 1.25               | 0.2                  | 30                        | 3 SOT23     | +FZGH    |
| MAX6006AESA+  | 1.25               | 0.2                  | 30                        | 8 SO        | —        |
| MAX6006BEUR+T | 1.25               | 0.5                  | 75                        | 3 SOT23     | +FZGI    |
| MAX6006BESA+  | 1.25               | 0.5                  | 75                        | 8 SO        | —        |
| MAX6007AEUR+T | 2.048              | 0.2                  | 30                        | 3 SOT23     | +FZGK    |
| MAX6007AESA+  | 2.048              | 0.2                  | 30                        | 8 SO        | —        |

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

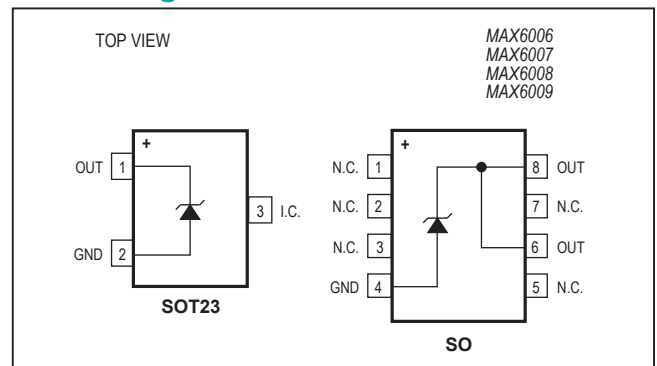
T = Tape and reel.

Ordering Information continued at end of data sheet.

## Typical Operating Circuit



## Pin Configurations



**Absolute Maximum Ratings**

|   |          |   |                 |
|---|----------|---|-----------------|
| Operating Current (OUT to GND) .....                  | 20mA     | Operating Temperature Range.....        | -40°C to +85°C  |
| Forward Current (GND to OUT).....                     | 20mA     | Storage Temperature Range.....          | -65°C to +150°C |
| Continuous Power Dissipation (T <sub>A</sub> = +70°C) |          | Lead Temperature (soldering, 10s) ..... | +300°C          |
| 3-Pin SOT23 (derate 3.65mW/°C above +70°C) ...        | 291.73mW | Soldering Temperature (reflow).....     | +260°C          |
| 8-Pin SO (derate 7.4mW/°C above +70°C).....           | 588.2mW  |   |                 |

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**

**3 SOT23**

| PACKAGE CODE                                 | U3+1                    |
|--|-------------------------|
| Outline Number                               | <a href="#">21-0051</a> |
| Land Pattern Number                          | <a href="#">90-0179</a> |
| <b>Thermal Resistance, Multilayer Board:</b> |                         |
| Junction to Ambient (θ <sub>JA</sub> )       | 274.23°C/W              |
| Junction to Case (θ <sub>JC</sub> )          | 86.19°C/W               |

**8 SO**

| PACKAGE CODE                                 | S8+2                    |
|--|-------------------------|
| Outline Number                               | <a href="#">21-0041</a> |
| Land Pattern Number                          | <a href="#">90-0096</a> |
| <b>Thermal Resistance, Multilayer Board:</b> |                         |
| Junction to Ambient (θ <sub>JA</sub> )       | 136°C/W                 |
| Junction to Case (θ <sub>JC</sub> )          | 38°/W                   |

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—MAX6006**

(T<sub>A</sub> = -40°C to +85°C, unless otherwise noted. Typical values are at T<sub>A</sub> = +25°C.) (Note 1)

| PARAMETER                             | SYMBOL            | CONDITIONS   | MIN             | TYP    | MAX    | UNITS             |   |
|---------------------------------------|-------------------|--|-----------------|--------|--------|-------------------|---|
| Reverse Breakdown Voltage             | V <sub>R</sub>    | T <sub>A</sub> = +25°C,<br>I <sub>R</sub> = 1.2µA                          | MAX6006A (0.2%) | 1.2475 | 1.2500 | 1.2525            | V |
|                                       |                   |  | MAX6006B (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  |                 |        | 1.0    | 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     |        | µV <sub>P-P</sub> |   |
| Temperature Coefficient (Note 3)      | TC                | I <sub>R</sub> = 1.2µA   | MAX6006A        |        | 30     | ppm/°C            |   |
|                                       |                   |  | MAX6006B        |        | 75     |                   |   |
| Long-Term Drift                       |                   | 1000h at T <sub>A</sub> = +25°C  |                 | 150    |        | ppm               |   |
| Thermal Hysteresis (Note 4)           |                   |  |                 | 200    |        | ppm               |   |

**Electrical Characteristics—MAX6007**(T<sub>A</sub> = -40°C to +85°C, unless otherwise noted. Typical values are at T<sub>A</sub> = +25°C.) (Note 1)

| PARAMETER                             | SYMBOL            | CONDITIONS   | MIN             | TYP    | MAX   | UNITS                  |   |
|---------------------------------------|-------------------|--|-----------------|--------|-------|------------------------|---|
| Reverse Breakdown Voltage             | V <sub>R</sub>    | T <sub>A</sub> = +25°C,<br>I <sub>R</sub> = 1.2 $\mu$ A                          | MAX6007A (0.2%) | 2.0439 | 2.048 | 2.0521                 | V |
|                                       |                   |  | MAX6007B (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> = 1.2 $\mu$ A |                 | 0.5    | 1.0   | $\mu$ A                |   |
| Reverse Breakdown Change with Current |                   | I <sub>R</sub> = 1.2 $\mu$ A to 200 $\mu$ A                                      |                 |        | 1.3   | mV                     |   |
|                                       |                   | I <sub>R</sub> = 200 $\mu$ A to 2mA  |                 |        | 2.3   |                        |   |
| Reverse Dynamic Impedance             |                   | I <sub>R</sub> = 1.2 $\mu$ A to 2mA (Note 2)                                     |                 |        | 1.8   | $\Omega$               |   |
| Low-Frequency Noise                   |                   | I <sub>R</sub> = 1.2 $\mu$ A, f = 0.1Hz to 10Hz                                  |                 | 50     |       | $\mu$ V <sub>P-P</sub> |   |
| Temperature Coefficient (Note 3)      | TC                | I <sub>R</sub> = 1.2 $\mu$ A   | MAX6007A        |        | 30    | ppm/°C                 |   |
|                                       |                   |  | MAX6007B        |        | 75    |                        |   |
| Long-Term Drift                       |                   | 1000h at T <sub>A</sub> = +25°C  |                 | 150    |       | ppm                    |   |
| Thermal Hysteresis (Note 4)           |                   |  |                 | 200    |       | ppm                    |   |

**Electrical Characteristics—MAX6008**(T<sub>A</sub> = -40°C to +85°C, unless otherwise noted. Typical values are at T<sub>A</sub> = +25°C.) (Note 1)

| PARAMETER                             | SYMBOL            | CONDITIONS   | MIN             | TYP    | MAX    | UNITS                  |   |
|---------------------------------------|-------------------|--|-----------------|--------|--------|------------------------|---|
| Reverse Breakdown Voltage             | V <sub>R</sub>    | T <sub>A</sub> = +25°C,<br>I <sub>R</sub> = 1.2 $\mu$ A                          | MAX6008A (0.2%) | 2.4950 | 2.5000 | 2.5050                 | V |
|                                       |                   |  | MAX6008B (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> = 1.2 $\mu$ A |                 | 0.5    | 1.0    | $\mu$ A                |   |
| Reverse Breakdown Change with Current |                   | I <sub>R</sub> = 1.2 $\mu$ A to 200 $\mu$ A                                      |                 |        | 1.5    | mV                     |   |
|                                       |                   | I <sub>R</sub> = 200 $\mu$ A to 2mA  |                 |        | 2.5    |                        |   |
| Reverse Dynamic Impedance             |                   | I <sub>R</sub> = 1.2 $\mu$ A to 2mA (Note 2)                                     |                 |        | 2      | $\Omega$               |   |
| Low-Frequency Noise                   |                   | I <sub>R</sub> = 1.2 $\mu$ A, f = 0.1Hz to 10Hz                                  |                 | 60     |        | $\mu$ V <sub>P-P</sub> |   |
| Temperature Coefficient (Note 3)      | TC                | I <sub>R</sub> = 1.2 $\mu$ A   | MAX6008A        |        | 30     | ppm/°C                 |   |
|                                       |                   |  | MAX6008B        |        | 75     |                        |   |
| Long-Term Drift                       |                   | 1000h at T <sub>A</sub> = +25°C  |                 | 150    |        | ppm                    |   |
| Thermal Hysteresis (Note 4)           |                   |  |                 | 200    |        | ppm                    |   |

**Electrical Characteristics—MAX6009**

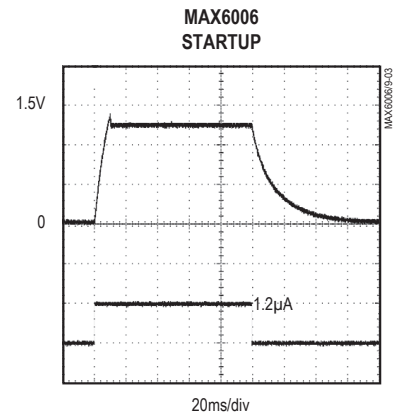
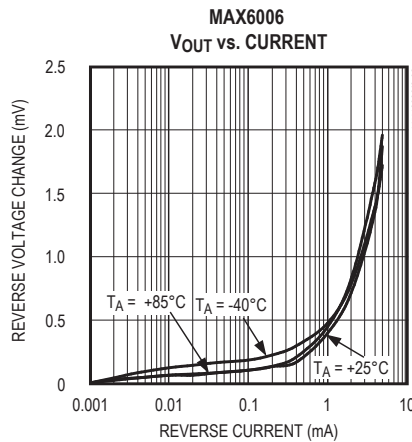
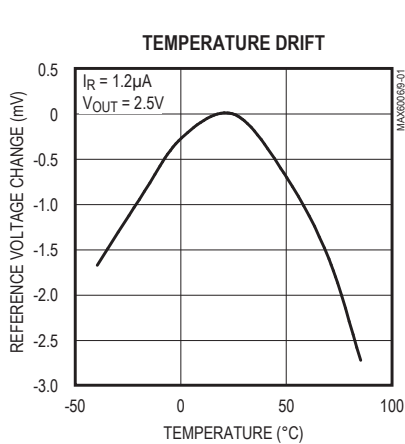
(T<sub>A</sub> = -40°C to +85°C, unless otherwise noted. Typical values are at T<sub>A</sub> = +25°C.) (Note 1)

| PARAMETER                             | SYMBOL            | CONDITIONS   |                 | MIN    | TYP   | MAX    | UNITS             |
|---------------------------------------|-------------------|--|-----------------|--------|-------|--------|-------------------|
| Reverse Breakdown Voltage             | V <sub>R</sub>    | T <sub>A</sub> = +25°C,<br>I <sub>R</sub> = 1.2μA                          | MAX6009A (0.2%) | 2.9940 | 3.000 | 3.0060 | V                 |
|                                       |                   |  | MAX6009B (0.5%) | 2.9850 | 3.000 | 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 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 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    |        | μV <sub>P-P</sub> |
| Temperature Coefficient (Note 3)      | TC                | I <sub>R</sub> = 1.2μA   | MAX6009A        |        |       | 30     | ppm/°C            |
|                                       |                   |  | MAX6009B        |        |       | 75     |                   |
| Long-Term Drift                       |                   | 1000h at T <sub>A</sub> = +25°C  |                 |        | 150   |        | ppm               |
| Thermal Hysteresis (Note 4)           |                   |  |                 |        | 200   |        | ppm               |

- Note 1:** All devices are 100% production tested at T<sub>A</sub> = +25°C and are guaranteed by design 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 the device from T<sub>MIN</sub> to T<sub>MAX</sub>.

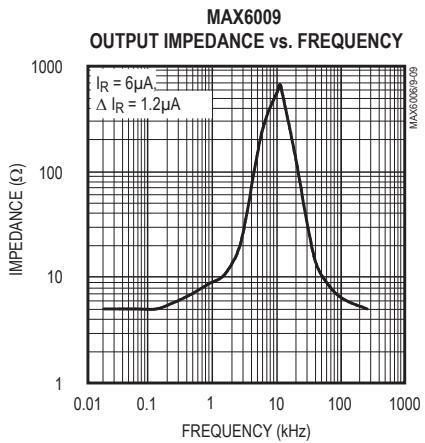
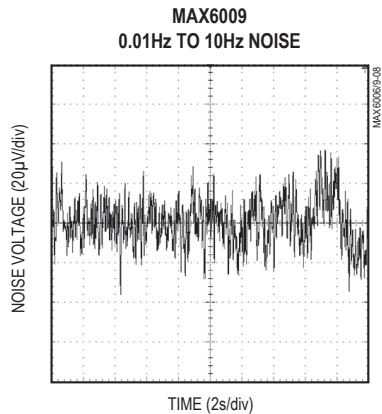
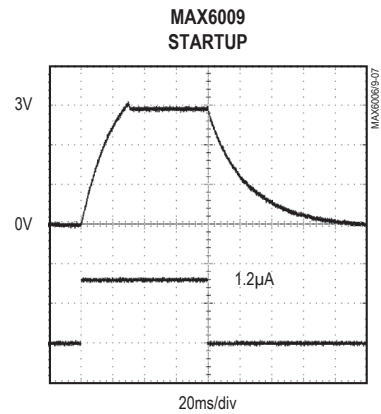
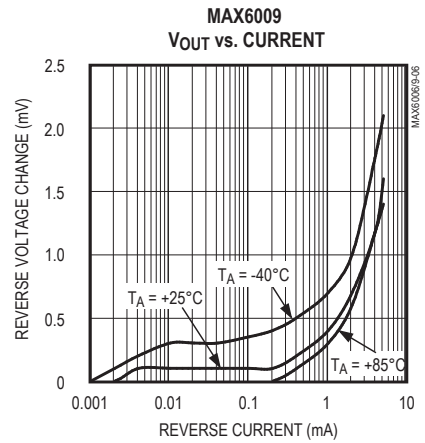
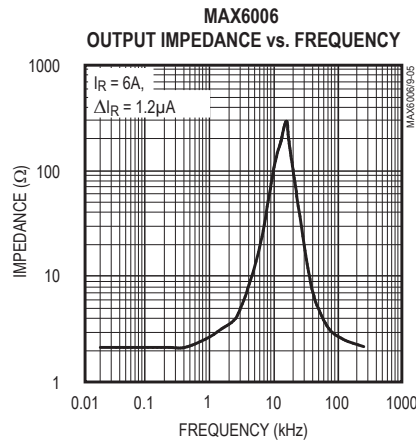
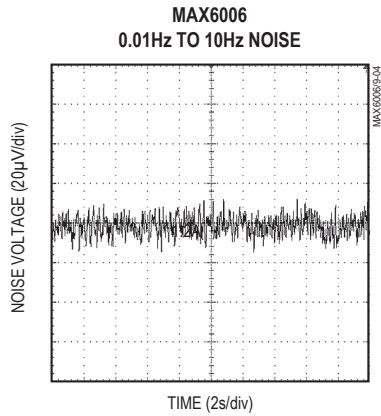
**Typical Operating Characteristics**

(C<sub>L</sub> = 0.01μF, T<sub>A</sub> = +25°C, unless otherwise noted.)



Typical Operating Characteristics (continued)

( $C_L = 0.01\mu\text{F}$ ,  $T_A = +25^\circ\text{C}$ , unless otherwise noted.)



### Pin Description

| PIN   |               | NAME | FUNCTION  |
|-------|---------------|------|---|
| SOT23 | SO            |      |   |
| 1     | 6, 8          | 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. |
| 2     | 4             | GND  | Ground  |
| 3     | —             | IC   | Internally connected test point. Leave this pin unconnected, or connect to GND.   |
| —     | 1, 2, 3, 5, 7 | N.C. | No connection. Not internally connected.  |

### Detailed Description

The MAX6006–MAX6009 are precision, two-terminal, series 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 the space-saving SOT23 package (2.1mm x 2.7mm).

### Applications Information

#### Output/Load Capacitance

For devices in this family, OUT needs to be bypassed 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 MAX6006–MAX6009 greatly affects 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 MAX6006–MAX6009 settle in 40ms. Settling time will linearly decrease in proportion to the circuit’s bias current.

### Typical Applications

In the typical shunt regulator application shown in Figure 1,  $R_{BIAS}$  is used to set the current through the load ( $I_L$ ) and the current through the shunt regulator ( $I_{RMIN}$ ). 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,  $I_{RMIN}$  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,  $I_{RMIN}$  is  $< 2\text{mA}$ .

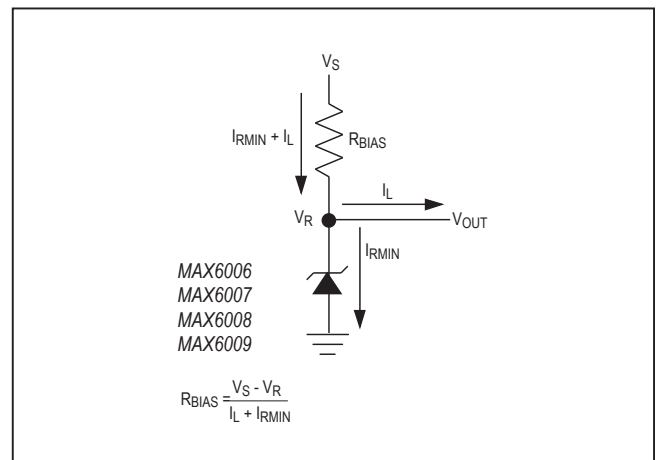


Figure 1. Typical Application Circuit

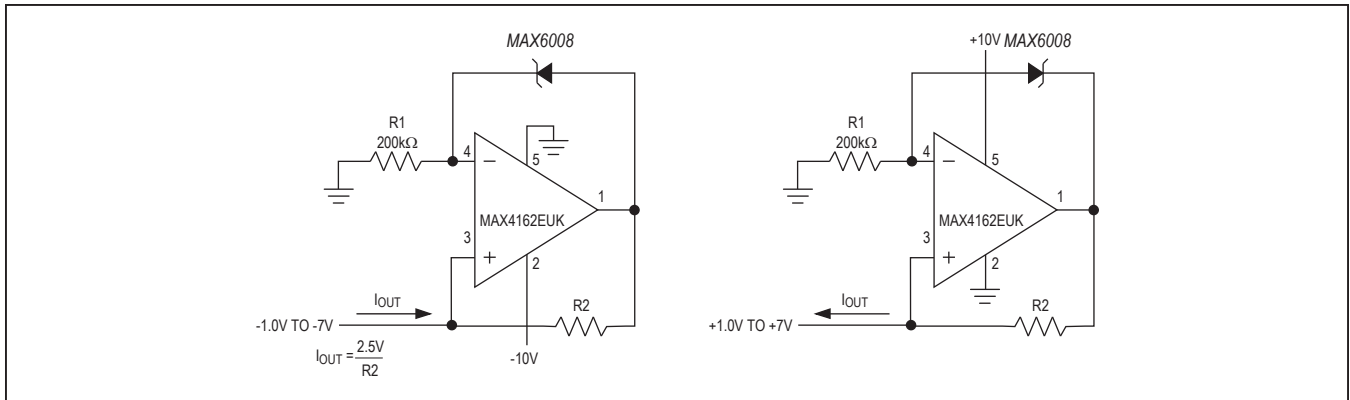


Figure 2. Precision 1µA to 1mA Current Sources

### Ordering Information (continued)

| PART                  | OUTPUT VOLTAGE (V) | INITIAL ACCURACY (%) | TEMP COEFFICIENT (ppm/°C) | PIN-PACKAGE | TOP MARK |
|-----------------------|--------------------|----------------------|---------------------------|-------------|----------|
| MAX6007BEUR+T         | 2.048              | 0.5                  | 75                        | 3 SOT23     | +FZGL    |
| MAX6007BESA+          | 2.048              | 0.5                  | 75                        | 8 SO        | —        |
| <b>MAX6008</b> AEUR+T | 2.50               | 0.2                  | 30                        | 3 SOT23     | +FZGN    |
| MAX6008AEUR/V+T       | 2.50               | 0.2                  | 30                        | 3 SOT23     | +FZWO    |
| MAX6008AESA+          | 2.50               | 0.2                  | 30                        | 8 SO        | —        |
| MAX6008BEUR+T         | 2.50               | 0.5                  | 75                        | 3 SOT23     | +FZGO    |
| MAX6008BESA+          | 2.50               | 0.5                  | 75                        | 8 SO        | —        |
| <b>MAX6009</b> AEUR+T | 3.00               | 0.2                  | 30                        | 3 SOT23     | +FZGQ    |
| MAX6009AESA+          | 3.00               | 0.2                  | 30                        | 8 SO        | —        |
| MAX6009BEUR+T         | 3.00               | 0.5                  | 75                        | 3 SOT23     | +FZGR    |
| MAX6009BESA+          | 3.00               | 0.5                  | 75                        | 8 SO        | —        |

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

/V denotes an automotive qualified part.

T = Tape and reel.

### Chip Information

PROCESS: BiCMOS

## Revision History

| REVISION NUMBER | REVISION DATE | DESCRIPTION  | PAGES CHANGED |
|-----------------|---------------|--|---------------|
| 0               | 8/00          | Initial release  | —             |
| 1               | 7/12          | Added <i>N</i> to MAX6008 and updated <i>Ordering Information</i> .                      | 7             |
| 2               | 9/17          | Added AEC statement to <i>Features</i> section   | 1             |
| 3               | 8/19          | Updated <i>Typical Operating Characteristics</i>   | 4, 5          |
| 4               | 11/19         | Updated <i>Absolute Maximum Ratings</i> and added new <i>Package Information</i> section | 2             |

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