19-3142; Rev 5; 11/09

# Low IBIAS, +1.4V/800nA, Rail-to-Rail Op Amps with +1.2V Buffered Reference



## General Description

The single MAX4036/MAX4037 and dual MAX4038/MAX4039 operational amplifiers operate from a single +1.4V to +3.6V (without reference) or +1.8V to +3.6V (with reference) supply and consume only 800nA of supply current per amplifier, and 1.1µA for the optional reference. The MAX4036/MAX4038 feature a common-mode input voltage range from 0V to $V_{DD}$ - 0.4V at $V_{DD}$ = 1.4V. The MAX4037/MAX4039 feature a 1.232V voltage reference capable of sourcing 100µA and sinking 20µA.

The MAX4036–MAX4039s' rail-to-rail outputs drive 5kΩ loads to within 25mV of the rails. Ultra-low supply current, low operating voltage, and rail-to-rail outputs make the MAX4036–MAX4039 ideal for use in single-cell lithium-ion (Li+), or two-cell NiCd/NiMH/alkaline battery-powered applications.

The MAX4036 is available in an SC70 package, the MAX4037 in a SOT23 package, and the MAX4038/MAX4039 in UCSP™, µMAX®, and TDFN packages.

## Applications

Battery-Powered/Solar-Powered Systems

Portable Medical Instrumentation

Pagers and Cell Phones

Micropower Thermostats and Potentiostats

Electrometer Amplifiers

Remote Sensor Amplifiers

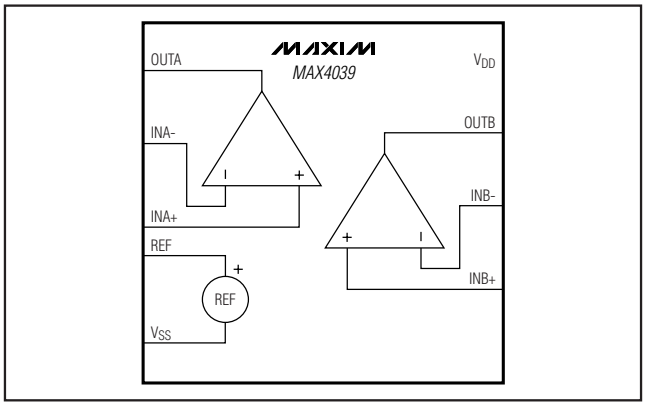
Active Badges

pH Meters

***Pin Configurations and Selector Guide appear at end of data sheet.***

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

## Functional Diagram




## Features

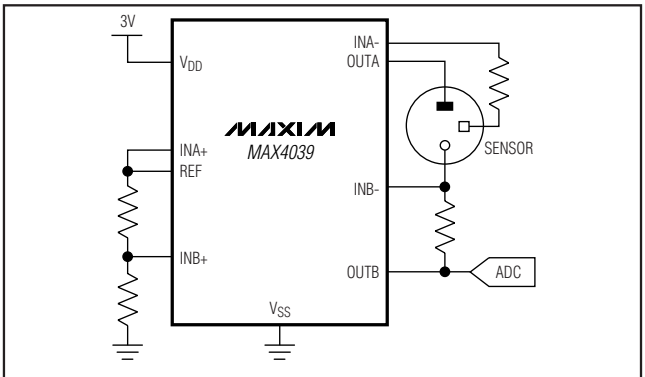
- **Ultra-Low 800nA per Amplifier Supply Current**
- **Ultra-Low 1.4V Supply Voltage Operation (1.8V for MAX4037/MAX4039)**
- **Rail-to-Rail Outputs Drive 5kΩ and 5000pF Load**
- **1.232V ±0.5%, 120ppm/°C (max) Reference (MAX4037/MAX4039)**
- **No External Reference Bypass Capacitor Required**
- **No Phase Reversal for Overdriven Inputs**
- **Low 1.0pA (typ) Input Bias Current**
- **Low 200µV Input Offset Voltage**
- **Unity-Gain Stable**
- **Available in Tiny UCSP, SC70, SOT23, TDFN, and µMAX Packages**
- **Available in -40°C to +125°C Temperature Range (MAX4036A/MAX4038A)**

## Ordering Information

| PART | TEMP RANGE | PIN-PACKAGE | TOP MARK |
|---|---|---|---|
| **MAX4036**EXK-T | -40°C to +85°C | 5 SC70 | AFR |
| MAX4036AAXK+T | -40°C to +125°C | 5 SC70 | ASN |
| **MAX4037**EUT-T | -40°C to +85°C | 6 SOT23 | ABRX |
| **MAX4038**ETA-T | -40°C to +85°C | 8 TDFN-EP* | AGO |
| MAX4038EUA | -40°C to +85°C | 8 µMAX | — |
| MAX4038EBL-T | -40°C to +85°C | 9 UCSP | AEG |
| MAX4038AAUA | -40°C to +125°C | 8 µMAX | — |

*+Denotes a lead(Pb)-free/RoHS-compliant package.*
*-Denotes a package containing lead.*
**EP = Exposed pad.*
***Ordering Information continued at end of data sheet.***

## Typical Operating Circuit




THREE-ELECTRODE POTENTIOSTAT APPLICATION



***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.***

# Low IBIAS, +1.4V/800nA, Rail-to-Rail Op Amps with +1.2V Buffered Reference

## ABSOLUTE MAXIMUM RATINGS

$V_{DD}$ to $V_{SS}$ .....-0.3V to +4.0V
INA+, INB+, INA-, INB-, IN+, IN-, OUTA, OUTB, OUT, REF .....($V_{SS}$ - 0.3V) to ($V_{DD}$ + 0.3V)
OUTA, OUTB, OUT, REF Shorted to $V_{SS}$ or $V_{DD}$ .....Continuous
Maximum Continuous Power Dissipation ($T_A$ = +70°C)
5-Pin SC70 (derate 3.1mW/°C above +70°C).....247mW
6-Pin SOT23 (derate 8.7mW/°C above +70°C).....696mW
8-Pin µMAX (derate 4.5mW/°C above +70°C).....362mW
8-Pin TDFN (derate 24.4mW/°C above +70°C) .....1951mW
9-Bump UCSP (derate 5.2mW/°C above +70°C).....412mW
10-Pin µMAX (derate 5.6mW/°C above +70°C).....444mW
10-Pin TDFN (derate 24.4mW/°C above +70°C) .....1951mW
Operating Temperature Range
MAX403_E_ _.....-40°C to +85°C
MAX403_A_ _ .....-40°C to +125°C
Junction Temperature .....+150°C
Storage Temperature Range .....-65°C to +150°C
Lead Temperature (soldering, 10s) .....+300°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

($V_{DD}$ = +3V, $V_{SS}$ = $V_{CM}$ = 0V, $V_{OUT_}$ = $V_{DD}$/2, $R_L$ to $V_{DD}$/2, $C_L$ = 15pF, **$T_A$ = +25°C**, unless otherwise specified.)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| Supply Voltage Range | $V_{DD}$ | MAX4036/MAX4038, guaranteed by PSRR tests | | 1.4 | | 3.6 | V |
| | | MAX4037/MAX4039, guaranteed by PSRR and line regulation tests | | 1.8 | | 3.6 | |
| Supply Current | $I_{DD}$ | MAX4036 | $V_{DD}$ = 1.4V | | 0.8 | 1.2 | µA |
| | | | $V_{DD}$ = 3.6V | | 0.9 | 1.3 | |
| | | MAX4037 | $V_{DD}$ = 1.8V | | 1.9 | 2.4 | |
| | | | $V_{DD}$ = 3.6V | | 2.0 | 2.5 | |
| | | MAX4038 | $V_{DD}$ = 1.4V | | 1.7 | 2.3 | |
| | | | $V_{DD}$ = 3.6V | | 1.9 | 2.5 | |
| | | MAX4039 | $V_{DD}$ = 1.8V | | 2.8 | 4.0 | |
| | | | $V_{DD}$ = 3.6V | | 3.0 | 4.1 | |
| **OPERATIONAL AMPLIFIERS** | | | | | | | |
| Input Offset Voltage | $V_{OS}$ | | | | ±0.2 | ±2.0 | mV |
| Input Bias Current | $I_B$ | (Note 1) | | | ±1.0 | ±10 | pA |
| Input Offset Current | $I_{OS}$ | (Note 1) | | | ±0.3 | ±20 | pA |
| Input Common-Mode Voltage Range | $V_{CM}$ | Guaranteed by CMRR test | $V_{DD}$ = 1.4V (MAX4036/MAX4038 only) | $V_{SS}$ | | $V_{DD}$ - 0.4 | V |
| | | | $V_{DD}$ = 1.8V | $V_{SS}$ | | $V_{DD}$ - 0.3 | |
| | | | $V_{DD}$ = 3.3V | $V_{SS}$ | | $V_{DD}$ - 0.2 | |
| Common-Mode Rejection Ratio | CMRR | $V_{DD}$ = 1.4V, $V_{SS} \le V_{CM} \le (V_{DD}$ - 0.4V) (MAX4036/MAX4038 only) | | 50 | 70 | | dB |
| | | $V_{DD}$ = 1.8V, $V_{SS} \le V_{CM} \le (V_{DD}$ - 0.3V) | | 50 | 70 | | |
| | | $V_{DD}$ = 3.3V, $V_{SS} \le V_{CM} \le (V_{DD}$ - 0.2V) | | 56 | 76 | | |
| Power-Supply Rejection Ratio | PSRR | 1.4V ≤ $V_{DD}$ ≤ 3.6V (MAX4036/MAX4038 only) | | 62 | 82 | | dB |
| | | 1.8V ≤ $V_{DD}$ ≤ 3.6V | | 62 | 84 | | |

## ELECTRICAL CHARACTERISTICS (continued)

($V_{DD}$ = +3V, $V_{SS}$ = $V_{CM}$ = 0V, $V_{OUT_}$ = $V_{DD}$/2, $R_L$ to $V_{DD}$/2, $C_L$ = 15pF, **$T_A$ = +25°C**, unless otherwise specified.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| Large-Signal Voltage Gain | $A_{VOL}$ | $R_L$ = 100kΩ, 50mV ≤ $V_{OUT}$ ≤ ($V_{DD}$ - 50mV) | 80 | 108 | | dB |
| | | $R_L$ = 5kΩ, 150mV ≤ $V_{OUT}$ ≤ ($V_{DD}$ - 150mV) | 78 | 105 | | |
| Output Voltage Swing High | $V_{DD}$ - $V_{OH}$ | $R_L$ = 100kΩ | | 2 | 5 | mV |
| | | $R_L$ = 5kΩ | | 25 | 50 | |
| Output Voltage Swing Low | $V_{OL}$ - $V_{SS}$ | $R_L$ = 100kΩ | | 2 | 5 | mV |
| | | $R_L$ = 5kΩ | | 25 | 50 | |
| Output Short-Circuit Current | $I_{SCO}$ | To $V_{DD}$ or $V_{SS}$ | | ±13 | | mA |
| Gain-Bandwidth Product | GBW | | | 4 | | kHz |
| Phase Margin | $\theta_M$ | | | 90 | | Degrees |
| Slew Rate | SR | | | 4 | | V/ms |
| Power-On Time | $t_{ON}$ | (Note 3) | | 0.25 | | ms |
| Input Noise-Voltage Density | $e_n$ | f = 1kHz | | 500 | | nV/√Hz |
| Capacitive-Load Stability | $C_{LOAD}$ | $A_{VCL}$ = 1V/V, no sustained oscillations | | 5000 | | pF |
| **REFERENCE (MAX4037/MAX4039)** | | | | | | |
| Reference Voltage | $V_{REF}$ | | 1.226 | 1.232 | 1.238 | V |
| Line Regulation | $\Delta V_{REF}/\Delta V_{DD}$ | $V_{DD}$ = +1.8V to +3.6V | | | 0.3 | %/V |
| Load Regulation | $\Delta V_{REF}/\Delta I_{LOAD}$ | 0 ≤ $I_{LOAD}$ ≤ 100µA, sourcing | | | 0.0015 | %/µA |
| | | -20µA ≤ $I_{LOAD}$ ≤ 0, sinking | | | 0.0075 | |
| Reference Output Voltage Noise | $e_n$ | 0.1Hz to 10Hz | | 60 | | $\mu V_{P-P}$ |
| Output Short-Circuit Current | $I_{SCR}$ | Short to $V_{DD}$ | | 0.25 | | mA |
| | | Short to $V_{SS}$ | | 1.9 | | |
| Capacitive-Load Stability Range | $C_{LOAD}$ | (Note 1) | 0 | | 250 | pF |

## ELECTRICAL CHARACTERISTICS

($V_{DD}$ = +3V, $V_{SS}$ = $V_{CM}$ = 0V, $V_{OUT_}$ = $V_{DD}$/2, $R_L$ to $V_{DD}$/2, $C_L$ = 15pF, **$T_A$ = $T_{MIN}$ to $T_{MAX}$**, unless otherwise specified.) (Note 2)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| Supply Voltage Range | $V_{DD}$ | MAX4036/MAX4038, guaranteed by PSRR test | | 1.4 | | 3.6 | V |
| | | MAX4037/MAX4039, guaranteed by PSRR and line regulation tests | | 1.8 | | 3.6 | |
| Supply Current | $I_{DD}$ | MAX4036 | $V_{DD}$ = 1.4V | | | 1.7 | µA |
| | | | $V_{DD}$ = 3.6V | | | 1.8 | |
| | | MAX4036A | $V_{DD}$ = 1.4V | | | 2.0 | |
| | | | $V_{DD}$ = 3.6V | | | 2.1 | |
| | | MAX4037 | $V_{DD}$ = 1.8V | | | 3.1 | |
| | | | $V_{DD}$ = 3.6V | | | 3.2 | |

# Low IBIAS, +1.4V/800nA, Rail-to-Rail Op Amps with +1.2V Buffered Reference

## ELECTRICAL CHARACTERISTICS (continued)

($V_{DD}$ = +3V, $V_{SS}$ = $V_{CM}$ = 0V, $V_{OUT_}$ = $V_{DD}$/2, $R_L$ to $V_{DD}$/2, $C_L$ = 15pF, **$T_A$ = $T_{MIN}$ to $T_{MAX}$**, unless otherwise specified.) (Note 2)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| Supply Current | $I_{DD}$ | MAX4038 | $V_{DD}$ = 1.4V | | | 2.9 | µA |
| | | | $V_{DD}$ = 3.6V | | | 3.2 | |
| | | MAX4038A | $V_{DD}$ = 1.4V | | | 3.4 | |
| | | | $V_{DD}$ = 3.6V | | | 3.7 | |
| | | MAX4039 | $V_{DD}$ = 1.8V | | | 5.2 | |
| | | | $V_{DD}$ = 3.6V | | | 5.3 | |
| **OPERATIONAL AMPLIFIERS** | | | | | | | |
| Input Offset Voltage | $V_{OS}$ | | | | | ±8 | mV |
| Input Offset Voltage Temperature Coefficient | $TCV_{OS}$ | | | | ±1 | | µV/°C |
| Input Bias Current | $I_B$ | | | | | ±100 | pA |
| Input Offset Current | $I_{OS}$ | | | | | ±200 | pA |
| Input Common-Mode Voltage Range | $V_{CM}$ | Guaranteed by CMRR test | $V_{DD}$ = 1.4V (MAX4036/MAX4038 only) | $V_{SS}$ | | $V_{DD}$ - 0.4 | V |
| | | | $V_{DD}$ = 1.8V | $V_{SS}$ | | $V_{DD}$ - 0.4 | |
| | | | $V_{DD}$ = 3.3V | $V_{SS}$ | | $V_{DD}$ - 0.2 | |
| Common-Mode Rejection Ratio | CMRR | $V_{DD}$ = 1.4V, $V_{SS} \le V_{CM} \le (V_{DD}$ - 0.5V) (MAX4036/MAX4038 only) | | 44 | | | dB |
| | | $V_{DD}$ = 1.8V, $V_{SS} \le V_{CM} \le (V_{DD}$ - 0.4V) | | 50 | | | |
| | | $V_{DD}$ = 3.3V, $V_{SS} \le V_{CM} \le (V_{DD}$ - 0.3V) | | 52 | | | |
| Power-Supply Rejection Ratio | PSRR | 1.4V ≤ $V_{DD}$ ≤ 3.6V (MAX4036/MAX4038 only) | | 60 | | | dB |
| | | 1.8V ≤ $V_{DD}$ ≤ 3.6V | | 60 | | | |
| Large-Signal Voltage Gain | $A_{VOL}$ | $R_L$ = 100kΩ, 50mV ≤ $V_{OUT} \le (V_{DD}$ - 50mV) | | 75 | | | dB |
| | | $R_L$ = 5kΩ, 150mV ≤ $V_{OUT} \le (V_{DD}$ - 150mV) | | 73 | | | |
| Output Voltage Swing High | $V_{DD}$ - $V_{OH}$ | $R_L$ = 100kΩ | | | | 10 | mV |
| | | $R_L$ = 5kΩ | | | | 100 | |
| Output Voltage Swing Low | $V_{OL}$ - $V_{SS}$ | $R_L$ = 100kΩ | | | | 10 | mV |
| | | $R_L$ = 5kΩ | | | | 100 | |
| **REFERENCE (MAX4037/MAX4039)** | | | | | | | |
| Reference Voltage Temperature Coefficient | $TCV_{REF}$ | (Note 1) | MAX4037EUT-T, MAX4039ETB, MAX4039EUB | | 25 | 120 | ppm/°C |
| | | | MAX4039EBL-T | | 35 | 200 | |
| Line Regulation | $\Delta V_{REF}/\Delta V_{DD}$ | $V_{DD}$ = 1.8V to 3.6V | | | | 0.6 | %/V |
| Load Regulation | $\Delta V_{REF}/\Delta I_{LOAD}$ | 0 ≤ $I_{LOAD}$ ≤ 100µA, sourcing | | | | 0.003 | %/µA |
| | | -20µA ≤ $I_{LOAD}$ ≤ 0, sinking | | | | 0.015 | |
| Capacitive-Load Stability Range | $C_{LOAD}$ | (Note 1) | | 0 | | 250 | pF |

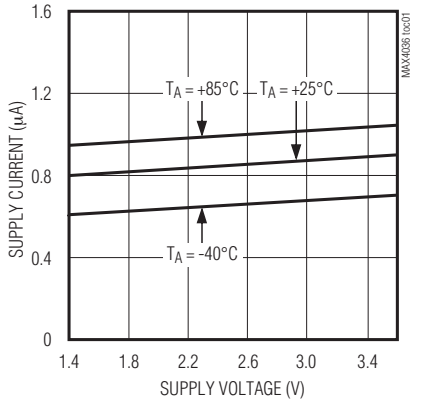
**Note 1:** Guaranteed by design.
**Note 2:** All devices are production tested at $T_A$ = +25°C. All temperature limits are guaranteed by design.
**Note 3:** Output settles within 1% of final value.

# Low IBIAS, +1.4V/800nA, Rail-to-Rail Op Amps with +1.2V Buffered Reference

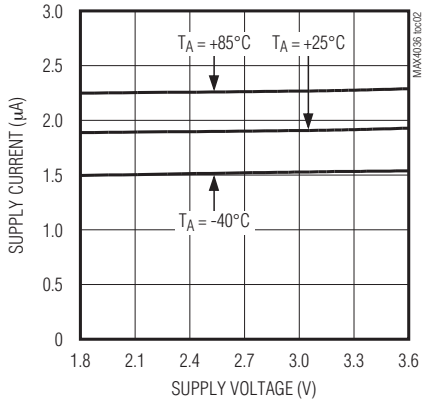
## Typical Operating Characteristics

($V_{DD}$ = 3V, $V_{SS}$ = $V_{CM}$ = 0V, $R_L$ to $V_{DD}$/2, $T_A$ = +25°C, unless otherwise noted.)

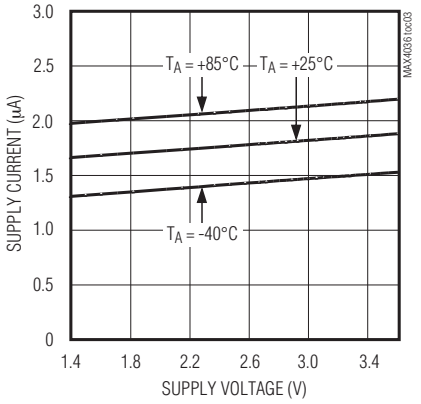
**MAX4036**
**SUPPLY CURRENT**
**vs. SUPPLY VOLTAGE AND TEMPERATURE**



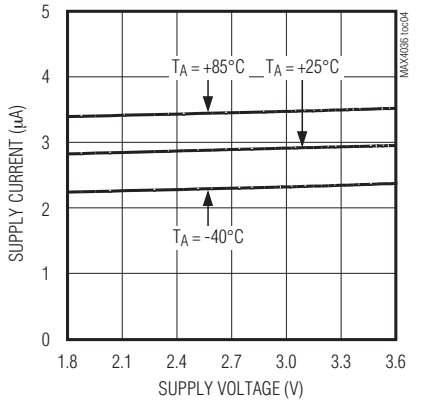

**MAX4037**
**SUPPLY CURRENT**
**vs. SUPPLY VOLTAGE AND TEMPERATURE**



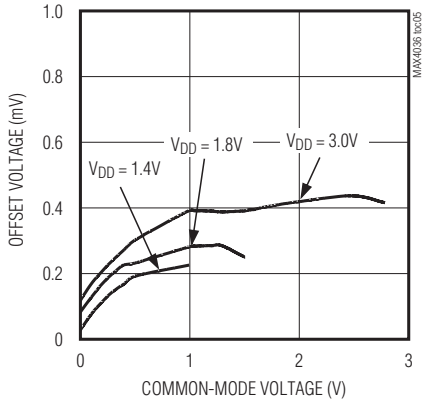

**MAX4038**
**SUPPLY CURRENT**
**vs. SUPPLY VOLTAGE AND TEMPERATURE**



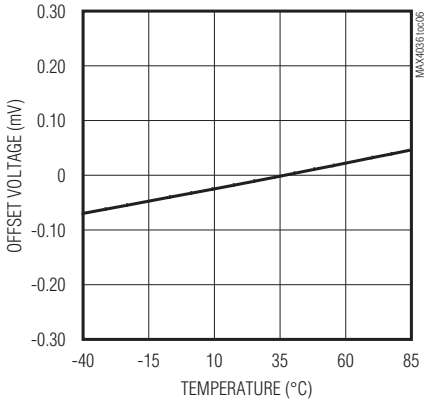

**MAX4039**
**SUPPLY CURRENT**
**vs. SUPPLY VOLTAGE AND TEMPERATURE**



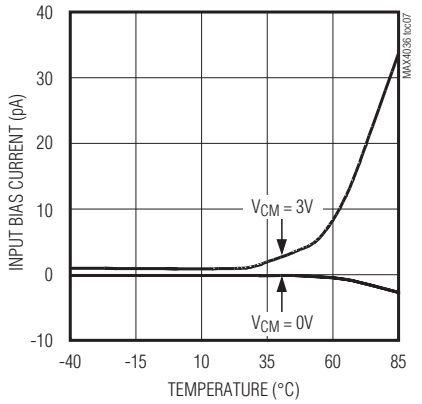

**OFFSET VOLTAGE**
**vs. COMMON-MODE VOLTAGE**



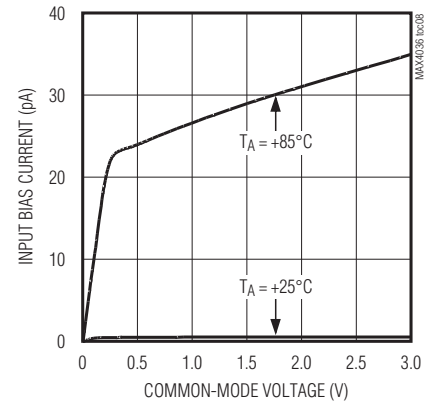

**OFFSET VOLTAGE**
**vs. TEMPERATURE**



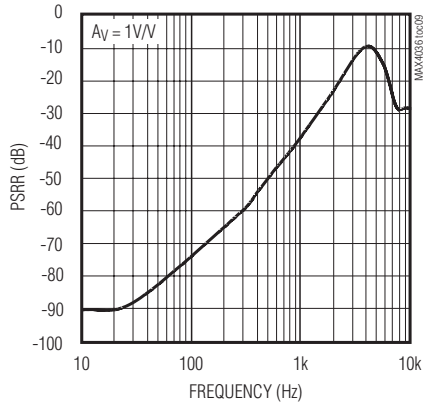

**INPUT BIAS CURRENT**
**vs. TEMPERATURE**




**INPUT BIAS CURRENT**
**vs. COMMON-MODE VOLTAGE**




**OP AMP POWER-SUPPLY REJECTION RATIO**
**vs. FREQUENCY**

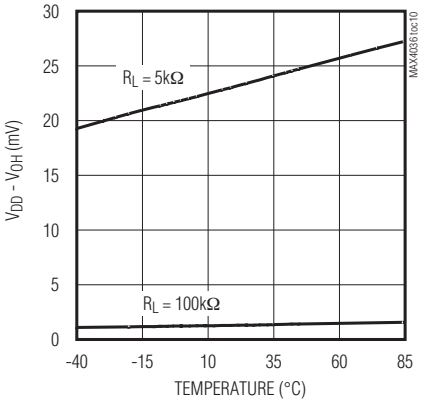


# Low IBIAS, +1.4V/800nA, Rail-to-Rail Op Amps with +1.2V Buffered Reference

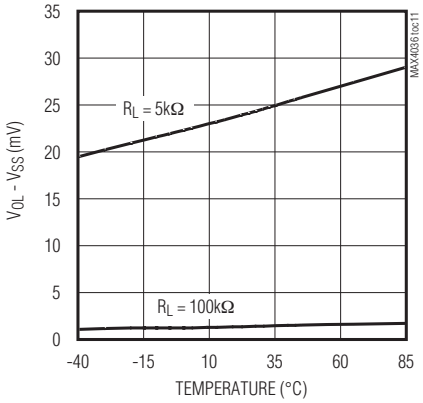
## Typical Operating Characteristics (continued)

($V_{DD}$ = 3V, $V_{SS}$ = $V_{CM}$ = 0V, $R_L$ to $V_{DD}/2$, $T_A$ = +25°C, unless otherwise noted.)

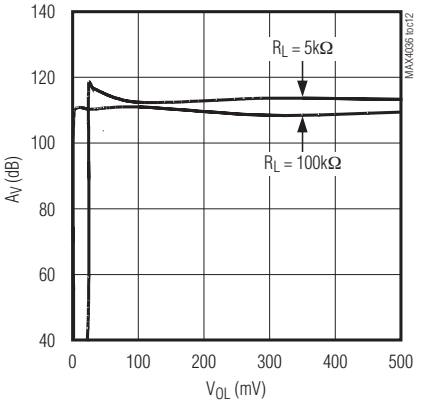
**OUTPUT VOLTAGE SWING HIGH vs. TEMPERATURE**



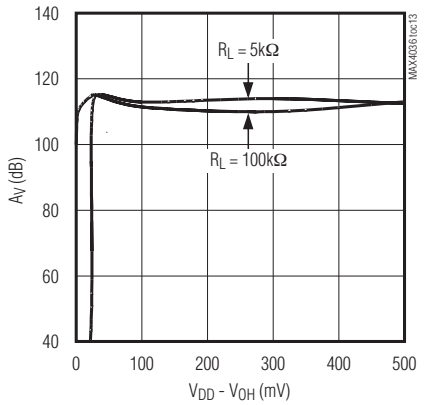

**OUTPUT VOLTAGE SWING LOW vs. TEMPERATURE**



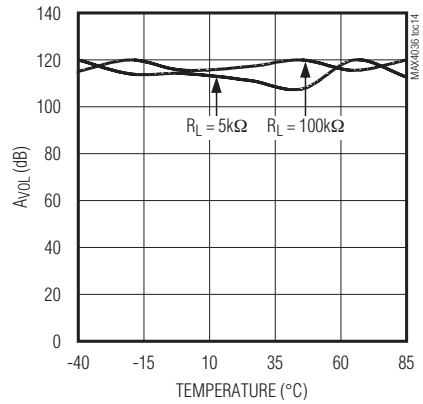

**AV vs. OUTPUT SWING LOW**



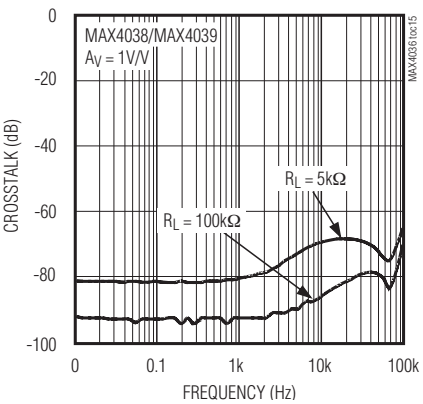

**AV vs. OUTPUT SWING HIGH**



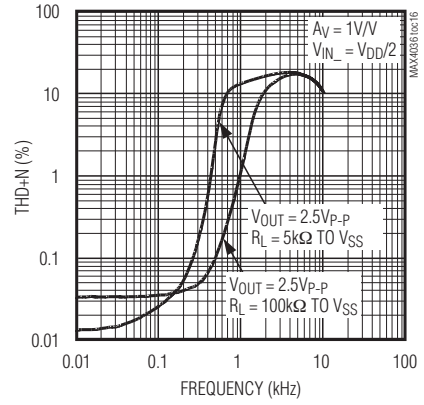

**AV vs. TEMPERATURE**



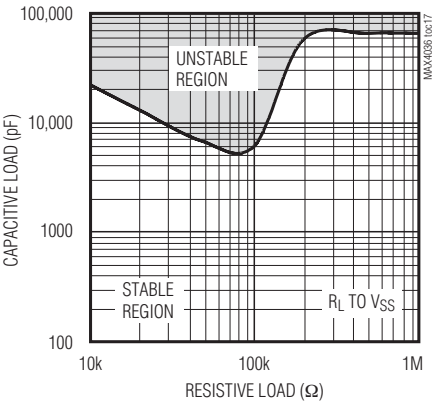

**CROSSTALK vs. FREQUENCY**



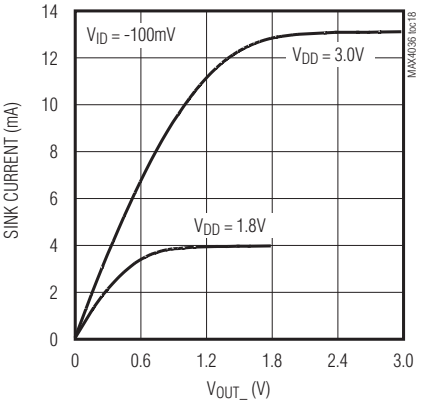

**TOTAL HARMONIC DISTORTION PLUS NOISE vs. FREQUENCY**




**OP AMP STABILITY vs. CAPACITIVE AND RESISTIVE LOADS**



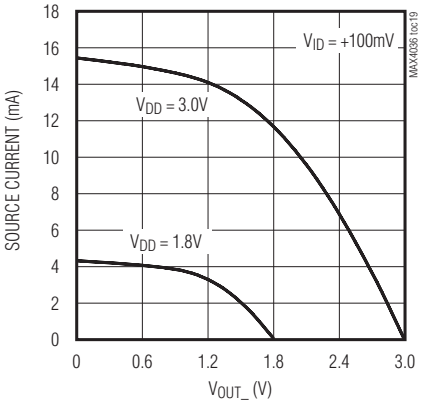

**OP AMP SINK CURRENT vs. OUTPUT VOLTAGE**



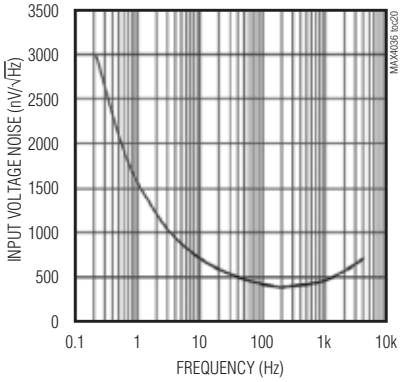
## Typical Operating Characteristics (continued)

($V_{DD}$ = 3V, $V_{SS}$ = $V_{CM}$ = 0V, $R_L$ to $V_{DD}$/2, $T_A$ = +25°C, unless otherwise noted.)

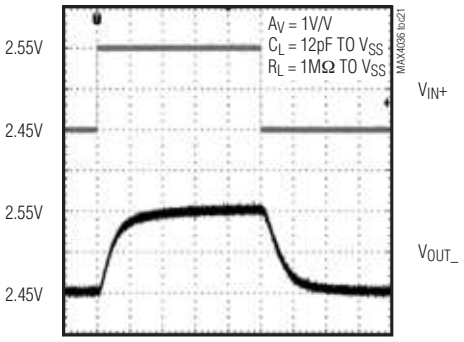
**OP AMP SOURCE CURRENT vs. OUTPUT VOLTAGE**



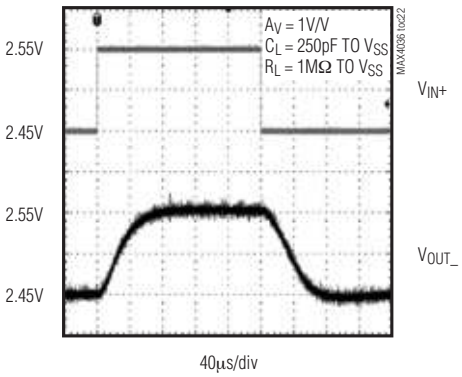

**INPUT VOLTAGE NOISE DENSITY vs. FREQUENCY**



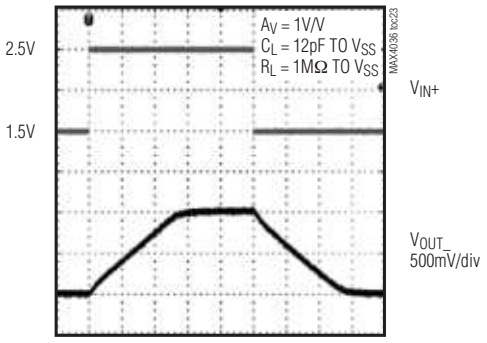

**OP AMP SMALL-SIGNAL TRANSIENT RESPONSE**



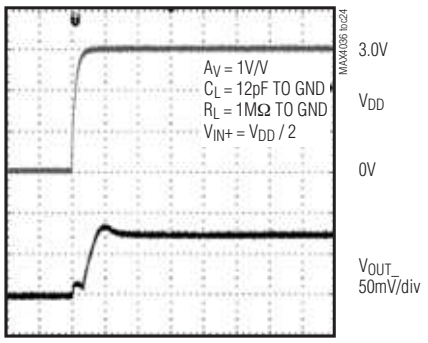

**OP AMP SMALL-SIGNAL TRANSIENT RESPONSE**




**OP AMP LARGE-SIGNAL TRANSIENT RESPONSE**




**OP AMP TURN-ON TRANSIENT RESPONSE**

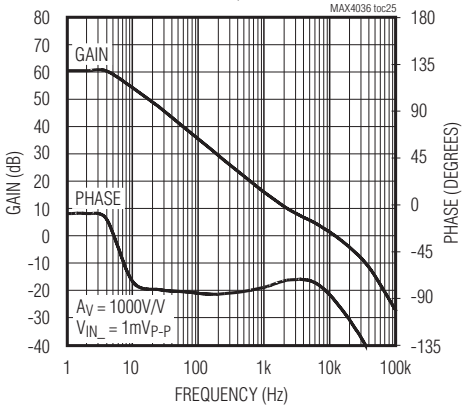


# Low IBIAS, +1.4V/800nA, Rail-to-Rail Op Amps with +1.2V Buffered Reference

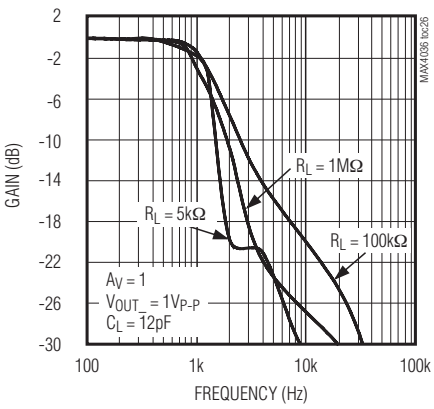
## Typical Operating Characteristics (continued)

($V_{DD}$ = 3V, $V_{SS}$ = $V_{CM}$ = 0V, $R_L$ to $V_{DD}$/2, $T_A$ = +25°C, unless otherwise noted.)

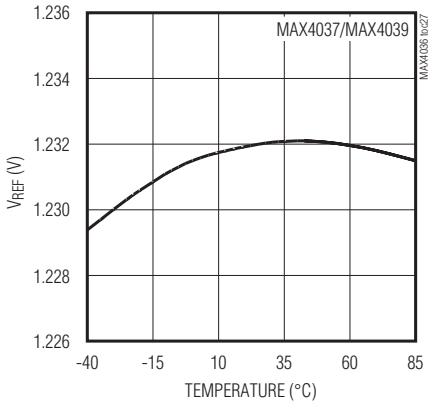
**GAIN AND PHASE vs. FREQUENCY**



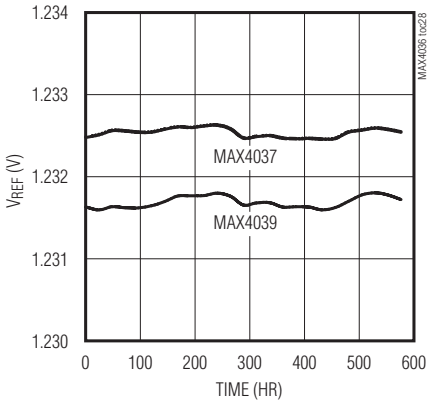

**LARGE-SIGNAL GAIN vs. FREQUENCY**



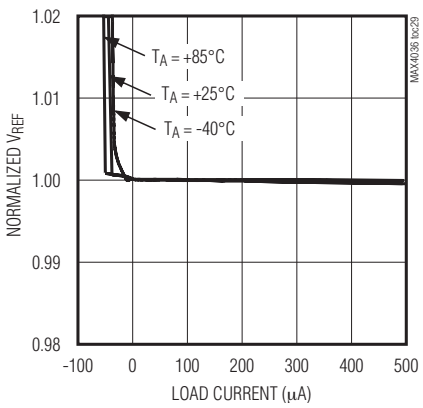

**REFERENCE VOLTAGE vs. TEMPERATURE**



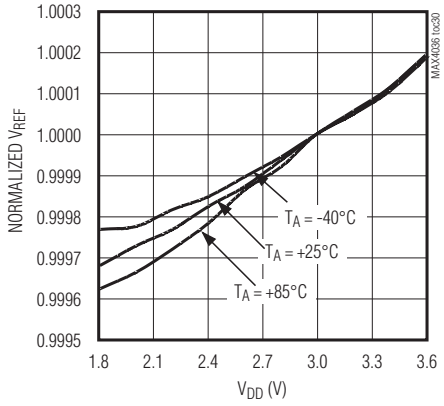

**REFERENCE VOLTAGE CHANGE vs. TIME**



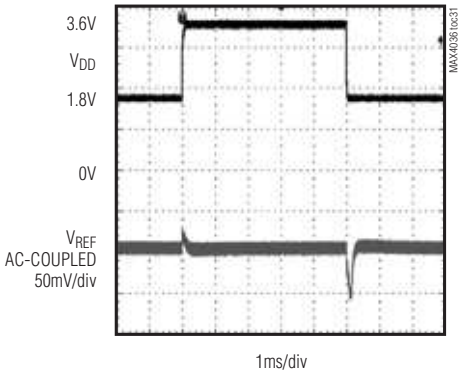

**REFERENCE VOLTAGE CHANGE vs. LOAD CURRENT**




**REFERENCE VOLTAGE CHANGE vs. SUPPLY VOLTAGE**



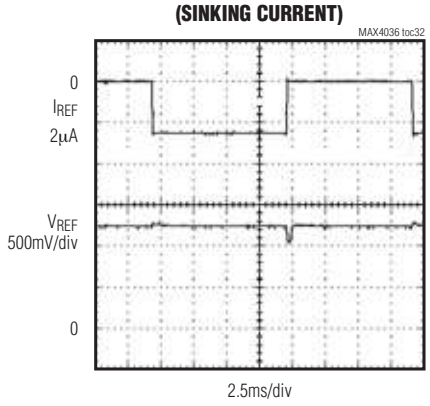

**REFERENCE LINE-TRANSIENT RESPONSE**



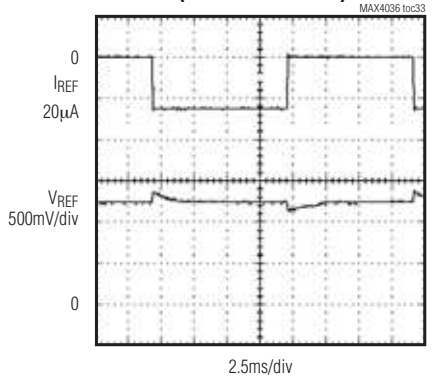
## Typical Operating Characteristics (continued)

($V_{DD}$ = 3V, $V_{SS}$ = $V_{CM}$ = 0V, $R_L$ to $V_{DD}$/2, $T_A$ = +25°C, unless otherwise noted.)

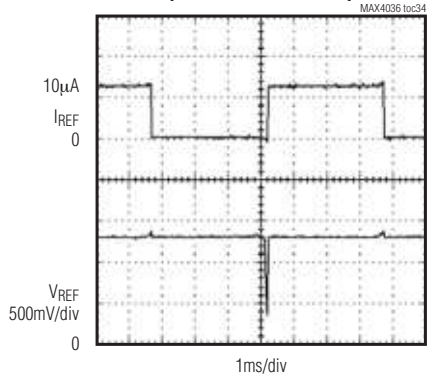
**REFERENCE LOAD-TRANSIENT RESPONSE (SINKING CURRENT)**



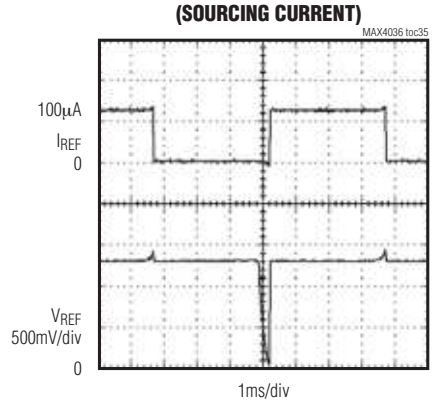

**REFERENCE LOAD-TRANSIENT RESPONSE (SINKING CURRENT)**



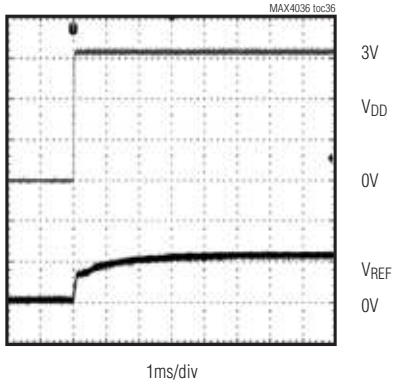

**REFERENCE LOAD-TRANSIENT RESPONSE (SOURCING CURRENT)**



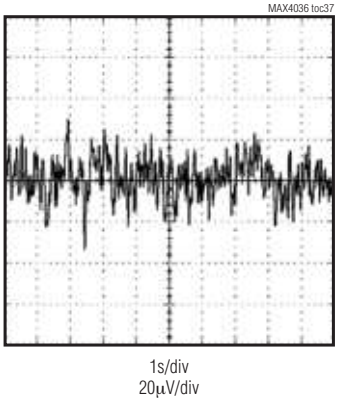

**REFERENCE LOAD-TRANSIENT RESPONSE (SOURCING CURRENT)**




**REFERENCE TURN-ON TRANSIENT RESPONSE**




**0.1Hz TO 10Hz REFERENCE NOISE**



# Low IBIAS, +1.4V/800nA, Rail-to-Rail Op Amps with +1.2V Buffered Reference

| PIN | | | | | | NAME | FUNCTION |
|---|---|---|---|---|---|---|---|
| MAX4036/ MAX4036A | MAX4037 | MAX4038/ MAX4038A | | MAX4039 | | | |
| | | µMAX*/TDFN | UCSP | µMAX/TDF | UCSP | | |
| 1 | 3 | — | — | — | — | IN+ | Noninverting Amplifier Input |
| 2 | 2 | 4 | A2 | 5 | A2 | $V_{SS}$ | Negative Power-Supply Voltage |
| 3 | 4 | — | — | — | — | IN- | Inverting Amplifier Input |
| 4 | 1 | — | — | — | — | OUT | Amplifier Output |
| 5 | 6 | 8 | C2 | 10 | C2 | $V_{DD}$ | Positive Power-Supply Voltage |
| — | 5 | — | — | 6 | B2 | REF | Reference Voltage Output |
| — | — | 1 | C1 | 1 | C1 | OUTA | Amplifier Output (Channel A) |
| — | — | 2 | B1 | 2 | B1 | INA- | Inverting Amplifier Input (Channel A) |
| — | — | 3 | A1 | 3 | A1 | INA+ | Noninverting Amplifier Input (Channel A) |
| — | — | 5 | A3 | 7 | A3 | INB+ | Noninverting Amplifier Input (Channel B) |
| — | — | 6 | B3 | 8 | B3 | INB- | Inverting Amplifier Input (Channel B) |
| — | — | 7 | C3 | 9 | C3 | OUTB | Amplifier Output (Channel B) |
| — | — | — | B2 | 4 | — | N.C. | No Connection. Not internally connected. |
| — | — | — | — | — | — | EP (TDFN only) | Exposed Paddle. Solder EP to $V_{SS}$ or leave unconnected (TDFN packages only). |

**Both MAX4038/MAX4038A available in µMAX package only.*

## Detailed Description

The MAX4036–MAX4039 consume an ultra-low supply current and have rail-to-rail output stages specifically designed for low-voltage operation. The input common-mode voltage range extends from $V_{DD}$ - 0.4V to $V_{SS}$, although full rail-to-rail input range is possible with degraded performance when operating from a supply voltage above 3.0V. The input offset voltage is typically 200µV. Low-operating supply voltage, low supply current, and rail-to-rail outputs make the MAX4036–MAX4039 an excellent choice for precision or general-purpose low-voltage, battery-powered systems.

### Rail-to-Rail Outputs

The MAX4036–MAX4039 output stages can drive a 5kΩ load and still swing to within 40mV of the rails. Figure 1 shows the output voltage swing of the MAX4036–MAX4039 configured as a unity-gain buffer, powered from a single 2.4V supply. The output for this setup typically swings from 5mV to $V_{DD}$ - 5mV with a 100kΩ load.

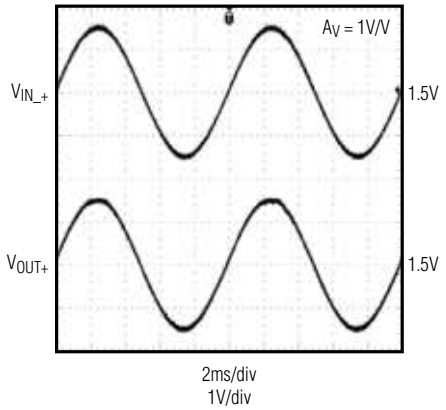



*Figure 1. Rail-to-Rail Input/Output Voltage Range*

## Applications Information

### Power-Supply Considerations

The MAX4036–MAX4039 operate from a single 1.4V (MAX4036/MAX4038) or 1.8V (MAX4037/MAX4039) to 3.6V supply. A high amplifier power-supply rejection ratio of 82dB and the excellent reference line regulation allow the devices to be powered directly from a decaying battery voltage, simplifying design and extending battery life. The MAX4036–MAX4039 are ideally suited for low-voltage battery-powered systems. The *Typical Operating Characteristics* show the changes in supply current and reference output as a function of supply voltage.

### Power-Up Settling Time

The MAX4036–MAX4039 typically require 0.25ms 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 amplifier and reference settling time curves.

### Driving Capacitive Loads: Op Amps

The MAX4036–MAX4039 amplifier(s) require no output capacitor for stability, and are unity-gain stable for loads up to 5000pF. Applications that require greater capacitive-drive capability should use an isolation resistor between the output and the capacitive load (Figure 2). Note that this solution reduces the gain and output voltage swing because $R_{ISO}$ forms a voltage-divider with the load resistor.

### Crossover Distortion

The MAX4036–MAX4039 output stages are capable of sourcing and sinking currents with orders of magnitude greater than the stages' quiescent current, which is less than 1µA. This ability to drive heavy loads with such a small quiescent current introduces crossover distortion as the output stage passes between sinking and sourcing. In the crossover regions, the output impedance of the MAX4036–MAX4039 increases substantially, thereby changing the load-driving characteristics. The distortion can be greatly reduced by increasing the load resistance. For applications where low load resistance is required, bias the load such that the output current is always in one direction, to avoid crossover distortion.

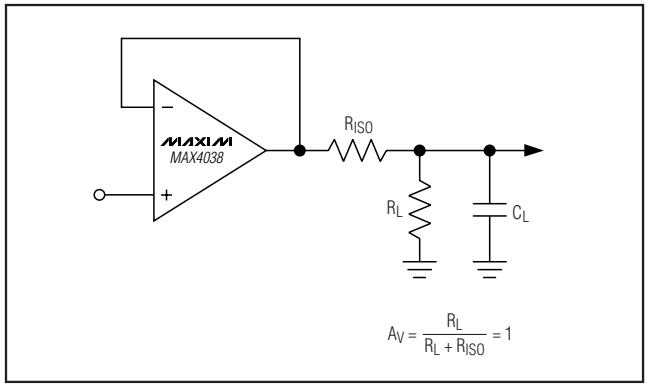



*Figure 2. Using a Resistor to Isolate a Capacitive Load from the Op Amp*

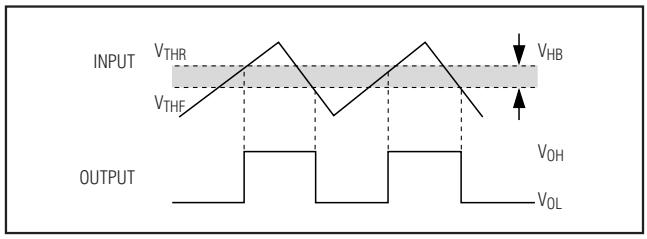



*Figure 3. Hysteresis*

### Reference Bypassing

The MAX4037/MAX4039 reference requires no external capacitors.

### Using the MAX4036–MAX4039 as a Comparator

Although optimized for use as an operational amplifier, the MAX4036–MAX4039 can be used as a rail-to-rail I/O comparator (Figures 3, 4). External hysteresis can be used to minimize the risk of output oscillation. The positive feedback circuit, shown in Figure 4, causes the input threshold to change when the output voltage changes state.

### Battery Monitoring Using the MAX4037/MAX4039 and Hysteresis

The internal reference and low operating voltage of the MAX4037/MAX4039 make the devices ideal for battery-monitoring applications. Hysteresis can be set using resistors as shown in Figure 4, and the following design procedure:

1) Choose R3. The input bias current of IN_+ is under 100pA over temperature, so a current through R3 around 100nA maintains accuracy. The current through R3 at the trip point is $V_{REF}$ / R3, or 100nA for R3 = 12MΩ. 10MΩ is a good practical value.
2) Choose the hysteresis voltage ($V_{HB}$), the voltage between the upper and lower thresholds. In this example, choose $V_{HB}$ = 50mV (see Figure 3).

# Low IBIAS, +1.4V/800nA, Rail-to-Rail Op Amps with +1.2V Buffered Reference

3) Calculate R1:

$$R1 = R3 \times \frac{V_{HB}}{V_{DD}}$$
$$= 10M\Omega \times \frac{0.5V}{2.4V}$$
$$= 210k\Omega$$

4) Choose the threshold voltage for $V_{IN}$ rising ($V_{THR}$). In this example, choose $V_{THR}$ = 2.0V.

5) Calculate R2:

$$R2 = \frac{1}{\left[\left(\frac{V_{THR}}{V_{REF} \times R1}\right) - \frac{1}{R1} - \frac{1}{R3}\right]}$$
$$= \frac{1}{\left[\left(\frac{2.0V}{1.2V \times 210k\Omega}\right) - \frac{1}{210k\Omega} - \frac{1}{10M\Omega}\right]}$$
$$= 325k\Omega$$

6) Verify the threshold voltages with these formulas:

$V_{IN}$ rising:

$$V_{THR} = V_{REF} \times R1 \times \left(\frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}\right)$$

$V_{IN}$ falling:

$$V_{THF} = V_{THR} - \left(\frac{R1 \times V_{DD}}{R3}\right)$$

In this application, the MAX4036–MAX4039 supply current will vary, depending on the output state of the comparator.

### Power Supplies and Layout

The MAX4036–MAX4039 operate from a single 1.4V (MAX4036/MAX4038) or 1.8V (MAX4037/MAX4039) to 3.6V power supply. Bypass $V_{DD}$ with a 0.1µF capacitor to ground to minimize noise.

Good layout techniques optimize performance by decreasing the amount of stray capacitance to the op amp's inputs and outputs. To decrease stray capacitance, minimize trace lengths by placing external components close to the device.

The exposed paddle (EP) on the TDFN packages of the MAX4038 and MAX4039 is internally connected to the device substrate, $V_{SS}$. Connect the exposed paddle to $V_{SS}$ or leave EP unconnected. Running traces below the exposed paddle is not recommended.

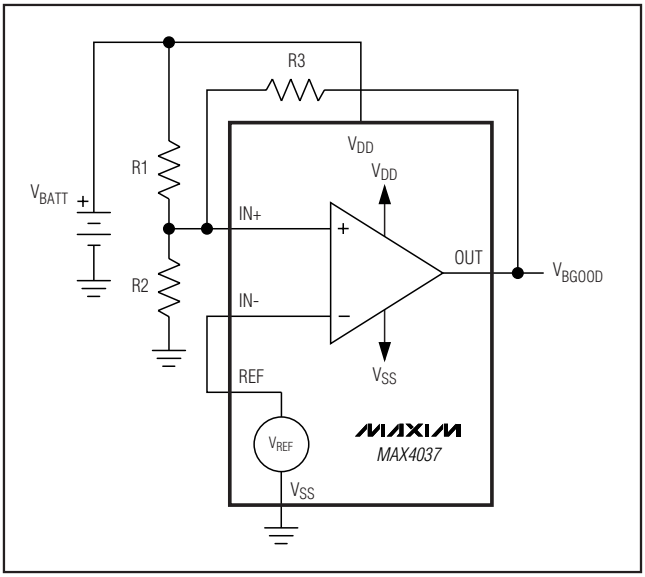



*Figure 4. Battery Monitoring*

## Selector Guide

| PART | NO. OF AMPLIFIERS | REFERENCE |
|---|---|---|
| MAX4036 | 1 | — |
| MAX4037 | 1 | √ |
| MAX4038 | 2 | — |
| MAX4039 | 2 | √ |

## Ordering Information (continued)

| PART | TEMP RANGE | PIN-PACKAGE | TOP MARK |
|---|---|---|---|
| **MAX4039**EBL-T | -40°C to +85°C | 9 UCSP | AEH |
| MAX4039ETB-T | -40°C to +85°C | 10 TDFN-EP* | AAN |
| MAX4039EUB | -40°C to +85°C | 10 µMAX | — |

*-Denotes a package containing lead.*
**EP = Exposed pad.*

## Chip Information

MAX4036 TRANSISTOR COUNT: 49

MAX4037 TRANSISTOR COUNT: 119

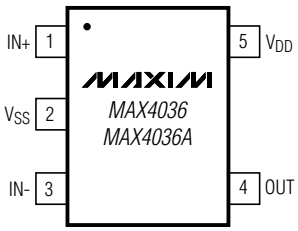
MAX4038 TRANSISTOR COUNT: 146

MAX4039 TRANSISTOR COUNT: 146

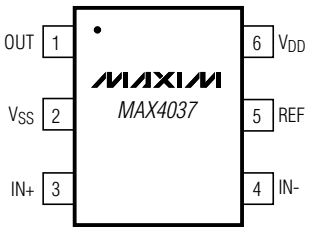
PROCESS: BiCMOS

## Pin Configurations

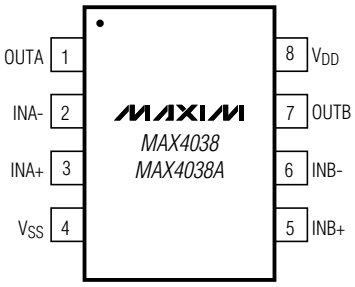
TOP VIEW



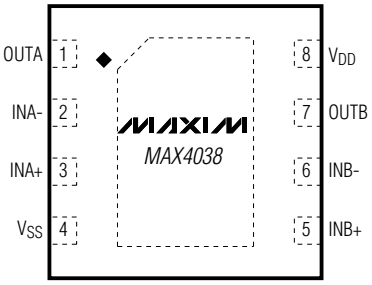

**SC70**



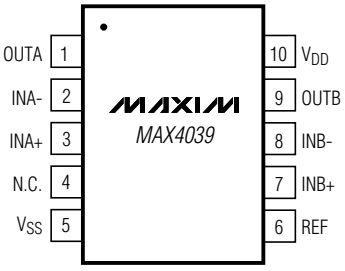

**SOT23**



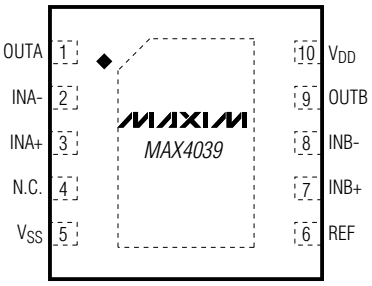

**µMAX**




**3mm x 3mm x 0.8mm TDFN**
TDFN EXPOSED PAD CONNECTED TO $V_{SS}$.

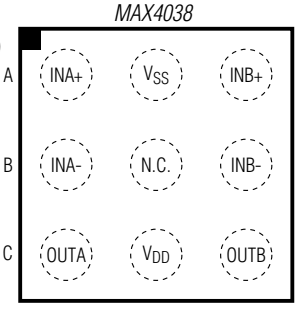



**µMAX**



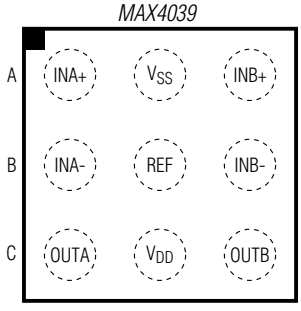

**3mm x 3mm x 0.8mm TDFN**
TDFN EXPOSED PAD CONNECTED TO $V_{SS}$.

(BUMP SIDE DOWN)




**UCSP**

(BUMP SIDE DOWN)



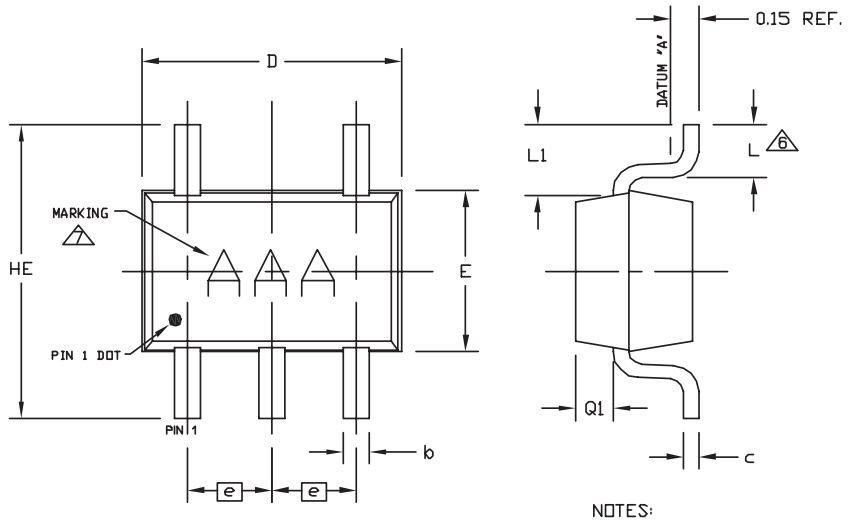

**UCSP**

# Low IBIAS, +1.4V/800nA, Rail-to-Rail Op Amps with +1.2V Buffered Reference

## 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.

SC70, 5L.EPS




| COMMON DIMENSIONS | | | |
|---|---|---|---|
| SYMBOL | MIN | NOM | MAX |
| A | 0.80 | 0.95 | 1.10 |
| A1 | 0.00 | 0.07 | 0.10 |
| A2 | 0.80 | 0.90 | 1.00 |
| b | 0.15 | 0.22 | 0.30 |
| c | 0.10 | 0.14 | 0.18 |
| D | 1.80 | 2.00 | 2.20 |
| e | 0.65 BSC. | | |
| E | 1.15 | 1.25 | 1.35 |
| HE | 1.80 | 2.20 | 2.40 |
| L | 0.26 | 0.34 | 0.46 |
| L1 | 0.425 TYP. | | |
| Q1 | 0.10 | 0.25 | 0.40 |
| PKG. CODE | X5-1 | | |

NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. DIMENSIONS ARE INCLUSIVE OF PLATING.
3. DIMENSIONS ARE EXCLUSIVE OF MOLD FLASH & METAL BURR.
4. COMPLY TO JEITA SC-88A EXCEPT FOR DIMENSION "L", ALL DIMENSIONS COMPLY TO JEDEC MO-203.
5. COPLANARITY 4 MILS. MAX.
6. FOOT LENGTH MEASURED AT INTERCEPT POINT BETWEEN DATUM "A" AND LEAD SURFACE.
7. MARKING IS FOR PACKAGE ORIENTATION REFERENCE ONLY.
8. LEAD CENTERLINES TO BE AT TRUE POSITION AS DEFINED BY BASIC DIMENSION "e", ±0.05.

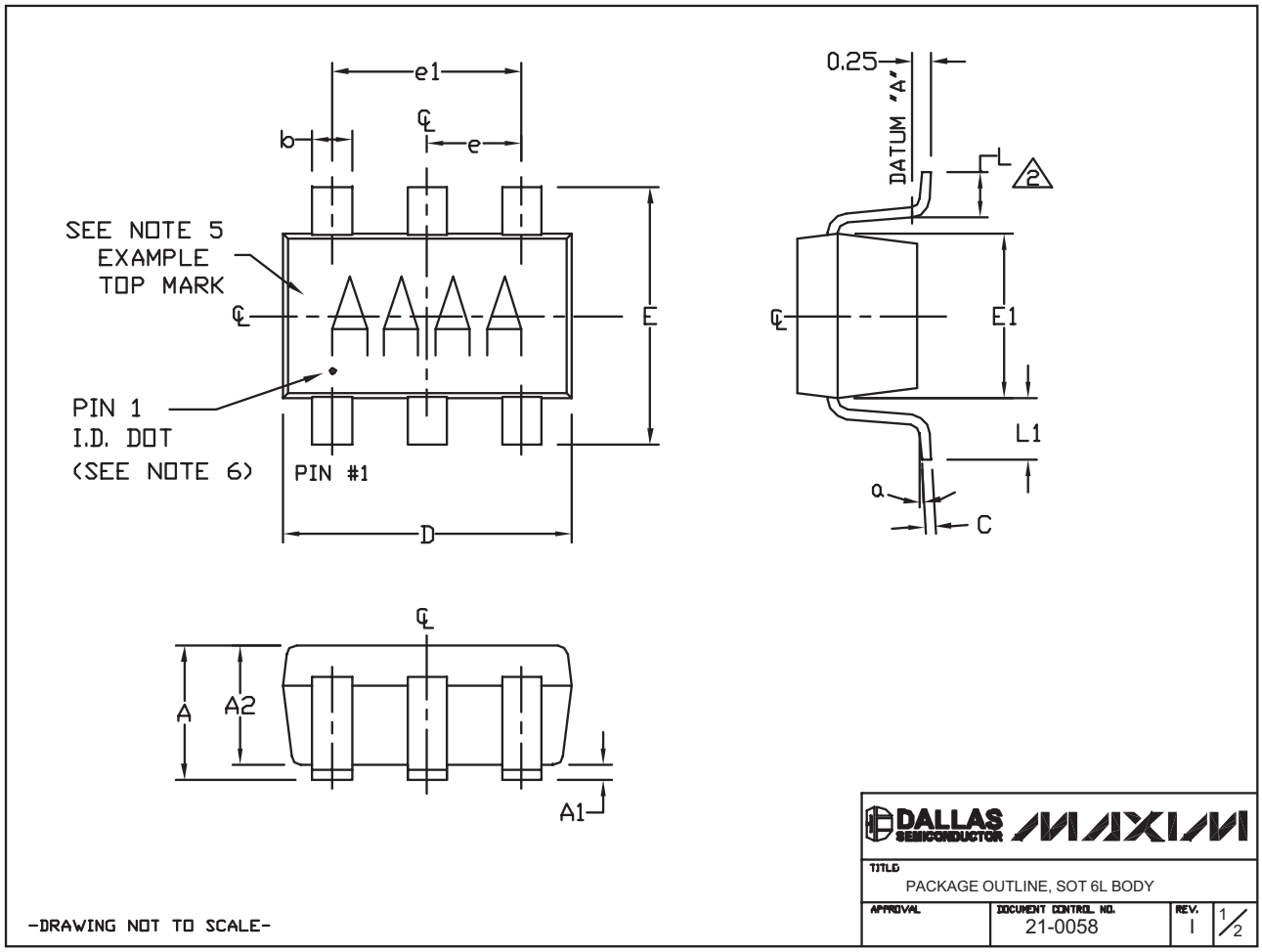
-DRAWING NOT TO SCALE-

DALLAS SEMICONDUCTOR MAXIM

| TITLE: PACKAGE OUTLINE, 5L SC70 | | | |
|---|---|---|---|
| APPROVAL | DOCUMENT CONTROL NO. 21-0076 | REV. E | 1/1 |

## Package Information (continued)

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.



# Low IBIAS, +1.4V/800nA, Rail-to-Rail Op Amps with +1.2V Buffered Reference

## Package Information (continued)

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.

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. FOOT LENGTH MEASURED AT INTERCEPT POINT BETWEEN DATUM A & LEAD SURFACE.
3. PACKAGE OUTLINE EXCLUSIVE OF MOLD FLASH & METAL BURR. MOLD FLASH, PROTRUSION OR METAL BURR SHOULD NOT EXCEED 0.25mm.
4. PACKAGE OUTLINE INCLUSIVE OF SOLDER PLATING.
5. PIN 1 IS LOWER LEFT PIN WHEN READING TOP MARK FROM LEFT TO RIGHT. (SEE EXAMPLE TOP MARK)
6. PIN 1 I.D. DOT IS 0.3mm ø MIN. LOCATED ABOVE PIN 1.
7. MEETS JEDEC MO178, VARIATION AB.
8. SOLDER THICKNESS MEASURED AT FLAT SECTION OF LEAD BETWEEN 0.08mm AND 0.15mm FROM LEADTIP.
9. LEAD TO BE COPLANAR WITHIN 0.1mm.
10. NUMBER OF LEADS SHOWN ARE FOR REFERENCE ONLY.
11. MARKING IS FOR PACKAGE ORIENTATION REFERENCE ONLY.

| SYMBOL | MIN | NOMINAL | MAX |
|---|---|---|---|
| A | 0.90 | 1.25 | 1.45 |
| A1 | 0.00 | 0.05 | 0.15 |
| A2 | 0.90 | 1.10 | 1.30 |
| b | 0.35 | 0.40 | 0.50 |
| C | 0.08 | 0.15 | 0.20 |
| D | 2.80 | 2.90 | 3.00 |
| E | 2.60 | 2.80 | 3.00 |
| E1 | 1.50 | 1.625 | 1.75 |
| L | 0.35 | 0.45 | 0.60 |
| L1 | | 0.60 REF. | |
| e1 | | 1.90 BSC. | |
| e | | 0.95 BSC. | |
| α | 0° | 2.5° | 10° |

PKG CODES:
U6-1, U6-2, U6-4, U6C-8, U6SN-1, U6CN-2, U6S-3, U6F-5, U6F-6, U6FH-5, U6FH-6

-DRAWING NOT TO SCALE-

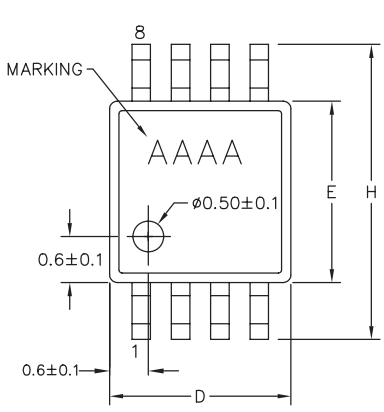
DALLAS SEMICONDUCTOR MAXIM

TITLE: PACKAGE OUTLINE, SOT 6L BODY

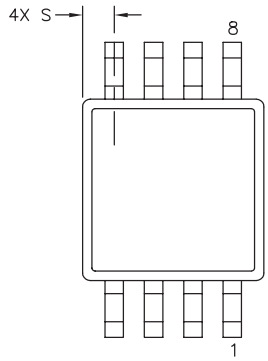
| APPROVAL | DOCUMENT CONTROL NO. | REV. | |
|---|---|---|---|
| | 21-0058 | I | 2/2 |

## Package Information (continued)

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.



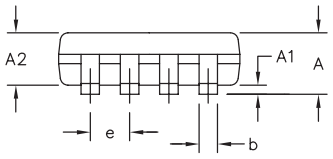

TOP VIEW



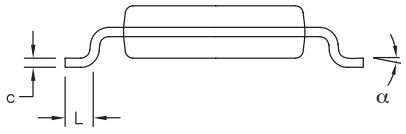

BOTTOM VIEW

| | INCHES | | MILLIMETERS | |
|---|---|---|---|---|
| DIM | MIN | MAX | MIN | MAX |
| A | – | 0.043 | – | 1.10 |
| A1 | 0.002 | 0.006 | 0.05 | 0.15 |
| A2 | 0.030 | 0.037 | 0.75 | 0.95 |
| b | 0.010 | 0.014 | 0.25 | 0.36 |
| c | 0.005 | 0.007 | 0.13 | 0.18 |
| D | 0.114 | 0.122 | 2.90 | 3.10 |
| e | 0.0256 BSC | | 0.65 BSC | |
| E | 0.114 | 0.122 | 2.90 | 3.10 |
| H | 0.188 | 0.198 | 4.78 | 5.03 |
| L | 0.016 | 0.026 | 0.41 | 0.66 |
| α | 0° | 6° | 0° | 6° |
| S | 0.0207 BSC | | 0.5250 BSC | |

PKG. CODES:
U8–1; U8–3; U8CN–1




FRONT VIEW




SIDE VIEW

NOTES:
1. D&E DO NOT INCLUDE MOLD FLASH.
2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED 0.15MM (.006").
3. CONTROLLING DIMENSION: MILLIMETERS.
4. COMPLIES TO JEDEC MO–187, LATEST REVISION, VARIATION AA.
5. MARKING SHOWN IS FOR PKG. ORIENTATION ONLY.
6. ALL DIMENSIONS APPLY TO BOTH LEADED (–) AND PbFREE (+) PKG. CODES.

–DRAWING NOT TO SCALE–

MAXIM

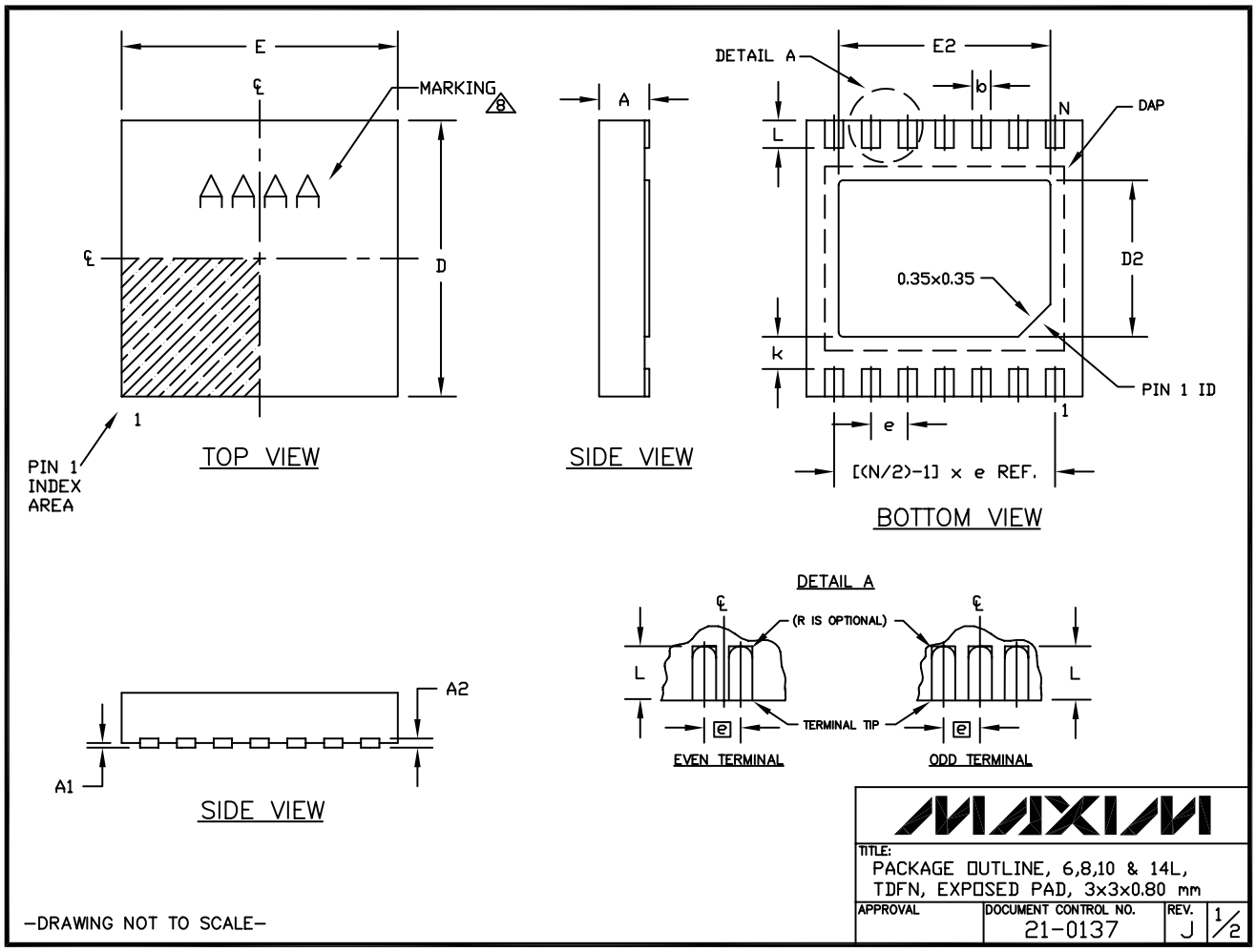
TITLE:
PACKAGE OUTLINE, 8L uMAX/uSOP

| APPROVAL | DOCUMENT CONTROL NO. | REV. | |
|---|---|---|---|
| | 21–0036 | L | 1/1 |

# Low IBIAS, +1.4V/800nA, Rail-to-Rail Op Amps with +1.2V Buffered Reference

## Package Information (continued)

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 Information (continued)

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.

| COMMON DIMENSIONS | | |
|---|---|---|
| SYMBOL | MIN. | MAX. |
| A | 0.70 | 0.80 |
| D | 2.90 | 3.10 |
| E | 2.90 | 3.10 |
| A1 | 0.00 | 0.05 |
| L | 0.20 | 0.40 |
| k | 0.25 MIN. | |
| A2 | 0.20 REF. | |

| PACKAGE VARIATIONS | | | | | | | |
|---|---|---|---|---|---|---|---|
| PKG. CODE | N | D2 | E2 | e | JEDEC SPEC | b | [(N/2)-1] x e |
| T633-2 | 6 | 1.50±0.10 | 2.30±0.10 | 0.95 BSC | MO229 / WEEA | 0.40±0.05 | 1.90 REF |
| T833-2 | 8 | 1.50±0.10 | 2.30±0.10 | 0.65 BSC | MO229 / WEEC | 0.30±0.05 | 1.95 REF |
| T833-3 | 8 | 1.50±0.10 | 2.30±0.10 | 0.65 BSC | MO229 / WEEC | 0.30±0.05 | 1.95 REF |
| T1033-1 | 10 | 1.50±0.10 | 2.30±0.10 | 0.50 BSC | MO229 / WEED-3 | 0.25±0.05 | 2.00 REF |
| T1033MK-1 | 10 | 1.50±0.10 | 2.30±0.10 | 0.50 BSC | MO229 / WEED-3 | 0.25±0.05 | 2.00 REF |
| T1033-2 | 10 | 1.50±0.10 | 2.30±0.10 | 0.50 BSC | MO229 / WEED-3 | 0.25±0.05 | 2.00 REF |
| T1433-1 | 14 | 1.70±0.10 | 2.30±0.10 | 0.40 BSC | - - - - | 0.20±0.05 | 2.40 REF |
| T1433-2 | 14 | 1.70±0.10 | 2.30±0.10 | 0.40 BSC | - - - - | 0.20±0.05 | 2.40 REF |
| T1433-3F | 14 | 1.70±0.10 | 2.30±0.10 | 0.40 BSC | - - - - | 0.20±0.05 | 2.40 REF |

NOTES:
1. ALL DIMENSIONS ARE IN mm. ANGLES IN DEGREES.
2. COPLANARITY SHALL NOT EXCEED 0.08 mm.
3. WARPAGE SHALL NOT EXCEED 0.10 mm.
4. PACKAGE LENGTH/PACKAGE WIDTH ARE CONSIDERED AS SPECIAL CHARACTERISTIC(S).
5. DRAWING CONFORMS TO JEDEC MO229, EXCEPT DIMENSIONS "D2" AND "E2", AND T1433-1 & T1433-2.
6. "N" IS THE TOTAL NUMBER OF LEADS.
7. NUMBER OF LEADS SHOWN ARE FOR REFERENCE ONLY.
8. MARKING IS FOR PACKAGE ORIENTATION REFERENCE ONLY.
9. ALL DIMENSIONS APPLY TO BOTH LEADED (-) AND PbFREE (+) PKG. CODES.

-DRAWING NOT TO SCALE-

MAXIM

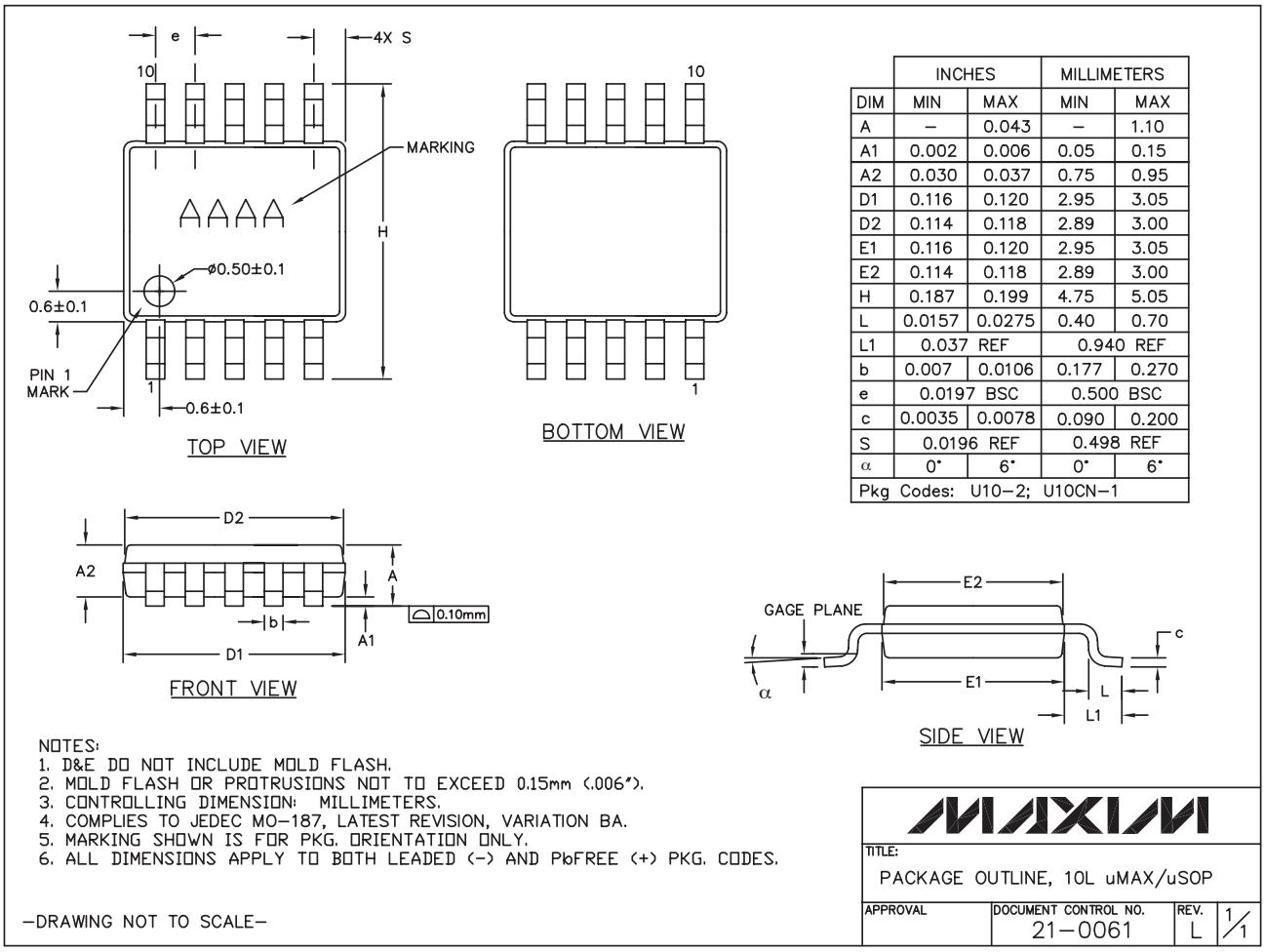
TITLE: PACKAGE OUTLINE, 6,8,10 & 14L, TDFN, EXPOSED PAD, 3x3x0.80 mm

| APPROVAL | DOCUMENT CONTROL NO. | REV. | |
|---|---|---|---|
| | 21-0137 | J | 2/2 |

# Low IBIAS, +1.4V/800nA, Rail-to-Rail Op Amps with +1.2V Buffered Reference

## Package Information (continued)

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.

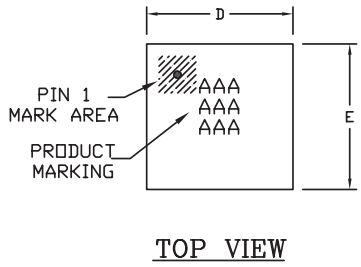



| | INCHES | | MILLIMETERS | |
|---|---|---|---|---|
| DIM | MIN | MAX | MIN | MAX |
| A | – | 0.043 | – | 1.10 |
| A1 | 0.002 | 0.006 | 0.05 | 0.15 |
| A2 | 0.030 | 0.037 | 0.75 | 0.95 |
| D1 | 0.116 | 0.120 | 2.95 | 3.05 |
| D2 | 0.114 | 0.118 | 2.89 | 3.00 |
| E1 | 0.116 | 0.120 | 2.95 | 3.05 |
| E2 | 0.114 | 0.118 | 2.89 | 3.00 |
| H | 0.187 | 0.199 | 4.75 | 5.05 |
| L | 0.0157 | 0.0275 | 0.40 | 0.70 |
| L1 | 0.037 REF | | 0.940 REF | |
| b | 0.007 | 0.0106 | 0.177 | 0.270 |
| e | 0.0197 BSC | | 0.500 BSC | |
| c | 0.0035 | 0.0078 | 0.090 | 0.200 |
| S | 0.0196 REF | | 0.498 REF | |
| α | 0° | 6° | 0° | 6° |
| Pkg Codes: U10-2; U10CN-1 | | | | |

## Package Information (continued)

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.

9LUCSP, 3x3.EPS

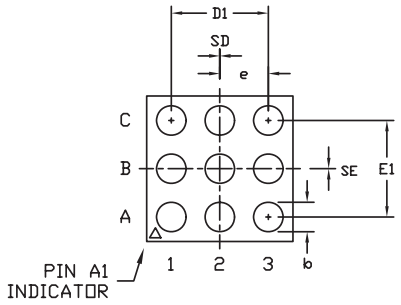



TOP VIEW

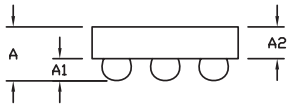
| COMMON DIMENSIONS | |
|---|---|
| A | 0.62+0.05-0.08 |
| A1 | 0.29±0.02 |
| A2 | 0.33 REF. |
| b | ø0.35±0.03 |
| D1 | 1.00 BASIC |
| E1 | 1.00 BASIC |
| e | 0.50 BASIC |
| SD | 0.00 BASIC |
| SE | 0.00 BASIC |

| PKG. CODE | VARIABLE DIMENSIONS | | DEPOPULATED SOLDER BALLS |
|---|---|---|---|
| | D | E | |
| B9-1 | 1.52±0.05 | 1.52±0.05 | NONE |
| B9-2 | 1.52±0.05 | 1.52±0.05 | B2 |
| B9-3 | 1.52±0.05 | 1.52±0.05 | B1, B2, B3 |
| B9-4 | 1.60±0.05 | 1.60±0.05 | NONE |
| B9-5 | 1.60±0.05 | 1.60±0.05 | B2 |
| B9-6 | 1.60±0.05 | 1.60±0.05 | B1, B2, B3 |
| B9-7 | 1.52±0.05 | 1.52±0.05 | A2, B1, B2, B3, C2 |
| B9-8 | 1.98±0.05 | 1.75±0.05 | B1, B2, B3 |

NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. PRODUCT MARKING: NUMBER OF CHARACTERS AND LINES VARY PER PRODUCT.




BOTTOM VIEW




SIDE VIEW

-DRAWING NOT TO SCALE-

DALLAS SEMICONDUCTOR MAXIM

TITLE: PACKAGE OUTLINE, 3x3 UCSP

| APPROVAL | DOCUMENT CONTROL NO. | REV. | |
|---|---|---|---|
| | 21-0093 | L | 1/1 |

# Low IBIAS, +1.4V/800nA, Rail-to-Rail Op Amps with +1.2V Buffered Reference

## Revision History

| REVISION NUMBER | REVISION DATE | DESCRIPTION | PAGES CHANGED |
|---|---|---|---|
| 5 | 11/09 | Updated TOC 20 | 7 |

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