19-3142; Rev 0; 1/04

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.

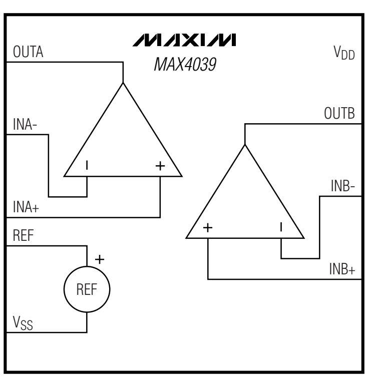
The MAX4036 is available in an SC70 package, the MAX4037 in a SOT23 package, and the MAX4038/MAX4039 in µMAX and TDFN packages. All devices are specified over the -40°C to +85°C extended temperature range.

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

Rail-to-Rail is a registered trademark of Nippon Motorola, Ltd.

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%, 80ppm/°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 SC70, SOT23, TDFN, and µMAX Packages

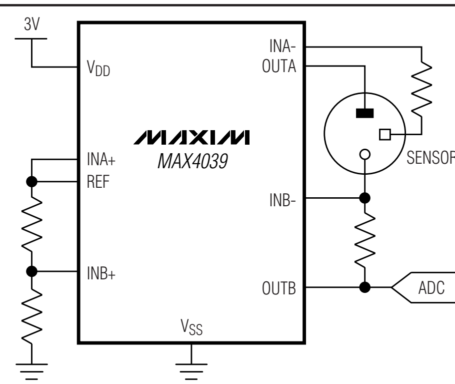
Ordering Information

PART	TEMP RANGE	PIN-PACKAGE	TOP MARK
MAX4036EXK-T*	-40°C to +85°C	5 SC70-5	AFR
MAX4037EUT-T	-40°C to +85°C	6 SOT23-6	ABRX
MAX4038ETA	-40°C to +85°C	8 TDFN-EP**	AGO
MAX4038EUA	-40°C to +85°C	8 µMAX	—
MAX4039ETB*	-40°C to +85°C	10 TDFN-EP**	AAN
MAX4039EUB	-40°C to +85°C	10 µMAX	—

**Future product—contact factory for availability.*
***EP = Exposed paddle.*

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

Typical Operating Circuit



THREE-ELECTRODE POTENTIOSTAT APPLICATION

MAX4036–MAX4039

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
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 ....-40°C to +85°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} † V_{CM} † (V_{DD} - 0.4V) (MAX4036/MAX4038 only)		50	70		dB
		V_{DD} = 1.8V, V_{SS} † V_{CM} † (V_{DD} - 0.3V)		50	70		
		V_{DD} = 3.3V, V_{SS} † V_{CM} † (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	θ_M			90		Degrees
Slew Rate	SR			0.4		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	ΔV_{REF}/ ΔV_{DD}	V_{DD} = +1.8V to +3.6V			0.3	%/V
Load Regulation	ΔV_{REF}/ ΔI_{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		μV_{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	
		MAX4037	V_{DD} = 1.8V			3.1	
			V_{DD} = 3.6V			3.2	
		MAX4038	V_{DD} = 1.4V			2.9	
			V_{DD} = 3.6V			3.2	
		MAX4039	V_{DD} = 1.8V			5.2	
			V_{DD} = 3.6V			5.3	

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)

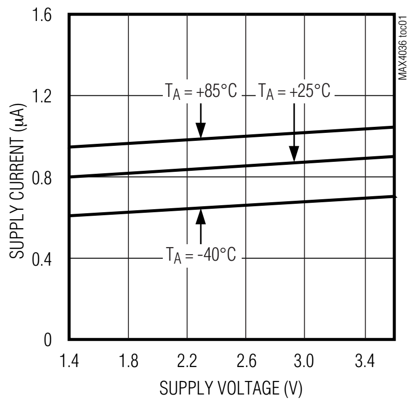
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
OPERATIONAL AMPLIFIERS						
Input Offset Voltage	V_{OS}				±8	mV
Input Offset Voltage Temperature Coefficient	TCV_{OS}			±1		µV/°C
Input Bias Current	I_B				±100	pA
Input Offset Current	I_{OS}				±200	pA
Input Common-Mode Voltage Range	V_{CM}	Guaranteed by CMRR test; V_{DD} = 1.4V (MAX4036/MAX4038 only)	V_{SS}		V_{DD} - 0.4	V
		Guaranteed by CMRR test; V_{DD} = 1.8V	V_{SS}		V_{DD} - 0.4	
		Guaranteed by CMRR test; V_{DD} = 3.3V	V_{SS}		V_{DD} - 0.2	
Common-Mode Rejection Ratio	CMRR	V_{DD} = 1.4V, V_{SS} ≤ V_{CM} ≤ (V_{DD} - 0.4V) (MAX4036/MAX4038 only)	44			dB
		V_{DD} = 1.8V, V_{SS} ≤ V_{CM} ≤ (V_{DD} - 0.4V)	50			
		V_{DD} = 3.3V, V_{SS} ≤ V_{CM} ≤ (V_{DD} - 0.2V)	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} ≤ (V_{DD} - 50mV)	75			dB
		R_L = 5kΩ, 150mV ≤ V_{OUT} ≤ (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)		20	80	ppm/°C
Line Regulation	ΔV_{REF}/ ΔV_{DD}	V_{DD} = 1.8V to 3.6V			0.6	%/V
Load Regulation	ΔV_{REF}/ ΔI_{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.

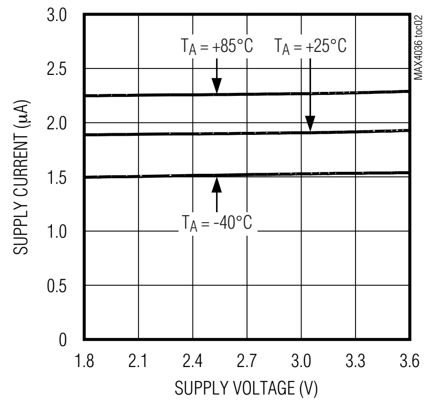
Typical Operating Characteristics

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

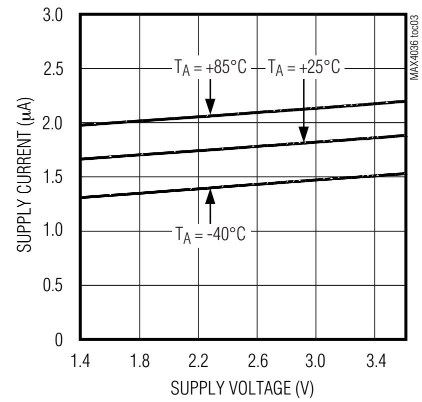
MAX4036 SUPPLY CURRENT vs. SUPPLY VOLTAGE AND TEMPERATURE



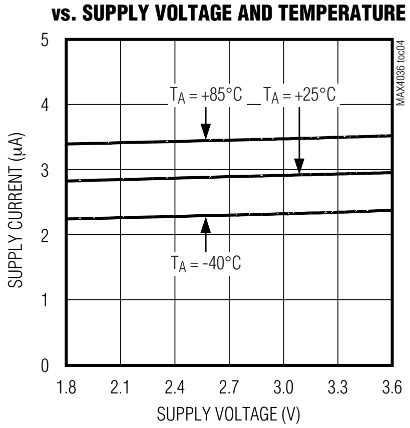
MAX4037 SUPPLY CURRENT vs. SUPPLY VOLTAGE AND TEMPERATURE



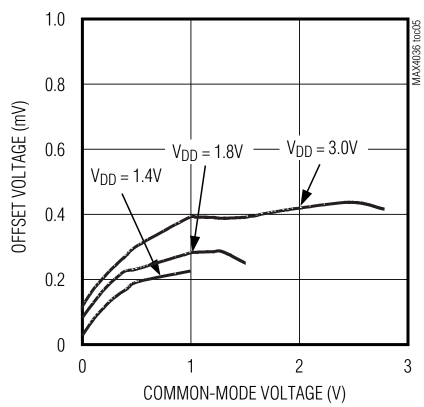
MAX4038 SUPPLY CURRENT vs. SUPPLY VOLTAGE AND TEMPERATURE



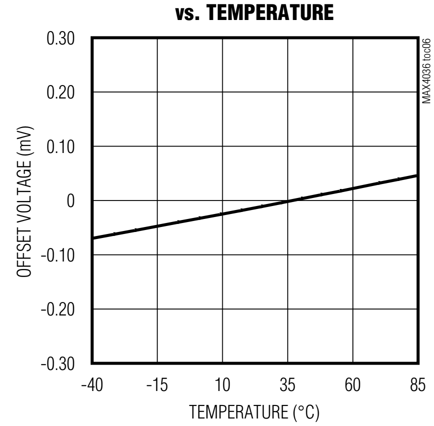
MAX4039 SUPPLY CURRENT vs. SUPPLY VOLTAGE AND TEMPERATURE



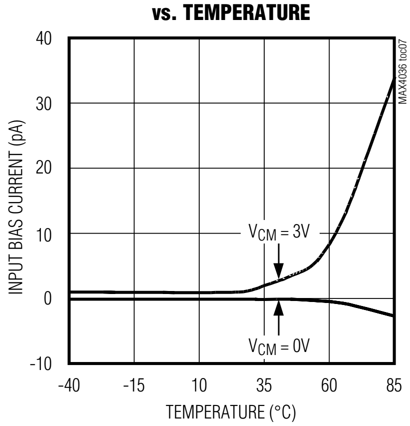
OFFSET VOLTAGE vs. COMMON-MODE VOLTAGE



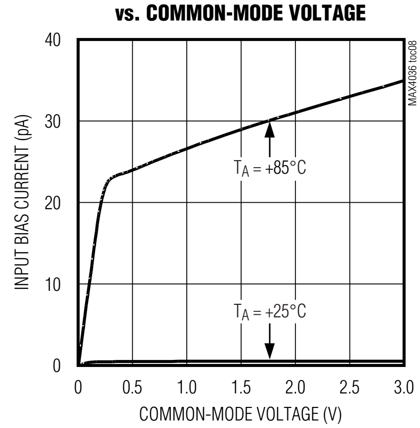
OFFSET VOLTAGE vs. TEMPERATURE



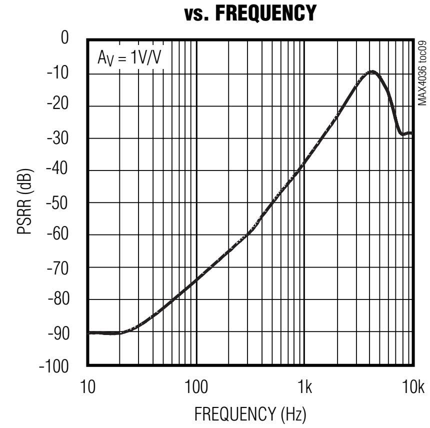
INPUT BIAS CURRENT vs. TEMPERATURE



INPUT BIAS CURRENT vs. COMMON-MODE VOLTAGE



OP AMP POWER-SUPPLY REJECTION RATIO vs. FREQUENCY

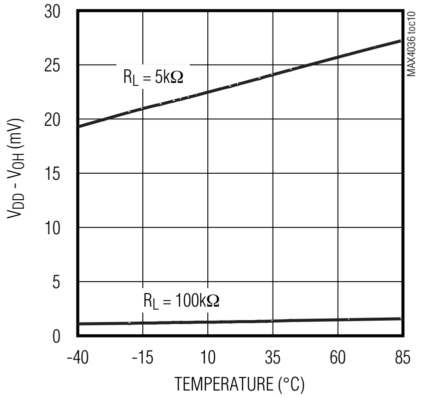


Low IBIAS, +1.4V/800nA, Rail-to-Rail Op Amps with +1.2V Buffered Reference

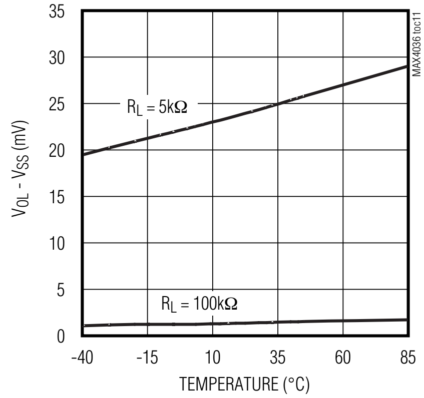
Typical Operating Characteristics (continued)

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

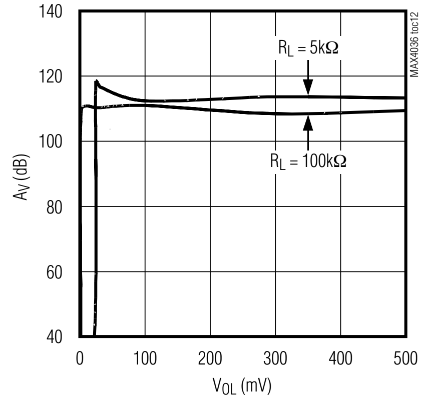
OUTPUT VOLTAGE SWING HIGH vs. TEMPERATURE



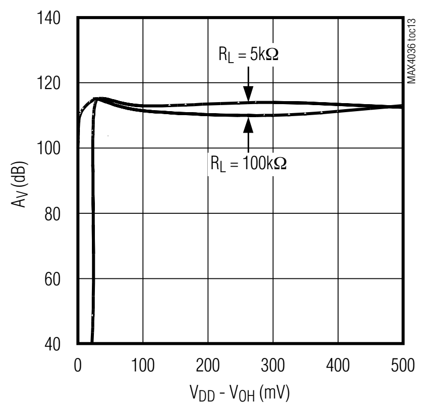
OUTPUT VOLTAGE SWING LOW vs. TEMPERATURE



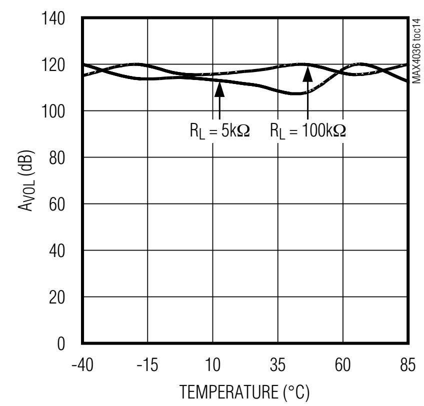
AV vs. OUTPUT SWING LOW



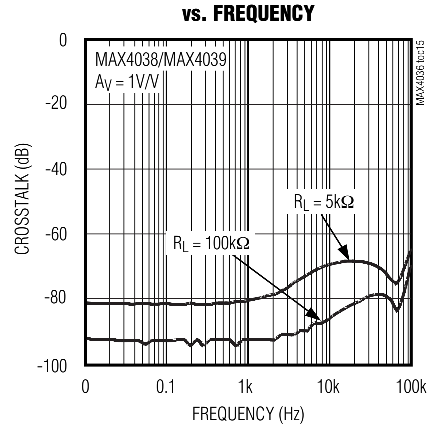
AV vs. OUTPUT SWING HIGH



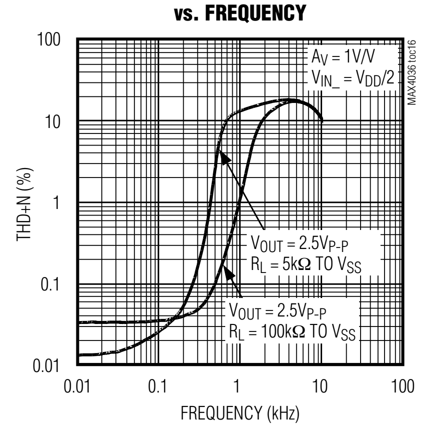
AV vs. TEMPERATURE



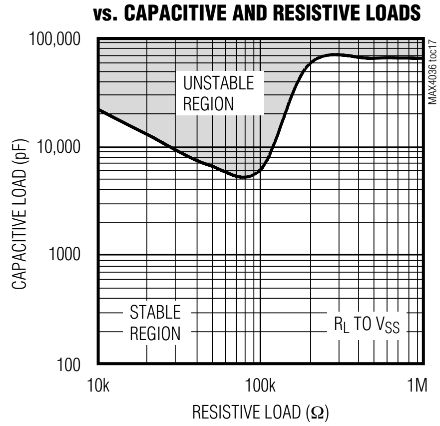
CROSSTALK vs. FREQUENCY



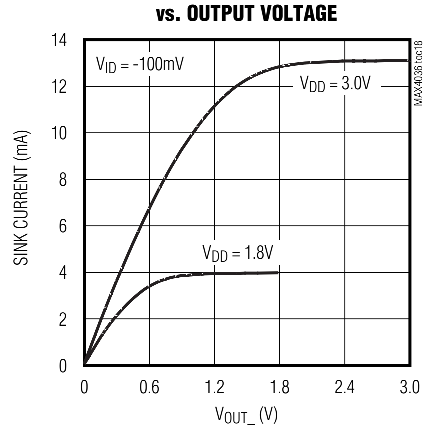
TOTAL HARMONIC DISTORTION PLUS NOISE vs. FREQUENCY



OP AMP STABILITY vs. CAPACITIVE AND RESISTIVE LOADS



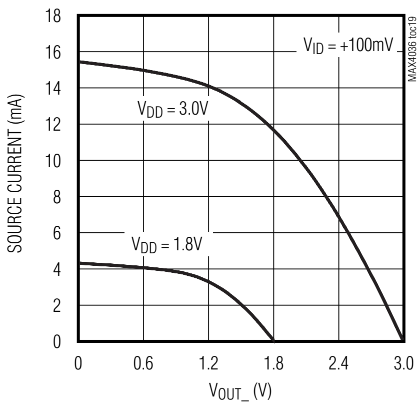
OP AMP SINK CURRENT vs. OUTPUT VOLTAGE



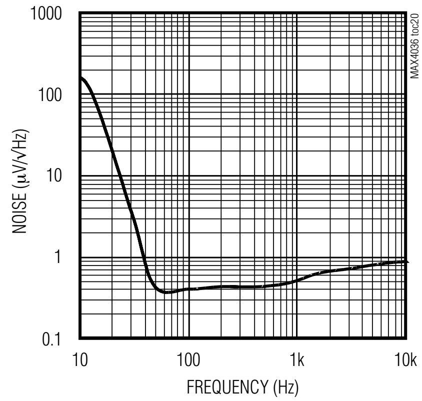
Typical Operating Characteristics (continued)

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

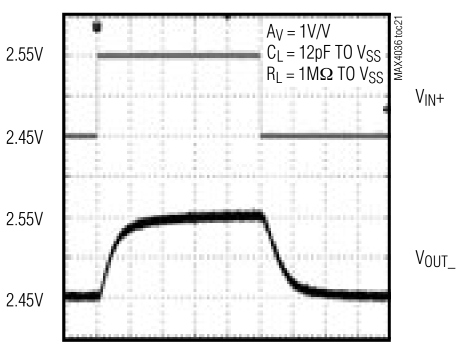
OP AMP SOURCE CURRENT vs. OUTPUT VOLTAGE



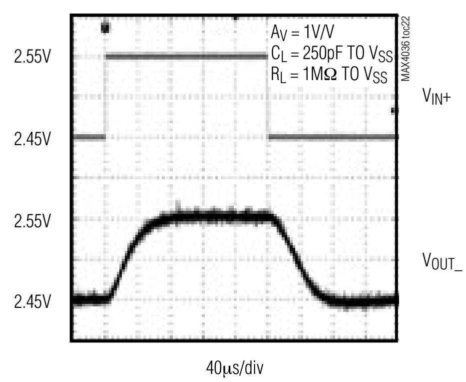
OP AMP VOLTAGE NOISE DENSITY vs. FREQUENCY



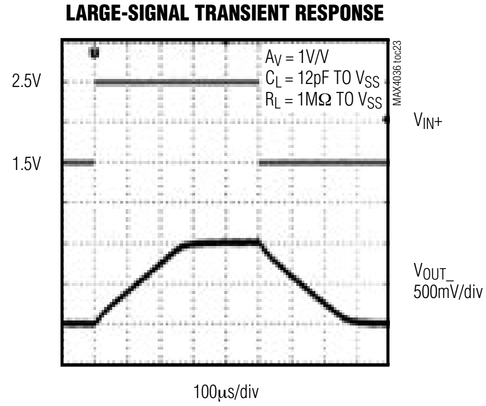
OP AMP SMALL-SIGNAL TRANSIENT RESPONSE



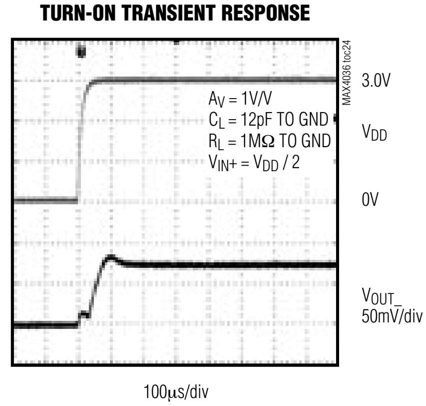
OP AMP SMALL-SIGNAL TRANSIENT RESPONSE



OP AMP LARGE-SIGNAL TRANSIENT RESPONSE



OP AMP TURN-ON TRANSIENT RESPONSE

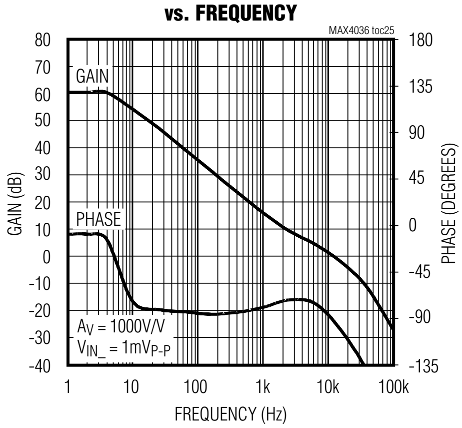


Low IBIAS, +1.4V/800nA, Rail-to-Rail Op Amps with +1.2V Buffered Reference

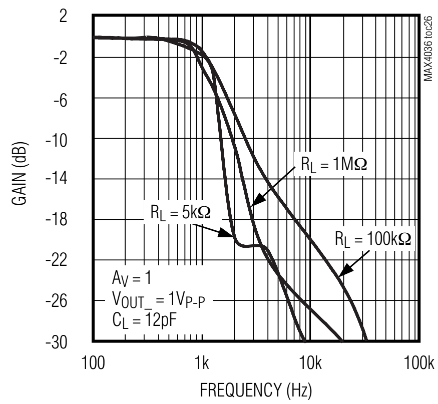
Typical Operating Characteristics (continued)

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

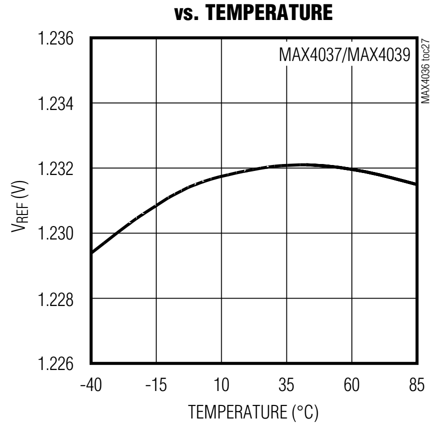
GAIN AND PHASE vs. FREQUENCY



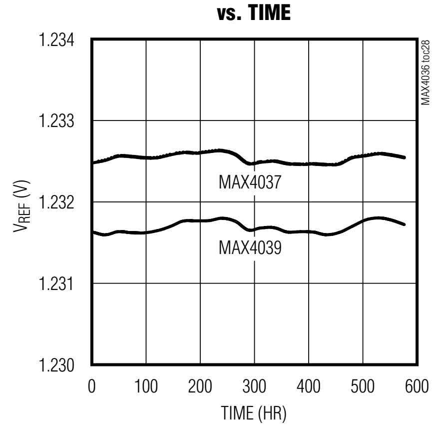
LARGE-SIGNAL GAIN vs. FREQUENCY



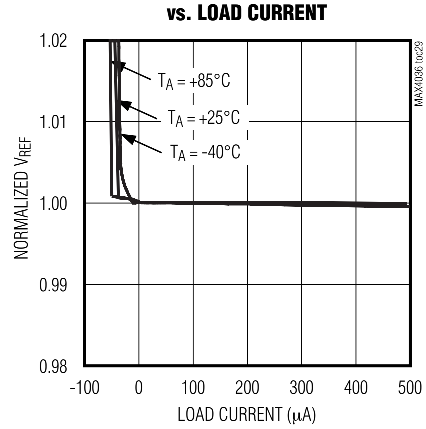
REFERENCE VOLTAGE vs. TEMPERATURE



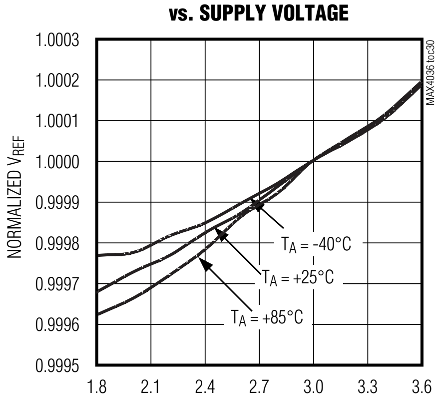
REFERENCE VOLTAGE CHANGE vs. TIME



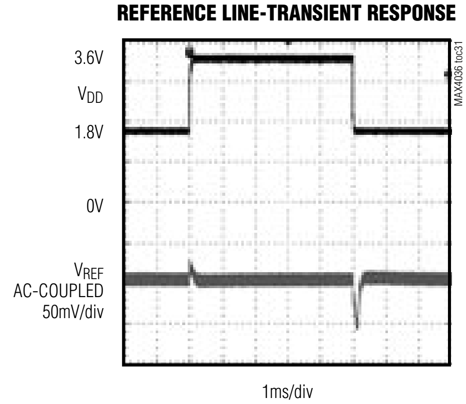
REFERENCE VOLTAGE CHANGE vs. LOAD CURRENT



REFERENCE VOLTAGE CHANGE vs. SUPPLY VOLTAGE



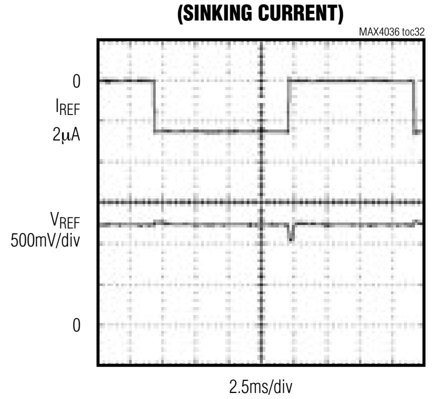
REFERENCE LINE-TRANSIENT RESPONSE



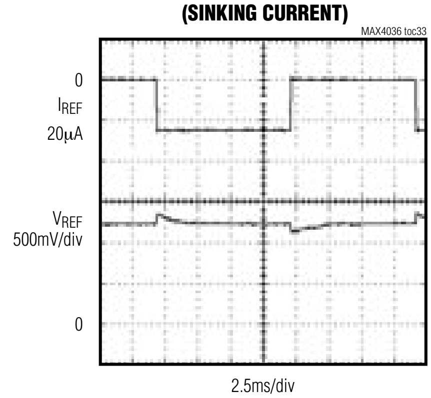
Typical Operating Characteristics (continued)

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

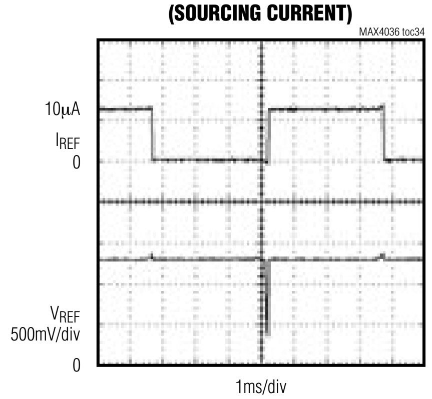
REFERENCE LOAD-TRANSIENT RESPONSE (SINKING CURRENT)



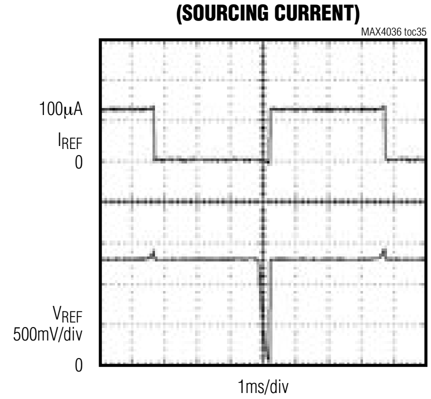
REFERENCE LOAD-TRANSIENT RESPONSE (SINKING CURRENT)



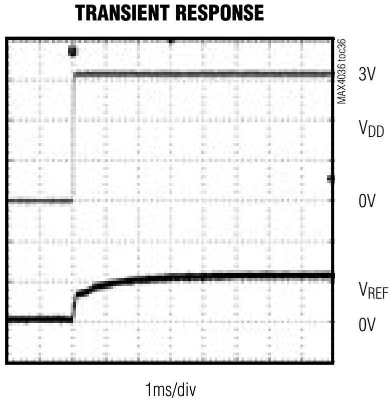
REFERENCE LOAD-TRANSIENT RESPONSE (SOURCING CURRENT)



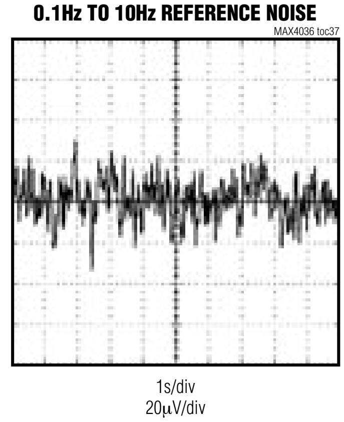
REFERENCE LOAD-TRANSIENT RESPONSE (SOURCING CURRENT)



REFERENCE TURN-ON TRANSIENT RESPONSE



0.1Hz TO 10Hz REFERENCE NOISE



Low I_{BIAS}, +1.4V/800nA, Rail-to-Rail Op Amps with +1.2V Buffered Reference

Pin Description

PIN				NAME	FUNCTION
MAX4036	MAX4037	MAX4038	MAX4039		
1	3	—	—	IN+	Noninverting Amplifier Input
2	2	4	5	V_{SS}	Negative Power-Supply Voltage
3	4	—	—	IN-	Inverting Amplifier Input
4	1	—	—	OUT	Amplifier Output
5	6	8	10	V_{DD}	Positive Power-Supply Voltage
—	5	—	6	REF	Reference Voltage Output
—	—	1	1	OUTA	Amplifier Output (Channel A)
—	—	2	2	INA-	Inverting Amplifier Input (Channel A)
—	—	3	3	INA+	Noninverting Amplifier Input (Channel A)
—	—	5	7	INB+	Noninverting Amplifier Input (Channel B)
—	—	6	8	INB-	Inverting Amplifier Input (Channel B)
—	—	7	9	OUTB	Amplifier Output (Channel B)
—	—	—	4	N.C.	No Connection. Not internally connected.
—	—	—	—	EP (TDFN only)	Exposed Paddle. Solder EP to V_{SS} or leave unconnected (TDFN packages 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.

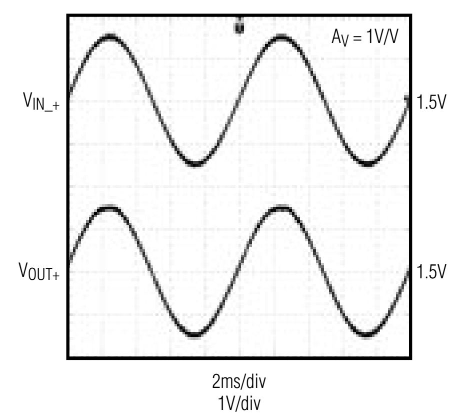


Figure 1. Rail-to-Rail Input/Output Voltage Range

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.

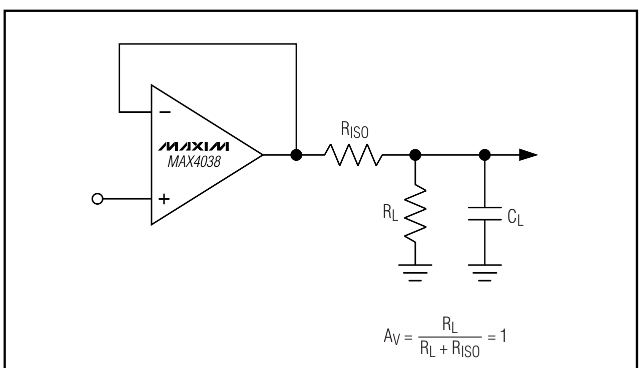


Figure 2. Using a Resistor to Isolate a Capacitive Load from the Op Amp

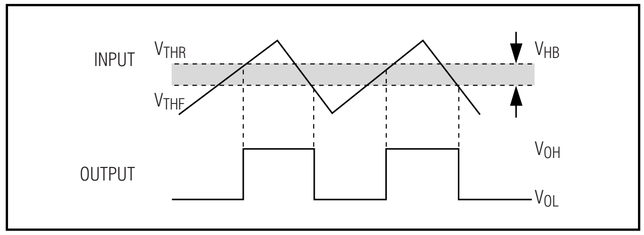


Figure 3. Hysteresis

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).

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.

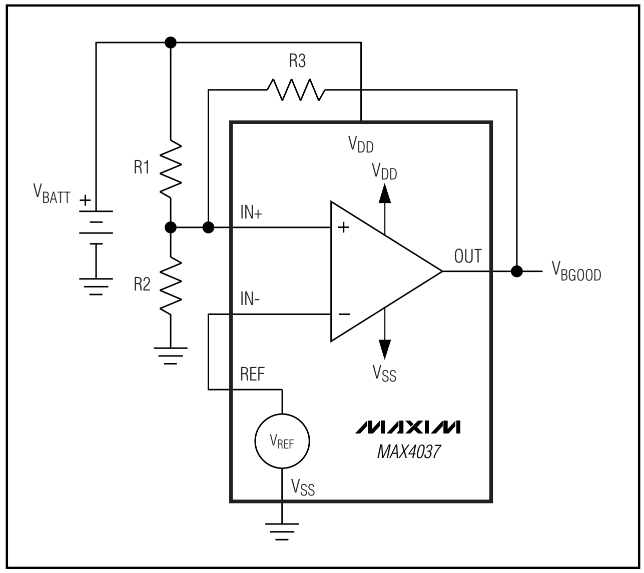


Figure 4. Battery Monitoring

Selector Guide

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

Chip Information

MAX4036 TRANSISTOR COUNT: 49

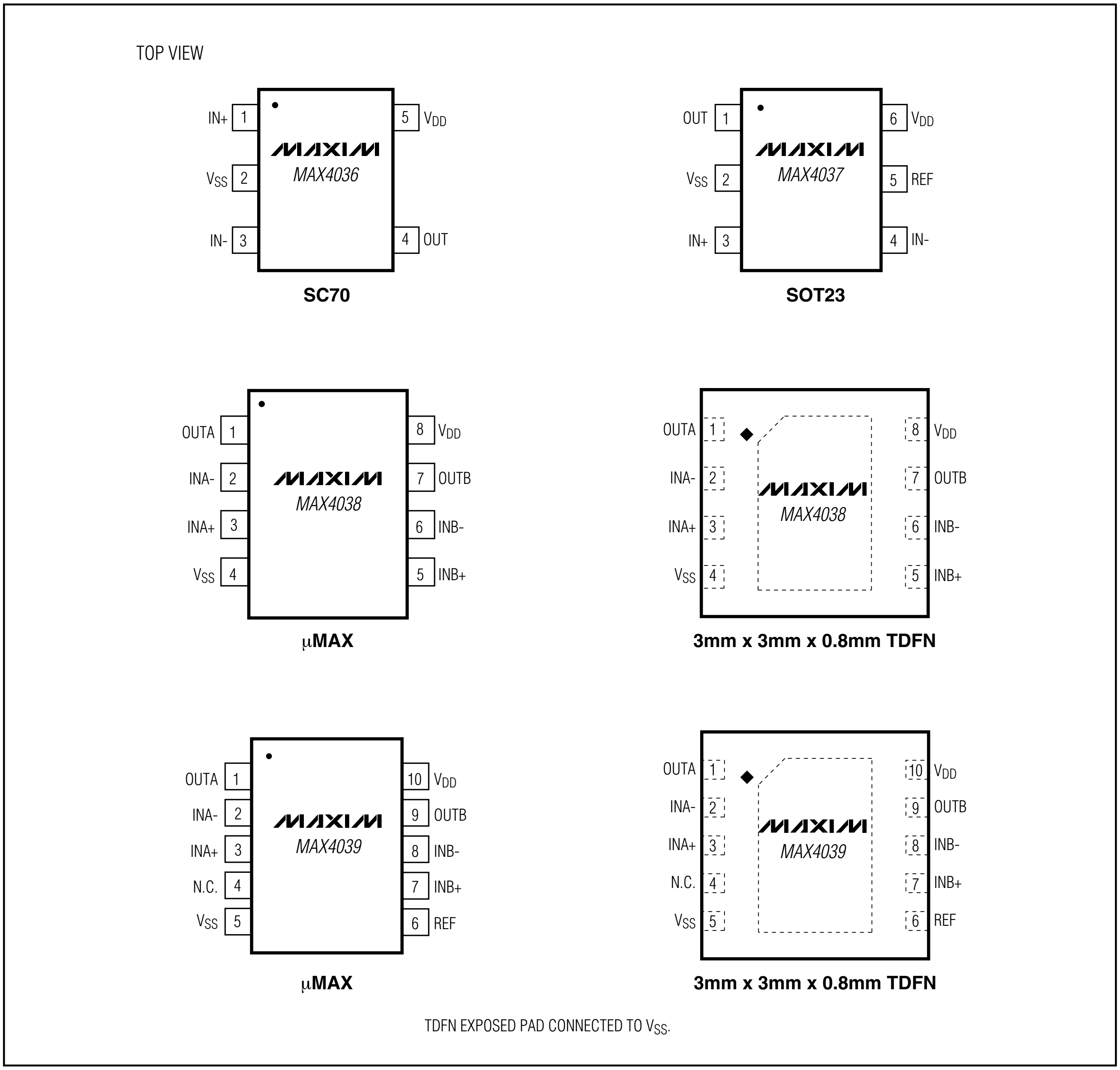
MAX4037 TRANSISTOR COUNT: 119

MAX4038 TRANSISTOR COUNT: 146

MAX4039 TRANSISTOR COUNT: 146

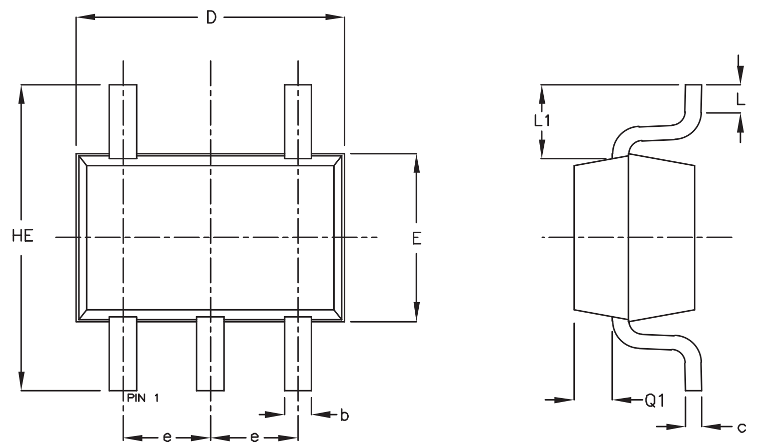
PROCESS: BiCMOS

Pin Configurations



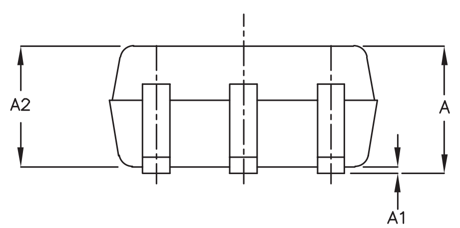
Package Information

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to **www.maxim-ic.com/packages**.)



SYMBOL	MIN	MAX
e	0.65 BSC	
D	1.80	2.20
b	0.15	0.30
E	1.15	1.35
HE	1.80	2.40
Q1	0.10	0.40
A2	0.80	1.00
A1	0.00	0.10
A	0.80	1.10
c	0.10	0.18
L	0.10	0.30
L1	0.425 TYP.	

NOTE:
1. ALL DIMENSIONS ARE IN MILLIMETERS
2. DIMENSIONS ARE INCLUSIVE OF PLATING
3. DIMENSIONS ARE EXCLUSIVE OF MOLD FLASH & METAL BURR
4. ALL SPECIFICATIONS COMPLY TO EIAJ SC70
5. COPLANARITY 4 MILS. MAX.



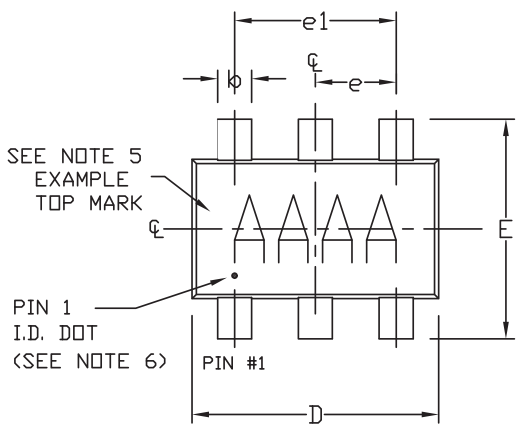
MAXIM
PROPRIETARY INFORMATION
TITLE:
PACKAGE OUTLINE, SC70, 5L

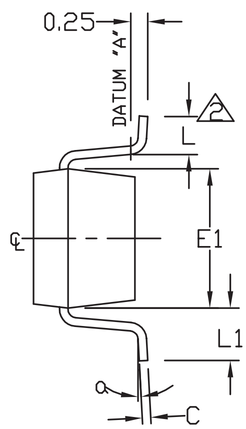
APPROVAL	DOCUMENT CONTROL NO.	REV	
	21-0076	B	1/1

Package Information (continued)

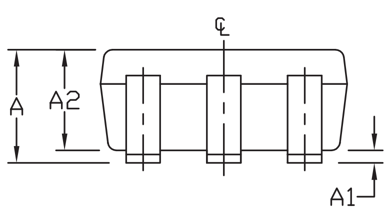
(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to **www.maxim-ic.com/packages**.)

6LSOT.EPS





SYMBOL	MIN	MAX
A	0.90	1.45
A1	0.00	0.15
A2	0.90	1.30
b	0.35	0.50
C	0.08	0.20
D	2.80	3.00
E	2.60	3.00
E1	1.50	1.75
L	0.35	0.60
L1	0.60 REF.	
e1	1.90 BSC.	
e	0.95 BSC.	
α	0°	10°



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 0.25 MM.
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 0.3 MM 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 0.1 MM.

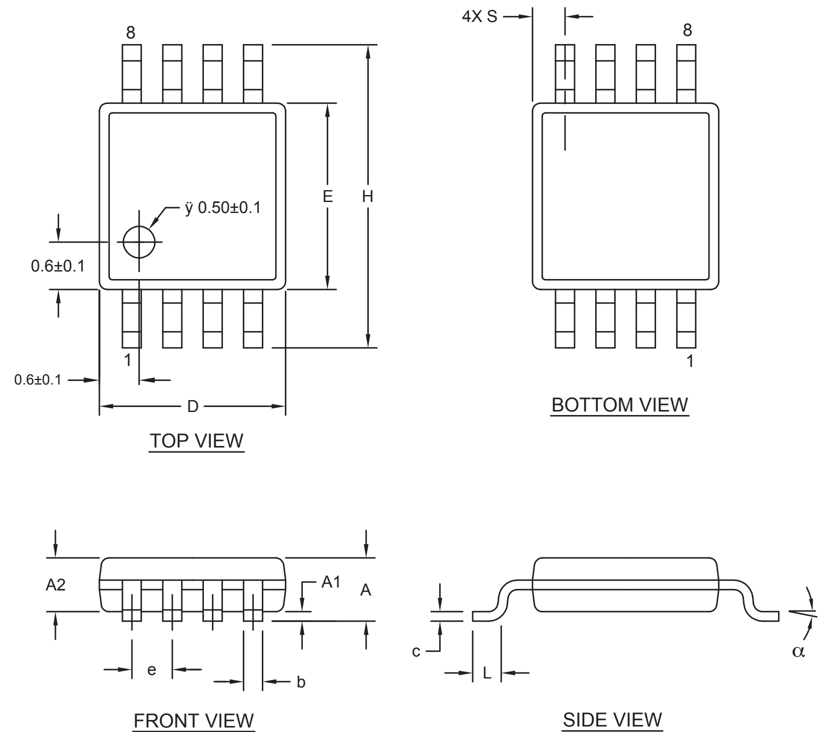
DALLAS SEMICONDUCTOR MAXIM
PROPRIETARY INFORMATION

TITLE: PACKAGE OUTLINE, SOT-23, 6L			
APPROVAL	DOCUMENT CONTROL NO. 21-0058	REV. F	1/1

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

Package Information (continued)

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to **www.maxim-ic.com/packages**.)



	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	0.116	0.120	2.95	3.05
e	0.0256 BSC		0.65 BSC	
E	0.116	0.120	2.95	3.05
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	

8LUMAXD.EPS

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. MEETS JEDEC MO-187C-AA.

DALLAS SEMICONDUCTOR MAXIM

PROPRIETARY INFORMATION

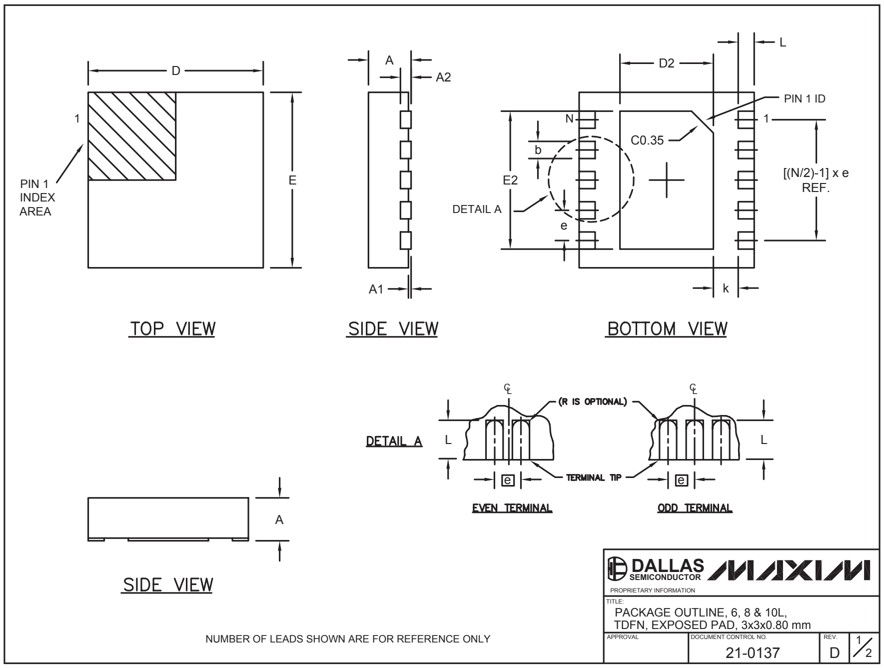
TITLE:

PACKAGE OUTLINE, 8L uMAX/uSOP

APPROVAL	DOCUMENT CONTROL NO.	REV.	
	21-0036	J	1/1

Package Information (continued)

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to **www.maxim-ic.com/packages**.)



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
T633-1	6	1.50±0.10	2.30±0.10	0.95 BSC	MO229 / WEEA	0.40±0.05	1.90 REF
T833-1	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

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".
6. "N" IS THE TOTAL NUMBER OF LEADS.

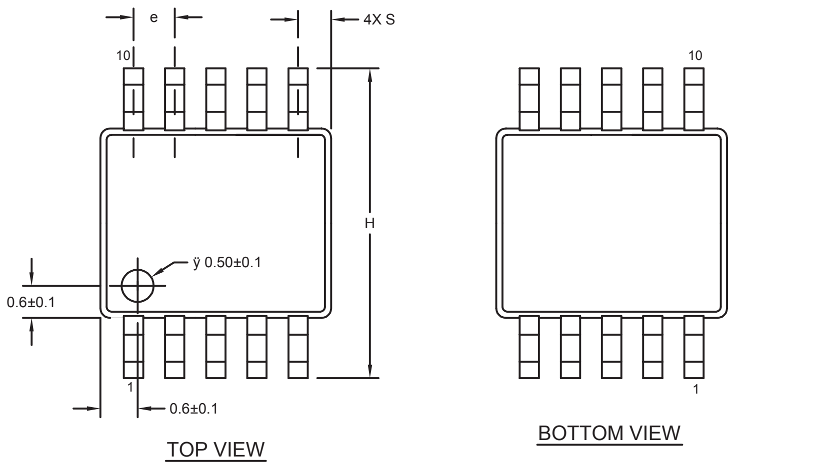
DALLAS SEMICONDUCTOR MAXIM
PROPRIETARY INFORMATION
TITLE: PACKAGE OUTLINE, 6, 8 & 10L, TDFN, EXPOSED PAD, 3x3x0.80 mm
APPROVAL | DOCUMENT CONTROL NO. 21-0137 | REV. D | 2/2

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

Package Information (continued)

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to **www.maxim-ic.com/packages**.)

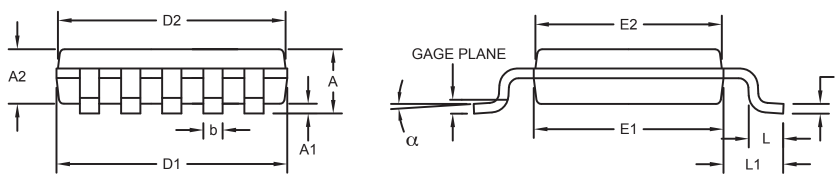
10LUMAX.EPS



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
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∞



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. MEETS JEDEC MO-187C-BA.

DALLAS SEMICONDUCTOR MAXIM

PROPRIETARY INFORMATION

TITLE:

PACKAGE OUTLINE, 10L uMAX/uSOP

APPROVAL	DOCUMENT CONTROL NO.	REV.	
	21-0061	I	1/1

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