

# High-Voltage, Precision, Low-Power Op Amps

## General Description

The MAX9943/MAX9944 is a family of high-voltage amplifiers that offers precision, low drift, and low-power consumption.

The MAX9943 (single) and MAX9944 (dual) op amps offer 2.4MHz of gain-bandwidth product with only 550 $\mu$ A of supply current per amplifier.

The MAX9943/MAX9944 family has a wide power supply range operating from  $\pm 3$ V to  $\pm 19$ V dual supplies or a 6V to 38V single supply.

The MAX9943/MAX9944 is ideal for sensor signal conditioning, high-performance industrial instrumentation and loop-powered systems (e.g., 4mA–20mA transmitters).

The MAX9943 is offered in a space-saving 6-pin TDFN or 8-pin  $\mu$ MAX<sup>®</sup> package. The MAX9944 is offered in an 8-pin SO or an 8-pin TDFN package. These devices are specified over the -40°C to +125°C automotive temperature range.

## Applications

Sensor Interfaces  
 Loop-Powered Systems  
 Industrial Instrumentation  
 High-Voltage ATE  
 High-Performance ADC/DAC Input/Output Amplifiers

$\mu$ MAX is a registered trademark of Maxim Integrated Products, Inc.

## Features

- ◆ Wide 6V to 38V Supply Range
- ◆ Low 100 $\mu$ V (max) Input Offset Voltage
- ◆ Low 0.4 $\mu$ V/°C Offset Drift
- ◆ Unity Gain Stable with 1nF Load Capacitance
- ◆ 2.4MHz Gain-Bandwidth Product
- ◆ 550 $\mu$ A Supply Current
- ◆ 20mA Output Current
- ◆ Rail-to-Rail Output
- ◆ Package Options
  - 3mm x 5mm, 8-Pin  $\mu$ MAX or 3mm x 3mm, 6-Pin TDFN Packages (Single)
  - 5mm x 6mm, 8-Pin SO or 3mm x 3mm, 8-Pin TDFN Packages (Dual)

## Ordering Information

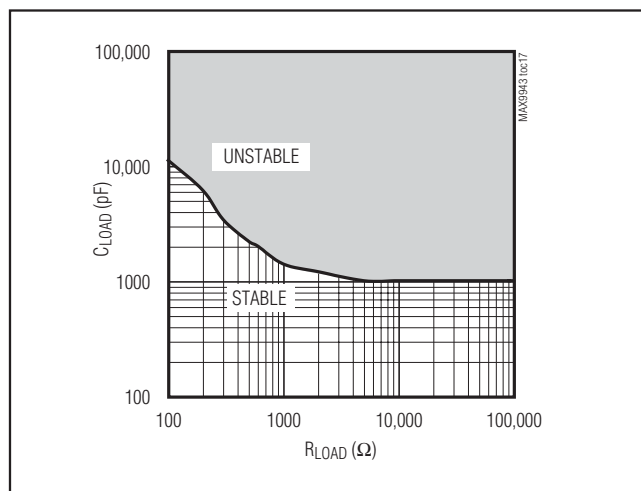
PART	TEMP RANGE	PIN-PACKAGE	TOP MARK
MAX9943AUA+	-40°C to +125°C	8 $\mu$ MAX	AACA
MAX9943ATT+	-40°C to +125°C	6 TDFN-EP*	AUF
MAX9944ASA+	-40°C to +125°C	8 SO	—
MAX9944ATA+	-40°C to +125°C	8 TDFN-EP*	BLN

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

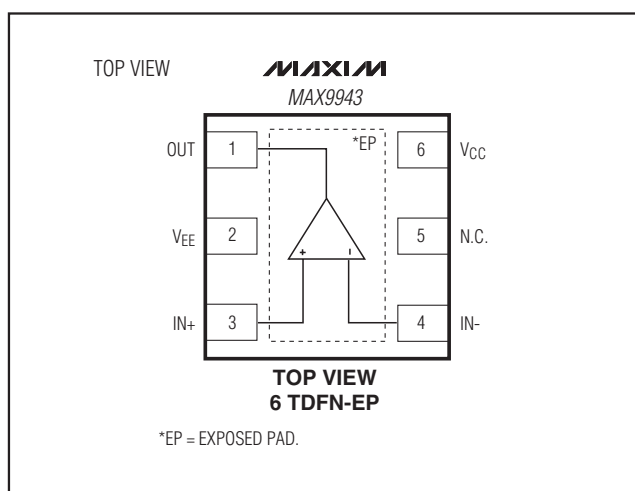
\*EP = Exposed pad.

MAX9943/MAX9944

## Capacitive Load vs. Resistive Load



## Package Detail



Pin Configurations appear at end of data sheet.

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## ABSOLUTE MAXIMUM RATINGS

Supply Voltage ( $V_{CC}$ to $V_{EE}$ )	-0.3V to +40V
All Other Pins (Note 1)	( $V_{EE} - 0.3V$ ) to ( $V_{CC} + 0.3V$ )
OUT Short-Circuit Current Duration	
8-Pin $\mu$ MAX ( $V_{CC} - V_{EE} \leq 20V$ )	3s
8-Pin $\mu$ MAX ( $V_{CC} - V_{EE} > 20V$ )	Momentary
6-Pin TDFN ( $V_{CC} - V_{EE} \leq 20V$ )	60s
6-Pin TDFN ( $V_{CC} - V_{EE} > 20V$ )	2s
8-Pin SO ( $V_{CC} - V_{EE} \leq 20V$ )	60s
8-Pin SO ( $V_{CC} - V_{EE} > 20V$ )	2s
8-Pin TDFN ( $V_{CC} - V_{EE} \leq 20V$ )	60s
8-Pin TDFN ( $V_{CC} - V_{EE} > 20V$ )	2s
Continuous Input Current (Any Pins)	$\pm 20mA$
Thermal Limits (Note 2)	
Multiple Layer PCB	
Continuous Power Dissipation ( $T_A = +70^\circ C$ )	
8-Pin $\mu$ MAX (derate 4.8mW/ $^\circ C$ above $+70^\circ C$ )	387.8mW

$\theta_{JA}$	206.3 $^\circ C/W$
$\theta_{JC}$	42 $^\circ C/W$
6-Pin TDFN-EP (derate 23.8mW/ $^\circ C$ above $+70^\circ C$ )	1904.8mW
$\theta_{JA}$	42 $^\circ C/W$
$\theta_{JC}$	9 $^\circ C/W$
8-Pin SO (derate 7.6mW/ $^\circ C$ above $+70^\circ C$ )	606.1W
$\theta_{JA}$	132 $^\circ C/W$
$\theta_{JC}$	38 $^\circ C/W$
8-Pin TDFN-EP (derate 24.4mW/ $^\circ C$ above $+70^\circ C$ )	1951.2mW
$\theta_{JA}$	41 $^\circ C/W$
$\theta_{JC}$	8 $^\circ C/W$
Operating Temperature Range	-40 $^\circ C$ to +125 $^\circ C$
Junction Temperature	+150 $^\circ C$
Lead Temperature (soldering, 10s)	+300 $^\circ C$

**Note 1:** Operation is limited by thermal limits.

**Note 2:** 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.maxim-ic.com/thermal-tutorial](http://www.maxim-ic.com/thermal-tutorial).

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

( $V_{CC} = 15V$ ,  $V_{EE} = -15V$ ,  $V_{CM} = 0$ ,  $R_L = 10k\Omega$  to GND, GND = 0,  $T_A = -40^\circ C$  to  $+125^\circ C$ . Typical values are at  $T_A = +25^\circ C$ , unless otherwise noted.) (Note 3)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>DC CHARACTERISTICS</b>						
Operating Supply Voltage Range	$V_{SUPPLY}$	Guaranteed by PSRR test	$\pm 3$		$\pm 19$	V
Quiescent Supply Current per Amplifier	$I_{CC}$			550	950	$\mu A$
Power-Supply Rejection Ratio	PSRR	$V_S = \pm 3V$ to $\pm 19V$	105	130		dB
Input Offset Voltage	$V_{OS}$	$T_A = +25^\circ C$		20	100	$\mu V$
		$T_A = -40^\circ C$ to $+125^\circ C$			240	
Input Offset Voltage Drift	$TCV_{OS}$			0.4		$\mu V/^\circ C$
Input Bias Current	$I_{BIAS}$	$V_{EE} + 0.3V \leq V_{CM} \leq V_{CC} - 1.8V$		4	20	nA
		$V_{EE} \leq V_{CM} \leq V_{CC} - 1.8V$			90	
Input Offset Current	$I_{OS}$	$V_{EE} \leq V_{CM} \leq V_{CC} - 1.8V$		1	10	nA
Input Voltage Range	$V_{IN+}$ , $V_{IN-}$	Guaranteed by CMRR test, $T_A = -40^\circ C$ to $+125^\circ C$	$V_{EE}$		$V_{CC} - 1.8$	V
Common-Mode Rejection Ratio	CMRR	$V_{EE} + 0.3V \leq V_{CM} \leq V_{CC} - 1.8V$	105	125		dB
		$V_{EE} \leq V_{CM} \leq V_{CC} - 1.8V$	105			

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## ELECTRICAL CHARACTERISTICS (continued)

( $V_{CC} = 15V$ ,  $V_{EE} = -15V$ ,  $V_{CM} = 0$ ,  $R_L = 10k\Omega$  to GND, GND = 0,  $T_A = -40^\circ C$  to  $+125^\circ C$ . Typical values are at  $T_A = +25^\circ C$ , unless otherwise noted.) (Note 3)

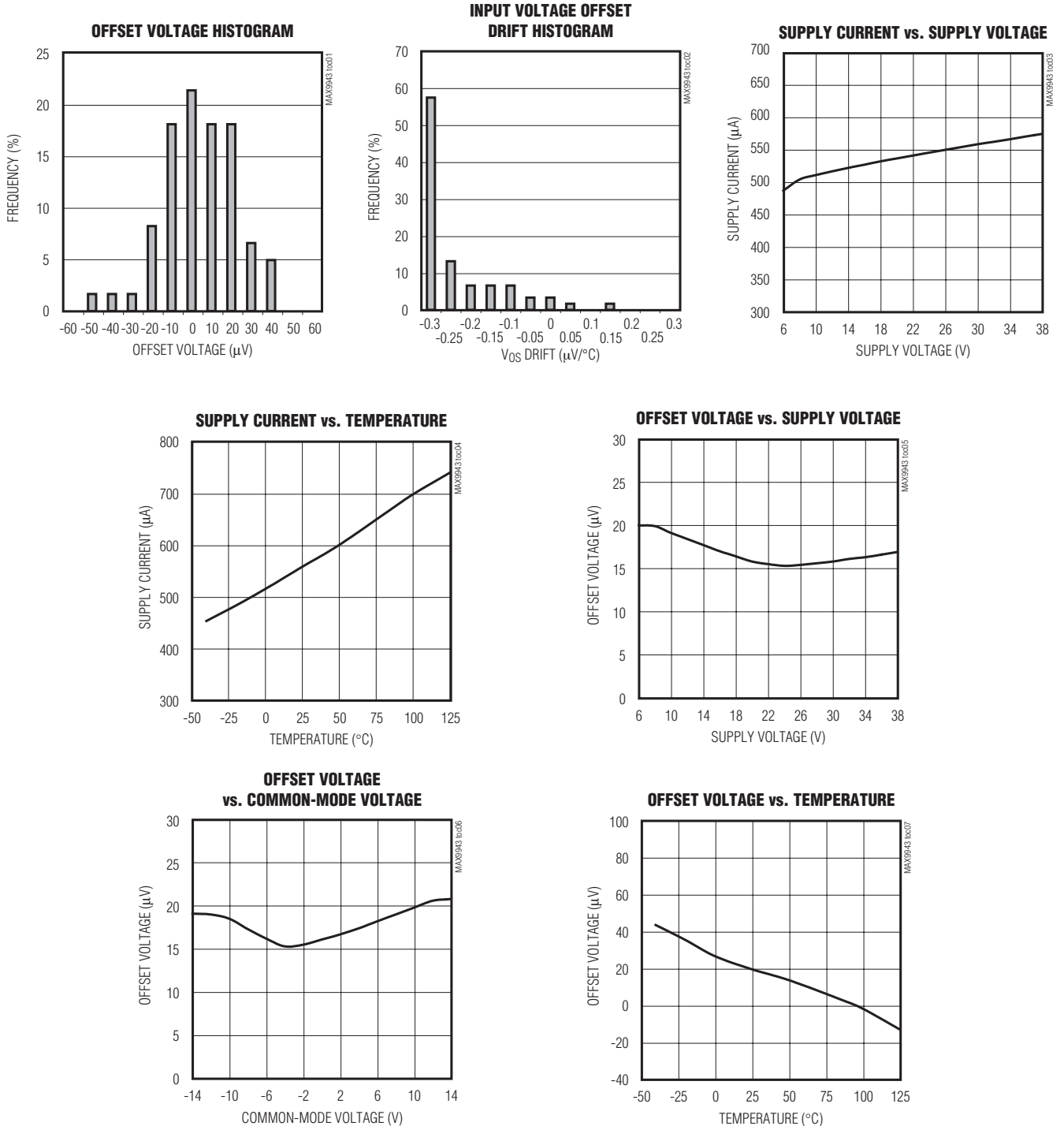
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Open-Loop Gain	$A_{VOL}$	$-13.5V \leq V_O \leq +13.5V$ , $R_L = 10k\Omega$ , $T_A = +25^\circ C$	115	130		dB
		$-13.5V \leq V_O \leq +13.5V$ , $R_L = 10k\Omega$ , $T_A = -40^\circ C$ to $+125^\circ C$	100			
		$-12V \leq V_O \leq +12V$ , $R_L = 600\Omega$ , $T_A = +25^\circ C$	100	110		
		$-12V \leq V_O \leq +12V$ , $R_L = 600\Omega$ , $T_A = -40^\circ C$ to $+85^\circ C$	90			
Output Voltage Swing	$V_{OH}$	$R_L = 10k\Omega$	$V_{CC} - 0.2$			V
		$R_L = 600\Omega$	$T_A = +25^\circ C$	$V_{CC} - 1.8$		
			$T_A = -40^\circ C$ to $+85^\circ C$	$V_{CC} - 2$		
	$V_{OL}$	$R_L = 10k\Omega$			$V_{EE} + 0.1$	
		$R_L = 600\Omega$	$T_A = +25^\circ C$		$V_{EE} + 1$	
			$T_A = -40^\circ C$ to $+85^\circ C$		$V_{EE} + 1.1$	
Short-Circuit Current	$I_{SC}$	$T_A = +25^\circ C$		60		mA
		$T_A = -40^\circ C$ to $+125^\circ C$		100		
<b>AC CHARACTERISTICS</b>						
Gain Bandwidth Product	GBWP			2.4		MHz
Slew Rate	SR	$-5V \leq V_{OUT} \leq +5V$		0.35		V/ $\mu s$
Input Voltage Noise Density	$e_n$	$f = 1kHz$		17.6		nV/ $\sqrt{Hz}$
Input Voltage Noise	TOTAL NOISE	$0.1Hz \leq f \leq 10Hz$		500		nV <sub>P-P</sub>
Input Current Noise Density	$i_n$	$f = 1kHz$		0.18		pA/ $\sqrt{Hz}$
Capacitive Loading	$C_{LOAD}$	No sustained oscillation		1000		pF

**Note 3:** All devices are 100% production tested at  $T_A = +25^\circ C$ . Temperature limits are guaranteed by design.

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## Typical Operating Characteristics

( $V_{CC} = 15V$ ,  $V_{EE} = -15V$ ,  $V_{CM} = 0$ ,  $R_L = 10k\Omega$  to GND,  $GND = 0$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

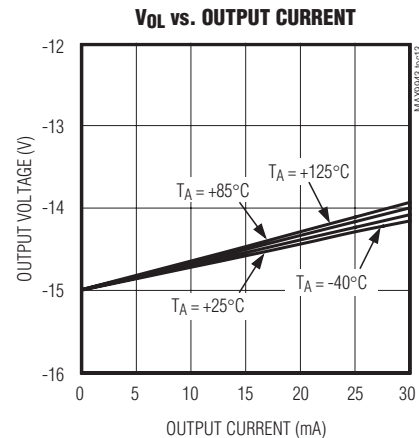
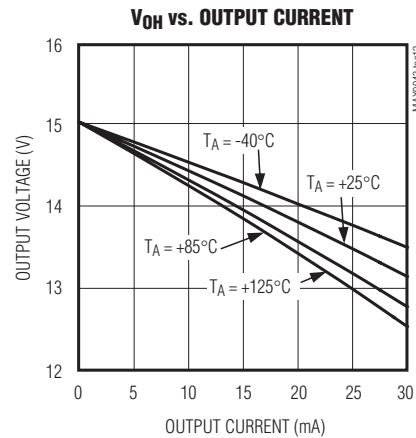
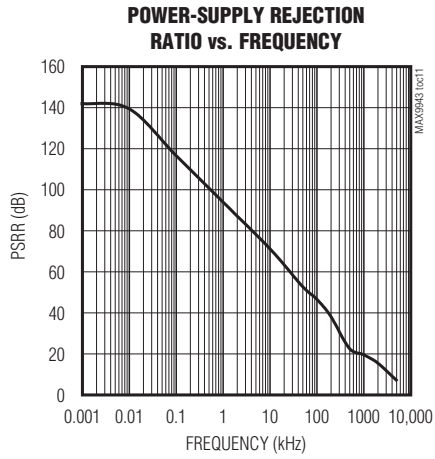
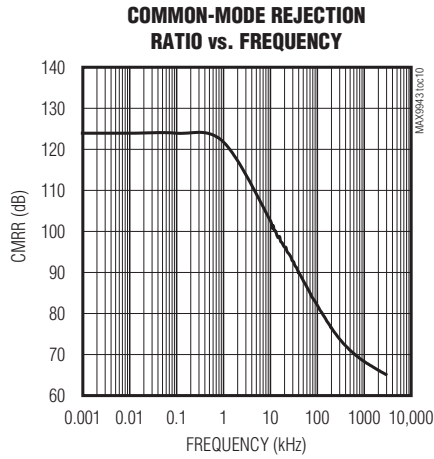
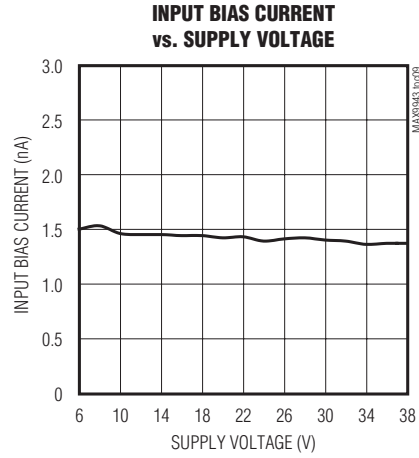
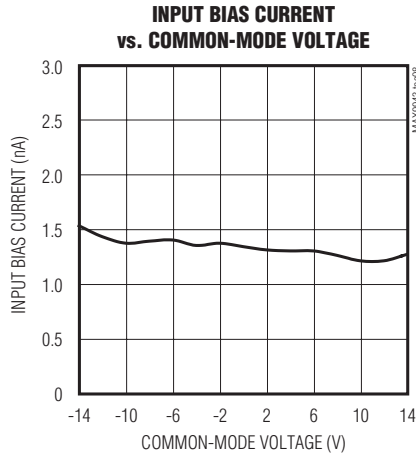


# High-Voltage, Precision, Low-Power Op Amps

MAX9943/MAX9944

## Typical Operating Characteristics (continued)

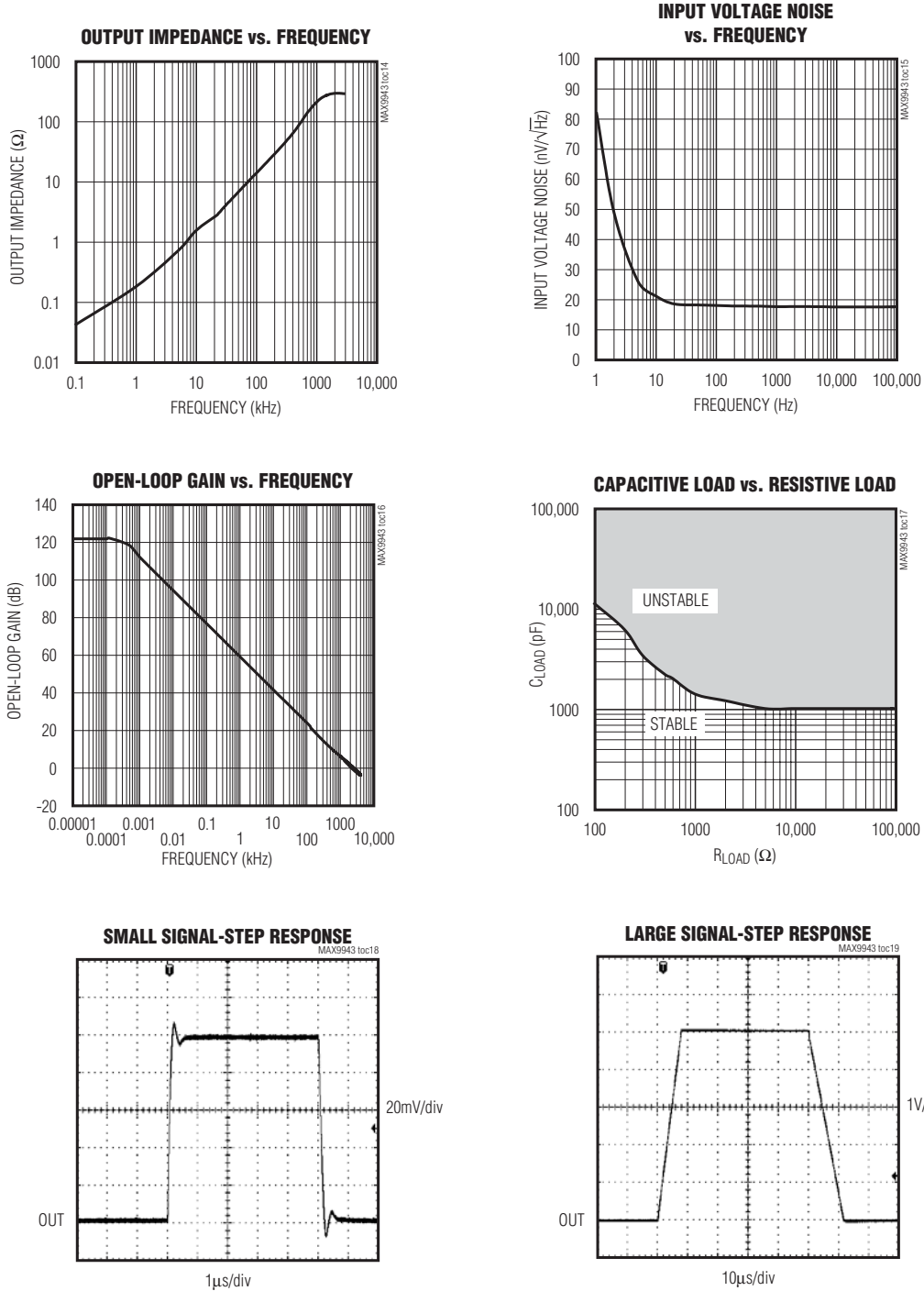
( $V_{CC} = 15V$ ,  $V_{EE} = -15V$ ,  $V_{CM} = 0$ ,  $R_L = 10k\Omega$  to GND,  $GND = 0$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



# High-Voltage, Precision, Low-Power Op Amps

## Typical Operating Characteristics (continued)

( $V_{CC} = 15V$ ,  $V_{EE} = -15V$ ,  $V_{CM} = 0$ ,  $R_L = 10k\Omega$  to GND,  $GND = 0$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



# High-Voltage, Precision, Low-Power Op Amps

## Pin Description

MAX9943 6 TDFN-EP	MAX9943 8 $\mu$ MAX	MAX9944 8 SO/TDFN-EP	NAME	FUNCTION
1	6	—	OUT	Output
—	—	1	OUTA	Output A
—	—	7	OUTB	Output B
2	4	4	VEE	Negative Power Supply. Bypass with a 0.1 $\mu$ F capacitor to ground.
3	3	—	IN+	Positive Input
—	—	3	INA+	Positive Input A
—	—	5	INB+	Positive Input B
4	2	—	IN-	Negative Input
—	—	2	INA-	Negative Input A
—	—	6	INB-	Negative Input B
5	1, 5, 8	—	N.C.	No Connection
6	7	8	VCC	Positive Power Supply. Bypass with a 0.1 $\mu$ F capacitor to ground.
—	—	—	EP	Exposed Pad (TDFN Only). Connect to a large ground plane to maximize thermal performance. Not intended as an electrical connection point.

MAX9943/MAX9944

## Detailed Description

The MAX9943/MAX9944 are single/dual operational amplifiers designed for industrial applications. They operate from 6V to 38V supply range while maintaining excellent performance. These devices utilize a three-stage architecture optimized for low offset voltage and low input noise with only 550 $\mu$ A supply current. The devices are unity gain stable with a 1nF capacitive load. These well-matched devices guarantee the high open-loop gain, CMRR, PSRR, and low voltage offset.

The MAX9943/MAX9944 provide a wide input/output voltage range. The input terminals of the MAX9943/MAX9944 are protected from excessive differential voltage with back-to-back diodes. The input signal current is also limited by an internal series resistor. With a 40V differential voltage, the input current is limited to 20mA. The output can swing to the negative rail while delivering 20mA of current, which is ideal for loop-powered system applications. The specifications and operation of the MAX9943/MAX9944 family is guaranteed over the -40°C to +125°C temperature range.

## Application Information

### Bias Current vs. Input Common Mode

The MAX9943/MAX9944 use an internal bias current cancellation circuit to achieve very low bias current over a wide input common-mode range. For such a circuit to function properly, the input common mode must be at least 300mV away from the negative supply VEE. The input common mode can reach the negative supply VEE. However, in the region between VEE and VEE + 0.3V, there is an increase in bias current for both inputs.

### Capacitive Load Stability

Driving large capacitive loads can cause instability in many op amps. The MAX9943/MAX9944 are stable with capacitive loads up to 1nF. The Capacitive Load vs. Resistive Load graph in the *Typical Operating Characteristics* gives the stable operation region for capacitive versus resistive loads. Stability with higher capacitive loads can be improved by adding an isolation resistor in series with the op-amp output, as shown in Figure 1. This resistor improves the circuit's phase margin by isolating the load capacitor from the amplifier's output.

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## Power Supplies and Layout

The MAX9943/MAX9944 can operate with dual supplies from  $\pm 3\text{V}$  to  $\pm 19\text{V}$  or with a single supply from  $+6\text{V}$  to  $+38\text{V}$  with respect to ground. When used with dual supplies, bypass both  $V_{CC}$  and  $V_{EE}$  with their own  $0.1\mu\text{F}$  capacitor to ground. When used with a single supply, bypass  $V_{CC}$  with a  $0.1\mu\text{F}$  capacitor to ground. Careful layout technique helps optimize performance by decreasing the amount of stray capacitance at the op amp's inputs and outputs. To decrease stray capacitance, minimize trace lengths by placing external components close to the op amp's pins.

## Output Current Capability

The MAX9943/MAX9944 are capable of driving heavy loads such as the ones that can be found in loop-powered systems for remote sensors. The information is transmitted through  $\pm 20\text{mA}$  or  $4\text{mA}$ – $20\text{mA}$  current output across long lines that are terminated with low resistance loads (e.g.,  $600\Omega$ ). The *Typical Application Circuit* shows the MAX9944 used as a voltage-to-current converter with a current-sense amplifier in the feedback loop. Because of the high output current capability of the MAX9944, the device can be used to directly drive the current-loop.

The specifications and operation of the MAX9943/MAX9944 family is guaranteed over the  $-40^\circ\text{C}$  to  $+125^\circ\text{C}$  temperature range. However, when used in applications with  $\pm 15\text{V}$  supply voltage (see Figure 3), the capability of driving more than  $\pm 20\text{mA}$  of current is limited to the  $-40^\circ\text{C}$  to  $+85^\circ\text{C}$  temperature range. Use a lower supply voltage if this current must be delivered at a higher temperature range.

## Input Common Mode and Output Swing

The MAX9943/MAX9944 input common-mode range can swing to the negative rail  $V_{EE}$ . The output voltage can swing to both the positive  $V_{CC}$  and the negative  $V_{EE}$  rails if the output stage is not heavily loaded. These two features are very important for applications where the MAX9943/MAX9944 are used with a single-supply ( $V_{EE}$  connected to ground). One of the applications that can benefit from these features is when the single-supply op amp is driving an ADC.

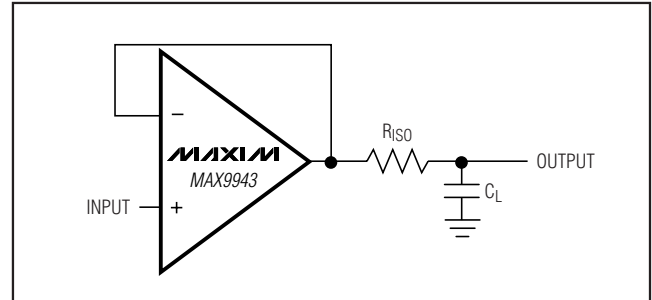


Figure 1. Capacitive Load Driving Circuit

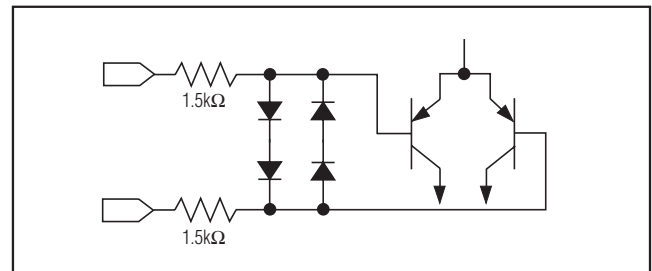


Figure 2. Input Protection Circuit

## Input Differential Voltage Protection

During normal op-amp operation, the inverting and non-inverting inputs of the MAX9943/MAX9944 are at essentially the same voltage. However, either due to fast input voltage transients or due to other fault conditions, these pins can be forced to be at two different voltages.

Internal back-to-back diodes and series resistors protect the inputs from an excessive differential voltage (see Figure 2). Therefore,  $IN+$  and  $IN-$  can be any voltage within the range shown in the absolute maximum rating. Note the protection time is still dependent on the package thermal limits.

## Chip Information

PROCESS: BiCMOS



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MAX9943/MAX9944

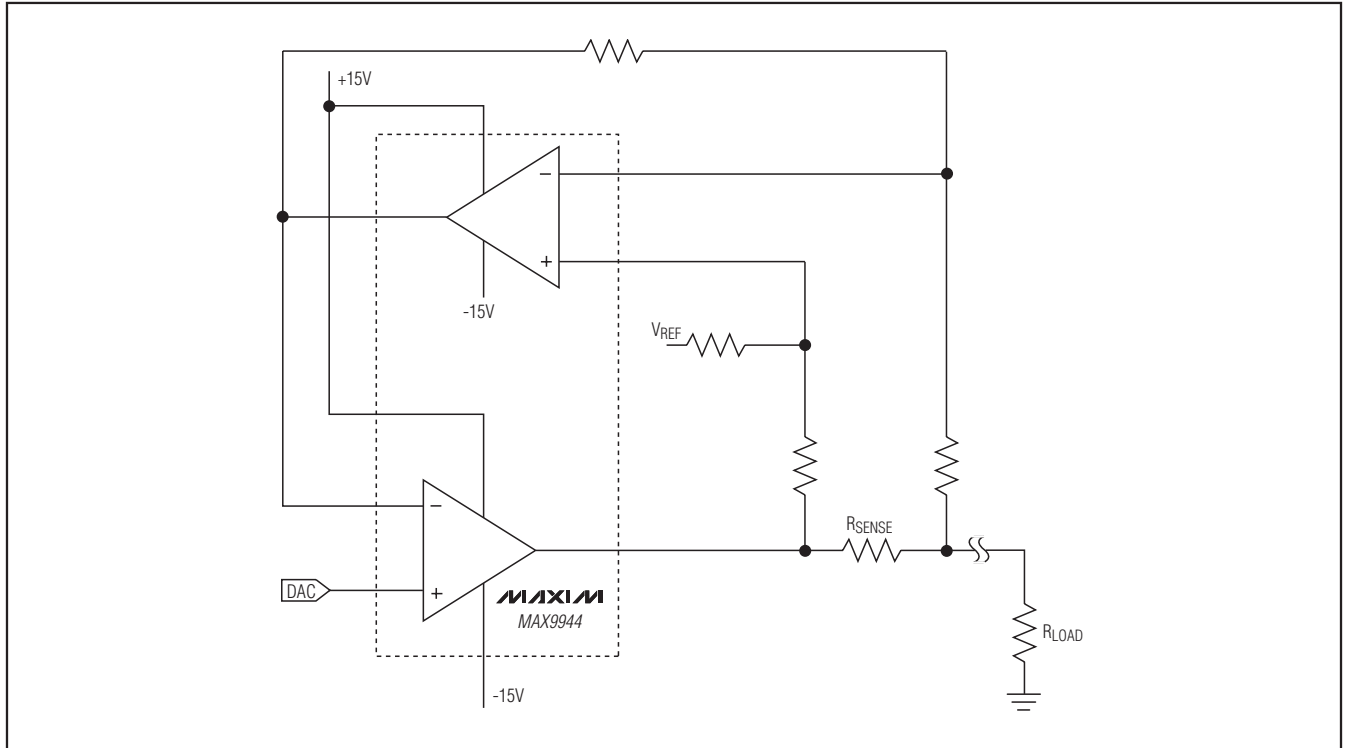
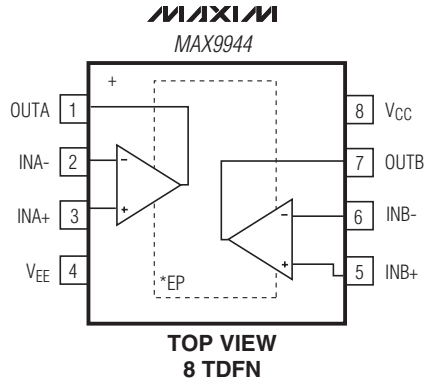
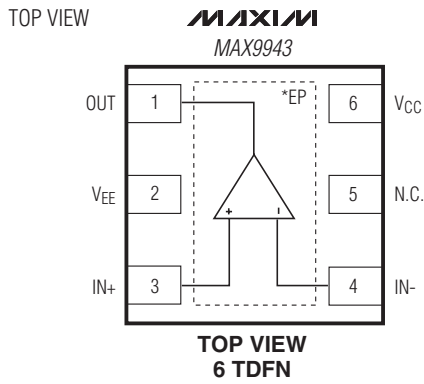
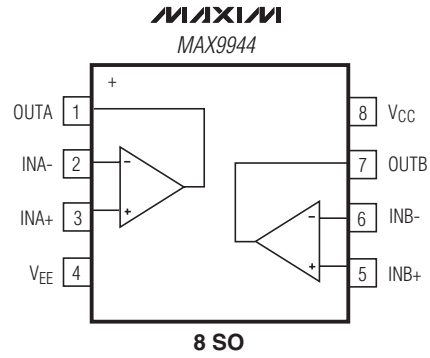
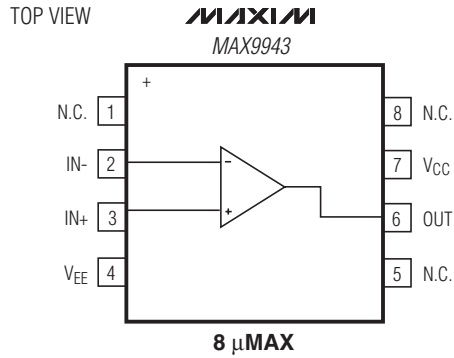


Figure 3. Typical  $\pm 20\text{mA}$  Current-Source in Loop-Powered Systems

# High-Voltage, Precision, Low-Power Op Amps

## Pin Configurations



NOT TO SCALE.  
\*EP = EXPOSED PAD.

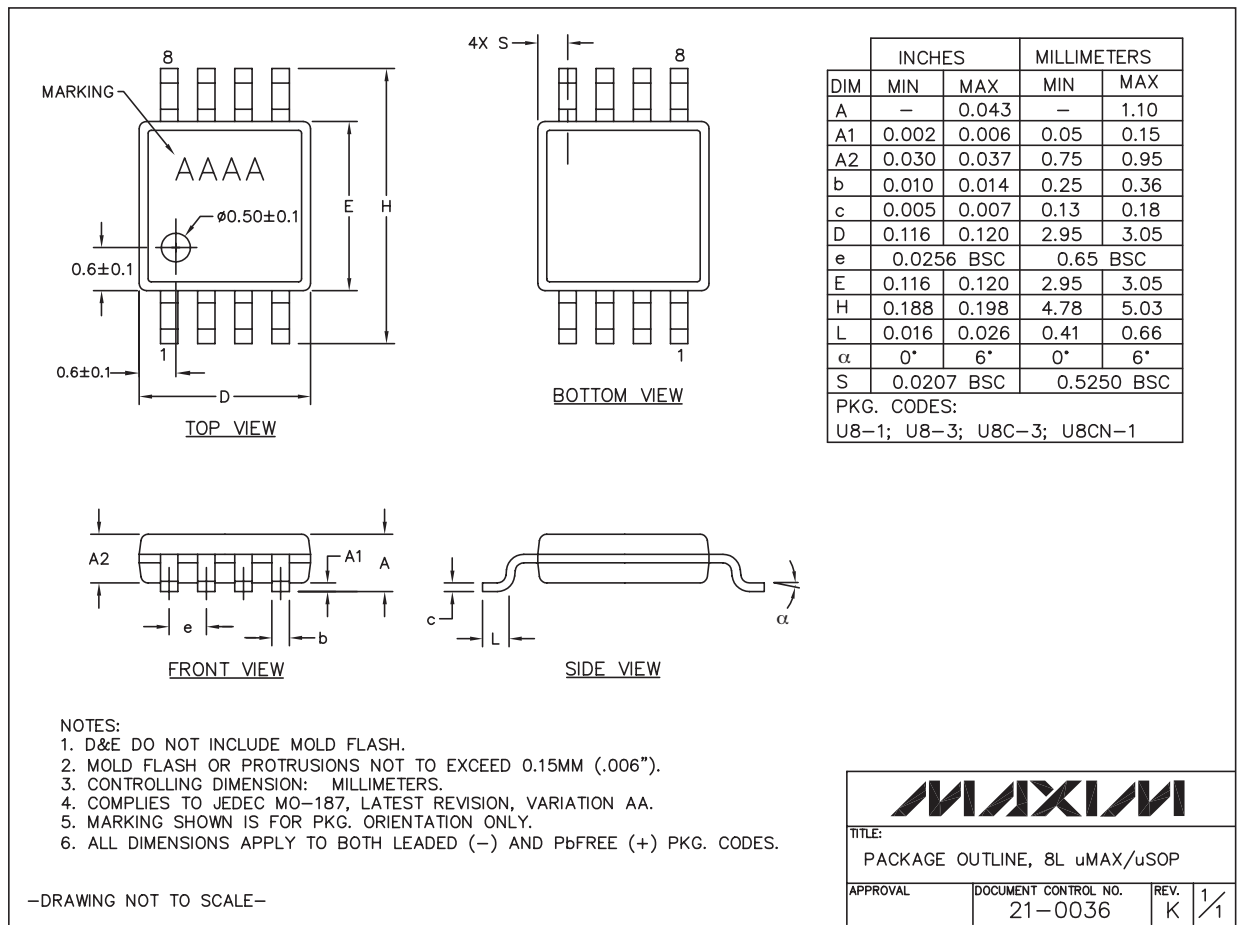
# High-Voltage, Precision, Low-Power Op Amps

## Package Information

For the latest package outline information and land patterns, go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages).

PACKAGE TYPE	PACKAGE CODE	DOCUMENT NO.
8 $\mu$ MAX	U8+1	<a href="#">21-0036</a>
6 TDFN-EP	T633+2	<a href="#">21-0137</a>
8 SO	S8+4	<a href="#">21-0041</a>
8 TDFN-EP	T833+2	<a href="#">21-0137</a>

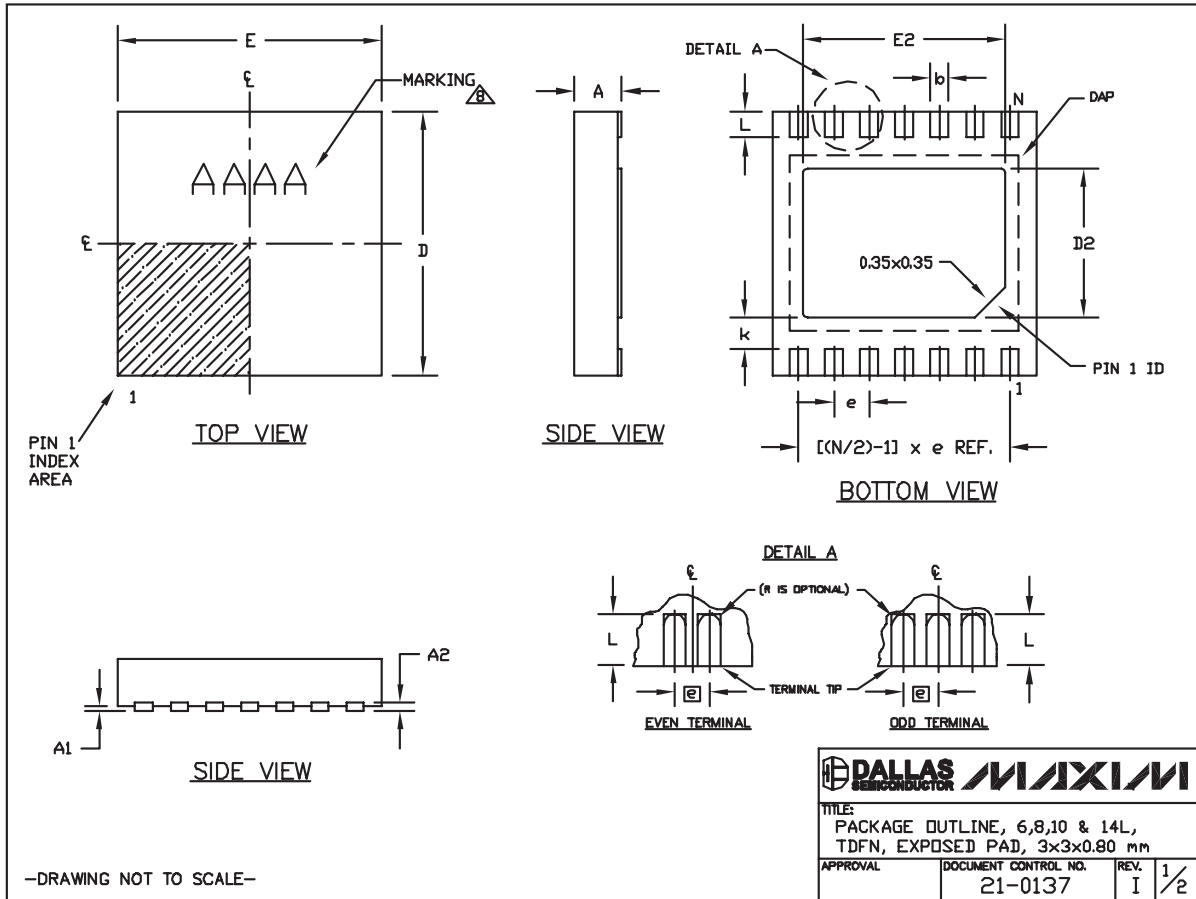
MAX9943/MAX9944



# High-Voltage, Precision, Low-Power Op Amps

## Package Information (continued)

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# High-Voltage, Precision, Low-Power Op Amps

## Package Information (continued)


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MAX9943/MAX9944


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	
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	

**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.
-  MARKING IS FOR PACKAGE ORIENTATION REFERENCE ONLY.

—DRAWING NOT TO SCALE—

			
TITLE: PACKAGE OUTLINE, 6,8,10 & 14L, TDFN, EXPOSED PAD, 3x3x0.80 mm			
APPROVAL	DOCUMENT CONTROL NO.	REV.	
	21-0137	I	2/2

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## Package Information (continued)

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SOICN .EPS

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.053	0.069	1.35	1.75
A1	0.004	0.010	0.10	0.25
B	0.014	0.019	0.35	0.49
C	0.007	0.010	0.19	0.25
e	0.050 BSC		1.27 BSC	
E	0.150	0.157	3.80	4.00
H	0.228	0.244	5.80	6.20
L	0.016	0.050	0.40	1.27

VARIATIONS:

DIM	INCHES		MILLIMETERS		N	MS012
	MIN	MAX	MIN	MAX		
D	0.189	0.197	4.80	5.00	8	AA
D	0.337	0.344	8.55	8.75	14	AB
D	0.386	0.394	9.80	10.00	16	AC

**NOTES:**

1. D&E DO NOT INCLUDE MOLD FLASH.
2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED 0.15mm (.006").
3. LEADS TO BE COPLANAR WITHIN 0.10mm (.004").
4. CONTROLLING DIMENSION: MILLIMETERS.
5. MEETS JEDEC MS012.
6. N = NUMBER OF PINS.

**DALLAS SEMICONDUCTOR** **MAXIM**

PROPRIETARY INFORMATION

TITLE: PACKAGE OUTLINE, .150" SOIC

APPROVAL	DOCUMENT CONTROL NO. 21-0041	REV. B	1/1
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# High-Voltage, Precision, Low-Power Op Amps

## Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	3/09	Initial release	—
1	4/09	Removed future product reference for the MAX9944, updated EC table	1, 2
2	6/09	Corrected TOC 13 and added rail-to-rail output feature	1, 3, 5, 8

**MAX9943/MAX9944**

Maxim cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in a Maxim product. No circuit patent licenses are implied. Maxim reserves the right to change the circuitry and specifications without notice at any time.

**Maxim Integrated Products, 120 San Gabriel Drive, Sunnyvale, CA 94086 408-737-7600** \_\_\_\_\_ 15

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