19-2103; Rev 1; 10/06

MAXIM

# Single/Dual/Quad, General-Purpose, Low-Voltage, Rail-to-Rail Output Op Amps



## General Description

The LMX321/LMX358/LMX324 are single/dual/quad, low-cost, low-voltage, pin-to-pin compatible upgrades to the LMV321/LMV358/LMV324 family of general purpose op amps. These devices offer rail-to-rail outputs and an input common-mode range that extends below ground. These op amps draw only 105µA of quiescent current per amplifier, operate from a single +2.3V to +7V supply, and drive 2kΩ resistive loads to within 40mV of either rail. The LMX321/LMX358/LMX324 are unity-gain stable with a 1.3MHz gain-bandwidth product capable of driving capacitive loads up to 400pF. The combination of low voltage, low cost, and small package size makes these amplifiers ideal for portable/battery-powered equipment.

The LMX321 single op amp is available in ultra-small 5-pin SC70 and space-saving 5-pin SOT23 packages. The LMX358 dual op amp is available in the tiny 8-pin SOT23 or the 8-pin µMAX® package. The LMX324 quad op amp is available in 14-pin TSSOP and SO packages.

## Applications

Cellular Phones

Laptops

Low-Power, Low-Voltage Applications

Portable/Battery-Powered Equipment

Cordless Phones

Active Filters

## Features

- **Upgrade to LMV321/LMV358/LMV324 Family**
- **Single +2.3V to +7V Supply Voltage Range**
- **Available in Space-Saving Packages**
  **5-Pin SC70 (LMX321)**
  **8-Pin SOT23 (LMX358)**
  **14-Pin TSSOP (LMX324)**
- **1.3MHz Gain-Bandwidth Product**
- **105µA Quiescent Current per Amplifier ($V_{CC}$ = +2.7V)**
- **No Phase Reversal for Overdriven Inputs**
- **No Crossover Distortion**
- **Rail-to-Rail Output Swing**
- **Input Common-Mode Voltage Range: $V_{EE}$ - 0.2V to $V_{CC}$ - 0.8V**
- **Drives 2kΩ Resistive Loads**

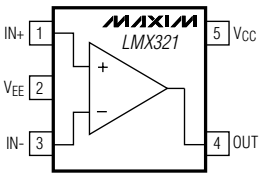
## Ordering Information

| PART | TEMP RANGE | PIN-PACKAGE | PKG CODE |
|---|---|---|---|
| **LMX321**AXK-T | -40°C to +125°C | 5 SC70-5 | X5-1 |
| LMX321AUK-T | -40°C to +125°C | 5 SOT23-5 | U5-1 |
| **LMX358**AKA-T | -40°C to +125°C | 8 SOT23-8 | K8-2 |
| LMX358ASA | -40°C to +125°C | 8 SO | S8-2 |
| LMX358AUA-T | -40°C to +125°C | 8 µMAX-8 | U8-1 |
| **LMX324**ASD | -40°C to +125°C | 14 SO | S14-4 |
| LMX324AUD | -40°C to +125°C | 14 TSSOP | U14-1 |

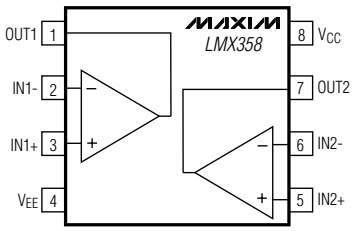
***Selector Guide appears at end of data sheet.***

## Pin Configurations

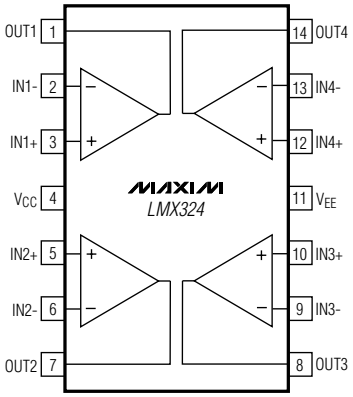
TOP VIEW




SC70-5/SOT23-5




SOT23-8/SO/µMAX




TSSOP/SO



***For pricing, delivery, and ordering information, please contact Maxim/Dallas Direct! at 1-888-629-4642, or visit Maxim's website at www.maxim-ic.com.***

# Single/Dual/Quad, General-Purpose, Low-Voltage, Rail-to-Rail Output Op Amps

## ABSOLUTE MAXIMUM RATINGS

Supply Voltage ($V_{CC}$ to $V_{EE}$) .....-0.3V to +8V
Differential Input Voltage ($V_{IN+}$ - $V_{IN-}$) .....$V_{EE}$ to $V_{CC}$
OUT_ to $V_{EE}$ .....-0.3V to ($V_{CC}$ + 0.3V)
Output Short-Circuit Duration
OUT_ Shorted to $V_{CC}$ or $V_{EE}$.....Continuous
Continuous Power Dissipation ($T_A$ = +70°C)
5-Pin SC70-5 (derate 3.1mW/°C above +70°C).....247mW
5-Pin SOT23-5 (derate 7.1mW/°C above +70°C) .....571mW
8-Pin SOT23-8 (derate 7.52mW/°C above +70°C) .....602mW
8-Pin SO (derate 5.9mW/°C above +70°C).....471mW
8-Pin µMAX (derate 4.5mW/°C above +70°C) .....362mW
14-Pin TSSOP (derate 9.1mW/°C above +70°C) .....727mW
14-Pin SO (derate 8.3mW/°C above +70°C).....667mW
Operating Temperature Range .....-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

($V_{CC}$ = +2.7V, $V_{EE}$ = 0V, $V_{OUT}$ = $V_{CC}$/2, $V_{CM}$ = 1V, $R_L$ > 1MΩ, **$T_A$ = +25°C**, unless otherwise noted.)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| **DC CHARACTERISTICS** | | | | | | | |
| Input Offset Voltage | $V_{OS}$ | | | | 1 | 6 | mV |
| Input Offset Voltage Average Drift | $TCV_{OS}$ | | | | 6 | | µV/°C |
| Input Bias Current | $I_B$ | | | | 18 | 50 | nA |
| Input Offset Current | $I_{OS}$ | | | | 1 | 8 | nA |
| Common-Mode Rejection Ratio | CMRR | -0.2V < $V_{CM}$ < 1.8V | | 72 | 92 | | dB |
| Power-Supply Rejection Ratio | PSRR | 2.3V ≤ $V_{CC}$ ≤ 7V, $V_{OUT}$ = 1V | | 82 | 96 | | dB |
| Input Common-Mode Voltage Range | $V_{CM}$ | For CMRR ≥ 72dB | Limit | -0.2 | | +1.8 | V |
| | | | Typ | -0.2 | | +1.9 | |
| Large-Signal Voltage Gain | $A_{VOL}$ | $R_L$ = 2kΩ to $V_{EE}$, 0.3V < $V_{OUT}$ < 2.4V | | 20 | 120 | | V/mV |
| Output-Voltage Swing | $V_{OUT}$ | $R_L$ = 10kΩ to 1.35V | $V_{CC}$ - $V_{OH}$ | | 12 | 50 | mV |
| | | | $V_{OL}$ | | 10 | 40 | |
| | | $R_L$ = 2kΩ to 1.35V | $V_{CC}$ - $V_{OH}$ | | 40 | 110 | |
| | | | $V_{OL}$ | | 25 | 60 | |
| Supply Current | $I_{CC}$ | LMX321 (single) | | | 105 | 150 | µA |
| | | LMX358 (dual) | | | 210 | 300 | |
| | | LMX324 (quad) | | | 420 | 600 | |
| **AC CHARACTERISTICS** | | | | | | | |
| Slew Rate | SR | 1V step Input | | | 1 | | V/µs |
| Gain-Bandwidth Product | GBW | $C_L$ = 200pF | | | 1.3 | | MHz |
| Phase Margin | ϕM | | | | 64 | | degrees |
| Gain Margin | GM | | | | 24 | | dB |
| Input Noise-Voltage Density | $e_n$ | f = 1kHz | | | 66 | | nV/√Hz |
| Input Current-Noise Density | $i_n$ | f = 1kHz | | | 0.13 | | pA/√Hz |

## ELECTRICAL CHARACTERISTICS

($V_{CC}$ = +2.7V, $V_{EE}$ = 0V, $V_{OUT}$ = $V_{CC}$/2, $V_{CM}$ = 1V, $R_L$ > 1MΩ, $T_A$ = **-40°C to +125°C**, unless otherwise noted.) (Note 1)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| **DC CHARACTERISTICS** | | | | | | | |
| Input Offset Voltage | $V_{OS}$ | | | | | 9 | mV |
| Input Bias Current | $I_B$ | | | | | 70 | nA |
| Input Offset Current | $I_{OS}$ | | | | | 15 | nA |
| Common-Mode Rejection Ratio | CMRR | -0.1 < $V_{CM}$ < +1.7V | | 60 | | | dB |
| Power-Supply Rejection Ratio | PSRR | 2.3V ≤ $V_{CC}$ ≤ 7V, $V_{OUT}$ = 1V | | 75 | | | dB |
| Input Common-Mode Voltage Range | $V_{CM}$ | For CMRR ≥ 60dB | Limit | -0.1 | | +1.7 | V |
| | | | Typ | -0.1 | | +1.8 | |
| Large-Signal Voltage Gain | $A_{VOL}$ | $R_L$ = 2kΩ to $V_{EE}$, 0.3V ≤ $V_{OUT}$ ≤ 2.4V | | 10 | | | V/mV |
| Output-Voltage Swing | $V_{OUT}$ | $R_L$ = 10kΩ to 1.55V | $V_{CC}$ - $V_{OH}$ | | | 130 | mV |
| | | | $V_{OL}$ | | | 50 | |
| | | $R_L$ = 2kΩ to 1.35V | $V_{CC}$ - $V_{OH}$ | | | 150 | |
| | | | $V_{OL}$ | | | 70 | |
| Supply Current | $I_{CC}$ | LMX321 (single) | | | | 180 | µA |
| | | LMX358 (dual) | | | | 360 | |
| | | LMX324 (quad) | | | | 720 | |

## ELECTRICAL CHARACTERISTICS

($V_{CC}$ = +5V, $V_{EE}$ = 0V, $V_{OUT}$ = $V_{CC}$/2, $V_{CM}$ = 2V, $R_L$ > 1MΩ, **$T_A$ = +25°C**, unless otherwise noted.)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| **DC CHARACTERISTICS** | | | | | | | |
| Input Offset Voltage | $V_{OS}$ | | | | 1 | 6 | mV |
| Input Offset Voltage Average Drift | $TCV_{OS}$ | | | | 6 | | µV/°C |
| Input Bias Current | $I_B$ | | | | 18 | 50 | nA |
| Input Offset Current | $I_{OS}$ | | | | 1 | 8 | nA |
| Input Differential Clamp Voltage | $V_{CLAMP}$ | Force 100µA into IN+, IN- = GND measure $V_{IN+}$ - $V_{IN-}$, Figure 1 | | | 3.1 | | V |
| Common-Mode Rejection Ratio | CMRR | -0.2 < $V_{CM}$ < +4.1V | | 72 | 92 | | dB |
| Power-Supply Rejection Ratio | PSRR | 2.3V ≤ $V_{CC}$ ≤ 7V, $V_{OUT}$ = 1V, $V_{CM}$ = 1V | | 82 | 96 | | dB |
| Input Common-Mode Voltage Range | $V_{CM}$ | For CMRR ≥ 72dB | Limit | -0.2 | | +4.1 | V |
| | | | Typ | -0.2 | | +4.2 | |
| Large-Signal Voltage Gain | $A_{VOL}$ | $R_L$ = 2kΩ to $V_{EE}$, 0.3V ≤ $V_{OUT}$ ≤ 4.7V | | 40 | 200 | | V/mV |

# Single/Dual/Quad, General-Purpose, Low-Voltage, Rail-to-Rail Output Op Amps

## ELECTRICAL CHARACTERISTICS (continued)

($V_{CC}$ = +5V, $V_{EE}$ = 0V, $V_{OUT}$ = $V_{CC}$/2, $V_{CM}$ = 2V, $R_L$ > 1MΩ, **$T_A$ = +25°C**, unless otherwise noted.)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| Output-Voltage Swing | $V_{OUT}$ | $R_L$ = 10kΩ to 2.5V | $V_{CC}$ - $V_{OH}$ | | 20 | 60 | mV |
| | | | $V_{OL}$ | | 12 | 40 | |
| | | $R_L$ = 2kΩ to 2.5V | $V_{CC}$ - $V_{OH}$ | | 65 | 130 | |
| | | | $V_{OL}$ | | 40 | 80 | |
| Output Short-Circuit Current | $I_{SC}$ | Sourcing, $V_{OUT}$ = 0V | | 5 | 25 | | mA |
| | | Sinking, $V_{OUT}$ = 5V | | 10 | 28 | | |
| Supply Current | $I_{CC}$ | LMX321 (single) | | | 120 | 170 | µA |
| | | LMX358 (dual) | | | 240 | 340 | |
| | | LMX324 (quad) | | | 480 | 680 | |
| **AC CHARACTERISTICS** | | | | | | | |
| Slew Rate | SR | 3V step input | | | 1 | | V/µs |
| Gain-Bandwidth Product | GBW | $C_L$ = 200pF | | | 1.3 | | MHz |
| Phase Margin | $\phi_M$ | | | | 65 | | degrees |
| Gain Margin | GM | | | | 25 | | dB |
| Input Noise-Voltage Density | $e_n$ | f = 1kHz | | | 65 | | nV/√Hz |
| Input Noise-Current Density | $i_n$ | f = 1kHz | | | 0.13 | | pA/√Hz |

## ELECTRICAL CHARACTERISTICS

($V_{CC}$ = +5V, $V_{EE}$ = 0V, $V_{OUT}$ = $V_{CC}$/2, $V_{CM}$ = 2V, $R_L$ > 1MΩ, **$T_A$ = -40°C to +125°C**, unless otherwise noted.) (Note 1)

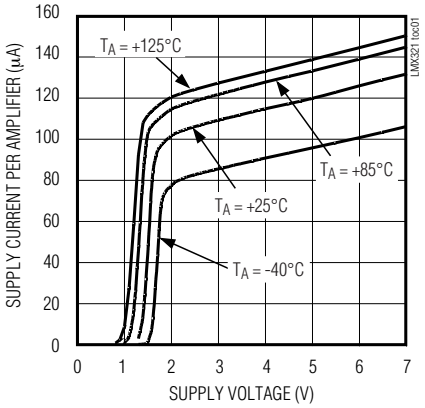
| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| **DC CHARACTERISTICS** | | | | | | | |
| Input Offset Voltage | $V_{OS}$ | | | | | 9 | mV |
| Input Bias Current | $I_B$ | | | | | 70 | nA |
| Input Offset Current | $I_{OS}$ | | | | | 15 | nA |
| Common-Mode Rejection Ratio | CMRR | -0.1 < $V_{CM}$ < +4.0V | | 63 | | | dB |
| Power-Supply Rejection Ratio | PSRR | 2.3V ≤ $V_{CC}$ ≤ 7V, $V_{OUT}$ = 1V, $V_{CM}$ = 1V | | 75 | | | dB |
| Input Common-Mode Voltage Range | $V_{CM}$ | For CMRR ≥ 63dB | Limit | -0.1 | | +4.0 | V |
| | | | Typ | -0.1 | | +4.1 | |
| Large-Signal Voltage Gain | $A_{VOL}$ | $R_L$ = 2kΩ to $V_{EE}$, 0.3V ≤ $V_{OUT}$ ≤ 4.7V | | 20 | | | V/mV |
| Output-Voltage Swing | $V_{OUT}$ | $R_L$ = 10kΩ to 2.5V | $V_{CC}$ - $V_{OH}$ | | | 170 | mV |
| | | | $V_{OL}$ | | | 70 | |
| | | $R_L$ = 2kΩ to 2.5V | $V_{CC}$ - $V_{OH}$ | | | 190 | |
| | | | $V_{OL}$ | | | 90 | |
| Supply Current | $I_{CC}$ | LMX321 (single) | | | | 210 | µA |
| | | LMX358 (dual) | | | | 420 | |
| | | LMX324 (quad) | | | | 840 | |

**Note 1:** Specifications are 100% tested at $T_A$ = +25°C (exceptions noted). All temperature limits are guaranteed by design.

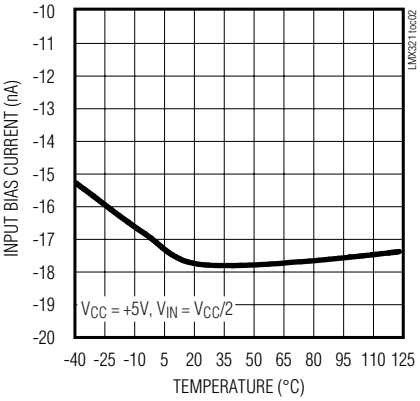
## Typical Operating Characteristics

($T_A$ = +25°C, $V_{EE}$ = 0V, unless otherwise noted.)

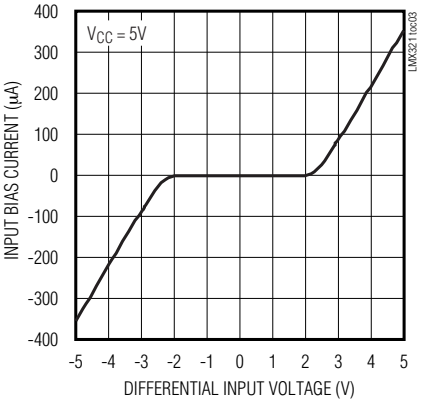
**SUPPLY CURRENT PER AMPLIFIER vs. SUPPLY VOLTAGE**



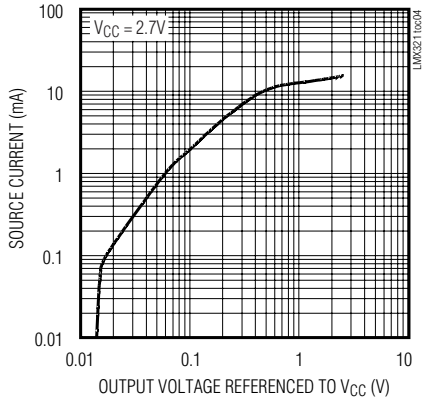

**INPUT BIAS CURRENT vs. TEMPERATURE**



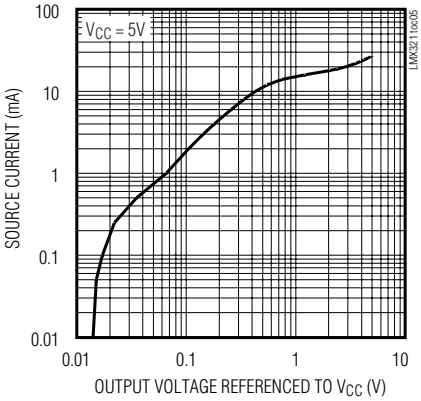

**INPUT BIAS CURRENT vs. DIFFERENTIAL INPUT VOLTAGE**



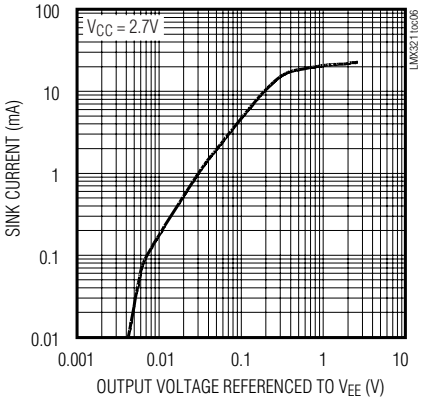

**SOURCE CURRENT vs. OUTPUT VOLTAGE**



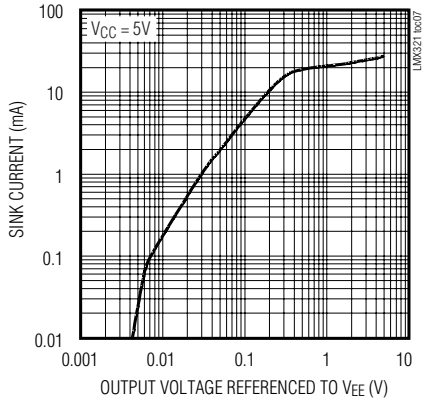

**SOURCE CURRENT vs. OUTPUT VOLTAGE**



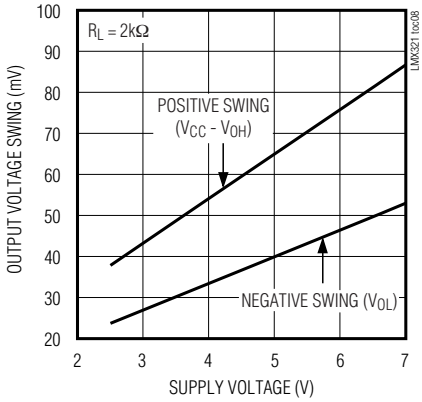

**SINK CURRENT vs. OUTPUT VOLTAGE**



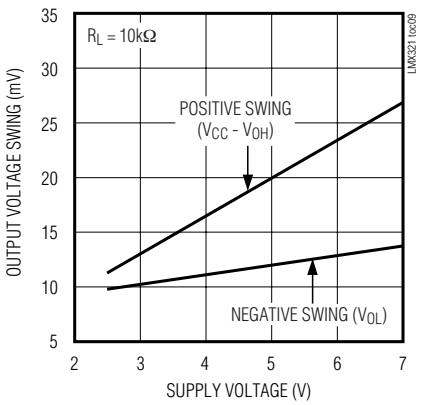

**SINK CURRENT vs. OUTPUT VOLTAGE**




**OUTPUT VOLTAGE SWING vs. SUPPLY VOLTAGE**




**OUTPUT VOLTAGE SWING vs. SUPPLY VOLTAGE**

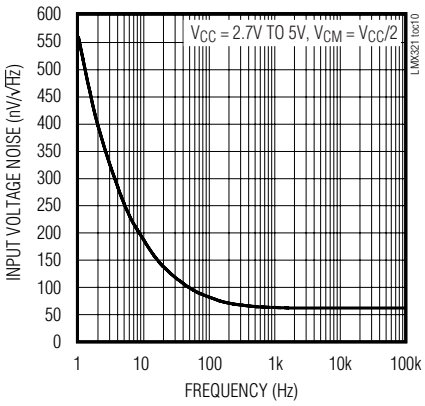


# Single/Dual/Quad, General-Purpose, Low-Voltage, Rail-to-Rail Output Op Amps

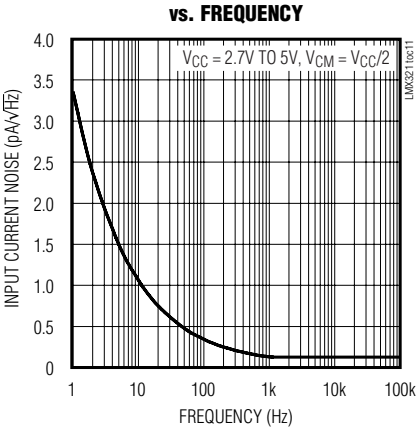
## Typical Operating Characteristics (continued)

($T_A$ = +25°C, $V_{EE}$ = 0V, unless otherwise noted.)

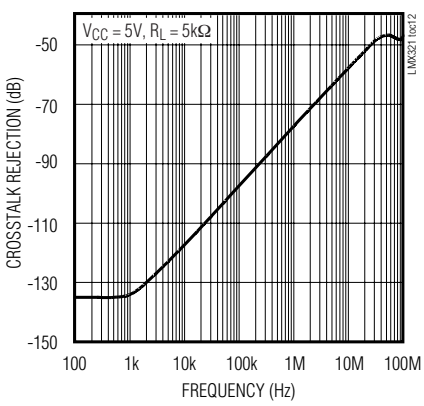
**INPUT VOLTAGE NOISE vs. FREQUENCY**



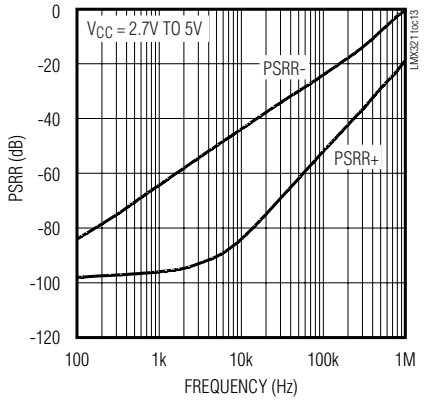

**INPUT CURRENT NOISE vs. FREQUENCY**



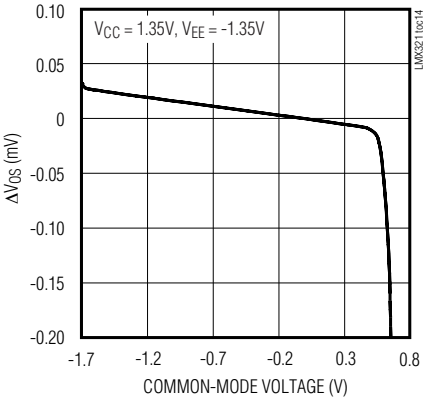

**CROSSTALK REJECTION vs. FREQUENCY**



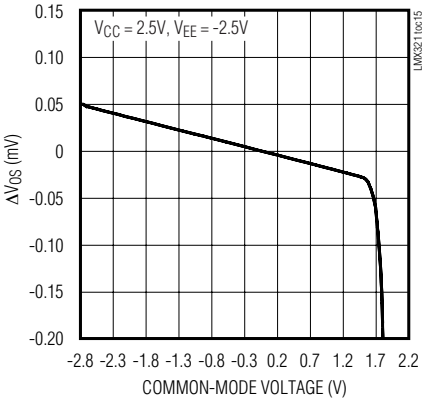

**POWER-SUPPLY REJECTION RATIO vs. FREQUENCY**



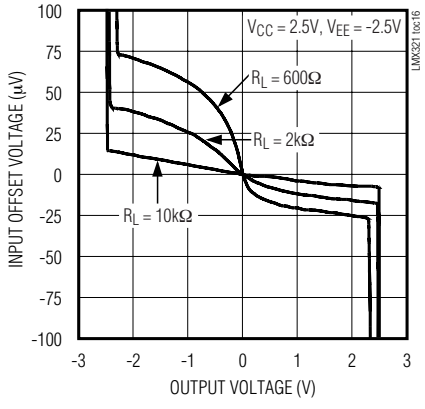

**INPUT OFFSET VOLTAGE vs. COMMON-MODE VOLTAGE**



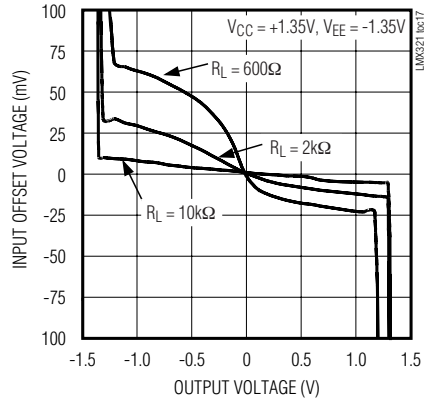

**INPUT OFFSET VOLTAGE vs. COMMON-MODE VOLTAGE**



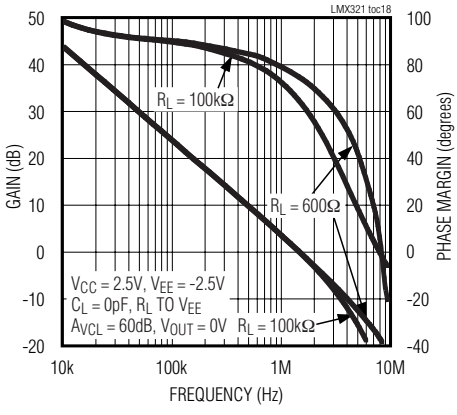

**INPUT OFFSET VOLTAGE vs. OUTPUT VOLTAGE**




**INPUT OFFSET VOLTAGE vs. OUTPUT VOLTAGE**



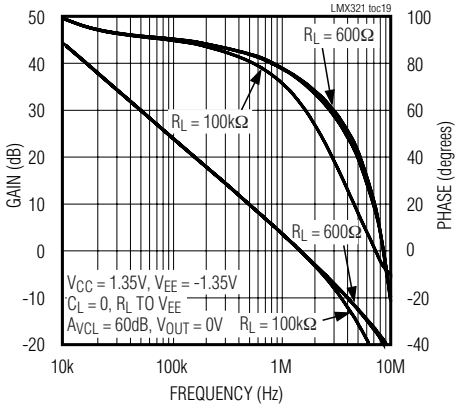

**GAIN AND PHASE vs. FREQUENCY and RESISTIVE LOAD**



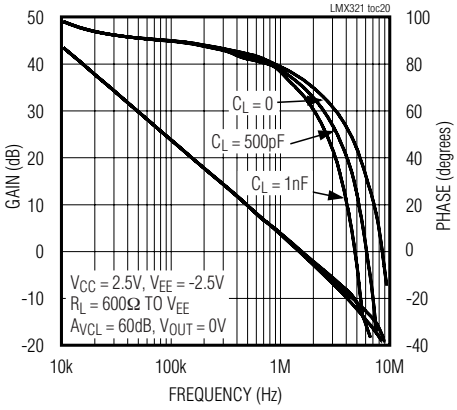
## Typical Operating Characteristics (continued)

($T_A$ = +25°C, $V_{EE}$ = 0V, unless otherwise noted.)

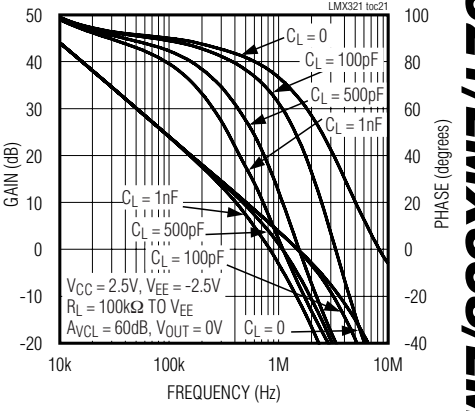
**GAIN AND PHASE vs. FREQUENCY and RESISTIVE LOAD**



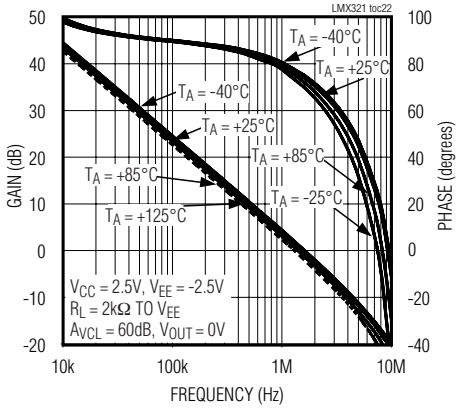

**GAIN AND PHASE vs. FREQUENCY AND CAPACITIVE LOAD**



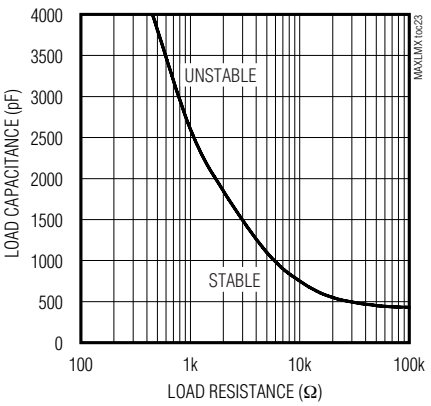

**GAIN AND PHASE vs. FREQUENCY AND CAPACITIVE LOAD**



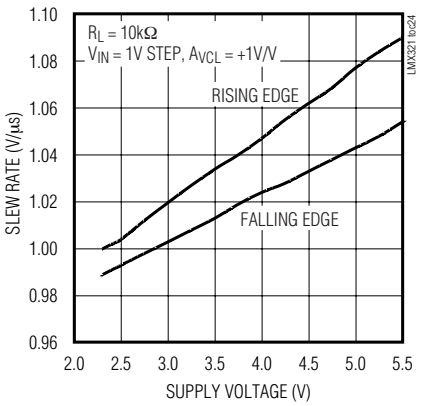

**GAIN AND PHASE vs. FREQUENCY AND TEMPERATURE**



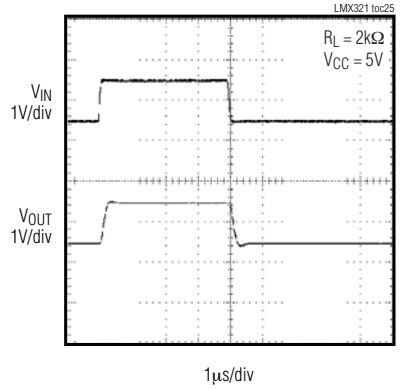

**CAPACITIVE-LOAD STABILITY**



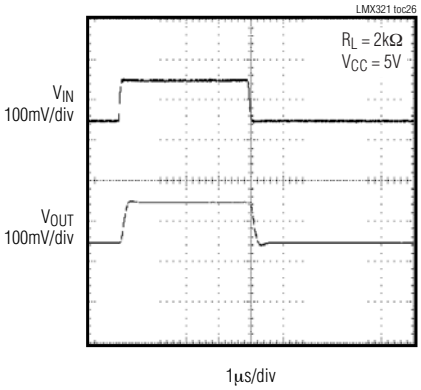

**SLEW RATE vs. SUPPLY VOLTAGE**



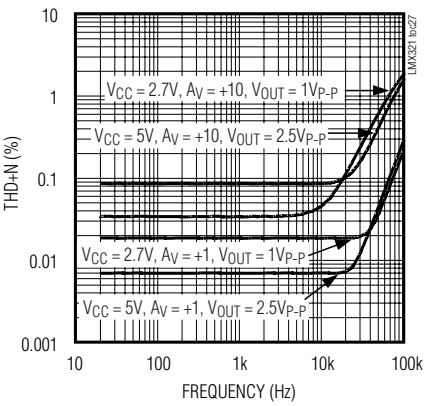

**NONINVERTING LARGE-SIGNAL RESPONSE**




**NONINVERTING SMALL-SIGNAL RESPONSE**




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

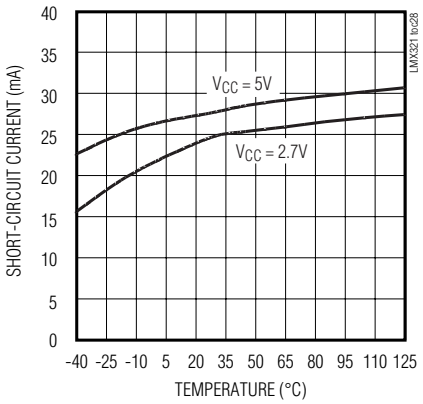


# Single/Dual/Quad, General-Purpose, Low-Voltage, Rail-to-Rail Output Op Amps

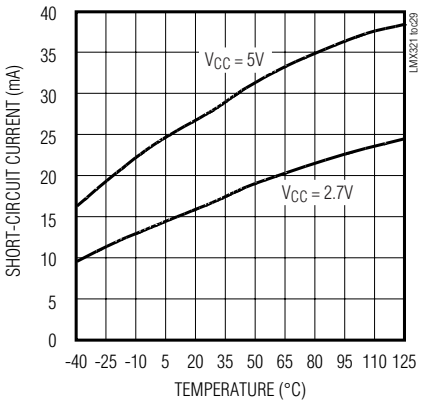
## Typical Operating Characteristics (continued)

($T_A$ = +25°C, $V_{EE}$ = 0V, unless otherwise noted.)

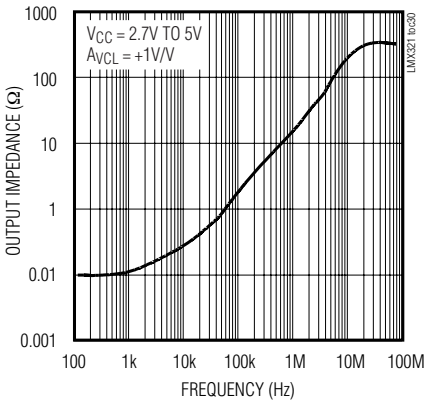
**SHORT-CIRCUIT CURRENT vs. TEMPERATURE (SINKING)**




**SHORT-CIRCUIT CURRENT vs. TEMPERATURE (SOURCING)**




**OUTPUT IMPEDANCE vs. FREQUENCY**




## Pin Description

| PIN | | | NAME | FUNCTION |
|---|---|---|---|---|
| LMX321 | LMX358 | LMX324 | | |
| 1 | — | — | IN+ | Noninverting Amplifier Input |
| 2 | 4 | 11 | $V_{EE}$ | Negative Supply. Connect to ground for single-supply operation. |
| 3 | — | — | IN- | Inverting Amplifier Input |
| 4 | — | — | OUT | Output |
| 5 | 8 | 4 | $V_{CC}$ | Positive Supply |
| — | 1 | 1 | OUT1 | Output for Amplifier 1 |
| — | 2 | 2 | IN1- | Inverting Input for Amplifier 1 |
| — | 3 | 3 | IN1+ | Noninverting Input for Amplifier 1 |
| — | 7 | 7 | OUT2 | Output for Amplifier 2 |
| — | 6 | 6 | IN2- | Inverting Input for Amplifier 2 |
| — | 5 | 5 | IN2+ | Noninverting Input for Amplifier 2 |
| — | — | 8 | OUT3 | Output for Amplifier 3 |
| — | — | 9 | IN3- | Inverting Input for Amplifier 3 |
| — | — | 10 | IN3+ | Noninverting Input for Amplifier 3 |
| — | — | 14 | OUT4 | Output for Amplifier 4 |
| — | — | 13 | IN4- | Inverting Input for Amplifier 4 |
| — | — | 12 | IN4+ | Noninverting Input for Amplifier 4 |

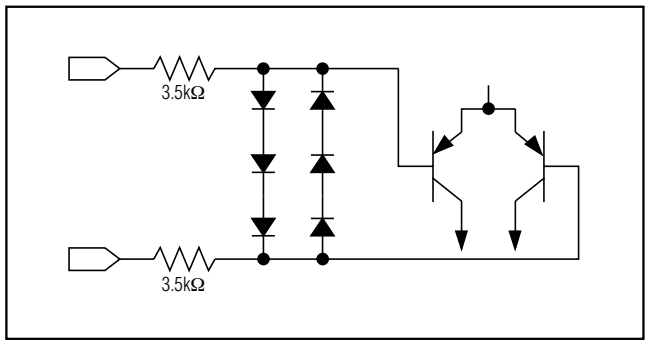



Figure 1. Input Protection Circuit

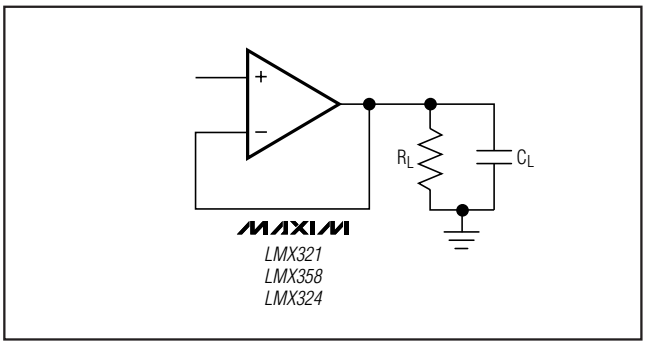



Figure 3. Capacitive-Load-Driving Circuit

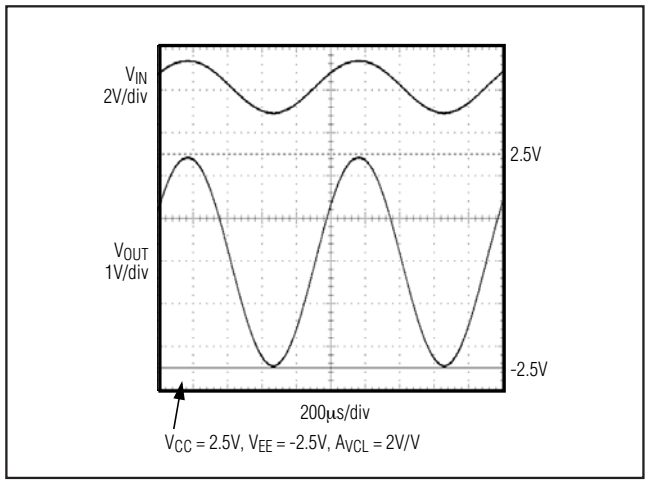



Figure 2. Rail-to-Rail Output Swing

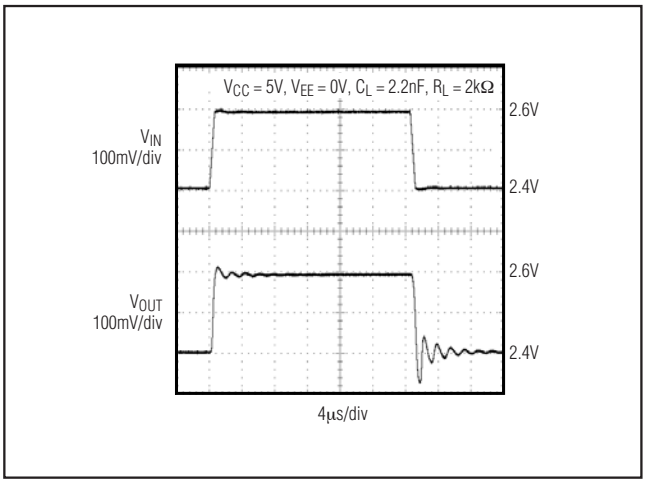



Figure 4. Output With Excessive Capacitive Load

## Detailed Description

### Input Protection Circuit

The LMX321/LMX358/LMX324's inputs are protected from large differential input voltages by internal 3.5kΩ series resistors and back-to-back triple diode stacks across the inputs (Figure 1). For differential input voltages (much less than 1.8V), input resistance is typically 3MΩ. For differential input voltages greater than 1.8V, input resistance is around 7kΩ, and the input bias current can be approximated by the following equation:

$$I_{BIAS} = (V_{DIFF} - 1.8V) / 7k\Omega$$

In the region where the differential input voltage approaches 1.8V, input resistance decreases exponentially from 3MΩ to 7kΩ as the diode block begins conducting. Inversely, the bias current increases with the same curve.

### Rail-to-Rail Output Stage

The LMX321/LMX358/LMX324 drive 2kΩ loads and still typically swing within 40mV of the supply rails. Figure 2 shows the output voltage swing of the LMX321 configured with $A_{VCL}$ = +2V/V.

### Driving Capacitive Loads

Driving a capacitive load can cause instability in many op amps, especially those with low quiescent current. The LMX321/LMX358/LMX324 are unity-gain stable for a range of capacitive loads to above 400pF. Figure 4 shows the response of the LMX321 with an excessive capacitive load. Adding a series resistor between the output and the load capacitor (Figure 5) improves the circuit's response by isolating the load capacitance from the op amp's output.

# Single/Dual/Quad, General-Purpose, Low-Voltage, Rail-to-Rail Output Op Amps

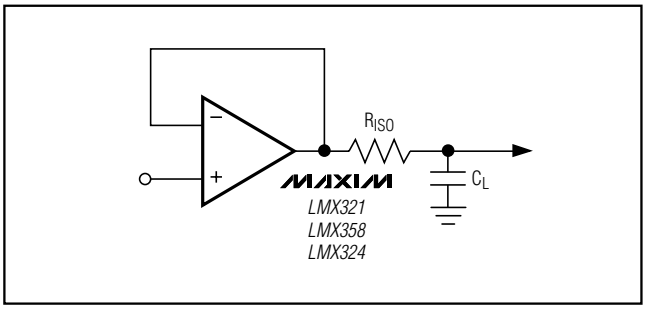



*Figure 5. Capacitive-Load-Driving Circuit With Isolation Resistor*

## Applications Information

### Power-Up

The LMX321/LMX358/LMX324 outputs typically settle within 10µs after power-up. Figure 6 shows the output voltage on power-up and power-down.

### Power Supplies and Layout

The LMX321/LMX358/LMX324 operate from a single +2.3V to +7V power supply. Bypass the power supply with a 0.1µF capacitor to ground as close to $V_{CC}$ as possible.

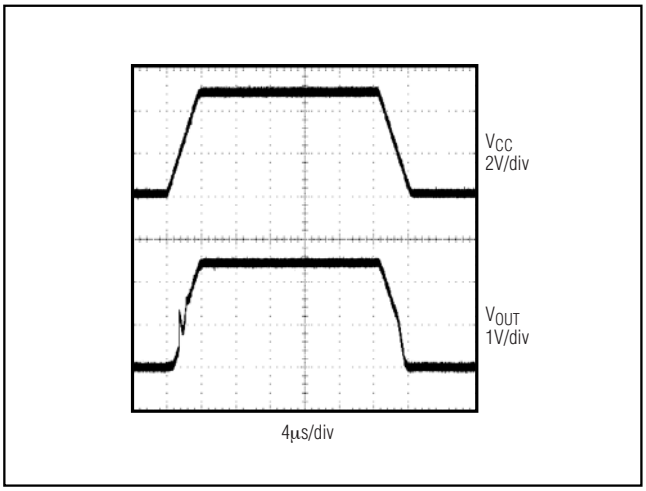



*Figure 6. Power-Up/Power-Down Waveform*

Good layout techniques optimize performance by minimizing the amount of stray capacitance at the op amp's inputs and outputs. Place external components close to the op amp to minimize trace lengths and stray capacitance.

## Selector Guide

| PART | AMPLIFIERS PER PACKAGE | TOP MARK |
|---|---|---|
| LMX321AXK-T | 1 | ACP |
| LMX321AUK-T | 1 | ADSQ |
| LMX358AKA-T | 2 | AAIR |
| LMX358ASA | 2 | — |
| LMX358AUA-T | 2 | — |
| LMX324ASD | 4 | — |
| LMX324AUD | 4 | — |

## Chip Information

LMX321 TRANSISTOR COUNT: 88

LMX358 TRANSISTOR COUNT: 175

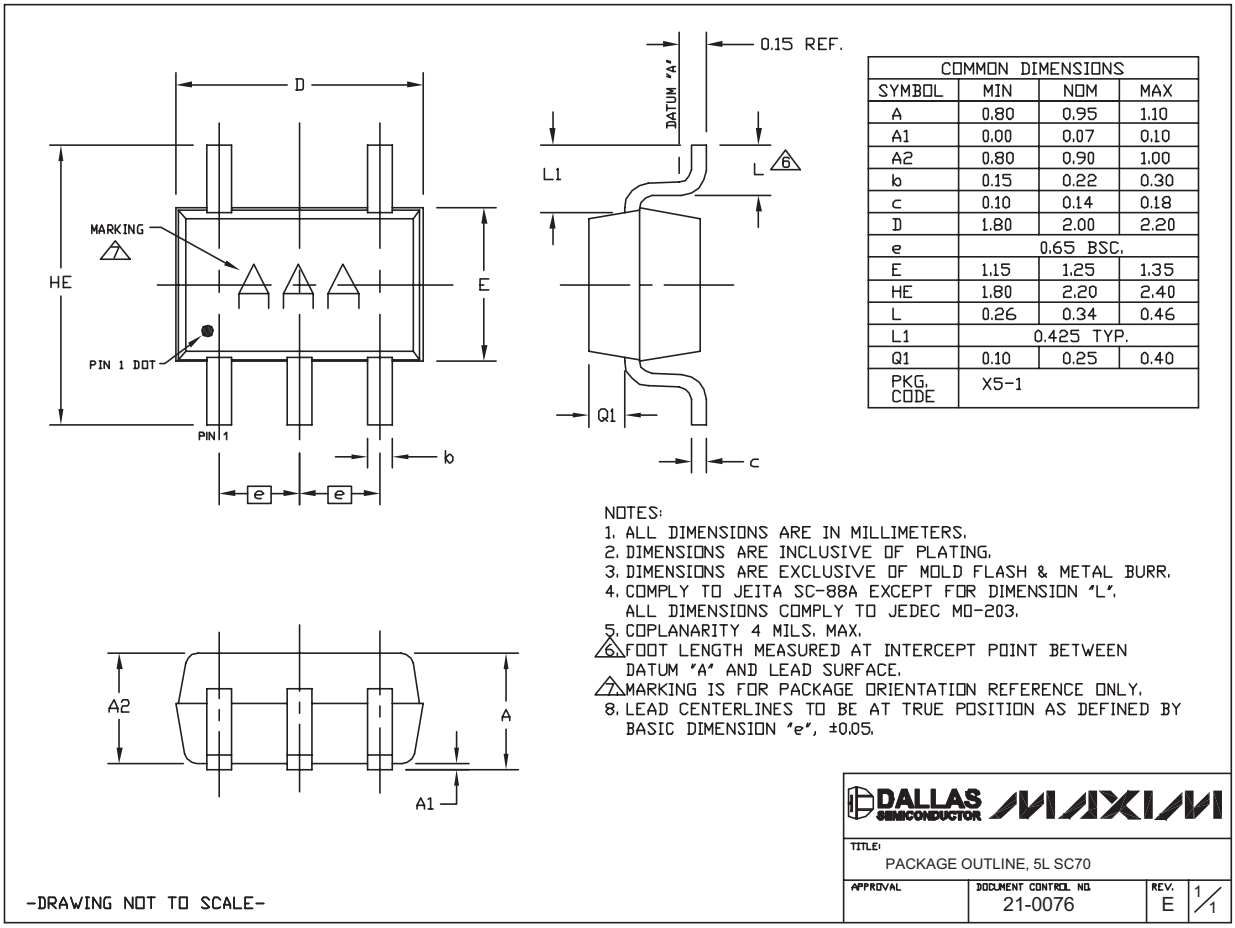
LMX324 TRANSISTOR COUNT: 349

PROCESS: Bipolar

## 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**.)

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.

DALLAS SEMICONDUCTOR MAXIM

TITLE: PACKAGE OUTLINE, 5L SC70

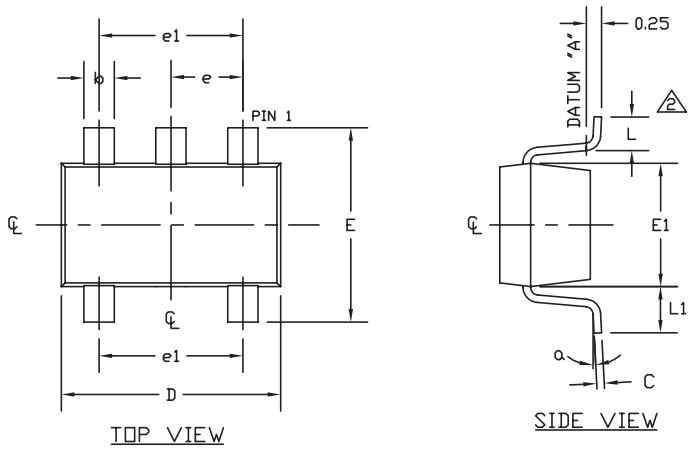
| APPROVAL | DOCUMENT CONTROL NO. | REV. | |
|---|---|---|---|
| | 21-0076 | E | 1/1 |

# Single/Dual/Quad, General-Purpose, Low-Voltage, Rail-to-Rail Output Op Amps

## 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**.)

SOT-23 5L .EPS




| SYMBOL | MIN | NOM | 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 | | |
| e | 0.95 BSC. | | |
| e1 | 1.90 BSC. | | |
| α | 0° | 2.5° | 8° |
| PKG CODES: U5-1, U5-2 | | | |

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. MEETS JEDEC MO178, VARIATION AA.
6. LEADS TO BE COPLANAR WITHIN 0.10 mm.
7. SOLDER THICKNESS MEASURED AT FLAT SECTION OF LEAD BETWEEN 0.08mm AND 0.15mm FROM LEAD TIP.

DALLAS SEMICONDUCTOR MAXIM
PROPRIETARY INFORMATION

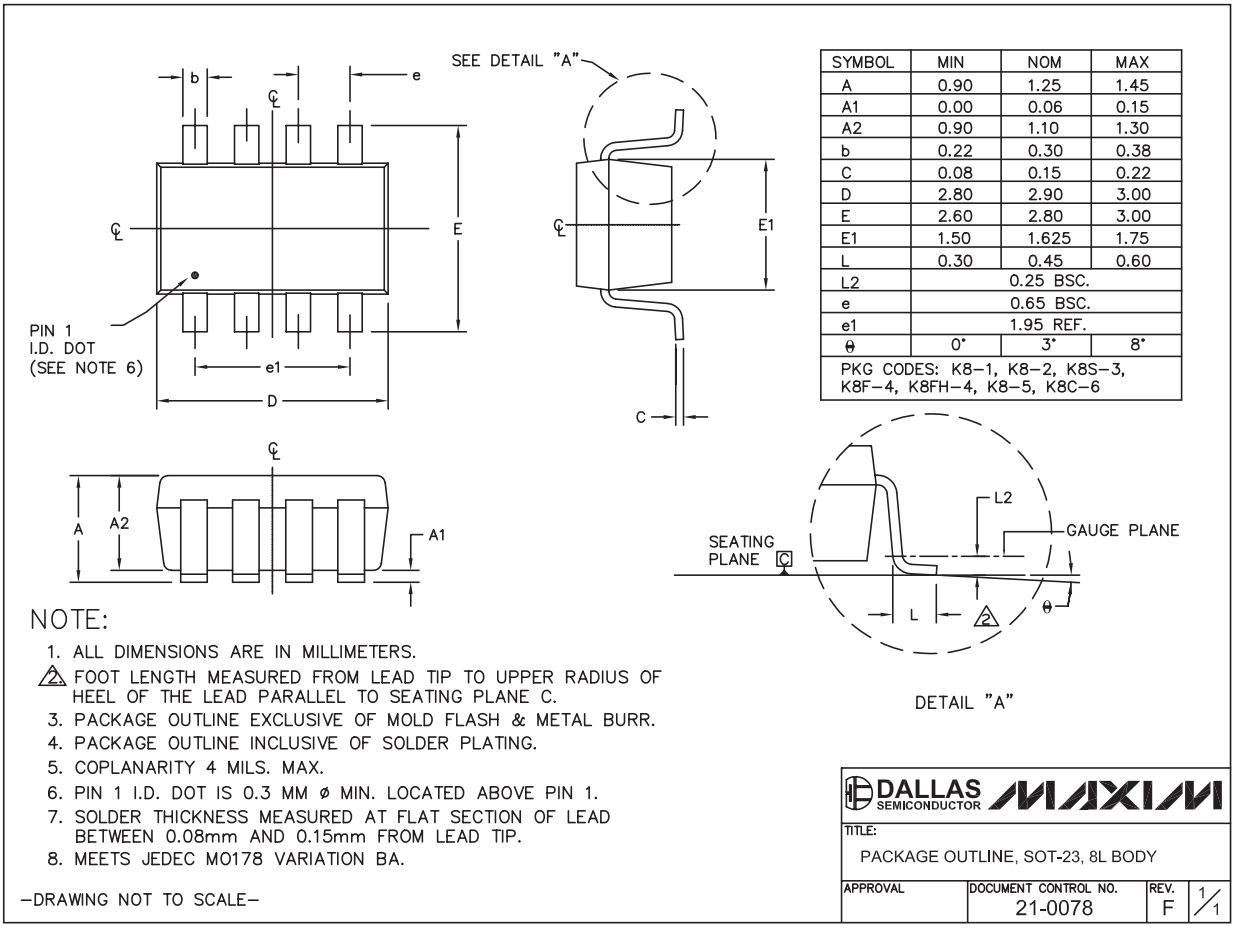
TITLE: PACKAGE OUTLINE, SOT-23, 5L

| APPROVAL | DOCUMENT CONTROL NO. | REV. | |
|---|---|---|---|
| | 21-0057 | F | 1/1 |

# Single/Dual/Quad, General-Purpose, Low-Voltage, Rail-to-Rail Output Op Amps

## 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**.)




| SYMBOL | MIN | NOM | MAX |
|---|---|---|---|
| A | 0.90 | 1.25 | 1.45 |
| A1 | 0.00 | 0.06 | 0.15 |
| A2 | 0.90 | 1.10 | 1.30 |
| b | 0.22 | 0.30 | 0.38 |
| C | 0.08 | 0.15 | 0.22 |
| D | 2.80 | 2.90 | 3.00 |
| E | 2.60 | 2.80 | 3.00 |
| E1 | 1.50 | 1.625 | 1.75 |
| L | 0.30 | 0.45 | 0.60 |
| L2 | 0.25 BSC. | | |
| e | 0.65 BSC. | | |
| e1 | 1.95 REF. | | |
| θ | 0° | 3° | 8° |
| PKG CODES: K8-1, K8-2, K8S-3, K8F-4, K8FH-4, K8-5, K8C-6 | | | |

NOTE:

1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. FOOT LENGTH MEASURED FROM LEAD TIP TO UPPER RADIUS OF HEEL OF THE LEAD PARALLEL TO SEATING PLANE C.
3. PACKAGE OUTLINE EXCLUSIVE OF MOLD FLASH & METAL BURR.
4. PACKAGE OUTLINE INCLUSIVE OF SOLDER PLATING.
5. COPLANARITY 4 MILS. MAX.
6. PIN 1 I.D. DOT IS 0.3 MM ø MIN. LOCATED ABOVE PIN 1.
7. SOLDER THICKNESS MEASURED AT FLAT SECTION OF LEAD BETWEEN 0.08mm AND 0.15mm FROM LEAD TIP.
8. MEETS JEDEC MO178 VARIATION BA.

–DRAWING NOT TO SCALE–

DALLAS SEMICONDUCTOR MAXIM

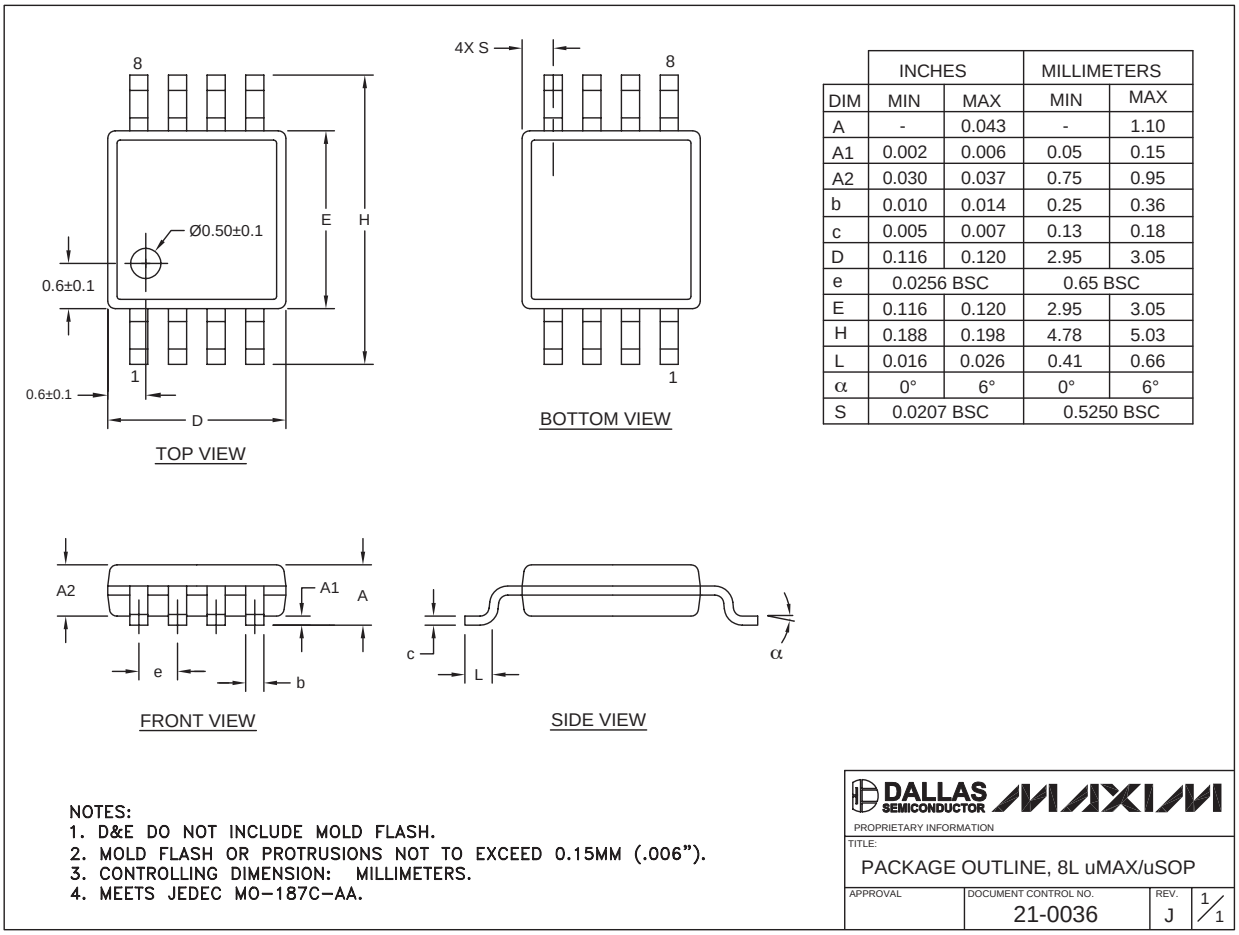
TITLE: PACKAGE OUTLINE, SOT-23, 8L BODY

| APPROVAL | DOCUMENT CONTROL NO. | REV. | |
|---|---|---|---|
| | 21-0078 | F | 1/1 |

# Single/Dual/Quad, General-Purpose, Low-Voltage, Rail-to-Rail Output Op Amps

## 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**.)




| DIM | INCHES MIN | INCHES MAX | MILLIMETERS MIN | MILLIMETERS 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 | |

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

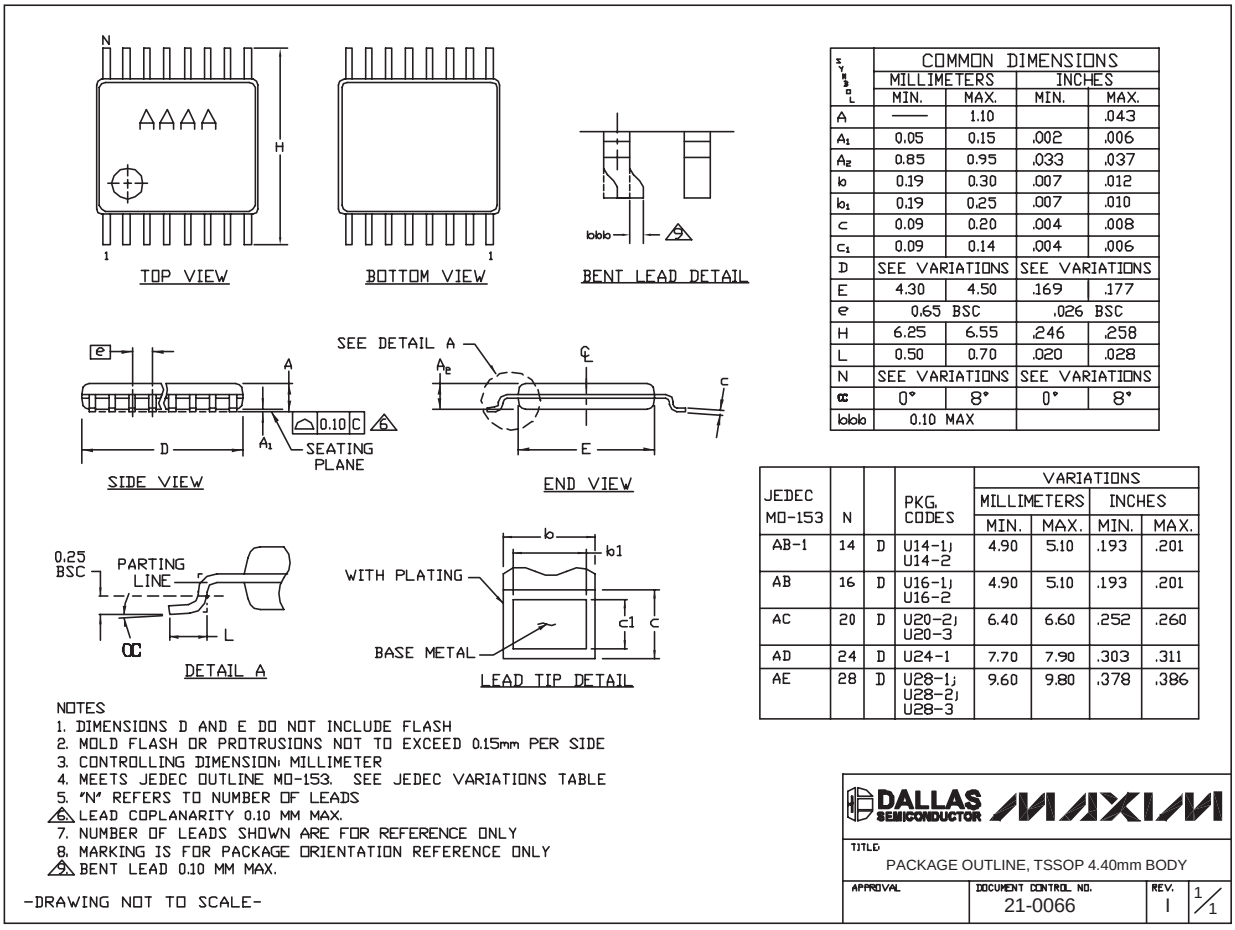
TITLE: PACKAGE OUTLINE, 8L uMAX/uSOP

| 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**.)

TSSOP4.40mm.EPS




| SYMBOL | COMMON DIMENSIONS | | | |
|---|---|---|---|---|
| | MILLIMETERS | | INCHES | |
| | MIN. | MAX. | MIN. | MAX. |
| A | —— | 1.10 | | .043 |
| $A_1$ | 0.05 | 0.15 | .002 | .006 |
| $A_2$ | 0.85 | 0.95 | .033 | .037 |
| b | 0.19 | 0.30 | .007 | .012 |
| $b_1$ | 0.19 | 0.25 | .007 | .010 |
| c | 0.09 | 0.20 | .004 | .008 |
| $c_1$ | 0.09 | 0.14 | .004 | .006 |
| D | SEE VARIATIONS | | SEE VARIATIONS | |
| E | 4.30 | 4.50 | .169 | .177 |
| e | 0.65 BSC | | .026 BSC | |
| H | 6.25 | 6.55 | .246 | .258 |
| L | 0.50 | 0.70 | .020 | .028 |
| N | SEE VARIATIONS | | SEE VARIATIONS | |
| α | 0° | 8° | 0° | 8° |
| bbb | 0.10 MAX | | | |

| JEDEC MO-153 | N | | PKG. CODES | VARIATIONS | | | |
|---|---|---|---|---|---|---|---|
| | | | | MILLIMETERS | | INCHES | |
| | | | | MIN. | MAX. | MIN. | MAX. |
| AB-1 | 14 | D | U14-1, U14-2 | 4.90 | 5.10 | .193 | .201 |
| AB | 16 | D | U16-1, U16-2 | 4.90 | 5.10 | .193 | .201 |
| AC | 20 | D | U20-2, U20-3 | 6.40 | 6.60 | .252 | .260 |
| AD | 24 | D | U24-1 | 7.70 | 7.90 | .303 | .311 |
| AE | 28 | D | U28-1, U28-2, U28-3 | 9.60 | 9.80 | .378 | .386 |

NOTES
1. DIMENSIONS D AND E DO NOT INCLUDE FLASH
2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED 0.15mm PER SIDE
3. CONTROLLING DIMENSION: MILLIMETER
4. MEETS JEDEC OUTLINE MO-153. SEE JEDEC VARIATIONS TABLE
5. "N" REFERS TO NUMBER OF LEADS
6. LEAD COPLANARITY 0.10 MM MAX.
7. NUMBER OF LEADS SHOWN ARE FOR REFERENCE ONLY
8. MARKING IS FOR PACKAGE ORIENTATION REFERENCE ONLY
9. BENT LEAD 0.10 MM MAX.

-DRAWING NOT TO SCALE-

DALLAS SEMICONDUCTOR MAXIM

TITLE: PACKAGE OUTLINE, TSSOP 4.40mm BODY

| APPROVAL | DOCUMENT CONTROL NO. | REV. | |
|---|---|---|---|
| | 21-0066 | I | 1/1 |