



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

**LMX321**

## 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

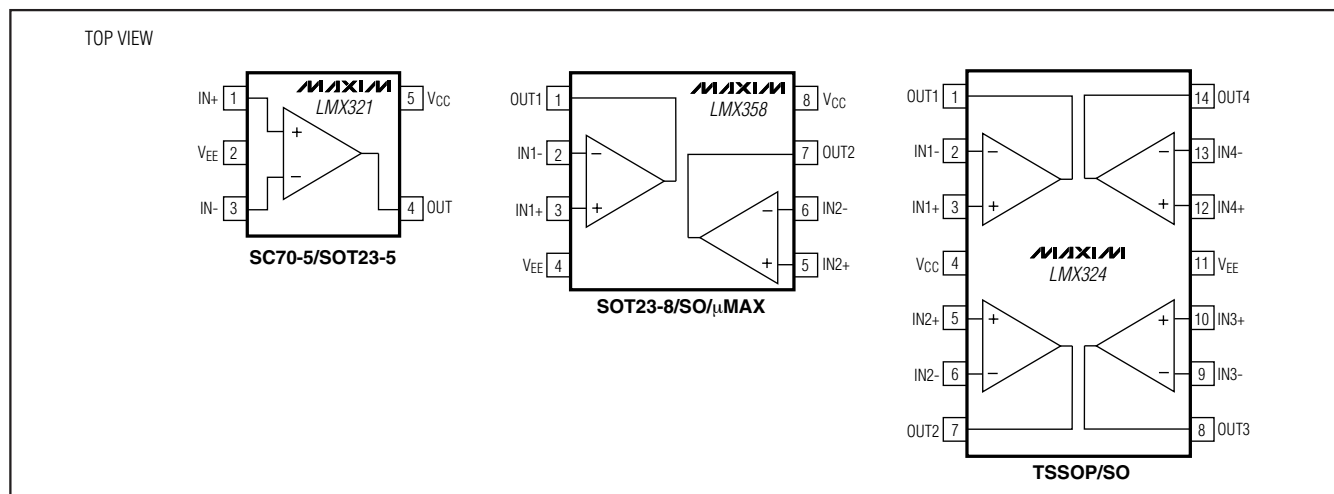
- ◆ Upgrade to LMV321/LMV358/LMV324 Family
- ◆ Single +2.3V to +7V Supply Voltage Range
- ◆ Available in Space-Saving Packages
  - 5-Pin SC70 (LMX321)
  - 8-Pin SOT23 (LMX358)
  - 14-Pin TSSOP (LMX324)
- ◆ 1.3MHz Gain-Bandwidth Product
- ◆ 105µA Quiescent Current per Amplifier (V<sub>CC</sub> = +2.7V)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

## Ordering Information

| PART        | TEMP RANGE      | PIN-PACKAGE | PKG CODE |
|-------------|-----------------|-------------|----------|
| LMX321AXK-T | -40°C to +125°C | 5 SC70-5    | X5-1     |
| LMX321AUK-T | -40°C to +125°C | 5 SOT23-5   | U5-1     |
| LMX358AKA-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     |
| LMX324ASD   | -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



[www.datasheetall.com](http://www.datasheetall.com)

Maxim Integrated Products 1

**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](http://www.maxim-ic.com).**

# Single, 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 ( $T_A = +70^\circ\text{C}$ )  
   5-Pin SC70-5 (derate 3.1mW/ $^\circ\text{C}$  above  $+70^\circ\text{C}$ ) ..... 247mW  
   5-Pin SOT23-5 (derate 7.1mW/ $^\circ\text{C}$  above  $+70^\circ\text{C}$ ) ..... 571mW  
   8-Pin SOT23-8 (derate 7.52mW/ $^\circ\text{C}$  above  $+70^\circ\text{C}$ ) ..... 602mW

8-Pin SO (derate 5.9mW/ $^\circ\text{C}$  above  $+70^\circ\text{C}$ ) ..... 471mW  
 8-Pin  $\mu\text{MAX}$  (derate 4.5mW/ $^\circ\text{C}$  above  $+70^\circ\text{C}$ ) ..... 362mW  
 14-Pin TSSOP (derate 9.1mW/ $^\circ\text{C}$  above  $+70^\circ\text{C}$ ) ..... 727mW  
 14-Pin SO (derate 8.3mW/ $^\circ\text{C}$  above  $+70^\circ\text{C}$ ) ..... 667mW  
 Operating Temperature Range .....  $-40^\circ\text{C}$  to  $+125^\circ\text{C}$   
 Junction Temperature .....  $+150^\circ\text{C}$   
 Storage Temperature Range .....  $-65^\circ\text{C}$  to  $+150^\circ\text{C}$   
 Lead Temperature (soldering, 10s) .....  $+300^\circ\text{C}$

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

( $V_{CC} = +2.7V$ ,  $V_{EE} = 0V$ ,  $V_{OUT} = V_{CC}/2$ ,  $V_{CM} = 1V$ ,  $R_L > 1M\Omega$ ,  $T_A = +25^\circ\text{C}$ , unless otherwise noted.)

| PARAMETER                          | SYMBOL            | CONDITIONS                                                               |                                   | MIN  | TYP | MAX  | UNITS   |
|------------------------------------|-------------------|--------------------------------------------------------------------------|-----------------------------------|------|-----|------|---------|
| DC CHARACTERISTICS                 |                   |                                                                          |                                   |      |     |      |         |
| Input Offset Voltage               | V <sub>OS</sub>   |                                                                          |                                   | 1    | 6   |      | mV      |
| Input Offset Voltage Average Drift | TCV <sub>OS</sub> |                                                                          |                                   | 6    |     |      | μV/°C   |
| Input Bias Current                 | I <sub>B</sub>    |                                                                          |                                   | 18   | 50  |      | nA      |
| Input Offset Current               | I <sub>OS</sub>   |                                                                          |                                   | 1    | 8   |      | nA      |
| Common-Mode Rejection Ratio        | CMRR              | -0.2V < V <sub>CM</sub> < 1.8V                                           |                                   | 72   | 92  |      | dB      |
| Power-Supply Rejection Ratio       | PSRR              | 2.3V ≤ V <sub>CC</sub> ≤ 7V, V <sub>OUT</sub> = 1V                       |                                   | 82   | 96  |      | dB      |
| Input Common-Mode Voltage Range    | V <sub>CM</sub>   | For CMRR ≥ 72dB                                                          | Limit                             | -0.2 |     | +1.8 | V       |
|                                    |                   |                                                                          | Typ                               | -0.2 |     | +1.9 |         |
| Large-Signal Voltage Gain          | A <sub>VOL</sub>  | R <sub>L</sub> = 2kΩ to V <sub>EE</sub> , 0.3V < V <sub>OUT</sub> < 2.4V |                                   | 20   | 120 |      | V/mV    |
| Output-Voltage Swing               | V <sub>OUT</sub>  | R <sub>L</sub> = 10kΩ to 1.35V                                           | V <sub>CC</sub> - V <sub>OH</sub> | 12   | 50  |      | mV      |
|                                    |                   |                                                                          | V <sub>OL</sub>                   | 10   | 40  |      |         |
|                                    |                   | R <sub>L</sub> = 2kΩ to 1.35V                                            | V <sub>CC</sub> - V <sub>OH</sub> | 40   | 110 |      |         |
|                                    |                   |                                                                          | V <sub>OL</sub>                   | 25   | 60  |      |         |
| Supply Current                     | I <sub>CC</sub>   | 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 <sub>L</sub> = 200pF                                                   |                                   | 1.3  |     |      | MHz     |
| Phase Margin                       | φ <sub>M</sub>    |                                                                          |                                   | 64   |     |      | degrees |
| Gain Margin                        | GM                |                                                                          |                                   | 24   |     |      | dB      |
| Input Noise-Voltage Density        | e <sub>n</sub>    | f = 1kHz                                                                 |                                   | 66   |     |      | nV/√Hz  |
| Input Current-Noise Density        | i <sub>n</sub>    | f = 1kHz                                                                 |                                   | 0.13 |     |      | pA/√Hz  |

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

**LMX321**

## ELECTRICAL CHARACTERISTICS

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

| PARAMETER                       | SYMBOL    | CONDITIONS                                                   | MIN               | TYP  | MAX  | UNITS   |
|---------------------------------|-----------|--------------------------------------------------------------|-------------------|------|------|---------|
| <b>DC CHARACTERISTICS</b>       |           |                                                              |                   |      |      |         |
| 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      | $2.3V \leq V_{CC} \leq 7V$ , $V_{OUT} = 1V$                  | 75                |      |      | dB      |
| Input Common-Mode Voltage Range | $V_{CM}$  | For CMRR $\geq 60dB$                                         | Limit             | -0.1 | +1.7 | V       |
|                                 |           |                                                              | Typ               | -0.1 | +1.8 |         |
| Large-Signal Voltage Gain       | $A_{VOL}$ | $R_L = 2k\Omega$ to $V_{EE}$ , $0.3V \leq V_{OUT} \leq 2.4V$ | 10                |      |      | V/mV    |
| Output-Voltage Swing            | $V_{OUT}$ | $R_L = 10k\Omega$ to 1.55V                                   | $V_{CC} - V_{OH}$ |      | 130  | mV      |
|                                 |           |                                                              | $V_{OL}$          |      | 50   |         |
|                                 |           | $R_L = 2k\Omega$ to 1.35V                                    | $V_{CC} - V_{OH}$ |      | 150  |         |
|                                 |           |                                                              | $V_{OL}$          |      | 70   |         |
| Supply Current                  | $I_{CC}$  | LMX321 (single)                                              |                   |      | 180  | $\mu A$ |
|                                 |           | LMX358 (dual)                                                |                   |      | 360  |         |
|                                 |           | LMX324 (quad)                                                |                   |      | 720  |         |

## ELECTRICAL CHARACTERISTICS

( $V_{CC} = +5V$ ,  $V_{EE} = 0V$ ,  $V_{OUT} = V_{CC}/2$ ,  $V_{CM} = 2V$ ,  $R_L > 1M\Omega$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

| PARAMETER                          | SYMBOL      | CONDITIONS                                                                        | MIN   | TYP  | MAX  | UNITS            |
|------------------------------------|-------------|-----------------------------------------------------------------------------------|-------|------|------|------------------|
| <b>DC CHARACTERISTICS</b>          |             |                                                                                   |       |      |      |                  |
| Input Offset Voltage               | $V_{OS}$    |                                                                                   |       | 1    | 6    | mV               |
| Input Offset Voltage Average Drift | $TCV_{OS}$  |                                                                                   |       | 6    |      | $\mu V/^\circ C$ |
| Input Bias Current                 | $I_B$       |                                                                                   |       | 18   | 50   | nA               |
| Input Offset Current               | $I_{OS}$    |                                                                                   |       | 1    | 8    | nA               |
| Input Differential Clamp Voltage   | $V_{CLAMP}$ | Force 100 $\mu A$ 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        | $2.3V \leq V_{CC} \leq 7V$ , $V_{OUT} = 1V$ , $V_{CM} = 1V$                       | 82    | 96   |      | dB               |
| Input Common-Mode Voltage Range    | $V_{CM}$    | For CMRR $\geq 72dB$                                                              | Limit | -0.2 | +4.1 | V                |
|                                    |             |                                                                                   | Typ   | -0.2 | +4.2 |                  |
| Large-Signal Voltage Gain          | $A_{VOL}$   | $R_L = 2k\Omega$ to $V_{EE}$ , $0.3V \leq V_{OUT} \leq 4.7V$                      | 40    | 200  |      | V/mV             |

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

## ELECTRICAL CHARACTERISTICS (continued)

( $V_{CC} = +5V$ ,  $V_{EE} = 0V$ ,  $V_{OUT} = V_{CC}/2$ ,  $V_{CM} = 2V$ ,  $R_L > 1M\Omega$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

| PARAMETER                    | SYMBOL           | CONDITIONS                      |                                   | MIN          | TYP | MAX     | UNITS |
|------------------------------|------------------|---------------------------------|-----------------------------------|--------------|-----|---------|-------|
| Output-Voltage Swing         | V <sub>OUT</sub> | R <sub>L</sub> = 10kΩ to 2.5V   | V <sub>CC</sub> - V <sub>OH</sub> | 20      60   |     | mV      |       |
|                              |                  |                                 | V <sub>OL</sub>                   | 12      40   |     |         |       |
|                              |                  | R <sub>L</sub> = 2kΩ to 2.5V    | V <sub>CC</sub> - V <sub>OH</sub> | 65      130  |     |         |       |
|                              |                  |                                 | V <sub>OL</sub>                   | 40      80   |     |         |       |
| Output Short-Circuit Current | I <sub>SC</sub>  | Sourcing, V <sub>OUT</sub> = 0V |                                   | 5            | 25  |         | mA    |
|                              |                  | Sinking, V <sub>OUT</sub> = 5V  |                                   | 10           | 28  |         |       |
| Supply Current               | I <sub>CC</sub>  | 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 <sub>L</sub> = 200pF          |                                   | 1.3          |     | MHz     |       |
| Phase Margin                 | φ <sub>M</sub>   |                                 |                                   | 65           |     | degrees |       |
| Gain Margin                  | GM               |                                 |                                   | 25           |     | dB      |       |
| Input Noise-Voltage Density  | e <sub>n</sub>   | f = 1kHz                        |                                   | 65           |     | nV/√Hz  |       |
| Input Noise-Current Density  | i <sub>n</sub>   | f = 1kHz                        |                                   | 0.13         |     | pA/√Hz  |       |

## ELECTRICAL CHARACTERISTICS

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

| PARAMETER                       | SYMBOL    | CONDITIONS                                                   | MIN               | TYP  | MAX  | UNITS   |
|---------------------------------|-----------|--------------------------------------------------------------|-------------------|------|------|---------|
| <b>DC CHARACTERISTICS</b>       |           |                                                              |                   |      |      |         |
| 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      | $2.3V \leq V_{CC} \leq 7V$ , $V_{OUT} = 1V$ , $V_{CM} = 1V$  | 75                |      |      | dB      |
| Input Common-Mode Voltage Range | $V_{CM}$  | For CMRR $\geq 63dB$                                         | Limit             | -0.1 | +4.0 | V       |
|                                 |           |                                                              | Typ               | -0.1 | +4.1 |         |
| Large-Signal Voltage Gain       | $A_{VOL}$ | $R_L = 2k\Omega$ to $V_{EE}$ , $0.3V \leq V_{OUT} \leq 4.7V$ | 20                |      |      | V/mV    |
| Output-Voltage Swing            | $V_{OUT}$ | $R_L = 10k\Omega$ to 2.5V                                    | $V_{CC} - V_{OH}$ |      | 170  | mV      |
|                                 |           |                                                              | $V_{OL}$          |      | 70   |         |
|                                 |           | $R_L = 2k\Omega$ to 2.5V                                     | $V_{CC} - V_{OH}$ |      | 190  |         |
|                                 |           |                                                              | $V_{OL}$          |      | 90   |         |
| Supply Current                  | $I_{CC}$  | LMX321 (single)                                              |                   |      | 210  | $\mu A$ |
|                                 |           | LMX358 (dual)                                                |                   |      | 420  |         |
|                                 |           | LMX324 (quad)                                                |                   |      | 840  |         |

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

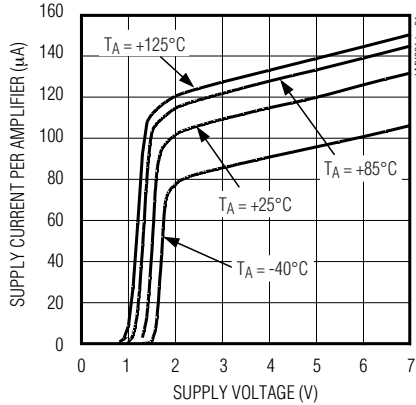
# Single, General-Purpose, Low-Voltage, Rail-to-Rail Output Op Amps

## Typical Operating Characteristics

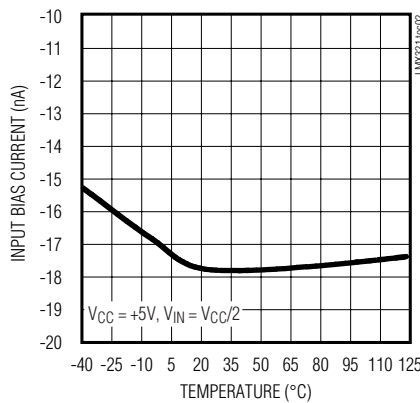
( $T_A = +25^\circ\text{C}$ ,  $V_{EE} = 0\text{V}$ , unless otherwise noted.)

**LMX321**

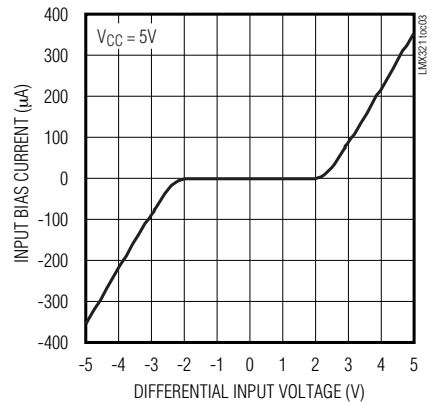
**SUPPLY CURRENT PER AMPLIFIER  
vs. SUPPLY VOLTAGE**



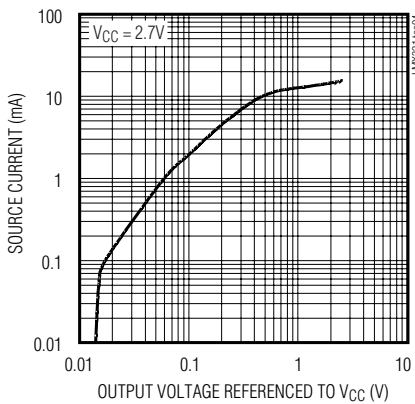
**INPUT BIAS CURRENT  
vs. TEMPERATURE**



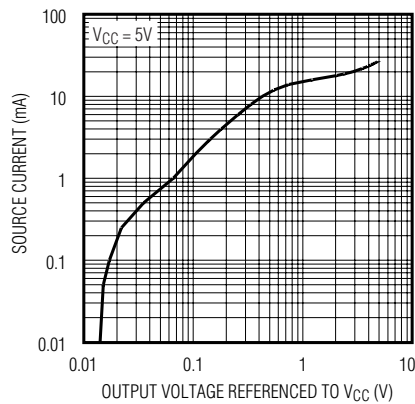
**INPUT BIAS CURRENT  
vs. DIFFERENTIAL INPUT VOLTAGE**



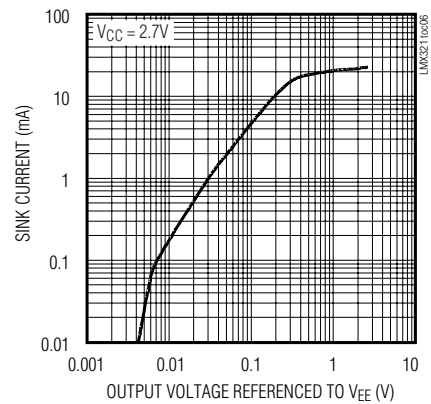
**SOURCE CURRENT  
vs. OUTPUT VOLTAGE**



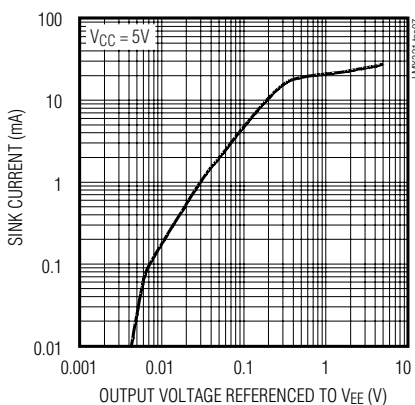
**SOURCE CURRENT  
vs. OUTPUT VOLTAGE**



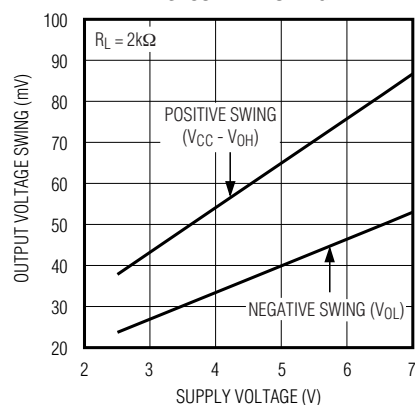
**SINK CURRENT  
vs. OUTPUT VOLTAGE**



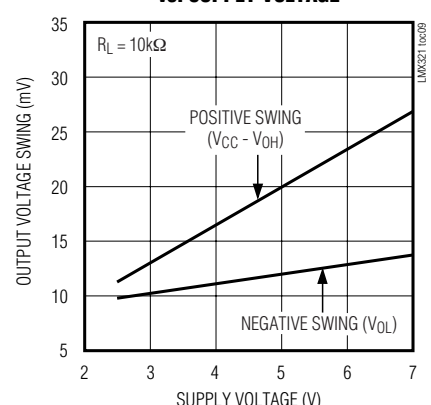
**SINK CURRENT  
vs. OUTPUT VOLTAGE**



**OUTPUT VOLTAGE SWING  
vs. SUPPLY VOLTAGE**



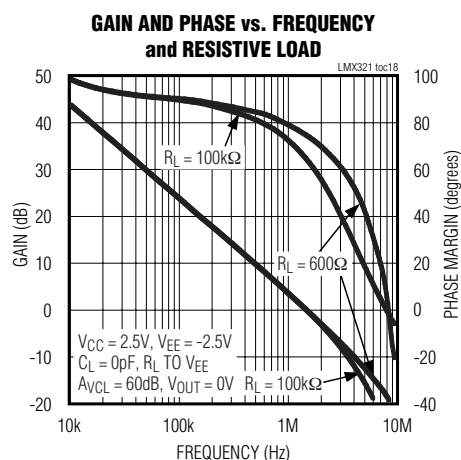
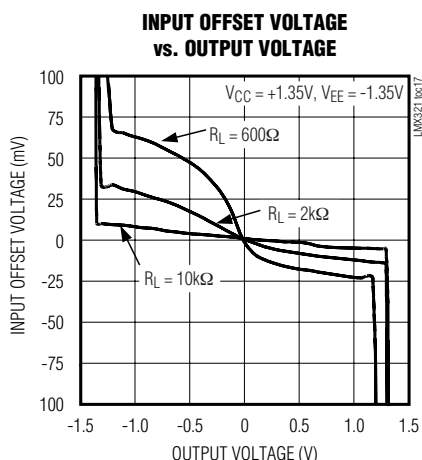
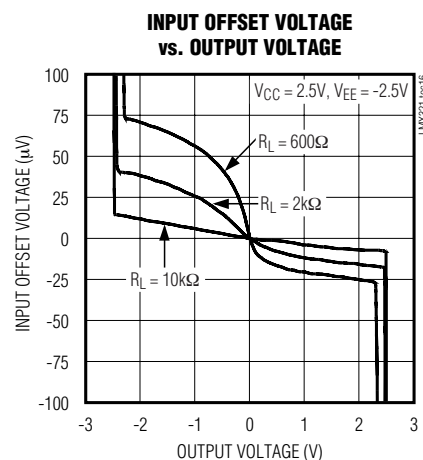
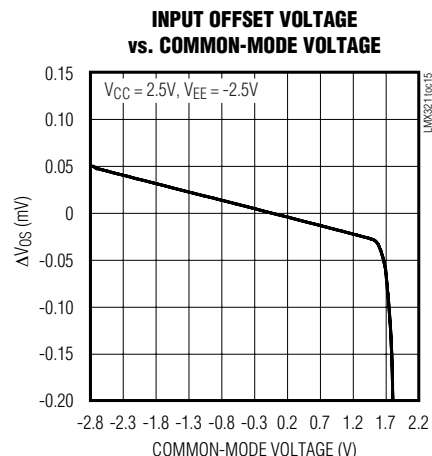
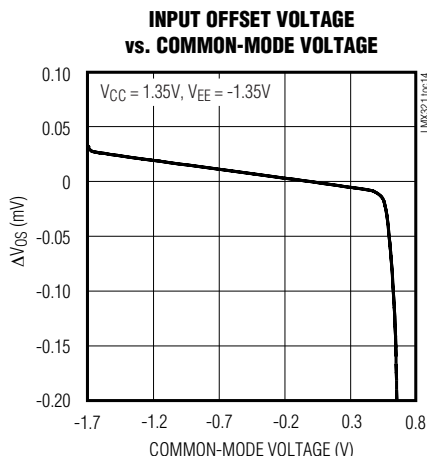
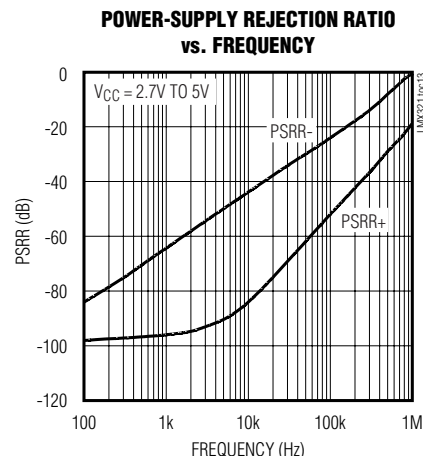
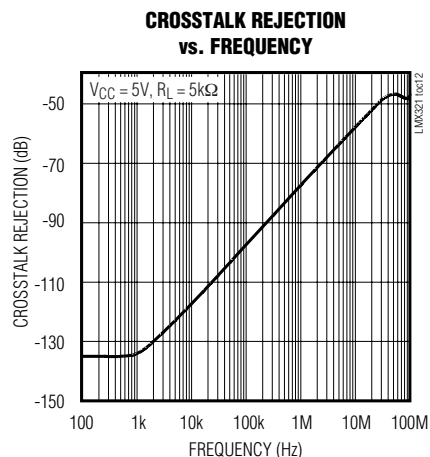
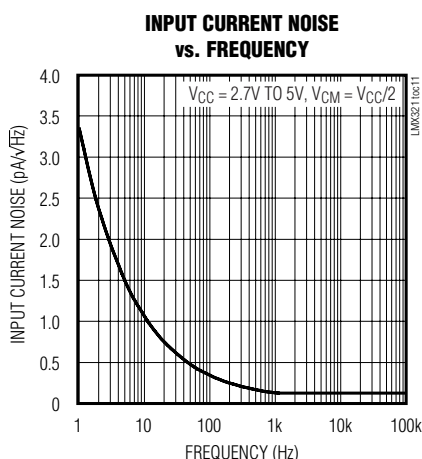
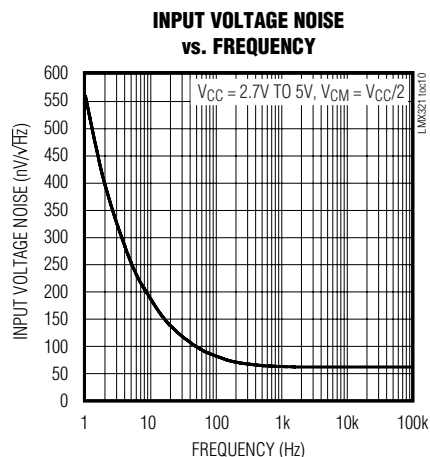
**OUTPUT VOLTAGE SWING  
vs. SUPPLY VOLTAGE**



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

## Typical Operating Characteristics (continued)

( $T_A = +25^\circ\text{C}$ ,  $V_{EE} = 0\text{V}$ , unless otherwise noted.)

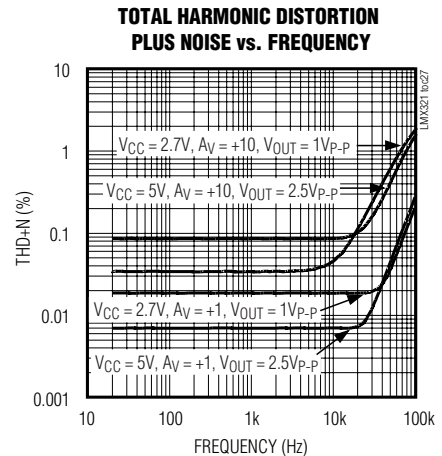
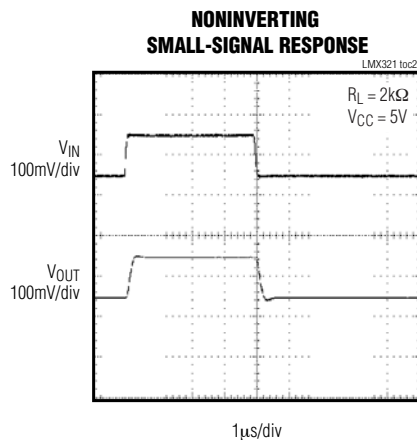
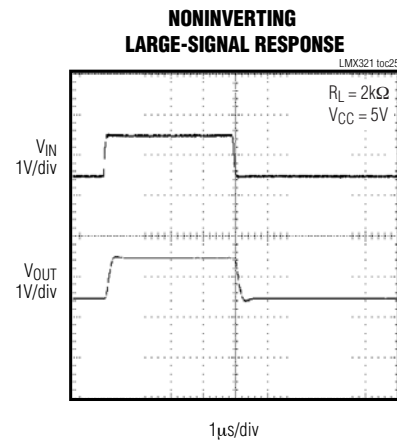
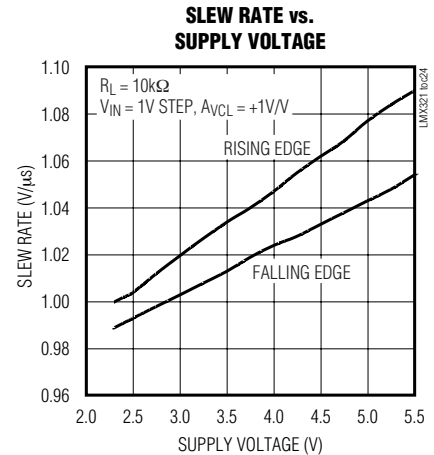
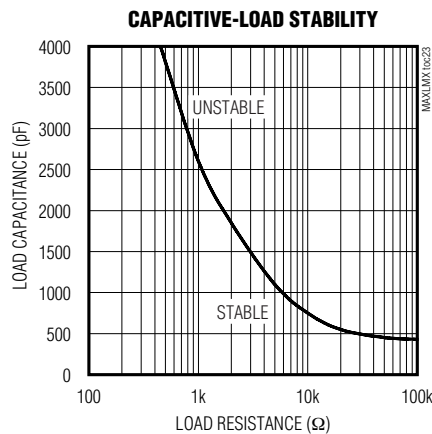
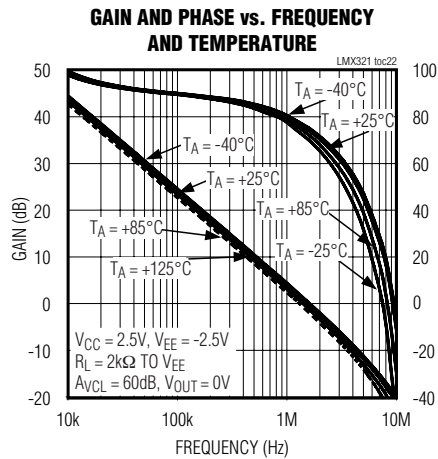
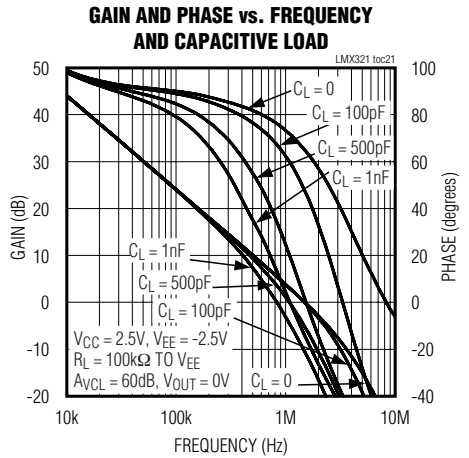
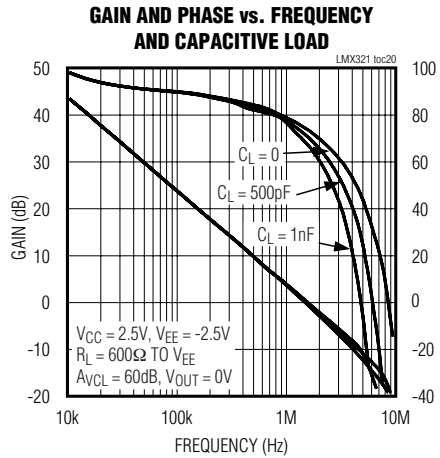
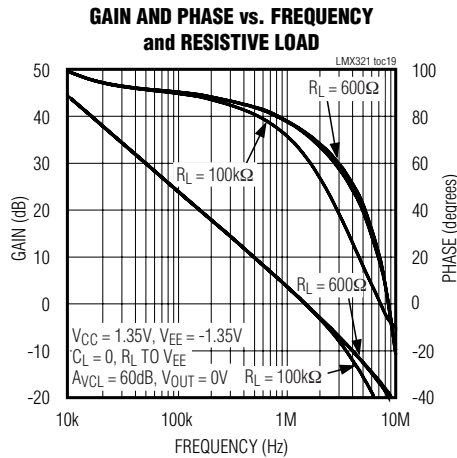


# Single, General-Purpose, Low-Voltage, Rail-to-Rail Output Op Amps

## Typical Operating Characteristics (continued)

( $T_A = +25^\circ\text{C}$ ,  $V_{EE} = 0\text{V}$ , unless otherwise noted.)

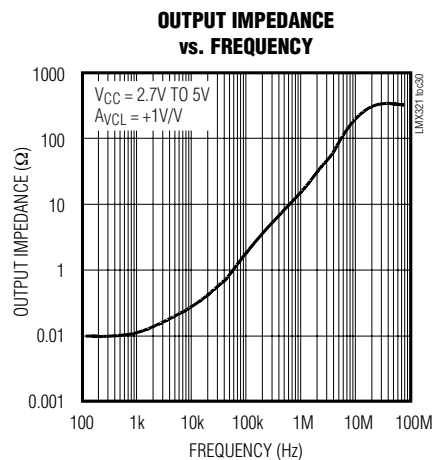
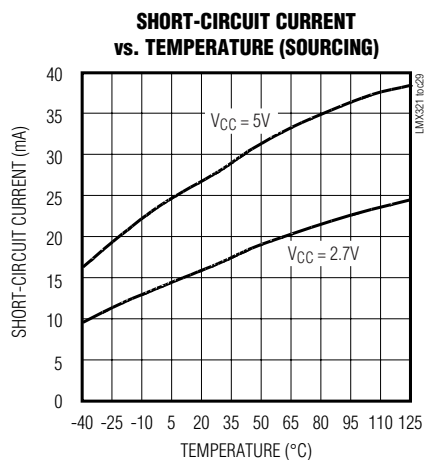
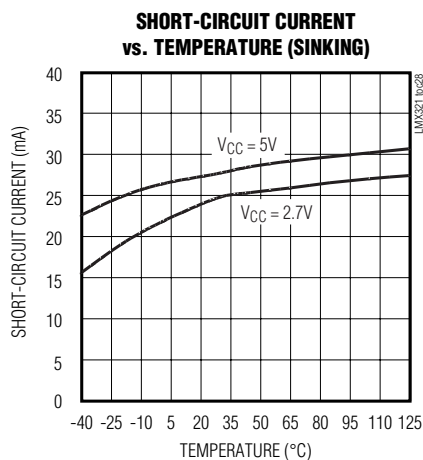
LMX321



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

## Typical Operating Characteristics (continued)

( $T_A = +25^\circ\text{C}$ ,  $V_{EE} = 0\text{V}$ , unless otherwise noted.)



## 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                              |



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

LMX321

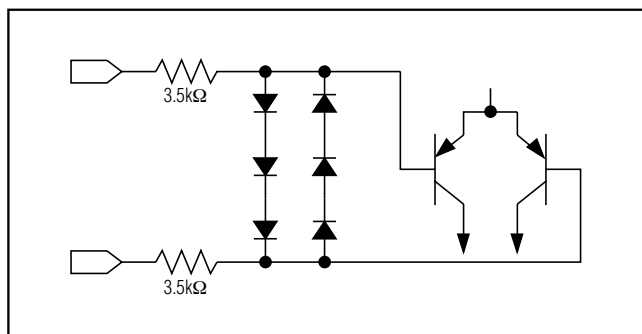


Figure 1. Input Protection Circuit

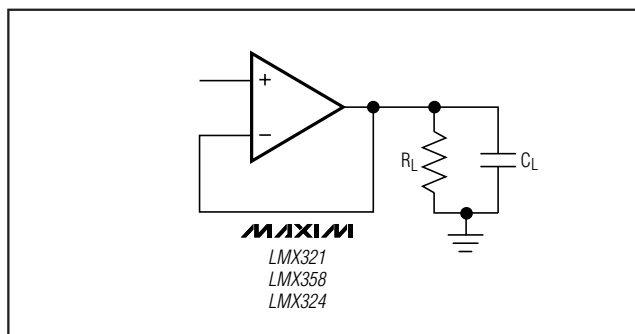


Figure 3. Capacitive-Load-Driving Circuit

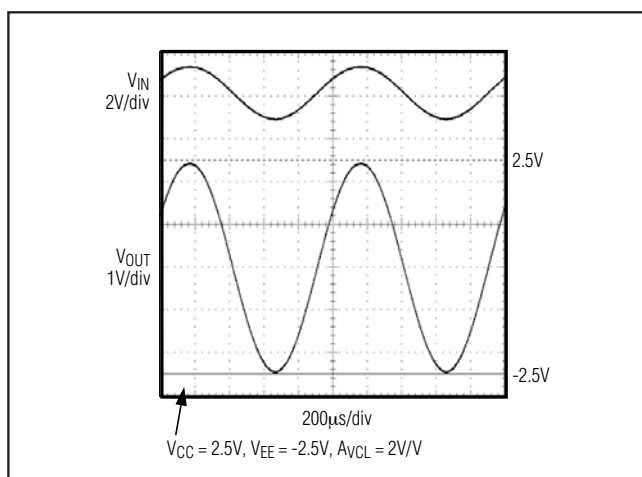


Figure 2. Rail-to-Rail Output Swing

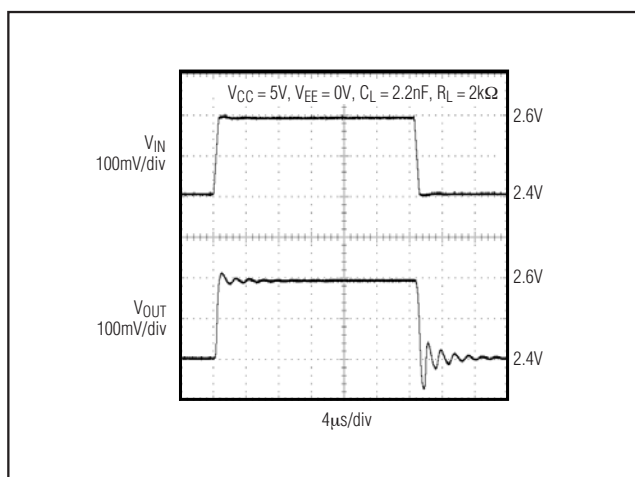


Figure 4. Output With Excessive Capacitive Load

## 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, General-Purpose, Low-Voltage, Rail-to-Rail Output Op Amps

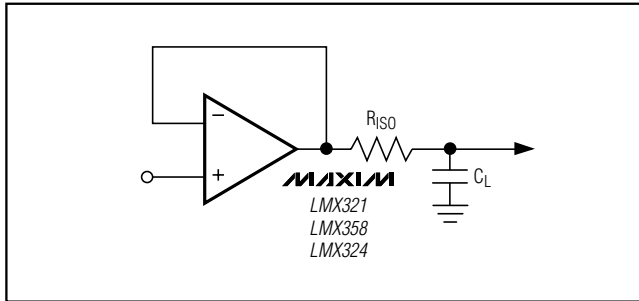


Figure 5. Capacitive-Load-Driving Circuit With Isolation Resistor

## 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 VCC as possible.

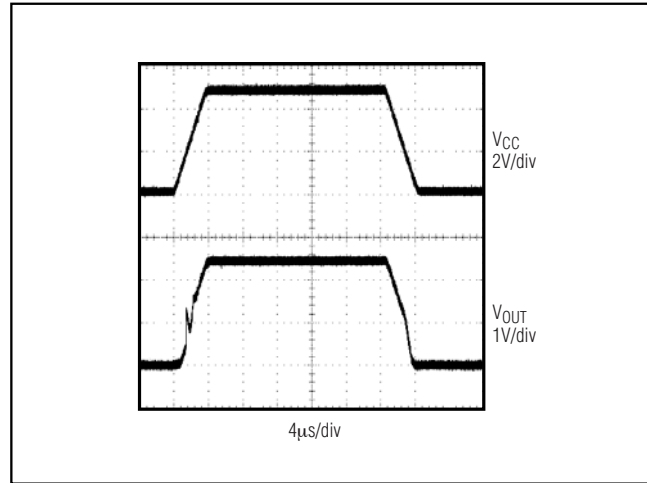


Figure 6. Power-Up/Power-Down Waveform

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

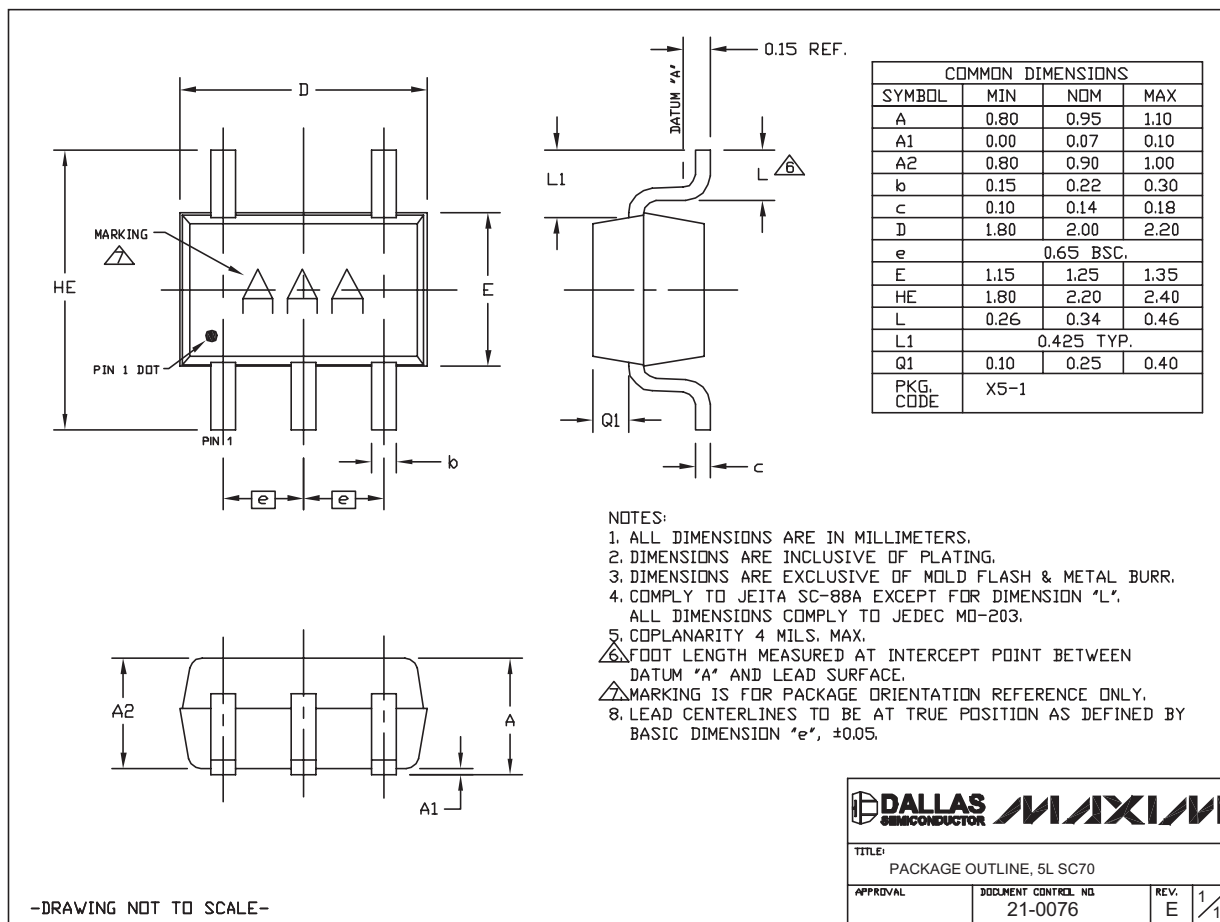
LMX321 TRANSISTOR COUNT: 88  
 LMX358 TRANSISTOR COUNT: 175  
 LMX324 TRANSISTOR COUNT: 349  
 PROCESS: Bipolar

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

## 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](http://www.maxim-ic.com/packages).)

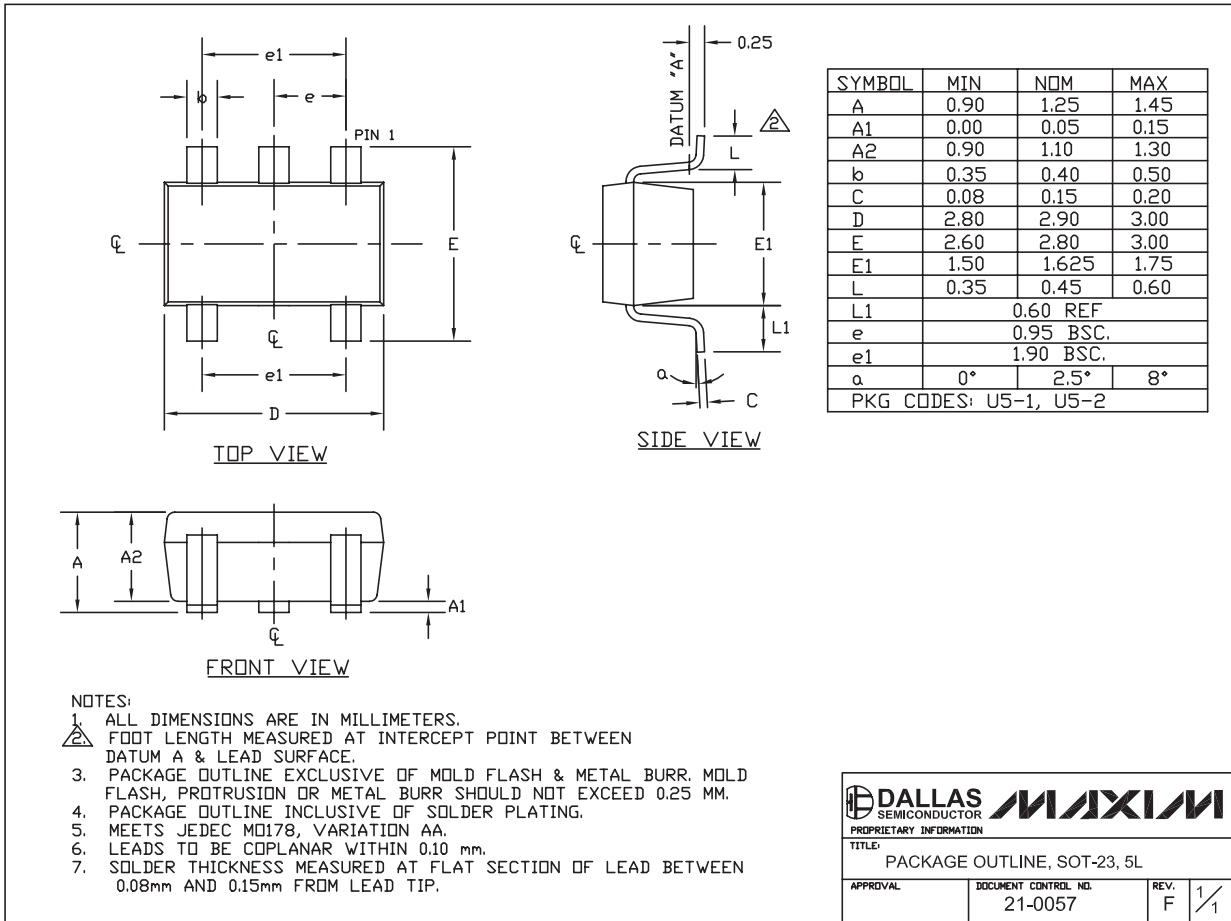
LMX321



# Single, 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](http://www.maxim-ic.com/packages).)



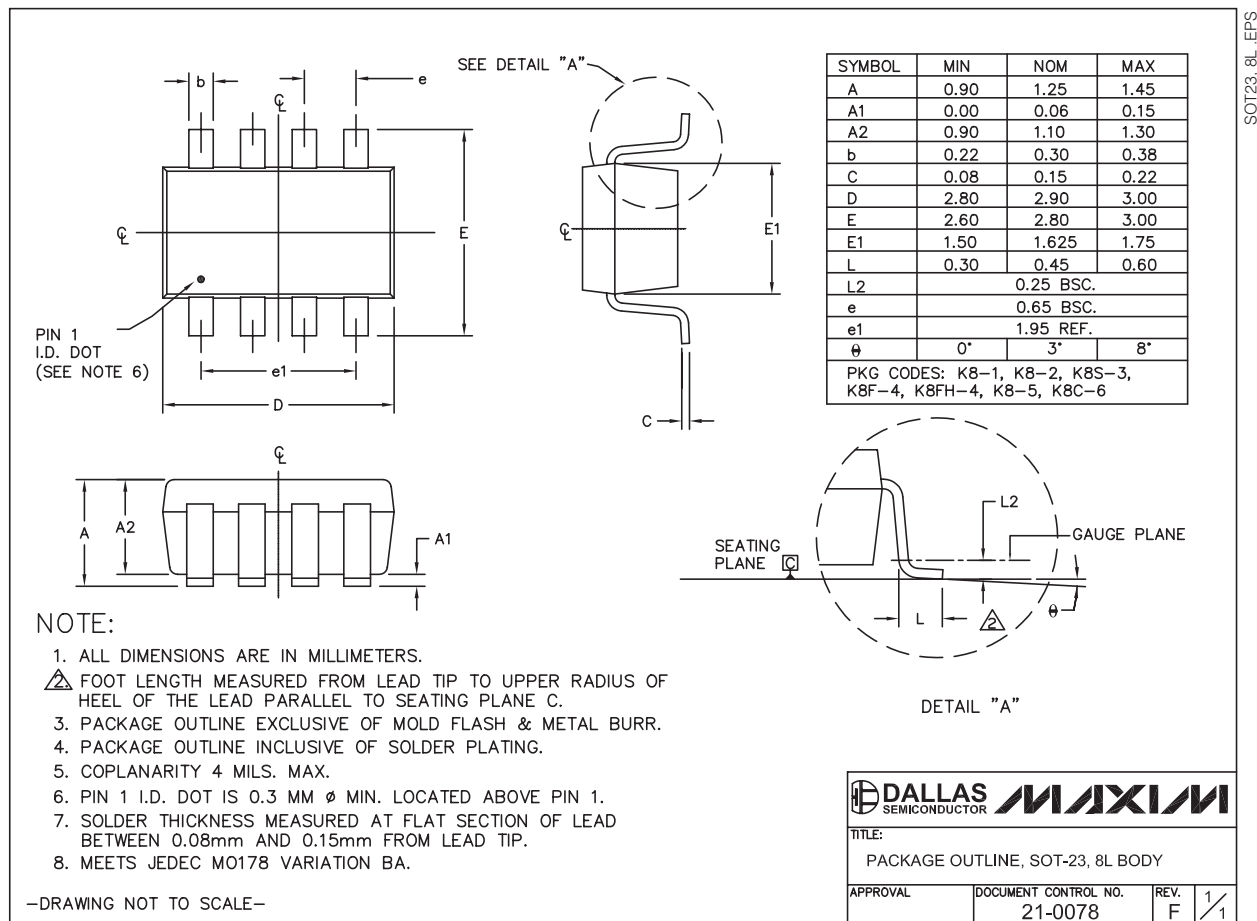
SOT-23 5L .EPS

# Single, 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](http://www.maxim-ic.com/packages).)

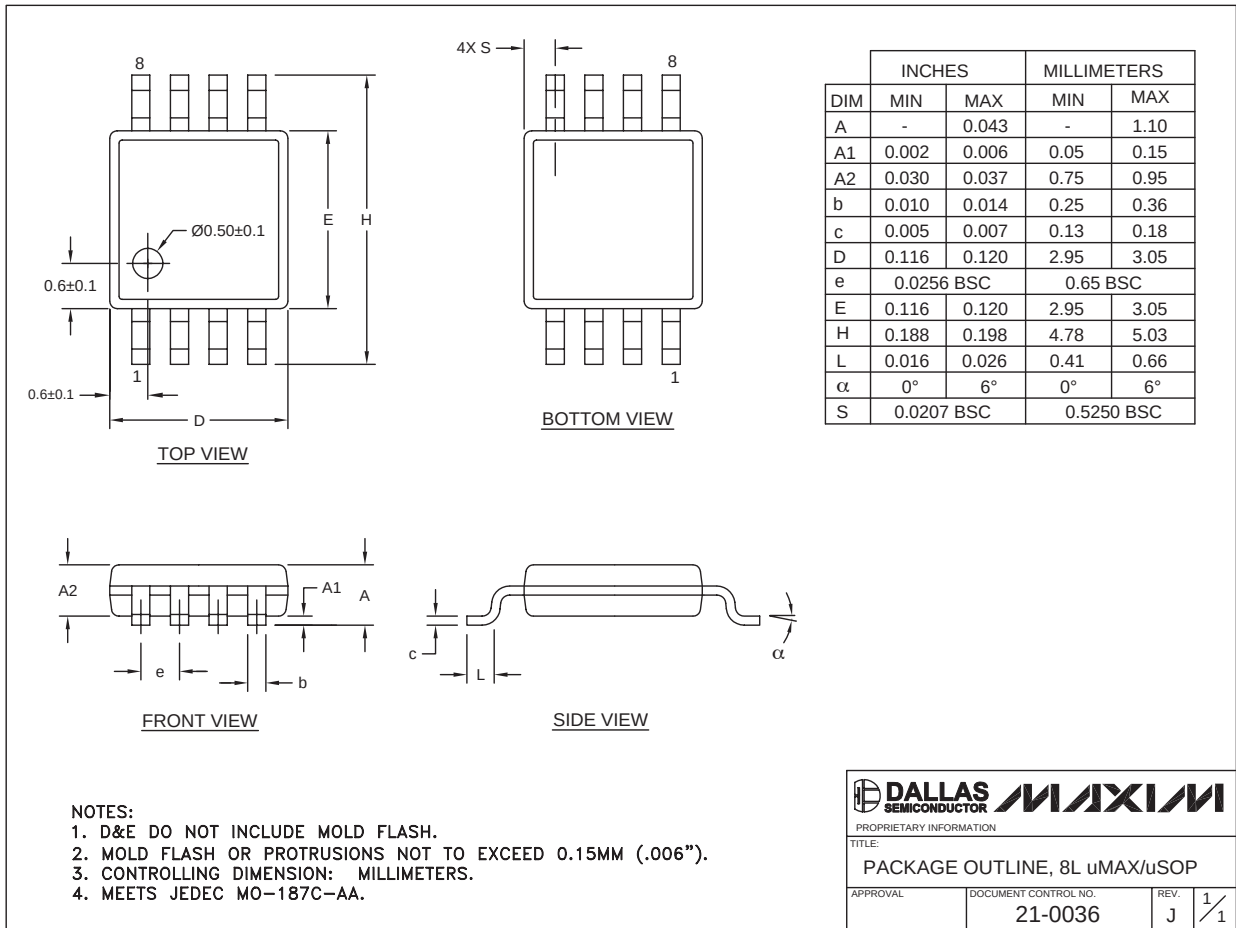
LMX321



# Single, 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](http://www.maxim-ic.com/packages).)

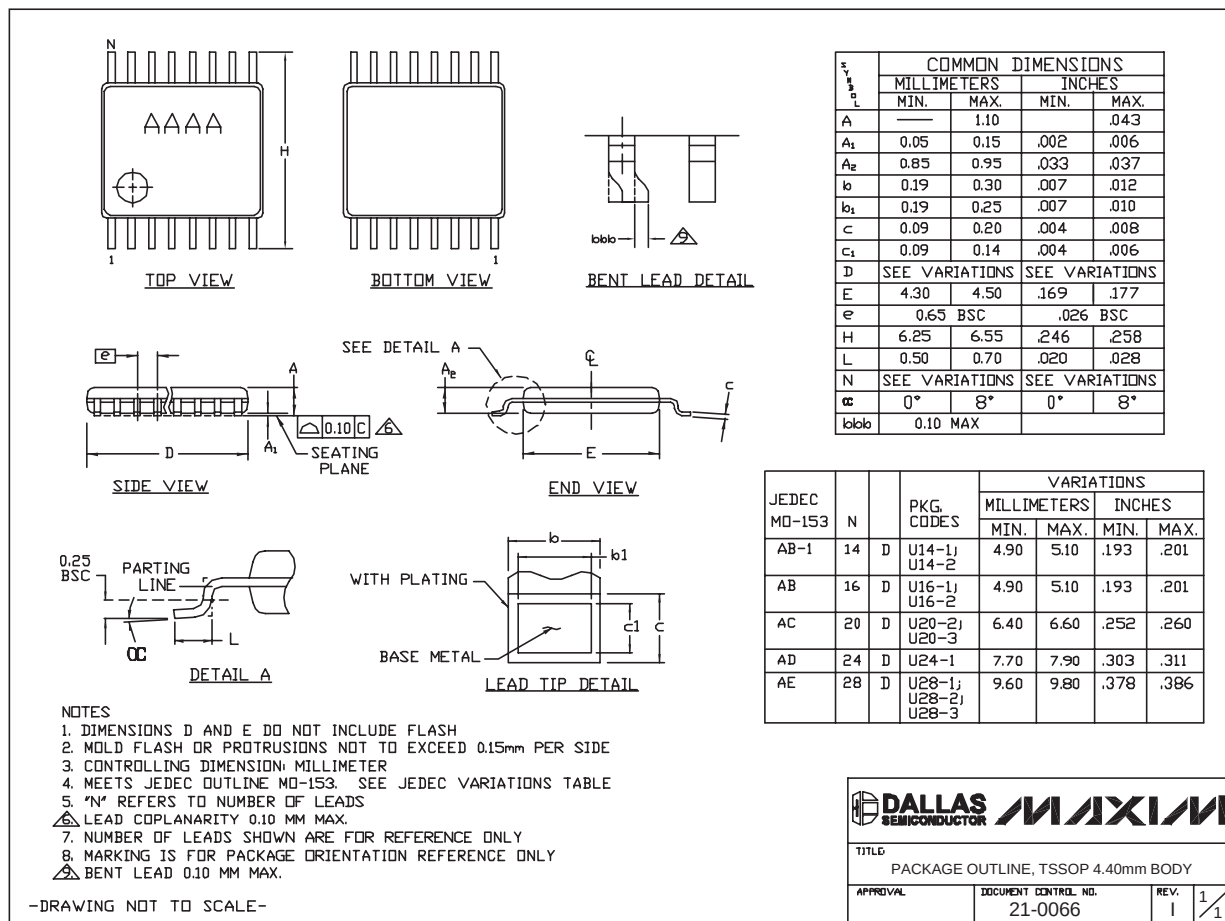


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# Single, General-Purpose, Low-Voltage, Rail-to-Rail Output Op Amps

## 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](http://www.maxim-ic.com/packages).)



TSSOP4, 40mm, EPS

LMX321

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15