

# LPV321 Single/LPV358 Dual/LPV324 Quad General Purpose, Low Voltage, Low Power, Rail-to-Rail Output Operational Amplifiers

## General Description

The LPV321/358/324 are low power (9  $\mu$ A per channel at 5.0V) versions of the LMV321/358/324 op amps. This is another addition to the LMV321/358/324 family of commodity op amps.

The LPV321/358/324 are the most cost effective solutions for the applications where low voltage, low power operation, space saving and low price are needed. The LPV321/358/324 have rail-to-rail output swing capability and the input common-mode voltage range includes ground. They all exhibit excellent speed-power ratio, achieving 5 kHz of bandwidth with a supply current of only 9  $\mu$ A.

The LPV321 is available in space saving 5-Pin SC70, which is approximately half the size of 5-Pin SOT23. The small package saves space on PC boards, and enables the design of small portable electronic devices. It also allows the designer to place the device closer to the signal source to reduce noise pickup and increase signal integrity.

The chips are built with National's advanced submicron silicon-gate BiCMOS process. The LPV321/358/324 have bipolar input and output stages for improved noise performance and higher output current drive.

## Features

(For  $V^+ = 5V$  and  $V^- = 0V$ , typical unless otherwise noted)

- Guaranteed 2.7V and 5V performance
- No crossover distortion
- Space saving package
 

|                |
|----------------|
| 5-Pin SC70     |
| 2.0x2.1x1.0 mm |
- Industrial temperature range
 

|                |
|----------------|
| -40°C to +85°C |
|----------------|
- Gain-bandwidth product
 

|         |
|---------|
| 152 kHz |
|---------|
- Low supply current
 

|        |            |
|--------|------------|
| LPV321 | 9 $\mu$ A  |
| LPV358 | 15 $\mu$ A |
| LPV324 | 28 $\mu$ A |
- Rail-to-rail output swing
 

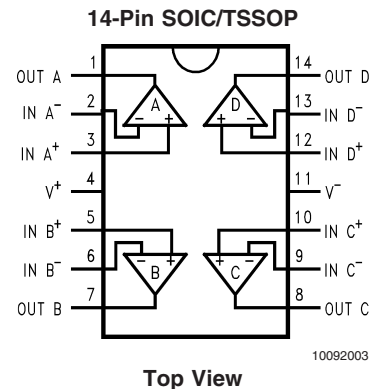
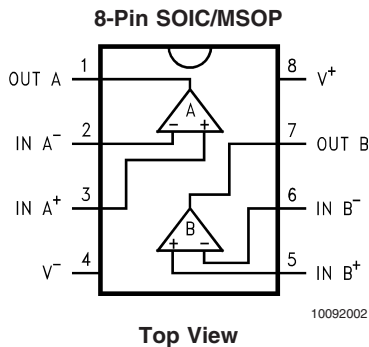
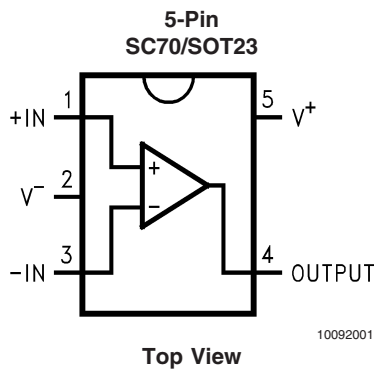
|                       |                |
|-----------------------|----------------|
| @ 100 k $\Omega$ Load | $V^+ - 3.5$ mV |
|                       | $V^- + 90$ mV  |
- $V_{CM}$ 

|                       |
|-----------------------|
| -0.2V to $V^+ - 0.8V$ |
|-----------------------|

## Applications

- Active filters
- General purpose low voltage applications
- General purpose portable devices

## Connection Diagrams



## Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

|  |                 |
|--|-----------------|
| ESD Tolerance (Note 2)                           |                 |
| Human Body Model                                 |                 |
| LPV324   | 2000V           |
| LPV358   | 1500V           |
| LPV321   | 1500V           |
| Machine Model                                    | 100V            |
| Differential Input Voltage                       | ±Supply Voltage |
| Supply Voltage (V <sup>+</sup> -V <sup>-</sup> ) | 5.5V            |
| Output Short Circuit to V <sup>+</sup>           | (Note 3)        |
| Output Short Circuit to V <sup>-</sup>           | (Note 4)        |
| Soldering Information                            |                 |

|  |                |
|--|----------------|
| Infrared or Convection (20 sec)                | 235°C          |
| Storage Temperature Range                      | -65°C to 150°C |
| Junction Temp. (T <sub>J</sub> , max) (Note 5) | 150°C          |

## Operating Ratings (Note 1)

|  |                |
|--|----------------|
| Supply Voltage                                 | 2.7V to 5V     |
| Temperature Range                              | -40°C to +85°C |
| Thermal Resistance (θ <sub>JA</sub> )(Note 10) |                |
| 5-Pin SC70                                     | 478°C/W        |
| 5-Pin SOT23                                    | 265°C/W        |
| 8-Pin SOIC                                     | 190°C/W        |
| 8-Pin MSOP                                     | 235°C/W        |
| 14-Pin SOIC                                    | 145°C/W        |
| 14-Pin TSSOP                                   | 155°C/W        |

## 2.7V DC Electrical Characteristics

Unless otherwise specified, all limits guaranteed for T<sub>J</sub> = 25°C, V<sup>+</sup> = 2.7V, V<sup>-</sup> = 0V, V<sub>CM</sub> = 1.0V, V<sub>O</sub> = V<sup>+</sup>/2 and R<sub>L</sub> > 1 MΩ.

| Symbol            | Parameter                          | Conditions  | Min<br>(Note 7)     | Typ<br>(Note 6)   | Max<br>(Note 7) | Units |
|-------------------|------------------------------------|---|---------------------|-------------------|-----------------|-------|
| V <sub>OS</sub>   | Input Offset Voltage               |   |                     | 1.2               | 7               | mV    |
| TCV <sub>OS</sub> | Input Offset Voltage Average Drift |   |                     | 2                 |                 | μV/°C |
| I <sub>B</sub>    | Input Bias Current                 |   |                     | 1.7               | 50              | nA    |
| I <sub>OS</sub>   | Input Offset Current               |   |                     | 0.6               | 40              | nA    |
| CMRR              | Common Mode Rejection Ratio        | 0V ≤ V <sub>CM</sub> ≤ 1.7V   | 50                  | 70                |                 | dB    |
| PSRR              | Power Supply Rejection Ratio       | 2.7V ≤ V <sup>+</sup> ≤ 5V<br>V <sub>O</sub> = 1V, V <sub>CM</sub> = 1V | 50                  | 65                |                 | dB    |
| V <sub>CM</sub>   | Input Common-Mode Voltage Range    | For CMRR ≥ 50 dB  | 0                   | -0.2              | 1.7             | V     |
| V <sub>O</sub>    | Output Swing                       | R <sub>L</sub> = 100 kΩ to 1.35V  | V <sup>+</sup> -100 | V <sup>+</sup> -3 |                 | mV    |
|                   |                                    |   |                     | 80                | 180             | mV    |
| I <sub>S</sub>    | Supply Current                     | LPV321  |                     | 4                 | 8               | μA    |
|                   |                                    | LPV358<br>Both Amplifiers   |                     | 8                 | 16              | μA    |
|                   |                                    | LPV324<br>All Four Amplifiers   |                     | 16                | 24              | μA    |

## 2.7V AC Electrical Characteristics

Unless otherwise specified, all limits guaranteed for T<sub>J</sub> = 25°C, V<sup>+</sup> = 2.7V, V<sup>-</sup> = 0V, V<sub>CM</sub> = 1.0V, V<sub>O</sub> = V<sup>+</sup>/2 and R<sub>L</sub> > 1 MΩ.

| Symbol         | Parameter                    | Conditions             | Min<br>(Note 7) | Typ<br>(Note 6) | Max<br>(Note 7) | Units                  |
|----------------|------------------------------|------------------------|-----------------|-----------------|-----------------|------------------------|
| GBWP           | Gain-Bandwidth Product       | C <sub>L</sub> = 22 pF |                 | 112             |                 | kHz                    |
| Φ <sub>m</sub> | Phase Margin                 |                        |                 | 97              |                 | Deg                    |
| G <sub>m</sub> | Gain Margin                  |                        |                 | 35              |                 | dB                     |
| e <sub>n</sub> | Input-Referred Voltage Noise | f = 1 kHz              |                 | 178             |                 | $\frac{nV}{\sqrt{Hz}}$ |
| i <sub>n</sub> | Input-Referred Current Noise | f = 1 kHz              |                 | 0.50            |                 | $\frac{pA}{\sqrt{Hz}}$ |

## 5V DC Electrical Characteristics

Unless otherwise specified, all limits guaranteed for  $T_J = 25^\circ\text{C}$ ,  $V^+ = 5\text{V}$ ,  $V^- = 0\text{V}$ ,  $V_{\text{CM}} = 2.0\text{V}$ ,  $V_O = V^+/2$  and  $R_L > 1\text{M}\Omega$ . **Boldface** limits apply at the temperature extremes.

| Symbol                   | Parameter                             | Conditions   | Min<br>(Note 7)                              | Typ<br>(Note 6)   | Max<br>(Note 7)   | Units                        |
|--------------------------|---------------------------------------|--|--|-------------------|-------------------|------------------------------|
| $V_{\text{OS}}$          | Input Offset Voltage                  |  |  | 1.5               | 7<br><b>10</b>    | mV                           |
| $\text{TCV}_{\text{OS}}$ | Input Offset Voltage Average Drift    |  |  | 2                 |                   | $\mu\text{V}/^\circ\text{C}$ |
| $I_{\text{B}}$           | Input Bias Current                    |  |  | 2                 | 50<br><b>60</b>   | nA                           |
| $I_{\text{OS}}$          | Input Offset Current                  |  |  | 0.6               | 40<br><b>50</b>   | nA                           |
| CMRR                     | Common Mode Rejection Ratio           | $0\text{V} \leq V_{\text{CM}} \leq 4\text{V}$  | 50   | 71                |                   | dB                           |
| PSRR                     | Power Supply Rejection Ratio          | $2.7\text{V} \leq V^+ \leq 5\text{V}$<br>$V_O = 1\text{V}$ , $V_{\text{CM}} = 1\text{V}$ | 50   | 65                |                   | dB                           |
| $V_{\text{CM}}$          | Input Common-Mode Voltage Range       | For CMRR $\geq 50$ dB  | 0  | -0.2<br>4.2       | 4                 | V                            |
| $A_V$                    | Large Signal Voltage Gain<br>(Note 8) | $R_L = 100\text{ k}\Omega$   | 15<br><b>10</b>                              | 100               |                   | V/mV                         |
| $V_O$                    | Output Swing                          | $R_L = 100\text{ k}\Omega$ to 2.5V   | $V^+ - 100$<br><b><math>V^+ - 200</math></b> | $V^+ - 3.5$<br>90 | 180<br><b>220</b> | mV                           |
| $I_O$                    | Output Short Circuit Current Sourcing | LPV324, LPV358, and LPV321<br>$V_O = 0\text{V}$  | 2  | 16                |                   | mA                           |
|                          | Output Short Circuit Current Sinking  | LPV321<br>$V_O = 5\text{V}$  | 20   | 60                |                   | mA                           |
|                          |                                       | LPV324 and LPV358<br>$V_O = 5\text{V}$   | 11   | 16                |                   | mA                           |
| $I_S$                    | Supply Current                        | LPV321   |  | 9                 | 12<br><b>15</b>   | $\mu\text{A}$                |
|                          |                                       | LPV358   |  | 15                | 20                | $\mu\text{A}$                |
|                          |                                       | Both amplifiers  |  |                   | <b>24</b>         | $\mu\text{A}$                |
|                          |                                       | LPV324   |  | 28                | 42                | $\mu\text{A}$                |
|                          |                                       | All four amplifiers  |  |                   | <b>46</b>         | $\mu\text{A}$                |

## 5V AC Electrical Characteristics

Unless otherwise specified, all limits guaranteed for  $T_J = 25^\circ\text{C}$ ,  $V^+ = 5\text{V}$ ,  $V^- = 0\text{V}$ ,  $V_{\text{CM}} = 2.0\text{V}$ ,  $V_O = V^+/2$  and  $R_L > 1\text{M}\Omega$ . **Boldface** limits apply at the temperature extremes.

| Symbol   | Parameter                    | Conditions           | Min<br>(Note 7) | Typ<br>(Note 6) | Min<br>(Note 7) | Units                                |
|----------|------------------------------|----------------------|-----------------|-----------------|-----------------|--------------------------------------|
| SR       | Slew Rate                    | (Note 9)             |                 | 0.1             |                 | V/ $\mu\text{s}$                     |
| GBWP     | Gain-Bandwidth Product       | $C_L = 22\text{ pF}$ |                 | 152             |                 | kHz                                  |
| $\Phi_m$ | Phase Margin                 |                      |                 | 87              |                 | Deg                                  |
| $G_m$    | Gain Margin                  |                      |                 | 19              |                 | dB                                   |
| $e_n$    | Input-Referred Voltage Noise | $f = 1\text{ kHz}$ , |                 | 146             |                 | $\frac{\text{nV}}{\sqrt{\text{Hz}}}$ |
| $i_n$    | Input-Referred Current Noise | $f = 1\text{ kHz}$   |                 | 0.30            |                 | $\frac{\text{pA}}{\sqrt{\text{Hz}}}$ |

## 5V AC Electrical Characteristics (Continued)

**Note 1:** Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but specific performance is not guaranteed. For guaranteed specifications and the test conditions, see the Electrical Characteristics.

**Note 2:** Human Body Model, applicable std. MIL-STD-883, Method 3015.7. Machine Model, applicable std. JESD22-A115-A (ESD MM std. of JEDEC)

Field-Induced Charge-Device Model, applicable std. JESD22-C101-C (ESD FICDM std. of JEDEC).

**Note 3:** Shorting output to  $V^+$  will adversely affect reliability.

**Note 4:** Shorting output to  $V^-$  will adversely affect reliability.

**Note 5:** The maximum power dissipation is a function of  $T_{J(MAX)}$ ,  $\theta_{JA}$ . The maximum allowable power dissipation at any ambient temperature is  $P_D = (T_{J(MAX)} - T_A) / \theta_{JA}$ . All numbers apply for packages soldered directly onto a PC Board.

**Note 6:** Typical values represent the most likely parametric norm as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration. The typical values are not tested and are not guaranteed on shipped production material.

**Note 7:** All limits are guaranteed by testing or statistical analysis.

**Note 8:**  $R_L$  is connected to  $V^-$ . The output voltage is  $0.5V \leq V_O \leq 4.5V$ .

**Note 9:** Connected as voltage follower with 3V step input. Number specified is the slower of the positive and negative slew rates.

**Note 10:** All numbers are typical, and apply for packages soldered directly onto a PC board in still air.

## Ordering Information

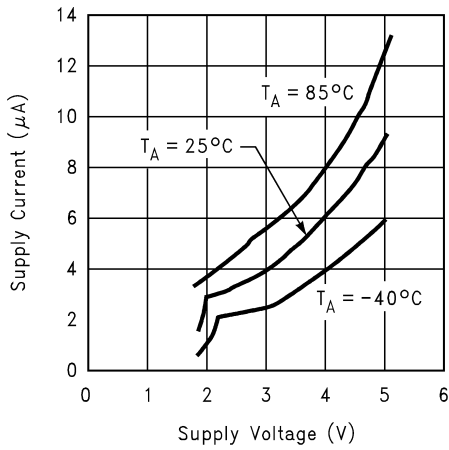
| Package      | Temperature Range            | Packaging Marking | Transport Media          | NSC Drawing |
|--------------|------------------------------|-------------------|--------------------------|-------------|
|              | Industrial<br>-40°C to +85°C |                   |                          |             |
| 5-Pin SC70   | LPV321M7                     | A19               | 1k Units Tape and Reel   | MAA05A      |
|              | LPV321M7X                    | A19               | 3k Units Tape and Reel   |             |
| 5-Pin SOT23  | LPV321M5                     | A27A              | 1k Units Tape and Reel   | MF05A       |
|              | LPV321M5X                    | A27A              | 3k Units Tape and Reel   |             |
| 8-Pin SOIC   | LPV358M                      | LPV358M           | Rails                    | M08A        |
|              | LPV358MX                     | LPV358M           | 2.5k Units Tape and Reel |             |
| 8-Pin MSOP   | LPV358MM                     | P358              | 1k Units Tape and Reel   | MUA08A      |
|              | LPV358MMX                    | P358              | 3.5k Units Tape and Reel |             |
| 14-Pin SOIC  | LPV324M                      | LPV324M           | Rails                    | M14A        |
|              | LPV324MX                     | LPV324M           | 2.5k Units Tape and Reel |             |
| 14-Pin TSSOP | LPV324MT                     | LPV324MT          | Rails                    | MTC14       |
|              | LPV324MTX                    | LPV324MT          | 2.5k Units Tape and Reel |             |

# Typical Performance Characteristics

Unless otherwise specified,  $V_S = +5V$ , single supply,

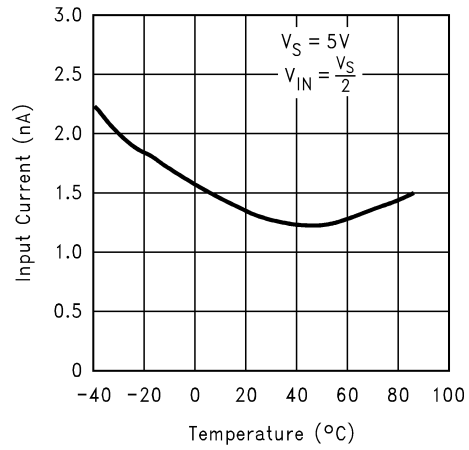
$T_A = 25^\circ C$ .

Supply Current vs. Supply Voltage (LPV321)



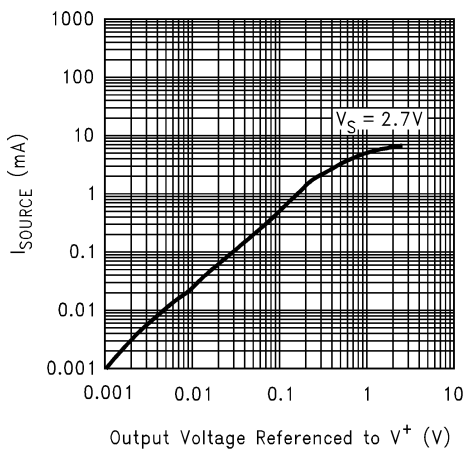
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Input Current vs. Temperature



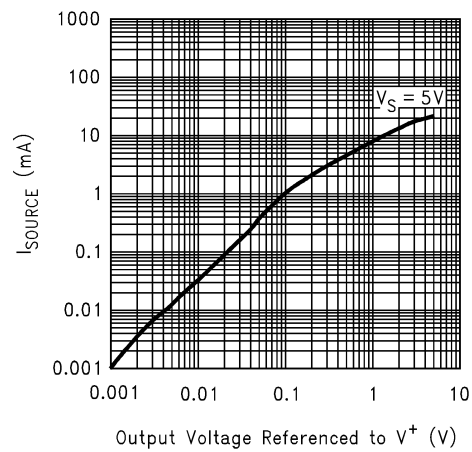
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Sourcing Current vs. Output Voltage



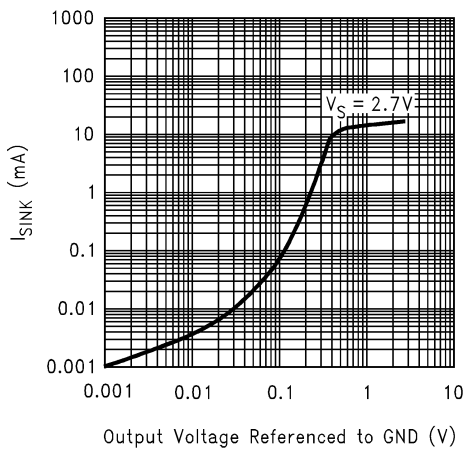
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Sourcing Current vs. Output Voltage



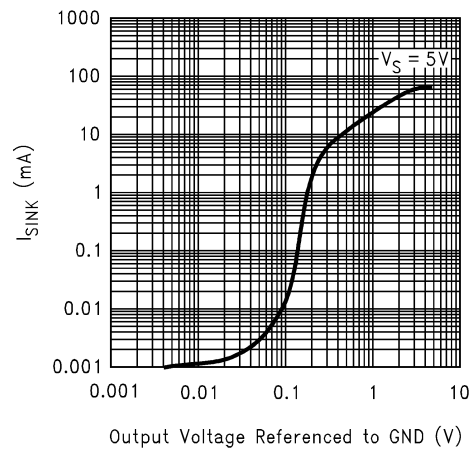
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Sinking Current vs. Output Voltage



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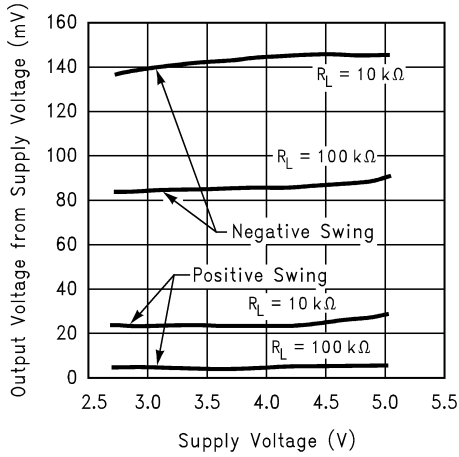
Sinking Current vs. Output Voltage



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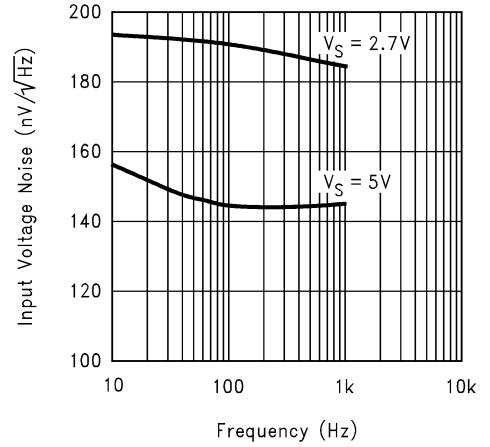
**Typical Performance Characteristics** Unless otherwise specified,  $V_S = +5V$ , single supply,  $T_A = 25^\circ C$ . (Continued)

**Output Voltage Swing vs. Supply Voltage**



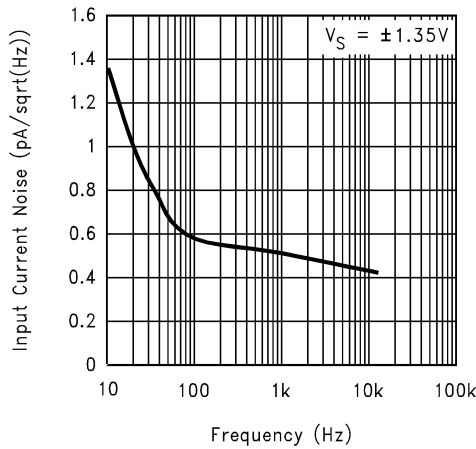
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**Input Voltage Noise vs. Frequency**



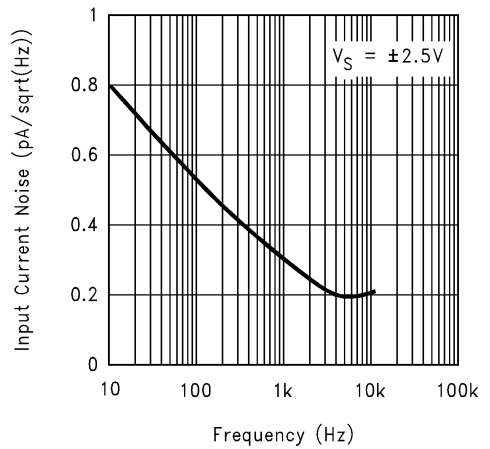
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**Input Current Noise vs Frequency**



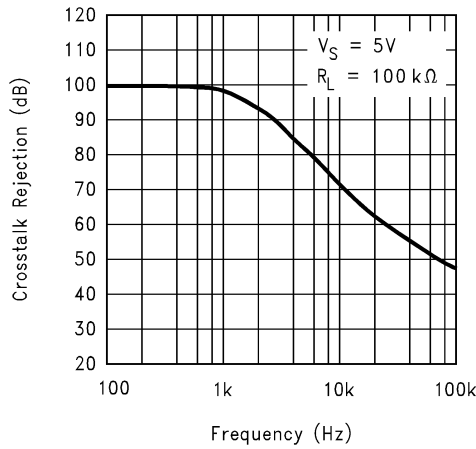
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**Input Current Noise vs Frequency**



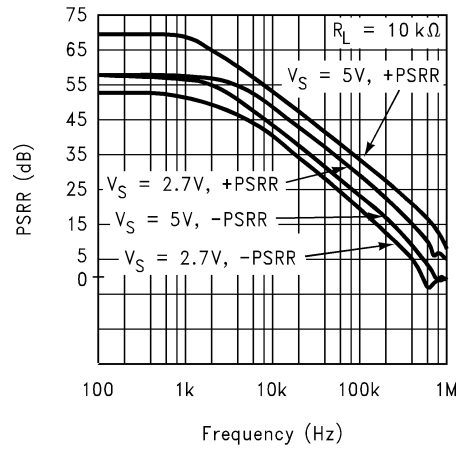
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**Crosstalk Rejection vs. Frequency**



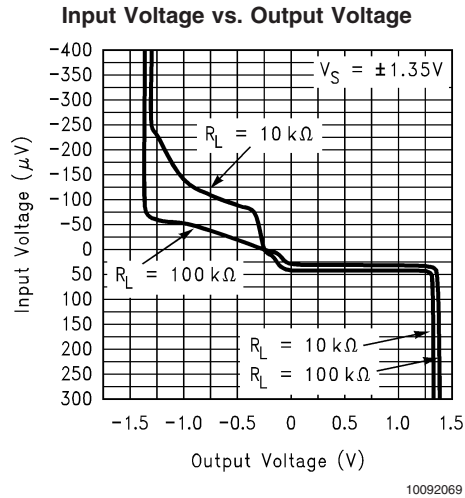
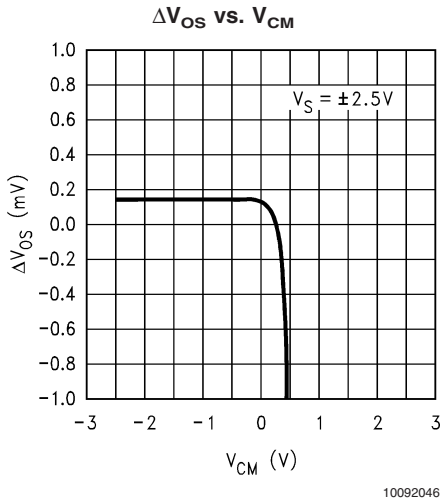
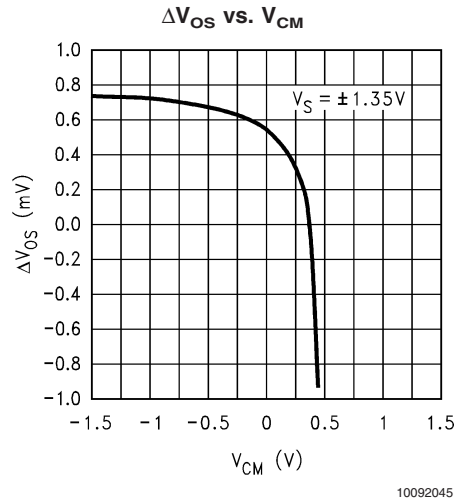
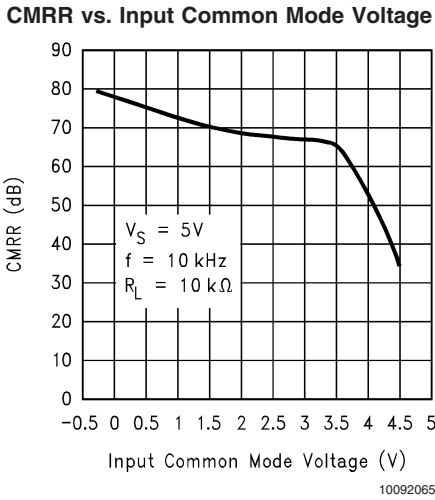
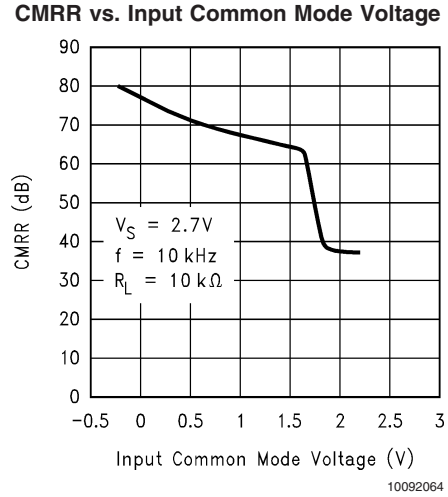
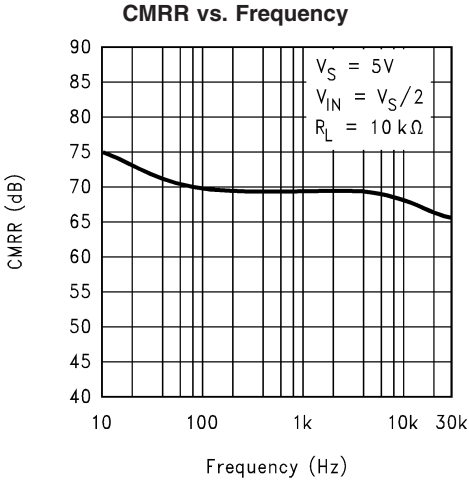
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**PSRR vs. Frequency**

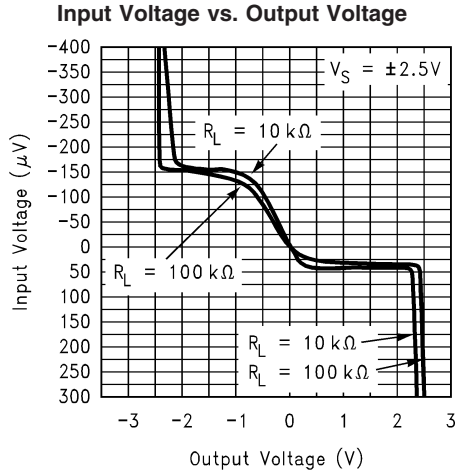


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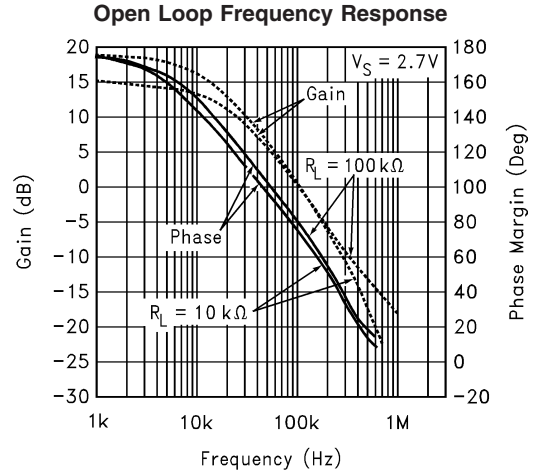
**Typical Performance Characteristics** Unless otherwise specified,  $V_S = +5V$ , single supply,  $T_A = 25^\circ C$ . (Continued)



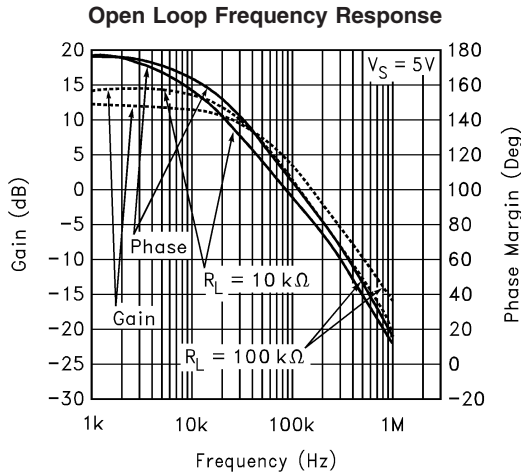
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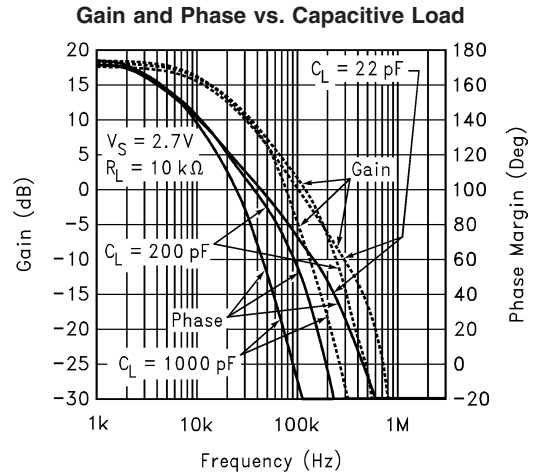
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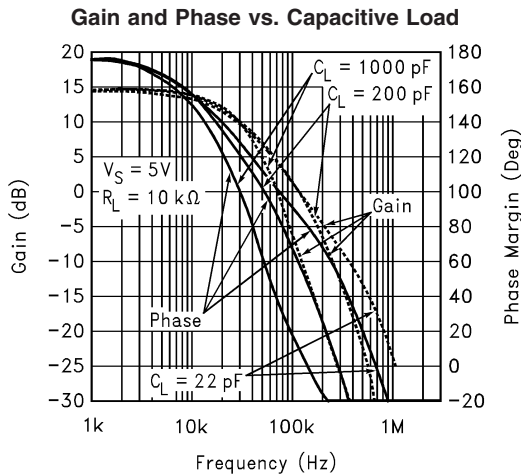
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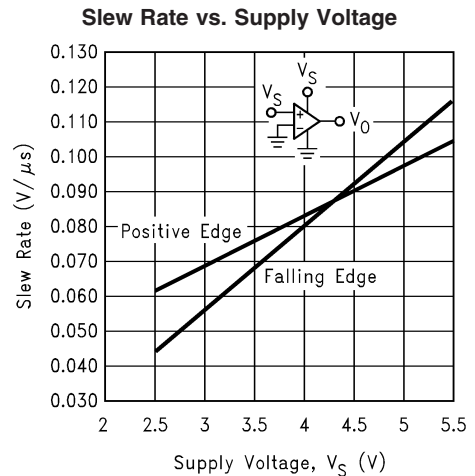
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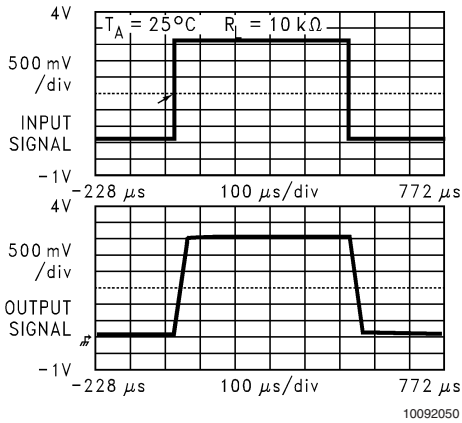


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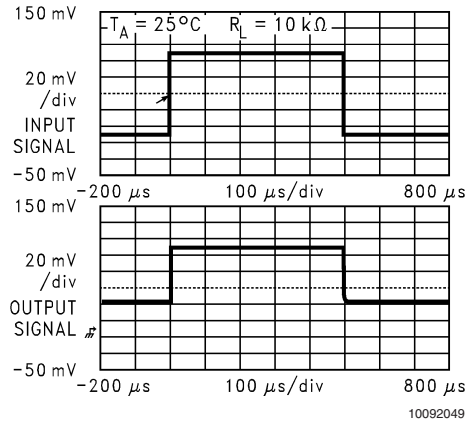


**Typical Performance Characteristics** Unless otherwise specified,  $V_S = +5V$ , single supply,  $T_A = 25^\circ C$ . (Continued)

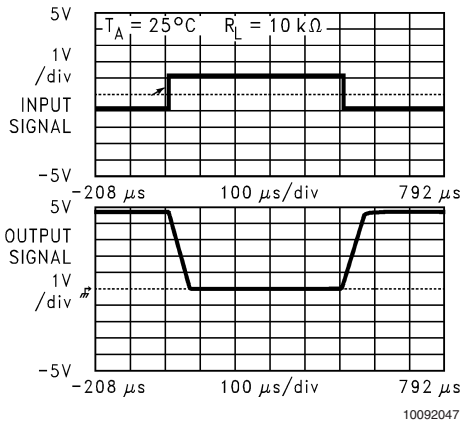
**Non-Inverting Large Signal Pulse Response**



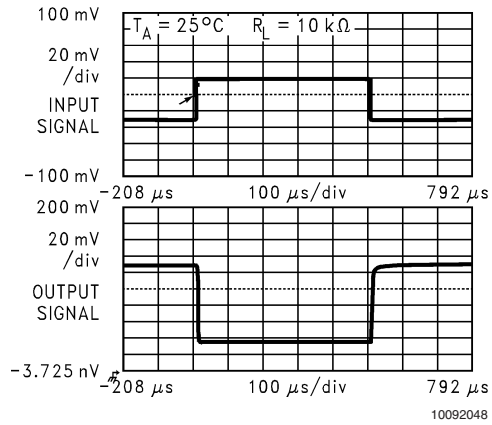
**Non-Inverting Small Signal Pulse Response**



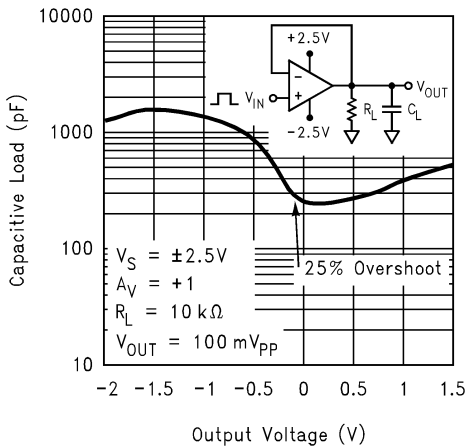
**Inverting Large Signal Pulse Response**



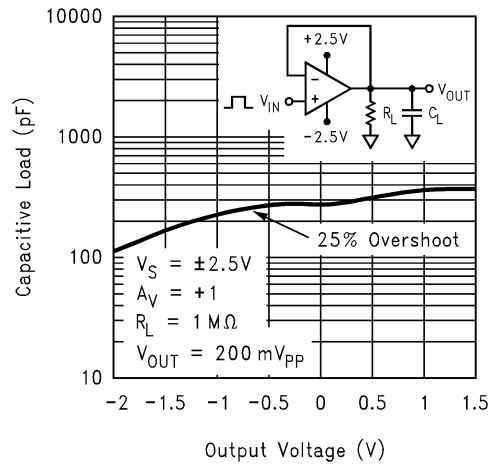
**Inverting Small Signal Pulse Response**



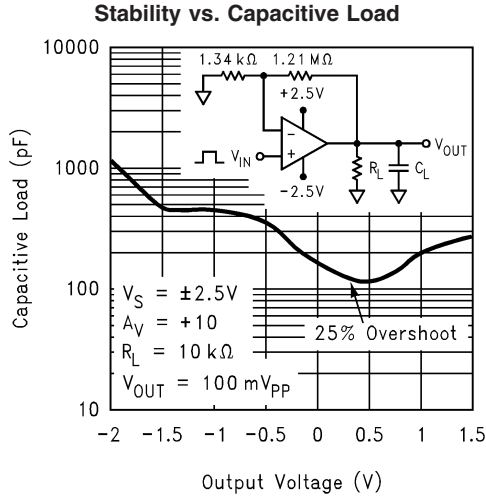
**Stability vs. Capacitive Load**



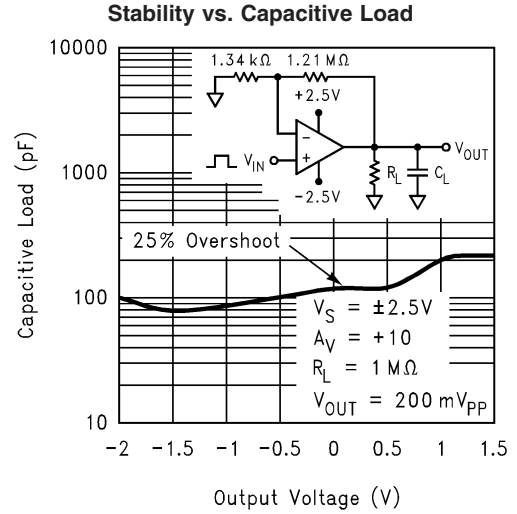
**Stability vs. Capacitive Load**



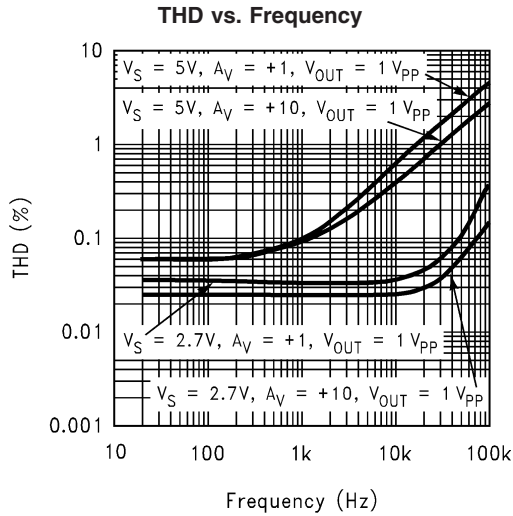
**Typical Performance Characteristics** Unless otherwise specified,  $V_S = +5V$ , single supply,  $T_A = 25^\circ C$ . (Continued)



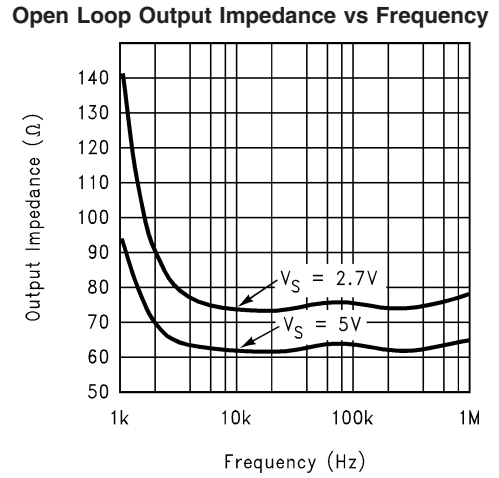
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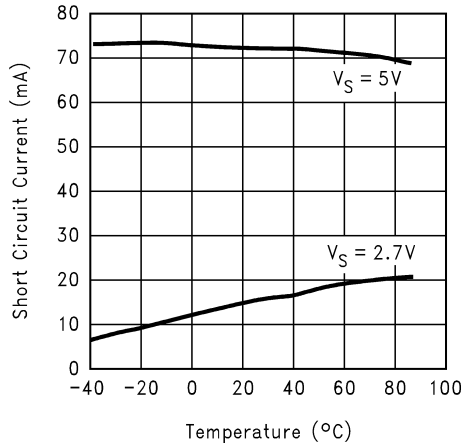


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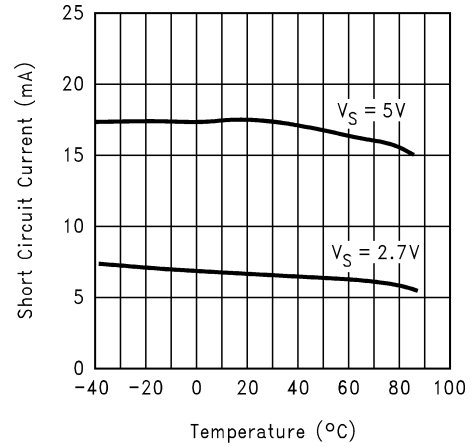
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**Short Circuit Current vs. Temperature (Sinking)**



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**Short Circuit Current vs. Temperature (Sourcing)**



100920B8

## Application Information

### BENEFITS OF THE LPV321/358/324

#### Size

The small footprints of the LPV321/358/324 packages save space on printed circuit boards, and enable the design of smaller electronic products, such as cellular phones, pagers, or other portable systems. The low profile of the LPV321/358/324 make them possible to use in PCMCIA type III cards.

#### Signal Integrity

Signals can pick up noise between the signal source and the amplifier. By using a physically smaller amplifier package, the LPV321/358/324 can be placed closer to the signal source, reducing noise pickup and increasing signal integrity.

#### Simplified Board Layout

These products help you to avoid using long pc traces in your pc board layout. This means that no additional components, such as capacitors and resistors, are needed to filter out the unwanted signals due to the interference between the long pc traces.

#### Low Supply Current

These devices will help you to maximize battery life. They are ideal for battery powered systems.

#### Low Supply Voltage

National provides guaranteed performance at 2.7V and 5V. These guarantees ensure operation throughout the battery lifetime.

#### Rail-to-Rail Output

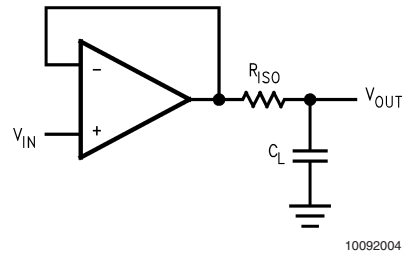
Rail-to-rail output swing provides maximum possible dynamic range at the output. This is particularly important when operating on low supply voltages.

#### Input Includes Ground

Allows direct sensing near GND in single supply operation. The differential input voltage may be larger than  $V^+$  without damaging the device. Protection should be provided to prevent the input voltages from going negative more than  $-0.3V$  (at  $25^\circ C$ ). An input clamp diode with a resistor to the IC input terminal can be used.

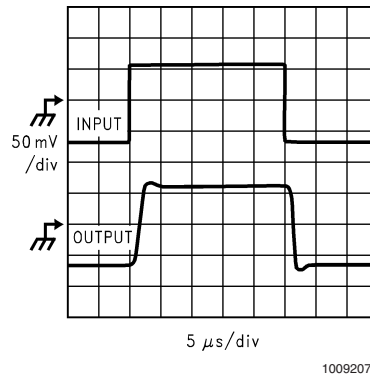
### CAPACITIVE LOAD TOLERANCE

The LPV321/358/324 can directly drive 200 pF in unity-gain without oscillation. The unity-gain follower is the most sensitive configuration to capacitive loading. Direct capacitive loading reduces the phase margin of amplifiers. The combination of the amplifier's output impedance and the capacitive load induces phase lag. This results in either an underdamped pulse response or oscillation. To drive a heavier capacitive load, circuit in *Figure 1* can be used.



**FIGURE 1. Indirectly Driving A Capacitive Load Using Resistive Isolation**

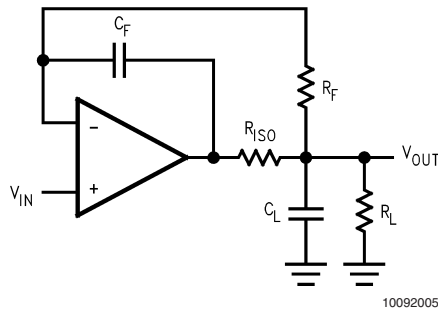
In *Figure 1*, the isolation resistor  $R_{ISO}$  and the load capacitor  $C_L$  form a pole to increase stability by adding more phase margin to the overall system. The desired performance depends on the value of  $R_{ISO}$ . The bigger the  $R_{ISO}$  resistor value, the more stable  $V_{OUT}$  will be. *Figure 2* is an output waveform of *Figure 1* using 100 k $\Omega$  for  $R_{ISO}$  and 1000 pF for  $C_L$ .



**FIGURE 2. Pulse Response of the LPV324 Circuit in Figure 1**

The circuit in *Figure 3* is an improvement to the one in *Figure 1* because it provides DC accuracy as well as AC stability. If there were a load resistor in *Figure 1*, the output would be voltage divided by  $R_{ISO}$  and the load resistor. Instead, in *Figure 3*,  $R_F$  provides the DC accuracy by using feed-forward techniques to connect  $V_{IN}$  to  $R_L$ . Caution is needed in choosing the value of  $R_F$  due to the input bias current of the LPV321/358/324.  $C_F$  and  $R_{ISO}$  serve to counteract the loss of phase margin by feeding the high frequency component of the output signal back to the amplifier's inverting input, thereby preserving phase margin in the overall feedback loop. Increased capacitive drive is possible by increasing the value of  $C_F$ . This in turn will slow down the pulse response.

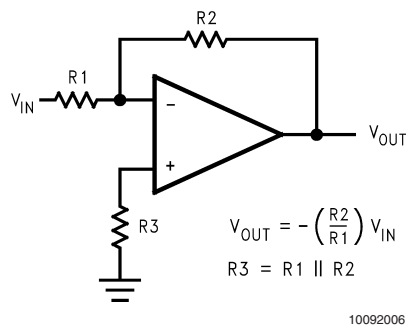
**Application Information** (Continued)



**FIGURE 3. Indirectly Driving A Capacitive Load with DC Accuracy**

**INPUT BIAS CURRENT CANCELLATION**

The LPV321/358/324 family has a bipolar input stage. The typical input bias current of LPV321/358/324 is 1.5 nA with 5V supply. Thus a 100 kΩ input resistor will cause 0.15 mV of error voltage. By balancing the resistor values at both inverting and non-inverting inputs, the error caused by the amplifier's input bias current will be reduced. The circuit in *Figure 4* shows how to cancel the error caused by input bias current.

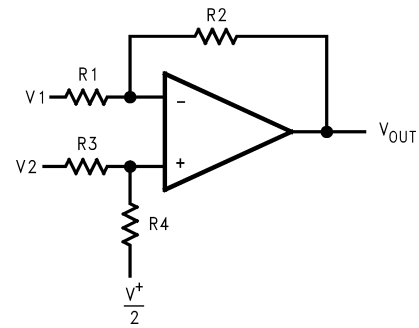


**FIGURE 4. Cancelling the Error Caused by Input Bias Current**

**TYPICAL SINGLE-SUPPLY APPLICATION CIRCUITS**

**Difference Amplifier**

The difference amplifier allows the subtraction of two voltages or, as a special case, the cancellation of a signal common to two inputs. It is useful as a computational amplifier, in making a differential to single-ended conversion or in rejecting a common mode signal.



$$V_{OUT} = \left(\frac{R1 + R2}{R3 + R4}\right) \frac{R4}{R1} V_2 - \frac{R2}{R1} V_1 + \left(\frac{R1 + R2}{R3 + R4}\right) \frac{R3}{R1} \cdot \frac{V^+}{2}$$

for  $R1 = R3$  and  $R2 = R4$

$$V_{OUT} = \frac{R2}{R1} (V_2 - V_1) + \frac{V^+}{2}$$

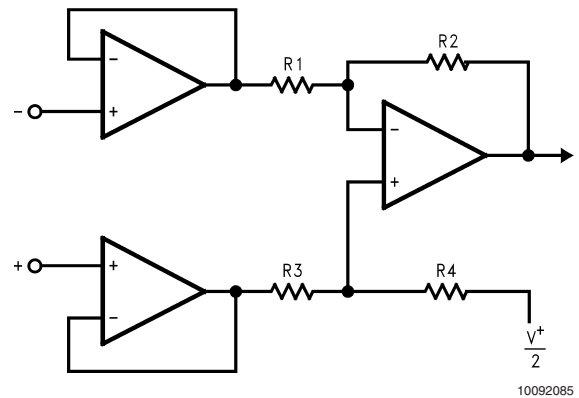
**FIGURE 5. Difference Amplifier**

**Instrumentation Circuits**

The input impedance of the previous difference amplifier is set by the resistor  $R_1$ ,  $R_2$ ,  $R_3$ , and  $R_4$ . To eliminate the problems of low input impedance, one way is to use a voltage follower ahead of each input as shown in the following two instrumentation amplifiers.

**Three-op-amp Instrumentation Amplifier**

The quad LPV324 can be used to build a three-op-amp instrumentation amplifier as shown in *Figure 6*



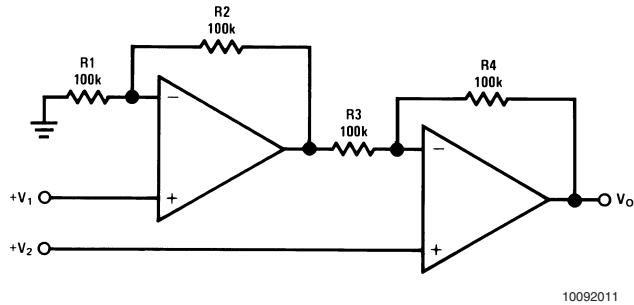
**FIGURE 6. Three-op-amp Instrumentation Amplifier**

The first stage of this instrumentation amplifier is a differential-input, differential-output amplifier, with two voltage followers. These two voltage followers assure that the input impedance is over 100 MΩ. The gain of this instrumentation amplifier is set by the ratio of  $R_2/R_1$ .  $R_3$  should equal  $R_1$  and  $R_4$  equal  $R_2$ . Matching of  $R_3$  to  $R_1$  and  $R_4$  to  $R_2$  affects the CMRR. For good CMRR over temperature, low drift resistors should be used. Making  $R_4$  slightly smaller than  $R_2$  and adding a trim pot equal to twice the difference between  $R_2$  and  $R_4$  will allow the CMRR to be adjusted for optimum.

## Application Information (Continued)

### Two-op-amp Instrumentation Amplifier

A two-op-amp instrumentation amplifier can also be used to make a high-input-impedance DC differential amplifier (Figure 7). As in the three-op-amp circuit, this instrumentation amplifier requires precise resistor matching for good CMRR.  $R_4$  should equal to  $R_1$  and  $R_3$  should equal  $R_2$ .



$$V_O = \left(1 + \frac{R_4}{R_3}\right)(V_2 - V_1), \text{ where } R_1 = R_4 \text{ and } R_2 = R_3$$

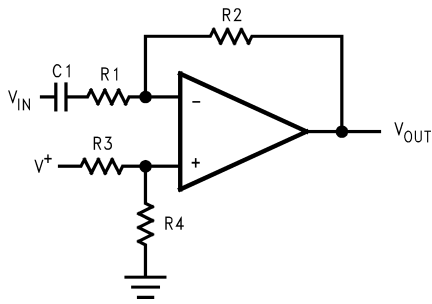
As shown:  $V_O = 2(V_2 - V_1)$

FIGURE 7. Two-op-amp Instrumentation Amplifier

### Single-Supply Inverting Amplifier

There may be cases where the input signal going into the amplifier is negative. Because the amplifier is operating in single supply voltage, a voltage divider using  $R_3$  and  $R_4$  is implemented to bias the amplifier so the input signal is within the input common-mode voltage range of the amplifier. The capacitor  $C_1$  is placed between the inverting input and resistor  $R_1$  to block the DC signal going into the AC signal source,  $V_{IN}$ . The values of  $R_1$  and  $C_1$  affect the cutoff frequency,  $f_c = 1/2\pi R_1 C_1$ .

As a result, the output signal is centered around mid-supply (if the voltage divider provides  $V^+/2$  at the non-inverting input). The output can swing to both rails, maximizing the signal-to-noise ratio in a low voltage system.



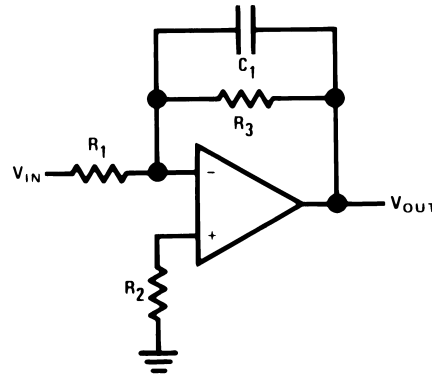
$$V_{OUT} = -\frac{R_2}{R_1} V_{IN}$$

FIGURE 8. Single-Supply Inverting Amplifier

## ACTIVE FILTER

### Simple Low-Pass Active Filter

The simple low-pass filter is shown in Figure 9. Its low-frequency gain ( $\omega \rightarrow 0$ ) is defined by  $-R_3/R_1$ . This allows low-frequency gains other than unity to be obtained. The filter has a  $-20$  dB/decade roll-off after its corner frequency  $f_c$ .  $R_2$  should be chosen equal to the parallel combination of  $R_1$  and  $R_3$  to minimize errors due to bias current. The frequency response of the filter is shown in Figure 10



$$A_L = -\frac{R_3}{R_1}$$

$$f_c = \frac{1}{2\pi R_3 C_1}$$

$$R_2 = R_1 \parallel R_3$$

FIGURE 9. Simple Low-Pass Active Filter

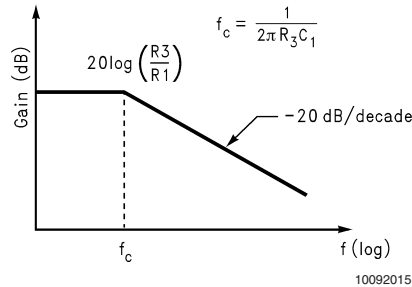


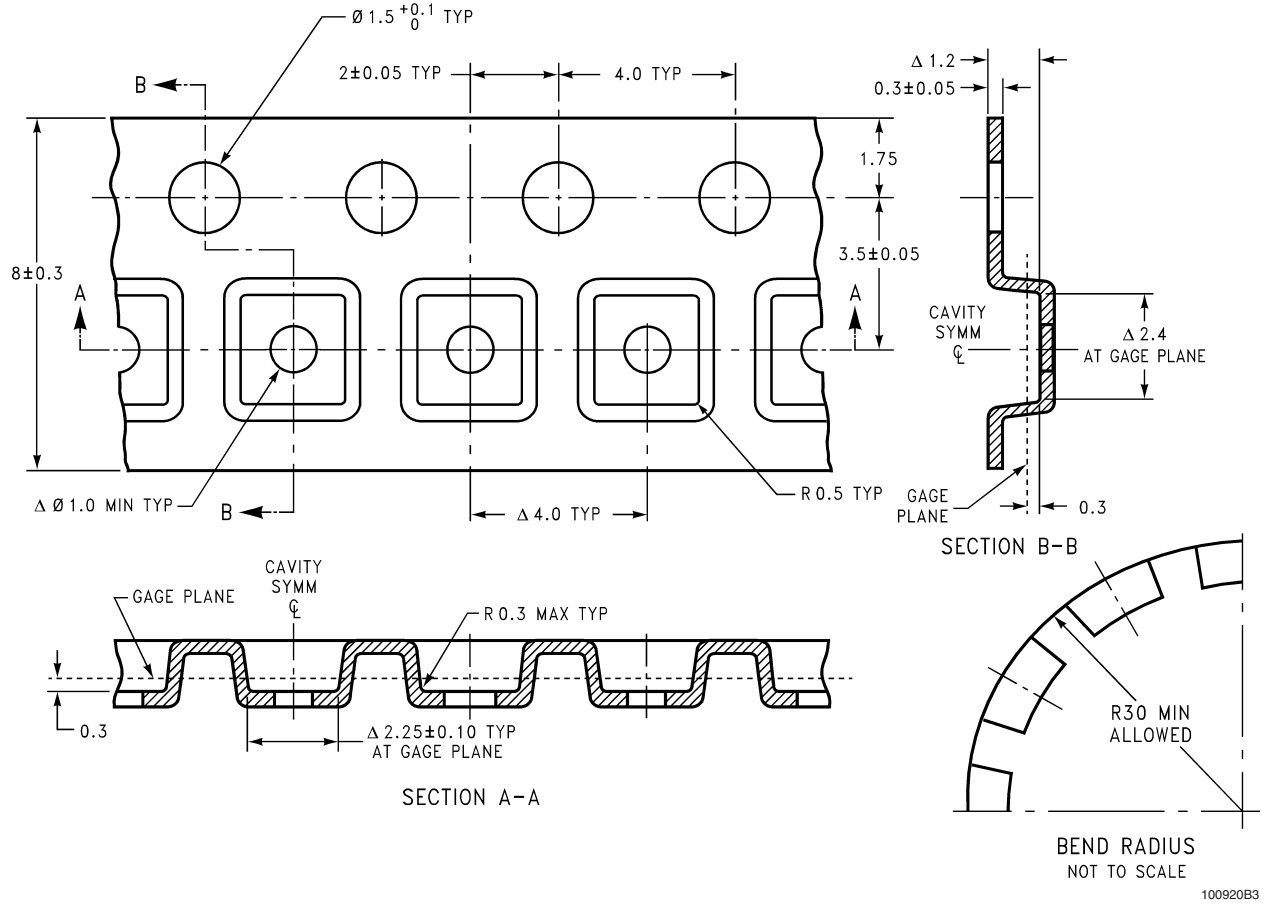
FIGURE 10. Frequency Response of Simple Low-pass Active Filter in Figure 9

Note that the single-op-amp active filters are used in to the applications that require low quality factor,  $Q (\leq 10)$ , low frequency ( $\leq 5$  kHz), and low gain ( $\leq 10$ ), or a small value for the product of gain times  $Q (\leq 100)$ . The op amp should have an open loop voltage gain at the highest frequency of interest at least 50 times larger than the gain of the filter at this frequency. In addition, the selected op amp should have a slew rate that meets the following requirement:

$$\text{Slew Rate} \geq 0.5 \times (\omega_H V_{OPP}) \times 10^{-6} \text{V}/\mu\text{sec}$$

Where  $\omega_H$  is the highest frequency of interest, and  $V_{OPP}$  is the output peak-to-peak voltage.

### SC70-5 Tape and Reel Specification



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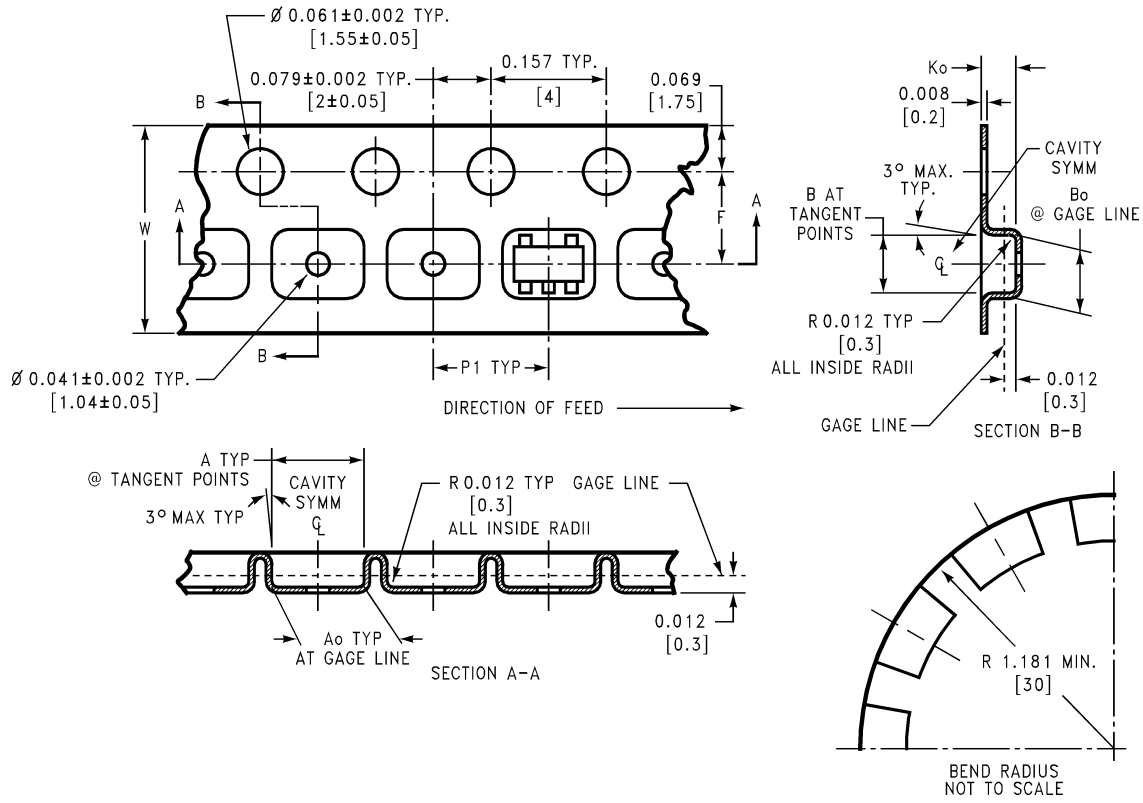
### SOT-23-5 Tape and Reel Specification

#### TAPE FORMAT

| Tape Section          | # Cavities | Cavity Status | Cover Tape Status |
|-----------------------|------------|---------------|-------------------|
| Leader<br>(Start End) | 0 (min)    | Empty         | Sealed            |
|                       | 75 (min)   | Empty         | Sealed            |
| Carrier               | 3000       | Filled        | Sealed            |
|                       | 250        | Filled        | Sealed            |
| Trailer<br>(Hub End)  | 125 (min)  | Empty         | Sealed            |
|                       | 0 (min)    | Empty         | Sealed            |

# SOT-23-5 Tape and Reel Specification (Continued)

## TAPE DIMENSIONS

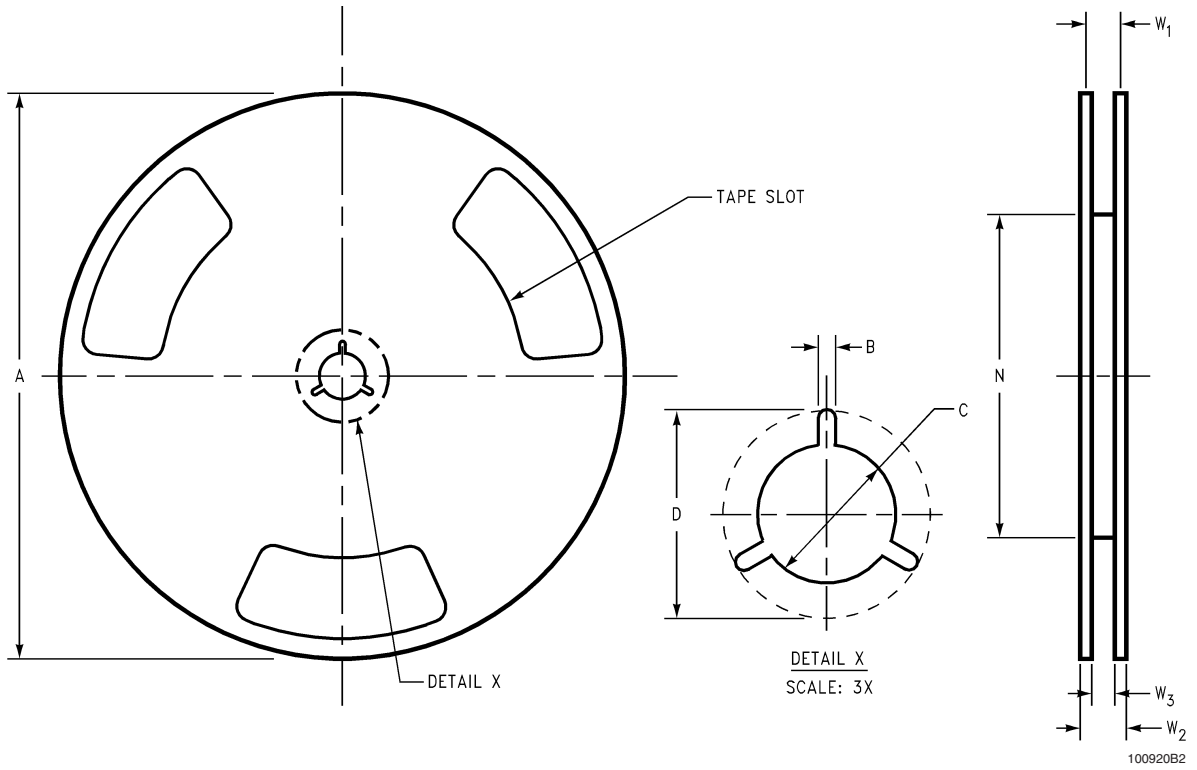


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|             |              |                    |              |                    |                      |                      |              |                      |
|-------------|--------------|--------------------|--------------|--------------------|----------------------|----------------------|--------------|----------------------|
| <b>8 mm</b> | <b>0.130</b> | <b>0.124</b>       | <b>0.130</b> | <b>0.126</b>       | <b>0.138 ± 0.002</b> | <b>0.055 ± 0.004</b> | <b>0.157</b> | <b>0.315 ± 0.012</b> |
|             | <b>(3.3)</b> | <b>(3.15)</b>      | <b>(3.3)</b> | <b>(3.2)</b>       | <b>(3.5 ± 0.05)</b>  | <b>(1.4 ± 0.11)</b>  | <b>(4)</b>   | <b>(8 ± 0.3)</b>     |
| Tape Size   | DIM A        | DIM A <sub>o</sub> | DIM B        | DIM B <sub>o</sub> | DIM F                | DIM K <sub>o</sub>   | DIM P1       | DIM W                |

# SOT-23-5 Tape and Reel Specification (Continued)

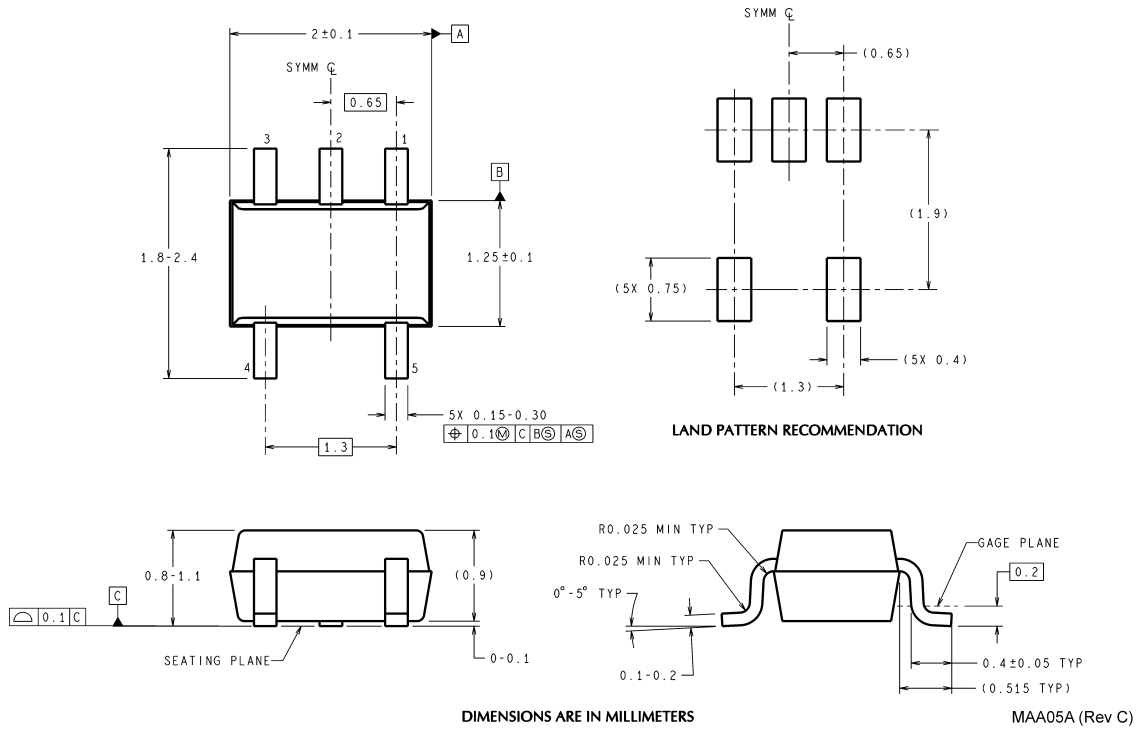
## REEL DIMENSIONS



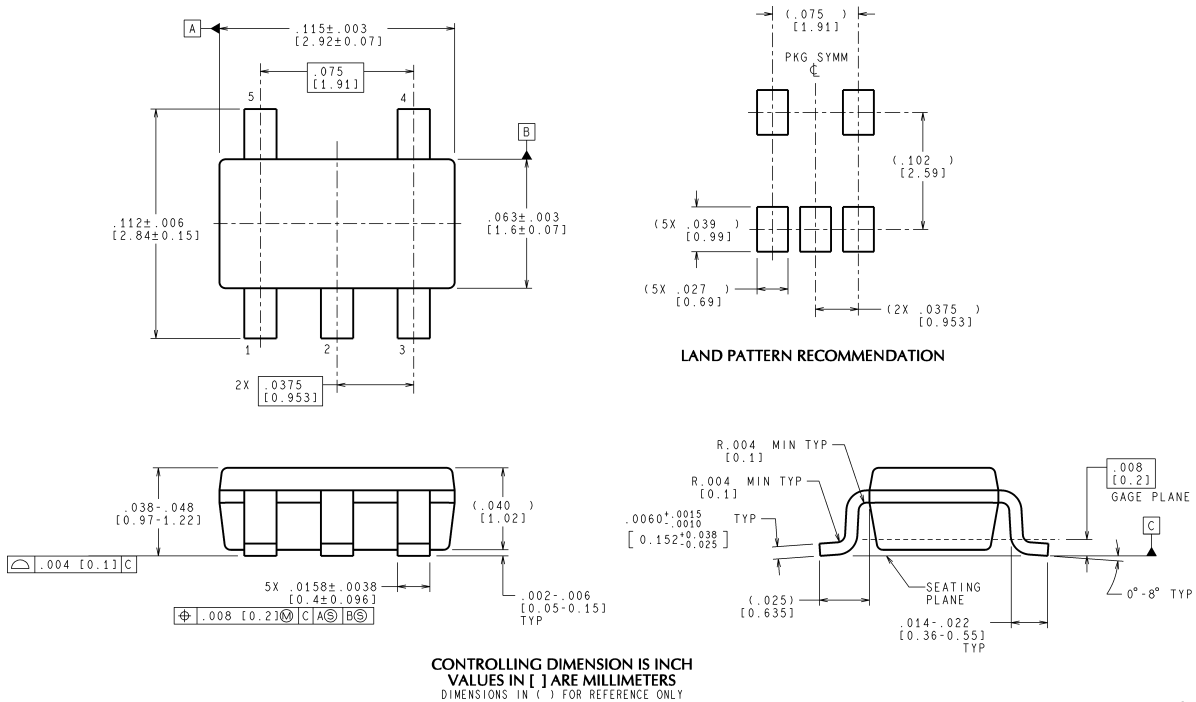
|           |        |       |       |       |       |                      |       |                   |
|-----------|--------|-------|-------|-------|-------|----------------------|-------|-------------------|
| 8 mm      | 7.00   | 0.059 | 0.512 | 0.795 | 2.165 | 0.331 + 0.059/-0.000 | 0.567 | W1 + 0.078/-0.039 |
|           | 330.00 | 1.50  | 13.00 | 20.20 | 55.00 | 8.40 + 1.50/-0.00    | 14.40 | W1 + 2.00/-1.00   |
| Tape Size | A      | B     | C     | D     | N     | W1                   | W2    | W3                |



**Physical Dimensions** inches (millimeters) unless otherwise noted

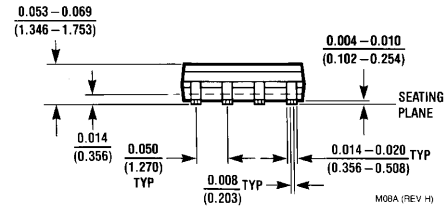
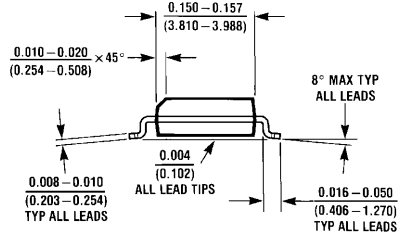
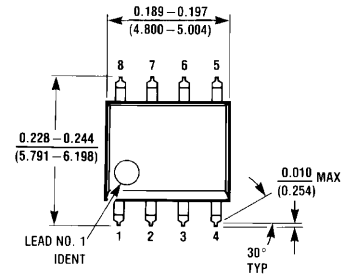


**5-Pin SC70**  
**NS Package Number MAA05A**

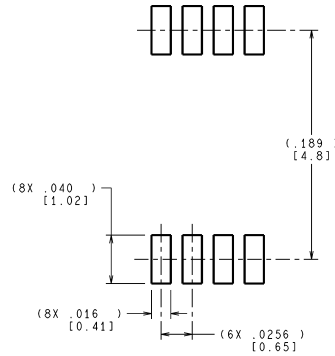
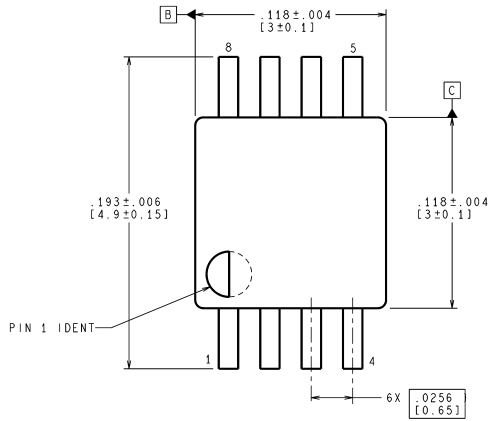


**5-Pin SOT23**  
**NS Package Number MF05A**

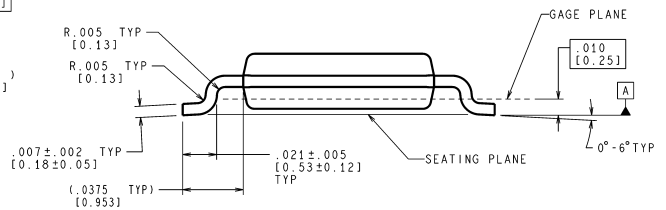
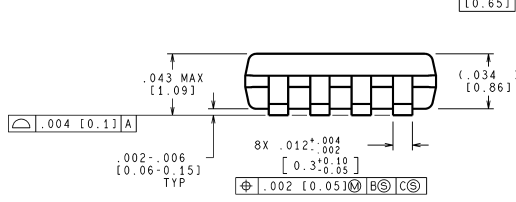
**Physical Dimensions** inches (millimeters) unless otherwise noted (Continued)



**8-Pin SOIC**  
NS Package Number M08A



**LAND PATTERN RECOMMENDATION**

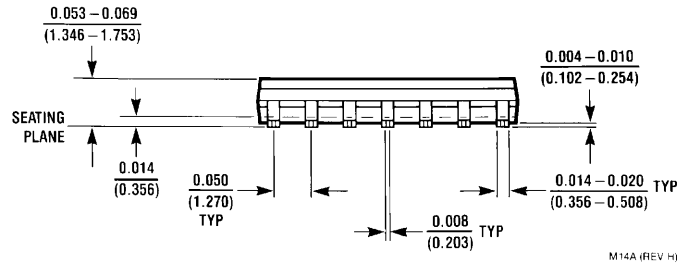
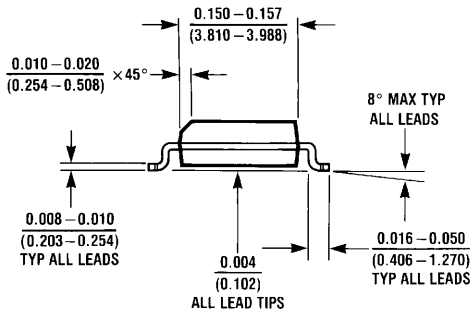
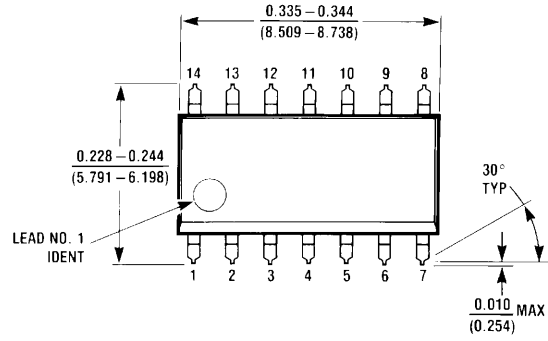


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VALUES IN [ ] ARE MILLIMETERS

**8-Pin MSOP**  
NS Package Number MUA08A

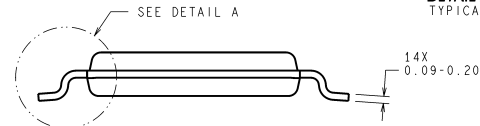
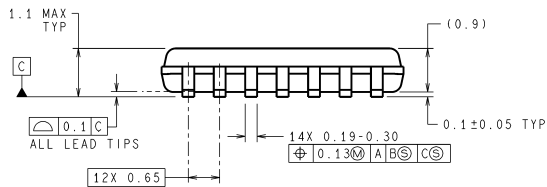
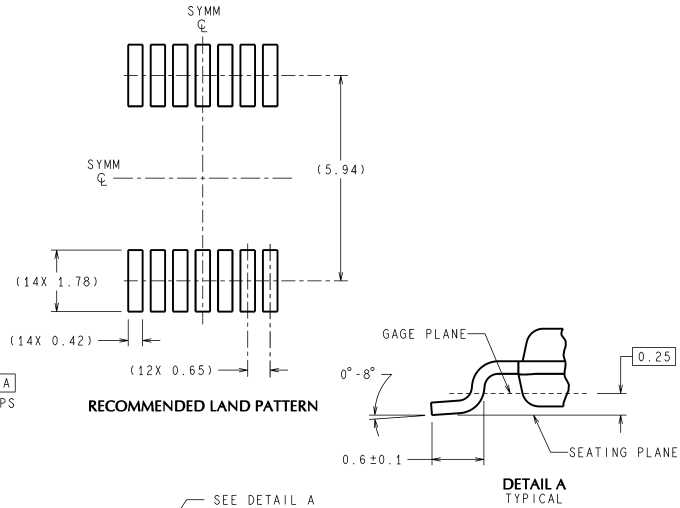
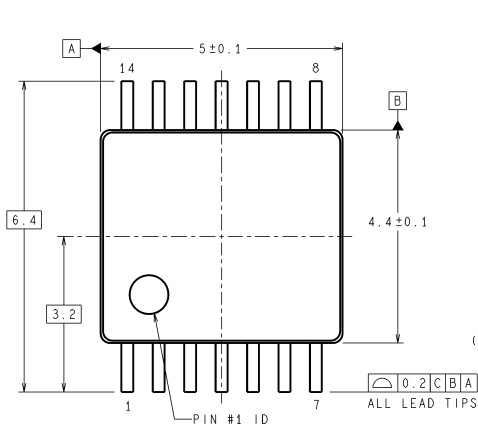
MUA08A (Rev E)

**Physical Dimensions** inches (millimeters) unless otherwise noted (Continued)



M14A (REV H)

**14-Pin SOIC**  
NS Package Number M14A



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DIMENSIONS IN ( ) FOR REFERENCE ONLY

MTC14 (Rev D)

**14-Pin TSSOP**  
NS Package Number MTC14

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