LPV321,LPV324,LPV358

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

Literature Number: SNOS413C

National Semiconductor

October 2006

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 µA 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 µA.

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)

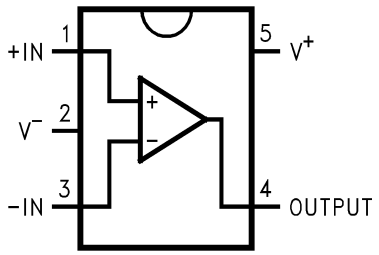
- Guaranteed 2.7V and 5V performance
- No crossover distortion
- Space saving package — 5-Pin SC70 2.0x2.1x1.0 mm
- Industrial temperature range — −40˚C to +85˚C
- Gain-bandwidth product — 152 kHz
- Low supply current
  - LPV321 — 9 µA
  - LPV358 — 15 µA
  - LPV324 — 28 µA
- Rail-to-rail output swing @ 100 kΩ 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

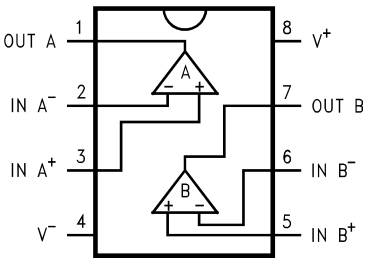
5-Pin SC70/SOT23



10092001

Top View

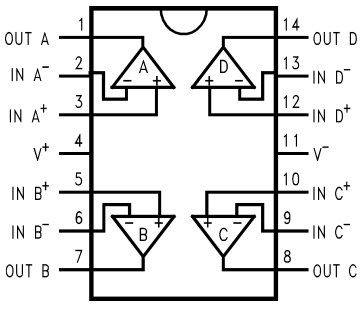
8-Pin SOIC/MSOP



10092002

Top View

14-Pin SOIC/TSSOP



10092003

Top View

© 2006 National Semiconductor Corporation

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^+–V^-)	5.5V
Output Short Circuit to V^+	(Note 3)
Output Short Circuit to V^-	(Note 4)
Soldering Information	
Infrared or Convection (20 sec)	235˚C
Storage Temperature Range	−65˚C to 150˚C
Junction Temp. (T_J, 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_{JA})(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_J = 25˚C, V^+ = 2.7V, V^- = 0V, V_{CM} = 1.0V, V_O = V^+/2 and R_L > 1 MΩ.

Symbol	Parameter	Conditions	Min (Note 7)	Typ (Note 6)	Max (Note 7)	Units
V_{OS}	Input Offset Voltage			1.2	7	mV
TCV_{OS}	Input Offset Voltage Average Drift			2		µV/˚C
I_B	Input Bias Current			1.7	50	nA
I_{OS}	Input Offset Current			0.6	40	nA
CMRR	Common Mode Rejection Ratio	0V ≤ V_{CM} ≤ 1.7V	50	70		dB
PSRR	Power Supply Rejection Ratio	2.7V ≤ V^+ ≤ 5V V_O = 1V, V_{CM} = 1V	50	65		dB
V_{CM}	Input Common-Mode Voltage Range	For CMRR ≥ 50 dB	0	−0.2		V
				1.9	1.7	
V_O	Output Swing	R_L = 100 kΩ to 1.35V	V^+ −100	V^+ −3		mV
				80	180	mV
I_S	Supply Current	LPV321		4	8	µA
		LPV358 Both Amplifiers		8	16	µA
		LPV324 All Four Amplifiers		16	24	µA

2.7V AC Electrical Characteristics

Unless otherwise specified, all limits guaranteed for T_J = 25˚C, V^+ = 2.7V, V^- = 0V, V_{CM} = 1.0V, V_O = V^+/2 and R_L > 1 MΩ.

Symbol	Parameter	Conditions	Min (Note 7)	Typ (Note 6)	Max (Note 7)	Units
GBWP	Gain-Bandwidth Product	C_L = 22 pF		112		kHz
Φ_m	Phase Margin			97		Deg
G_m	Gain Margin			35		dB
e_n	Input-Referred Voltage Noise	f = 1 kHz		178		$\frac{nV}{\sqrt{Hz}}$
i_n	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˚C, V^+ = 5V, V^- = 0V, V_{CM} = 2.0V, V_O = V^+/2 and R_L > 1 MΩ. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min (Note 7)	Typ (Note 6)	Max (Note 7)	Units
V_{OS}	Input Offset Voltage			1.5	7 **10**	mV
TCV_{OS}	Input Offset Voltage Average Drift			2		µV/˚C
I_B	Input Bias Current			2	50 **60**	nA
I_{OS}	Input Offset Current			0.6	40 **50**	nA
CMRR	Common Mode Rejection Ratio	0V ≤ V_{CM} ≤ 4V	50	71		dB
PSRR	Power Supply Rejection Ratio	2.7V ≤ V^+ ≤ 5V V_O = 1V, V_{CM} = 1V	50	65		dB
V_{CM}	Input Common-Mode Voltage Range	For CMRR ≥ 50 dB	0	–0.2		V
				4.2	4	
A_V	Large Signal Voltage Gain (Note 8)	R_L = 100 kΩ	15 **10**	100		V/mV
V_O	Output Swing	R_L = 100 kΩ to 2.5V	V^+ –100 **V^+ –200**	V^+ –3.5		mV
				90	180 **220**	
I_O	Output Short Circuit Current Sourcing	LPV324, LPV358, and LPV321 V_O = 0V	2	16		mA
	Output Short Circuit Current Sinking	LPV321 V_O = 5V	20	60		mA
		LPV324 and LPV358 V_O = 5V	11	16		mA
I_S	Supply Current	LPV321		9	12 **15**	µA
		LPV358 Both amplifiers		15	20 **24**	µA
		LPV324 All four amplifiers		28	42 **46**	µA

5V AC Electrical Characteristics

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

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

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 $T_{J(MAX)}$, θ_{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 ˉ. The output voltage is $0.5V \le V_O \le 4.5V$.

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.

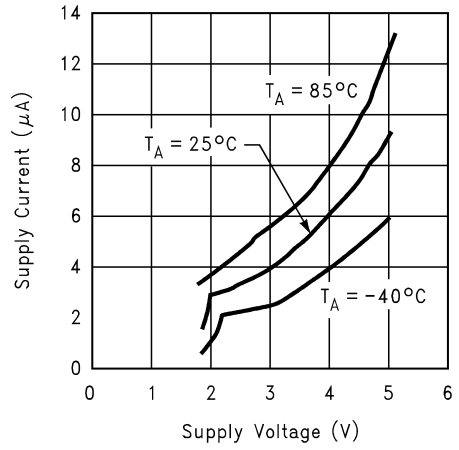
Ordering Information

Package	Temperature Range	Packaging Marking	Transport Media	NSC Drawing
	Industrial –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

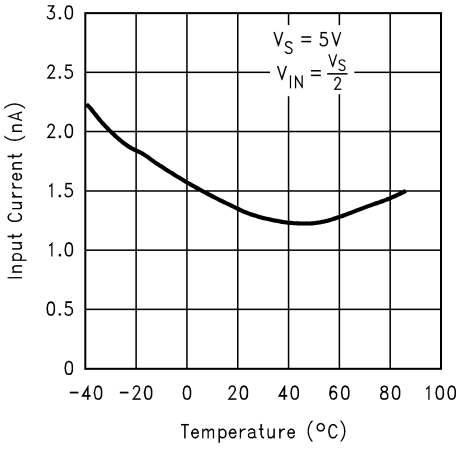
Unless otherwise specified, V_S = +5V, single supply, T_A = 25˚C.

Supply Current vs. Supply Voltage (LPV321)



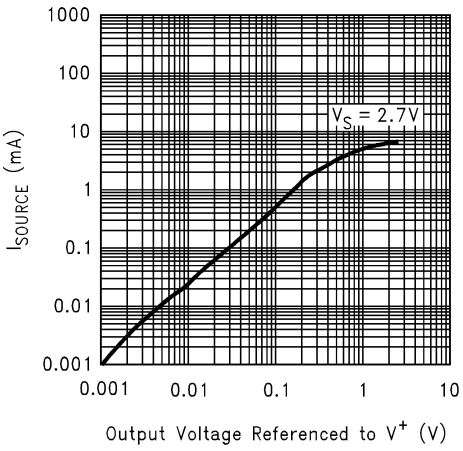
100920B4

Input Current vs. Temperature



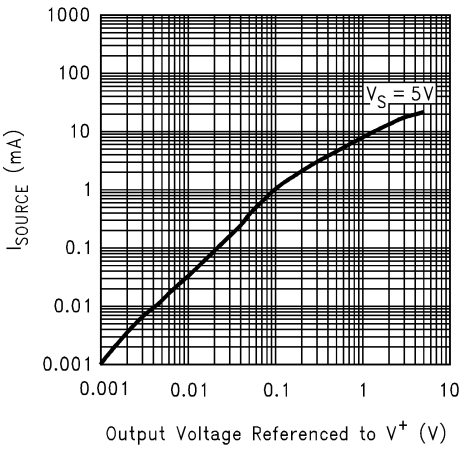
100920B5

Sourcing Current vs. Output Voltage



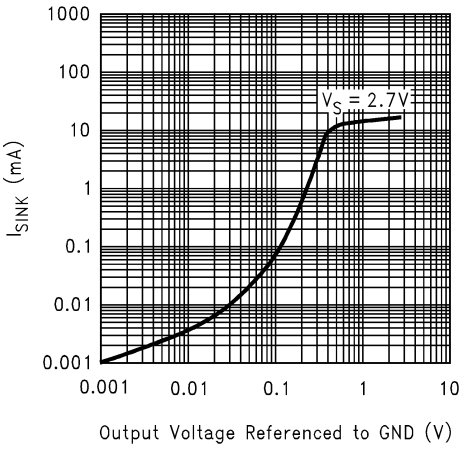
10092041

Sourcing Current vs. Output Voltage



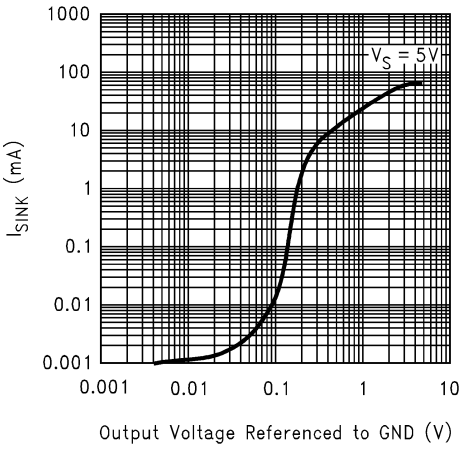
10092042

Sinking Current vs. Output Voltage



10092043

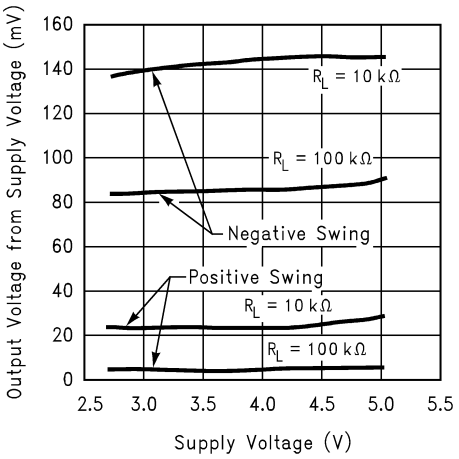
Sinking Current vs. Output Voltage



10092044

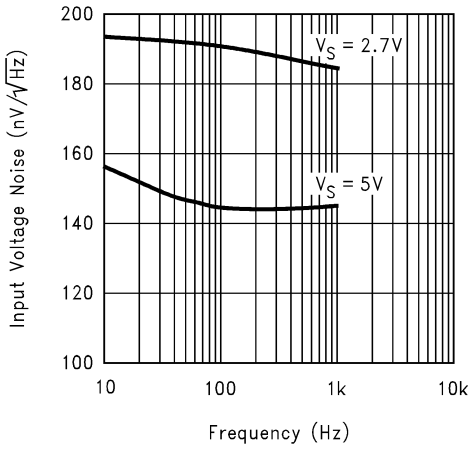
Typical Performance Characteristics Unless otherwise specified, V_S = +5V, single supply, T_A = 25˚C. (Continued)

Output Voltage Swing vs. Supply Voltage



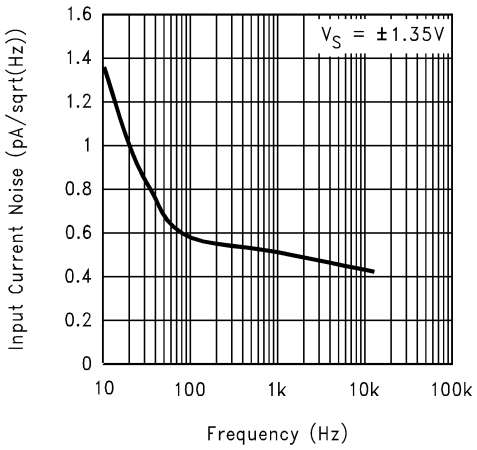
100920B6

Input Voltage Noise vs. Frequency



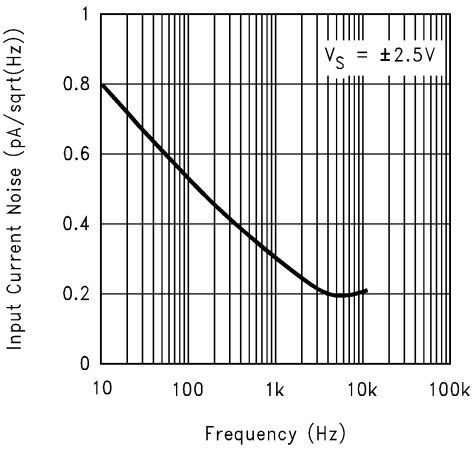
10092056

Input Current Noise vs Frequency



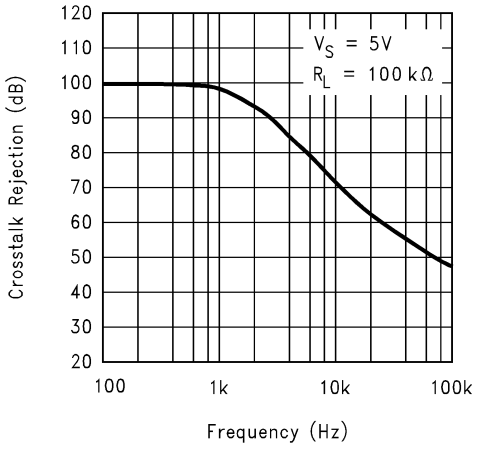
10092070

Input Current Noise vs Frequency



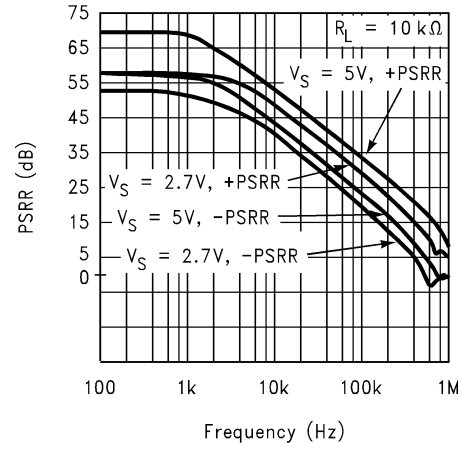
10092068

Crosstalk Rejection vs. Frequency



10092073

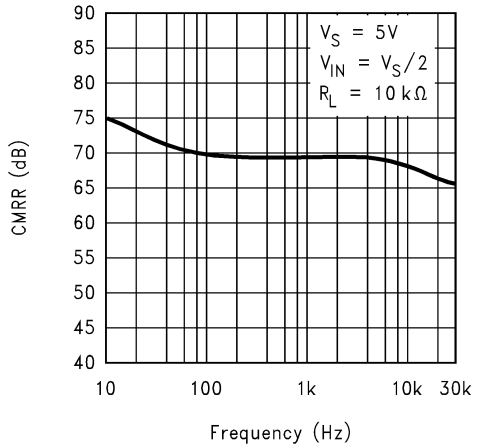
PSRR vs. Frequency



10092072

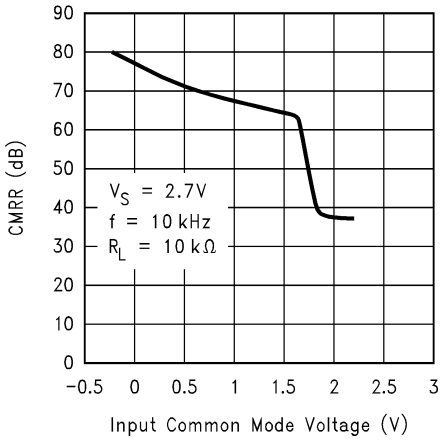
Typical Performance Characteristics Unless otherwise specified, V_S = +5V, single supply, T_A = 25˚C. (Continued)

CMRR vs. Frequency



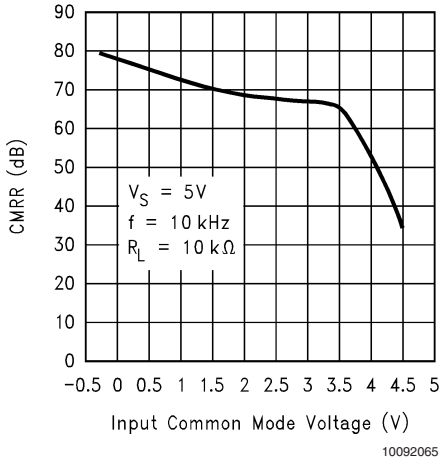
10092063

CMRR vs. Input Common Mode Voltage



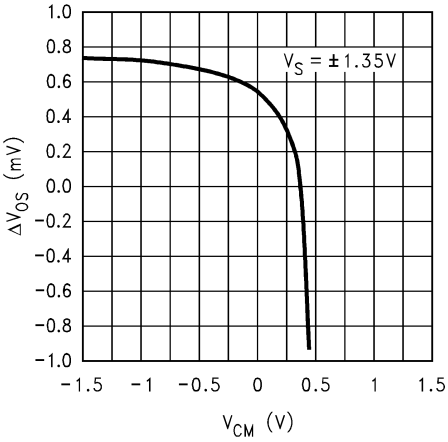
10092064

CMRR vs. Input Common Mode Voltage



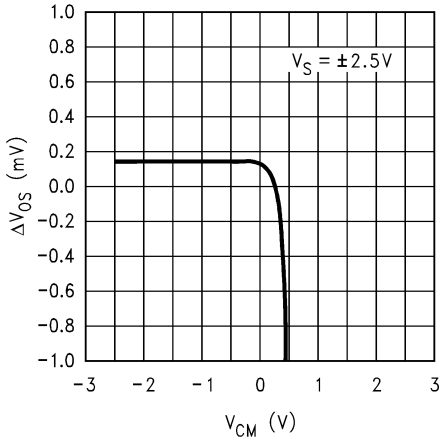
10092065

ΔV_{OS} vs. V_{CM}



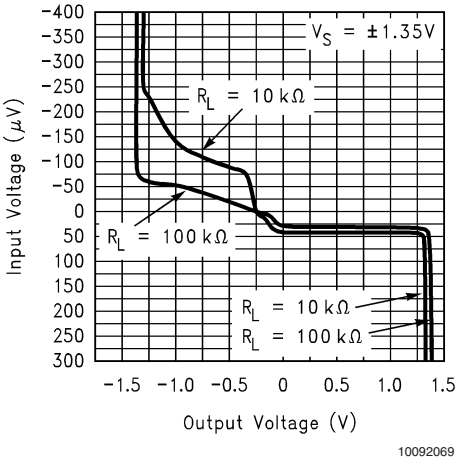
10092045

ΔV_{OS} vs. V_{CM}



10092046

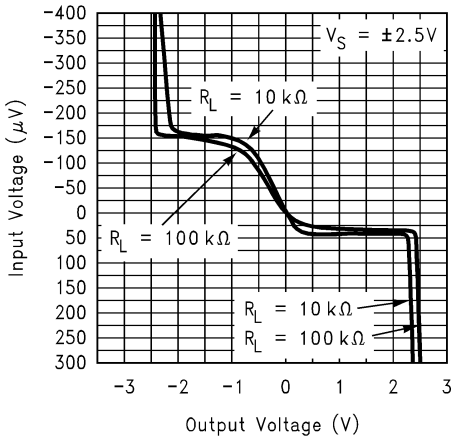
Input Voltage vs. Output Voltage



10092069

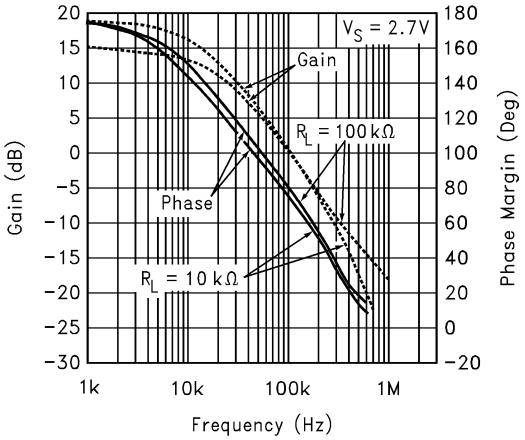
Typical Performance Characteristics Unless otherwise specified, V_S = +5V, single supply, T_A = 25˚C. (Continued)

Input Voltage vs. Output Voltage



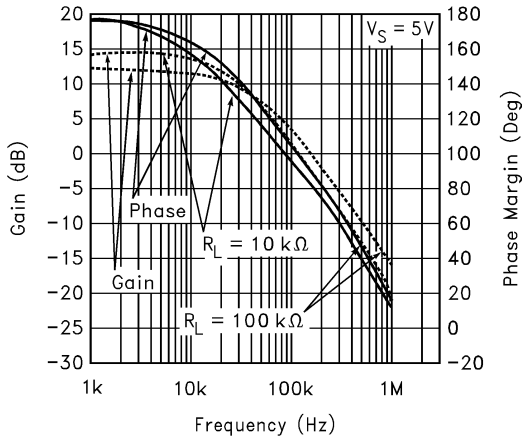
10092071

Open Loop Frequency Response



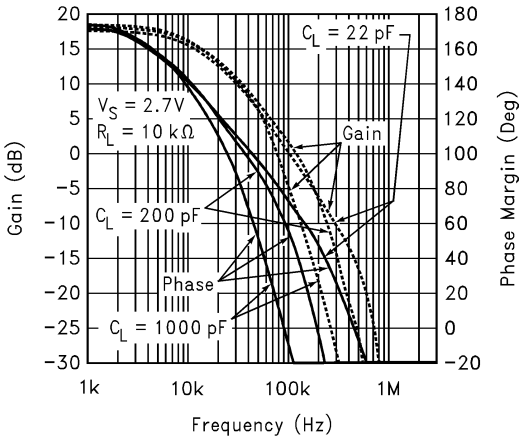
10092052

Open Loop Frequency Response



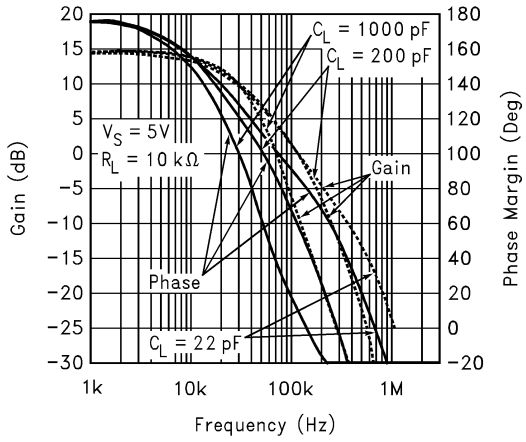
10092051

Gain and Phase vs. Capacitive Load



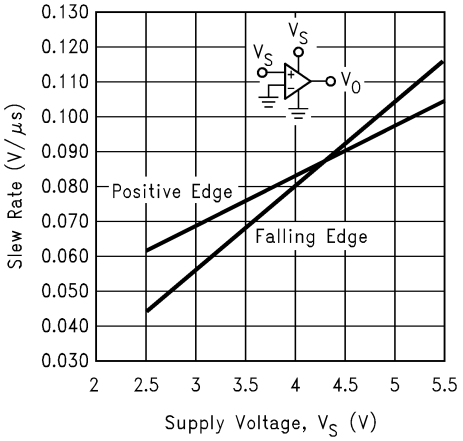
10092054

Gain and Phase vs. Capacitive Load



10092053

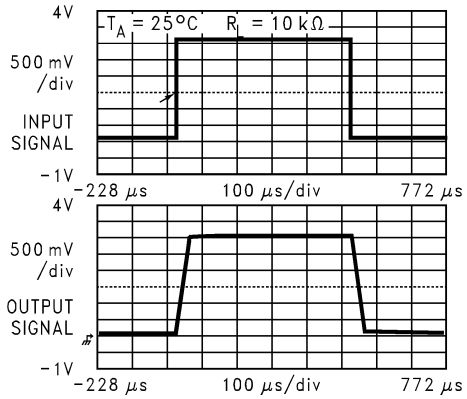
Slew Rate vs. Supply Voltage



10092055

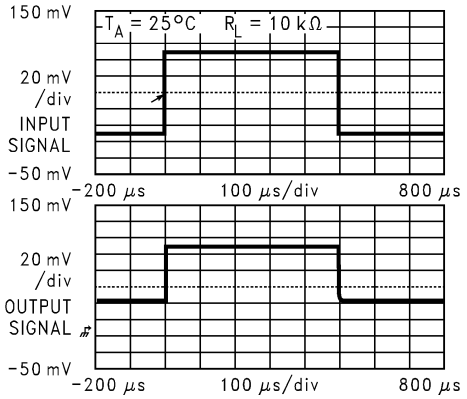
Typical Performance Characteristics Unless otherwise specified, V_S = +5V, single supply, T_A = 25˚C. (Continued)

Non-Inverting Large Signal Pulse Response



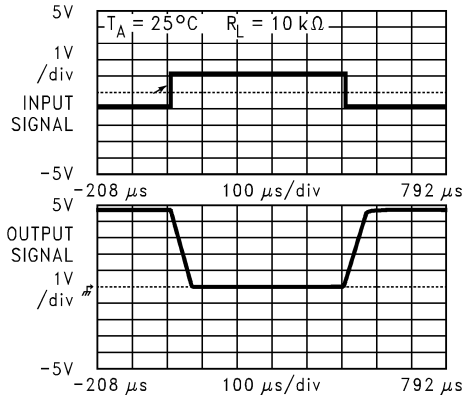
10092050

Non-Inverting Small Signal Pulse Response



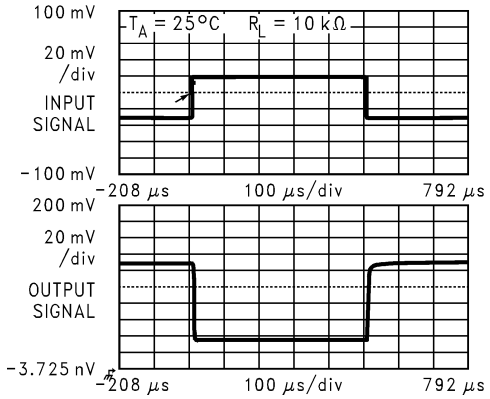
10092049

Inverting Large Signal Pulse Response



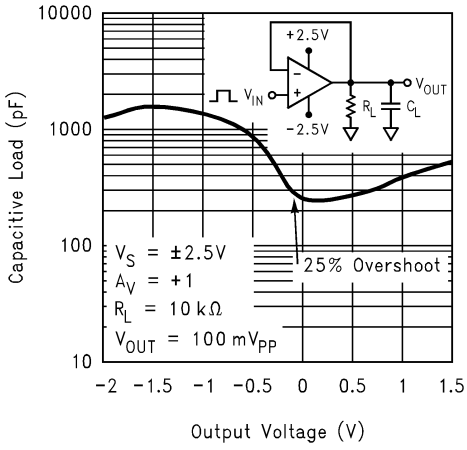
10092047

Inverting Small Signal Pulse Response



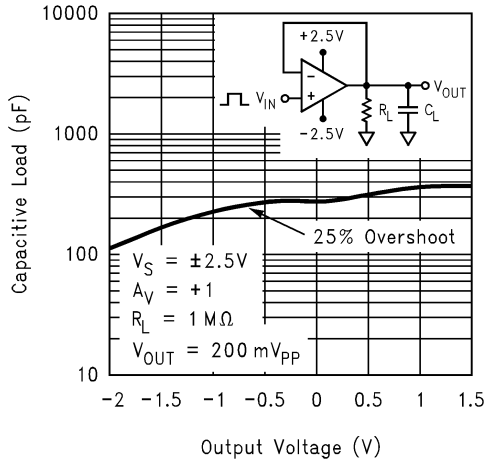
10092048

Stability vs. Capacitive Load



10092061

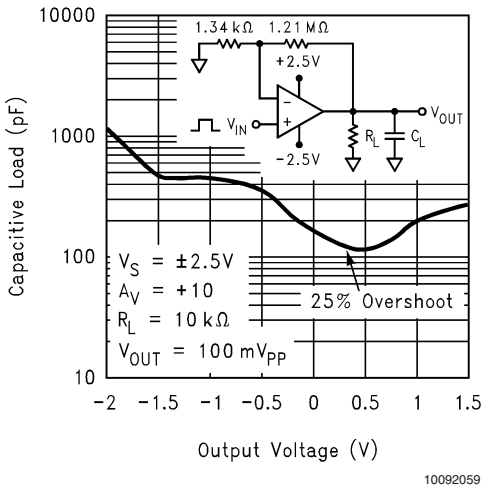
Stability vs. Capacitive Load



10092060

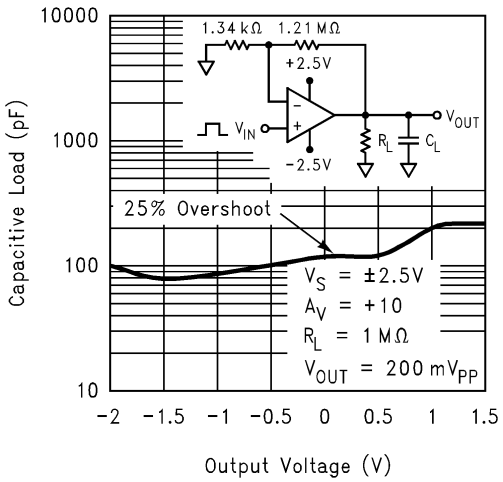
Typical Performance Characteristics Unless otherwise specified, V_S = +5V, single supply, T_A = 25˚C. (Continued)

Stability vs. Capacitive Load



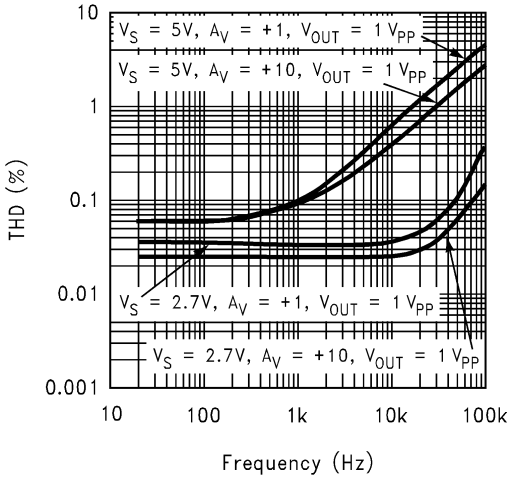
10092059

Stability vs. Capacitive Load



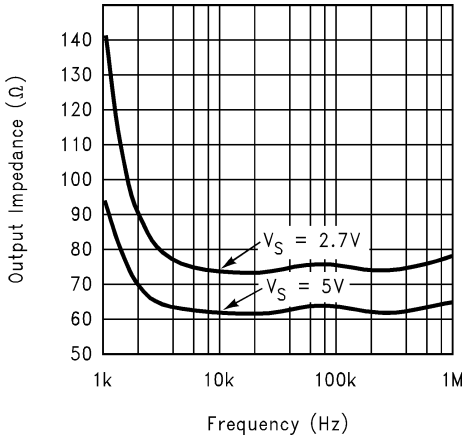
10092058

THD vs. Frequency



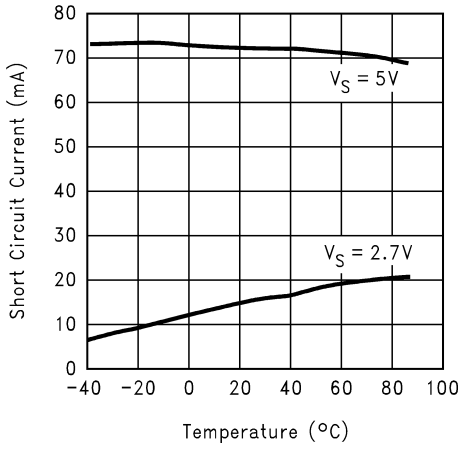
10092062

Open Loop Output Impedance vs Frequency



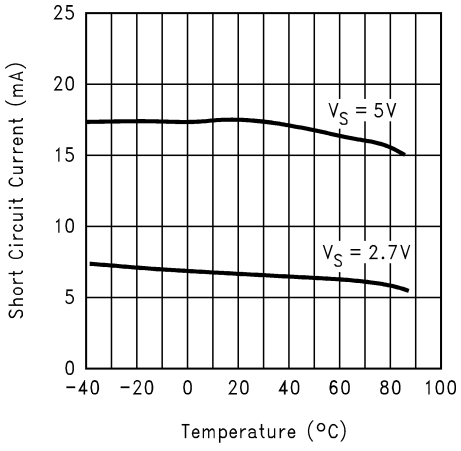
10092074

Short Circuit Current vs. Temperature (Sinking)



100920B7

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˚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.

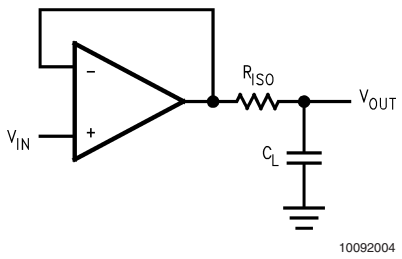


FIGURE 1. Indirectly Driving A Capacitive Load Using Resistive Isolation

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 kΩ for R_{ISO} and 1000 pF for C_L.

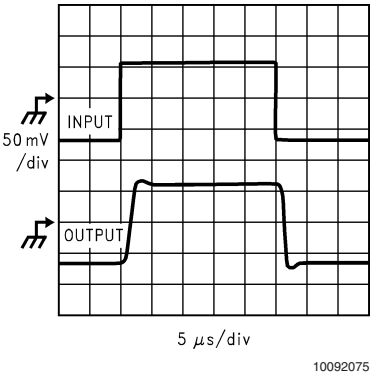


FIGURE 2. Pulse Response of the LPV324 Circuit in *Figure 1*

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 feedforward 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)

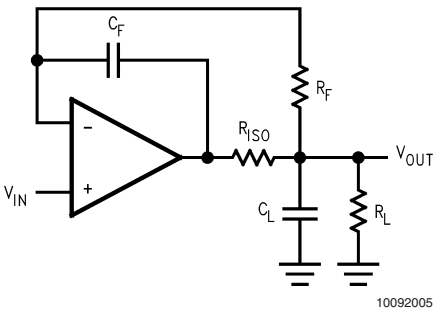


FIGURE 3. Indirectly Driving A Capacitive Load with DC Accuracy

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.

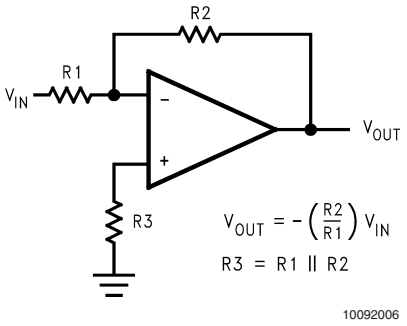
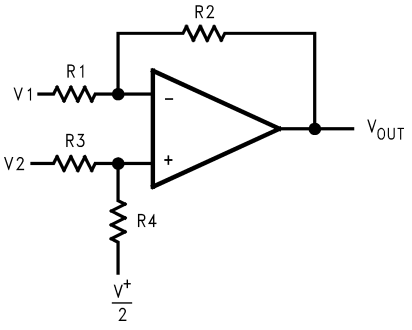


FIGURE 4. Cancelling the Error Caused by Input Bias Current

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.



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

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*

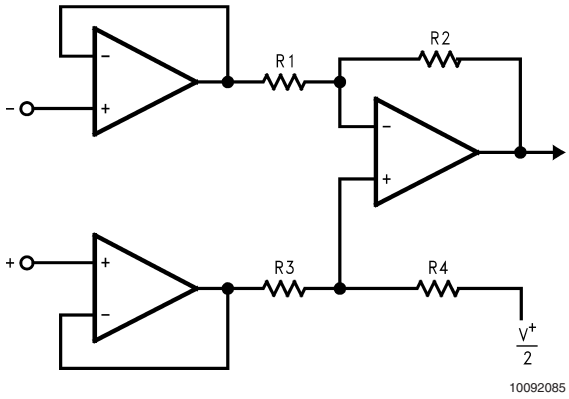


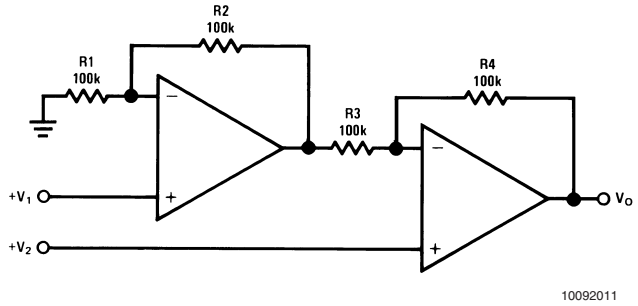
FIGURE 6. Three-op-amp Instrumentation Amplifier

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.



$$V_O = \left(1 + \frac{R4}{R3}\right)(V_2 - V_1), \text{ where } R1 = R4 \text{ and } R2 = R3$$

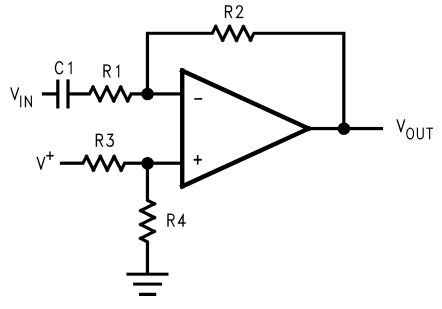
$$\text{As shown: } V_O = 2(V_2 - V_1)$$

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-common 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, fc = 1/2π 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.



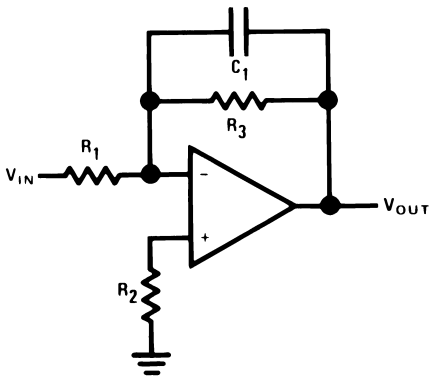
$$V_{OUT} = -\frac{R2}{R1} V_{IN}$$

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($\omega \rightarrow o$) 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 fc. R_2 should be chosen equal to the parallel combination of R_1 and R_3 to minimize errors due to bais current. The frequency response of the filter is shown in *Figure 10*



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

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

$$R_2 = R_1 \,||\, R_3$$

FIGURE 9. Simple Low-Pass Active Filter

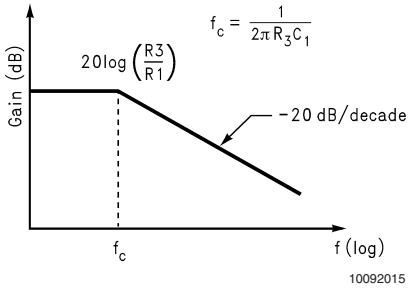


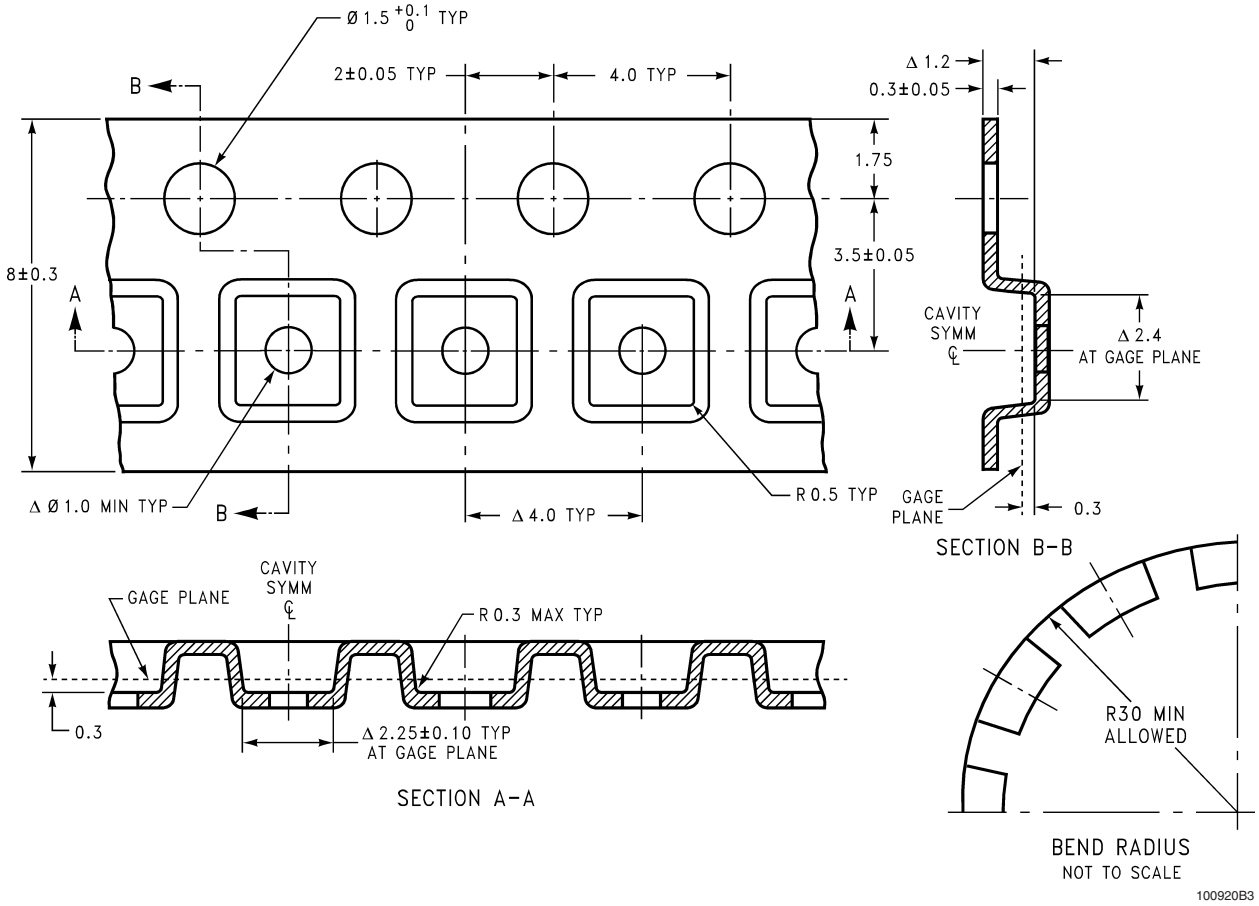
FIGURE 10. Frequency Response of Simple Low-pass Active Filter in Figure 9

Note that the single-op-amp active filters are used in to the applications that require low quality factor, Q (≤ 10), low frequency (≤ 5 kHz), and low gain (≤ 10), or a small value for the product of gain times Q (≤ 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:

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

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

SC70-5 Tape and Reel Specification



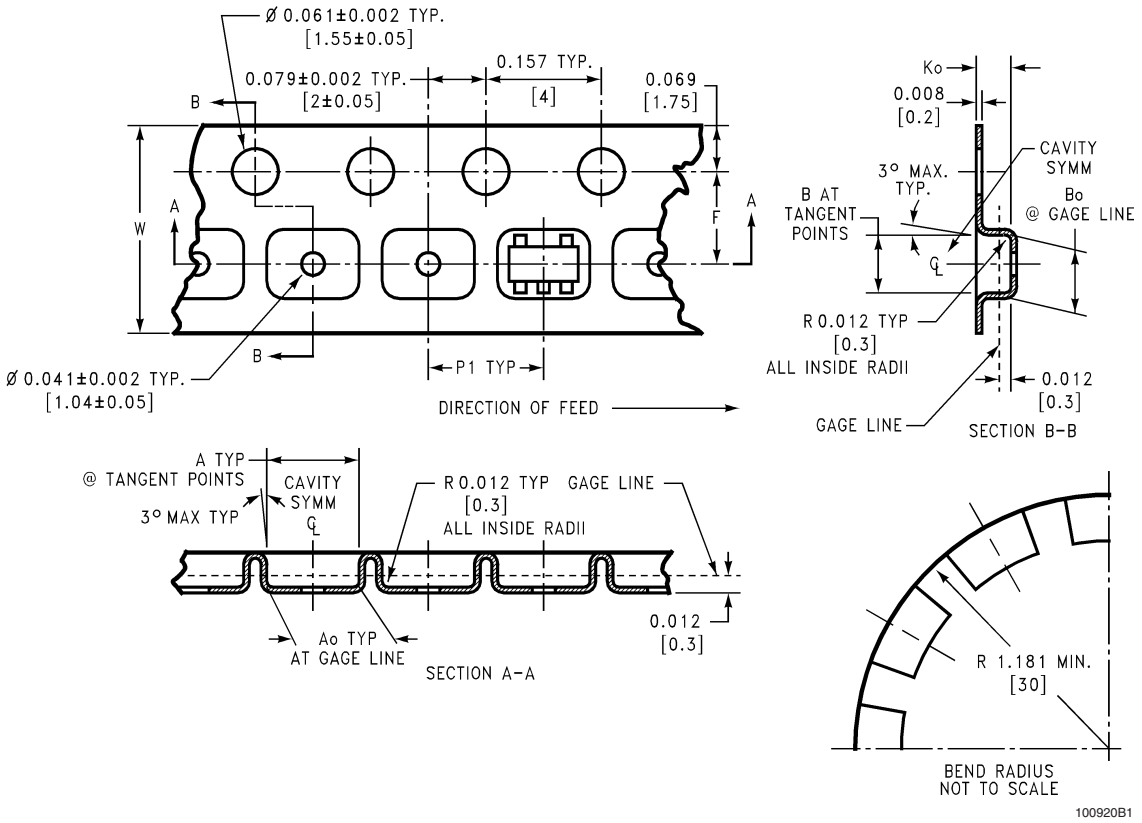
SOT-23-5 Tape and Reel Specification

TAPE FORMAT

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

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

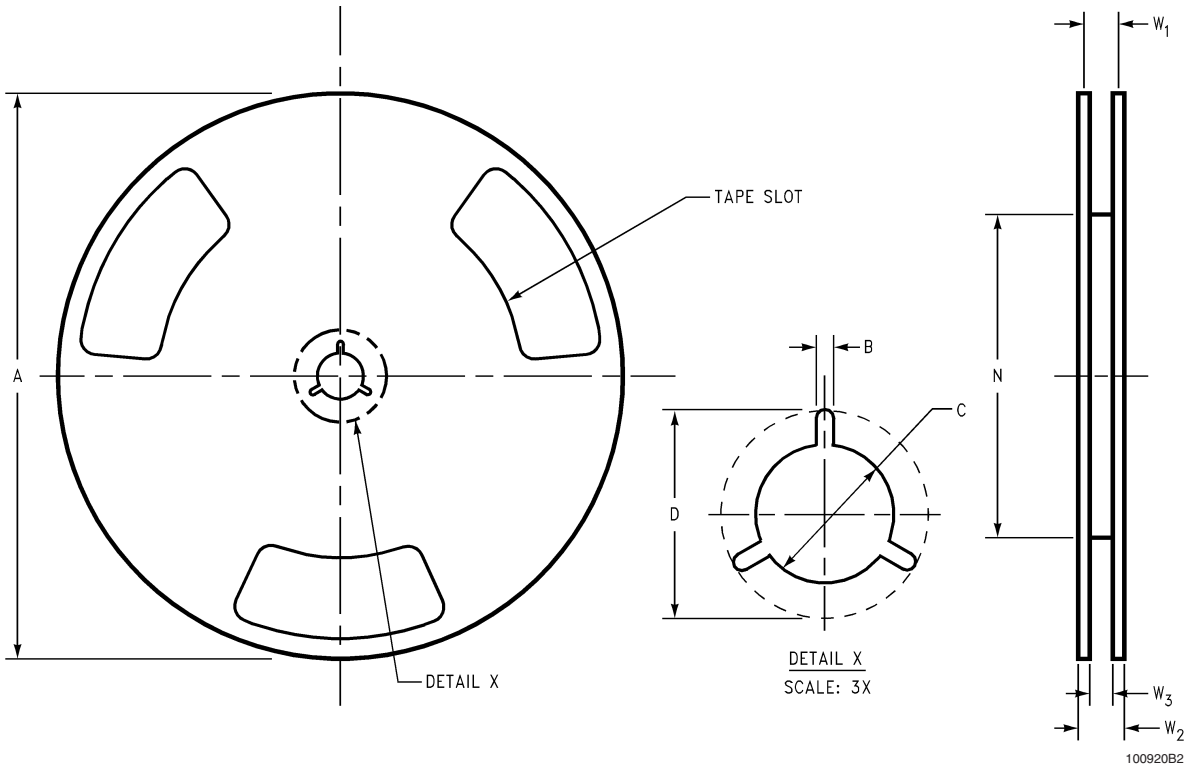
TAPE DIMENSIONS



8 mm	0.130 (3.3)	0.124 (3.15)	0.130 (3.3)	0.126 (3.2)	0.138 ±0.002 (3.5 ±0.05)	0.055 ±0.004 (1.4 ±0.11)	0.157 (4)	0.315 ±0.012 (8 ±0.3)
Tape Size	DIM A	DIM Ao	DIM B	DIM Bo	DIM F	DIM Ko	DIM P1	DIM W

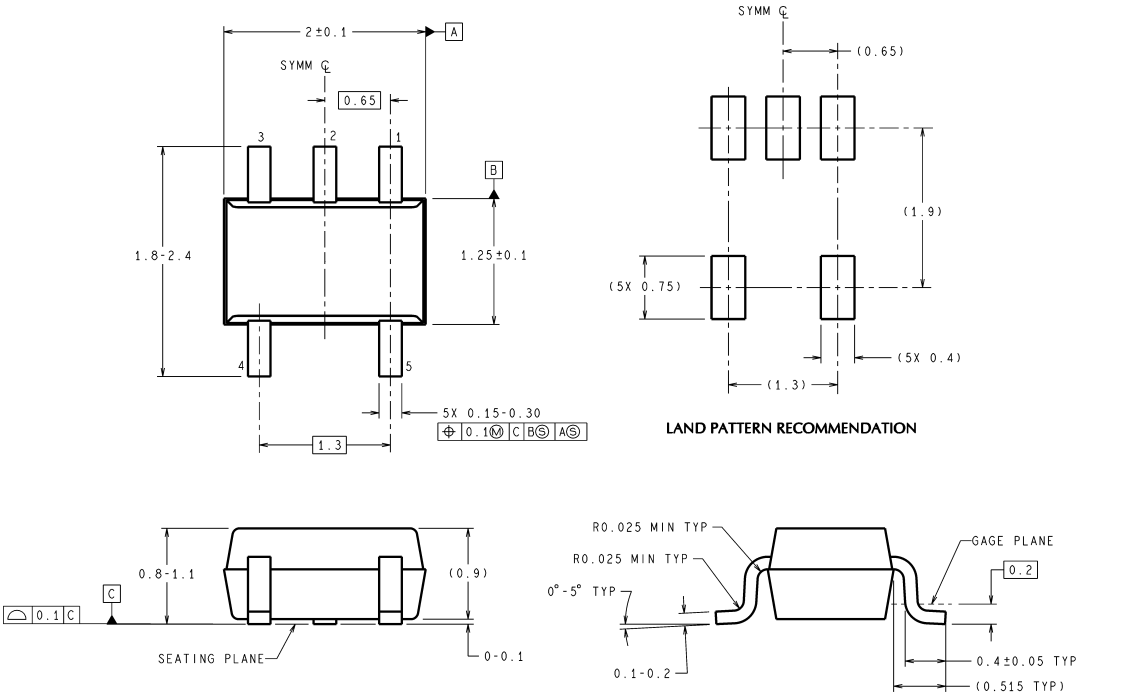
SOT-23-5 Tape and Reel Specification (Continued)

REEL DIMENSIONS

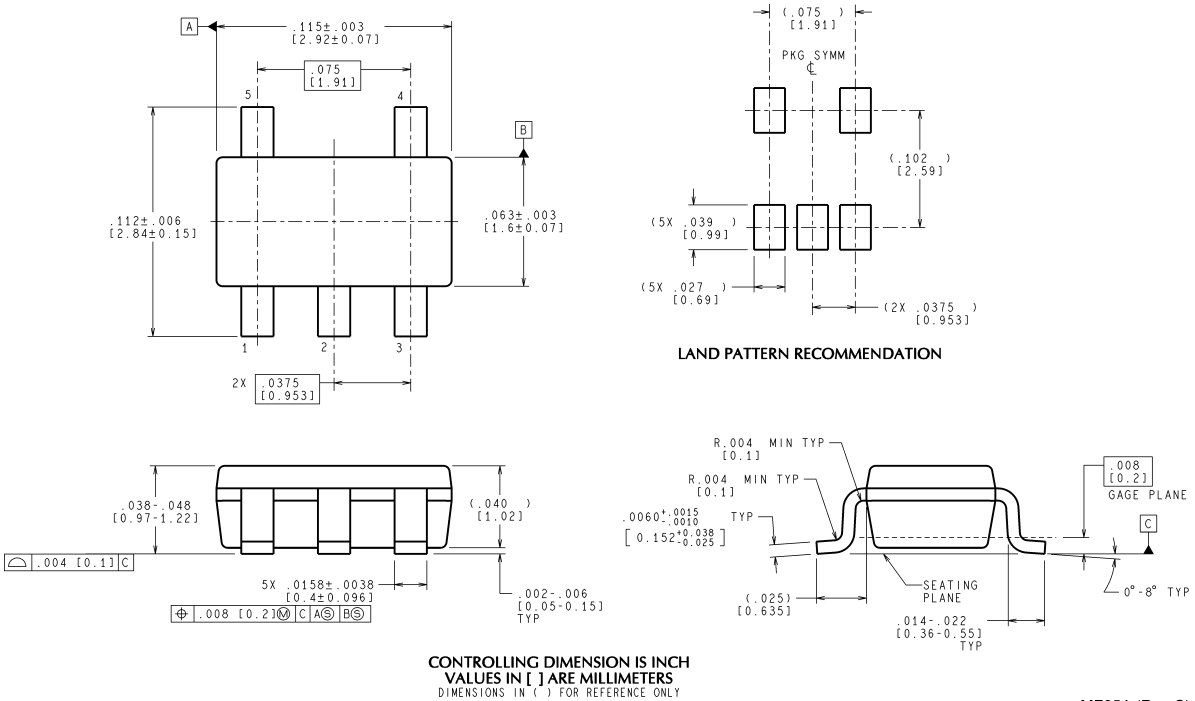


8 mm	7.00 330.00	0.059 1.50	0.512 13.00	0.795 20.20	2.165 55.00	0.331 + 0.059/–0.000 8.40 + 1.50/–0.00	0.567 14.40	W1+ 0.078/–0.039 W1 + 2.00/–1.00
Tape Size	A	B	C	D	N	W1	W2	W3

Physical Dimensions inches (millimeters) unless otherwise noted

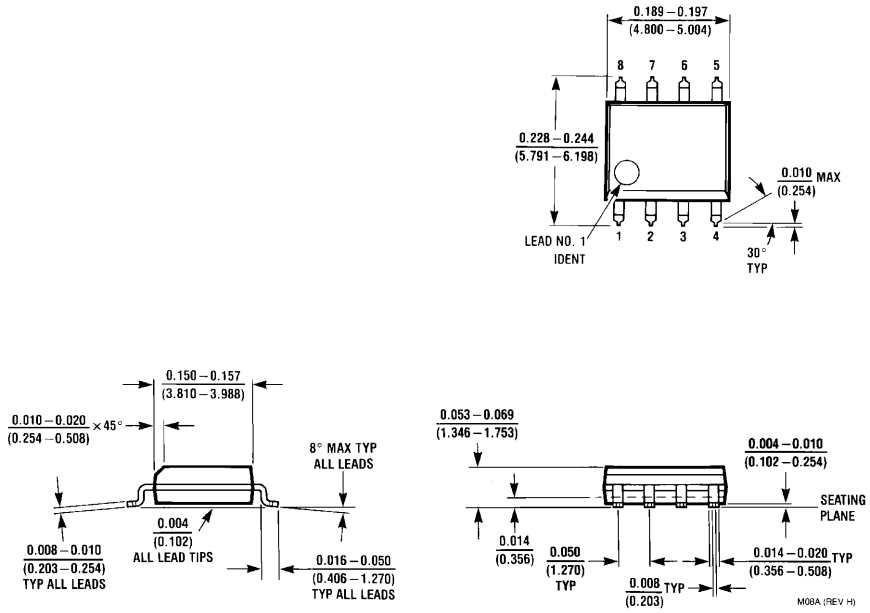


5-Pin SC70
NS Package Number MAA05A

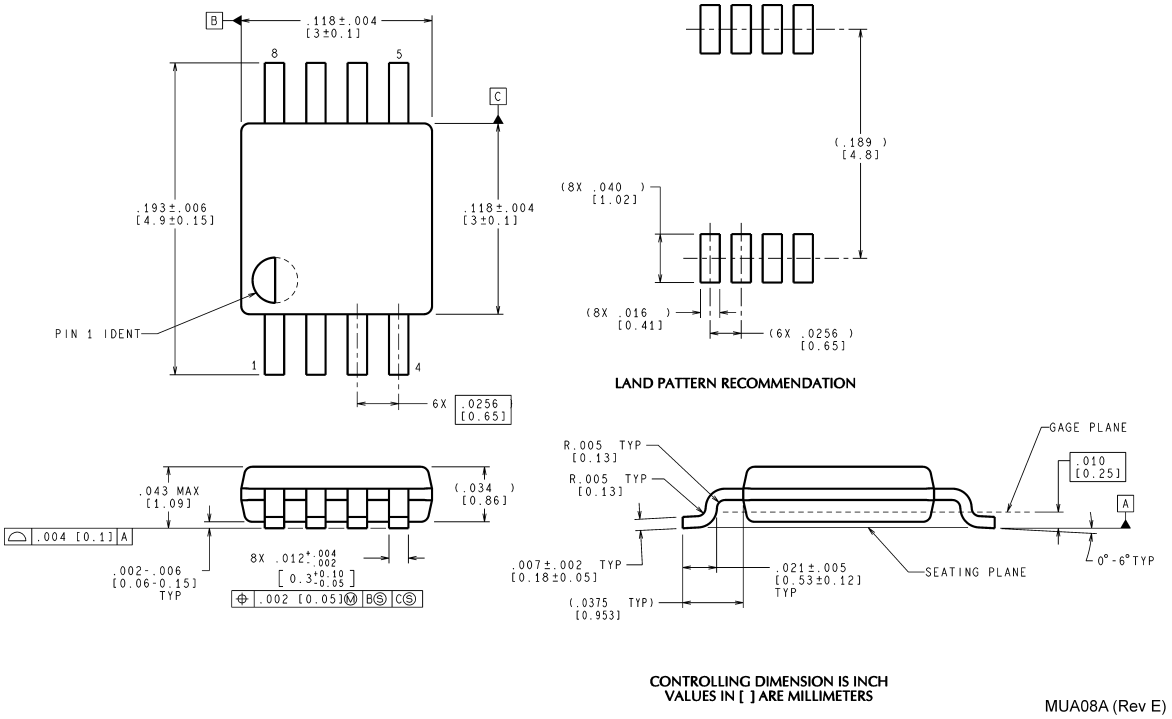


5-Pin SOT23
NS Package Number MF05A

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

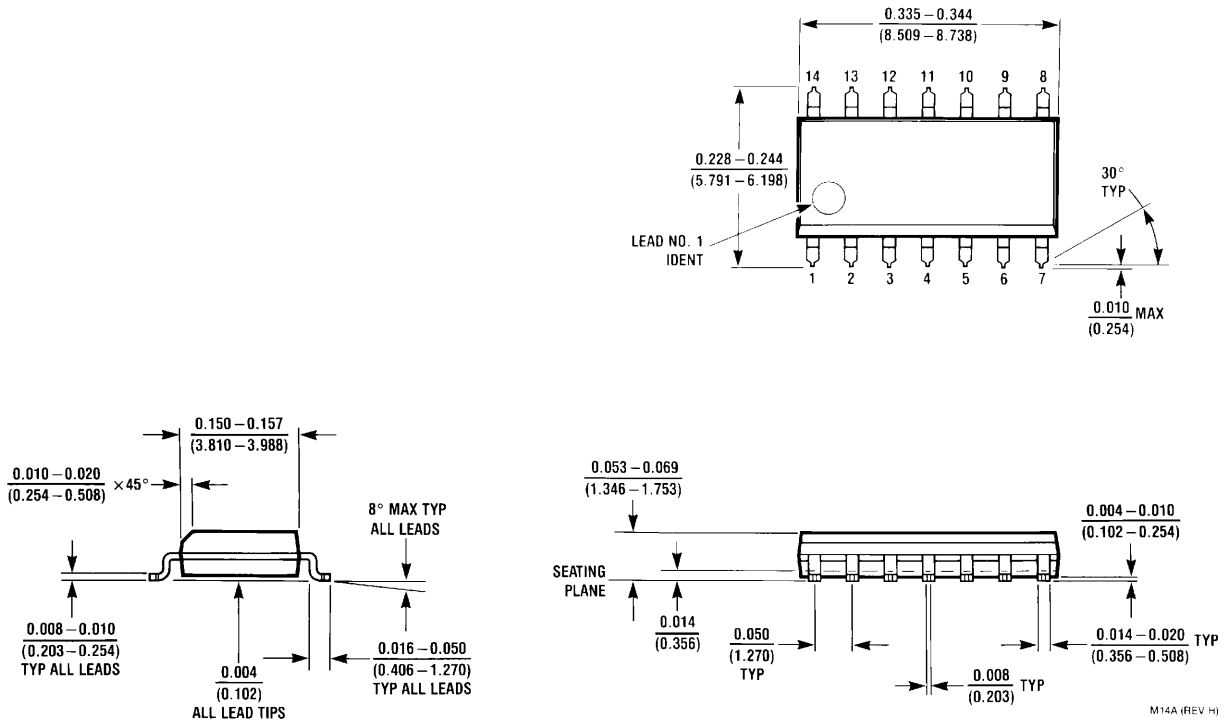


8-Pin SOIC
NS Package Number M08A

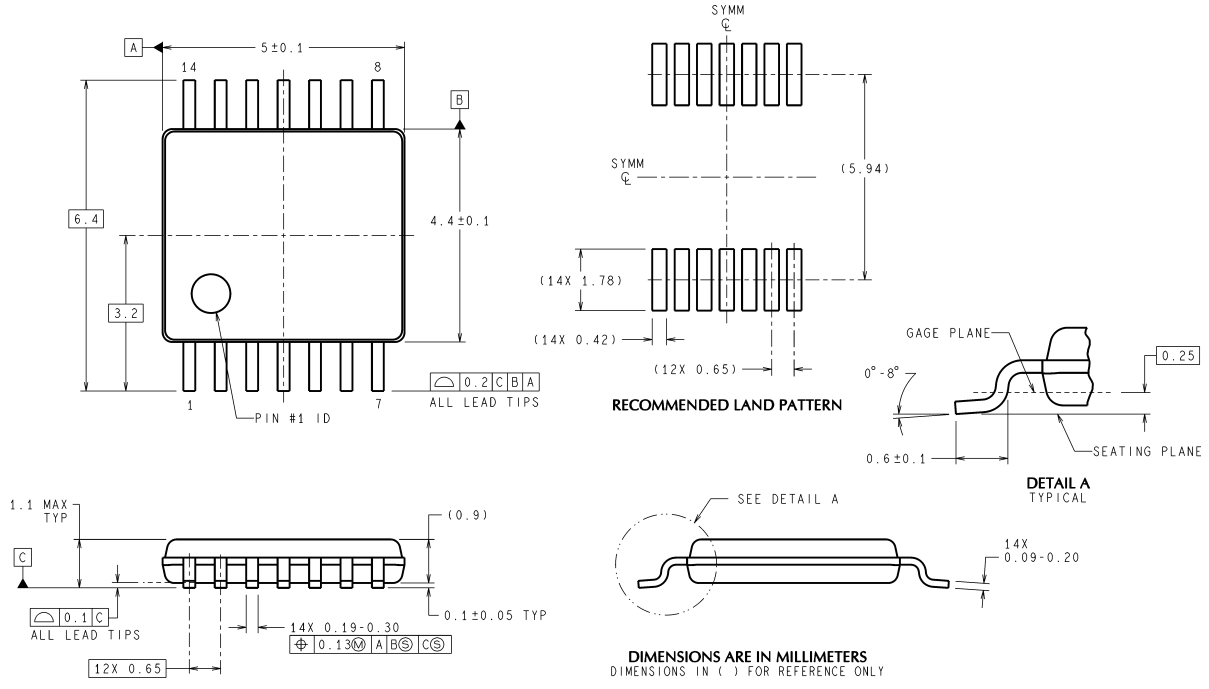


8-Pin MSOP
NS Package Number MUA08A

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



14-Pin SOIC
NS Package Number M14A



MTC14 (Rev D)

14-Pin TSSOP
NS Package Number MTC14

Notes

National does not assume any responsibility for use of any circuitry described, no circuit patent licenses are implied and National reserves the right at any time without notice to change said circuitry and specifications.

For the most current product information visit us at www.national.com.

LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

BANNED SUBSTANCE COMPLIANCE

National Semiconductor follows the provisions of the Product Stewardship Guide for Customers (CSP-9-111C2) and Banned Substances and Materials of Interest Specification (CSP-9-111S2) for regulatory environmental compliance. Details may be found at: www.national.com/quality/green.

Lead free products are RoHS compliant.

National Semiconductor
Americas Customer
Support Center
Email: new.feedback@nsc.com
Tel: 1-800-272-9959

www.national.com

National Semiconductor
Europe Customer Support Center
Fax: +49 (0) 180-530 85 86
Email: europe.support@nsc.com
Deutsch Tel: +49 (0) 69 9508 6208
English Tel: +44 (0) 870 24 0 2171
Français Tel: +33 (0) 1 41 91 8790

National Semiconductor
Asia Pacific Customer
Support Center
Email: ap.support@nsc.com

National Semiconductor
Japan Customer Support Center
Fax: 81-3-5639-7507
Email: jpn.feedback@nsc.com
Tel: 81-3-5639-7560

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		**Applications**	
Audio	www.ti.com/audio	Communications and Telecom	www.ti.com/communications
Amplifiers	amplifier.ti.com	Computers and Peripherals	www.ti.com/computers
Data Converters	dataconverter.ti.com	Consumer Electronics	www.ti.com/consumer-apps
DLP® Products	www.dlp.com	Energy and Lighting	www.ti.com/energy
DSP	dsp.ti.com	Industrial	www.ti.com/industrial
Clocks and Timers	www.ti.com/clocks	Medical	www.ti.com/medical
Interface	interface.ti.com	Security	www.ti.com/security
Logic	logic.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Power Mgmt	power.ti.com	Transportation and Automotive	www.ti.com/automotive
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Mobile Processors	www.ti.com/omap		
Wireless Connectivity	www.ti.com/wirelessconnectivity		
	TI E2E Community Home Page		e2e.ti.com

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2011, Texas Instruments Incorporated