

## LMP2231 Single Micropower, 1.6V, Precision Operational Amplifier with CMOS Inputs

Check for Samples: [LMP2231](#)

### FEATURES

(For  $V_S = 5V$ ,  $T_A = 25^\circ C$ , Typical Unless Otherwise Noted)

- Supply Current 10  $\mu A$
- Operating Voltage Range 1.6V to 5.5V
- $TCV_{OS}$  (LMP2231A)  $\pm 0.4 \mu V/^\circ C$  (max)
- $TCV_{OS}$  (LMP2231B)  $\pm 2.5 \mu V/^\circ C$  (max)
- $V_{OS} \pm 150 \mu V$  (max)
- Input Bias Current 20 fA
- PSRR 120 dB
- CMRR 97 dB
- Open Loop Gain 120 dB
- Gain Bandwidth Product 130 kHz
- Slew Rate 58 V/ms
- Input Voltage Noise,  $f = 1 \text{ kHz}$  60 nV/ $\sqrt{Hz}$
- Temperature Range  $-40^\circ C$  to  $125^\circ C$

### APPLICATIONS

- Precision Instrumentation Amplifiers
- Battery Powered Medical Instrumentation
- High Impedance Sensors
- Strain Gauge Bridge Amplifier
- Thermocouple Amplifiers

### DESCRIPTION

The LMP2231 is a single micropower precision amplifier designed for battery powered applications. The 1.6V to 5.5V operating supply voltage range and quiescent power consumption of only 16  $\mu W$  extend the battery life in portable battery operated systems. The LMP2231 is part of the LMP™ precision amplifier family. The high impedance CMOS input makes it ideal for instrumentation and other sensor interface applications.

The LMP2231 has a maximum offset of 150  $\mu V$  and maximum offset voltage drift of only 0.4  $\mu V/^\circ C$  along with low bias current of only  $\pm 20$  fA. These precise specifications make the LMP2231 a great choice for maintaining system accuracy and long term stability.

The LMP2231 has a rail-to-rail output that swings 15 mV from the supply voltage, which increases system dynamic range. The common mode input voltage range extends 200 mV below the negative supply, thus the LMP2231 is ideal for use in single supply applications with ground sensing.

The LMP2231 is offered in 5-Pin SOT-23 and 8-pin SOIC packages.

The dual and quad versions of this product are also available. The dual, LMP2232 is offered in 8-pin SOIC and VSSOP. The quad, LMP2234 is offered in 14-pin SOIC and TSSOP.



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

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### Typical Application

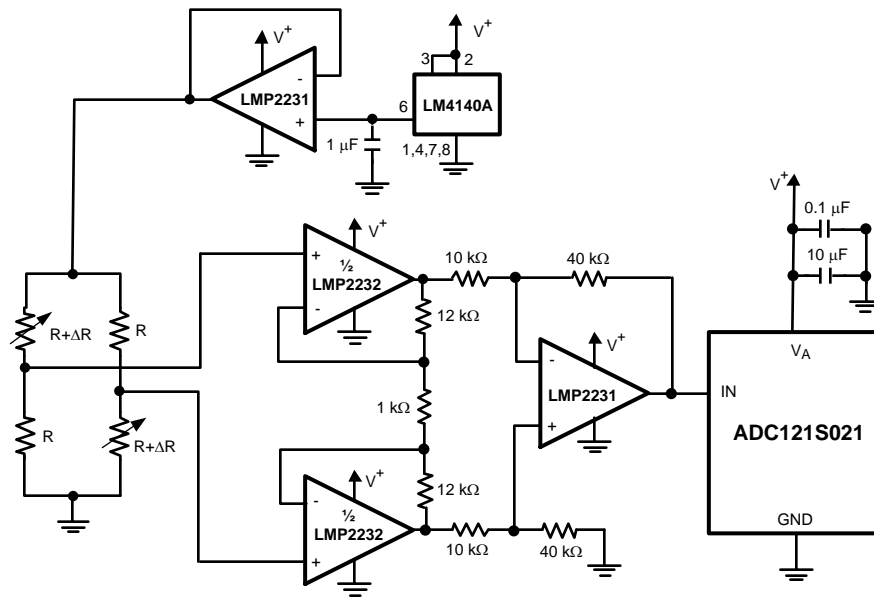


Figure 1. Strain Gauge Bridge Amplifier



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

### Absolute Maximum Ratings<sup>(1)(2)</sup>

ESD Tolerance <sup>(3)</sup>	Human Body Model	2000V
	Machine Model	100V
Differential Input Voltage		±300 mV
Supply Voltage ( $V_S = V^+ - V^-$ )		6V
Voltage on Input/Output Pins		$V^+ + 0.3V, V^- - 0.3V$
Storage Temperature Range		-65°C to 150°C
Junction Temperature <sup>(4)</sup>		150°C

For soldering specifications: see product folder at [www.ti.com](http://www.ti.com) and <http://www.ti.com/lit/SNOA549>.

- (1) Absolute Maximum Ratings indicate limits beyond which damage may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but specific performance is not ensured. For ensured specifications and test conditions, see the Electrical Characteristics.
- (2) If Military/Aerospace specified devices are required, please contact the TI Sales Office/ Distributors for availability and specifications.
- (3) 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).
- (4) 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.

## Operating Ratings<sup>(1)</sup>

Operating Temperature Range <sup>(2)</sup>		-40°C to 125°C
Supply Voltage ( $V_S = V^+ - V^-$ )		1.6V to 5.5V
Package Thermal Resistance ( $\theta_{JA}$ ) <sup>(2)</sup>	5-Pin SOT-23	160.6 °C/W
	8-Pin SOIC	116.2 °C/W

- (1) Absolute Maximum Ratings indicate limits beyond which damage may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but specific performance is not ensured. For ensured specifications and test conditions, see the Electrical Characteristics.
- (2) 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.

## 5V DC Electrical Characteristics<sup>(1)</sup>

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

Symbol	Parameter	Conditions	Min <sup>(2)</sup>	Typ <sup>(3)</sup>	Max <sup>(2)</sup>	Units
$V_{OS}$	Input Offset Voltage			$\pm 10$	$\pm 150$ <b><math>\pm 230</math></b>	$\mu\text{V}$
$TCV_{OS}$	Input Offset Voltage Drift	LMP2231A		$\pm 0.3$	$\pm 0.4$	$\mu\text{V}/^\circ\text{C}$
		LMP2231B		$\pm 0.3$	$\pm 2.5$	
$I_{BIAS}$	Input Bias Current			0.02	$\pm 1$ <b><math>\pm 50</math></b>	pA
$I_{OS}$	Input Offset Current			5		fA
CMRR	Common Mode Rejection Ratio	$0\text{V} \leq V_{CM} \leq 4\text{V}$	81 <b>80</b>	97		dB
PSRR	Power Supply Rejection Ratio	$1.6\text{V} \leq V^+ \leq 5.5\text{V}$ $V^- = 0\text{V}$ , $V_{CM} = 0\text{V}$	83 <b>83</b>	120		dB
CMVR	Common Mode Voltage Range	CMRR $\geq 80\text{ dB}$ CMRR $\geq 79\text{ dB}$	-0.2 <b>-0.2</b>		4.2 <b>4.2</b>	V
$A_{VOL}$	Large Signal Voltage Gain	$V_O = 0.3\text{V}$ to $4.7\text{V}$ $R_L = 10\text{ k}\Omega$ to $V^+/2$	110 <b>108</b>	120		dB
$V_O$	Output Swing High	$R_L = 10\text{ k}\Omega$ to $V^+/2$ $V_{IN}(\text{diff}) = 100\text{ mV}$		17	50 <b>50</b>	mV from either rail
	Output Swing Low	$R_L = 10\text{ k}\Omega$ to $V^+/2$ $V_{IN}(\text{diff}) = -100\text{ mV}$		17	50 <b>50</b>	
$I_O$	Output Current <sup>(4)</sup>	Sourcing, $V_O$ to $V^-$ $V_{IN}(\text{diff}) = 100\text{ mV}$	27 <b>19</b>	30		mA
		Sinking, $V_O$ to $V^+$ $V_{IN}(\text{diff}) = -100\text{ mV}$	17 <b>12</b>	22		
$I_S$	Supply Current			10	16 <b>18</b>	$\mu\text{A}$

- (1) Electrical Table values apply only for factory testing conditions at the temperature indicated. Factory testing conditions result in very limited self-heating of the device such that  $T_J = T_A$ . No ensured specification of parametric performance is indicated in the electrical tables under conditions of internal self-heating where  $T_J > T_A$ . Absolute Maximum Ratings indicate junction temperature limits beyond which the device may be permanently degraded, either mechanically or electrically.
- (2) All limits are specified by testing, statistical analysis or design.
- (3) Typical values represent the most likely parametric norm 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 ensured on shipped production material.
- (4) The short circuit test is a momentary open loop test.

### 5V AC Electrical Characteristics<sup>(1)</sup>

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

Symbol	Parameter	Conditions	Min <sup>(2)</sup>	Typ <sup>(3)</sup>	Max <sup>(2)</sup>	Units
GBW	Gain-Bandwidth Product	$C_L = 20\text{ pF}$ , $R_L = 10\text{ k}\Omega$		130		kHz
SR	Slew Rate	$A_V = +1$	Falling Edge	33 <b>32</b>	58	V/ms
			Rising Edge	33 <b>32</b>	48	
$\theta_m$	Phase Margin	$C_L = 20\text{ pF}$ , $R_L = 10\text{ k}\Omega$		78		deg
$G_m$	Gain Margin	$C_L = 20\text{ pF}$ , $R_L = 10\text{ k}\Omega$		27		dB
$e_n$	Input-Referred Voltage Noise Density	$f = 1\text{ kHz}$		60		$\text{nV}/\sqrt{\text{Hz}}$
	Input-Referred Voltage Noise	0.1 Hz to 10 Hz		2.3		$\mu\text{V}_{\text{PP}}$
$i_n$	Input-Referred Current Noise	$f = 1\text{ kHz}$		10		$\text{fA}/\sqrt{\text{Hz}}$
THD+N	Total Harmonic Distortion + Noise	$f = 100\text{ Hz}$ , $R_L = 10\text{ k}\Omega$		0.002		%

- (1) Electrical Table values apply only for factory testing conditions at the temperature indicated. Factory testing conditions result in very limited self-heating of the device such that  $T_J = T_A$ . No ensured specification of parametric performance is indicated in the electrical tables under conditions of internal self-heating where  $T_J > T_A$ . Absolute Maximum Ratings indicate junction temperature limits beyond which the device may be permanently degraded, either mechanically or electrically.
- (2) All limits are specified by testing, statistical analysis or design.
- (3) Typical values represent the most likely parametric norm 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 ensured on shipped production material.

### 3.3V DC Electrical Characteristics<sup>(1)</sup>

Unless otherwise specified, all limits ensured for  $T_A = 25^\circ\text{C}$ ,  $V^+ = 3.3\text{V}$ ,  $V^- = 0\text{V}$ ,  $V_{\text{CM}} = V_O = V^+/2$ , and  $R_L > 1\text{ M}\Omega$ . **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min <sup>(2)</sup>	Typ <sup>(3)</sup>	Max <sup>(2)</sup>	Units
$V_{\text{OS}}$	Input Offset Voltage			$\pm 10$	$\pm 160$ <b><math>\pm 250</math></b>	$\mu\text{V}$
$\text{TCV}_{\text{OS}}$	Input Offset Voltage Drift	LMP2231A		$\pm 0.3$	$\pm 0.4$	$\mu\text{V}/^\circ\text{C}$
		LMP2231B		$\pm 0.3$	$\pm 2.5$	
$I_{\text{BIAS}}$	Input Bias Current			0.02	$\pm 1$ <b><math>\pm 50</math></b>	pA
$I_{\text{OS}}$	Input Offset Current			5		fA
CMRR	Common Mode Rejection Ratio	$0\text{V} \leq V_{\text{CM}} \leq 2.3\text{V}$	79 <b>77</b>	92		dB
PSRR	Power Supply Rejection Ratio	$1.6\text{V} \leq V^+ \leq 5.5\text{V}$ $V^- = 0\text{V}$ , $V_{\text{CM}} = 0\text{V}$	83 <b>83</b>	120		dB
CMVR	Common Mode Voltage Range	CMRR $\geq 78\text{ dB}$ CMRR $\geq 77\text{ dB}$	-0.2 <b>-0.2</b>		2.5 <b>2.5</b>	V
$A_{\text{VOL}}$	Large Signal Voltage Gain	$V_O = 0.3\text{V}$ to $3\text{V}$ $R_L = 10\text{ k}\Omega$ to $V^+/2$	108 <b>107</b>	120		dB
$V_O$	Output Swing High	$R_L = 10\text{ k}\Omega$ to $V^+/2$ $V_{\text{IN}}(\text{diff}) = 100\text{ mV}$		14	50 <b>50</b>	mV from either rail
	Output Swing Low	$R_L = 10\text{ k}\Omega$ to $V^+/2$ $V_{\text{IN}}(\text{diff}) = -100\text{ mV}$		14	50 <b>50</b>	

- (1) Electrical Table values apply only for factory testing conditions at the temperature indicated. Factory testing conditions result in very limited self-heating of the device such that  $T_J = T_A$ . No ensured specification of parametric performance is indicated in the electrical tables under conditions of internal self-heating where  $T_J > T_A$ . Absolute Maximum Ratings indicate junction temperature limits beyond which the device may be permanently degraded, either mechanically or electrically.
- (2) All limits are specified by testing, statistical analysis or design.
- (3) Typical values represent the most likely parametric norm 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 ensured on shipped production material.

### 3.3V DC Electrical Characteristics<sup>(1)</sup> (continued)

Unless otherwise specified, all limits ensured for  $T_A = 25^\circ\text{C}$ ,  $V^+ = 3.3\text{V}$ ,  $V^- = 0\text{V}$ ,  $V_{\text{CM}} = V_O = V^+/2$ , and  $R_L > 1\text{M}\Omega$ . **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min <sup>(2)</sup>	Typ <sup>(3)</sup>	Max <sup>(2)</sup>	Units
$I_O$	Output Current <sup>(4)</sup>	Sourcing, $V_O$ to $V^-$ $V_{\text{IN(diff)}} = 100\text{ mV}$	11 <b>8</b>	14		mA
		Sinking, $V_O$ to $V^+$ $V_{\text{IN(diff)}} = -100\text{ mV}$	8 <b>5</b>	11		
$I_S$	Supply Current			10	15 <b>16</b>	$\mu\text{A}$

(4) The short circuit test is a momentary open loop test.

### 3.3V AC Electrical Characteristics<sup>(1)</sup>

Unless otherwise is specified, all limits ensured for  $T_A = 25^\circ\text{C}$ ,  $V^+ = 3.3\text{V}$ ,  $V^- = 0\text{V}$ ,  $V_{\text{CM}} = V_O = V^+/2$ , and  $R_L > 1\text{M}\Omega$ . **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min <sup>(2)</sup>	Typ <sup>(3)</sup>	Max <sup>(2)</sup>	Units
GBW	Gain-Bandwidth Product	$C_L = 20\text{ pF}$ , $R_L = 10\text{ k}\Omega$		128		kHz
SR	Slew Rate	$A_V = +1$ , $C_L = 20\text{ pF}$ $R_L = 10\text{ k}\Omega$	Falling Edge		58	V/ms
			Rising Edge		48	
$\theta_m$	Phase Margin	$C_L = 20\text{ pF}$ , $R_L = 10\text{ k}\Omega$		76		deg
$G_m$	Gain Margin	$C_L = 20\text{ pF}$ , $R_L = 10\text{ k}\Omega$		26		dB
$e_n$	Input-Referred Voltage Noise Density	$f = 1\text{ kHz}$		60		$\text{nV}/\sqrt{\text{Hz}}$
	Input-Referred Voltage Noise	0.1 Hz to 10 Hz		2.4		$\mu\text{V}_{\text{PP}}$
$i_n$	Input-Referred Current Noise	$f = 1\text{ kHz}$		10		$\text{fA}/\sqrt{\text{Hz}}$
THD+N	Total Harmonic Distortion + Noise	$f = 100\text{ Hz}$ , $R_L = 10\text{ k}\Omega$		0.003		%

- Electrical Table values apply only for factory testing conditions at the temperature indicated. Factory testing conditions result in very limited self-heating of the device such that  $T_J = T_A$ . No ensured specification of parametric performance is indicated in the electrical tables under conditions of internal self-heating where  $T_J > T_A$ . Absolute Maximum Ratings indicate junction temperature limits beyond which the device may be permanently degraded, either mechanically or electrically.
- All limits are specified by testing, statistical analysis or design.
- Typical values represent the most likely parametric norm 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 ensured on shipped production material.

### 2.5V DC Electrical Characteristics<sup>(1)</sup>

Unless otherwise specified, all limits ensured for  $T_A = 25^\circ\text{C}$ ,  $V^+ = 2.5\text{V}$ ,  $V^- = 0\text{V}$ ,  $V_{\text{CM}} = V_O = V^+/2$ , and  $R_L > 1\text{M}\Omega$ . **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min <sup>(2)</sup>	Typ <sup>(3)</sup>	Max <sup>(2)</sup>	Units
$V_{\text{OS}}$	Input Offset Voltage			$\pm 10$	$\pm 190$ <b><math>\pm 275</math></b>	$\mu\text{V}$
$\text{TCV}_{\text{OS}}$	Input Offset Voltage Drift	LMP2231A		$\pm 0.3$	$\pm 0.4$	$\mu\text{V}/^\circ\text{C}$
		LMP2231B		$\pm 0.3$	$\pm 2.5$	
$I_{\text{BIAS}}$	Input Bias Current			0.02	$\pm 1.0$ <b><math>\pm 50</math></b>	pA
$I_{\text{OS}}$	Input Offset Current			5		fA
CMRR	Common Mode Rejection Ratio	$0\text{V} \leq V_{\text{CM}} \leq 1.5\text{V}$	<b>77</b> 76	91		dB

- Electrical Table values apply only for factory testing conditions at the temperature indicated. Factory testing conditions result in very limited self-heating of the device such that  $T_J = T_A$ . No ensured specification of parametric performance is indicated in the electrical tables under conditions of internal self-heating where  $T_J > T_A$ . Absolute Maximum Ratings indicate junction temperature limits beyond which the device may be permanently degraded, either mechanically or electrically.
- All limits are specified by testing, statistical analysis or design.
- Typical values represent the most likely parametric norm 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 ensured on shipped production material.

## 2.5V DC Electrical Characteristics<sup>(1)</sup> (continued)

Unless otherwise specified, all limits ensured for  $T_A = 25^\circ\text{C}$ ,  $V^+ = 2.5\text{V}$ ,  $V^- = 0\text{V}$ ,  $V_{\text{CM}} = V_O = V^+/2$ , and  $R_L > 1\text{M}\Omega$ . **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min <sup>(2)</sup>	Typ <sup>(3)</sup>	Max <sup>(2)</sup>	Units
PSRR	Power Supply Rejection Ratio	$1.6\text{V} \leq V^+ \leq 5.5\text{V}$ $V^- = 0\text{V}$ , $V_{\text{CM}} = 0\text{V}$	83 <b>83</b>	120		dB
CMVR	Common Mode Voltage Range	CMRR $\geq 77$ dB CMRR $\geq 76$ dB	-0.2 <b>-0.2</b>		1.7 <b>1.7</b>	V
$A_{\text{VOL}}$	Large Signal Voltage Gain	$V_O = 0.3\text{V}$ to $2.2\text{V}$ $R_L = 10\text{ k}\Omega$ to $V^+/2$	104 <b>104</b>	120		dB
$V_O$	Output Swing High	$R_L = 10\text{ k}\Omega$ to $V^+/2$ $V_{\text{IN}}(\text{diff}) = 100\text{ mV}$		12	50 <b>50</b>	mV from either rail
	Output Swing Low	$R_L = 10\text{ k}\Omega$ to $V^+/2$ $V_{\text{IN}}(\text{diff}) = -100\text{ mV}$		13	50 <b>50</b>	
$I_O$	Output Current <sup>(4)</sup>	Sourcing, $V_O$ to $V^-$ $V_{\text{IN}}(\text{diff}) = 100\text{ mV}$	5 <b>4</b>	8		mA
		Sinking, $V_O$ to $V^+$ $V_{\text{IN}}(\text{diff}) = -100\text{ mV}$	3.5 <b>2.5</b>	7		
$I_S$	Supply Current			10	14 <b>15</b>	$\mu\text{A}$

(4) The short circuit test is a momentary open loop test.

## 2.5V AC Electrical Characteristics<sup>(1)</sup>

Unless otherwise specified, all limits ensured for  $T_A = 25^\circ\text{C}$ ,  $V^+ = 2.5\text{V}$ ,  $V^- = 0\text{V}$ ,  $V_{\text{CM}} = V_O = V^+/2$ , and  $R_L > 1\text{M}\Omega$ . **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min <sup>(2)</sup>	Typ <sup>(3)</sup>	Max <sup>(2)</sup>	Units
GBW	Gain-Bandwidth Product	$C_L = 20\text{ pF}$ , $R_L = 10\text{ k}\Omega$		128		kHz
SR	Slew Rate	$A_V = +1$ , $C_L = 20\text{ pF}$ $R_L = 10\text{ k}\Omega$	Falling Edge		58	V/ms
			Rising Edge		48	
$\theta_m$	Phase Margin	$C_L = 20\text{ pF}$ , $R_L = 10\text{ k}\Omega$		74		deg
$G_m$	Gain Margin	$C_L = 20\text{ pF}$ , $R_L = 10\text{ k}\Omega$		26		dB
$e_n$	Input-Referred Voltage Noise Density	$f = 1\text{ kHz}$		60		$\text{nV}/\sqrt{\text{Hz}}$
	Input-Referred Voltage Noise	0.1 Hz to 10 Hz		2.5		$\mu\text{V}_{\text{PP}}$
$i_n$	Input-Referred Current Noise	$f = 1\text{ kHz}$		10		$\text{fA}/\sqrt{\text{Hz}}$
THD+N	Total Harmonic Distortion + Noise	$f = 100\text{ Hz}$ , $R_L = 10\text{ k}\Omega$		0.005		%

- Electrical Table values apply only for factory testing conditions at the temperature indicated. Factory testing conditions result in very limited self-heating of the device such that  $T_J = T_A$ . No ensured specification of parametric performance is indicated in the electrical tables under conditions of internal self-heating where  $T_J > T_A$ . Absolute Maximum Ratings indicate junction temperature limits beyond which the device may be permanently degraded, either mechanically or electrically.
- All limits are specified by testing, statistical analysis or design.
- Typical values represent the most likely parametric norm 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 ensured on shipped production material.

## 1.8V DC Electrical Characteristics <sup>(1)</sup>

Unless otherwise specified, all limits ensured for  $T_A = 25^\circ\text{C}$ ,  $V^+ = 1.8\text{V}$ ,  $V^- = 0\text{V}$ ,  $V_{\text{CM}} = V_O = V^+/2$ , and  $R_L > 1\text{M}\Omega$ . **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min <sup>(2)</sup>	Typ <sup>(3)</sup>	Max <sup>(2)</sup>	Units
$V_{\text{OS}}$	Input Offset Voltage			$\pm 10$	$\pm 230$ <b><math>\pm 325</math></b>	$\mu\text{V}$
$\text{TCV}_{\text{OS}}$	Input Offset Voltage Drift	LMP2231A		$\pm 0.3$	$\pm 0.4$	$\mu\text{V}/^\circ\text{C}$
		LMP2231B		$\pm 0.3$	$\pm 2.5$	
$I_{\text{BIAS}}$	Input Bias Current			0.02	$\pm 1.0$ <b><math>\pm 50</math></b>	pA
$I_{\text{OS}}$	Input Offset Current			5		fA
CMRR	Common Mode Rejection Ratio	$0\text{V} \leq V_{\text{CM}} \leq 0.8\text{V}$	76 <b>75</b>	92		dB
PSRR	Power Supply Rejection Ratio	$1.6\text{V} \leq V^+ \leq 5.5\text{V}$ $V^- = 0\text{V}$ , $V_{\text{CM}} = 0\text{V}$	83 <b>83</b>	120		dB
CMVR	Common Mode Voltage Rang	CMRR $\geq 76\text{ dB}$ CMRR $\geq 75\text{ dB}$	-0.2 <b>0</b>		1.0 <b>1.0</b>	V
$A_{\text{VOL}}$	Large Signal Voltage Gain	$V_O = 0.3\text{V}$ to $1.5\text{V}$ $R_L = 10\text{ k}\Omega$ to $V^+/2$	103 <b>103</b>	120		dB
$V_O$	Output Swing High	$R_L = 10\text{ k}\Omega$ to $V^+/2$ $V_{\text{IN}}(\text{diff}) = 100\text{ mV}$		12	50 <b>50</b>	mV from either rail
	Output Swing Low	$R_L = 10\text{ k}\Omega$ to $V^+/2$ $V_{\text{IN}}(\text{diff}) = -100\text{ mV}$		13	50 <b>50</b>	
$I_O$	Output Current <sup>(4)</sup>	Sourcing, $V_O$ to $V^-$ $V_{\text{IN}}(\text{diff}) = 100\text{ mV}$	2.5 <b>2</b>	5		mA
		Sinking, $V_O$ to $V^+$ $V_{\text{IN}}(\text{diff}) = -100\text{ mV}$	2 <b>1.5</b>	5		
$I_S$	Supply Current			10	14 <b>15</b>	$\mu\text{A}$

- (1) Electrical Table values apply only for factory testing conditions at the temperature indicated. Factory testing conditions result in very limited self-heating of the device such that  $T_J = T_A$ . No ensured specification of parametric performance is indicated in the electrical tables under conditions of internal self-heating where  $T_J > T_A$ . Absolute Maximum Ratings indicate junction temperature limits beyond which the device may be permanently degraded, either mechanically or electrically.
- (2) All limits are specified by testing, statistical analysis or design.
- (3) Typical values represent the most likely parametric norm 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 ensured on shipped production material.
- (4) The short circuit test is a momentary open loop test.

## 1.8V AC Electrical Characteristics <sup>(1)</sup>

Unless otherwise is specified, all limits ensured for  $T_A = 25^\circ\text{C}$ ,  $V^+ = 1.8\text{V}$ ,  $V^- = 0\text{V}$ ,  $V_{\text{CM}} = V_O = V^+/2$ , and  $R_L > 1\text{M}\Omega$ . **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min <sup>(2)</sup>	Typ <sup>(3)</sup>	Max <sup>(2)</sup>	Units
GBW	Gain-Bandwidth Product	$C_L = 20\text{ pF}$ , $R_L = 10\text{ k}\Omega$		127		kHz
SR	Slew Rate	$A_V = +1$ , $C_L = 20\text{ pF}$ $R_L = 10\text{ k}\Omega$	Falling Edge		58	V/ms
			Rising Edge		48	
$\theta_m$	Phase Margin	$C_L = 20\text{ pF}$ , $R_L = 10\text{ k}\Omega$		70		deg
$G_m$	Gain Margin	$C_L = 20\text{ pF}$ , $R_L = 10\text{ k}\Omega$		25		dB
$e_n$	Input-Referred Voltage Noise Density	$f = 1\text{ kHz}$		60		$\text{nV}/\sqrt{\text{Hz}}$
	Input-Referred Voltage Noise	0.1 Hz to 10 Hz		2.4		$\mu\text{V}_{\text{PP}}$

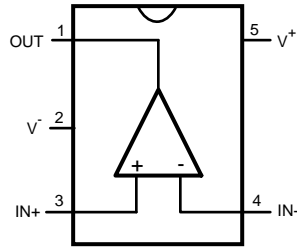
- (1) Electrical Table values apply only for factory testing conditions at the temperature indicated. Factory testing conditions result in very limited self-heating of the device such that  $T_J = T_A$ . No ensured specification of parametric performance is indicated in the electrical tables under conditions of internal self-heating where  $T_J > T_A$ . Absolute Maximum Ratings indicate junction temperature limits beyond which the device may be permanently degraded, either mechanically or electrically.
- (2) All limits are specified by testing, statistical analysis or design.
- (3) Typical values represent the most likely parametric norm 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 ensured on shipped production material.

### 1.8V AC Electrical Characteristics<sup>(1)</sup> (continued)

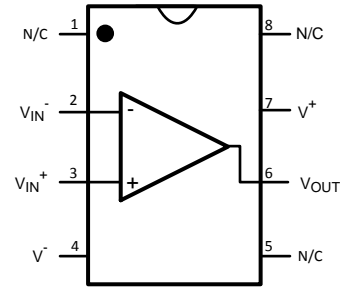
Unless otherwise is specified, all limits ensured for  $T_A = 25^\circ\text{C}$ ,  $V^+ = 1.8\text{V}$ ,  $V^- = 0\text{V}$ ,  $V_{CM} = V_O = V^+/2$ , and  $R_L > 1\text{M}\Omega$ . **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min <sup>(2)</sup>	Typ <sup>(3)</sup>	Max <sup>(2)</sup>	Units
$i_n$	Input-Referred Current Noise	$f = 1\text{ kHz}$		10		$\text{fA}/\sqrt{\text{Hz}}$
THD+N	Total Harmonic Distortion + Noise	$f = 100\text{ Hz}$ , $R_L = 10\text{ k}\Omega$		0.005		%

### Connection Diagram



**Figure 2. 5-Pin SOT-23 (Top View)**  
See Package Number DBV0005A



**Figure 3. 8-Pin SOIC (Top View)**  
See Package Number D0008A

### Typical Performance Characteristics

Unless otherwise Specified:  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{V}$ ,  $V_{CM} = V_S/2$ , where  $V_S = V^+ - V^-$

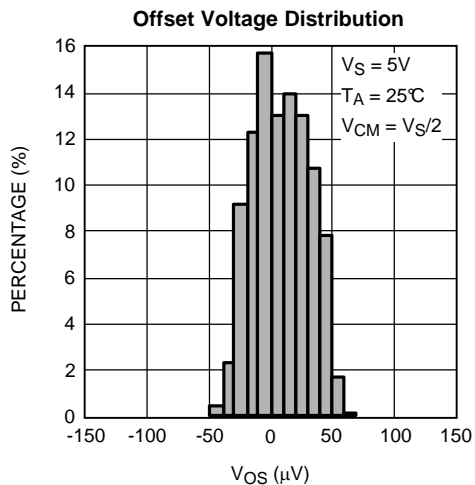


Figure 4.

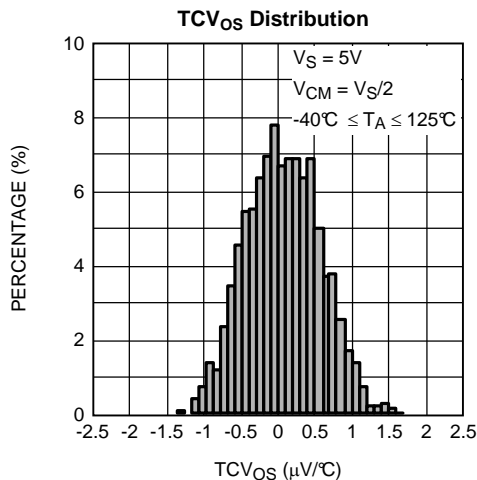


Figure 5.

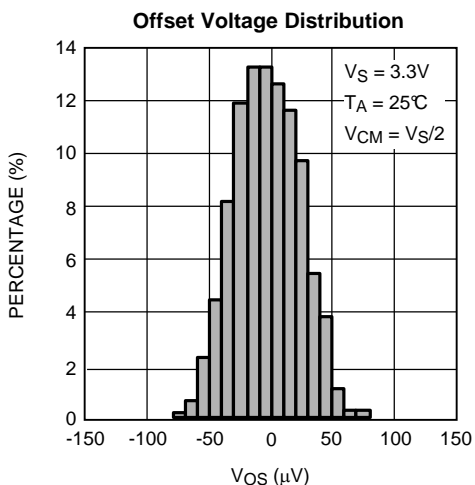


Figure 6.

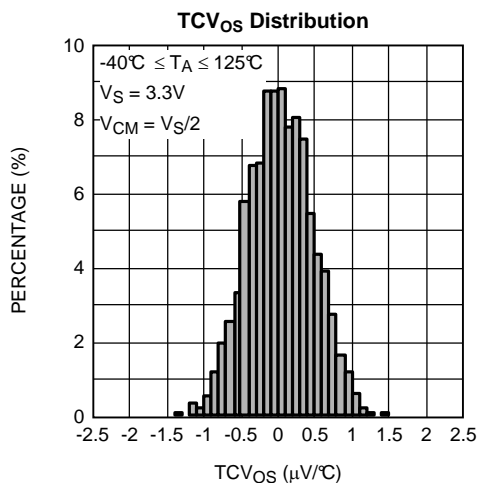


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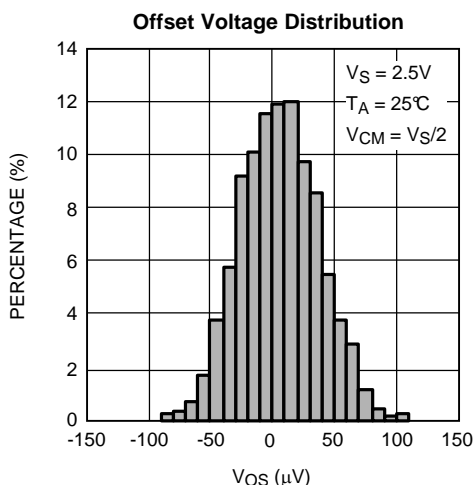


Figure 8.

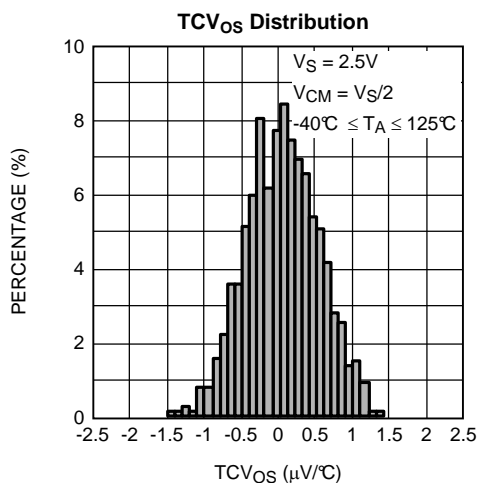


Figure 9.

**Typical Performance Characteristics (continued)**

Unless otherwise Specified:  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{V}$ ,  $V_{CM} = V_S/2$ , where  $V_S = V^+ - V^-$

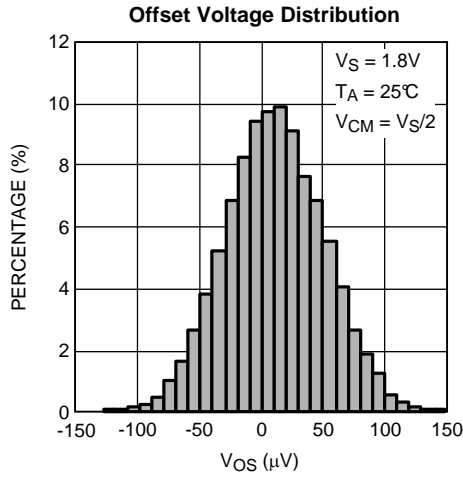


Figure 10.

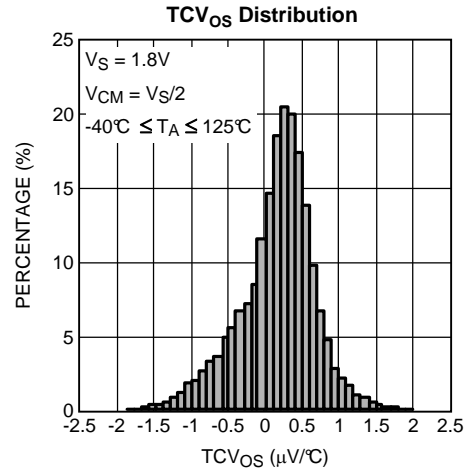


Figure 11.

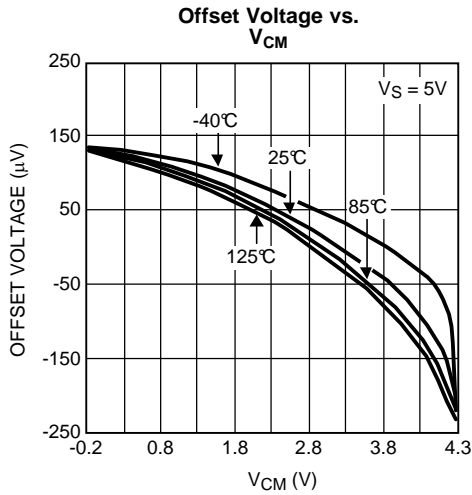


Figure 12.

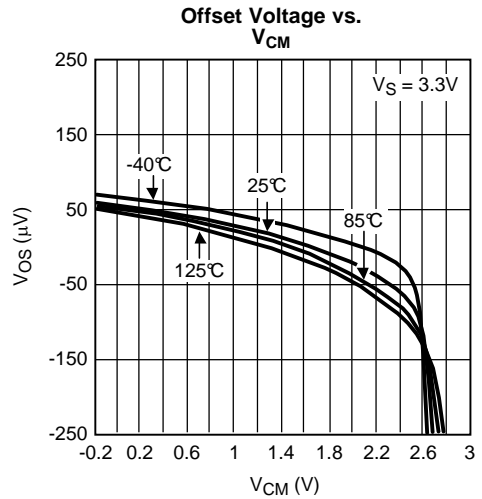


Figure 13.

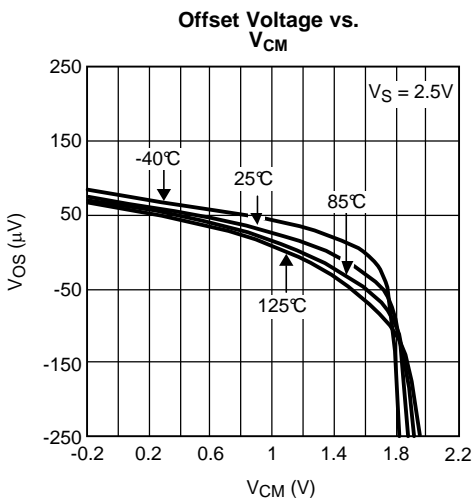


Figure 14.

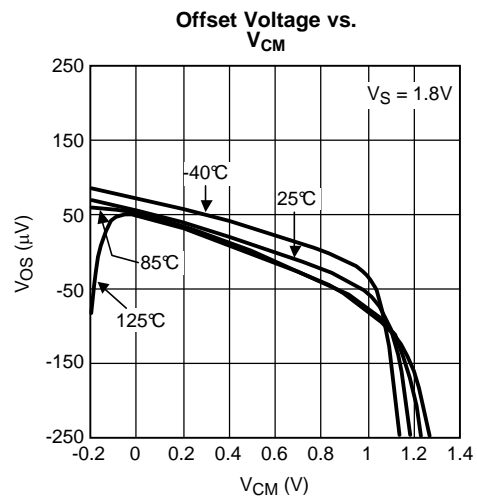


Figure 15.

**Typical Performance Characteristics (continued)**

Unless otherwise Specified:  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{V}$ ,  $V_{CM} = V_S/2$ , where  $V_S = V^+ - V^-$

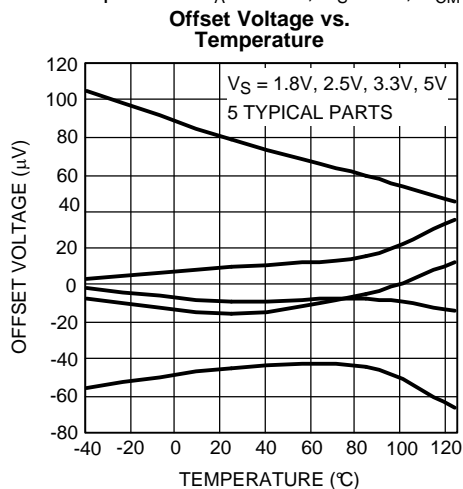


Figure 16.

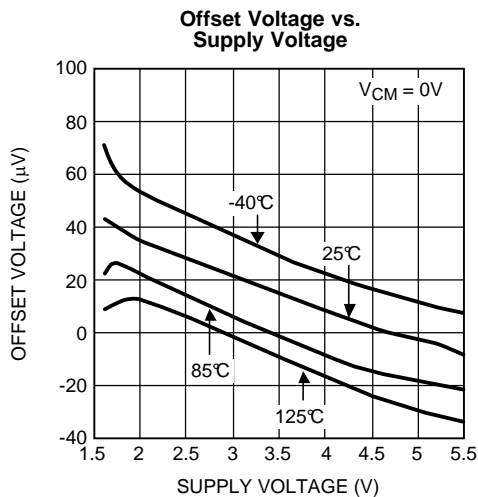


Figure 17.

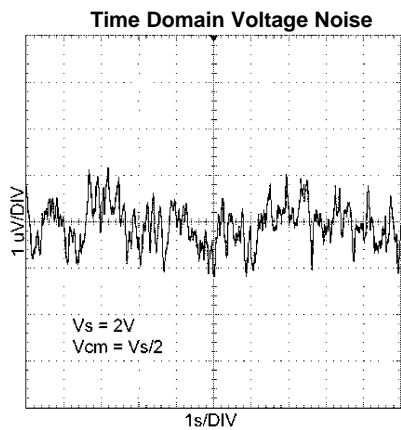


Figure 18.

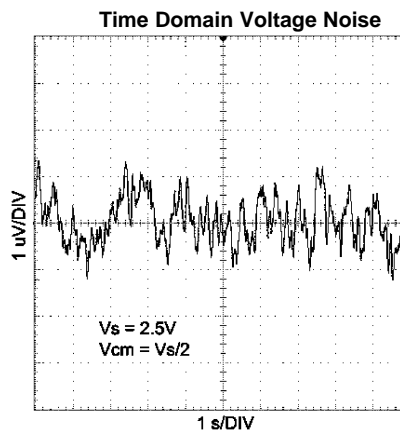


Figure 19.

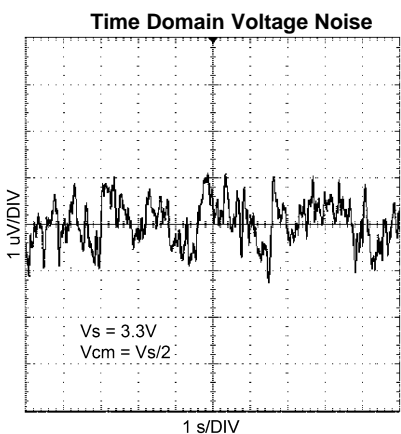


Figure 20.

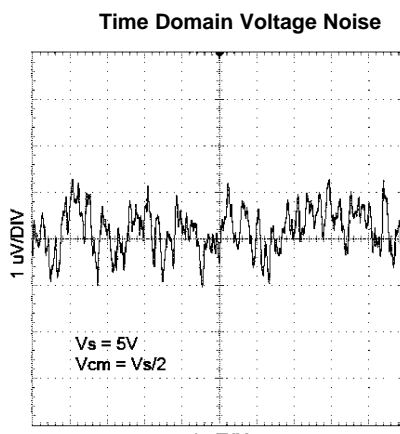
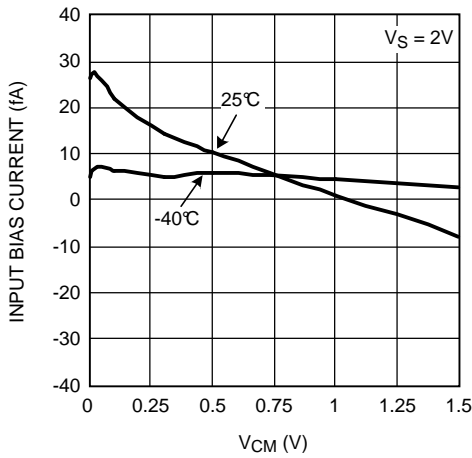


Figure 21.

**Typical Performance Characteristics (continued)**

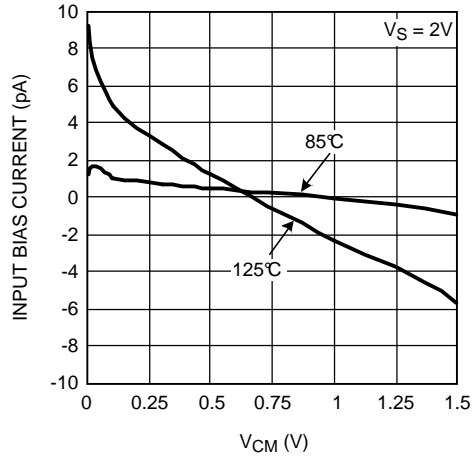
Unless otherwise Specified:  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{V}$ ,  $V_{CM} = V_S/2$ , where  $V_S = V^+ - V^-$

**Input Bias Current vs.  $V_{CM}$**



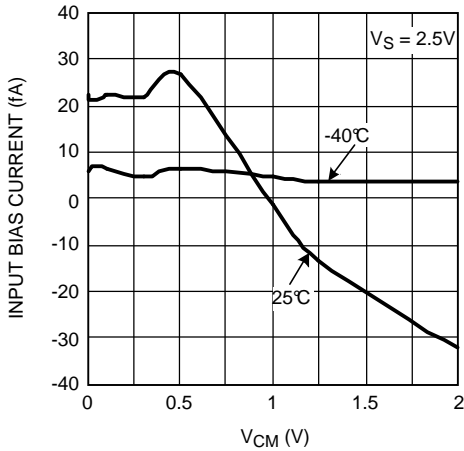
**Figure 22.**

**Input Bias Current vs.  $V_{CM}$**



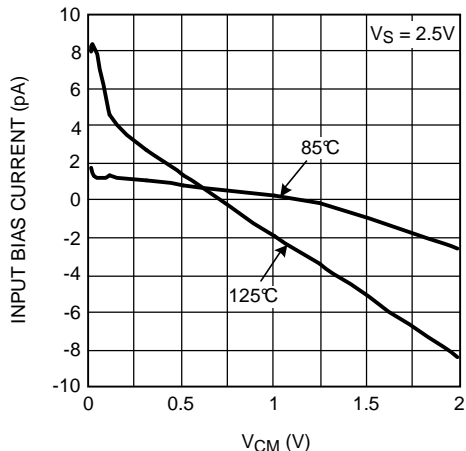
**Figure 23.**

**Input Bias Current vs.  $V_{CM}$**



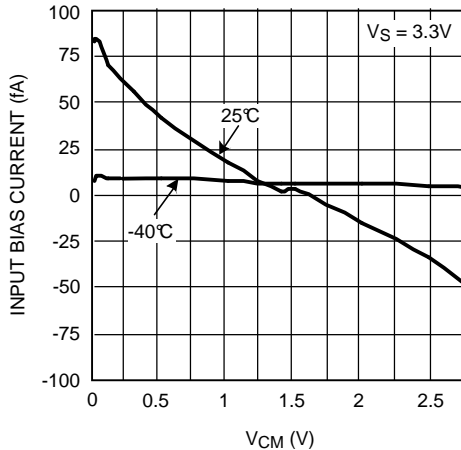
**Figure 24.**

**Input Bias Current vs.  $V_{CM}$**



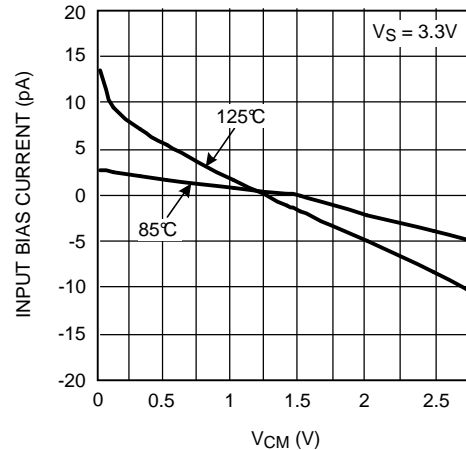
**Figure 25.**

**Input Bias Current vs.  $V_{CM}$**



**Figure 26.**

**Input Bias Current vs.  $V_{CM}$**



**Figure 27.**

**Typical Performance Characteristics (continued)**

Unless otherwise Specified:  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{V}$ ,  $V_{CM} = V_S/2$ , where  $V_S = V^+ - V^-$

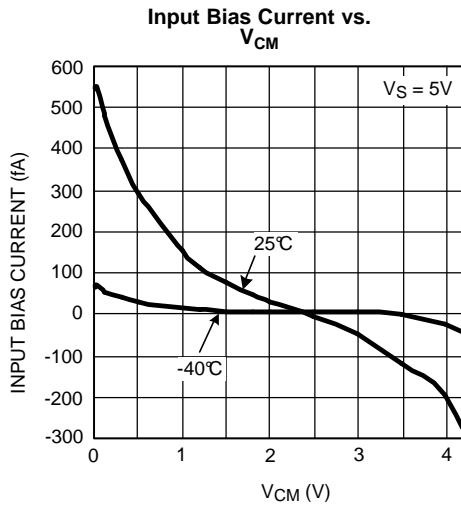


Figure 28.

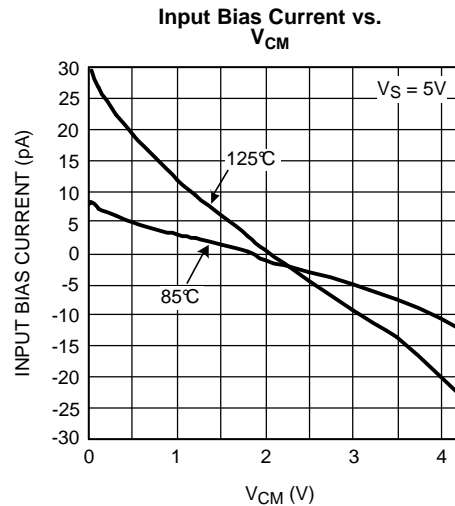


Figure 29.

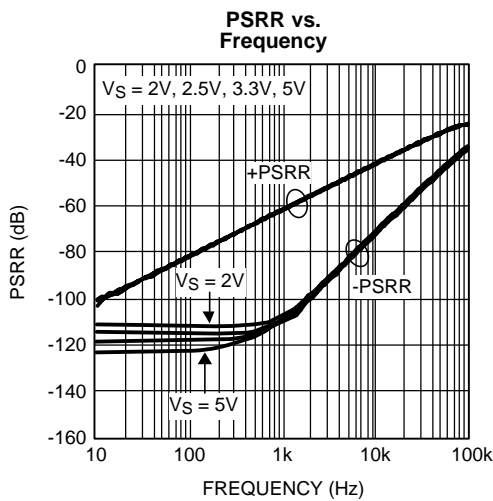


Figure 30.

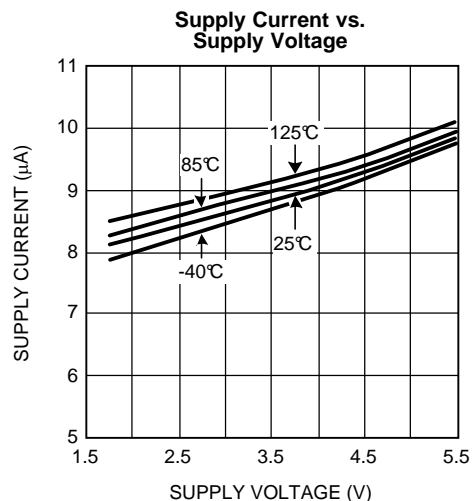


Figure 31.

**Typical Performance Characteristics (continued)**

Unless otherwise Specified:  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{V}$ ,  $V_{CM} = V_S/2$ , where  $V_S = V^+ - V^-$

**Sinking Current vs. Supply Voltage**

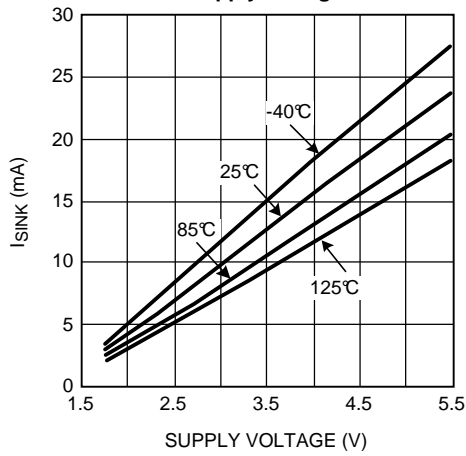


Figure 32.

**Sourcing Current vs. Supply Voltage**

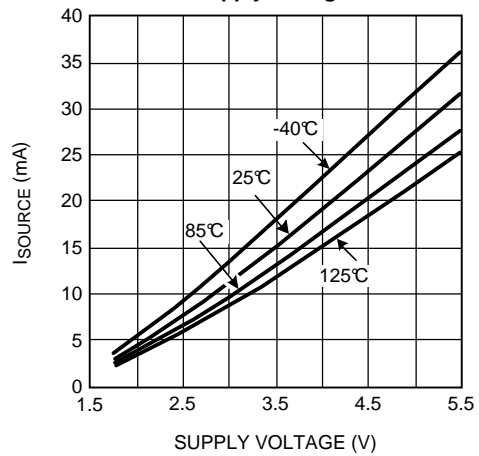


Figure 33.

**Output Swing High vs. Supply Voltage**

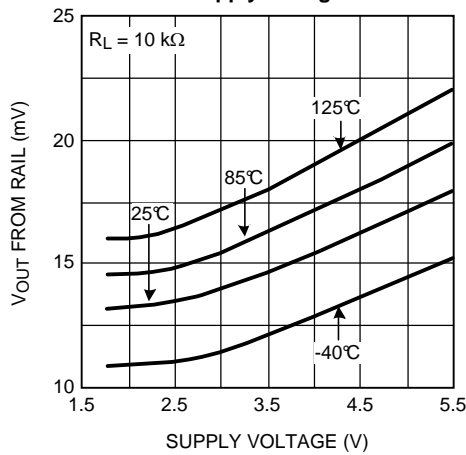


Figure 34.

**Output Swing Low vs. Supply Voltage**

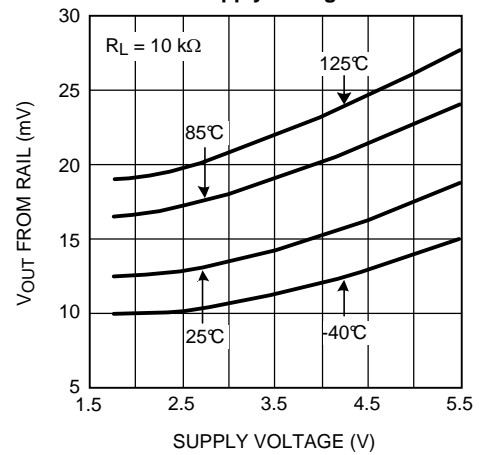


Figure 35.

**Open Loop Frequency Response**

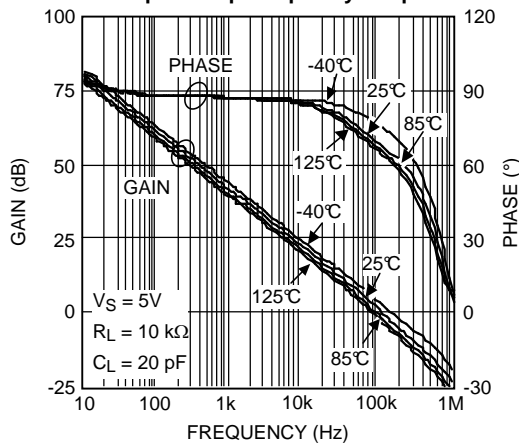


Figure 36.

**Open Loop Frequency Response**

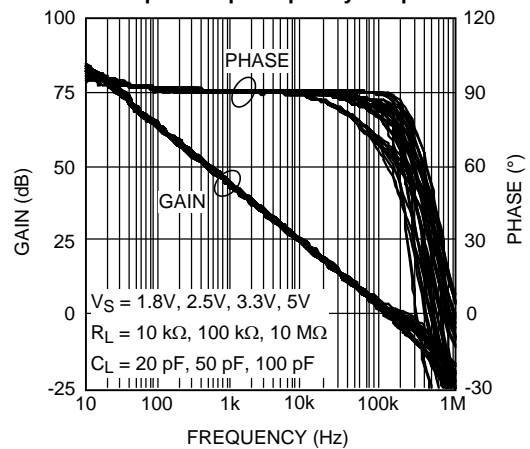


Figure 37.

Typical Performance Characteristics (continued)

Unless otherwise Specified:  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{V}$ ,  $V_{CM} = V_S/2$ , where  $V_S = V^+ - V^-$

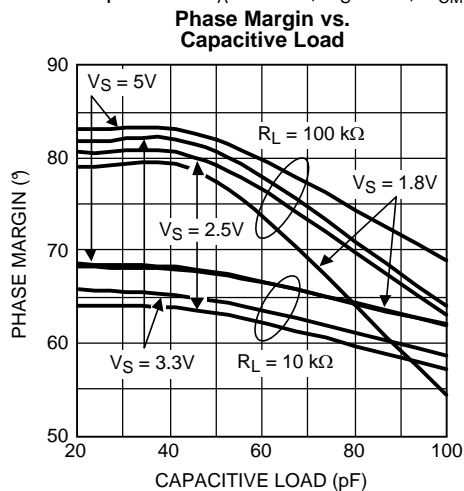


Figure 38.

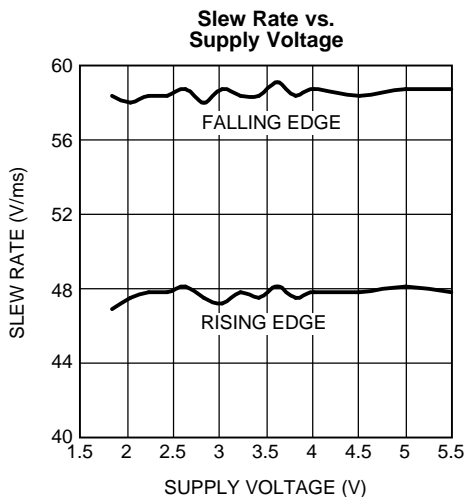


Figure 39.

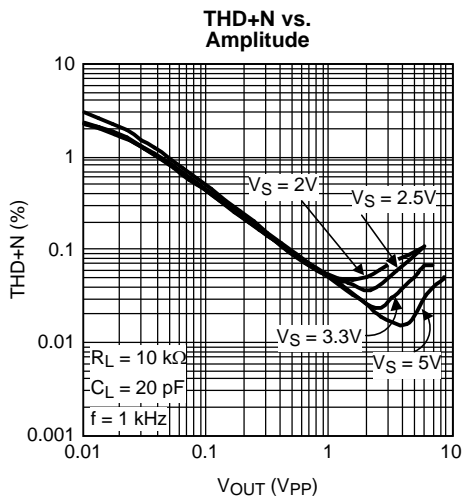


Figure 40.

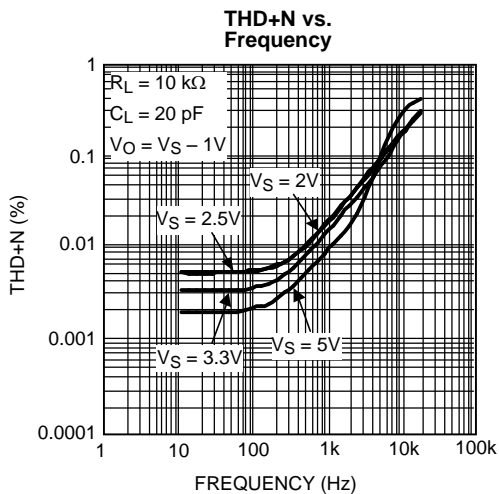


Figure 41.

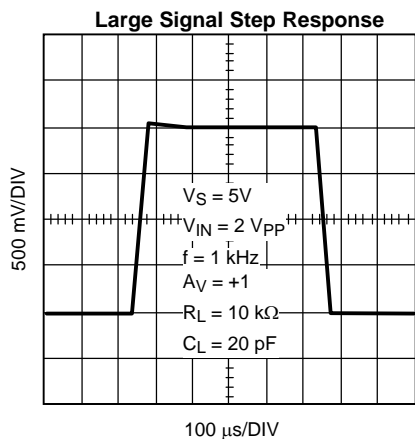


Figure 42.

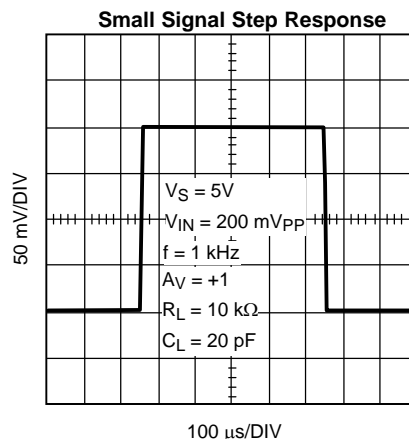


Figure 43.

**Typical Performance Characteristics (continued)**

Unless otherwise Specified:  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{V}$ ,  $V_{CM} = V_S/2$ , where  $V_S = V^+ - V^-$

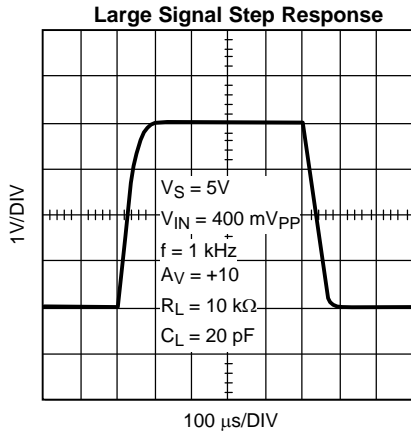


Figure 44.

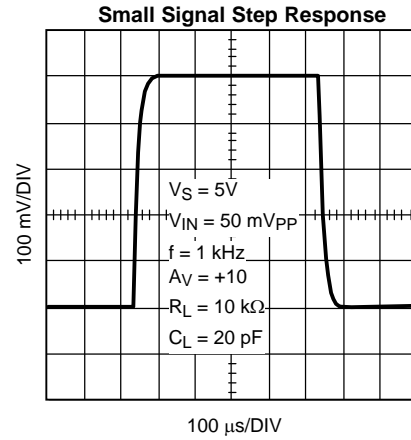


Figure 45.

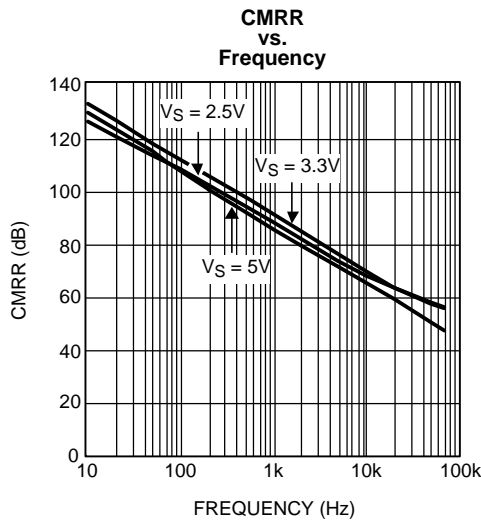


Figure 46.

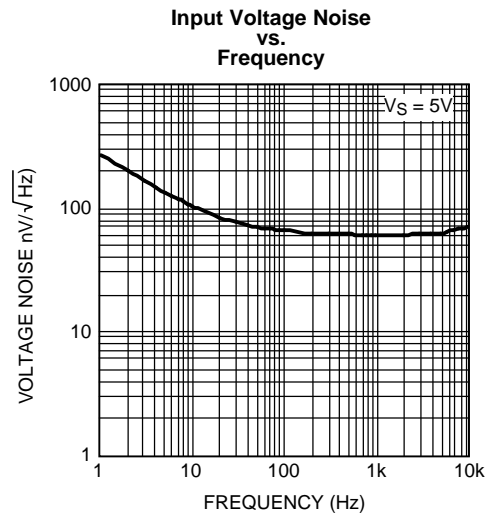


Figure 47.

## APPLICATION INFORMATION

### LMP2231

The LMP2231 is a single CMOS precision amplifier that offer low offset voltage and low offset voltage drift, and high gain while only consuming 10  $\mu\text{A}$  of current per channel.

The LMP2231 is a micropower op amp, consuming only 10  $\mu\text{A}$  of current. Micropower op amps extend the run time of battery powered systems and reduce energy consumption in energy limited systems. The ensured supply voltage range of 1.8V to 5.0V along with the ultra-low supply current extend the battery run time in two ways. The extended ensured power supply voltage range of 1.8V to 5.0V enables the op amp to function when the battery voltage has depleted from its nominal value down to 1.8V. In addition, the lower power consumption increases the life of the battery.

The LMP2231 has an input referred offset voltage of only  $\pm 150 \mu\text{V}$  maximum at room temperature. This offset is ensured to be less than  $\pm 230 \mu\text{V}$  over temperature. This minimal offset voltage along with very low  $\text{TCV}_{\text{OS}}$  of only  $0.3 \mu\text{V}/^\circ\text{C}$  typical allows more accurate signal detection and amplification in precision applications.

The low input bias current of only  $\pm 20 \text{ fA}$  gives the LMP2231 superiority for use in high impedance sensor applications. Bias Current of an amplifier flows through source resistance of the sensor and the voltage resulting from this current flow appears as a noise voltage on the input of the amplifier. The low input bias current enables the LMP2231 to interface with high impedance sensors while generating negligible voltage noise. Thus the LMP2231 provides better signal fidelity and a higher signal-to-noise ration when interfacing with high impedance sensors.

Texas Instruments is heavily committed to precision amplifiers and the market segment they serve. Technical support and extensive characterization data is available for sensitive applications or applications with a constrained error budget.

The operating supply voltage range of 1.8V to 5.5V over the extensive temperature range of  $-40^\circ\text{C}$  to  $125^\circ\text{C}$  makes the LMP2231 an excellent choice for low voltage precision applications with extensive temperature requirements.

The LMP2231 is offered in the space saving 5-Pin SOT-23 and 8-pin SOIC package. These small packages are ideal solutions for area constrained PC boards and portable electronics.

### TOTAL NOISE CONTRIBUTION

The LMP2231 has a very low input bias current, very low input current noise, and low input voltage noise for micropower amplifier. As a result, this amplifier makes a great choice for circuits with high impedance sensor applications.

**Figure 48** shows the typical input noise of the LMP2231 as a function of source resistance where:

$e_n$  denotes the input referred voltage noise

$e_i$  is the voltage drop across source resistance due to input referred current noise or  $e_i = R_S * i_n$

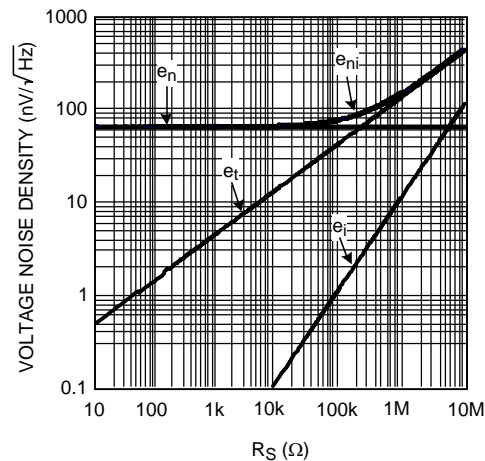
$e_t$  shows the thermal noise of the source resistance

$e_{ni}$  shows the total noise on the input.

Where:

$$e_{ni} = \sqrt{e_n^2 + e_i^2 + e_t^2}$$

The input current noise of the LMP2231 is so low that it will not become the dominant factor in the total noise unless source resistance exceeds 300  $\text{M}\Omega$ , which is an unrealistically high value. As is evident in **Figure 48**, at lower  $R_S$  values, total noise is dominated by the amplifier's input voltage noise. Once  $R_S$  is larger than a 100  $\text{k}\Omega$ , then the dominant noise factor becomes the thermal noise of  $R_S$ . As mentioned before, the current noise will not be the dominant noise factor for any practical application.



**Figure 48. Total Input Noise**

### VOLTAGE NOISE REDUCTION

The LMP2231 has an input voltage noise of  $60 \text{ nV}/\sqrt{\text{Hz}}$ . While this value is very low for micropower amplifiers, this input voltage noise can be further reduced by placing  $N$  amplifiers in parallel as shown in Figure 49. The total voltage noise on the output of this circuit is divided by the square root of the number of amplifiers used in this parallel combination. This is because each individual amplifier acts as an independent noise source, and the average noise of independent sources is the quadrature sum of the independent sources divided by the number of sources. For  $N$  identical amplifiers, this means:

$$\begin{aligned}
 \text{REDUCED INPUT VOLTAGE NOISE} &= \frac{1}{N} \sqrt{e_{n1}^2 + e_{n2}^2 + \dots + e_{nN}^2} \\
 &= \frac{1}{N} \sqrt{N e_n^2} = \frac{\sqrt{N}}{N} e_n \\
 &= \frac{1}{\sqrt{N}} e_n
 \end{aligned}$$

Figure 49 shows a schematic of this input voltage noise reduction circuit. Typical resistor values are:  $R_G = 10\Omega$ ,  $R_F = 1 \text{ k}\Omega$ , and  $R_O = 1 \text{ k}\Omega$ .

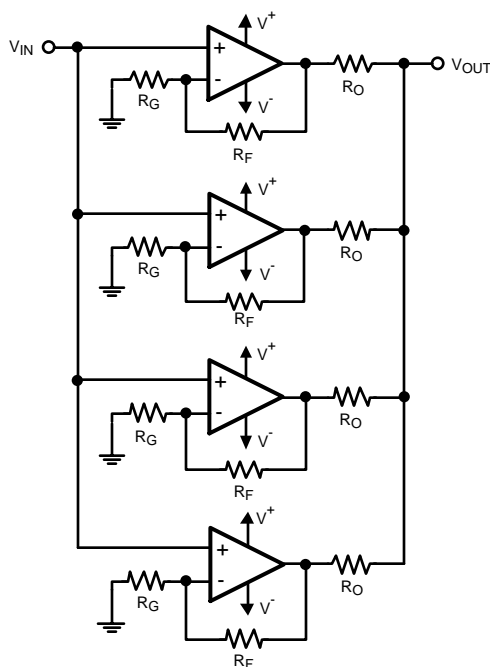


Figure 49. Noise Reduction Circuit

### PRECISION INSTRUMENTATION AMPLIFIER

Measurement of very small signals with an amplifier requires close attention to the input impedance of the amplifier, gain of the overall signal on the inputs, and the gain on each input of the amplifier. This is because the difference of the input signal on the two inputs is of the interest and the common signal is considered noise. A classic circuit implementation is an instrumentation amplifier. Instrumentation amplifiers have a finite, accurate, and stable gain. They also have extremely high input impedances and very low output impedances. Finally they have an extremely high CMRR so that the amplifier can only respond to the differential signal. A typical instrumentation amplifier is shown in Figure 50.

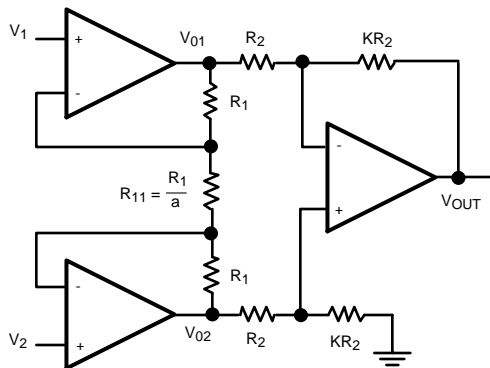


Figure 50. Instrumentation Amplifier

There are two stages in this amplifier. The last stage, output stage, is a differential amplifier. In an ideal case the two amplifiers of the first stage, input stage, would be set up as buffers to isolate the inputs. However they cannot be connected as followers because of mismatch of amplifiers. That is why there is a balancing resistor between the two. The product of the two stages of gain will give the gain of the instrumentation amplifier. Ideally, the CMRR should be infinite. However the output stage has a small non-zero common mode gain which results from resistor mismatch.

In the input stage of the circuit, current is the same across all resistors. This is due to the high input impedance and low input bias current of the LMP2231.

$$\text{GIVEN: } I_{R_1} = I_{R_{11}} \quad (1)$$

By Ohm's Law:

$$\begin{aligned} V_{O1} - V_{O2} &= (2R_1 + R_{11}) I_{R_{11}} \\ &= (2a + 1) R_{11} \cdot I_{R_{11}} \\ &= (2a + 1) V_{R_{11}} \end{aligned} \quad (2)$$

However:

$$V_{R_{11}} = V_1 - V_2 \quad (3)$$

So we have:

$$V_{O1} - V_{O2} = (2a + 1)(V_1 - V_2) \quad (4)$$

Now looking at the output of the instrumentation amplifier:

$$\begin{aligned} V_O &= \frac{KR_2}{R_2} (V_{O2} - V_{O1}) \\ &= -K (V_{O1} - V_{O2}) \end{aligned} \quad (5)$$

Substituting from [Equation 4](#):

$$V_O = -K (2a + 1) (V_1 - V_2) \quad (6)$$

This shows the gain of the instrumentation amplifier to be:

$$-K(2a + 1) \quad (7)$$

Typical values for this circuit can be obtained by setting:  $a = 12$  and  $K = 4$ . This results in an overall gain of  $-100$ .

## SINGLE SUPPLY STRAIN GAGE BRIDGE AMPLIFIER

Strain gauges are popular electrical elements used to measure force or pressure. Strain gauges are subjected to an unknown force which is measured as a the deflection on a previously calibrated scale. Pressure is often measured using the same technique; however this pressure needs to be converted into force using an appropriate transducer. Strain gauges are often resistors which are sensitive to pressure or to flexing. Sense resistor values range from tens of ohms to several hundred kilo ohms. The resistance change which is a result of applied force across the strain gauge might be 1% of its total value. An accurate and reliable system is needed to measure this small resistance change. Bridge configurations offer a reliable method for this measurement.

Bridge sensors are formed of four resistors, connected as a quadrilateral. A voltage source or a current source is used across one of the diagonals to excite the bridge while a voltage detector across the other diagonal measures the output voltage.

Bridges are mainly used as null circuits or to measure a differential voltages. Bridges will have no output voltage if the ratios of two adjacent resistor values are equal. This fact is used in null circuit measurements. These are particularly used in feedback systems which involve electrochemical elements or human interfaces. Null systems force an active resistor, such as a strain gauge, to balance the bridge by influencing the measured parameter.

Often in sensor applications at least one of the resistors is a variable resistor, or a sensor. The deviation of this active element from its initial value is measured as an indication of change in the measured quantity. A change in output voltage represents the sensor value change. Since the sensor value change is often very small, the resulting output voltage is very small in magnitude as well. This requires an extensive and very precise amplification circuitry so that signal fidelity does not change after amplification.

Sensitivity of a bridge is the ratio of its maximum expected output change to the excitation voltage change.

Figure 51 (a) shows a typical bridge sensor and Figure 51(b) shows the bridge with four sensors. R in Figure 51(b) is the nominal value of the sense resistor and the deviations from R are proportional to the quantity being measured.

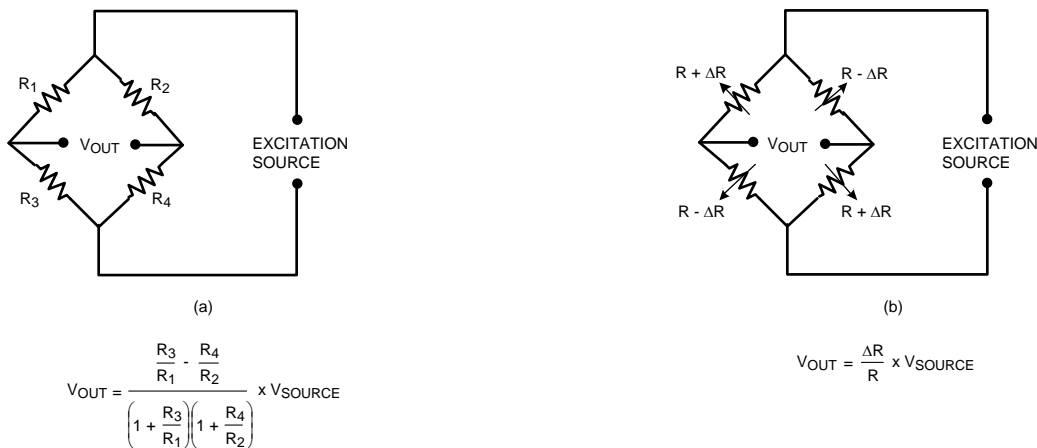


Figure 51. Bridge Sensor

Instrumentation amplifiers are great for interfacing with bridge sensors. Bridge sensors often sense a very small differential signal in the presence of a larger common mode voltage. Instrumentation amplifiers reject this common mode signal.

Figure 52 shows a strain gauge bridge amplifier. In this application the LMP2231 is used to buffer the LM4140's precision output voltage. The LM4140A is a precision voltage reference. The other three LMP2231s are used to form an instrumentation amplifier. This instrumentation amplifier uses the LMP2231's high CMRR and low  $V_{OS}$  and  $TCV_{OS}$  to accurately amplify the small differential signal generated by the output of the bridge sensor. This amplified signal is then fed into the ADC121S021 which is a 12-bit analog to digital converter. This circuit works on a single supply voltage of 5V.

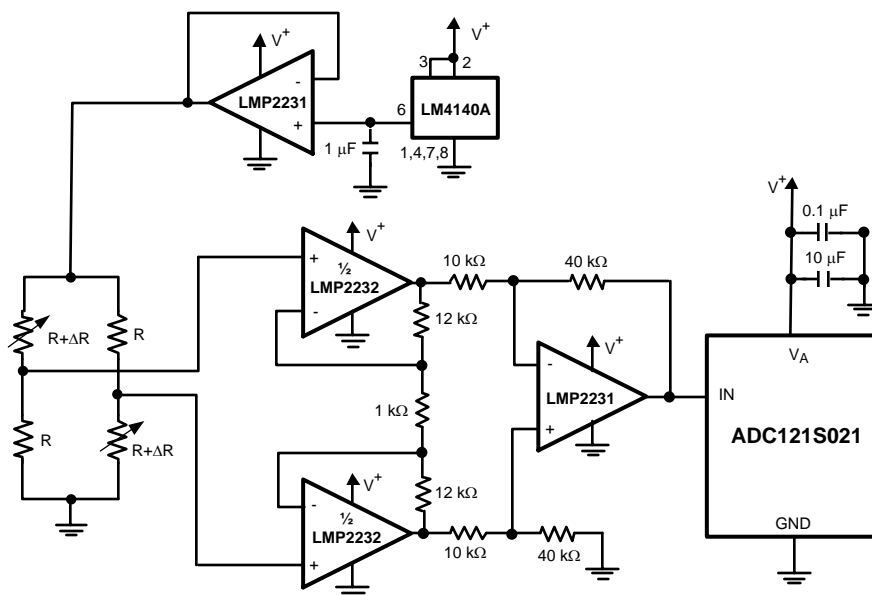


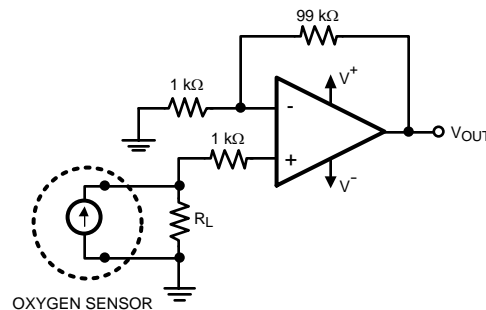
Figure 52. Strain Gauge Bridge Amplifier

## PORTABLE GAS DETECTION SENSOR

Gas sensors are used in many different industrial and medical applications. They generate a current which is proportional to the percentage of a particular gas sensed in an air sample. This current goes through a load resistor and the resulting voltage drop is measured. Depending on the sensed gas and sensitivity of the sensor, the output current can be in the order of tens of microamperes to a few milliamperes. Gas sensor datasheets often specify a recommended load resistor value or they suggest a range of load resistors to choose from.

Oxygen sensors are used when air quality or oxygen delivered to a patient needs to be monitored. Fresh air contains 20.9% oxygen. Air samples containing less than 18% oxygen are considered dangerous. Oxygen sensors are also used in industrial applications where the environment must lack oxygen. An example is when food is vacuum packed. There are two main categories of oxygen sensors, those which sense oxygen when it is abundantly present (i.e. in air or near an oxygen tank) and those which detect traces of oxygen in ppm.

Figure 53 shows a typical circuit used to amplify the output of an oxygen detector. The LMP2231 makes an excellent choice for this application as it only draws 10  $\mu\text{A}$  of current and operates on supply voltages down to 1.8V. This application detects oxygen in air. The oxygen sensor outputs a known current through the load resistor. This value changes with the amount of oxygen present in the air sample. Oxygen sensors usually recommend a particular load resistor value or specify a range of acceptable values for the load resistor. Oxygen sensors typically have a life of one to two years. The use of the micropower LMP2231 means minimal power usage by the op amp and it enhances the battery life. Depending on other components present in the circuit design, the battery could last for the entire life of the oxygen sensor. The precision specifications of the LMP2231, such as its very low offset voltage, low  $\text{TCV}_{\text{OS}}$ , low input bias current, low CMRR, and low PSRR are other factors which make the LMP2231 a great choice for this application.



**Figure 53. Precision Oxygen Sensor**

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**REVISION HISTORY**

<b>Changes from Revision D (March 2013) to Revision E</b>	<b>Page</b>
<hr/> <ul style="list-style-type: none"><li>• Changed layout of National Data Sheet to TI format .....</li></ul>	<hr/> <a href="#">22</a>

**PACKAGING INFORMATION**

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Top-Side Markings (4)	Samples
LMP2231AMA/NOPB	ACTIVE	SOIC	D	8	95	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	LMP22 31AMA	<a href="#">Samples</a>
LMP2231AMAE/NOPB	ACTIVE	SOIC	D	8	250	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	LMP22 31AMA	<a href="#">Samples</a>
LMP2231AMAX/NOPB	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	LMP22 31AMA	<a href="#">Samples</a>
LMP2231AMF/NOPB	ACTIVE	SOT-23	DBV	5	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	AL5A	<a href="#">Samples</a>
LMP2231AMFE/NOPB	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	AL5A	<a href="#">Samples</a>
LMP2231AMFX/NOPB	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	AL5A	<a href="#">Samples</a>
LMP2231BMA/NOPB	ACTIVE	SOIC	D	8	95	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	LMP22 31BMA	<a href="#">Samples</a>
LMP2231BMAE/NOPB	ACTIVE	SOIC	D	8	250	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	LMP22 31BMA	<a href="#">Samples</a>
LMP2231BMAX/NOPB	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	LMP22 31BMA	<a href="#">Samples</a>
LMP2231BMF/NOPB	ACTIVE	SOT-23	DBV	5	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	AL5B	<a href="#">Samples</a>
LMP2231BMFE/NOPB	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	AL5B	<a href="#">Samples</a>
LMP2231BMFX/NOPB	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	AL5B	<a href="#">Samples</a>

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

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**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

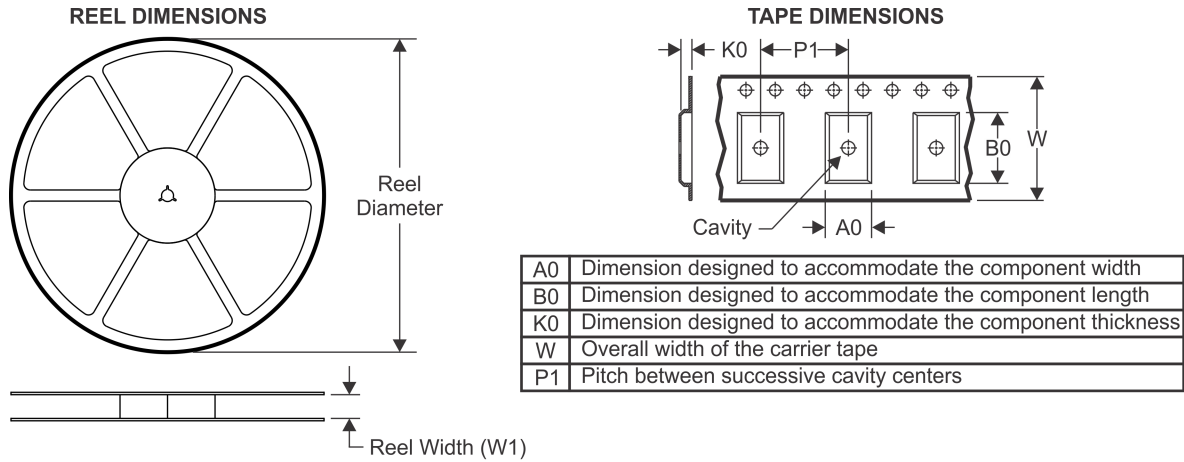
**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

<sup>(3)</sup> MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

<sup>(4)</sup> Multiple Top-Side Markings will be inside parentheses. Only one Top-Side Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Top-Side Marking for that device.

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**TAPE AND REEL INFORMATION**

**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LMP2231AMAE/NOPB	SOIC	D	8	250	178.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1
LMP2231AMAX/NOPB	SOIC	D	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1
LMP2231AMF/NOPB	SOT-23	DBV	5	1000	178.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
LMP2231AMFE/NOPB	SOT-23	DBV	5	250	178.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
LMP2231AMFX/NOPB	SOT-23	DBV	5	3000	178.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
LMP2231BMAE/NOPB	SOIC	D	8	250	178.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1
LMP2231BMAX/NOPB	SOIC	D	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1
LMP2231BMF/NOPB	SOT-23	DBV	5	1000	178.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
LMP2231BMFE/NOPB	SOT-23	DBV	5	250	178.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
LMP2231BMFX/NOPB	SOT-23	DBV	5	3000	178.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3

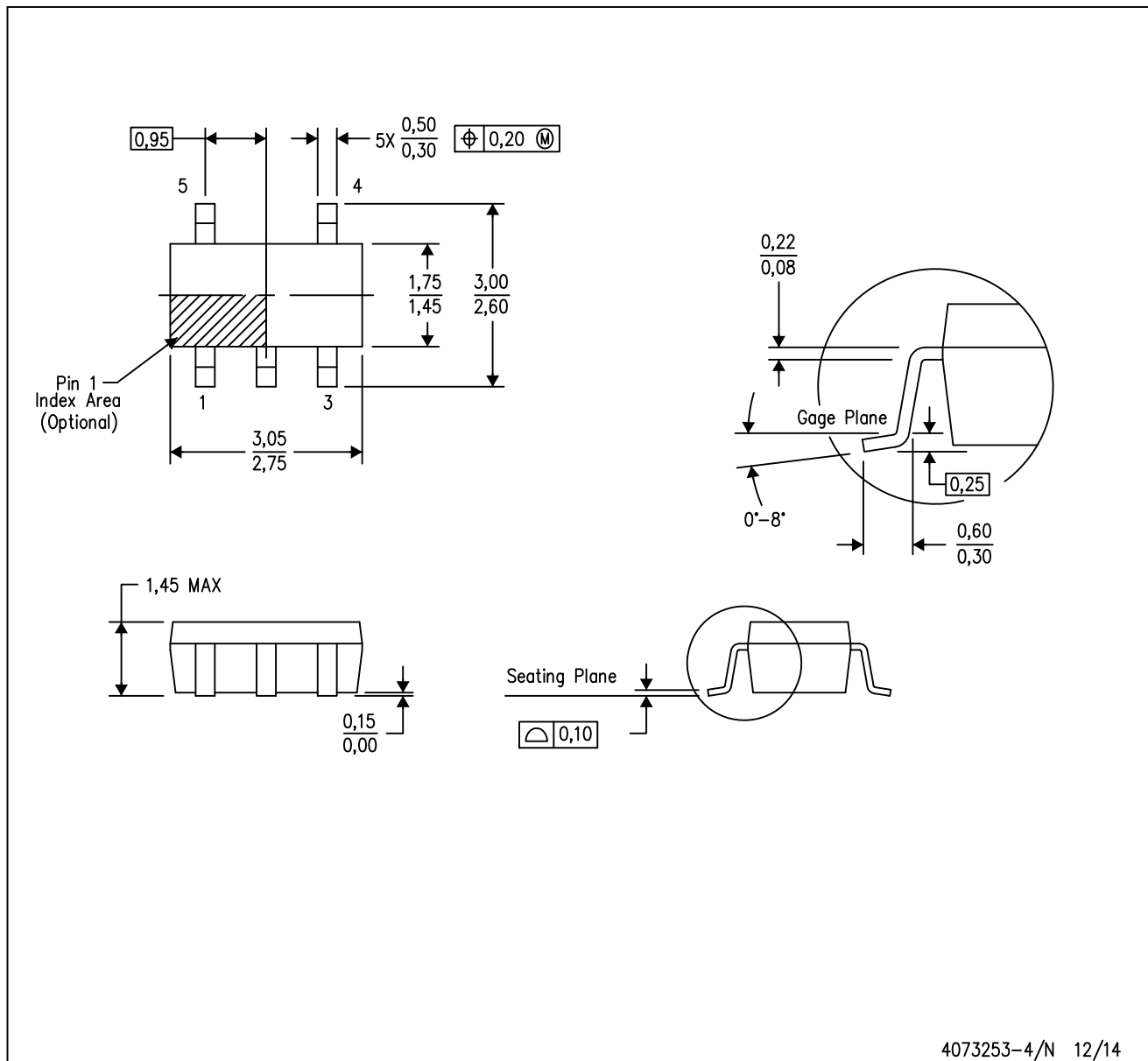
**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LMP2231AMAE/NOPB	SOIC	D	8	250	210.0	185.0	35.0
LMP2231AMAX/NOPB	SOIC	D	8	2500	367.0	367.0	35.0
LMP2231AMF/NOPB	SOT-23	DBV	5	1000	210.0	185.0	35.0
LMP2231AMFE/NOPB	SOT-23	DBV	5	250	210.0	185.0	35.0
LMP2231AMFX/NOPB	SOT-23	DBV	5	3000	210.0	185.0	35.0
LMP2231BMAE/NOPB	SOIC	D	8	250	210.0	185.0	35.0
LMP2231BMAX/NOPB	SOIC	D	8	2500	367.0	367.0	35.0
LMP2231BMF/NOPB	SOT-23	DBV	5	1000	210.0	185.0	35.0
LMP2231BMFE/NOPB	SOT-23	DBV	5	250	210.0	185.0	35.0
LMP2231BMFX/NOPB	SOT-23	DBV	5	3000	210.0	185.0	35.0

DBV (R-PDSO-G5)

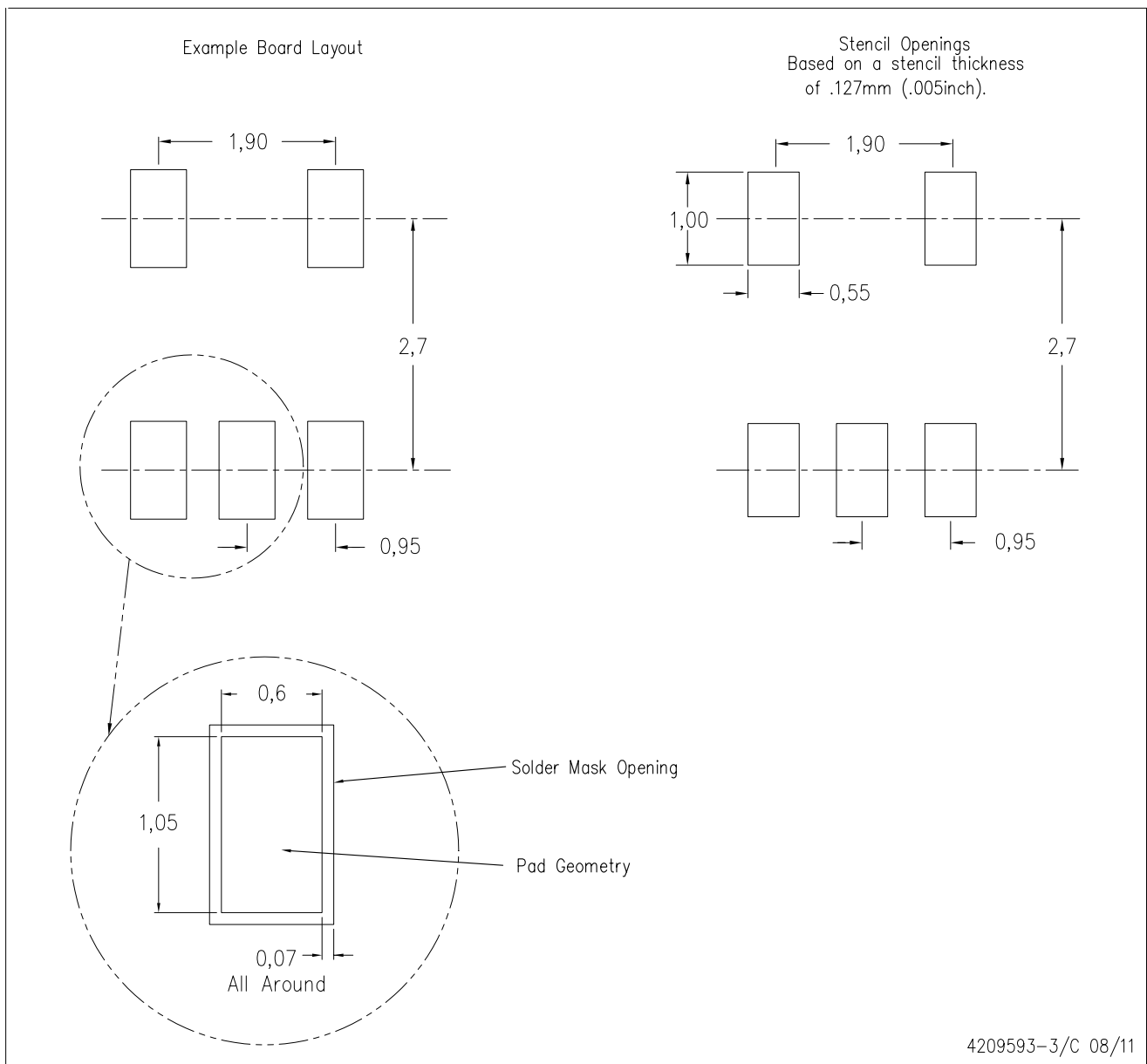
PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
  - D. Falls within JEDEC MO-178 Variation AA.

DBV (R-PDSO-G5)

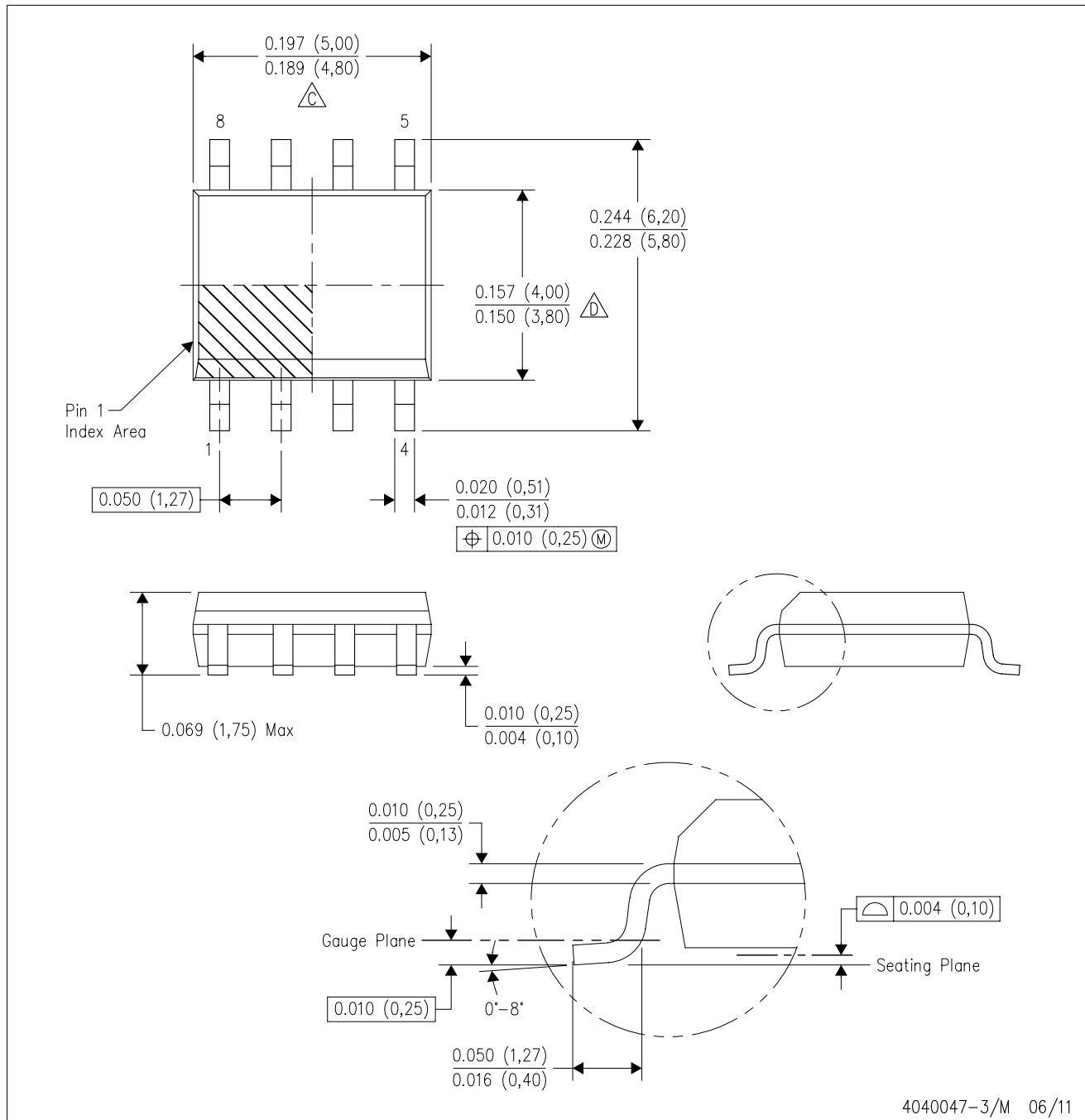
PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
  - D. Publication IPC-7351 is recommended for alternate designs.
  - E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC-7525 for other stencil recommendations.

D (R-PDSO-G8)

PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
  - D. Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
  - E. Reference JEDEC MS-012 variation AA.

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