

LMP2232 Dual Micropower, 1.6V, Precision, Operational Amplifier with CMOS Input

General Description

The LMP2232 is a dual micropower precision amplifier designed for battery powered applications. The 1.6V to 5.5V operating supply voltage range and quiescent power consumption of only 26 μ W extend the battery life in portable systems. The LMP2232 is part of the LMP® precision amplifier family. The high impedance CMOS input makes it ideal for instrumentation and other sensor interface applications.

The LMP2232 has a maximum offset voltage of 150 μ V and maximum offset voltage drift of only 0.5 μ V/°C along with low bias current of only ± 20 fA. These precise specifications make the LMP2232 a great choice for maintaining system accuracy and long term stability.

The LMP2232 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 LMP2232 is ideal for ground sensing in single supply applications.

The LMP2232 is offered in 8-pin SOIC and MSOP packages. The LMP2231 is the single version of this product and the LMP2234 is the quad version of this product. Both of these products are available on National Semiconductor's website.

Features

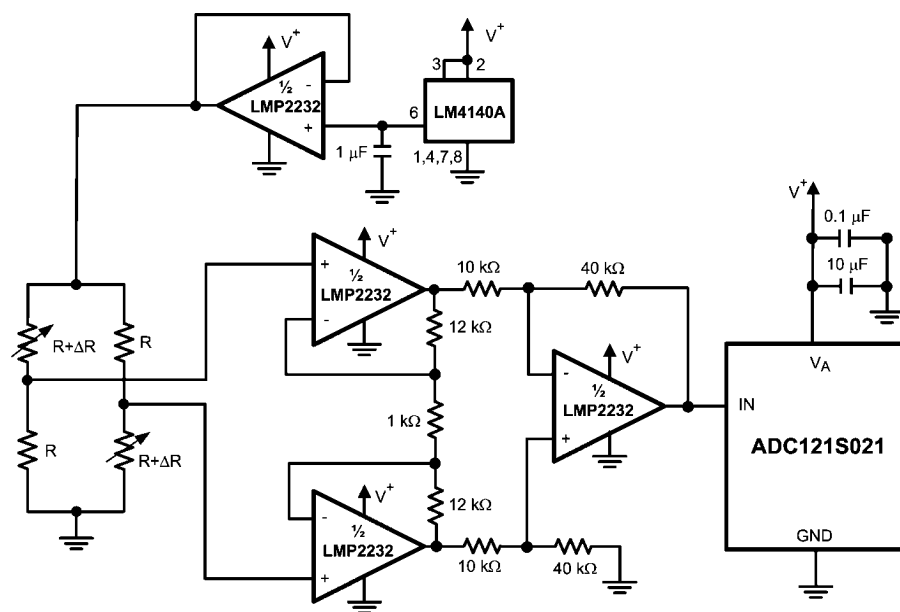
(For $V_S = 5$ V, Typical unless otherwise noted)

■ Supply current at 1.8V	16 μ A
■ Operating voltage range	1.6V to 5.5V
■ Low TCV_{OS}	± 0.5 μ V/°C (max)
■ V_{OS}	± 150 μ 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, $f = 1$ kHz	60 nV/ \sqrt{Hz}
■ Temperature range	-40°C to 125°C

Applications

- Precision instrumentation amplifiers
- Battery powered medical instrumentation
- High impedance sensors
- Strain gauge bridge amplifier
- Thermocouple amplifiers

Typical Application



Strain Gauge Bridge Amplifier

30033974

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	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 (Note 3)	150°C

Mounting Temperature

Infrared or Convection (20 sec.)	+235°C
Wave Soldering Lead Temperature (10 sec.)	+260°C

Operating Ratings (Note 1)

Operating Temperature Range (Note 3)	-40°C to 125°C
Supply Voltage ($V_S = V^+ - V^-$)	1.6V to 5.5V
Package Thermal Resistance (θ_{JA})(Note 3)	
8-Pin SOIC	111.2 °C/W
8-Pin MSOP	147.4 °C/W

5V DC Electrical Characteristics (Note 4)

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

Symbol	Parameter	Conditions	Min (Note 6)	Typ (Note 5)	Max (Note 6)	Units
V_{OS}	Input Offset Voltage			±10	±150 ±230	µV
TCV_{OS}	Input Offset Voltage Drift	LMP2232A		±0.3	±0.5	µV/°C
		LMP2232B		±0.3	±2.5	
I_{BIAS}	Input Bias Current			0.02	±3 ±125	pA
I_{OS}	Input Offset Current			5		fA
CMRR	Common Mode Rejection Ratio	$0V \leq V_{CM} \leq 4V$	81 80	97		dB
PSRR	Power Supply Rejection Ratio	$1.6V \leq V^+ \leq 5.5V$ $V^- = 0V, V_{CM} = 0V$	83 83	120		dB
CMVR	Common Mode Voltage Range	CMRR ≥ 80 dB CMRR ≥ 79 dB	-0.2 -0.2		4.2 4.2	V
A_{VOL}	Large Signal Voltage Gain	$V_O = 0.3V$ to $4.7V$ $R_L = 10\text{ k}\Omega$ to $V^+/2$	110 108	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 50	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 50	
I_O	Output Current (Note 7)	Sourcing, V_O to V^- $V_{IN}(\text{diff}) = 100\text{ mV}$	27 19	30		mA
		Sinking, V_O to V^+ $V_{IN}(\text{diff}) = -100\text{ mV}$	17 12	22		
I_S	Supply Current			19	27 28	µA

5V AC Electrical Characteristics (Note 4)

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

Symbol	Parameter	Conditions	Min (Note 6)	Typ (Note 5)	Max (Note 6)	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 32	58	V/ms
			Rising Edge	33 32	48	
θ_m	Phase Margin	$C_L = 20\text{ pF}, R_L = 10\text{ k}\Omega$		68		deg

Symbol	Parameter	Conditions	Min (Note 6)	Typ (Note 5)	Max (Note 6)	Units
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		μV_{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		%

3.3V DC Electrical Characteristics (Note 4)

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

Symbol	Parameter	Conditions	Min (Note 6)	Typ (Note 5)	Max (Note 6)	Units
V_{OS}	Input Offset Voltage			± 10	± 160 ± 250	μV
TCV_{OS}	Input Offset Voltage Drift	LMP2232A		± 0.3	± 0.5	$\mu\text{V}/^\circ\text{C}$
		LMP2232B		± 0.3	± 2.5	
I_{BIAS}	Input Bias Current			0.02	± 3 ± 125	pA
I_{OS}	Input Offset Current			5		fA
CMRR	Common Mode Rejection Ratio	$0\text{V} \leq V_{CM} \leq 2.3\text{V}$	79 77	92		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 83	120		dB
CMVR	Common Mode Voltage Range	CMRR $\geq 78 \text{ dB}$ CMRR $\geq 77 \text{ dB}$	-0.2 -0.2		2.5 2.5	V
A_{VOL}	Large Signal Voltage Gain	$V_O = 0.3\text{V}$ to 3V $R_L = 10 \text{ k}\Omega$ to $V^+/2$	108 107	120		dB
V_O	Output Swing High	$R_L = 10 \text{ k}\Omega$ to $V^+/2$ $V_{IN}(\text{diff}) = 100 \text{ mV}$		14	50 50	mV from either rail
	Output Swing Low	$R_L = 10 \text{ k}\Omega$ to $V^+/2$ $V_{IN}(\text{diff}) = -100 \text{ mV}$		14	50 50	
I_O	Output Current (Note 7)	Sourcing, V_O to V^- $V_{IN}(\text{diff}) = 100 \text{ mV}$	11 8	14		mA
		Sinking, V_O to V^+ $V_{IN}(\text{diff}) = -100 \text{ mV}$	8 5	11		
I_S	Supply Current			17	25 26	μA

3.3V AC Electrical Characteristics (Note 4)

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

Symbol	Parameter	Conditions	Min (Note 6)	Typ (Note 5)	Max (Note 6)	Units
GBW	Gain-Bandwidth Product	$C_L = 20 \text{ pF}$, $R_L = 10 \text{ k}\Omega$		128		kHz
SR	Slew Rate	$A_V = +1$, $C_L = 20 \text{ pF}$ Falling Edge		58		V/ms
		$R_L = 10 \text{ k}\Omega$ Rising Edge		48		
θ_m	Phase Margin	$C_L = 20 \text{ pF}$, $R_L = 10 \text{ k}\Omega$		66		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		μV_{PP}

Symbol	Parameter	Conditions	Min (Note 6)	Typ (Note 5)	Max (Note 6)	Units
i_n	Input-Referred Current Noise	$f = 1 \text{ kHz}$		10		$\text{fA}/\sqrt{\text{Hz}}$
THD+N	Total Harmonic Distortion + Noise	$f = 100 \text{ Hz}$, $R_L = 10 \text{ k}\Omega$		0.003		%

2.5V DC Electrical Characteristics (Note 4) Unless otherwise specified, all limits guaranteed for $T_A = 25^\circ\text{C}$, $V^+ = 2.5\text{V}$, $V^- = 0\text{V}$, $V_{CM} = V_O = V^+/2$, and $R_L > 1\text{M}\Omega$. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min (Note 6)	Typ (Note 5)	Max (Note 6)	Units
V_{OS}	Input Offset Voltage			± 10	± 190 ± 275	μV
TCV_{OS}	Input Offset Voltage Drift	LMP2232A		± 0.3	± 0.5	$\mu\text{V}/^\circ\text{C}$
		LMP2232B		± 0.3	± 2.5	
I_{Bias}	Input Bias Current			0.02	± 3 ± 125	pA
I_{OS}	Input Offset Current			5		fA
CMRR	Common Mode Rejection Ratio	$0\text{V} \leq V_{CM} \leq 1.5\text{V}$	77 76	91		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 83	120		dB
CMVR	Common Mode Voltage Range	CMRR $\geq 77 \text{ dB}$ CMRR $\geq 76 \text{ dB}$	-0.2 -0.2		1.7 1.7	V
A_{VOL}	Large Signal Voltage Gain	$V_O = 0.3\text{V}$ to 2.2V $R_L = 10 \text{ k}\Omega$ to $V^+/2$	104 104	120		dB
V_O	Output Swing High	$R_L = 10 \text{ k}\Omega$ to $V^+/2$ $V_{IN}(\text{diff}) = 100 \text{ mV}$		12	50 50	mV from either rail
	Output Swing Low	$R_L = 10 \text{ k}\Omega$ to $V^+/2$ $V_{IN}(\text{diff}) = -100 \text{ mV}$		13	50 50	
I_O	Output Current (Note 7)	Sourcing, V_O to V^- $V_{IN}(\text{diff}) = 100 \text{ mV}$	5 4	8		mA
		Sinking, V_O to V^+ $V_{IN}(\text{diff}) = -100 \text{ mV}$	3.5 2.5	7		
I_S	Supply Current			16	24 25	μA

2.5V AC Electrical Characteristics (Note 4) Unless otherwise specified, all limits guaranteed for $T_A = 25^\circ\text{C}$, $V^+ = 2.5\text{V}$, $V^- = 0\text{V}$, $V_{CM} = V_O = V^+/2$, and $R_L > 1\text{M}\Omega$. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min (Note 6)	Typ (Note 5)	Max (Note 6)	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		
θ_m	Phase Margin	$C_L = 20 \text{ pF}$, $R_L = 10 \text{ k}\Omega$		64		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		μV_{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		%

1.8V DC Electrical Characteristics (Note 4)

Unless otherwise specified, all limits guaranteed 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 (Note 6)	Typ (Note 5)	Max (Note 6)	Units
V_{OS}	Input Offset Voltage			± 10	± 230 ± 325	μV
TCV_{OS}	Input Offset Voltage Drift	LMP2232A		± 0.3	± 0.5	$\mu\text{V}/^\circ\text{C}$
		LMP2232B		± 0.3	± 2.5	
I_{BIAS}	Input Bias Current			0.02	± 3 ± 125	pA
I_{OS}	Input Offset Current			5		fA
CMRR	Common Mode Rejection Ratio	$0\text{V} \leq V_{\text{CM}} \leq 0.8\text{V}$	76 75	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 83	120		dB
CMVR	Common Mode Voltage Range	CMRR $\geq 76\text{ dB}$ CMRR $\geq 75\text{ dB}$	-0.2 0		1.0 1.0	V
A_{VOL}	Large Signal Voltage Gain	$V_O = 0.3\text{V}$ to 1.5V $R_L = 10\text{ k}\Omega$ to $V^+/2$	103 103	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 50	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 50	
I_O	Output Current (Note 7)	Sourcing, V_O to V^- $V_{\text{IN}}(\text{diff}) = 100\text{ mV}$	2.5 2	5		mA
		Sinking, V_O to V^+ $V_{\text{IN}}(\text{diff}) = -100\text{ mV}$	2 1.5	5		
I_S	Supply Current			16	24 25	μA

1.8V AC Electrical Characteristics (Note 4)

Unless otherwise is specified, all limits guaranteed 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 (Note 6)	Typ (Note 5)	Max (Note 6)	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		
θ_m	Phase Margin	$C_L = 20\text{ pF}$, $R_L = 10\text{ k}\Omega$		60		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		μV_{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		%

Note 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 guaranteed. For guaranteed specifications and 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: The maximum power dissipation is a function of $T_{J(MAX)}$, θ_{JA} , and T_A . 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.

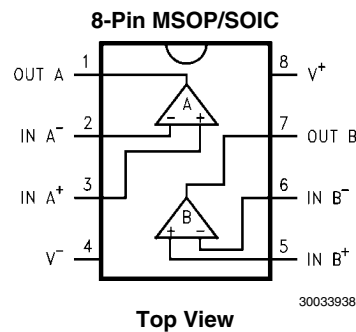
Note 4: Electrical Table values apply only for factory testing conditions at the temperature indicated. Factory testing conditions result in very limited self-heating of the device such that $T_J = T_A$. No guarantee of parametric performance is indicated in the electrical tables under conditions of 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.

Note 5: 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 guaranteed on shipped production material.

Note 6: All limits are guaranteed by testing, statistical analysis or design.

Note 7: The short circuit test is a momentary open loop test.

Connection Diagram



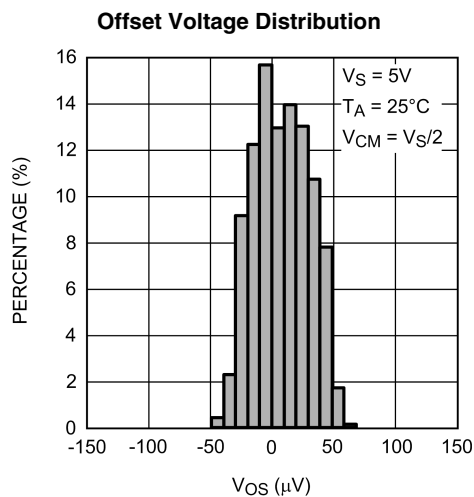
Ordering Information

Package	Part Number	Temperature Range	Package Marking	Transport Media	NSC Drawing
8-Pin SOIC	LMP2232AMA	-40°C to 125°C	LMP2232AMA	95 Units/Rail	M08A
	LMP2232AMAE			250 Units Tape and Reel	
	LMP2232AMAX			2.5k Units Tape and Reel	
	LMP2232BMA		LMP2232BMA	95 Units/Rail	
	LMP2232BMAE			250 Units Tape and Reel	
	LMP2232BMAX			2.5k Units Tape and Reel	
8-Pin MSOP	LMP2232AMM		AK5A	1k Units Tape and Reel	MUA08A
	LMP2232AMME			250 Units Tape and Reel	
	LMP2232AMMX			3.5k Units Tape and Reel	
	LMP2232BMM		AK5B	1k Units Tape and Reel	
	LMP2232BMME			250 Units Tape and Reel	
	LMP2232BMMX			3.5k Units Tape and Reel	

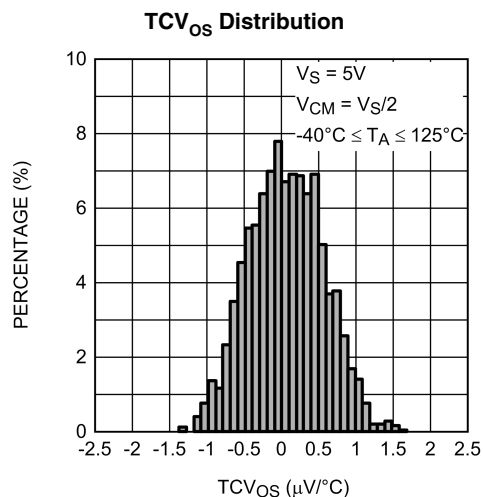
Typical Performance Characteristics

$$V_S = V^+ - V^-$$

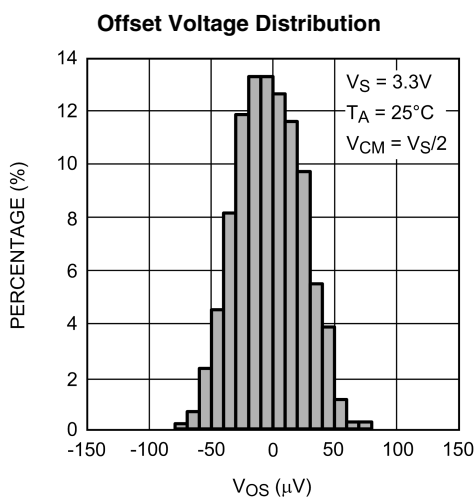
Unless otherwise Specified: $T_A = 25^\circ\text{C}$, $V_S = 5\text{V}$, $V_{CM} = V_S/2$, where



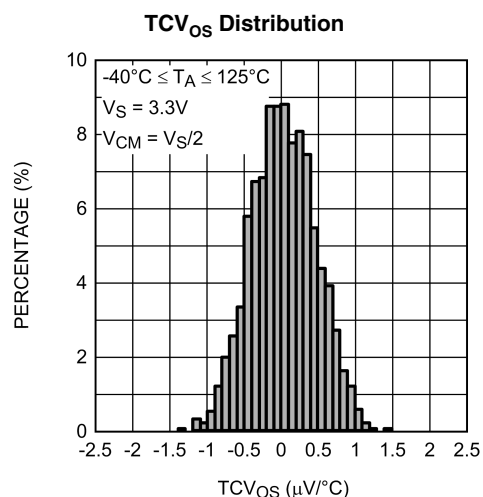
30033907



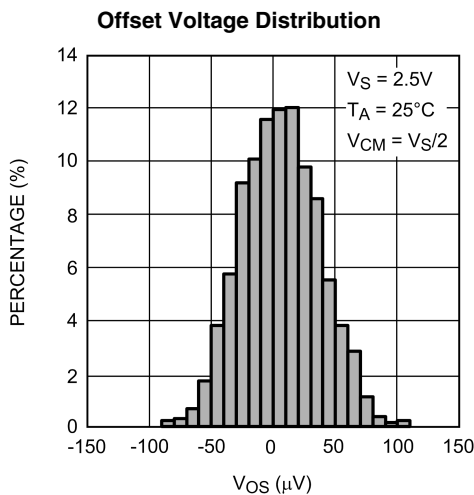
30033911



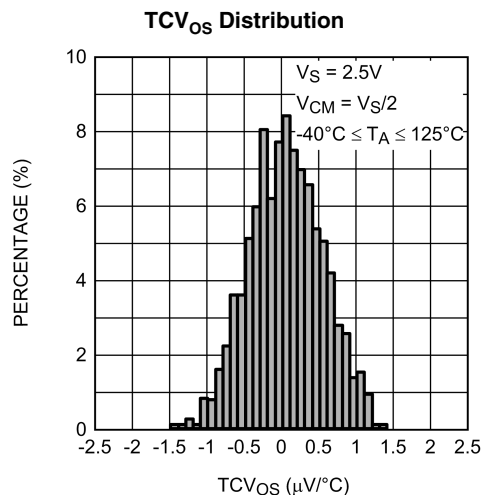
30033906



30033910

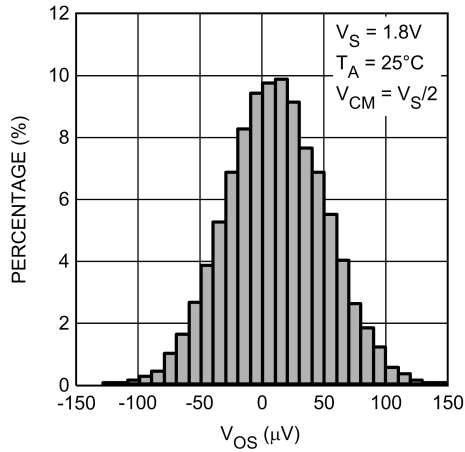


30033905

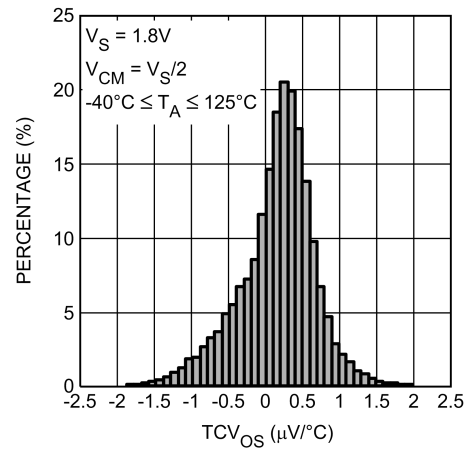


30033909

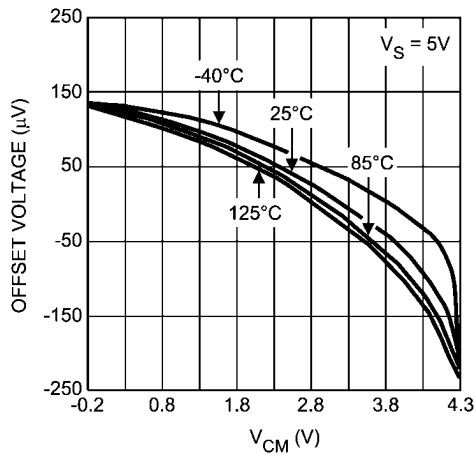
Offset Voltage Distribution



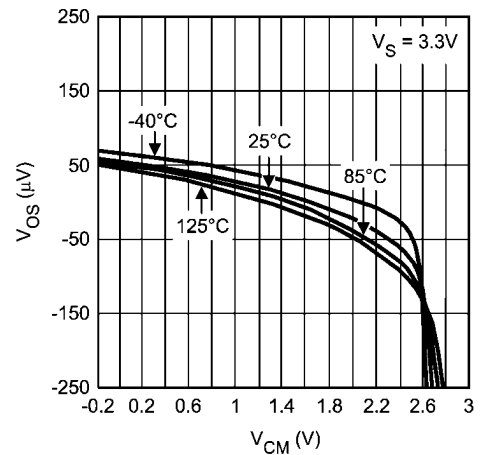
30033973

TCV_{OS} Distribution

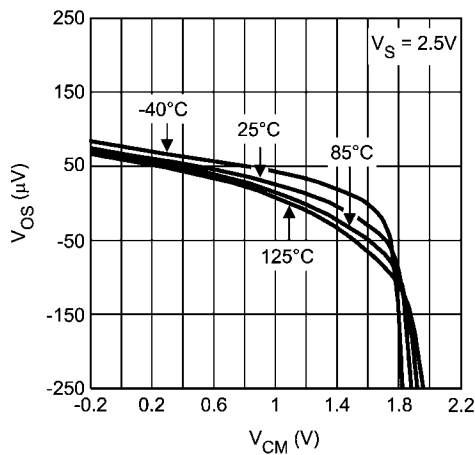
30033969

Offset Voltage vs. V_{CM} 

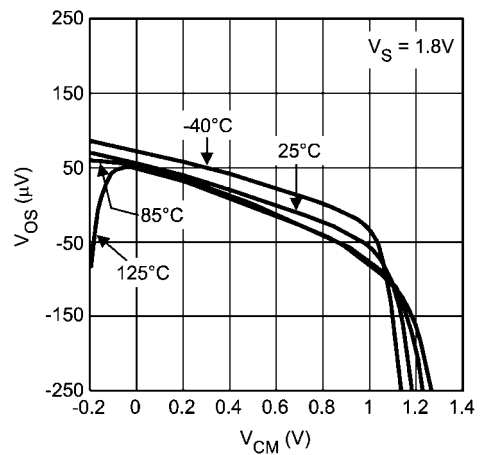
30033918

Offset Voltage vs. V_{CM} 

30033965

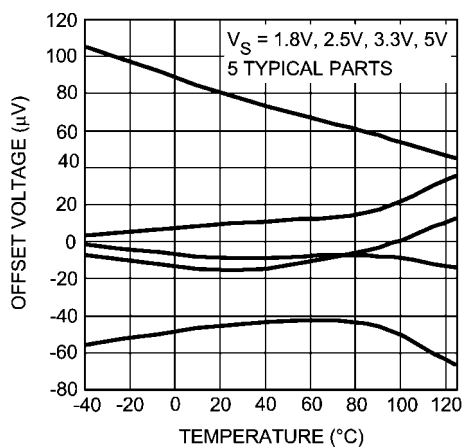
Offset Voltage vs. V_{CM} 

30033964

Offset Voltage vs. V_{CM} 

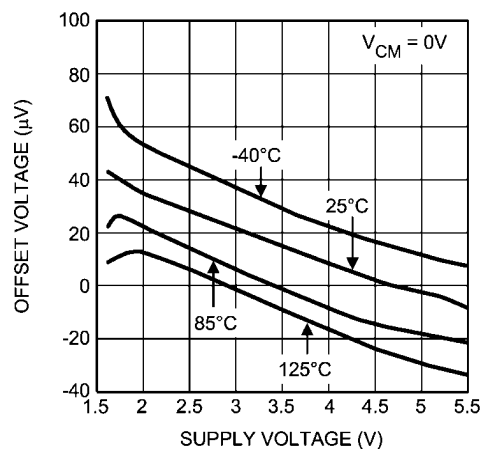
30033972

Offset Voltage vs. Temperature



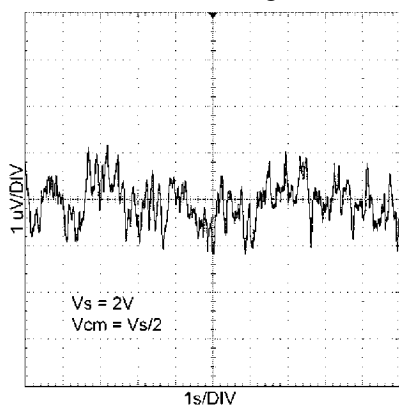
30033971

Offset Voltage vs. Supply Voltage



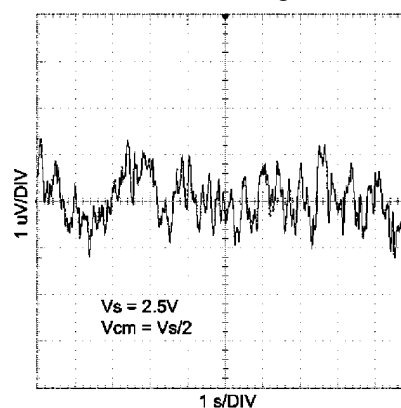
30033970

0.1 Hz to 10 Hz Voltage Noise



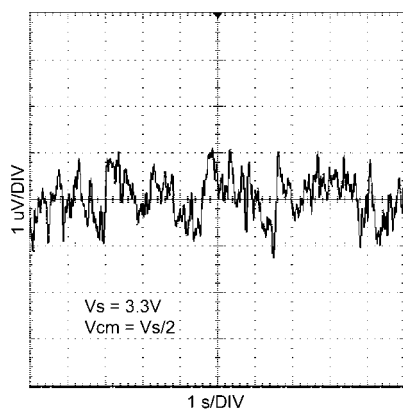
30033933

0.1 Hz to 10 Hz Voltage Noise



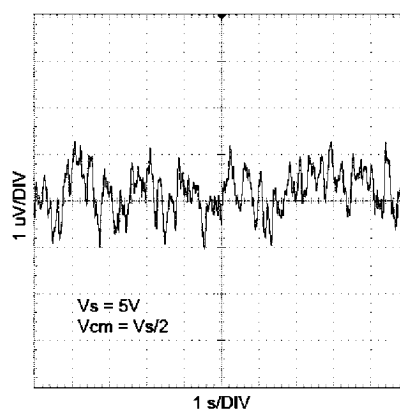
30033934

0.1 Hz to 10 Hz Voltage Noise

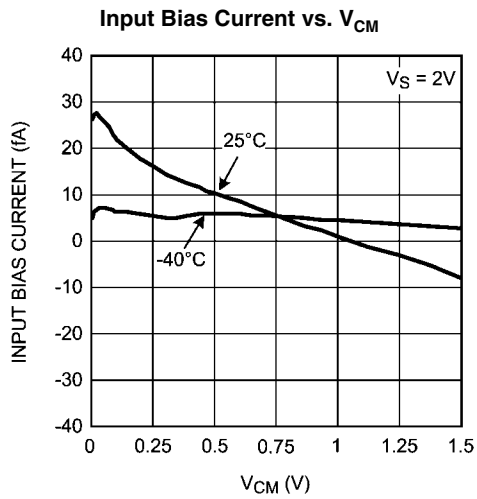


30033932

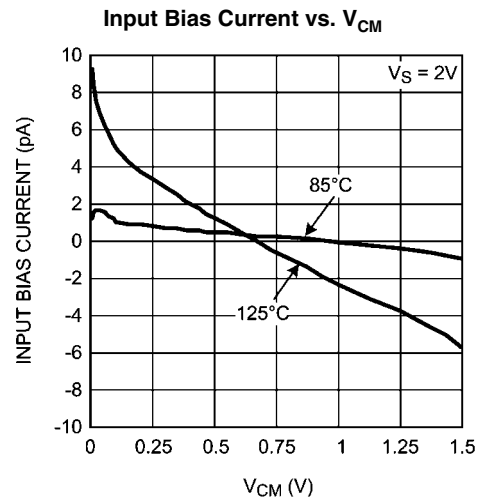
0.1 Hz to 10 Hz Voltage Noise



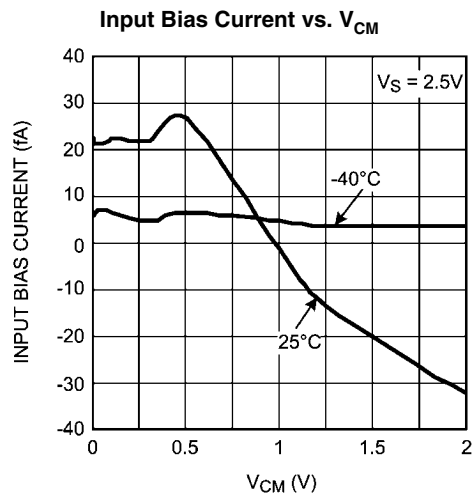
30033931



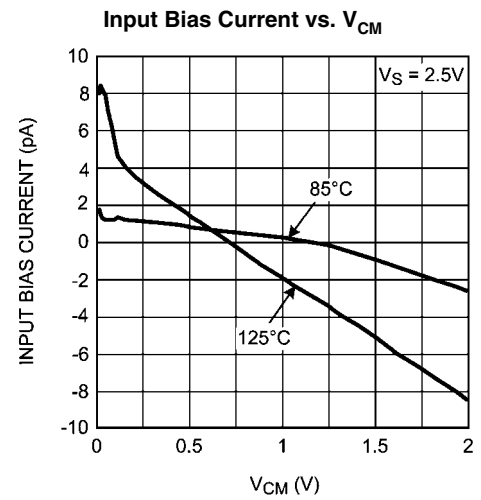
30033955



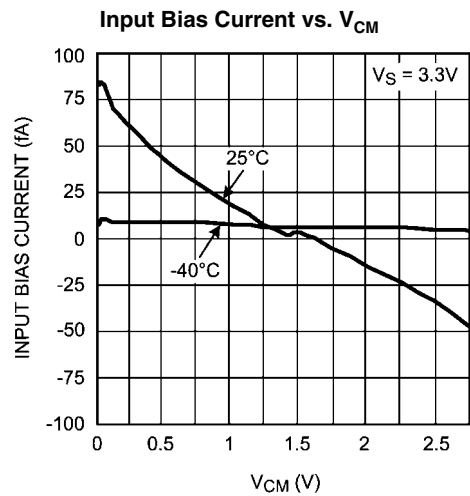
30033956



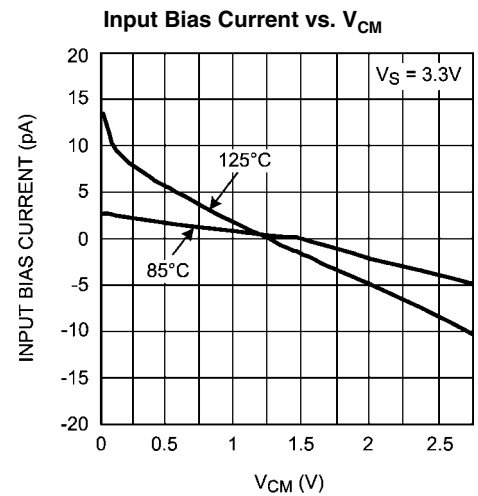
30033957



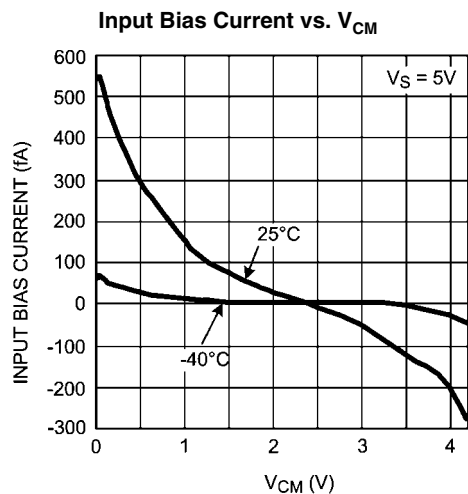
30033958



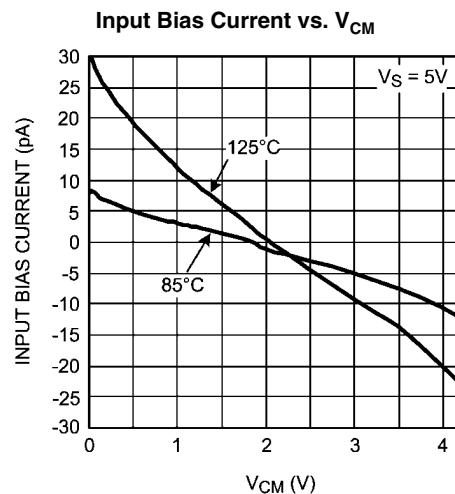
30033959



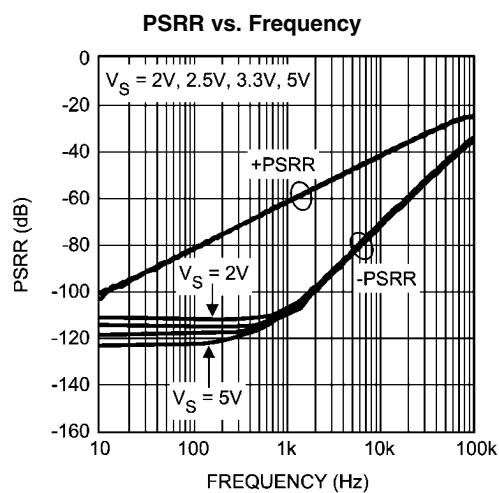
30033960



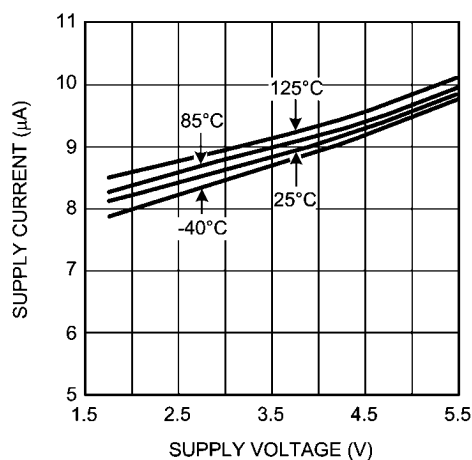
30033961



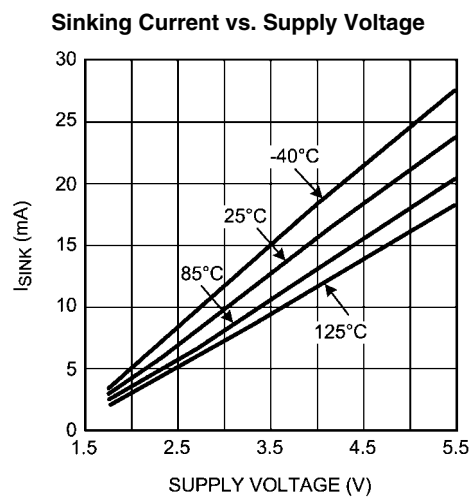
30033962



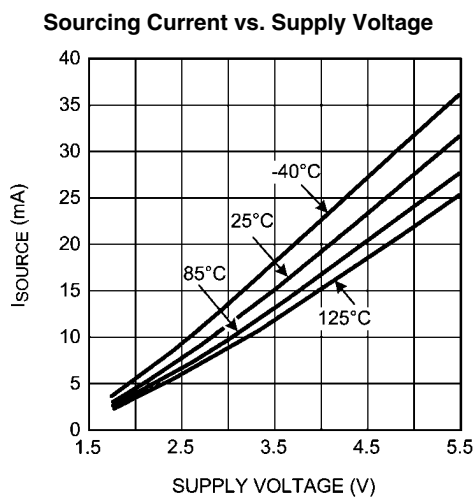
30033966

Supply Current vs. Supply Voltage (per channel)

30033912

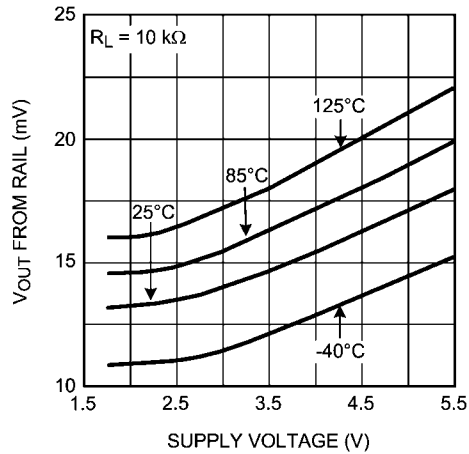


30033913



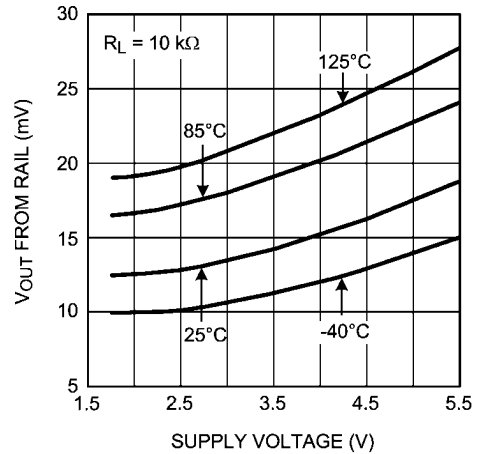
30033914

Output Swing High vs. Supply Voltage



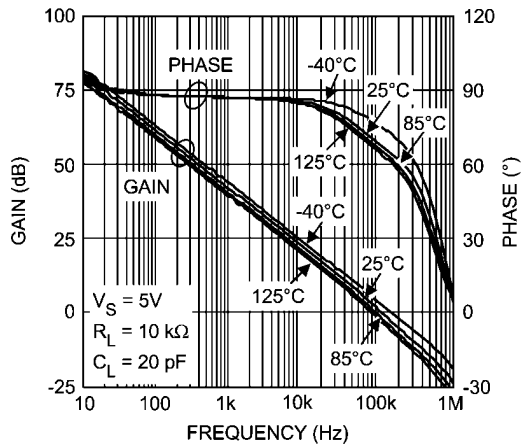
30033915

Output Swing Low vs. Supply Voltage



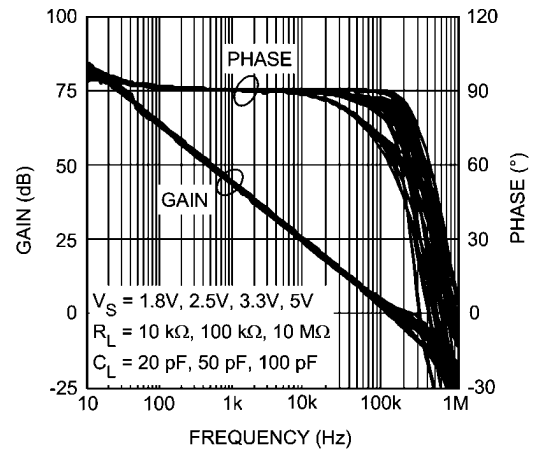
30033916

Open Loop Frequency Response



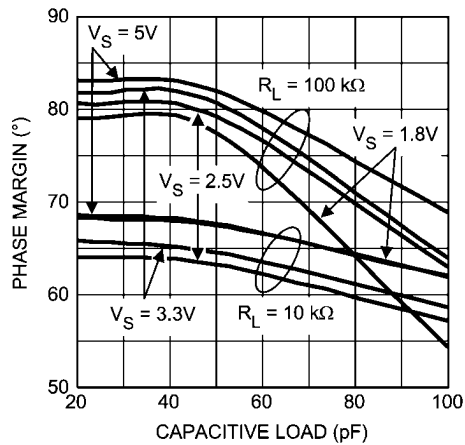
30033921

Open Loop Frequency Response



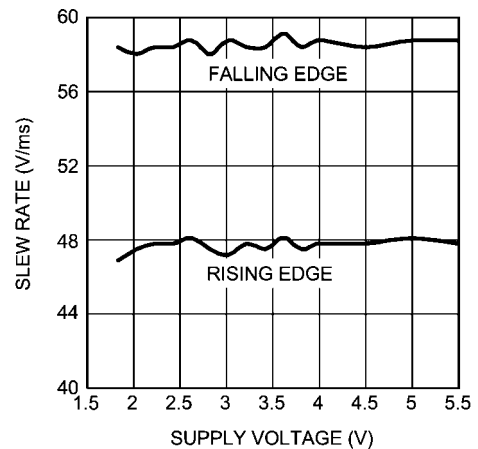
30033922

Phase Margin vs. Capacitive Load

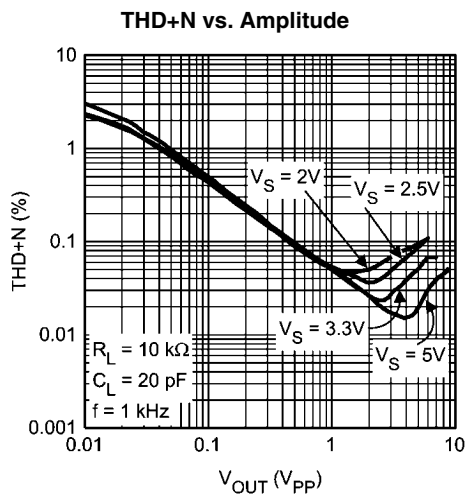


30033963

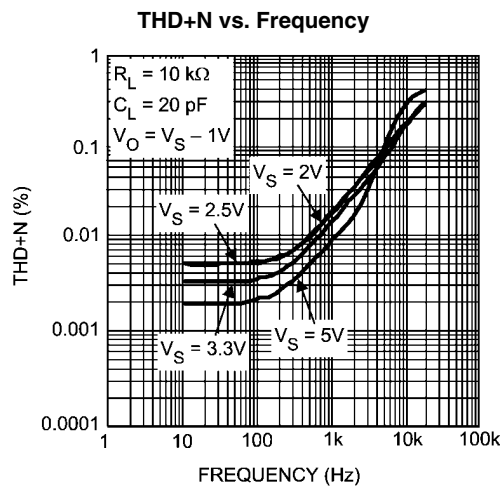
Slew Rate vs. Supply Voltage



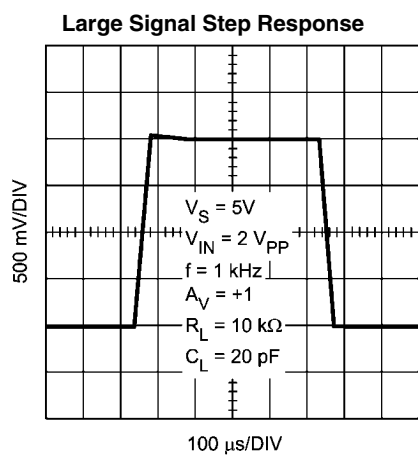
30033930



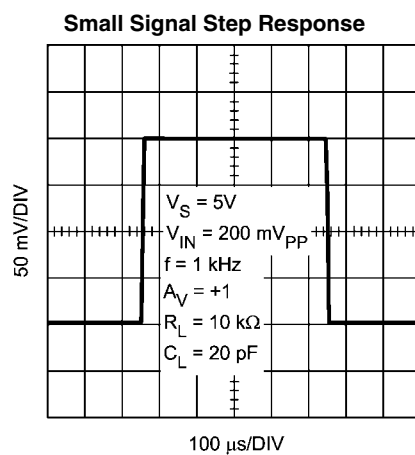
30033928



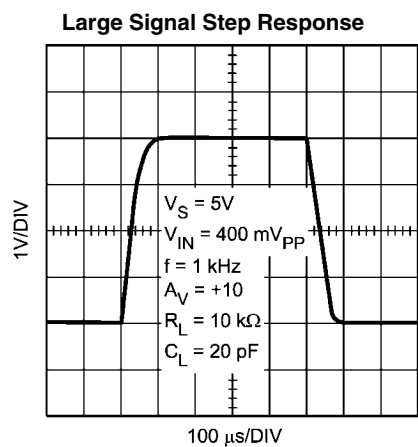
30033929



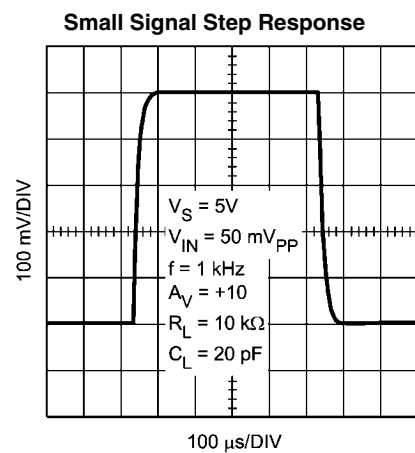
30033924



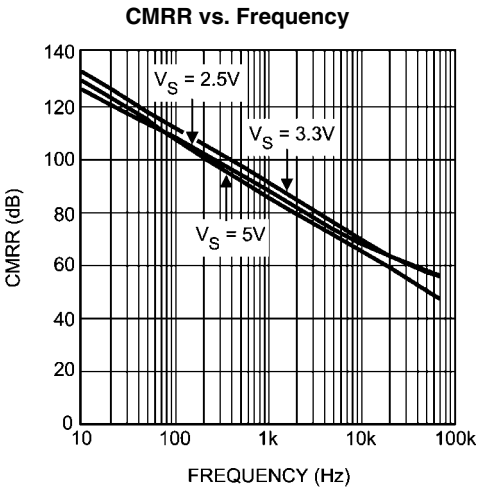
30033923



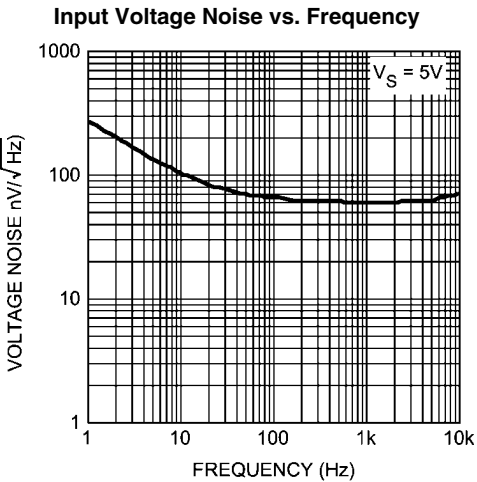
30033926



30033925



30033967



30033919

Application Information

LMP2232

The LMP2232 is a quad CMOS precision amplifier that offers low offset voltage, low offset voltage drift, and high gain while consuming less than 10 μA of supply current per channel.

The LMP2232 is a micropower op amp, consuming only 36 μA of current. Micropower op amps extend the run time of battery powered systems and reduce energy consumption in energy limited systems. The guaranteed 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 guaranteed 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 LMP2232 has input referred offset voltage of only $\pm 150 \mu\text{V}$ maximum at room temperature. This offset is guaranteed to be less than $\pm 230 \mu\text{V}$ over temperature. This minimal offset voltage along with very low TCV_{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 LMP2232 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 LMP2232 to interface with high impedance sensors while generating negligible voltage noise. Thus the LMP2232 provides better signal fidelity and a higher signal-to-noise ratio when interfacing with high impedance sensors.

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

The operating voltage range of 1.6V to 5.5V over the extensive temperature range of -40°C to 125°C makes the LMP2232 an excellent choice for low voltage precision applications with extensive temperature requirements.

The LMP2232 is offered in the 8-pin MSOP and 8-pin SOIC packages. These small packages are ideal solutions for area constrained PC boards and portable electronics.

TOTAL NOISE CONTRIBUTION

The LMP2232 has very low input bias current, very low input current noise, and low input voltage noise for micropower amplifiers. As a result, these amplifiers make great choices for circuits with high impedance sensor applications.

Figure 1 shows the typical input noise of the LMP2232 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 $e_i = R_S \cdot i_n$

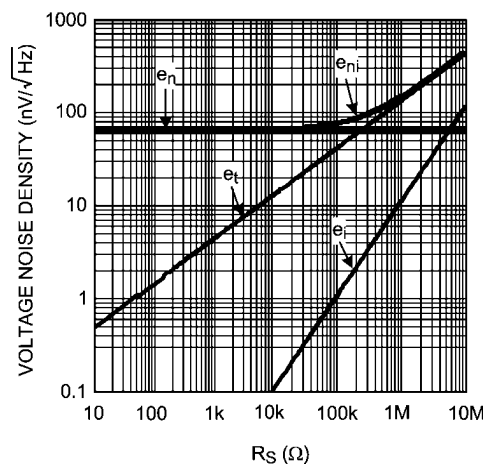
e_t shows the thermal noise of the source resistance

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 LMP2232 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 1, 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.



30033948

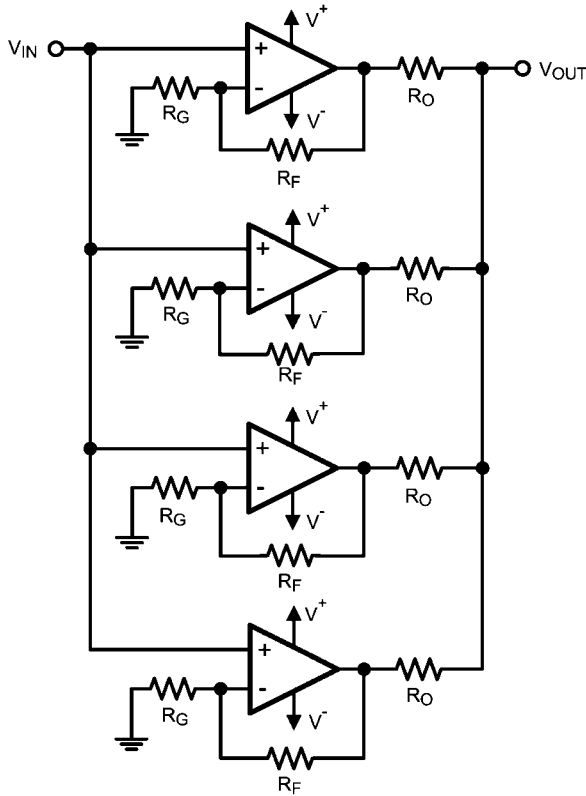
FIGURE 1. Total Input Noise

VOLTAGE NOISE REDUCTION

The LMP2232 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 2. 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 2 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 $R_O = 1\text{ k}\Omega$.

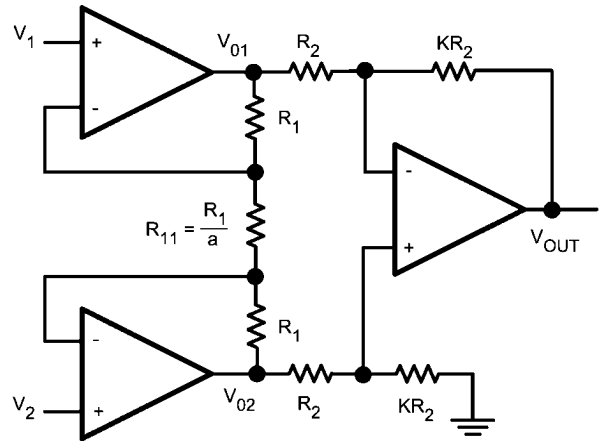


30033946

FIGURE 2. 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 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 3.



30033936

FIGURE 3. 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, the 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 LMP2232.

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

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:

$$-K(2a + 1)$$

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 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.

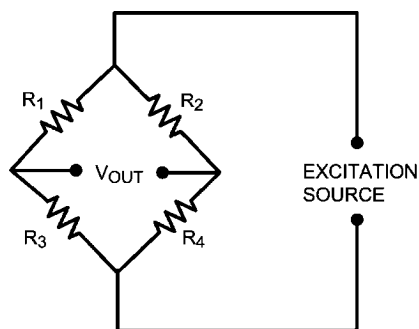
Bridges are mainly used as null circuits or to measure differential voltages. Bridges will have no output voltage if the ratios

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.

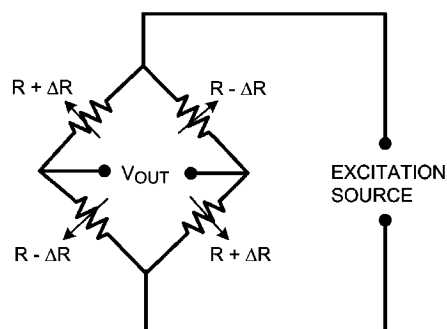
Figure 4(a) shows a typical bridge sensor and Figure 4(b) shows the bridge with four sensors. R in Figure 4(b) is the nominal value of the sense resistor and the deviations from R are proportional to the quantity being measured.



(a)

$$V_{OUT} = \frac{\frac{R_3}{R_1} - \frac{R_4}{R_2}}{\left(1 + \frac{R_3}{R_1}\right)\left(1 + \frac{R_4}{R_2}\right)} \times V_{SOURCE}$$

30033950



(b)

$$V_{OUT} = \frac{\Delta R}{R} \times V_{SOURCE}$$

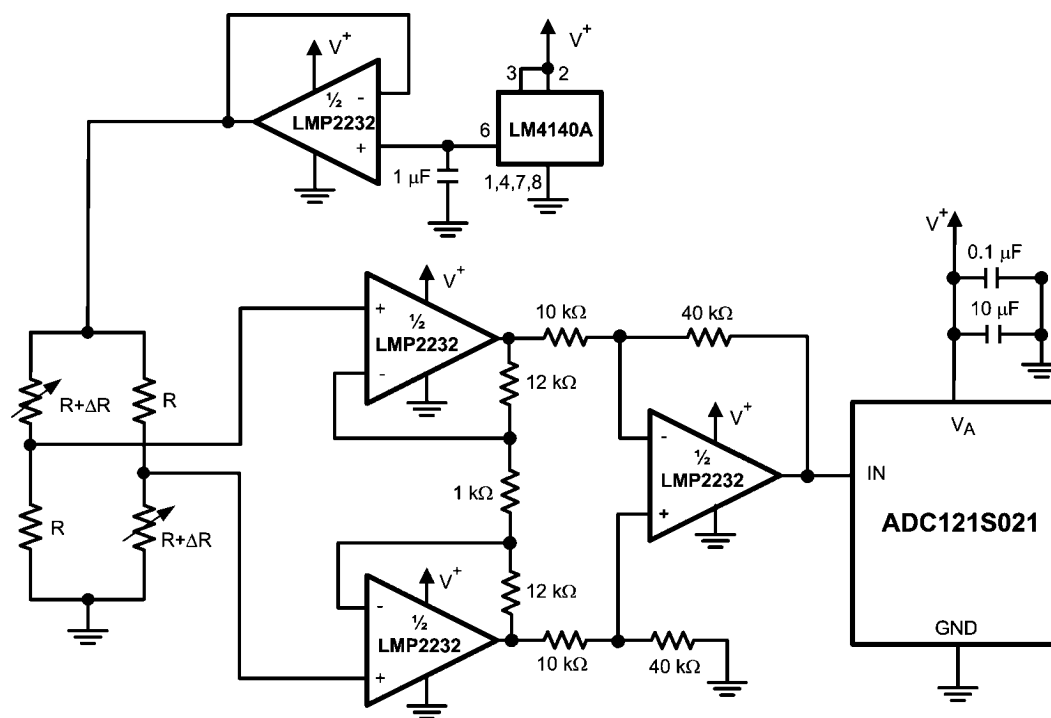
30033951

FIGURE 4. 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 5 shows a strain gauge bridge amplifier. In this application one of the LMP2232 amplifiers is used to buffer the LM4140A's precision output voltage. The LM4140A is a precision voltage reference. The other three amplifiers in the

LMP2232 are used to form an instrumentation amplifier. This instrumentation amplifier uses the LMP2232'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.



30033974

FIGURE 5. Strain Gage Bridge Amplifier

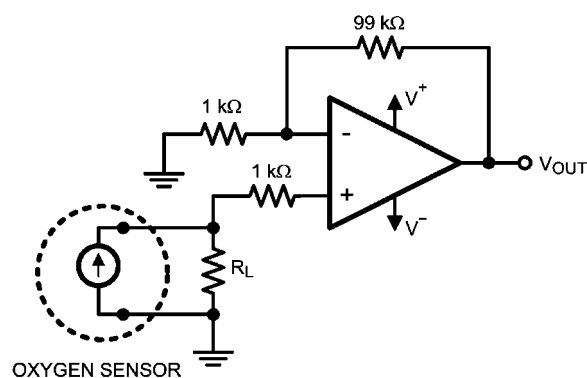
PORTABLE GAS DETECTION SENSOR

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 very small traces of oxygen in ppm.

Figure 6 shows a typical circuit used to amplify the output signal of an oxygen detector. The LMP2232 makes an excellent choice for this application as it draws only 36 μA 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

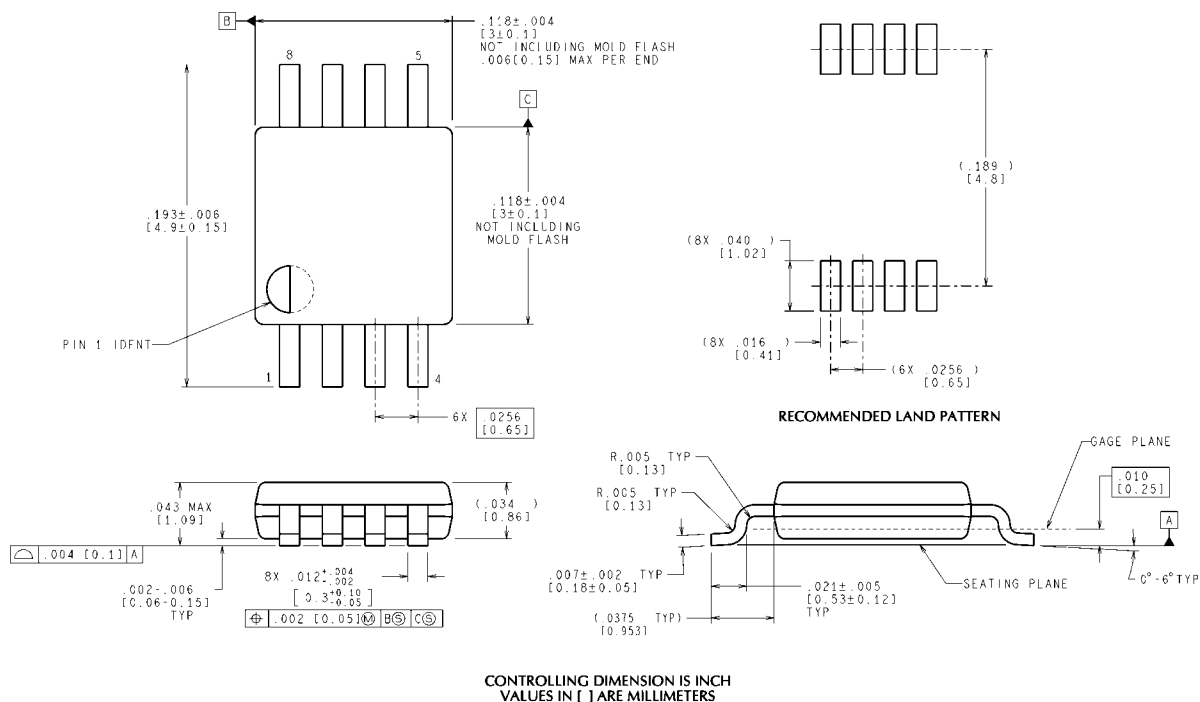
or specify a range of acceptable values for the load resistor. Oxygen sensors typically have a life of one to two years. The use of the micropower LMP2232 means minimal power usage by the op amp and it enhances the battery life. Depending on other components present in the circuit design, the battery could last for the entire life of the oxygen sensor. The precision specifications of the LMP2232, such as its very low offset voltage, low TCV_{OS} , low input bias current, low CMRR, and low PSRR are other factors which make the LMP2232 a great choice for this application..



30033949

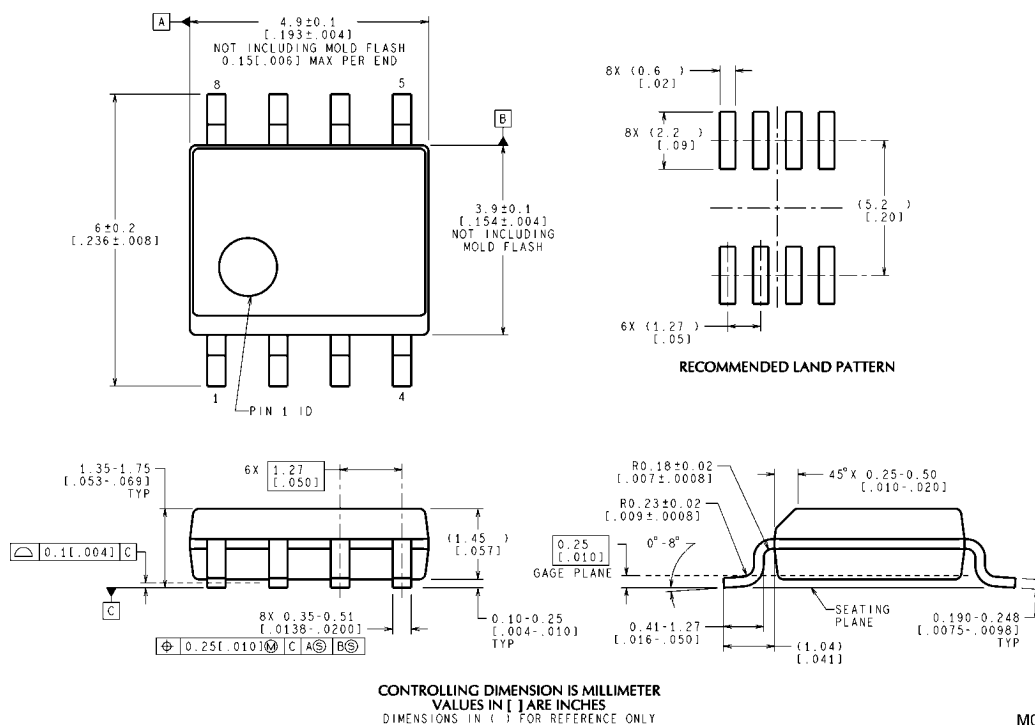
FIGURE 6. Precision Oxygen Sensor

Physical Dimensions inches (millimeters) unless otherwise noted



MUA08A (Rev F)

8-Pin MSOP NS Package Number MUA08A



M08A (Rev L)

8-Pin SOIC NS Package Number M08A

Notes

For more National Semiconductor product information and proven design tools, visit the following Web sites at:

Products		Design Support	
Amplifiers	www.national.com/amplifiers	WEBENCH® Tools	www.national.com/webench
Audio	www.national.com/audio	App Notes	www.national.com/appnotes
Clock and Timing	www.national.com/timing	Reference Designs	www.national.com/refdesigns
Data Converters	www.national.com/adc	Samples	www.national.com/samples
Interface	www.national.com/interface	Eval Boards	www.national.com/evalboards
LVDS	www.national.com/lvds	Packaging	www.national.com/packaging
Power Management	www.national.com/power	Green Compliance	www.national.com/quality/green
Switching Regulators	www.national.com/switchers	Distributors	www.national.com/contacts
LDOs	www.national.com/ldo	Quality and Reliability	www.national.com/quality
LED Lighting	www.national.com/led	Feedback/Support	www.national.com/feedback
Voltage Reference	www.national.com/vref	Design Made Easy	www.national.com/easy
PowerWise® Solutions	www.national.com/powerwise	Solutions	www.national.com/solutions
Serial Digital Interface (SDI)	www.national.com/sdi	Mil/Aero	www.national.com/milaero
Temperature Sensors	www.national.com/tempsensors	Solar Magic®	www.national.com/solarmagic
Wireless (PLL/VCO)	www.national.com/wireless	Analog University®	www.national.com/AU

THE CONTENTS OF THIS DOCUMENT ARE PROVIDED IN CONNECTION WITH NATIONAL SEMICONDUCTOR CORPORATION ("NATIONAL") PRODUCTS. NATIONAL MAKES NO REPRESENTATIONS OR WARRANTIES WITH RESPECT TO THE ACCURACY OR COMPLETENESS OF THE CONTENTS OF THIS PUBLICATION AND RESERVES THE RIGHT TO MAKE CHANGES TO SPECIFICATIONS AND PRODUCT DESCRIPTIONS AT ANY TIME WITHOUT NOTICE. NO LICENSE, WHETHER EXPRESS, IMPLIED, ARISING BY ESTOPPEL OR OTHERWISE, TO ANY INTELLECTUAL PROPERTY RIGHTS IS GRANTED BY THIS DOCUMENT.

TESTING AND OTHER QUALITY CONTROLS ARE USED TO THE EXTENT NATIONAL DEEMS NECESSARY TO SUPPORT NATIONAL'S PRODUCT WARRANTY. EXCEPT WHERE MANDATED BY GOVERNMENT REQUIREMENTS, TESTING OF ALL PARAMETERS OF EACH PRODUCT IS NOT NECESSARILY PERFORMED. NATIONAL ASSUMES NO LIABILITY FOR APPLICATIONS ASSISTANCE OR BUYER PRODUCT DESIGN. BUYERS ARE RESPONSIBLE FOR THEIR PRODUCTS AND APPLICATIONS USING NATIONAL COMPONENTS. PRIOR TO USING OR DISTRIBUTING ANY PRODUCTS THAT INCLUDE NATIONAL COMPONENTS, BUYERS SHOULD PROVIDE ADEQUATE DESIGN, TESTING AND OPERATING SAFEGUARDS.

EXCEPT AS PROVIDED IN NATIONAL'S TERMS AND CONDITIONS OF SALE FOR SUCH PRODUCTS, NATIONAL ASSUMES NO LIABILITY WHATSOEVER, AND NATIONAL DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY RELATING TO THE SALE AND/OR USE OF NATIONAL PRODUCTS INCLUDING LIABILITY OR WARRANTIES RELATING TO FITNESS FOR A PARTICULAR PURPOSE, MERCHANTABILITY, OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.

LIFE SUPPORT POLICY

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

Life support devices or systems are devices 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. A critical component is any component in 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.

National Semiconductor and the National Semiconductor logo are registered trademarks of National Semiconductor Corporation. All other brand or product names may be trademarks or registered trademarks of their respective holders.

Copyright© 2008 National Semiconductor Corporation

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



**National Semiconductor
Americas Technical
Support Center**
Email: support@nsc.com
Tel: 1-800-272-9959

**National Semiconductor Europe
Technical Support Center**
Email: europe.support@nsc.com
German Tel: +49 (0) 180 5010 771
English Tel: +44 (0) 870 850 4288

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

**National Semiconductor Japan
Technical Support Center**
Email: jpn.feedback@nsc.com