LMP2234 Quad Micropower, 1.6V, Precision, Operational Amplifier with CMOS Input

Check for Samples: LMP2234

FEATURES

(For V_S = 5V, Typical Unless Otherwise Noted)

- **Supply Current at 1.8V 31 μA**
- **Operating Voltage Range 1.6V to 5.5V**
- **Low TCV_{OS} ±0.75 μV/°C (max)**
- **V_{OS} ±150 μV (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/√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**

DESCRIPTION

The LMP2234 is a quad micropower precision amplifier designed for battery powered applications. The 1.6 to 5.5V operating supply voltage range and quiescent power consumption of only 50 μW extend the battery life in portable systems. The LMP2234 is part of the LMP™ precision amplifier family. The high impedance CMOS input makes it ideal for instrumentation and other sensor interface applications.

The LMP2234 has a maximum offset voltage of 150 μV and 0.3 μV/°C offset drift along with low bias current of only ±20 fA. These precise specifications make the LMP2234 a great choice for maintaining system accuracy and long term stability.

The LMP2234 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 LMP2234 is ideal for ground sensing in single supply applications.

The LMP2234 is offered in 14-Pin SOIC and TSSOP packages.

TYPICAL APPLICATION

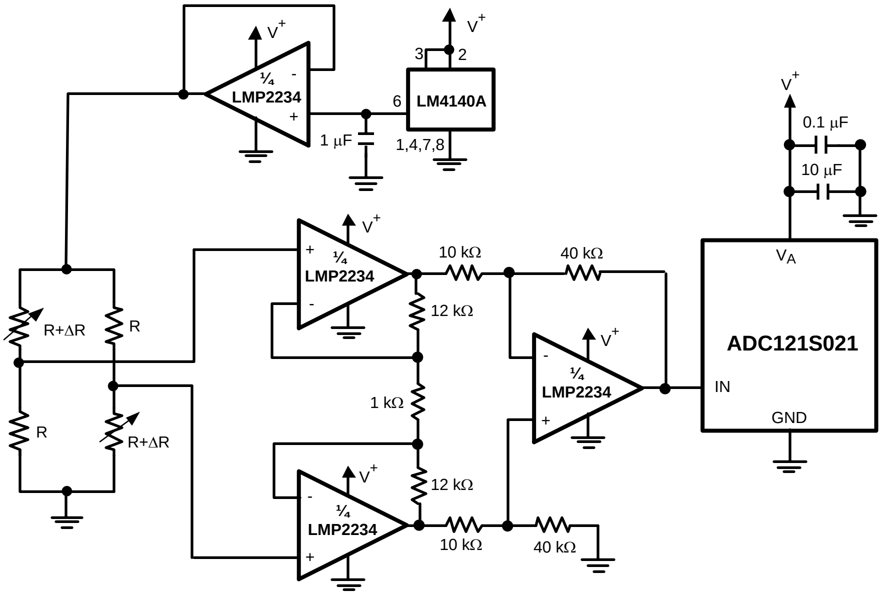

Figure 1. Strain Gauge Bridge Amplifier

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 (1)(2)

ESD Tolerance(3)	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(4)		150°C
Mounting Temperature Infrared or Convection (20 sec.)		+235°C
Wave Soldering Lead Temperature (10 sec.)		+260°C

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

Operating Ratings (1)

Operating Temperature Range (2)		−40°C to 125°C
Supply Voltage ($V_S = V^+ - V^-$)		1.6V to 5.5V
Package Thermal Resistance (θ_{JA}) (2)	14-Pin SOIC	101.5 °C/W
	14-Pin TSSOP	121 °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 $T_{J(MAX)}$, θ_{JA}. The maximum allowable power dissipation at any ambient temperature is $P_D = (T_{J(MAX)} - T_A)/\theta_{JA}$. All numbers apply for packages soldered directly onto a PC Board.

5V DC Electrical Characteristics (1)

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

Symbol	Parameter	Conditions	Min (2)	Typ (3)	Max (2)	Units
V_{OS}	Input Offset Voltage			±10	±150 **±230**	μV
TCV_{OS}	Input Offset Voltage Drift	LMP2234A		±0.3	±0.75	μV/°C
		LMP2234B		±0.3	±2.5	
I_{BIAS}	Input Bias Current			±0.02	±1 **±50**	pA
I_{OS}	Input Offset Current			±5		fA
CMRR	Common Mode Rejection Ratio	$0V \le V_{CM} \le 4V$	81 **80**	97		dB
PSRR	Power Supply Rejection Ratio	$1.6V \le V^+ \le 5.5V$ $V_{CM} = 0V$	83 **82**	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 $R_L = 10\ k\Omega$ to $V^+/2$	110 **108**	120		dB
V_O	Output Swing High	$R_L = 10\ k\Omega$ to $V^+/2$ $V_{IN}(diff) = 100\ mV$		17	50 **50**	mV from either rail
	Output Swing Low	$R_L = 10\ k\Omega$ to $V^+/2$ $V_{IN}(diff) = -100\ mV$		17	50 **50**	
I_O	Output Current (4)	Sourcing, V_O to V^- $V_{IN}(diff) = 100\ mV$	27 **19**	30		mA
		Sinking, V_O to V^+ $V_{IN}(diff) = -100\ mV$	17 **12**	22		
I_S	Supply Current			36	48 **50**	μA

(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 as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration. The typical values are not tested and are not ensured on shipped production material.

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

5V AC Electrical Characteristics(1)

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

Symbol	Parameter	Conditions		Min (2)	Typ (3)	Max (2)	Units
GBWP	Gain Bandwidth Product	$C_L = 20\ pF$, $R_L = 10\ k\Omega$			130		kHz
SR	Slew Rate	$A_V = +1$	Falling Edge	33 **32**	58		V/ms
			Rising Edge	33 **32**	48		
θ_m	Phase Margin	$C_L = 20\ pF$, $R_L = 10\ k\Omega$			68		deg
G_m	Gain Margin	$C_L = 20\ pF$, $R_L = 10\ k\Omega$			27		dB
e_n	Input-Referred Voltage Noise Density	f = 1 kHz			60		$nV/\sqrt{Hz}$
	Input-Referred Voltage Noise	0.1 Hz to 10 Hz			2.3		μV_{PP}
i_n	Input-Referred Current Noise Density	f = 1 kHz			10		$fA/\sqrt{Hz}$
THD+N	Total Harmonic Distortion + Noise	f = 100 Hz, $R_L = 10\ k\Omega$			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.
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3.3V DC Electrical Characteristics(1)

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

Symbol	Parameter	Conditions	Min (2)	Typ (3)	Max (2)	Units
V_{OS}	Input Offset Voltage			±10	±160 **±250**	μV
TCV_{OS}	Input Offset Voltage Drift	LMP2234A		±0.3	±0.75	μV/°C
		LMP2234B		±0.3	±2.5	
I_{BIAS}	Input Bias Current			±0.02	±1 **±50**	pA
I_{OS}	Input Offset Current			±5		fA
CMRR	Common Mode Rejection Ratio	$0V \le V_{CM} \le 2.3V$	79 **77**	92		dB
PSRR	Power Supply Rejection Ratio	$1.6V \le V^+ \le 5.5V$ $V_{CM} = 0V$	83 **82**	120		dB
CMVR	Common Mode Voltage Range	CMRR ≥ 78 dB CMRR ≥ 77 dB	−0.2 **−0.2**		2.5 **2.5**	V
A_{VOL}	Large Signal Voltage Gain	$V_O = 0.3V$ to $3V$ $R_L = 10\ k\Omega$ to $V^+/2$	108 **107**	120		dB
V_O	Output Swing High	$R_L = 10\ k\Omega$ to $V^+/2$ $V_{IN}(diff) = 100\ mV$		14	50 **50**	mV from either rail
	Output Swing Low	$R_L = 10\ k\Omega$ to $V^+/2$ $V_{IN}(diff) = -100\ mV$		14	50 **50**	

(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 as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration. The typical values are not tested and are not ensured on shipped production material.

3.3V DC Electrical Characteristics(1) (continued)

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

Symbol	Parameter	Conditions	Min (2)	Typ (3)	Max (2)	Units
I_O	Output Current (4)	Sourcing, V_O to V^- V_{IN}(diff) = 100 mV	11 **8**	14		mA
		Sinking, V_O to V^+ V_{IN}(diff) = −100 mV	8 **5**	11		
I_S	Supply Current			34	44 **46**	µA

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

3.3V AC Electrical Characteristics(1)

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

Symbol	Parameter	Conditions		Min (2)	Typ (3)	Max (2)	Units
GBWP	Gain Bandwidth Product	C_L = 20 pF, R_L = 10 kΩ			128		kHz
SR	Slew Rate	A_V = +1, C_L = 20 pF R_L = 10 kΩ	Falling Edge		58		V/ms
			Rising Edge		48		
θ_m	Phase Margin	C_L = 20 pF, R_L = 10 kΩ			66		deg
G_m	Gain Margin	C_L = 20 pF, R_L = 10 kΩ			26		dB
e_n	Input-Referred Voltage Noise Density	f = 1 kHz			60		nV/√Hz
	Input-Referred Voltage Noise	0.1 Hz to 10 Hz			2.4		μV_{PP}
i_n	Input-Referred Current Noise Density	f = 1 kHz			10		fA/√Hz
THD+N	Total Harmonic Distortion + Noise	f = 100 Hz, R_L = 10 kΩ			0.003		%

(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 as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration. The typical values are not tested and are not ensured on shipped production material.

2.5V DC Electrical Characteristics(1)

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

Symbol	Parameter	Conditions	Min (2)	Typ (3)	Max (2)	Units
V_{OS}	Input Offset Voltage			±10	±190 **±275**	µV
TCV_{OS}	Input Offset Voltage Drift	LMP2234A		±0.3	±0.75	µV/°C
		LMP2234B		±0.3	±2.5	
I_{BIAS}	Input Bias Current			±0.02	±1.0 **±50**	pA
I_{OS}	Input Offset Current			±5		fA

(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 as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration. The typical values are not tested and are not ensured on shipped production material.

2.5V DC Electrical Characteristics[1] (continued)

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

Symbol	Parameter	Conditions	Min[2]	Typ[3]	Max[2]	Units
CMRR	Common Mode Rejection Ratio	0V ≤ V_{CM} ≤ 1.5V	77 **76**	91		dB
PSRR	Power Supply Rejection Ratio	1.6V ≤ V^+ ≤ 5.5V V_{CM} = 0V	83 **82**	120		dB
CMVR	Common Mode Voltage Range	CMRR ≥ 77 dB CMRR ≥ 76 dB	−0.2 **−0.2**		1.7 **1.7**	V
A_{VOL}	Large Signal Voltage Gain	V_O = 0.3V to 2.2V R_L = 10 kΩ to $V^+/2$	104 **104**	120		dB
V_O	Output Swing High	R_L = 10 kΩ to $V^+/2$ V_{IN}(diff) = 100 mV		12	50 **50**	mV from either rail
	Output Swing Low	R_L = 10 kΩ to $V^+/2$ V_{IN}(diff) = −100 mV		13	50 **50**	
I_O	Output Current[4]	Sourcing, V_O to V^- V_{IN}(diff) = 100 mV	5 **4**	8		mA
		Sinking, V_O to V^+ V_{IN}(diff) = −100 mV	3.5 **2.5**	7		
I_S	Supply Current			32	44 **46**	μA

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

2.5V AC Electrical Characteristics[1]

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

Symbol	Parameter	Conditions		Min[2]	Typ[3]	Max[2]	Units
GBWP	Gain Bandwidth Product	C_L = 20 pF, R_L = 10 kΩ			128		kHz
SR	Slew Rate	A_V = +1, C_L = 20 pF R_L = 10 kΩ	Falling Edge		58		V/ms
			Rising Edge		48		
θ_m	Phase Margin	C_L = 20 pF, R_L = 10 kΩ			64		deg
G_m	Gain Margin	C_L = 20 pF, R_L = 10 kΩ			26		dB
e_n	Input-Referred Voltage Noise Density	f = 1 kHz			60		nV/√Hz
	Input-Referred Voltage Noise	0.1 Hz to 10 Hz			2.5		μV_{PP}
i_n	Input-Referred Current Noise Density	f = 1 kHz			10		fA/√Hz
THD+N	Total Harmonic Distortion + Noise	f = 100 Hz, R_L = 10 kΩ			0.005		%

(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 as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration. The typical values are not tested and are not ensured on shipped production material.

1.8V DC Electrical Characteristics [1]

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

Symbol	Parameter	Conditions	Min [2]	Typ [3]	Max [2]	Units
V_{OS}	Input Offset Voltage			±10	±230 **±325**	µV
TCV_{OS}	Input Offset Voltage Drift	LMP2234A		±0.3	±0.75	µV/°C
		LMP2234B		±0.3	±2.5	
I_{BIAS}	Input Bias Current			±0.02	±1.0 **±50**	pA
I_{OS}	Input Offset Current			±5		fA
CMRR	Common Mode Rejection Ratio	0V ≤ V_{CM} ≤ 0.8V	76 **75**	92		dB
PSRR	Power Supply Rejection Ratio	1.6V ≤ V^+ ≤ 5.5V V_{CM} = 0V	83 **82**	120		dB
CMVR	Common Mode Voltage Range	CMRR ≥ 76 dB CMRR ≥ 75 dB	-0.2 **0**		1.0 **1.0**	V
A_{VOL}	Large Signal Voltage Gain	V_O = 0.3V to 1.5V R_L = 10 kΩ to $V^+/2$	103 **103**	120		dB
V_O	Output Swing High	R_L = 10 kΩ to $V^+/2$ V_{IN}(diff) = 100 mV		12	50 **50**	mV from either rail
	Output Swing Low	R_L = 10 kΩ to $V^+/2$ V_{IN}(diff) = −100 mV		13	50 **50**	
I_O	Output Current [4]	Sourcing, V_O to V^- V_{IN}(diff) = 100 mV	2.5 **2**	5		mA
		Sinking, V_O to V^+ V_{IN}(diff) = −100 mV	2 **1.5**	5		
I_S	Supply Current			31	42 **44**	µA

(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 as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration. The typical values are not tested and are not ensured on shipped production material.

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

1.8V AC Electrical Characteristics [1]

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

Symbol	Parameter	Conditions		Min [2]	Typ [3]	Max [2]	Units
GBWP	Gain Bandwidth Product	C_L = 20 pF, R_L = 10 kΩ			127		kHz
SR	Slew Rate	A_V = +1, C_L = 20 pF R_L = 10 kΩ	Falling Edge		58		V/ms
			Rising Edge		48		
θ_m	Phase Margin	C_L = 20 pF, R_L = 10 kΩ			70		deg
G_m	Gain Margin	C_L = 20 pF, R_L = 10 kΩ			25		dB
e_n	Input-Referred Voltage Noise Density	f = 1 kHz			60		nV/√Hz
	Input-Referred Voltage Noise	0.1 Hz to 10 Hz			2.4		μV_{PP}
i_n	Input-Referred Current Noise Density	f = 1 kHz			10		fA/√Hz
THD+N	Total Harmonic Distortion + Noise	f = 100 Hz, R_L = 10 kΩ			0.005		%

(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.

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(3) Typical values represent the most likely parametric norm as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration. The typical values are not tested and are not ensured on shipped production material.

Connection Diagram

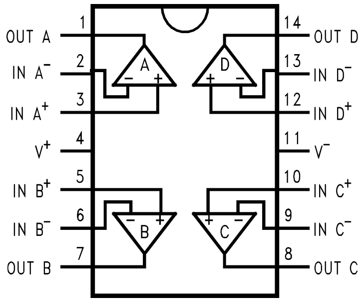


Figure 2. 14-Pin TSSOP/SOIC

Typical Performance Characteristics

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

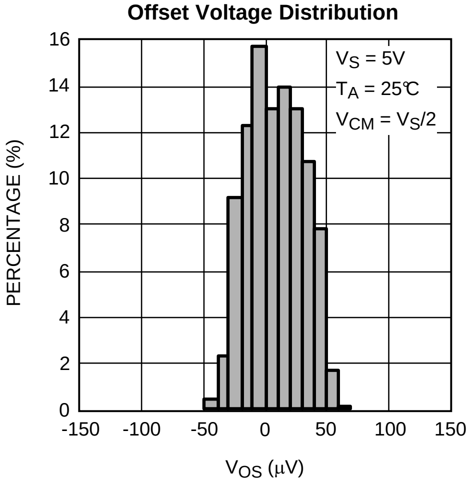


Figure 3.

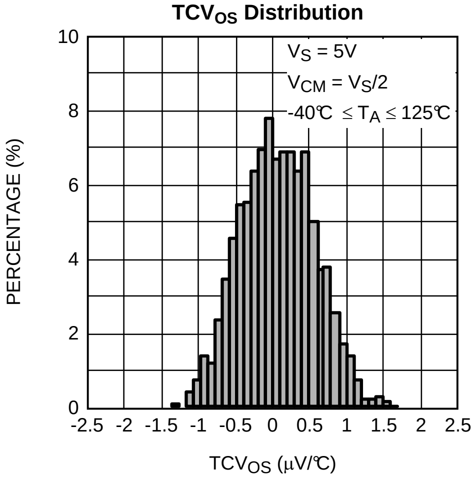


Figure 4.

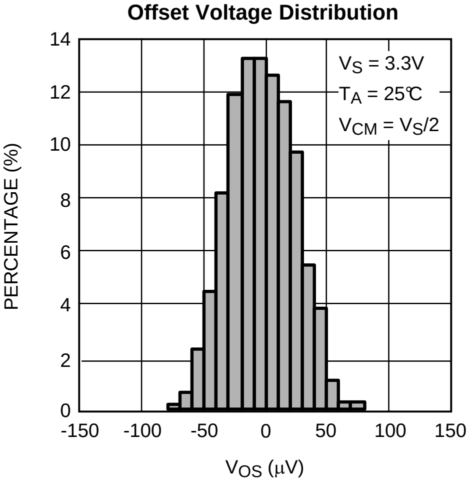


Figure 5.

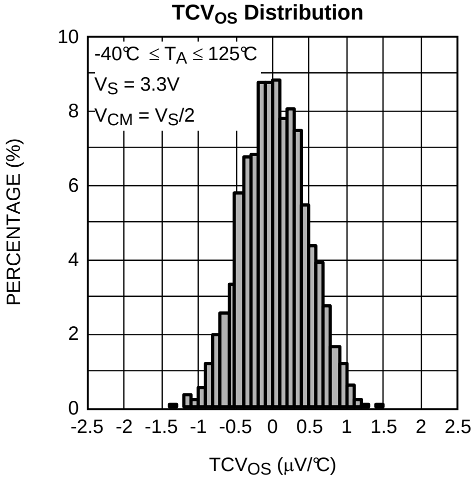
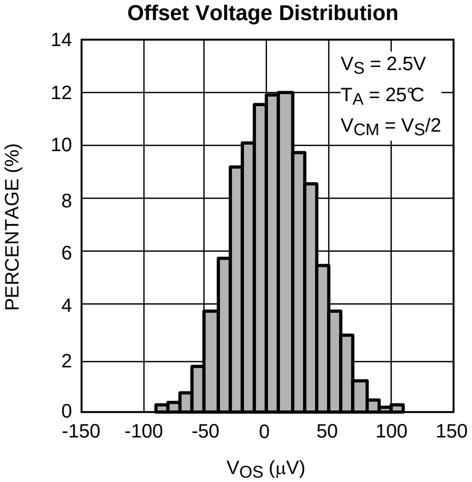


Figure 6.



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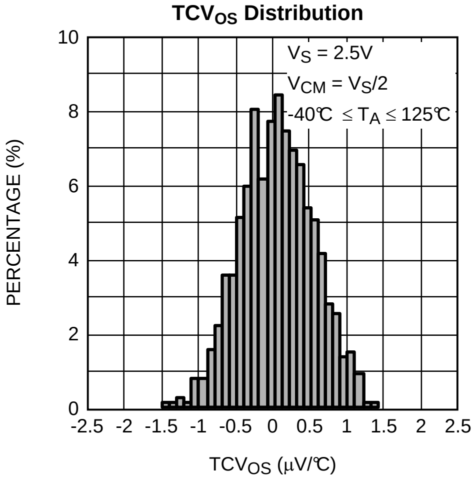


Figure 8.

Typical Performance Characteristics (continued)

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

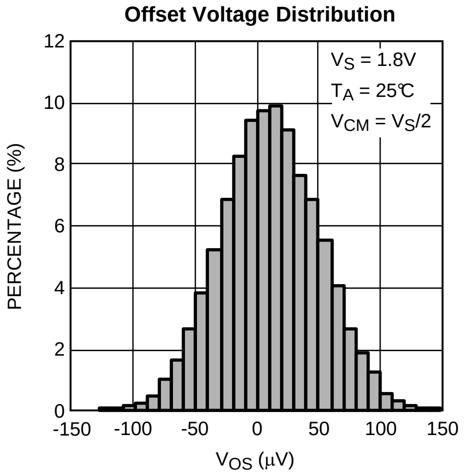


Figure 9.

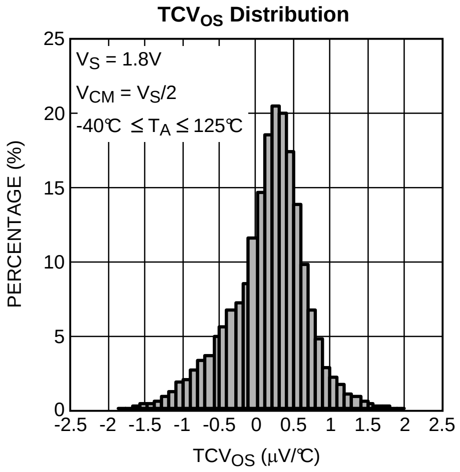
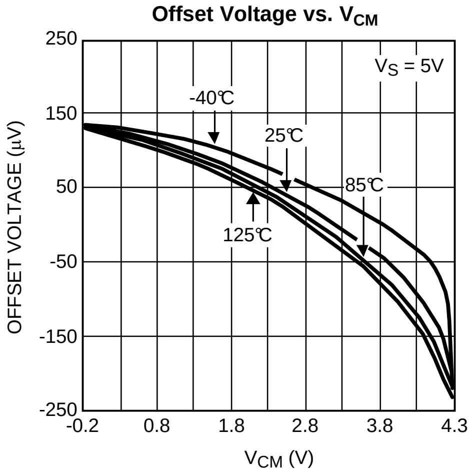


Figure 10.



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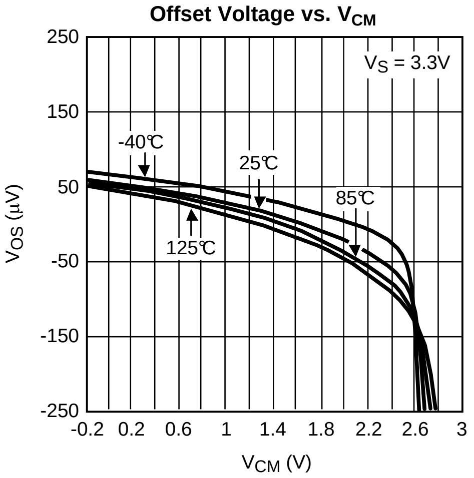

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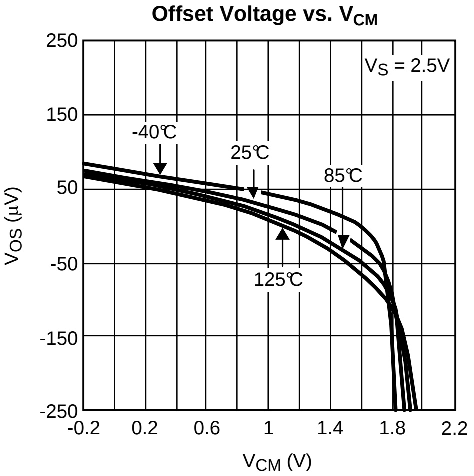

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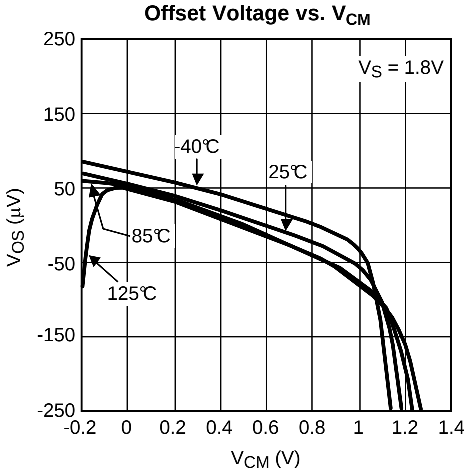
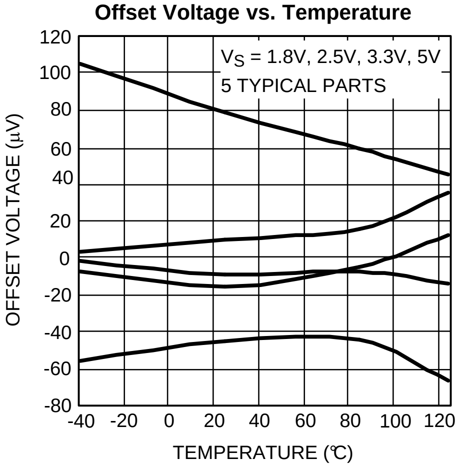


Figure 14.

Typical Performance Characteristics (continued)

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



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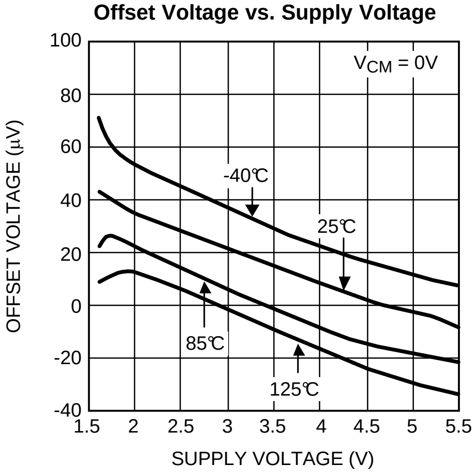

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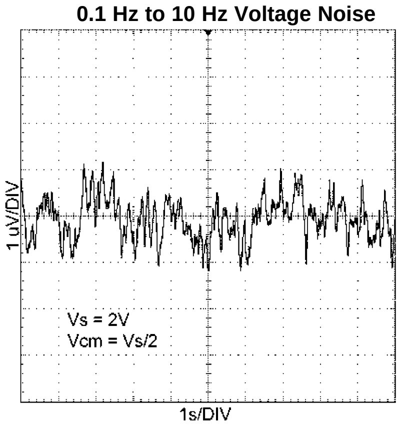

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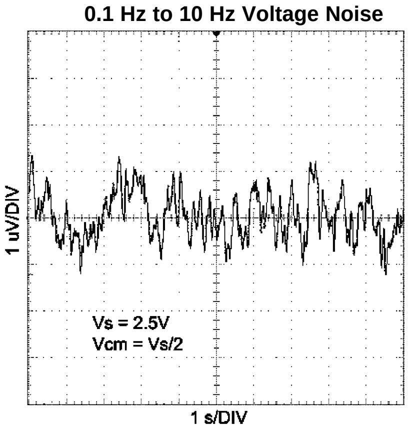

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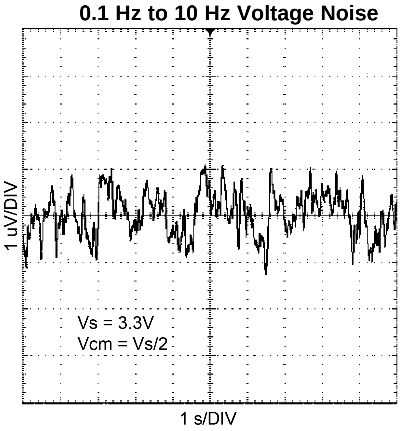

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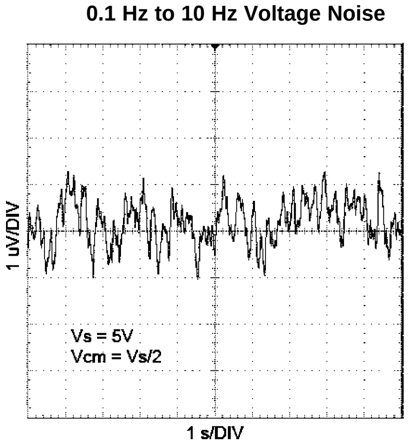


Figure 20.

Typical Performance Characteristics (continued)

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

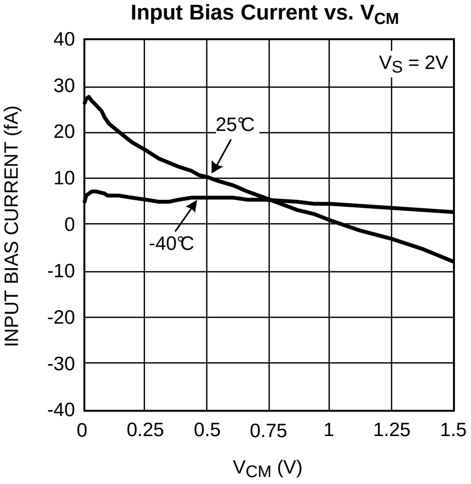

Input Bias Current vs. V_{CM}

Figure 21.

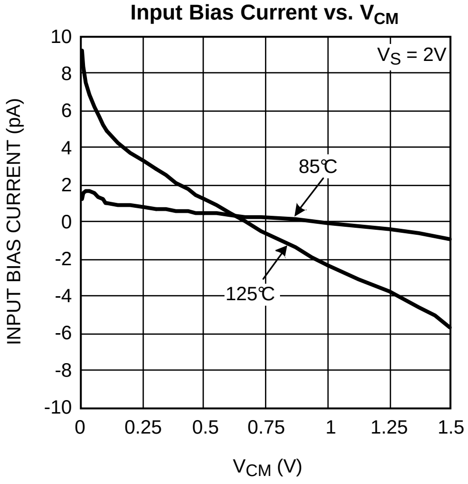

Input Bias Current vs. V_{CM}

Figure 22.

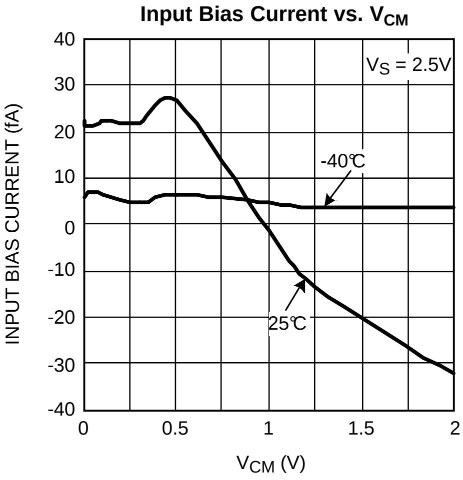

Input Bias Current vs. V_{CM}

Figure 23.

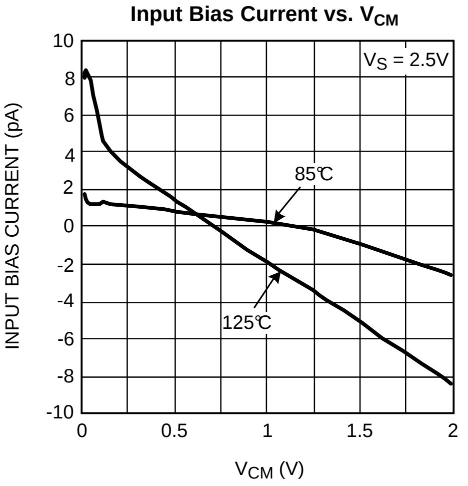

Input Bias Current vs. V_{CM}

Figure 24.

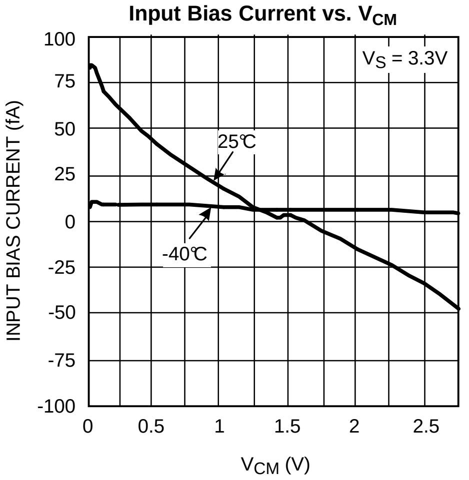

Input Bias Current vs. V_{CM}

Figure 25.

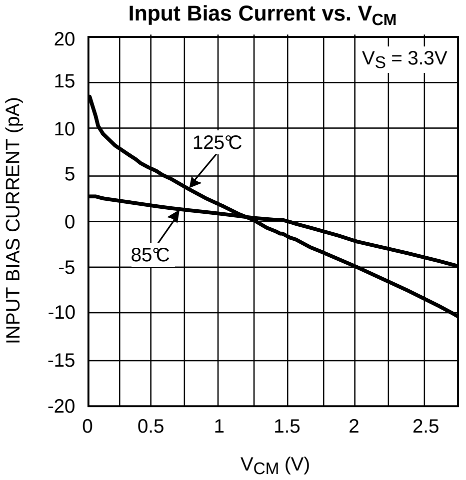

Input Bias Current vs. V_{CM}

Figure 26.

Typical Performance Characteristics (continued)

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

Input Bias Current vs. V_{CM}

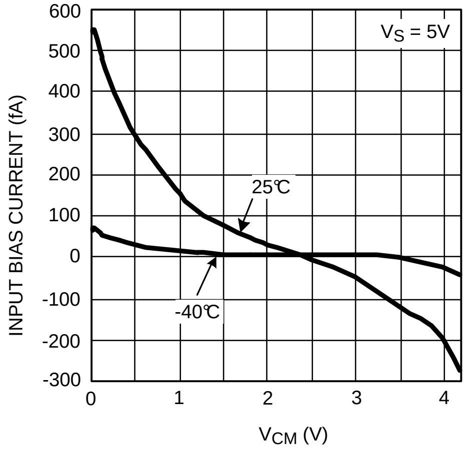


Figure 27.

Input Bias Current vs. V_{CM}

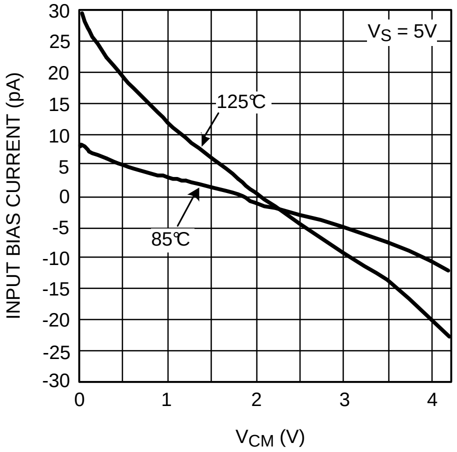


Figure 28.

PSRR vs. Frequency

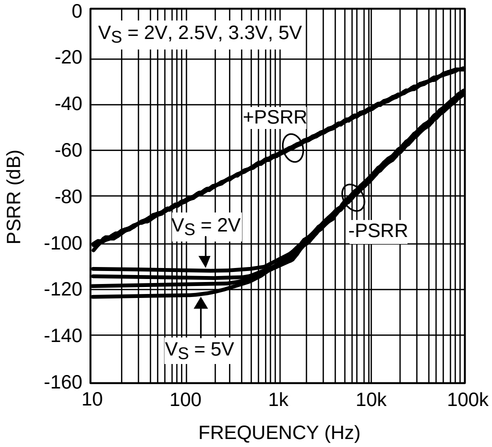


Figure 29.

Supply Current vs. Supply Voltage (per channel)

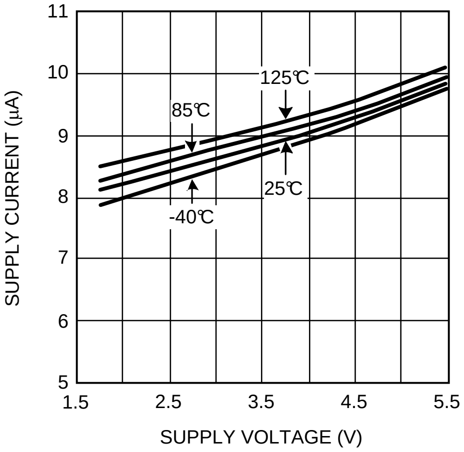


Figure 30.

Sinking Current vs. Supply Voltage

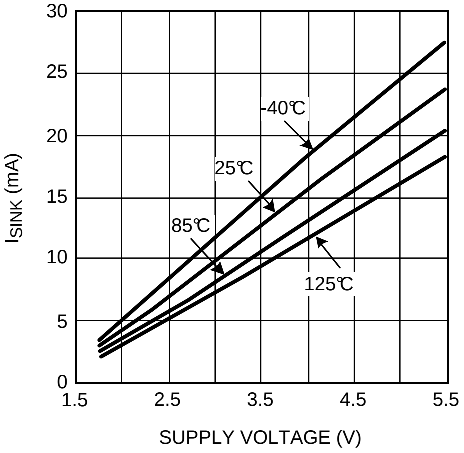


Figure 31.

Sourcing Current vs. Supply Voltage

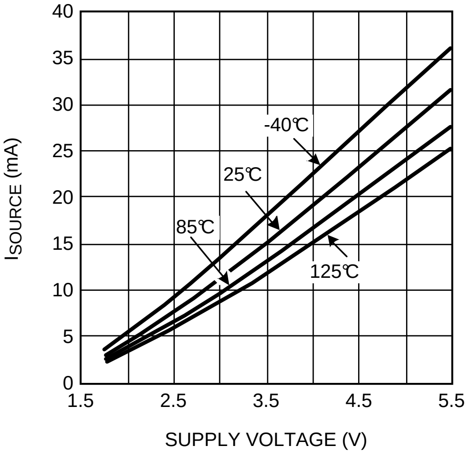


Figure 32.

Typical Performance Characteristics (continued)

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

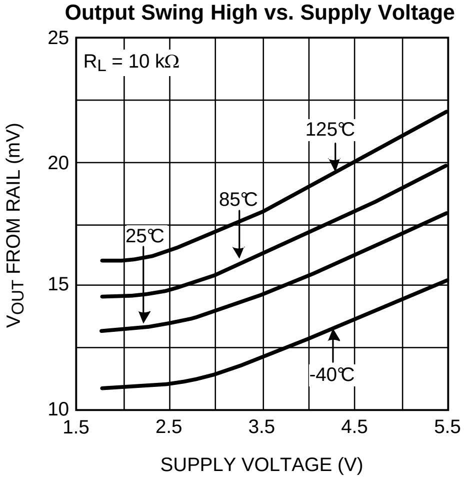
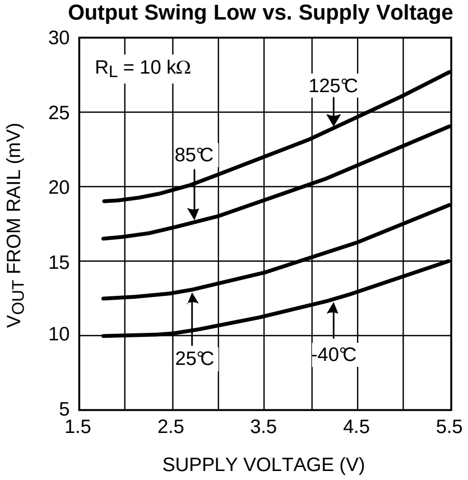


Figure 33.



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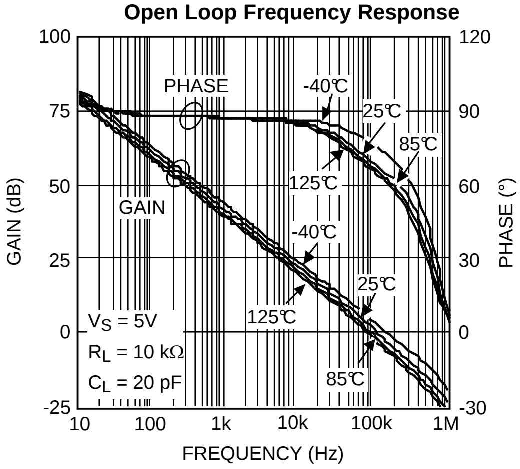

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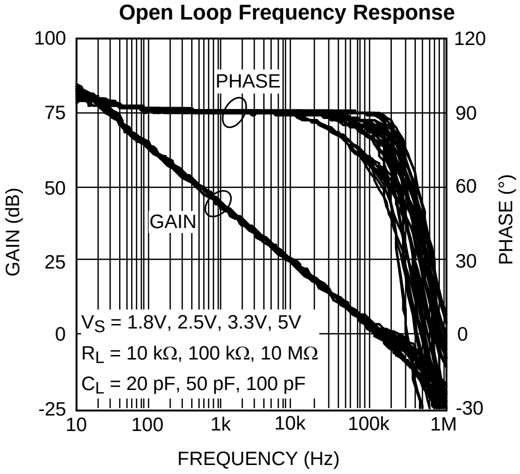

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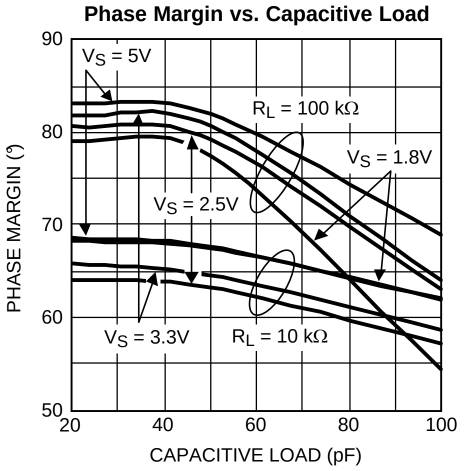

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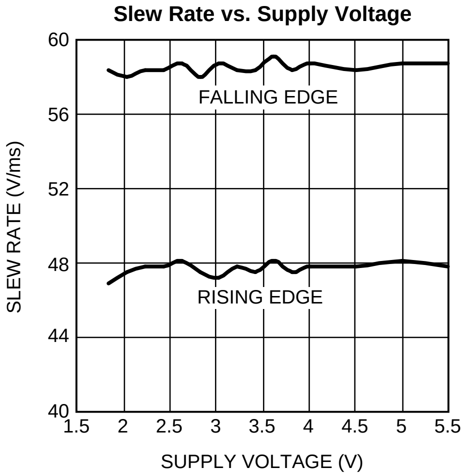


Figure 38.

Typical Performance Characteristics (continued)

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

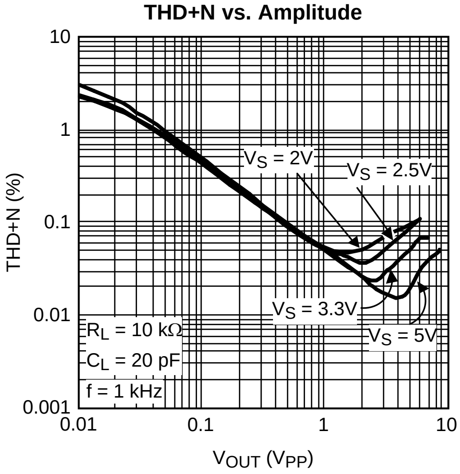


Figure 39.

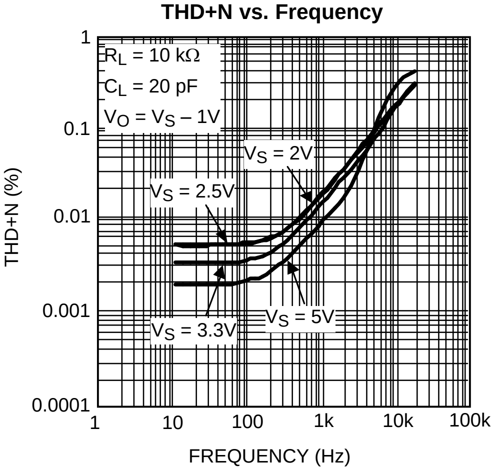


Figure 40.

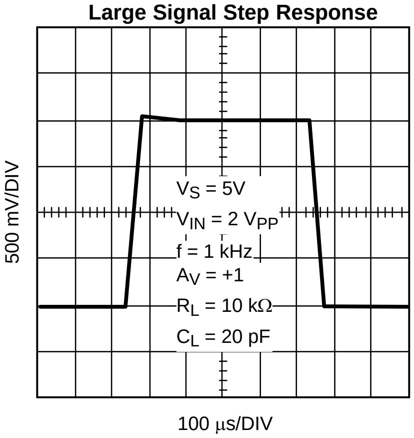
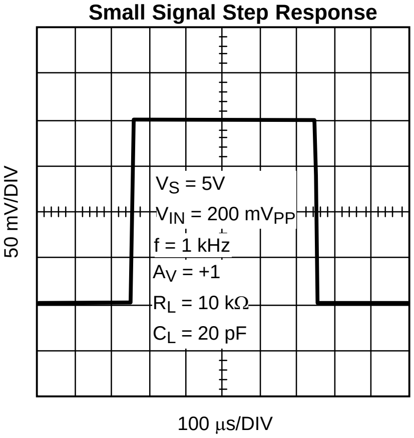


Figure 41.



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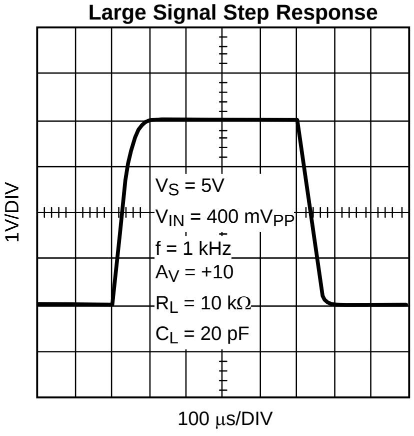


Figure 43.

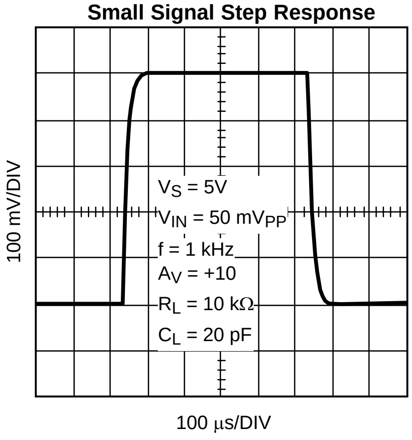


Figure 44.

Typical Performance Characteristics (continued)

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

CMRR vs. Frequency

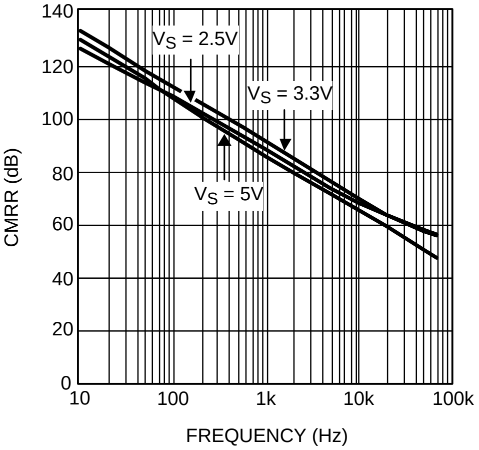


Figure 45.

Input Voltage Noise vs. Frequency

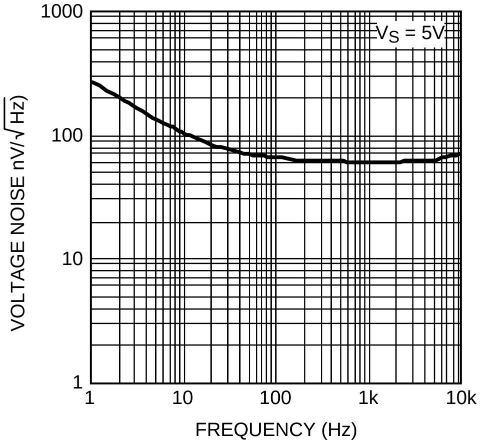


Figure 46.

APPLICATION INFORMATION

LMP2234

The LMP2234 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 LMP2234 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 ensured supply voltage range of 1.8V to 5.5V along with the ultra-low supply current extend the battery run time in two ways. The extended power supply voltage range of 1.8V to 5.5V 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 LMP2234 has input referred offset voltage of only ±150 µV maximum at room temperature. This offset is ensured to be less than ±230 µV over temperature. This minimal offset voltage along with very low TCV_{OS} of only 0.3 µV/°C typical allows more accurate signal detection and amplification in precision applications.

The low input bias current of only ±20 fA gives the LMP2234 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 LMP2234 to interface with high impedance sensors while generating negligible voltage noise. Thus the LMP2234 provides better signal fidelity and a higher signal-to-noise ratio when interfacing with high impedance sensors.

Texas Instruments 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 1.8V to 5.5V over the extensive temperature range of −40°C to 125°C makes the LMP2234 an excellent choice for low voltage precision applications with extensive temperature requirements.

The LMP2234 is offered in the 14-pin TSSOP and 14-pin SOIC package. These small packages are ideal solutions for area constrained PC boards and portable electronics.

TOTAL NOISE CONTRIBUTION

The LMP2234 has very low input bias current, very low input current noise, and low input voltage noise for micropower amplifiers. As a result, this amplifier makes a great choice for circuits with high impedance sensor applications.

shows the typical input noise of the LMP2234 as a function of source resistance at f = 1 kHz 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:

$$e_{ni} = \sqrt{e_n^2 + e_i^2 + e_t^2} \tag{1}$$

The input current noise of the LMP2234 is so low that it will not become the dominant factor in the total noise unless source resistance exceeds 300 MΩ, which is an unrealistically high value. As is evident in Figure 47, at lower R_S values, total noise is dominated by the amplifier's input voltage noise. Once R_S is larger than 100 kΩ, 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.

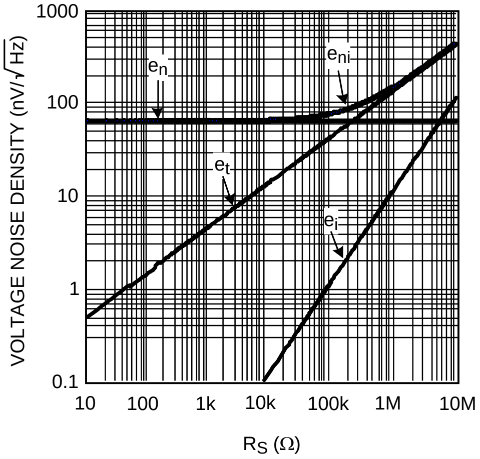


Figure 47. Total Input Noise

VOLTAGE NOISE REDUCTION

The LMP2234 has an input voltage noise of 60 nV/√Hz . While this value is very low for micropower amplifiers, this input voltage noise can be further reduced by placing multiple amplifiers in parallel as shown in Figure 48. 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:

$$\text{REDUCED INPUT VOLTAGE NOISE} = \frac{1}{N}\sqrt{e_{n1}^2 + e_{n2}^2 + \cdots + e_{nN}^2}$$
$$= \frac{1}{N}\sqrt{Ne_n^2} = \frac{\sqrt{N}}{N}\ e_n$$
$$= \frac{1}{\sqrt{N}}\ e_n \tag{2}$$

Figure 48 shows a schematic of this input voltage noise reduction circuit using the LMP2234. Typical resistor values are: R_G = 10Ω, R_F = 1 kΩ, and R_O = 1 kΩ.

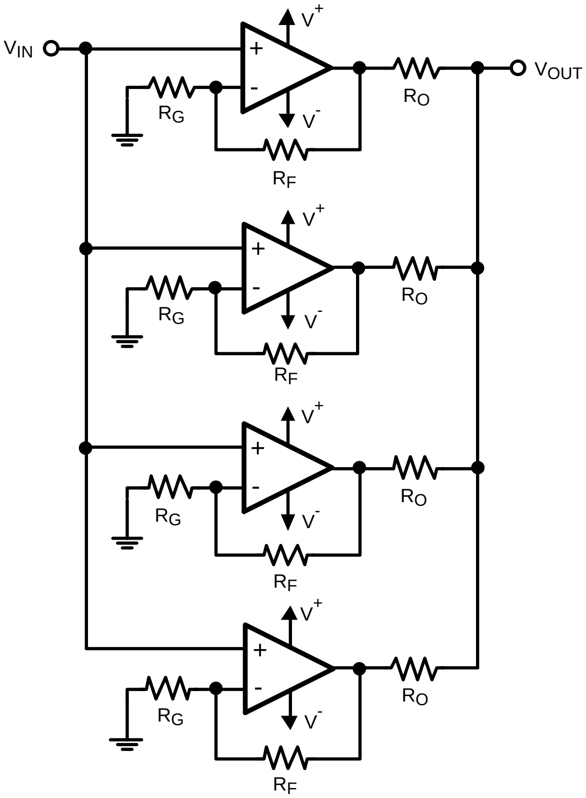


Figure 48. Noise Reduction Circuit

PRECISION INSTRUMENTATION AMPLIFIER

Measurement of very small signals with an amplifier requires close attention to the input impedance of the amplifier, the 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 interest and the common signal is considered noise. A classic circuit implementation that is used 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 49.

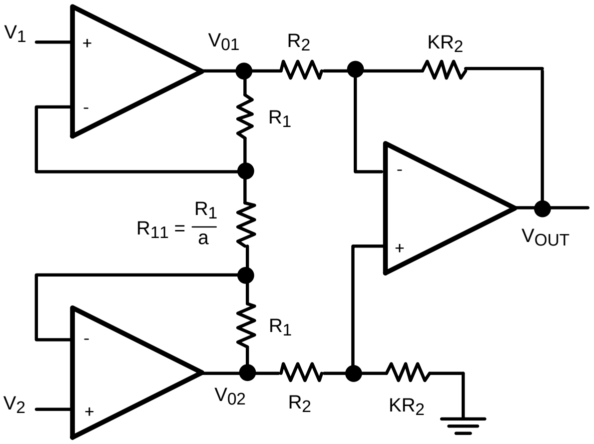


Figure 49. Instrumentation Amplifier

There are two stages in this amplifier. The last stage, the output stage, is a differential amplifier. In an ideal case the two amplifiers of the first stage, the input stage, would be configured as buffers to isolate the inputs. However they cannot be connected as followers because of mismatch in 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 LMP2234.

$$\text{GIVEN: } I_{R_1} = I_{R_{11}} \quad (3)$$

By Ohm's Law:

$$\begin{aligned} V_{O1} - V_{O2} &= (2R_1 + R_{11})\, I_{R_{11}} \\ &= (2a + 1)\; R_{11} \bullet I_{R_{11}} \\ &= (2a + 1)\, V_{R_{11}} \end{aligned} \quad (4)$$

However:

$$V_{R_{11}} = V_1 - V_2 \quad (5)$$

So we have:

$$V_{O1}–V_{O2} = (2a+1)(V_1–V_2) \quad (6)$$

Now looking at the output of the instrumentation amplifier:

$$\begin{aligned} V_O &= \frac{KR_2}{R_2}\,(V_{O2} - V_{O1}) \\ &= -K\,(V_{O1} - V_{O2}) \end{aligned} \quad (7)$$

Substituting from Equation 6:

$$V_O = -K\,(2a + 1)\,(V_1 - V_2) \quad (8)$$

This shows the gain of the instrumentation amplifier to be:

$$-K(2a+1) \quad (9)$$

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 GAUGE 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.

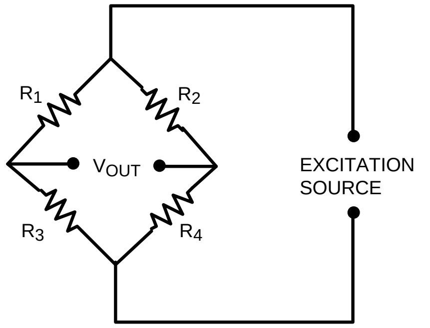
Bridge sensors are formed of four resistors, connected as a quadrilateral. A voltage source or a current source is used across one of the diagonals to excite the bridge while a voltage detector across the other diagonal measures the output voltage.

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 lease 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.

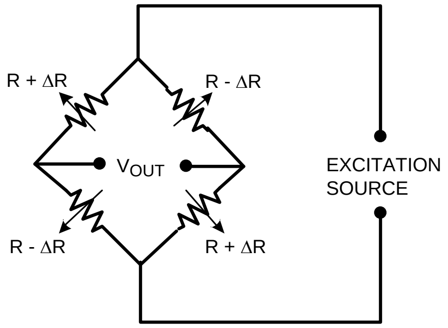
Sensitivity of a bridge is the ratio of its maximum expected output change to the excitation voltage change.

Figure 50(a) shows a typical bridge sensor and Figure 50(b) shows the bridge with four sensors. R in Figure 50(b) is the nominal value of the sense resistor and the deviations from R are proportional to the quantity being measured.



(a)

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



(b)

$$V_{OUT} = \frac{\Delta R}{R} \text{ x } V_{SOURCE}$$

Figure 50. 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 51 shows a strain gauge bridge amplifier. In this application one of the LMP2234 amplifiers is used to buffer the LM4140A's precision output voltage. The LM4140A is a precision voltage reference. The other three amplifiers in the LMP2234 are used to form an instrumentation amplifier. This instrumentation amplifier uses the LMP2234'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.

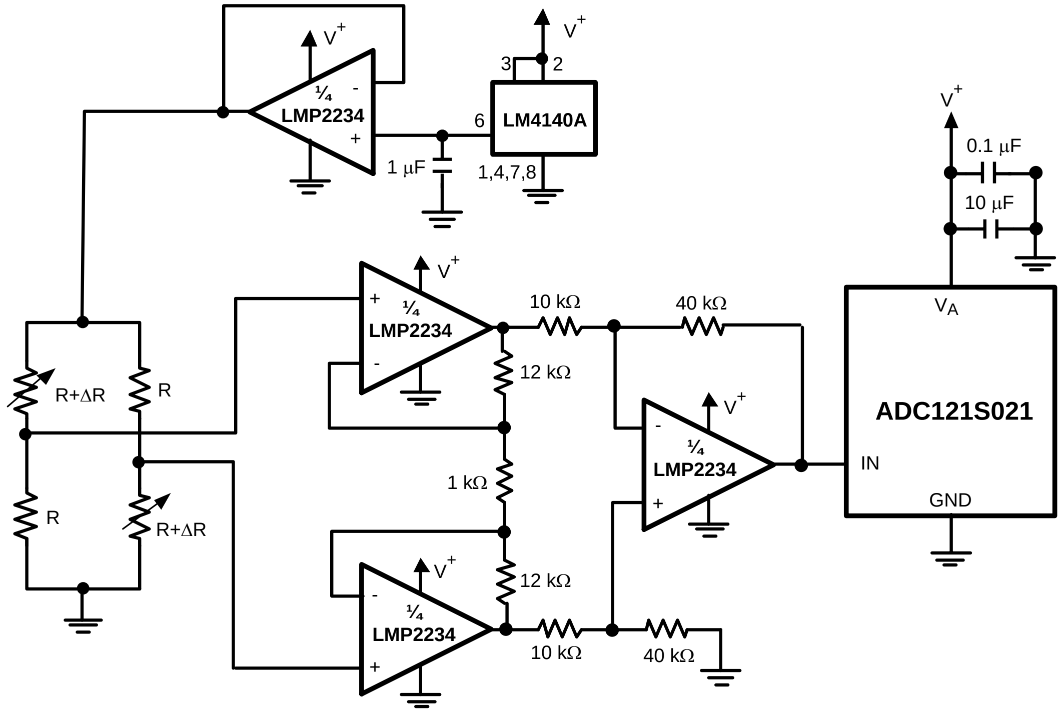


Figure 51. Strain Gauge Bridge Amplifier

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 very small traces of oxygen in ppm.

Figure 52 shows a typical circuit used to amplify the output signal of an oxygen detector. The LMP2234 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 LMP2234 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 LMP2234, 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 LMP2234 a great choice for this application.

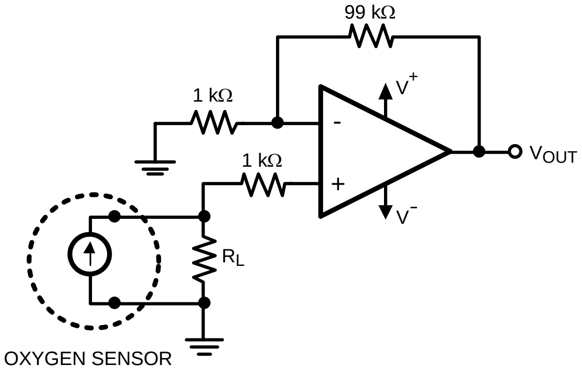


Figure 52. Precision Oxygen Sensor

REVISION HISTORY

Changes from Revision C (March 2013) to Revision D	**Page**
• Changed layout of National Data Sheet to TI format	22

PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
LMP2234AMA/NOPB	Active	Production	SOIC (D) | 14	55 | TUBE	Yes	SN	Level-1-260C-UNLIM	-40 to 125	LMP2234 AMA
LMP2234AMA/NOPB.A	Active	Production	SOIC (D) | 14	55 | TUBE	Yes	SN	Level-1-260C-UNLIM	-40 to 125	LMP2234 AMA
LMP2234AMAE/NOPB	Active	Production	SOIC (D) | 14	250 | SMALL T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	LMP2234 AMA
LMP2234AMAE/NOPB.A	Active	Production	SOIC (D) | 14	250 | SMALL T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	LMP2234 AMA
LMP2234AMAX/NOPB	Active	Production	SOIC (D) | 14	2500 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	LMP2234 AMA
LMP2234AMAX/NOPB.A	Active	Production	SOIC (D) | 14	2500 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	LMP2234 AMA
LMP2234AMT/NOPB	Active	Production	TSSOP (PW) | 14	94 | TUBE	Yes	SN	Level-1-260C-UNLIM	-40 to 125	LMP223 4AMT
LMP2234AMT/NOPB.A	Active	Production	TSSOP (PW) | 14	94 | TUBE	Yes	SN	Level-1-260C-UNLIM	-40 to 125	LMP223 4AMT
LMP2234AMTE/NOPB	Active	Production	TSSOP (PW) | 14	250 | SMALL T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	LMP223 4AMT
LMP2234AMTE/NOPB.A	Active	Production	TSSOP (PW) | 14	250 | SMALL T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	LMP223 4AMT
LMP2234BMA/NOPB	Active	Production	SOIC (D) | 14	55 | TUBE	Yes	SN	Level-1-260C-UNLIM	-40 to 125	LMP2234 BMA
LMP2234BMA/NOPB.A	Active	Production	SOIC (D) | 14	55 | TUBE	Yes	SN	Level-1-260C-UNLIM	-40 to 125	LMP2234 BMA
LMP2234BMAE/NOPB	Active	Production	SOIC (D) | 14	250 | SMALL T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	LMP2234 BMA
LMP2234BMAE/NOPB.A	Active	Production	SOIC (D) | 14	250 | SMALL T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	LMP2234 BMA
LMP2234BMAX/NOPB	Active	Production	SOIC (D) | 14	2500 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	LMP2234 BMA
LMP2234BMAX/NOPB.A	Active	Production	SOIC (D) | 14	2500 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	LMP2234 BMA

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
LMP2234BMT/NOPB	Active	Production	TSSOP (PW) | 14	94 | TUBE	Yes	SN	Level-1-260C-UNLIM	-40 to 125	LMP223 4BMT
LMP2234BMT/NOPB.A	Active	Production	TSSOP (PW) | 14	94 | TUBE	Yes	SN	Level-1-260C-UNLIM	-40 to 125	LMP223 4BMT
LMP2234BMTE/NOPB	Active	Production	TSSOP (PW) | 14	250 | SMALL T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	LMP223 4BMT
LMP2234BMTE/NOPB.A	Active	Production	TSSOP (PW) | 14	250 | SMALL T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	LMP223 4BMT
LMP2234BMTX/NOPB	Active	Production	TSSOP (PW) | 14	2500 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	LMP223 4BMT
LMP2234BMTX/NOPB.A	Active	Production	TSSOP (PW) | 14	2500 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	LMP223 4BMT

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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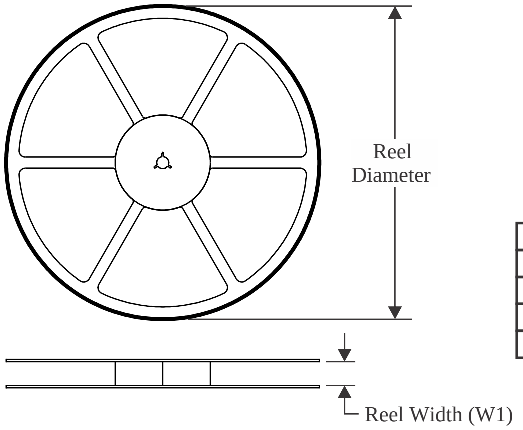
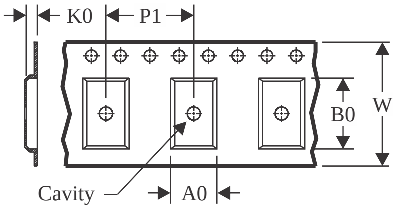
TAPE AND REEL INFORMATION

REEL DIMENSIONS

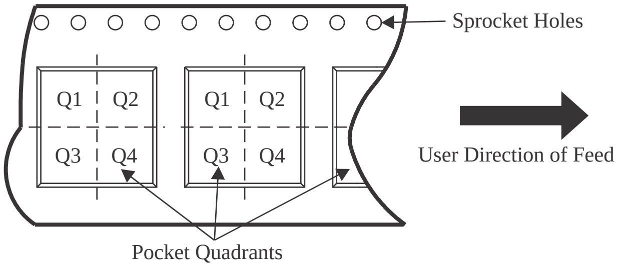


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

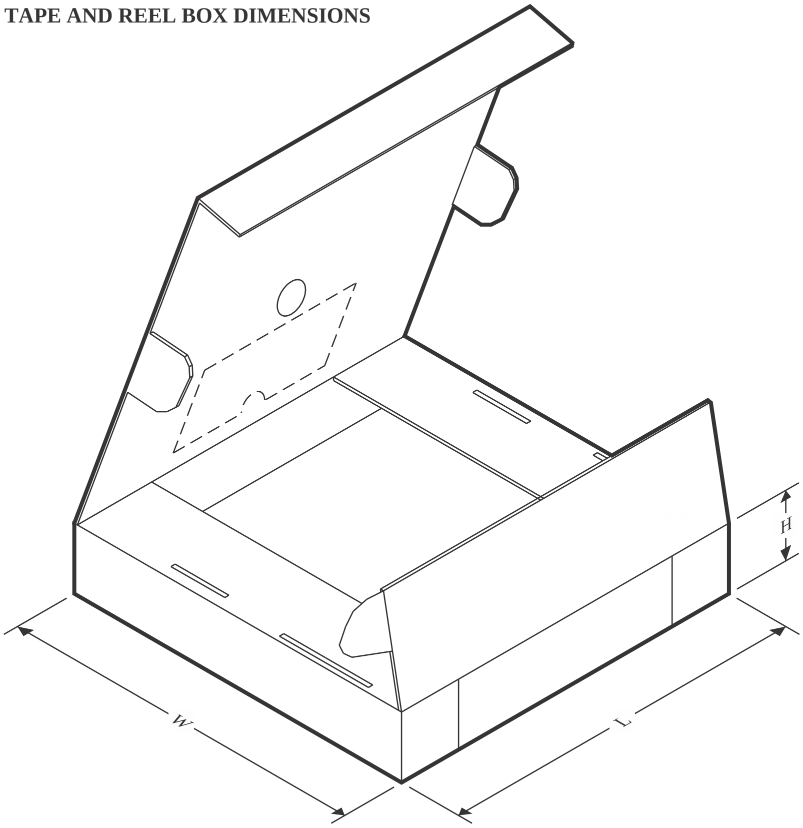
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
LMP2234AMAE/NOPB	SOIC	D	14	250	178.0	16.4	6.5	9.35	2.3	8.0	16.0	Q1
LMP2234AMAX/NOPB	SOIC	D	14	2500	330.0	16.4	6.5	9.35	2.3	8.0	16.0	Q1
LMP2234AMTE/NOPB	TSSOP	PW	14	250	177.8	12.4	6.95	5.6	1.6	8.0	12.0	Q1
LMP2234BMAE/NOPB	SOIC	D	14	250	178.0	16.4	6.5	9.35	2.3	8.0	16.0	Q1
LMP2234BMAX/NOPB	SOIC	D	14	2500	330.0	16.4	6.5	9.35	2.3	8.0	16.0	Q1
LMP2234BMTE/NOPB	TSSOP	PW	14	250	177.8	12.4	6.95	5.6	1.6	8.0	12.0	Q1
LMP2234BMTX/NOPB	TSSOP	PW	14	2500	330.0	12.4	6.95	5.6	1.6	8.0	12.0	Q1

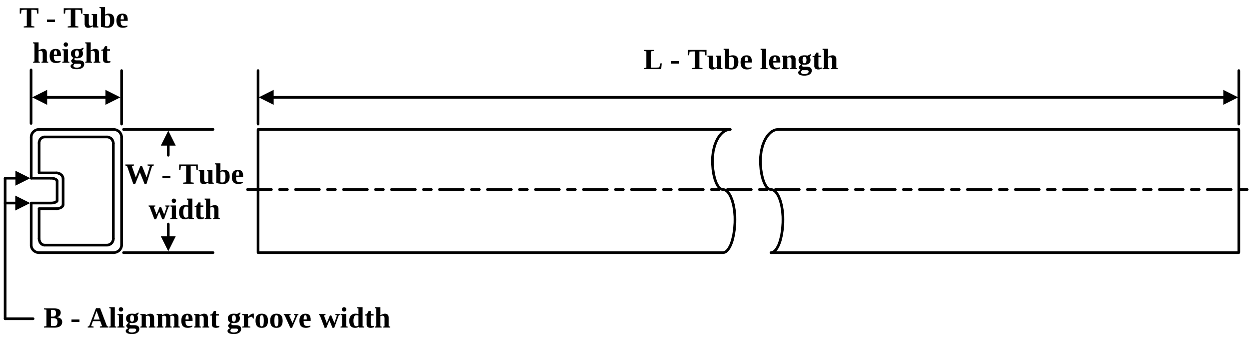
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

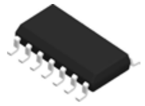
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LMP2234AMAE/NOPB	SOIC	D	14	250	208.0	191.0	35.0
LMP2234AMAX/NOPB	SOIC	D	14	2500	356.0	356.0	35.0
LMP2234AMTE/NOPB	TSSOP	PW	14	250	208.0	191.0	35.0
LMP2234BMAE/NOPB	SOIC	D	14	250	208.0	191.0	35.0
LMP2234BMAX/NOPB	SOIC	D	14	2500	356.0	356.0	35.0
LMP2234BMTE/NOPB	TSSOP	PW	14	250	208.0	191.0	35.0
LMP2234BMTX/NOPB	TSSOP	PW	14	2500	356.0	356.0	35.0

TUBE



*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (µm)	B (mm)
LMP2234AMA/NOPB	D	SOIC	14	55	495	8	4064	3.05
LMP2234AMA/NOPB.A	D	SOIC	14	55	495	8	4064	3.05
LMP2234AMT/NOPB	PW	TSSOP	14	94	495	8	2514.6	4.06
LMP2234AMT/NOPB.A	PW	TSSOP	14	94	495	8	2514.6	4.06
LMP2234BMA/NOPB	D	SOIC	14	55	495	8	4064	3.05
LMP2234BMA/NOPB.A	D	SOIC	14	55	495	8	4064	3.05
LMP2234BMT/NOPB	PW	TSSOP	14	94	495	8	2514.6	4.06
LMP2234BMT/NOPB.A	PW	TSSOP	14	94	495	8	2514.6	4.06

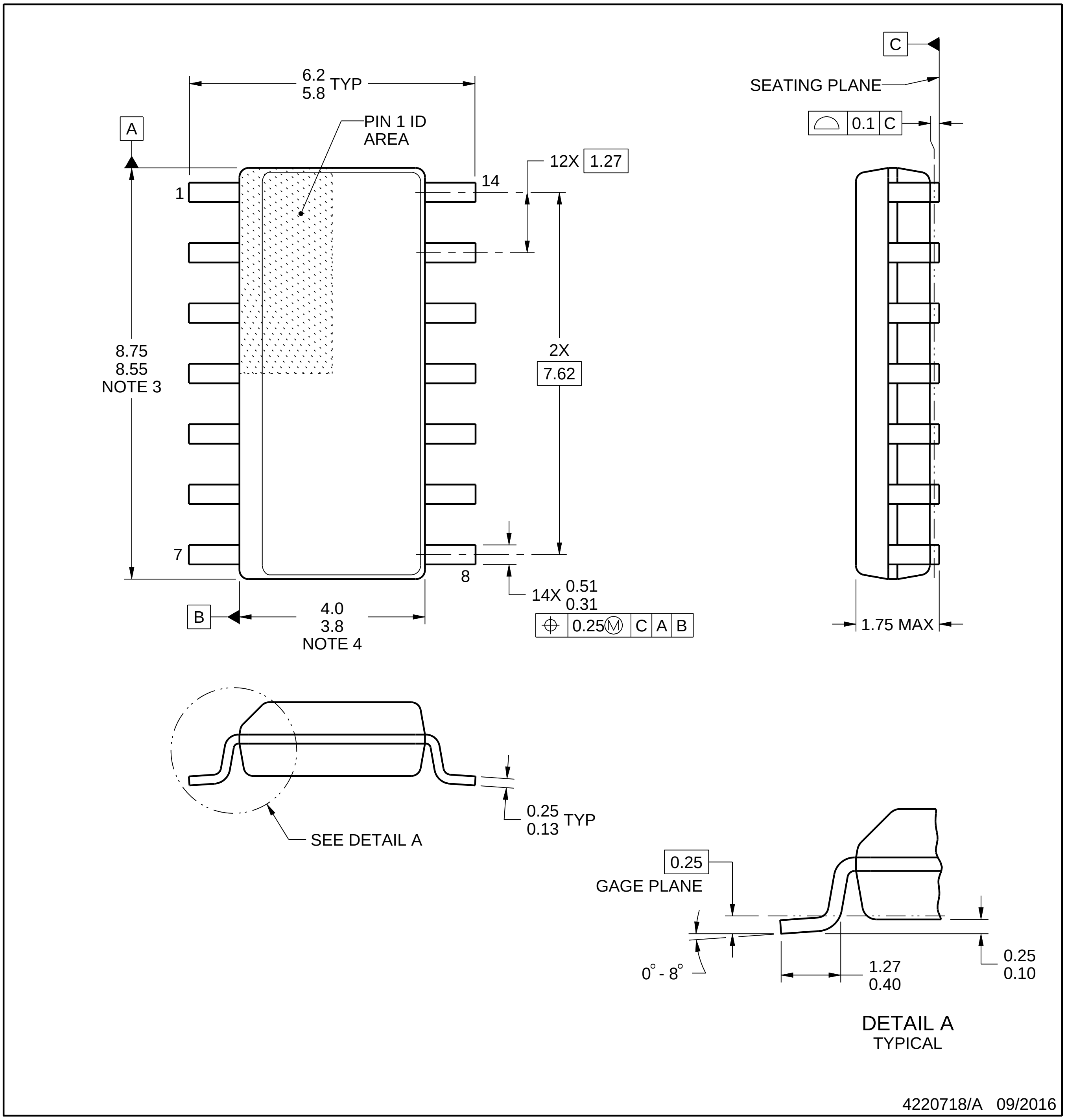


PACKAGE OUTLINE

D0014A

SOIC - 1.75 mm max height

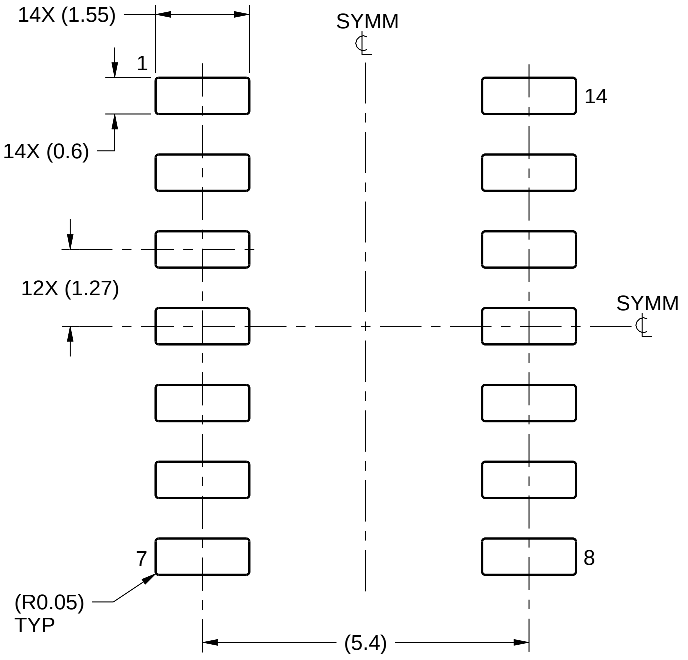
SMALL OUTLINE INTEGRATED CIRCUIT



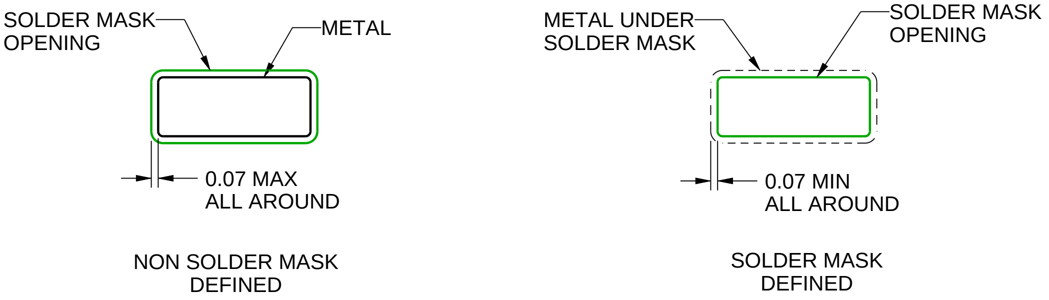
4220718/A 09/2016

NOTES:

1. All linear dimensions are in millimeters. Dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm, per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.43 mm, per side.
5. Reference JEDEC registration MS-012, variation AB.



LAND PATTERN EXAMPLE
SCALE:8X

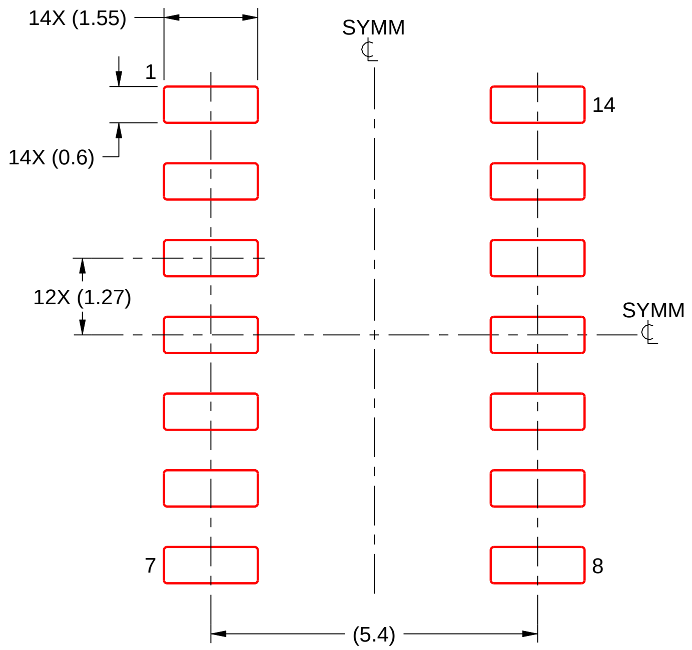


SOLDER MASK DETAILS

4220718/A 09/2016

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

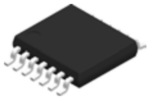


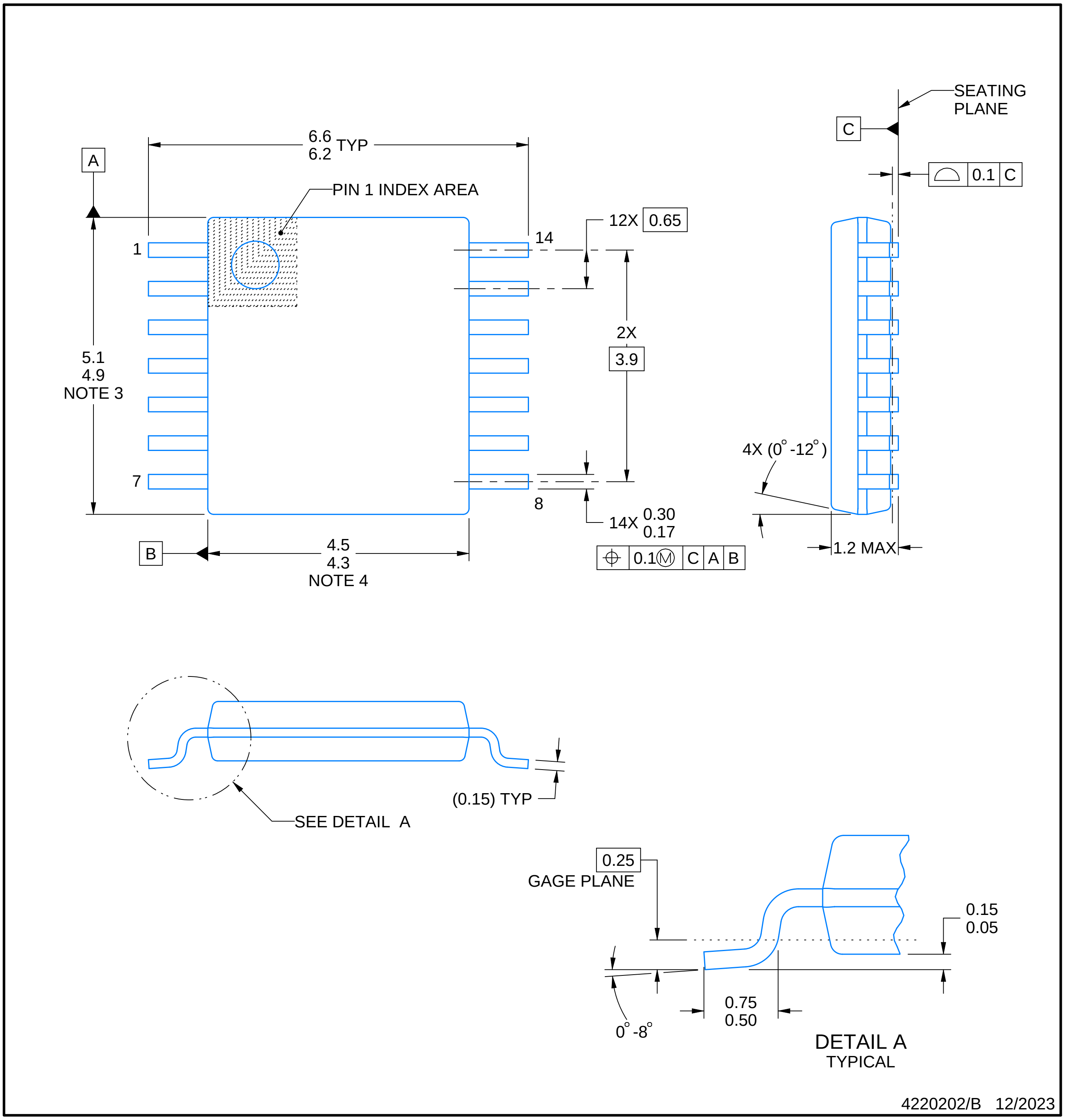
SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:8X

4220718/A 09/2016

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.





4220202/B 12/2023

NOTES:

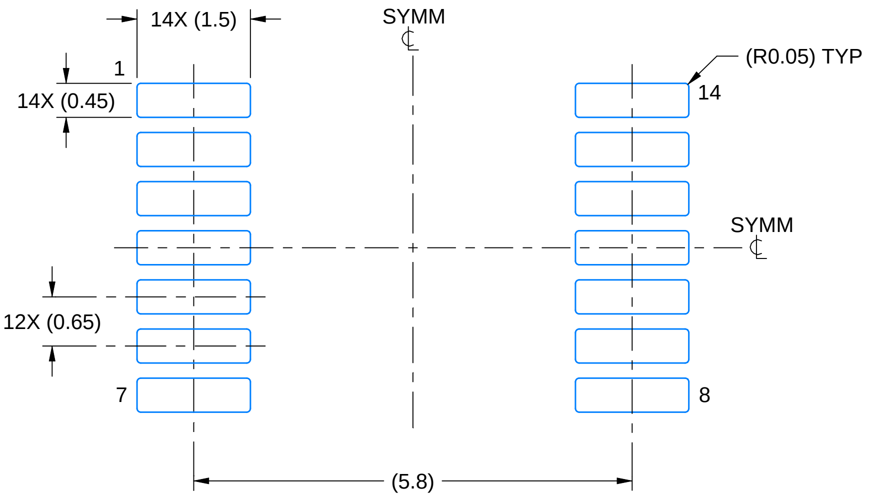
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-153.

EXAMPLE BOARD LAYOUT

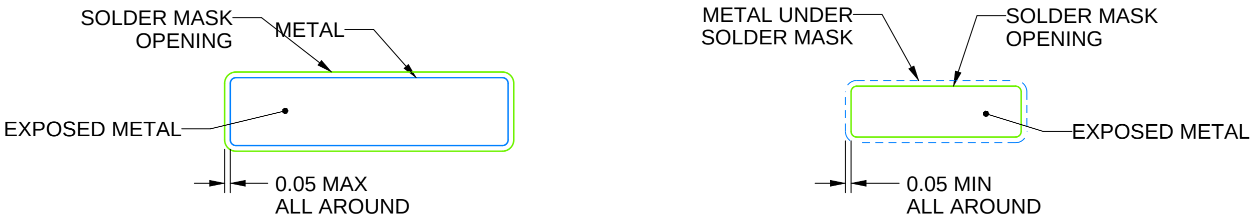
PW0014A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 10X



NON-SOLDER MASK
DEFINED
(PREFERRED)

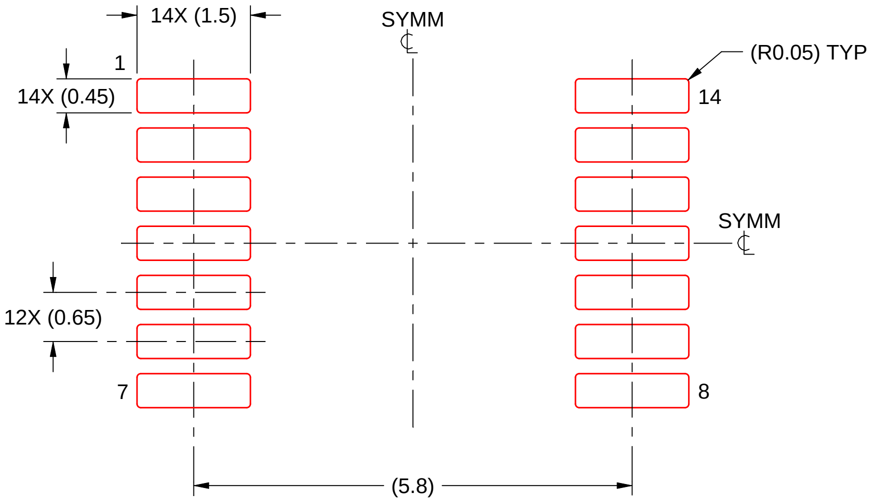
SOLDER MASK
DEFINED

SOLDER MASK DETAILS

4220202/B 12/2023

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE: 10X

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

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