Small, Low Power, 3-Axis ±16 *g* Accelerometer

ADXL326

FEATURES

3-axis sensing
Small, low profile package
4 mm × 4 mm × 1.45 mm LFCSP
Low power: 350 μA typical
Single-supply operation: 1.8 V to 3.6 V
10,000 *g* shock survival
Excellent temperature stability
Bandwidth adjustment with a single capacitor per axis
RoHS/WEEE lead-free compliant

APPLICATIONS

Cost-sensitive, low power, motion- and tilt-sensing applications
- **Mobile devices**
- **Gaming systems**
- **Disk drive protection**
- **Image stabilization**
- **Sports and health devices**

GENERAL DESCRIPTION

The ADXL326 is a small, low power, complete 3-axis accelerometer with signal conditioned voltage outputs. The product measures acceleration with a minimum full-scale range of ±16 *g*. It can measure the static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration, resulting from motion, shock, or vibration.

The user selects the bandwidth of the accelerometer using the C_X, C_Y, and C_Z capacitors at the X_{OUT}, Y_{OUT}, and Z_{OUT} pins. Bandwidths can be selected to suit the application with a range of 0.5 Hz to 1600 Hz for X and Y axes and a range of 0.5 Hz to 550 Hz for the Z axis.

The ADXL326 is available in a small, low profile, 4 mm × 4 mm × 1.45 mm, 16-lead, plastic lead frame chip scale package (LFCSP_LQ).

FUNCTIONAL BLOCK DIAGRAM

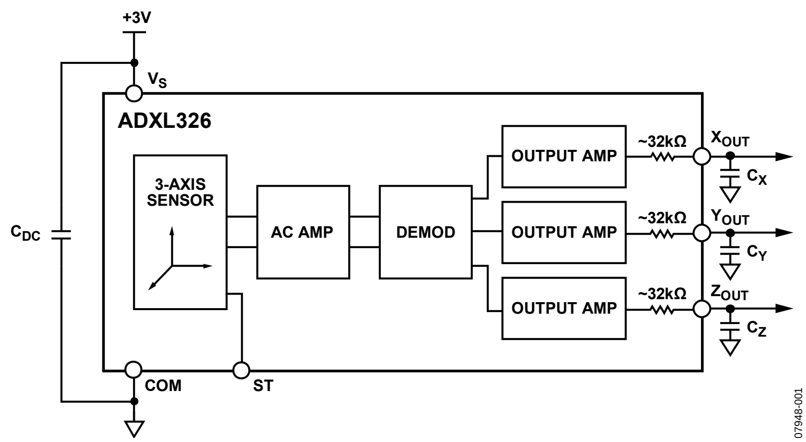

Figure 1.

One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 781.329.4700 **www.analog.com**
Fax: 781.461.3113

TABLE OF CONTENTS

REVISION HISTORY

8/09—Revision 0: Initial Version

SPECIFICATIONS

T_A = 25°C, V_S = 3 V, C_X = C_Y = C_Z = 0.1 µF, acceleration = 0 *g*, unless otherwise noted. All minimum and maximum specifications are guaranteed. Typical specifications are not guaranteed.

Table 1.

Parameter	Conditions	Min	Typ	Max	Unit
SENSOR INPUT	Each axis				
Measurement Range		±16	±19		*g*
Nonlinearity	Percent of full scale		±0.3		%
Package Alignment Error			±1		Degrees
Interaxis Alignment Error			±0.1		Degrees
Cross Axis Sensitivity[1]			±1		%
SENSITIVITY (RATIOMETRIC)[2]	Each axis				
Sensitivity at X_{OUT}, Y_{OUT}, Z_{OUT}	V_S = 3 V	51	57	63	mV/*g*
Sensitivity Change Due to Temperature[3]	V_S = 3 V		±0.01		%/°C
ZERO *g* BIAS LEVEL (RATIOMETRIC)					
0 *g* Voltage at X_{OUT}, Y_{OUT}	V_S = 3 V	1.35	1.5	1.65	V
0 *g* Voltage at Z_{OUT}	V_S = 3 V	1.2	1.5	1.8	V
0 *g* Offset vs. Temperature			±1		m*g*/°C
NOISE PERFORMANCE					
Noise Density X_{OUT}, Y_{OUT}, Z_{OUT}			300		µ*g*/√Hz rms
FREQUENCY RESPONSE[4]					
Bandwidth X_{OUT}, Y_{OUT}[5]	No external filter		1600		Hz
Bandwidth Z_{OUT}[5]	No external filter		550		Hz
R_{FILT} Tolerance			32 ± 15%		kΩ
Sensor Resonant Frequency			5.5		kHz
SELF TEST[6]					
Logic Input Low			+0.6		V
Logic Input High			+2.4		V
ST Actuation Current			+60		µA
Output Change at X_{OUT}	Self test 0 to 1	−29	−62	−114	mV
Output Change at Y_{OUT}	Self test 0 to 1	+29	+62	+114	mV
Output Change at Z_{OUT}	Self test 0 to 1	+29	+105	+190	mV
OUTPUT AMPLIFIER					
Output Swing Low	No load		0.1		V
Output Swing High	No load		2.8		V
POWER SUPPLY					
Operating Voltage Range		1.8		3.6	V
Supply Current	V_S = 3 V		350		µA
Turn-On Time[7]	No external filter		1		ms
TEMPERATURE					
Operating Temperature Range		−40		+85	°C

[1] Defined as coupling between any two axes.
[2] Sensitivity is essentially ratiometric to V_S.
[3] Defined as the output change from ambient-to-maximum temperature or ambient-to-minimum temperature.
[4] Actual frequency response controlled by user-supplied external filter capacitors (C_X, C_Y, C_Z).
[5] Bandwidth with external capacitors = 1/(2 × π × 32 kΩ × C). For C_X, C_Y = 0.003 µF, bandwidth = 1.6 kHz. For C_Z = 0.01 µF, bandwidth = 500 Hz. For C_X, C_Y, C_Z = 10 µF, bandwidth = 0.5 Hz.
[6] Self test response changes cubically with V_S.
[7] Turn-on time is dependent on C_X, C_Y, C_Z and is approximately 160 × C_X or C_Y or C_Z + 1 ms, where C_X, C_Y, C_Z are in µF.

ABSOLUTE MAXIMUM RATINGS

Table 2.

Parameter	Rating
Acceleration (Any Axis, Unpowered)	10,000 *g*
Acceleration (Any Axis, Powered)	10,000 *g*
V_S	−0.3 V to +3.6 V
All Other Pins	(COM − 0.3 V) to (V_S + 0.3 V)
Output Short-Circuit Duration (Any Pin to Common)	Indefinite
Temperature Range (Powered)	−55°C to +125°C
Temperature Range (Storage)	−65°C to +150°C

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ESD CAUTION

ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

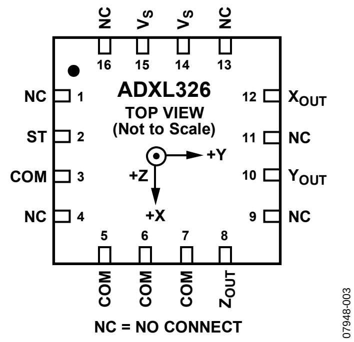

Figure 2. Pin Configuration

Table 3. Pin Function Descriptions

Pin No.	Mnemonic	Description
1	NC	No Connect (or Optionally Ground)
2	ST	Self Test
3	COM	Common
4	NC	No Connect
5	COM	Common
6	COM	Common
7	COM	Common
8	Z_{OUT}	Z Channel Output
9	NC	No Connect (or Optionally Ground)
10	Y_{OUT}	Y Channel Output
11	NC	No Connect
12	X_{OUT}	X Channel Output
13	NC	No Connect
14	V_S	Supply Voltage (1.8 V to 3.6 V)
15	V_S	Supply Voltage (1.8 V to 3.6 V)
16	NC	No Connect
EP	Exposed pad	Not internally connected. Solder for mechanical integrity.

TYPICAL PERFORMANCE CHARACTERISTICS

N > 1000 for all typical performance plots, unless otherwise noted.

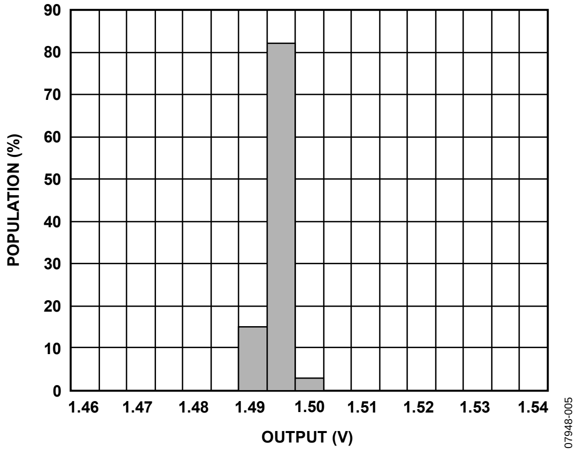

Figure 3. X-Axis Zero g *Bias at 25°C, V_S = 3 V*

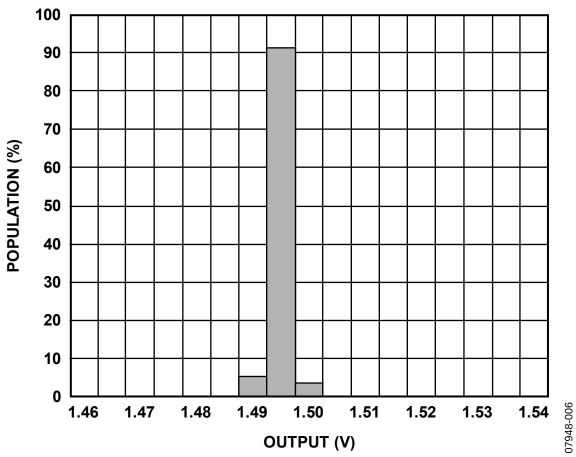

Figure 4. Y-Axis Zero g *Bias at 25°C, V_S = 3 V*

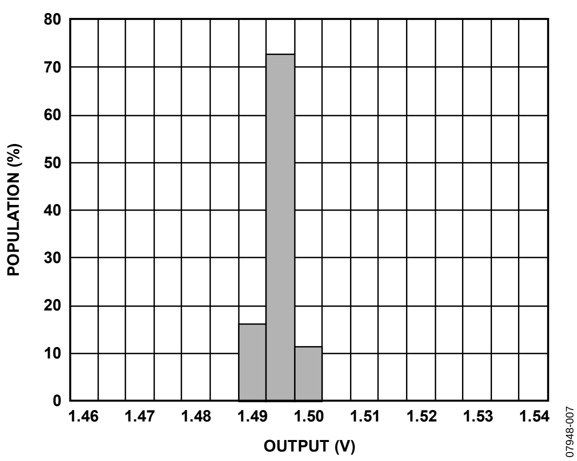

Figure 5. Z-Axis Zero g *Bias at 25°C, V_S = 3 V*

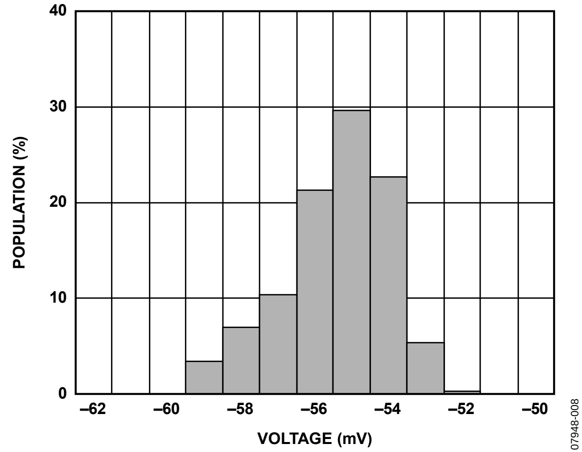

Figure 6. X-Axis Self Test Response at 25°C, V_S = 3 V

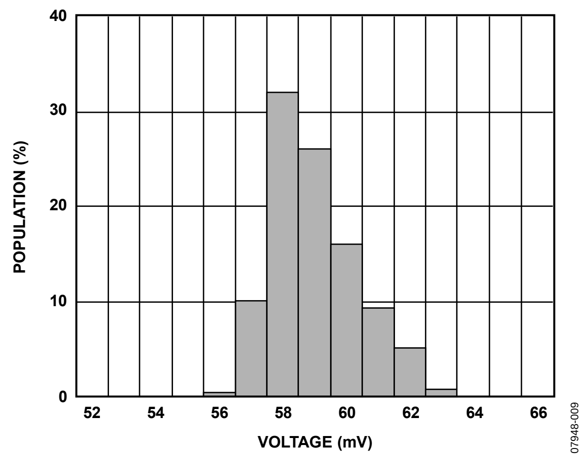

Figure 7. Y-Axis Self Test Response at 25°C, V_S = 3 V

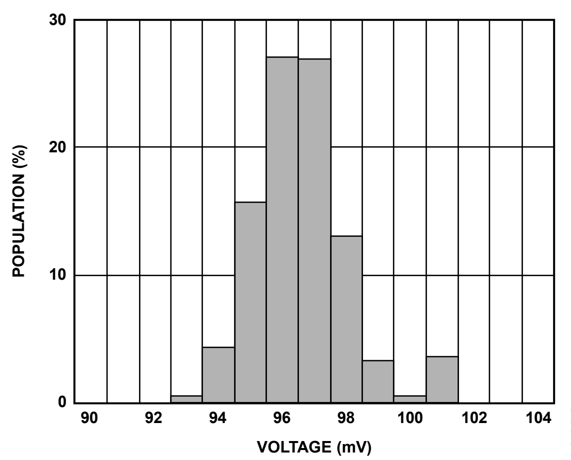

Figure 8. Z-Axis Self Test Response at 25°C, V_S = 3 V

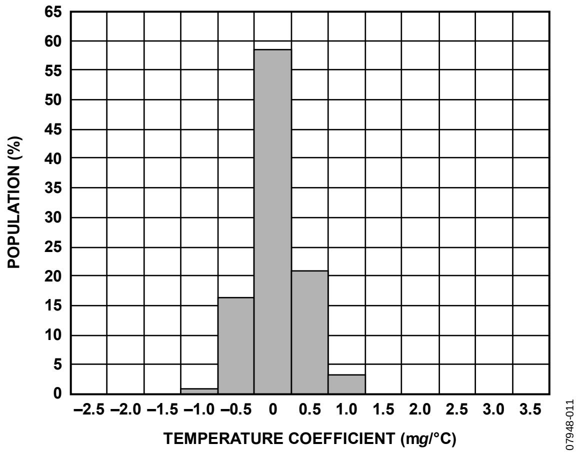

Figure 9. X-Axis Zero g Bias Temperature Coefficient, V_S = 3 V

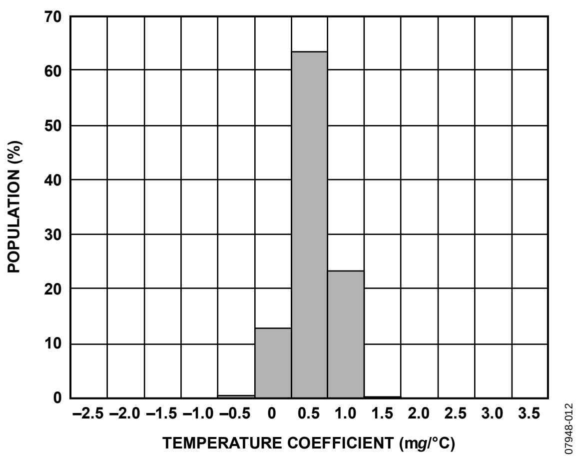

Figure 10. Y-Axis Zero g Bias Temperature Coefficient, V_S = 3 V

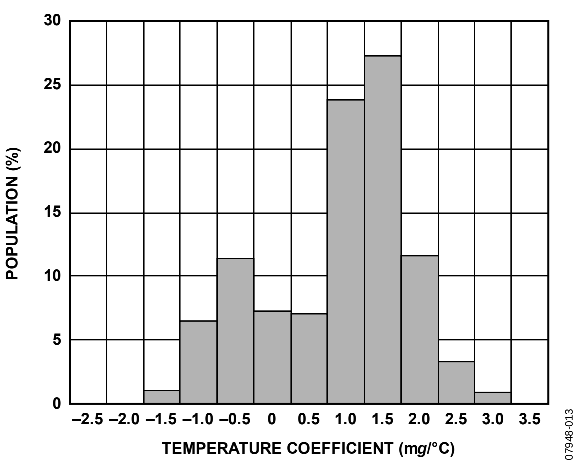

Figure 11. Z-Axis Zero g Bias Temperature Coefficient, V_S = 3 V

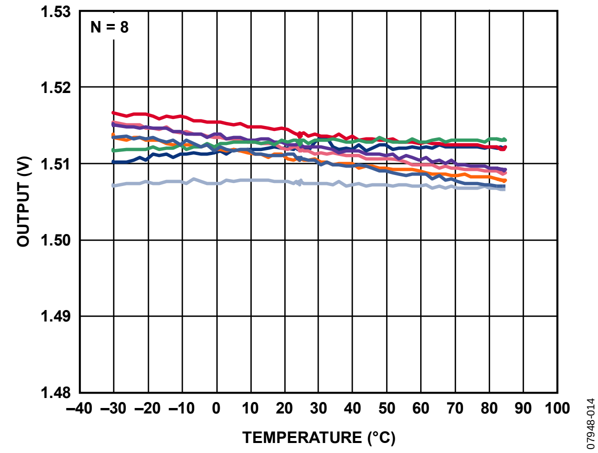

Figure 12. X-Axis Zero g Bias vs. Temperature, Eight Parts Soldered to PCB

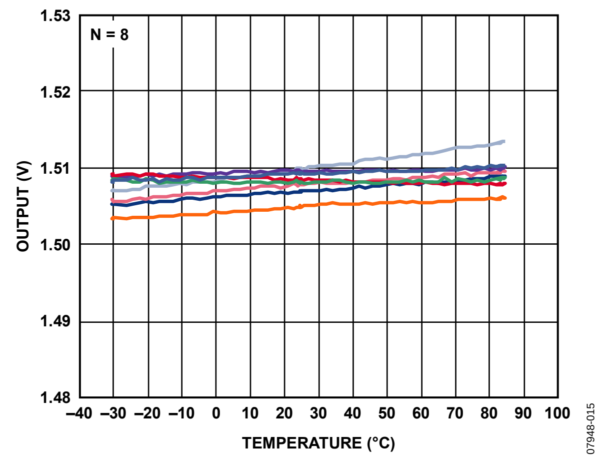

Figure 13. Y-Axis Zero g Bias vs. Temperature, Eight Parts Soldered to PCB

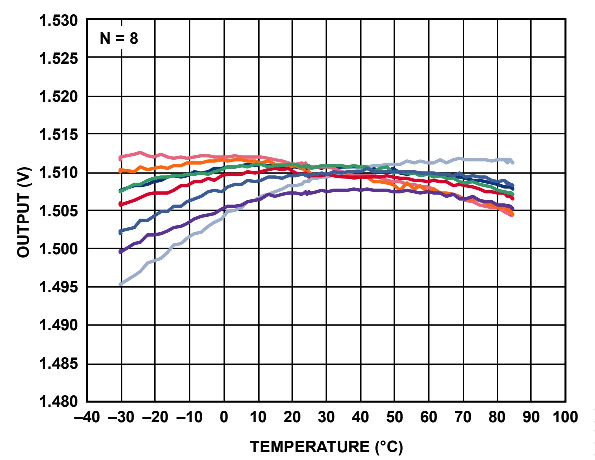

Figure 14. Z-Axis Zero g Bias vs. Temperature, Eight Parts Soldered to PCB

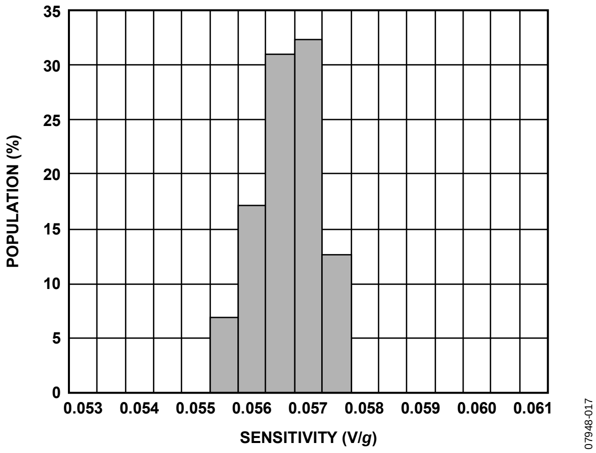

Figure 15. X-Axis Sensitivity at 25°C, V_S = 3 V

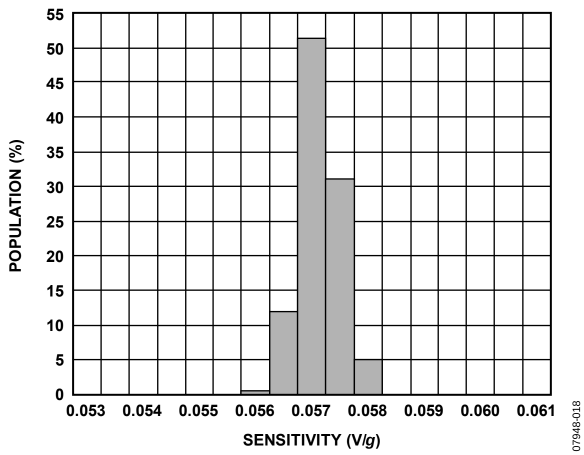

Figure 16. Y-Axis Sensitivity at 25°C, V_S = 3 V

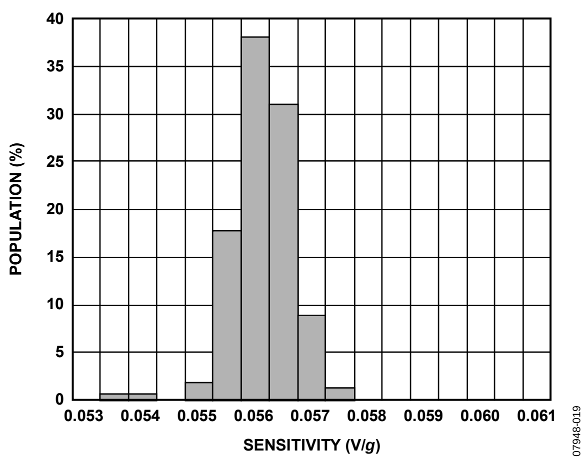

Figure 17. Z-Axis Sensitivity at 25°C, V_S = 3 V

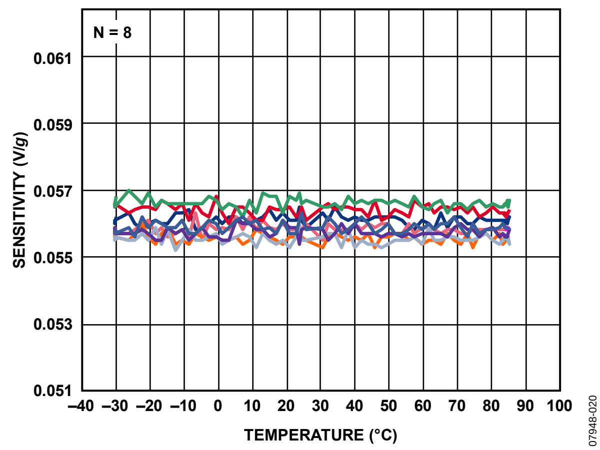

Figure 18. X-Axis Sensitivity vs. Temperature, Eight Parts Soldered to PCB, V_S = 3 V

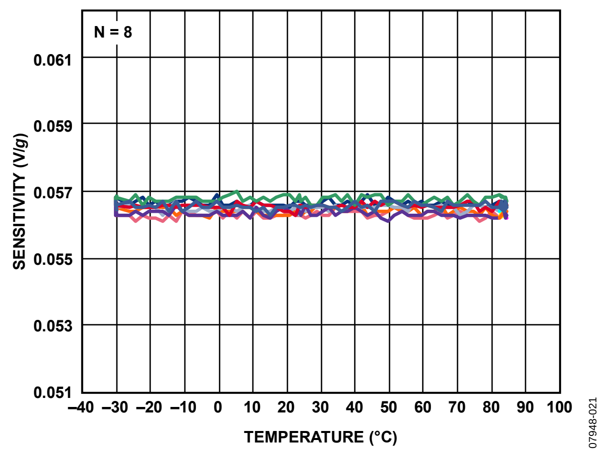

Figure 19. Y-Axis Sensitivity vs. Temperature, Eight Parts Soldered to PCB, V_S = 3 V

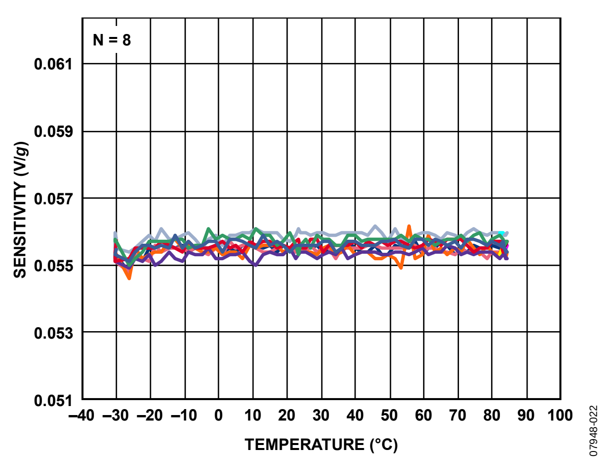

Figure 20. Z-Axis Sensitivity vs. Temperature, Eight Parts Soldered to PCB, V_S = 3 V

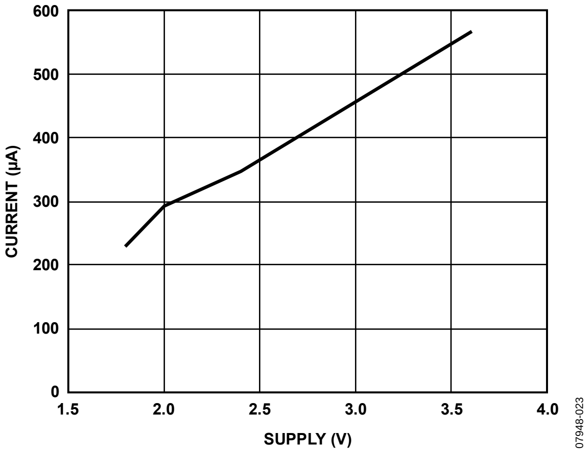

Figure 21. Typical Current Consumption vs. Supply Voltage

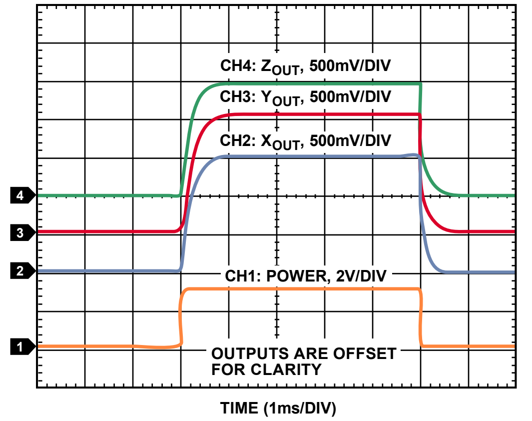

Figure 22. Typical Turn-On Time, V_S = 3 V, C_X = C_Y = C_Z = 0.0047 µF

THEORY OF OPERATION

The ADXL326 is a complete 3-axis acceleration measurement system. The ADXL326 has a measurement range of ±16 *g* minimum. It contains a polysilicon surface micromachined sensor and signal conditioning circuitry to implement an open-loop acceleration measurement architecture. The output signals are analog voltages that are proportional to acceleration. The accelerometer can measure the static acceleration of gravity in tilt sensing applications, as well as dynamic acceleration, resulting from motion, shock, or vibration.

The sensor is a polysilicon surface micromachined structure built on top of a silicon wafer. Polysilicon springs suspend the structure over the surface of the wafer and provide a resistance against acceleration forces. Deflection of the structure is measured using a differential capacitor that consists of independent fixed plates and plates attached to the moving mass. The fixed plates are driven by 180° out-of-phase square waves. Acceleration deflects the moving mass and unbalances the differential capacitor resulting in a sensor output whose amplitude is proportional to acceleration. Phase-sensitive demodulation techniques are then used to determine the magnitude and direction of the acceleration.

The demodulator output is amplified and brought off-chip through a 32 kΩ resistor. The user then sets the signal bandwidth of the device by adding a capacitor. This filtering improves measurement resolution and helps prevent aliasing.

MECHANICAL SENSOR

The ADXL326 uses a single structure for sensing the X, Y, and Z axes. As a result, the three axes sense directions are highly orthogonal with little cross-axis sensitivity. Mechanical misalignment of the sensor die to the package is the chief source of cross-axis sensitivity. Mechanical misalignment can, of course, be calibrated out at the system level.

PERFORMANCE

Rather than using additional temperature compensation circuitry, innovative design techniques ensure that high performance is built-in to the ADXL326. As a result, there is neither quantization error nor nonmonotonic behavior, and temperature hysteresis is very low (typically <3 m*g* over the −25°C to +70°C temperature range).

APPLICATIONS INFORMATION

POWER SUPPLY DECOUPLING

For most applications, a single 0.1 µF capacitor, C_{DC}, placed close to the ADXL326 supply pins adequately decouples the accelerometer from noise on the power supply. However, in applications where noise is present at the 50 kHz internal clock frequency (or any harmonic thereof), additional care in power supply bypassing is required because this noise can cause errors in acceleration measurement. If additional decoupling is needed, a 100 Ω (or smaller) resistor or ferrite bead can be inserted in the supply line. Additionally, a larger bulk bypass capacitor (1 µF or greater) can be added in parallel to C_{DC}. Ensure that the connection from the ADXL326 ground to the power supply ground is low impedance because noise transmitted through ground has a similar effect as noise transmitted through V_S.

SETTING THE BANDWIDTH USING C_X, C_Y, AND C_Z

The ADXL326 has provisions for band limiting the X_{OUT}, Y_{OUT}, and Z_{OUT} pins. Capacitors must be added at these pins to implement low-pass filtering for antialiasing and noise reduction. The 3 dB bandwidth equation is

$$f_{-3\,dB} = 1/(2\pi(32\ k\Omega) \times C_{(X, Y, Z)})$$

or more simply

$$f_{-3\,dB} = 5\ \mu F/C_{(X, Y, Z)}$$

The tolerance of the internal resistor (R_{FILT}) typically varies as much as ±15% of its nominal value (32 kΩ), and the bandwidth varies accordingly. A minimum capacitance of 0.0047 µF for C_X, C_Y, and C_Z is recommended in all cases.

Table 4. Filter Capacitor Selection, C_X, C_Y, and C_Z

Bandwidth (Hz)	Capacitor (µF)
1	4.7
10	0.47
50	0.10
100	0.05
200	0.027
500	0.01

SELF TEST

The ST pin controls the self test feature. When this pin is set to V_S, an electrostatic force is exerted on the accelerometer beam. The resulting movement of the beam allows the user to test whether the accelerometer is functional. The typical change in output is −1.08 *g* (corresponding to −62 mV) in the X axis, +1.08 *g* (+62 mV) on the Y axis, and +1.83 *g* (+105 mV) on the Z axis. This ST pin can be left open circuit or connected to common (COM) in normal use.

Never expose the ST pin to voltages greater than V_S + 0.3 V. If this cannot be guaranteed due to the system design (for instance, there are multiple supply voltages), then a low V_F clamping diode between ST and V_S is recommended.

DESIGN TRADE-OFFS FOR SELECTING FILTER CHARACTERISTICS: THE NOISE/BW TRADE-OFF

The selected accelerometer bandwidth ultimately determines the measurement resolution (smallest detectable acceleration). Filtering can be used to lower the noise floor to improve the resolution of the accelerometer. Resolution is dependent on the analog filter bandwidth at X_{OUT}, Y_{OUT}, and Z_{OUT}.

The output of the ADXL326 has a typical bandwidth greater than 500 Hz. The user must filter the signal at this point to limit aliasing errors. The analog bandwidth must be no more than half the analog-to-digital sampling frequency to minimize aliasing. The analog bandwidth can be further decreased to reduce noise and improve resolution.

The ADXL326 noise has the characteristics of white Gaussian noise, which contributes equally at all frequencies and is described in terms of µ*g*/√Hz (the noise is proportional to the square root of the accelerometer bandwidth). The user should limit bandwidth to the lowest frequency needed by the application to maximize the resolution and dynamic range of the accelerometer.

With the single-pole roll-off characteristic, the typical noise of the ADXL326 is determined by

$$rms\ Noise = Noise\ Density \times (\sqrt{BW \times 1.6})$$

Often, the peak value of the noise is desired. Peak-to-peak noise can only be estimated by statistical methods. Table 5 is useful for estimating the probabilities of exceeding various peak values, given the rms value.

Table 5. Estimation of Peak-to-Peak Noise

Peak-to-Peak Value	% of Time That Noise Exceeds Nominal Peak-to-Peak Value
2 × rms	32
4 × rms	4.6
6 × rms	0.27
8 × rms	0.006

USE WITH OPERATING VOLTAGES OTHER THAN 3 V

The ADXL326 is tested and specified at V_S = 3 V; however, it can be powered with V_S as low as 1.8 V or as high as 3.6 V. Note that some performance parameters change as the supply voltage is varied.

The ADXL326 output is ratiometric; therefore, the output sensitivity (or scale factor) varies proportionally to the supply voltage. At V_S = 3.6 V, the output sensitivity is typically 68 mV/*g*. At V_S = 2 V, the output sensitivity is typically 38 mV/*g*.

The zero *g* bias output is also ratiometric; therefore, the zero *g* output is nominally equal to $V_S/2$ at all supply voltages.

The output noise is not ratiometric but is absolute in volts; therefore, the noise density decreases as the supply voltage increases. This is because the scale factor (mV/*g*) increases while the noise voltage remains constant. At V_S = 3.6 V, the X- and Y-axis noise density is typically 120 µ*g*/√Hz, while at V_S = 2 V, the X- and Y-axis noise density is typically 270 µ*g*/√Hz.

Self test response in *g* is roughly proportional to the square of the supply voltage. However, when ratiometricity of sensitivity is factored in with supply voltage, the self test response in volts is roughly proportional to the cube of the supply voltage.

For example, at V_S = 3.6 V, the self test response for the ADXL326 is approximately −107 mV for the X axis, +107 mV for the Y axis, and +181 mV for the Z axis. At V_S = 2 V, the self test response is approximately −18 mV for the X axis, +18 mV for the Y axis, and −31 mV for the Z axis.

The supply current decreases as the supply voltage decreases. Typical current consumption at V_S = 3.6 V is 375 µA, and typical current consumption at V_S = 2 V is 200 µA.

AXES OF ACCELERATION SENSITIVITY

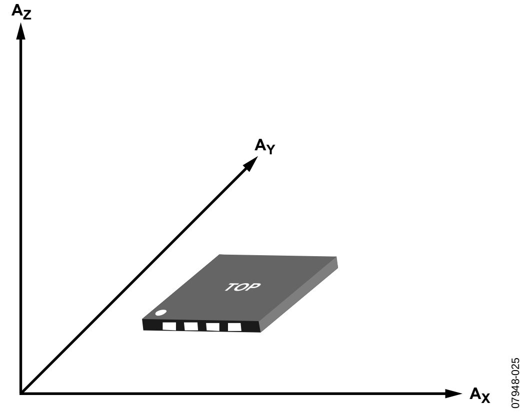

Figure 23. Axes of Acceleration Sensitivity (Corresponding Output Voltage Increases When Accelerated Along the Sensitive Axis)

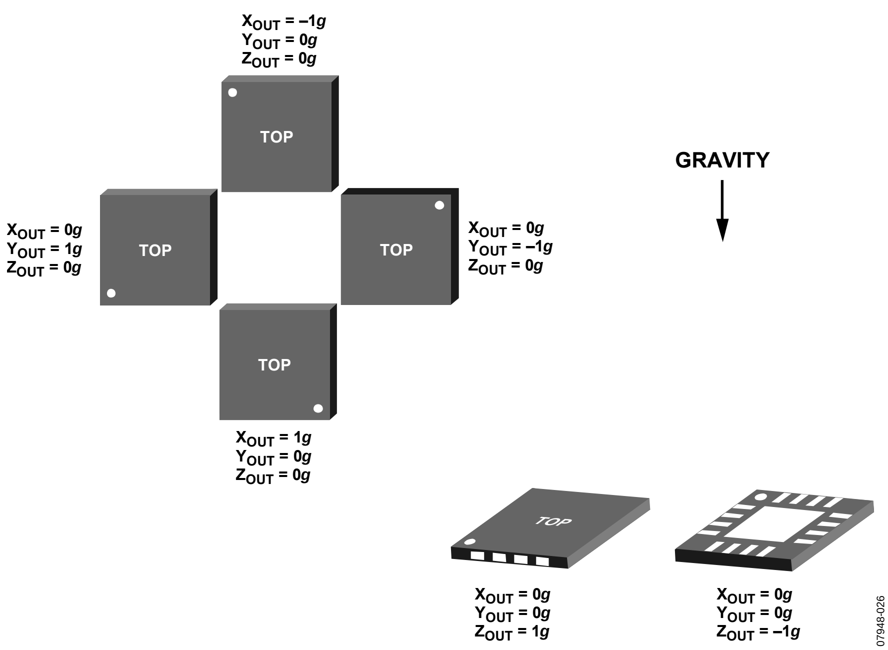

Figure 24. Output Response vs. Orientation to Gravity

LAYOUT AND DESIGN RECOMMENDATIONS

The recommended soldering profile is shown in Figure 25, followed by a description of the profile features in Table 6. The recommended PCB layout or solder land drawing is shown in Figure 26.

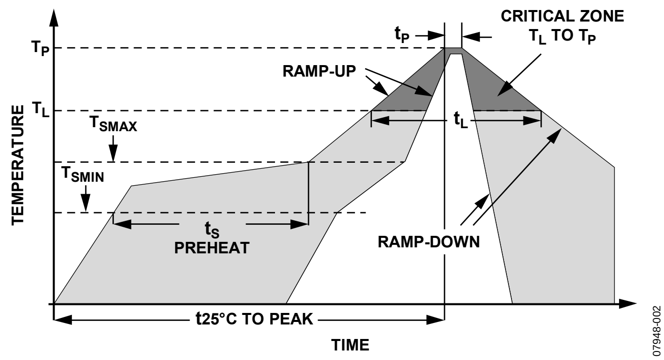

Figure 25. Recommended Soldering Profile

Table 6. Recommended Soldering Profile

Profile Feature	Sn63/Pb37	Pb-Free
Average Ramp Rate (T_L to T_P)	3°C/sec maximum	3°C/sec maximum
Preheat		
Minimum Temperature (T_{SMIN})	100°C	150°C
Maximum Temperature (T_{SMAX})	150°C	200°C
Time (T_{SMIN} to T_{SMAX}), t_S	60 sec to 120 sec	60 sec to 180 sec
T_{SMAX} to T_L		
Ramp-Up Rate	3°C/sec maximum	3°C/sec maximum
Time Maintained Above Liquidous (T_L)		
Liquidous Temperature (T_L)	183°C	217°C
Time (t_L)	60 sec to 150 sec	60 sec to 150 sec
Peak Temperature (T_P)	240°C + 0°C/−5°C	260°C + 0°C/−5°C
Time Within 5°C of Actual Peak Temperature (t_P)	10 sec to 30 sec	20 sec to 40 sec
Ramp-Down Rate	6°C/sec maximum	6°C/sec maximum
Time 25°C to Peak Temperature	6 minutes maximum	8 minutes maximum

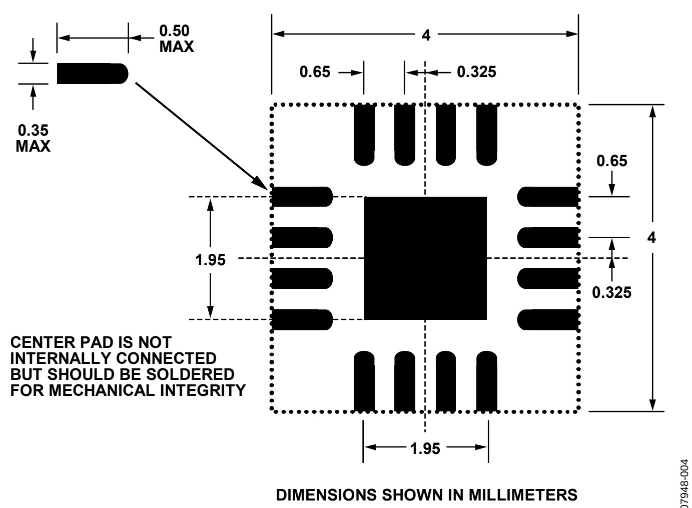

Figure 26. Recommended PCB Layout

OUTLINE DIMENSIONS

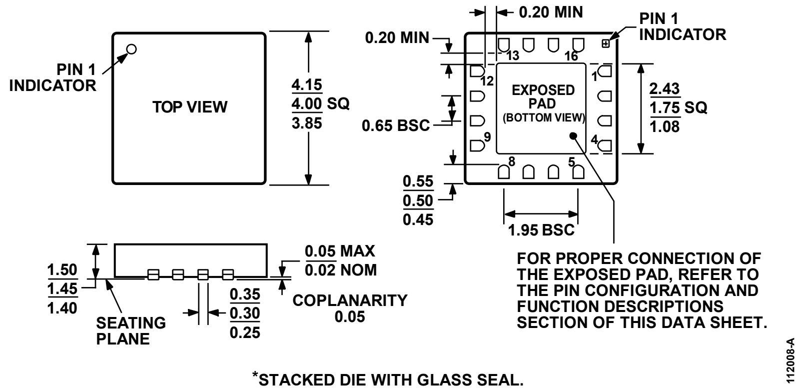

Figure 27. 16-Lead Lead Frame Chip Scale Package [LFCSP_LQ]
4 mm × 4 mm Body, 1.45 mm Thick Quad
(CP-16-5a)*
Dimensions shown in millimeters

ORDERING GUIDE

Model	Measurement Range	Specified Voltage	Temperature Range	Package Description	Package Option
ADXL326BCPZ[1]	±16 *g*	3 V	−40°C to +85°C	16-Lead LFCSP_LQ	CP-16-5a
ADXL326BCPZ–RL[1]	±16 *g*	3 V	−40°C to +85°C	16-Lead LFCSP_LQ	CP-16-5a
ADXL326BCPZ–RL7[1]	±16 *g*	3 V	−40°C to +85°C	16-Lead LFCSP_LQ	CP-16-5a
EVAL-ADXL326Z[1]				Evaluation Board	

[1] Z = RoHS Compliant Part.

NOTES

NOTES

D07948-0-8/09(0)

ANALOG DEVICES

www.analog.com