Precision ±18 *g* Single-/Dual-Axis *i*MEMS Accelerometer

ADW22035/ADW22037

FEATURES

High performance, single-/dual-axis accelerometer on a single IC chip
Low power: 740 μA at V_S = 5 V (typical)
High zero *g* bias stability
High sensitivity accuracy
–40°C to +125°C temperature range
X and Y axes aligned to within 0.1° (typical)
BW adjustment with a single capacitor
Single-supply operation
3500 *g* shock survival
RoHS-compliant
Compatible with Sn/Pb- and Pb-free solder processes
5 mm × 5 mm × 2 mm LCC package

APPLICATIONS

Vibration monitoring and compensation
Abuse event detection
Sports equipment
Vehicle dynamic control

GENERAL DESCRIPTION

The ADW22035/ADW22037 are high precision, low power, complete single- and dual-axis *i*MEMS® accelerometers with signal conditioned voltage outputs, all on a single, monolithic IC. The ADW22035/ADW22037 measure acceleration with a full-scale range of ±18 *g*. The ADW22035/ADW22037 can measure both dynamic acceleration, such as vibration, and static acceleration, such as gravity.

The user selects the bandwidth of the accelerometer using Capacitor C_X and Capacitor C_Y at the X_{OUT} and Y_{OUT} pins. Bandwidths of 0.5 Hz to 2.5 kHz can be selected to suit the application.

The ADW22035/ADW22037 are available in 5 mm × 5 mm × 2 mm, 8-terminal hermetic LCC packages.

FUNCTIONAL BLOCK DIAGRAMS

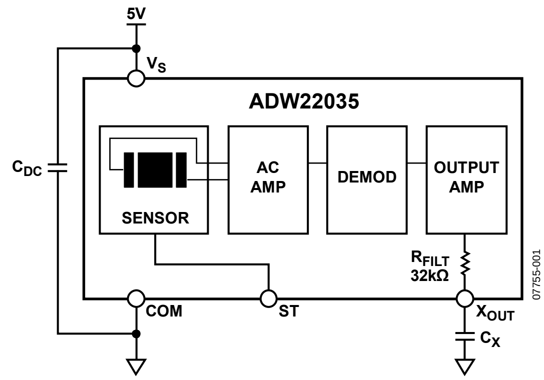

Figure 1.

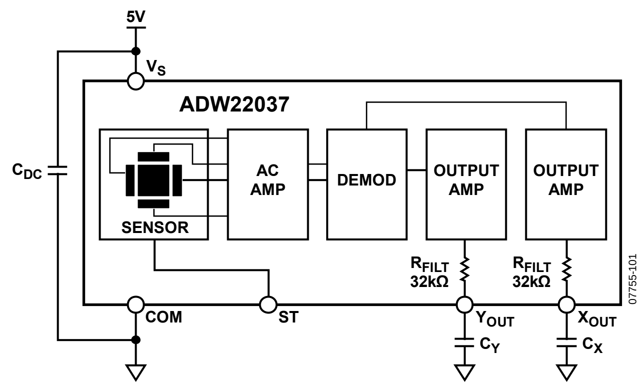

Figure 2.

Rev. 0

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REVISION HISTORY

10/08—Revision 0: Initial Version

SPECIFICATIONS

T_A = −40°C to +125°C, V_S = 5 V, C_X = C_Y = 0.1 μF, acceleration = 0 *g*, unless otherwise noted.

Table 1.

Parameter	Conditions	Min[1]	Typ	Max[1]	Unit
SENSOR INPUT	Each axis				
Measurement Range[2]		±18			*g*
Nonlinearity	% of full scale		±0.2	±1.25	%
Package Alignment Error			±1		Degrees
Alignment Error (ADW22037)	X sensor to Y sensor		±0.1		Degrees
Cross-Axis Sensitivity			±1.5	±3	%
SENSITIVITY (RATIOMETRIC)[3]	Each axis				
Sensitivity at X_{OUT}, Y_{OUT}	V_S = 5 V	94	100	106	mV/*g*
Sensitivity Change Due to Temperature[4]	V_S = 5 V		±0.3		%
ZERO *g* BIAS LEVEL (RATIOMETRIC)	Each axis				
0 *g* Voltage at X_{OUT}, Y_{OUT}	V_S = 5 V	2.4	2.5	2.6	V
Initial 0 *g* Output Deviation from Ideal	V_S = 5 V, 25°C		±125		m*g*
0 *g* Offset vs. Temperature			±1		m*g*/°C
NOISE PERFORMANCE					
Output Noise	<4 kHz, V_S = 5 V			2	mV rms
Noise Density			130		μ*g*/√Hz rms
FREQUENCY RESPONSE[5]					
C_X, C_Y Range[6]		0.002		10	μF
R_{FILT} Tolerance		24	32	40	kΩ
Sensor Resonant Frequency			5.5		kHz
SELF-TEST (ST)[7]					
Logic Input Low				1	V
Logic Input High		4			V
ST Input Resistance to Ground		30	50		kΩ
Output Change at X_{OUT}, Y_{OUT}	Self-Test 0 to Self-Test 1	60	80	100	mV
OUTPUT AMPLIFIER					
Output Swing Low	No load	0.05	0.2		V
Output Swing High	No load		4.5	4.8	V
POWER SUPPLY					
Operating Voltage Range		3		6	V
Quiescent Supply Current			0.7	1.1	mA
Turn-On Time[8]			20		ms

[1] All minimum and maximum specifications are guaranteed. Typical specifications are not guaranteed.
[2] Guaranteed by measurement of initial offset and sensitivity.
[3] Sensitivity is essentially ratiometric to V_S. For V_S = 4.75 V to 5.25 V, sensitivity is 18.6 mV/V/*g* to 21.5 mV/V/*g*.
[4] Defined as the output change from ambient-to-maximum temperature or ambient-to-minimum temperature.
[5] Actual frequency response controlled by user-supplied external capacitor (C_X, C_Y).
[6] Bandwidth = 1/(2 × π × 32 kΩ × C). For C_X, C_Y = 0.002 μF, bandwidth = 2500 Hz. For C_X, C_Y = 10 μF, bandwidth = 0.5 Hz. Minimum/maximum values are not tested.
[7] Self-test response changes cubically with V_S.
[8] Larger values of C_X, C_Y increase turn-on time. Turn-on time is approximately 160 × C_X or C_Y + 4 ms, where C_X, C_Y are in μF.

ABSOLUTE MAXIMUM RATINGS

Table 2.

Parameter	Rating
Acceleration (Any Axis, Unpowered)	3500 *g*
Acceleration (Any Axis, Powered)	3500 *g*
Drop Test (Concrete Surface)	1.2 m
V_S	−0.3 V to +7.0 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.

THERMAL RESISTANCE

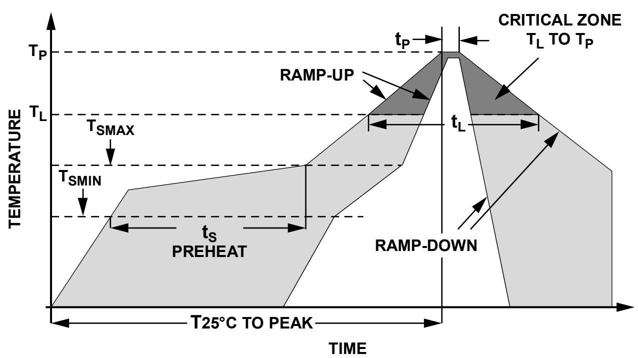
θ_{JA} is specified for the worst-case conditions, that is, a device soldered in a circuit board for surface-mount packages.

Table 3. Thermal Resistance

Package Type	θ_{JA}	θ_{JC}	Device Weight
8-Terminal Ceramic LCC	120°C/W	20°C/W	<1.0 gram

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.



Profile Feature	Condition Sn63/Pb37	Condition Pb-Free
Average Ramp Rate (T_L to T_P)	3°C/sec max	3°C/sec max
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 to 120 s	60 to 150 s
T_{SMIN} to T_L Ramp-Up Rate	3°C/sec max	3°C/sec max
Time Maintained above Liquidous (T_L)		
Liquidous Temperature (T_L)	183°C	217°C
Time (t_L)	60 to 150 s	60 to 150 s
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)	10s to 30 s	20s to 40 s
Ramp-Down Rate	6°C/sec max	6°C/sec max
Time 25°C to Peak Temperature	6 minutes max	8 minutes max

07755-002

Figure 3. Recommended Soldering Profile

PIN CONFIGURATIONS AND FUNCTION DESCRIPTIONS

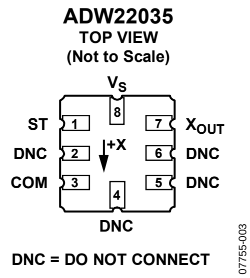


Figure 4. ADW22035 Pin Configuration

Table 4. ADW22035 Pin Function Descriptions

Pin No.	Mnemonic	Description
1	ST	Self Test
2	DNC	Do Not Connect
3	COM	Common
4	DNC	Do Not Connect
5	DNC	Do Not Connect
6	DNC	Do Not Connect
7	X_{OUT}	X Channel Output
8	V_S	3 V to 6 V

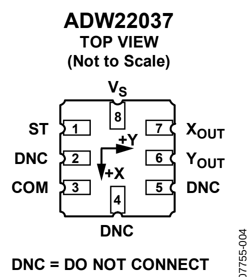


Figure 5. ADW22037 Pin Configuration

Table 5. ADW22037 Pin Function Descriptions

Pin No.	Mnemonic	Description
1	ST	Self Test
2	DNC	Do Not Connect
3	COM	Common
4	DNC	Do Not Connect
5	DNC	Do Not Connect
6	Y_{OUT}	Y Channel Output
7	X_{OUT}	X Channel Output
8	V_S	3 V to 6 V

TYPICAL PERFORMANCE CHARACTERISTICS

V_S = 5 V for all graphs, unless otherwise noted.

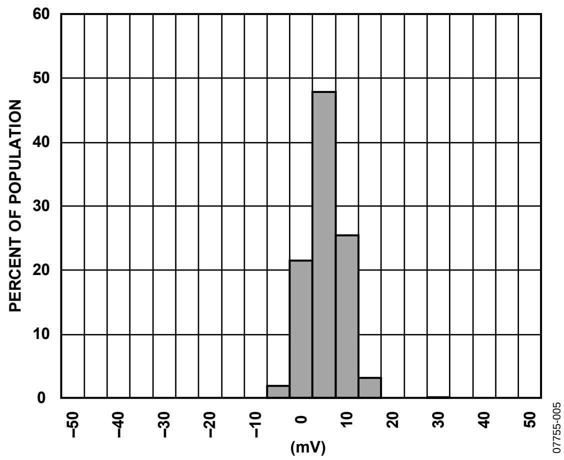


Figure 6. X-Axis Zero g *Bias Deviation from Ideal at 25°C*

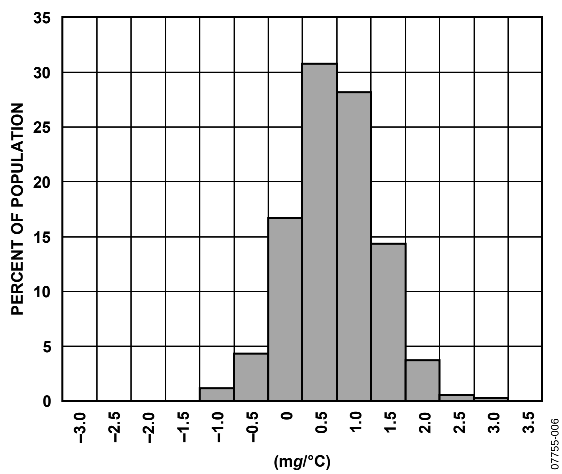


Figure 7. X-Axis Zero g *Bias Tempco*

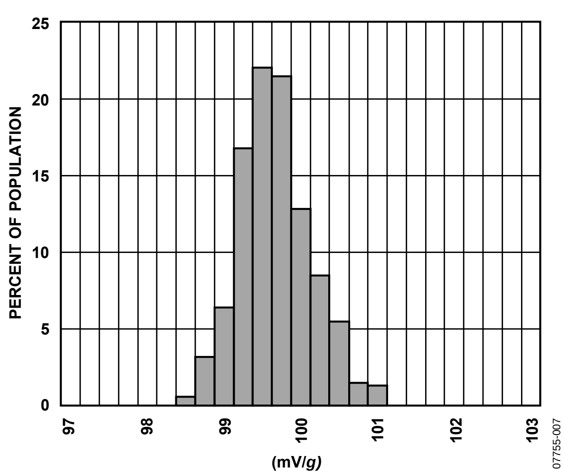


Figure 8. X-Axis Sensitivity at 25°C

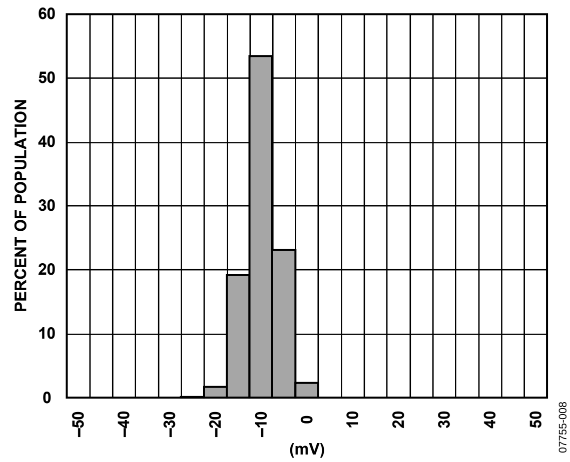


Figure 9. Y-Axis Zero g *Bias Deviation from Ideal at 25°C*

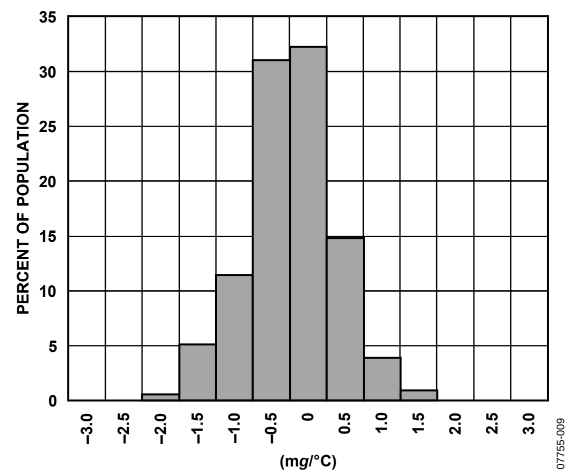


Figure 10. Y-Axis Zero g *Bias Tempco*

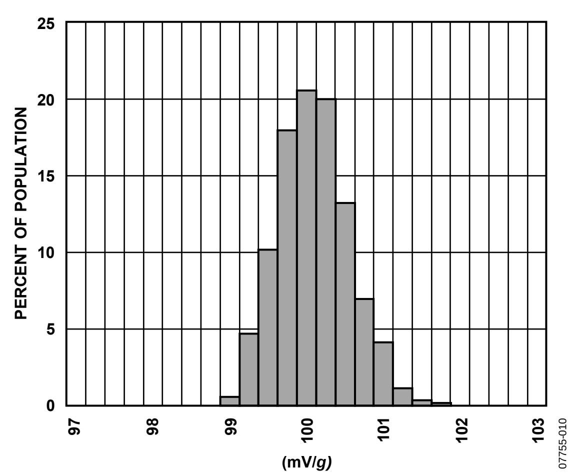


Figure 11. Y-Axis Sensitivity at 25°C

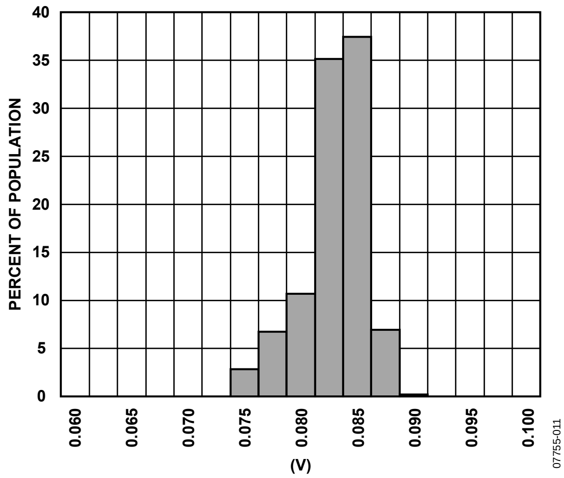


Figure 12. X-Axis Self-Test Response at 25°C

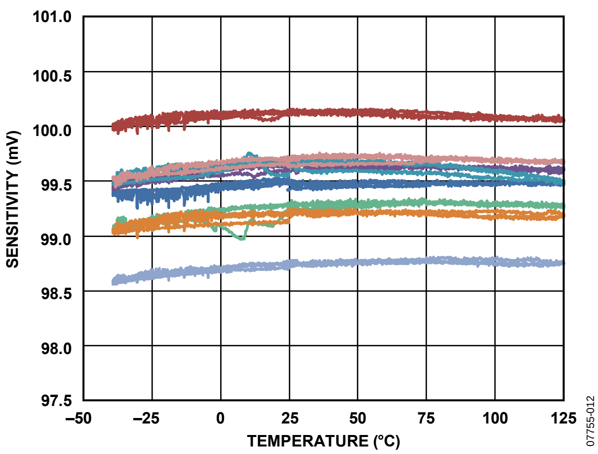


Figure 13. Sensitivity vs. Temperature; Parts Soldered to PCB

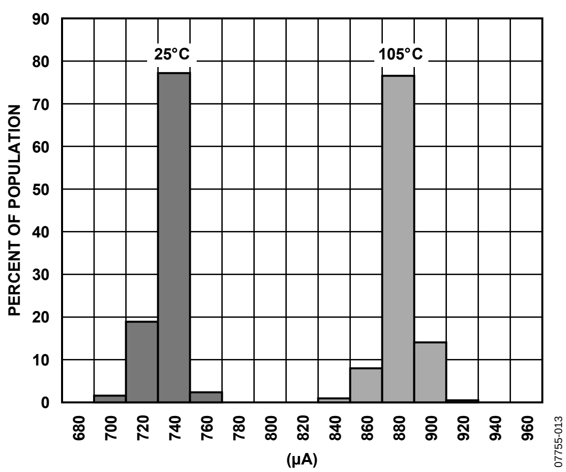


Figure 14. Supply Current vs. Temperature

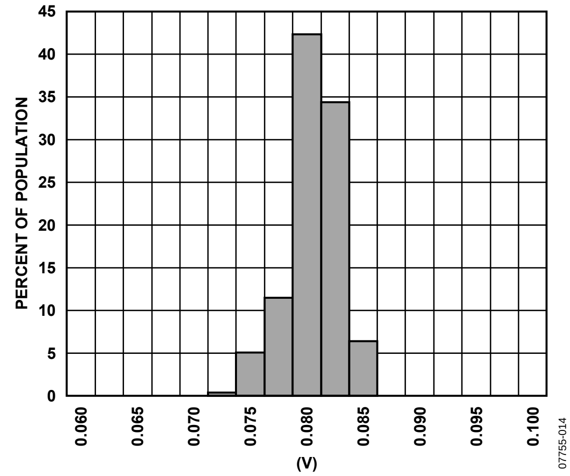


Figure 15. Y-Axis Self-Test Response at 25°C

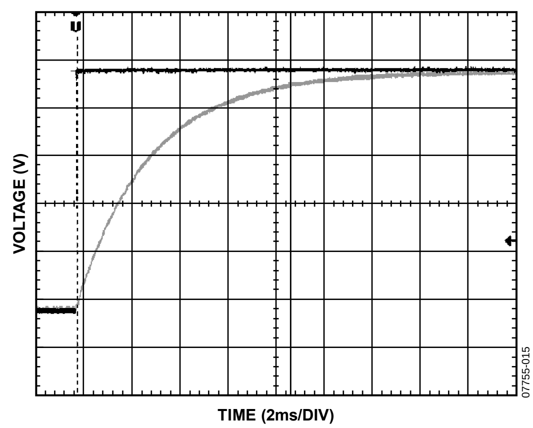


Figure 16. Turn-On Time: C_X, C_Y = 0.1 µF, Time Scale = 2 ms/div

THEORY OF OPERATION

The ADW22035/ADW22037 is a complete acceleration measurement system on a single, monolithic IC. The ADW22035/ADW22037 is a dual-axis accelerometer. This device contains a polysilicon surface-micromachined sensor and signal conditioning circuitry to implement an open-loop acceleration measurement architecture. The output signals are analog voltages proportional to acceleration. The ADW22035/ ADW22037 are capable of measuring both positive and negative accelerations to at least ±18 *g*.

The sensor is a surface-micromachined polysilicon structure built on top of the 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 beam and unbalances the differential capacitor, resulting in an output square wave whose amplitude is proportional to acceleration. Phase-sensitive demodulation techniques are then used to rectify the signal and determine the direction of the acceleration.

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

PERFORMANCE

Rather than using additional temperature compensation circuitry, innovative design techniques ensure that high performance is built in to these devices. As a result, there is essentially no quantization error or nonmonotonic behavior, and temperature hysteresis is very low (typically less than 15 m*g* over the −40°C to +125°C temperature range).

Figure 17 demonstrates the typical sensitivity shift over temperature for V_S = 5 V. Sensitivity stability is optimized for V_S = 5 V, but is still very good over the specified range; it is typically better than ±1% over temperature at V_S = 3 V.

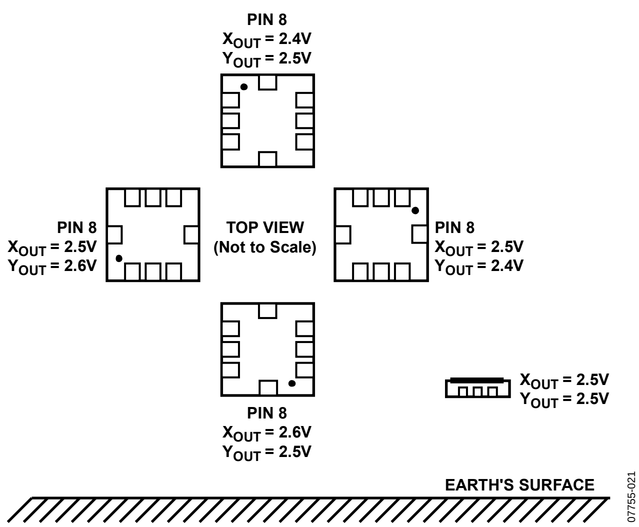


Figure 17. Output Response vs. Orientation

APPLICATIONS INFORMATION

POWER SUPPLY DECOUPLING

For most applications, a single 0.1 µF capacitor, C_{DC}, adequately decouples the accelerometer from noise on the power supply. However in some cases, particularly where noise is present at the 140 kHz internal clock frequency (or any harmonic thereof), noise on the supply can cause interference on the ADW22037 output. If additional decoupling is needed, a 100 Ω (or smaller) resistor or ferrite beads can be inserted in the supply line of the ADW22035/ADW22037. Additionally, a larger bulk bypass capacitor (in the 1 µF to 22 µF range) can be added in parallel to C_{DC}.

SETTING THE BANDWIDTH USING C_X AND C_Y

The ADW22035/ADW22037 have provisions for band limiting the X_{OUT} and Y_{OUT} pins. Capacitors must be added at these pins to implement low-pass filtering for antialiasing and noise reduction. The equation for the 3 dB bandwidth is

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

or more simply,

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

The tolerance of the internal resistor (R_{FILT}) can vary typically as much as ±25% of its nominal value (32 kΩ); thus, the bandwidth varies accordingly. A minimum capacitance of 2000 pF for C_X and C_Y is required in all cases.

Table 6. Filter Capacitor Selection, C_X and C_Y

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 beam of the accelerometer. The resulting movement of the beam allows the user to test if the accelerometer is functional. The typical change in output is 800 m*g* (corresponding to 80 mV). This pin can be left open-circuit or connected to common in normal use.

The ST pin should never be exposed to voltage greater than V_S + 0.3 V. If the system design is such that this condition cannot be guaranteed (that is, multiple supply voltages are present), 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 accelerometer bandwidth selected ultimately determines the measurement resolution (smallest detectable acceleration). Filtering can be used to lower the noise floor, improving the resolution of the accelerometer. Resolution is dependent on the analog filter bandwidth at X_{OUT} and Y_{OUT}.

The output of the ADW22035/ADW22037 has a typical bandwidth of 2.5 kHz. 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 ADW22035/ADW22037 noise has the characteristics of white Gaussian noise, which contributes equally at all frequencies and is described in terms of µ*g*/√Hz (that is, 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 ADW22035/ADW22037is determined by

$$rmsNoise = (130\ \mu g/\sqrt{Hz}) \times (\sqrt{BW \times 1.6})$$

At 100 Hz, the noise is

$$rmsNoise = (130\ \mu g/\sqrt{Hz}) \times (\sqrt{100 \times 1.6}) = 1.64\ mg$$

Often, the peak value of the noise is desired. Peak-to-peak noise can only be estimated by statistical methods. Table 7 is useful for estimating the probabilities of exceeding various peak values, given the rms value.

Table 7. 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

Peak-to-peak noise values provide the best estimate of the uncertainty in a single measurement. Peak-to-peak noise is estimated by 6 × rms. Table 8 gives the typical noise output of the ADW22035/ADW22037 for various C_X and C_Y values.

Table 8. Filter Capacitor Selection (C_X, C_Y)

Bandwidth (Hz)	C_X, C_Y (µF)	RMS Noise (m*g*)	Peak-to-Peak Noise Estimate (m*g*)
10	0.47	0.5	3.0
50	0.1	1.2	7.2
100	0.047	1.6	9.6
500	0.01	3.7	22.2

USING THE ADW22035/ADW22037 WITH OPERATING VOLTAGES OTHER THAN 5 V

The ADW22035/ADW22037 are tested and specified at V_S = 5 V; however, it can be powered with V_S as low as 3 V or as high as 6 V. Some performance parameters change as the supply voltage is varied.

The ADW22035/ADW22037 output is ratiometric, thus the output sensitivity (or scale factor) varies proportionally to the supply voltage. At V_S = 3 V the output sensitivity is typically 56 mV/*g*.

The zero *g* bias output is also ratiometric, thus 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 V, the noise density is typically 240 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, self-test response in volts is roughly proportional to the cube of the supply voltage. Thus, at V_S = 3 V, the self-test response is approximately equivalent to 15 mV or equivalent to 270 m*g* (typical).

OUTLINE DIMENSIONS

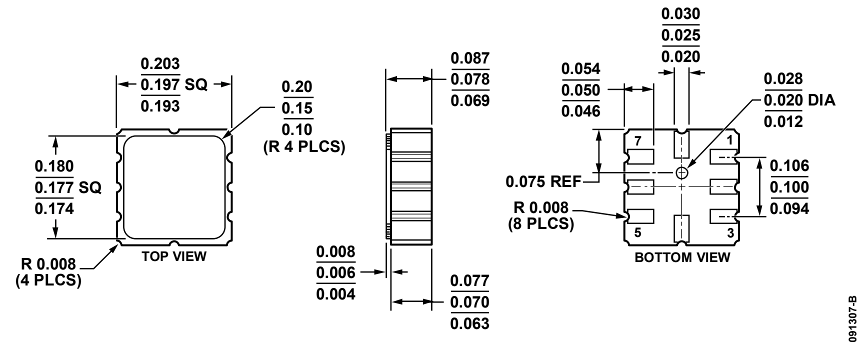


Figure 18. 8-Terminal Ceramic Leadless Chip Carrier [LCC]
(E-8-1)
Dimensions shown in inches

ORDERING GUIDE

Model	Number of Axes	Specified Voltage (V)	Temperature Range	Package Description	Package Option
ADW22035Z[1]	1	5	–40°C to +125°C	8-Terminal Ceramic Leadless Chip Carrier [LCC]	E-8-1
ADW22035Z-RL[1]	1	5	–40°C to +125°C	8-Terminal Ceramic Leadless Chip Carrier [LCC]	E-8-1
ADW22035Z-RL7[1]	1	5	–40°C to +125°C	8-Terminal Ceramic Leadless Chip Carrier [LCC)	E-8-1
ADW22037Z[1]	2	5	–40°C to +125°C	8-Terminal Ceramic Leadless Chip Carrier [LCC]	E-8-1
ADW22037Z-RL[1]	2	5	–40°C to +125°C	8-Terminal Ceramic Leadless Chip Carrier [LCC]	E-8-1
ADW22037Z-RL7[1]	2	5	–40°C to +125°C	8-Terminal Ceramic Leadless Chip Carrier [LCC]	E-8-1

[1] Z = RoHS Compliant Part.

NOTES