Single-Axis, High-*g*, *i*MEMS® Accelerometers

ADXL78

FEATURES

Complete acceleration measurement system on a single monolithic IC
Available in ±35 *g*, ±50 *g*, or ±70 *g* output full-scale ranges
Full differential sensor and circuitry for high resistance to EMI/RFI
Environmentally robust packaging
Complete mechanical and electrical self-test on digital command
Output ratiometric to supply
Sensitive axes in the plane of the chip
High linearity (0.2% of full scale)
Frequency response down to dc
Low noise
Low power consumption (1.3 mA)
Tight sensitivity tolerance and 0 *g* offset capability
Largest available prefilter clipping headroom
400 Hz, 2-pole Bessel filter
Single-supply operation
Compatible with Sn/Pb and Pb-free solder processes
Qualified for automotive applications

APPLICATIONS

Vibration monitoring and control
Vehicle collision sensing
Shock detection

GENERAL DESCRIPTION

The ADXL78 is a low power, complete single-axis accelerometer with signal conditioned voltage outputs that are on a single monolithic IC. This product measures acceleration with a full-scale range of ±35 *g*, ±50 *g*, or ±70 *g* (minimum). It can also measure both dynamic acceleration (vibration) and static acceleration (gravity).

The ADXL78 is the fourth-generation surface micromachined *i*MEMS® accelerometer from ADI with enhanced performance and lower cost. Designed for use in front and side impact airbag applications, this product also provides a complete cost-effective solution useful for a wide variety of other applications.

The ADXL78 is temperature stable and accurate over the automotive temperature range, with a self-test feature that fully exercises all the mechanical and electrical elements of the sensor with a digital signal applied to a single pin.

The ADXL78 is available in a 5 mm × 5 mm × 2 mm, 8-terminal ceramic LCC package.

FUNCTIONAL BLOCK DIAGRAM

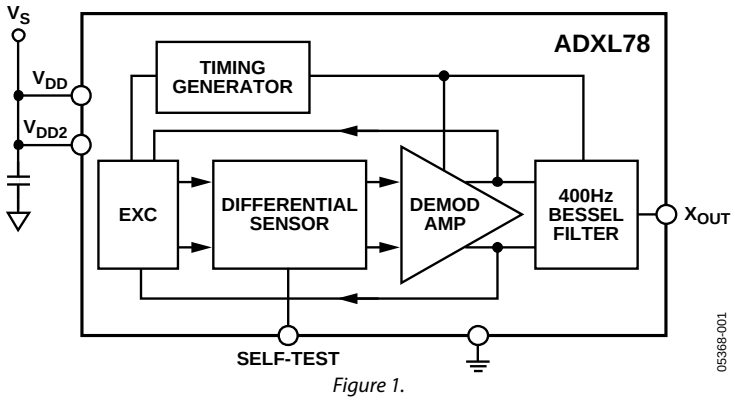


Figure 1.

Rev. B
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REVISION HISTORY

7/10—Rev. A to Rev. B

Updated Format ..... Universal
Change to Features Section 1
Updated Outline Dimensions 9
Changes to Ordering Guide 9
Added Automotive Products Section 9

5/05—Rev. 0 to Rev. A

SPECIFICATIONS[1]

At T_A = −40°C to +105°C, 5.0 V dc ± 5%, acceleration = 0 *g*, unless otherwise noted.

Table 1.

Parameter	Conditions	Model No. AD22279			Model No. AD22280			Model No. AD22281			Unit
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
SENSOR											
Output Full-Scale Range	$I_{OUT} \leq \pm 100$ µA	37			55			70			*g*
Nonlinearity			0.2	2		0.2	2		0.2	2	%
Package Alignment Error			1			1			1		Degree
Cross-Axis Sensitivity		−5		+5	−5		+5	−5		+5	%
Resonant Frequency			24			24			24		kHz
Sensitivity, Ratiometric (Over Temperature)	V_{DD} = 5 V, 100 Hz	52.25	55	57.75	36.1	38	39.9	25.65	27	28.35	mV/*g*
OFFSET											
Zero-*g* Output Voltage (Over Temperature)[2]	$V_{OUT} - V_{DD}/2$, V_{DD} = 5 V	−200		+200	−150		+150	−150		+150	mV
NOISE											
Noise Density	10 Hz – 400 Hz, 5 V		1.1	3		1.4	3		1.8	3.5	m*g*/√Hz
Clock Noise			5			5			5		mV p-p
FREQUENCY RESPONSE	2-pole Bessel										
−3 dB Frequency		360	400	440	360	400	440	360	400	440	Hz
−3 dB Frequency Drift	25°C to T_{MIN} or T_{MAX}		2			2			2		Hz
SELF-TEST											
Output Change (Cube vs. V_{DD})[3]	V_{DD} = 5 V	440	550	660	304	380	456	216	270	324	mV
Logic Input High	V_{DD} = 5 V	3.5			3.5			3.5			V
Logic Input Low	V_{DD} = 5 V			1			1			1	V
Input Resistance	Pull-down resistor to GND	30	50		30	50		30	50		kΩ
OUTPUT AMPLIFIER											
Output Voltage Swing	I_{OUT} = ±400 µA	0.25		V_{DD} – 0.25	0.25		V_{DD} – 0.25	0.25		V_{DD} – 0.25	V
Capacitive Load Drive		1000			1000			1000			pF
PREFILTER HEADROOM			280			400			560		*g*
CFSR @ 400 kHz			5			4			3		V/V
POWER SUPPLY (V_{DD})		4.75		5.25	4.75		5.25	4.75		5.25	V
Functional Range		3.5		6	3.5		6	3.5		6	V
Quiescent Supply Current	V_{DD} = 5 V		1.3	2		1.3	2		1.3	2	mA
TEMPERATURE RANGE		−40		+105	−40		+105	−40		+105	°C

[1] All minimum and maximum specifications are guaranteed. Typical specifications are not guaranteed.
[2] Zero *g* output is ratiometric.
[3] Self-test output at V_{DD} = (Self-Test Output at 5 V) × (V_{DD}/5 V)[3].

ABSOLUTE MAXIMUM RATINGS

Table 2.

Parameter	Rating
Acceleration (Any Axis, Unpowered)	4000 *g*
Acceleration (Any Axis, Powered)	4000 *g*
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
Operating Temperature Range	−65°C to +150°C
Storage Temperature	−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

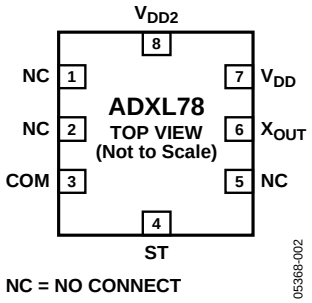


Figure 2. Pin Configuration

Table 3. Pin Function Descriptions

Pin No.	Mnemonic	Description
1	NC	Do Not Connect
2	NC	Do Not Connect
3	COM	Common
4	ST	Self-Test
5	NC	Do Not Connect
6	X_{OUT}	X Channel Output
7	V_{DD}	3.5 V to 6 V
8	V_{DD2}	3.5 V to 6 V

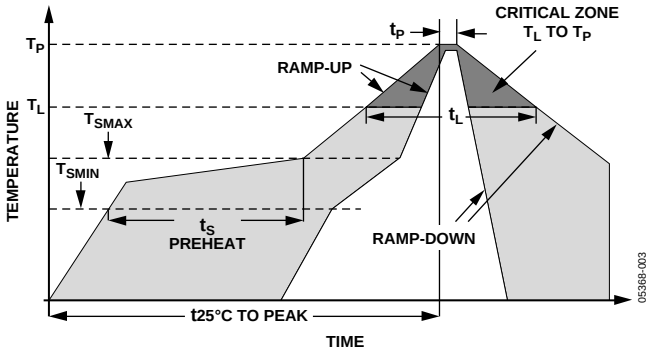


Figure 3. Recommended Soldering Profile

Table 4. Recommended Soldering Profile

Profile Feature	Sn63/Pb37	Pb-Free
AVERAGE RAMP RATE (T_L TO T_P)	3°C/s max	3°C/s 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 s – 120 s	60 s – 150 s
T_{SMAX} TO T_L		
Ramp-Up Rate	3°C/s	3°C/s
TIME MAINTAINED ABOVE LIQUIDOUS (T_L)		
Liquidous Temperature (T_L)	183°C	217°C
Time (t_L)	60 s – 150 s	60 s – 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)	10 s – 30 s	20 s – 40 s
RAMP-DOWN RATE	6°C/s max	6°C/s max
TIME 25°C TO PEAK TEMPERATURE	6 min max	8 min max

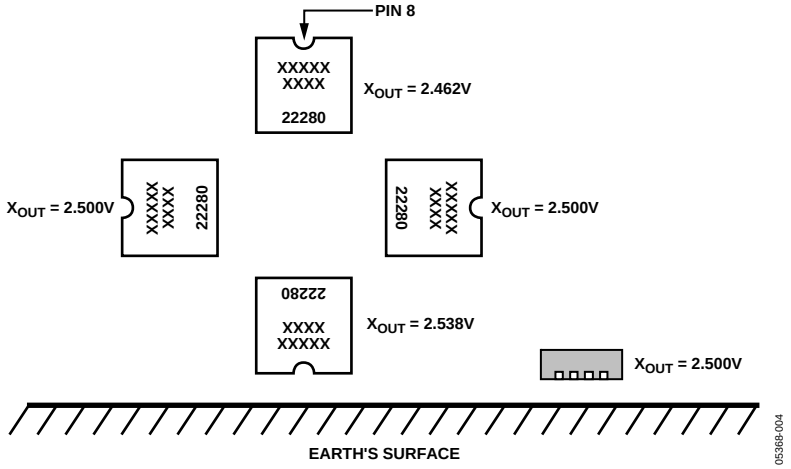


Figure 4. Output Response vs. Orientation

THEORY OF OPERATION

The ADXL78 provides a fully differential sensor structure and circuit path, resulting in the industry's highest resistance to EMI/RFI effects. This latest generation uses electrical feedback with zero-force feedback for improved accuracy and stability. The sensor resonant frequency is significantly higher than the signal bandwidth set by the on-chip filter, avoiding the signal analysis problems caused by resonant peaks near the signal bandwidth.

Figure 5 is a simplified view of one of the differential sensor elements. Each sensor includes several differential capacitor unit cells. Each cell is composed of fixed plates attached to the substrate and movable plates attached to the frame. Displacement of the frame changes the differential capacitance, which is measured by the on-chip circuitry.

Complementary 400 kHz square waves drive the fixed plates. Electrical feedback adjusts the amplitudes of the square waves such that the ac signal on the moving plates is 0. The feedback signal is linearly proportional to the applied acceleration. This unique feedback technique ensures that there is no net electrostatic force applied to the sensor. The differential feedback control signal is also applied to the input of the filter, where it is filtered and converted to a single-ended signal.

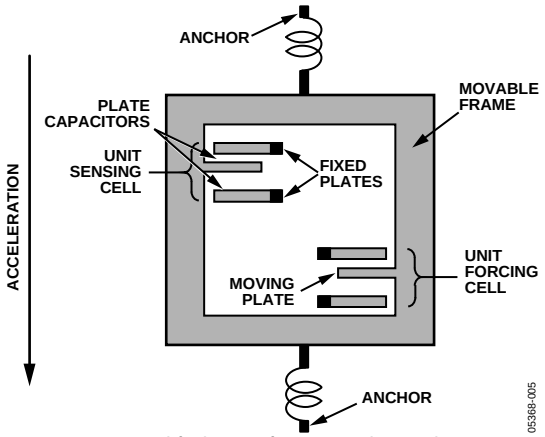


Figure 5. Simplified View of Sensor Under Acceleration

APPLICATIONS

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 400 kHz internal clock frequency (or any harmonic thereof), noise on the supply can cause interference on the ADXL78's output. If additional decoupling is needed, a 50 Ω (or smaller) resistor or ferrite bead can be inserted in the supply line. Additionally, a larger bulk bypass capacitor (in the 1 µF to 4.7 µF range) can be added in parallel to C_{DC}.

SELF-TEST

The fixed fingers in the forcing cells are normally kept at the same potential as that of the movable frame. When the self-test digital input is activated, the voltage on the fixed fingers on one side of the moving plate in the forcing cells is changed. This creates an attractive electrostatic force, which causes the frame to move toward those fixed fingers. The entire signal channel is active; therefore, the sensor displacement causes a change in V_{OUT}. The ADXL78 self-test function is a comprehensive method of verifying the operation of the accelerometer.

Because electrostatic force is independent of the polarity of the voltage across capacitor plates, a positive voltage is applied in half of the forcing cells, and its complement in the other half of the forcing cells. Activating self-test causes a step function force to be applied to the sensor, while the capacitive coupling term is canceled. The ADXL78 has improved self-test functionality, including excellent transient response and high speed switching capabilities. Arbitrary force waveforms can be applied to the sensor by modulating the self-test input, such as test signals to measure the system frequency response or even crash signals to verify algorithms within the limits of the self-test swing.

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

CLOCK FREQUENCY SUPPLY RESPONSE

In any clocked system, power supply noise near the clock frequency may have consequences at other frequencies. An internal clock typically controls the sensor excitation and the signal demodulator for micromachined accelerometers.

If the power supply contains high frequency spikes, they may be demodulated and interpreted as an acceleration signal. A signal appears as the difference between the noise frequency and the demodulator frequency. If the power supply spikes are 100 Hz away from the demodulator clock, there is an output term at 100 Hz. If the power supply clock is at exactly the same frequency as the accelerometer clock, the term appears as an offset.

If the difference frequency is outside of the signal bandwidth, the filter attenuates it. However, both the power supply clock and the accelerometer clock may vary with time or temperature, which can cause the interference signal to appear in the output filter bandwidth.

The ADXL78 addresses this issue in two ways. First, the high clock frequency eases the task of choosing a power supply clock frequency such that the difference between it and the accelerometer clock remains well outside of the filter bandwidth. Second, the ADXL78 is the only micromachined accelerometer to have a fully differential signal path, including differential sensors. The differential sensors eliminate most of the power supply noise before it reaches the demodulator. Good high frequency supply bypassing, such as a ceramic capacitor close to the supply pins, also minimizes the amount of interference.

The clock frequency supply response (CFSR) is the ratio of the response at V_{OUT} to the noise on the power supply near the accelerometer clock frequency. A CFSR of 3 means that the signal at V_{OUT} is 3× the amplitude of an excitation signal at V_{DD} near the accelerometer internal clock frequency. This is analogous to the power supply response, except that the stimulus and the response are at different frequencies. The ADXL78's CFSR is 10× better than a typical single-ended accelerometer system.

SIGNAL DISTORTION

Signals from crashes and other events may contain high amplitude, high frequency components. These components contain very little useful information and are reduced by the 2-pole Bessel filter at the output of the accelerometer. However, if the signal saturates at any point, the accelerometer output does not look like a filtered version of the acceleration signal.

The signal may saturate anywhere before the filter. For example, if the resonant frequency of the sensor is low, the displacement per unit acceleration is high. The sensor may reach the mechanical limit of travel if the applied acceleration is high enough. This can be remedied by locating the accelerometer where it does not see high values of acceleration, and by using a higher resonant frequency sensor such as the ADXL78.

Also, the electronics may saturate in an overload condition between the sensor output and the filter input. Ensuring that the internal circuit nodes operate linearly to at least several times the full-scale acceleration value can minimize electrical saturation. The ADXL78's circuits are linear to approximately 8× full scale.

OUTLINE DIMENSIONS

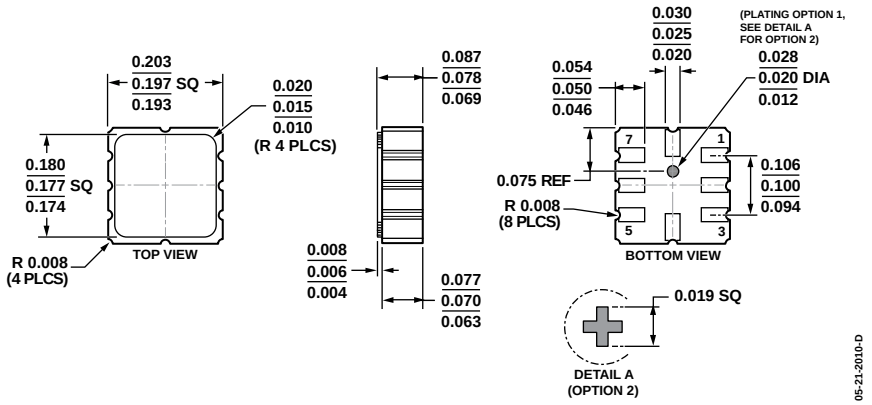


Figure 6. 8-Terminal Ceramic Leadless Chip Carrier [LCC]
(E-8-1)
Dimensions shown in inches

ADXL78 ORDERING GUIDE

Model[1, 2, 3]	Parts per Reel	Measurement Range	Specified Voltage (V)	Temperature Range	Package Description	Package Option
AD22279-A-R2	250	±35 *g*	5	−40°C to +105°C	8-Terminal Ceramic Leadless Chip Carrier	E-8-1
AD22279-A	3,000	±35 *g*	5	−40°C to +105°C	8-Terminal Ceramic Leadless Chip Carrier	E-8-1
ADW22279ZC	3,000	±35 *g*	5	−40°C to +105°C	8-Terminal Ceramic Leadless Chip Carrier	E-8-1
ADW22279ZC-RL7	250	±35 *g*	5	−40°C to +105°C	8-Terminal Ceramic Leadless Chip Carrier	E-8-1
AD22280-R2	250	±50 *g*	5	−40°C to +105°C	8-Terminal Ceramic Leadless Chip Carrier	E-8-1
AD22280	3,000	±50 *g*	5	−40°C to +105°C	8-Terminal Ceramic Leadless Chip Carrier	E-8-1
ADW22280ZC	3,000	±50 *g*	5	−40°C to +105°C	8-Terminal Ceramic Leadless Chip Carrier	E-8-1
ADW22280ZC-RL7	250	±50 *g*	5	−40°C to +105°C	8-Terminal Ceramic Leadless Chip Carrier	E-8-1
AD22281-R2	250	±70 *g*	5	−40°C to +105°C	8-Terminal Ceramic Leadless Chip Carrier	E-8-1
AD22281	3,000	±70 *g*	5	−40°C to +105°C	8-Terminal Ceramic Leadless Chip Carrier	E-8-1
ADW22281ZC	3,000	±70 *g*	5	−40°C to +105°C	8-Terminal Ceramic Leadless Chip Carrier	E-8-1
ADW22281ZC-RL7	250	±70 *g*	5	−40°C to +105°C	8-Terminal Ceramic Leadless Chip Carrier	E-8-1

[1] All models are on tape and reel and are RoHS compliant parts.
[2] Z = RoHS Compliant Part.
[3] W = Qualified for Automotive Applications.

AUTOMOTIVE PRODUCTS

The ADW22279, ADW22280, and ADW22281 models are available with controlled manufacturing to support the quality and reliability requirements of automotive applications. Note that these automotive models may have specifications that differ from the commercial models; therefore, designers should review the Specifications section of this data sheet carefully. Only the automotive grade products shown are available for use in automotive applications. Contact your local Analog Devices account representative for specific Automotive Reliability reports for these models.

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