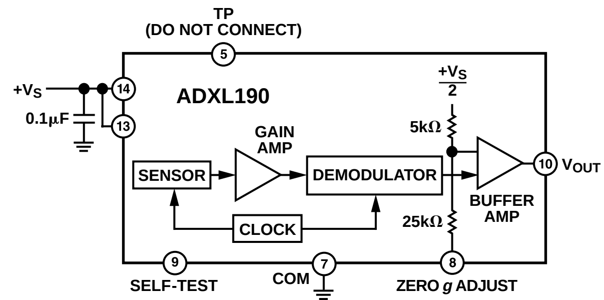
Low Cost ±100 *g* Single Axis Accelerometer with Analog Output

ADXL190*

FEATURES
- *i*MEMS® Single Chip IC Accelerometer
- 40 Milli-*g* Resolution
- Low Power 2 mA
- 400 Hz Bandwidth
- +5.0 V Single Supply Operation
- 2000 *g* Shock Survival

APPLICATIONS
- Shock and Vibration Measurement
- Machine Health
- Shipping Recorders
- Military Fuze, Safe and Arm

FUNCTIONAL BLOCK DIAGRAM



GENERAL DESCRIPTION

The ADXL190 is a complete acceleration measurement system on a single monolithic IC. It contains a polysilicon surface-micromachined sensor and signal conditioning circuitry to implement an open-loop acceleration measurement architecture. The ADXL190 is capable of measuring both positive and negative accelerations up to ±100 *g*, making it suitable for shock and vibration measurement.

Typical noise floor is 4 m*g*/$\sqrt{Hz}$ allowing signals below 40 milli-*g* to be resolved. The ADXL190 can measure both dynamic accelerations, (typical of vibration) or static accelerations, (such as inertial force or gravity).

The ADXL190 has a two-pole Bessel switched-capacitor filter. Bessel filters, sometimes called linear phase filters, have a step response with minimal overshoot and a maximally flat group delay. The –3 dB frequency of the poles is preset at the factory to 400 Hz. These filters are also completely self-contained and buffered, requiring no external components.

The product features a built-in self-test feature that exercises both the mechanical structure and electrical circuitry. When triggered by a logic high on the self-test pin, an electrostatic force acts on the beam equivalent to approximately 20% of full-scale acceleration input, and thus a proportional voltage change appears on the output pin. No external components other than a decoupling capacitor are required.

The ADXL190 is available in a hermetic 14-lead surface mount cerpak, specified over the –40°C to +105°C temperature range.

*Patent Pending.
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ADXL190–SPECIFICATIONS ($T_A = T_{MIN}$ to T_{MAX}, V_S = +5 V, Acceleration = 0 *g* unless otherwise noted)

Parameter	Conditions	ADXL190WQC Min	Typ	Max	Units
SENSOR INPUT					
Dynamic Range[1, 2, 3]	Without Zero-*g* Adjust	±105			*g*
Alignment Error			±1		Degrees
Nonlinearity			0.2		%
Cross Axis Sensitivity			±2		%
SENSITIVITY					
Initial[4]	Ratiometric	16.5	18.0	19.5	mV/*g*
Temperature Drift[5]	Δ from +25°C		±0.5		%
ZERO *g* BIAS LEVEL					
Initial[2, 3]	Ratiometric	2.3	2.5	2.7	V
0 *g* Offset vs. Temperature[5]	Δ from +25°C		1.0		*g*
Zero *g* Adjustment Gain		0.45	0.50	0.55	$\Delta V_{OUT}/\Delta V$ 0 *g* Adjust
Zero *g* Adjust Pin Input Impedance		20	30	40	kΩ
NOISE PERFORMANCE					
Noise Density			4	12	m*g*/$\sqrt{Hz}$ rms
FREQUENCY RESPONSE					
3 dB Bandwidth		360	400		Hz
Sensor Resonant Frequency			24		kHz
SELF-TEST					
Output Change[6]		450		990	mV
Logic "1" Voltage		3.5			V
Logic "0" Voltage				1.0	V
Input Impedance			50		kΩ
ANALOG OUTPUT					
Output Voltage Range	I_{OUT} = ±100 µA	0.25		V_S – 0.25	V
Capacitive Load Drive		1000			pF
POWER SUPPLY					
Specified Performance		4.75		5.25	V
Quiescent Supply Current			2.0	5.0	mA
TEMPERATURE RANGE					
Specified Performance		–40		+105	°C

NOTES

[1] Product is tested at ±50 *g*, and the combination of 0-*g* error, sensitivity error, and output voltage swing measurements provide the calculations for dynamic range.

[2] 0-*g* is nominally $V_S/2$. Use of the 0-*g* adjustment pin is used to null the 0-*g* error, resulting in increased dynamic range. It can also be used to create an asymmetrical dynamic range if so desired.

[3] The output response is ratiometric and is described by the following equation. $V_{OUT}(accel, V_S) = [V_S/2 \pm (a\,V_S/5\text{ V})] + [(accel)(b\,V_S + c\,V_S^2)(1 \pm 0.08)]$
Where a = 0.2 V, b = 2.712×10^{-3} 1/*g*, c = 0.178×10^{-3} 1/*g*/V.

[4] Measured at 100 Hz, ±50 *g*.

[5] Specification refers to the maximum change in parameter from its initial value at +25°C to its worst case value at T_{MIN} or T_{MAX}.

[6] ST pin Logic "0" to "1"; $\Delta V_{OUT} = (\Delta V_{OUT} @ 5\text{ V}) \times (V_S/5\text{ V})$.

All min and max specifications are guaranteed. Typical specifications are not tested or guaranteed.
Specifications subject to change without notice.

ABSOLUTE MAXIMUM RATINGS*

Acceleration (Any Axis, Unpowered for 0.5 ms) . . . . . . 2000 *g*
Acceleration (Any Axis, Powered for 0.5 ms) . . . . 1000 *g*
$+V_S$ . . . . –0.3 V to +7.0 V
Short Circuit Duration (Any Pin to Common) . . . . Indefinite
Operating Temperature . . . . –55°C to +125°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; the functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Drops onto hard surfaces can cause shocks of greater than 2000 *g* and exceed the absolute maximum rating of the device. Care should be exercised in handling to avoid damage.

PIN FUNCTION DESCRIPTIONS

Pin No.	Function
1, 2, 3, 4, 6, 11, 12	No Connect
5	Test Point (Do Not Connect)
7	Common
8	Zero *g* Adjust
9	Self-Test
10	V_{OUT}
13, 14	V_S

PACKAGE CHARACTERISTICS

Package	θ_{JA}	θ_{JC}	Device Weight
14-Lead Cerpak	+110°C/W	+30°C/W	5 Grams

PIN CONFIGURATION

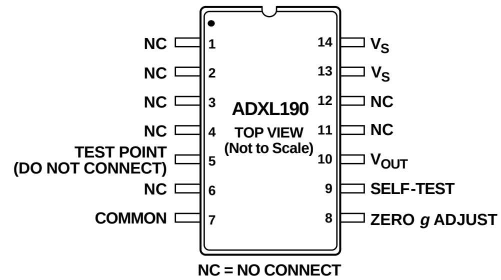


Figure 1 shows the response of the ADXL190 to the earth's gravitational field. The output values shown are nominal. They are presented to show the user what type of response to expect from each of the output pins due to changes in orientation with respect to the earth.

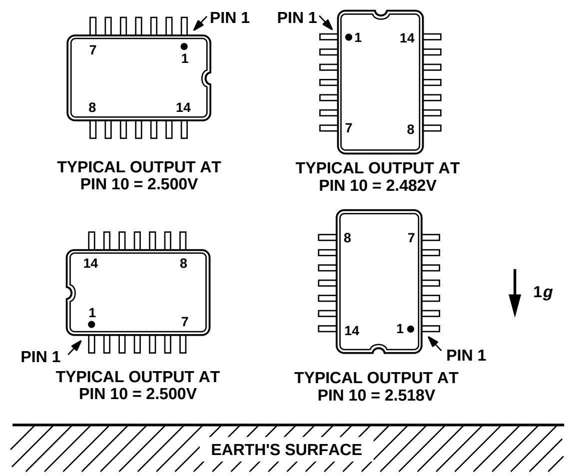


Figure 1. ADXL190 Response Due to Gravity

ORDERING GUIDE

Model	# Axis	Specified Voltage	Temperature Range	Package Description	Package Option
ADXL190WQC	1	+5 V	–40°C to +105°C	14-Lead Cerpak	QC-14

CAUTION

ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although the ADXL190 features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.

APPLICATIONS

All the circuitry needed to drive the sensor and convert the capacitance change to voltage is incorporated on-chip requiring no external components except for standard power supply decoupling. Both sensitivity and the zero-*g* value are ratiometric to the supply voltage, so that ratiometric devices following the accelerometer (such as an ADC, etc.) will track the accelerometer if the supply voltage changes. The output voltage (V_{OUT}) is a function of both the acceleration input (a) and the power supply voltage (V_S) as follows:

$$V_{OUT} = V_S/2 - (Sensitivity \times V_S/5\ V \times a)$$

Adjusting the 0 *g* Bias Level

In some cases the user may have an asymmetrical input or may want to fine adjust the zero-*g* output level to obtain maximum dynamic range. The zero-*g* level is adjusted by supplying a voltage to the zero-*g* adjustment pin (see Figure 2).

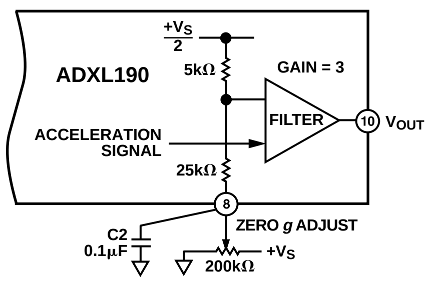


Figure 2. Optional Zero-g Adjust Circuit Detail

Any voltage difference between the zero-*g* adjustment pin and $V_S/2$ is reduced by a factor of 6 by the internal resistor divider. This is then gained by the factor of 3 in the output stage for a total gain of 0.5 for the zero-*g* adjustment. (Note: The ratio of the resistors in the divider is consistent from part-to-part; however, the absolute values can have a ±30% tolerance). The zero-*g* adjustment voltage can be set up by a variety of methods including a potentiometer (as shown in Figure 2), a PWM signal, or with a simple three-state output.

The simplest way is by adding a resistor between the ZERO *g* ADJUST pin and V_S or ground. The output will be offset by:

$$Offset\ (V) = (7.5 \times V_S)/(30 + R)$$

where R is in kΩ and connected to V_S.

$$Offset\ (V) = (-7.5 \times V_S)/(30 + R)$$

where R is in kΩ and connected to ground.

Resistors may also be connected to microcontroller I/O pins as shown in Figure 3. Using two I/Os that may be set to V_S, ground, or three-state, there are seven possibilities as shown in Table I (one cannot set one I/O pin to V_S and the other to ground). Using such a system, any ADXL190 may be user trimmed to output 2.5 V ± 35 mV at zero *g*.

Table I. Offsets Produced Using the Circuit in Figure 3 for V_S = 5 V

P1	P0	Offset Voltage Produced	Offset in *g*
Three-State	Three-State	0 mV	0
Three-State	0	–71 mV	–4
0	Three-State	–134 mV	–7.4
0	0	–191 mV	–10.6
Three-State	1	71 mV	4
1	Three-State	134 mV	7.4
1	1	191 mV	10.6

Another way to adjust the zero *g* offset is to supply a voltage to the ZERO *g* ADJUST pin. The difference between $V_S/2$ and the voltage at the ZERO *g* ADJUST pin is reduced by a factor of 6 (as a result of the internal 5 kΩ and 25 kΩ voltage divider) and then multiplied by a factor of 3 in the output stage of the ADXL190 resulting in a total gain of 0.5. Offset is thus described by the following equation:

$$Offset\ (V) = (Voltage\ at\ the\ ZERO\ g\ ADJUST\ Pin - V_S/2)/2$$

This voltage may be produced by a variety of methods including a PWM signal from a microcontroller. Care must be taken that the output impedance of this voltage source is less than 5 kΩ and that there is very little ripple (noise). Any noise at the ZERO *g* ADJUST pin will cause output errors.

If an asymmetric range of acceleration is required (e.g., +75 *g* to –125 *g*) a resistor may be connected between the ZERO *g* ADJUST and ground or V_S as described above. For example:

For a range of +75 *g* to –125 *g* the offset required is –25 *g*.

–25 *g* at 18 mV/*g* = 450 mV of offset is required.

Rearranging the offset equations above:

$R = [(7.5 \times V_S)/offset] - 30 = 53.3\ k\Omega$ connected to ground.

For asymmetric operation the *g* range midpoint may be shifted up to ±80 *g* typically.

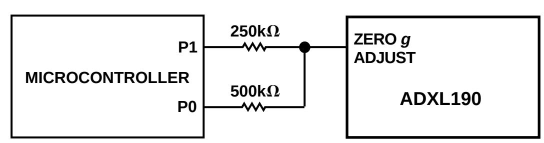
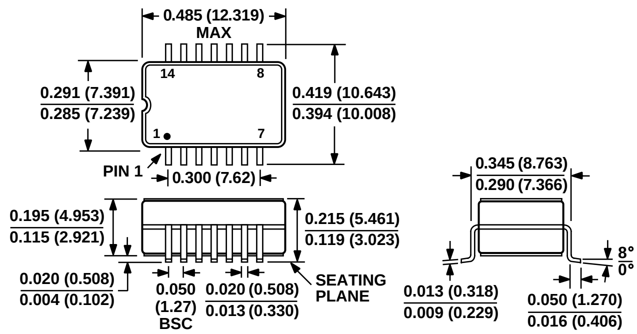


Figure 3. An Offset Adjustment Scheme

OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).

14-Lead Cerpak (QC-14)



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