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a

Low Cost ±10g Dual Axis Accelerometer with Duty Cycle Output

Preliminary Technical Data ADXL210*

FEATURES
2 Axis Acceleration Sensor on a Single IC Chip
5 milli-g Resolution
Duty Cycle Output with 1ms Acquisition Time
Low power < 0.6mA
Direct Interface to Low Cost Microcontrollers
BW Adjustment with a Single Capacitor
+2.7V to +5.25V Single Supply Operation
1000g Shock Survival

GENERAL DESCRIPTION

The ADXL210 is a low cost, complete 2 axis accelerometer with a digital output, all on a single monolithic IC. The ADXL210 will measure accelerations with a full-scale range of ±10g, making it suitable for tilt measurement.

The output is a duty cycle whose ratio is proportional to acceleration. The output can be directly measured by a microprocessor counter, without an A/D converter or glue logic. Typical noise floor is 500ug√Hz allowing signals below 5 milli-g to be resolved. The ADXL210 is a dc accelerometer with the capability to measure both ac accelerations, (typical of vibration) or dc accelerations, (such as inertial force or gravity).

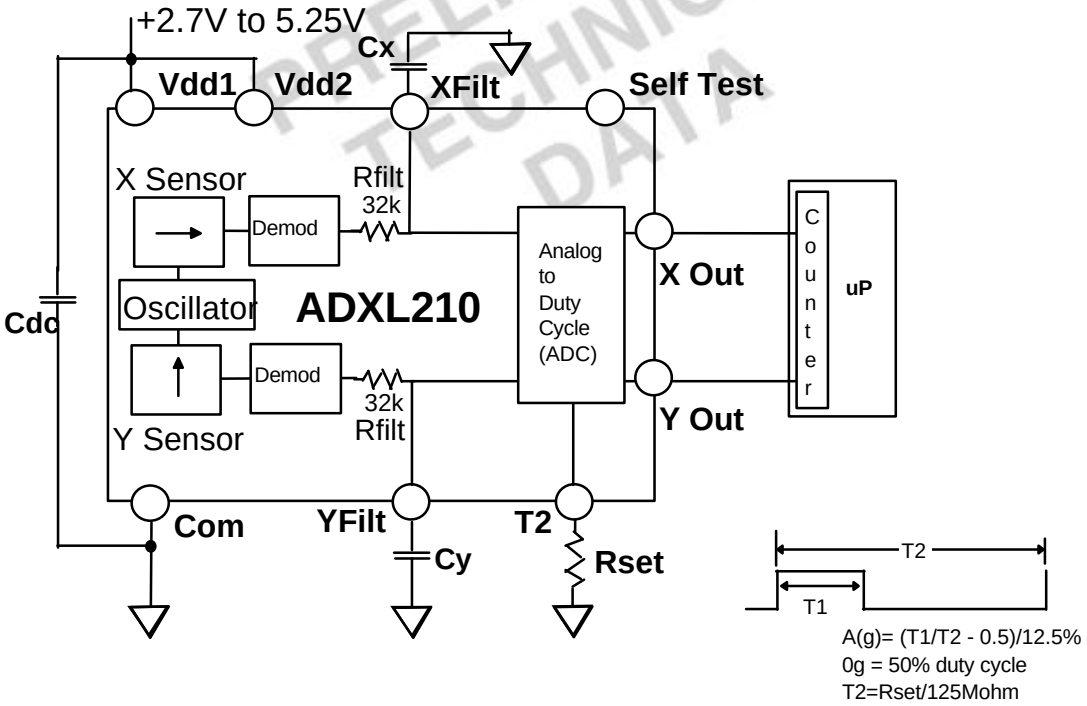
The duty cycle repetition is adjustable from 1ms to 10ms by a single resistor, Rset. The bandwidth of the accelerometer is set with capacitors Cx and Cy at the Xfilt and Yfilt pins. An analog output can be reconstructed by filtering the duty cycle output.

The ADXL210 is available in a hermetic 14 pin surface mount Cerpak, specified over the 0°C to +70°C commercial and –40 to 85 C temperature range.

APPLICATIONS

- Vehicle monitors
- Fleet Management
- Vibration Measurement
- Alarms and motion detectors
- Battery powered motion sensing applications

PRELIMINARY TECHNICAL DATA



*Patents Pending

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Analog Devices, One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 617-329-4700 Fax 617-326-8703

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ADXL210-SPECIFICATIONS

(TA = Tmin to Tmax, TA = +25C for J grade only, Vs=+5V, Rset = 125kohm , Acceleration = 0g, unless otherwise noted)

Parameter	Conditions	ADXL202JQC/AQC Min	Typ	Max	Units
SENSOR INPUT	Each axis				
Measurement Range[1]		+/-8	+/-10		g
Nonlinearity	Best fit straight line		0.2		% of FS
Alignment Error[2]			±1		degrees
Alignment Error	X sensor to Y sensor		0.01		degrees
Cross Axis Sensitivity[3]			±2		%
SENSITIVITY	Each axis				
Duty Cycle per g	T1/T2 @ 25C	3.2	4.0	4.8	%/g
Sensitivity, Analog Output	At Pins Xfilt, Yfilt		100		mV/g
Temperature Drift[4]	Delta from 25C		±0.5		%
ZERO g BIAS LEVEL	Each axis				
0g Duty Cycle	T1/T2	42	50	58	%
Initial Offset			+/-2g		g
0g Duty Cycle vs Supply	Vs +-5%		1.0	4.0	%/V
0g Offset vs Temp4	Delta from 25C		2.0		mg/deg C
NOISE PERFORMANCE					
Noise Density	@25C		500	1000	ug/Root Hz RMS
FREQUENCY RESPONSE					
3dB Bandwidth	Duty cycle Output		500		Hz
3 dB Bandwidth	At Pins Xfilt, Yfilt		6		kHz
Sensor Resonant Frequency			14		kHz
FILTER					
Rfilt Tolerance	32k Ohm Nominal		+/-15		%
SELF TEST					
Duty Cycle Change	Self Test '0' to '1'		10		%
DUTY CYCLE OUTPUT STAGE					
Fset	Fset(Hz)= 1/T2(s) = 125Mohm/Rset(ohm)				
Fset Tolerance	Rset =124kohm	0.7		1.3	kHz
Output High Voltage	I = 25uA	Vs-200mV			V
Output Low Voltage	I = 25uA			200	mV
T2 Drift vs Temperature			35		PPM/deg C
Rise/Fall Time			200		ns
POWER SUPPLY					
Operating Voltage Range		2.70		5.25	V
Quiescent Supply Current	XL202		0.6	1.0	mA
Turn on time[5]	To 99%		160 Cfilt +0.3		mS
TEMPERATURE RANGE					
Operating Range	JQC	0		70	C
Specified Performance	AQC	-40		85	C

PRELIMINARY TECHNICAL DATA

Notes

[1] Guaranteed for all combinations of offset and sensitivity variation

[2] Alignment between sensor X,Y axis and the edges of the bottom of the cerpak package

[3] Cross axis sensitivity is the algebraic sum of the alignment and the inherent sensitivity errors.

[4] Specification refers to the maximum change in parameter from its initial value at +25C to its worst case value at Tmin or Tmax

[5] Turn on time specified with Xfilt and Yfilt open. Addition of filter capacitor will increase turn on time. Please see application section on power cyclin

[6] Noise Density (ug/root Hz) is the average noise at any frequency in the BW of the part

All min and max specifications are guaranteed. Typical specifications are not tested or guaranteed

Specifications subject to change without notice

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ABSOLUTE MAXIMUM RATINGS*

Acceleration (Any Axis, Unpowered for 0.5ms)	1000g
Acceleration (Any Axis, Powered for 0.5ms)	500g
+Vs	-0.3V to +7.0V
Output Short Circuit Duration, (any pin to common)	Indefinite
Operating Temperature	-55°C to +125°C
Storage Temperature	-65°C to +150°C

Package Characteristics

Package	ThetaJA	ThetaJC	Device Weight
14 Pin Cerpak	110°C/W	30°C/W	5 grams

Ordering Guide

Model	# Axes	Specified Voltage	Temperature Range
ADXL210JQC	2	+5V	0°C to +70°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 indicate in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

CAUTION

ESD (electrostatic discharge) sensitive device.

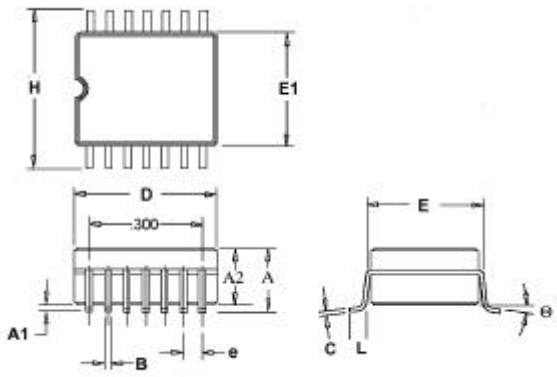
Drops onto hard surfaces can cause shocks of greater than 1000g and exceed the absolute maximum rating of the device. Care should be exercised in handling to avoid damage.

PIN DESCRIPTION

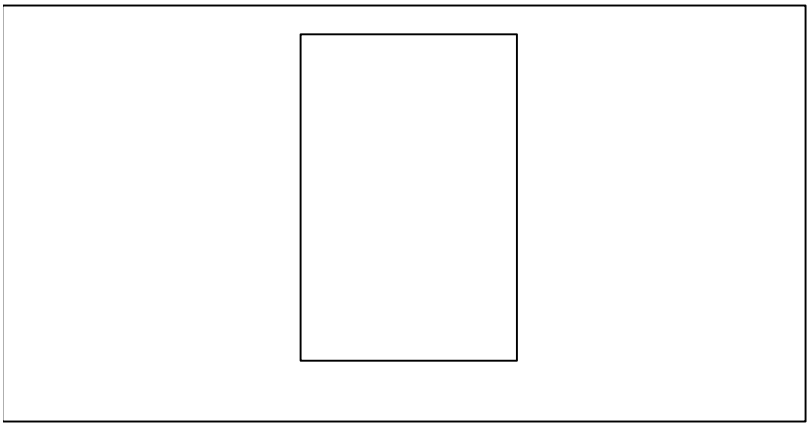
Pin	Name	Description
1		
2	Vtp	Test Point, Do Not Connect
3	ST	Self Test
4	Common	Common
5	T2	Connect Rset to set T2 Period
6		
7	Common	Common
8		
9	Y Out	Y Accelerometer Output
10	X Out	X Accelerometer Output
11	Y Filt	Connect Capacitor for Y Filter
12	X Filt	Connect Capacitor for X Filter
13	Vdd1	+2.7 to +5.25V, connect to 14
14	Vdd2	+2.7 to +5.25V, connect to 13

OUTLINE DIMENSIONS

(Dimensions shown in inches and mm)



Dimension	Min	Max	Min	Max
	Inches	Inches	mm	mm
A	0.119	0.215	3.023	5.461
A1	0.004	0.020	0.	0.508
A2	0.115	0.195	2.921	4.953
B	0.013	0.020	0.330	0.508
C	0.009	0.013	0.229	0.318
D	-	0.485	-	12.319
E	0.290	0.345	7.366	8.763
E1	0.220	0.310	5.588	7.874
H	0.394	0.419	10.008	10.643
e	0.050 typ	0.050 typ	1.27 typ	1.27 typ
L	0.016	0.050	0.406	1.270
θ	0 deg	8 deg	0 deg	8 deg



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DEFINITIONS

T1 Length of the 'on' cycle
T2Length of the total duty cycle.
Duty CycleRatio of the 'on' time (T1) of the cycle to the total cycle (T2). Defined as T1/T2 for the XL210
Pulse WidthTime period of the 'on' pulse. Defined as T1 for the XL210.

THEORY OF OPERATION

The ADXL210 is a complete 2 axis 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 output circuit converts the analog signal to a duty cycle modulated (DCM) signal that can be decoded with a counter/timer port on a microprocessor. The ADXL210 is capable of measuring both positive and negative accelerations to a maximum level of ±10g. The accelerometer measures static dc acceleration forces such a gravity allowing it to be used as a tilt sensor.

The sensor is a surface micro-machined 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 structure that consists of two independent fixed plates and a central plate attached to the moving mass. The fixed plates are driven by 180° out of phase square waves. An acceleration causing the beam to deflect will unbalance the differential capacitor, resulting in a 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.

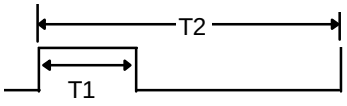
The output of the demodulator drives the final analog to duty cycle converter stage through a resistor. At this point a pin is available on each channel to allow the user to add a capacitor to form a low pass filter to set signal bandwidth and prevent alaising.

The analog signal is converted to a duty cycle modulated signal by the final stage. A single resistor sets the period for a complete cycle (T2) and which can be set between 1ms and 10ms, see figure A. A 0g acceleration is nominally 50% duty cycle. The acceleration signal is decoded by measuring the length of the T1 and T2 pulses with a counter/timer or a polling loop using a low cost microcontroller.

The device can produce an analog output by either buffering the signal from the Xfilt and Yfilt pin, or by running the duty cycle signal into an RC filter to reconstruct the DC value.

The ADXL210 will operate on voltages as low as 2.7V or as high as 5.25V.

Figure: Simplified diagram of the ADXL210 Sensor



A(g)= (T1/T2 - 0.5)/12.5%
0g = 50% duty cycle
T2(s)=Rset(ohms)/125Mohm

Figure A: Typical Output Duty Cycle

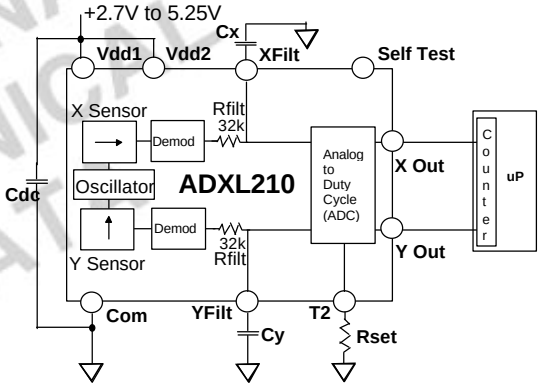


Figure B: ADXL210 Block Diagram

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APPLICATIONS

DESIGN PROCEDURE FOR THE XL210

The design procedure for using the XL210 with a duty cycle output involves selecting a duty cycle period and a filter capacitor. A proper design will take into account the application requirements for bandwidth, signal resolution, and acquisition time, as discussed in the following sections.

Vdd1 and Vdd2

The XL210 has two power supply pins: Vdd1 and Vdd2. These two pins should be at exactly the same voltage and should be connected together with the shortest possible pc board trace.

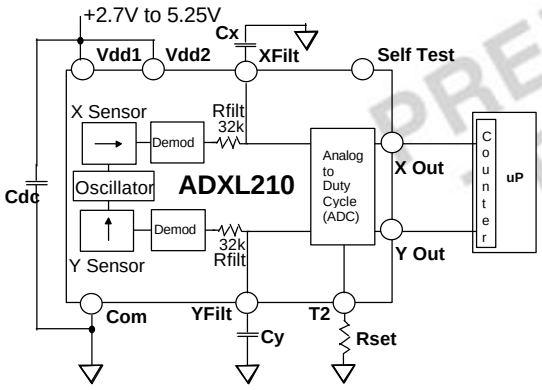
Care should be taken to avoid parasitic resistance in the supply line that will cause the power supply to vary at the accelerometer Vdd pins as this will affect accuracy.

Vtp

This pin is to be left open, make no connections of any kind to this pin.

Decoupling Capacitor Cdc

A 0.1uF capacitor is recommended from Vdd to Com for power supply decoupling..



Duty Cycle Decoding

The recommended decoding scheme for the XL210 is to use the output of the duty cycle modulator. Acceleration is proportional to T1/T2 and requiring the user to measure both. Duty cycle modulation is internally ratiometric and allows for the cancellation of component drift inside the XL210 duty cycle converter; this improves overall accuracy. The nominal output of the XL210 is:

0g = 50% duty cycle
Scale factor is 4.0% duty cycle change per g

These nominal values are affected by the initial tolerance of the device including zero g offset error and sensitivity error.

T2 does not have to be measured for ery measurement cycle. It only needs to be updated to account for changes in temperature, (a relatively slow process). Since the T2 time period is shared by both X and Y channels, it is only necessary to measure it on one channel of the XL210.

Setting the BW with Cx and Cy

The ADXL210 has an analog output present at the Xfilt and Yfilt pins. A capacitor can be added at the Xfilt and Yfilt pin to implement a low pass filter for anti-aliasing and noise reduction. The equation for the 3db bandwidth is

F3db = 1/(2pi 32kΩ x C(x,y))

The tolerance of the internal resistor, (Rfilt) can vary as much as ±25% of its nominal value, however, its value is typically ±15% of the 32kΩ nominal value.

The frequency response of the analog output should always be at less than half of the sample rate of the duty cycle section to avoid aliasing. For example, for a 1mS T2 rate (1kHz) the BW should be set to 500Hz or less.

Table 1: Filter Capacitor Selection, Cx and Cy

Bandwidth	Capacitor Value
10Hz	0.47uF
50Hz	0.10uF
100Hz	0.05uF
200Hz	0.027uF
500Hz	0.01uF

Setting the Duty Cycle Period with Rset

The length of the duty cycle is set for both channels by a single resistor to ground. The equation for the period is:

Fset(Hz) = 1/T2 = 125MΩ/Rset(Ω)

A 125kΩ resistor will set the duty cycle repetition rate to 1khz, or 1mS. The devices is designed to operate at duty cycles between 1ms and 10mS.

The duty cycle converter may be shut off by connecting the T2 pin to the positive supply (Vdd).

Table 2: Resistor Values to Set T2

T2	Rset
1ms	125kΩ
2ms	250kΩ
5ms	625kΩ
10ms	1.25MΩ

MICROCOMPUTER INTERFACES

The ADXL210 was designed specifically to work with low cost microcontrollers available from a number of manufacturers. Specific code and reference designs and application notes are available from the factory. This

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section will outline a general design procedure, and discuss the various trade-offs that need to be considered.

The designer should have some idea of the required performance of the system in terms of:

- Resolution: the smallest signal change that needs to be detected.
- Bandwidth: the highest frequencies that need to be detected.
- Acquisition time: the longest time that will be available to acquire the signal.

These requirements will help to determine the accelerometer bandwidth, the speed of the microcontroller clock, and the length of the T2 period.

When selecting a microcontroller it is helpful to have a counter timer port available. However, it is relatively simple to write an efficient SW polling loop that will decode the XL210 signal. Polling loops are often the preferred implementation as they can generally count faster.

The microcontroller must have provisions for software calibration. While the ADXL210 is a highly accurate accelerometer, it has a wide tolerance for initial offset. The easiest way to null this offset is with a calibration factor saved on the microcontroller or by a user calibration for zero g. In the case where the offset is calibrated during manufacture, there are several options, including external EPROM, and microcontrollers with 'one time programmable' features.

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

The accelerometer bandwidth selected will determine the measurement resolution, (smallest detectable acceleration), and should meet Nyquist criteria before going into the duty cycle converter.

The ADXL210 converts an acceleration signal to a digital representation and Nyquist criteria should be observed in the system design. In other words, the sample rate needs to be at least 2 times faster then the fastest signal coming into the duty cycle converter. In addition, filtering can be used to reduce the noise floor and improve the resolution of the accelerometer. Resolution is dependent on both the analog filter bandwidth at Xfilt and Yfilt and on the speed of the microcontroller counter.

The analog output of the XL210 has a typical bandwidth of 6kHz, much higher than the duty cycle stage is capable of converting. The user must filter the signal at this point to limit the analog bandwidth below the Nyquist frequency, (duty cycle frequency/2). Failure to filter to at least this level will cause both signals and noise to be aliased into the pass band.

The analog bandwidth may be further decreased to reduce noise and improve resolution. The XL210 Noise has the characteristics of white gaussian noise that contributes equally at all frequencies and is described in terms of ug per root Hz; i.e. the noise is proportional to the square root of the bandwidth of the accelerometer. It is recommended that the user limit bandwidth to the lowest frequency needed by the application, to maximize the resolution and dynamic range of the accelerometer. The exception to this is when the device is power cycled to reduce average current consumption.

With the single pole roll-off characteristic, the typical noise of the XL210 is determined by the following equation:

Noise(RMS) = 500ug/squareroot(Hz) X Squareroot(BW x (1.5))

At 100Hz the noise will be:

Noise(RMS) = 500ug/squareroot(Hz) X Squareroot(100(1.5)) =

Because the XL210's noise is Gaussian in amplitude distribution, the highest noise amplitudes have the smallest (yet nonzero) probability. Peak-to-peak noise is therefore difficult to predict and can only be estimated by statistical methods. Table X is useful for estimating the probabilities of exceeding various peak values, given the rms value.

Table X: Estimation of Peak to Peak Noise

Nominal Peak-to Peak Value	% of Time that Noise Will Exceed Nominal Peak-to Peak Value
2.0 x rms	32%
4.0 x rms	4.6%
6.0 x rms	0.27%
8.0 x rms	0.006%

The peak-to-peak noise value will give the best estimate of the uncertainty in a single measurement. This uncertainty can be reduced by lowering the bandwidth or averaging multiple readings.

Table Y gives typical noise output of the XL210 for various Cx and Cy values.

Table Y: Filter Capacitor Selection, Cx and Cy

Bandwidth	Cx, Cy	rms Noise	Peak-to-Peak Noise Estimate 95% Probability (RMS x 4)
10Hz	0.47uF	1.9mg	7.6mg
50Hz	0.10uF	4.3mg	17.2mg
100Hz	0.05uF	6.1mg	24.4mg
200Hz	0.027uF	8.7mg	35.8mg
500Hz	0.01uF	13.7mg	54.8mg

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CHOOSING T2 AND COUNTER FREQUENCY: DESIGN TRADE-OFFS

The noise level is one determinant of accelerometer resolution. The second relates to the measurement resolution of the counter when decoding the duty cycle output.

The ADXL210's duty cycle converter has a resolution of approximately 14bits; more resolution than the accelerometer itself. The actual resolution of the acceleration signal however, is limited by the time resolution of the counting devices used to decode the duty cycle. The faster the counter clock, the higher the resolution of the duty cycle and the shorter the T2 period can be. The following table shows some of the trade-offs. It is important to note that this is the resolution of the duty cycle converter. It is possible that the accelerometer's noise floor may actually set the lower limit on the resolution, as discussed in the previous section.

Table 3: Trade-offs between microcontroller counter rate, T2 period and resolution of duty cycle modulator.

T2(ms)	Rset (kohm)	XL202 Sample Rate	Counter Clock Rate(Mhz)	Counts per T2 Cycle	Counts per g	Resolution (mg)
1.0	1250	1000	2.0	2000	250	4.0
1.0	1250	1000	1.0	1000	125	8.0
1.0	1250	1000	0.5	500	62.5	16.0
5.0	250	200	2.0	10000	1250	0.8
5.0	250	200	1.0	5000	625	1.6
5.0	250	200	0.5	2500	312.5	3.2
10.0	125	100	2.0	20000	2500	0.4
10.0	125	100	1.0	10000	1250	0.8
10.0	125	100	0.5	5000	625	1.6

USING THE ANALOG OUTPUT

The XL210 was designed specifically for use with its digital output, but has provisions to make an analog output.

Duty Cycle Filtering

An analog output can be reconstructed by filtering the duty cycle output. This technique requires only passive components. The duty cycle period should be set to a 1ms duty cycle period (T2). An RC filter with a 3db point at least a factor of 10 less than the duty cycle frequency is connected to the duty cycle output. The filter resistor should be no less than 100kΩ to prevent loading of the output stage. The analog output signal will be ratiometric to the supply voltage. The advantage of this method is an output scale factor of approximately 625mV/g. Its disadvantage is that the frequency response will be lower than when using the Xfilt, Yfilt output.

Xfilt, Yfilt Output

The second method is to use the analog output present at the Xfilt and Yfilt pin. Unfortunately, these pins have a 32kΩ output impedance and are not designed to drive a load directly. An op-amp follower may be required to buffer this pin; some A/D converters can be driven directly. The advantage of this method is that the full 6kHz bandwidth of the accelerometer is available to the user. A capacitor may still be added at this point for filtering. The duty cycle converter should be disabled in this mode by shorting the T2 pin to Vdd. Note that the accelerometer offset and sensitivity are ratiometric to the supply voltage. The offset and sensitivity are nominally:

0g Offset = Vs/2	2.5V at +5V
Sensitivity = (20mVx Vs) /g	100mV/g at +5V Vdd

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SUNSTAR商斯达实业集团是集研发、生产、工程、销售、代理经销 、技术咨询、信息服务等为一体的高科技企业，是专业高科技电子产品生产厂家，是具有 10 多年历史的专业电子元器件供应商，是中国最早和最大的仓储式连锁规模经营大型综合电子零部件代理分销商之一,是一家专业代理和分銷世界各大品牌IC芯片和電子元器件的连锁经营綜合性国际公司。在香港、北京、深圳、上海、西安、成都等全国主要电子市场设有直属分公司和产品展示展销窗口门市部专卖店及代理分销商，已在全国范围内建成强大统一的供货和代理分销网络。 我们专业代理经销、开发生产电子元器件、集成电路、传感器、微波光电元器件、工控机/DOC/DOM电子盘、专用电路、单片机开发、MCU/DSP/ARM/FPGA软件硬件、二极管、三极管、模块等，是您可靠的一站式现货配套供应商、方案提供商、部件功能模块开发配套商。**专业以现代信息产业（计算机、通讯及传感器）三大支柱之一的传感器为主营业务，专业经营各类传感器的代理、销售生产、网络信息、科技图书资料及配套产品设计、工程开发。我们的专业网站——中国传感器科技信息网（全球传感器数据库） www.SENSOR-IC.COM 服务于全球高科技生产商及贸易商，为企业科技产品开发提供技术交流平台。欢迎各厂商互通有无、交换信息、交换链接、发布寻求代理信息。欢迎国外高科技传感器、变送器、执行器、自动控制产品厂商介绍产品到 中国，共同开拓市场。**本网站是关于各种传感器-变送器-仪器仪表及工业自动化大型专业网站,深入到工业控制、系统工程计 测计量、自动化、安防报警、消费电子等众多领域，把最新的传感器-变送器-仪器仪表买卖信息,最新技术供求,最新采购商,行业动态，发展方向，最新的技术应用和市场资讯及时的传递给广大科技开发、科学研究、产品设计人员。本网站已成功为石油、化工、电力、医药、生物、航空、航天、国防、能源、冶金、电子、工业、农业、交通、汽车、矿山、煤炭、纺织、信息、通信、IT、安防、环保、印刷、科研、气象、仪器仪表等领域从事科学研究、产品设计、开发、生产制造的科技人员、管理人员 、和采购人员提供满意服务。 **我公司专业开发生产、代理、经销、**销售各种传感器、变送器、敏感元器件、开关、执行器、仪器仪表、自动化控制系统： 专门从事设计、生产、销售各种传感器、变送器、各种测控仪表、热工仪表、现场控制器、计算机控制系统、数据采集系统、各类环境监控系统、专用控制系统应用软件以及嵌入式系统开发及应用等工作。如热敏电阻、压敏电阻、温度传感器、温度变送器、湿度传感器、 湿度变送器、气体传感器、 气体变送器、压力传感器、 压力变送、称重传感器、物（液）位传感器、物（液）位变送器、流量传感器、 流量变送器、电流（压）传感器、溶氧传感器、霍尔传感器 、图像传感器、超声波传感器、位移传感器、速度传感器、加速度传感器、扭距传感器、红外传感器、紫外传感器、 火焰传感器、激光传感器、振动传感器、轴角传感器、光电传感器、接近传感器、干簧管传感器、继电器传感器、微型电泵、磁敏（阻）传感器 、压力开关、接近开关、光电开关、色标传感器、光纤传感器、齿轮测速传感器、 时间继电器、计数器、计米器、温控仪、固态继电器、调压模块、电磁铁、电压表、电流表等特殊传感器 。 同时承接传感器应用电路、产品设计和自动化工程项目。

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TEL：021-28311762 56703037 13701955389 FAX：021-56703037
西安分公司：西安高新开发区 20 所(中国电子科技集团导航技术研究所)
西安劳动南路 88 号电子商城二楼 D23 号
TEL：029-81022619 13072977981 FAX:029-88789382