Ultra High Performance ±1g Dual Axis Accelerometer with Digital Outputs
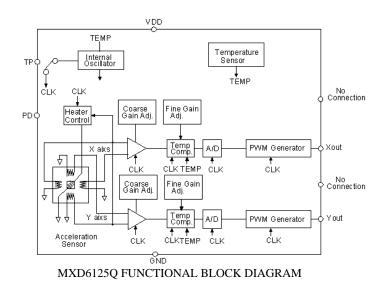
MXD6125Q

FEATURES

Ultra Low Noise 0.13 m$g/\sqrt{Hz}$ typical
Ultra Low Offset Drift 0.1 mg/°C typical
Resolution better than 1 mg
Monolithic CMOS IC
On chip mixed signal processing
50,000 g shock survival rating
Low profile LCC package
2.7V to 3.6V single supply
No adjustment needed outside

APPLICATIONS

Automotive – Vehicle Security/Active Suspension/ABS
     Headlight Angle Control/Tilt Sensing
Security – Gas Line/Elevator/Fatigue Sensing
Office Equipment – Computer Peripherals/PDA's/Mouse
     Smart Pens/Cell Phones
Gaming – Joystick/RF Interface/Menu Selection/Tilt Sensing

MXD6125Q FUNCTIONAL BLOCK DIAGRAM

GENERAL DESCRIPTION

The MXD6125Q is a low noise, low profile, dual axis accelerometer fabricated on a standard CMOS process. It is a complete sensing system with on-chip mixed mode signal processing. The MXD6125Q measures acceleration with a full-scale range of ±1 g and a sensitivity of 12.5%/g @3V at 25°C. It can measure both dynamic acceleration (e.g., vibration) and static acceleration (e.g., gravity). The MXD6125Q design is based on heat convection and requires no solid proof mass. This eliminates stiction and particle issues normally found with capacitive based technology, and significantly lowers field failure rate and in-line loss due to handling during assembly.
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The MXD6125Q provides two ratiometric analog outputs. The maximum noise floor is 0.18 m$g/\sqrt{Hz}$ allowing signals below 0.5 mg to be resolved at 1 Hz bandwidth and the 3dB rolloff of the device occurs at 8 Hz. The MXD6125Q is available in a hermetically sealed low profile LCC surface mount package measuring 5mm x 5mm x 1.55m.

MXD6125Q SPECIFICATIONS (Measurements @ 25°C, Acceleration = 0 g unless otherwise noted; V_{DD} = 3.0V unless otherwise specified)

Parameter	Conditions	MXD6125Q			Units
		Min	Typ	Max	
SENSOR INPUT	Each Axis				
Measurement Range[1]		±1.0			g
Nonlinearity	Best fit straight line		0.5	1.0	% of FS
Alignment Error[2]			±1.0		degrees
Transverse Sensitivity[3]			±2.0		%
SENSITIVITY	Each Axis				
D_{OUTX} and D_{OUTY}	@3.0V supply	11.8	12.5	13.2	% duty cycle/g
Change over Temperature	Δ from 25°C@-40°C			170	%
	Δ from 25°C@105°C	-70			%
ZERO g BIAS LEVEL	Each Axis				
0 g Offset		-0.04	0.0	+0.04	g
0 g Duty Cycle		49.5	50	50.5	% duty cycle
0 g Offset over Temperature	Based on 12.5%/g		0.1	0.5	mg/°C
PWM Frequency		95	100	105	Hz
NOISE PERFORMANCE					
Noise Density, rms			0.13	0.18	mg/$\sqrt{Hz}$
FREQUENCY RESPONSE					
3dB Bandwidth		6	8	10	Hz
SELF TEST					
Continuous Voltage at D_{OUTX}, D_{OUTY} under Failure	@3.0V Supply, output rails to supply voltage		3.0		V
D_{OUTX} and D_{OUTY} OUTPUTS					
Normal Output Range	Output High	2.8			V
	Output Low			0.2	V
Current	Source or sink, @ 2.7V-3.6V supply			100	μA
Rise/Fall Time	2.7 to 3.6V supply	90	100	110	nS
Turn-On Time[4]	@3.0V Supply		150		mS
POWER SUPPLY					
Operating Voltage Range		2.7	3.0	3.6	V
Supply Current	@ 3.0 V		1.5		mA
TEMPERATURE RANGE					
Operating Range		-40		+105	°C

NOTES

[1] Guaranteed by measurement of initial offset and sensitivity.

[2] Alignment error is specified as the angle between the true and indicated axis of sensitivity.

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

[4].Settled to within ±17mg.

ABSOLUTE MAXIMUM RATINGS*

Supply Voltage (V_{DD})   …………………...-0.5 to +7.0V
Storage Temperature   …….…….………-65°C to +150°C
Acceleration …………………………………..50,000 g

*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.
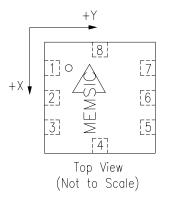
Pin Description: LCC-8 Package

Pin	Name	Description
1	PD	Power down pin
2	TP	Connected to ground
3	COM	Common
4	Yout	Y Channel Duty Cycle Output
5	Xout	X Channel Duty Cycle Output
6	NC	Do Not Connect
7	NC	Do Not Connect
8	V_{DD}	2.7V to 3.6 V

Ordering Guide

Model	PWM Frequency	Temperature Range	Package
MXD6125QB	100Hz	-40 to 105°C	LCC8, Pb-free

All parts are shipped in tape and reel packaging.
Caution: ESD (electrostatic discharge) sensitive device.

Top View
(Not to Scale)

Note: The MEMSIC logo's arrow indicates the -X sensing direction of the device. The +Y sensing direction is rotated 90° away from the +X direction following the right-hand rule. Small circle indicates pin one(1).

THEORY OF OPERATION

The MEMSIC device is a complete dual-axis acceleration measurement system fabricated on a monolithic CMOS IC process. The device operation is based on heat transfer by natural convection and operates like other accelerometers having a proof mass. The proof mass in the MEMSIC sensor is a gas.

A single heat source, centered in the silicon chip is suspended across a cavity. Equally spaced aluminum/polysilicon thermopiles (groups of thermocouples) are located equidistantly on all four sides of the heat source (dual axis). Under zero acceleration, a temperature gradient is symmetrical about the heat source, so that the temperature is the same at all four thermopiles, causing them to output the same voltage.

Acceleration in any direction will disturb the temperature profile, due to free convection heat transfer, causing it to be asymmetrical. The temperature, and hence voltage output of the four thermopiles will then be different. The differential voltage at the thermopile outputs is directly proportional to the acceleration. There are two identical acceleration signal paths on the accelerometer, one to measure acceleration in the x-axis and one to measure acceleration in the y-axis. Please visit the MEMSIC website at www.memsic.com for a picture/graphic description of the free convection heat transfer principle.

DISCUSSION OF TILT APPLICATIONS AND RESOLUTION

Tilt Applications: One of the most popular applications of the MEMSIC accelerometer product line is in tilt/inclination measurement. An accelerometer uses the force of gravity as an input to determine the inclination angle of an object.

A MEMSIC accelerometer is most sensitive to changes in position, or tilt, when the accelerometer's sensitive axis is perpendicular to the force of gravity, or parallel to the Earth's surface. Similarly, when the accelerometer's axis is parallel to the force of gravity (perpendicular to the Earth's surface), it is least sensitive to changes in tilt.

Table 1 and Figure 2 help illustrate the output changes in the X- and Y-axes as the unit is tilted from +90° to 0°. Notice that when one axis has a small change in output per degree of tilt (in m*g*), the second axis has a large change in output per degree of tilt. The complementary nature of these two signals permits low cost accurate tilt sensing to be achieved with the MEMSIC device (reference application note AN-00MX-007).
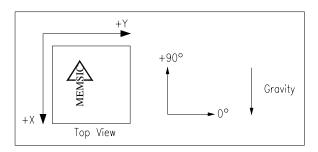

Figure 2: Accelerometer Position Relative to Gravity

X-Axis Orientation To Earth's Surface (deg.)	X-Axis		Y-Axis	
	X Output (*g*)	Change per deg. of tilt (m*g*)	Y Output (*g*)	Change per deg. of tilt (m*g*)
90	1.000	0.15	0.000	17.45
85	0.996	1.37	0.087	17.37
80	0.985	2.88	0.174	17.16
70	0.940	5.86	0.342	16.35
60	0.866	8.59	0.500	15.04
45	0.707	12.23	0.707	12.23
30	0.500	15.04	0.866	8.59
20	0.342	16.35	0.940	5.86
10	0.174	17.16	0.985	2.88
5	0.087	17.37	0.996	1.37
0	0.000	17.45	1.000	0.15

Table 1: Changes in Tilt for X- and Y-Axes

Resolution: The accelerometer resolution is limited by noise. The output noise will vary with the measurement bandwidth. With the reduction of the bandwidth, by applying an external low pass filter, the output noise drops. Reduction of bandwidth will improve the signal to noise ratio and the resolution. The output noise scales directly with the square root of the measurement bandwidth. The maximum amplitude of the noise, its peak- to- peak value, approximately defines the worst case resolution of the measurement. With a simple RC low pass filter, the rms noise is calculated as follows:

$$\text{Noise (mg rms)} = \text{Noise}(mg/\sqrt{Hz}) * \sqrt{(Bandwidth(Hz)*1.6)}$$

The peak-to-peak noise is approximately equal to 6.6 times the rms value (for an average uncertainty of 0.1%).

DIGITAL INTERFACE
The MXD6125Q is easily interfaced with low cost microcontrollers. For the digital output accelerometer, one digital input port is required to read one accelerometer output. For the analog output accelerometer, many low cost microcontrollers are available today that feature integrated A/D (analog to digital converters) with resolutions ranging from 8 to 12 bits.

In many applications the microcontroller provides an effective approach for the temperature compensation of the sensitivity and the zero *g* offset. Specific code set, reference designs, and applications notes are available from the factory. The following parameters must be considered in a digital interface:

Resolution: smallest detectable change in input acceleration
Bandwidth: detectable accelerations in a given period of time
Acquisition Time: the duration of the measurement of the acceleration signal
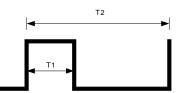
DUTY CYCLE DEFINITION
The MXD6125Q has two PWM duty cycle outputs (x,y). The acceleration is proportional to the ratio T1/T2. The zero *g* output is set to 50% duty cycle and the sensitivity scale factor is set to 12.5% duty cycle change per *g*. These nominal values are affected by the initial tolerance of the device including zero *g* offset error and sensitivity error. This device is offered from the factory programmed to either a 10ms period (100 Hz).

T1	Length of the "on" portion of the cycle.
T2 (Period)	Length of the total cycle.
Duty Cycle	Ratio of the "0n" time (T1) of the cycle to the total cycle (T2). Defined as T1/T2.
Pulse width	Time period of the "on" pulse. Defined as T1.

A (g)= (T1/T2 - 0.5)/12.5%
0g = 50% Duty Cycle
T2=10ms (factory programmable)
Figure 3: Typical output Duty Cycle

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 actual resolution of the acceleration signal 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 for a given resolution. Table 2 shows some of the trade-offs. It is important to note that this is the resolution due to the microprocessors' counter. It is probable that the accelerometer's noise floor may set the lower limit on the resolution.

T2 (ms)	MEMSIC Sample Rate	Counter-Clock Rate (MHz)	Counts Per T2 Cycle	Counts per g	Reso-lution (mg)
10.0	100	2.0	20000	2500	0.4
10.0	100	1.0	10000	1250	0.8
10.0	100	0.5	5000	625	1.6

Table 2: Trade-Offs Between Microcontroller Counter Rate and T2 Period.

MXD6125Q PIN DESCRIPTIONS

V_{DD} – This is the supply input for the circuits and the sensor heater in the accelerometer. The DC voltage should be between 2.7 and 3.6 volts. Refer to the section on PCB layout and fabrication suggestions for guidance on external parts and connections recommended.

COM– This is the ground pin for the accelerometer.

TP– This pin should be connected to ground.
Xout – This pin is the digital output of the X-axis acceleration sensor. It is factory programmable to 100Hz. The user should ensure the load impedance is sufficiently high as to not source/sink >100µA typical. While the sensitivity of this axis has been programmed at the factory to be the same as the sensitivity for the y-axis, the accelerometer can be programmed for non-equal sensitivities on the x- and y-axes. Contact the factory for additional information.

Yout – This pin is the digital output of the Y-axis acceleration sensor. It is factory programmable to 100Hz. The user should ensure the load impedance is sufficiently high as to not source/sink >100µA typical. While the sensitivity of this axis has been programmed at the factory to be the same as the sensitivity for the x-axis, the accelerometer can be programmed for non-equal sensitivities on the x- and y-axes. Contact the factory for additional information.
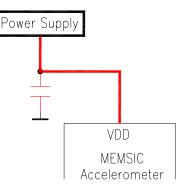
PD – Pin1 is the power down control pin. Pull this pin HIGH will put the accelerometer into power down mode.

When the part does into power down mode, the total current will be smaller than 0.1uA at 3V.
   In normal operation mode, this pin should be connected to Ground.
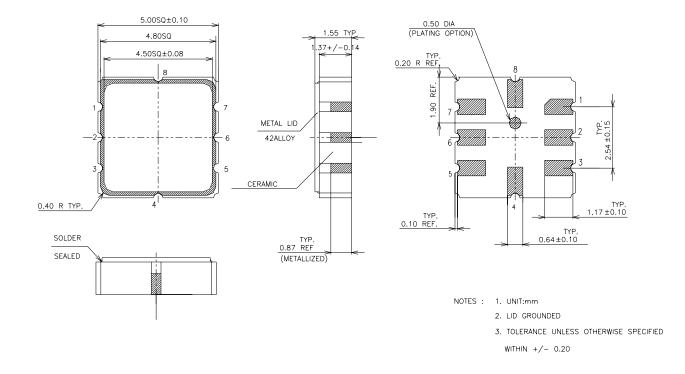
POWER SUPPLY NOISE REJECTION
One capacitor is recommended for best rejection of power supply noise (reference Figure 5 below). The capacitor should be located as close as possible to the device supply pin (V_{DD}). The capacitor lead length should be as short as possible, and surface mount capacitor is preferred. For typical applications, the capacitor can be ceramic 0.1 µF.

PCB LAYOUT AND FABRICATION SUGGESTIONS

1. Liberal use of ceramic bypass capacitors is recommended. It is best to solder a 0.1uF capacitor directly across V_{DD} and COM pin.
2. Robust low inductance ground wiring should be used.
3. Care should be taken to ensure there is "thermal symmetry" on the PCB immediately surrounding the MEMSIC device and that there is no significant heat source nearby.
4. A metal ground plane should be added directly beneath the MEMSIC device. The size of the plane should be similar to the MEMSIC device's footprint and be as thick as possible.
5. Vias can be added symmetrically around the ground plane. Vias increase thermal isolation of the device from the rest of the PCB.

LCC-8 PACKAGE DRAWING

Hermetically Sealed Package Outline