Ultra Low Cost, ±2.0 *g* Dual Axis Accelerometer with Digital Outputs

MXD2125J/K

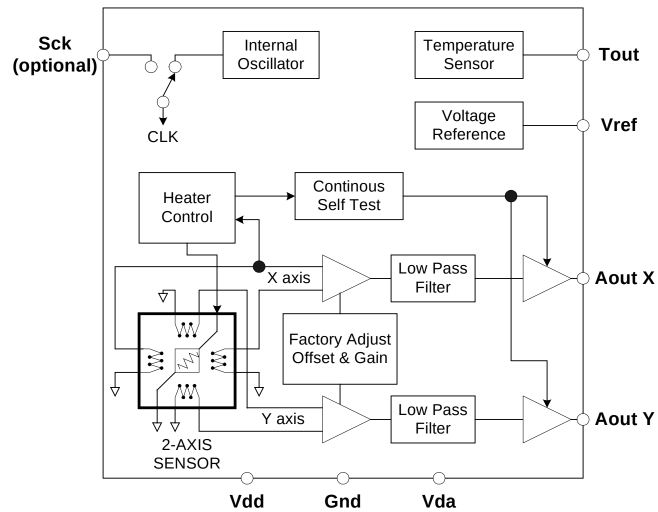
FEATURES
RoHS Compliant
Dual axis accelerometer
Monolithic CMOS construction
On-chip mixed mode signal processing
Resolution better than 2 mg
30Hz bandwidth
2.70V to 5.25V single supply operation
Low height surface mount package

APPLICATIONS
Consumer Electronics
- Cell phones, PDAs, MP3 Players, Gaming consoles
- Screen and image orientation
- Tilt and motion input
- Menu navigation
- Auto power on/off
- Active HDD protection
- Pedometer

Security
- Tamper detection
- Catastrophic event detection
- Black box event recorders

Office Equipment
- Computer Peripherals
- Mouse input

GENERAL DESCRIPTION
The MXD2125J/K is an ultra low cost, dual axis accelerometer fabricated on a standard, submicron CMOS process. The MXD2125J/K measures acceleration with a full-scale range of ±2.0 *g* and a sensitivity of 12.5%/g @5V power supply at 25°C. It can measure both dynamic acceleration (e.g., vibration) and static acceleration (e.g., gravity).



MXD2125J/K FUNCTIONAL BLOCK DIAGRAM

The MXD2125J/K design is based on heat convection and requires no solid proof mass. This eliminates stiction and particle problems, leading to significantly lower failure rates and lower loss due to handling during assembly.

The MXD2125J/K provides two PWM outputs which are set to 50% duty cycle at zero g input.

The typical noise floor is 1.0 m*g*/$\sqrt{Hz}$ allowing signals below 2mg to be resolved at 1Hz bandwidth. The MXD2125J/K has an inherent low pass frequency response with a 30Hz 3dB cutoff frequency, which eliminates unwanted higher frequency vibrations from obscuring the measurement. The MXD2125J/K is available in a LCC surface mount package (5.5mm x 5.5mm x 1.40mm height, with maximum height of 1.50mm). It is operational over a 0°C to +70°C (J) and -40°C to +85°C (K) temperature range.

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MXD2125J/K SPECIFICATIONS (Measurements @ 25°C, Acceleration = 0 *g* unless otherwise noted; V_{DD}, V_{DA} = 5.0V unless otherwise specified)

Parameter	Conditions	MXD2125J			MD2125K			Units
		Min	Typ	Max	Min	Typ	Max	
SENSOR INPUT	Each Axis							
Measurement Range[1]		±2.0			±2.0			*g*
Nonlinearity	Best fit straight line		1.0	2.0		1.0	2.0	% of FS
Alignment Error[2]			±1.0			±1.0		degrees
Transverse Sensitivity[3]			±2.0			±2.0		%
SENSITIVITY	Each Axis							
Sensitivity, Analog Outputs at pins D_{OUTX} and D_{OUTY}	@5.0V supply	11.0	12.5	14.0	11.0	12.5	14.0	%/*g*
Change over Temperature	Δ from 25°C			10			20	%
ZERO *g* BIAS LEVEL	Each Axis							
0 *g* Offset		-0.4	0.00	+0.4	-0.4	0.00	+0.4	*g*
0 *g* Duty Cycle		45	50.0	55	45	50.0	55	%
0 *g* Offset over Temperature	Δ from 25°C		±3.0			±3.0		m*g*/°C
	Δ from 25°C, based on 12.5%/*g*		±0.0375			±0.0375		%/°C
NOISE PERFORMANCE								
Noise Density, rms	Without frequency compensation		1.0			1.0		m*g*/$\sqrt{Hz}$
FREQUENCY RESPONSE								
3dB Bandwidth - uncompensated		25	30	35	25	30	35	Hz
TEMPERATURE OUTPUT								
T_{out} Voltage		1.0	1.25	1.5	1.0	1.25	1.5	V
Sensitivity		4.4	5.0	5.6	4.4	5.0	5.6	mV/°K
VOLTAGE REFERENCE								
V_{Ref}	@2.7V-5.25V supply	2.3	2.5	2.7	2.3	2.5	2.7	V
Change over Temperature			0.1			0.1		mV/°C
Current Drive Capability	Source			100			100	µA
SELF TEST								
Continuous Voltage at D_{OUTX}, D_{OUTY} under Failure	@5.0V Supply, output rails to supply voltage		5.0			5.0		V
D_{OUTX} and D_{OUTY} OUTPUTS								
Normal Output Range	Output High	4.8			4.8			V
	Output Low			0.2			0.2	V
Output Frequency		90	100	110	90	100	110	Hz
Current	Source or sink, @ 2.7V-5.25V supply			100			100	µA
Turn-On Time[4]	@5.0V Supply		200			200		mS
POWER SUPPLY								
Operating Voltage Range		2.7		5.25	2.7		5.25	V
Supply Current	@ 5.0V		4.2			4.2		mA
TEMPERATURE RANGE								
Operating Range		0		+70	-40		85	°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] Transverse sensitivity is the algebraic sum of the alignment and the inherent sensitivity errors.
[4] Output settled to within +/-17mg.

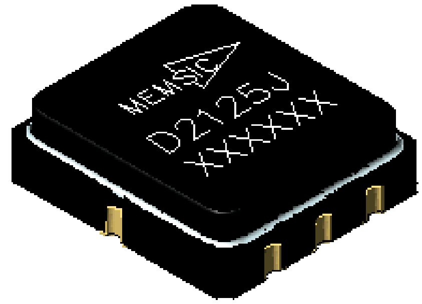
ABSOLUTE MAXIMUM RATINGS*

Supply Voltage (V_{DD}, V_{DA}) ………………...-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.



Package Characteristics

Package	θ_{JA}	θ_{JC}	Device Weight
LCC8	110°C/W	22°C/W	< 1 gram

Pin Description: LCC8 Package

Pin	Name	Description
1	T_{OUT}	Temperature (Analog Voltage)
2	D_{OUTY}	Y-Axis Acceleration Signal
3	Gnd	Ground
4	V_{DA}	Analog Supply Voltage
5	D_{OUTX}	X-Axis Acceleration Signal
6	V_{ref}	2.5V Reference
7	Sck	Connect to Ground
8	V_{DD}	Digital Supply Voltage

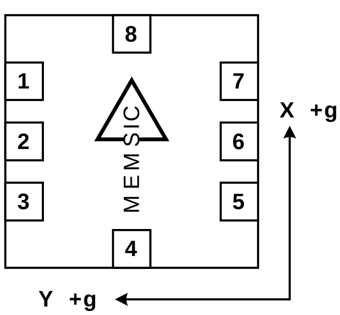
Ordering Guide

Model	Temperature Range	Package Style
MXD2125JV	0~70°C	LCC8, RoHS compliant
MXD2125KV	-40~85°C	LCC8, RoHS compliant

*LCC parts are shipped in tape and reel packaging.

Caution

ESD (electrostatic discharge) sensitive device.



Top View

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.

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 except it is a gas in the MEMSIC sensor.

A single heat source, centered in the silicon chip is suspended across a cavity. Equally spaced aluminum/poly-silicon 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.

PIN DESCRIPTIONS

V_{DD} – This is the supply input for the digital circuits and the sensor heater in the accelerometer. The DC voltage should be between 2.70 and 5.25 volts.

V_{DA} – This is the power supply input for the analog amplifiers in the accelerometer. The DC voltage should be between 2.70 and 5.25 volts

Gnd – This is the ground pin for the accelerometer.

D_{OUTX} – This pin is the digital output of the x-axis acceleration sensor. It is factory programmable to 100 Hz. The user should ensure the load impedance is sufficiently high as to not source/sink >100μA typical.

D_{OUTY} – This pin is the digital output of the y-axis acceleration sensor. It is factory programmable to 100 Hz. The user should ensure the load impedance is sufficiently high as to not source/sink >100μA typical.

T_{OUT} – This pin is the buffered output of the temperature sensor. The analog voltage at T_{OUT} is an indication of the die temperature. This voltage is useful as a differential measurement of temperature from ambient and not as an absolute measurement of temperature.

Sck – This pin should be grounded.

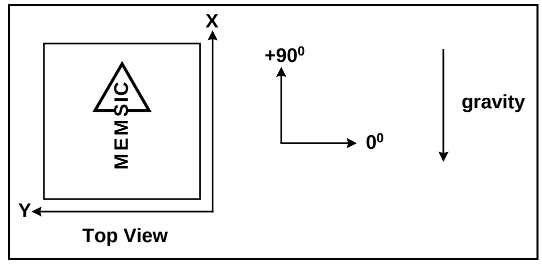
V_{ref} – A reference voltage is available from this pin. It is set at 2.50V typical and has 100μA of drive capability.

DISCUSSION OF TILT APPLICATIONS AND MINIMUM 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.

Following table and figure 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).



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

Changes in Tilt for X- and Y-Axes

Minimum 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. The peak-to-peak noise is approximately equal to 6.6 times the rms value (with an average uncertainty of .1%).

DIGITAL INTERFACE

The MXD2125J/K is easily interfaced with low cost microcontroller. For the digital output accelerometer, one digital input port is required to read one accelerometer output. For the analog output accelerometer, many low cost microcontroller are available today that feature integrated a/d (analog to digital converters) with resolutions ranging from 8 to 12 bits.

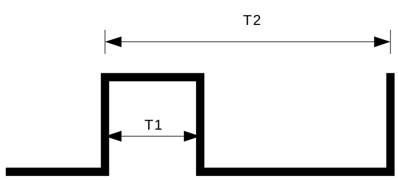
In many applications the microcontroller provides an effective approach for the temperature compensation of the sensitivity and the zero *g* offset. Specific code set, reference designs, and applications notes are available from the factory. The following parameters must be considered in a digital interface:

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 MXD2125J/K 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 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)

Typical output Duty C ycle

CHOOSING T2 AND COUNTER FREQUENCY DESIGN TRADE-OFFS

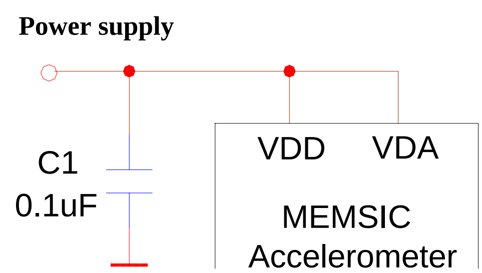
The noise level is one determinant of accelerometer resolution. The second relates to the measurement resolution of the counter when decoding the duty cycle output. The actual resolution of the acceleration signal is limited by the time resolution of the counting devices used to decode the duty cycle. 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 below 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 (m*g*)
10.0	100	2.0	20000	4000	0.25
10.0	100	1.0	10000	2000	0.5
10.0	100	0.5	5000	1000	1.0

Trade-Offs Between Microcontroller Counter Rate and T2 Period.

POWER SUPPLY NOISE REJECTION

A capacitor is recommended for best rejection of power supply noise (reference following figure). The capacitor should be located as close as possible to the device supply pins V_{DA}. The capacitor lead length should be as short as possible, and surface mount capacitors are preferred. For typical applications, capacitors C1 can be ceramic 0.1 µF.

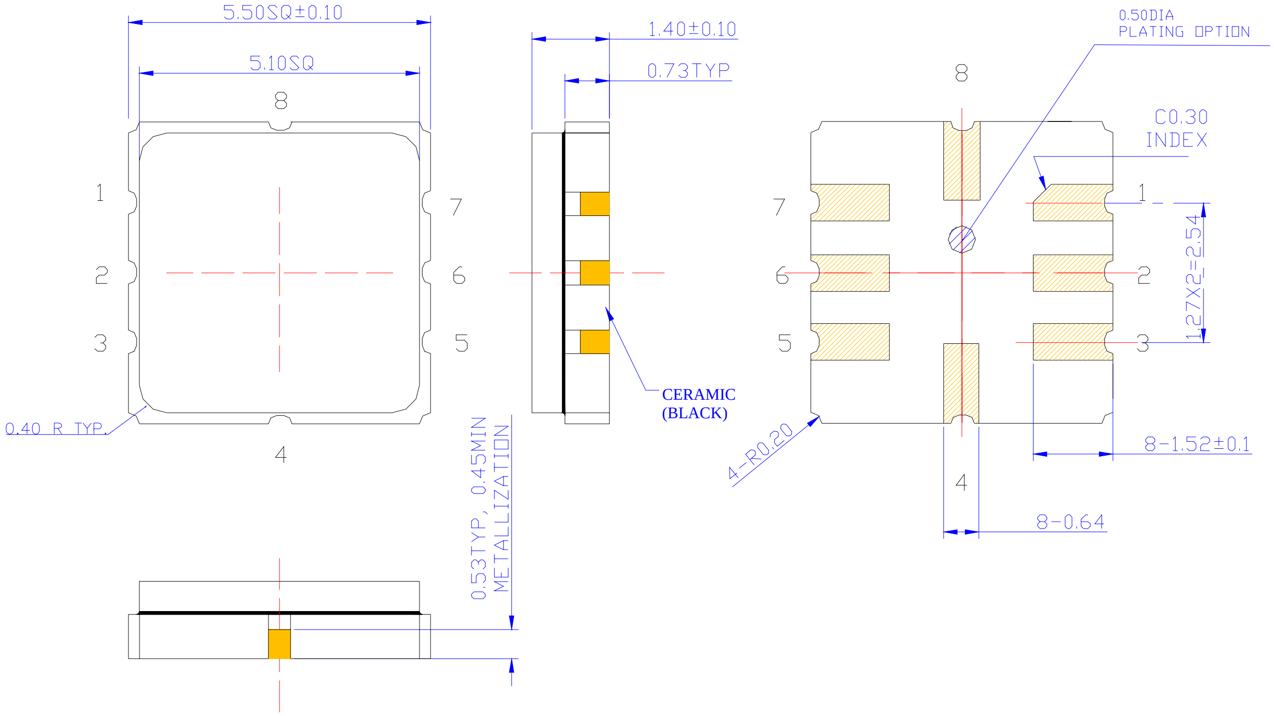


Power Supply Noise Rejection

PCB LAYOUT AND FABRICATION SUGGESTIONS

1. The Sck pin should be grounded to minimize noise.
2. Liberal use of ceramic bypass capacitors is recommended.
3. Robust low inductance ground wiring should be used.
4. 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.
5. A metal ground plane should be added directly beneath the MEMSIC device. The size of the ground plane should be similar to the MEMSIC device's footprint and as thick as possible.
6. Vias can be added symmetrically around the ground plane. Vias increase thermal isolation of the device from the rest of the PCB.

Package Drawing



Package Outline