

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.

Pin Description: LCC-8 Package

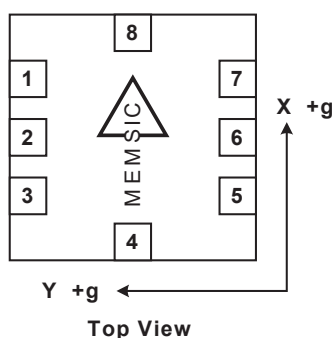
Pin	Name	Description
1	T_{OUT}	Temperature (Analog Voltage)
2	D_{OUTY}	Y-Axis Acceleration Digital Signal
3	Gnd	Ground
4	V_{DA}	Analog Supply Voltage
5	D_{OUTX}	X-Axis Acceleration Digital Signal
6	V_{ref}	2.5V Reference
7	Sck	Optional External Clock
8	V_{DD}	Digital Supply Voltage

Ordering Guide

Model	Package Style	Digital Output	Temperature Range
MXD2125GL	LCC8 RoHS compliant	100 Hz	0 to 70°C
MXD2125GF	LCC8, Pb-free	100 Hz	0 to 70°C
MXD2125HL	LCC8 RoHS compliant	400Hz	0 to 70°C
MXD2125HF	LCC8, Pb-free	400Hz	0 to 70°C
MXD2125ML	LCC8 RoHS compliant	100 Hz	-40 to 105°
MXD2125MF	LCC8, Pb-free	100 Hz	-40 to 105°
MXD2125NL	LCC8 RoHS compliant	400 Hz	-40 to 105°
MXD2125NF	LCC8, Pb-free	400 Hz	-40 to 105°

All parts are shipped in tape and reel packaging.

Caution: ESD (electrostatic discharge) sensitive device.



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.

MXD2125G/H/M/N 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 3.0 and 5.25 volts. Refer to the section on PCB layout and fabrication suggestions for guidance on external parts and connections recommended.

V_{DA} – This is the power supply input for the analog amplifiers in the accelerometer. V_{DA} should always be connected to V_{DD}. Refer to the section on PCB layout and fabrication suggestions for guidance on external parts and connections recommended.

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 or 400 Hz. 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.

D_{OUTY} – This pin is the digital output of the y-axis acceleration sensor. It is factory programmable to 100 Hz or 400 Hz. 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.

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 – The standard product is delivered with an internal clock option (800kHz). **This pin should be grounded when operating with the internal clock.** An external clock option can be special ordered from the factory allowing the user to input a clock signal between 400kHz And 1.6MHz

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 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 mg), 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).

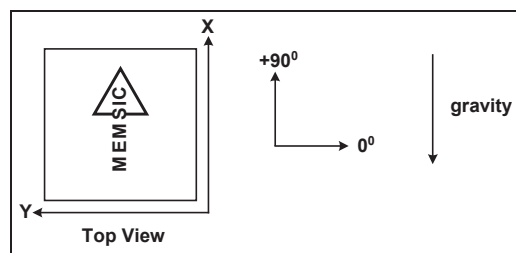


Figure 2: Accelerometer Position Relative to Gravity

X-Axis Orientation To Earth's Surface (deg.)	X-Axis		Y-Axis	
	X Output (g)	Change per deg. of tilt (mg)	Y Output (g)	Change per deg. of tilt (mg)
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:

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

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 MXD2125G/H/M/N 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:

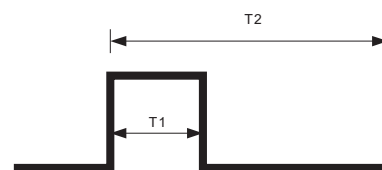
Resolution: smallest detectable change in input acceleration
Bandwidth: detectable accelerations in a given period of time

Acquisition Time: the duration of the measurement of the acceleration signal

DUTY CYCLE DEFINITION

The MXD2125G/H/M/N 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) or a 2.5ms period (400Hz).

T1	Length of the “on” portion of the cycle.
T2 (Period)	Length of the total cycle.
Duty Cycle	Ratio of the “On” 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= 2.5ms or 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	Resolution (mg)
2.5	400	2.0	5000	625	1.6
2.5	400	1.0	2500	312.5	3.2
2.5	400	0.5	1250	156.3	6.4
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.

CONVERTING THE DIGITAL OUTPUT TO AN ANALOG OUTPUT

The PWM output can be easily converted into an analog output by integration. A simple RC filter can do the conversion. Note that the impedance of the circuit following the integrator must be much higher than the impedance of the RC filter. Reference figure 4 for an example.

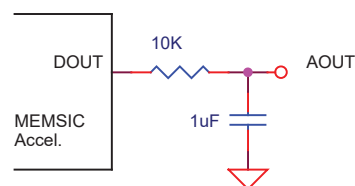


Figure 4: Converting the digital output to an analog voltage