Ultra Low Cost, ±1.5 *g* Dual Axis Accelerometer with Absolute Outputs

MXA2300J/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
>50,000 *g* shock survival rating
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

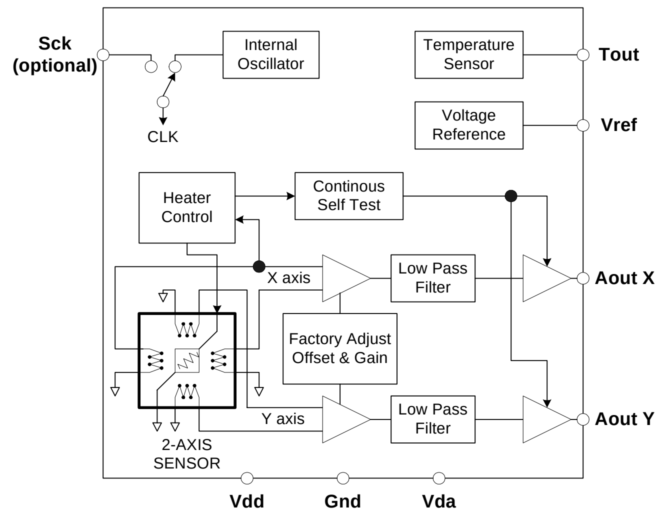
- Tamper detection
- Catastrophic event detection
- Black box event recorders

Office Equipment

- Computer Peripherals
- Mouse input

GENERAL DESCRIPTION

The MXA2300J/K is an ultra low cost, dual axis accelerometer fabricated on a standard, submicron CMOS process. The MXA2300J/K measures acceleration with a full-scale range of ±1.5 *g* and a sensitivity of 300mV/g @3V power supply at 25°C. It can measure both dynamic acceleration (e.g., vibration) and static acceleration (e.g., gravity).



MXA2300J/K FUNCTIONAL BLOCK DIAGRAM

The MXA2300J/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 MXA2300J/K provides two absolute analog outputs.

The typical noise floor is 1.0 m*g*/$\sqrt{Hz}$ allowing signals below 2mg to be resolved at 1Hz bandwidth. The MXA2300J/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 MXA2300J/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 -10°C to +70°C (J) and -40°C to +85°C (K) temperature range.

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MXA2300J/K SPECIFICATIONS (Measurements @ 25°C, Acceleration = 0 *g* unless otherwise noted; V_{DD}, V_{DA} = 3.0V unless otherwise specified)

Parameter	Conditions	MXA2300J			MXA2300K			Units
		Min	Typ	Max	Min	Typ	Max	
SENSOR INPUT	Each Axis							
Measurement Range[1]		±1.5			±1.5			*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 A_{OUTX} and A_{OUTY}	@3.0V supply	270	300	330	270	300	330	mV/*g*
Change over Temperature	Δ from 25°C			10			20	%
ZERO *g* BIAS LEVEL	Each Axis							
0 *g* Offset		-0.48	0.00	+0.48	-0.48	0.00	+0.48	*g*
0 *g* Voltage		1.10	1.25	1.40	1.10	1.25	1.40	V
0 *g* Offset over Temperature	Δ from 25°C		±5.0			±5.0		m*g*/°C
	Δ from 25°C, based on 300mV/*g*		±1.5			±1.5		mV/°C
NOISE PERFORMANCE								
Noise Density, rms	Without frequency compensation		1.0			1.0		$mg/\sqrt{Hz}$
FREQUENCY RESPONSE								
3dB Bandwidth - uncompensated		25	30	35	25	30	35	Hz
TEMPERATURE OUTPUT								
T_{out} Voltage		1.15	1.25	1.35	1.15	1.25	1.35	V
Sensitivity		4.6	5.0	5.4	4.6	5.0	5.4	mV/°K
VOLTAGE REFERENCE								
V_{Ref} Output	@2.7V-5.25V supply	2.4	2.5	2.65	2.4	2.5	2.65	V
Change over Temperature			0.1			0.1		mV/°C
Current Drive Capability	Source			100			100	μA
SELF TEST								
Continuous Voltage at A_{OUTX}, A_{OUTY} under Failure	@3.0V Supply, output rails to supply voltage		3.0			3.0		V
A_{OUTX} and A_{OUTY} OUTPUTS								
Normal Output Range	@3.0V Supply	0.1		2.9	0.1		2.9	V
Current	Source or sink, @ 2.7V-5.25V supply			100			100	μA
Turn-On Time[4]	@3.0V Supply		300			300		mS
POWER SUPPLY								
Operating Voltage Range		2.7		5.25	2.7		5.25	V
Supply Current	@ 3.0V		4.8			4.8		mA
TEMPERATURE RANGE								
Operating Range		-10		+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

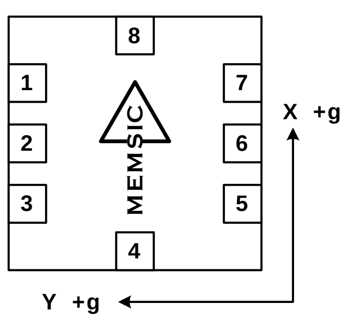
Ordering Guide

Model	Temperature Range	Package Style
MXA2300JV	-10~70°C	LCC8, RoHS compliant
MXA2300KV	-40~85°C	LCC8, RoHS compliant

*LCC parts are shipped in tape and reel packaging.

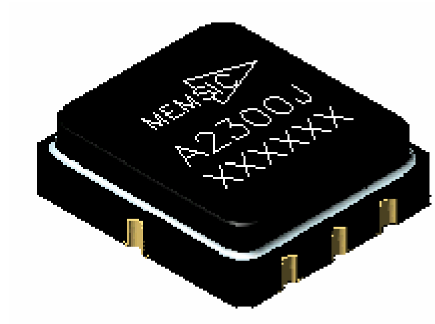
Caution

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.



Pin Description: LCC8 Package

Pin	Name	Description	I/O
1	T_{OUT}	Temperature output	O
2	Yout	Y-Axis Acceleration Signal	O
3	Gnd	Ground	I
4	V_{DA}	2.7V to 5.25V	I
5	Xout	X-Axis Acceleration Signal	O
6	VREF	2.5V Reference Output	O
7	SCK	Connect to Ground	I
8	V_{DD}	2.7V to 5.25V	I

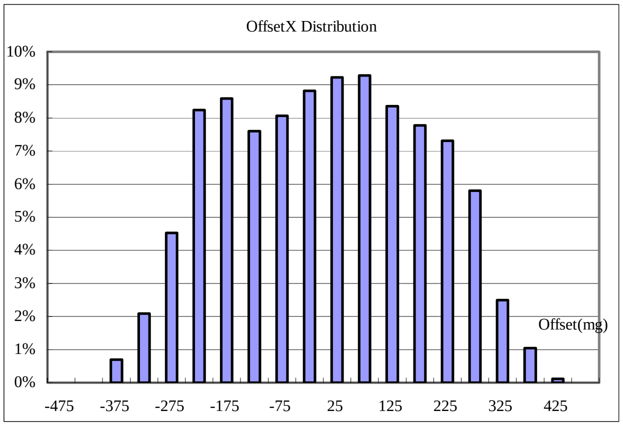
THEORY OF OPERATION

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.

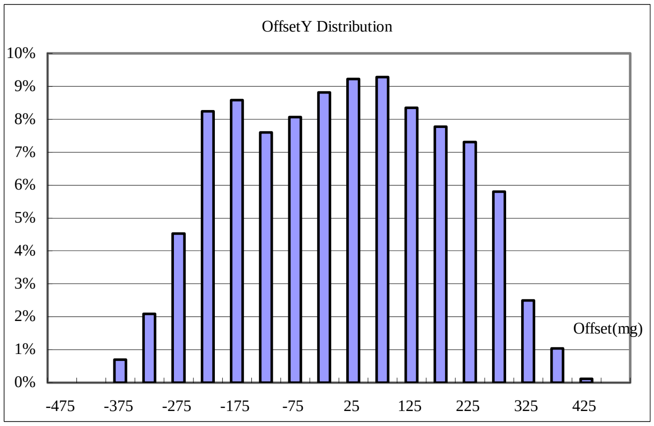
A single heat source, centered in the silicon chip is suspended across a cavity. Equally spaced aluminum/poly-silicon thermopiles (groups of thermocouples) are located equidistantly on all four sides of the heat source (dual axis). Under zero acceleration, a temperature gradient is symmetrical about 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.

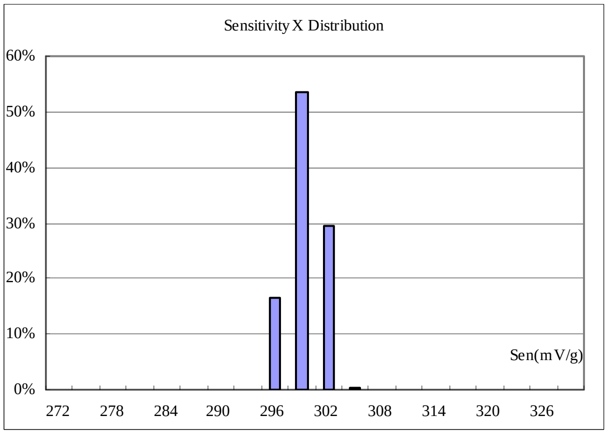
TYPICAL CHARACTERISTICS, % OF UNITS (@ 25°C, V_{DD} = 3.0V)



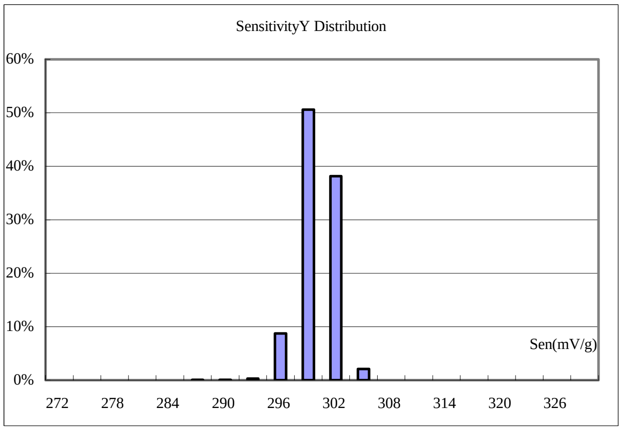
0g OffsetX Deviation



0g OffsetY Deviation

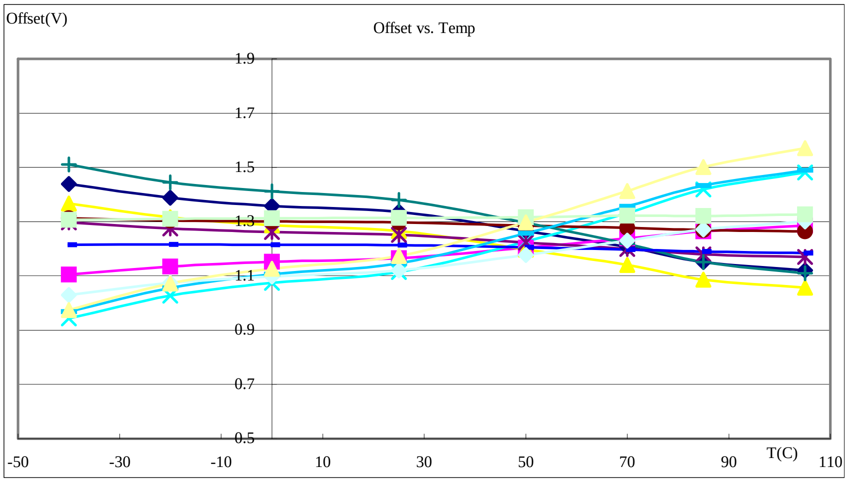


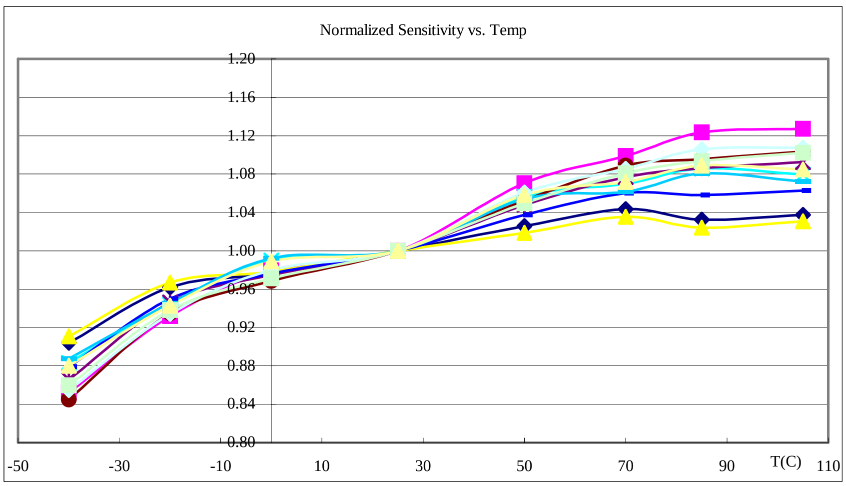
X-axis Sensitivity Distribution



Y-axis Sensitivity Distribution

OVER TEMPERATURE CHARACTERISTICS





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).

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.

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

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

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.

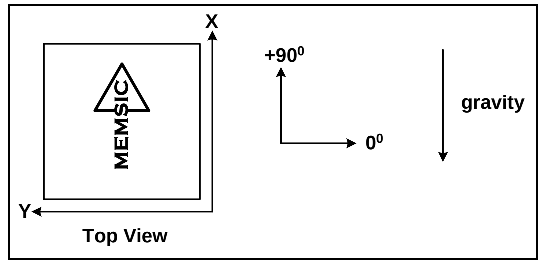
V_{ref} – A reference output voltage is available from this pin. It is set at 2.50V typical and has 100μA of drive capability.

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



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

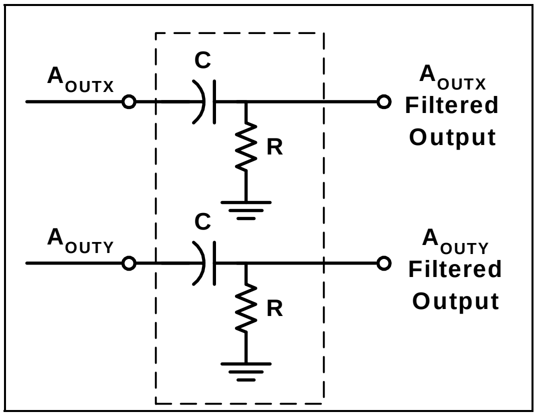
Changes in Tilt for X- and Y-Axes

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%).

EXTERNAL FILTERS

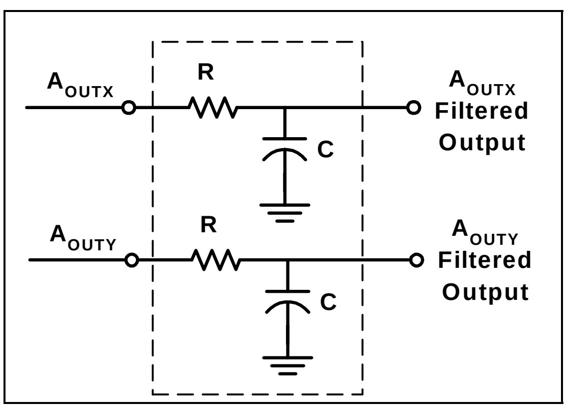
AC Coupling: For applications where only dynamic accelerations (vibration) are to be measured, it is recommended to ac couple the accelerometer output as shown in following figure. The advantage of ac coupling is that variations from part to part of zero *g* offset and zero *g* offset versus temperature can be eliminated.

Following figure is a HPF (high pass filter) with a –3dB breakpoint given by the equation: $f = \frac{1}{2\pi RC}$. In many applications it may be desirable to have the HPF –3dB point at a very low frequency in order to detect very low frequency accelerations. Sometimes the implementation of this HPF may result in unreasonably large capacitors, and the designer must turn to digital implementations of HPFs where very low frequency –3dB breakpoints can be achieved.



High Pass Filter

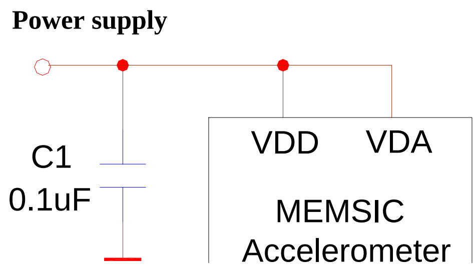
Low Pass Filter: An external low pass filter is useful in low frequency applications such as tilt or inclination. The low pass filter limits the noise floor and improves the resolution of the accelerometer**.** When designing with MEMSIC ratiometric output accelerometers (MXR2xxx series), it is highly recommended that an external, 200 Hz low pass filter be used to eliminate internally generated periodic noise that is coupled to the output of the accelerometer.
The low pass filter shown in following figure has a –3dB breakpoint given by the equation: $f = \frac{1}{2\pi RC}$. For the 200 Hz ratiometric output device filter, C=0.1μF and R=8kΩ, ±5%, 1/8W.



Low Pass Filter

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.

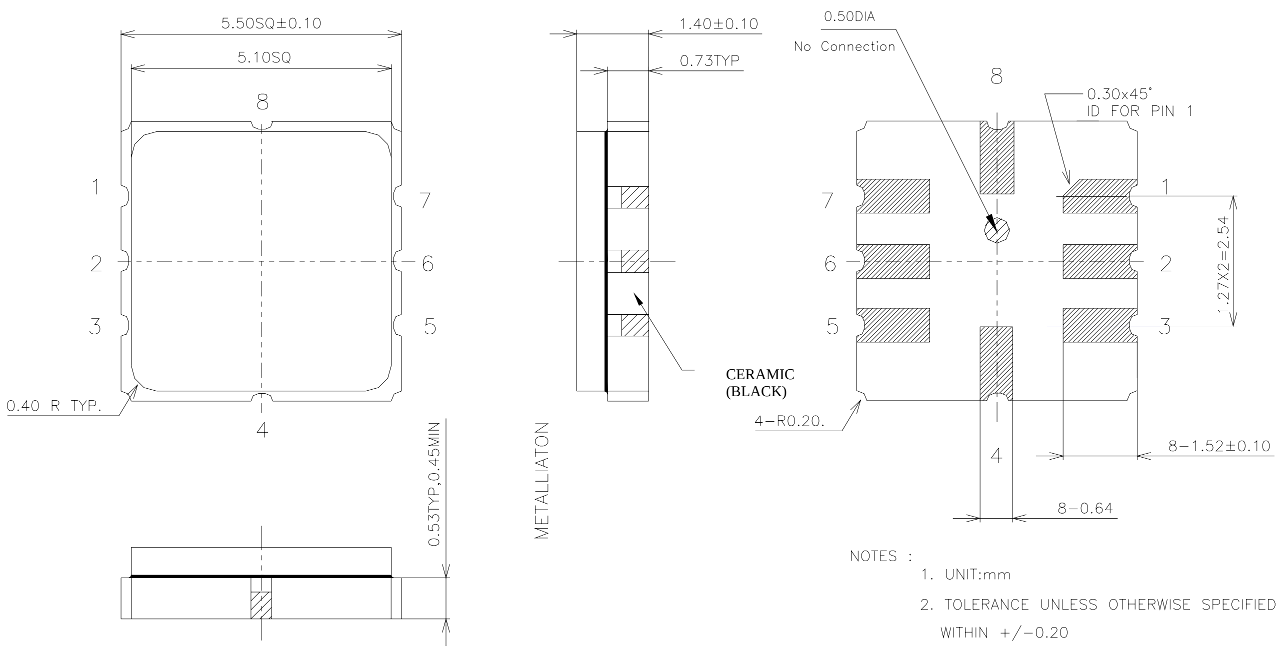


Power Supply Noise Rejection

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