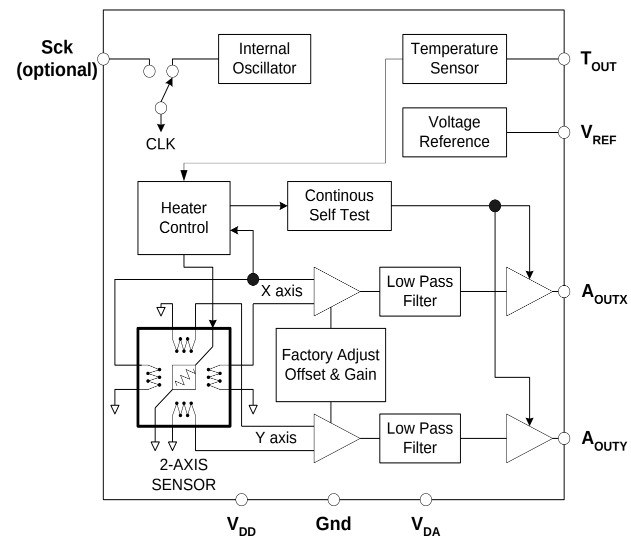
# Improved, Ultra Low Noise ±1.7 *g* Dual Axis Accelerometer with Absolute Outputs

# MXA2500G/M

## FEATURES

**Resolution better than 1 m*g***
**Dual axis accelerometer fabricated on a monolithic CMOS IC**
**RoHS compliant**
**On chip mixed mode signal processing**
**No moving parts**
**50,000 *g* shock survival rating**
**17 Hz bandwidth expandable to >160 Hz**
**3.0V to 5.25V single supply continuous operation**
**Continuous self test**
**Independent axis programmability (special order)**




**MXA2500G/M FUNCTIONAL BLOCK DIAGRAM**

## APPLICATIONS

**Automotive –** Vehicle Security/Vehicle Stability control/ Headlight Angle Control/Tilt Sensing
**Security** – Gas Line/Elevator/Fatigue Sensing/Computer Security
**Information Appliances** – Computer Peripherals/PDA's/ Cell Phones
**Gaming** – Joystick/RF Interface/Menu Selection/Tilt Sensing
**GPS** – Electronic compass tilt correction
**Consumer** – LCD projectors, pedometers, blood pressure Monitor, digital cameras

## GENERAL DESCRIPTION

The MXA2500G/M is a low cost, dual axis accelerometer fabricated on a standard, submicron CMOS process. It is a complete sensing system with on-chip mixed mode signal processing. The MXA2500G/M measures acceleration with a full-scale range of ±1.7*g* and a sensitivity of 500mV/g @5V at 25°C. It can measure both dynamic acceleration (e.g. vibration) and static acceleration (e.g. gravity). The MXA2500G/M design is based on heat convection and requires no solid proof mass. This eliminates stiction and particle problems associated with competitive devices and provides shock survival of 50,000 *g*, leading to significantly lower failure rate and lower loss due to handling during assembly.

The MXA2500G/M provides two absolute analog outputs. The typical noise floor is 0.2 m$g/\sqrt{Hz}$ allowing signals below 1 m*g* to be resolved at 1 Hz bandwidth. The 3dB rolloff of the device occurs at 17 Hz but is expandable to >160 Hz.
The MXA2500G/M is packaged in a hermetically sealed LCC surface mount package (5 mm x 5 mm x 2 mm height) and is operational over a -40°C to 105°C (M) and 0°C to 70°C(G) temperature range.



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**MXA2500G/M SPECIFICATIONS (**Measurements @ 25°C, Acceleration = 0 *g* unless otherwise noted; $V_{DD}$, $V_{DA}$ = 5.0V unless otherwise specified)

| | | MXA2500G | | | MXA2500M | | | |
|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Conditions** | **Min** | **Typ** | **Max** | **Min** | **Typ** | **Max** | **Units** |
| SENSOR INPUT | Each Axis | | | | | | | |
| Measurement Range[1] | | ±1.7 | | | ±1.7 | | | *g* |
| Nonlinearity | Best fit straight line | | 0.5 | 1.0 | | 0.5 | 1.0 | % of FS |
| Alignment Error[2] | X Sensor to Y Sensor | | ±1.0 | | | ±1.0 | | degrees |
| Transverse Sensitivity[3] | | | ±2.0 | | | ±2.0 | | % |
| SENSITIVITY | Each Axis | | | | | | | |
| Sensitivity, Analog Outputs at pins $A_{OUTX}$ and $A_{OUTY}$[5] | | 475 | 500 | 525 | 475 | 500 | 525 | mV/*g* |
| Change over Temperature | | -10 | | +8 | -25 | | +8 | % |
| ZERO *g* BIAS LEVEL | Each Axis | | | | | | | |
| 0 *g* Offset[5] | | -0.1 | 0.0 | +0.1 | -0.1 | 0.0 | +0.1 | *g* |
| 0 *g* Voltage[5] | | 1.20 | 1.25 | 1.30 | 1.20 | 1.25 | 1.30 | V |
| 0 *g* Offset over Temperature | | | ±1.5 | | | ±1.5 | | m*g*/°C |
| | Based on 500 mV/g | | ±0.75 | | | ±0.75 | | mV/°C |
| NOISE PERFORMANCE | | | | | | | | |
| Noise Density, rms | Without frequency compensation | | 0.2 | 0.4 | | 0.2 | 0.4 | m*g*/ $\sqrt{Hz}$ |
| FREQUENCY RESPONSE | | | | | | | | |
| 3dB Bandwidth - uncompensated | | 15 | 17 | 19 | 15 | 17 | 19 | Hz |
| 3dB Bandwidth – compensated[4] | | | >160 | | | >160 | | 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 OUTPUT | | | | | | | | |
| $V_{Ref}$ output | @3.0V-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 | @5.0V Supply, output rails to supply voltage | | 5.0 | | | 5.0 | | V |
| 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 | @5.0V Supply | 0.1 | | 4.9 | 0.1 | | 4.9 | V |
| | @3.0V Supply | 0.1 | | 2.9 | 0.1 | | 2.9 | V |
| Current | Source or sink, @ 3.0V-5.25V supply | | | 100 | | | 100 | µA |
| Turn-On Time[6] | @5.0V Supply | | 160 | | | 160 | | mS |
| | @3.0V Supply | | 300 | | | 300 | | mS |
| POWER SUPPLY | | | | | | | | |
| Operating Voltage Range | | 3.0 | | 5.25 | 3.0 | | 5.25 | V |
| Supply Current | @ 5.0V | 2.5 | 3.1 | 3.9 | 2.5 | 3.1 | 3.9 | mA |
| Supply Current[5] | @ 3.0V | 3.0 | 3.8 | 4.6 | 3.0 | 3.8 | 4.6 | mA |
| TEMPERATURE RANGE | | | | | | | | |
| Operating Range | | 0 | | +70 | -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 Transverse sensitivity is the algebraic sum of the alignment and the inherent sensitivity errors.

4 External circuitry is required to extend the 3dB bandwidth

5 The device operates over a 3.0V to 5.25V supply range. Please note that sensitivity and zero *g* bias level will be slightly different at 3.0V operation. For devices to be operated at 3.0V in production, they can be trimmed at the factory specifically for this lower supply voltage operation, in which case the sensitivity and zero *g* bias level specifications on this page will be met. Please contact the factory for specially trimmed devices for low supply voltage operation.

5 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, constant…………….……………..50,000 *g*
Shock (Powered) , Half Sine (shock rating limited by test equipment, virtually unlimited by design)

| Level (g) | Duration(ms) |
|---|---|
| 3000 | 0.5 |
| 2000 | 1.0 |
| 1000 | 2.0 |
| 700 | 3.0 |
| 500 | 5.0 |

*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 | $\theta_{JA}$ | $\theta_{JC}$ | Device Weight |
|---|---|---|---|
| LCC-8 | 110°C/W | 22°C/W | < 1 gram |

**Pin Description: LCC-8 Package**

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

**Ordering Guide**

| Model | Package Style | Temperature Range |
|---|---|---|
| MXA2500GL | LCC8<br>RoHS compliant | 0 to 70°C |
| MXA2500GF | LCC8, Pb-free<br>RoHS compliant | 0 to 70°C |
| MXA2500ML | LCC8<br>RoHS compliant | -40 to 105°C |
| MXA2500MF | LCC8, Pb-free<br>RoHS compliant | -40 to 105°C |

All parts are shipped in tape and reel packaging.

**Caution:** ESD (electrostatic discharge) sensitive device.

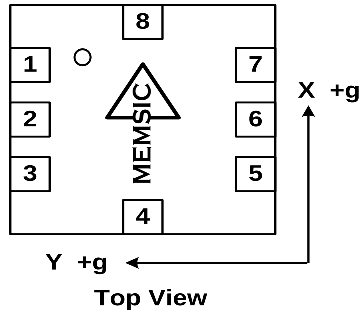
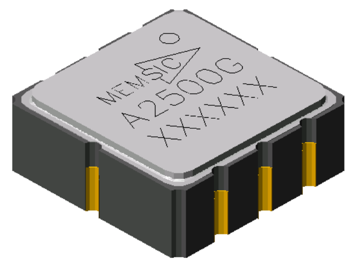



*Figure 1:* **Note - The** MEMSIC logo's arrow indicates the +X sensing direction of the device. The +Y sensing direction is rotated 90° away from the +X direction following the right-hand rule. Small circle indicates pin one (1).



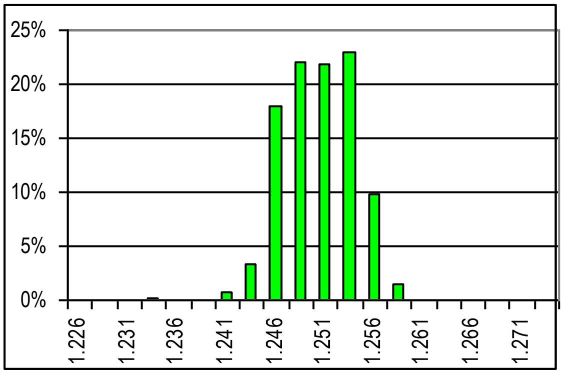

**THEORY OF OPERATION**

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 except it is a gas in the MEMSIC sensor.

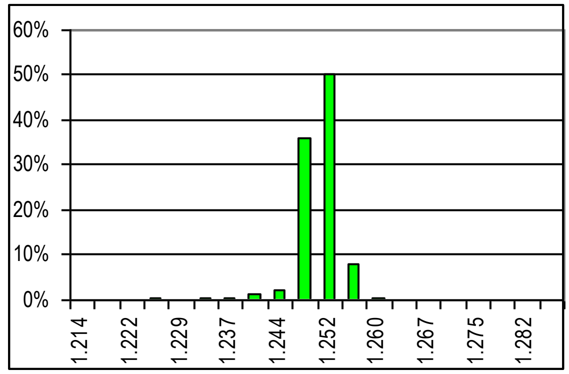
A single heat source, centered in the silicon chip is suspended across a cavity. Equally spaced aluminum/polysilicon thermopiles (groups of thermocouples) are located equidistantly on all four sides of the heat source (dual axis). Under zero acceleration, a temperature gradient is symmetrical about the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

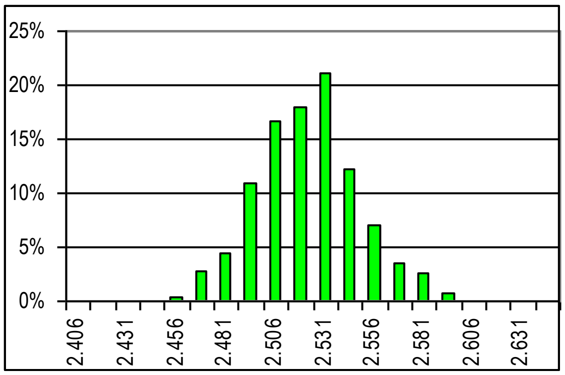
**TYPICAL CHARACTERISTICS, % OF UNITS ( @ 25°C, Vdd = 5V , unless specified)**



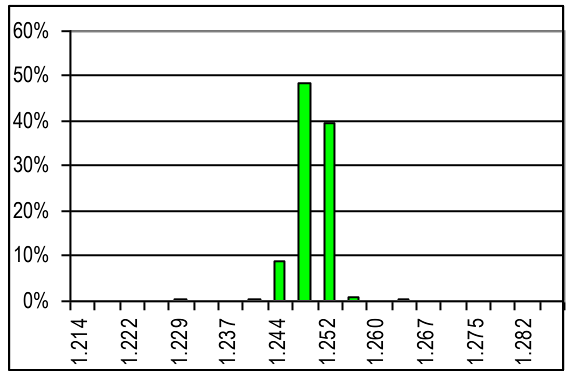

*Graph 1. Distribution of* Tout *(Volts)*



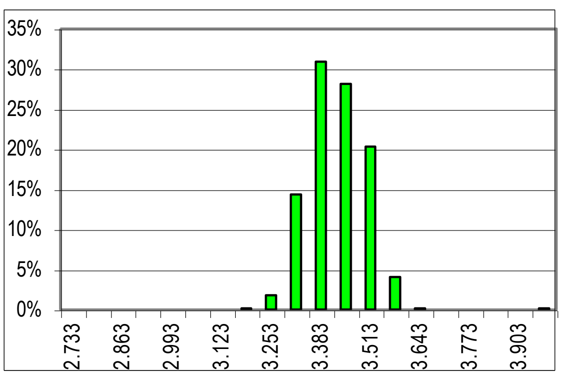

*Graph 5. Distribution of 0g Offset* AOUTX *(Volts)*



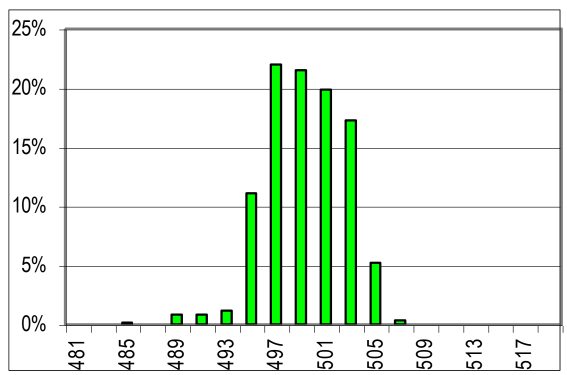

*Graph 2. Distribution of* Vref *(Volts)*



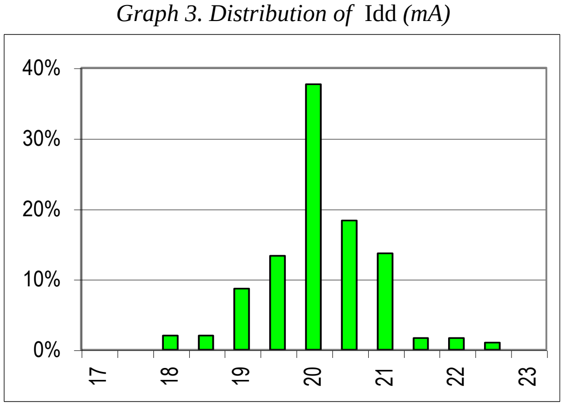

*Graph 6. Distribution of 0g Offset* AOUTY *(Volts)*



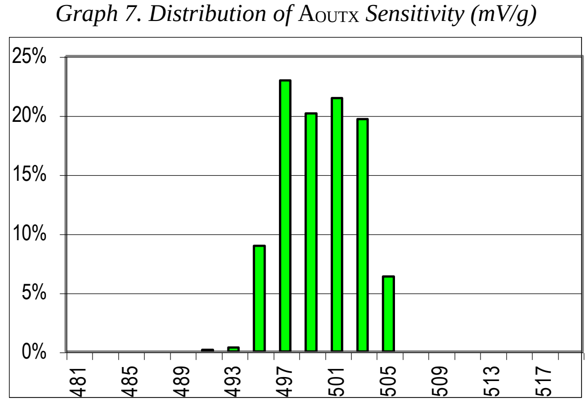

*Graph 3. Distribution of* Idd *(mA)*




*Graph 7. Distribution of* AOUTX *Sensitivity (mV/g)*

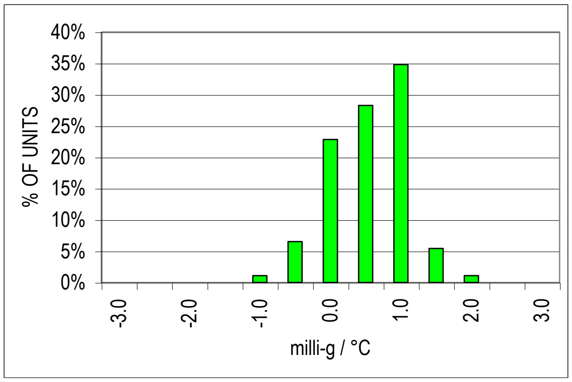



*Graph 4. Distribution of Freq. Resp. (Hz)*

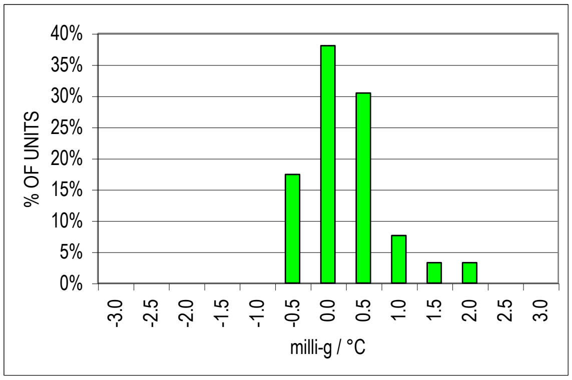



*Graph 8. Distribution of* AOUTY *Sensitivity (mV/g)*

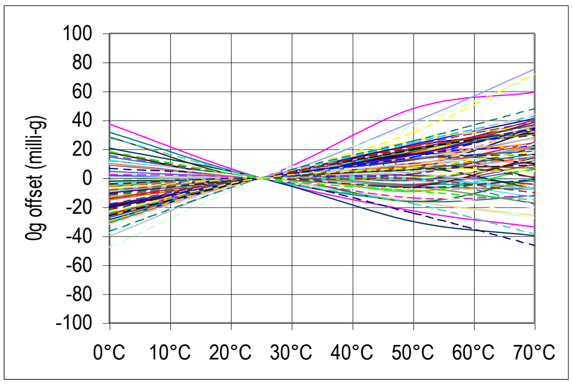
## TYPICAL CHARACTERISTICS OVER TEMPERATURE ( 0°C to 70°C, Vdd = 5V , unless specified)



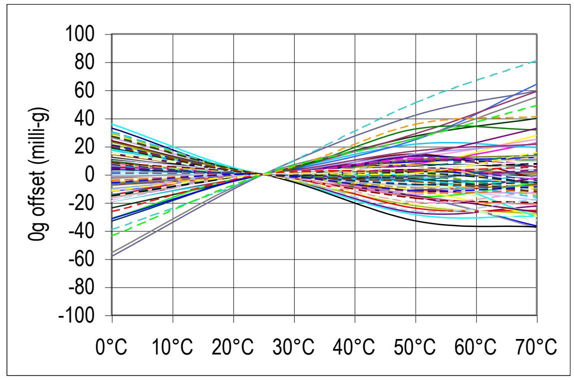

*Graph 9. Distribution of* AOUTX *0g offset over temperature*



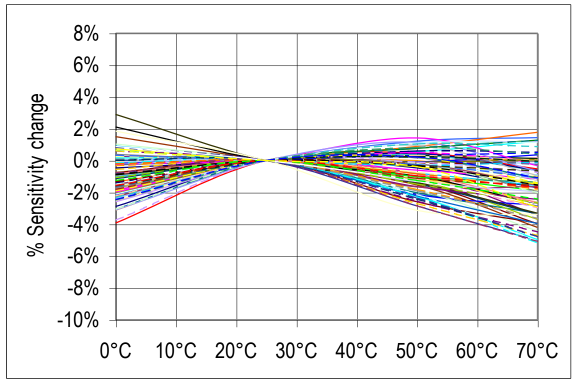

*Graph 10. Distribution of* AOUTY *0g offset over temperature*



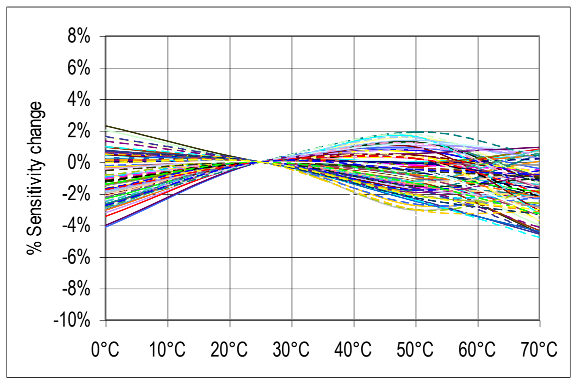

*Graph 11. Examples of* AOUTX *0g offset vs. temperature*




*Graph 12. Examples of* AOUTY *0g offset vs. temperature*




*Graph 13. Examples of* AOUTX *Sensitivity change over temperature*




*Graph 14. Examples of* AOUTY *Sensitivity change over temperature*

## MXA2500G/M 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. 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.

**$A_{OUTX}$** – 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. 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 on this feature.

**$A_{OUTY}$** – 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. 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 on this feature.

**$T_{OUT}$** – 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.

**$V_{ref}$** – This pin is the output of a reference voltage. It is set at 2.50V typical and has 100µA of drive capability.

## POWER SUPPLY NOISE REJECTION

Two capacitors and a resistor are recommended for best rejection of power supply noise (reference Figure 5 below). The capacitors should be located as close as possible to the device supply pins ($V_{DA}$, $V_{DD}$). The capacitor lead length should be as short as possible, and surface mount capacitors are preferred. For typical applications, capacitors C1 and C2 can be ceramic 0.1 µF, and the resistor R can be 10 Ω.

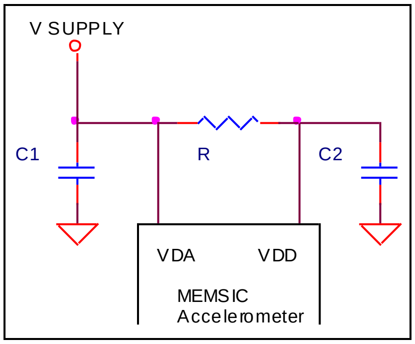


*Figure 5: Power Supply Noise Rejection*

## 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 plane should be similar to the MEMSIC device’s footprint and be 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.

## LCC-8 PACKAGE DRAWING

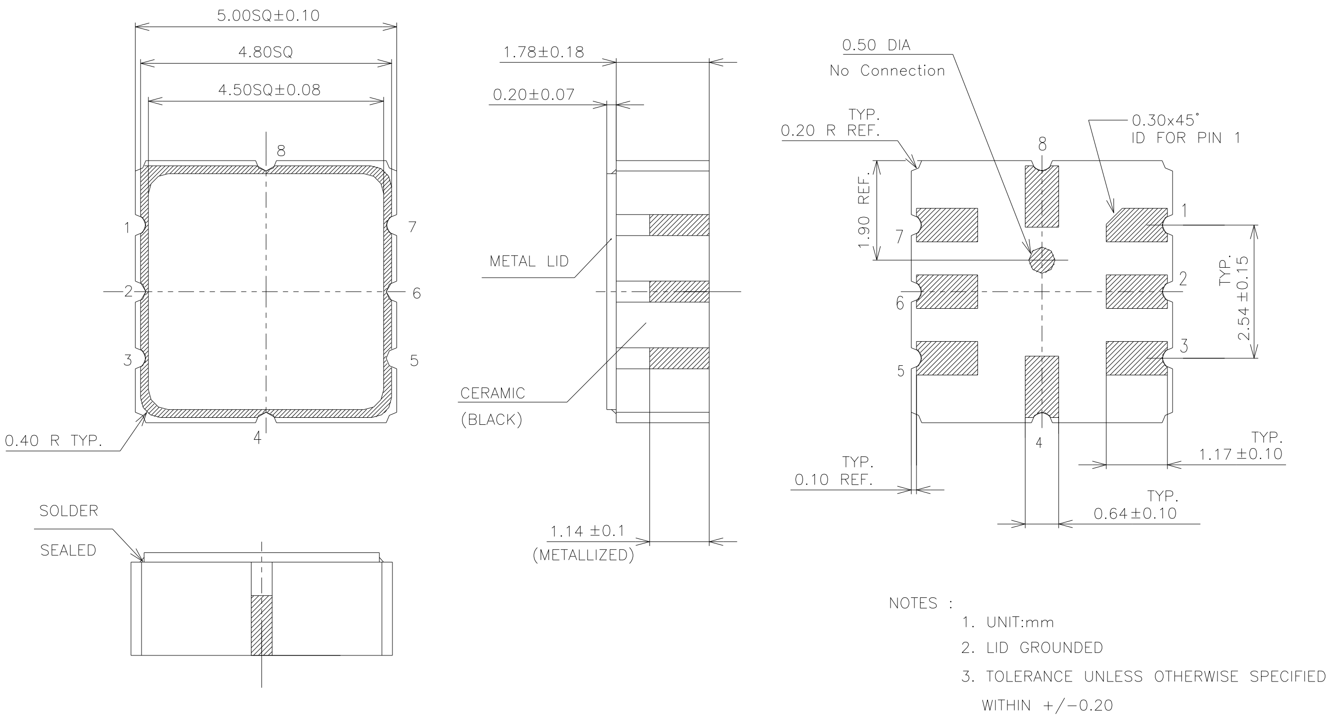



*Fig 6: Hermetically Sealed Package Outline*