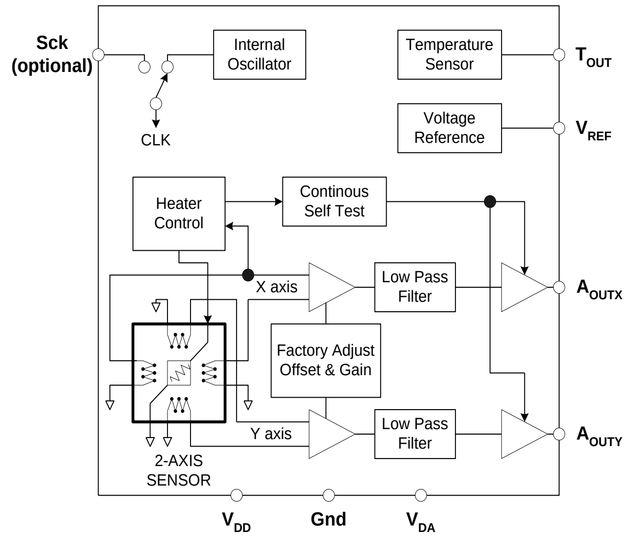
Ultra Low Noise, Offset Drift ±1 *g* Dual Axis Accelerometer with Analog Outputs

MXA2500E

FEATURES
Better than 1 mg resolution
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
3V to 5.25V single supply continuous operation
Small (5mm x 5mm x 2mm) surface mount package
Continuous self test
Custom programmable specifications
Independent axis programmability (special order)

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



MXA2500E FUNCTIONAL BLOCK DIAGRAM

GENERAL DESCRIPTION

The MXA2500E is an ultra low noise and 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 MXA2500E measures acceleration with a full-scale range of ±1 *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 MXA2500E 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 rates and lower loss due to handling during assembly.

The MXA2500E 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 MXA2500E is available in a LCC surface mount package (5 mm x 5 mm x 2 mm). It is hermetically sealed and is operational over a -40°C to +105°C temperature range. It also contains an on-chip temperature sensor and a bandgap voltage reference.

©MEMSIC, Inc.
One Technology Drive Suite 325, Andover MA01810, USA
Tel: +1 978 738 0900 Fax: +1 978 738 0196
www.memsic.com

MXA2500E SPECIFICATIONS (Measurements @ 25°C, Acceleration = 0 *g* unless otherwise noted; V_{DD}, V_{DA} = 5.0V unless otherwise specified)

		MXA2500E			
Parameter	**Conditions**	**Min**	**Typ**	**Max**	**Units**
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		degree
Transverse Sensitivity[3]			±2.0		%
SENSITIVITY	Each Axis				
Sensitivity, Analog Outputs at pins A_{OUTX} and A_{OUTY}[6]		475	500	525	mV/*g*
Change over Temperature (uncompensated)[4]	Δ from 25°C, at –40°C			+120	%
	Δ from 25°C, at +105°C	-55			%
Change over Temperature (compensated)[4]	Δ from 25°C, –40°C to +105°C		<3.0		%
ZERO *g* BIAS LEVEL	Each Axis				
0 *g* Offset[6]		-0.1	0.00	+0.1	*g*
0 *g* Voltage[6]		1.20	1.25	1.30	V
0 *g* Offset over Temperature	Δ from 25°C		±0.4		m*g*/°C
	Δ from 25°C, based on 500mV/*g*		±0.2		mV/°C
NOISE PERFORMANCE					
Noise Density, rms	Without frequency compensation		0.2	0.4	$mg/\sqrt{Hz}$
FREQUENCY RESPONSE					
3dB Bandwidth - uncompensated			17		Hz
3dB Bandwidth - compensated[5]			>160		Hz
TEMPERATURE OUTPUT					
T_{out} Voltage		1.15	1.25	1.35	V
Sensitivity		4.6	5.0	5.4	mV/°C
VOLTAGE REFERENCE OUTPUT					
V_{Ref} output	@3V-5.25V supply	2.4	2.5	2.65	V
Change over Temperature			0.1		mV/°C
Current Drive Capability	Source			100	µA
SELF TEST					
Continuous Voltage at A_{OUTX}, A_{OUTY} under Failure	@5.0V Supply, output rails to supply voltage		5.0		V
Continuous Voltage at A_{OUTX}, A_{OUTY} under Failure	@3.0V Supply, output rails to supply voltage		3.0		V
A_{OUTX} and A_{OUTY} OUTPUTS					
Normal Output Range	@5.0V Supply	0.1		4.9	V
	@3.0V Supply	0.1		2.9	V
Current	Source or sink, @ 3.0V-5.25V supply			100	µA
Turn-On Time[7]	@5.0V Supply		160		mS
	@3.0V Supply		300		mS
POWER SUPPLY					
Operating Voltage Range		3.0		5.25	V
Supply Current	@ 5.0V	2.7	3.3	4.1	mA
Supply Current[6]	@ 3.0V	3.2	4.0	4.8	mA
TEMPERATURE RANGE					
Operating Range		-40		+105	°C

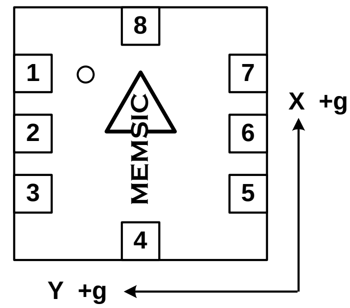
NOTES

[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] Transverse sensitivity is the algebraic sum of the alignment and the inherent sensitivity errors.
[4] The sensitivity change over temperature for thermal accelerometers is based on variations in heat transfer that are governed by the laws of physics and it is highly consistent from device to device. Please refer to the section in this data sheet titled "Compensation for the Change of Sensitivity over Temperature" for more information.
[5] External circuitry is required to extend the 3dB bandwidth.
[6] 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.
[7] Output settled to within ±17mg.

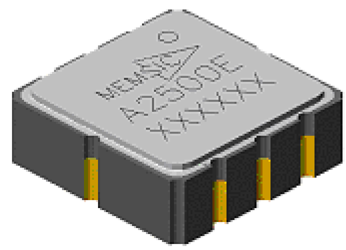
ABSOLUTE MAXIMUM RATINGS*

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.



Top View



Package Characteristics

Package	**θ_{JA}**	**θ_{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

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).

Ordering Guide

Model	**Package Style**
MXA2500EL	LCC8 RoHS compliant
MXA2500EF	LCC8, Pb-free RoHS compliant

*LCC parts are shipped in tape and reel packaging.

Caution

ESD (electrostatic discharge) sensitive device.

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.

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 volts 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. After correlating the voltage at TOUT to 25°C ambient, the change in this voltage due to changes in the ambient temperature can be used to compensate for the change over temperature of the accelerometer offset and sensitivity. Please refer to the section on Compensation for the Change in Sensitivity Over Temperature for more information.

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.

COMPENSATION FOR THE CHANGE IN SENSITIVITY OVER TEMPERATURE

All thermal accelerometers display the same sensitivity change with temperature. The sensitivity change depends on variations in heat transfer that are governed by the laws of physics. Manufacturing variations do not influence the sensitivity change, so there are no unit-to-unit differences in sensitivity change. The sensitivity change is governed by the following equation (and shown in Figure 1 in °C):

$$S_i \times T_i^{2.90} = S_f \times T_f^{2.90}$$

where S_i is the sensitivity at any initial temperature T_i, and S_f is the sensitivity at any other final temperature T_f with the temperature values in °K.

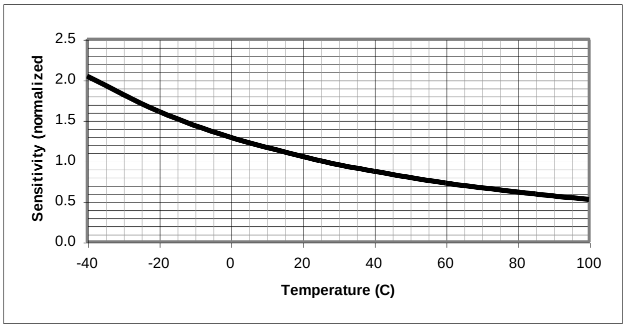


Figure 1: Thermal Accelerometer Sensitivity

In gaming applications where the game or controller is typically used in a constant temperature environment, sensitivity might not need to be compensated in hardware or software. Any compensation for this effect could be done instinctively by the game player.

For applications where sensitivity changes of a few percent are acceptable, the above equation can be approximated with a linear function. Using a linear approximation, an external circuit that provides a gain adjustment of –0.9%/°C would keep the sensitivity within 10% of its room temperature value over a 0°C to +50°C range.

TEMPERATURE OUTPUT NOISE REDUCTION

It is recommended that a simple RC low pass filter is used when measuring the temperature output. Temperature output is typically a very slow changing signal, so a very low frequency filter eliminates erroneous readings that may result from the presence of higher frequency noise. A simple filter is shown in Figure 8.

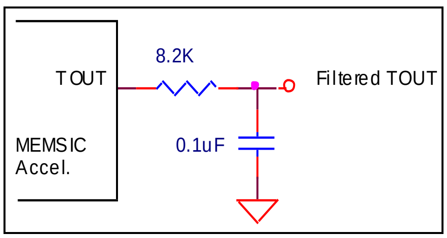


Figure 8: Temperature Output Noise Reduction

POWER SUPPLY NOISE REJECTION

Two capacitors and a resistor are recommended for best rejection of power supply noise (reference Figure 9 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.

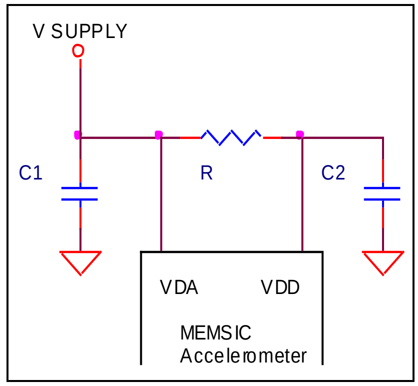


Figure 9: Power Supply Noise Rejection

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 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.

PACKAGE DRAWING

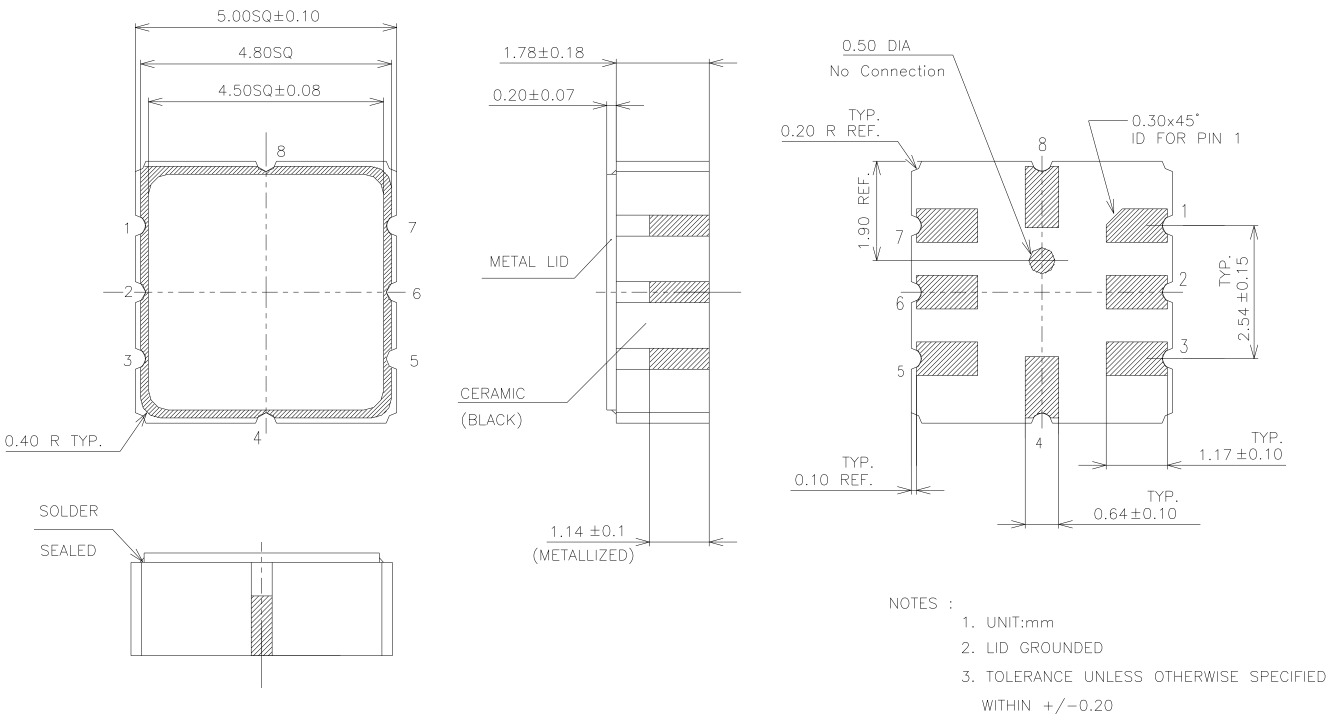


Fig 10: Hermetically Sealed Package Outline