Low Cost, Low Noise ±10 *g* Dual Axis Accelerometer with Ratiometric Analog Outputs

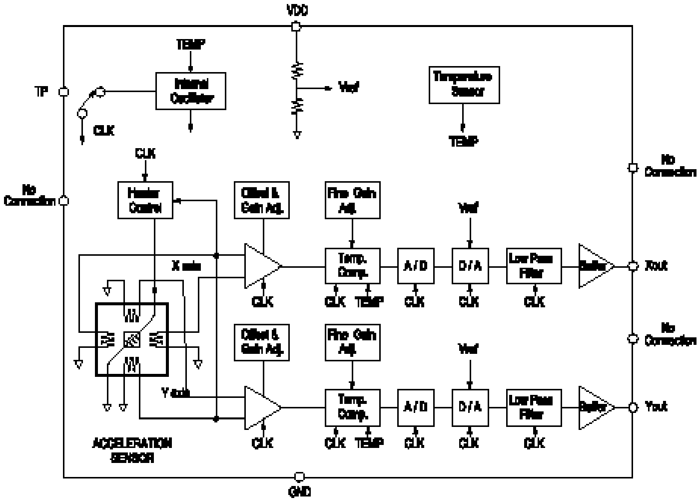
MXR7210GL/ML

FEATURES

Low cost
Resolution better than 1milli-*g* at 1Hz
Dual axis accelerometer fabricated on a monolithic CMOS IC
On chip mixed signal processing
No moving parts; No loose particle issues
>50,000 *g* shock survival rating
5mm X 5mm X 2mm LCC package
2.7V to 5.25V single supply continuous operation
Compensated for Sensitivity over temperature
Ultra low initial Zero-g Offset
No adjustment needed outside

APPLICATIONS

Computer Peripherals
Information Appliances
Alarms and Motion Detectors
Disk Drives
Vehicle Security



MXR7210GL/ML FUNCTIONAL BLOCK DIAGRAM

GENERAL DESCRIPTION

The MXR7210GL/ML is a low cost, dual axis accelerometer fabricated on a standard, submicron CMOS process. It is a complete sensing system with on-chip mixed signal processing. The MXR7210GL/ML measures acceleration with a full-scale range of ±10 *g* and a sensitivity of 100mV/g @5V. It can measure both dynamic acceleration (e.g. vibration) and static acceleration (e.g. gravity). The MXR7210GL/ML 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 greater than 50,000 *g*, leading to significantly lower failure rate and lower loss due to handling during assembly and at customer field application.

The MXR7210GL/ML provides two ratiometric analog outputs that are proportional to 50% of the supply at zero g acceleration.

The typical noise floor is 0.4 m*g*/$\sqrt{Hz}$ allowing signals below 1milli-*g* to be resolved at 1 Hz bandwidth. The MXR7210GL/ML is packaged in a hermetically sealed LCC surface mount package (5 mm x 5 mm x 2 mm height) and is operational over a 0°C to 70°C(GL) or a -40°C to +85°C(ML) temperature range.

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MXR7210GL/ML SPECIFICATIONS (Measurements @ 25°C, Acceleration = 0 *g* unless otherwise noted; V_{DD} = 5.0V unless otherwise specified)

		MXR7210GL			**MXR7210ML**			
Parameter	**Conditions**	**Min**	**Typ.**	**Max**	**Min.**	**Typ.**	**Max.**	**Units**
SENSOR INPUT	Each Axis							
Measurement Range[1]		±10.0			±10.0			*g*
Nonlinearity	Best fit straight line		0.5			0.5		% of FS
Alignment Error[2]			±1.0			±1.0		degrees
Alignment Error	X Sensor to Y Sensor		0.01			0.01		degrees
Cross Axis Sensitivity[3]			±0.5			±0.5		%
SENSITIVITY	Each Axis							
Sensitivity Xout, Yout	V_{DD}=5.0V	90	100	110	90	100	110	mV/g
Sensitivity Xout, Yout	V_{DD}=3.0V	54	60	66	54	60	66	mV/g
Sensitivity Change over Temperature[4]	Delta from 25°C			10			15	%
ZERO *g* BIAS LEVEL	Each Axis							
0 *g* Voltage Xout, Yout	V_{DD}=5.0V	2.47	2.50	2.53	2.47	2.50	2.53	V
0 *g* Voltage Xout, Yout	V_{DD}=5.0V	-0.3	0.00	0.3	-0.3	0.00	0.3	g
0 *g* Voltage Xout, Yout	V_{DD}=3.0V	1.46	1.50	1.54	1.46	1.50	1.54	V
0 *g* Voltage Xout, Yout	V_{DD}=3.0V	-0.4	0.00	0.4	-0.4	0.00	0.4	g
0 *g* Offset vs. Temperature[4]	Delta from 25°C		1.5			1.5		mg/°C
NOISE PERFORMANCE								
Noise Density, rms	@25°C		0.4	1.0		0.4	1.0	$mg/\sqrt{Hz}$
FREQUENCY RESPONSE								
3dB Bandwidth			19			19		Hz
POWER SUPPLY								
Operating Voltage Range		2.7		5.25	2.7		5.25	V
Quiescent Supply Current	@5.0V		3.9	4.7		3.9	4.7	mA
Quiescent Supply Current	@3.0V		4.0	4.9		4.0	4.9	mA
AoutX and AoutY OUTPUTS								
Output High Voltage	@5.0V Supply	Vs-0.4			Vs-0.4			V
Output Low Voltage				0.4			0.4	V
Current	Source or sink			250			250	uA
Turn-On Time	@3.0V-5.0VSupply Level (0g), @5.0V Supply		100			100		mS
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] Cross axis sensitivity is the algebraic sum of the alignment and the inherent sensitivity errors.

[4] Defined as the output change from ambient to maximum temperature or ambient to minimum temperature.

ABSOLUTE MAXIMUM RATINGS*

Supply Voltage (V_{DD}) ………………...-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.

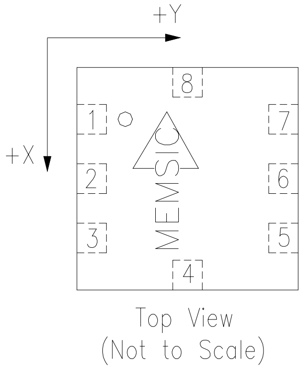
Pin Description: LCC-8 Package

Pin	Name	Description
1	NC	Do Not Connect
2	TP	Connect to ground
3	COM	Common
4	NC	Do Not Connect
5	NC	Do Not Connect
6	Yout	Y Channel Output
7	Xout	X Channel Output
8	V_{DD}	2.7V to 5.25V

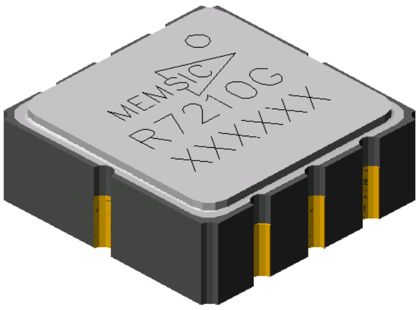
Ordering Guide

Model	Package Style	Temperature Range	Device Weight
MXR7210GL	LCC - 8	0 to 70°C	<1.0 gram
MXR7210ML	LCC - 8	-40 to +85°C	<1.0 gram

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 stationary element, or '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.

MXR7210GL/ML PIN DESCRIPTIONS

V_{DD} – This is the supply input for the circuits and the sensor heater in the accelerometer. The DC voltage should be between 2.7 and 5.25 volts. Refer to the section on PCB layout and fabrication suggestions for guidance on external parts and connections recommended.

COM– This is the ground pin for the accelerometer.

TP– This pin should be connected to ground.

Xout – 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 >250µA 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.

Yout – 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 >250µA 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.

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 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).

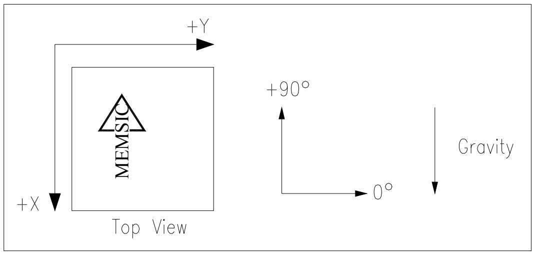


Figure 2: Accelerometer Position Relative to Gravity

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

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:

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

The peak-to-peak noise is approximately equal to 6.6 times the rms value (for an average uncertainty of 0.1%).

USING THE MXR7210GL/ML WITH OPERATING VOLTAGES OTHER THAN 5V

The MXR7210GL/ML is tested and specified at V_{DD}=5V; however, it can be powered with V_{DD} as low as 2.7V or as high as 5.25V. Some performance parameters will change as the supply voltage is varied. The MXR7210GL/ML output sensitivity will be linearly proportional to supply voltage. At 3V the output sensitivity is 3.0/5.0* 100mV/g =60mV/g. The zero g bias output is also ratiometric, so the zero g is normally equal to $V_{DD}/2$ at all supply voltages.

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 Figure 3. The advantage of ac coupling is that zero *g* offset variations from part to part and zero *g* offset change over temperature can be eliminated. Figure 3 is a HFP (high pass filter) with a –3dB breakpoint given by the equation: $f = {}^{1}\!/_{2\pi RC}$. In many applications it may be desirable to have the HFP –3dB point at a very low frequency in order to detect very low frequency accelerations. Sometimes the implementation of this HFP may result in unreasonably large capacitors, and the designer may turn to digital implementations of HFPs where very low frequency –3dB breakpoints can be achieved.

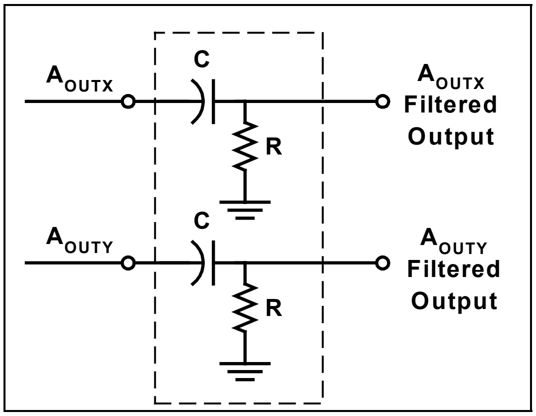


Figure 3: High Pass Filter

Low Pass Filter: An external low pass filter would be 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**.** The low pass filter shown in Figure 4 has a –3dB breakpoint given by the equation: $f = {}^{1}\!/_{2\pi RC}$. For the 200 Hz ratiometric output device filter, C=0.1µF and R=8kΩ, ±5%, 1/8W.

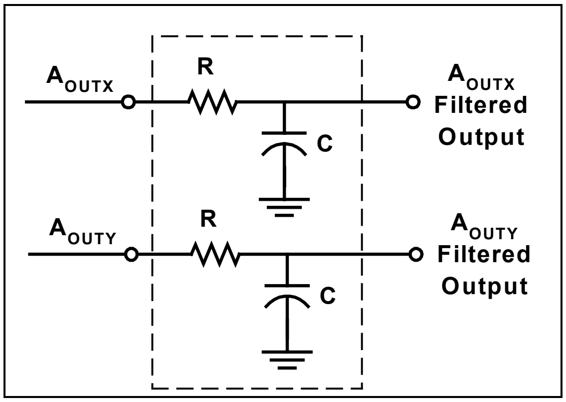


Figure 4: Low Pass Filter

POWER SUPPLY NOISE REJECTION

One capacitor is recommended for best rejection of power supply noise (reference Figure 5 below). The capacitor should be located as close as possible to the device supply pin (V_{DD}). The capacitor lead length should be as short as possible, and surface mount capacitor is preferred. For typical applications, the capacitor can be ceramic 0.1 µF.

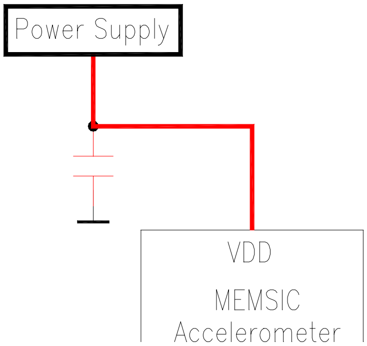


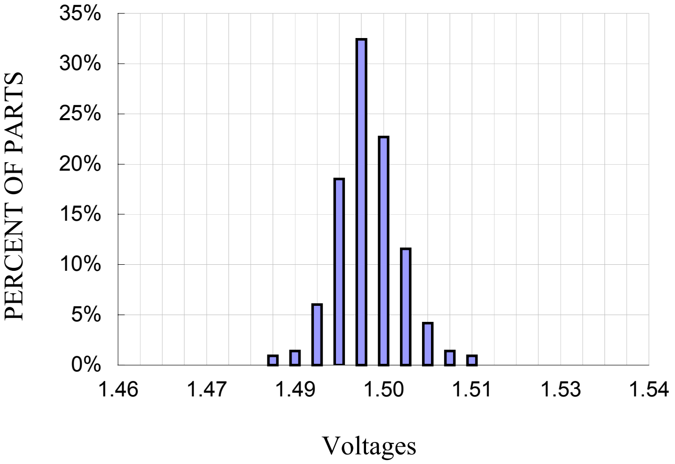
Figure 5: Power Supply Noise Rejection

PCB LAYOUT AND FABRICATION SUGGESTIONS

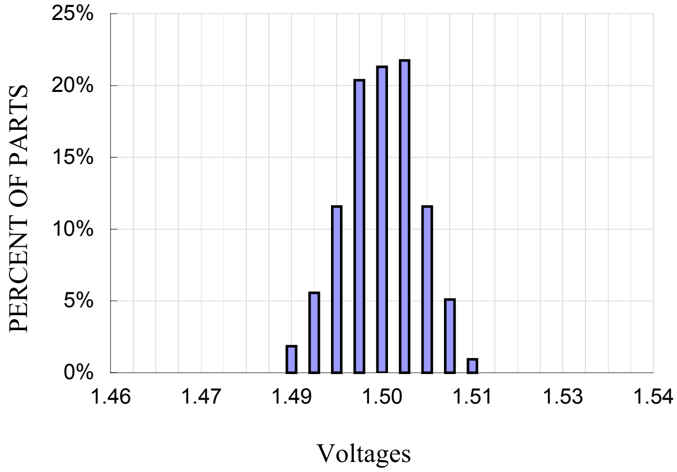
1. Liberal use of ceramic bypass capacitors is recommended.
2. Robust low inductance ground wiring should be used.
3. Care should be taken to ensure there is "thermal symmetry" on the PCB immediately surrounding the MEMSIC device and that there is no significant heat source nearby.
4. A metal ground 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.
5. Vias can be added symmetrically around the ground plane. Vias increase thermal isolation of the device from the rest of the PCB.

MXR7210GL/ML TYPICAL PERFORMANCE CHARACTERISTICS (@ 25°C, unless otherwise specified)

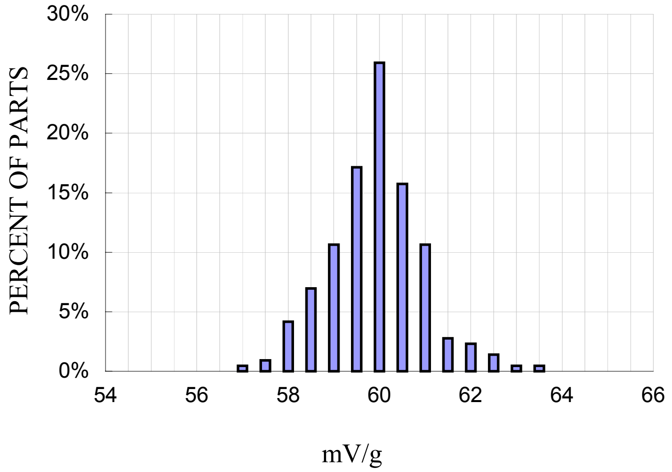
V_{DD}=3V



X-axis Zero g Bias Distribution at Xout, V_{DD}=3V

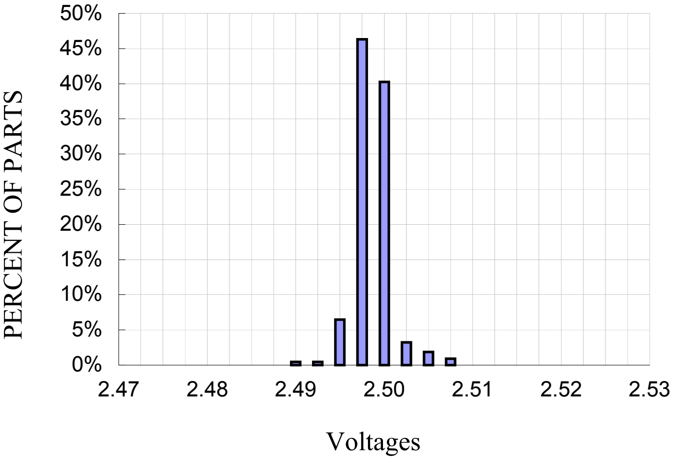


Y-axis Zero g Bias Distribution at Yout, V_{DD}=3V

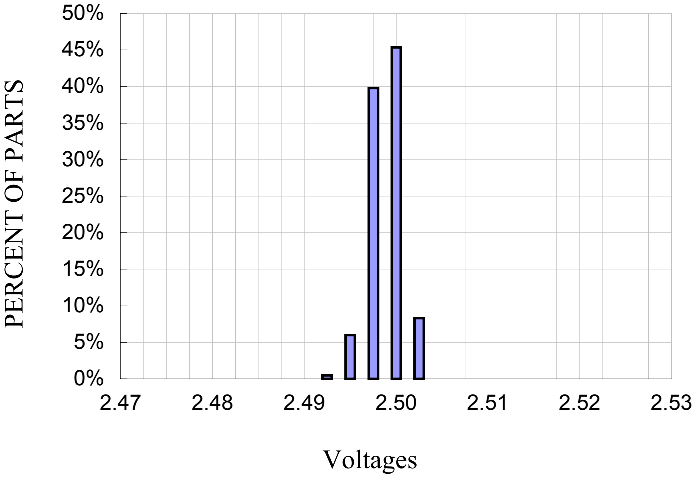


X-axis Sensitivity Distribution at Xout, V_{DD}=3V

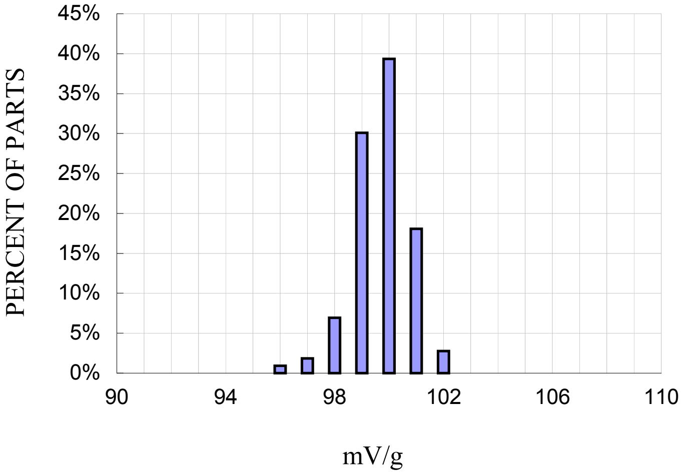
V_{DD}=5V



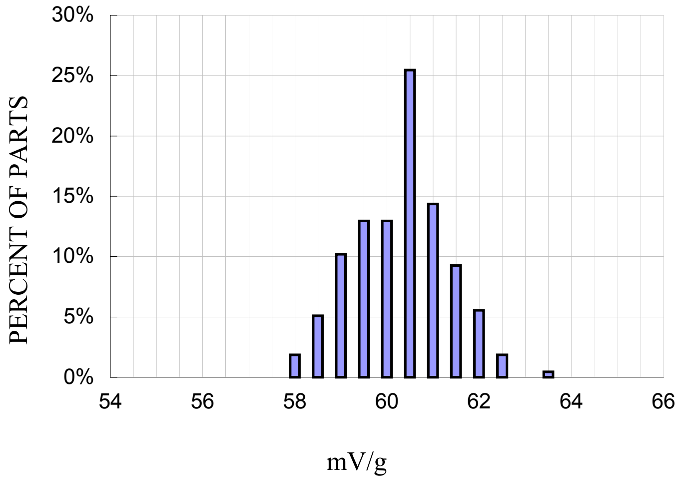
X-axis Zero g Bias Distribution at Xout, V_{DD}=5V



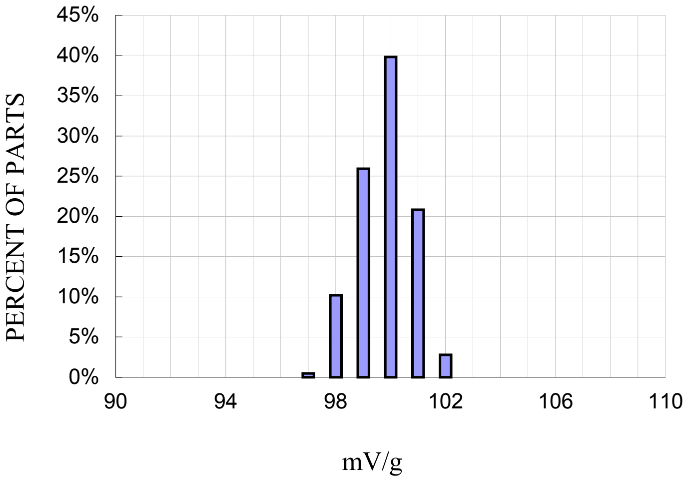
Y-axis Zero g Bias Distribution at Yout, V_{DD}=5V



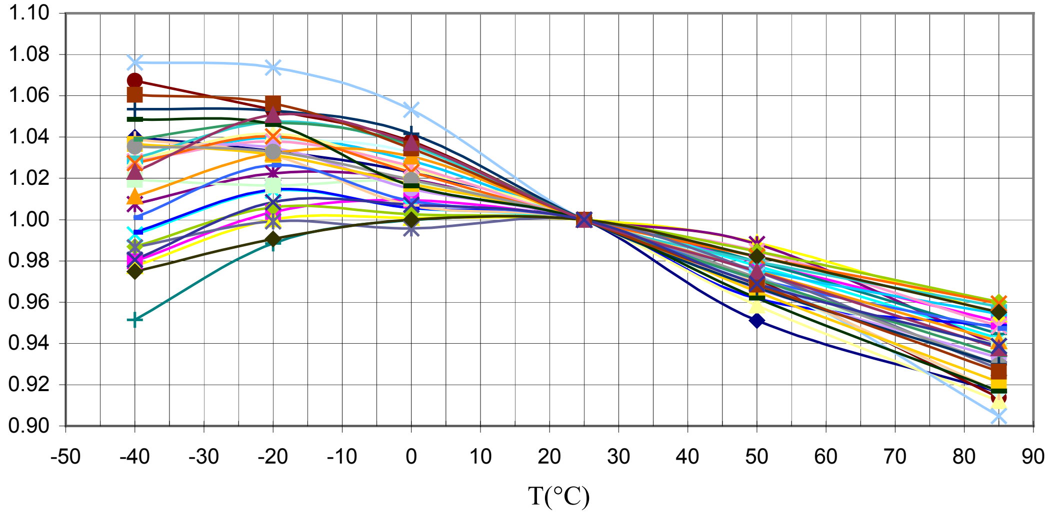
X-axis Sensitivity Distribution at Xout, V_{DD}=5V



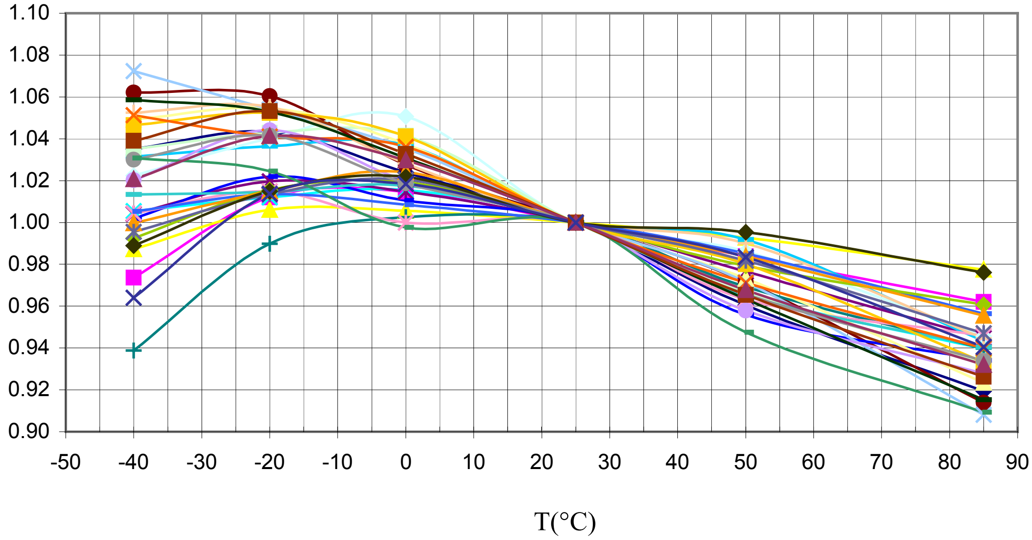
Y-axis Sensitivity Distribution at Yout, V_{DD}=3V



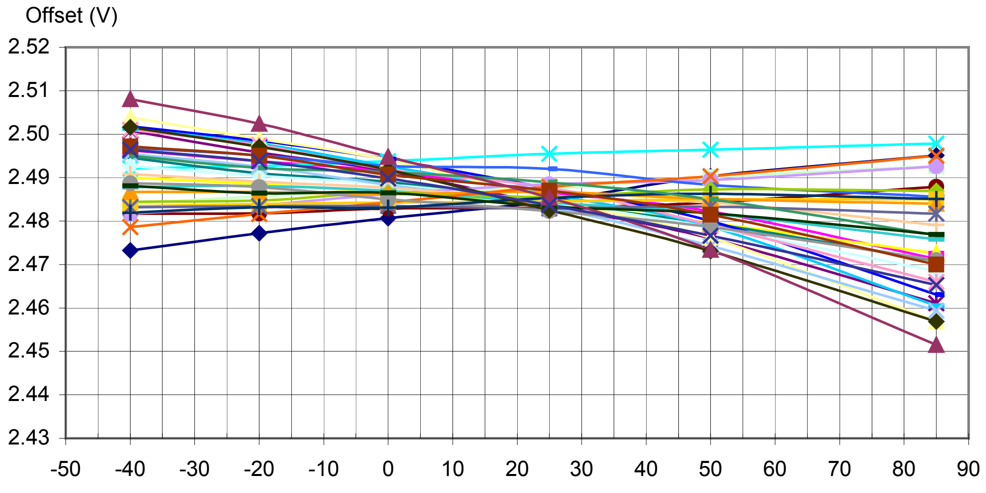
Y-axis Sensitivity Distribution at Yout, V_{DD}=5V



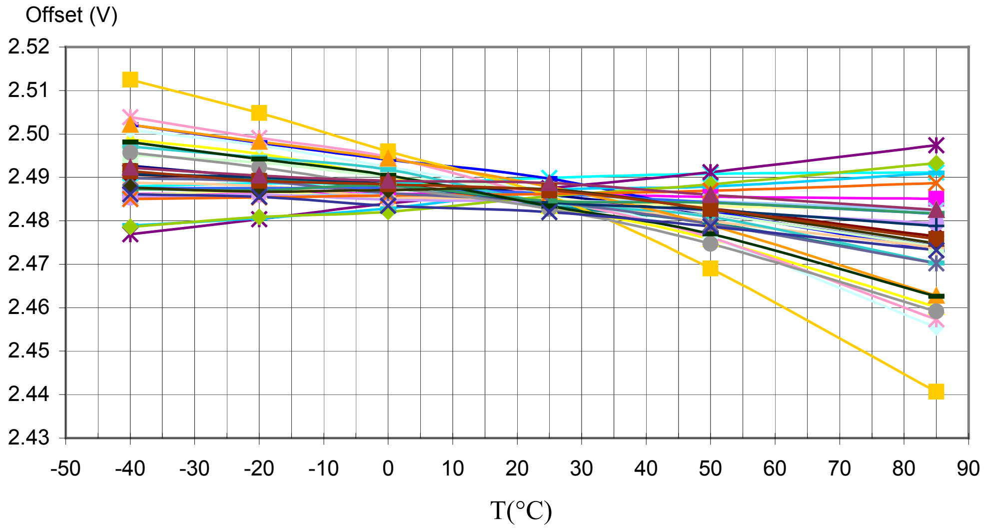
Normalized (with 25°C) X-axis Sensitivity vs. Temperature, V_{DD}=5V



Normalized (with 25°C) Y-axis Sensitivity vs. Temperature, V_{DD}=5V

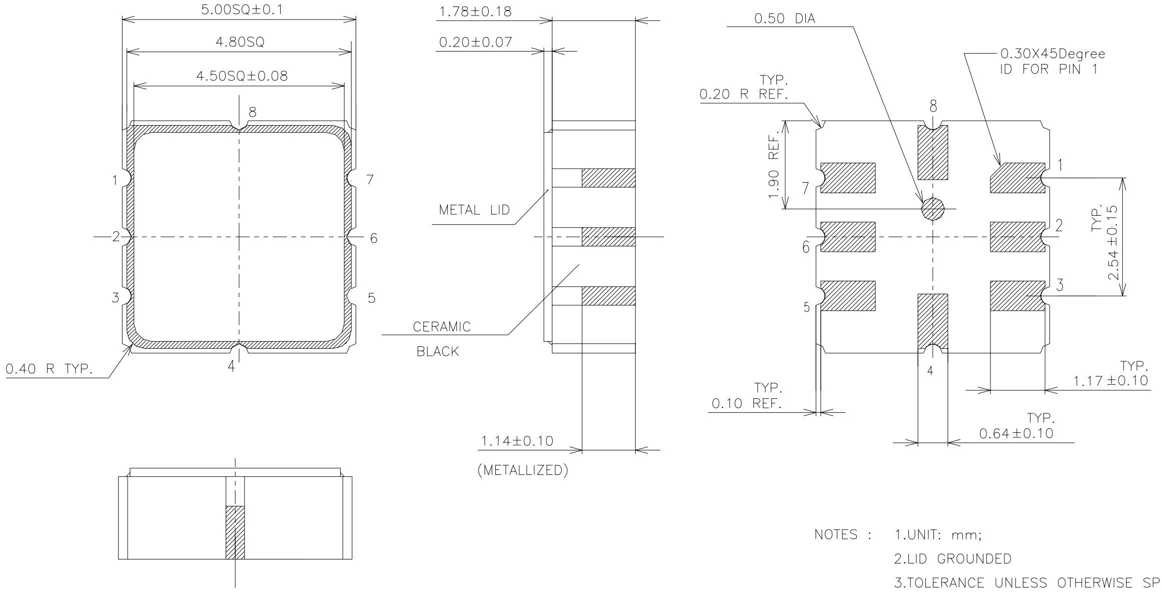


X-axis Zero g Offset vs. Temperature, V_{DD}=5V



Y-axis Zero g Offset vs. Temperature, V_{DD}=5V

LCC-8 PACKAGE DRAWING



NOTES : 1.UNIT: mm;
2.LID GROUNDED
3.TOLERANCE UNLESS OTHERWISE SPECIFIED:
WITHIN +/−0.20

Fig 6: Hermetically Sealed Package Outline