Low Cost ±7 g Dual-Axis Accelerometer with Ratiometric Outputs

MXR7150V

FEATURES

Dual axis accelerometer fabricated on a single CMOS IC
Monolithic design with mixed mode signal processing

On-chip sensitivity compensation for temperature variations
On Demand Self Test

± 7g dynamic range, 150mV/g sensitivity
Independent axis programmability (special order)
Resolution better than 2mg

Zero-g Output Temperature drift, better than ± 2.0 mg/C

31 Hz bandwidth
>50,000 g shock survival rating
2.70V to 5.50V single supply operation
Small surface mount package, 5mm x 5mm x 2mm

APPLICATION

Automotive – Roll over sensing systems

GENERAL DESCRIPTION

The MXR7150V is a low cost, dual axis accelerometer built on a standard, submicron CMOS process. It measures acceleration with a full-scale range of ±7g and a sensitivity of 150mV/g.

The MXR7150V provides a g-proportional ratiometric analog output above/below the zero-g point at 50% of the supply voltage.
(Ref. other MEMSIC data sheets for absolute analog or digital outputs).

The typical noise floor is $1.5mg/\sqrt{Hz}$, allowing signals below 2 milli-g to be resolved at 1Hz bandwidth. The 3dB roll-off of the device occurs at 31Hz.

The MXR7150V is available in a low profile LCC surface mount package (5mm x 5mm 2mm). It is hermetically sealed and operational over a -40°C to +85°C temperature range.

MEMSIC's accelerometer technology allows for designs from ±1 g to ±70 g with custom versions available above ±70 g. It can measure both dynamic acceleration (e.g., vibration) and static acceleration (e.g., gravity).
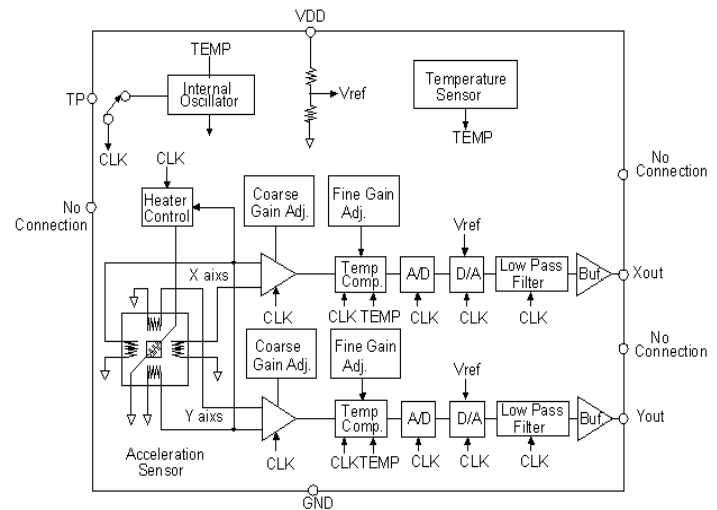
MXR7150V FUNCTIONAL BLOCK DIAGRAM

The design is based on heat convection and requires no solid proof mass. This eliminates stiction and particle problems associated with competitive devices and provide shock survival greater than 50,000 g, leading to significantly lower failure rates and lower loss due to handling during assembly and at customer field application. Due to the standard CMOS structure of the MXR7150V, additional circuitry can easily be incorporated into custom versions for high volume applications. Contact Memsic's local office for more information.

MXR7150V SPECIFICATIONS (Measurements @ 25°C, Acceleration = 0 g unless otherwise noted; V_{DD} = 5.0V unless otherwise specified)

Parameter	Conditions	MXR7150V			Units
		Min	Typ	Max	
SENSOR INPUT	Each Axis				
Measurement Range[1]		±7.0			g
No linearity	Best fit straight line		1.0	2.0	% of FS
Alignment Error[2]			±1.0		degrees
Transverse Sensitivity[3]			±2.0		%
SENSITIVITY	Each Axis				
Sensitivity, Analog Outputs at pins					
Xout and Yout[4]	@5.0V supply	140	150	160	mV/g
Change over Temperature	Δ from 25°C –40°C to +85°C			<8	%
ZERO g BIAS LEVEL	Each Axis				
0 g Offset		-0.53	0.00	+0.53	g
0 g Voltage		2.42	2.5	2.58	V
0 g Offset over Temperature	Δ from 25°C		±0.5	±2.0	mg/°C
	Δ from 25°C, based on 150mV/g		±0.075	±0.3	mV/°C
NOISE PERFORMANCE					
Noise Density, rms			1.50	2.2	mg/$\sqrt{Hz}$
FREQUENCY RESPONSE					
3dB Bandwidth			31		Hz
SELF TEST					
Delta Output changes at Xout, Yout	At 25°C, +85°C	- 165		- 625	mV
Delta Output changes at Xout, Yout	At -40°C	-165		-1000	mV
Self Test Pin Pull-Down Resistor (Internal)			50		Kohms
Xout and Yout OUTPUTS					
Normal Output Range			VDD/2		V
(Guaranteed symmetric clipping)			±2.1		V
Current	Source or sink, @ 2.7V-5.0V supply		100		μA
Turn-On Time	@5.0V Supply		150		mS
	@2.7V Supply		250		mS
POWER SUPPLY					
Operating Voltage Range		2.70	5.0	5.5	V
Supply Current	@ 5.0V	3.4	4.2	4.9	mA
Supply Current[5]	@ 2.7V		4.8	5.6	mA
TEMPERATURE RANGE					
Operating Range		-40		+85	°C
PRESSURE RANGE					
Operating Range		40		300	KPa.

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 device operates over a 2.7V to 5.5V supply range. The output zero g reference voltage scales 50% of the supply voltage. Sensitivity has a linear scale over the supply range of 2.7 to 5.5 volts according to the ratio (Vdd/5.0 volts) x (150mV/g).
recommended to filter with a minimum of 200Hz low pass filter.

[5] Note that the accelerometer has a constant heater power control circuit thereby requiring higher supply current at lower operating voltage.

ABSOLUTE MAXIMUM RATINGS*

Supply Voltage (V_{DD}, V_{DA}) [1] ……………....-0.5 to +7.0V
Storage Temperature …………..…………-70°C to +150°C
Storage Pressure…………………………………1,378 kPa
Acceleration (any axis, Un-powered for 0.5 msec)..50,000 g
Acceleration (any axis, Powered for 0.5 msec)…… .2,000 g
Output Short Circuit Duration, any pin to common…….Indefinite

*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.

[1] Exposure for up to 60 minutes to absolute maximum ratings for supply voltages will not affect device reliability.

Package Characteristics

Package	θ_{JA}	θ_{JC}	Device Weight
LCC-8	110°C/W	22°C/W	< 1 gram

Ordering Guide

Model	Package Style
MXR7150VL	LCC-8 SMD, Seam Seal RoHS compliant
MXR7150VF	LCC-8 SMD, Solder Seal RoHS compliant

* Parts are shipped in tape and reel packaging.

Caution

ESD (electrostatic discharge) sensitive device.

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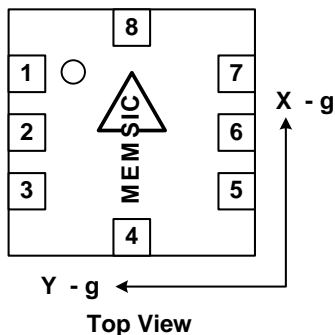
Note: The MEMSIC logo's arrow indicates the -X sensing direction of the device.
The +Y sensing direction is rotated 90° away from the +X direction.
Small circle indicates pin one(1).

Pin Description: LCC-8 Package

| Pin	Name	Description
1	ST$_{IN}$	Self -Test Input
2	CLK	To be grounded. (Optional Serial Clock Input)
3	COM	Ground
4	NC	No Connect
5	NC	No Connect
6	Y$_{OUT}$	Y-Channel Ratiometric Output
7	X$_{OUT}$	X-Channel Ratiometric Output
8	V_{DD}	Supply Voltage 2.7 to 5.5 V

ESD Compliance:

The MXR7150V sensor is in compliance with the following ESD standards:
Human Body and 2500V per AEC-Q100-002 Rev. F
Machine Model and 250V per AEC-Q100-003 Rev. F

Mounting Orientation:

The package orientation of the MXR7150V does not affect the performance of the sensor. The specifications as stated in page 2 remain the same.
Thus, if the sensor is installed with one of its axis of sensitivity in the vertical plane, it detects accelerations in the Z-axis.
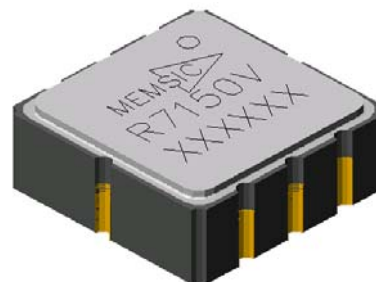
THEORY OF OPERATION

The MXR7150V is a complete dual-axis acceleration measurement system on a monolithic CMOS IC.
The MXR7150V is based on the laws of natural convection (thermal gradient). The 'proof mass' of MEMSIC's 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 MXR7150V, one to measure acceleration in the x-axis and one to measure acceleration in the Y-axis. For more details visit the MEMSIC website at www.memsic.com for a picture/graphic description of the free convection heat transfer principle.

PIN DESCRIPTIONS

V_{DD} – (pin 8). Supply voltage input for digital and analog circuits.
For proper operation V_{DD} must be between 2.70 and 5.50 volts. Refer to the section on PCB layout and fabrication suggestions for guidance on external parts and connections recommended.

X_{OUT} – (pin 7). X-axis acceleration signal output
It is capable of sinking or sourcing up to 100μA. 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 MXR7150V can be programmed for non-equal sensitivities on the x- and y-axes.
Contact Memsic's local office for additional information.

Y_{OUT} – (pin 6) Y-axis acceleration signal output.
It is capable of sinking or sourcing up to 100μA. 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 MXR7150V can be programmed for non-equal sensitivities on the X- and Y-axes.
Contact Memsic's local office for additional information.

NC – (pin 5, 4) No connect. These pins can be tied to common if the application does not allow pins to remain unconnected.

COM – (pin 3) This is the ground pin for the MXR7150V

CLK – (pin 2) This is an optional serial clock input. The standard product is delivered with an internal clock (800kHz. However, an external clock between 400kHz and 1.6MHz, can be used as an option, if the sensor is programmed from the factory to run in external clock mode. This pin is grounded internally with a 50Kohm resistor if an external clock is used it should be able to drive this load. But if external clock is not used, in order to minimize noise and ESD this pin should be grounded externally as well.

ST IN– (pin 1) Self –Test Input
This pin controls the self-test function of the sensor. Bringing STIN high will cause a negative deflection between 165 mV to 1000 mV to the AoutX AoutY from the 0g value.
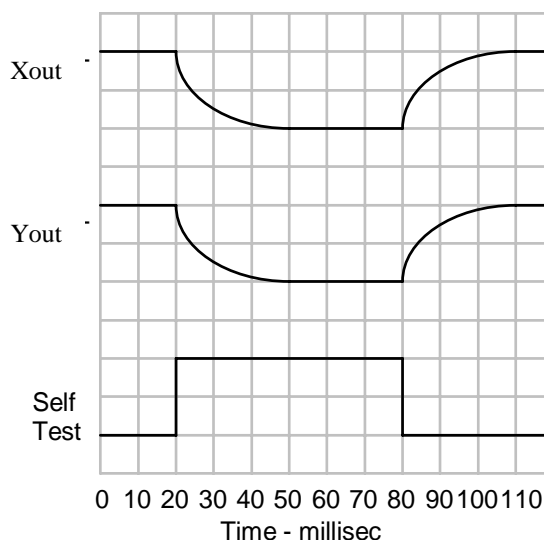
SELF-TEST DESCRIPTION
When Self-test is enabled the sensitivity compensation is turned off (disabled). With the sensitivity compensation disabled, the 1.0g offset voltages will double it's value as compared with the zero g condition. With an exponent of 2.9 in the equation, the sensitivity will be $(298K / 233K)^{2.9}$ = 2.04 times larger. The 1.0g signal will be 2.04 times larger than the 0g self test signal. Example: In the case for the device MXR7150V with a 150 mV/g sensitivity, the self-test signal will increase by 156mV. With all tolerances included, an extra 450mV will guarantee a save margin in the self-test limits. Therefore, in this case the increase in the self-test limit for 625mV to 1000mV at –40 °C will be the correct limit.

The gas law governs 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):

$$S_i \times T_i^{2.9} = S_f \times T_f^{2.9}$$

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.
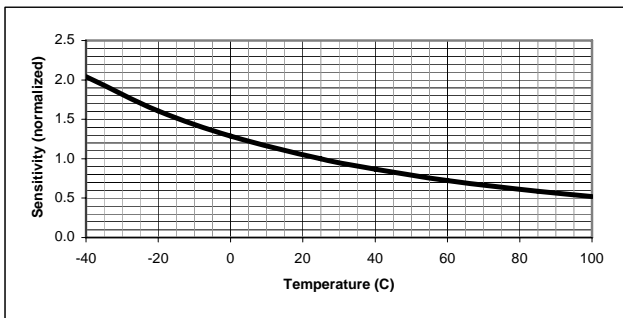

Figure 1: Thermal Accelerometer Sensitivity

Note1: The self test will be performed over specified temperatures and in the -1.0g orientation Ref fig 2. This will guarantee limits over complete temperature range.
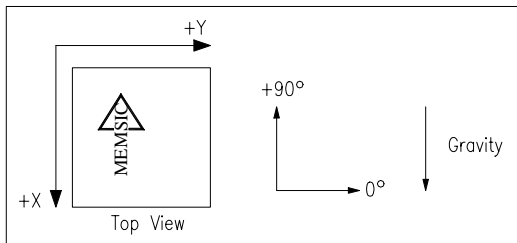

Figure 2: Accelerometer Position Relative to Gravity

Note2: When the temperature compensation is disabled and self-test is enabled. Self-test follows different gas law from sensitivity temperature dependence. It changes much smaller than sensitivity, this is why the temperature compensation is not done on self-test conditions.

Note3: Initial offset monitoring is a much better and reliable method to ensure sensor integrity ,since it is ultra sensitive to sensor structure defect and damage. As long as initial offset is within specification the sensor is functioning correctly.
The sensor structure for the Thermal technology is guaranteed to fall outside the specified initial zero g offset

parameters if the sensor is damaged or thermopile is failing . In most cases this will result in the output voltage hitting the rail at 5.0 volts.

PCB LAYOUT AND FABRICATION SUGGESTIONS

Reference Figure 3 and the notes below for recommendations on connecting a power source to the MEMSIC device and PCB fabrication.

Notes:
1. $C_1 = 0.2\mu F$
2. The capacitor should be located as close as possible to the device supply pin V_{DD}. Surface mount capacitors are preferred.
3. The CLK is grounded internally with a 50 kOhm resistor, however, in order to minimize noise and ESD this pin should be grounded externally as well.
4. Robust low inductance ground wiring should be used.
6. 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. This will minimize any errors in the measurement of acceleration.
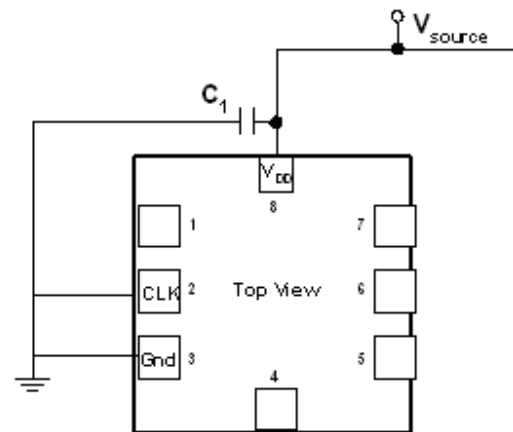

Figure 3: PCB Layout

MECHANICAL PACKAGE OUTLINE DIMENSIONS
Dimensions shown in mm.

LCC-8, Eight Pin, Hermetically Sealed, Surface Mount Package

Solder Seal

4.50SQ±0.08
5.00SQ±0.1
4.80SQ
0.40 R TYP.
1.78±0.18
0.20±0.07
METAL LID
CERAMIC (BLACK)
SOLDER SEALED
1.14 ±0.1 (METALLIZED)
MXR7150VF

0.50 DIA
0.30x45Degree ID FOR PIN 1
TYP. 0.20 R REF.
1.90 REF.
TYP. 2.54 ±0.15
TYP. 1.17 ±0.10
TYP. 0.10 REF.
TYP. 0.64 ±0.10

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

Seam Seal

4.40±0.10(S/R)
4.24±0.08
R0.30TYP
5.00SQ±0.1
4.80SQ
R0.40TYP
1.88±0.21
0.10±0.02
SEAL RING
METAL LID
CERAMIC (BLACK)
SEAM SEALED
1.26±0.13 (METALLIZED)
MXR7150VL

0.50 DIA
TYP. 0.20 R REF.
1.90 REF.
TYP. 2.54 ±0.15
TYP. 1.17 ±0.10
TYP. 0.10 REF.
TYP. 0.64 ±0.10

NOTES :
1. UNIT:mm
2. LID NOT GROUNDED
3. TOLERANCE UNLESS OTHERWISE SPECIFIED WITHIN +/−0.20