Low Cost Dual-Axis Accelerometer with Ratiometric Outputs

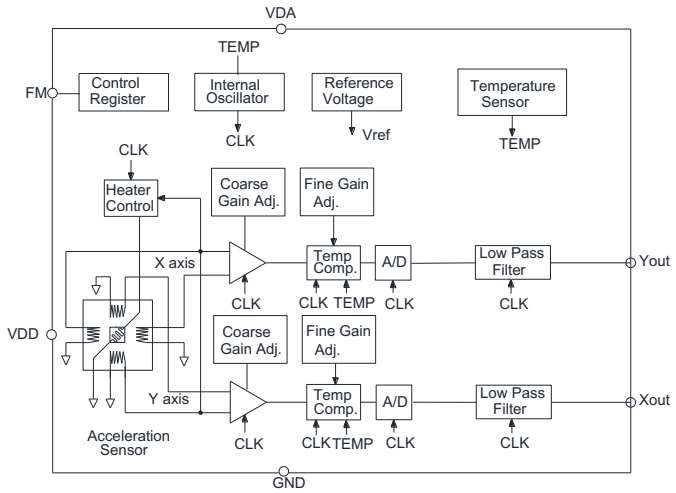
Automotive Grade MXR7999VW

FEATURES

Dual axis accelerometer fabricated on a single CMOS IC
Monolithic design with mixed mode signal processing
Zero-g temperature stability better than ±100mg from –40C to 125C
Sensitivity temperature compensation better that ±5% from -40C to 125C
+/- 2.0g dynamic range, 1000mV/g sensitivity
29Hz bandwidth
On Demand Self Test
>50,000 g shock survival rating
4.90V to 5.25V single supply operation
Small surface mount package, 5.5mm x 5.5mm x 2.7mm
XZ mounting

AUTOMOTIVE APPLICATIONS

- Suspention(low range G sensor)
- Roll Over Detection
- Electronic Parking Break – Hill Start Assist



MXR7999VW FUNCTIONAL BLOCK DIAGRAM

GENERAL DESCRIPTION

The MXR7999VW is a low cost, dual axis accelerometer built on a standard, submicron CMOS process. It measures acceleration with a full-scale range of ±2.0g and a sensitivity of 1000mV/g.

The MXR7999VW provides a g-proportional rationmetric analog output above/ below the zero-g point at 50% of the supply voltage.

The typical noise floor is 2 mg / $\sqrt{Hz}$, allowing signals below 1mg to be resolved at 1Hz bandwidth. The inherent 3dB roll off of the device is 27Hz providing immunity to and attenuation of higher frequency vibrations present in automotive applications.

The MXR7999VW is packaged in a hermetically sealed LCC surface mount package (5.5 mm x 5.5 mm x 2.7 mm height), and the package can be used for XZ sensing, its operation temperature is -40°C to +125°C.

It can measure both dynamic acceleration (e.g., vibration) and static acceleration (e.g., gravity).

The design is based on heat convection and requires no solid proof mass. This eliminates stiction, particle, and inherent resonant frequency problems associated with competitive devices and provides shock survivability to greater that 50,000g, 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 MXR7999VW, additional circuitry can easily be incorporated into custom versions for high volume applications. Contact MEMSIC's local office for more information.

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MXR7999VW SPECIFICATIONS (Measurements @ 25°C, Acceleration = 0 g unless otherwise noted; V_{DD} = V_{DA} =5.0V unless otherwise specified)

Parameter	Conditions	MXR7999VW Min	Typ	Max	Units
SENSOR INPUT	Each Axis				
Measurement Range		±2.0			g
Non linearity	Best fit straight line		0.5	1.0	% of FS
Alignment Error[2]			±0.5		degrees
Transverse Sensitivity[3]			±0.5		%
SENSITIVITY	Each Axis				
Sensitivity, Analog Outputs at pins Xout and Yout[4]	@5.0V supply	950	1000	1050	mV/g
Change over Temperature	Δ from 25°C, –40°C to +125°C	-5		+5	%
Offset BIAS LEVEL	Each Axis				
Offset		-150	0	+150	mg
Voltage		2.35	2.50	2.65	V
Offset over Temperature	Δ from 25°C, –40°C to +125°C based on 1000mV/g			±100	mg
NOISE PERFORMANCE					
Noise Density, rms			2		mg/ $\sqrt{Hz}$
FREQUENCY RESPONSE					
3dB Bandwidth		26	29	32	Hz
SELF TEST					
Delta Output changes at Xout, Yout			1		g
Self Test Pin Pull-Down Resistor (Internal)			50		Kohms
Xout and Yout OUTPUTS					
Normal Output Range (Guaranteed symmetric clipping)		0.3		4.7	V
Current	Source or sink, @ 4.5V-5.25V supply			100	µA
Turn-On Time[1]	@5.0V Supply		150		mS
POWER SUPPLY					
Operating Voltage Range		4.90	5.10	5.25	V
Supply Current	@ 5.0V		4.0	6.0	mA
TEMPERATURE RANGE					
Operating Range		-40		+125	°C
PRESSURE RANGE					
Operating Range		40		300	KPa.

Note: [1]: Output settled to within +/-17mg of the final value.

ABSOLUTE MAXIMUM RATINGS*

Supply Voltage (V_{DD}, V_{DA}) [1] ……...-0.5 to +7.0V
Storage Temperature …….……-55°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)… 10,000 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.

Ordering Guide

Model	Package Style
MXR7999VW	LCC-8 SMD*

* Parts are shipped in tape and reel packaging.

Pin Description: LCC Package

Pin	Name	Description
1	Xout	X-Channel Ratiometric Output
2	VDA	Analog Supply
3	VDD	Digital Supply, V_{DA} and V_{DD} must be the same voltage
4	FM	Ground. Connect to VSS
5/J	PD/SCK	Clock Input/PD
6/M	Zout	Z-Channel Ratiometric Output
7/L	VSS	Ground
8/K	ST	Self -Test Input

Caution

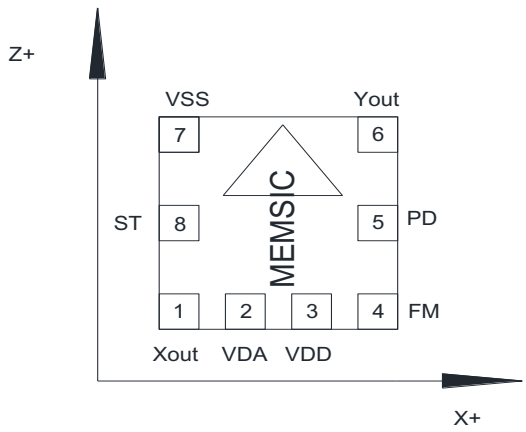
ESD (electrostatic discharge) sensitive device.

Note: The MEMSIC logo's arrow indicates the +Z sensing direction of the device.
Small circle indicates pin one (7).

ESD Compliance:

The MXR7999VW sensor is in compliance with the following ESD standards:
HBM class H2 per AEC-Q100-002 Rev. E
MM class M2 per AEC-Q100-003 Rev. E

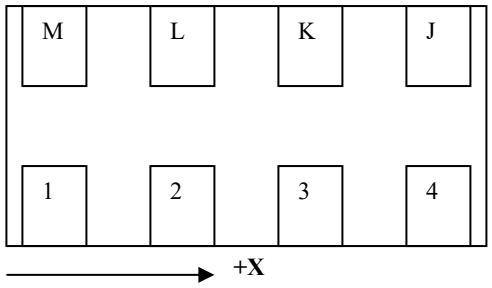
XZ Sensing:



(Top View, do not scale)

Note: Small circle indicates pin seven (7).

XZ Sensing:



(Bottom View, do not scale)

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 MXP7205VW, one to measure acceleration in the x-axis and one to measure acceleration in the y/z-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

XOUT – (pin 1) X-axis acceleration signal output.

VDA – (pin 2) This is the analog power supply. This pin supplies current to the analog circuitry. The DC voltage should be equal to the voltage supplied to the VDD pin.

VDD - (pin 3) This is the digital power supply for the MXR7999VW. This pin supplies current to the heater element and digital circuitry. The DC voltage should be between 4.5V and 5.25V.

FM – (pin 4) Ground. Connect to VSS.

PD/SCK – (pin 5) TBD.

ZOUT – (pin 6) Y-axis acceleration signal output.

VSS – (pin 7) This is the ground pin.

STIN–(pin 8)Self –Test Input

This pin controls the self-test function of the sensor. Bringing STIN high will cause a negative deflection to the Zout and Xout from initial value.

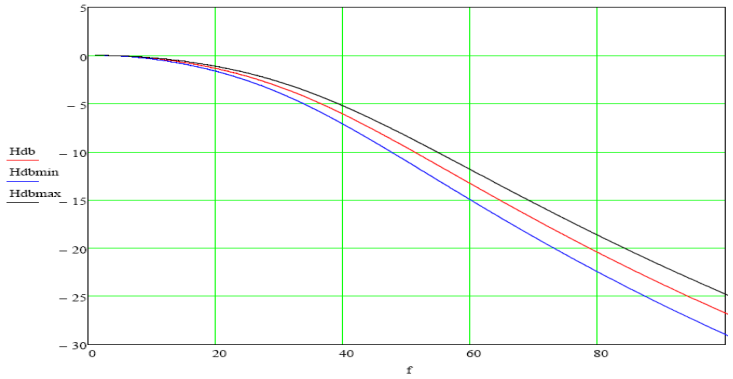
SIGNAL PATH FREQUENCY RESPONSE

The frequency response of the MXR7999VW is primarily determined by the thermal sensor characteristics and a digital lowpass filter included in the signal path to eliminate quantization noise and limit thermal noise bandwidth. The sensor is modelled as a two pole lowpass filter, with real poles located nominally at 40 Hz and 85 Hz. The lowpass filter is a second order Butterworth filter with a 3 dB cutoff frequency of nominally 44 Hz. Sensor poles have a tolerance of approximately ±10%, and the Butterworth filter cutoff frequency has a tolerance of approximately ±5%.

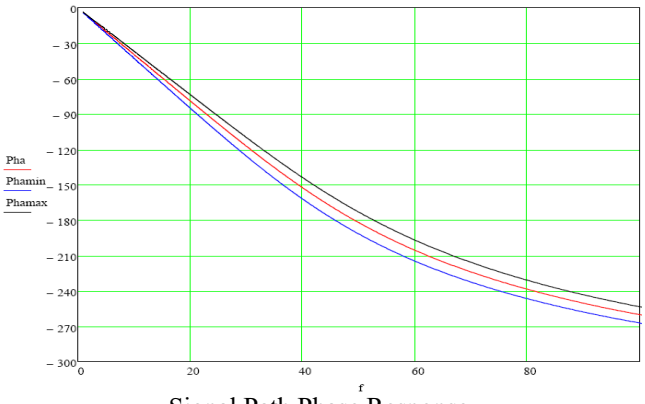
The nominal complex transfer function of the signal path is given by:

$$H(f) = \frac{1}{1+j\left(\frac{f}{40}\right)} \bullet \frac{1}{1+j\left(\frac{f}{85}\right)} \bullet \frac{1}{1-\left(\frac{f}{44}\right)^2 + j\sqrt{2}\left(\frac{f}{44}\right)}$$

Plots of the amplitude (in dB, relative to DC sensitivity) and phase response (in degrees) of the signal path for typical, minimum, and maximum sensor and filter pole frequencies are shown below.



Signal Path Amplitude Response



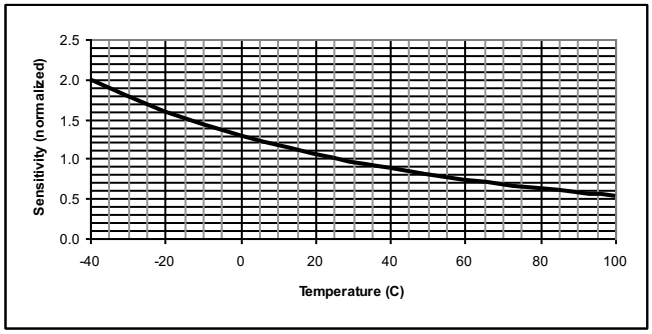
Signal Path Phase Response

SELF-TEST DESCRIPTION

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):

$$S_i \times T_i^{2.8} = k \times S_f \times T_f^{2.8}$$

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 °C, k is the ratio between uncompensated sensitivity and compensated sensitivity at 25°C.



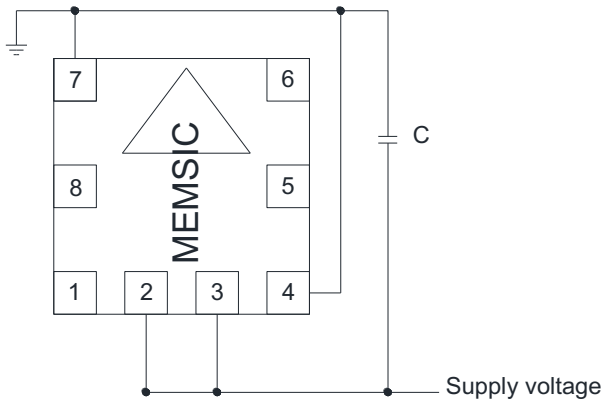
Thermal Accelerometer Sensitivity

Note1: 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.

Note2: 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 either signal path saturation or in the Hardware Error (HE) status bit being set.

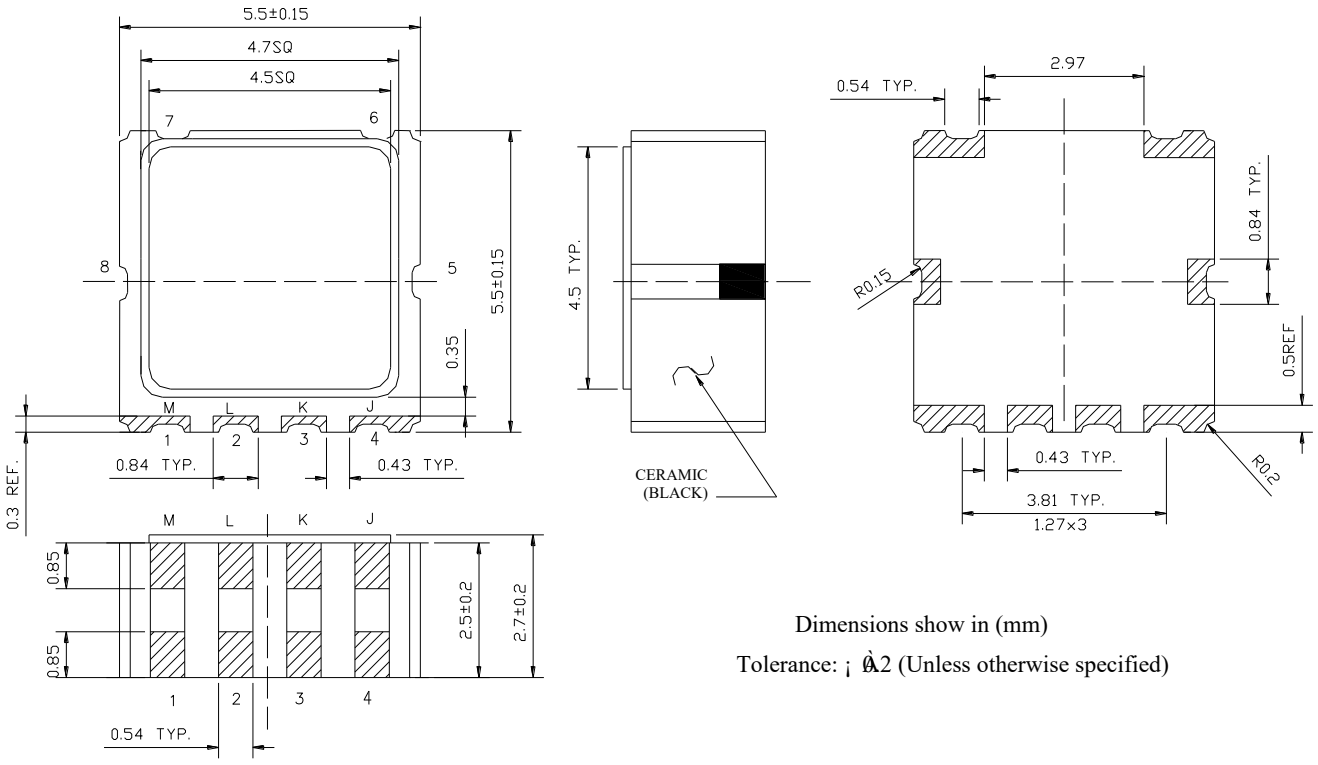
PCB LAYOUT AND FABRICATION SUGGESTIONS
Reference figure and the notes below for recommendations on connecting a power source to the MEMSIC device and PCB fabrication.



PCB Layout

Notes:
1. C = 1.0µF
2. The bypass capacitance should be placed near the VDD and VSS pins to ensure low noise performance and accurate outputs. The predominant transient currents on the MXR7999VW are supplied to the heater element in the thermal sensor through the VDD and VSS pins. The nominal heater resistance is about 500ohm, and nominal heater power is about 7.5 mW. With VDD=5.0V, peak current in the heater element is approximately 10 mA. An internal switching regulator ensures that heater power remains essentially constant with temperature and supply voltage variations. This regulator uses Pulse Width Modulation (PWM) and operates at a fundamental frequency of 1.6 MHz. At VDD=5V, the PWM regulator duty cycle is nominally 15-20%. The bypass capacitor should be able to deliver the required charge during each regulator switching period to ensure low supply noise.
3. Robust low inductance ground and supply wiring should be used.
4. Care should be taken (like isolated rings and planes, signal route out perpendicular to the external thermal gradient) 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.

MECHANICAL PACKAGE OUTLINE DIMENSIONS



Dimensions show in (mm)

Tolerance: ¡ 0.2 (Unless otherwise specified)