Low Cost, High Performance ±1.0 g Dual-Axis Accelerometer with Ratiometric Outputs

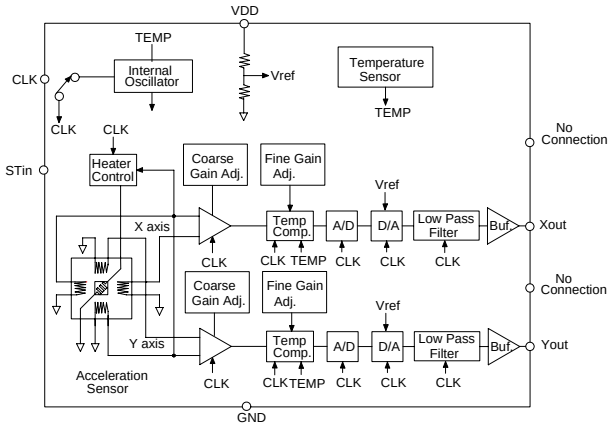
MXR7900A/C/DF

FEATURES

Dual axis accelerometer fabricated on a single CMOS IC
Monolithic design with mixed mode signal processing
RoHS compliant
On-chip sensitivity compensation for temperature variations
On Demand Self Test
900mV/g sensitivity
Independent axis programmability (special order)
Resolution better than 1mg
19Hz bandwidth
>50,000 g shock survival rating
4.50V to 5.25V single supply operation
Small surface mount package, 5mm x 5mm x 2mm

APPLICATION

Automotive – Roll over sensing, VSC/EPB application



MXR7900A/C/D FUNCTIONAL BLOCK DIAGRAM

GENERAL DESCRIPTION

The MXR7900A/C/DF is a low cost, dual axis accelerometer built on a standard, submicron CMOS process. It measures acceleration with a sensitivity of 900mV/g.

The MXR7900A/C/DF provides a g-proportional ratiometric analog output above/below the zero-g point at 50% of the supply voltage.

(Ref. other MEMSIC datasheets for absolute analog or digital outputs).

The typical noise floor is 0.3mg / $\sqrt{Hz}$, allowing signals below 1mg to be resolved at 1Hz bandwidth. The 3dB roll-off of the device occurs at 17Hz.

The MXR7900A/C/D is available in a low profile LCC surface mount package (5mm x 5mm 2mm). It is hermetically sealed and operational over a -30°C to +105°C temperature range.

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 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 MXR7900A/C/D, 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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MXR7900A/C/D SPECIFICATIONS (Measurements @ 25°C, Acceleration = 0 *g* unless otherwise noted; V_{DD} = 5.0V unless otherwise specified)

		MXR7900A/C/D			
Parameter	**Conditions**	**Min.**	**Typ.**	**Max.**	**Units**
SENSOR INPUT	MXR7900A/C	±1.0			g
Measurement Range[1]	MXR7900D	±1.7			g
Nonlinearity	Best fit straight line		0.5	1.0	% of FS
Alignment Error[2]			±1.0	±3.0	degrees
Alignment Error	X Sensor to Y Sensor		0.01		degrees
Cross Axis Sensitivity[3]			±0.5	±1.0	%
SENSITIVITY	Each Axis				
Sensitivity Xout, Yout	V_{DD}=5.0V	855	900	945	mV/g
Sensitivity Change over	MXR7900A/C	-60%		100%	%
Temperature[4] Delta from 25°C	MXR7900D	-6%		3%	%
ZERO *g* BIAS LEVEL	Each Axis				
0 *g* Voltage Xout, Yout	V_{DD}=5.0V	2.41	2.50	2.59	V
0 g Voltage Xout, Yout	V_{DD}=5.0V	-0.10	0.00	0.10	g
0 *g* Offset vs. Temperature[4]	MXR7900A		0.4	1.0	m*g*/°C
Delta from 25°C	MXR7900C		0.1	0.3	m*g*/°C
	MXR7900D		0.4	1.0	m*g*/°C
NOISE PERFORMANCE					
Noise Density, rms	@25°C		0.3	0.8	$mg/\sqrt{Hz}$
FREQUENCY RESPONSE					
3dB Bandwidth		17	19	21	Hz
Selftest					
Delta output change at Xout and Yout			-1.0		g
POWER SUPPLY					
Operating Voltage Range		4.50		5.25	V
Quiescent Supply Current	@5.0V		4.0	5.5	mA
Xout and Yout OUTPUTS					
Output High Voltage	@5.0V Supply	4.5			V
Output Low Voltage				0.5	V
Current	Source or sink @4.5V-5.25V Supply			100	uA
Turn-On Time[5]			160	200	mS
TEMPERATURE RANGE					
Operating Range		-30		+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] 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.

[5] Output settled to within ±17mg.

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)……50,000 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.

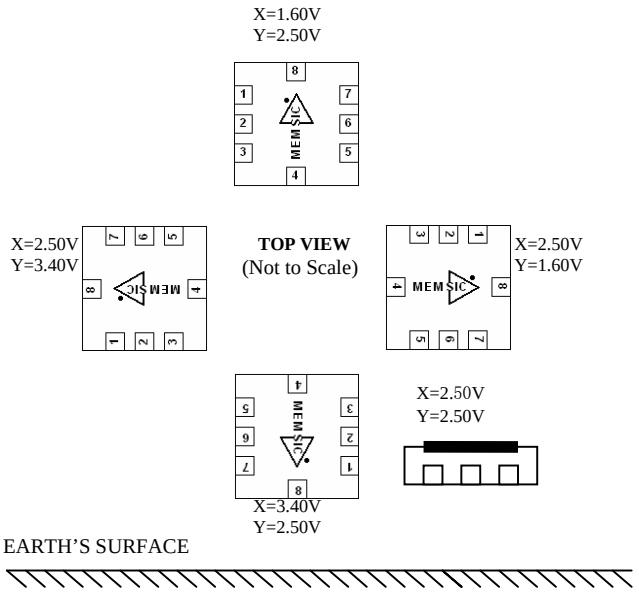
Pin Description: LCC-8 Package

Pin	Name	Description
1	ST_{IN}	Self -Test Input
2	CLK	To be grounded. (Optional Serial Clock Input)
3	GND	Ground
4	NC	Do Not Connect
5	NC	Do Not Connect
6	Yout	Y Channel Output
7	Xout	X Channel Output
8	V_{DD}	4.5V to 5.25V

Ordering Guide

Model	Package Style	Temperature Range
MXR7900AF	LCC8 RoHS compliant	-30 to +105°C
MXR7900CF	LCC8 RoHS compliant	-30 to +105°C
MXR7900CF-01	LCC8 RoHS compliant	-30 to +105°C with temperature data at 25°C
MXR7900DF	LCC8 RoHS compliant	-30 to +105°C

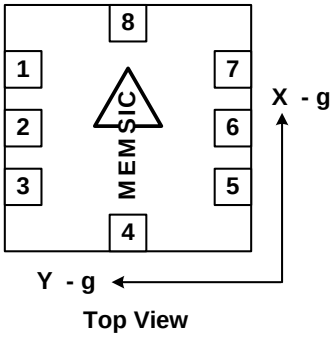
All parts are shipped in tape and reel packaging.



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).

ESD Compliance:
The MXR7900A/C/D sensor is in compliance with the following ESD standards:
Human Body and 2500V per AEC-Q100-002 Rev. E
Machine Model and 250V per AEC-Q100-003 Rev. E

Mounting Orientation:
The package orientation of the MXR7900A/C/D 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 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 MXR7900A/C/D, 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.

MXR7900A/C/D 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 4.5 and 5.25 volts. 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.

TP- This pin should be connected to the 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 >100μA 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 >100μA 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.

CLK – This is an optional serial clock input. The standard product is delivered with an internal clock (1000 kHz**.** However, an external clock between 400 kHz and 1.6 MHz 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 50 Kohm 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}– Self –Test Input

This pin controls the self-test function of the sensor**.** Bringing STIN high will cause a negative deflection around -1g signal to the Xout and Yout from the 0g value.

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.

Following table and figure 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).

	X-Axis		Y-Axis	
X-Axis Orientation To Earth's Surface (deg.)	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

Changes in Tilt for X- and Y-Axes

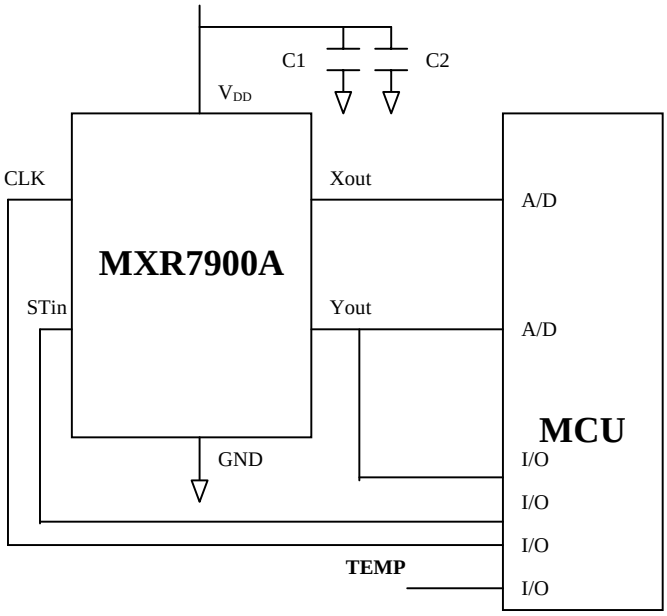
Resolution: The accelerometer resolution is limited by noise. The output noise will vary with the measurement bandwidth. With the reduction of the bandwidth, by applying an external low pass filter, the output noise drops. Reduction of bandwidth will improve the signal to noise ratio and the resolution. 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:

Noise (mg rms) = Noise(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%).

2nd SOFTWARE COMPENSATAION

1.Block Diagram



2.Components:

2.1 Temperature Sensor

Any type of sensor which can have at least +/-3°C accuracy over -40~125°C temperature range, one possible choice is TMP141 from Texas Instruments.

Also, the temperature sensor need to be mounted as close as to MXR7900xF part as possible to sense the temperature correctly.

2.2 Capacitor

C1: Grade higher than X7R, at least 0.22uF capacitor

C2: 10uF electrolytic, Low-ESR capacitor

Both the two capacitors need to be soldered as close as to the V_{DD} pin, since the internal heater is in PWM (1MHz) control mode, with all V_{DD} on the heater at some portion of the time, by using larger value capacitor can minimize the induced noise on the outputs.

2.3 MCU

Anyway type of MCU with 2 of 12bits A/D port is OK.

3. Part Identity Reading

3.1 Digital Switching Characteristics

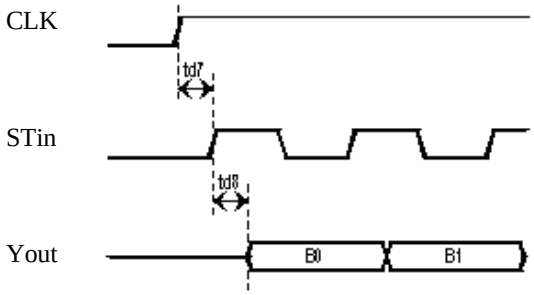
SYMBOL	PARAMETER	MIN	TYP	MAX	UNITS
td7	Rising edge of CLK to rising edge of TP	2.0			ns
td8	Rising edge of TP to valid data out	10.0			ns
STin Frequency		1		800	KHz

Note: Total delay time of td7+td8 should be less than half of cycling time of STin signal to make sure the data can be read out correctly at the falling edge of the STin signal.

3.2 Digital Parameters

SYMBOL	PARAMETER	MIN	TYP	MAX	UNITS
VIH	High Level Input Voltage	V_{DD} -.5			Volts
VIL	Low Level Input Voltage			0.5	Volts
IIL	Input Leakage, All Inputs			1.0	uA
VOH	High Level Output Voltage	V_{DD} -.5			Volts
VOL	Low Level Output Voltage			0.5	Volts

3.3 Waveform



Timing for Identity Code

3.4 Identity code number

After the first rising edge of the STin, the first bit of the identity code will be appeared at pin Yout with a time td8 delay and exists for the whole STin cycle, the second bit of the identity code will be appeared at pin Yout after the second rising edge of STin, etc.

There are totally 72bits, MEMSIC will use the 72bits data to identify each device, and provide its offset, sensitivity and selftest at 25°C with the identity code.

4. Detail Procedure

4.1 Each time when the parts shipped out, MEMSIC will provide a data file whose name is the same as the tape-reel (normally 2500pcs per lot), MEMSIC will guarantee there is no duplicate identity code in one data file (but there will be duplicate identity code within different tape reels).

4.2 The data file will contain the lot number (laser marked on the lid of the device), offset, sensitivity and selftest data at 25°C, and the data file may contain more data, even the customer cannot find actual part with the same identity code, this is just for manufacturability issue.

4.3 The data file will be sent out to the customer either by Email or the customer can setup a FTP server, then MEMSIC can upload the data file right after the shipping of devices.

4.4 Customer readout the identity code of each device per instructions mentioned in 3.

4.5 Find the corresponded data provided by MEMSIC.

PCB LAYOUT AND FABRICATION SUGGESTIONS

1. Robust low inductance ground wiring should be used.
2. 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 shown in mm.

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

