The block diagram of the MMA2240EG is shown in Figure 1. The X-axis g-cell is constructed using surface micromachining; and the interface IC is fabricated in a 1.2 micron (60%) silicon gate CMOS process.

The signal conditioning of the accelerometer channel begins with a capacitance to voltage conversion (C to V) followed by a 2-stage switched capacitor amplifier. This 2-stage amplifier has adjustable offset and gain trimming. The offset and gain of the interface IC can be controlled by the serially accessed EPROM trimming register.

Following the 2-stage amplifier the signal passes through a 2-pole, switched capacitor filter with a Bessel characteristic. The rolloff frequency of the filter is trimmed by adjusting the frequency of the single on-chip oscillator. The frequency is adjusted by trimming the bias current to the oscillator using the EPROM trim register.

The output of the filter is then amplified by the output stage which also has a temperature compensation circuit for sensitivity which can be adjusted using the EPROM trim register.

An adjustable self-test voltage to be applied to the electrostatic deflection plate in the sensing element. Other support circuits include a bandgap voltage reference for the bias sources and the self-test voltage. The interface IC also has its own power supply filter which feeds all the analog functions in order to increase the power supply rejection ratio (PSRR).

Included are several fault checks for low voltage detect (LVD), clock and/or bias monitoring, and a check of the stored "even" parity of the EPROM trim register. **Failure of any of these monitoring functions will result in the STATUS input being driven high.**

Table 1. Maximum Ratings

(Maximum ratings are the limits to which the device can be exposed without causing permanent damage.)

Rating	Symbol	Value	Unit
Unpowered Acceleration (all axes)(1)	g_{shock}	2000 0.5 ms duration	g
In use g shocks powered or unpowered Capable of < 5 ppm device failure rate	$G_{shock\ in\ use}$	< 100 any duration	g
In use g shocks powered or unpowered Capable of < 50 ppm device failure rate	$G_{shock\ in\ use}$	< 100 - 1500 ≤ 0.6 ms duration	g
Supply Voltage	V_{DD}	–0.3 to +7.0	V
Storage Temperature Range	T_{stg}	–40 to +125	°C

1. This device is sensitive to mechanical shock. Improper handling can cause permanent damage of the part or cause the part to otherwise fail.

ELECTRO STATIC DISCHARGE (ESD)

WARNING: This device is sensitive to electrostatic discharge.

Although the Freescale accelerometers contain internal 2kV ESD protection circuitry, extra precaution must be taken by the user to protect the chip from ESD. A charge of over 2000 volts can accumulate on the human body or associated test equipment. A charge of this magnitude can alter the performance or cause failure of the chip. When handling the accelerometer, proper ESD precautions should be followed to avoid exposing the device to discharges which may be detrimental to its performance.

Table 2. Operating Characteristics

(Unless otherwise noted: –40°C ≤ T_A ≤ +85°C, 4.75 ≤ V_{DD} ≤ 5.25, Acceleration = 0g, Loaded output.[1])

Characteristic	Symbol	Min	Typ	Max	Unit
Operating Range[2]					
Supply Voltage[3]	V_{DD}	4.75	5.00	5.25	V
Supply Current	I_{DD}	4.0	5.0	6.0	mA
Operating Temperature Range	T_A	–40	—	+85	C
Acceleration Range	g_{FS}	—	7	—	g
Output Signal					
Zero-g (T_A = 25°C, V_{DD} = 5.0 V)[4]	V_{OFF}	2.300	2.500	2.700	V
Zero-g	$V_{OFF,V}$	0.44 V_D	0.50 V_{DD}	0.56 V_{DD}	V
Sensitivity (T_A = 25°C, V_{DD} = 5.0 V)[5]	S	285.0	300.0	315.0	mV/g
Sensitivity	S_V	55.8	60.0	64.2	mV/g/V
Bandwidth Response	f_{-3dB}	360	400	440	Hz
Nonlinearity	NL_{OUT}	–1.0	—	+1.0	% FSO
Noise					
RMS (10 Hz – 1 kHz)	n_{RMS}	—	3.5	—	mVrms
Self-Test					
Output Response	V_{ST}	0.45	0.60	0.75	V
Input Low	V_{IL}	V_{SS}	—	0.3 x V_{DD}	V
Input High	V_{IH}	0.7 x V_{DD}	—	V_{DD}	V
Input Loading[6]	I_{IN}	–30	–100	–300	μA
Response Time[7]	t_{ST}	—	2.0	10	ms
Status[8], [9]					
Output Low (I_{load} = 100 μA)	V_{OL}	—	—	0.4	V
Output High (I_{load} = 100 μA)	V_{OH}	V_{DD} –0.8	—	—	V
Minimum Supply Voltage (LVD Trip)	V_{LVD}	2.7	3.25	4.0	V
Clock Monitor Fail Detection Frequency	f_{min}	150	—	400	kHz
Output Stage Performance					
Electrical Saturation Recovery Time[10]	t_{DELAY}	—	0.2	—	ms
Full Scale Output Range (I_{OUT} = 200 μA)	V_{FSO}	0.25	—	V_{DD} –0.25	V
Capacitive Load Drive[11]	C_L	—	—	100	pF
Output Impedance	Z_O	—	300	—	Ω
Mechanical Characteristics					
Transverse Sensitivity[12]	$V_{XZ,YZ}$	—	—	5.0	% FSO
Package Resonance	f_{PKG}	—	10	—	kHz

1. For a loaded output the measurements are observed after an RC filter consisting of a 1 kΩ resistor and a 0.01 μF capacitor to ground.
2. These limits define the range of operation for which the part will meet specification.
3. Within the supply range of 4.75 V and 5.25 V, the device operates as a fully calibrated linear accelerometer. Beyond these supply limits the device may operate as a linear device but is not guaranteed to be in calibration.
4. The device can measure both + and – acceleration. With no input acceleration the output is at midsupply. For positive acceleration the output will increase above V_{DD}/2 and for negative acceleration the output will decrease below V_{DD}/2.
5. The device is calibrated at 5g.
6. The digital input pin has an internal pull-down current source to prevent inadvertent self test initiation due to external board level leakages.
7. Time for the output to reach 90% of its final value after a self-test is initiated.
8. The Status pin output is not valid following power-up until at least one rising edge has been applied to the self-test pin. The Status pin is high whenever the self-test input is high, as a means to check the connectivity of the self-test and Status pins in the application.
9. The Status pin output latches high if a Low Voltage Detection or Clock Frequency failure occurs, or the EPROM parity changes to odd. The Status pin can be reset low if the self-test pin is pulsed with a high input for at least 100 μs, unless a fault condition continues to exist.
10. Time for amplifiers to recover after an acceleration signal causing them to saturate.
11. Preserves phase margin (60°) to guarantee output amplifier stability.
12. A measure of the device's ability to reject an acceleration applied 90° from the true axis of sensitivity.

PRINCIPLE OF OPERATION

The Freescale accelerometer is a surface-micromachined integrated-circuit accelerometer.

The device consists of a surface micromachined capacitive sensing cell (g-cell) and a CMOS signal conditioning ASIC contained in a single integrated circuit package. The sensing element is sealed hermetically at the wafer level using a bulk micromachined “cap" wafer.

The g-cell is a mechanical structure formed from semiconductor materials (polysilicon) using semiconductor processes (masking and etching). It can be modeled as a set of beams attached to a movable central mass that moves between fixed beams. The movable beams can be deflected from their rest position by subjecting the system to an acceleration (Figure 3).

When the beams attached to the center mass move, the distance from them to the fixed beams on one side will increase by the same amount that the distance to the fixed beams on the other side decreases. The change in distance is a measure of acceleration.

The g-cell beams form two back-to-back capacitors (Figure 3). As the center plate moves with acceleration, the distance between the beams change and each capacitor's value will change, ($C = NA\varepsilon/D$). Where A is the area of the facing side of the beam, ε is the dielectric constant, and D is the distance between the beams, and N is the number of beams.

The CMOS ASIC uses switched capacitor techniques to measure the g-cell capacitors and extract the acceleration data from the difference between the two capacitors. The ASIC also signal conditions and filters (switched capacitor) the signal, providing a high level output voltage that is ratiometric and proportional to acceleration.

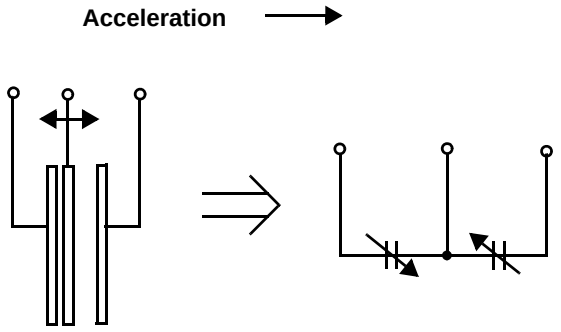


Figure 3. Simplified Transducer Physical Model

SPECIAL FEATURES

Filtering

The Freescale accelerometers contain an onboard 2-pole switched capacitor filter. A Bessel implementation is used because it provides a maximally flat delay response (linear phase) thus preserving pulse shape integrity. Because the filter is realized using switched capacitor techniques, there is no requirement for external passive components (resistors and capacitors) to set the cut-off frequency.

Self-Test

The sensor provides a self-test feature that allows the verification of the mechanical and electrical integrity of the accelerometer at any time before or after installation. This feature is critical in applications such as automotive airbag systems where system integrity must be ensured over the life of the vehicle. A fourth “plate" is used in the g-cell as a self-test plate. When the user applies a logic high input to the self-test pin, a calibrated potential is applied across the self-test plate and the moveable plate. The resulting electrostatic force ($Fe = {}^{1}/_{2}\ AV^2/d^2$) causes the center plate to deflect. The resultant deflection is measured by the accelerometer's control ASIC and a proportional output voltage results. This procedure assures that both the mechanical (g-cell) and electronic sections of the accelerometer are functioning.

Ratiometricity

Ratiometricity simply means that the output offset voltage and sensitivity will scale linearly with applied supply voltage. That is, as you increase supply voltage the sensitivity and offset increase linearly; as supply voltage decreases, offset and sensitivity decrease linearly. This is a key feature when interfacing to a microcontroller or an A/D converter because it provides system level cancellation of supply induced errors in the analog to digital conversion process.

Status

Freescale accelerometers include fault detection circuitry and a fault latch. The Status pin is an output from the fault latch, OR'd with self-test, and is set high whenever one (or more) of the following events occur:

- Supply voltage falls below the Low Voltage Detect (LVD) voltage threshold
- Clock oscillator falls below the clock monitor minimum frequency
- Parity of the EPROM bits becomes odd in number.

The fault latch can be reset by a falling edge on the self-test input pin, unless one (or more) of the fault conditions continues to exist.

BASIC CONNECTIONS

Pinout Description

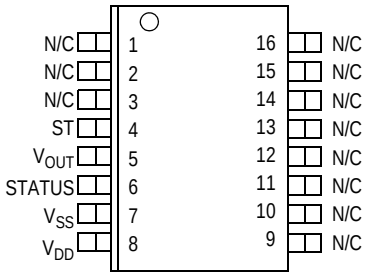


Table 3. Pin Descriptions

Pin No.	Pin Name	Description
1 thru 3	—	No internal connection. Leave unconnected.
4	ST	Logic input pin used to initiate self-test.
5	V_{OUT}	Output voltage of the accelerometer.
6	STATUS	Logic output pin to indicate fault.
7	V_{SS}	The power supply ground.
8	V_{DD}	The power supply input.
9 thru 13	Trim pins	Used for factory trim. Leave unconnected.
14 thru 16	—	No internal connection. Leave unconnected.

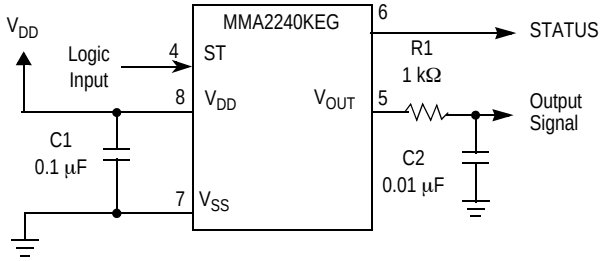


Figure 4. SOIC Accelerometer with Recommended Terminations

PCB Layout

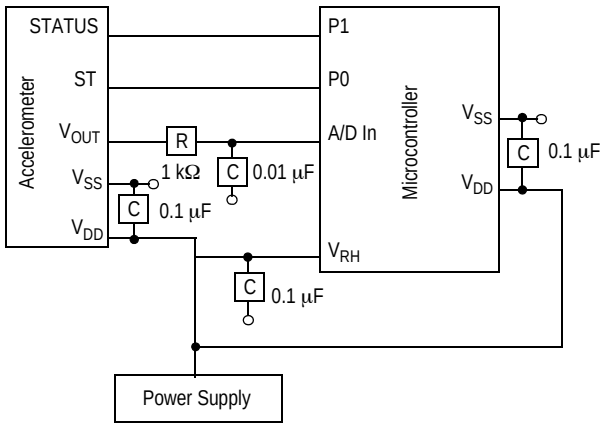


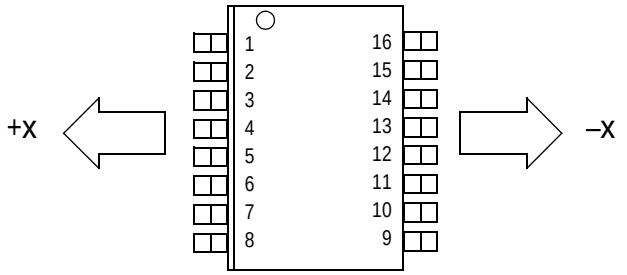
Figure 5. Recommended PCB Layout for Interfacing Accelerometer to Microcontroller

NOTES:

1. Use a 0.1 µF capacitor on V_{DD} to decouple the power source.
2. Physical coupling distance of the accelerometer to the microcontroller should be minimal.
3. Place a ground plane beneath the accelerometer to reduce noise, the ground plane should be attached to all of the open ended terminals shown in Figure 5.
4. Use an RC filter of 1 kΩ and 0.01 µF on the output of the accelerometer to minimize clock noise (from the switched capacitor filter circuit).
5. PCB layout of power and ground should not couple power supply noise.
6. Accelerometer and microcontroller should not be a high current path.
7. A/D sampling rate and any external power supply switching frequency should be selected such that they do not interfere with the internal accelerometer sampling frequency. This will prevent aliasing errors.

Dynamic Acceleration Sensing Direction

Acceleration of the package in the +X direction (center plate moves in the –X direction) will result in an increase in the output.

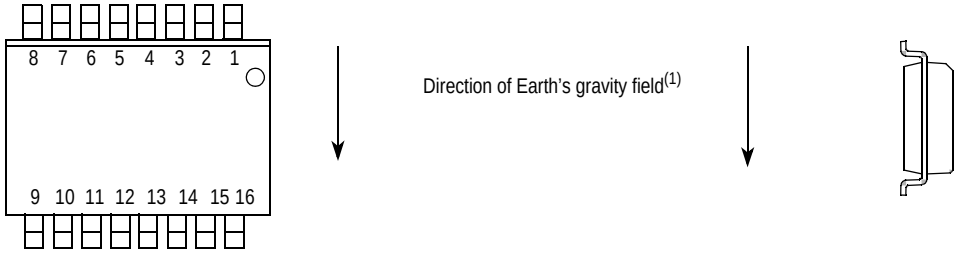


Activation of Self Test moves the center plate in the –X direction, resulting in an increase in the output.

16-Pin SOIC Package
N/C pins are recommended to be left FLOATING

Top View

Static Acceleration Sensing Direction



Front View

Side View

1. When positioned as shown, the Earth's gravity will result in a positive 1g output.

MINIMUM RECOMMENDED FOOTPRINT FOR SURFACE MOUNTED APPLICATIONS

Surface mount board layout is a critical portion of the total design. The footprint for the surface mount packages must be the correct size to ensure proper solder connection interface between the board and the package. With the correct footprint, the packages will self-align when subjected to a solder reflow process. It is always recommended to design boards with a solder mask layer to avoid bridging and shorting between solder pads.

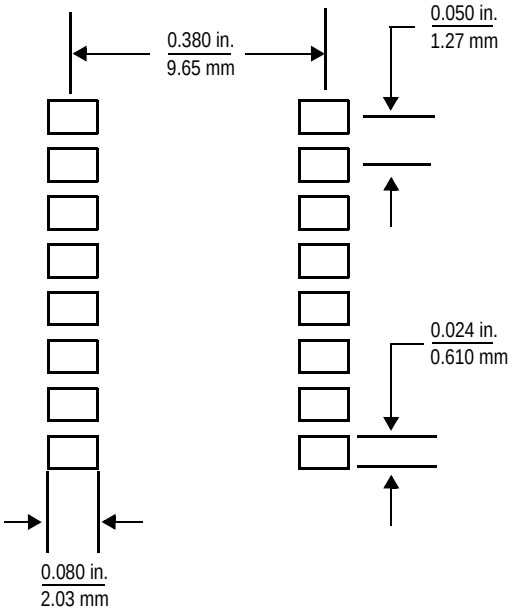
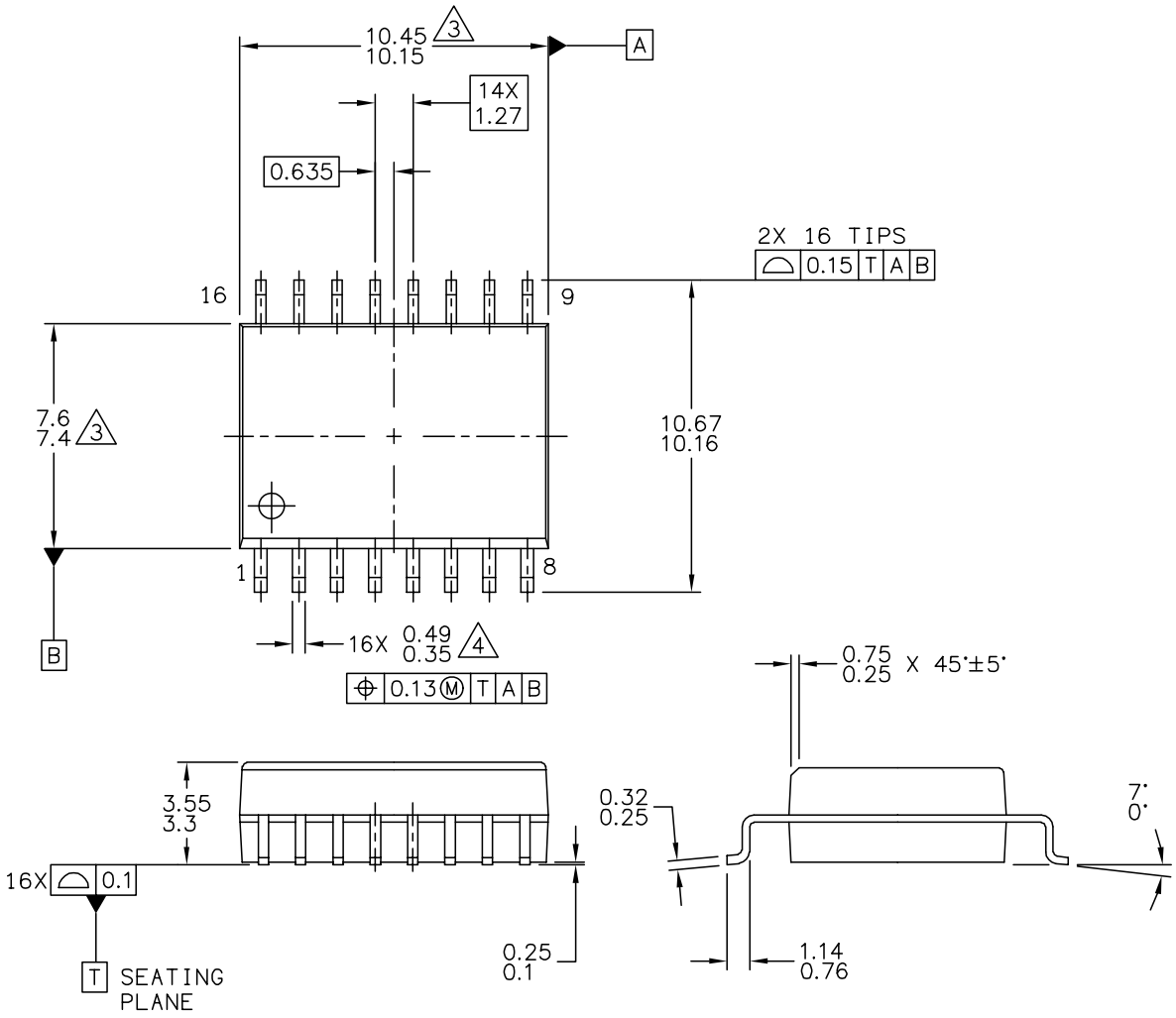


Figure 6. Footprint SOIC-16 (Case 475-01)

PACKAGE DIMENSIONS



© FREESCALE SEMICONDUCTOR, INC. ALL RIGHTS RESERVED.	MECHANICAL OUTLINE	PRINT VERSION NOT TO SCALE
TITLE: 16 LEAD SOIC ACCELEROMETER	DOCUMENT NO: 98ASB16926C	REV: C
	CASE NUMBER: 475-01	17 MAR 2005
	STANDARD: NON-JEDEC	

PAGE 1 OF 2

CASE 475-01
ISSUE C
16-LEAD SOIC

PACKAGE DIMENSIONS

NOTES:

1. ALL DIMENSONS ARE IN MILLIMETERS.

2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M–1994.

3. THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.15 PER SIDE.

4. THIS DIMENSION DOES NOT INCLUDE DAMBAR PROTRUSION.
PROTRUSIONS SHALL NOT CAUSE THE LEAD WIDTH TO EXCEED 0.75

MECHANICAL OUTLINE	PRINT VERSION NOT TO SCALE

TITLE:	DOCUMENT NO: 98ASB16926C	REV: C
16 LEAD SOIC ACCELEROMETER	CASE NUMBER: 475–01	17 MAR 2005
	STANDARD: NON–JEDEC	

CASE 475-01
ISSUE C
16-LEAD SOIC

How to Reach Us:

Home Page:
www.freescale.com

Web Support:
http://www.freescale.com/support

USA/Europe or Locations Not Listed:
Freescale Semiconductor, Inc.
Technical Information Center, EL516
2100 East Elliot Road
Tempe, Arizona 85284
1-800-521-6274 or +1-480-768-2130
www.freescale.com/support

Europe, Middle East, and Africa:
Freescale Halbleiter Deutschland GmbH
Technical Information Center
Schatzbogen 7
81829 Muenchen, Germany
+44 1296 380 456 (English)
+46 8 52200080 (English)
+49 89 92103 559 (German)
+33 1 69 35 48 48 (French)
www.freescale.com/support

Japan:
Freescale Semiconductor Japan Ltd.
Headquarters
ARCO Tower 15F
1-8-1, Shimo-Meguro, Meguro-ku,
Tokyo 153-0064
Japan
0120 191014 or +81 3 5437 9125
support.japan@freescale.com

Asia/Pacific:
Freescale Semiconductor China Ltd.
Exchange Building 23F
No. 118 Jianguo Road
Chaoyang District
Beijing 100022
China
+86 010 5879 8000
support.asia@freescale.com

For Literature Requests Only:
Freescale Semiconductor Literature Distribution Center
1-800-441-2447 or +1-303-675-2140
Fax: +1-303-675-2150
LDCForFreescaleSemiconductor@hibbertgroup.com

RoHS-compliant and/or Pb-free versions of Freescale products have the functionality and electrical characteristics of their non-RoHS-compliant and/or non-Pb-free counterparts. For further information, see http:/www.freescale.com or contact your Freescale sales representative.

For information on Freescale’s Environmental Products program, go to http://www.freescale.com/epp.

MMA2240KEG
Rev. 0
11/2009