

## Product Preview

# $\pm 10g$ Micromachined Accelerometer

The PMMA series of silicon micromachined, capacitive accelerometers features signal conditioning, a 4-pole low pass filter and temperature compensation. Zero-g offset, sensitivity, and filter cut-off are factory set and require no external devices. A component self-test capability verifies device functionality.

### Features

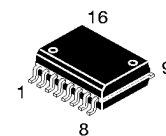
- Integral Signal Conditioning
- Linear Output
- Ratiometric Performance
- 4th Order Bessel Filter Preserves Pulse Shape Integrity
- Calibrated Self-Test
- Transducer Hermetically Sealed at Wafer Level for Superior Reliability
- Robust Design, High Shock Survivability

### Typical Applications

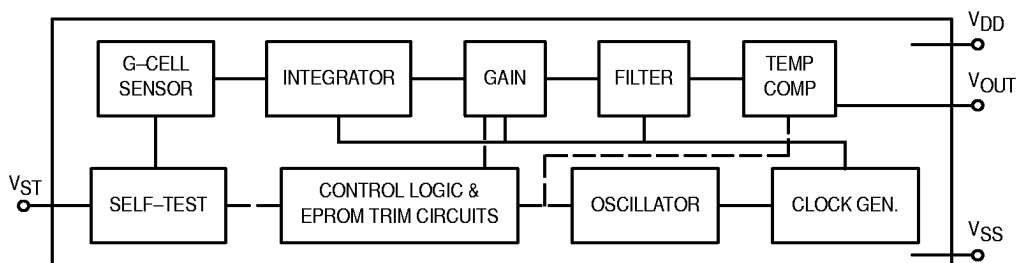
- Vibration Monitoring and Recording
- Appliance Control
- Mechanical Bearing Monitoring
- Computer Hard Drive Protection
- Computer Mouse and Joysticks
- Virtual Reality Input Devices
- Sports Diagnostic Devices and Systems

**PMMA2500D**

**PMMA2500D: X AXIS SENSITIVITY  
MICROMACHINED  
ACCELEROMETER  
 $\pm 10g$**



**16 LEAD SOIC**  
CASE 475-01



**Figure 1. Simplified Accelerometer Functional Block Diagram**

This document contains information on a new product. Specifications and information herein are subject to change without notice.

## PMMA2500D

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

Rating	Symbol	Value	Unit
Powered Acceleration (all axes)	G <sub>pd</sub>	500	g
Unpowered Acceleration (all axes)	G <sub>upd</sub>	1000	g
Supply Voltage	V <sub>DD</sub>	−0.3 to +7.0	V
Drop Test <sup>(1)</sup>	D <sub>drop</sub>	1.2	m
Storage Temperature Range	T <sub>stg</sub>	−40 to +105	°C

### ELECTRO STATIC DISCHARGE (ESD)

**WARNING: This device is sensitive to electrostatic discharge.**

Although the Motorola 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.

## OPERATING CHARACTERISTICS

(Unless otherwise noted:  $0^{\circ}\text{C} \leq T_A \leq +70^{\circ}\text{C}$ ,  $4.75 \leq V_{DD} \leq 5.25$ , Acceleration = 0g, Loaded output<sup>(2)</sup>)

Characteristic	Symbol	Min	Typ	Max	Unit
Operating Range <sup>(3)</sup>					
Supply Voltage <sup>(4)</sup>	$V_{DD}$	4.75	5.00	5.25	V
Supply Current	$I_{DD}$	4.0	5.0	6.0	mA
Operating Temperature Range	$T_A$	0	+25	+70	$^{\circ}\text{C}$
Acceleration Range	gFS	—	10	—	g
Output Signal					
Zero g ( $V_{DD} = 5.0\text{ V}$ ) <sup>(5)</sup>	$V_{OFF}$	2.0	2.5	3.0	V
Zero g	$V_{OFF,V}$	$0.44 V_{DD}$	$0.50 V_{DD}$	$0.56 V_{DD}$	V
Sensitivity ( $T_A = 25^{\circ}\text{C}$ , $V_{DD} = 5.0\text{ V}$ ) <sup>(6)</sup>	S	135	150	165	mV/g
Sensitivity	$S_V$	27	30	33	mV/V/g
Bandwidth Response	$f_{-3dB}$	340	400	460	Hz
Nonlinearity	NL-OUT	-1.0	—	+1.0	% FSO
Noise					
RMS (0.1 to 400 Hz)	$n_{RMS}$	—	7.5	12	mVrms
Power Spectral Density	$n_{PSD}$	—	300	—	$\mu\text{V}/(\text{Hz}^{1/2})$
Clock Noise (without RC load on output) <sup>(8)</sup>	$n_{CLK}$	—	2.0	—	mVpk
Self-Test					
Output Response	gST	—	8.0	—	g
Input Low	$V_{IL}$	$V_{SS}$	—	$0.3 \times V_{DD}$	V
Input High	$V_{IH}$	$0.7 \times V_{DD}$	—	$V_{DD}$	V
Input Loading <sup>(7)</sup>	$I_{IN}$	-30	-110	-300	$\mu\text{A}$
Response Time <sup>(9)</sup>	$t_{ST}$	—	2.0	—	ms
Output Stage Performance					
Electrical Saturation Recovery Time <sup>(10)</sup>	$t_{DELAY}$	—	0.2	—	ms
Full Scale Output Range ( $I_{OUT} = 200\text{ }\mu\text{A}$ )	$V_{FSO}$	0.3	—	$V_{DD} - 0.3$	V
Capacitive Load Drive <sup>(11)</sup>	$C_L$	—	—	100	pF
Output Impedance	$Z_O$	—	300	—	$\Omega$
Mechanical Characteristics					
Alignment Error	$\theta_A$	—	+/- 3	—	degrees
Transverse Sensitivity <sup>(12)</sup>	$V_{ZX,YX}$	—	—	5.0	% FSO
Package Resonance	$f_{PKG}$	—	10	—	kHz

## NOTES:

1. Dropped onto concrete surface from any axis.
2. For a loaded output the measurements are observed after an RC filter consisting of a 1 k $\Omega$  resistor and a 0.01  $\mu\text{F}$  capacitor to ground.
3. These limits define the range of operation for which the part will meet specification.
4. Within the supply range of 4.75 and 5.25 volts, 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.
5. 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  $V_{DD}/2$ .
6. The device is calibrated at 5g.
7. At clock frequency  $\cong 65\text{ kHz}$ .
8. The digital input pin has an internal pull-down current source to prevent inadvertent self test initiation due to external board level leakages.
9. Time for the output to reach 90% of its final value after a self-test is initiated.
10. Time for amplifiers to recover after an acceleration signal causing them to saturate.
11. Preserves phase margin (60 $^{\circ}$ ) to guarantee output amplifier stability.
12. A measure of the device's ability to reject an acceleration applied 90 $^{\circ}$  from the true axis of sensitivity.

## PRINCIPLE OF OPERATION

The Motorola 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 consists of interdigitated finger structures (comb patterns) which can be modeled as two stationary plates with a moveable plate in-between. The center plate can be deflected from its rest position by subjecting the system to an acceleration (Figure 2).

When the center plate deflects, the distance from it to one fixed plate will increase by the same amount that the distance to the other plate decreases. The change in distance is a measure of acceleration.

The g-cell plates form two back-to-back capacitors (Figure 3). As the center plate moves with acceleration, the distance between the plates changes and each capacitor's value will change, ( $C = A\epsilon/D$ ). Where A is the area of the plate,  $\epsilon$  is the dielectric constant, and D is the distance between the plates.

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 ratio-metric and proportional to acceleration.

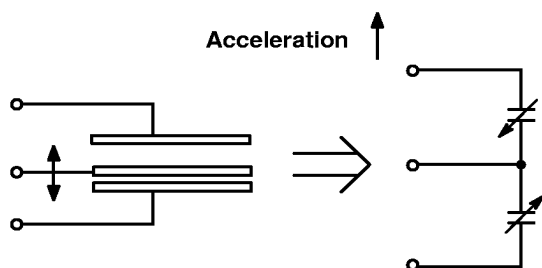


Figure 2. Transducer Physical Model

Figure 3. Equivalent Circuit Model

## SPECIAL FEATURES

### Filtering

The Motorola accelerometers contain an onboard 4-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

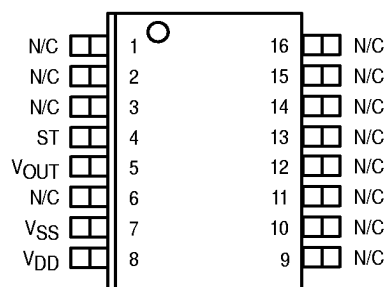
The sensor provides a self-test feature that allows the verification of the mechanical and electrical integrity of the accelerometer at any time before or after installation. This feature is critical in applications such as automotive airbag systems where system integrity must be ensured over the life 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 ( $F_e = 1/2 AV^2/d^2$ ) 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.

## BASIC CONNECTIONS

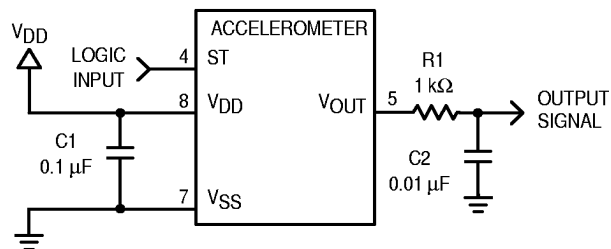
### Pinout Description



Pin No.	Pin Name	Description
1 thru 3	—	No internal connection. Leave unconnected.
4	ST	Logic input pin used to initiate self-test.
5	VOUT	Output voltage of the accelerometer.
6	—	No internal connection. Leave unconnected.
7	VSS	The power supply ground.
8	VDD	The power supply input.
9 thru 13	Trim pins	Used for factory trim. Leave unconnected.
14 thru 16	—	No internal connection. Leave unconnected.

### Circuit Schematic

Figure 4 shows the recommended connection diagram for operating the accelerometer. Pins 1, 2, 3, 6, 14, 15, and 16 have no internal connections, and pins 9 through 13 are used for calibration and trimming in the factory. These pins should all be left unconnected.

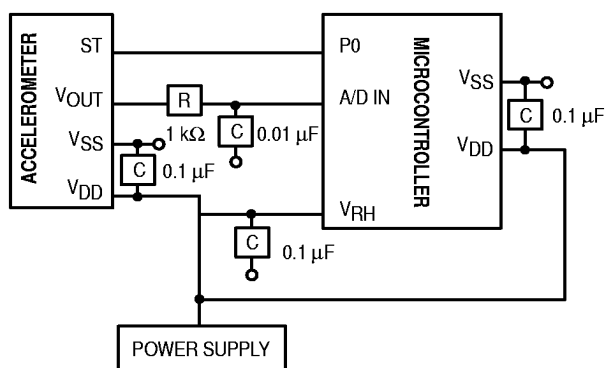


**Figure 4. Accelerometer with Recommended Connection Diagram**

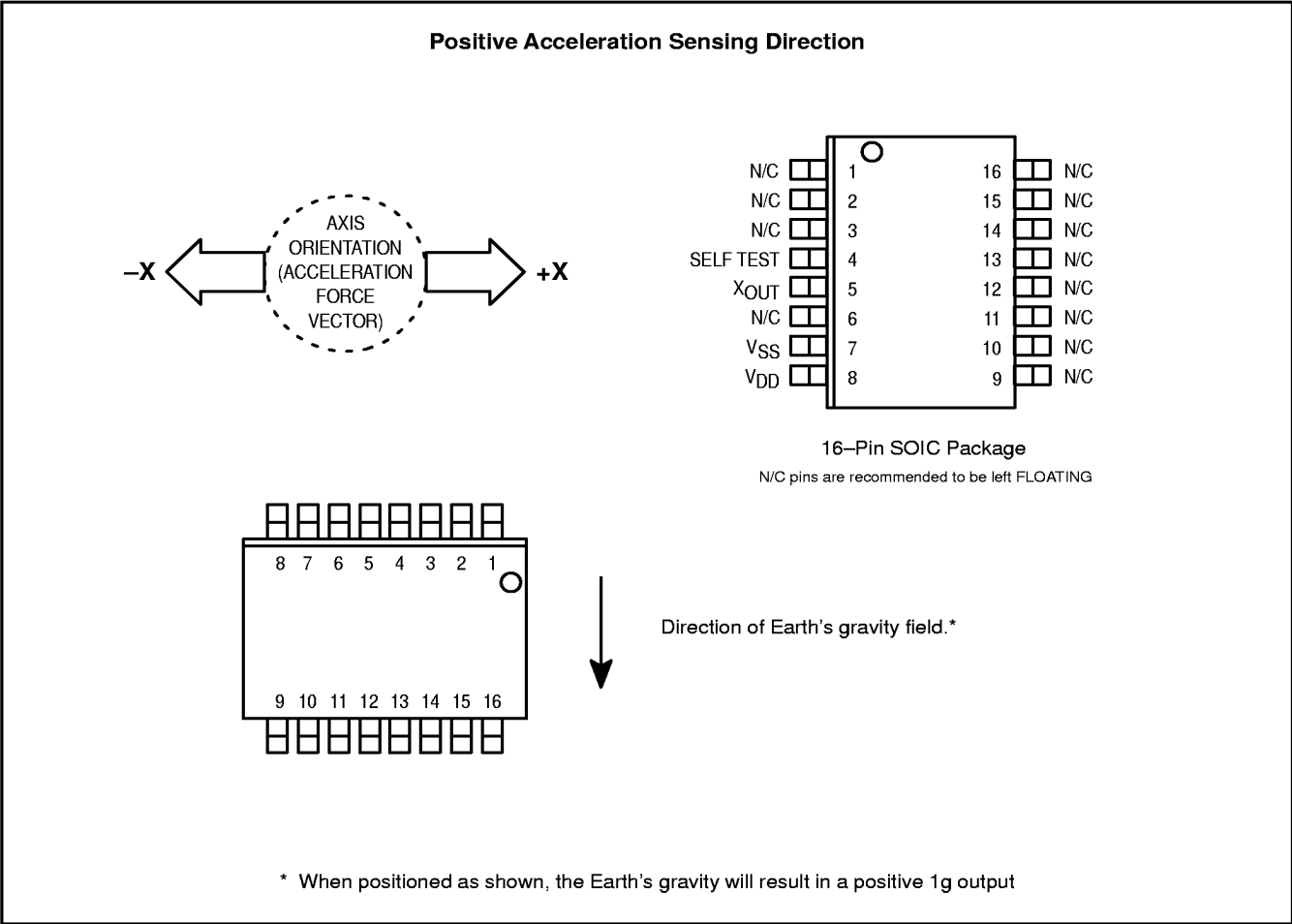
### NOTES:

- Use a .1  $\mu\text{F}$  capacitor on  $V_{DD}$  to decouple the power source.
- Physical coupling distance of the accelerometer to the microcontroller should be minimal.
- Place a ground plane beneath the accelerometer to reduce noise, the ground plane should be attached to all of the open ended terminals shown above.
- Use an RC filter of 1  $\text{k}\Omega$  and 0.01  $\mu\text{F}$  on the output of the accelerometer to minimize clock noise (from the switched capacitor filter circuit).
- Accelerometer and microcontroller should not be supplied by a trace that is connected to a high current path.
- 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.

### PCB Layout



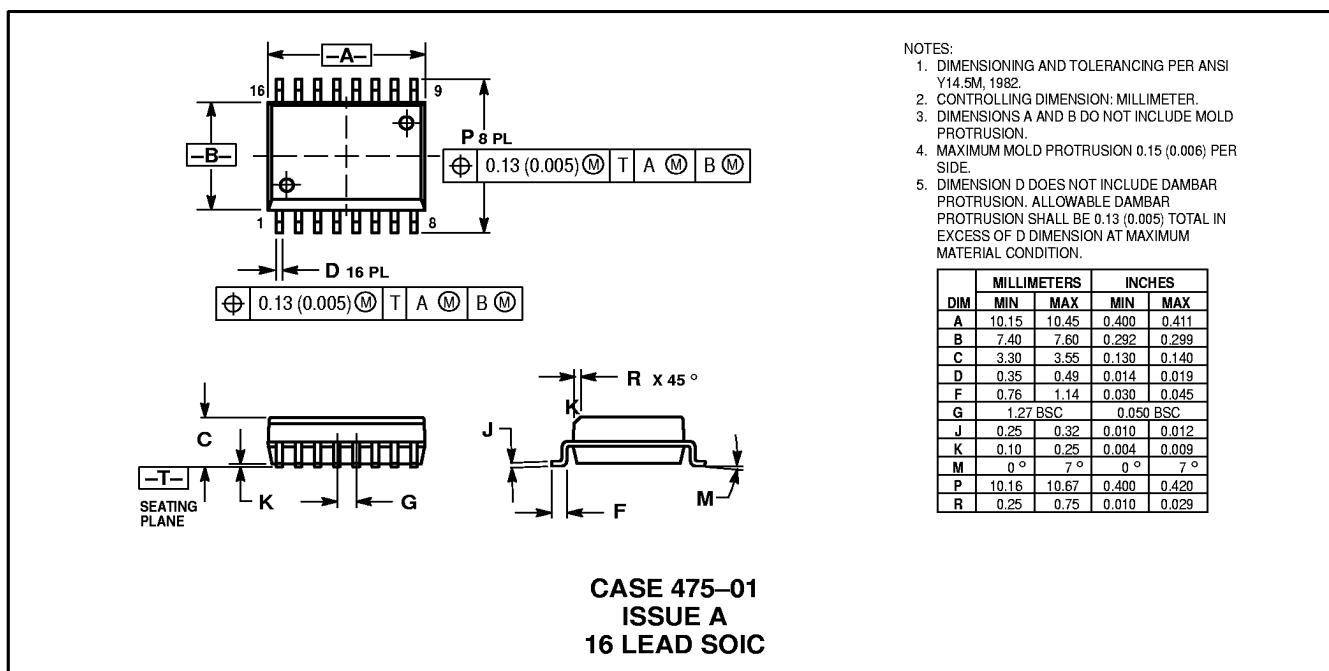
**Figure 5. Recommend PCB Layout for Interfacing Accelerometer to Microcontroller**



**ORDERING INFORMATION**

Device	Temperature Range	Case No.	Package
PMMA2500D	0 to +70°C	Case 475-01	16 Lead SOIC

## PACKAGE DIMENSIONS



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4-32-1 Nishi-Gotanda, Shinagawa-ku, Tokyo, Japan. 81-3-5487-8488

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