

±1.5g X-Axis Micromachined Accelerometer

The MMA series of silicon capacitive, micromachined accelerometers features signal conditioning, a 2-pole low pass filter and temperature compensation. Zero-g offset full scale span and filter cut-off are factory set and require no external devices. A full system self-test capability verifies system functionality.

Features

- Integral Signal Conditioning
- High Sensitivity
- Linear Output
- 2nd Order Bessel Filter
- Calibrated Self-test
- EPROM Parity Check Status
- Transducer Hermetically Sealed at Wafer Level for Superior Reliability
- Robust Design, High Shock Survivability

Typical Applications

- Tilt Monitoring
- Inclinometers
- Appliance Control
- Mechanical Bearing Monitoring
- Vibration Monitoring and Recording
- Sports Diagnostic Devices and Systems
- Trailer Brake Controls
- Automotive Aftermarket

ORDERING INFORMATION

| Device | Temperature Range | Case No. | Package |
|------------|-------------------|-------------|----------------------|
| MMA2260D | -40 to +105°C | Case 475-01 | SOIC-16 |
| MMA2260DR2 | -40 to +105°C | Case 475-01 | SOIC-16, Tape & Reel |

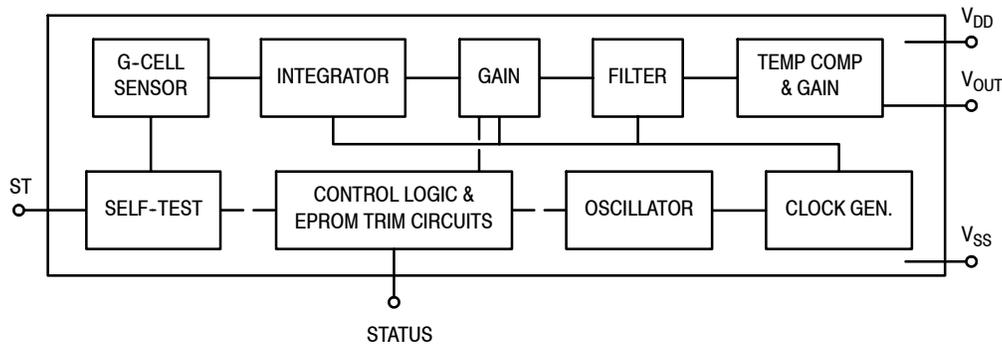
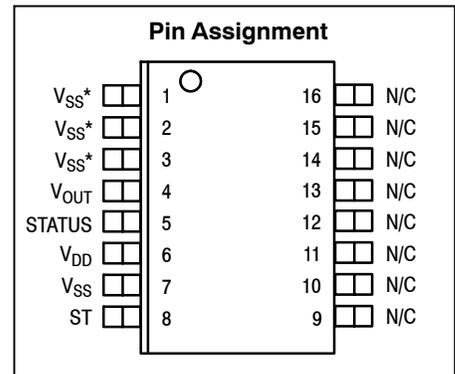
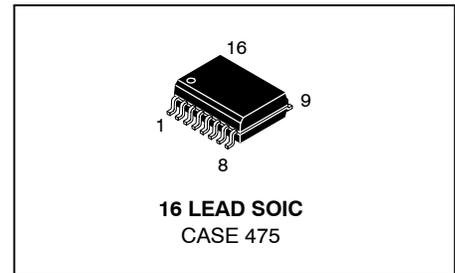
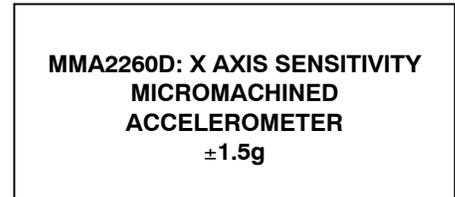


Figure 1. Simplified Accelerometer Functional Block Diagram

REV 0

Freescale Semiconductor, Inc.

Freescale Semiconductor, Inc.

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) | g_{upd} | 2000 | g |
| Supply Voltage | V_{DD} | -0.3 to +7.0 | V |
| Drop Test ⁽¹⁾ | H_{drop} | 1.2 | m |
| Storage Temperature Range | T_{stg} | -40 to +125 | °C |

NOTES:

1. Dropped onto concrete surface from any axis.

ELECTRO STATIC DISCHARGE (ESD)

WARNING: This device is sensitive to electrostatic discharge.

Although the Motorola accelerometers contain internal 2000V 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: $-40^{\circ}\text{C} \leq T_A \leq +105^{\circ}\text{C}$, $4.75 \leq V_{DD} \leq 5.25$, 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} | 1.1 | 2.2 | 3.2 | mA |
| Operating Temperature Range | T_A | -40 | — | +105 | $^{\circ}\text{C}$ |
| Acceleration Range | gFS | — | 1.5 | — | g |
| Output Signal | | | | | |
| Zero g ($V_{DD} = 5.0\text{ V}$) ⁽⁴⁾ | V_{OFF} | 2.3 | 2.5 | 2.7 | V |
| Sensitivity ($T_A = 25^{\circ}\text{C}$, $V_{DD} = 5.0\text{ V}$) ⁽⁵⁾ | S | 1140 | 1200 | 1260 | mV/g |
| Sensitivity ($V_{DD} = 5.0\text{ V}$) ⁽⁵⁾ | S | 1110 | 1200 | 1290 | mV/g |
| Bandwidth Response | f_{-3dB} | 40 | 50 | 60 | Hz |
| Nonlinearity | NL _{OUT} | -1.0 | — | +1.0 | % FSO |
| Noise | | | | | |
| RMS (0.1 Hz - 1.0 kHz) | n_{RMS} | — | 3.5 | — | mVrms |
| Spectral Density (RMS, 0.1 Hz - 1.0 kHz) ⁽⁶⁾ | n_{SD} | — | 350 | — | $\mu\text{g}/\sqrt{\text{Hz}}$ |
| Self-Test | | | | | |
| Output Response ($V_{DD} = 5.0\text{ V}$) | ΔV_{ST} | 0.3 | 0.4 | 0.5 | V |
| Input Low | V_{IL} | V_{SS} | — | $0.3 V_{DD}$ | V |
| Input High | V_{IH} | $0.7 V_{DD}$ | — | V_{DD} | V |
| Input Loading ⁽⁷⁾ | I_{IN} | -50 | -125 | -300 | μA |
| Response Time ⁽⁸⁾ | t_{ST} | — | 20 | 25 | ms |
| Status ⁽¹²⁾⁽¹³⁾ | | | | | |
| Output Low ($I_{load} = 100\ \mu\text{A}$) | V_{OL} | — | — | 0.4 | V |
| Output High ($I_{load} = -100\ \mu\text{A}$) | V_{OH} | $V_{DD} - 0.8$ | — | — | V |
| Output Stage Performance | | | | | |
| Electrical Saturation Recovery Time ⁽⁹⁾ | t_{DELAY} | — | — | 2.0 | ms |
| Full Scale Output Range ($I_{OUT} = -200\ \mu\text{A}$) | V_{FSO} | $V_{SS} + 0.25$ | — | $V_{DD} - 0.25$ | V |
| Capacitive Load Drive ⁽¹⁰⁾ | C_L | — | — | 100 | pF |
| Output Impedance | Z_O | — | 50 | — | Ω |
| Mechanical Characteristics | | | | | |
| Transverse Sensitivity ⁽¹¹⁾ | $V_{YX,ZX}$ | — | — | 5.0 | % FSO |

NOTES:

- For a loaded output the measurements are observed after an RC filter consisting of a 1 k Ω resistor and a 0.1 μF capacitor to ground.
- These limits define the range of operation for which the part will meet specification.
- 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.
- 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 $V_{DD}/2$.
- Sensitivity limits apply to 0 Hz acceleration.
- At clock frequency $\cong 34\text{ kHz}$.
- The digital input pin has an internal pull-down current source to prevent inadvertent self test initiation due to external board level leakages.
- Time for the output to reach 90% of its final value after a self-test is initiated.
- Time for amplifiers to recover after an acceleration signal causing them to saturate.
- Preserves phase margin (60°) to guarantee output amplifier stability.
- A measure of the device's ability to reject an acceleration applied 90° from the true axis of sensitivity.
- 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.
- The Status pin output latches high if the EPROM parity changes to odd. The Status pin can be reset by a rising edge on self-test, unless a fault condition continues to exist.

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 can be modeled as a set of beams attached to a movable central mass that move between fixed beams. The movable beams can be deflected from their rest position by subjecting the system to an acceleration (Figure 2).

As the beams attached to the central 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 2). As the central mass moves with acceleration, the distance between the beams change and each capacitor's value will change, ($C = NA\epsilon/D$). Where A is the area of the facing side of the beam, ϵ is the dielectric constant, 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 ratio-metric and proportional to acceleration.

SPECIAL FEATURES

Filtering

Motorola accelerometers contain an onboard 2-pole switched capacitor filter. 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. 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.

Status

Motorola 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 the following event occurs:

- Parity of the EPROM bits becomes odd in number.

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

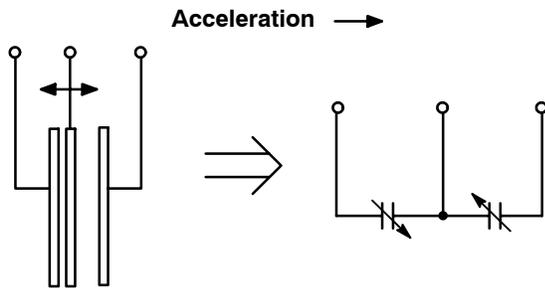


Figure 2. Simplified Transducer Physical Model

BASIC CONNECTIONS

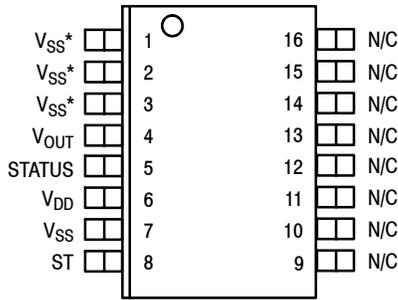


Figure 3. Pinout Description

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

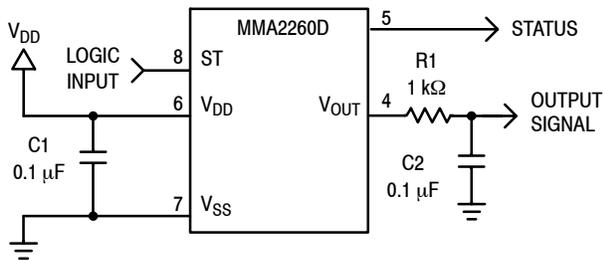


Figure 4. SOIC Accelerometer with Recommended Connection Diagram

PCB Layout

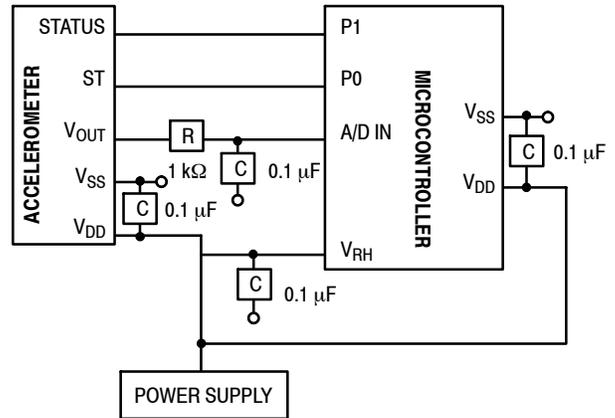
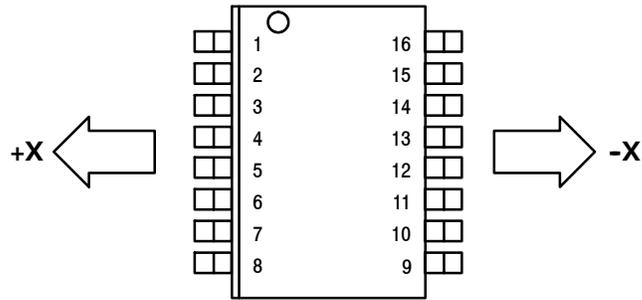


Figure 5. Recommended PCB Layout for Interfacing Accelerometer to Microcontroller

NOTES:

- Use a 0.1 μF 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 internal V_{SS} terminals shown in Figure 3.
- Use an RC filter of 1 k Ω and 0.1 μF on the output of the accelerometer to minimize clock noise (from the switched capacitor filter circuit).
- PCB layout of power and ground should not couple power supply noise.
- Accelerometer and microcontroller should not be 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.

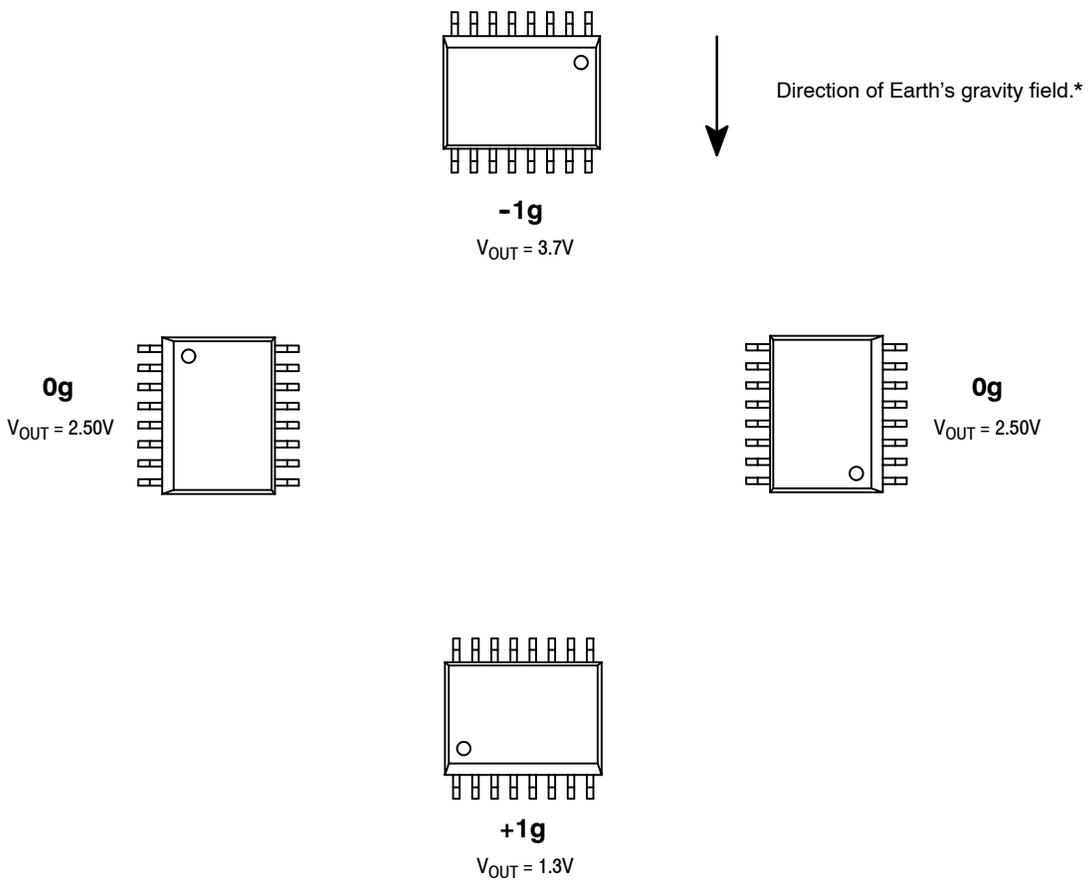
DYNAMIC ACCELERATION



16-Pin SOIC Package

Top View

STATIC ACCELERATION

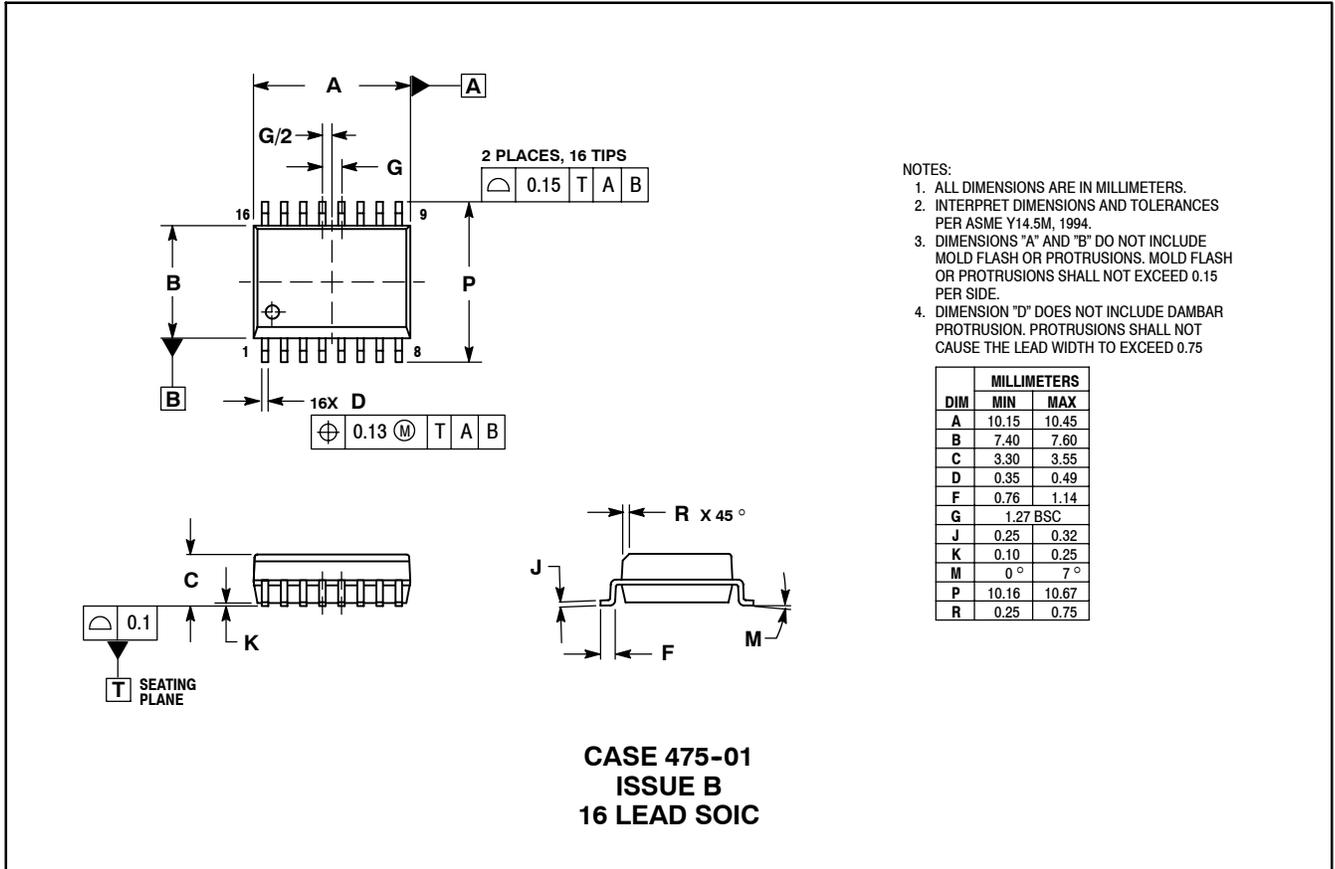


* When positioned as shown, the Earth's gravity will result in a positive 1g output

Freescale Semiconductor, Inc.

PACKAGE DIMENSIONS

Freescale Semiconductor, Inc.



- NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETERS.
 2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M, 1994.
 3. DIMENSIONS "A" AND "B" DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.15 PER SIDE.
 4. DIMENSION "D" DOES NOT INCLUDE DAMBAR PROTRUSION. PROTRUSIONS SHALL NOT CAUSE THE LEAD WIDTH TO EXCEED 0.75

| DIM | MILLIMETERS | |
|-----|-------------|-------|
| | MIN | MAX |
| A | 10.15 | 10.45 |
| B | 7.40 | 7.60 |
| C | 3.30 | 3.55 |
| D | 0.35 | 0.49 |
| F | 0.76 | 1.14 |
| G | 1.27 BSC | |
| J | 0.25 | 0.32 |
| K | 0.10 | 0.25 |
| M | 0° | 7° |
| P | 10.16 | 10.67 |
| R | 0.25 | 0.75 |

Information in this document is provided solely to enable system and software implementers to use Motorola products. There are no express or implied copyright licenses granted hereunder to design or fabricate any integrated circuits or integrated circuits based on the information in this document.

Motorola reserves the right to make changes without further notice to any products herein. Motorola makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does Motorola assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation consequential or incidental damages. "Typical" parameters that may be provided in Motorola data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals", must be validated for each customer application by customer's technical experts. Motorola does not convey any license under its patent rights nor the rights of others. Motorola products are not designed, intended, or authorized for use as components in systems intended for surgical implant into the body, or other applications intended to support or sustain life, or for any other application in which the failure of the Motorola product could create a situation where personal injury or death may occur. Should Buyer purchase or use Motorola products for any such unintended or unauthorized application, Buyer shall indemnify and hold Motorola and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that Motorola was negligent regarding the design or manufacture of the part.

MOTOROLA and the Stylized M Logo are registered in the US Patent and Trademark Office. All other product or service names are the property of their respective owners. Motorola, Inc. is an Equal Opportunity/Affirmative Action Employer.

© Motorola Inc. 2003

HOW TO REACH US:

USA/EUROPE/LOCATIONS NOT LISTED:
Motorola Literature Distribution
P.O. Box 5405, Denver, Colorado 80217
1-800-521-6274 or 480-768-2130

JAPAN: Motorola Japan Ltd.; SPS, Technical Information Center,
3-20-1, Minami-Azabu, Minato-ku, Tokyo 106-8573, Japan
81-3-3440-3569

ASIA/PACIFIC: Motorola Semiconductors H.K. Ltd.; Silicon Harbour Centre,
2 Dai King Street, Tai Po Industrial Estate, Tai Po, N.T., Hong Kong
852-26668334

HOME PAGE: <http://motorola.com/semiconductors>



MOTOROLA

**For More Information On This Product,
Go to: www.freescale.com**

MMA2260D