

# Micromachined Accelerometer

The MMA series of silicon capacitive, micromachined accelerometers features signal conditioning, a 4-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

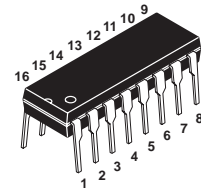
- Integral Signal Conditioning
- Linear Output
- Ratiometric Performance
- 4th Order Bessel Filter Preserves Pulse Shape Integrity
- Calibrated Self-test
- Low Voltage Detect, Clock Monitor, and EPROM Parity Check Status
- Transducer Hermetically Sealed at Wafer Level for Superior Reliability
- Robust Design, High Shocks Survivability
- Two Packaging Options Available:
  - 1) Plastic DIP for Z Axis Sensing (MMA1201P)
  - 2) Wingback for X Axis Sensing (MMA2200W)

## Typical Applications

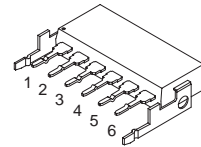
- Vibration Monitoring and Recording
- Appliance Control
- Mechanical Bearing Monitoring
- Computer Hard Drive Protection
- Computer Mouse and Joysticks
- Virtual Reality Input Devices
- Sports Diagnostic Devices and Systems

**MMA1201P**  
**MMA2200W**

**MMA1201P: Z AXIS SENSITIVITY**  
**MMA2200W: X AXIS SENSITIVITY**  
**MICROMACHINED**  
**ACCELEROMETER**  
**±40g**

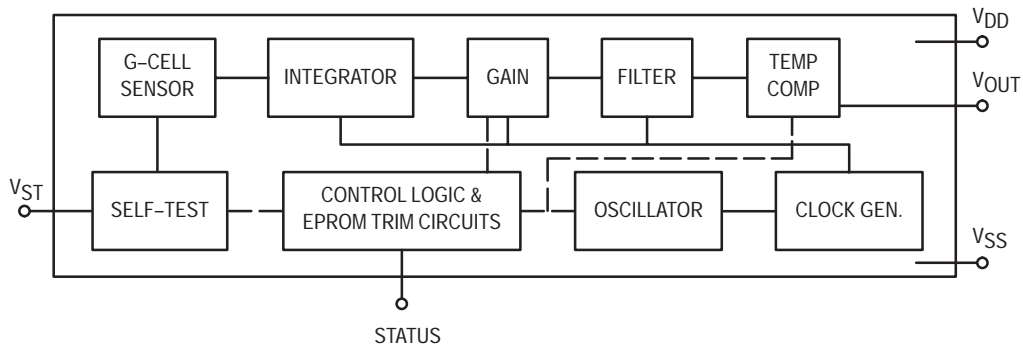


**DIP PACKAGE**  
CASE 648C-04  
MMA1201P



**WB PACKAGE**  
CASE 456-06  
MMA2200W

**SIMPLIFIED ACCELEROMETER FUNCTIONAL BLOCK DIAGRAM**



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

REV 0



**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)	$G_{pd}$	500	g
Unpowered Acceleration (all axes)	$G_{upd}$	2000	g
Supply Voltage	$V_{DD}$	-0.3 to +7.0	V
Drop Test <sup>(1)</sup>	$D_{drop}$	1.2	m
Storage Temperature Range	$T_{stg}$	-40 to +105	°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 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:  $0^{\circ}\text{C} \leq T_A \leq +85^{\circ}\text{C}$ ,  $4.75 \leq V_{DD} \leq 5.25$ , Acceleration = 0g, Loaded output<sup>(1)</sup>)

Characteristic	Symbol	Min	Typ	Max	Unit
Operating Range <sup>(2)</sup>					
Supply Voltage <sup>(3)</sup>	$V_{DD}$	4.75	5.00	5.25	V
Supply Current	$I_{DD}$	4.0	5.0	6.0	mA
Operating Temperature Range	$T_A$	-40	—	+85	$^{\circ}\text{C}$
Acceleration Range	gFS	—	38	—	g
Output Signal					
Zero g ( $V_{DD} = 5.0\text{ V}$ ) <sup>(4)</sup>	$V_{OFF}$	2.2	2.5	2.8	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>(5)</sup>	S	47.5	50	52.5	mV/g
Sensitivity ( $V_{DD} = 5.0\text{ V}$ )	$S_V$	9.3	10	10.7	mV/g/V
Bandwidth Response	$f_{-3dB}$	360	400	440	Hz
Nonlinearity	NL <sub>OUT</sub>	-1.0	—	+1.0	% FSO
Noise					
RMS (.01–1 kHz)	$n_{RMS}$	—	—	3.5	mVrms
Power Spectral Density	$n_{PSD}$	—	110	—	$\mu\text{V}/(\text{Hz}^{1/2})$
Clock Noise (without RC load on output) <sup>(6)</sup>	$n_{CLK}$	—	2.0	—	mVpk
Self-Test					
Output Response	gST	20	—	30	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>(8)</sup>	t <sub>ST</sub>	—	2.0	10	ms
Status <sup>(12)</sup> <sup>(13)</sup>					
Output Low ( $I_{load} = 100\ \mu\text{A}$ )	$V_{OL}$	—	—	0.4	V
Output High ( $I_{load} = 100\ \mu\text{A}$ )	$V_{OH}$	$V_{DD} - .8$	—	—	V
Minimum Supply Voltage (LVD Trip)	$V_{LVD}$	2.7	3.25	4.0	V
Clock Monitor Fail Detection Frequency	$f_{min}$	50	—	260	kHz
Output Stage Performance					
Electrical Saturation Recovery Time <sup>(9)</sup>	t <sub>DELAY</sub>	—	0.2	—	ms
Full Scale Output Range ( $I_{OUT} = 200\ \mu\text{A}$ )	$V_{FSO}$	0.3	—	$V_{DD} - 0.3$	V
Capacitive Load Drive <sup>(10)</sup>	$C_L$	—	—	100	pF
Output Impedance	$Z_O$	—	300	—	$\Omega$
Mechanical Characteristics					
Transverse Sensitivity <sup>(11)</sup>	$V_{ZX,YX}$	—	—	5.0	% FSO
Package Resonance	f <sub>PKG</sub>	—	10	—	kHz

#### NOTES:

- 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.
- 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  $V_{DD}/2$ .
- The device is calibrated at 20g.
- At clock frequency  $\cong 70\text{ kHz}$ .
- 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 ( $60^{\circ}$ ) to guarantee output amplifier stability.
- A measure of the device's ability to reject an acceleration applied  $90^{\circ}$  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 a Low Voltage Detection or Clock Frequency failure occurs, or 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.

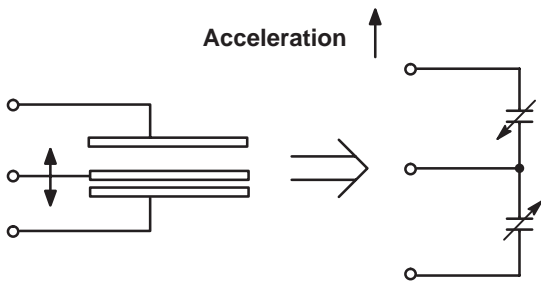
The device consists of a surface micromachined capacitive sensing cell (g-cell) and a CMOS signal conditioning ASIC contained in a single integrated circuit package. The sensing element is sealed hermetically at the wafer level using a bulk micromachined "cap" wafer.

The g-cell is a mechanical structure formed from semiconductor materials (polysilicon) using semiconductor processes (masking and etching). It can be modeled as 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.

**Status**

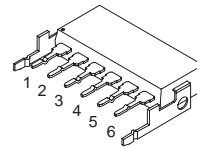
Motorola accelerometers include fault detection circuitry and a fault latch. The Status pin is an output from the fault latch, OR'd with self-test, and is set high whenever one (or more) of the following events occur:

- 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 rising edge on the self-test input pin, unless one (or more) of the fault conditions continues to exist.

**BASIC CONNECTIONS**

**Pinout Description for the Wingback Package**



Pin No.	Pin Name	Description
1	—	Leave unconnected or connect to signal ground
2	ST	Logic input pin to initiate self test
3	VOUT	Output voltage
4	Status	Logic output pin to indicate fault
5	VSS	Signal ground
6	VDD	Supply voltage (5 V)
—	Wings	Support pins, internally connected to lead frame. Tie to VSS.

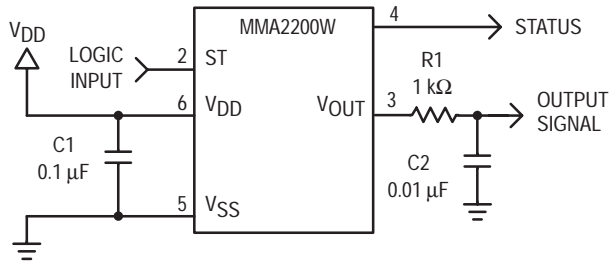


Figure 4. Wingback Accelerometer with Recommended Connection Diagram

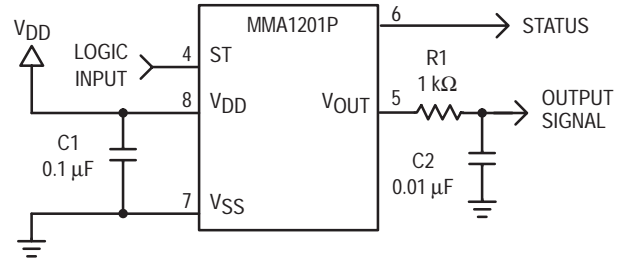
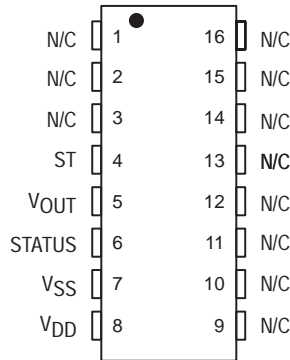


Figure 5. DIP Accelerometer with Recommended Connection Diagram

Pinout Description for the DIP Package



Pin No.	Pin Name	Description
1	—	Leave unconnected or connect to signal ground.
2 thru 3	—	No internal connection. Leave unconnected.
4	ST	Logic input pin to initiate self test.
5	VOUT	Output voltage
6	Status	Logic output pin to indicate fault.
7	VSS	Signal ground
8	VDD	Supply voltage (5 V)
9 thru 13	Trim Pins	Used for factory trim. Leave unconnected.
14 thru 16	—	No internal connection. Leave unconnected.

PCB Layout

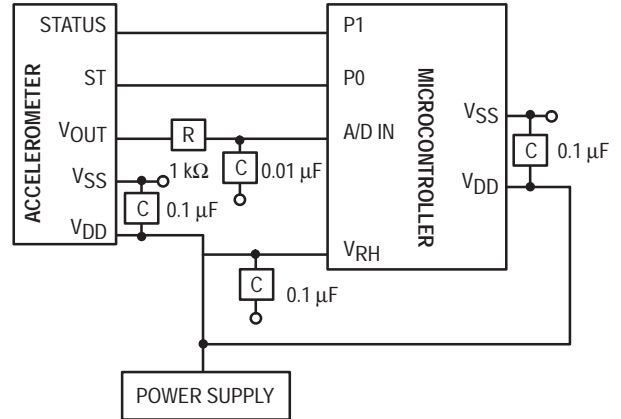


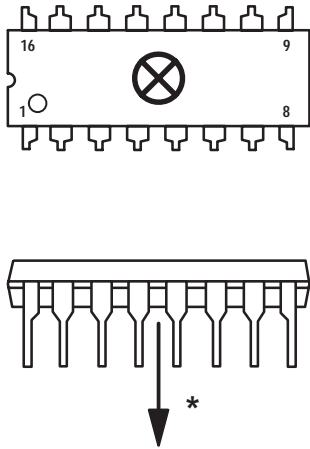
Figure 6. Recommend PCB Layout for Interfacing Accelerometer to Microcontroller

NOTES:

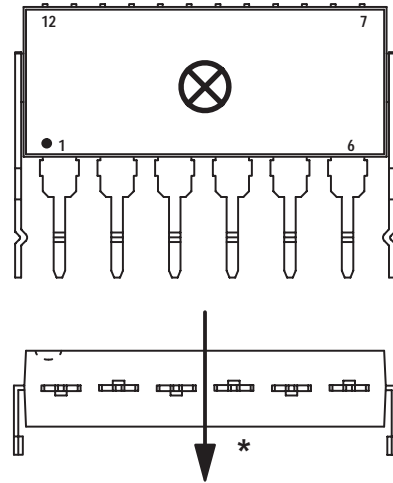
- Use a 0.1 μF capacitor on VDD to decouple the power source.
- Physical coupling distance of the accelerometer to the microcontroller should be minimal.
- Place a ground plane beneath the accelerometer to reduce noise, the ground plane should be attached to all of the open ended terminals shown in Figure 6.
- 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).
- 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.

Positive Acceleration Sensing Direction

DIP PACKAGE



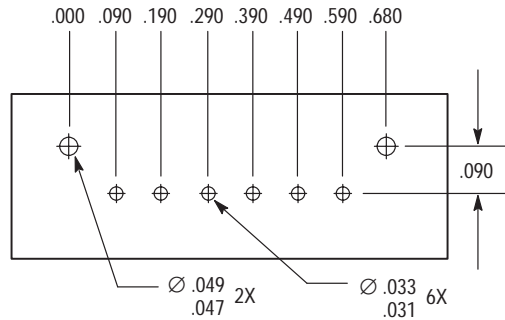
WINGBACK PACKAGE



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

Drilling Patterns

WB PACKAGE DRILLING PATTERN

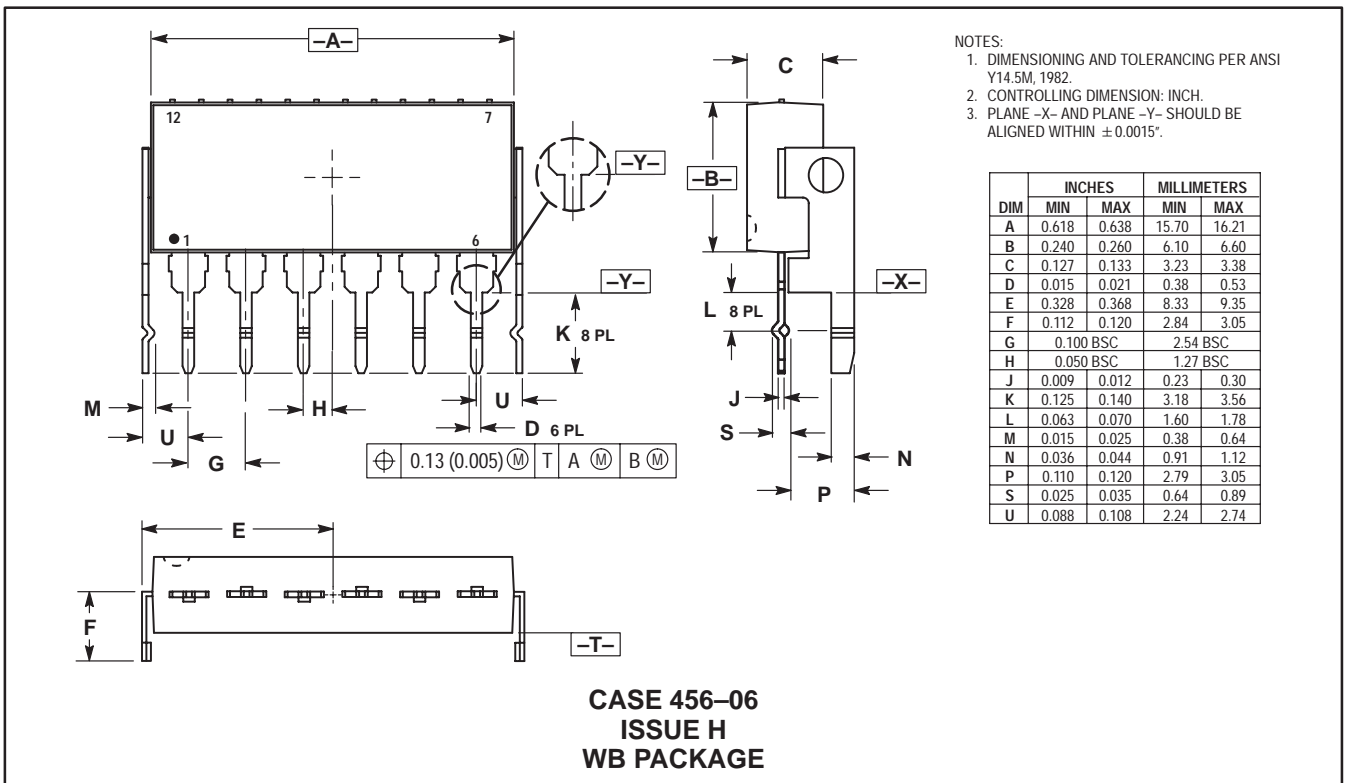
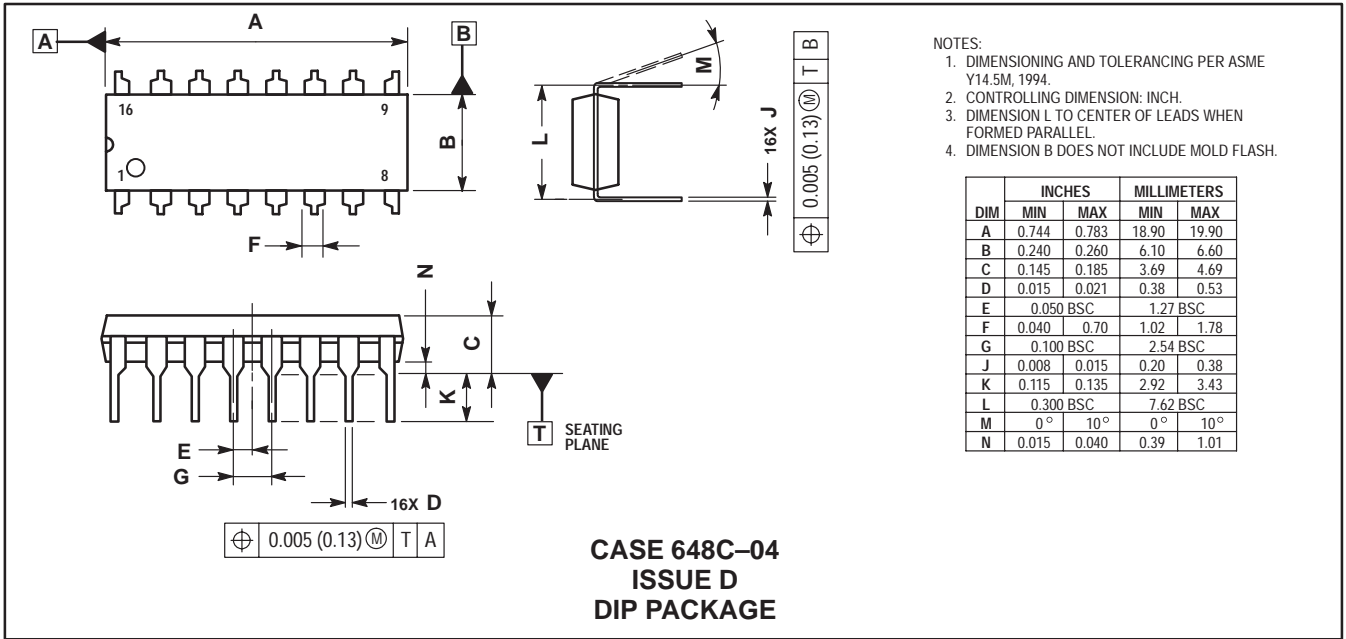


Measurement in inches


ORDERING INFORMATION

Device	Temperature Range	Case No.	Package
MMA1201P	-40 to +85°C	Case 648C-04	Plastic DIP
MMA2200W	-40 to +85°C	Case 456-06	Plastic Wingback

**PACKAGE DIMENSIONS**



Mfax is a trademark of Motorola, Inc.

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 which 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  are registered trademarks of Motorola, Inc. Motorola, Inc. is an Equal Opportunity/Affirmative Action Employer.

**How to reach us:**

**USA/EUROPE/Locations Not Listed:** Motorola Literature Distribution; P.O. Box 5405, Denver, Colorado 80217.  
1-303-675-2140 or 1-800-441-2447

**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

**Customer Focus Center: 1-800-521-6274**

**Mfax™:** RMFAX0@email.sps.mot.com – TOUCHTONE 1-602-244-6609  
Motorola Fax Back System – US & Canada ONLY 1-800-774-1848  
– <http://sps.motorola.com/mfax/>

**HOME PAGE:** <http://motorola.com/sps/>





SUNSTAR商斯达实业集团是集研发、生产、工程、销售、代理经销、技术咨询、信息服务等为一体的高科技企业，是专业高科技电子产品生产厂家，是具有10多年历史的专业电子元器件供应商，是中国最早和最大的仓储式连锁规模经营大型综合电子零部件代理分销商之一，是一家专业代理和分销世界各大品牌IC芯片和电子元器件的连锁经营综合性国际公司。在香港、北京、深圳、上海、西安、成都等全国主要电子市场设有直属分公司和产品展示展销窗口门市部专卖店及代理分销商，已在全国范围内建成强大统一的供货和代理分销网络。我们专业代理经销、开发生产电子元器件、集成电路、传感器、微波光电元器件、工控机/DOC/DOM电子盘、专用电路、单片机开发、MCU/DSP/ARM/FPGA软件硬件、二极管、三极管、模块等，是您可靠的一站式现货配套供应商、方案提供商、部件功能模块开发配套商。专业以现代信息产业（计算机、通讯及传感器）三大支柱之一的传感器为主营业务，专业经营各类传感器的代理、销售生产、网络信息、科技图书资料及配套产品设计、工程开发。我们的专业网站——中国传感器科技信息网（全球传感器数据库）[www.SENSOR-IC.COM](http://www.SENSOR-IC.COM) 服务于全球高科技生产商及贸易商，为企业科技产品开发提供技术交流平台。欢迎各厂商互通有无、交换信息、交换链接、发布寻求代理信息。欢迎国外高科技传感器、变送器、执行器、自动控制产品厂商介绍产品到中国，共同开拓市场。本网站是关于各种传感器-变送器-仪器仪表及工业自动化大型专业网站，深入到工业控制、系统工程计 测量、自动化、安防报警、消费电子等众多领域，把最新的传感器-变送器-仪器仪表买卖信息，最新技术供求，最新采购商，行业动态，发展方向，最新的技术应用和市场资讯及时的传递给广大科技开发、科学研究、产品设计人员。本网站已成功为石油、化工、电力、医药、生物、航空、航天、国防、能源、冶金、电子、工业、农业、交通、汽车、矿山、煤炭、纺织、信息、通信、IT、安防、环保、印刷、科研、气象、仪器仪表等领域从事科学研究、产品设计、开发、生产制造的科技人员、管理人员、和采购人员提供满意服务。我公司专业生产、代理、经销、销售各种传感器、变送器、敏感元器件、开关、执行器、仪器仪表、自动化控制系统：专业从事设计、生产、销售各种传感器、变送器、各种测控仪表、热工仪表、现场控制器、计算机控制系统、数据采集系统、各类环境监控系统、专用控制系统应用软件以及嵌入式系统开发及应用等工作。如热敏电阻、压敏电阻、温度传感器、温度变送器、湿度传感器、湿度变送器、气体传感器、气体变送器、压力传感器、压力变送、称重传感器、物（液）位传感器、物（液）位变送器、流量传感器、流量变送器、电流（压）传感器、溶氧传感器、霍尔传感器、图像传感器、超声波传感器、位移传感器、速度传感器、加速度传感器、扭距传感器、红外传感器、紫外传感器、火焰传感器、激光传感器、振动传感器、轴角传感器、光电传感器、接近传感器、干簧管传感器、继电器传感器、微型电泵、磁敏（阻）传感器、压力开关、接近开关、光电开关、色标传感器、光纤传感器、齿轮测速传感器、时间继电器、计数器、计米器、温控仪、固态继电器、调压模块、电磁铁、电压表、电流表等特殊传感器。同时承接传感器应用电路、产品设计和自动化工程项目。

更多产品请看本公司产品专用销售网站：

商斯达中国传感器科技信息网：<http://www.sensor-ic.com/>

商斯达工控安防网：<http://www.pc-ps.net/>

商斯达电子元器件网：<http://www.sunstare.com/>

商斯达微波光电产品网：[HTTP://www.rfoe.net/](http://www.rfoe.net/)

商斯达消费电子产品网：<http://www.icasic.com/>

商斯达军工产品网：<http://www.junpinic.com/>

商斯达实业科技产品网：<http://www.sunstars.cn/> 传感器销售热线：

地址：深圳市福田区福华路福庆街鸿图大厦1602室

电话：0755-83607652 83376489 83376549 83370250 83370251 82500323

传真：0755-83376182 (0) 13902971329 MSN: [SUNS888@hotmail.com](mailto:SUNS888@hotmail.com)

邮编：518033 E-mail: [szss20@163.com](mailto:szss20@163.com) QQ: 195847376

深圳赛格展销部：深圳华强北路赛格电子市场2583号 电话：0755-83665529 25059422

技术支持：0755-83394033 13501568376

欢迎索取免费详细资料、设计指南和光盘；产品凡多，未能尽录，欢迎来电查询。

北京分公司：北京海淀区知春路132号中发电子大厦3097号

TEL: 010-81159046 82615020 13501189838 FAX: 010-62543996

上海分公司：上海市北京东路668号上海赛格电子市场D125号

TEL: 021-28311762 56703037 13701955389 FAX: 021-56703037

西安分公司：西安高新开发区20所(中国电子科技集团导航技术研究所)

西安劳动南路88号电子商城二楼D23号

TEL: 029-81022619 13072977981 FAX: 029-88789382