

# ±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

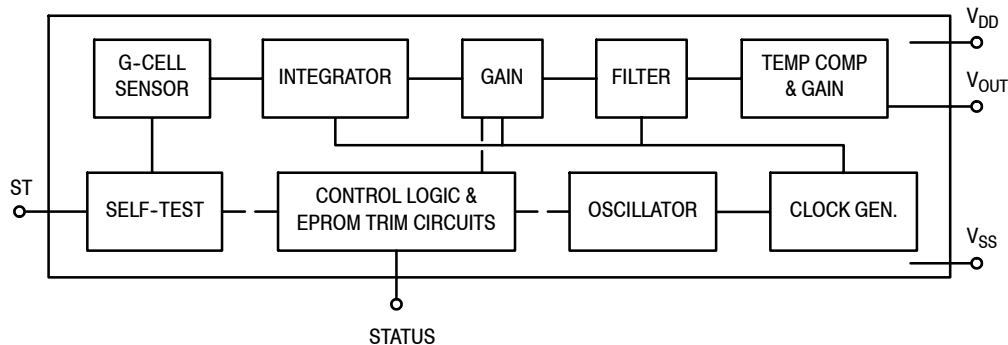
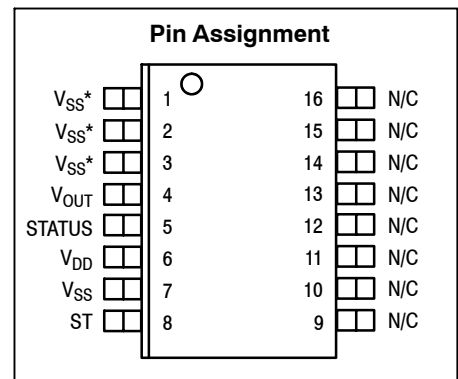
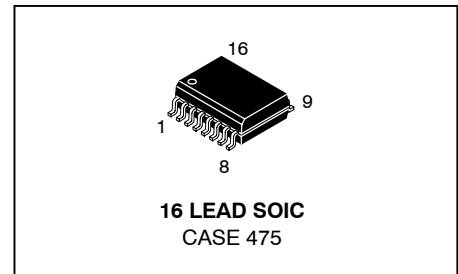
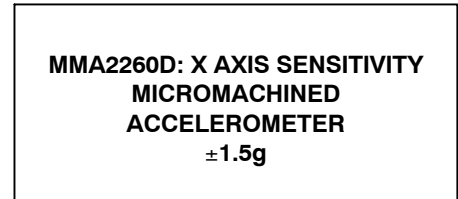


Figure 1. Simplified Accelerometer Functional Block Diagram

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**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 <sup>(1)</sup>	$H_{drop}$	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.

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## 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<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	$I_{DD}$	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 ( $V_{DD} = 5.0\text{ V}$ ) <sup>(4)</sup>	$V_{OFF}$	2.3	2.5	2.7	V
Sensitivity ( $T_A = 25^{\circ}\text{C}$ , $V_{DD} = 5.0\text{ V}$ ) <sup>(5)</sup>	S	1140	1200	1260	mV/g
Sensitivity ( $V_{DD} = 5.0\text{ V}$ ) <sup>(5)</sup>	S	1110	1200	1290	mV/g
Bandwidth Response	$f_{-3dB}$	40	50	60	Hz
Nonlinearity	NL <sub>OUT</sub>	-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) <sup>(6)</sup>	$n_{SD}$	—	350	—	$\mu\text{g}/\sqrt{\text{Hz}}$
Self-Test					
Output Response ( $V_{DD} = 5.0\text{ V}$ )	$\Delta V_{ST}$	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 <sup>(7)</sup>	$I_{IN}$	-50	-125	-300	$\mu\text{A}$
Response Time <sup>(8)</sup>	$t_{ST}$	—	20	25	ms
Status <sup>(12)(13)</sup>					
Output Low ( $I_{load} = 100\ \mu\text{A}$ )	$V_{OL}$	—	—	0.4	V
Output High ( $I_{load} = -100\ \mu\text{A}$ )	$V_{OH}$	$V_{DD} - 0.8$	—	—	V
Output Stage Performance					
Electrical Saturation Recovery Time <sup>(9)</sup>	$t_{DELAY}$	—	—	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 <sup>(10)</sup>	$C_L$	—	—	100	pF
Output Impedance	$Z_O$	—	50	—	$\Omega$
Mechanical Characteristics					
Transverse Sensitivity <sup>(11)</sup>	$V_{YX,ZX}$	—	—	5.0	% FSO

### NOTES:

- For a loaded output the measurements are observed after an RC filter consisting of a 1 k $\Omega$  resistor and a 0.1  $\mu\text{F}$  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  $V_{DD}/2$ .
- 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 ( $60^{\circ}$ ) 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 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,  $\epsilon$  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.

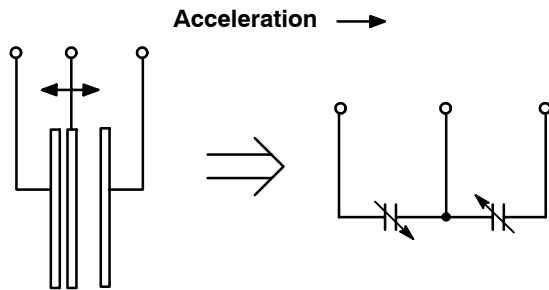


Figure 2. Simplified Transducer Physical Model

## BASIC CONNECTIONS

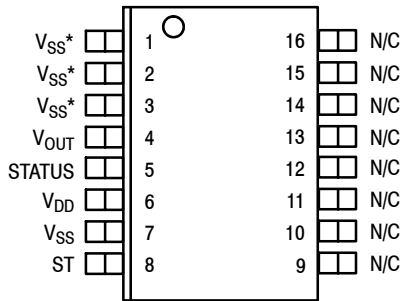


Figure 3. Pinout Description

Pin No.	Pin Name	Description
1 thru 3	V <sub>SS</sub> *	Redundant connections to the internal V <sub>SS</sub> and may be left unconnected.
4	V <sub>OUT</sub>	Output voltage of the accelerometer.
5	STATUS	Logic output pin used to indicate fault.
6	V <sub>DD</sub>	The power supply input.
7	V <sub>SS</sub>	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.

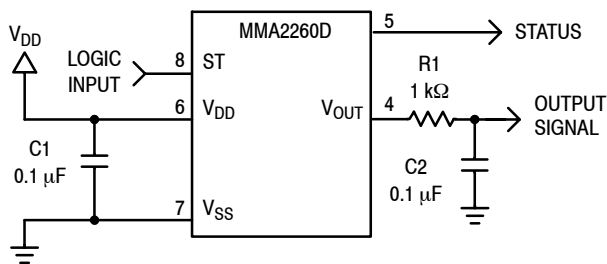


Figure 4. SOIC Accelerometer with Recommended Connection Diagram

## PCB Layout

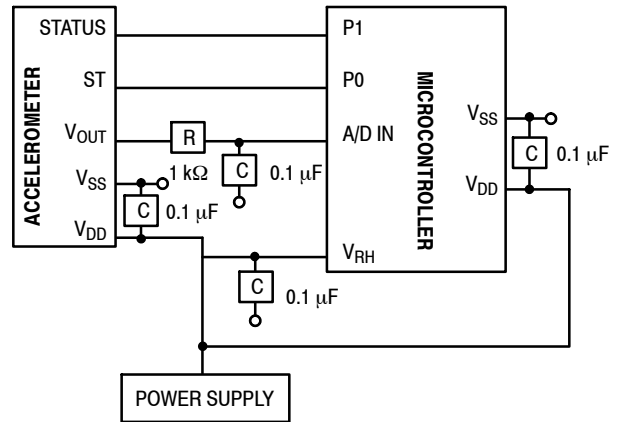
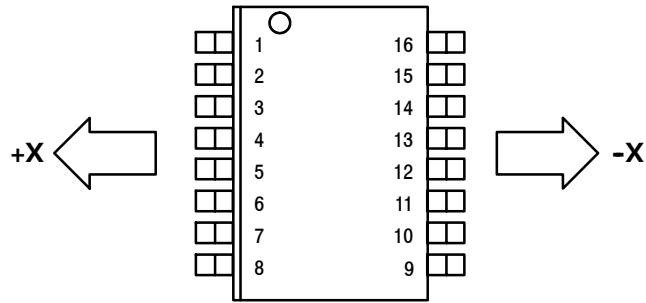


Figure 5. Recommended PCB Layout for Interfacing Accelerometer to Microcontroller

### NOTES:

- Use a 0.1 µF capacitor on V<sub>DD</sub> 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<sub>SS</sub> terminals shown in Figure 3.
- Use an RC filter of 1 kΩ 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.

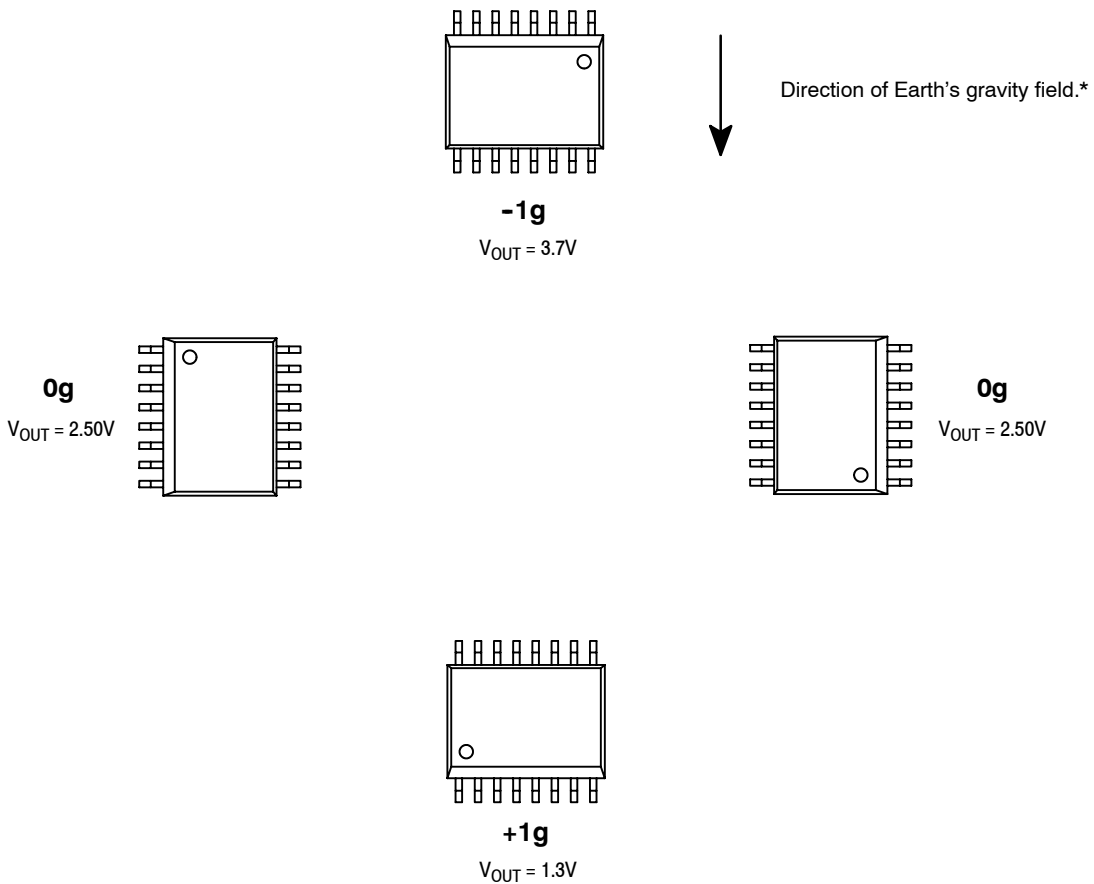
**DYNAMIC ACCELERATION**



16-Pin SOIC Package

**Top View**

**STATIC ACCELERATION**

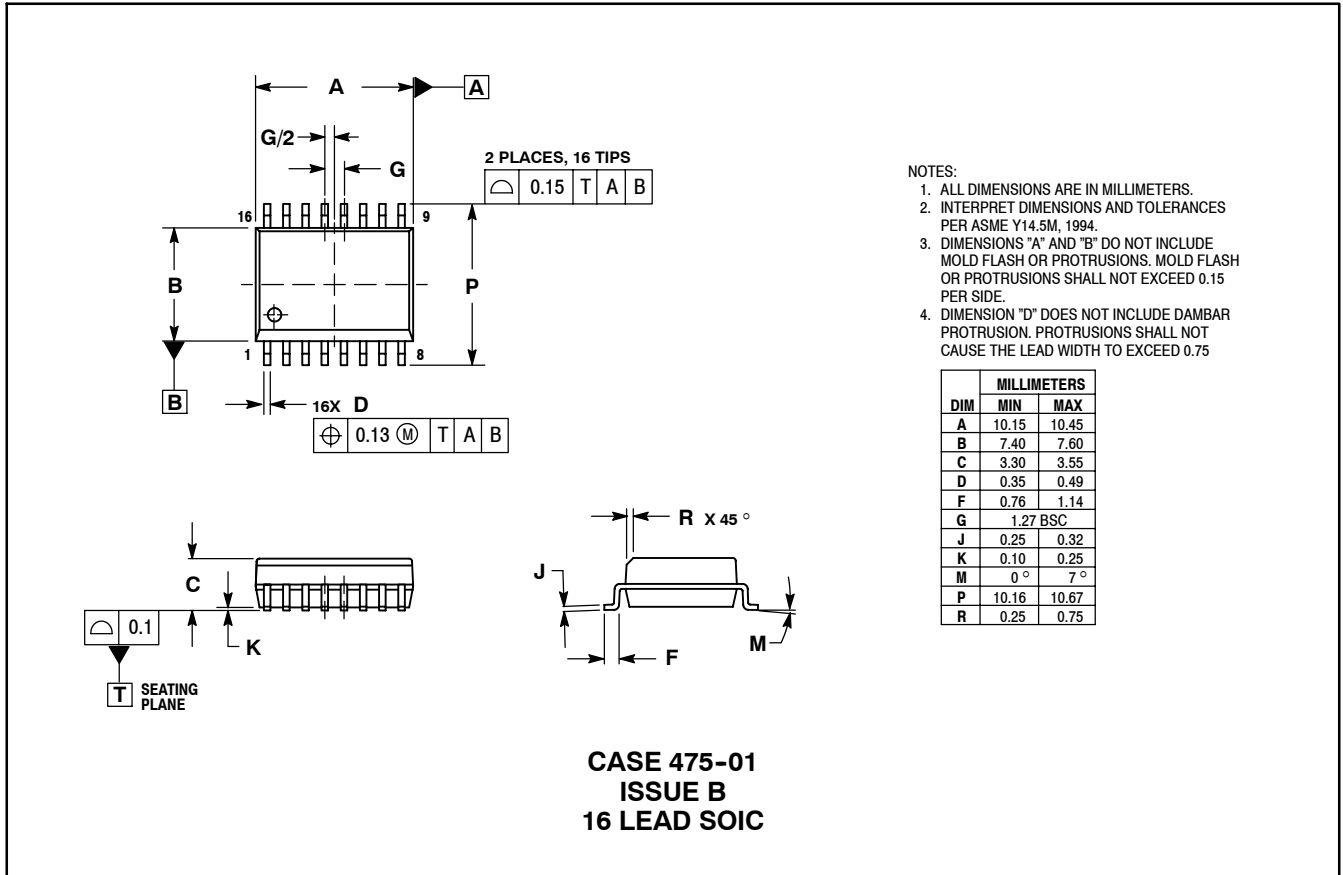


\* When positioned as shown, the Earth's gravity will result in a positive 1g output

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## PACKAGE DIMENSIONS

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**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

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