ECGR 6185

Advanced Embedded Systems

Accelerometers

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Summary

- Definition of Acceleration
- Acceleration fundamentals
- Need for Acceleration measurement.
- Types of Accelerometers.
  - **Capacitive Acceleration Sensor (CAS).**
  - **Piezoelectric Acceleration sensor.**
  - **Piezo-resistive Acceleration sensor.**
  - **Hall Effect.**
  - **Magneto resistive sensor.**
- Applications of Accelerometers

Acceleration Fundamentals

- **What is Acceleration?**
  - Definition: the time rate of change of velocity
  - A.K.A.: the time rate of change of the time rate of change of distance

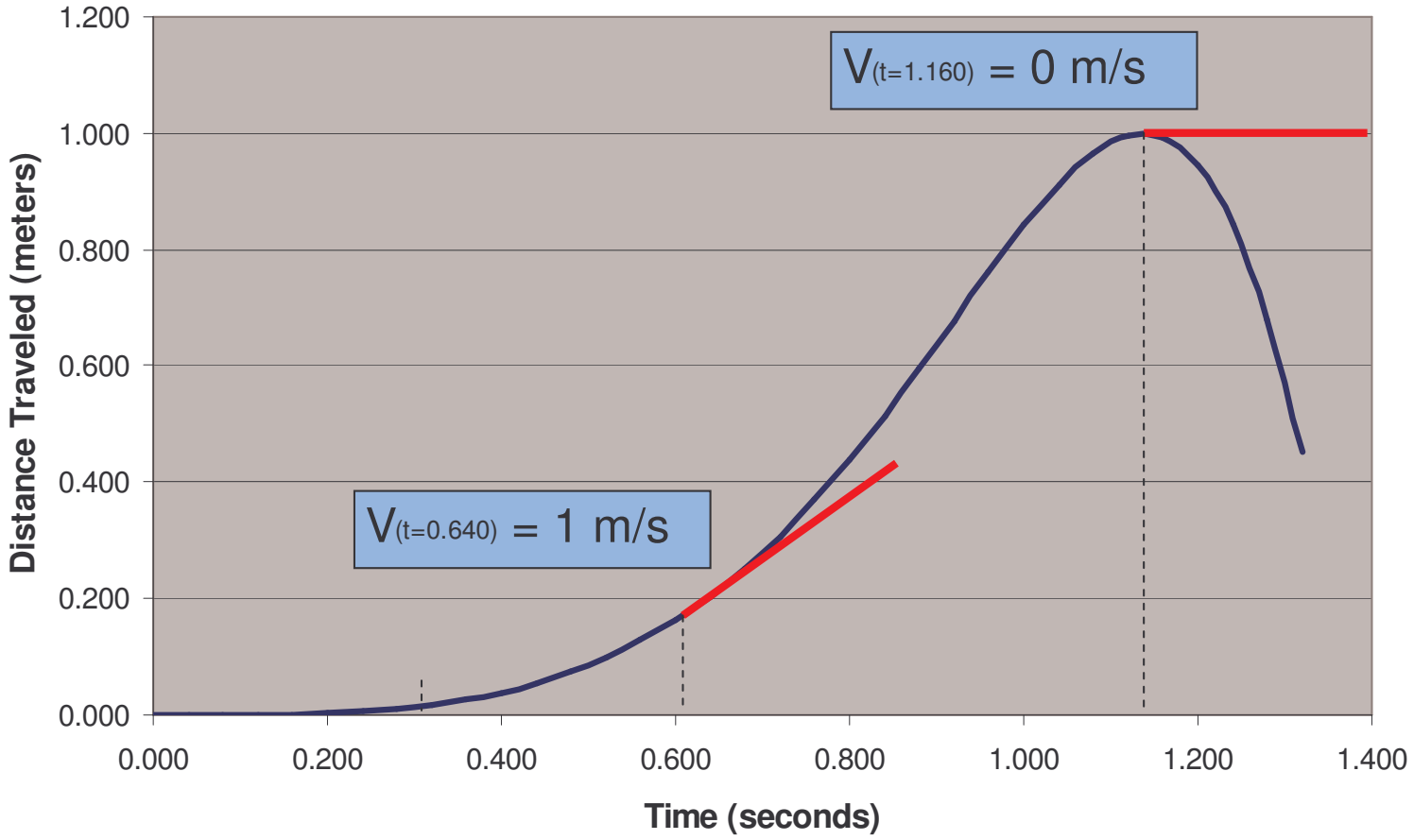
$$a = \frac{\partial v}{\partial t} = \frac{\partial^2 x}{\partial t^2}$$

- **What are the units?**
  - Acceleration is measured in (ft/s)/s or (m/s)/s
- **What is a "g"?**
  - A "g" is a unit of acceleration equal to Earth's gravity at sea level
    - 1 g = 32.2 ft/s2 or 9.81 m/s2

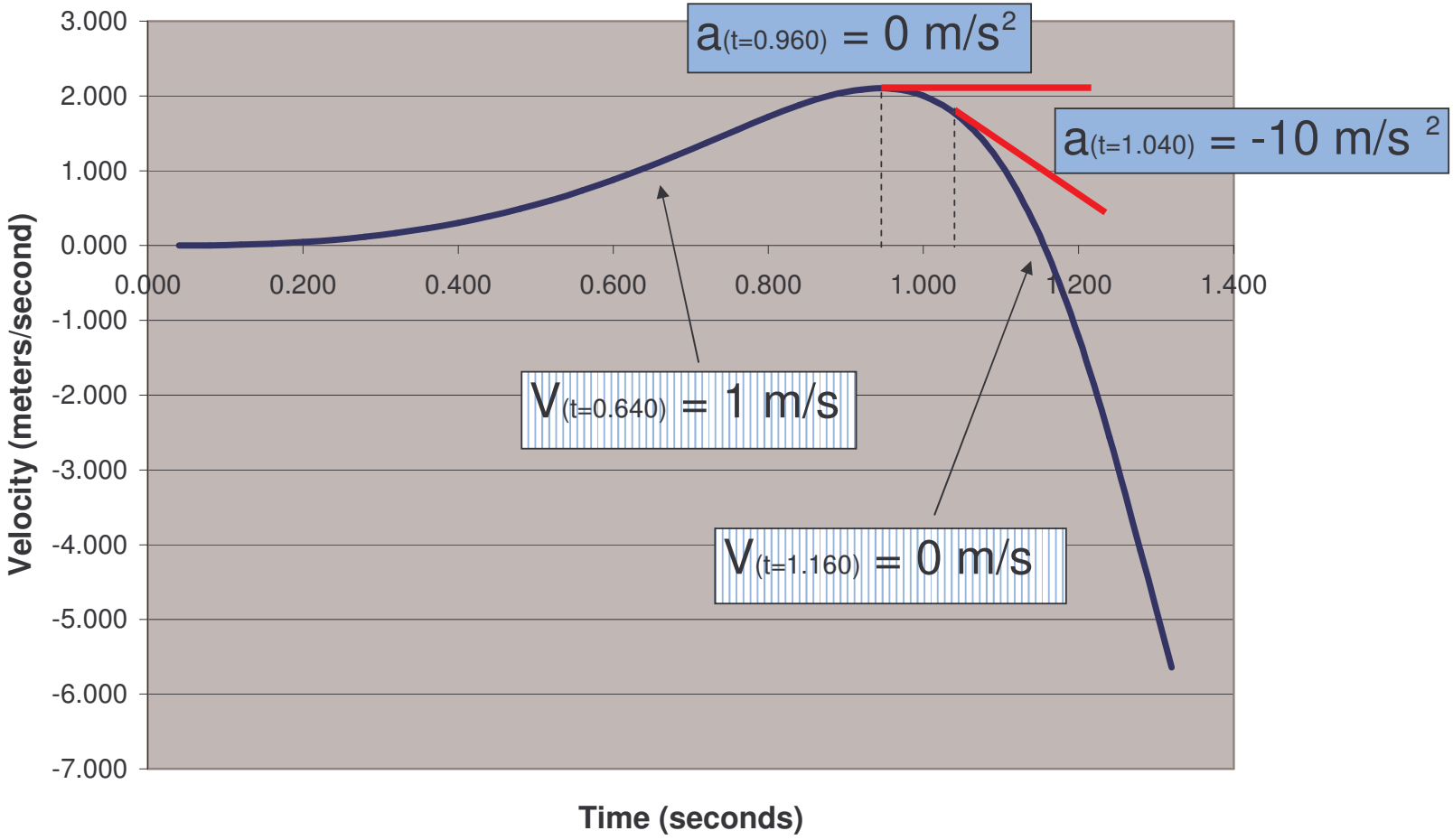
Acceleration concepts

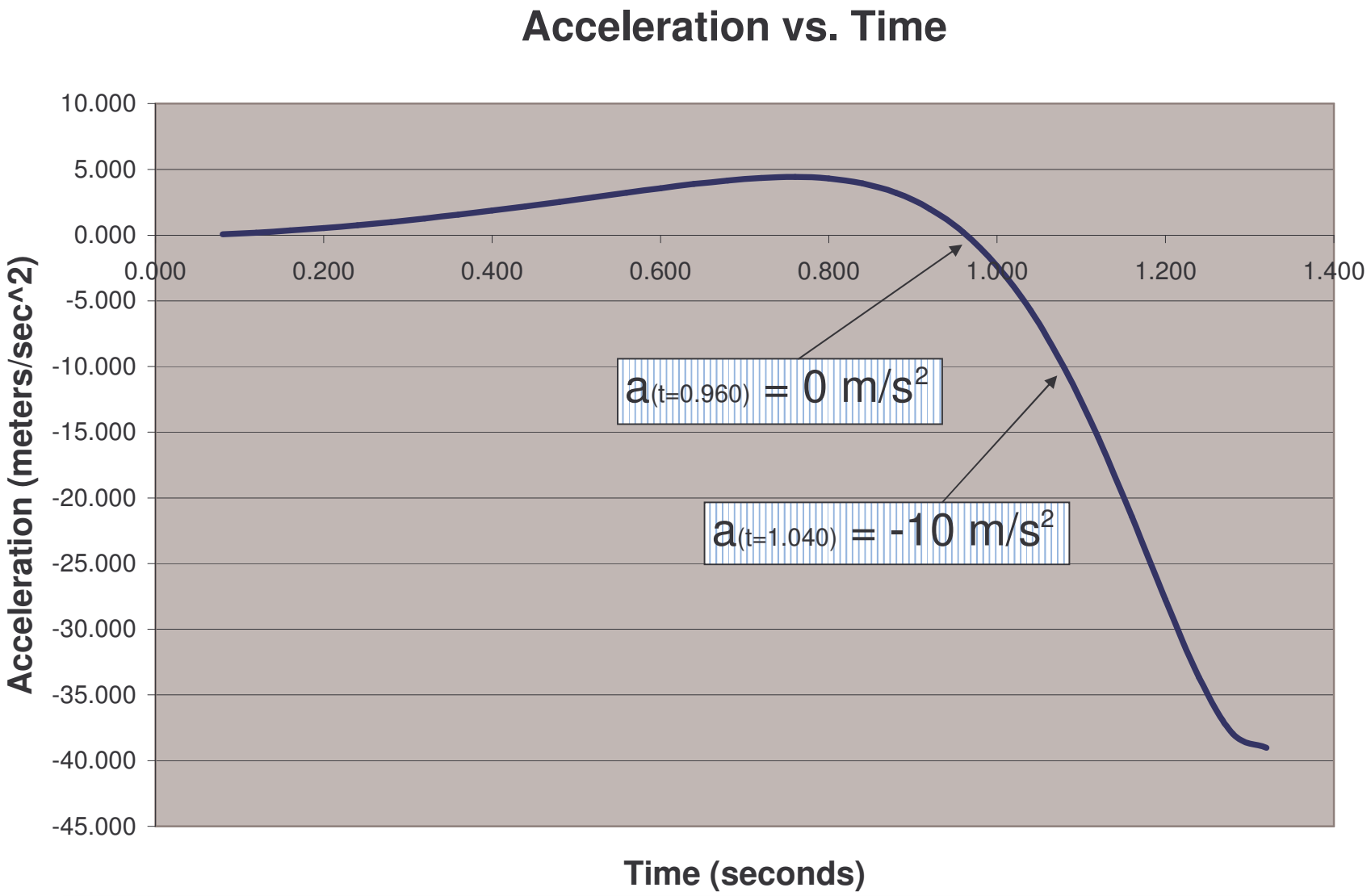
- **What is the time rate of change of velocity?**
  - When plotted on a graph, velocity is the slope of distance versus time
  - Acceleration is the slope of velocity versus time

How to find velocity from distance travelled



How to find acceleration from velocity




Acceleration vs. Time
Acceleration (meters/sec^2)
10.000
5.000
0.000
-5.000
-10.000
-15.000
-20.000
-25.000
-30.000
-35.000
-40.000
-45.000
0.000
0.200
0.400
0.600
0.800
1.000
1.200
1.400
a(t=0.960) = 0 m/s2
a(t=1.040) = -10 m/s2
Time (seconds)

Acceleration in Human Terms

- **What are some "g" reference points?**

Description	"g" level
Earth's gravity	1g
Passenger car in corner	2g
Bumps in road	2g
Indy car driver in corner	3g
Bobsled rider in corner	5g
Human unconsciousness	7g
Space shuttle	10g

Need for Acceleration measurement.

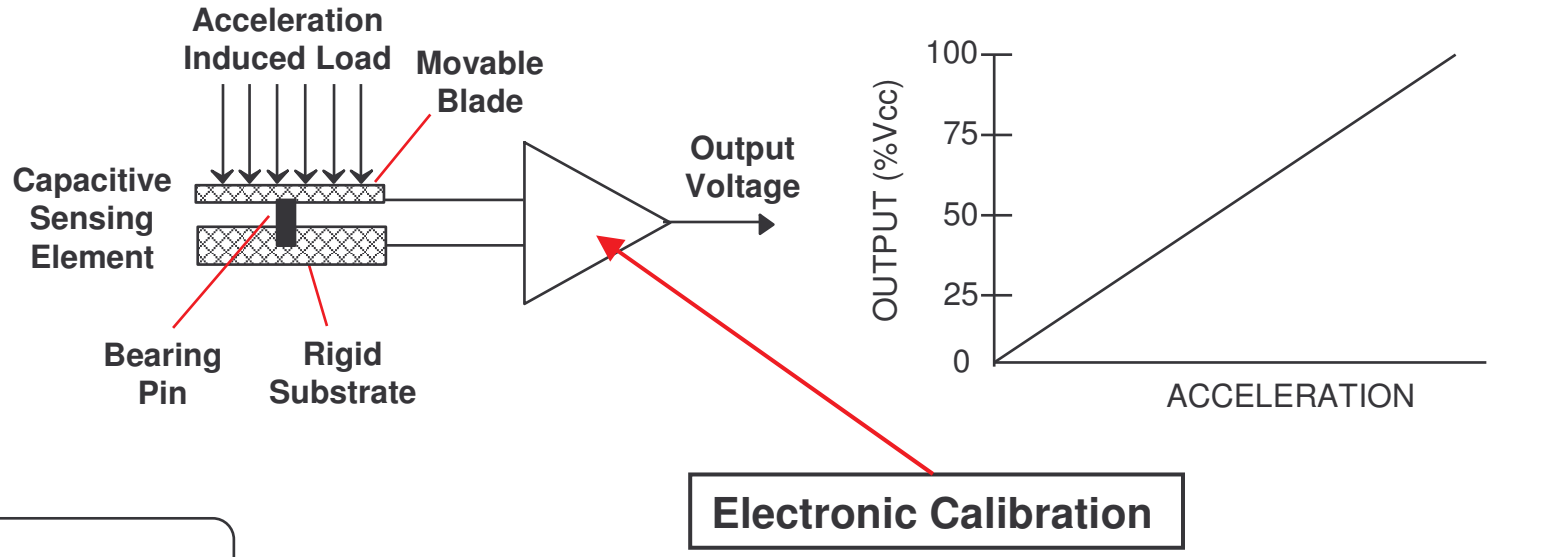
- **Why measure acceleration?**
  - Acceleration is a physical characteristic of a system.
  - The measurement of acceleration is used as an input into some types of control systems.
  - The control systems use the measured acceleration to correct for changing dynamic conditions

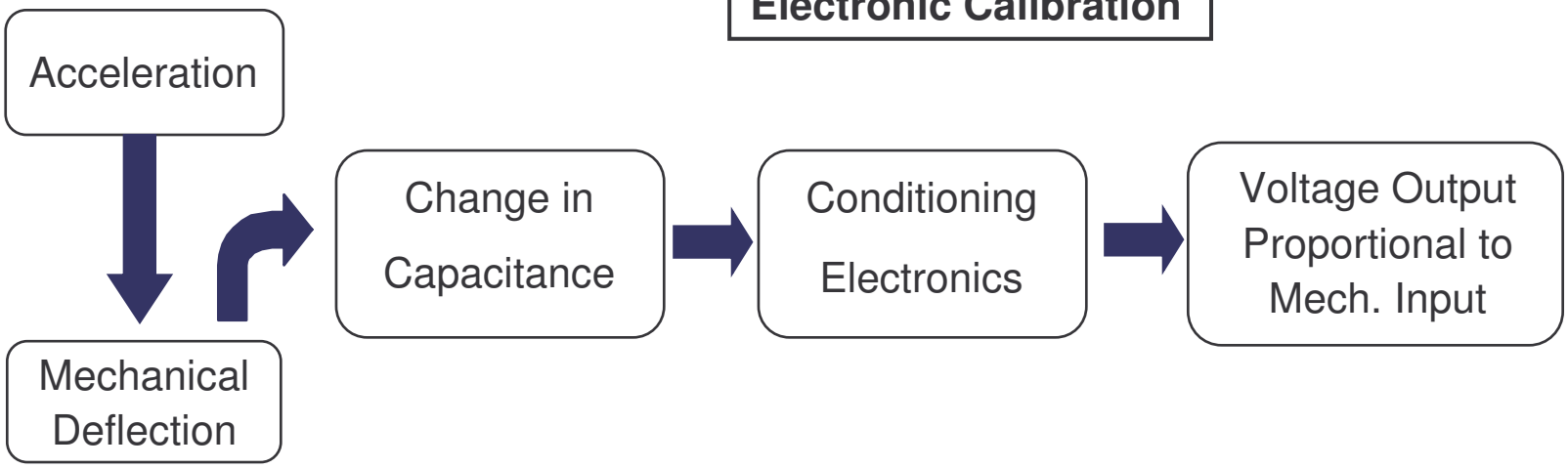
Common types of Accelerometers

Sensor Category	Key Technologies
Capacitive	-Metal beam or micromachined feature produces capacitance; change in capacitance related to acceleration
Piezoelectric	-Piezoelectric crystal mounted to mass – voltage output converted to acceleration
Piezoresistive	-Beam or micromachined feature whose resistance changes with acceleration
Hall Effect	-Motion converted to electrical signal by sensing of changing magnetic fields
Magnetoresistive	-Material resistivity changes in presence of magnetic field
Heat Transfer	-Location of heated mass tracked during acceleration by sensing temperature

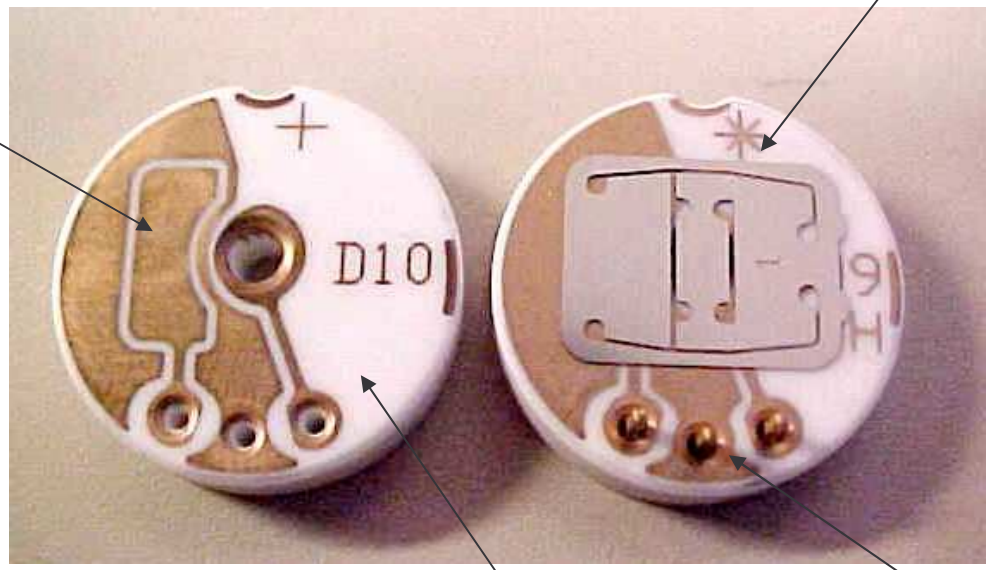
CAS - Capacitive Acceleration Sensor

Conceptual Design





Capacitive Sensing Element



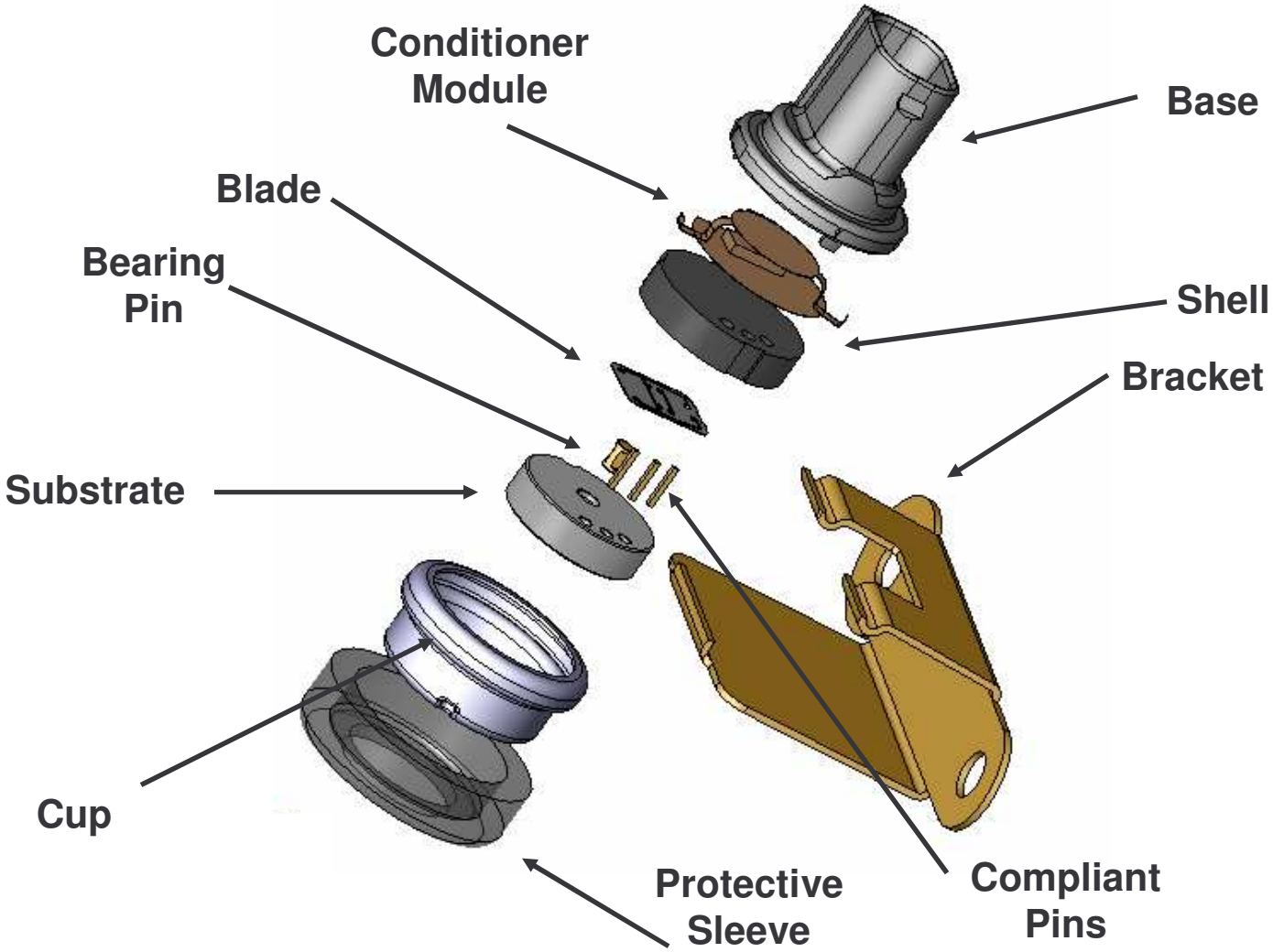
Capacitance generated by electrical current through parallel plates:

$$C = \frac{Ke_oA}{d}$$

C = capacitance
K = dielectric constant of the insulating medium
e_o = permittivity of free space
A = effective area
d = distance between plates (gap)

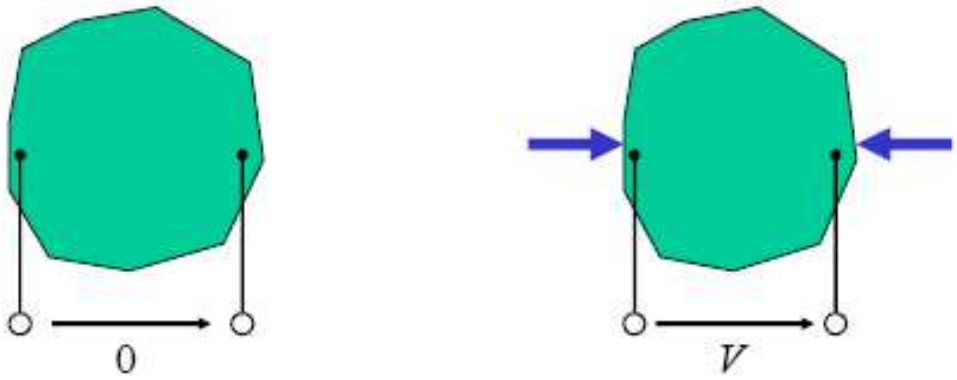
function of acceleration

Capacitive Acceleration Sensor



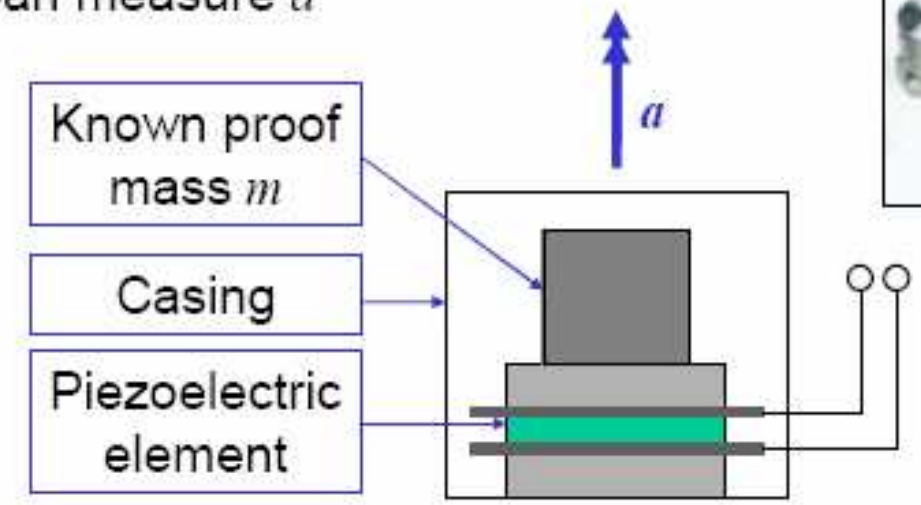
Piezoelectric: Operation

The Piezoelectric effect: some crystalline materials (e.g. quartz) generate a small voltage when they are distorted.



Piezoelectric: Applications

- Accelerometers
  - F measured (force in piezo)
  - m known
  - $F = ma$
  - Can measure a

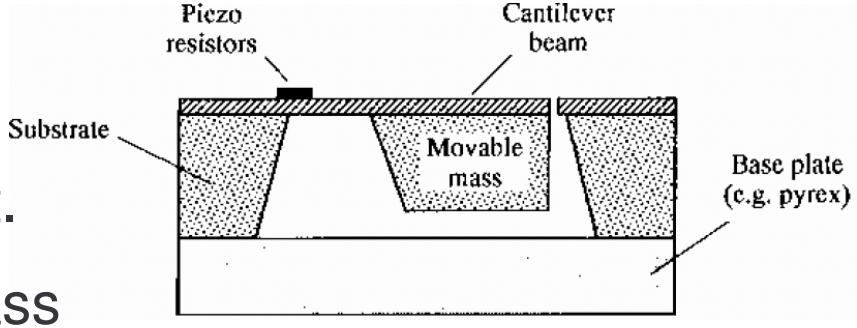


Piezoresistive Accelerometers

Piezoresistance: Resistance of the material changes due to force applied.

Piezoresistive Accelerometer

- Incorporates a cantilever beam that works as a spring element.
- The crystal carries a seismic mass
- Piezo resistors are an integral part of the beam.
- The deflection of the cantilever beam under the acceleration causes deformation of the piezoresistors.
- Temperature dependent



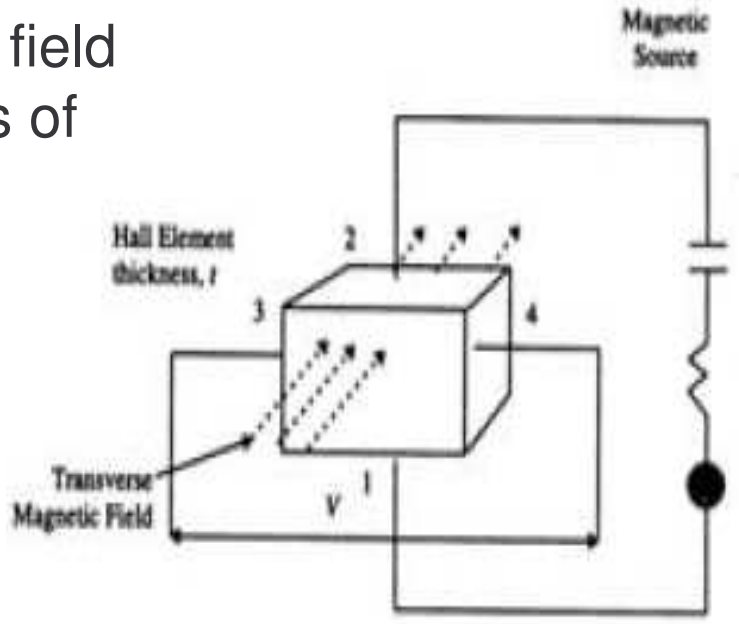
Piezoresistive Accelerometers

- Use one or more resistive legs
- Measure DC coupled steady state conditions
- Externally powered
- Sensitivity of bridge varies with the input excitation voltage.
- Requires a highly stable and quiet excitation supply
- Differential amplifier is required between the two output leads
- Or both leads are floating, allows one output line to be tied to ground
- Amplifier cancels any equal noise picked up at the output

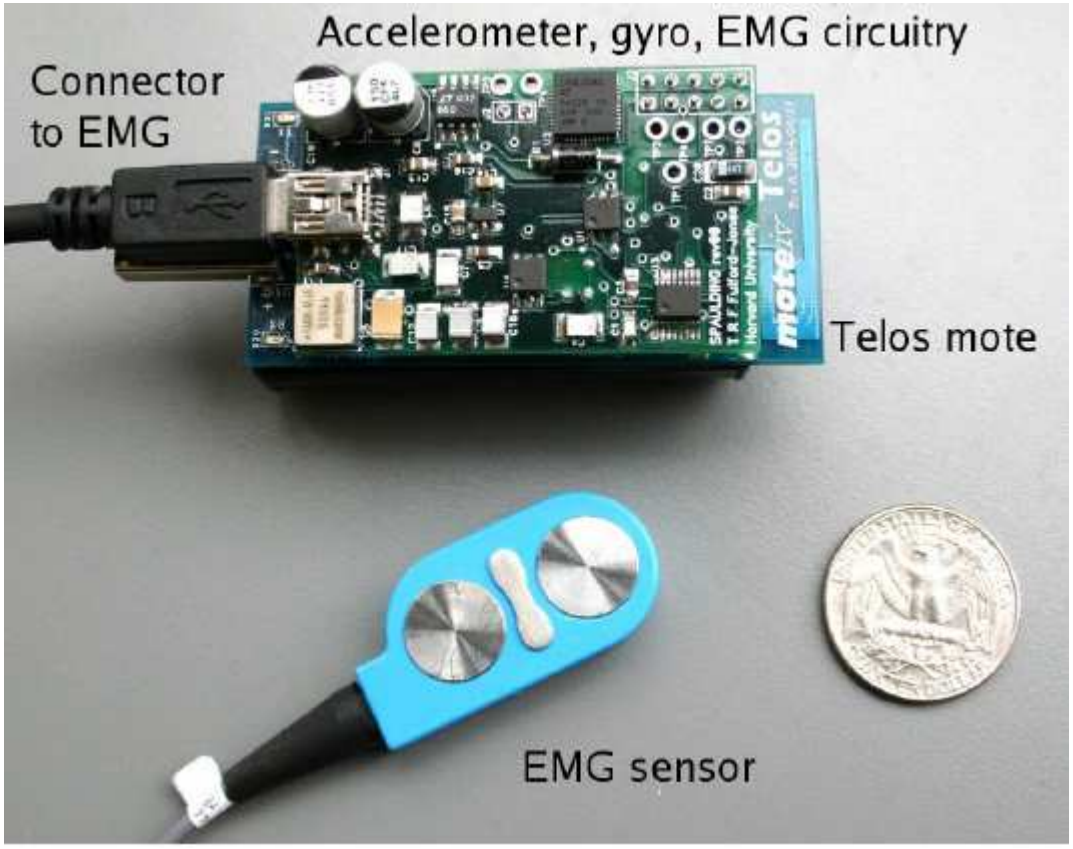
Hall Effect Transducers

Hall effect occurs when a strip of conducting material carries current in the presence of a transverse magnetic field. The hall effect results in the production of electric field perpendicular to the directions of both magnetic filed and the current with the magnitude proportional to the product of magnetic field strength, current and various properties of the conductor.

In the absence of magnetic field, potential between 3 & 4 are same. When magnetic flux passes through the conductor as shown, potential V appears between 3 &4.



Micro Electro Mechanical Systems



Typical Accelerometer Applications

- Tilt / Roll
- Vibration / “Rough-road” detection
  - Can be used to isolate vibration of mechanical system from outside sources
- Vehicle skid detection
  - Often used with systems that deploy “smart” braking to regain control of vehicle
- Impact detection
  - To determine the severity of impact, or to log when an impact has occurred
- Input / feedback for active suspension control systems
  - Keeps vehicle level

References

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Accelerometer Application Video

Thank You

?????Questions?????