CSE 162 Mobile Computing

Moble Sensors

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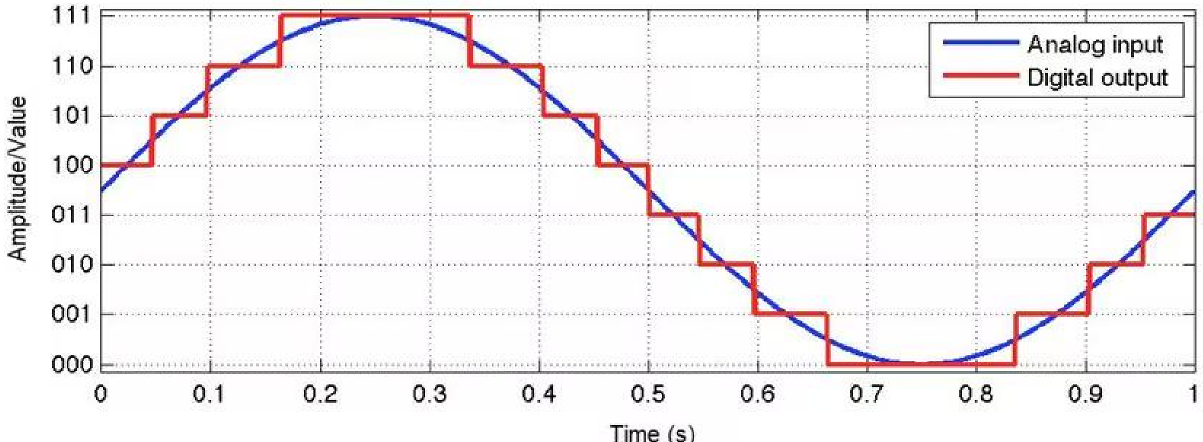
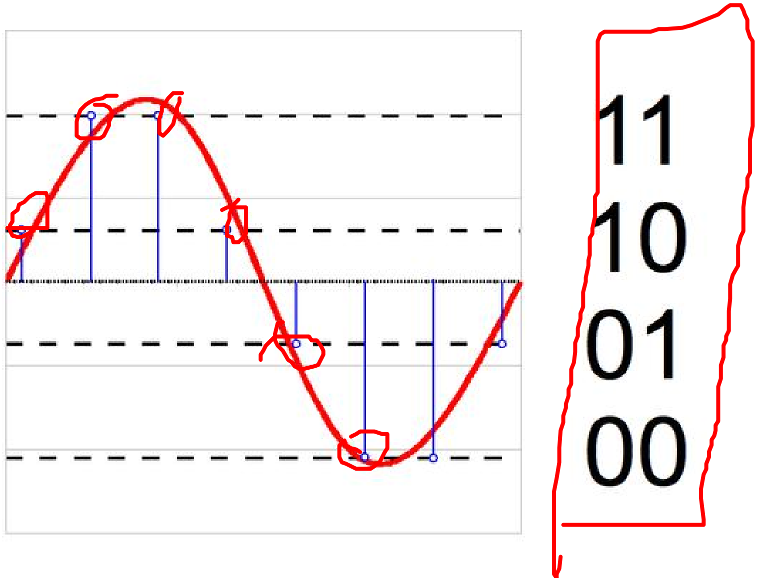
Analog to Digital Converter

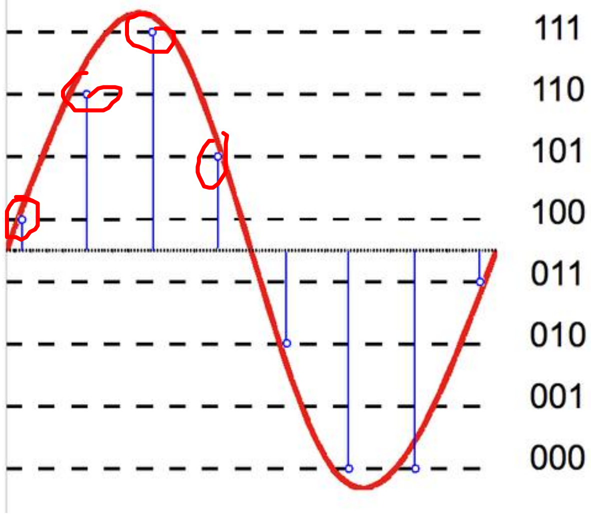
How does an ADC work?

- Analog signals are signals that have a continuous sequence with continuous values
- Digital signals are represented by a sequence of discrete values broken down into sequences
- Computers can’t read values unless it’s digital data.
  - They can only see “levels” of the voltage



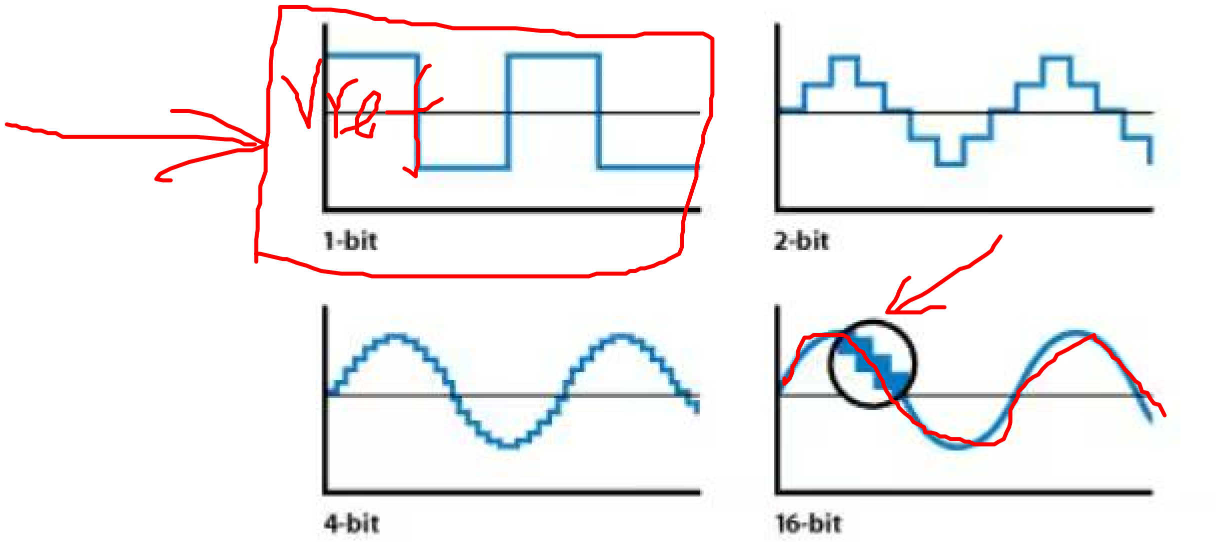
- An analog-to-digital converter (ADC) can be modeled as two processes: sampling and quantization.
  - Sampling converts a time-varying voltage signal into a discrete-time signal, a sequence of real numbers.
  - Quantization replaces each real number with an approximation from a finite set of discrete values.





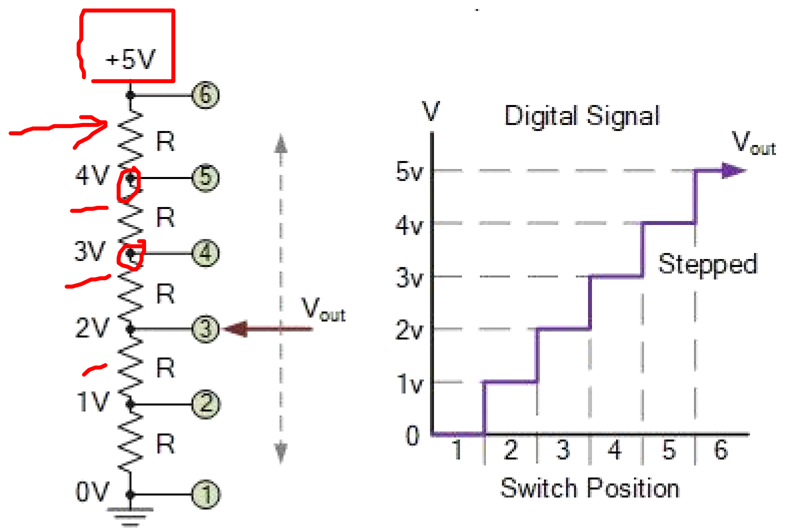
Resolution of ADC

- The resolution of the ADC can be determined by its bit length.
  - 1-bit only has two "levels".
  - As the bit length increases, the levels increase making the signal more closely represent the original analog signal.



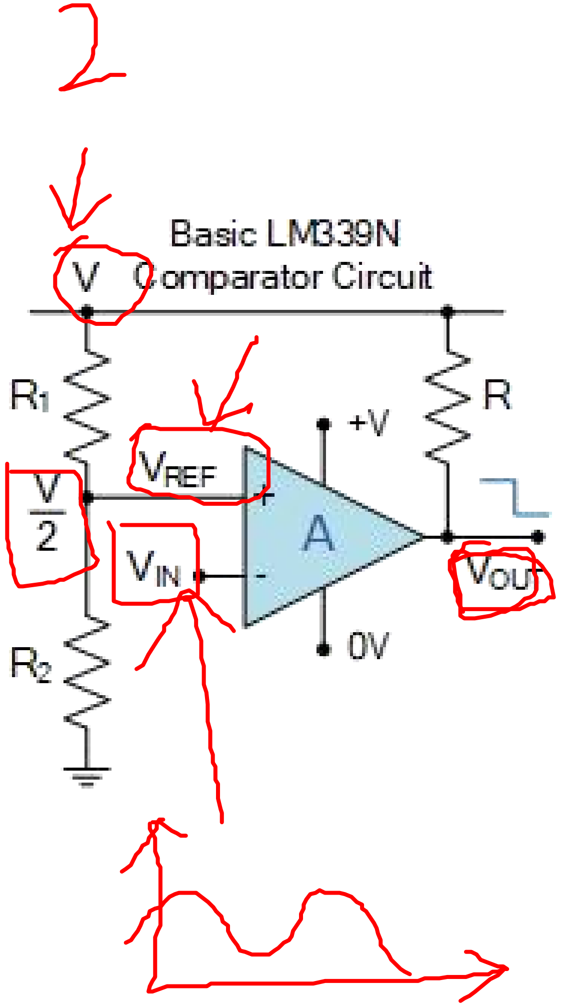
ADC Building blocks

- How to generate the Vref?
- Series resistor chain, forms a basic potential divider network.
  - When the switch is rotated from one position (or node) to the next the output voltage, Vref changes quickly in discrete and distinctive voltage steps representing multiples of 1.0 volts on each switching action as shown.

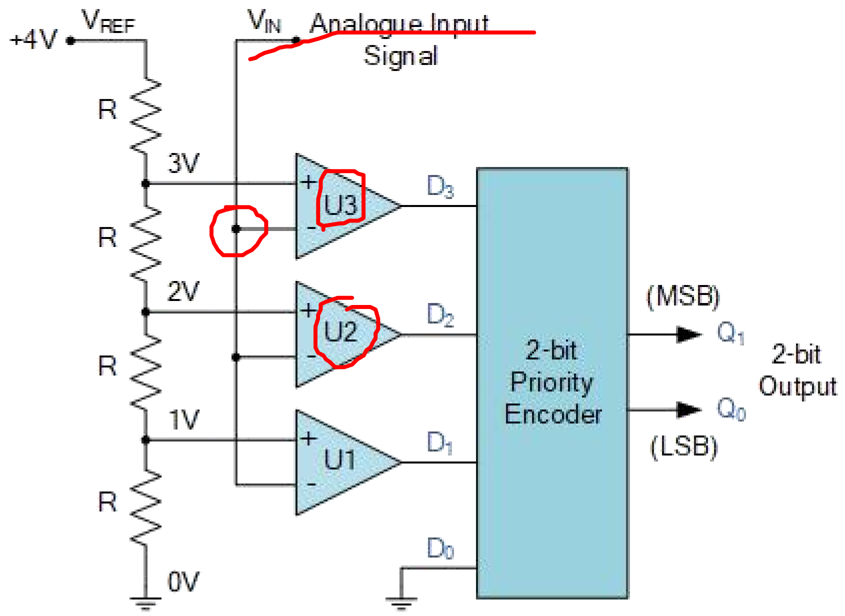


ADC Building blocks

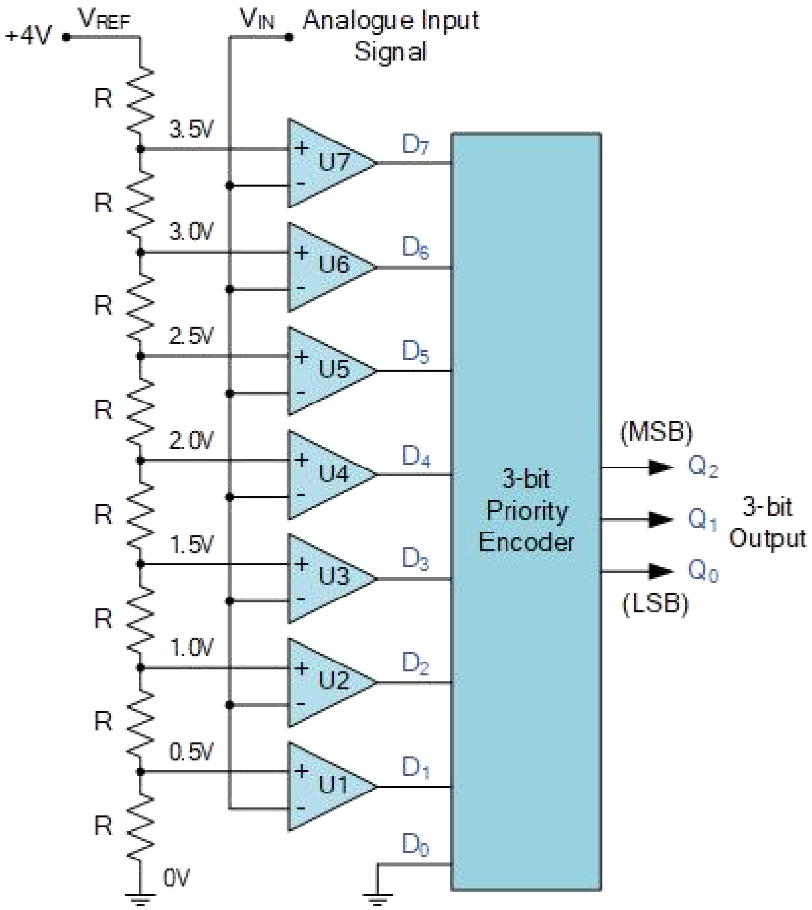
- An analogue comparator has two analogue inputs, one positive and one negative
  - Can compare the magnitudes of two different voltage levels.
- A voltage input, (VIN) signal is applied to one input of the comparator, while a reference voltage, (VREF) to the other.
- A comparison of the two voltage levels at the comparator's input is made to determine the comparators digital logic output state, either a "1" or a "0".



- By adding more resistors to the voltage divider network we can effectively "divide" the supply voltage by an amount determined by the resistances of the resistors.
- In general, 2^n– 1 comparators would be required for conversion of an "n"-bit binary output, where "n" is typically in the range from 8 to 16.
- If we now create a 2-bit ADC, then we will need 2^2– 1 which is "3" comparators as we need four different voltage levels corresponding to the 4 digital values required for a 4-to-2 bit encoder circuit as shown.



Analogue Input Voltage (V_{IN})	Comparator Outputs				Digital Outputs	
	D_3	D_2	D_1	D_0	Q_1	Q_0
0 to 1 V	0	0	0	0	0	0
1 to 2 V	0	0	1	X	0	1
2 to 3 V	0	1	X	X	1	0
3 to 4 V	1	X	X	X	1	1



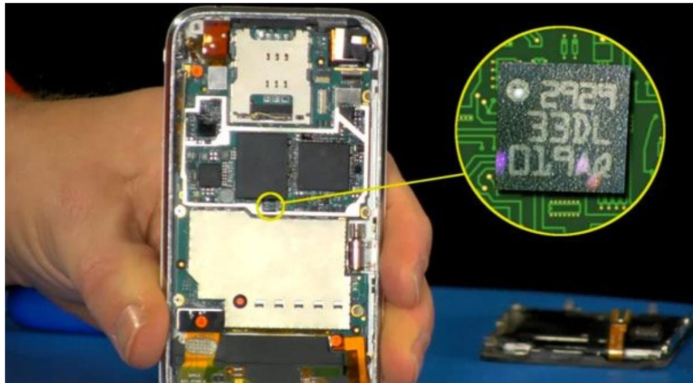
Analogue Input Voltage (V_{IN})	Comparator Outputs								Digital Outputs		
	D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	Q_2	Q_1	Q_0
0 to 0.5 V	0	0	0	0	0	0	0	**0**	0	0	0
0.5 to 1.0 V	0	0	0	0	0	0	**1**	X	0	0	1
1.0 to 1.5 V	0	0	0	0	0	**1**	X	X	0	1	0
1.5 to 2.0 V	0	0	0	0	**1**	X	X	X	0	1	1
2.0 to 2.5 V	0	0	0	**1**	X	X	X	X	1	0	0
2.5 to 3.0 V	0	0	**1**	X	X	X	X	X	1	0	1
3.0 to 3.5 V	0	**1**	X	X	X	X	X	X	1	1	0
3.5 to 4.0 V	**1**	X	X	X	X	X	X	X	1	1	1

Where again “X” is a “don’t care”, that is either a logic “0” or a logic “1” input condition.

Micro-electromechanical systems (MEMS)

MEMS

- Accelerometer+Gyroscope=6 DoF Inertia Motion Units(IMU)
- Very small and low-cost
    - less than 6 mm × 6 mm in footprint can weigh less than a gram
    - MEMS vendors have been shipping high volumes for mobiles, tablets, and automotive applications since 1990.
- Robust to environmental changes
    - The shock specifications of today’s generation of devices are stated to 10,000 g, but in reality can tolerate much higher
    - Normal humans can withstand no more than 9 g's

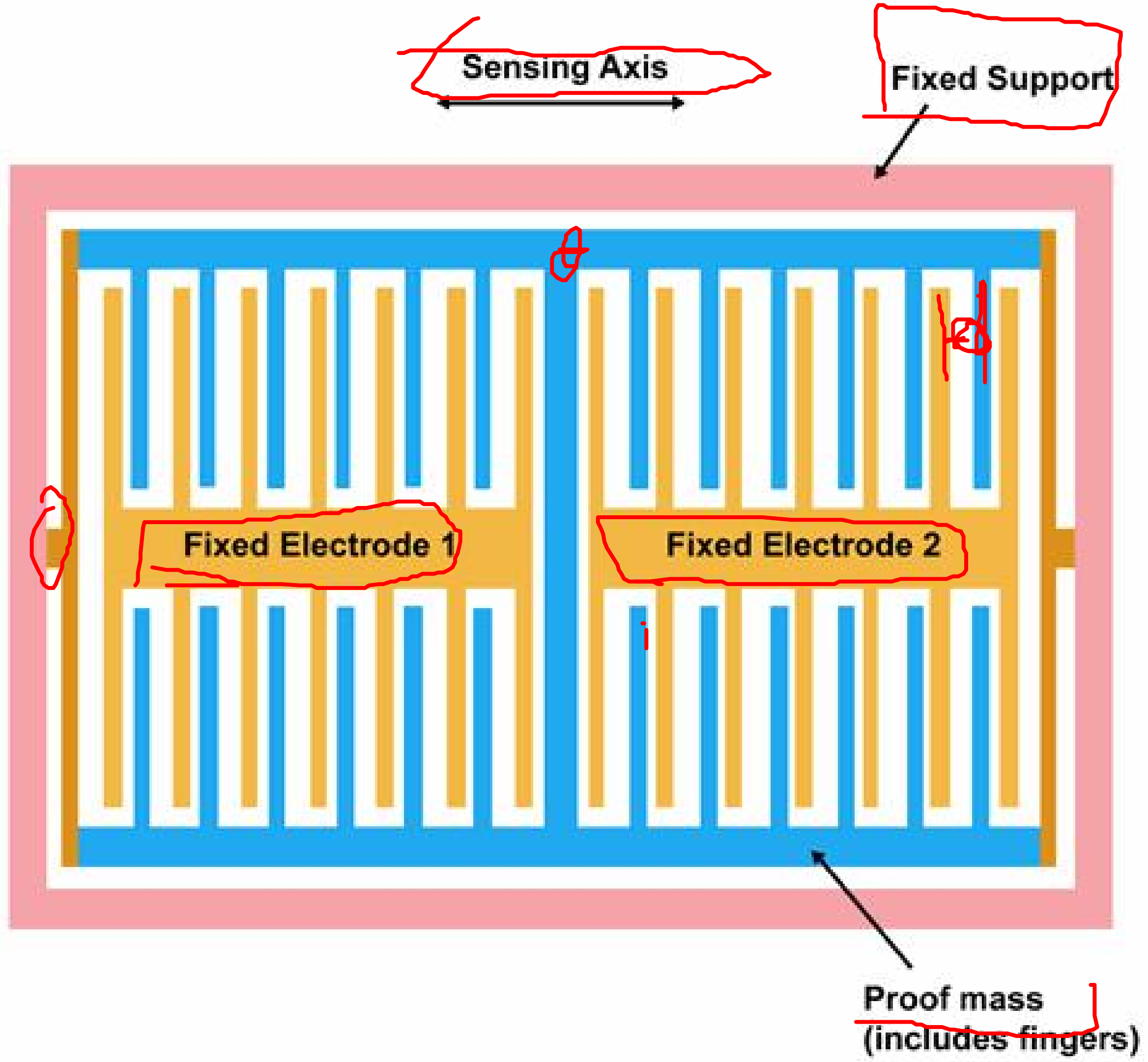


MEMS

- Where do you see these?
  - Wii Nunchuks
  - Orientation sensing in smartphones
  - Image Stabilization in cameras
  - Collision detection in cars
  - Pedometers
  - Monitoring equipment for failure (vibrations in ball bearings, etc)

MEMS: Accelerometer

- Accelerometers:
  - Measures change in velocity in x y z axes
- How does it work?
  - The “proof mass” shown above is allowed to move in a plane.
  - The attached fingers form a capacitor with the two plates around it.
  - The rate of change of the capacitance is measured and translated into an acceleration



- With the device flat on a surface what, roughly, will be the magnitude of the largest acceleration?

A. $0\ m/s^2$

B. $1\ m/s^2$

C. $5\ m/s^2$

D. $10\ m/s^2$

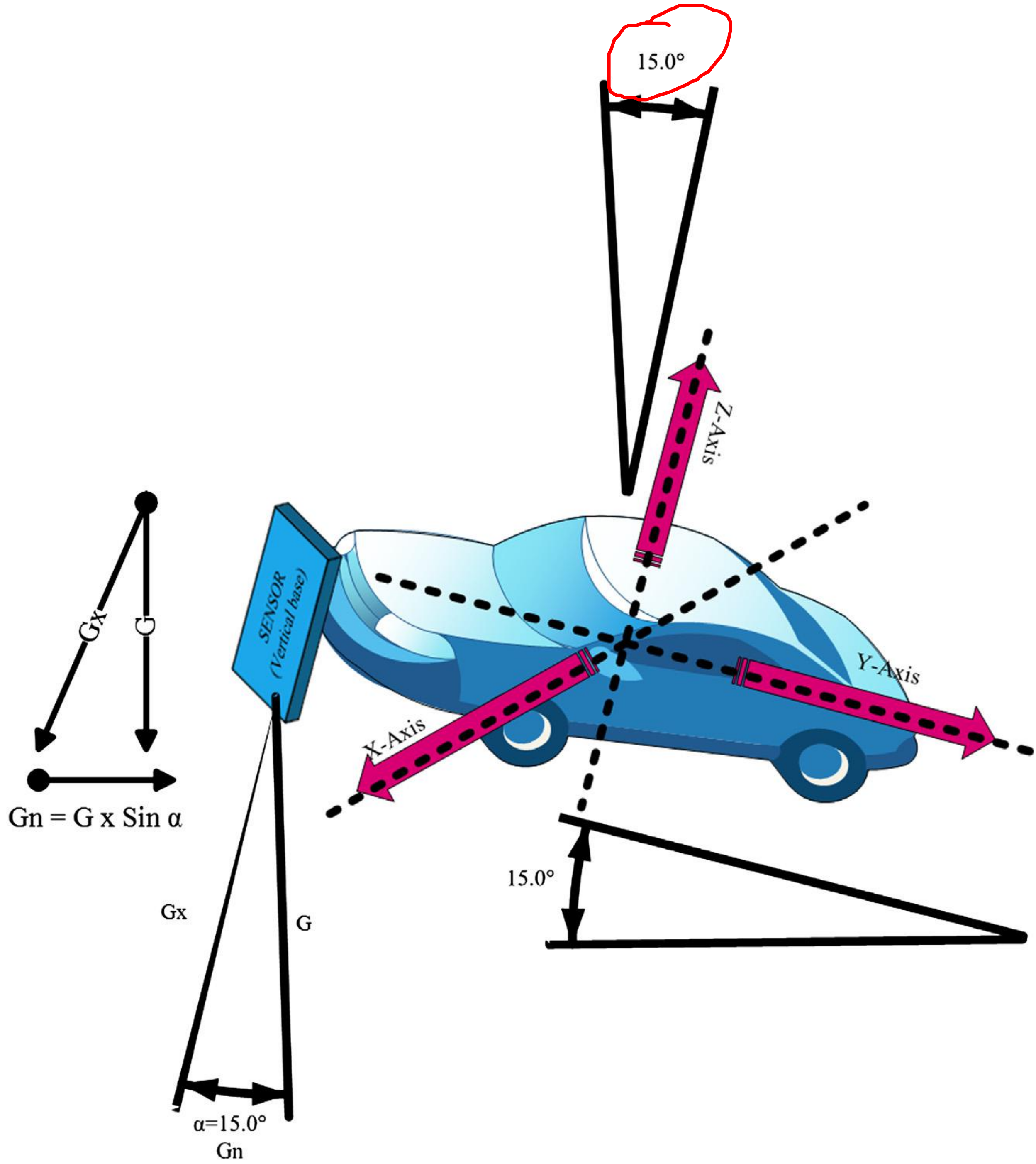
E. $32\ m/s^2$

Influence of Gravity

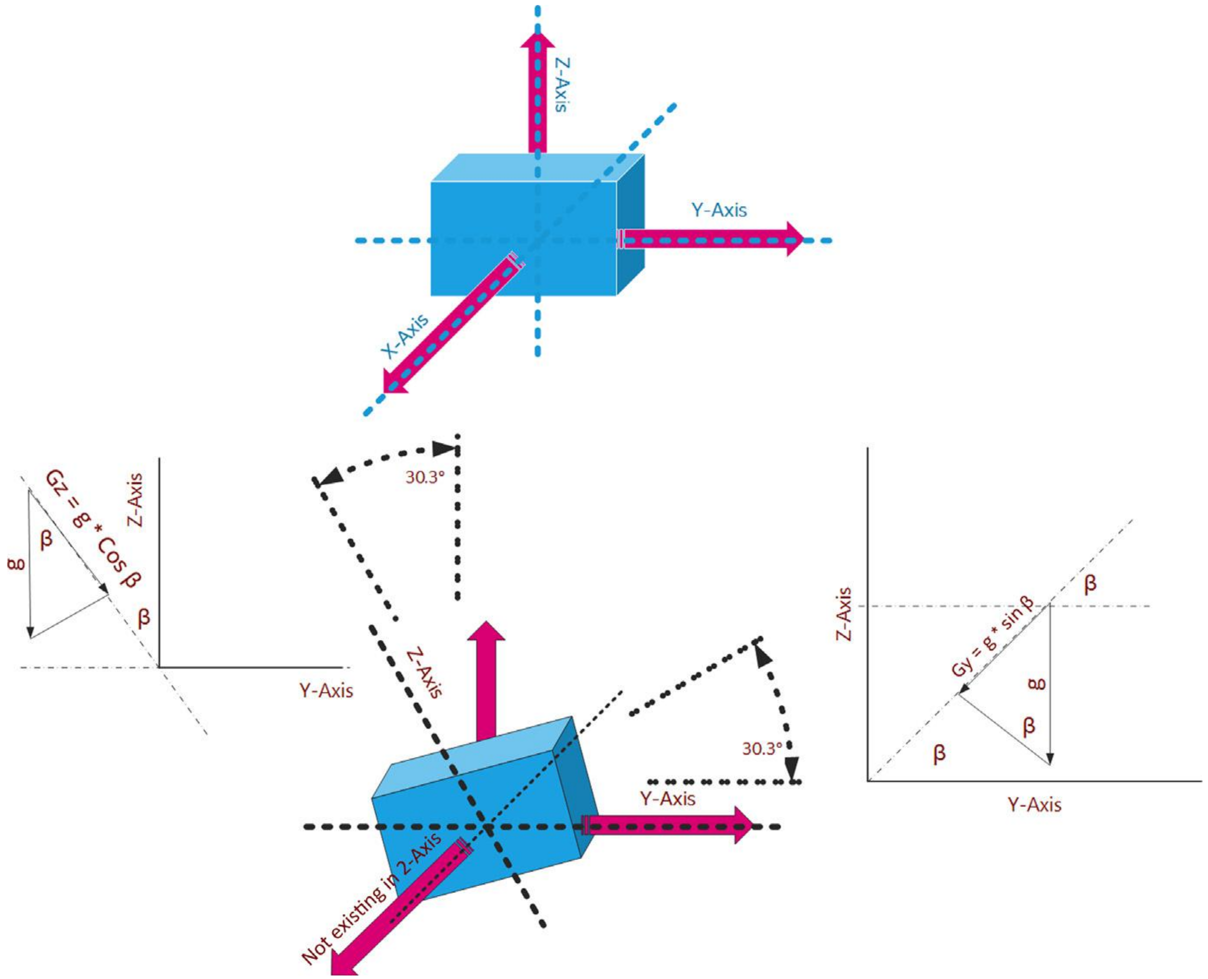
- An accelerometer at rest will not have a zero measurement. Instead, it measures $9.8m/s^2$
- A free-falling sensor will measure 0

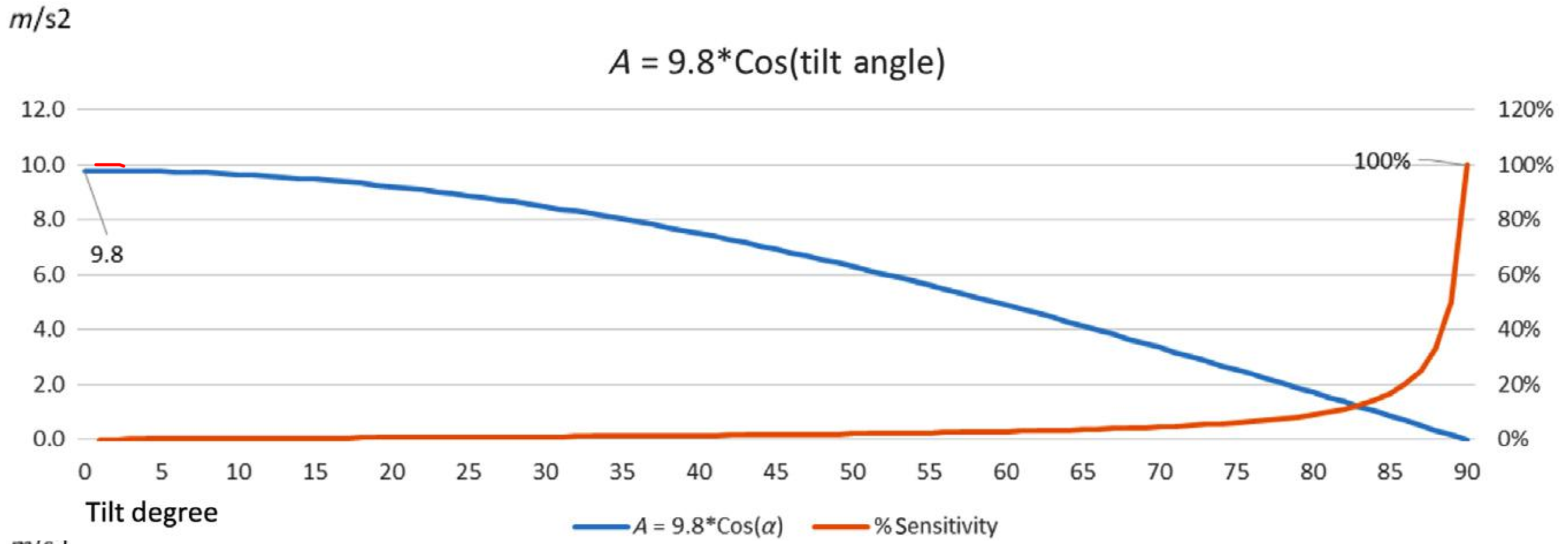
Influence of Tilt Angle

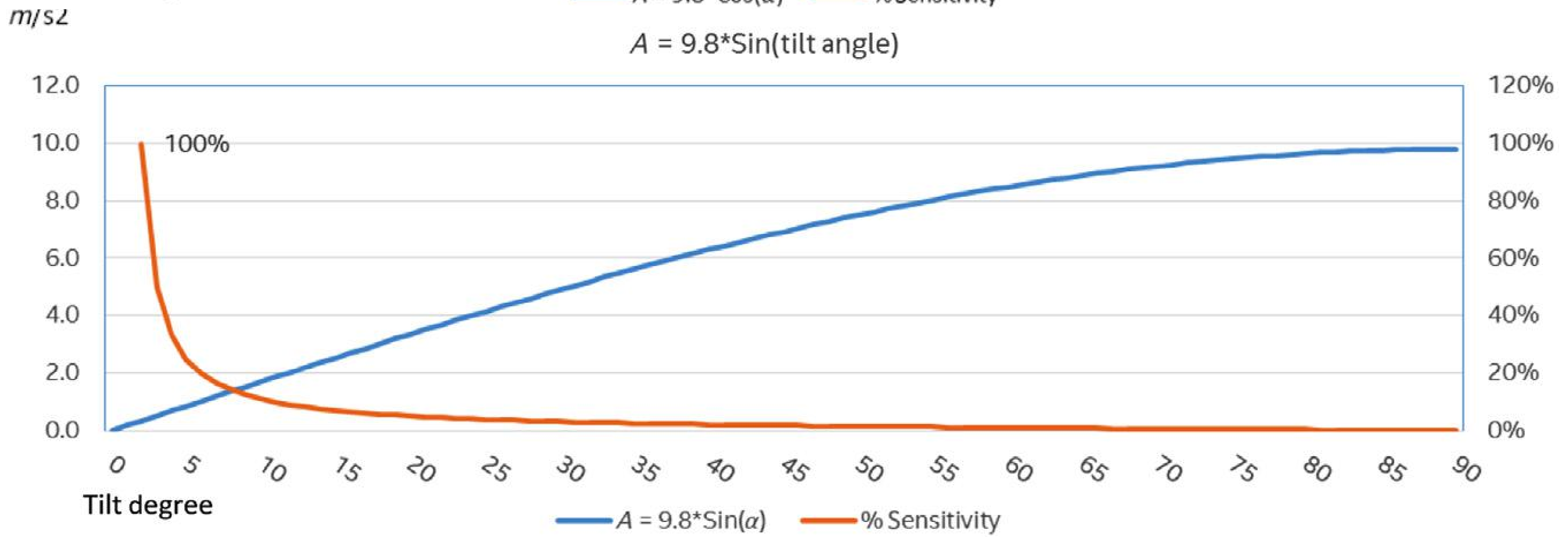
- $a_z = g * \cos(\alpha)$
- $a_y = g * \sin(\alpha)$



Sensitivity to Tilt Angle

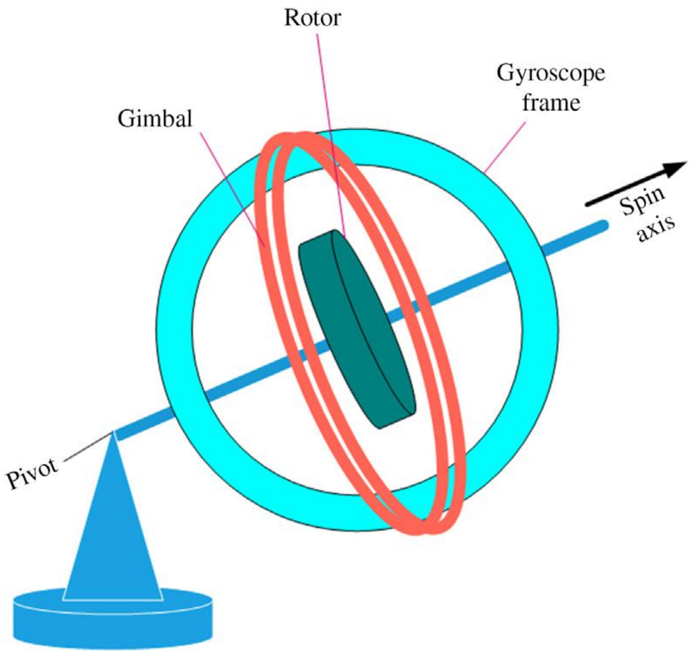



m/s2
A = 9.8*Cos(tilt angle)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
120%
100%
80%
60%
40%
20%
0%
9.8
100%
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90
Tilt degree
A = 9.8*Cos(α)
% Sensitivity

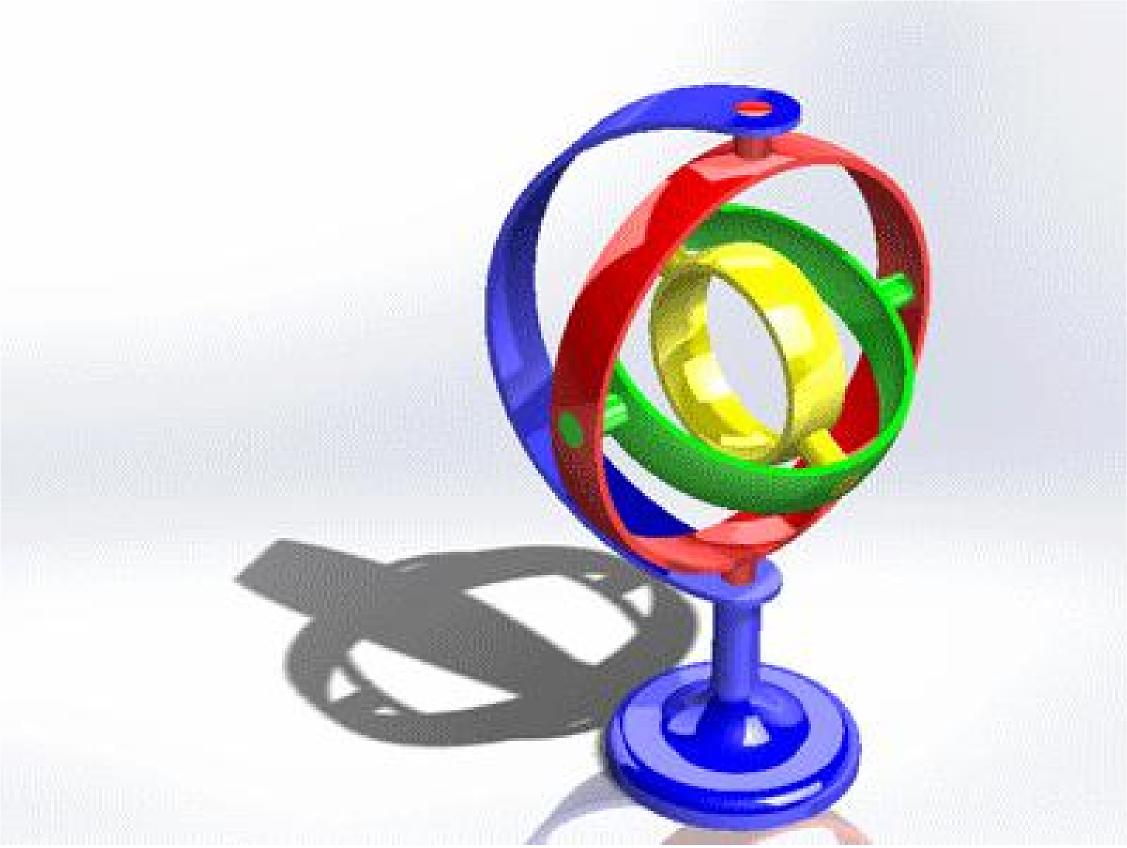

m/s2
A = 9.8*Sin(tilt angle)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
120%
100%
80%
60%
40%
20%
0%
100%
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90
Tilt degree
A = 9.8*Sin(α)
% Sensitivity

Gyroscope

- Measures rotation speed

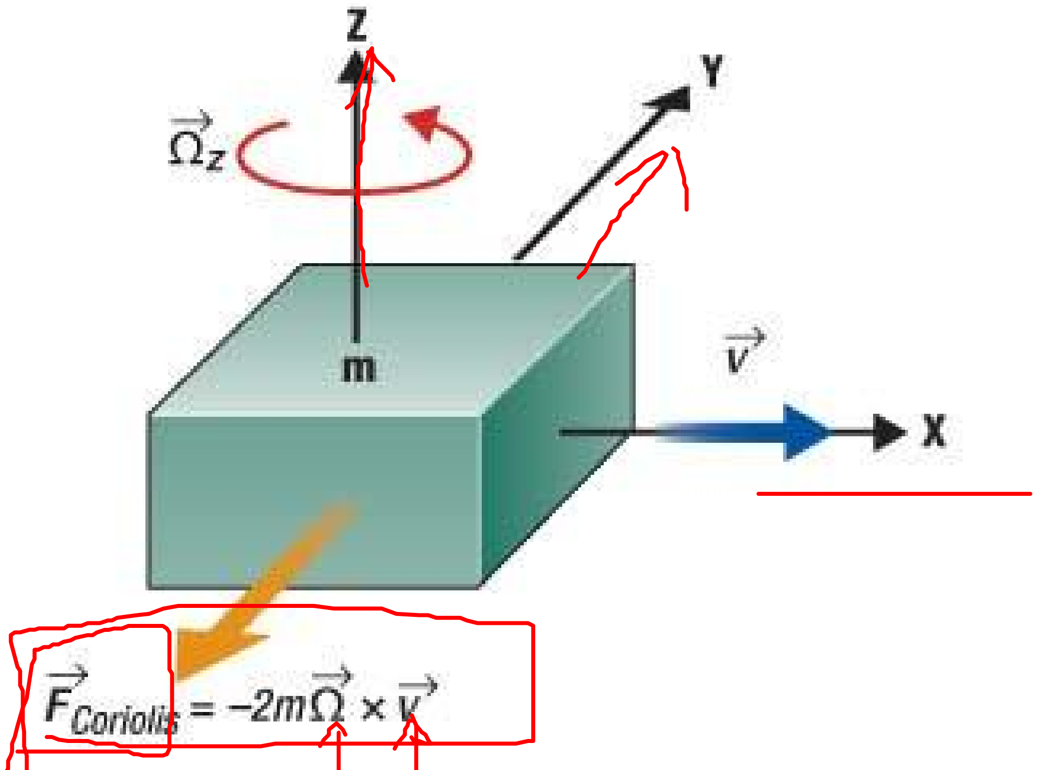


Mechanical Gyroscope



How MEMS Gyroscope works?

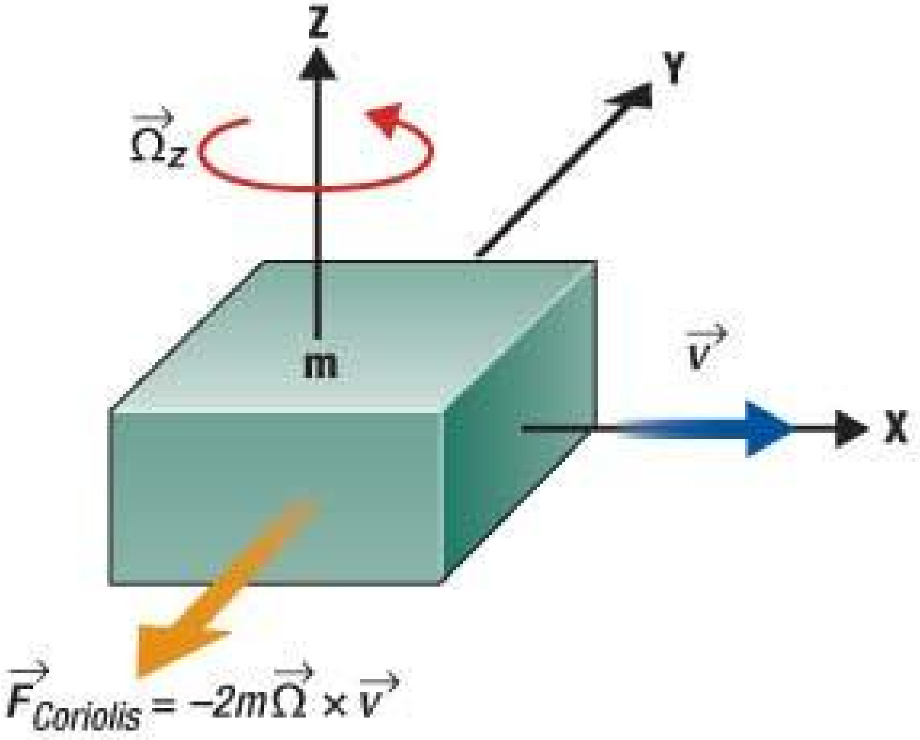
- The Coriolis force
  - If an object is moving along one axis, and it is rotated above another, it will feel a Coriolis force in the third axial direction



The Direction of Coriolis Force

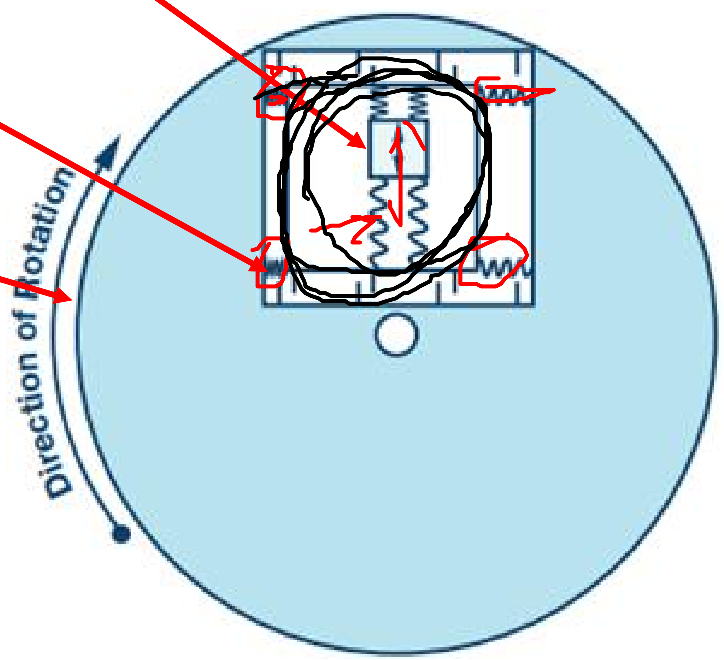
- To memorize using the right hand rules. Steps:

1. Find the rotation axis using the right hand rule (z).
2. Cross product the movement direction(x) and rotation axis (z), and get the force direction. Using the right hand rule



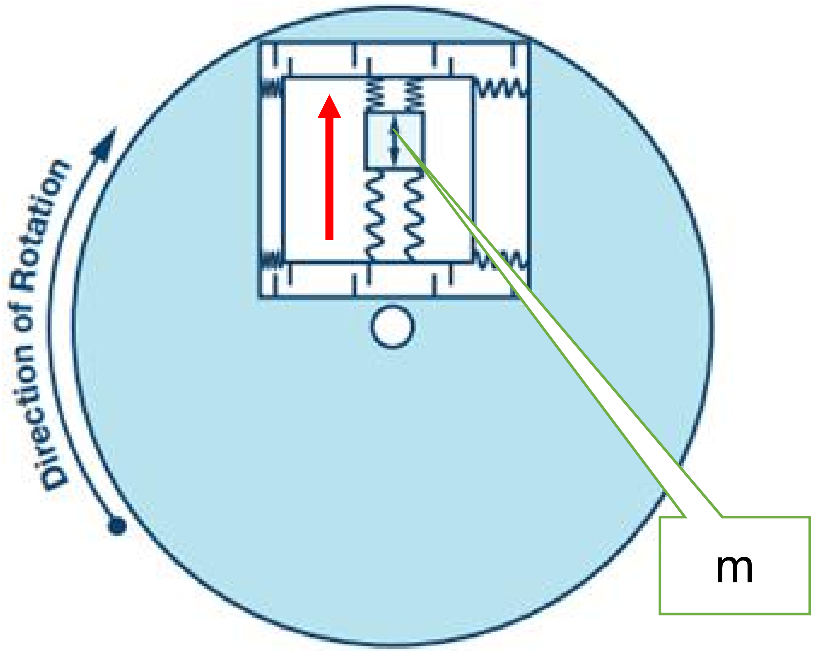
How MEMS Gyroscope works?

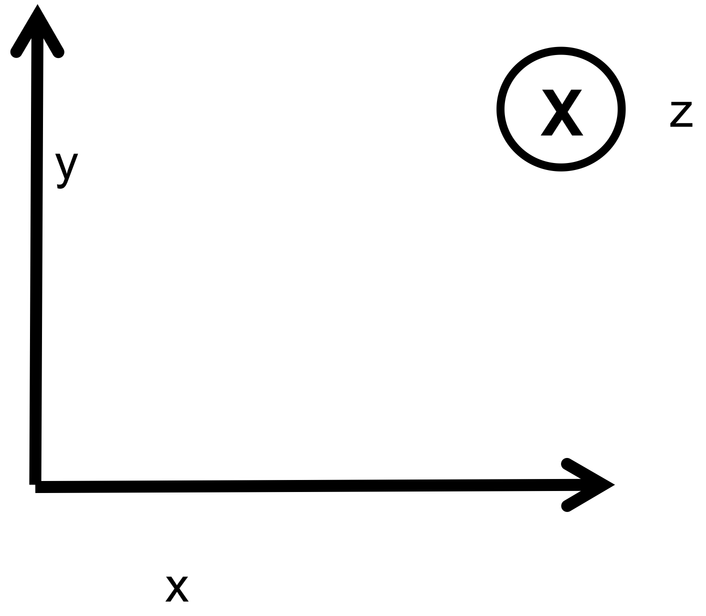
- A gyroscope will have a mass oscillating back and force along the first axis. Easy to implement using a minuscule mass.
- This oscillating mass is then placed on a second spring controlled pads. The capacitance is proportional to there positions
- These structures are placed on a disc that is free to rotate.
- When a rotating is detected around the second direction, the capacitance changes



Inside an MEMS gyroscope

- A mass, m, vibrating along y axis
- When the mass moves +y direction, rotating along z clockwise
  - What is Coriolis force direction?
  - -x





Exercise

- Explain the direction of Coriolis force when object moves along –y direction