DIGITAL WE DAYS 2024

INERTIAL MEASUREMENT UNIT (IMU) – A TINY SENSOR SYSTEMS WITH WIDE RANGE OF APPLICATIONS

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AGENDA

- IMU: Ineritial Measurement Unit
- Accelerometers & Gyroscopes
  - MEMS technology
  - Working principle
- Applications & use cases
- Motion sensor portfolio from Würth Elektronik
- Added values

I M U

Inertial Measurement Unit

IMU – INERTIAL MEASUREMENT UNIT

What is an IMU ?

Accelerometer

3 DOF/Axis

Gyroscope

+ 3 DOF/Axis= 6 DOF/ 6 Axis

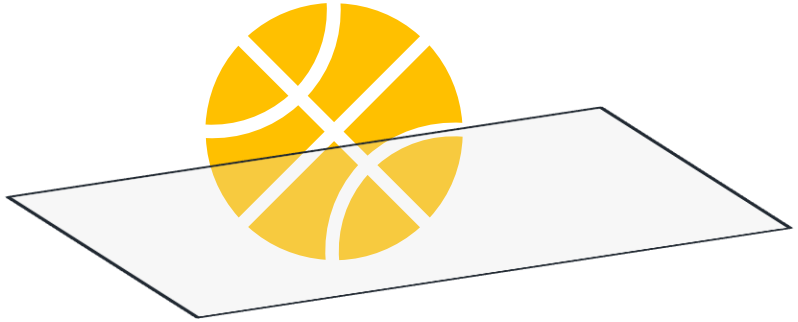
Magnetometer

+ 3 Axis= 9 Axis

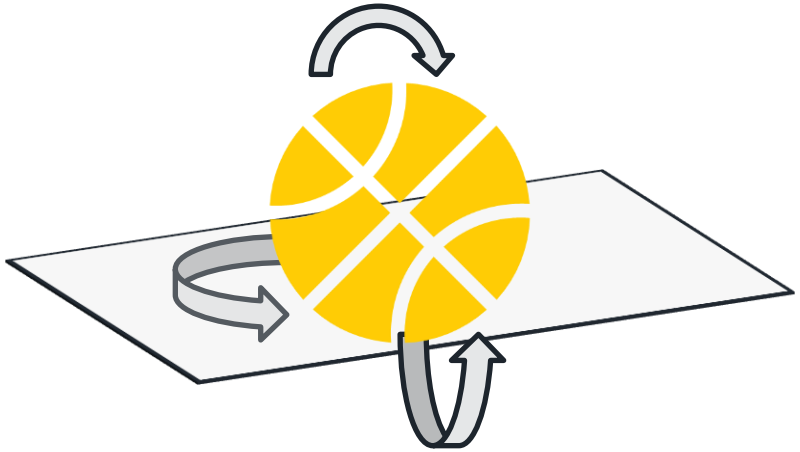
Inertial Measurement Unit

IMU – INERTIAL MEASUREMENT UNIT

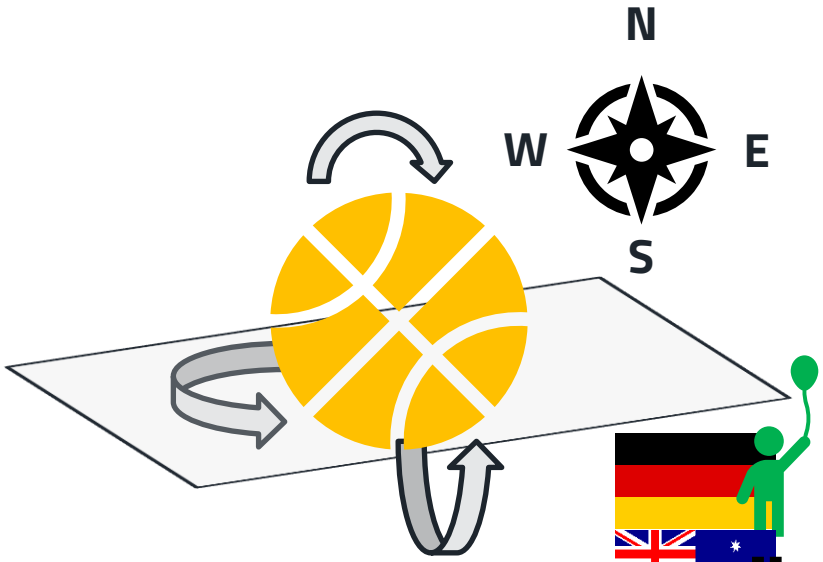
DOF – Degrees of Freedom



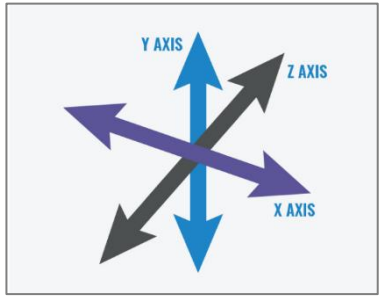
3 DOF of Movement

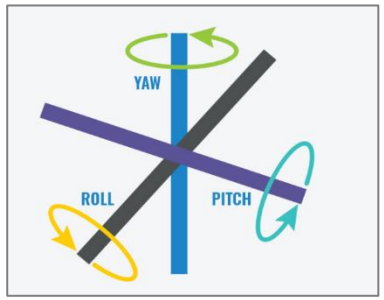


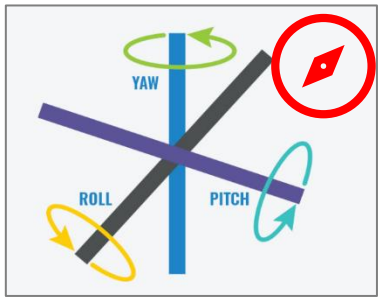
3 DOF of Rotation



3 Axis for directon







- **More axis we can measure = More accurate orientation of an object in 3D space we can get**

WHAT IS ACCELERATION AND ACCELEROMETER?

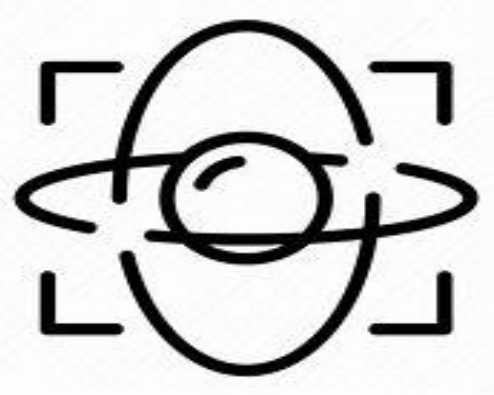
- Acceleration is the rate of change in velocity.
- SI unit is m/s^2.

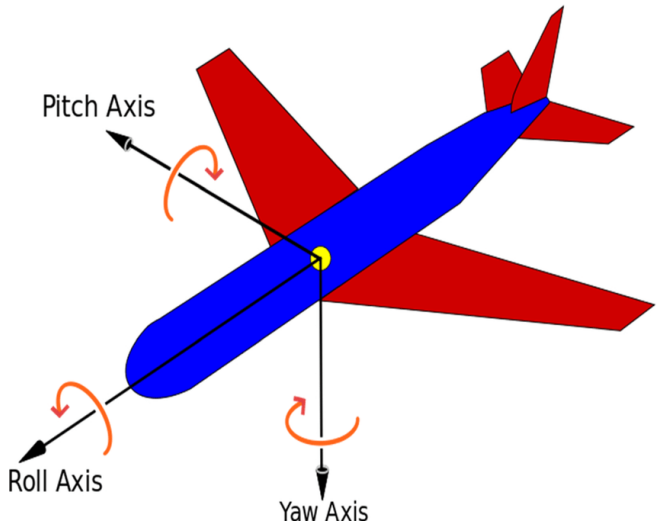
$$a = \frac{\Delta v}{\Delta t}$$

- Accelerometer is the sensor used to measure acceleration.
- It usually measures acceleration in gravitational units like ‘g’ or ‘mg’.
- 1 g equals 9.81 m/s^2 , which is the acceleration due to gravity.

WHAT ARE GYROSCOPES?

- Gyroscope is a sensor used to measure angular rotation or angular velocity along a particular axis.
- Unit of measurement - degrees per second (dps).





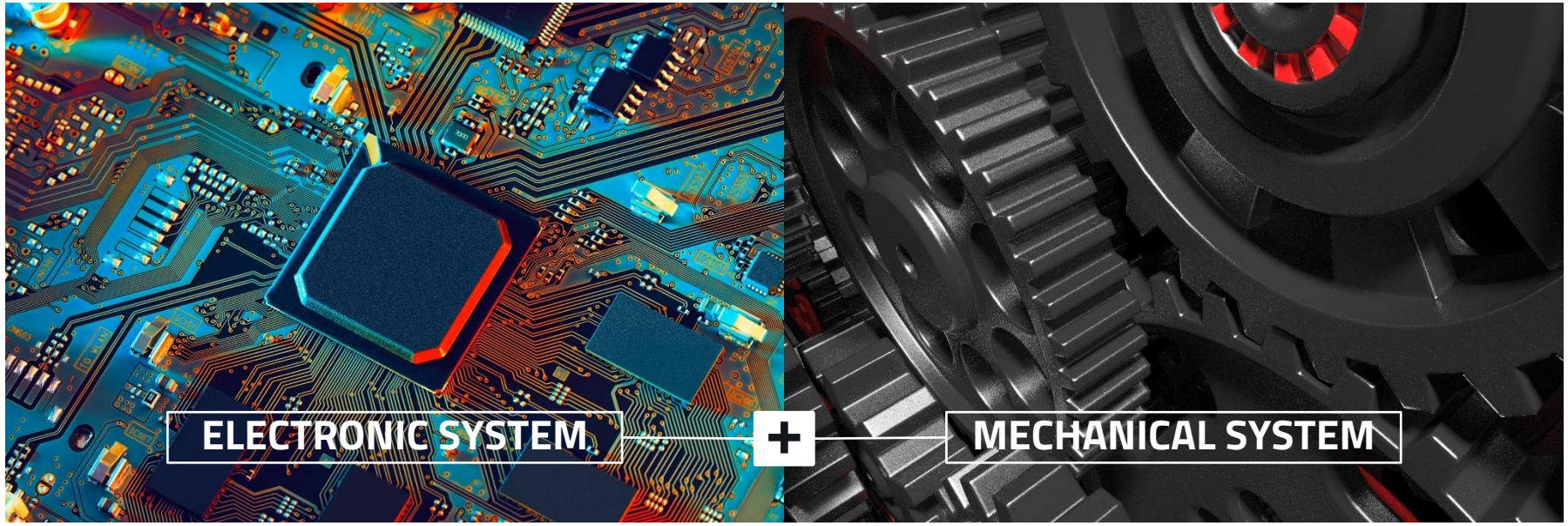
- 3 Types of rotation – roll, pitch and yaw
- Several Gyroscope technologies – MEMS Gyroscope, Mechanical Gyroscope, Fiber Optic Gyroscopes, etc.
- MEMS Gyroscopes are the most popular.

ACCELEROMETER-DIFFERENT TECHNOLOGIES

	MEMS Capacitive	Piezoelectric	Piezoresistive	Optical
Technology	They measure capacitance between the fixed and movable electrodes to determine acceleration	They generate an electrical charge in response to mechanical deformation caused by acceleration.	They utilize changes in resistance within a semiconductor material due to mechanical stress caused by acceleration	They measure changes in light interference in response to acceleration
Accuracy & Sensitivity	✓ ✓	✓ ✓ ✓	✓ ✓	✓ ✓ ✓ ✓
Power Efficiency				
Cost	€	€ € €	€ €	€ € € €
Size				

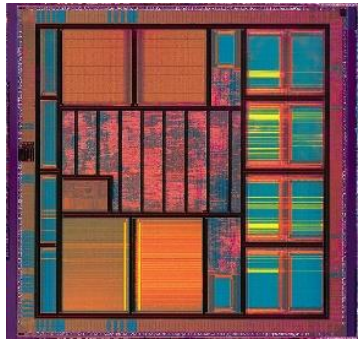
MEMS TECHNOLOGY

Micro-**E**lectro-**M**echanical-**S**ystem



Downscaling to micro and nano levels...

- Faster measurement time
- Higher sensitivity



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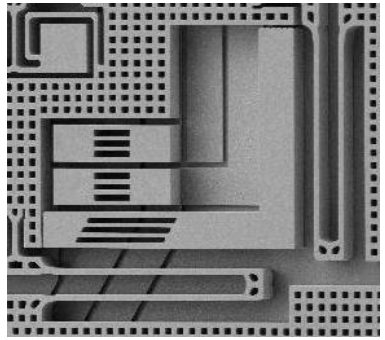
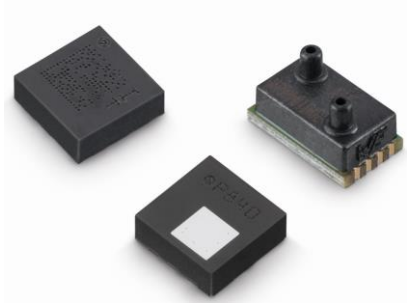
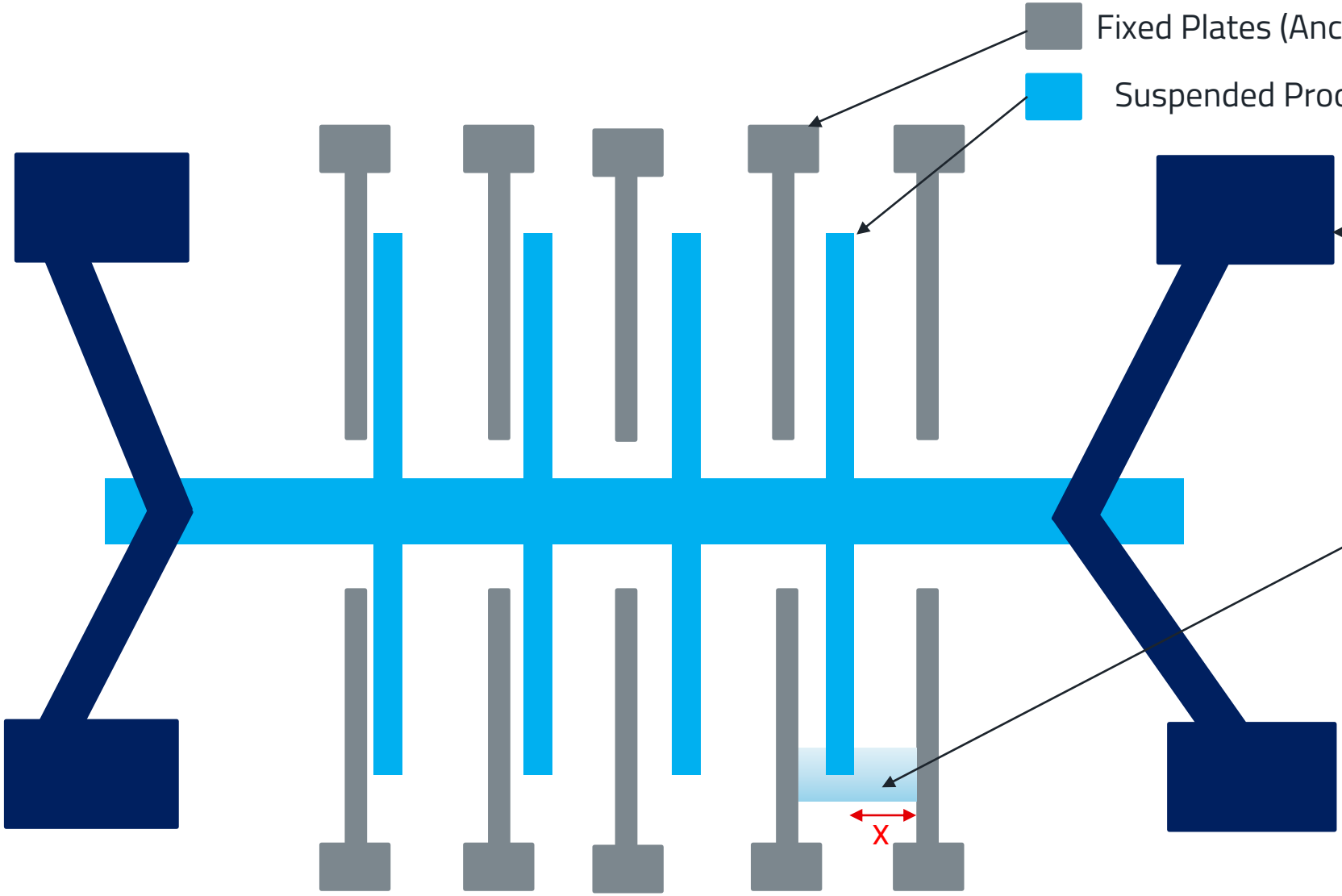


MEMS

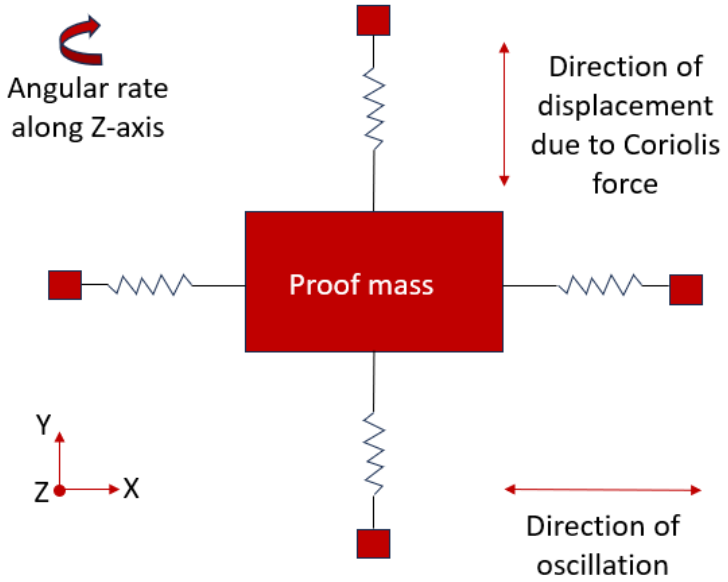


WORKING PRINCIPLE OF MEMS ACCELEROMETER

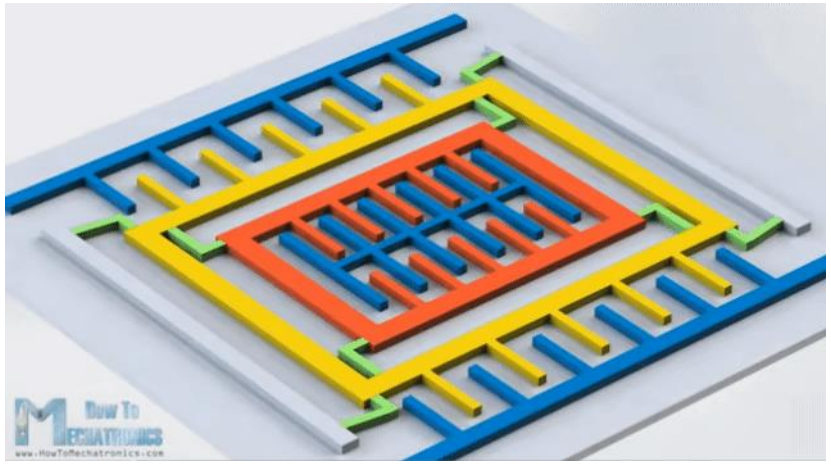


- This change in capacitance is proportional to the acceleration along that axis.
- The change in capacitance is converted to an analog output voltage (additionally an AC to DC convertor for digital output)

WORKING PRINCIPLE OF MEMS GYROSCOPE



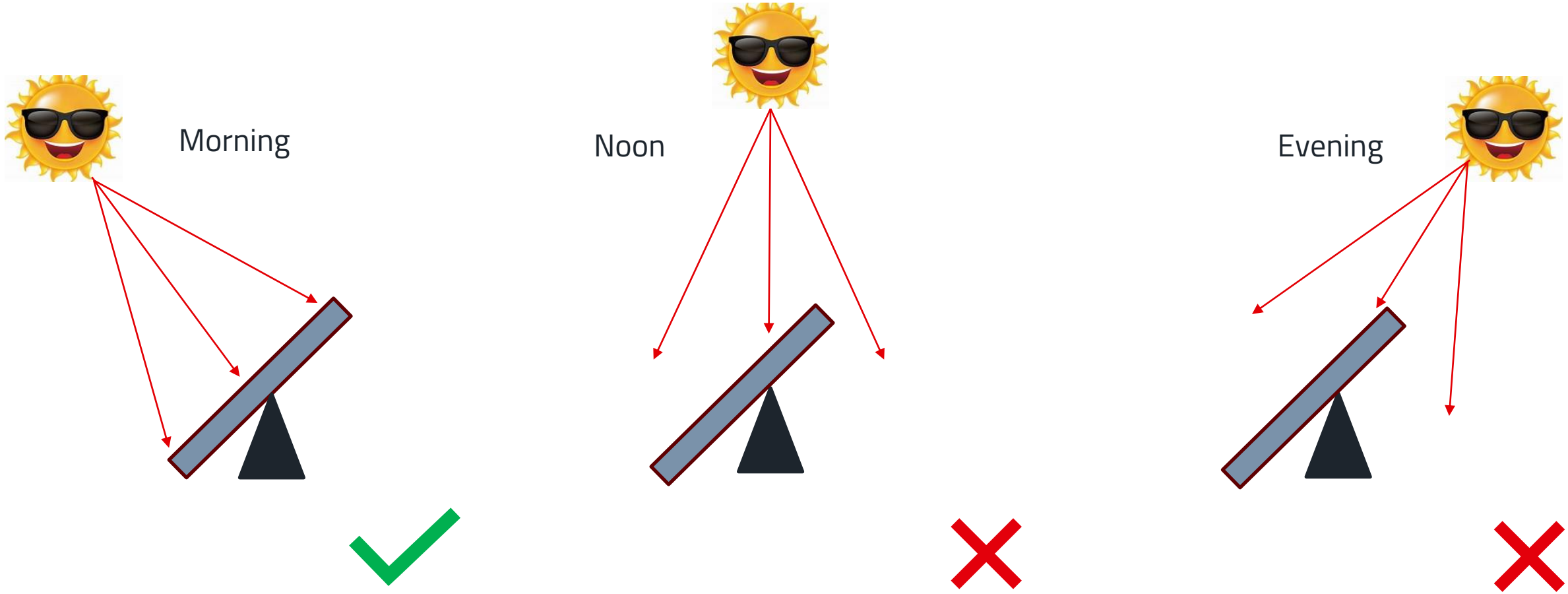
- MEMS Gyroscope consist of a suspended proof mass, a driving system to oscillate the proof mass, and a sensing system.
- Angular rotation in one axis → Coriolis force in a perpendicular axis → Displacement → change in capacitance.



- A tuning fork configuration is used in our MEMS gyroscopes to make the sensor's operation independent of linear accelerations.

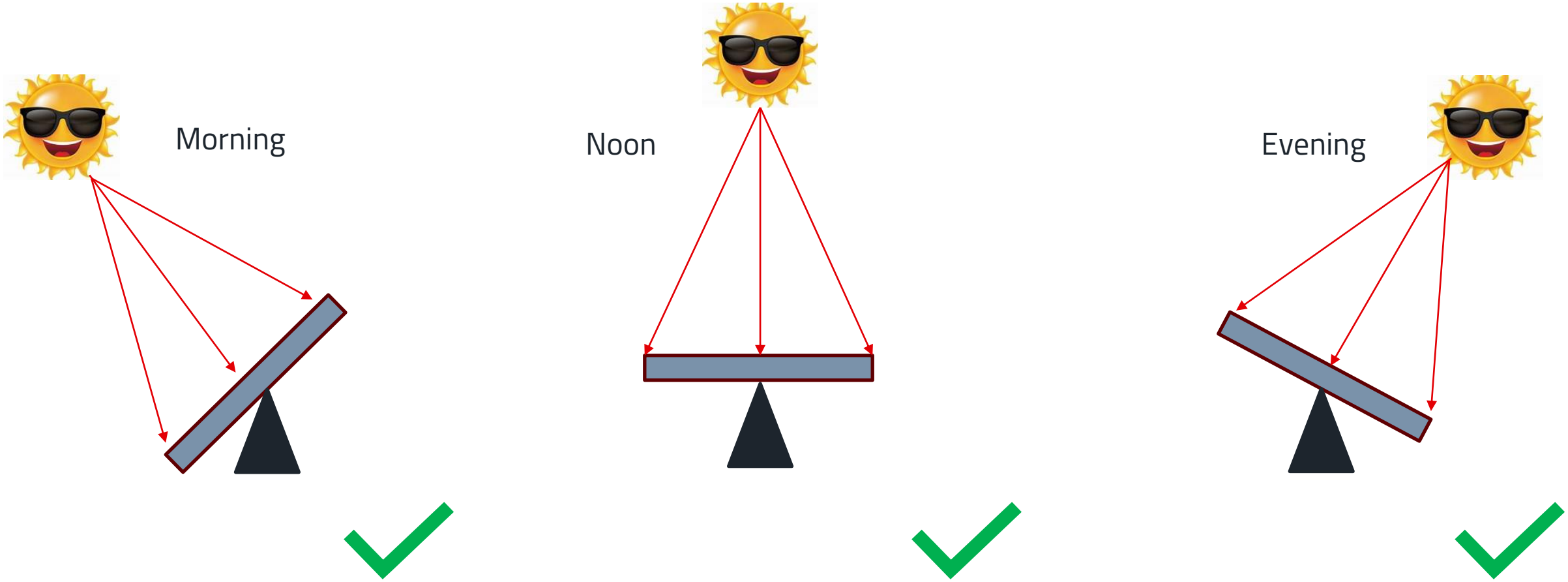
TILT DETECTION

Solar trackers



TILT DETECTION

Solar trackers



TILT DETECTION

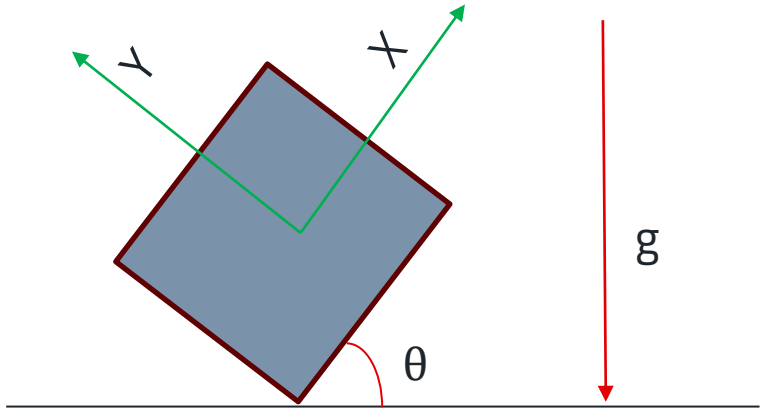
How to measure the inclination?

- Accelerometer at rest measures only the acceleration caused due to gravity.
- Ideally, accelerometer placed horizontally should read (0, 0, 1000mg).

- If the sensor is placed in this orientation, then the X and Y axes would show non-zero values and Z axis would show zero.
- The acceleration due to gravity is resolved in X and Y axes.

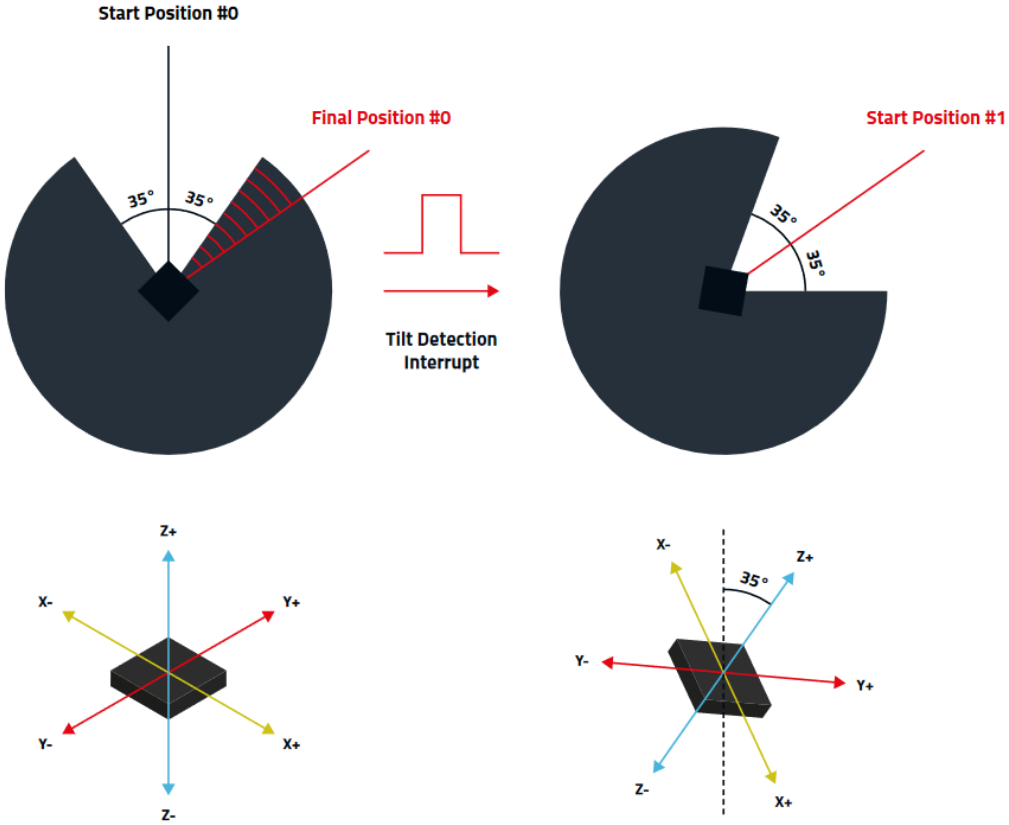
$$X = g * \sin(\theta)$$
$$Y = g * \cos(\theta)$$

- The inclination, θ, can be easily calculated from solving these equations.

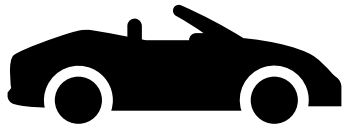


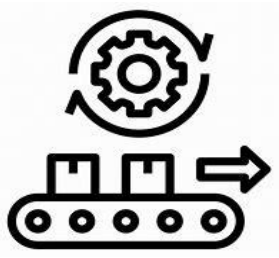
DYNAMIC TILT MEASUREMENT

- Accelerometer for tilt/rotation measurement is not enough…
  - Do not work for moving objects
  - Tilt/rotation cannot be measured at all 3 axis simultaneously
  - Drift over time



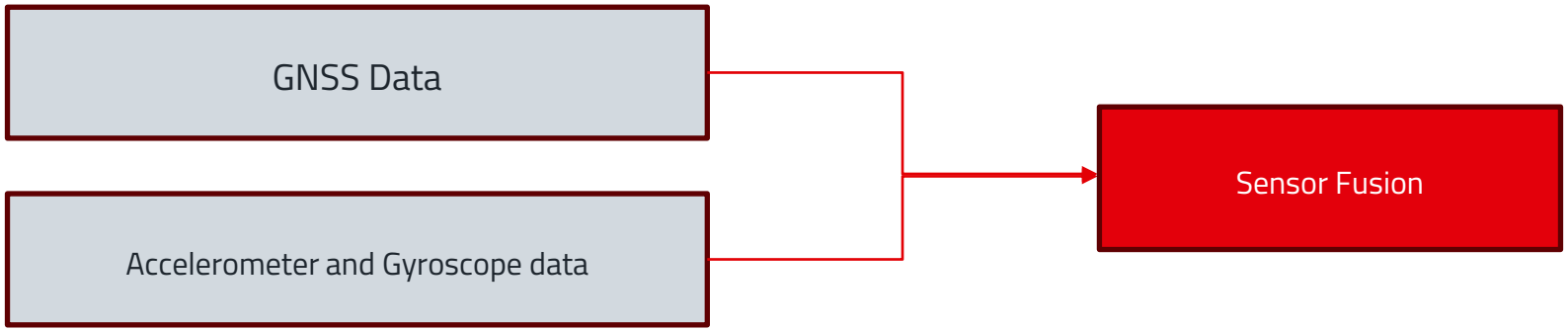
ASSET TRACKING & INDOOR POSITIONING






- GNSS alone cannot provide accurate information of an asset especially in conditions like indoor or tunnels.

- In such cases GNSS data can be combined with accelerometer and gyroscope data to understand the exact location and heading of an object.



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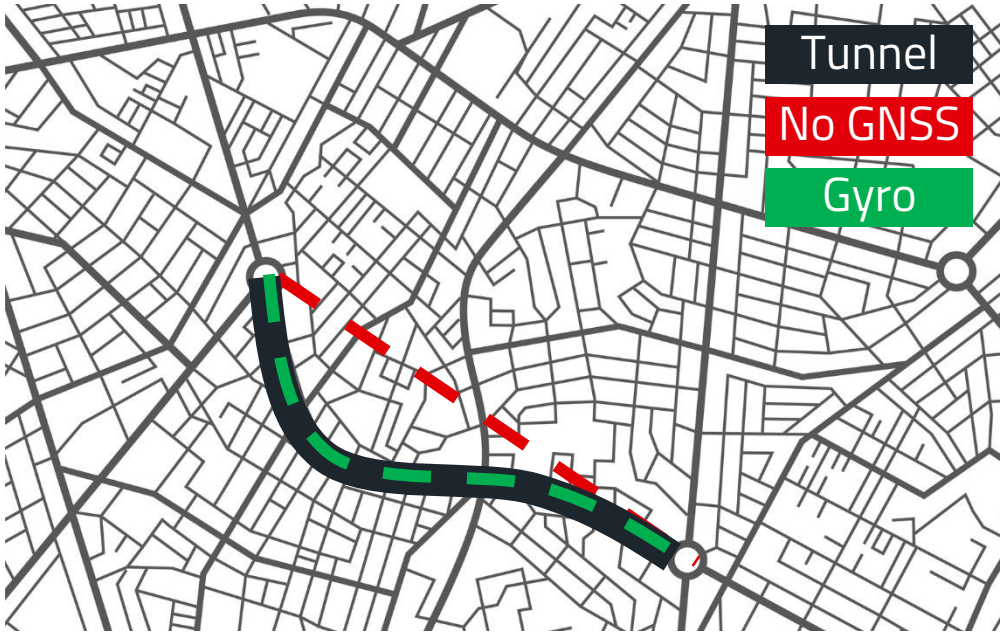
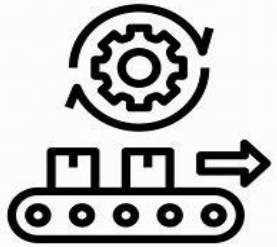




- Sensing impacts for damages
- Track the movements accurately

GNSS data

+

Accelerometer Gyroscope

Accurate Positionng

- Indoor warehouses
- Production lines

MORE APPLICATIONS

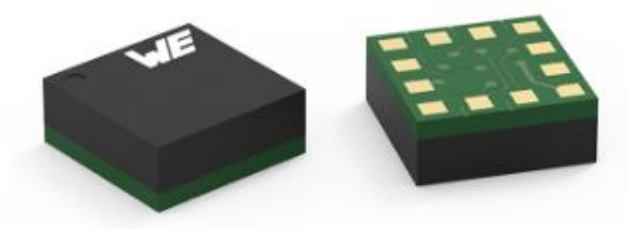
- Predictive maintanance
- Track 6-D orientation

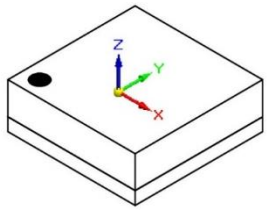
- Real time monitoring at higher data rates
- Battery operated

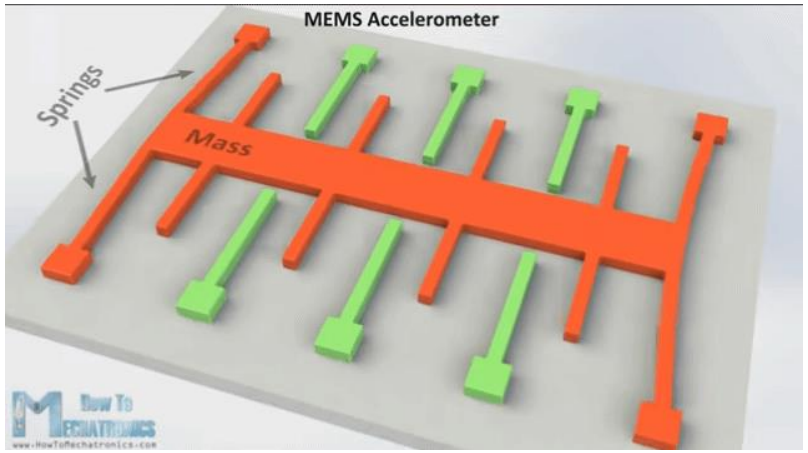
- Track 6-D orientation
- Detect free fall
- Battery operated

3 AXIS ACCELERATION SENSOR

WSEN-ITDS from Würth Elektronik



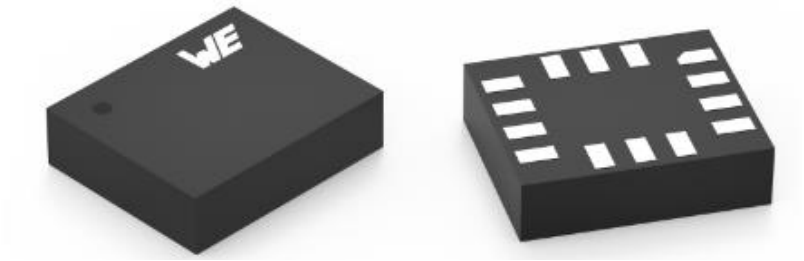


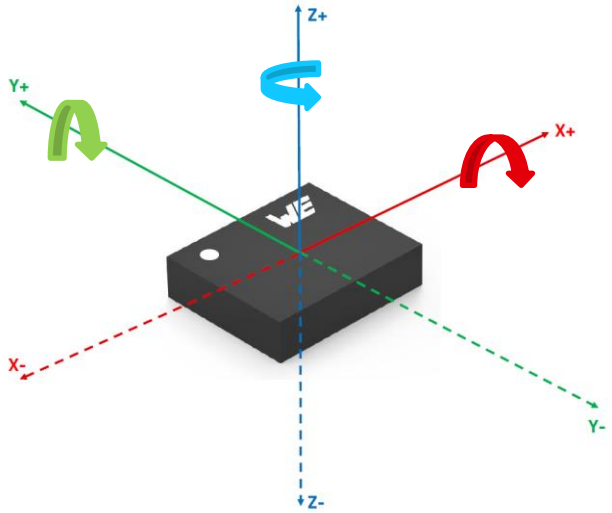


- MEMS Capacitive sensing principle
- Outputs acceleration in X,Y and Z axis
- 14-bit Digital output
- Small size – 2mm*2mm*0.7mm
- I2C and SPI communication
- Two independent interrupt pins
- Operating temperature, -40° C to +85° C

6 AXIS IMU: ACCELEROMETER & GYROSCOPE

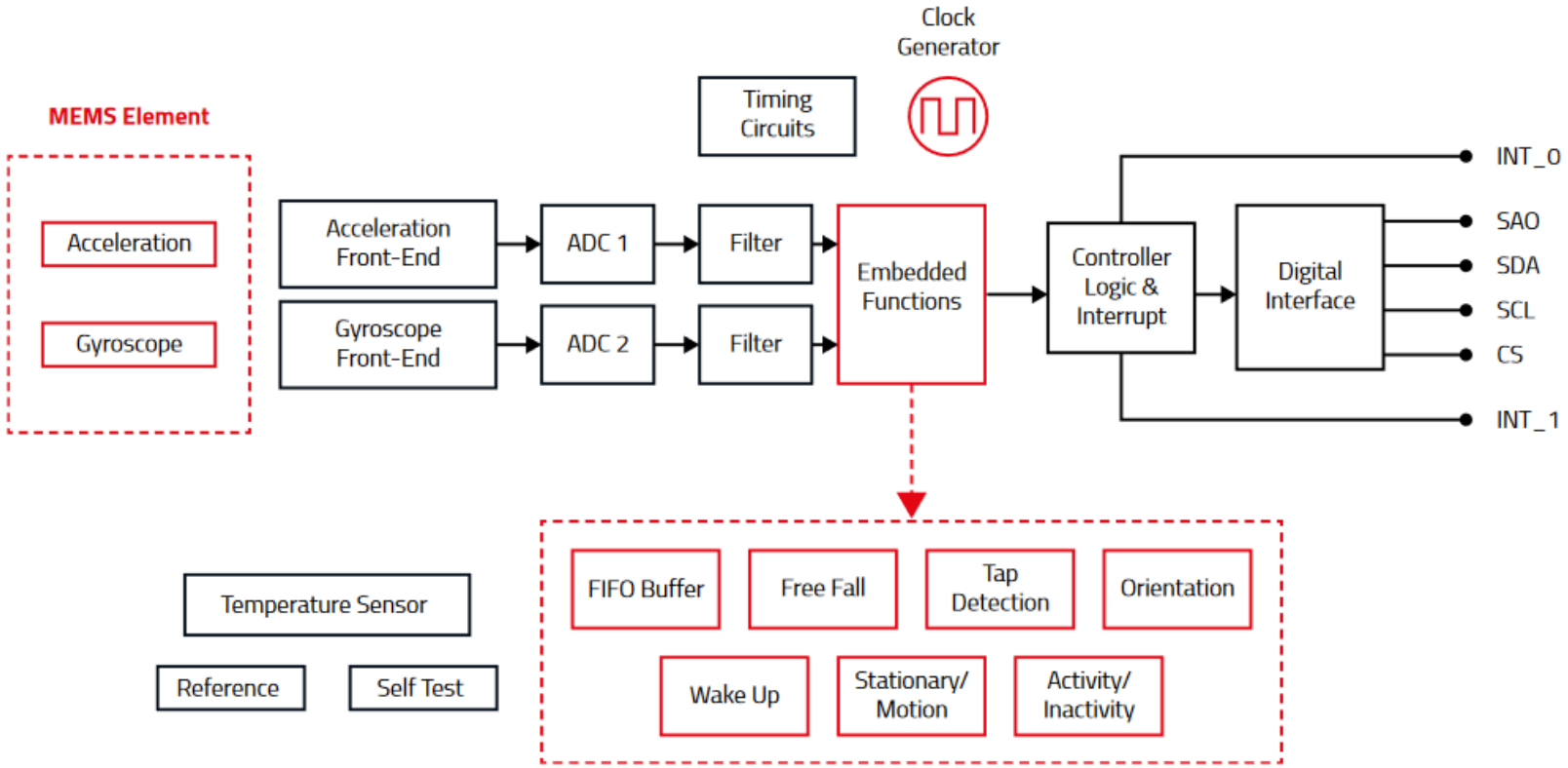
WSEN-ISDS from Würth Elektronik





- MEMS capacitive sensing
- 3-Axis Accelerometer + 3-Axis Gyroscope combined
- 16-bit digital output
- Small size - 3mm * 2.5mm * 0.86mm
- Two programmable interrupt pins
- I^2C and SPI communication interface
- 4 Kb FIFO memory
- Operating temperature, -40° C to +85° C

BLOCK DIAGRAM



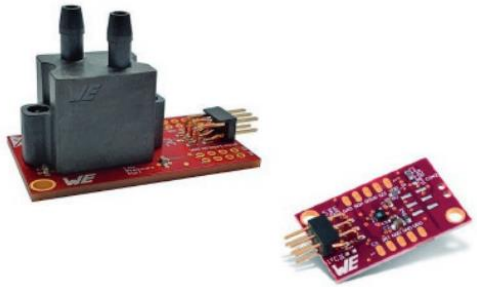
KEY SPECIFICATIONS

	WSEN-ITDS	WSEN-ISDS
Full scale 	±2g, ±4g, ±8g, ±16g	Accelerometer - ±2g, ±4g, ±8g, ±16g Gyroscope - ±250 dps, ±500 dps, ±1000 dps, ±2000 dps
Output data rate 	1.6Hz to 1600Hz	1.6Hz to 6664Hz
Offset 	±30mg	Accelerometer - ±40mg Gyroscope - ±2000mdps
Noise density 	90 µg /$\sqrt{Hz}$	Accelerometer– 70 µg /$\sqrt{Hz}$ Gyroscope– 3.8 mdps/$\sqrt{Hz}$
Power consumption 	16 - 155 µA	280 - 694 µA

MORE THAN YOU EXPECT

Accelerate your Project with the added resources…

- Evaluation boards



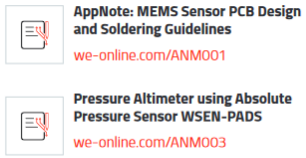
- Sensor feather wing

- Sensor Shield for Arduino

- Any other Microcontroller

- CAD Layouts

- Application Notes



- Software Davelopment kit

Sensor Boards	HW Platform	HW Design	SW Implementation & Application integration

Questions

& Answers

We are here for you now!
Ask us directly via our chat or via E-Mail.

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wcs@we-online.com