

*Automotive Sensors*

# Sensor Principle and Types

Automotive Intelligence Lab.



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## ■ Sensor's role in vehicle

## ■ Switch sensor

## ■ Resistive sensor

- ▶ Potentiometer
- ▶ Thermistor

## ■ Optical sensor

## ■ Piezoelectric sensor

## ■ Capacitance sensor

## ■ Inductance sensor

## ■ Magnetic sensor

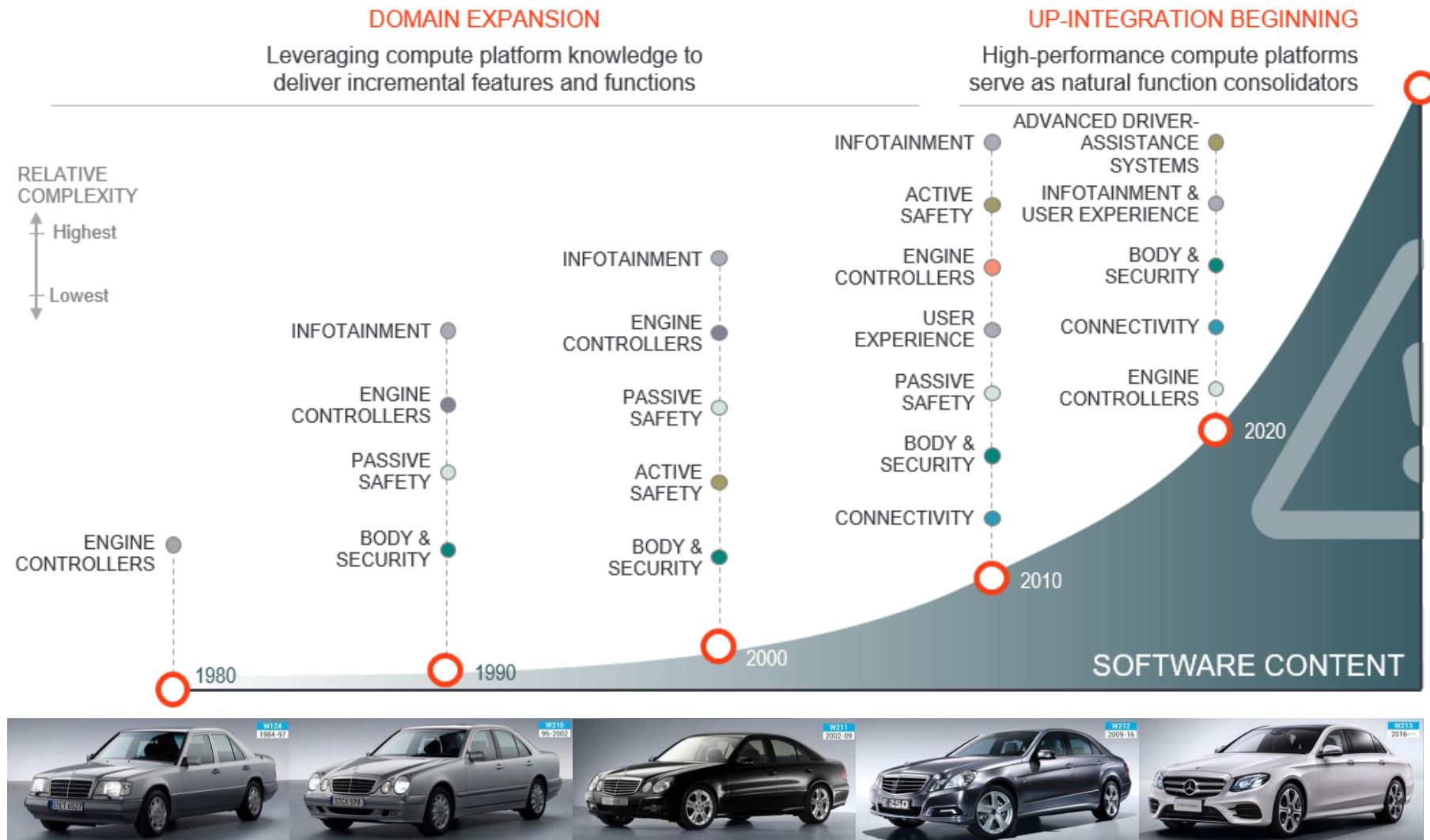
# Sensor's role in vehicle



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# Intelligence Functions on Automobile

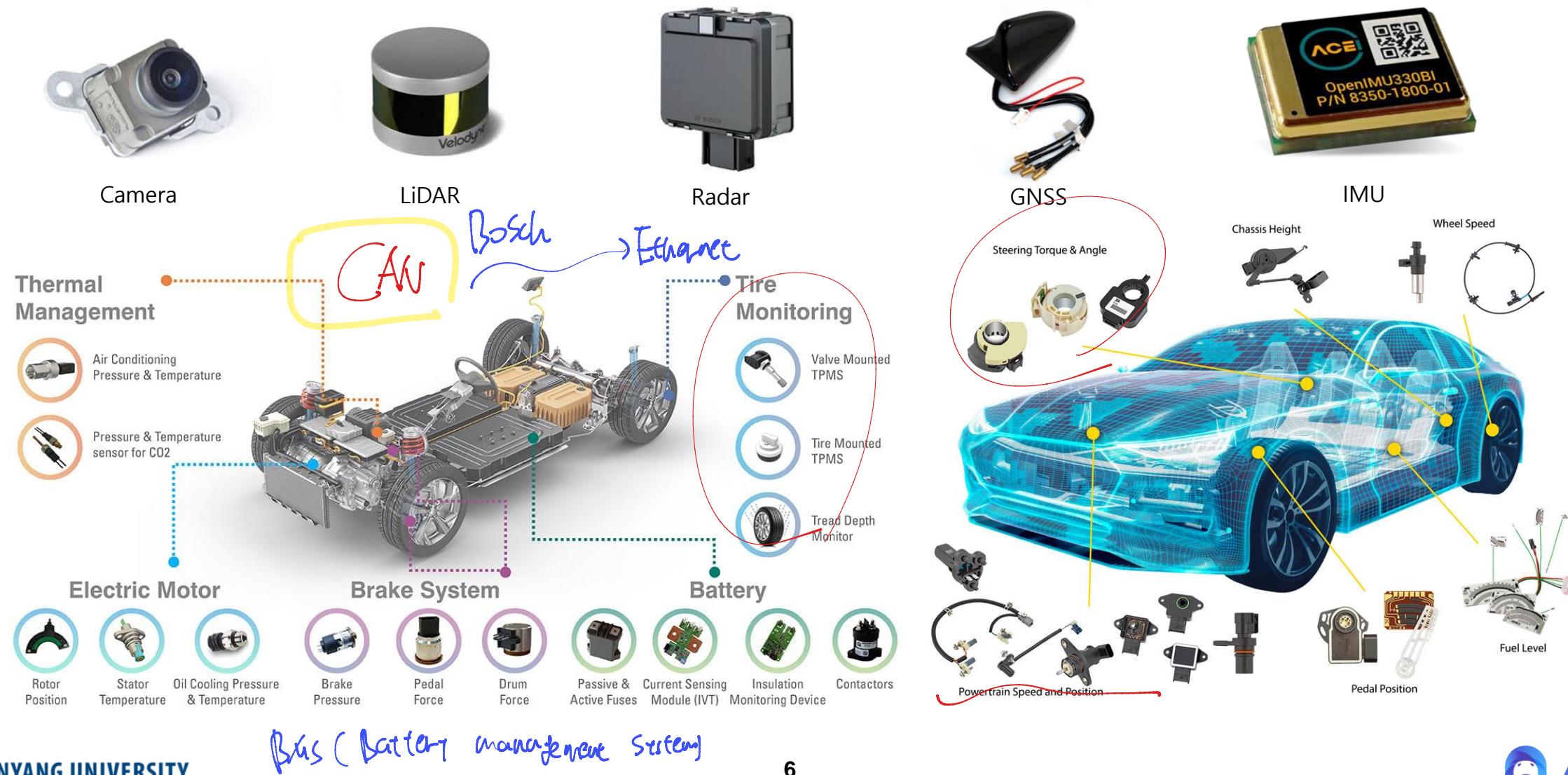


# Advanced Driver Assistance System (ADAS)



# What Makes These Functions Possible?

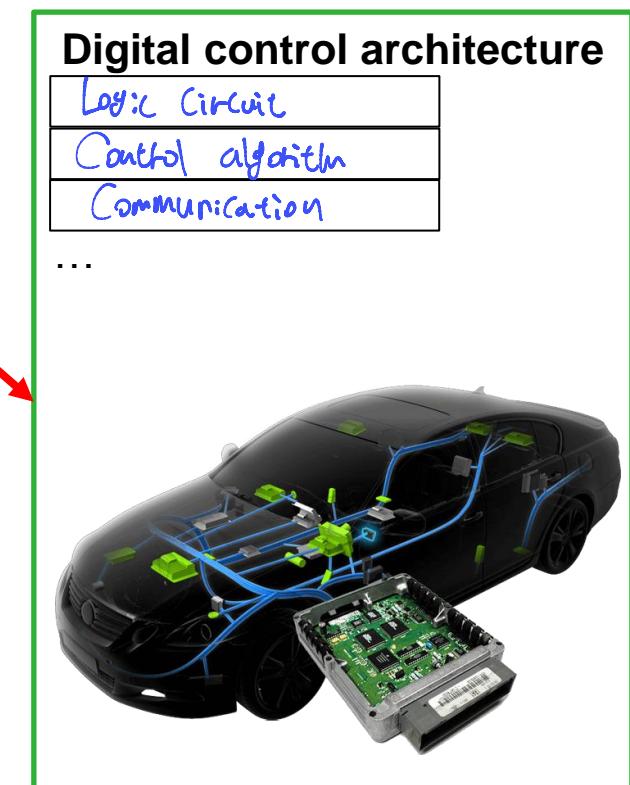
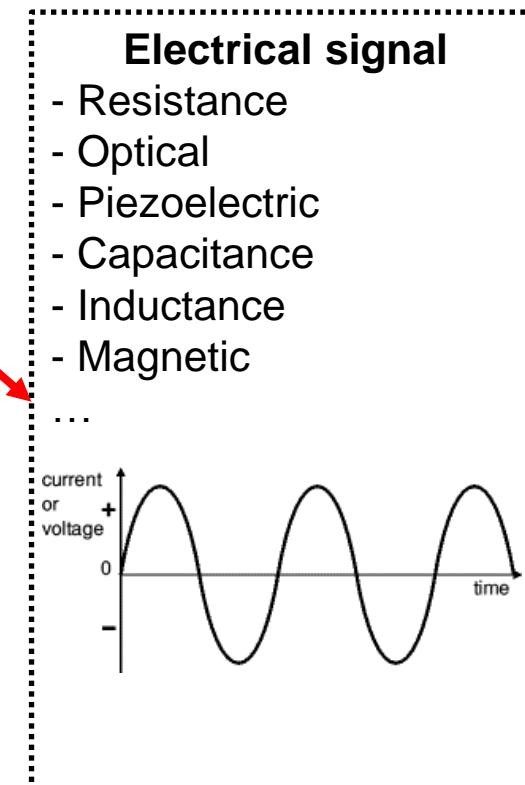
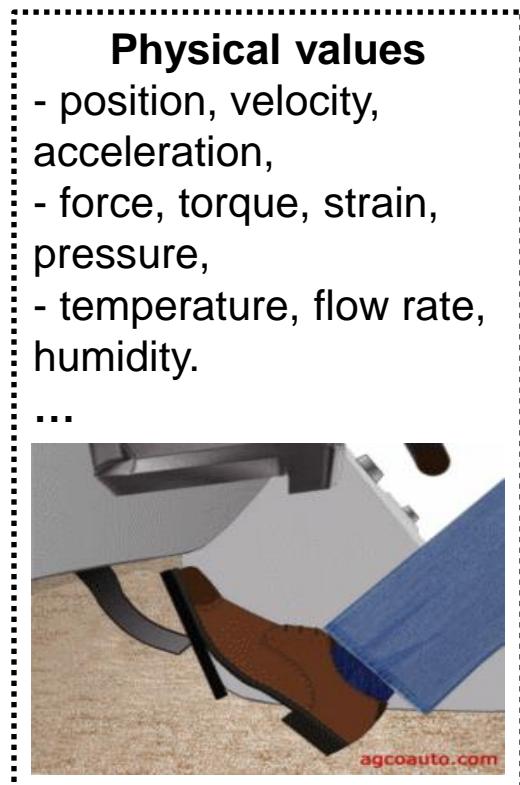
The numerous sensors in the vehicle make this possible!



# How Do Sensors Make This Possible?

## Measurement device for monitoring and control of mechatronics system

- ▶ Sensor: changes “real world” parameter into electrical signal.
- ▶ Signal conditioning and interfacing: converts electrical signal into analog or digital values.



# Switch sensor



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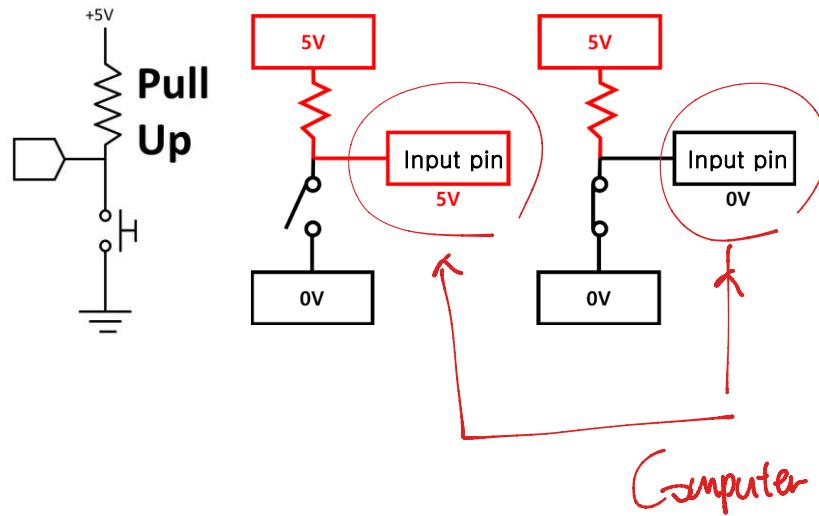
# Switch Sensor

## ■ Mechanical switch sensor

- ▶ A sensor that converts **physical force or movement** into **electrical signals**.

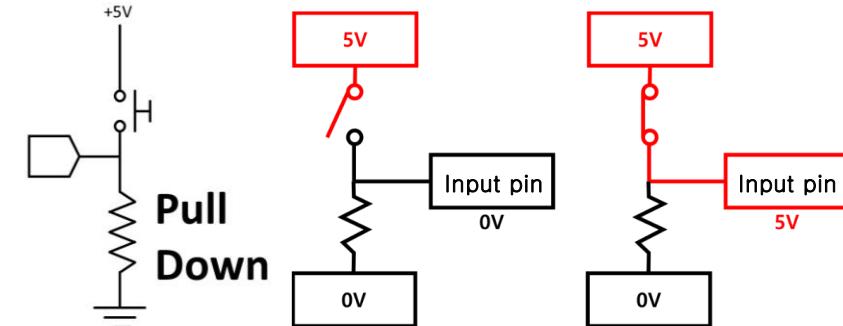
## ■ PULL-UP resistor

- ▶ Switch open → **High**
- ▶ Switch close → **Low**



## ■ PULL-DOWN resistor

- ▶ Switch open → **Low**
- ▶ Switch close → **High**



# Example of Switch Sensor

## ■ Car door (trunk, hood) opening sensor



# Resistive sensor



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# Resistance

## ■ Resistance

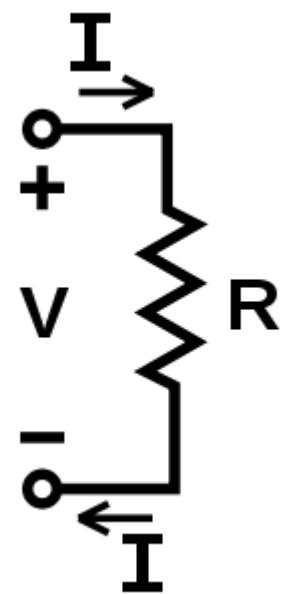
- ▶ Device or material's reduction of current flow.

## Resistor



## ■ Ohm's law

- ▶ Current flow through a conductor is proportional to voltage and inversely proportional to resistance.



$$I = \frac{V}{R}$$

# Resistivity formula

## ■ Factors affecting resistance

- ▶ Conductor length, diameter, material resistivity, and temperature.

## ■ Resistivity formula

- ▶ Proportional to the length and resistivity of the conductor.
- ▶ Inversely proportional to the cross-sectional area.

The diagram shows a cylindrical conductor with its length labeled as **L=length**. The cross-sectional area is labeled as **A=area**. The resistivity of the material is labeled as  **$\rho$ =resistivity**. To the right of the cylinder is a resistor symbol consisting of a zigzag line with the letter **R** below it.

$$\text{R} = \rho \frac{L}{A}$$

# Potentiometer

## Potentiometer

- Used for rotational or straight displacement instruments.

## Voltage divider rule

$$R = \frac{\rho L}{A}$$

( $\rho$  : Resistivity)

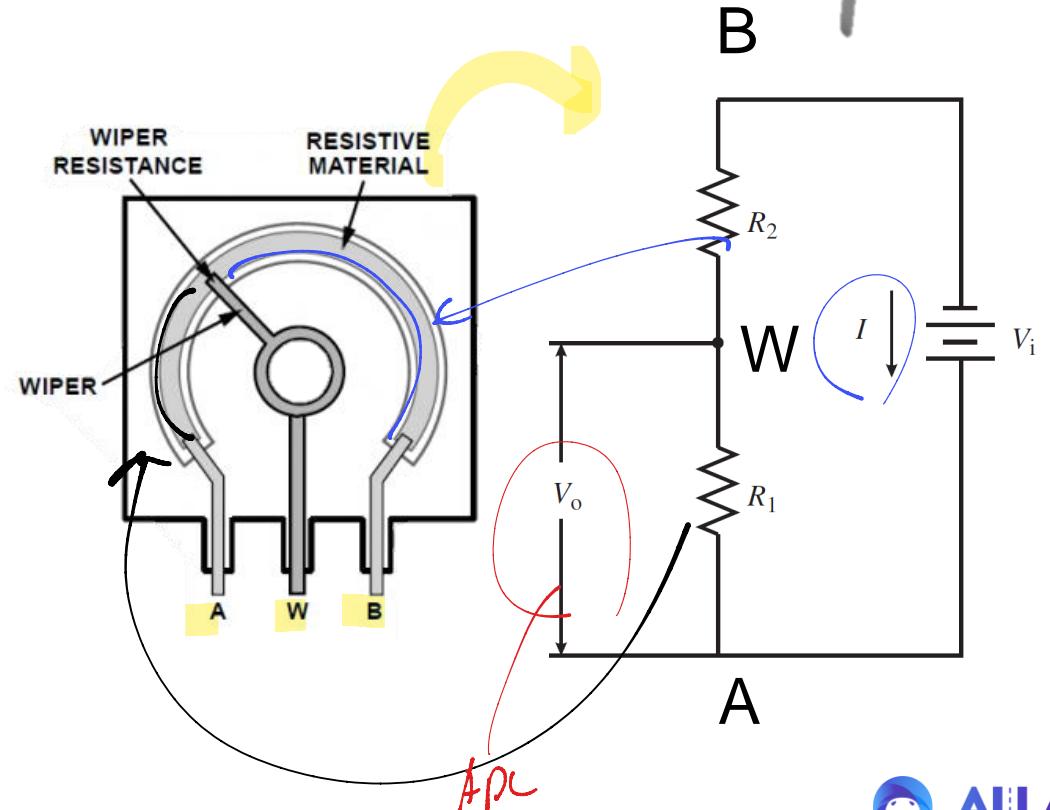
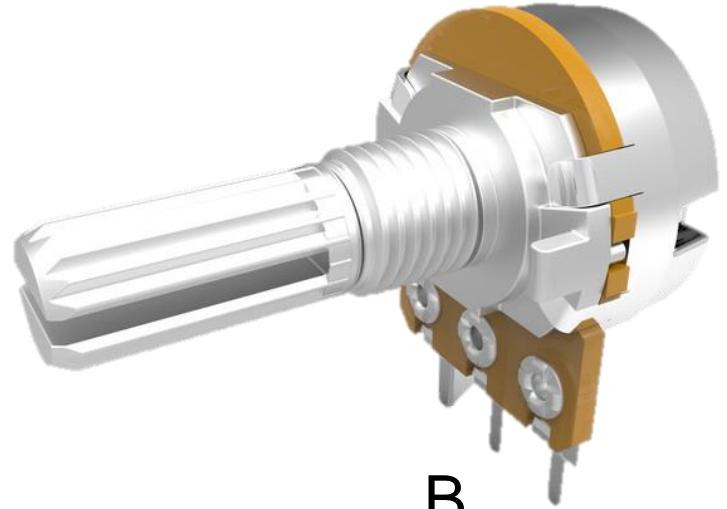
$$R_1 = xR$$

$$R_2 = (1-x)R$$

$$U_o = \frac{R_1}{R_1 + R_2} U_i = \frac{x}{x+1} U_i$$

2.5

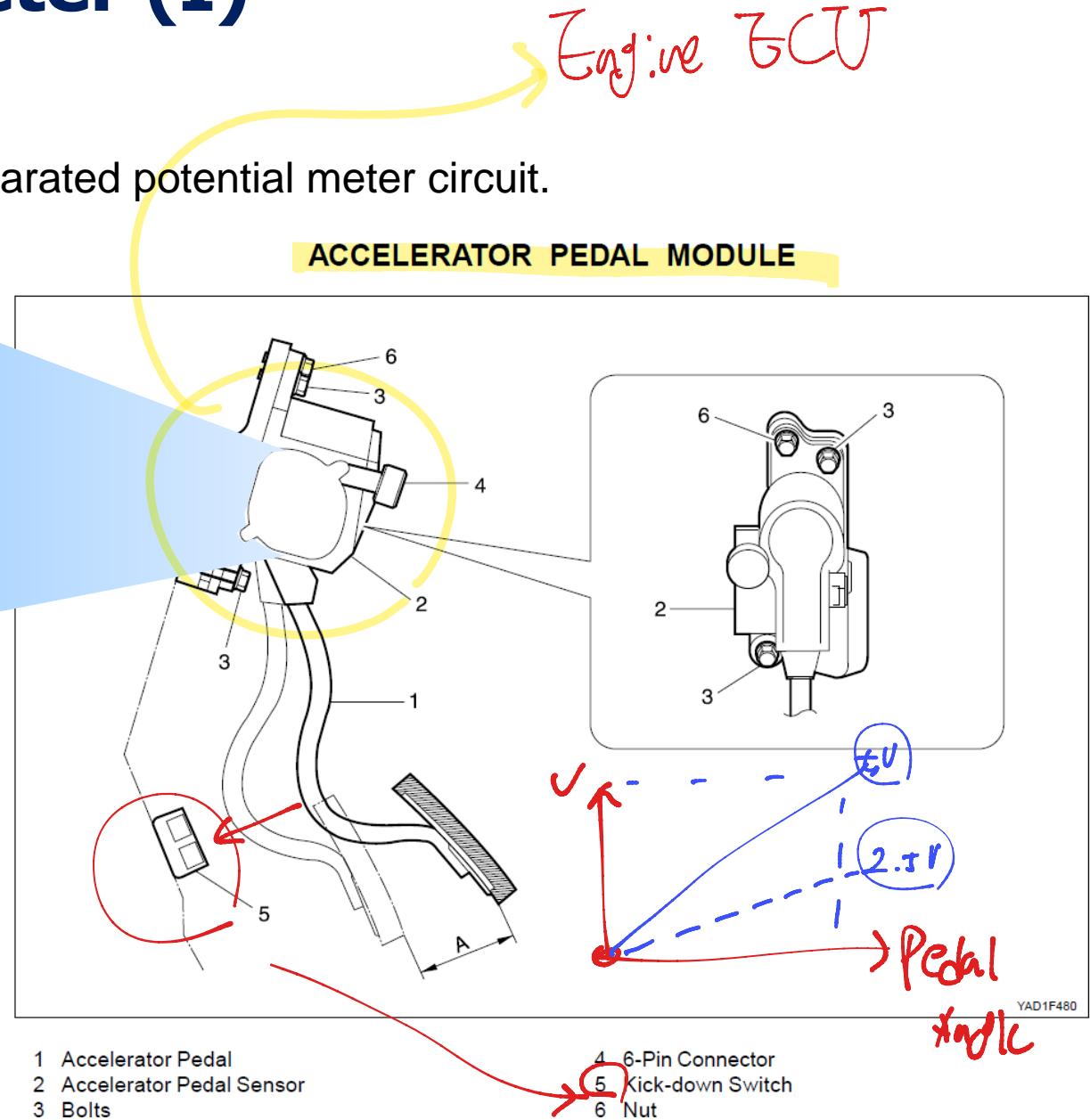
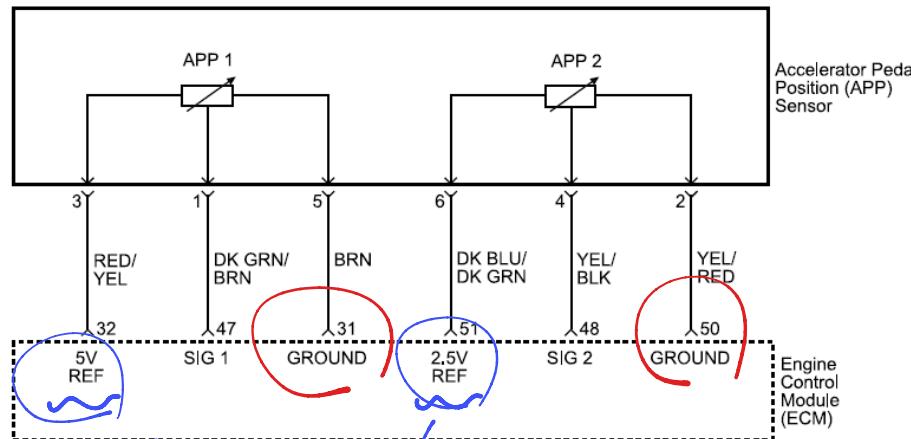
0.5 Voltage Divider Rule



# Example of Potentiometer (I)

## Accelerator pedal module

- Two output signal for fail-safe from separated potential meter circuit.



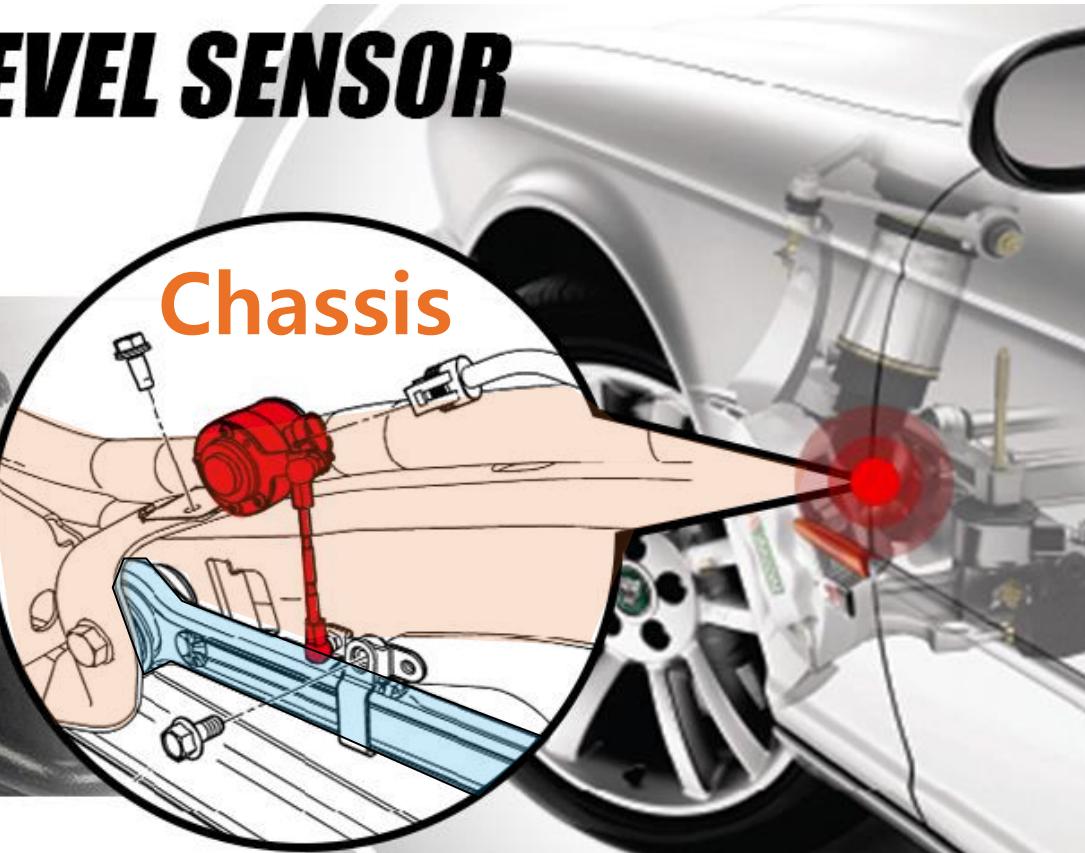
# Example of Potentiometer (II)

## ■ Ride height sensor

- ▶ Provides information on the height of the body.
- ▶ Ride height sensor body is attached to the **chassis**, the rod is linked to the **wishbone** or **control arm**.

## **RIDE HEIGHT LEVEL SENSOR**

- Properly maintain the vehicle's height
- Also called suspension ride height sensor



# Thermistor

*→ Resistance*

## ■ Thermistor

- ▶ Resistor that changes depending on temperature.
- ▶ Semiconductor type of resistor.

## ■ NTC (negative temperature coefficient)

- ▶ Temperature **rises**, resistance **decreases**

## ■ PTC (positive temperature coefficient)

- ▶ Temperature **rises**, resistance **increases**

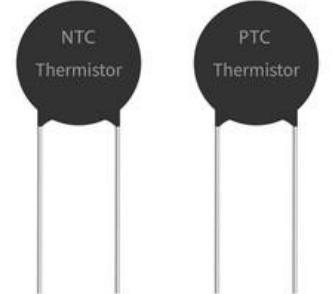
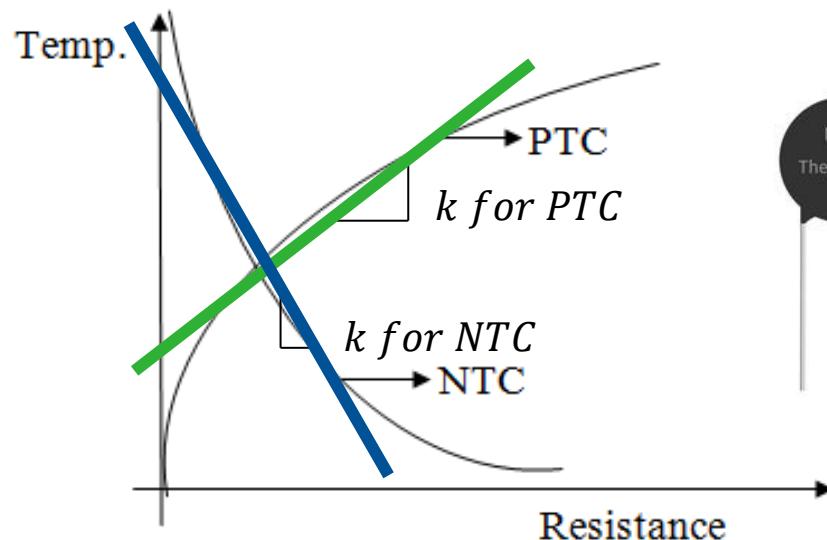
$$\Delta R = k \Delta T$$

$\Delta R$ : change in resistance

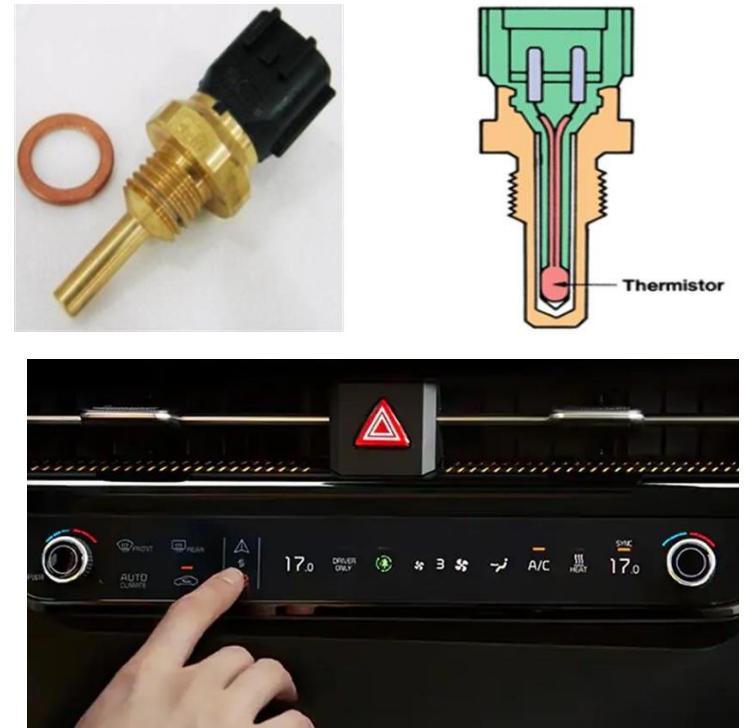
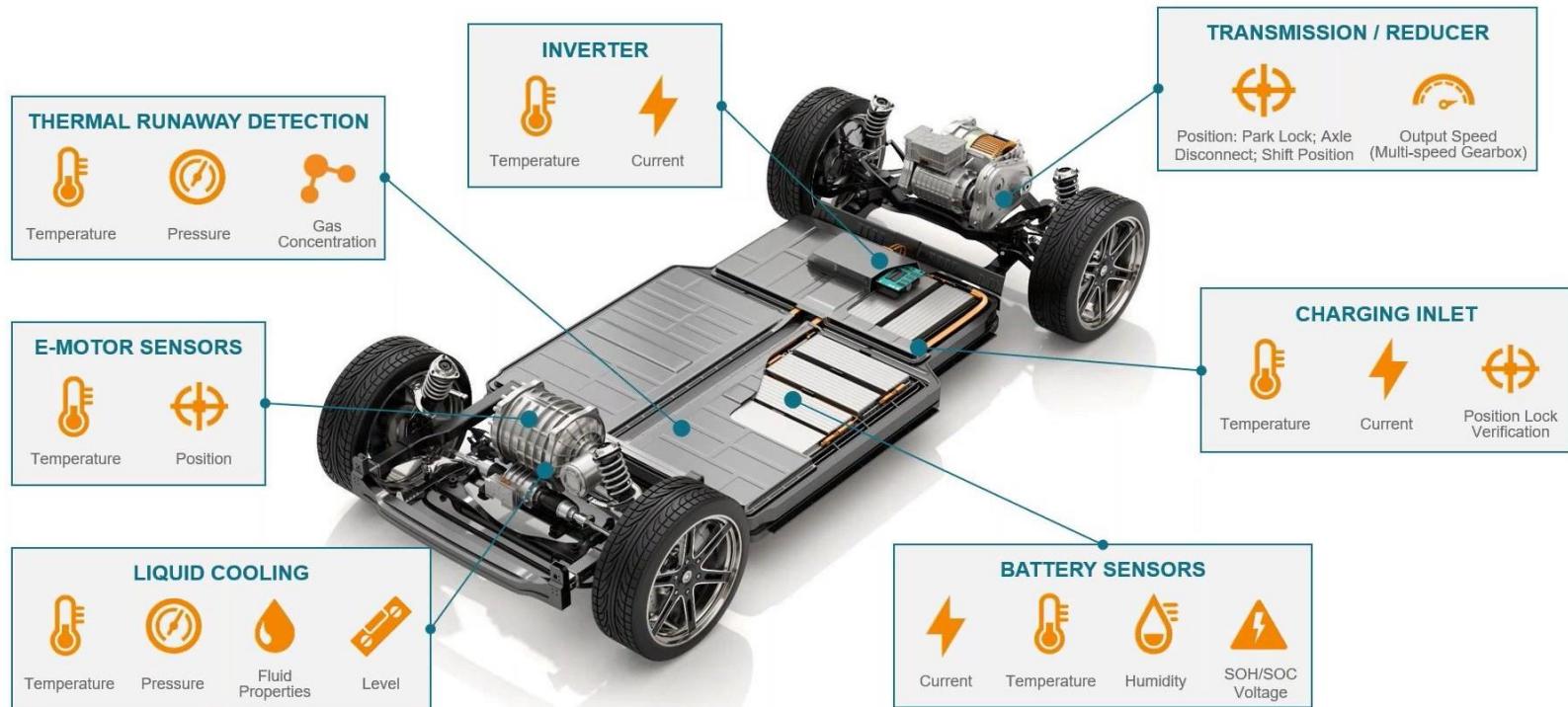
$\Delta T$ : change in temperature

$k$ : approximated first – order temperature coefficient of resistance

( $k < 0$ : NTC,  $k > 0$ : PTC)



# Example of Thermistor



# Optical sensor

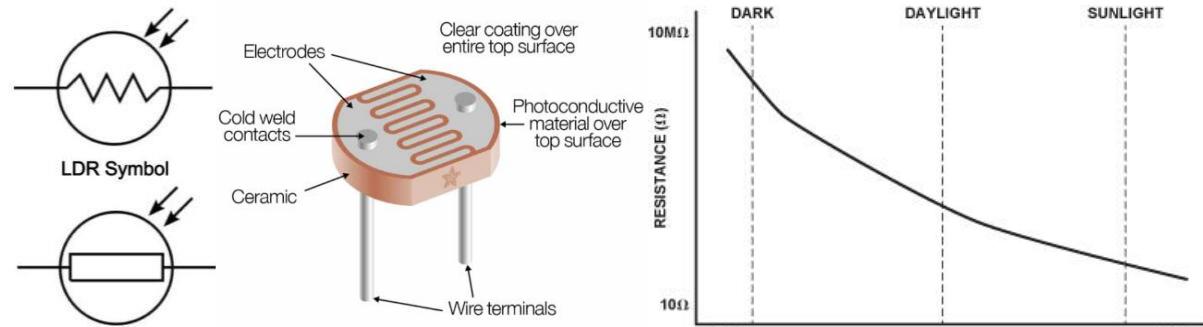


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# Optical Sensor

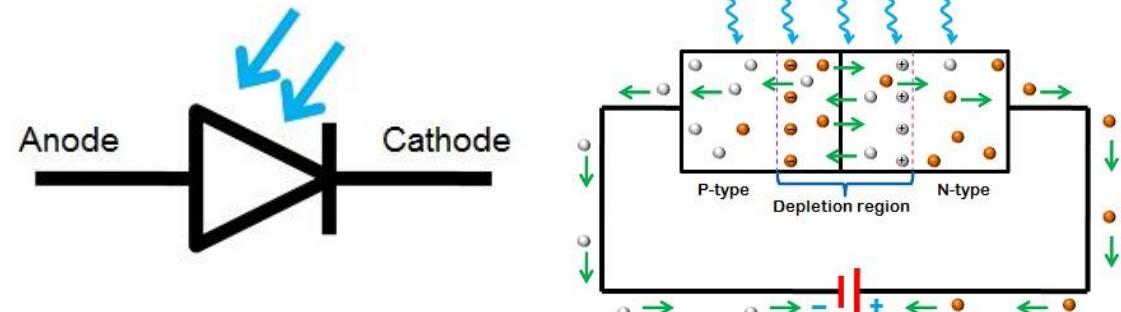
## Photoresistor

- ▶ Light dependent resistor
- ▶ Cadmium sulfide (CdS)
  - Also called Light Detection Register (LDR).
- ▶ The brighter the lower the resistance.



## Photo diode

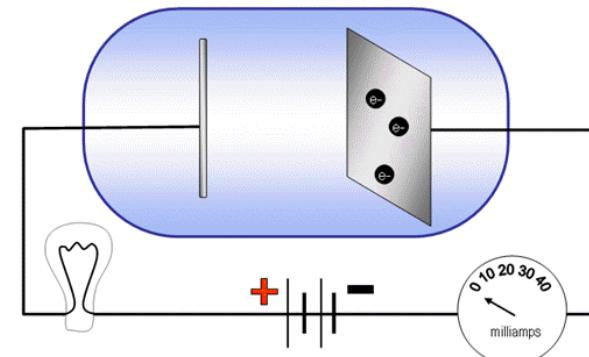
- ▶ P-N junction diode
- ▶ Convert photons (light) to electrical current.



## Photoelectric effect

- ▶ Electrons are emitted because of absorbing electromagnetic waves greater than the limit frequency.

<https://m.blog.naver.com/joon9497/221599336814>



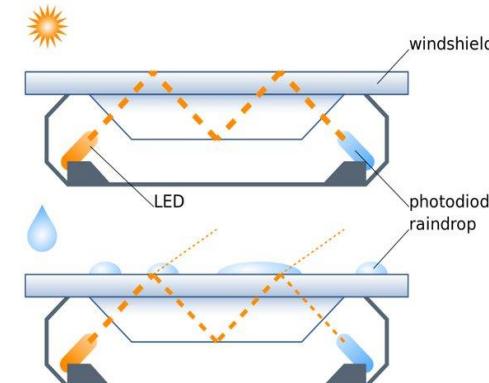
## Photoelectric Effect

# Example of Optical Sensor

## ■ Automatic headlight



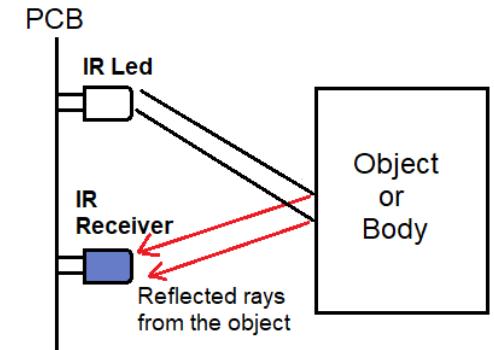
## ■ Rain sensor



# Optical Encoder

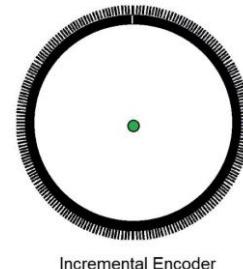
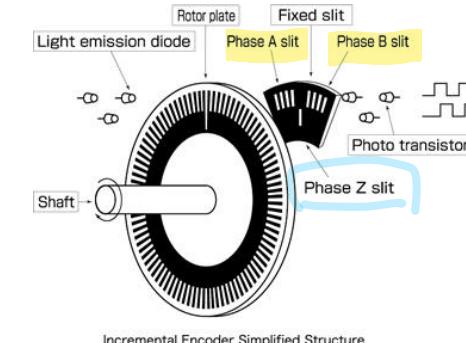
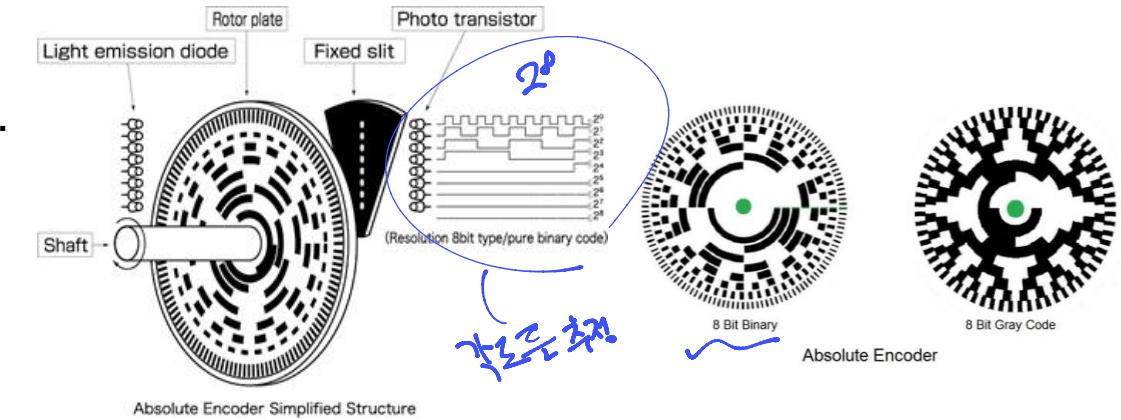
## ■ IR sensors

- ▶ IR LED (emitter): emits infrared light ( $780\text{ nm} \sim 50\text{ }\mu\text{m}$ ).
- ▶ Receiver (photo diode): detects infrared signals.



## ■ Encoder

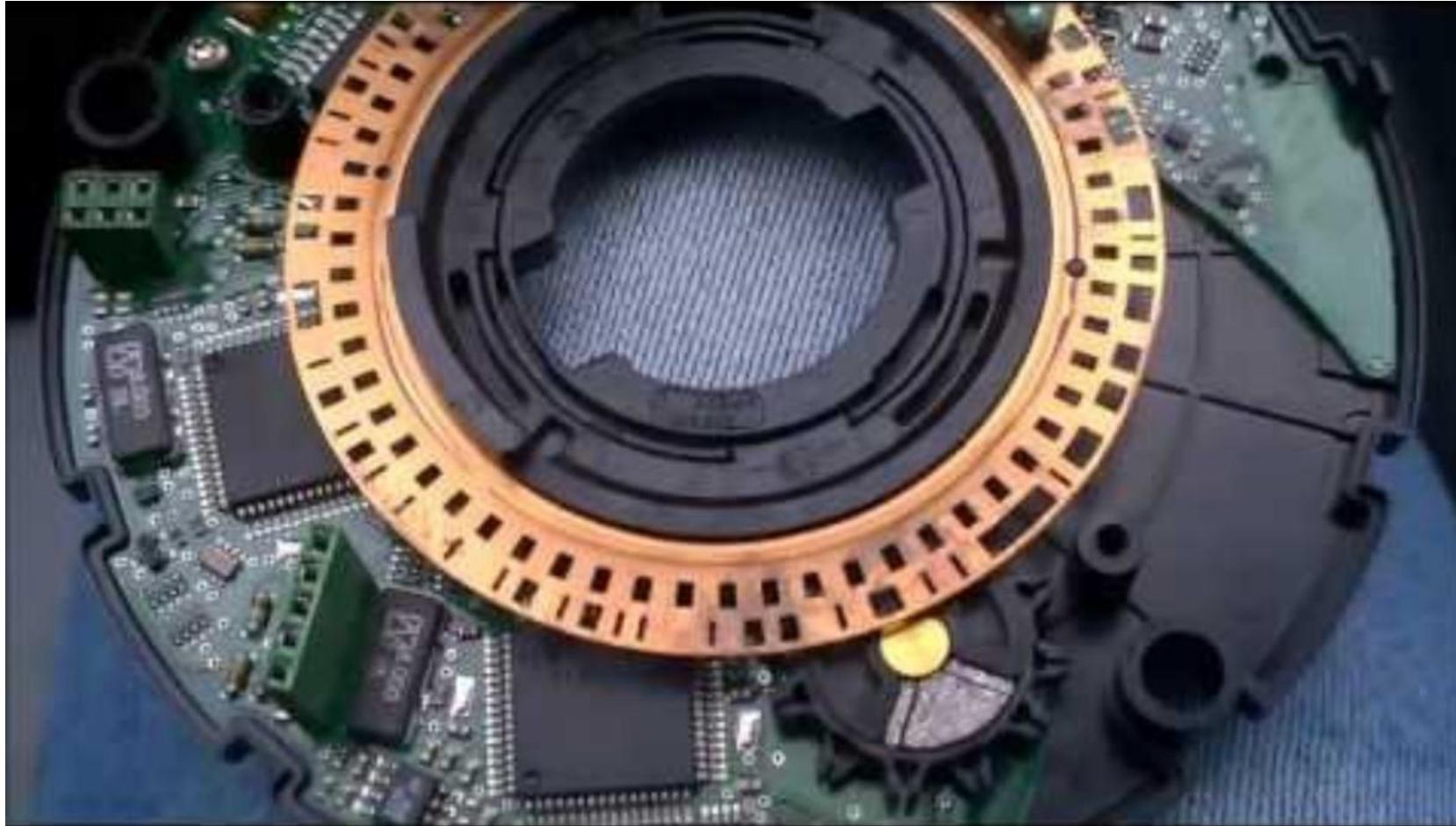
- ▶ Detect changes in slot position by measuring light.
- ▶ Absolute
  - Indicates the current shaft position, making it an angle transducer.
- ▶ Incremental
  - Provides information about the motion of the shaft, such as position, speed, and distance.



# Example of Encoder

## ■ Steering angle sensor

- ▶ Measure absolute steering angle position.



# Piezoelectric sensor



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# Piezoelectric Effect

-THE-  
**PIEZOELECTRIC EFFECT**



# Piezoelectric

— 페조이렉트릭. 물리학과 핵심

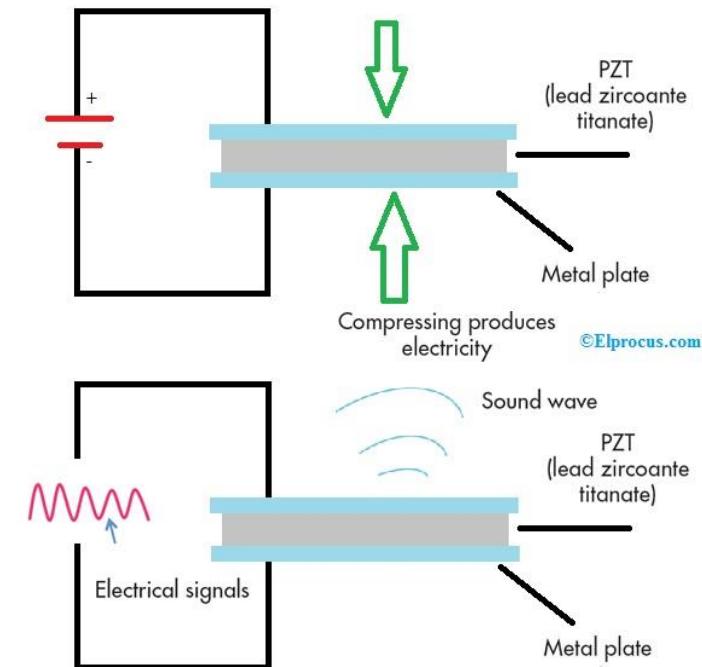
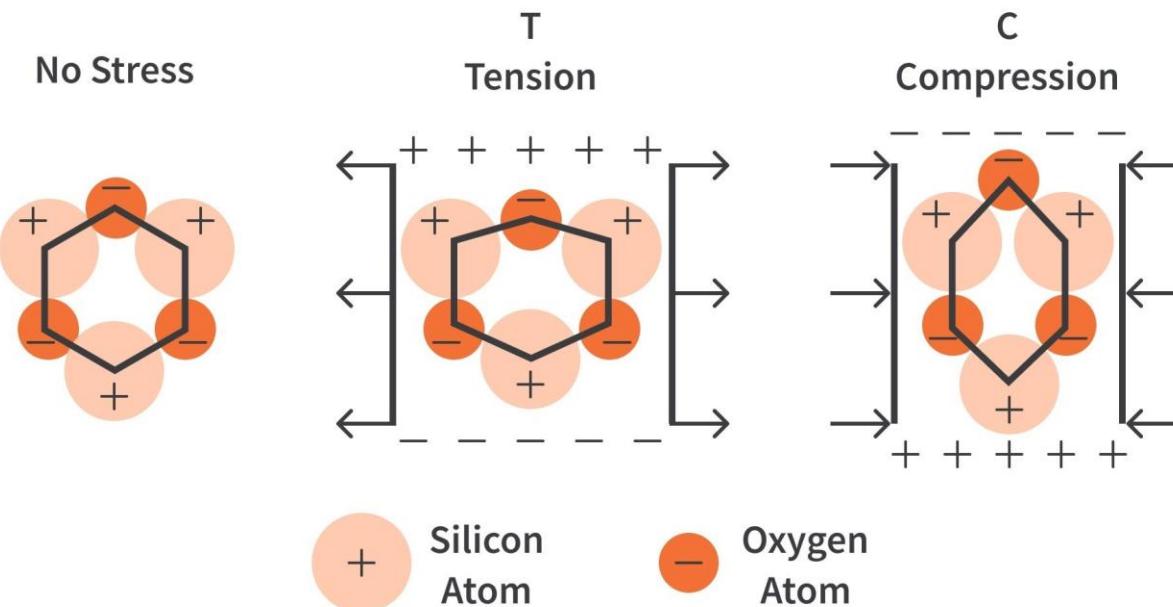
## ■ Piezoelectric effect

- ▶ Piezoelectricity can be generated whenever the material is squeezed by mechanical stress.

## ■ Inverse piezoelectric effect

- ▶ Convert electrical energy into mechanical energy.

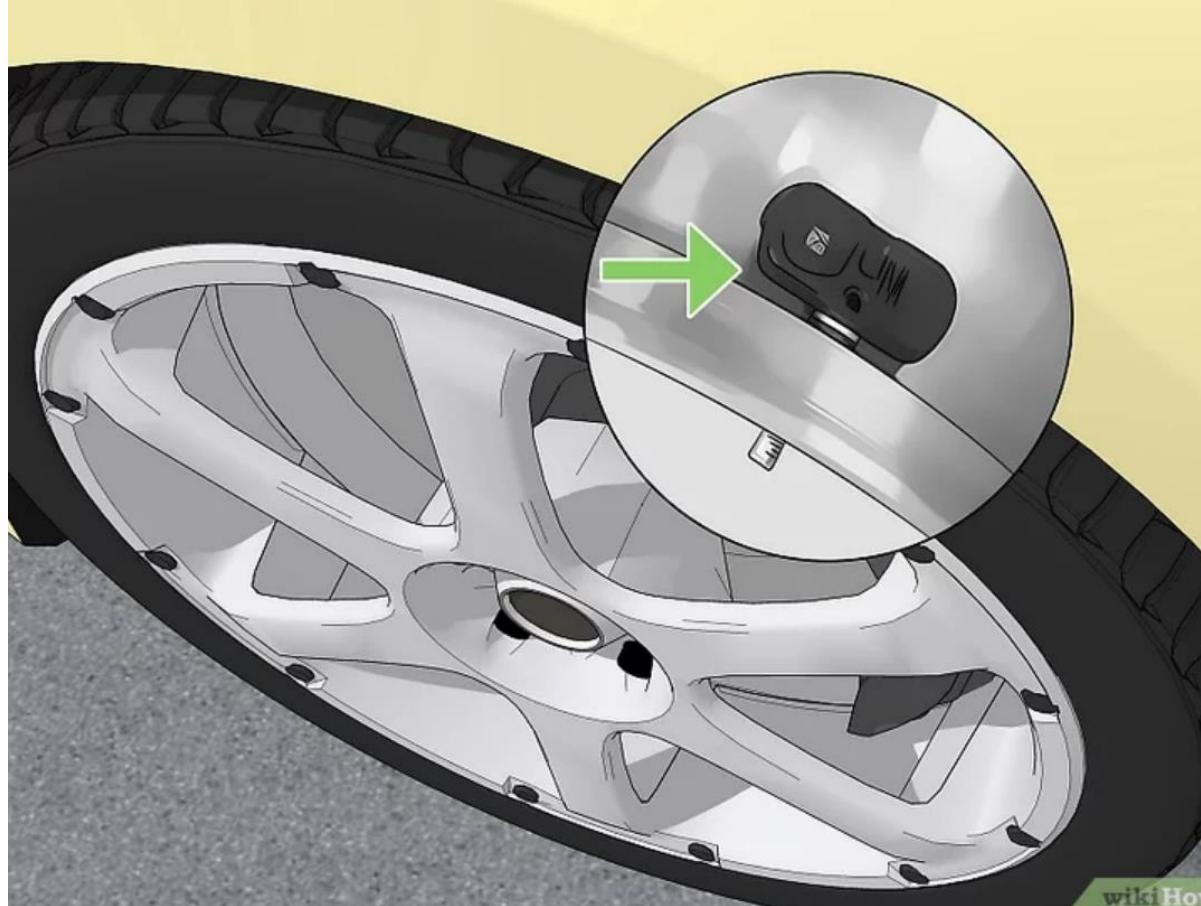
▲ 등장하는 감지



# Example of Piezoelectric Sensor (I)

## ■ Tire pressure measurement systems

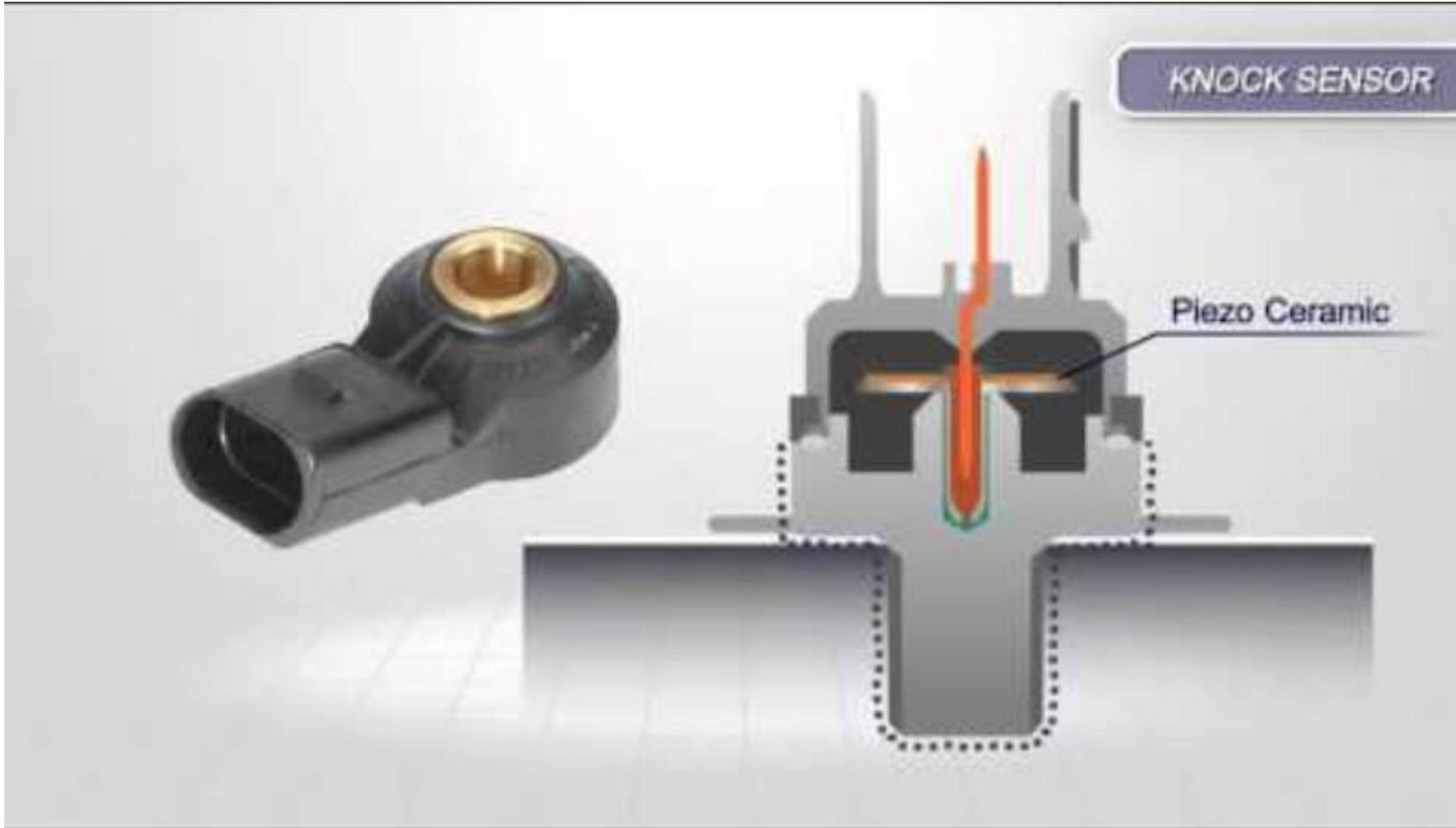
- ▶ A system that monitors the air pressure inside the pneumatic tires on vehicle.



# Example of Piezoelectric Sensor (II)

## ■ Knock sensor

- ▶ Detects abnormal combustion such as knocking and early ignition inside the engine.



# Capacitance sensor



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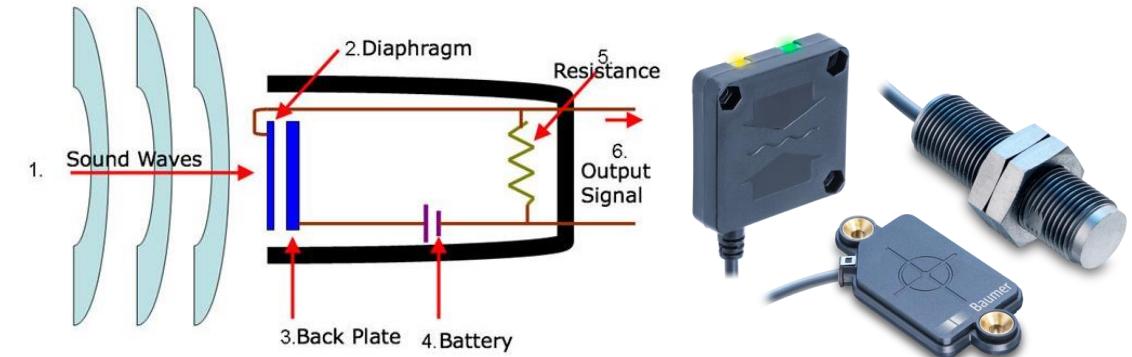
# Capacitance Sensor

## ■ Capacitance (C)

- Capability of capacitors to store charges.

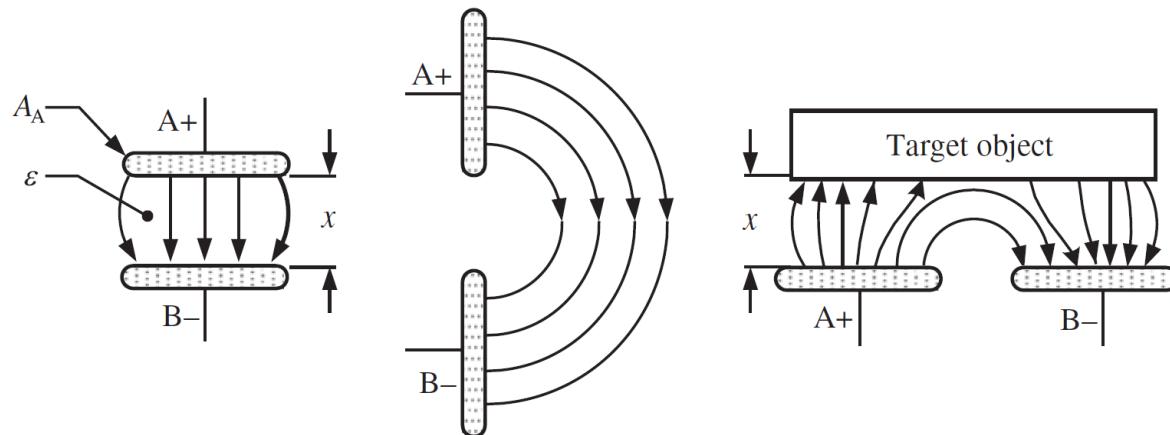
$$C = \epsilon_r \epsilon_0 \frac{A}{x}$$

$\epsilon_0$  : permittivity of vacuum  
 $\epsilon_r$  : permittivity of the insulator used  
 $A$  : area of overlap of the two plates  
 $x$  : distance between two plate



Condenser Microphone

Capacitive Sensors



Projected capacitive touchscreen.

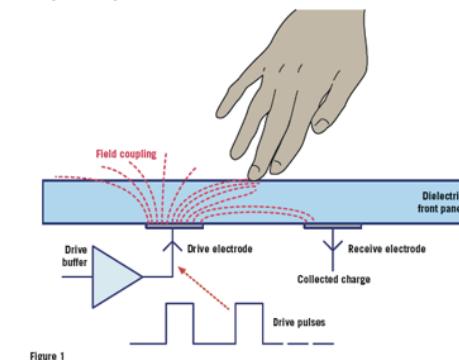


Figure 1

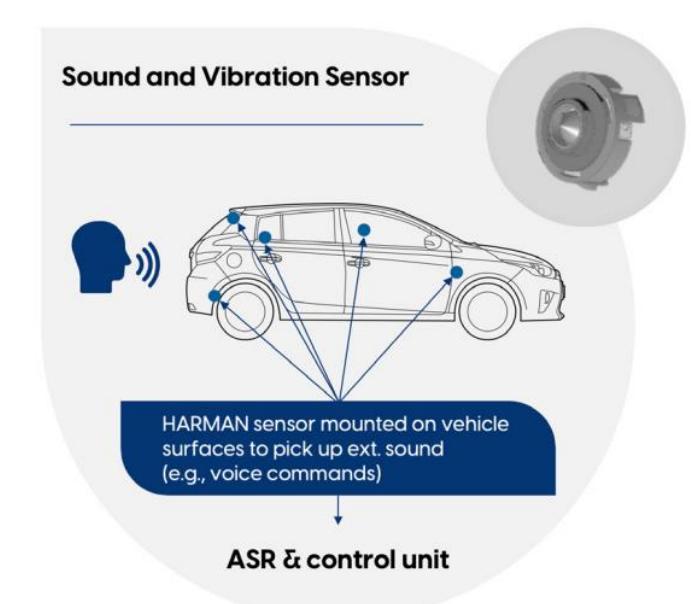
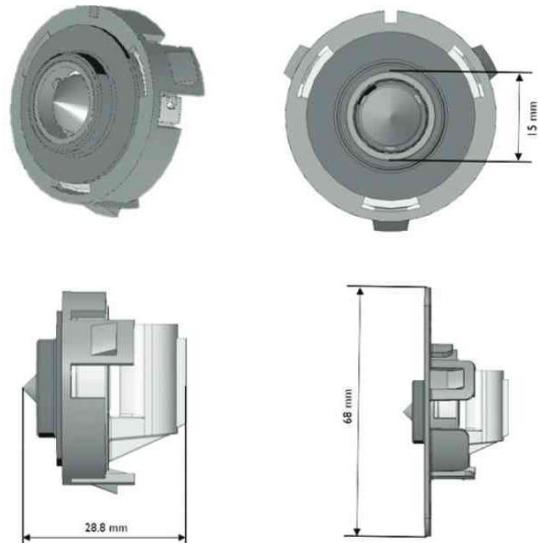


Touch panel

# Example of Capacitance Sensor

## External microphone

- ▶ Using for exterior vehicle speech recognition and acoustic sensing.



# Inductance sensor



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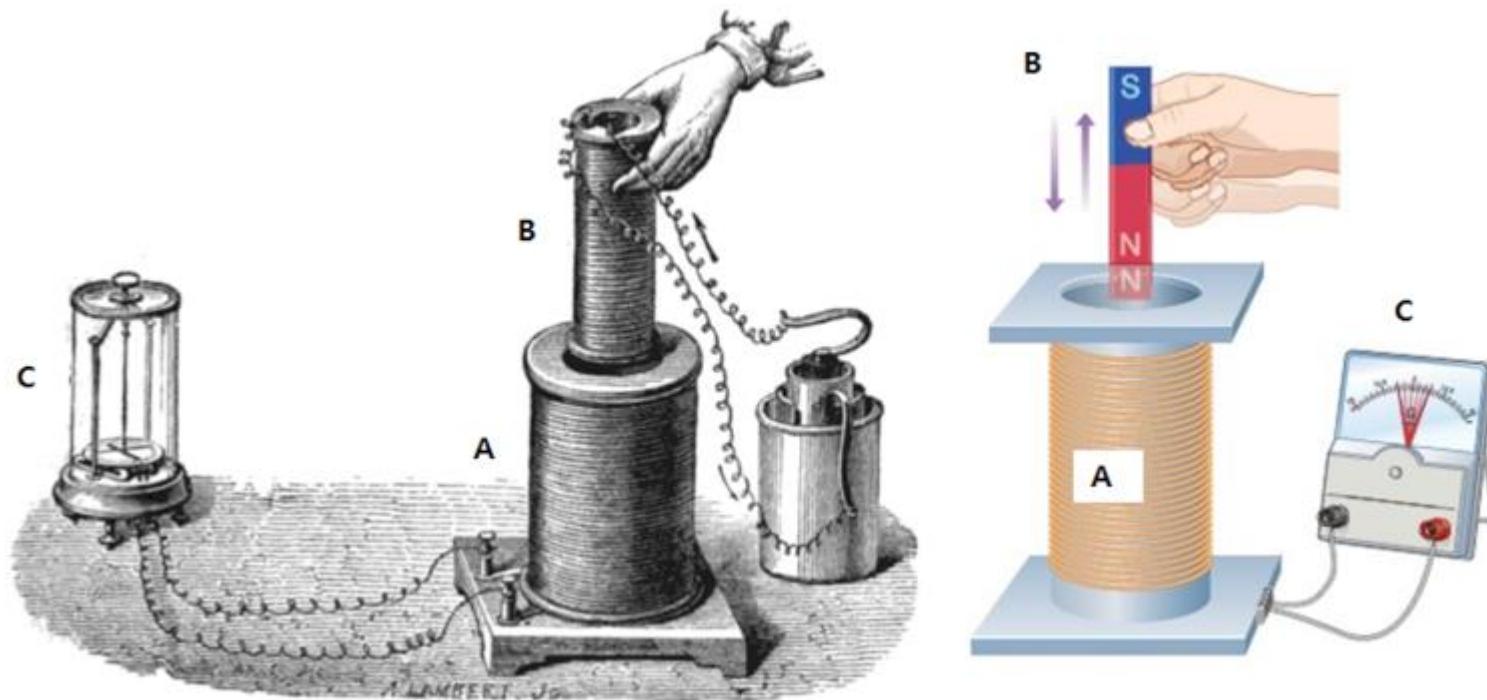


# Faraday's Law of Induction

## ■ Faraday's law of induction

►  $\mathcal{E} = -N \frac{d\Phi}{dt}$

$\Phi_B$  : magnetic flux,  $\mathcal{E}$  : electromotive force  
 $N$  : number of windings

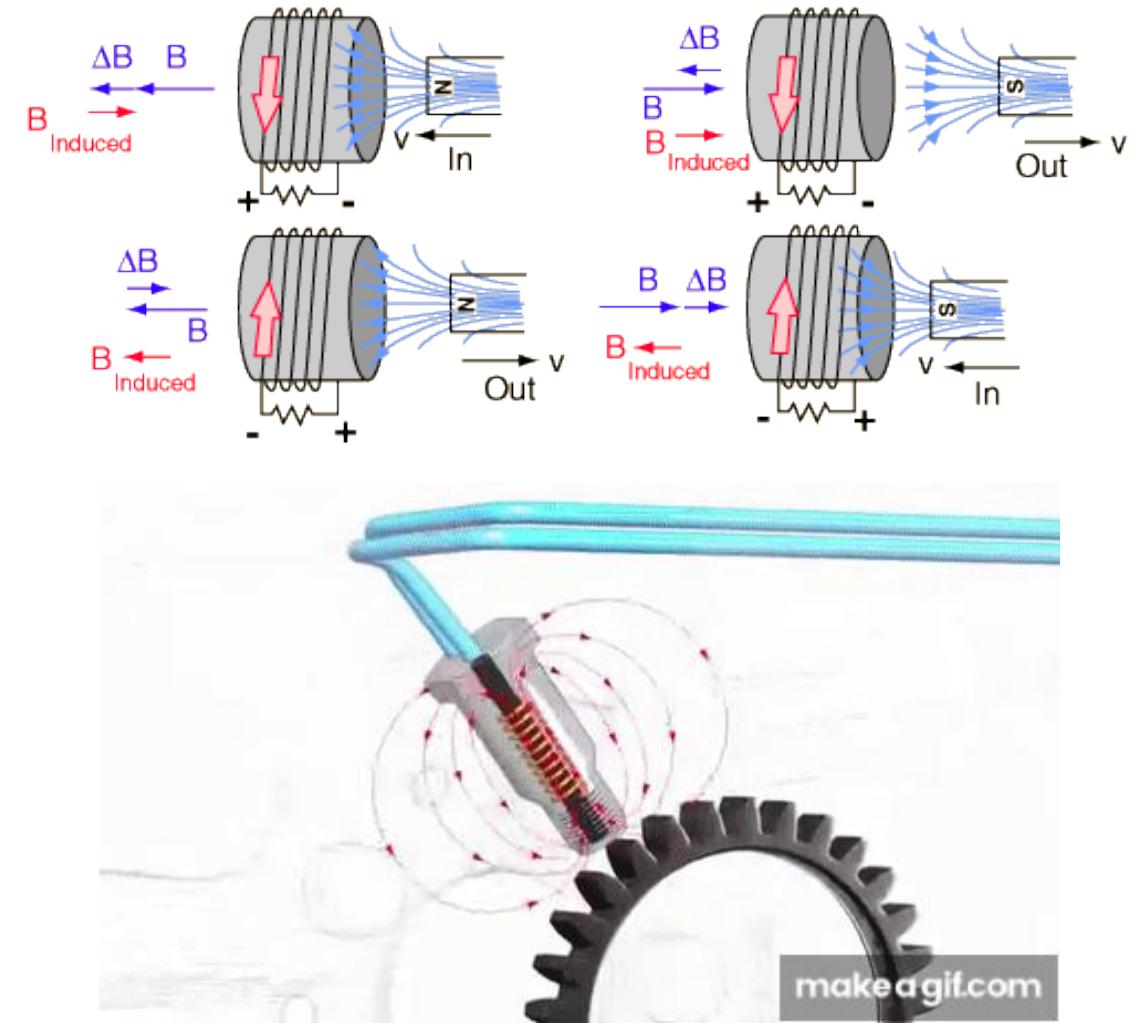
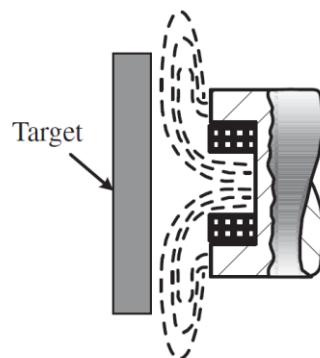
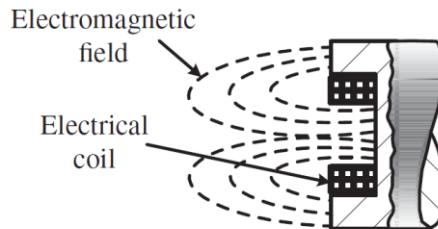


<https://m.blog.naver.com/PostView.nhn?blogId=ssh123451&logNo=221001665110&proxyReferer=https%3A%2F%2Fwww.google.com%2F>

# Inductance Sensor

## ■ Inductive proximity sensor

- ▶ Detect changes in magnetic field by nearby ferrous metal target.



<https://youtu.be/YeXlmdiXp2s?t=40>



# Magnetic sensor



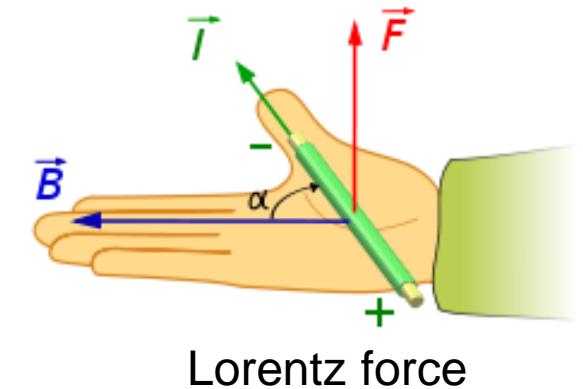
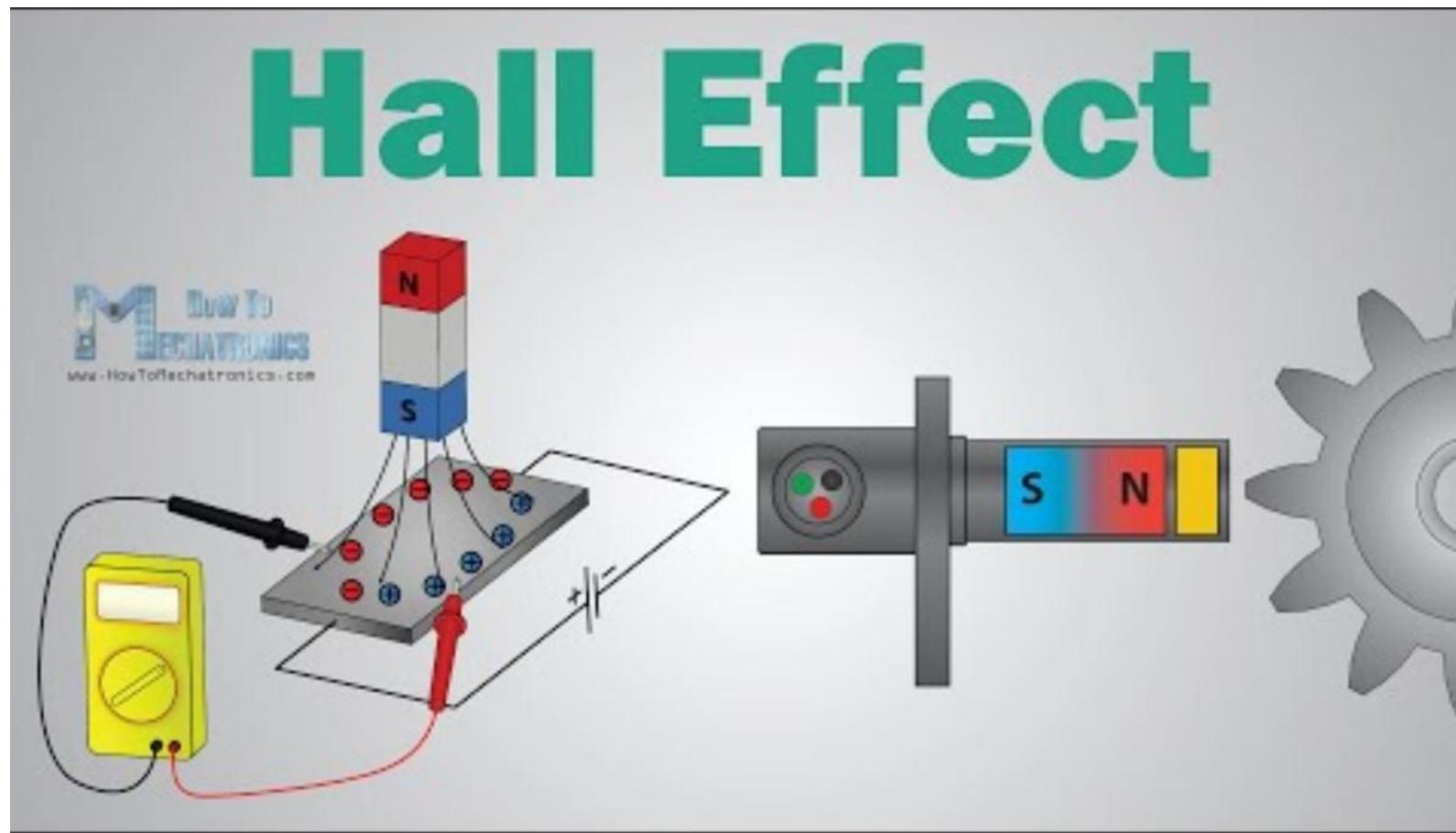
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# Magnetic

## Hall effect

- ▶ Production of the Hall voltage occurs in an electrical conductor when it is subjected to an electric current and an applied magnetic field perpendicular to the current.



Hall sensor

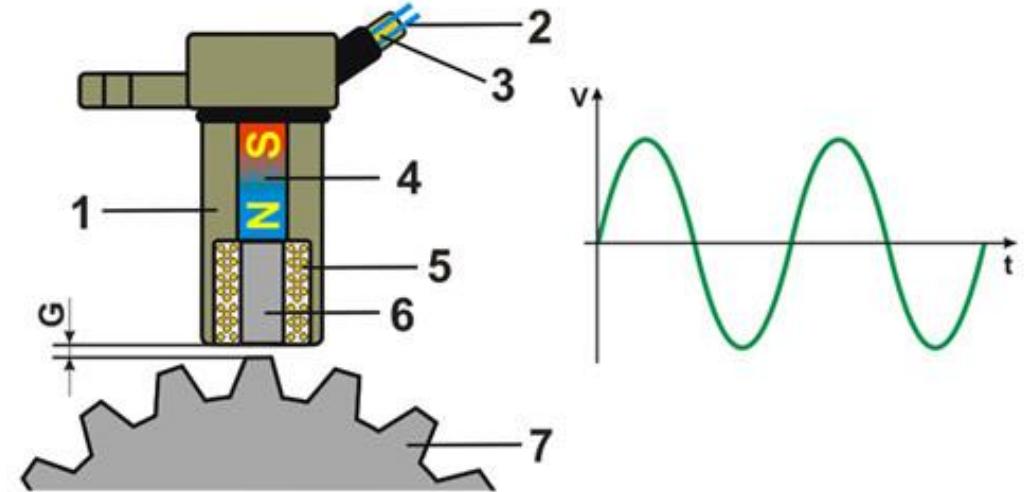
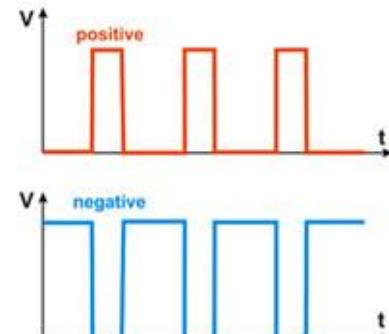
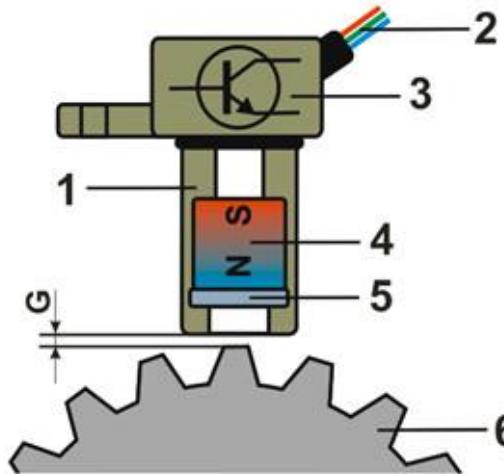
# Crank Angle Sensor (CAS)

## ■ Used in internal combustion engine

- ▶ Monitor the position or rotational speed of the crankshaft.

## ■ Types of sensors

- ▶ Hall effect sensor
  - Static (unchanging) magnetic fields can be detected.
- ▶ Inductive sensor
  - Usually purely passive devices (no power supply required).





**THANK YOU  
FOR YOUR ATTENTION**



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