

Automotive Sensors

Sensor Principle and Types

Automotive Intelligence Lab.

Contents

■ Sensor's role in vehicle

■ Switch sensor

■ Resistive sensor

- ▶ Potentiometer

- ▶ Thermistor

■ Optical sensor

■ Piezoelectric sensor

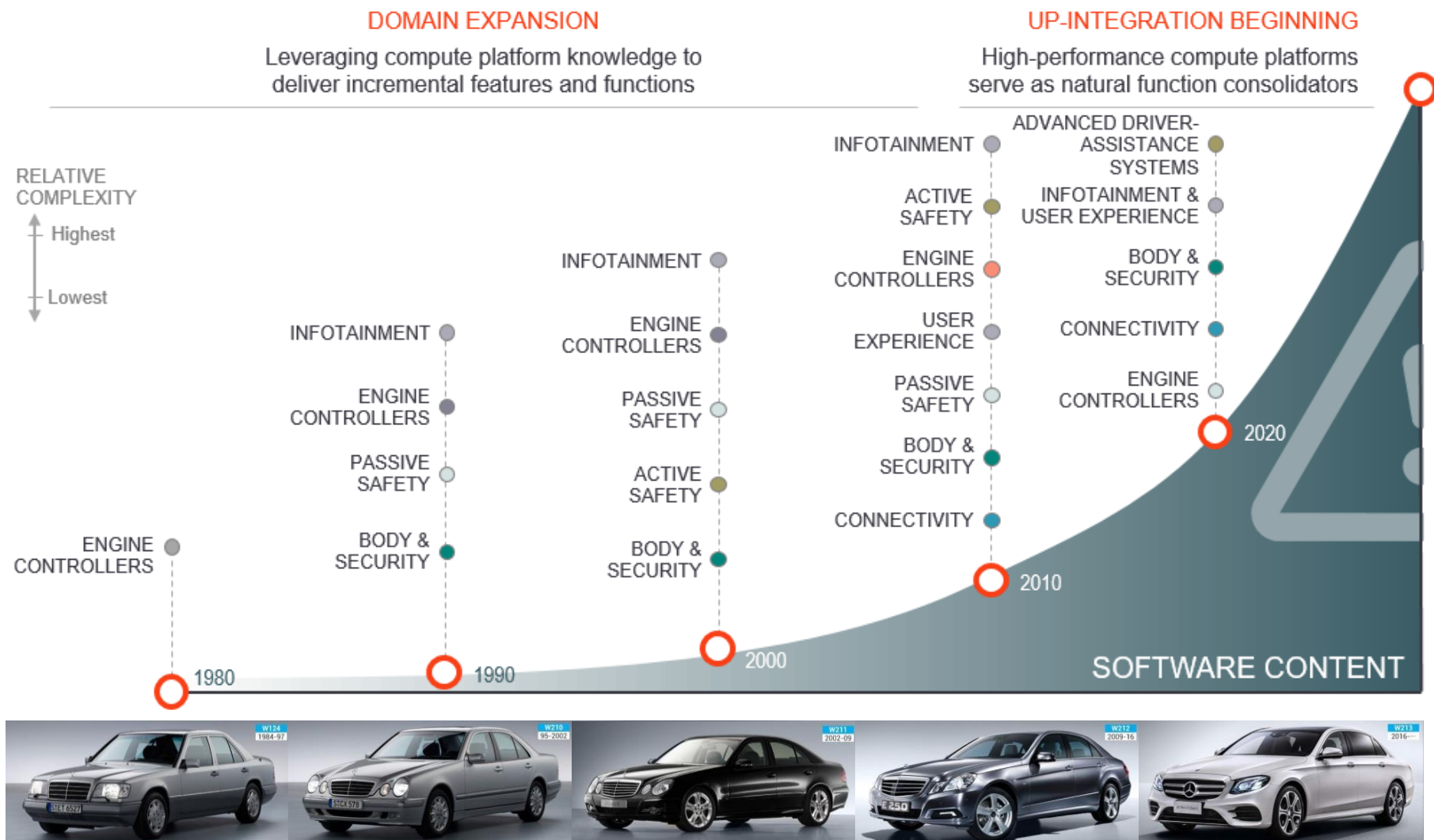
■ Capacitance sensor

■ Inductance sensor

■ Magnetic sensor

Sensor's role in vehicle

Intelligence Functions on Automobile



[출처: Aptiv]

Advanced Driver Assistance System (ADAS)



What Makes These Functions Possible?

■ The numerous sensors in the vehicle make this possible!



Camera



LiDAR



Radar



GNSS



IMU

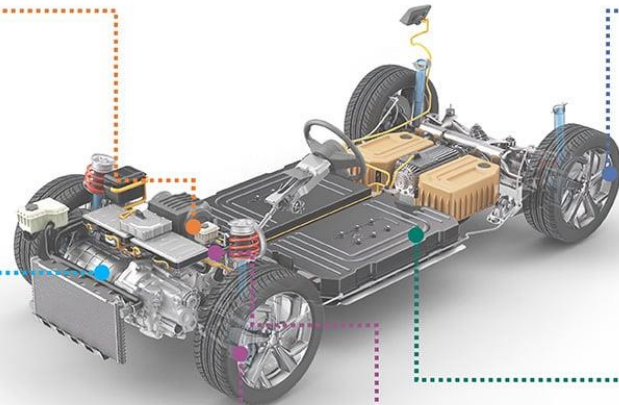
Thermal Management



Air Conditioning Pressure & Temperature



Pressure & Temperature sensor for CO2



Tire Monitoring



Valve Mounted TPMS



Tire Mounted TPMS



Tread Depth Monitor

Electric Motor



Rotor Position



Stator Temperature



Oil Cooling Pressure & Temperature



Brake Pressure



Pedal Force



Drum Force



Passive & Active Fuses



Current Sensing Module (IVT)



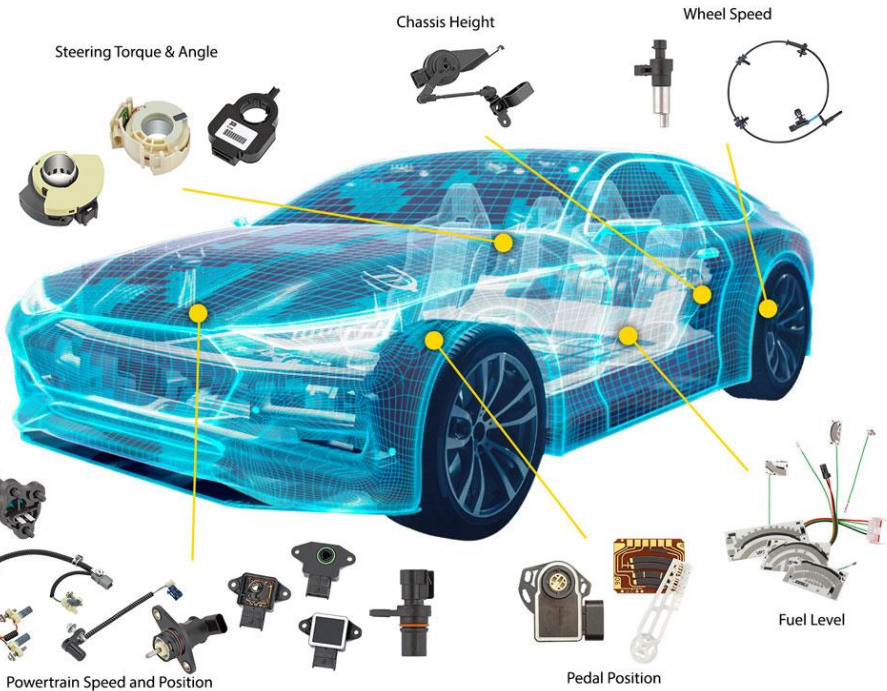
Insulation Monitoring Device



Contactor

Brake System

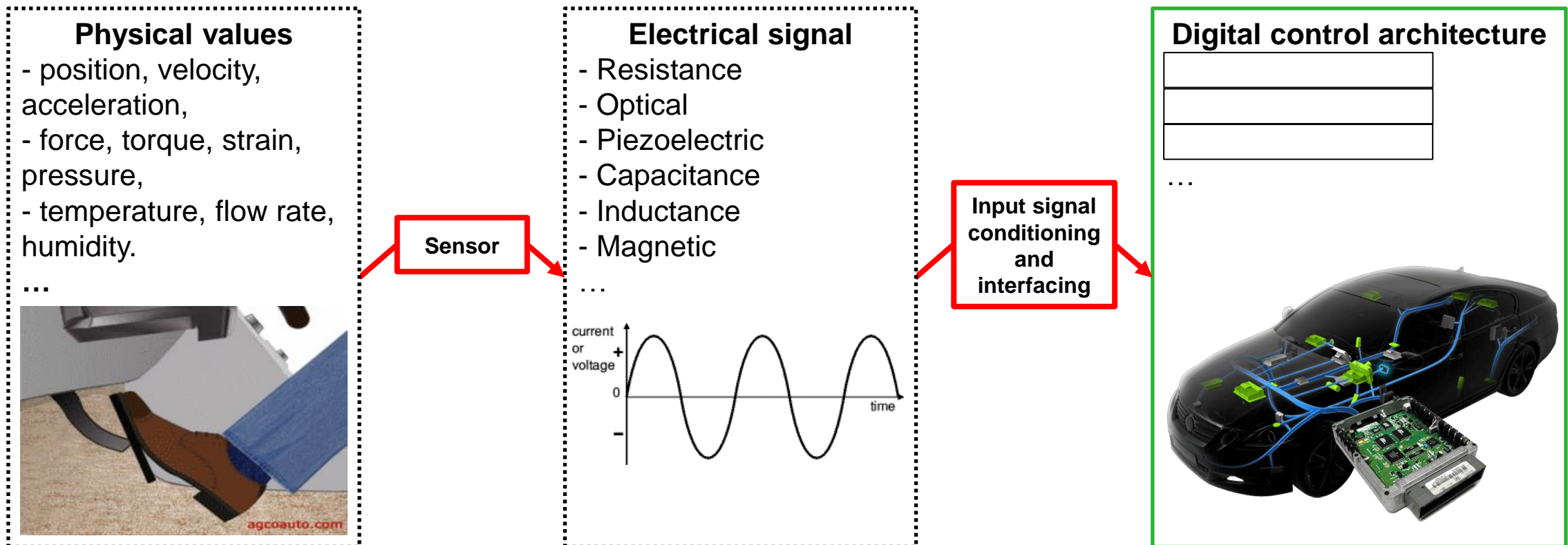
Battery



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

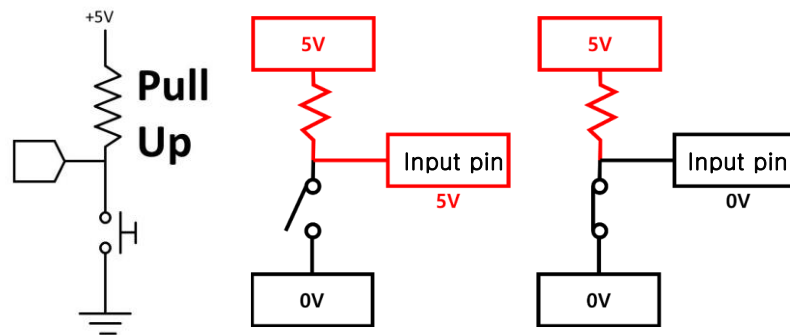
Switch Sensor

■ Mechanical switch sensor

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

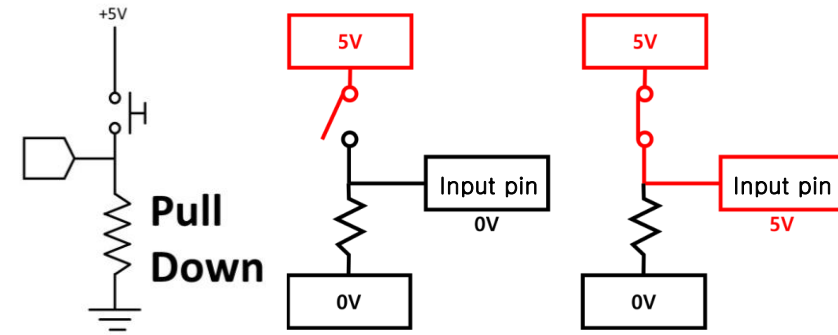
■ PULL-UP resistor

- ▶ Switch open →
- ▶ Switch close →



■ PULL-DOWN resistor

- ▶ Switch open →
- ▶ Switch close →



Example of Switch Sensor

■ Car door (trunk, hood) opening sensor



Resistive sensor

Resistance

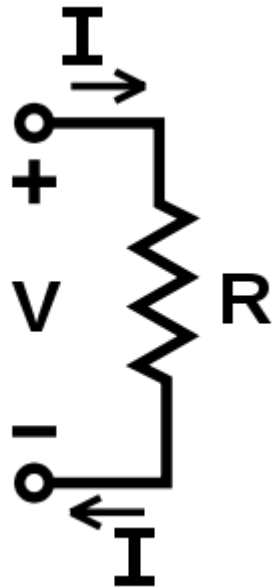
■ Resistance

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

■ Ohm's law

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

Resistor



$$I = \boxed{}$$

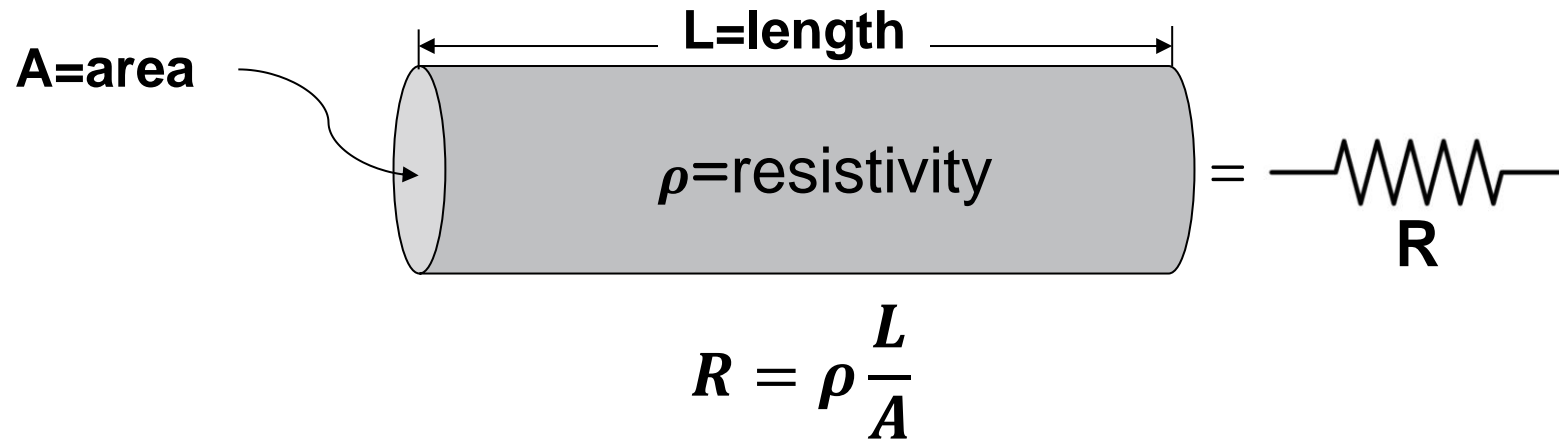
Resistivity formula

■ 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.

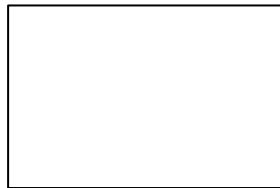


Potentiometer

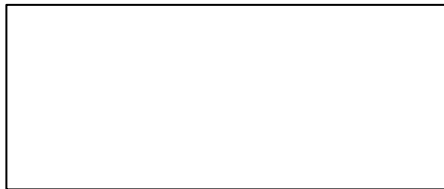
■ Potentiometer

- ▶ Used for rotational or straight displacement instruments.

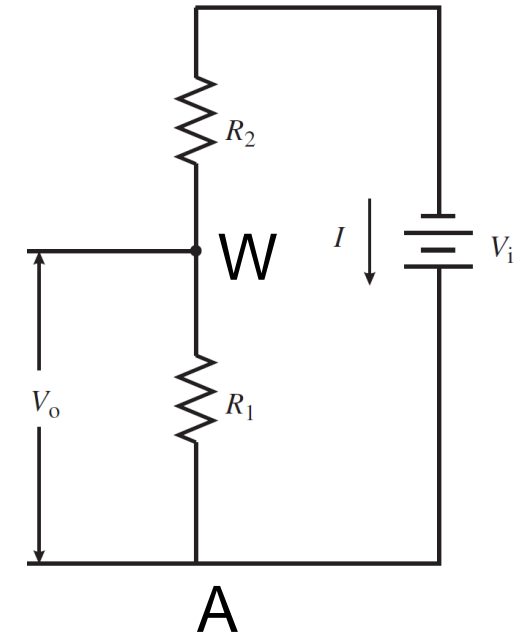
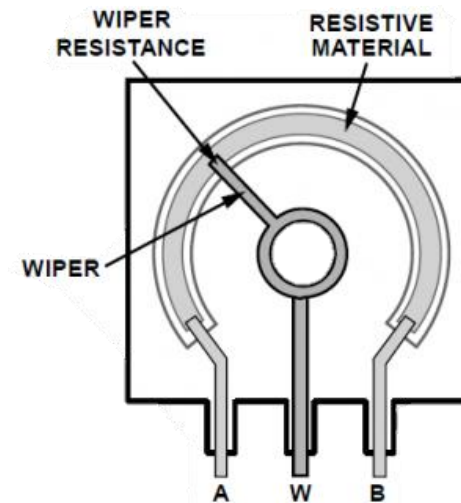
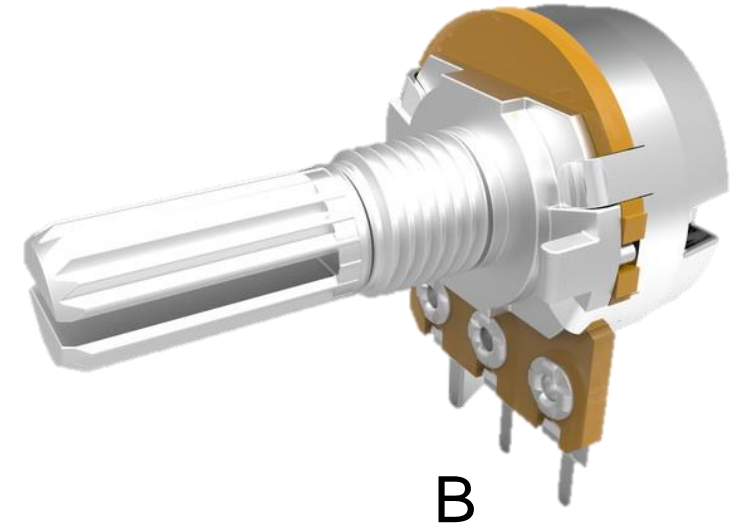
■ Voltage divider rule



(ρ : Resisitivity)



Voltage Divider Rule



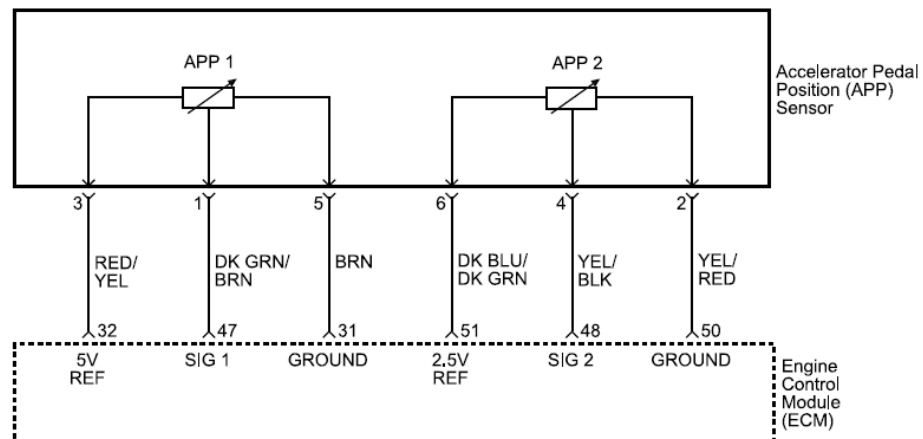
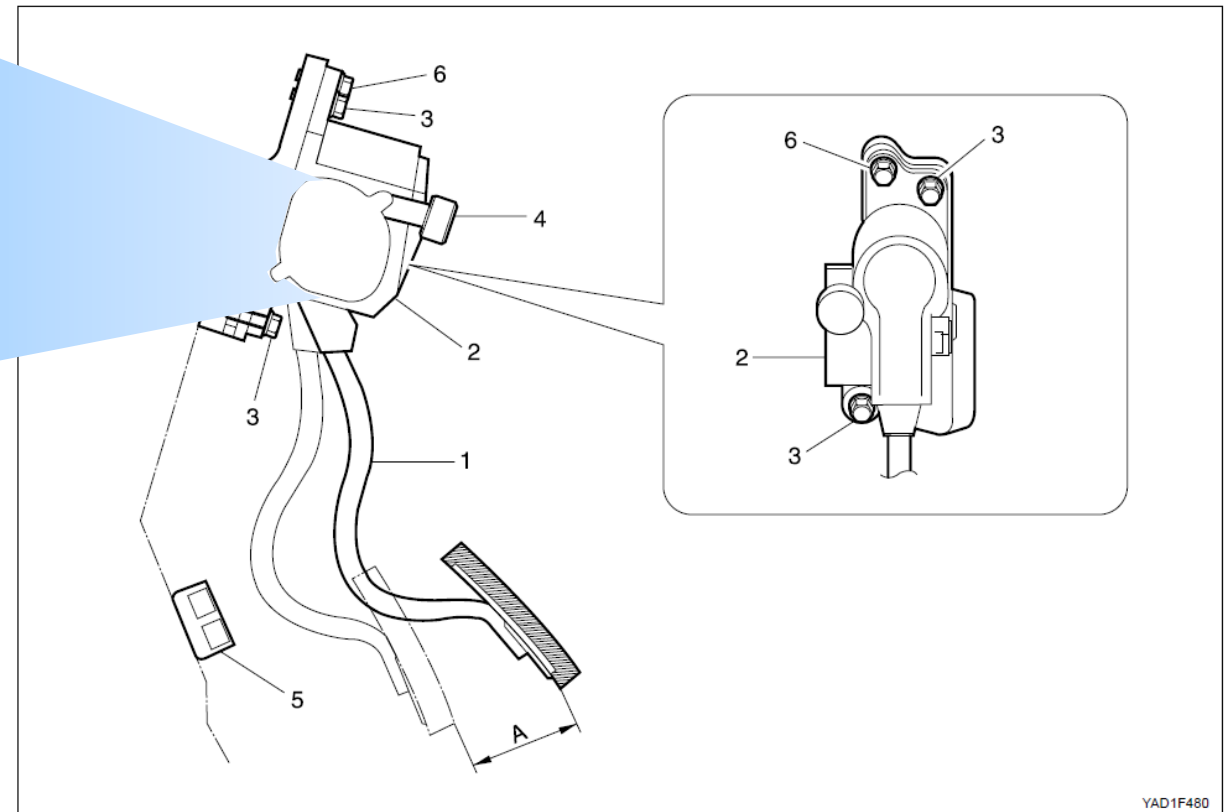
Example of Potentiometer (I)

■ Accelerator pedal module

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



ACCELERATOR PEDAL MODULE



- 1 Accelerator Pedal
- 2 Accelerator Pedal Sensor
- 3 Bolts

- 4 6-Pin Connector
- 5 Kick-down Switch
- 6 Nut

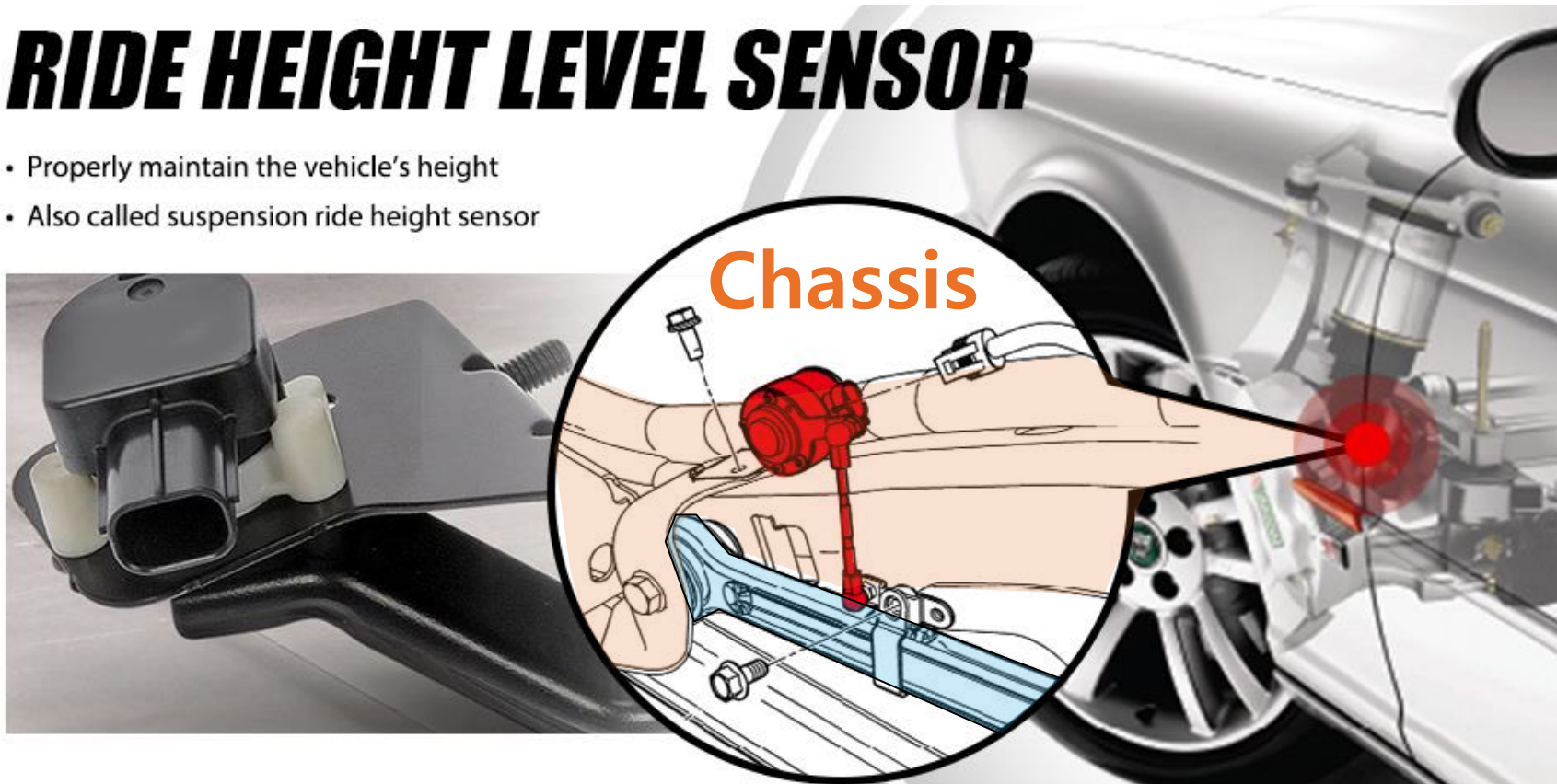
Example of Potentiometer (II)

■ 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



Control arm

Thermistor

■ Thermistor

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

■ NTC (negative temperature coefficient)

- ▶ Temperature **rises**, resistance

■ PTC (positive temperature coefficient)

- ▶ Temperature **rises**, resistance

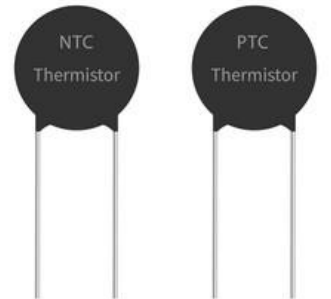
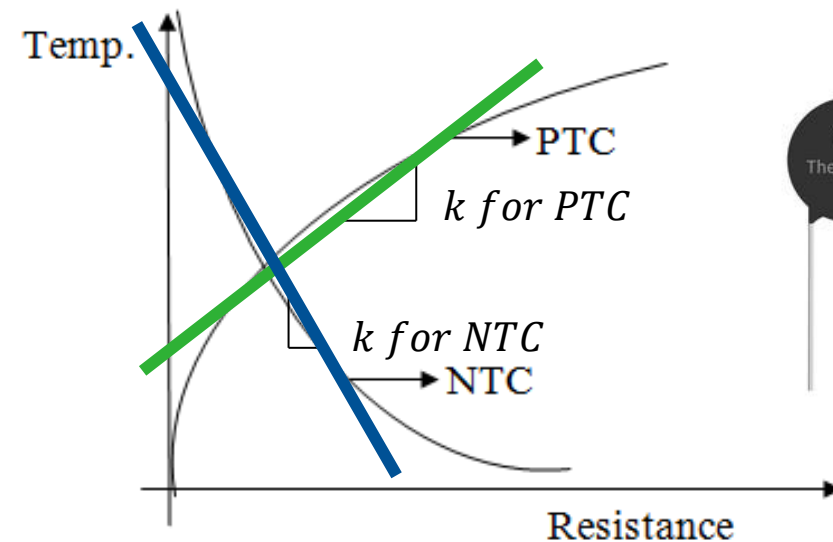
$$\Delta R = \boxed{}$$

ΔR : change in resistance

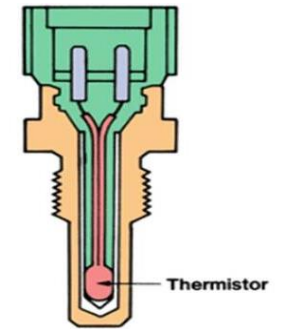
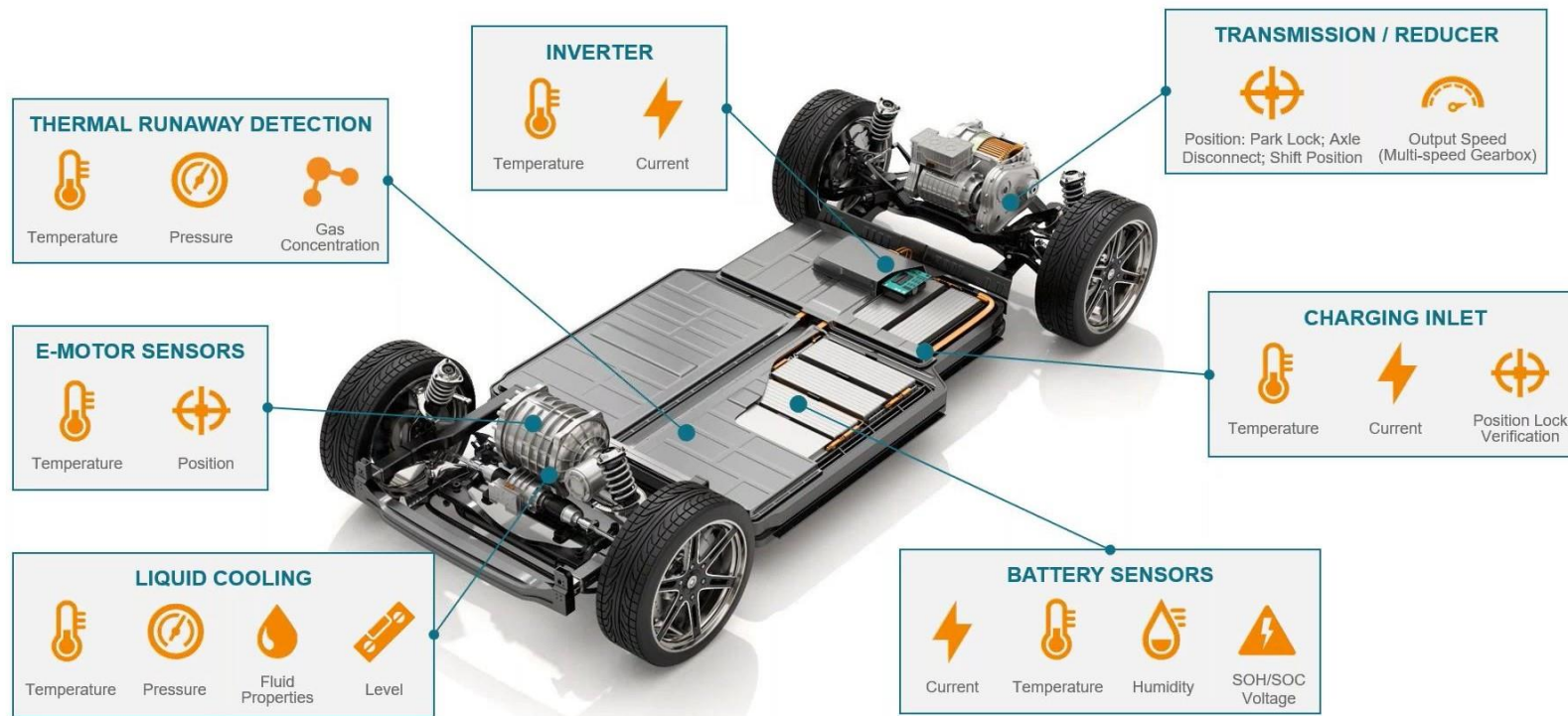
ΔT : change in temperature

k : approximated first – order temperature coefficient of resistance

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



Example of Thermistor

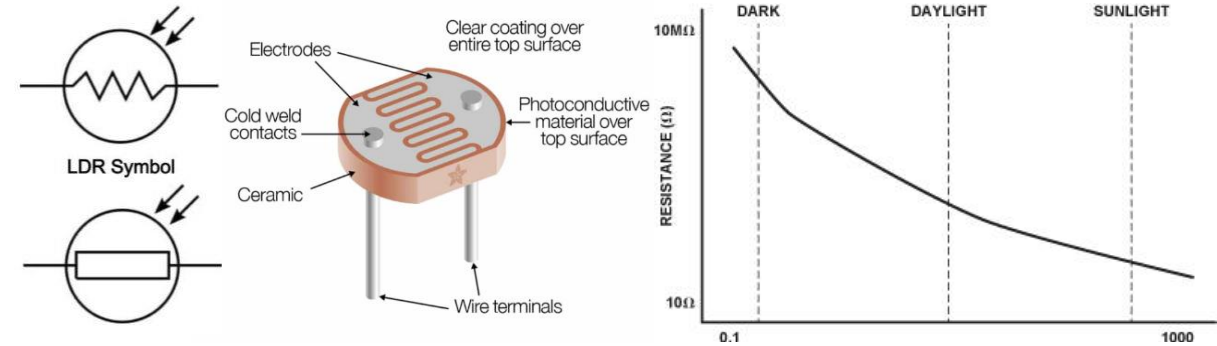


Optical sensor

Optical Sensor

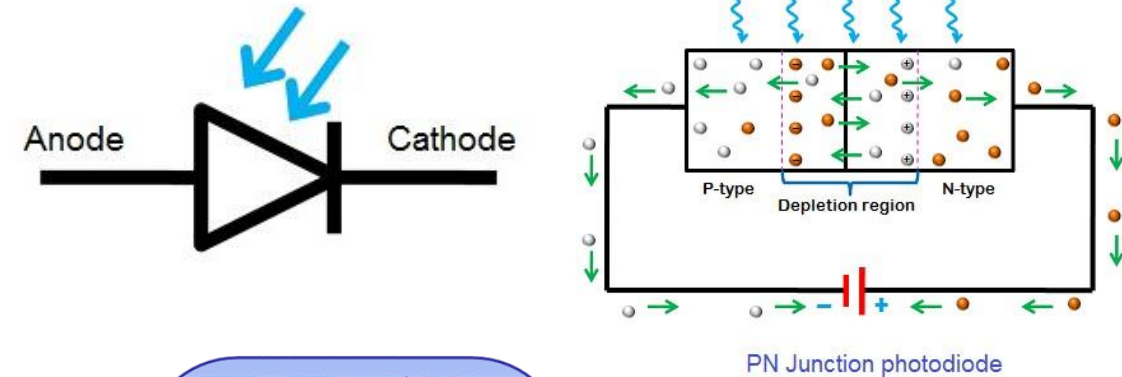
■ Photoresistor

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



■ Photo diode

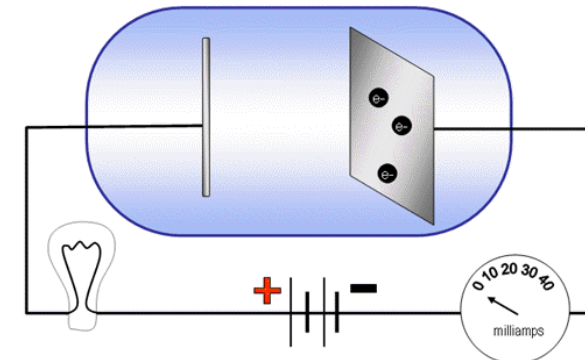
- ▶ P-N junction diode
- ▶ Convert photons (light) to electrical current.



■ Photoelectric effect

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

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



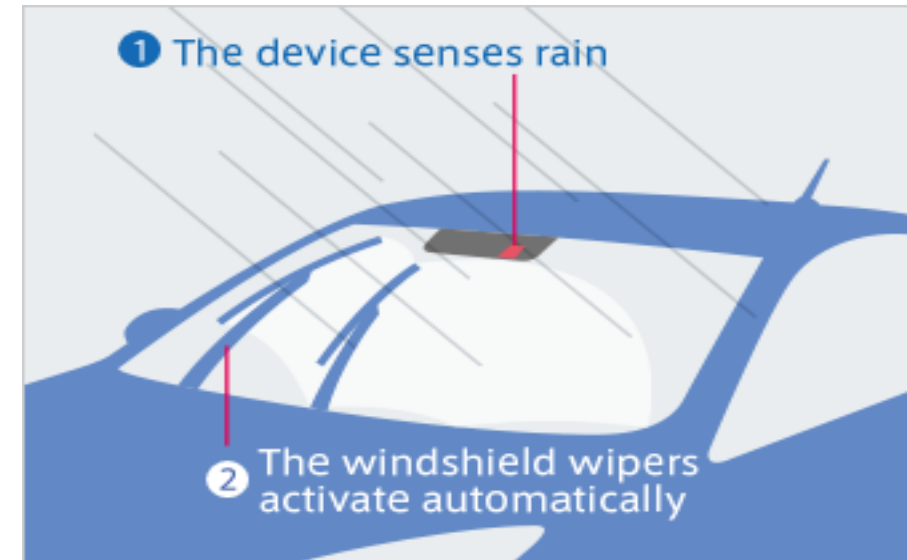
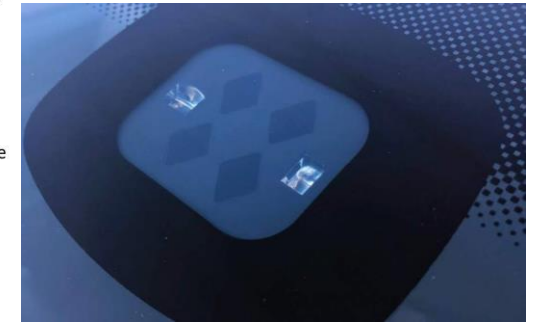
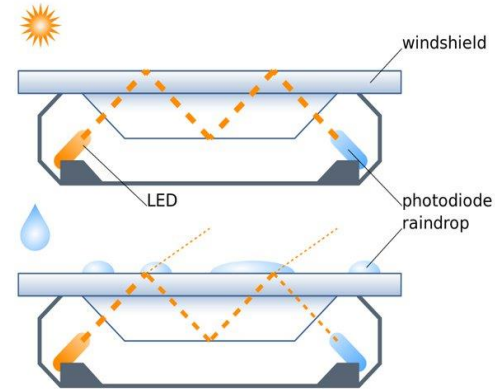
Photoelectric Effect

Example of Optical Sensor

Automatic headlight



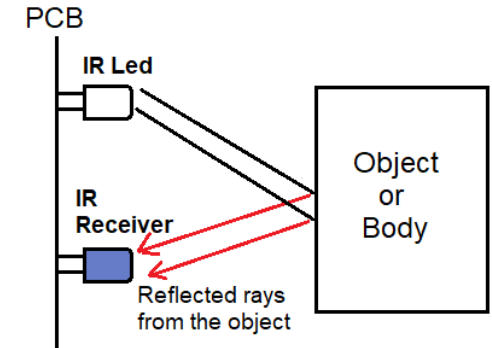
Rain sensor



Optical Encoder

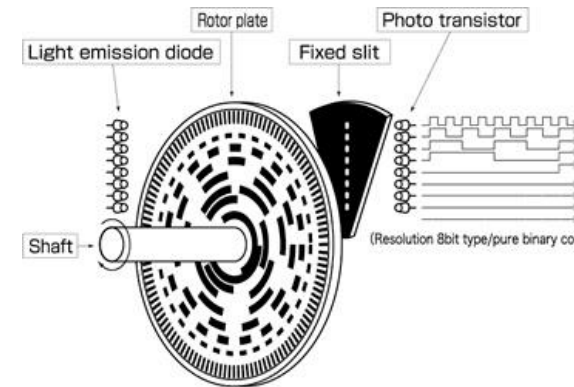
IR sensors

- ▶ IR LED (emitter): emits infrared light (780 nm ~ 50 μ m).
- ▶ Receiver (photo diode): detects infrared signals.

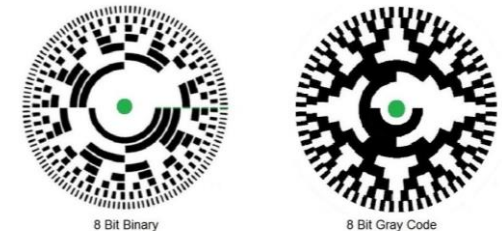


Encoder

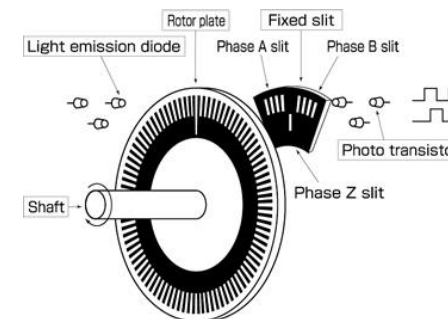
- ▶ Detect changes in slot position by measuring light.
- ▶ Absolute
 - Indicates the current shaft position, making it an angle transducer.
- ▶ Incremental
 - Provides information about the motion of the shaft, such as position, speed, and distance.



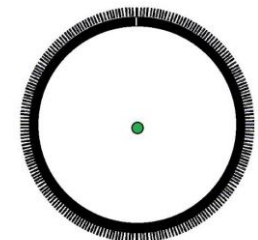
Absolute Encoder Simplified Structure



Absolute Encoder



Incremental Encoder Simplified Structure

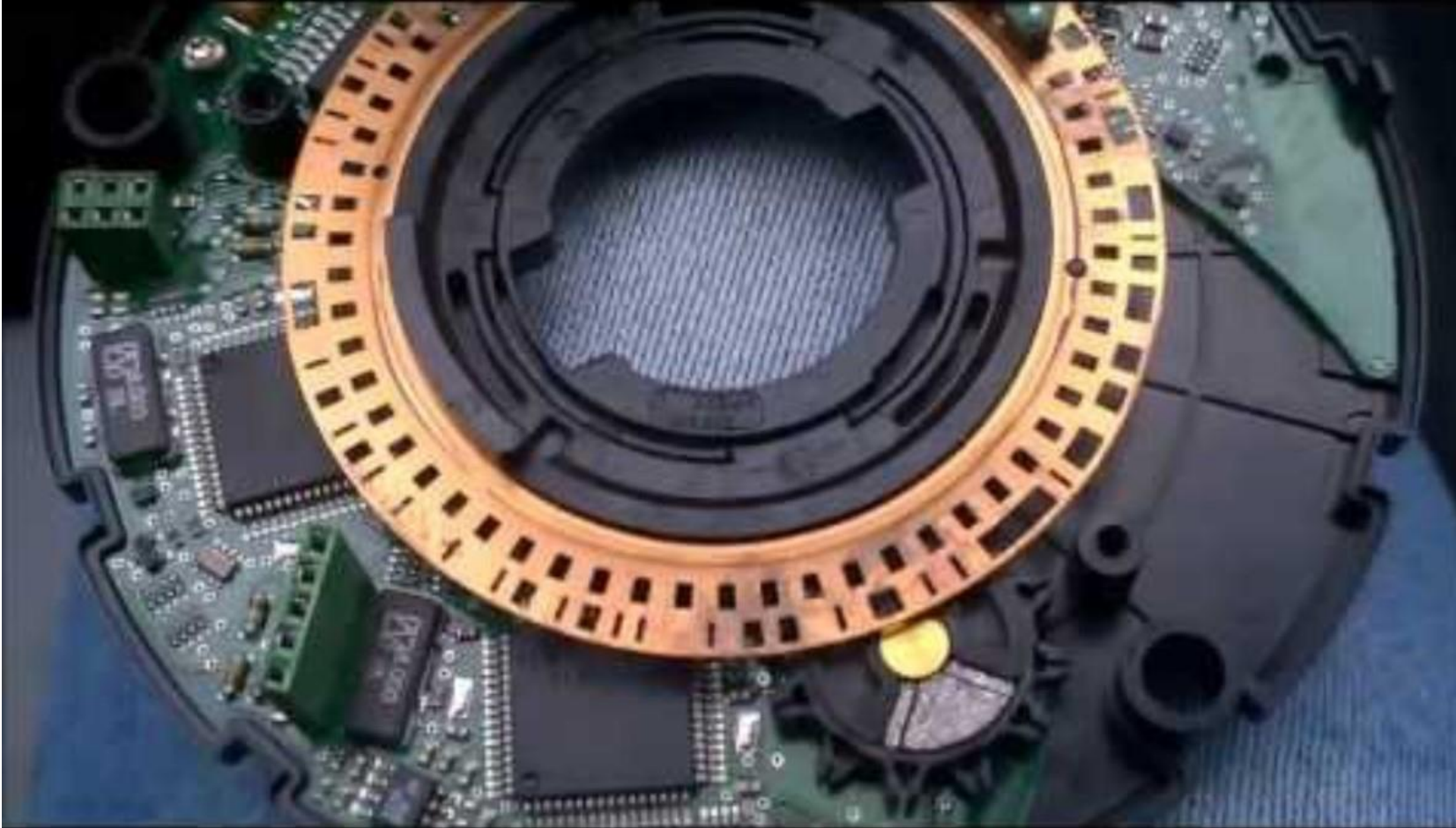


Incremental Encoder

Example of Encoder

■ Steering angle sensor

- ▶ Measure absolute steering angle position.



Piezoelectric sensor

Piezoelectric Effect



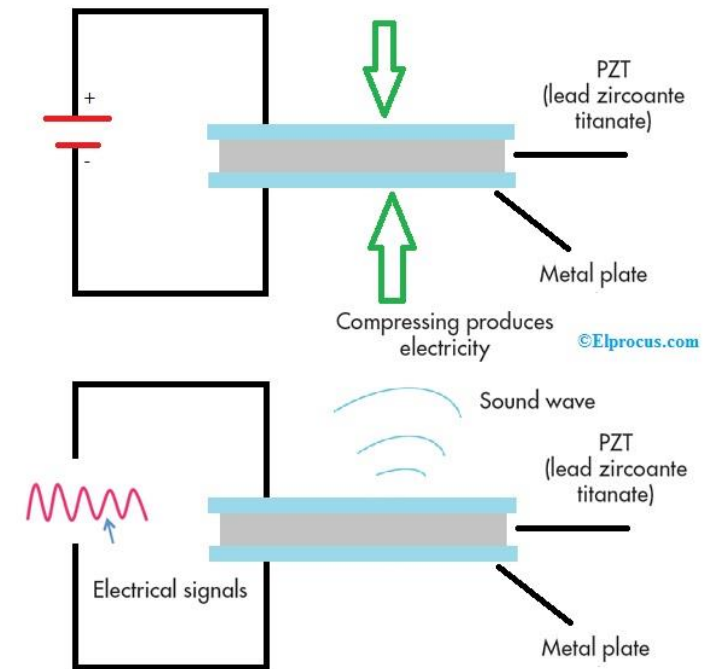
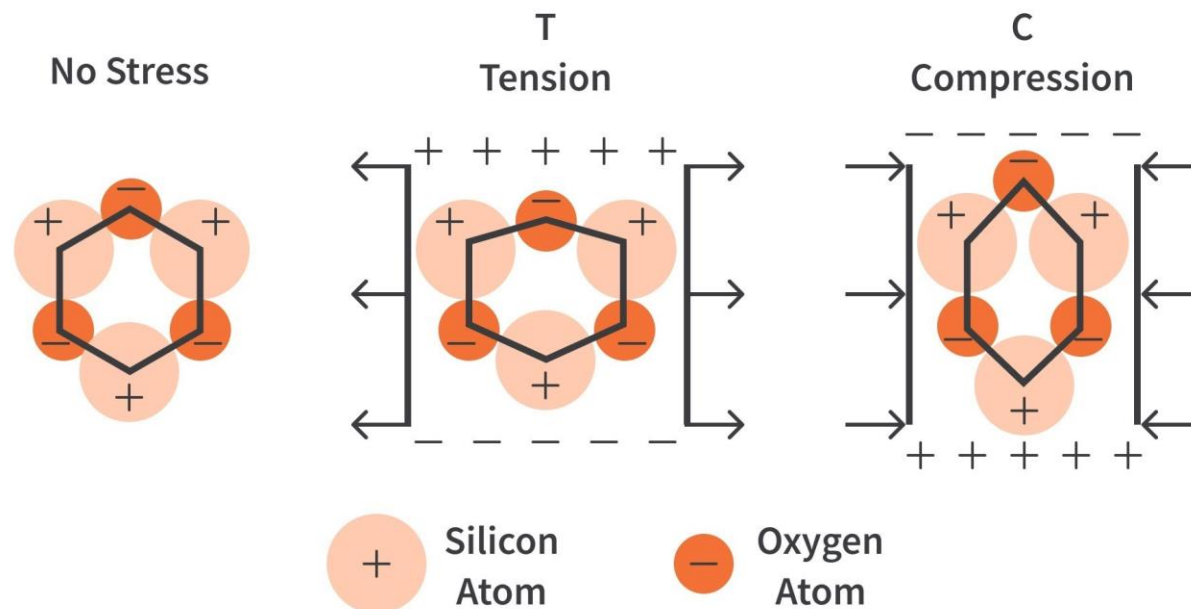
Piezoelectric

■ Piezoelectric effect

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

■ Inverse piezoelectric effect

- ▶ Convert electrical energy into mechanical energy.

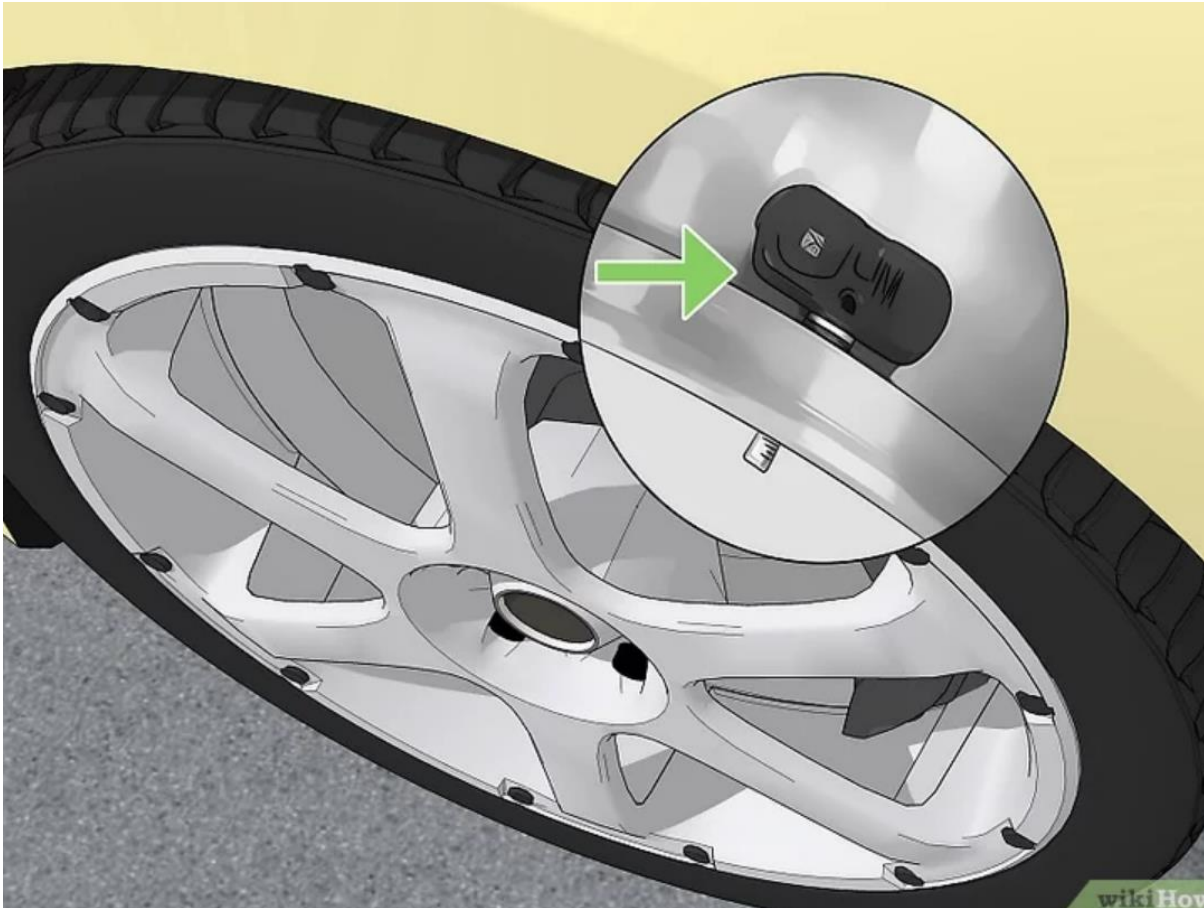


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Example of Piezoelectric Sensor (I)

■ Tire pressure measurement systems

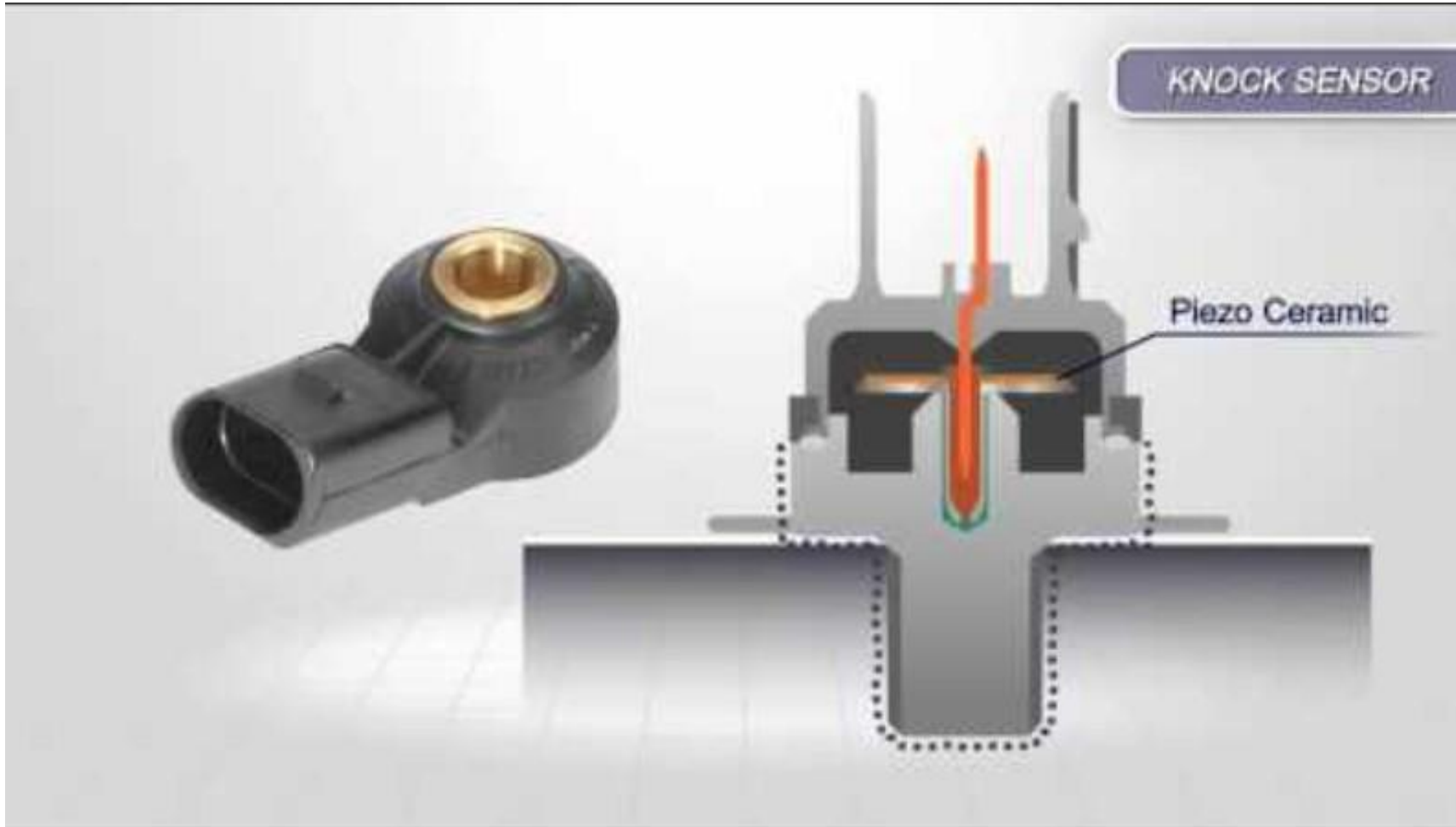
- ▶ A system that monitors the air pressure inside the pneumatic tires on vehicle.



Example of Piezoelectric Sensor (II)

■ Knock sensor

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



Capacitance sensor

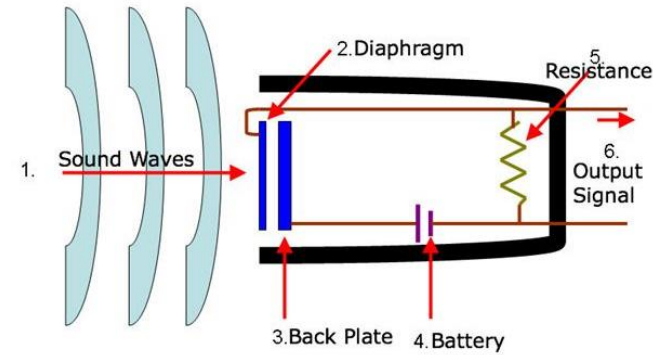
Capacitance Sensor

■ Capacitance (C)

- ▶ Capability of capacitors to store charges.



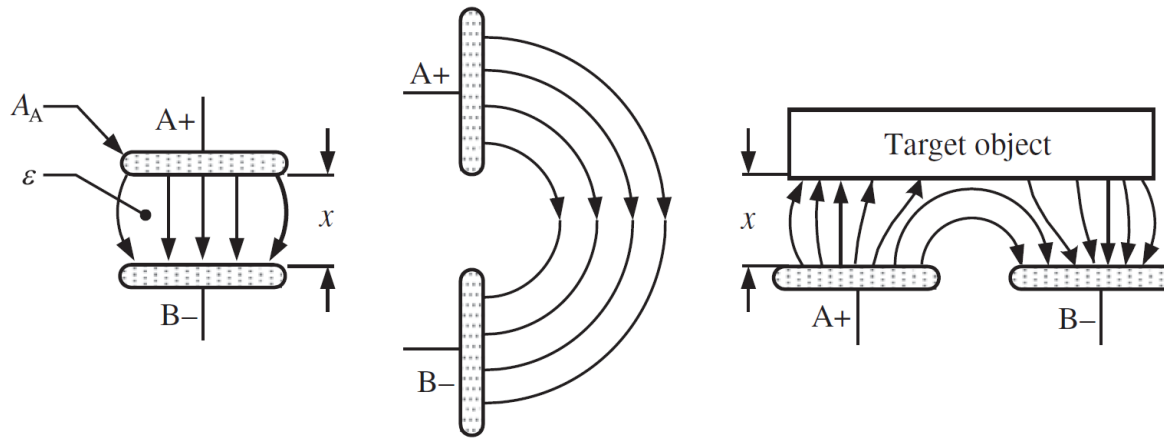
ϵ_0 : permittivity of vacuum
 ϵ_r : permittivity of the insulator used
 A : area of overlap of the two plates
 x : distance between two plate



Condenser Microphone



Capacitive Sensors



Projected capacitive touchscreen.

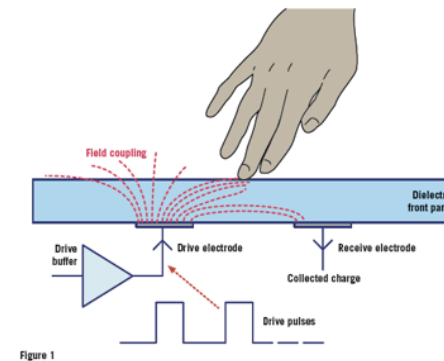


Figure 1

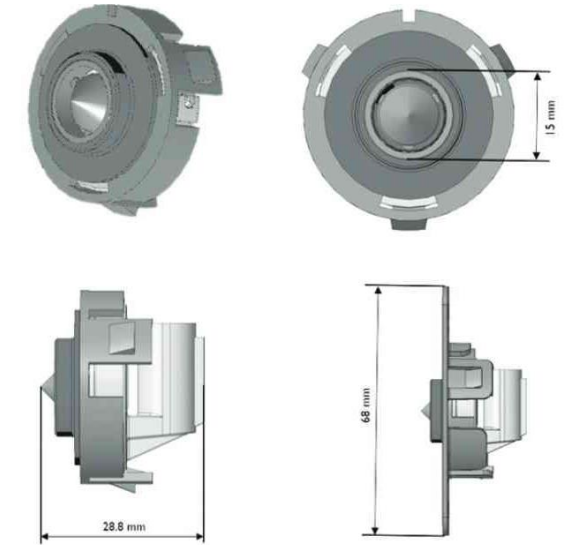


Touch panel

Example of Capacitance Sensor

■ External microphone

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



Sound and Vibration Sensor



HARMAN sensor mounted on vehicle surfaces to pick up ext. sound (e.g., voice commands)

ASR & control unit



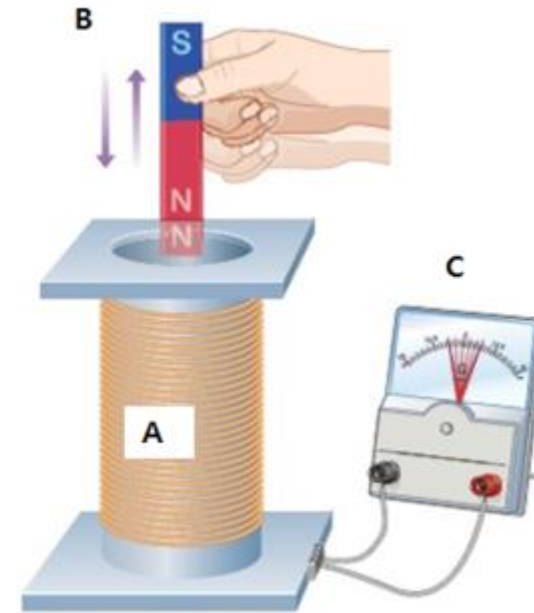
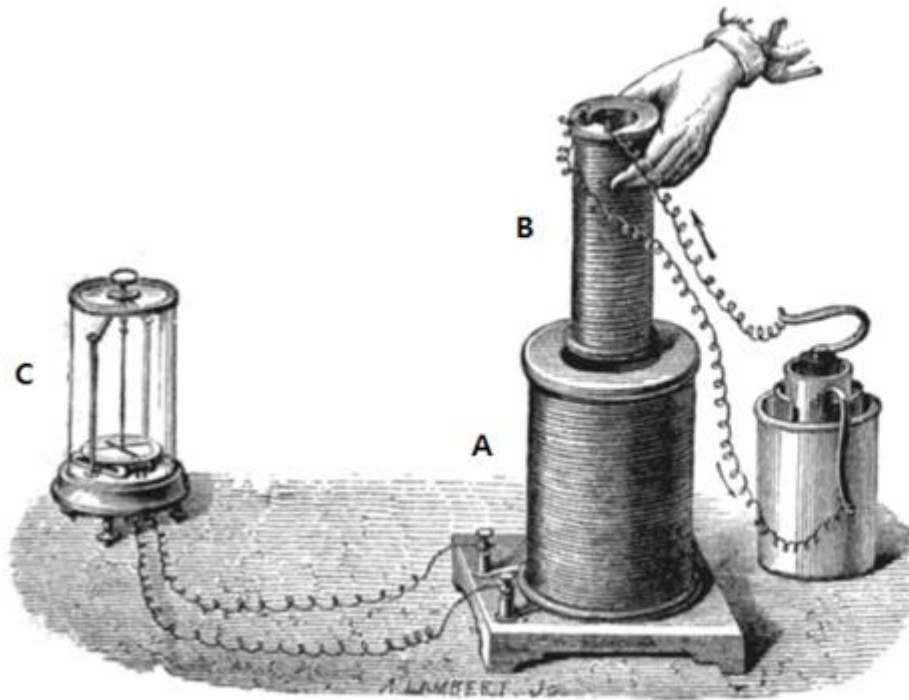
Inductance sensor

Faraday's Law of Induction

Faraday's law of induction



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

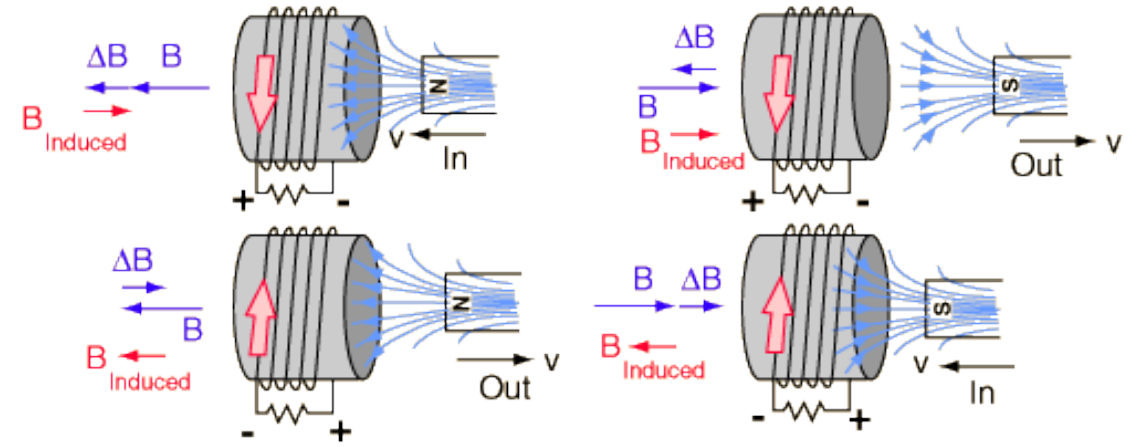
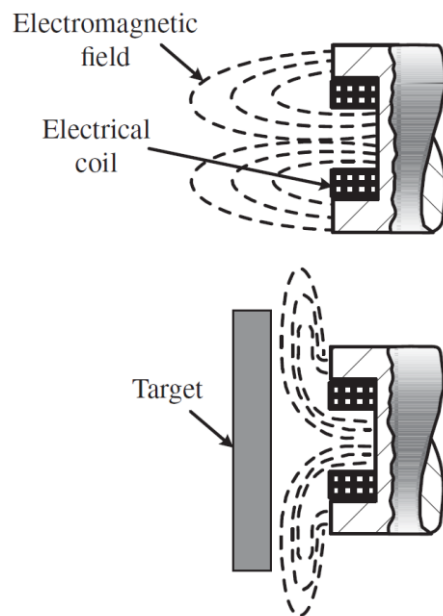


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Inductance Sensor

■ Inductive proximity sensor

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



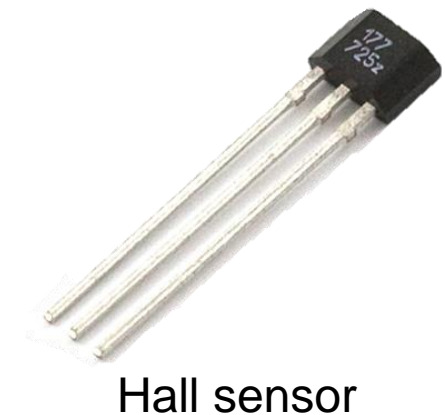
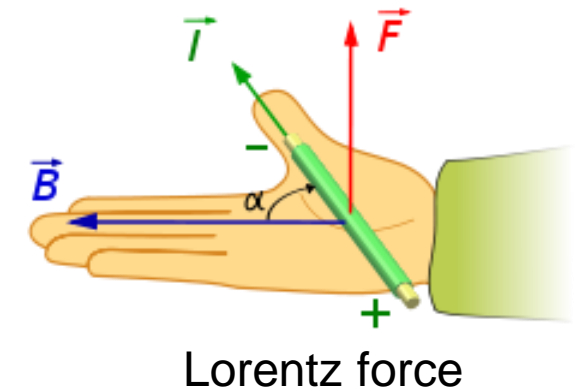
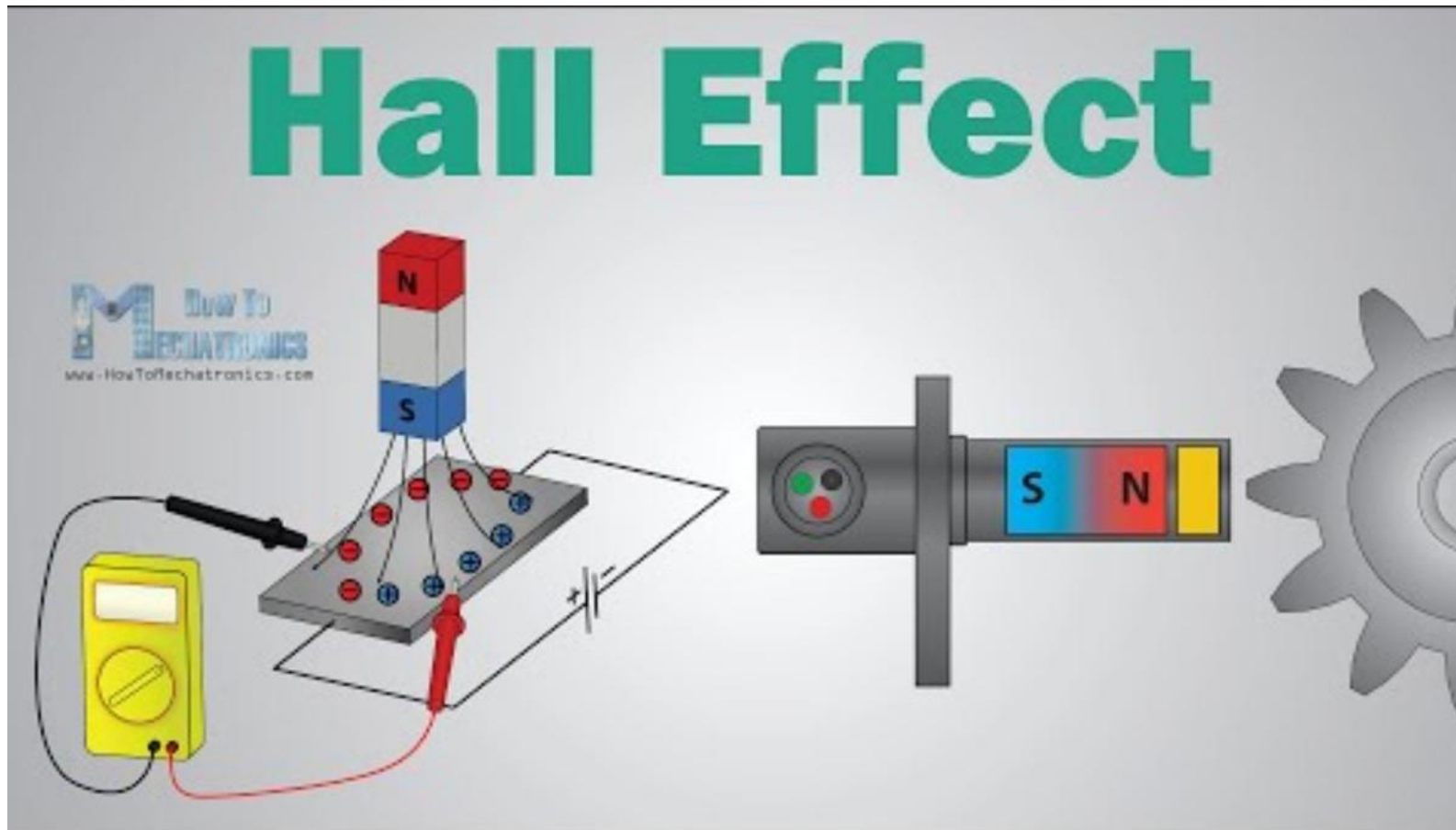
<https://youtu.be/YeXlmdIXp2s?t=40>

Magnetic sensor

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.



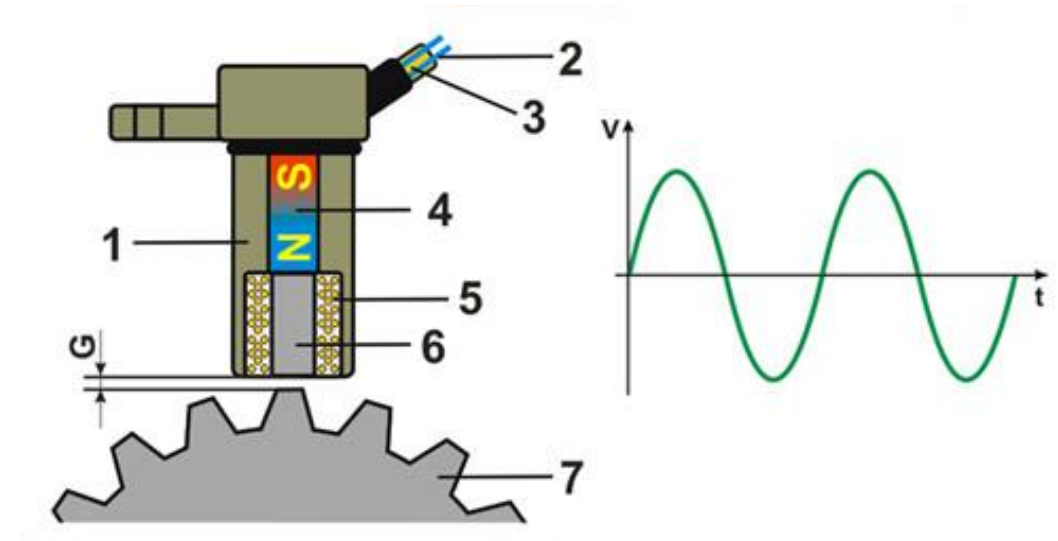
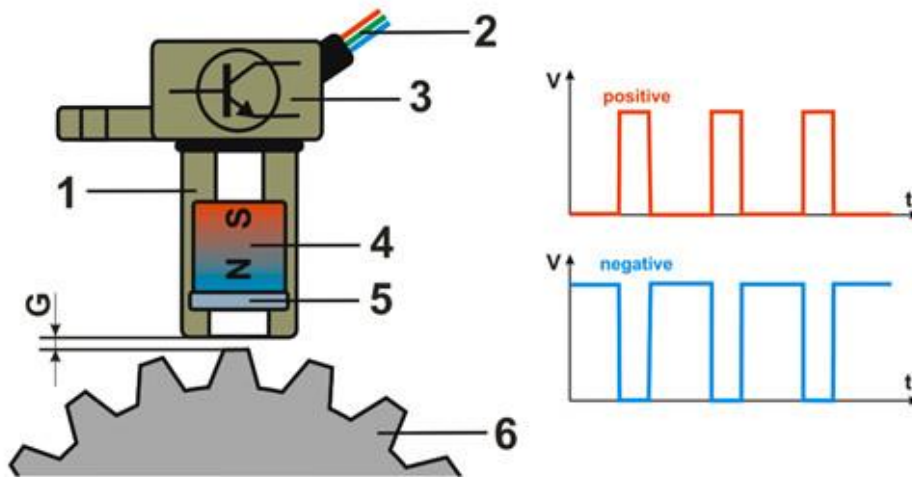
Crank Angle Sensor (CAS)

■ 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**