University of Dhaka
Department of Computer Science and Engineering
CSE-2205: Introduction to Mechatronics

Lec-4: Displacement Sensors (Potentiometer + LVDT)

Mechatronics: Electronic Control Systems in Mechanical Engineering by W. Bolton

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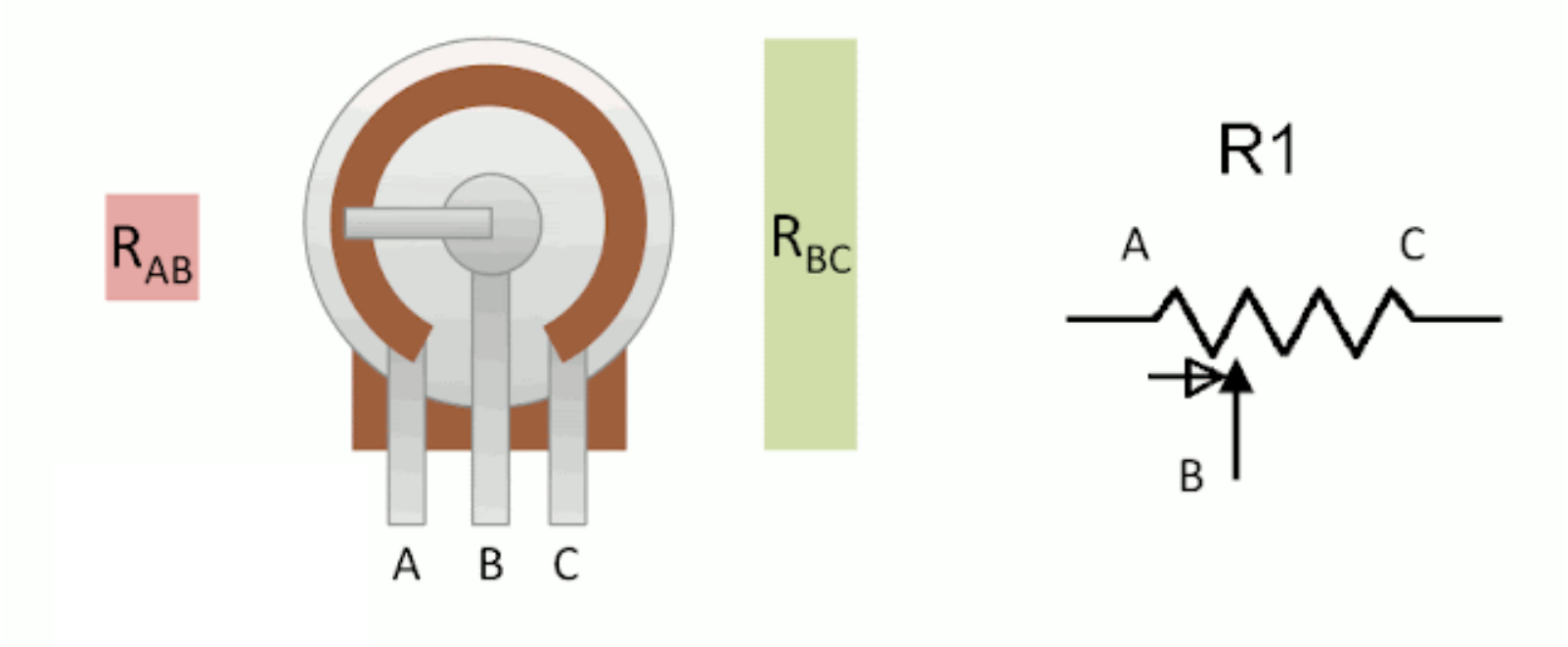
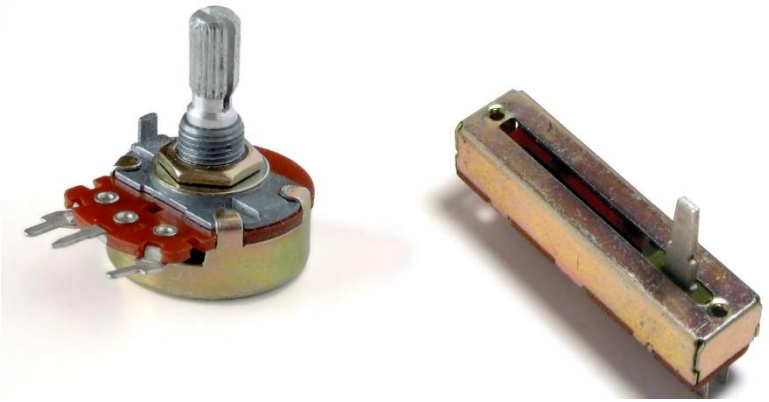
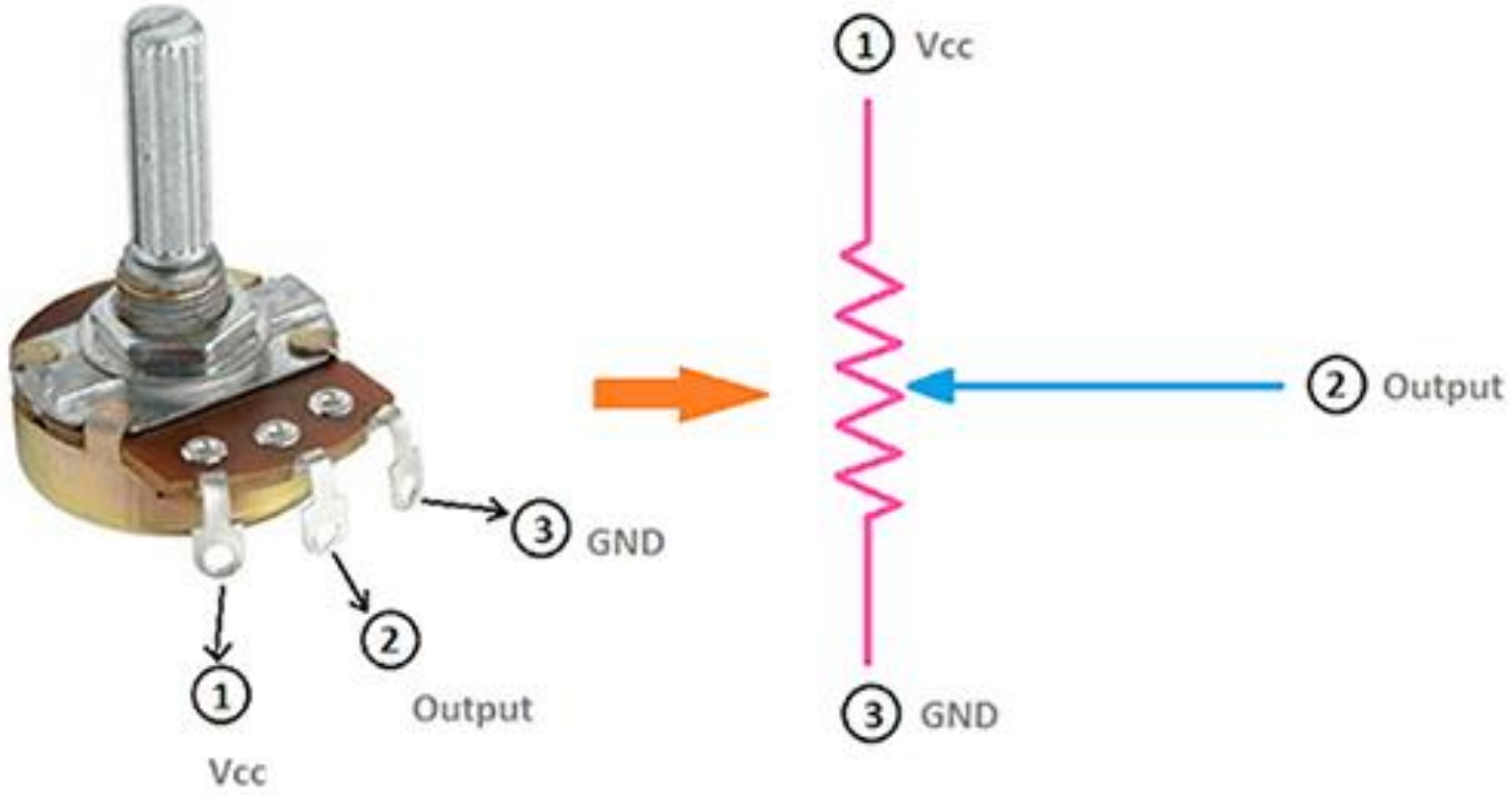
1. Potentiometer

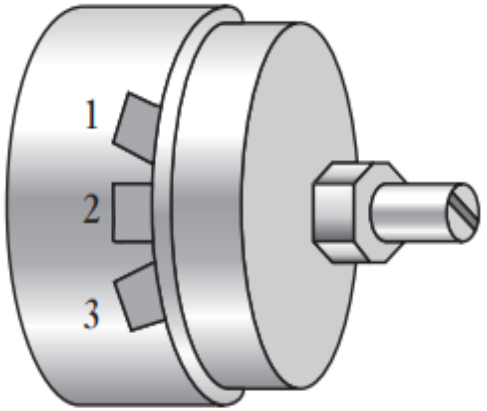
A potentiometer is an electrical component with *three terminals*. It acts as a *variable resistor*, allowing for *adjustable voltage division* by *sliding or rotating a wiper arm* across a resistive element.



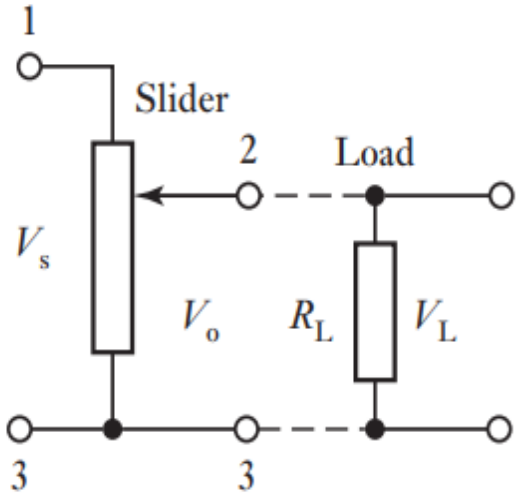


The rotary potentiometer consists of a *circular wire-wound track* or a film of conductive plastic over which a *rotatable sliding contact can be rotated* .



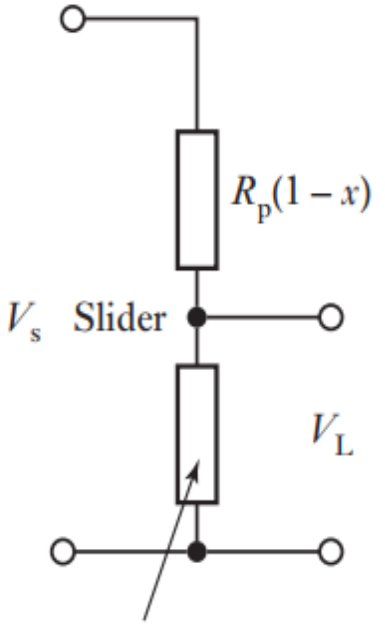


A rotary potentiometer



The circuit when connected to a load

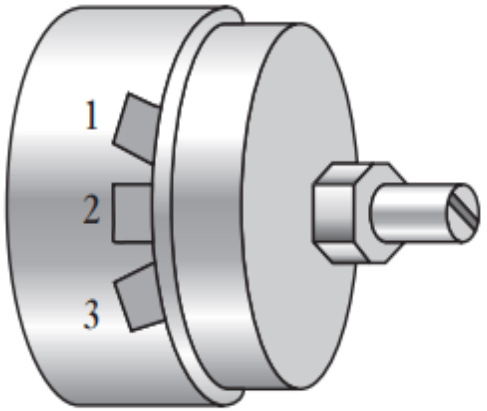
The circuit as a potential divider



R_L in parallel with xR_p

Voltage divider rule $V_o/V_s = R_{23}/R_{13}$

combined resistance is $R_L x R_p/(R_L + xR_p)$



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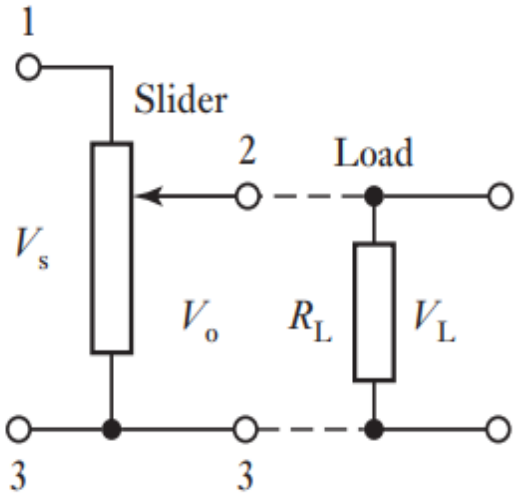

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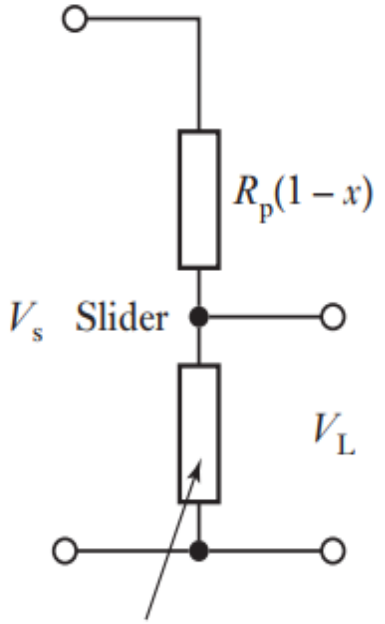


R_L in parallel with xR_p

the voltage across the load is

$$\frac{V_L}{V_s} = \frac{xR_LR_p/(R_L + xR_p)}{R_p(1 - x) + xR_LR_p/(R_L + xR_p)}$$

$$= \frac{x}{(R_p/R_L)x(1 - x) + 1}$$

If the load is of infinite resistance $V_L = xV_s$

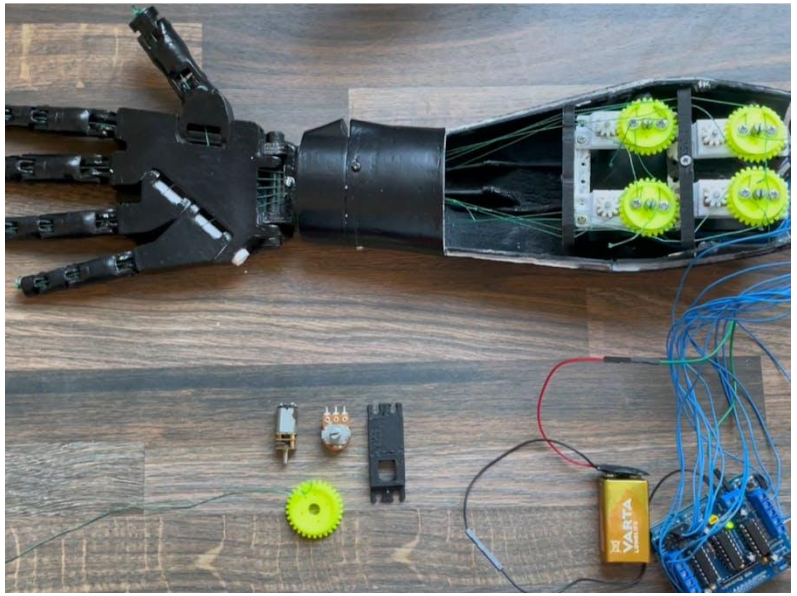
1.1 Applications of Potentiometer Sensor

1.1.1 Position Sensing

Measures the *position of an object*.

Automotive: Accelerator pedal position sensors.

Industrial: Position feedback in robotic arms.

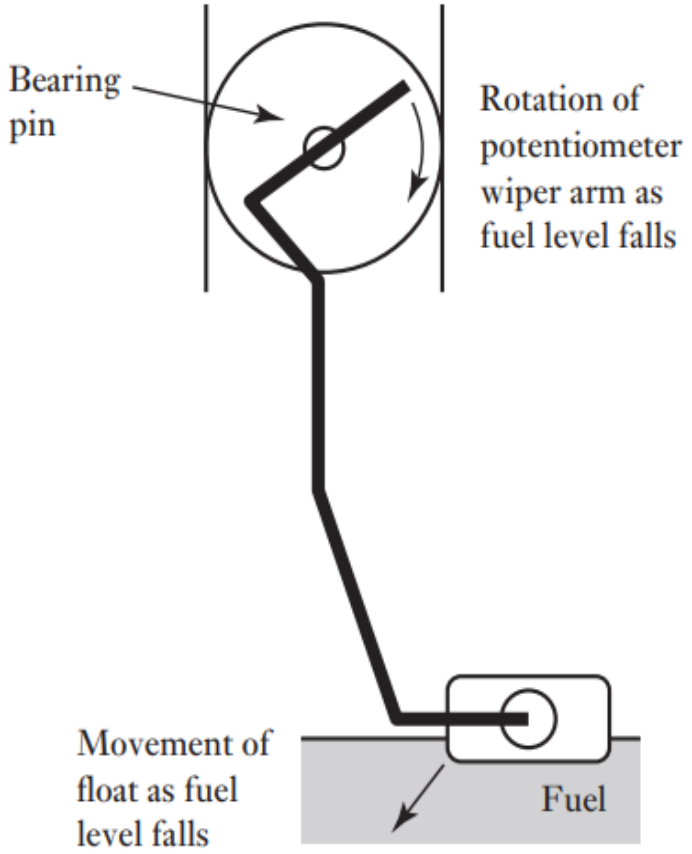


1.1.2 Potentiometer-Based Fuel-Level Sensor

Wiper Arm: *Moves along the resistive element* to change the resistance and output voltage.

Float: Positioned on the surface of the fuel in the tank, *moves up and down with the fuel level*.

Lever: Connects the float to the wiper arm of the potentiometer, translating the *float's vertical motion into rotational motion*.

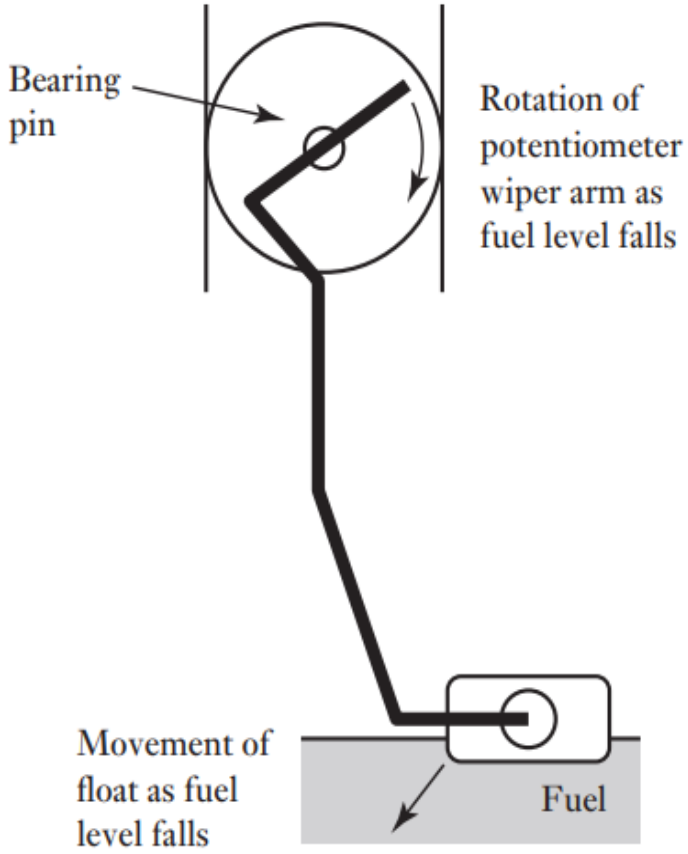


Voltage Interpretation

Full Tank: The float is at its highest position, causing the *wiper arm to be at a position where the output voltage is maximum*.

Empty Tank: The float is at its lowest position, *moving the wiper arm to a position where the output voltage is minimum.*

Intermediate Levels: Any position of the float *between the full and empty positions* will result in an *intermediate voltage output proportional to the fuel level*.

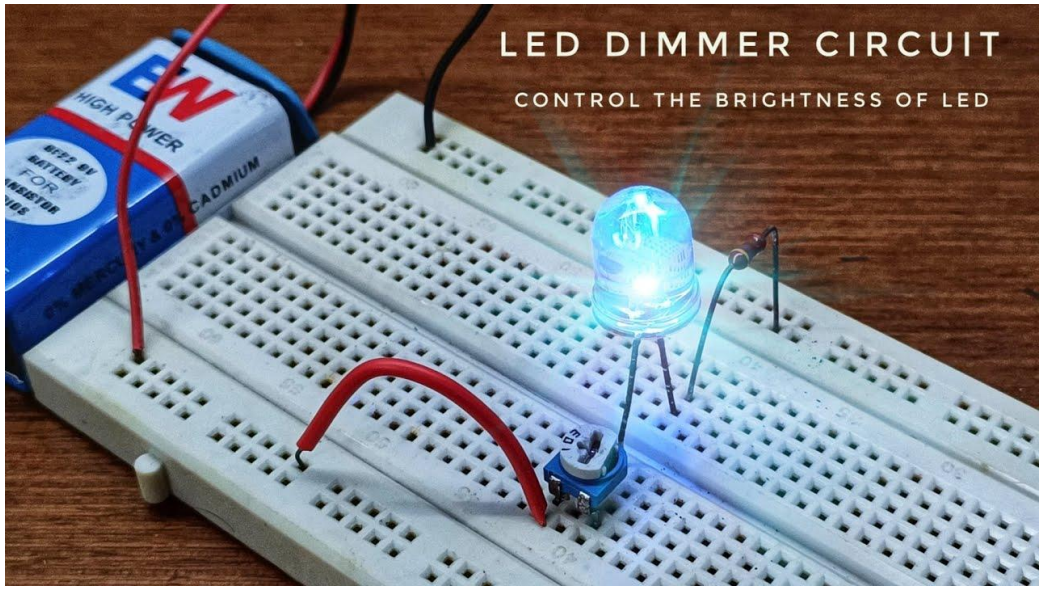


1.1.3 Light Dimmer Controls

Adjusts the brightness of lighting.

Home Lighting: Wall-mounted dimmer switches for controlling room lighting.

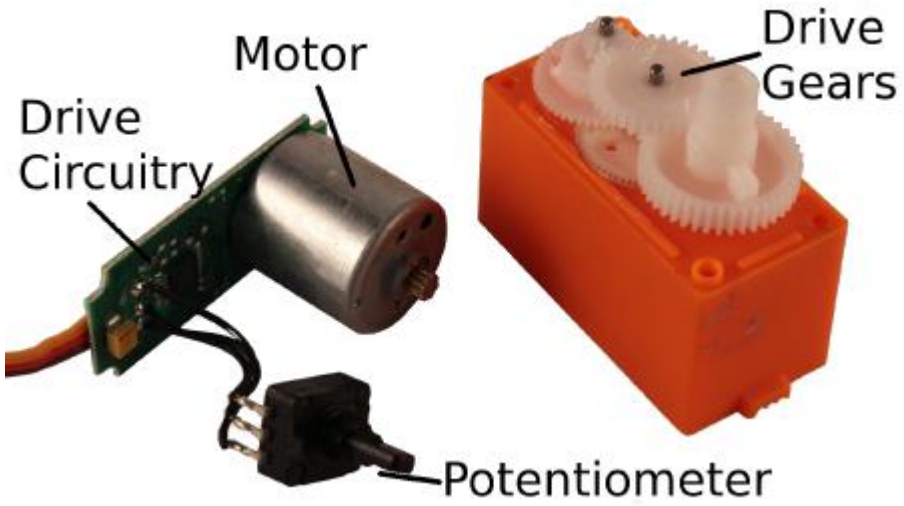
Theatrical Lighting: Control panels for stage lighting adjustments.



1.1.4 Feedback Systems

Provides *feedback for closed-loop control systems*.

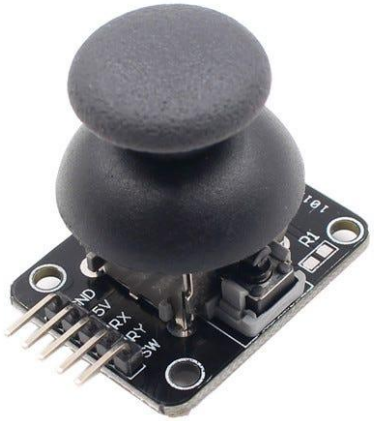
Servo Motors: Position feedback for precise control of servo motors.



1.1.5 Game Controllers

Sensing movement and providing input in gaming devices.

Game Consoles: Joysticks and thumbsticks in game controllers to detect movement direction and intensity.

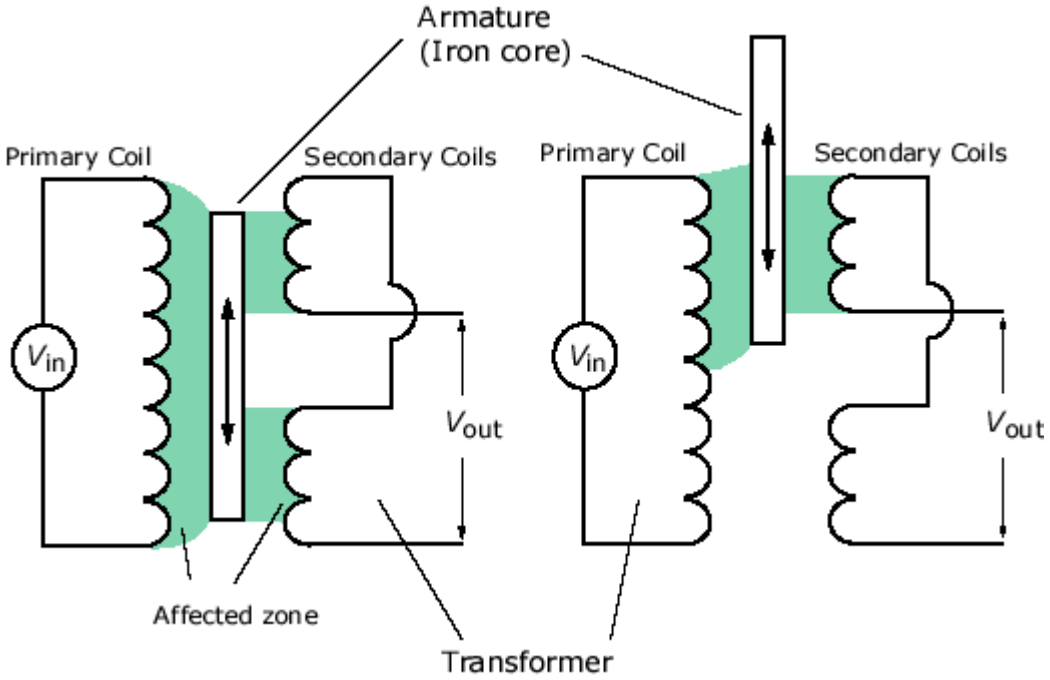


2. Linear Variable Differential Transformer (LVDT)

An LVDT (Linear Variable Differential Transformer) is an electromechanical transducer that *converts linear motion (displacement) into an electrical signal*.

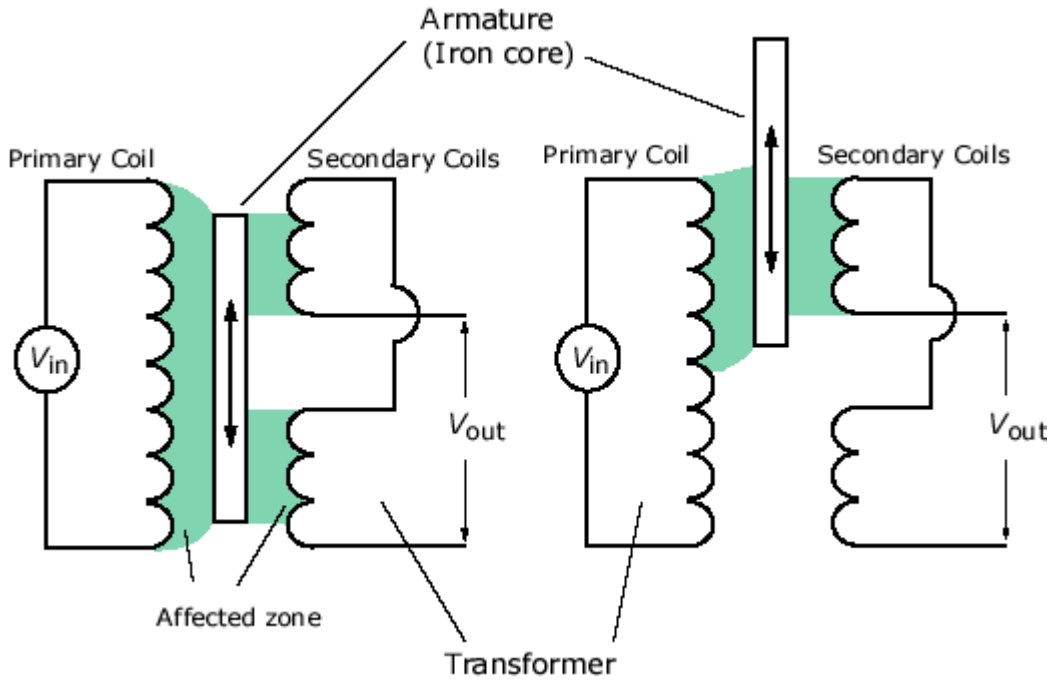
Primary Coil

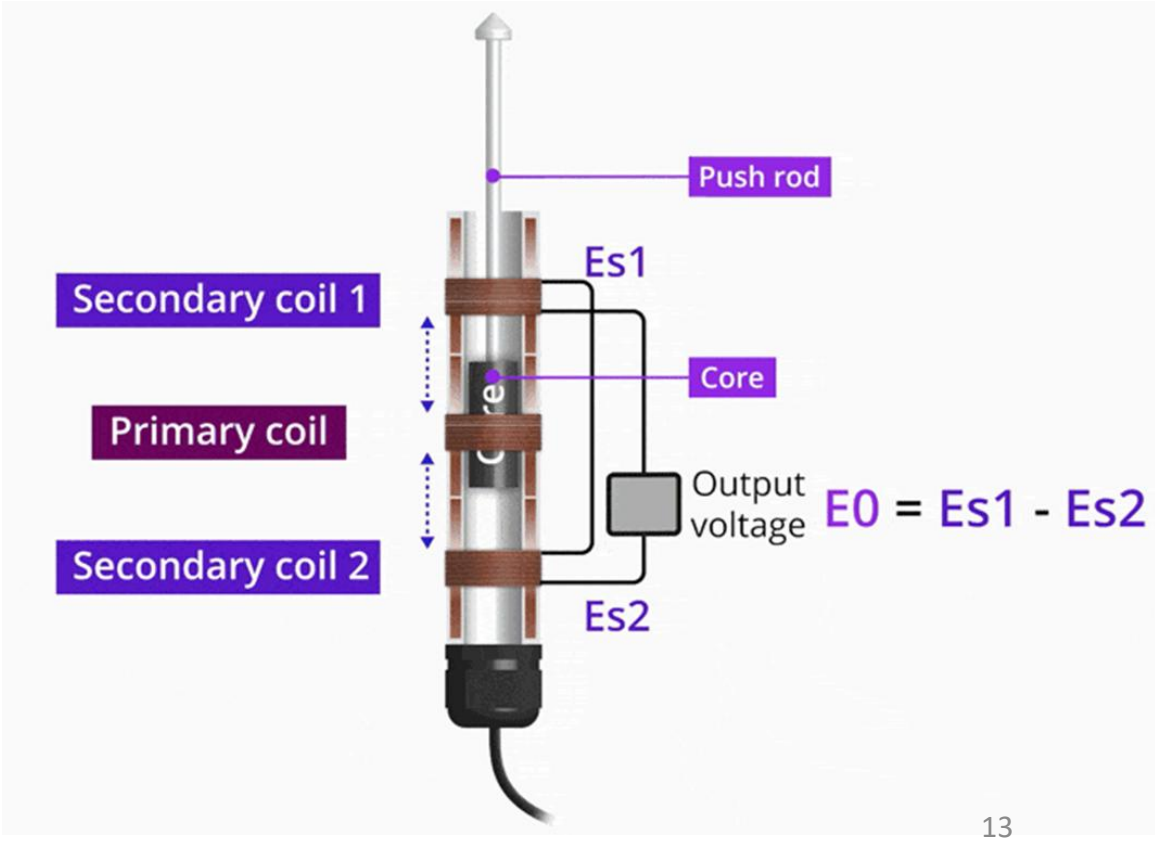
An alternating current (AC) is applied to this coil, *creating a magnetic field*.



Secondary Coils

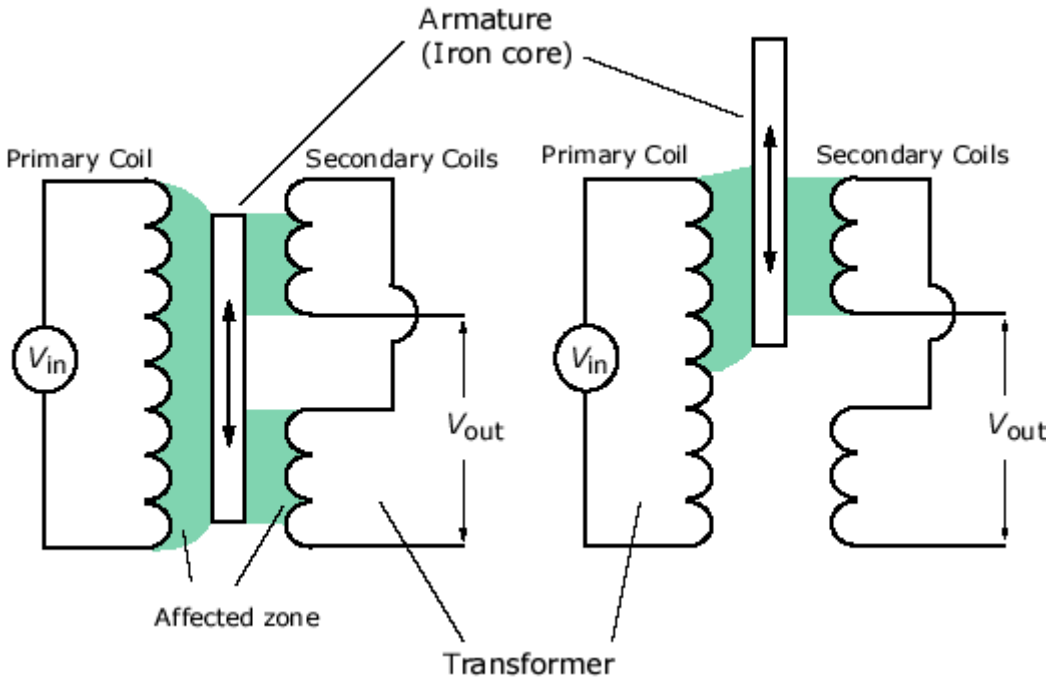
Two secondary coils are *symmetrically placed on either side of the primary coil*. They are *connected in series opposition*, meaning the *output voltage is the difference* between the *voltages induced in the two secondary coils*.

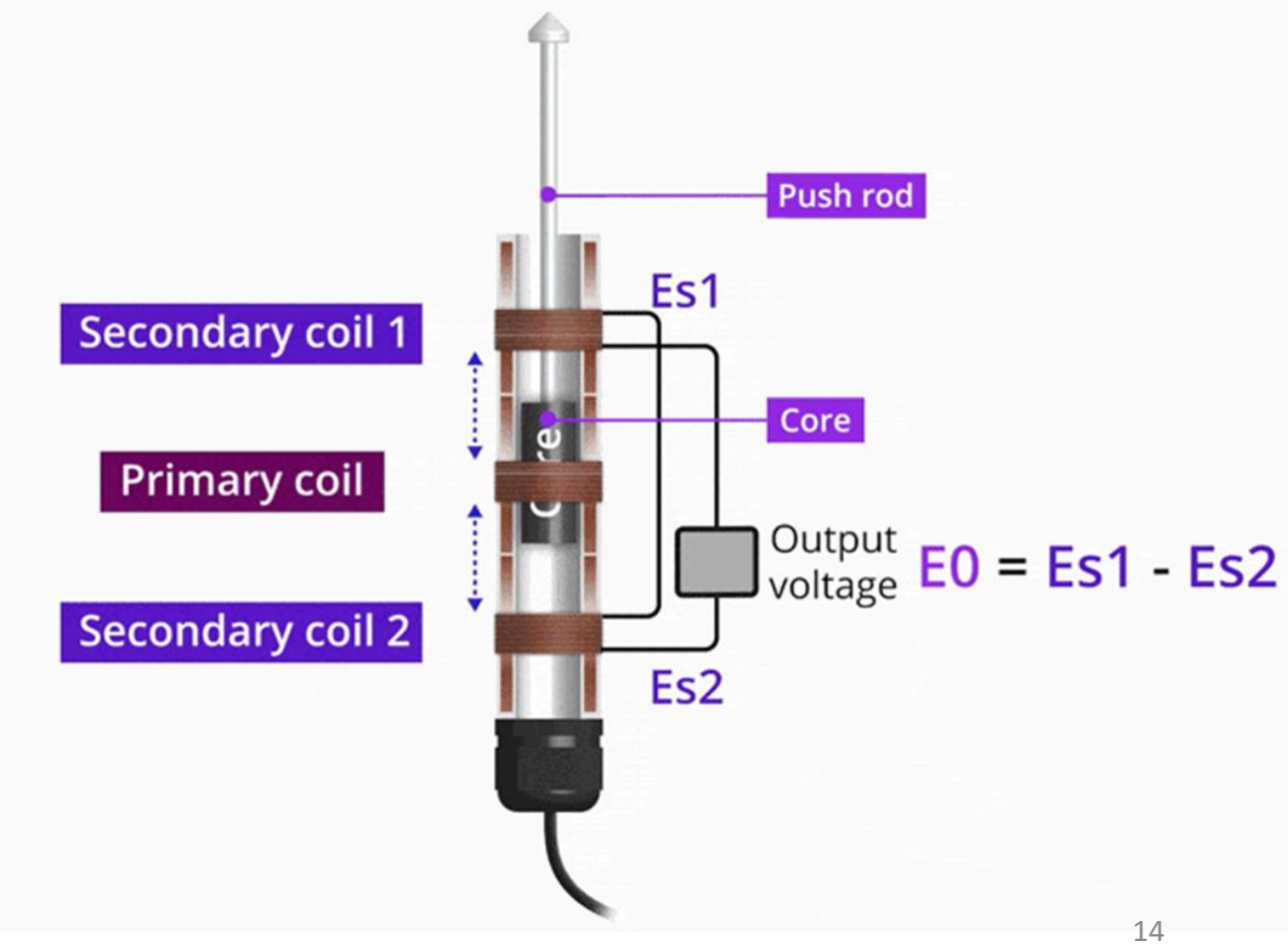




Core

A movable *ferromagnetic rod (core) that is attached to the object* whose displacement is to be measured. The *core moves linearly along the axis of the coils*.

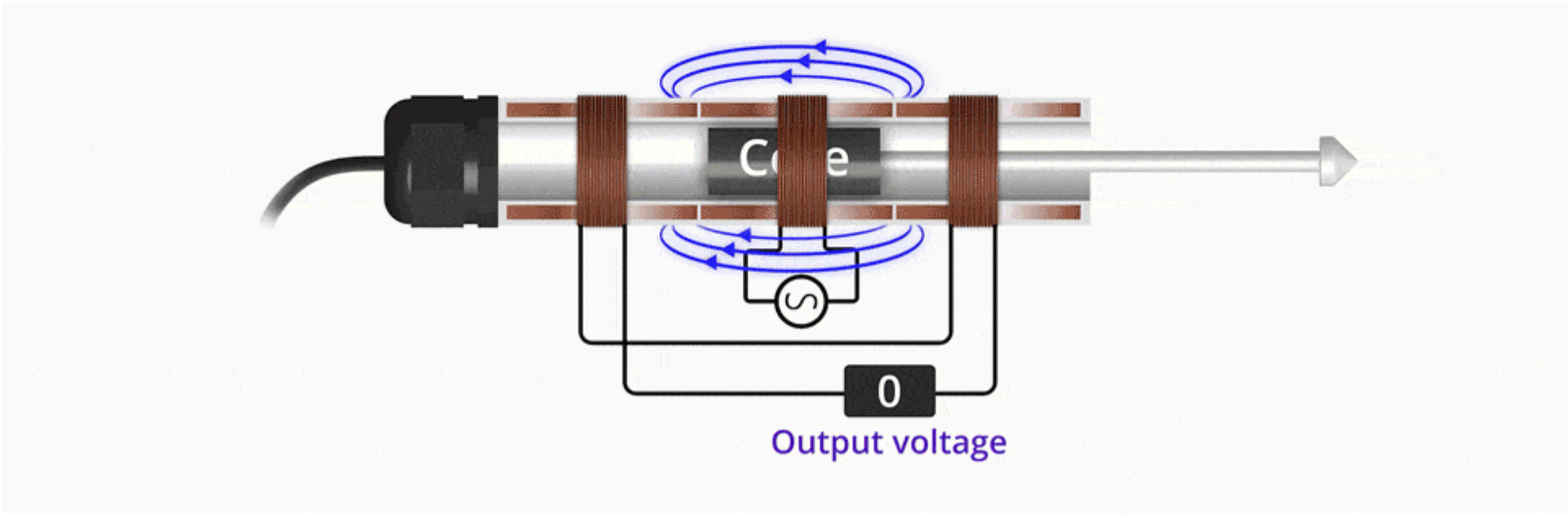




2.1 Working Principle of an LVDT

AC Excitation

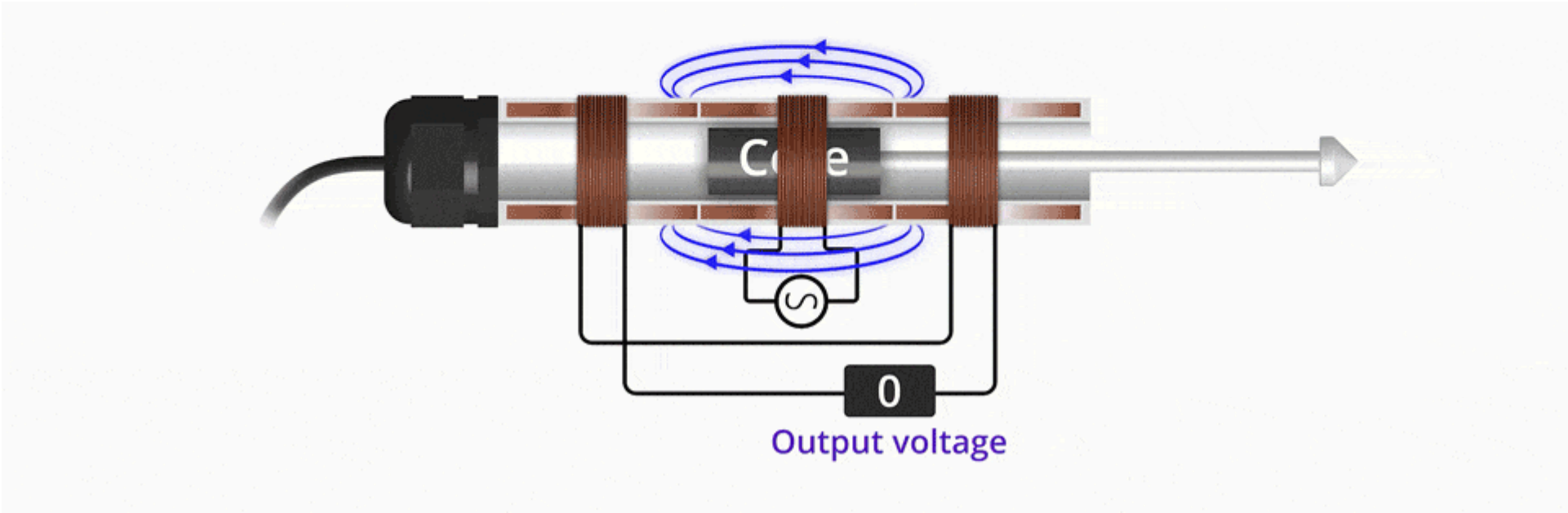
An AC voltage is applied to the primary coil, *generating a magnetic field that induces voltages in the secondary coils*.



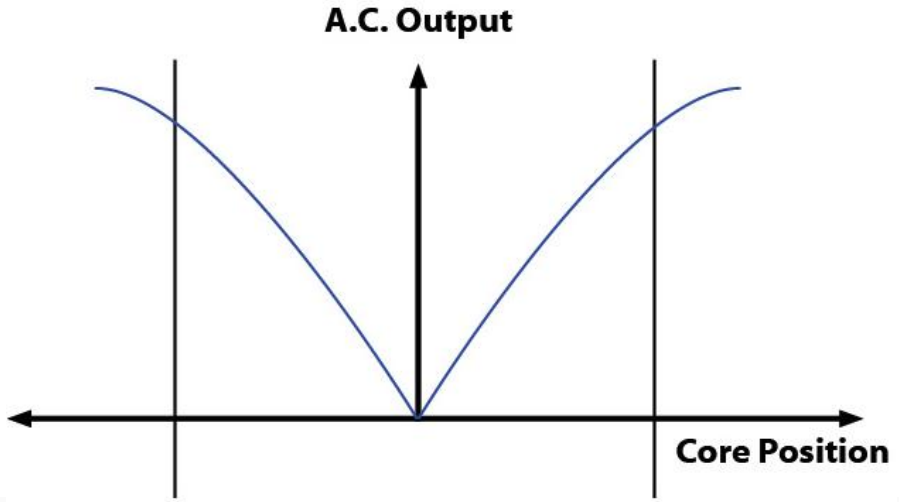
Core Position and Voltage Induction:

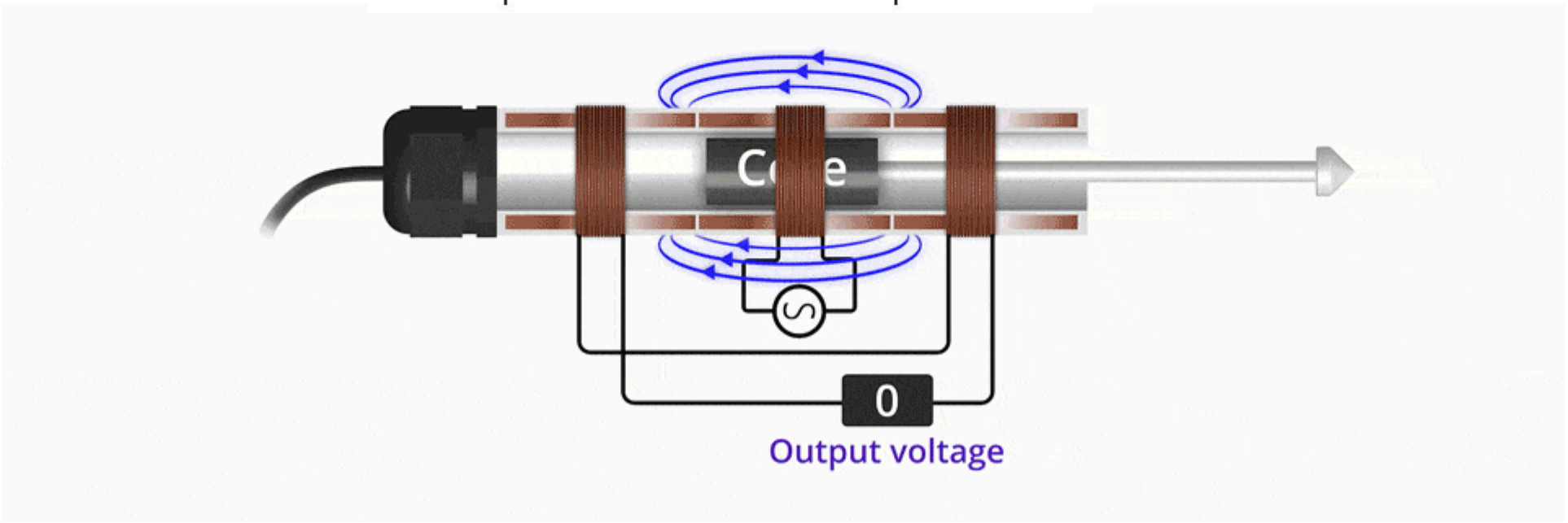
The position of the core affects the magnetic coupling between the primary and secondary coils.

When the core is at the central (null) position, the voltages induced in the two secondary coils are *equal and opposite*, resulting in a *net output voltage of zero*.



When the core moves from the central position, it changes the magnetic coupling, *causing a differential voltage output proportional to the displacement*.

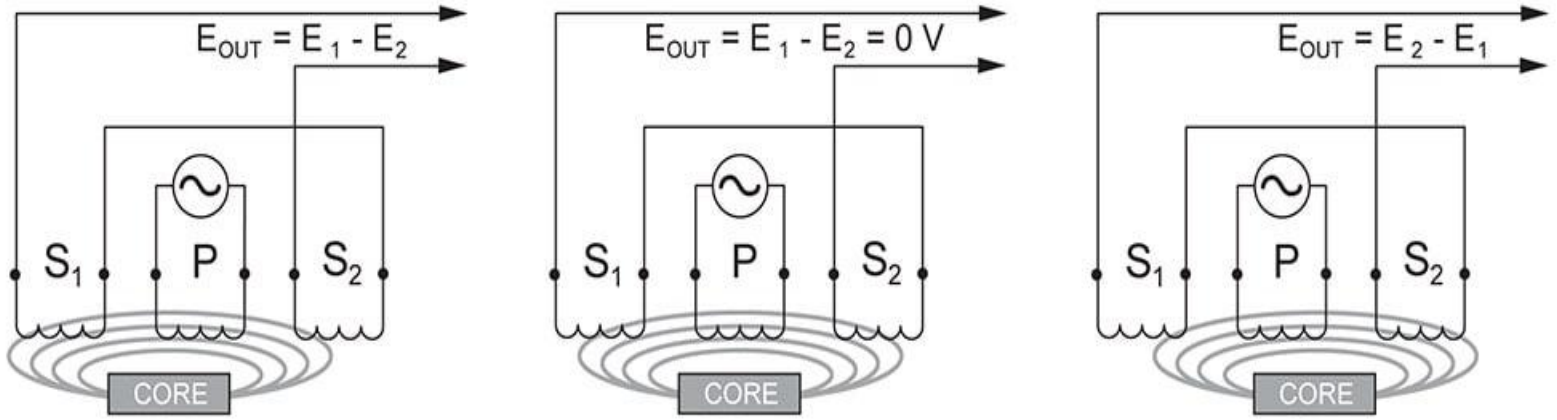




Output Voltage:

The output voltage (difference between the voltages in the secondary coils) varies linearly with the position of the core.

The phase of the output voltage indicates the direction of the displacement (whether the core has moved to the left or right from the central position).



Problem: An LVDT with a primary coil and two secondary coils, $S1$ and $S2$, is set up so that when the core is in the null (central) position, the induced voltages in $S1$ and $S2$ are equal and opposite, resulting in a net output voltage of zero.

When the core moves 2 mm to the right of the null position, the voltage in $S1$ increases by 2 V, and the voltage in $S2$ decreases by 2 V.

- What is the net output voltage at this new position?
- If the core moves 3 mm to the left of the null position, causing the voltage in $S1$ to decrease by 3 V and the voltage in $S2$ to increase by 3 V, what is the new net output voltage?

First Displacement (2 mm to the right):

Voltage in S_1: $+2\,\mathrm{V}$

Voltage in S_2: $-2\,\mathrm{V}$

Net output voltage V_{out} is the difference between the two secondary voltages:

$$V_{out} = V_{S1} - V_{S2} = 2\,\mathrm{V} - (-2\,\mathrm{V}) = 2\,\mathrm{V} + 2\,\mathrm{V} = 4\,\mathrm{V}$$

Second Displacement (3 mm to the left):

Voltage in S_1: $-3\,\mathrm{V}$

Voltage in S_2: $+3\,\mathrm{V}$

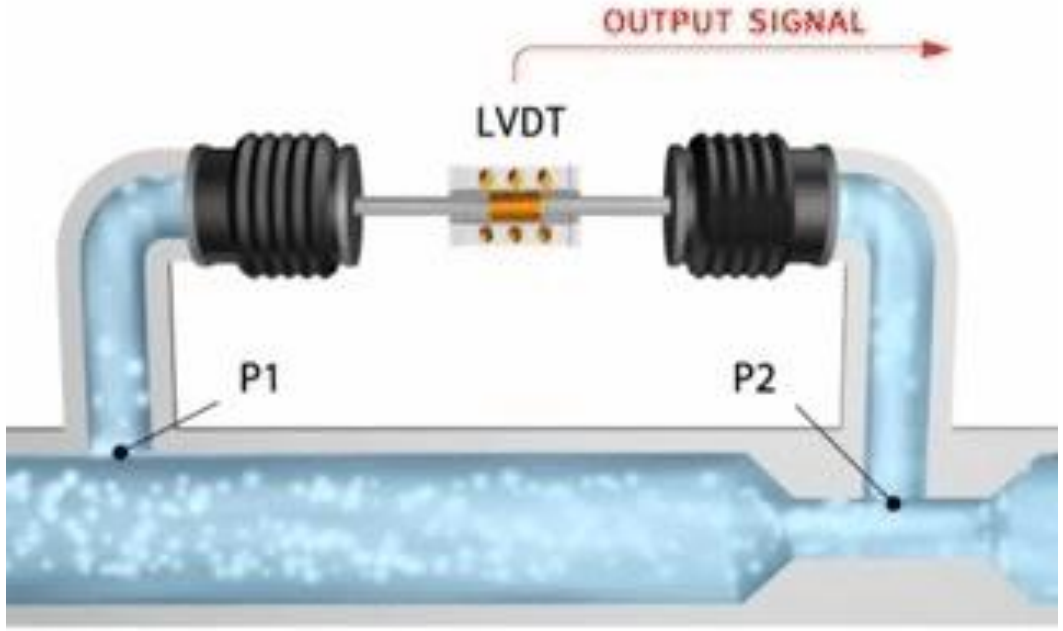
The net output voltage V_{out} is now:

$$V_{out} = V_{S1} - V_{S2} = -3\,\mathrm{V} - 3\,\mathrm{V} = -6\,\mathrm{V}$$

2.2 Application of LVDT: Determining the Pressure of Fluids Flowing Through a Pipe

LVDT can be used indirectly to *measure the pressure of fluids in a pipe* by *converting pressure changes into linear displacement*, which the LVDT can then measure.

This process typically involves a diaphragm or Bourdon tube that deforms in response to pressure changes, with this deformation being translated into linear motion.



Applications in Industry:

Oil and Gas:
Monitoring pipeline pressure to ensure safe and efficient operation.

Chemical Processing:
Measuring fluid pressures in reactors and other process equipment.

Water Supply Systems:
Monitoring pressures in distribution networks to detect leaks and ensure proper operation.

Automotive:
Measuring fuel and hydraulic pressures in various systems.