POWER ELECTRONICS

Engr. Edwin C. Cuizon, Jr.

POWER ELECTRONICS

It refers to electronic circuits and devices used to control and convert electrical power efficiently. It acts as an interface between the controller and the actuators.

The controller generates low-power control signals, while the motor requires high power to operate. Power electronic circuits amplify and regulate these signals to drive the motors.

FUNCTIONS OF POWER ELECTRONICS IN ROBOTICS

Power electronics performs the following functions:

- **Motor Speed Control** - controls the rotational speed of motors.

  Example:
  - Increasing motor voltage increases motor speed.
  - Decreasing motor voltage decreases speed.

- **Direction Control** - it allows the motor to rotate.
  - Clockwise (CW)
  - Counterclockwise (CCW)

  This is essential in robotic joints that require bidirectional movement.

FUNCTIONS OF POWER ELECTRONICS IN ROBOTICS

- **Torque Control** - controls the amount of force generated by the motor.

  Applications:
  - Robot grippers
  - Manipulators
  - Mobile robot traction systems

- **Energy Efficiency** - power electronics minimizes energy losses, allowing:
  - Longer battery life
  - Reduced heat generation
  - Improved system reliability

In many robotics applications, actuators must be controlled precisely so that desired motions of arms and legs may be attained. This requires a power amplifier to drive a desired level of voltage (or current indirectly) to the motor armature.

PULSE WIDTH MODULATION

Pulse Width Modulation (PWM) is a method of controlling the average power delivered to a load by rapidly switching the power supply ON and OFF.

Rather than continuously varying the voltage, PWM controls the effective voltage by varying the amount of time the voltage remains ON.

DUTY CYCLE

Duty Cycle is defined as the percentage of time that a PWM signal remains in the ON state during one complete switching period.

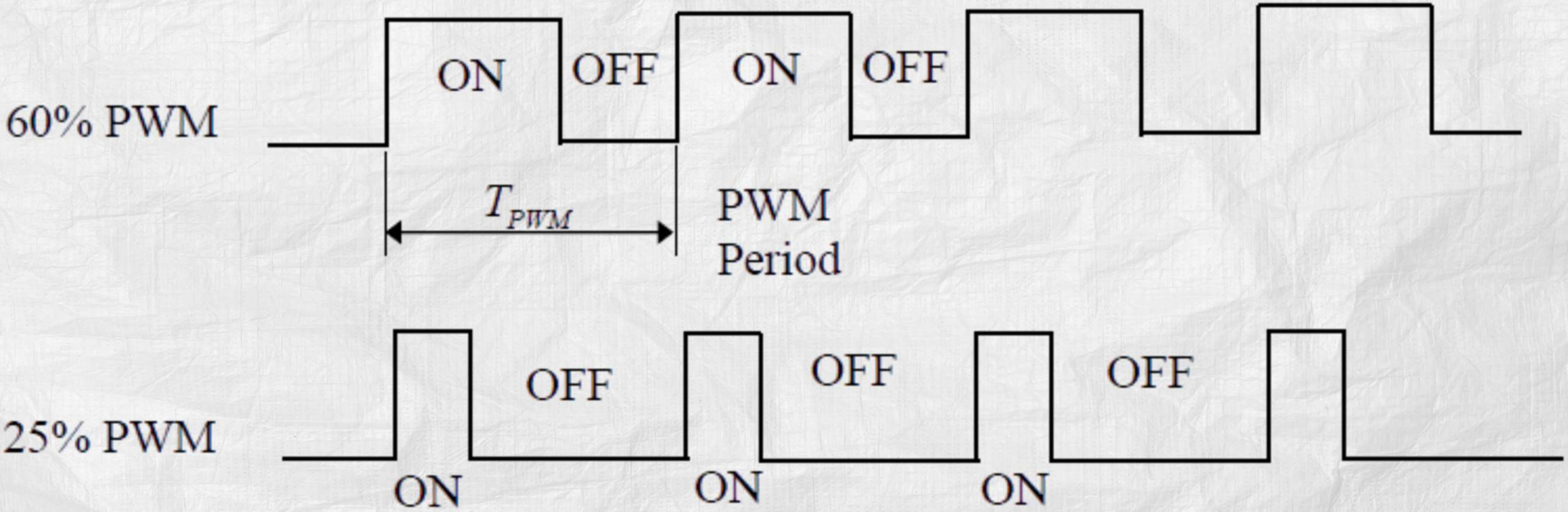
$$Duty\ Cycle = \frac{T_{ON}}{T_{ON} + T_{OFF}} \times 100\%$$

$$T_{PWM} = T_{ON} + T_{OFF}$$

Where:

- T_{ON} = time signal remains HIGH
- T_{OFF} = time signal remains LOW

DUTY CYCLE



Pulse Width Modulation

PULSE WIDTH MODULATION

Example: Mobile Robot Car

A microcontroller sends PWM to motor driver:

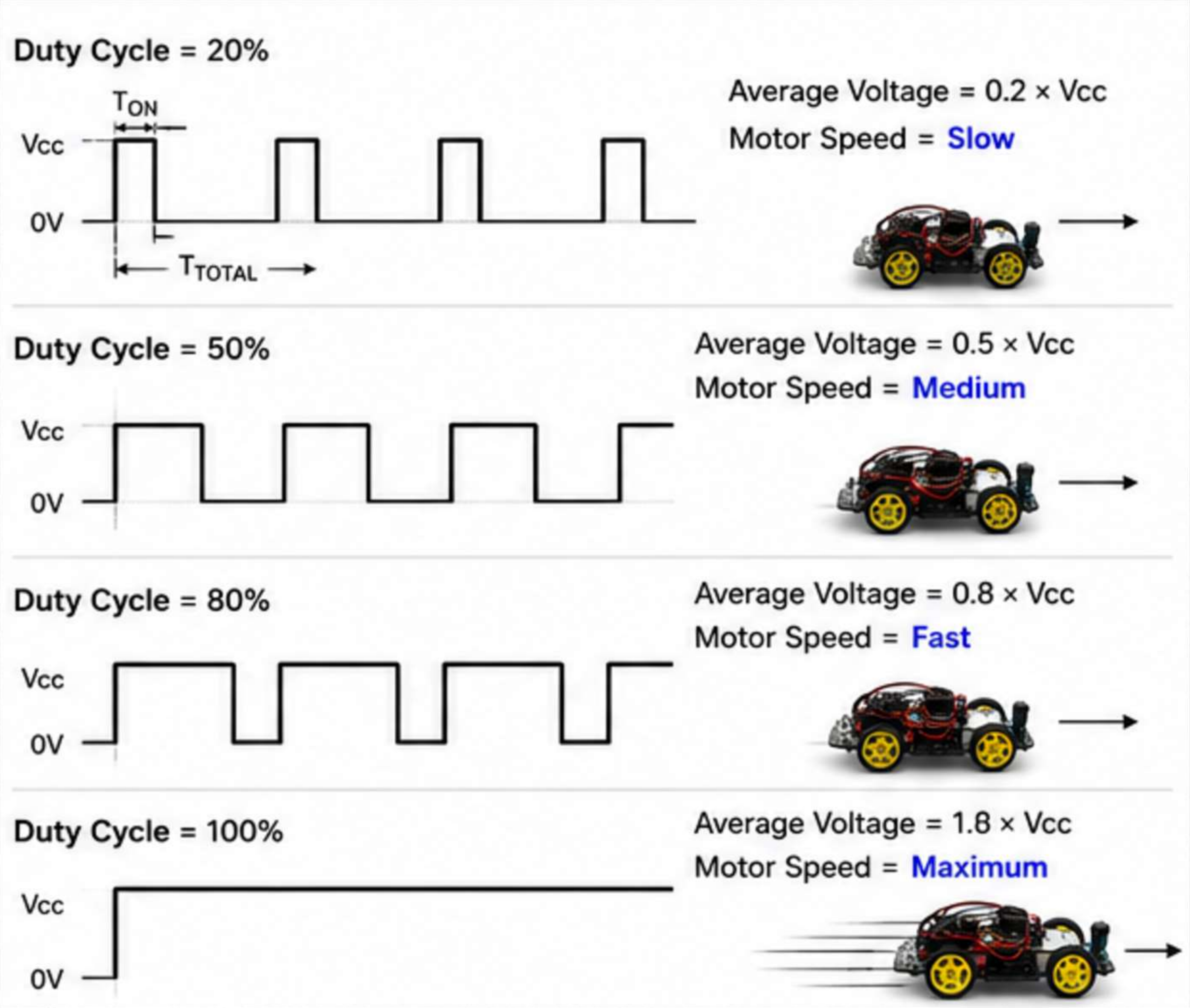
Duty Cycle	Motor Response
25%	Slow movement
50%	Medium speed
75%	Fast speed
100%	Full speed

So if your robot needs to slow down when avoiding obstacles, it just **reduces PWM duty cycle** instead of cutting power completely.

PWM controls **"how much power"** by changing **"how long the signal stays ON"**, not by changing voltage.

PULSE WIDTH MODULATION

Duty Cycle	Motor Response
25%	Slow movement
50%	Medium speed
75%	Fast speed
100%	Full speed



PWM AMPLIFIERS

The controller output signal is usually small.

Example:

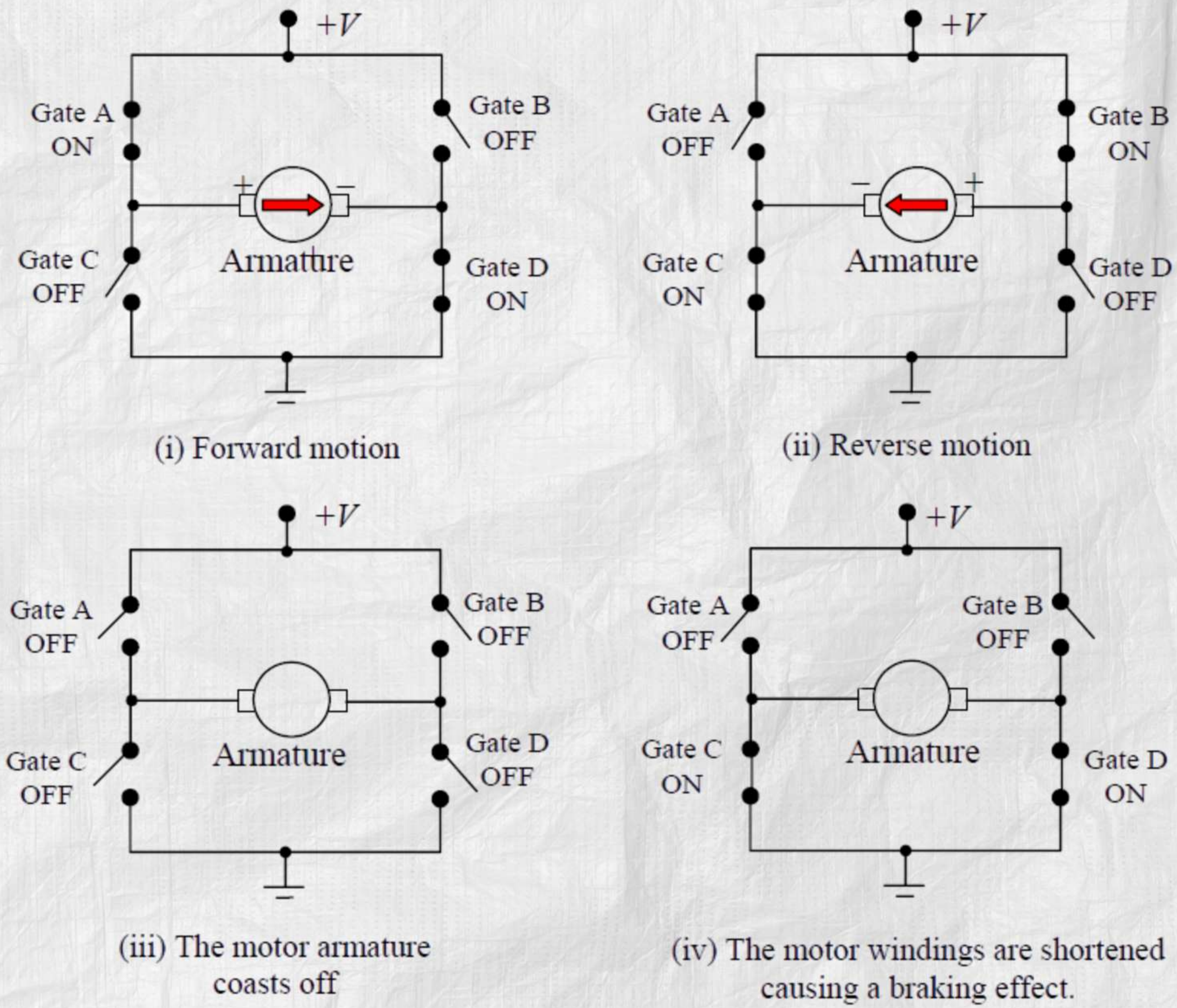
Arduino output: 5 V, few milliamperes
Motor requirement: 12 V, several amperes

The PWM amplifier increases voltage and current while preserving control information.

THE H-BRIDGE AND BIPOLAR PWM AMPLIFIERS

Robotic systems require motors to rotate in both directions.

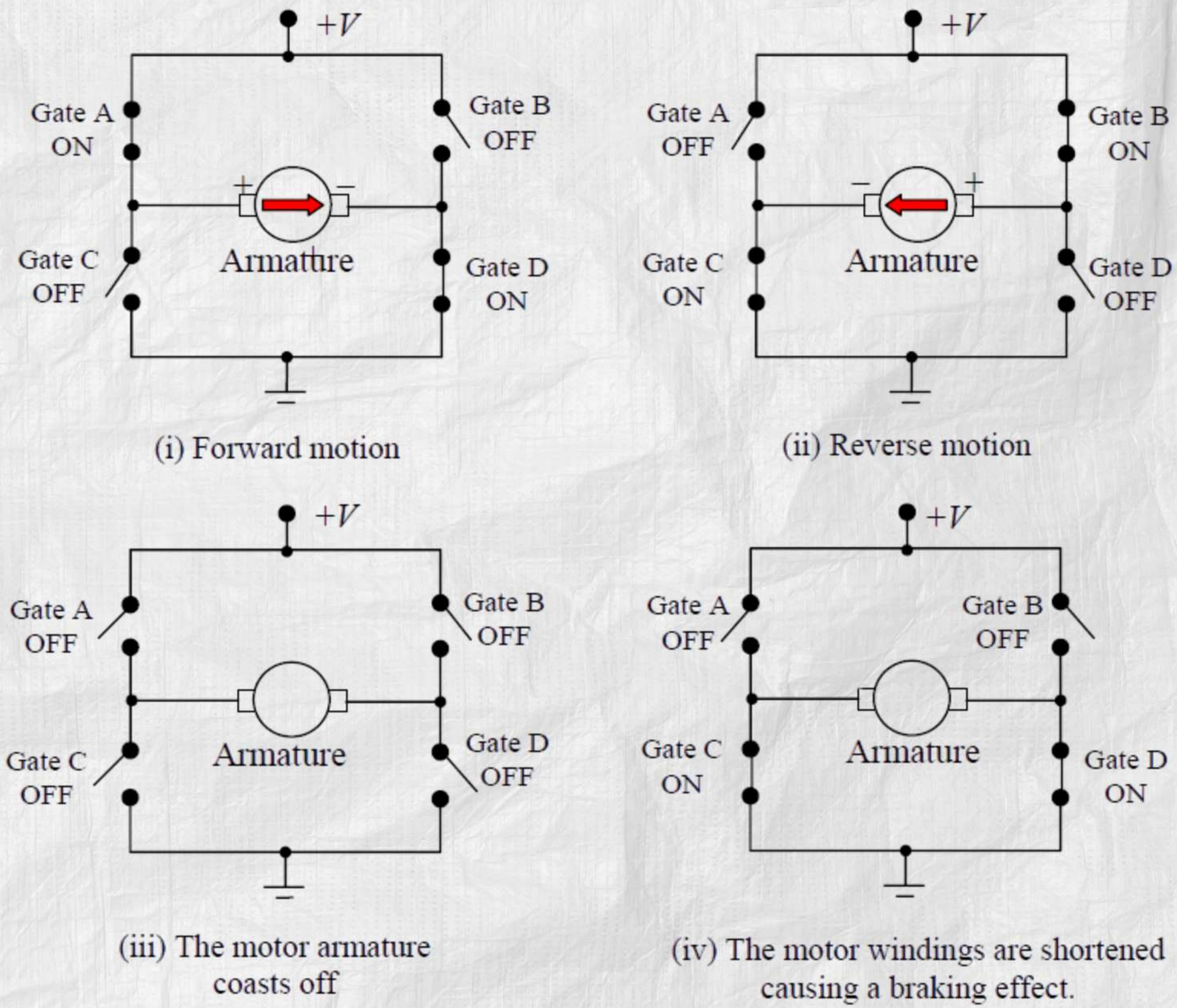
An H-Bridge circuit enables this.



THE H-BRIDGE AND BIPOLAR PWM AMPLIFIERS

Robotic systems require motors to rotate in both directions.

An H-Bridge circuit enables this.



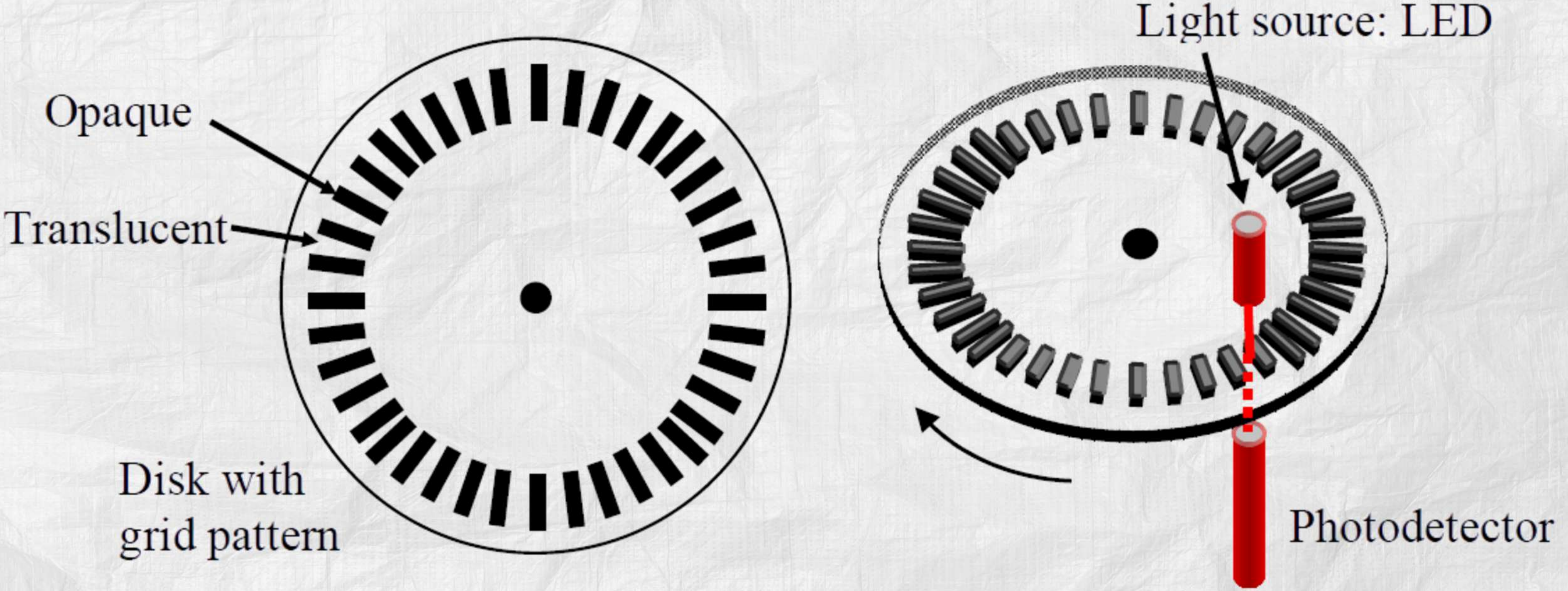
OPTICAL SHAFT ENCODERS

OPTICAL SHAFT ENCODERS

*In robotics, it is important to know the **position, direction, and speed of a motor shaft**. An Optical Shaft Encoder is a **sensor attached to a rotating shaft** that **converts mechanical rotation into digital electrical signals.***

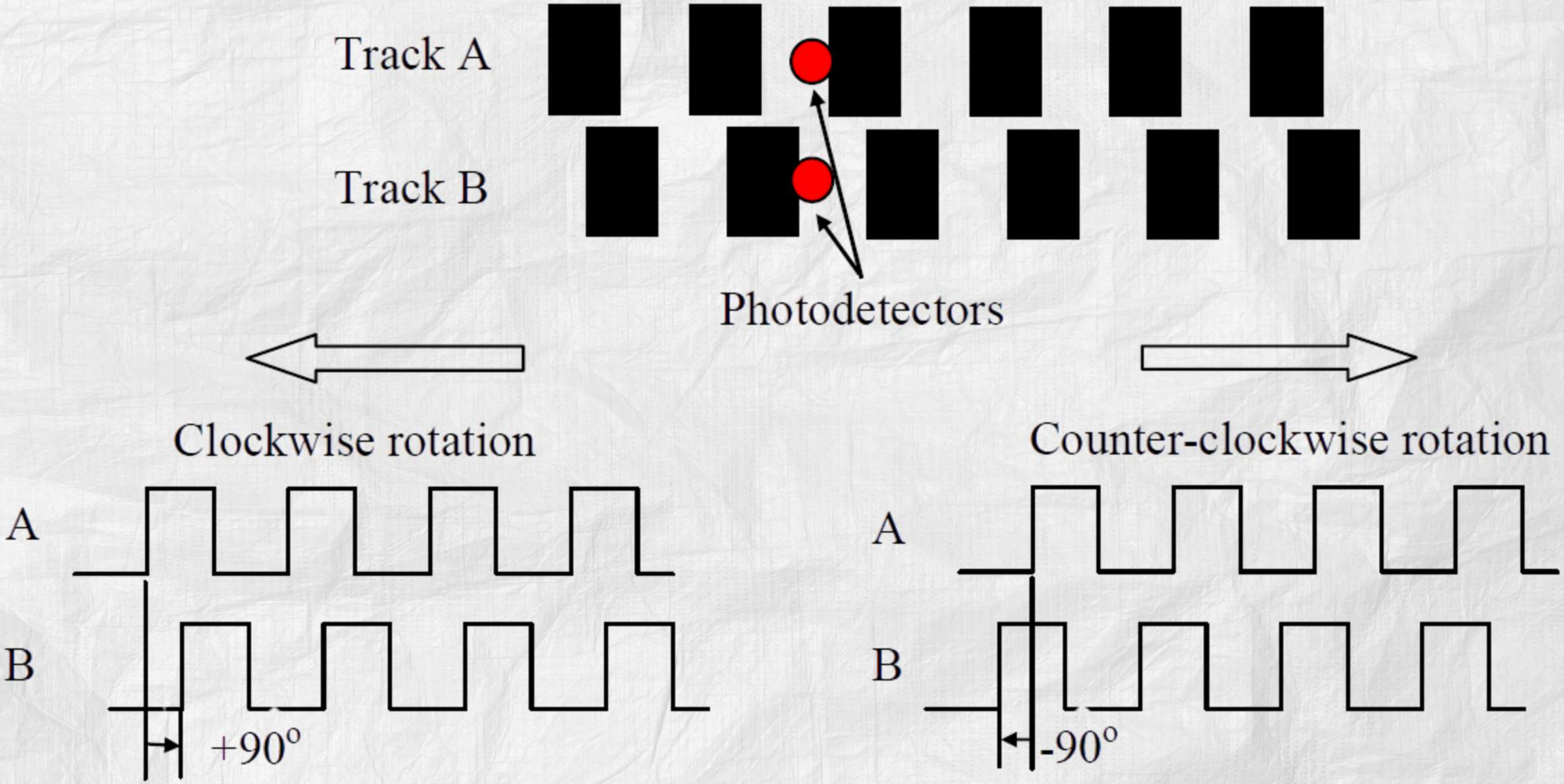
*These signals help the robot determine how far, how fast, and in which direction a motor has rotated. **An encoder measures the location (position) of a rotating shaft.***

OPTICAL SHAFT ENCODERS



BASIC CONSTRUCTION OF OPTICAL SHAFT ENCODER

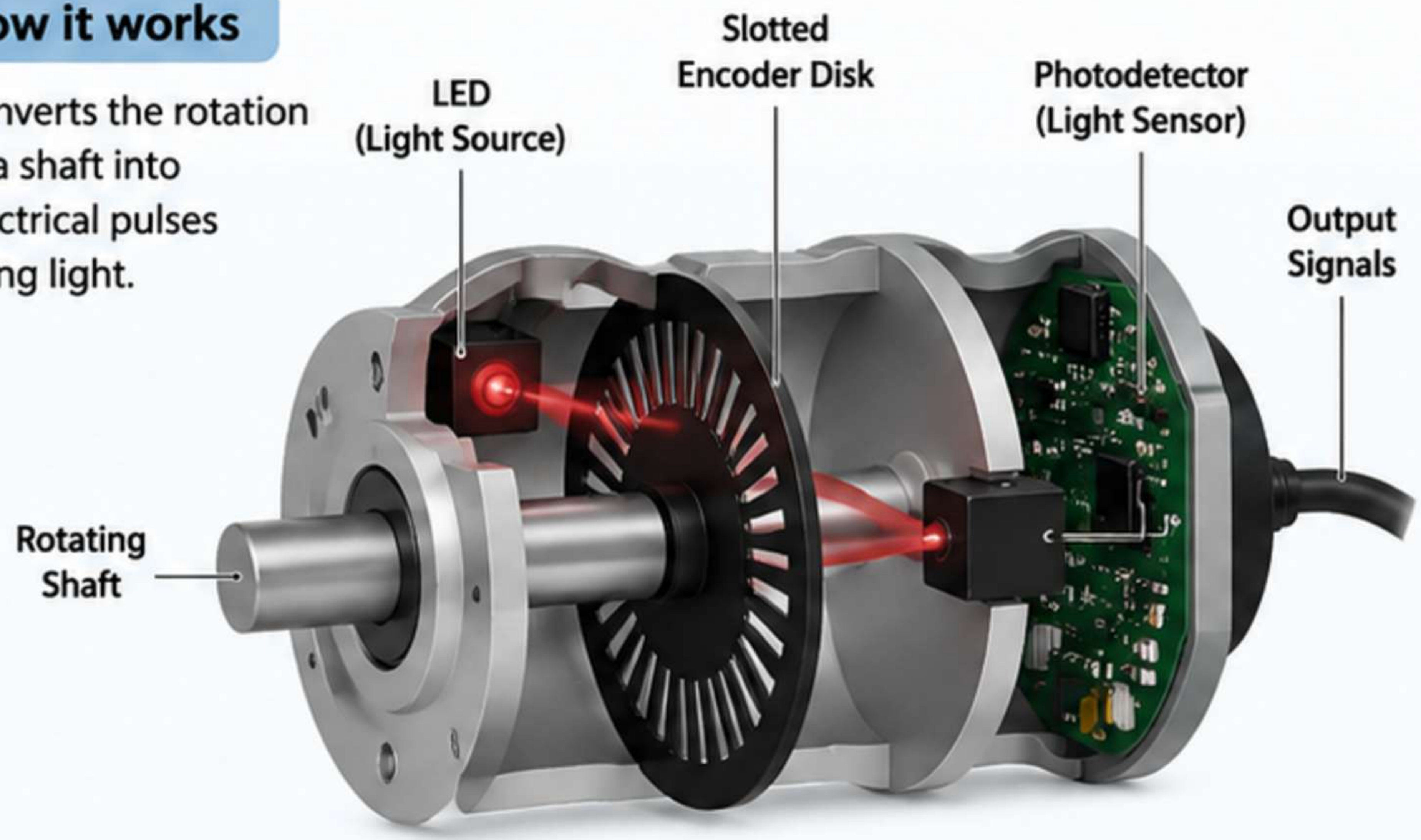
OPTICAL SHAFT ENCODERS



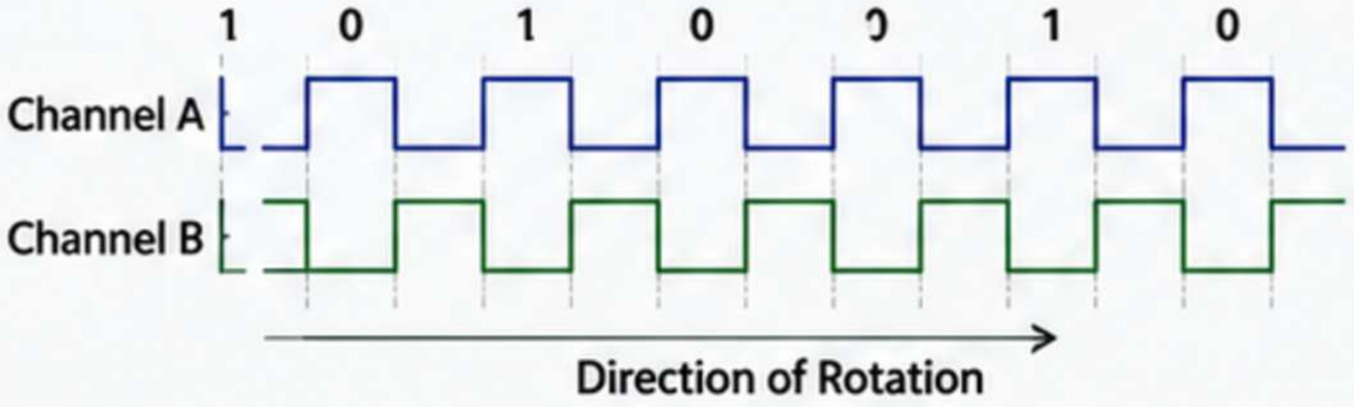
OPTICAL SHAFT ENCODER – EXAMPLE

How it works

Converts the rotation of a shaft into electrical pulses using light.



Output Signals (Incremental Encoder)



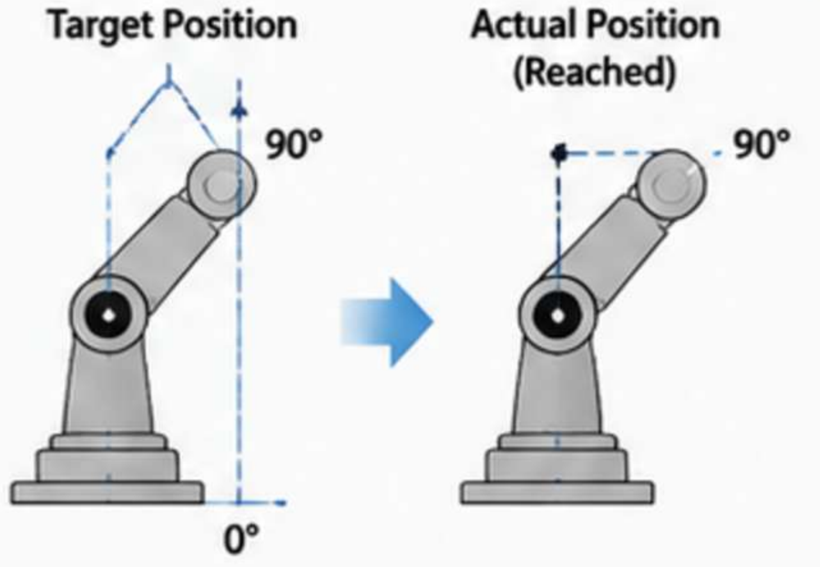
Two signals (A and B) are 90° out of phase. The controller counts the pulses and knows the position, speed and direction.

EXAMPLE 1: ROBOTIC ARM JOINT

The encoder helps the robotic arm rotate the joint exactly 90° to pick an object.

How it works

1. Motor tries to rotate the joint.
2. Encoder counts the rotation.
3. Controller compares with target (90°).
4. Motor stops exactly at 90°.



DEPARTMENT OF
ELECTRO-MECHANICAL TECHNOLOGY
Engr. Edwin C. Cuizon, Jr.

INCREMENTAL ENCODER

Characteristics

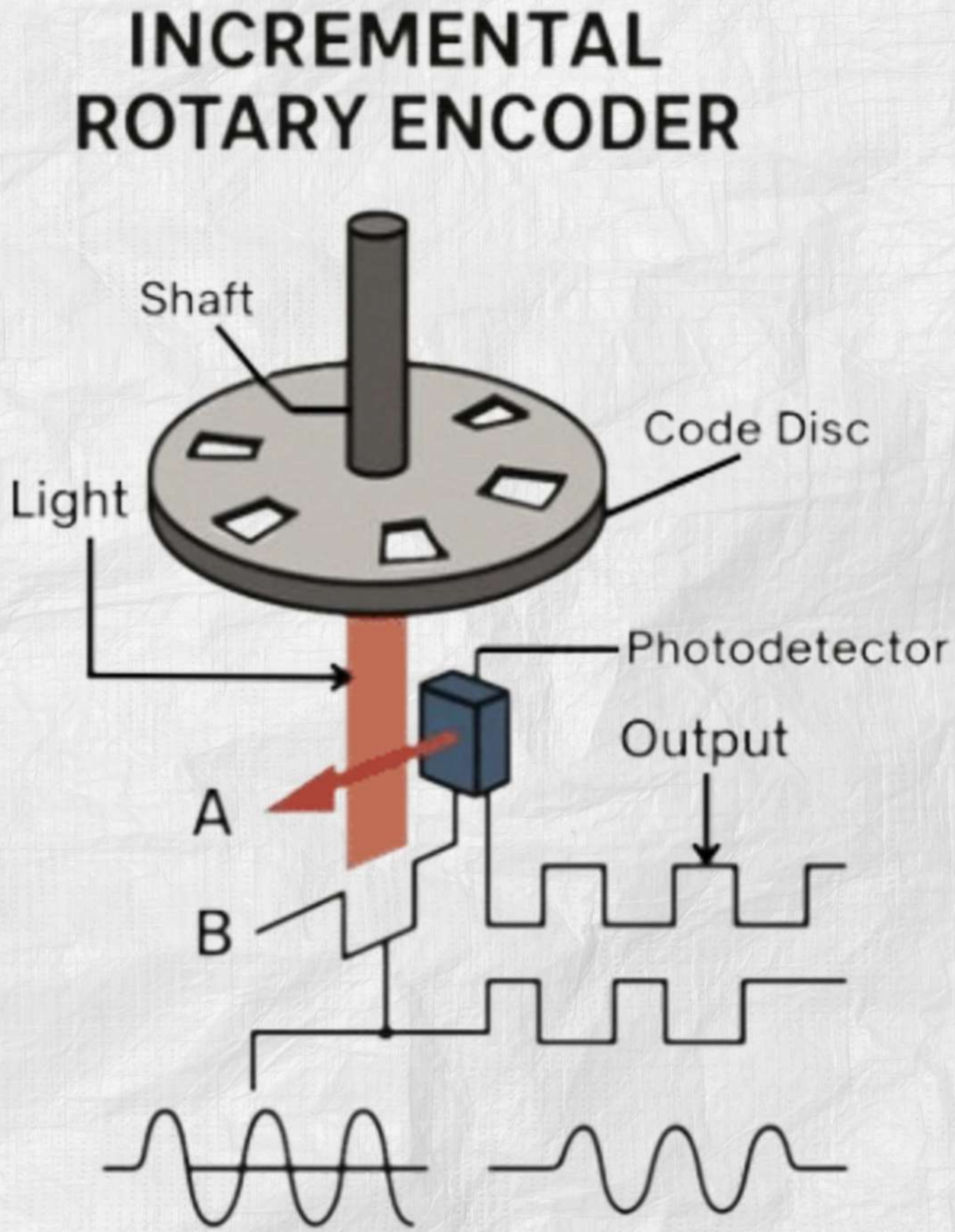
- Produces pulses as the shaft rotates.
- Measures relative movement.
- Most common in robotics.

Advantages

- Simple
- Low cost
- High speed

Applications

- Robot wheels
- Conveyor systems
- CNC machines



ABSOLUTE ENCODER

Characteristics

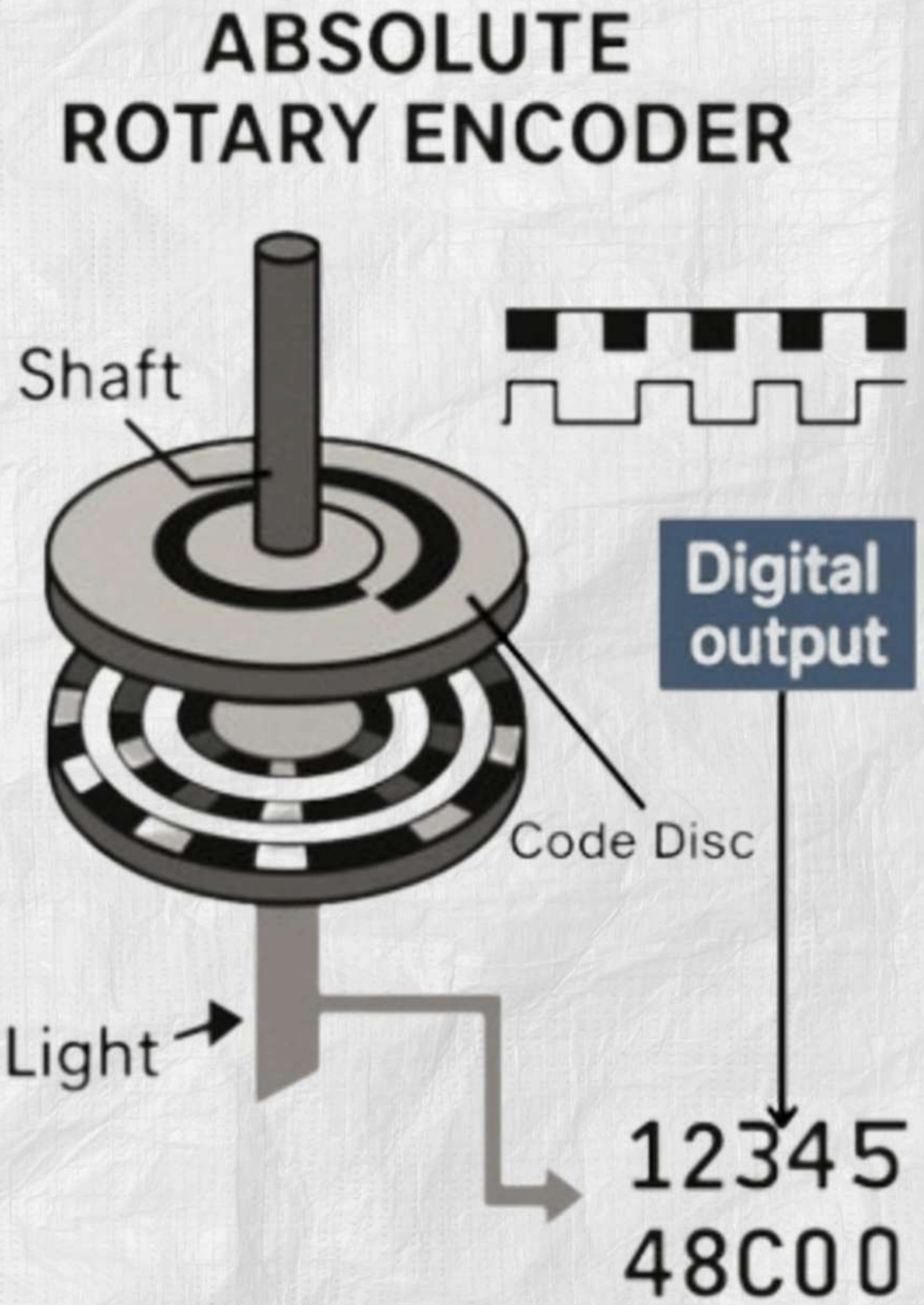
- Each shaft position has a unique digital code.
- Retains position information after power loss.

Advantages

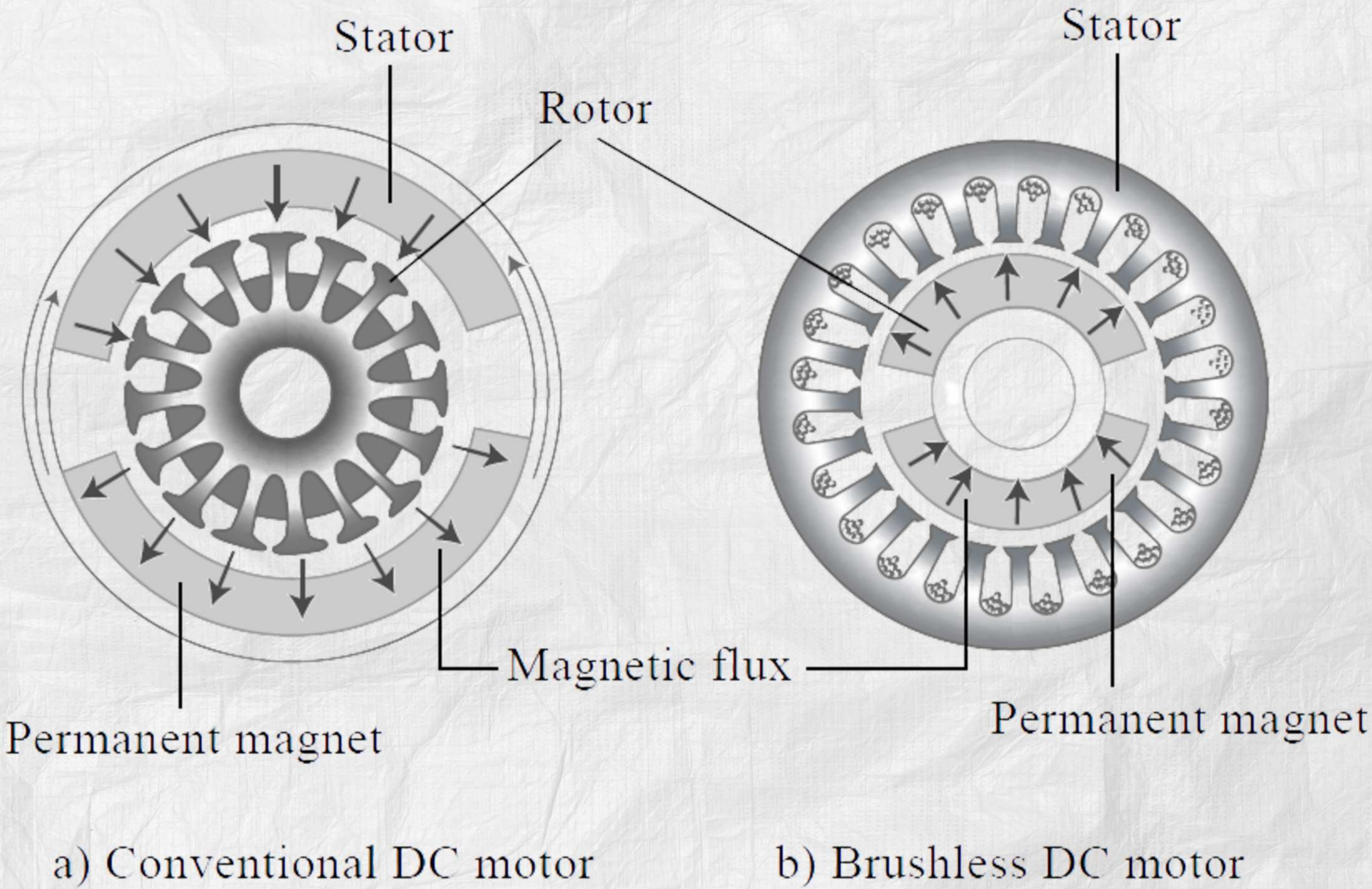
- Very accurate
- No need to re-home the system

Applications

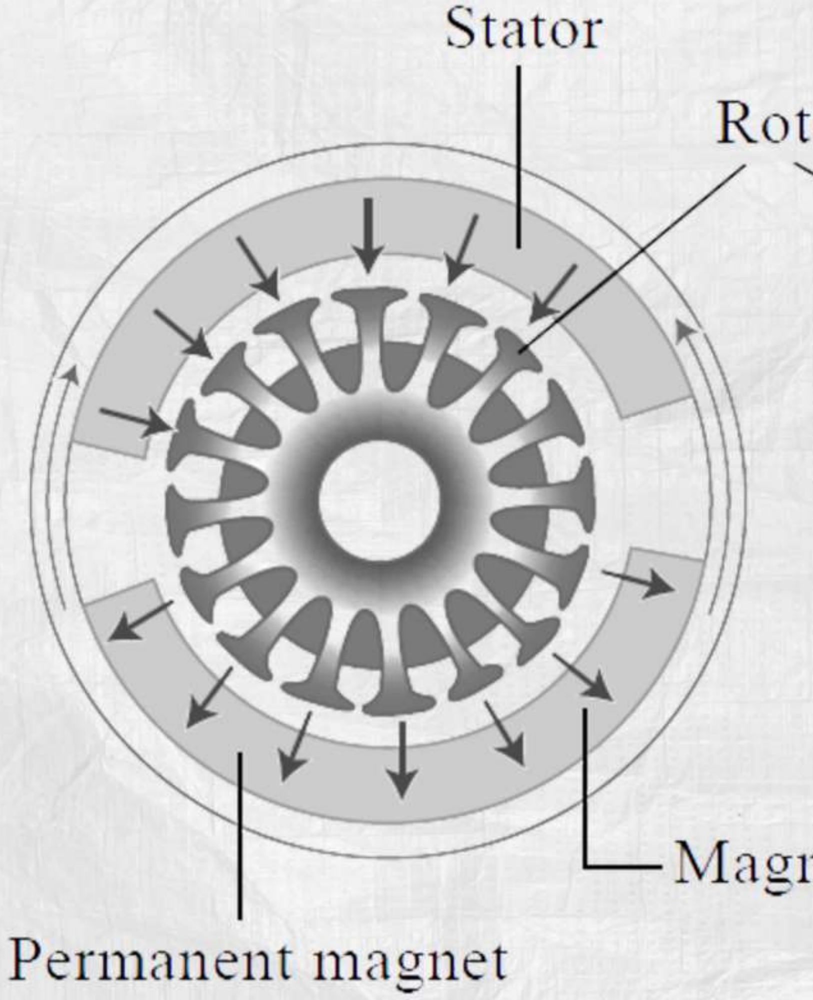
- Industrial robots
- Aerospace systems
- Precision positioning



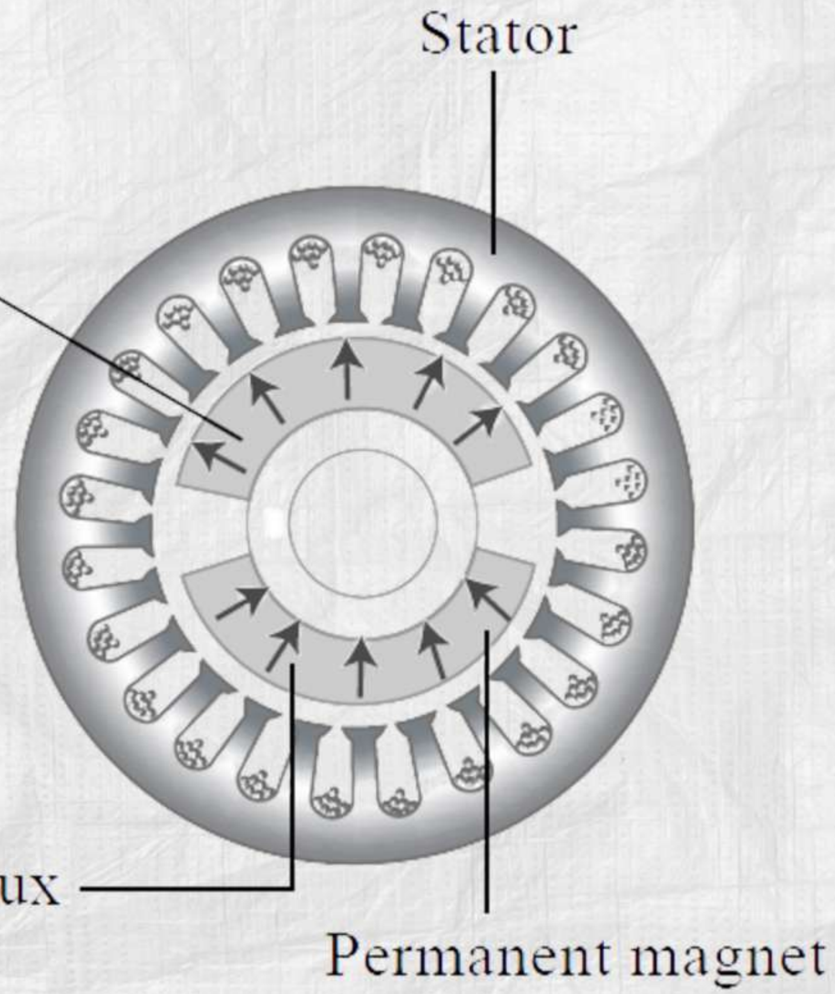
BRUSHLESS DC MOTORS


Stator
Rotor
Stator
Magnetic flux
Permanent magnet
Permanent magnet
a) Conventional DC motor
b) Brushless DC motor

CONVENTIONAL VS BRUSHLESS DC MOTOR



a) Conventional DC motor



b) Brushless DC motor

Conventional (Brushed) DC Motor

A brushed DC motor uses brushes and a commutator to supply electrical current to the rotating part (rotor). As the motor rotates, the brushes physically touch the commutator to switch the current direction.

Brushless DC Motor

A BLDC motor eliminates brushes and commutators. Instead, an electronic controller switches the current in the stator windings, causing the rotor (which contains permanent magnets) to rotate.

Conventional (Brushed) DC Motor

Uses brushes that physically touch moving parts, causing friction, heat, and wear.

Brushless DC Motor

Uses electronic switching instead of brushes, making it more efficient, quieter, more reliable, and longer-lasting.

THREE PHASE CURRENT EQUATIONS

$$I_A = I_0 \sin\theta$$

$$I_B = I_0 \sin\left(\theta + \frac{2\pi}{3}\right)$$

$$I_C = I_0 \sin\left(\theta + \frac{4\pi}{3}\right)$$

TORQUE EQUATION

$$T_m = \frac{3}{2} k_0 I_0$$

where:

- T_m = Motor torque (N·m)
- k_0 = Motor constant
- I_0 = Magnitude of phase current

END OF MODULE 2

Engr. Edwin C. Cuizon, Jr.
Faculty, Department of Electro-Mechanical Technology
University of Science and Technology of Southern Philippines