PROCESS AUTOMATION · 2026/27

Sensors & Actuators

From a physical event to a reliable PLC decision



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Today: understand the device, then program the behavior

01 · Observe

Which sensor gives the PLC the information it needs?

Input

02 · Decide

What should happen when the input changes?

PLC logic

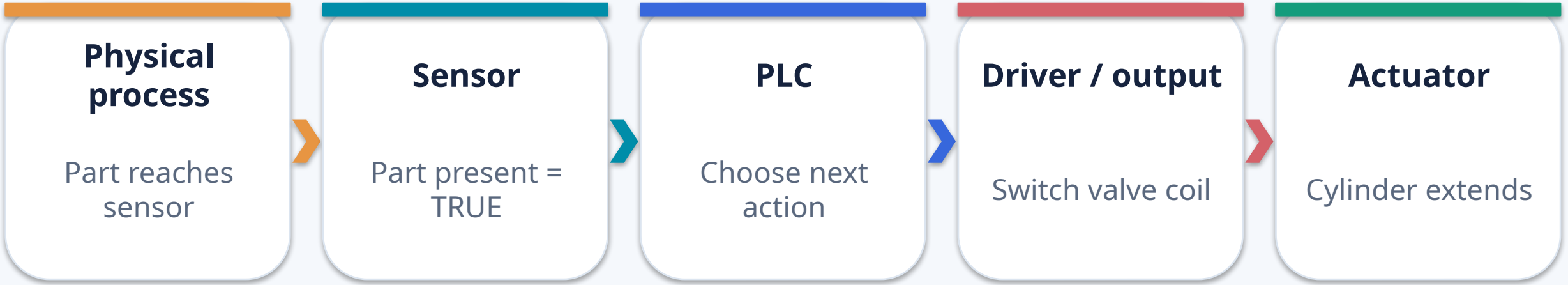
03 · Act

Which output makes the machine move, heat or stop?

Output

We will use your conveyor, pneumatic system and robotic arm as recurring examples.

An automation system is a closed information loop



Feedback: an end-position sensor confirms the cylinder really moved.

What does the PLC receive?

BOOLEAN

TRUE / FALSE

Limit switch or photoelectric detector

ANALOG

0–10 V or 4–20 mA

Tank level, temperature or pressure

DIGITAL DATA

Measured value + status

IO-Link distance or diagnostic sensor

Treat each sensor output as an interface contract: data type, update speed, meaning and failure modes.

Choose a sensor by asking what must be known

Is a metal part present?	Inductive proximity
Is a bottle passing?	Photoelectric sensor
How far is the object?	Ultrasonic or laser distance
Where is the rotating axis?	Encoder
How hot / full / heavy?	Temperature / level / load cell

Start with the measurement need; only then select technology and wiring.

Before selecting a sensor, check its environment

Industrial constraints

- Dust, splashing water and cleaning
- Operating temperature and vibration
- Cable length, interference and mounting
- Replacement and calibration effort

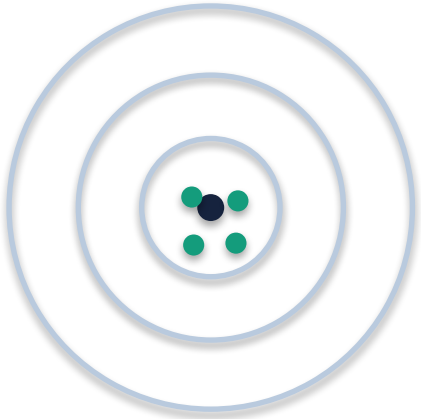
IP67 ≠ indestructible

6 = dust-tight
7 = temporary immersion

It does not automatically certify impact or chemical resistance.

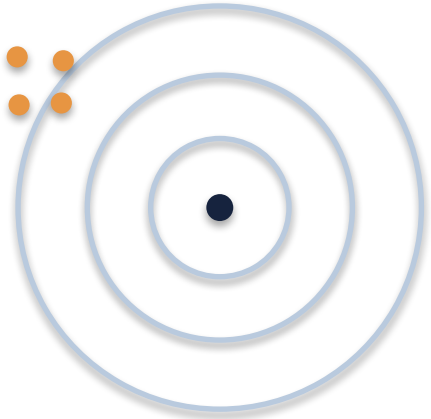
Accuracy and repeatability matter for different reasons

ACCURATE



Cluster near target

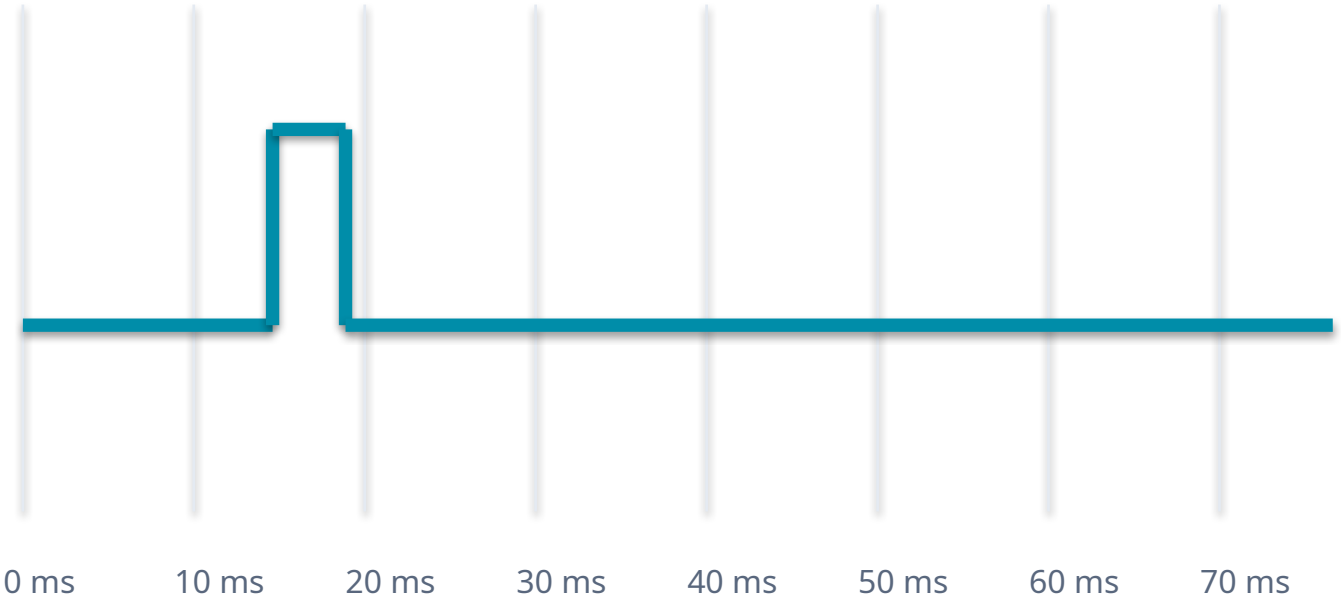
PRECISE, BUT BIASED



Repeatable, wrong location

Fast objects can disappear between PLC scans

Short sensor pulse



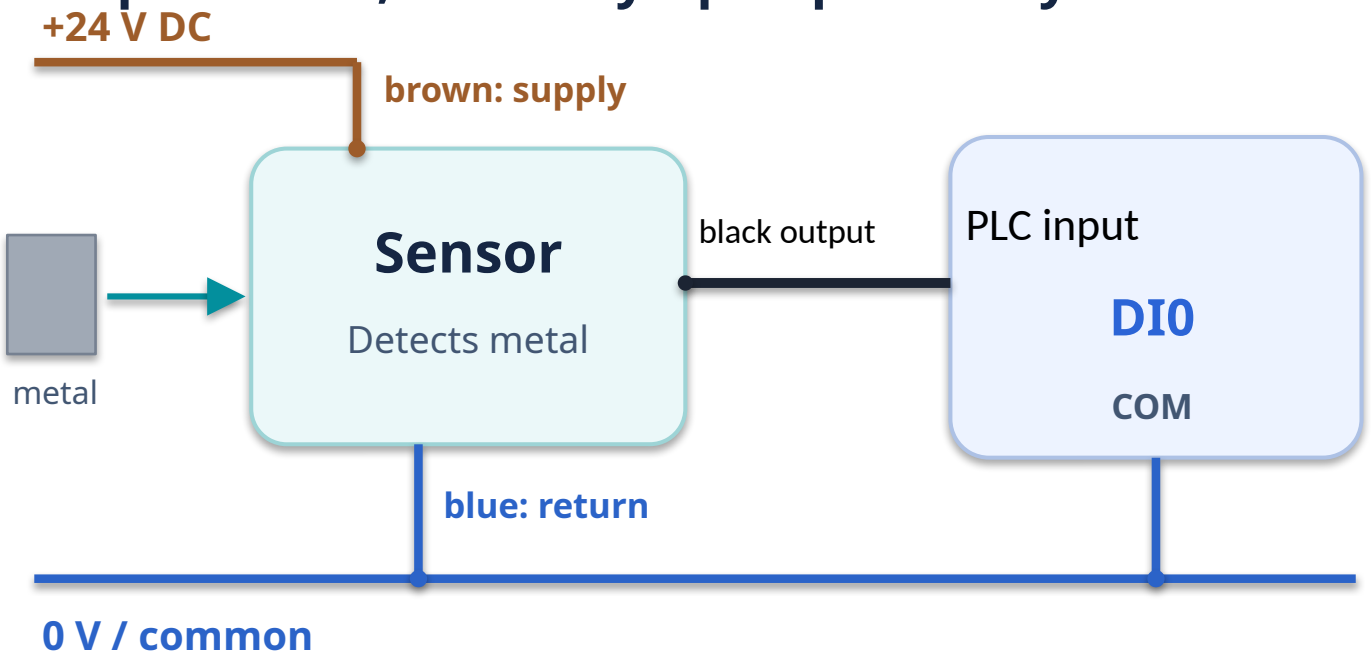
A 3–4 ms pulse may fall between snapshots.

What helps?

- Use suitable sensor / PLC input filtering.
- Use pulse capture or counters when needed.
- Check scan time and event duration.

How a 3-wire sensor connects to a PLC

Example: a PNP, normally-open proximity sensor



Target detected → black wire HIGH → PLC input TRUE

Two different choices

NO or NC

When the output becomes active relative to detection.

PNP or NPN

Whether the output supplies +24 V or switches to 0 V.

Always verify the device wiring and input common.

Commission a digital sensor in four steps

1. **1. Power** — Check voltage and common/ground.
2. **2. Detect** — Does the sensor indicator change?
3. **3. Read** — Does the mapped PLC input change?
4. **4. Trust** — Test the real object and fault cases.



Lab habit: troubleshoot the signal path before changing PLC logic.

4–20 mA: an analog value with a live zero

4 mA	12 mA	20 mA
0%	50%	100%

A current loop is often more robust to cable voltage drops than a voltage signal.

Why 4, not 0?

- A disconnected loop can be detected.
- Some transmitters are powered by the loop.
- Supply voltage must cover cable and device drop.

From current to engineering units: one simple formula

```
// Example sensor range: 0–100%


levelPercent :=
    (current_mA - 4.0) * 6.25;



// For a real project, check limits and
faults.
```

Why it matters

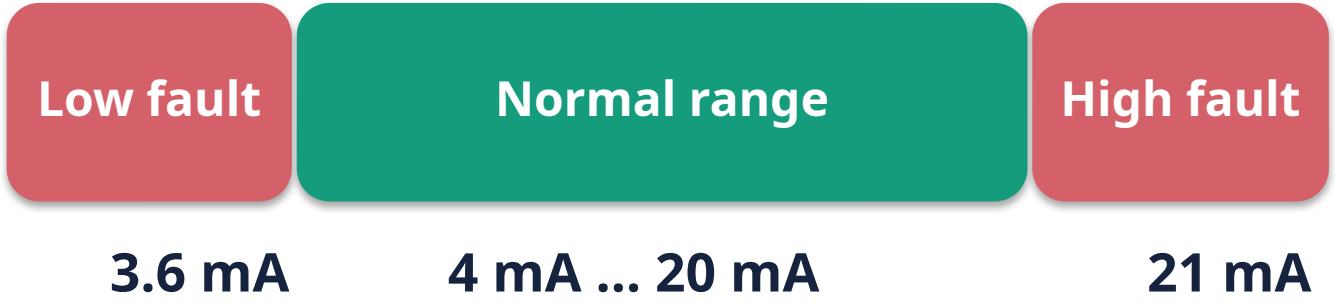
12 mA → 50%

Store and display values in meaningful units, not just raw ADC counts.

Lab note: CX7000 analog inputs are 0–10 V. A 4–20 mA sensor needs matching I/O.

Handle invalid measurements before using them

ILLUSTRATIVE FAULT WINDOWS — DEVICE CONFIGURATION MAY DIFFER



Typical NE43-style fault conventions; verify the transmitter configuration.

PLC behavior

- Validate measurement.
- Raise a clear alarm.
- Use a documented safe fallback.

Four ways to detect an object

INDUCTIVE

Metal target

Metal part / shaft

CAPACITIVE

Material or liquid

Powder / plastic

PHOTOELECTRIC

Light beam

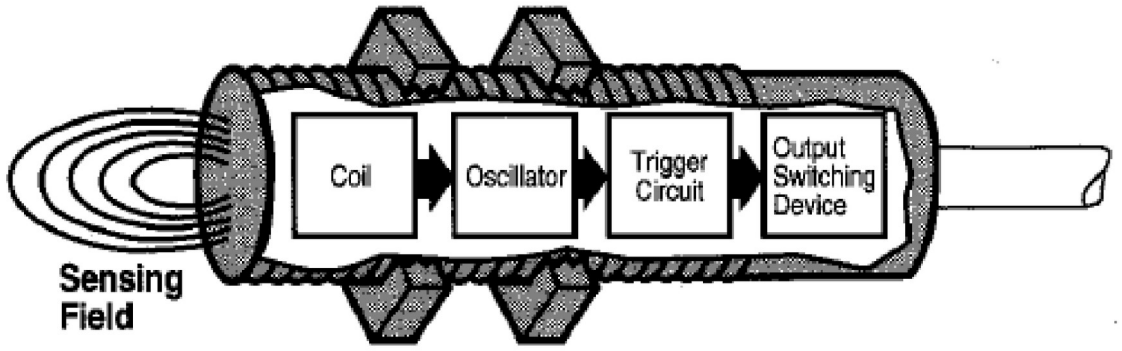
Bottle / box

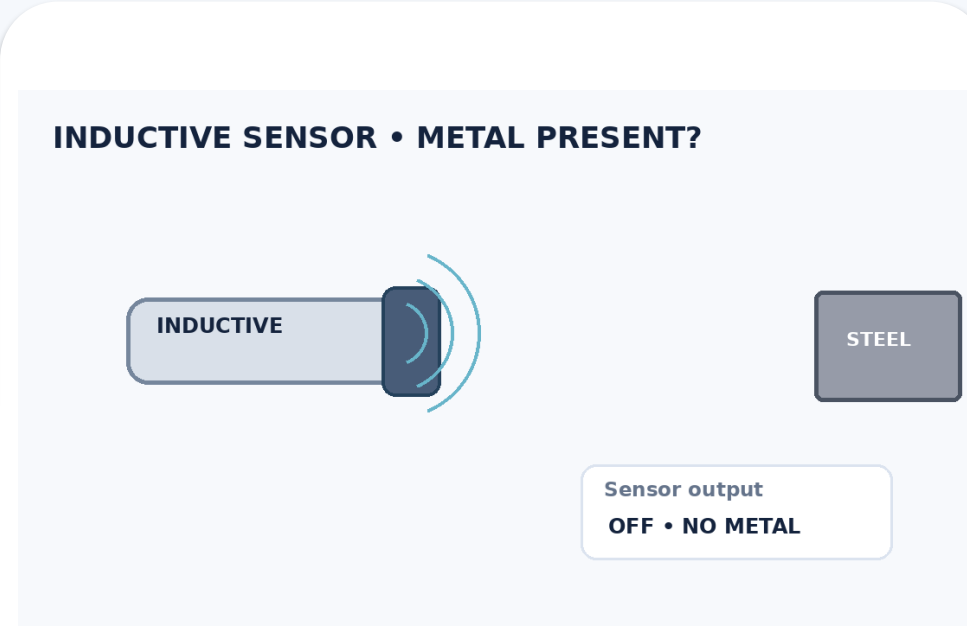
ULTRASONIC

Echo / distance

Height / level

Inductive proximity: detect a metal part



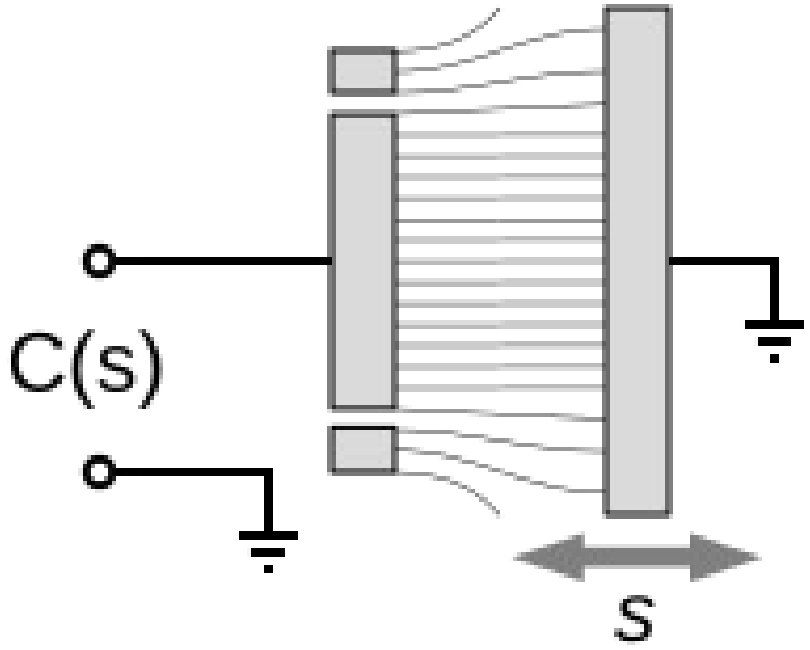


A metal target changes the sensor’s oscillating field; its output switches when detected.

Capacitive sensors: when the target is not metal

Good for

- Plastics, powders and many liquids.
- Detecting contents through some nonmetallic walls.
- Situations where an inductive sensor cannot detect the target.

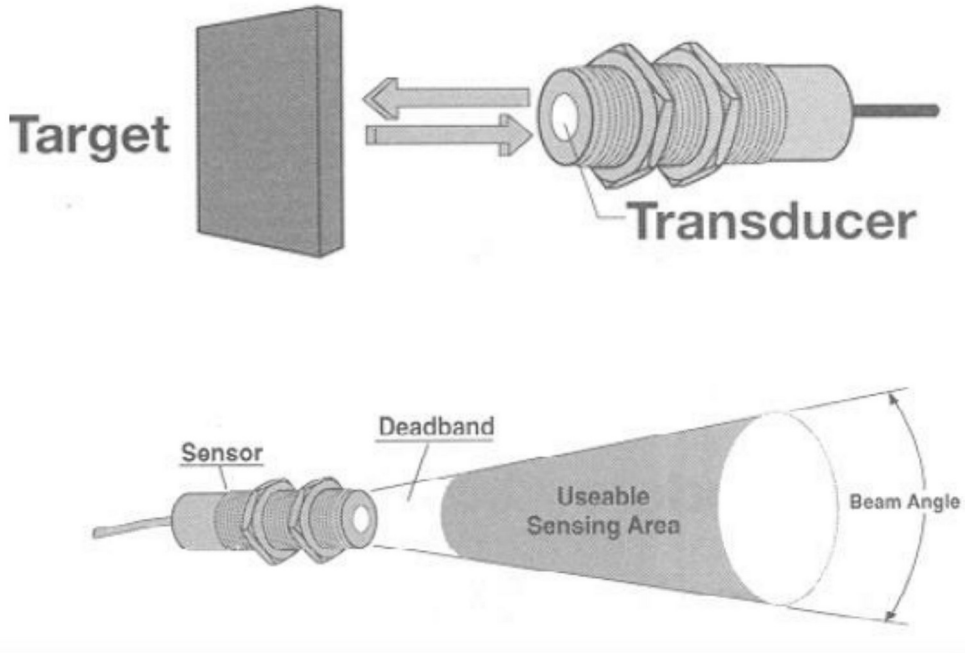


Caution: moisture, buildup and target geometry can affect switching.

Ultrasonic sensors measure how long an echo takes

Think of it as sonar

- Transmit a sound pulse.
- Listen for the reflected echo.
- Return distance or an in-range signal.



Useful when colour varies; consider blind zone, angle and target shape.

Photoelectric sensors: three ways to use a light beam

THROUGH-BEAM



Emitter and receiver face each other.

RETROREFLECTIVE



Reflector returns the beam.

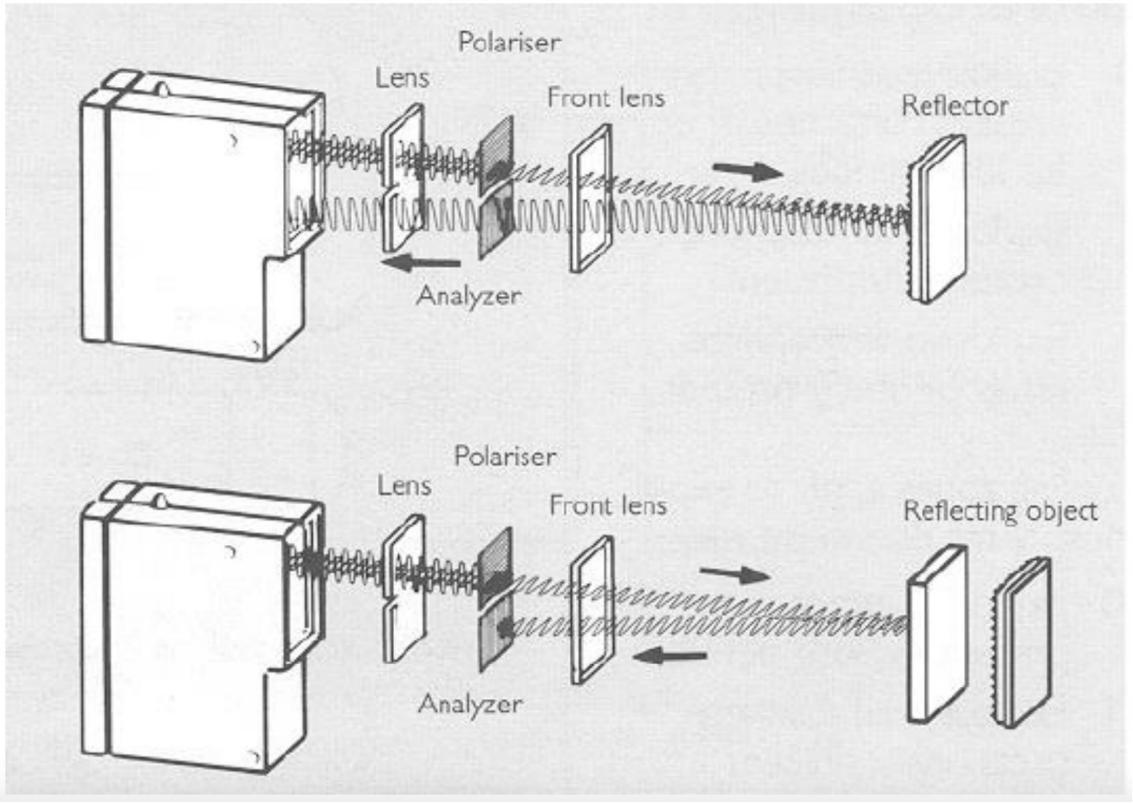
DIFFUSE



The object reflects light back.

Choose the arrangement based on object material, distance, mounting and background.

Transparent and shiny targets require extra care

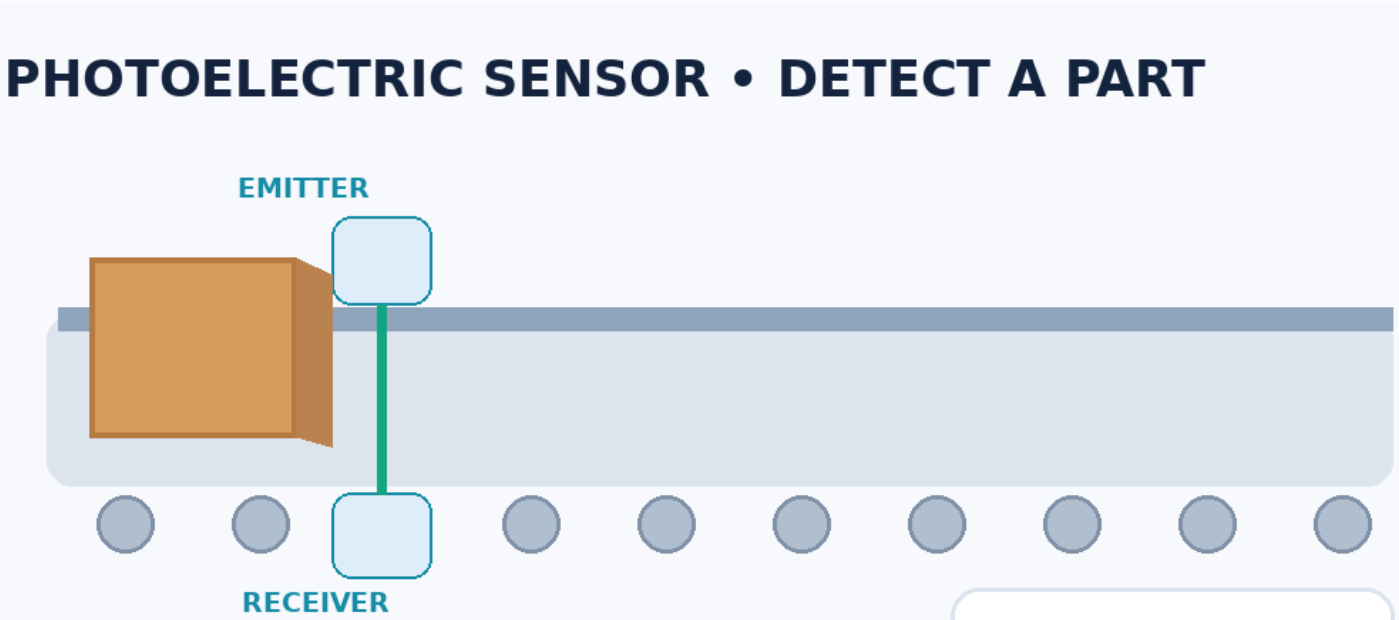


Typical problems

- Transparent bottles may transmit light.
- Shiny objects can reflect the wrong way.
- Dark targets may return too little light.

Watch: photoelectric sensor modes

Demo: the passing box changes one PLC input



Sensor

TRUE while beam is blocked

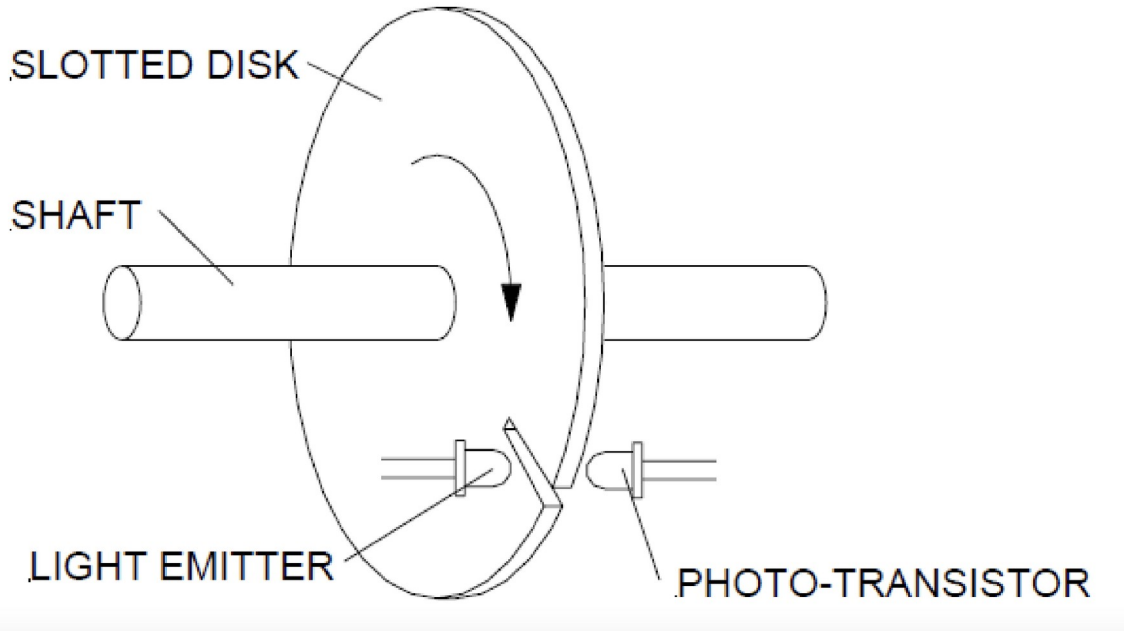
PLC

Recognize part present

Program

Advance the sequence once

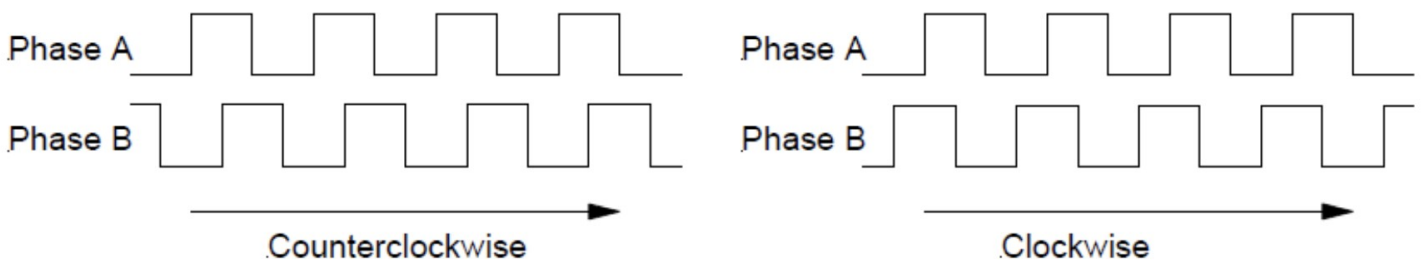
Encoders turn shaft rotation into counts



Two familiar ideas

- An index pulse says “this reference position”.
- Many repeated pulses measure incremental movement.
- Count changes to estimate distance or speed.

Two encoder channels reveal direction



Look for

- Two signals: A and B.
- A phase shift between them.
- Pulse order indicates direction.

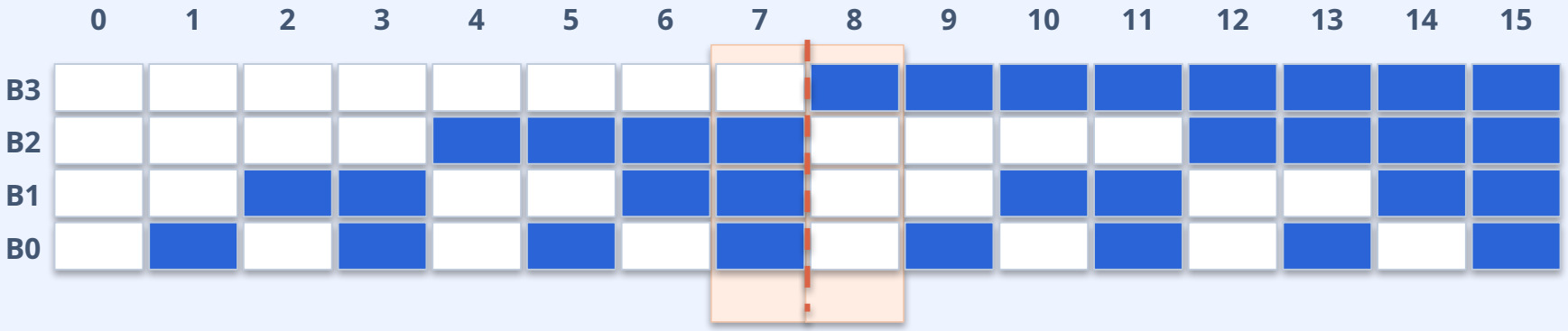
Absolute encoders: binary versus Gray code

BINARY CODE

0111 → 1000

4 bits change

Several tracks change at once.

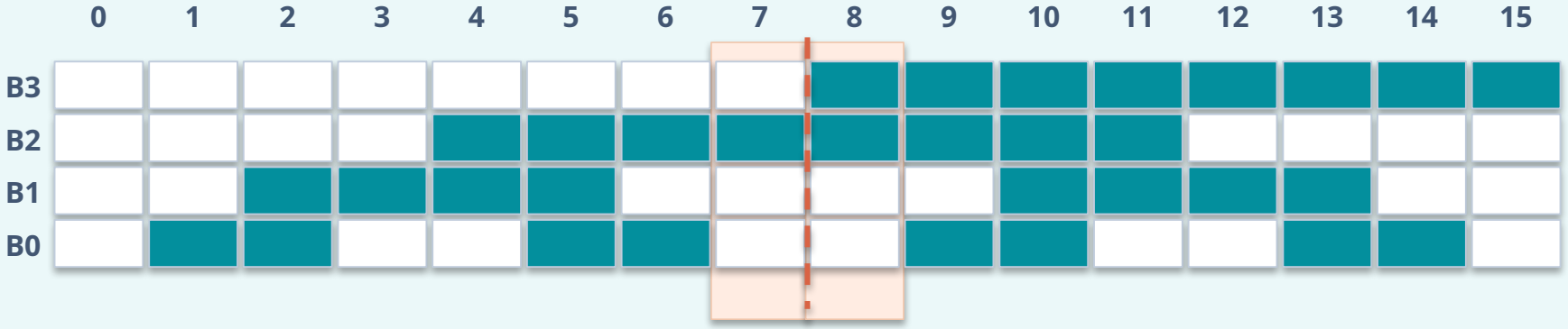


GRAY CODE

0100 → 1100

1 bit change

Only one track changes at the boundary.



Compare the change from position 7 to 8 · filled cells represent a binary 1.

Common methods for measuring distance and position

ULTRASONIC

Sound echo

Good across many colours.



LASER / OPTICAL

Light and optics

Precise for suitable surfaces.



LVDT

Magnetic coupling

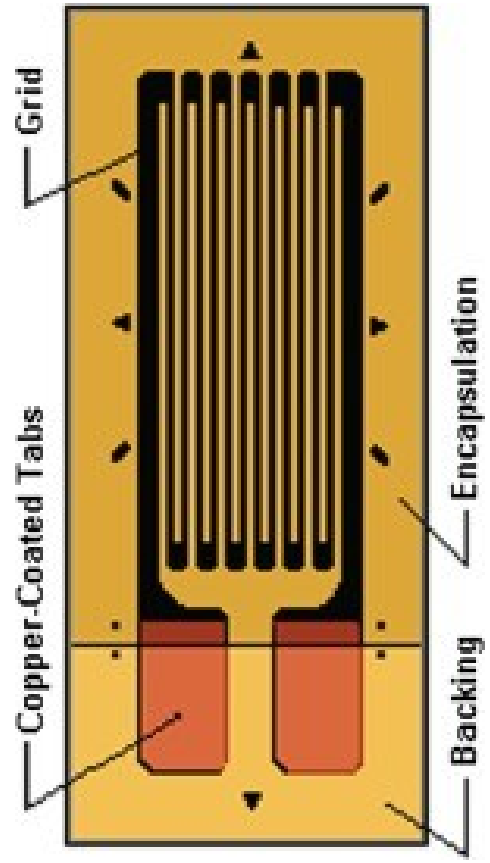
Short precision travel.



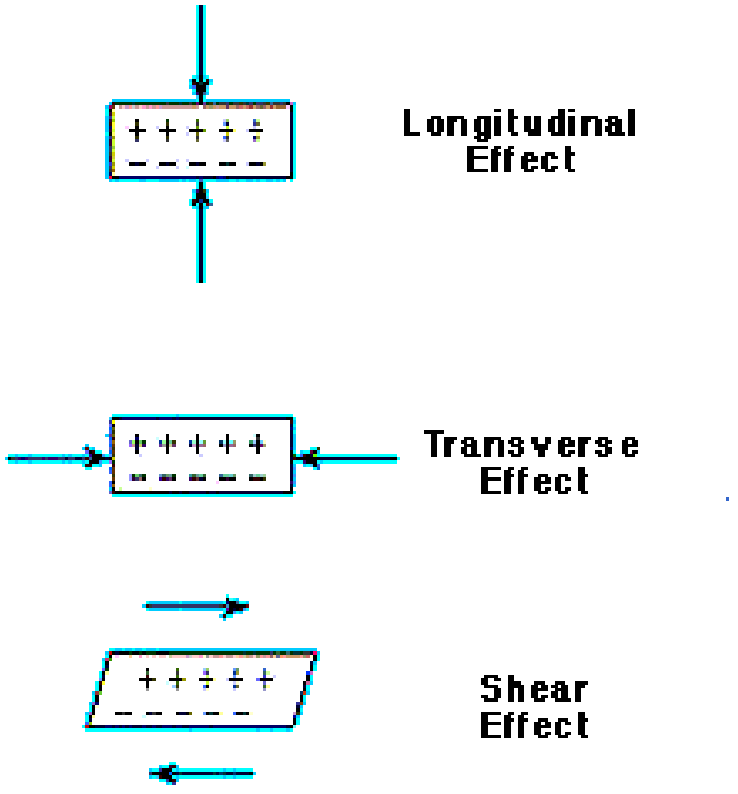
Force and weight: detect a tiny deformation

A load cell

- A loaded metal element flexes slightly.
- Strain gauges turn that into a small signal.
- An amplifier converts it to a useful reading.



Vibration sensing is about changes over time



Why measure it?

- Detect impacts and machine vibration.
- Spot unusual trends before a failure.
- A sensor value is only useful with context and a baseline.

Temperature: three common instruments, three jobs

Pt100 / RTD

Stable contact measurement.

Thermocouple

Wide range, including very hot processes.

Infrared sensor

Non-contact surface temperature.



Pt100: measuring temperature with a PLC

What the PLC programmer needs to know

- A Pt100 is a platinum RTD; its resistance increases with temperature.
- Use a compatible temperature input module, with the right units.
- Lead resistance and wiring affect accuracy; check for disconnected sensors.

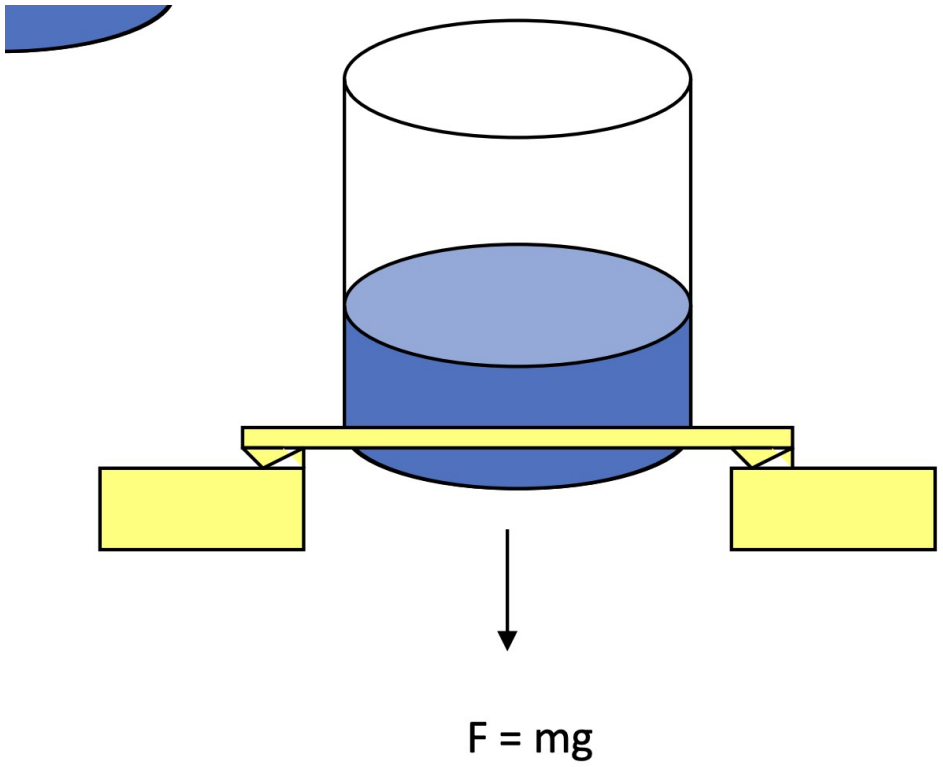
From sensor to PLC variable



The input module converts resistance into a temperature value.

Your program uses that value for control, alarms and monitoring.

Tank level: one variable, several sensor choices



Float switch

Low / high threshold

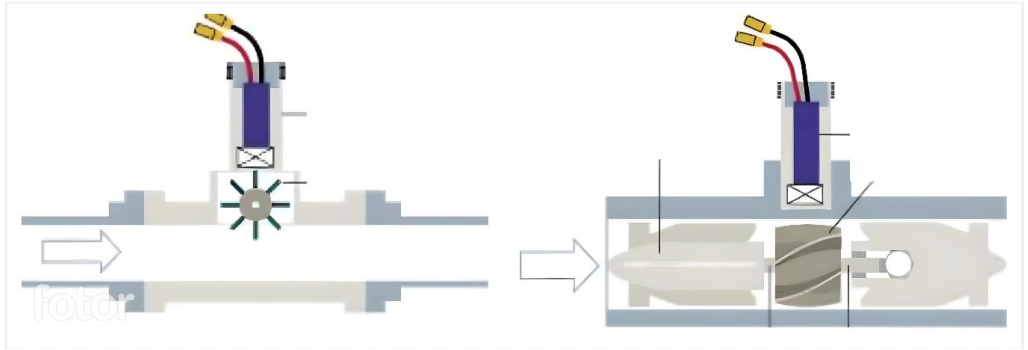
Ultrasonic / radar

Distance to surface

Load cell

Liquid mass / estimated level

Flow sensing: choose what the process needs



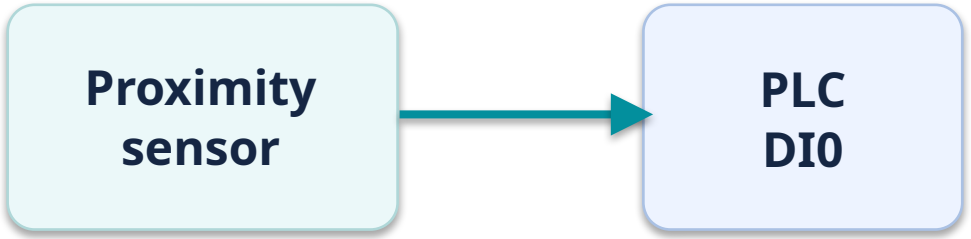
Three practical routes

- Turbine or paddle-wheel: count rotation.
- Thermal flow: detect heat carried away.
- Differential pressure: estimate flow across a restriction.

IO-Link: from a simple signal to useful sensor data

Ordinary 24 V sensor

One switching signal



TRUE / FALSE

Example: is a bottle present?

IO-Link sensor + master

Digital, two-way communication



Depending on the device, the PLC may receive:

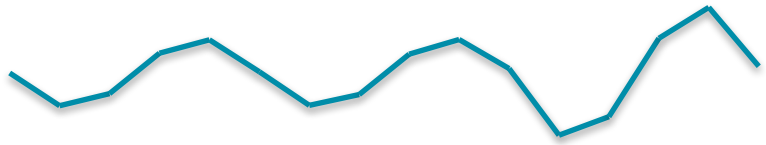
- Distance or switching value
- Device warnings / diagnostics
- Sensor settings and identification

A modern sensor can report values and faults. We revisit this in Industrial Communication.

Smarter sensing: monitor machines and inspect parts

Condition monitoring

Vibration + temperature trends can highlight unusual machine behavior.



Vibration trace

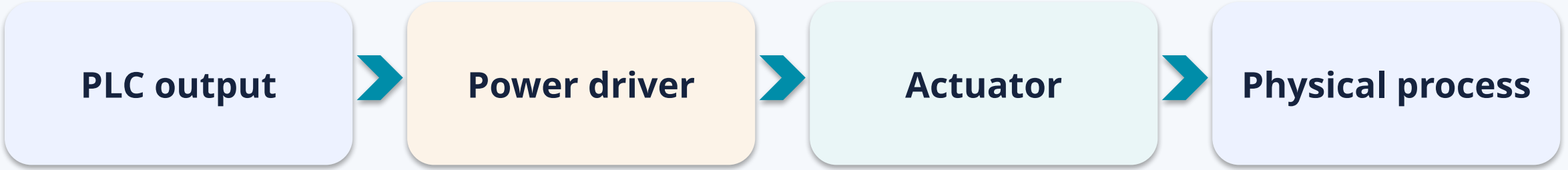
Edge vision

A camera and local processing can check labels, shape or missing pieces.



Detect missing part

Now make something move, heat, or switch



The PLC gives a command. Energy comes from a suitable power source.

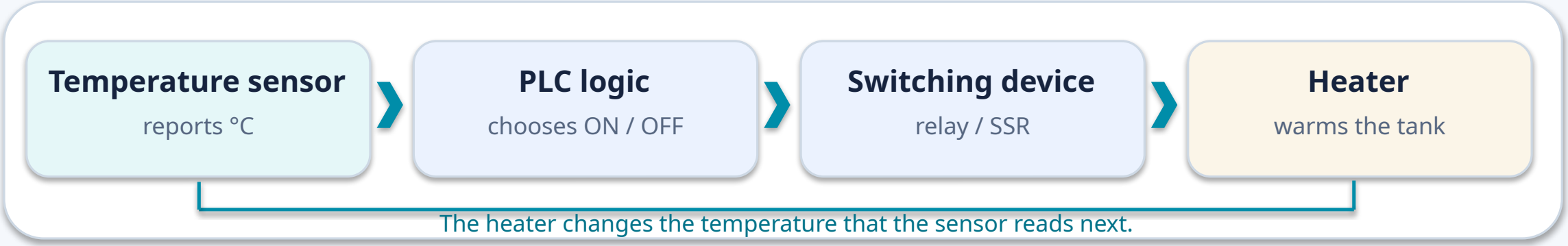
Relays and contactors switch larger loads



The software view

- PLC output energizes a coil (or driver).
- Contacts switch a separate power circuit.
- Check voltage, current, suppression and feedback.

A heater example: two thresholds prevent rapid switching



Example Structured Text

```
IF TempC <= 45.0 THEN
    HeaterOn := TRUE;
ELSIF TempC >= 50.0 THEN
    HeaterOn := FALSE;
END_IF;
```

What happens between 45 and 50°C?

The output keeps its previous value.

This is hysteresis: small changes near a threshold do not repeatedly switch the heater.

Independent overtemperature protection remains a separate safeguard.

A valve turns a PLC command into motion

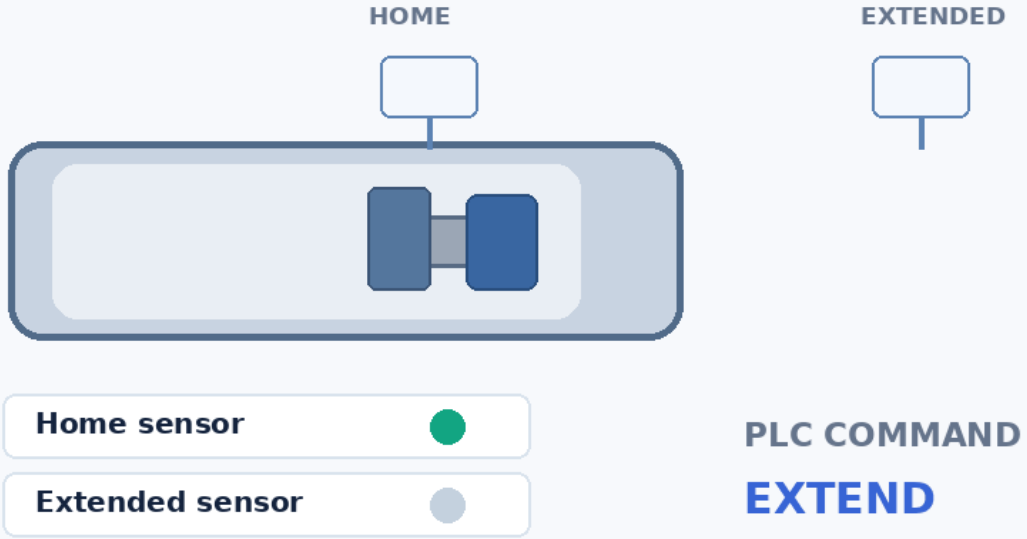


Pneumatic example

- PLC output energizes a solenoid.
- Valve changes the air path.
- Cylinder extends or retracts.

Watch: Festo actuator demos

A cylinder movement should have confirmation



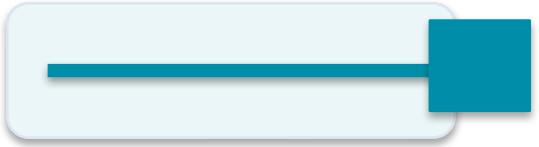
In PLC logic

- Command extend.
- Wait for end sensor.
- Timeout → stop / alarm.

Choose the right actuator for the movement

PNEUMATIC

Simple, fast linear moves.
Needs compressed air.



ELECTRIC

Good control of speed/position.
Needs a motor/drive.



HYDRAULIC

Very high force.
More demanding fluid system.



Three motor families worth recognizing

Induction motor

Robust continuous rotation.

Servo system

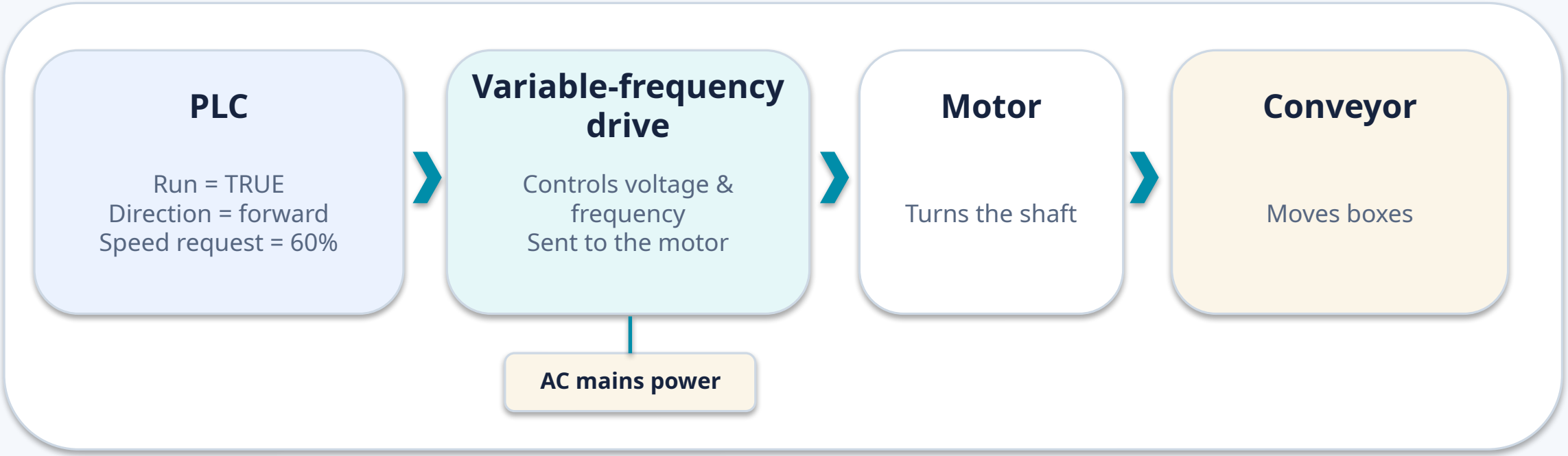
Position / speed with feedback.

Stepper motor

Commanded discrete steps; may lose steps.



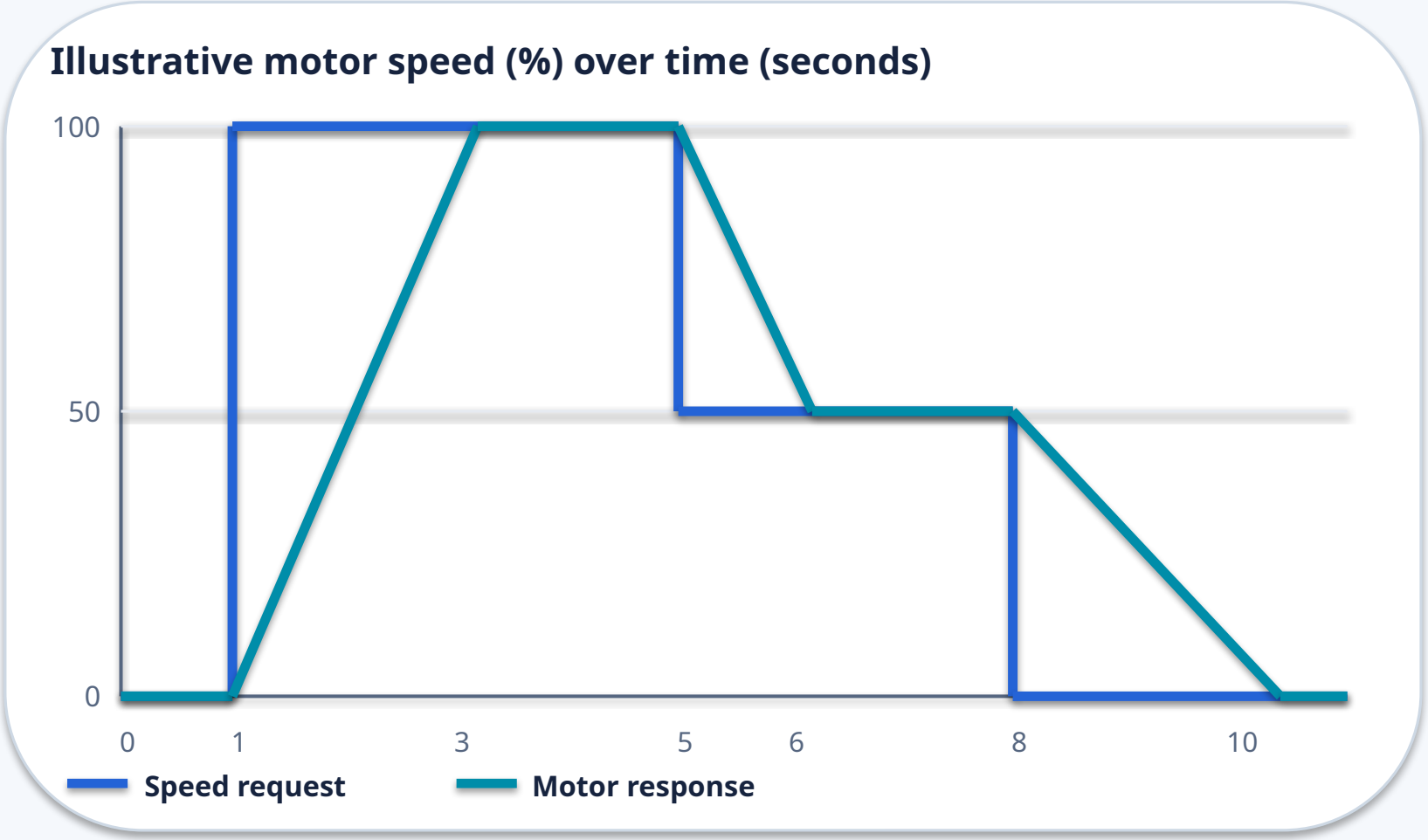
Conveyor speed: PLC command → motor drive → motion



Why do we need a motor drive?

A PLC output sends low-power commands; it cannot directly power an industrial AC motor.
The drive takes mains power and supplies adjustable voltage and frequency to control motor speed.

Speed command and actual movement are different



1 START at 1 s

PLC requests 100%; drive accelerates.

2 New target at 5 s

Requested speed becomes 50%.

3 STOP at 8 s

Drive ramps motor speed down to zero.

Ramp times depend on drive settings and load.

Process control and functional safety

Normal process control

- Sequence machine steps.
- Show alarms and status.
- Optimize operation.

Functional safety

- Reduce risk to people.
- Use appropriate safety devices.
- Validate stopping behavior.

Emergency-stop functions use suitable safety-rated components and a verified stopping design.

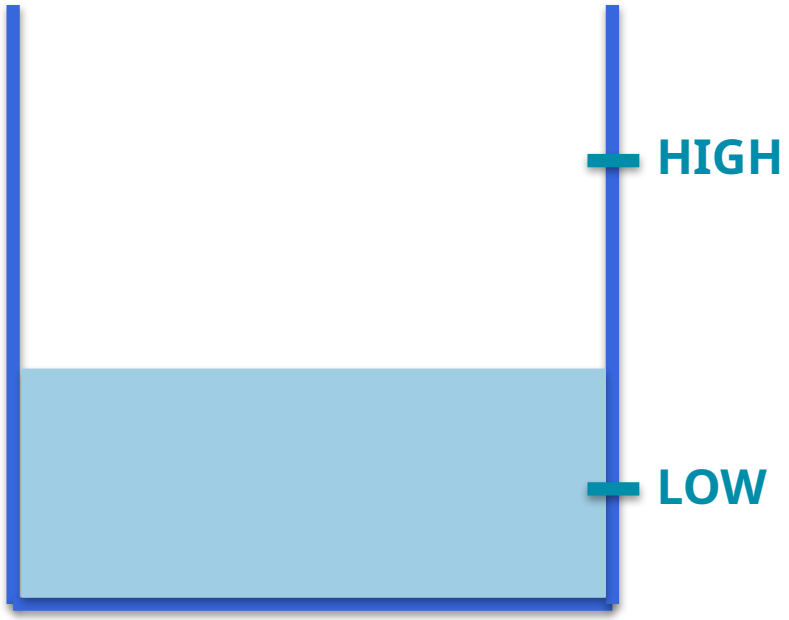
Worked example: detect and reject a bottle



PLC sequence

- Detect bottle.
- Wait for reject position.
- Extend cylinder.
- Confirm movement.

Worked example: a small tank with two level switches



Simple behavior

If LOW becomes FALSE: open inlet valve.

When HIGH becomes TRUE: close inlet valve.

Add timeouts and inconsistent-sensor alarms.

Three things to remember

OBSERVE A sensor has a meaning, timing and failure mode.

DECIDE PLC logic should check both commands and feedback.

ACT An actuator needs energy, limits and safe stopping.

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