جامعة الملك عبدالله للعلوم والتقنية
King Abdullah University of Science and Technology

أكاديمية كاوست
KAUST ACADEMY

Internet of Things (IoT)

DAY 2 Sensing the physical world, and acting on it

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KGSP Summer Enrichment Program 2026
KAUST Academy, KAUST

Salah Abdeljabar
salah.abdeljabar@kaust.edu.sa

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🗺️ On Today's Agenda

1. **Analog vs digital sensors**, and how the ADC bridges them
2. **Common sensors**: a tour of what we can measure
3. **Connecting them up**: I²C, SPI & UART
4. **Controlling actuators**: PWM & the DAC
5. **Common actuators**: a tour of what we can do

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Analog vs Digital Sensors 

...and how a digital device reads an analog world

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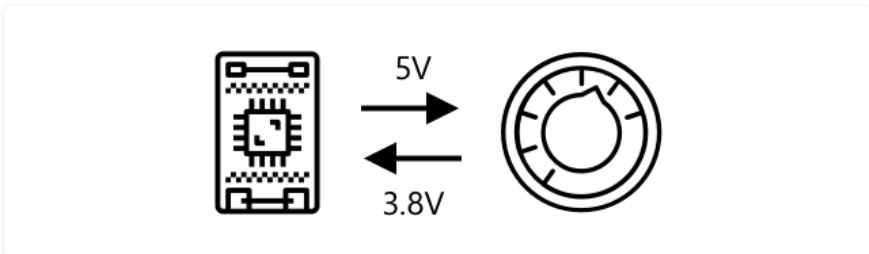
Analog Sensors

An **analog** sensor returns a **variable voltage** that maps to what it measures.

- A **potentiometer**: 5 V in → 0–5 V out as the dial turns
- A thermistor's voltage → converted to °C in code
- The value can be **anything** in a range



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The ADC: Analog → Digital

IoT devices are **digital**: they only understand 0s and 1s. An **analog-to-digital converter (ADC)** turns a voltage into a number.

- A light sensor at 3.3 V outputs **1 V** → ADC value **300**
- Resolution sets the range (e.g. **10-bit** = 0–1023)
- Built into the device, or on a connector **HAT**

Libraries hide the math

Arduino: `analogRead(pin)` → **300** · Python: the `light` property → **300**

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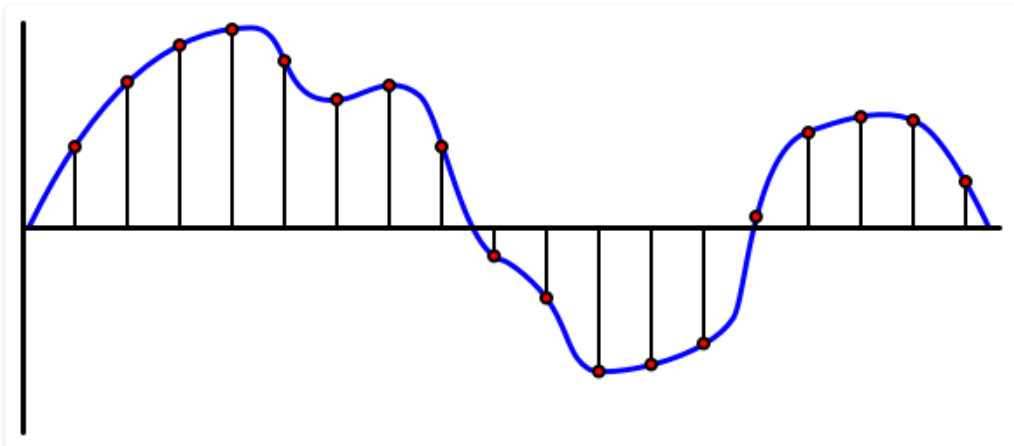
Sampling: Snapshots of a Continuous World

The ADC can’t capture every instant, so it **samples**: reading the voltage at a fixed rate and keeping the dots, not the curve.

- **Sample rate** = readings per second
- Sample **too slowly** and you miss what happened in between
- Sample **faster** and you get a truer signal, at the cost of power, memory, and bandwidth



A few readings a minute is plenty for soil moisture. Audio needs thousands per second.

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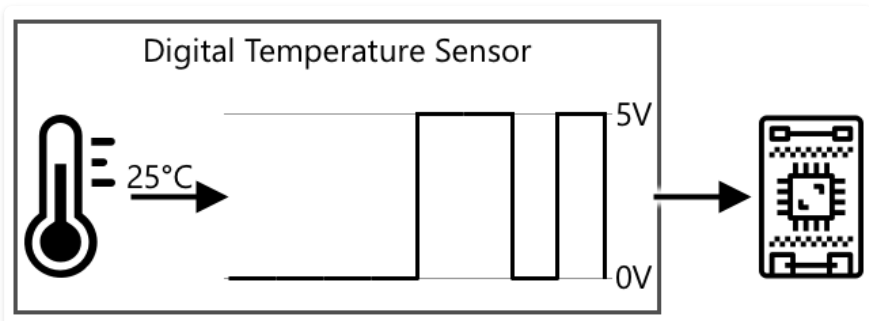
Digital Sensors

A **digital** sensor sends its signal as 0s and 1s directly: no external ADC needed.

- Simplest: a **button**, 3.3 V = **1**, 0 V = **0**
- Complex ones have a **built-in ADC** and send serialized data
- Enables richer, even **encrypted** data (e.g. a camera)



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Common Sensors 🔎

A tour of what IoT devices can measure

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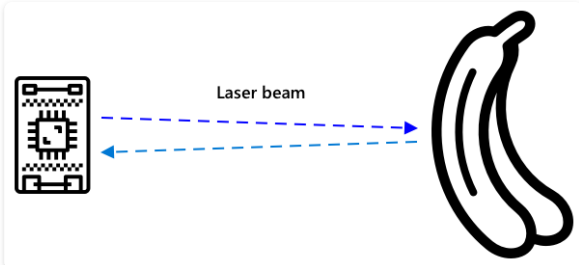
The Sensor Catalog

- 🌡️ **Temperature**: air or immersion (often + pressure & humidity)
- 🔘 **Button / switch**: pressed or not
- 💡 **Light**: visible, UV, or IR
- 📷 **Camera**: photo or video
- 📈 **Accelerometer**: movement in 3 axes
- 🎤 **Microphone**: sound level or direction
- 📡 **Proximity**: distance to an object

Every sensor converts something physical into an electrical signal.



Think

What sensors does your **phone** have?

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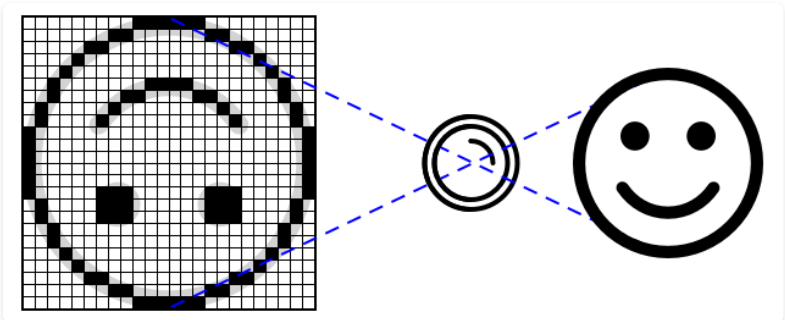
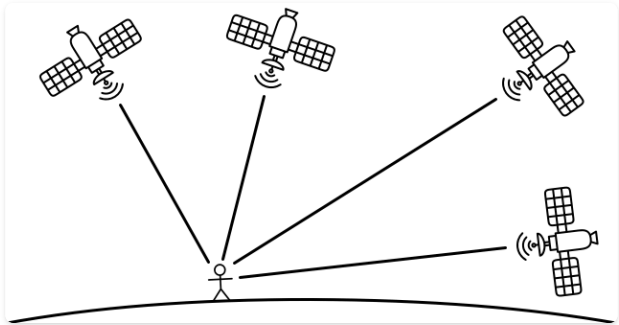
Inside Two of Them





📷 **Camera**: a lens focuses light onto a grid of pixels, and each pixel reports how much light it caught. The image is just a big array of numbers.

🛰️ **GPS**: the receiver never transmits. It listens to several satellites and works out where it is from how long each signal took to arrive.

> ⓘ **Note**
>
> Both are **digital** sensors: too much data to send as a single voltage, so they do the conversion on board.

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How Sensors Talk to the Board 🔌

The buses behind every digital sensor

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Three Ways to Wire a Peripheral

A digital sensor or actuator sends 0s and 1s, but *over what*? Nearly every board uses one of three buses.

I²C	SPI	UART
Two wires, **many** devices, each with an address. Slower, but cheap on pins.	Faster, **full duplex**, one extra select wire per device.	Two devices, **no clock**: both sides just agree on a speed.

> **Tip**
>
> You rarely wire these by hand: a library exposes `read()` and hides the bus. But knowing which bus a sensor uses tells you how many you can connect.

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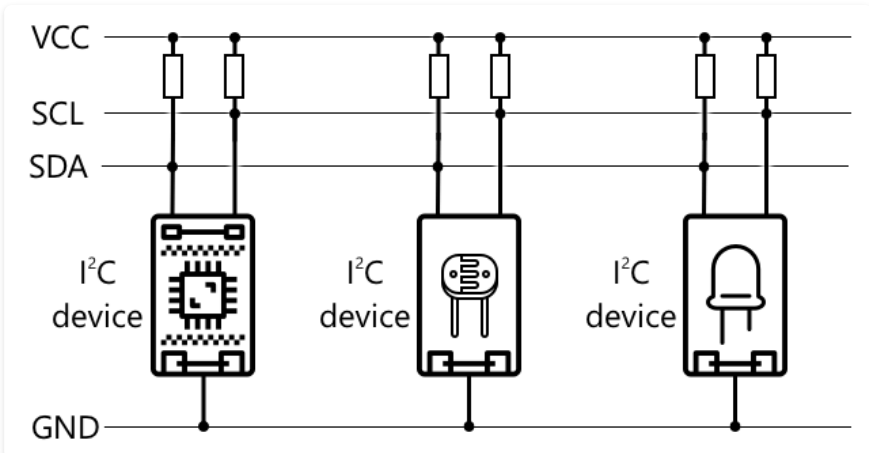
I²C: One Bus, Many Devices

Inter-Integrated Circuit shares just two lines across every device:

- **SDA** carries the data, **SCL** the clock
- Each device has an **address**, so the controller can name who it wants
- Add sensors without adding pins
- Typical of temperature, humidity, and light sensors



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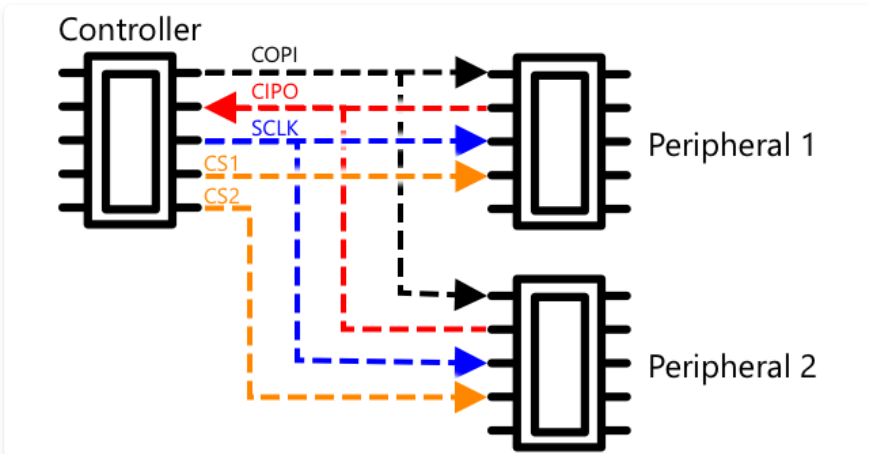
SPI: Fast and Full Duplex

Serial Peripheral Interface trades pins for speed:

- **COPI** and **CIPO** send in both directions at once
- **SCLK** keeps both sides in step
- A **chip select** line per peripheral picks who is listening
- Good for displays, SD cards, and cameras



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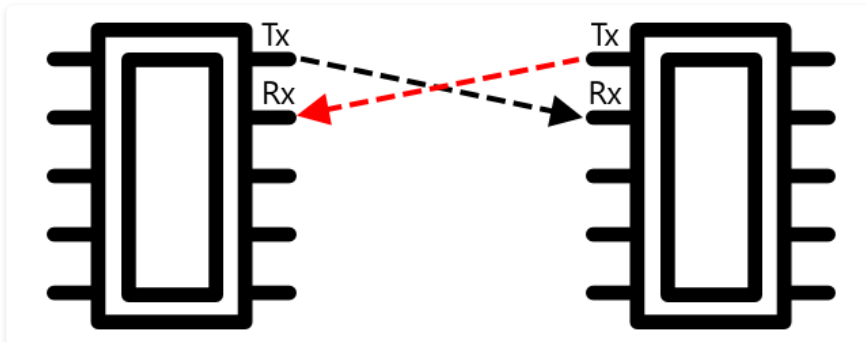
UART: A Direct Conversation

Universal Asynchronous Receiver-Transmitter connects exactly two devices:

- **Tx** on one side wires to **Rx** on the other, and back again
- **Asynchronous**: no clock line, so both must agree on a **baud rate**
- The serial monitor on your laptop is a UART
- Common for GPS and radio modules



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Controlling Actuators 🎛️

Analog voltages, PWM, and simple on/off

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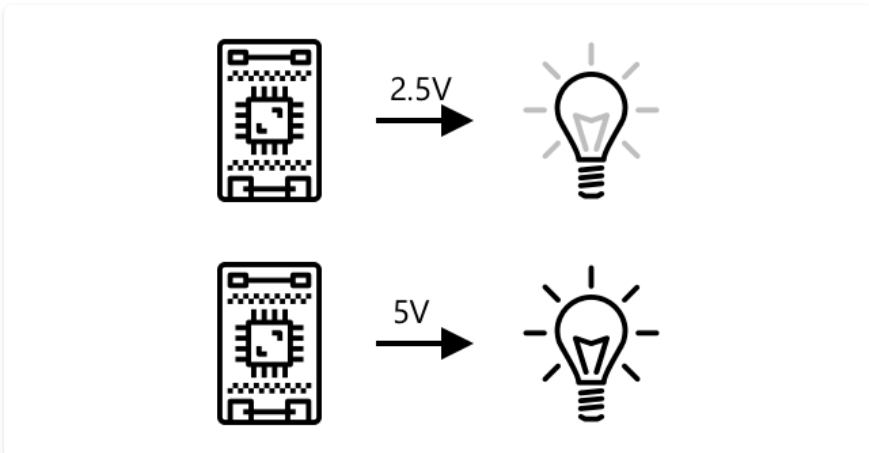
Analog Actuators & the DAC

An **analog** actuator responds to the **voltage** supplied, like a **dimmable light**.

- The device is digital, so it needs a **DAC** (digital-to-analog converter)
- The DAC turns 0s and 1s into a real voltage the actuator can use



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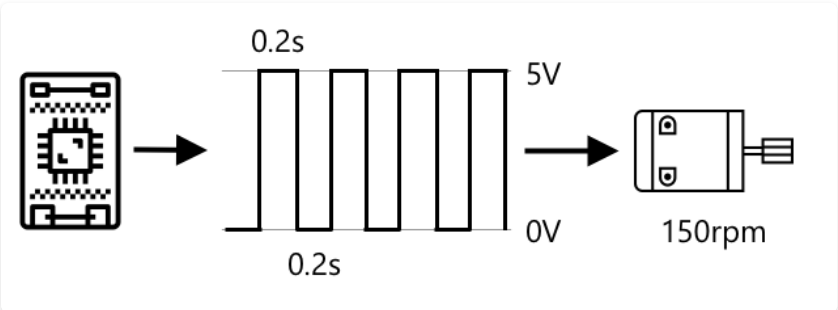
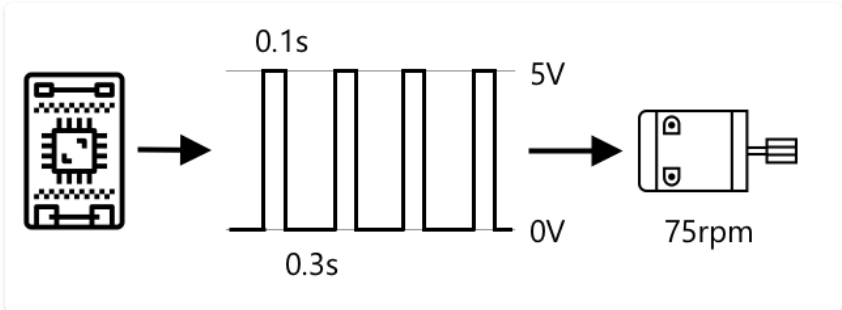
PWM: Faking Analog with Digital

Pulse-Width Modulation sends rapid on/off pulses. The **duty cycle** (the % of time it's on) sets the effective power.



50% duty → motor at **150 RPM**



25% duty → motor at **75 RPM**

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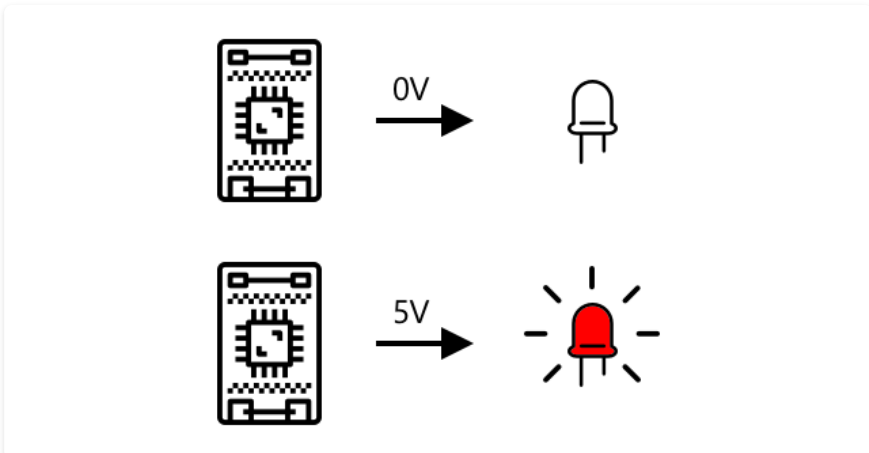
Digital Actuators

The simplest actuators have just **two states**: on or off.

- An **LED**: 0 V = off, 5 V = on
- A **relay**: a small voltage switches a larger circuit
- Complex ones (screens) need **libraries**

```
digitalWrite(LED_PIN, HIGH); // on
digitalWrite(LED_PIN, LOW);  // off
```



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Common Actuators 🔧

A tour of how IoT devices affect the world

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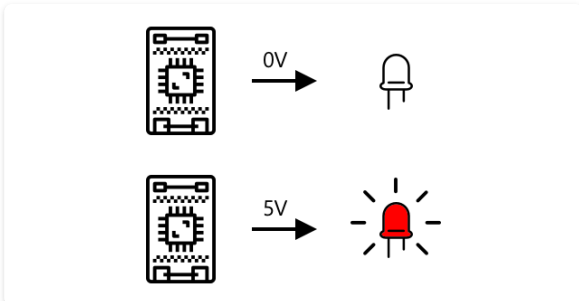
The Actuator Catalog

- 💡 **LED**: emit light
- 🔊 **Speaker / buzzer**: sound, from beeps to music
- ⚙️ **Stepper motor**: precise, defined rotation
- 🔀 **Relay**: a small signal switches a big circuit
- 🖥️ **Screen**: from simple segments to HD video

Actuators are the output half of IoT, turning signals into action.



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