IoT and Sensors

The Internet, Things;
touching you, touching me.

Welcome!

Your Instructor: Ryan (Ryan cosplays as a hardware engineer). Slides are not his strong point.

What is happening: This is a IoT quickstart course (with a focus on hardware/code *with extra sauce*).

Goal: ~understand the hardware building blocks so you can DIY a solution vs paying $$$$ for a proprietary thing that loses support in 3 years.

Is there lunch? Yes

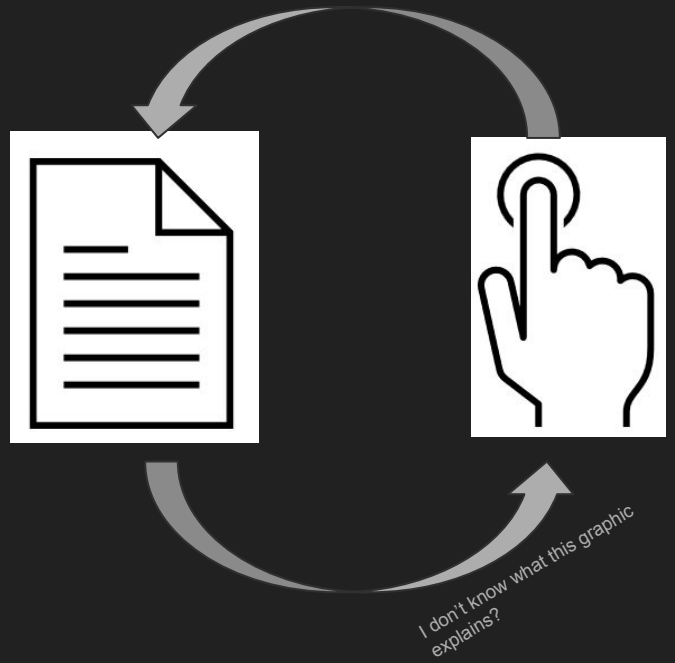
Building FAQs: Coffee/ bathroom locations.

Why are you here? *warning! possible ice breaker.*

Ask questions any time! *Dumb questions are encouraged.*

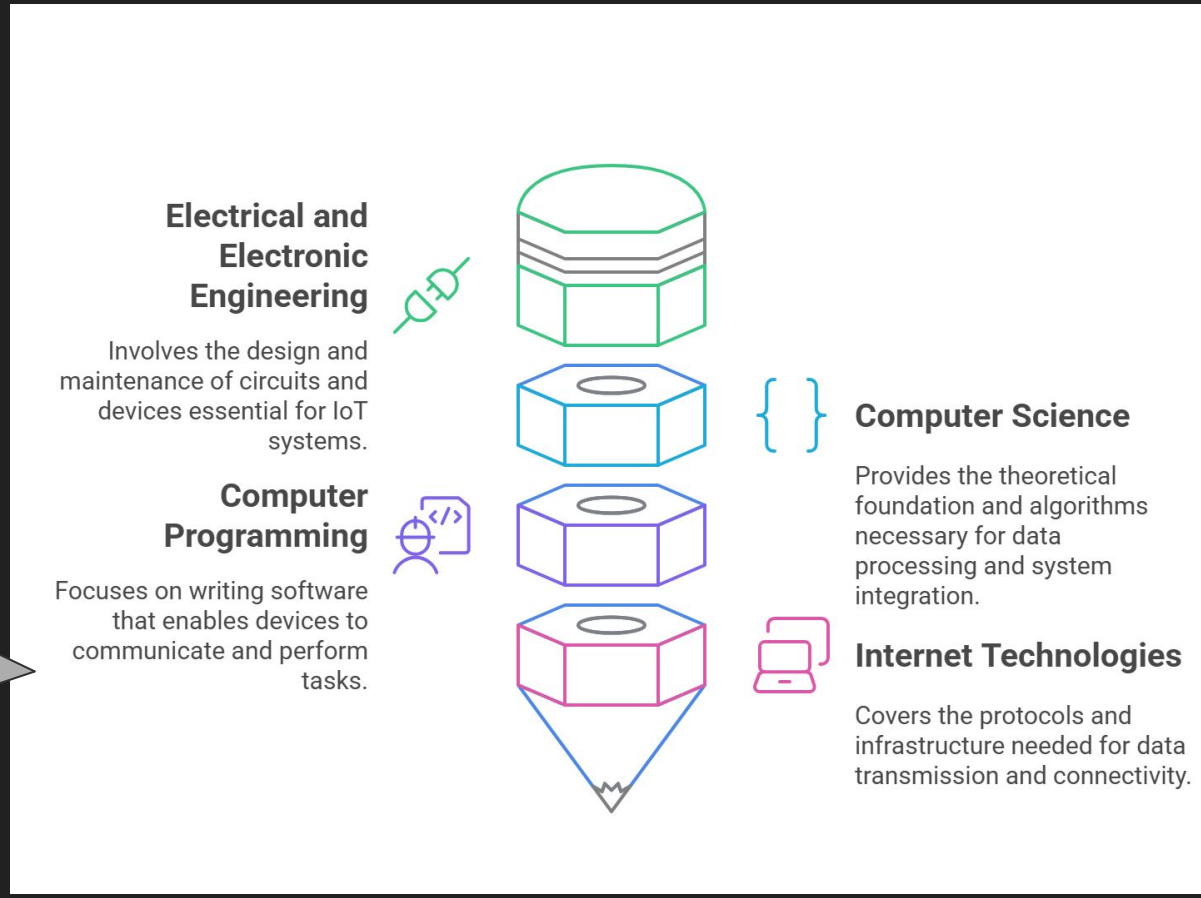
[Learning] Road Map for Today:

1: What is IoT?
2: Exploring IoT Hardware
3: IoT Hardware and Sensor Integration
4: IoT Communication with MQTT
5: IoT Network Layer
6: Applications of IoT
7: Sensors in Manufacturing Automation
8: open-ended code funtime ?



[Skill] Road Map

Some topics might seem confusing. That's ok!

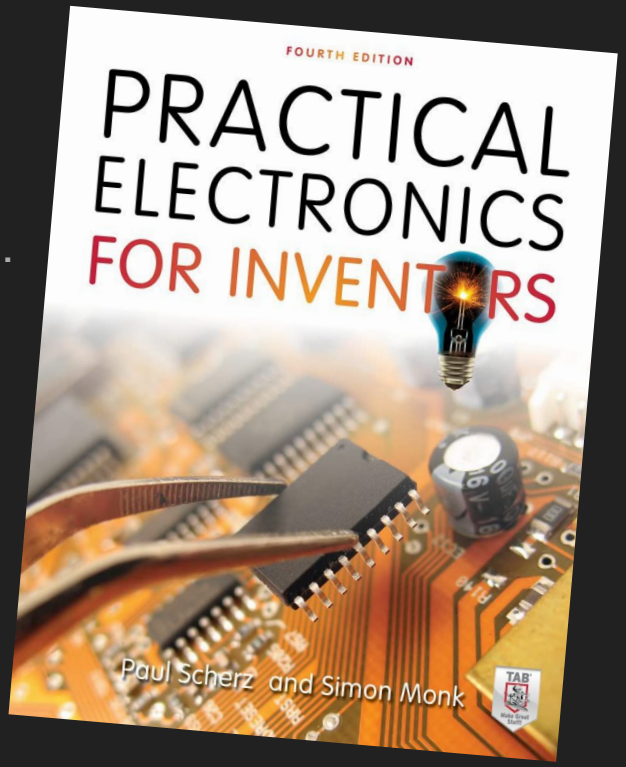


[Skill] Road Map

… just the knowledge you need
to push forward through this course's topics.

Useful knowledge comes from experience.
You have to build stuff.

Relax. Have fun, be curious.



IoT Goals

Understand the benefits.

Grasp some technical fundamentals of:

- Computer Science: Memory, Processing,
- IT: Networking basics *(relax, nothing obscure)*
- Hardware: Microcontrollers, SoC, Sensors
- Software: C/C++, Arduino IDE
- ChatGPT: it writes and explains code for you.
- MQTT: Publisher Subscriber Model

Play with hardware: Monitor Temperature over WiFi, toggle a relay.

Internet of Things

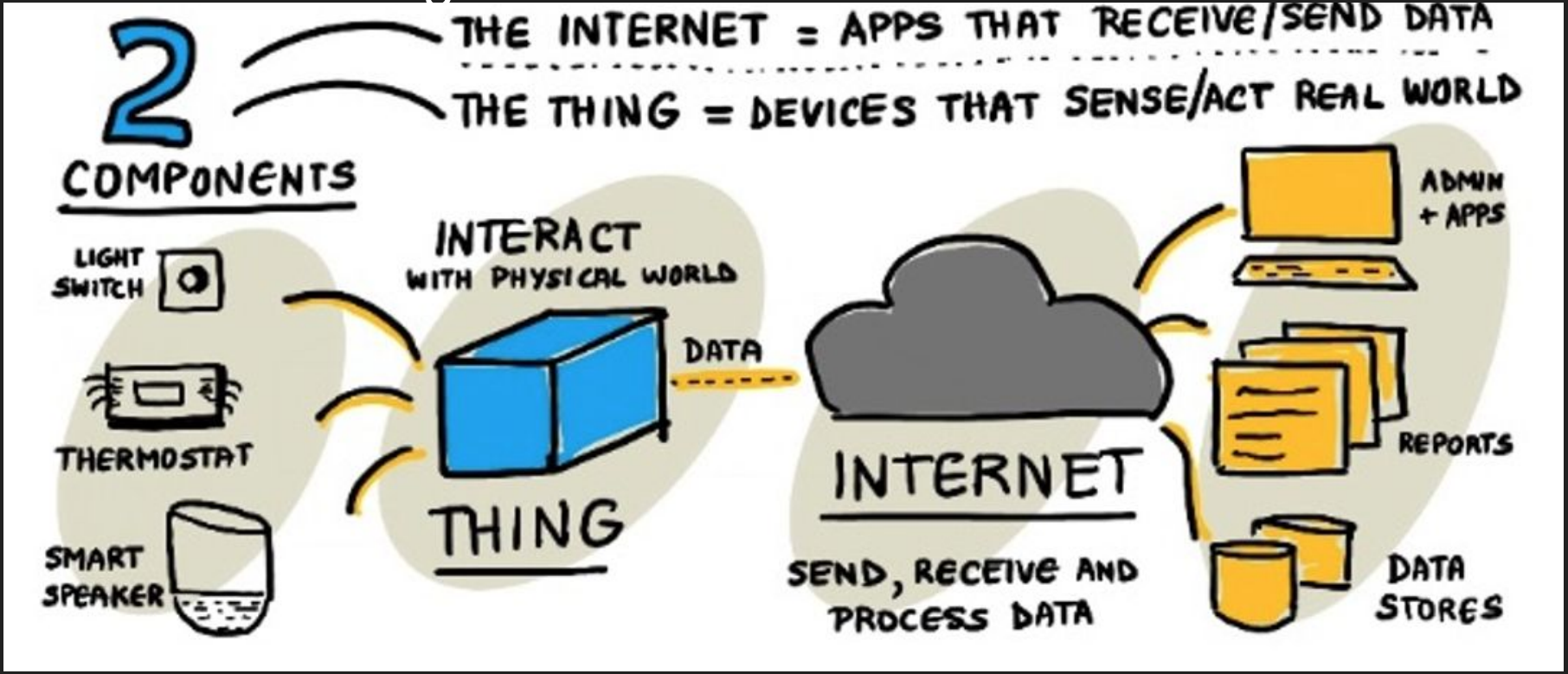
Definition, Scope, Importance.

The term 'Internet of Things' was coined by Kevin Ashton in 1999, to refer to connecting the Internet to the physical world via sensors.

Connect the physical world to the internet using sensors.

Since then, the term has been used to describe any device that interacts with the physical world around it, either by gathering data from sensors, or providing real-world interactions via actuators (devices that turn on a switch or light an LED), generally connected to other devices or the Internet.

Internet of Things

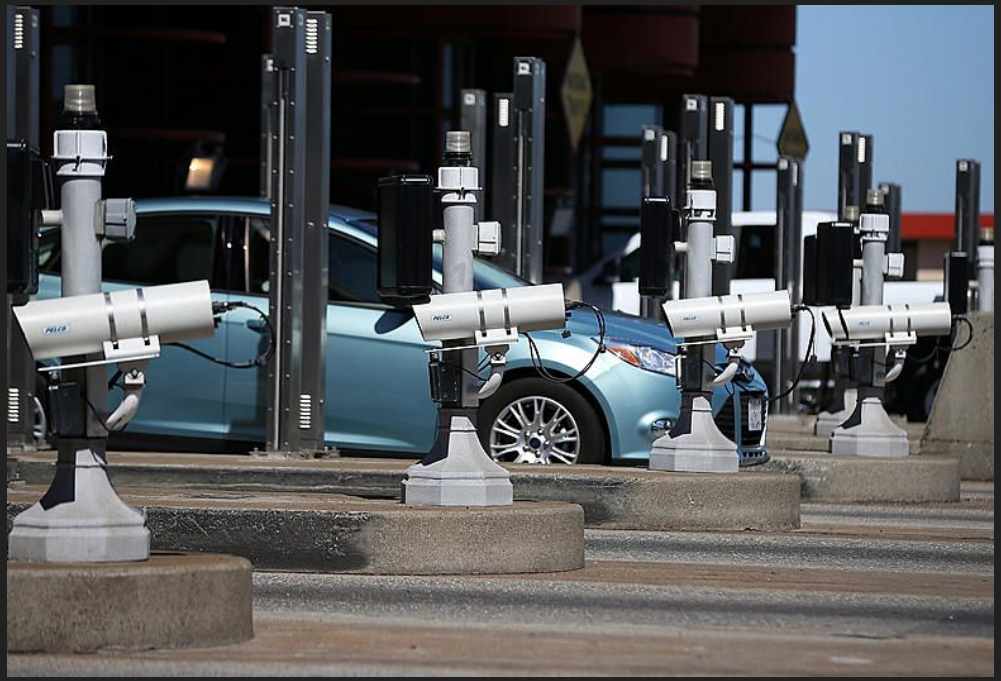


https://github.com/microsoft/IoT-For-Beginners/blob/main/sketchnotes/lesson-2.jpg

Internet of Things

Definition, Scope, Importance.

Examples!



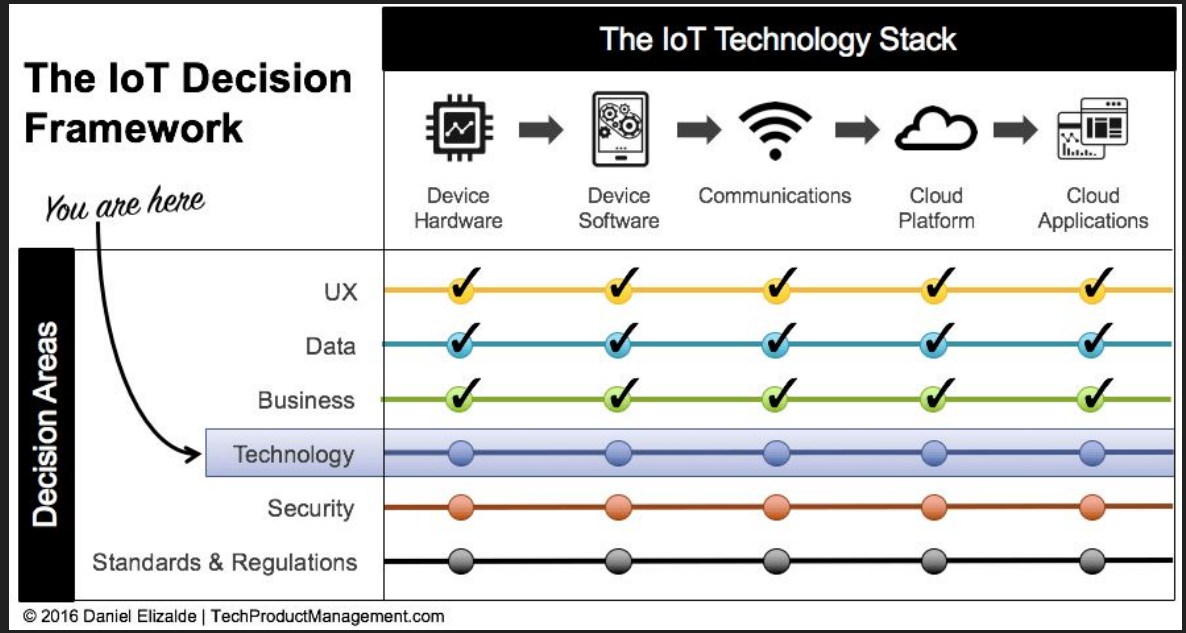
Internet of Things

Scope, Importance.

CONNECT ☑

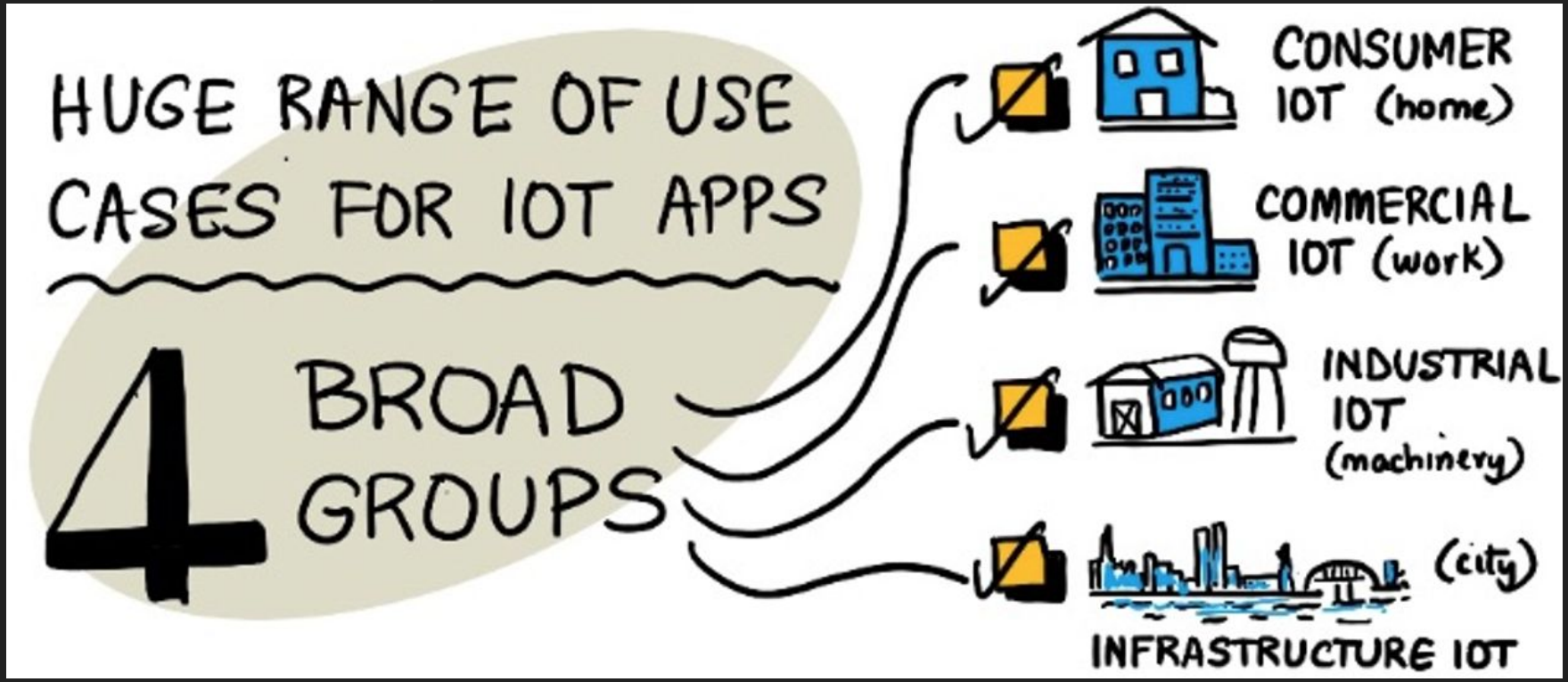
GATHER DATA ☑

INTERACT ☑



https://danielelizalde.com/iot-hw-blocks/

Internet of Things



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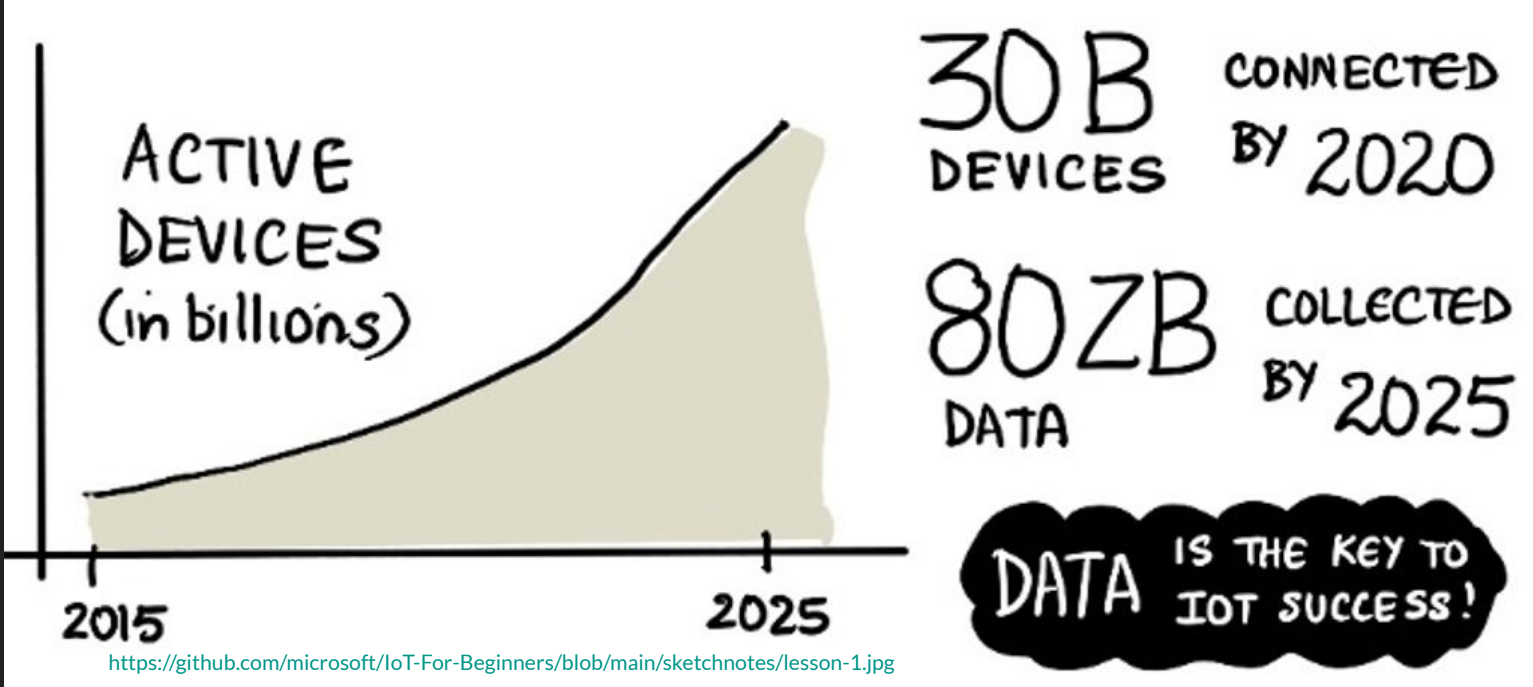
Internet of Things

Definition, **Scope**, Importance.



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Internet of Things

Definition, Scope, **Importance**.

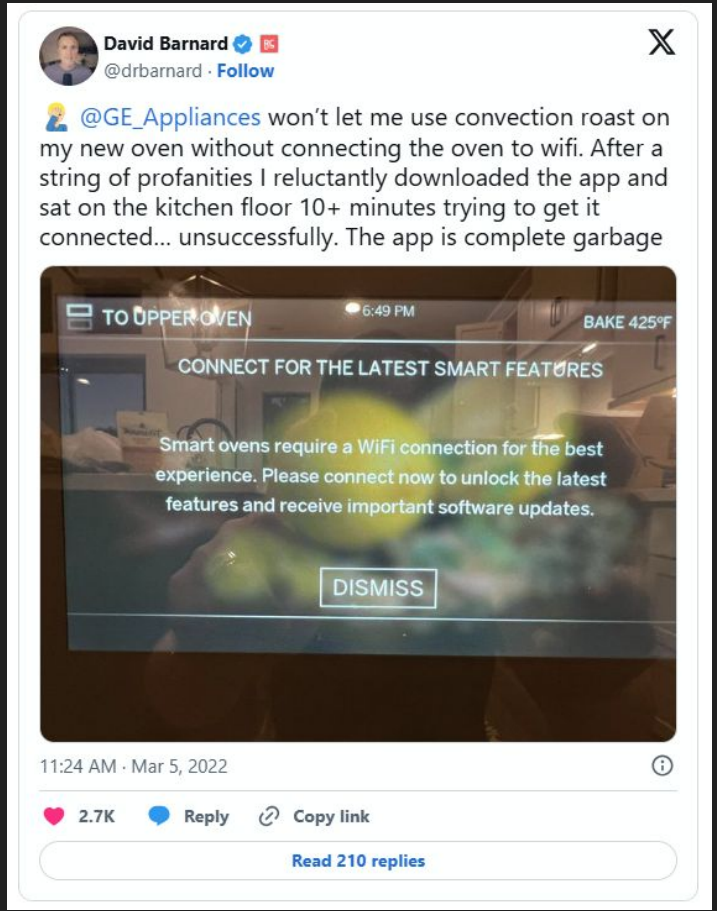
1. Enhanced Efficiency and Automation
2. Improved Data Collection and Insights (Real-Time Decision Making)
3. Cost Savings
4. Better Health and Safety
5. Enhanced Connectivity and Convenience

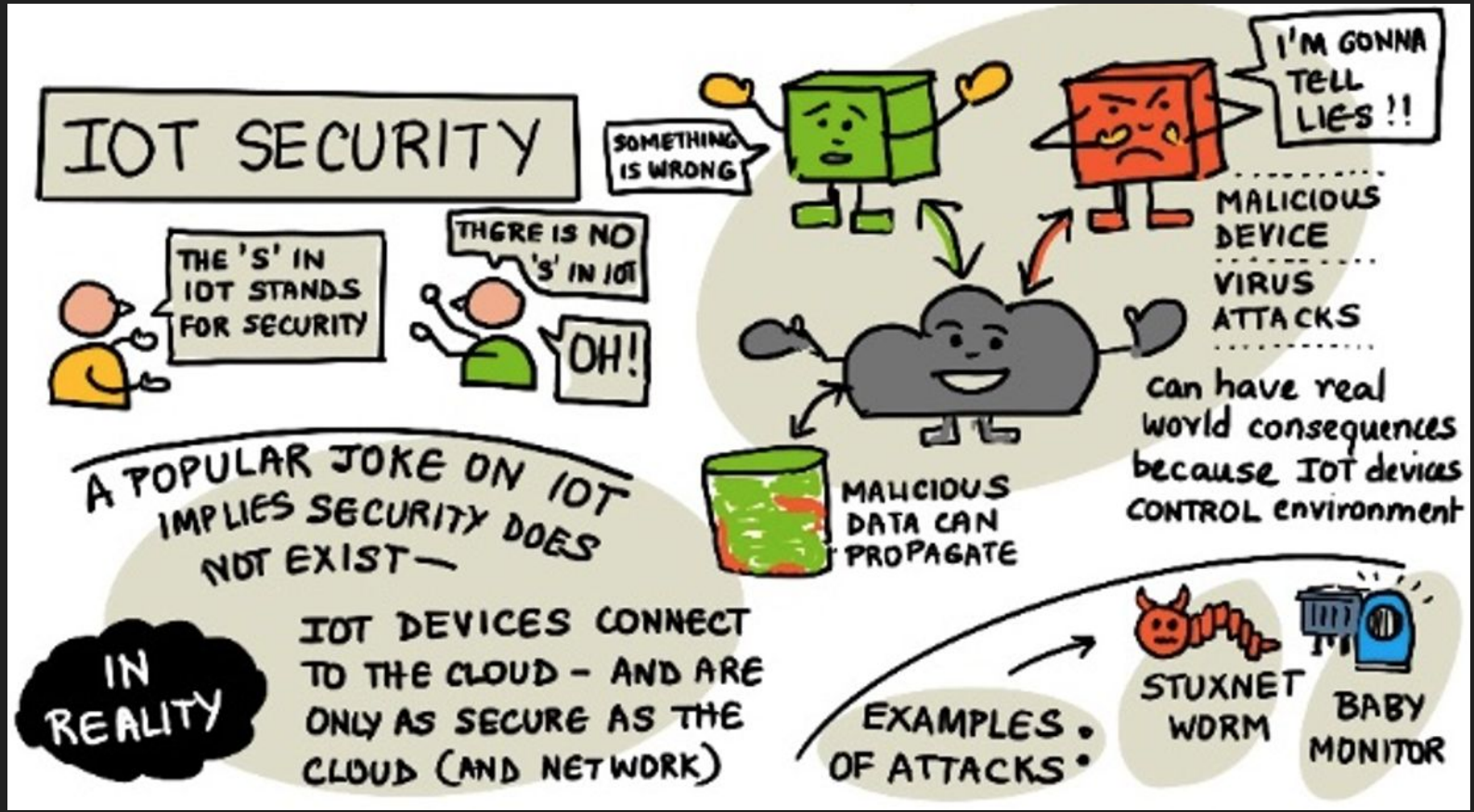
PRO TIPs:

WHATEVER DATA YOU COLLECT, IS IT USEFUL?
BE COST CONSCIOUS ON SCALABILITY

Sh*ternet of Things

Practicality… Usefulness…
Should we? vs. *Could we?*





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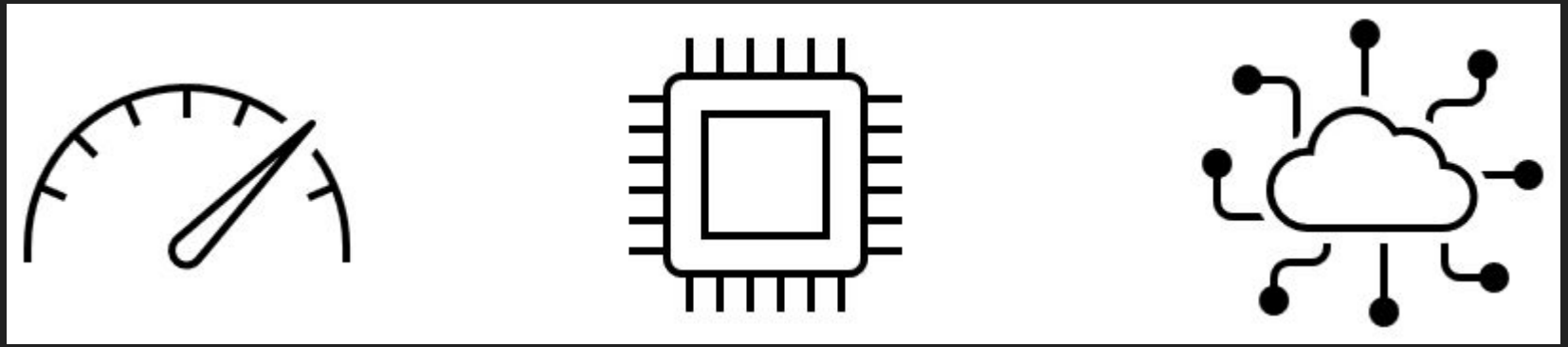
IoT Hardware

Sensors.



68F

Things.

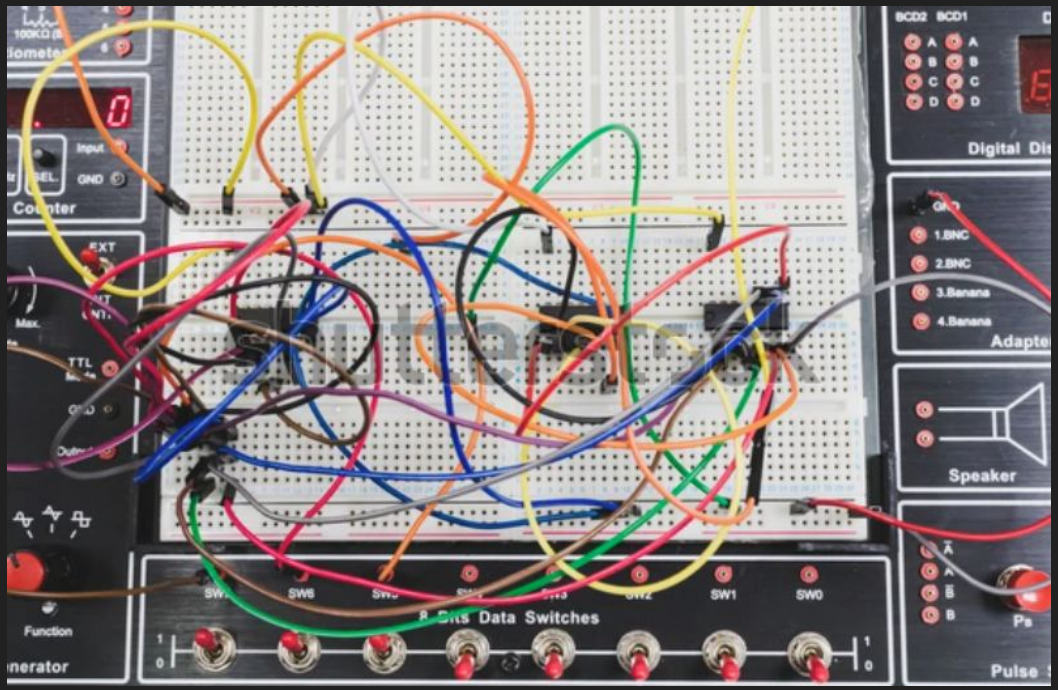
Publish: “Room is 68”

Internet.

Notice Room under temp.
Action: Heater = ON.

IoT Hardware (custom?)

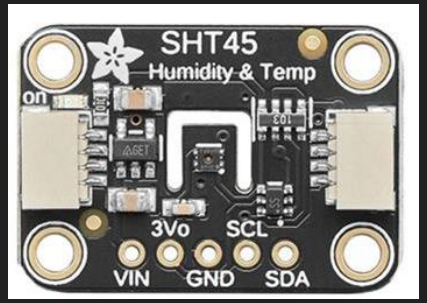
Hardware is easy?
But in the classroom,
simple/reliable wins.

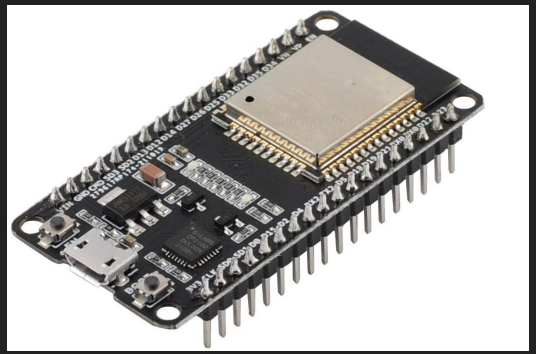


IoT Hardware (what we are using)

Sense the physical world.
Record Data, Action

Handle Data, publish to Internet.



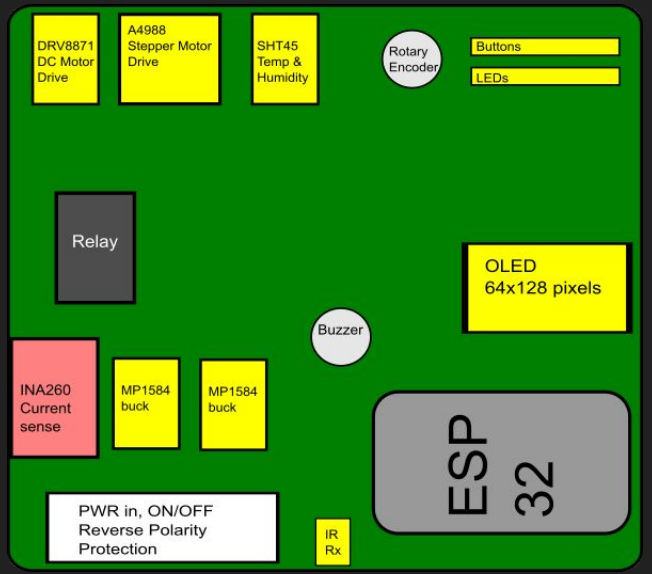


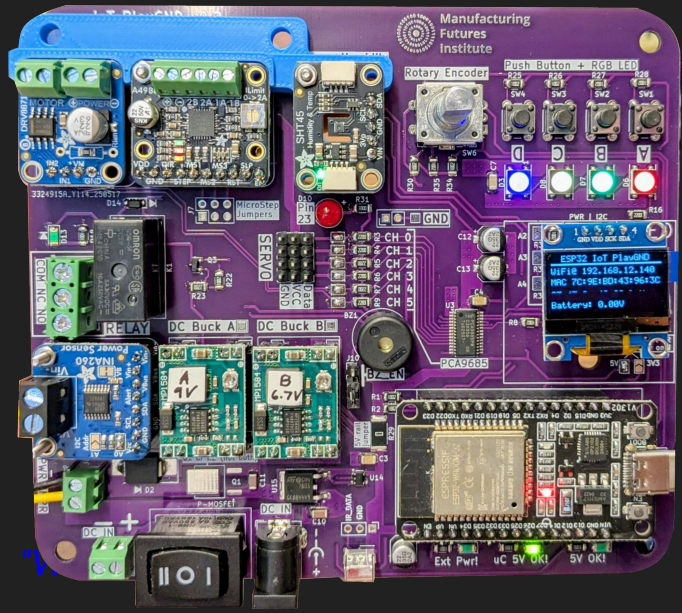
68F

Publish: [“Room is 68”]

Notice Room under Temp.
Action: Heater = ON.

IoT Hardware (custom)

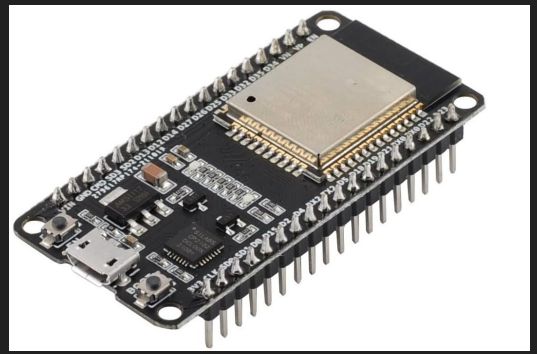




IoT Devices: Development Kit/ Hardware

Microcontrollers
Computers

Single-board



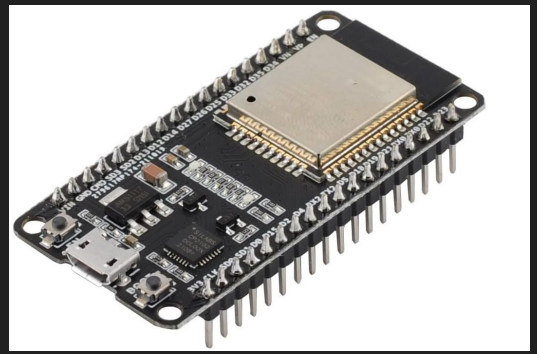
ESP32

Microcontroller
Vs
Microprocessor

Raspberry Pi 5

IoT Devices: Development Kit/ Hardware

Microcontrollers



ESP32

+ cheap! ($)
+ small
+ low power
+ light framework (no OS required)
+ rugged
+ c/c++, python are most common frameworks

- limited processing ability
- one-at-a-time instruction limitation
- slower than CPUs
- limited memory
- hardware interfacing has its challenges
- requires Integrated Development Environment (IDE)

IoT Devices: Development Kit/ Hardware

Single-board Computers

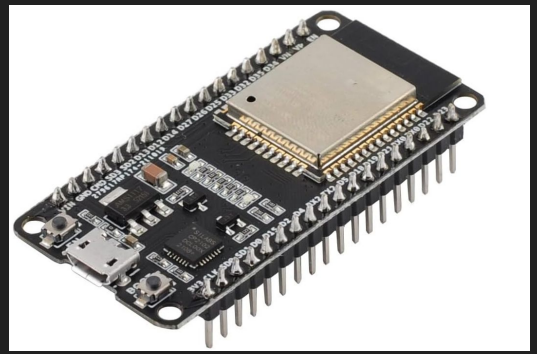
+ needs more power
+ OS (linux environment or run headless- no OS)
+ python typical for linux systems
+ supports remote connections
+ many ports/ connections!

- thermal considerations
- one wrong connection and x_x
- features you might not need
- not as cheap ($$)
- supply chain limitations

Raspberry Pi 5

IoT Devices: Development Kit/ Hardware

Microcontrollers



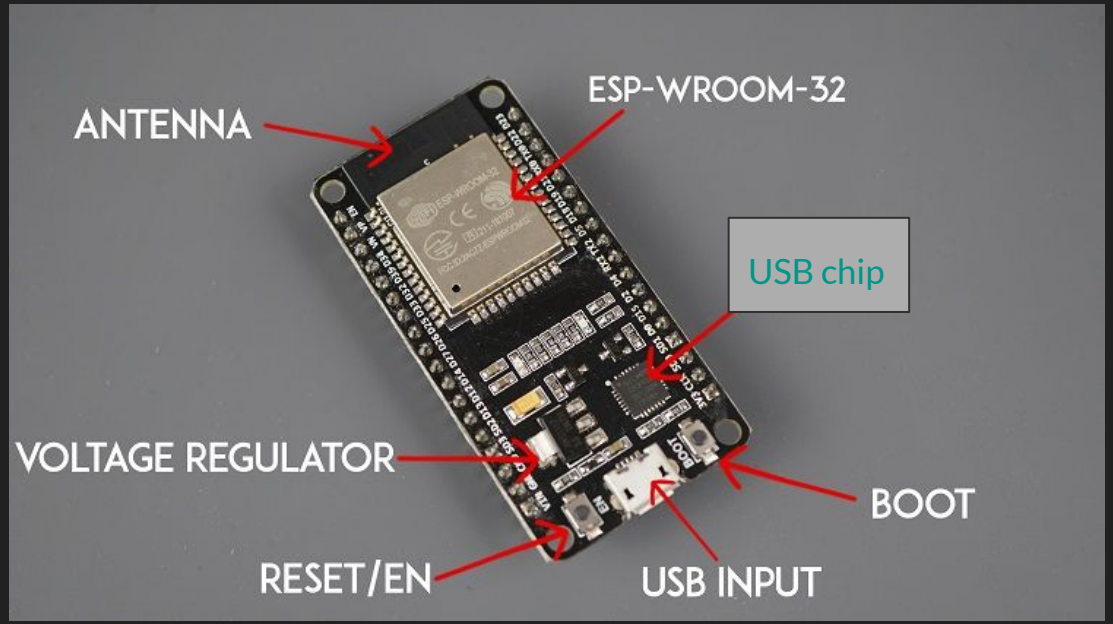
ESP32

Our focus = **microcontroller development kits**.

+ simplicity
+ affordability
+ support
+ practical for our simple example

Cost effective and versatile

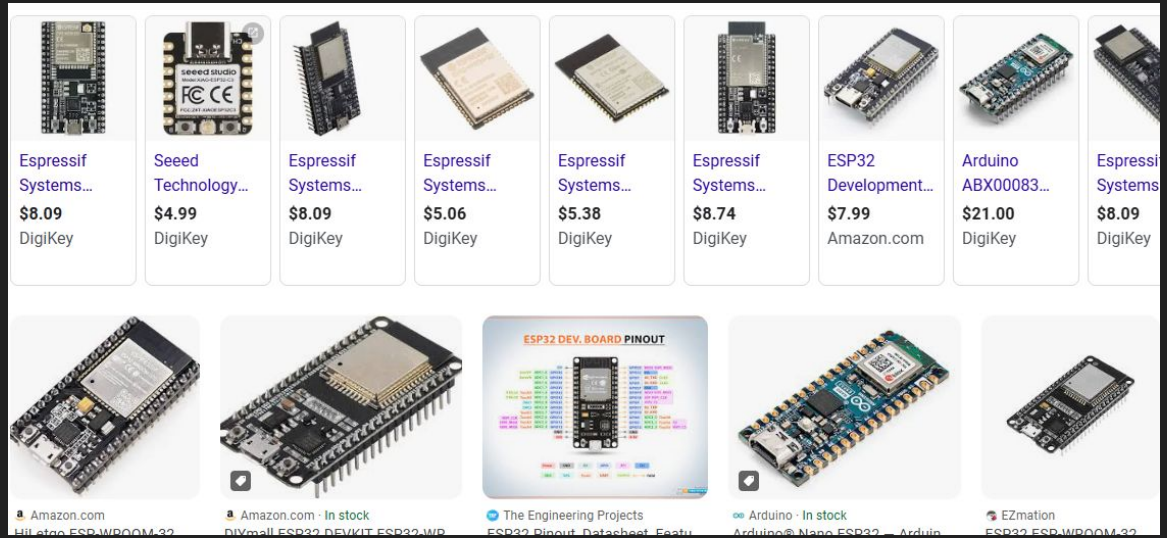
ESP32 Hardware Detail ($5 Wi-Fi Microcontroller)



ESP32 Hardware Detail ($5 Wi-Fi Microcontroller)

THERE ARE LOTS OF ESP32 VARIANTS.

Not all pinouts (GPIO) order are similar.

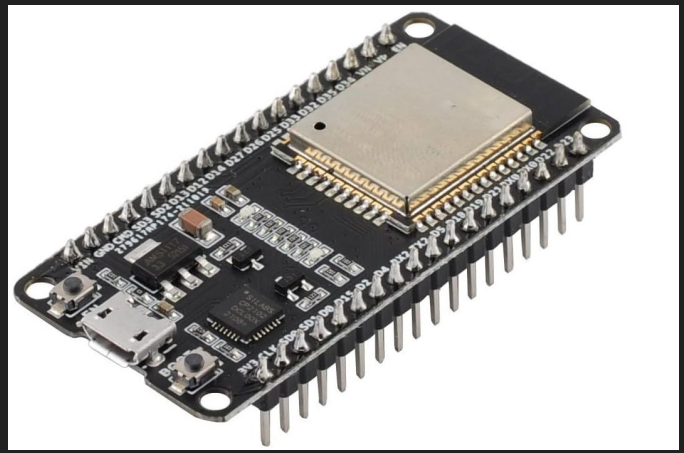


IoT Devices: Development Kit/ Hardware

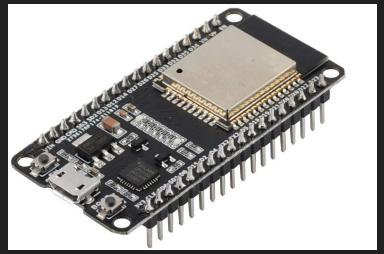
ESP32-WROOM-32 Specs

CPU Manufacturer:	Espressif
CPU Speed:	240 MHz
Memory:	4 **MB**
RAM:	160 **KB**
WiFi:	802.11b
Bluetooth:	yes

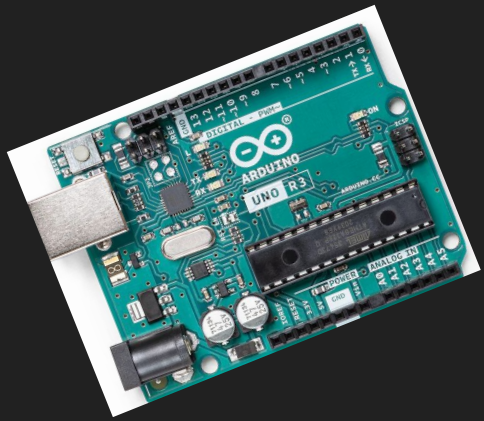
~$8



IoT Devices: Development Kit/ Hardware

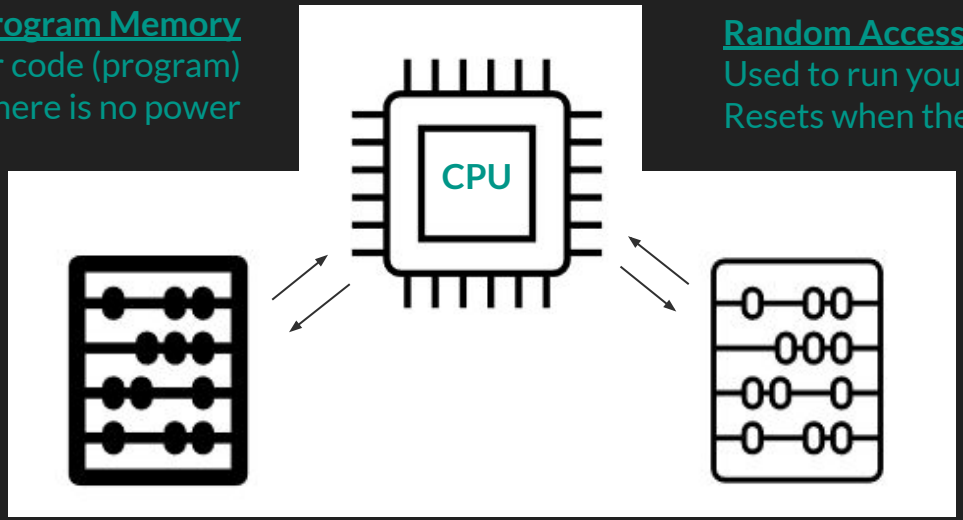


Feature	ESP32-WROOM-32	Arduino Uno (ATmega328P)
CPU	Dual-core Tensilica Xtensa LX6 @ **240 MHz**	8-bit AVR @ **16 MHz**
RAM	520 KB SRAM	2 KB SRAM
Flash Memory	4 MB *(~125x more flash)*	32 KB
Wi-Fi	**Yes** (802.11 b/g/n)	No
Bluetooth	**Yes** (Classic + BLE)	No
GPIOs	~30 (depends on module)	14
ADC Resolution	12-bit	10-bit
DAC	2 × 8-bit DACs	No
PWM Channels	16	6
Price	~$8–12	~$3–10



Computer Fundamentals: Memory Types

Program Memory
Stores your code (program)
Persists when there is no power



Random Access Memory (RAM)
Used to run your code when powered
Resets when there is no power

Computer Fundamentals: Memory Size

Computer Fundamentals: Memory Size

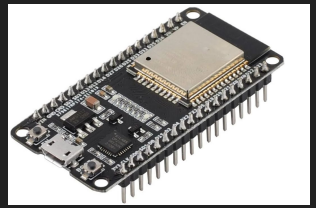
1080P movie blu-ray disc ~ 50 GB

The letter “A” in binary = 01000001

terabyte (TB)	x1024
gigabyte (GB)	x1024
megabyte (MB)	x1024
kilobyte (KB)	x1024
byte (B)	x8
bit (b)	

Computer Fundamentals: Memory Size

ESP32 Specs
CPU Speed: 240 MHz
Storage: 4 MB
RAM: 160 KB

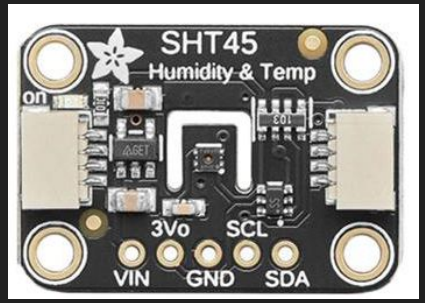


iPhone 15 (2023) Specs
CPU Speed: 3.46 GHz
Storage: 128 GB
RAM: 6 GB

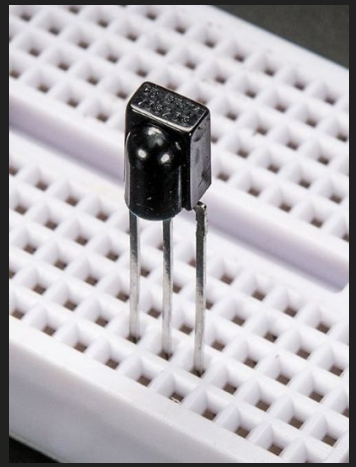
39,300 times larger

Sensors Example (Collects data from something)

SHT45 (Temperature/Humidity)



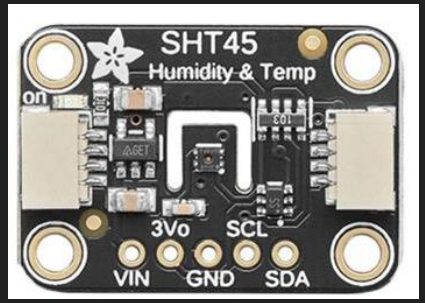
Infrared Receiver

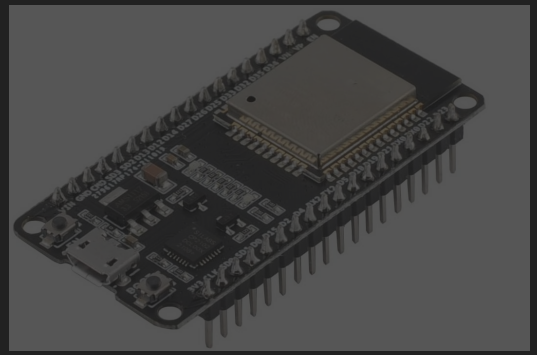


Microswitch

IoT Hardware: Sensors

Hardware that can touch the physical world.

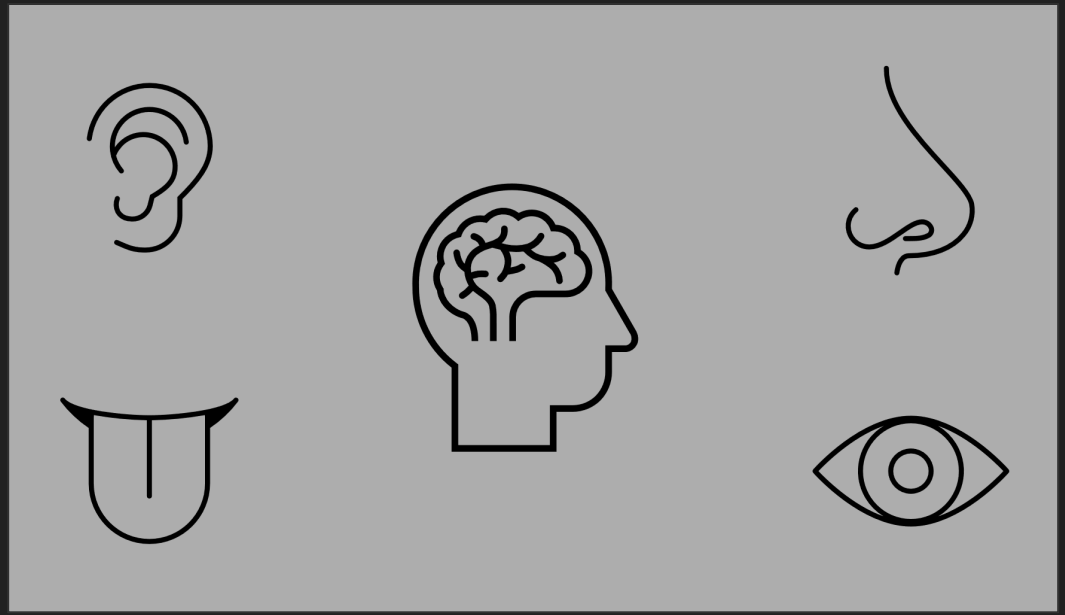




IoT Devices (Sensors)

What “sensors” do you have?

What can you sense?



IoT Devices (Sensors)

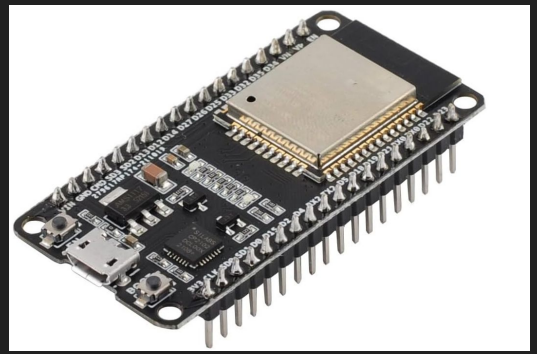
What senses can be detected by hardware?

Human Sense	Application
Taste	Chemical Detection, PH level, Salinity
Smell	Vapor (VoC), Smoke, Particulate Detection [gas]
Touch	Physical [impact, force, pressure], Heat, Distance, Roughness, Capacitance
Feel	Gravity, Acceleration, Orientation/ Direction, Voltage, Current, Magnetic Orientation
Vision	Light, Color, Infrared, Motion, Point Cloud Map,
Hear	Sound, Vibration, Noise, Ultrasonic Echo,

Sensors Critical Thinking

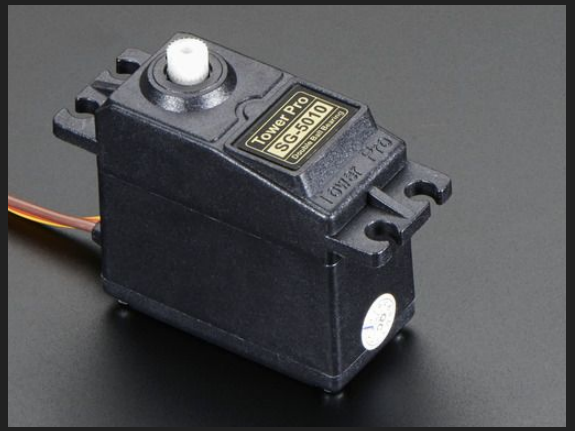
What sensors are in a dishwasher?

IoT Hardware: Review/ Questions?

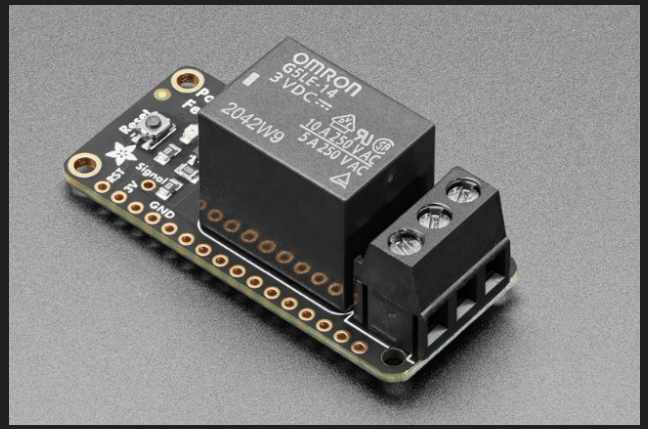


Actuators Example (Interacts with something)

Servo Motor



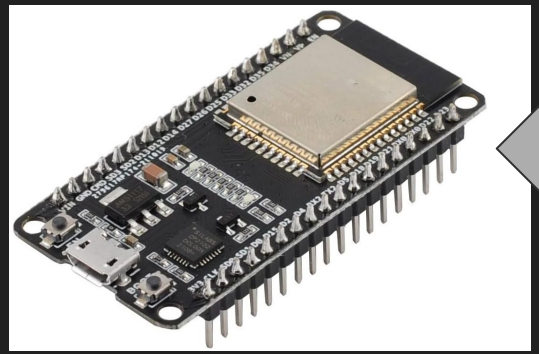
Relay



HARDWARE detail START

Arduino Integrated Development Environment (IDE)

Let’s upload code to our Microcontroller!



Blink | Arduino IDE 2.3.2

File Edit Sketch Tools Help

NodeMCU 1.0 (ESP-12E ...

Blink.ino

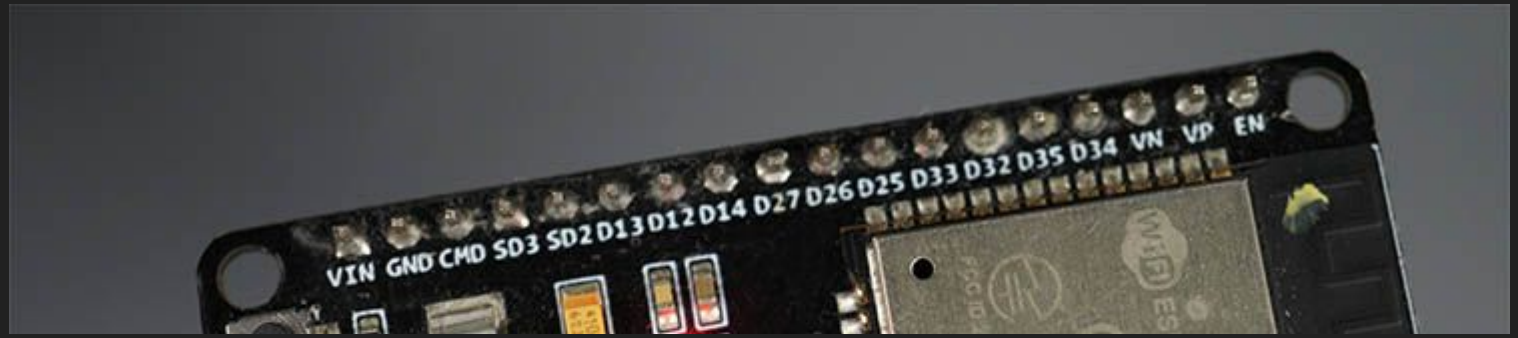
```
// the setup function runs once when you press reset or power the board
void setup() {
  // initialize digital pin LED_BUILTIN as an output.
  pinMode(LED_BUILTIN, OUTPUT);
}

// the loop function runs over and over again forever
void loop() {
  digitalWrite(LED_BUILTIN, HIGH);  // turn the LED on (HIGH is the voltage level)
  delay(1000);                      // wait for a second
  digitalWrite(LED_BUILTIN, LOW);   // turn the LED off by making the voltage LOW
  delay(1000);                      // wait for a second
}
```

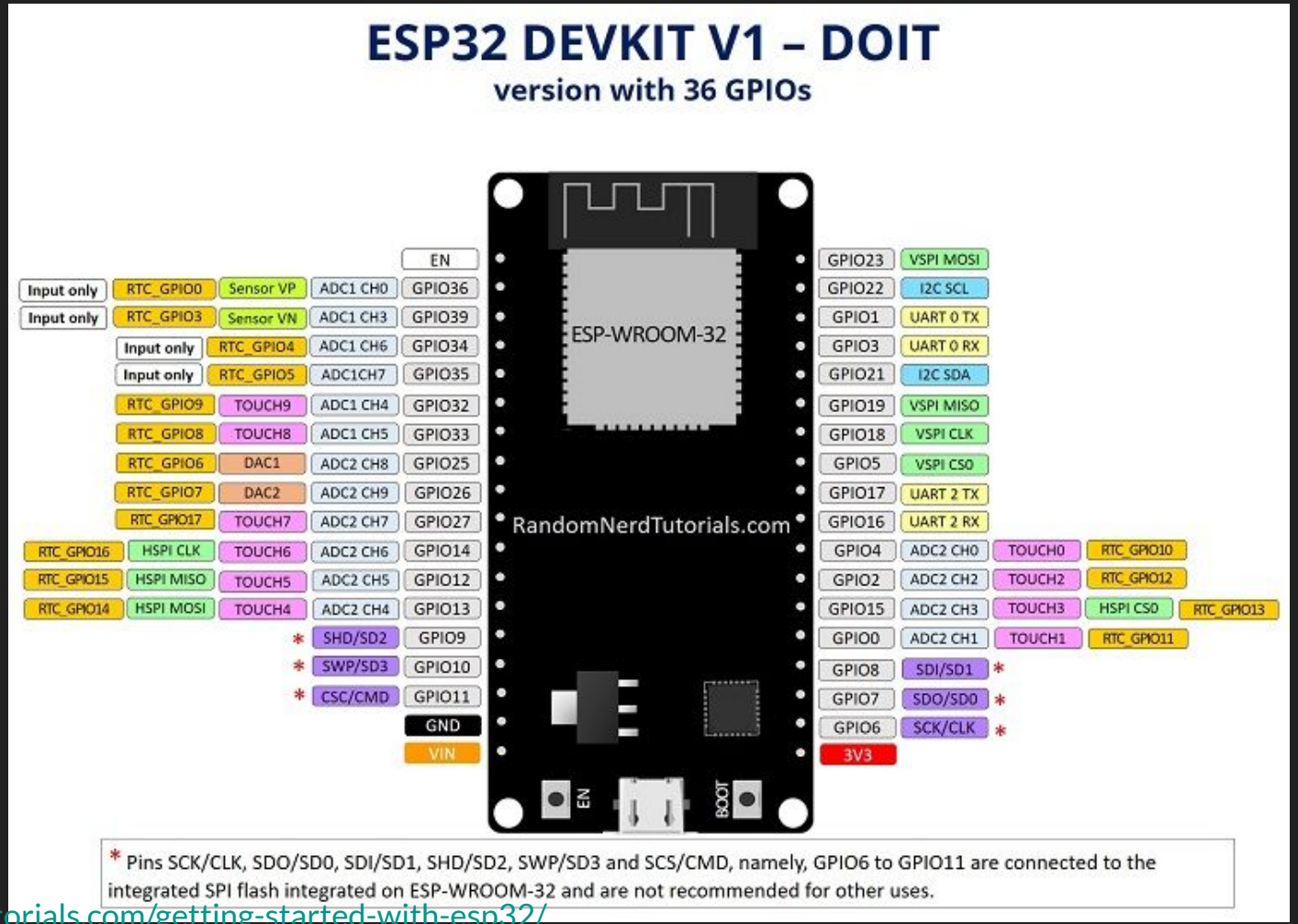
indexing: 54/86

Ln 1, Col 1 NodeMCU 1.0 (ESP-12E Module) on COM3 [not connected]

General Purpose Input/Output (GPIO) Pins



Pinout

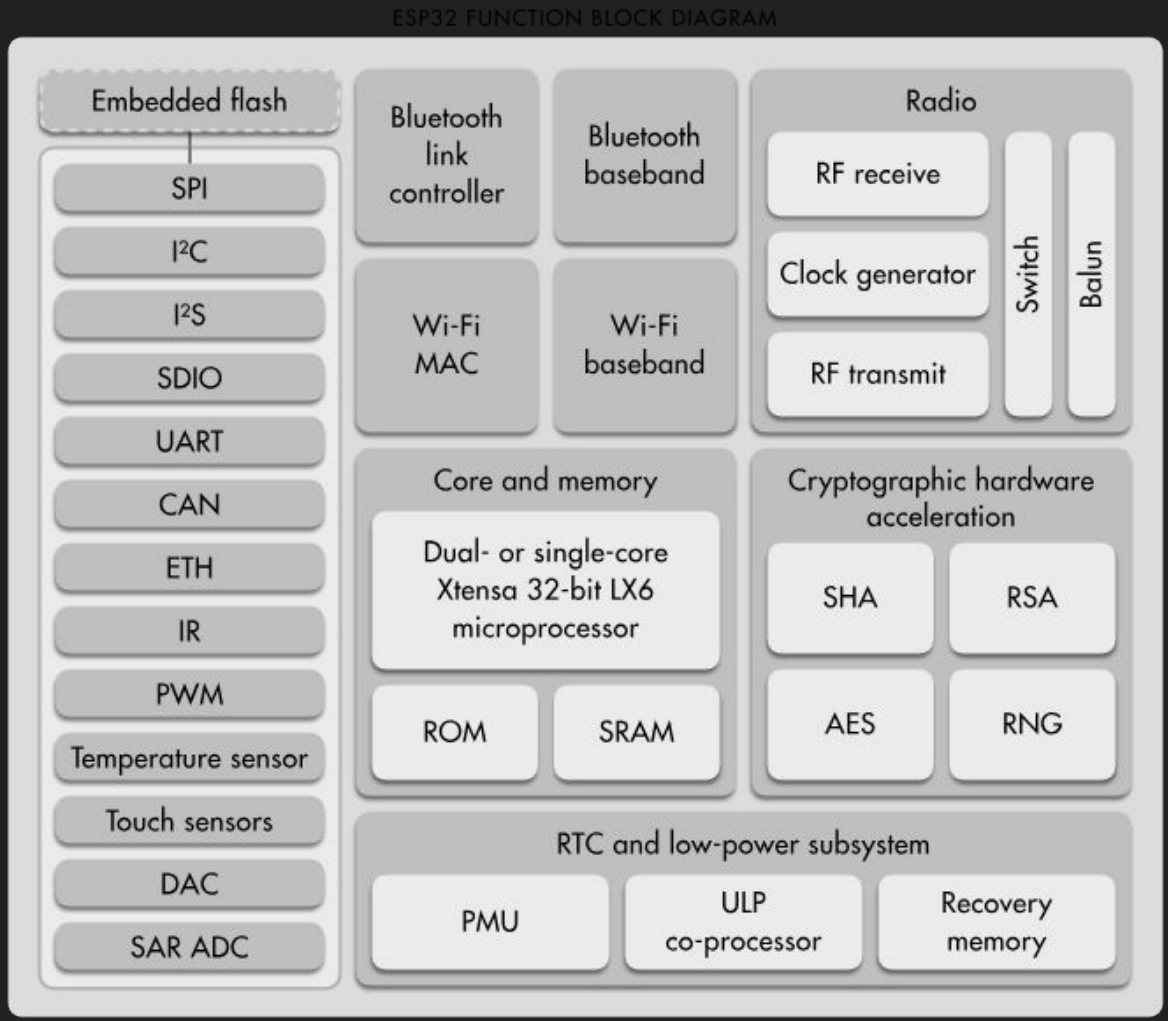


https://randomnerdtutorials.com/getting-started-with-esp32/

Hardware (Functional Diagram)

Communication protocols for wired GPIO and wireless interfacing.

We are using i2c and WiFi



http://esp32.net/

Arduino Integrated Development Environment (IDE)

Blink | Arduino IDE 2.3.2

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10   delay(1000);                      // wait for a second
11   digitalWrite(LED_BUILTIN, LOW);   // turn the LED off by making the voltage LOW
12   delay(1000);                      // wait for a second
13 }
14
```

indexing: 54/86

Ln 1, Col 1 NodeMCU 1.0 (ESP-12E Module) on COM3 [not connected]

Digital Pins: Output vs Input

```
const int ledPin = 13;
pinMode(LEDpin, OUTPUT);
digitalWrite(ledPin, HIGH); //
turn LED on:
```

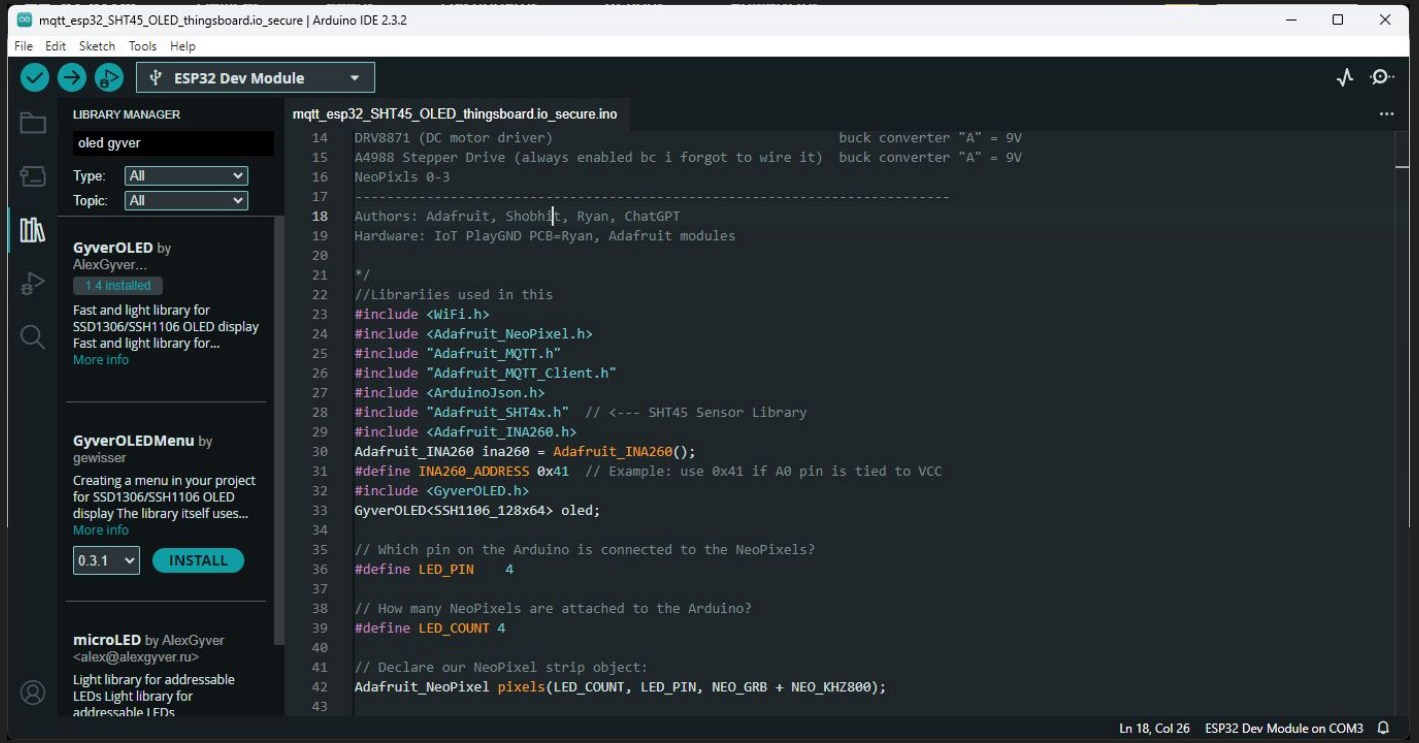
Tip! Max current drawn per GPIO = **40mA**

```
const int buttonPin = 2;
pinMode(buttonPIN, INPUT);
If (digitalRead(buttonPin) == HIGH)//
    {digitalWrite(ledPin, HIGH);}
check if pressed, do something.
```

Tip! Do not exceed **3.3V** (working voltage of board).

Arduino IDE: Whaaaaaaaaaat?

- Libraries
- Board manager
- Dark theme
- COM ports
- Serial Monitor



Analog Pins: Output (PWM) vs Input

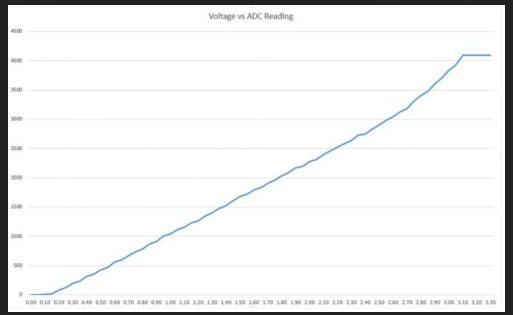
```
const int ledPin = 13;
pinMode(LEDpin, OUTPUT);
analogWrite(ledPin, 127); //
turn LED to 50% duty cycle:
```

Max current drawn per GPIO = **40mA**

```
const int potPin = 13;
(analogRead(potPin)// read the voltage
at the pin
```

ADC Sensitivity = 12-bit resolution (2^{12})
3.3 V / 4096 = 0.008v

Always read your device's datasheet for details.

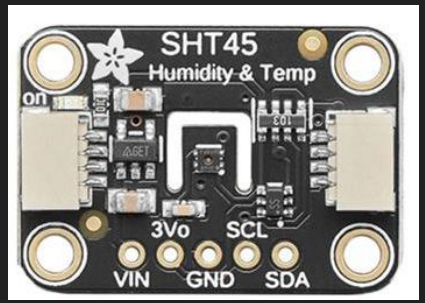


Temp and Humidity Sensor (SHT45)

Talks over i2c.

I²C (Inter-Integrated Circuit) is a **two-wire serial communication protocol** used to connect low-speed **peripheral devices (sensors, displays, etc.)** to microcontrollers (like Arduino, ESP32, etc.) over short distances.

-Short range (1 meter)
- Slow (400khz) *USB 1.0 is about 10x to 100x faster.*



Temp and Humidity Sensor (SHT45)

Upload code to ESP32, watch the serial monitor

JSON

JSON (JavaScript Object Notation) open standard file / data interchange format that uses human-readable text to store and transmit data objects consisting of name–value pairs and arrays (or other serializable values).

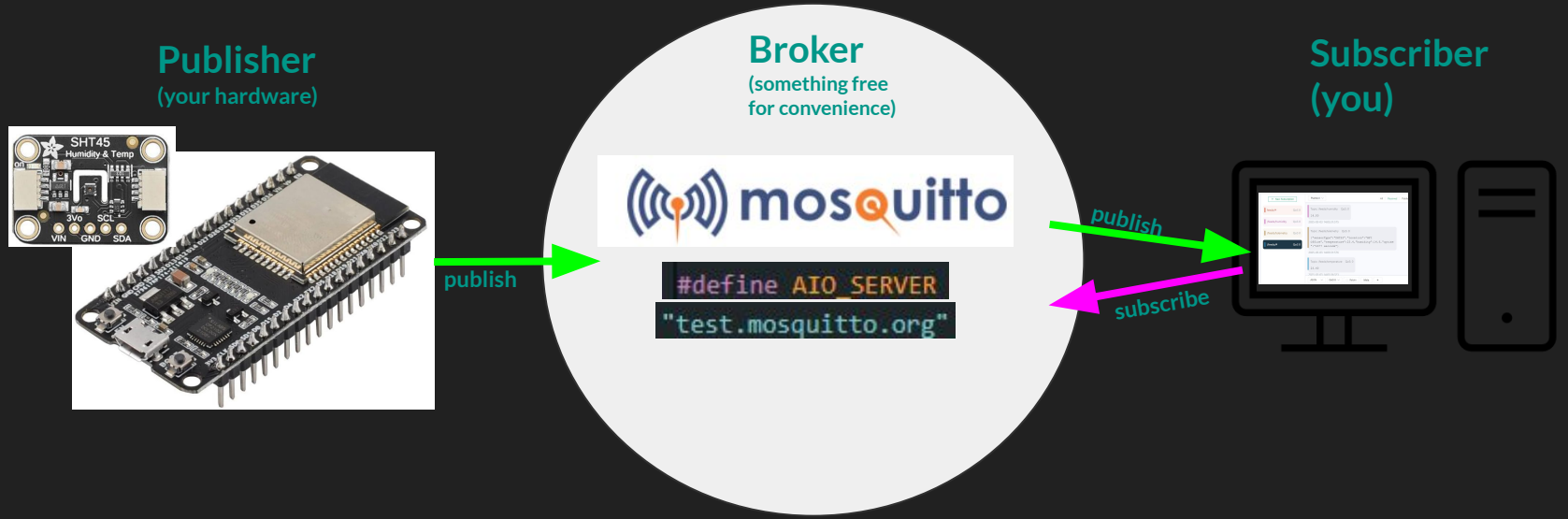
```
{"first_name": "John","last_name": "Smith"},
```

JSON format example

```
{
  "first_name": "John",
  "last_name": "Smith",
  "is_alive": true,
  "age": 27,
  "address": {
    "street_address": "21 2nd Street",
    "city": "New York",
    "state": "NY",
    "postal_code": "10021-3100"
        }
}
```

Explanation: It's text labels & text with formatting.
Objects, arrays, and values.

What is MQTT ?

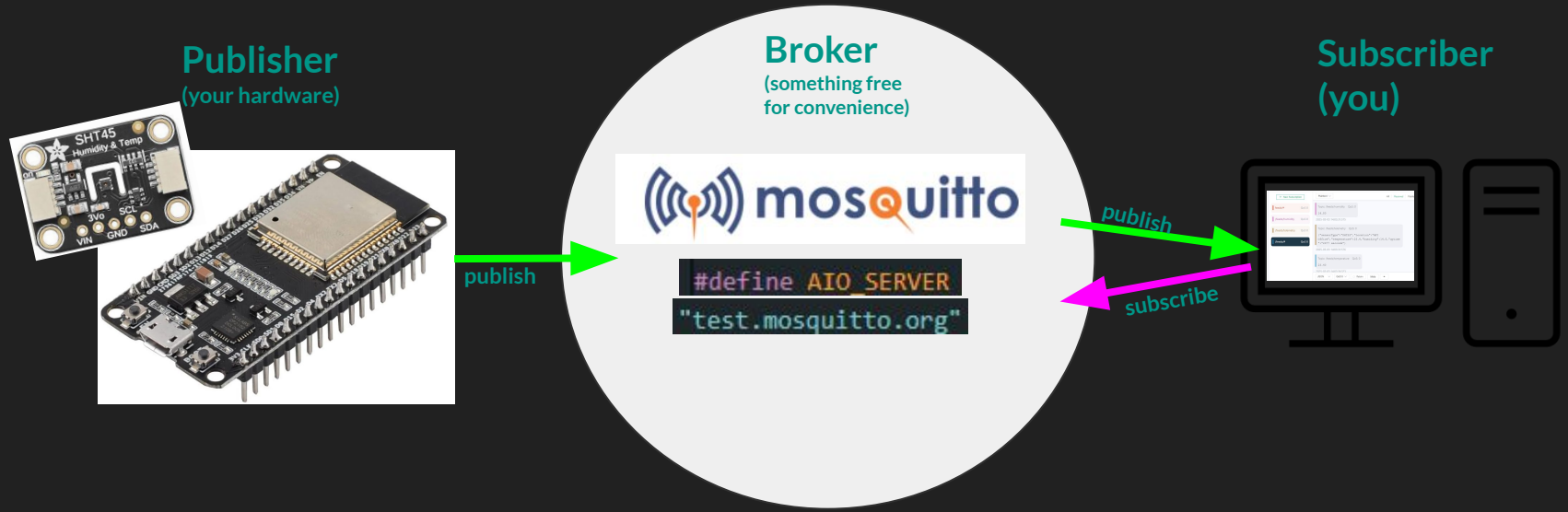

Publisher
(your hardware)
SHT45
Humidity & Temp
3Vo
SCL
VIN
GND
SDA
publish
Broker
(something free
for convenience)
mosquitto
#define AIO_SERVER
"test.mosquitto.org"
publish
subscribe
Subscriber
(you)

MQTT is kinda like the post office

Think of MQTT like a postal service for smart devices:

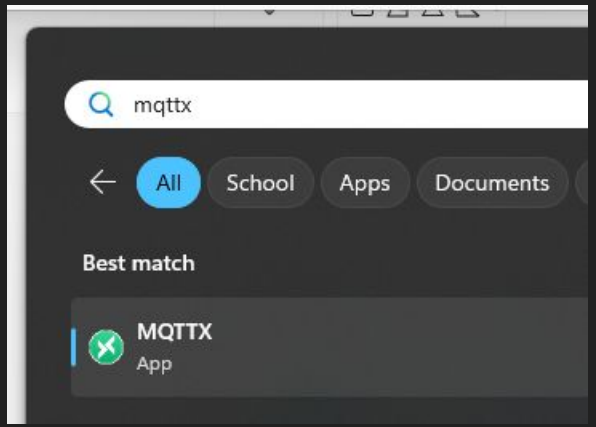
- The **broker** is the post office—it sorts and delivers messages to the right recipients.
- Devices (**clients**) subscribe to topics like people receiving mail at their home address.
- Other devices (**clients**) publish messages like someone sending a letter to a specific topic (mailbox).
- Only those subscribed to that topic get the message—just like only the right recipient gets the mail.

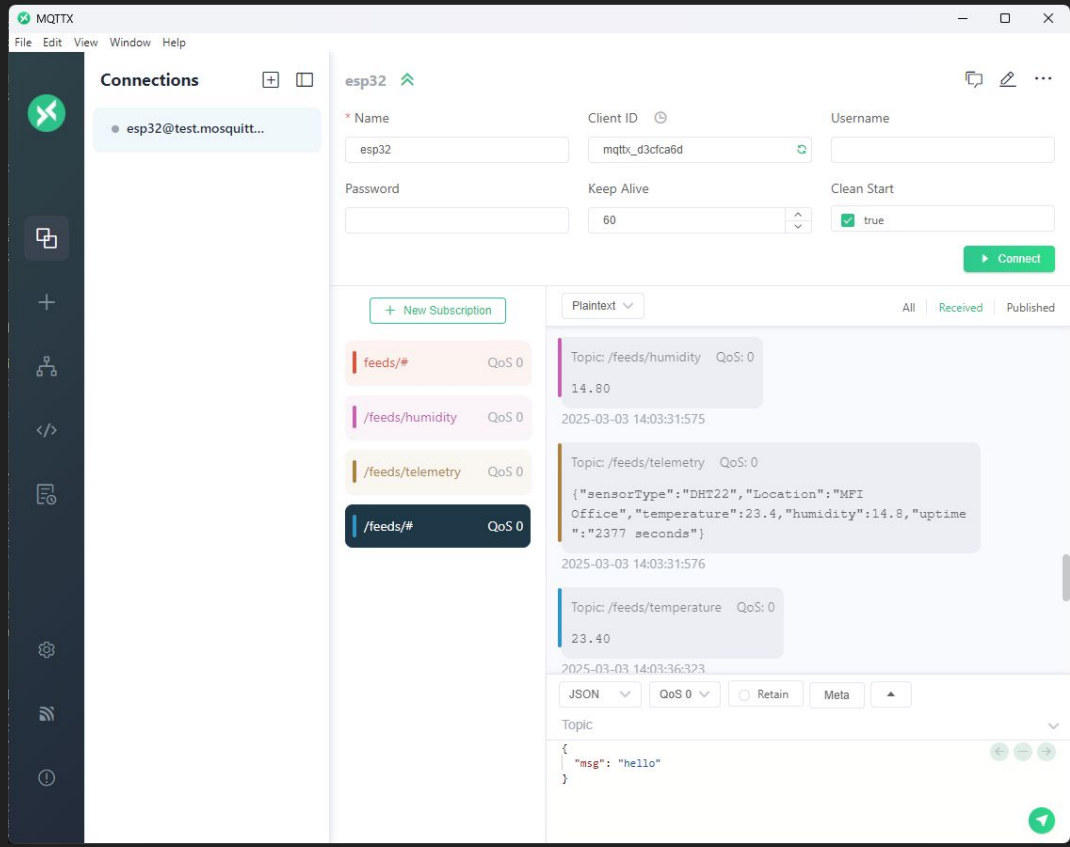
MQTT with our Hardware



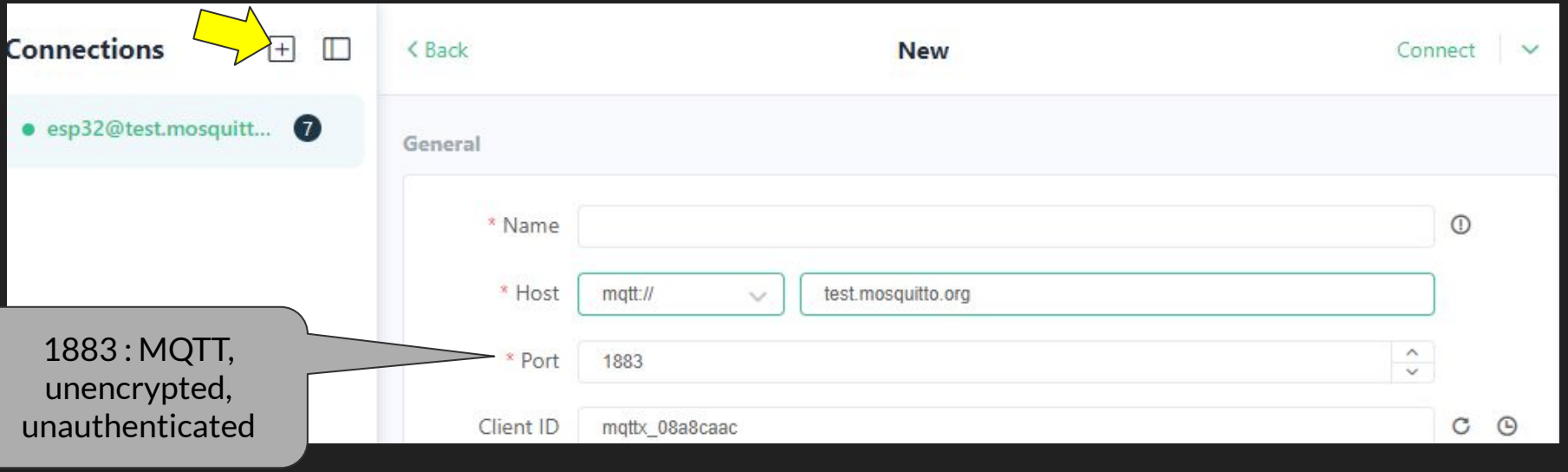
Client Toolbox: MQTTX

WinKey + “MQTTX”

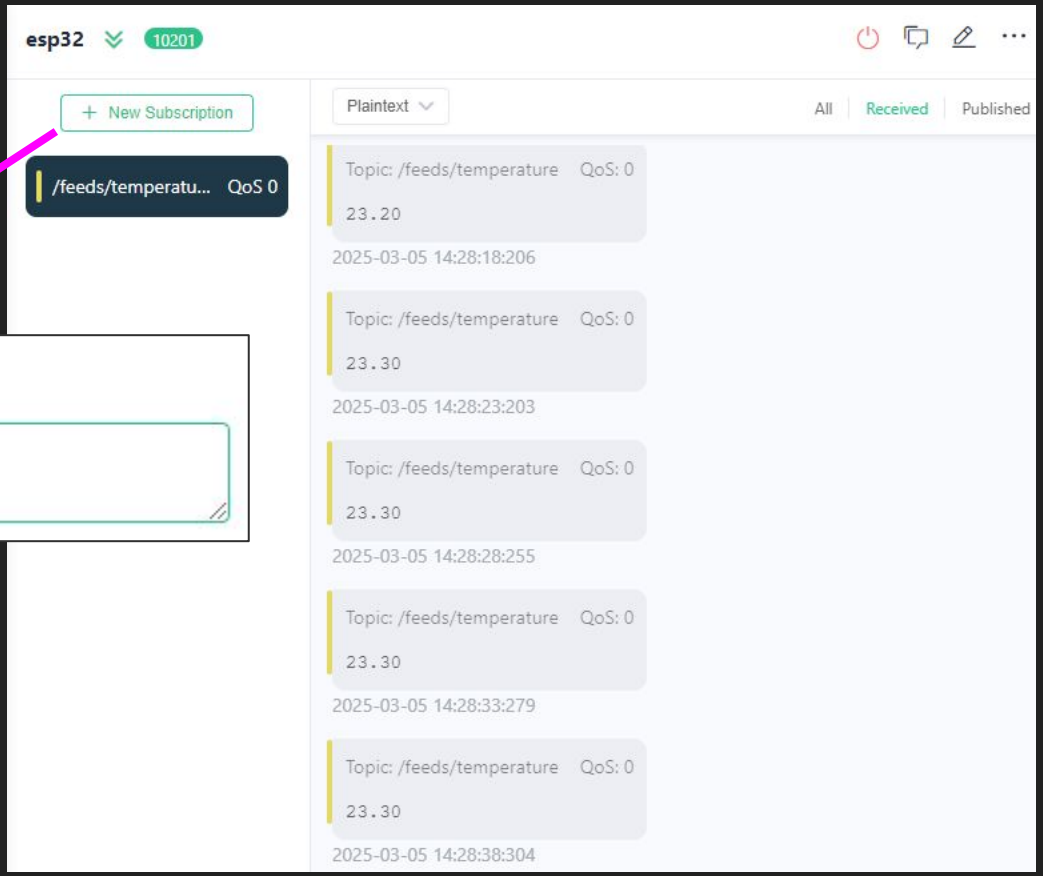




Connect to Broker

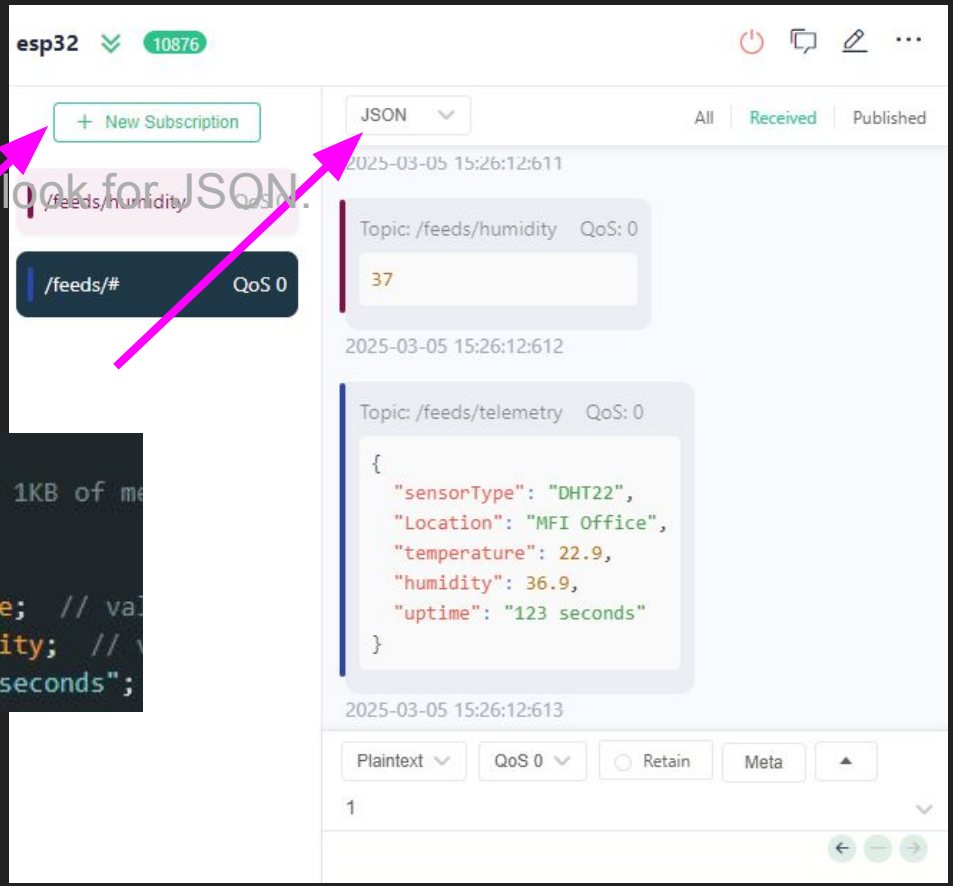


Subscribe to a topic.



Subscribe to all topics.

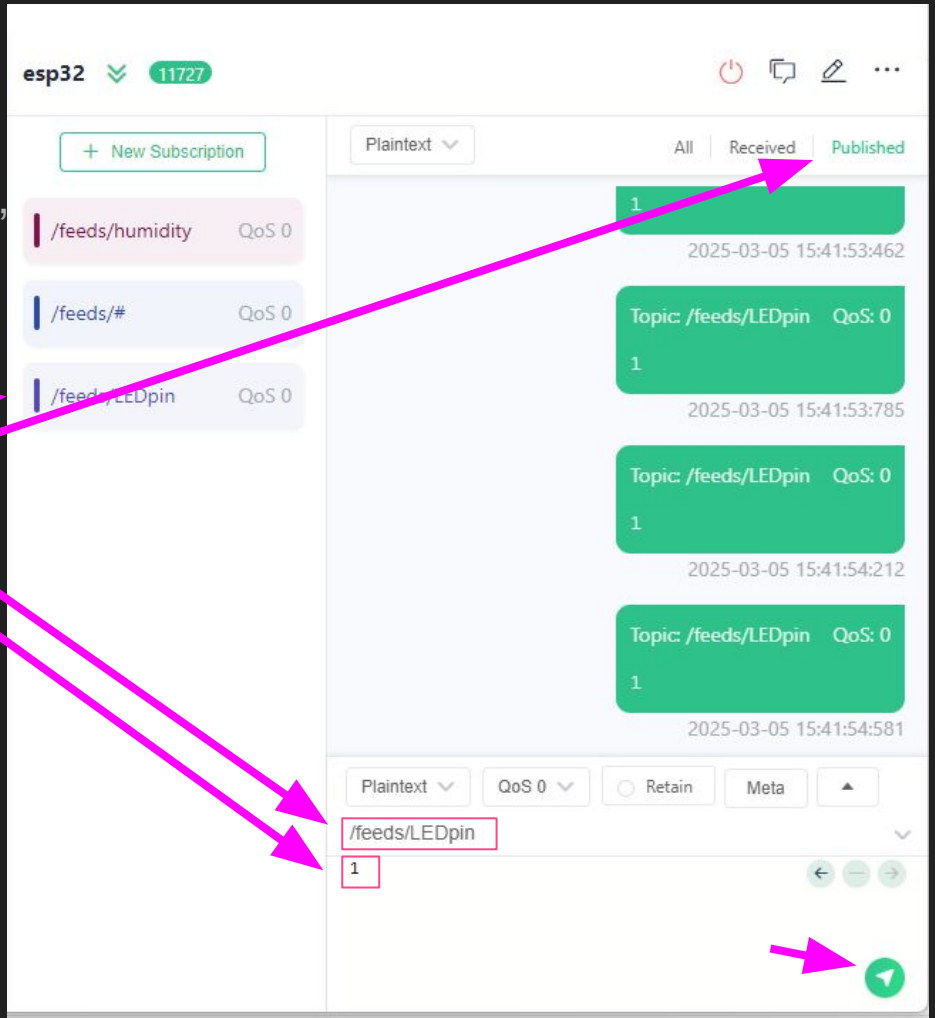
1) Subscribe to the topic “/feeds/#”
2) Change the incoming formatting to look for JSON. Payload is a JSON string




```
// Create the JSON document
DynamicJsonDocument doc(1024); //allocate 1KB of me
doc["sensorType"]= "DHT22";
doc["Location"]= "MFI Office";
doc["temperature"] = tempEvent.temperature;  // va
doc["humidity"] = humEvent.relative_humidity;  //
doc["uptime"] = String(millis()/1000)+ " seconds";
```

Publish to Device

1) Subscribe to the topic “/feeds/LEDpin”
2) Switch to Published tab.
3) Type in the Topic “/feeds/LEDpin”
4) Send the message “0” or “1”



Broker Services (Dashboard)

Review Topics!

What are IoT benefits?

Explain some technical fundamentals of:

- Computer Science: Memory, Processing,
- IT: Networking basics *(relax, nothing obscure)*
- Hardware: Microcontrollers, SoC, Sensors
- Software: C/C++, Arduino IDE
- ChatGPT: it writes and explains code for you.
- MQTT: Publisher Subscriber Model

What does our hardware do: Monitor Temperature over WiFi, toggle a relay.