Freeways

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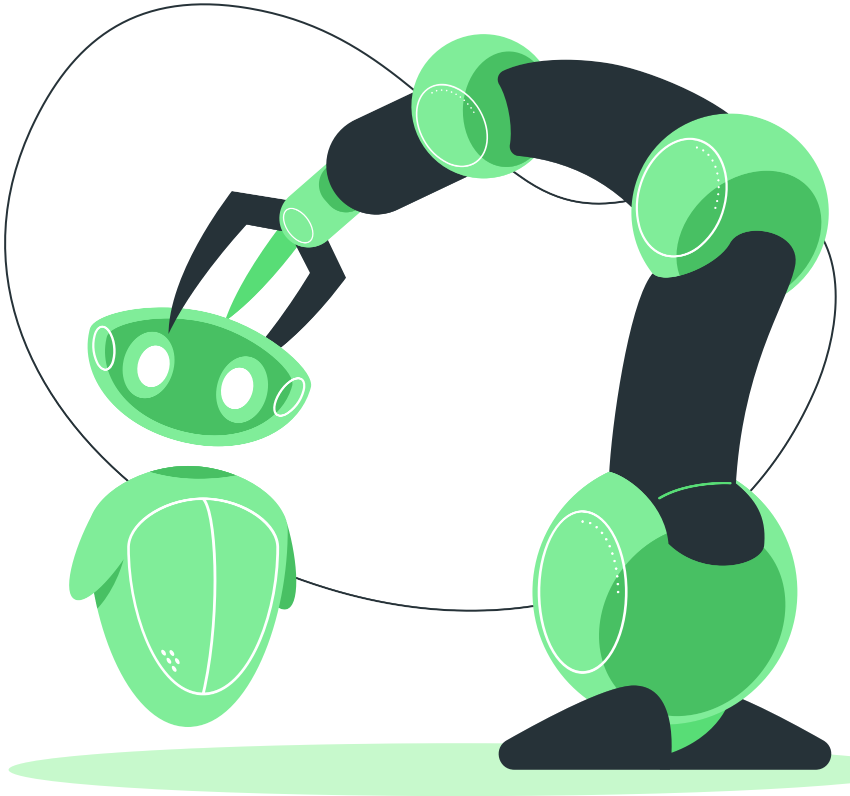
STM32 Workshop

By Moktar SELLAMI



Plan

1 ***Why you should be here ?***

2 ***Intro to embedded systems***

3 ***Microcontroller***

4 ***Motherboard VS Microcontroller***

5 ***STM32***

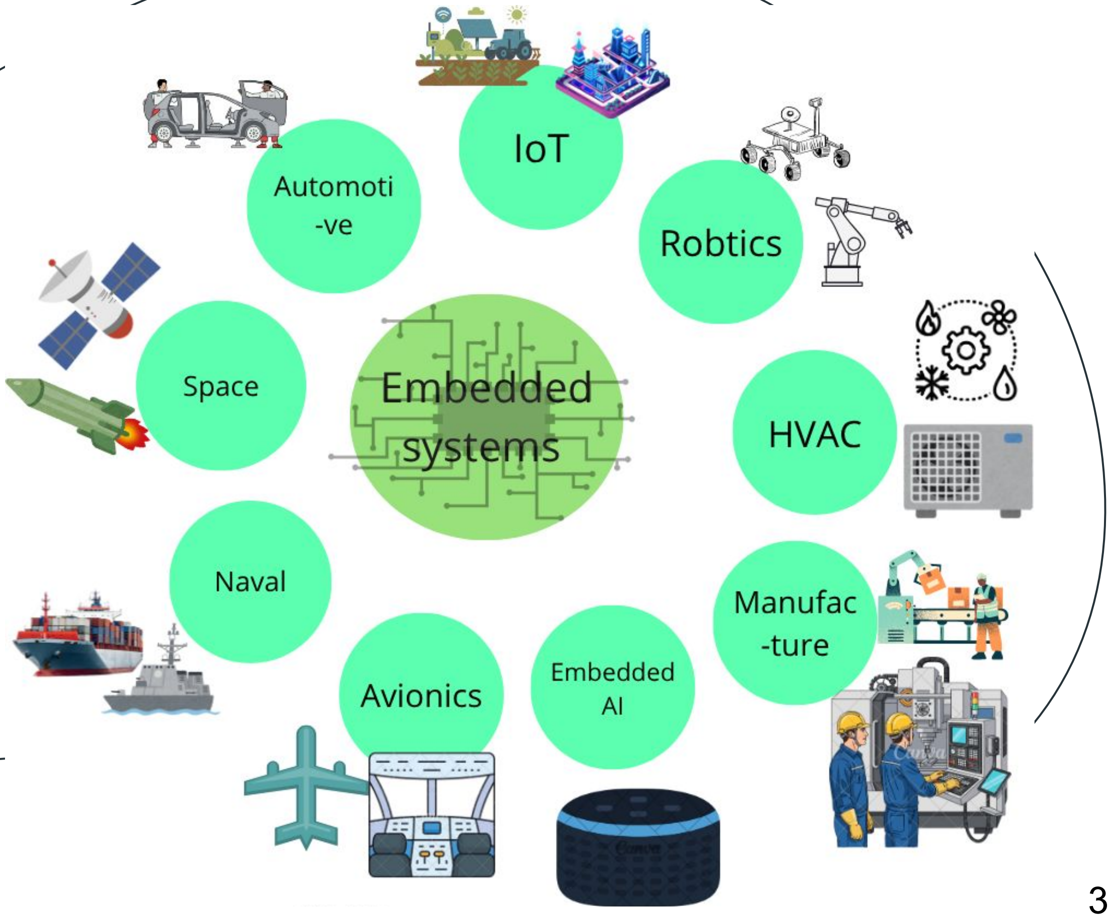
6 ***Let's do something***

7 ***STM32 GPIO***

8 ***Writing the Software: HAL***

Why you should be here ?

The field Embedded systems:



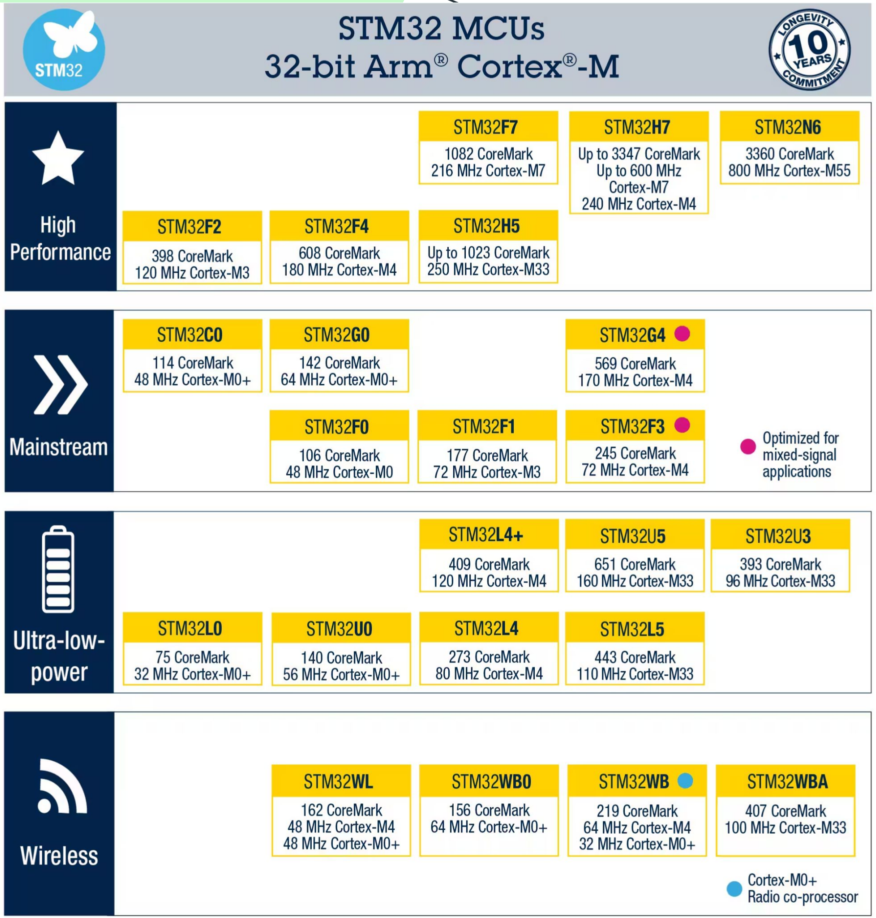
Why you should be here ?

Why STM32: (For MCU)

1. Unmatched Scalability & Portfolio
 (+ 1500 MCU variants)
2. Powerful & Comprehensive Ecosystem
3. Leadership in Performance & Power Efficiency

Why STM32: (For Students)

1. A way to get an internship
2. A bridge from Arduino
3. Provides an ecosystem for newbies (CubeMX)
4. Community



STM32 MCUs
32-bit Arm® Cortex®-M

High Performance

STM32F7
1082 CoreMark
216 MHz Cortex-M7

STM32H7
Up to 3347 CoreMark
Up to 600 MHz
Cortex-M7
240 MHz Cortex-M4

STM32N6
3360 CoreMark
800 MHz Cortex-M55

STM32F2
398 CoreMark
120 MHz Cortex-M3

STM32F4
608 CoreMark
180 MHz Cortex-M4

STM32H5
Up to 1023 CoreMark
250 MHz Cortex-M33

Mainstream

STM32C0
114 CoreMark
48 MHz Cortex-M0+

STM32G0
142 CoreMark
64 MHz Cortex-M0+

STM32G4 ●
569 CoreMark
170 MHz Cortex-M4

STM32F0
106 CoreMark
48 MHz Cortex-M0

STM32F1
177 CoreMark
72 MHz Cortex-M3

STM32F3 ●
245 CoreMark
72 MHz Cortex-M4

● Optimized for mixed-signal applications

Ultra-low-power

STM32L4+
409 CoreMark
120 MHz Cortex-M4

STM32U5
651 CoreMark
160 MHz Cortex-M33

STM32U3
393 CoreMark
96 MHz Cortex-M33

STM32L0
75 CoreMark
32 MHz Cortex-M0+

STM32U0
140 CoreMark
56 MHz Cortex-M0+

STM32L4
273 CoreMark
80 MHz Cortex-M4

STM32L5
443 CoreMark
110 MHz Cortex-M33

Wireless

STM32WL
162 CoreMark
48 MHz Cortex-M4
48 MHz Cortex-M0+

STM32WB0
156 CoreMark
64 MHz Cortex-M0+

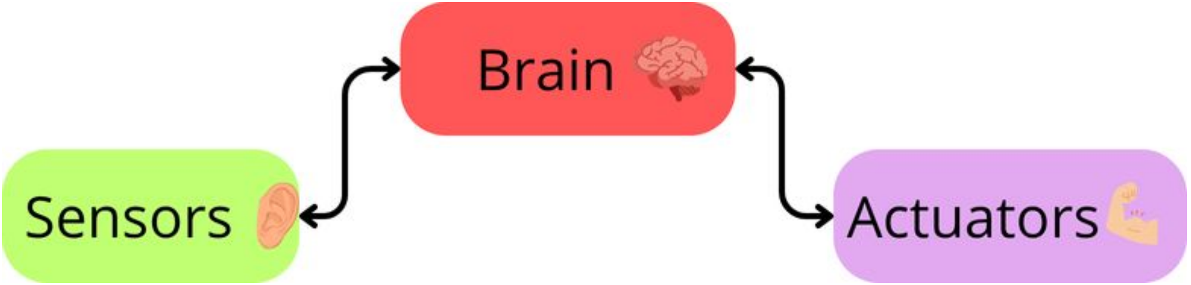
STM32WB ●
219 CoreMark
64 MHz Cortex-M4
32 MHz Cortex-M0+

STM32WBA
407 CoreMark
100 MHz Cortex-M33

● Cortex-M0+ Radio co-processor

Introduction to embedded systems

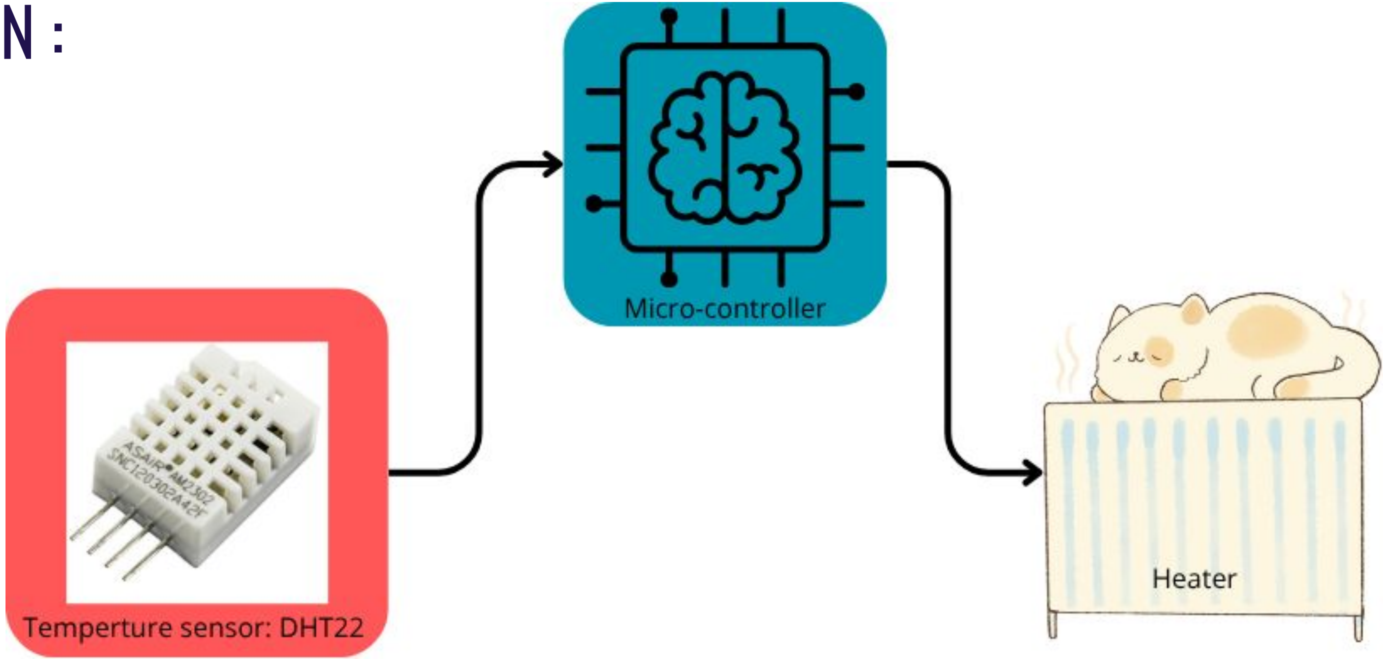
Embedded systems are specialized computing systems designed to perform specific functions within larger systems.



Thermostat

Introduction to embedded systems

THE BRAIN :



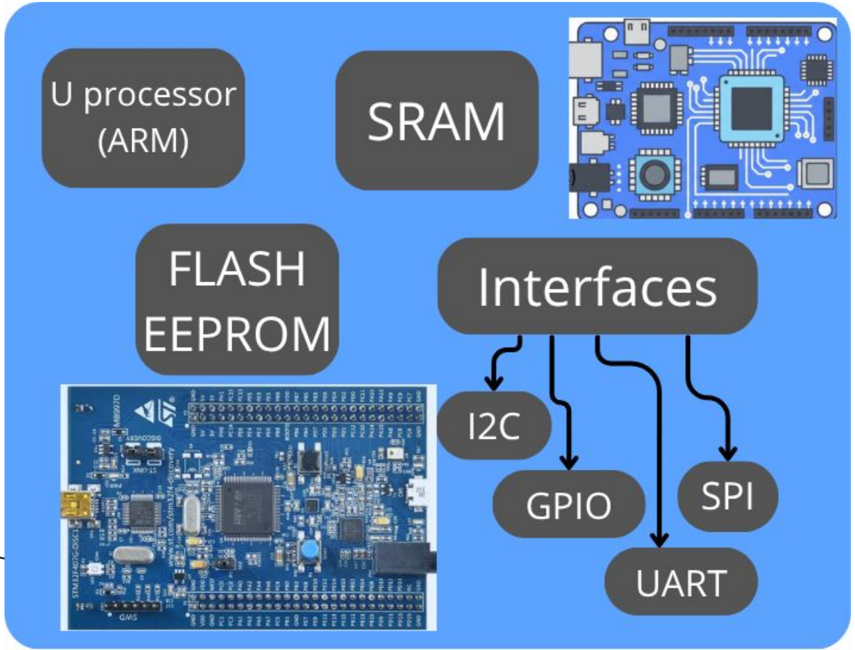
Microcontroller

A microcontroller is a compact integrated circuit that integrates many components.
It is categorized with its limit resources:

- Low processing power : 12 Mhz to 700 Mhz
- Low memory capacity: 2KB to 1MB
- Low storage capacity: 4KB to 20MB
- Energy consumption: 10 mW to 2W

Analogy between motherboard and Microcontroller

Microcontroller



U processor (ARM)

SRAM

FLASH EEPROM

Interfaces

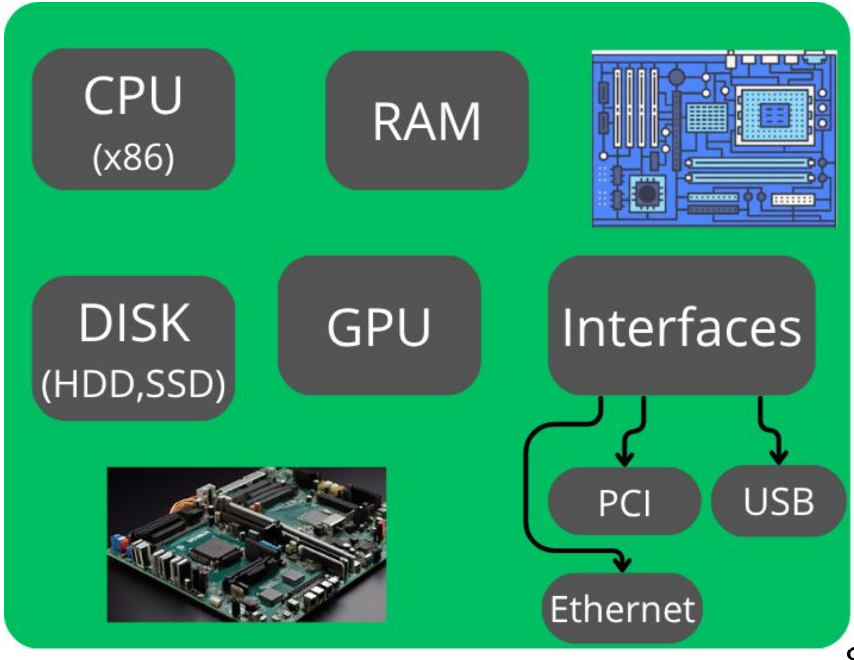
I2C

GPIO

UART

SPI

Motherboard



CPU (x86)

RAM

DISK (HDD,SSD)

GPU

Interfaces

PCI

USB

Ethernet

STM32

What is STM32?

Family of 32-bit microcontrollers by STMicroelectronics

Use ARM Cortex-M cores (M0, M0+, M3, M4, M7, M33)

Launched in 2007 with F1 series

STMicroelectronics

Largest semiconductor company in Europe

Founded in 1987 (France + Italy merger)

Headquarters: Geneva, Switzerland

49,602 employees, $13.27B revenue (2024)

Families

Mainstream:	C0/G0/G4/F0/F1/F3
High Performance:	H7/H5/F7/F4/F2
Low Power:	L0/L4/L5/U0/U3/U5
Wireless:	WL/WB0/WB/WA
AI:	N6

Applications & Fields

Industrial automation (PLCs, robots, HMIs)

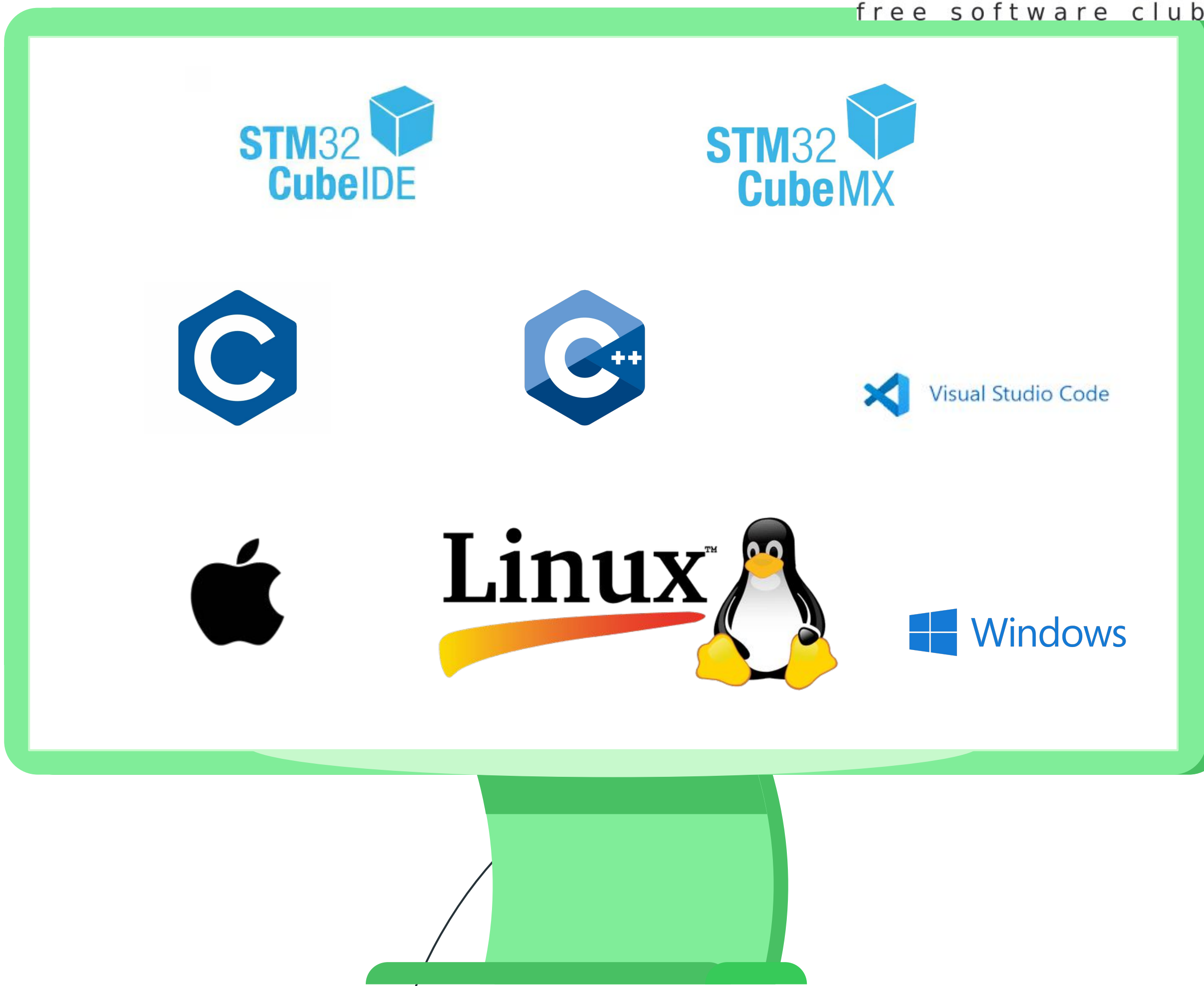
Consumer electronics (smart devices, wearables)

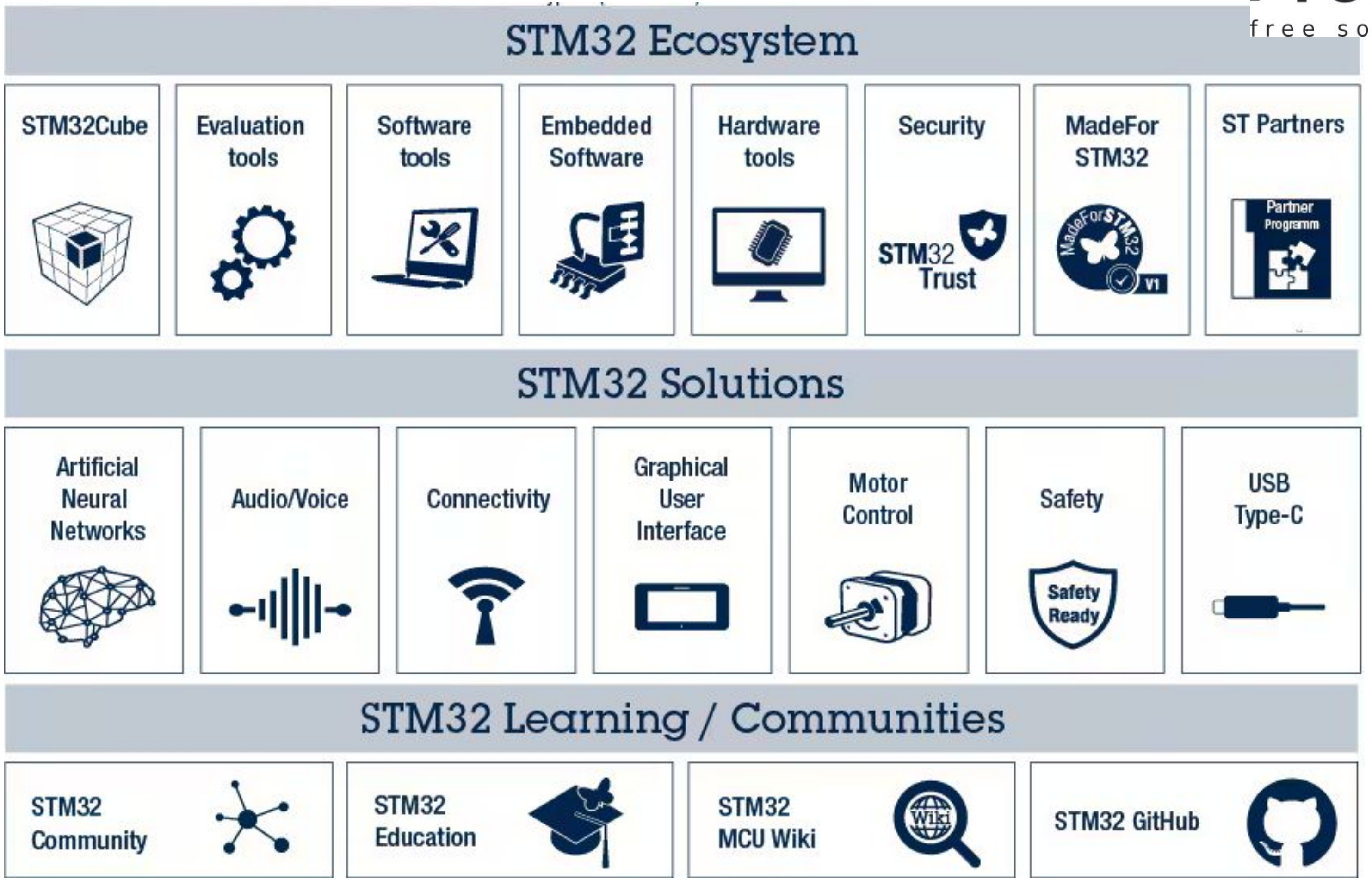
Internet of Things (IoT)

Medical equipment

Automotive systems

STM32 Ecosystem:





STM32 Ecosystem

STM32Cube | Evaluation tools | Software tools | Embedded Software | Hardware tools | Security | MadeFor STM32 | ST Partners

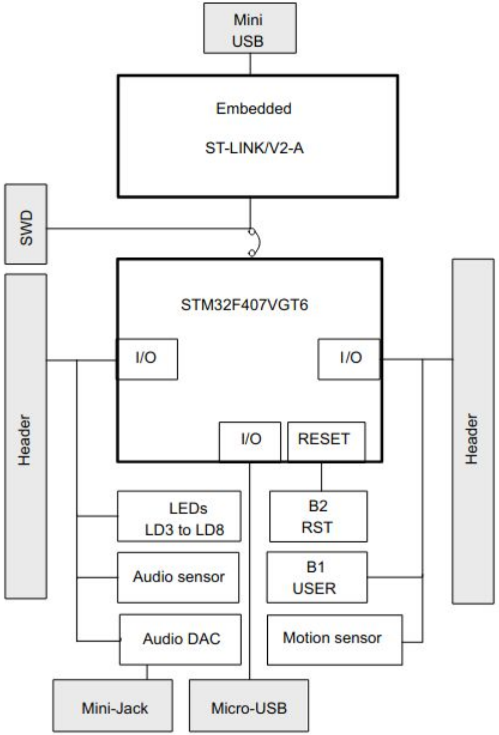
STM32 Solutions

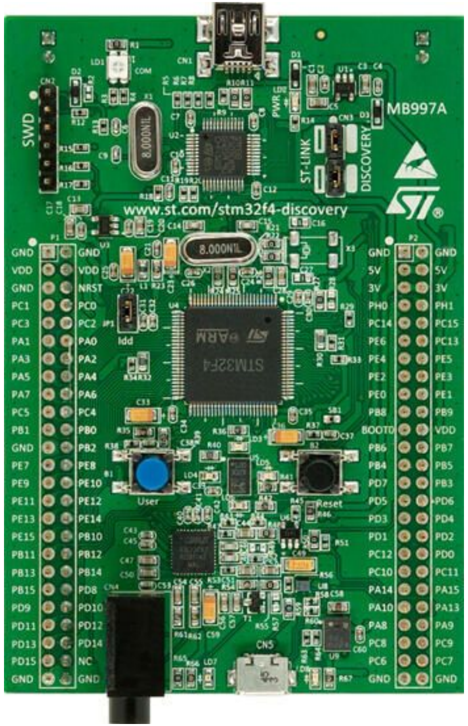
Artificial Neural Networks | Audio/Voice | Connectivity | Graphical User Interface | Motor Control | Safety | USB Type-C

STM32 Learning / Communities

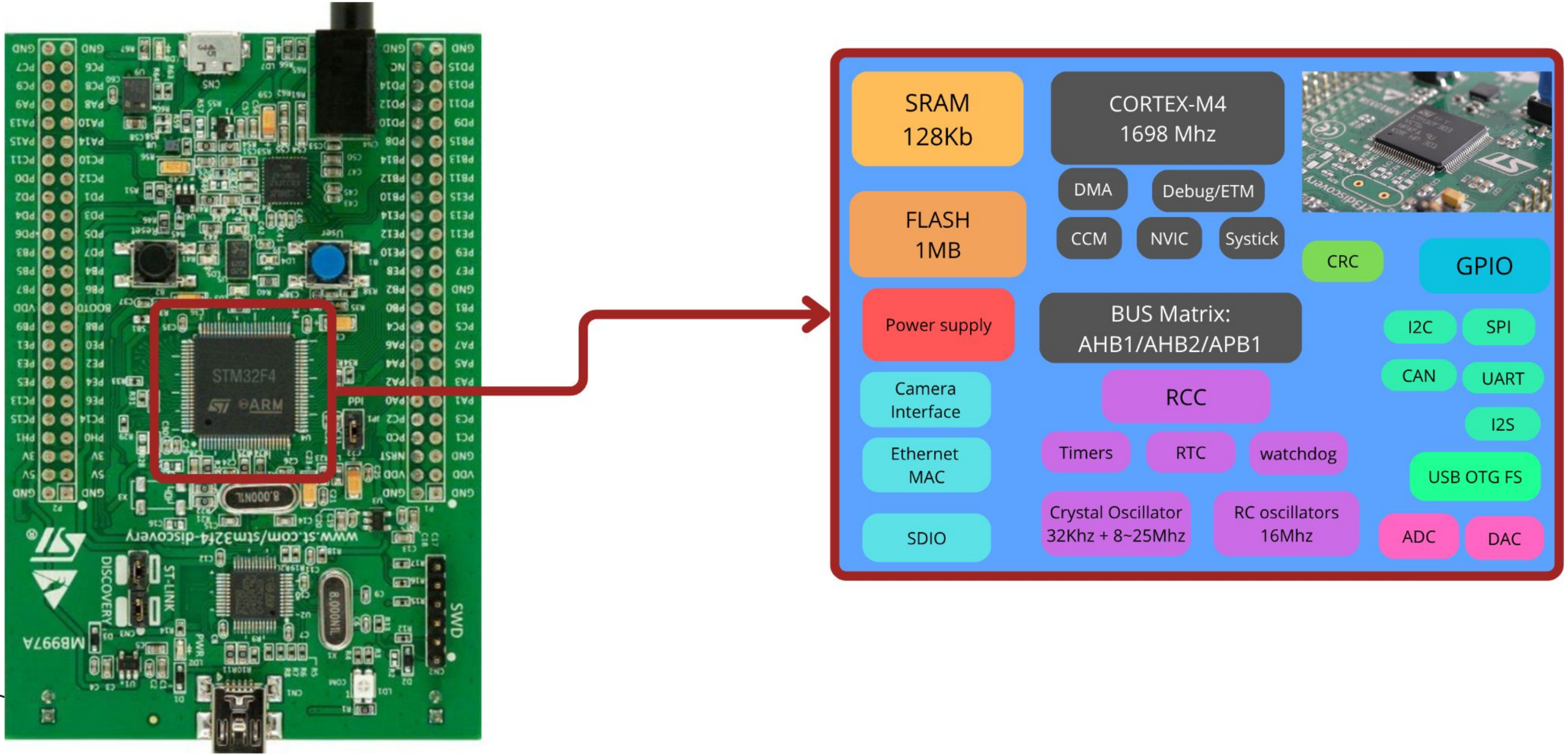
STM32 Community | STM32 Education | STM32 MCU Wiki | STM32 GitHub

Overview: STM32F407-DISCO1





Overview: STM32F407 Microcontroller



SRAM
128Kb

CORTEX-M4
1698 Mhz

DMA

Debug/ETM

FLASH
1MB

CCM

NVIC

Systick

CRC

GPIO

Power supply

BUS Matrix:
AHB1/AHB2/APB1

I2C

SPI

CAN

UART

Camera
Interface

RCC

I2S

Ethernet
MAC

Timers

RTC

watchdog

USB OTG FS

SDIO

Crystal Oscillator
32Khz + 8~25Mhz

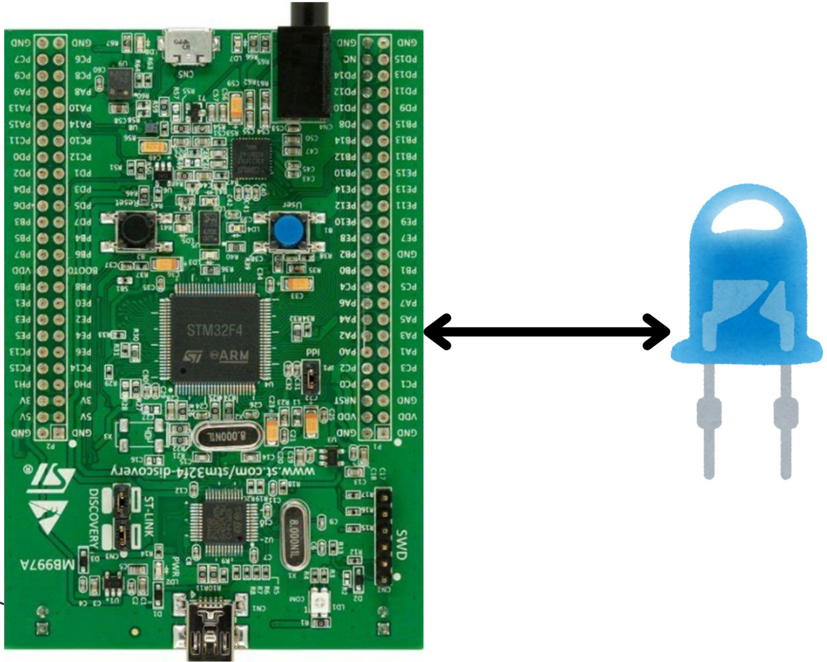
RC oscillators
16Mhz

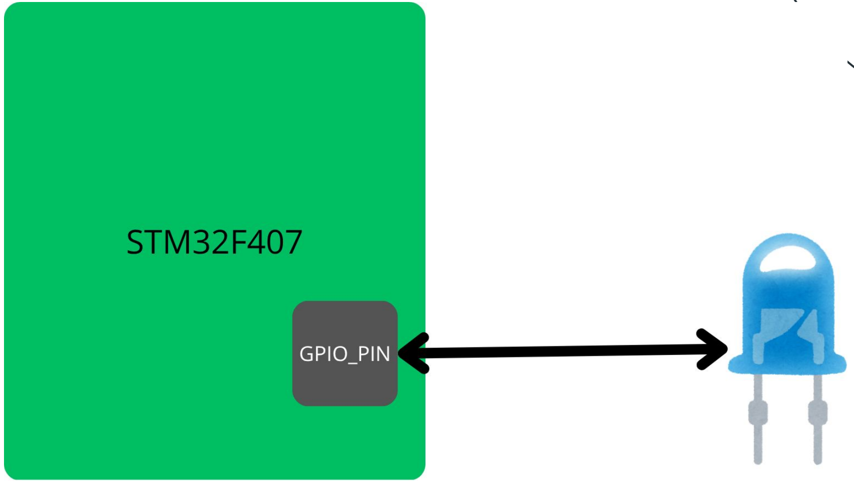
ADC

DAC

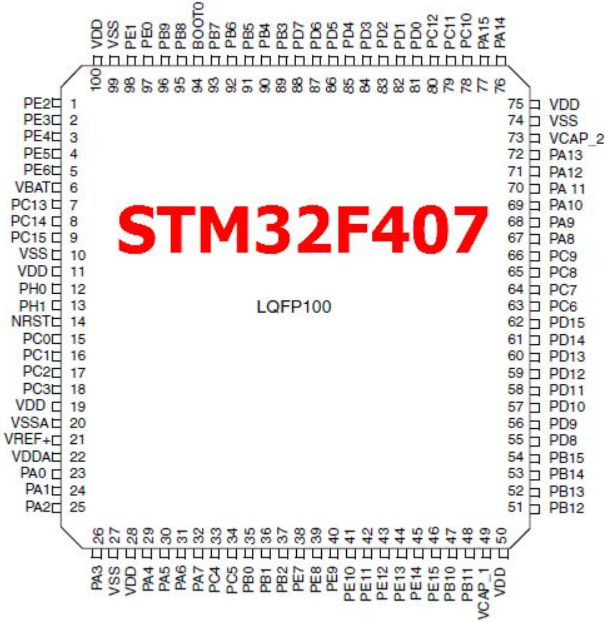
Let’s Do something :

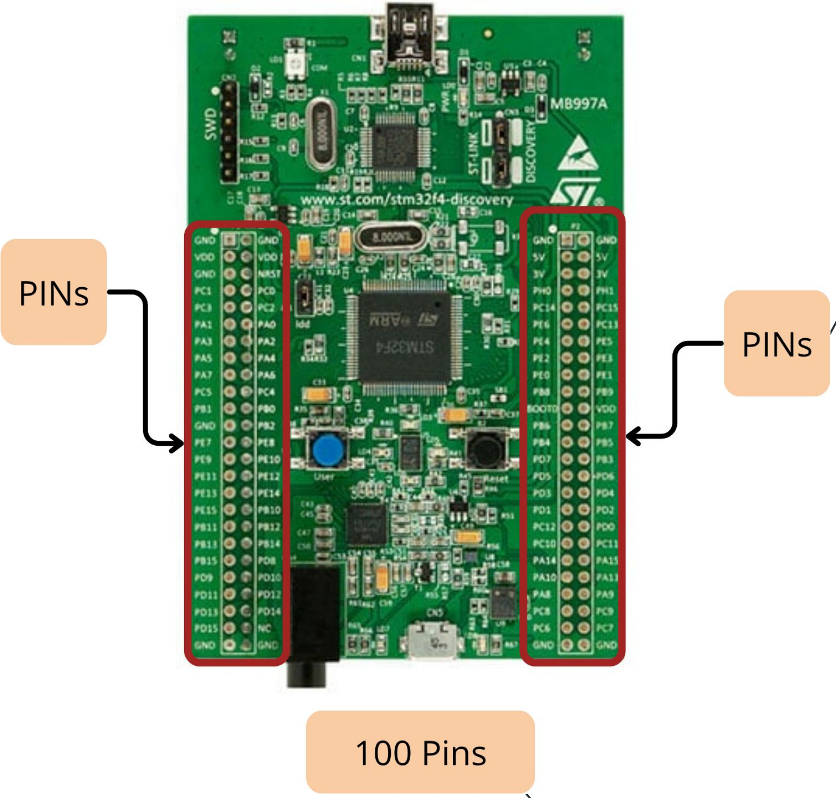
Case Study: Toggling an LED





STM32 GPIO : General purpose Input Output





PINs

PINs

100 Pins

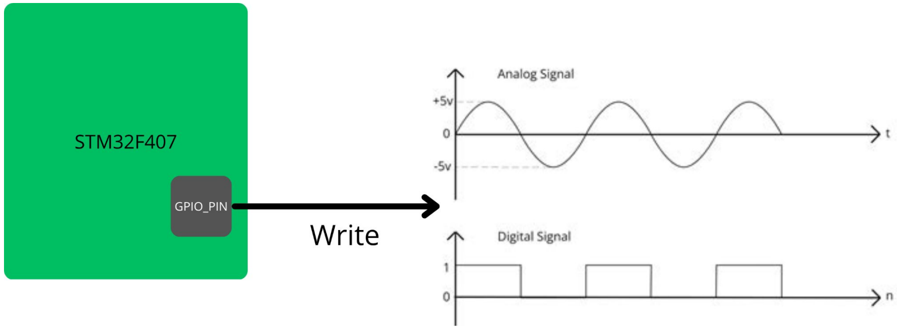
STM32 GPIO : General purpose Input Output

GPIO stands for General Purpose Input/Output.

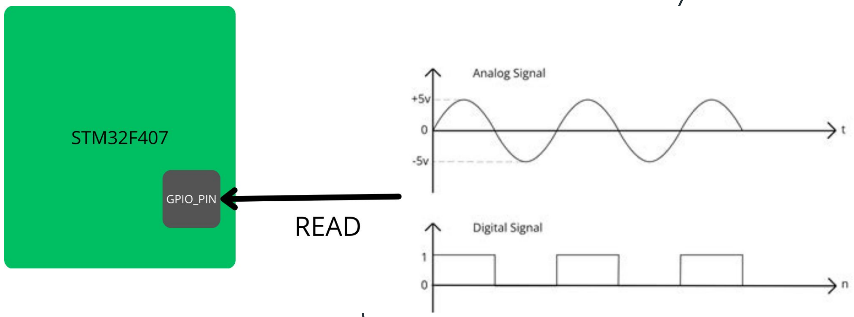
It’s the most basic and versatile feature of a microcontroller, the way it interacts with the outside world.

You can think of a GPIO pin as a configurable electrical pin on the chip that can either:

Send a signal to outside (as an output)



Read a signal coming from outside (as an input



STM32 GPIO : GPIO Modes

The STM32 groups the GPIOS in to clusters called PORTs indicated by GPIOx .
By x we mean: GPIOA to GPIOI .
Each port has 16 pins: From 0 to 15
For example:

- the internal Green LED PD12: GPIOD pin 12
- The internal BTN PA0: GPIOA pin 0

The GPIO has 4 Modes:

- Input
- Output
- Alternate function
- analog

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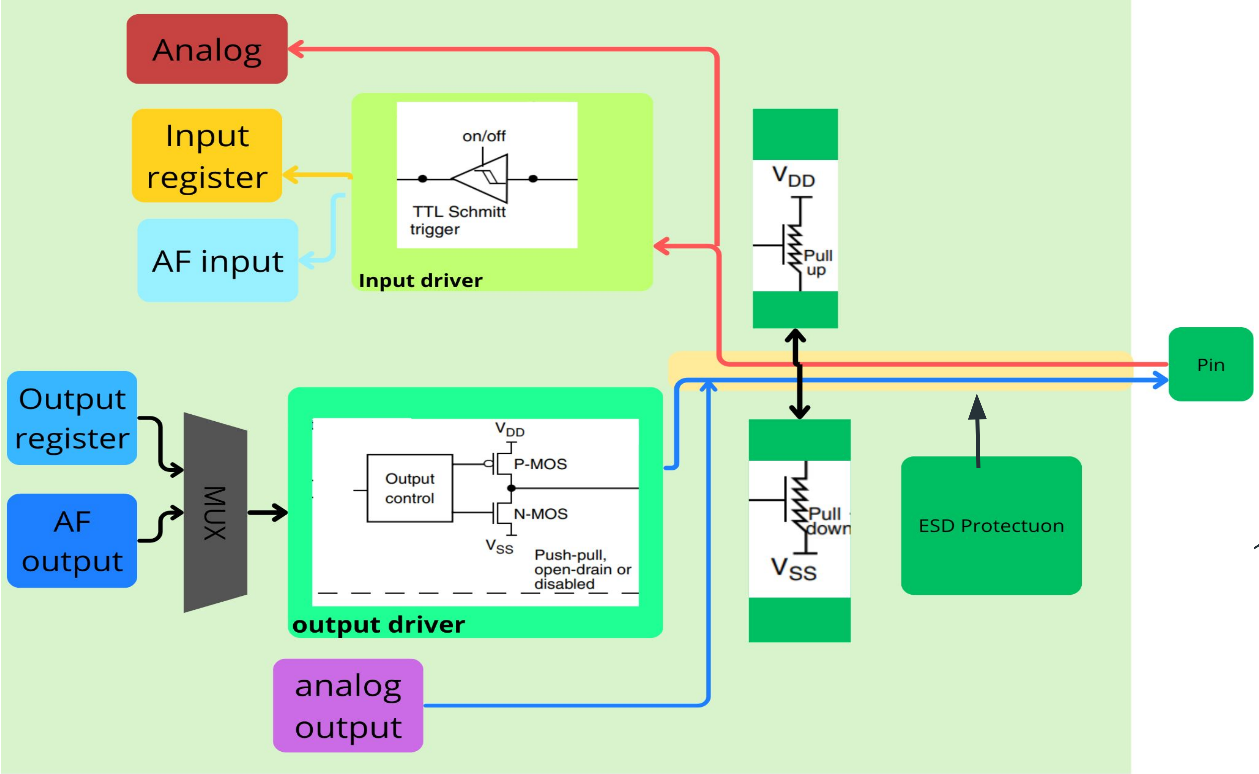
STM32 GPIO : GPIO Structure

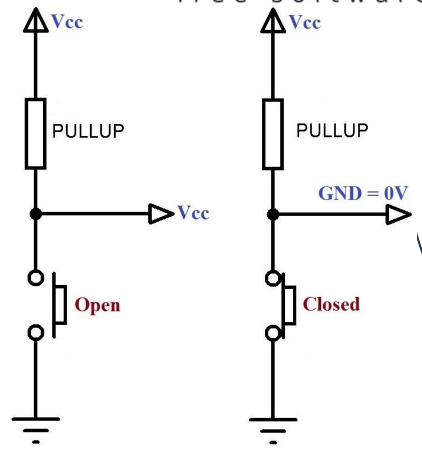


STM32 GPIO : GPIO Modes

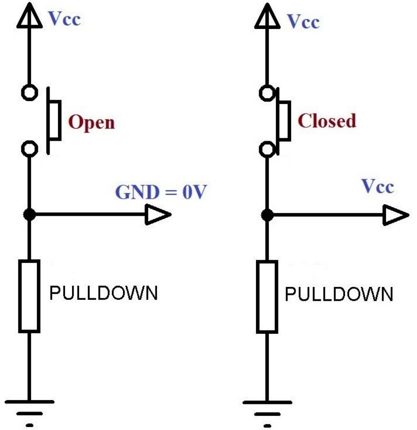
Input Mode:

NoPull: Floating input
PullDown: The input is set to logic low (0)
PullUp: The input is set to logic High (1)

PullUP



PullDown



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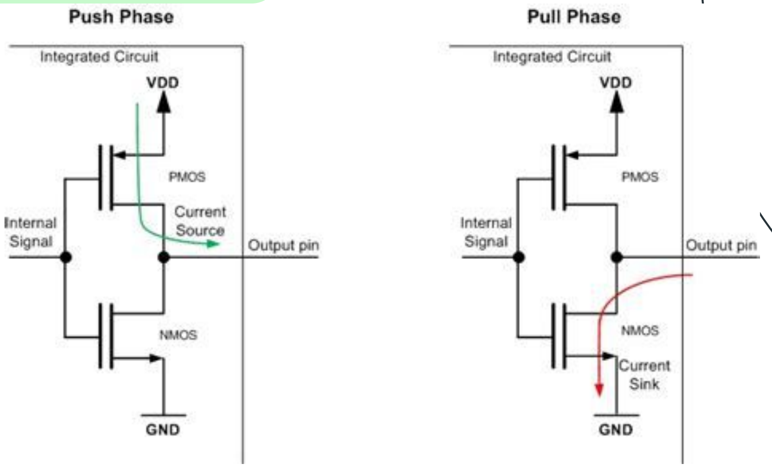
STM32 GPIO : GPIO Modes

Output Mode:

PushPull: Drives the pin to output a steady and stable voltage (3.3v).
Used for devices that doesn’t exceed the maximum output voltage that the stm32 can support
Example: Powering and LED, sensor



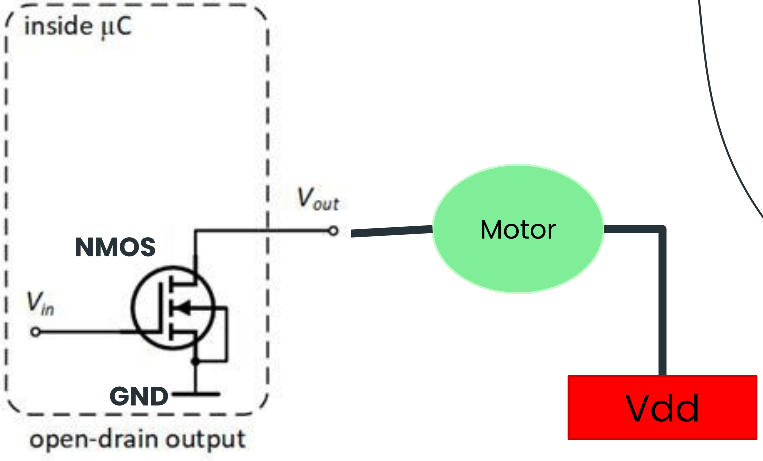
- It contains 2 transistors: **PMOS** and **NMOS**, They both act as switches letting current in and out.
- The **PMOS** is **ON** when he gets a **LOGIC 0,** hence he lets current pass form **Vdd** to the **output pin (3.3V).**
- The **NMOS** is **ON** when he gets **LOGIC 1**, hence connecting the **GND** the the **output pin (0V)**.

NOTE: Only one transistor works at a time, so when the **PMOS** is **ON** the **NMOS** is **OFF** and vice versa.

STM32 GPIO : GPIO Modes

Output Mode:

OpenDrain: Drives the pin Low (0V).
Used when there is a external energy Source (**Vdd**)
Example: Motor control, or controlling and LED or sensors that needs higher than (3.3V) to work.

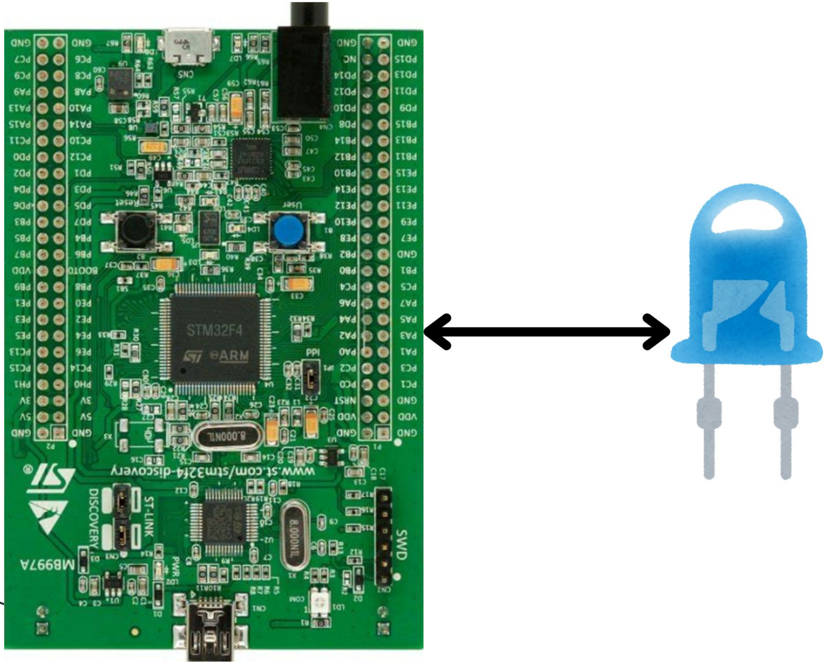


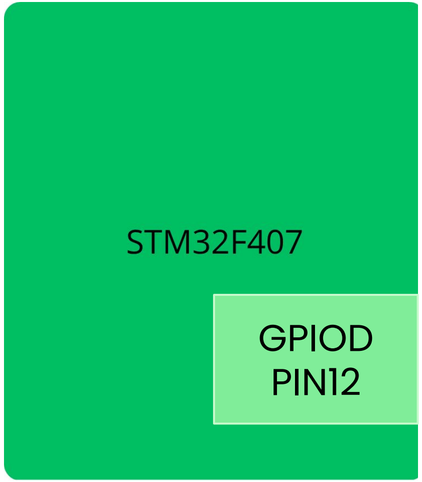
open-drain output

- It contains 1 transistors: **NMOS**:
- The **NMOS** is **ON** when he gets **LOGIC 0**, hence connecting the **GND** the the **output pin (0V)**, the circuit closes and the motor spins.
- **LOGIC 1** closes the circuit and the **NMOS** is **OFF**.

Programming:

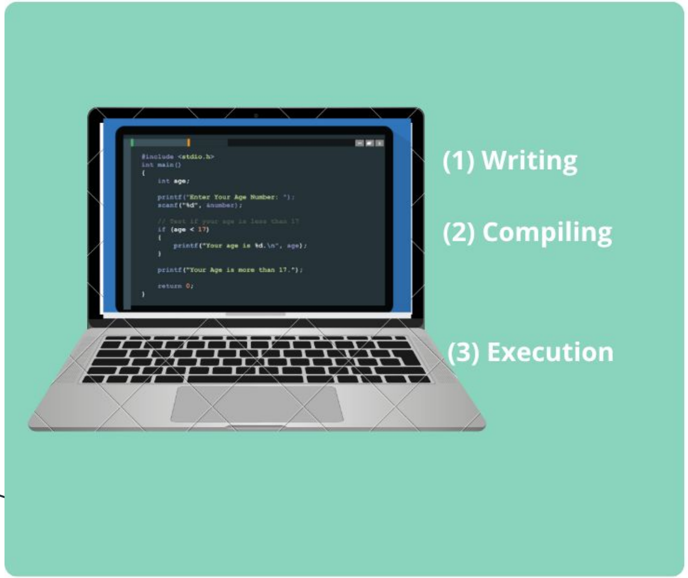
Toggling an LED connected in PD12





Programming:

Software Engineer



```
#include <stdio.h>
int main()
{
    int age;

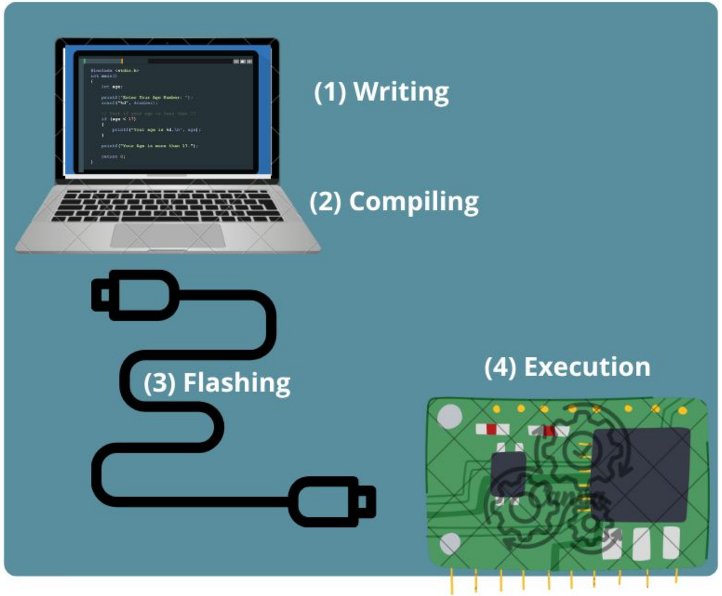
    printf("Enter Your Age Number: ");
    scanf("%d", &number);

    // Test if your age is less than 17
    if (age < 17)
    {
        printf("Your age is %d.\n", age);
    }

    printf("Your Age is more than 17.");

    return 0;
}
```

Embedded systems Engineer



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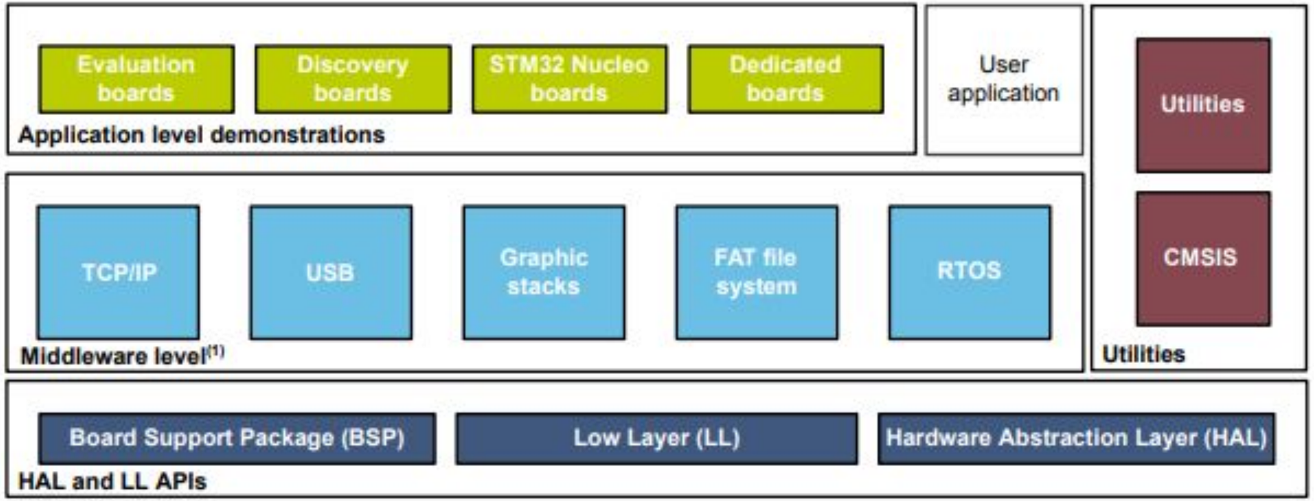
}
```

Writing the Software: HAL

STM32CubeF4 package: Github Link



Writing the Software: HAL

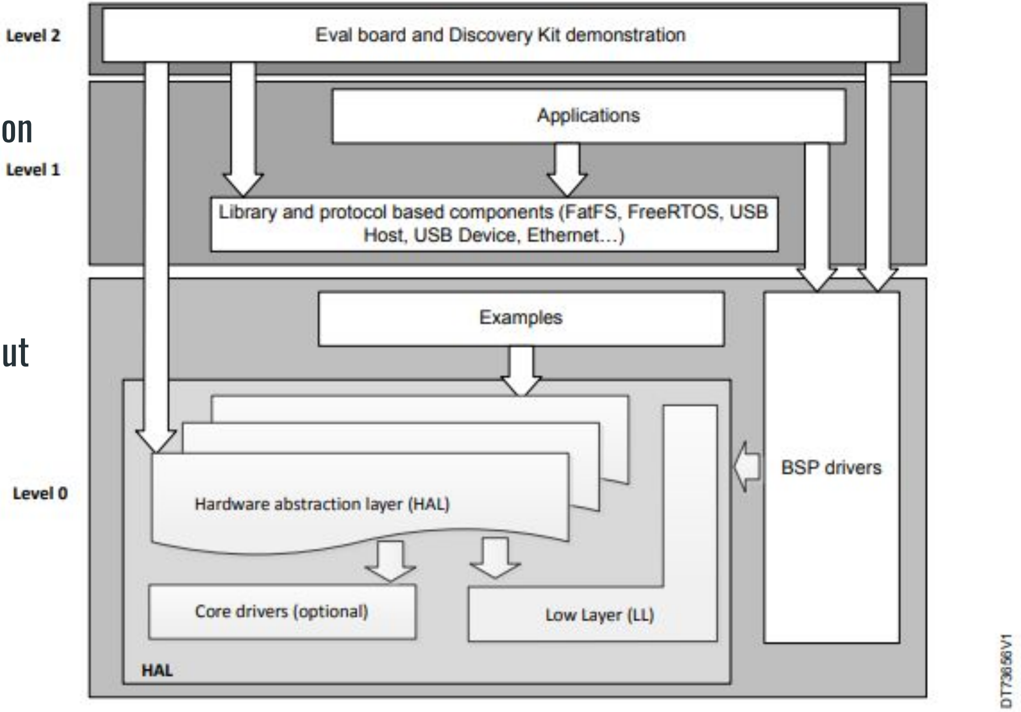
Level 0: Hardware Interaction
This is the foundation that talks directly to the MCU and board components.

BSP (Board Support Package): Drivers for components on the board (LEDs, buttons, LCD screen). Example: BSP_LED_On().

HAL (Hardware Abstraction Layer): Easy & Portable. Generic APIs to use MCU peripherals (like UART, I2C) without deep register knowledge. Uses interrupts/DMA for you.

LL (Low-Layer): Lean & Fast. Lightweight, register-level drivers for experts who need maximum performance and minimal overhead.

Figure 2. **STM32CubeF4 firmware architecture**


Level 2
Eval board and Discovery Kit demonstration
Applications
Level 1
Library and protocol based components (FatFS, FreeRTOS, USB Host, USB Device, Ethernet...)
Examples
BSP drivers
Level 0
Hardware abstraction layer (HAL)
Core drivers (optional)
Low Layer (LL)
HAL
DT73658V1

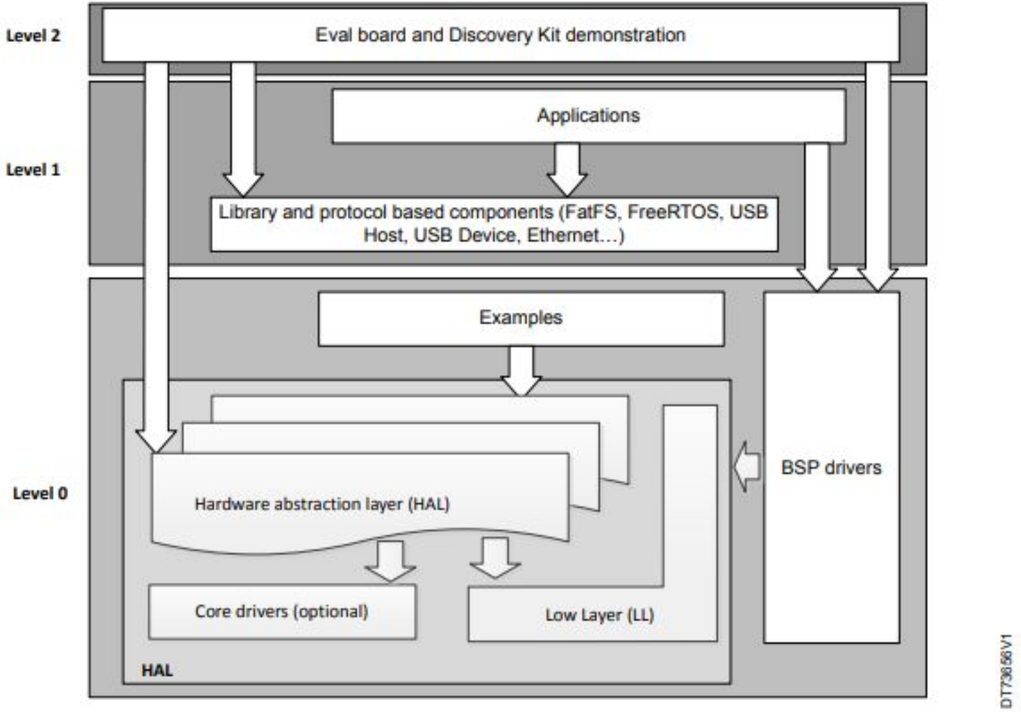
Writing the Software: HAL

Level 1: Middleware & Services
This level provides advanced software features that sit on top of the HAL/LL.
Libraries & Stacks: Ready-to-use components like:

- USB Host/Device libraries
- Graphics Libraries (STemWin, TouchGFX)
- Real-Time OS (FreeRTOS)
- File System (FatFS)
- TCP/IP Network Stack (LwIP)
- SSL/TLS Security (mbedTLS)

Level 2: Final Application
This is the top level, where everything comes together.

Figure 2. STM32CubeF4 firmware architecture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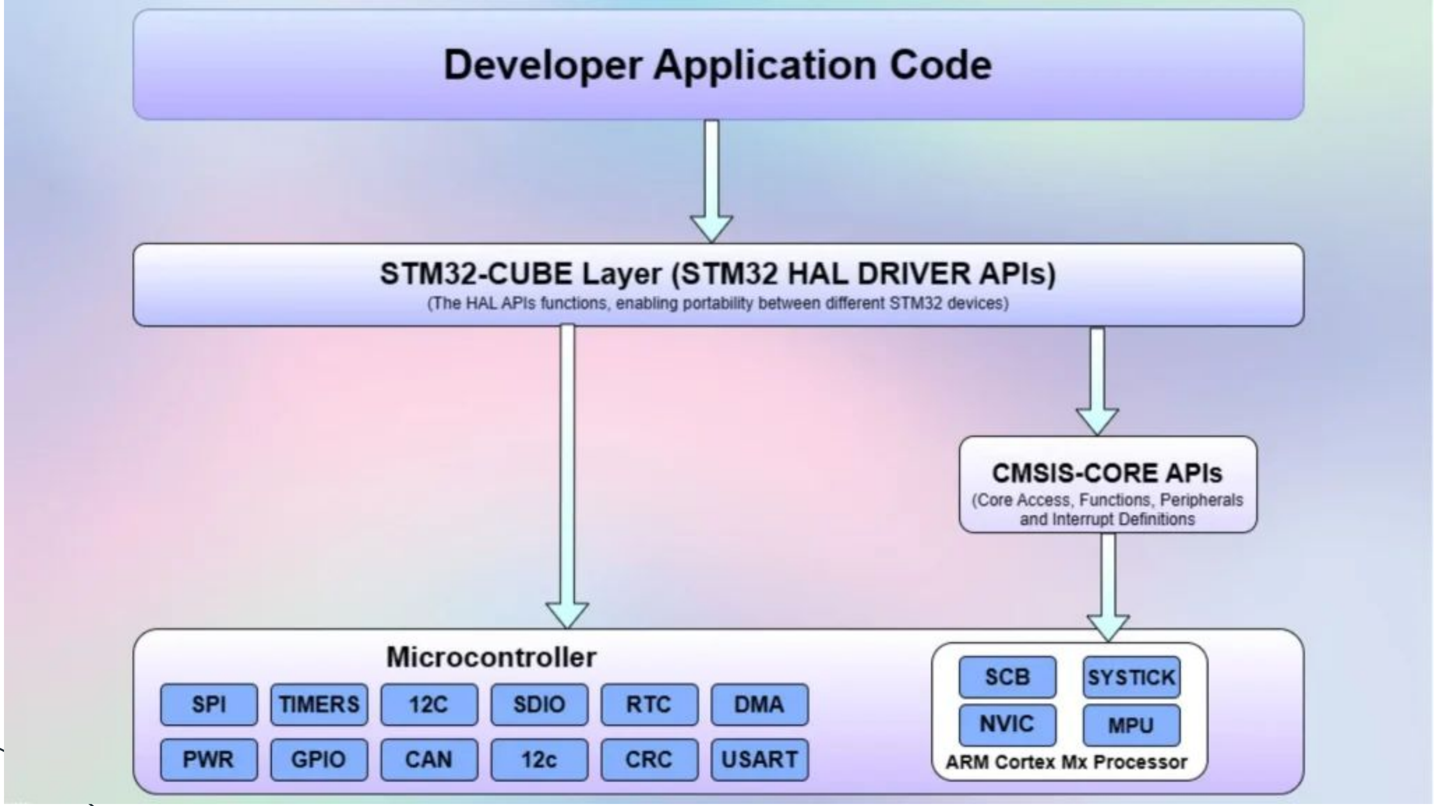
Core drivers (optional)
Low Layer (LL)
HAL
DT73656V1

Writing the Software: HAL


Developer Application Code
STM32-CUBE Layer (STM32 HAL DRIVER APIs)
(The HAL APIs functions, enabling portability between different STM32 devices)
CMSIS-CORE APIs
(Core Access, Functions, Peripherals and Interrupt Definitions
Microcontroller
SPI
TIMERS
12C
SDIO
RTC
DMA
PWR
GPIO
CAN
12c
CRC
USART
SCB
SYSTICK
NVIC
MPU
ARM Cortex Mx Processor

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Thank You