Modul 2

Mikrokontroler dan Sistem Embedded

II2260 Sistem Embedded

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Pembahasan

1. Mikrokontroler: Pengertian dan Definisi
2. Pengembangan Sistem berbasis Mikrokontroler (Microcontroller Development Board)
3. Memilih mikrokontroler
4. Mikrokontroler ESP32

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2.1. Mikrokontroler

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What is a Microcontroller ?

Embedded System: Applications of Microcontroller

- microcontroller inside a TV takes input from the remote control and displays output on the TV screen. The controller controls the channel selector, the speaker system and certain adjustments on the picture tube electronics such as tint and brightness
- The engine controller in a car takes input from sensors such as the oxygen and knock sensors and controls things like fuel mix and spark plug timing.
- A microwave oven controller takes input from a keypad, displays output on an LCD display and controls a relay that turns the microwave generator on and off.

Image taken from https://www.vlsifacts.com/different-applications-microcontroller/

Apa itu Mikrokontroler

- Microcontroller is a computer
- **Microcontroller are special purpose computer**. Do one thing well.
- Berbeda dengan mikroprosesor pada general purpose computer (MPU) yang merupakan sebuah IC dengan CPU saja di dalamnya
- Mikrokontroler (MCU) merupakan sebuah **komputer mini dalam sebuah chip**, sehingga ada CPU, ROM, RAM, dan lain-lain

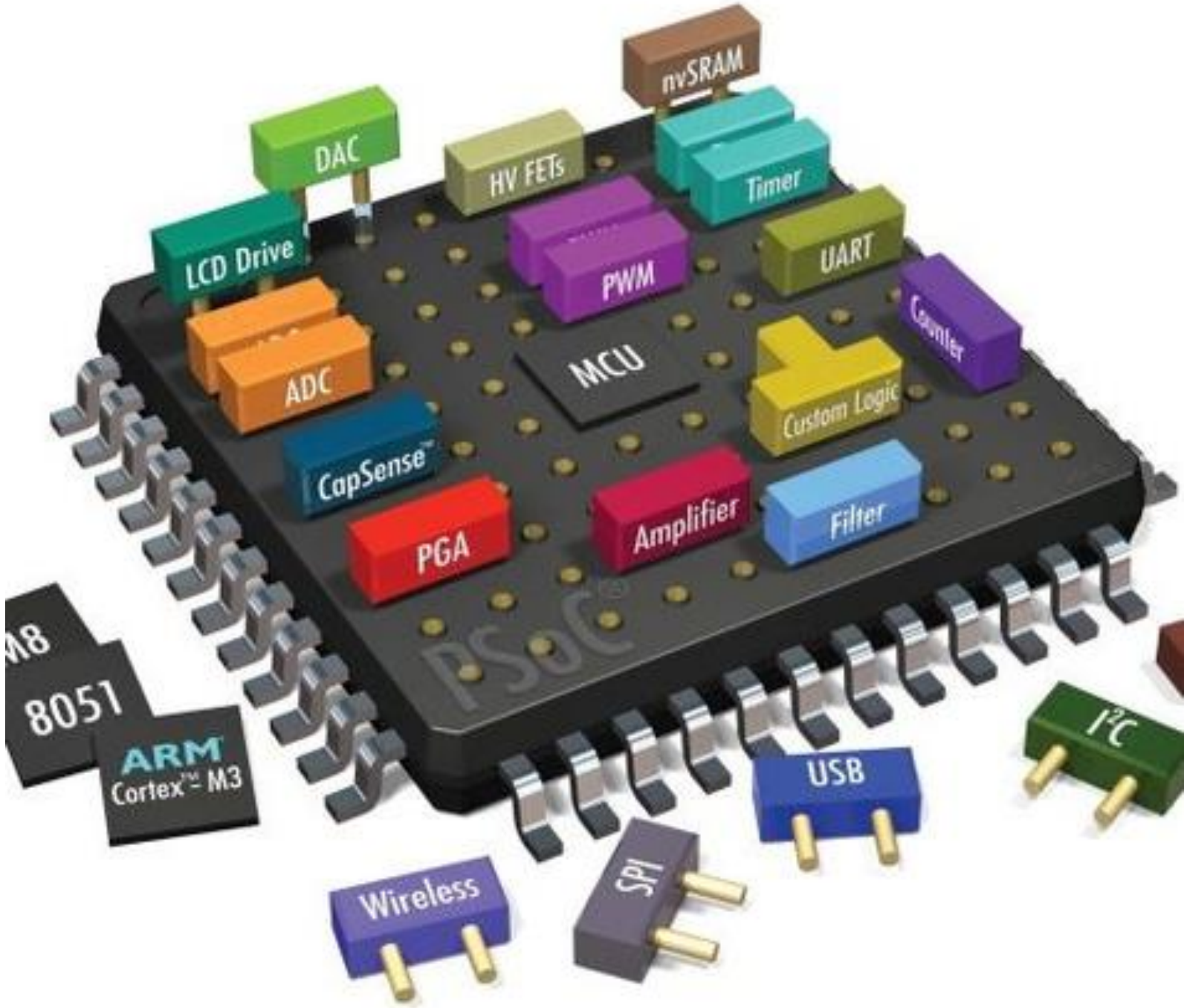
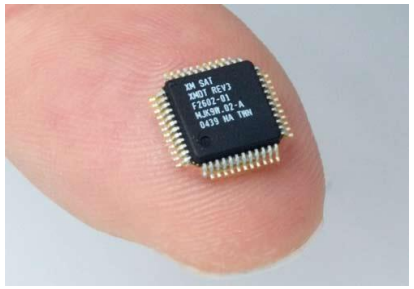
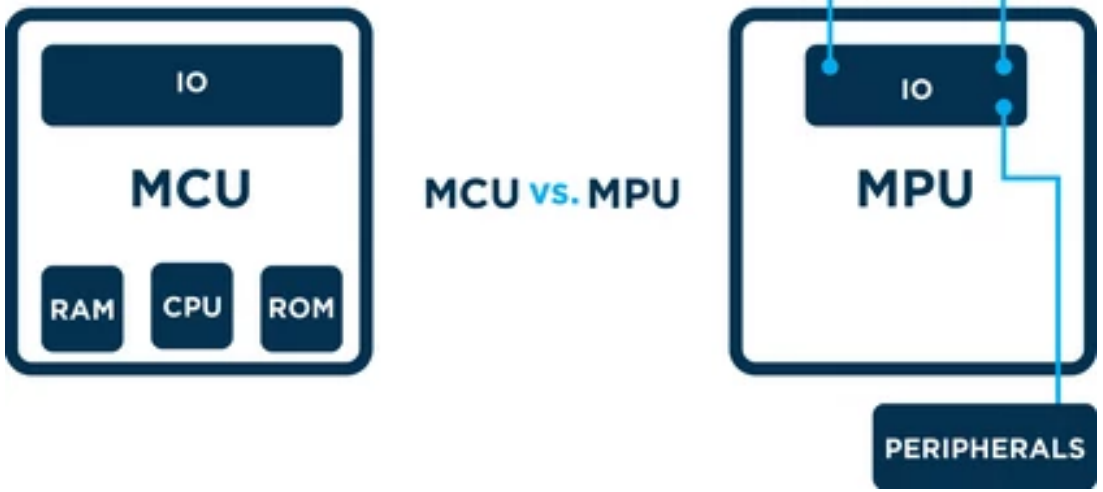


Image taken from https://www.indiamart.com/proddetail/embedded-systems-17697681388.html

Single Chip Computer vs Single Board Computer





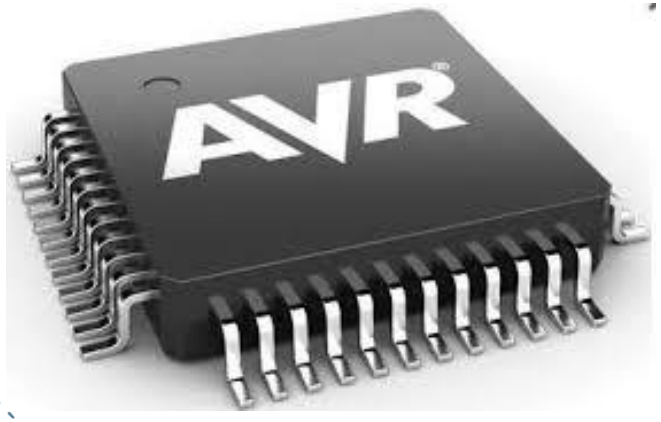
- Computer system on one chip (also called microcontroller unit/MCU)
- Computer system on single circuit board (microprocessor/ MPU, memory, input/output I/O on separate components)

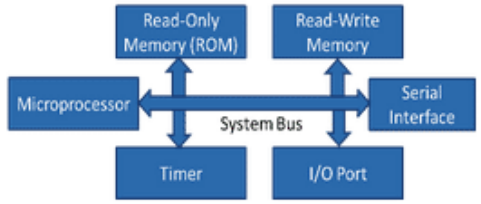
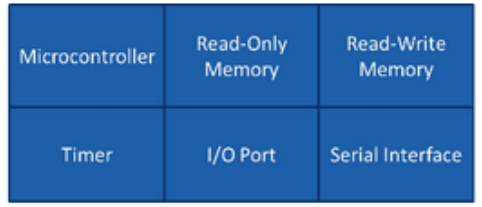
Characteristics of Microcontroller

A computer will be called “microcontroller” if it meets several characteristics:

- Microcontroller are “**embedded**” inside some other device (often a consumer product). They can control the features or actions of the product. Embedded controller.
- Microcontroller are **dedicated** to one task and run one specific program.
- Microcontroller has a **dedicated input devices** and often has a **small display output**. Take input from the device it is controlling and controls the devide by sending signals to different components in the device.
- Microcontroller are often **low-power devices**. A battery-operated.
- Microncontroller is often **small and low cost**.
- A microcontroller is often **ruggedized** in some way. Has to work in extreme environment that a normal computer generally cannot handle. Exp. car’s microcontroller

MPU vs MCU



Microprocessor	Micro Controller
	
Microprocessor is heart of Computer system.	Micro Controller is a heart of embedded system.
It is just a processor. Memory and I/O components have to be connected externally	Micro controller has external processor along with internal memory and i/O components
Since memory and I/O has to be connected externally, the circuit becomes large.	Since memory and I/O are present internally, the circuit is small.
Cannot be used in compact systems and hence inefficient	Can be used in compact systems and hence it is an efficient technique
Cost of the entire system increases	Cost of the entire system is low
Due to external components, the entire power consumption is high. Hence it is not suitable to used with devices running on stored power like batteries.	Since external components are low, total power consumption is less and can be used with devices running on stored power like batteries.
Most of the microprocessors do not have power saving features.	Most of the micro controllers have power saving modes like idle mode and power saving mode. This helps to reduce power consumption even further.
Since memory and I/O components are all external, each instruction will need external operation, hence it is relatively slower.	Since components are internal, most of the operations are internal instruction, hence speed is fast.
Microprocessor have less number of registers, hence more operations are memory based.	Micro controller have more number of registers, hence the programs are easier to write.
Microprocessors are based on von Neumann model/architecture where program and data are stored in same memory module	Micro controllers are based on Harvard architecture where program memory and Data memory are separate
Mainly used in personal computers	Used mainly in washing machine, MP3 players

Taken from https://electronicsforu.com/resources/difference-between-microprocessor-and-microcontroller

RISC and CISC Architecture

- **RISC** is a **reduced instruction set computer**, which is able to perform **more instructions with lower cycles** than a **CISC** architecture (**complex instruction set computer**). CISC processors include the Intel x86 and 8051, Motorola 68000 and Zilog Z80 families.
- **RISC processors are common in embedded** or smaller systems that use a small set of simple and general instructions. RISC include ARM stands for Advanced RISC Machine, AVR is a family of microcontrollers developed by Atmel (AVR are most commonly used in the Arduino), PIC stands for Peripheral Interface Controller.

List of Common Microcontrollers

- Analog Devices : Blackfin, SHARC
- Atmel : AT89 series, ATmega series, AVR32
- Maxim Integrated : 8051 family, MIPS 4kSD
- Espressif Systems : ESP8266, ESP32
- Intel : MCS-51 family, MCS-96 family
- Microchip Technology : PIC Series
- NXP Semiconductor : ARM7, ARM9, ARM Cortex
- Nuvoton Technology : 8051 MCU, ARM Cortex
- Parallax : Basic Stamp, Propeller
- Silicon Laboratories : C8051, ARM Cortex
- ST Microelectronics : ARM7, ARM9, ARM Cortex
- Texas Instruments : TMS320 DSP, TMS570 ARM Cortex
- etc ..

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2.2. Microcontroller Development Board

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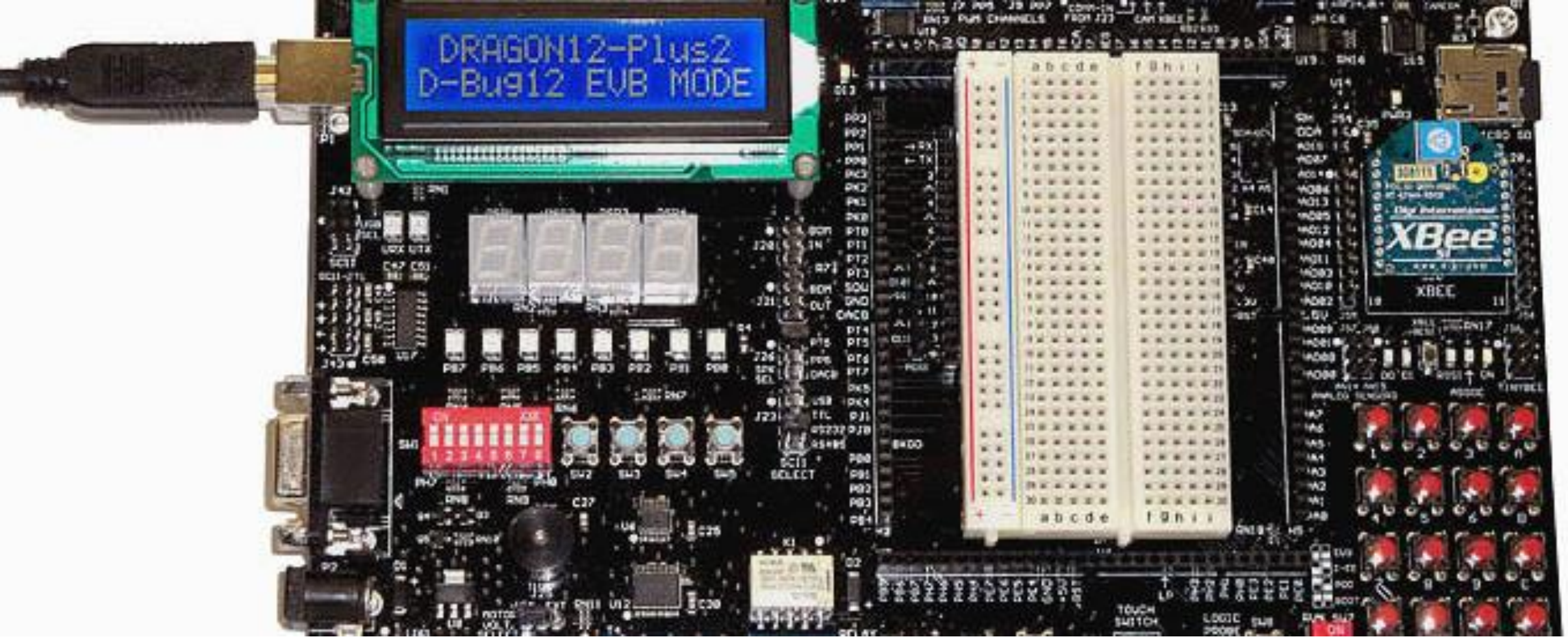
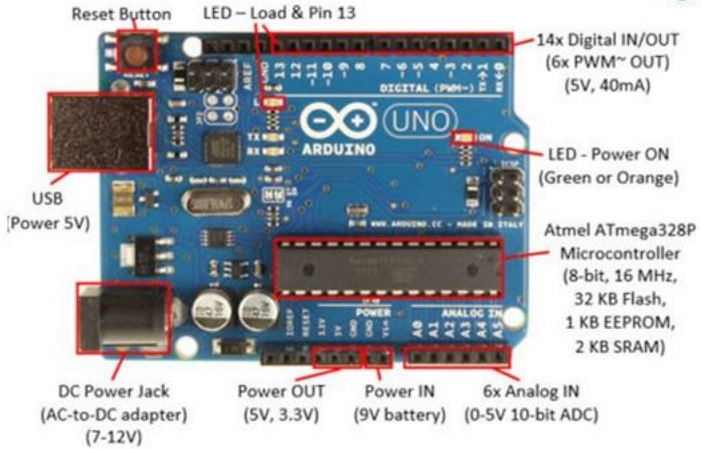


Microcontroller Development Board

- A **development board** is a printed circuit board containing a microcontroller and the minimal support logic needed for a computer engineer to prototype applications in products.

Arduino

- Arduino project was started at 2005
- Broadly used Microcontroller development board
- Arduino is an open-source electronics platform based on easy-to-use hardware and software
- It's intended for anyone making interactive projects.
- https://www.arduino.cc/



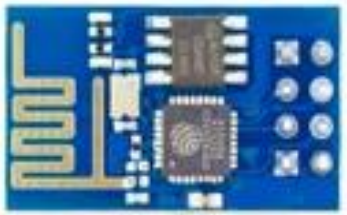
Arduino Development Board

ESP8266

- **Modul ESP8266** merupakan platform yang sangat murah tetapi benar-benar efektif untuk digunakan berkomunikasi atau kontrol melalui internet baik digunakan secara standalone (berdiri sendiri) maupun dengan menggunakan mikrokontroler tambahan dalam hal ini Arduino sebagai pengendalinya.
- Di pasaran ada beberapa tipe dari **keluarga ESP8266** yang beredar, tetapi yang paling banyak dan mudah dicari di Indonesia yaitu tipe ESP-01, ESP-07, dan ESP-12.
- Untuk secara fungsi hampir sama tetapi perbedaannya terletak pada pin **GPIO** (*General Purpose Input Output*) pada masing – masing tipe.
- Modul ini tergolong ***StandAlone*** atau ***System on Chip*** yang tidak selalu membutuhkan mikrokontroler untuk mengontrol Input Ouput yang biasa dilakukan pada Arduino dikarenakan ESP-01 dapat bertindak sebagai mini komputer, tetapi dengan kondisi jumlah GPIO yang terbatas.

Keluarga Module ESP8266

ww.nyebarilmu.com



ESP-01

ESP-02

ESP-03

ESP-04

ESP-05

ESP-06

ESP-07

ESP-08

ESP-09

ESP-10

ESP-11

ESP-12

ESP-12E

ESP-12F

ESP-12S

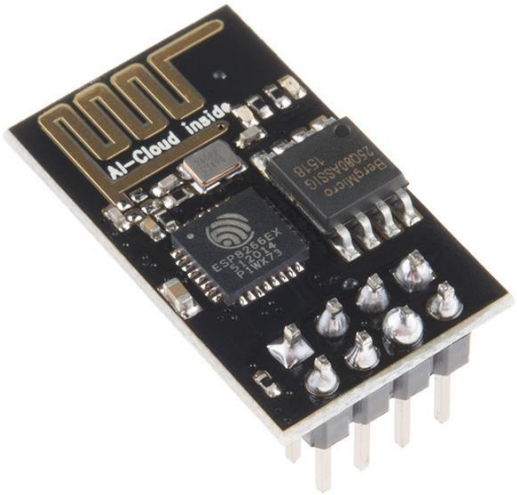
ESP-13

ESP-14

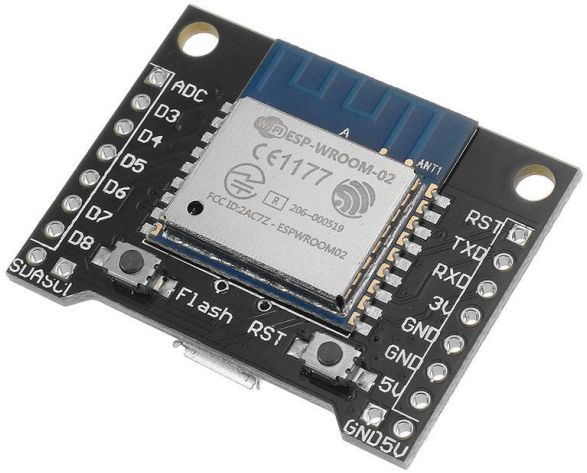
ESP-WROOM-02

ESP-WT8266-S1

ESP8266



ESP-01 module by Ai-Thinker, 2014



ESP-WROOM-02, the series of ESP8266-based modules made by Espressif

EPS8266 NodeMCU Development board. Use the ESP-12 module; includes USB to serial interface.

ESP32 Development Board

- ESP32 Development board adalah low-footprint, breadboard-friendly, minimum system development board (https://www.espressif.com/en/products/hardware/esp32/overview)
- Board ini powered by the ESP32-WROOM-32 module (https://circuits4you.com/2018/12/31/esp32-devkit-esp32-wroom-gpio-pinout/)

ESP32 vs Arduino Uno

Feature	Arduino Uno	ESP32
Processor	ATmega328P - 8-bit AVR family microcontroller, 8-11 MIPS	Xtensa® dual (or single)-core 32-bit LX6 microprocessor(s), up to 600 MIPS
Operating Voltage	5V	3.3V
Analog Input Pins	6 (A0 – A5)	12-bit SAR ADC up to 18 channels
Analog Output	-	2 × 8-bit DAC
Digital I/O Pins	14	34 × programmable GPIOs
Flash Memory	32 KB (0.5 KB is used for Bootloader)	QSPI supports multiple flash
SRAM	2 KB	520 KB
EEPROM	1 KB	448 KB
Frequency (Clock Speed)	16 MHz	160/240 MHz
Wired Communication	UART, I2C, SPI	UART, I2S, I2C, SPI, etc
Wireless Communication	none	WiFi, Bluetooth, BLE

Specifications	Arduino	ESP8266	ESP32
Processor	8-bit 20 MHz	32-bit Single Core 80MHz	32-bit Dual Core 160 - 240MHz
MCU	Atmega 328	Xtensa Single-core 32-bit L106	Xtensa Dual-Core 32-bit LX6
Clock speed	16 MHz	80 MHz	160 - 240 MHz
SRAM	2 kB	160 KB	512 KB
ROM / EEPROM	1 kB		448 KB
Flash Memory	32 kB	SPI Flash	4 MB and SPI Flash
Input Output pin	14 digital I/O, 6 analog input	17 GPIO	36 GPIO
PWM		8 channels	16 channels
Wireless	n/a	802.11 b/g/n Wi-Fi HT20	802.11 b/g/n Wi-Fi HT40 (faster), Bluetooth 4.2, BLE
Working Voltage	5 V	3.3V	3.3V
SPI/I2C/I2S/UART	SPI, I2C, UART	2/1/2/2	4/2/2/2
ADC	10 bit	10 bit	18 channel/ 12 bit
Internal Sensor	n/a	n/a	touch sensor, hall-effect sensor, temperature sensor

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2.3. Memilih Mikrokontroler

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How to Choose a Microcontroller

There are thousands of microcontrollers on offer and it's a daunting task trying to choose the right one

Choosing the Right Microcontroller

Few key questions to aid in choosing the right microcontroller:

1. What is the application?
2. 8bit, 16bit or 32bit?
3. What processor? 8051, ARM, PIC, or AVR?
4. What's the operating voltage?
5. What package size is needed?
6. What communication interfaces are needed and how many?
7. How much memory is needed? (including program memory and data memory)

1. What is the application?

Will the application need a lot of processing? Can this processing be done in an 8 bit microcontroller? How complex is the design?

- If the design needs to perform numerous calculations, more memory may be needed.
- Performing an FFT on an audio signal will require more RAM, greater sampling rates and high-resolution ADCs, as well as other features.
- Taking a temperature reading and sending commands over UART are relatively light weight and much smaller microcontrollers can be used with less memory.
- The application dictates which type of microcontroller and the features. Some common applications include wearables, automotive, industrial, smart home/energy and the internet of things.

2. Bit Size? 8-bit, 16-bit and 32-bit

- Usually **8-bit microcontrollers tend to be lower cost, lower power and faster control**, but technological advancements mean 16-bit and 32-bit microcontrollers can now compete with each other.
- An 8-bit microcontroller will be **sufficient when communicating with low speed buses**, taking sensor measurements or even controlling a buzzer. **However, it will have a lot of trouble trying to control an LCD touch screen** or Ethernet interface. This is where a 32-bit microcontroller will excel.

3. ARM/AVR/PIC/8051 Architecture

- There are a few **different microcontroller architectures** available on the market including the 8051, ARM, AVR and the PIC. Microchip's PICs have been around a long time. Atmel's AVR microcontrollers have been popularized through the Arduino development platform. ARM processors are newer, faster and have been adopted by NXP Semiconductors, Texas Instruments and STMicroelectronics.
- **The major differences focus around how they operate at the lower level**. While 8051, AVR and PIC all have offerings in 8-bit, 16-bit and 32-bit, the ARMs generally come in 32-bit and even 64-bit. The 8051, AVR and PIC work closer with the I/O peripherals and can be lower power and faster as a result.

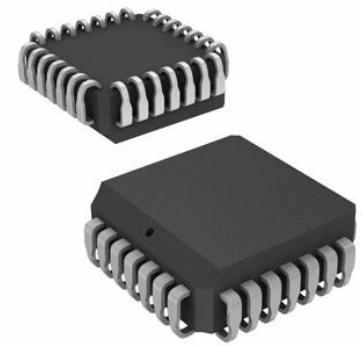
4. The Operating Voltage

- This is generally one of two options, but still important to note. **Microcontrollers generally operate at either 3.3V or 5V**.
- If the microcontroller is powered from 3.3V and other devices in the system that communicate with the microcontroller operate at 5V, then **level translation** may be necessary, which complicates the circuit and adds extra cost. It is good practice to try and keep everything in the one voltage domain.

5. Package Size

- If the project is to start off on a breadboard, then a **DIP package** will be necessary. This isn't usually available for many of the microcontrollers. Alternatively, **SOIC, SSOP and TSSOP** parts are relatively easy enough to solder by hand, where **QFN, QFP and BGA/LGA** devices need proper reflow to assemble.

28,40-pin DIP



28,44,68,84- pin PLCC

32,44,80,100-pin QFP

6. Communication interfaces are needed?

This comes back to the application and the devices added to the circuit.

- A serial EEPROM may need a **I2C or SPI** interface.
- Other devices may require **UARTs/USART/EUSARTs** for serial communication.
- Some displays require **parallel interfaces**, which can be pin heavy.

It’s good to scope out the various devices in the circuit first to gauge what is needed.

7. How much memory is needed?

- Again, this is application dependent. Will the project need a lot of local processing or will it perform very basic tasks? There are different memory types available in each microcontroller. These are usually **volatile memory**; RAM and ROM. There are a few microcontrollers that have **non-volatile memory EEPROMs** as well. It can be difficult to gauge how much of each is needed at first and takes some experience to get the hang of it. This is also dictated by the bit size mentioned earlier.
- It's important to note the difference between program and data memory. Program memory is where the compiled code will be stored and run from and the data memory is used during run time. If a lot of processing is needed, then more data memory will be needed. If the project needs to use look up tables or store a lot of pre-defined values, then larger program memory will be needed.

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2.4. Mikrokontroler ESP32

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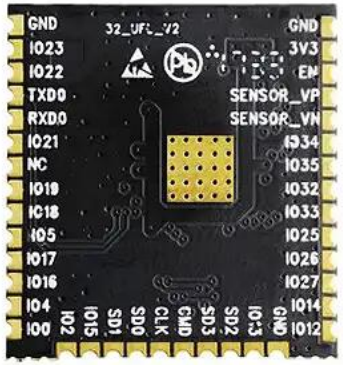
ESP32 Microcontroller



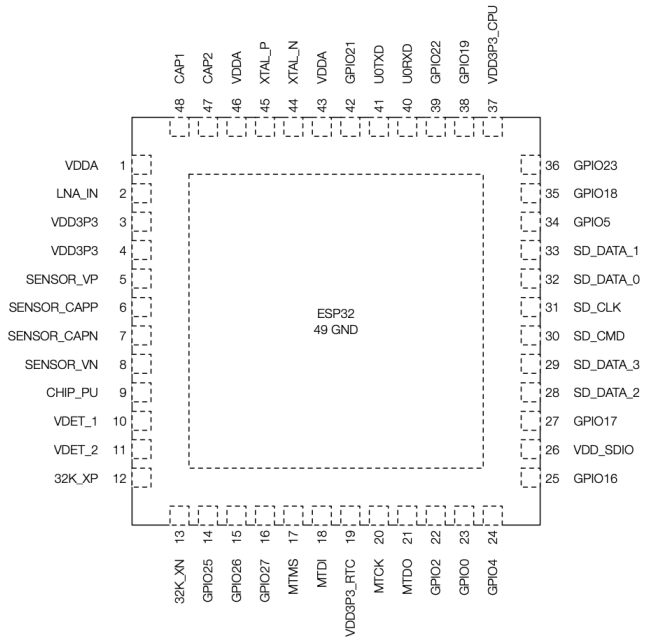
- ESP32 adalah SoC (System on Chip) microcontroller, dibuat oleh Espressif System (https://www.espressif.com/)
- Penerus dari ESP8266 yang selain memiliki fitur WiFi juga dilengkapi dengan Bluetooth, dan juga telah dual-core.

Fitur dan Spesifikasi ESP32

- **Processor**: mikroprosesor Tensilica Xtensa Dual-Core 32-bit LX6, Frekuensi clock hingga 240 MHz
- **WiFi**: 2.4GHz up to 150 Mbit/s
- **Bluetooth**: BLE (Bluetooth Low Energy) dan Bluetooth legacy.
- **ROM**: 448 KB
- **SRAM**: 512 KB
- **Low Power**: bercatu daya rendah, bahkan dapat menjalankan fungsi ADC dalam mode sleep

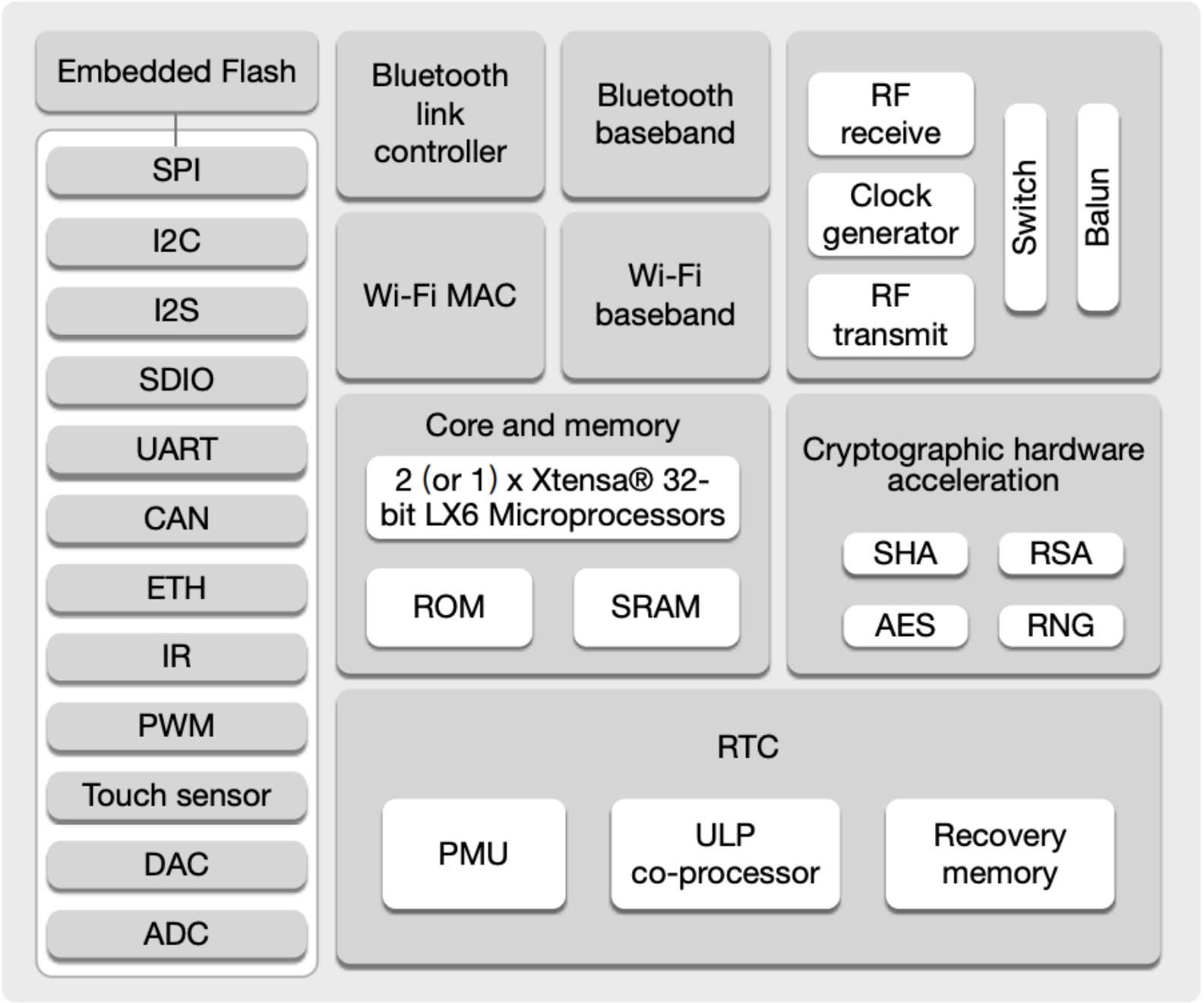
Fitur dan Spesifikasi ESP32

- **Peripheral Input/Output:** ADC (Analog-to-Digital Converter), DAC (Digital-to-Analog Converter), I²C (Inter-Integrated Circuit), UART (Universal Asynchronous Receiver/Transmitter), CAN 2.0 (Controller Area Network), SPI (Serial Peripheral Interface), I²S (Integrated Interchip Sound), RMII (Reduced Media-Independent Interface), dan PWM (Pulse-Width Modulation).
- **Built-in Sensor**: Hall-Effect Sensor, Temperature Sensor
- **Keamanan**: akselerator hardware untuk AES dan SSL/TLS

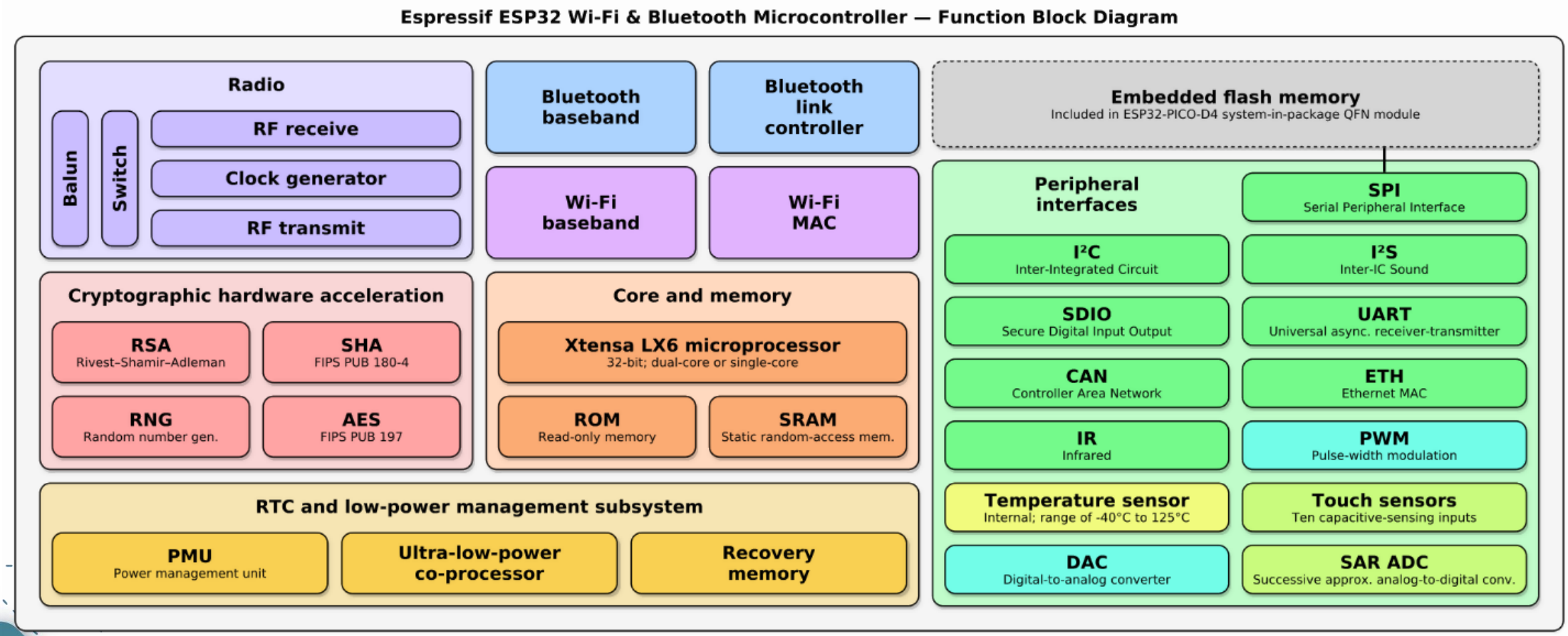

CAP1 48
CAP2 47
VDDA 46
XTAL_P 45
XTAL_N 44
VDDA 43
GPIO21 42
U0TXD 41
U0RXD 40
GPIO22 39
GPIO19 38
VDD3P3_CPU 37
VDDA 1
LNA_IN 2
VDD3P3 3
VDD3P3 4
SENSOR_VP 5
SENSOR_CAPP 6
SENSOR_CAPN 7
SENSOR_VN 8
CHIP_PU 9
VDET_1 10
VDET_2 11
32K_XP 12
ESP32
49 GND
36 GPIO23
35 GPIO18
34 GPIO5
33 SD_DATA_1
32 SD_DATA_0
31 SD_CLK
30 SD_CMD
29 SD_DATA_3
28 SD_DATA_2
27 GPIO17
26 VDD_SDIO
25 GPIO16
13 32K_XN
14 GPIO25
15 GPIO26
16 GPIO27
17 MTMS
18 MTDI
19 VDD3P3_RTC
20 MTCK
21 MTDO
22 GPIO2
23 GPIO0
24 GPIO4

Pin Layout

B


Embedded Flash
SPI
I2C
I2S
SDIO
UART
CAN
ETH
IR
PWM
Touch sensor
DAC
ADC
Bluetooth link controller
Bluetooth baseband
Wi-Fi MAC
Wi-Fi baseband
RF receive
Clock generator
RF transmit
Switch
Balun
Core and memory
2 (or 1) x Xtensa® 32-bit LX6 Microprocessors
ROM
SRAM
Cryptographic hardware acceleration
SHA
RSA
AES
RNG
RTC
PMU
ULP co-processor
Recovery memory

ESP32 Functional Block Diagram



ESP32 Development Board

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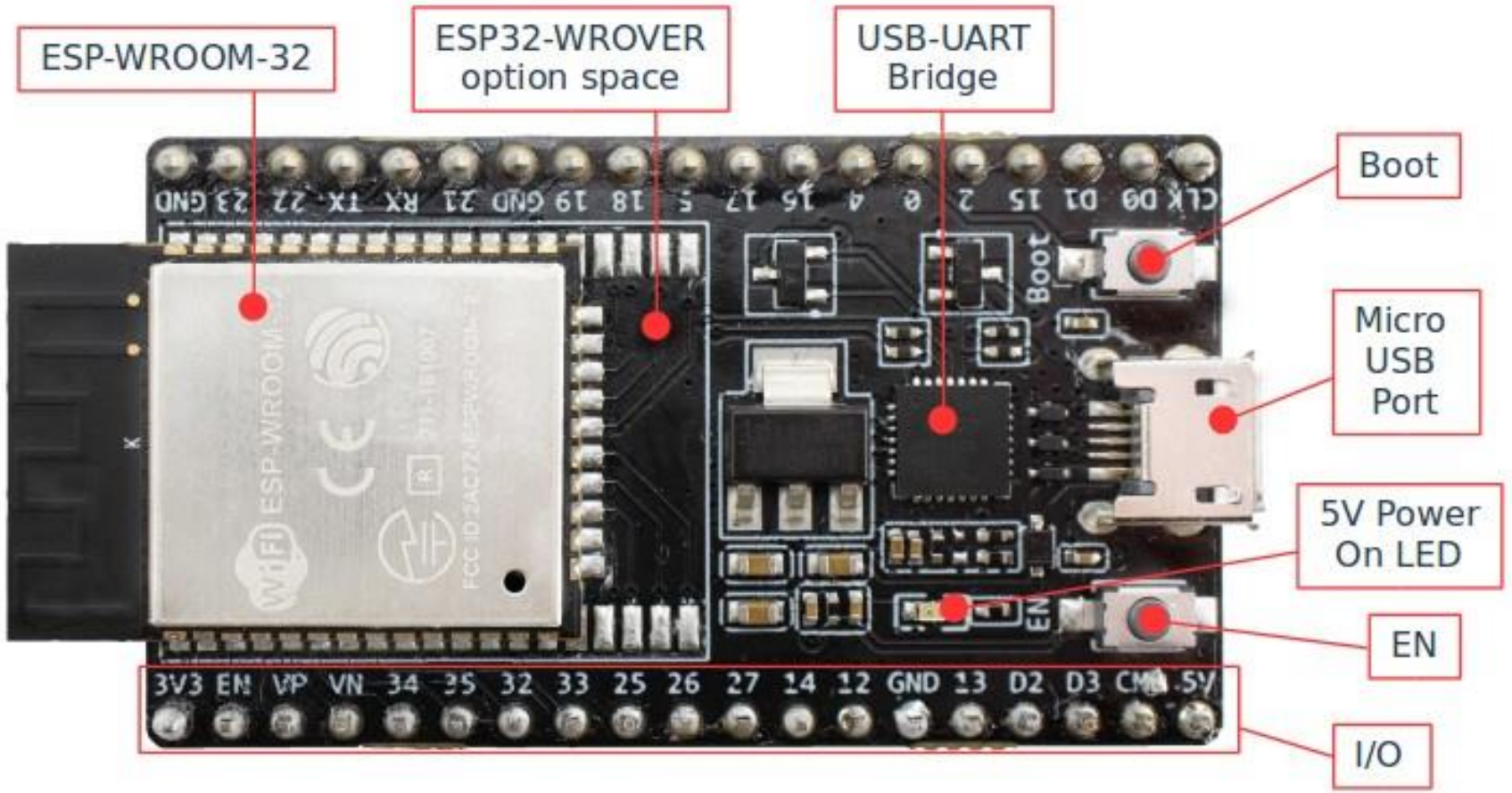


Contoh ESP32 Development Board

DOIT DEVKIT V1

ESP32 DevKit

ESP-32S NodeMCU

ESP32 Thing

WEMOS LOLIN32

"WeMos" OLED

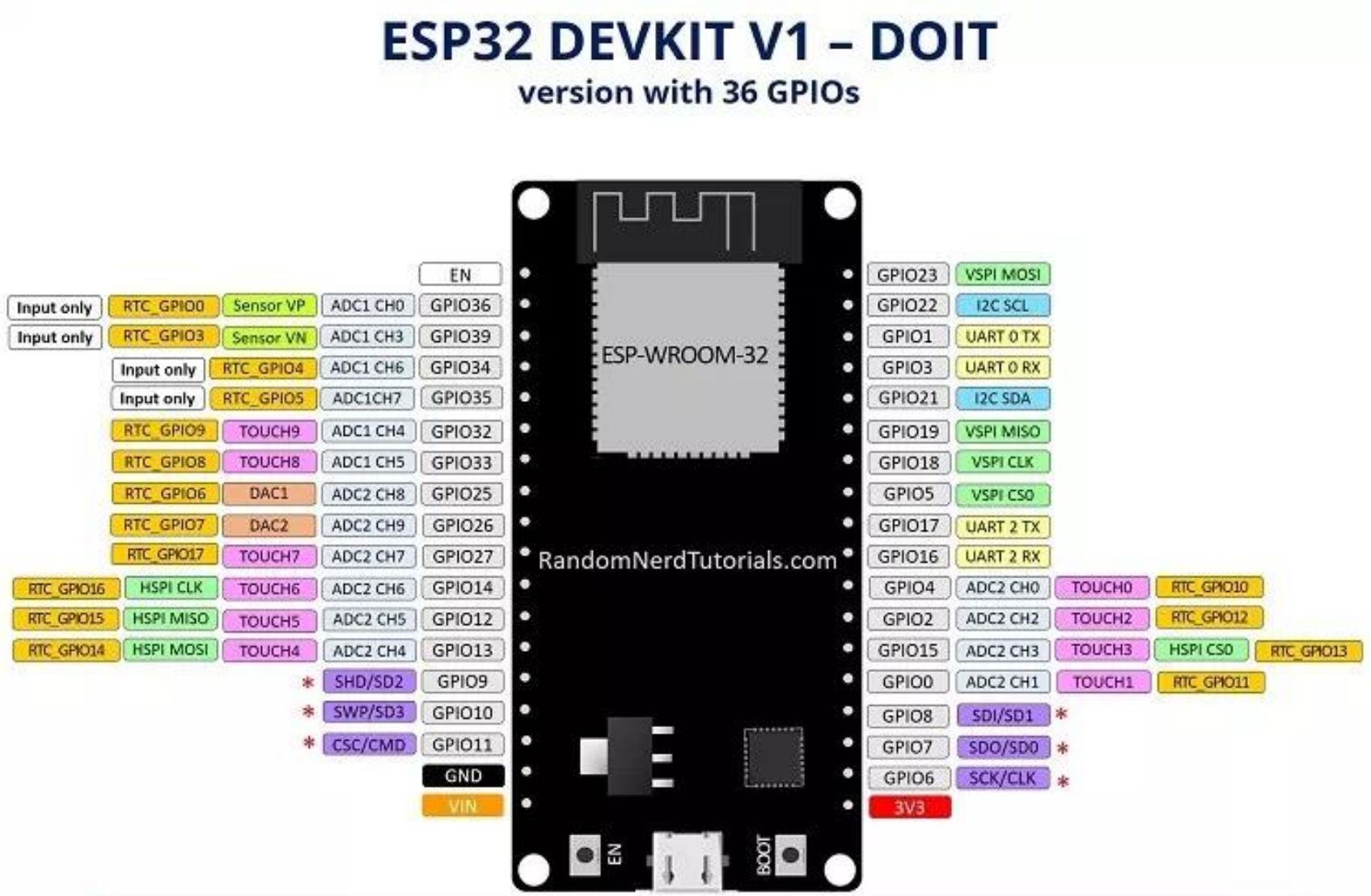
HUZZAH32

(...)

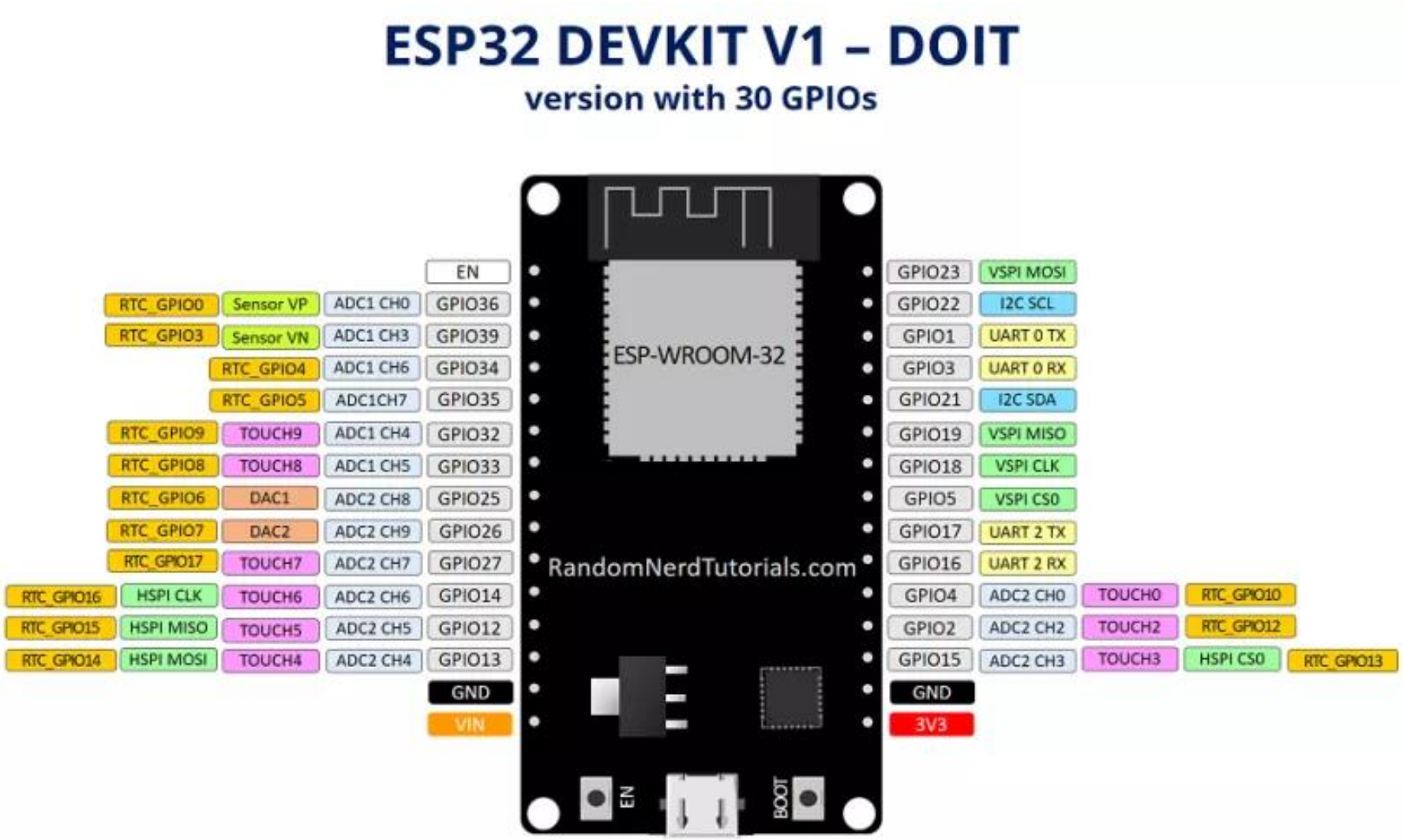
How to Select ESP32 Development Board

- **Pin configuration** and number of pins. To properly use the ESP32 in your projects you need to have access to the board pinout. Make sure you have access to the board pinout you're getting.
- **USB-to-UART interface** and **voltage regulator circuit**. Most full-feature development boards have these two features.
- **BOOT** and **RESET** buttons.
- **Battery connector**. If you want to power your ESP32 using batteries, there are development boards that come with connectors for liPo batteries.
- **Extra features**. There are ESP32 development boards with extra features like an OLED display, a LoRa module or a camera.

ESP32 DevKit DOIT (36 pin)



ESP32 DevKit DOIT (30 pin)



ESP-32S NodeMCU (38 pin)

ESP32 Dev Board PINMAP

					3.3V		GND						
(pu)				RESET	EN		GPIO23	VSPI MOSI					SPI MOSI
SVP			ADC0		GPIO36		GPIO22						Wire SCL
SVN			ADC3		GPIO39		GPIO1	TX0					Serial TX
			ADC6		GPIO34		GPIO3	RX0					Serial RX
			ADC7		GPIO35		GPIO21						Wire SDA
		TOUCH9	ADC4		GPIO32		GND						
		TOUCH8	ADC5		GPIO33		GPIO19	VSPI MISO					SPI MISO
DAC1			ADC18		GPIO25		GPIO18	VSPI SCK					SPI SCK
DAC2			ADC19		GPIO26		GPIO5	VSPI SS				(pu)	SPI SS
		TOUCH7	ADC17		GPIO27		GPIO17						
	TMS	TOUCH6	ADC16	HSPI SCK	GPIO14		GPIO16						
(pd)	TDI	TOUCH5	ADC15	HSPI MISO	GPIO12		GPIO4		ADC10	TOUCH0		(pd)	
					GND		GPIO0	BOOT	ADC11	TOUCH1		(pu)	
	TCK	TOUCH4	ADC14	HSPI MOSI	GPIO13		GPIO2		ADC12	TOUCH2		(pd)	
				FLASH D2	GPIO9		GPIO15	HSPI SS	ADC13	TOUCH3	TDO	(pu)	
				FLASH D3	GPIO10		GPIO8	FLASH D1					
				FLASH CMD	GPIO11		GPIO7	FLASH D0					
					5V		GPIO6	FLASH SCK					

ESP32 Development Board

- Pada DEVKIT DOIT terdapat 2 versi board dengan 30 atau 36 GPIO.
- Pada ESP32S NodeMCU terdapat 38 pin GPIO.
- Setiap board dilengkapi dengan tombol on-board REST (EN) dan BOOT
- Board dilengkapi interface USB-to-UART untuk komunikasi dengan PC (untuk memprogram ESP32)
- Terdapat rangkaian regulator tegangan sehingga board dapat dicatu dengan konektor microUSB

esp32.net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ESP32-D0WDQ6
322016
P6W255
the INTERNET of THINGS with ESP32
Features/Specs
Community
Readings/Videos
Development
Hardware
Purchasing
Created by Espressif Systems, ESP32 is a low-cost, low-power system on a chip (SoC) series with Wi-Fi & dual-mode Bluetooth capabilities! The ESP32 family includes the chips ESP32-D0WDQ6 (and ESP32-D0WD), ESP32-D2WD, ESP32-S0WD, and the system in package (SiP) ESP32-PICO-D4. At its heart, there's a dual-core or single-core Tensilica Xtensa LX6 microprocessor with a clock rate of up to 240 MHz. ESP32 is highly integrated with built-in antenna switches, RF balun, power amplifier, low-noise receive amplifier, filters, and power management modules. Engineered for mobile devices, wearable electronics, and IoT applications, ESP32 achieves ultra-low power consumption through power saving features including fine resolution clock gating, multiple power modes, and dynamic power scaling.
For news and information, follow @ESP32net on Twitter!

Programming Environment

- **Arduino IDE**
- Espressif IDF (IoT Development Framework)
- Micropython (https://micropython.org/)
- JavaScript (Espruino https://www.espruino.com/ESP32)
- LUA
- ...

Pada modul ini akan menggunakan Arduino IDE