Intro To ESP8266/ESP32

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Microcontrollers

- Small, inexpensive, low power, runs cool, slow, highly integrated
- CPU, RAM, flash, GPIO (I2C, SPI, UART, digital, ADC, DAC)
- No or low speed (2.4GHz wifi, < 1Gbps ethernet) networking
- No USB (this is changing), Thunderbolt, HDMI, SSDs, PCI Express
- Light or no OS (linked in, not resident)
- No integrated human interface
- Examples: Arduino, ESP8266, ESP32, Nordic NRF*, STM32

General Purpose Computers (inc tablets & phones)

- Bigger, more expensive, power hungry, hotter
- CPU, RAM, storage,
- high speed (5GHz wifi, 1+Gbps ethernet, LTE) networking
- USB, Thunderbolt, HDMI, SSDs, PCI Express
- Heavy, resident OS that loads programs (Linux, macOS, Windows)
- Integrated human interface (connections, display, keyboard, shell)
- Examples: Intel Core, ARM, Snapdragon, PowerPC, MIPS

CPU Comparison

CPU	cores	speed	RAM	GPIO	Cost
Arduino Uno	1	16MHz	2KB	20	$23
Arduino nano	1	16MHz	32KB	22	$20
Arduino Mega2560	1	16MHz	8KB	60	$40
ESP8266	1	80MHz	112KB	11	$5
ESP32	2	240MHz	520KB	~32	$10
Pi Zero	1	1GHz	512MB	25	$5
Pi 4	4	1.5GHz	2 - 8GB	25	$35
16” MacBook Pro	6 - 8	2.3 - 2.6GHz	16 - 64GB	0	$2399

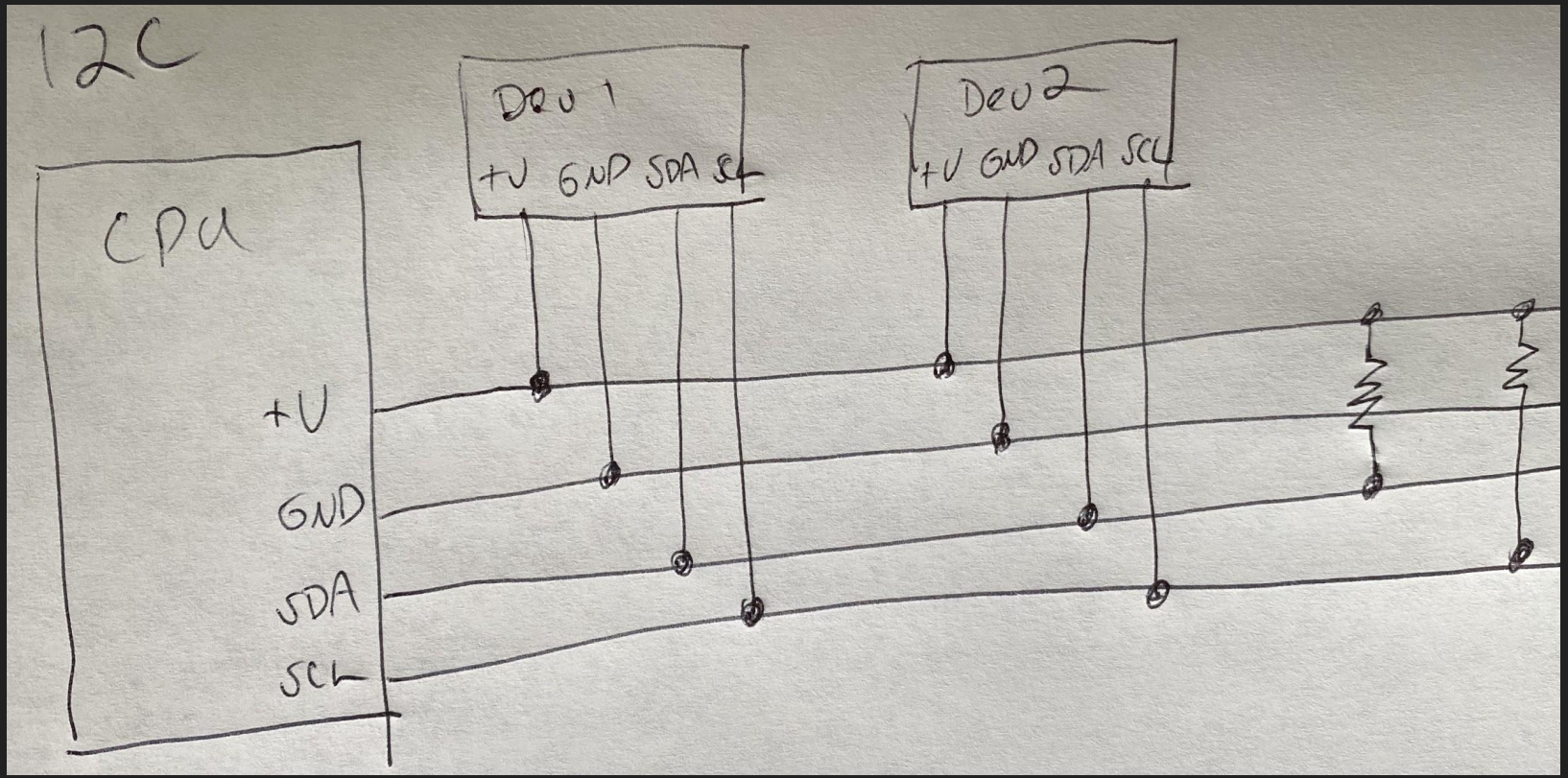
GPIO

- “General Purpose” Input/Output pins
- digital (1/0 - high/low) read and write
- analog (voltage) read and write (power supply voltage to 0)
- pulse width modulation (PWM) for servos (motors) and LEDs
- I2C and SPI - connecting sensors, displays and more
- serial (UART) communications

I2C Bus

- I-two-C or I-squared-C (I^2C) - Inter-Integrated Circuit
- four wires - power, ground, bidirectional data, clock
- 3.3 or 5V
- multiple speeds but most devices only support 400Kbps
- daisy chain multiple devices on one bus
- devices have a 7 bit address assigned by the manufacturer
- All instances of one device have the same address
- Some devices can choose from 2 or 4 addresses

I2C Connections



I2C Devices

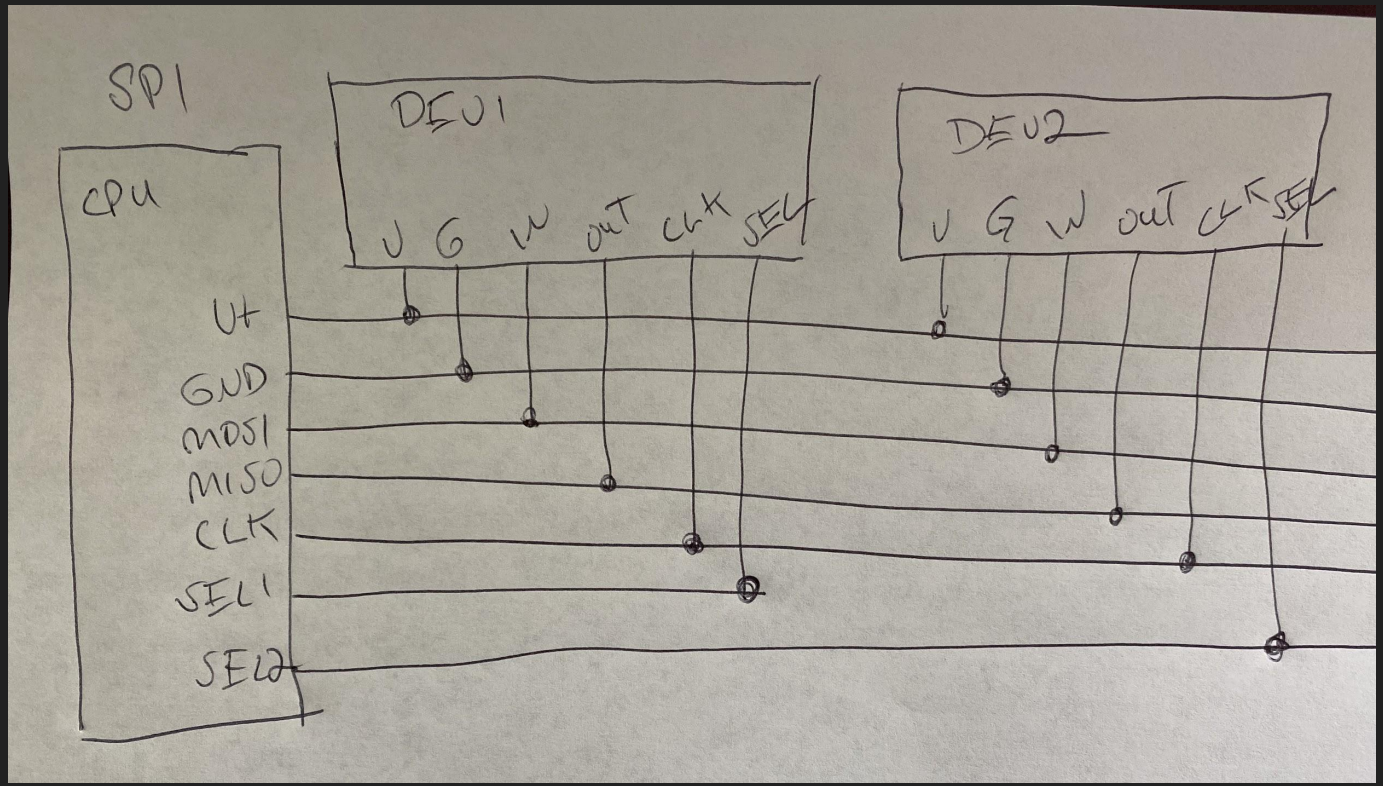
I2C Device Directory: https://i2cdevices.org/

BME280	0x76, 0x77	Air temp, humidity, pressure
TSL2561	0x39, 0x49	Light intensity
ADS1115	0x48, 0x49, 0x4a, 0x4b	4 channel analog to digital
SSD1306	0x3c, 0x3d	128x64 OLED controller
DS1307	0x68	Real time clock
ADXL345	0x1d, 0x53	Accelerometer
VI53L0x	0x29	Time of flight distance sensor

SPI

- Serial Peripheral Interface
- Six wires - power, ground, MOSI (output), MISO (input), SS (select), SCLK (clock)
- No addresses - each device is selected
- Faster than I2C

SPI Connections



Persistent Storage

- Usually 1MB to 4MB (sometimes 16MB) of flash storage
- Cheap NOR flash with limited (10,000 - 100,000 writes) lifetime
- Writing once per second to same location -> fail in 3 to 30 hours
- Filesystem does wear leveling, may get 100x more writes
- **Not suitable for frequent writing**
- Arduino-compatible EEPROM library
- ESP32 - “nvs” key/value store

Persistent Storage Alternatives

- Battery backed RAM (RTC modules, SRAM modules)
- FRAM - ferroelectric RAM - fast, I2C, 95 year lifespan, 10 trillion cycles, pricey
- EERAM - automatic backup of SRAM to EEPROM on power loss, SPI, cheap,easy, 100,000 backups
- SD card
- Cloud storage if Internet available

Power Management

- Devices have multiple sleep modes than reduce power needs
- “Deep sleep” wakeup on external input or timer
- “Deep sleep” wakeup is same as power on
- Batteries require power conditioning and charging circuitry
- Some boards have battery support built-in (LOLIN32)
- Wifi and Bluetooth take a lot of power
- LEDs take a lot of power
- USB serial chip and voltage regulator may waste a lot of power

Wifi and Internet

- 2.4GHz 802.11b/g wifi
- IPv4
- Default 5 TCP connections
- IP, UDP, TCP, DNS, mDNS, HTTP, MQTT, NTP
- Difficult to work with HTTPS/SSL/TLS - no certificate store or management
- Encryption slow and difficult
- Can run servers
- Slow and very limited compared to Linux

Bluetooth

- ESP32-only (add-ons like HC-06 or Bluefruit can let ESP8266 use Bluetooth)
- Shares antenna with Wifi - can’t use both simultaneously
- Bluetooth “Classic” -
- Bluetooth Low Energy - BLE
- Audio support limited by audio codecs and ADC/DAC quality
- Bluetooth stack is huge

Native “OS”

- ESP8266 and ESP32 - FreeRTOS
- C, lightweight non-preemptive multitasking
- Linked into your program
- “Flashed” to ESP each time the program is updated
- ESP8266 - NON-OS SDK for Arduino software
- ESP-IDF for ESP32
- Arduino Core compatibility layer for ESP8266 and ESP32

Programming

- C/C++ - Arduino Core
- LUA - NodeMCU
- microPython/Circuit Python
- Javascript - Espruino

C/C++

- Hostile, dangerous programming environment
- Direct access to memory
- Strings are dangerous and confusing - terrible for JSON
- Easy to exhaust available memory
- Standard C/C++ libraries barely supported
- Compiled and downloaded
- Fast and compact
- Great for real time/time critical programming
- Drivers available for many I2C and SPI devices
- Foundation for all other languages on ESP8266 and ESP32

C/C++ Arduino Example

```
#include <Arduino.h>

void setup() {
  Serial.begin(115200);
  Serial.println(“Hello World”);
}

void loop() {
}
```

LUA

- NodeMCU - has nothing to do with NodeJS
- Runs on any ESP8266/ESP32, not just “NodeMCU” boards
- Semi-obscure scripting language
- Used for World of Warcraft interface add-ons
- Easy to write and understand
- Easy string handling
- Interpreted on ESP8266/ESP32 - interpreter flashed to board
- Build your own interpreter with needed modules linked in
- REPL available
- Much slower than C/C++

LUA Example

```
uart.setup(0, 9600, 8, uart.PARITY_NONE, uart.STOPBITS_1, 1)

uart.write(0, "Hello, world\n")
```

Micro/CircuitPython

- ESP8266 and ESP32 support
- Well known, common scripting language
- Easy to write and understand
- Easy string handling
- Interpreted on ESP8266/ESP32 - interpreter flashed to board
- REPL available
- Much slower than C/C++ (20x)
- Can’t use many normal Python modules
- Many fewer I2C/SPI device drivers than C/C++
- CircuitPython - Adafruit derivative of MicroPython

Micro/Circuit Python Example

```
from machine import UART

uart = UART(0, baudrate=9600)

uart.write('hello')
```

Javascript

- Espruino - ESP8266 - ESP32
- Runs on any ESP8266/ESP32, not just “Espruino” boards
- Common scripting language
- Easy string handling
- Interpreted on ESP8266/ESP32 - interpreter/VM flashed to board
- REPL available
- Slower than C/C++

Javascript Example

```
Serial0.setup(9600);
Serial0.println(“Hello World”);
```

Using Without Programming

Tasmota

HTTP, MQTT, serial, sensors, timers, rules

ESP Easy

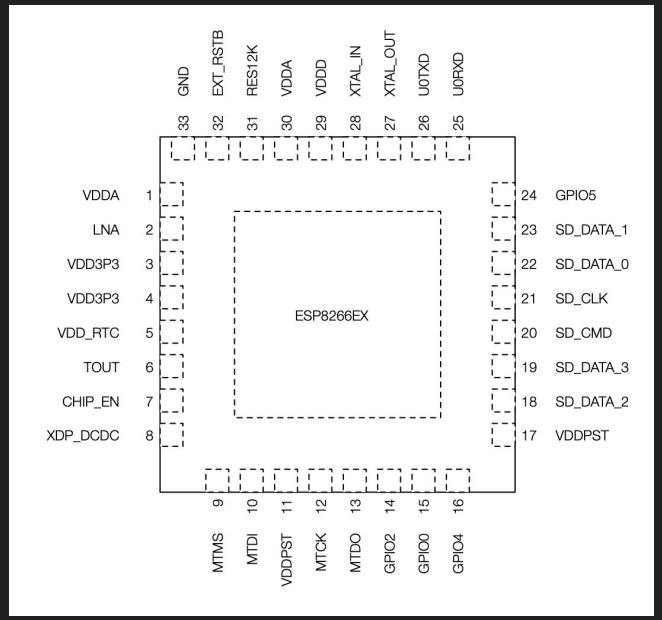
Web interface, sensors, switches, actuators, timers, rules

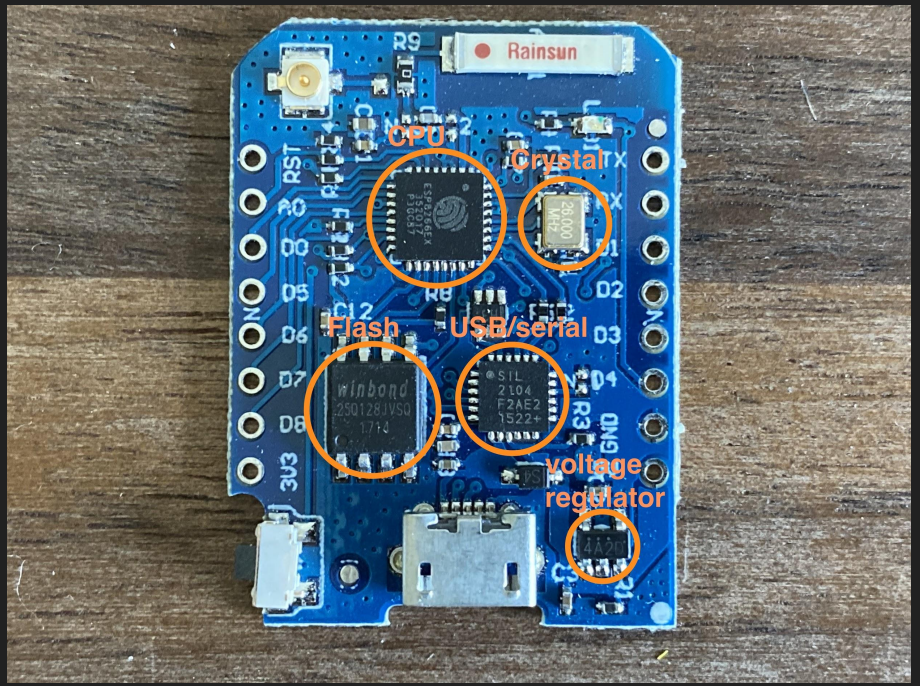
Easy to configure to do things that are supported and planned for. Hard to expand.

ESP8266 Specs

- 3.3V
- 32 bit CPU
- 80 or 160MHz
- 32KB instruction RAM, 80KB “user RAM”
- 2.4GHz wifi - 802.11b/g/n - **driver is closed source**
- Non-volatile storage - Flash RAM over SPI
- Official web site
- 1 ADC, 1 SPI, 1 I2C, 2 UART (serial)

ESP8266 Chip and Modules

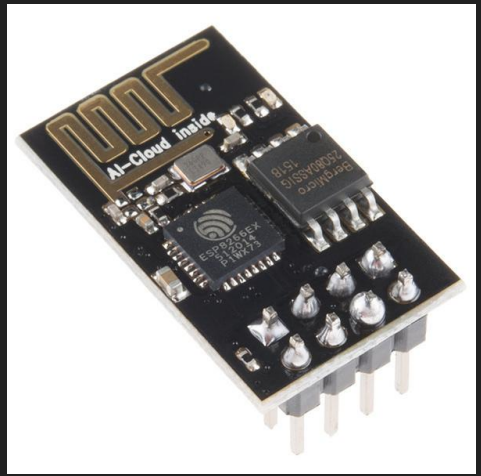




ESP-01: ESP8266 Wifi Modem

2014 -

- Power, serial, reset, programming and one GPIO pin
- Hayes modem “ATDT” firmware
- AT+HTTPCLIENT=2,0,http://example.com/,,,1
- No USB port - needs FTDI or similar USB/serial



NodeMCU

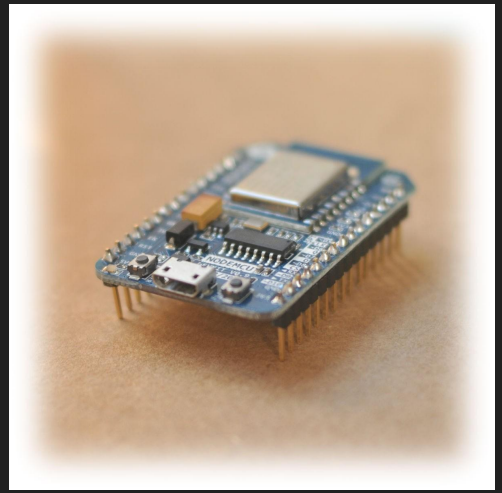
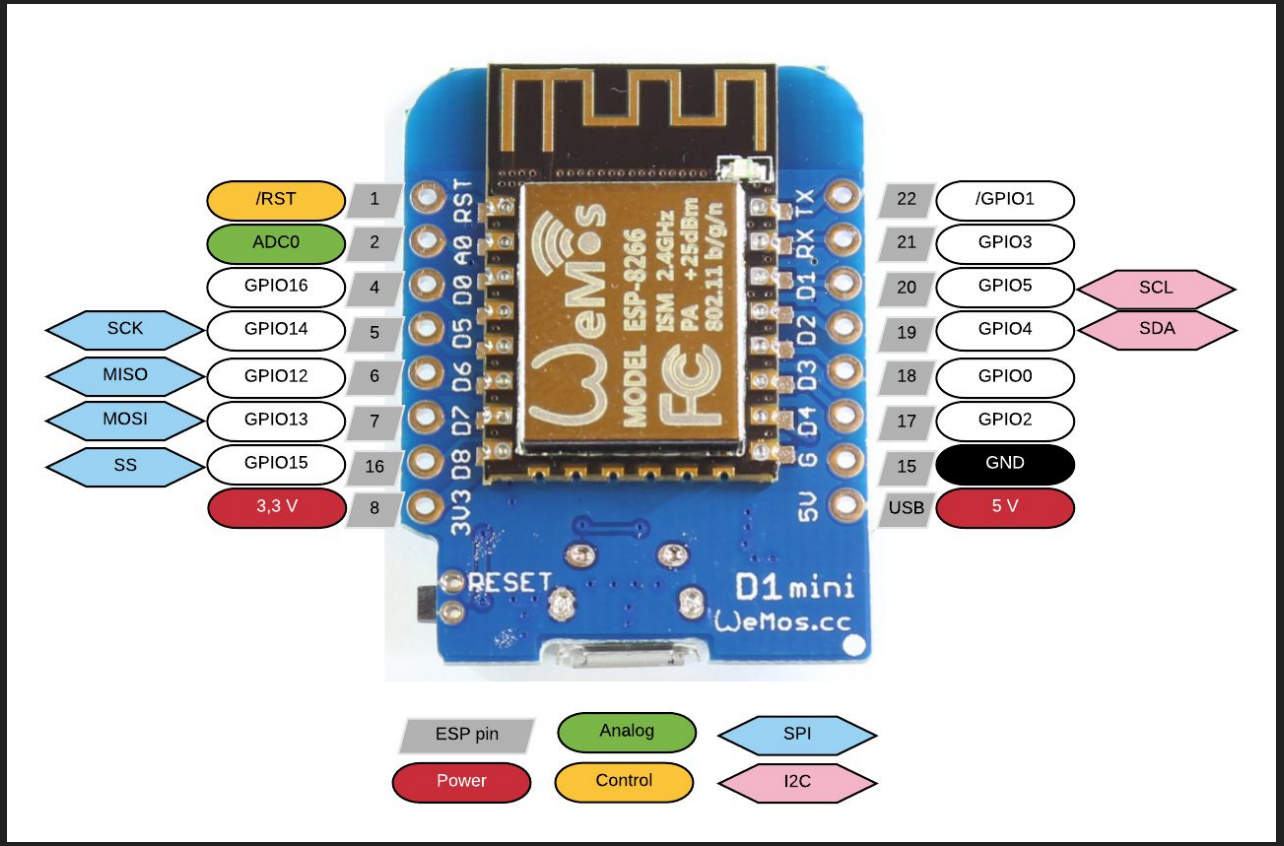


Photo from nodemcu.com

Wemos D1 mini (HackPack module)



ESP32 Chip and Module

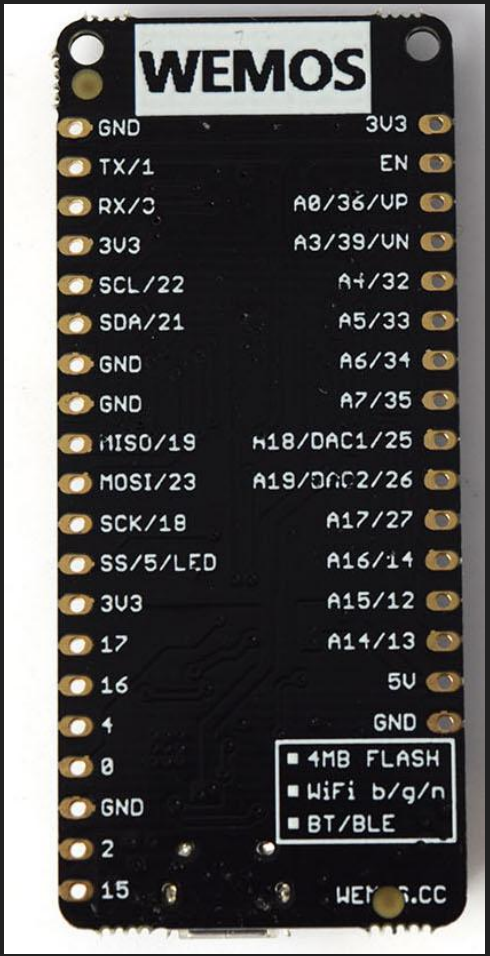
- 3.3V
- 32 bit CPU
- 240MHz
- 520KB instruction RAM
- 2.4GHz wifi - 802.11b/g/n - **driver is closed source**
- Bluetooth
- Non-volatile storage - Flash RAM over SPI
- Official web site

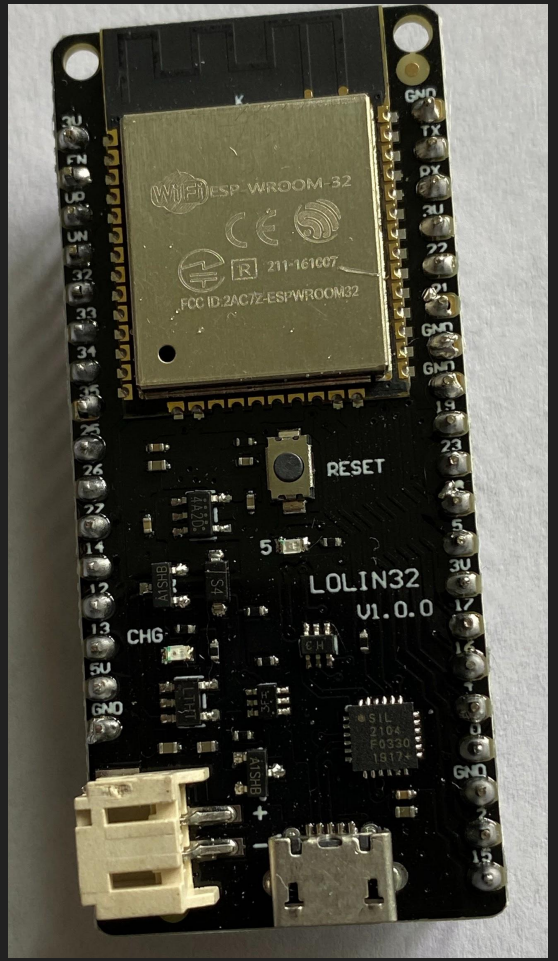
ESP32 Features

- 4 SPI controllers
- 2 I2C controllers
- 3 UARTs
- 18 channels of ADC
- 2 8 bit DAC
- 2 I2S controllers
- 8 pulse counters
- 16 PWM channels
- SD/SDIO/MMC controller
- 10/100Mbps Ethernet MAC interface
- …. And more (infrared, touch controllers)

LOLIN32

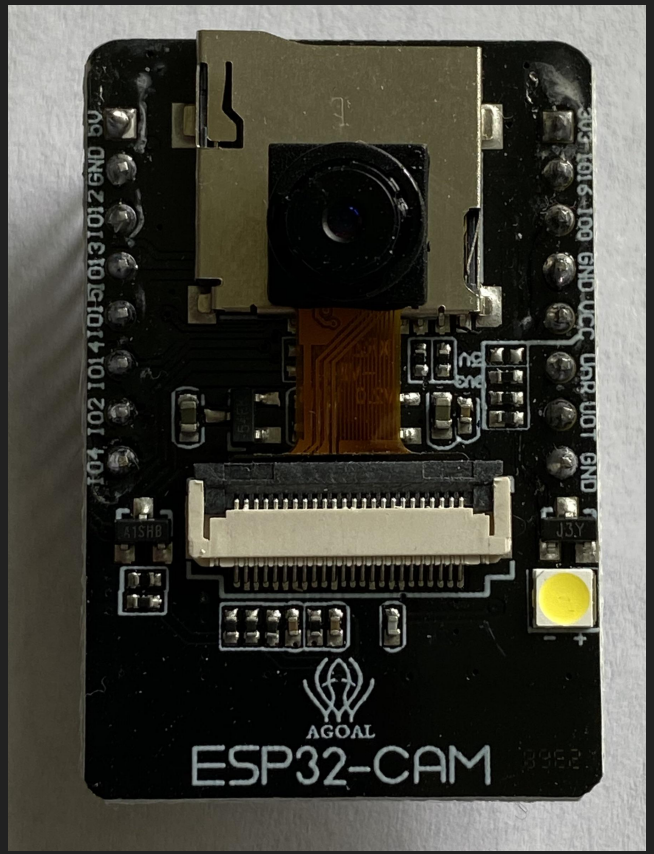
- ESP32
- 4MB flash
- USB serial
- LiPO battery charger





ESP32Cam

- ESP32
- 4MB flash
- Camera
- microSD card
- External antenna
- LED
- No USB/serial
- Few usable GPIO



Where To Get Parts

Adafruit, Sparkfun - open source, good companies, tutorials, code

Amazon - fast (always check lead time, sometimes ships from China!), more $$

AliExpress - slow, cheaper, less reliable, many cheap clones of Adafruit boards

eBay - mixed bag, sometimes ships from China

Digikey/Mouser - parts suppliers

OctoPart - search service across many suppliers