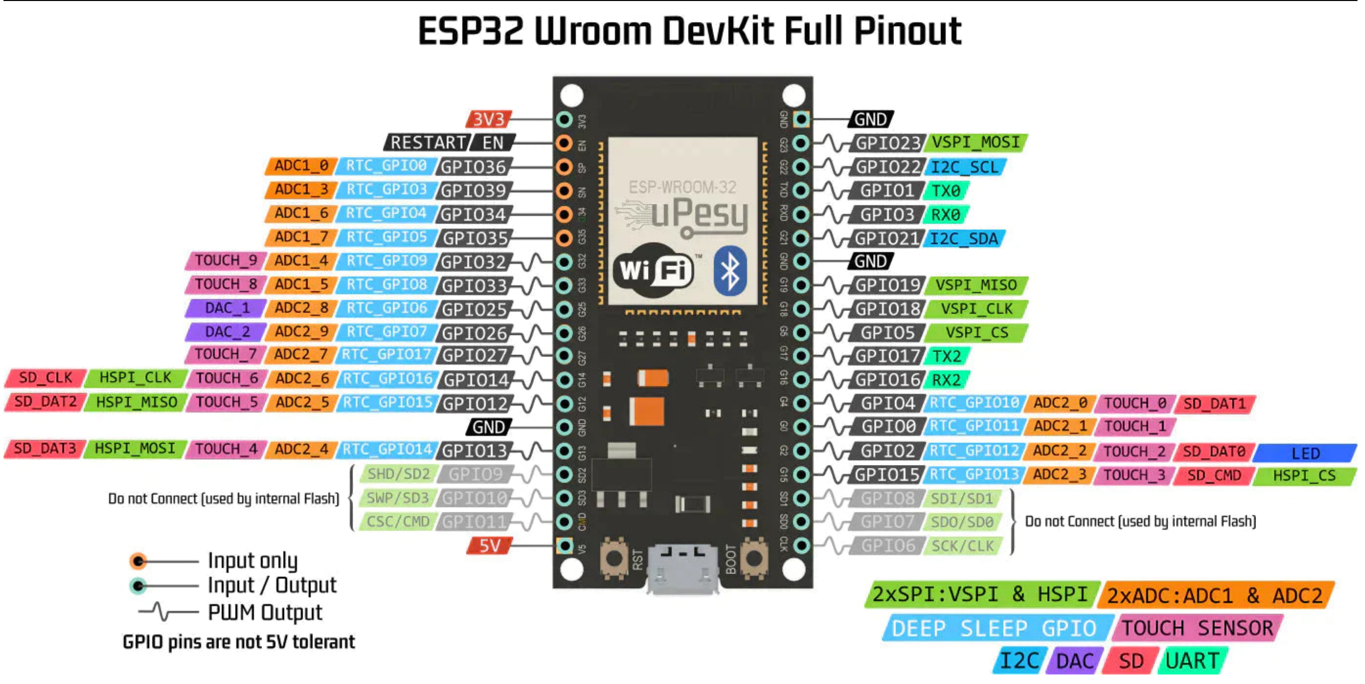
Use the GPIO pins of the ESP32

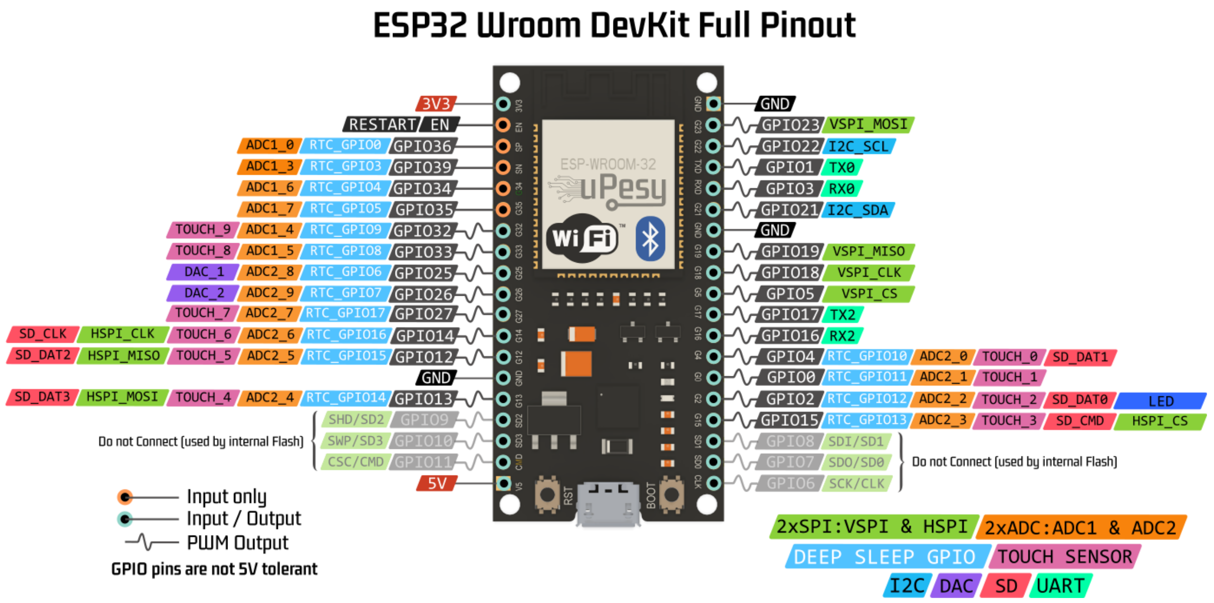

ESP32 Wroom DevKit Full Pinout
3V3
RESTART/ EN
ADC1_0 RTC_GPIO0 GPIO36
ADC1_3 RTC_GPIO3 GPIO39
ADC1_6 RTC_GPIO4 GPIO34
ADC1_7 RTC_GPIO5 GPIO35
TOUCH_9 ADC1_4 RTC_GPIO9 GPIO32
TOUCH_8 ADC1_5 RTC_GPIO8 GPIO33
DAC_1 ADC2_8 RTC_GPIO6 GPIO25
DAC_2 ADC2_9 RTC_GPIO7 GPIO26
TOUCH_7 ADC2_7 RTC_GPIO17 GPIO27
SD_CLK HSPI_CLK TOUCH_6 ADC2_6 RTC_GPIO16 GPIO14
SD_DAT2 HSPI_MISO TOUCH_5 ADC2_5 RTC_GPIO15 GPIO12
GND
SD_DAT3 HSPI_MOSI TOUCH_4 ADC2_4 RTC_GPIO14 GPIO13
SHD/SD2 GPIO9
SWP/SD3 GPIO10
CSC/CMD GPIO11
Do not Connect (used by internal Flash)
5V
GND
GPIO23 VSPI_MOSI
GPIO22 I2C_SCL
GPIO1 TX0
GPIO3 RX0
GPIO21 I2C_SDA
GND
GPIO19 VSPI_MISO
GPIO18 VSPI_CLK
GPIO5 VSPI_CS
GPIO17 TX2
GPIO16 RX2
GPIO4 RTC_GPIO10 ADC2_0 TOUCH_0 SD_DAT1
GPIO0 RTC_GPIO11 ADC2_1 TOUCH_1
GPIO2 RTC_GPIO12 ADC2_2 TOUCH_2 SD_DAT0 LED
GPIO15 RTC_GPIO13 ADC2_3 TOUCH_3 SD_CMD HSPI_CS
GPIO8 SDI/SD1
GPIO7 SDO/SD0
GPIO6 SCK/CLK
Do not Connect (used by internal Flash)
ESP-WROOM-32
uPesy
RST
BOOT
Input only
Input / Output
PWM Output
GPIO pins are not 5V tolerant
2xSPI:VSPI & HSPI
2xADC:ADC1 & ADC2
DEEP SLEEP GPIO
TOUCH SENSOR
I2C
DAC
SD
UART

(Updated at 08/18/2022)

Find all the relevant information about the ESP32 pinout on a single page to use these GPIO pins for your DIY electronics project correctly. Even though there are many variations of ESP32 boards, the function of the pins remains the same. However, some pins may not be available, depending on your model.

There are plenty of ESP32 boards out there with different pin arrangements. Here is a detailed pin diagram of 2 different ESP32 boards. It will be beneficial to know the specific functions of each pin:

- **ESP32 WROOM Generic DevKit**


ESP32 Wroom DevKit Full Pinout
3V3
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SD_CLK HSPI_CLK TOUCH_6 ADC2_6 RTC_GPIO16 GPIO14
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GND
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SWP/SD3 GPIO10
CSC/CMD GPIO11
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GND
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GPIO1 TX0
GPIO3 RX0
GPIO21 I2C_SDA
GND
GPIO19 VSPI_MISO
GPIO18 VSPI_CLK
GPIO5 VSPI_CS
GPIO17 TX2
GPIO16 RX2
GPIO4 RTC_GPIO10 ADC2_0 TOUCH_0 SD_DAT1
GPIO0 RTC_GPIO11 ADC2_1 TOUCH_1
GPIO2 RTC_GPIO12 ADC2_2 TOUCH_2 SD_DAT0 LED
GPIO15 RTC_GPIO13 ADC2_3 TOUCH_3 SD_CMD HSPI_CS
GPIO8 SDI/SD1
GPIO7 SDO/SD0
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Do not Connect (used by internal Flash)
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RST
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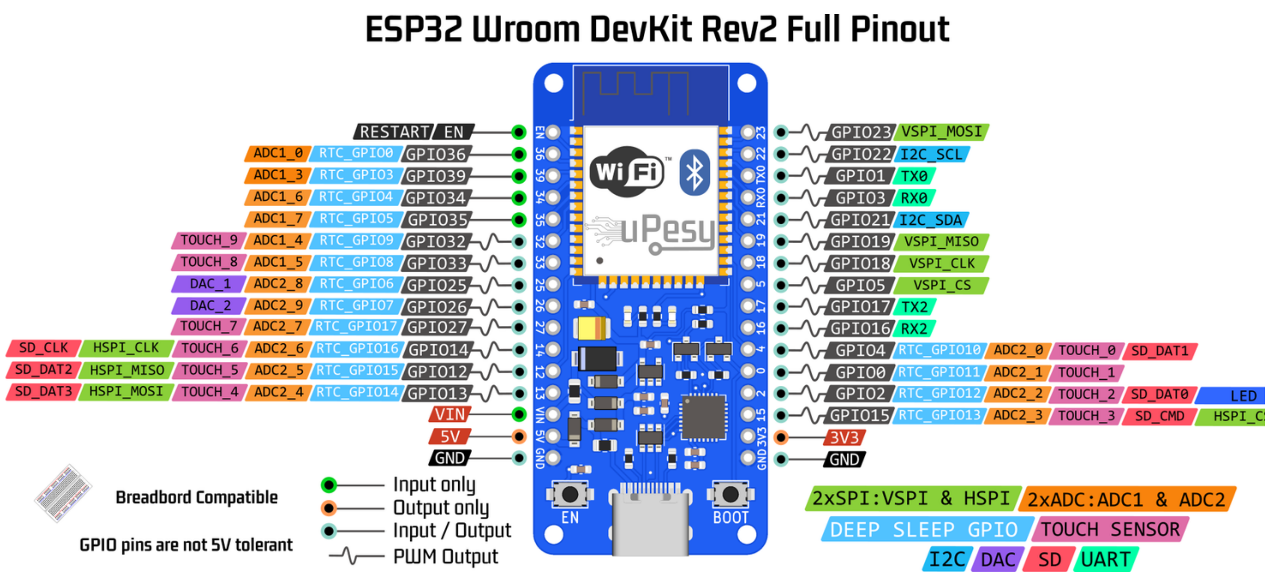
Input / Output
PWM Output
GPIO pins are not 5V tolerant
2xSPI:VSPI & HSPI
2xADC:ADC1 & ADC2
DEEP SLEEP GPIO
TOUCH SENSOR
I2C
DAC
SD
UART

Pinout of an ESP32 board

- **uPesy ESP32 WROOM DevKit**


ESP32 Wroom DevKit Rev2 Full Pinout
RESTART/ EN
ADC1_0 RTC_GPIO0 GPIO36
ADC1_3 RTC_GPIO3 GPIO39
ADC1_6 RTC_GPIO4 GPIO34
ADC1_7 RTC_GPIO5 GPIO35
TOUCH_9 ADC1_4 RTC_GPIO9 GPIO32
TOUCH_8 ADC1_5 RTC_GPIO8 GPIO33
DAC_1 ADC2_8 RTC_GPIO6 GPIO25
DAC_2 ADC2_9 RTC_GPIO7 GPIO26
TOUCH_7 ADC2_7 RTC_GPIO17 GPIO27
SD_CLK HSPI_CLK TOUCH_6 ADC2_6 RTC_GPIO16 GPIO14
SD_DAT2 HSPI_MISO TOUCH_5 ADC2_5 RTC_GPIO15 GPIO12
SD_DAT3 HSPI_MOSI TOUCH_4 ADC2_4 RTC_GPIO14 GPIO13
VIN
5V
GND
GPIO23 VSPI_MOSI
GPIO22 I2C_SCL
GPIO1 TX0
GPIO3 RX0
GPIO21 I2C_SDA
GPIO19 VSPI_MISO
GPIO18 VSPI_CLK
GPIO5 VSPI_CS
GPIO17 TX2
GPIO16 RX2
GPIO4 RTC_GPIO10 ADC2_0 TOUCH_0 SD_DAT1
GPIO0 RTC_GPIO11 ADC2_1 TOUCH_1
GPIO2 RTC_GPIO12 ADC2_2 TOUCH_2 SD_DAT0 LED
GPIO15 RTC_GPIO13 ADC2_3 TOUCH_3 SD_CMD HSPI_C
3V3
GND
EN
BOOT
uPesy
Breadbord Compatible
GPIO pins are not 5V tolerant
Input only
Output only
Input / Output
PWM Output
2xSPI:VSPI & HSPI
2xADC:ADC1 & ADC2
DEEP SLEEP GPIO
TOUCH SENSOR
I2C
DAC
SD
UART

Pinout of the uPesy ESP32 Wroom DevKit board

The particular behavior of some pins of the ESP32

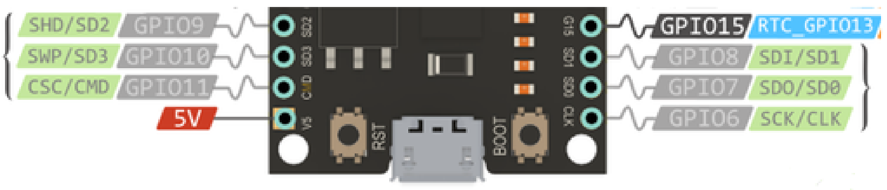
Note

A significant difference between the two boards that are not necessarily obvious is their width: The uPesy ESP32 board can be put on a breadboard, and you can access the pins on both sides, unlike most other ESP32 boards that are too “big” to be used on a breadboard.

The goal is to inform you about the limitations of some GPIO pins of the ESP32 to avoid unpleasant surprises during your projects or having an incomprehensible bug in your code.

ESP32-based development boards typically have 33 pins except those for the power supply. Some GPIO pins have a little bit particular functionings:

- If your ESP32 board has the GPIO6, GPIO7, GPIO8, GPIO9, GPIO10, and GPIO11 pins, **you must not use them** because they are connected to the flash memory of the ESP32: if you use them, the ESP32 will not work.



Pins connected to the Flash memory of the ESP32

GPIO	Possible name
6	SCK/CLK
7	SDO/SD0
8	SDI/SD1
9	SHD/SD2
10	SWP/SD3
11	CSC/CMD

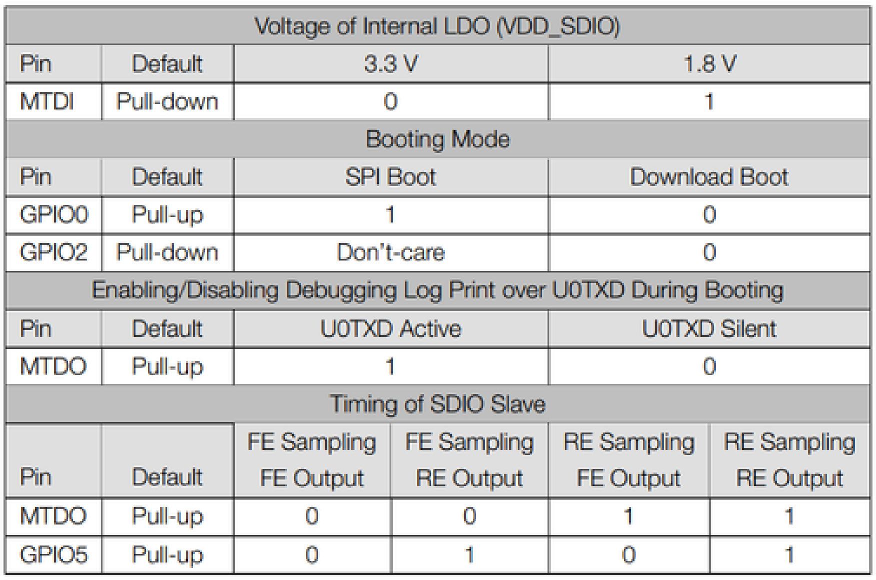
Note

For this reason, these pins are not available on uPesy ESP32 boards.

- The GPIO1 (TX0) and GPIO3 (RX0) pins are used to communicate with the computer in UART via USB. If you use them, you will not be able to upload programs to the board or use the serial monitor via the USB port. They can be useful for programming the board without a USB but with an external programmer instead. Fortunately, there are other UART interfaces available.

- Pins GPIO36 (VP), GPIO39 (VN), GPIO34, and GPIO35 can only be used as input. They also do not have internal pull-up and pull-down resistors (`pinMode(36, INPUT_PULLUP)` or `pinMode(36,` `INPUT_PULLDOWN)` cannot be used).

- Some pins have a unique function when starting the ESP32. These are called **ESP32 Strapping Pins** .



Voltage of Internal LDO (VDD_SDIO)					
Pin	Default	3.3 V		1.8 V	
MTDI	Pull-down	0		1	
Booting Mode					
Pin	Default	SPI Boot		Download Boot	
GPIO0	Pull-up	1		0	
GPIO2	Pull-down	Don't-care		0	
Enabling/Disabling Debugging Log Print over U0TXD During Booting					
Pin	Default	U0TXD Active		U0TXD Silent	
MTDO	Pull-up	1		0	
Timing of SDIO Slave					
Pin	Default	FE Sampling FE Output	FE Sampling RE Output	RE Sampling FE Output	RE Sampling RE Output
MTDO	Pull-up	0	0	1	1
GPIO5	Pull-up	0	1	0	1

Strapping pins of the ESP32

They are used to put the ESP32 in **BOOT** mode (to run the program written in the flash memory) or in **FLASH** mode (to upload the program to the flash memory). Depending on the voltage available on these pins, the ESP32 will start either in **BOOT** mode or in **FLASH** mode.

The strapping pins are the **GPIO0, GPIO2, GPIO12 (MTDI) and GPIO15 (MTDO)** . You can use them, but you must be careful when setting a logic state (3.3V or 0V) with an external pull-up or pull-down resistor.

Tip

If your ESP32 board works correctly, but when you add a sensor, nothing works anymore (it is impossible to upload a program or launch it), it is most likely related to these famous strapping pins.

- When booting the ESP32, during a short period, some pins quickly change their logic states (0V → 3.3V). You may have weird bugs with these pins: for example, a relay that temporarily activates. The faulty pins are the following:
    - **GPIO 1** : Sends the ESP32 boot logs via the UART
    - **GPIO 3** : 3.3V voltage at boot time
    - **GPIO 5** : Sends a PWM signal at boot time
    - **GPIO 14** : Sends a PWM signal at boot time
    - **GPIO 15** : Sends the ESP32 boot logs via the UART
- The EN pin can activate or deactivate the ESP32 via an external wire. It is connected to the board's EN button. When the ESP32 is on, it is at 3.3V. If you put this pin to the ground, the ESP32 is off. This can be used when the ESP32 is in a box and you want to be able to turn it on/off with a switch.

Note

Note that we can use these pins. If you encounter a strange behavior when starting the ESP32 by using one of these pins, you will probably have to choose another one.

- On boards that use an ESP32-WROVER module to have more RAM (for example, on the uPesy ESP32 Wrover DevKit board), then the GPIO16 and GPIO17 pins are not available because they are used internally by the PSRAM.
- Others GPIO pins have no particular restrictions.

Summary of all ESP32 GPIO pins

Summary of all ESP32 GPIO pins

GPIO	INPUT	OUTPUT	Comments
0	YES (Internal pull-up)	YES	Must be at 0V during the FLASH
1 (TX0)	NO	YES	UART communication with the PC
2	YES (Internal pull-down)	YES	Must be at 0V during the FLASH
3 (RX0)	YES	NO	UART communication with the PC
4	YES	YES	
5	YES	YES	
6	NO	NO	Connected to the internal flash
7	NO	NO	Connected to the internal flash
8	NO	NO	Connected to the internal flash
9	NO	NO	Connected to the internal flash
10	NO	NO	Connected to the internal flash
11	NO	NO	Connected to the internal flash
12 (MTDI)	YES (Internal pull-down)	YES	Must be at 0V during the BOOT
13	YES	YES	
14	YES	YES	
15 (MTDO)	YES (Internal pull-up)	YES	Startup log if at 3.3V
16	YES	YES	Not available on WROVER
17	YES	YES	Not available on WROVER
18	YES	YES	
19	YES	YES	
21	YES	YES	
22	YES	YES	
23	YES	YES	
25	YES	YES	
26	YES	YES	
27	YES	YES	
32	YES	YES	
33	YES	YES	
34	YES	NO	No internal pull-up/pull-down
35	YES	NO	No internal pull-up/pull-down
36 (VP)	YES	NO	No internal pull-up/pull-down
39 (VN)	YES	NO	No internal pull-up/pull-down
EN	NO	NO	Connected to the EN button (ESP32 Reset)

ESP32 Peripherals

To interact with the modules, sensors or electronic circuits, the ESP32, like any microcontroller, has a multitude of peripherals. They are much more numerous than on a classic Arduino Uno board.

The ESP32 has the following peripherals:

- 3 UART interfaces
- 2 I2C interfaces
- 3 SPI interfaces
- 16 PWM outputs
- 10 capacitive sensors

- 18 ADC channels
- 2 DAC outputs

The ESP32 already uses some peripherals in its essential operation. So, in reality, there are fewer possible interfaces for each device.

Tip

The pins of the ESP32 are much more modular than those of the Arduino: **You can " attach " a UART, I2C, SPI, and PWM peripheral on the pins you want.** The SPI, I2C, UART, PWM, and DAC are no longer associated with specific pins. For example, on the Arduino Uno, you could only have SPI on pins 10, 11, 12, and 13. With the ESP32, you can choose the ones you want. Only the ADC and the capacitive sensors are assigned to fixed pins. ESP32 Pinouts available on the Internet show the default association (if you do not specify the pins used). It remains a good practice to use the pins by default to keep good compatibility with external libraries as long as this does not limit the connection of your wires.

UART on ESP32

The UART is the serial protocol that allows easy data exchange between 2 devices. On the ESP32, 3 UART buses are available: UART0, UART1 and UART2. We can use them to communicate with a sensor, an Arduino, a Raspberry Pi, a computer …

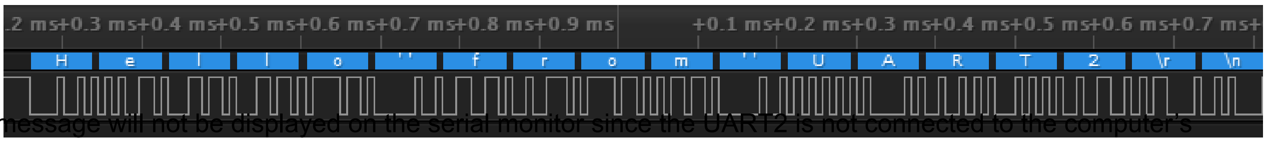
- The UART0 is by default on pins GPIO1(TX0) and GPIO3(RX0) of the ESP32. It is used to communicate with the computer through the serial monitor. It is also the one used to flash the ESP32 board when uploading a new program. It generally displays messages in the console with `Serial.println()` .
- To use the UART2, simply add `Serial2.begin()` in the function `setup()` and to use the``Serial2.println()`` to send messages. By default, the UART2 bus is on pins GPIO16(RX2) and GPIO17(TX2), but you can change them (useful with a Wrover module) during setup. This simple code allows you to use the UART2 bus:

```
void setup() {
  Serial2.begin(115200);
}

void loop() {
  Serial2.println("Hello from UART2");
  delay(100);
}
```

Note

The message will not be displayed on the serial monitor since the UART2 is not connected to the computer's USB.

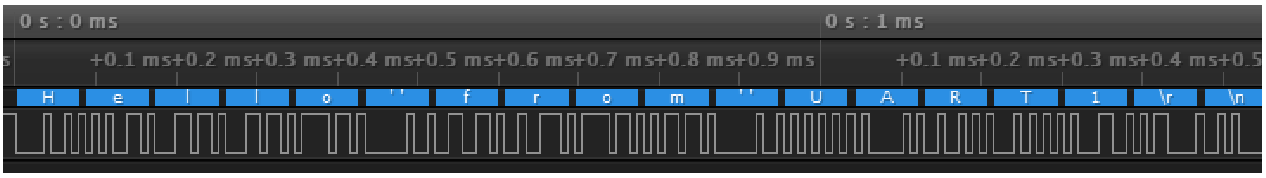

.2 ms+0.3 ms+0.4 ms+0.5 ms+0.6 ms+0.7 ms+0.8 ms+0.9 ms
+0.1 ms+0.2 ms+0.3 ms+0.4 ms+0.5 ms+0.6 ms+0.7 ms+
H e l l o ' ' f r o m ' ' U A R T 2 \r \n
Message sent via UART2 from pin GPIO17

- The UART1 is by default on the pins used by the ESP32 flash. However, We can use it by choosing the pins you want, thanks to the "GPIO matrix" of the ESP32. Thus this code allows having a serial interface on the pins GPIO14 and GPIO12 by using the UART1 bus.

```
void setup() {
  /*
  * UART1  -> Serial1
  * RX Pin -> GPIO 14
  * TX Pin -> GPIO 12
  * UART Configuration -> SERIAL_8N1
  */
  Serial1.begin(115200,SERIAL_8N1,14,12);

}

void loop() {
  Serial1.println("Hello from UART1");
  delay(100);
}
```


0 s : 0 ms
0 s : 1 ms
+0.1 ms +0.2 ms +0.3 ms +0.4 ms +0.5 ms +0.6 ms +0.7 ms +0.8 ms +0.9 ms
+0.1 ms +0.2 ms +0.3 ms +0.4 ms +0.5
H e l l o ' ' f r o m ' ' U A R T 1 \r \n

Message sent via UART1 from pin GPIO12

I2C on ESP32

The ESP32 has **2 I2C buses** :

- The I2C0 bus is the one used by default by Arduino libraries. It is connected to the pins **GPIO22 (SCL) and GPIO21 (SDA)** of the ESP32. It can be used on any pin of the ESP32 when you use the `Wire.h` library by specifying the pins with the function `Wire.begin(SDA_PIN, SCL_PIN)` .
- The I2C1 bus can also be used on any pin (pay attention to the “limited pins” described previously). Here is an example that uses the second I2C bus:

```
#include <Wire.h>

TwoWire I2C1 = TwoWire(1);

void setup() {
  I2C1.begin(14,12,400000); // SDA pin 14, SCL pin 12, 400kHz frequency
}

void loop() {
  I2C1.beginTransmission(0x42);
  I2C1.write(140);
  I2C1.endTransmission();
  delay(100);
}
```

SPI on ESP32

Even if the ESP32 has 3 SPI buses, we can use only two because the internal flash memory uses one. The two available SPI buses are called VSPI and HSPI.

By default, the pin mapping is as follows:

Note

Arduino libraries that use SPI use the VSPI bus by default.

SPI	MOSI	MISO	SCK/CLK	CS/SS
VSPI	GPIO 23	GPIO 19	GPIO 18	GPIO 5
HSPI	GPIO 13	GPIO 12	GPIO 14	GPIO 15

As for the I2C, it is possible to manually choose the pins you want to use for the SPI by specifying the pins during the initialization of the SPI `bus.begin(CLK_PIN, MISO_PIN, MOSI_PIN, SS_PIN);`

PWM on ESP32

The ESP32 has 16 channels that can be used to generate PWM signals: you can have up to 16 different PWM outputs. All the pins configured as output can be used to output a PWM signal. The use of PWM differs from Arduino's, and you can configure more parameters. I suggest you check the usage of PWM on ESP32 with Arduino code to use it in your projects.

Capacitive sensors on the ESP32

The ESP32 has ten capacitive sensors (9 if the GPIO0 pin is unavailable). They can be used as touch buttons. They are the famous *TOUCH* pins that can be found on some ESP32 pinouts. They can also be used to wake it up when the ESP32 is in DeepSleep mode (a power-saving mode). I invite you to read the use of capacitive sensors on the ESP32 with the Arduino code for more details.

The internal capacitive sensors are connected to the following GPIO pins:

TOUCH0	**TOUCH1**	**TOUCH2**	**TOUCH3**	**TOUCH4**
GPIO 4	GPIO 0	GPIO 2	GPIO 15	GPIO 13
TOUCH5	**TOUCH6**	**TOUCH7**	**TOUCH8**	**TOUCH9**
GPIO 12	GPIO 14	GPIO 27	GPIO 33	GPIO 32

ADC on ESP32

The ESP32 has two separate ADC: ADC1 with eight channels and ADC2 with ten channels for a total of 18 analog inputs. For example, on the GPIO34, you will find channel number 6 of the ADC1 (ADC1_CH6). But in practice, there are far fewer available because of Wi-Fi.

Warning

The ADC2 cannot be used when Wi-Fi is enabled: The ESP32 Wi-Fi driver uses it to work.

Mapping for ADC1

ADC1_CH0	**ADC1_CH1**	**ADC1_CH2**	**ADC1_CH3**
GPIO 36	GPIO 37	GPIO 38	GPIO 39
ADC1_CH4	**ADC1_CH5**	**ADC1_CH6**	**ADC1_CH7**
GPIO 32	GPIO 33	GPIO 34	GPIO 35

Mapping for ADC2 (rarely used)

ADC2_CH0	**ADC2_CH1**	**ADC2_CH2**	**ADC2_CH3**	**ADC2_CH4**
GPIO 4	GPIO 0	GPIO 2	GPIO 15	GPIO 13
ADC2_CH5	**ADC2_CH6**	**ADC2_CH7**	**ADC2_CH8**	**ADC2_CH9**
GPIO 12	GPIO 14	GPIO 27	GPIO 25	GPIO 26

Note

Generally, the GPIO37 and GPIO38 pins are not available if your board has a WROOM or WROVER module. These modules do not expose these pins. Only boards that use the ESP32 board directly (without a module) may expose them.

In general, the ESP32 ADC is not very reliable despite its 12-bit resolution. I invite you to read the article on the use and limitations of the ESP32 ADC for more information.

DAC on ESP32

The ESP32 has two 8-bit DAC outputs to convert a digital signal into an analog signal (generate a sine signal, for example). The pins used are the following:

DAC1	**DAC2**
GPIO 25	GPIO 26

Note

The DAC only has a resolution of eight bits. It is insufficient for audio applications without deterioration. It is better to use an external DAC with a higher resolution (12-24 bits) with the I2S bus of the ESP32.