
ESP8266 Arduino Core Documentation

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1.1 Boards Manager

This is the suggested installation method for end users.

1.1.1 Prerequisites

- Arduino 1.6.8, get it from [Arduino website](#).
- Internet connection

1.1.2 Instructions

- Start Arduino and open Preferences window.
- Enter `http://arduino.esp8266.com/stable/package_esp8266com_index.json` into *Additional Board Manager URLs* field. You can add multiple URLs, separating them with commas.
- Open Boards Manager from Tools > Board menu and find *esp8266* platform.
- Select the version you need from a drop-down box.
- Click *install* button.
- Don't forget to select your ESP8266 board from Tools > Board menu after installation.

You may optionally use *staging* boards manager package link: `http://arduino.esp8266.com/staging/package_esp8266com_index.json`. This may contain some new features, but at the same time, some things might be broken.

For more information on the Arduino Board Manager, see:

- <https://www.arduino.cc/en/guide/cores>

1.2 Using git version

This is the suggested installation method for contributors and library developers.

1.2.1 Prerequisites

- Arduino 1.6.8 (or newer, current working version is 1.8.5)
- git
- Python 2.7 (<http://python.org>)
- terminal, console, or command prompt (depending on your OS)
- Internet connection

1.2.2 Instructions - Windows 10

- First, make sure you don't already have the ESP8266 library installed using the Board Manager (see above)
- Install git for Windows (if not already; see <https://git-scm.com/download/win>)
- Open a command prompt (cmd) and go to Arduino default directory. This is typically the *sketch-book* directory (usually `C:\users\{username}\Documents\Arduino` where the environment variable `%USERPROFILE%` usually contains `C:\users\{username}`)
- Clone this repository into `hardware/esp8266com/esp8266` directory.

```
cd %USERPROFILE%\Documents\Arduino\  
if not exist hardware mkdir hardware  
cd hardware  
if not exist esp8266com mkdir esp8266com  
cd esp8266com  
git clone https://github.com/esp8266/Arduino.git esp8266
```

You should end up with the following directory structure in

`C:\Users\{your username}\Documents\`

```
Arduino  
|  
--- libraries  
--- hardware  
    |  
    --- esp8266com  
        |  
        --- esp8266  
            |  
            --- bootloaders  
            --- cores  
            --- doc  
            --- libraries  
            --- package  
            --- tests  
            --- tools  
            --- variants  
            --- platform.txt
```

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```

--- programmers.txt
--- README.md
--- boards.txt
--- LICENSE

```

- Initialize the submodules

```

cd %USERPROFILE%\Documents\hardware\esp8266com\esp8266
git submodule update --init

```

If error messages about missing files related to `SoftwareSerial` are encountered during the build process, it should be because this step was missed and is required.

- Download binary tools

```

cd esp8266/tools
python get.py

```

- Restart Arduino
- If using the Arduino IDE for Visual Studio (<https://www.visualmicro.com/>), be sure to click Tools - Visual Micro - Rescan Toolchains and Libraries
- When later updating your local library, goto the esp8266 directory and do a git pull

```

cd %USERPROFILE%\Documents\hardware\esp8266com\esp8266
git status
git pull

```

Note that you could, in theory install in `C:\Program Files (x86)\Arduino\hardware` however this has security implications, not to mention the directory often gets blown away when re-installing Arduino IDE. It does have the benefit (or drawback, depending on your perspective) - of being available to all users on your PC that use Arduino.

1.2.3 Instructions - Other OS

- Open the console and go to Arduino directory. This can be either your *sketchbook* directory (usually `<Documents>/Arduino`), or the directory of Arduino application itself, the choice is up to you.
- Clone this repository into `hardware/esp8266com/esp8266` directory. Alternatively, clone it elsewhere and create a symlink, if your OS supports them.

```

cd hardware
mkdir esp8266com
cd esp8266com
git clone https://github.com/esp8266/Arduino.git esp8266

```

You should end up with the following directory structure:

```

Arduino
|
--- hardware
    |
    --- esp8266com
        |
        --- esp8266
            |

```

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```
--- bootloaders
--- cores
--- doc
--- libraries
--- package
--- tests
--- tools
--- variants
--- platform.txt
--- programmers.txt
--- README.md
--- boards.txt
--- LICENSE
```

- Initialize the submodules

```
cd esp8266
git submodule update --init
```

If error messages about missing files related to `SoftwareSerial` are encountered during the build process, it should be because this step was missed and is required.

- Download binary tools

```
cd esp8266/tools
python get.py
```

- Restart Arduino
- When later updating your local library, goto the esp8266 directory and do a git pull

```
cd hardware\esp8266com\esp8266
git status
git pull
```

2.1 Digital IO

Pin numbers in Arduino correspond directly to the ESP8266 GPIO pin numbers. `pinMode`, `digitalRead`, and `digitalWrite` functions work as usual, so to read GPIO2, call `digitalRead(2)`.

Digital pins 0—15 can be `INPUT`, `OUTPUT`, or `INPUT_PULLUP`. Pin 16 can be `INPUT`, `OUTPUT` or `INPUT_PULLDOWN_16`. At startup, pins are configured as `INPUT`.

Pins may also serve other functions, like Serial, I2C, SPI. These functions are normally activated by the corresponding library. The diagram below shows pin mapping for the popular ESP-12 module.

Digital pins 6—11 are not shown on this diagram because they are used to connect flash memory chip on most modules. Trying to use these pins as IOs will likely cause the program to crash.

Note that some boards and modules (ESP-12ED, NodeMCU 1.0) also break out pins 9 and 11. These may be used as IO if flash chip works in DIO mode (as opposed to QIO, which is the default one).

Pin interrupts are supported through `attachInterrupt`, `detachInterrupt` functions. Interrupts may be attached to any GPIO pin, except GPIO16. Standard Arduino interrupt types are supported: `CHANGE`, `RISING`, `FALLING`.

2.2 Analog input

ESP8266 has a single ADC channel available to users. It may be used either to read voltage at ADC pin, or to read module supply voltage (VCC).

To read external voltage applied to ADC pin, use `analogRead(A0)`. Input voltage range of bare ESP8266 is 0 — 1.0V, however some many boards may implement voltage dividers. To be on the safe side, <1.0V can be tested. If e.g. 0.5V delivers values around ~512, then maximum voltage is very likely to be 1.0V and 3.3V may harm the ESP8266. However values around ~150 indicates that the maximum voltage is likely to be 3.3V.

To read VCC voltage, use `ESP.getVcc()` and ADC pin must be kept unconnected. Additionally, the following line has to be added to the sketch:

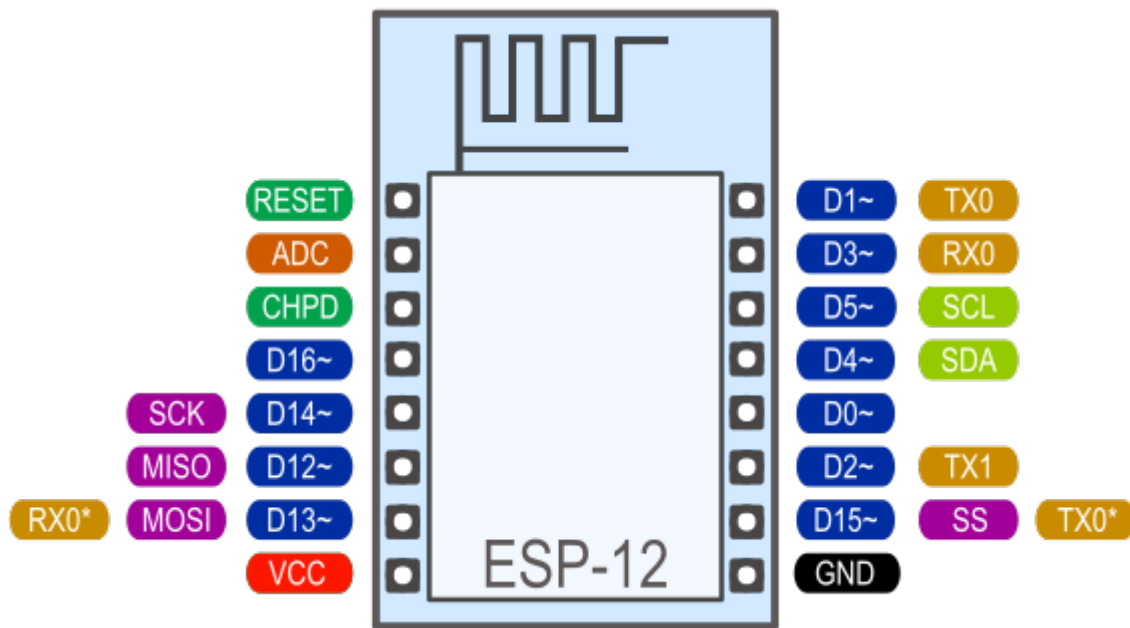


Fig. 1: Pin Functions

```
ADC_MODE (ADC_VCC) ;
```

This line has to appear outside of any functions, for instance right after the `#include` lines of your sketch.

2.3 Analog output

`analogWrite(pin, value)` enables software PWM on the given pin. PWM may be used on pins 0 to 16. Call `analogWrite(pin, 0)` to disable PWM on the pin. `value` may be in range from 0 to `PWMRANGE`, which is equal to 1023 by default. PWM range may be changed by calling `analogWriteRange(new_range)`.

PWM frequency is 1kHz by default. Call `analogWriteFreq(new_frequency)` to change the frequency.

2.4 Timing and delays

`millis()` and `micros()` return the number of milliseconds and microseconds elapsed after reset, respectively.

`delay(ms)` pauses the sketch for a given number of milliseconds and allows WiFi and TCP/IP tasks to run. `delayMicroseconds(us)` pauses for a given number of microseconds.

Remember that there is a lot of code that needs to run on the chip besides the sketch when WiFi is connected. WiFi and TCP/IP libraries get a chance to handle any pending events each time the `loop()` function completes, OR when `delay` is called. If you have a loop somewhere in your sketch that takes a lot of time (>50ms) without calling `delay`, you might consider adding a call to `delay` function to keep the WiFi stack running smoothly.

There is also a `yield()` function which is equivalent to `delay(0)`. The `delayMicroseconds` function, on the other hand, does not yield to other tasks, so using it for delays more than 20 milliseconds is not recommended.

2.5 Serial

`Serial` object works much the same way as on a regular Arduino. Apart from hardware FIFO (128 bytes for TX and RX) `Serial` has additional 256-byte TX and RX buffers. Both transmit and receive is interrupt-driven. Write and read functions only block the sketch execution when the respective FIFO/buffers are full/empty. Note that the length of additional 256-bit buffer can be customized.

`Serial` uses UART0, which is mapped to pins GPIO1 (TX) and GPIO3 (RX). `Serial` may be remapped to GPIO15 (TX) and GPIO13 (RX) by calling `Serial.swap()` after `Serial.begin()`. Calling `swap` again maps UART0 back to GPIO1 and GPIO3.

`Serial1` uses UART1, TX pin is GPIO2. UART1 can not be used to receive data because normally it's RX pin is occupied for flash chip connection. To use `Serial1`, call `Serial1.begin(baudrate)`.

If `Serial1` is not used and `Serial` is not swapped - TX for UART0 can be mapped to GPIO2 instead by calling `Serial.set_tx(2)` after `Serial.begin()` or directly with `Serial.begin(baud, config, mode, 2)`.

By default the diagnostic output from WiFi libraries is disabled when you call `Serial.begin()`. To enable debug output again, call `Serial.setDebugOutput(true)`. To redirect debug output to `Serial1` instead, call `Serial1.setDebugOutput(true)`.

You also need to use `Serial.setDebugOutput(true)` to enable output from `printf()` function.

The method `Serial.setRxBufferSize(size_t size)` allows to define the receiving buffer depth. The default value is 256.

Both `Serial` and `Serial1` objects support 5, 6, 7, 8 data bits, odd (O), even (E), and no (N) parity, and 1 or 2 stop bits. To set the desired mode, call `Serial.begin(baudrate, SERIAL_8N1)`, `Serial.begin(baudrate, SERIAL_6E2)`, etc.

A new method has been implemented on both `Serial` and `Serial1` to get current baud rate setting. To get the current baud rate, call `Serial.baudRate()`, `Serial1.baudRate()`. Return a `int` of current speed. For example

```
// Set Baud rate to 57600
Serial.begin(57600);

// Get current baud rate
int br = Serial.baudRate();

// Will print "Serial is 57600 bps"
Serial.printf("Serial is %d bps", br);
```

`Serial` and `Serial1` objects are both instances of the `HardwareSerial` class.

I've done this also for official ESP8266 [Software Serial](#) library, see this [pull request](#).

Note that this implementation is **only for ESP8266 based boards**, and will not work with other Arduino boards.

To detect an unknown baudrate of data coming into `Serial` use `Serial.detectBaudrate(timeoutMillis)`. This method tries to detect the baudrate for a maximum of `timeoutMillis` ms. It returns zero if no baudrate was detected, or the detected baudrate otherwise. The `detectBaudrate()` function may be called before `Serial.begin()` is called, because it does not need the receive buffer nor the `SerialConfig` parameters.

The uart can not detect other parameters like number of start- or stopbits, number of data bits or parity.

The detection itself does not change the baudrate, after detection it should be set as usual using `Serial.begin(detectedBaudrate)`.

Detection is very fast, it takes only a few incoming bytes.

SerialDetectBaudrate.ino is a full example of usage.

2.6 Progmem

The Program memory features work much the same way as on a regular Arduino; placing read only data and strings in read only memory and freeing heap for your application. The important difference is that on the ESP8266 the literal strings are not pooled. This means that the same literal string defined inside a `F(" ")` and/or `PSTR(" ")` will take up space for each instance in the code. So you will need to manage the duplicate strings yourself.

There is one additional helper macro to make it easier to pass `const PROGMEM` strings to methods that take a `__FlashStringHelper` called `FPSTR()`. The use of this will help make it easier to pool strings. Not pooling strings...

```
String response1;
response1 += F("http:");
...
String response2;
response2 += F("http:");
```

using `FPSTR` would become...

```
const char HTTP[] PROGMEM = "http: ";
...
{
    String response1;
    response1 += FPSTR(HTTP);
    ...
    String response2;
    response2 += FPSTR(HTTP);
}
```

3.1 WiFi(ESP8266WiFi library)

ESP8266WiFi library has been developed basing on ESP8266 SDK, using naming convention and overall functionality philosophy of the [Arduino WiFi Shield library](#). Over time the wealth Wi-Fi features ported from ESP8266 SDK to this library outgrew the APIs of WiFi Shield library and it became apparent that we need to provide separate documentation on what is new and extra.

[ESP8266WiFi library documentation](#)

3.2 Ticker

Library for calling functions repeatedly with a certain period. [Two examples](#) included.

It is currently not recommended to do blocking IO operations (network, serial, file) from Ticker callback functions. Instead, set a flag inside the ticker callback and check for that flag inside the loop function.

Here is library to simplify Ticker usage and avoid WDT reset: [TickerScheduler](#)

3.3 EEPROM

This is a bit different from standard EEPROM class. You need to call `EEPROM.begin(size)` before you start reading or writing, size being the number of bytes you want to use. Size can be anywhere between 4 and 4096 bytes.

`EEPROM.write` does not write to flash immediately, instead you must call `EEPROM.commit()` whenever you wish to save changes to flash. `EEPROM.end()` will also commit, and will release the RAM copy of EEPROM contents.

EEPROM library uses one sector of flash located just after the SPIFFS.

[Three examples](#) included.

3.4 I2C (Wire library)

Wire library currently supports master mode up to approximately 450KHz. Before using I2C, pins for SDA and SCL need to be set by calling `Wire.begin(int sda, int scl)`, i.e. `Wire.begin(0, 2)` on ESP-01, else they default to pins 4(SDA) and 5(SCL).

3.5 SPI

SPI library supports the entire Arduino SPI API including transactions, including setting phase (CPHA). Setting the Clock polarity (CPOL) is not supported, yet (SPI_MODE2 and SPI_MODE3 not working).

The usual SPI pins are:

- MOSI = GPIO13
- MISO = GPIO12
- SCLK = GPIO14

There's an extended mode where you can swap the normal pins to the SPI0 hardware pins. This is enabled by calling `SPI.pins(6, 7, 8, 0)` before the call to `SPI.begin()`. The pins would change to:

- MOSI = SD1
- MISO = SD0
- SCLK = CLK
- HWCS = GPIO0

This mode shares the SPI pins with the controller that reads the program code from flash and is controlled by a hardware arbiter (the flash has always higher priority). For this mode the CS will be controlled by hardware as you can't handle the CS line with a GPIO, you never actually know when the arbiter is going to grant you access to the bus so you must let it handle CS automatically.

3.6 SoftwareSerial

An ESP8266 port of SoftwareSerial library done by Peter Lerup (@plerup) supports baud rate up to 115200 and multiples SoftwareSerial instances. See <https://github.com/plerup/espsoftwareserial> if you want to suggest an improvement or open an issue related to SoftwareSerial.

3.7 ESP-specific APIs

Some ESP-specific APIs related to deep sleep, RTC and flash memories are available in the ESP object.

`ESP.deepSleep(microseconds, mode)` will put the chip into deep sleep. `mode` is one of `WAKE_RF_DEFAULT`, `WAKE_RFCAL`, `WAKE_NO_RFCAL`, `WAKE_RF_DISABLED`. (GPIO16 needs to be tied to RST to wake from deepSleep.) The chip can sleep for at most `ESP.deepSleepMax()` microseconds.

`ESP.deepSleepInstant(microseconds, mode)` works similarly to `ESP.deepSleep` but sleeps instantly without waiting for WiFi to shutdown.

`ESP.rtcUserMemoryWrite(offset, &data, sizeof(data))` and `ESP.rtcUserMemoryRead(offset, &data, sizeof(data))` allow data to be stored in and retrieved from the RTC user memory of the chip respectively. `offset` is measured in blocks of 4 bytes and can range from

0 to 127 blocks (total size of RTC memory is 512 bytes). data should be 4-byte aligned. The stored data can be retained between deep sleep cycles, but might be lost after power cycling the chip. Data stored in the first 32 blocks will be lost after performing an OTA update, because they are used by the Core internals.

`ESP.restart()` restarts the CPU.

`ESP.getResetReason()` returns a String containing the last reset reason in human readable format.

`ESP.getFreeHeap()` returns the free heap size.

`ESP.getHeapFragmentation()` returns the fragmentation metric (0% is clean, more than ~50% is not harmless)

`ESP.getMaxFreeBlockSize()` returns the maximum allocatable ram block regarding heap fragmentation

`ESP.getChipId()` returns the ESP8266 chip ID as a 32-bit integer.

`ESP.getCoreVersion()` returns a String containing the core version.

`ESP.getSdkVersion()` returns the SDK version as a char.

`ESP.getCpuFreqMHz()` returns the CPU frequency in MHz as an unsigned 8-bit integer.

`ESP.getSketchSize()` returns the size of the current sketch as an unsigned 32-bit integer.

`ESP.getFreeSketchSpace()` returns the free sketch space as an unsigned 32-bit integer.

`ESP.getSketchMD5()` returns a lowercase String containing the MD5 of the current sketch.

`ESP.getFlashChipId()` returns the flash chip ID as a 32-bit integer.

`ESP.getFlashChipSize()` returns the flash chip size, in bytes, as seen by the SDK (may be less than actual size).

`ESP.getFlashChipRealSize()` returns the real chip size, in bytes, based on the flash chip ID.

`ESP.getFlashChipSpeed(void)` returns the flash chip frequency, in Hz.

`ESP.getCycleCount()` returns the cpu instruction cycle count since start as an unsigned 32-bit. This is useful for accurate timing of very short actions like bit banging.

`ESP.getVcc()` may be used to measure supply voltage. ESP needs to reconfigure the ADC at startup in order for this feature to be available. Add the following line to the top of your sketch to use `getVcc`:

```
ADC_MODE(ADC_VCC);
```

TOUT pin has to be disconnected in this mode.

Note that by default ADC is configured to read from TOUT pin using `analogRead(A0)`, and `ESP.getVCC()` is not available.

3.8 mDNS and DNS-SD responder (ESP8266mDNS library)

Allows the sketch to respond to multicast DNS queries for domain names like “foo.local”, and DNS-SD (service discovery) queries. See attached example for details.

3.9 SSDP responder (ESP8266SSDP)

SSDP is another service discovery protocol, supported on Windows out of the box. See attached example for reference.

3.10 DNS server (DNSServer library)

Implements a simple DNS server that can be used in both STA and AP modes. The DNS server currently supports only one domain (for all other domains it will reply with NXDOMAIN or custom status code). With it, clients can open a web server running on ESP8266 using a domain name, not an IP address.

3.11 Servo

This library exposes the ability to control RC (hobby) servo motors. It will support up to 24 servos on any available output pin. By default the first 12 servos will use Timer0 and currently this will not interfere with any other support. Servo counts above 12 will use Timer1 and features that use it will be affected. While many RC servo motors will accept the 3.3V IO data pin from a ESP8266, most will not be able to run off 3.3v and will require another power source that matches their specifications. Make sure to connect the grounds between the ESP8266 and the servo motor power supply.

3.12 Improved EEPROM library for ESP (ESP_EEPROM)

An improved EEPROM library for ESPxxxx. Uses flash memory as per the standard ESP EEPROM library but reduces reflash - so reducing wear and improving commit() performance.

As actions on the flash need to stop the interrupts, an EEPROM reflash could noticeably affect anything using PWM, etc.

3.13 Other libraries (not included with the IDE)

Libraries that don't rely on low-level access to AVR registers should work well. Here are a few libraries that were verified to work:

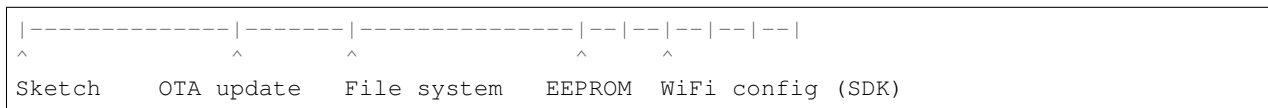
- [Adafruit_ILI9341](#) - Port of the Adafruit ILI9341 for the ESP8266
- [arduinoVNC](#) - VNC Client for Arduino
- [arduinoWebSockets](#) - WebSocket Server and Client compatible with ESP8266 (RFC6455)
- [aREST](#) - REST API handler library.
- [Blynk](#) - easy IoT framework for Makers (check out the [Kickstarter page](#)).
- [DallasTemperature](#)
- [DHT-sensor-library](#) - Arduino library for the DHT11/DHT22 temperature and humidity sensors. Download latest v1.1.1 library and no changes are necessary. Older versions should initialize DHT as follows: `DHT dht (DHTPIN, DHTTYPE, 15)`
- [DimSwitch](#) - Control electronic dimmable ballasts for fluorescent light tubes remotely as if using a wall switch.
- [Encoder](#) - Arduino library for rotary encoders. Version 1.4 supports ESP8266.
- [esp8266_mdns](#) - mDNS queries and responses on esp8266. Or to describe it another way: An mDNS Client or Bonjour Client library for the esp8266.
- [ESP-NOW](#) - Wrapper lib for ESP-NOW (See [#2227](#))
- [ESPAsyncTCP](#) - Asynchronous TCP Library for ESP8266 and ESP32/31B

- [ESPAsyncWebServer](#) - Asynchronous Web Server Library for ESP8266 and ESP32/31B
- [Homie for ESP8266](#) - Arduino framework for ESP8266 implementing Homie, an MQTT convention for the IoT.
- [NeoPixel](#) - Adafruit's NeoPixel library, now with support for the ESP8266 (use version 1.0.2 or higher from Arduino's library manager).
- [NeoPixelBus](#) - Arduino NeoPixel library compatible with ESP8266. Use the "DmaDriven" or "UartDriven" branches for ESP8266. Includes HSL color support and more.
- [PubSubClient](#) - MQTT library by @Imroy.
- [RTC](#) - Arduino Library for Ds1307 & Ds3231 compatible with ESP8266.
- [Souliss, Smart Home](#) - Framework for Smart Home based on Arduino, Android and openHAB.
- [ST7735](#) - Adafruit's ST7735 library modified to be compatible with ESP8266. Just make sure to modify the pins in the examples as they are still AVR specific.
- [Task](#) - Arduino Nonpreemptive multitasking library. While similar to the included Ticker library in the functionality provided, this library was meant for cross Arduino compatibility.
- [TickerScheduler](#) - Library provides simple scheduler for `Ticker` to avoid WDT reset
- [Teleinfo](#) - Generic French Power Meter library to read Teleinfo energy monitoring data such as consumption, contract, power, period, ... This library is cross platform, ESP8266, Arduino, Particle, and simple C++. French dedicated [post](#) on author's blog and all related information about [Teleinfo](#) also available.
- [UTFT-ESP8266](#) - UTFT display library with support for ESP8266. Only serial interface (SPI) displays are supported for now (no 8-bit parallel mode, etc). Also includes support for the hardware SPI controller of the ESP8266.
- [WiFiManager](#) - WiFi Connection manager with web captive portal. If it can't connect, it starts AP mode and a configuration portal so you can choose and enter WiFi credentials.
- [OneWire](#) - Library for Dallas/Maxim 1-Wire Chips.
- [Adafruit-PCD8544-Nokia-5110-LCD-Library](#) - Port of the Adafruit PCD8544 - library for the ESP8266.
- [PCF8574_ESP](#) - A very simplistic library for using the PCF8574/PCF8574A I2C 8-pin GPIO-expander.
- [Dot Matrix Display Library 2](#) - Freetronics DMD & Generic 16 x 32 P10 style Dot Matrix Display Library
- [SdFat-beta](#) - SD-card library with support for long filenames, software- and hardware-based SPI and lots more.
- [FastLED](#) - a library for easily & efficiently controlling a wide variety of LED chipsets, like the Neopixel (WS2812B), DotStar, LPD8806 and many more. Includes fading, gradient, color conversion functions.
- [OLED](#) - a library for controlling I2C connected OLED displays. Tested with 0.96 inch OLED graphics display.
- [MFRC522](#) - A library for using the Mifare RC522 RFID-tag reader/writer.
- [Ping](#) - lets the ESP8266 ping a remote machine.
- [AsyncPing](#) - fully asynchronous Ping library (have full ping statistic and hardware MAC address).

4.1 Flash layout

Even though file system is stored on the same flash chip as the program, programming new sketch will not modify file system contents. This allows to use file system to store sketch data, configuration files, or content for Web server.

The following diagram illustrates flash layout used in Arduino environment:



File system size depends on the flash chip size. Depending on the board which is selected in IDE, you have the following options for flash size:

Board	Flash chip size, bytes	File system size, bytes
Generic module	512k	64k, 128k
Generic module	1M	64k, 128k, 256k, 512k
Generic module	2M	1M
Generic module	4M	1M, 2M, 3M
Adafruit HUZZAH	4M	1M, 2M, 3M
ESPRESSO Lite 1.0	4M	1M, 2M, 3M
ESPRESSO Lite 2.0	4M	1M, 2M, 3M
NodeMCU 0.9	4M	1M, 2M, 3M
NodeMCU 1.0	4M	1M, 2M, 3M
Olimex MOD-WIFI-ESP8266(-DEV)	2M	1M
SparkFun Thing	512k	64k
SweetPea ESP-210	4M	1M, 2M, 3M
WeMos D1 R1, R2 & mini	4M	1M, 2M, 3M
ESPduino	4M	1M, 2M, 3M
WiFiduino	4M	1M, 2M, 3M

Note: to use any of file system functions in the sketch, add the following include to the sketch:

```
#include "FS.h"
```

4.2 File system limitations

The filesystem implementation for ESP8266 had to accomodate the constraints of the chip, among which its limited RAM. **SPIFFS** was selected because it is designed for small systems, but that comes at the cost of some simplifications and limitations.

First, behind the scenes, SPIFFS does not support directories, it just stores a “flat” list of files. But contrary to traditional filesystems, the slash character `'/'` is allowed in filenames, so the functions that deal with directory listing (e.g. `openDir("/website")`) basically just filter the filenames and keep the ones that start with the requested prefix (`/website/`). Practically speaking, that makes little difference though.

Second, there is a limit of 32 chars in total for filenames. One `'\0'` char is reserved for C string termination, so that leaves us with 31 usable characters.

Combined, that means it is advised to keep filenames short and not use deeply nested directories, as the full path of each file (including directories, `'/'` characters, base name, dot and extension) has to be 31 chars at a maximum. For example, the filename `/website/images/bird_thumbnail.jpg` is 34 chars and will cause some problems if used, for example in `exists()` or in case another file starts with the same first 31 characters.

Warning: That limit is easily reached and if ignored, problems might go unnoticed because no error message will appear at compilation nor runtime.

For more details on the internals of SPIFFS implementation, see the [SPIFFS readme file](#).

4.3 Uploading files to file system

ESP8266FS is a tool which integrates into the Arduino IDE. It adds a menu item to *Tools* menu for uploading the contents of sketch data directory into ESP8266 flash file system.

Warning: Due to the move from the obsolete `esptool-ck.exe` to the supported `esptool.py` upload tool, upgraders from pre 2.5.1 will need to update the ESP8266FS tool referenced below to 0.4.0 or later. Prior versions will fail with a “esptool not found” error because they don’t know how to use `esptool.py`.

- Download the tool: <https://github.com/esp8266/arduino-esp8266fs-plugin/releases/download/0.4.0/ESP8266FS-0.4.0.zip>
- In your Arduino sketchbook directory, create `tools` directory if it doesn’t exist yet
- Unpack the tool into `tools` directory (the path will look like `<home_dir>/Arduino/tools/ESP8266FS/tool/esp8266fs.jar`) If upgrading, overwrite the existing JAR file with the newer version.
- Restart Arduino IDE
- Open a sketch (or create a new one and save it)
- Go to sketch directory (choose Sketch > Show Sketch Folder)
- Create a directory named `data` and any files you want in the file system there
- Make sure you have selected a board, port, and closed Serial Monitor
- Select Tools > ESP8266 Sketch Data Upload. This should start uploading the files into ESP8266 flash file system. When done, IDE status bar will display `SPIFFS Image Uploaded` message.

4.4 File system object (SPIFFS)

4.4.1 setConfig

```
SPIFFSConfig cfg;
cfg.setAutoFormat(false);
SPIFFS.setConfig(cfg);
```

This method allows you to configure the parameters of a filesystem before mounting. All filesystems have their own `*Config` (i.e. `SDFSCfg` or `SPIFFSCfg` with their custom set of options. All filesystems allow explicitly enabling/disabling formatting when mounts fail. If you do not call this `setConfig` method before performing `begin()`, you will get the filesystem's default behavior and configuration. By default, SPIFFS will autoformat the filesystem if it cannot mount it, while SDFS will not.

4.4.2 begin

```
SPIFFS.begin()
```

This method mounts SPIFFS file system. It must be called before any other FS APIs are used. Returns `true` if file system was mounted successfully, false otherwise. With no options it will format SPIFFS if it is unable to mount it on the first try.

4.4.3 end

```
SPIFFS.end()
```

This method unmounts SPIFFS file system. Use this method before updating SPIFFS using OTA.

4.4.4 format

```
SPIFFS.format()
```

Formats the file system. May be called either before or after calling `begin`. Returns `true` if formatting was successful.

4.4.5 open

```
SPIFFS.open(path, mode)
```

Opens a file. `path` should be an absolute path starting with a slash (e.g. `/dir/filename.txt`). `mode` is a string specifying access mode. It can be one of "r", "w", "a", "r+", "w+", "a+". Meaning of these modes is the same as for `fopen` C function.

r	Open text file for reading. The stream is positioned at the beginning of the file.
r+	Open for reading and writing. The stream is positioned at the beginning of the file.
w	Truncate file to zero length or create text file for writing.

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	The stream is positioned at the beginning of the file.
w+	Open for reading and writing. The file is created if it does not exist, otherwise it is truncated. The stream is positioned at the beginning of the file.
a	Open for appending (writing at end of file). The file is created if it does not exist. The stream is positioned at the end of the file.
a+	Open for reading and appending (writing at end of file). The file is created if it does not exist. The initial file position for reading is at the beginning of the file, but output is always appended to the end of the file.

Returns *File* object. To check whether the file was opened successfully, use the boolean operator.

```
File f = SPIFFS.open("/f.txt", "w");
if (!f) {
    Serial.println("file open failed");
}
```

4.4.6 exists

```
SPIFFS.exists(path)
```

Returns *true* if a file with given path exists, *false* otherwise.

4.4.7 openDir

```
SPIFFS.openDir(path)
```

Opens a directory given its absolute path. Returns a *Dir* object.

4.4.8 remove

```
SPIFFS.remove(path)
```

Deletes the file given its absolute path. Returns *true* if file was deleted successfully.

4.4.9 rename

```
SPIFFS.rename(pathFrom, pathTo)
```

Renames file from pathFrom to pathTo. Paths must be absolute. Returns *true* if file was renamed successfully.

4.4.10 info

```
FSInfo fs_info;
SPIFFS.info(fs_info);
```

Fills *FSInfo structure* with information about the file system. Returns `true` is successful, `false` otherwise.

4.5 Filesystem information structure

```
struct FSInfo {
    size_t totalBytes;
    size_t usedBytes;
    size_t blockSize;
    size_t pageSize;
    size_t maxOpenFiles;
    size_t maxPathLength;
};
```

This is the structure which may be filled using `FS::info` method. - `totalBytes` — total size of useful data on the file system - `usedBytes` — number of bytes used by files - `blockSize` — SPIFFS block size - `pageSize` — SPIFFS logical page size - `maxOpenFiles` — max number of files which may be open simultaneously - `maxPathLength` — max file name length (including one byte for zero termination)

4.6 Directory object (Dir)

The purpose of *Dir* object is to iterate over files inside a directory. It provides the methods: `next()`, `fileName()`, `fileSize()`, and `openFile(mode)`.

The following example shows how it should be used:

```
Dir dir = SPIFFS.openDir("/data");
while (dir.next()) {
    Serial.print(dir.fileName());
    if(dir.fileSize()) {
        File f = dir.openFile("r");
        Serial.println(f.size());
    }
}
```

4.6.1 next

Returns `true` while there are files in the directory to iterate over. It must be called before calling `fileName()`, `fileSize()`, and `openFile()` functions.

4.6.2 fileName

Returns the name of the current file pointed to by the internal iterator.

4.6.3 fileSize

Returns the size of the current file pointed to by the internal iterator.

4.6.4 openFile

This method takes *mode* argument which has the same meaning as for `SPIFFS.open()` function.

4.7 File object

`SPIFFS.open()` and `dir.openFile()` functions return a *File* object. This object supports all the functions of *Stream*, so you can use `readBytes`, `findUntil`, `parseInt`, `println`, and all other *Stream* methods.

There are also some functions which are specific to *File* object.

4.7.1 seek

```
file.seek(offset, mode)
```

This function behaves like `fseek` C function. Depending on the value of `mode`, it moves current position in a file as follows:

- if `mode` is `SeekSet`, position is set to `offset` bytes from the beginning.
- if `mode` is `SeekCur`, current position is moved by `offset` bytes.
- if `mode` is `SeekEnd`, position is set to `offset` bytes from the end of the file.

Returns *true* if position was set successfully.

4.7.2 position

```
file.position()
```

Returns the current position inside the file, in bytes.

4.7.3 size

```
file.size()
```

Returns file size, in bytes.

4.7.4 name

```
String name = file.name();
```

Returns file name, as `const char*`. Convert it to *String* for storage.

4.7.5 close

```
file.close()
```

Close the file. No other operations should be performed on *File* object after `close` function was called.

ESP8266WiFi library

ESP8266 is all about Wi-Fi. If you are eager to connect your new ESP8266 module to Wi-Fi network to start sending and receiving data, this is a good place to start. If you are looking for more in depth details of how to program specific Wi-Fi networking functionality, you are also in the right place.

5.1 Introduction

The [Wi-Fi library](#) for ESP8266 has been developed based on [ESP8266 SDK](#), using naming convention and overall functionality philosophy of [Arduino WiFi library](#). Over time the wealth Wi-Fi features ported from ESP8266 SDK to [esp8266 / Arduino](#) outgrew [Arduino WiFi library](#) and it became apparent that we need to provide separate documentation on what is new and extra.

This documentation will walk you through several classes, methods and properties of [ESP8266WiFi](#) library. If you are new to C++ and Arduino, don't worry. We will start from general concepts and then move to detailed description of members of each particular class including usage examples.

The scope of functionality offered by [ESP8266WiFi](#) library is quite extensive and therefore this description has been broken up into separate documents marked with `:arrow_right:`.

5.1.1 Quick Start

Hopefully you are already familiar how to load [Blink.ino](#) sketch to ESP8266 module and get the LED blinking. If not, please check [this tutorial](#) by Adafruit or [another great tutorial](#) developed by Sparkfun.

To hook up ESP module to Wi-Fi (like hooking up a mobile phone to a hot spot), you need just couple of lines of code:

```
#include <ESP8266WiFi.h>

void setup()
{
  Serial.begin(115200);
  Serial.println();
}
```

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```

WiFi.begin("network-name", "pass-to-network");

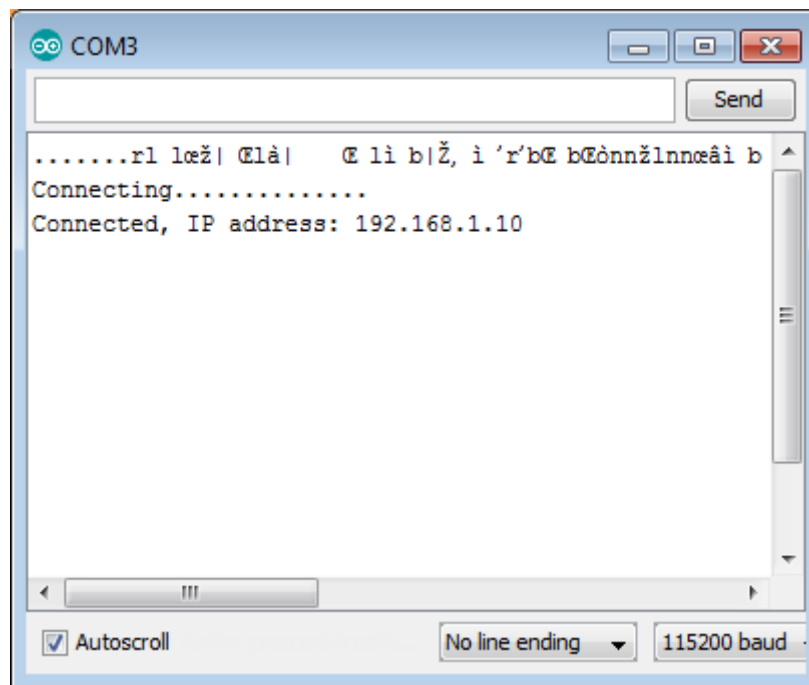
Serial.print("Connecting");
while (WiFi.status() != WL_CONNECTED)
{
    delay(500);
    Serial.print(".");
}
Serial.println();

Serial.print("Connected, IP address: ");
Serial.println(WiFi.localIP());
}

void loop() {}

```

In the line `WiFi.begin("network-name", "pass-to-network")` replace `network-name` and `pass-to-network` with name and password to the Wi-Fi network you like to connect. Then upload this sketch to ESP module and open serial monitor. You should see something like:



How does it work? In the first line of sketch `#include <ESP8266WiFi.h>` we are including [ESP8266WiFi](#) library. This library provides ESP8266 specific Wi-Fi routines we are calling to connect to network.

Actual connection to Wi-Fi is initialized by calling:

```
WiFi.begin("network-name", "pass-to-network");
```

Connection process can take couple of seconds and we are checking for this to complete in the following loop:

```
while (WiFi.status() != WL_CONNECTED)
{
```

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```

delay(500);
Serial.print(".");
}

```

The `while()` loop will keep looping while `WiFi.status()` is other than `WL_CONNECTED`. The loop will exit only if the status changes to `WL_CONNECTED`.

The last line will then print out IP address assigned to ESP module by **DHCP**:

```
Serial.println(WiFi.localIP());
```

If you don't see the last line but just more and more dots, then likely name or password to the Wi-Fi network in sketch is entered incorrectly. Verify name and password by connecting from scratch to this Wi-Fi a PC or a mobile phone.

Note: if connection is established, and then lost for some reason, ESP will automatically reconnect to last used access point once it is again back on-line. This will be done automatically by Wi-Fi library, without any user intervention.

That's all you need to connect ESP8266 to Wi-Fi. In the following chapters we will explain what cool things can be done by ESP once connected.

5.1.2 Who is Who

Devices that connect to Wi-Fi network are called stations (STA). Connection to Wi-Fi is provided by an access point (AP), that acts as a hub for one or more stations. The access point on the other end is connected to a wired network. An access point is usually integrated with a router to provide access from Wi-Fi network to the internet. Each access point is recognized by a SSID (**S**ervice **S**et **I**dentifier), that essentially is the name of network you select when connecting a device (station) to the Wi-Fi.

ESP8266 module can operate as a station, so we can connect it to the Wi-Fi network. It can also operate as a soft access point (soft-AP), to establish its own Wi-Fi network. Therefore we can connect other stations to such ESP module. ESP8266 is also able to operate both in station and soft access point mode. This provides possibility of building e.g. [mesh networks](#).

The [ESP8266WiFi](#) library provides wide collection of C++ [methods](#) (functions) and [properties](#) to configure and operate an ESP8266 module in station and / or soft access point mode. They are described in the following chapters.

5.2 Class Description

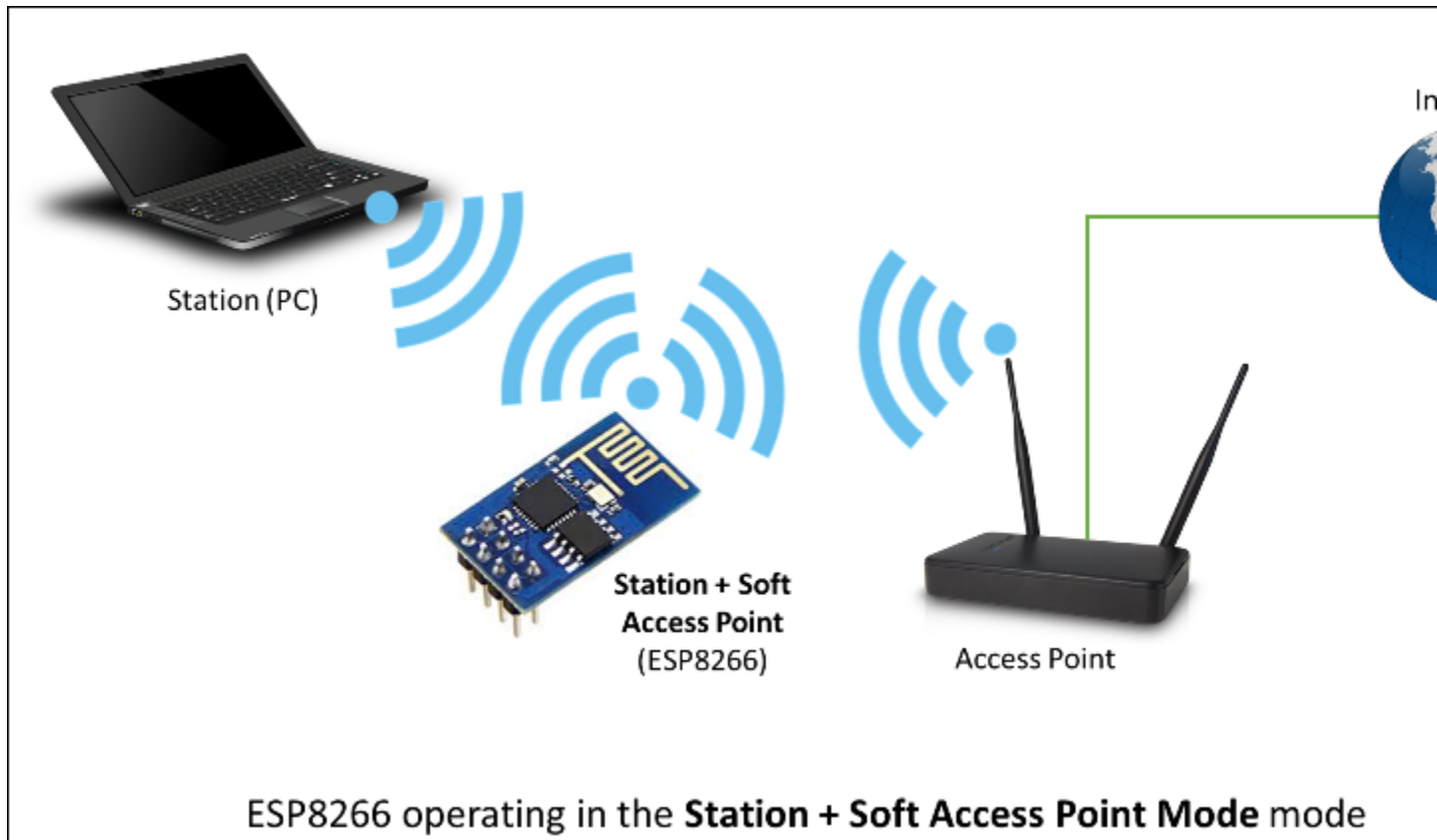
The [ESP8266WiFi](#) library is broken up into several classes. In most of cases, when writing the code, user is not concerned with this classification. We are using it to break up description of this library into more manageable pieces.

Chapters below describe all function calls ([methods](#) and [properties](#) in C++ terms) listed in particular classes of [ESP8266WiFi](#). Description is illustrated with application examples and code snippets to show how to use functions in practice. Most of this information is broken up into separate documents. Please follow to access them.

5.2.1 Station

Station (STA) mode is used to get ESP module connected to a Wi-Fi network established by an access point.

Station class has several features to facilitate management of Wi-Fi connection. In case the connection is lost, ESP8266 will automatically reconnect to the last used access point, once it is again available. The same happens on module reboot. This is possible since ESP is saving credentials to last used access point in flash (non-volatile) memory.

**B**

BufferDataSource
BufferedStreamDataSource

C

ClientContext

D

DataSource

E

ESP8266WiFiAPClass
ESP8266WiFiClass
ESP8266WiFiGenericClass
ESP8266WiFiMulti
ESP8266WiFiScanClass
ESP8266WiFiSTAClass

P

ProgmemStream

S

SList
SSLContext

U

UdpContext

W

WifiAPList_t

WiFiClient

WiFiClientSecure

WiFiEventHandlerOpaque

WiFiEventModeChange

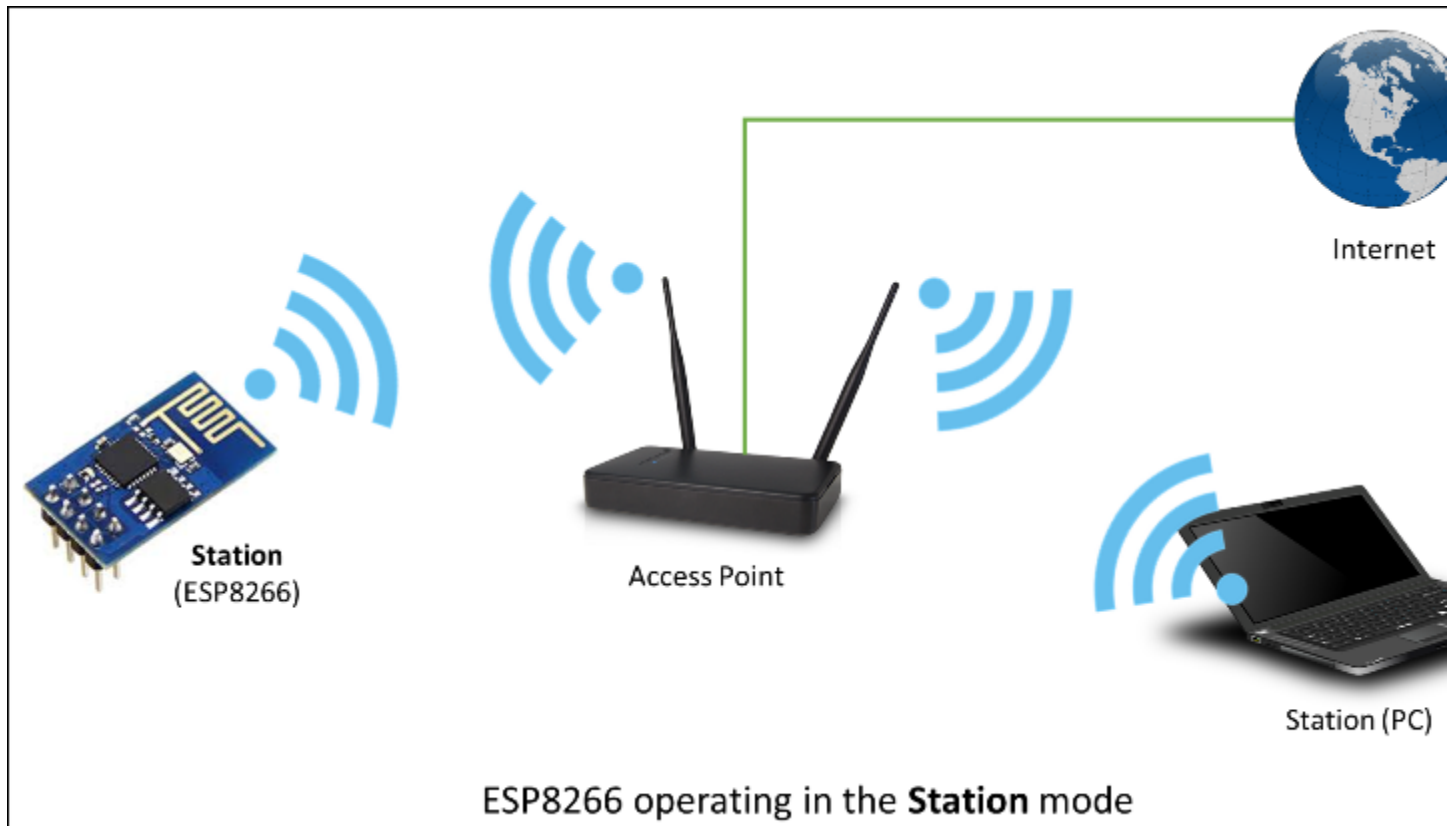
WiFiEventSoftAPModeProbeRequest

WiFiEventSoftAPModeStationConnect

WiFiEventSoftAPModeStationDisconnect

WiFiEventStationModeAuthModeChange

WiFiEventStationModeConnected



Using the saved data ESP will also reconnect if sketch has been changed but code does not alter the Wi-Fi mode or credentials.

Station Class documentation

Check out separate section with examples.

5.2.2 Soft Access Point

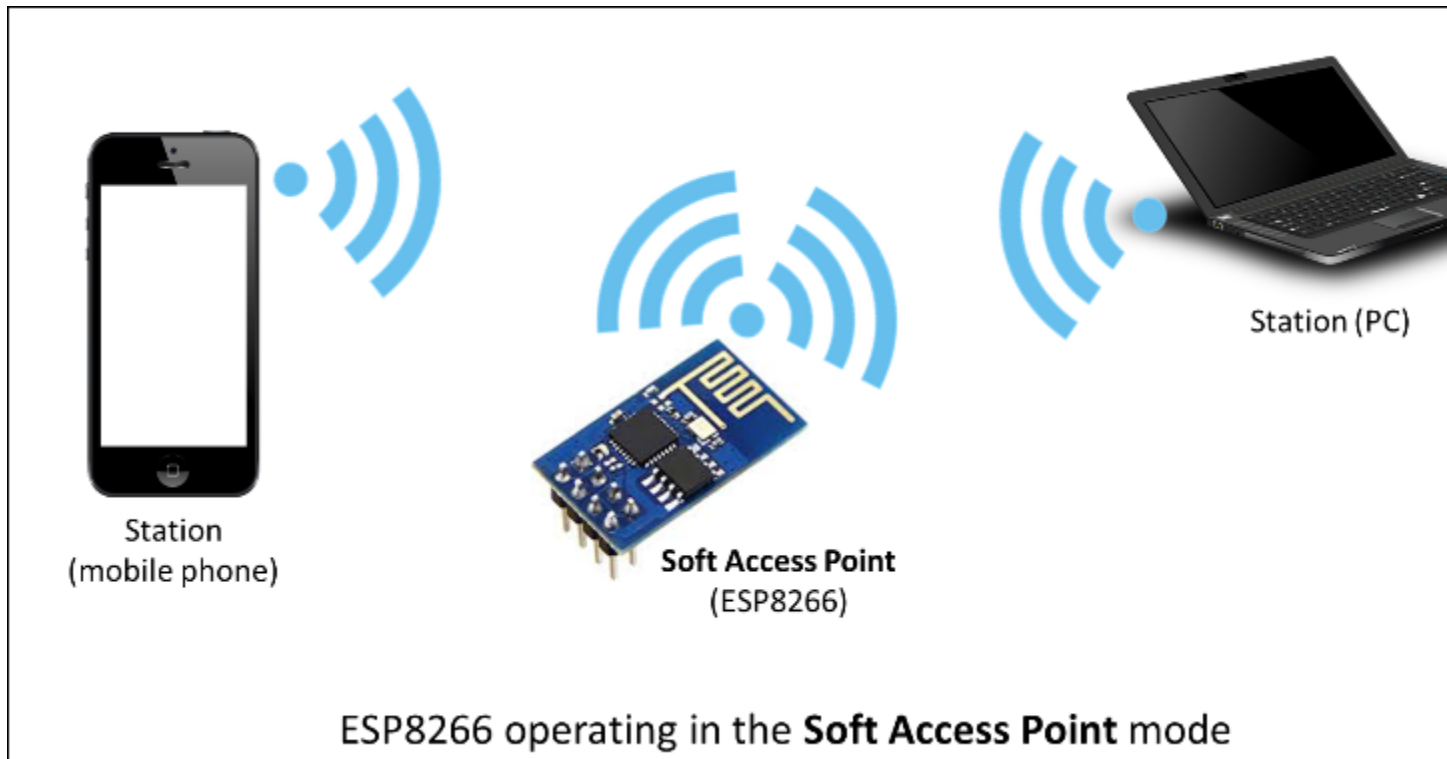
An [access point \(AP\)](#) is a device that provides access to Wi-Fi network to other devices (stations) and connects them further to a wired network. ESP8266 can provide similar functionality except it does not have interface to a wired network. Such mode of operation is called soft access point (soft-AP). The maximum number of stations that can simultaneously be connected to the soft-AP can be set [from 0 to 8](#), but defaults to 4.

The soft-AP mode is often used as an intermediate step before connecting ESP to a Wi-Fi in a station mode. This is when SSID and password to such network is not known upfront. ESP first boots in soft-AP mode, so we can connect to it using a laptop or a mobile phone. Then we are able to provide credentials to the target network. Once done ESP is switched to the station mode and can connect to the target Wi-Fi.

Another handy application of soft-AP mode is to set up [mesh networks](#). ESP can operate in both soft-AP and Station mode so it can act as a node of a mesh network.

Soft Access Point Class documentation

Check out separate section with examples.



5.2.3 Scan

To connect a mobile phone to a hot spot, you typically open Wi-Fi settings app, list available networks and pick the hot spot you need. Then enter a password (or not) and you are in. You can do the same with ESP. Functionality of scanning for, and listing of available networks in range is implemented by the Scan Class.

Scan Class documentation

Check out separate section with examples.

5.2.4 Client

The Client class creates [clients](#) that can access services provided by [servers](#) in order to send, receive and process data.

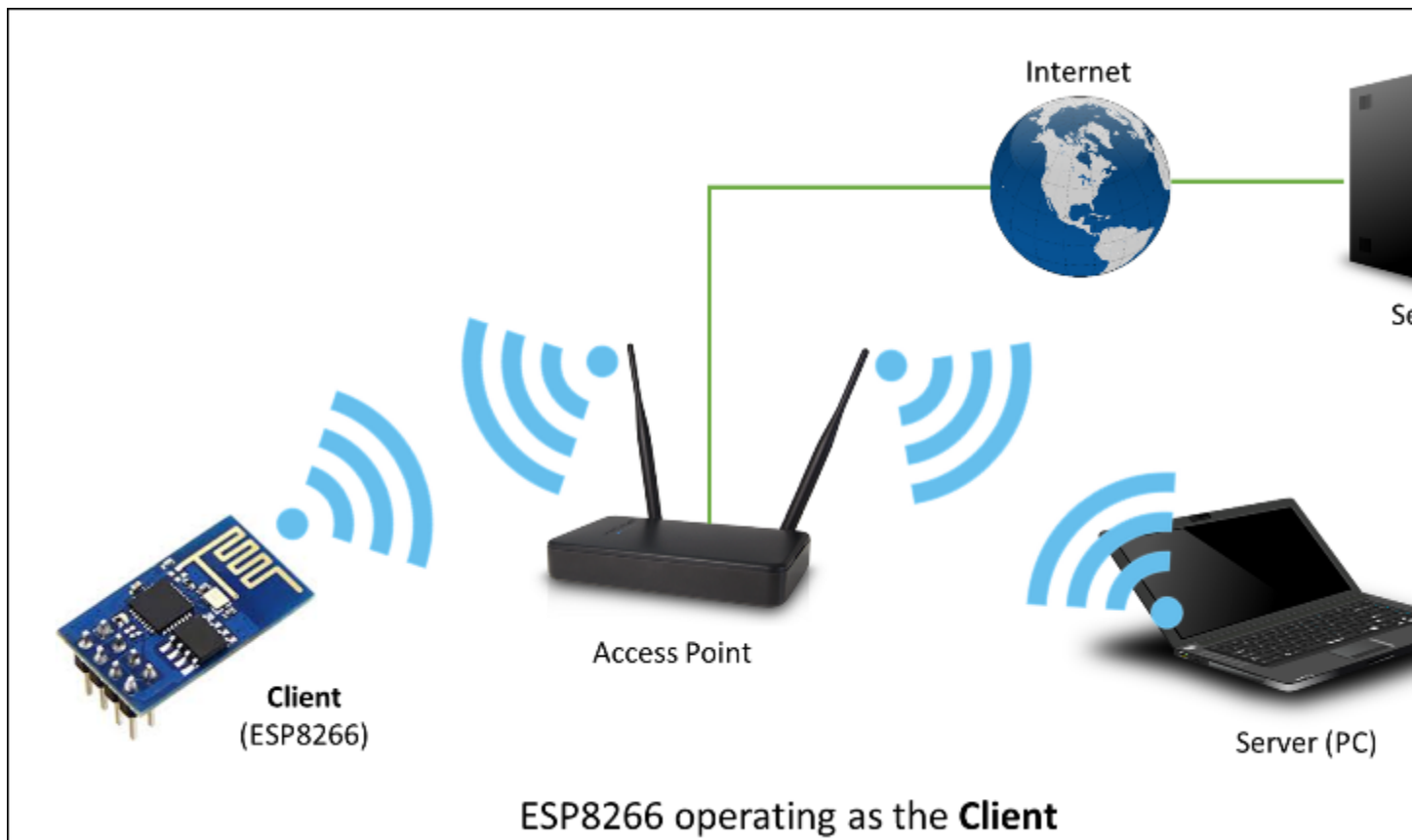
Check out separate section with examples / list of functions

5.2.5 axTLS Client Secure - DEPRECATED

The following section details axTLS, the older TLS library used by the project. It is still supported, but additional fixes and documentation will generally not be undertaken. See the following section for the updated TLS client object.

The axTLS Client Secure is an extension of [Client Class](#) where connection and data exchange with servers is done using a [secure protocol](#). It supports TLS 1.1. The TLS 1.2 is not supported.

Secure applications have additional memory (and processing) overhead due to the need to run cryptography algorithms. The stronger the certificate's key, the more overhead is needed. In practice it is not possible to run more than a single secure client at a time. The problem concerns RAM memory we can not add, the flash memory size is usually not the issue. If you like to learn how [client secure library](#) has been developed, access to what servers have been tested, and how memory limitations have been overcome, read fascinating issue report [#43](#).



Check out separate section with examples / list of functions

5.2.6 BearSSL Client Secure and Server Secure

BearSSL::WiFiClientSecure and *BearSSL::WiFiServerSecure* are extensions of the standard *Client* and *Server* classes where connection and data exchange with servers and clients using [secure protocol](#). It supports TLS 1.2 using a wide variety of modern ciphers, hashes, and key types.



Secure clients and servers require significant amounts of additional memory and processing to enable their cryptographic algorithms. In general only a single secure client or server connection at a time can be processed given the little RAM present on the ESP8266, but there are methods of reducing this RAM requirement detailed in the relevant sections.

BearSSL::WiFiClientSecure contains more information on using and configuring TLS connections.

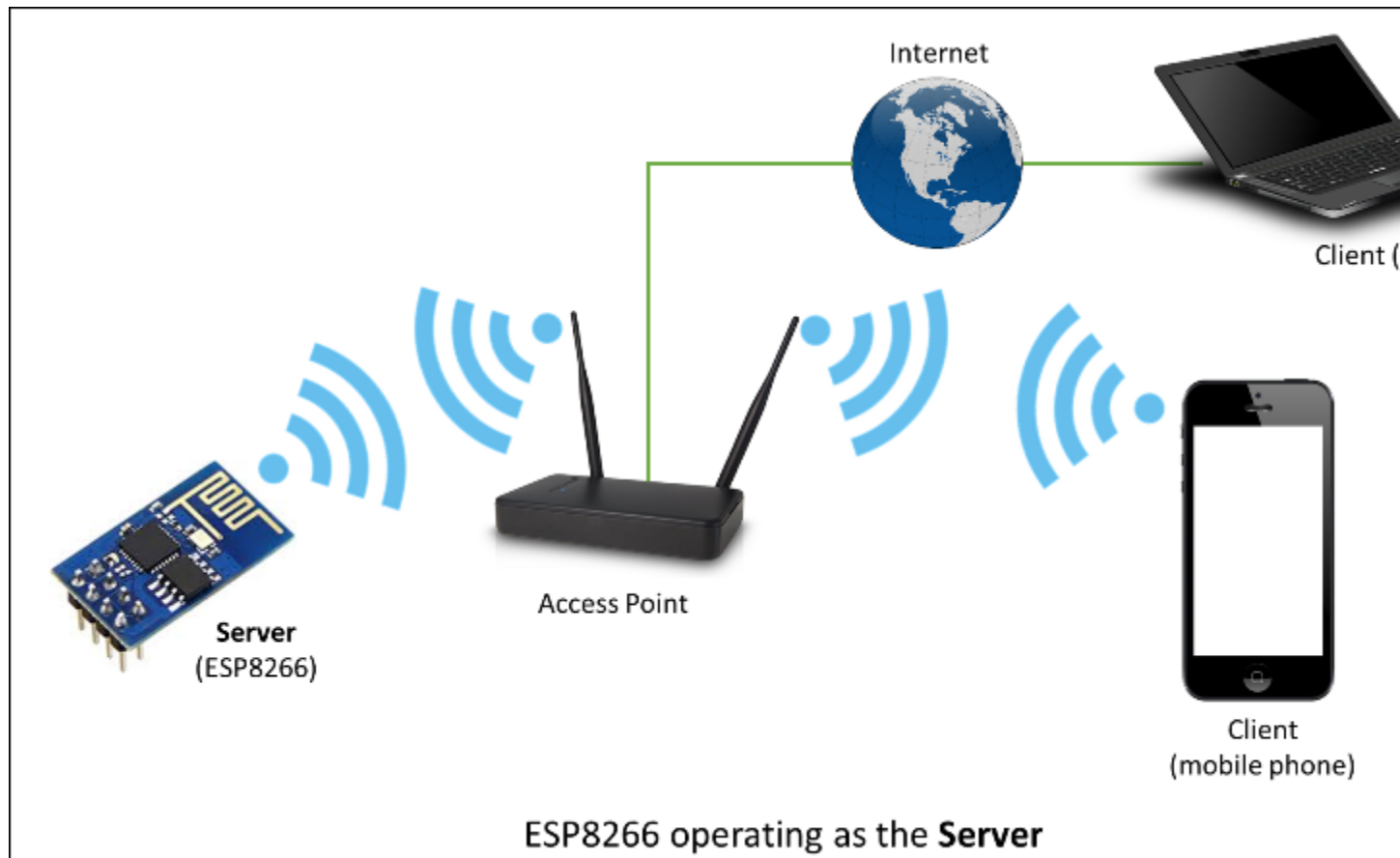
BearSSL::WiFiServerSecure discusses the TLS server mode available. Please read and understand the *BearSSL::WiFiClientSecure* first as the server uses most of the same concepts.

5.2.7 Server

The Server Class creates [servers](#) that provide functionality to other programs or devices, called [clients](#).

Clients connect to sever to send and receive data and access provided functionality.

Check out separate section with examples / list of functions.



5.2.8 UDP

The UDP Class enables the [User Datagram Protocol \(UDP\)](#) messages to be sent and received. The UDP uses a simple “fire and forget” transmission model with no guarantee of delivery, ordering, or duplicate protection. UDP provides checksums for data integrity, and port numbers for addressing different functions at the source and destination of the datagram.

Check out separate section with examples / list of functions.

5.2.9 Generic

There are several functions offered by ESP8266’s [SDK](#) and not present in [Arduino WiFi library](#). If such function does not fit into one of classes discussed above, it will likely be in Generic Class. Among them is handler to manage Wi-Fi events like connection, disconnection or obtaining an IP, Wi-Fi mode changes, functions to manage module sleep mode, hostname to an IP address resolution, etc.

Check out separate section with examples / list of functions.

5.3 Diagnostics

There are several techniques available to diagnose and troubleshoot issues with getting connected to Wi-Fi and keeping connection alive.

5.3.1 Check Return Codes

Almost each function described in chapters above returns some diagnostic information.

Such diagnostic may be provided as a simple `boolean` type `true` or `false` to indicate operation result. You may check this result as described in examples, for instance:

```
Serial.printf("Wi-Fi mode set to WIFI_STA %s\n", WiFi.mode(WIFI_STA) ? "" : "Failed!\n");
```

Some functions provide more than just a binary status information. A good example is `WiFi.status()`.

```
Serial.printf("Connection status: %d\n", WiFi.status());
```

This function returns following codes to describe what is going on with Wi-Fi connection:

- 0: `WL_IDLE_STATUS` when Wi-Fi is in process of changing between statuses
- 1: `WL_NO_SSID_AVAIL` in case configured SSID cannot be reached
- 3: `WL_CONNECTED` after successful connection is established
- 4: `WL_CONNECT_FAILED` if password is incorrect
- 6: `WL_DISCONNECTED` if module is not configured in station mode

It is a good practice to display and check information returned by functions. Application development and troubleshooting will be easier with that.

5.3.2 Use printDiag

There is a specific function available to print out key Wi-Fi diagnostic information:

```
WiFi.printDiag(Serial);
```

A sample output of this function looks as follows:

```
Mode: STA+AP
PHY mode: N
Channel: 11
AP id: 0
Status: 5
Auto connect: 1
SSID (10): sensor-net
Passphrase (12): 123!$#0&*esP
BSSID set: 0
```

Use this function to provide snapshot of Wi-Fi status in these parts of application code, that you suspect may be failing.

5.3.3 Enable Wi-Fi Diagnostic

By default the diagnostic output from Wi-Fi libraries is disabled when you call `Serial.begin`. To enable debug output again, call `Serial.setDebugOutput(true)`. To redirect debug output to `Serial1` instead, call `Serial1.setDebugOutput(true)`. For additional details regarding diagnostics using serial ports please refer to [the documentation](#).

Below is an example of output for sample sketch discussed in [Quick Start](#) above with `Serial.setDebugOutput(true)`:

```
Connecting
state: 0 -> 2 (b0)
state: 2 -> 3 (0)
state: 3 -> 5 (10)
add 0
aid 1
cnt

connected with sensor-net, channel 6
dhcp client start...
chg_B1:-40
...ip:192.168.1.10,mask:255.255.255.0,gw:192.168.1.9
.
Connected, IP address: 192.168.1.10
```

The same sketch without `Serial.setDebugOutput(true)` will print out only the following:

```
Connecting...
Connected, IP address: 192.168.1.10
```

5.3.4 Enable Debugging in IDE

Arduino IDE provides convenient method to *enable debugging* for specific libraries.

5.4 What's Inside?

If you like to analyze in detail what is inside of the ESP8266WiFi library, go directly to the [ESP8266WiFi](#) folder of esp8266 / Arduino repository on the GitHub.

To make the analysis easier, rather than looking into individual header or source files, use one of free tools to automatically generate documentation. The class index in chapter [Class Description](#) above has been prepared in no time using great [Doxygen](#), that is the de facto standard tool for generating documentation from annotated C++ sources.

The screenshot shows the Doxygen-generated documentation for the ESP8266WiFi library. The browser address bar indicates the path: C:\Users\Krzysztof\Documents\Projects\esp82666-doc\esp8266wifi\Doxygen\cl. The page title is "ESP8266WiFi 1" and the subtitle is "ESP8266WiFi Library Documentation". The navigation tabs include "Main Page", "Modules", "Classes", and "Files". Under "Classes", there are sub-tabs: "Class List", "Class Index", "Class Hierarchy", and "Class Members". The "Class List" tab is active, showing a tree view of the library's structure. The "ESP8266WiFiClass" is highlighted in the tree. The main content area displays the "ESP8266WiFiClass Class Reference". It includes the preprocessor directive `#include <ESP8266WiFi.h>` and an inheritance diagram for ESP8266WiFiClass. The diagram shows ESP8266WiFiGenericClass and ESP8266WiFiSTAClass as base classes for ESP8266WiFiClass. Below the diagram, the "Public Member Functions" section lists the functions: `void printDiag (Print &dest)` and lists inherited functions from ESP8266WiFiGenericClass, ESP8266WiFiSTAClass, ESP8266WiFiScanClass, and ESP8266WiFiAPClass.

The tool crawls through all header and source files collecting information from formatted comment blocks. If developer of particular class annotated the code, you will see it like in examples below.


```

wl_status_t ESP8266WiFiSTAClass::begin ( const char *   ssid,
                                           const char *   passphrase = NULL,
                                           int32_t        channel = 0,
                                           const uint8_t * bssid = NULL,
                                           bool           connect = true
                                           )

```

Start Wifi connection if passphrase is set the most secure supported mode will be automatically selected

Parameters

ssid const char* Pointer to the SSID string.
passphrase const char * Optional. Passphrase. Valid characters in a passphrase must be between ASCII 32-126
bssid uint8_t[6] Optional. BSSID / MAC of AP
channel Optional. Channel of AP
connect Optional. call connect

Returns

Definition at line 97 of file [ESP8266WiFiSTA.cpp](#).

```

bool ESP8266WiFiSTAClass::hostname ( char * aHostname )

```

Set ESP8266 station DHCP hostname

Parameters

aHostname max length:32

Returns

ok

Definition at line 422 of file [ESP8266WiFiSTA.cpp](#).

If code is not annotated, you will still see the function prototype including types of arguments, and can use provided links to jump straight to the source code to check it out on your own. Doxygen provides really excellent navigation between members of library.

```
uint8_t WiFiUDP::begin ( uint16_t port )
```

Definition at line 77 of file [WiFiUdp.cpp](#).

Several classes of [ESP8266WiFi](#) are not annotated. When preparing this document, [Doxygen](#) has been tremendous help to quickly navigate through almost 30 files that make this library.

6.1 Introduction

OTA (Over the Air) update is the process of loading the firmware to ESP module using Wi-Fi connection rather than a serial port. Such functionality became extremely useful in case of limited or no physical access to the module.

OTA may be done using:

- *Arduino IDE*
- *Web Browser*
- *HTTP Server*

Arduino IDE option is intended primarily for software development phase. The two other options would be more useful after deployment, to provide module with application updates manually with a web browser, or automatically using a http server.

In any case, the first firmware upload has to be done over a serial port. If the OTA routines are correctly implemented in a sketch, then all subsequent uploads may be done over the air.

By default there is no imposed security on OTA process. It is up to developer to ensure that updates are allowed only from legitimate / trusted sources. Once the update is complete, the module restarts, and the new code is executed. The developer should ensure that the application running on the module is shut down and restarted in a safe manner. Chapters below provide additional information regarding security and safety of OTA process.

6.1.1 Security Disclaimer

No guarantees as to the level of security provided for your application by the following methods is implied. Please refer to the GNU LGPL license associated for this project for full disclaimers. If you do find security weaknesses, please don't hesitate to contact the maintainers or supply pull requests with fixes. The MD5 verification and password protection schemes are already known as supplying a very weak level of security.

6.1.2 Basic Security

The module has to be exposed wirelessly to get it updated with a new sketch. That poses chances of module being violently hacked and loaded with some other code. To reduce likelihood of being hacked consider protecting your uploads with a password, selecting certain OTA port, etc.

Check functionality provided with [ArduinoOTA](#) library that may improve security:

```
void setPort(uint16_t port);  
void setHostname(const char* hostname);  
void setPassword(const char* password);
```

Certain protection functionality is already built in and do not require any additional coding by developer. [ArduinoOTA](#) and [espot.py](#) use [Digest-MD5](#) to authenticate upload. Integrity of transferred data is verified on ESP side using [MD5](#) checksum.

Make your own risk analysis and depending on application decide what library functions to implement. If required, consider implementation of other means of protection from being hacked, e.g. exposing module for uploads only according to specific schedule, trigger OTA only be user pressing dedicated “Update” button wired to ESP, etc.

6.1.3 Advanced Security - Signed Updates

While the above password-based security will dissuade casual hacking attempts, it is not highly secure. For applications where a higher level of security is needed, cryptographically signed OTA updates can be required. It uses SHA256 hashing in place of MD5 (which is known to be cryptographically broken) and RSA-2048 bit level encryption to guarantee only the holder of a cryptographic private key can generate code accepted by the OTA update mechanisms.

These are updates whose compiled binary are signed with a private key (held by the developer) and verified with a public key (stored in the application and available for all to see). The signing process computes a hash of the binary code, encrypts the hash with the developer’s private key, and appends this encrypted hash to the binary that is uploaded (via OTA, web, or HTTP server). If the code is modified or replaced in any way by anyone by the developer with the key, the hash will not match and the ESP8266 will reject the upload and not accept it.

Cryptographic signing only protects against tampering of binaries delivered OTA. If someone has physical access they will always be able to flash the device over the serial port. Signing also does not encrypt anything but the hash (so that it can’t be modified), so this does not provide protection for code inside the device. Again, if a user has physical access they can read out your program.

Securing your private key is paramount. The same private/public keypair needs to be used to sign binaries as the original upload. Loss of the private key associated with a binary means that you will not be able to OTA to update any of your devices in the field. Alternatively, if the private key is copied, then the copy can be used to sign binaries which will be accepted.

Signed Binary Format

The format of a signed binary is compatible with the standard binary format, and can be uploaded to a non-signed ESP8266 via serial or OTA without any conditions. Note, however, that once an unsigned OTA app is overwritten by this signed version, further updates will require signing.

As shown below, the signed hash is appended to the unsigned binary followed by the total length of the signed hash (i.e. if the signed hash was 64 bytes, then this uint32 will contain 64). This format allows for extensibility (such as adding in a CA-based validation scheme allowing multiple signing keys all based off of a trust anchor), and pull requests are always welcome.

```
NORMAL-BINARY <SIGNED HASH> <uint32 LENGTH-OF-SIGNING-DATA-INCLUDING-THIS-32-BITS>
```

Signed Binary Prerequisites

OpenSSL is required to run the standard signing steps, and should be available on any UNIX-like or Windows system. As usual, the latest stable version of OpenSSL is recommended.

Signing requires the generation of an RSA-2048 key (other bit lengths are supported as well, but 2048 is a good selection today) using any appropriate tool. The following lines will generate a new public/private keypair. Run them in the sketch directory:

```
openssl genrsa -out private.key 2048
openssl rsa -in private.key -outform PEM -pubout -out public.key
```

Automatic Signing – Only available on Linux and Mac

The simplest way of implementing signing is to use the automatic mode, which is only possible on Linux and Mac presently due to missing tools under Windows. This mode uses the IDE to configure the source code to enable signing verification with a given public key, and signs binaries as part of the standard build process using a given public key.

To enable this mode, just include *private.key* and *public.key* in the sketch *.ino* directory. The IDE will call a helper script (*tools/signing.py*) before the build begins to create a header to enable key validation using the given public key, and after the build process to actually do the signing, generating a *sketch.bin.signed* file. When OTA is enabled (ArduinoOTA, Web, or HTTP) the binary will only accept signed updates automatically.

When the signing process starts, the message:

```
Enabling binary signing
```

Will appear in the IDE window before a compile is launched, and at the completion of the build the signed binary file will be displayed in the IDE build window as:

```
Signed binary: /full/path/to/sketch.bin.signed
```

If you receive either of the following messages in the IDE window, the signing was not completed and you will need to verify the *public.key* and *private.key*:

```
Not enabling binary signing
... or ...
Not signing the generated binary
```

Manual Signing Binaries

Users may also manually sign executables and require the OTA process to verify their signature. In the main code, before enabling any update methods, add the call:

```
<in globals>
BearSSL::PublicKey signPubKey( ... key contents ... );
BearSSL::HashSHA256 hash;
BearSSL::SigningVerifier sign( &signPubKey );
...
<in setup()>
Update.installSignature( &hash, &sign );
```

The above snippet creates a BearSSL public key, a SHA256 hash verifier, and tells the Update object to use them to validate any updates it receives from any method.

Compile the sketch normally and, once a `.bin` file is available, sign it using the signer script:

```
<ESP8266ArduioPath>/tools/signing.py --mode sign --privatekey <path-to-private.key> --  
↪bin <path-to-unsigned-bin> --out <path-to-signed-binary>
```

6.1.4 Safety

OTA process takes ESP's resources and bandwidth during upload. Then module is restarted and a new sketch executed. Analyse and test how it affects functionality of existing and new sketch.

If ESP is placed in remote location and controlling some equipment, you should put additional attention what happens if operation of this equipment is suddenly interrupted by update process. Therefore, decide how to put this equipment into safe state before starting the update. For instance, your module may be controlling a garden watering system in a sequence. If this sequence is not properly shut down and a water valve left open, your garden may be flooded.

The following functions are provided with [ArduinoOTA](#) library and intended to handle functionality of your application during specific stages of OTA, or on an OTA error:

```
void onStart(OTA_CALLBACK(fn));  
void onEnd(OTA_CALLBACK(fn));  
void onProgress(OTA_CALLBACK_PROGRESS(fn));  
void onError(OTA_CALLBACK_ERROR(fn));
```

6.1.5 OTA Basic Requirements

Flash chip size should be able to hold the old sketch (currently running) and the new sketch (OTA) at the same time.

Keep in mind that the File system and EEPROM for example needs space too (one time) see [Flash layout](#).

```
ESP.getFreeSketchSpace();
```

can be used for checking the free space for the new sketch.

For overview of memory layout, where new sketch is stored and how it is copied during OTA process, see [Update process - memory view](#).

The following chapters provide more details and specific methods of doing OTA.

6.2 Arduino IDE

Uploading modules wirelessly from Arduino IDE is intended for the following typical scenarios: - during firmware development as a quicker alternative to loading over a serial, - for updating small quantity of modules, - only if modules are available on the same network as the computer with Arduino IDE.

6.2.1 Requirements

- The ESP and the computer must be connected to the same network.

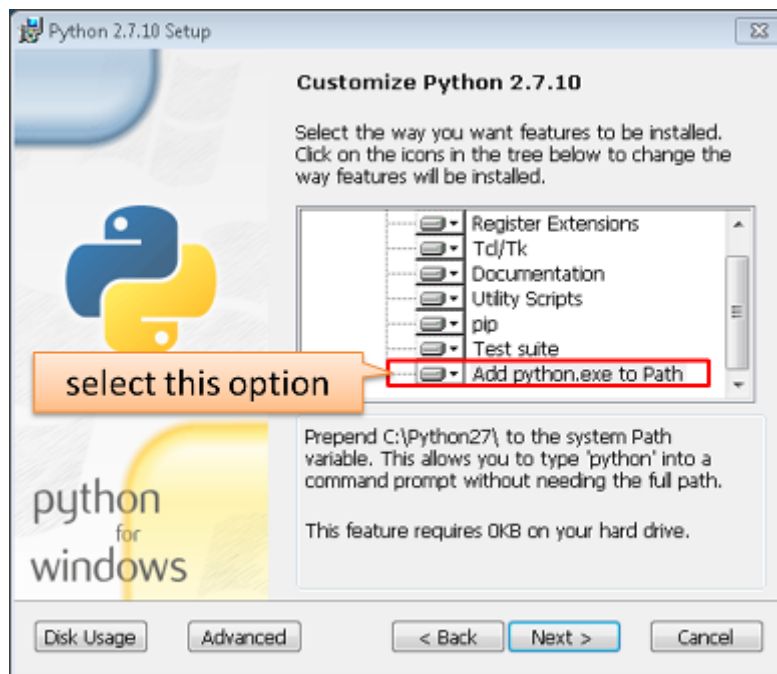
6.2.2 Application Example

Instructions below show configuration of OTA on NodeMCU 1.0 (ESP-12E Module) board. You can use any other board assuming that it meets *requirements* described above. This instruction is valid for all operating systems supported by Arduino IDE. Screen captures have been made on Windows 7 and you may see small differences (like name of serial port), if you are using Linux and MacOS.

1. Before you begin, please make sure that you have the following s/w installed:

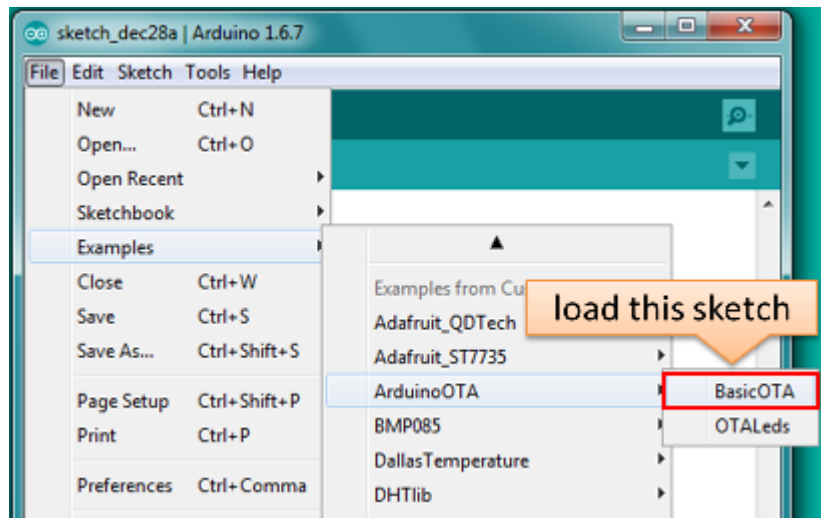
- Arduino IDE 1.6.7 or newer - <https://www.arduino.cc/en/Main/Software>
- esp8266/Arduino platform package 2.0.0 or newer - for instructions follow <https://github.com/esp8266/Arduino#installing-with-boards-manager>
- Python 2.7 - <https://www.python.org/>

Note: Windows users should select “Add python.exe to Path” (see below – this option is not selected by default).

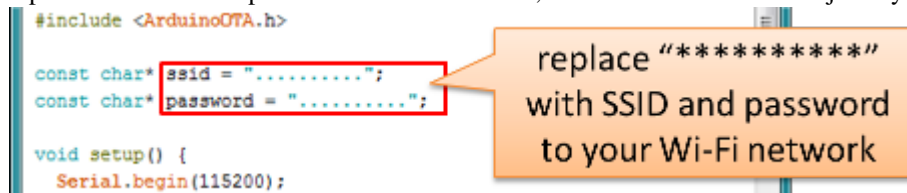


2. Now prepare the sketch and configuration for the upload over a serial port.

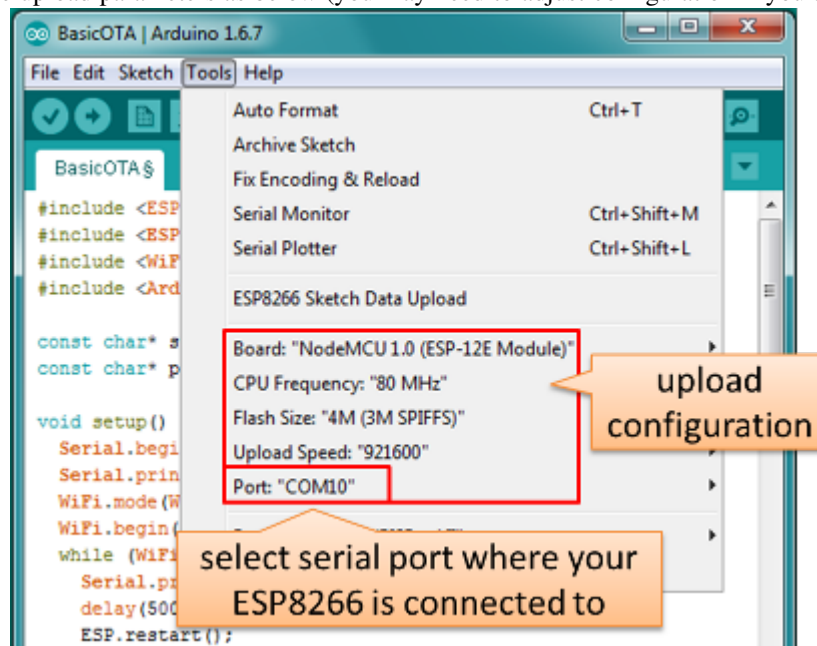
- Start Arduino IDE and load sketch BasicOTA.ino available under File > Examples > ArduinoOTA



- Update SSID and password in the sketch, so the module can join your Wi-Fi network



- Configure upload parameters as below (you may need to adjust configuration if you are using a different

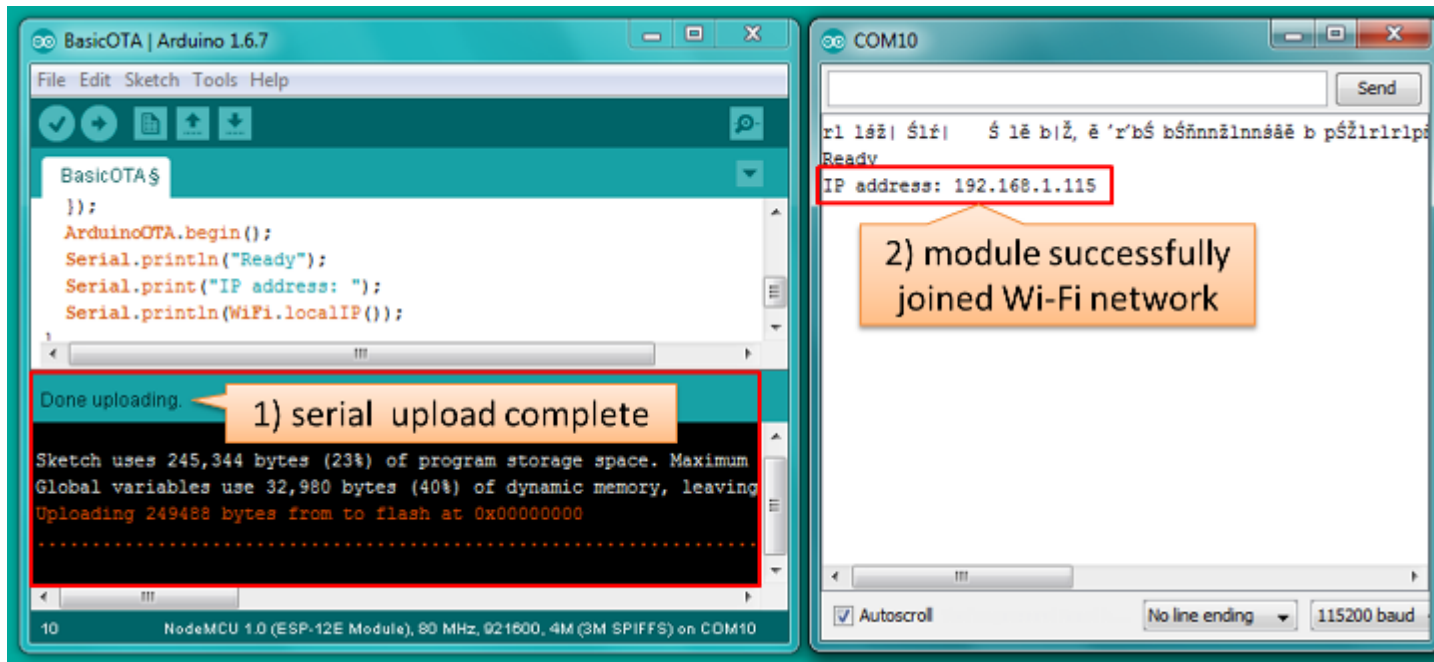


module):

Note: Depending on version of platform package and board you have, you may see Upload Using: in the menu above. This option is inactive and it does not matter what you select. It has been left for compatibility with older implementation of OTA and finally removed in platform package version 2.2.0.

3. Upload the sketch (Ctrl+U). Once done, open Serial Monitor (Ctrl+Shift+M) and check if module has joined your Wi-Fi network:

Note: ESP module should be reset after serial upload. Otherwise subsequent steps will not work. Reset may be done



automatically for you after opening serial monitor as visible on the screenshot above. It depends on how you have DTR and RTS wired from USB-Serial converter to the ESP. If reset is not done automatically, then do it by pressing reset button or manually cycling the power. For more details why this should be done please refer to [FAQ](#) regarding `ESP.restart()`.

- Only if module is connected to network, after a couple of seconds, the esp8266-ota port will show up in Arduino IDE. Select port with IP address shown in the Serial Monitor window in previous step:

Note: If OTA port does not show up, exit Arduino IDE, open it again and check if port is there. If it does not help, check your firewall and router settings. OTA port is advertised using mDNS service. To check if port is visible by your PC, you can use application like Bonjour Browser.

- Now get ready for your first OTA upload by selecting the OTA port:

Note: The menu entry `Upload Speed:` does not matter at this point as it concerns the serial port. Just left it unchanged.

- If you have successfully completed all the above steps, you can upload (Ctrl+U) the same (or any other) sketch over OTA:

Note: To be able to upload your sketch over and over again using OTA, you need to embed OTA routines inside. Please use `BasicOTA.ino` as an example.

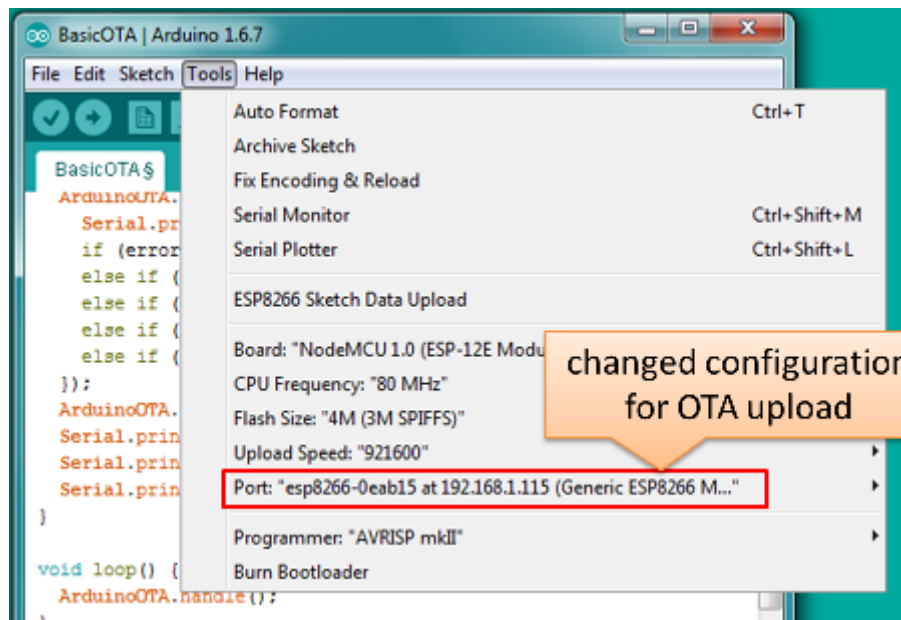
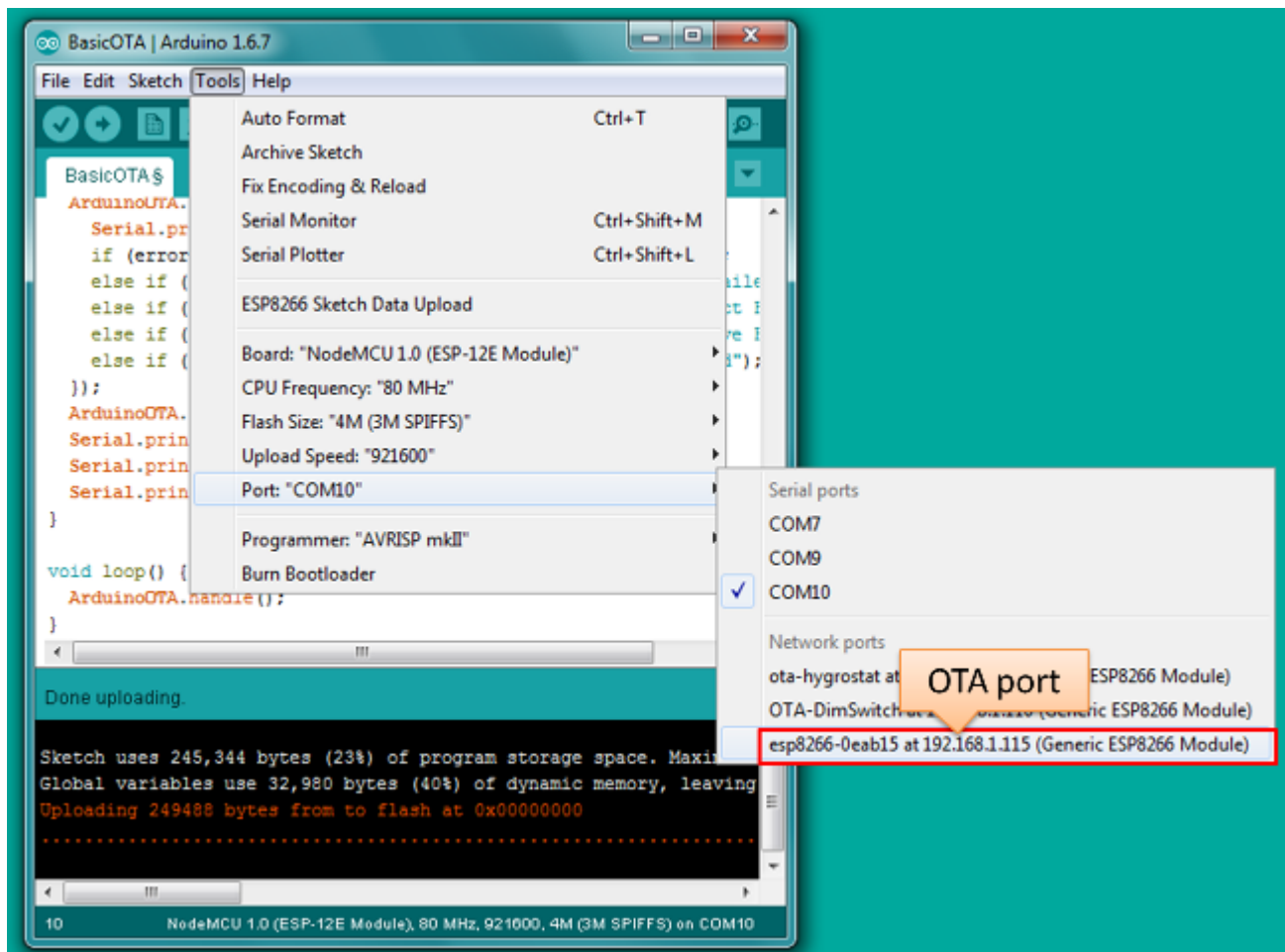
Password Protection

Protecting your OTA uploads with password is really straightforward. All you need to do, is to include the following statement in your code:

```
ArduinoOTA.setPassword((const char *) "123");
```

Where 123 is a sample password that you should replace with your own.

Before implementing it in your sketch, it is a good idea to check how it works using `BasicOTA.ino` sketch available under `File > Examples > ArduinoOTA`. Go ahead, open `BasicOTA.ino`, uncomment the above statement that is already there, and upload the sketch. To make troubleshooting easier, do not modify example sketch besides what is absolutely





required. This is including original simple 123 OTA password. Then attempt to upload sketch again (using OTA). After compilation is complete, once upload is about to begin, you should see prompt for password as follows:

Enter the password and upload should be initiated as usual with the only difference being `Authenticating...OK` message visible in upload log.

You will not be prompted for a reentering the same password next time. Arduino IDE will remember it for you. You will see prompt for password only after reopening IDE, or if you change it in your sketch, upload the sketch and then try to upload it again.

Please note, it is possible to reveal password entered previously in Arduino IDE, if IDE has not been closed since last upload. This can be done by enabling *Show verbose output during: upload* in *File > Preferences* and attempting to upload the module.

The picture above shows that the password is visible in log, as it is passed to `espot.py` upload script.

Another example below shows situation when password is changed between uploads.

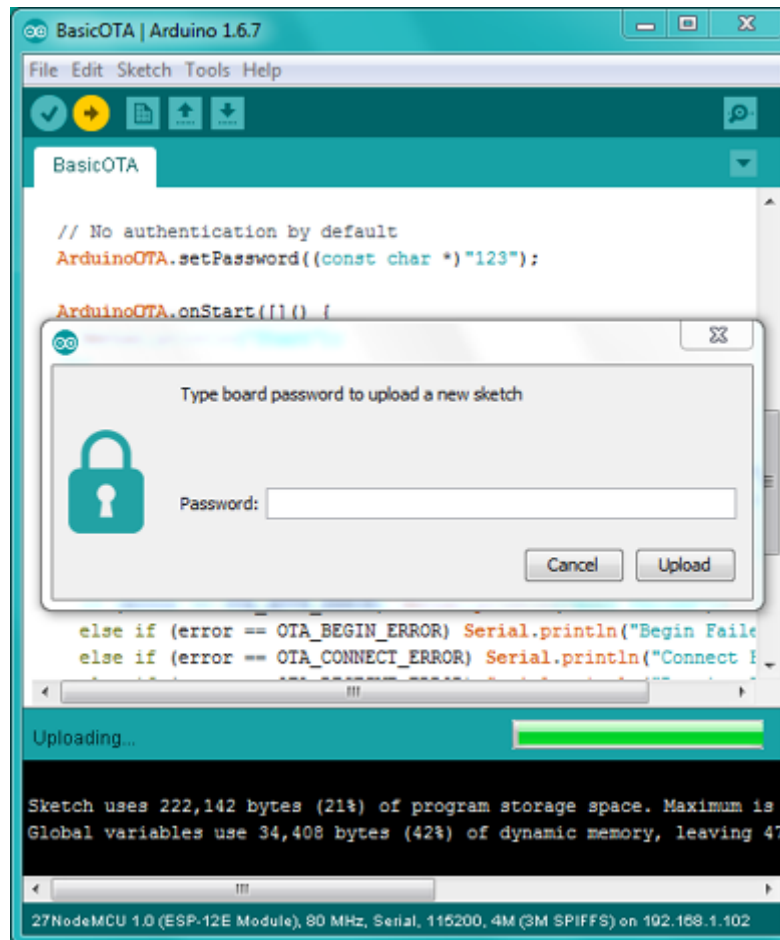
When uploading, Arduino IDE used previously entered password, so the upload failed and that has been clearly reported by IDE. Only then IDE prompted for a new password. That was entered correctly and second attempt to upload has been successful.

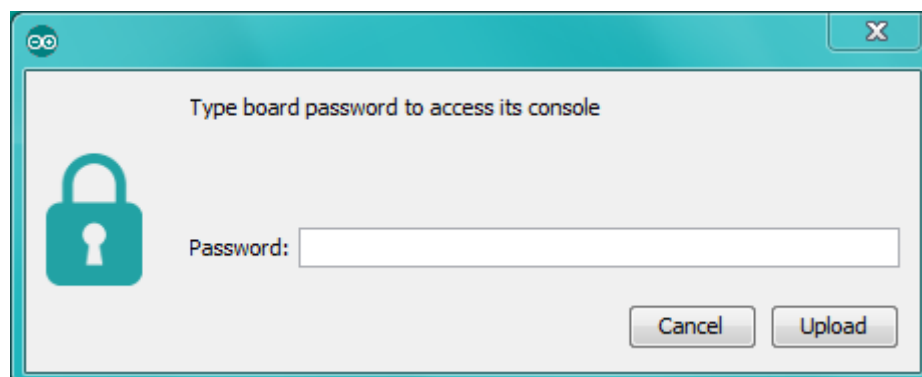
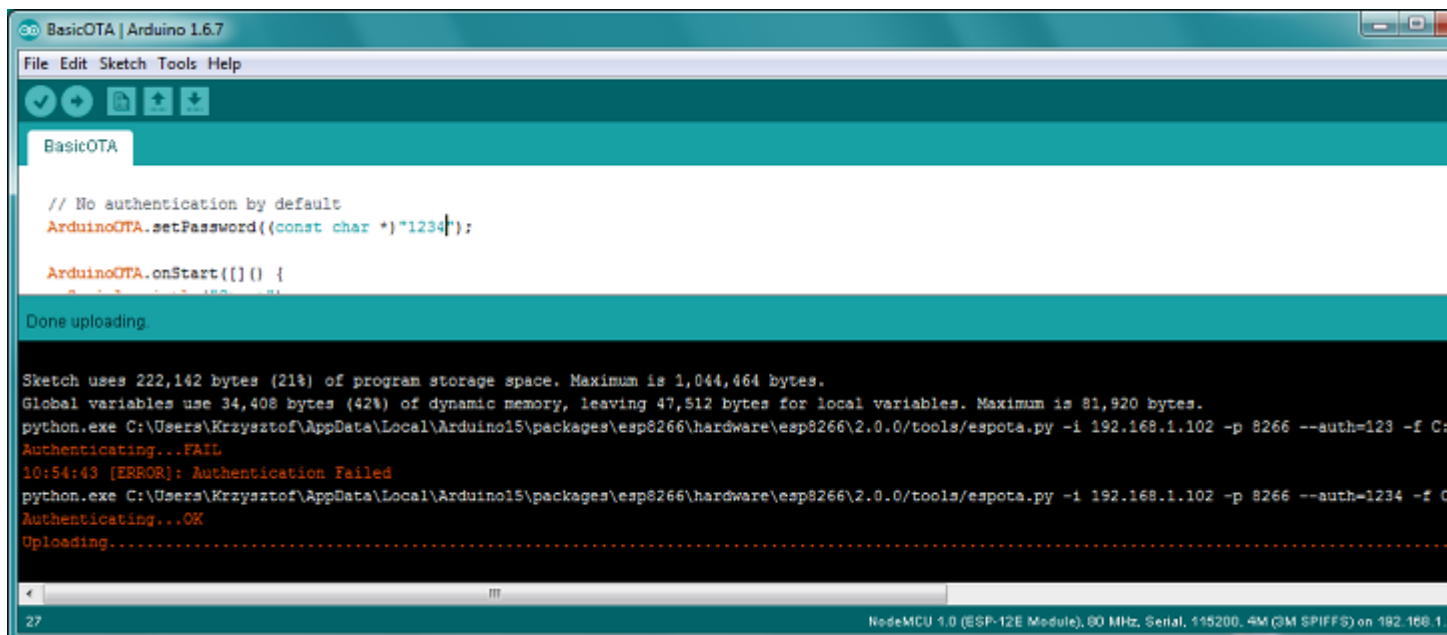
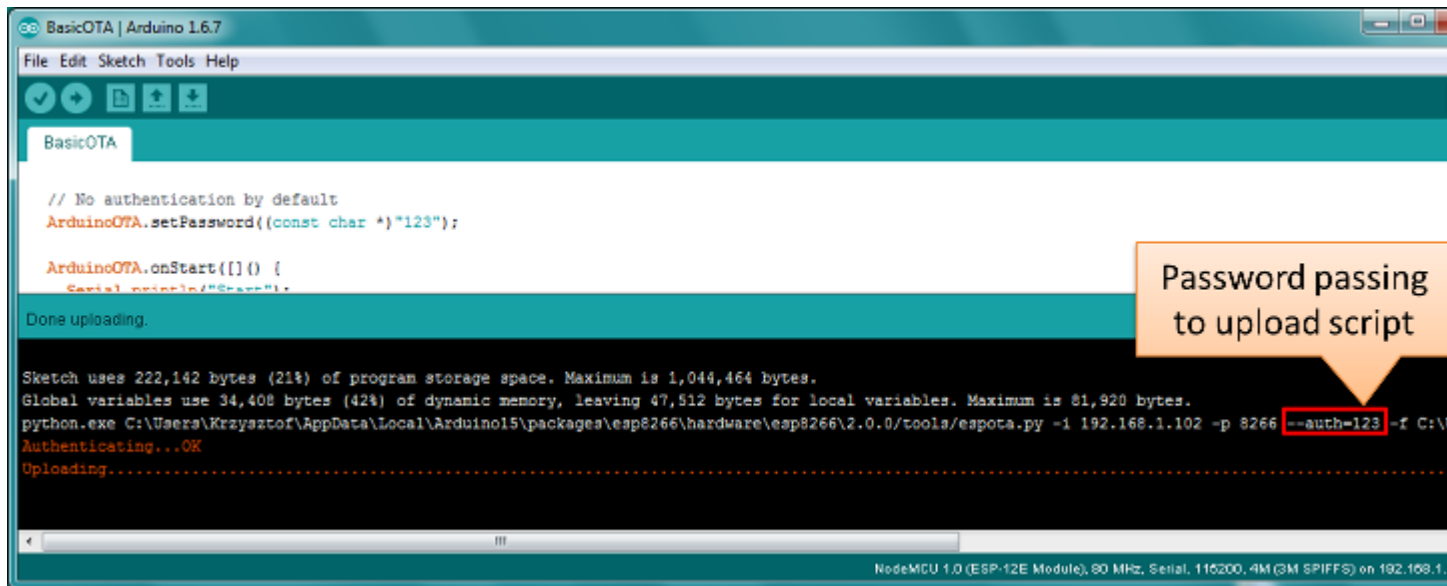
Troubleshooting

If OTA update fails, first step is to check for error messages that may be shown in upload window of Arduino IDE. If this is not providing any useful hints, try to upload again while checking what is shown by ESP on serial port. Serial Monitor from IDE will not be useful in that case. When attempting to open it, you will likely see the following:

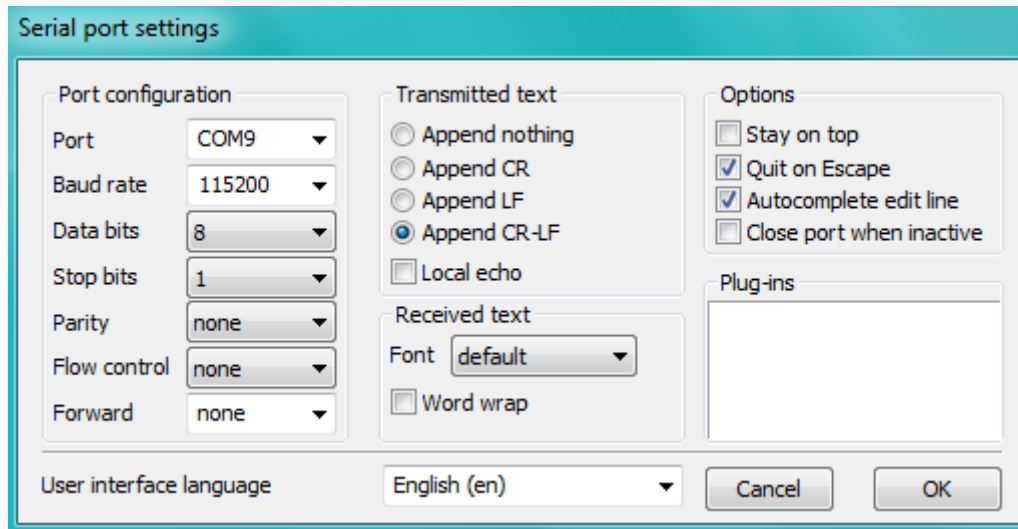
This window is for Arduino Yún and not yet implemented for esp8266/Arduino. It shows up because IDE is attempting to open Serial Monitor using network port you have selected for OTA upload.

Instead you need an external serial monitor. If you are a Windows user check out [Termite](#). This is handy, slick and simple RS232 terminal that does not impose RTS or DTR flow control. Such flow control may cause issues if you are using respective lines to toggle GPIO0 and RESET pins on ESP for upload.





Select COM port and baud rate on external terminal program as if you were using Arduino Serial Monitor. Please see typical settings for [Termite](#) below:



Then run OTA from IDE and look what is displayed on terminal. Successful *ArduinoOTA* process using *BasicOTA.ino* sketch looks like below (IP address depends on your network configuration):

If upload fails you will likely see errors caught by the uploader, exception and the stack trace, or both.

Instead of the log as on the above screen you may see the following:

If this is the case, then most likely ESP module has not been reset after initial upload using serial port.

The most common causes of OTA failure are as follows:

- not enough physical memory on the chip (e.g. ESP01 with 512K flash memory is not enough for OTA).
- too much memory declared for SPIFFS so new sketch will not fit between existing sketch and SPIFFS – see [Update process - memory view](#).
- too little memory declared in Arduino IDE for your selected board (i.e. less than physical size).
- not resetting the ESP module after initial upload using serial port.

For more details regarding flash memory layout please check [File system](#). For overview where new sketch is stored, how it is copied and how memory is organized for the purpose of OTA see [Update process - memory view](#).

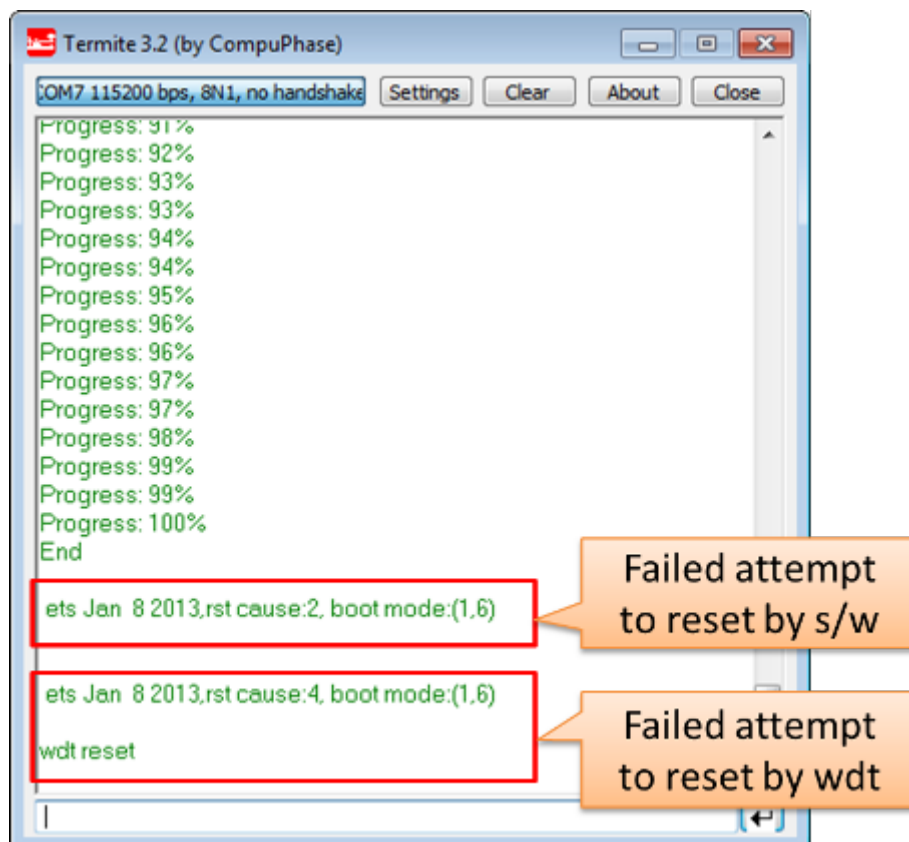
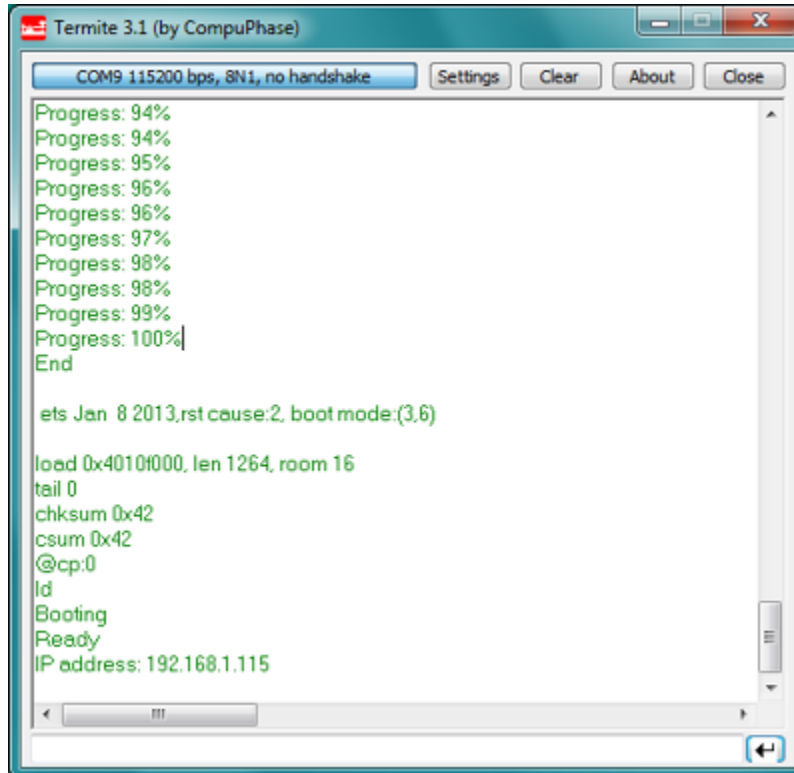
6.3 Web Browser

Updates described in this chapter are done with a web browser that can be useful in the following typical scenarios:

- after application deployment if loading directly from Arduino IDE is inconvenient or not possible,
- after deployment if user is unable to expose module for OTA from external update server,
- to provide updates after deployment to small quantity of modules when setting an update server is not practicable.

6.3.1 Requirements

- The ESP and the computer must be connected to the same network.



6.3.2 Implementation Overview

Updates with a web browser are implemented using `ESP8266HTTPUpdateServer` class together with `ESP8266WebServer` and `ESP8266mDNS` classes. The following code is required to get it work:

`setup()`

```
MDNS.begin(host);

httpUpdater.setup(&httpServer);
httpServer.begin();

MDNS.addService("http", "tcp", 80);
```

`loop()`

```
httpServer.handleClient();
```

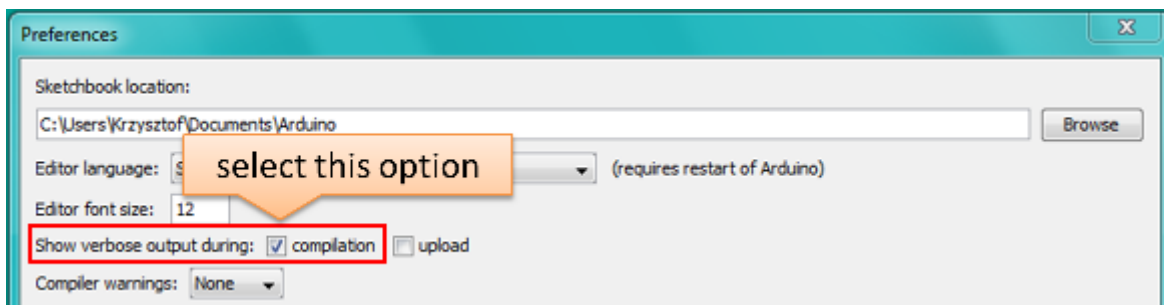
6.3.3 Application Example

The sample implementation provided below has been done using:

- example sketch `WebUpdater.ino` available in `ESP8266HTTPUpdateServer` library,
- NodeMCU 1.0 (ESP-12E Module).

You can use another module if it meets previously described *requirements*.

1. Before you begin, please make sure that you have the following software installed:
 - Arduino IDE and 2.0.0-rc1 (of Nov 17, 2015) version of platform package as described under <https://github.com/esp8266/Arduino#installing-with-boards-manager>
 - Host software depending on O/S you use:
 - (a) Avahi <http://avahi.org/> for Linux
 - (b) Bonjour <http://www.apple.com/support/bonjour/> for Windows
 - (c) Mac OSX and iOS - support is already built in / no any extra s/w is required
2. Prepare the sketch and configuration for initial upload with a serial port.
 - Start Arduino IDE and load sketch `WebUpdater.ino` available under `File > Examples > ESP8266HTTPUpdateServer`.
 - Update SSID and password in the sketch, so the module can join your Wi-Fi network.
 - Open `File > Preferences`, look for “Show verbose output during:” and check out “compilation” option.



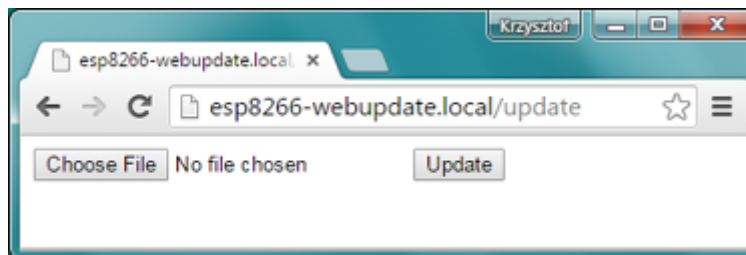
Note: This setting will be required in step 5 below. You can uncheck this setting afterwards.

3. Upload sketch (Ctrl+U). Once done, open Serial Monitor (Ctrl+Shift+M) and check if you see the following message displayed, that contains url for OTA update.



Note: Such message will be shown only after module successfully joins network and is ready for an OTA upload. Please remember about resetting the module once after serial upload as discussed in chapter [Arduino IDE](#), step 3.

4. Now open web browser and enter the url provided on Serial Monitor, i.e. `http://esp8266-webupdate.local/update`. Once entered, browser should display a form like below that has been served by your module. The form invites you to choose a file for update.



Note: If entering `http://esp8266-webupdate.local/update` does not work, try replacing `esp8266-webupdate` with module's IP address. For example, if your module IP is `192.168.1.100` then url should be `http://192.168.1.100/update`. This workaround is useful in case the host software installed in step 1 does not work. If still nothing works and there are no clues on the Serial Monitor, try to diagnose issue by opening provided url in Google Chrome, pressing F12 and checking contents of "Console" and "Network" tabs. Chrome provides some advanced logging on these tabs.

5. To obtain the file, navigate to directory used by Arduino IDE to store results of compilation. You can check the path to this file in compilation log shown in IDE debug window as marked below.
6. Now press "Choose File" in web browser, go to directory identified in step 5 above, find the file "WebUpdater.cpp.bin" and upload it. If upload is successful, you will see "OK" on web browser like below.

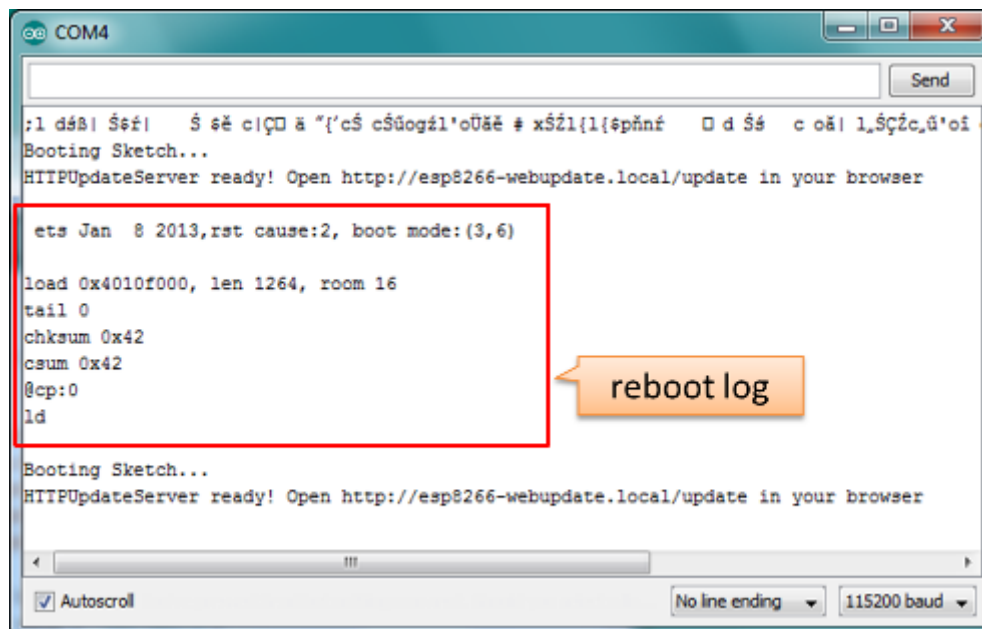
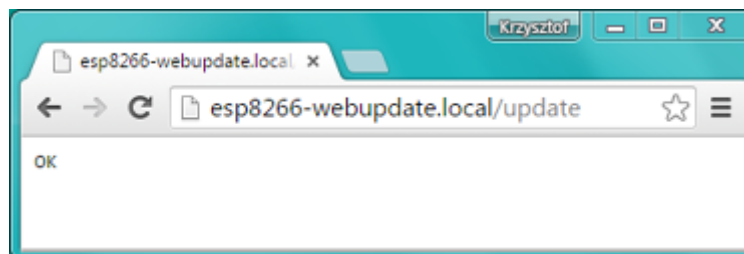
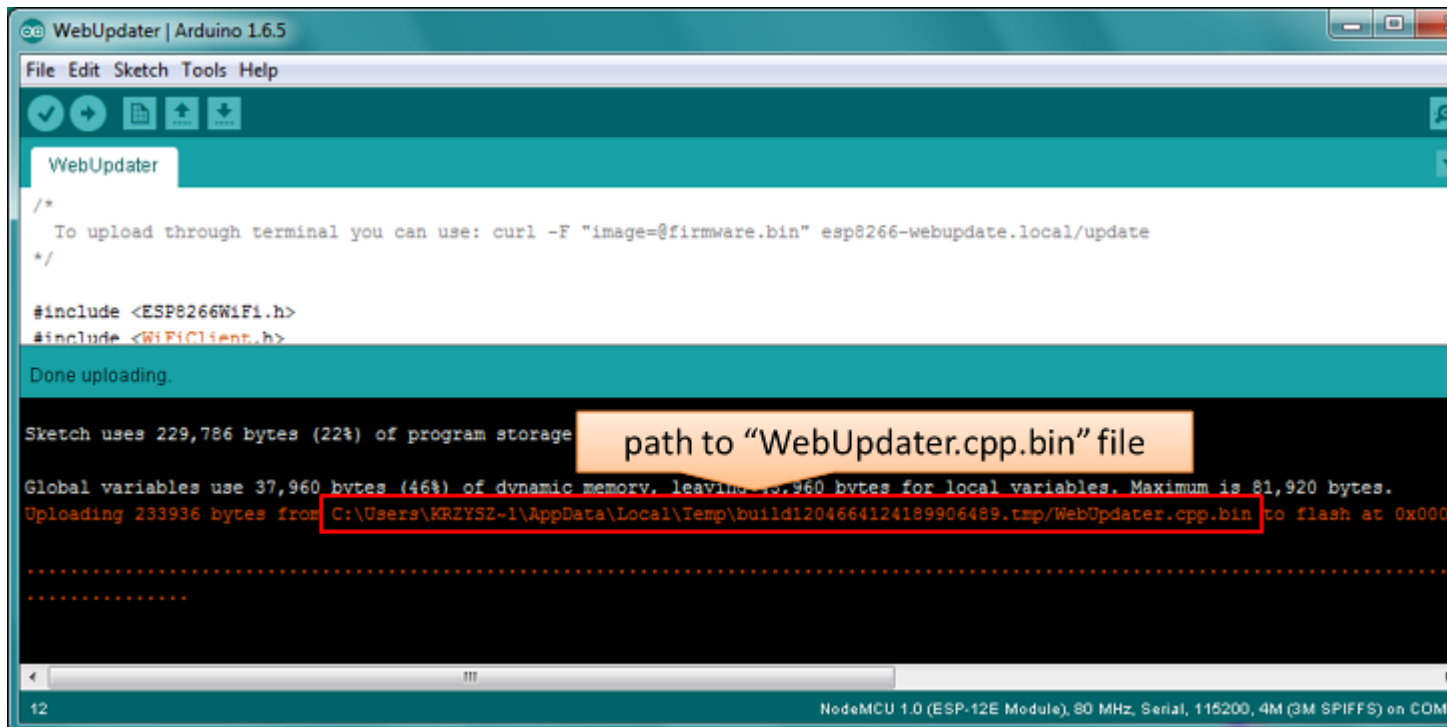
Module will reboot that should be visible on Serial Monitor:

Just after reboot you should see exactly the same message `HTTPUpdateServer ready! Open http://esp8266-webupdate.local /update` in your browser like in step 3. This is because module has been loaded again with the same code – first using serial port, and then using OTA.

Once you are comfortable with this procedure, go ahead and modify `WebUpdater.ino` sketch to print some additional messages, compile it, locate new binary file and upload it using web browser to see entered changes on a Serial Monitor.

You can also add OTA routines to your own sketch following guidelines in [Implementation Overview](#) above. If this is done correctly, you should be always able to upload new sketch over the previous one using a web browser.

In case OTA update fails dead after entering modifications in your sketch, you can always recover module by loading it over a serial port. Then diagnose the issue with sketch using Serial Monitor. Once the issue is fixed try OTA again.



6.4 HTTP Server

ESPhttpUpdate class can check for updates and download a binary file from HTTP web server. It is possible to download updates from every IP or domain address on the network or Internet.

6.4.1 Requirements

- web server

6.4.2 Arduino code

Simple updater

Simple updater downloads the file every time the function is called.

```
ESPhttpUpdate.update("192.168.0.2", 80, "/arduino.bin");
```

Advanced updater

Its possible to point update function to a script at the server. If version string argument is given, it will be sent to the server. Server side script can use this to check if update should be performed.

Server side script can respond as follows: - response code 200, and send the firmware image, - or response code 304 to notify ESP that no update is required.

```
t_httpUpdate_return ret = ESPhttpUpdate.update("192.168.0.2", 80, "/esp/update/
↳arduino.php", "optional current version string here");
switch(ret) {
    case HTTP_UPDATE_FAILED:
        Serial.println("[update] Update failed.");
        break;
    case HTTP_UPDATE_NO_UPDATES:
        Serial.println("[update] Update no Update.");
        break;
    case HTTP_UPDATE_OK:
        Serial.println("[update] Update ok."); // may not called we reboot the ESP
        break;
}
```

6.4.3 Server request handling

Simple updater

For the simple updater the server only needs to deliver the binary file for update.

Advanced updater

For advanced update management a script needs to run at the server side, for example a PHP script. At every update request the ESP sends some information in HTTP headers to the server.

Example header data:

```
[HTTP_USER_AGENT] => ESP8266-http-Update
[HTTP_X_ESP8266_STA_MAC] => 18:FE:AA:AA:AA:AA
[HTTP_X_ESP8266_AP_MAC] => 1A:FE:AA:AA:AA:AA
[HTTP_X_ESP8266_FREE_SPACE] => 671744
[HTTP_X_ESP8266_SKETCH_SIZE] => 373940
[HTTP_X_ESP8266_SKETCH_MD5] => a56f8ef78a0bebd812f62067daf1408a
[HTTP_X_ESP8266_CHIP_SIZE] => 4194304
[HTTP_X_ESP8266_SDK_VERSION] => 1.3.0
[HTTP_X_ESP8266_VERSION] => DOOR-7-g14f53a19
```

With this information the script now can check if an update is needed. It is also possible to deliver different binaries based on the MAC address for example.

Script example:

```
<?PHP

header('Content-type: text/plain; charset=utf8', true);

function check_header($name, $value = false) {
    if(!isset($_SERVER[$name])) {
        return false;
    }
    if($value && $_SERVER[$name] != $value) {
        return false;
    }
    return true;
}

function sendFile($path) {
    header($_SERVER["SERVER_PROTOCOL"].' 200 OK', true, 200);
    header('Content-Type: application/octet-stream', true);
    header('Content-Disposition: attachment; filename='.basename($path));
    header('Content-Length: '.filesize($path), true);
    header('x-MD5: '.md5_file($path), true);
    readfile($path);
}

if(!check_header('HTTP_USER_AGENT', 'ESP8266-http-Update')) {
    header($_SERVER["SERVER_PROTOCOL"].' 403 Forbidden', true, 403);
    echo "only for ESP8266 updater!\n";
    exit();
}

if(
    !check_header('HTTP_X_ESP8266_STA_MAC') ||
    !check_header('HTTP_X_ESP8266_AP_MAC') ||
    !check_header('HTTP_X_ESP8266_FREE_SPACE') ||
    !check_header('HTTP_X_ESP8266_SKETCH_SIZE') ||
    !check_header('HTTP_X_ESP8266_SKETCH_MD5') ||
    !check_header('HTTP_X_ESP8266_CHIP_SIZE') ||
    !check_header('HTTP_X_ESP8266_SDK_VERSION')
) {
    header($_SERVER["SERVER_PROTOCOL"].' 403 Forbidden', true, 403);
    echo "only for ESP8266 updater! (header)\n";
    exit();
}
```

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```

$db = array(
  "18:FE:AA:AA:AA:AA" => "DOOR-7-g14f53a19",
  "18:FE:AA:AA:AA:BB" => "TEMP-1.0.0"
);

if(!isset($db[$_SERVER['HTTP_X_ESP8266_STA_MAC']])) {
  header($_SERVER["SERVER_PROTOCOL"].' 500 ESP MAC not configured for updates',
  true, 500);
}

$localBinary = "./bin/".$db[$_SERVER['HTTP_X_ESP8266_STA_MAC']].".bin";

// Check if version has been set and does not match, if not, check if
// MD5 hash between local binary and ESP8266 binary do not match if not.
// then no update has been found.
if((!check_header('HTTP_X_ESP8266_SDK_VERSION') && $db[$_SERVER['HTTP_X_ESP8266_STA_
MAC']] != $_SERVER['HTTP_X_ESP8266_VERSION'])
|| $_SERVER["HTTP_X_ESP8266_SKETCH_MD5"] != md5_file($localBinary)) {
  sendFile($localBinary);
} else {
  header($_SERVER["SERVER_PROTOCOL"].' 304 Not Modified', true, 304);
}

header($_SERVER["SERVER_PROTOCOL"].' 500 no version for ESP MAC', true, 500);

```

6.5 Stream Interface

TODO describe Stream Interface

The Stream Interface is the base for all other update modes like OTA, http Server / client.

6.6 Updater class

Updater is in the Core and deals with writing the firmware to the flash, checking its integrity and telling the bootloader (eboot) to load the new firmware on the next boot.

Note: The bootloader command will be stored into the first 128 bytes of user RTC memory, then it will be retrieved by eboot on boot. That means that user data present there will be lost ([per discussion in #5330](#)).

6.6.1 Update process - memory view

- The new sketch will be stored in the space between the old sketch and the spiff.
- on the next reboot the “eboot” bootloader check for commands.
- the new sketch is now copied “over” the old one.
- the new sketch is started.

start:

current sketch



spiffs



update:

current sketch



new sketch



spiffs



reboot:

new sketch



spiffs



Guide to PROGMEM on ESP8266 and Arduino IDE

7.1 Intro

PROGMEM is a Arduino AVR feature that has been ported to ESP8266 to ensure compatability with existing Arduino libraries, as well as, saving RAM. On the esp8266 declaring a string such as `const char * xyz = "this is a string"` will place this string in RAM, not flash. It is possible to place a String into flash, and then load it into RAM when it is needed. On an 8bit AVR this process is very simple. On the 32bit ESP8266 there are conditions that must be met to read back from flash.

On the ESP8266 PROGMEM is a macro:

```
#define PROGMEM    ICACHE_RODATA_ATTR
```

ICACHE_RODATA_ATTR is defined by:

```
#define ICACHE_RODATA_ATTR    __attribute__((section(".irom.text")))
```

Which places the variable in the .irom.text section in flash. Placing strings in flash requires using any of the methods above.

Declare a global string to be stored in flash.

```
static const char xyz[] PROGMEM = "This is a string stored in flash";
```

7.2 Declare a flash string within code block.

For this you can use the PSTR macro. Which are all defined in [pgmspace.h](#)

```
#define PGM_P      const char *
#define PGM_VOID_P const void *
#define PSTR(s) (__extension__({static const char __c[] PROGMEM = (s); &__c[0];}))
```

In practice:

```
void myfunction(void) {
PGM_P xyz = PSTR("Store this string in flash");
const char * abc = PSTR("Also Store this string in flash");
}
```

The two examples above will store these strings in flash. To retrieve and manipulate flash strings they must be read from flash in 4byte words. In the Arduino IDE for esp8266 there are several functions that can help retrieve strings from flash that have been stored using PROGMEM. Both of the examples above return `const char *`. However use of these pointers, without correct 32bit alignment you will cause a segmentation fault and the ESP8266 will crash. You must read from the flash 32 bit aligned.

7.3 Functions to read back from PROGMEM

Which are all defined in `pgmspace.h`

```
int memcmp_P(const void* buf1, PGM_VOID_P buf2P, size_t size);
void* memcpy_P(void* dest, PGM_VOID_P src, int c, size_t count);
void* memmem_P(const void* buf, size_t bufSize, PGM_VOID_P findP, size_t findPSize);
void* memcpy_P(void* dest, PGM_VOID_P src, size_t count);
char* strncpy_P(char* dest, PGM_P src, size_t size);
char* strcpy_P(dest, src)
char* strncat_P(char* dest, PGM_P src, size_t size);
char* strcat_P(dest, src)
int strncmp_P(const char* str1, PGM_P str2P, size_t size);
int strcmp_P(str1, str2P)
int strncasecmp_P(const char* str1, PGM_P str2P, size_t size);
int strcasecmp_P(str1, str2P)
size_t strlen_P(PGM_P s, size_t size);
size_t strlen_P(strP)
char* strstr_P(const char* haystack, PGM_P needle);
int printf_P(PGM_P formatP, ...);
int sprintf_P(char *str, PGM_P formatP, ...);
int snprintf_P(char *str, size_t strSize, PGM_P formatP, ...);
int vsnprintf_P(char *str, size_t strSize, PGM_P formatP, va_list ap);
```

There are a lot of functions there but in reality they are `_P` versions of standard c functions that are adapted to read from the esp8266 32bit aligned flash. All of them take a `PGM_P` which is essentially a `const char *`. Under the hood these functions all use, a process to ensure that 4 bytes are read, and the request byte is returned.

This works well when you have designed a function as above that is specialised for dealing with PROGMEM pointers but there is no type checking except against `const char *`. This means that it is totally legitimate, as far as the compiler is concerned, for you to pass it any `const char *` string, which is obviously not true and will lead to undefined behaviour. This makes it impossible to create any overloaded functions that can use flash strings when they are defined as `PGM_P`. If you try you will get an ambiguous overload error as `PGM_P == const char *`.

Enter the `__FlashStringHelper...` This is a wrapper class that allows flash strings to be used as a class, this means that type checking and function overloading can be used with flash strings. Most people will be familiar with the `F()` macro and possibly the `FPSTR()` macro. These are defined in [WString.h](#):


```
#define FPSTR(pstr_pointer) (reinterpret_cast<const __FlashStringHelper *>(pstr_
↪pointer))
#define F(string_literal) (FPSTR(PSTR(string_literal)))
```

So `FPSTR()` takes a `PROGMEM` pointer to a string and casts it to this `__FlashStringHelper` class. Thus if you have defined a string as above `xyz` you can use `FPSTR()` to convert it to `__FlashStringHelper` for passing into functions that take it.

```
static const char xyz[] PROGMEM = "This is a string stored in flash";
Serial.println(FPSTR(xyz));
```

The `F()` combines both of these methods to create an easy and quick way to store an inline string in flash, and return the type `__FlashStringHelper`. For example:

```
Serial.println(F("This is a string stored in flash"));
```

Although these two functions provide a similar function, they serve different roles. `FPSTR()` allows you to define a global flash string and then use it in any function that takes `__FlashStringHelper`. `F()` allows you to define these flash strings in place, but you can't use them anywhere else. The consequence of this is sharing common strings is possible using `FPSTR()` but not `F()`. `__FlashStringHelper` is what the `String` class uses to overload its constructor:

```
String(const char *cstr = ""); // constructor from const char *
String(const String &str); // copy constructor
String(const __FlashStringHelper *str); // constructor for flash strings
```

This allows you to write:

```
String mystring(F("This string is stored in flash"));
```

How do I write a function to use `__FlashStringHelper`? Simple: cast the pointer back to a `PGM_P` and use the `_P` functions shown above. This an example implementation for `String` for the `concat` function.

```
unsigned char String::concat(const __FlashStringHelper * str) {
    if (!str) return 0; // return if the pointer is void
    int length = strlen_P((PGM_P)str); // cast it to PGM_P, which is basically const_
↪char *, and measure it using the _P version of strlen.
    if (length == 0) return 1;
    unsigned int newlen = len + length;
    if (!reserve(newlen)) return 0; // create a buffer of the correct length
    strcpy_P(buffer + len, (PGM_P)str); //copy the string in using strcpy_P
    len = newlen;
    return 1;
}
```

7.4 How do I declare a global flash string and use it?

```
static const char xyz[] PROGMEM = "This is a string stored in flash. Len = %u";

void setup() {
    Serial.begin(115200); Serial.println();
    Serial.println( FPSTR(xyz) ); // just prints the string, must convert it to_
↪FlashStringHelper first using FPSTR().
```

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```

Serial.printf_P( xyz, strlen_P(xyz)); // use printf with PROGMEM string
}

```

7.5 How do I use inline flash strings?

```

void setup() {
  Serial.begin(115200); Serial.println();
  Serial.println( F("This is an inline string")); //
  Serial.printf_P( PSTR("This is an inline string using printf %s"), "hello");
}

```

7.6 How do I declare and use data in PROGMEM?

```

const size_t len_xyz = 30;
const uint8_t xyz[] PROGMEM = {
  0x53, 0x61, 0x79, 0x20, 0x48, 0x65, 0x6c, 0x6c, 0x6f, 0x20,
  0x74, 0x6f, 0x20, 0x4d, 0x79, 0x20, 0x4c, 0x69, 0x74, 0x74,
  0x6c, 0x65, 0x20, 0x46, 0x72, 0x69, 0x65, 0x6e, 0x64, 0x00};

void setup() {
  Serial.begin(115200); Serial.println();
  uint8_t * buf = new uint8_t[len_xyz];
  if (buf) {
    memcpy_P(buf, xyz, len_xyz);
    Serial.write(buf, len_xyz); // output the buffer.
  }
}

```

7.7 How do I declare some data in PROGMEM, and retrieve one byte from it.

Declare the data as done previously, then use `pgm_read_byte` to get the value back.

```

const size_t len_xyz = 30;
const uint8_t xyz[] PROGMEM = {
  0x53, 0x61, 0x79, 0x20, 0x48, 0x65, 0x6c, 0x6c, 0x6f, 0x20,
  0x74, 0x6f, 0x20, 0x4d, 0x79, 0x20, 0x4c, 0x69, 0x74, 0x74,
  0x6c, 0x65, 0x20, 0x46, 0x72, 0x69, 0x65, 0x6e, 0x64, 0x00
};

void setup() {
  Serial.begin(115200); Serial.println();
  for (int i = 0; i < len_xyz; i++) {
    uint8_t byteval = pgm_read_byte(xyz + i);
    Serial.write(byteval); // output the buffer.
  }
}

```

7.8 In summary

It is easy to store strings in flash using `PROGMEM` and `PSTR` but you have to create functions that specifically use the pointers they generate as they are basically `const char *`. On the other hand `FPSTR` and `F()` give you a class that you can do implicit conversions from, very useful when overloading functions, and doing implicit type conversions. It is worth adding that if you wish to store an `int`, `float` or pointer these can be stored and read back directly as they are 4 bytes in size and therefor will be always aligned!

Hope this helps.

Using GDB to Debug Applications

ESP applications can be debugged using GDB, the GNU debugger, which is included with the standard IDE installation. This note will only discuss the ESP specific steps, so please refer to the [main GNU GDB documentation](#).

Note that as of 2.5.0, the toolchain moved from the ESPRESSIF patched, closed-source version of GDB to the main GNU version. The debugging formats are different, so please be sure to use only the latest Arduino toolchain GDB executable.

8.1 CLI and IDE Note

Because the Arduino IDE doesn't support interactive debugging, the following sections describe debugging using the command line. Other IDEs which use GDB in their debug backends should work identically, but you may need to edit their configuration files or options to enable the remote serial debugging required and to set the standard options. PRs are happily accepted for updates to this document with additional IDEs!

8.2 Preparing your application for GDB

Applications need to be changed to enable GDB debugging support. This change will add 2-3KB of flash and around 700 bytes of IRAM usage, but should not affect operation of the application.

In your main `sketch.ino` file, add the following line to the top of the application:

```
#include <GDBStub.h>
```

And in the `void setup()` function ensure the serial port is initialized and call `gdbstub_init()`:

```
Serial.begin(115200);  
gdbstub_init();
```

Rebuild and reupload your application and it should run exactly as before.

8.3 Starting a Debug Session

Once your application is running, the process to attach a debugger is quite simple: . Close the Arduino Serial Monitor . Locate Application.ino.elf File . Open a Command Prompt and Start GDB . Apply the GDB configurations . Attach the Debugger . Debug Away!

8.3.1 Close the Arduino Serial Monitor

Because GDB needs full control of the serial port, you will need to close any Arduino Serial Monitor windows you may have open. Otherwise GDB will report an error while attempting to debug.

8.3.2 Locate Application.ino.elf File

In order for GDB to debug your application, you need to locate the compiled ELF format version of it (which includes needed debug symbols).

Under Linux these files are stored in `/tmp/arduino_build_*` and the following command will help locate the right file for your app:

```
find /tmp -name "*.elf" -print
```

Under Windows these files are stored in `%userprofile%\AppData\Local\Temp\arduino_build_*` and the following command will help locate the right file for your app:

```
dir %userprofile%\appdata\*.elf /s/b
```

Note the full path of ELF file that corresponds to your sketch name, it will be needed later once GDB is started.

8.3.3 Open a Command Prompt and Start GDB

Open a terminal or CMD prompt and navigate to the proper ESP8266 toolchain directory.

Linux

```
~/arduino15/packages/esp8266/hardware/xtensa-lx106-elf/bin/xtensa-lx106-elf-gdb
```

Windows (Using Board Manager version)

```
%userprofile%\AppData\Local\Arduino15\packages\esp8266\tools\xtensa-lx106-elf-gcc\2.5.0-3-20ed2b9\bin\xtensa-lx106-elf-gdb.exe
```

Windows (Using Git version)

```
%userprofile%\Documents\Arduino\hardware\esp8266com\esp8266\tools\xtensa-lx106-elf\bin\xtensa-lx106-elf-gdb.exe
```

Please note the proper GDB name is “xtensa-lx106-elf-gdb”. If you accidentally run “gdb” you may start your own operating system’s GDB, which will not know how to talk to the ESP8266.

8.3.4 Apply the GDB Configurations

At the `(gdb)` prompt, enter the following options to configure GDB for the ESP8266 memory map and configuration:

```

set remote hardware-breakpoint-limit 1
set remote hardware-watchpoint-limit 1
set remote interrupt-on-connect on
set remote kill-packet off
set remote symbol-lookup-packet off
set remote verbose-resume-packet off
mem 0x20000000 0x3fefffff ro cache
mem 0x3ff00000 0x3fffffff rw
mem 0x40000000 0x400fffff ro cache
mem 0x40100000 0x4013ffff rw cache
mem 0x40140000 0x5fffffff ro cache
mem 0x60000000 0x60001fff rw
set serial baud 115200

```

Now tell GDB where your compiled ELF file is located:

```
file /tmp/arduino_build_257110/sketch_dec26a.ino.elf
```

8.3.5 Attach the Debugger

Once GDB has been configured properly and loaded your debugging symbols, connect it to the ESP with the command (replace the ttyUSB0 or COM9 with your ESP's serial port):

```
target remote /dev/ttyUSB0
```

or

```
target remote \\.\COM9
```

At this point GDB will send a stop the application on the ESP8266 and you can begin setting a breakpoint (break loop) or any other debugging operation.

8.4 Example Debugging Session

Create a new sketch and paste the following code into it:

```

#include <GDBStub.h>

void setup() {
  Serial.begin(115200);
  gdbstub_init();
  Serial.printf("Starting...\n");
}

void loop() {
  static uint32_t cnt = 0;
  Serial.printf("%d\n", cnt++);
  delay(100);
}

```

Save it and then build and upload to your ESP8266. On the Serial monitor you should see something like

```
1
2
3
....
```

Now close the Serial Monitor.

Open a command prompt and find the ELF file:

```
earle@server:~$ find /tmp -name "*.elf" -print
/tmp/arduino_build_257110/testgdb.ino.elf
/tmp/arduino_build_531411/listfiles.ino.elf
/tmp/arduino_build_156712/SDWebServer.ino.elf
```

In this example there are multiple elf files found, but we only care about the one we just built, `testgdb.ino.elf`.

Open up the proper ESP8266-specific GDB

```
earle@server:~$ ~/.arduino15/packages/esp8266/hardware/xtensa-lx106-elf/bin/xtensa-
↳ lx106-elf-gdb
GNU gdb (GDB) 8.2.50.20180723-git
Copyright (C) 2018 Free Software Foundation, Inc.
License GPLv3+: GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>
This is free software: you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law.
Type "show copying" and "show warranty" for details.
This GDB was configured as "--host=x86_64-linux-gnu --target=xtensa-lx106-elf".
Type "show configuration" for configuration details.
For bug reporting instructions, please see:
<http://www.gnu.org/software/gdb/bugs/>.
Find the GDB manual and other documentation resources online at:
<http://www.gnu.org/software/gdb/documentation/>.

For help, type "help".
Type "apropos word" to search for commands related to "word".
(gdb)
```

We're now at the GDB prompt, but nothing has been set up for the ESP8266 and no debug information has been loaded. Cut-and-paste the setup options:

```
(gdb) set remote hardware-breakpoint-limit 1
(gdb) set remote hardware-watchpoint-limit 1
(gdb) set remote interrupt-on-connect on
(gdb) set remote kill-packet off
(gdb) set remote symbol-lookup-packet off
(gdb) set remote verbose-resume-packet off
(gdb) mem 0x20000000 0x3feffffff ro cache
(gdb) mem 0x3ff00000 0x3fffffff rw
(gdb) mem 0x40000000 0x400fffff ro cache
(gdb) mem 0x40100000 0x4013ffff rw cache
(gdb) mem 0x40140000 0x5fffffff ro cache
(gdb) mem 0x60000000 0x60001fff rw
(gdb) set serial baud 115200
(gdb)
```

And tell GDB where the debugging info ELF file is located:


```
(gdb) file /tmp/arduino_build_257110/testgdb.ino.elf
Reading symbols from /tmp/arduino_build_257110/testgdb.ino.elf...done.
```

Now, connect to the running ESP8266:

```
(gdb) target remote /dev/ttyUSB0
Remote debugging using /dev/ttyUSB0
0x40000f68 in ?? ()
(gdb)
```

Don't worry that GDB doesn't know what is at our present address, we broke into the code at a random spot and we could be in an interrupt, in the ROM, or elsewhere. The important bit is that we're now connected and two things will now happen: we can debug, and the app's regular serial output will be displayed on the GDB console..

Continue the running app to see the serial output:

```
(gdb) cont
Continuing.
74
75
76
77
...
```

The app is back running and we can stop it at any time using Ctrl-C:

```
113
^C
Program received signal SIGINT, Interrupt.
0x40000f68 in ?? ()
(gdb)
```

At this point we can set a breakpoint on the main loop() and restart to get into our own code:

```
(gdb) break loop
Breakpoint 1 at 0x40202e33: file /home/earle/Arduino/sketch_dec26a/sketch_dec26a.ino, line 10.
(gdb) cont
Continuing.
Note: automatically using hardware breakpoints for read-only addresses.
bcn_timeout,ap_probe_send_start

Breakpoint 1, loop () at /home/earle/Arduino/sketch_dec26a/sketch_dec26a.ino:10
10 void loop()
(gdb)
```

Let's examine the local variable:

```
(gdb) next
loop () at /home/earle/Arduino/sketch_dec26a/sketch_dec26a.ino:13
13 Serial.printf("%d\n", cnt++);
(gdb) print cnt
$1 = 114
(gdb)
```

And change it:

```
$2 = 114
(gdb) set cnt = 2000
(gdb) print cnt
$3 = 2000
(gdb)
```

And restart the app and see our changes take effect:

```
(gdb) cont
Continuing.
2000
Breakpoint 1, loop () at /home/earle/Arduino/sketch_dec26a/sketch_dec26a.ino:10
10 void loop() {
(gdb) cont
Continuing.
2001
Breakpoint 1, loop () at /home/earle/Arduino/sketch_dec26a/sketch_dec26a.ino:10
10 void loop() {
(gdb)
```

Looks like we left the breakpoint on `loop()`, let's get rid of it and try again:

```
(gdb) delete
Delete all breakpoints? (y or n) y
(gdb) cont
Continuing.
2002
2003
2004
2005
2006
....
```

At this point we can exit GDB with `quit` or do further debugging.

8.5 ESP8266 Hardware Debugging Limitations

The ESP8266 only supports a single hardware breakpoint and a single hardware data watchpoint. This means only one breakpoint in user code is allowed at any time. Consider using the `thb` (temporary hardware breakpoint) command in GDB while debugging instead of the more common `break` command, since `thb` will remove the breakpoint once it is reached automatically and save you some trouble.

9.1 Generic ESP8266 Module

These modules come in different form factors and pinouts. See the page at [ESP8266 community wiki](#) for more info: [ESP8266 Module Family](#).

Usually these modules have no bootstapping resistors on board, insufficient decoupling capacitors, no voltage regulator, no reset circuit, and no USB-serial adapter. This makes using them somewhat tricky, compared to development boards which add these features.

In order to use these modules, make sure to observe the following:

- **Provide sufficient power to the module.** For stable use of the ESP8266 a power supply with 3.3V and $\geq 250\text{mA}$ is required. Using the power available from USB to Serial adapter is not recommended, these adapters typically do not supply enough current to run ESP8266 reliably in every situation. An external supply or regulator alongwith filtering capacitors is preferred.
- **Connect bootstapping resistors** to GPIO0, GPIO2, GPIO15 according to the schematics below.
- **Put ESP8266 into bootloader mode** before uploading code.

9.2 Serial Adapter

There are many different USB to Serial adapters / boards. To be able to put ESP8266 into bootloader mode using serial handshaking lines, you need the adapter which breaks out RTS and DTR outputs. CTS and DSR are not useful for upload (they are inputs). Make sure the adapter can work with 3.3V IO voltage: it should have a jumper or a switch to select between 5V and 3.3V, or be marked as 3.3V only.

Adapters based around the following ICs should work:

- FT232RL
- CP2102
- CH340G

PL2303-based adapters are known not to work on Mac OS X. See <https://github.com/igrr/esptool-ck/issues/9> for more info.

9.3 Minimal Hardware Setup for Bootloading and Usage

PIN	Resistor	Serial Adapter
VCC		VCC (3.3V)
GND		GND
TX or GPIO2*		RX
RX		TX
GPIO0	PullUp	DTR
Reset*	PullUp	RTS
GPIO15*	PullDown	
CH_PD	PullUp	

- Note
- GPIO15 is also named MTDO
- Reset is also named RSBT or REST (adding PullUp improves the stability of the module)
- GPIO2 is alternative TX for the boot loader mode
- **Directly connecting a pin to VCC or GND is not a substitute for a PullUp or PullDown resistor, doing this can break upload management and the serial console, instability has also been noted in some cases.**

9.4 ESP to Serial

9.4.1 Minimal Hardware Setup for Bootloading only

ESPxx Hardware

PIN	Resistor	Serial Adapter
VCC		VCC (3.3V)
GND		GND
TX or GPIO2		RX
RX		TX
GPIO0		GND
Reset		RTS*
GPIO15	PullDown	
CH_PD	PullUp	

- Note
- if no RTS is used a manual power toggle is needed

9.4.2 Minimal Hardware Setup for Running only

ESPxx Hardware

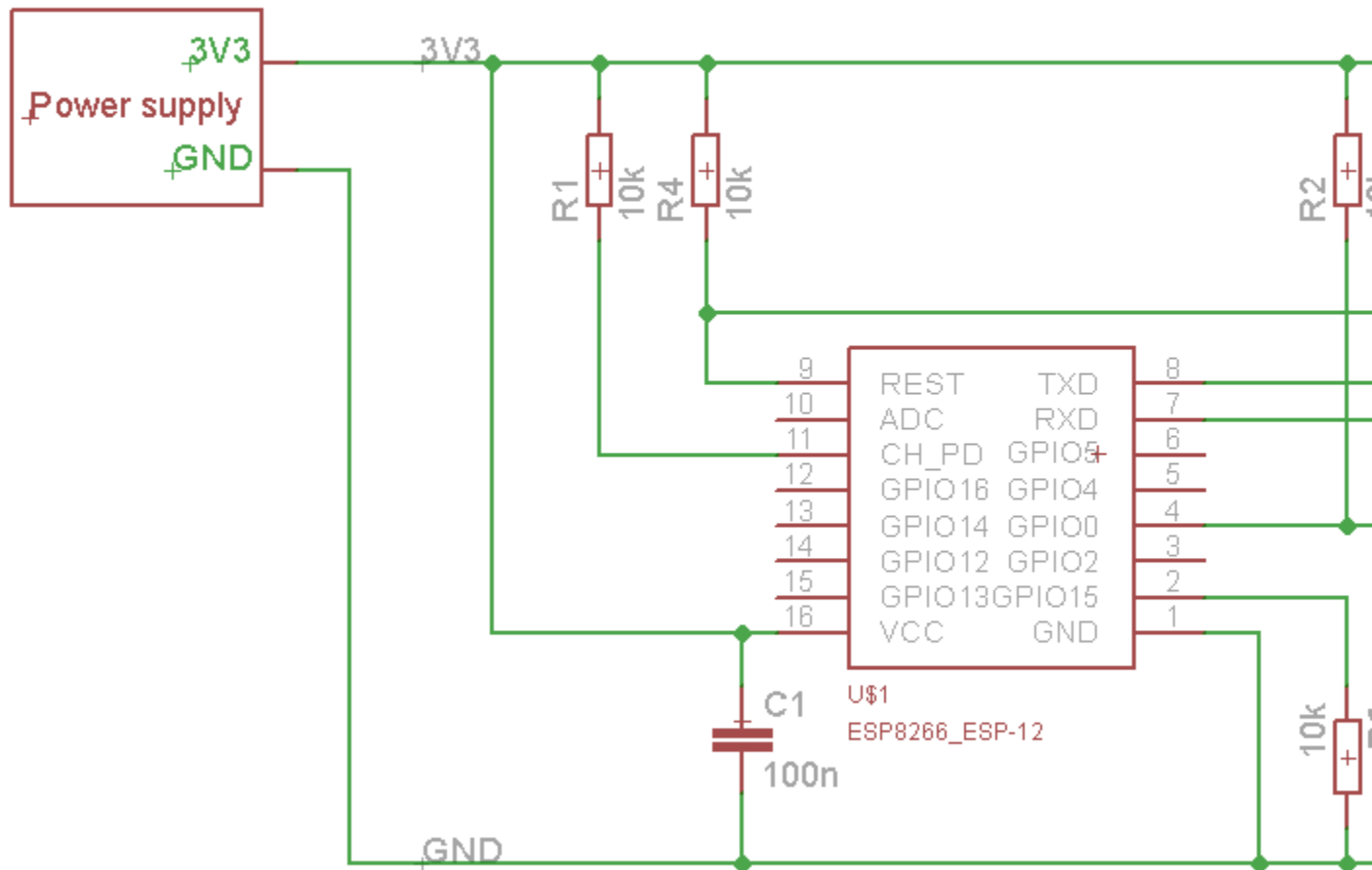


Fig. 1: ESP to Serial

PIN	Resistor	Power supply
VCC		VCC (3.3V)
GND		GND
GPIO0	PullUp	
GPIO15	PullDown	
CH_PD	PullUp	

9.5 Minimal

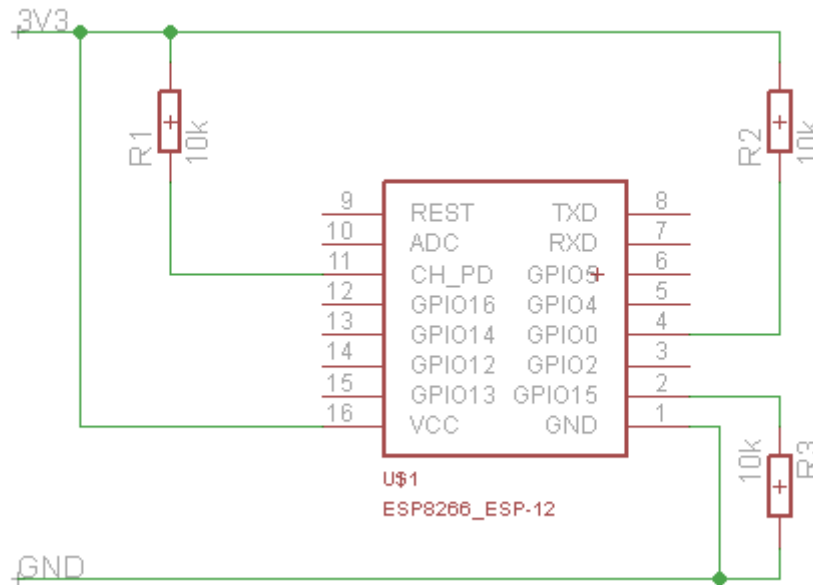


Fig. 2: ESP min

9.6 Improved Stability

9.7 Boot Messages and Modes

The ESP module checks at every boot the Pins 0, 2 and 15. based on them its boots in different modes:

GPIO15	GPIO0	GPIO2	Mode
0V	0V	3.3V	Uart Bootloader
0V	3.3V	3.3V	Boot sketch (SPI flash)
3.3V	x	x	SDIO mode (not used for Arduino)

at startup the ESP prints out the current boot mode example:

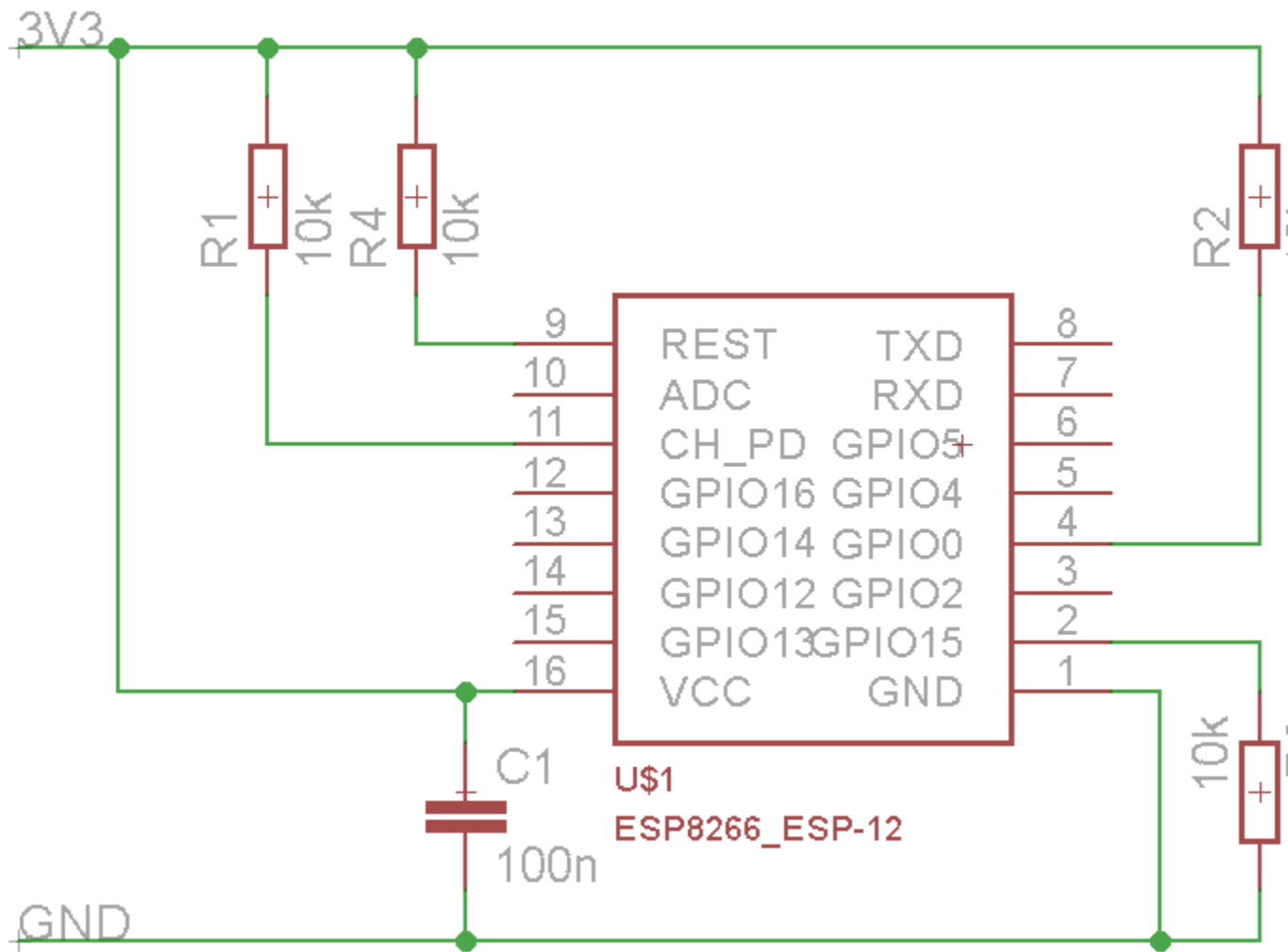


Fig. 3: ESP improved stability

```
rst cause:2, boot mode:(3,6)
```

note: - GPIO2 is used as TX output and the internal Pullup is enabled on boot.

9.7.1 rst cause

Number	Description
0	unknown
1	normal boot
2	reset pin
3	software reset
4	watchdog reset

9.7.2 boot mode

the first value respects the pin setup of the Pins 0, 2 and 15.

Number	GPIO15	GPIO0	GPIO2	Mode
0	0V	0V	0V	Not valid
1	0V	0V	3.3V	Uart
2	0V	3.3V	0V	Not valid
3	0V	3.3V	3.3V	Flash
4	3.3V	0V	0V	SDIO
5	3.3V	0V	3.3V	SDIO
6	3.3V	3.3V	0V	SDIO
7	3.3V	3.3V	3.3V	SDIO

note: - number = ((GPIO15 << 2) | (GPIO0 << 1) | GPIO2);

9.8 Generic ESP8285 Module

ESP8285 ([datasheet](#)) is a multi-chip package which contains ESP8266 and 1MB flash. All points related to bootstrapping resistors and recommended circuits listed above apply to ESP8285 as well.

Note that since ESP8285 has SPI flash memory internally connected in DOUT mode, pins 9 and 10 may be used as GPIO / I2C / PWM pins.

9.9 ESPDuino (ESP-13 Module)

TODO

9.10 Adafruit Feather HUZZAH ESP8266

The Adafruit Feather HUZZAH ESP8266 is an Arduino-compatible Wi-Fi development board powered by Ai-Thinker's ESP-12S, clocked at 80 MHz at 3.3V logic. A high-quality SiLabs CP2104 USB-Serial chip is included so

that you can upload code at a blistering 921600 baud for fast development time. It also has auto-reset so no noodling with pins and reset button pressings. A 3.7V Lithium polymer battery connector is included, making it ideal for portable projects. The Adafruit Feather HUZZAH ESP8266 will automatically recharge a connected battery when USB power is available.

Product page: <https://www.adafruit.com/product/2821>

9.11 Invent One

The Invent One is an Arduino-compatible Wi-Fi development board powered by Ai-Thinker's ESP-12F, clocked at 80 MHz at 3.3V logic. It has an onboard ADC (PCF8591) so that you can have multiple analog inputs to work with. More information can be found here: <https://blog.inventone.ng>

Product page: <https://inventone.ng>

9.12 XinaBox CW01

The XinaBox CW01(ESP8266) is an Arduino-compatible Wi-Fi development board powered by an ESP-12F, clocked at 80 MHz at 3.3V logic. The CW01 has an onboard RGB LED and 3 xBUS connection ports.

Product page: <https://xinabox.cc/products/CW01>

9.13 ESPresso Lite 1.0

ESPresso Lite 1.0 (beta version) is an Arduino-compatible Wi-Fi development board powered by Espressif System's own ESP8266 WROOM-02 module. It has breadboard-friendly breakout pins with in-built LED, two reset/flash buttons and a user programmable button. The operating voltage is 3.3VDC, regulated with 800mA maximum current. Special distinctive features include on-board I2C pads that allow direct connection to OLED LCD and sensor boards.

9.14 ESPresso Lite 2.0

ESPresso Lite 2.0 is an Arduino-compatible Wi-Fi development board based on an earlier V1 (beta version). Re-designed together with Cytron Technologies, the newly-revised ESPresso Lite V2.0 features the auto-load/auto-program function, eliminating the previous need to reset the board manually before flashing a new program. It also feature two user programmable side buttons and a reset button. The special distinctive features of on-board pads for I2C sensor and actuator is retained.

9.15 Phoenix 1.0

Product page: <http://www.espert.co>

9.16 Phoenix 2.0

Product page: <http://www.espert.co>

9.17 NodeMCU 0.9 (ESP-12 Module)

9.17.1 Pin mapping

Pin numbers written on the board itself do not correspond to ESP8266 GPIO pin numbers. Constants are defined to make using this board easier:

```
static const uint8_t D0 = 16;  
static const uint8_t D1 = 5;  
static const uint8_t D2 = 4;  
static const uint8_t D3 = 0;  
static const uint8_t D4 = 2;  
static const uint8_t D5 = 14;  
static const uint8_t D6 = 12;  
static const uint8_t D7 = 13;  
static const uint8_t D8 = 15;  
static const uint8_t D9 = 3;  
static const uint8_t D10 = 1;
```

If you want to use NodeMCU pin 5, use D5 for pin number, and it will be translated to ‘real’ GPIO pin 14.

9.18 NodeMCU 1.0 (ESP-12E Module)

This module is sold under many names for around \$6.50 on AliExpress and it’s one of the cheapest, fully integrated ESP8266 solutions.

It’s an open hardware design with an ESP-12E core and 4 MB of SPI flash.

According to the manufacturer, “with a micro USB cable, you can connect NodeMCU devkit to your laptop and flash it without any trouble”. This is more or less true: the board comes with a CP2102 onboard USB to serial adapter which just works, well, the majority of the time. Sometimes flashing fails and you have to reset the board by holding down FLASH + RST, then releasing FLASH, then releasing RST. This forces the CP2102 device to power cycle and to be re-numbered by Linux.

The board also features a NCP1117 voltage regulator, a blue LED on GPIO16 and a 220k/100k Ohm voltage divider on the ADC input pin. The ESP-12E usually has a led connected on GPIO2.

Full pinout and PDF schematics can be found [here](#)

9.19 Olimex MOD-WIFI-ESP8266(-DEV)

This board comes with 2 MB of SPI flash and optional accessories (e.g. evaluation board ESP8266-EVB or BAT-BOX for batteries).

The basic module has three solder jumpers that allow you to switch the operating mode between SDIO, UART and FLASH.

The board is shipped for FLASH operation mode, with jumpers TD0JP=0, IO0JP=1, IO2JP=1.

Since jumper IO0JP is tied to GPIO0, which is PIN 21, you’ll have to ground it before programming with a USB to serial adapter and reset the board by power cycling it.

UART pins for programming and serial I/O are GPIO1 (TXD, pin 3) and GPIO3 (RXD, pin 4).

You can find the board schematics [here](#)

9.20 SparkFun ESP8266 Thing

Product page: <https://www.sparkfun.com/products/13231>

9.21 SparkFun ESP8266 Thing Dev

Product page: <https://www.sparkfun.com/products/13711>

9.22 SweetPea ESP-210

TODO

9.23 LOLIN(WEMOS) D1 R2 & mini

Product page: <https://www.wemos.cc/>

9.24 LOLIN(WEMOS) D1 mini Pro

Product page: <https://www.wemos.cc/>

9.25 LOLIN(WEMOS) D1 mini Lite

9.25.1 Parameters in Arduino IDE:

- Card: “WEMOS D1 Mini Lite”
- Flash Size: “1M (512K SPIFFS)”
- CPU Frequency: “80 Mhz”
- Upload Speed: “230400”

9.25.2 Power:

- 5V pin : 4.7V 500mA output when the board is powered by USB ; 3.5V-6V input
- 3V3 pin : 3.3V 500mA regulated output
- Digital pins : 3.3V 30mA.

9.25.3 links:

- Product page: <https://www.wemos.cc/>
- Board schematic: https://wiki.wemos.cc/_media/products:d1:sch_d1_mini_lite_v1.0.0.pdf
- ESP8285 datasheet: https://www.espressif.com/sites/default/files/0a-esp8285_datasheet_en_v1.0_20160422.pdf
- Voltage regulator datasheet: <http://pdf-datasheet.datasheet.netdna-cdn.com/pdf-down/M/E/6/ME6211-Microne.pdf>

9.26 WeMos D1 R1

Product page: <https://www.wemos.cc/>

9.27 ESPino (ESP-12 Module)

ESPino integrates the ESP-12 module with a 3.3v regulator, CP2104 USB-Serial bridge and a micro USB connector for easy programming. It is designed for fitting in a breadboard and has an RGB Led and two buttons for easy prototyping.

For more information about the hardware, pinout diagram and programming procedures, please see the [datasheet](#).

Product page: <http://www.espino.io/en>

9.28 ThaiEasyElec's ESPino

ESPino by ThaiEasyElec using WROOM-02 module from Espressif Systems with 4 MB Flash.

We will update an English description soon. - Product page: <http://thaieasyelec.com/products/wireless-modules/wifi-modules/espino-wifi-development-board-detail.html> - Schematics: www.thaieasyelec.com/downloads/ETEE052/ETEE052_ESPino_Schematic.pdf - Dimensions: http://thaieasyelec.com/downloads/ETEE052/ETEE052_ESPino_Dimension.pdf - Pinouts: http://thaieasyelec.com/downloads/ETEE052/ETEE052_ESPino_User_Manual_TH_v1_0_20160204.pdf (Please see pg. 8)

9.29 WifInfo

WifInfo integrates the ESP-12 or ESP-07+Ext antenna module with a 3.3v regulator and the hardware to be able to measure French telemetry issue from ERDF powering meter serial output. It has a USB connector for powering, an RGB WS2812 Led, 4 pins I2C connector to fit OLED or sensor, and two buttons + FTDI connector and auto reset feature.

For more information, please see WifInfo related [blog](#) entries, [github](#) and [community](#) forum.

9.30 Arduino

TODO

9.31 4D Systems gen4 IoD Range

gen4-IoD Range of ESP8266 powered Display Modules by 4D Systems.

2.4", 2.8" and 3.2" TFT LCD with uSD card socket and Resistive Touch. Chip Antenna + uFL Connector.

Datasheet and associated downloads can be found on the 4D Systems product page.

The gen4-IoD range can be programmed using the Arduino IDE and also the 4D Systems Workshop4 IDE, which incorporates many additional graphics benefits. GFX4d library is available, along with a number of demo applications.

- Product page: <http://www.4dsystems.com.au/product/gen4-IoD>

9.32 Digistump Oak

The Oak requires an *Serial Adapter* for a serial connection or flashing; its micro USB port is only for power.

To make a serial connection, wire the adapter's **TX to P3**, **RX to P4**, and **GND to GND**. Supply 3.3v from the serial adapter if not already powered via USB.

To put the board into bootloader mode, configure a serial connection as above, connect **P2 to GND**, then re-apply power. Once flashing is complete, remove the connection from P2 to GND, then re-apply power to boot into normal mode.

9.33 WiFiduino

Product page: <https://wifiduino.com/esp8266>

9.34 Amperka WiFi Slot

Product page: <http://wiki.amperka.ru/wifi-slot>

9.35 Seeed Wio Link

Wio Link is designed to simplify your IoT development. It is an ESP8266 based open-source Wi-Fi development board to create IoT applications by virtualizing plug-n-play modules to RESTful APIs with mobile APPs. Wio Link is also compatible with the Arduino IDE.

Please DO NOTICE that you MUST pull up pin 15 to enable the power for Grove ports, the board is designed like this for the purpose of peripherals power management.

Product page: <https://www.seeedstudio.com/Wio-Link-p-2604.html>

9.36 ESPECTRO Core

ESPECTRO Core is ESP8266 development board as the culmination of our 3+ year experience in exploring and developing products with ESP8266 MCU.

Initially designed for kids in mind, everybody should be able to use it. Yet it's still hacker-friendly as we break out all ESP8266 ESP-12F pins.

More details at <https://shop.makestro.com/product/espectrocore/>

The purpose of this FAQ / Troubleshooting is to respond to questions commonly asked in [Issues](#) section and on [ESP8266 Community forum](#).

Where possible we are going right to the answer and provide it within one or two paragraphs. If it takes more than that, you will see a link to “Read more” details.

Please feel free to contribute if you believe that some frequent issues are not covered below.

10.1 I am getting “`espcomm_sync failed`” error when trying to upload my ESP. How to resolve this issue?

This message indicates issue with uploading ESP module over a serial connection. There are couple of possible causes, that depend on the type of your module, if you use separate USB to serial converter.

[Read more](#).

10.2 Why esptool is not listed in “Programmer” menu? How do I upload ESP without it?

Do not worry about “Programmer” menu of Arduino IDE. It doesn’t matter what is selected in it — upload now always defaults to using esptool.

Ref. [#138](#), [#653](#) and [#739](#).

10.3 My ESP crashes running some code. How to troubleshoot it?

The code may crash because of s/w bug or issue with your h/w. Before entering an issue report, please perform initial troubleshooting.

[Read more.](#)

10.4 How can I get some extra KBs in flash ?

- Using `*printf()` with floats is enabled by default. Some KBs of flash can be saved by using the option `--nofloat` with the boards generator:

```
./tools/boards.txt.py --nofloat --boardsgen
```

- Use the debug level option `NoAssert-NDEBUG` (in the Tools menu)

[Read more.](#)

10.5 About WPS

From release 2.4.2 and ahead, not using WPS will give an extra ~4.5KB in heap.

In release 2.4.2 only, WPS is disabled by default and the board generator is required to enable it:

```
./tools/boards.txt.py --allowWPS --boardsgen
```

[Read more.](#)

For platformIO (and maybe other build environments), you will also need to add the build flag: `-D NO_EXTRA_4K_HEAP`

This manual selection is not needed starting from 2.5.0 (and in git version). WPS is always available, and not using it will give an extra ~4.5KB compared to releases until 2.4.1 included.

10.6 This Arduino library doesn't work on ESP. How do I make it work?

You would like to use this Arduino library with ESP8266 and it does not perform. It is not listed among libraries verified to work with ESP8266.

[Read more.](#)

10.7 In the IDE, for ESP-12E that has 4M flash, I can choose 4M (1M SPIFFS) or 4M (3M SPIFFS). No matter what I select, the IDE tells me the maximum code space is about 1M. Where does my flash go?

The reason we cannot have more than 1MB of code in flash has to do with a hardware limitation. Flash cache hardware on the ESP8266 only allows mapping 1MB of code into the CPU address space at any given time. You can switch mapping offset, so technically you can have more than 1MB total, but switching such “banks” on the fly is not easy and efficient, so we don't bother doing that. Besides, no one has so far complained about 1MB of code space being insufficient for practical purposes.

The option to choose 3M or 1M SPIFFS is to optimize the upload time. Uploading 3MB takes a long time so sometimes you can just use 1MB. Other 2MB of flash can still be used with `ESP.flashRead` and `ESP.flashWrite` APIs if necessary.

10.8 I have observed a case when `ESP.restart()` doesn't work. What is the reason for that?

You will see this issue only if serial upload was not followed by a physical reset (e.g. power-on reset). For a device being in that state `ESP.restart` will not work. Apparently the issue is caused by [one of internal registers not being properly updated until physical reset](#). This issue concerns only serial uploads. OTA uploads are not affected. If you are using `ESP.restart`, the work around is to reset ESP once after each serial upload.

Ref. [#1017](#), [#1107](#), [#1782](#)

10.9 How to resolve “Board generic (platform esp8266, package esp8266) is unknown” error?

This error may pop up after switching between [staging](#) and [stable](#) esp8266 / Arduino package installations, or after upgrading the package version Read more.

10.10 How to clear TCP PCBs in time-wait state ?

This is not needed anymore:

PCBs in time-wait state are limited to 5 and removed when that number is exceeded.

Ref. [lwIP-v1.4](#), [lwIP-v2](#)

For reference:

Time-wait PCB state helps TCP not confusing two consecutive connections with the same (s-ip,s-port,d-ip,d-port) when the first is already closed but still having duplicate packets lost in internet arriving later during the second. Artificially clearing them is a workaround to help saving precious heap.

The following lines are compatible with both lwIP versions:

```
// no need for #include
struct tcp_pcb;
extern struct tcp_pcb* tcp_tw_pcb;
extern "C" void tcp_abort (struct tcp_pcb* pcb);

void tcpCleanup (void) {
    while (tcp_tw_pcb)
        tcp_abort (tcp_tw_pcb);
}
```

Ref. [#1923](#)

10.11 Why is there a board generator and what about it ?

The board generator is a python script originally intended to ease the Arduino IDE's *boards.txt* configuration file about the multitude of available boards, especially when common parameters have to be updated for all of them.

This script is also used to manage uncommon options that are currently not available in the IDE menu.

[Read more.](#)

CHAPTER 11

Exception Causes (EXCCAUSE)

EXCCAUSE Code	Cause Name	Cause Description
0	IllegalInstructionCause	Illegal instruction
1	SyscallCause	SYSCALL instruction
2	InstructionFetchErrorCause	Processor internal physical address or data error during instruction fetch
3	LoadStoreErrorCause	Processor internal physical address or data error during load or store
4	Level1InterruptCause	Level-1 interrupt as indicated by set level-1 bits in the INTERRUPT register
5	AllocaCause	MOVSP instruction, if caller's registers are not in the register file
6	IntegerDivideByZeroCause	QUOS, QUOU, REMS, or REMU divisor operand is zero
7	Reserved for Tensilica	
8	PrivilegedCause	Attempt to execute a privileged operation when CRING != 0
9	LoadStoreAlignmentCause	Load or store to an unaligned address
10..11	Reserved for Tensilica	
12	InstrPIFDataErrorCause	PIF data error during instruction fetch
13	LoadStorePIFDataErrorCause	Synchronous PIF data error during LoadStore access
14	InstrPIFAddrErrorCause	PIF address error during instruction fetch
15	LoadStorePIFAddrErrorCause	Synchronous PIF address error during LoadStore access
16	InstTLBMissCause	Error during Instruction TLB refill
17	InstTLBMultiHitCause	Multiple instruction TLB entries matched
18	InstFetchPrivilegeCause	An instruction fetch referenced a virtual address at a ring level less than CRING
19	Reserved for Tensilica	
20	InstFetchProhibitedCause	An instruction fetch referenced a page mapped with an attribute that does not permit loads
21..23	Reserved for Tensilica	
24	LoadStoreTLBMissCause	Error during TLB refill for a load or store
25	LoadStoreTLBMultiHitCause	Multiple TLB entries matched for a load or store
26	LoadStorePrivilegeCause	A load or store referenced a virtual address at a ring level less than CRING
27	Reserved for Tensilica	
28	LoadProhibitedCause	A load referenced a page mapped with an attribute that does not permit loads
29	StoreProhibitedCause	A store referenced a page mapped with an attribute that does not permit stores
30..31	Reserved for Tensilica	

Table 1 – continued from previous page

EXCCAUSE Code	Cause Name	Cause Description
32..39	CoprocessornDisabled	Coprocessor n instruction when cpn disabled. n varies 0..7 as the cause varies
40..63	Reserved	

Infos from Xtensa Instruction Set Architecture (ISA) Reference Manual

12.1 Introduction

Since 2.1.0-rc1 the core includes a Debugging feature that is controllable over the IDE menu.

The new menu points manage the real-time Debug messages.

12.1.1 Requirements

For usage of the debugging a Serial connection is required (Serial or Serial1).

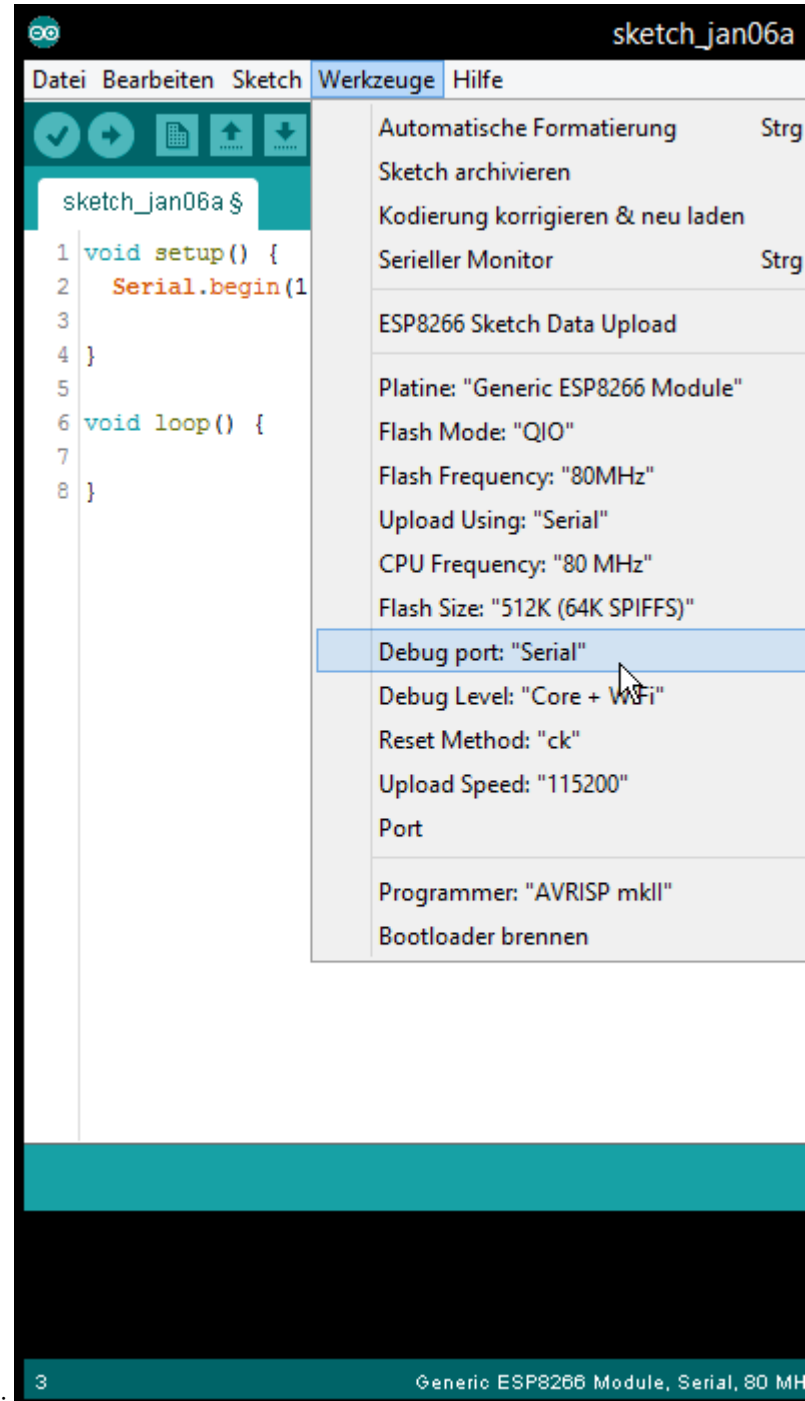
The Serial Interface need to be initialized in the `setup()`.

Set the Serial baud rate as high as possible for your Hardware setup.

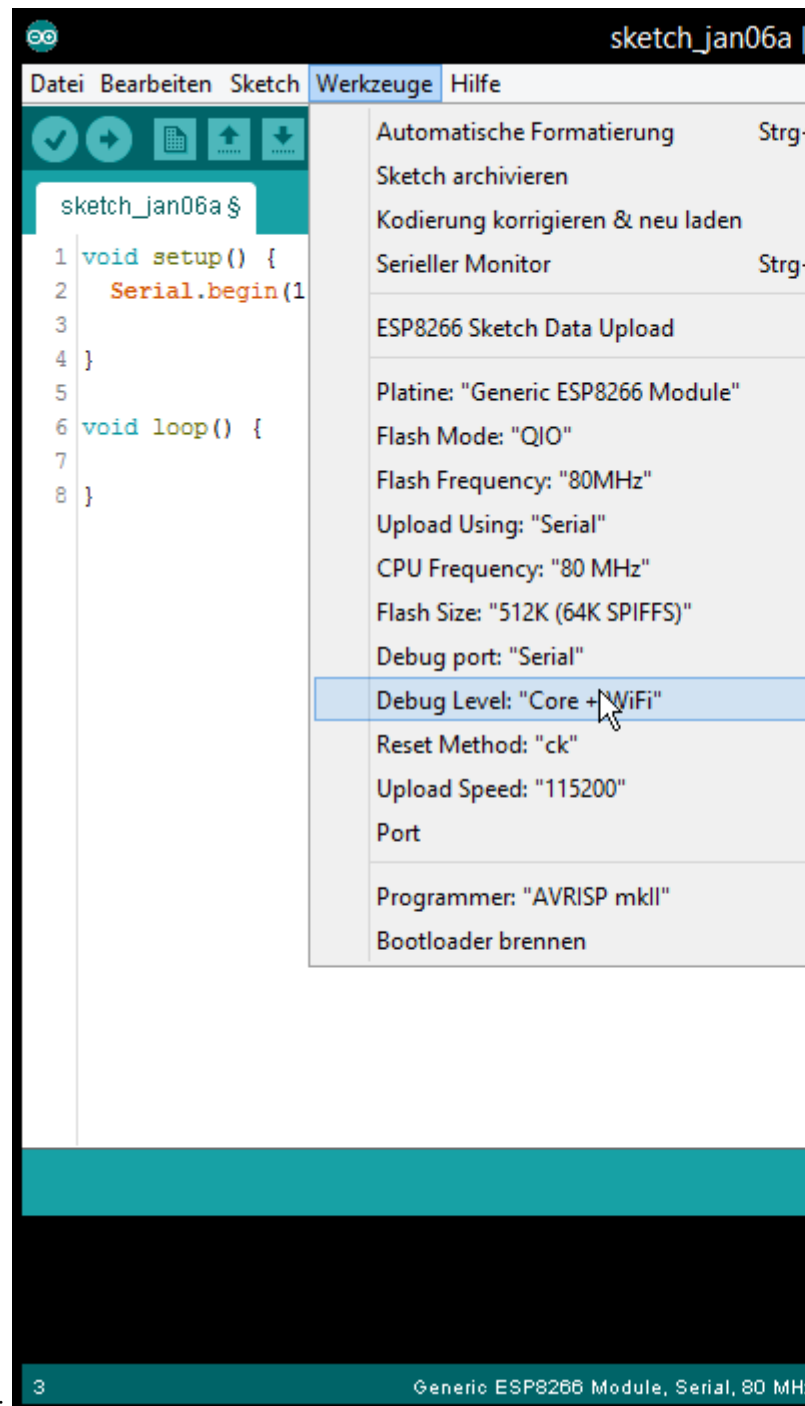
Minimum sketch to use debugging:

```
void setup() {  
    Serial.begin(115200);  
}  
  
void loop() {  
}
```

12.1.2 Usage



1. Select the Serial interface for the Debugging messages:



2. Select which type / level you want debug messages for:
3. Check if the Serial interface is initialized in `setup()` (see [Requirements](#))
4. Flash sketch
5. Check the Serial Output

12.2 Informations

It work with every sketch that enables the Serial interface that is selected as debug port.

The Serial interface can still be used normal in the Sketch.

The debug output is additional and will not disable any interface from usage in the sketch.

12.2.1 For Developers

For the debug handling uses defines.

The defined are set by command line.

Debug Port

The port has the define `DEBUG_ESP_PORT` possible value: - Disabled: define not existing - Serial: Serial - Serial1: Serial1

Debug Level

All defines for the different levels starts with `DEBUG_ESP_`

a full list can be found here in the [boards.txt](#)

Example for own debug messages

The debug messages will be only shown when the Debug Port in the IDE menu is set.

```
#ifndef DEBUG_ESP_PORT
#define DEBUG_MSG(...) DEBUG_ESP_PORT.printf( __VA_ARGS__ )
#else
#define DEBUG_MSG(...)
#endif

void setup() {
    Serial.begin(115200);

    delay(3000);
    DEBUG_MSG("bootup...\n");
}

void loop() {
    DEBUG_MSG("loop %d\n", millis());
    delay(1000);
}
```


13.1 Introduction

If the ESP crashes the Exception Cause will be shown and the current stack will be dumped.

Example:

```
Exception (0): epc1=0x402103f4 epc2=0x00000000 epc3=0x00000000 excvaddr=0x00000000_
↳ depc=0x00000000

ctx: sys
sp: 3ffffc10 end: 3fffffb0 offset: 01a0

>>>stack>>>
3ffffdb0: 40223e00 3fff6f50 00000010 60000600
3ffffdc0: 00000001 4021f774 3fffc250 4000050c
3ffffdd0: 400043d5 00000030 00000016 ffffffff
3ffffde0: 400044ab 3fffc718 3ffffed0 08000000
3ffffdf0: 60000200 08000000 00000003 00000000
3ffffe00: 0000ffff 00000001 04000002 003fd000
3ffffe10: 3fff7188 000003fd 3fff2564 00000030
3ffffe20: 40101709 00000008 00000008 00000020
3ffffe30: c1948db3 394c5e70 7f2060f2 c6ba0c87
3ffffe40: 3fff7058 00000001 40238d41 3fff6ff0
3ffffe50: 3fff6f50 00000010 60000600 00000020
3ffffe60: 402301a8 3fff7098 3fff7014 40238c77
3ffffe70: 4022fb6c 40230ebe 3ffff1a5b 3fff6f00
3ffffe80: 3ffffec8 00000010 40231061 3fff0f90
3ffffe90: 3fff6848 3ffed0c0 60000600 3fff6ae0
3ffffea0: 3fff0f90 3fff0f90 3fff6848 3fff6d40
3ffffeb0: 3fff28e8 40101233 d634fe1a ffffffff
3ffffec0: 00000001 00000000 4022d5d6 3fff6848
3ffffed0: 00000002 4000410f 3fff2394 3fff6848
3ffffee0: 3fffc718 40004a3c 000003fd 3fff7188
```

(continues on next page)

(continued from previous page)

```
3ffffef0: 3fffc718 40101510 00000378 3ffff1a5b
3fffff00: 000003fd 4021d2e7 00000378 000003ff
3fffff10: 00001000 4021d37d 3fff2564 000003ff
3fffff20: 000003fd 60000600 003fd000 3fff2564
3fffff30: ffffffff00 55aa55aa 00000312 0000001c
3fffff40: 0000001c 0000008a 0000006d 000003ff
3fffff50: 4021d224 3ffecf90 00000000 3ffed0c0
3fffff60: 00000001 4021c2e9 00000003 3fff1238
3fffff70: 4021c071 3ffecf84 3ffecf30 0026a2b0
3fffff80: 4021c0b6 3fffdab0 00000000 3fffdcb0
3fffff90: 3ffecf40 3fffdab0 00000000 3fffdcc0
3fffffa0: 40000f49 40000f49 3fffdab0 40000f49
<<<stack<<<
```

The first number after `Exception` gives the cause of the reset. a full list of all causes can be found [here](#) the hex after are the stack dump.

13.1.1 Decode

It's possible to decode the Stack to readable information. For more info see the [Esp Exception Decoder](#) tool.

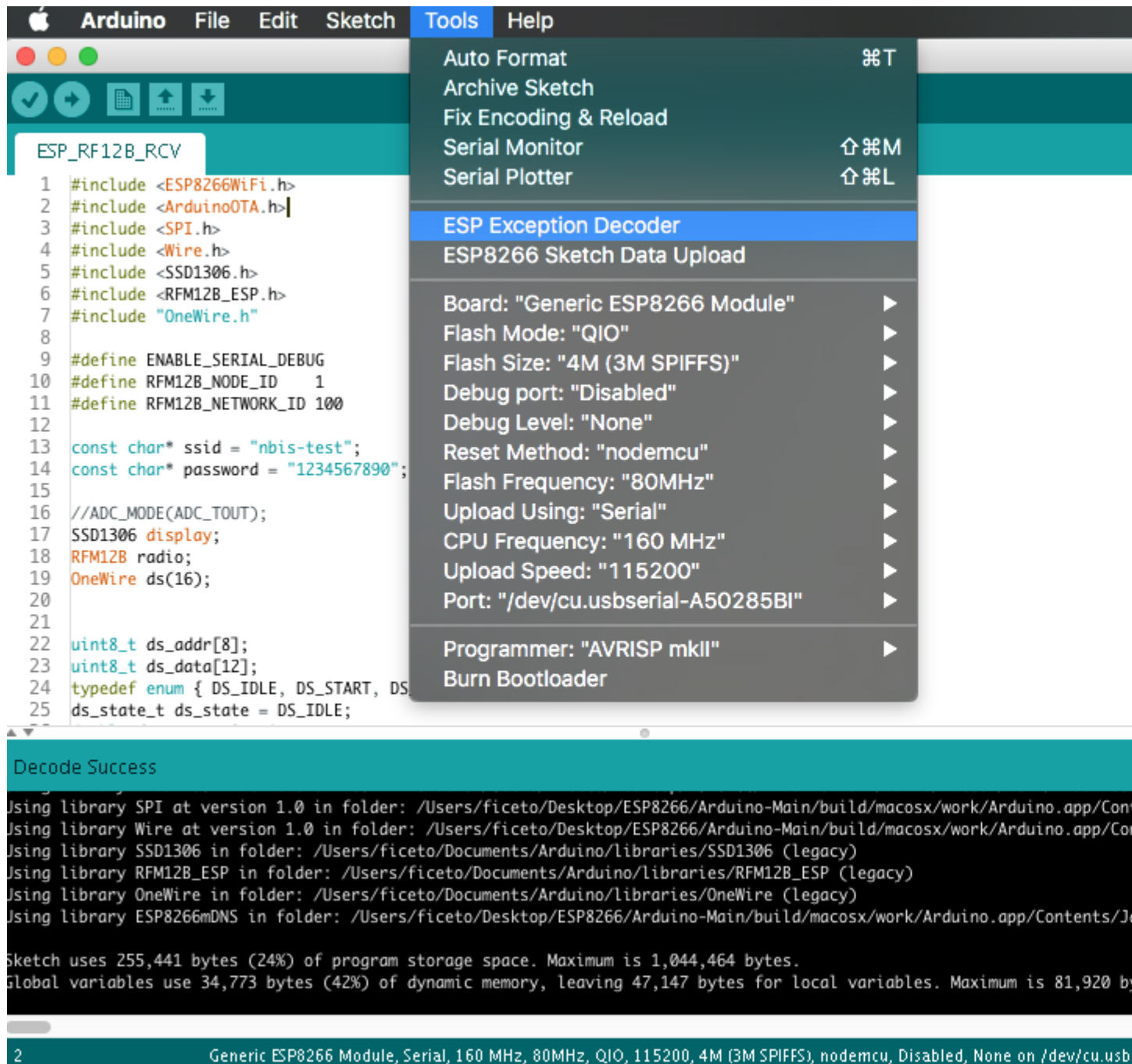


Fig. 1: ESP Exception Decoder

Using Eclipse with Arduino ESP8266

14.1 What to Download

- [arduino IDE](#)
- [Eclipse IDE for C/C++ Developers](#)
- [Java](#)

14.2 Setup Arduino

See the [Readme](#)

14.3 Setup Eclipse

- [step 1](#)
- [step 2](#)
- go to Window → preferences → Arduino
- add as private hardware path the Part to the ESP8266

example private hardware path

```
Windows: C:\Users\[username]\AppData\Roaming\Arduino15\packages\esp8266\hardware  
Linux: /home/[username]/.arduino15/packages/esp8266/hardware
```

14.4 Eclipse wont build

if eclipse dont find the path to the Compiler add to the platform.txt after:

```
version=1.6.4
```

this:

```
runtime.tools.xtensa-lx106-elf-gcc.path={runtime.platform.path}/../../../../tools/xtensa-  
↳lx106-elf-gcc/1.20.0-26-gb404fb9  
runtime.tools.esptool.path={runtime.platform.path}/../../../../tools/esptool/0.4.4
```

Note: - the path may changed, check the current version. - each update over the Arduino IDE will remove the fix - may not needed in future if Eclipse Plugin get an Update