# EE3080 UAVIONICS DIP Guide

Micro-drone and Its Applications

Version 1.1.0

(25 August 2021)

**School of EEE**

**Nanyang Technological University**

## Table of Content

## Changelog

This section lists the changes to this document as it is updated. Version number format is MAJOR.MINOR.PATCH.

### Version 1.0 (12 August 2021)

Initial version.

### Version 1.0.1 (18 August 2021)

Add Git clone instruction under "The `espdrone` Project" section.

### Version 1.0.2 (19 August 2021)

- Add instruction on how to generate the `c_cpp_properties.json`, and `.vscode` under "The espdrone Project" section.
- Change the formatting of the `c_cpp_properties.json`.
- Add instructions on how to install and setup Python.
- Add `cd` instructions to navigate between directories.

### Version 1.1.0 (25 August 2021)

- Add the section "Assembling and Testing the ESP-Drone":
    - Uploading firmware to the drone
    - Assembling the drone
    - Flying the drone manually with mobile app
- Add the section "Developing with Docker".

## Overview

### DIP Overview

UAVONICS DIP is administered in 2 phases.

The first phase involves building and constructing a drone with a form factor of less than 10x10 cm. To achieve this, students will engage in building a flying drone equipped with a camera, powered by the ESP32 Microcontroller.

The second phase emphasizes on collaborative work to create a novel solution to a real-world problem scenario to be unveiled during the project. The application solution should demonstrate aspects of embedded AI, leveraging on the hardware built in phase one. The whole project brings forth a holistic experience of hands-on practicality; harnessing creativity to innovate and improvise in problem-solving.

In short, the objective of the first phase is building and getting familiar with the camera-equipped micro drone, while the aim of the second phase is to utilize the quadcopter for real-world applications.

### Overview of the Micro Drone Hardware

The quadcopter we will be using for this project is small and lightweight (also known as MAV; Micro Aerial Vehicle) for safety and legal reasons. The micro drone is based on **ESP-Drone**, an open-source project for a micro drone powered by the ESP32 microcontroller.

For this DIP, we designed our own circuit board (PCB) for the drone and will use a modified version of the firmware of the ESP-drone project. We will refer to the micro drone as “ESP-drone” henceforth.

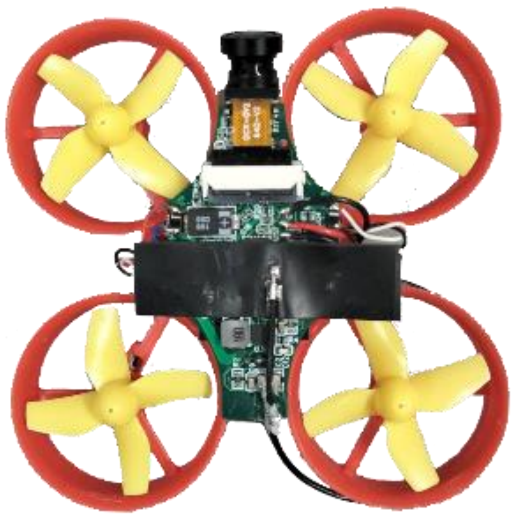


**Figure 1.** The ESP-drone specifically designed for this DIP project.

**General specifications:**

- Motor: 4x brushed motors
- Flight time: around 5 minutes
- Charge time: approx. 30 minutes (battery is removable)

- Dimension: approx. 85 x 85 x 30 mm
- Net weight: 26 gr
- Main processor: ESP32-S microcontroller
- Features: onboard Wi-Fi and Bluetooth, onboard camera, connector for external antenna

Due to the small size of the drone, it has **short flight time** and **small payload** (we cannot add much weight to the drone), which are one of the limiting factors for this project.

The main features of this drone are Wi-Fi connectivity and onboard camera. With the Wi-Fi capability, it can communicate with a computer (or **even other drones**) and exchange data. We discuss the main components of the ESP-drone circuit board below.

### i. ESP32 Microcontroller

A microcontroller is a device with multiple input/output pins that can be programmed to perform lots of different tasks. You can think of it as a single-chip, tiny computer that can interface with sensors and actuators (motors, etc.). Arduino boards are also development boards featuring microcontrollers on them.

The ESP32 is a widely popular family of microcontroller. It has a quite powerful CPU as well as Wi-Fi and Bluetooth capability built-in, which makes it highly suitable for IoT (Internet of Things) or applications requiring internet connectivity.

**Figure 2.** Various development boards featuring ESP32 microcontroller.
From https://randomnerdtutorials.com/getting-started-with-esp32/.

The ESP-drone is using the ESP32-S, a member of the ESP32 family featuring **dual-core** CPU, allowing us to perform multiple tasks concurrently. An example would be interfacing with a camera and streaming the image over Wi-Fi, maintaining communication with an external computer, and running control loops to stabilize the drone at the same time.

The ESP32-S board that we are using also features a connector for external antenna. We will use this to extend the range and signal quality of the drone's Wi-Fi.

### ii. Inertial Measurement Unit

To stabilize the drone's flight, we need an Inertial Measurement Unit (IMU). The IMU we will be using is a 6-axis IMU[1]; 3-axis accelerometer and 3-axis gyroscope. The accelerometer measures the linear

[1] Specifically, we are using the popular MPU-6050 by Invensense.

acceleration (including gravity) while the gyroscope measures angular velocity (rotational speed). The data from this sensor will be used as an input to the control loop of the drone.

**iii. RGB Camera**
Since the ESP32-S houses a dual-core CPU, we have enough processing power to integrate an onboard camera onto the drone. This is an RGB camera[2] which image can be streamed to an external computer via Wi-Fi. The computer can then perform image processing algorithms such as object detection or fiducial marker[3] detection. We will be using the camera for a vision-based positioning system for the ESP-drone.

**iv. Other Sensor Modules**
The circuit board of the ESP-drone has pads for adding an additional sensor to the drone[4]. For example, a ToF (time of flight) sensor module can be handy to measure the height of the drone above ground accurately, which is hard to get from IMU sensor alone. We need to keep in mind of the **payload limitation** of the drone, though.

The full hardware schematics of the ESP-drone's circuit board is available in **Appendix A** if you are interested to check it out.

## Overview of The Software

Software is also a very important part of this project. The software part of this project can be divided into several categories based on the functionality:

**i. `espdrone-nh` – The Drone's Firmware**
This is the firmware running directly on the ESP32 microcontroller on the drone. It is responsible for all low-level controls of the drone (e.g. controlling all 4 motors, talking with the onboard camera, reading sensor data and filtering them, generating flight trajectory, etc.) as well as handling Wi-Fi communication to and from the drone. The firmware is written in **C** and makes use of ESP32's official development framework, *ESP-IDF* (we will see this in later parts).

This firmware is based on the open-source `espdrone` project. We have made the necessary modifications to this project to suit our custom-designed hardware.

**ii. `espdrone-lib-python (edlib)` – The API**
This is a library/API for communicating with the drone running on (external) computer. This API can be used to write scripts to fetch data and/or send instructions to the drone, or used by other software, as the backend engine, for similar purposes. It is written in **Python**.

[2] Specifically, the camera model is OV2640 by Omnivision.
[3] This is a marker which can be used as point of reference placed on the environment where the camera operates.
[4] The sensor added via this pad communicates with the ESP32 on the drone using the $I^2C$ communication protocol.

### iii. `espdrone-client` – GUI for Debugging and Testing

This is a graphical user interface written in Python with **PyQt5** for testing and debugging with the drone. With it we can view sensor and other readings, change the drone's parameters, and control the drone (e.g. using joysticks). This tool uses `espdrone-lib-python` as the backend.

### iv. Others

Apart from the three mentioned above, we will also be using a simple Android app to fly the drone manually, as well as some other software to augment the capability of the drone (e.g. **ROS**). All these will be discussed in later parts.

Before we start, we will setup the toolchain and software needed to develop with the drone, as well as assemble the drone. These are discussed in the following parts.

## Setting Up the ESP32 Toolchain

### Installing Necessary Software

In order to develop and upload programs to the ESP32 on the drone, we need to set up the toolchain. We are going to use ***ESP-IDF*** (Espressif IoT Development Framework), which is provided directly by the company behind ESP32. We are not going to use Arduino IDE as it is not powerful enough for the task.

Before setting up the toolchain, install these on your computer if you have not already:

1. **Git** (not to be mistaken with **Github**), a version control software. You do *not* need to install Github on your desktop. Link: https://git-scm.com/download
2. **Microsoft Visual Studio Code (VS Code)**, not to be mistaken with **Visual Studio**. This is a powerful code editor that we will use. Link: https://code.visualstudio.com/download

Additional setup for Mac users using terminal (in order):

3. **Homebrew**, MacOS package manager.

```
    /bin/bash -c "$(curl -fsSL
https://raw.githubusercontent.com/Homebrew/install/HEAD/install.sh)"
```

4. **CMake**, build process integration for cross environment.

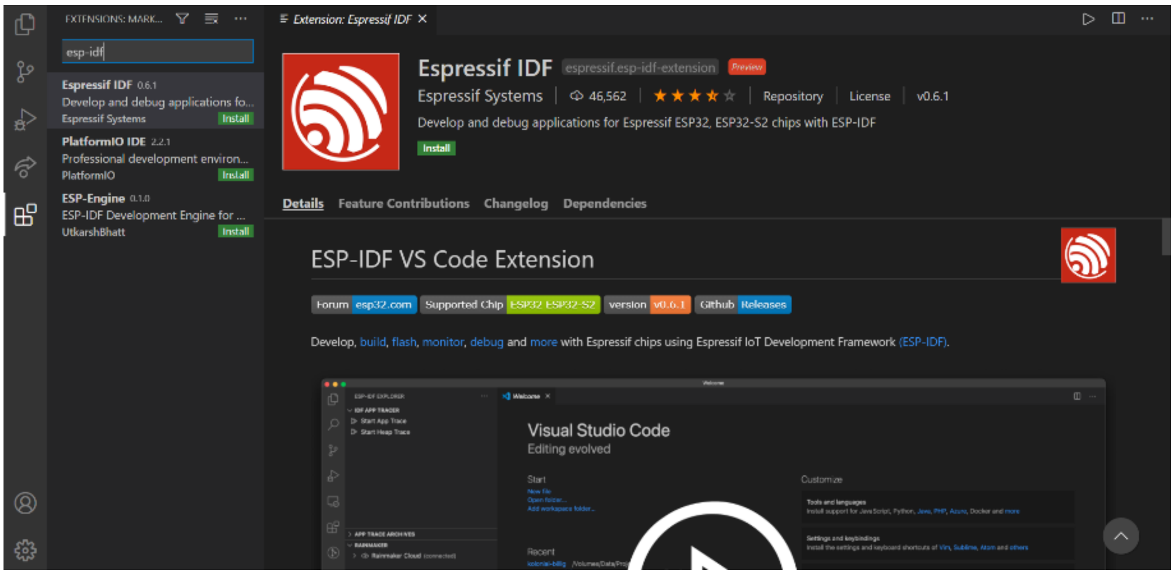
```
brew install cmake
```

5. **Ninja**, a small build system for speed.

```
brew install ninja
```

### Installing ESP-IDF

After installing all the above software, launch VS Code and install the **ESP-IDF extension**.



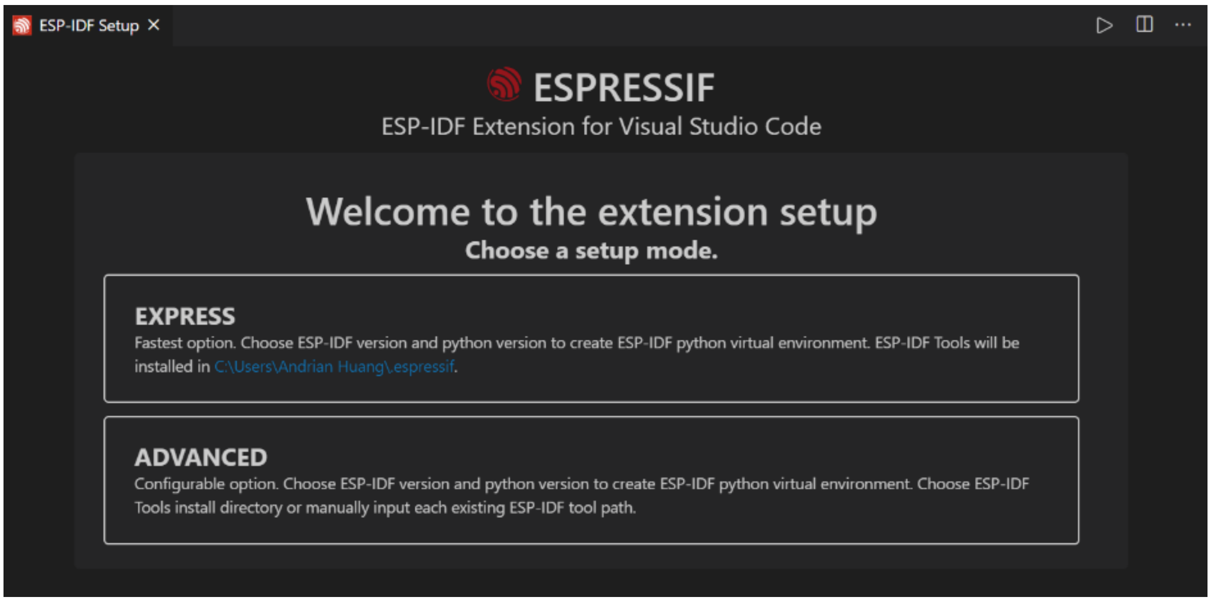
Develop and debug applications for Espressif ESP32, ESP32-S2 chips with ESP-IDF

ESP-IDF VS Code Extension

Develop, build, flash, monitor, debug and more with Espressif chips using Espressif IoT Development Framework (ESP-IDF).

**Figure 3.** ESP-IDF extension on VS Code extension marketplace.

After you finish installing the extension, you should see this on VS code:


ESP-IDF Setup

ESPRESSIF
ESP-IDF Extension for Visual Studio Code

Welcome to the extension setup
Choose a setup mode.

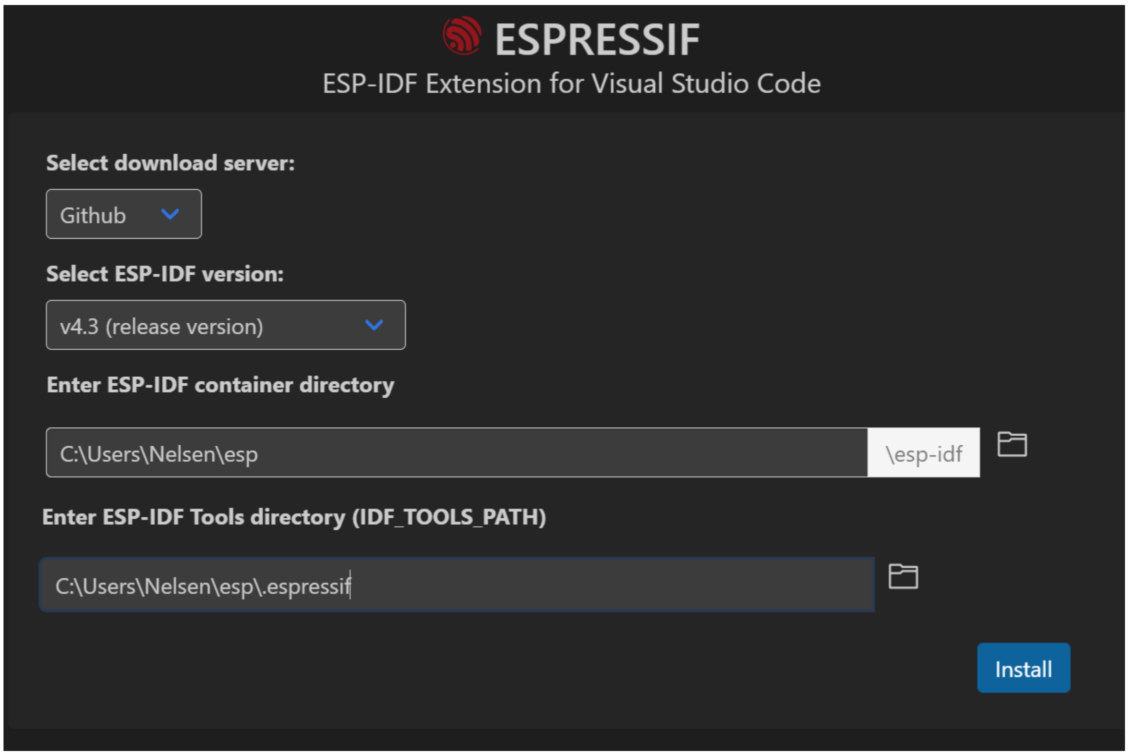
EXPRESS
Fastest option. Choose ESP-IDF version and python version to create ESP-IDF python virtual environment. ESP-IDF Tools will be installed in C:\Users\Andrian Huang\.espressif.

ADVANCED
Configurable option. Choose ESP-IDF version and python version to create ESP-IDF python virtual environment. Choose ESP-IDF Tools install directory or manually input each existing ESP-IDF tool path.

**Figure 4.** ESP-IDF setup screen after installing the extension.

Next, choose **"Express".**

The ESP-IDF container directory **does not support directory with whitespaces in its full path**. As such, choose a folder which full path does not contain spaces.


ESPRESSIF
ESP-IDF Extension for Visual Studio Code

Select download server: Github

Select ESP-IDF version: v4.3 (release version)

Enter ESP-IDF container directory: C:\Users\Nelsen\esp \esp-idf

Enter ESP-IDF Tools directory (IDF_TOOLS_PATH): C:\Users\Nelsen\esp\.espressif

**Figure 5.** Choose the ESP-IDF container directory to be a path without whitespaces, like shown above.

For example, on Windows computer you may create a folder called "esp" on C: drive and choose this folder to be the directory for ESP-IDF container. For the other dropdown lists:

- Download server: we tested with Github but this choice should not matter.
- ESP-IDF version: “v4.3 (release version)”.

By default, ESP-IDF Tools is put under the folder “`.espressif`” (a hidden folder, **please remember this directory**). You can leave this as is as long as the full path has no spaces. In this case, it is put under the same directory as the ESP-IDF container directory inside the “esp” folder.

Then, click “Install” and wait for the installation to finish. After everything has been installed, you should see the following window:

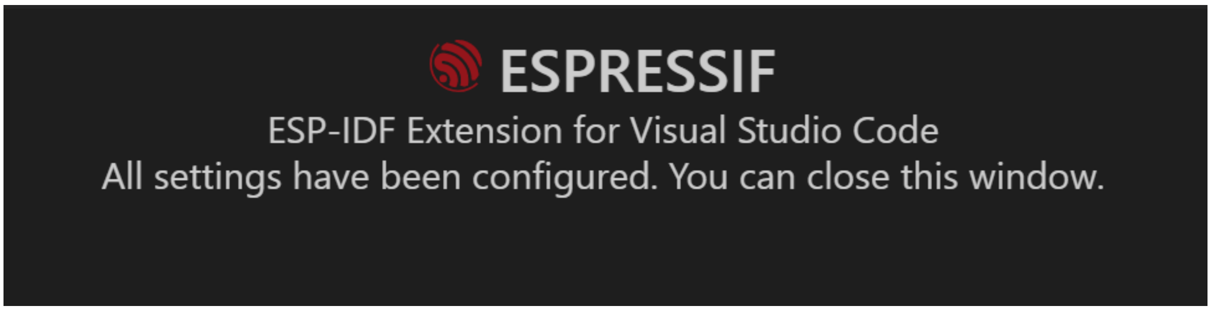
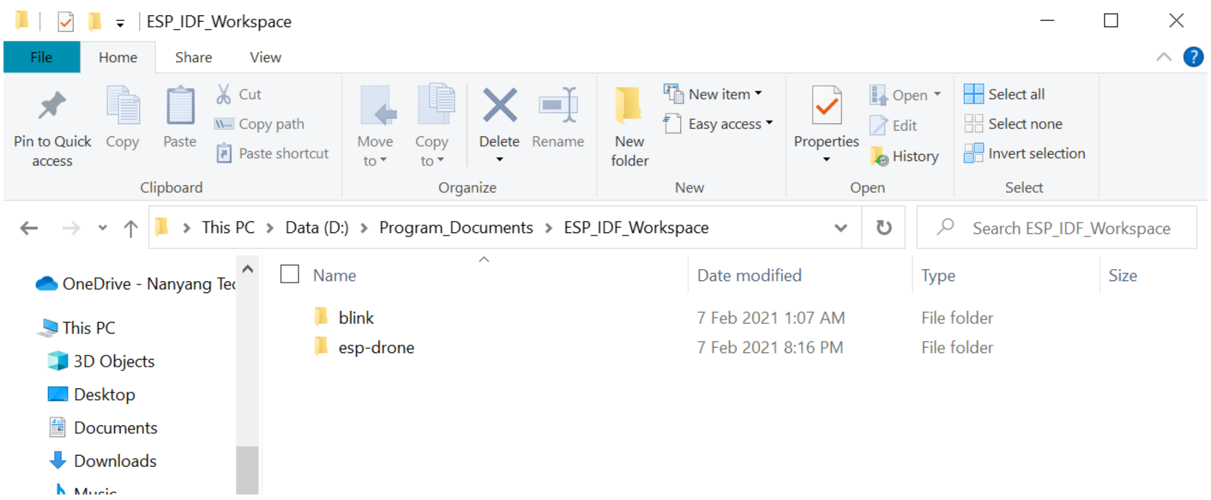

ESPRESSIF
ESP-IDF Extension for Visual Studio Code
All settings have been configured. You can close this window.

**Figure 6.** ESP-IDF installation window after finishing the installation process.

Next, you can optionally create another folder where you will put all your ESP-IDF projects in. You can place this folder anywhere and name it whatever you like, as long as the full path **does not contain whitespaces**. An example is **C:/espressif/workspaces**. Another example is shown below:



| Name | Date modified | Type | Size |
|---|---|---|---|
| blink | 7 Feb 2021 1:07 AM | File folder | |
| esp-drone | 7 Feb 2021 8:16 PM | File folder | |

**Figure 7.** Example of a workspace folder with two projects inside it (the full path here is **D:/Program_Documents/ESP_IDF_Workspace**). Notice that **there are no spaces in the full path**.

## Testing ESP-IDF Installation

To confirm that the ESP-IDF installation works fine, we will try to compile a built-in example project in ESP-IDF. We will also look at several important things for working with ESP-IDF, such as how to build a project.

To open example projects, press “F1” or “Ctrl+Shift+P” to open the Command Palette, then type “esp-idf examples”, then choose “ESP-IDF: Show Examples Projects” -> “Use current ESP-IDF”.

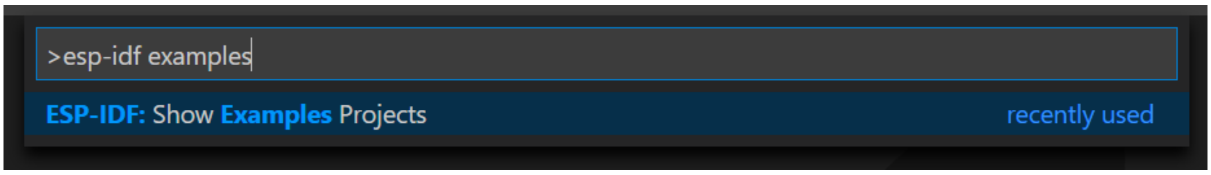
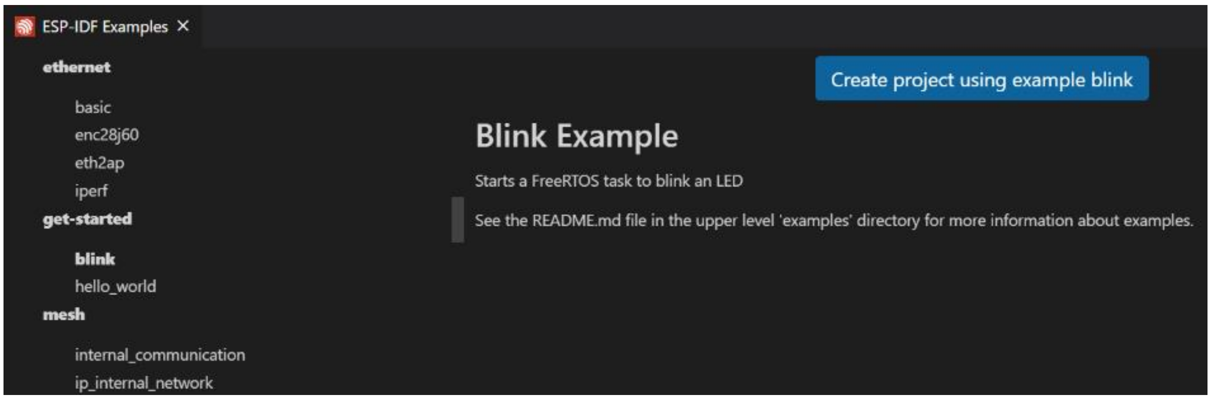


**Figure 8.** Accessing ESP-IDF example projects.

We will try a simple example: the blinking LED. Find the project `blink` under `get_started` and click "Create project using example blink".



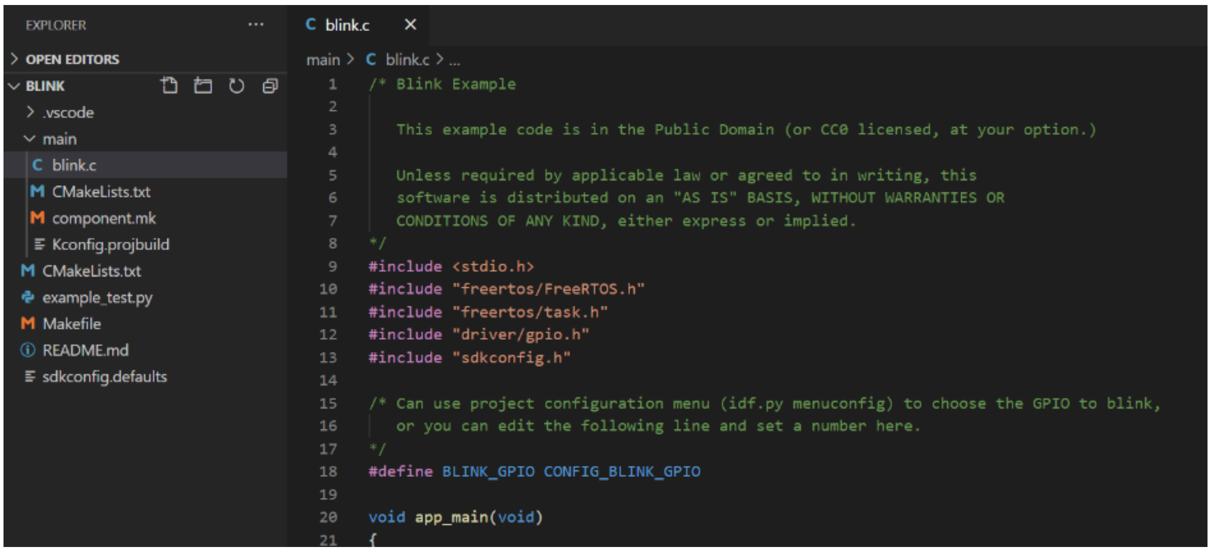
Blink Example

Starts a FreeRTOS task to blink an LED

See the README.md file in the upper level 'examples' directory for more information about examples.

**Figure 9.** Opening the `blink` example.

You will be asked to choose the folder in which you want to put the new example project in. Choose the folder that you have created previously. You should now see the new example project open automatically.



```
/* Blink Example

   This example code is in the Public Domain (or CC0 licensed, at your option.)

   Unless required by applicable law or agreed to in writing, this
   software is distributed on an "AS IS" BASIS, WITHOUT WARRANTIES OR
   CONDITIONS OF ANY KIND, either express or implied.
*/
#include <stdio.h>
#include "freertos/FreeRTOS.h"
#include "freertos/task.h"
#include "driver/gpio.h"
#include "sdkconfig.h"

/* Can use project configuration menu (idf.py menuconfig) to choose the GPIO to blink,
   or you can edit the following line and set a number here.
*/
#define BLINK_GPIO CONFIG_BLINK_GPIO

void app_main(void)
{
```

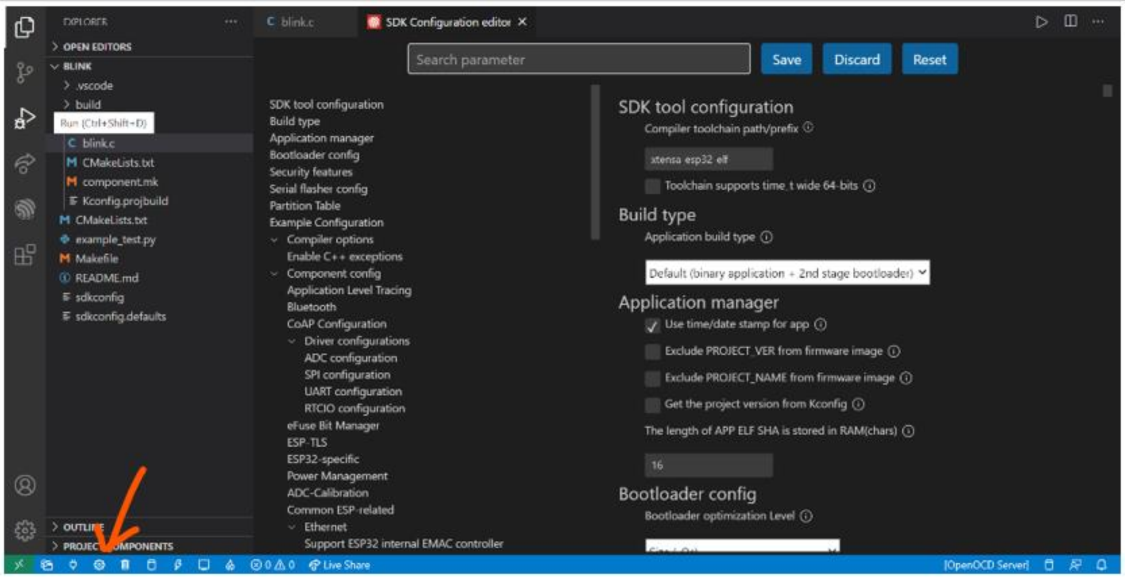
**Figure 10.** Example project `blink`.

The code here has been written as this is an example project, so we only need to set the configuration and build the project.

**ESP-IDF SDK Configuration**

Every ESP-IDF project has its own SDK configuration to set many aspects of the ESP32 for the project (including pins that are used in the code). For the `blink` example, the pin which the LED is attached to is configured in the SDK configuration.

To access the SDK configuration editor, click the gear icon on the bottom left of the screen. You should then see the following window:



EXPLORER | blink.c | SDK Configuration editor

Search parameter | Save | Discard | Reset

OPEN EDITORS
BLINK
- .vscode
- build
- Run (Ctrl+Shift+D)
- blink.c
- CMakeLists.txt
- component.mk
- Kconfig.projbuild
- CMakeLists.txt
- example_test.py
- Makefile
- README.md
- sdkconfig
- sdkconfig.defaults

OUTLINE
PROJECT COMPONENTS

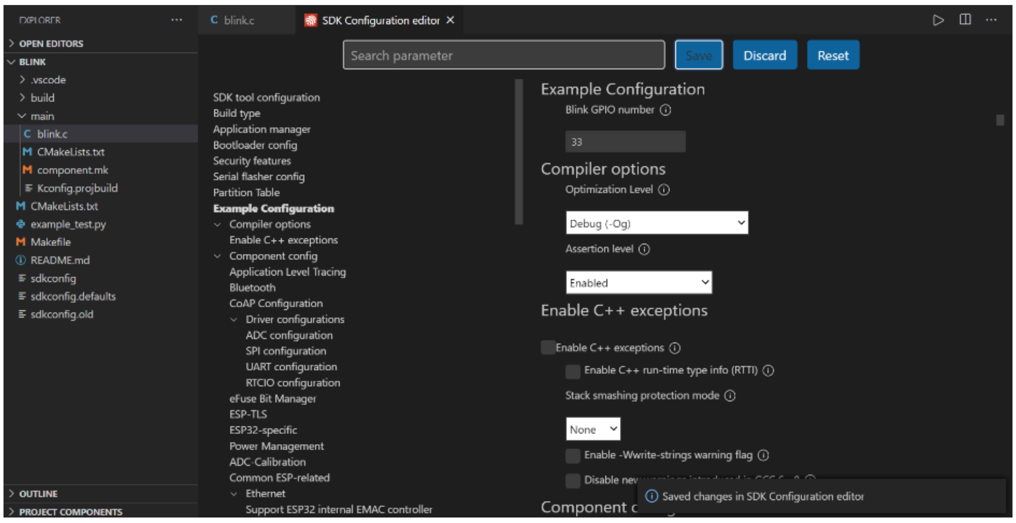
SDK tool configuration
Build type
Application manager
Bootloader config
Security features
Serial flasher config
Partition Table
Example Configuration
Compiler options
Enable C++ exceptions
Component config
Application Level Tracing
Bluetooth
CoAP Configuration
Driver configurations
ADC configuration
SPI configuration
UART configuration
RTCIO configuration
eFuse Bit Manager
ESP-TLS
ESP32-specific
Power Management
ADC-Calibration
Common ESP-related
Ethernet
Support ESP32 internal EMAC controller

SDK tool configuration
Compiler toolchain path/prefix: xtensa-esp32-elf
Toolchain supports time_t wide 64-bits
Build type
Application build type: Default (binary application + 2nd stage bootloader)
Application manager
[✓] Use time/date stamp for app
Exclude PROJECT_VER from firmware image
Exclude PROJECT_NAME from firmware image
Get the project version from Kconfig
The length of APP ELF SHA is stored in RAM(chars): 16
Bootloader config
Bootloader optimization Level

[OpenOCD Server]

Figure 11. ESP-IDF SDK Configuration editor window.

Scroll down to find "Blink GPIO number" in the configuration. Change it to **33** since the red LED on our drone PCB is on that GPIO pin (you can also use GPIO 13 for the blue LED if you want to). After that, click "Save". You should see a new `sdkconfig.old` file appear on the left[5].



EXPLORER | blink.c | SDK Configuration editor

Search parameter | Save | Discard | Reset

OPEN EDITORS
BLINK
- .vscode
- build
- main
  - blink.c
  - CMakeLists.txt
  - component.mk
  - Kconfig.projbuild
- CMakeLists.txt
- example_test.py
- Makefile
- README.md
- sdkconfig
- sdkconfig.defaults
- sdkconfig.old

OUTLINE
PROJECT COMPONENTS

SDK tool configuration
Build type
Application manager
Bootloader config
Security features
Serial flasher config
Partition Table
**Example Configuration**
Compiler options
Enable C++ exceptions
Component config
Application Level Tracing
Bluetooth
CoAP Configuration
Driver configurations
ADC configuration
SPI configuration
UART configuration
RTCIO configuration
eFuse Bit Manager
ESP-TLS
ESP32-specific
Power Management
ADC-Calibration
Common ESP-related
Ethernet
Support ESP32 internal EMAC controller

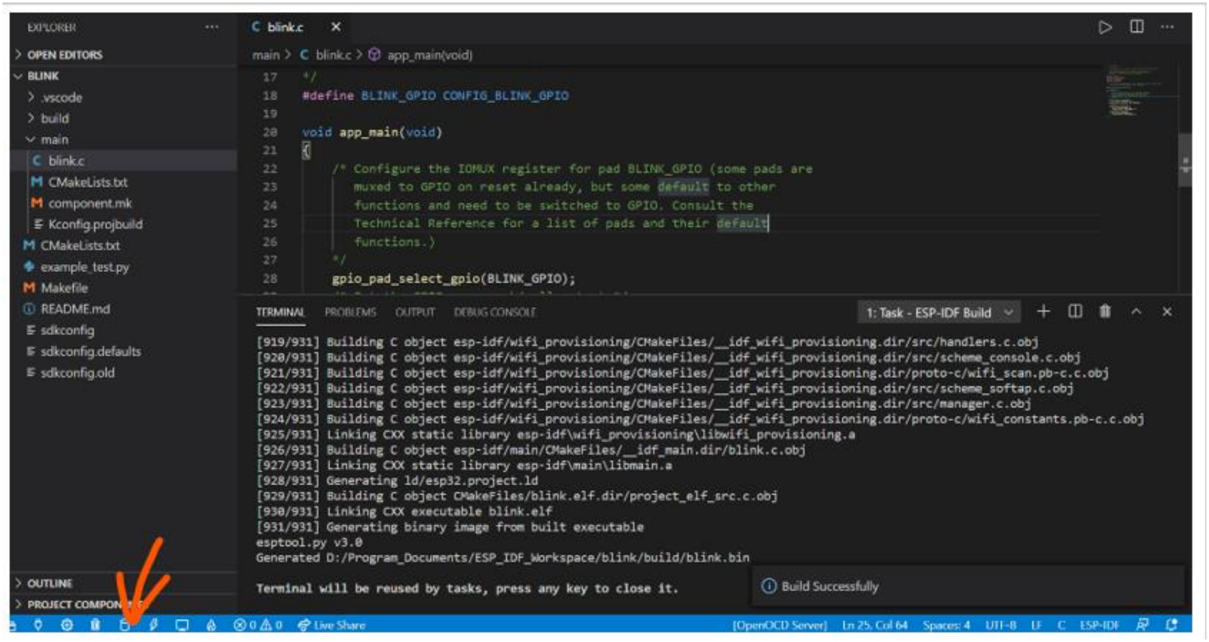
Example Configuration
Blink GPIO number: 33
Compiler options
Optimization Level: Debug (-Og)
Assertion level: Enabled
Enable C++ exceptions
Enable C++ exceptions
Enable C++ run-time type info (RTTI)
Stack smashing protection mode: None
Enable -Wwrite-strings warning flag
Disable new
Component c

Saved changes in SDK Configuration editor

Figure 12. Configure the GPIO pin number to blink to either 33 or 13 in the SDK Configuration editor.

[5] This `sdkconfig.old` file is actually the former `sdkconfig` file. The `sdkconfig` file contains all the configuration that will be used when compiling the code. When we modify the blink GPIO number and save the configuration, a new `sdkconfig` file is generated, hence the old one is automatically renamed into `sdkconfig.old`.

**Building the Example Project**
After modifying and saving the configuration, we can build (compile) the project. To do so, click the cylinder icon on the bottom left of the screen (to the right of the trash can icon). Wait for the build process to finish. A successful build should look like the following:



```c
*/
#define BLINK_GPIO CONFIG_BLINK_GPIO

void app_main(void)
{
    /* Configure the IOMUX register for pad BLINK_GPIO (some pads are
       muxed to GPIO on reset already, but some default to other
       functions and need to be switched to GPIO. Consult the
       Technical Reference for a list of pads and their default
       functions.)
    */
    gpio_pad_select_gpio(BLINK_GPIO);
```

```
[919/931] Building C object esp-idf/wifi_provisioning/CMakeFiles/__idf_wifi_provisioning.dir/src/handlers.c.obj
[920/931] Building C object esp-idf/wifi_provisioning/CMakeFiles/__idf_wifi_provisioning.dir/src/scheme_console.c.obj
[921/931] Building C object esp-idf/wifi_provisioning/CMakeFiles/__idf_wifi_provisioning.dir/proto-c/wifi_scan.pb-c.c.obj
[922/931] Building C object esp-idf/wifi_provisioning/CMakeFiles/__idf_wifi_provisioning.dir/src/scheme_softap.c.obj
[923/931] Building C object esp-idf/wifi_provisioning/CMakeFiles/__idf_wifi_provisioning.dir/src/manager.c.obj
[924/931] Building C object esp-idf/wifi_provisioning/CMakeFiles/__idf_wifi_provisioning.dir/proto-c/wifi_constants.pb-c.c.obj
[925/931] Linking CXX static library esp-idf\wifi_provisioning\libwifi_provisioning.a
[926/931] Building C object esp-idf/main/CMakeFiles/__idf_main.dir/blink.c.obj
[927/931] Linking CXX static library esp-idf\main\libmain.a
[928/931] Generating ld/esp32.project.ld
[929/931] Building C object CMakeFiles/blink.elf.dir/project_elf_src.c.obj
[930/931] Linking CXX executable blink.elf
[931/931] Generating binary image from built executable
esptool.py v3.0
Generated D:/Program_Documents/ESP_IDF_Workspace/blink/build/blink.bin

Terminal will be reused by tasks, press any key to close it.
```

**Figure 13.** Example of a successful build.

If your build is successful, great! You have installed ESP-IDF correctly.

*(Optional)* While building, you may encounter an error similar to:

```
Invalid escape sequence \o
```

If this happens, do the following modifications:

1. Find the Python script `idf.py` inside `esp-idf/tools` directory. For example, if you chose `C:/espressif` as the directory to install ESP-IDF into, find the Python script inside `C:/espressif/esp-idf/tools`.

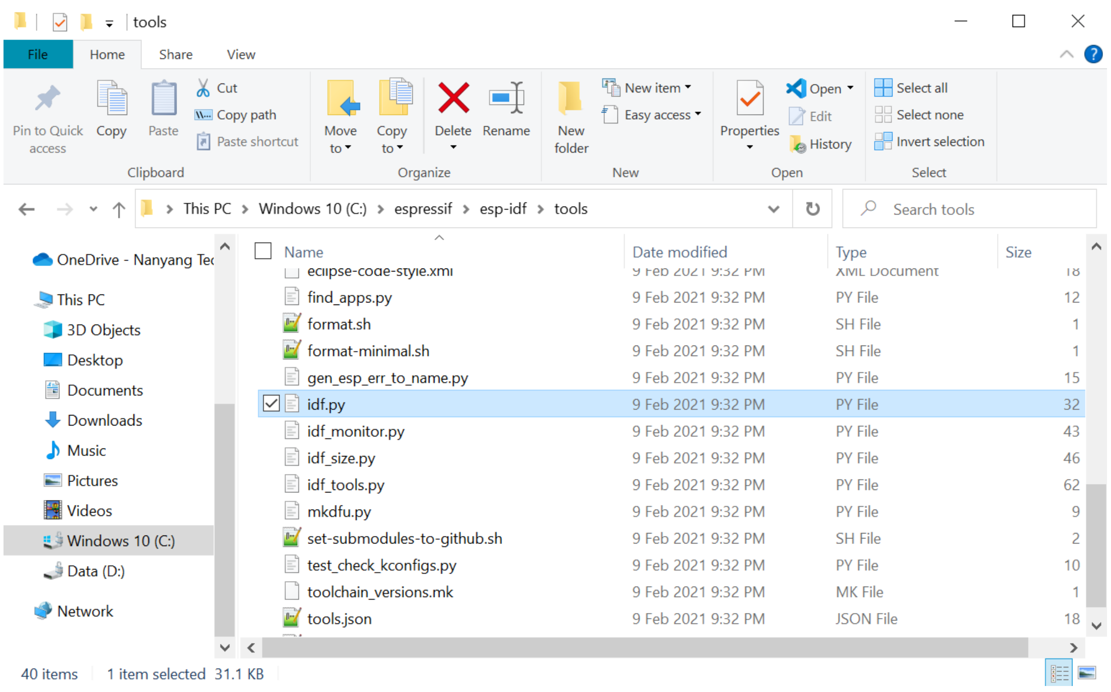
   Now, inside the Python script, change the code at line 52

   ```
   os.environ["PYTHON"] = sys.executable
   ```

   into

   ```
   import pathlib
   os.environ["PYTHON"] = pathlib.Path(sys.executable).as_posix()
   ```

   Save the modified script (do not rename or save as).



| Name | Date modified | Type | Size |
|---|---|---|---|
| eclipse-code-style.xml | 9 Feb 2021 9:32 PM | XML Document | 18 |
| find_apps.py | 9 Feb 2021 9:32 PM | PY File | 12 |
| format.sh | 9 Feb 2021 9:32 PM | SH File | 1 |
| format-minimal.sh | 9 Feb 2021 9:32 PM | SH File | 1 |
| gen_esp_err_to_name.py | 9 Feb 2021 9:32 PM | PY File | 15 |
| idf.py | 9 Feb 2021 9:32 PM | PY File | 32 |
| idf_monitor.py | 9 Feb 2021 9:32 PM | PY File | 43 |
| idf_size.py | 9 Feb 2021 9:32 PM | PY File | 46 |
| idf_tools.py | 9 Feb 2021 9:32 PM | PY File | 62 |
| mkdfu.py | 9 Feb 2021 9:32 PM | PY File | 9 |
| set-submodules-to-github.sh | 9 Feb 2021 9:32 PM | SH File | 2 |
| test_check_kconfigs.py | 9 Feb 2021 9:32 PM | PY File | 10 |
| toolchain_versions.mk | 9 Feb 2021 9:32 PM | MK File | 1 |
| tools.json | 9 Feb 2021 9:32 PM | JSON File | 18 |

40 items    1 item selected 31.1 KB

**Figure 14.** Example of where to find `idf.py` (if you installed ESP-IDF in C:/espressif).

2. Open the ESP-IDF extension setting window. To do so, click the gear icon to the right of “Espressif IDF” under Extensions. Then, click “Extension Settings”.

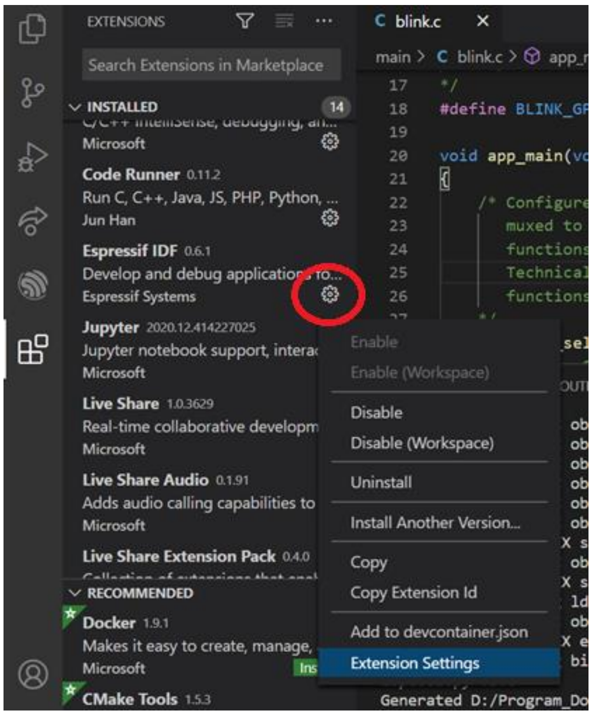
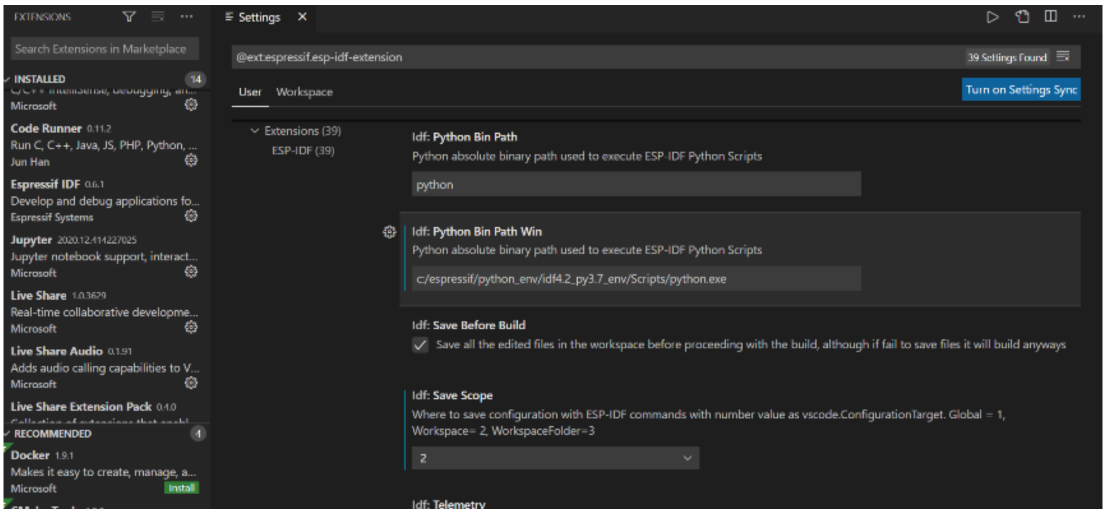


**Figure 15.** Accessing extension settings.

Then, find “Idf: Python Bin Path Win” and replace all backslashes (\) with forward slashes (/).


EXTENSIONS
Search Extensions in Marketplace
INSTALLED 14
Microsoft
Code Runner 0.11.2
Run C, C++, Java, JS, PHP, Python, ...
Jun Han
Espressif IDF 0.6.1
Develop and debug applications fo...
Espressif Systems
Jupyter 2020.12.414227025
Jupyter notebook support, interact...
Microsoft
Live Share 1.0.3629
Real-time collaborative developme...
Microsoft
Live Share Audio 0.1.91
Adds audio calling capabilities to V...
Microsoft
Live Share Extension Pack 0.4.0
RECOMMENDED 4
Docker 1.9.1
Makes it easy to create, manage, a...
Microsoft
Install
Settings
@ext:espressif.esp-idf-extension
39 Settings Found
User
Workspace
Turn on Settings Sync
Extensions (39)
ESP-IDF (39)

Idf: **Python Bin Path**
Python absolute binary path used to execute ESP-IDF Python Scripts
python

Idf: **Python Bin Path Win**
Python absolute binary path used to execute ESP-IDF Python Scripts
c:/espressif/python_env/idf4.2_py3.7_env/Scripts/python.exe

Idf: **Save Before Build**
✓ Save all the edited files in the workspace before proceeding with the build, although if fail to save files it will build anyways

Idf: **Save Scope**
Where to save configuration with ESP-IDF commands with number value as vscode.ConfigurationTarget. Global = 1, Workspace= 2, WorkspaceFolder=3
2

Idf: **Telemetry**

**Figure 16.** Python Bin Path Win under Extension Settings.

## Preparing the Drone Software

### The `espdrone-nh` Project

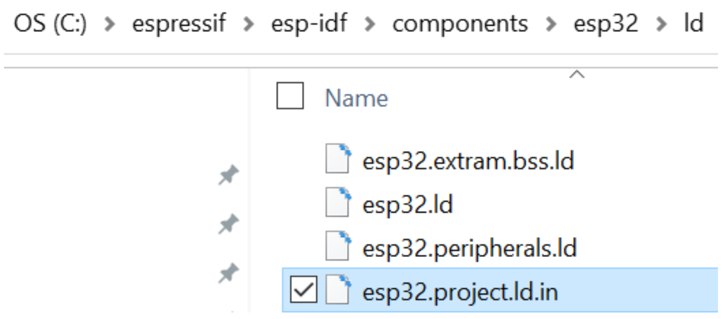
As a reminder, this is the firmware that runs directly on the drone (ESP32). In the following weeks, we will base our developments on this project. You can fetch it from Github:

```
git clone https://github.com/NelsenEW/espdrone-nh.git
```

You can put this inside the folder that you have previously created.

To use this project, two project link scripts must be modified.

1. Go to `"C:\Users\Username\esp\esp-idf\components\esp32\ld"` and find the script `esp32.project.ld.in`.



OS (C:) > espressif > esp-idf > components > esp32 > ld

Name

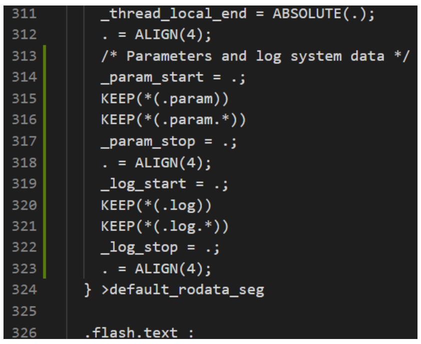
esp32.extram.bss.ld
esp32.ld
esp32.peripherals.ld
esp32.project.ld.in

**Figure 17.** ESP32 project link script.

Right click on the script and click "Open with Code" to open the script. Then, add the following lines before `} >default_rodata_seg`:

```
/* Parameters and log system data */
 _param_start = .;
 KEEP(*(.param))
 KEEP(*(.param.*))
 _param_stop = .;
 . = ALIGN(4);
 _log_start = .;
 KEEP(*(.log))
 KEEP(*(.log.*))
 _log_stop = .;
 . = ALIGN(4);
```

The newly added lines (highlighted in green) should look as follow:

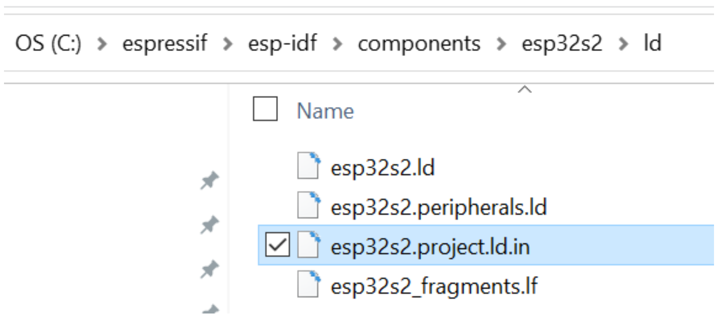


```
    _thread_local_end = ABSOLUTE(.);
    . = ALIGN(4);
    /* Parameters and log system data */
    _param_start = .;
    KEEP(*(.param))
    KEEP(*(.param.*))
    _param_stop = .;
    . = ALIGN(4);
    _log_start = .;
    KEEP(*(.log))
    KEEP(*(.log.*))
    _log_stop = .;
    . = ALIGN(4);
  } >default_rodata_seg

  .flash.text :
```

**Figure 18.** ESP32 project link script modification.

2. Similarly, go to "`C:\Users\Username\esp\esp-idf\components\esp32s2\ld`" and find the script `esp32s2.project.ld.in`.

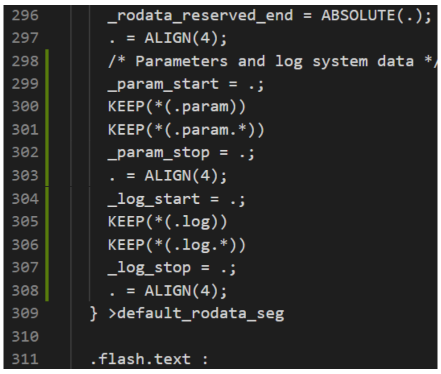


OS (C:) > espressif > esp-idf > components > esp32s2 > ld

Name
- esp32s2.ld
- esp32s2.peripherals.ld
- esp32s2.project.ld.in
- esp32s2_fragments.lf

**Figure 19.** ESP32S2 Project link script.

Add the same lines to the script at the same location:



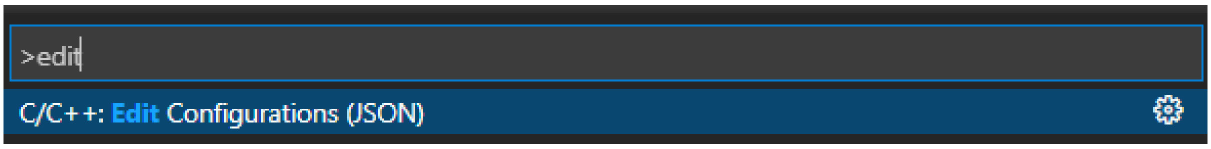
```
    _rodata_reserved_end = ABSOLUTE(.);
    . = ALIGN(4);
    /* Parameters and log system data */
    _param_start = .;
    KEEP(*(.param))
    KEEP(*(.param.*))
    _param_stop = .;
    . = ALIGN(4);
    _log_start = .;
    KEEP(*(.log))
    KEEP(*(.log.*))
    _log_stop = .;
    . = ALIGN(4);
  } >default_rodata_seg

  .flash.text :
```

**Figure 20.** ESP32S2 Project link script modification.

## Testing the `espdrone-nh` Workspace

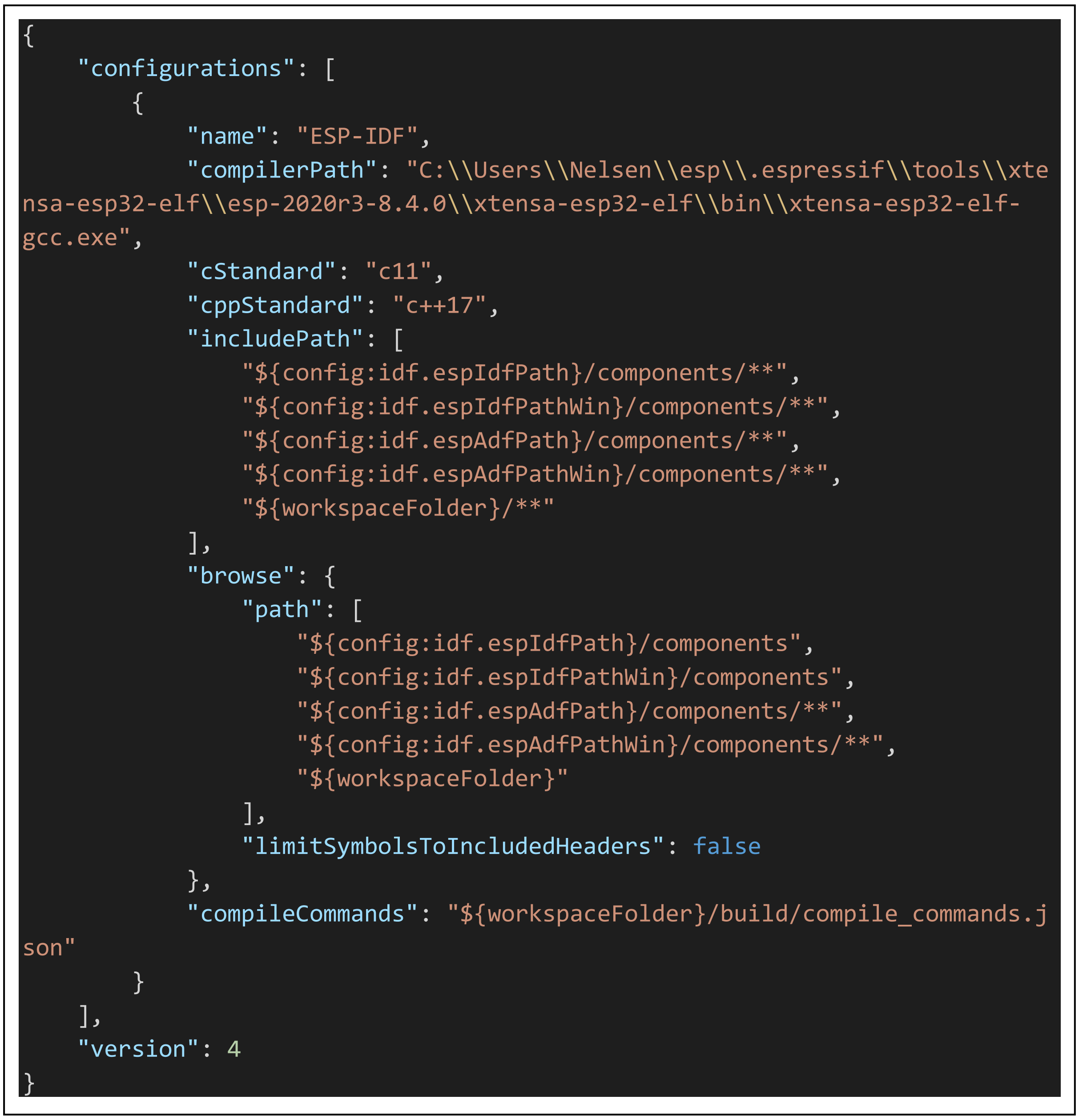
Once you have downloaded the `espdrone-nh` project, open VS Code and click "Open Folder…" on the menu bar and choose `espdrone-nh`. To generate the "`.vscode`" directory, and the `c_cpp_properties.json`, go to the command palette by pressing **View -> Command Palette** and type Edit configurations (JSON).



```
>edit
C/C++: Edit Configurations (JSON)
```

**Figure 21.** Command Palette for creating `c_cpp_properties.json`

Now, go to "`.vscode`" inside the `espdrone-nh` directory. You should add the following:



```json
{
    "configurations": [
        {
            "name": "ESP-IDF",
            "compilerPath": "C:\\Users\\Nelsen\\esp\\.espressif\\tools\\xtensa-esp32-elf\\esp-2020r3-8.4.0\\xtensa-esp32-elf\\bin\\xtensa-esp32-elf-gcc.exe",
            "cStandard": "c11",
            "cppStandard": "c++17",
            "includePath": [
                "${config:idf.espIdfPath}/components/**",
                "${config:idf.espIdfPathWin}/components/**",
                "${config:idf.espAdfPath}/components/**",
                "${config:idf.espAdfPathWin}/components/**",
                "${workspaceFolder}/**"
            ],
            "browse": {
                "path": [
                    "${config:idf.espIdfPath}/components",
                    "${config:idf.espIdfPathWin}/components",
                    "${config:idf.espAdfPath}/components/**",
                    "${config:idf.espAdfPathWin}/components/**",
                    "${workspaceFolder}"
                ],
                "limitSymbolsToIncludedHeaders": false
            },
            "compileCommands": "${workspaceFolder}/build/compile_commands.json"
        }
    ],
    "version": 4
}
```

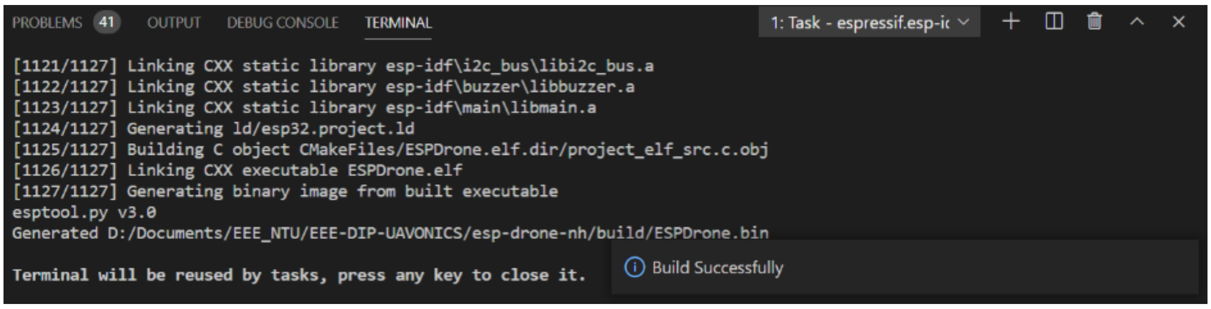
**Figure 22.** Visual Studio Code with `espdrone-nh c_cpp_properties.json`.

When you copy the entire thing from above, the text could be unformatted, to solve this, right click anywhere on the document and press “**Format Document**”.

**Don’t forget to change the compilerPath**! Compiler path is the path to `.espressif` directory followed by `tools\xtensa-esp32-elf\esp-2020r3-8.4.0\xtensa-esp32-elf\bin\xtensa-esp32-elf-gcc.exe`. Don’t forget to change single back slash (\) to double back slash (**\\**) between each directory name.

The purpose of the `c_cpp_properties.json` is to let `vscode` know that we are working with an ESP32 microcontroller, and setup the include path for smoother development. Do not worry if the `compile_commands.json` is not found, it will be generated when you build the project.

Next, try building the workspace by clicking the cylinder icon on the bottom left of the screen (to the right of the trash can icon). Wait for the build process to finish. A successful build should look like the following:



```
[1121/1127] Linking CXX static library esp-idf\i2c_bus\libi2c_bus.a
[1122/1127] Linking CXX static library esp-idf\buzzer\libbuzzer.a
[1123/1127] Linking CXX static library esp-idf\main\libmain.a
[1124/1127] Generating ld/esp32.project.ld
[1125/1127] Building C object CMakeFiles/ESPDrone.elf.dir/project_elf_src.c.obj
[1126/1127] Linking CXX executable ESPDrone.elf
[1127/1127] Generating binary image from built executable
esptool.py v3.0
Generated D:/Documents/EEE_NTU/EEE-DIP-UAVONICS/esp-drone-nh/build/ESPDrone.bin

Terminal will be reused by tasks, press any key to close it.
```

ⓘ Build Successfully

**Figure 23.** `espdrone-nh` successfully built.

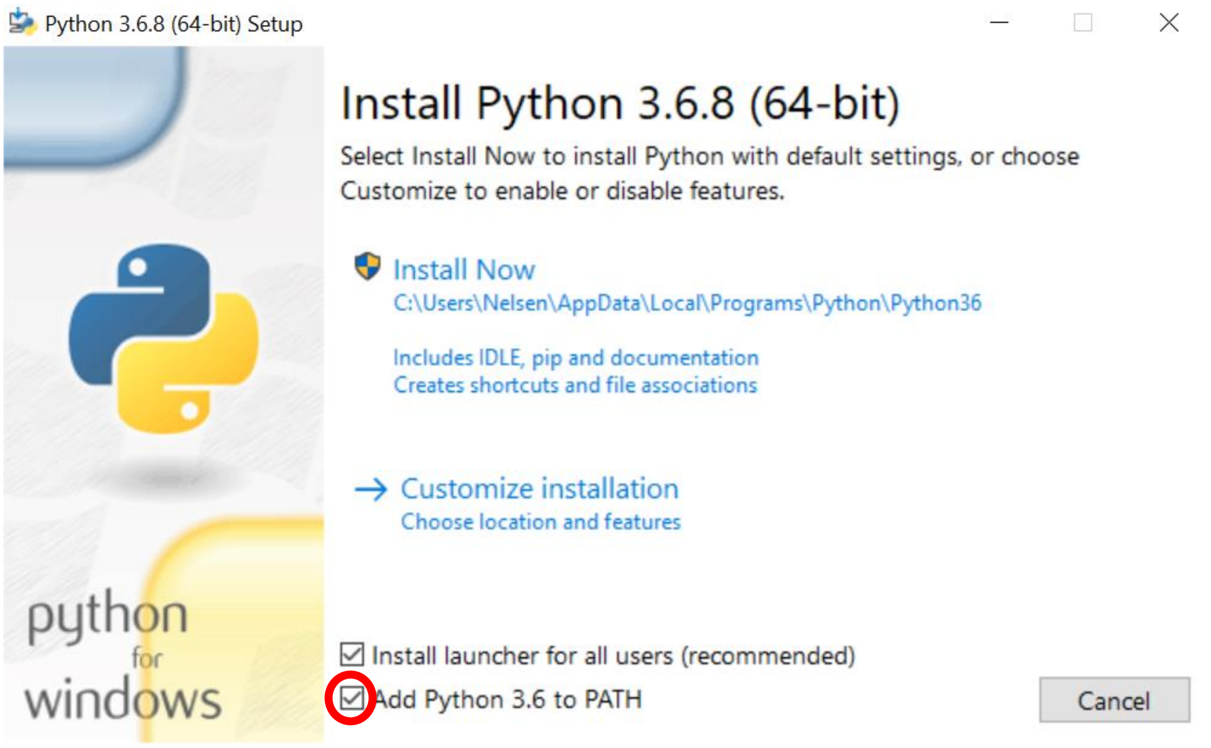
***For future developments with this repository, you can refer to the documentation:***

***https://github.com/NelsenEW/espdrone-nh/blob/main/docs/esp-drone-docs.pdf***

## Installing and Setting Up espdrone-lib-python and espdrone-client

Before setting up, install these on your computer if you have not already:

1. **Python 3.6 only!** You can install **Python 3.6** using Anaconda, although you do not have to. Link: https://www.python.org/downloads/release/python-368/



Python 3.6.8 (64-bit) Setup

Install Python 3.6.8 (64-bit)

Select Install Now to install Python with default settings, or choose Customize to enable or disable features.

Install Now
C:\Users\Nelsen\AppData\Local\Programs\Python\Python36

Includes IDLE, pip and documentation
Creates shortcuts and file associations

→ Customize installation
Choose location and features

☑ Install launcher for all users (recommended)
☑ Add Python 3.6 to PATH

Cancel

**Figure 24.** Installing Python.

Don’t forget to tick **Add Python 3.6 to PATH** if you are installing it with the python installation, then press Install Now.

Now, open the command prompt, update pip to the latest version

```
python -m pip install --upgrade pip
```

We will use `espdrone-client` (`edclient`) to interface with the drone (e.g. read sensor readings). To use it, clone it (as well as `espdrone-lib-python`, which it uses as backend) from Github:

```
git clone https://github.com/NelsenEW/espdrone-clients

git clone https://github.com/NelsenEW/espdrone-lib-python
```

Then, the next step is to navigate to the folder `espdrone-lib-python` and install the required packages:

To navigate to the `espdrone-lib-python` directory, do the following command

```
cd espdrone-lib-python
```

To install the dependencies of the `espdrone-lib-python` package, do the following command

```
pip install -r requirements.txt
```

Then, install the `espdrone-lib-python` in the editable mode:

```
pip install -e .
```

Finally, return to the previous directory

```
cd ..
```

The next step is to install the `espdrone-client`, to do that navigate to `espdrone-client`.

To navigate to the `espdrone-client` directory, do the following command

```
cd espdrone-client
```

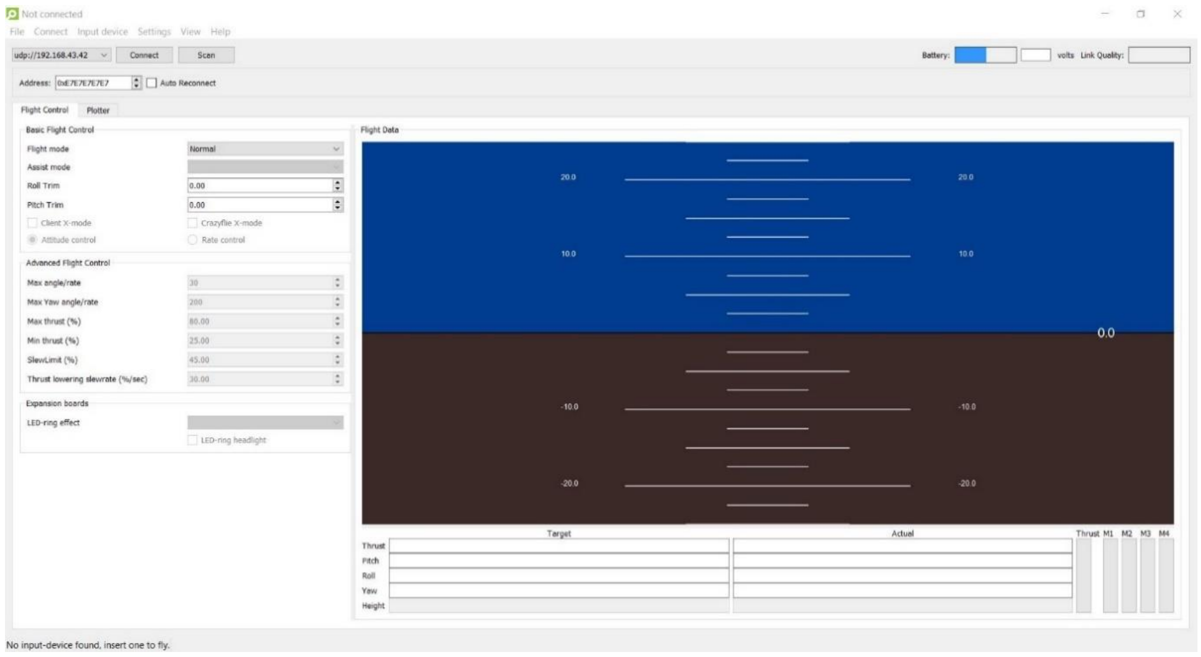
Then, install the `espdrone-client` in the editable mode:

```
pip install -e .
```

Finally, inside the same directory, launch the GUI interface (`edclient`):

```
edclient
```

You should then be greeted with the following window:



udp://192.168.43.42

Address: 0xE7E7E7E7E7 Auto Reconnect

Basic Flight Control

| | |
|---|---|
| Flight mode | Normal |
| Assist mode | |
| Roll Trim | 0.00 |
| Pitch Trim | 0.00 |
| Client X-mode | Crazyflie X-mode |
| Attitude control | Rate control |

Advanced Flight Control

| | |
|---|---|
| Max angle/rate | 30 |
| Max Yaw angle/rate | 200 |
| Max thrust (%) | 80.00 |
| Min thrust (%) | 25.00 |
| SlewLimit (%) | 45.00 |
| Thrust lowering slewrate (%/sec) | 30.00 |

Expansion boards

| | |
|---|---|
| LED-ring effect | |
| | LED-ring headlight |

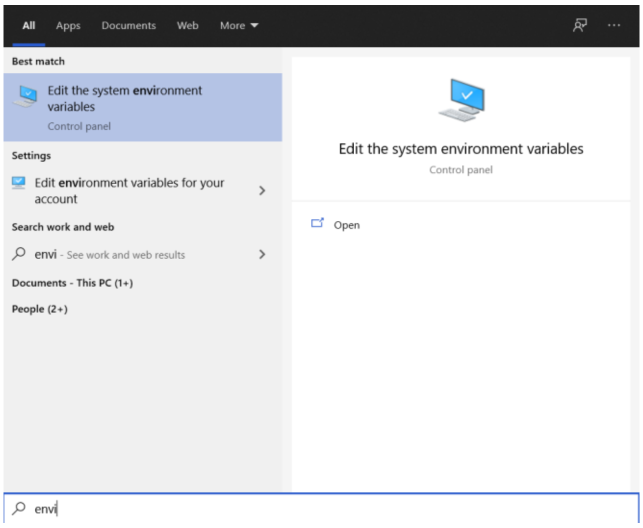
No input-device found, insert one to fly.

**Figure 25.** The `edclient` GUI.

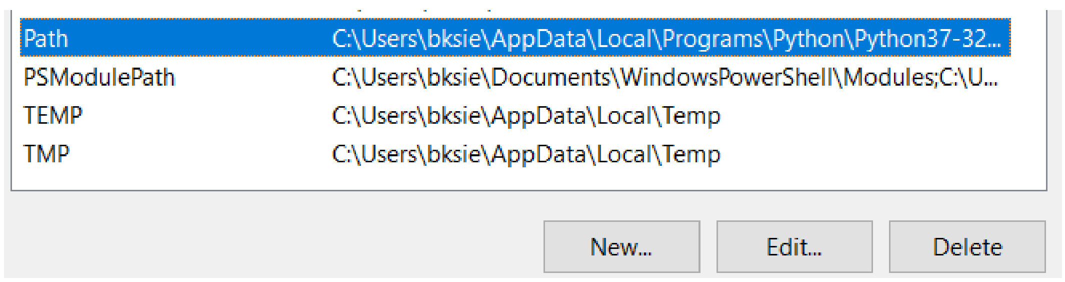
**Additional Setup (for Windows)**

Up to now, you need to navigate to the `espdrone-clients` directory inside command prompt (CMD) in order to run `edclient`. To call `edclient` in CMD without needing to navigate to that directory, you can add a new Path pointing to it in system environment variables. You only need to do this if Python is not added to your system Path variable.

1. Open the "Edit system environment variables" window by typing "path" or "environment" in the Windows search box.


All
Apps
Documents
Web
More
Best match
Edit the system environment variables
Control panel
Settings
Edit environment variables for your account
Search work and web
envi - See work and web results
Documents - This PC (1+)
People (2+)
Edit the system environment variables
Control panel
Open
envi

2. On that window, click Path and press Edit...

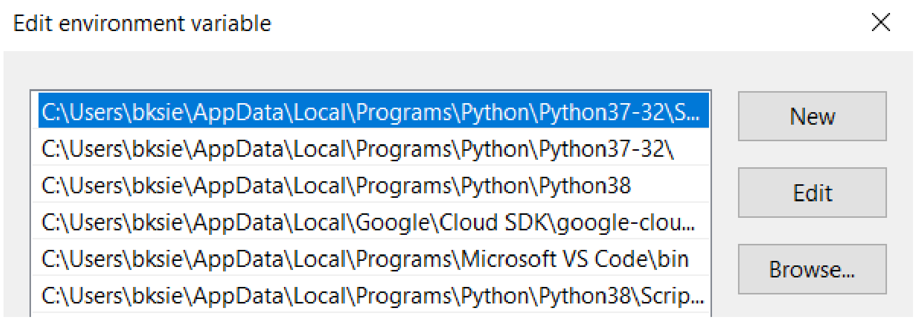


| | |
|---|---|
| Path | C:\Users\bksie\AppData\Local\Programs\Python\Python37-32... |
| PSModulePath | C:\Users\bksie\Documents\WindowsPowerShell\Modules;C:\U... |
| TEMP | C:\Users\bksie\AppData\Local\Temp |
| TMP | C:\Users\bksie\AppData\Local\Temp |

3. Create a new path pointing to python scripts, e.g.

   C:\Users\< your username >\AppData\Local\Programs\Python\Python36\Scripts

   or to other directories where Python stores its scripts at.



```
C:\Users\bksie\AppData\Local\Programs\Python\Python37-32\S...
C:\Users\bksie\AppData\Local\Programs\Python\Python37-32\
C:\Users\bksie\AppData\Local\Programs\Python\Python38
C:\Users\bksie\AppData\Local\Google\Cloud SDK\google-clou...
C:\Users\bksie\AppData\Local\Programs\Microsoft VS Code\bin
C:\Users\bksie\AppData\Local\Programs\Python\Python38\Scrip...
```

## Assembling and Testing the ESP-Drone

### Uploading Firmware to ESP-Drone PCB

The ESP-drone PCB does not have onboard USB connector, so an external programmer is required to upload program to it. We will use an Arduino Nano as the programmer.

Make the following connection on your breadboard:

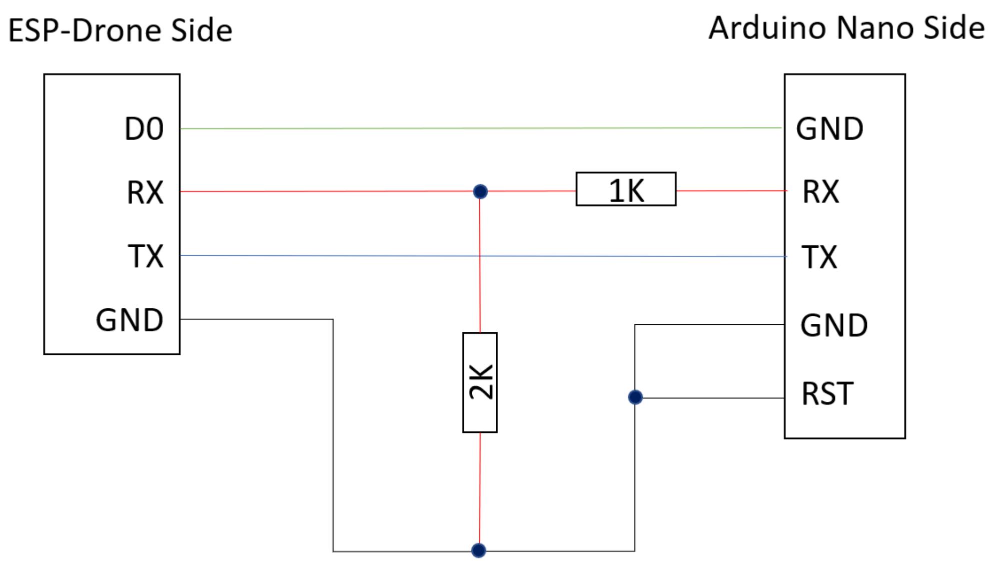


**Figure 26.** Configuration to upload program to ESP-Drone.

You can identify which resistor is which by looking at the color bands on them.

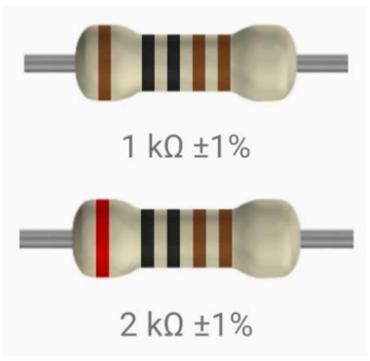


**Figure 27.** Resistor value as indicated by their color bands.

Please **remember this configuration and do not dismantle the circuit you have built on your breadboard**; we will keep using this for uploading firmware to the drone in the future.

Now that the hardware has been set up, open the `espdrone-nh` project in ESP-IDF (recall that this is the firmware, we will upload this onto the drone PCB). Perform the following steps in VScode/ESP-IDF to upload the firmware to the drone:

- Build the project by clicking the cylinder icon on the bottom left of the screen. Wait for it to finish.

- Choose the correct port that the board is connected to by clicking the plug icon on the bottom left of the screen (to the left of the gear icon). A selection list will then appear on the top of the screen:

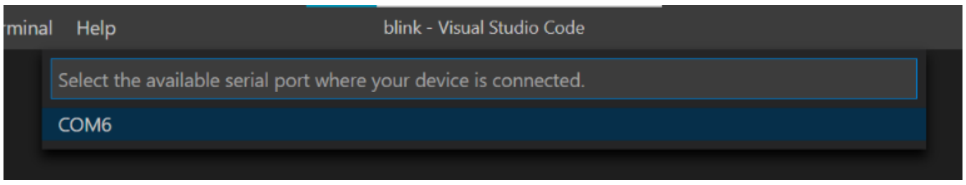

minal Help
blink - Visual Studio Code
Select the available serial port where your device is connected.
COM6

**Figure 28.** Selecting the port before uploading. One way to check which port is correct is to unplug the drone PCB (the Arduino) from the computer and see which port disappears.

- Finally, upload to the board by clicking the flash icon on the bottom left of the screen (to the left of the monitor icon). A selection list will then appear on the top of the screen. **Choose "UART"**.

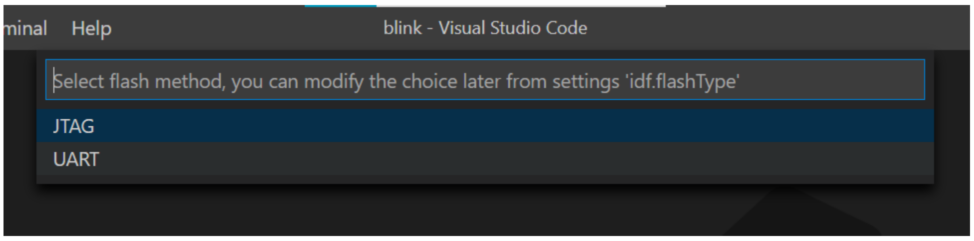
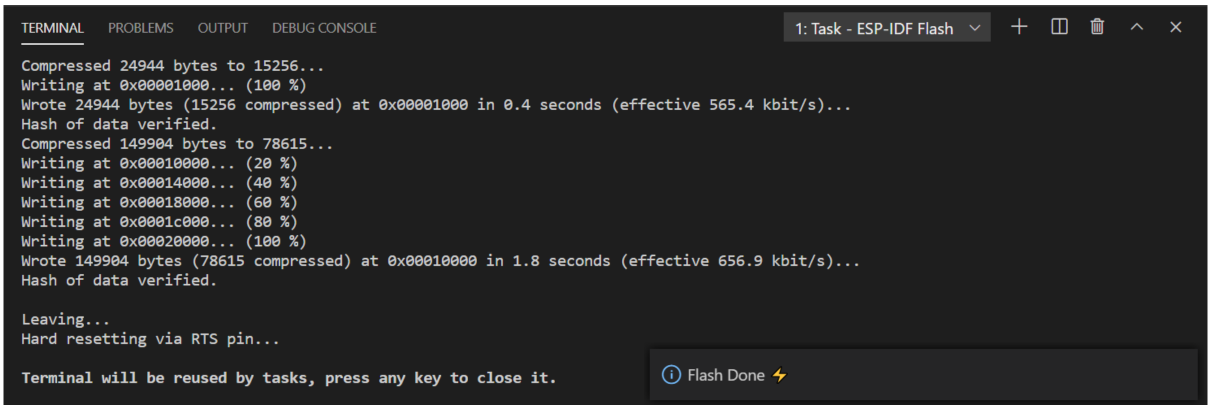

minal Help
blink - Visual Studio Code
Select flash method, you can modify the choice later from settings 'idf.flashType'
JTAG
UART

**Figure 29.** Uploading the program to the ESP32. Choose "UART" (which is the serial communication protocol we use to upload the program to the board).

A successful upload should look like this:



```
Compressed 24944 bytes to 15256...
Writing at 0x00001000... (100 %)
Wrote 24944 bytes (15256 compressed) at 0x00001000 in 0.4 seconds (effective 565.4 kbit/s)...
Hash of data verified.
Compressed 149904 bytes to 78615...
Writing at 0x00010000... (20 %)
Writing at 0x00014000... (40 %)
Writing at 0x00018000... (60 %)
Writing at 0x0001c000... (80 %)
Writing at 0x00020000... (100 %)
Wrote 149904 bytes (78615 compressed) at 0x00010000 in 1.8 seconds (effective 656.9 kbit/s)...
Hash of data verified.

Leaving...
Hard resetting via RTS pin...

Terminal will be reused by tasks, press any key to close it.
```

**Figure 30.** Terminal output after a successful upload to the ESP32 board.

## Assembling the Drone

Before assembling the drone, please **check if you have all the necessary parts:**

- The drone PCB **with the `espdrone-nh` firmware programmed to it**
- Drone plastic frame
- 4 brushed motors; 2 with red-blue wires (clockwise), 2 with white-black wires (counterclockwise)
- 4 propellers; 2 clockwise, 2 counterclockwise (see below)
- Paper antenna

- Wide-angle camera
- Drone battery

Also, please pay attention to **texts in bold** as they are important.

**Step 1: Attach the antenna to the PCB**
Make sure that the antenna is firmly attached to the connector.

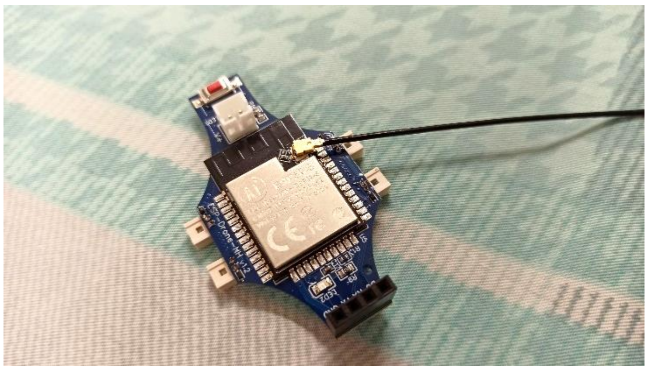


**Figure 31.** The drone PCB with antenna attached.

**Step 2: Twist the motor wires**
This helps reduce electrical noise and makes the wires fit better in the wire slot on the drone frame.

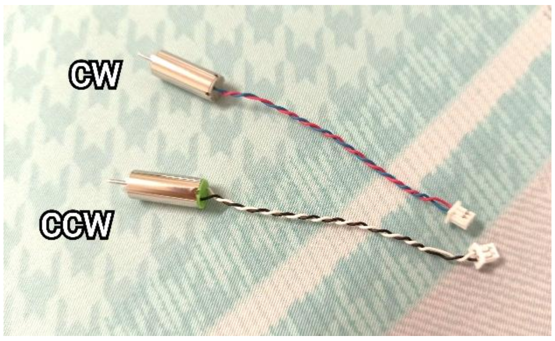


**Figure 32.** Twisted Motor Wires

Do note that you should have 1 pair of counterclockwise and 1 pair of clockwise motors for each drone. The counterclockwise motors have black and white wires, while the clockwise ones have red and blue wires.

**Step 3: Install the motors onto the drone frame**
You need to apply some force to insert the motors. You can use a long nose plier to help insert the motor. **Be careful not to deform or damage the drone frame, especially the propeller guard ring** as the clearance between the ring and the propeller is small.

Also, **mind which motor goes to which hole**:

- The clockwise (red-blue) motors should go to the front-left and rear-right sides.
- The counterclockwise (white-black) motors should go to the front-right and rear-left sides.
- Note the front side of the drone frame.

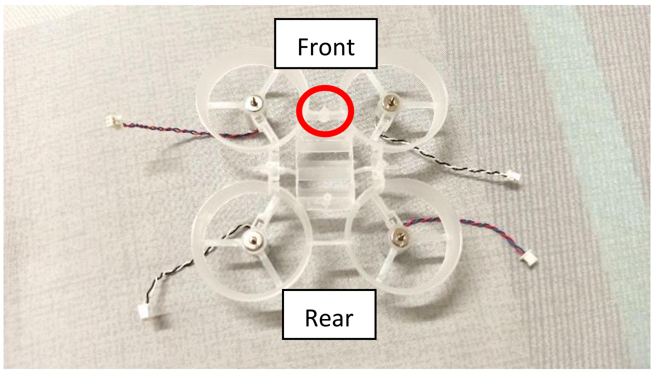


**Figure 33.** Top view of the drone frame with motors installed.

Make sure to insert the motors all the way in, as depicted below.

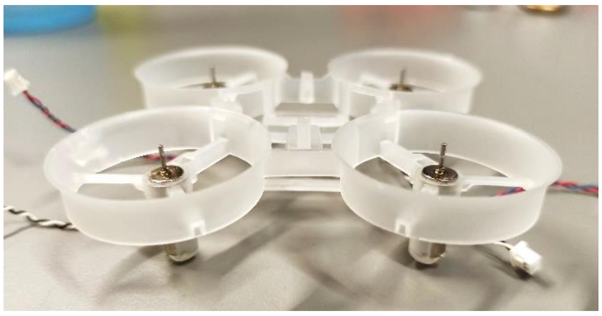


**Figure 34.** Side view of the drone frame.

**Step 4: Motor wire management**

After installing the motors, slip the wires into the slot on the drone frame. Each slot has a small hook to keep the wires in place.

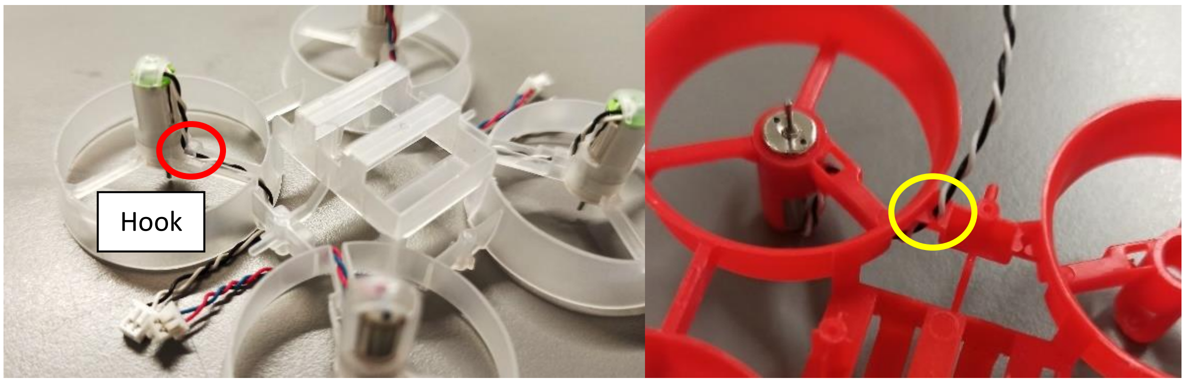


**Figure 35.** Insert the motor wires into the slots on the frame and secure the wires under the hook.

The result should look like the following:

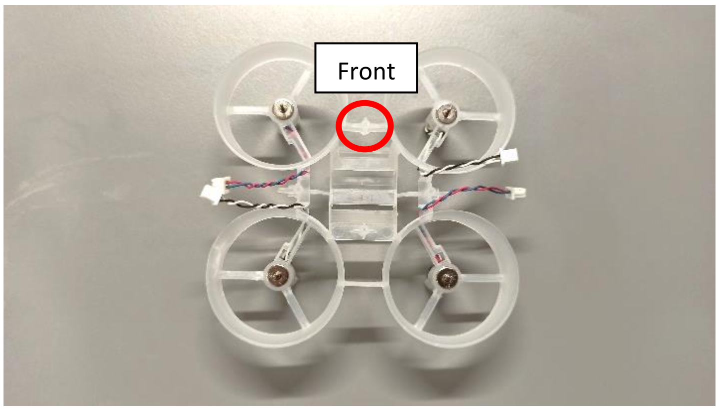


**Figure 36.** Top view of the frame after motor wire management.

**Step 5: Place the PCB on the drone frame**
The shape of the PCB should align with the curvature of the propeller guards. **Match the orientation of the PCB with the orientation of the drone frame**. The front side of the PCB is the side with the camera connector.

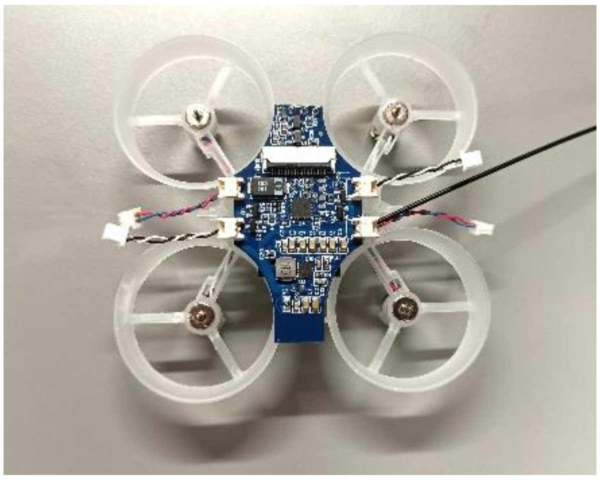


**Figure 37.** The PCB on the frame.

The PCB should lay flat on the frame, as depicted below.

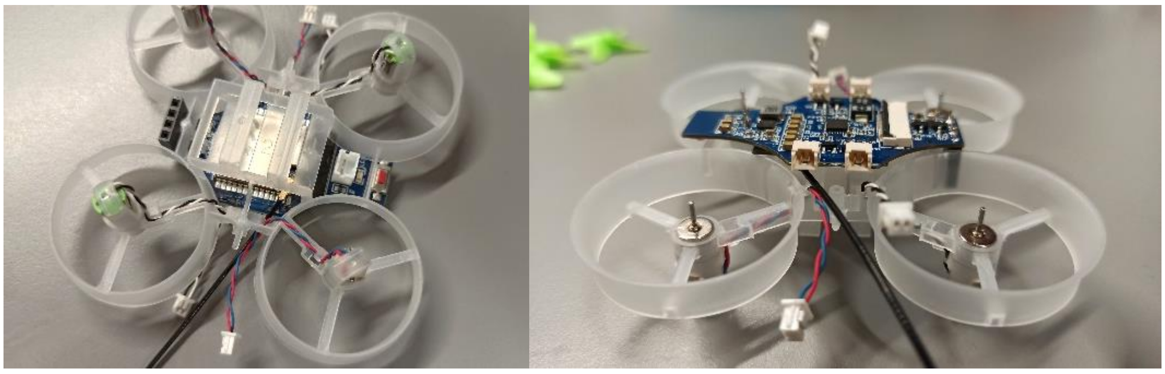


**Figure 38.** The PCB should lay flat on the frame.

**Step 6: Connect the motors to the PCB**

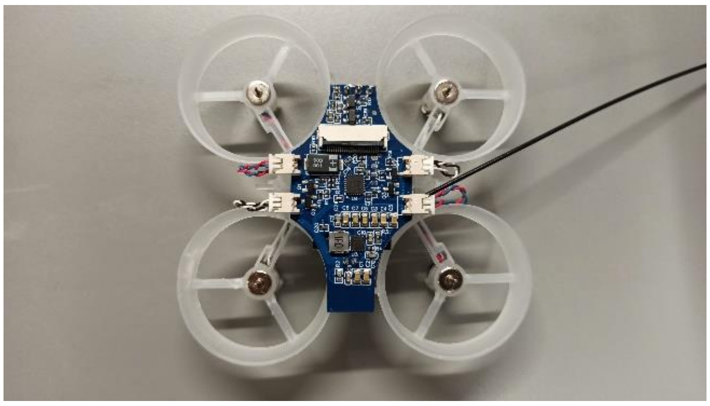


**Figure 39.** The drone PCB with the motor connectors plugged in.

Plug the motor wires into the motor connectors on the PCB. The front-left motor should go to the front-left connector on the PCB, as so on. **Be careful not to twist the PCB connector sideways or apply to much force to it** as it is quite fragile. Make sure you plug the connectors all the way in.

**Step 7: Install the propellers to the motors**
Just like the motors, the propellers have spin direction. **Make sure to install the correct propeller to the correct motor** (counterclockwise propeller is for counterclockwise motor and vice versa).

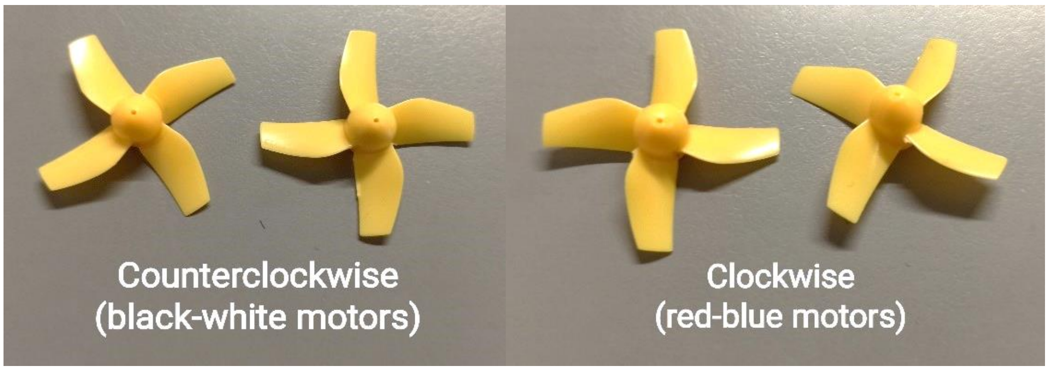


**Figure 40.** Propeller spin direction.

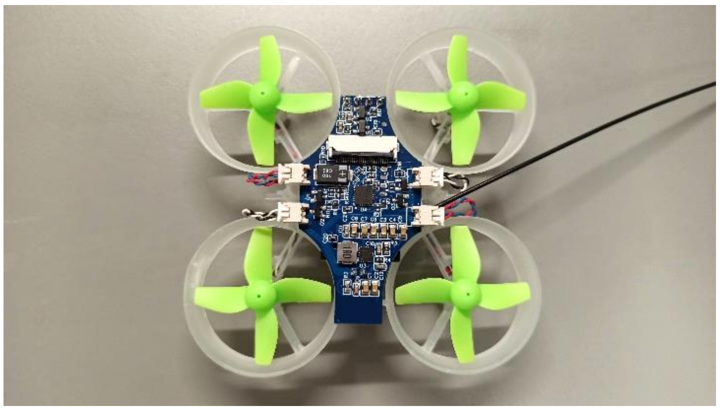


**Figure 41.** The drone with the propellers attached to the correct motors.

**Step 8: Install the camera and test the drone**
Proceed by installing the wide-angle camera onto the PCB:

- Unlock the camera connector by lifting up the black flap on the camera connector. **Avoid applying too much force on the camera connector as it is fragile**.
- Insert the camera's ribbon cable into the slot on the camera connector. **The camera should face up, not down.**
- Re-lock the camera connector by pushing the camera connector's black flap back down. This will secure the camera to the connector.

Congratulations, you have completed the assembly of the drone! You can now plug the battery to power the drone.

**Please put the drone on the table right after plugging the battery in and do not move it until you see a quickly blinking red LED (twice every second)**. This is to allow the drone's IMU to calibrate.

If you have done all the assembly steps correctly, the drone should indicate that it is working properly by showing these signs:

- All motors spin one-by-one in the correct orientation (motor test)

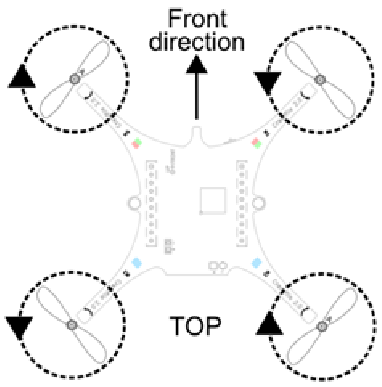


**Figure 42.** The motors' spin direction.

- The motors sound a start up tone when spinning (during the initial motor test)
- The red LED blinks twice in a second (not 5 rapid blinks every few seconds)

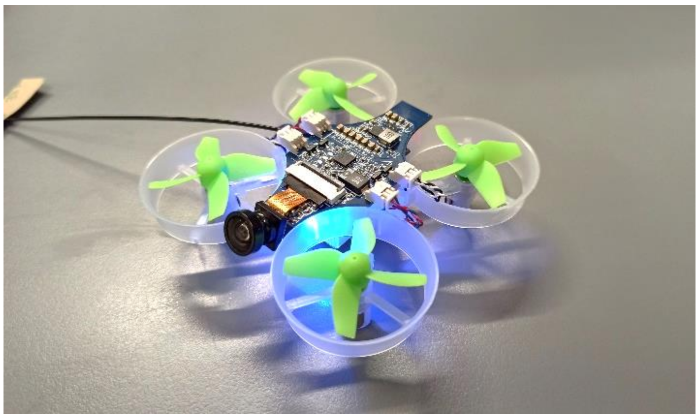


**Figure 43.** The drone fully assembled. It is now ready to fly!

## Flying the Drone Manually using Mobile App

The ESP-Drone app is available for Android and iOS. We can use it to control the drone (i.e. the app acts as remote control).

For Android, please scan the QR below to download the app (APK). For iOS, please search and download the ESP-Drone APP in App Store.

**Figure 44.** QR code to installation of ESP-drone App for Android.

Launch the app and connect your phone to the drone's Wifi network. Then, tap the "Connect" button/icon on the top right of the screen. **The blue LED on the drone should light up**, indicating established connection between the phone and the drone.

You can now try gently increasing thrust (sliding the left joystick slightly upwards) to fly the drone. See the figure below for the manual control.

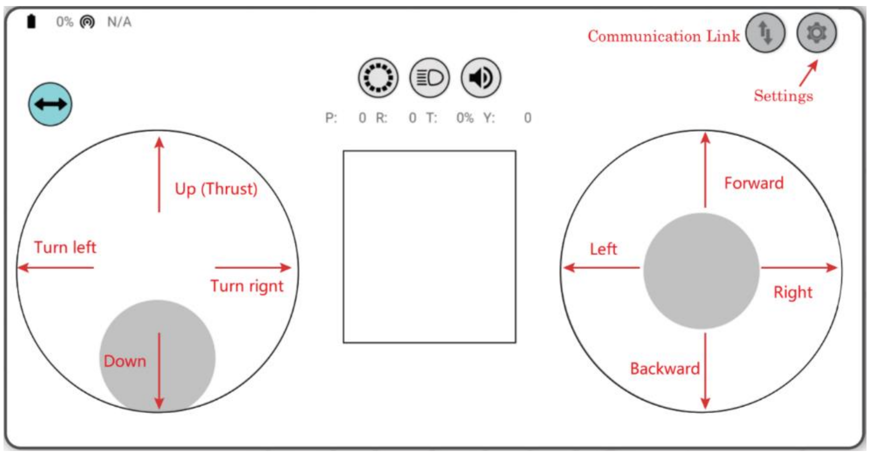


**Figure 45.** Android app Interface.

## Developing with Docker

Docker is a containerization system that allows us to package and ship software with their dependencies. Using Docker, we can avoid the hassle of setting up the system or dependencies and even ship software intended to run on specific Operating Systems (OS) on another OS.

For this DIP, we will be developing with Robot Operating System (ROS) in addition to all the repositories we have introduced so far. We will be using ROS Noetic, which is recommended for Ubuntu 20.04. However, with Docker we can run ROS Noetic and all the packages we have for this DIP on computers running OSes other than Ubuntu 20.04.

First, make sure you have downloaded and installed docker on your device. You can follow the guide here. **Make sure to follow the installation guide according to your computer's OS**.

### Getting Espdrone Docker Images

The following repository hosts the Docker image for `espdrone` project.

https://hub.docker.com/r/nelsenew/espdrone

To pull the Docker image:

```
docker pull nelsenew/espdrone
```

### Setting Up GUI with Docker

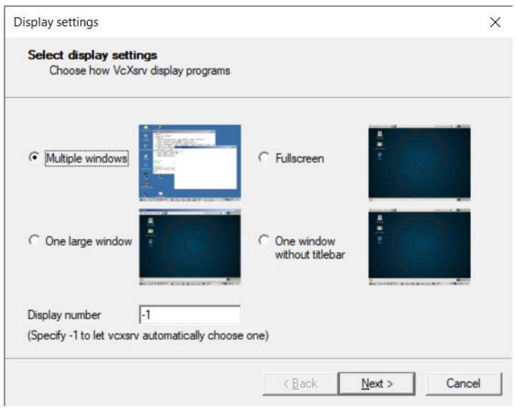
To run GUI applications inside the docker container (i.e Rviz, Gazebo), X11 port forwarding is required.

**i. For Windows Users:**

**1. Installing VcXsrv and Configuration**

Install VcXsrv Windows X Server. (Xming can be used also but the package hasn't been updates since years ago).

After installation, run Xlaunch from the start menu and follow the configuration steps below:



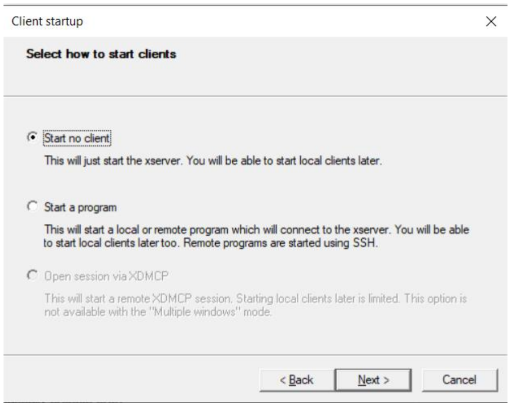
Display settings

**Select display settings**
Choose how VcXsrv display programs

[✓ Multiple windows] Fullscreen One large window One window without titlebar

Display number: -1
(Specify -1 to let vcxsrv automatically choose one)

< Back | Next > | Cancel



Client startup

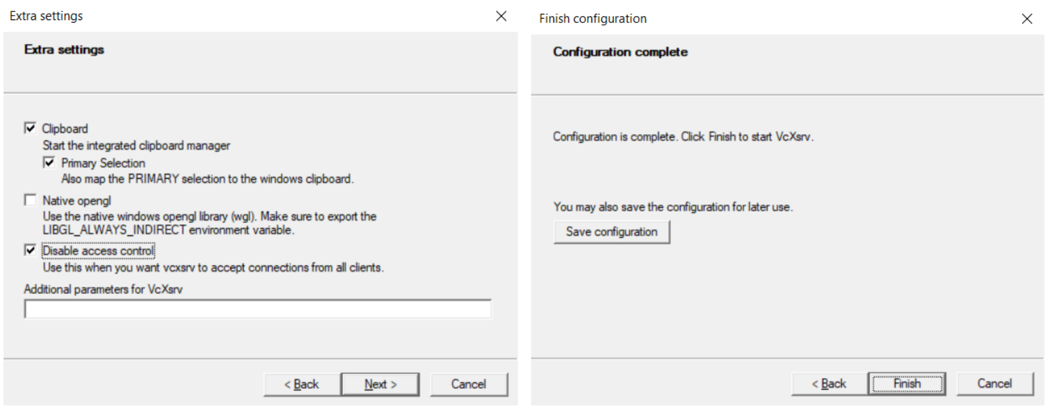
**Select how to start clients**

[✓ Start no client]
This will just start the xserver. You will be able to start local clients later.

Start a program
This will start a local or remote program which will connect to the xserver. You will be able to start local clients later too. Remote programs are started using SSH.

Open session via XDMCP
This will start a remote XDMCP session. Starting local clients later is limited. This option is not available with the "Multiple windows" mode.

< Back | Next > | Cancel


Extra settings

**Extra settings**

[✓] Clipboard
Start the integrated clipboard manager
[✓] Primary Selection
Also map the PRIMARY selection to the windows clipboard.
[ ] Native opengl
Use the native windows opengl library (wgl). Make sure to export the LIBGL_ALWAYS_INDIRECT environment variable.
[✓] Disable access control
Use this when you want vcxsrv to accept connections from all clients.
Additional parameters for VcXsrv

Finish configuration

**Configuration complete**

Configuration is complete. Click Finish to start VcXsrv.

You may also save the configuration for later use.

**Figure 46.** VcXsrv Configuration

## 2. Running the Espdrone Container

Open a terminal in Command Prompt and input the following command:

```
docker run -it --volume="<path/to/catkin_ws>:/catkin_ws" --volume="<path/to/espdrone-lib-python>:/espdrone-lib-python" -e DISPLAY=host.docker.internal:0.0 -e LIBGL_ALWAYS_INDIRECT=0 nelsenew/espdrone:latest
```

Remarks: remember to change <path/to/catkin_ws> and <path/to/espdrone-lib-python> to the corresponding to the path on your computer.

Do also note that if you must have espdrone-lib-python from the github on your working directory. If you do not have a catkin_ws directory, just create a folder with the name catkin_ws or you can type the following on your command line

```
mkdir catkin_ws
```

### Additional Info

The two environment variables (-e) are important for connecting to X11 server.

```
DISPLAY=host.docker.internal:0.0
```

This is what allows the application to find the X server. In Docker, there will be a special IP to designate your container.

```
LIBGL_ALWAYS_INDIRECT=0
```

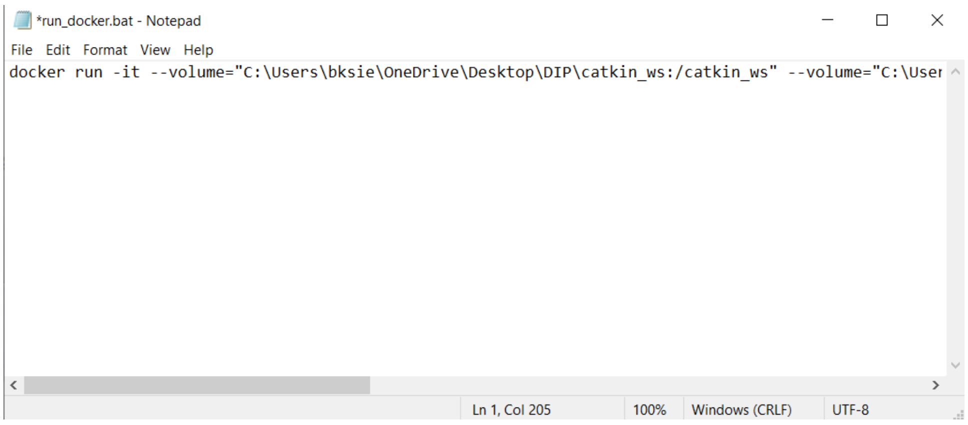
This designates how your application will be rendered.

Tips: You can save the command into a .bat file so that you can just double click to launch the docker container next time.

To create a bat file, follow these 5 easy steps:

1. Open your notepad.
2. Add your commands (see the figure below).
3. Save with the extension **.bat**

4. Go to the directory where you saved the .bat file and click it to run
5. To edit just right click and select **Edit**



```
docker run -it --volume="C:\Users\bksie\OneDrive\Desktop\DIP\catkin_ws:/catkin_ws" --volume="C:\User
```

**Figure 47.** Bat file

**ii. For Ubuntu Users:**

**1. Run the bash file**

In ubuntu, X11 port forwarding has been installed. The following bash script is sufficient to run the docker container with GUI applications.

***run_espdrone_container.bash:***

```
XAUTH=/tmp/.docker.xauth

xauth_list=$(xauth nlist :0 | tail -n 1 | sed -e 's/^..../ffff/')
if [ ! -f $XAUTH ]; then
    if [ ! -z "$xauth_list" ]; then
        echo $xauth_list | xauth -f $XAUTH nmerge -
    else
        touch $XAUTH
    fi
    chmod a+r $XAUTH
fi

file $XAUTH
ls -FAlh $XAUTH

docker run -it \
    --env="DISPLAY=$DISPLAY" \
    --env="QT_X11_NO_MITSHM=1" \
    --volume="/tmp/.X11-unix:/tmp/.X11-unix:rw" \
    --env="XAUTHORITY=$XAUTH" \
    --volume="$XAUTH:$XAUTH" \
    --volume="<path/to/your_catkin_ws>:/catkin_ws" \
    --volume="<path/to/espdrone-lib-python>:/espdrone-lib-python" \
    --net=host \
    --privileged \
    --runtime=nvidia \
    nelsenew/espdrone:latest \
    bash
```

**2. Making the script executable**

```
chmod a+x run_espdrone_container.bash
```

**3. Execute the script**

```
./run_espdrone_container.bash
```

For more information on GPU acceleration with docker on Ubuntu, please check this link from ROS Wiki.

**iii. For Mac Users:**

**1. Install XQuartz for X11 forwarding**

https://www.xquartz.org/

**2. Launch XQuartz. Under the XQuartz menu, select Preferences**

Go to the security tab and ensure “Allow connections from network clients” is checked.

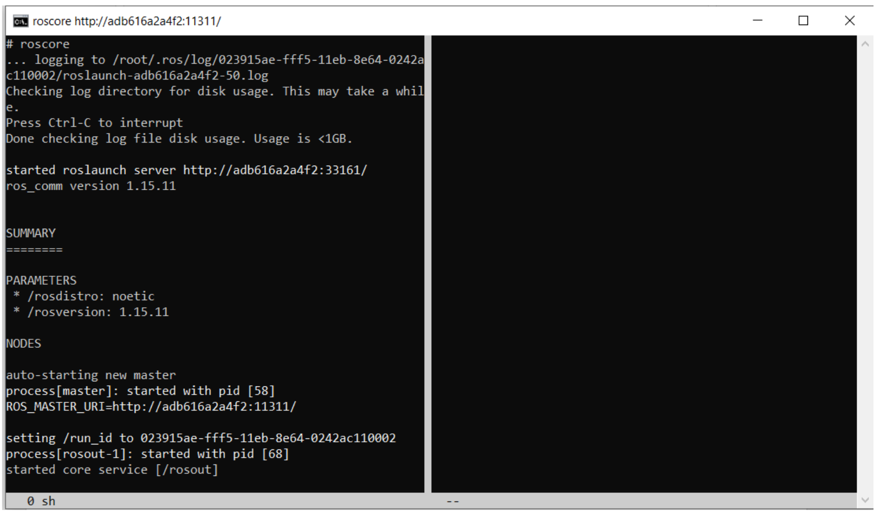
**3. Running the espdrone container**

```
docker run -it --volume="<path/to/catkin_ws>:/catkin_ws" --
volume="<path/to/espdrone-lib-python>:/espdrone-lib-python" -e
DISPLAY=host.docker.internal:0.0 -e LIBGL_ALWAYS_INDIRECT=0
nelsenew/espdrone:latest
```

## Launching ROS Applications with Docker

In the terminal where you typed the command line, try running roscore. If you are able to run roscore, that means docker container has been setup sucessfully. Note that it would not work for a new terminal where you have not put the docker run command!

```
roscore
```



```
roscore http://adb616a2a4f2:11311/
# roscore
... logging to /root/.ros/log/023915ae-fff5-11eb-8e64-0242a
c110002/roslaunch-adb616a2a4f2-50.log
Checking log directory for disk usage. This may take a whil
e.
Press Ctrl-C to interrupt
Done checking log file disk usage. Usage is <1GB.

started roslaunch server http://adb616a2a4f2:33161/
ros_comm version 1.15.11


SUMMARY
========

PARAMETERS
 * /rosdistro: noetic
 * /rosversion: 1.15.11

NODES

auto-starting new master
process[master]: started with pid [58]
ROS_MASTER_URI=http://adb616a2a4f2:11311/

setting /run_id to 023915ae-fff5-11eb-8e64-0242ac110002
process[rosout-1]: started with pid [68]
started core service [/rosout]
   0 sh
```

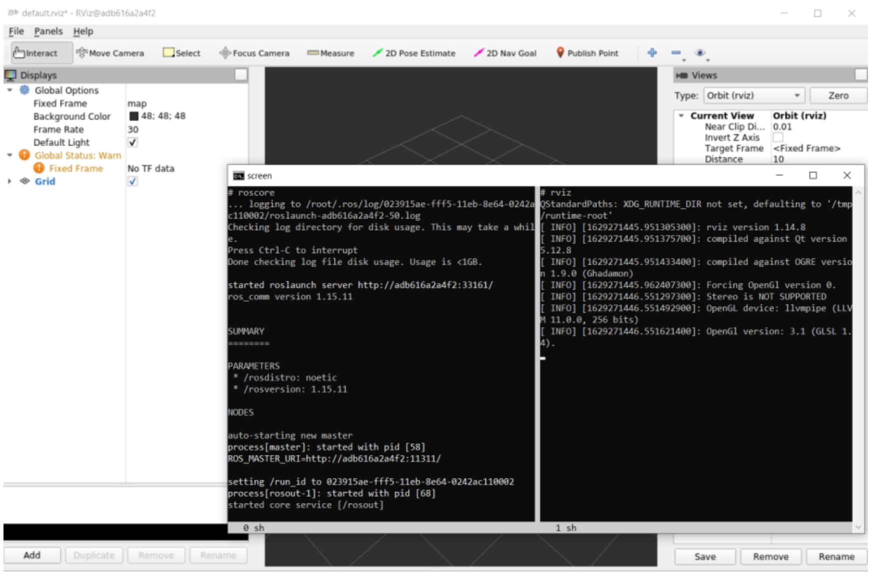
**Figure 48.** Launching roscore

Next, try running rviz in a new terminal. You should see Rviz launch immediately as shown below:

```
rviz
```

You can also use this command line if you want to run both on the same tab/terminal

```
roscore > dev/null & rviz
```



```
# roscore
... logging to /root/.ros/log/023915ae-fff5-11eb-8e64-0242a
c110002/roslaunch-adb616a2a4f2-50.log
Checking log directory for disk usage. This may take a whil
e.
Press Ctrl-C to interrupt
Done checking log file disk usage. Usage is <1GB.

started roslaunch server http://adb616a2a4f2:33161/
ros_comm version 1.15.11


SUMMARY
========

PARAMETERS
 * /rosdistro: noetic
 * /rosversion: 1.15.11

NODES

auto-starting new master
process[master]: started with pid [58]
ROS_MASTER_URI=http://adb616a2a4f2:11311/

setting /run_id to 023915ae-fff5-11eb-8e64-0242ac110002
process[rosout-1]: started with pid [68]
started core service [/rosout]
```

```
# rviz
QStandardPaths: XDG_RUNTIME_DIR not set, defaulting to '/tmp
/runtime-root'
[ INFO] [1629271445.951305300]: rviz version 1.14.8
[ INFO] [1629271445.951375700]: compiled against Qt version
5.12.8
[ INFO] [1629271445.951433400]: compiled against OGRE versio
n 1.9.0 (Ghadamon)
[ INFO] [1629271445.962407300]: Forcing OpenGl version 0.
[ INFO] [1629271446.551297300]: Stereo is NOT SUPPORTED
[ INFO] [1629271446.551492900]: OpenGL device: llvmpipe (LLV
M 11.0.0, 256 bits)
[ INFO] [1629271446.551621400]: OpenGl version: 3.1 (GLSL 1.
4).
```

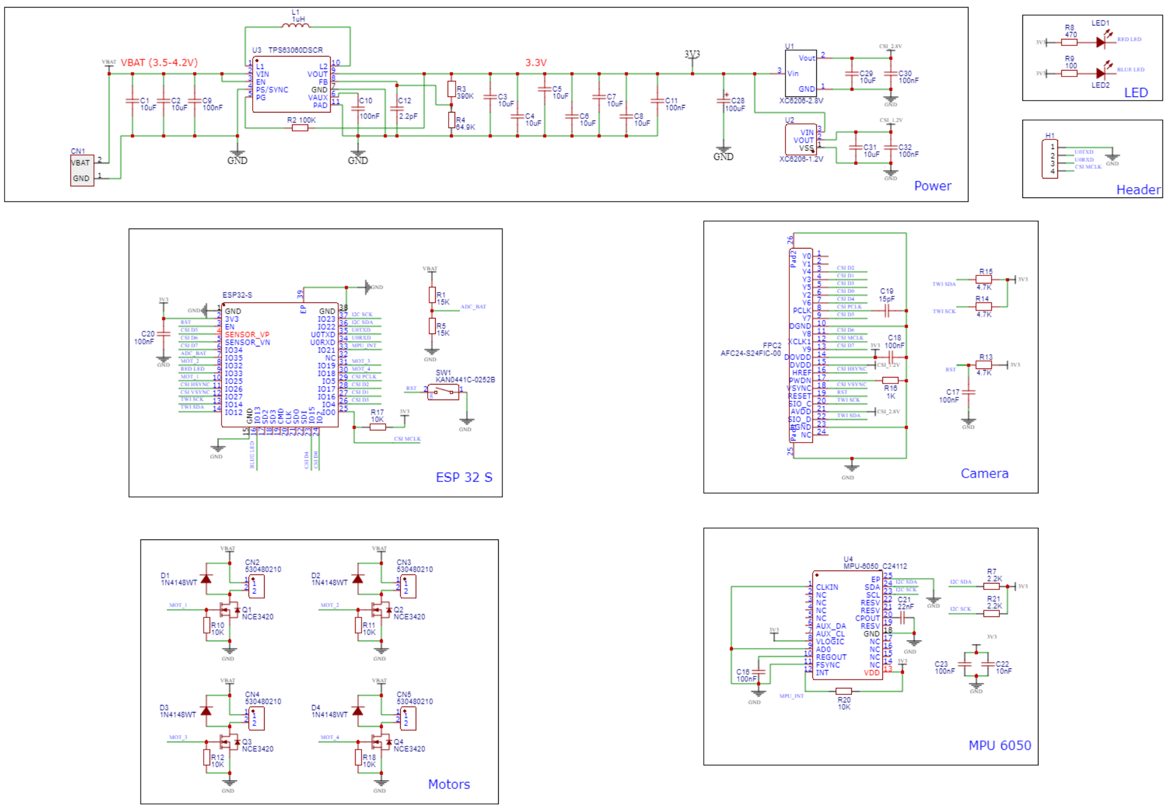
Fixed Frame: map
Background Color: 48; 48; 48
Frame Rate: 30
Default Light: ✓
Global Status: Warn
Fixed Frame: No TF data
Grid: ✓

Type: Orbit (rviz)
Current View: Orbit (rviz)
Near Clip Di...: 0.01
Invert Z Axis:
Target Frame: <Fixed Frame>
Distance: 10

**Figure 49.** Launching Rviz

# Appendix

## Appendix A – Hardware Schematics of the ESP-Drone



VBAT (3.5-4.2V)
3.3V
Power
LED
Header
ESP 32 S
Camera
Motors
MPU 6050