RRoble Double Dimmer

Single and Double dimmer with IoT over WiFi

Revision History		
Version date	**Author**	**Change Summary**
Tuesday, June 25, 2019	Jesus Amozurrutia	First Draft
Saturday, November 07, 2020	Jesus Amozurrutia	Version 1
Friday, April 30, 2021	Jesus Amozurrutia	Version 2
Monday, November 01, 2021	Jesus Amozurrutia	Version 3

Contents

1. Introduction

This project is quite involved, so first, why go this route?

There are essentially two ways to control the lights at home, Smart Bulbs or with Smart Light Switches / dimmers, both with advantages and disadvantages.

Smart Light Switches are cheaper. Purely based on cost, smart light switches are likely to be far cheaper than smart bulbs, especially since one light switch can control multiple light fixtures, depending on how your house's wiring is set up.

You can use any bulb with Smart Light Switches. Since the traditional light bulb industry is very mature, the range of styles and accessories is much broader.

Smart Light Switches can control your existing fixtures without complex modifications.

The main disadvantage is that special wiring is required in the electric boxes where the switches are to be installed (the wires for hot, neutral, as well as the wire for the light are required). In most recent installations, this is not an issue, but it can be a problem for older installations; also, there are different standards in each country.

While smart bulbs offer more flexibility and have the possibility of adding color, they are more expensive and the need for this level of control, from my point of view, only makes sense in a few specific areas and in the end, you can combine the two solutions.

For these reasons, I leaned towards Smart Light Switches for the bulk of my lights.

Now since there are several options on the market, why go the DIY path?

Mainly I return to the point of the range of styles and accessories. In the arena of traditional light switches, there are thousands of colors, styles, textures and accessory options that are not yet available in smart switches.

On the other hand, inexpensive smart switches do not offer enough functionality, and some of the more expensive ones did not fit the form factor of my installation.

By taking the DIY path, I can get the flexibility in style, form factor, and functionality at a reasonable cost.

With that out of the way, let's go to the project itself.

2. IoT Double Dimmer

This project consists of an AC light dimmer for one or two incandescent light bulbs or dimmable LED bulbs, with mains AC voltage of 110 to 220 V, 50 or 60Hz, up to 400W, using the WiFi enabled microcontroller ESP-12E / F.

The Dimmer functionality is achieved using the phase control method, using a TRIAC for each bulb, varying the total power applied. This method works very well with incandescent light bulbs and with LED lamps that have the Dimmable specification.

Features:

- Lights can be dimmed from 10% to 100% power.
- Supports transitions between brightness levels.

- One push button per light bulb to control the ON/OFF state and brightness.
- A LED indicator for each button/light bulb.
- LED indicators change intensity if light is ON or OFF.
- LED indicators intensity can be set remotely or turned off for day / night mode.
- Smart control and configuration using MQTT over WiFi; An MQTT broker is required.
- ON/OFF state and brightness can be set via the push buttons or remotely via WiFi/MQTT.
- Integrated into Home-Assistant or other MQTT compatible IoT Hubs, with auto discovery.
- Setup Portal over WiFi, to configure WiFi/MQTT parameters.
- The Setup Portal is started by a double reset or optionally with multi-click of any of the light buttons.
- On Power Up the device resets to the last known state, using MQTT retain or EEPROM.
- Optional double click to trigger additional actions.
- Advanced configuration through MQTT.

The finished product.

2.1. Definitions

- Device: Refers to the component as a whole. It is used to identify the status of the device and to set the configuration.
- Instance: It refers to each of the lights. The status of each of the instances can be set individually.

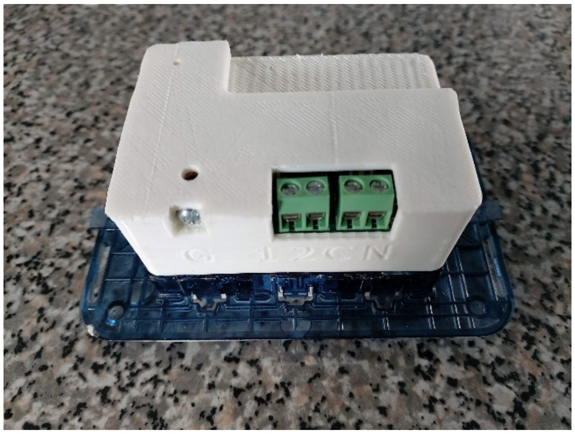
- Brightness: Relative brightness for each of the light bulbs. Brightness is scaled from 0, for minimum brightness, to 100, for maximum brightness.
- Zero Crossing is a pulse that detects every time the AC sinusoidal electrical voltage signal crosses the zero volt zone. It is used to synchronize the phase control.
- Power: The electrical power applied to the light bulb to achieve the desired brightness. Power is regulated using phase control, by varying the time to trigger the TRIAC after the zero crossing detection. The applied power is linear and proportional to the brightness value.
- Minimum Power: The minimum power applied to the light bulb when the brightness has a value of zero. The default value is 10% and it can be configured to any value between 10% and 50%.
- Duty Cycle: The time that the TRIAC is ON in relation to the duration of the AC power signal period.
- OTA: Over The Air updates. Allow the firmware to be updated over WiFi.

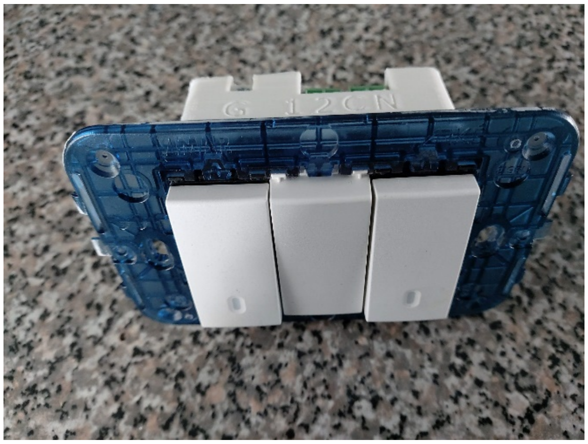
3. Hardware

The hardware is based on an ESP-12E/F micro controller, using TRIACs to control the total power applied to the light bulbs. The controller board is mounted over some Vimar® wall switches. I choose this particular brand because it features a wide range of styles and colors for the decorative plates. Finally, a 3D printed cover to protect the circuit.

The switches I am using are:

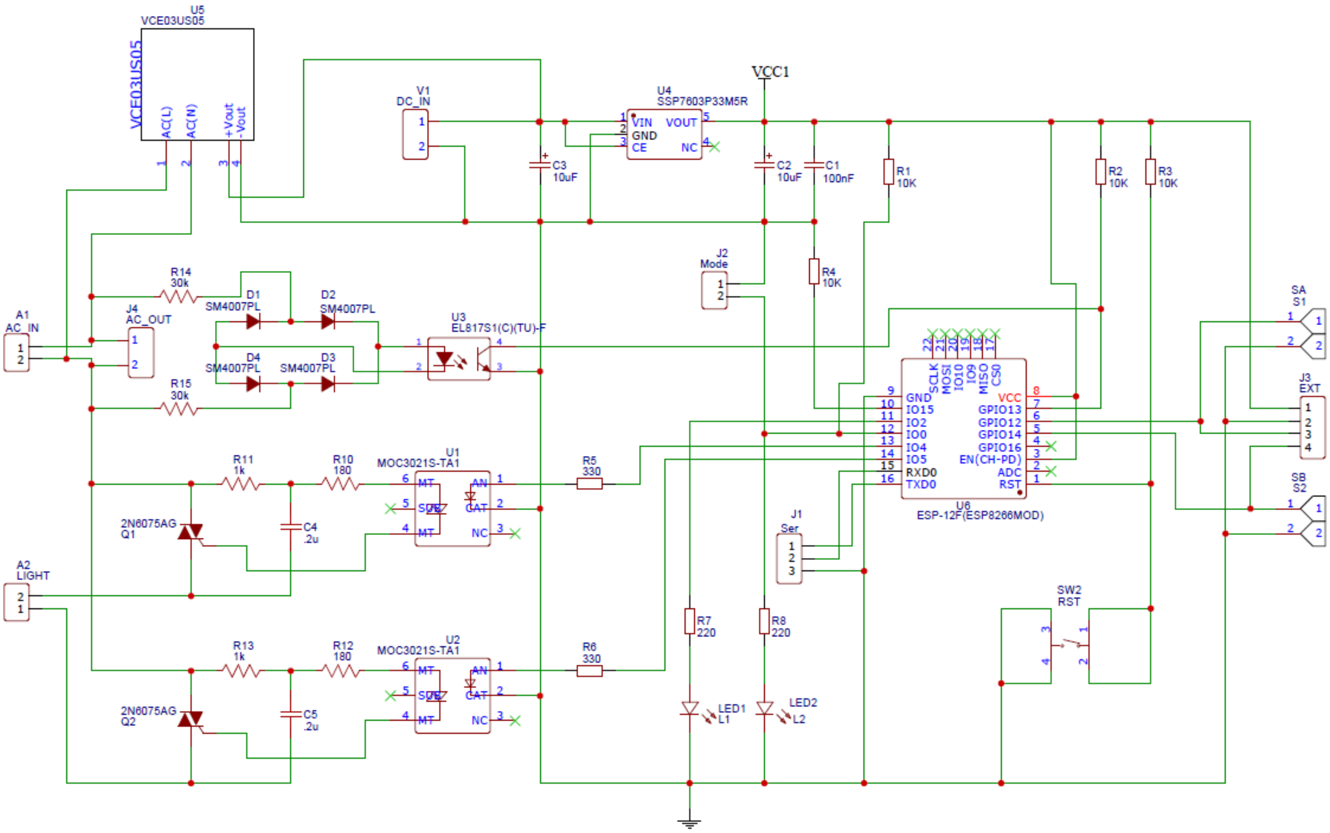
- https://www.vimar.com/en/int/catalog/product/index/code/19613
- https://www.vimar.com/en/int/catalog/product/index/code/19008.B
- https://www.vimar.com/en/int/catalog/product/index/code/19041.B





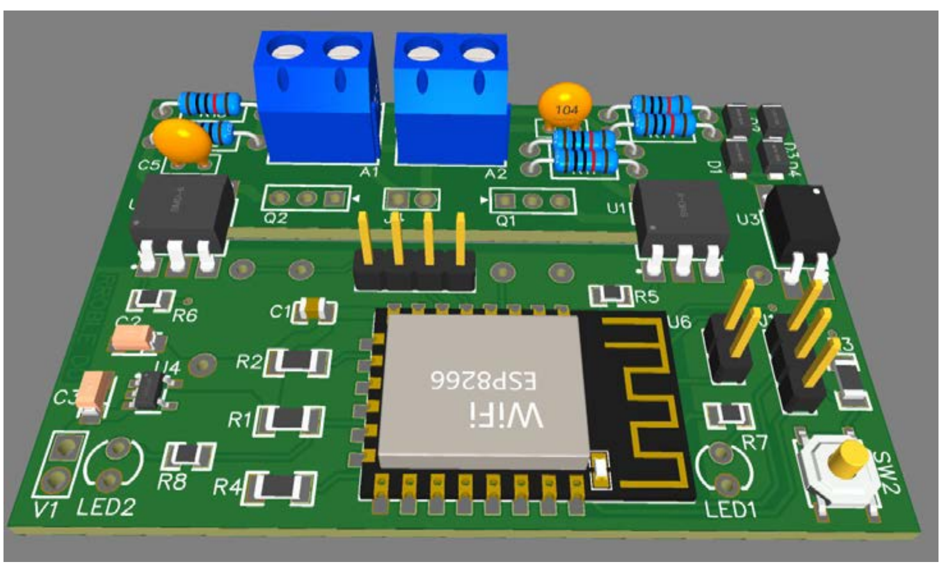
Full assembly.

3.1. Schematic diagram



3.2. PCB

The latest version of the PCB is based on surface mount components, to minimize board dimensions.



PCB with components (Missing TRIACs and LEDs).

The details of the PCB are available here:

https://oshwlab.com/jamozu/multi_project_copy_copy_copy_copy_copy

3.3. Bill of material

ID	Designator	Quantity	Name	Description	LCSC Assembly
2	A1, A2	1	TERM	Screw terminal	
3	C1	1	100nF	Capacitor	Yes
4	C2,C3	2	10uF	Electrolytic capacitor	Yes
5	C4,C5	2	.2u	Capacitor	
6	D1,D2,D3,D4	4	SM4007PL	Diode	Yes
7	J1	1	3 Pin Header	2.5 mm Header	
8	J2	1	2 Pin Header	2.5 mm Header	
9	J3	1	4 Pin Header	2.5 mm Header	
10	J4	1	2 Pin Header	2.5 mm Header	
11	LED1	1	5mm LED	LED	
12	LED2	1	5mm LED	LED	
13	Q1,Q2	2	2N6075AG	TRIAC	
14	R1,R2,R3,R4	4	10K Ohm Resistor	SMT Resitor	Yes
15	R5,R6	2	330 Ohm Resistor	SMT Resitor	Yes
16	R7,R8	2	220 Ohm Resistor	SMT Resitor	Yes
17	R10,R12	2	180 Ohm Resistor	Resitor 1/2 W	
18	R11,R13	2	1K Ohm Resistor	Resitor 1/2 W	
19	R14,R15	2	30K Ohm Resistor	Resitor 1/2 W	
20	SA	1	19008.B	Vimar Push Button	
21	SB	1	19008.B	Vimar Push Button	
22	SW2	1	RST	Push Button	Yes
23	U1,U2	2	MOC3021S-TA1	TRIAC Opto-cupler	Yes
24	U3	1	EL817S1(C)(TU)-F	Opto transistor	Yes
25	U4	1	SSP7603P33M5R	3.3V Voltage regulator	Yes
26	U5	1	VCE03US05	5V AC-DC converter	
27	U6	1	ESP-12F(ESP8266MOD)	ESP Microcontroller	

4. Software

The hardware is compatible with libraries such as ESPHome, using the AC Dimmer component, but this is out of the scope of this document.

For this project, I decided to create my own software to have more granular control of the features, which is what is described below.

The software is developed with the ***Arduino®*** platform.

4.1. Dimmer

The dimmer function as follows:

- If the light State is OFF, the signal for TRIACs stays down.
- If the light State is ON, waits for the Zero Crossing Pulse (ZCP) signal and triggers the TRIAC according to the current duty cycle.
- The minimum power level that can be applied to any Light is 10%. The minimum power can be adjusted for each Light through MQTT configuration.
- Brightness value can be set between 0 and 100: 100 = Maximum brightness; 0 = Minimum brightness, where 0 corresponds to the minimum power and 100 to 100% power.
- A button control the State and brightness.
  - Short press = Toggle State ON/OFF.
  - Long press = Change brightness from 100% to 0% and back, while the button remains pressed.
  - Button release after Long press = Sets the brightness and calculates the powe/duty cycle.
- The dimmer can be configured as a switch. In this case the TRIAC only turns ON or OFF.

On power up, the device detects the AC power frequency and the duration of the zero crossing pulse (**ZCP**), using an interruption in the zero crossing pulse pin.

Once the AC parameters are obtained, the device enters normal operation mode. The dimmer operation is performed with interruptions. The main interruption is executed in the rise part of the **ZCP**. This interrupt calculates the duty cycle and defines the timers to trigger the TRIACs.

If one or both lights are turned on, up to 4 timers can be defined:

1) **Trigger first set of TRIACs**. This can trigger Light 1 and/or Light 2. If both lights have the same duty cycle they will trigger at the same time.

2) **Trigger second set of TRIACs**. (conditional) This can trigger Light 1 and/or 2. If the lights have a different duty cycle value the light with the lower duty cycle is triggered with the second timer.

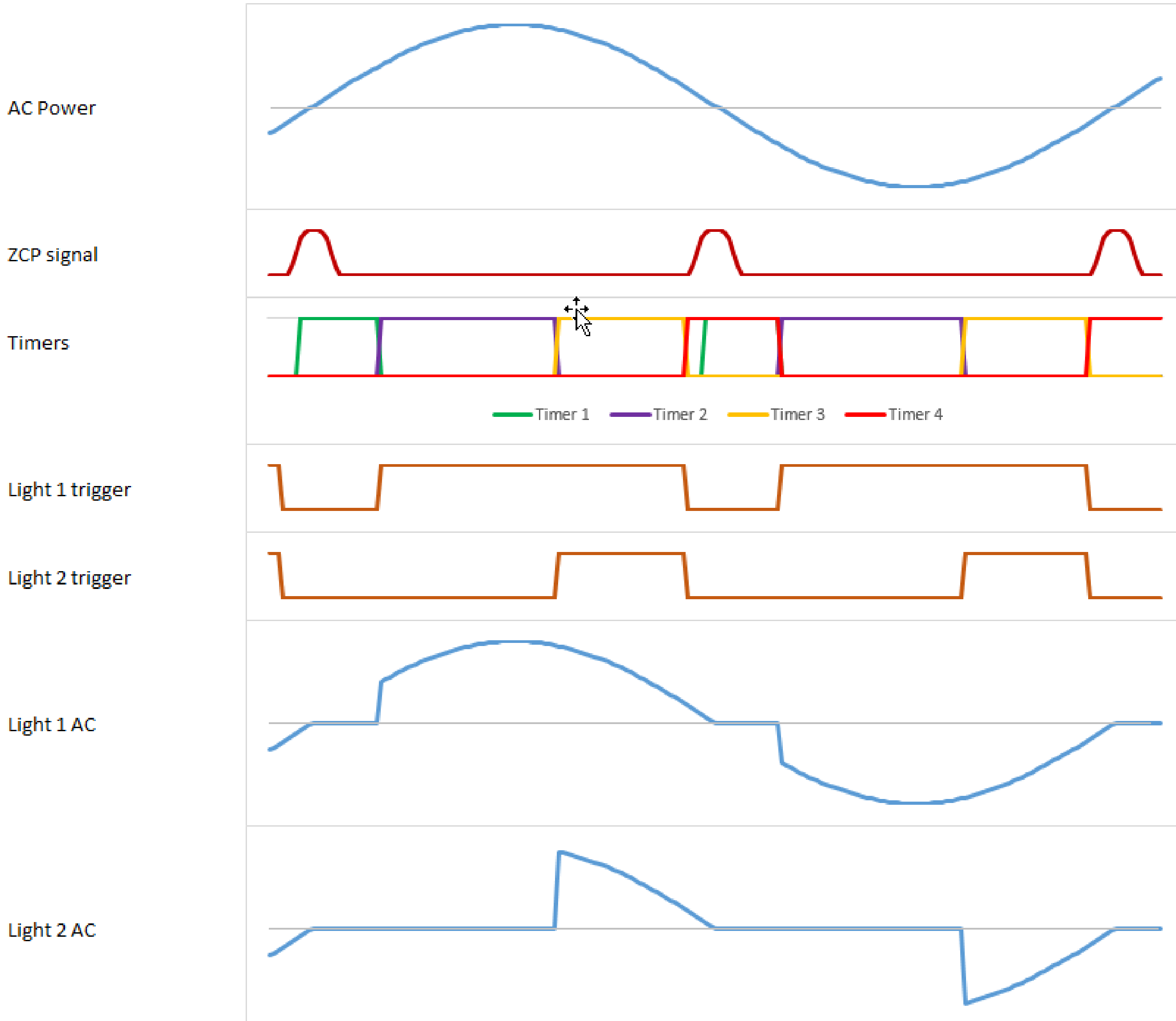
3) **Turn Off trigger signal**. At 95% of the time before the next **ZCP**, the trigger signal for the TRIACs is turned off.

4) **Repeat cycle at step 1**. The last timer is the time between the **Turn Off trigger signal** and the trigger of the next cycle. This timer is overridden by the next **ZCP** interrupt, but in case the pulse is not detected, it prevents light flickering.

The timers use ESP's timer_1 interrupt and are triggered in sequence using a single hardware timer.

The following graph shows the operation of a double dimer, with a light on at 95% power and the second light on at 27% power.

You can see the ZCP signal, the calculated timers, the signals to trigger the TRIACs and the power applied to the light bulbs.



The program loop takes care of the rest of the tasks like:

- Detects the button status and sets the On/Off/Duty-cycle of each light.
- Sets the indicator LEDs brightness.
- Connect to WiFi
- Connect to the MQTT broker.

The incoming MQTT messages are handled by a callback function.

4.2. WiFi

The ESP microcontroller communicates with an MQTT borker, using WiFi in normal operation mode; in this case the device is a client in an existing WiFi network.

The device can be set for the initial configuration mode; in this case, the device uses WiFi in access point mode and an internal web server catches the requests for initial configuration.

4.2.1. MQTT Topics

The Dimmer uses 2 or 3 **MQTT** topics for publishing:

1) General device status:

`NAMESPACE/light/DEVICE_ID/state`

2 & 3) Status of each Light:

`NAMESPACE/light/INSTANCE_ID/state`

It also subscribes to 2 or 3 **MQTT** topics:

1) Configure the device:

`NAMESPACE/light/DEVICE_ID/set`

2 & 3) Set the light status or request feedback:

`NAMESPACE/light/INSTANCE_ID/set`

The **`NAMESPACE`** can be configured on the WiFi setup portal or trough MQTT

The MAC Address defines the **`DEVICE_ID`** in the form: *XXXXXXXXXXXX*.

`INSTANCE_ID`s are defined as:

- **N***XXXXXXXXXXXX***1**
- **N***XXXXXXXXXXXX***2**

The Instance ID can be overridden using the configuration parameters "***name1***" and "***name2***".

4.2.2. MQTT Messages

The Dimmer publishes the following messages:

- **`NAMESPACE/light/DEVICE_ID/state`**
  - ***{"state":“golive”}*** → This message is published after the device is turned on, or after a reset. This is can be used to obtain the last known state in the IoT Hub after a reset or power outage
  - ***{" state ":"online"}*** → Published periodically every minute.
  - ***{" state ":"reset"}*** → Published before the device resets.
  - ***{"feedback":"configuration saved"}*** → Published after a configuration change is saved.
- **`NAMESPACE/light/INSTANCE_ID/state`**
  - ***{"state":["ON"|"OFF"], "brightness":[0-100], "power":[0-100], "indicator":["ON"|"OFF"]}***

The dimmer is constantly listening on the feedback topics and it accepts the following messages:

- **`NAMESPACE/light/DEVICE_ID/set`**
  - ***{"action":"config",
"secret":CONFIG_SECRET,
"mqttbroker":MQTT_BROKER_NAME-IP,
"mqttport":MQTT_PORT,
"mqttuser":MQTT_USER,
"mqttpass":MQTT_PASSWD,
"namespc":MQTT_NAME_SPACE,
"mqttdisc":MQTT_AUTO_DISCOVERY,
"mqttkey":MQTT_SHARED_KEY,
"keepAlive":KEEP_ALIVE_SECONDS}***
  - ***{"action":"config",
"secret":CONFIG_SECRET,
"LgtMode":BOOL,
"LgtDimm1":BOOL,
"LgtTrns1":BOOL,
"LgtDimm2":BOOL,
"LgtTrns2":BOOL,
"LedBright":INT,
"LedDimm":INT,
"dimmTime":INT,
"edgeSpeed":INT,
"transitionOn":INT,
"transitionOff":INT,
"name1":LIGHT1_NAME,
"name2":LIGHT2_NAME,
"minPow1":LIGHT1_NAME,
"minPow 2":LIGHT2_NAME,
"brightness1":LIGHT1_NAME,
"brightness2":LIGHT2_NAME}***
  - ***{"action":"getStatus","instance":NUMBER}***
  - ***{"action":"indicators","bright":NUMBER,"dimm":NUMBER}***
  - ***{"action":"reset"}***

- **`NAMESPACE/light/INSTANCE_ID/set`**
  - ***{"state":["ON"|"OFF"],"brightness":[0-100],"transition":[0-10],"indicator":["ON"|"OFF"]}***
  - ***{"action":"getState"}***
  - ***{"action":"getConfig"}***

4.2.3. Configuration

The device can be configured trough the WiFi Portal and through MQTT messages.

WiFi Portal

The portal is used for the initial device configuration. It allows to configure the **SSID** and Key of the WiFi network, as well as the MQTT broker and optionally the IDs for each light.

To enter the configuration mode, you need physical access to the reset button on the back of the Dimmer or do a multiple click (6 clicks within 4 seconds).

A Wi-Fi-enabled ***device***, such as a phone, tablet or computer, is also required.

To enter the configuration, perform a double reset; press the reset button and wait a second and press a second time, or do a multi-click. The LED Indicators start flashing slowly, about once per second.

Open the WiFi configuration on the ***device*** and look for an **SSID** called something like "RDimmer_XXXXXXXXXXXX", connect to the network and then point the browser to “http://192.168.4.1/”

Follow the on screen instructions.

MQTT Configuration

Once the device is connected to the network through WiFi and MQTT, the device configuration can be changed via a MQTT messages to the topic:

```
NAMESPACE/light/DEVICE_ID/set
```

The parameters that can be configured are:

Parameter	Type	Description	Values	Default
LgtMode	bool	Operation mode. The device can be operated as a dimmer or a simple switch (for non-dimmable lights)	TRUE = Dimmer; FALSE = Switch	TRUE
LgtDimm1	bool	Light 1 mode.	TRUE = Dimmer; FALSE = Switch	TRUE
LgtTrns1	bool	Light 1 transitions. Enable a fade effect whet the light is turned On or Off.	TRUE = Enabled; FALSE = Disabled	TRUE
LgtDimm2	bool]	Light 2 mode.	TRUE = Dimmer; FALSE = Switch	TRUE
LgtTrns2	bool	Light 2 transitions. Enable a fade effect whet the light is turned On or Off.	TRUE = Enabled; FALSE = Disabled	TRUE
LedBright	int	Duty Cycle for LED indicators in Bright mode. (lights On).	0 – 1000	1000
LedDimm	int	Duty Cycle for LED indicators in Dimmed mode (lights Off).	0 - 1000	250
LedDefault	bool	Default state for LED Indicators.	TRUE = On; FALSE = Off	TRUE

dimmTime	int	Time to go from 0% brightness to 100% brightness or vice versa (ms)	500 - 20000	2500
edgeTime	int	Delay at the edge of the dimmable range (makes it easy to select the Minimum or Maximum brightness).	100 – 3000	800
transitionOn	int	Transitions speed to turn ON. Each level adds around 0.85 seconds of transition from off to full on. 1 = 0.85 s 2 = 1.7 s 3 = 2.55 s 4 = 3.4 s …	0 – 10	0
transitionOff	int	Transitions speed to turn OFF.	0 – 10	0
name1	string	Name of first light. It must be unique inside the MQTT namespace. If the name is not defined, it uses the INSTANCE_ID (See section MQTT Topics).	[a-z_0-9]	“”
name2	string	Name of second light. It must be unique inside the MQTT namespace. If the name is not defined, it uses the INSTANCE_ID (See section MQTT Topics).	[a-z_0-9]	“”
minPow1	int	Minimum Power % for Light 1.	10 – 100	10
minPow2	int	Minimum Power % for Light 2.	10 – 100	10
brightness1	int	Default brightness for Light 1.	1 – 100	100
brightness2	int	Default brightness for Light 2.	1 – 100	100
myId	string	Device ID	[a-z0-9_.]	MAC Address
mqttbroker	string	Name or IP of the MQTT Broker.	[a-z0-9_.]	""
mqttport	int	Port number for MQTT.	[0-9]	1883
mqttuser	string	MQTT User.	[a-z0-9@#$%&*_.]	""
mqttpass	string	MQTT Password.	[a-z0-9@#$%&*_.]	""
retain	bool	MQTT Retain flag.	TRUE = On; FALSE = Off	TRUE
namespc	string	Namespace for MQTT devices and Hub.	[a-z0-9@#$%&*_.]	"RRoble"

mqttkey	string	Shared key for HMAC signature (Not implemented yet).	[a-z0-9@#$%&*_.]	""
keepAlive	int	Keep alive in seconds.	60 – 10000	Default [300]

The size of the messages that the device can receive is limited by the IP buffer, so it is recommended to change one parameter at a time.

Mosquitto Examples

Below are some examples of how to perform the configuration and change settings using Mosquitto, a popular MQTT broker used with Home Assistant.

- Set the second light to Switch mode:

```
mosquitto_pub -h my.broker.net -p 1883 -t "MyHome/light/3423A3B687D1/set" -m '{"action":"config",
"secret":"secret", "LgtDimm2":false}' -u USER -P PASS
```

- Set the name for both lights:

```
mosquitto_pub -h my.broker.net -p 1883 -t "MyHome/light/3423A3B687D1/set" -m '{"action":"config",
"secret":"secret", "name1":"living_room", "name02":"dinning_room"}' -u USER -P PASS
```

- Turn On the Living Room light at 50% brightness:

```
mosquitto_pub -h my.broker.net -p 1883 -t " MyHome/light/living_room/set" -m '{"state":"ON",
"brightness":50}' -u USER -P PASS
```

4.3. Home Assistant

By default, auto-discovery is enabled, so Home Assistant should discover the dimmer as soon as the initial configuration is done.

It is possible to configure the light manually like:.

4.3.1. configuration.yaml

The parameters for the configuration YAML file are:

```
    light:
      - platform: mqtt
        schema: json
        name: INSTANCE_ID
        title: Friendly_Name
        state_topic: "NAMESPACE/light/INSTANCE_ID/state"
        command_topic: "NAMESPACE/light/INSTANCE_ID/set"
        brightness: true
        brightness_scale: 100
        optimistic: false
        qos: 0
```

4.3.2. dashboard.dash

If the installation has the HADashboard, the configuration for each light in the dashboard configuration file is:

```
    lightN:
        widget_type: light
        title: INSTANCE_NAME
        entity: light.INSTANCE_ID
```

4.4. Persistent status

In the event of a blackout or if the power supply is cut, or after a reset, the dimmer can return to its last known state using one of 2 mechanisms:

- EEPROM: The Dimmer saves each state change in EEPROM and retrieves it on boot. See *PERSISTENT_STATE* parameter in the sketch configuration.
- Retain Flag: By using the "retain" flag on MQTT messages, the dimmer saves its last state in the broker. The MQTT broker must be configured to accept retained messages.

The device can follow one of the following go live sequences, depending on the retain configuration:

- EEPROM: If "*PERSISTENT_STATE*" is defined and the "retain" parameter is turned OFF (set to FALSE), on power up or after a reset the device enters the "**Go Live**" sequence:
    a. The device reads the last known state from EEPROM.
    b. Start dimming.
    c. Connects to WiFi.
    d. Connects to the MQTT Broker.
    e. Publishes a "golive" message on the device's "Sate Topic" (NAMESPACE/INSTANCE_TYPE/DEVICE_ID/state).
    This can be optionally used by the Broker or Hub to override the initial state.
    f. Subscribes to the "Instance Set" topics (NAMESPACE/INSTANCE_TYPE/INSTANCE_ID/set) and listens for commands.
    g. Continues normal operation.
    Any state change is published to the "Instance State" topics with the retain flag turned OFF.
- Retain: If the "retain" parameter is turned ON (set to TRUE), on power up or after a reset the device enters a different "**Go Live**" sequence:
    - Start dimming.
    - Connects to WiFi.
    - Connects to the MQTT Broker.
    - Subscribes to the "Instance State" topics (NAMESPACE/INSTANCE_TYPE/INSTANCE_ID/state).
    - The broker sends the last known state back to the device, per MQTT standards with retain.
    - After getting the last known state from the broker for all instances the dimmer, or if the initial state is not received after 60 seconds (see GO_LIVE_DURATION), the device un-subscribes from the "Instance State" topics.

- o Subscribes to the "Instance Set" topics (NAMESPACE/INSTANCE_TYPE/INSTANCE_ID/set)
- o Continues normal operation.
  Any state change is published to the "Instance State" topics with the retain flag turned ON.

If WiFi or the MQTT Broker are not available during power up, the device will resume normal operation after 60 seconds. Also, if the user sets the status manually before the device can reach the MQTT broker, the "**Go Live**" sequence is canceled.

With this method the dimmer can establish its initial state with an MQTT broker using the retain standard and without additional functionality required by the Hub.

If Home Assistant (HA) is used, this method is preferred as it reduces the risk of HA and the dimmer being out of sync. In the event of temporary network failures or rebooting of any of the involved devices.

Any user activity, like pressing a button cancels the "**Go Live**" sequences.

4.5. OTA Update

This sketch supports OTA updates for development purposes, using the Arduino IDE or an HTTP server.

Currently, HTTP updates only support unsecured http, therefore it is only recommended in a local environment for development purposes.

It is possible to implement secure https, as in the next example, if a public deployment is required: https://gist.github.com/igrr/24dd2138e9c8a7daa1b4, but at the moment it is out of scope.

> *Note: Temporarily disable the firewall in the computer while uploading a new image to the controller, to avoid disconnection problems when using OTA with the Arduino IDE.*

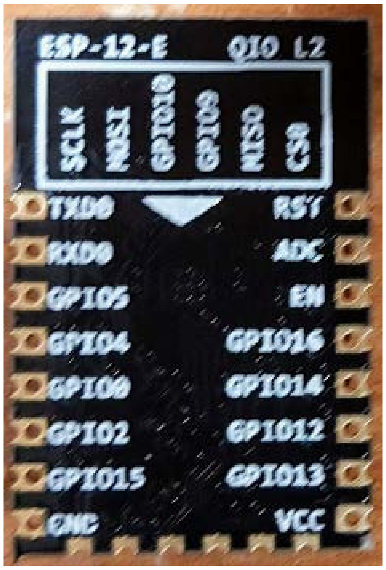
4.6. Libraries

The software uses the following libraries:

- ESP8266 core for Arduino (https://github.com/esp8266/Arduino).
- ESP8266 WiFi Connection manager (https://github.com/tzapu/WiFiManager).
- Double Reset Detect (https://github.com/jenscski/DoubleResetDetect).
- Arduino Json (https://github.com/bblanchon/ArduinoJson/)
- Asynchronous MQTT Client (https://github.com/marvinroger/async-mqtt-client/releases/tag/v0.8.1).

4.7. Flashing device

For this device we are using the ESP-12E (ESP8266) controller with QIO.

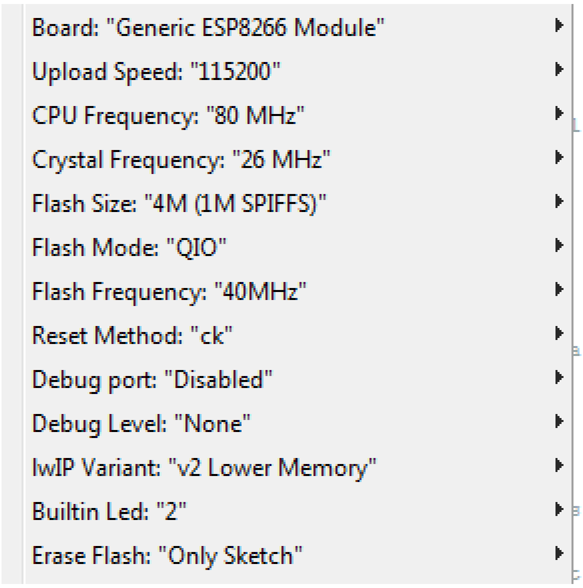


In order to upload the software, the PCB is designed to connect to the PC via USB with a 3.3V FTDI adapter. Other FTDI can be used with jumper cables if the pinout is not compatible with the PCB. Only the 3 pins TX0, RX0 and GND are used.

Connect the FTDI to J1, RX, TX and GND, put a jumper in J2 and power with 5V to V1.

The ESP will boot on flash mode. Remove the J2 jumper after flashing.

For this controller, the following parameters are used to flash the image:



The file system (SPIFFS) is required to save configuration parameters.