

Embedded System Design EE712

Project Report

Group 7

Multi Load Dimmer

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1. Abstract

This paper presents the development of multi load dimmer using a TRIAC control circuitry. TRIAC is a bidirectional semiconductor controlled rectifier which can be turned on in either of the direction by providing triggering pulse at its gate. In this dimmer, the current is not passed through the load in entire positive and negative cycles but in fractions of the cycles. The fractions of the cycles are controlled by providing firing pulse to its gate terminal with respect to zero crossing pulse. The firing angle for load is provided by the user through an android app. It is received by the wi-fi module over the wifi network and it is then processed by the arduino microcontroller. The firing pulse generated by the microcontroller turns on the TRIAC for specific fraction of cycle. This eventually controls the average voltage across the load. This dimmer has replaced the traditional resistive and capacitive dimmer. These dimmer are efficient as losses will be only present only at the time of switching.

2. INTRODUCTION

A dimmer is a power electronic device for controlling average voltage across the load. It is typically used for lighting , motor speed control and home appliances. The use of dimmers offers many advantages to customers. One advantage is that dimmers provide way to adjust the lighting level of a bulb or lamp. Dimmer circuit also provides energy conservation. In these dimmers the TRIAC is triggered into conduction after some delay with respect to zero crossing detector. That delay information is provided by the user through an android app. The user sends delay information over the wifi network. So after zero crossing is detected, the arduino microcontroller gives firing pulse after the delay as provided by the user. This gives chopped sine wave. This mechanism controls the average area under the sine curve. This eventually controls the average voltage across the load.

3. Problem Statement:

To develop a Multi-load Electronic Dimmer Circuit for controlling average value of voltage across the load.

4. Literature review

- R. Baris Dai et al [1] proposed dimmer circuit for controlling three different light sources incandescent bulb, CFL and LED. Different kind of light sources are studied and tested with AC and DC sources. Experiments were performed in order to observe the electrical characteristic of the dimmer and optical characteristic of the lighting devices when they are used with the dimmer circuit. The experimental results showed that the proposed dimmer can be used with these kinds of lighting devices within specific output voltage ranges.
- Jong-Hyun Kim et al [2] proposed a simple dimmer using a MOSFET for AC driven lamp such as AC LED and incandescent lamp. The control method of the proposed dimmer is pulse width control (PWM) method. Compared with the conventional phasecontrolled dimmer, the proposed PWM dimmer can produce sine wave and it does not cause harmonics problem.

5. Design

5.1 Block Diagram

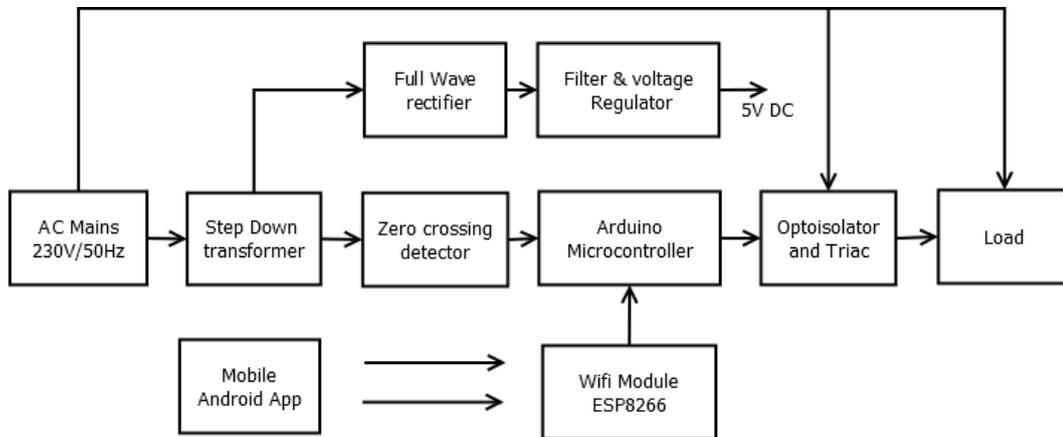


Fig. 1 Block Diagram

5.2 Power Supply Section

The 230V 50Hz ac main supply is stepped down by a step down center tapped transformer (12V - 0 - 12V). The output of center tapped transformer is provided to full wave rectifier circuit. The output of full wave rectifier circuit is given to filter and voltage regulator 7805. This provides stable 5V dc supply. This is used to power up zero crossing detector circuit, arduino microcontroller and ESP8266 wifi module.

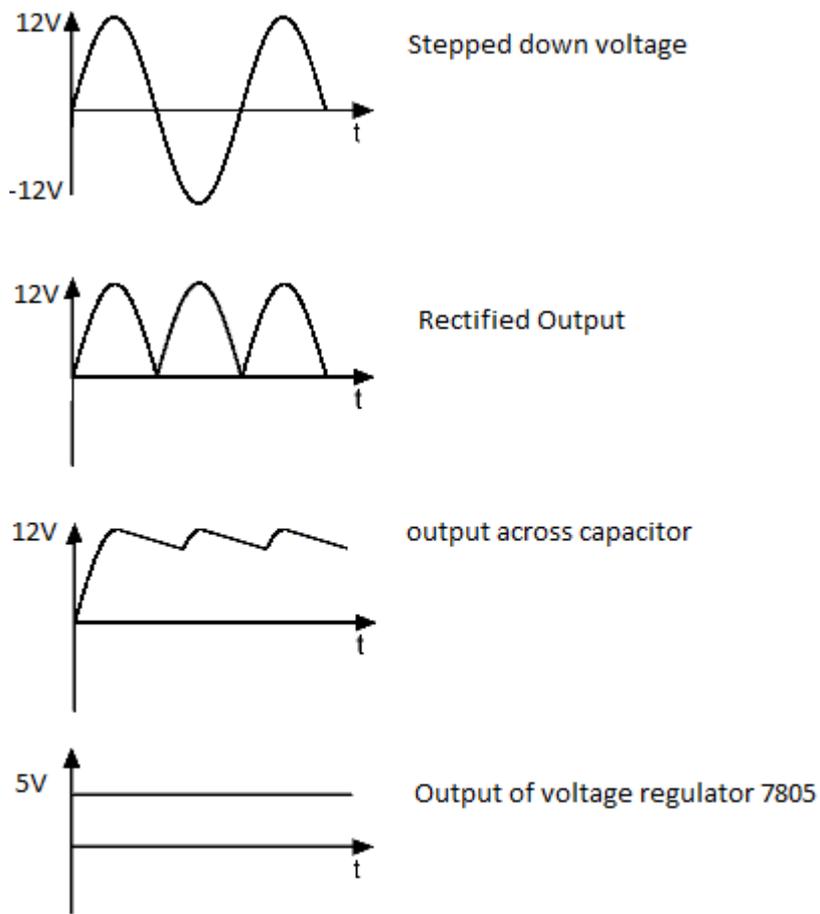


Fig. 2 Power Supply Voltages

5.3 Zero crossing detector implementation

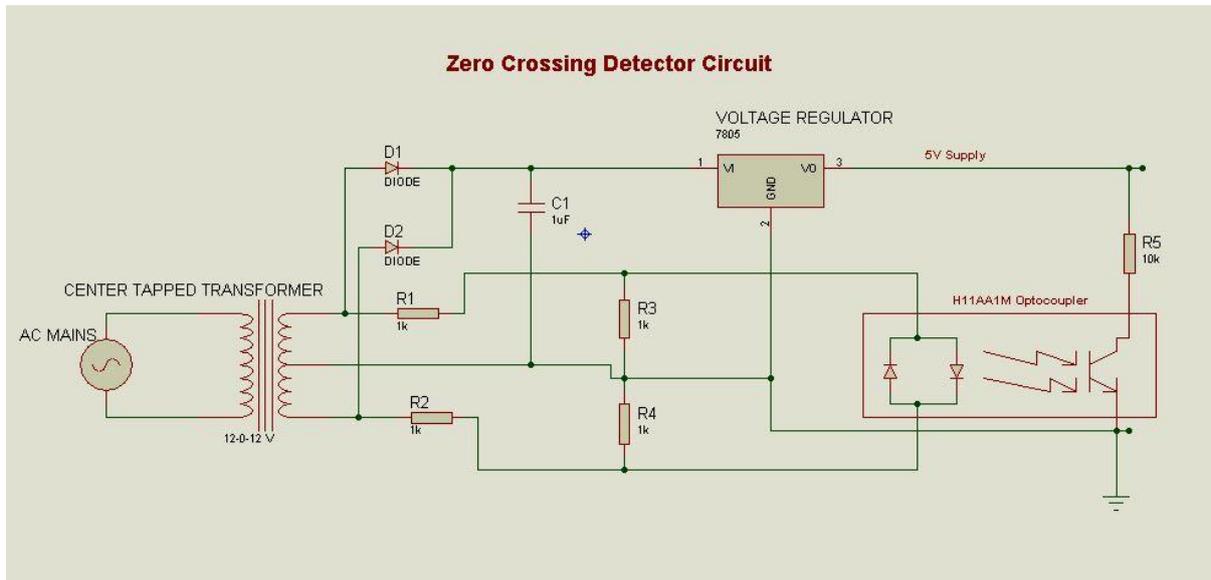


Fig. 3 Zero Crossing Detector

Zero crossing detector is implemented by optocoupler H11AA1. It is a bidirectional optically coupled isolator consisting two inverse parallel LEDs. When the output of center tap transformer is between $\pm 1.2V$, both the diodes are off and eventually BJT is off. So the output of ZCD at zero crossings is at 5V. When input voltage goes above 1.2V or below -1.2V, one of the LED will turn on. This makes opto transistor turns on and eventually output of ZCD will be zero volt. The amplitude of ZCD pulse is independent of the fluctuations of ac mains. If it would have dependent on amplitude of ac mains, then any fluctuations on mains would have impact of zero crossing pulse amplitude. This would have damaged the microcontroller pins

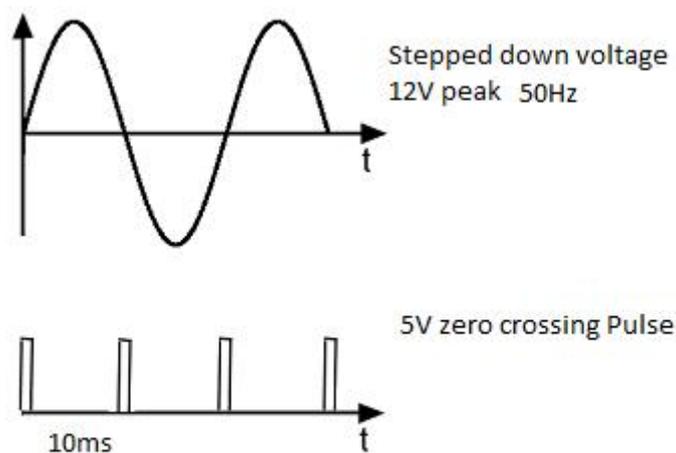


Fig. 4 ZCD output

5.4 Wifi Module ESP8266 and Arduino microcontroller.

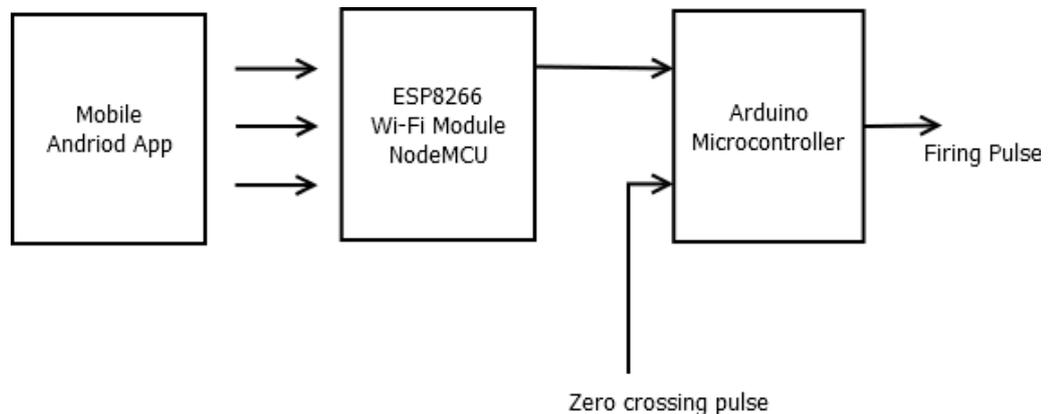


Fig. 5 Wi-Fi and Microcontroller interface

ESP8266 wifi module allows to host the application and wifi networking functions from another application processor. It serves as a wifi adapter. The user sends the firing angle data depending upon requirement. The data is sent in the form of string. The string consist of which load is to be controlled, its on/off status, and delay of firing pulse. The string is received by wifi module. It processes the string and communicates with microcontroller via TxD/RxD pin. Microcontroller also receives zero crossing pulse. The firing pulse is given out of microcontroller to TRIAC circuit with respect to zero crossing pulse after specified delay as provided by the user. The variation in firing angle can control the average voltage across the load.

5.5 Fractional cycle control circuit.

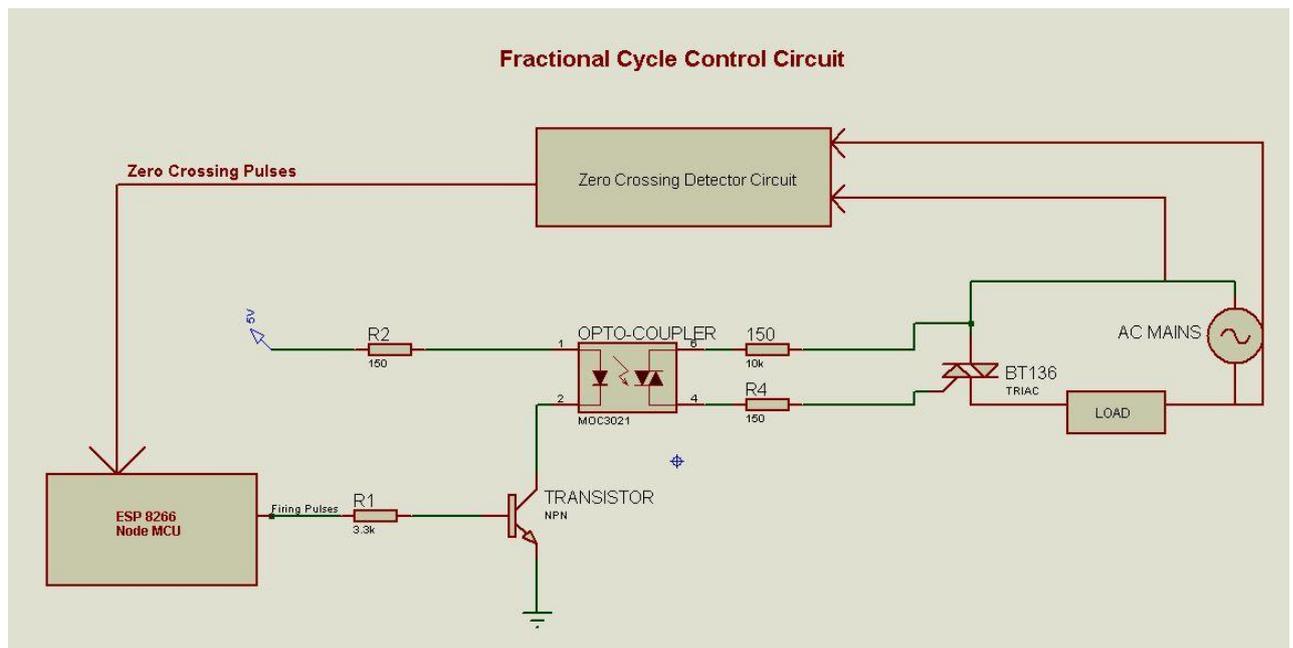


Fig. 6 Fraction Cycle Control Circuit

The fractional cycle control circuit consist of opto triac MOC3021 and triac BT136. The firing pulse is given to the base of BJT BC547. BJT provides current boosting as required by MOC3021. This will turn on opto triac thereby providing triggering pulse to the gate of BT136. It will then remain on for that fraction of the cycle.

5.6 ESP8266 NodeMCU wifi module

NodeMCU is a board with wifi and processor. It needs to be loaded with firmware version 0.9.6 . It uses arduino IDE (Esplorer). The code for nodeMCU is written in lua script. It takes ID, status and firing angle information and processes and outputs string to the arduino via UART communication.

In nodeMCU communication takes place in three ways

- AT commands
- HTTP URL
- MQTT

Here HTTP URL protocol is used for communication between nodeMCU and mobile device. Selected HTTP URL uses GET method for communication. NodeMCU acts as the access point (server) and mobile device acts as the client.

5.7 NodeMCU Lua script

Flow Chart

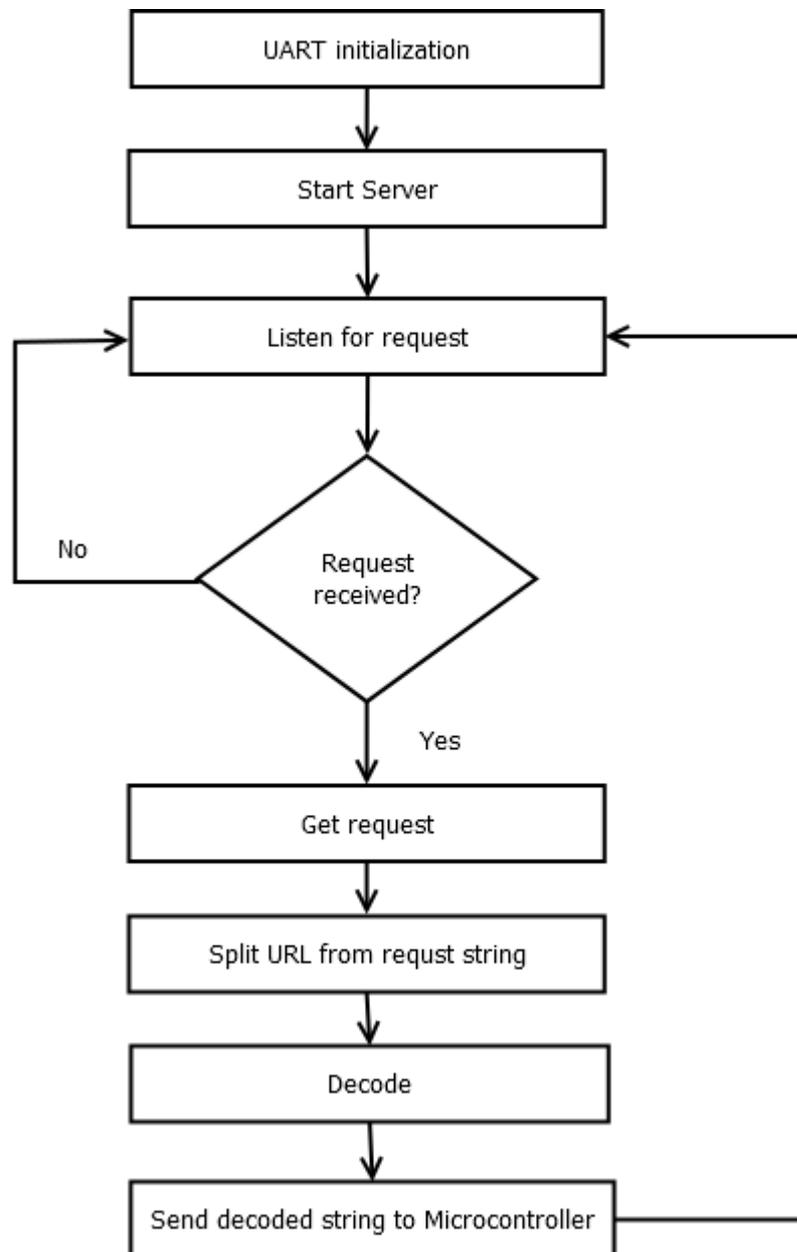


Fig. 7 Flow Chart

5.8 Android App

Android Application is created using Android Studio IDE. The user gives the data using the GUI interface. This information given by the interface is sent through the wifi asynchronously.

There are 3 functions implemented in the application

1. Slider: The range of values is set from 0 to 100. If the value is less than 10, it is considered the appliance need to be switched off. Else if the value is used to set the power level.
2. Reset: The time for which the appliance need to reduce the power level gradually is set in this implementation.
3. Communication: The value set from the slider and reset profile setting is reformatted to <https://URL> form and sent to the wifi server through an asynchronous function. This function is used to send URL through mobile to the server.

We are using GET method wherein, the user data is encoded with parameters, these parameters are concatenated and prefixed with the server IP address.

5.9 Voltage Compensation

Line voltage compensation is very important for dimmer circuit. If ac main voltage fluctuates, then firing angle needs to be controlled accordingly otherwise the average voltage across the load will also vary which is undesirable. So we have adopted a mechanism which ensures that average voltage across the load remains constant. Using this concept we can proceed as follows.

The average voltage across the load is given by,

$$V_{avg} = (V_m/\pi)(1+\cos\alpha)$$

where V_m is the peak voltage of the ac mains.

α is the firing angle.

α is also given as $(\pi d/10)$, d is the delay wrt zero crossing detector in milli sec.

Let V_{m1} is the fluctuated mains voltage and corresponding new firing angle be α_1 and d_1 be the corresponding new delay wrt zero crossing detector.

The average voltage should remain constant. So we can write as

$$(V_m/\pi)(1+\cos\alpha) = (V_{m1}/\pi)(1+\cos\alpha_1)$$

$$d_1 = (10/\pi) \cos^{-1} [(V_m/ V_{m1})(1+\cos\alpha) -1] \dots\dots\dots (1)$$

The above equation is implemented in arduino code. The filtered output of the power supply section is stepped down to 3.19V using voltage divider. The voltage compensation is designed for 230 ± 50 V. The stepped down voltage is read into

arduino microcontroller and converted by an internal ADC between 0 to 1023. 5V corresponds to 1023. So accordingly, the ADC output value at 230 ± 50 V is known.

V_{rms} (Volts)	Voltage after resistor divider circuit	Output of ADC
180	2.49	795
230	3.19	653
280	3.88	511

Ideally ADC output should remain at 653 if there is no voltage fluctuation. If there is any fluctuations in the ac mains voltage, then there would be corresponding change in ADC output value. The new value of ADC output is employed in the equation (1) to calculate the new delay.

So equation (1) is modified as

$$d_1 = (10/\pi) \cos^{-1} [(653/k)(1+\cos\alpha) - 1]$$

where k is the ADC output.

6. Conclusion

Control of voltage across load is achieved using multi load dimmer by controlling it through mobile using an android app. Line voltage compensation is also achieved. This allows multi load dimmer to be robust against line voltage fluctuations.

7. References

- [1] R. Baris Dai et al, A Dimmer Circuit for Various Lighting Devices, IEEE conference paper.
- [2] Jong-Hyun Kim , Jee-Hoon Jung , Myung-Hyo Ryu, and Ju-Won Baek , A Simple Dimmer Using a MOSFET for AC Drive Lamp, IEEE conference paper.