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Profiling of Home Equipment using WiFi

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Abstract

Profiling of home equipment is an ongoing process of hour. IOT-based home automation has allowed users to operate various home appliances using micro-controller systems and thus eliminating the human intervention. Along with operating the equipment, user shall be able to profile the basic control actions of the same equipment.

Example, optimizing the intensity of light and or controlling the speed of fan for a particular work station. A user friendly GUI, i.e graphic user interface or HMI, i.e human machine interface should also be available to gain a better control over the embedded system to control a specific equipment.

We propose a hardware to control the intensity of light and speed of fan over Wifi connection. A buck converter based dimming logic of light is used to not to compromise the power quality of grid. TRAIC based fan controller is used because of its robust, cheap and almost linear control.

TIVA TM4C123GH6PM micro- controller is used for hardware control while keeping in mind the multiple connectivity of peripherals using GPIO and or its logic extensions.

ESP8266 Wifi module is used to establish Wifi connection and communication with micro-controller to send user defined information received on website from client. ESP8266 creates a web-server as well where it takes the URI of the HTTP request.

1 Introduction

An embedded system is a dedicated hardware and software combined system which is designed for a specific function. The system is embedded as a part of a complete device system that includes hardware, such as electrical and mechanical components. It is different from the general purpose computer, which is designed to perform a variety of tasks.

High power LEDs in lighting applications are very popular. The cost effectiveness of LED is because of its longer life, high power conversion efficiency and higher reliability. They can further be used for power saving by appropriately dimming the intensity thus drawing less power from the supply. A Buck Converter based dimming circuit is designed as a variable voltage source to achieve the better lighting performance of LEDs.

Almost every fan in its particular appointed application has a feature of its speed control. A wide literature is available to control the speed of single phase induction motor. From inverter based V/f control for improved quality performance to basic voltage divider variable flux control for cost effective solution. TRAIC based speed control is very common and cost effective solution to control the dynamic speed variation of a single phase induction motor.

2 Modules Used

- Controller (Tiva TM4C123GH6PM)
- Wifi Module (ESP 8266 12E Node MCU 1.0)
- SMPS (To generate constant 24V DC Supply from AC Mains)
- Power Supply Circuit (To generate various voltage levels)
- Buck Converter (To Control LED)
- Zero Crossing Detection Circuit (To synchronise FAN control signals)
- FAN Traic Driver Circuit(To Control FAN)

Figure 1: TM4C123GH6PM

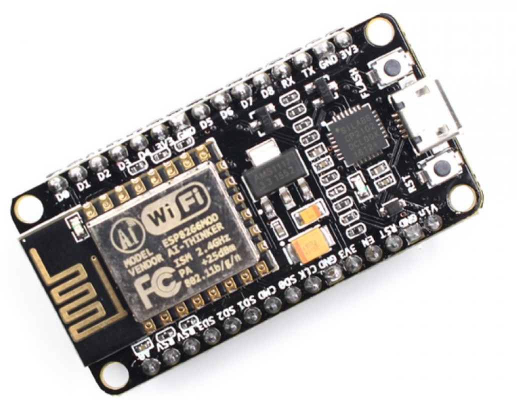


Figure 2: ESP 8266 12E Node MCU 1.0

3 Software

The software part of this project can be broadly classified into five parts

- Initialising the Wifi Module to act as standalone web server and WiFi Access Point.
- Communicating TM4C13GH6PM with NodeMCU 1.0 WiFi Module over UART
- Generating Control signals based on the input received from UART
- Generating Triggering pulses which are in phase sync with the input signal from zero crossing detector
- Displaying IP Address on LCD

The following figure shows the block diagram which represents the actions which are under control of software

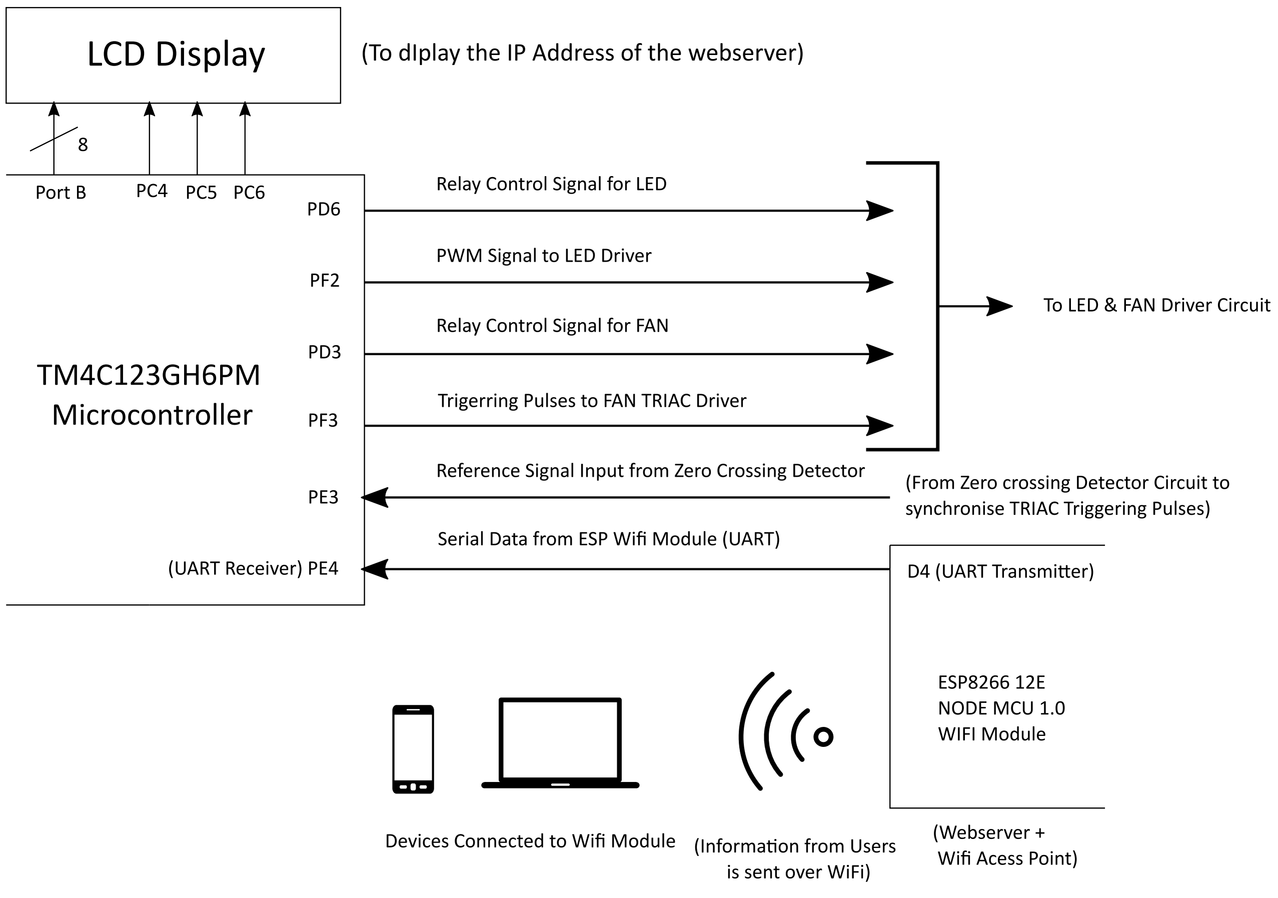


Figure 3: Block Diagram showing Interfacing between various devices

Initializing WiFi Module as WiFI Access Point and Web server

NodeMCU 1.0 has many features one among them is, It can act as a WiFi Access Point. NodeMCU 1.0 has been programmed using Arduino IDE. When acting as wifi access point, a maximum of 5 devices can be connected to it at a given time. NodeMCU 1.0 can also act like a webserver listening for requests. In order to control Intensity of LED and speed of FAN, a webpage is hosted on this webserver by which users can send request to the server and then it is communicated down to micro controller using UART.

The webpage related files (html,javacript,css etc.,) has been stored on NodeMCU 1.0 using SPIFFS (Serial Peripheral Interface Flash File System). Using SPIFFS, we can access the flash memory as if it was a normal file system like the one on the computers (but much simpler). SPIFFS lets us read and write files, create folders etc., NodeMCU 1.0 has 4MB of space for SPIFFS.

Communication between TM4C123GH6PM and NodeMCU 1.0

The UI for the webpage has controls for LED ON/OFF, LED Intensity Level, FAN ON/OFF, FAN Speed Level. All this data along with IP address of the webserver or NodeMCU IP itself is sent to TM4C123GH6PM using UART in the following format.

(LEDSTATUS)_(LEDINTENSITY)_(FANSTATUS)_(FANSPEED)_(IPADDRESS)#

For example if LED status is ON, Fan Status is OFF, LED Intensity is 40%, Fan Speed is 30% then UART sends following data : O_40_F_30_192.188.4.1#

The baud rate used here for communication is 9600.

Tiva TM4C123GH6PM has 8 UARTs out of which one (UART 0) is dedicated for USB serial communication and to communicate with NodeMCU 1.0, UART 5 is used. UART 5 uses PE4 as Receiver and PE5 as Transmitter. NodeMCU has 2 UARTS one dedicated for USB Serial communication and other to communicate with other peripheral devices. UART 1 of NodeMCU 1.0 is used to communicate with Tiva Micro-controller. UART 1 has only transmission capability i.e it can only send data (i.e., via D4 pin).

This data is transmitted on every web request from user and also every 5 seconds from the user (irrespective of a request is made or not). The processor uses busy-wait approach to check for available data on the receiver buffer. Once data is present, it is fetched character by character until a '#' character is encountered. This character denotes end of one command request from user via WiFi module. This data is stored in an array and processed to decode the status of FAN and LED. '_' character is used as a delimiter to separate out the status for FAN and LED.

Generating Control signals based on the input received from UART

Once data from UART is processed and decoded, control signals has to be generated which has to be sent to the respective hardware to control the end device. TM4C123GH6PM has dedicated hardware for Pulse Width Modulation (PWM). The TM4C123GH6PM micro-controller contains two PWM modules, each with four PWM generator blocks and a control block, for a total of 16 PWM outputs. Here second module, fourth PWM block, first PWM is used, which is tied to PF2. On every command request from user, once UART data has been decoded, width of PWM (based on user requested command) is adjusted by program. The relay control signals for LED and FAN are also set here. PD6 is used as relay control signal for LED and PD3 is used as relay control signal for FAN.

Control signals to Hardware unit	
PD6	Relay control signal - LED
PD3	Relay control signal - FAN
PF2	PWM signal - LED

Control signal to control the speed of FAN is discussed in the next section.

Generating Triggering pulses which are in phase sync with the input signal from zero crossing detector

Speed of FAN can be controlled by alpha angle control i.e., delaying the gate triggering by an angle alpha. This alpha is relative to zero crossing of the AC input voltage and to produce delay with respective to this, we have to synchronise our triac gate pulse generation with the zero crossing of AC input supply. Zero crossings of AC input voltage is obtained using a external zero crossing detector circuit. Ouput of this is fed to microcontroller from pin PE3. This pin has been configured for **hardware interrupt**. Whenever a rising edge is detected, it generates an interrupt and respective interrupt service routine is called.

The service routine enables a timer which counts for appropriate delay (based on angle alpha) and on completion of this it write high on the designated pin (i.e PF3) and enable another timer which counts upto 1ms. After 1ms, timer generates an interrupt where it writes low to PF3 and this process continues.

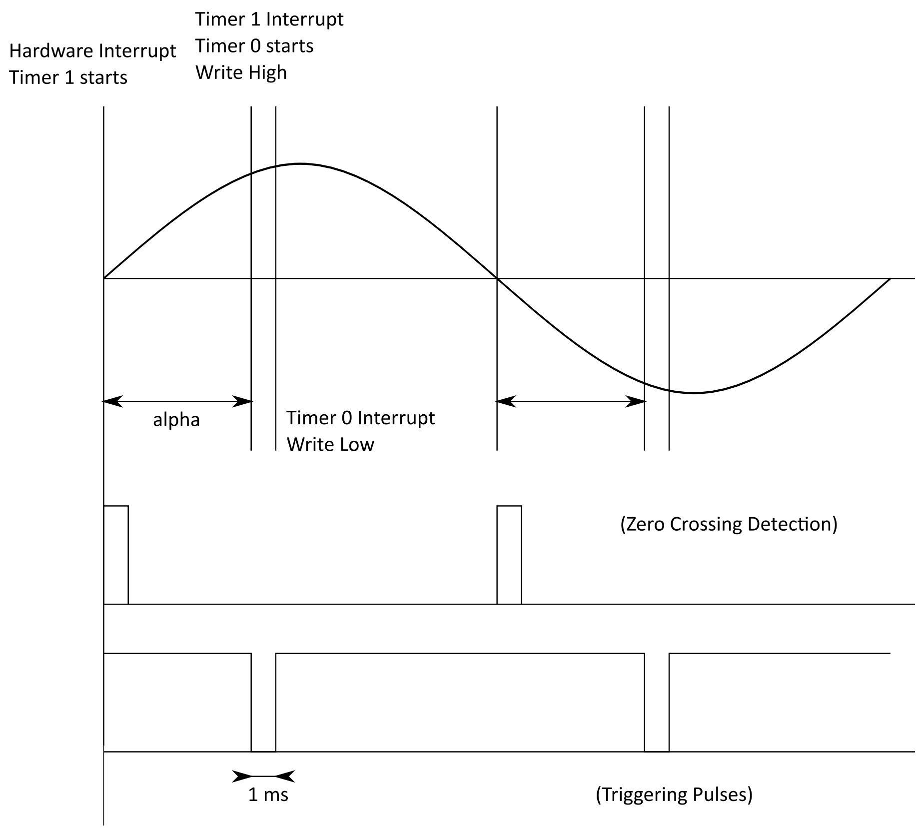


Figure 4: Generation of Triac Gate Pulses

Displaying IP Address on LCD

The IP address of webserver which was decoded from UART is stored in an array and is displayed on LCD. This data is refreshed at every 10 seconds using Timer. Data and Command signal for LCD is passed using PORT B and controls signals using pins PC4, PC5, PC6

4 Hardware

LED Dimming

Dimming of LEDs in lighting applications be used for power saving by appropriately dimming the intensity thus drawing less power from the supply. Also, the dynamic behaviour of dimming can fit in any workstation. Luminous intensity for a particular work station can be realized and modify the luminous flux of a fixture. LED dimming can also serve the purpose of aesthetic beautification of modern or historical architectures.

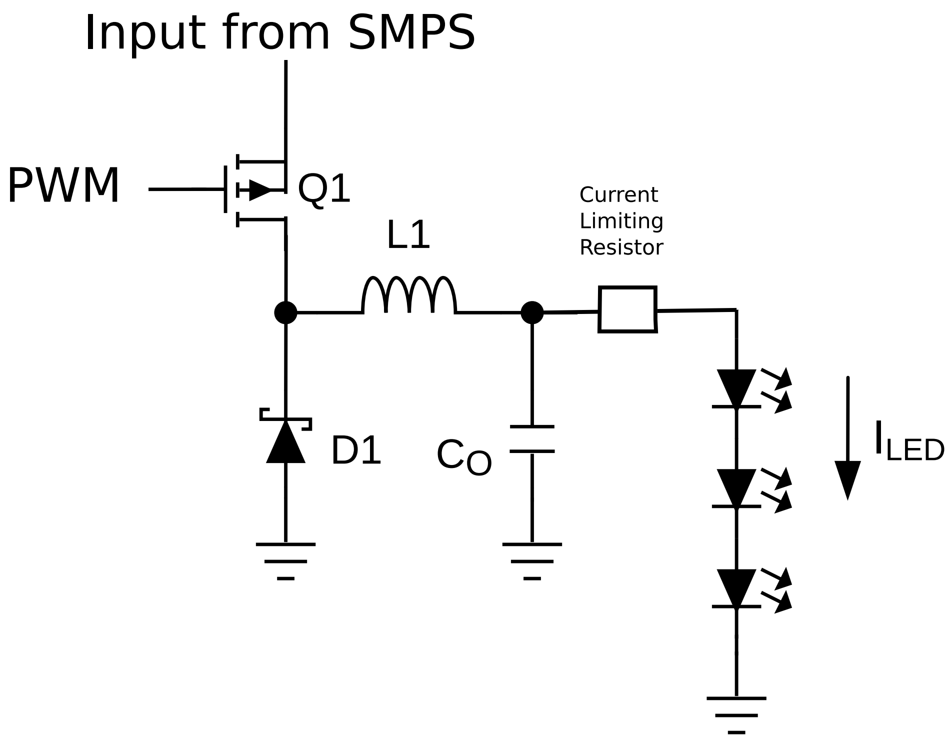


Figure 5: Buck Converter for LED dimming

Dimming of LEDs can easily be implemented. Comparing to other light sources, LEDs are more robust and offer wider design flexibility. A converter called, Buck Converter, is designed as a voltage source to achieve the better lighting performance from the LEDs.

Filtered output voltage of converter is fed to current limiting resistor and LED as shown in above figure. The step-down(buck)current regulator is chosen for driving LED load. This converter topology has direct connection of inductor to the load during entire switching cycle.Thus, inductor will control the rate of change of current and thus, the load connected to it will experience varying average current which is directly proportional to duty ratio of switch.

A duty ratio control provides wide input voltage range which allows regulation of variety of LED loads. Thus, the current drawn by LED is proportional to controlled voltage applied across is. The current drawn by LED will vary the intensity of the LED.

During t_{ON} i.e. Q1 is turned on, the input voltage charge the inductor(L_1). When switch Q1 is turned off t_{OFF}, the free wheeling diode (D1) becomes forward biased and L1 discharges.During both intervals,the current is supplied to the load through the inductor thus, keeping LEDs forward biased. Following figure shows the inductor current $i_{L(t)}$ waveform.

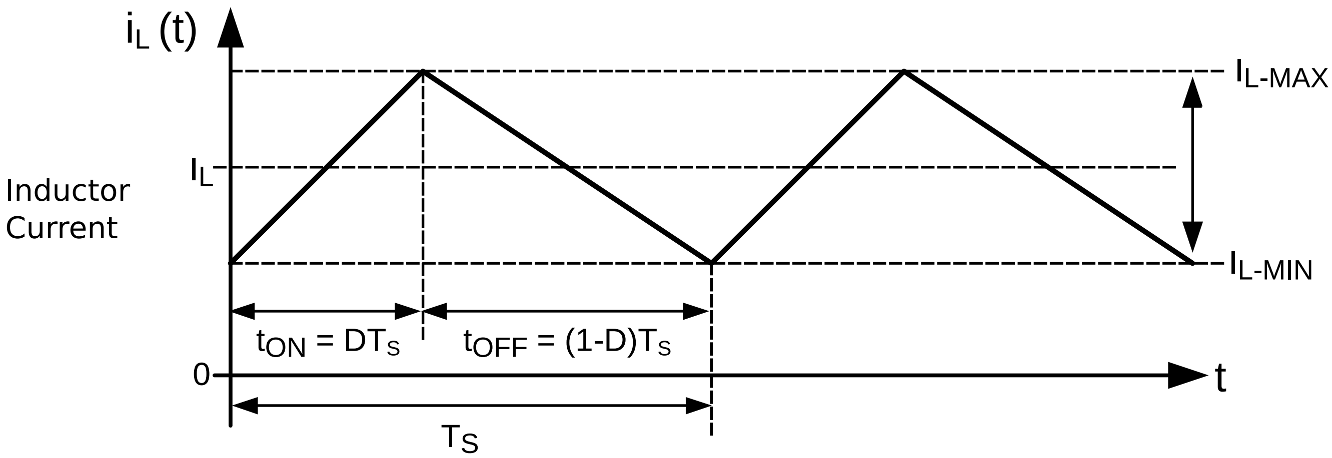


Figure 6: Inductor Current

The average inductor current is equal to the average output LED current I_{LED}, I_L is controlled which then will regulate I_{LED}. Below figure shows the LED current waveform.

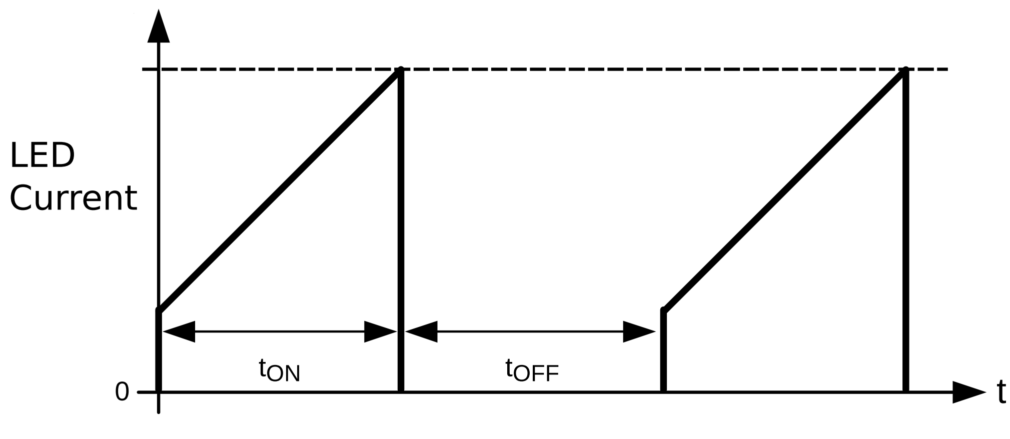


Figure 7: Average LED Current

Supply voltage 220V mains converted to DC supply input supply using SMPS. This is fed to input of buck converter, thus, output voltage is varied to regulate I_L and ultimately I_{LED}.

Dimming Curve

While dimming it was observed that luminous intensity does not change linearly. It was gradually increasing for low value of duty ratio and suddenly rises to almost constant illumination for higher duty ratio. It is because of human eye perception. Eye perceive brightness in non linear manner. Even if the LED driver is varying light linearly but a human eye observe it as non linear. Below figure shows the brightness vs intensity curve.

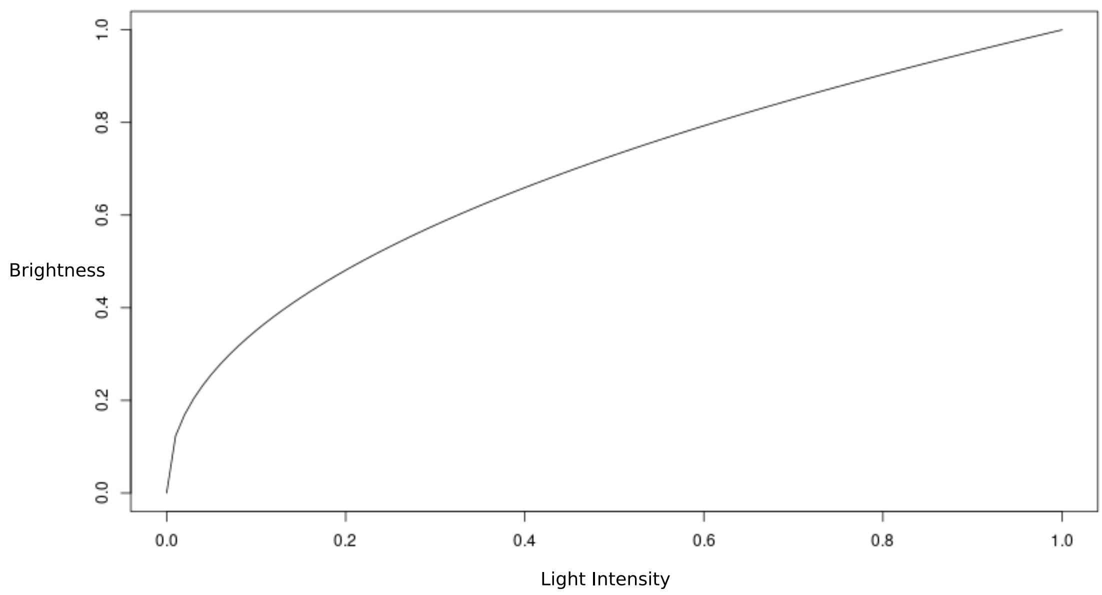


Figure 8: Perceived Brightness vs Light Intensity

Thus, a logarithmic dimming curve to be used in the control scheme such that driver drives it accordingly so that human eye can see linear variation in brightness.

Power Supply Requirements

Power supply has also been designed to power micro-controller TIVA TM4C123GH6PM and wifi module ESP8266. 220V rms line voltage supply has stepped down to 15Vpp using step down transformer and bridge rectifier is used to convert it to DC. Then series of regulator ICs are used to further step down to 12V for relays using LM7812, 5V for TIVA TM4C123GH6PM using LM7805 and then 3.3V for ESP8266 using 3.3V zener diode.

Fan Speed Control

A Fan is a single phase induction motor whose speed can be controlled by varying the voltage applied across it. To chop the AC voltage a semiconductor device called a “Triode AC Switch” or Triac can be used.

It is a bidirectional switching device. It can be triggered into conduction in both positive and negative direction of supply waveform applied to its main terminals. Thus, making it a two-quadrant switching Gate controlled device.

MT_1, is Main Terminal 1 and MT_2 is Main Terminal 2. It shares a common Gate terminal G. Phase control scheme is applied to control dimming 220V AC across Fan.

A zero crossing detector is needed to synchronize with line voltage zero crossing. This pulse is fed to controller where a timer can be instantiated to properly delay the firing of Traic. It controls the RMS voltage appearing across Fan, therefore gives a predictable level of dimming.

When a zero crossing is acknowledged by controller, the Triac remains off for a controlled amount of time. When this time elapses, the controller turns on the triac by applying a gate signal.

Turing on of Traic is controlled while it turns off at next zero crossing, i.e. line.

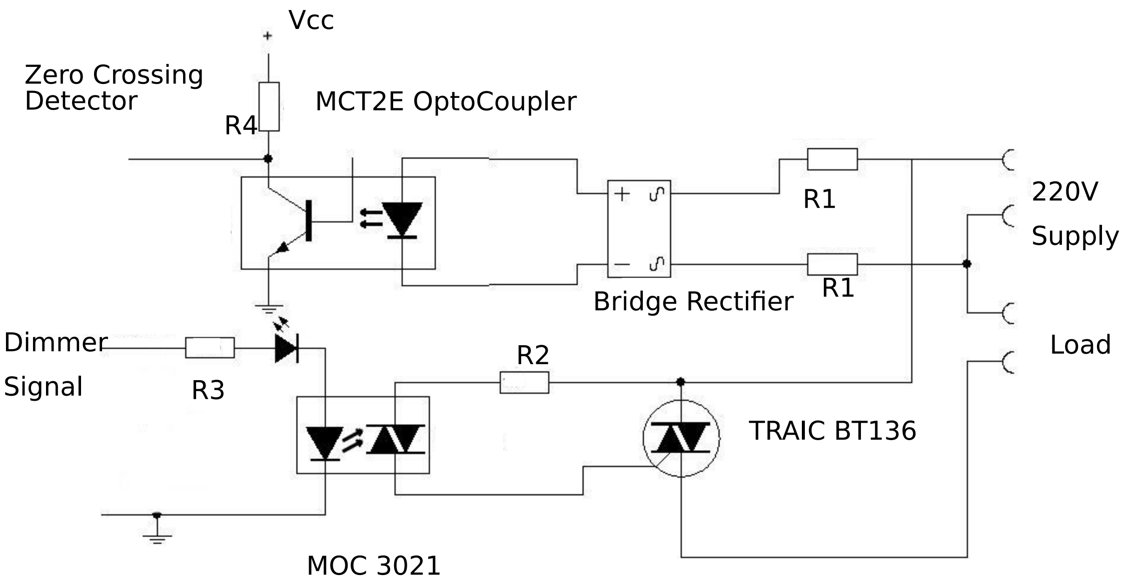


Figure 9: Traic Firing Circuit

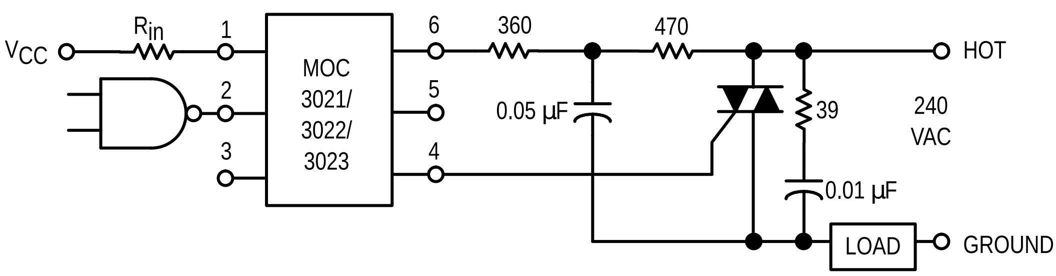


Figure 10: Traic Driver Circuit

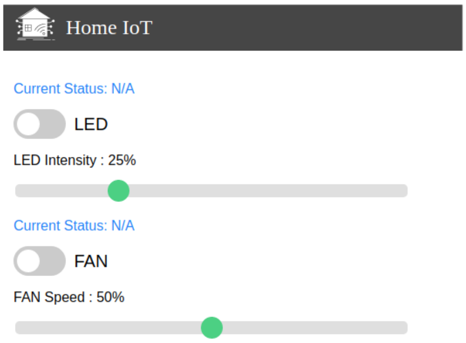
The gate signal from controller is fed to Traic driver circuit which is opto coupled Daic switching circuit. The pulse generated by a Daic is synced with mains automatically. Also, Daic will provide gate pulse to Traic in both positive and negative direction of supply waveform.

5 Test Procedure

The hardware developed can easily be appointed at the user's workstation. Power Supply has been designed for micro-controller and wifi-module. Thus, one need to plug in hardware and connect to WIFI access point called EMBED21G.

The LCD connected will show the IP address of the website hosted by module. One shall connect their device to the web page whose address is shown on LCD. This will give the access to the user to control the equipment connected to it.

A user friendly GUI, where number of button to turn on/off the device are available. A slider to smoothly control the intensity of light and the speed of fan is provided.



6 Results

6.1 LED PWM

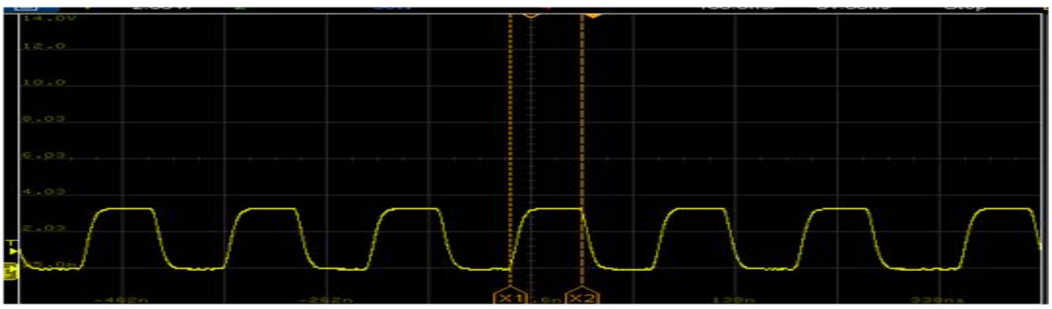


Figure 11: PWM for LED @50Khz

6.2 TRAIC

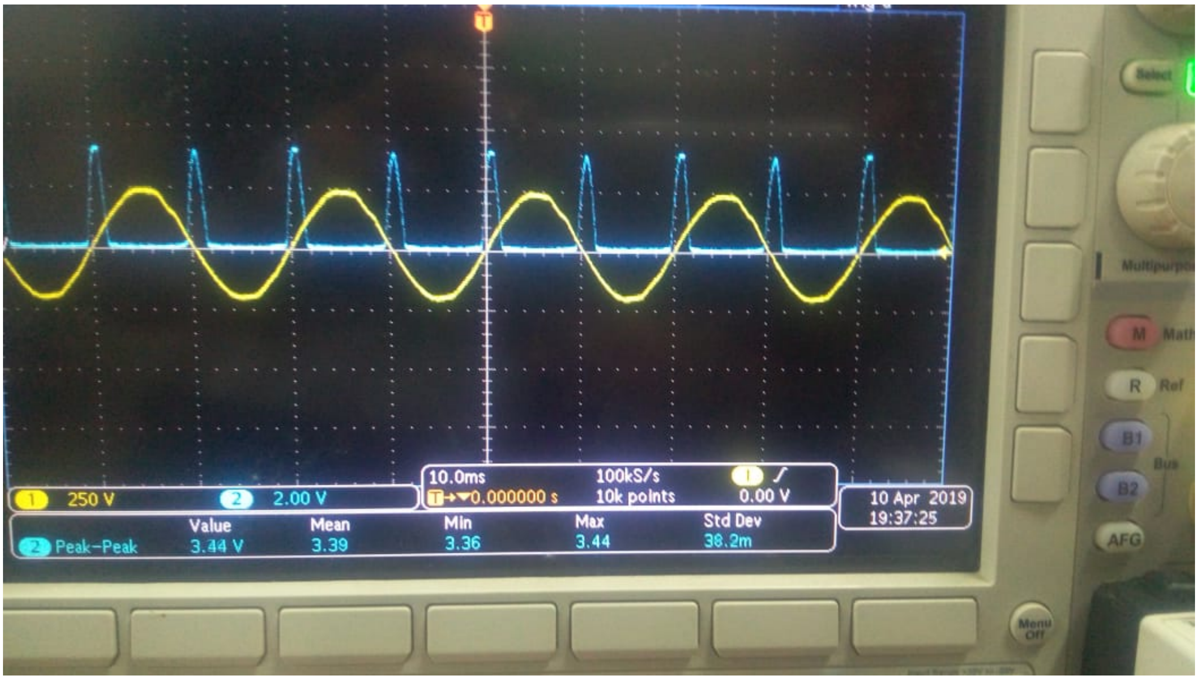


Figure 12: Zero Crossing Detection

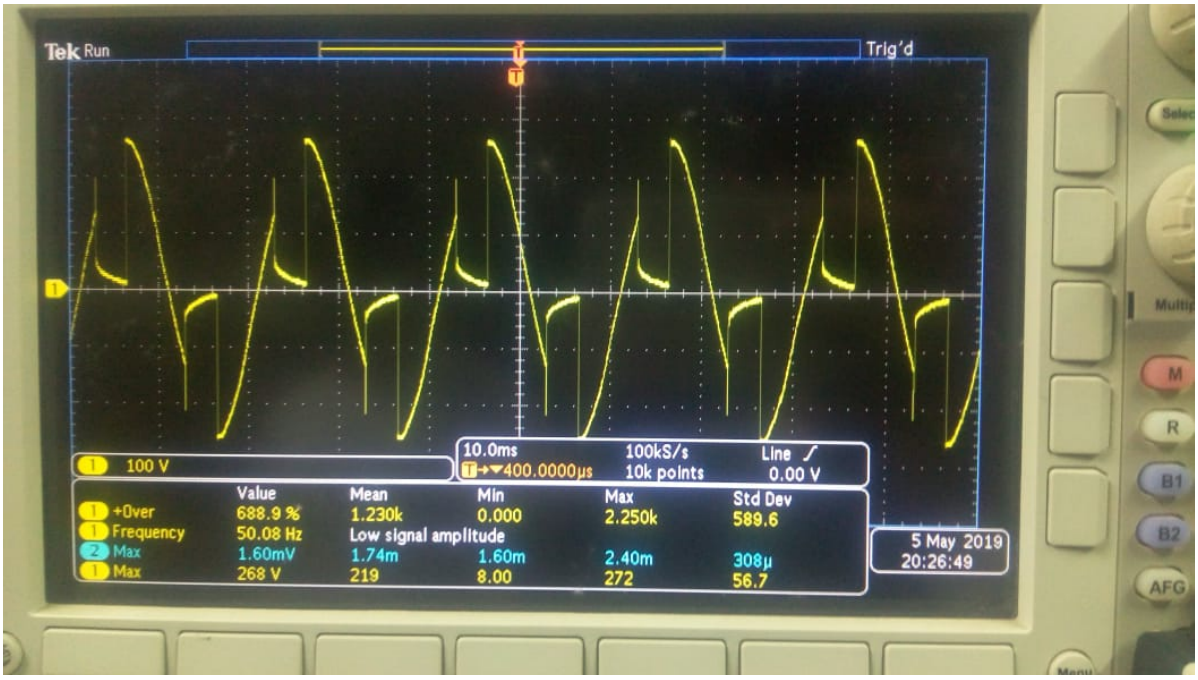


Figure 13: Chopped TRAIC waveform across fan load

7 Conclusion

A satisfactory performance from profiling embedded system has been observed. Smooth Wifi based communication and friendly GUI experience enhance the performance of ordinary equipment. However, prototype catered to only one fan and LED but can easily be extended to a number of peripherals. Logarithmic curve fitting for human eye gives linearity of operation. Firing angle control makes the rpm vary in wide range almost linearly and thus, proves to be simple and effective. Thus, a cost effective profiling solution has been proposed and realised on hardware.

An extension to proposed prototype would be adding more features for user experience. A drop down menu for setting up the type of work station so that predefined air-flow, luminous flux and height of work space to be used up to lock the settings of equipment. A constant brightness throughout the day at working stations and a variable fan speed depending on the natural breeze would make the experience more effective. Another example of profiling would be to develop a GUI where user can set initial and final speed and or brightness along with the set timings for the change of event to happen. Thus, the prototype proposed can easily perform above mentioned user experiences only through the software adjustments. TIVA TM4C123GH6PM provides enough roof head to cater above mentioned implementations.

8 References

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- TRAIC to control speed for single phase induction motor load.
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