Zero-Crossing Module IoT-Based for Light Intensity Control with NodeMCU ESP8266

Muchammad Fardin Alifi[1], Addriyan Bagus Syahputra[1], Delia Riza Mayora[1], M. Ibrahim Nur Hidayatullah[1] , Nur Vidia Laksmi B.[1*]

[1]Faculty of Vocational, Universitas Negeri Surabaya, Surabaya, Indonesia

*nurvidialaksmi@unesa.ac.id

Abstract. The progression of time is accompanied by advancements in technology, which is IoT (Internet of Things). The IoT offers innovative solutions across various fields, including lighting systems. IoT is a technology that connects devices to the internet, simplifying many tasks. This paper focuses on the development and use of an IoT-based dimmer system. The system is designed for lighting control by utilizing zero-crossing method, which detects changes in electrical current as it passes through zero volts. By using a zero-crossing module, the IoT-based dimmer system can adjust light intensity through pulse-width modulation (PWM) techniques. The system circuit consists of an ESP8266 microcontroller that sends signals to a 4N25 opt isolator IC, which then transmits to a MOC3021 optocoupler IC and TRIAC for controlling light intensity including 25%, 50%, 75% and 100%. Additionally, this system is equipped with the ESP8266, enabling real-time light intensity adjustments via MQTT from anywhere at any time.

Keywords: Dimmer, Microcontroller, Zero Crossing Module, IC 4N25, IC MOC3021

1. Introduction

In the era technological advancement, human needs are increasingly expanding in tandem with technological and lifestyle developments. The Internet of Things (IoT) provides a solution to simplify meeting these needs and expedite tasks. IoT employs a concept aimed at extending the benefits of continuous internet connectivity [1]. Efforts to reduce energy consumption are not always successful; however, energy conservation is crucial today due to the limited nature of energy resources, which can be depleted at any time if not managed properly [2]. This situation demands a reduction in energy usage, and an IoT-based dimmer system can be an innovative solution.

C. D. M. Putri et al. (eds.), *Proceedings of the International Joint Conference on Science and Engineering 2024 (IJCSE 2024)*, Advances in Engineering Research 250,
https://doi.org/10.2991/978-94-6463-626-0_10

Integrating IoT and connectivity into lighting systems offers advantages in controlling light intensity, reducing costs, and saving energy.

The IoT dimmer system can control the intensity of light using IoT technology. In Purnama et al., 2021, the light intensity can be controlled through devices connected to the internet for egg incubator application [3]. The ESP8266 microcontroller is a device with Wi-Fi capabilities that can connect to the internet [4]. By using the ESP8266 microcontroller, the IoT dimmer system can be controlled remotely via a smartphone application. To control it remotely Murthy et al., 2018 proposes the application used is the Message Queuing Telemetry Transport (MQTT) Dashboard, which can send and receive MQTT messages [5]. However, Khera et al., 2018, uses of a TRIAC component serve to regulate the amount of AC voltage going to the lamp, allowing for smoother control of light intensity [6].

Zero crossing refers to the instances when a (digital) signal crosses zero during its transition from positive to negative in a signal waveform. The zero-crossing detector (ZCD) component is used to optimize the performance of the TRIAC for smart home system in Sulaeman et al., 2017 [7]. The use of the 4N25 IC as an opt isolator in this system is beneficial for isolation, thereby protecting the microcontroller from damage. Meanwhile, the MOC3021 IC is used to control the TRIAC. By combining these two components, the dimmer system can control light intensity more smoothly, safely, and precisely [8]. With the IoT dimmer system utilizing zero crossing, user comfort is enhanced, tasks are simplified, and light intensity control is highly flexible. This system also contributes to energy savings

2. Method

2.1. IoT-Based Dimmer System Scheme

The scheme for implementing this IoT Dimmer requires several sources and specific needs, which become essential components to ensure the IoT Dimmer functions as desired. The system scheme is shown in Figure 1 as follows.

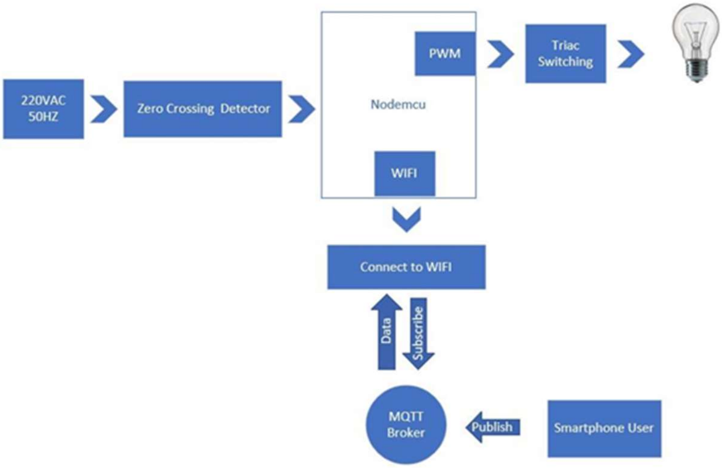

Fig. 1. IoT-Based Dimmer System Scheme

In Figure 1 illustrates the working mechanism of the IoT-based Dimmer System. The IoT Dimmer can control the current supplied to the lamp load, allowing the brightness level to be adjusted using MQTT. The system applies zero-crossing detection connected to the microcontroller to detect the AC voltage crossing zero, process the signal from the Zero Crossing Detector (ZCD), and send a Pulse Width Modulation (PWM) signal to the TRIAC Driver, which is the MOC3021, and then to the TRIAC. The TRIAC outputs the voltage based on the delay set by the user through the MQTT IoT application.

2.2. System Components

The development of IoT-based Dimmer Systems requires several components. Key components for constructing this system include the NodeMCU 8266 as the microcontroller, zero-crossing module for AC signal zero-crossing detection, TRIAC Switching for power control to the lamp, and IoT system for remote control. Below are explanations of each component used in the system development:

2.2.1 NodeMCU ESP8266

NodeMCU ESP8266 is depicted as a microcontroller module featuring the ESP8266 chip, capable of Wi-Fi connectivity, which is shown in Figure 2. The ESP8266 is a low-cost Wi-Fi chip developed by Espressif Systems, utilizing TCP/IP protocol. NodeMCU utilizes the SPIFFS (Serial Peripheral Interface Flash File System) flash-based file system, implemented in C language with Espressif NON_OS SDK. It features programmable pins along its edges for software integration and boasts ample internal storage, facilitating integration with sensors [9].

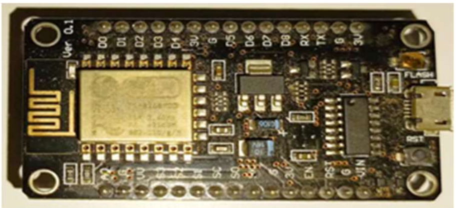

Fig. 2. NodeMCU ESP8266

2.2.2 Zero Crossing Module

In Fig. 3 the Zero Crossing Module consists of two main components: the zero-crossing detector and TRIAC switching. Each of these components serves distinct purposes. The zero-crossing detector is utilized to detect when the AC voltage passes through zero and sends a signal to the microcontroller. Meanwhile, the TRIAC switching message is employed to control the TRIAC or serve as its driver, enabling controlled output voltage levels using the microcontroller's PWM signal.

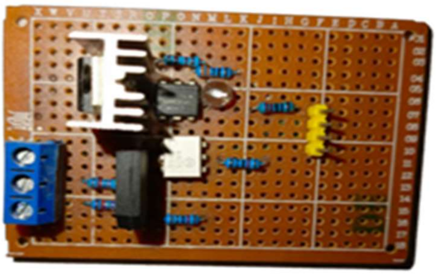

Fig. 3. Zero Crossing Module

2.3. Internet of Things System

IoT, or the Internet of Things, refers to a network comprising devices, instruments, and buildings equipped with electronic components, circuits, software, sensors, and internet connectivity. It enables remote control of objects through network infrastructure. Kevin Ashton, a technology pioneer from the United Kingdom, coined the term "Internet of Things" to describe an interconnected internet system integrated with sensors [10].

MQTT is a lightweight message-based communication protocol designed for Machine-to-Machine (M2M) and IoT connections. It operates effectively on devices with low bandwidth or unstable network connections. Originally developed by IBM in 1999 and later standardized by OASIS (Organization for the Advancement of Structured Information Standards), MQTT employs a publish-subscribe model within its system. In MQTT systems, IoT devices such as Esp8266 and esp32 can act as publishers, transmitting data to an MQTT broker, and/or as subscribers, receiving data from the broker. This approach allows for distributed message delivery, enabling data from one device to be accessed by many others subscribing to the same topic. Furthermore, MQTT facilitates scalability whereby new IoT devices can easily join the network and begin communicating by subscribing to relevant topics. In addition to Publish and Subscribe, MQTT employs a central server known as an MQTT broker, which acts as an intermediary for all communications between IoT devices [11]. To calculate the AC voltage for a light based on the brightness percentage received from MQTT messages, the equation is:

$$\text{AC Voltage} = \text{Maximum Voltage} \times \frac{Brightnes\ \ Percentage}{100} \tag{1}$$

For example, if the maximum AC voltage is assumed to be 220V and the brightness percentage is 50%, then:

$$\text{AC Voltage} = 220 \times \frac{50}{100} = 110\text{ V} \tag{2}$$

As the received brightness percentage from MQTT increases, the AC voltage supplied to the light will also increase.

3. Result and Discussion

The application of zero crossing is utilized to regulate the brightness of lamp lights. The assembly of software/simulation for zero crossing applications using a microcontroller is depicted in Figure 4. In this figure shows the simulation results using Proteus 8 as a simulator. The systems including zero crossing circuit, Arduino UNO and additional circuits. Then, figure 5 presents the assembly of hardware for zero crossing applications using NodeMCU ESP8266.

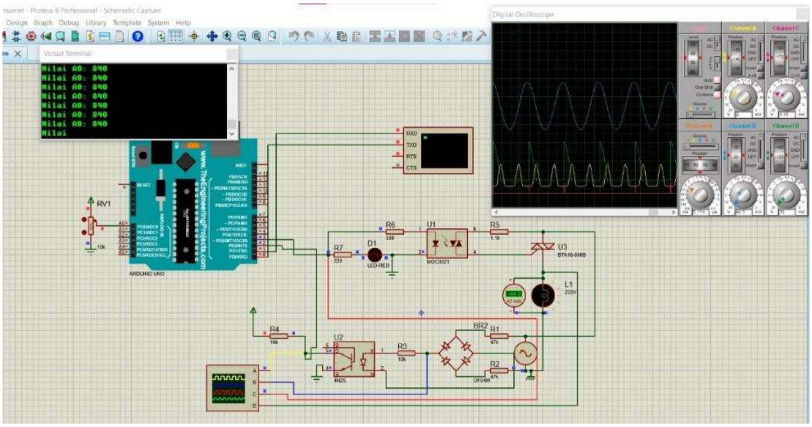

Fig. 4. Assembly of Zero Crossing Dimmer Software with Arduino R3 in Proteus

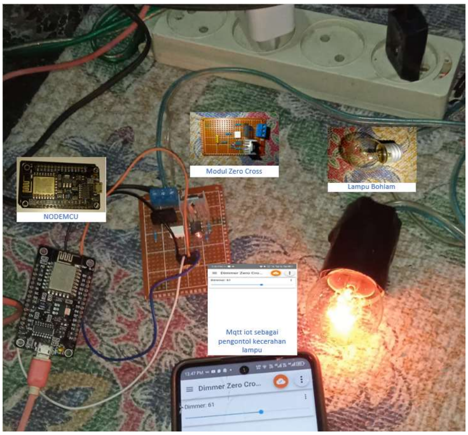

Fig. 5. Assembly of Zero Crossing Hardware Dimmer with NodeMCU ESP866

In Figure 6, we observe the Zero Detector circuit designed using Proteus software. When a 220VAC voltage is applied, it is initially reduced to 17VAC by a 47K ohm resistor. This 17VAC voltage then passes through a diode bridge, converting it from AC to DC within a range of 0-1V DC, thereby activating an internal LED. As current flows through the internal LED (from anode to cathode), the LED illuminates. The light emitted by the LED is detected by a phototransistor situated on the opposite side of the opt isolator.

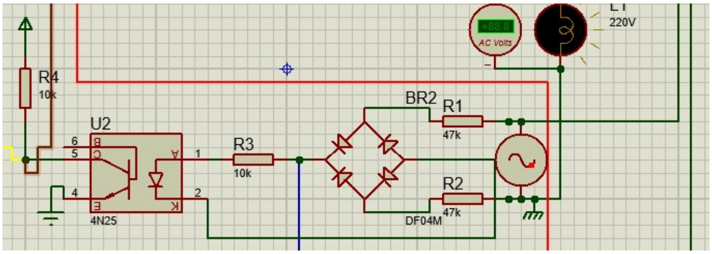

Fig. 6. Zero Detector

Activating the phototransistor causes current to flow from the collector to the emitter. The collector, connected to pin 2 of the microcontroller, is used to detect when the PWM on pin 3 turns on and off, or to detect zero crossing, which is the point where the sinusoidal wave crosses the zero point.

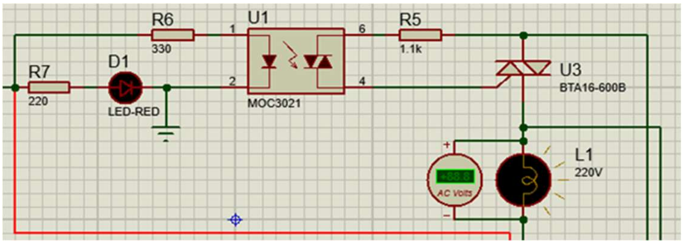

Fig. 7. Triac Switching

Fig. 7 depicts the Triac Switching circuit. In Proteus, upon detecting zero crossing, the microcontroller activates or deactivates PWM in accordance with this signal. This PWM signal then turns on both the 3V LED and the internal LED of the MOC3021. When the control signal from the microcontroller is applied to the anode (Pin 1) and cathode (Pin 2) of the MOC3021, current flows through the internal LED, thereby illuminating the LED.

- Activation of Phototriac: Internal LED light triggers the internal phototriac, enabling current flow between its primary terminals (Pin 4 and Pin 6).
- AC Load Control: When the internal phototriac is active, AC current can flow through the main terminals (Pin 4 and Pin 6), thereby controlling the connected load (such as lights or AC motors).
- Dimming Control: By adjusting the potentiometer connected to A0, you can regulate the dimming level, which governs the delay time before the TRIAC is activated after zero crossing. This capability allows you to adjust the power delivered to an AC load, thereby controlling the brightness of a lamp or the speed of a motor.

Electronic devices controlled include incandescent lamps. The controlled system is the light intensity of the lamp. The lamp intensity settings are divided into 4 levels: 0%

lamp setting, 25% lamp setting, 50% lamp setting, 75% lamp setting, and 100% lamp setting. Here is a display of the experiment from the IoT-based Dimmer System:

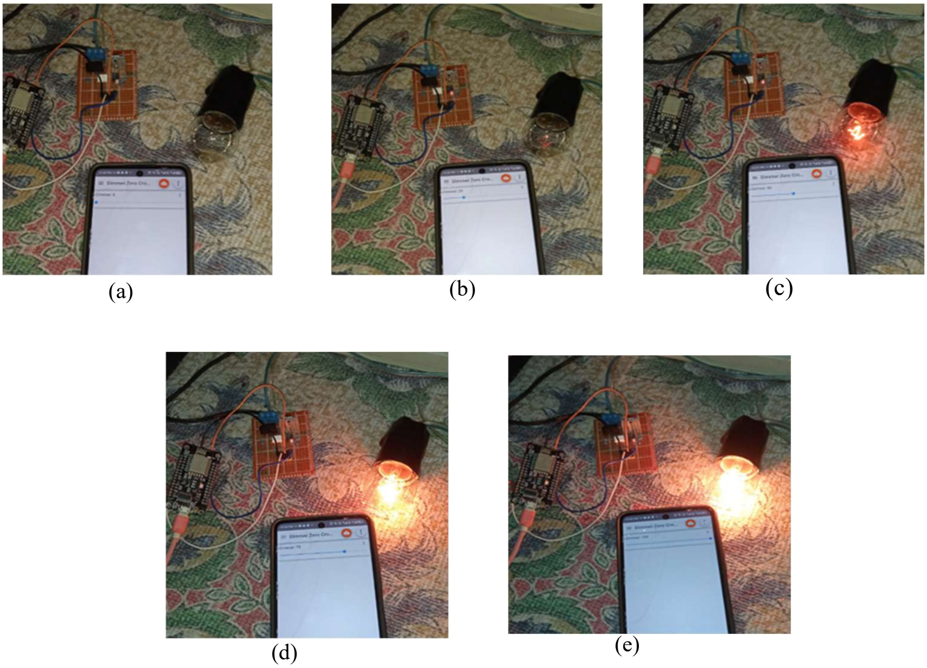

Fig. 8. The Results of Light Intensity Control Testing (a) 0% lamp setting (b) 25% lamp setting (c) 50% lamp setting (d) 75% lamp setting (e) 100% lamp setting

4. Conclusion

Dimmer zero crossing is a device used to control the brightness of a lamp by regulating the flow of electrical output that powers the lamp. The zero-crossing technology in this dimmer operates by detecting the point where the AC (alternating current) waveform crosses zero voltage, precisely when the voltage passes through zero. By switching at this zero-crossing point, the dimmer reduces noise and electromagnetic interference that typically occur when switching at points other than zero. This feature enhances the efficiency and stability of light intensity control while minimizing damage to lamps and other electronic devices connected to the same electrical circuit. Adding a NodeMCU allows users to leverage existing WiFi features to connect to the internet, facilitating remote control of the zero-crossing module via MQTT IoT applications. Using an IoT-based zero crossing dimmer enables users to adjust lamp brightness through an Android application called MQTT IoT, provided that the user's smartphone is connected to the internet via network provider or WiFi. By employing a zero-crossing dimmer, users not only extend the lifespan of lamps but also enhance convenience by adjusting lamp brightness according to their preferences.

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article

References

1. Rizky, Hakim, Yunita, Wardah, Neli. Implementasi Teknologi IOT (Internet of Think) Pada Rumah Pintar Berbasis Mikrokontroler ESP8266. JTI (Jurnal Teknologi Informasi) Vol.4, No.2, 278-281, ISSN 2615-2738, Desember 2020, doi: 10.36294/jurti. v4i2.1452
2. Sorrell, Steve. Reducing Energy Demand: A Review of Issues, Challenges And Approaches. Elsevier Access,74–82, (2015) doi 10.1016/j.rser.2015.03.002
3. Purnama Iwan, Ambiyar, Rizal Fahmi, Verawardina Unung, Raharjo Dwi Sutrino, Karim Abdul, Mesin Penetas Telor Otomatis Berbasis Mikrokontroler Atmega328., Volume 5, Nomor 2, April 2021, Page 431-438, ISN: 2614-5278, doi: 10.30865/mib. v5i2.2816
4. Bhat, Omkar. Gokhale, Pradyumna. Bhat, Sagar. Introduction to IOT. International Advanced Research Journal in Science, Engineering and Technology ISO (2007) IARJSET Access, 41-44, Vol. 5, Issue 1, January (2018), doi 10.17148/IARJSET.2018.517
5. Karthik S Murthy, Parul Herur, Adithya B R, Harshita Lokesh. IoT-Based Light Intensity Controller. IEEE Access, 455-460, (ICIRCA 2018), doi: 10.1109/ICIRCA.2018.8597416
6. Khera Neeraj, Biswal Prateekshya, Likhith Chintalapudi, Development of Microcontroller Based Digital AC Dimmer for Light Intensity Control, IEEE Access, G.L. Bajaj Inst. of Technology and Management, Greater Noida, U.P., India, (2018), doi: 10.1109/PEEIC.2018.8665457
7. Sulaeman, Dewi Kartika, Pangerang, Fitriaty,. Implementasi Zero Crossing Pada Sistem Kendali Perangkat Rumah Cerdas Menggunakan Smartphone Android. (2017) Prosiding Seminar Hasil Penelitian (SNP2M) 2017 (pp.33-38), ISBN; 9786026076632
8. D. C. Toledo-Pérez, J. Rodríguez-Reséndiz and R. A. Gómez-Loenzo, A Study of Computing Zero Crossing Methods and An Improved Proposal for Emg Signals, IEEE Access, 8, 8783-8790 (2020). doi: 10.1109/ACCESS.2020.2964678G
9. Singh Parihar, Yogendra. Parihar, Yogendra Singh. Internet of Things and Nodemcu A review of use of Nodemcu ESP8266 in IoT products. (2019), 9 JETIR, Volume 6, Issue 6, ISSN: 2349-5162
10. Syafa'ah, Lailis. Agus, Eko, Minarno. ESP 8266 For Control and Monitoring In Smart Home Application. IEEE Access, 123-128, Indonesia (2019), doi: 10.1109/ICOMITEE.2019.8921287
11. Soni Dipa, Makwana Ashwin, A Survey on Mqtt: A Protocol of Internet Of Things (IoT). Gujarat India (2017), https://www.researchgate.net/publication/316018571