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WIRELESS CONTROL OF INDUSTRIAL LOADS

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Abstract— **The primary objective of this project is to simultaneously control both DC and AC loads. Specifically, we aim to regulate the speed of a DC fan and a DC motor, as well as adjust the intensity of an AC bulb. Traditional button-based control systems often lack sensitivity and require multiple buttons presses to navigate through options, making it difficult for users to locate the desired function. Our proposed universal remote control addresses these limitations by utilizing a MATLAB interface on a computer display. This Project approach provides a user friendly and efficient means of controlling devices. By leveraging a standardized wireless platform, we aim to offer a solution that is simple, reliable, cost-effective, and energy-efficient, suitable for a wide range of remote monitoring and control applications.**

The system comprises a microcontroller, input, and output modules. The microcontroller acts as a central control unit, mediating between the input and output components. Users interact with the system through a computer equipped with MATLAB software, which serves as a graphical user interface (GUI). The GUI enables users to control the bulb, DC fan, and DC motor by sending commands to the microcontroller. The microcontroller, in turn, processes these commands and executes the necessary control actions.

***Keywords*—MATLAB Software, GUI interface in MATLAB, Microcontroller, ZigBee Technology, TRAIC.**

I. INTRODUCTION

This paper presents a wireless automation system designed for controlling various industrial electrical loads such as DC motors, fans, and AC lamps using a MATLAB-based graphical user interface (GUI). The system utilizes a PIC16F73 microcontroller for processing control signals and driving the output loads. Communication between the PC and the embedded hardware is established using Zigbee modules, which provide a stable and efficient wireless medium.

To enhance safety and performance, the system incorporates opto-isolated TRIAC drivers for AC loads and transistor-based drivers for DC loads. A Zero Crossing Detector (ZCD) is used to ensure phase-synchronized switching of AC loads, reducing electrical noise and improving system reliability. Additionally, the system can be extended to include feedback mechanisms such as a tachometer for monitoring motor speed in real-time.

II. SYSTEM ARCHITECTURE

The system is designed as a wireless control framework that integrates both software and hardware components for managing industrial electrical loads. It is structured into two primary modules: a control interface and an embedded load management unit**.** The control interface is developed using MATLAB, where a GUI is designed to allow the user to interact with the system in real-time. This GUI transmits control signals in the form of serial data through a Zigbee transmitter module connected to the PC.

On the receiving end, the core of the embedded system is a PIC16F73 microcontroller**,** which interprets incoming serial data from the Zigbee receiver. Depending on the received command, the microcontroller activates specific output ports to operate connected loads. The microcontroller interprets these commands and controls the respective output drivers.

- **DC loads** (fan, motor) are controlled using NPN transistors (BC547).
- **AC loads** (lamp) are controlled through an opto-isolated TRIAC driver (MOC3011 + BT136).
- A **Zero Crossing Detector (ZCD)** is included for phase-synchronized AC switching.

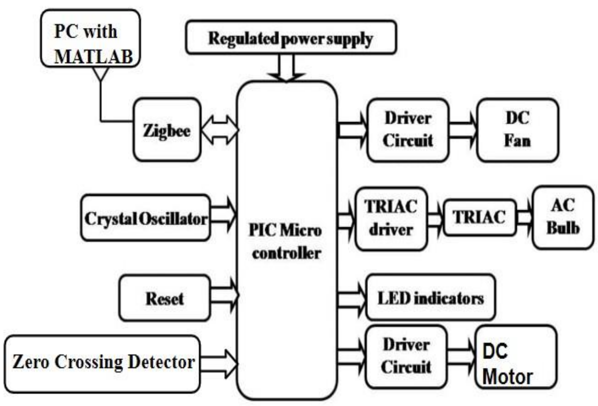

Fig. 1. Block Diagram

- **DC devices** such as motors and fans, driven through transistor-based switching circuits.

- **AC appliances**, such as incandescent bulbs, controlled via TRIACs, which are optically isolated using MOC series drivers for electrical safety.

A **Zero Crossing Detector (ZCD)** is incorporated to ensure AC load switching occurs at zero voltage levels, enhancing operational stability and reducing electrical noise. The architecture supports modular expansion, making it adaptable for additional loads or sensors in future enhancements. Its wireless nature eliminates complex wiring, making it suitable for both industrial automation and smart home applications.

III. Hardware Design

The hardware implementation is structured to enable seamless control of AC and DC loads using a centralized microcontroller unit. Th

e foundation of the system is the PIC16F73, a versatile 8-bit microcontroller that provides adequate I/O ports and built-in UART for serial communication. All peripheral components are organized around this controller to enable responsive and reliable load switching.

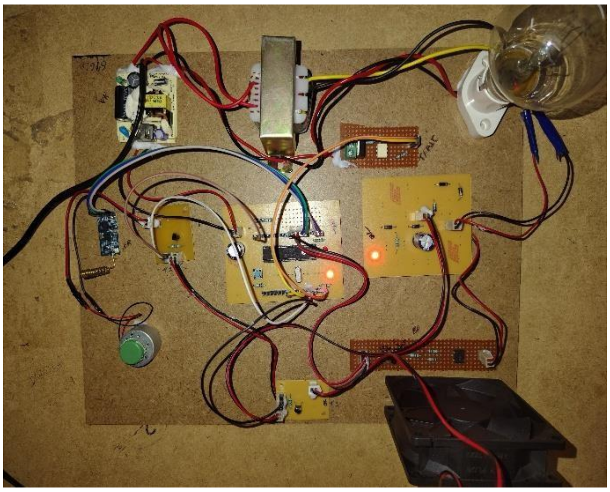

Fig. 2. Hardware Prototype

A. Power Supply Unit

A 230V AC mains supply is stepped down using a 12V transformer, followed by a bridge rectifier and smoothing capacitor to produce unregulated DC. A 7805-voltage regulator ensures a stable 5V DC output, which powers the microcontroller, Zigbee module, and logic-level circuitry.

B. Clock(Oscillator) and Reset Circuit

A 20 MHz crystal oscillator connected across the OSC1 and OSC2 pins of the PIC16F73 provides the clock signal necessary for internal timing operations. A pair of 22pF ceramic capacitors is used for frequency stabilization. A push-button reset circuit is tied to the MCLR pin via a 10kΩ pull-up resistor, allowing manual system restarts.

C. Wireless Communication

A Zigbee module is interfaced with the TX and RX pins of the PIC16F73 to receive serial commands from the MATLAB GUI. This module forms the backbone of the system's wireless communication, eliminating the need for physical cabling.

D. Load Switching Interface

- DC loads such as fans and motors are controlled via BC547 NPN transistors**,** which act as switches. When the base receives a high signal from the microcontroller, the transistor conducts and energizes the load.

- AC loads are switched using a TRIAC (BT136) controlled through an optically isolated TRIAC driver (MOC3011)**.** This setup prevents the microcontroller from direct exposure to high-voltage AC, enhancing safety

E. Zero Crossing Detector (ZCD)

To ensure that AC loads are triggered at the optimal point in the waveform, a Zero Crossing Detector circuit is implemented. It provides logic-level pulses to the microcontroller each time the AC voltage crosses zero, enabling precise TRIAC control and minimizing electrical noise.

IV. SOFTWARE IMPLEMENTATION

The software framework of the system is developed in two layers: the Graphical User Interface (GUI) on the control side and the firmware code running on the microcontroller. Together, they coordinate the wireless control and monitoring of industrial loads.

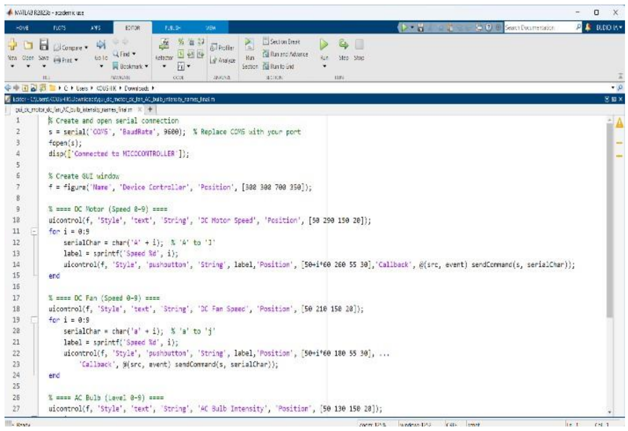

Fig. 3. MATLAB Code

A. MATLAB GUI Development

The Graphical User Interface (GUI) is created using MATLAB to provide a user-friendly control panel. It includes push buttons labelled for each load type:

- DC Motor Speed Control (A to J)
- DC Fan Speed Control (a to j)
- AC Bulb Intensity (0 to 9)

Each button triggers a callback function that sends a unique ASCII character to the serial port connected to a Zigbee transmitter. MATLAB's built-in serial object and print function are used to handle the data transfer. Additionally, a timer is configured to periodically check for incoming serial data (e.g., RPM feedback) and display it on the GUI.

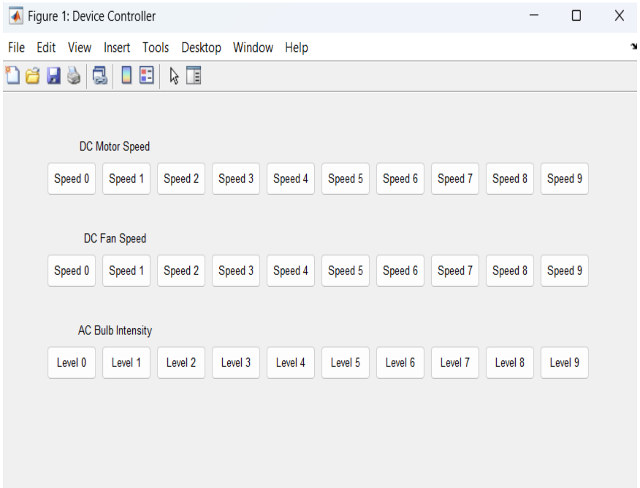

Fig. 4. MATLAB GUI

B. PIC Microcontroller Programming

The PIC16F73 is programmed in Embedded C using the MPLAB IDE with XC8 compiler. The firmware is designed to:

- Initialize UART for serial communication at 9600 baud.
- Continuously monitor the serial buffer for incoming commands.
- Match received characters with predefined control functions.

For example, characters A–J may represent different duty cycles or digital levels for controlling motor speed.

- Activate digital output pins to trigger transistor switches for DC loads or opto-isolated TRIAC drivers for AC loads.

For AC load timing, the firmware also includes an interrupt-driven Zero Crossing Detector (ZCD) input. This ensures that the TRIAC is fired only at zero-voltage points in the AC cycle, improving switching efficiency.

When RPM monitoring is enabled, the PIC counts pulses from a tachometer sensor over a one-second interval using timers and interrupts, calculates speed in RPM, and transmits this value back to MATLAB using UART.

This bi-directional communication between the GUI and microcontroller enhances both control and feedback, making the system responsive and interactive.

V. RESULTS AND DISCUSSIONS

The proposed wireless load control system was successfully designed, implemented, and tested. The integration of MATLAB GUI, Zigbee communication, and PIC16F73 microcontroller enabled seamless control of multiple electrical loads without the need for physical wiring between the controller and the end devices.

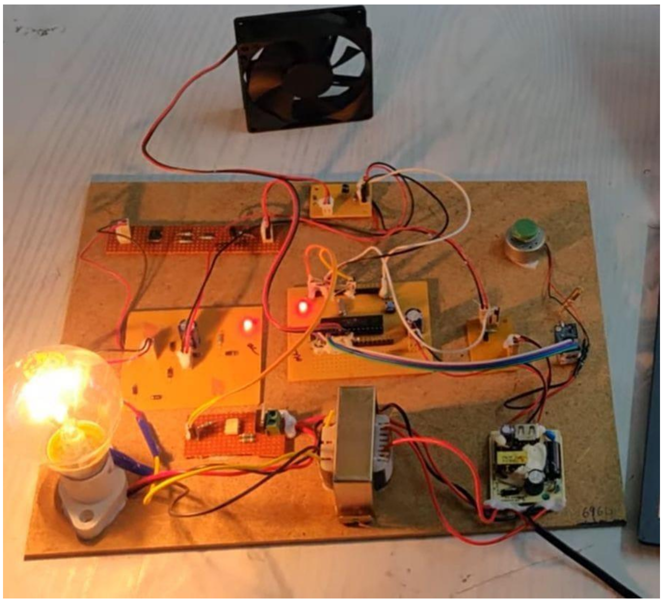

Fig. 5. OUTPUT

During testing, the following results were observed:

- **DC Motor and Fan Control**: The DC loads responded accurately to the speed commands issued from the GUI. Each button from 'A' to 'J' (motor) and 'a' to 'j' (fan) triggered the corresponding output at the microcontroller, switching the BC547 transistors effectively. The motor RPM increased proportionally with the selected speed level, confirming correct PWM logic and control flow.
- **AC Bulb Intensity Control**: The AC lamp exhibited proper brightness control corresponding to GUI inputs ('0' to '9'). The inclusion of the Zero Crossing Detector ensured stable and flicker- free switching of the TRIAC, and improved performance was evident in reduced power surges and audible noise.
- **Wireless Communication Range**: Zigbee modules provided a reliable wireless range of approximately **25–30 meters** in open space, with negligible delay in command reception. The system maintained stable communication without data loss or interference under typical indoor conditions.
- **Feedback Display**: When the tachometer circuit was connected, the calculated motor RPM was displayed in real time on the GUI. This

demonstrated effective bidirectional communication and system responsiveness.

- **Power Supply and Noise Performance**: Proper decoupling capacitors and regulated power ensured stable system operation. No unintended triggering or load flickering was observed, even when multiple loads were activated simultaneously.

The system performed consistently across multiple test cycles and demonstrated the practicality of combining microcontroller-based control with a MATLAB interface for industrial or smart-home automation applications.

VI. CONCLUSION

This paper presented the design and implementation of a wireless automation system for controlling industrial electrical loads using a MATLAB-based GUI and a PIC16F73 microcontroller interfaced with Zigbee modules. The system successfully demonstrated real-time wireless control of both AC and DC loads, including fan, motor, and bulb, with reliable switching and minimal delay.

The use of opto-isolated TRIACs for AC loads and transistor drivers for DC loads ensured safe and efficient operation. The integration of a Zero Crossing Detector improved the stability and quality of AC switching. Additionally, the optional inclusion of a tachometer feedback system added a monitoring capability, enhancing the practicality of the design.

The system proved to be modular, cost-effective, and scalable for various industrial or home automation applications. Future enhancements could include IoT integration, sensor-based automation, or mobile app control to further expand functionality and accessibility.

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