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Embedded Systems-Based AC Device Controller

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***Abstract*—The Embedded Systems-based AC Device Controller represents a multifaceted and intelligent apparatus devised to regulate the functioning of single-phase AC devices, including motors, lighting fixtures, and various electrical appliances, for a user-defined duration. This system is constructed around a microcontroller that automates the switching mechanism, thereby obviating the necessity for manual intervention. Users possess the capability to program the controller to activate a device for a predetermined duration such as one hour subsequently leading to its automatic deactivation. The fundamental operation is facilitated through the integration of a real-time clock (RTC), which furnishes precise timekeeping to ensure meticulous control over the operational duration. The system is designed for ease of configuration, enabling the user to establish diverse time intervals tailored to specific applications. It guarantees efficient energy consumption by precluding devices from remaining powered unnecessarily, thereby mitigating power wastage and enhancing operational safety. This attribute is particularly advantageous in contexts where timely regulation of appliances is imperative, such as in industrial automation, domestic appliances, and agricultural machinery. Moreover, the controller can be modified to accommodate various load types and power ratings, rendering it a versatile solution for a wide array of use cases. This AC device controller enhances convenience and energy efficiency and offers a safer, more trustworthy alternative to conventional manual switching systems by providing dependable and automated control.**

***Keywords*—Embedded Systems, AC Device Controller, Microcontroller, Timed control.**

I. Introduction

The escalating requirement for automation and energy-conserving solutions within both residential and industrial domains has precipitated the advancement of intelligent device controllers. Among these technological advancements, an Embedded Systems-based AC Device Controller assumes a pivotal position by providing accurate regulation of single-phase AC devices, including motors, lighting systems, and various other electrical apparatuses [1, 2]. This controller facilitates the automation of the operation of such devices for a specified temporal duration, thereby ensuring their activation and deactivation occur without necessitating manual intervention.

At the core of this system resides a microcontroller, meticulously programmed to oversee the temporal management and regulation of the interconnected devices. Through the integration of a real-time clock (RTC), the controller is capable of precisely tracking and sustaining the operational intervals, thereby facilitating exact timing for the initiation and cessation of the devices [3]. This capability is particularly advantageous in contexts where the devices must operate for defined durations, such as in irrigation systems, domestic appliances, or industrial machinery [4].

The primary advantage of this system is its ability to conserve energy by preventing devices from operating longer than necessary. Moreover, it enhances safety by reducing the risk of overheating or electrical faults due to prolonged usage. The Embedded Systems-based AC Device Controller thus serves as a practical and reliable solution for managing power and improving the overall efficiency of AC-powered devices in various environments [5].

II. Materials Required

In this study, we utilized several essential components to build and test the system. These components include:

- PIC Microcontroller (PIC16C72A)
- Push Buttons
- Transistor
- DC Power Supply
- Relay
- PCB Board
- 7 Segment display
- Capacitor
- Oscillator
- LEDs
- Terminal blocks

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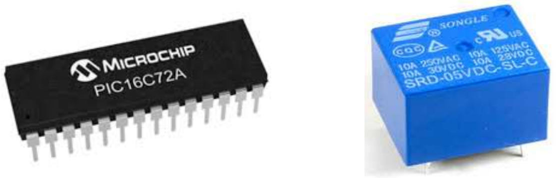

(a) (b)

Fig. 1. Some of the components (a) PIC16C72A, (b) Relay 5V.

Some of these components are highlighted in Fig. 1, including the PIC16C72A and the 5V Relay [6].

III. METHODOLOGY

The methodology for designing and implementing the Embedded Systems-based AC Device Controller involves several key stages, from hardware setup to software development, ensuring the efficient control of single-phase AC devices [6]. The following steps outline the approach:

A. Component Selection and Circuit Design

The undertaking commences with the selection of the PIC16C72A microcontroller as the fundamental component, tasked with the regulation of timing and switching operations [7]. The circuit is meticulously engineered to incorporate several essential components, including a 5V DC power supply to energize the microcontroller and ancillary elements, push buttons to facilitate user input, a 7-segment display to provide visual feedback, and a relay to oversee the management of the AC load [7]. Resistors, transistors, capacitors, and terminal blocks are integrated to guarantee appropriate signal conditioning, switching functionality, and comprehensive circuit protection. An external oscillator is interfaced with the microcontroller to deliver precise clock signals necessary for its internal timer functionalities. Furthermore, LEDs are employed to signify the status of the system, such as power on/off and operational states of the device, thereby providing unequivocal visual feedback throughout the system's operation.

B. Circuit Assembly

All components are mounted on a Printed Circuit Board (PCB), ensuring the system's compactness and reliability. The relay is connected to the AC device, enabling the microcontroller to control the device by switching it on and off according to user-defined timing settings, ensuring precise and automated operation of the AC load.

C. Programming the Microcontroller

The PIC16C72A microcontroller is programmed using embedded C language, leveraging its built-in timers to handle time-based operations. A push button is configured to enable the user to set the desired duration (e.g., 1 hour), after which the microcontroller activates the relay to turn on the AC device[8]. Once the specified duration elapses, the microcontroller automatically switches off the device. Meanwhile, the 7-segment display provides real-time feedback by showing the remaining time for which the device will stay on, offering a clear and continuous update on the countdown timer.

D. Testing and Validation

Once assembled, the system undergoes testing by simulating various operation times to ensure that the relay controls the AC device according to the preset durations. The accuracy of the countdown timer and relay switching is validated through multiple test cycles, with adjustments made to the program as necessary. Additionally, safety tests are conducted to confirm that the system can reliably handle the switching of high-power AC devices and effectively prevent overloading, ensuring the system's robustness and safe operation equations are an exception to the prescribed specifications of this template.

E. System Integration and Final Deployment

After successful testing, the system is integrated into the target environment, such as industrial or home appliance control applications. Final calibrations and adjustments to the user interface are made to optimize performance and ensure ease of use. With these refinements complete, the device controller is fully prepared to automate AC devices for time-bound operations, providing efficient and reliable control in its intended setting equations are an exception to the prescribed specifications of this template.

IV. WORKING PRINCIPLE

A. Block Diagram

The block diagram explains the working of the project as follows: The AC load is connected to the AC unit and is controlled through a relay. The relay is operated by the microcontroller, which manages the timing and switching operations. User input is provided through four push buttons. The remaining time is displayed on a 7-segment display, providing real-time feedback on the duration for which the AC load will stay (see Fig.2).

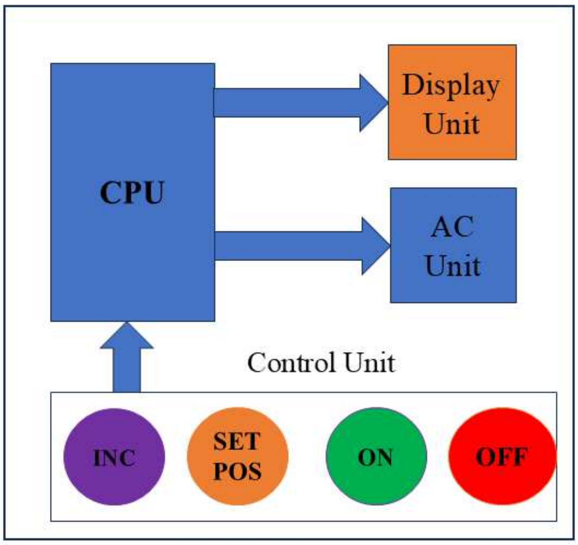

Fig. 2. System Architecture of AC Device Controller.

This AC load controller is designed for versatile applications, including household settings. In this design, an additional button (CH) and four relays allow users to control separate devices within a room. The CH button lets users switch between relays to manage individual devices effectively. For example, if relay 1 is active and the user wants to activate relay 2, they can press the CH button to select relay 2 and set its operation time [9,10,11]. Once set, all processes continue as shown in Fig. 3. This flexible setup enables users to manage multiple appliances with ease, tailoring control to their specific needs.

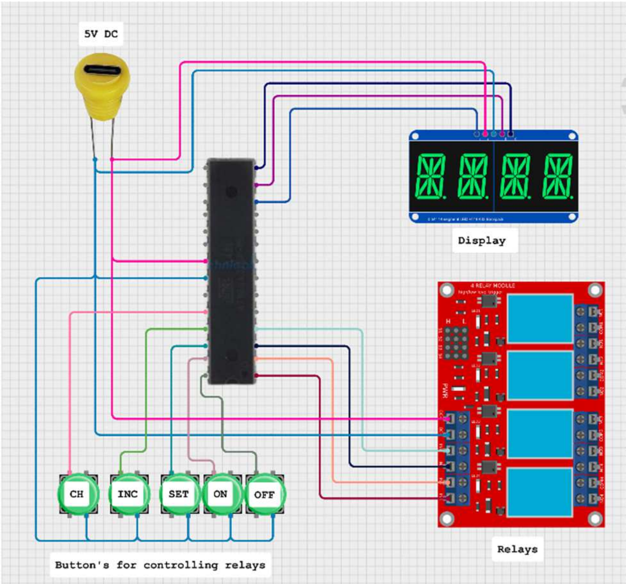

Fig. 3. System Architecture of AC Device Controller for household appliance.

Another design variation, intended for heavy-duty or high-current applications, incorporates magnetic contactors into the circuit, as shown in Fig. 4. This addition enables the controller to handle higher current loads safely and efficiently [12].

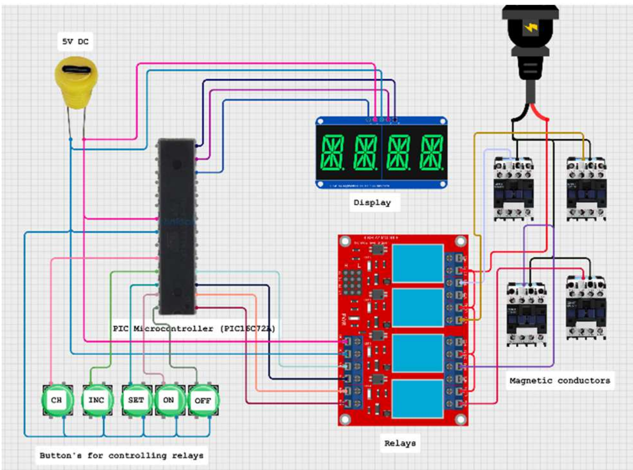

Fig. 4. System Architecture of AC Device Controller for high current using area using magnetic conductors.

B. Circuit Diagram

The schematic representation of the circuit delineates the operational functionality of the project as follows: The principal computational unit employed in the project is the PIC16C72A microcontroller, which orchestrates all procedural functions. The buttons function as the user interface for the system, enabling users to configure and regulate the operation of the air conditioning unit. The circuit encompasses a dual-digit seven-segment display that indicates the remaining operational duration of the air conditioning unit (refer to Fig. 5).

- Increment (INC) Button: Increases the displayed value from 0 to 9.
- Set Position (SET POS) Button: Sets the position of the number on the display, allowing users to input the first and second digits of the time duration.
- ON Button: Activates the system. Once pressed, the relay is turned on, and the seven-segment display shows the set value. The relay remains on for the duration displayed (e.g., 32 minutes).
- OFF Button: This button off the system in any emergency situation.

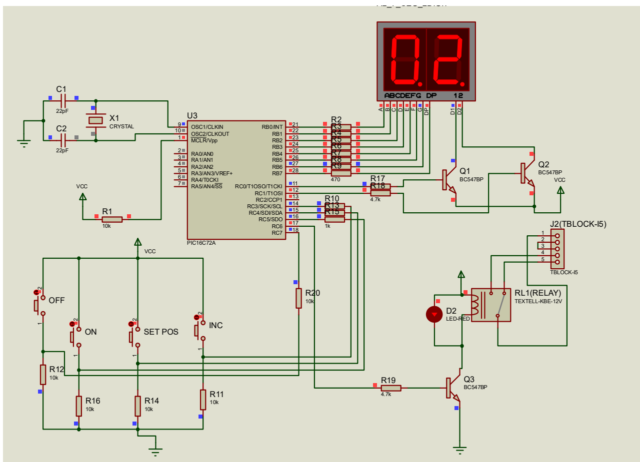

Fig. 5. The Circuit Diagram of the AC device controller.

As time elapses, the display decreases from 32 down to 0, and once the countdown reaches zero, the relay is automatically turned off. This process ensures that the AC unit operates for the user-defined period and then shuts off as required.

V. Result and Discussion

The AC Device Controller, which is predicated on Embedded Systems, successfully accomplished its intended objectives, thereby illustrating proficient regulation over a single-phase AC load through the utilization of the PIC16C72A microcontroller. The system exhibited consistent reliability, with the microcontroller overseeing the timing and relay functionalities to govern the AC load in accordance with specifications established by the user [13]. The operational integrity of the push buttons, namely INC, SET Pos, and ON, was affirmed: the INC button effectively increased the displayed value, the SET Pos button facilitated the configuration of digit placements, and the ON button was responsible for activating the relay [14]. The 7-segment display precisely conveyed the countdown corresponding to the predetermined duration (e.g., 32 minutes), with the relay disengaging accurately at the moment the countdown reached zero. The system underwent testing over protracted durations, thereby substantiating its dependability in regulating the AC load without any operational failures, as illustrated in Fig. 6.

The project effectively illustrated the pragmatic utilization of embedded systems for the automated regulation of alternating current devices, thereby offering a robust and dependable solution. The intuitive user interface, along with its accurate timing and countdown functionalities, facilitated efficient operation and user-friendliness. The system's capacity to safely manage high-power alternating current devices was validated through comprehensive testing, emphasizing its dependability and safety. The successful incorporation of user feedback via the 7-segment display and precise relay functionality accentuates the efficacy of the design. Prospective enhancements may encompass wireless control alternatives or more sophisticated user interfaces to further augment the system's capabilities and convenience.

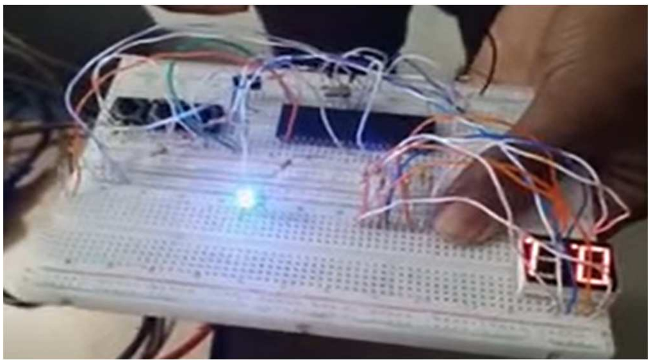

Fig. 6. Real-time testing of AC device controller.

VI. CONCLUSION

The project centered on the Embedded Systems-based AC Device Controller proficiently illustrates the assimilation of a PIC16C72A microcontroller for the accurate and automated management of single-phase AC loads. The system adeptly regulates the AC load in accordance with user-specified time intervals, exhibiting dependable performance alongside precise countdown capabilities. The user interface, which incorporates push buttons and a 7-segment display, ensures transparent and intuitive control and feedback, thereby rendering the system both user-centric and effective in real-world applications. The dependable functioning of the relay, coupled with its capacity to manage high-power AC devices without complications, highlights the project's accomplishment in fulfilling its design objectives.

Future enhancements for this project may encompass the integration of wireless control functionalities, thereby enabling users to manage the air conditioning load remotely through smartphones or alternative devices. Furthermore, the incorporation of sophisticated user interfaces, such as touchscreens or graphical displays, could significantly augment user interaction and operational control. The expansion of the system to accommodate multiple air conditioning loads or the integration of programmable schedules for automated functioning could enhance its adaptability and applicability across diverse environments. The implementation of supplementary safety measures and performance enhancements could also bolster the system's reliability and efficiency, rendering it suitable for more rigorous industrial or residential applications.

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