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Design and Implementation of Microcontroller based Borewell Timer

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Abstract: *This paper presents an intelligent time-based control system for borewell motors to address the challenge of water wastage and unregulated groundwater extraction. In many industrial and agricultural setups, borewell motors are operated without adequate monitoring, resulting in tank overflows, energy loss, and excessive water consumption. The proposed system introduces a microcontroller-based automation framework that limits motor operation to a pre-calibrated duration per day, aligned with a total daily extraction capacity of 25 kL according to industrial demand. The system supports real-time monitoring, countdown tracking, and pause/resume operations, thereby ensuring equitable water distribution among multiple sectors. Implemented on the STM32F103C8T6 microcontroller with an RTC module, relay control, and digital display interface, the solution offers high processing speed, industrial-grade precision, and low power consumption. Test results confirm the system's reliability, accuracy, and suitability for continuous 24/7 operation in water-stressed regions. The approach is scalable and cost-effective, contributing to sustainable water management practices.*

Keywords: *Borewell Timer, STM32F103C8T6, Water Conservation, Automation, RTC Module, Relay Control.*

I. INTRODUCTION

Water scarcity has emerged as a critical challenge in both industrial and agricultural sectors, driven by rapid urbanization, population growth, and climate variability. In many regions, groundwater serves as the primary source for daily operations, with borewells providing a convenient yet often overexploited means of extraction. Excessive and uncontrolled pumping of groundwater has led to a continuous decline in water tables, aquifer depletion, and increased pumping costs.

According to a recent global assessment, in situ groundwater-level trends from over 170,000 monitoring wells and 1,693 aquifer systems—covering approximately 75% of global groundwater withdrawals—indicate that rapid declines (>0.5 m year⁻¹) are widespread in the twenty-first century, particularly in arid agricultural regions. Alarming, groundwater-level declines have accelerated over the past four decades in nearly 30% of the world's regional aquifers, underscoring the urgent need for efficient extraction control mechanisms.

In industries and agricultural setups where water consumption is regulated—such as a fixed daily quota of 25 kL—manual tracking of borewell usage is both inefficient and error-prone. Dependence on human operators for monitoring often results in inconsistent operation schedules, tank overflows, and wastage of a limited resource. Furthermore, non-compliance with governmental or environmental regulatory limits can lead to penalties and strained sustainability metrics.

Traditional timer-based control systems are often rigid, lacking real-time adaptability to varying flow rates and operational needs. In contrast, automated solutions offer the potential for precise control, optimized usage, and integration with monitoring systems.

This paper proposes a microcontroller-based automated borewell timer system designed to allocate a fixed operational duration to each sector, determined by the storage tank capacity and measured flow rate. The system integrates a Real-Time Clock (RTC) for accurate timekeeping, relay-based motor control for direct actuation, and a display module for real-time usage indication. Upon reaching the preset daily limit, the system initiates an automated shutdown sequence, preventing further extraction and ensuring compliance with water usage policies.

The main contributions of this work are as follows:

- 1) Development of a low-cost, standalone microcontroller-based borewell timer for regulated water usage.
- 2) Implementation of precise daily limit enforcement using RTC-based control logic.
- 3) Relay-actuated motor control with real-time user feedback through a 7-segment display interface.

The proposed solution not only reduces human intervention but also enhances operational efficiency, conserves water, and enables scalable integration with future IoT-based monitoring platforms for remote management and data logging.

II. RELATED WORK REVIEW

In [1], a simple water level alarm circuit was designed using a 555 timer integrated circuit configured as an astable multivibrator. The circuit triggered an audible buzzer once the water in an overhead tank reached a predefined probe level, thereby alerting the user and preventing overflow. The design was low-cost and effective for domestic and small-scale applications, since the output oscillations and alarm were directly dependent on the presence of water at the probe.

Automatic control of a 3-ph submersible motor is proposed in [2], where the AT89s52 a low power high performance CMOS 8-bit microcontroller with 8k bytes of in system programmable flash memory. The device is manufactured using Atmel's high-density nonvolatile memory technology and is compatible with the industry standard 80C51 instruction set and pin out. The on chip flash allows the program memory to be reprogrammed in system or by a conventional nonvolatile memory programmer. Additionally, it has a relay block that can drive the 3-phase motor or submersible motor. In this we are using relays for controlling the wire based sensor is sensed to delivery pipe.

Output signal from 89s52 is given to pull up register through ULN2003 and than the further energizing relay.

In [3], the authors proposed a programmable auto-switch for three-phase agricultural motor control, employing a ATmega328 microcontroller as the central unit. The system integrated a Real-Time Clock (RTC) to enable precise scheduling of motor operation according to user-defined time slots. To enhance reliability, scheduling data was stored in EEPROM memory, ensuring that programmed settings were retained even during power outages. The design also incorporated phase-presence detection to safeguard the motor against single-phasing conditions, a common issue in rural electricity supply. Furthermore, the system was equipped with a GSM module, which provided remote notifications to users regarding motor status and operating schedules. This added a layer of convenience by alerting farmers in case of failures or abnormal conditions.

The authors in [4] presented a microcontroller-based automatic pump controller designed to simplify water pumping operations in household and agricultural contexts. The system employed ultrasonic sensors to monitor tank water levels and an RF communication link between the monitoring and pumping units, enabling wireless status updates and control. An integrated Real-Time Clock (RTC) facilitated programmable scheduling, allowing pumps to operate automatically within predefined time slots. This approach effectively prevented overflow, optimized water delivery, and reduced unnecessary energy consumption associated with continuous manual operation.

In [5], the authors implemented a real-time clock system by interfacing an STM32 microcontroller with the DS1302 RTC chip. The DS1302 is a low-power, serial-interface clock capable of tracking seconds, minutes, hours, dates, months, and years, with leap year compensation valid up to 2100. It operates with an external 32.768 kHz crystal oscillator for stable timekeeping and supports backup power for continuous operation. Communication between the STM32 and DS1302 was achieved through a three-wire serial interface, where RST selects command or data modes, SCLK synchronizes transfers, and the I/O pin handles data input/output. The design highlighted the chip's wide operating voltage range (2.5–5.5 V) and its extremely low power consumption, making it suitable for long-term, battery-backed applications. While the work successfully demonstrated accurate timekeeping through STM32–RTC integration, it was limited to time display and tracking, without extending functionality to motor control or water usage regulation.

In [6], an automatic watering system model was developed using an Arduino Uno R3 as the controller, interfaced with a soil moisture sensor and a raindrop sensor. The system regulated a solenoid valve and water pump to supply water only when soil moisture dropped below a threshold and no rainfall was detected. Additional manual and timer-based control options were included for reliability. The design proved effective in conserving water and reducing manual intervention, making it suitable for agricultural applications.

The authors in [7] presents a digital timer using a 555 timer, 74LS192 counter, SN74LS47 decoder, and 7-segment display. The initial design caused the buzzer to ring indefinitely after countdown completion. Improvements included adding a music chip, then a monostable multivibrator (74LS123) to limit buzzer duration, and finally synchronizing reset signals for stable automatic operation.

In [8], the authors present the development of a precise and efficient DC motor control system. The STM32 microcontroller serves as the core controller, leveraging its advanced timers and PWM capabilities to regulate motor speed. The design incorporates a closed-loop feedback mechanism using sensors to monitor real-time speed and adjust PWM duty cycles accordingly. Simulation and hardware validation demonstrated that the system achieved stable speed regulation, quick response, and robustness against load variations, making it suitable for industrial and automation applications.

The paper in [9] presents an IoT-based borewell monitoring system aimed at automating the measurement and management of groundwater usage in agriculture. The system integrates Arduino Uno, NodeMCU, water level sensors, water flow sensors, relays, and an LCD display to continuously monitor borewell conditions. Parameters such as water availability, quantity of water extracted, and leakage in pipelines are measured with high accuracy.

The data is displayed locally on an LCD and remotely through the Blynk mobile application, enabling farmers to monitor borewell status in real-time. The automation reduces manpower, minimizes uncertainty regarding water resources, and enhances decision-making for irrigation. The system thus provides a cost-effective, user-friendly solution for efficient water management in farming practices.

The project in [10] presents the design and implementation of an IoT-based system for controlling and protecting borewell motors used in agricultural irrigation. The proposed Automated Motor Starter Unit (AMSU) integrates an Arduino Pro Mini (ATmega328), GSM module, relays, and sensors to provide remote monitoring and control via mobile application or SMS. The system allows farmers to start/stop motors, schedule operations, and receive power status updates from remote locations. Key protection features include prevention of dry running, overload detection, single-phase tripping, and automatic shutdown under fault conditions. Testing results show reliable operation with instant status feedback and fault detection. The innovation lies in combining GSM-based remote control with IoT-enabled safety mechanisms, thereby reducing manual intervention, protecting motors from damage, and improving irrigation efficiency. Future scope includes integration with IoT cloud platforms, renewable energy sources, and advanced sensor-based performance monitoring.

The paper [11] presents the design and implementation of a real-time clock (RTC) system using the Arduino Uno and DS3231 RTC module. The system ensures precise and reliable timekeeping by leveraging the DS3231's temperature-compensated crystal oscillator, which minimizes time drift. A 20x4 LCD is used for displaying date and time, while the Arduino manages data retrieval and display via the I²C communication protocol. The setup is tested under different environmental conditions, demonstrating high accuracy, battery backup reliability, and ease of integration. Applications of this system include smart home automation, data logging, scheduling, and AI-driven embedded solutions where dependable time management is crucial. The study concludes that RTC modules like DS3231, when paired with microcontrollers, form a cost-effective and efficient foundation for real-time embedded systems.

III. METHODOLOGY

The design and construction of the microcontroller-based automatic water pump controller takes several planned steps that were necessary to achieve a good and reliable monitoring system. The methodology adopted for this work is represented by the block diagram in **Fig. 1**, which illustrates the major hardware and software components of the system and their interactions.

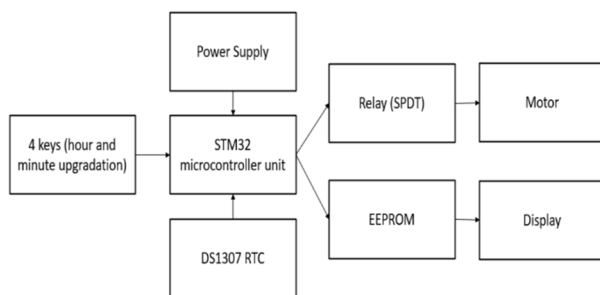


Figure 1 Block Diagram of the system.

IV. UNIT DESCRIPTION

A. Power Supply

This block provides a regulated 5V DC supply to the microcontroller unit, EEPROM module, RTC module and the display while 12V DC to the SPDT relay. While provides 230V AC to motor.

B. Microcontroller unit

This block consists of STM32F103C8T6 microcontroller which serves as the brain of the system. The microcontroller serves as the core processing unit of the system, coordinating timing, relay control, and display operations. It features industrial-grade precision with advanced 16/32-bit hardware timers for accurate countdown and scheduling, and a 72 MHz ARM Cortex-M3 core that ensures high-speed real-time task handling without lag. With support for multiple peripherals (RTC, relays, 7-segment/LCD) through built-in communication interfaces such as I²C, SPI, and UART, the MCU provides seamless integration. Its low power consumption, compact architecture, and cost-effectiveness make it highly suitable for continuous 24/7 industrial deployment.

C. Keys/ Push Buttons

The system includes manual input keys that allow the operator to adjust the motor runtime as required. It includes 4 keys – 2 each for ‘hour’ increment/decrement and ‘minute’ increment/decrement. This provides precise and user-friendly control over timer adjustments without modifying the program code.

D. DS1307 RTC module

The RTC (DS1307/DS1302) is responsible for accurate timekeeping and provides information on seconds, minutes, hours, days, months, and years, including leap year compensation. It communicates with the microcontroller over an I²C or 3-wire serial interface and maintains time even during power failures using a backup battery. The RTC module employs a 32.768 kHz external crystal oscillator, which ensures long-term stability and precise timing. Its extremely low power consumption allows continuous operation over extended periods, making it ideal for 24/7 water management systems.

E. Relay

The relay block is responsible for switching the borewell motor ON and OFF based on the control signals from the microcontroller. A 12 V DC Single-Pole Double-Throw (SPDT) relay is used, which provides both normally-open (NO) and normally-closed (NC) contacts, allowing flexible control of the motor circuit. Since the microcontroller cannot directly drive the relay, a transistor is employed to amplify the control signal and energize the relay coil. When activated, the relay establishes a safe interface between the low-power control circuit and the high-power motor load, ensuring reliable operation under continuous usage.

F. EEPROM module

To ensure that the user-defined time settings are retained even during power interruptions, the system integrates an FM24C64 EEPROM module. The FM24C64 is a 64-Kbit non-volatile memory device that uses ferroelectric RAM (FRAM) technology, offering high endurance and fast read/write operations compared to conventional EEPROM. It communicates with the microcontroller over an I²C serial interface, making it simple to integrate with existing circuitry. The stored timer values are automatically recalled at system startup, eliminating the need for reconfiguration after every power cycle. Its low power consumption and virtually unlimited write cycles make it highly reliable for continuous 24/7 borewell timer applications.

G. Motor

The output of the relay drives the motor pump, which delivers water to the storage tank. Automatic cutoff ensures that the motor stops once the preset time or daily water limit is reached.

H. Display

The system employs a 4-digit 7-segment display to present the motor runtime in hours and minutes (HH:MM format). The display is directly controlled by the microcontroller, which continuously updates the digits through multiplexing to ensure stable and flicker-free operation. User-defined timer settings are stored in the FM24C64 EEPROM module, allowing the microcontroller to retrieve and display the stored time values even after power interruptions. This provides operators with real-time visual feedback of the countdown and ensures that configured settings are retained reliably across multiple operating cycles.

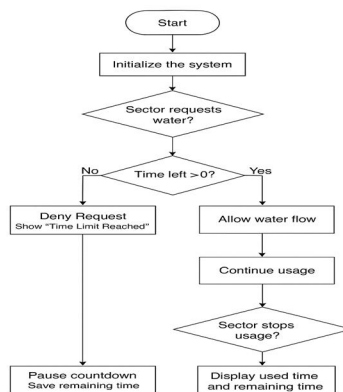


Figure 2 Flowchart of the system.

V. WORKING

- 1) System Initialization
 - o The system powers on and starts the main control loop.
- 2) Time Acquisition
 - o Reads real-time clock (RTC) to fetch the current time.
- 3) User Configuration
 - o User sets the desired motor start and stop time using keypad/buttons.
 - o Settings may include duration, days of operation, or manual start/stop.
- 4) Time Comparison Logic
 - o The microcontroller continuously compares current time with the configured start time.
- 5) Decision Making
 - o If it matches the start time, the motor is started by activating the relay.
 - o If not, the motor remains off.
- 6) Relay Control
 - o A relay is switched ON to supply power to the motor.
 - o Relay acts as an electronic switch.
- 7) EEPROM Updates
 - o System may read or write settings to EEPROM (non-volatile memory).
 - o Ensures persistent data across restarts.
- 8) Display Feedback
 - o Real-time status is shown on a 7-segment display.
 - o Users can see time, motor state, or other alerts.
- 9) Looping or Termination
 - o The system continues checking time and performing actions based on user settings.
 - o May run continuously or terminate based on program logic.

VI. SYSTEM DESIGN AND DEVELOPMENT

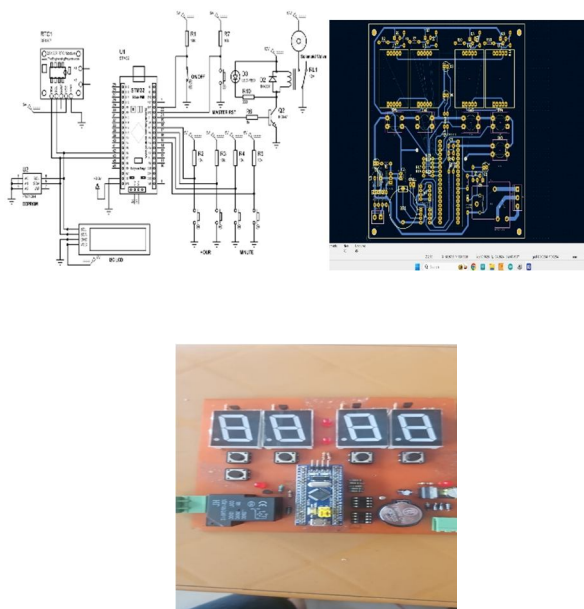


Figure 3 Initial Design of the system.

The initial design phase involved circuit simulation, schematic drafting, PCB layout generation, and prototype assembly. Figure 3 illustrates the progressive development of the system. The first image shows the complete circuit schematic developed in Proteus, consisting of the microcontroller, RTC module, EEPROM, and relay driver circuitry. The second image presents the PCB layout design, highlighting optimized component placement and routing for compact implementation and minimal noise interference. The third image shows the fabricated prototype hardware, featuring a 4-digit 7-segment display for real-time countdown visualization, tactile keys for manual time adjustment, and a 12 V DC relay for motor control. This prototype served as the functional validation model for the proposed automated borewell timer.

VII. RESULTS

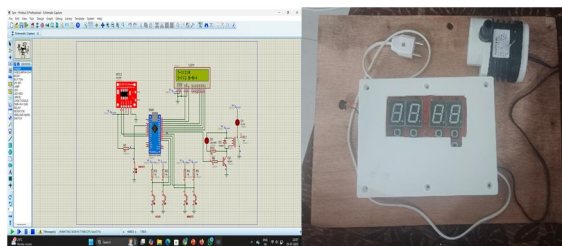


Figure 4 Result of the system.

- 1) The RTC-based borewell timer system was successfully simulated and verified in Proteus 8, demonstrating correct coordination between the STM32 microcontroller, RTC, EEPROM, relay driver, and display modules.
- 2) The DS1307 RTC module provided precise and stable real-time clock pulses, enabling accurate countdown and automated motor control sequences.
- 3) The 4-digit 7-segment display correctly showed the current time, scheduled start time, and active duration for each tank or sector, ensuring clear visual feedback.
- 4) The relay driver circuit functioned reliably, with the 12 V SPDT relay energizing precisely at the set start time and de-energizing automatically after the programmed duration, confirming effective timing control.
- 5) The flow indicator LED accurately reflected pump activity — illuminating when the relay was active and turning off immediately after deactivation, validating proper operational status indication.
- 6) The Hour and Minute set keys allowed users to configure time settings easily, with changes being stored in the EEPROM to retain configurations even after power interruptions.
- 7) Overall, both simulation and hardware testing confirmed stable, repeatable operation, achieving accurate timing, seamless automation, and minimal human intervention.

VIII. CONCLUSION

The designed system successfully achieved its objective of automating water flow control based on real-time scheduling. The integration of the RTC (DS1307) with the Arduino/STM32 microcontroller ensured highly accurate and reliable timekeeping, which is essential for consistent daily scheduling. The 7-segment display interface provided clear and continuous real-time feedback of system parameters, including current time and motor runtime, while the EEPROM (FM24C64) effectively preserved user-configured settings during power interruptions.

Experimental verification confirmed that relay switching operations were precise, safe, and robust, enabling secure control of external devices such as water pumps or solenoid valves. The overall system demonstrated stable performance, minimal timing deviation, and high operational efficiency under varying load conditions.

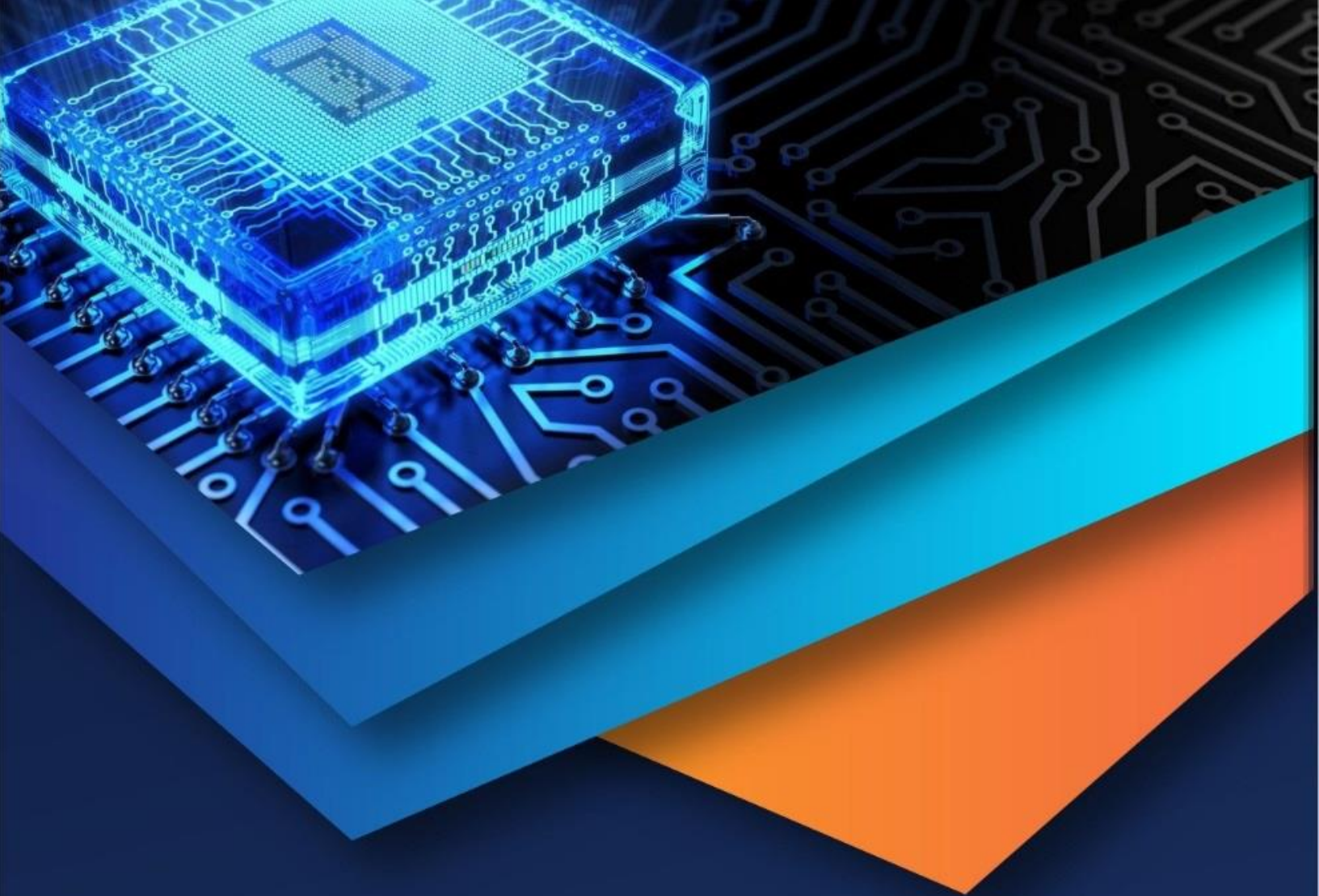
This design can be effectively implemented in automatic water distribution, irrigation management, and industrial scheduling systems, where controlled daily water usage is essential. Future enhancements may include IoT-based monitoring, remote control via Wi-Fi or GSM, and flow sensor feedback integration for volume-based automation and cloud data logging.

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