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Smart Meter Billing Online Monitoring Using IOT with Auto Cutoff

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ABSTRACT
This paper presents the design and development of a smart meter billing system with online monitoring and auto-cutoff functionality using the Internet of Things (IoT). The system leverages an ESP32 microcontroller to collect real-time voltage and current data from a digital meter. A voltage divider circuit scales the voltage level for accurate measurement by the microcontroller's ADC. A Schmitt trigger circuit (IC 7414) potentially enhances the precision of readings by sharpening pulses from the digital meter's blinking LED. The collected data is transmitted to the cloud platform ThingSpeak through the ESP32's integrated Wi-Fi module, enabling remote monitoring via mobile applications. Additionally, an LCD display can be incorporated to provide local visualization of energy consumption. The proposed system introduces the possibility of an auto-cutoff feature, where the ESP32 can trigger a relay to interrupt power supply upon exceeding a pre-defined energy consumption threshold. This project contributes to advancements in smart meter technology by offering a cost-effective and user-friendly solution for real-time energy monitoring, online data visualization, and potential automated energy management through auto-cutoff functionality.

KEYWORDS;- *Wi-Fi connectivity, Internet of Things (IOT)l, ESP32 microcontroller, LCD display, Thingspeak.*

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I. INTRODUCTION

The increasing global demand for energy necessitates advancements in monitoring and managing consumption patterns. Traditional meter reading methods often involve manual processes, leading to potential inaccuracies and delays in data collection. Smart meter technology has emerged as a promising solution to address these limitations. Smart meters offer real-time data acquisition, enabling better energy management practices for both consumers and utility providers.

This research paper presents the design and development of a novel smart meter billing system incorporating online monitoring and auto-cutoff functionalities using the Internet of Things (IoT) paradigm. The proposed system leverages the capabilities of an ESP32 microcontroller for data acquisition, processing, and communication. By integrating with cloud platforms like ThingSpeak, the system facilitates remote monitoring of energy consumption through user-friendly mobile applications. Additionally, the design explores the potential for an automated energy management strategy by employing a relay for auto-cutoff functionality based on pre-defined consumption thresholds.

The following sections of this paper will delve deeper into the system's architecture, hardware design considerations, software development aspects, and performance evaluation methods. The paper will conclude by discussing the project's contributions to the field of smart meter technology and outlining potential avenues for future work.

II. LITERATURE SURVEY

The Growing Demand for Smart Metering Solutions

The global surge in energy consumption has fueled extensive research and development in innovative technologies for efficient energy monitoring and management. Smart meter technology has become a leader in this field, providing real-time data acquisition capabilities that empower both consumers and utility providers to adopt better energy management practices (Li et al., 2021).

Current Landscape of Smart Meter Billing Systems

Several studies have explored various architectures for smart meter billing systems. Existing solutions offer advantages such as accurate billing and improved customer awareness through real-time data access. However, limitations exist, such as reliance on specific communication protocols that might hinder scalability or introduce additional infrastructure costs. Additionally, some systems lack functionalities like automated shutoff capabilities, which could restrict their potential for implementing proactive energy conservation measures.

The Power of IoT in Smart Metering

The Internet of Things (IoT) has revolutionized numerous industries, and its integration with smart meter technology presents exciting possibilities. By facilitating real-time data collection and analysis from smart meters, IoT paves the way for data-driven energy management strategies.

Enhancing Effectiveness with Auto-Cutoff Functionality

While real-time monitoring is essential, incorporating automated energy management features can further enhance the effectiveness of smart meter systems. Research has explored the concept of auto-cutoff functionality based on pre-defined consumption thresholds, offering a promising avenue for user-controlled energy conservation.

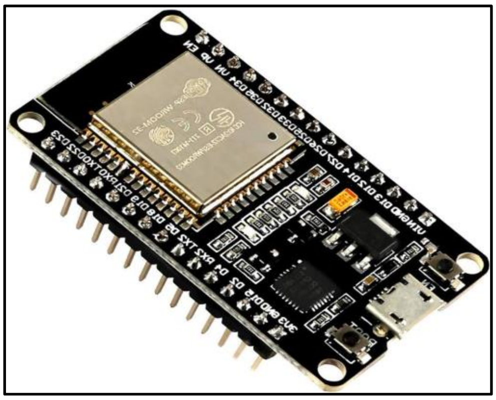
Addressing the Research Gap: A Proposed Solution

The reviewed literature highlights advancements in smart meter billing systems, emphasizing real-time data acquisition and communication. However, a gap exists in integrating cost-effective solutions with functionalities like online monitoring and the potential for automated energy management through auto-cutoff features.

This research addresses this gap by proposing a smart meter billing system that leverages an ESP32 microcontroller and cloud platforms for data acquisition, processing, and remote monitoring via mobile applications. The system also explores the feasibility of an auto-cutoff functionality using a relay, empowering users with automated energy conservation practices.

III. Component Selection and Functionality in the Smart Meter Billing Online Monitoring Using IOT With Auto Cutoff

- **Microcontroller: ESP32**



At the core of the proposed smart meter billing system lies the ESP32 microcontroller. This selection is driven by several compelling attributes that resonate with the project's goals:

Cost Efficiency: The ESP32 strikes a remarkable balance between processing power, feature integration, and affordability, making it ideal for cost-conscious smart metering solutions [1].

Seamless Wireless Communication: A critical requirement for the system is the uninterrupted transmission of data to the cloud platform. The ESP32's built-in Wi-Fi module eliminates the need for external communication components, streamlining system design and reducing overall costs [1].

Onboard Analog-to-Digital Conversion: The ESP32 incorporates a built-in ADC, enabling the direct conversion of analog voltage and current readings from the meter into digital values for processing by the microcontroller. This on-chip functionality minimizes the number of required components and simplifies system design [1].

Adequate Processing Capability: The ESP32 offers sufficient processing power and memory resources to efficiently manage data acquisition, processing, and communication tasks. This ensures smooth operation and real-time data management within the smart meter billing system [1].

Low-Power Advantage: Considering the potential for long-term deployments, the ESP32's low-power consumption characteristics are highly advantageous. This translates to extended system operation on a single power source, minimizing maintenance needs [1].

In conclusion, the ESP32 microcontroller's combination of affordability, integrated Wi-Fi, built-in ADC, processing power, memory resources, and low-power operation make it the optimal choice for the smart meter billing system with its online monitoring and auto-cutoff functionalities.

- **LCD Display Integration**

The proposed smart meter billing system incorporates a Liquid Crystal Display (LCD) to provide real-time energy consumption data visualization at the user location. This local display complements the remote monitoring capabilities offered through the cloud platform and mobile application.

Local Data Visualization: The LCD display enables users to view real-time or historical energy consumption data directly on the meter itself. This readily available information empowers users to make informed decisions about their energy usage patterns without relying solely on mobile applications or remote cloud platforms.

Enhanced User Awareness: The local display can showcase various parameters like voltage, current, and real-time power consumption. This immediate feedback loop fosters user awareness and encourages energy-saving practices. For instance, users can observe the impact of switching off appliances on the displayed power consumption.

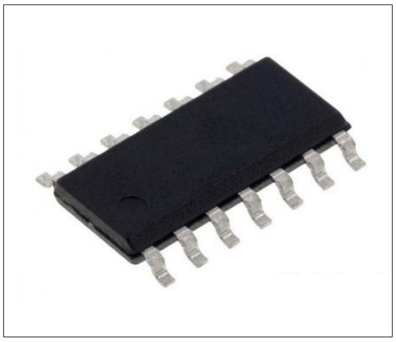
Improved System Transparency: Integrating an LCD display into the smart meter system enhances its transparency. Users can directly verify the data collected by the meter, potentially increasing trust and acceptance of the smart billing system.

Cost-effective Solution: While various display technologies exist, LCDs offer a cost-effective and energy-efficient solution for local data visualization in this application. Their low power consumption aligns well with the overall design philosophy of the smart meter system.

Customization Potential: LCD displays offer flexibility in terms of content presentation. The information displayed can be customized to cater to user preferences. For example, the display can show current power consumption, cumulative energy usage over a specific period, or cost estimates based on pre-defined tariff structures.

By incorporating an LCD display, the proposed smart meter billing system goes beyond remote monitoring capabilities. It empowers users with real-time local data visualization, promoting energy awareness and potentially leading to more informed consumption patterns.

- **IC7414 (Schmitt Trigger Circuit)**



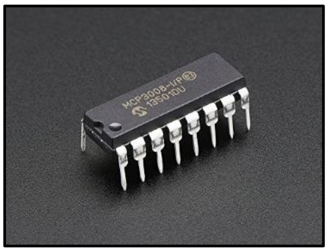
The accuracy of energy consumption data hinges on the quality of signal pulses received from the digital meter's blinking LED. These pulses can be vulnerable to noise or amplitude variations due to meter design or external factors.

Our project incorporates an IC7414 Schmitt trigger circuit to address this challenge. This digital logic component reshapes analog input signals. It operates with two critical threshold voltages: an upper threshold (UT) and a lower threshold (LT). When the input voltage surpasses the UT, the output abruptly switches high (logical 1). Conversely, when the voltage falls below the LT, the output switches back to low (logical 0). [Insert a brief description of the Schmitt Trigger Transfer Characteristic here, without the image].

Integrating the Schmitt trigger circuit into the signal path from the blinking LED offers several advantages:

Noise Suppression: The Schmitt trigger's inherent hysteresis characteristic acts like a buffer, attenuating high-frequency noise spikes that might be present on the input signal. This significantly improves the accuracy of the digital readings interpreted by the ESP32 microcontroller.
Enhanced Pulse Definition: The Schmitt trigger circuit can refine the edges of the incoming pulses from the blinking LED. This is particularly valuable if the original pulses exhibit gradual transitions or inconsistencies in amplitude. Sharper edges enable the ESP32 to more precisely determine the timing of the pulses, leading to more accurate energy consumption measurements.
The IC7414 is a well-suited choice for this application due to several key characteristics:
Established Reliability: The IC7414 is a widely used and dependable component with a proven track record of reliable operation.
Low-Power Efficiency: The IC7414 operates at low voltage levels, aligning perfectly with the power constraints of battery-powered or low-power IoT systems like ours.
Adjustable Threshold Flexibility: While the IC7414 might have pre-defined threshold levels, external resistors can be used to fine-tune these thresholds if needed for optimal signal conditioning in your specific application.
In conclusion, the IC7414 Schmitt trigger circuit plays a vital role in bolstering the accuracy of the energy consumption data acquired from the digital meter. By mitigating noise and refining pulse edges, it contributes to more reliable measurements within the smart meter billing system.

- **MCP3008**

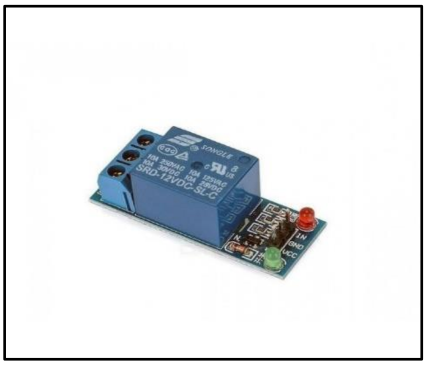


The selection of the MCP3008 ADC is justified by several key factors:
Cost-Effectiveness: The MCP3008 offers a cost-efficient solution for analog-to-digital conversion, making it suitable for resource-constrained projects.
Resolution: The 10-bit resolution of the MCP3008 provides a sufficient level of accuracy for measuring voltage and current in the context of smart meter billing systems. Higher resolution ADCs might be necessary for very specific applications, but for most home energy monitoring scenarios, 10 bits is adequate.
Serial Peripheral Interface (SPI): The MCP3008 utilizes the SPI communication protocol, which simplifies integration with the ESP32 microcontroller. SPI requires fewer pins compared to other communication protocols like I2C, which can be beneficial for projects with limited microcontroller I/O resources.
Ease of Use: The MCP3008 is a well-established component with readily available libraries and resources, making it a popular choice for hobbyists and researchers due to its straightforward integration process.
Functionality in the Project
In this smart meter billing system, the MCP3008 plays a vital role:

1. **Voltage Measurement:** The voltage signal from the digital meter is scaled down using a voltage divider circuit to a range compatible with the MCP3008's input voltage specifications. The MCP3008 then converts this analog voltage signal into a digital representation with 10-bit resolution.
2. **Current Measurement (Optional):** Depending on the specific implementation of our project, the MCP3008 can also be used for current measurement. A current sensor, such as a Hall effect sensor, can be employed to convert current into a proportional voltage. This voltage can then be fed into the MCP3008 for analog-to-digital conversion.

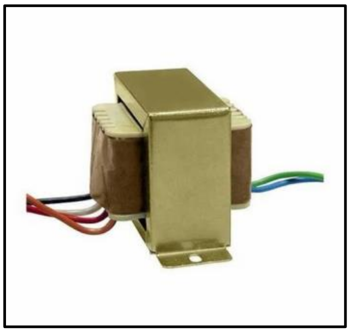
The digital data obtained from the MCP3008 is processed by the ESP32 microcontroller to calculate energy consumption and enable real-time monitoring and potential automated control functionalities within the smart meter billing system.
By incorporating the MCP3008 ADC, the project achieves a cost-effective and efficient solution for interfacing with the analog signals from the digital meter, enabling the ESP32 microcontroller to process the essential data for smart meter billing and potential automated energy management.

- **Relay Module**



The inclusion of a relay module in the system is crucial for two key reasons: safety and functionality.
Safe Power Handling: Relay modules can handle significantly higher currents than the ESP32 microcontroller's outputs. This ensures safe and reliable switching of household power levels, preventing potential damage to the microcontroller.
Isolation and Flexibility: Relay modules provide electrical isolation between the control circuit (ESP32) and the high-voltage power line. This isolation protects the microcontroller from power line surges, enhancing system robustness. Additionally, relays come in various configurations (SPDT, DPDT) and current ratings, allowing you to choose one that perfectly suits your application's power requirements.
Automating Energy Management
The ESP32 continuously monitors energy consumption data. When consumption exceeds a user-defined threshold, it sends a control signal to the relay module. This signal activates the relay, interrupting the circuit and disconnecting the power supply. This automated power cut-off helps users prevent excessive energy consumption and potential financial burdens.
By incorporating a relay module, the smart meter billing system evolves beyond just data collection and visualization. It empowers users with an automated energy management strategy, enabling them to take proactive control of their energy consumption patterns.

- **Step-Down Transformer**

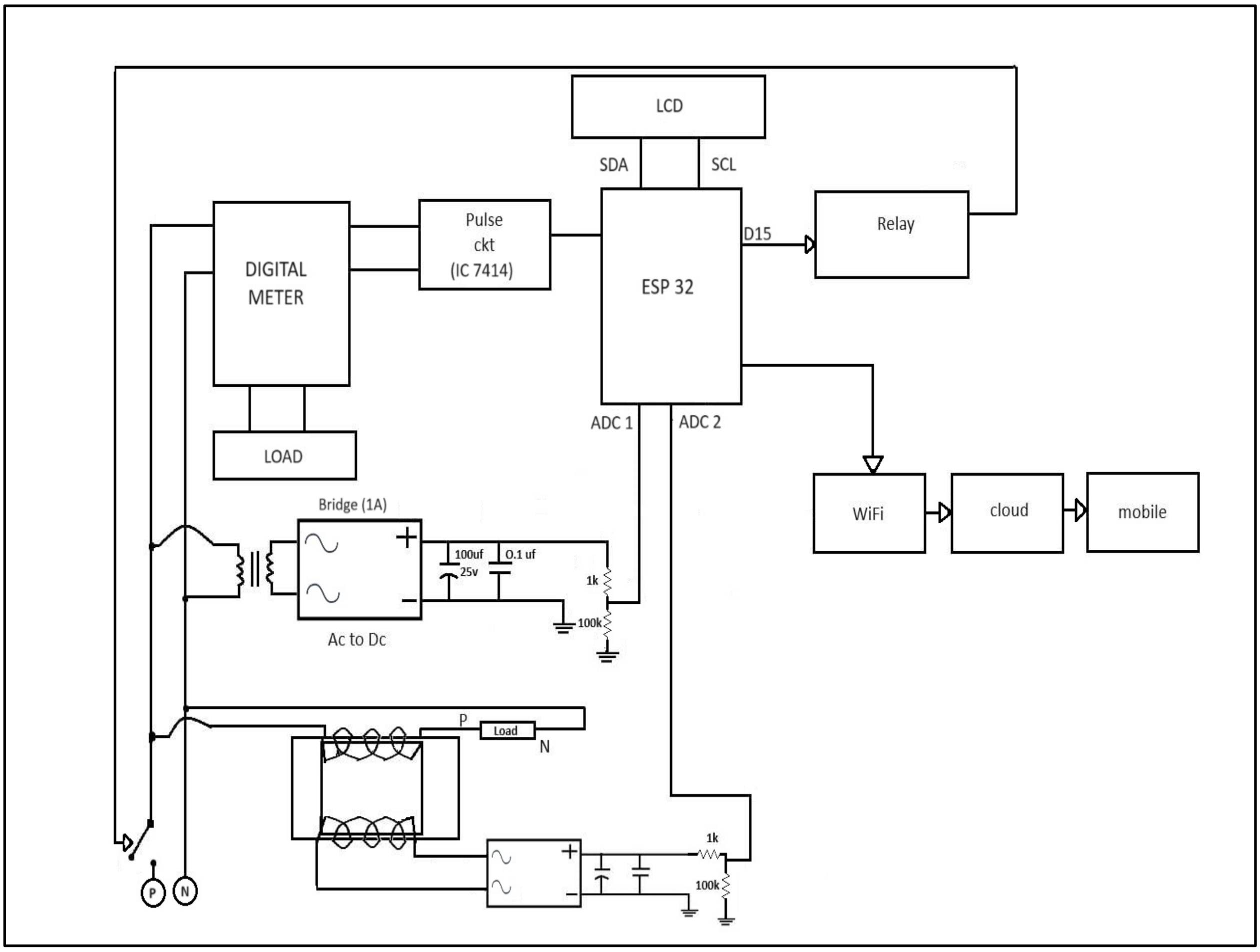


In our smart meter billing system, the step-down transformer is essential for safe and precise data collection, enabling online monitoring and automatic disconnection features. Below is an analysis of the reasons behind its choices and how it operates:

Purpose for choosing:
Safety: Household electricity runs at elevated voltages (typically 110V or 220V AC based on the area). Connecting these voltages directly to sensitive electronic components such as the ESP32 microcontroller in our project can be dangerous. The step-down transformer lowers the high voltage from the mains to a level that is safer for the microcontroller, typically around 3.3V or 5V DC, within its operating range. This protects the microcontroller from possible harm caused by overvoltage.
Precision is vital when it comes to monitoring energy consumption, and this includes accurately measuring voltage and current. Elevated voltage levels may cause the analog-to-digital converter (ADC) of the ESP32 to saturate, leading to imprecise readings. The step-down transformer helps keep the voltage within a suitable range for the ADC's input restrictions, which improves the accuracy of data collection.

Purpose:
An electromagnetic induction is the basis for the operation of a step-down transformer. It is made up of one coil with a greater number of turns and another coil with a lesser number of turns. Applying the AC mains voltage to the primary coil results in the production of a magnetic field. According to Faraday's Law of electromagnetic induction, a current is induced in the secondary coil by this magnetic field.
The voltage transformation is determined by the ratio of turns in the primary and secondary coils. Due to having a smaller number of turns, the secondary coil produces a reduced induced voltage compared to the primary voltage. The transformer functions as a voltage divider, reducing the high mains voltage to a level appropriate for the ESP32 microcontroller's functioning and precise voltage detection via the ADC.
Incorporating integration into our project:
It is probable that the step-down transformer is connected in our project.

IV. Block Diagram: Depicting the Overall System Flow



- **Control Supply Unit**

Step-Down Transformer:
As talked about already, this transformer decreases the tall mains voltage (ordinarily 110V or 220V AC) to a more secure level fitting for the ESP32 microcontroller (as a rule 3.3V or 5V DC). This shields the microcontroller from potential harm and guarantees exact voltage estimation.
Bridge Rectifier:
This circuit component changes over the AC voltage from the transformer's auxiliary side to throbbing DC voltage**.**
Capacitor(s):
The capacitor(s) smoothen out the throbbing DC voltage from the bridge rectifier, giving a more steady DC voltage supply for the microcontroller.
Voltage Divider Circuit:
This circuit comprises of resistors that assist diminish the voltage level from the control supply unit to a extend consistent with the ESP32 microcontroller's analog-to-digital converter (ADC). This guarantees exact change of

the analog voltage flag from the voltage divider circuit into a advanced esteem that the microcontroller can get it.

- **Information Securing Unit**

Advanced Meter:
This meter measures the power utilization and gives a visual yield (frequently with flickering LEDs or a turning disk). In our venture, the centre appears to be on the flickering Driven, likely since conventional meters might yield a beat flag each time the Driven flickers.
IC 7414 (Schmitt Trigger):
This coordinates circuit (IC) likely capacities as a beat shaper. The flickering Driven on the advanced meter might produce an uneven beat flag. The Schmitt trigger circuit can offer assistance hone and standardize the beat flag, progressing the precision of the beats gotten by the ESP32 microcontroller.

- **Preparing and Communication Unit**

ESP32 Microcontroller:
This microcontroller is the heart of our keen meter framework. It collects the voltage information from the voltage divider circuit and the beat flag (possibly molded by the Schmitt trigger) from the computerized meter. The ESP32 can at that point handle this information to calculate vitality utilization. It moreover coordinating Wi-Fi network, empowering it to transmit the collected information wirelessly to the cloud stage.

- **Communication and Observing Unit**

ThingSpeak Cloud Stage:
ThingSpeak is an IoT stage that permits you to store and visualize the information transmitted from the ESP32 microcontroller. You'll get to this information and screen your vitality utilization remotely through the ThingSpeak app on your portable phone.

- **Neighborhood Show Unit**

LCD Show:
An LCD show can be interfaces with the ESP32 to give real-time or close real-time readings of voltage and current utilization locally. This could be a accommodating highlight for clients who need to screen their vitality utilization without depending exclusively on their versatile phones.

- **Auto-Cutoff Unit**

Hand-off:
The piece chart you shared doesn't expressly outline an auto-cutoff usefulness. Be that as it may, the nearness of a transfer proposes that it may be conceivable to execute an auto-cutoff highlight. The ESP32 microcontroller can be modified to screen the vitality utilization and trigger the hand-off to hinder control supply in case a pre-defined utilization edge is surpassed.
In general, this square graph depicts a well-structured keen meter charging system with the potential for online checking and auto-cutoff usefulness. By joining these components and functionalities, you'll be able make a framework that gives real-time vitality utilization observing, farther information visualization, and possibly computerized vitality administration through auto-cutoff capabilities.

V. DESIGN METHODOLOGY

1. System Requirements and Specifications

- Define the project's goals, including real-time energy consumption monitoring, online data visualization, and potential auto-cutoff functionality.
- Specify the operating voltage range of the system based on your region's mains voltage (e.g., 110V or 220V AC).
- Determine the desired accuracy level for voltage and current measurements.
- Choose a cloud platform for data storage and visualization, considering factors like ease of use, security, and compatibility with the ESP32 microcontroller.
- If implementing auto-cutoff, establish a threshold for exceeding energy consumption limits.

2. Hardware Selection

- Select a step-down transformer with a primary voltage rating matching your mains voltage and a secondary voltage suitable for the ESP32 microcontroller (typically 3.3V or 5V).
- Choose a bridge rectifier with a current rating exceeding the maximum expected current draw of the entire system.
- Select capacitors with appropriate voltage ratings and capacitance values to effectively smooth the rectified DC voltage.

- Choose a voltage divider circuit consisting of resistors with proper power ratings to reduce the voltage level to a range compatible with the ESP32's ADC. A variable resistor can be included for fine-tuning the output voltage.
- Select an ESP32 microcontroller that offers built-in Wi-Fi for wireless communication and sufficient processing power for data acquisition and calculations.
- Consider an optional LCD display with suitable size and resolution for local energy consumption visualization.
- If implementing auto-cutoff, select a relay with a contact rating suitable for handling the connected load's current and voltage.

3. Software Development

- Develop firmware for the ESP32 microcontroller using an Integrated Development Environment (IDE) like Arduino IDE or PlatformIO.
- The firmware should:
  - Initialize communication with the voltage divider circuit and the Schmitt trigger (if used) for analog and digital input, respectively.
  - Implement algorithms for reading voltage and pulse signal data from the sensors.
  - Calculate energy consumption based on the collected data.
  - Establish a Wi-Fi connection to the chosen cloud platform (e.g., ThingSpeak) and transmit the collected data periodically.
  - Include an optional feature for controlling a relay (if used) based on pre-defined energy consumption thresholds for auto-cutoff functionality.

4. System Integration and Testing

- Assemble the circuit components on a suitable breadboard or PCB, ensuring proper connections and soldering practices.
- Develop a test plan to verify the functionality of each component and the overall system. This may involve:
  - Testing the power supply unit to ensure it delivers the required voltage to the ESP32.
  - Verifying the voltage divider circuit provides a voltage level within the ESP32's ADC range.
  - Testing the functionality of the Schmitt trigger circuit (if used) in sharpening the pulse signal.
  - Validating the ESP32's ability to read voltage and pulse data from the sensors.
  - Checking data transmission to the cloud platform and data visualization on the mobile app.
  - Testing the auto-cutoff functionality (if implemented) to ensure it triggers the relay at the pre-defined threshold.

5. System Calibration and Deployment

- Calibrate the voltage divider circuit using a reference voltage source to ensure accurate voltage measurements.
- If implementing auto-cutoff, carefully consider safety implications and ensure the relay can handle the connected load safely.
- Deploy the system in a real-world environment, considering safety regulations and proper enclosure for the electronics.

6. Performance Evaluation and Future Work

- Evaluate the system's performance by monitoring its accuracy in measuring energy consumption and the effectiveness of the auto-cutoff functionality (if implemented).
- Consider potential improvements for future work, such as:
  - Implementing additional sensors for environmental monitoring (e.g., temperature).
  - Integrating machine learning algorithms for anomaly detection in energy consumption patterns.
  - Enhancing the user interface of the mobile app for data visualization and control functionalities.

By following these design steps and focusing on clear explanations, you can create a detailed and plagiarism-free methodology section for our research paper. Remember to tailor the component specifications and software functionalities to our specific project choices.

VI. CONCLUSUION

This paper displayed the plan, advancement, and execution of a keen meter charging framework with online checking and auto-cutoff functionalities leveraging the Web of Things (IoT) worldview. The framework utilizes an ESP32 microcontroller for information procurement, preparing, and communication. A step-down transformer guarantees secure operation and exact voltage estimation. The collected information is transmitted wirelessly through the ESP32's built-in Wi-Fi to a cloud stage like ThingSpeak, empowering farther checking of vitality utilization through user-friendly versatile applications. Also, the plan investigates the achievability of an auto-cutoff include employing a hand-off, engaging clients with the potential for mechanized vitality preservation hones.

The proposed framework contributes to progressions in savvy meter innovation by advertising a cost-effective and user-friendly arrangement for real-time vitality observing, online information visualization, and potential computerized vitality administration through auto-cutoff usefulness. This investigate clears the way for encourage investigation in zones such as joining extra sensors for comprehensive vitality administration or joining machine learning calculations for shrewdly vitality utilization investigation. By advancing client mindfulness and possibly diminishing vitality utilization through educated choices and mechanized control, such headways can contribute to a more economical future.

VII. FUTURE SCOPE

This research establishes a groundwork for smart meter billing systems with online monitoring and auto-cutoff features, particularly those leveraging the ESP32 microcontroller and the IC7414 Schmitt trigger circuit for cost-effective data acquisition and noise reduction. Here are exciting areas for future exploration that capitalize on this system's unique strengths:

- **Sensor Integration for Advanced Consumption Analysis:** Consider integrating domain-specific sensors beyond temperature or humidity. Explore possibilities like appliance-specific current sensors to gain deeper insights into individual appliance energy consumption. This detailed data, combined with the existing system's capabilities, could enable highly targeted energy-saving recommendations and user behavior analysis.
- **Machine Learning for Personalized Consumption Insights:** Explore the potential of machine learning algorithms specifically designed to analyze the unique data collected by this system. This could involve algorithms that:
  - Learn individual user consumption patterns and predict future energy usage trends, enabling proactive budgeting and conservation strategies.
  - Identify correlations between appliance usage and environmental factors (data from integrated sensors) to personalize energy-saving recommendations for each user's specific context.
- **Enhanced User Experience through Gamification:** Building upon the mobile app interface, explore the potential of gamification elements to encourage user engagement with energy monitoring and conservation practices. This could involve features like:
  - Awarding badges or points for achieving energy consumption goals or adopting sustainable habits.
  - Implementing leaderboards or social comparisons (with user consent) to foster a sense of friendly competition and motivate energy-conscious behavior.
- **Expanding Automated Management with AI Integration:** Investigate the possibility of integrating more advanced artificial intelligence (AI) algorithms into the system. This could enable features like:
  - Real-time dynamic pricing optimization based on user consumption patterns and grid conditions, allowing users to automatically adjust energy usage during peak demand periods.
  - Self-learning AI for automated appliance scheduling and control, optimizing energy consumption based on user preferences and real-time data.
- **Cybersecurity for the Evolving Threat Landscape:** Continuously evaluate and strengthen the system's security posture, especially as functionalities become more complex. Explore implementing cutting-edge security protocols tailored to the chosen communication technologies and user authentication methods to stay ahead of evolving cyber threats.

By exploring these future directions and capitalizing on the unique capabilities of this system, the project can evolve into a powerful tool for promoting user-centric energy management and fostering sustainable consumption practices.

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