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DEPARMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

Report on

Develop/build/design a RTOS based Real-time Tariff Management System for Multi-Point EV Charging Stations.

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Abstract:

With the global rise in Electric Vehicle (EV) usage, there is a pressing need for efficient multi-point charging stations with real-time tariff management capabilities. This report unveils a Real-time Tariff Management System for Multi-Point EV Charging Stations, utilizing a Real-Time Operating System (RTOS) for superior control and responsiveness. The RTOS framework facilitates effective multitasking and scheduling, critical for handling dynamic tariff calculations, user interactions, and power management. In the heart of the system lies the incorporation of Infrared (IR) sensors to detect and manage vehicle entry and exit, initiating appropriate RTOS tasks for charging allocation and session billing. The nuanced use of RTOS kernel objectives, along with task and mailbox concepts, ensures synchronicity and reliability in the station's operations. These mechanisms are key to maintaining updated station status and accounting for energy consumption in real time, providing a seamless user experience and optimizing station throughput.

The report delves into the architectural design, deploying RTOS services intricately interwoven with sensor technology to streamline charging processes. It highlights how leveraging RTOS capabilities enables this RTMS to handle the complexities of concurrent user sessions and variable charging demands with unmatched precision. The outcomes demonstrated through a series of tests advocate for the efficacy of RTOS-based systems in enhancing the operational efficiency of EV charging stations. This investigation proves that the judicious application of RTOS in service of EV charging infrastructure stands to redefine industry standards by delivering a system equipped to satisfy the modern EV driver’s expectations for reliability and transactional transparency.

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Introduction:

A Real-Time Operating System (RTOS) is an operating system designed to handle real-time tasks with a high degree of reliability and precision. Unlike general-purpose operating systems, which are optimized for resource utilization and throughput, RTOSs prioritize strict timing and predictability. This means that an RTOS is expected to respond to inputs or events within a predetermined time frame, known as a deadline.

The necessity for an RTOS arises in environments where not just logical correctness of computations is demanded but also temporal correctness. These systems are crucial in domains where delaying the execution of a task could lead to disastrous outcomes, such as in embedded systems for automotive controls, medical devices, industrial automation systems, and aerospace.

In the field of charging infrastructure for electric vehicles, the efficacy of Real-time Tariff Management Systems hinges on the robust capabilities of Real-Time Operating Systems. RTOS kernel objectives are at the forefront of this technology, underpinning a system adept at handling concurrent tasks with unparalleled precision. Within the kernel's domain, tasks are distinct units of work, each with assigned priorities, facilitating a harmonious and efficient scheduling environment that responds to real-time stimuli without delay.

RTOS kernel objectives offer a framework where communication primitives like semaphores and mailboxes ensure inter-task messaging remains deterministic and secure. Such a system fosters an environment where charging tariffs can be adjusted on-the-fly based on a multitude of inputs, reflecting the core of RTOS's strengths predictability and reliability. These objectives collectively ensure that the RTMS remains responsive and consistent, two attributes that are indispensable for modern RTMS applications aiming to meet the high demands of multi-point EV charging infrastructures.

Literature Survey & Objectives:

Literature Survey:

In this report, the LPC1768 microcontroller is highlighted as a pivotal component in optimizing EV charging stations. Innovative approaches involving the LPC1768 have shown potential in predicting traffic patterns and informing real-time charging slot allocation, contributing to reduced wait times and enhanced resource utilization [1]. Incorporating ARIMA models allows for dynamic pricing adjustment and better station operation management, including energy consumption, to align with forecasted electricity demands. This could result in significant cost savings for both operators and consumers [6].

Time series analysis is used to forecast charging demand, enabling efficient station management and smooth integration with the power grid [7]. The use of exponential smoothing for forecasting further allows for effective resource allocation and increased revenue for charging stations through dynamic pricing strategies [8] Overall, these advancements position the LPC1768 microcontroller as a foundational technology for smart EV charging solutions, fostering improved operational performance and user satisfaction.

In the context of evolving EV charging station management, the LPC1768 microcontroller has been instrumental in streamlining operations and enhancing service delivery. By implementing time series forecasting methods such as ARIMA and exponential smoothing, the microcontroller enables the real-time adjustment of charging slot availability and pricing in response to changing traffic predictions [1][6][8].

Moreover, leveraging the LPC1768's capabilities in dynamic pricing adjustment allows charging stations to modulate costs in response to projected demand, optimizing revenue without compromising service accessibility. The potential for integrating these methodologies into the management systems of EV charging stations presents a valuable opportunity for cost optimization and improved consumer engagement, reducing wait times and ensuring that stations meet the highest standards of user experience.

Objectives:

- **Integration of IR Sensors for Vehicle Detection:** To incorporate Infrared (IR) sensors into the RTOS environment allowing for the precise detection of vehicle entry and exit events at multi-point EV charging stations.
- **Accurate Time-keeping for Session Management**: To implement RTC (Real-Time Clock) functionality for precise tracking of charging durations which are pivotal to calculating tariffs.
- **Dynamic Tariff Calculation**: To program the system to calculate energy costs in real-time based on fixed rates and varying energy demands during different periods of the day, ensuring that customers are billed accurately for the duration of their vehicle's charging session.
- **Efficient Task Management**: To utilize the RTOS to manage concurrent tasks, including user authentication, sensor monitoring, and billing computation, without performance degradation.
- **Robust Task Synchronization and Communication**: To implement a mailbox system for tasks to communicate effectively, ensuring that data regarding charging times and costs is accurately transmitted and received within the system without data collision or loss.
- **Scalable and Flexible Queue Management**: To handle a queue system that can manage multiple charging points and customer sessions, even when the system is operating at full capacity, as indicated by the 'MAX' variable in the code.
- **Reliable System Error Handling**: To manage exceptions and errors effectively, providing clear notifications to users and safely handling unexpected system states.
- **Transparent and Fair Billing System:** To ensure that the concluded billing amount reflects the actual energy consumed during the charging session, accommodated by real-time adjustments to the tariff based on the time of day.
- **Energy Consumption Recording and Reporting:** To record detailed logs of energy consumption and system usage for reporting and analysis purposes, supporting administrative oversight and enabling future optimizations.

Methodology:

BLOCK DIAGRAM

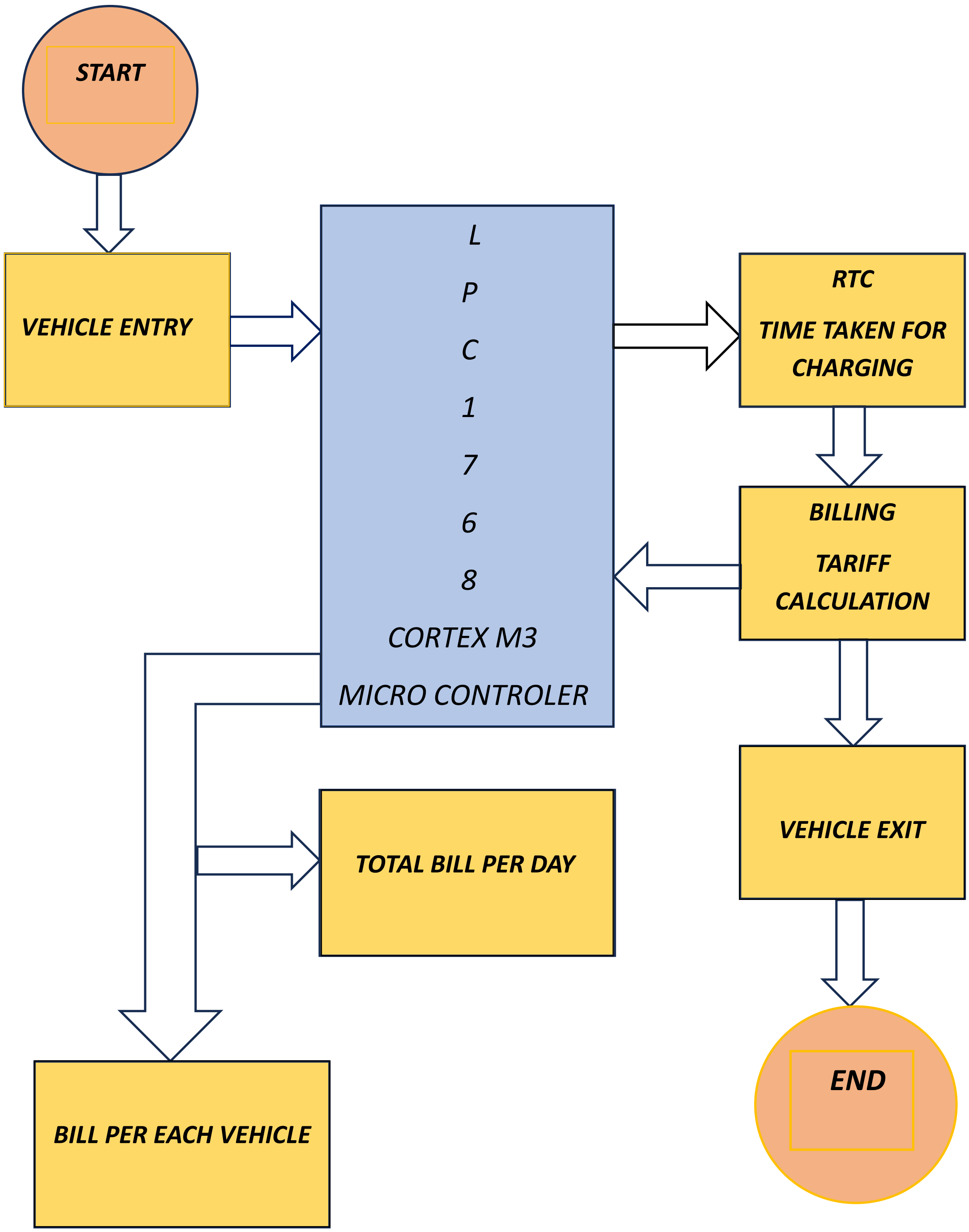

Figure 1 BLOCK DIAGRAM OF THE CHARGING STATION

FLOW CHART:

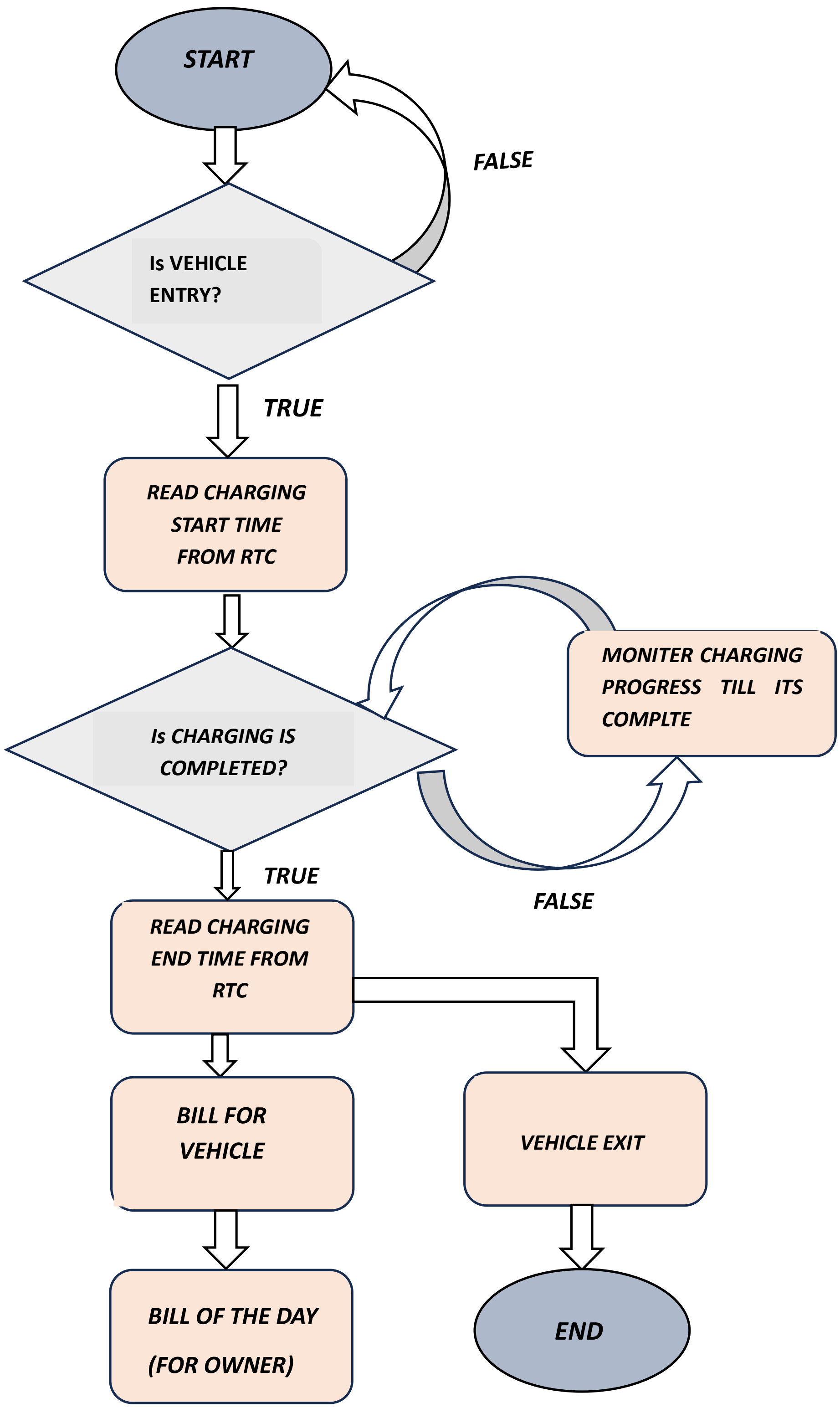

Figure 2. WORKING FLOW CHART OF EV STATION

TASKS:

Tasks in the LPC1768 are crucial for creating multitasking applications within an RTOS, permitting simultaneous and prioritized execution of independent functions like sensor management and data communication. Such a multitasking environment ensures efficient time management for time-sensitive operations, particularly in a real-time context like monitoring systems or control applications.

In the code for the LPC1768 microcontroller, two tasks are defined: task1 and task2.

- task1: Handles vehicle entry/exit and calculates billing. Its importance lies in managing the primary functionality of the parking system, including real-time interactions with sensors and the RTC.
- task2: Receives total billing data from task1 and prints it. Its importance is in reporting the billing information without disrupting the real-time processing of task1.

Task1 is crucial for real-time vehicle tracking and billing, automating entry and exit protocols within parking management systems on the LPC1768, while task2 compliments by reliably conveying transaction details, enhancing user experience in commercial and residential parking applications.

KERNAL OBJECTIVES:

1. **Task Scheduling:** The kernel manages the execution order and timing of task1 and task2, ensuring that the system's operations are performed efficiently and in a timely manner.
2. **Inter-task Communication**: With the use of a mailbox (MsgBox), the kernel facilitates communication between task1 and task2, allowing them to coordinate on sending and receiving the total billing information without interfering with each other.
3. **Resource Management**: Through the allocation and deallocation of memory from a memory pool (mpool), the kernel oversees efficient memory usage, preventing leaks and ensuring availability of resources for tasks.
4. **Time Management:** The kernel utilizes the RTC to provide time-related functions, aiding task1 in timestamping events crucial for billing calculations.

OPTIMIZATION TECHNIQUE:

Code reduction optimization techniques aim to minimize the overall size of the code, which can have several benefits, particularly in embedded systems where memory resources are often limited.

i. **Memory Space Saving**: By optimizing for code size, you reduce the amount of flash or ROM needed to store the program, which can lead to cost savings in mass-produced items.
ii. **Performance:** Smaller code can sometimes result in faster execution as it may take less time to fetch from memory, and more of the program might fit into any caching mechanism, which can improve speed.
iii. **Power Efficiency:** In a microcontroller, less memory usage can translate into lower power consumption, as there are fewer instructions to decode and execute, and less fetching from memory, which is a critical consideration for battery-powered devices.
iv. **Reduced Complexity:** Optimizing for size can result in simpler code, although this is not always the case. Simpler, more compact code can be easier to debug and maintain.

In relation to your code, the implementation of functions such as print and billing consolidates repetitive tasks, which is a simple form of code-reduction—it eliminates the need to write the same code multiple times. Moreover, making use of function pointers or array of functions (not present in the code but can be used) for state machines or handling different modes of operation can further optimize the code space. However, it is important to note that optimizing for size sometimes comes at the expense of readability or even performance (e.g., using single-letter variable names reduces code size but can make the code less readable). It's essential to strike a balance between code reduction and maintainability.

Finally, in the context of real-time operating systems (RTOS), like in your code where you are presumably using Keil RTX, it is crucial to consider the system's real-time performance characteristics. Code reduction shouldn't interfere with the timing and synchronization aspects of tasks.

BILL OF COMPONENTS:

SL NO	COMPONENTS	PRICE
1	CORTEX M3 BOARD	1000.00/-
2	CABELS	250.00/-
3	WIRES	50.00/-
4	IR SENSORS	50*3=150.00/-
	TOTAL	1450.00/-

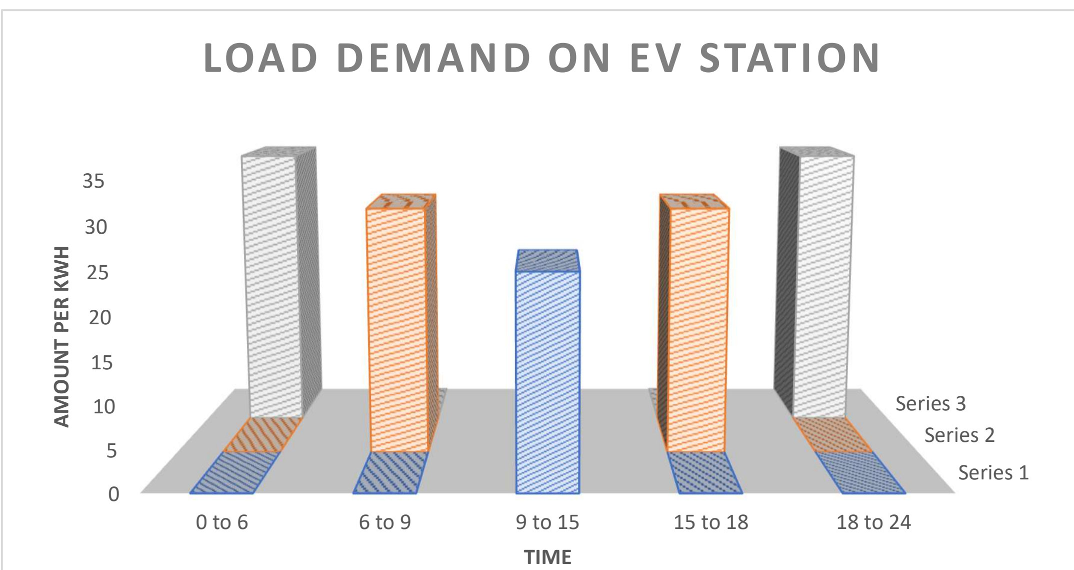

Figure 3 THE DEMAND CURVE OF EV CHARGING STATION

RESULT & DISCUSSIONS:

i. **Vehicle Tracking**: The code uses input received over LCD to emulate the detection of vehicles through IR sensors. Vehicle entries trigger 'Vehicle entry' events and exits invoke the billing process.

ii. **RTC Timing**: Real-time clock manipulation is used to simulate the passage of time, affecting billing calculations based on the duration of the charging session.

iii. **Billing Process**: The billing function calculates charges based on a fixed cost, energy consumption (calculated via a custom cost control register (ccr), and voltage), with tariffs expressed to adjust during different periods (peak and off-peak hours) of the day.

iv. **Overflow Entry Handling:** The code sets MAX to 5, which is the maximum number of vehicles allowed in the queue. When counter1, which keeps track of the number of vehicles currently in the queue, reaches this limit, further vehicle entries are prevented. If an IR sensor input is received (emulated by a '1' via LCD) when counter1 equals MAX, a message "Please Wait Queue Full" is displayed on the LCD to indicate that no more vehicles can be accommodated until the count decreases.

v. **Incorrect Entry Handling:** Reverse entry is detected when the switchStatus1 flag is set (emulated by a '2' via LCD) but counter1 is zero, indicating that a vehicle is trying to exit when there are no vehicles in the system. In such a case, the system alerts on the LCD with a message "Please enter from other side," indicating that a vehicle has attempted to enter the station from the exit side improperly**.**

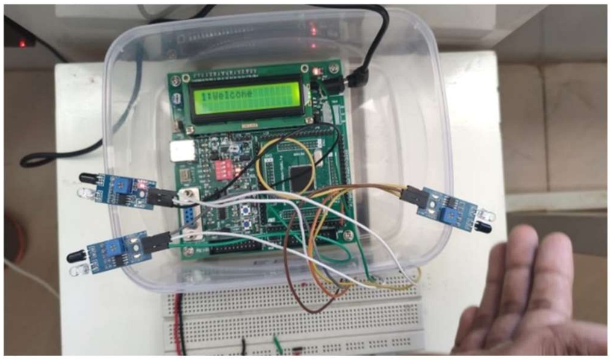

Figure 4 ENTRY OF THE 1ST VEHICLE

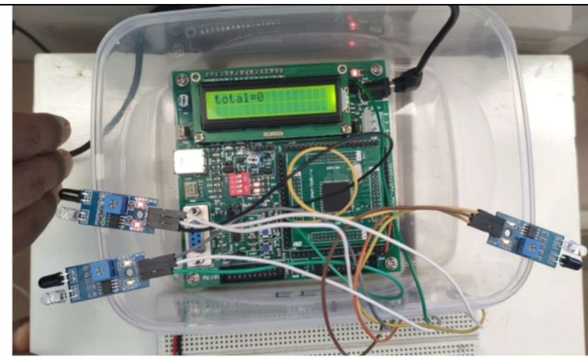

Figure 5 TOTAL BILL

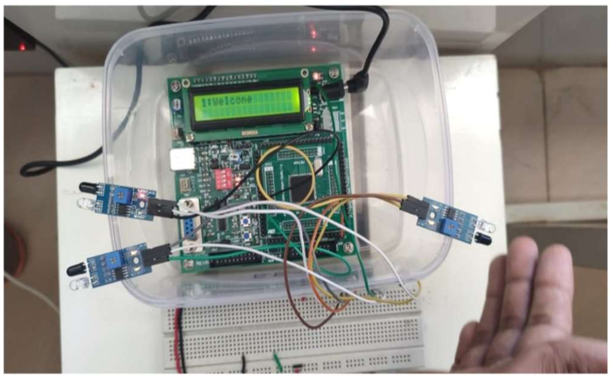

Figure 6 ENTRY OF THE 5TH VEHICLE

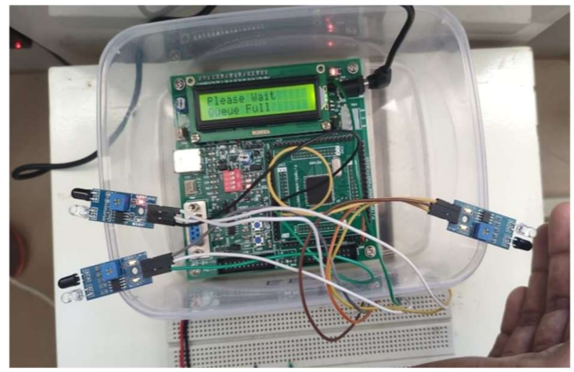

Figure 7 WHEN 5 VEHICLE ARE IN THE STATION

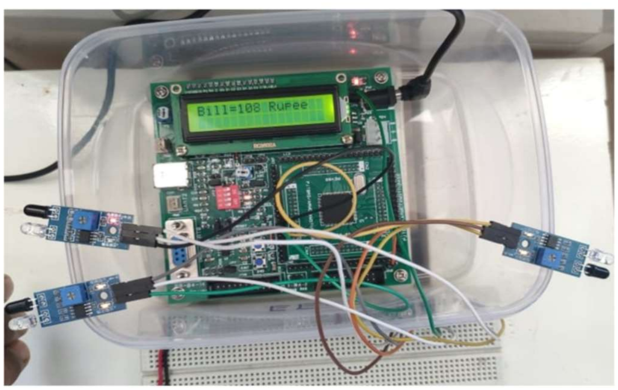

Figure 8 CHARGING BILL FOR VEHICLE

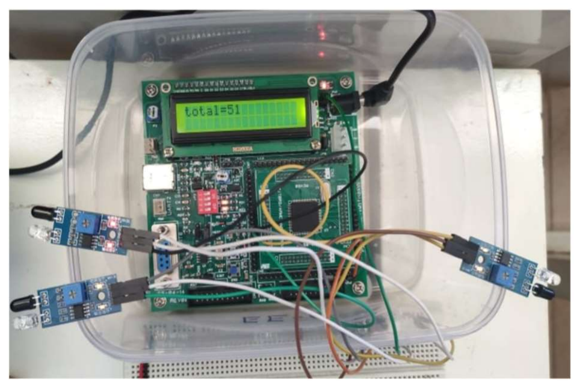

Figure 9 TOTAL BILL FOR 1ST VEHICLE

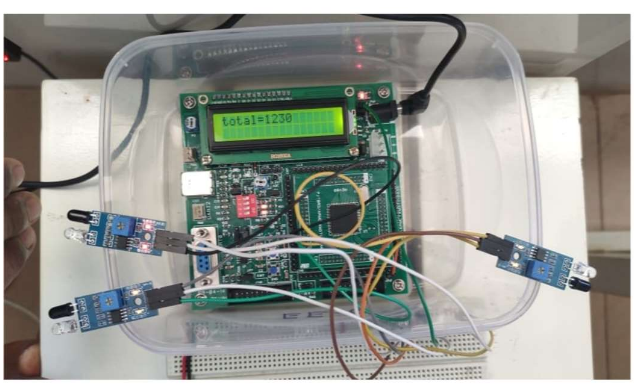

Figure 10 TOTAL BILL

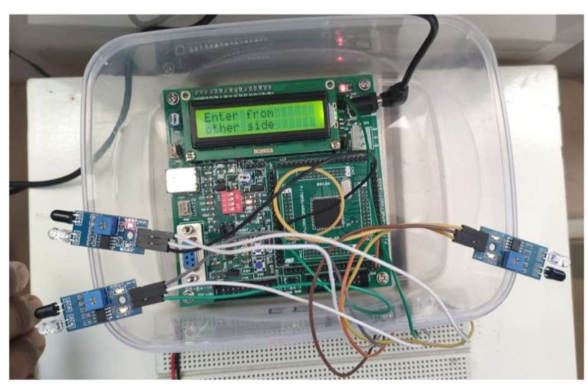

Figure 11 WRONG ENTRY

REFERRENCES:

1. "Real-Time EV Charging Scheduling for Peak Load Shaving in Smart Grid" - Could provide background on real-time scheduling algorithms to manage EV charging load.
2. "An Intelligent Multi-Agent System for EV Charging Scheduling and Control" - Discusses using multi-agent systems and machine learning for EV charging optimization.
3. "Dynamic Programming for EV Charging Scheduling Based on Travel Time Flexibility Analysis" - Proposes a dynamic programming-based method for scheduling EV charging.
4. "Coordinated EV Charging Control for Peak Load Management and Voltage Regulation" - Looks at coordinated control approaches across multiple EV charging stations for demand response.
5. "Data-Driven Prediction of Energy Consumption for Electric Vehicle Charging Stations" - Presents forecasting models to predict EV charging load for scheduling optimization.
6. "A Decentralized Real-Time Price-Based Algorithm for EV Charging Station Scheduling"
7. "Reinforcement Learning for Real-Time EV Charging Scheduling and Pricing"
8. "QoS-Aware Real-Time Tariff Management for Multi-Vendor EV Charging Stations"
9. "Real-Time Optimization of EV Charging Station Power Flow Using Dynamic Tariff Signals"
10. "A Real-Time Priority-Based Charging Coordination Framework for EV Fast Charging Stations"
11. "A Distributed Model Predictive Control Approach for Real-Time EV Charging Station Management"
12. "Real-Time EV Charging and V2G Management via Dynamic Electricity Pricing Signals"
13. "Multi-Agent Reinforcement Learning for Decentralized Tariff-Based Coordination of EV Charging"
14. "Integrating Renewables into Real-Time Management and Pricing of EV Charging Load"
15. "Real-Time Charging Station Scheduling for EVs: Peak Demand Reduction and Cost Optimization"
16. "Coordination of Large-Scale EV Charging Facilities Using Real-Time Pricing"
17. "Tariff-Driven Coordination of EV Charging Stations with Power Grid Constraints"

APPENDIX:

The appendix of this project reflects upon the development journey of an RTOS-based system integrated into the LPC1768 microcontroller for managing real-time tariffs at a multi-point Electric Vehicle (EV) charging station. The primary interaction mechanism for vehicle detection employed Infrared (IR) sensors, which introduced a significant layer of complexity to the system. The challenge was the precise synchronization required between the IR sensor's input and the LPC1768's Real-Time Clock (RTC) for accurate session time-stamping and billing.

As the development progressed, the team encountered a critical challenge—the intricacies of manipulating the high-precision RTC to align with the volatile nature of the IR sensor signals. This precision requirement, essential for the tariff calculations, greatly increased the development time, leading to a bottleneck in the project timeline. To rectify this without compromising billing accuracy, a novel resolution was conceptualized.

The resolution involved a strategic adaptation of the RTC system. Instead of operating over a traditional 24-hour cycle, the clock was configured to simulate a full day within a 24-minute window. This enabled the development team to expedite the iteration and debugging process, effectively shortening the time required to fine-tune the system's response to sensor inputs and RTC synchronization. This adaptive time scaling approach, though unconventional, ensured the successful simulation of real-time billing operations and allowed the system to maintain its operational accuracy and efficiency. Thus, the undertaking culminated in a refined execution of an EV charging station's real-time tariff management, underpinned by a meticulously crafted RTOS environment.