AUTOMATED FUEL VENDING MACHINE

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ABSTRACT

This paper introduced an Automated Fuel Vending Machine system meticulously designed to address fuel dispensing challenges in developing countries. Traditional vending machines entail significant yearly installation costs and substantially burden economies with limited resources. This system emerged as a practical solution to alleviate long queues at petrol pumps, particularly in densely populated regions such as India. The system reduced labor costs and simplified fuel dispensing by eliminating the need for a salesperson. The design focused on creating a cost-effective and easily installable solution, meeting the modern demand for efficient and rapid service. The automated system proved a feasible alternative, offering convenience and operational efficiency. It successfully demonstrated how automation could address economic constraints while enhancing service speed and accessibility, making it a valuable contribution to automated fuel dispensing technology.

KEYWORDS: *Automated, Cost-effective, Micro-controller, RFID tag, Vending Machine*

I. INTRODUCTION

Vending machines originated during the Industrial Revolution and are a crucial invention today. The development of modern coin-operated vending machines began in the early 1880s. They are commonly used in many developed countries, including the USA, Canada, and Australia. A vending machine is an embedded system that dispenses a specific product once the consumer inserts the appropriate amount of money. It can offer products at competitive prices around the clock, unaffected by holidays. This paper covers the hardware architecture, including high-level block diagrams, component selection, and system integration. While firmware code is not detailed, the document briefly outlines how to access it. This represents just one practical implementation of the concept. The system's flexibility allows for creating automated environments where manual verification is minimized or designing vending machines requiring minimal hardware operation. The potential applications are vast, inspiring innovative uses and showcasing the system's ability to transform various industries. The paper is sectionized as follows: Section 1 details the high-level block diagram for the proposed Automated Fuel Vending Machine, Section 2 discusses critical component selection, Section 3 discusses discrete component selection, Section 4 presents the flow diagram for firmware implementation, Section 5 covers system-level code sequencing, Section 6 module-level code sequencing, Section 7 reviews the firmware code editor and compiler, Section 8 explains the firmware code loader, Section 9 describes circuit design and simulation, and concludes with future directions.

II. THE PROPOSED AUTOMATED FUEL VENDING MACHINE

The central processing unit's microcontroller handles all data storage and processing. The RFID tag-scanning module, an accessory to the controller, simplifies user authentication—a 16x2 LCD information for each task, improving user comprehension. The balance for the required fuel or manually entered data is managed via a HEX keypad, giving users control. Fuel flow is precisely regulated through a solenoid valve, flow sensor, and relay circuit connected to the pipe outlet from the container. A fuel-level indicator circuit attached to the tank ensures effective operation and safety. RFID tags are scanned by the module, which transmits user data to the microcontroller. The microcontroller stores user data associated with various RFID tags and cross-verifies it with the received tag data. If verification fails, a buzzer alarm will sound. Once the user is authenticated, their balance is shown on the LCD, and they can enter the desired amount of fuel through the HEX keypad, which is then displayed on an LED interface. The buzzer will sound if the balance is insufficient, and the LCD will show a low balance warning. Users can recharge their accounts by paying the responsible person with a critical password to update the user balance. Upon entering the correct amount, the vending process will begin, allowing users to access the necessary fuel through an easy-to-navigate interface, providing a smooth and hassle-free experience. This system eliminates the need for intermediaries at gas stations, creating a fully autonomous fuel dispensing system.

2.1 Block Diagram

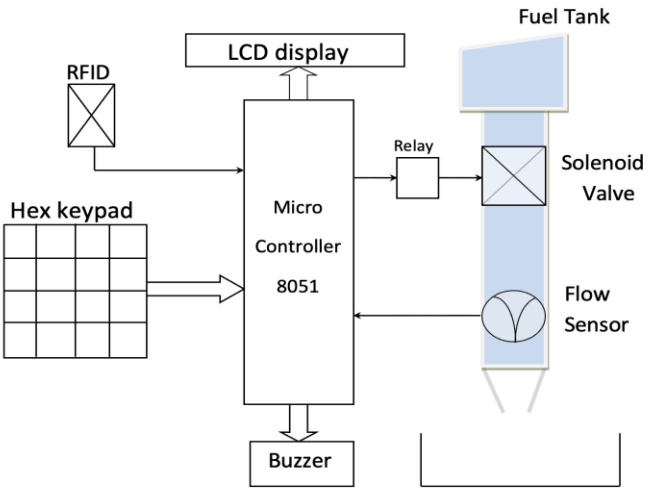

Figure 1: Block Diagram

2.2 WORKING

The system utilizes Radio-Frequency Identification (RFID) for scanning, involving an RFID tag and scanner. The RFID tag is a digital ID card containing all user, account, and balance information. When the user scans their card with the RFID scanner, the scanner sends the data to the microcontroller, which verifies the user's details. The user can enter the desired fuel amount via the Hex-Keypad, provided their account balance is sufficient. If the balance is inadequate, the microcontroller will receive this information and trigger an automatic buzzer alarm. Should the user need additional funds, they can pay directly to the manager or administrator who controls the machine. The administrator can grant users access to dispense fuel using their admin key. In this scenario, the user can pay the admin directly, ensuring their fuel needs are met even if their account balance is insufficient for the transaction.

2.3Critical Component Selection

2.3.1 Microcontroller (AT89S52)

The AT89S52 is a high-performance, low-power CMOS 8-bit microcontroller featuring 8K bytes of Flash memory that can be programmed in the system. It is produced using Atmel's advanced, nonvolatile memory technology and is compatible with the standard 80C51 instruction set and pin configuration. The built-in Flash memory allows program updates directly within the system or through a traditional nonvolatile memory programmer. Integrating a versatile 8-bit CPU with in-system programmable Flash on a single chip, the Atmel AT89S52 offers a robust and adaptable solution for a wide range of embedded control applications.

The AT89S52 includes several standard features: 8K bytes of Flash memory, 256 bytes of RAM, 32 I/O lines, a Watchdog timer, two data pointers, three 16-bit timer/counters, a six-vector, two-level interrupt system, a full-duplex serial port, and integrated oscillator and clock circuitry.

The AT89S52 includes static logic that supports zero-frequency operation and provides two selectable power-saving modes. In Idle Mode, the CPU ceases operation while the RAM, timer/counters, serial port, and interrupt system remain functional. Power-down Mode preserves the RAM contents but shuts down the oscillator, halting all other chip functions until the next interrupt or hardware reset.

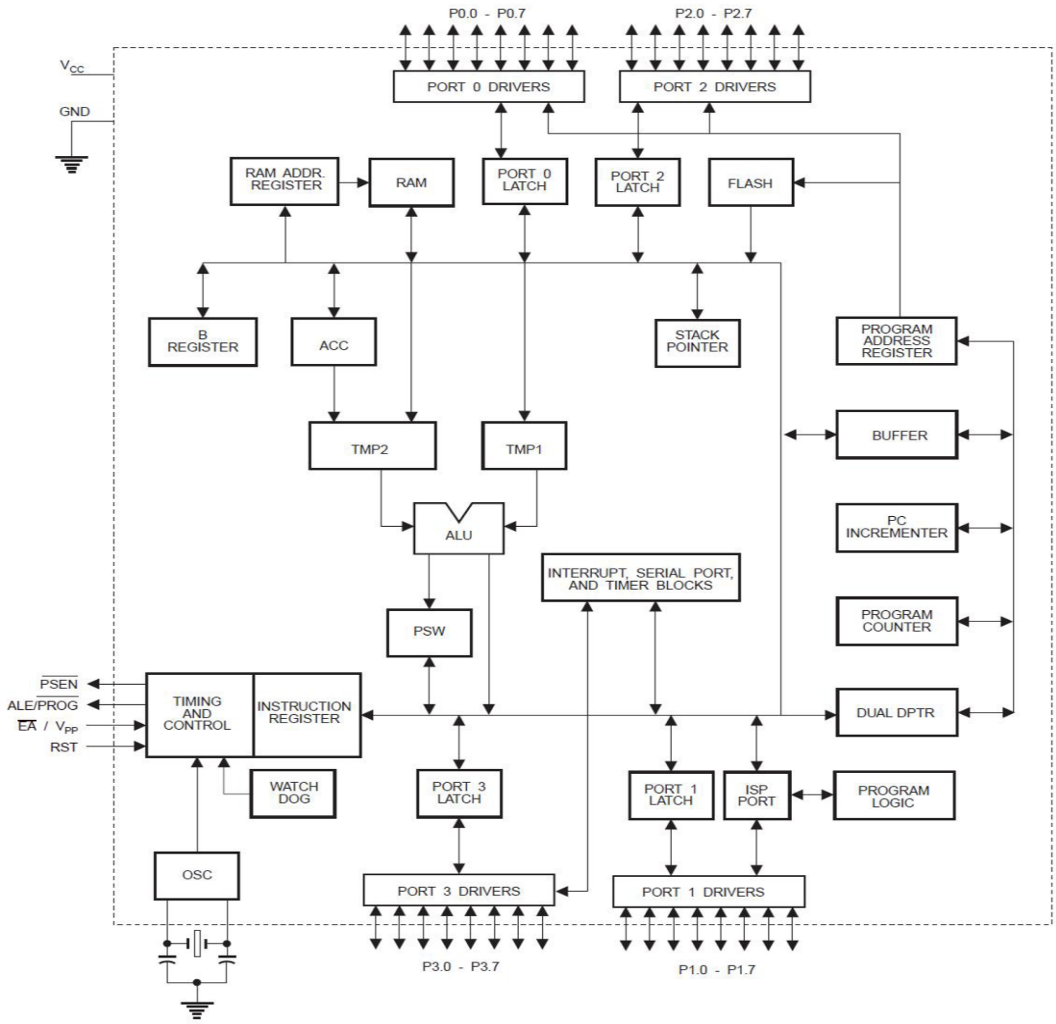

Figure 2: Internal Architecture of ATS89S52

2.3.2 RFID TAG

RFID technology is used to track items through intelligent barcodes within a store. Radio Frequency Identification (RFID) Card Readers offer an economical way to read passive RFID tags up to 2 inches away. These readers detect the RFID tag and transmit its unique identification code at a baud rate 9600. A microcontroller or a computer can process this data.

RFID encompasses a range of non-contact technologies that utilize radio waves to identify people or objects automatically. Typically, these systems store a unique serial number on a microchip attached to an antenna. The combination of the antenna and microchip is known as an "RFID transponder" or "RFID tag," which works in conjunction with an "RFID reader."

RFID Card Readers are applicable in various fields, such as access control, automatic identification, robotics navigation, inventory management, payment systems, and vehicle immobilization. When the RFID reader is activated, it generates an RF field and waits for a tag to enter its range. The tag's antenna captures the radio waves, converting them into electrical energy to power the chip.

Once the tag is detected, it reflects electromagnetic waves to return stored information. The reader then processes the unique ID and sends the data through a serial interface. An LED and buzzer signal the successful detection of a valid tag. For accurate reading, the RFID tag should be positioned parallel to the antenna; holding it sideways may lead to reading errors. Only one tag should be presented to the antenna to avoid interference and ensure accurate scanning.

Figure 3: RFID TAG

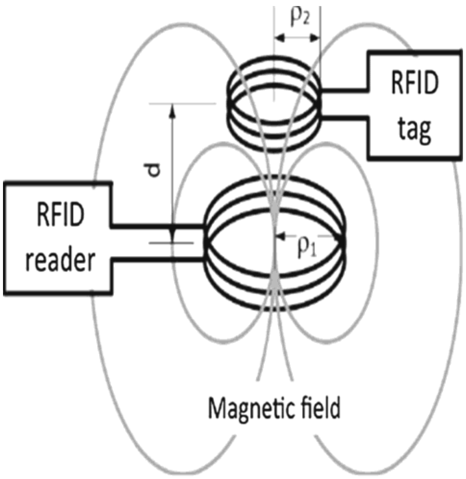

Figure 4: RFID Reader and Transponder

2.3.3 HEX KEYPAD

The hex keypad is an accessory that interfaces with the DE2 board through JP1 or JP2 using a 40-pin ribbon cable. It features 16 keys arranged in a 4x4 matrix, with labels ranging from 0 to F. This input device allows users to enter their ID and password for authentication and specify the fuel required.

The internal design of the hex keypad is simple. It comprises vertical column wires (C0 to C3) and horizontal row wires (R0 to R3). These eight wires are connected to the lower 8 bits of the port. Pressing a key creates an electrical link between a row and a column wire, enabling the keypress detection.

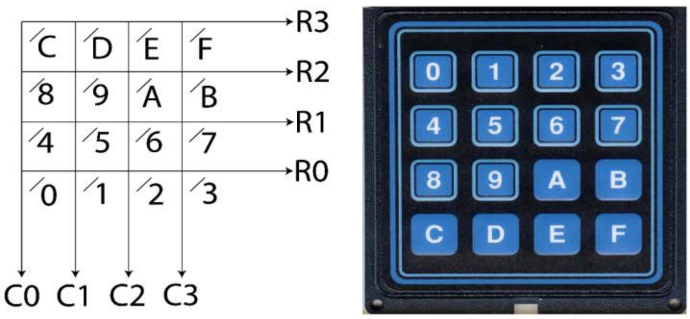

Figure 5: Hex Keypad [1]

2.3.4 LCD

The LCD 2x16 A Module offers a range of display capabilities with straightforward connections that facilitate its use across various applications. This module features two display lines, each capable of showing 16 characters. Users can adjust the position of characters on the screen using cursor control commands. The module also includes a backlight function, enhancing readability. Additionally, it allows the display of custom characters to meet specific requirements.

The RTC Module, on the other hand, functions as a real-time or primary electronic clock. It can present the operational status of different applications at any time and display status or error messages directly on the screen without needing a PC. Using user-defined characters makes it possible to create unique patterns for custom messages.

Figure 6: LCD

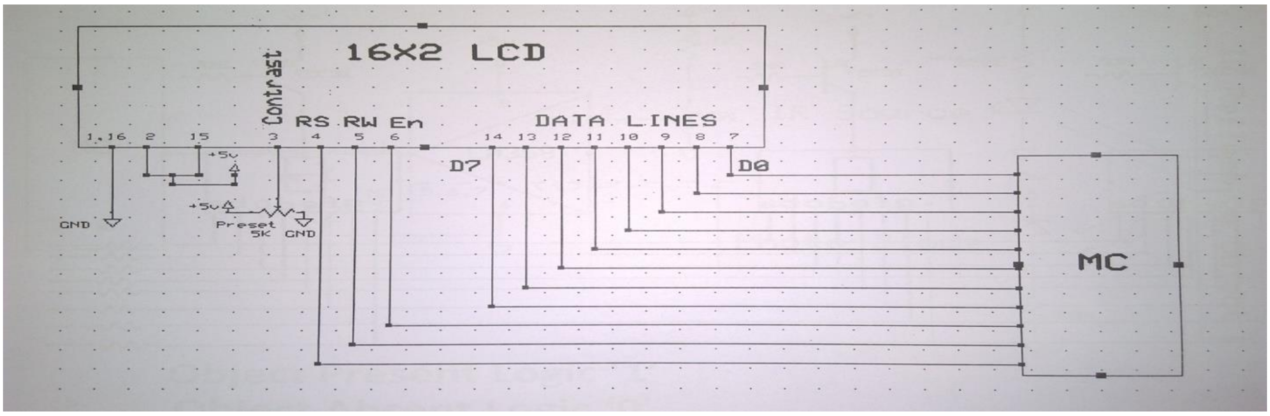

Figure 7: LCD interfacing with Microcontroller

2.3.5 PIEZOELECTRIC BUZZER

A buzzer or beeper is a device used for audio signaling. It can be mechanical, electromechanical, or piezoelectric. These devices are commonly employed in alarm systems and timers to confirm user actions like mouse clicks or keystrokes. Typically, a piezoelectric element may be driven by an oscillating electronic circuit or another audio signal source, such as a piezoelectric amplifier. Familiar sounds produced by these devices to signal actions include clicks, rings, or beeps.

Figure 8: Buzzer

2.3.6 RELAY

A relay functions similarly to a switch and can be open or closed. When the relay is open, it breaks the circuit and prevents current from flowing through, meaning the connected load does not receive any power. Conversely, when the relay is closed, it completes the circuit, allowing current to flow through and supply power to the load.

Figure 9: Sugar Cube Relay

A relay functions as an electrically controlled switch. When current flows through its coil, it generates a magnetic field that moves a lever to alter the switch contacts. Relays have two positions corresponding to the on or off states of the coil, making them double-throw switches that can changeover between circuits.

Relays enable the control of one circuit by another, even if they are entirely separate. For instance, a relay can switch a high-voltage 230V AC circuit using a low-voltage battery circuit. The connection between the two circuits is purely magnetic and mechanical, with no direct electrical link inside the relay.

The relay coil typically requires a relatively high current, such as 30mA for a 12V relay or up to 100mA for those designed for lower voltages. Since most integrated circuits (ICs) cannot supply this amount of current directly, a transistor is often used to boost the small current from the IC to the higher level needed for the relay coil.

However, the 555 timer IC can provide up to 200mA of output current, making it capable of directly driving relay coils without additional amplification. Relays commonly come in single-pole double-throw (SPDT) or double-pole double-throw (DPDT) configurations. However, options with more switch contacts, such as those with four changeover contacts, are also available.

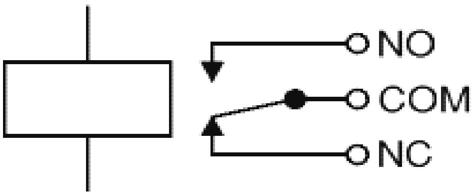

Figure 10: Working of Relay

2.3.7 SOLENOID VALVE

A solenoid valve operates electrically through a solenoid to control fluid flow. A two-port solenoid valve either opens or closes the flow, while a three-port valve directs the flow between two outlet ports.

Fuel managed by the solenoid valve enters through the inlet, passing through an orifice before reaching the outlet port. The plunger within the valve regulates the opening and closing of the orifice.

The solenoid valve shown is a normally closed type. Typically, these valves use a spring to press the plunger against the orifice opening, preventing flow. The plunger's tip, which is sealed to block the orifice, is lifted by an electromagnetic field generated by the coil when the valve is activated.

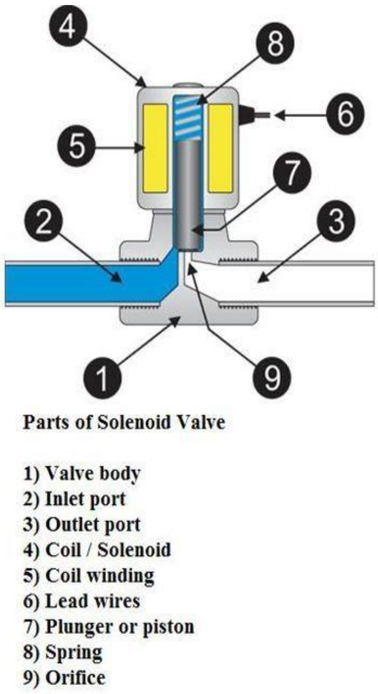

Figure 11: Solenoid Valve [2]

2.3.8 FUEL SENSOR

A flow sensor tracks the flow rate and is often found in tools such as flow meters or flow loggers for monitoring fuel flow. These sensors are equipped with calibration capabilities to provide accurate readings.

A capacitor comprises two conductive plates with a dielectric material placed between them. When voltage is applied, the dielectric material becomes charged, and the dielectric influences the level of charge held. In this instance, the capacitor comprises two aluminum tubes of different sizes, with the gap between them serving as the dielectric.

When the capacitor is empty, the space is filled with air. As fuel begins to enter, it replaces the air in the space. Since fuel has a higher dielectric constant than air, the capacitance increases proportionally with the fuel level.

The capacitor is charged to measure capacitance, and the time it stabilizes is recorded. The sensor compares this time with predefined minimum and maximum values rather than focusing on precise capacitance measurements.

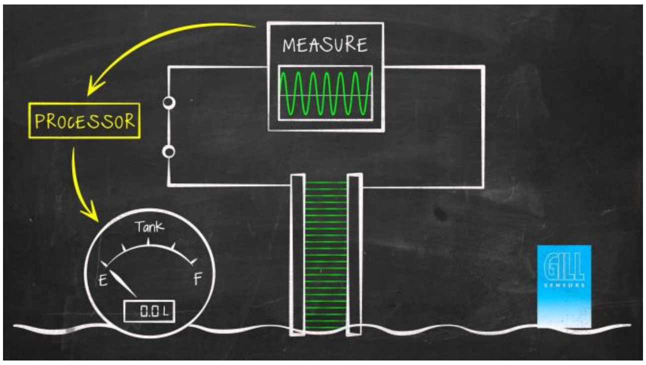

Figure 12: Working of Fuel Sensor

III. DISCRETE COMPONENT-SELECTION

3.1 RESISTOR

A resistor is an essential electrical component with two terminals that introduces resistance into a circuit. Its primary function is to reduce the flow of current and lower voltage levels. Resistors can be either fixed or variable, as seen in components like thermistors, varistors, trimmers, photoresistors, and potentiometers. According to Ohm's law, the current flowing through a resistor is proportioned to the voltage applied across its terminals.

$$I = \frac{V}{R}$$

Here, ***I*** represents the current flowing through the conductor in amperes, ***V*** denotes the voltage difference across the conductor in volts, and ***R*** signifies the resistance of the conductor in ohms (Ω). A resistor's resistance is the voltage's ratio across its terminals to the current flowing through the circuit. Typically, resistors operate within their specified ratings, assuming their resistance remains constant regardless of the voltage applied.

Figure 13: Resistor

3.2 TRANSISTOR

The BC547 is an NPN BJT, a transistor used primarily for amplifying current. It operates by allowing a small current at its base to control a larger current between the collector and emitter terminals.

The BC547 is utilized for amplification and switching tasks and has a maximum current gain of 800. It is like other transistors, such as the BC548 and BC549. To function correctly, the transistor terminals need a fixed DC voltage to ensure operation within the desired region of their characteristic curves, a process known as biasing. The transistor is set to operate partially on all input conditions for amplification.

In standard amplifier configurations, the BC547 is used in the common emitter arrangement, with voltage divider biasing being a typical method. For switching purposes, the transistor is biased to fully turn on when a signal is applied to the base and completely turn off without a signal.

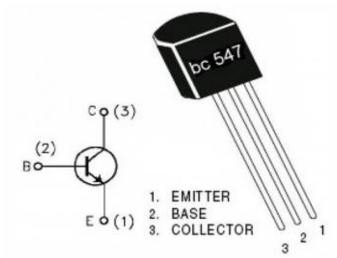

Figure 14: Transistor [3]

3.3 LED

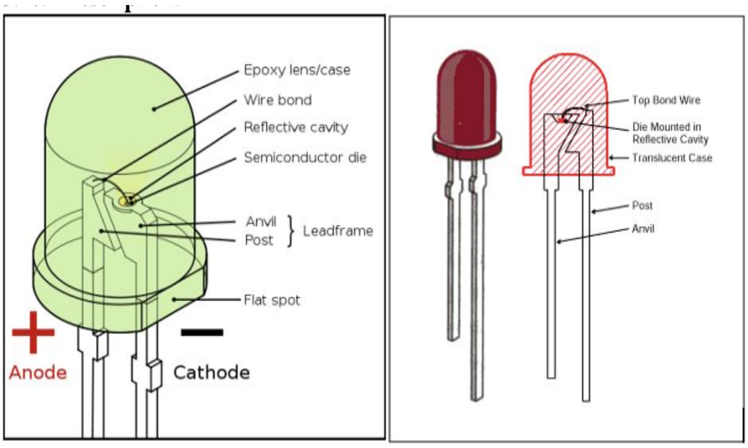

Figure 15: LED

A light-emitting diode (LED) is a type of semiconductor that produces light. Initially, LEDs only emitted dim red light, but modern LEDs are available in various intensities and colors, including visible, ultraviolet, and infrared light.

When an LED is forward-biased (turned on), electrons combine with holes in the semiconductor material, emitting energy as photons. This process, known as electroluminescence, results in light whose color is determined by the energy gap of the semiconductor material.

Typically small (less than one mm²), LEDs may include optical components to direct and shape their light output. Compared to incandescent bulbs, LEDs offer several benefits, such as lower energy usage, longer lifespan, more excellent durability, reduced size, and quicker switching capabilities. However, LEDs designed for general room lighting can be more costly and require careful current and heat management than compact fluorescent lamps with similar light output.

LEDs are utilized across various fields, such as aviation lighting, vehicle lights, advertising screens, general lighting, and traffic signals. Their versatility has also led to innovations in text and video displays, sensors, and advanced communication technologies. Infrared LEDs are commonly found in remote controls for various consumer electronics, such as TVs and DVD players.

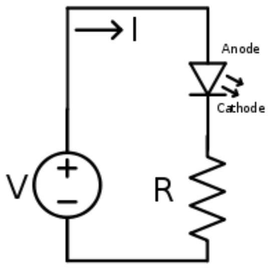

Figure 16: Circuit Diagram

IV. FLOW-DIAGRAM FOR FIRMWARE IMPLEMENTATION:

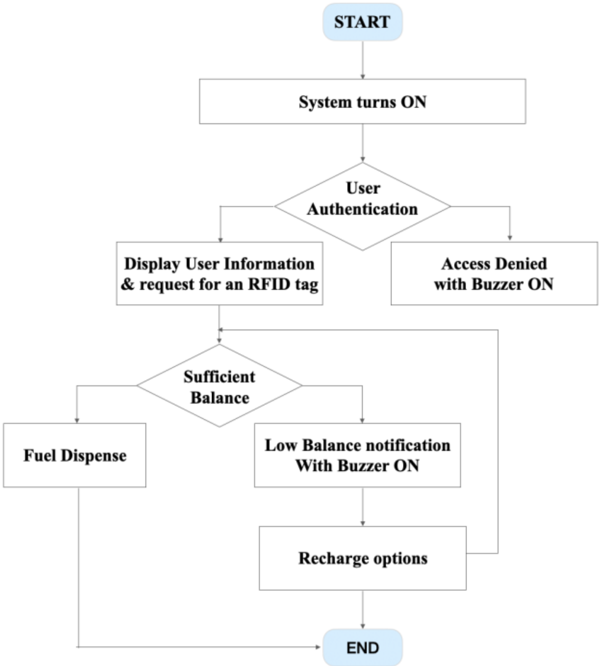

Figure 17: FW Flow Diagram

V. SYSTEM-LEVEL CODE SEQUENCING

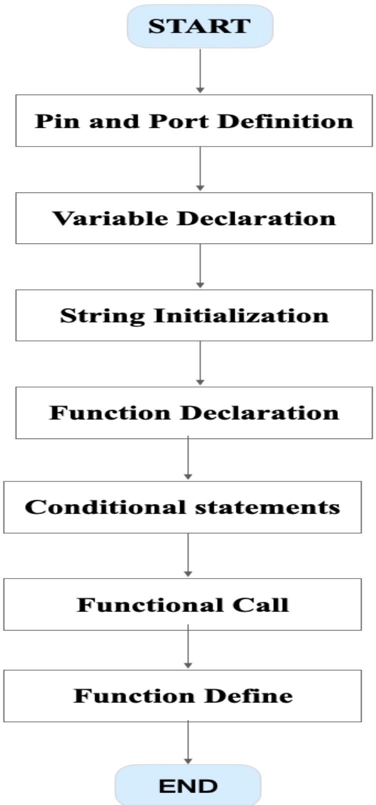

Figure 18: System Design Flow

VI. MODULE-LEVEL CODE SEQUENCING

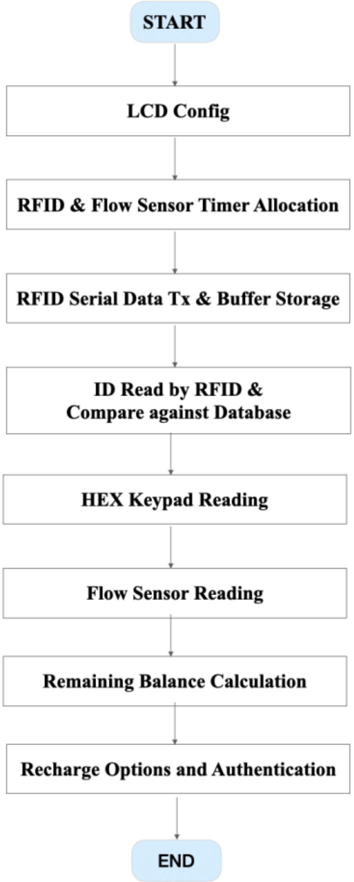

Figure 19: Module Design Flow

VII. FW CODE EDITOR AND COMPILER

Keil µVision is software that provides an Integrated Development Environment (IDE) that integrates a text editor. In this environment, we can write programs; a compiler compiles them and even converts our source codes to hex files. Keil is used for different purposes, such as writing programs in C/C++ or Assembly language, compiling and assembling programs, debugging programs, and creating hex files.

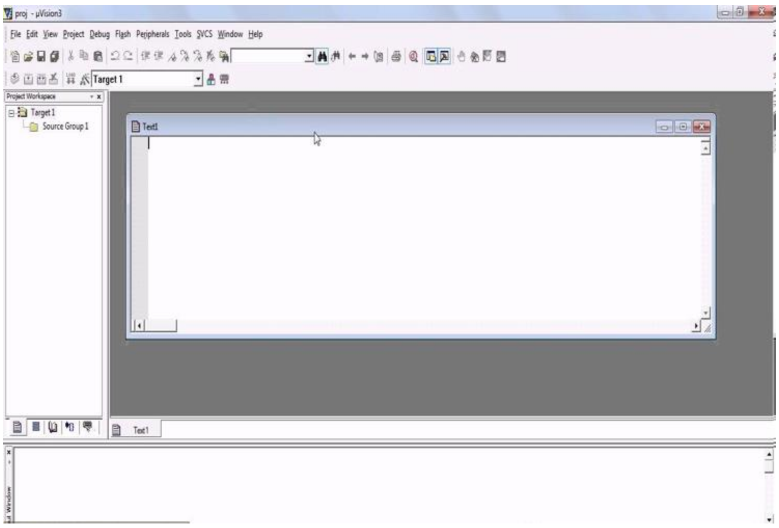

Figure 20: Keil GUI

VIII. FW CODE LOADER

ProLoad is software that accepts hex files generated from the program codes to be loaded into the microcontroller to initiate programming in action on the microcontroller and its peripherals. The hex code is taken, and after placing the microcontroller on a programmer kit, a supply is given to the kit to initiate power supply in it, and by hardware interface of the kit through a serial port (COM port), we can load the required files into the microcontroller.

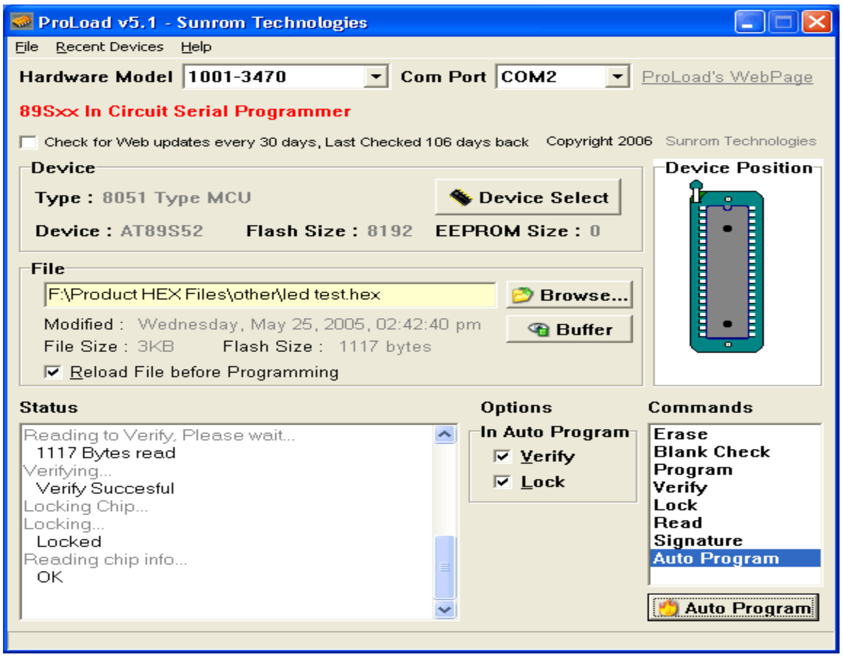

Figure 21: ProLoad GUI [4]

IX. CIRCUIT DESIGN AND SIMULATION

Proteus is an integrated, easy-to-use suite of design tools used for designing and simulating circuits before their implementation and fabrication on Printed Circuit Boards (PCB). It is a handy tool mainly popular for checking circuits and embedded designs, considering the availability of all different types of microcontrollers.

The software allows the simulation of the interaction of software running on a microcontroller and any other analog or digital component interfaced with it. It gives real-time experience of physical prototypes on any circuit.

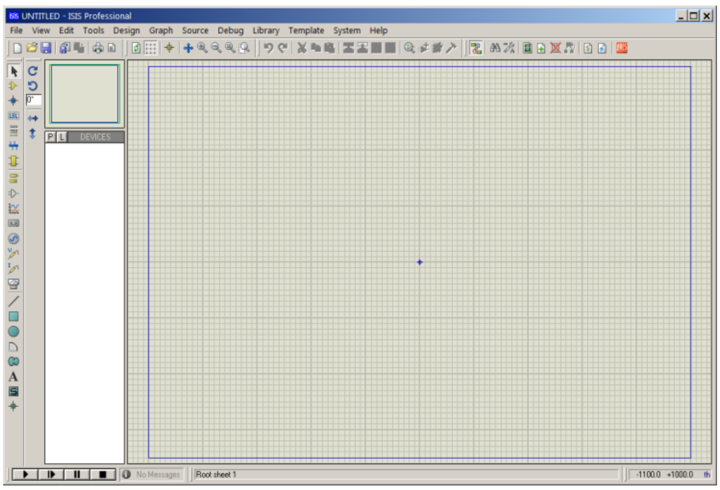

Figure 22: Proteus GUI

X. CONCLUSIONS

Since its inception during the Industrial Revolution, it has become indispensable in modern economies worldwide. They offer convenient, around-the-clock access to products without direct human intervention, making them a cost-effective solution particularly valuable in densely populated countries. This paper highlights the development of an Automated Fuel Vending Machine system as a response to these needs, emphasizing its potential to reduce operational costs and enhance service efficiency. The discussion on hardware architecture, component selection, and system integration provides a foundational understanding of future advancements in automated vending technologies. Further research and development in firmware code implementation promise to enhance the functionality and reliability of such systems, ensuring they continue to meet the evolving demands of global markets.

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