राष्ट्रीय प्रौद्योगिकी संस्थान राउरकेला
NATIONAL INSTITUTE OF TECHNOLOGY ROURKELA

Embedded Systems Project
REPORT

Vending Machine
For Night Canteens

Submitted by

Medipally Saivivek -122EE0378
P Sai Ramesh Kumar-122EE0601
Kotyada Yaswanth Sai-122EE0838

Bachelor of Technology
Electrical Engineering
National Institute of Technology
Rourkela, Odisha

Contents

Chapter 1

Abstract

This project focuses on developing a vending machine system where shopkeepers provide tokens to customers,who then use a Bluetooth-based interface to select and dispense products. The system integrates an HC-05 Bluetooth module with an 8051 microcontroller for wireless communication and product selection. Customers interact with the vending machine via a mobile application, which sends commands through Bluetooth to the microcontroller. The microcontroller processes these commands and activates the corresponding dispensing mechanism.

The vending machine offers an efficient, low-maintenance alternative to manual canteen operations, enhancing convenience for students and reducing operational costs. Using tokens ensures controlled access to the machine, while the Bluetooth interface simplifies the selection process, making it more intuitive and efficient. A 16x2 LCD provides real-time feedback on product selection and dispensing status, enhancing user interaction. This approach combines modern wireless technology with a traditional token-based system, providing a practical and user-friendly solution for vending operations. Future enhancements could include features like inventory tracking and digital payment integration for expanded functionality.

This report details the hardware design, software implementation, and potential applications of the system, emphasizing its suitability for educational institutions and similar environments.

Chapter 2

Introduction

In modern hostel environments, access to snacks is often limited at night due to restricted canteen operations. To address this, we propose an automated vending machine designed specifically for hostel use. This machine uses tokens provided by canteen management, ensuring secure, cashless transactions and reducing operational overhead.

Hostel canteens typically close at night, limiting students' access to essential items. Staffing canteens 24/7 is impractical due to high labor costs and low demand during off-peak hours. Manual cash handling also poses security and accounting challenges. Therefore, an automated solution is needed to provide a convenient, secure, and efficient service without human intervention.

2.1 Potential Use Case:

Our vending machine is designed to serve as an unmanned snack dispenser during nighttime hours. Potential applications include:

Night-time Canteens: Students can purchase snacks using tokens, ensuring convenience and accessibility.

Security Enhancement: Reduces the need for cash transactions, preventing theft and mismanagement.

Resource Efficiency: Eliminates the need for late-night staff, reducing operational costs.

This project integrates 8051 microcontroller technology with a coin detection mechanism and an HC-05 Bluetooth module to deliver a robust and user-friendly solution for the hostel environment.

2.2 Bill of Materials

S No	Components Required	Specifications	Quantity	Cost(₹)
1	8051 Developer board		1	350
2	Microcontroller	AT89C52	1	110
3	IR Sensors		4	190
4	LCD Display	1602a	1	250
5	LED's	Red, Green, Yellow	3	20
6	Buzzer		1	66
7	DC Motor		1	75
8	Bluetooth Module	HC-05	1	280
9	Transistor	BC547, BJT	2	4
10	Motor Driver	L298N	1	50
12	Jumper Wires		As required	50
13	Bread Board		1	90
14	Connecting wires		As required	50
15	Potentiometer	10k ohm	1	40

Total Cost: ₹1625

2.3 Components Description

This pipeline consists of five main components.

- **AT89C52:**
  1. Compatible with MCS-51™ Products
  2. 8K Bytes of In-System Reprogrammable Flash Memory
  3. Endurance: 1,000 Write/Erase Cycles
  4. Fully Static Operation: 0 Hz to 24 MHz
  5. Three-level Program Memory Lock
  6. 256 x 8-bit Internal RAM
  7. 32 Programmable I/O Lines
  8. Three 16-bit Timer/Counters
  9. Eight Interrupt Sources
  10. Programmable Serial Channel
  11. Low-power Idle and Power-down Modes

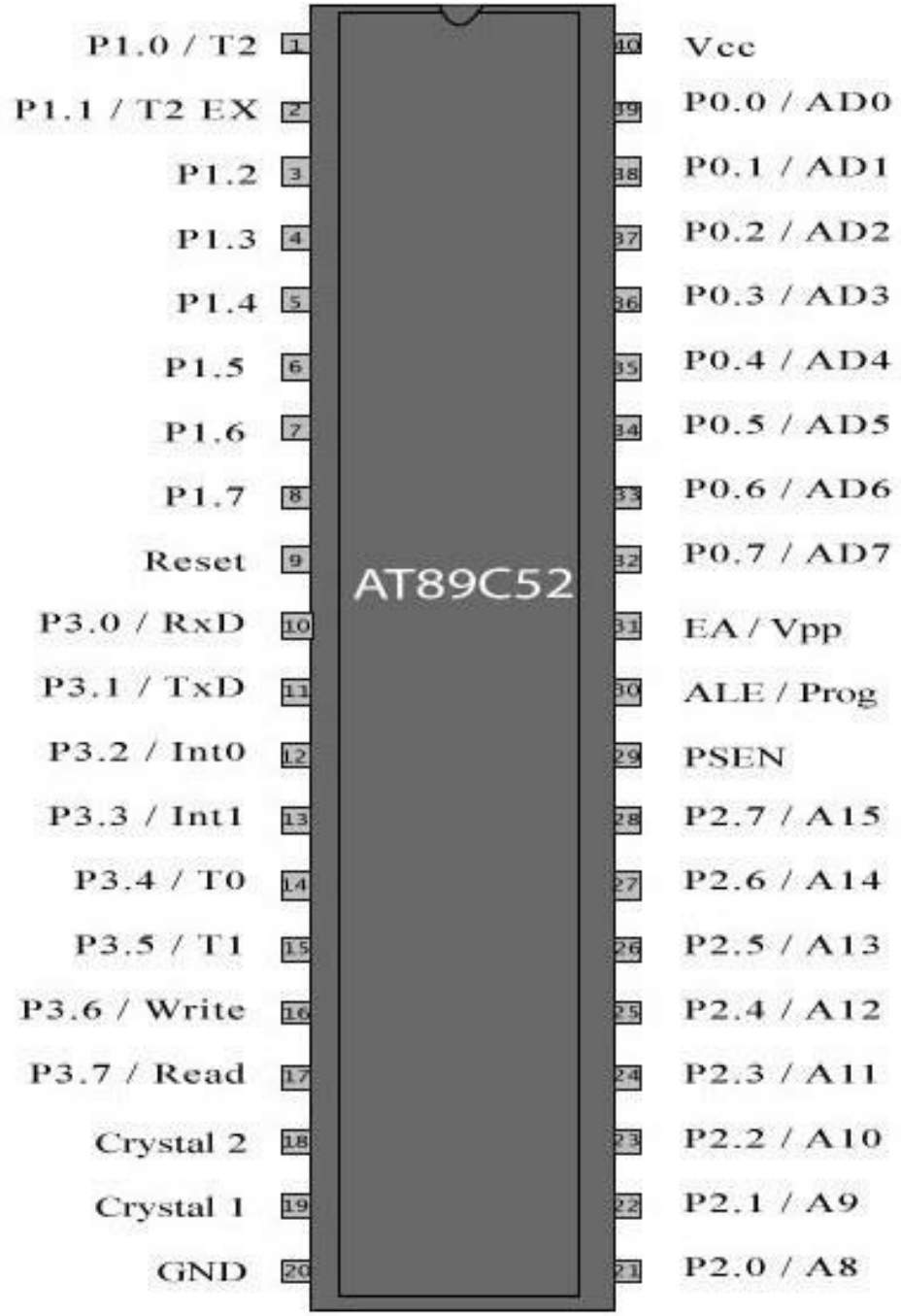

Figure 2.1: AT89C52 Microcontroller

- **MLCD display(1602a):**
  Features:
  Display Format: 16 Character x 2 Line
  Power Supply : Single Power Supply (5V)

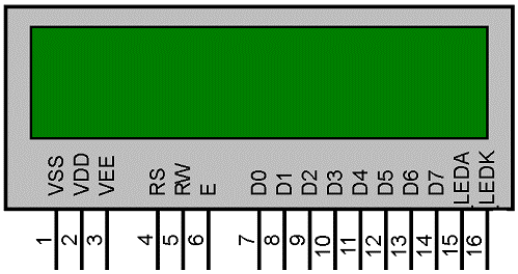

Figure 2.2: MLCD 1602a

Pin No.	Symbol	Level	Description
1	V_{SS}	0V	Ground
2	V_{DD}	5.0V	Supply Voltage for logic
3	VO	(Variable)	Operating voltage for LCD
4	RS	H/L	H: DATA, L: Instruction code
5	R/W	H/L	H: Read(MPU→Module) L: Write(MPU→Module)
6	E	H,H→L	Chip enable signal
7	DB0	H/L	Data bit 0
8	DB1	H/L	Data bit 1
9	DB2	H/L	Data bit 2
10	DB3	H/L	Data bit 3
11	DB4	H/L	Data bit 4
12	DB5	H/L	Data bit 5
13	DB6	H/L	Data bit 6
14	DB7	H/L	Data bit 7
15	A	—	LED +
16	K	—	LED —

Figure 2.3: LCD description

- **Motor Driver (L298N):**
  The L298 Dual H-Bridge Motor Driver controls two DC motors (up to 2A each) or one stepper motor independently, making it ideal for robotics and microcontroller projects. It requires minimal control lines and supports connections with TTL logic gates, switches, or relays.
  Key Features:
  1.Dual H-Bridge Design:
  Controls two DC motors or one stepper motor with forward and reverse motion.
  2.Operating Voltage:
  5V logic (from a microcontroller); motor supply up to 46V
  3.Current Capacity:
  2A continuous per channel, with a 3A peak.
  Additional: On-board +5V regulator, power LED indicators, and protection diodes for back EMF...

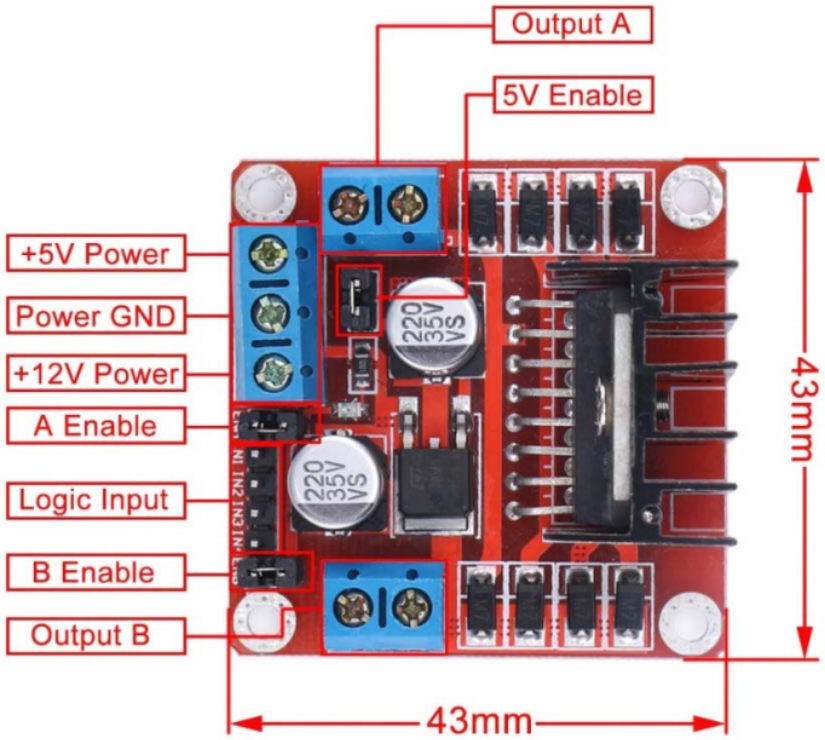

Figure 2.4: L298N Motor Driver

- **IR sensor:**
  The IR Sensor-Single is a general purpose proximity sensor. Here we use it for collision detection. The module consist of a IR emitter and IR receiver pair. The high precision IR receiver always detects an IR signal. The module consists of 358 comparator ICs. The output of the sensor is high whenever it is IR frequency and low otherwise. The onboard LED indicator helps the user to check the status of the sensor without using any additional hardware. The power consumption of this module is low. It gives a digital output.

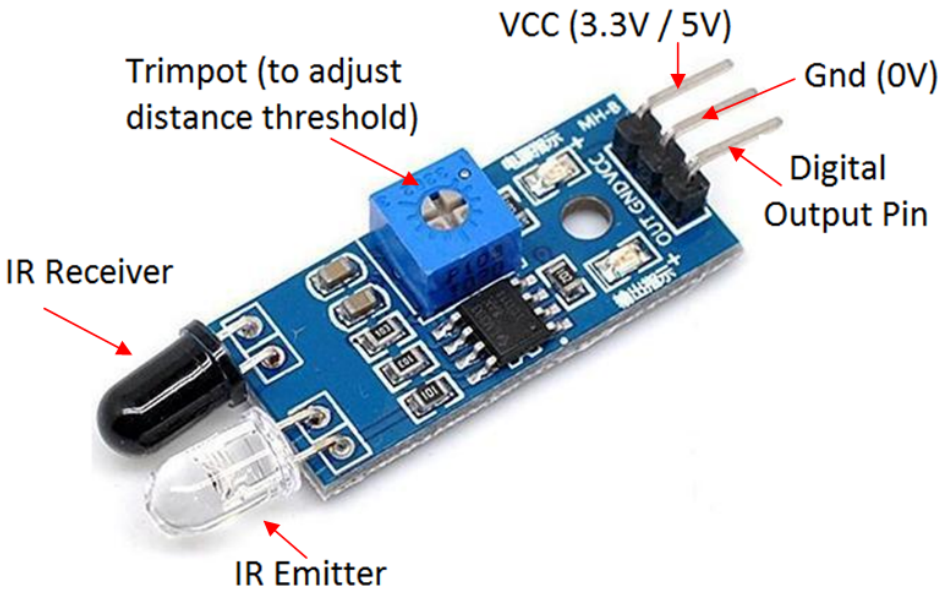

Figure 2.5: IR Sensor

- **HC-05 Bluetooth Module:**
  The HC-05 uses serial communication to connect small devices like mobile phones via a short-range wireless connection (2.45 GHz frequency). It supports data transfer rates up to 1 Mbps within a 10-meter range.
  Key features:
  Power Supply: 4-6V
  Baud Rates: 9600, 19200, 38400, 57600, etc.
  Modes: Operates in Master-Slave mode (either sends or receives data).
  Data Mode: Used for Bluetooth communication and data transfer with other devices.

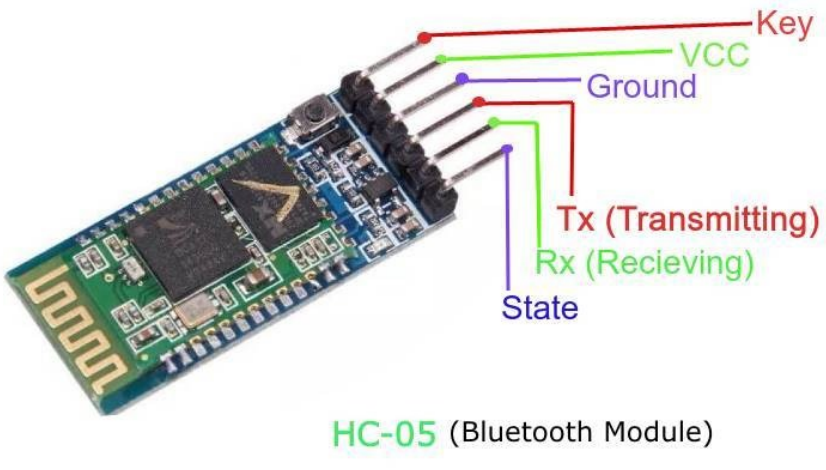

Figure 2.6: HC-05 Bluetooth Module

2.4 Circuit Description:

This vending machine circuit, based on the 8051 microcontroller (AT89C52), integrates various components such as sensors, LEDs, relays, a motor driver, a display, and the HC-05 Bluetooth module to deliver an automated and wireless-controlled solution. Here's a detailed breakdown of the circuit's functionality

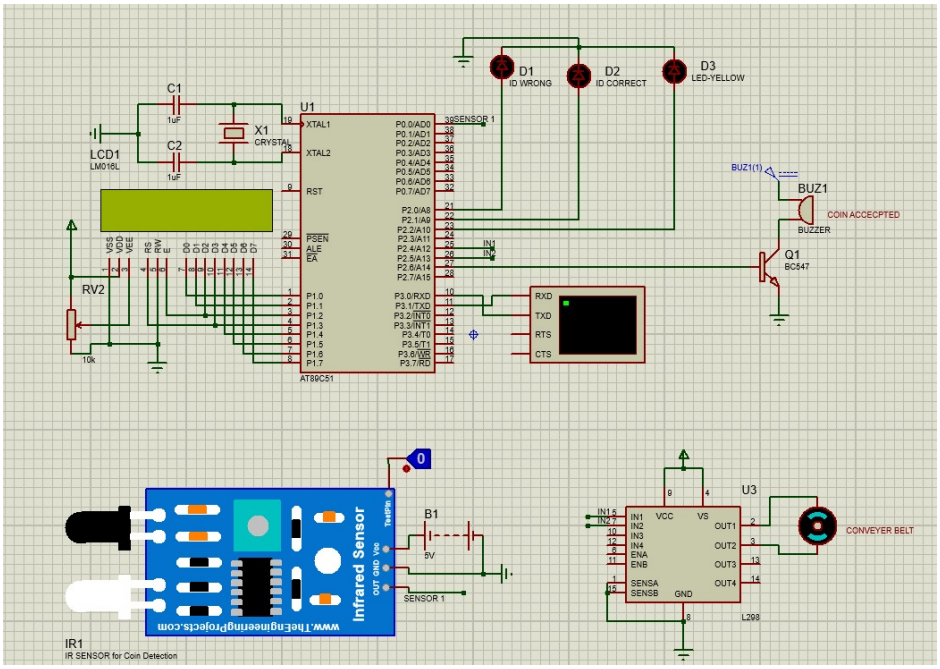

Figure 2.7: Circuit Diagram

1. **Microcontroller (U1 - AT89C51):**
   The 8051 microcontroller manages all operations, including input from sensors, controlling LEDs, activating relays, interfacing with the display, and now, enabling wireless communication through the HC-05 module.

   Ports:
   •P0: Connected to the LCD for data display.
   •P1: Drives control signals for the LEDs and sensors.
   •P2: Linked to relay control and status LEDs.
   •P3: Used for UART communication (for the HC-05 module).

2. **Infrared (IR) Sensor (IR1):**
   Detects coin insertion. When a coin is detected, it sends a signal to the microcontroller, which validates the input and initiates the product dispensing sequence.

3. **LCD Display (LCD1 - LM016L):** Provides real-time feedback to the user, displaying messages such as available products, coin acceptance, or errors.
   Data Pins (D0-D7) connected to P0 of the 8051. Control pins (RS, RW, EN) interface with P2.0, P2.1, and P2.2.

4. **LED Indicators (D1, D2, D3):**
   •D1 (Red LED): Indicates an incorrect or invalid coin.
   •D2 (Green LED): Lights up when the coin is accepted.
   •D3 (Yellow LED): Signals when the machine is operational.

5. **Relay (RL1) and Optocoupler (U2 - PC817):**

   Relay RL1: Controls the power supply to the motor, which drives the conveyor belt.
   Optocoupler: Provides electrical isolation between the microcontroller and high-power devices.

6. **Motor Driver (U3 - L298):** Controls the conveyor motor to dispense the product.
   •IN1-IN4: Control inputs from the microcontroller.
   •OUT1-OUT4: Outputs connected to the conveyor motor.

7. **Buzzer (BUZ1):**
   Provides audio feedback when a coin is accepted or when an error occurs.

8. **HC-05 Bluetooth Module:**
   Connection: Connected to the UART pins of the microcontroller (TXD and RXD on P3.0 and P3.1).

(a) *Functionality:*
•Enables wireless communication, allowing remote monitoring and control of the vending machine via a Bluetooth-enabled device (such as a smartphone or laptop).
•Can transmit machine status (coin acceptance, product dispensing, errors) and receive commands for diagnostics or administrative purposes.

(b) *Integration:*
The module communicates using AT commands for configuration and transmits data to the microcontroller, providing flexibility for wireless operation.

9. **Power Supply:**
• *VCC:* Supplies 5V power to the microcontroller, IR sensor, and HC-05 module.
• *L1:* Represents the AC load (220V) controlled by the relay for connected peripherals.

2.5 Operation Flow (Algorithm):

Algorithm:

Operation Flow Description

1. *Welcome Message:*
The vending machine system starts by displaying a welcome message to the user, indicating that the machine is ready for interaction.

2. *Request for User ID:*
The system prompts the user to enter their ID. This ensures access control and proper tracking of transactions.

3. *Entering ID through Mobile (HC-05 Bluetooth Module):*
•The user enters their ID through a mobile device, which is communicated to the microcontroller using the HC-05 Bluetooth module.
•This wireless communication allows easy interaction with the vending machine without physical input on the device.

4. *ID Verification:*
   The microcontroller checks the validity of the entered ID:
   •Correct ID: If the ID is correct, a green LED glows, and the process continues.
   •Incorrect ID: If the ID is incorrect, a red LED glows, and the system loops back to ask for the correct ID.

5. *Menu Display:*
   Upon successful ID verification, the system displays the available item menu. The user is now ready to make a selection.

6. *Item Selection through Mobile:*
   The user selects the desired item by entering their choice via mobile, communicated through the HC-05 Bluetooth module.

7. *Selection Validation:*
   The system checks if the selected item is within the available range:
   •Valid Selection: If the selection is within bounds, the system proceeds.
   •Invalid Selection: If the selection is out of bounds, a yellow LED glows, and the system prompts the user to make a valid selection.

8. *Coin Insertion Request:*
   Once a valid item is selected, the system asks the user to insert a coin for payment.

9. *Coin Detection through IR Sensor:*
   The system uses an IR sensor to detect the coin:
   •Coin Detected: If the coin is detected, the system proceeds to the next step.
   •Coin Not Detected: If no coin is detected, the system waits until the coin is inserted.

10. *Activation of Buzzer and Motor:*
    •After detecting the coin, the buzzer is turned ON to signal the beginning of the dispensing process.
    •The motor rotates to dispense the selected item.

11. *Item Collection:*
    The user collects the dispensed item, completing the transaction cycle.

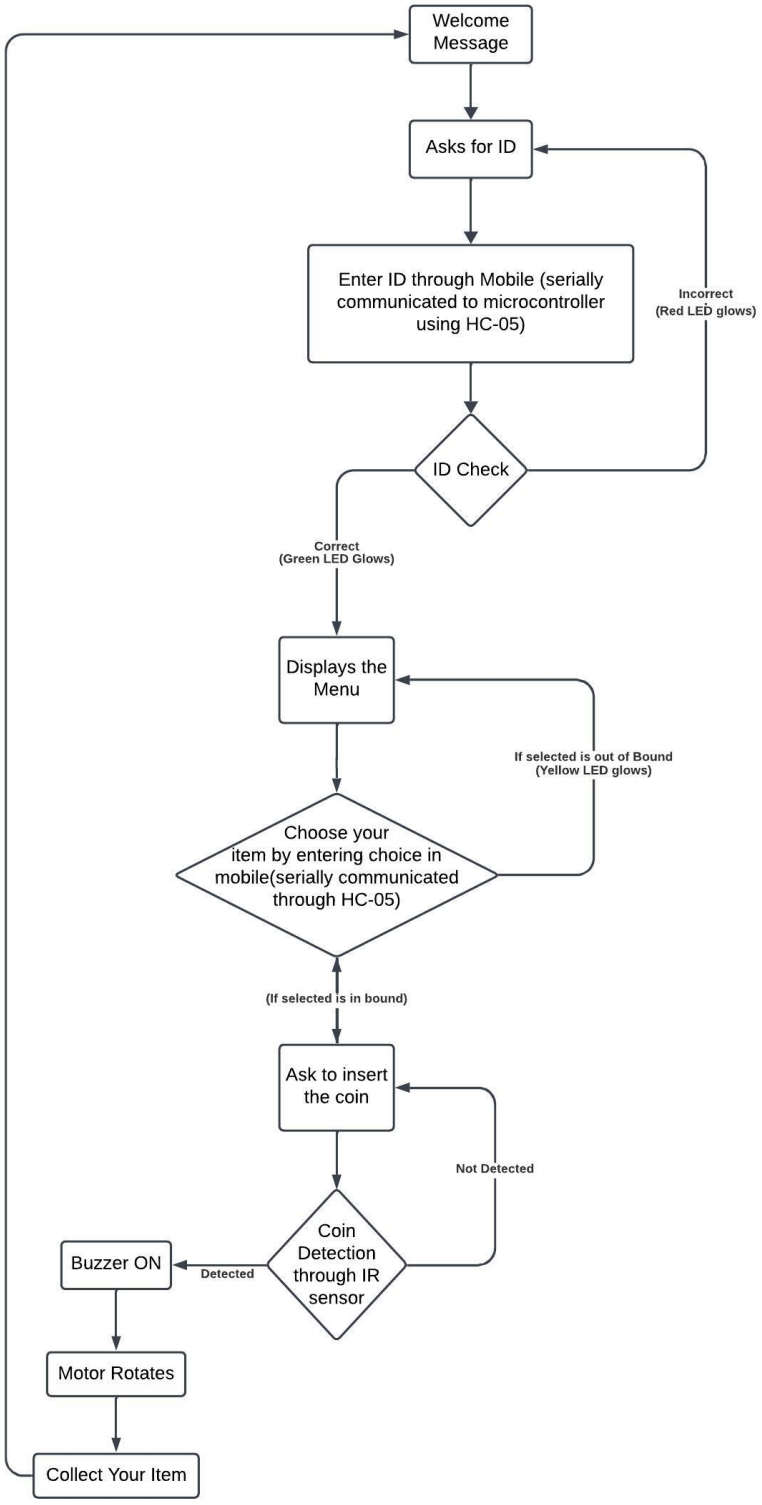

Figure 2.8: Flow Chart (or) Pseudo Code

Chapter 3

Software Development: Code, Challenges, and Testing

3.1 Code Implementation

This section presents the complete assembly code for the vending machine project. The code is designed for the 8051 microcontroller and includes the implementation of core functionalities such as coin detection, LCD interfacing, motor control, and Serial communication using the HC-05 Bluetooth module. Each part of the code is structured to ensure efficient operation and seamless integration of hardware components.

3.2 Learnings & Challenges

- **Technical Learnings**
  During the development of this vending machine project, we gained valuable insights into key embedded systems concepts. We learned how to interface components such as IR sensors and understood the crucial role of motor drivers in controlling hardware efficiently. Additionally, we explored various serial communication protocols, particularly UART, which were essential for establishing proper communication with the microcontroller. Integrating complex modules like the HC-05 Bluetooth module and the LCD provided practical experience and helped us appreciate the importance of precise wiring and configuration.

- **Challenges Faced**
  One significant technical challenge we faced was interfacing the 4x4 matrix keypad with the microcontroller for user interaction. Despite our efforts, integration issues led us to explore alternatives. We selected the HC-05 Bluetooth module for serial communication, which involved studying datasheets and learning its interfacing process. This solution not only resolved the problem but also improved the system's functionality.
  During simulation in Proteus, we faced issues as the IR sensor was not available in the library. We imported it from an external source, but no HEX file was available. After researching, we found and downloaded the necessary files online, enabling successful simulation.

- **Team Dynamics**
  As a team of three members from the same department but different theory sections, coordinating effectively was initially challenging due to varying class schedules. The deadline coincided with our end-semester exams, adding to the pressure. However, an extension provided after the exams allowed us to regroup and focus on successfully completing the project. This experience reinforced the importance of effective time management and clear communication within the team.

- **Testing and Debugging**
  Testing the coin detection mechanism posed challenges, especially in differentiating coins from other objects under varying lighting conditions. We calibrated the IR sensor based on datasheet specifications for precise detection. For the LCD display, we adjusted the potentiometer to ensure proper contrast and functionality. Signal instability issues from wiring and power fluctuations were resolved through improved circuit design. Stable communication of the HC-05 Bluetooth module was verified with repeated data transmission tests. Systematic debugging and simulation tools were crucial in ensuring overall system reliability.

- **Circuit Design**
  The circuit design involved integrating key components such as the IR sensor, AT89C52 microcontroller, LCD display, LEDs, and the L298 motor driver. Key design considerations included accurate sensor placement for reliable coin detection, stable power supply regulation, and effective noise filtering with decoupling capacitors. Breadboarding presented challenges such as maintaining stable connections and managing signal noise, particularly for motor and sensor operations. Through careful simulation, module testing, and systematic debugging, we optimized the circuit's functionality and reliability. This process highlighted the importance of a structured and methodical design approach.

3.3 Simulation & Test Results

The project was simulated in Proteus to verify functionality before hardware implementation. Key components—8051 microcontroller, IR sensor, LCD, HC-05 Bluetooth module, and DC motor—were integrated and tested virtually. Coin detection and motor control were validated under various simulated conditions. We also tested the same on hardware, ensuring the design met all functional requirements.

1. **System Initialization:** Upon starting the simulation, a welcome message appeared on the LCD display, confirming the correct initialization of the system.

2. **ID Verification:** When an ID was entered via the mobile device through HC-05 Bluetooth, it was verified by the microcontroller.
   –For correct IDs, the Green LED glowed, indicating successful authentication.
   –For incorrect IDs, the Red LED glowed, and the system returned to the ID entry state, ensuring no unauthorized access.

3. **Menu Display and Product Selection:**
   After successful ID verification, the LCD displayed the product menu. The product selection communicated through Bluetooth was tested:
   –If the selected item was within the available range, the system proceeded to the next step.
   –If the item was out of range, the Yellow LED glowed, prompting the user to make a valid selection.

4. **Coin Detection Mechanism:**
   Upon prompting to insert the coin, the IR sensor detected the coin's presence.
   –If the coin was detected, the system activated the buzzer and proceeded to rotate the motor.
   –If no coin was detected, the system looped back, waiting for valid input.

5. **Motor Operation and Item Dispensing:**
   When the coin detection was confirmed: –The DC motor rotates, simulating item dispense.
   –The motor's operation was verified for consistent response times and accurate functioning.

6. **Final Output:**
   The final message on the LCD displayed "Collect Your Item," confirming the completion of the transaction.

3.4 Future Enhancements

- **Selection and Design Considerations:**
  The prototype uses a DC motor for demonstration, but a stepper motor or AC motor would be more suitable for a practical vending machine due to better control and higher torque. Key considerations include:

  1. *Optocoupler Integration:* Essential for isolating low-power control circuitry from the high current of an AC motor.
  2. *Power Supply:* A 220V AC supply with a relay ensures safe and efficient switching operations.

- **Enhanced Coin Detection System:**
  Upgrading to an advanced coin detection system that checks size, weight, and material composition would improve accuracy and reduce fraud, enhancing security and reliability.

- **User Authentication and Security:**
  Assigning unique IDs to users instead of a single ID would strengthen security, ensuring only authorized individuals can access the machine.

- **Expanded Product Options:** The current design supports limited products. Expanding it to handle more products with varying prices would better serve students' needs, requiring additional compartments and code updates for dynamic pricing.

- **UPI-Enabled Online Payments:**
  Adding a QR code system for UPI payments would provide a convenient, cashless option, enhancing usability and reducing dependency on coins.

Chapter 4

Conclusion

The development of the vending machine project utilizing the 8051 microcontroller successfully demonstrates an automated system capable of dispensing snacks based on coin detection. The integration of IR sensors, motor drivers, and HC-05 Bluetooth module showcases the practical application of embedded systems and highlights the seamless communication between hardware and software components. The inclusion of wireless communication via the HC-05 module further enhances functionality, allowing for remote monitoring and control.

This project addresses a practical problem, particularly for night canteens in hostel premises, offering a reliable, cost-effective, and user-friendly solution. Throughout the design, simulation (using Proteus), and implementation phases, valuable technical insights were gained, particularly in microcontroller programming, sensor interfacing, and Serial communication protocols.

Overall, the project demonstrates not only technical proficiency but also problem-solving and teamwork skills, serving as a foundation for more advanced embedded system applications in real-world scenarios.

4.1 References & Bibliography

Theses are the list of resources and technical documents referenced during the development of the vending machine project. These include datasheets and manuals for the key components used, and some research papers which were essential for understanding component specifications, interfacing, and ensuring accurate circuit design.

1. **AT89C52:** https://www.keil.com/dd/docs/datashts/atmel/at89c52$_{d}s.pdf$
2. **LCD Display:** https://www.openhacks.com/uploadsproductos/eone-1602a1.pdf
3. **HC-05 Bluetooth Module:** https://components101.com/sites/default/files/component$_{d}atasheet/HC-05\%20Datasheet.pdf$
4. **Motor Driver:** https://www.handsontec.com/dataspecs/L298N%20Motor%20Driver.pdf
5. **Research Paper:** https://ijarse.com/images/fullpdf/1494234168$_{i}jarse649.pdf$

Acknowledgments

We would like to express our sincere gratitude to all those who contributed to the successful completion of our 8051 microcontroller-based vending machine project.

First and foremost, we extend our heartfelt thanks to our course professor, Dr. Supratim Gupta, for encouraging us to undertake projects that provide practical, hands-on knowledge in Embedded Systems. His guidance and motivation played a pivotal role in shaping our understanding and approach to this project.

We also wish to thank the Teaching Assistants (TAs) for their constant support and invaluable assistance throughout the process. Their guidance helped us navigate technical challenges effectively.

Special thanks to the lab technician for providing the necessary components and ensuring we had access to the resources required for successful project implementation.

Lastly, we extend our appreciation to our team members for their dedication, collaboration, and hard work. Their contributions were instrumental in the successful completion of this project.