

Design a Smart Digital Vending Control Unit Using VHDL

Dr. Punam Chati¹, Mr. Himanshu Khobarkar², Mr. Harsh Ruikar³, Mr. Valay Sukhdeve⁴

¹Assistant Professor, ETC Department, Priyadarshini College of Engineering Nagpur, Maharashtra India, 440019

^{2,3,4}Research Scholar, ETC Department, Priyadarshini College of Engineering Nagpur, Maharashtra India, 440019

Abstract - The Smart Digital Vending Control Unit Using VHDL is designed to automate the process of product selection, payment confirmation, and product dispensing in a vending machine system. The proposed system integrates FPGA-based control logic with a Raspberry Pi based user interface to create a modern and efficient vending solution. The VHDL controller is used to manage the internal machine operations such as product selection, payment validation, stock checking, and dispense control, while the Raspberry Pi provides an interactive display for the user.

This system is developed to overcome the limitations of conventional vending machines by introducing a digital user interface, quantity display, total price calculation, and support for simulated digital payment methods. The machine improves user convenience by displaying clear product information and enabling smooth interaction between software and hardware modules. The proposed design is reliable, modular, and suitable for simulation as well as practical FPGA-based implementation. It also provides a foundation for future enhancements such as real online payment gateway integration, IoT monitoring, and inventory management.

I. INTRODUCTION

A vending machine is an automated system that dispenses products such as cold drinks, snacks, or packaged items when the required payment is made by the user. Traditional vending machines are mainly based on simple hardware logic and limited payment methods, which reduce flexibility and user friendliness. In today's digital era, users expect better interfaces, faster operation, and support for modern payment options.

The proposed project, Design a Smart Digital Vending Control Unit Using VHDL, aims to develop an intelligent vending machine controller that combines digital hardware design with a user-friendly software interface. The main control logic of

the system is implemented using VHDL on an FPGA board. The FPGA handles core operations such as product selection, payment approval, stock verification, and dispensing control. A Raspberry Pi is used to create a modern graphical user interface for displaying products, quantity, total price, and payment options.

The system is especially useful for academic demonstration, digital control learning, and real-time automation applications. It shows how hardware description languages like VHDL can be used to build practical industrial systems. The project also demonstrates the integration of FPGA and Raspberry Pi for smart embedded applications. This approach increases system flexibility, improves user interaction, and brings a modern digital experience to vending automation.

II. LITERATURE SURVEY

1. Design and Implementation of Vending Machine Controller using VHDL

A literature review of VHDL-based vending machine controllers shows that hardware description language is highly suitable for implementing reliable and structured vending logic. In the work by S. Thele, P. Gaikwad, V. Divekar, S. Shelar, and R. Shastri, the vending machine controller was designed using Finite State Machine (FSM) concepts and simulated in VHDL, with implementation on a Basys 3 FPGA board. The study highlights that VHDL-based design provides better control over product selection, payment verification, and output generation. The use of FPGA hardware also improves speed and hardware-level reliability.

This work is important because it proves that vending machine automation can be effectively implemented using VHDL and digital logic design.

2. FSM based Vending Machine Controller

The literature on FSM-based vending machine controllers emphasizes that finite state machine modeling is one of the most effective methods for handling the sequence of operations in automated systems. The work by Mala Swadi, Aditya, and B. S. Chaithrashree presents a vending machine controller in *IJEDR*, Volume 13, Issue 4, December 2025, pages 641–646. The paper explains that FSM design helps divide the full operation into separate logical states such as idle state, money acceptance state, product selection state, validation state, dispensing state, and change-return state.

This structured approach improves predictability, modularity, and ease of implementation on FPGA hardware. Such work is highly relevant to the proposed project because the smart digital vending control unit also relies on FSM-based sequencing for organized control.

3. Implementation of Vending Machine through Verilog HDL

A review of HDL-based vending systems also includes Verilog-based designs, which demonstrate similar advantages in digital control and simulation. In the work by R. H. Naik, R. Sravya, P. Gopi Chand, Y. Venkata Ravi, and P. Jagadeesh, the vending machine was implemented through Verilog HDL using FSM methodology. The paper explains that the machine operation is divided into states such as idle, accepting coins, dispensing item, and returning change.

This shows that HDL-based vending controllers can be simulated and verified before hardware realization, reducing errors and improving design accuracy. Although the proposed project uses VHDL, this study is still useful because it confirms the value of HDL-based FSM modeling for vending applications.

4. FPGA Based Smart Vending Machine

Recent research also focuses on FPGA-based smart vending machines with improved flexibility and faster control. Mukul Suthar's 2021 IEEE conference paper, *A Novel Implementation of FPGA Based Smart Vending Machine*, presented at the International Conference on Technology, Research, and Innovation for Betterment of Society (TRIBES), shows that FPGA platforms are highly suitable for

smart vending applications because they support real-time processing, reconfigurability, and reliable hardware control.

The study demonstrates that FPGA-based vending systems can be extended more easily than fixed hardware designs, making them useful for smart and modern automation systems. This directly supports the proposed project, where FPGA is used as the main control platform for vending operations.

5. Modeling and Simulation of a Vending Machine Through FSM Using VHDL

Another important direction in the literature is the detailed modeling and simulation of vending machines using FSM with VHDL. A 2024 Springer chapter, *Modeling and Simulation of a Vending Machine Through FSM Using VHDL*, highlights the importance of designing vending operations in a systematic state-driven manner.

The work explains that VHDL and FSM together provide a strong platform for organizing user input, transaction validation, item dispensing, and reset behavior in a clear and testable way. Such an approach is particularly useful in academic and hardware design environments because it allows simulation before implementation and makes the overall system easier to analyze.

This is closely related to the proposed project, which uses FSM and VHDL for implementing a smart digital vending controller.

III. OBJECTIVE

The main objectives of the proposed system are as follows:

1. To design a smart vending machine controller using VHDL.
2. To implement the vending control logic on an FPGA platform.
3. To provide a digital and user-friendly interface using Raspberry Pi.
4. To display product details, quantity, and total price on the screen.
5. To simulate modern payment methods such as digital payment in the vending process.
6. To generate proper control signals for product dispensing.
7. To improve the reliability, flexibility, and automation of conventional vending machines.
8. To create a system that can be expanded in

future with real payment gateway and inventory features.

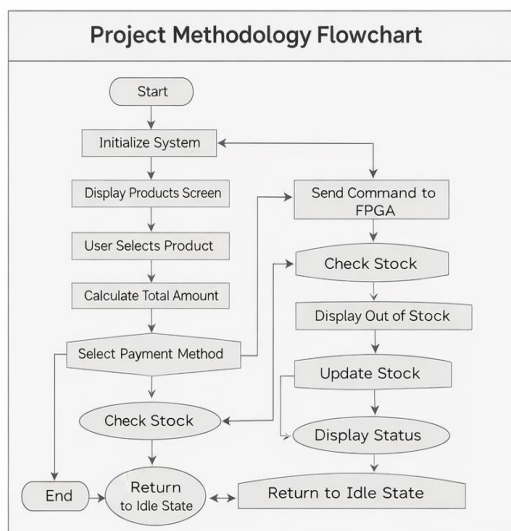
IV. PROJECT METHODOLOGY

The proposed smart vending machine works by integrating a graphical user interface running on Raspberry Pi with a VHDL-based control unit implemented on FPGA. The complete operation of the system can be explained in a sequence of steps.

First, the user interacts with the Raspberry Pi display interface. The available products are shown on the screen along with their prices. The user selects the desired product and quantity. After selection, the total price is calculated and displayed automatically.

Next, the user chooses the payment method. In this project, digital payment and cash payment are considered in simulated form for demonstration purposes. Once the payment is confirmed through the interface, a signal is sent from the Raspberry Pi to the FPGA controller.

The FPGA, programmed using VHDL, acts as the central control unit of the vending machine. It checks the received selection input, verifies product availability, and activates the dispense control output. If sufficient stock is available and payment is successful, the controller generates the required signal to dispense the selected product. If the product is unavailable, the system displays an out-of-stock message.



User Interface Module:

This module is developed on Raspberry Pi and is responsible for displaying products, taking user input, showing quantity, total price, and payment status.

Product Selection Module:

This module allows the user to choose a product and quantity. The selected data is forwarded to the controller.

Payment Processing Module:

This module handles payment confirmation. In the current design, the payment process is simulated for digital operation and demonstration.

FPGA Control Module:

This is the core module implemented in VHDL. It manages state transitions, validates the process, checks stock status, and controls dispensing signals.

Dispensing Module:

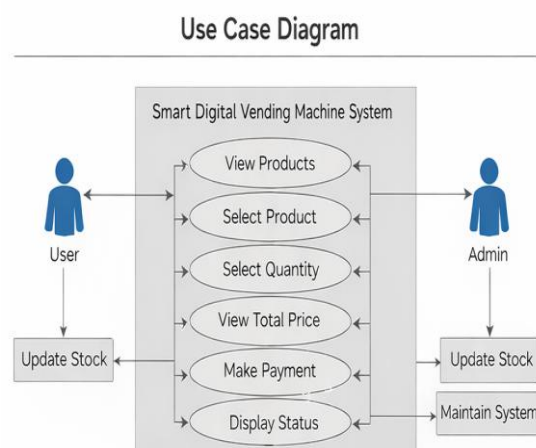
This module represents the output control section of the vending machine. It receives the control signal from the FPGA and initiates product dispensing.

Stock Monitoring Module:

This module checks whether the selected item is available. If stock is not available, the system prevents dispensing and shows an error message.

V. USE CASE DIAGRAM

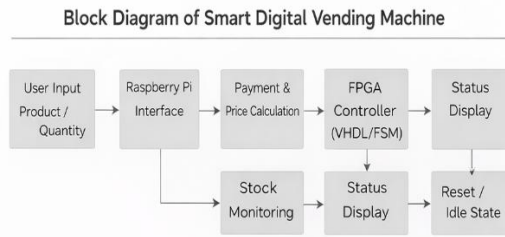
The use case diagram shows the interaction between the user, admin, and the smart digital vending machine system. It represents the main functions such as product selection, quantity selection, payment processing, stock updating, and product dispensing.



VI. BLOCK DIAGRAM

The block diagram of the smart digital vending machine shows the overall system architecture. It includes user input, Raspberry Pi interface, payment

and price calculation module, FPGA controller, stock monitoring unit, status display, and reset/idle state, which together perform product selection, payment verification, dispensing control, and system status management.



VII. CONCLUSION

The Smart Digital Vending Control Unit Using VHDL is an efficient and modern approach for automating vending machine operations. The project successfully combines FPGA-based digital control with a Raspberry Pi based user interface to create an interactive and intelligent vending system. The use of VHDL makes the controller precise, fast, and suitable for hardware implementation, while the Raspberry Pi improves the overall usability by providing a clear and attractive user interface.

The proposed system demonstrates product selection, quantity handling, total price display, payment confirmation, stock checking, and dispensing control in a structured manner. It overcomes many limitations of conventional vending machines and creates a strong base for future smart vending applications. Thus, the project is useful not only as an academic implementation of VHDL and FSM concepts but also as a practical model for modern automated vending technology.

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