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Coffee-Making Machine Using Verilog HDL

M. Krishna Vamsi[1], K. Lakshman Teja[1], R. Yeswanth Narayana[1], K. Bhaskara Sai Srivardhan[1], K. Siva Ranjini[2,*]

Abstract

This paper focuses on the design and implementation of a coffee machine using Verilog, aimed at understanding how real-life machines can be controlled using digital logic. In daily life, a coffee machine works by taking user inputs, processing them, and giving the required output, such as preparing coffee. The main objective of this project is to design a simple digital system that controls the basic working of a coffee machine. The design is created using Verilog hardware description language, where different states of the coffee machine, such as idle, taking input, preparing coffee, and dispensing coffee, are modeled using digital logic. Simple control signals are used to represent actions like starting the machine, selecting coffee, and completing the process. This approach helps beginners understand how hardware behaves step by step in a real-world system. The design is tested and verified using simulation, which confirms that the coffee machine works correctly for all inputs. Furthermore, the design highlights modularity and scalability, facilitating future improvements like multiple beverage options, timing control, and user interface integration. Additionally, it familiarizes students with practical elements of designing digital systems, such as state optimization and resource efficiency. The project highlights include easy understanding, real- life relevance, and clear control flow, making it suitable for beginners. Overall, the project demonstrates how everyday machines can be represented and controlled using simple hardware logic.

Keywords: Verilog HDL, automatic coffee machine, digital logic design, finite state machine (FSM), FPGA implementation

INTRODUCTION

Automatic coffee machines have become an important part of modern life because of their ability to prepare beverages quickly and consistently. These machines are commonly used in offices, hotels, restaurants, and public places where large numbers of people require instant coffee services. Traditional coffee preparation methods involve manual effort and time, which may lead to inconsistencies in taste and quality. Automation can help solve these issues by precisely and efficiently controlling the preparation process.

***Author for Correspondence**
Siva Ranjini
E-mail: ranjanikankala@gmail.com

[1]UG Scholar, Department of Electronics and Communication Engineering, Bonam Venkata Chalamayya Engineering College (Autonomous), Odalarevu, Andhra Pradesh, India
[2]Assistant Professor, Department of Electronics and Communication Engineering, Bonam Venkata Chalamayya Engineering College (Autonomous), Odalarevu, Andhra Pradesh, India

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Recent developments in very large-scale integration (VLSI) technology have made it possible to design compact digital systems capable of controlling complex appliances. Using hardware description languages such as Verilog HDL, engineers can model digital systems at the register transfer level and verify their behavior before implementing them in hardware. This approach provides reliable performance and precise control over system operations [1, 2].

The proposed automatic coffee-making machine uses digital logic to control various operations, including ingredient selection, heating, mixing, and beverage dispensing. The system accepts user inputs that determine the type of beverage to be prepared. Based on the selected option, the machine activates the required components, such as coffee powder dispensing, milk addition, sugar addition, and water supply.

The system guarantees the correct order of operations by managing each phase in a regulated manner, from dispensing the ingredients to producing the final output. This ensures that the taste and quality remain consistent using predefined logic conditions. Moreover, safety features help avert problems such as overheating or the use of incorrect ingredient combinations. By enhancing reliability and efficiency, the system is better suited for practical, real-world use while guaranteeing smooth and precise automated beverage preparation [3, 4].

Unlike many conventional designs that rely heavily on microcontrollers or software-based control, this system was implemented entirely using hardware logic. This approach ensures deterministic timing, reduced power consumption, and high reliability. The design also demonstrates the practical application of the Verilog HDL in modeling real-world automated systems.

RELATED WORK

Several studies have explored automated beverage dispensing systems using embedded systems and digital controllers. Early coffee machines were electromechanical devices that relied on relays and timers for operation. Although these machines perform basic tasks, they lack the flexibility and precision required to control the brewing process.

Subsequently, many researchers introduced microcontroller-based vending machines that use software programs to control dispensing operations. These systems use sensors and programmable logic to manage heating, mixing, and the distribution of ingredients. Although such systems provide flexibility, they require continuous processor operation, which increases power consumption and introduces software dependency [5, 6].

In digital hardware design, Verilog HDL has been widely used to implement automation systems, such as vending machines and industrial controllers. Most of these designs rely on finite state machines (FSMs) to manage sequential operations. FSM-based designs provide structured state transitions but often become complicated when the number of states increases.

With increasing system complexity, the design may necessitate additional states, transitions, and control signals. This can complicate the management and debugging of the overall implementation. If not managed correctly, this can result in a greater use of hardware resources and diminished design efficiency. Designers adopt techniques such as state minimization, hierarchical FSM design, and modular coding practices to simplify the architecture and address these challenges. In addition, appropriate documentation and simulations are essential for confirming system behavior and ensuring reliability.

Owing to the development of design tools and synthesis techniques, contemporary Verilog-based systems are increasingly optimized, scalable, and easier to implement, even for complex automation applications [7, 8].

The proposed work introduces a simplified approach by implementing the coffee machine control logic using conditional statements and synchronous counters instead of an FSM-based architecture. This method reduces hardware complexity while maintaining a reliable operation and a clear design structure.

SYSTEM ARCHITECTURE

Block Diagram

The automatic coffee-making machine was designed as a modular digital system consisting of several functional units. The system operates using a global clock signal that synchronizes all the operations.

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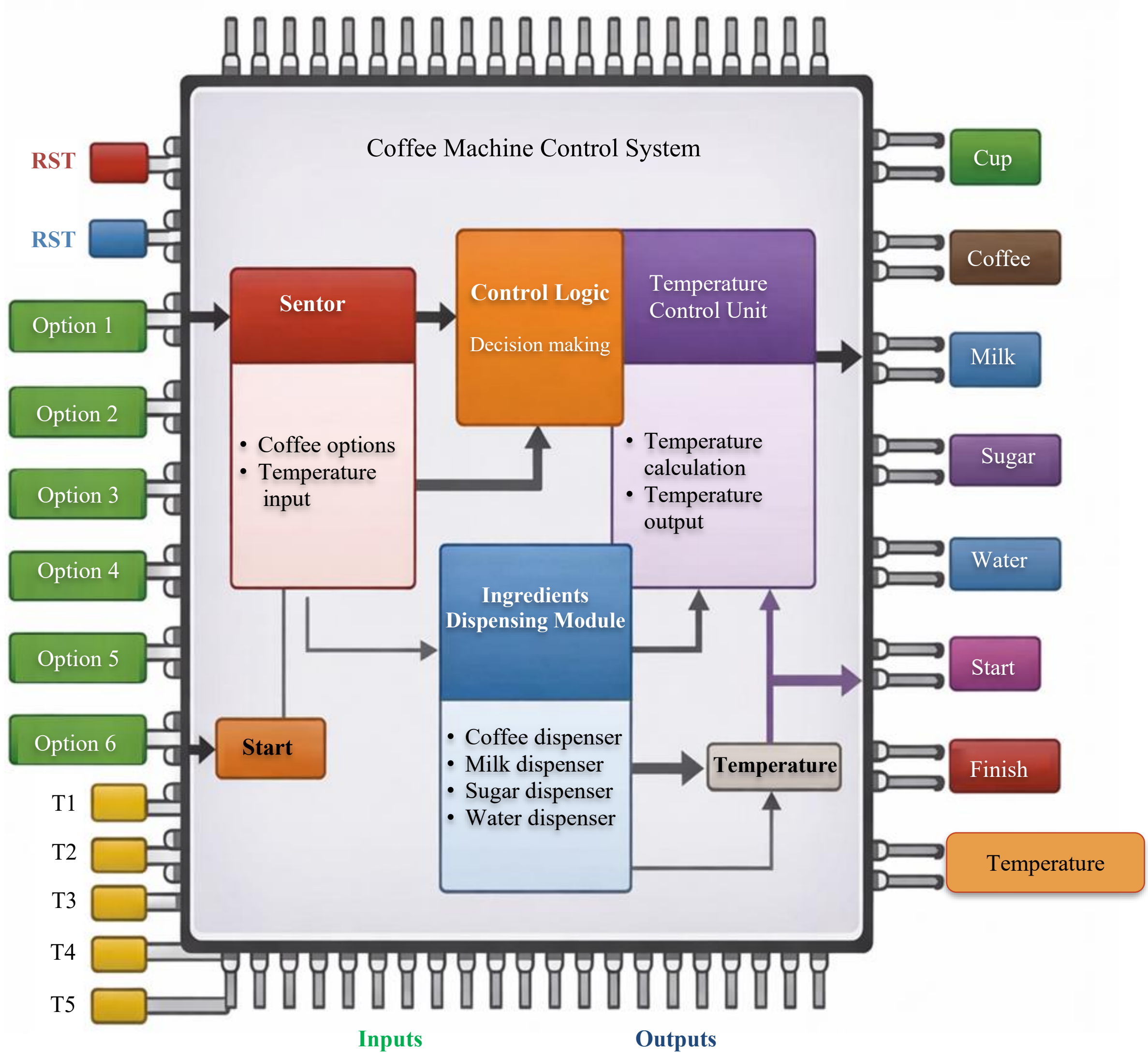

Figure 1. Architecture of an automatic coffee-making machine.

The major components of the system include:

- Input selection unit.
- Control logic unit.
- Ingredient dispensing modules.
- Temperature control unit.
- Output and completion unit.

The input section receives user selections and control signals, such as start and reset. These inputs are processed by the control logic unit, which determines the operations required to prepare the selected beverage [9, 10].

Ingredient dispensing modules activate the appropriate outputs, such as coffee powder, milk, water, and sugar. The temperature control module manages the heating operations, ensuring that the beverage reaches the desired temperature before being dispensed. Figure 1 shows the architecture of automatic coffee-making machines.

Input Signals

The system uses the following input signals:

- *Clock (clk):* Synchronizes all system operations.
- *Reset (rst):* Initializes the system.
- *Start:* Begins the coffee preparation process.
- *Option inputs (Option 1–Option 6):* Select beverage type.
- *Temperature inputs (T1–T5):* Select heating level.

The system functions based on a collection of input signals that manage and synchronize its operations. The clock (clk) signal is essential for synchronizing all system operations, guaranteeing that each process occurs in a timely and organized manner. The reset (rst) signal initializes the system, reverting it to a known starting state whenever necessary. Once the user has made all the selections, the start signal activates the coffee preparation process. Moreover, the system features option inputs (Option1–Option6) that enable users to select different types of beverages based on their preferences. These options determine the combination of ingredients used during preparation. Inputs (T1–T5) are also provided to control the heating level and customize the beverage temperature. Collectively, these input signals provide flexibility and user control while ensuring that the automated coffee-making system operates smoothly.

Output Signals

The design produces several output control signals:

- Cup placement signal.
- Coffee dispensing signal.
- Milk supply signal.
- Water dispensing signal.
- Sugar dispensing signal.
- Stirring control signal.
- Finish signal indicating completion of beverage preparation.

These outputs control the operations required to prepare the selected beverage. The design produces several output control signals that manage the entire operation of the coffee-making process. This includes a signal for cup placement to guarantee the correct positioning of the cup prior to the commencement of the process, followed by signals for coffee dispensing, milk supply, and water dispensing, according to the chosen beverage type. Moreover, when the user chooses sugar, a signal for dispensing sugar is triggered, guaranteeing customization based on the user's preference. The stirring control signal ensures that all the components are mixed correctly to attain the intended consistency and flavor. Finally, a signal is produced to indicate that beverage preparation is completed [11].

These output signals work in coordination to control each step systematically, guaranteeing precise functioning, minimizing mistakes, and enhancing the efficiency of the automated system, all while providing a dependable and uniform user experience.

WORKING PRINCIPLE

The coffee machine begins working when the user selects a beverage option and presses the start button. The system evaluates the selected option using conditional logic statements implemented in Verilog HDL.

Each beverage option corresponds to a specific combination of the ingredients. For example, cappuccino options require both coffee powder and milk, whereas espresso options require coffee and water. If sugar is selected, the sugar dispensing module is activated, and the stirring mechanism enables you to mix the ingredients.

The system can be expanded to include timing control for each operation, in addition to ingredient selection, ensuring that each ingredient is dispensed in the correct order and for the correct duration for optimal taste and consistency. To improve the machine's reliability and safety, sensors can be added to track the ingredient levels, temperature, and availability of cups. In addition, methods for dealing with mistakes can be put into practice to oversee situations such as a lack of ingredients or malfunctions in the system, supplying suitable notifications to the user. This enhances the user's experience and contributes to a more resilient design that is appropriate for practical use.

The temperature control unit determines the heating level using predefined temperature values. Each temperature input contributes a weighted value to the final temperature output, allowing for a simple hardware-based temperature calculation.

Once all the required operations are completed, the system activates a finish signal to indicate that the coffee is ready. All the control signals are then reset to prepare the machine for the next operation.

IMPLEMENTATION AND RESULTS

The proposed coffee machine design was implemented using Verilog HDL and simulated using the Xilinx Vivado Design Suite. The simulation process verified the behavior of the design under different input conditions and beverage selections.

A testbench module was developed to generate clock signals, reset signals, and various coffee selection inputs. The simulation waveforms confirmed that the system activated the correct output signals for each selected beverage option.

The results shown in Figure 2 indicate that the machine correctly performed ingredient dispensing, temperature control, and mixing operations according to the selected configuration. The finish signal is generated once the preparation process is completed, indicating a successful system operation.

APPLICATIONS

The proposed automated coffee-making system can be applied in several environments:

- Coffee vending machine.
- Offices and corporate workplaces.
- Educational institutions.
- Airports and railway stations.
- Hotels and restaurants.

These applications benefit from fast and consistent beverage preparation with minimal human intervention.

The suggested automated coffee-making system is suitable for diverse settings in which fast and dependable drink preparation is crucial. This is appropriate for coffee vending machines, as users anticipate rapid service that maintains uniform quality. In offices and corporate environments, it boosts convenience by minimizing manual labor and conserving employees' time. Such systems can be advantageous for educational institutions by offering students and staff easy access to refreshments. Furthermore, this system can be employed in high-traffic locations such as airports and train stations to provide effective services to a large volume of customers. This technology can also be integrated into hotels and restaurants to ensure consistency in beverage preparation. Overall, these applications guarantee rapidity and precision in daily operations while minimizing the need for human involvement.

CONCLUSION AND FUTURE SCOPE

This study presented the design and implementation of an automatic coffee-making machine using Verilog HDL. The system automates the coffee preparation process by controlling the dispensing, heating, and mixing operations of the ingredients using digital logic. The simulation results demonstrate that the design functions correctly under different input conditions.

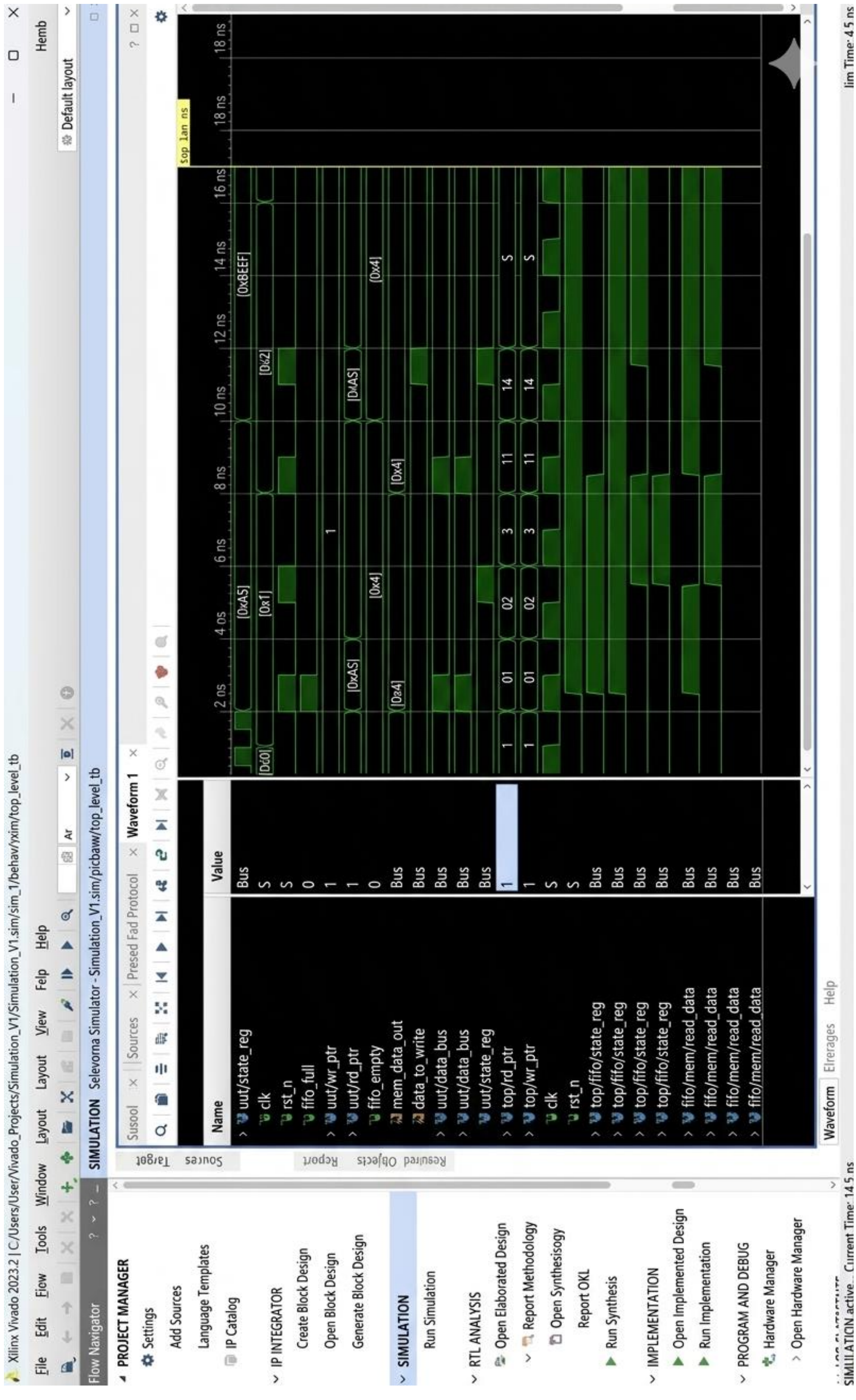

Figure 2. Coffee machine simulation waveform result.

CONCLUSION AND FUTURE SCOPE

This study presented the design and implementation of an automatic coffee-making machine using Verilog HDL. The system automates the coffee preparation process by controlling the dispensing, heating, and mixing operations of the ingredients using digital logic. The simulation results demonstrate that the design functions correctly under different input conditions. The behavioral modeling approach simplifies the design by eliminating the need for complex FSM structures. The proposed architecture is scalable, reliable, and suitable for Field-programmable gate array (FPGA)-based implementations.

Additionally, the design promotes modular development, where individual components, such as dispensing, heating, and control units, can be independently optimized and reused. This improves maintainability and reduces the development time for similar applications. The system also demonstrates efficient resource utilization, making it practical for real-time, embedded hardware systems.

Future improvements may include hardware implementation using FPGA boards, integration with sensors for safety monitoring, and support for additional beverage options, such as tea or hot chocolate.

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