Documentation

SL TEAM
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1. Team members

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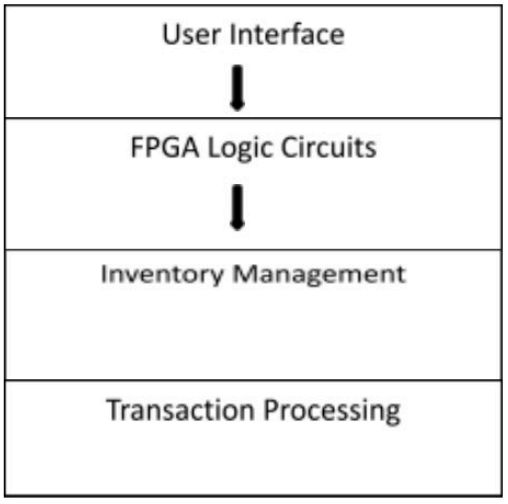
2. Introduction

The focus of the project was to design and implement a vending machine using FPGA technology. Our role in this endeavor was to contribute to the development and realization of the vending machine functionality. Using FPGA, We designed the logic circuits and programmed them to handle various aspects of the vending machine operation, including user input, product selection, inventory management, and transaction processing. Through our contributions, we successfully created a functional FPGA-based vending machine that demonstrated the potential of this technology.

3. Concept description



User Interface
This component represents the user interaction with the vending machine. It includes input mechanisms such as buttons or a keypad for product selection and payment options. The user interface also provides feedback through a display or indicator lights.

FPGA Logic Circuits
This central component consists of programmable logic circuits implemented on the FPGA. It handles the overall control and coordination of the vending machine's operation. The FPGA

logic circuits manage the communication between different components and ensure proper execution of functionalities.

Inventory Management

This component is responsible for tracking the available products and their quantities. It interfaces with sensors or mechanisms to detect product availability and updates the inventory accordingly. The inventory management system ensures that the vending machine only offers products that are in stock.

Transaction Processing
This component manages the financial transactions that occur during the vending machine operation. It securely handles payment methods, such as cash or electronic payments, ensuring proper authentication and verification. The transaction processing system calculates the amount due, deducts the payment, and provides appropriate change if required.

4. Project/Team management

	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Ravindu	Concept	Implementation	VHDL Coding	Program FPGA	PCB Design
Cajeeban	Concept	Implementation	VHDL Coding	Program FPGA	PCB Design
Dapsara	Concept	Implementation	VHDL Coding	Program FPGA	PCB Design

5. Technologies

- *VHDL*
- *FPGA*
- *KiCAD*

6. VHDL and FPGA Implementation

Design Specification
The project began with a thorough analysis of the requirements and functionality expected from the vending machine.The design specification outlined the various components, their interactions, and the desired behavior of the system.

Architecture Design
Based on the design specification, the architecture of the vending machine was defined. The different modules, such as user interface, inventory management, and transaction

processing, were identified and their interconnections established. The FPGA logic circuits were allocated and partitioned accordingly to accommodate the required functionalities.

VHDL Coding

VHDL (VHSIC Hardware Description Language) was used to describe the behavior of the vending machine at the register-transfer level. Each module was implemented as a separate VHDL entity, defining its inputs, outputs, and internal logic. The behavior of each module was described using VHDL processes, signals, and concurrent statements.

RTL Simulation

To ensure the correctness of the design, RTL (Register Transfer Level) simulation was performed. Test benches were created to generate stimuli and simulate the operation of the vending machine. The simulation results were analyzed to verify that the design met the desired specifications and produced the expected outputs.

Synthesis

Once the RTL simulation was successful, the design was synthesized into a netlist using synthesis tools specific to the FPGA platform. The synthesis process mapped the VHDL code to FPGA resources, such as lookup tables, flip-flops, and interconnects. The synthesized netlist represented the low-level implementation of the design in terms of FPGA resources.

Place and Route

The synthesized netlist was subjected to the place and route (P&R) process. P&R tools determined the physical locations of the design's components on the FPGA chip and established the interconnections between them. Constraints were applied to ensure proper timing, power optimization, and other design considerations.

Bitstream Generation

Once the design was successfully placed and routed, the bitstream, a binary file containing configuration data for the FPGA, was generated. The bitstream file contained the programming information necessary to configure the FPGA with the implemented design.

FPGA Configuration

The final step involved configuring the FPGA with the generated bitstream file. The bitstream was loaded onto the FPGA using programming tools specific to the FPGA platform. Once programmed, the FPGA executed the digital design, allowing the vending machine to function according to the specified behavior

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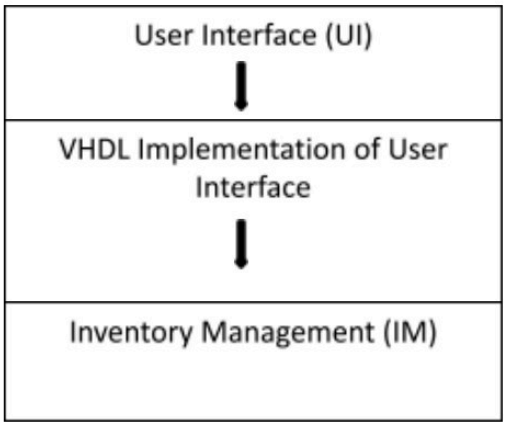

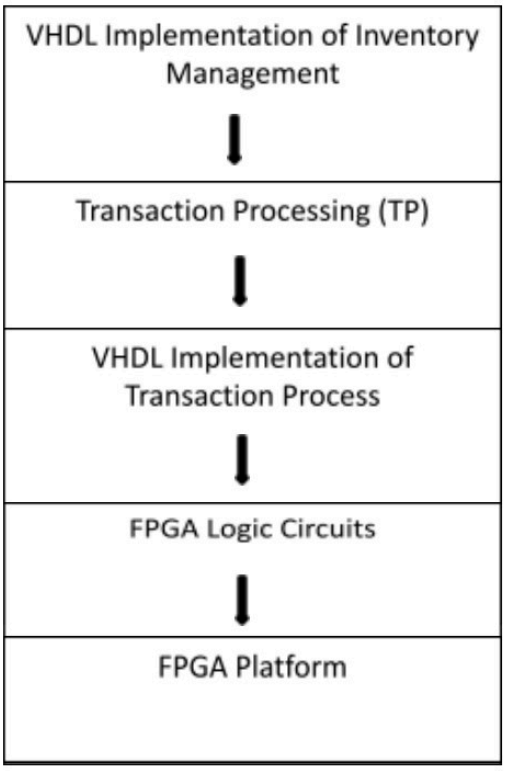

User Interface (UI)
This component represents the physical interface through which users interact with the vending machine. It includes input devices such as buttons, a keypad, or a touch screen for product selection and payment options. The UI component also provides visual feedback through a display or indicator lights.

VHDL Implementation of User Interface
This module represents the VHDL implementation of the User Interface. It handles the signals from the physical UI components and communicates with other modules in the design.

Inventory Management (IM)
This component is responsible for managing the inventory of products in the vending machine.
It tracks the availability and quantity of each product and updates the inventory accordingly.
IM communicates with other modules to ensure that products are dispensed correctly and inventory is updated accordingly.

VHDL Implementation of Inventory Management
This module represents the VHDL implementation of the Inventory Management component.
It handles the logic for monitoring and updating the inventory based on product selection and dispensing.

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Transaction Processing (TP)
This component manages the financial transactions that occur during the vending machine operation. It handles payment methods, calculates the amount due, deducts the payment, and provides change if necessary. TP communicates with other modules to validate payments and ensure proper transaction processing.

VHDL Implementation of Transaction Processing
This module represents the VHDL implementation of the Transaction Processing component. It handles the logic for processing payments, calculating the amount due, and managing the transaction flow.

FPGA Logic Circuits
This central component consists of programmable logic circuits implemented on the FPGA. It includes the logic for coordinating the different modules and ensuring the overall operation of the vending machine. The FPGA logic circuits handle communication between modules, synchronization, and control signals.

FPGA Platform
This represents the physical FPGA platform that hosts the implemented digital design. It provides the necessary resources, such as lookup tables, flip-flops, and interconnects, to execute the design.The block diagram illustrates the modular structure of the implementation, where each module represents a specific functionality of the vending machine. The FPGA logic circuits act as the backbone, coordinating the communication and interaction.

7. VHDL Code Implemetation

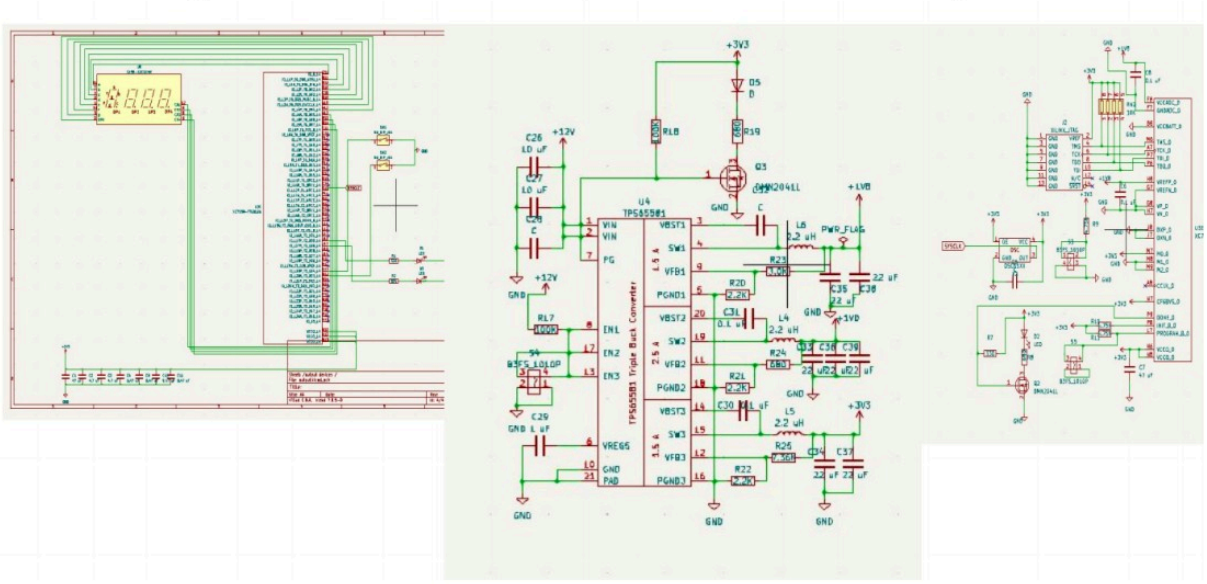
Vhdl code was implemented on the basis of Finite state machine. We use states in order to make a functional output of the vending machine. As the vending machine has 3 states Idle, item select, and coin select. dispense. These three states determine the process of vending machine. in an idle state, vending machine will not do any function it will be waiting for the user input. In Item select. the user determines which product he needs from the vending machine. During this state process, we trigger the event by using a 3-bit encoder switch that uses a case statement. to select the item. In the case of coin_select, the user gives input for coins by selecting 2-bit encoder switches. and finally, in the case of the dispense state, the vhdl code is programmed to dispense the product if the user-given amount and the item selected have the same value

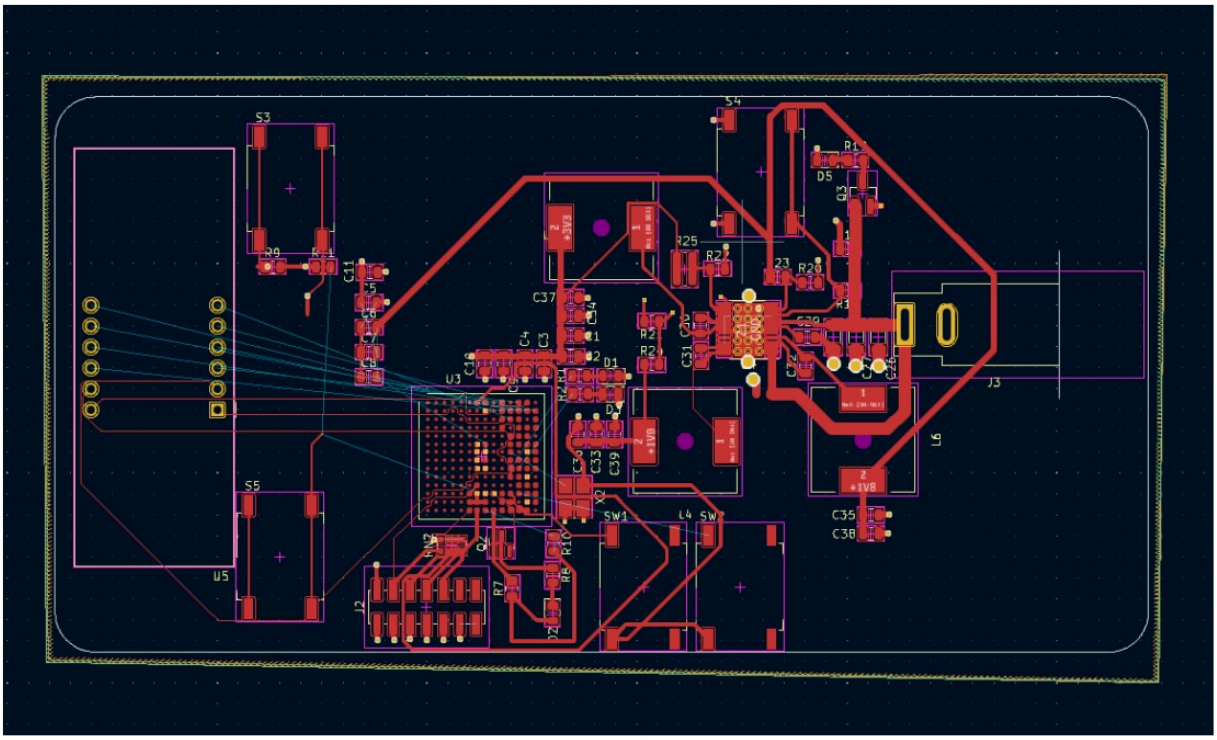
8. PCB Design

First we made the schematic for our PCB. We used and worked with different kinds of Components(Symbols). And understood how each should be connected. After the schematic design the next step was assigning footprints for the used electronic components. After that step we did the Electrical rule check (ERC) and corrected all the mistakes. we managed to get 0 errors on ERC.

Then we started the routing process for our PCB. That was challenging because you need to arrange the connecting electronic components in a proper manner or else you won't be able to route. We used 4 layers for our PCB. We made two layers as GND and 3.3V, and connected electronic components to them via Vias. Finally we made our PCB designs edges round because there was a designer rule check(DRC) error.

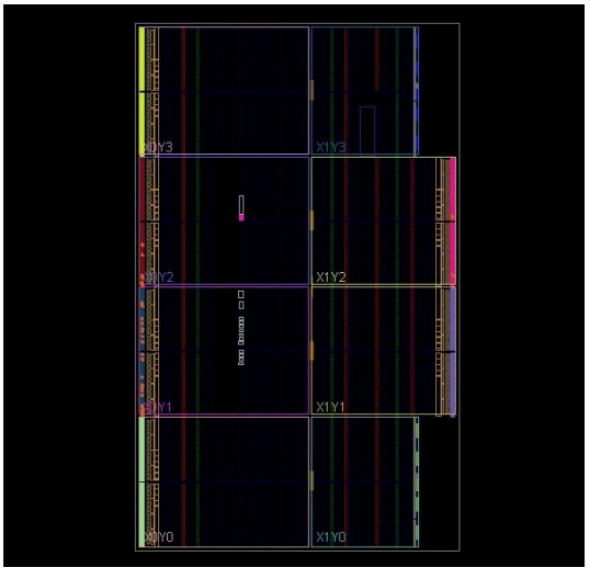
As a summery for this PCB we used a FPGA board, LED display, Switches,J tag,CLK,Resistors, Transistors, Capacitors, LEDs as our electronic compornents. Because this design is not very complex this boards manufacture cost wont be too expensive. When you take PCB size into account we assigned small but functional footprints for our electronic components.





9. Synthesis Design and Implementation Design

The vending machine design was successfully implemented on the Artix 7 FPGA. The VHDL code was synthesized and mapped, resulting in a functional design. A finite state machine (FSM) was used to control the vending machine's behavior, with states including Idle, Coin1, Coin2, and Dispense. The FSM transitions between states based on user input and the selected amount. The implementation demonstrates the versatility of the Artix 7 FPGA for building complex digital systems. The figure below shows the Implementation design generated on xilinx vivado software.



10. Sources/References

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2. Surf-VHDL. (2021, December 27). *Vivado project tutorial - surf-VHDL*. Surf. https://surf-vhdl.com/vivado-project-tutorial/
3. FPGA Programming for BeginnersBring your ideas to life by creating hardware designs and electronic circuits with SystemVerilogb Frank Bruno(You?)|2021|

Affidavit

I hereby confirm that I have written this paper independently and have not used any sources or aids other than those indicated. All statements taken from other sources in wording or sense are clearly marked. Furthermore, I Assure that this paper has not been part of a course or examination in the same or a similar version.

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