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DESIGN AND IMPLEMENTATION OF A WEBSITE BASED VENDING MACHINE USING FSM ON FPGA

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Abstract : This paper presents the design and implementation of a website based vending machine controlled by FSM on a FPGA platform. This approach offers a cost effective and efficient solution for modern vending machines combining the advantages of the web connectivity and a FPGA based control [1]. The vending machine system integrates a web interface for user interaction, enabling real-time selection, payment and product dispensing through a seamless online experience. The core of the system is modeled as a finite machine which manages state transitions for user inputs, product availability, and a transaction process. The FSM is implemented in Verilog and synthesized on a FPGA to achieve low latency, reliability, flexibility, high performance and high-speed transition.

***Keywords*- Website code, Vending machine, FSM(Finite State machine), FPGA(Field Programmable Gate Array), Xilinx Vivado, Raspberry Pi, Verilog, Synopsys Software.**

I. INTRODUCTION

A vending machine is an automated system that dispenses product such as snacks, cold drinks, chocolates and even tickets once the user has done the payment [2]. Vending machine is more accessible and practical then conventional method and it also helps in reducing overhead costs by not hiring of staff that increase profit margin.

Finite state machine is made to construct in the project because they are robust performance for modeling sequential logic, making ideal for applications like vending machine that requires step by step operations and decision making process [3]. Vending system based on state machines increases productivity, lower system development cost and shorten time to market. By integrating FSM logic into FPGA the system benefits for high speed operation. FPGA is a silicon chip containing two dimensional arrays of logic blocks and with electrically programmable interconnects [4]. The main reason behind using FPGA, it can be reprogrammed at any time with different functionality time and if any error occurs we can easily recompile the code and can dumped into FPGA board. Due to FPGA technology, manufacturers can customize their product to meet their variety needs, and user interface can select any products that he require and the pricing schemes and payment methods. FPGA can be effectively used for the for the credit/debit transactions, UPI system and a cashless system [5]. Therefore vending machine can run on low electricity while running on good performance due to FPGA technology.

This project mainly focuses on designing and implementing of vending machine that dispenses medicines related items such as ORS, general medicines, masks, sanitary pads for women, diapers for the children and first aid kits. These medicine dispensing vending machine should be available in railway station, bus stands and airports such that the passengers if they feel sick or if women requires sanitary pads or if diapers require for the children, which is easily available and can access the products. In this, website is made an user interface for the vending machine by scanning the QR code that is placed on the vending machine. The website also incorporates online payment interface for secure and convenient transactions.

II. Block Diagram And Flowchart Description

1.1 Block Diagram

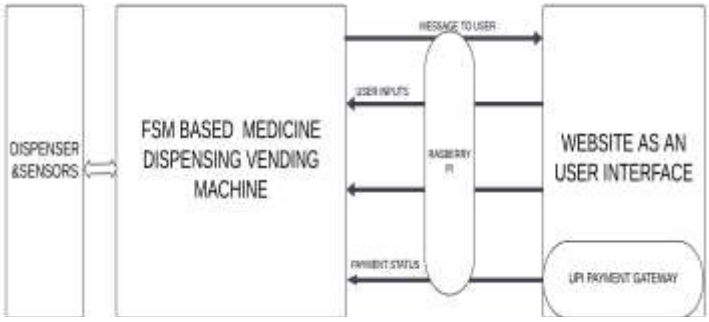

fig.1. block diagram of website based vending machine

Website: The QR code that is placed on the vending machine by scanning that it externally links to the webpage. It displays all the available products and acts as an user interface. It displays the available quantity and price of the each product. Due to this website we can overcome the use of led display in the vending machine which consumes power.

Raspberry Pi: It serves as the central processing unit, handling communication between the user interface(website) and the vending machine. It takes user inputs, processes the request, checks payment status, and sends commands to the dispenser. It also sends status updates and messages to the user.

Vending Machine: It operates using a finite state machine model, which follows a predefined sequence of states based on user inputs and payment verification. The FSM ensures that the machine transitions through states such as initial, product select, payment and dispense.

UPI Payment Gateway: The payment process is handled through a Unified Payment Interface(UPI) Gateway, allowing users to complete transactions digitally. The payment status is sent back to Raspberry Pi for verification before dispensing the medicine.

Dispenser and Sensors: The dispenser is responsible for storing and dispensing medicines as per user selection. It is designed to handle different types of medicines in a controlled manner, ensuring that only the required quantity is dispensed. With the help of servo motors, springs and sensors, the machine will dispense the requested product/s upon successful transactions.

1.2 Flow chart

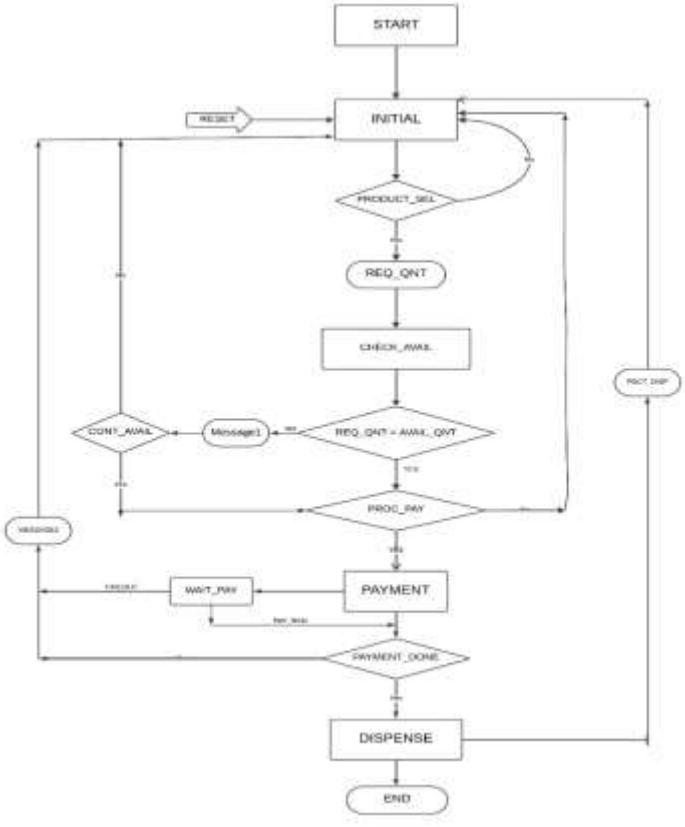

fig.2. flow chart of proposed vending machine.

Flowchart description

- Step-1: The vending machine will be in initial state.
- Step-2: Next, the user select the product through website as a user interface.
- Step-3: In this step the user selects the required quantity of the product and after selecting the user checks with availability.
- Step-4: In check availability state if the user selects the products of the required quantity less than the available quantity then it goes to proceed with payment state.
- Step-5: If in case, the user selects the product required quantity greater than the available quantity then it displays a message1.
- Step-6: In message 1 it displays a message stating that "Are You Want To Continue With The Available Quantity", if user selects the yes option it directs to the proceed with payment state or else if user selects the no option then directs to the initial state.
- Step-7: If the user selects proceed with payment then it directs to payment state.
- Step-8: In Payment state the timer is given for user to pay the amount. If the payment is done within the time it displays that payment is done and product will be dispensed.
- Step-09: If the user fails to pay within the time or if the payment done is cancelled it displays a message 2 stating that "Are You Want to Proceed With The Payment" if the user selects yes then it is redirected to Payment state or if the user selects no option then it directed to initials state.
    - *Step-10:* Once the payment is done the product is dispensed and once the product is dispensed the vending machine resets.

III. State Diagram And Its Explanation

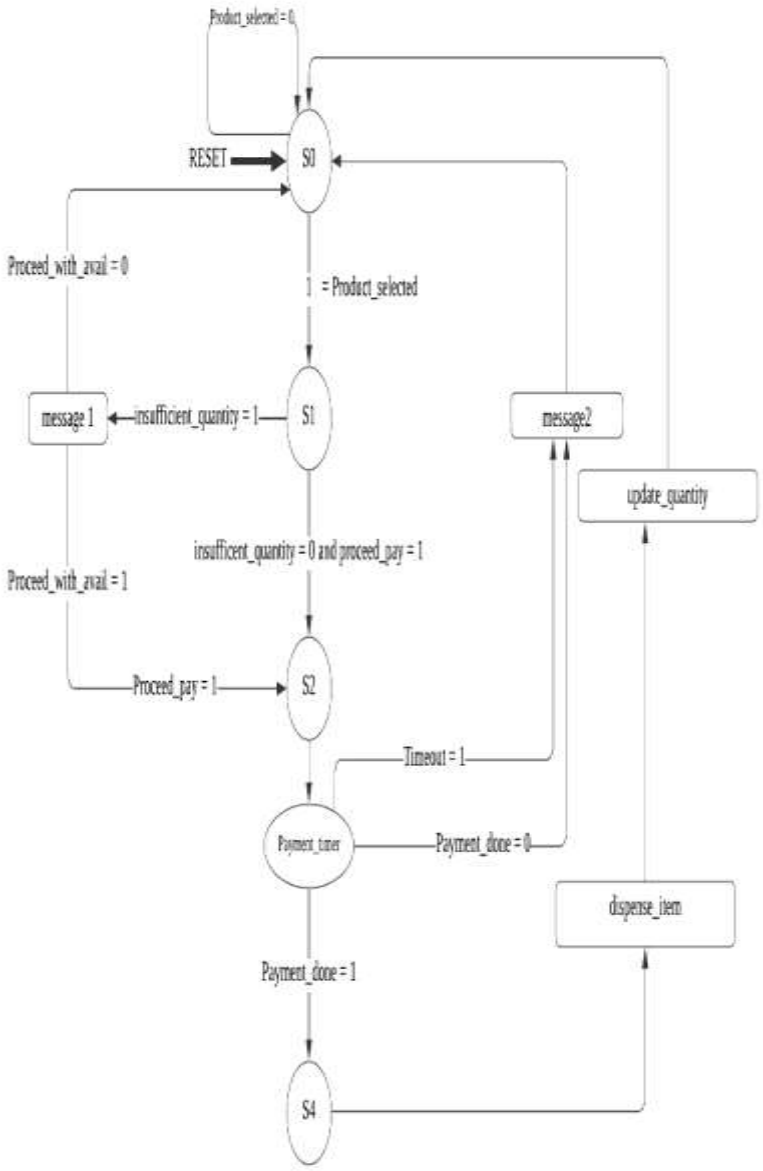

fig .3. state diagram of vending machine

Explanation of State Diagram:

a. S0: Initial State (Reset State)
Initially, the machine will be in the initial state where it waits for input from the user to select the product. If no product is selected, it remains in this state. If a product is selected, the system moves to S1.

b. S1: Product Availability Check
The system checks if the selected product is available in sufficient quantity. If selected quantity of product is not available then the system sends message 1 to inform the user and returns to S0. If required quantity is available, the system proceeds to S2.

c. S3: Payment State
The user to prompted to make the payment. A payment timer is activated, if the payment is successful within the time, the system moves to S4. If payment is not completed within the time, message 2 is displayed to inform the user that payment is failed and the system returns to S0.

d. S4: Dispense State
If the payment is successful, the machine dispenses the item. After dispensing, the system updates the quantity of the dispensed item. The system the resets to S0 for the next transaction.

IV. SIMULATION RESULTS

4.1 Case A: In this case the user selects the product A, is selected along with the required quantity less than available quantity, then it proceeds with payment and the payment is done within the time and then the product is dispensed. After dispense the available quantity is updated and returns to initial state after dispensing the item.

fig.4. simulated waveform of case A

4.2 Case B : In this case the user selects the product A and selected the required quantity (101) greater than the available quantity (100), then the user notified with the message 1(01) and he wants to proceed with the available quantity and finally the payment is done followed by the payment then all the available products is dispensed and the available_quantity_a is updated (000).

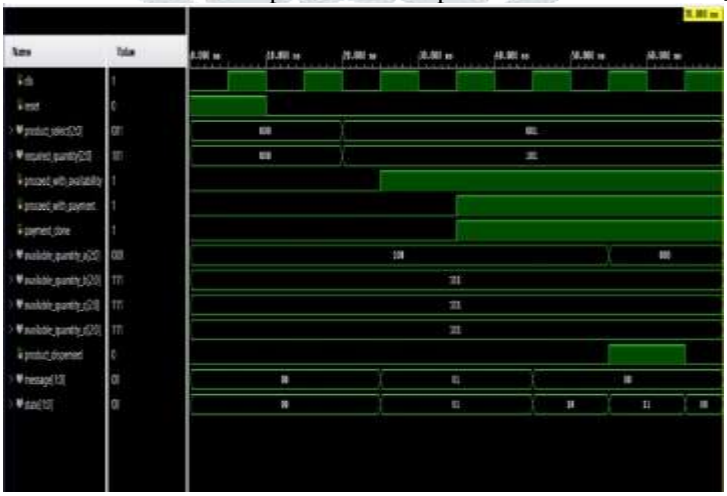

fig.5. simulated waveform of case B

4.3 Case C : In this case the user selects a product and selected required quantity(101) is greater is than the available quantity(100), then the user notified with the message1(01) stating that to proceed with the available quantity, then if user don't want to continue with the available quantity then it will be reset and return back to initial state. Therefore no product will be dispensed.

fig.6. simulated waveform of case C

4.4 Case D : In this case the user selects the product and selects the required quantity with the available quantity and then the user proceed with payment. In payment the user failed to pay within the time, then the message 2(10) is displayed and then the machine returns to initial state and no product is dispensed.

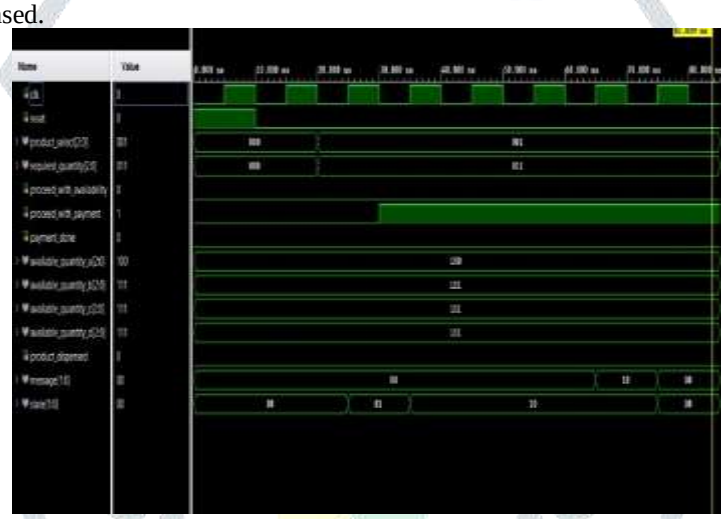

Fig.7. Simulated Waveform of Case D

V. Results And Analysis

Simulation results show the output signals responses to the change in the inputs. The power, area and timing utilization summary of vending machine in synopsys software is detailed below in the Fig.8, Fig.9, and Fig.10.

5.1 Area Report

```
Number of ports:                          26
Number of nets:                          139
Number of cells:                         116
Number of combinational cells:            96
Number of sequential cells:               20
Number of macros/black boxes:              0
Number of buf/inv:                        16
Number of references:                     24

Combinational area:                221.613571
Buf/Inv area:                       20.585664
Noncombinational area:             135.712900
Macro/Black Box area:                0.000000
Net Interconnect area:              76.525113

Total cell area:                   357.326470
Total area:                        433.851584
1
```

fig.8. area report

5.2 Power Report

```
Global Operating Voltage = 1.05
Power-specific unit information :
    Voltage Units = 1V
    Capacitance Units = 1.000000ff
    Time Units = 1ns
    Dynamic Power Units = 1uW    (derived from V,C,T units)
    Leakage Power Units = 1pW


Attributes
----------
i - Including register clock pin internal power


  Cell Internal Power  =  14.4961 uW   (95%)
  Net Switching Power  = 683.3171 nW    (5%)
                         ---------
Total Dynamic Power    =  15.1794 uW  (100%)
```

Power Group	Internal Power	Switching Power	Leakage Power	Total Power	(%)	Attrs
io_pad	0.0000	0.0000	0.0000	0.0000	(0.00%)	
memory	0.0000	0.0000	0.0000	0.0000	(0.00%)	
black_box	0.0000	0.0000	0.0000	0.0000	(0.00%)	
clock_network	13.1278	0.0000	0.0000	13.1278	(26.24%)	i
register	0.3500	0.1682	2.0711e+07	21.2291	(42.43%)	
sequential	0.0000	0.0000	0.0000	0.0000	(0.00%)	
combinational	1.0182	0.5151	1.4144e+07	15.6772	(31.33%)	
Total	14.4961 uW	0.6833 uW	3.4855e+07 pW	50.0341 uW		

fig.9. power report

5.3 Timing Report

```
Startpoint: required_quantity[0]
            (input port clocked by clk)
Endpoint: insufficient_quantity_reg
          (rising edge-triggered flip-flop clocked by clk)
Path Group: clk
Path Type: max

Des/Clust/Port     Wire Load Model       Library
------------------------------------------------
avenue             8000                  saed32rvt_tt1p05v25c

Point                                                   Incr       Path
-----------------------------------------------------------------------
clock clk (rise edge)                                   0.00       0.00
clock network delay (ideal)                             0.00       0.00
input external delay                                    1.00       1.00 r
required_quantity[0] (in)                               0.00       1.00 r
U88/Y (INVX0_RVT)                                       0.04       1.04 f
U124/Y (NOR2X0_RVT)                                     0.07       1.11 r
U125/Y (OA222X1_RVT)                                    0.07       1.18 r
U126/Y (OR2X1_RVT)                                      0.05       1.23 r
U127/Y (AOI222X1_RVT)                                   0.07       1.30 f
U130/Y (OA21X1_RVT)                                     0.05       1.35 f
U131/Y (AO222X1_RVT)                                    0.05       1.39 f
U133/Y (OAI22X1_RVT)                                    0.06       1.45 r
U135/Y (MUX21X1_RVT)                                    0.06       1.51 r
insufficient_quantity_reg/D (DFFX1_RVT)                 0.01       1.52 r
data arrival time                                                  1.52 r
clock clk (rise edge)                                  10.00      10.00
clock network delay (ideal)                             0.00      10.00
insufficient_quantity_reg/CLK (DFFX1_RVT)               0.00      10.00 r
library setup time                                     -0.03       9.97
data required time                                                 9.97
-----------------------------------------------------------------------
data required time                                                 9.97
data arrival time                                                 -1.52
-----------------------------------------------------------------------
slack (MET)                                                        8.45
```

fig.10. timing report

The vending machine obtained a positive slack hence no violations in the vending machine.

5..4 RTL Schematic

The RTL schematic(Synthesised gate level netlist) representation of vending machine is obtained from synthesis having input ports at the upper side and the output ports at the lower side. Fig.11. depicts RTL schematic Of Vending Machine.

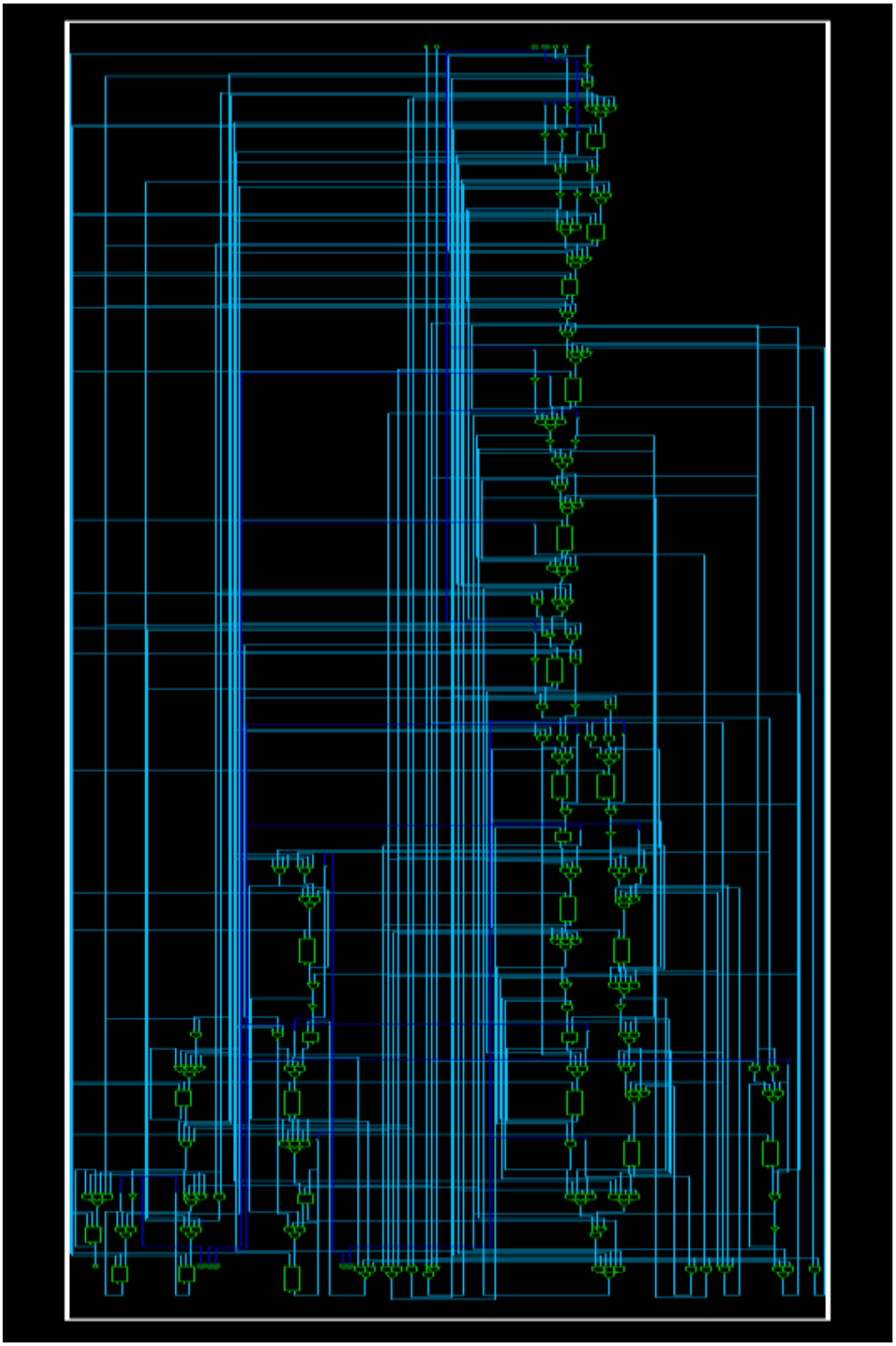

fig.11. RTL schematic of vending machine

VI. Conclusion

In this research paper we presented the design and implementation of a website based vending machine controlled by a finite state machine on a FPGA platform. The integration of a website based user interface with FPGA based control enhances the efficiency, reliability, and accessibility of modern vending machines. By introducing FSM logic, the system ensures seamless state transitions, improving responsiveness's and reducing processing delays. The proposed vending machine is particularly useful for dispensing essential medical supplies such as ORS, sanitary pads, diapers and first aid kits in public spaces such as railway stations, bus stands and airports. The system web based interface simplifies user interaction by enabling product selection and secure online payment via UPI. Future improvements can include integration of advanced payment methods, AI based inventory management and enhanced security features for fraud prevention.

This research lays the foundation for scalable, efficient and intelligent automated retail solutions across various industries.

VII. ACKNOWLEDGEMENT

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