EasyChair Preprint

№ 2274

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December 31, 2019

DESIGN AND IMPLEMENTATION OF FPGA BASED VENDING MACHINE FOR INTEGRATED CIRCUIT (IC)

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Abstract: Vending machine that dispense items like as snacks, coffee, beverages, lottery ticket, consumer products automatically when a customer insert a coin or token are increasing rapidly in metropolitan's cities due to contemporary and fast life style requiring excellent quality products. This paper give the details account of the designing and implementation of a multi select state vending machine using State Machine with which users can select the product and insert the desired token for respective products to dispense the Integrated Circuit (IC) or it will return the inserted token if wrong token is inserted for each Integrated Circuit (IC). We choose FPGA for this vending machine since FPGA based vending give quicker response and absorbed less power and reprogrammed anytime as compared to CMOS vending machine. The intended design is implemented in VHDL and simulated using Xilinx VIVADO 2019.1 and it's implemented on FPGA basy -3 Artix 7 series FPGA (xc7a200tfbg676) development board. Synthesis results and FPGA experimental results are shown in this paper.

Keywords: FSM, FPGA, VHDL, Vending machine,IC

I. Introduction

Vending machine are an automated machine which dispenses a products like coffee, cold drinks, snacks, tickets etc. to consumers when a vendee inserts a coin, token or cards into the machine[1]. The first modern vending machine was introduced in England in around early 1880s which was used to vend out postcards. The machine was later invented by Percival Everett in late 1883 and after which it become popular features at railway stations, bank and post offices, for vending envelopes, postcards and notepaper. Nowadays this can be found everywhere in railway station for dispensing rail ticket, in school and street for dispensing cold drinks and beverages and snacks, in bank as ATM machine and token generators [5]. The vending machines designs from FPGA based are flexible and quicker than the machine designed from CMOS based [2]. The vending machine designed from FPGA based are easier to program and can be reconfigured anytime without changing the whole machine design architecture if the designers want to enhance the design of the machine. This flexibility is not possible in case of Embedded based machine. In this vending machine designed using FPGA the user can add more number of items with other facilities.

In our research, to vend out IC a mealy based state machine is design and implemented on FPGA. The machine is design in way that user can select the desired IC and insert the token; each token for each IC is uniquely designed. This machine also support cancel and return features which mean the vendee can withdraw the request and the token will be returned back to vendee. This machine was mainly design for use in the college LAB and other research LAB where electronics component are used for design purposed to reduce time and put in required order.

1.1 DESIGN OPERATION FOR VENDING MACHINE [1][8]

- **I.** When the users presses select button to select the IC he wants to vend out, the control units will direct the command the token sensor.
- **II.** When the users insert the token, sensors will detect the token and inform the control units the inserted token if the inserted token match with the selected IC it will dispense the IC out.
- **III.** If the inserted token doesn't match with selected IC it will automatically return the inserted token.

IV. The machine needs to be servicing if the available product is less than 1.

II. RELATED WORK

Various researches has carried out different ways to designing of vending machine of which some are discussed below as: B Jyothi [1] [2], [8] proposed a vending machine for implementation of FPGA based smart vending machine in which process has four main state (Selection, waiting for user to insert token, product delivery and servicing) which emphasis on the process flow and control logic to construct smart street snack vending machine application. Fauziah zainuddin designed a steaming frozen food vending machine using conceptual modeling in which the three main states (user's selection state, freezer and steaming) has been implemented considering the approach which focus on the process flow and control logic to implement the model for steam buns machine application. Conceptual modeling is described in [4]. In [5] Coffee vending machine has been carried out using SEEL singled electron encoded logic. The designed circuit is tested and its power and switching time is compared with the CMOS technology.

III. IMPLIMENTATION [1][11][4]

The propose machine state diagram is constructed to vend out seven Integrated Circuit (IC) that is AND-GATE,OR-GATE,NOT-GATE,NOR-GATE,NAND-GATE,EXOR-GATE,EXNORGATE. The seven select vector input state are of 3bits wide with encoding (ANDGATE (001), ORGATE (010), NOTGATE (011), NORGATE (100), NANDGATE (101), EXORGATE.Table3.1 shows the selection of IC with their respective encoding and token- in with color and each encoding. Here to select AND-GATE user has to input binary code 001 so that the controller will transfer the command to waiting state. (110) and EXNORGATE (111) for selection IC. The select ANDGATE is used for selection of AND-GATE, similarly for ORGATE, NOTGATE, NORGATE, NANDGATE, EXORGATE, EXNORGATE for selection of OR-GATE, NOT-GATE, NOT-GATE, NOR-GATE, NAND-GATE, EXOR-GATE, EXNOR-GATE. The Token_ in vectors for respective IC are also of 3bits wide with different colors and encoded as (GREEN (001), BLUE (010), WHITE (011), YELLOW (100), BLACK (101), ORANGE (110) and RED (111). A cancel is used when the customers want to withdraw the process, if the user has inserted the token and want to cancel the process then the inserted token will be automatically return to the user [1]. The return token vectors are of 3 bits to return the inserted token if it doesn't match with selected IC. There are two input signal clock and reset [4]. This machine work when clock signal is on positive edge and when reset signal is high the process will return to the initial state. The proposed vending machine is designed using VHDL

Table 3.1. Selection of IC with their respective encoding

Serial number	Selection	Encoding for selection	TOKEN-IN	TOKEN-IN encoding
1	AND_GATE	001	GREEN	001
2	OR_GATE	010	BLUE	010
3	NOT_GATE	011	WHITE	011
4	NOR_GATE	100	YELLOW	100
5	NAND_GATE	101	BLACK	101
6	EXOR_GATE	110	ORANGE	110
7	EXNOR_GATE	111	RED	111

Table 3.2 shows the pin description of the FPGA board with their description.

For input we used FPGA switches SWO, SW1, SW2, selection of product and switches SW8, SW9, SW10 for token_ in and switches SW4 for product available. For output we use LED of FPGA board to indicate either Token return or product_ out.

Table 3.2 inputs/ outputs assigned to FPGA board with description

INPUTS/OUTPUTS	FPGA RESOURCES	DESCRIPTION
CLOCK	Clock = CLK100MHz(W5) Which is connected to 100mhz crystal oscillator	This is used as system clock
RESET	RESET =BTNU(T12)	The reset button will reset the whole vending machine to initial states to accept the new signal '0' or '1'
Product available	Product available=SW4(V15)	To indicates product available in vending machine when signal is greater than 1 and product not available when the signal is '0'
Cancel	Cancel= BTNC(U18)	Cancel are used to cancel any process of vending and to return to initial states
Selection of product(input) (2 down to 0)	Select_ product[2] =SW2(W16) Select_ product[1] = SW1(V16) Select_ product[0] = SW0(V17)	Selection of product is to select the product from the select option. Selection of product is of 7 types of 3 bits AND-GATE, ORGATE, NOTGATE, NORGATE, NANDGATE, EXORGATE and EXNORGATE. Encoded to binary equivalent as (001, 010, 011, 100, 101, 110, 111)
Token_ in (input) (2 down to 0)	TOKEN_IN[2] = SW10(ST2) TOKEN_IN[1] = SW9(ST3) TOKEN_IN[0] = SW8(SV2)	This is 3bit token_ in and implemented using switches of FPGA board. We have seven types of token_ in AND-GATE, ORGATE, NOTGATE, NORGATE, NANDGATE, EXORGATE and EXNORGATE. Encoded to binary equivalent as (001, 010, 011, 100, 101, 110, 111)
Token_ return (output) (2 down to 0)	TOKEN_RETURN[2] =LD10(W3) TOKEN_RETURN[1] =LD9(V3) TOKEN_RETURN[0] =LD8(V13)	The token_ return is 3bit and implemented using switches of FPGA board. We have seven types of token_ return i.e. AND-GATE, ORGATE, NOTGATE, NORGATE, NANDGATE, EXORGATE and EXNORGATE. Encoded to binary equivalent as (001, 010, 011, 100, 101, 110, 111)
Product_ out(output) (2 down to 0)	PRODUCT_OUT[2] =LD2(U19) PRODUCT_OUT[1] =LD1(E19) PRODUCT_OUT[0] =LD0(U16)	The product out is use to indicates delivery of product When a product is selected and a token_ in is given for each product

IV. DESIGN METHODOLOGY

The state diagram composed of four states (selection, waiting state, product delivery and token return) here it is assumed the product available is always greater than 1. The machine is in initial state when reset signal is low. When reset is high the users can select IC to be dispensed. This state can be anyone of the select state (AND_GATE, OR_GATE, NOT_GATE, NOR_GATE, NAND_GATE, EXOR_GATE and EXNOR_GATE). The machine will accept seven types of token _ in i.e. Green, Blue, White, Yellow, Black, Orange, and Red their encoding are (001,010,011,100,101,110,111). Assuming that the users want to dispense ANDGATE he has to select AND_GATE input from the selection option [11]. The availability of product is check in the first state of the machine [5]. After this the control units will direct the command to the waiting state where it will wait for users to insert the token. And if product available is less than 1 it will go back to initial state for servicing. If the users insert token Green (001) for select AND_GATE then it will dispensed the Integrated Circuit (IC) ANDGATE. Else if the users has selected AND_GATE and inserted the token Blue, White, Yellow, Black, Orange, Red (010, 011,100,101,110,111) it will automatically return the inserted token [1],[6]. If in any state of process cancel is pressed then it will return the inserted token and return to the initial state. The algorithmic stages of the proposed design are shown Figure 4.1 .Figure 4.2.represents the state diagram of the proposed design.

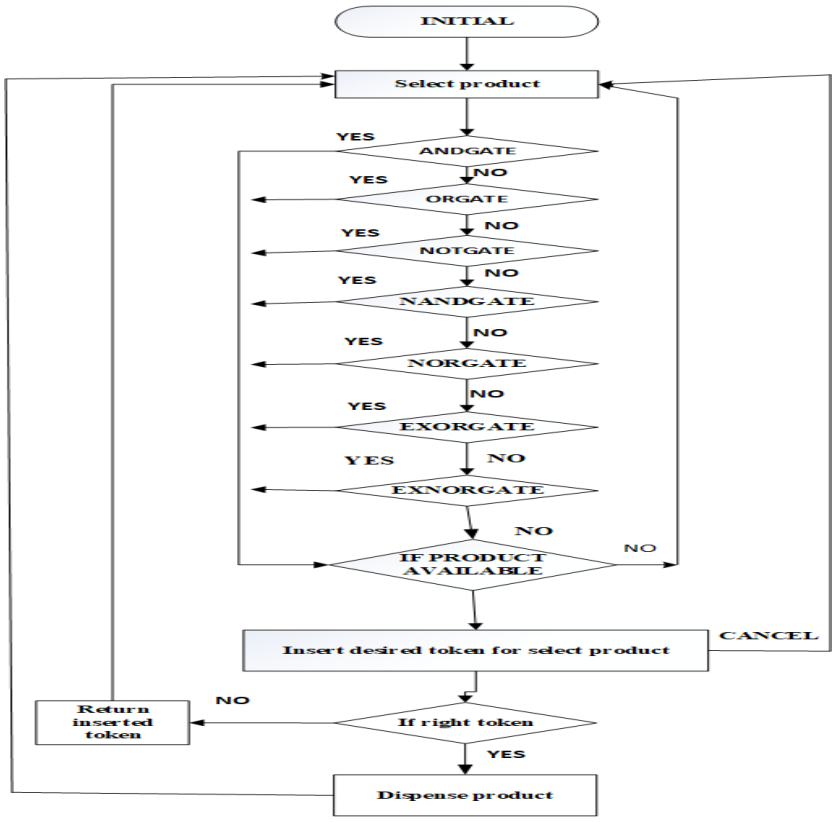

Figure4.1: flow chart of the proposed vending machine

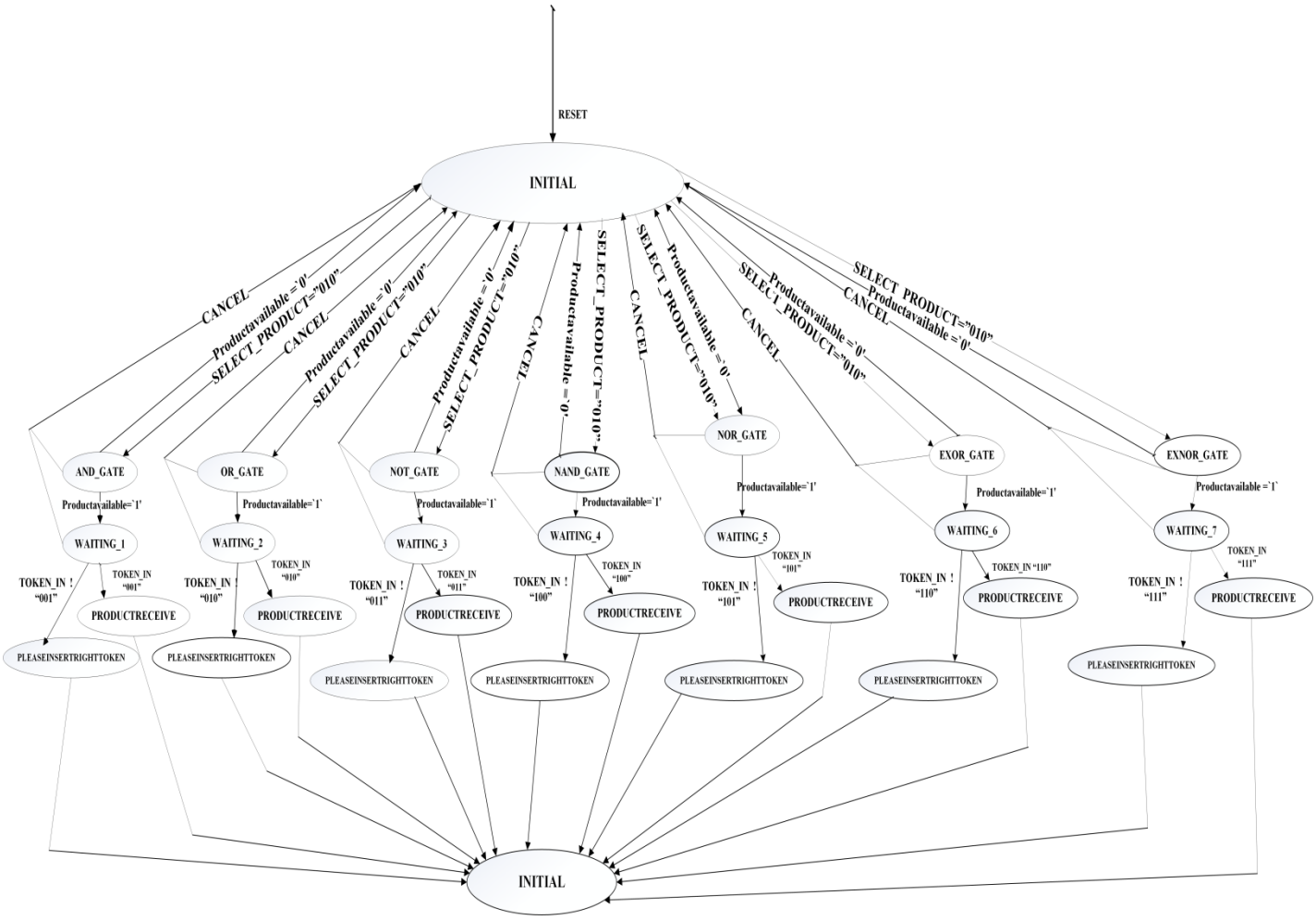

Figure 4.2. State diagram of proposed vending machine

Description of states

The selection of product and all the state are shown in followings ways

- When **initial =>**
  Product out =”000”
  Return token =”000”
- When select is on **AND_GATE** =>
  AND_GATE&! OR_GATE&! NOT_GATE&! NOR_GATE&! NAND_GATE&! EXOR_GATE&! EXNOR_GATE
  When **product available =1 =>**
  Next state < waiting1;
  When **product available = 0 =>**
  Next state <= initial;
- When **waiting1=>**
  When Green&! Blue&! White&! Yellow&! Black&! Orange&! Red
  Token return = 000;
  Next state <= product _out;
- When **product_ out=>**

When **token_ in =Green;**
Product _out = ANDGATE;
Token _return =”000”
Next state <= initial;

- When **Token_ return=>**
  When
  Token_ in = Blue;
  Token_ return =Blue;
  Next state <= initial;
  Product_ out = “000”;
- When **cancel =>**
  Cancel = ‘1’;
  Product_ out =”000”;

Similarly we can select the other products in this manner to vend out the other different products.

V.SIMULATION RESULTS

The state diagram shown in the above is simulated using Xilinx Vivado 2019.1 simulator. The simulation wave form for selection of all seven products with token_ in, product available and return token when users insert wrong token for selected product are as shown below.

Taking the example that the users wants to dispensed EXNORGATE he has to select the EXNOR_GATE (111) from select option. The machine will check whether the product is available or not, if available then it will go waiting7 state and wait for the users to insert the token once the users inserted the token for EXNORGATE i.e Red (111) then it will go to product_ out state and will dispense the EXNOR-GARE.

5.1.Product delivery after inserting the token for EXNOR_GATE(111)

Figure 5.1. Shows the simulated waveform for product delivery after the users has selected the product, product available is greater than zero and also after the users has inserted the token for EXNOR-GATE i.e. Red (111).

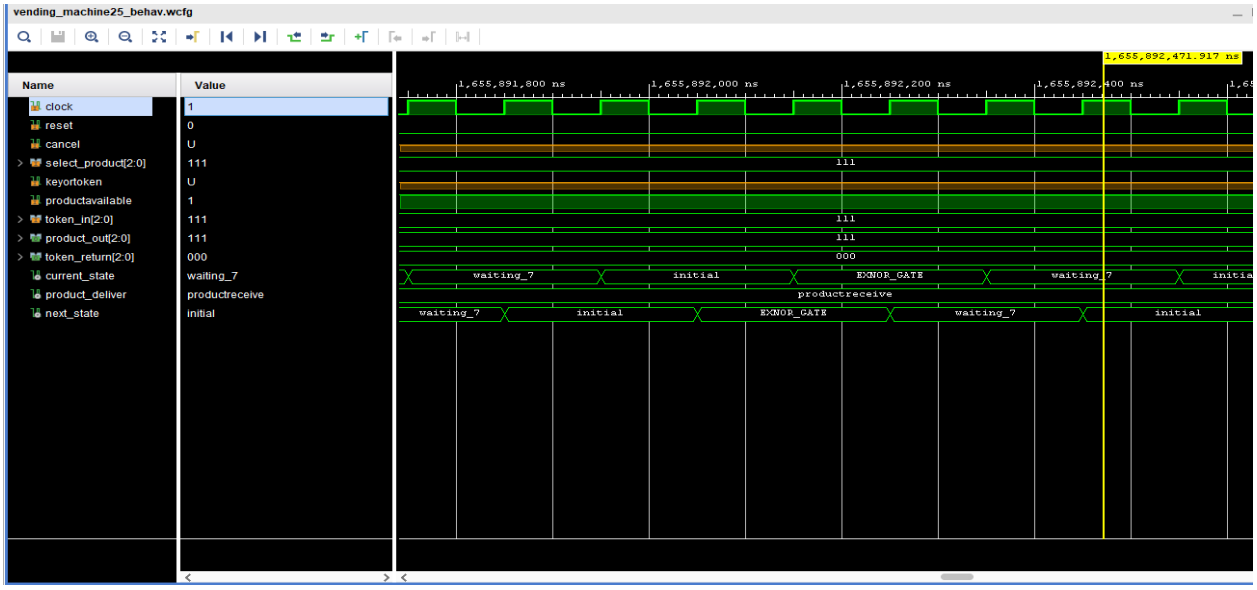

Figure5.3. simulated waveform for product delivery

5.2 When selection of product and token _in is different

Figure 5.2. Shows the simulated waveform for Token_ return in This state the users has selected NOR-GATE(101) and has inserted the token for AND-GATE i.e. Green(001) in this case since the selected product and inserted token does not match as results it will return the inserted token Green(001) and ask the users to insert the desired token.

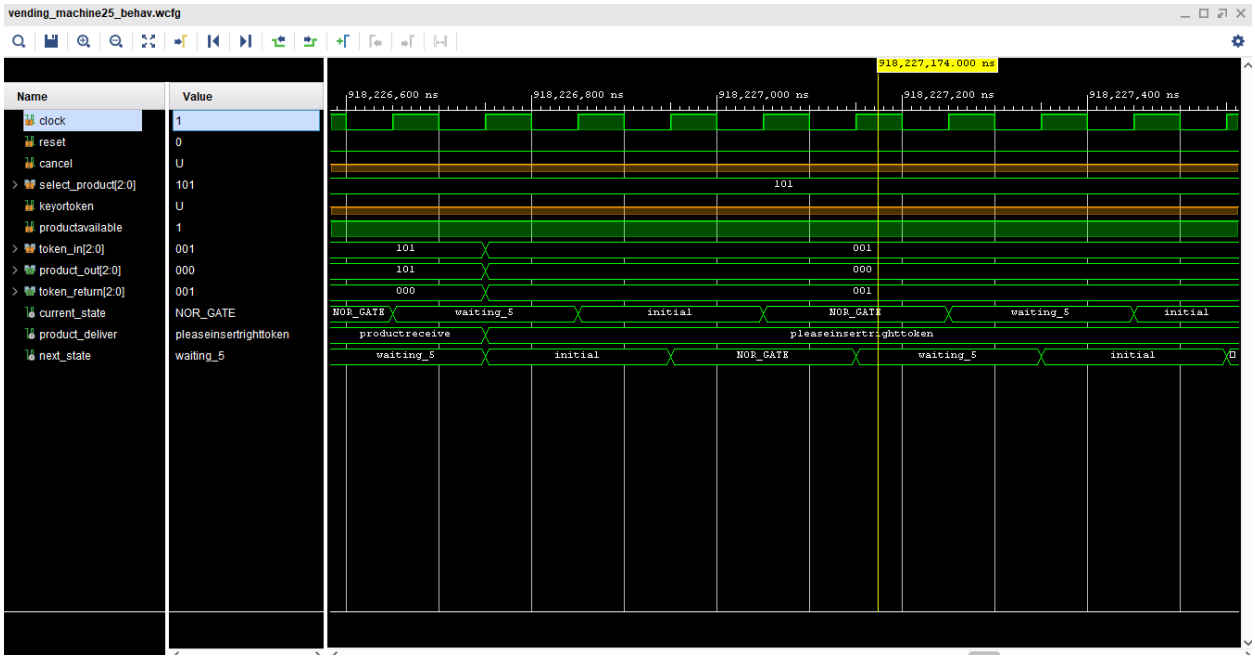

Figure 5.4. Simulated waveform for Return of Token

5.5 Register transfer level schematic

Figure 5.5 represents RTL schematic of proposed vending machine.

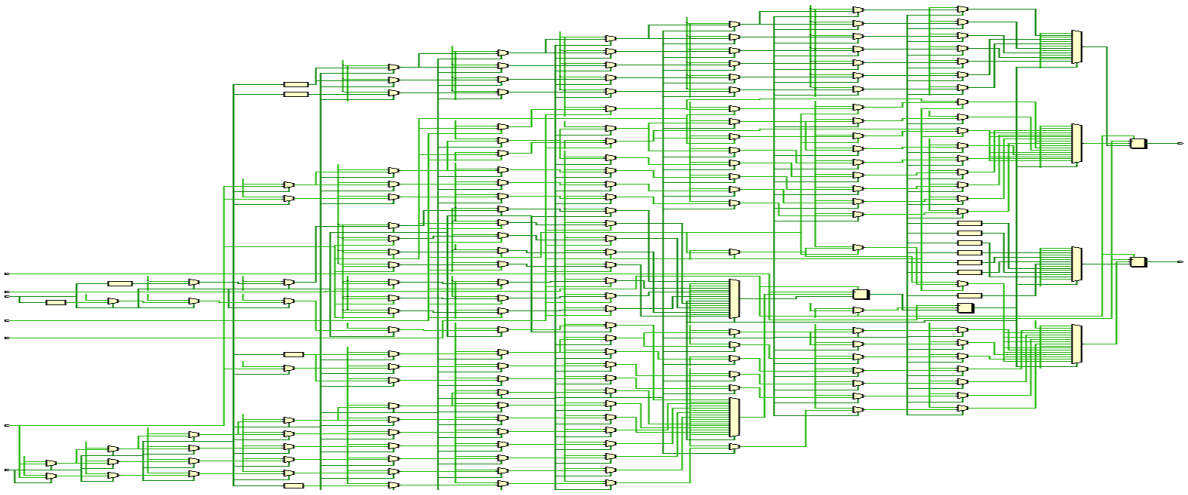

Figure 5.5. RTL diagram of proposed vending machine

VI. Experiments results: The experiments results of the vending machine designed as carried out on FPGA basy -3 Artix 7 series FPGA (xc7a200tfbg676) development board are as shown below. Here the output is assigned to LED (V16), (E19), (V19). And the input selection of product is assigned to switches pin (W16), (V16), (V17) and switch pin (V15) is assigned for PRODUCT AVAILABLE HIGH. And the token- in input pins is assigned to switch's pin (T2), (T3), (V2) of FPGA basy-3 board.

1. **When selection of product is EXNOR-GATE(111) and the token-in is Green(111)**
   Figure 6.1 shows the experiment results for product delivery of EXNOR-GATE.
   Here the Selection of product input switches pins (W16), (V16), (V17) are making high to select EXNOR-GATE from select option. Switches Pin (V15) is make high for PRODUCT AVAILABLE. And the token-in input switch's pin (T2), (T3), (V2) of the FPGA board is making high to dispense the product. The output is assigned to LED (V18), (E19), (V19) shows high signal indicating product delivery.

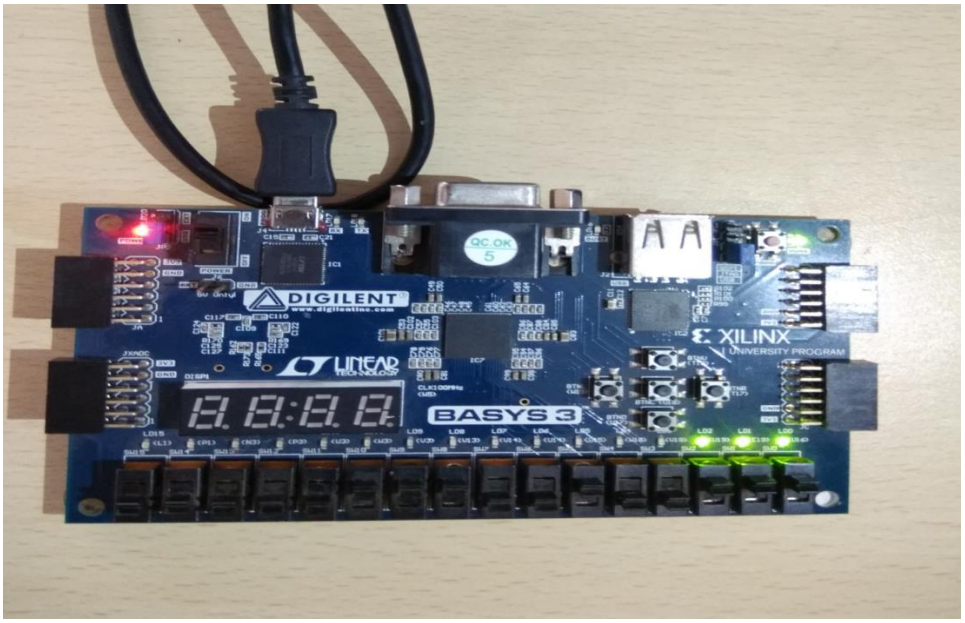

Figure 6.1 Experiments results for product delivery of EXNOR-GATE

VII. Performance analysis:

Comparisons between the existing and the proposed design we can observed that the VHDL base machine give lesser delays as compared to that of the CMOS base machine technology and the existing machine. Table 6.1 shows the contrast of switching speed between proposed and existing vending machine. Table 6.2 represents device utilization reports for proposed and existing vending machine. Figure 6.1 represents the power results of the implemented vending machine.

Table 6.1: Comparisons of switching speed

parameter	FPGA[1]	CMOS[1]	Proposed design
Switching speed	9.3ns	300ns	4.956ns

Table 6.2. The designed device utilization summary comparison with existing machine [7]

Resource	Used	available	utilization
Number Of Slices[7]	**56**	**768**	**7%**
Number of slice flip flop[7]	**35**	**1536**	**2%**
Number of 4 inputs LUTs[7]	**107**	**1536**	**6%**
Number of bonded IOBs[7]	**16**	**124**	**12%**
Number of GCLKs[7]	**1**	**8**	**12%**
Proposed architecture			
Number of slice flip flop	**14**	**41600**	**0.03%**
slice LUTs	**35**	**20800**	**0.17%**

On-Chip	Power (W)	Used	Available	Utilization (%)
Slice Logic	0.229	64	---	---
LUT as Logic	0.209	35	20800	0.17
F7/F8 Muxes	0.008	8	32600	0.02
Register	0.006	14	41600	0.03
BUFG	0.006	1	32	3.13
Others	0.000	1	---	---
Signals	0.263	48	---	---
I/O	2.542	17	106	16.04
Static Power	0.081			
Total	3.115			

Figure 6.1 Power results for design vending machine

II. CONCLUSIONS

The intended designed of vending machine based on the FPGA is carry out by using a Finite State Machine and simulated using Xilinx Vivado 2019.1. The design is verified in the BASY-3 development board. The code works as a user friendly machine and the code can actually provide a variety of options to the users. State machine based vending escalate productivity, lower the system development cost. The vending machine gives quick responses and can be easily operated by even an ordinary person. The proposed vending machine can be utilized in many application and the users can very well manipulate the number of selection of product based on requirement. Proposed designed has less LUT as compared to existing vending machine. The proposed vending machine has less speed as compared to that of existing vending machine.

IX. AKNOWLEGMENT

I am so much great full to my project supervisor Dr. Manoj Kumar who has assisted in my project work without his guidance this paper would have not been accomplished. I am also much thankful to all my respected teachers and friends for their excellent contributions and support for the completion of this paper.

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