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Design and Implementation of FPGA based Vending Machine for Integrated Circuits (IC's)

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***Abstract*: Over the years, there has been a drastic evolution in Vending Machines, from a simple "convenient unmanned shop" to a station providing several services in various domains. Among its various advantages, some are listed as follows portability in terms of its set up, being low cost-driven, and offer a wide reach due to less consumption of space. The project, includes IC bifurcation, IC testing and vending out of customer desired IC's. The intended design is implemented on a Spartan 6 FPGA development board using Verilog programming and simulated using Xilinx software. FPGA based devices consume less time, allow rapid prototyping, are flexible, reprogrammable and also reduce hardware, while there are any changes made. Use of such technologies saves time, power and cost. Segregates and does the functional verification of IC's, thereby lending a helping hand to the lab attendees and also ensuring the use of functional IC's by students in experiments.**

***Keywords*: Functional verification, IC vending machine, Segregates, Spartan 6 FPGA, Verilog programming, Xilinx Software.**

1. Introduction

A vending machine is defined as an automatic machine that provides numerous products such as snacks, cigarettes, beverages and lottery tickets to consumers after an amount is deposited via cash or card, or a specifically designed token is inserted into the vending machine. The major concern of the project is with regard to the manpower, time spent on IC segregation and delay in outputs of experiments due to defective IC's. Based on the literature survey conducted the vital enhancements are segregation and verification of IC's. The utilization of color sensors and FPGA controlled robotic arm facilitates the preferred objectives. IC's are arranged over a motor-driven conveyer belt, and further segregated using color sensors, on the user's demand each IC is tested and vended out, respective to input given. Thus making the device user-defined and service-oriented. FPGA based machines are less time consuming, allow rapid prototyping, flexible, programmable and reduces the usage of multiple hardware as it is reprogrammable.

2. Literature Survey

A brief overview of the surveyed papers are as follows, different techniques such as PLC, data acquisition and pneumatics, HTML, JavaScript, IoT technology, HS-SPME-GC-MS are used. Migration of the compounds from various types of cardboard-cups used in vending machines for coffee was performed and suggested that printed cardboard -cups can be used but some of the compounds found were not authorized to be utilized in food packaging materials as they may lead to dietary Cramer– threshold exceedance. Various inputs required to make the machine function efficiently was the main focus of the design of a control system for a vending machine by introducing PLC technology which lead way to flexible payment methods. Implementation of the control unit with an additional module for interaction with the user was the main feature of vending machine management based on IoT platform. The design and implementation of a reverse vending machine which had features such as of low weight, small size and pocket-friendly price were developed using data acquisition and pneumatics. Safety and security of the machine are based on fingerprint sensing and the alarm system was a new advancement in the vending machine which paved the way for the design of a high – tech vending machine.

The utilization of CMOS, SED, microcontroller technology although contribute to less power consumption, depicts a limitation in speed and efficiency of the vending machine. This is further evolved through the usage of an FPGA development board. In the projects such as low power implementation of FSM based vending machine on FPGA, design and implementation of automatic beverages vending machine and its performance. Evaluation using Xilinx ISE and cadence, where FPGA is used, the major limitations addressed is a limited lookup table.

Some vending machine uses RFID technology, it is user friendly, affordable, less power consumption but the disadvantage is this vending machine can only read RFID tag. The vending machine can be based on ARDUINO technology it reduces the problem of giving balance amount, consumes less power but the disadvantage is this vending machine cannot

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differentiate real coin and fake coin. Even vending machine can be developed using HTML, javascript to dispense a variety of products at the same time but this vending machine is not recommended for mass production.

Mainly vending machines are designed to reduce the workload for humans like in coffee shops, it will be difficult for workers to prepare and give coffee for each person and doing billing at a time so for this, unmanned coffee vending machine is designed using technologies like ARDUINO, IDE and IOT to reduce the workload and there is no need for a person all the time to stay near a machine, but the main disadvantage of this type of machine is that it is time consuming, some vending machines are designed using other technologies also like multinomial logic model, UNO, Java to ensure various benefits to future generation some vending machines are also designed based on SMS gateway for easy and safe general transactions but it is not suitable for mass production for less time consumption of monitoring of the people who entered online a java based vending machine monitoring system is designed integrated with the webserver but the main disadvantage of this is it is more costly.

The main disadvantage of vending machine used for sales is that it does not return the balance amount, so to overcome this problem a vending machine is designed using ARDUINO and UNO technology to return the balanced amount after buying products so like this many advanced vending machines are coming into existence FPGA has wide application includes bioinformatics, device controllers, software-defined radio, digital signal processing, computer hardware emulation, random logic, ASIC prototyping, voice recognition, cryptography, filtering and communication encoding, medical imaging and many more.

FPGA based vending machine with mainframe computers. Its algorithm is extremely flexible and also reliable as the vendors can easily enhance the algorithm for a larger number of products and the number of different denominations at cheaper costs when compared to vending machines based on microprocessors.

Some of the paper also specify research on enhancing safety and security of the machine using fingerprint sensing and the alarm system as a new advancement in the vending machine which has paved way for the design of a high-tech vending machine.

Hence the major conclusions from our literature survey are, the utilization of CMOS, SED, microcontroller technology although contribute to less power consumption, depicts a limitation in speed and efficiency of the vending machine.

3. Block Diagram

Fig. 1 comprises of the Block Diagram of the FPGA based vending machine. The entire operation is divided into the IC Arranging Block (comprising of a DC motor driven conveyor belt and a color sensor), IC Checking Circuit (comprising of a robotic arm and 40 pin ZIF Socket), IC Segregating Circuit (comprising of a Robotic arm and seven slotted sections) and the rest of the components such as relay, LCD display, DC motors belong to the IC Vending Circuit. Here each block represents the different objectives of the project such as Identification of IC's, Testing of IC's, Segregation of IC's and Vending out desired IC's, all being monitored and controlled using a SPARTAN 6 FPGA board.

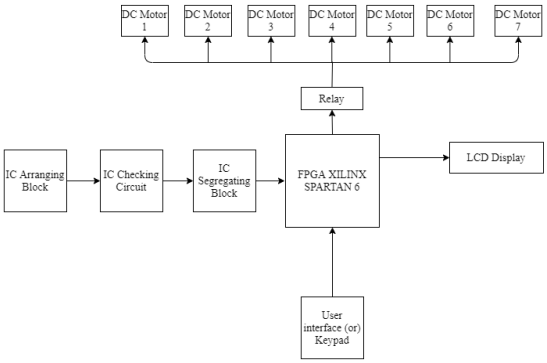

Fig. 1. The block diagram of FPGA based vending machine for IC's.

4. Flow Chart

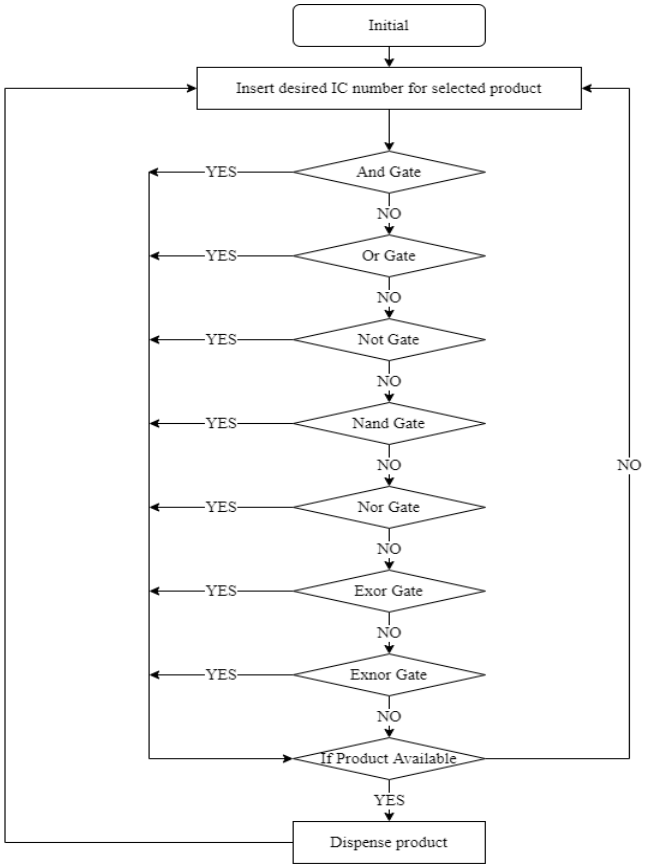

Fig. 2. Flow chart of FPGA based vending machine for IC's

The Flow Chart of the FPGA based vending Machine is shown in Fig.2. Based on the IC number input given by the user via a 4*4 Keypad, the FPGA analyses which IC is to be vended out. Further the availability of that respective IC is checked and if available the product is dispensed. In the case of unavailability, "OUT OF STOCK" is displayed on the LCD Screen indicating to the user, absence of desired IC. The machine is then available for the next request.

5. Methodology

A. *Objective 1: Identification of IC's*

The first objective of our project deals with the identification of IC'S, based on color coding using the following Algorithm,

1. The IC's once verified with regard to their pins (should not be bent or damaged) are arranged over the DC driven conveyor belt manually. The belt bears the load of 5 IC's at a time arranged each in one marked section
2. They are further illuminated by the 4 LED 'S of the color sensor (TCS3200-Color-Light-to-Frequency-Converter) kept in a closed dark space. Based on the color sensed, the output is provided in terms of frequency to the FPGA Board
3. The frequency is measured with reference to the clock of the FPGA board using the below code
4. Once the frequency is measured, the color is analysed and the IC is identified

B. *Objective 2: Testing of IC's*

The second objective of our project deals with the functional verification of IC's with the help of a ZIF Socket using the following algorithm:

1. Once the FPGA identifies the IC type, the robotic arm is programmed to pick the IC from the conveyor belt and lock it into the ZIF Socket, for which it moves at specified angle.
2. Based on IC identified, in order to provide corresponding inputs and verify the outputs, required code is chosen and executed by the FPGA.
3. If the outputs verified are similar to the desired outputs then the IC is placed into the segregation slots, else dumped into the dustbin.
4. All these operations are carried out using a single robotic arm, programmed using Verilog codes. As a result of which one IC is verified at a time.
5. After the complete verification and segregation of 1 IC is completed, the next IC is picked from the conveyor belt.

C. *Objective 3: Segregation of IC's*

All the functional IC's, picked by the robotic arm are to be delivered into the specific IC sections thereby completely segregating all our functional IC's, this is done by using the block diagram as shown in Fig.1 and following the below algorithm:

1. The entire IC Section is divided into 7 slot, each of one kind, where one type of IC is to be placed.
2. As the tested IC is verified to be functional, the robotic arm is programmed to move at angles, such that the IC is placed into the corresponding recognized IC Section
3. Once the IC is dropped, the robotic arm continues the process of verification and segregation of IC's from objective 2.
4. Each slotted section ends with two proximity sensors, a coil and a dc motor, which further function in vending out the IC's on the user's.

D. *Objective 4: Vending out of desired IC's*

The user enters the desired IC number, through a Keypad interface. The required IC is vended out by using the block diagram as shown in Fig. 2 and following the below algorithm:

1. Each slotted section ends with two proximity sensors, a DC motor and a coil. The proximity sensor at the end of the slotted section, senses the entry of the IC just dropped by the Robotic arm.
2. Based on the input received by the FPGA from proximity sensor, the DC Motor rotates the coil, every time an IC is dropped from the robotic arm.
3. Hence each IC is stored in each turn of the coil. On receiving the input from the user, the corresponding DC motor is rotated and IC is vended out
4. The proximity sensor at the end of the coil, senses absence of IC's, and displays the same on the LED.

6. Results

A. *Interfacing results for identification of IC's*

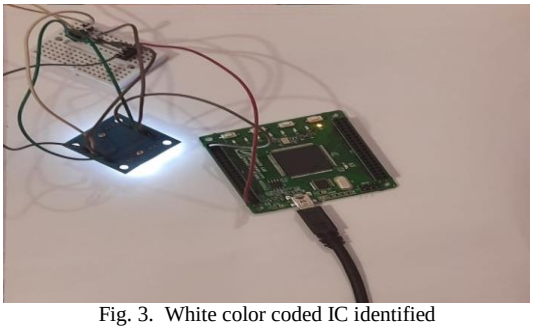

Fig. 3. White color coded IC identified

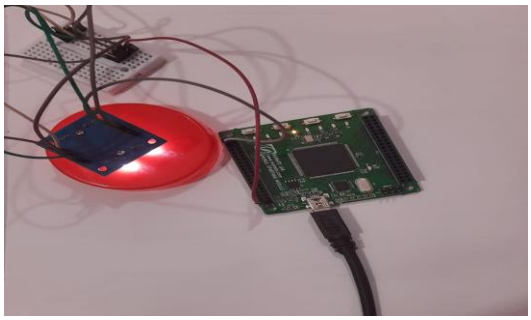

Fig. 4. Red color coded IC identified

Fig. 3 and Fig. 4 shows the interfacing result for identifying red and white colored IC's respectively.

B. *Interfacing results for testing of IC's*

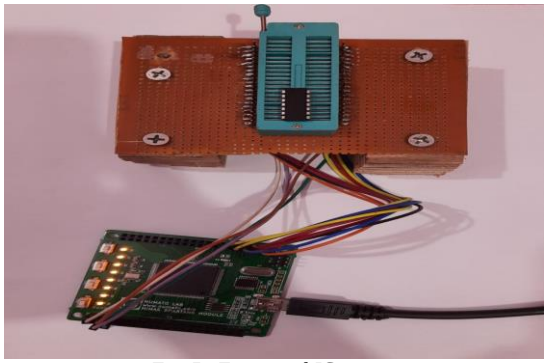

Fig. 5. Functional IC output

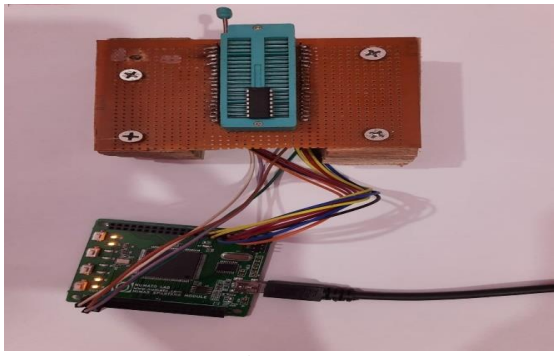

Fig. 6. Nonfunctional IC output

Fig. 5 and Fig. 6 shows the interfacing result for testing of the IC's. Such that all LED's glow for a functional IC and 4 LED's glow for non-functional IC's respectively.

C. Interfacing results for proximity sensor

Fig. 7 and Fig. 8 shows the interfacing result of Proximity Sensor. Such that when the IC is sensed both the LED's of the proximity sensor, first four LED's of FPGA glow as shown in Fig.7 and single LED of the proximity sensor, last four LED's of FPGA glow as shown in Fig. 8.

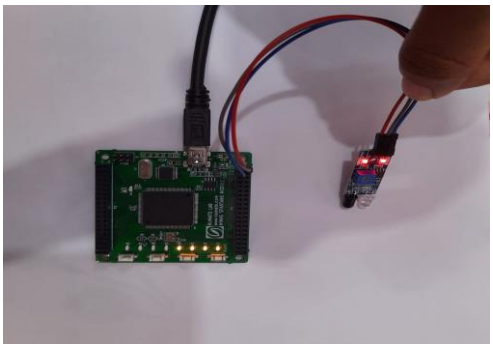

Fig. 7. IC available and sensed

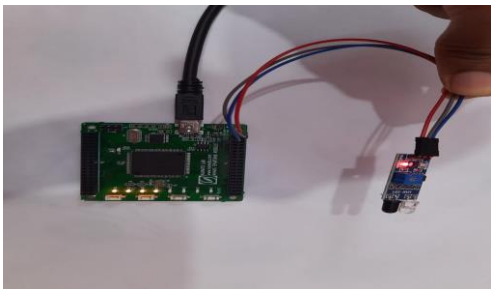

Fig. 8. IC not available

*D. Interfacing result for 4*4 keypad*

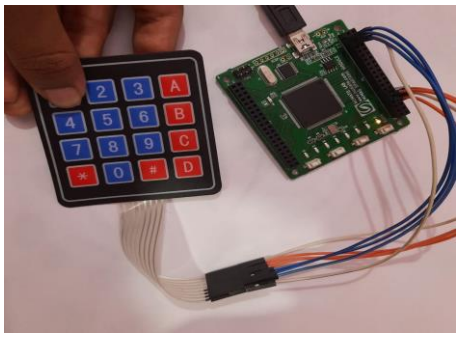

Fig. 9. Keypad interface output

The Fig. 9 shows the interfacing result of a 4*4 keypad. Such that for every Input from keypad respective LED's glow.

E. Interfacing result for dc motor controlling relay

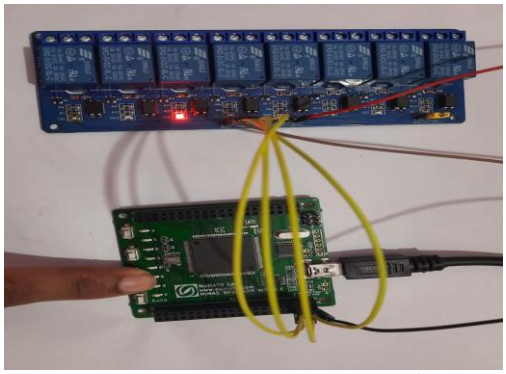

Fig. 10. DC motor controlling relay interface

The above Fig. 10 shows the interfacing result of the DC Controlling Relay. Such that based on DC Motor to be rotated the relays are switched on by the FPGA output pins.

F. Interfacing result for LCD display

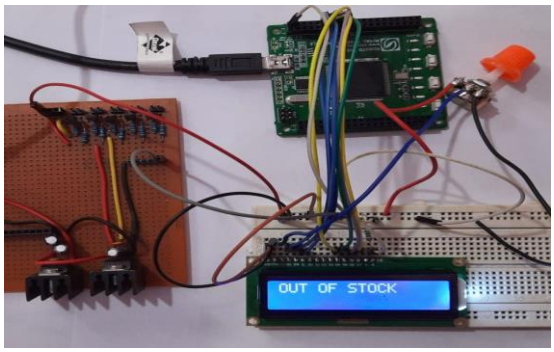

Fig. 11. LCD display interface

The Fig. 11 shows the interfacing result of the LCD Display. Such that on the absence of IC's, "OUT OF STOCK" is displayed on the LCD screen.

G. Interfacing result for servo motor [robotic arm]

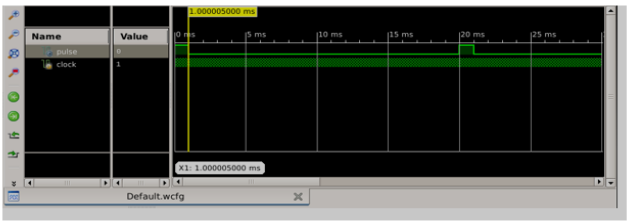

Fig. 12. 1ms PWM wave form from FPGA to servo motor

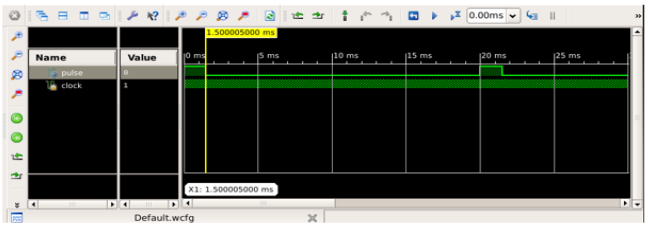

Fig. 13. 1.5ms PWM wave form from FPGA to servo motor

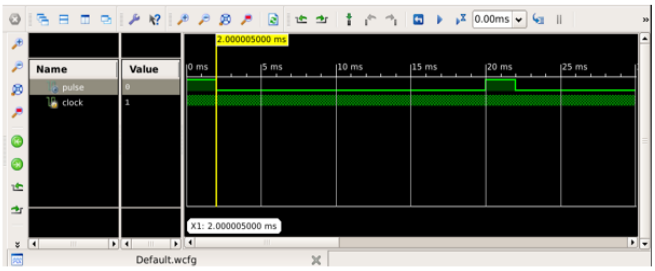

Fig. 14. 2ms PWM wave form from FPGA to servo motor

Fig. 12, Fig. 13 and Fig. 14 shows the interfacing result of FPGA to run the Servo Motors. Such that a 1ms, 1.5ms, 2ms PWM wave is generated by FPGA.

H. Hardware

The Final Outcome is the FPGA based IC Vending machine as shown above where Fig. 15 is the external view and Fig. 16 is the top view of the IC Vending Machine.

Fig. 15. External view of IC vending machine

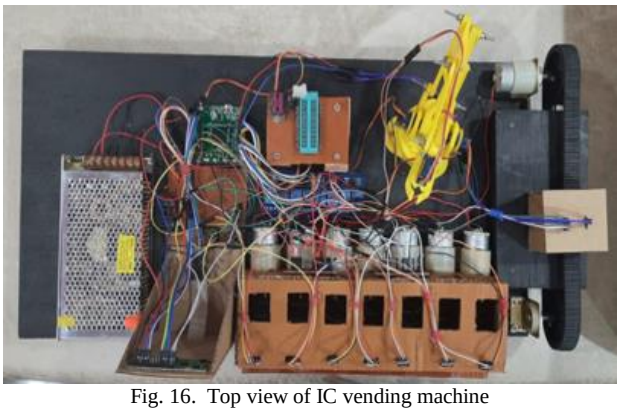

Fig. 16. Top view of IC vending machine

7. Conclusion

The intended design of our vending machine for IC'S based on the FPGA is carried out using Verilog programming and simulation is done using Xilinx Software. It is observed through different scenarios, that FPGA based vending machine give a faster response, show low power consumption and can be easily used by any layman. The project, includes IC bifurcation, IC testing and vending out of customer desired ICs. The code works in a user-friendly manner and provides a variety of options to the users. State machine based vending lower the system development cost and escalate productivity. The proposed vending machine can be utilized in many applications and the users can very well manipulate the number of selection and type of product based on their requirements. FPGA has a wide range of application which includes ASIC prototyping, bioinformatics, device controllers, software-defined radio, random logic, digital signal processing, medical imaging, computer hardware emulation, filtering and communication encoding, voice recognition, integrating multiple SPLDs, cryptography and many more.

8. Future Scope

The Vending Machine is designed to vend out basic and universal gate IC's, this can further be extended to different IC's such as 555 Timer, 741 Opamp IC etc. The Vending Machine segregates IC's using the frequency output of a color sensor, this technique can be replaced with other methods such as bar codes, image processing etc. As shown in the first objective, the IC's are manually placed over the conveyor belt, this vending machine can be made completely automated, by using another robotic arm for the same. In such cases proper alignment of the IC's is to be ensured.

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