Rancang Bangun Perangkat Keras Sistem Informasi Lahan Parkir Secara Waktu Nyata Berbasis Mikrokontroller AT89S52
Guido Eko Nugroho dan Sarifuddin Madenda.

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### DAFTAR ISI

1-13  
Rancang Bangun Perangkat Keras Sistem Informasi Lahan Parkir Secara Waktu Nyata Berbasis Mikrokontroller AT89S52  
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14-20  
Ekstraksi Tabel di Internet : dalam Format HTML dan PDF  
*Detty Purnamasari, I Wayan Simri Wicaksana, Lintang Yuniar Banowosari*

21-26  
Arsitektur Mikroprosesor Berbasiskan Perangkat Lunak LatticeMico32  
*Sunny Arief Sudiro, Aditya Nugraha dan Zainuddin Al Bunjari*

27-35  
Prototype of Electronic Voucher Vending Machine Based on FPGA  
*Priska Restu Utami dan Bheta Agus Wardijono*

36-45  
Aplikasi Panduan Calon Taruna POLRI Menggunakan Pemrograman Java Android  
*Mohamad Saefudin*

46-51  
Alat Pendeteksi Level Zat Cair Sistem Digital  
*Andika Widiyanto*

52-57  
Prosesor Intel Itanium  
*Bintang Wiradjati, Caesar P. Herlambang*

58-64  
Prosesor Intel ® Core Duo  
*Antony Wicaksono, Indra Ramdani Pratama*
Prototype of Electronic Voucher Vending Machine Based On FPGA

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ABSTRACT
To provide innovation, vending machines can be created for electronic voucher. The objective is to minimize errors made by the buyer and seller in writing phone numbers. This vending machine based on FPGA. It can be made flexible to modify and reconfigure the existing data within the module. Concept used in designing this vending machine is using concept of finite state machine and output forming logic. After design, then performed simulation by using Xilinx ISE 9.2i software that contains behavioral simulation and Post Route Simulation. The simulation results show the vending machine system capable of running as scenario. From this thesis has designed vending machine system of electronic voucher with 10 scenarios. This scenario contains possibilities that occur when the vending machine system is operating. From the each scenario, simulation results are in a compare with output displayed along with that process. From the simulation results of all scenarios can be used for many kinds of mobile operators and how much nominal difference value.

Keywords: finite state machine, FPGA, output forming logic, vending machine

1 Introduction

Recently, telecommunication technology is developing rapidly, especially mobile communications or phone mobile. Recorded more than 140 million mobile phone users in Indonesia, and 95% were dominated by prepaid card users. The growth of mobile subscribers in Indonesia as much as 15% per year. Communication is required by everyone. Supporting communication between fellow mobile users is voucher refill, where still used cost for communicate.

To providing innovation in the world of telecommunications technology, vending machines can be created for electronic voucher refill. By utilizing the SMS mobile technology, can provide electronic voucher refill solutions by using vending machines. Where by using this tool buyer do not need to write phone numbers went to electronic voucher refill, but buyers can do electronic voucher refill alone. [Hendrasto Andeski, 2008]

In general, the vending machine control system still uses microcontroller so that tends to be static and very difficult to change, is it money or the nominal input and product prices [Wini Rizkiningayu, et al, 2007]. Then, designed a vending machine control system based on FPGA (Field Programmable Gate Array). FPGA (Field Programmable Gate Array) is a suitable tool for the design of a prototype digital circuit, especially with large scale complexity. Besides being able to be reconfigured, the number of gates and flip-flop in the FPGA is also very much. Writing this thesis was made to minimize errors made by buyers and sellers. The use of FPGAs in the system is so that existing hardware can still be flexible because of the logic circuit can be reconfigured in it if want to use a different algorithm vending machines.

Based on existing problems, this thesis has purpose to determine the solution of problems that often occur in reload conventional system and design application electronic voucher reload vending machine based on FPGA.

2 Related work

There are many approaches from many papers or research presented about vending machine. Joshua C. and Jeckson T. have done research on Microcontroller based SMS Micro E-load vending machine in 2006.
The research was done because under existing problems in their country. There is a need to automate the current auto loading system implemented here in the Philippines. As seen in most stores, the prepaid auto reloading services are being done manually with the vendor using his/her cellular phone to make the transaction [16]. In same year, Elvin Ricky Faizal has done research about Designing and Constructing a Vending Machine for Offices using microcontroller. His project aims to design and implement a vending machine for office use [11]. In other thesis, [Wini Rizkiningayu, 2007] explained that, vending machines are usually designed to keep control over the nominal money input and product prices and variations, due to user requests. The control system has a tendency to be static and not difficult to modify the nominal money input and product prices and variety [13].

A. Finite State Machine

Designing a synchronous finite state machine (FSM) is a common task for a digital logic engineer. A finite state machine has the general structure shown in figure 1. The current state of the machine is stored in the state memory, a set of n flip-flops clocked by a single clock signal (hence "synchronous" state machine). The state vector (also current state or just state) is the value currently stored by the state memory. The next state of the machine is a function of the state vector and the inputs. Mealy outputs are a function of the state vector and the inputs while Moore outputs are a function of the state vector only.

B. FPGA

A field-programmable gate array (FPGA) is an integrated circuit designed to be configured by the customer or designer after manufacturing, hence "field programmable". The FPGA configuration is generally specified using a hardware description language (HDL), similar to that used for an application specific integrated circuit (ASIC) (circuit diagrams were previously used to specify the configuration, as they were for ASICs, but this is increasingly rare). [23]

The design flow broadly refers to the sequence of activities encompassing various design tools that begin with some abstract specification of a design and ends with a configured FPGA. The design flow described is that of the Xilinx Foundation Express environment and illustrated in figure 2. However most of the activities will have a counterpart in any vendors design flow.

C. Output Forming Logic

Forming the output logic is similar to the counter but the translational Output forming logic function has more to designing a glitch free and in use for more complex input to a decoder which is the basis digital circuits based on output.[12]

Some of the circuit to generate pulse for forming output logic can be seen in figure 3. Definitions of the transition state on generating pulse circuit of Output Forming Logic:

Figure 1 : State Machine Structure
Source : Golson (2000)

Figure 2 : An example FPGA design flow,
Xilinx Foundation Express
Source : Roth(2008)
3 Vending Machine Design

There is several process of designing vending machine system. The first is problems identifier, where the specified input and output of the circuit. Then do the state identification followed by a depiction of state diagrams. From the state diagram can be determined truth table. With help Karnough Map (K-Map), Boolean algebra equation it can be formed simple as an input to D Flip-Flop or as Input Forming Logic (IFL). After determining the type of the output waveform can be determined Output Forming Logic (OFL). The next, process describes the results obtained by the digital circuit equations and simulate the circuit. The simulation results are analyzed, whether the scenarios has been created as expected.

A. State Diagram

From the objects of the state identification, then the state diagram can be described as follows in figure 4.

4 Vending machine control system

Vending machine control system is design using modular approach to obtain the flexibility in design configuration and error source detection. These modules, which later would be integrated, consist of sub modules. The basic reason for modular approach is to achieve design simplicity, and to avoid system complexity that will lead to longer design time spent. From the user point of view, the modular approach design allows the user to easily change or configure the data, since if the user wants to do some configuration, they only need to refer to the related modules and does not need to change the whole system design.[13]

Circuit of vending machine system as whole is shown in figure 5. From the circuit consists of modules for forming the circuit into one united system.

Each active module can be running in vending machine system, if other one module is ignored and it will be impact on the output from the vending machine system. The modules are formed based on formulation of the state diagram and then translation to the state translational that made using truth table. The following describes the usefulness of each module.

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**Figure 3 : Generating pulse circuit of Output Forming Logic**

Source : Siswono(2005)
Figure 4 : State diagram of vending machine

1. Module 'Main Menu'
2. Module 'IFL'
3. Module 'kind of mobile operators'
4. Module 'Spending money'
5. Module 'sending electronic voucher'
6. Module 'secrete bill paper'
7. Module 'Menu Operators'
8. Module 'get out change'
Scenario testing in this system consists of 10 scenarios. Scenario contains possibilities that occur when the vending machine system is operating. The 10 scenarios can be used for any choice of operators and with different nominal. This is some scenario used in this system. Figure 6 shown state graph of the first scenario, the third scenario shown in figure 7 and the tenth scenario shown in figure 8.

5 Simulation result and analysis

After creating a design, then the next step is to do simulation. Simulation is done using help Xilinx ISE 9.2i software. In the simulation, there are 2 types of simulations. They are behavioral simulation and post route simulation. In addition, to further clarify the course simulations are then made display of each menu. Verify menu is exactly what can prevent human error when enter phone number. After viewing a form menu transaction, users can corrected phone number return and choice of operator cellular and nominal voucher. If all data is correct then the transaction can proceed, if there is an error then the process transaction can be cancelled by pressing cancel button, so that going back to the start menu. Simulation result of the first scenario shown in figure 9, the third scenario shown in figure 10 and the tenth scenario shown in figure 11.
Based on experiments on the first scenario (figure 6), simulation results obtained are shown in figure 9. The first beginning with statement ‘00000’, in scenario is state a. Of state a produces output MU (main menu). So, if no activity occurs, the output is always shown. Output of mu shown if clock value is ‘0’. So in this system uses active low. Meaning is that the resulting output will be active if the clock value is ‘0’ and will be switched off if a clock value is ‘1’. Furthermore, the system given input with value ‘1’ in ma, then output of the simulation will be shown mo. Meaning is that if MA button in vending machine system is on then it will be shown kinds of operator menu (symbolized by mo). After that will be continue to statement ‘00001’ (in scenario is state b). In state b is given input with value of ‘1’ on symbol me (Mentari operator option). Then the simulation will be continue to statement ‘00010’ (in scenario is state c). From state c given input with value of ‘1’ at symbol in_2 and produce the output me_10 (Mentari operator with nominal electronic voucher 10000). Then next proceed to statement ‘01100’ (in scenario is state m). Of state m given input hp with value of ‘1’ then continues to statement ‘01101’ (in scenario is state n). Then the system given input ent with value ‘1’ then it will be continues to statement ‘01110’ (in scenario is state o). From the state o continues with the given input pay_10 with given value of ‘1’ then continues to statement ‘01111’ (according to scenario of state p). Of state p given by the value ‘1’ on input symbol ent and continues to statement ‘10001’ (in scenario is state q). After that, given input pas with value ‘1’ and continues to statement ‘10011’ (in scenario is state t). From the result output state t is a proof of the transaction or receipt (in simulation symbolized by s). Then continues to statement ‘10100’ (state u in the scenario). In state u resulting output is sending electronic voucher (in simulation symbolized by mp). Once the process is complete, then back again to statement ‘00000’ (state a) and the output will be shown like at the beginning of transaction is the main menu (symbolized by mu).
Based on experiments on the third scenario (figure 7), simulation results obtained are shown in figure 10. Same as the previous simulation results (figure 4.20 and figure 4.21), starting from \textit{statenum} ‘00000’ (state a) to \textit{statenum} ‘01110’ (state o) has the same simulation results with the simulation in figure 4.22. Then continues with given value of 010 at input pay_5 then generate \textit{statenum} ‘01111’ (in scenario is state p). Then given a value of ‘1’ on input ent and progress to \textit{statenum} ‘10001’ (in scenario is state q). In state q is given a value of ‘1’ at input symbol krg. Then it will be continue to \textit{statenum} ‘01110’ (in scenario is state o). The meaning is commanded for to enter some less money for transaction process can do be well done.
Based on experiments on the tenth scenario (figure 8), simulation results obtained are shown in figure 11. In figure 11 displayed simulation result also has similarities with the simulation shown in figure 9. It is beginning from state num ‘00000’ (in scenario is state a) to state num ‘10001’ (in scenario is state q). Then in the state q is given a value of ‘1’ on input by symbol x. Then continues to state num ‘10000’ (referred to state r in scenario). In this state r the result output is spending money because the transaction is cancelled (in the simulation symbolized by v). After that, because the transaction process cancel state num go back to the beginning of ‘00000’ (state a). And displays the Main Menu (symbolized by mu).

![Simulation result of the tenth scenario](image)

**6 Conclusions**

Vending machine manufacturing system design has been achieved in accordance with the purpose to solve the problem. By making display verify menu then the possibility of human error when writing phone numbers can be avoided or minimized.

Designed system vending machine has been successfully and simulated with Xilinx ISE (Project Navigator) based on FPGA. The simulation results show that vending machine electronic voucher system capable of running as scenario. From each scenario, the simulation results are in accordance with the output displayed and process flow. With number of 4 input LUTs is 143, number of occupied Slices is 73, number of bonded IOBs uses is 91 and total equivalent gate count for design is 901.

This vending machine control system using FPGA as alternate of microcontroller that makes flexible in modifying data within the module. In this thesis have also been described advantages compared to the system microcontroller and FPGA can be concluded that FPGA is better than microcontroller to design a vending machine system.

**ACKNOWLEDGMENT**

Gunadarma university for supporting this paper.

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