A Home-Made and Low-Cost Basic Logic Kit for Learning Basic Digital System

Endah Rahmawati[1,#], Imam Sucahyo[1], Khairurrijal[2]

[1]Physics Department, Universitas Negeri Surabaya, Kampus Unesa Ketintang, Surabaya 60231, Indonesia

[2]Physics Department, Institut Teknologi Bandung, Jalan Ganesa 10, Bandung 40132, Indonesia

[#]E-mail: e.rahmawati@gmail.com

Abstract - A home-made and low-cost basic logic kit equipped with lecture notes has been developed. The main purpose of developing this kit is to support undergraduate students in learning basic digital system, which is delivered in the digital electronics topic of Basic Electronics-2 course, at Physics Department, Surabaya State University. This kit consists of input switches, output indicators, a battery, and several logic gates, i.e. AND, OR, INVERTER, NAND, NOR, XOR, XNOR, which are assembled on a matrix board and plywood. The kit, which was packed in a plastic box and its front panel was made from a glossy photo paper, is simply portable to be used in classroom and laboratory. The lecture notes contain of digital system principle with emphasis on practical experiments and applications. The kit and the lecture notes were composed so that students easily understand those using provided examples to conduct experiments of digital logic. They were developed using a 4-D model that includes *define*, *design*, *develop*, and *disseminate*. The usefulness of the kit and the readability of the lecture notes were evaluated by distributing a questionnaire to 20 students taking the course. It was found that the students give the score of 4.6, 4.15, 4.03, 4 out of 5 for content, language, helpful for understanding basic logic, and layout, respectively, which indicate that the kit and the lecture, notes is advantageous tools in achieving better understanding of basic digital system.

Keywords: digital system, electronics, logic kit, lecture notes

1. Introduction

Basic Electronics-2 course is delivered in the second year of undergraduate students at Physics Department of Universitas Negeri Surabaya. This course contains digital electronics topics. Physics Department in most universities in Indonesia also sets up digital electronics as one of compulsory courses. This has been characterized as theoretical. Thus, it is necessary for providing students to didactic lecture-based instruction accompanied by problem solving exercises both physical and mathematical analysis [1]. Several researchers conducted alternatives of instructional methodology for the course in the form of computer simulation as well as hardware [1-6].

However, the fact that the amount of sciences and technologies that based on digital electronics is exponentially increased, all relevant material cannot be covered in lectures. Therefore, students must be well equipped to acquire an understanding of the expanding field of digital electronics. There is also a responsibility on universities to produce creative thinkers among their graduates based on theoretical thinking and practical works.

In order to support theoretical concepts on the digital electronics that were explained by lecturers in classroom, laboratory works can be done by students must be provided. By conducting laboratory works, it is believed that the students will learn the theoretical concepts easily and grasp them more. Rickel [7] mentioned that students retain 25% of what they hear, 45% of what they hear and see, and 70% if they do what they hear and see or known as ‘learning by doing’ method.

A number of interesting educational kits are already available in market [8]. However, they are expensive, so we have to spend more money.

This paper presents basic logic kit equipped with lecture notes, a teaching aid that can be used to introduce undergraduate students to fundamental concepts of basic digital logic system. The kit has great potential, particularly in the delivery concepts and skills of students. It also easy to clone into several other kits, so more students can use them.

2. Problem with Current Digital Electronics Learning

The development of the kit was initiated to overcome of the existing manner in which digital logic is taught in many university courses. This revealed certain deficiencies. There are three main problems with current mainstream instructional strategies for teaching digital logic to university students [1].

Firstly is lack of prior knowledge. Digital logic topics are commonly delivered in second year and it becomes a new experience for students. Most students have no prior information as a foundation that can be used to understand new information and understanding. It situation challenges lecturers to introduce the course to the students by relating digital logic concepts to existing application of it, such as black and white printing and images.

Secondly is lack of time to discuss advanced concepts. Digital logic concepts are taught in two or three credits of semester. It means students have opportunities only 100 to 150 minutes to study and discuss with lecturers. Due to the time, lecturers should manage their teaching material and time suppose they can introduce new ideas of students.

In addition to the lack of prior knowledge and the resulting of time for discussion of advanced topics, most lecturers teach concepts of digital logic and introduce the language of the discipline simultaneously. The learner has insufficient time to construct his/her own understanding of the concepts in this discipline by manipulating: (i) actual objects (simple electronics components), (ii) image-based and mixed representations (blocks diagrams, schematic of circuits), and (iii) highly-abstract and efficient symbolic formal language (Boolean logic).

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3. Basic Logic Kit and Lecture Notes

A. Kit

The kit size is 40 cm × 30 cm. It provides both physical and electrical basic of the logic system. It is simply portable to be brought in the classroom for demonstration as well as for experiments in the laboratory. The kit consists of three main parts: inputs, logic gates, and outputs.

The inputs are eight toggle switches, which have logic ‘1’ when the switch ON and logic ‘0’ when it is OFF. There are six logic gates are available on the board. Logic gates are electronic circuits that can be used to implement the most elementary logic expressions, also known as Boolean expressions. The logic gate is the most basic building block of combinational logic. There are three basic logic gates, namely the OR gates, the AND gates and the NOT gates. Other logic gates that are derived from these basic gates are the NAND gates, the NOR gates, the EXCLUSIVE-OR gates and the EXCLUSIVE-NOR gates. In this kit, EXCLUSIVE-NOR gates are not available but we can connect the output of EXCLUSIVE-OR gate with NOT gate. Output panel was made from eight LEDs, which mean logic “1” when the LEDs are ON and logic “0” when the LEDs are OFF.

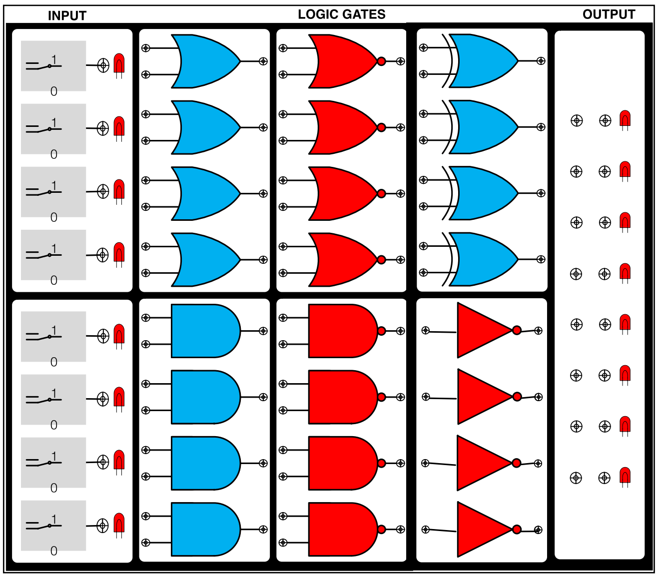

Fig. 1 Front panel of the kit.

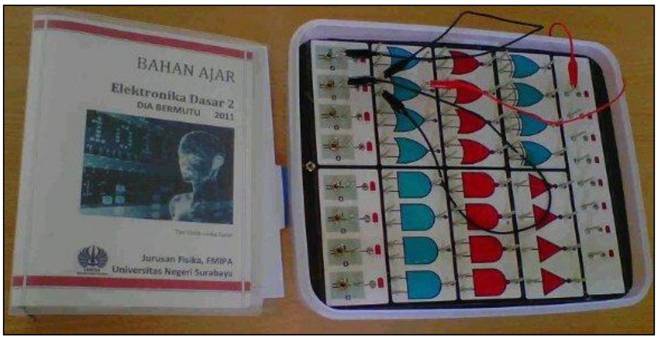

Fig. 2 Kit and Lecture Notes on Digital Electronics.

The front panel was printed on a glossy photo paper, which is glued on plywood. The logic gates ICs were soldered on matrix board. Those components were packed in a handy plastic box. We have been used battery for the supply and also equipped the kit with connector cables, so the students and lecturers can use it to conduct several different combinational logic circuits such as half adder and full adder circuits.

B. Lecture Notes

Along with this kit, a lecture notes were written as a learning material and guidance for the students. This lecture notes content topics of number system; binary codes; and logic gates and related devices. This kit and notes were composed based on 4-D model. Firstly, we define the problem that should be overcome by the lecture notes. Secondly, we design a proper kit and lecture notes to solve the problems, and begin to develop them. Lastly, we disseminate the kit and lecture notes for teaching and learning process.

Some example problems are available in lecture notes, provides opportunity for the students to solve it by mathematical analysis and prove the answer by conducting experiments using the logic kit.

C. Examples of Use

This following are two examples of experiments of logic gates for Boolean algebra. While laws of Boolean algebra could be used to do manipulation with binary variables and simplify logic expressions, these are actually implemented in any digital system including computers.

First example is half adder, which is a combinational circuit that performs the addition of two bits. This circuit needs two binary inputs and two binary outputs. Both Fig. 3 and Fig. 4 is half adder, which has different combinational of gates, but has same result as show (1) and (2).

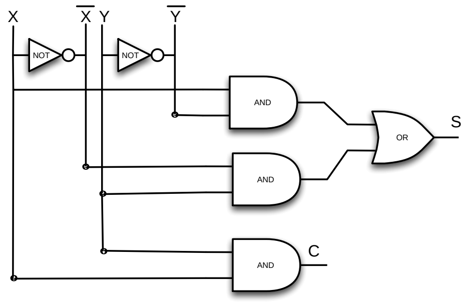

Fig. 3 Implementation of half-adder using sum of product.

Half-adder using sum of product form, which S is Sum and C is carry.

$$S = \bar{X}Y + X\bar{Y}$$
$$C = XY \qquad (1)$$

The other half adder is using XOR and AND gates is shown Fig. 4. Equation (2) shows the result of S and C.

$$S = X \oplus Y$$
$$C = XY \qquad (2)$$

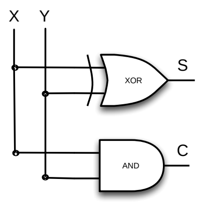

Fig. 4 Implementation of half-adder using XOR and AND gates.

The second example is full-adder, which is a combinational circuit that performs the addition of three bits (two significant bits and previous carry). It consists of *three inputs and two outputs*, two inputs are the bits to be added, and the third input represents the carry form the previous position. The full adder is usually a component in a cascade of adders, which add 8, 16, etc, binary numbers. It is shown in Fig (5).

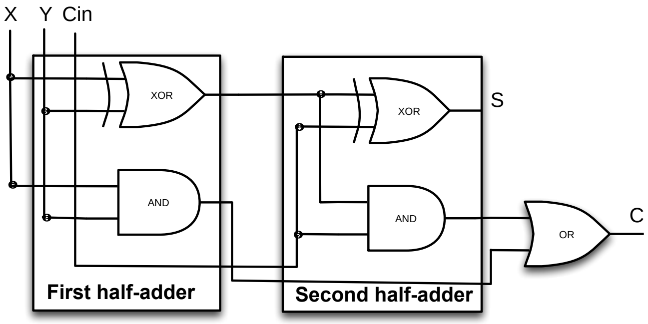

Fig. 5 Implementation of full-adder using two half adder and OR gate.

The students can implement this combinational and proof the result of full-adder is equal to (3).

$$S = C_{in} \oplus (X \oplus Y)$$
$$C = Cin \cdot (X \oplus Y) + XY \quad (3)$$

D. Assessment

The main goal of the kit and lecture notes development, used for both practical work in the laboratory and demonstration in the classroom in the Digital Electronics course since the academic years 2011 is to improve student learning in digital system. At the end of the course, 20 students who took this course are surveyed using questionnaire.

The result of questionnaire is used to evaluate the usefulness and the readability of the kit and lecture notes. Statements of questionnaire covering several aspects of the kit and lecture notes such as [2]; students were asked on a scale of 1 to 5, where '1' signifies 'I strongly disagree' and '5' signifies 'I strongly agree'. For example, due to the overall results which is shown in Fig. 6, students felt that the content of the kit and lecture notes are suitable with curriculum and syllabi (4.6), the language is easy to understand (4.15), helpful for understanding basic logic system (4.03), and layout is interesting (4).

Globally, the responses of students to the project were quite positive. This result indicates that the kit and the lecture, notes is advantageous tools in achieving better understanding of basic digital system.

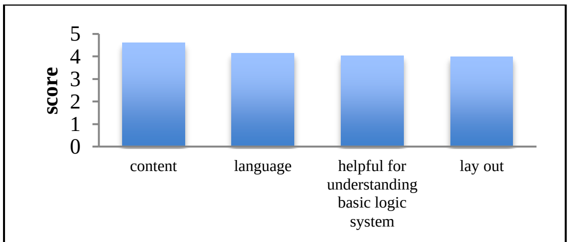

Fig 5. The result of questionnaire.

4. Conclusion

We have developed a basic logic kit and lecture-notes. The kit consists of three panels of inputs, logic gates, and outputs. The kit was constructed from plywood, matrix board, and electronics components such as logic gates ICs. They were packed in a plastic box. Some experiments have been conducted such as implementation of logic gates for simple Boolean algebra half-adder and full adder. The lecture notes contain learning material and guidance for laboratory works, in which for facilitating undergraduate students in basic digital system. Both the kit and lecture notes were composed based on 4-D model. Questionnaires were administrated to evaluate four aspects of the kit and lecture notes. It was found that 20 students give the score of 4.6, 4.15, 4.03, 4 out of 5 for content, language, helpful for understanding basic logic, and layout, respectively, which indicate that the kit and the lecture, notes is advantageous tools in achieving better understanding of basic digital system.

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