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Development of Digital Electronics Book Trainer

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ABSTRACT

Digital electronics trainer is a device that is functions as a tool for learning, teaching and testing digital electronic circuits. It also designed to offer an option for student to quickly build, modify and troubleshoot all sort of circuit and it is ideal for academician to use it as a learning aid tool. Conventional electronic trainer boards consist of breadboard as their main part for circuit connection and some other features such as LED display and switches. However, this device has some limitations, which are very expensive, non-portable and high cost of maintenance. Thus, this study introduced a new electronic book based trainer named "Digital Electronic Book Trainer" to overcome the limitations of the conventional trainer boards. This trainer kit consists of four main components: the trainer books, steel sheet, conductive pen and electronic components module kit. The study shows that "Digital Electronic Book Trainer" is portable, user friendly and suitable to be use as a learning aid tool at primary or secondary school even for higher education.

Keywords: Conductive Pen, Electronic Trainer, Modular Kit, Digital Trainer.

1. INTRODUCTION

Scientific technical courses are important components in current science and engineering based education. Traditionally, these courses required students to execute experiments in specific laboratories. This leads to an extremely high costs, reduction in the maximum number of possible participants and also the time constraint in learning[1][2][3]. Digital electronics trainer is a device functions as a main platform for construction and testing of electronic circuits in most of electronic laboratories. Electronic trainer board has become increasingly popular in a wide range of applications in teaching and learning method[4]. The electronic trainer boards use a breadboard as their main part for circuit connection and it also include some features such as LEDs and seven segments for display output. Commonly this electronics trainer is using prototype circuit, which is implementing the rectangular plastic construction bases with a grid of holes spaced to fit the leads components. The main limitation of using breadboards is the temporary connections of the circuit, due to this, the component can be easily loose and sometimes the circuit is not properly connected. The circuits construction also a bit messy due to jumper wire that cross each other's.

The common digital electronics trainer is very expensive to obtain and normally available in limited numbers in electronic laboratories. Thus, students and lecturers can only use the trainers during the laboratory session. Moreover, due to limited numbers of unit, students need to share the trainers and this reduces the contact times of each student to use the trainer.

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Besides that, digital electronics trainer board requires a high maintenance cost and not portable due to its large size. Therefore, due to these drawbacks, this project focus to develop a digital trainer that is similar to the basic functional of digital electronic trainer, but it provides new method on circuit construction thus portable and affordable. Table 1 show the comparison between Digital Electronics Book Trainer and conventional digital electronics trainer board.

Table 1 Comparison between digital electronics book trainer and conventional digital electronics trainer board

Digital Electronics Book Trainer	**Conventional Digital Electronics Trainer Board**
	
Low cost maintenance	High cost maintenance
Affordable(less electronic component was used in this trainer)	Expensive (more complex and have lot of expensive electronic component)
Used battery for power supply (easy to carry)	Required an external power supply from plug.
Easy and simple in circuit connection process (using conductive pen)	Complicated process in circuit connection (using a lot of jumper wire)

1.1 The Integration of Electronics with Paper

Recently, considerable amount of research in circuit construction method has been focusing a lot on paper substrates as a low-cost and enabling platform for flexible, lightweight, and disposable devices[5][6]. Besides that, there are also other research works that have seen electronic integration with paper. In[7], the authors have combined microcontrollers with craft material and developed simple and robust techniques for drawing circuits on paper. Perner-Wilson, addressed in his research a series of techniques that allow to build electronics as a craft using a craft materials as well as the skills and creativity of the builder[8]. It can be seen that most of these authors focus on the development of electronic circuits specifically on paper as they are accessible and versatile. It is accessible in the sense that it is abundant, low-cost, and easy to work with[4]. Jacoby *et al*. provide a story telling platform for children using conductive pen, paper and electronics tool. The author exploit craft practice to motivate the exploration of electronic technology[9]. Therefore, due to these reasons, the Digital Electronic Book Trainer was developed using paper as the main platform for circuit connection.

2. METHODOLOGY

2.1 Components of the Trainer

Figure 1 shows the design of Digital Electronics Book Trainer. The trainer consists of four main parts, which are the trainer book, steel sheet, conductive pen and electronic module kits. The

trainer book is made of 210 mm x 297 mm white colour A4 papers (120 gm). The trainer book functions as the main platform for circuit construction. The conductive pen with silver ink will replace the function of jumper wire for circuit connection. Conductive pen is look like a normal roller ball pen but contain a conductive ink. The steel sheet functions to hold the kits and the circuit together and to provide better connection between the module pins and the conductive ink.

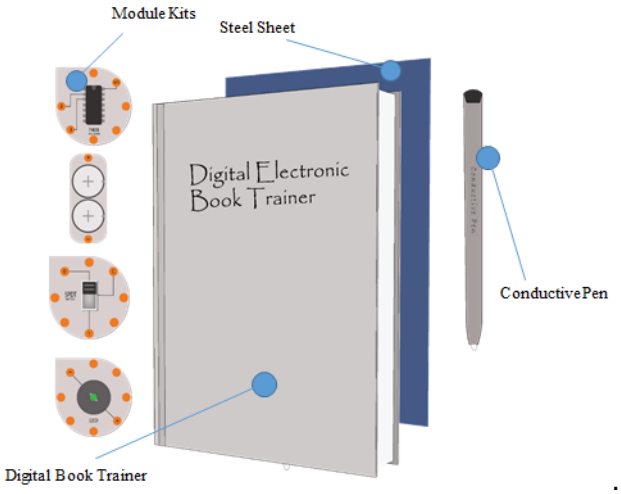

Figure 1. Design of digital electronics book trainer.

The construction for digital book trainer consists of four stages. Referring to Figure 2**,** the first stage is the process of selecting the conductive material to be used as a conducting material between the circuits. The next stage is the construction of the modular kit that involves design of product dimensions, etching and soldering. Next, is the testing process where the circuit will be tested to ensure it is operating accordingly and accurately. Finally, survey questions are distributed to attain feedback on product efficiencies.

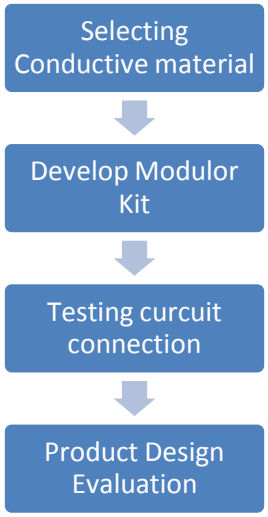

Figure 2. Developing proses for digital electronics book trainer.

2.2 Selection of Conductive Materials

Several materials have been considered as a conductive material to replace the function of jumper wires. It is crucial to ensure the materials able to transmit currents from power supply to the electrical modules kits. Table 2 shows the value of current and voltage of several type of materials tested as the conductor. The copper conductive tape demonstrated the lowest resistance and the highest value of current flow compared to other materials. However, this method is not preferable because it consume time and special skill to apply the conductive tape on the trainer book. Meanwhile, carbon is the least preferable materials because it generates the highest resistance and the lowest current flow compared to the other materials. Therefore, silver ink is chosen as the conductor material. The conductive pen functions like a normal roller ball pen and easy to operate. The Circuit Scribe Conductive Pen has been used as the conductive pen for this study.

Table 2 Materials considered as conductor

Type	Materials (10 cm × 0.5 cm)	Resistance (ohm)	Current (mA)
2B pencil	Carbon	15.34K	0.003
Conductive Tape	Copper	0.3	1.54
Conductive Pen	Silver	9.2	0.84

2.3 Electronics Modular Kits

The field of new methods and techniques for building electronics is quickly growing, from research in new materials for circuit building, to modular toolkits, and more recently to untoolkits, which aim to incorporate more off the-shelf parts[10]. Modular design is a design approach that subdivides a system into smaller parts called modules. Modular design can reduce maintenance costs, if there have any damage to electronic components the maintenance is made by changing the damaged parts only. The conventional digital trainers have higher cost maintenance, where it needs to repair the whole trainer part. The module kit was developed using PCB board and used a magnet for pin terminal. Figure 3 shows the prototype of the module kit and Figure 4 shows the etching process and magnet soldering process of the module kit. The module kit contains 3 modulars design. They are 14-pins modular, 3-pins modular and 2-pins modular. The first modular can be used with ICs such as IC 7408, IC 7432, IC7404 and IC 7406 while the second and third modular can be used with any other 3-pin and 2-pin components. The module kit also contains with rechargeable battery as a supply voltage.

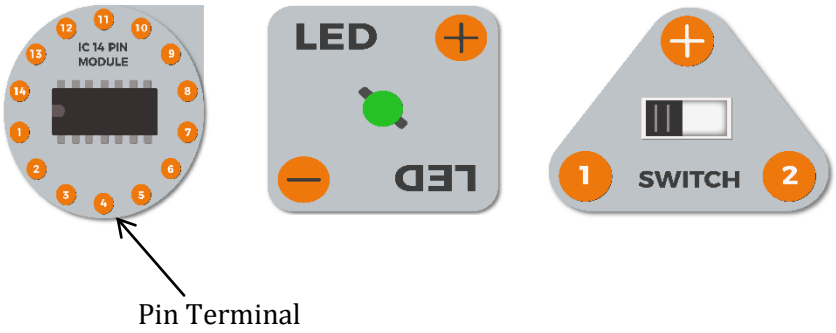

Figure 3. Prototype design of module kit.

Figure 4. Etching and soldering process.

2.4 Circuit Connection Using Book Trainer

As shown in Figure 5, the conductive pen with silver ink used to draw the electric circuit diagram on the trainer book. The lines draw on the paper represents the wires that connect each of the electrical components. Then, the steel sheet is position under the paper and electronic module kits is placed on the paper. The module kits attach to the paper by the magnet at the bottom of the kits. The steel sheet holds the kits and the circuit together and to provide better connection between the module pins and the conductive ink.

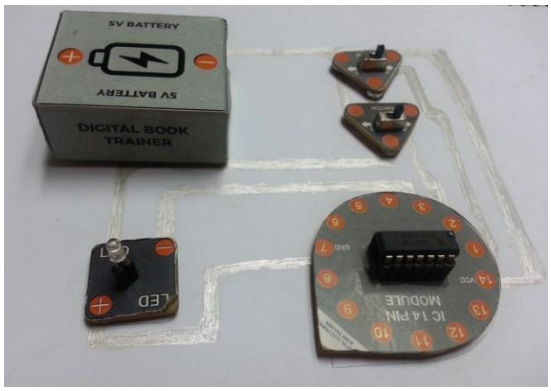

Figure 5. Circuit connection on the digital electronic book trainer.

2.5 Product Design Evaluation

Product design evaluation has been conducted using a survey questions. The questionnaire aims to determine the effectiveness of use and development of "Digital Electronic Book Trainer". The survey contains 14 questions and divides into 3 subtopics, which are motivational aspect, design aspect and comfortable aspect of the digital trainer. The 23 respondents (3 lecturers and 20 diplomas of electronic engineering students) have volunteered to answer the survey. Each respondent has been given a chance to try the book trainer before they answered the survey questions.

3. RESULTS AND DISCUSSION

Before circuit testing was conducted using the Digital Electronics Book Trainer and module kit, each circuit in the module was tested in the laboratory using the Livewire software as shown in Fig 6. This process is to ensure the connection of the circuits are in the correct state. The circuit connections are also tested on the breadboard using the conventional method as shown in Fig 7. Finally, the testing process indicates that the circuit is in good condition and achieve expected results as shown in Figure 8.

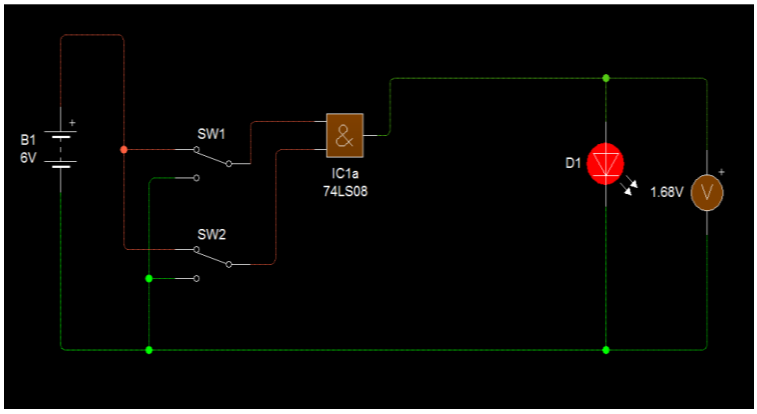

Figure 6. Circuit testing using livewire software.

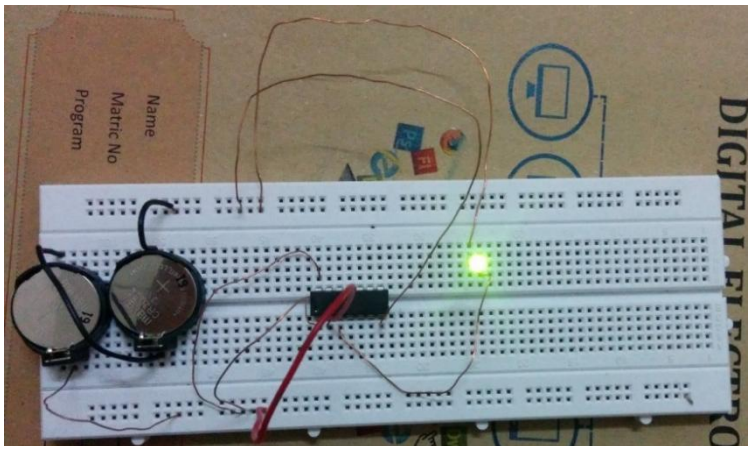

Figure 7. Circuit testing using conventional method.

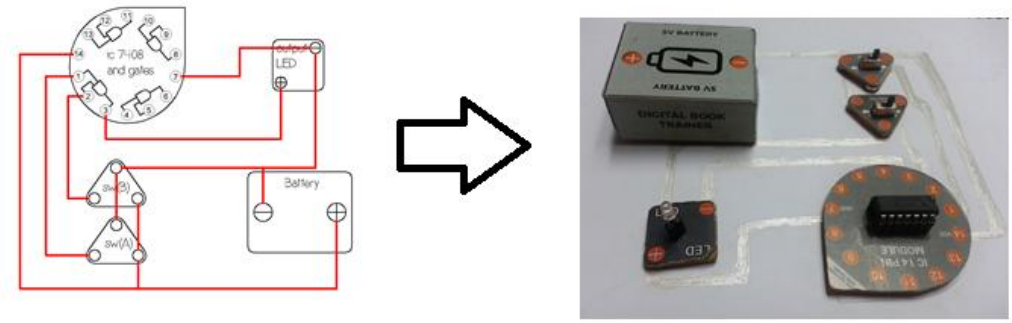

Figure 8. The circuit connection between input and output for AND gate using IC 7408.

Table 3 shows the output results for the AND gate circuit connection and the output yields the equivalent logic circuit for the AND gate. The expecting output of AND gate will be in High (1) condition if both inputs are in High (1) condition.

Table 3 Output Result for Circuit Connection of AND gate using IC 7408

Input Switch A	Input Switch B	Output LED
0	0	0
0	1	0
1	0	0
1	1	1

Regarding to the product design evaluation, the results of the survey conducted imply that all indicators achieve high average mean which is more than 3.5. From the design and comfort aspects, it can be seen that respondents strongly agree that the "Digital Electronic Book Trainer" design are portable and user-friendly as shown in Table 4. The trainer can be used as a starter kit to introduce to the primary and high school also diploma student to a simple electronic circuit construction. However, the conventional digital electronic trainer is needed for construction of complex circuits.

Table 4 Average for interpretation stage

Aspect	Average Mean	Interpretation Stage
Motivational	4.46	Agree
Design	4.55	Strongly Agree
Comfortable	4.52	Strongly Agree

4. CONCLUSION

"Digital Electronic Book Trainer" is a new option to support the limitation of the current conventional digital electronic trainer. Currently, all technical and vocational education required students to be competent with engineering skills. Therefore, with "Digital Electronic Book Trainer", it can help students to have their own trainer to do practical work at any time and place. Based on the book concept, this trainer is portable, affordable and does not require high cost in maintenance.

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