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The Electronic Educational Quiz Board Development to Test Student's Timing Diagram Knowledge of the Ladder Diagram in Programmable Logic Controller

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ABSTRACT
PLC educational quiz board or its acronym, PLC EQB, is a training package designed to test students ' comprehension of translating the timing diagram into an analogous ladder diagram. This is achieved by configuring the educational package to display questions about the mnemonic code. The student must configure an identical ladder diagram relation on the educational package. If the link has been made, the training kit will verify the consistency of the circuit. The purpose of this project is to get students interested in translating the timing diagram into the ladder diagram learning process. The project uses Arduino Mega, a commonly used microcontroller, to reduce the cost of the prototype. A survey is performed by students of the two Faculties of Engineering Technology at the Teknikal University of Malaysia Melaka. The results of the survey indicate positive feedback on the proposed educational package.

Key words : educational kit; electronic quiz board; educational quiz board; timing and ladder diagram; programmable logic controller.

1. INTRODUCTION

Programmable Logic Controller (PLC) is one of the commonly used Controller in industries. This due to its' high reliability and easiness to program. Thus, it is one of the controllers that had dedicated subject taught at tertiary level for most of the electrical-based engineering or technology subject. One of the commonly taught topics in PLC is the conversion of the timing diagram of a sequence-based operation into its ladder diagram equivalent. This project attempts to create an electronic quiz board to aid the process of testing students' knowledge on the topic matter. The aim of this project is to create the quiz board that is automatic which requires no supervision of the teaching personal when student operating it.

Based on the literatures done, there are many educational kits has been developed to help students learn and apply the knowledge with real engineering application. The kits usually will combine with hardware and software to implement the application and cover small sub-topics in the subjects.

As example, flowchart in learning C programming language is one of the most important concepts that students required to understand. M. R. Yaacob et. al [1] has proposed an educational kit to learn this concept using microcontroller. M. S. Karis et. al [2] has developed a hardware for Laplace Circuit Solver for the students to learn Laplace Transform Equation with Arduino Microcontroller. M. I. Z. M Zabidi [3] has developed a kit to understand the concept of mathematical transformation with practical hands-on. Learning to translate mnemonic codes in E-PLC has been developed by M. H. A. H. A. M. Faseh et. al [4].

Meanwhile, [5], [6], [7], [8], [9], [10], [11], [12] and [13] were the example of educational kits projects that implements hardware with Arduino microcontroller and other software such as android apps.

Other example educational kits that related to Control Systems includes learning transient response by applying water level by K. A Kadiran et. al [14] and applying DC motor speed controller with second order transient response by M. I. Z. M. Zakaria et. al [15]. The paper from Thanh-Nhan Huynh-Ly et. al [16] done the research on courses relationship to predict students' performance.

At a meta-level, the aim to develop the PLC EQB project is to attract the students' interest in learning PLC. It is observed that engineering students prefer spontaneous, pragmatic, and concrete style of learning [17]. Pragmatic shows that the students prefer practical hands-on and application in their learning style. Even studies like [18] and [19] shows the important of hands-on-learning. Having said that, it is a known fact that the hands-on activities are resource extensive [20]. Thus, the PLC EQB is seen practical where it is not only inexpensive, portable and function without any teaching personal's supervision.

This project has its limitation. The first limitation comes from the educational kit, itself. PLC EQB is only a proof of concept which being built to test the concept of having an automatic quiz board to test student knowledge on a specific topic in PLC. The word specific earlier suggests that the quiz board only covers the topic of conversion from ladder diagram

to timing diagram which is a single topic in PLC. The number of questions is only limited to five questions. This is seen adequate to show the concept rather than to proof the effectiveness of the product. The second limitation comes from the methodology employed measuring feedback from the respondents. Rather than employing a complex quantitative methodology in designing the survey questions and analyzing the data obtained. This study keeps the question simple and the focus the functionality of the product rather than its effectiveness in improving students' marks.

The package has five questions which are presented in terms of the timing diagram. Students are then expected to create an equivalent ladder diagram relation on the educational package. If the connection is completed, the kit will automatically simulate the wiring connection of the ladder diagram made by the student and display the corresponding simulated timing diagram on the TFT LCD screen. Then, the quiz board compares the simulated timing diagram with the question timing diagram and provide the feedback to the student whether the student's ladder diagram connection is correct or wrong. This interactive element is believed to keep the student's interest and by doing so, the authors hope that the kit will be able to make students understand the translating timing diagram into equivalent ladder diagram.

2. METHODOLOGY

The PLC EQB consists of two parts, which are simulation and quiz. In the simulation section, students must first connect an equivalent ladder diagram so that they can see the output of the timing diagram. Whereas in the quiz part, the student should observe the question provided by the quiz board first before they configure the ladder diagram connection. The users must configure what will be the equivalent ladder diagram for the timing diagram in order to get a positive feedback from PLC EQB.

2.1 Project Layout

Figure 1 show the top view of the project layout which contains several important components for this project such as female header, 4x4 array keypad and thin-film-transistor of the liquid-crystal display (TFT LCD).

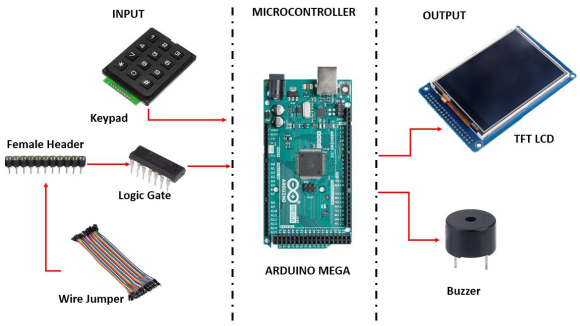


Figure 1: Project layout

2.2 Block Diagram

Figure 2 is a block diagram that shows the relationship between the components stated in Figure 1. The controller employed is Arduino Mega as this microcontroller provide more input output (I/O) pins. The inputs to Arduino Mega consist of a) 4X4 keypad; b) female headers; c) AND logic gate ICs; d) male-to-male jumpers. The 4x4 keypad is used to receive input related to the selection by user. The AND logic gate ICs is used to hold the current when reading the connection done by the user via the female header. The female headers and male-to-male jumper are used as connection apparatus for user to recreate the equivalent timing diagram on PLC EQB.

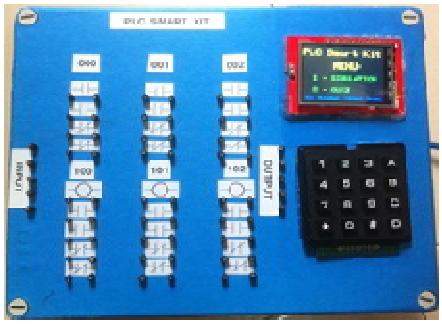


Figure 2: Project Block Diagram

2.3 Connection Pins of Components on Arduino MEGA Board

Instead of providing the schematic drawing of the product, this paper includes pin-to-pin connection of the product. This is deemed more suitable because it is not suitable to display the circuitry connection within the limited space of this article. Table 1 shows the complete pin connections of the product.

Table 1: Connection Pins of Components On Arduino MEGA Board

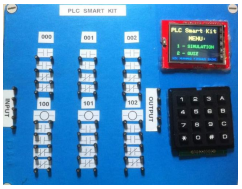
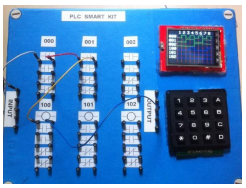
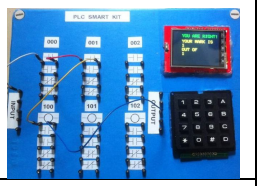
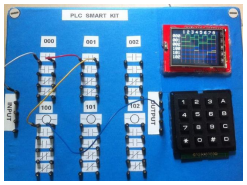
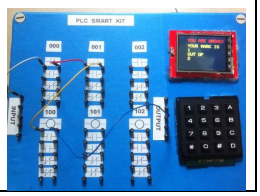
Components	Component pins	Arduino pins
Buzzer	Anode(+)	A15
	Cathode(-)	Gnd
TFT LCD	5V	5V
	3V	3V
	Gnd	Gnd
	LCD_D2	D3
	LCD_D3	D4
	LCD_D4	D5
	LCD_D5	D6
	LCD_D6	D7
	LCD_D7	D8
	LCD_D0	D9

	LCD_D1	D10
	SD_SS	D11
	SD_D1	D12
	SD_D0	D13
4x4 Matrix Keypad	A	D49
	B	D48
	C	D47
	D	D46
	1	D50
	2	D51
	3	D52
	4	D53
First AND GATE IC	2(NO)	D22
	5(NO)	D23
	9(NC)	D24
	12(NC)	D25
Second AND GATE IC	2(NO)	D26
	5(NO)	D27
	9(NC)	D28
	12(NC)	D29
Third AND GATE IC	2(NO)	D30
	5(NO)	D31
	9(NC)	D32
	12(NC)	D33
Forth AND GATE IC	2(NO)	D34
	5(NO)	D35
	9(NC)	D36
	12(NC)	D37
Fifth AND GATE IC	2(NO)	D38
	5(NO)	D39
	9(NC)	D40
	12(NC)	D41
Sixth AND GATE IC	2(NO)	D42
	5(NO)	D43
	9(NC)	D44
	12(NC)	D45
Resistor 1		A8
Resistor 2		A9
Resistor 3		A10

3. RESULT AND DISCUSSION

A scenario test is performed to ensure that the PLC EQB user's flow is as expected. Table 2 shows the step-by-step of the flow of the scenario testing for a single question.

Table 2: Scenario of The PLC EQB

No	Scenario	Expected Result	Actual Result
1.	The PLC EQB is connected with the power source.	The TFT LCD will display the main menu of the kit which consist of selection simulation part and quiz part.	Image below show the screen of TFT LCD when it get started. 
2.	The user will make the right ladder diagram relation from the given question.	When the connection is correct, the output answer of timing diagram will overlap the output timing diagram of question followed by the scores.	Image below show the actual results as same with the expected results.  
3.	The user make the wrong equivalent ladder diagram connection from the given question.	When the relation is incorrect, the TFT LCD shows the timing diagram output for that relation. The performance timing diagram from the given query will not overlap and will be accompanied by the scores received.	Image below show the actual results as same with the expected results.  

To gauge the functionality of the EQB, a survey consists of 10 questions had been distributed among respondents from the third year Bachelor of Electronic Engineering Technology students of Faculty of Electrical and Electronics Engineering Technology, Universiti Teknikal Malaysia Melaka. Table 3 shows the details of the survey questions asked to the respondents. The questions used 5-scale of Linkert Scale which are: Highly Agreed, Agreed, Neutral, Disagreed, and Highly Disagreed.

Table 3: Details Of Survey Questions

No	Question	Type
1	If it is a PLC trainer kit during the simulation, it will offer true answers according to the link.	5-scale Linkert (5SL)
2	To assess student awareness, the questions asked by the PLC trainer kit are appropriate.	5SL
3	During class sessions, PLC trainer kits can be a highly interactive activity.	5SL
4	The PLC trainer kit will help students build their hands-on skills.	5SL
5	After answering the full questions in the PLC trainer pack, students gained a better understanding.	5SL
6	During the laboratory session, the PLC trainer kit can be used for the Automation subject.	5SL
7	Students tend to study the topic of automation rather than theoretically by using the PLC trainer package.	5SL
8	This training kit will assist lecturers to teach ladder diagram to students.	5SL
9	Without the guidance of an educator / teacher , students may operate this educational kit.	5SL
10	Do you think that this PLC Trainer kit can be commercialised in the industry?	5SL

The survey is then distributed to 50 students from Faculty of Electrical & Electronics Engineering Technology, University Teknikal Malaysia Melaka in order to obtain the feedback. The methodology of conducting the survey is as follows: 1) the kit is being demonstrated (for around 10 minutes) to each of the respondent; 2) respondent is given at least 15 minutes to try out the quiz baord; 3) respondent is require to answer the survey. Figure 3 shows the frequency of the feedback for all of the questions.

According to the bar chart shown in Figure 3, base on question 1 survey, 35 repondents indicated agree that this trainer will give true answer during simulation, provided that the connection is correct while 13 respondents strongly agreed. Only 2 respondents were neutral. On the second questions, 31 respondents agree with the questions asked on the trainer whether or not it could help to test students knowledge in PLC. 18 students voted strongly agreed and 1 were neutral in their respond.

On the third questions, 24 respondents were agree that this trainer kit will introduce interactive activity during class session. The other 24 repondents voted strongly agree and only two respondents side as neutral. The fouth survey questions shows that 22 of the respondents voted agree with the suggestion that this kit will help to improve their hands-on skill on PLC. 26 repondents strongly agree with the survey and again only two respondents is neither agree nor disagree with the questions.

As for the fifth questionnaire study, 28 respondents decided that after answering all the questions in this trainer kit, students gained a better understanding. Two respondents voted neutral while the rest said strongly agree. Base on the sixth survey questionaire, 30 respondents voted agree that this trainer can be used during laboratory session for subject Automation. Only one respondents neither agree nor disagree and the rest mentioned strongly agreed.

There were 21 respondents and 23 respondents voted for agree and strongly agree respectively for the questionare number seven. While about six respondents were neutral when compare learning base on this trainer kit versus theoritical learning method. Base on the eighth questionaire, 30 respondents agree that this kit could help lecturer to teach on ladder diagram. While 28 respondents said strongly agree with the statement. Only two respondents voted for neutral.

Referring to the ninth questionaires, there are 29 respondents strongly agree with the suggestion that students could operate this trainer kit without the guidance from the educator or lecturer. While 20 respondents also agree with the statement, however, there one respondents disagree and strongky disagree respectively that students could operate without lecturer guidance. On the final questionaire, 27 respondents strongly agree and 31 respondents voted agree that this trainer kit could be commercialize in the market. Only two respondents was neutral on the last questionaire survey.

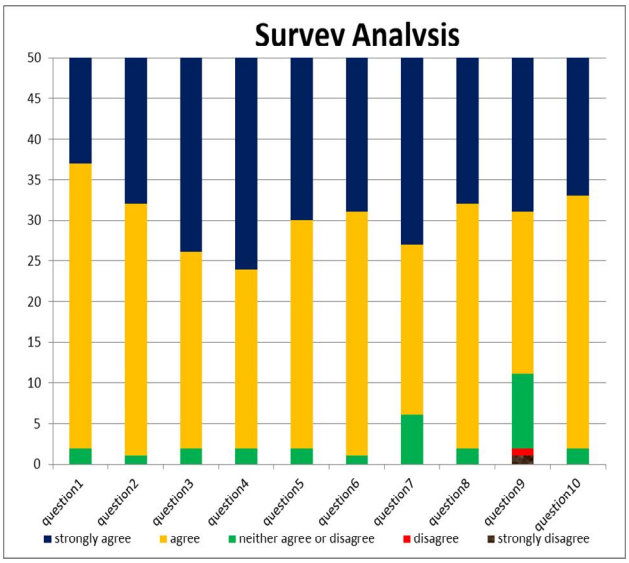


Figure 3: Result from the survey

Starting from Fig. 3, the respondents strongly indicated that the instructional kits are useful for checking student awareness, helping to develop their hands-on abilities, and can be applied to Automation subjects similar to the Ladder Diagram Timing Diagram during the lab session. Overall, respondents decided that they prefer to practise instead of theoretically using the PLC trainer kit, and educators will benefit from using the training kit during the laboratory session. If they have to operate the educational kit without the advice, some respondents disagree. Respondents also agree that in business, this education package can be marketable.

4. CONCLUSIONS

This paper presented the development of the PLC EQB Kit, an electronic training kit that tests the knowledge of students in translating the timing diagram to the PLC Ladder Diagram. Using Scenario testing, the proof of concept functionality is checked when its user acceptance has been verified by a short survey.

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