Development of measuring instrument based on microcontroller for physics laboratory

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Abstract. A Multitools instrument was developed to measure physical variables such as temperature, magnetic field, and light intensity. Multitools developed using the device of ATMEGA 8535 microcontroller that consists of three sensors: LM35 as a temperature sensor, LDR as a light sensor, and UGN3503 as magnetic field sensor. The design consisted of three stages, namely system design, hardware design, and calibration phase. The calibration test result of Multitools shows alignment level of the temperature sensor 0.9893, light sensor 0.9787 and magnetic sensor 0.9996. Measurement result displayed in physical quantities data and graph on the LCD screen of Multitools. The Multitools can be used in physics lab activity to reduce the effectiveness and train the students’ skill in understanding and interpreting the graph.

1. Introduction

Advancement of technology and information in the 21st century greatly assist the work of people. One of these is microcontroller technology as semiconductor technology products that contributing to support human activities. The development of the latest microcontroller able to perform as well as the introduction of picture recognition conversation (pronunciation recognition and visual recognition) within the context of the needs of users. The realization of these technologies can’t be separated from the growing variety of software development tools microcontroller with language that is easily understood by developers (developers).

In laboratory practice, scientific modeling very well to be applied to meaningful learning. For mediation between the theory and the real world, ICT model design is needed to facilitate students in understanding the abstract concept through scientific inquiry activities. However, scientific modeling is rarely applied in science lab both school and college level. Still, the factual condition shows the measuring instruments are not supported by ICT yet.

Chen proposes an ICT approach in learning laboratories, Microcomputer Base Laboratory (MBL) to solve the challenging problems in laboratory experiments[1]. This approach uses small device microcontroller and mobile acquisition data with tools that are embedded inside a microprocessor, so it has high speed in displaying data and graphs by real-time [2, 3]. This way is believed to facilitate students in understanding the relationship among data variables from the experiments. Almost all of
the foundations of physics are taught to students based on test/experiment, where the experiment requires physics variable measurement and drawing a graph of these variables.

A Multitools is a measurement tool developed by utilizing the principle of MBL to measure the variables such as temperature, magnetic field, and light intensity. This Multitools is developed to get students easy about reading measurement data and drawing relation among various physical variable in graphical form. The purpose of this research is to build a physics measurement tool based on microcontroller which has high accuracy in reading data from the results of physics experiments.

2. Methods
This research process follows 3 steps: of system design, hardware design, and calibration.

2.1. System Design
The system built on this research is a multi-measurement, named Multitools. The system consists of three sensors that LM35 as a temperature sensor, LDR as a light sensor, and UGN3503 as magnetic field sensors. The third sensor is connected directly to the microcontroller ATMEGA 8535. The tool is also equipped with a 16x2 LCD monochrome. This tool uses direct voltage Direct Current (DC) in the range of 9 to 12 volts.

2.2. Design Hardware and Software
Hardware design of Multitools consists of a sensor LM35, UGN3503, LDR, 16x2 LCD, and push Button strung based schematic presented in Figure 1 below.

Figure 1. Schematic hardware design

After design the hardware, the next step is to do programming on a microcontroller using BASCOM. Programming could be done as expected. Programming system based on the flowchart presented in Figure 2 below.
2.3. Testing and Calibration

Multitools testing performed on each sensor and followed by calibration on each sensor. Multitools calibration carried due to determine the accuracy readings from each sensor. Calibration technique did by comparing the received sensor input signal with manual measurement tools (manual instrument).

3. Result and Discussion.

Successfully design a multi-measurement tool, named Multitools. It works on DC voltage 9 to 12 volts which is capable of measuring temperature, light intensity, and the magnetic field.

3.1. LM35 Temperature Sensor Testing

Testing the temperature sensors of multitools using a standard thermometer temperature that is by comparing the temperature on the thermometer standards and analog signal (ADC) that is received by the LM35 temperature sensor. From the test data LM35 temperature sensor can be seen in Table 1.

| No. | Temperature (°C) | ADC (volt)     |
|-----|------------------|----------------|
| 1   | 60               | 0.1233216      |
| 2   | 30               | 0.055840923    |
| 3   | 7                | 0.020671525    |

The data obtained from the average of measurements result repeatedly at 60, 30, and 7 °C. Based on data from Table 1 can be described as a graph of temperature on ADC as shown in Figure 3 below:
3.2. LDR Sensor Testing

LDR sensor tested by comparing the measurement results on sensor formed ADC (volt) by intensity value and using Lux meter. From the measurement results obtained the measurement data as follows (Figure 4):

\[ y = -3.288x + 3.3117 \] \hspace{1cm} (2)

Equation 2 is obtained an alignment of 0.9787. Equation 2 is also inputo the programming calculation as the conversion equation of analog signals into digital displayed as Output on the LCD.
3.3. Sensor Testing UGN3505

Hall Effect Sensor UGN3505 do measure electrical current in coil Leybold P6271 non-destructively. The electric current measured as a result of the sensor voltage conversion to a magnetic field generated. Besides the electric current, the magnetic field on the coil can be also measured using a tesla meter. The data is collected on the 0 to 4.5 A as presented in Table 2.

**Table 2.** Relationship Flows (I), ADC (volts), Gauss

| I     | ADC | Gauss |
|-------|-----|-------|
| 0     | 517 | -5631 |
| 0.5   | 544 | 60419 |
| 1     | 572 | 126469|
| 1.5   | 601 | 192519|
| 2     | 631 | 258569|
| 2.5   | 662 | 324619|
| 3     | 692 | 390669|
| 3.5   | 724 | 456719|
| 4     | 750 | 522769|
| 45    | 778 | 588819|

Using Table 2, we can draw a graph as in Figure 5 and can be determined straight line equation. Straight line equation between magnetic field and voltage on the sensor (ADC) is as follows.

\[ y = 2.2439x - 1160.4 \ldots \ldots \ldots \ (3) \]

With an alignment of 0.9996. Equation 3 is an equation that is programmed in the block UGN3503 as calculation value of output displayed on the LCD.

![Figure 5. ADC vs Gaus](image_url)

From the explanation of each main sensor on multi tools, calibration is required for each sensor, it served to determine the accuracy of each sensor so that the calibration of multi tools is located on each sensor. Although in general characteristic of the sensor is reading the input voltage due to stimulation from the outside system. The voltage on the sensor can be changed due to interference (noise) from outside or inside the system. However, each sensor has a different responsive characteristic. It due many factors included the constituent material of the sensor so that it necessary the calibration for each sensor on multi tools. Microcontroller technology-based laboratory has several advantages include: first, students can do a scientific investigation realistically; second, it can store data in graphical form; Third, the experimental results can be presented in representative form; and fourth, reduce the time to
read and analyze the data [4, 5, 6]. Besides this, Arduino is a data acquisition system that is low cost and easy to obtain [7, 8, 9]. Therefore, multitools can be utilized in implementation physics experiments such as quantities of temperature, electricity and magnetism, and light intensity.

Regarding the current practicum tools, they are generally still manual and less attractive, causing the learning to be passive and retrieval of data often causes considerable human error. In addition, physics learning is sometimes difficult to be concreted into abstract things, for example electric current, resistance, and voltage in electricity topic. If this topic explained by lecture method, the students will get difficulty in understanding the topic because it is abstract. Therefore, it is very important to be concrete so that students easily understand this topic. Thus, teaching aids (practicum) can be used as a visualization of teaching materials that are useful for analyzing phenomena features and other advantages in the science learning process.

In engineering and industry world, microcontrollers often used is digital-based electronic equipment because the obtained data is more accurate and thorough. Therefore, microcontrollers often applied to electronic equipment. The utilization of microcontrollers in physics practicum activities will produce digital outputs that can produce digital data that is more accurate and thorough. Arduino is a microcontroller that has been rated for its convenience at this time and can be used properly and easily by teachers, especially physics teachers. In its development, we are freely to develop open source hardware-based projects that are affordable and increase student creativity in creating realistic physics experiments [10]. Utilization of microcontroller-based measuring instruments in practicum activities results the effectiveness of learning and increases student motivation.

4. Conclusion
Multitools based MBL has accuracy degree in measuring the variables of temperature, magnetic field, and light intensity. The calibration test result of Multitools shows alignment level of the temperature sensor (0.9893), light sensor (0.9787) and magnetic sensor (0.9996). This measuring instrument can be applied in a physics lab activity, due to advantages including speed and accuracy in reading data, displaying measurement data in a graph, and can train students' skills in defining and interpreting the graphs.

5. References
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