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A TURBIDIMETER DESIGN EXPERIMENT FOR BIOMEDICAL ENGINEERING UNDERGRADUATES

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Abstract: This article describes a laboratory experiment to teach phototransistor and LED driver circuits and analog to digital conversion using a microcontroller through a turbidimeter design for biomedical engineering undergraduates. Teaching electrical circuits and concepts using a real design helps students to use the theoretical knowledge practically and apply it. This type of real application motivates students. The purpose of this design is to drive an LED by BJT transistor and to get a voltage value related to the absorbed light from the LED by phototransistor and to convert the voltage signal of the absorbed light into digital by using microcontroller. The test of turbidimeter in the experiment is applied by measuring the added soil to water in cuvettes. In this paper, similar experiments are reviewed, the experimental procedures are explained, the methods for evaluation the success of the experiment are determined. As a further work experiment will be applied to biomedical engineering undergraduates and evaluation of their success and motivation will be reviewed.

Keywords: Turbidimeter, transistor, microcontroller, laboratory experiment.

Introduction

Student motivation is an important influence on learning. Working with practical application can increase the motivation and enthusiasm of the students according to the results observed in laboratory studies. This laboratory experiment aims to increase the motivation of students by designing an electronic measurement device name Turbidimeter that can be used in biomedical applications.

In Başkent University Biomedical Engineering Department, Biomedical Engineering undergraduates take circuit theory, electromagnetics, electronics and digital logic lessons until the third grade. In the curriculum for biomedical engineering, Medical Electronics and microcontroller courses are thought to third-year students and those courses are a combination of theoretical and practical knowledge of the other courses which they took. This study concerns a Turbidimeter design laboratory experiment for Medical Electronic Course.

The experiment aims to test the student's knowledge about light emitting diode (LED) driving circuits, transistor and phototransistor circuits, microcontroller programming. During the experiment, the student, sets up the BJT controlled Infrared LED driver circuit, obtains a voltage value for the light absorbed from the LED by a phototransistor, and converts this voltage value from analog to digital using microcontroller.

There are several similar laboratory experiments reported in the literature. Doğan (Ibrahim, 2015), designed and report a laboratory experiment of a low-cost educational liquid-level sensor circuit. The author report a survey that was conducted among 15 students completing the laboratory experiment where students were asked to comment on the system and most of the students (80%) had good results and found the experiment very informative.

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Chen, et. all (Chen et al., 2016) describe the development of a home-assembled, low-cost blue light-emitting diode (LED) photometer. This photometer measure the contents of substances in biochemical samples such as protein, amino acids. It can enable students to develop well-rounded professional knowledge and skill in bio detection electronics. According to this paper, this photometer is cheaper than existing systems. It has significant advantages and ease of use.

Kim et. all (Kim & Schubert, 2015) explored a simple laboratory exercise that would allow students to determine transistor model. In the experiment, the aim is to carry out a meaningful laboratory study on the amplifier frequency response to find the actual capacitor values. The course teachers evaluated whether this experiment increased student knowledge about modeling high-frequency transistors.

This paper describes the laboratory experiment plan and the theoretical knowledge that it requires. In the first section the turbidimeter is explained. Than in the materials and methods section theoretical information of circuit elements, microcontroller setup is described step by step. In the evaluation methods section, the experiment performed by the student and the success of the experiment on the student education will be evaluated according to the pre-determined survey questions.

Turbidimeter

Turbidity is the cloudiness of a fluid medium. Turbidimetry is the measurement method by measuring the absorbed light passing through the sample where the particle is located. Turbidimeter is a device that measures turbidity. Most turbidimeters have a cuvette to hold the fluid, a light source directed to the cuvette, and one or more photo detectors to measure light passing through the fluid. Turbidimeter can be used in microbiology analyzers and coagulation analyzers. It is also used to determine the protein content in biological fluids such as urine and body fluids. (Duggal, 2007)

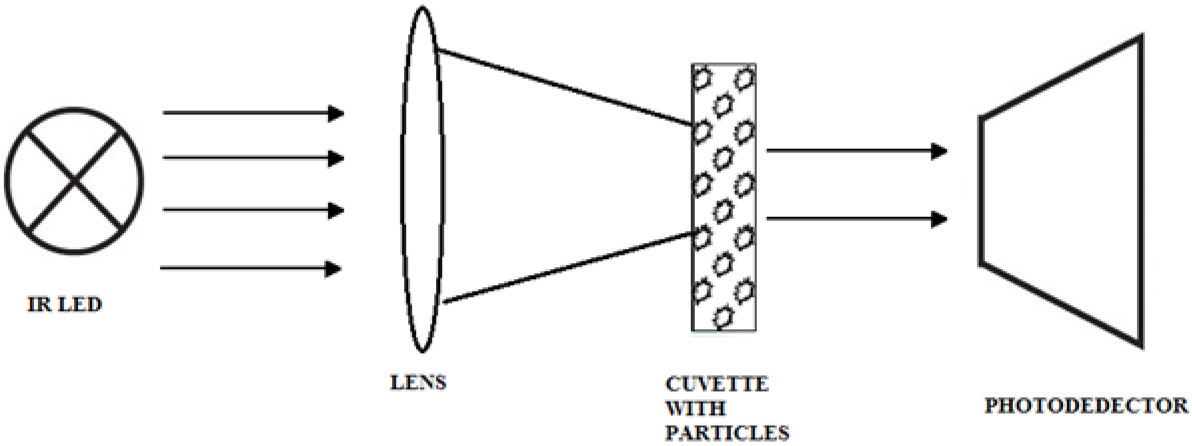

Figure 1. Turbidimeter diagram

Material and Methods

LED Driver Circuit

In the LED driver circuits (Figure 1), the received electrical signals are transformed to light. The light emitter is a 5mm Infrared LED (Everlight, IR533C) with peak wavelength of 940 nm. Its spectral bandwidth is 45 nm (Free & Diode, n.d.). One of the main components of the LED driver circuit is the transistor.

The transistor is an NPN Silicon amplifier transistor (On Semiconductor, BC337) with maximum collector current of 800 mA (Ratings, Characteristics, & Diagram, 2013).

The infrared light emitter is driven by the collector current of the transistor. The collector current value is controlled by a variable resistor and the current passing through the LED is changed according to that. This change affects the brightness of the LED.

LED driver circuit is used as variable intensity light source for Turdimeter design.

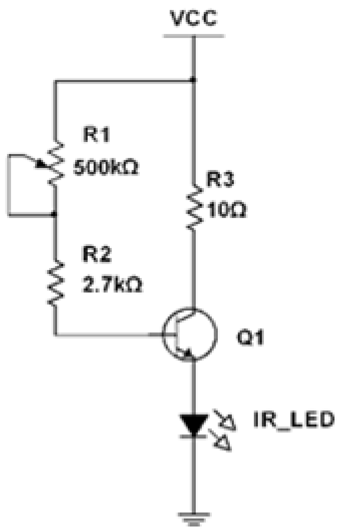

Figure 2. The LED driver circuit

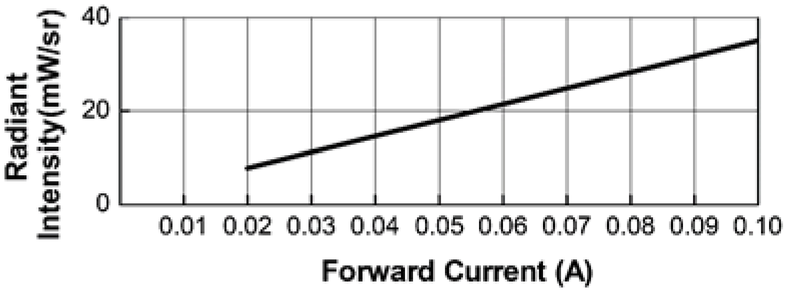

Figure 3. The LED's intensity/forward current graph

Phototransistor Circuit

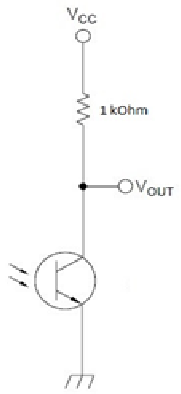

Figure 4, Phototransistor circuit

Phototransistor uses light rather than electricity to control an electrical current to flow from its collector to emitter. Silicon NPN Phototransistor (Siemens, SFH303-FA) operates at wavelengths between 450 nm and 880 nm (Merkmale & Group, n.d.). This working range is suitable for the wavelength range of the LED used in the experiment. The light from the LED is received by the phototransistor and converted into base current. The current flow from collector of phototransistor is proportional to the absorbed light. By using a resistor on the collector input of phototransistor the current change can be monitored as a voltage value as shown in Fig 3.

Microcontroller Circuit

In order to display the measured light intensity a turbidimeter should have a display. In the designed experimented a microcontroller demo board with a built in Liquid Crystal Display (LCD) is used for monitoring the output voltage of phototransistor circuit. Microcontroller is an element that combines all parts of a microprocessor based system into a single integrated circuit. In this experimental setup, a microcontroller with an A/D is used to convert received analog voltage value to digital. Voltage values converted from analog to digital by the microcontroller are displayed using LCD.

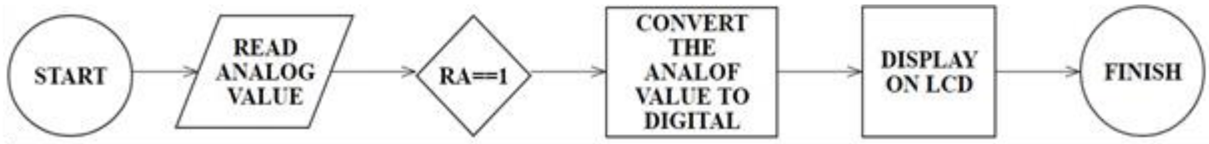

Figure 5. Microcontroller diagram

The output voltage of phototransistor circuit is an analog value. This value should be converted to digital to be displayed on LCD. To apply this conversion to ADC channels of PIC Clicker was used. The PIC Clicker which be used in the experimental design has 12-bit ADC. It has been shown how the ADC unit apply this conversion in Fig.4 With the A-D control register ADCON1, which ports and bits are to be used as analog inputs, is selected. The analog input channel (AN0, AN1, etc.) is also selected with channel control register ADCON0.

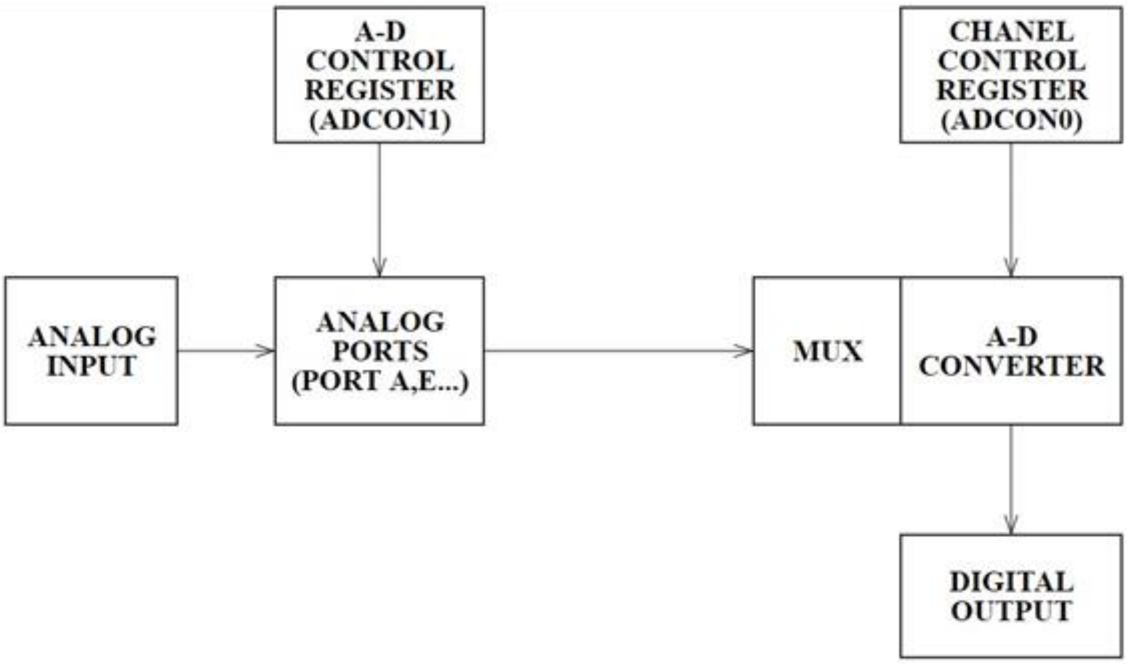

Figure 6. Analog digital converter (ADC) algorithm

Experiment Design

First of all, the student sets up the led driver circuit with the BJT transistor, changes the current through the LED by controlling the variable resistor in the circuit and records the result. Then establishes a circuit with the phototransistor to receive the light that the Led has been emitting and measures the voltage value of the phototransistor from the collector. This value, which is measured without putting a sample with particle between LED and phototransistor, is accepted as default. The student makes a comparison between the other measurements taking into account this value. The student uses water samples with different levels of particles prepared in advance to observe the working principle of the turbidimeter. Five different levels of water samples with soil are prepared by students. The five levels at which the measured voltage variation on the phototransistor is best observed are provided by 50 mg to 250 mg of soil. The student records the measured voltage values by placing the samples at each level between the LED and the phototransistor.

In the next step of the experiment, the student converts the voltage values measured from the collector into digital with the microcontroller and displays on the LCD. To be able to do this process, the student must program the microcontroller. At the end of the experiment, the students are expected to fill in a report in the direction of their observations.

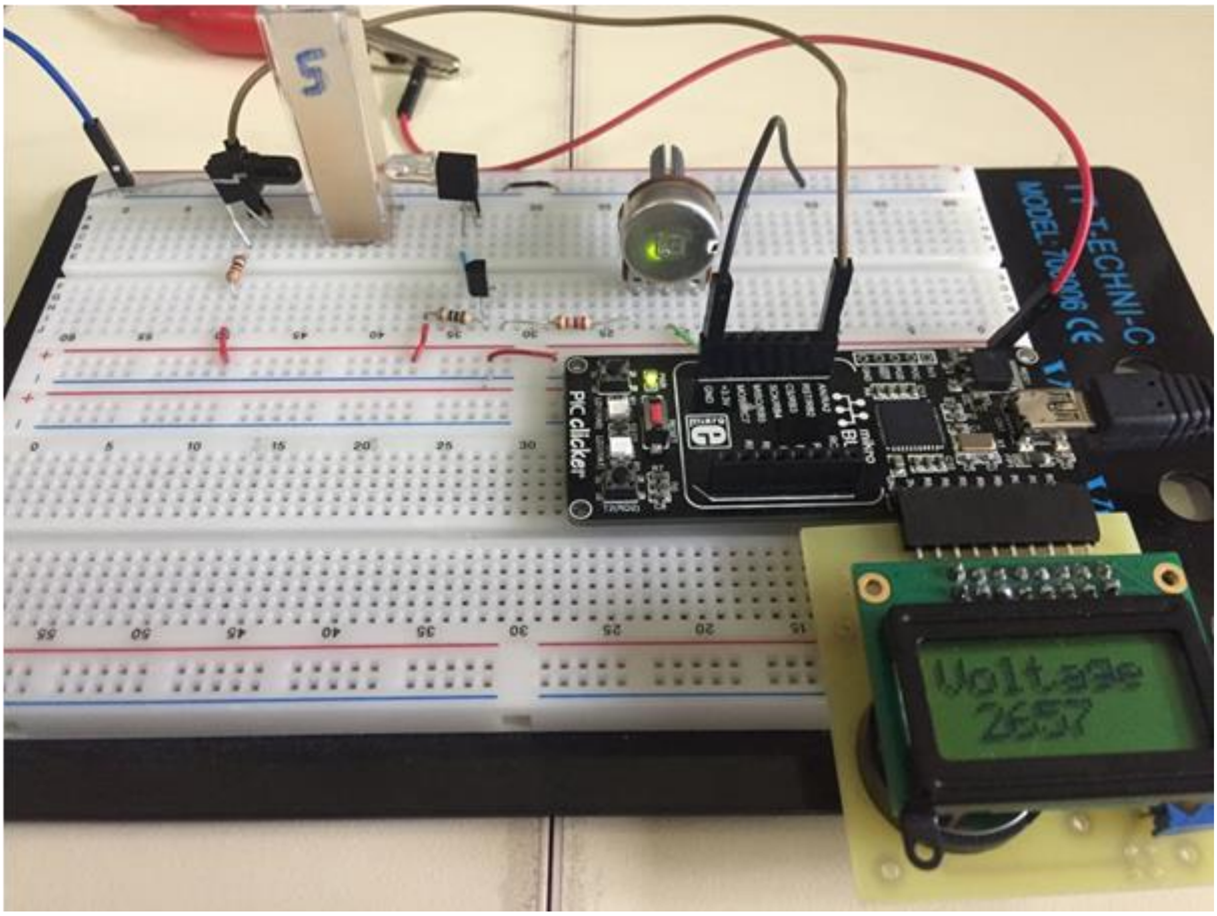

Figure 7. Experiment design

Evaluation Method

In order to evaluate the performance of the experiment, survey before and after experiment and grading will be used.(Subudhi, 2016) For the survey questions, similar applications are reviewed and questions in Table.1 and Table.2 defined.(de A Dias, da Silva, Kitani, Lagana, & Justo, 2016)

Table 1. Questionnaire used to evaluate students general approach about laboratory experiments on medical electronics

Questions	On a scale of 1 to 5 rate: (1=very poor, 2=poor, 3=satisfactory, 4=strong, 5=very strong)
Q1	Do laboratories attract your interest?
Q2	What is the difficulty level of laboratories?
Q3	Do you think the laboratories are instructive?
Q4	Do you think projects, related to a real application, enhance your skills in hardware and software?
Q5	Did laboratory experiments increase your understanding of the course?

Preliminary work, student performance and prepared test report are considered and graded. In the preliminary study, basic theoretical information is given about the experimental subjects and it is requested to answer the preparation questions for the experiment. The assistants assess students' performance by observing them during the experiment. The report delivered by the students is graded at the end of the experiment.

Table 2. Questionnaire used to evaluate students general approach about this laboratory experiment on medical electronics

Questions	**On a scale of 1 to 5 rate: (1=very poor, 2=poor, 3=satisfactory, 4=strong, 5=very strong)**
Q1	Did this laboratory experiment attract your interest?
Q2	What is the difficulty level of this laboratory?
Q3	Do you think this laboratory experiment was instructive?
Q4	Do you think this project, enhance your skills in hardware and software?
Q5	Did this laboratory experiment increased your understanding of the course?

Conclusion

In engineering education, laboratory experiments are mandatory for practicing theoretical knowledge. It is hard for the students to design something they did not before. Most of the students try to pass the experiment by memorizing it. And also students’ motivation about what they learn at school is very important. Laboratory experiment should increase their interest about the lessons.

In this experiment, a basic turbidimeter circuit designed to measure students' knowledge of the courses which they take and to increase their motivation. If the experimental process is carried out as intended, the theoretical and practical knowledge and skills of the students develop. The designed turbidimeter circuit will be practically tested by the students and the results will be evaluated by the teachers. The designed test plan increases the skill and motivation of the student as it is a real device application.

The experiment designed in this paper will be used at Başkent University in third year medical electronic laboratory by students of the biomedical engineering department. Here, students designs LED driver circuit and photo detector circuit for basic turbidimeter design. The system includes a light source, a photo detector to receive the light, and water samples with soil to test the design. The microcontroller used in the turbidimeter design is used as the analog to digital converter. A survey will be conducted among the students before and after the laboratory experiment. A literature survey of similar studies was done. In the results of the research, the experiment described in the article was planned. Experiment will be evaluated according to the methods described in the paper.

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