LED CIRCUIT DESIGN WITH IOT SYSTEM FOR AN OPTICAL SENSOR IN PRODUCT QUALITY MONITORING

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

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DECLARATION

I declare that this report entitled "LED Circuit Design With IoT System For An Optical Sensor In Product Quality Monitoring" is the result of my own work except for quotes as cited in the references. UNIVERSITI MALAYSIA MEL KNIK Δ1 Signature : Muhamad Haziq Syahir Bin Suffian Author :

Date : 13 January 2023

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Electronic Engineering with



DEDICATION



This thesis is dedicated to my beloved parents, family members and supervisor for

ABSTRACT

The optical sensing market is expected to witness market growth at a rate of 15.39% in the forecast period of 2021 to 2028. However, with the rapidly evolving optical sensing technology, most equipment has more sophisticated functions thus making every price of equipment in the system used become more expensive and difficult to operate. It is due to the equipment used in this field which are laser, fiber optic, modulator and lock-in amplifier which lead to higher investment in the system's application. The idea for this project was based on existing systems used in the industry sector by applying the same application but have few additional functions in terms of system, different electronic equipment used and price cost. The main objective is to design an LED circuit with an IoT system for an optical sensor in product quality monitoring. RGB LEDs are expected to be the light source in this application. It will be directed directly to the photodetector and will display the data received from the readings of each different light color source. Different color and thickness of transparent PVC sheet will be used as a product. Finally, all the collected data will be sent to the user's email using the IoT technology then doing research and analysis of each performance reading of all different types of transparent sheet with RGB light will be analyzed in terms of sensitivity, linearity and resolution.

ABSTRAK

Pasaran penderiaan optic dijangka akan menyaksikan pertumbuhan pasaran pada kadar 15.39% dalam tempoh ramalan 2021 higgan 2028. Namun dengan teknologi penderiaan optik yang berkembang pesat, kebanyakan peralatan mempunyai fungsi yang lebih canggih sekali gus menjadikan setiap harga peralatan dalam sistem yang digunakan menjadi lebih mahal dan sukar untuk dikendalikan. Ini kerana peralatan yang digunakan dalam bidang ini iaitu laser, gentian optic dan modulator yang membawa kepada pelaburan yang lebih tinggi dalam aplikasi ini. Idea bagi projek ini adalah berdasarkan sistem sedia ada yang digunakan dalam sektor industri dengan mengekalkan aplikasi yang sama tetapi mempunyai beberapa fungsi lain dari segi sistem, peralatan dan kos. Objektif utama adalah untuk mereka bentuk litar LED dengan sistem IoT untuk sensor optik dalam pemantauan kualiti produk. LED RGB sebagai sumber cahaya akan diarahkan terus ke pengesan foto dan akan memaparkan data yang diterima daripada bacaan setiap sumber warna cahaya yang berbeza. Warna dan ketebalan lembaran PVC lutsinar yang berbeza akan digunakan sebagai produk. Akhir sekali, semua data yang dikumpul kemudianya penyelidikan dan analisis setiap bacaan prestasi semua jenis helaian lutsinar yang berbeza dengan cahaya RGB akan dianalisis dari segi sensitiviti, lineariti dan pengesanan.

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LIST OF SYMBOLS AND ABBREVIATIONS

For examples:

RGB	:	Red Green Blue
LED	:	Light Emitting Diode
LCD	:	Liquid Crystal Display
IoT		Internet of Things
PCB	:	Printed Circuit Board
PVC	:	Polyvinyl Chloride
FODS	21	Fiber Optic Displacement Sensor
POFDS	X	Plastic Optical Fiber Displacement Sensor
	IV	Integrated Development Environment
UV	:	Ultraviolet

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CHAPTER 1

INTRODUCTION



In a variety of production processes and industrial sectors, color provides an important information that may be used to measure the product's color consistency or any other applicable measurement. There are several applications for color sensor including monitoring plant growth, detecting and identifying objects for robots, monitoring soil changes, grading fruit ripeness and etc. Moreover, in the realm of color sensing, one of the most common and straight forward functions of color sensors is to identify the color of an object for sorting purposes. In general, a color sensor is used to recognize unknown colors and classify them into the appropriate color groups. The fundamental operating principle of a color sensor is based on the concept of light reflection, such that when incident light is shone onto the surface of a material. A portion of the light will be reflected with a given intensity proportional to the surface color's brightness. The sensor will then sense the reflected light to measure the output

intensity. The sensor then will detect the surface color on the RGB scale which the interaction outcome from the light source, an object and receiver.

1.1 Problem Statement

Over the past few years, measurement of thickness and color technology has become important in some areas of industries. Hence, the technology in this field needs to be in line with the passage of time so that optoelectronic field can be given more attention as one of the important technologies in today's industrial system. So the main idea for this project is to fix some of the problems in the existing system of this optical sensor technology. Among the problems that arise in the field of optical sensors are as follows :-

- The optical equipment used these two applications such as laser, modulator, lock-in amplifier and etc contribute to high cost optical sensor.
- The detection and measurement used are complicated and not suitable to be used at home or small industries.
- There is no IoT integration applied for these two optical sensors. UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Most of the technologies are designed using laser technology as the light source in their systems. This causes the prices for both applications to be expensive and higher power to generate the light source. Other than that, there is no IoT integration applied for these two optical sensor technique. Thus, in this project RGB LED will be used as the light source where it can simultaneously reduce the overall cost of the optical sensor system. In addition, with the addition of the IoT system user can monitor the data and specifications of the tested sample.

1.2 Objective

The main objective of this research study is to analyze the possibility of the use of a simple and inexpensive optical device based in product quality monitoring. The following sub objectives have to be met :

- To design LED light source and photodetector circuits for an optical sensor for measuring thickness and color of the transparent flat surface.
- To integrate the designed optical sensor with the IoT platform.
- To experimentally analyze the optical sensor with IoT platform for measuring thickness and color of the transparent surface.

1.3 Scope of Project

The process of accomplishing the objectives has been subdivided into several steps. The first step is this project requires colored transparent PVC sheet, which come with variety of color and thickness. Next, prepare for the light source, RGB LED will be used. Three main colors will be used as the light source for this project which are red, green and blue. The light beams from the LED will be transmitted directly onto the transparent sheet and then received by the photodetector before it sends the information to the NodeMCU to produce an output in term of voltage value that later will be shown on the display and in the email platform as this project includes the IOT. There are also four other parameters that will be analyze which are sensitivity, standard deviation, linearity and resolution in order to determine the sensing performances. There are three major hypothesis that can be listed out for this research study which are :

- By using different color of LEDs as a light source (RGB) are expected to demonstrate different reading on PVC transparent sheets.
- In sensing different type of thickness and color of PVC transparent sheets is expected to produce different sensing performances by the optical sensor.
- The optical sensor system is expected to store and send the information into the cloud (email).

1.5 Report Structure

This thesis is organized and arranged into 5 major chapters. Initially, chapter 1 provides an overview of this work, outlining the project's aims and scope of the research study, as well as the problem statement, project's objectives and hyphothesis. Chapter 2 presents a theoretical assessment of related research, including an in-depth examination of optical sensor technology, the idea and also applications. This article reviewed a study on the use of LEDs as light sources in an optical sensor idea. The final section of this chapter discusses on the existence of IoT with optical and electrical sensors.

Chapter 3 details the methods used to accomplish the objectives of this project, which is separated into three sections. The first is to create LED light sources and photodetectors for the optical sensors. Secondly, integrate the designed optical sensor concept with the IOT platform which in this case e-mail will be used as the medium. The final methodology is to conduct an experimental analysis of an optical sensor paired to an IOT platform for the purpose of detecting the thickness and color of colored transparent sheets.

Chapter 4 examines and analyses the sensing data for various thickness and colour for PVC transparent sheet by a RGB LED. Graphs and tables illustrate the findings. Chapter 5 concludes with a conclusion and suggests additional research to improve the proposed technique.



CHAPTER 2

BACKGROUND STUDY



Optical sensors have become a major sensor technology in industrial use involving

2.1

sensors due to their wide application due to the advantages available to them. Many outside applications have used optical sensor technology as an example of monitoring system in product quality, structural health monitoring and essential solution for monitoring harsh environments. Since their first development over this thirty years ago, they also found that security applications used this type of technology.

2.1.1 Thickness Measurement using Optical Sensor

Thin films are generally implemented to offer particular functionality to coated devices in the optical, semiconductor and material industry sectors. Effective evaluation of the film surface and thickness is critical for achieving a particular function and improved performances for a coated device. Non-contact optical measurement of the thickness and refractive index of glass and thin films have recently become important in a variety of application which make some optical industry nowadays looking forward through the advanced technology for the system. several techniques have been developed and proven.

2.1.1.1 Example of thickness measurement technology

- Thickness measurement using Reflection technique
- Thickness measurement using Reflective FODS
- Thickness measurement using Transmitting technique (beam-through)

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2.1.1.1.1 Thickness Measurement using Reflective Technique

First example of thickness measurement technology used in industry sectors nowadays is based on a reflection technique development. For this techniques it requires the light source is a halogen lamp, followed by the fiber optic probe, which is made up of two fibers, one is emitting fiber that sends the light from the halogen lamp to the target region and another one is receiving fiber that receive the reflected light from the target and transmit it to the photodetector. The photodetector transforms light into current, while the amplifier takes the photodetector signal and displays it in ampere. The experimental setup has shown on the figure 2.1 below.



Figure 2.1 : Reflective Technique Experiment Setup & Apparatus

The most crucial part of the system is fiber optic. Two different kind of fiber optic are employed. The smallest utilized has a 300m pure silica core, 30m doped silica cladding, 40m polymide buffer and a numerical aperture of 0.22. Before start the experiment, the angular characteristic of the fiber should be examined. The process is moving the fiber probe form vertical to horizontal and measuring the reflected light from the mirror surface. There would be no more light collected by the receiving fiber at a particular angle. Figure below depicts the angular characteristics of the two fiber used. As shown in figure 2.2, the fiber probe works well only when the surface is perpendicular to the probe.



Figure 2.2 : Angular Characteristics of the Largest Fiber Optic Probe

2.1.1.1.2 Thickness Measurement using Reflective FODS

Thickness is an important physical parameter in the manufacture of transparent plates [1]. Large scale of transparent plate production requires a high accuracy, simple and low cost approach for thickness measuring which fiber optics displacement sensors (FODS) may provide. FODS developed using the reflection approach have been described[2]. Reflective FODS is often used to determine the thickness of transparent plates. The sensor is made up of two optical fibers connected at one end as can be seen on figure 2.3 below. One function as a light transmitting fiber (TF) and another one as a receiving fiber (RF) and a reflecting surface similar to clear plate for thickness measurement. The sensor operates on the following principles. A considerable percentage of the light generated by the TF cores is transmitted through the transparent plate with a minor fraction reflected at the plate's surface. By reflecting a little quantity of light from the surface of transparent plate, the light cone emerging form TF is linked into RF. The difference of the output signal conveyed by the RF will be detected by altering the displacement of the fiber probe form the surface.



Figure 2.3 : Reflection Technique Experimental setup and Apparatus

2.1.1.1.3 Thickness Measurement using Transmitting Technique (Beamthrough)

Light travelling through a transparent plate is reduced by tow type of mechanism which are transparent material absorption and reflection at interfaces. The first mechanism is determined by the medium's path length, material characteristics and light wavelength. The latter happens when light travels across the contact between two media.

The receiving fiber probe in beam through FODS is coupled to a photodetector, which is responsible for capturing the transmitted light from the plate[3]. The output transmission should follow the theoretical analysis provided by Van Etten and Van Der Plaats by increasing the displacement between the probe and the transmitting fiber probe[4].

Same as experimental set up of reflective FODS technique, it has a common configuration which consists of a Helium Neon (He-Ne) laser with 633nm as a light source. The fiber then linked to a Si photodetector head (Model 883-SL) and finally to a lock in amplifier (Model SR-10). A revolving mechanical chopper with a frequency of 63 Hz is used to modify the continuous light source into pulse mode at first. A reference signal is provided into the lock in amplifier to enable sensitive light detection without interference from any ambient light.



Figure 2.4 : Transmitting Technique Experimental Setup and Apparatus

2.1.2 Color Detection using Optical Sensor

Color provides substances information that may be employed in the assessment of product color consistency or any other acceptable measurement depending on the application in different manufacturing processes and industrial sectors[5][6]. The application of color sensors such as monitor product quality and for sorting purposes are very important. For examples to monitor plant growth, detect and identify for robotic application, and observe certain fruit or vegetable to be graded as shown in Table 1. Furthermore, in the scope of color sensing, a simpler and more typical use of color sensor is to detect the color of an object for the purpose of sorting[7]. In general, a color sensor is used to perceive multiple colors and detect an unknown color so that it may be classified correctly.

No.	TITLE	DETAILS	APPLICATION
1	Low cost colour sensors for monitoring plant growth in a laboratory.	Seelye, M & Sen Gupta, G & Bailey, D & Seelye, J. (2011). Low cost colour sensors for monitoring plant growth in a laboratory. Paper presented at: 2011 IEEE Instrumentation and Measurement Technology Conference, pp. 1-6. <u>https://doi.org/10.1109/IMTC</u> . 2011.5944221.	Plant growth monitoring[8]
2	Detecting objects using color and depth segmentation with Kinect sensor.	Hernández-Lópeza J-J, Quintanilla-Olveraa A- L, LópezRamíreza J-L, Rangel-Butandaa F-J, Ibarra-Manzanoa M-A, Almanza-Ojedab D-L. Detecting objects using color and depth segmentation with Kinect sensor. Proc Technol. 2012;3:196-204. https://doi.org/10.1016/j.protcy.2012.03.021	Detect and identify object for robots[9]
3	Soil color sensor data collection using a GPS- enabled smartphone application	Stiglitz R, Mikhailova E, Post C, et al. Soil color sensor data collection using a GPS- enabled smartphone application. Geoderma. 2017; 296:108-114. https://doi.org/10.1016/j.geoderma.2017.02.018.	Monitor soil changes[10]
4	Fuzzy ripening mango index using RGB colour sensor model.	Mansor R, Mahmod O, Bakar MA, Ahmad KA, Razak TR. Fuzzy ripening mango index using RGB colour sensor model. Res World J Arts Sci Commer. 2014;5:1-9	Examine the ripeness of fruit[11]
5	Use of RGB color sensor in colorimeter for better clinical measurement of blood glucose	Avaninathan S, Sankaranarayanan K. Use of RGB color sensor in colorimeter for better clinical measurement of blood glucose. BIME J. 2006;6(1):23-28	Measure the blood glucose[12]

Table 2.1 : The Important of Color Sensor and its Application

Fiber optics is presently employed as the light transmission medium in the majority of color sensor systems due to advantages such as high mechanical strength against bending and outstanding transmission efficiency.

2.1.2.1 Plastic Optical Fiber Displacement Sensor (POFDS)

Plastic Optical Fiber Displacement Sensor (POFDS) is an example of color detection technology nowadays. POFDS has evolve as an extrinsic optical fiber sensor that employs non-contact measuring. It has several benefits, including strong electrical resistance, non-electrical conductivity, compact size and the ability to work independent of the surrounding or environment[13]. Furthermore, it has a broad range of dynamic capabilities for detecting a large range of physical and chemical factors and it is susceptible to high temperature and chemical reactive situations.

For the experiment apparatus setup is shown on figure 2.5 below. This color detection setup requires the OBIS Coherant laser light source with a wavelength of 780nm and a maximum output power of 130mW. The laser beam is guided into the Polymethyl Methacrylate (PMMA) plastic optical fiber core with length of 2m by the Newport M-10X objective lens with 0.25 numerical aperture. Within the tip of the fiber probe, both ends of the transmitting fiber output and the receiving fiber input are joined in parallel so that both ends face the target. The diameter of the fiber optic probe, which is composed of both transmitting and receiving fiber ends is 1mm. the fiber has a numerical aperture of 0.5 and refractive indices of 1.492 and 1.402 respectively. The laser is directed directly onto colored sample to be lighted through the transmission fiber. The reflected laser from the colored sample is made to travel through the receiving fiber probe and its output power is monitored by an optical detector with an optical response range from 700nm to 1800nm. The use of the OBIS Coherant laser as the light source in this investigation has the benefit of reducing the aforementioned effects, hence limiting the fluctuation of the light source.



Figure 2.5 : POFDS Experimental Setup and Apparatus[14]

Different colors of paper are used while running this project which are red, green, white, black and blue. By using this type of technique, the experiment has found that the distance between the probe tip and the target is relatively close at 0mm displacement causing light from the transmitting fiber to be reflected back into itself. It is because only a small percentage of the light is reflected back into the receiving fiber makes the observed output power for all colors is around 0.13mW. As the distance between the laser and the receiving fiber increase to 0.5mm, the laser beam begins to be reflected into the receiving fiber, increasing the observes output values to ranging from 0.039 to 0.233mW for all colors. The output power rise as the distance increase until 1.5mm at which time the maximum output power is obtained, range from 0.053 to 0.337mW for all colors. Next increase the distance value to 5.5mm, the output power gradually decreases to a value between 0.026 and 0.158mW for all hues. The intensity of the light decreases when the reflected light begins to vary and just a little quantity of light penetrates the receiving fiber. All results from this experiment is shown on the figures below.



Figure 2.6 : Output power against Displacement for all type of color paper



Figure 2.8 : Peak output power for each color

2.2 Photodetector Circuit

A commercial green LED with a core wavelength of 517.5nm with bandwidth of 5nm was used as the light source and a photodiode as the light detector to create a low cost sensor device. The LED holder with a diameter of 5mm and a length of 9mm was put at one end of the sample while the photodiode holder with a diameter of 5mm and a length of 5mm was positioned at the other end. During the operation of sensor device, light from LED travels through the experiment's sample and the light output which pass through the sample is collected and converted by the photodiode to a linearly proportional current. The intensity of light that captured by the photodiode is in small amount due to the sample as an obstacle between transmitter and receiver. Therefore, an amplifier was used to convert the output current from photodiode into suitable voltage used for the microcontroller[15]. Figure 2.9 below, shows the schematic diagram of the photodetector circuit as a receiver.



Figure 2.9 : Schematic Diagram of Photodetector Amplifier[15]

2.3 RGB Light Emitting Diode (LED)

RGB which stand for Red, Green and Blue LED can emits different type of colors in one LED by mixing it with the three basic colors. LED which a semiconductor diode that generates incoherent narrow-spectrum light when electrically bias in the forward direction of the p-n junction, as in the standard LED circuit. This is a form that is electroluminescent. A LED is a light source with a small surface area, frequently with optics added to the chip to shape the emission pattern and aid in reflection. By using it as a light source will reduce the problem in power consumption and lack of temperature problem[16]. LEDs are also employed as a small indicator of lights in mobile devices and in higher-power applications such as flashlights and area lighting. It also is the most widely utilized form of semiconductor diode accessible today. Additionally, LEDs can be utilized as a standard domestic light source.

2.3.1 Working Principle of LED

The LED operates exclusively in the forward bias condition. When the LED is forward biased, the free electrons from the n-side and the holes from the p-side are driven towards the junction[17]. When free electrons reach a junction or depletion zone, a portion of them reintegrate with the holes in positive ions. Because positive ions have fewer electrons than protons, they are more willing to receive electrons. Thus, at the depletion area, unbound electrons recombine with holes. Similarly, in the depletion area, holes from the p-side recombine with electrons. Due to the recombination of free electrons and holes in the depletion region, the diameter of the depletion area diminishes. As a result, more load carriers would pass via the p-n intersection[18]. Following that, recombination occurs in both the depletion field and the semiconductor p-type and n-type. The unbound electrons in the conduction band release energy in the form of light until they recombine with gaps in the valence band[19]. The majority of energy is lost as heat in silicon and germanium diodes, and the output light is insufficient. However, the photons emitted have sufficient energy to generate extreme visible light in gallium arsenide and gallium phosphide.



2.3.2 Efficiency and Wavelengths

One of the LED's main advantage is the high luminous efficacy as a lighting sources[20]. However, for RGB LED it can produce various type of color with the combination of primary colors element. For this reason, color rendering need to be implemented to allow the visual approximation of a certain RGB combination to a specific tone. Based on the color representation, the light wavelength contained in the range from 380nm to 700nm[16].



Figure 2.11 : RGB LED Color Spectrum

2.4 Internet of Things (IoT)

The Internet of Things (IoT) refers to the networked interconnectivity of common things, many of which are endowed with omnipresent intelligence[21]. By integrating every object for interaction via embedded systems, IoT will improve the Internet's ubiquity, resulting in a massively scattered network. A network of devices that communicate with each other and with humans. Rapid advancements in underlying technology have made it possible to achieve this. Besides, IoT is an emerging topic of technical, social, and economic relevance[22]. Consumer products, durable goods, automobiles and trucks, industrial and utility components, sensors, and other ordinary objects are being integrated with internet connectivity and strong data analysis capabilities that promise to alter the way people work, live, and play. The most important aspect of constructing an IoT network begins with the right selection of hardware and software platforms, followed by the determination of architecture complexity based on the application under development[23].
CHAPTER 3

METHODOLOGY



The approach used in this research will be explained in this chapter. Figure below shows the approach flowchart for achieving the three research project sub-objectives, which is separated into three primary procedures. Initially, an optical sensor concept will be designed with an RGB LED and photodetector circuit. Second, the IOT platform was integrated with the proposed optical sensor in thickness and color detection idea.



Figure 3.1 : Project Flowchart

3.2 System Architecture

The system in this project consists of software and hardware implementation. For the software, Arduino IDE is the major system used for designing, compiling and execute the code for desired hardware functioning process while for circuit designing, Proteus software is used as shown in Figure 3.2. While for the hardware part, during the development of optical sensor circuit from the scratch consist of NodeMCU ESP8266 microcontroller, RGB LED as a light source, photodiode, operational amplifier (op-amp), switch and 10M variable resistor.



Figure 3.2 : Software Implementation

3.3 Software Used

In this project, there are few software that have been used in making this project success. All of these software is installed to give instruction and also give different function to the development on the project. The software used such as Arduino IDE, Proteus, Blynk application and SMProMx.

3.3.1 Arduino IDE

Due to the limited exposure to multicore environment in embedded system, skills are necessary to construct such a complicated application are still unusual. There is a need for a platform that enables the learning and development of multicore processors in embedded systems while keeping the learning curve as simple as possible. The Arduino IDE is a popular and user-friendly platform however it only officially supports a single core CPU. The open source software makes writing code and uploading it into the board simple. It is compatible with Windows, Mac OS and Linux. Developer may direct the board by delivering a series of instructions to the board's microcontroller. By utilize the programming language which based on the circuit and wiring and the software based on processing to do this. Figure below shows the Arduino IDE workspace interface where all the code will be created. The Arduino programming language has been changed to make it easier for beginners to program from the original language. Inside the Arduino itself, there is already a microcontroller IC that has been planted with a program called Bootloader. The function of the bootloader is to mediate between the Arduino compiler and the microcontroller. Arduino IDE is made from the JAVA programming language which is equipped with a C/C++ (wiring) library, which makes input and output operations easier.



Proteus is a proprietary software which suite mainly used for electronic design automation. Usually for electronic design engineers and electronic technicians primarily utilize the program to develop electronic schematics and electronic print for the fabrication of the printed boards. This Proteus ISIS is the best software for diverse electronics and microcontroller designs. It is popular among electronic students and employees due to its functionality which consists of nearly all microcontrollers in it. As a result, it is a useful tool for electronic students and experts to test the program and embedded systems. This simulation software is used to simulate the microcontroller used in this project. Once done with simulation, will proceed to PCB design after modelling all of the circuit by using Proteus software.

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Figure 3.4 : Proteus ISIS software and its workspace

3.3.3 Blynk Application

Blynk application is an IoT platform for iOS and Android devices that enables internet based control of Arduino, Raspberry Pi and NodeMCU. This programme is used to generate a graphical user interface (GUI) or human machine interface (HMI) by compiling and giving the correct widget address. Some function that application capable of is it can be remotely manageable devices, show sensor data, save data and visualize it among other fascinating features. This platform consists of three primary components which are Blynk App, Blynk Server and Blynk Libraries. For application, it enables the creation of impressive interfaces for the project using various type of provided widget. Blynk Server function is in charge for all communication between the devices as smartphone to hardware connectivity. It is an open source and can be easily handle a lot of devices. Lastly, libraries facilitate communication with the server for all common hardware platform and processes all incoming and outgoing instructions.

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Figure 3.5 : Blynk Dashboard on PC



UNIVER Figure 3.6 : Blynk Application on Smartphone

3.4 Electrical Hardware Design

The design of electronic is explained in this subsection. The photodetector will need an electronic system that is able to receive reading from a light source, then execute the measured value into LCD and Blynk application interface for display purposes. This system will consist of a few components such RGB LED, microcontroller, opamp, wireless communication and photodiode. All this part is crucial for the optical sensor system to fully function. Figure 3.7 below shows the schematics design of overall component in developed this project.



Figure 3.7 : Components Schematic Design

3.4.1 Microcontroller

The main component needed to process the system design is a microprocessor. A microprocessor is a central processing unit on a single integrated circuit chip that contains millions of extremely small components that operate together, such as transistors, resistors, diodes and etc. The best microprocessor that fulfils the requirement of this system is NodeMCU ESP8266. NodeMCU is an open source IoT platform microcontroller. It includes firmware which runs on the ESP8266 WiFi SoC from Espressif Systems and hardware which is based on the ESP12 module. This NodeMCU function as a microcontroller to control the systems and devices input and output based on the design program that user or developer set and upload into it.



Figure 3.8 : NodeMCU ESP8266 Top View & Pin Details

3.4.2 RGB Light Source & Photodetector Circuit Design

The project started with the development of the circuit itself that requires several process including the designing, fabricating and sensing validation process. In the designing process, the circuit was created by using a block diagram as shown in Figure 3.9 below before it was designed in the Proteus software in order to fabricate the circuit onto the UV board later.



Figure 3.9 : Block Diagram of Optical Sensor and LED System

3.4.2.1 RGB LED Circuit Design (Light Source)

After the circuit has been finalized in the form of block diagram, the circuit is continued to be redrawn in the Proteus software accordingly to all specifications require for every component so that the circuit could work and give the expected output later. On the LED circuit part that has been designed there is a push button that will function as on and off the LED and works to change the color of the LED from red to green and then blue. As the RGB has a common anode function, then the longest leg will be connected to the 3.3 voltage supply from NodeMCU. The diagram below shows a circuit that has been designed using a Proteus software.



Figure 3.10 : RGB Circuit Design Part on Proteus

3.4.2.2 Photodetector Circuit Design

The photodiode will be a major component on the next part of the circuit. In designing a circuit for a photodiode, it requires several components such as variable resistor, op-amp and capacitor to complete the entire photodiode circuit. This is because the photodiode will read and produce a very low voltage value in the absence of other components. With a component such as an operational amplifier, it will serve as a signal amplifier from the photodiode so the reading that will be received by the microcontroller is not too small and easy to read. LCD 12x12 will be used to display the voltage read by photodetector. On the figure below shows the photodiode amplifier circuit connected to NodeMCU using Proteus software.



3.4.3 Circuit Design and Fabrication

There were two types of drawing that needs to be done in the Proteus software. First was the standard configuration of the circuit while the other one was the layout of the circuit that will be printed on the UV board. Component connections between these two circuits are intertwined in a manner so critical that a single mistake might cause the entire circuit to malfunction, or worse, stop working altogether. So, every connection was configured carefully to each end before developing the PCB layout afterwards. The circuit layout design in Proteus is shown in the Figure 3.13 below with their respective label.



Figure 3.12 : Schematic Diagram for the Optical Sensor Monitoring System



As for the PCB layout, all components need to be rearranged again within the yellow border which shows the PCB board edge. The arrangement of the copper connection needs to be done neatly so that it will not overlap from other components that are not related which leads to malfunction circuits. In the development of PCB layout, the smaller the circuit arrangement and PCB board, the better it is.



Figure 3.14 : 3D Visualizer

3.5 RGB Spectrometer Color Test

The first aim in this method is to identify and compare if the theory concept of RGB color wavelength graph is same to the reading from spectrometer value that emits from the light source. In this method SM442 spectrometer was used to measures the intensity of light over the wider range by dividing it into several smaller steps. This enables precise measurements of the wavelength specific characteristics of a substance. The measurement includes color information visible to the human eye. SM442 are precise and adaptable. But more complicated than colorimeters. They enable the identification of more than one color appear by anticipating the appearance of colors under different lighting conditions. RGB LED will be directed to the receiver of SM442 as shown in the figure 3.15 below.



Figure 3.15 : SM442 Spectrometer Setup

In this this part, SMPro MX software need to be installed as a platform to collect all the data set output that come from spectrometer. By getting the data from the software, LED need to be turn on and all data regarding red, blue and green light come from RGB LED was taken and recorded.



(a)

(b)



(c)









Figure 3.17 : Wavelength x Time x Intensity 3D Graph-(a)red (b)green (c)blue

3.6 Optical Sensor IoT Platform Integration Process

In this project, the raw data of the transmitted light received by the photodetector is expected to be send into the e-mail. For that purpose, an application called Blynk is used to connect the designed circuit with the email via Wi-Fi. Initially, a configuration must be set up before the microcontroller, NodeMCU may be used to carry out the function in concern, and this is done by developing the coding used in the software. The initial setup code for Blynk can be observed in Figure 3.18 below.



Figure 3.18 : Declaration & Define line code in Arduino IDE

The code that has been successfully developed was then upload into the NodeMCU microcontroller to allow the Blynk application to connect with it later. Meanwhile, in the Blynk software, a function called SuperChart is used which it will displayed the received data in the form of graph as depicted in figure below.



Figure 3.19 : Blynk Application with SuperChart Widget Box



Figure 3.20 : Blynk Web Dashboard with SuperChart Widget Box

The raw data of the output voltage will be continuously received by the apps as long as the circuit is operated but as for the analysis, the limit of data received is set to be at 100 readings. So, whenever the number of data readings has met the requirements, the data of the raw output voltage has to be manually exported into the specified e-mail in the form of excel files by clicking the download report button as shown in Figure 3.16 on the web dashboard. This process has to be repeated for several times for each type of LED color, thickness and also color of transparent sheet.

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Figure 3.21 : Download Report of Raw Data in Excel Format



CHAPTER 4

RESULTS AND DISCUSSION

This chapter is about the analysis process of the proposed optical sensor in order to achieve the three objectives of this research work. First and foremost, the RGB LED light source and photodetector circuit was analyzed in order to ensure that the circuit is working as planned. Then, the designed circuit was integrated with the IoT platform by using Blynk application as the medium. Once the IoT integration working as expected, the sensing performance of the optical sensor in measuring thickness and color of transparent plate was performed with the IoT platform to sense the different of the sensing performance and the result will be analyzed.

4.1 Analysis of the Designed Circuit and IoT Integration

As illustrated in figure 4.2 below, since the LED light source was launch straight to the photodetector, the light was detected and amplified before being display on the LCD and Blynk application. Due to the op-amps LT1884 specification and the maximum reading for NodeMCU, the maximum output voltage received by the photodetector is 5V. The initial output voltage through this test in constant surrounding lighting is set to 0.57v. Figure 4.1 below shows the project circuit's configuration setup on distribution board.



Figure 4.2 : Project Hardware

After successfully integrating the IoT with the LED and photodetector circuits, its performance was evaluated in order to monitor the output voltage displayed on the Blynk interface as shown in figure 4.3. The displayed output voltage was averaged using the equation set on the command line from Arduino IDE software in NodeMCU. Then figure 4.4 shows the graph indicating the variability of the raw output voltage measured by the photodetector. It indicates that the IoT integration has been complete successfully.



Figure 4.3 : Blynk Application Interface



Figure 4.4 : Received Data in Blynk Web Dashboard Interface

Once the project has been running for few minutes, 100 sets of was collected from each color of transparent sheet for red, green and blue light. Then, project analysis can be done after all the desired data already been collected. The exported data of the output voltage in Microsoft excel as shown in figure 4.5 below.

1	Α	В	С	D	E	F	G	н	1	J	K	L	м	N	0	Р	Q	R	S
1 R	0	6	в			R	G	в			R	G	в			R	G	в	
2	1.984	0.626	0.65	1 paper		1.935	0.606	0.577	2 paper		1.843	0.601	0.572	3 paper		1.735	0.596	0.572	4 pape
3	1.984	0.63				1.935	0.601	0.572			1.843	0.596	0.577			1.74	0.591	0.577	
4		0.626	0.65			1.935	0.601	0.572			1.838	0.601	0.577			1.74	0.596	0.572	
5	1.984	0.63	0.655			1.935	0.606	0.577			1.843	0.601	0.572			1.74	0.596	0.572	
6	1.984	0.626	0.65			1.935	0.606	0.577			1.848	0.596	0.577			1.74	0.596	0.572	
7	1.984	0.626	0.65			1.935	0.601	0.577			1.843	0.596	0.572			1.74	0.591	0.577	
8	1.984	0.626	0.655			1.935	0.606	0.577			1.848		0.572			1.74	0.591	0.572	
9	1.984	0.626	0.65			1.935	0.606	0.572			1.843	0.596	0.577			1.745	0.596	0.572	2
10	1.984	0.626	0.65			1.935	0.606	0.577			1.843	0.601	0.572					0.572	
11	1.994	0.626	0.65			1.935	0.606	0.577			1.838	0.601	0.577			1.74	0.591	0.572	2
12	1.994	0.635	0.65				0.606	0.572			1.838	0.596				1.74	0.596	0.577	
13	1.984	0.626	0.655			1.935	0.606	0.577			1.843	0.596	0.577			1.74	0.596	0.572	2
14	1.984	0.63	0.65			1.935	0.606	0.577			1.838	0.596	0.572			1.74	0.596	0.572	2
15	1.994	0.626	0.65			1.935	0.606	0.572			1.838	0.596	0.572			1.74	0.596	0.577	
16	1.984	0.63	0.65			1.935	0.606	0.577			1.838	0.596	0.572			1.74	0.596	0.572	
17	1.994	0.626	0.655			1.935	0.606	0.577				0.601	0.577			1.74	0.596	0.572	
18	1.984	0.626	0.65			1.935	0.606				1.838	0.601	0.577			1.735	0.591	0.572	
19	1.984	0.626	0.65			1.935	0.606	0.577			1.843	0.601	0.572			1.735	0.591	0.572	
20	1.984	0.626	0.655			1.935	0.601	0.577			1.838	0.601	0.577			1.735	0.596	0.572	2
21			0.65			1.935		0.577			1.838	0.601	0.572			1.74	0.596		
22	1.984	0.63				1.935	0.606	0.577			1.843	0.596	0.572			1.735	0.596	0.572	
23	1.984	0.626	0.655			1.935	0.601	0.577			1.843	0.601	0.572			1.74	0.596	0.572	
-		RedShe	et Gre	enSheet	BlueShee	t +								•	•				

Figure 4.5 : Arrays of the Output Voltage Data

4.2 Analysis of The Optical Sensor Performance with Different LED Light Source (RGB) for Different Color of Transparent Sheet

After finishing the project's hardware and testing the three color of LED voltage readings, this project continues into the next step which by analyzing the performance of each paper color and its thickness with each RGB color. For each color paper, 6 types of thickness need to be run and recorded. Therefore, a total of 6 tests need to be done for each color paper and then the process is repeated with the other color light source. Based on diagram 4.6, the slope of the graph is calculated through the formula y = mx + c. Based on the analysis graph that has been done, it can be seen that the results from the experiment show the thicker the color paper tested, the lower the voltage reading received by the sensor.



Sensing of Different Thickness for Transparent PVC Red Sheet

Figure 4.6 : Sensing of Different Thickness of Red Transparent Sheet with RGB Light Source

Tables 4.1, 4.2 and 4.3 provide a summary of the sensor performance based on the graphs in figure 4.6, 4.7 and 4.8. Performances assessed include sensitivity (V/mm), linearity (%), standard deviation (V) and resolution. To compute the value of sensitivity, equation V/mm was used where V is the output voltage and *mm* is the thickness of colored transparent sheet. For linearity, standard deviation and resolution were determined in Microsoft Excel software itself.

Table 4.1 : Performance of Optical Sensor based on Red Transparent Sheet and

Thickness

SENSOR PERFORMANCE	RED	GREEN	BLUE
SENSITIVITY (V/THICK)	-0.33	-0.03	-0.03
LINEARITY (%)	99.83%	85.67%	65.73%
STANDARD DEVIATION (V)	0.183	0.017	0.024
RESOLUTION	-0.2613676	0.0000000	-2.8349668



Sensing of Different Thickness for Transparent PVC Green Sheet

Figure 4.7 : Sensing of Different Thickness of Green Transparent Sheet with RGB Light Source

Table 4.2 : Performance of Optical Sensor based on Green Transparent Sheet and

Thickness

SENSOR PERFORMANCE	RED	GREEN	BLUE
SENSITIVITY (V/THICK)	-0.27	1A 1-44 AK	-1.02
LINEARITY (%)	67.86%	95.49%	87.55%
STANDARD DEVIATION (V)	0.183	0.828	0.610
RESOLUTION	-0.0213833	-0.0626285	-0.0706971



Sensing of Different Thickness for Transparent PVC Blue Sheet

Figure 4.8 : Sensing of Different Thickness of Blue Transparent Sheet with RGB Light Source

Table 4.3 : Performance of Optical Sensor based on Blue Transparent Sheet and

Thickness

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SENSOR PERFORMANCE	RED	GREEN	BLUE
SENSITIVITY (V/THICK)	-0.11	-1.35	-1.12
LINEARITY (%)	64.53%	92.62%	97.99%
STANDARD DEVIATION (V)	0.075	0.788	0.636
RESOLUTION	-0.7624088	-0.1410004	-0.1432287

Based on the result obtained, it is effected by the light absorption, transmission and reflection concept. The amount of light intensity that travel from the light source either be reflected or absorbed by the transparent film which cause the photodetector not received the exact amount of emitted light. As theory, the light absorption will depend on the thickness of the material, different thickness has the different value of light absorption rate. From the graph pattern above can say that the thicker the thickness of a transparent sheet, the higher the amount of light that can be absorb.

Furthermore, the light intensity absorbed by the transparent film also effected by the colored or its own narrow band of wavelength and frequency. When waves are absorbed by a surface, their energy is transferred to the surface's particles. Typically, this will raise the internal energy of the particles. As an example when white light is emitted and travels through a colored transparent film, all colors except the film's color are absorbed. A green transparent sheet for example, transmit green light while absorbing all other colors. If white light is projected through a green sheet, the human eye will only perceive green wavelengths. If based on the result gained, that's why when the green transparent sheet is used as the experimental material, green LED light source has the greatest output voltage reads by the photodetector compare to blue and red due to the color wavelength absorption theory. Same goes to other color of transparent sheet and the other LED color as a light source.

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4.2.1 Sensing Mechanism

The sensing mechanism of this optical sensor is illustrated in figure 4.9 below. The LED's light signal was emerged directly to the transparent film then go to photodetector. In this project mechanism, there are two mechanisms that reduce light flowing through a transparent plate which are absorption by the transparent material and reflection at the interface. The first mechanism is determined by the travel distance of light in the medium, the material's characteristics and the wavelength of light. This occurs when light goes through the boundary between two media. Reflection occurs on both the front and back surfaces of a single transparent plate, whereas reflection

occurs at each contact between layered sheets. By increasing the number of film, attenuation is predicted to increase and the transmitted light intensity would decrease. Once photodetector received the transmitted light then it will be converted into electrical signal. Lastly, the voltage value has to be displayed on the LCD screen based on the amount of light intensity received.



Figure 4.10 shows the comparison of sensing sensitivity between different thickness of transparent film and its colors with different color as a light source. From the result, it can be clearly seen that green LED as a light source has the best sensitivity compared to other two red and blue. It means that more transmitted light detected by photodetector as green light was applied.



Figure 4.10 : Comparison of Sensing Sensitivity between Transparent Sheet

Linearity is a measure of the accuracy of measurement throughout the entire measurement range. In general, it is a reliable indicator of a sensor's performance quality. Figure 4.11 below compares the sensing linearity between transparent sheet and RGB light source. From the result obtained, green color as a light source have the best consistency result among other LED color.





Figure 4.11 : Comparison of Sensing Linearity between Transparent Sheet Color and RGB Light Source

The last parameter observed for this project's analysis was optical sensor resolution compared between RGB LED light source and colored transparent sheet. Basically resolution known as the smallest value that can be recognize or measure by an optical sensor. From the result, can conclude that the sensor can measure better when green LED is used as the light source in experiment of thickness and color of transparent sheets.



Figure 4.12 : Comparison of Sensing Resolution between Transparent Sheet Color and RGB Light Source UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CHAPTER 5

CONCLUSION AND FUTURE WORKS



As a conclusion, all three project objectives were met and this research illustrates the creation of a low cost and simple optical sensor for product quality monitoring system. by using commercial RGB LEDs as a light source and low cost photodiode incorporated into ESP8266, a simple and cost effective sensor device was created. According to the result gained, the larger the thickness of a transparent sheet, the lower the output voltage read by photodetector. From this project also found that the optical sensor is suitable for variety of applications based on its sensing capability which is dependent on the wavelength of the LED light source whether red, green or blue.

5.2 Future Works

This project is a low cost sensor based on the product quality monitoring. These sensor systems will be widely used in the near future for detecting the thickness and color of any transparent material or substance, widely used in the industrial food, medical field and plant growth monitoring have a high commercialization potential as sensor based project. This application generally better at transmitting data compared to other electronic components, as the data is transmitted in a visible light.

In future plan, this project's circuit can be utilized for different applications involving light properties such as reflection, refraction and absorption. In addition, it is also able to measure other physical substance's parameter such as the water turbidity level and surface area of a transparent object. Theoretically, with the different presence of water turbidity will have a different light absorption rate.



Figure 5.1 : Block Diagram of the Optical Sensor Circuit For Future Work

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APPENDICES

Appendix A : Code for Microcontroller ;

#define BLYNK_TEMPLATE_ID " template id "

#define BLYNK_DEVICE_NAME " device name "



#include <BlynkSimpleEsp8266.h>

#include <LiquidCrystal_I2C.h>

#define ON_Board_LED 2 //--> Defining an On Board LED, used for indicators when the process of connecting to a wifi router LiquidCrystal_I2C lcd(0x27, 16, 2); // set LCD address, number of columns and rows

char auth[] = BLYNK_AUTH_TOKEN;

char ssid[] = "BarliAis"; // Enter your Wifi Username

char pass[] = "12345678"; // Enter your Wifi password



const byte PIN_LED_R = D7;

const byte PIN_LED_G = D6;

const byte PIN_LED_B = D5;

const int buttonPin = D3; //declare button pin

int photodiode = A0; // declare photodiode pin
int readvalue;

float voltage;

int counter = 0;

void setup()

{

pinMode(buttonPin, INPUT);

pinMode(PIN_LED_R, OUTPUT);

pinMode(PIN_LED_G, OUTPUT);

pinMode(PIN_LED_B, OUTPUT);

pinMode(photodiode,INPUT); KAL MALAYSIA MELAKA

displayColor(COLOR_BLACK);

lcd.init();

// initialize LCD

lcd.backlight();

// turn on LCD backlight

Serial.begin(9600);

WiFi.begin(ssid, pass); //--> Connect to your WiFi router

Serial.println("");

pinMode(ON_Board_LED,OUTPUT); //--> On Board LED port Direction output

digitalWrite(ON_Board_LED, HIGH); //--> Turn off Led On Board



of connecting to the wifi router.

digitalWrite(ON_Board_LED, LOW);

delay(250);

digitalWrite(ON_Board_LED, HIGH);

delay(250);

//-----

//-----

digitalWrite(ON_Board_LED, HIGH); //--> Turn off the On Board LED when it is connected to the wifi router.

//-----If successfully connected to the wifi router, the IP Address that will be visited is displayed in the serial monitor.

Serial.println("");

}

Serial.print("Successfully connected to : ");



Blynk.begin(auth, ssid, pass);

} void loop()

{

Blynk.run();

int buttonState;

buttonState = digitalRead(buttonPin);

Blynk.virtualWrite(V1,counter);

if (buttonState == LOW) {



else if (counter == 0) { TEKNIKAL MALAYSIA MELAKA

displayColor(COLOR_BLACK);

lcd.setCursor(0,0);

lcd.print("RGB OFF ");

delay(500);

}

else if (counter == 1) {

displayColor(COLOR_RED);

Serial.println("Red");

lcd.setCursor(0,0);

lcd.print("RED RGB");

delay(500);



lcd.setCursor(0,0);

lcd.print("GREEN RGB");

delay(500);

}

else if (counter == 3) {

displayColor(COLOR_BLUE);

Serial.println("Blue");

lcd.setCursor(0,0);

lcd.print("BLUE RGB ");

delay(500);



readvalue = analogRead(photodiode);

voltage = (5./1023.)*readvalue;

Serial.print("voltage = ");

Serial.println(voltage);

lcd.setCursor(0,1);

lcd.print("Voltage = ");

lcd.setCursor(10,1);

lcd.print(voltage);

Blynk.virtualWrite(V2,voltage);

delay(500);





FORMULA