

DEVELOPMENT NON-INVASIVE BLOOD TYPE DETECTOR OF SPECTRAL RESPONSIVITY

NOOR AQMA BINTI HJ. MOHD YAZID

UNIVERSITI PENDIDIKAN SULTAN IDRIS

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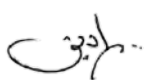
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ABSTRACT

The conventional method of blood grouping, reliant on antigen-antibody reactions, entails invasive blood sampling and is susceptible to time-consuming procedures and potential mismatches, leading to severe consequences during transfusions. This study endeavors to develop a non-invasive human blood type detector, assessing spectral responsivity relative to blood types and comparing it with conventional methods. A cross-sectional descriptive study involving 120 participants was conducted, with the spectral responsivity serving as the dependent variable. The non-invasive detector, comprising input (power supply, OPT101, IR LED), processing (Arduino), and output (LCD Display) components, was employed. Participants, meeting inclusion criteria of healthy adults aged 18-50 with blood typing records, underwent trials using the setup, excluding those under anticoagulant medication, pregnant, or with blood cancer. Subjects placed their middle finger into the setup for comfortable positioning, undergoing three trials on each side to determine output voltage ranges for ABO Blood groups. Results revealed voltage ranges: Blood type A (0.10V - 0.15V), Blood type B (0.16V - 0.23V), Blood type O (0.00V - 0.09V), and Blood type AB (0.23V - 0.5V). The study signifies the potential of non-invasive blood typing technology in enhancing efficiency and accuracy in blood group detection.

PEMBANGUNAN PENGESAN JENIS DARAH BUKAN INVASIF MELALUI TINDAK BALAS SPEKTRUM

ABSTRAK

Kaedah konvensional bagi pengkelompokan darah, bergantung pada tindak balas antigen-antibodi, melibatkan pengambilan sampel darah yang invasif dan terdedah kepada prosedur yang memakan masa serta kemungkinan tidak sepadan, yang boleh membawa kepada konsekuensi yang serius semasa transfusi. Kajian ini bertujuan untuk membangunkan pengesan jenis darah manusia yang tidak invasif, menilai responsiviti spektral berdasarkan jenis darah dan membandingkannya dengan kaedah konvensional. Satu kajian deskriptif rentas-seksyen melibatkan 120 peserta telah dijalankan, dengan responsiviti spektral berperanan sebagai pembolehubah bergantung. Pengesan tidak invasif, yang terdiri daripada komponen input (bekalan kuasa, OPT101, IR LED), pemprosesan (Arduino), dan output (LCD Display), telah digunakan. Peserta, yang memenuhi kriteria penyertaan dewasa sihat berumur 18-50 tahun dengan rekod penjenisan darah, menjalani ujian menggunakan persediaan, dengan mengecualikan mereka yang di bawah ubat antikoagulan, mengandung, atau mempunyai kanser darah. Subjek meletakkan salah satu jari mereka ke dalam persediaan untuk kedudukan yang selesa, menjalani tiga ujian pada setiap sisi untuk menentukan julat voltan output bagi kumpulan darah ABO. Keputusan menunjukkan julat voltan: Jenis darah A (0.10V - 0.15V), Jenis darah B (0.16V - 0.23V), Jenis darah O (0.00V - 0.09V), dan Jenis darah AB (0.23V - 0.5V). Kajian ini menandakan potensi teknologi penjenisan darah yang tidak invasif dalam meningkatkan kecekapan dan ketepatan dalam pengesanan kumpulan darah.

CONTENTS

	Pages
DECLARATION OF ORIGINAL WORK	i
DECLARATION OF DISSERTATION	ii
ACKNOWLEDGMENT	iii
ABSTRACT	iv
ABSTRAK	v
CONTENT	vi
LIST OF TABLES	vii
LIST OF FIGURES	viii
LIST OF ABBREVIATIONS	ix
APPENDIX	x
CHAPTER 1 INTRODUCTION	
1.1 Introduction	1
1.2 Research Background	2
1.3 Problem Statement	28
1.4 Research Objectives	31
1.5 Research Questions	32
1.6 Research Hypotheses	32



1.7	Significance of Study	32
1.8	Limitation of study	33
1.9	Operational Definition	33
1.9.1	Non-invasive	33
1.9.2	Invasive	33
1.9.3	Spectral Responsivity	34
1.9.4	Blood Typing	34
1.10	Summary	35

CHAPTER 2 LITERATURE REVIEW

2.1	Introduction	36
2.2	The Intricacies of Human Blood Anatomy	37
2.3	Clinical applications of human blood	43
2.4	Properties of blood	48
2.5	Electrical properties of blood	53
2.6	Invasive and non-invasive method	58
2.7	Invasive technique to detect blood group	59
2.7.1	Imaging Technique	62
2.7.2	Gel Card Agglutination	71
2.7.3	Tube agglutination method	73
2.7.4	Slides test technique	77
2.7.5	Other techniques	80



2.8	Non-invasive techniques to detect blood group	95
2.9	Spectral responsivity in human blood	99
2.10	Sensor to detect spectral responsivity in human blood	102
2.10.1	Light-emitting diode	107
2.10.2	Optical Sensor	114
2.11	Discussion based on previous work	122
2.12	Summary	125

CHAPTER 3 METHODOLOGY

3.1	Introduction	127
3.2	Research Design	128
3.3	Population and Sampling	132
3.3.1	Inclusion Criteria	133
3.3.2	Exclusion Criteria	134
3.4	Block diagram	136
3.4.1	Components of Prototype	138
3.4.1.1	OPT101 Sensor	140
3.4.1.2	IR LED	143
3.4.1.3	Arduino Uno	146
3.4.1.4	LCD Display	150
3.5	Schematic diagram	154
3.6	Principal operations of spectral responsivity	156

3.7	Prototype	160
3.8	Experimental procedure	162
3.9	Statistical Analysis	165
3.10	Summary	169

CHAPTER 4 RESULTS

4.1	Introduction	171
4.2	Background Data	173
4.3	Descriptive Statistics	175
4.4	Independent t-test	178
4.5	One-way ANOVA	180
4.6	Correlation between Conventional Method and Non-Invasive Type Blood Detector	185
4.7	Classification of Blood type based on Spectral Responsivity	190
4.8	Summary	193

CHAPTER 5 DISCUSSION

5.1	Introduction	198
5.2	Spectral Responsivity Based on Blood Type	199
5.3	Comparison with conventional method	210
5.4	Summary	226

CHAPTER 6 CONCLUSION AND RECOMMENDATION

6.1	Introduction	228
6.2	Conclusion	229
6.3	Recommendation	238
6.3.1	Movements	239
6.3.2	Temperature	241
6.3.3	Large sample	243

REFERENCES

APPENDIX



LIST OF TABLES

Table No.		Pages
2.1	Advantages and disadvantages of invasive and non-invasive techniques	84
2.2	Advantages and disadvantages of invasive techniques	88
2.3	Time is taken for several techniques of blood type detector	97
2.4	Previous research on blood type detector	119
4.2	Descriptive Analysis for the subject by demographic in total	177
4.3	Subjects Demographic-based on Blood Type	178
4.4	Independent t-test between gender and weight, height, and BMI	180
4.5	One-way ANOVA between blood type and spectral responsivity	183
4.6	Post hoc test between blood group	183
4.7	Correlation between Conventional method and Non-Invasive Blood Type Detector	189
4.8	Spectral Responsivity range based on blood type	192
4.10	Minimum and maximum voltage value for blood type	194
5.1	Voltage range according to blood grouping using NIBTD	220



LIST OF FIGURES

No. Figures	Pages
3.1 Flowchart of the research design	128
3.2 Block diagram of prototype	136
3.3 Schematic Diagram of NIBTD	154
3.4 Schematic diagram used multisim software	155
3.5 After the simulation of the circuit designation using Multisim	155
3.6 Spectral Responsivity of OPT101	158
3.7 Prototype of NIBTD	160
3.8 Flowchart of the blood group detection process	162
4.1 Percentage of subjects according to blood type	175
4.9 Range of spectral responsivity based on blood type	192

LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
BMI	Body Mass Index
Cl ⁻	Chloride Ion
CO ₂	Carbon Dioxide
DNA	Deoxyribonucleic Acid
ECG	Electrocardiogram
GHz	GigaHertz
Hz	Hertz
IR	Infrared
kHz	kiloHertz
kg	kilogram
LED	Light-Emitting Diode
LISS	Low Ionic Strength Saline
MWL	Multi-Wavelength Light
Na ⁺	Sodium Ion
NaCl	Sodium Chloride
NIBTD	Non-invasive Blood Type Detector
O ₂	Oxygen



PBS	Phosphate Buffered Saline
PCR	Polymerase chain reaction
pH	Potential of Hydrogen
RBC	Red Blood Cell
RMP	Resting Potential of The Membrane
PPG	Photoplethysmography
SNPs	Single Nucleotide Polymorphisms
SPO2	Saturation of Oxygen
SPSS	Statistical Package for the Social Sciences
V	Volts
WBC	White Blood Cell



APPENDIXES LIST

- A Title Pages
- B Declaration of Original Work
- C Dissertation Status Verification Form
- D Acknowledgement
- E1 *Abstrak*
- E1 Abstract
- F Contents
- G List of Tables
- H List of Figures
- I List of Abbreviations
- J Appendixes 1



CHAPTER 1

INTRODUCTION



1.1 Introduction

The chapter presents background research on the spectral responsivity of non-invasive blood type detectors, concentrating on the basic concepts and their link to recognizing blood types without intrusive procedures. It also addresses the science and technology underlying spectral responsivity, emphasizing its relevance in medical practice. The problem statement emphasizes the disadvantages of traditional invasive blood typing technologies, such as patient pain, infection risks, and experienced workers. These studies include analyzing the detector's accuracy and reliability, determining ideal spectral bands, and comparing its performance to intrusive approaches. The study questions and hypotheses narrow the focus even more by emphasizing predicted results





or correlations between variables. The chapter finishes with a review of the study's limits and significance, addressing potential constraints such as sample size and technological issues. The results have the potential to expand medical knowledge, revolutionize blood type testing, and improve patient care.

1.2 Research Background

Blood is an essential fluid that travels through the body's circulatory system, carrying oxygen and nutrients to the various tissues while also carrying away waste items. It comprises several different parts, the most notable of which are the red blood cells, white blood cells, platelets, and plasma(Hansen et al., 2015).



Erythrocytes, another name for red blood cells, are the cells in the blood that are in charge of transporting oxygen to the body's various tissues. They are packed with a protein known as hemoglobin, which binds to oxygen in the lungs and then transports that oxygen to other tissues in the body that require it.(Quirino et al., 2019)

White blood cells, which are often referred to as leukocytes, are a component of the immune system in the body and aid in the battle against infections and other types of foreign substances. There are many different kinds of white blood cells, and each one serves a particular purpose in the body.(Burnouf et al., 2015; Nishiyama et al., 2016; Tewabe et al., 2022)





Platelets are the cells in the blood that are responsible for the clotting process, which stops excessive bleeding in the case that blood vessels are injured. Plasma is the liquid component of blood, and it is responsible for transporting nutrients, hormones, and waste materials to and from the various parts of the body. In addition to this, it has protein components, such as albumin and fibrinogen, both of which play important roles in the regulation of fluid balance and the clotting of blood.(Burnouf et al., 2015)

Blood can have a different chemical make-up based on a person's age, gender, health, and a variety of other factors. The presence or lack of particular antigens on the surface of red blood cells is what determines a person's blood type. Various blood types are often incompatible with one another, this can result in adverse reactions to blood transfusions. Overall, blood is necessary for life and plays an important part in the regulation of internal body temperature (homeostasis).(Naderi & Kwong, 2020; Nishiyama et al., 2016; Teissie, 1993)

Several different components and functions can be attributed to blood, including the following. Blood is a specialized fluid that flows throughout the human body's circulatory system. It delivers oxygen and nutrition to the cells and tissues of the body while also carrying away waste products. Blood is found only in humans. Blood is made up of many different kinds of cells and proteins, all of which collaborate to carry out the diverse duties that blood performs.(Burnouf et al., 2015)





Research has shown that the electrical characteristics of human blood can be detected and analyzed. The following is a list of some of the most important electrical properties that human blood possesses. An electrocardiogram, often known as an ECG, is a diagnostic tool that measures the electrical activity of the heart (ECG). Electrodes are positioned on the skin in order to perform an electrocardiogram, which is a non-invasive test that analyses the electrical activity of the heart. An electrocardiogram (ECG) can be used to assist in the diagnosis of a variety of cardiac problems, including arrhythmias, myocardial infarction (often known as a "heart attack"), and heart failure.(Kim, 2021)

Blood-brain barrier the blood-brain barrier, also known as the blood-brain barrier (BBB), is a highly selective barrier that separates the brain's extracellular fluid from the flowing blood. BBB is created when the endothelial cells that make up the walls of the brain's capillaries form tight connections with one another. BBB plays a vital role in preserving homeostasis in the brain and shielding it from potentially dangerous compounds that are present in the blood. The behavior of the BBB is significantly influenced by the electrical characteristics that it possesses.(Naderi & Kwong, 2020)

Bioimpedance is a method that measures the electrical characteristics of biological tissues such as blood. The components of the body, such as total body water, fat-free mass, and fat mass, can all be determined through the use of bioimpedance as a measuring tool. Bioimpedance is a non-invasive approach that is used in medical



research and clinical practice to monitor changes in body composition as a reaction to various medical diseases such as malnutrition, obesity, and cancer. Technology was developed in the 1970s.(Naderi & Kwong, 2020)

The electrical characteristics of human blood play a vital part in a variety of physiological processes and have the potential to provide insightful information that can be used for diagnosis and further scientific investigation. The following is a list of methods that can be utilized in the process of measuring the electrical characteristics of blood vessels.(Jaspard et al., 2003)

Doppler ultrasound is a method that makes use of sound waves in order to calculate the speed at which blood is moving through blood vessels. It is possible to assess the rate of blood flow and the direction of blood flow by conducting an analysis of the changes in the frequency of the reflected sound waves. The impedance and resistance of blood arteries can be determined with the use of this approach. (Teissie, 1993)

Impedance plethysmography is a non-invasive method that measures variations in the electrical resistance of a limb or another part of the body. It is possible to utilize it to detect variations in blood volume, such as those that take place as blood flows through the various vessels in the body. This method has the potential to reveal information regarding the electrical characteristics of blood arteries.(Dal Pont & Marques, 2020; Kakarla et al., 2019; Pinto et al., 2020; Version, 1992)



Magnetic resonance imaging (MRI) can be used to quantify the speed and direction of blood flow as well as view blood flow via arteries. In this way, information on the electrical properties of blood vessels, such as their impedance, can be obtained. Although these methods can inadvertently yield information on the electrical characteristics of blood vessels, it is essential to keep in mind that direct measurements of the electrical properties of blood are not typically utilized in clinical practice. This is a crucial point to keep in mind.(Mete et al., 2012; Teissie, 1993; Turgeon et al., 2019; Zelepukin et al., 2020)

Some methods that may be utilized in order to evaluate the electrical characteristics of blood arteries include electrocardiography, often known as an electrocardiogram or an electrocardiogram, is a technique that analyses the electrical activity of the heart, which in turn reflects, in a roundabout way, the electrical properties of the blood arteries that supply the heart. The electrocardiogram (ECG) is able to offer information on the electrical properties of the blood arteries in the heart, such as their conductivity and resistance.(Kim, 2021)

The force that the blood exerts on the walls of the blood vessels is what is meant to be measured when attempting to get an accurate reading of blood pressure. Variations in blood pressure can be used to estimate variations in the electrical properties of blood vessels, such as their resistance to blood flow. These variations in blood vessel resistance can be caused by changes in blood pressure.(Bhatia & Singh, 2015; Teissie, 1993; Turgeon et al., 2019)





Photoplethysmography is a method that makes use of light in order to determine how the volume of blood in tissues has changed. Indirectly measuring changes in the electrical characteristics of blood vessels in the skin or other superficial tissues can be accomplished with its assistance.(Stojanovic et al., 2008)

In general, although there are techniques that can provide information on the electrical properties of blood vessels, direct measurements of the electrical properties of blood are typically not performed in clinical practice. In contrast, indirect techniques can provide information on the electrical properties of blood vessels.(Abdalla et al., 2010)

The spectral responsivity of a device is a measurement of how sensitive it is to different wavelengths or frequencies of electromagnetic radiation (light). To put it another way, it defines how a gadget or substance behaves when exposed to light of varying colors or wavelengths. The spectrum responsivity of a material can be utilized in the process of determining the spectral sensitivity of a detector or in the process of characterizing the optical qualities of a substance. Spectral responsivity is often stated as a function of wavelength or frequency.(Kraitl et al., 2005; J. Wang et al., 2019; Zhang et al., 2017)

For instance, the degree to which a camera sensor is sensitive to red, green, and blue light in terms of spectral responsivity is what defines how accurately it can record colors in an image. In a similar vein, a photodiode might have a high spectral





responsivity in the ultraviolet range, which would make it appropriate for the detection of ultraviolet light.(Turgeon et al., 2019)

A calibrated light source and a detector that has a known spectrum response are typically used in the measurement process when trying to determine spectral responsivity. After subjecting the detector to the light source at varying wavelengths, the signal it produces is measured and compared to the signal produced by a reference detector that has a spectral response that is already known. The spectrum responsivity of the detector can be calculated using the ratio of the signals emitted by the detector at each wavelength or frequency.(Pedro et al., 2020)

Imaging, sensing, and spectroscopy are just a few of the numerous applications in which spectral responsivity plays an essential role as a characteristic. It is used to characterize the performance of light-sensitive equipment, including cameras, photodiodes, solar cells, and spectrographs, among other things.(Damborský et al., 2016; Mete et al., 2012)

Researching the optical properties of different materials is another application for spectral responsivity. For instance, the spectral responsivity of a material can be utilized to ascertain its absorption spectrum, which defines the wavelengths of light that are absorbed by the material. This can be done by comparing the spectral responsivity to the absorption spectrum. This information may be used to establish the chemical





composition of the material or to build new materials with certain optical properties.(Sultan et al., 2019)

The field of radiometry, which is the study of the measurement of electromagnetic radiation, also makes use of spectrum responsivity in its work. In order to accurately measure radiometric quantities, one must have precise information regarding the spectrum responsivity of detectors. This information is necessary for converting the signal from the detector into a measurement of the radiant power or energy of the incident radiation.(Cousins et al., 2019; Kakarla et al., 2019; Moslemi et al., 2023; Teissie, 1993)

In general, the spectral responsivity of a material or device is an important quantity to consider in many different areas because these fields include the interaction of light with either materials or technologies. In the process of designing, optimizing, and using technologies that make use of light in a variety of different ways, its measurement and characterization play an extremely important role.(J. Wang et al., 2019)

There is no correlation between the spectral responsivity of human blood and the human blood itself. In contrast, human blood is a biological fluid that does not directly interact with light in the visible or near-infrared regions of the electromagnetic spectrum. Spectral responsivity is a property of a device that measures or detects light,





and spectral responsivity is a property of a device that measures or detects light.(Nishiyama et al., 2016)

Spectral responsivity, on the other hand, can be used to investigate in a roundabout way certain optical features of human blood, such as its absorption spectrum. A spectrophotometer, an instrument that measures the amount of light absorbed by a sample at various wavelengths, can be utilized in order to accomplish this goal. It is possible to identify the wavelengths of light that are absorbed by hemoglobin and other components of blood by measuring the absorption spectrum of human blood. This allows for the diagnosis of certain medical conditions, such as anemia or oxygen saturation levels, which would not be possible without this information.(Pinto et al., 2020; E. J. Wang et al., 2017).



In addition, spectral responsivity can be utilized in medical imaging techniques, such as optical coherence tomography (OCT) and near-infrared spectroscopy (NIRS). Both of these techniques make use of light in order to image or measure biological tissues, such as blood vessels and brain tissue, respectively. The spectrum responsivity of the detectors utilized in various imaging techniques is essential to ensuring that the techniques' accuracy and sensitivity are not compromised.(Turgeon et al., 2019)

Although there is no direct relationship between spectral responsivity and human blood, it can be used to study certain optical properties of blood in a roundabout way and to optimize medical imaging techniques that rely on light-based





measurements. This is despite the fact that there is no direct relationship between the two. (J. Wang et al., 2019)

It is possible to measure spectral responsivity with specialist equipment such as spectroradiometers or spectrophotometers. The purpose of these instruments is to determine a detector's or system's spectral responsivity, which is defined as the ratio of the detector's or system's output signal to the input radiant power across the electromagnetic spectrum at each wavelength. (Burr-Brown, 2015; Haxha & Jhoja, 2016)

A calibrated light source that has a known spectral power distribution is utilized to illuminate the detector or system that is being evaluated in order to perform spectral responsivity measurements. In order to calculate the spectrum responsivity, the output signal of the detector or system is first measured, and then that value is divided by the radiant power that was fed into the system at each wavelength. (Burr-Brown, 2015; Stojanovic et al., 2008).

Measurements of spectral responsivity are essential for guaranteeing the precision and dependability of light-based measurements in a variety of applications. Some examples of these applications include spectroscopy, colorimetry, and photometry. They are also utilized in the process of characterizing the performance of optical detectors and imaging systems, including those utilized in the field of medical imaging and applications involving remote sensing. (Pedro et al., 2020)





A detector's or system's spectral responsivity can be thought of as a measurement of how sensitive it is to light of varying wavelengths across the electromagnetic spectrum. It is the ratio of the signal that is generated by the detector or system to the radiant power that is being input at each wavelength. This ratio is commonly stated in terms of amps per watt or volts per watt as its units of measurement. (Kraitl et al., 2005)

A calibrated light source that has a known spectral power distribution is utilized to illuminate the detector or system that is being evaluated in order to perform spectral responsivity measurements. After that, the signal that is produced by the detector or system is measured. This is often accomplished with a high-precision instrument such as a photodiode or spectroradiometer. In order to calculate the spectral responsivity, the output signal is divided by the input radiant power at each wavelength. This results in a graph that shows the relationship between the spectral responsivity and the wavelength. (Naizathul Akmha S*3, 2018; Turgeon et al., 2019; E. J. Wang et al., 2017)

The spectral responsivity plot has the potential to supply significant amounts of information regarding the operation of the detector or system. For instance, it can be put to use in the process of determining the spectral range of the detector or system in question, which refers to the spectrum of light wavelengths that it is capable of detecting. In addition to this, it can be utilized to evaluate the linearity of the detector or system, which refers to the extent to which the detector or system's output signal is





proportionate to the radiant power that is being fed into it.(Kim, 2021; Stojanovic et al., 2008)

In addition, the spectral responsivity plot can be used to determine the sensitivity of the detector or system, which refers to the minimum amount of radiant power that must be input in order to generate a detectable output signal, as well as the accuracy of the detector or system, which refers to the degree to which the output signal matches the actual radiant power that is being input. Both of these measurements can be made using the plot.(Kakarla et al., 2019; Stojanovic et al., 2008; E. J. Wang et al., 2017)

The level of sensitivity of a photodetector to various wavelengths of light can be quantified using a metric called spectral responsivity. In the discipline of optics, it is often used to characterize the performance of sensors, cameras, and other devices that detect light in various environments.(Naderi & Kwong, 2020)

Although spectral responsivity is capable of measuring the amount of light that is absorbed by a variety of substances, including blood, in practice, it is not utilized in the process of blood group identification. In order to determine a person's blood group, it is customarily necessary to make use of certain antibodies. These antibodies are designed to react with the various blood group antigens that are found on the surface of red blood cells. A variety of methods, such as agglutination tests, can be used to detect





these reactions since they cause visible changes to the blood sample.(Bajpai et al., 2012; Plapp et al., 1989)

A sensor known as a photoplethysmography (PPG) sensor is an example of a spectral responsivity sensor that is employed in biomedical applications sensors monitor blood flow and the amount of oxygen that is saturated throughout the body by measuring the amount of light that is absorbed by blood vessels. These sensors, in most cases, make use of light-emitting diodes, or LEDs, to emit light of a certain wavelength. A photodetector is then used to measure the amount of light that is either transmitted or reflected back from the tissue that is being monitored.(Dal Pont & Marques, 2020; Kim, 2021)



to as its spectral responsivity. Accurately measuring the amount of light that is absorbed by the blood vessels requires that the sensor be able to detect light at these precise wavelengths. In general, PPG sensors have a high spectral responsivity in the red and infrared parts of the spectrum. This is because these are the regions of the spectrum in which the amount of light absorbed by hemoglobin is greatest.(Bhatia & Singh, 2015; Pinto et al., 2020)

PPG sensors are frequently found in medical equipment like pulse oximeters, which are utilized to monitor the levels of oxygen saturation in the blood of patients who have disorders related to their respiratory systems. They are also utilized in the





construction of wearable fitness trackers, which measure a variety of vital indications in addition to the heart rate.(Stojanovic et al., 2008)

Using spectral responsivity in biomedical instruments has led to several breakthroughs in medical technology, particularly in the areas of sensing, imaging, and diagnostics. These three subfields have benefited the most from these developments. In a wide variety of medical devices, such as pulse oximeters, glucose sensors, and spectroscopic imaging systems, spectral responsivity sensors, also known as photodetectors, can be employed. These sensors enable the detection and measurement of particular wavelengths of light, which in turn can provide essential information about physiological characteristics such as blood oxygen saturation, glucose levels, and tissue composition.(Haxha & Jhoja, 2016; Pedro et al., 2020)



For instance, a spectral responsivity sensor is utilized in the process of pulse oximetry in order to detect the amount of light that is absorbed by oxygenated and deoxygenated hemoglobin found in the blood. Patients suffering from respiratory disorders can now have their blood oxygen saturation levels monitored in a non-invasive manner, thanks to this.(Fidanboyulu, K.a, * , and Efendioğlu, 2009)

Spectral responsivity sensors are utilized in the process of glucose sensing in order to determine the concentration of glucose present in biological fluids like blood or saliva. These sensors often make use of enzymes or other chemical compounds that specifically react with glucose to generate a change in the spectral response of the





sensor. This change can be attributed to the presence of glucose. After that, a correlation can be drawn between this change in response and glucose levels.(Haxha & Khoja, 2016)

In imaging systems, spectral responsivity sensors can also be utilized to offer information about the composition and function of tissue. For instance, spectroscopic imaging systems can make use of the spectrum responsivity of a sensor to generate images that depict the distribution of particular molecular or cellular components in tissue samples. These images can be used in a variety of diagnostic and research applications. This can be helpful in detecting disorders such as cancer and monitoring their progression.(Damborský et al., 2016)



instrumentation has resulted in many significant advancements in medical technology. These advancements have made it possible to monitor, diagnose, and treat a wide variety of medical conditions without the need for invasive procedures. The following are some other applications of spectral responsivity that can be found in biomedical instrumentation. In fluorescence microscopy, spectral responsivity sensors are frequently utilized as a detection method for fluorescent compounds present in biological samples. In fluorescence microscopy, light of a certain wavelength is used to excite fluorescent molecules, which in turn causes the molecules to emit light with a distinctly different wavelength. The spectral receptivity of the sensor may be adjusted to match the particular wavelength of the light that is being emitted. This makes it





possible to identify and image fluorescent molecules with a high degree of sensitivity.(Fidanboyly, K.a, * , and Efendioğlu, 2009; Kakarla et al., 2019)

In magnetic resonance imaging (MRI), spectral responsivity sensors are utilized to detect the magnetic fields generated by protons within the body. MRI stands for magnetic resonance imaging. In an MRI scan, a powerful magnetic field is used to first align the protons in the body, and then radio frequency waves of a predetermined frequency are used to excite the aligned protons. After then, the protons give off a signal that can be picked up by a sensor that measures spectral responsivity to produce an image of the body's internal organs and structures.(Damborský et al., 2016)

In Spectroscopy, spectral responsivity sensors can be utilized in a variety of spectroscopy techniques in order to quantify the way in which light interacts with a variety of materials. For instance, in Raman spectroscopy, the spectral responsivity of a sensor is used to quantify the change in frequency of light scattered by a sample. This measurement, in turn, provides information on the sample's molecular structure. In a similar manner, infrared spectroscopy takes advantage of the spectrum responsivity of a sensor in order to quantify the absorption of infrared radiation by a sample. This enables the identification of certain molecules.(Plapp et al., 1989)

Colorimetry used Spectral responsivity sensors are a useful tool for determining the colour of a given sample while engaged in colorimetry. Colorimetry normally entails beaming light of a certain wavelength onto a sample, followed by the utilization





of a spectral responsivity sensor in order to measure the light that is reflected or transmitted from the sample. This can be put to use in a variety of biological applications, such as determining the severity of certain medical diseases by analyzing the color of a patient's urine or blood samples.(Duguid, 1990; Zhang et al., 2017)

Overall, the application of spectral responsivity in biomedical instruments has enabled the development of measurement techniques that are highly sensitive and specific, which has led to improvements in the diagnosis and treatment of a wide range of medical problems. The idea of spectral responsivity has been utilized by a great number of researchers in the course of their work in the field of biomedicine. A spectral responsivity sensor was utilized in order to design a photoacoustic imaging method that is capable of distinguishing between lipids and melanin in the skin. This enabled highly sensitive and particular imaging of these two biomolecules, as the sensor was utilized to detect the light released by the sample after being stimulated with a specified wavelength.(Pedro et al., 2020; Schwan, 1983; J. Wang et al., 2019)

A non-invasive technique for monitoring glucose levels based on near-infrared spectroscopy was developed with the use of a spectral responsivity sensor. The sensor was utilized to assess the change in spectral responsivity generated by the interaction of near-infrared light with glucose in the blood, making it possible to conduct glucose monitoring that is both very sensitive and accurate.(Bhatia & Singh, 2015; Mete et al., 2012; Pinto et al., 2020)





High-speed multispectral fluorescence lifetime imaging microscopy approach for live cell imaging by using a spectral responsivity sensor. The fluorescence that was released by several fluorophores in the sample was detected by the sensor, which enabled highly sensitive and specific imaging of cellular processes in real-time.(J. Wang et al., 2019)

In general, the application of spectral responsivity in biomedical research is a subject that is quickly expanding, and numerous researchers are developing novel methods and applications based on this notion. All of the research that was discussed make use of the idea of spectral responsivity in order to generate novel methods of imaging or sensing that may be used in the medical field. These investigations all make use of this quality in order to identify and photograph specific molecules or tissues inside biological samples, and the term "spectral responsivity" refers to the sensitivity of a detector or sensor to light of different wavelengths.(Kraitl et al., 2005; J. Wang et al., 2019; Zhang et al., 2017)

In addition, the purpose of each of the investigations is to advance previously established methods of biomedical imaging or sensing in order to create diagnostic and monitoring procedures that are less intrusive, more accurate, and sensitive to a particular medical condition's unique characteristics. This illustrates the promise of spectral responsivity in biomedical research as well as the extensive range of applications that it offers within this field of study.(Zelepukin et al., 2020)



In order to develop novel applications in the field of biomedicine, each of the studies takes an interdisciplinary approach and combines the ideas and methodologies of a number of different disciplines. For instance, in order to develop new imaging and sensing approaches, the research that was discussed used information and methodologies from the fields of optics, spectroscopy, and biomedical engineering.(Bhatia & Singh, 2015; Teissie, 1993)

Each of the studies depends on utilizing sophisticated instrumentation in addition to various measuring techniques. For instance, in order to gather data and images of high quality, the research that was discussed made use of highly sensitive spectrum responsivity sensors, cutting-edge imaging systems, and sophisticated methods for data analysis. Each and every one of the investigations is predicated on a profound comprehension of the physical and chemical characteristics of biological materials. It is essential to have a detailed understanding of how light interacts with biological tissues and molecules, as well as how this interaction can be measured and analyzed, in order to develop new imaging and sensing techniques. This interaction can be measured by how light interacts with biological molecules.(Sultan et al., 2019)

All of the investigations have the potential to be applied in clinical settings, where they have the possibility of enhancing the diagnosis and treatment of a wide variety of medical disorders. For instance, the research that was discussed has potential applications in dermatology, glucose monitoring, and live cell imaging; these are all fields that are of great significance in clinical medicine.(Zhang et al., 2017)

Overall, the results of these investigations highlight the relevance of interdisciplinary cooperation and the use of advanced instrumentation in the process of developing novel applications for biomedicine, as well as the potential of spectral responsivity in the field of biomedical research. The identification of a person's blood type can be accomplished using any one of a number of methods. The following are some strategies that are frequently used. Testing for the presence or absence of antigens A and B on the surface of red blood cells is included in the ABO blood typing method. This is the most frequent method of blood typing and is used to determine a person's blood type. Agglutination tests are commonly used for this purpose. These tests entail mixing the blood of a patient with known antibodies and examining the clumping, or agglutination, that happens as a result of the mixing. If the patient's blood contains the relevant antigens, clumping will occur.(Bajpai et al., 2012; Plapp et al., 1989)

Testing to determine whether or not red blood cells have the Rh(D) antigen on their surface is an important part of the process known as Rh factor typing. Agglutination tests, which are quite similar to the ABO type, are often used for this purpose as well.(Bajpai et al., 2012)Typing a patient based on their DNA requires doing an analysis of the patient's DNA in order to identify their blood type. This technique may be more accurate than the standard agglutination tests that have been used in the past; however, it is also more time-consuming and expensive.(Quirino et al., 2019)

Mass spectrometry-based typing is a more recent way of blood typing. In this method, proteins found on the surface of red blood cells are analyzed using mass



spectrometry. This is a more recent method of blood typing. The potential exists for this technology to be very exact and specific; nevertheless, it is currently in the process of being developed and improved.(Garratty, 2010)

In general, the procedure that is utilized to identify a person's blood type will be determined by the unique situation at hand as well as the resources that are at hand. Because of their ease of use and low cost, ABO and Rh typing are normally the most extensively used methods; however, more modern techniques like DNA-based typing and mass spectrometry-based typing may be utilized in some specific applications.(Nakamura et al., 2019; Teissie, 1993)

Much research has been conducted to investigate the possibility of using non-invasive methods to determine a person's blood type. Infrared spectroscopy is a non-invasive technique that measures the amount of infrared light that is absorbed by a variety of different substances. The possibility of using infrared spectroscopy to determine a person's blood type by studying the spectra of absorption produced by blood samples was conducted. According to the findings of the study, the method possessed both a high degree of sensitivity and specificity in its ability to determine an individual's ABO blood type.(Malomgré & Neumeister, 2009; Sultan et al., 2019)

Raman spectroscopy is an additional non-invasive technology that measures the scattering of light by various substances. Raman spectroscopy was developed in the 1940s. The feasibility of using Raman spectroscopy to determine an individual's ABO



blood type through the examination of the samples' scattering spectra. According to the findings of the study, the method possessed both a high degree of sensitivity and specificity in its ability to determine an individual's ABO blood type. (Pedro et al., 2020)

Imaging using near-infrared light: This imaging method is called near-infrared imaging, and it is a non-invasive approach that employs near-infrared light to obtain images of blood vessels and other structures by penetrating tissue. A study that was accomplished by comparing the spectral characteristics of the light that was reflected from the various types of blood vessels. According to the findings of the study, the method possessed both a high degree of sensitivity and specificity in its ability to determine an individual's ABO blood type.(Banu, 2018; Kakarla et al., 2019; M, 2017)

Photoacoustic spectroscopy is a non-invasive approach that makes use of light to generate acoustic waves in tissue, which can then be detected and studied. This technique is known as photoacoustic spectroscopy. By conducting an analysis of the acoustic the method possessed both a high degree of sensitivity and specificity in its ability to determine an individual's ABO blood type. Impedance spectroscopy is a non-invasive technique that analyses the electrical impedance of tissue. This information may then be used to study the properties of a variety of different substances and cells. Impedance spectroscopy is a method that measures the electrical impedance of blood samples to determine an individual's ABO blood type. (Haxha & Jhoja, 2016; Zelepukin et al., 2020)

Fluorescence spectroscopy is a non-invasive technique that examines the fluorescence released by various molecules when they are exposed to light. Fluorescence spectroscopy is also known as fluorescence imaging spectroscopy. Overall, the findings of these investigations point to the possibility that non-invasive methods could one day reliably determine blood type.(Damborský et al., 2016; Nakamura et al., 2019)

Four blood types exist in human nature designated by A, B, AB, and O. The AB blood type is recognized as the universal acceptor and the O type is known as the universal donor. (Tovey, 1969) Blood type detection is an essential step to ensure the safety of the blood transfusion process. During an emergency blood transfusion, rapid identification of the type of blood is essential, which is directly related to the patient's

Several techniques are available to determine blood type, such as the plate test, microplate, and tube test. The plate test is widely used and suitable for emergencies allowing fast results. However, invasive tests can lead to the risk of human error associated with the procedure and the reading and interpretation of results. Furthermore, this invasive blood typing procedure and automated systems present undesirable and unwanted drawbacks, such as requiring more time and non-standardized accuracy.(Naderi & Kwong, 2020)



During a transfusion, the blood is formed of a few different parts, including red and white cells, plasma, and platelets. There are many reasons why someone must receive a transfusion. These are a number of them that might have medical procedures or a vital injury and must replace lost blood (Patel et al., 2019). Second, people that experienced bleeding in their duct from an ulcer or other condition. The third one is that someone has an illness like leukemia or anemia. (Abdalla et al., 2010) (Bhatia & Singh, 2015)

In standard testing, a blood typing reagent that contains specific antibodies mixes with a sample of the patient's red blood cells. The reaction that happens then clarifies what blood type the patient is. Whatever antibodies make the red blood cells agglutinate (clump together) are the people of the patient. (Garratty, 2010) (Plapp et al., 1989). For example, if the red cells agglutinate when mixed with a reagent containing anti-A antibodies, then the red blood cells of the patient contain A antigens, and the patient claims to be A-positive. Each peopling reagent is capable of detecting a specific blood type. In Europe, the blood of a blood donor is typed for a minimum of 8 different blood types, requiring eight different blood types of reagents before the blood donation is released to a patient for transfusion. (Marianne Belleza, n.d.)

Voltage is a measure of the potential energy generated by a separate charge. It is measured in volts or in millivolts. The higher the charge difference between the two points, the higher the voltage. Voltage is equal to the work that would have to be done per unit charge to move the charge between two points against the static electrical field.





Voltage may be a source of energy (electromotive force) or a lost or stored energy (potential drop). (Haxha & Jhoja, 2016; Patel et al., 2019; J. Wang et al., 2019)

All living eucaryotic cells have a transmembrane potential which is a difference in charges between the intracellular and extracellular fluid. While the cell is at rest or unstimulated, the transmembrane potential is stable and is called the resting potential of the membrane (RMP). Right at the cell membrane, there is a little excess of negative charge on the inside of the cell membrane and a little excess of positive charge on the outside. Because the load separation creates a voltage, a very small voltmeter probe can be used to measure the voltage across the cell membrane. (Version, 1992)

The voltage outside the cell is set to zero by convention. In a typical cell, the voltage recorded across the membrane is between -60 and -90 millivolts or -.06 to -.09 volts with a negative sign indicating that the inside of the cell is negative to the outside. Some cells have the ability to temporarily alter their transmembrane potential, such as excitable cells, while non-excitable cells do not. The range of the blood voltage is used as a reference to class the blood type. (Naderi & Kwong, 2020) Blood type is a method to divide the classification of blood. Spectral responsivities of silicon photodiodes were obtained using various spectral bandwidths, ranging from laser lines to interference filters through monochromators, and all of them were used to interpolate the spectral responsivity function of the photodiode. (Duguid, 1990) (J. Wang et al., 2019)



Several laboratories are able to make responsivity calibrations with very low uncertainty at specific laser wavelengths that are transferred to the whole spectral interval through the relative spectral responsivity curve. This curve is usually determined by a monochromator or any other broad spectral analysis system, which necessarily has to be broad in many situations to get a high signal-to-noise ratio. Since the surface reflectance and the internal quantum uncertainty in spectral responsivity efficiency of silicon photodiodes are spectral functions, the effective responsivity obtained in the calibration will depend on the spectral bandwidth used (Ferraz et al., 2010).

Since the photodiode's reflectance and the absorption of light and excitation of charge carriers are not affected by the degree of coherence of the light, it is more acceptable in this study to consider the responsivity function rather than its components, namely the absorption coefficient, quantum yield, and quantum efficiency. (Patel et al., 2019; Sultan et al., 2019; J. Wang et al., 2019)

The electrical properties of blood and its constituents are reviewed over the frequency range from 100 Hz to most 100 GHz. A microfluidic device may be a workable and easy solution for determining the electrical and rheological behaviors of blood samples (Tovey, 1969; Wang et al., 2017; Zhang et al., 2017; Sultan et al., 2019). Generally, human blood's electrical properties earned much interest some decades ago for several reasons. First, they determine the pathways of current flow through the body. (Katti et al., 2015; Teissie, 1993) Second, on a more integral level, knowledge of those electrical properties can help understand the underlying basic biological processes

either on macroscopic or microscopic levels and interactions between the two extents. Moreover, any changes in blood physiology should produce changes within the blood's electrical properties. (Jaspard et al., 2003; Schwan, 1983)

1.3 Problem Statement

Methods that are invasive, blood type tests, for example, need a patient to supply a blood sample, can be time-consuming, costly, and pose possible dangers to patients, including the risk of infection and the risk of experiencing discomfort.(Pinto et al., 2020) In addition, the implementation of these procedures might not be possible in some contexts, such as during times of crisis or in secluded locations with restricted access to medical facilities and workers who have received appropriate training. Therefore, there is a need for the development and implementation of non-invasive blood type detection methods that are accurate, reliable, cost-effective, and can be easily implemented in a variety of settings in order to improve patient care and outcomes. These methods should also be as easy to implement as possible.

By utilising a blood type detector that does not involve any invasive procedures. Methods of invasive blood type identification require competent individuals to collect and analyse blood samples, which may not be available in all types of healthcare settings. These blood samples must be taken in order for the procedures to be effective. This can result in diagnostic and treatment delays, both of which can have negative



repercussions for the patients involved.(Bhatia & Singh, 2015; Mete et al., 2012; Pinto et al., 2020)

Blood typing tests that are invasive and difficult for patients can be another factor that contributes to a patient's unwillingness to undertake testing, which can then lead to missed or delayed diagnosis. In some instances, invasive blood type tests may additionally involve the utilisation of specialist apparatus as well as reagents. This apparatus and these reagents can be rather pricey, and they may not be readily available in all medical settings.(Cousins et al., 2019; Naizathul Akmha S*3, 2018). Non-invasive methods of blood type identification have the potential to overcome these constraints by providing a quick, uncomplicated, and cost-effective method of determining a patient's blood type. This can be especially essential in instances where time is of the essence, such as during medical emergencies.(Haxha & Jhoja, 2016; Mehare et al., 2018; Turgeon et al., 2019)

Hundreds of blood samples must be analysed in the hospital, especially in the emergency room, every day. Blood typing done so far is an invasive process that uses a needle as the primary process. The invasive process is a laborious and time-consuming one, and during a blood transfusion, any mismatch can lead to the death of a person. The conventional method involves drawing blood samples from patients. It depends upon the antigen-antibody reaction blood type is determined; this method will involve the addition of chemical reagents; the time of operation and throughput analysis is high; it is also challenging to interpret. Currently, the determination of blood types,



it has required human intervention, not only in performing the analytical procedures but also in reading and interpreting the results, being then the strategy more in danger of errors (Tovey, 1969; Bularzik et al., 2010; Patel et al., 2019; Garratty, 2010).

The invasive method used to check the blood type may cause pain to people. Trypanophobia or commonly termed needle phobia, significantly impacts many people, especially those served by speciality pharmacies. Fear of needles may keep people from obtaining medical care, visiting the dentist, following recommended medications, and needing laboratory work. (Kraitl et al., 2005; Zelepukin et al., 2020)

A person who suffers from trypanophobia has an extreme and illogical dread of injections or needles. It is a form of specific phobia, which is a sort of anxiety disorder characterised by an excessive or irrational dread of a particular object, place, or action. This type of phobia affects people who have a fear of flying. When confronted with needles or injections, those who suffer from trypanophobia may exhibit a variety of psychological and physiological symptoms, including anxiety or panic to an extreme degree, rapid beating of the heart, trembling or sweating profusely, a nauseated stomach or puking, dizziness or fainting and behaviour that avoids situations (such as refusing medical treatment or not attending medical appointments)(Anne D. Martens, 2014)

Trypanophobia is a potentially life-threatening illness that can have a negative effect not only on a person's quality of life but also on their overall health because it might cause a person to avoid important medical procedures or treatments. It is not



completely understood what develops trypanophobia; nonetheless, the following are some circumstances that may contribute to the growth of this phobia: such as attempts to inject themselves or experiences with needles that were traumatic (such as a painful injection during childhood), anxiety and other illnesses related to mental health, a history of anxiety or phobias running through the family, aspects of heredity, therapies (such as cognitive-behavioural therapy or exposure therapy), medications (such as anti-anxiety medication), and relaxation techniques may all be used in the treatment of trypanophobia (such as deep breathing or meditation). Thus, this non-invasive portable device will allow pain-free, low-cost, real-time, and straightforward check of the blood type.(Anne D. Martens, 2014)



The following are the study's objectives:

1. To develop a non-invasive human blood type detector
2. To analyse the spectral responsivity based on human blood type.
3. To compare the human blood type result using the non-invasive human blood type and using conventional method result





1.5 Research Questions

Since this research is developed the spectral responsivity of a non-invasive blood type detector. The research questions of this study are:

1. What are the factors influencing the determination of blood type using non-invasive techniques?
2. What is the voltage range for each blood type?
3. What is the spectral responsivity of human blood type?

1.6 Research Hypothesis

H₀₁: There is no significant difference in spectral responsivity based on human blood type.

H₀₂: There is no significant difference between the result of human blood type by using Non- invasive blood type detectors and conventional practice.

1.7 Significance of the Study

This non-invasive method aids the doctor, especially in hospitals, to determine and simplify the patient's blood type procedure. The proposed system is user-friendly and timesaving. Besides, the measurement is accurately measured by a computer using spectral responsivity data. Thus, the systematic error of faulty equipment is reduced



while determining blood type. Furthermore, this non-invasive method does not use a single-use needle, which is practically cost-effective and environmentally friendly.

1.8 Limitations of the Study

This study is only limited to determining the human blood type using a non-invasive method. The subject was excluded from the experiment if they are under anticoagulant medicine such as heparin, pregnant, or experienced blood cancer. Data were acquired in a similar venue and environment setting.

1.9 Operational definition

1.9.1 Non-invasive

A non-invasive procedure is a conservative treatment that does not require incision into the body or the removal of tissue. (Teissie, 1993)

1.9.2 Invasive

Invasive is a procedure of access to the body such as incision, natural orifice or percutaneous access (Teissie, 1993)



1.9.3 Spectral responsivity

Spectral responsivity is the response of the output signal to the detector's monochromatic radiation event, modulated at a frequency that specifies the amplifier's gain to carry the detector output to appropriate levels (Daniels, 2018).

1.9.4 Blood typing

Blood typing is the process of determining an individual's blood type based on the presence or absence of specific antigens on the surface of red blood cells and antibodies in the plasma. This process is important for medical purposes, such as blood transfusions and organ transplants, as it helps ensure compatibility between the donor's and recipient's blood. (Malomgré & Neumeister, 2009)

Blood typing typically involves a series of tests to identify the presence of ABO antigens (A and B) and the Rh factor (Rh) on the surface of red blood cells. The most common blood typing system categorizes blood into four main types: A, B, AB, and O. These blood types are determined by the presence or absence of antigens on the red blood cells and antibodies in the plasma. (Sultan et al., 2019)

The process of blood typing is essential for ensuring safe and successful medical procedures involving blood transfusions or organ transplants, as compatibility between



donor and recipient blood types is critical to prevent adverse reactions.(Banu, 2018)
Blood typing is a method to divide the classification of blood (Kakarla et al., 2014).

1.10 Summary

The first chapter of the thesis presents an outline of the non-invasive blood type detector and acts as an introduction to the research. This chapter establishes the background for the whole thesis, providing readers with a clear idea of the scope and objectives of the study. The first chapter of the thesis sets the context for the succeeding parts by providing a complete overview of the research, explaining the non-invasive blood type detector, and establishing the research goals, questions, and importance. It lays a solid framework for readers to comprehend the goal of the study and its possible influence on blood type testing and medical diagnostics.