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An Analysis of Protection System the Quality of Blood Warmer Device Based on Over Temperature Sensor

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ABSTRACT
A blood warmer is a medical device used to warm blood before transfusion to prevent hypothermia in patients. One of the main challenges in using this device is maintaining the blood temperature within a safe range, preventing blood quality degradation and potential harm to the patient. To address this issue, an effective protection system is required, one of which involves an over-temperature sensor. This study analysed the implementation of a protection system based on an over-temperature sensor in blood warmer devices to ensure both blood quality and patient safety. The method used in this research involves the design and testing of a protection system with temperature sensors that can detect over-temperature conditions in real-time. If the temperature exceeds the specified limit, the system automatically shuts off the heating process to prevent damage to the blood. Data obtained from testing show that the developed protection system operates accurately with a fast response time. The test results also demonstrate that the blood quality is maintained within a safe temperature range during the transfusion process. Thus, the over-temperature sensor-based protection system implemented in the blood warmer device can enhance the device's safety and reliability, ensuring that the quality of blood transfused to patients remains intact. This study is expected to serve as a reference in the development of safer and more effective medical devices.

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INTRODUCTION

Blood is a fluid that exists in humans as a means of transportation, functioning to deliver substances and oxygen needed by body tissues, transport chemical substances resulting from metabolism, and also as a body defense against viruses or bacteria (Dr. H. Mohamad Sadikin, Dsc. 2002).

If there is a lack of blood, living things can die. One way to overcome blood deficiency in humans is by performing a blood transfusion. Blood transfusion is related to medical conditions such as large blood loss due to trauma, surgery, shock and the failure of red blood cell-forming organs. However, blood transfusions are not always successful. Factors that influence blood transfusion failure, one of which is because the blood transfused into

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the body has a relatively lower temperature than the normal temperature of the human body, then the patient can experience hypothermia, while if the blood transfused into the body is too hot then the patient will experience hyperthermia (Irmanusil. 2014).

Hypothermia or hyperthermia can cause death in patients, so to prevent hypothermia or hyperthermia, the temperature of the blood to be transfused must be the same as the patient's body temperature. Patients who are under anesthesia, patients who are undergoing surgery and elderly patients are very susceptible to hypothermia or hyperthermia when undergoing blood transfusion because the system in their bodies cannot work optimally and makes it difficult to maintain body temperature to remain at normal temperature (Minarsih, Rini 2013).

In line with the rapid development of electronic technology, it will have a positive impact on the development of medical equipment, for example in the blood transfusion process. Efforts made to prevent hypothermia and hyperthermia during blood transfusion are by stabilizing the blood according to the patient's body temperature (normal temperature 36oC - 38oC).

Based on research conducted by Annisa Gina Husnia in 2018 entitled "Blood infusion warmer With LDR Sensor" said that data collection was taken using 1 room thermometer, and 1 thermometer for measuring room temperature and the temperature of the device made by the author, measurements were carried out at temperatures of 36ºC, 37ºC, 38ºC, 39ºC.

Table 1. Comparison Test Results At 36 ºC

Time (minutes)	Thermometer (ºC)	Module (ºC)	Deviation (ºC)
1	37.0	36.5	0.5
2	36.8	36.5	0.3
3	36.6	36	0.6
4	36.5	36	0.5
5	36.4	36	0.4
6	36.4	36	0.4
7	36.2	36	0.2
8	36.3	36	0.3
9	36.3	36	0.3
10	36.4	36	0.4
Average	36.49	36	36.49

The aim of collecting the data above is to determine the temperature difference with the graph produced at each interval on the thermometer and module. Based on the description of the background above, the researcher identified the problems to be studied as follows:

1. Patients under anesthesia, patients undergoing surgery and elderly patients are very susceptible to hypothermia. Therefore, a heater must be made to maintain the temperature of the blood entering the patient according to the patient's body temperature (normal temperature 36oC - 38oC).

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1. Before use, blood bags are stored in the Blood Bank at a temperature of 2 ℃ – 6 ℃. To avoid blood clotting for too long, patients need a blood infusion warmer for the transfusion process.
2. Hyperthermia also often occurs during the blood transfusion process. Hyperthermia is a condition where the body temperature is above 40 ℃ or exceeds normal temperature. To avoid this from happening, a tool is needed to keep the patient's body temperature stable (normal temperature 36oC - 38oC).

Literature Review

Blood

Blood is a body tissue that is different from other body tissues, it has a liquid consistency, circulates in a closed system called blood vessels and carries out the function of transporting various substances such as oxygen, metabolic products of the body, the body's defense against germ attacks, and so on. Blood transfusion is the process of transferring blood or blood-based products from one person to another person's circulatory system. Blood transfusion is associated with medical conditions such as massive blood loss due to trauma, surgery, shock and the failure of red blood cell-forming organs (Dr. H. Mohamad Sadikin, Dsc. 2002).

Blood infusion warmer devices are commonly used in emergency situations, in operating rooms and in intensive care rooms to prevent hypothermia / cold. This device warms blood to a safe temperature for transfusion into the patient's body (Gesunde Medika. 2016). If a large amount of blood is to be transfused in a short time, then warm blood is needed, because cold blood will cause ventricular arrhythmia and even death. Warming blood with warm water should be at a temperature of 37℃-39℃. Because if it is more than 40℃, erythrocytes will be damaged (Ms. 2009). Blood is a special supporting tissue that has many functions, including the following (Evi Andriani. 2010):

1. As a means of transport, namely transporting:
    a. Food substances from intestinal muscle cells to all body tissues.
    b. Oxygen from the respiratory tract to all body tissues that require oxygen, this task is carried out by hemoglobin.
    c. Carbon dioxide (CO2) from all body tissues to the respiratory tract, namely the lungs.
    d. Metabolic substances from all body tissues to the excretory organs.
    e. Hormones from the ductless or endocrine glands to certain parts of the body.
    f. Water to be circulated throughout the body's tissues.
2. As a defense fortress of the body from infection by various germs. This function is carried out by antibodies, white blood cells and blood clotting cells.
3. Maintaining body temperature stability by transferring heat produced by active body organs to inactive body organs.
4. Regulates the balance of acids and bases to avoid damage to body tissues.

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Blood Infusion Warmer

*Blood infusion warmer*is a tool that functions to warm blood according to human body temperature (35°C - 37°C). This tool is used for blood transfusions, where previously this blood bag was stored in a Blood Bank at a temperature of 2°C - 6°C. In order to prevent blood clotting for too long, patients need a Blood infusion warmer for the transfusion process.

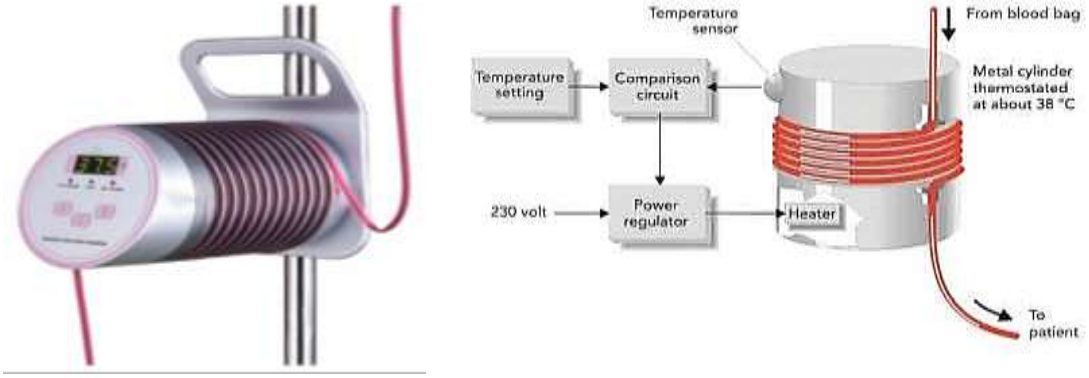

Figure 1. Block Diagram Blood infusion warmer

Block diagram description:

1. *Temperature setting*functions to regulate the desired temperature
2. *Heater*functions as a heating element to warm the patient's blood
3. *Comparison circuit*is a comparator circuit that functions as a circuit control system.
4. *Power regulator*isa regulation circuit or output voltage regulator from a power supply so that the effects of rising or falling mains voltage do not affect the power supply voltage so that it becomes stable.

Thermostat as a Temperature Sensor

Thermostat is a device that can disconnect and connect electric current when detecting changes in temperature in the surrounding environment according to the specified temperature setting. Thermostats are divided into two types, namely:

1. Mechanical Thermostat
   Mechanical Thermostat is a type of contact temperature sensor that uses the Electro-Mechanical principle, while Electronic Thermostat uses electronic components to detect changes in temperature.
   A mechanical thermostat consists of two different types of metals and attached together to form a shape called a Bi-Metallic strip (Bi-Metal Strip). The two strips will function as a bridge to deliver or disconnect the electric current to the heating or cooling system circuit.

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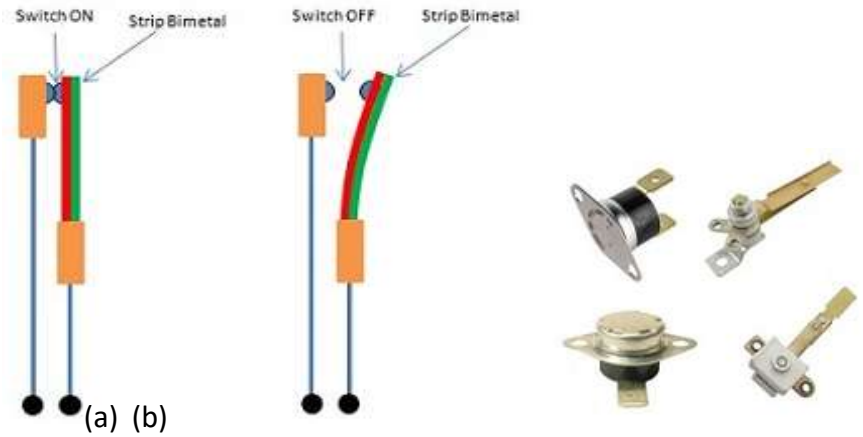

Figure 2. (a) How the Thermostat works (b) Physical form of the Thermostat

During normal times, the Strip that functions as a bridge will always be connected and flowing electric current, the circuit it connects will also be in ON condition. When the Strip gets hot, one of the metals will expand and change shape to become slightly curved and will become more curved as the strip gets hotter which will eventually separate the connection of the strip with its circuit so that the flow of electricity to the heating or cooling system circuit is also cut off or becomes OFF.

The thermostat then changes to the OFF condition (Switch OFF) or there is a disconnection of the electric current to the heating or cooling system connected to the thermostat. When in OFF condition, no electric current flows through the Bimetal strip. Gradually the Bimetal Strip will cool down again. The bent metal will start to change shape to its original shape so that it reconnects and electric current starts to flow through the bimetal strip again. The Thermostat condition becomes ON again and the heating or cooling system circuit becomes ON again.

2. Electronic Thermostat (Electronic Thermostat)

This thermostat uses electronic components to detect changes in temperature and the system for disconnecting or connecting the electric current. The Working Principle of Electronic Thermostat uses the Electro-Mechanical concept. Electronic Thermostat is basically in the form of an electronic circuit consisting of various electronic components. The main component for detecting temperature changes is a Thermistor, a resistor whose resistance value can be affected by the surrounding temperature.

When the Thermistor detects a high temperature, the resistance of the Thermistor will also change so that the electronic circuit will disconnect the electrical connection to the connected heating or cooling system. When the Thermistor cools down again, the resistance of the thermistor will also return to normal so that the electronic circuit that functions as the controller will reconnect the flow of electric current to the heating and cooling system so that it becomes ON again.

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Buzzer

Buzzer is an electronic component that functions to convert electrical vibrations into sound vibrations. Basically the working principle of the buzzer is almost the same as the loud speaker, the buzzer consists of a coil attached to the diaphragm and then the coil is flowed with current so that it becomes an electromagnet, the coil will be pulled in or out, depending on the direction of the current and the polarity of the magnet, because the coil is mounted on the diaphragm then every movement of the coil will move the diaphragm back and forth so that the air vibrates which will produce sound.

(a) b)

Figure 3. (a) Physical Form of Buzzer, and (b) Buzzer Symbol

In the design, this buzzer is used as an indicator that when the given setting is not achieved or exceeds the setting limit, the alarm will sound.

Relay

Relayis an electromagnetic switch that uses low DC voltage to turn on and off a device or system connected to high DC voltage or AC voltage. The simplest relay arrangement consists of a coil of conducting wire wound on an iron core. The relay contact arrangement, in general, consists of:

1. Normally Open(NO) : the switch position is in the open state when relayin a state of no current flowing.
2. Normally Close(NC): the switch position is in the closed state when the relay is not flowing with current. The image below shows the condition of the relay with a normally open state.

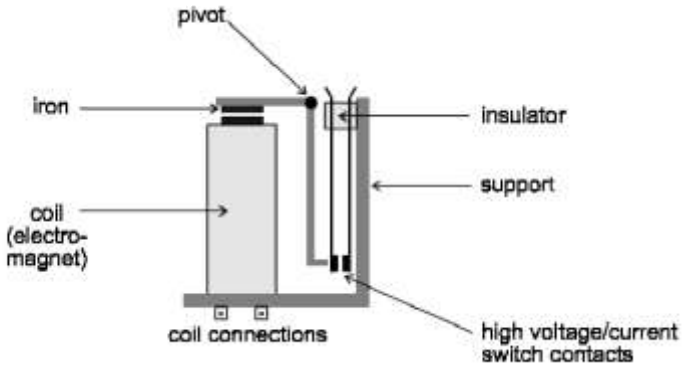

Figure 4. Relay condition when normally open

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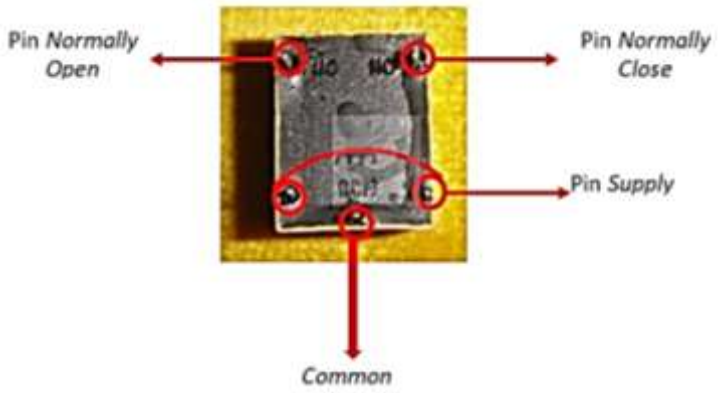

Figure 5. Relay Pin Configuration

Based on the basic principle of how it works, the relay can work because of the magnetic field used to move the switch. When the coil is given a voltage of the relay's working voltage, a magnetic field will arise in the coil because of the current flowing in the wire coil. The coil that acts as an electromagnet will then pull the switch from the NC contact to the NO contact. If the voltage on the coil is turned off, the magnetic field on the coil will disappear so that the spring will pull the switch to the NC contact.

Figure 6. Physical form of relay

Tabel 2.. Pin LCD

No	Symbol	Information
1	GND	Ground
2	VCC	+5V
3	VEE	LCD contrast voltage
4	RS	Register Select
5	R/W	1=Read, 0=Write
6	E	Enable LCD Clock
7	D0	Bus Data 0
8	D1	Bus Data 1
9	D2	Bus Data 2
10	D3	Bus Data 3
11	D4	Bus Data 4
12	D5	Bus Data 5

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13	D6	Bus Data 6
14	D7	Bus Data 7
15	Anode	Backlight Voltage +
16	Cathode	Backlight Voltage -

Hypothesis

The conceptual framework is the relationship between theories or concepts that support the research used as a guideline in compiling a systematic research. The conceptual framework is a guideline for researchers to systematically explain the theories used in the research. This research has a conceptual framework that will be explained in the image below and will be explained more clearly in the following discussion. Hardware design is a hardware design activity consisting of mechanical system design and electronic circuit system design.

a. Software design is the activity of designing software in the form of programs that aim to move hardware according to the desired tool function in the design.
b. Tool making is the process of making modules/tools.
c. Tool testing is the process of testing a system or tool as a whole by comparing it to the conceptual framework that has been implemented.
d. Measurement and data collection are activities that involve taking measurements from each specified measurement point and taking data that will be created in a measurement table.

METHOD

The research approach is the whole way or activity in a research that starts from formulating the problem to making a conclusion. The type of research used is experiment by designing, testing, and measuring at the measurement points that have been determined. The discussion is done using the descriptive analysis method, namely by explaining how the circuit works based on the facts of the measurement results obtained.

The research location is a place or object for conducting a research. This research activity will be carried out at the research location, namely the Electronics Laboratory of STIKes Binalita Sudama Medan, JL. PBSI Building No.1, Dusun Kenangan Baru, Medan Estate. This research was conducted over a period of 3 months, namely February 2022 to May 2022. Operational Definition of Variable means to briefly explain the variable. The research in writing this final assignment entitled "improving the quality of blood infusion warmer equipment by adding an over temperature sensor as its protection system". Lifting one independent variable and one dependent variable, one independent variable is a digital thermometer and the dependent variable is a temperature of 36oC, 37 oC, 38 oC.

RESULT

Result Communication Protocol

Digital pins 1 and 0 are Arduino serial pins which are usually used to connect Arduino to a Bluetooth module.

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Serial Communication

Serial communication is generally used to exchange data between Arduino circuit boards and other serial devices such as computers, displays, sensors, and so on. There is at least one serial port on each Arduino board. Serial communication occurs on digital pins (RX) and 1 (TX) as well as via USB.

The presence of a serial software library and digital pins allows Arduino to support serial communication, allowing users to connect multiple serial-enabled devices and leave the main serial port available for USB. Serial ports on software use a pin-change interrupt system to communicate. There is a built-in library for serial communication. The only downside to serial software is that it requires more processing and cannot support the same high speeds as serial hardware.

SPI

SPI or Serial Peripheral Interface is a serial data protocol used by microcontrollers to communicate with one or more external devices in bus-like conditions. SPI can also be used to connect 2 microcontroller devices.In an SPI bus, there is always one device that is considered the master device, and the rest are peripheral devices.

In most cases, the microcontroller is generally considered the master device. And the SS (Slave Select) pin is responsible for determining which device is communicating with the master. Typically SPI enabled devices always have the following Uno ISP pinout:

1. MISO (Master In Slave Out), which is the line for sending data to the master device.
2. MOSI (Master Out Slave In), which is the master line for sending data to peripheral devices.
3. SCK (Serial Clock), which is a clock signal generated by the master device to synchronize data transmission.

I2C

I2C is a communication protocol that is also commonly called I2C bus. This protocol is specifically designed to allow communication between components on a single circuit board. In I2C there are two cables, namely:

1. SDA (Serial Data), is the path used to send data.
2. SCL (Serial Clock), is a clock line designed to synchronize data transfers.

Each device on the I2C bus has a unique address. Users can connect 255 devices on the same bus.

1. AREF pin, serves as a reference voltage for analog input.
2. INTERRUPT pins, consisting of INT0 and INT1 on Arduino.
3. External interrupts, namely system interrupts that occur when there is external interference. The general use of this interrupt is to read the encoder-generated square wave or wake the processor in an external event.

There are at least two forms of interrupts, namely external interrupts and pin change interrupts.

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Potentiometer

Potentiometer (POT) is one type of Resistor whose Resistance Value can be adjusted according to the needs of the Electronic Circuit or the needs of the user. Potentiometer is a Resistor Family that is included in the Variable Resistor Category. Structurally, the Potentiometer consists of 3 Terminal legs with a shaft or lever that functions as a regulator. The image below shows the Internal Structure of the Potentiometer along with its shape and Symbol.

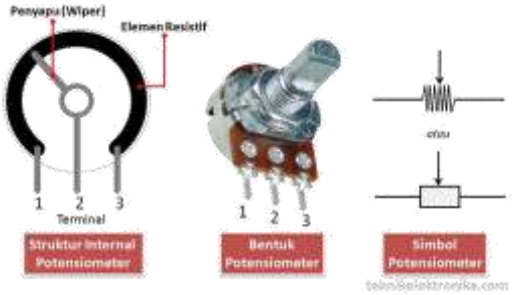

Figure 7. Potentium meter

The type of potentiometer used in this circuit is a Rotary Potentiometer, which is a potentiometer whose resistance value can be adjusted by rotating its wiper along a circular path. Usually using the thumb to rotate the wiper. Therefore, the Rotary Potentiometer is often also called the Thumbwheel Potentiometer. In the experiment, the potentiometer is used to adjust the LCD contrast voltage.

Ribbon Cables and BreadBoards

In this circuit, a Ribbon Cable is used, this type of cable is often also called a Rainbow Cable and is usually used in applications or electronic circuits that require many conductor wires as connectors. Ribbon Cables that have high flexibility are generally used in circuits that require low voltage, especially in digital system circuits. Ribbon Cables are generally divided into 3 types, namely, Male to Male, Female to Male, and Female to Female. This cable is used as a Jumper cable with a Solderless system that is connected in an arranged manner on a breadboard.

Result Software

The software used in this circuit is ARDUINO IDE. Arduino IDE is software used to create programming sketches or in other words Arduino IDE as a medium for programming on the board to be programmed. Arduino IDE is useful for editing, creating, uploading to the specified board, and coding certain programs. Arduino IDE is made from the JAVA programming language, which is equipped with a C/C++ (wiring) library, which makes input/output operations easier.

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Figure 8. Arduino IDE software

Basic Structure of Sketch Writing

Every Arduino program (usually called a sketch) has two functions that must be present in every program, namely:

Figure 9. void setup and void loop

1. *Void setup*(){}
   *Void setup*is a function that only runs the program inside the curly braces once.
2. *Void loop*(){}
   This function will be executed after the setup (void setup function) is complete, after being executed once, this function will be executed again and again continuously until the power supply is removed.

***Syntax*in Program Writing**

1. // (1 line comment)
   Used to provide comments or notes on the codes created.
2. /* */ (2 line comment)
   To write notes on multiple lines as comments.
3. {} (curly brackets)
   Used to define when a program block starts and ends and is also used in functions and loops.
4. ; (semicolon)
   Each line of code must end with a ; (semicolon), if a semicolon is missing the program will not run.

Features of the Arduino IDE Software

1. *Verify*used to compile or verify sketch coding whether there are still errors or not. If there is still wrong coding, usually a description appears below, namely error. Or in other words, verify is used to check whether the program created can run or not.
2. *Upload*used to send or enter programs into the specified board.
3. *New*used to open a new object or open a new sketch page.

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4. *Open*used to open a project that has been created, provided that the project has been saved.
5. *Save*is intended to save sketches or programs that have been created.
6. The Serial Monitor is used to display data that has been created after the sketch has been uploaded to the required board, then it will be run, and can be seen on the serial monitor.

Arduino IDE software menu

*Files,*In this file menu there are several features that can be used, namely:

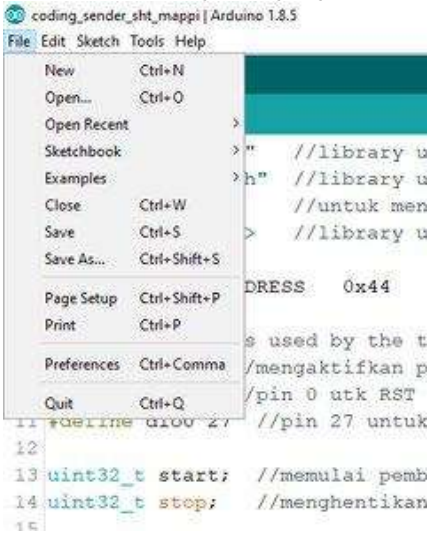

Figure 10. File Menu in Arduino IDE

a. *New (Ctrl+N),*used to open a new sketch sheet.
b. *Open (Ctrl+O),*used to open a project that has been created.
c. *Open Recent*, used to shorten the time in opening files that have been created.
d. *Sketchbook*, functions to show the sketch hierarchy that you want to create, including its folder structure.
e. *Examples*, contains coding examples.
f. *Close (Ctrl+C),*functions to close the Arduino IDE sketch or close the Arduino IDE software page.
g. *Save (Ctrl+S),*used to save sketches that have been created.
h. *Save as...(Ctrl+Shift+S),*functions to save sketches created with other names.
i. *Page Setup (Ctrl+Shift+P),*Set the page display during the printing process.
j. *Print*, functions to print sketches on printing machines.
k. *Preferences*, functions to add libraries to the Arduino IDE.
l. *Quit,*functions to exit the Arduino IDE software.

The following is a schematic of hardware design;

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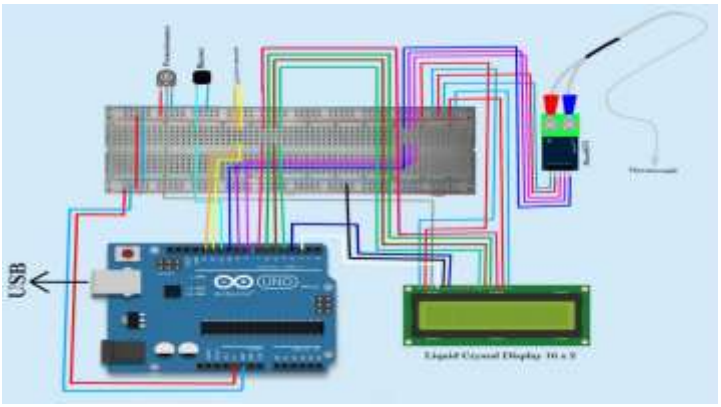

Figure 11. Circuit Wiring Schematic

Temperature Reading

The temperature reading is taken from the thermocouple which is displayed via the LCD with a reading period of every 5 seconds, the temperature displayed on the LCD corresponds to the temperature of the current room conditions. Performing an Overtemperature test by heating the sensor beyond The setting limit is > 37 ºC, the result is that the temperature sensor indicator displays the temperature exceeds 37 ºC on the LCD and activates the Buzzer indicator as a signOverheating occurs as read by the Thermocouple device.

Protection System

The device protection system refers to the disconnection of the current supply to the OUTPUT device, namely BloodWarmer, while the sensor device continues to work to measure the temperature in a period of every 5 seconds. After the temperature is read back below 37ºC then the current supply to the OUTPUT device is automatically returned. And the result is that the device can cut off the current to the OUTPUT and reconnect the current when the OUTPUT temperature has returned below the setting.

CONCLUSION

The conclusion from the analysis of the protection system for the quality of a blood warmer device based on over-temperature sensors is as follows: The protection system with an over-temperature sensor effectively prevents overheating of the blood warmer device. This is crucial to ensure that the warmed blood remains at a safe temperature, reventing damage to blood cells and reducing the risk of complications for the patient. Implementing an over-temperature sensor improves the accuracy of temperature control. The sensor quickly detects any temperature rise beyond the allowed limit and promptly activates protection mechanisms such as power shutdown or alarms, preventing device failures that could endanger patients. The sensor-based protection enhances the reliability and lifespan of the blood warmer. Equipped with this feature, the device can operate efficiently without suffering from undetected overheating, which could lead to damage. The over-temperature sensor protection system helps the blood warmer meet safety and health standards set by medical regulators. This boosts confidence in the device, particularly among medical

professionals who rely on it during blood transfusions. The use of a sensor-based over-temperature protection system not only increases safety but also positively impacts the overall performance of the device. It stabilizes the blood temperature, ensuring consistent quality of care delivered to the patient.

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