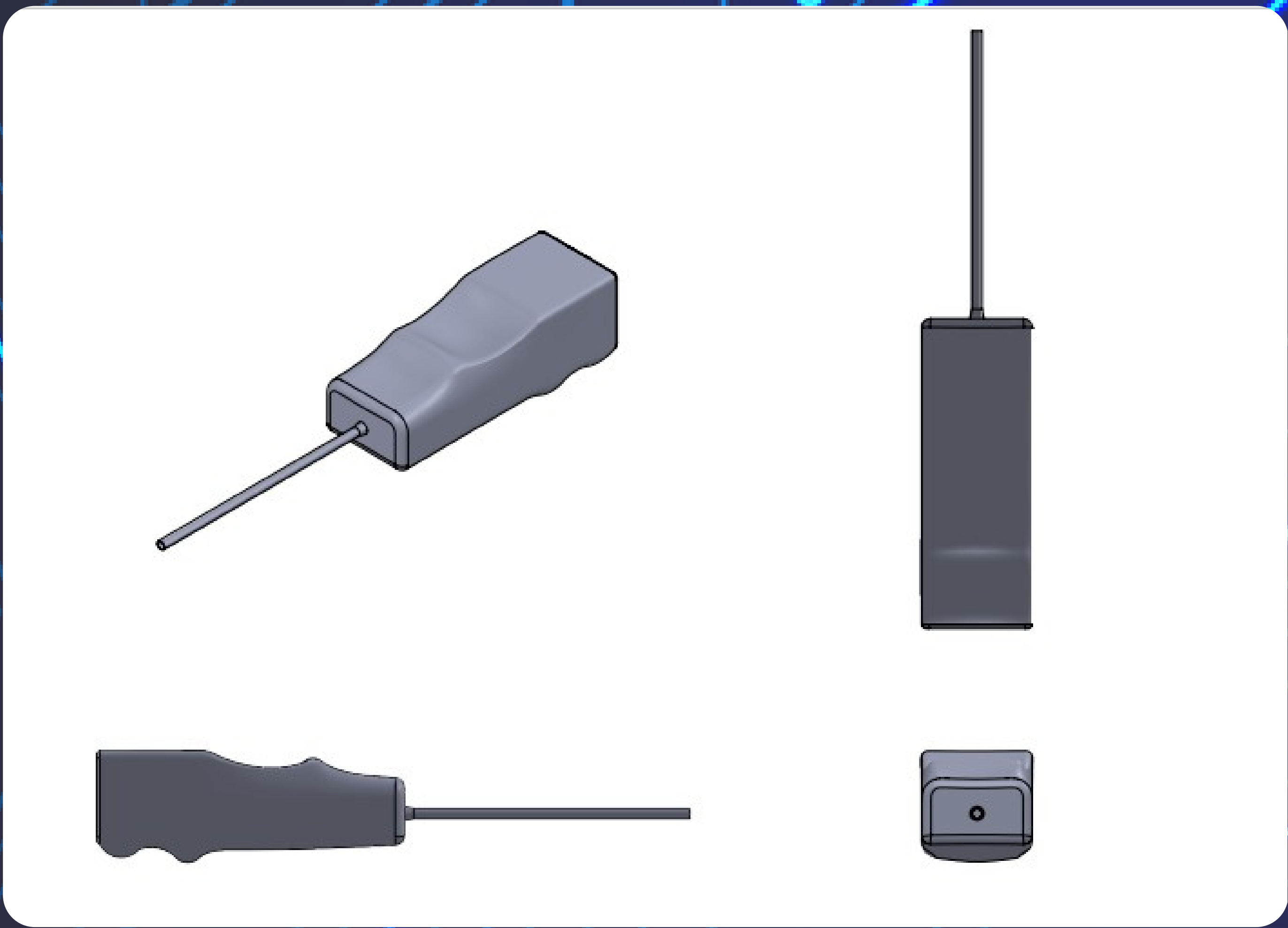
DIGITAL THERMOMETER



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Introduction:

Nowadays temperature sensors are digital chips that take in analogue reading, convert to digital and automatically condition their output signal for use in digital appliances. However, if previous iterations of the temperature sensor are observed, it is evident that an external signal conditioning system was required to ensure the analogue reading obtained was stable. The electronic circuit could also include filters to smoothen the reading further. In this case study, an instrumentation system based on an analogue thermistor sensor is built, along with external signal conditioning circuit, as well as display modules such as an lcd screen. Furthermore, the data obtained is transmitted to an external application that can illustrate real time change in readings, similar to IoT systems. The effectiveness and accuracy of the system is determined.

Background

A thermistor is a widely used temperature sensor that measures and monitors temperature changes in various applications. The name "thermistor" comes from combining "thermal" and "resistor," accurately describing its principle of operation.

This semiconductor device's electrical resistance varies with temperature. And it is typically composed of metal oxides like manganese, nickel, cobalt, or iron mixed with ceramic materials. These materials are then shaped into small beads or discs.

The specific metal oxide used determines the thermistors characteristics, such as its resistance temperature relationship. In the most common type called a negative temperature coefficient (NTC) thermistor the resistance decreases as the temperature increases. On the other hand, positive temperature coefficient (PTC) thermistors show an increase in resistance with a rise in temperature.

NTC thermistors are more frequently utilized due to their higher sensitivity and broader operating range.

The relationship between temperature and resistance in a thermistor is nonlinear meaning that the resistance change is not directly proportional to the temperature change. To accurately represent this behavior over a specific temperature range, a mathematical equation like the Steinhart Hart equation can describe the resistance temperature curve of a thermistor.

Thermistors offer several advantages as temperature sensors. They have a relatively small size, high sensitivity, fast response time, and wide operating temperature range. These characteristics make them suitable for a wide range of applications, including temperature control systems, automotive electronics, medical devices, HVAC systems, and more.

One important consideration when using thermistors is their self-heating effect. Due to the current passing through the thermistor, it generates heat, which can affect the accuracy of temperature measurements. To minimize this effect, thermistors are typically operated at low current levels or with short measurement intervals to allow for heat dissipation between readings. Thermistors are also available in different packaging configurations to suit specific application requirements. Common types include bead thermistors, which are small, encapsulated sensors that can be directly immersed in a fluid or placed on a surface, and glass-encapsulated thermistors, which are hermetically sealed for improved stability and protection.

In summary, thermistors are versatile temperature sensors that utilize the change in resistance with temperature to measure and monitor temperature variations. They offer advantages such as small size, high sensitivity, and wide operating temperature range. By accurately measuring temperature, thermistors enable precise temperature control and monitoring in various industrial, commercial, and consumer applications.

Literature Review

Thermistors are widely used temperature sensors known for their high sensitivity and accuracy. To understand the recent advancements in thermistor technology, let's review some relevant literature and explore the latest developments in this field.

"Characterization of NTC Thermistors for Temperature Measurement" by N. Ahmed and A. F. M. Arifuzzaman: This research paper discusses the characterization and calibration of negative temperature coefficient (NTC) thermistors. The paper "Design and Modeling of Thin Film Thermistors" authored by V.

N. Singhal et al. delves into various techniques and methods used to determine the resistance temperature relationship in thermistors and enhance their accuracy in temperature measurements. This study also emphasizes the benefits of thin film thermistors, including their low power consumption, rapid response time, and potential for miniaturization. Furthermore it explores the fabrication techniques and performance characteristics of thin film thermistors specifically for high temperature applications.

In another research work titled "Development of Self Heated Thermistors for Temperature Measurement" by M. A. Khan and H. F. Britton. The focus lies on enhancing precision in temperature measurements through the development of self heated thermistors. The paper extensively discusses self heating compensation techniques such as constant current excitation and Wheatstone bridge configurations.

It also highlights the advancements in self heated thermistor design along with their applications in precise temperature sensing.

Additionally R.J Collier and R.M Crooks present a review paper called "Thermistors for Biomedical Applications" that explores the utilization of thermistors in biomedical settings. This comprehensive review discusses the requirements and challenges involved in temperature measurements for medical devices and systems. The authors shine a light on recent advancements in thermistor technology such as miniaturization, wireless sensing capabilities, and integration with wearable devices which make them ideal for healthcare monitoring and diagnostics.

It is worth noting that recent advancements in thermistor technology have been centered around improving accuracy. Minimizing size. Reducing response time. Integrating with emerging technologies. Some notable developments include:

Thin Film Thermistors: Thin film thermistors offer advantages such as low power consumption, faster response time, and the potential for integration into microelectronic devices. They are manufactured using deposition techniques like sputtering or chemical vapor deposition, enabling precise control over their properties and dimensions.

Self-Heating Compensation: Researchers have been working on developing advanced self-heated thermistors that minimize the self-heating effect and improve measurement accuracy. Techniques like constant current excitation and bridge configurations help compensate for self-heating and enable more accurate temperature readings.

Miniaturization and Integration: With the increasing demand for miniaturized sensors, thermistors have also undergone miniaturization to fit into smaller spaces. This advancement allows for their integration into compact electronic devices, wearables, and Internet of Things (IoT) applications.

Wireless Thermistors: Integration of thermistors with wireless communication technologies, such as Bluetooth or Zigbee, allows for remote temperature monitoring and data transmission. This enables real-time temperature sensing and monitoring in various applications, including industrial processes, environmental monitoring, and healthcare.

Enhanced Material Properties: Ongoing research focuses on developing new thermistor materials with improved stability, accuracy, and reliability. This includes exploring novel oxide materials, nanocomposites, and hybrid structures to enhance the performance and durability of thermistors.

In summary, recent advancements in thermistor technology have brought improvements in accuracy, miniaturization, response time, and integration capabilities. Thin film thermistors, self-heating compensation techniques, wireless capabilities, and enhanced material properties are some of the key areas of development. These advancements pave the way for the application of thermistors in diverse fields such as healthcare, automotive, aerospace, and IoT devices. Further research and development in thermistor technology are expected to drive innovation and enhance their performance in temperature sensing applications.

Commercial Product

NTC Thermistors (Negative Temperature Coefficient):

NTC (Negative Temperature Coefficient) thermistors are highly popular and extensively utilized in industries. These thermistors exhibit a characteristic whereby their resistance decreases in response to increasing temperatures. They are crafted from semiconductor materials like manganese, nickel or cobalt oxides which possess temperature coefficients. NTC thermistors find application in areas such as equipment, consumer electronics, automotive systems and HVAC systems, as reliable temperature sensors. The estimate cost is in range of 200-400 rm depend on the applications

PTC Thermistors (Positive Temperature Coefficient):

PTC thermistors have a positive temperature coefficient, meaning their resistance increases as the temperature rises. They are typically made from ceramic materials containing barium titanate or other similar compounds. PTC thermistors are often used as self-regulating heating elements, overcurrent protectors, and in motor starting applications. The estimate cost is in range of 20-4000 rm depend on the applications

ICL Thermistors (Interchangeable Thermistors):

ICL thermistors are designed to have a highly accurate and well-defined resistance-temperature relationship. They are used as standard reference resistors for temperature measurement and calibration purposes. These thermistors provide a predictable and repeatable response, making them suitable for high-precision applications. The estimate cost is in range of 3-30 rm depend on the applications

Epoxy-Coated Thermistors:

Epoxy-coated thermistors are NTC or PTC thermistors encapsulated in a protective epoxy resin. The epoxy coating provides mechanical protection, making them more robust and suitable for applications where they might be exposed to environmental factors like moisture, dust, or chemicals. The estimate cost is in range of 10-60 rm depend on the applications

Glass-Encapsulated Thermistors:

Glass encased thermistors are securely sealed within glass enclosures ensuring stability and protection, against factors. These thermistors find use in areas such as medical devices, laboratory equipment and even aerospace applications, where precision and dependability are of utmost importance. The estimate cost is in range of 3-20 rm depend on the applications

Surface-Mount Thermistors:

Surface-mount thermistors are designed for easy integration onto printed circuit boards (PCBs). They come in compact packages and can be directly soldered onto the PCB, making them suitable for high-volume manufacturing processes and compact electronic devices. The estimate cost is in range of 2-40 rm depend on the applications

Probe Thermistors:

Probe thermistors consist of a thermistor element embedded in a metal or plastic probe. They are used for temperature measurements in liquids, gasses, and surfaces. Probe thermistors find applications in food processing, environmental monitoring, and industrial automation. The estimate cost is in range of 25-400 rm depend on the applications

Chip Thermistors:

Chip thermistors are small, bare-bone thermistor elements without additional packaging. They are commonly used in applications where size constraints are significant, such as medical implants, wearable devices, and miniaturized electronics. The estimate cost is in range of 15-1500 rm depend on the applications

Links for all commercial products listed are provided in the references section.

Mechanical Design:

Instrumentation System

An Instrumentation system is a device that "converts an unknown quantity into a record or display which human faculties can interpret." [13]. This unknown quantity is often an external stimulus that influences the changes in properties of an entity that are measurable. Hence by relating the known change of property by the change in stimuli; it can be quantified and thus monitored, and controlled. In this project, the stimulus to be measured is temperature - a fundamental scalar quantity - using a thermistor device.

The following figure will illustrate and visualize the thermistor's instrumentation system via a block diagram. After which each block/step will be explained.

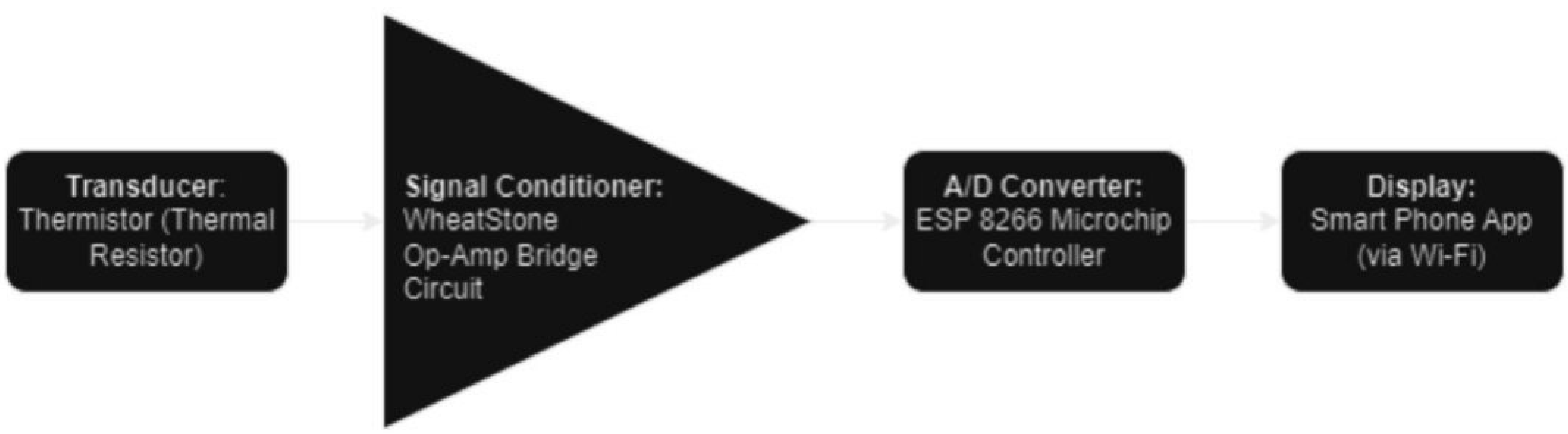


Figure. Block Diagram of Thermistor Instrumentation System

Transducer:

The diagram starts with the input transducer; the sensor that first reacts to the external stimuli - temperature; which is the thermal resistor or Thermistor. This type of resistive transducer experiences a decrease in resistance as the temperature that is sensed by the component surface increases. The change in resistance to temperature is not always linear; which was proven to be the case in this project.

Signal Conditioner:

A signal conditioner is often a circuit that is used to prepare the transducer output signal - in this case change in resistance - to be read by the computer/microchip controller. The signal conditioner used in this temperature sensor is a wheatstone bridge circuit. This circuit consists of 4 resistors in a diamond or "bridge" configuration; three of which act as reference and the fourth being the thermistor. A voltage divider can then be connected (like a bridge) between the reference and the thermistor sides; and the potential difference can be obtained and input into the Op-Amp Circuit featuring a microchip.

The signal can then be said to be conditioned after the Op-Amp circuit outputs an analog signal in the form of voltage; which is to be sent to the A/D converter and processor.

Please refer to the next chapter for a more detailed explanation on the signal conditioning circuit used in this project.

A/D Converter & Computer:

This component in the instrumentation system is normally solely for the purpose of converting the analog voltage signal to a digital one that can be understood by the computer. However, the computer used in this project is equipped with an in-built A/D converter pin; hence reducing the number of components needed.

The microchip controller used in this project is the ESP 8266 board. One of the most common boards following the Arduino Uno. The decision to use the ESP board was due to its built-in Wi-Fi transmitter; which will be used to send the digital output to the display - a smartphone. This feature was found lacking in the Arduino Uno version that was available.

The ESP computer chip was programmed to perform a series of calculations in order to convert the digital output to the final temperature reading and send the output to, via Wi-Fi, to the display.

Please refer to the next chapter for a more detailed explanation on the code used to program the ESP 8266 board.

Display

The display is the final station to obtain the output of the thermistor instrumentation system. It receives the data transmitted from the ESP board via Wi-Fi and "prints" it to the smartphone screen via an application.

Physical Design

There are several electrical components involved in this thermometer, many of which are somewhat fragile and may be damaged easily if they come in contact with liquids. Considering that a thermometer may be used in various settings; which include the measuring of liquids, a protective enclosure must be designed and created in order to ensure the functionality of the instrument. In addition, designing the thermometer case must take into consideration the user interaction with the instrument.

The design of the enclosure must be compact, sturdy, durable, and easy to handle while also ensuring that all the electrical components are away from any fluid and are well stabilized to prevent rattling around during handling. Moreover, if any component of the instrument were to malfunction or get damaged; the enclosure design must counter the ease of replacing the defective parts. Additionally, since the entire circuit relies on voltage power from a battery; it must be made convenient to replace the battery without having to unscrew any bolts.

Using a tray was found to be the best solution. The tray is connected with the cap; which slides out of the thermometer shell to reveal all the components in an easily accessible way. The batteries were made on top as changing the batteries is more likely to be the reason the tray is used. The tray is supported by two pillars to decrease the load on the cap and to account for the small thickness of the tray shelves. The components are fitted with brackets to be slid into the trays.

In the technical drawings, it can be immediately noticed that the shell of the thermometer is shaped in a unique way. This design was specifically developed in order to provide maximum grip and comfort while handling the thermometer. The grooves at the bottom are for the user's fingers to rest on, while the one at the top is for the thumb. This profile of the shell ensures the instrument does not slip from the user's hands and potentially drop into a liquid while trying to measure its temperature.

Material Selection

The materials used to manufacture the thermometer enclosure depend on various factors. One of which is the temperature range that the thermometer is expected to operate in. For this project, the thermometer is mainly focused on measuring temperatures around 0 and 100 °C; which is usually for cooking purposes.

The chosen material for this application was PBT plastic. This type of plastic is known for its durable and long-lasting properties. According to the Ensinger.com website, PBT possesses great strength, rigidity and most importantly great dimensional stability when exposed to high temperatures. It is also suitable for food processing applications due to its corrosion resistance against cleaning solutions. Hence the probe can be safely wiped using cleaning solutions without fear of wearing the material. [14]

Fabrication Technique:

The manufacturing process used to produce the thermometer casing must certainly be suitable to its application, material and cost. Injection molding is the most common method of production when it comes to plastic products. This is due to its ease and semi (if not fully) automatic nature.

The PBT plastic pellets of the desired color are simply melted and injected into a mold that has the impression of the required product. The tray can be easily made by assembling two different sizes of plastic sheets into the cap; or for convenience it can be also made by injection molding.

The parts are trimmed and cleaned before being inspected for errors and defects. The components (such as the battery, breadboard and ESP board) are then fitted with standard brackets and slid into the tray - battery being on the top shelf. The thermistor probe is inserted into the probe tube to protrude to the surrounding, then the tray cap assembly is inserted into the thermometer shell to complete the production of the thermometer.

Electrical Design:

Signal Conditioning System:

As previously mentioned, an external signal conditioning circuit is used for the instrumentation system. For this project, a wheatstone bridge circuit is implemented. Unlike a common wheatstone bridge circuit, where three constant resistors along with a transducer are used. For this circuit, two constant resistors, a potentiometer and the thermal transducer are used. The application of the potentiometer is to vary the voltage divider within the bridge, until the output of the bridge only depends on a change of the transducers resistance.

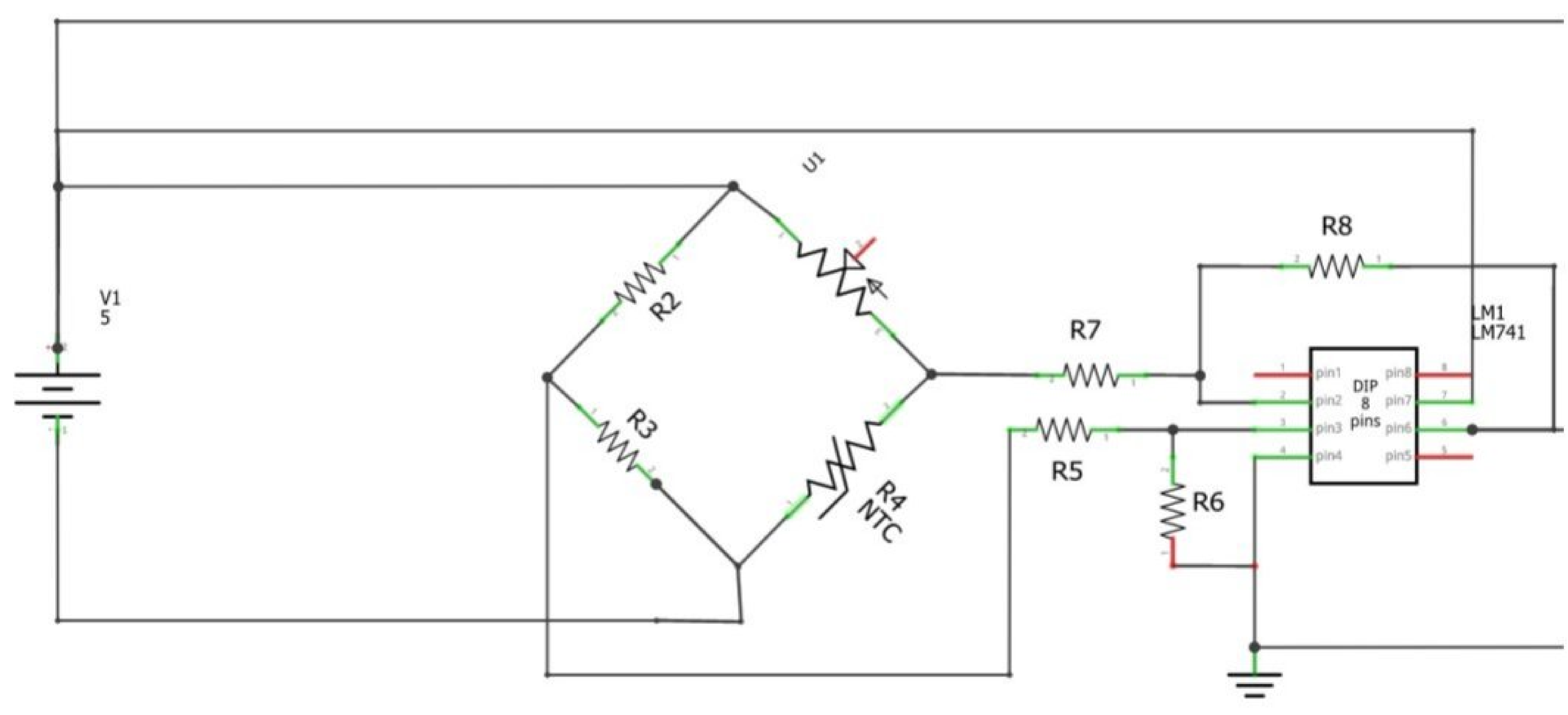


Fig Signal Conditioning Schematic

As illustrated in the circuit schematic above, resistor R2 and R3 are constant resistors, whereas R1 is a variable resistor, and R4 is the NTC transducer. This circuit design simplifies the balancing process required.

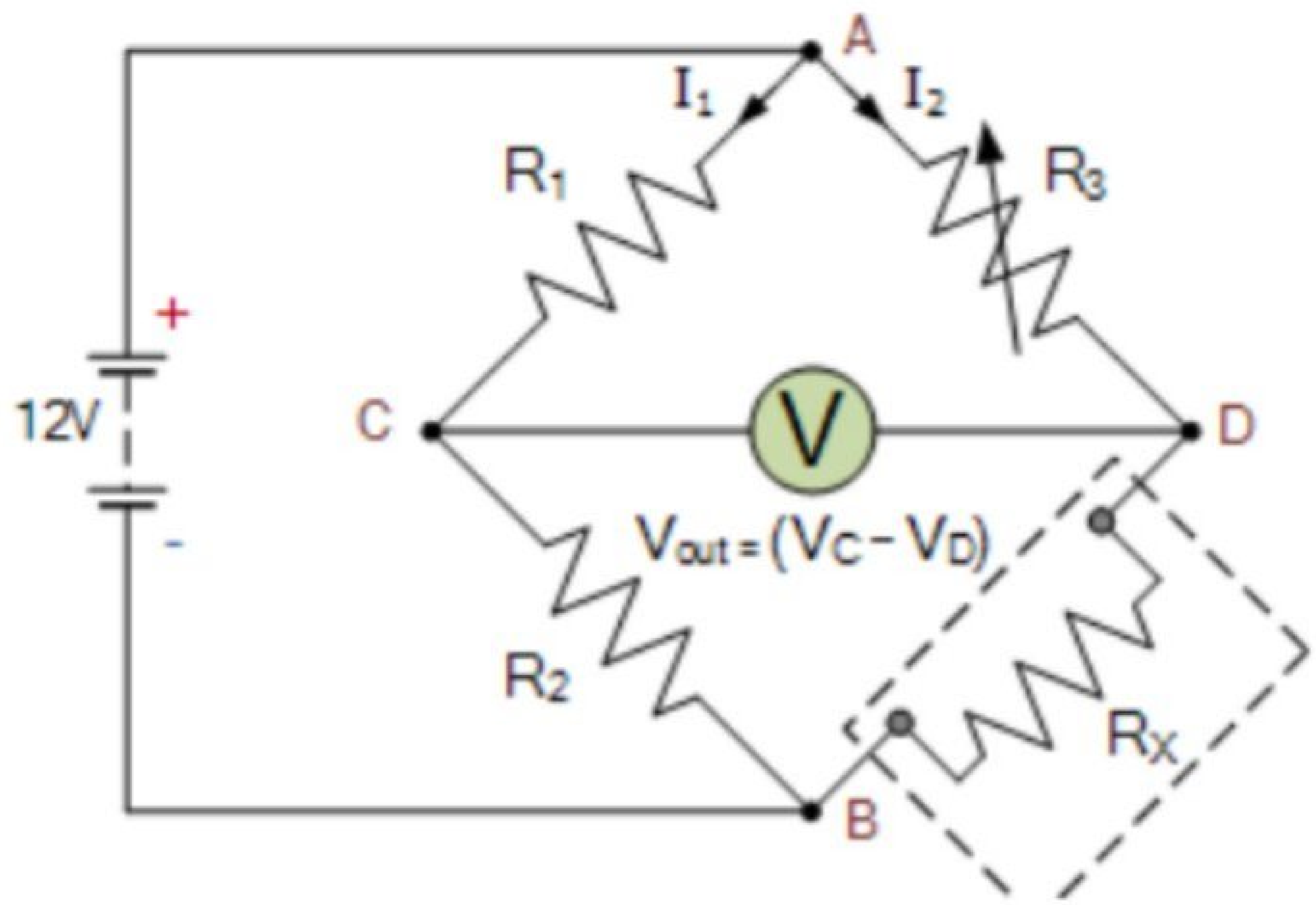


Fig. Wheatstone Bridge Calculation

As illustrated in the figure above, the purpose of the wheatstone bridge is to limit the factors affecting the output of the circuit. For a temperature sensing circuit, with a transducer at Rx, the only factor affecting the output voltage should be the varying resistor of the transducer due to change in temperature. Hence, by including a potentiometer/variable resistor at R3, the leg of the voltage divider can be adjusted. For an unknown resistance at Rx, the resistor at R3 can be adjusted until voltage at point C is equivalent to voltage at point D. Similar to the equation below.

$$\frac{R_1}{R_2} = \frac{R_3}{R_x} = 1\ (\text{Balanced})$$

The circuit is balanced when both legs of the wheatstone bridge have equal resistance ratios. Once the circuit is balanced, the output voltage is calculated:

$$Vout = Vc - Vd$$

Hence, any arbitrary value of R1 and R2 can be set that simplifies the process of balancing. For this case study, R1 and R2 are both $30K\Omega$ resistors. The potentiometer's maximum resistance is also $30K\Omega$, whereas the resistance of the transducer varies largely according to its probe temperature. However, this configuration allows a very easy balance, and the voltage at point C differs by only 0.05 V from voltage at point D, which is a negligible error.

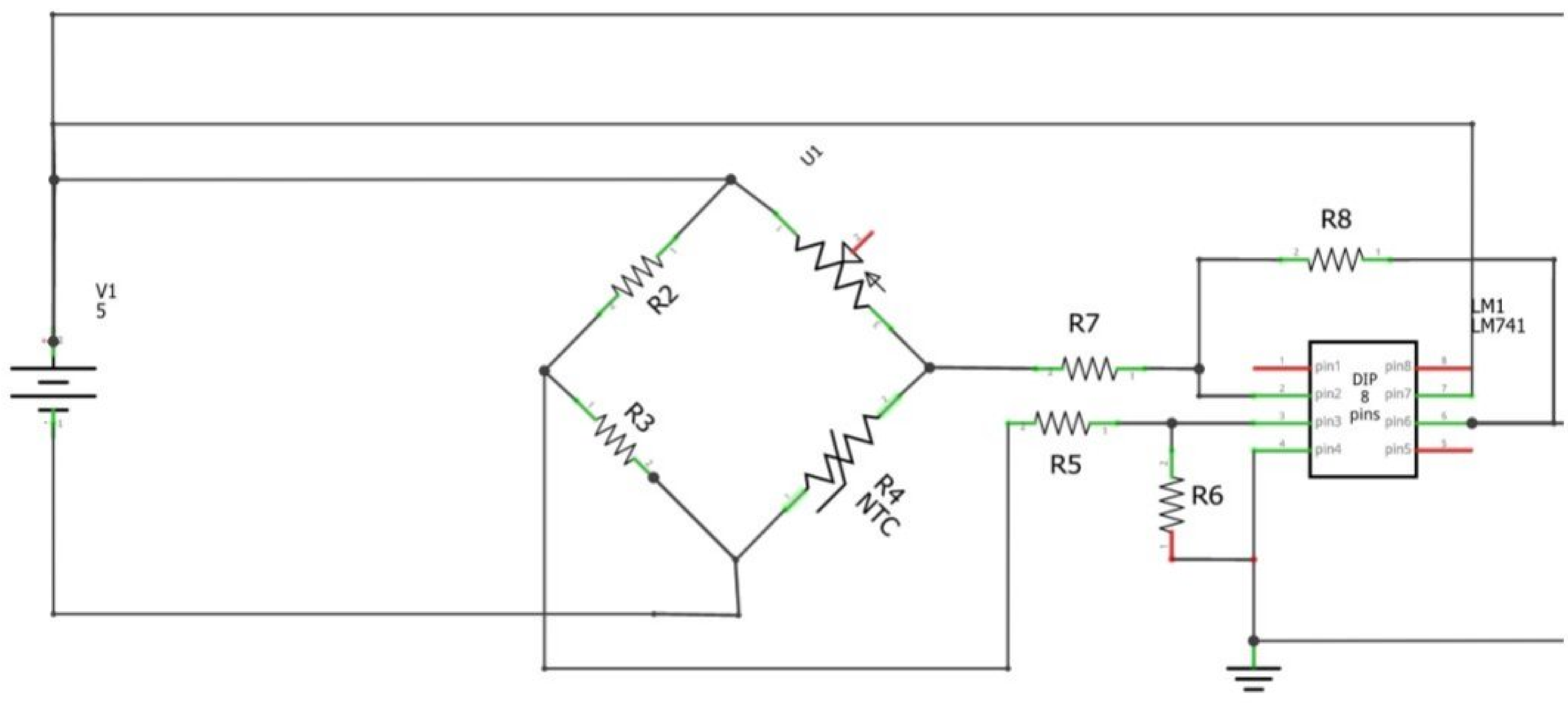


Fig Signal Conditioning Schematic

Observing the signal conditioning once more, an op-amp is also included within the circuit. As illustrated above, the output of the wheatstone bridge from point C and D follows through to the amplifier. Analyzing the configuration of resistors, it is a differential circuit that essentially subtracts the voltages at point C and point D, which is the output voltage, and then either attenuates or amplifies it. The choice between amplification and attenuation lies in the application of the voltage. If the voltage is too high, it can be attenuated, whereas if it is too low, the amplifier can be used to amplify the output. The main principle behind it is the gain value of the amplifier.

Firstly, to simplify the differential amplifier analysis, certain assumptions for the resistors are made as shown below.

$$R6 = R8$$

$$R5 = R7$$

Hence, the gain of the inverting differential circuit can be calculated using the equation below.

$$Gain\ (A) = -\ (R8/R7)$$

Hence, the output voltage of the differential amplifier can be written as:

$$Vout = A(V2 - V1)$$

If gain A of the inverting differential circuit is lower than 1, the circuit will attenuate the signal, whereas if it is higher than 1, the circuit will amplify the output voltage. The purpose of this output voltage is to be used as input to the ESP8266 board in order to convert the voltage change to temperature using the calibration equation of the transducer.

Components:

The components used in this signal conditioning circuit are as follows.

- ESP8266 (WiFi Board)
- BreadBoard
- Cables/Jumper wire
- Resistors
- Potentiometer
- Capacitor
- NTC Thermistor Probe

- Op-Amp LM324N
- LCD Screen/ Arduino Serial Monitor

The component selection can be justified through the discussion above. A potentiometer allows variation of resistance which simplifies the balancing process of the wheatstone bridge. The capacitor chosen can be used in a low pass filter circuit to smoothen the output from the differential amplifier. Furthermore, an ESP8266 is chosen instead of an arduino board, particularly due to its wireless capabilities. By using an application like Blynk IOT, the ESP8266 board can send sensor data wirelessly to a phone app or a website, where it can be viewed by the user in order to monitor their instrumentation system instead of an Arduino Serial Monitor. Lastly, the probe transducer is selected due to its ease in use, the probe extends and can be dipped into any liquid to check its temperature, without causing any water damage to its base circuit.

Overall Circuit Schematic

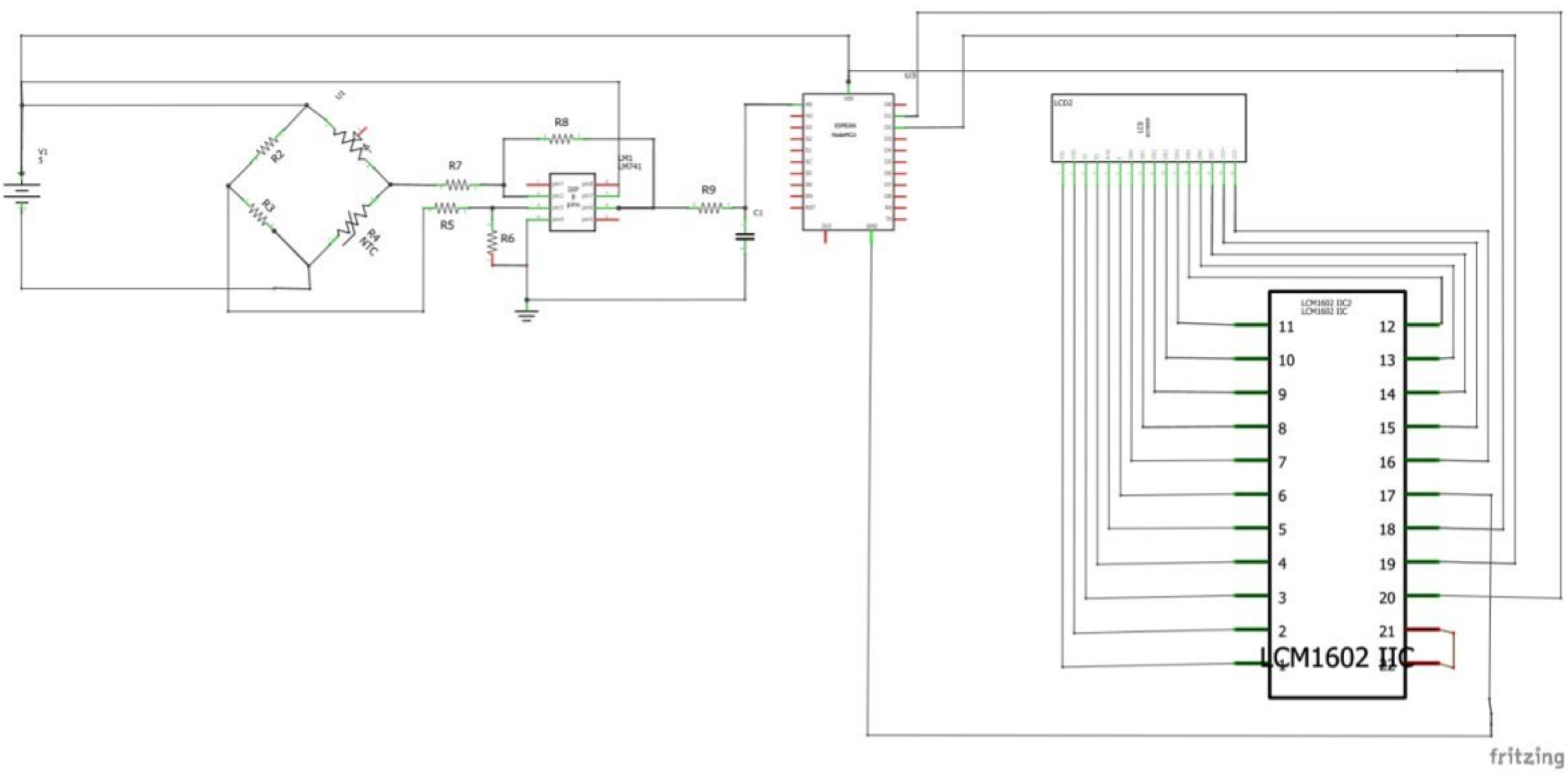


Fig. Overall Circuit Schematic

System Flowchart:

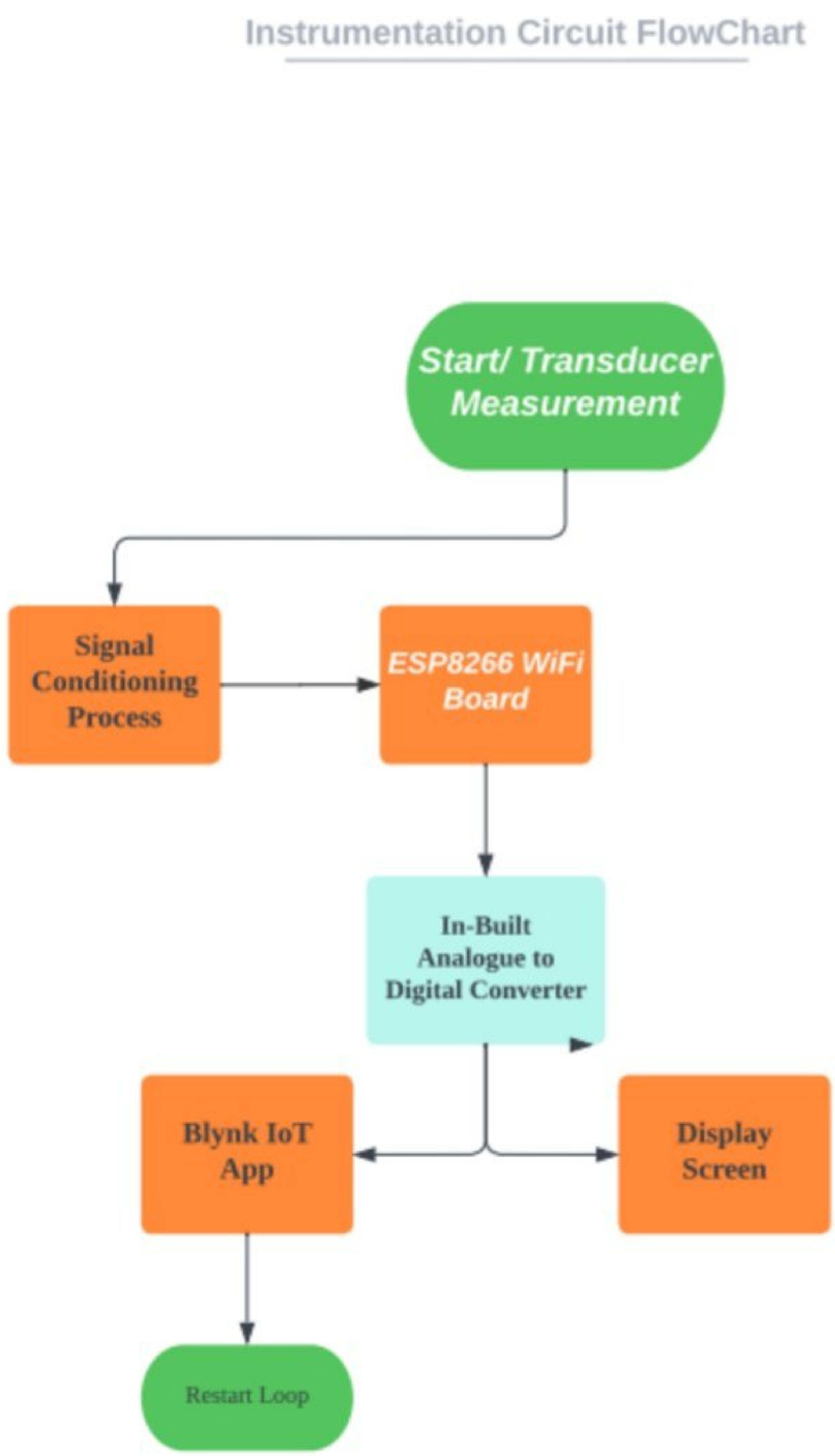


Fig. System Flowchart

Observing the system flowchart as shown above, a general outline of the process is shown. A detailed overview of the process can be seen using the algorithm steps shown below.

1. Transducer Measurement starts the Process
2. The transducer's output voltage undergoes signal conditioning through the wheatstone bridge and the differential amplifier
3. The output of the differential amplifier is sent to the ESP8266 Wifi Board
4. Using the Arduino IDE program, the board can be programmed to convert the 10bit reading back to voltage. Furthermore, using the calibration equation obtained, convert the voltage reading to a suitable temperature value.
5. This value is then sent to the LCD screen to display, or virtually written to a datastream in the Blynk IOT App
6. The Blynk IOT App displays the value through its cloud, however a timer in the Blynk IOT program pings the temperature value multiple times a second, repeating the loop.
7. The loop repeats each second within several intervals, to ensure the reading obtained is consistent. If any change is sensed by the probe transducer, it is shown on the screen and the Blynk IOT app.

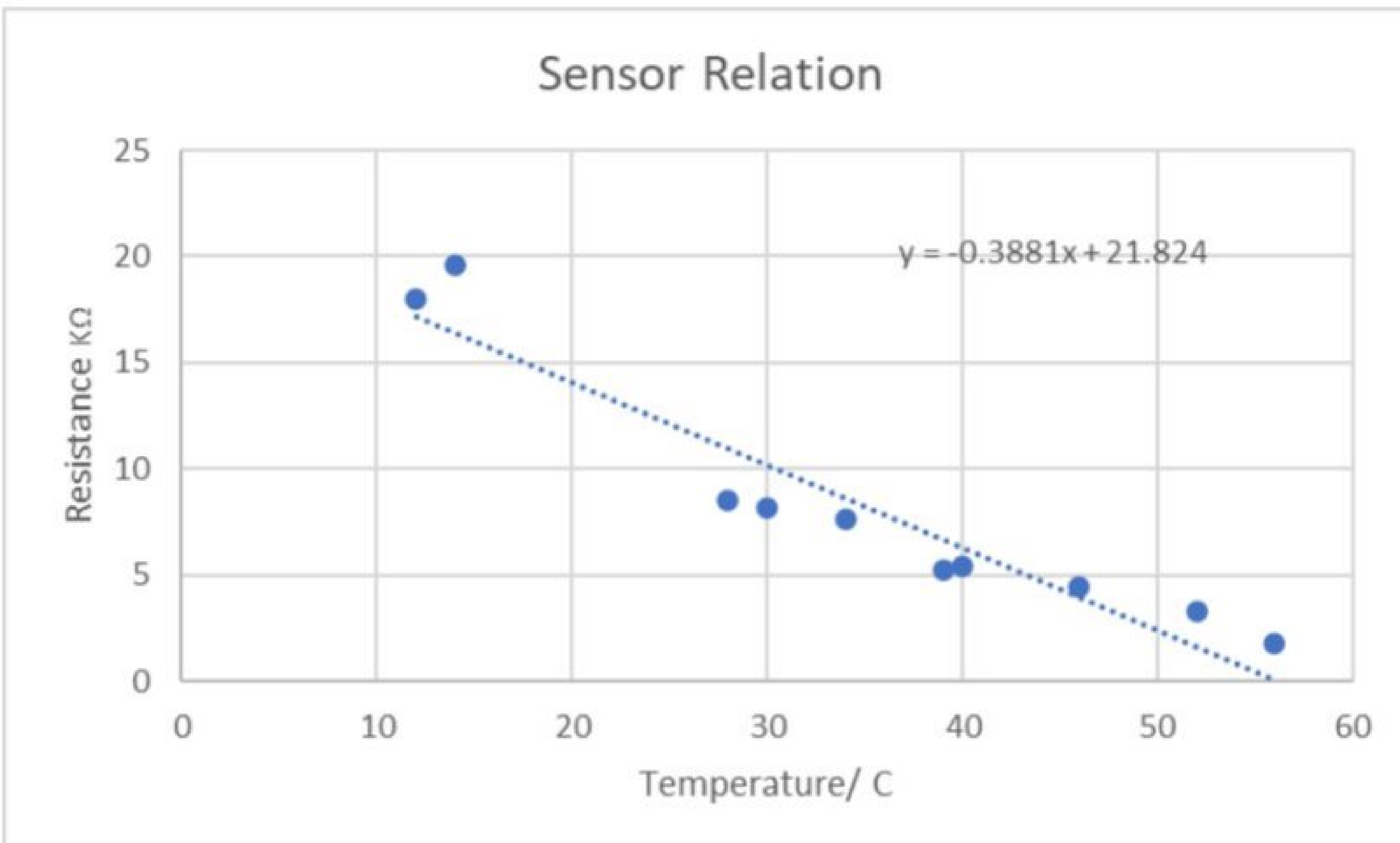
Sensor Transfer Equations

As shown in the flowchart above, the ESP8266 board has to convert the 10-bit voltage value to a temperature reading. Although this transfer equation is usually stated in the data sheet of a thermistor component, the particular thermistor probe used couldn't be identified with a datasheet. In such scenarios, it is essential to equate the relationship of the transducers resistance change with respect to temperature. For this test, the transducer is used at varying temperatures and the resistance is measured using a multimeter, ten such readings were carried out as shown tabulated below.

Temperature/ C	Resistance KΩ
28	8.5
12	18
14	19.6
56	1.8
30	8.2
34	7.6
40	5.4
39	5.2
46	4.4
52	3.3

Table1. Resistance and Temperature relation for sensor

As such, a scatter diagram can be plotted from the data and the trendline can be equated. The results are illustrated in the figure below.



The line equation is found to be $Y = -0.3881X + 21.824$

As expected of a NTC thermistor probe, the resistance of the probe decreases as temperature is increased, hence the linear equation obtained is accurate. This relation is then used to derive the relation of the output voltage and variation in temperature. As previously mentioned, in the equations above.

$$Vout = Vc - Vd$$

Observing the circuit schematic once more, the voltage at point C is a constant 1.65 V. Using a simple voltage divider calculation as R2= R3, with an input of 3.3 V.

$$Vc = 1/2\,(Vin) = 3.3/2 = 1.65\,V$$

Furthermore by balancing the wheatstone bridge, the potentiometer measures at 4.5 KΩ. Hence, the resistance of the probe can be used to find the voltage at point D and as such, the output voltage can be found, as tabulated below.

Temperature/ C	Output Voltage (V)
28	0.598
12	0.115
14	0.072
56	1.813
30	0.625
34	0.683
40	0.956
39	0.986
46	1.124
52	1.359

Table. Sensor Output Voltage Relation

The data can then be used to equate a linear relation between the temperature and output voltage of the circuit as illustrated below.

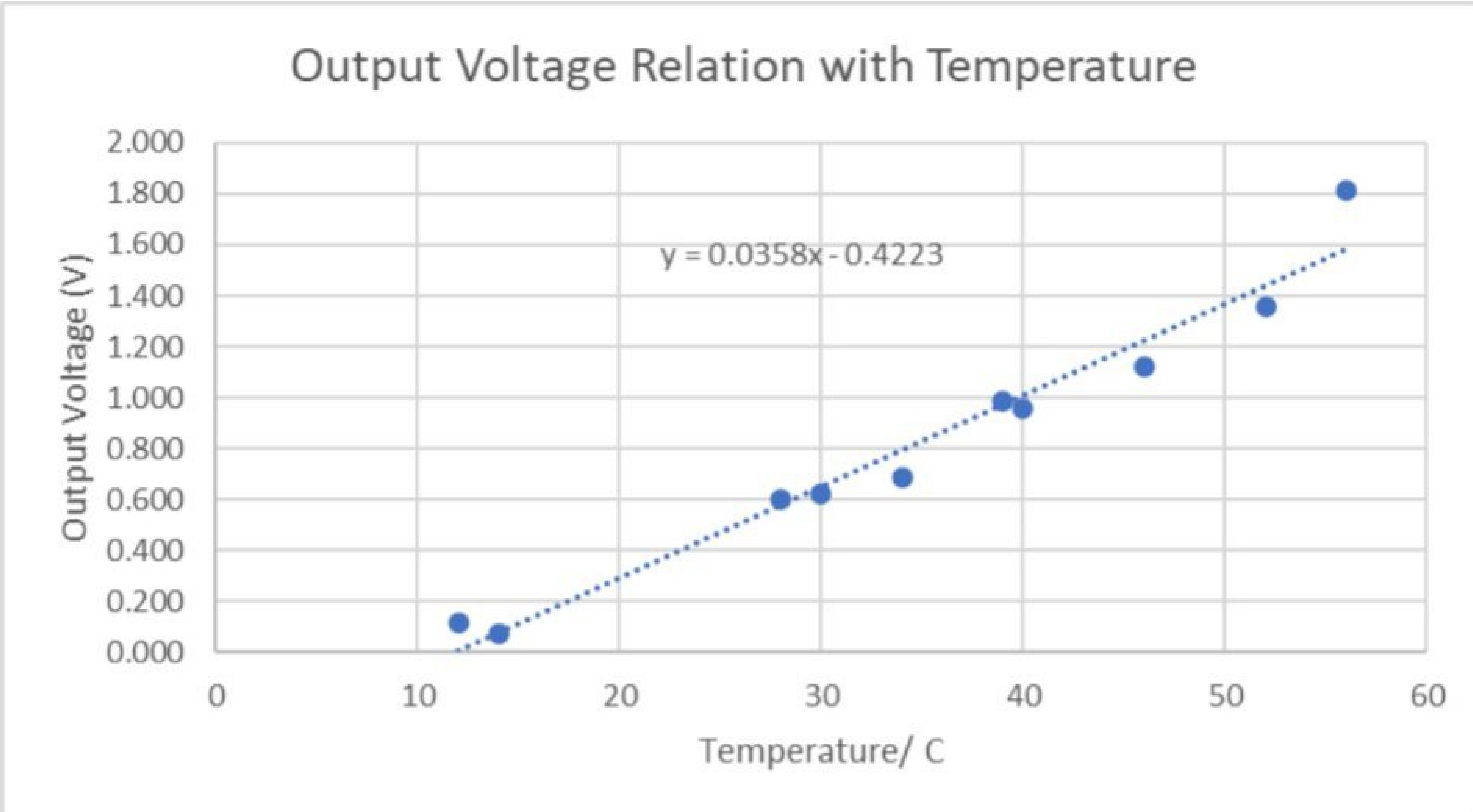


Fig. Temperature and Output Voltage Relation

Hence, the trendline equation is obtained to be:

$$Y = 0.0358X - 0.4223$$

As such, this equation is used with the output voltage (Y) as the subject to approximate the temperature measured by the thermistor probe sensor. This calculation is done as the analogue data of the voltage is sent to the ESP8266 Board, as shown in the flowchart diagram. However, it is important to distinguish between this approximation of temperature using a thermistor probe and the actual temperature value of the measured object. Hence, the next section outlines the accuracy of the thermistor probe as compared to a thermometer.

Sensor Accuracy Test

To test the accuracy of the sensors a procedure is followed.

- An object or liquid at a constant temperature, which is first measured using a conventional thermometer.
- Then measured using the temperature sensing circuit designed.
- The two values are compared to a test for accuracy.

For this particular case study, a glass of water at room temperature (26 ℃) which is measured using a conventional metal thermometer, is then measured using the thermistor probe circuit. The readings are repeated four times to obtain the average results. Furthermore, the error percentage in each reading is calculated and the average error is obtained as tabulated below.

Error Percentage Calculation		
True Reading/ C	Circuit Reading/C	Error Percentage
26	25.85	0.576923077
26	26.12	0.461538462
26	26.03	0.115384615
26	26.58	2.230769231
Average Error Percentange		0.846153846

Table.Percentage Error in Readings

The table above shows four readings at a true value of 26 ℃, and four readings taken using the temperature sensor circuit that vary from a minimum of 25.85℃ to a maximum of 26.58℃. Additionally, the average percentage error is calculated to be 0.846%,, a maximum error percentage of 2.23% and a minimum error percentage of 0.11%, all readings are within the limits of experimental accuracy.

Discussion

System Accuracy

As illustrated previously, the thermistor circuit has an average error percentage of 0.846%. Signifying that the system is accurate tot 99% of the true value. However, disregarding the error percentage of the system, as can be observed in table above, the error percentage varies frequently, from a minimum of 0.11% to a maximum of 2.2% or more.

This variation in accuracy can largely be attributed to the jumper cable connections. A breadboard is a temporary solution to soldering or using a PCB. It is not a permanent fix to many circuits in applications or projects. Mainly, due to the fact that, breadboard connections are fidgety and unsecure, hence causing many circuits to short, burning or damaging components which usually cannot easily be identified by the user. This results in random errors throughout the circuit. Although, this type of random error can easily be solved by using a PCB (Printed Circuit Board) or soldering which perfectly secures the wirings.

Furthermore, breadboards are also prone to systematic errors, such as faulty components inserted into the breadboard. Repetitive testing of the breadboard circuit may cause certain components to short or burn due to repetitive cycling of power through the system

. In this case study, such an offset error is present. Resulting from a faulty Op-Amp chip that provides a 1.4V offset value due to uneven wiring or burnt components that cannot be worked around,unless the whole circuit is replaced. Such an error can be identified using a multimeter to read voltage at various nodes across the circuit, however, as mentioned previously, it cannot be fixed. For this particular circuit, the offset was considered and programmed against in arduino IDE in order to obtain accurate readings.

Overall, considering all factors of error involved in the circuit design and implementation, real-time testing of the circuit proves the accuracy of the system to be well above 90% even through repetitive trials. It proves the effectiveness of the system as well as the instrumentation circuit.

ESP Programming

Aside from mechanical and electrical design of the instrumentation system, the pivotal factor in its operation was the programming for the esp8266 WiFi board within the system. The code allowed the circuit to broadcast the sensor data obtained wirelessly to an app that could be monitored easily by the user. For this project, the programming was done in Arduino IDE, with the following libraries included.

```
#include <ESP8266WiFi.h>
#include <BlynkSimpleEsp8266.h>
```

The ESP8266WiFi.h allows the microchip board to connect to a mobile hotspot to gain wireless capabilities, whereas the BlynkSimpleEsp8266.h allows the transmission of data to Blynk Cloud which can then be viewed on the app. The main principles behind the program are very basic.

- Credentials for the mobile hotspot are provided to the microprocessor

```
// WiFi credentials.
// SSID = Netowrk Name and PASS is password.
char ssid[] = "INSTRUMENTATION";
char pass[] = "espnodemcu";
```

- A timer event with uptime is set for the Blynk Cloud to monitor the operation time of the board.

```
BlynkTimer timer;

// This function sendss the uptime every second to Virtual Pin 2.
void myTimerEvent()
{
  Blynk.virtualWrite(V2, millis() / 1000);
}
```

- The constants to be measured are defined, along with a setup command to configure the esp8266 board with the Blynk application account using an authorization token and password

```
const int analogInPin= A0;

float Tempvalue = 0;
float voltageValue = 0;
int sensorValue = 0;


void setup()
{
  // Debug console
  Serial.begin(115200);

  Blynk.begin(BLYNK_AUTH_TOKEN, ssid, pass);
  timer.setInterval(1000L, myTimerEvent);

}
```

- Create the events for voltage and temperature values to be virtually written to Blynk datastreams

```
void myVoltageEvent()
{

  Blynk.virtualWrite(V4, voltageValue);  // Send the results to Gauge Widget
}
void myTempEvent()
{
  Blynk.virtualWrite(V5, Tempvalue);  // Send the results to Gauge Widget
}

```

- Lastly, a void loop is set up to ensure that the circuit measures the value from the probe with the timing intervals set, and to initiate the Timer and Blynk run commands

```
void loop()
{
  sensorValue = analogRead(analogInPin);  // Read the analog in value:
  voltageValue = (sensorValue * (3.3/1023)-1.4);
  Tempvalue = ((voltageValue+0.4223)/0.0358);
  Serial.print("Voltage = ");  // Print the results...
  Serial.println(voltageValue);  // ...to the serial monitor:
  Blynk.virtualWrite(V4, voltageValue);  // Send the results to Gauge Widget
  Blynk.virtualWrite(V5, Tempvalue);

  Blynk.run();
  timer.run();

}
```

In summary, the code ensures that the circuit outputs and receives the data as needed for the system to function properly. The data is processed using the code, whereas the electrical systems ensure the data is measured properly. The sync with the Blynk account is then used to display the results of the sensor and code towards the end user.

(The full code outline for the project is available within the appendix.)

Conclusion

The objective of this report was to configure a thermistor temperature sensing circuit from scratch, covering its mechanical, electrical and digital design. The following report covers the materials, the instrumentation system design, electronic circuit design as well as the components used and the programming required to fulfill the task.

In conclusion, coupled with transfer functions, test readings, accuracy tests and discussion, the instrumentation circuit design has fulfilled its primary objectives of functioning similar to a commercial thermal sensor. Additionally, with a 97% to 99% accuracy rating the system ensures its readings are stable and the instrumentation circuit functions perfectly, signifying the successful implementation of an instrumentation circuit and electronics involved.

References

1.N. Ahmed and A. F. M. Arifuzzaman, "Characterization of NTC Thermistors for Temperature Measurement," Proceedings of the International Conference on Electrical and Computer Engineering (ICECE), 2016.

2.V. N. Singhal et al., "Design and Modeling of Thin Film Thermistors," Journal of Sensors, vol. 2015, Article ID 963494, 2015.

3.M. A. Khan and H. F. Britton, "Development of Self-Heated Thermistors for Temperature Measurement," IEEE Transactions on Instrumentation and Measurement, vol. 58, no. 1, pp. 94-100, 2009.

4.R. J. Collier and R. M. Crooks, "Thermistors for Biomedical Applications," Measurement Science and Technology, vol. 16, no. 6, pp. R23-R36, 2005.

5..https://www.google.com/aclk?sa=l&ai=DChcSEwj4h_qdlZKAAxUqk2YCHVPuCzkYABANGgJzbQ&sig=AOD64_1u1FTYdRhY9v1AF2Q47LsAMPd3ig&ctype=5&q=&ved=2ahUKEwjx-PKdlZKAAxXp2DgGHRtaCq0Q9aACKAB6BAgHEBI&adurl=

6.https://www.google.com/aclk?sa=l&ai=DChcSEwjS3OGLlZKAAxW7mWYCHc6KALAYABAPGgJzbQ&sig=AOD64_0LzJvJiuS98iaAS46Gcq0yvqU-jg&ctype=5&q=&ved=2ahUKEwiJn9qLlZKAAxXP2DgGHUg_CLYQ9aACKAB6BAgGECw&adurl=

7.https://www.google.com/aclk?sa=l&ai=DChcSEwjS3OGLlZKAAxW7mWYCHc6KALAYABALGgJzbQ&sig=AOD64_1FEpTkxlnXv8KhUK9sYpbbnl2IGg&ctype=5&q=&ved=2ahUKEwiJn9qLlZKAAxXP2DgGHUg_CLYQ9aACKAB6BAgGEB4&adurl=

8.https://www.digikey.my/product-detail/en/murata-electronics/NCU18XH103D6SRB/490-18148-1-ND/9686728

9.https://www.google.com/aclk?sa=l&ai=DChcSEwi3_MPDlJKAAxXRk2YCHYqxAZQYABADGgJzbQ&ase=2&sig=AOD64_0y9U2wYtPANfVvVQsNwV2xc0MTiA&ctype=5&nis=5&adurl&ved=2ahUKEwjFxbbDlJKAAxXZ7TgGHY4xDlwQvhd6BAgBEFU

10. https://www.google.com/aclk?sa=l&ai=DChcSEwj99NiqlJKAAxWfk2YCHcN-C-IYABAFGgJzbQ&ase=2&sig=AOD64_1dqXdil_GB9Rf6O8pznJ00Ry13uA&ctype=5&nis=5&adurl&ved=2ahUKEwjmys2qlJKAAxWOyKACHZa9DiQQvhd6BAgBEFw

11. https://www.google.com/aclk?sa=l&ai=DChcSEwjR6Jrpk5KAAxW6_EwCHZS4B8AYABAFGgJ0bQ&ase=2&sig=AOD64_2P8cFCy6NKXmqW-zvjXVZpxi0NuA&ctype=5&nis=5&adurl&ved=2ahUKEwjigo_pk5KAAxXPyaACHVmKAjEQvhd6BAgBEFc

12. https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.amazon.in%2FNTC-Thermistor-Temperature-Sensor-Module%2Fdp%2FB095WLVTQT&psig=AOvVaw2ggs1aodt_0IDMd75hgfAy&ust=1689561249865000&source=images&cd=vfe&opi=89978449&ved=2ahUKEwim-aGimJKAAxX-amwGHWZIBMsQr4kDegUIARDrAQ

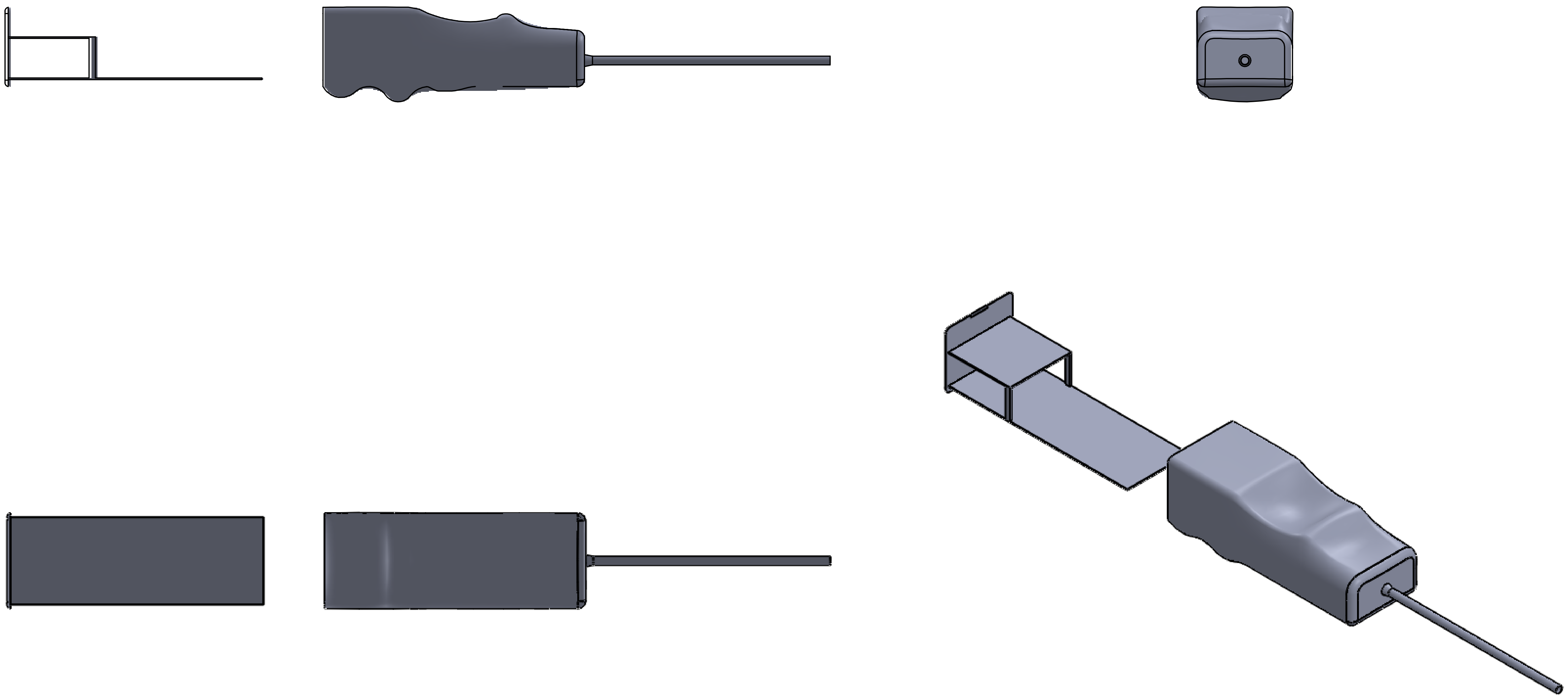
13. Gregory, B. A. (1981). Instrumentation Systems. *An Introduction to Electrical Instrumentation and Measurement Systems*, 379–397. https://doi.org/10.1007/978-1-349-16482-0_9

14. *PBT plastic | Ensinger*. (n.d.). PBT Plastic | Ensinger. https://www.ensingerplastics.com/en/thermoplastic-materials/pbt-plastic

Appendix

```
/* Device Information from Blynk IOT APP*/
#define BLYNK_TEMPLATE_ID           "TMPL6SilnMu9b"
#define BLYNK_TEMPLATE_NAME         "Instrumentation Circuit"
#define BLYNK_AUTH_TOKEN            "SJ500Bb4Li-TtKo-pKDkyMMXLfX2IKR3"

/* Comment this out to disable prints and save space */
#define BLYNK_PRINT Serial


  #include <ESP8266WiFi.h>
  #include <BlynkSimpleEsp8266.h>

// WiFi credentials.
// SSID = Netowrk Name and PASS is password.
char ssid[] = "INSTRUMENTATION";
char pass[] = "espnodemcu";

BlynkTimer timer;

// This function sendss the uptime every second to Virtual Pin 2.
void myTimerEvent()
{
  Blynk.virtualWrite(V2, millis() / 1000);
}
const int analogInPin= A0;

float Tempvalue = 0;
float voltageValue = 0;
int sensorValue = 0;


void setup()
{
  // Debug console
  Serial.begin(115200);

  Blynk.begin(BLYNK_AUTH_TOKEN, ssid, pass);
  timer.setInterval(1000L, myTimerEvent);

}
void myVoltageEvent()
{

  Blynk.virtualWrite(V4, voltageValue);  // Send the results to Gauge Widget
```

```
}
void myTempEvent()
{
  Blynk.virtualWrite(V5, Tempvalue);  // Send the results to Gauge Widget
}

// void AnalogPinRead() {
//   sensorValue = analogRead(analogInPin);  // Read the analog in value:
//   voltageValue = (sensorValue * (3.3/1023));
//   Serial.print("Voltage = ");  // Print the results...
//   Serial.println(voltageValue);  // ...to the serial monitor:

// }

void loop()
{
  sensorValue = analogRead(analogInPin);  // Read the analog in value:
  voltageValue = (sensorValue * (3.3/1023)-1.4);
  Tempvalue = ((voltageValue+0.4223)/0.0358);
  Serial.print("Voltage = ");  // Print the results...
  Serial.println(voltageValue);  // ...to the serial monitor:
  Blynk.virtualWrite(V4, voltageValue);  // Send the results to Gauge Widget
  Blynk.virtualWrite(V5, Tempvalue);

  Blynk.run();
  timer.run();

}
```



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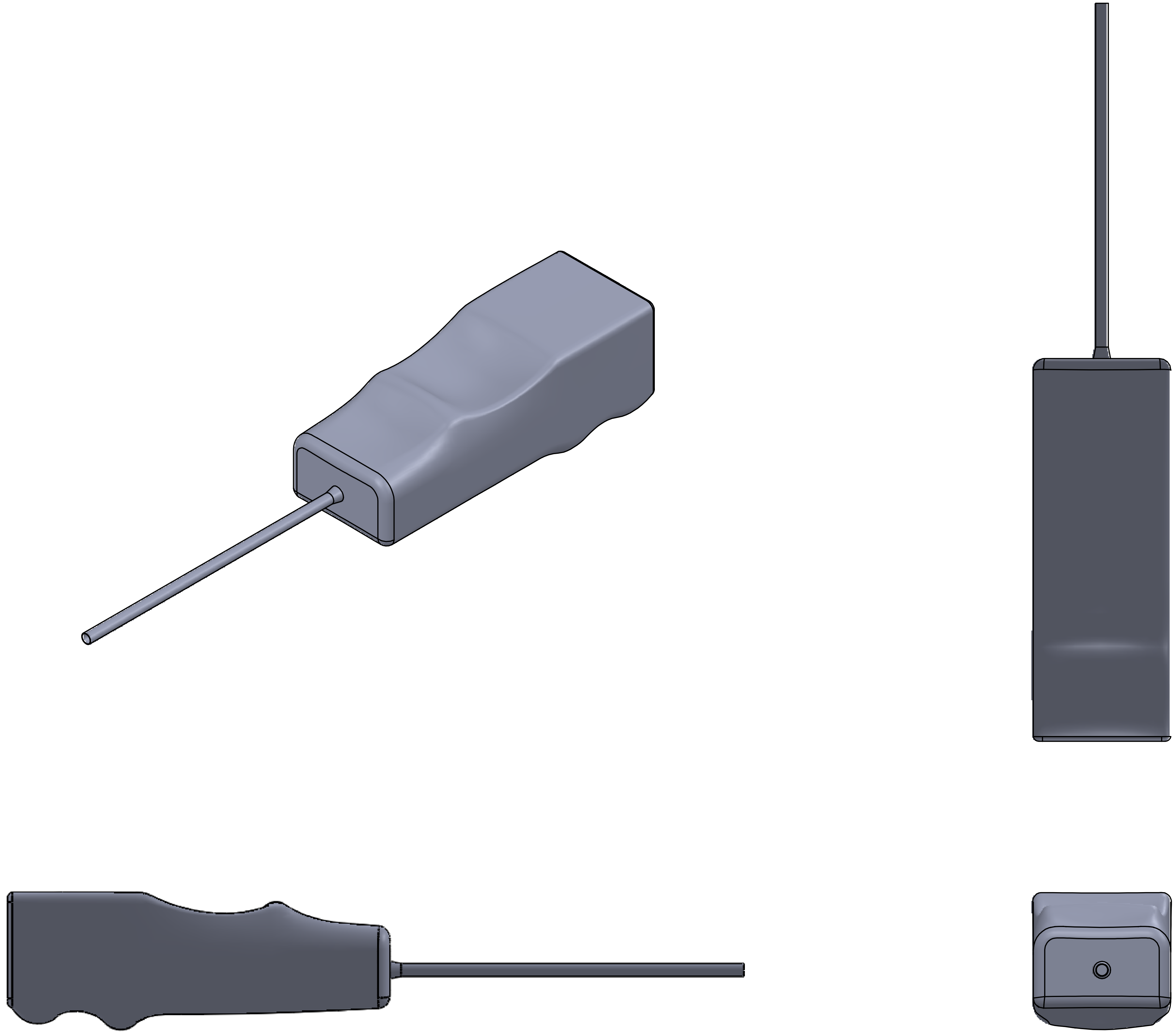
TITLE:	Exploded Thermometer Enclosure	COURSE:	SEMM 3242 Instrumentation	DATE:	16 JUL 2023
		SECTION:	30	SCALE:	1:3



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TITLE:	Assembled Thermometer Enclosure	COURSE:	SEMM 3242 Instrumentation
		SECTION:	30
DATE:	16 JUL 2023	SCALE:	1:1