

Performance Evaluation of K-Type Thermocouple-Based Temperature Measurement Using ESP32

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Abstract - This paper describes the experimental testing of a temperature measurement system that uses a K-type thermocouple and an ESP32 microcontroller. The experimental setup was designed to measure temperatures ranging from 25°C to 600°C, with a laboratory furnace serving as the heat source. The K-type thermocouple was connected to the ESP32 via a MAX6675 converter, which translates thermocouple signals into digital data. The temperature readings were then displayed on the ESP32 Serial Monitor. To assess the accuracy of the system, the temperature values recorded by the ESP32-based system were compared to those from a standard reference meter at various temperature points. The collected data were examined to evaluate how closely the measurements from the system matched the reference values. The findings indicate that the readings from the ESP32-based system closely align with those from the standard meter across the tested temperature range. This comparison confirms that the integration of a K-type thermocouple with the ESP32 provides consistent and dependable temperature readings. The developed system serves as an affordable option for laboratory temperature monitoring and has potential for expansion into real-time monitoring, data recording, and IoT-enabled high-temperature measurement applications.

Keywords: K-Type, Thermocouple, MAX6675, ESP32, Serial Monitor, Developed System.

1. Introduction

Accurate temperature measurement is essential in industrial processes, laboratory experiments, heating systems, and scientific applications. Various temperature sensors such as RTDs, thermistors, infrared sensors, and thermocouples are widely used. Among these, K-type thermocouples are commonly preferred for high-temperature applications because of their wide measurement range, simple construction, fast response, and low cost [1], [2].

A K-type thermocouple operates based on the Seebeck effect, in which a temperature difference between two dissimilar metals generates a thermoelectric voltage [3]. The generated signal can be converted into digital temperature data using a MAX6675 thermocouple-to-digital converter. The ESP32 microcontroller can then process and display the measured temperature, providing a compact and flexible solution for temperature monitoring [4], [5].

In this study, a K-type thermocouple integrated with an ESP32 and MAX6675 module is experimentally evaluated for

temperature measurement. The temperature readings obtained from the ESP32 Serial Monitor are compared with readings from a standard temperature meter at different temperature levels. The study evaluates the measurement agreement and performance of the proposed system for laboratory and high-temperature monitoring applications [6].

2. Methodology

The experiment was conducted in a laboratory furnace setup to evaluate the temperature measurement performance of a K-type thermocouple interfaced with an ESP32 through a MAX6675 module. Temperature readings were recorded at different operating conditions from both the standard temperature meter and the ESP32 Serial Monitor. The collected data were compared to examine the agreement, measurement deviation, and consistency of the ESP32-based temperature measurement system over the selected temperature range.

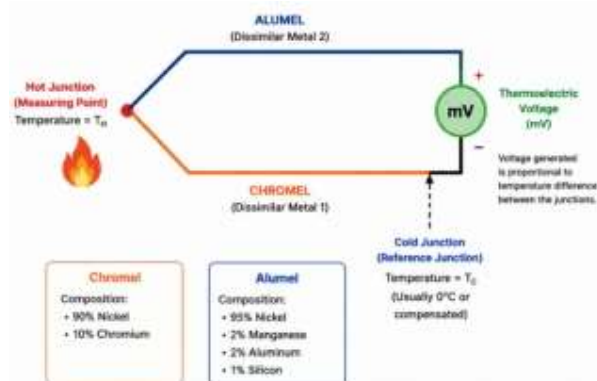


Figure 1 shows the Operating Principle of K-Type Thermocouple and Figure 2 shows experimental setup for K-type thermocouple temperature measurement using ESP32 and MAX6675 as shown below;

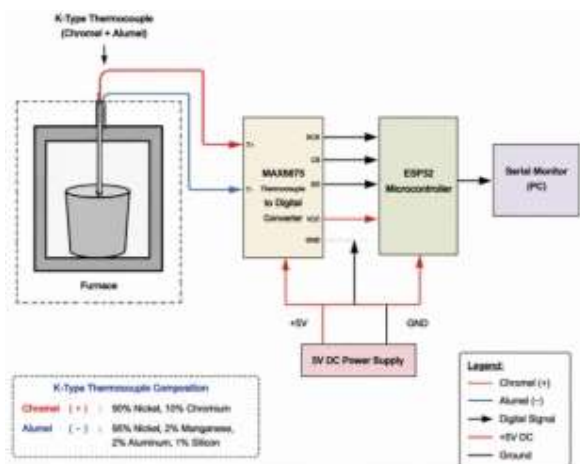


Figure 1: Operating Principle of K-Type Thermocouple.

Figure 2: Experimental setup for K-type thermocouple temperature measurement using ESP32 and MAX6675.

The experiment was performed on a laboratory furnace to check the temperature reading obtained from a K-type thermocouple with an ESP32. The thermocouple was kept inside the furnace and connected to the MAX6675 module. This module was connected to the ESP32 for reading the temperature. During the test, the furnace temperature was increased step by step. At every selected temperature, the value shown by the standard meter was noted first. The corresponding value shown on the ESP32 Serial Monitor was then recorded.

The readings from both instruments were taken under the same furnace conditions. These observations were arranged in a table for comparison. The difference between the standard meter value and the ESP32 value was considered while evaluating the performance of the measurement system. A graph was also plotted using the recorded readings to observe how closely the ESP32 measurements followed the reference values.

The experiment was carried out for the selected temperature range under laboratory conditions. The correspondence readings of temperature are taken in four different room temperature such as 35 °C, 36 °C, 37 °C and 38 °C respectively. The obtained readings were used to study the consistency and practical performance of the K-type thermocouple with the ESP32-based measurement arrangement [7].

3. Result

The experimental data obtained from the thermocouple measurements are presented in Figure 3 at room temperature 35°C, in Figure 4 at room temperature 36°C, in Figure 5 at room temperature 37°C and in Figure 6 at room temperature 38°C which compares the thermocouple output and ESP32 Serial Monitor temperature, and the reference temperature obtained from the furnace.

Table 1 shows the readings at room temperature 35°C.

Figure 3 shows relationship between Standard Meter and Serial Monitor at room temperature 35oC.

Room Temperature 35°C

SN	Std. Meter (°C)	SR. Monitor (oC)
1	35	35.25
2	85	87.5
3	135	136.5
4	185	186.5
5	235	236.25
6	285	286.5

Table 1: Readings at room temperature 35°C.

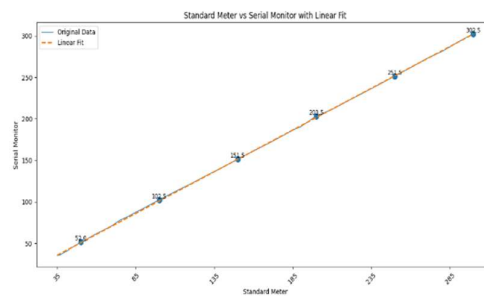
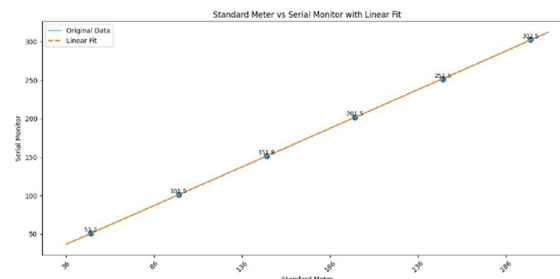


Figure 3: Relationship between Standard Meter and Serial Monitor at room temperature 35oC.

Table 2 shows the readings at room temperature 36°C.

Figure 4 shows relationship between Standard Meter and Serial Monitor at room temperature 36oC.



Room Temperature 36°C

SN	Std. Meter (°C)	SR. Monitor (oC)
1	36	35.25
2	86	87.25
3	136	137.5

4	186	187.25
5	236	237.75
6	286	287.75

Table 2: Readings at room temperature 36°C.

Figure 4: Relationship between Standard Meter and Serial Monitor at room temperature 36°C.

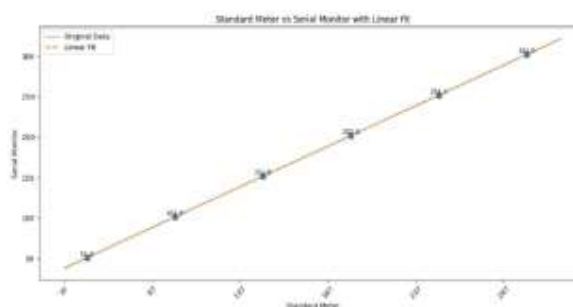


Table 3 shows the readings at room temperature 37°C.

Figure 5 shows relationship between Standard Meter and Serial Monitor at room temperature 37°C.

Room Temperature 37°C

SN	Std. Meter (°C)	SR. Monitor (oC)
1	37	37.75
2	87	87.75
3	137	138.5
4	187	188.5
5	237	238.25
6	287	288.75

Table 3: Readings at room temperature 37°C.

Figure 5: Relationship between Standard Meter and Serial Monitor at room temperature 37°C.

Table 4 shows the readings at room temperature 38°C.

Figure 6 shows relationship between Standard Meter and Serial Monitor at room temperature 38°C.

Room Temperature 38°C

SN	Std. Meter (°C)	SR. Monitor (oC)
1	38	37.75
2	88	91.25
3	138	140.75
4	188	192.5
5	238	241.25
6	288	292.75

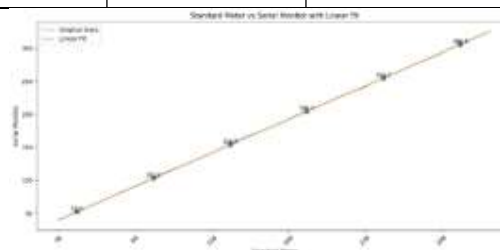


Table 4: Readings at room temperature 38°C.

Figure 6: Relationship between Standard Meter and Serial Monitor at room temperature 38°C.

4. Comparison of Output Graphs with Standard K Type Graph

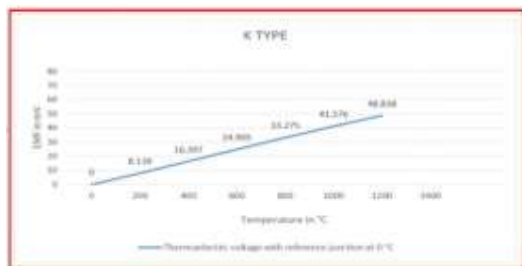


Figure 7: Comparison Graph.

Above Figure 7 represents the standard K type graph and figure 3, 4, 5 and 6 shows the experimental results at different room temperatures. The experimental results are nearly linear with respect to the standard results of k type at temperature 35°C, 36°C, 37°C and 38°C degree Centigrade.

The K-type thermocouple's output consistently appears linear when plotted graphically, which reflects its typical characteristic behavior. A linear trend can also be seen in the graphs produced at three distinct room temperatures (Figures 3, 4, 5 and 6). This validates the correctness of our comparison by confirming that our experimental output graph closely resembles the K-type thermocouple's standard output graph [7].

5. Linear Regression Analysis of Thermocouple Characteristics

Linear regression analysis was performed on the experimental temperature-versus-output-voltage data to quantitatively evaluate the relationship between temperature and thermocouple output voltage. It can be calculated by formula $y = mx + c$,

Where,

- x = Temperature (°C).
- y = Thermocouple Output Voltage (mV).
- m = slope → It indicates how much the thermocouple output voltage changes for a given change in temperature.
- c = intercept → It represents the voltage value predicted by the equation when the temperature (x) is zero.

For the four ESP32-based readings, the obtained regression equations and R^2 values are presented in Table 5.

Experimental Reading	Linear Equation	R^2
Room Temp. 35°C	$y = 1.004929x + 0.568129$	0.999892
Room Temp. 36°C	$y = 1.003651x + 0.783672$	0.999989
Room Temp. 37°C	$y = 1.003587x + 1.021854$	0.999986
Room Temp. 38°C	$y = 1.014353x + 1.467362$	0.99993

Table 5: Linear Regression Analysis of ESP32-Based K-Type Thermocouple.

Where:

- x = Temperature measured by the reference/standard meter (°C).
- y = Temperature measured by the ESP32 Serial Monitor (°C).
- R^2 = Coefficient of determination.

The linear regression analysis of the four ESP32-based experimental readings resulted in R^2 values of 0.999892, 0.999989, 0.999986, and 0.999930 for room temperatures of 35°C, 36°C, 37°C, and 38°C, respectively. The obtained R^2 values, which are very close to unity, indicate a very strong linear relationship between the reference meter readings and the ESP32-based temperature measurements. This confirms the consistency and reliability of the ESP32-based temperature measurement system under the tested experimental conditions.

6. Discussion

The experimental results show that the temperature values recorded by the K-type thermocouple through the ESP32 are in close agreement with the readings obtained from the standard meter. The observed variation between the two measurements is relatively small, indicating consistent temperature sensing over the tested range. The plotted results further demonstrate the stable response of the ESP32-based measurement system and its suitability for laboratory temperature monitoring [8].

The main purpose of this experiment was to evaluate the temperature measurement response of a K-type thermocouple when interfaced with the ESP32. The temperature values obtained from the ESP32 were compared with the corresponding readings of the standard meter at different temperature levels. The comparison provides a direct indication of how closely the developed measurement system follows the reference temperature.

The plotted results show a similar increasing trend for both the standard meter and ESP32 readings as the furnace temperature rises. Small differences can be observed between the two sets of measurements, which may be due to sensor response, measurement resolution, thermal conditions, or experimental variations. However, the overall trend remains consistent throughout the tested range.

The experimental observations indicate that the K-type thermocouple with the MAX6675 and ESP32 provides stable temperature readings under laboratory conditions. The agreement between the reference and ESP32 measurements demonstrates the practical suitability of the developed system for temperature monitoring. The system can therefore be considered a useful and low-cost approach for laboratory and high-temperature measurement applications [9].

7. Conclusion

The experimental evaluation confirms that the K-type thermocouple interfaced with the MAX6675 and ESP32 can be effectively used for temperature measurement. The temperature values obtained from the ESP32 Serial Monitor showed good agreement with the corresponding readings of the standard meter over the tested temperature range. The observed differences between the two measurements were relatively

small, indicating consistent and stable operation of the developed system.

The results demonstrate that the ESP32-based temperature measurement arrangement provides a simple, reliable, and low-cost method for laboratory temperature monitoring. With suitable calibration and further data analysis, the system can also be extended for real-time monitoring, data logging, and IoT-based temperature applications.

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