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Experimental Design, Characterization, coupling and calibration of type k thermocouple

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Abstract
There has been a gap in using type-k thermocouple to produce a low, but still significant voltage, to be utilized in low voltage applications that deal with temperature control. Therefore, there is need to understand the inner workings of thermocouples to ascertain its incorporation into various system applications. This work focused on the characterization, coupling and calibration of the thermocouple in this context, the type-k thermocouple, to see how it will perform under certain temperature conditions in terms of its voltage output. This work designed an experimental method for the characterization, coupling and calibration of type-k thermocouple using Thermal Bath and temperature regulator method as control circuit. Three type-k units were deployed to exploit the hot and cold junction of the device in order to produce a low but significant voltage. A second heat source, the soldering iron, was utilized using 4 type-k thermocouples. For the Thermal Bath, a range of designated variables were considered for a temperature value between 65ºC and 100 ºC. The optimal power peak temperature was pegged at 76 ºC for the Thermal Bath and temperature regulator method. A maximum voltage of 3700 µWatts was produced with a power output of 0.00925 µWatts. The result of using soldering iron as heat source method produced a voltage output of 57900 µV and a power output of 0.06 watts. This concluded the premise that type-k thermocouple could be utilized for low voltage applications such as systems that deploy operational amplifier, digital multimeter and fire alarm sensors for buildings without needing the grid to power the sensor. It also could be observed that the higher the temperature of the heat source, the higher the power output making the type-k thermocouple favorable for nuclear plant application. The minor setback was obtaining the right multimeter to get a voltage reading.

Keywords: characterization, coupling, calibration, type-k thermocouple, low voltage application

1. Introduction

Over the years, there has been challenges in using thermocouples to produce low but significant voltages that could be applied to low voltage systems that deal with temperature control. In modern system setup, that has to deal with thermostat for fridge, Peltier cooling systems or systems that deal with regulating the temperature of the environment, including systems that use low power voltage within micro to milli-range, the thermocouples has to be characterized. Thus, there is need to characterize the thermocouple to know the level of power that can be produced at hot or cold temperature ranges. The power profile also has to be characterized. To execute this, there is need to calibrate and couple the thermocouple using several heat sources and cold points to ascertain their best optimal performance standards. Also, the optimal temperature for the thermocouple peak power has to be determined.

Firstly, the best thermal electric device to be suitable for this work will be determined. At this preliminary stage, the type k thermocouple was considered. It should be noted that the higher the sensitivity of the thermocouple to changes in temperature by 1 degree Celsius to produce a voltage output, the better the result will be. Type k has two dissimilar metals from chrome wire and Alumei wire used to get temperature differentials to produce the voltage.

Currently, type K thermocouple device is available in the Nigerian market. About several thermocouples are connected in series to have a significant voltage output. After a potential difference or voltage is produced in micro volts after been calibrated and simulated using a temperature voltage regulator device, the type-k thermocouples will utilize different heat sources which will be coupled and calibrated in order to compare and size-up their differences and the benefit of one over the other.

The research problem is to ascertain the performance and functionality of a type-k thermocouple to ascertain how it will work when exposed to low or high temperature heat source. This helps to evaluate the general performance and efficiency of different systems for low voltage applications like the operation amplifier system, fire alarm sensor without electricity grid and digital thermometer using a type-k thermocouple probe. The gap in this work wished to provide significant voltage and power using type-k thermocouple in order to apply in low voltage systems which has been difficult in the academic research literatures. Due to the fact that, every type-k thermocouple has a peak power optimal temperature condition, it is good to take note of that in designing a system in case of fire alarm sensors, the peak optimal temperature will be the alarm trigger temperature set point, if suitable for kitchen temperature, or other rooms of a building. (Nguyen etal., 2023). The scope of this work is limited to low-voltage system applications.

The significance of this study is very vital to powering low voltage and power systems like fire alarm sensor systems in which a series of type-k thermocouples can be deployed without been connected to the grid, while generating its energy source from the fire heat source and triggering the alarm sound in cases of gas fire outbreak where no electricity is supplied; like in contrast to the microwave cooker where the electricity supply is needed. If alarm sensors require electricity to function, it defeats the goal in cases where cooking gas is involved in situations where there is power outage and a fire outbreak occurs while utilizing the cooking gas Thus, this work could be justified for low voltage applications in third world countries where there is epileptic power and creating employment opportunity in the context of designing fire alarm sensors to save many lives that don't use much power and use gas which does require no electric power in case of a fire outbreak. Thus, making it easy to power the fire alarm sensor without the grid, unlike in first world countries where the power supply is continuous and steady. The type-k thermocouple will just have to use the heat from the fire to trigger the alarm depending on the set temperature trigger limit. The type-k thermocouple is also readily available in the market, in-expensive and easy to couple with long lasting durability.

By characterizing the thermocouple, through coupling, calibration and testing with different heat sources, its performance can be enhanced and controlled under such characterized conditions. This work has a significant contribution to knowledge because few or no literature has carried out the experimental aspect of this work in this way. In case of any other similar work discovered, it has not been able to follow the experimental pattern result of this work due to the introduction of the robust and efficient temperature regulator system incorporation, giving the experimental method an edge over other works for its validation, result data reliability and consistency. The methodology of the experimental procedure is very unique due to a robust temperature regulator system living no space for little or no errors. The following objectives are as stated below: Firstly**,** to Identify and Select the suitable thermal-electric device and other components and secondly; to Design and Implement the experimental stage for Coupling, calibration and characterization of the type k-thermal electric device with other components to produce voltage and power. This helps to evaluate the performance of the thermocouple device under different temperature conditions.

1.1 Background: History and Principle of Operation

In 1821, a German Physicist Thomas Johann Seebeck, made a discovery in which a magnetic needle held in close proximity with a circuit, made up of two dissimilar metals got deflected when one of the dissimilar metal junctions was heated. At this time, Seebeck referred to this consequence as thermo-magnetism. The magnetic field he observed was later shown to be due to thermo-electric current. In practical reality of its use, the voltage generated at a single junction of two different types of wire, is what was of interest as this can be used to measure temperature at very high and low values. The magnitude of the voltage depends on the type of wire being utilized. Generally, the voltage is in the microvolt range and care must be taken to obtain a usable measurement. Although, very little current flows, however power can be generated by a single thermocouple junction. Thus, the use of coupling multiple thermocouples together to improve the power performance level is very common (Johnson, 1964).

1.2 Coupling and Calibration Process for type K thermocouple

The process is to connect the thermocouples in series or in parallel. The next phase will be to characterize and calibrate, in order to determine the parametric properties of the thermocouples in question, in order to see how it will function and perform as it undergoes changes in temperature (Thomas, 2022). For the calibration process for a thermocouple, various types of measuring equipment standards and procedures must be set up. (Thomas, 2022). Firstly a controlled or regulated temperature, must be established and must be stabilized and must provide a constant temperature; it must be uniform and cover a large span of area in which the thermocouple can easily be inserted into an ice bath. The sources of controlled temperature are called fixed points. There are two temperature junctions; the cold-end junction and the hot-end junction. (Thomas, 2022). The cold end junction should be at the freezing point, which occurs when a material reaches the point between solid and liquid phases. (Thomas, 2022). A reference junction defined as the cold-end junction must be established at 0 ° C.

A simple calibration process can be done by following some series of algorithmic method. A basic calibration involves heating water to 30 ° C in a Thermal Bath. Next each of the two multi-meter leads are attached to the cold-end junction. The multimeter should register zero micro-volts as the end of the cold end junction of the thermocouple and also the hot end junction should also be zero before transferring it to the Thermal Bath water. (Thomas, 2022). The voltage can be recorded once the multimeter reading becomes stable. The water temperature is increased to 35° C and again voltage is recorded. The process is repeated by increasing the temperature by 5° C increments and recording the voltage until 60° C is reached. Once the whole measurements have been taken, the voltage for the thermocouple type at room temperature is determined. Then, the given figures are added to each of the recorded voltage. Base-metal thermocouples play an essential role in industrial measurements, and among the many varieties and formats, bare-wire Type K is often preferred. The reason for this preference is its low cost durability and tolerance of high temperature. (Thomas, 2022)

In the coupling and calibration of thermocouples, thermoelectric inhomogeneity constitutes a major contribution to calibration uncertainty and must be taken into consideration for accurate measurements. However, theoretical work is slightly different from the experimental work, so some modifications were made by increasing the thermocouples involved and characterizing the threshold minimum temperature difference, within which the voltage from the thermocouple wires can be generated. In understanding the inner workings of the thermocouple the model governing equations that describe the pattern of the voltage output and the temperature gradient of the wires was illustrated in section 1.3 below.

1.3 Governing Equation of Type k Thermocouple

The standard configuration for the thermocouple device use is shown in the Figure 1 below. The desired temperature T_{sence} is obtained using three inputs- the characteristic function E(T) of the thermocouple, the measured voltage V and the reference junctions' temperature T_{ref} . As a result of these three values, the solution to the equation is

$$E(T_{Sense}) = V + E(T_{ref}) \qquad (1) \text{ (Governing Equation)}$$

From the above equation, we can see that the characteristic function is a function of the desired temperature. (Thomas, 2022). These details are hidden from the user, since the reference junction block (with T_{ref} thermometer), voltmeter and equation solver are combined into a single output. The subscripts in the equation are too long. Therefore, shorter terms like T_{rf} for T_{ref}, T_{sn} for T_{sense} , T_{mt} for T_{meter} are used.

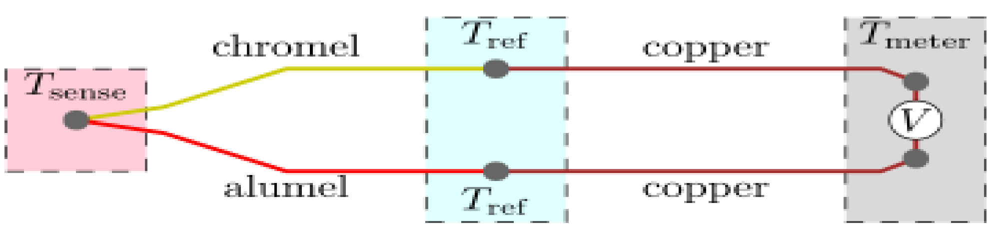


Figure 1: K-Type Thermocouple (Chromei-alumei)

In the standard thermocouple measurement configuration, it the measured voltage should be noted. The Figure 1 above shows the schematic setup of the Type-k thermocouple.

1.4 Theory of thermocouple device

Seebeck Effect

The Seebeck effect is defined as the development of an electromotive force across the two points of an electrically conducting material when there is a temperature difference between those two points. Under open circuit conditions where there is no internal current flow, the gradient voltage (∇V) IS directly proportional to the gradient in temperature (∇T). This implies that, the more increase in the difference in the temperature of the two dissimilar materials, the more the increase in the electromotive force. (Thomas, 2022).

$$\nabla V = -S(T)\,\nabla T \quad (2)$$

Where S(T) is the temperature material dependent property known as the Seebeck Coefficient.

The standard or conventional measurement configuration shown in the Figure 1 above shows four temperature regions and thus four voltage contribution.

Change from T_{meter} to T_{ref}, in the lower copper wire.

Change from T_{ref} to $T_{sense,}$ in the alumei wire.

Change from T_{sense} to T_{ref} in the chrome wire.

Change from T_{ref} to T_{meter} in the upper copper wire.

1.5 Reference junction sensor (Also known as cold junction compensation)

The reference junction block is permitted to vary in temperature, but the temperature is measured at this block using a separate temperature sensor. This secondary measurement is used to compensate for the varying temperature at the junction block. The thermocouple junction is exposed to extreme temperature hazardous environments, while the reference junction is mounted near the instruments location. Semiconductor materials are used in modern thermocouple instruments. In both cases the value V + E(T_{ref}) is calculated then the function E(T) is searched for a matching value. The argument where the match occur is the value of T_{sense}. One common myth regarding thermocouples is that junctions must be manufactured without involving a third metal, to avoid unwanted added EMFs (Thomas, 2022). This may result from another common misunderstanding that the voltage is generated at the junction. (Thomas, 2022).

In fact, the junctions should in principle have uniform internal temperature: therefore no voltage that is generated at the junction. **The voltage is generated in thermal gradient along the wire.** A thermocouple produces small signals, usually in magnitude of microvolts. Precise measurements of this signal require an amplifier with low input offset voltage and with care taken to avoid thermal EMFs from self-heating within the voltmeter itself. If the thermocouple wire has a high resistance for some reason, probably as a result of poor contact at junctions or very thin wires used for fast thermal response, the measuring instrument should have high impedance to prevent an offset in the measured voltage. A useful feature in thermocouple instrumentation is to simultaneously measure resistance and detect faulty connections in the wiring or at the thermocouple junctions. (Thomas, 2022)

NOTE: The maximum temperature expected in this type of device is not going to be high like those experienced in furnace operations. In high temperature conditions, it is therefore expected that the thermoelectric device life span could be shortened due to drift phenomena which was explained in section 1.6.

1.6 Reviewed works on Type-k Thermocouple

About few works were reviewed, as majority of the work published did not address the gap I have in my work. This main work is unique (novel research) as it demonstrated how much voltage and power can be generated with limited thermocouple materials and a well robust temperature regulator system which can be deployed for low voltage and power applications. Webster conducted a study on the "Thermal preconditioning of MIMS Type-k Thermocouple with an objective to use drift. However, this work was conducted on high temperatures between 800ºC and 1000 ºC to test for drift. Drift is defined as a downward decrease in the temperature of the thermocouple readings due to several different phenomena and can result in the thermocouple failure (Webster, 2017). It indicates that there was heat and power losses at the designated operating temperatures of this reviewed work. The gap in this work was addressed in this main study, in the sense that, temperature of this main experimental work, was on or below 100 ºC as the operating temperature limit which yielded significant results that can be applied to power house building fire sensors without even been connected to the electric grid due to the generated voltage from applying the heat source in this context of the fire outbreak. The gap in my work had negligible or no error .No drift phenomena was observed in the experimental stage. It was also observed, that the experiment of this main study had reliable and consistent results after having been repeated at different times, however the result output varied due to application of different heat sources for example: Thermal Bath water and soldering iron. There was no drift observed in the soldering iron heat source method.

Nguyen and co-authors carried out a study on “Method of measuring the temperature of wood exposed to fire with type-k thermocouples. The study exposed the thermocouple to fire with type-k thermocouples in order to evaluate the accuracy measurement according to the implementation of the method adopted (Nguyen etal., 2023). The gap in this work did not address the voltage and power characteristics of the how it works under the exposure to fire. In thermocouple measurements, when the thermocouple is exposed to heat, a voltage is supposed to be produced. This main work addressed the gap of the thermocouple exposure to heat with the voltage and power characteristics profile.

2.0 Material and methods

There was great difficulty in sourcing for the thermocouple components required in the preliminary design. Also, there was problem of no reading result because of wrong connections.

Identification and selection of suitable thermocouple device

Due to the in-expensive and readily available benefits of type-k thermocouple. It was selected and deployed for this methodology.

2.1Methodology of the characterization, coupling and calibration using Temperature Regulator connections

In order to characterize the type-k thermocouple, there is need to design an experiment setup and then couple and calibrate the type-k thermocouple testing it under different heat sources to know the characteristics performance level of the device. There are ten port terminals in the temperature regulator with 1 to 5 ports above and 6 to 10 ports below. The port 6, 7.and 8 are for the relay switch for controlling the switch for the desired output temperature. Port 1 and 2 are connected to the first thermocouple which was immersed in the Thermal Bath, port 9 and 10 which is for the mains power supply connection is connected by green copper wires. The green copper wire (positive polarity) and black copper wire (negative polarity) were connected to the 2 connectors for connector 3 and 4 respectively at the right section of the connector device. Also a green copper (polarity) and black wire (negative polarity) wire is connected from 8 and 10 respectively to the connectors at the left .which connector 1 and 2.

Type k thermocouple wires

Four 76-inche thermocouple type k wires were gotten for the first part of this work and 3 type-k thermocouple wires were utilized for this work. Type k wire one was used to calibrate the temperature value for the hot junction. The type k wire 2 were used for hot junction in the thermal bath with the type k wire 1 to calibrate the thermocouple hot junction wire 2 with the temperature regulator system and the type k wire 3 was used for the cold end junction connected to the ice block. Both type k wire 2 and 3 were connected with a copper wire at the connector 1 and 2 port to obtain the voltage of the result. Figure 2 below shows the type-k thermocouple wire which is about 78 inches in length.

Figure 2: 76-inch Type-k Thermocouple

2.1.1Methodology of Experimental setup using Thermal Bath and Temperature regulator as control circuit

Figure 3 shows a pic of the experimental set up of the design, characterization, coupling and calibration of the type-k thermocouple using a temperature regulator as the brain component. No work has ever been produced in this simple and straightforward form in majority of the published work. This main work addresses the experimental set up using Thermal Bath as heat source. The red gadget is the multimeter, the gray system is the temperature regulator controlling the high junction temperature. The connectors was deployed to couple the type-k thermocouple in series which produced a higher voltage. The black gadget in Figure 3 shows the digital thermometer also shows the indication of type-k thermocouple probe to record the lower colder ice-block temperature range.

Figure 3: Picture of experimental setup of the Design, characterization, coupling and calibration of a type-k thermocouple (Source: Field of authors)

2.1.2. Block Diagram of the entire setup of the Design and implementation of Experimental procedure of Coupling, calibration and characterization of Type k-thermocouples

The first thermocouple was used to calibrate the temperature of the Thermal Bath water which was connected to port 1 and 2 of the temperature regulator.

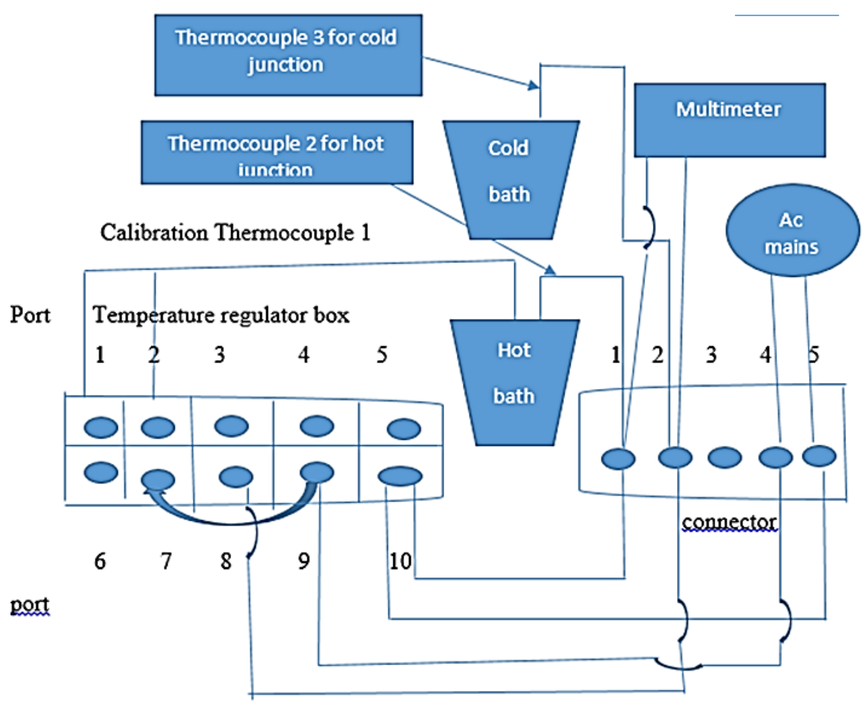


Figure 4: Block Diagram of the entire set up of the Design and implementation of Experimental procedure of Coupling, calibration and characterization of Type k-thermocouples
(Source: Field of authors)

The second was connected to the same hot water and the end connected to the third thermocouple for the cold end. The cold sensor metal was put in an ice block bath. The copper wire was connected to the connectors and the two hot and cold terminals of the thermocouple to get the voltage and the current with a copper wire having both negative and positive polarity for connector 1 and 2. This connector 1 and 2 was joined with the two thermocouple wires to get the voltage produced that was connected to the multimeter. An addition analog meter was utilized to corroborate and confirm for continuity, current and voltage value. Figure 4 shows the entire block diagram of the coupling and calibration of the type–k thermocouple during which the characterization to know its functionality and intrinsic characteristics. Figure 4 above shows the block diagram of the entire experimental setup that could be observed in Figure 3 above. The current reading was also obtained using a multimeter. Since the thermocouple 2 and3 were connected in series, the current will be constant, a value of 2.5 µA was obtained.

2.1.3 Second trial of 4 Type k Thermocouple series connection using soldering iron as heat source

In order to simulate better dealing with solid than liquid state Thermal Bath, four type thermocouples were connected in series using a 4-port connector and then the four hot sensor points were placed on a soldering iron, the 4 cold points of the sensor was placed on a cold ice bottle water, their end terminals were connected to voltmeter for reading the voltage value. This gave a better output than the hot water bath calibration and simulation. The result was displayed and interpreted in Table 3 and Figure 7 in the result and discussion section. This shows the heat signature of a solid metal in comparison with a liquid substance tends to convert more useful power as a result of the lattice structure of solids in which the particles are closely compact creating room for useful thermal conduction and conversion to work and then electrical power.

3.0 Results and Discussions

3.1 Results

Results OF 3-4 Series connection of Type k Thermocouple Design, coupling, calibration and characterization

In the first part of this work the result obtained for the temperature of the hot junction with their produced voltage gotten from the digital multimeter is captured after 4 type-k thermocouples are connected in series for coupling, calibration and characterization. Regression value is directly proportional to the correlation value times the Y-axis value divided by the x-Axis value.

$$R=\frac{C\times Y}{X} \qquad (3)$$

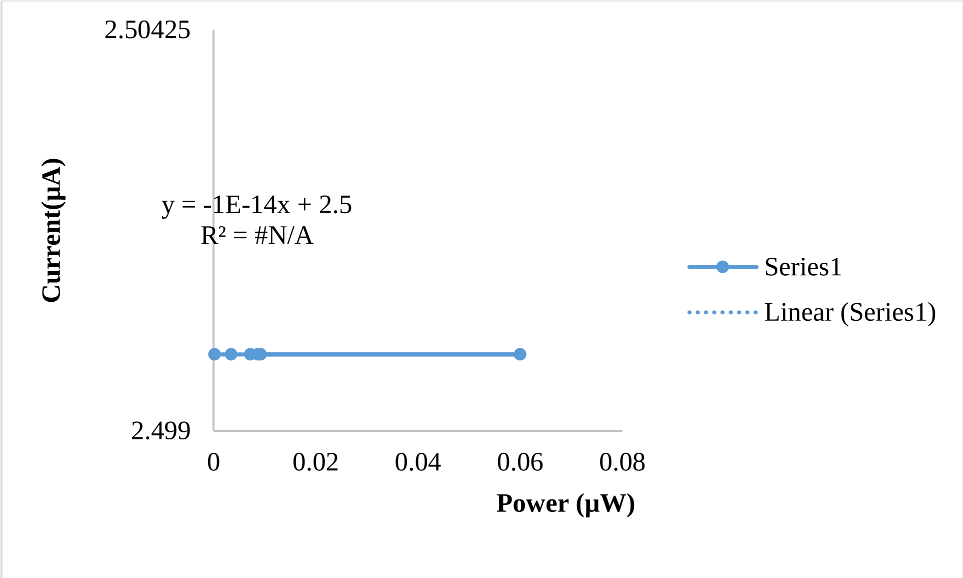
Where R is the regression value

And c is the correlation point

And Y is the y- axis points and x is x-axis points.

Table 1: Table of temperature, voltage, current and power using 4 type k units with hot water (Source: Field of authors)

S/N	Temperature(°C)	Voltage µV	Current (µA)	Power(µW)
1	Minimum Temperature Threshold=52.6	Minimum significant Threshold voltage =100	2.5	0.00025
2	65	1400	2.5	0.0035
3	73.9	2400	2.5	0.06
4	89.4	2900	2.5	0.00725
5	96.3	3500	2.5	0.00875
6	100	3700	2.5	0.00925



`Figure 5: Graph plot of current against power of the 4 series-Type k Thermocouple of the thermal-electric device calibration, characterization and coupling (Source: Field of authors)

Table 2: Table of result of Temperature data against Power of 4-Type k thermocouples in series using hot water

Temperature(°C)	Power(μW)
52.6	0.00025
65	0.0035
73.9	0.06
89.4	0.00725
96.3	0.00875
100	0.00925

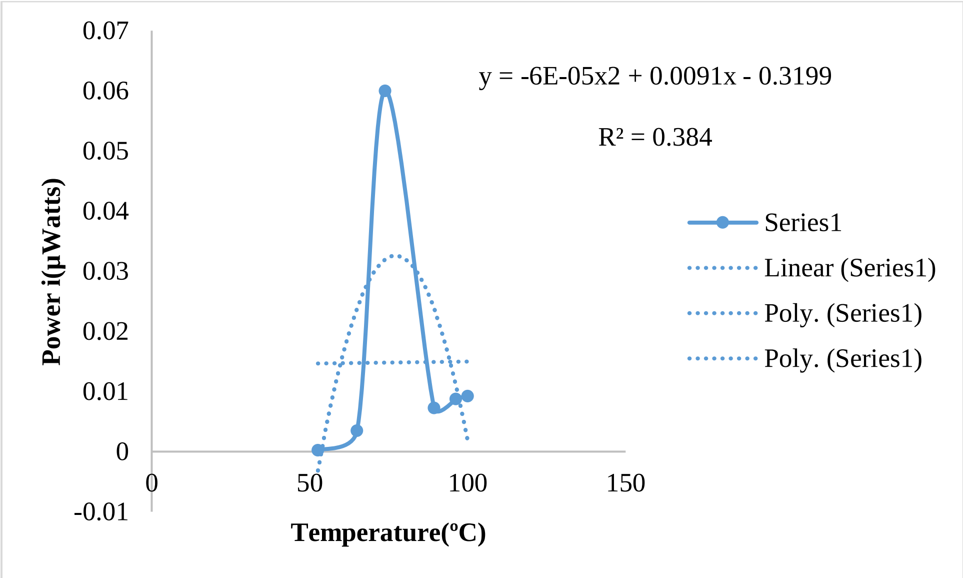


Figure 6: A graph plot of power against Temperature for the 4 series-Type k- thermal-Electric device calibration, characterization and coupling (4th-order Polynomial Equation)
(Source: Field of authors)

Table 3 Table of Temperature, voltage and current, power For 4-type k thermocouple in series using soldering iron as heat source and cold bottle water as hot source for simulation.
(Source: Field of authors)

S/N	Temperature (° C)	Voltage (µV)	Current(Amps)	Power (Watts)
1	65	8900	1.04	0.009256
2	70	14900	1.04	0.015496
3	86.5	28800	1.04	0.029952
4	90.6	40000	1.04	0.041600
5	88.7	49000	1.04	0.050960
6	100	579000	1.04	0.060216

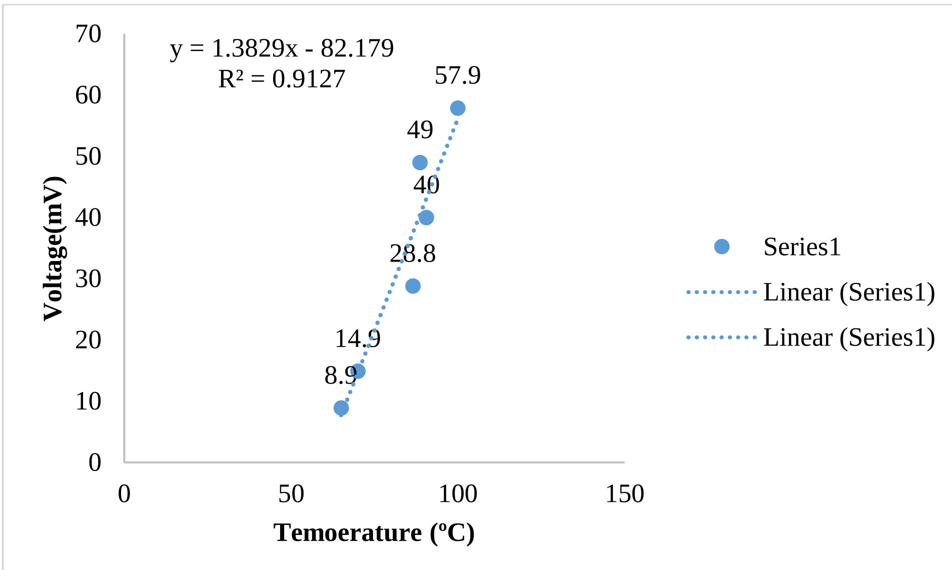


Figure 7: Plot of Voltage against temperature for second trial with soldering iron a as heat source and 4 thermocouples in series (Source: Field of authors)

3.2 Discussions

3.2.1 Interpretation of Table 1 and Figure 5

The Fig 5 represents relationship between current and power in the thermoelectric system in series which shows a straight line whose current is constant with variable voltage due to temperature difference. The model is guided by the equation being generated:

The relationship model equation is Y= -1E-14x + 2.5 (3)

It can be seen from the equation of a line

Y=mx + c where c is the constant.

Therefore, in equation (3), 2.5 is the constant which 2.5µ Amps current for series connection indicating and validating the principle of connecting thermocouple in series, which states that thermocouples being connected in series will have a constant current but varying voltages. This result is still significant for the type-k thermocouple to be incorporated into low voltage systems like operational amplifiers.

3.2.2 Interpretation of Table 2 and Figure 6

The Figure 6 is a plot of power against temperature. The model equation of the graph is represented by:

$Y=-8E-05x^2 +0.0091x-0.3199$ (4)

The regression value is at 0.3481.This is does not indicate a large deviation error in experiment but validates the fact that it is natural or normal for polynomial equations. The maximum power was obtained at 0.00025 µWatts. This is very poor and it is not enough to power a phone which was the initial original intention. However, it can applied in low voltage applications like operational amplifiers, digital thermometers, and sensors. The power peaks when the temperature is around 76º C and the power drops as it gets towards 100º C. So this indicates that even at higher temperatures the voltage produced from the thermocouple dropped after reaching a peak voltage at 76º C. This can be applied in designing temperature trigger set limit for fire alarm to ensure the peak power is reached to power the sensor when there is power outage and fire outbreak.

3.2.3 Interpretation of second trail from Table 3 and Figure7 using 4 type k- thermocouples in series with soldering iron as hot source and cold bottle water as cool source

The result data of the plot for Figure 7 shows a linear equation given as:

$$Y = 1.3829x-82.179 \quad (5)$$

The regression value was obtained at 0.9127 indicating a good experimental result with no significant errors. The increase in temperature caused an increase in voltage peaking at 100º C with a maximum voltage pegged at 57900 µV. It is also observed that the maximum power of was pegged at 0.06 Watts for soldering iron heat source. The current was pegged at 1.04 Amps. This is a good result for powering a low voltage sensor or operational amplifiers for various system applications. Moreover, this could be used for systems that deal with the milli-Volt range like the operational amplifier. This operational amplifier can be combined with the type k device in applications for regulating temperature of the system. This also gives an indicator that, type-k thermocouple could thrive in high temperature systems; like nuclear power plants due to the hypothesis from the experiment that observed that says that the higher the heat source the higher and more significant the voltage, current and power will be. This type-k thermocouple could even be enough to even charge a mobile phone in nuclear plant environment depending on the number of series connection or series-parallel connection of the type-k thermocouple device.

4.0. Conclusion

In this work, we have been able to address and achieve the specific objectives as seen in Figure 3 and Figure 4 such as: Identification and Selection of the suitable thermal-electric device and other components and the design and Implementation of the experimental stage for Coupling, calibration and characterization of the type k-thermal electric device with other components to produce voltage and power. This work has a target audience of scientists and developers who want to use milli-Volt range power components and incorporate temperature regulators for their device from ranges of 25º C - 100ºC range applications.

The findings of this work showed that using a higher heat source like the waste heat from soldering iron different from the low temperature heat source of Thermal Bath water, led to the increase in the power output of the system setup. The Thermal Bath and temperature regulator setup with three thermocouples connected in series obtained a maximum Voltage and maximum power of 3700µV and 0.00925µWatts respectively. The above statement is in comparison with soldering iron heat source using 4-type k thermocouples that obtained a maximum voltage and maximum power of 57900µV and 0.06 Watts respectively. This indicates that, the higher the heat source, the higher the power, and also the more type-k thermocouples are coupled in higher numbers, the better the voltage and power output that can be deployed to low voltage applications including those that need operational amplifiers and digital logic circuits for switch alarm sensors (Nguyen etal., 2023).

However, the type-k thermocouples can be used for higher temperatures. It can have its application in research and development used for operational amplifier system applications that require monitoring of temperature such as digital thermometer, where the probe is a type-k thermocouple component and also in fire alarm sensors for buildings without needing the grid to power the alarm sensor as mentioned in the introduction. This will have an impact in saving lives in the third world countries where power might not be available to power and trigger the alarm to sound during emergency. The type-k thermocouple will just work with the heat from the fire during an emergency thus triggering the alarm after reaching the trigger temperature set point. It can also be used for nuclear applications due to its radiation resistance hardness.

Moreover, the power for the Thermal Bath and temperature regulator method peaked when the temperature is around 76º C and the power dropped as it gets towards 100º C. So this indicates that even at higher temperatures the voltage produced from the thermocouple dropped after reaching a peak voltage at 76º C. This can be applied in designing temperature trigger set limit for fire alarm to ensure the optimal peak power is reached to power the sensor when there is power outage and fire outbreak. This creates impact in mitigating environmental hazard conditions such as fire outbreak. The initial goal of this work was to use the type-k thermocouple to charge a mobile phone. However, due to the low voltage and power output, it could not be applied for that purpose, except more thermocouples above 70 units will be considered making it cumbersome and inefficient. This was the minor set-back or limitation of this work. However, as mentioned above, it can work for low voltage applications such as digital thermometer and fire alarm sensor.

The cost of a type-k thermocouple is very cheap. It is as low as ₦500 -₦1500 for one unit considering annual inflation and will be easily be incorporated into a cheap fire alarm sensor used to derisk environmental hazards. To replicate a series of type–k thermocouple experiment using the methodology system set up for characterization, coupling and calibration, it will cost roughly between ₦10000- ₦25000 excluding measuring mutltimeter device which was about ₦35000.(Source: Field of authors). This work is a novel research work that was not been repeated by any existing literature making it unique, thus limiting and leaving little room for only few references considering research ethics standard. Finally, the significance of this work of the soldering iron heat source was able to produce a significant low current, voltage and power which maximum values were 1.04 Amps, 57900µV and 0.06 watts respectively, which is adequate enough to be applied in low voltage systems such as: fire alarm sensors, digital thermocouple thermometers and operational amplifier systems.as mentioned earlier before throughout the work.

5.0 Recommendation

I recommend the type k systems can be incorporated into operational amplifiers used for different applications including complex systems. As this can assist these applications to deal with temperature regulation issues. Moreover, type k may be used for regulating temperature in Polymer electrolyte membrane fuel-cell power systems to keep the temperature range within the operating conditions. There is also need to couple series of thermocouples for application in fire alarm sensor circuit for buildings and consider research on powering the alarm system with the type k thermocouples without needing the grid for emergency situations with power outage. For instance; in situations when there is a power outage and a building user utilizes a lit match stick while trying to light the gas and throws it into the bin without quenching it well. If such utility occupant leaves the enclosed environment, and there is power outage, if the fire alarm sensor needs the power from the grid, it will not be able to function thus impeding the notification of the occupant of a fire outbreak. If alarm sensors need electricity to function, it defeats the goal in cases in third world countries where cooking gas is involved in situations where there is power outage while utilizing the cooking gas in case of an error, such as; situations of emergencies like gas fire outbreak in cases of power outage. The type –k thermocouple incorporated with sensor unit can work without the electricity grid and just need the heat from the fire to trigger an alarm depending on the temperature limit trigger point. Finally, it is recommended that a quarterly routine maintenance test should be done to evaluate the emergency readiness and functionality of a type-k incorporated with fire alarm sensor unit in case of system failure, in time of need or emergency. This routine maintenance test also creates employment opportunity for the technician or engineer.

Nomenclature

∇T = Gradient Temperature
∇V =Gradient voltage
$E(T_{ref})$ = Voltage produced at reference temperature
$E(T_{Sense})$ = Characteristic function at desired temperature
R = Regression Value for experimental measurement accuracy and error percentage
S(T) = Seebeck Coefficient
Tmeter =Temperature obtained from the meter along the copper wire
Tref = Reference Junction temperature
Tsense = Desired temperature
V = Measured Voltage
X= Independent variable parameter
Y= Dependent Variable parameter

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