



## Design and Implementation of a Multi-Channel Temperature Measurement System Based on LabVIEW

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**ABSTRACT:** As computer technology and instrument technology advance rapidly, both virtual instrument and Lab-VIEW have significantly grown. LabVIEW is extensively employed in the industrial and academic sectors for developing data acquisition systems, instrument control software, and analysis software. This paper presents the design of a multi-channel temperature measurement system based on a single-chip CPU and LabVIEW. The system consists of analog-to-digital conversion modules, temperature measurement modules, and data acquisition modules. The system uses the Nyquist-Shannon sampling theorem and the advantages of various digital filter types to obtain temperature uncertainty, including the compensation uncertainty of the reference junction. The system is of high quality in measuring accuracy, stability, scalability and other aspects. The complete system was inspected and verified using a superconducting magnetic energy storage device (SMES). The results demonized the ease of construction, practicality and precise regulation of the system. These results also show that temperature measurement devices are less than 0.1°C absolute error and are highly accurate, making them valuable for applications that require precise temperature measurements.

**KEYWORDS:** Data acquisition component, Labview; sensor, Multi-Channel Temperature, Thermocouple.

### I. INTRODUCTION

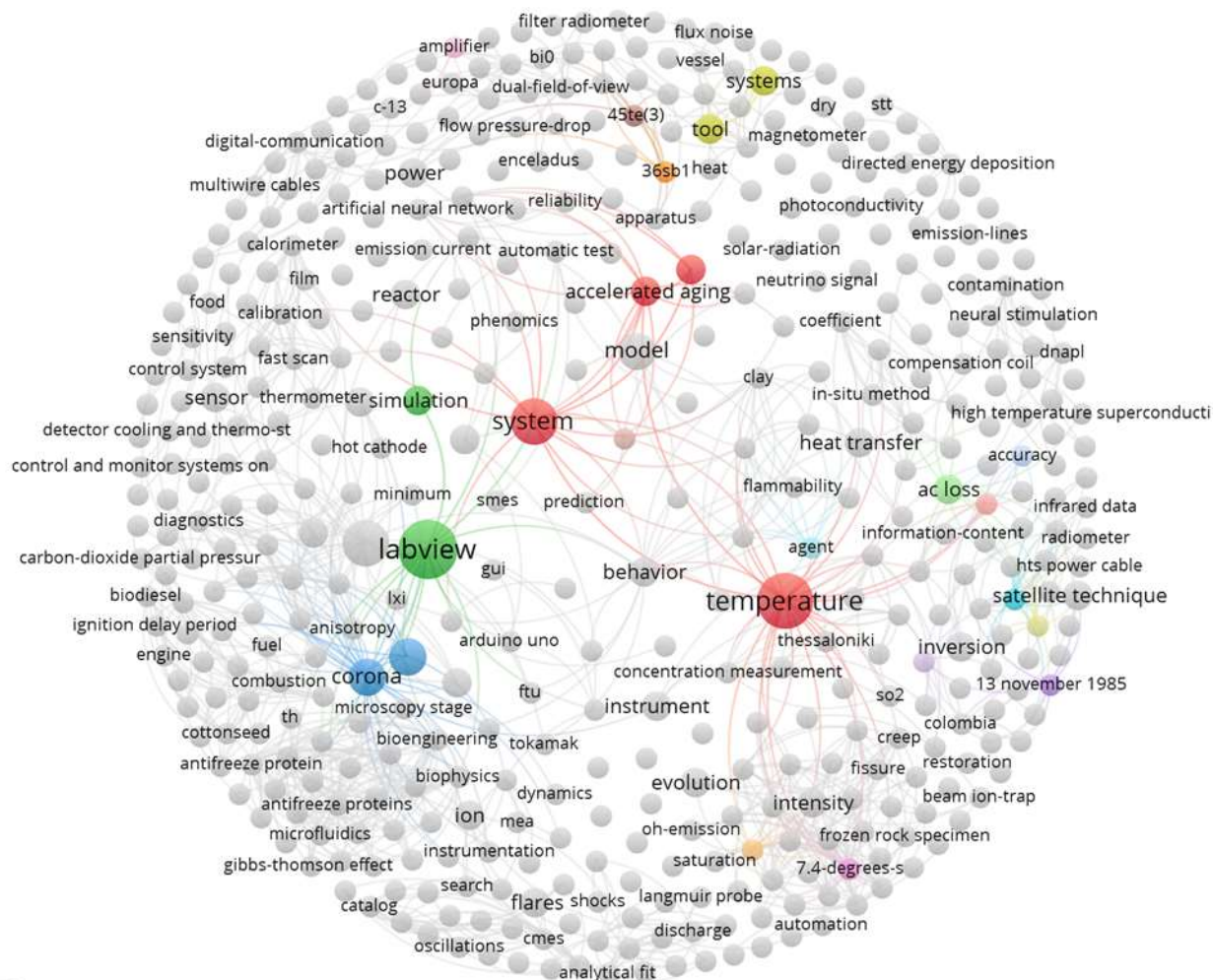
Nowadays, temperature sensors are used in a wide variety of devices. Temperature sensors can be found in almost all of the devices used in daily life, such as automobiles where the engine's temperature must be kept within a certain temperature range in order for it to function properly. The most common uses of temperature sensing include Monitoring, Compensation and Control. A proper temperature measurement is necessary for modern equipment, notably expensive laptop computers and other portable gadgets with tightly packed circuitry that lose a majority of power as heat. Small, high-power portable equipment usually uses fan cooling to maintain junction temperatures within acceptable ranges. To prolong battery life, the fan should only operate when absolutely essential. For precise fan control, it is important to know the critical temperatures from the appropriate temperature sensor. As a result, numerous researchers used a variety of technologies to create a multi-channel temperature meter.

In [1], the authors described the design, construction, and experimental validation of a new multi-channel monitoring system for Polymer Electrolyte Fuel Cells (PEFCs). It is multi-channel, affordable, and scalable. This built monitoring system can measure stacks of 1 to 120 cells and takes non-intrusive voltage readings of each individual cell in a PEFC stack, making it scalable. In this research [2], a VI-based measuring and protection system for HTS device applications is presented. The associated protective mechanism has also been created for the secure functioning of HTS devices. The complete system has been inspected and validated using a superconducting magnetic energy storage (SMES) device. The outcomes demonstrate how easily it is to build, practical, and precisely regulated the VI measuring and protection system. The researchers showed in [3] that how the rapid development of computer and instrument technology has substantially advanced virtual instruments and the LabVIEW programming language. Lab-VIEW, grounded in the G language, is extensively utilized in both educational and professional environments for developing data acquisition systems, instrument control applications, and analysis software. This multi-channel temperature measurement system is constructed using Labview. Such a multi-channel system offers the advantage of decoupling hardware and software components, enhancing its adaptability and scalability. The temperature acquisition module's design takes up the majority of the system's hardware. In order to



obtain a strong temperature signal, the system will process the temperature of the specified physical amount using an amplifier circuit. Then, in order for a computer to process the analogue impulses, and convert them to digital signals using a data acquisition card. The Labview application is primarily used to read and initially process temperature signals in terms of the software component.

The Labview software program can be used to retrieve the temperature signal, transform it, acquire it, analyze it, and then display it as a waveform graph. The multi-channel temperature measurement system built on Labview can be created rapidly, affordably, and to exacting performance and reliability standards. Additionally, it has a wide range of uses for temperature processing and measurement. Additionally, the multi-channel temperature measurement system based on Labview may be used to solve the drawbacks of the standard temperature measuring system, making the design of the temperature measuring system more useful. The major element of the experiment is a LabVIEW software programming module that extracts the temperature signal from the obtained temperature data using a data collection card. Next, the signal is evaluated. The ability to visualize experimental operations on a computer is made possible by writing a Labview applications.



Visualization of the bibliometric maps between 'design', 'temperature', and 'LabVIEW'.

The authors of [4] conducted research and found that Labview is a graphical programming language that can be used to create applications as opposed to text lines. This paper demonstrates the design of a multi-channel data acquisition system based on a single chip CPU and LabVIEW. The authors said in [5] that calibration is necessary for the industrial and agricultural sectors that use temperature sensors. A temperature calibration system, designed within the LabVIEW programming platform, is proposed to conduct parameter calibration and characteristics analysis of the temperature sensor. This design interfaces with the serial bus using the VISA programming interface, enabling calibration of the FLUKE9171 temperature sensor and data acquisition from the multi-channel DS18B20 temperature sensor.



There are numerous problems with temperature sensor verification in Chinese automatic weather stations (AWTs), including inefficiency and a lack of automation, according to the authors in [6]. The massive demand for verification cannot be satisfied by the prefectural metrological verification departments' verification method. To overcome these problems, this study [6] transforms the initial temperature sensor verification system into a multi-channel automatic verification system. The authors of [7] stated that as weather monitoring is crucial to daily living, it's essential to learn about the temporal dynamics of weather changes. Every industry needs to monitor the weather when there are particular threats. The system uses a compact LPC1768 (ARM9) microprocessor-based circuitry. The IDE Keiluvision4 is used to create Embedded C programs. Microcontrollers can be programmed via the JTAG programming interface.

The LabVIEW virtual instrument is divided into 3 stages by the authors in [8]: data acquisition, data testing and analysis, and output display. System control, data collecting, processing, and recording, as well as alarm and historical data read back, are all performed using the LabVIEW platform. The system uses a DS18B20 to gauge the temperature. The creation of a temperature measuring and data acquisition system utilizing LabVIEW as a virtual instrument is discussed in the paper. In [9] study, by using HIOKI data loggers, experiments were conducted to determine reference junction compensation error and data volatility (LR8400-20). The method for obtaining the measured temperature's uncertainty, including the reference junction's compensating uncertainty, is suggested. The K thermocouple uncertainty determined by this study was 0.42 °C [9]. A high precision temperature measuring device based on the thermocouple concept is created using the LabVIEW software platform [10]. The system uses an AD7076 analogue to digital converter and the STM32 MCU as its primary control chip. The authors in [11] develop a high precision temperature measurement system with Pt100 platinum resistance since the Pt100 platinum resistance temperature measurement system has low accuracy, duplicate hardware circuit design, and other challenges. The Pt100 temperature sensor is used in the article [11], which uses the STM32F103 as the control centre. By using signal conditioning circuits including filtering, amplification, and software look-up tables, it is possible to achieve high-precision temperature measurement. The system has a high level of measurement accuracy, stability, scalability, and other qualities, according to research results.

One of the most crucial factors in the study of the marine environment is temperature [12]. This research has designed a unique measurement circuit, which utilizes platinum resistance to accurately gauge the temperature of sea water. The signal obtained from the platinum resistance undergoes amplification, filtration, and conversion through the integrated PGA 24 high-precision Analog to Digital Converter (ADC) ADS1220 in this design. To configure and read the ADS1220 chip, each internal functional module was developed using a programmable device CPLD and Verilog hardware description language (HDL). The MAX-V [13] series CPLD from Altera, employed in the design of this study's high-precision temperature acquisition module, manages and executes the analog-to-digital conversion functions, offering advantages such as low power consumption and high efficiency. At the specified data rate, new data are available. Data can be viewed at any time without worrying about it becoming corrupt, and it always reflects the most current conversion that has been finished [14]. The outcome demonstrates that the controller is capable of meeting the requirements of the general design. Following verification, the design uses the programmable AID converter ADS 1220 to acquire temperature data. The study [15] develops a PWM regulation-based air-cooled temperature management system that can modify fan speed in response to changes in ambient temperature, allowing for energy savings and noise reduction.

The primary environmental factor affecting industrial and agricultural production is temperature. The importance of precise and timely measurement cannot be overstated. Temperature measurement is required for huge warehouses, thermal equipment, and a lot of production machinery. The capacity to develop a type of temperature automatic detecting system has numerous applications [16]. The Labview virtual instrument platform is mostly used in this design to create a temperature acquisition system. Data is gathered in the Labview environment for data processing and analysis, and the findings of the analysis can be used to regulate the temperature of a single-chip microcomputer [17-19].

Industrial automation has become a significant marker of contemporary advancement across various economic sectors. The extent of automation in central air conditioning systems can affect people's socioeconomic living standards. However, due to the inherent characteristics of central air conditioning systems, such as large-delay and nonlinear time-varying system properties, these factors can influence the efficacy of a basic fuzzy controller for control purposes[20]. Studies on thermal environments suggest that an individual's comfort perception is determined by the interaction between their body and various environmental factors such as temperature, humidity, wind speed, and average radiation temperature. An effective measure for gauging general effects is the Predicted Mean Vote (PMV) indicators as proposed by Professor Fanger[21]. This research aims to optimize energy efficiency by applying intelligent



control methodology to central air conditioning systems, which would not only provide a comfortable living and working environment. The paper[22] scrutinizes the central air conditioning systems' large-delay and high-inertia properties, introduces fuzzy control theory for process control, and suggests a design methodology for a fuzzy PID controller with self-tuning parameters[23-25]. In our paper, by employing analogue circuitry to detect environmental phenomena, transferring the data to digital representation, and then processing the data digitally, and completed the most fundamental and essential phases of developing a digital system. The multi-channel temperature measurement system based on Labview may be used to solve the drawbacks of the standard temperature measuring system, making the design of the temperature measuring system more useful. In this study, a number of needs for digital systems have been examined, including the Nyquist Shannon sampling theorem and the benefits of various digital filter types. In section 3, the study discusses about the methodology, which tells about the approach which is taken to solve the given tasks. Then, a complete block diagram of the project is discussed in section 4. In last, Section 5 discussed the conclusion and future recommendations.

## II. METHODOLOGY

This project was carried out using a top-down method of system design. The project was broken down into modules using this strategy, and each module was further separated into components in smaller sub modules, which could then be integrated to fulfill the development aim of the desired system. This project was completed by using the modular design processes. Different modules of the system are shown in figure 1 below.

There are numerous instances in which it is important to know the temperature of the environment in our daily lives and various industrial sectors, such as the temperature inside a reactor or the winding of an electrical machine. RTDs, thermocouples, thermistors, and semiconductor type elements are a few of the most popular types of sensors. A sensor, transducer, or transmitter is a physical device that has the ability to convert one type of process variable into another sort of signal.

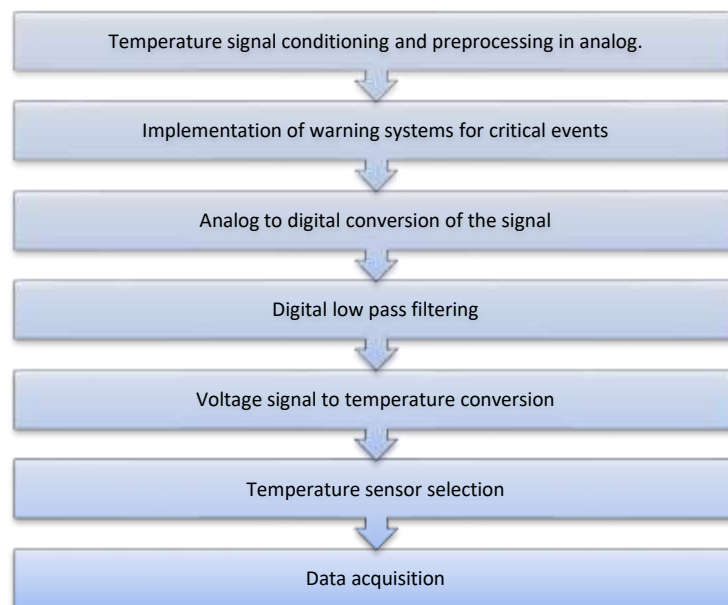


Fig 1: Modular design process

No matter how little the electrical signal may be, a temperature sensor is a device that turns temperature into an electrical signal. This signal may have a variety of ranges, but for industrial purposes, it must only be used within a few generally recognized electrical signal ranges. A temperature transmitter, on the other hand, is a device that transforms a temperature transducer's tiny output into one of many common signal ranges, such as 4 to 20 milliamps, 1 to 5 volts, 0 to 10 volts, and a few more. Different types of temperature sensors are described in Table 1.

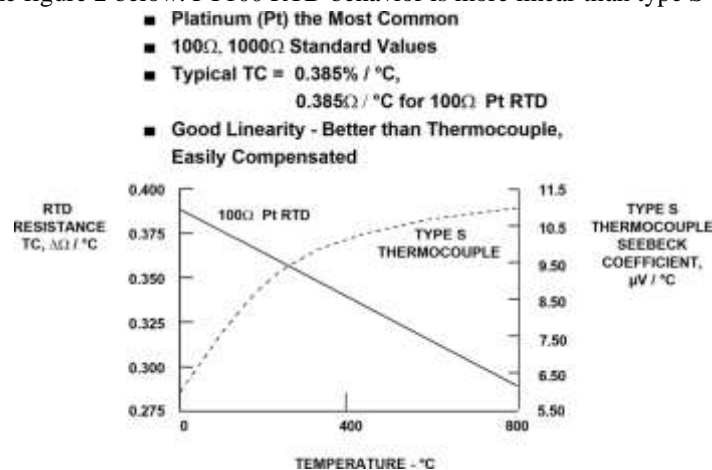


**Table I:** Types of Temperature Sensors

THERMOCOUPLE	RTD	THERMISTOR	SEMICONDUCTOR
Widest Range: -184°C to +2300°C	Range: -200°C to +850°C	Range: 0°C to +100°C	Range: -55°C to +150°C
High Accuracy and Repeatability	Fair Linearity	Poor Linearity	Linearity: 1°C Accuracy: 1°C
Needs Cold Junction Compensation	Requires Excitation	Requires Excitation	Requires Excitation
Low-Voltage Output	Low Cost	High Sensitivity	10mV/K, 20mV/K, or 1µA/K Typical Output

**A. Thermocouples**

The comparison of an APT100 sensor and a type S thermocouple throughout the temperature range of 0 degrees Celsius to 850 degrees Celsius is shown in the figure 2 below. PT100 RTD behavior is more linear than type S thermocouple activity.



**Fig 2:** Differences between RTD's and thermocouples.

**B. Seebeck and Peltier Effects**

This part will also go into the building of the sensor hardware as this project is employing thermocouples to develop a temperature monitoring system. The preceding part just provided a cursory overview of thermocouples; however, in this section, The thermoelectric effect is a phenomenon that underlies the functioning of thermocouples. The Seebeck effect uses both thermal and electrical energy, as its name indicates. It is quite astounding that the joining of two different alloys, when heated at one end, may cause a current to flow through the loop. It's also crucial to remember that connecting two wires composed of different alloys and then applying external voltage to the loop will result in the reverse of the seebeck effect. In this scenario, one end of the loop will heat up while the other end cools down. Modern appliances exploit the Seebeck effect, often referred to as the Peltier effect, in a variety of ways. Any material may be heated or cooled using the Peltier effect. It may be used, for instance, as a cooling system for microprocessors. A Peltier cel is the name of the instrument. On the other hand, if the experiment is carried out in the opposite manner, that is, if external current is applied to the union of two metal wires, the results will be the exact reverse, with one end of the union being hotter and the other becoming cooler.

**C. Analog Preprocessing**

The conditioning and amplification of the temperature signal from a thermocouple will be covered in this section. The study discusses how to extract the temperature signal from a thermocouple before the signal conditioning. The potential difference between

two junctions of an alloy wire is what determines the voltage across a thermocouple's terminal. This voltage, as shown, is the potential difference between two points (voltage at 1 junction with reference to the other one) as shown in Fig 3 below.

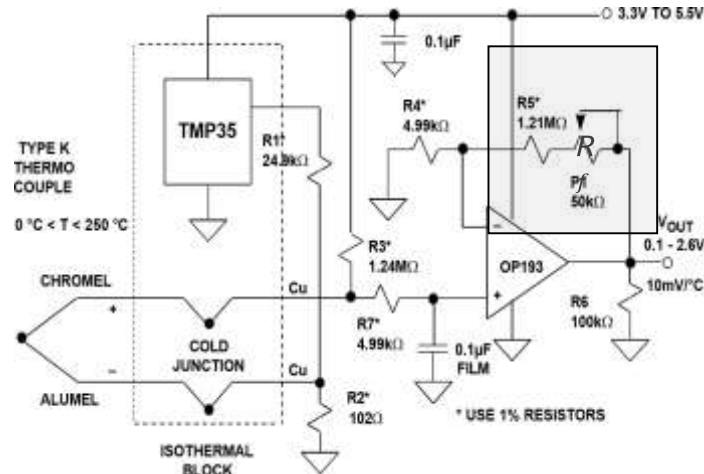


Fig 3: Voltage across the two junctions.

1) Cold junction compensation

Nowadays, it is not very practical to provide a reference from zero degrees Celsius, so instead of compensating the cold junction's deviation from zero degrees Celsius and adding that into the conditioning circuit, it could compensate the coal junction's deviation from zero degrees Celsius. This entire process is known as coal junction compensation. The conditioning of the signal from the OK type thermocouple is shown in the above figure 3, along with the corner junction compensation using the temperature sensor TMP 35. Since the TMP 35 sensor has 41 V/OC sensitivity, it must add a negative 41 V/OC to compensate for the cold junction. To achieve this, the study uses the TMP 35 sensor along with the resistors R1 and R2. as the focus is in voltage difference between the terminal T1 and T2.

$$V_{T1T2} = V_{T10} - V_{T20} \tag{1}$$

$$V_{T10} = V_{T1T2} + V_{T20} \tag{2}$$

The aforementioned computation shows that we need to add -VT2200. The circuit in the following diagram employs the temperature sensor TMP 35 together with the resistors R11 and R22 to increase the voltage of T22 at a rate of 41 microvolts per degree centigrade from the ground, thus adding negative voltage to the circuit VT2200(vR22)

To output potential difference. The figure 4 below shows how we do this to compensate for the cold junction.

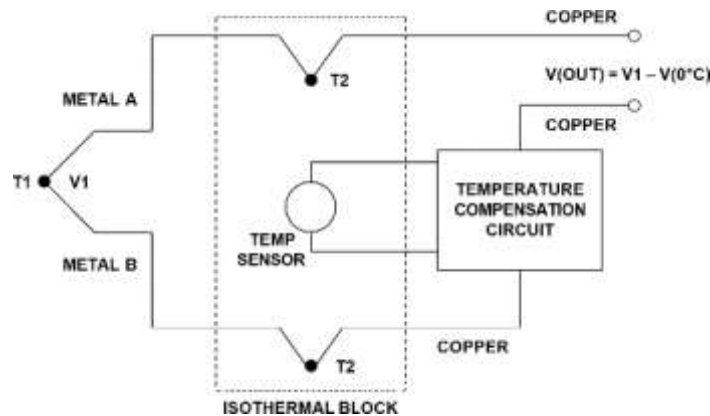


Fig 4: Diagram of cold junction.



The TMP 35 sensor, whose sensitivity is 10 millivolts per degree Celsius, is split between the R11 and R22 resistors in the circuit shown above. Its value at these two points is as follows:

$$V_{R2} = \left[ \frac{R_2}{R_1 + R_2} \right] \times V_{TMP} \tag{3}$$

$$V_{R2} = \left[ \frac{.102k}{24.9k + .102k} \right] \times 10mv / ^\circ C \tag{4}$$

$$V_{R2} = 0.04079mv / ^\circ C \tag{5}$$

$$V_{R2} \approx 41\mu v / ^\circ C$$

The voltage across R22 introduces a temperature coefficient of -41  $\mu v / ^\circ C$ .

### 2) Amplification

We must convert the 10.15 mv that an OK type thermocouple produces at 250  $^\circ C$  into 2.5 volts i.e.

$$Gain = \frac{2.5}{10.15m} = 246.305 \tag{6}$$

As we know that gain of non-inverting amplifier is given by the following equation.

$$Gain = \frac{P_1 + R_5}{R_4} \tag{7}$$

$$Gain = \frac{P_1 + 1.21M}{4.99k}$$

$$246 = \frac{P_1 + 1.21M}{4.99k}$$

$$246 \times 4.99k = P_1 + 1.21M$$

$$P_1 = 1227.54k - 1210k$$

$$P_1 = 17.54k$$

To achieve a gain of 246 we need to make the resistance

$$R_f = P_1 + R_5 = 1210k + 17.54k = 1.227M \tag{8}$$

The combination of two resistors, P1 and R5, has been used to represent RF. The potentiometer P11 has been added to R5 in order to tune the overall resistance to the resistor's nearest available value of 1.21M.

### 3) Dead Zone Compensation

The dead zone for the operational amplifier, OP193, which is not a true to rail amplifier, is just 0.1 Volt below this value. To compensate, R33 was added, which provides and now places an offset voltage of 0.1 Volt.

### D. Data Acquisition

A 16-input data collection card is one of our research goals. Multiplexing allows a 16-input data collection device to capture 32 signals.

#### 1) Multiplexing

In the telecommunications and computer networking sectors, multiplexers often referred to as muxing are the most common devices utilized. They are employed when there is a limited amount of a resource, such as a channel, to transport the data. For instance, the 16-input data acquisition card utilized in this research can only handle 16 inputs at once; as a result, multiplexing is employed to input all 32 signals while still utilizing the resource. In order to accommodate additional inputs, the primary idea of multiplexing is to switch between the inputs. The idea is to divide up a scarce resource like a channel or other kind of physical

transmission medium. This section will explain how multiplexers work and how they may be used in this project to bring 32 signals into LabVIEW for DSP.

A multiplexer is essentially made up of logical gates that are managed by enable and select lines. Let's use an application where we need to get eight inputs into the system using a channel with just one input. In this case, we need some sort of identifying technique for each individual input so that every single input may be sent to the output every time. Then we went to the other input; for this, we have a set of lines, and we require eight distinct binary data combinations, each of which uniquely identifies one input. A 32 to 8 multiplexer can input 32 signals, for example, if the delta acquisition card's 8 inputs are used. A 32 to 8 multiplexer must choose from four sets of eight signals at once, therefore the selection combination is 4, and two choose lines are required to represent four distinct combinations.

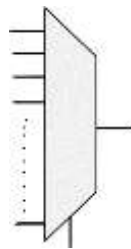


Fig 5: Multiplexer.

Number of inputs= 32, Selected lines =?

In this case, the choose variable, as we may refer to it, must be used to choose from four sets of signals.

Select Variable  $n=2$ , as  $2^2=4$

Consequently, we must choose lines from 4 sets of inputs.

Table II: Multiplexer Data

E	s1	s1	y1	y2	y3	y4	y5	y6	y7	y8
1	0	0	I <sub>1</sub>	I <sub>2</sub>	I <sub>3</sub>	I <sub>4</sub>	I <sub>5</sub>	I <sub>6</sub>	I <sub>7</sub>	I <sub>8</sub>
1	1	0	I <sub>9</sub>	I <sub>10</sub>	I <sub>11</sub>	I <sub>12</sub>	I <sub>13</sub>	I <sub>14</sub>	I <sub>15</sub>	I <sub>16</sub>
1	0	1	I <sub>17</sub>	I <sub>18</sub>	I <sub>19</sub>	I <sub>20</sub>	I <sub>21</sub>	I <sub>22</sub>	I <sub>23</sub>	I <sub>24</sub>
1	1	1	I <sub>25</sub>	I <sub>26</sub>	I <sub>27</sub>	I <sub>28</sub>	I <sub>29</sub>	I <sub>30</sub>	I <sub>31</sub>	I <sub>32</sub>

If we sample our signal at a rate of 250 samples per second, we must switch between these four groups once every 1 millisecond in order to get 250 samples of each of the 32 signals. We can manage the select lines from the lab view by setting up two data acquisition card ports as digital output ports, adding a loop, and adding a 2-bit digital counter with a delay of 1 millisecond.

**E. Digitalization of Analog Signals**

Analog to digital conversion involves the following two steps; Quantization and Digitization. Due to the restricted memory resources available for the signal processing, we create an analogue continuous signal at discrete times of values through the technique of quantization. Once the signal has been quantized, each discretely defined signal value can then be converted into digital format, which converts a voltage value into a stream of bits and it is known as digitization.

**F. Filter**

Filters are used to either remove or reduce undesirable signals. Filters may be digital or analogue. One of the most popular and efficient ways to convert an analogue system into a digital system that is shifting from an s-plan to z-plan is through the use of bilinear transformation.

Bilinear transformation:





$$s = \frac{2}{T} \left( \frac{z-1}{z+1} \right) \quad (9)$$

Inverse Bilinear transformation:

$$z = \frac{1 + \frac{T}{2}s}{1 - \frac{T}{2}s} \quad (10)$$

The system could be transformed into and out of a discrete system using the aforementioned bilinear transformation equation and inverse bilinear transformation equation. Bilinear transformation has a number of benefits, but the most significant one is that the filters' amplitude characteristics are maintained when the frequency axis is compressed (warping). Additionally, the original analogue frequency response is not aliased.

When building a digital system or filter, one of the most important issues to consider is that when executing a bilinear transformation, we shift from the s-plane to the z-plane, which compresses the frequency axis and produces frequency wrapping, or frequency drift. Frequency pre-wrapping after the bilinear transition solves this.

Digital Butterworth filter design:

The general model of Butterworth's filter is given by the following equation.

$$H(s) = \frac{1}{s^2 + \sqrt{2}s + 1} \quad (11)$$

Design specifications:

$$f_c = 10\text{hz}$$

$$f_s = 500\text{hz}$$

$$\omega_d = ? \quad (\text{digital cutoff frequency})$$

$$\omega_d = 2\pi f_c$$

$$\omega_d = 2\pi \times 10$$

$$\omega_d = 20\pi$$

Pre-wrapping:

$$\omega_p = \frac{2}{T} \tan\left(\frac{\omega_d T}{2}\right) \quad (12)$$

$$\omega_p = \frac{2}{T} \tan\left(\frac{20\pi T}{2}\right) \quad (13)$$

$$T = \frac{1}{f_c}$$

$$T = \frac{1}{500} = 2\text{ms}$$

$$\omega_p = \frac{2}{T} \tan(10 \times 3.14 \times 2 \times 10^{-3}) \quad (14)$$

$$\omega_p = \tan(0.01628)$$

Now replacing s in H(s) by  $\frac{s}{\omega_{ac}}$  as we get,

$$H(s) = \frac{\omega_{ac}^2}{s^2 + \sqrt{2}\omega_{ac}s + \omega_{ac}^2} \quad (15)$$

Now we convert  $H(s)$  to  $H(z)$  by replacing  $s$  by  $[\frac{z-1}{z+1}]$

$$H(z) = \frac{\omega_{ac}^2}{\left(\frac{z-1}{z+1}\right)^2 + \sqrt{2}\omega_{ac}\left(\frac{z-1}{z+1}\right) + \omega_{ac}^2} \tag{16}$$

$$H(z) = \frac{\omega_{ac}^2}{\left(\frac{z-1}{z+1}\right)^2 + \sqrt{2}\omega_{ac}\left(\frac{z-1}{z+1}\right) + \omega_{ac}^2} \times \frac{(z+1)^2}{(z+1)^2} \tag{17}$$

$$H(z) = \frac{\omega_{ac}^2 \times (z+1)^2}{(z-1)^2 + \sqrt{2}\omega_{ac}(z^2-1) + \omega_{ac}^2} \tag{18}$$

Now substituting  $\omega_{ac}$  by  $\omega_p = 0.01628$

$$H(z) = \frac{2.650384 \times 10^{-4} \times (z+1)^2}{(z-1)^2 + \sqrt{2}\omega_{ac}(z^2-1) + \omega_{ac}^2} \tag{19}$$

$$H(z) = \frac{0.002089 + 0.0041796z^{-1} + 0.002089z^{-2}}{1 - 1.0523z^{-1} + 0.0604z^{-2}} \tag{20}$$

**G. Labview VI program**

During this study lab view program is used for simulations. A complete diagram showing basic architecture of the workflow is shown in figure 6. It shows the structure of simulations and its working. Following digital operations are performed on the signal step by step throughout the process. Figure 7 describes the basic block diagram and work flow.

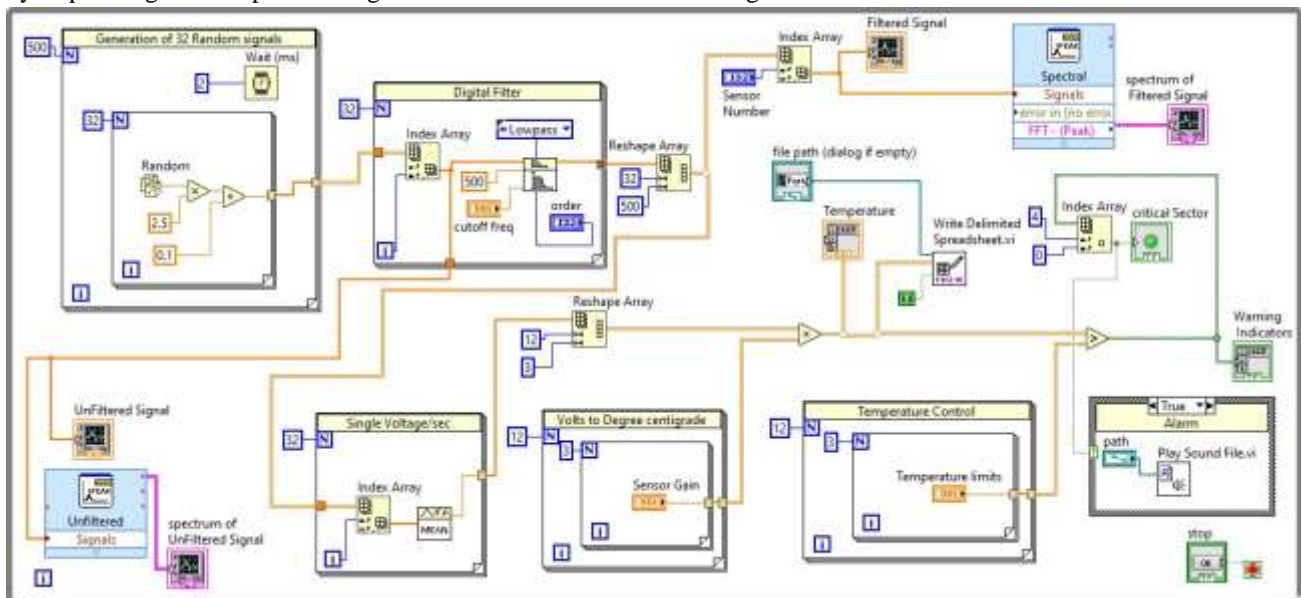


Fig 6: Labview architecture of Multi-Channel Temperature Design

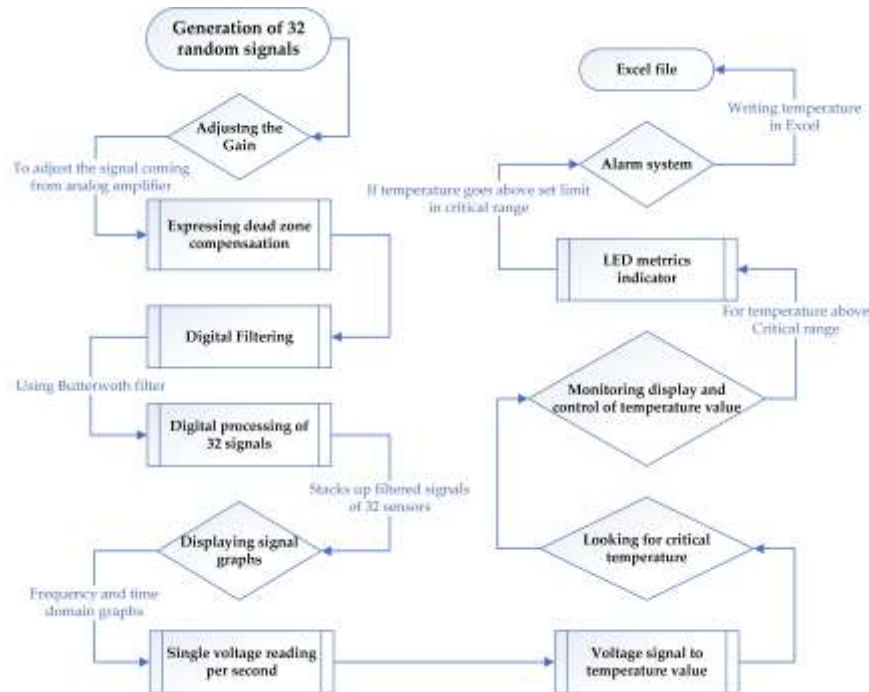


Fig 7: Block diagram of proposed workflow

1) Generation of 32 Random Signals

The first part of the simulation simulates the generation of 32 different random sequences from a numerical pallet using 32 different temperature sensor signals. Each sequence consists of 500 random values that are obtained in a second to simulate a temperature sensor signal that is really sampled at a rate of 500 samples per second. The block in the figure 8 has two nested loops with an inner loop that repeats 32 times to produce a series of 32 random numbers. The inner loop also contains a multiplier and an adder. And it repeats this process after each of the outer for loop's 500 iterations, producing 32 sequences of random numbers, each of which has 500 samples. This indicates that after each iteration, the outer loop weights two milliseconds since the outer loop contains a weight function that is derived from a numerical constant that causes it to wait milliseconds multiples of the constant tied to the wait function. With the outer loop set to run 500 times before the next iteration, the entire process of producing 32 random signals will be finished in one second when the sampling rate is set to 500. The section above on digital filter design discusses the decision to choose a sampling rate of 500. Every two milliseconds, a sample is acquired from each of the 32 temperature sensors, resulting in an overall sampling frequency of 500. These random number series are transformed by LabVIEW into a 2D array with 500 rows and 32 columns. The LabVIEW auto indexing feature performs this automatically. The LabVIEW indexes the data with the number of iterations of the innermost loop as columns and the number of iterations of the outer loop as rows. As you can see in the below image, auto indexing has been enabled on both loops. As a result, we receive a 2D array of order 500 into 32.

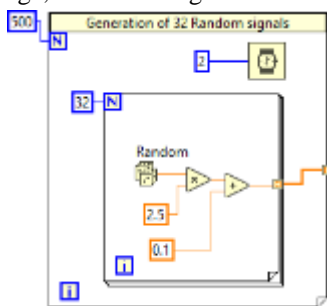


Fig 8: Block with two nested loops.

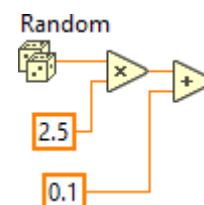


Fig 9: Number amplifying

2) *Tweak the gain to make the analog amplifier's output signal clear.*

The figure 9 has a multiplier that multiplies each random integer by a factor of 2.5 to replicate the behavior of an analogue amplifier that amplifies the signal from each sensor to a range of 0 to 2.5 volts.

3) *Expression of dead zone compensation*

By adding an additional value of 0.1 to each sample, we must go from 0.1 Volt to 2.6 Volt. This 0.1 volt addition simulates the dead zone adjustment that is covered in the section on analogue signal preprocessing.

4) *Digital Butterworth filtering*

The block of digital filters in the above figure 6 only comprises digital Butterworth filters. The digital filter block receives a 2D array of 32 signals and filters each call off to the array of 32 temperature sensor signals using a for loop that iterates 32 times. Supplied into the index array function from a separate pallet, We may access a single element of a 1D or 2D array or a full column or row by inputting the index address of the element and the 2D array input. This index array function accepts a 2D array of 32 signals, each of which has 500 samples, and stores them in 32 columns of the array. As a result, we must access each column of the 2D array separately for each accessing in order to feed the array into the digital Butterworth filter function. Because of this, the row intake of the index array function has been left empty, allowing the number of filtration to be sent to the column input during each accessing to signify the full column of the 2D array, as shown in fig 10.

The Butterworth filter has certain built-in capabilities, including Low pass, High pass, Bandpass, and Band Stop filters. For instance, if a band pass filter is to be used, we must determine its high cutoff frequency (FH) and low cutoff frequency (FL). We must additionally provide the filter type, in this instance a low pass filter, in order to identify the setup. In contrast, lab view will show up if we just pass low cutoff frequency values.

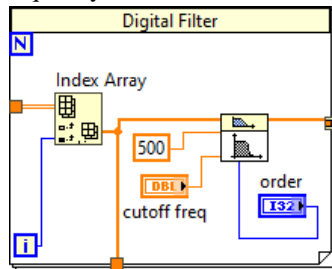


Fig 10: Digital filter block diagram

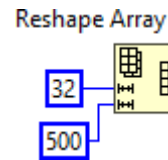


Fig 11: Reshape array

Digital Butterworth filter:

In addition to its primary use as a Butterworth filter, it also serves as a Low pass filter, High pass filter, Bandpass filter, and Band stop filter. In order to design a band pass filter, we must, for instance, determine the high cutoff frequency FH and the low cutoff frequency FL. The filter type, low pass in this example, must also be selected in order to properly identify the setup. Lab view will also be shown if just low cut off frequency data are provided.

5) *Stacks up filtered signal of 32 sensors after digital processing*

The 32 signals are digitally filtered one at a time in a sequential fashion by the VI simulation's digital filtering module. As can be seen in Fig. 11 of the block diagram, the for loop's auto indexing has been set to concatenation mode, which means that the 50 processed signals will be stacked vertically into a single row. It is necessary to separate these signals and then reassemble them into a 2D array. As a consequence, a 32row, 500column array was generated through the array palette's reshape operation. Since the 2D array of random signals was formed in the sequence of 500 rows and 32 columns, and each row now comprises 500 samples of processed data and processed signal from a digital filter, we may say that the 2D array has been transposed. Any array type is welcome in the reshape array procedure. The block diagram shows that 32 rows and 500 columns have been established by supplying constant values to the processor, and that the result is then passed on for further digital processing if the input is of any dimension and is converted into an array of that dimension.

6) *Displays the time and frequency domain graphs of signals*

Having 32 graphs in both the time and frequency domains would be cumbersome, so instead we use the index array function to access each signal independently, allowing us to choose which signal is sent to the spectrum analyzer and which is sent to the time domain graph. The index array function accesses each 2D array row independently. The index array function's column input is

empty and useless. Thus, the frequency analyzer, graphs, and time domain graphs have had their controls moved to the index array function row on the front panel.

7) *Convert the signal into single voltage reading per second*

Given how frequently we check the temperature, a temperature readout per second is deemed sufficient for seamless operation. Thus, we must transform the 500-sample-per-second data into a single temperature value each second.. Here, it's crucial to note why we need 500 samples per second from each sensor if we only required one temperature value per second. The correct response is that doing so is required. This study project uses a random signal generator to create the signals, but since a simulation was conducted as part of the experiment, the variation of the values that the generator generates is fairly substantial, giving the signal the appearance of being significantly influenced by the noise. Therefore, sampling is required to analyze the signal and eliminate all of the noise.

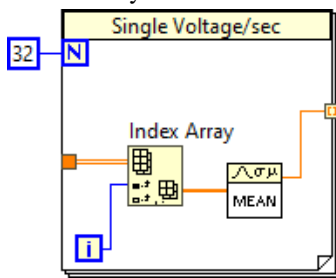


Fig 12: Single voltage diagram.

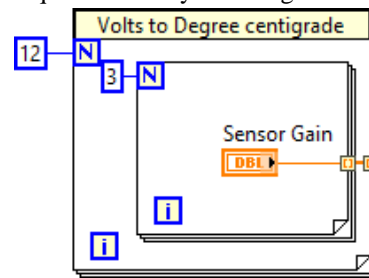


Fig 13: voltage signal to temperature converter.

The mean of the angry row of the 2D array has been calculated and passed on as a one-dimensional array of order one row and 32 columns in order to indicate the temperature reading that is the most accurate. These are the voltage per second readings from each sensor, which are then sent to the reshape array function to produce a 2D array with three columns and an order value raised that could aid in processing and organizing data for front panel indications. Figure 12 shows single voltage diagram.

8) *Convert the voltage signal into a temperature value*

Given that the connection between the output voltage from a K type thermocouple and the temperature is shown in the block diagram and the preceding sections, we must convert the voltages to temperature values in order to transform this signal into meaningful information. The signal up until this part of the VI, which is the output of the preprocessing analogue amplifier, is still a voltage signal with a range of 0.1 Volt to 2.6 Volts, as can be observed from the block diagram and the preceding sections. At this level of processing, the linear relationship between the voltage signal and temperature, which is the output voltage, changes by 10 millivolts per degree Celsius.

We must multiply the voltage by a factor of 100 in order to get the temperature value, which can then be converted from the voltage value. As seen in the block diagram of figure 13 above, two for loops have been utilized in nested arrangement to produce a 2D array of gain factors that is 100. By aligning the dimension of the previously formed signal array with it, this makes it possible to multiply elements one by one to get the temperature value. In the block diagram above, the output of this block is delivered to a multiplier, which multiplies the reshaped array of voltage values provided on by the reshape array function. The outer loop iterates 12 times and the inner loop three times. The temperature value is calculated by multiplying the voltage signal by the gain factor and displaying or alerting.

9) *Monitors display and control temperature value*

Visual analysis of the processing of signals and the resulting data is quite useful. One must also specify the temperature choice values before sending the signal on to be transformed into a single value per second by the group indicator and spectral measurement function tissue the boat signal and frequency spectrum of the signal food processing and unprocessing. We can see filtered and unfiltered signal specturms in figure 14.

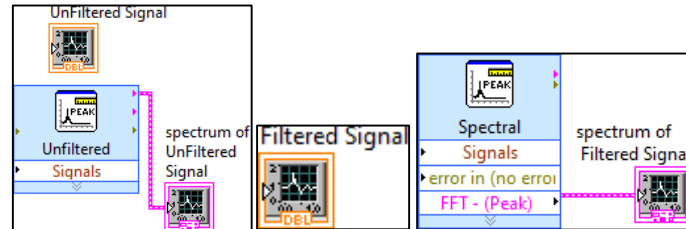


Fig 14: Filtered and unfiltered signal's Spectrums.

**10) Critical temperature control**

Adding a control for temperature limit is a useful feature since it is often required to define various temperature limits for the different applications and industries. We need a measure with the same order to compare a 2D array of temperature data. Entering one value from the front end control and giving it to the compare procedure creates a 2D array. This function compares each temperature value to the control panel's input before comparing the 2D array of temperature values to the control's single-value array. The comparison function returns a Boolean result of true, false, zero, or one. When the control function's comparison function returns a true result, it means that the pressure in that sector is greater than the target temperature. Cooling fans might be switched on and off using this information.

**11) LED metric temperature indicator for temperatures over critical range**

As was said in the previous sentence, the temperature value and the designated temperature limit were compared to create a 2D array of true and false values. An LED indicator was made from this array of true and false values to indicate when the actual temperature exceeded the predetermined temperature limit.

**12) Critical area temperature alarm.**

Because one sector was meant to be the most crucial for which alarm should activate if the temperature exceeds the sector pressure limits, the same metrics of two and false values are utilized to trigger the alarm system if temperature exceeds permissible doing pressure value in this research. As shown in block diagram 7, the indicator function, which is used to access a specific element of the array, returns a value of true or false depending on whether the temperature in that sector is over the critical limit. Her direct index value would be true if the temperature was higher than the crucial level, sounding the alarm and turning on the LED indication. To do this, a conditional statement that takes the values true or false as inputs is positioned around the play sound function, which can be seen in the block diagram. Because the play sound function was called within the truth case of the case statement, the alarm will sound if the input value is true. A sound function is shown figure 15.

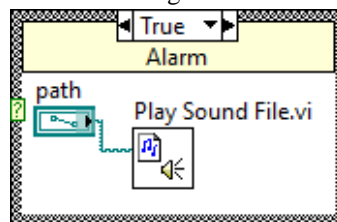


Fig 15: Sound function.

**13) Write the temperature value onto an excel file**

The last action taken by this simulation, which is depicted in the block diagram, is to use the function write to delaminated spreadsheet to record the temperature value in an excel file, which is one of the project's goals. The part of the file to be written on, which may be selected from the front panel, is an input for the right to delaminated spreadsheet function. A constant of type Boolean has also been supplied to the function in order to concatenate all of the writing together.

III. RESULTS AND DISCUSSIONS

A. Front panel:

While running the program, figure 16 is showing the front panel when the program it in running mode. It is presenting many indicators and control while in running mode. We can see different indicators for signals, temperature, stop and many others. We can discuss one by one in this section for this project.

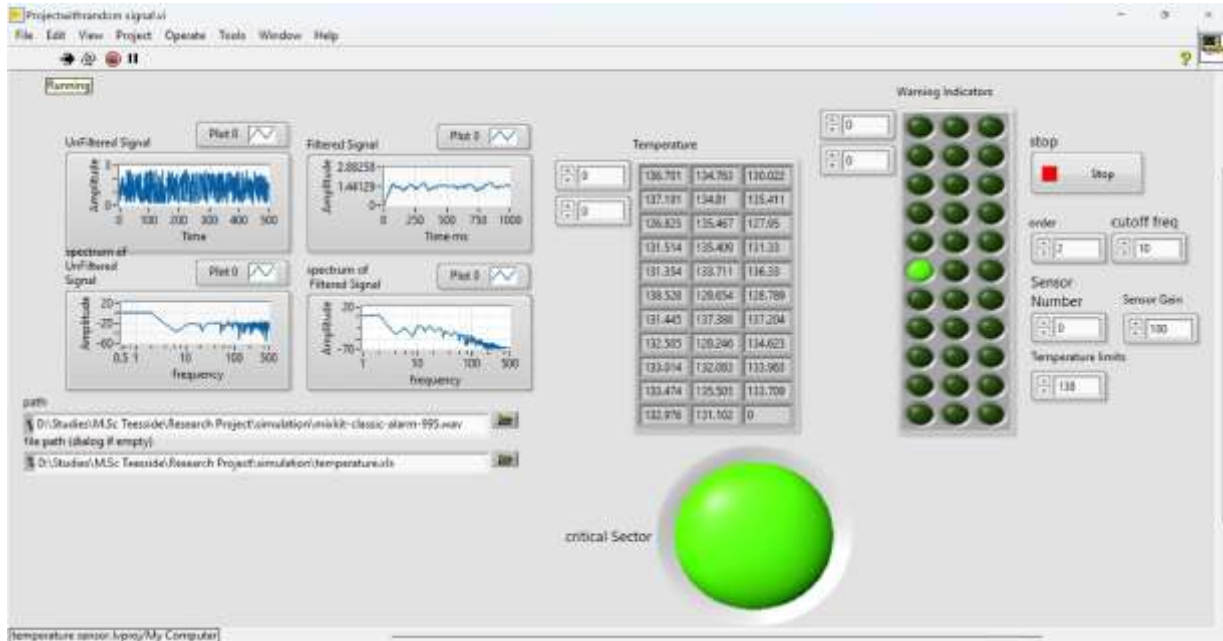


Fig 16: Graph indicators for processed and unprocessed signals

Graph indicators for the processed and unprocessed signals can be seen from this section of front panel. We can see unfiltered signal, filtered one and their spectrums. Amplitude with respect to frequency and time can be seen in this section area of front panel while running the program.

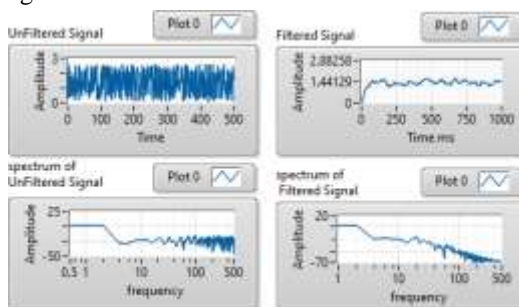


Fig 17: Graphs of signal (time domain).



Fig 18: Indication of temperature from individual sensors.

B. Temperature indicator for 32 temperature sensors

This study uses 32 temperature sensors in running mode. This is accomplished by adding an indicator to the final 2D array of temperature data, which is covered in the figure 18 above.

C. LED temperature indicator that flashes when the temperature exceeds the predetermined threshold

Being able to view an indicator is always extremely beneficial when there is a lot of data being shown. Because of this, it is very helpful to install a visual indicator, such as an LED, for each temperature sensor. This way, if the temperature at any one of these 32 locations rises above the predetermined limit, the LED starts to glow to notify the system controller that the sector's temperature is rising above the limits and some action is required. Figure 19 is showing LED indicator.



Fig 19: LED indicator.



Fig 20: Stop control of Simulation.

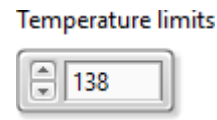


Fig 21: Temperature control limit.

**D. Simulation Stop control**

Since the entire process of monitoring the temperature must run continuously, we must put every VI application into a while loop. Additionally, we require some sort of control to halt the simulation when necessary, so they stop the while loop's execution using the stop control that is built into the VI. Figure 20 is showing stop control.

**E. Control for limit of temperature**

When temperatures are present in the workplace, they are controlled to stay within predetermined ranges in order to generate cooling fans. Due to the need to control the temperature limit, which was also discussed in the previous section, it is possible to do so by comparing the current temperature values to a set of metrics with 11 rows and 3 columns. From there, we can compare each element to the location in the control array where the same element is present, with the results being used to derive various functionalities.

Figure 21 shows temperature control limit icon.

**F. Sensor number control for signal analysis**

This article outlines the design of a K type thermocouple-based high precision temperature measurement system. The device's benefits over conventional temperature measurement techniques include a simple circuit construction, high precision, and outstanding stability. The device has a strong chance of working in hard conditions with high pressure, high impact, and other requirements for temperature testing in hot test processes. The findings reveal that the temperature measuring device has a high degree of accuracy and an absolute error of less than 0.1 degrees Celsius, which makes it useful for applications needing accurate temperature readings.

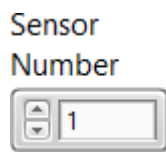


Fig 22: Number control

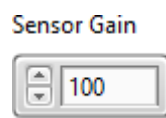


Fig 23: Gain control

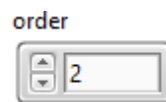


Fig 24: Order control

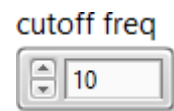


Fig 25: Cutoff control

**G. Sensors gain control**

In the industrial setting, making a system interoperable with various hardware setups is quite helpful. For instance, the sensor in this project recorded the temperature using RK type thermocouples, which are available in a variety of models with somewhat varied characteristics. It would be really helpful if the system in this situation enabled alternate hardware with somewhat different settings. In order to allow for the usage of several pieces of hardware, control has been built up for such an event to digitally vary the sensor gain. The control button used for this purpose in this research is depicted in the figure 23.

**H. Filter order control**

In light of this, a control to raise or lower the order of the digital filter has been established, and it can be seen on the front panel and in the figure below. We sometimes need to exert additional effort to eliminate noise from the signal in order to get an accurate measurement, depending on the surroundings and if the temperature signal might be altered. Order control for filter is shown in figure 24.



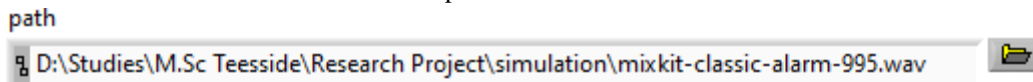


**I. Cutoff frequency control**

A control for the signal's cutoff frequency is added to the design in addition to the order filter control. The majority of the signal will be suppressed when using a filter since higher frequencies have a lot of energy, which is naturally muted by the filter and may affect temperature readings. We are utilizing a random number generator to produce the signal, which is not true signal. Because the variance of these numbers is high, we may see a great deal of fluctuation in the unfiltered signal, which appears to be noise. By increasing the Butterworth filter's cutoff frequency, we would then be able to adjust the cutoff frequency to account for a somewhat larger variation in temperature each second. Therefore, to be able to change the cutoff frequency, a numerical control is placed on the Butterworth filter's low cutoff frequency. Its icon is shown in figure 25.

**J. Control for path of alarm audio input**

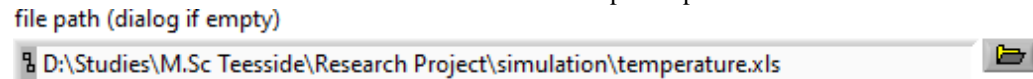
In the temperature monitoring system, crucial features are the alarm system and LED indicators, which provide alerts for irregularities. The alarm system, constructed using LabVIEW's play sound function, triggers when temperatures exceed set limits. The system logic evaluates temperature data against set limits, and if exceeded, a true Boolean value activates the alarm. The audio file path for the alarm sound can be modified on the front panel.



**Fig 26:** Path control for audio input

**K. Control path of excel file**

The last job of the project is to utilize the temperature on an excel file in a manner similar to how we did in the previous part, which was to play an alert sound for a certain occurrence, in this instance the temperature exceeding defined limits. The write to delaminated spreadsheet function on the left view and the excel file's file path input control were utilized to achieve this.



**Fig 27:** Path control for excel file

**TABLE III.** Result and Error of Temperature Measurement

The output voltage value (mV)	The thermostatic bath temperature (°C)	Fitting temperature conversion (°C)	Measurement error (°C)
-2.909	-50	-49.937	0.063
-1.036	0	0.015	0.015
0.984	50	50.047	0.047
3.071	100	99.981	-0.019
5.159	150	150.036	0.036
7.248	200	199.926	-0.074
9.337	250	249.944	-0.056
11.423	300	299.953	-0.047
13.509	350	350.083	0.083
15.67	400	399.937	-0.063
17.842	450	450.049	0.049
20.011	500	500.072	0.072

During data acquisition for cold and hot end voltages, electromagnetic interference or zero drift can cause fluctuating voltage, leading to inconsistent temperature readings and reduced measurement accuracy. To address this, 100 voltage values were collected within 0.1 seconds and averaged using software programming. This approach effectively mitigated voltage fluctuations and ensured better measurement accuracy.

A thermocouple temperature sensor was placed in a thermostat and tested at -50°C, with subsequent 50°C increments.



## IV. CONCLUSTIONS

In conclusion, this study outlines a multi-sensor temperature monitoring system using LabVIEW, featuring a temperature indicator for 32 sensors, LED alerts for temperatures above set limits, and simulation controls. The system also provides controls for temperature limits, sensor gain, filter order, cutoff frequency, and alarm path input, facilitating comprehensive temperature control and ensuring effective response to deviations in monitored parameters. This article outlines the design of a K type thermocouple-based high precision temperature measurement system. The device's benefits over conventional temperature measurement techniques include a simple circuit construction, high precision, and outstanding stability. The device has a strong chance of working in hard conditions with high pressure, high impact, and other requirements for temperature testing in hot test processes. The findings reveal that the temperature measuring device has a high degree of accuracy and an absolute error of less than 0.1 degrees Celsius, which makes it useful for applications needing accurate temperature readings.

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