DESIGN OF MULTI-POINT TEMPERATURE AND HUMIDITY MONITORING SYSTEM BASED ON LabVIEW

Zhao YANG, Rui WU*, Bo WU, Yuhan WANG

This paper unveils the blueprint of a sophisticated multi-point temperature and humidity monitoring system, crafted using LabVIEW software. The article is meticulously organized into five chapters: an overview of the system's architecture, the design of the intuitive front panel, the intricacies of the program panel, the system's debugging and operational phases, and a concluding remark. The front panel is functional and aesthetic, segmented into a temperature display module, a humidity display module, and a data acquisition module that tirelessly gathers vital information. Meanwhile, the program panel is divided into a temperature module that senses the heat, a humidity module that gauges the dampness, a time module that marks the passage, and a data acquisition module that orchestrates the influx of data. The final running result shows that the system can achieve the expected effect. The system can perform real-time measurement, display, and alarm for multi-point temperature and humidity in environments such as homes and outdoors. It plays an important and positive role in people's production and daily life.

Keywords: LabVIEW, temperature, humidity, software; monitoring system

1. Introduction

In the realm of industrial production, the vigilant monitoring of environmental temperature and humidity holds a position of utmost importance, while in the modern home, the detection of these elements is equally vital and indispensable. In 2025, Zhao and others from the School of Mining Engineering of Taiyuan University of Technology in China addressed the complexity of underground coal mine environments and the safety issues workers face during geothermal disasters. They researched and designed a LoRa-based communication system for real-time monitoring and control of temperature and humidity in underground coal mine working environments [1]. In 2023, Chen and others from Xiamen University of Technology in China designed a warehouse temperature and humidity data acquisition system based on the STM32 microcontroller. Additionally, a pair of infrared photoelectric modules were installed near the warehouse entrance to count the number of people in the warehouse in real time, aiding in crowd control and implementing epidemic prevention measures [2]. In 2024, Dipendra Pal Singh Chundawat and others in India designed a device capable

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of real-time monitoring of temperature and humidity during the tobacco curing process. It alerts when thresholds are exceeded and transmits data to the cloud. The system can predict future temperature and humidity values to calculate operational efficiency [3]. In 2023, the team of P. F. C. de Marinho designed an "Intelligent, low-cost, high-performance system for environmental air quality monitoring through integrated gas, temperature, and humidity analysis." This system uses an Arduino microcontroller and IoT applications to monitor air quality by comprehensively analyzing gases (carbon dioxide, carbon monoxide, and liquefied petroleum gas), room temperature, and humidity [4]. In 2024, Fan and others designed a "Polymer microsphere integrated" sensor based on fiber Bragg gratings capable of detecting relative humidity and temperature [5]. In 2024, the Amar Kapic team developed a "Multichannel Radiation-Compensated Systems for Temperature and Humidity Monitoring for High Energy Physics Detectors" [6]. In 2025, Deng and others from Guangxi University in China designed a comprehensive method for monitoring temperature and humidity in grain storage facilities based on antibacterial sensors, which is of great significance for effectively ensuring grain storage [7].

LabVIEW is a programming environment developed by National Instruments (NI: National Instruments) that uses the graphical programming language G [8-9]. As a programming tool, LabVIEW enables scientists and engineers—even those without extensive programming expertise—to quickly and easily create custom applications for their test and measurement systems, as noted in references such as "An Effective Concept for Teaching LabVIEW Programming to Engineering Students" [10], "Agrisense: MyRio and LabVIEW-Powered Precision Farming for Sustainable Agriculture" [11], and "Design of automated testing system for electronic safety and disarming devices based on Labview" [12].

As highlighted in previous research [13-15], temperature and humidity monitoring plays a crucial role in industrial production. Meanwhile, LabVIEW has proven to be a powerful tool for industrial programming [16-17]. This project combines these two elements by developing a multi-point temperature and humidity monitoring system on the LabVIEW platform. The system enables real-time monitoring of temperature and humidity at multiple locations in industrial or environmental settings. When readings exceed predefined thresholds, the system triggers an alarm to notify administrators, thereby achieving effective environmental control.

Since this system is developed based on LabVIEW software, it has the following advantages compared with other temperature and humidity measurement systems:

High efficiency of graphical programming: LabVIEW adopts graphical programming (G language), constructing programs through wires and icons instead of text code. This allows developers to design data acquisition, analysis, and display processes more intuitively. It is particularly suitable for non-professional programmers to quickly build systems, significantly shortening the development cycle.

Powerful data acquisition integration capability: LabVIEW is deeply integrated with various types of hardware (such as NI data acquisition cards, sensor modules, etc.). It has built-in rich driver libraries and APIs, enabling easy connection to devices like temperature and humidity sensors and transmitters. This simplifies the hardware configuration and data reading process, reducing compatibility issues.

Rich data analysis and processing functions: It comes with a large number of function libraries for signal processing and statistical analysis (such as filtering, trend analysis, FFT, etc.). These libraries can directly perform real-time analysis on the collected temperature and humidity data, eliminating the need for additional development of complex algorithms. This facilitates the implementation of functions such as data calibration and anomaly detection.

Flexible user interface design: LabVIEW provides convenient front panel design tools, allowing for the quick creation of interactive interfaces containing elements such as charts, dashboards, and alarm indicators. These interfaces intuitively display the changing trends of temperature and humidity data and support custom layouts to meet the display needs of different scenarios.

Excellent scalability and modularity: It supports modular programming, where each function of the system (such as acquisition, analysis, alarm, and storage) can be independently designed and then combined. This makes it easy for later function expansion (such as adding new monitoring points or integrating control functions) or maintenance and upgrades.

Strong hardware compatibility and cross-platform capability: Not only can it seamlessly collaborate with NI's own hardware, but it also supports mainstream third-party sensors and device protocols (such as RS485, Modbus, etc.). Meanwhile, it can run on systems like Windows and Linux, adapting to different deployment environments.

Outstanding real-time performance and reliability: When combined with real-time operating systems (such as NI Linux Real-Time), it can achieve high-precision timed data acquisition and real-time data processing. This ensures the timeliness of temperature and humidity monitoring, meeting scenarios with high requirements for response speed (such as laboratory environmental control).

Convenient deployment and secondary development: The generated executable files (.exe) are easy to deploy on devices without a LabVIEW development environment. At the same time, it supports integration with other systems (such as PLC, SCADA) through APIs or SDKs, enhancing the system's versatility.

This paper is divided into five parts, which are as follows: Introduction, Methods, Results, Conclusions and Acknowledgments.

2. Methods

This chapter first introduces the system's functional requirements and design scheme. Then it conducts specific design for the front panel and program panel.

2.1 System Functional Requirements

The system designed this time fulfills the following requirements:

1) Data acquisition function. It effortlessly captures real-time temperature and humidity readings from multiple vantage points;
2) Real-time display function. The system can achieve real-time display of the temperature and humidity from multiple points;
3) Alarm function. The system can trigger an alarm when the temperature or humidity exceeds pre-determined limits;
4) Real-time storage function. The system meticulously stores all collected temperature and humidity data in a dedicated database, ensuring retrieval and profound analysis in the future.

2.2 System Design Scheme

The system is primarily structured into four core modules: the multi-point temperature visualization module, the multi-point humidity visualization module, the data Lagging Module, and the time Module.

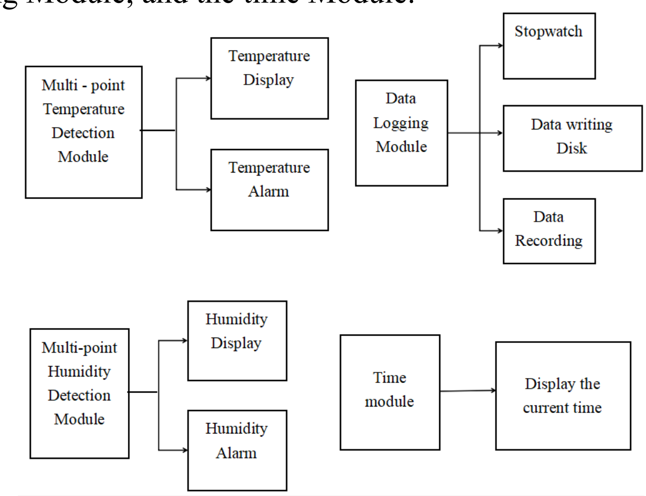

Fig. 1. System Design Module Diagram

As depicted in Fig. 1, each module caters to unique demands. The multi-point temperature visualization module is entrusted with the duty of presenting real-time temperature readings and instantly triggering alarms. Likewise, the multi-point humidity visualization module echoes the functionality of its temperature counterpart, offering real-time humidity displays and prompt alarm activations. Meanwhile, the data acquisition hub embraces three pivotal roles: logging data, committing data to disk, and possessing stopwatch timing proficiencies. Finally, the time keeper module stands as the guardian of the present moment, providing the current time with precision.

2.3 Temperature and Humidity Acquisition Algorithm

When temperature and humidity data are collected, the system needs to process the data using appropriate algorithms.

2.3.1 Selection of Algorithms

Random noise in temperature and humidity sensors typically manifests as high-frequency components, while real environmental changes are mostly concentrated in the low-frequency range. In temperature and humidity measurement, the moving average algorithm is generally more convenient and easier to implement. However, in this design, the Fourier Transform (DFT) algorithm is selected to process the collected temperature and humidity data for removing high-frequency noise. The reasons are as follows:

Targeted Noise Suppression: FFT can decompose signals into the frequency domain, directly identifying and filtering out interference at specific frequencies. In contrast, the moving average algorithm only reduces high-frequency noise through time-domain smoothing and cannot distinguish frequency differences between noise and valid signals.

Capability to Handle Periodic Interference: If there is periodic interference in temperature signals (e.g., mechanical vibrations or environmental fluctuations), FFT can accurately locate and eliminate the interference frequency through spectral analysis. However, the moving average algorithm has limited effectiveness in suppressing periodic interference, and low-frequency interference may remain.

Computational Efficiency Optimization: The computational complexity of FFT is $O(N \log N)$, which is more efficient than the moving average (with a complexity of $O(N)$) when processing long signals. It is particularly suitable for scenarios with high real-time requirements (such as high-speed sampling systems).

Frequency Domain Feature Extraction: FFT can provide spectral information of temperature signals, assisting in analyzing signal components (e.g., fundamental waves, harmonics). In contrast, the moving average algorithm only outputs time-domain smoothed results, lacking frequency-domain details.

Flexibility and Scalability: FFT can be combined with filter designs (such as band-pass filtering) to further optimize signal processing. The moving average algorithm, however, can only balance noise suppression and signal delay by adjusting the window length, resulting in lower flexibility.

In summary, FFT has advantages in targeted noise suppression, periodic interference handling, computational efficiency, and frequency-domain analysis. However, it should be noted that FFT has higher real-time requirements and may introduce spectral leakage issues. In practical applications, the algorithm should be selected based on signal characteristics, or a combination of both (e.g., FFT preprocessing + moving average post-processing) can be used to optimize results. Therefore, FFT was chosen in this design.

2.3.2 Implementation and results

The specific implementation method in this design involves performing an FFT on the acquired temperature and humidity signals, applying a low-pass filter to the results (e.g., retaining frequency components below 0.1 Hz), and then reconstructing the clean signal using an IFFT. The program implementation is shown in Fig. 2.

In the program, the original collected data is displayed on the Waveform Chart (Fig. 3). We perform a Fourier transform on this data with 128 points, and the resulting output is shown in Waveform Chart 2. In LabVIEW, the Butterworth filter is selected to apply low-pass filtering to the aforementioned results, and the filtered waveform is displayed on Waveform Chart 3. Waveform Chart 4 presents the final result after the inverse Fourier transform. By comparing these four waveforms, it is evident that high-frequency noise has been eliminated.

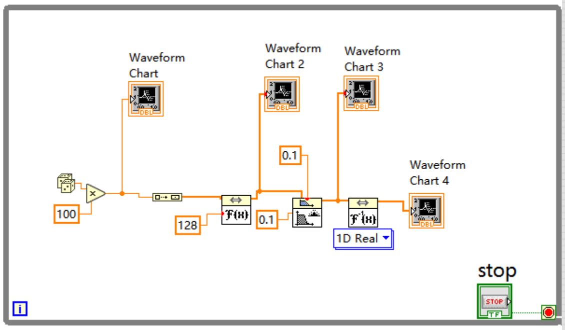

Fig. 2. Algorithm Program Design

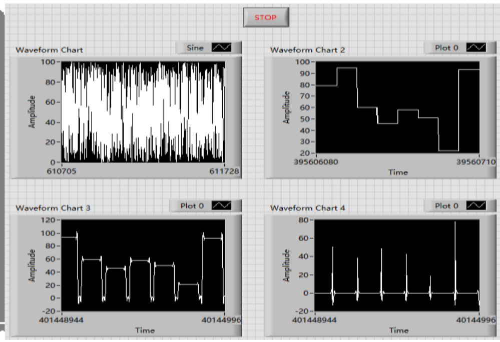

Fig. 3. Waveform Chart of Algorithm Implementation

2.4 System Design

2.4.1 Front Panel Design of the System

The temperature sensor module, crafted with the prowess of LabVIEW, boasts a sophisticated display mode that accommodates four concurrent visualizations. Each display point is adorned with five indicator lights: excessively high, hot, suitable, cold, and excessively low, elegantly depicting the temperature's status quo. Should the real-time temperature at any point deviate from the preset threshold, be it lower or higher, the alarm system springs into action, notifying the user of the unsuitable temperature in the displayed area and prompting necessary cooling or heating adjustments. The five lights offer a quick glimpse into the prevailing conditions at each point, while for a more nuanced understanding, one's gaze can turn to the thermometer situated on the left. This thermometer, too, provides a real-time snapshot of the approximate actual temperature. For those who seek unparalleled precision in their real-time temperature readings, the real-time temperature data display box stands ready, ideally capable of delivering accuracy down to four decimal places.

The Humidity Module is much like the temperature counterpart, it measures four points simultaneously, with the data categorized in a gradient from broad to specific, mirroring the approach used for humidity sensors. The key divergence lies in the visual depiction: whereas the temperature display employs a thermometer, the humidity display opts for a dial gauge, a nod to the conventional wisdom where thermometers are the go-to for temperature readings, and humidity gauges, reminiscent of dials, reign supreme for measuring moisture levels. Each humidity display point is meticulously divided into five categories: excessively humid, humid, suitable, dry, and excessively dry, offering a comprehensive view of the humidity landscape.

When configuring the front panel, minor adjustments were made to the indicator lights, which were designed into flame shapes with variable colors. When illuminated, the lights will display flames in various colors, ensuring that observers do not become overly fatigued while monitoring. To infuse a bit of visual interest and alleviate monotony, pattern elements are incorporated. Under appropriate conditions, a Tai Chi [18] pattern will be displayed to signify that the current temperature is comfortable for people.

The Data Logging Module meticulously chronicles every fleeting instant of temperature and humidity readings throughout the system's operation. This tool is primarily tasked with monitoring the relentless march of time and recording the present (actual) temperature and humidity conditions in an instantaneous, real-time manner. It ensures that these vital readings are swiftly captured and securely stored, leaving no room for any crucial data to slip through the cracks. Moreover, it effortlessly saves these records into a designated text file on the computer's hard drive, thus safeguarding the real-time preservation of the collected data and eliminating any possibility of missing out on essential readings when they matter most.

2.4.2 System Program Panel Design

The program block diagram on the rear panel is meticulously designed, comprising four distinct programmatic sections: the multi-point temperature display section, the multi-point humidity display section, the clock section, and the real-time recording section.

In the temperature and humidity display section, the system will pop up a corresponding dialog box on the front panel through program design, reminding the user whether the current temperature and humidity are suitable.

The program design diagram of the temperature and the humidity acquisition module of this system employs two basic programming structures. The system adopts the FFT algorithm introduced earlier in the text. To enhance the clarity and conciseness of the program, some parts of the program have been replaced with sub-VIs in the design. This method ensures that the program interface remains neat and smooth while completely retaining its core functions. The programs encapsulated in these sub-VIs are mainly used to compare input values with established fixed parameters, thereby achieving efficient and smooth data filtering [19-20].

Fig. 4 showcases the incorporation of a sophisticated time module into the temperature and humidity sensor system, enabling it to render the precise current time in real-time.

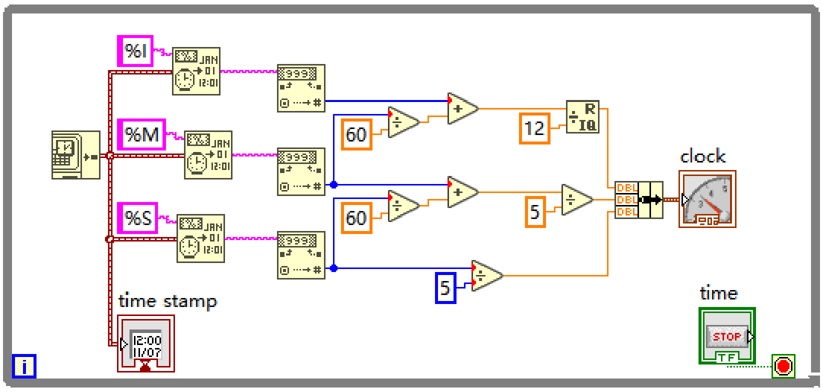

Fig. 4. Program Design of the Time Module

Harnessing the power of a While loop structure, it guarantees seamless and unceasing operation, meticulously adjusting and calibrating the time via time stamps. The time data is then seamlessly transmitted to the display interface, where it is elegantly presented on the dial with utmost accuracy.

Fig. 5 presents the program block diagram of the Data Logging Module, which records and backs up the collected data in real-time by utilizing a program that writes to a text file. This mechanism ensures the implementation of a real-time recording function, where the complete set of recorded data is displayed through the concatenation of strings, presenting a comprehensive view of the information.

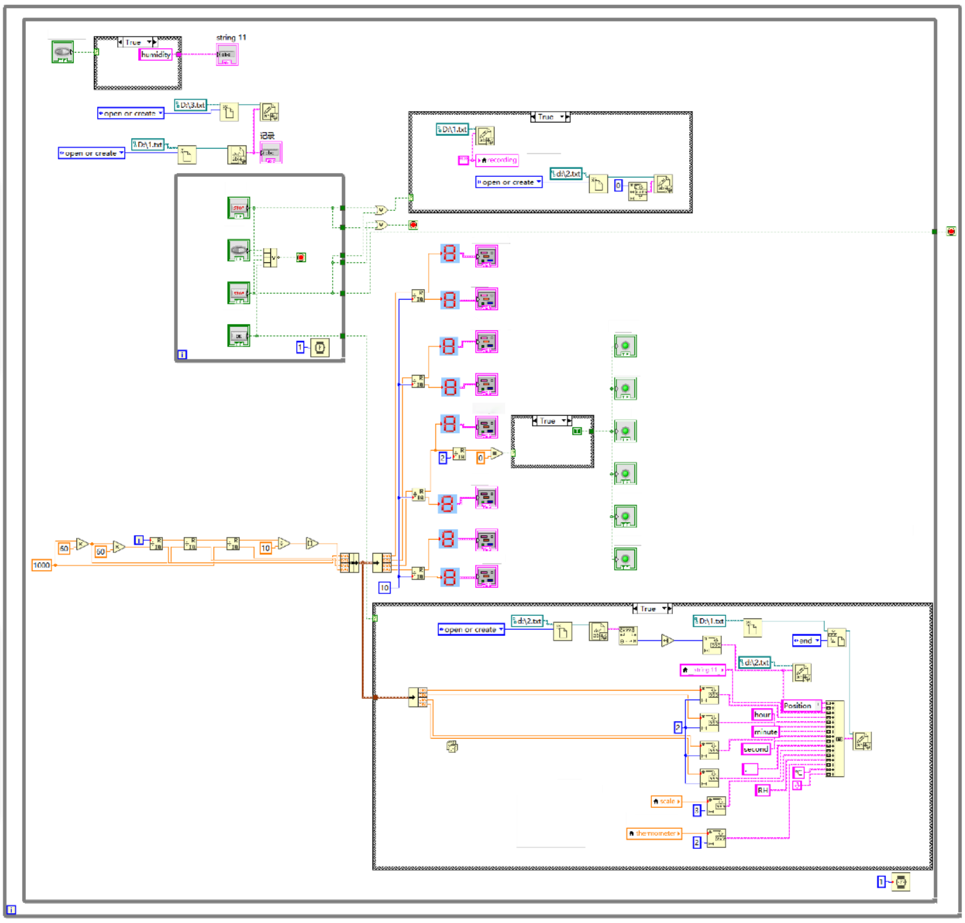

Fig. 5. Program Design of the Data Logging Module

3. Results

Upon the completion of the system design, a meticulous debugging process is undertaken step by step. Initially, each module of the system program is scrutinized to ensure its ability to function independently and normally. Subsequently, the overall operation of the system is examined to verify its proper functionality. The following presents the operational effects of the system.

Fig. 6 showcases a captivating real-time screenshot of the multi-point temperature display during the system's initial operation. The image vividly reveals that points one and two are marked as "hot," while points three and four exhibit temperatures that are "excessively high." The waveform graph elegantly illustrates the present temperature fluctuations, offering an intuitive glimpse into the dynamic changes. Furthermore, the circular indicator lights and the adjacent numerical display widget on the thermometer provide a refined and precise portrayal of the current temperature data. Nestled beneath the thermometer, a stop button awaits;

with a simple press, it effortlessly terminates the program's execution by halting the while loop, thus ceasing the program's continuous operation and gracefully bringing it to a halt.

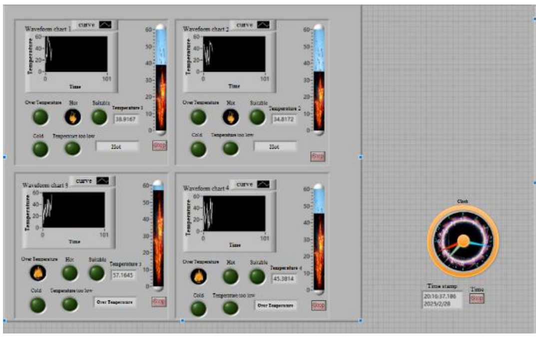

Fig. 6. Design Diagram of the Temperature Module Front Panel

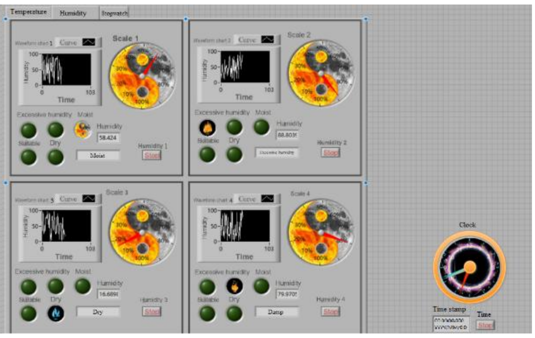

Fig. 7. Design Diagram of the Humidity Module Front Panel

When the temperature breaches its predetermined alarm threshold or dips below the designated alarm level, the system will sound an alert.

Illustrated in Fig. 7 is the operational interface of the humidity multi-point display system, where the data recording process mirrors that of the temperature multi-point display system. It offers three distinct modes for representing the collected data, enabling users to effortlessly access the desired information in a highly intuitive manner. Similar to the temperature multi-point acquisition system, the humidity display system is also equipped with predefined warning thresholds. When these thresholds are reached, the system will trigger an alarm.

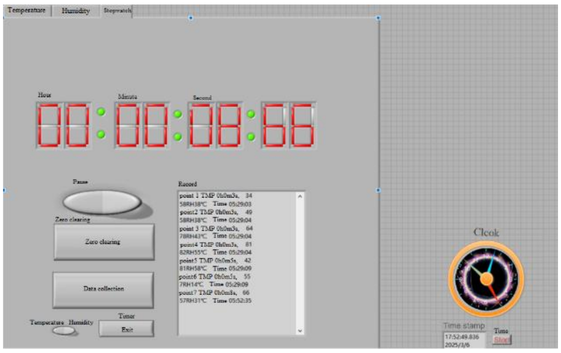

Fig. 8. Design Diagram of the Data Logging Module Front Panel

Fig. 8 unveils the operational interface of the system's acquisition module, masterfully blending a stopwatch with a real-time clock mode into a harmonious design. This ingenious fusion not only facilitates the instant capture of temperature and humidity data under prevailing conditions but also ensures the seamless storage of the collected data into a pre-established txt file, thus elegantly fulfilling the mission of recording and preserving the invaluable acquired information.

4. Conclusions

This article has crafted a sophisticated temperature and humidity surveillance system utilizing the robust platform of LabVIEW. Following rigorous testing, the system has been verified to function seamlessly, aligning perfectly with the design criteria.

The primary focus of this research is the software-based design of a temperature and humidity monitoring system, where the temperature and humidity data are generated by software random numbers and have not yet been connected to actual sensors. In the subsequent phase, efforts will be directed towards completing the data transmission between hardware and software, thereby enhancing the credibility of the data.

This design primarily utilizes LabVIEW's data processing library for the acquisition, processing, storage, display, and playback of signals. Compared to traditional instruments, it offers a higher cost-performance ratio and is more convenient. During the actual development process, LabVIEW demonstrates high flexibility and excellent practical performance, which enables its widespread application in various fields.

Acknowledgments

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