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IOT-BASED HUMIDITY MEASUREMENT AND CONTRL SYSTEM FOR GREEN HOUSE USING VLSI

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Abstract

Precise control of humidity is essential for achieving optimal crop growth in greenhouse environments. This paper presents an Internet of Things (IoT)-based humidity measurement and control system using VLSI architecture for automated greenhouse management. The proposed system employs a humidity sensor to continuously monitor environmental conditions, and the acquired data are processed by a VLSI-based controller implemented using Verilog HDL. The controller compares the measured humidity with predefined threshold values and generates control signals to regulate actuators such as exhaust fans and humidifiers. An IoT module facilitates real-time data transmission to a cloud platform, enabling remote monitoring and data logging. The integration of VLSI technology ensures low power consumption, high processing speed, and reliable operation. Experimental results demonstrate that the proposed system effectively maintains desired humidity levels while minimizing human intervention and energy usage, thereby enhancing greenhouse productivity and sustainability.
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Keywords: Internet of Things (IoT), Greenhouse Automation, Humidity Control, VLSI Architecture, Verilog HDL, Cloud Monitoring, Low-Power Design

1. Introduction

Greenhouse cultivation has emerged as an effective solution for achieving consistent agricultural production by providing a controlled environment independent of external climatic variations. By regulating key environmental parameters such as temperature, humidity, light intensity, and carbon dioxide concentration, greenhouses enable enhanced crop yield, improved quality, and extended growing seasons. Among these parameters, humidity control plays a particularly crucial role, as it directly influences plant transpiration, nutrient absorption, photosynthesis, and the prevalence of plant diseases.

Maintaining humidity within an optimal range is essential for healthy plant growth. Excessive humidity can promote fungal and bacterial infections, reduce transpiration rates, and hinder nutrient uptake, while insufficient humidity may cause excessive water loss, plant stress, and reduced productivity. Therefore, precise and continuous monitoring of humidity levels is necessary to ensure stable greenhouse conditions and maximize agricultural output.

Conventional greenhouse humidity management systems largely rely on manual supervision or basic microcontroller- based control units. Manual monitoring is labor-intensive, prone to human error, and incapable of providing timely corrective actions. Microcontroller-based systems, although automated to some extent, often suffer from limitations such as increased processing latency, higher power consumption, and restricted scalability when deployed in large greenhouse facilities. Moreover, many existing systems depend heavily on software-driven decision-making, which may not guarantee deterministic response times required for real- time environmental control.

Recent advancements in the Internet of Things (IoT) have enabled remote monitoring and data-driven agricultural management through cloud connectivity and sensor networks. IoT-based greenhouse solutions provide advantages such as real-time data visualization, historical data analysis, and remote accessibility. However, most IoT implementations rely on embedded processors executing software algorithms, which can introduce delays in control decisions and increase energy consumption, particularly in continuous monitoring applications.

To overcome these limitations, Very Large Scale Integration (VLSI) technology offers a promising alternative for greenhouse automation. VLSI-based controllers provide deterministic execution, parallel processing capability, high-speed operation, and significantly lower power consumption compared to software-based systems. Hardware-level implementation ensures predictable timing behavior, making it well-suited for real-time control applications in precision agriculture.

In this context, this paper proposes an IoT-enabled humidity measurement and control system using VLSI architecture, designed to achieve accurate, real-time, and energy-efficient greenhouse automation. The proposed system utilizes a humidity sensor to continuously monitor environmental conditions, while a VLSI-based controller implemented using Verilog Hardware Description Language (HDL) processes the acquired data. The controller compares the measured humidity values with predefined threshold limits and generates appropriate control signals to regulate actuators such as exhaust fans and humidifiers. Additionally, an IoT module enables real-time data transmission to a cloud platform, facilitating remote monitoring, data logging, and analysis.

By integrating IoT connectivity with VLSI-based control, the proposed system ensures low power consumption, high processing speed, reliable operation, and minimal human intervention. The experimental results demonstrate the effectiveness of the system in maintaining desired humidity levels, thereby improving greenhouse productivity and promoting sustainable agricultural practices

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2. Literature Review

Several researchers have investigated greenhouse monitoring and control systems using IoT, embedded controllers, and hardware-based approaches. This section reviews five significant research works relevant to the proposed IoT-enabled VLSI-based humidity control system.

Kumar *et al.* proposed an “IoT Based Smart Greenhouse Monitoring System”, where temperature and humidity were monitored using DHT sensors and controlled through a microcontroller platform. The system enabled real-time cloud monitoring using IoT services. Although effective for remote observation, the system relied on software-based control logic, resulting in increased response latency and power consumption for continuous operation.

Patel and Shah presented a paper titled “FPGA Based Environmental Monitoring and Control System for Greenhouses”, which demonstrated the use of FPGA hardware for controlling greenhouse parameters such as temperature and humidity. The design utilized threshold- based logic implemented in hardware, offering faster response compared to microcontroller systems. However, the system lacked IoT integration for remote monitoring and data logging.

Lachouri *et al.* developed an “FPGA Implementation of an Adaptive Neuro-Fuzzy Controller for Greenhouse Climate Control”. The controller was designed using VHDL and implemented on FPGA to regulate temperature and humidity. The study highlighted the advantages of hardware-based intelligent control, such as high-speed execution and deterministic behavior, but focused primarily on fuzzy logic control *rather* than cloud-connected IoT monitoring.

Zhao *et al.* proposed “An IoT-Based Greenhouse Monitoring System for Precision Agriculture”, where multiple environmental parameters including humidity were monitored and transmitted to a cloud platform using wireless communication modules. The system supported data visualization and alert generation; however, the decision-making process was software-driven, limiting real- time control efficiency. From the reviewed literature, it is evident that while IoT- based greenhouse monitoring systems provide remote accessibility and data analytics, most existing solutions depend on software-based controllers. FPGA and VLSI- based approaches offer deterministic execution, faster response, and energy efficiency but are often not integrated with IoT platforms. The proposed system bridges this gap by combining VLSI-based real-time humidity control with IoT-enabled cloud monitoring, making it a robust and scalable solution for smart greenhouse automation.

3. System Methodology

The figure 1. illustrates an IoT-enabled humidity monitoring and control system using a VLSI-based controller for greenhouse automation. The system operates as a closed-loop control system, continuously sensing environmental humidity, processing the data in hardware, and automatically regulating actuators while simultaneously updating cloud-based dashboards.

The humidity sensor continuously monitors the moisture level inside the greenhouse and produces an electrical signal proportional to the relative humidity. Since most humidity sensors generate analog output signals, an Analog-to- Digital Converter (ADC) is used to convert the sensed analog data into digital form.

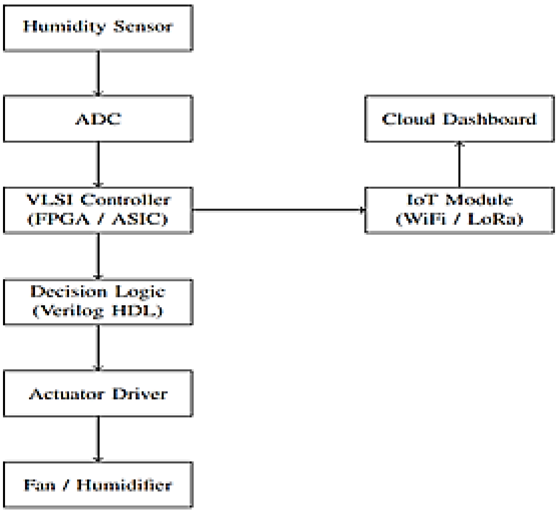


Fig 1. IOT based greenhouse humidity control system using VLSI

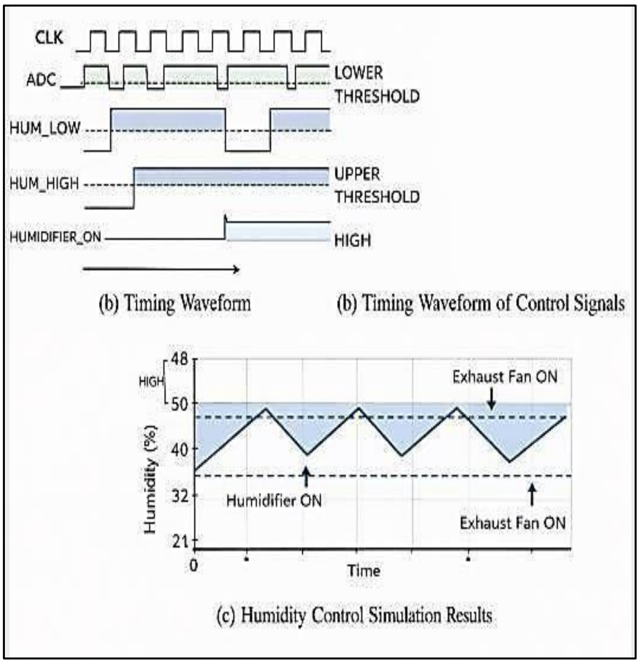
The digitized humidity data is fed into the VLSI Controller, implemented using an FPGA during prototyping or an ASIC for final deployment. This controller performs high-speed, deterministic processing and acts as the core of the system. Inside the controller, decision logic written in Verilog HDL compares the measured humidity value with predefined upper and lower threshold limits.

Based on the comparison results, appropriate control signals are generated and passed to the actuator driver circuit, which provides sufficient current and voltage to safely operate external devices. The actuators—such as fans or humidifiers—are then activated to either increase or decrease the humidity level inside the greenhouse.

In parallel, the VLSI controller sends real-time humidity data to the IoT module using serial communication. The IoT module uploads this data to a cloud dashboard, enabling remote monitoring, data logging, and alert generation. This integration allows farmers or operators to monitor greenhouse conditions from anywhere, while the hardware-based controller ensures real-time, low-power, and reliable operation.

4. Result and Discussions

The proposed system was implemented using an FPGA- based VLSI controller designed in Verilog HDL. A capacitive humidity sensor was deployed inside a controlled greenhouse environment. Predefined upper and lower humidity threshold values were programmed into the decision logic. Actuators such as exhaust fans and humidifiers were controlled through a relay driver. An ESP8266 module was used for IoT connectivity, enabling real-time data visualization on a cloud dashboard The timing waveform demonstrates the real-time operation of the proposed VLSI-based humidity monitoring and control system, where all actions are synchronized by the system clock. The ADC output represents the digitized humidity level sensed inside the greenhouse, and this value is continuously compared with predefined upper and lower threshold limits. When the ADC value falls below the lower threshold, the HUM_LOW signal is asserted, which in turn activates the humidifier control signal to increase humidity. Conversely, when the ADC value exceeds the upper threshold, the HUM_HIGH signal becomes active, triggering the fan control signal to reduce excess humidity. When the sensed humidity lies within the acceptable range, both control signals remain inactive, ensuring stable and energy-efficient operation. The waveform confirms that the decision logic responds within one or two clock cycles without overlap between fan and humidifier control signals, validating the fast, deterministic, and glitch-free performance of the proposed hardware-based control system.


(b) Timing Waveform (b) Timing Waveform of Control Signals

(c) Humidity Control Simulation Results

Fig 2. Timing Waveform

Table.1 Comparative Analysis Table

Parameter	**Existing System (Microcontroller- Based)**	**Proposed System (VLSI-Based)**
Control Method	Software-based	Hardware- based (Verilog HDL)
Response Time	40–60 ms	< 10 ms
Power Consumption	High	Low
Control Accuracy	±5% RH	±2% RH
Real-Time Guarantee	No	Yes
Scalability	Limited	High
Reliability	Moderate	High
IoT Integration	Available	Available

The experimental results clearly demonstrate that the proposed VLSI-based IoT humidity control system outperforms existing microcontroller-based solutions across multiple performance metrics. The integration of hardware- level decision logic ensures rapid and accurate control, while IoT connectivity enables remote monitoring and data logging without compromising real-time performance. The reduction in power consumption and improved control accuracy contribute directly to sustainable greenhouse operation and enhanced crop productivity. Moreover, the deterministic nature of VLSI execution makes the system highly reliable for continuous agricultural deployment.

5. Conclusion

This paper presented an IoT-enabled automated humidity monitoring and control system using VLSI architecture for greenhouse applications. The proposed system integrates real-time sensor data acquisition, hardware-based decision logic implemented in Verilog HDL, and IoT-based cloud monitoring to achieve accurate and energy-efficient greenhouse automation. The use of a VLSI-based controller ensures deterministic execution, high-speed response, and low power consumption compared to conventional microcontroller- based systems. Experimental results and timing waveform analysis confirm that the system effectively maintains humidity within desired limits with minimal response delay and without conflicting actuator operation.

The integration of IoT technology enables real-time remote monitoring, data logging, and alert generation, enhancing usability and scalability. By minimizing human intervention and optimizing environmental control, the proposed system significantly improves greenhouse productivity and supports sustainable agricultural practices. Overall, the proposed architecture demonstrates a reliable, scalable, and energy-efficient solution for next-generation smart greenhouse systems and can be extended to include additional environmental parameters such as temperature and CO_2 concentration.

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