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Multichannel FPGA-Based System for Data Acquisition and Monitoring with Network Control

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ARTICLE INFO	ABSTRACT

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Traditional data collection systems based on microcontrollers have a hard time swiftly data acquiring and storing massive volumes of data. With their high clock rates, short delays, quick speeds, and abundance of RAM, field-programmable gate arrays (FPGAs) make sophisticated peripheral circuit control straightforward. This paper presents a method for remotely monitoring server rooms using FPGAs and multimedia. A/D converter modules, environmental sensors, electrical energy, carbon monoxide, smoke, and an FPGA serve as the main controllers in the proposed system, which tracks server room locations. The FPGA also uses the serial interface to send data from all of the sensors to the LCD screen. When there are changes in the environment, alarms go off. Using butterfly operations and the rapid Fourier transform method; the system determines AC voltage and current and uses temperature changes to identify server room equipment issues. Functionality, usability, and reliability testing is conducted on the system. The fact that all performance measurements meet the basic design criteria demonstrates that FPGA technology may be used for monitoring. The superior processing speed and performance of FPGAs are shown when compared to conventional microcontroller systems.

Keywords: Microcontrollers, Data Acquiring, Field-Programmable Gate Arrays, Electrical Energy, Carbon Monoxide, AC Voltage.

INTRODUCTION

A multitude of measuring and control systems use the data processing and acquisition system. The primary objective of data collection is to evaluate electrical phenomena such as voltage, current, temperature, pressure, and sound. The process of obtaining, digitizing, and analyzing data from diverse sources is referred to as the DAQ system. The data-gathering hardware components provide communication between the computer and the external world. This research presents a cost-effective real-time application based on a multi-channel Analog Signal Acquisition and Processing (ASAP) system. The AT91SAM7X256 embedded microprocessor functions as the central processing unit (CPU) for a remote temperature monitoring platform [1]. Applications for the system platform include remote monitoring in smart agriculture, smart furniture, smart warehouses, and other analogous functions. The accuracy of the temperature measurement is within 0.5˚C. There have been no cases of communication failure, and the system is reliable and stable. Thus, it has significant social potential; yet, its data transfer rate is insufficient for real-time applications.

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Gogate and Bakal [2] devised a technique for remote monitoring via Wireless Sensor Networks (WSNs). The system architecture facilitates remote equipment monitoring and minimizes network latency and packet loss using dynamic window data and adjustments to message intervals. Sensor control is an integral component of this design. The system's complex design arises from the need for both sensors and remote controllers. Yan et al. [3] developed a remote monitoring system using an SDK. Acquire the necessary credentials to configure the .NET platform and remotely oversee the operations of industrial robots. A more sophisticated system of controls and monitoring is necessary. Rana et al. [4] developed a robust platform for staff to fulfill daily monitoring requirements, using the .NET framework and C# language; it is a client/server architectural environment for mental monitoring information management. Fotouhi et al. [5] developed a dynamic loop monitoring method for mobile communication base stations. The system employs C# to facilitate self-management, capture photos, assess, repair, and refurbish equipment, as well as monitor power ambient conditions. Rah Man and Wahid [6] developed a dynamic loop monitoring system that utilizes 3G networks and on-site ZigBee wireless technology to relay data from the field. Our team created software on the J2EE platform and offered suggestions for the system's architecture, temperature, and humidity control. Zhang et al. [7] created innovative ways for intelligent monitoring using the J2EE architecture. The key topics of research include system dependability, stability, and the use of clustering and load-balancing strategies to enhance these. Kolesnikov et al. [8] assert that the primary computer received multimedia data from sensors over a 100 Gigabit Ethernet connection, facilitated by an STM32 microcontroller integrated with a W5500 hardware Ethernet protocol stack. Prasojo et al. [9] used the AT89S52 microprocessor to communicate multipoint temperature data from the server room to a distant host computer via the RS232 link. We exhibited and archived the data for further observation.

Contribution

- Using field-programmable gate arrays (FPGAs), this study suggests a novel approach to remote multimedia monitoring. This approach addresses the problems of real-time, low-cost server room monitoring and automated control.
- Environmental, electrical, carbon monoxide, smoke, and A/D converter modules are all easily integrated into the system. Rapid detection of environmental hazards is made possible by this all-encompassing integration, which permits monitoring of many server room locations.
- An FPGA and serial ports allow the system to transmit data collected from all monitoring points to a serial screen LCD where it may be seen in real-time. Users may easily check monitoring data and identify any irregularities using this capability.
- The system employs butterfly operations and the fast Fourier transform technique to precisely track voltage and current fluctuations. To find problems with server room equipment, it also employs relative temperature differences.
- We take a close look at the proposed system's reliability, usability, and usefulness. The system's ability to achieve performance measurements and design goals has been validated by thorough testing.

RELATED WORKS

Digital communication systems and other real-time digital signal processing applications need fast, power-efficient, appropriately accurate logarithm operators [10]. The correct calculation of the logarithm has been the subject of several methods. These approaches aren't good for low-power; high-speed tasks since they need complicated technologies or have big latencies.

The Mitchell approach has an approximation error of around 0.08639 and is only 3.53 bits exact. This is a major problem with the method. The binary logarithm can be computed quickly and cheaply using the design that was suggested. Results were compared with other low-cost designs when this design was implemented in an FPGA device [11]. Although it needs a lot of power, it can attain fast speeds with minimal space.

Data collection terminals were often linked in the past, as reference [12] shows. This approach, however, becomes very challenging when data collection is required in a very complex environment or from dispersed locations. A data-gathering terminal based on WSNs and including a central CPU was suggested by us [13]. Utilizing a wireless sensor network rather than conventional wires, it transmits the data it gathers to a command center or higher PC via a

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wireless multi-hop approach. By using the inherent self-organization and self-management characteristics of wireless sensor networks, it streamlines equipment installation, maintenance, and replacement processes while doing away with the need for cables.

A multi-channel data gathering system could make it simpler to track temperature, pressure, and humidity, among other industrial [14-15] factors. The system's LCD, which shows various parameters in different colors, is controlled by the AT89S52. A digital filter is shared across the program's input channels to simplify hardware construction and reduce expenses. There may be room for improvement in the rate of data collection, even if the technique has grown in size, cost, and dependability [16].

Due to the cable's complexity, the large frequency of cable-related mishaps, and the requirement to execute tasks in an industrial environment without wires, an integrated Bluetooth device is utilized to decrease the cable connection [17]. Wireless networking communication via Bluetooth is based on the LPC2142, and the Bluetooth chip has an integrated Bluetooth data collection mechanism [18]. While 150 kHz is the maximum data gathering rate, the greatest data transfer rate is 460 kbps.

METHODOLOGY

A monitoring console similar to an FPGA server is part of the server room's equipment. Environmental data may be sent wirelessly or by Ethernet by terminals. Selecting and assembling various parts of a system is what hardware design is all about. Xilinx Spartan-6 series FPGAs were chosen as the primary controller due to their robust design, ample logic resources, and ability to handle complicated logic with ease. Smoke, carbon monoxide, electricity, and environmental sensors are also installed in the server room. The software enhances real-time operations and system administration. The efficient scheduling of tasks and modular programming are both supported by the C/OS-III operating system. Power measurement, serial transmission, and alerts for abnormal conditions are all part of the program design. A multimedia remote monitoring system's interplay is shown in Figure 1.

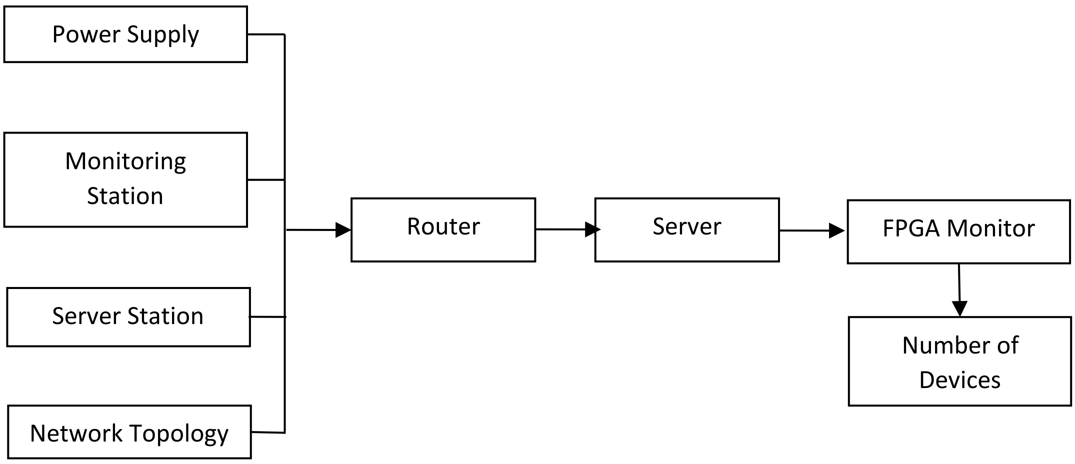

Figure 1. Proposed Architecture.

3.1 Processing and Data Acquisition for Multiple Channels

The process of converting non-electrical impulses into electrical signals is accomplished by the use of sensors or transducers. Various heterogeneous factors may be detected by sensors in industrial settings. These elements include but are not limited to, velocity, viscosity, pressure, temperature, friction, and vibrations. To serve medical needs, the analog electrical impulses recorded by equipment like electrocardiograms (ECGs), electroencephalograms (EEGs), and similar ones need to be transformed into digital format. Common waveforms for these signals include sine, sawtooth, and cosine. Using a signal generator, the present approach requires four channel inputs with frequencies of 1, 4, 8, and 10 kHz. One way to take advantage of n-channel inputs is via a n:1 multiplexer.

The FPGA-based monitoring system incorporates many internal blocks, allowing it to efficiently acquire, analyze, and monitor sensor data in real-time. Keep in mind that the corresponding peripheral devices are closely associated

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with the specific functions of each internal block. The smooth functioning of the monitoring system and uninterrupted communication.

In place of the conventional microcontroller, the main controller in this study makes use of a 50MHz-running Xilinx Spartan-6 series FPGA. Because of its reliability, an array of gate resources, flexibility for complex logic control, and ability to handle several communication interfaces, the field-programmable gate array (FPGA) was selected as the principal controller.

For a wide variety of incoming and outgoing lines, the electrical sensor records data in three-phase fundamental, harmonic, and full wave modes. The server room's dust, temperature, and humidity levels are tracked by the AS02HT-K84NW sensor. The Ad7606 digitally converts the analog voltage output of the MQ-7 module and uses it to calibrate the carbon monoxide concentration. Environmental data and carbon monoxide levels are recorded in RAM by the FPGA at each monitoring point. Through the use of the UDP protocol, data is sent from the RTL8211EG Ethernet PHY chip to the switch, and from there, it is routed to the control center and host PCs. The MFC framework is used by the host machine. Furthermore, the LCD serial port receives monitoring data from the FPGA. The display is according to the serial communication protocol. A red flag will be triggered if the data is anomalous. The hardware configuration of the monitoring terminal is shown in Figure 2.

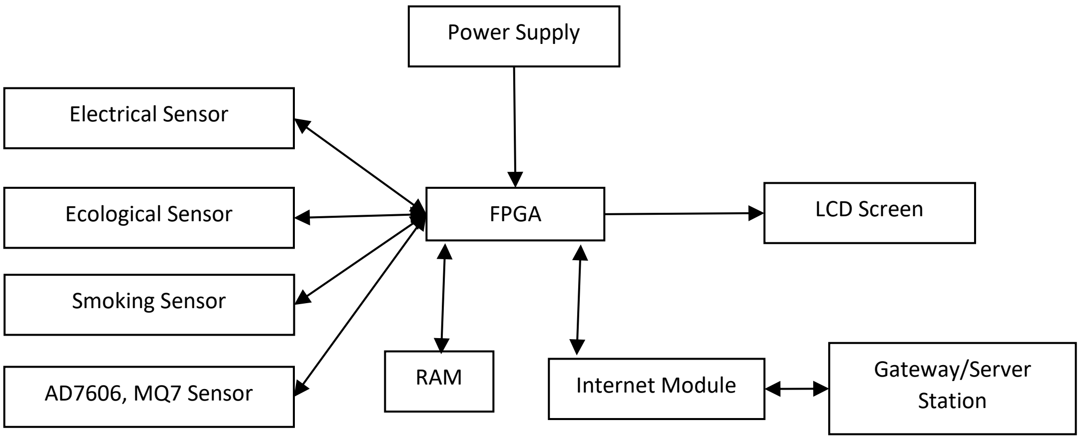

Figure 2. FPGA System Architecture.

Using a single sensor to gather environmental data may produce serial port congestion on the lower computer control circuit due to the wide range of physical parameters. The weaker computer operating system may struggle to interpret environmental data, limiting monitoring system performance. Smart homes, server room monitoring, health care, and other sectors use environmental sensors to recognize traits. After extensive testing, Arsend's AS02HT K84NW three-in-one integrated environmental sensor fulfilled the server room environmental monitoring system's functional specifications and national standards for each condition parameter. Temperature, humidity, and dust indicators enhance environmental monitoring in big IT rooms. FPGA control flow accesses AS02HT-K84NW for environmental data via DQ. The server room power sensor module measures power usage, checks power, voltage, current, and equipment, and regulates power. The Shenzhen Ruineng Micro Technology RN8302B multipurpose power metering chip measures power parameters, and meters, prevents theft, and calibrates software meters in this design. The device has seven 24-bit ADC channels for full-wave and fundamental-wave power measurements, with <1% nonlinear error in the 5000:1 dynamic range and 0.5S and 0.2S active power accuracy. MQ-7 sensors use VH, VL, and VC. The voltage across the load resistor RL in series with the sensor is VC, while the operating temperature is VH and VL. Carbon monoxide gas is detected by heating low-temperature VL and increasing conductivity with air concentration. High-temperature VH removes low-temperature heating stray gas. Through circuit design, gas concentration may translate conductivity change to an analog voltage output signal. The FPGA must utilize the MQ-7 concentration calibration curve to convert the MQ-7 output analog voltage to a digital CO gas concentration. The integrated 8-channel data synchronization system is AD7606. This device converts 16-bit analog-to-digital signals with ±5 and ±10V bipolar inputs under very noisy settings utilizing a single +5V supply. SPI and parallel data

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transmission are supported by AD7606. This study promotes parallel processing for speed. Here, smoke sensors alert server room smoke concentration. It communicates with the bottom computer control system via RS232. The smoke sensor is serially linked to the server room bottom computer. A fire triggers the sensor to buzz the bottom computer. This design met functional requirements with a photoelectric smoke detector. Unlike smoke sensors, photoelectric monitoring is constant, sensitive, and adaptable to varied working settings. This system's RTL8211EG Ethernet PHY chip supports 10, 100, and 1000Mb/s adaptive network speeds. The FPGA and RTL8211EG exchange multimedia data over the GMII bus for Gigabit Ethernet. PHY clocks receive, and FPGA sends 125MHz. LCD uses Guangzhou Dachai's F series serial screen. Industrial standards, RS232/TTL serial connection method, and several baud rate possibilities make it useful in smart home appliances and security monitoring, for Vintage serial screen interface.

RESULTS AND DISCUSSIONS

To ensure the overall reliability and practicality of the monitoring system, this chapter examines each critical function of the server room remote monitoring system that is integrated with FPGAs.

Test Content: This test measures the quality, performance, and functionality of the multimedia remote monitoring system that is incorporated in the server room's FPGA. The majority of the exam questions revolve around practicality, ease of use, and reliability. To find out whether the monitoring system works as expected and achieves the performance and functional objectives set by the designers. The testing procedure confirmed the correctness of the hardware, found logic errors and design issues in the software, and guaranteed the monitoring system's stable operation.

Data Acquisition Test

An integral part of the whole monitoring system is the multimedia data-collecting capabilities of the environmental parameter-gathering equipment in the server room. The primary focus of this function's testing is the transfer and reception of multimedia data between the control system and each submodule device. Make sure to disconnect any submodule devices from the control system before connecting it to a personal computer. Attach the control system to the PC via the RS232 serial communication port on each submodule device. The control system can continually send status inquiry requests to each serial port with data that is exact since the PC has connected to the control system via serial debugging assistance. Using the serial connection on the bottom computer, the data from the three-in-one environmental sensor device may be retrieved, as shown in Figure 3.

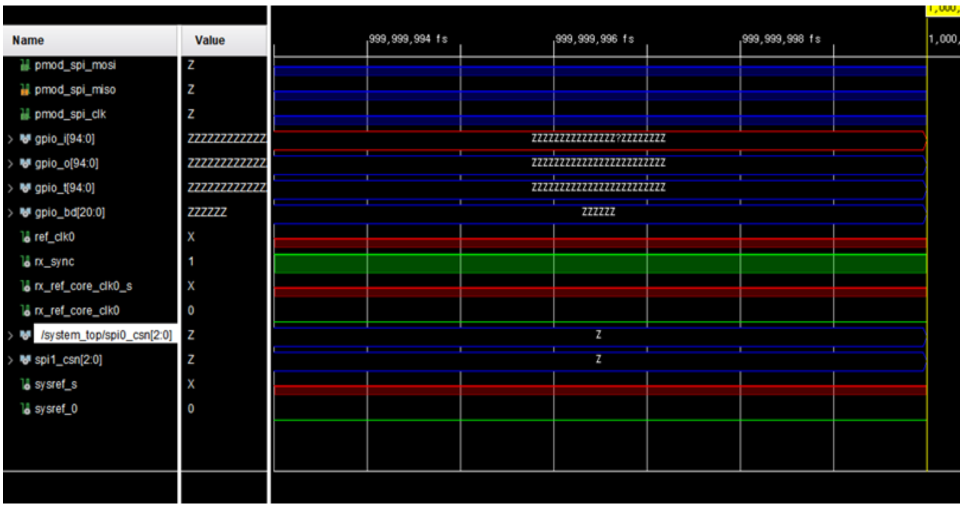

Figure 3. Data Acquisition Monitoring System.

Display Test

The server station environmental data is provided via command user interfaces (CUIs) via the platform control system and multimedia remote monitoring host applications. When the monitoring system is running as it should, the environmental information display part presents multimedia data such as humidity, dust, temperature, and the

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condition of the UPS equipment. The user-friendly design of the platform app is also shown in Figure 4. This apparatus generates more precise circumstances by comparing the present ambient data with laboratory parameters. More precise multimedia data and typical server room ambient conditions are shown on the host side of the remote network monitoring. The multimedia data query latency is minimal and the full monitoring system's information display function is normal after twelve hours of continuous operation and numerous tests, satisfying the software design index.

The ease of use was also a key component of the usability testing, with an emphasis on the design of the interface. This article describes platform control systems and host software that are easy to use for remote network monitoring. While yet being easy to use, the user interface is rational and built with science in mind. The software's use of documentation is reduced thanks to its straightforward design and simplicity of operation. When it comes to keeping tabs on system administration and maintenance, user-friendliness is key as shown in Figure 4.

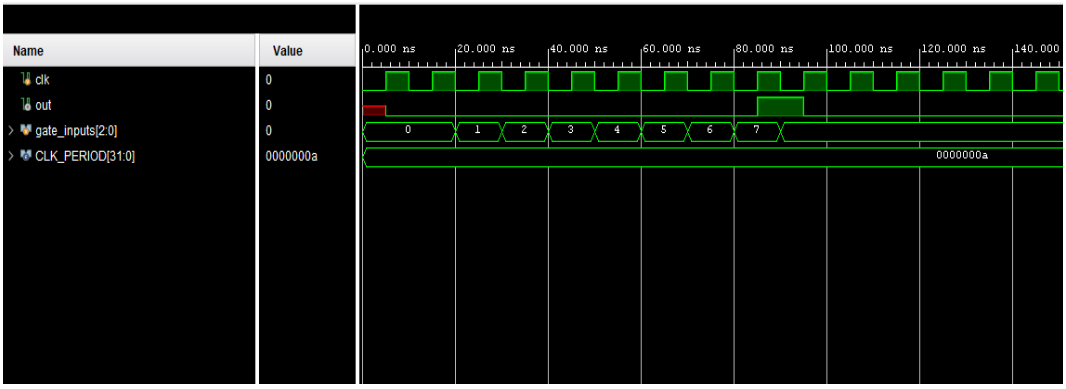

Figure 4. Data Multimedia Data Clock.

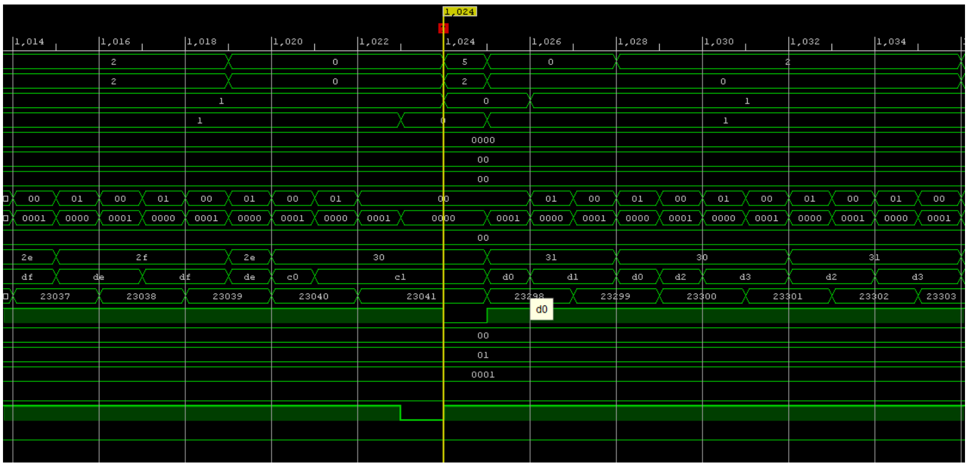

Figure 5. Fault Tolerance Data Clock.

Tests for Fault Tolerance

A fault tolerance test for a monitoring system assures that it will work properly even under unusual or unexpected scenarios. The test turns off or removes machine room sub-module components while the system is running to simulate equipment damage. The proposed monitoring system worked effectively and delivered valuable error notices. This significant fault tolerance reflects the system's capacity to endure unexpected disruptions and maintain operational integrity, meeting high-reliability standards. Based on our analysis of the simulation data for the timing diagram, we have determined that the system requires 13 clock cycles, or 260 nanoseconds, to process. System efficiency is shown here. Applications requiring responsiveness in real-time need fast processing. Additionally, the sequence of the input and output data remains consistent during processing, which further confirms the system's correctness. We validate the accuracy and performance of the system via the use of a timing diagram simulation. The

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precision and speed of the FPGA-based system's data processing are shown by its 260ns processing time. It is critical to respond quickly to changing data inputs in real-time scenarios. The approach is well-suited to circumstances that are both dynamic and time-sensitive because of the constant process across the phases shown in Figure 5.

CONCLUSION

An FPGA-based multimedia remote server room monitoring system is presented in this work. Hardware and software for the multimedia remote monitoring system in the server room with FPGAs incorporated have been developed extensively. The monitoring system was created using hardware. Every submodule is then built after a comprehensive evaluation. Energy metering, serial connectivity, and notifications for abnormal conditions are all part of the software. Following rigorous testing, this remote monitoring system with multimedia capabilities accomplishes all initial design goals. To demonstrate the benefits of our FPGA technology, we compared it against microcontrollers. Fast field-programmable gate arrays (FPGAs) accelerate data collection and processing compared to microcontrollers. Field-programmable gate arrays (FPGAs) allow complex data processing, Fourier transforms, and decrease latency. Accurate monitoring of the server room requires this. Our system's sensor integration may be tested with the help of FPGA technology's large I/O resources. This approach examines all aspects of the server room simultaneously. Our approach has flaws, and we must acknowledge them. Scalability and interoperability testing in server rooms are areas where our system is lacking. Environmental monitoring might be enhanced in future studies with the addition of more sensing sensors. The usefulness and depth of our research will be enhanced by comparing it to other studies. Lastly, we provide academics and practitioners with some advice. It is important to keep an eye on the server room and make note of any limitations or demands. Hardware, communication protocols, and software algorithms should all be examined for maximum performance and reliability.

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