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An FPGA Implementation of Health Monitoring System using IOT

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Abstract: The objective of this study is to establish a highly efficient health monitoring system that focuses on key parameters such as heart rate and temperature. To achieve this, the proposed system utilizes FPGA technology for rapid information processing. Health data, collected through a Pulse sensor and Temperature sensor, is transmitted using an ADC. The system continuously monitors the heart rate and temperature of the patient's body. For instance, the heart rate is measured using a Pulse sensor, while the Temperature sensor detects the body temperature. The encoded serial data is then transmitted through a transmitting module, which is connected to a patient's location. The receiver unit can be an LCD display at the patient's place, or it can be a laptop, desktop, or mobile phone connected to the internet. The receiver can be either a doctor or a person close to the patient. A transmitter unit near the patient sends the data through an FPGA and a Wi-Fi module, which is connected to it, receives and updates the data on a server. The data is continuously displayed on a user interface visible on a PC or laptop using the IP address. This allows doctors or responsible individuals to observe and monitor multiple patients simultaneously. The system also continuously monitors the patient's data, displaying it near the patient and updating it on the server. By using the IP address of a specific patient, doctors can easily assess the patient's condition. The receiver, an LCD display at the patient's location, and another connected device (laptop, desktop, or mobile phone) constantly update and display the data. The system enables remote monitoring and real-time observation by doctors or caregivers. The research highlights the accessibility of FPGA-based design resources.

Index Terms: ADC, Pulse sensor, Temperature sensor, Wifi module, IP address, FPGA, UART.

I. INTRODUCTION

In the current situation, there is a lack of timely support for many elderly individuals and patients in hospitals. This study presents a health monitoring system that can be accessed from anywhere and is compatible with mobile devices. The use of FPGA allows for fast data processing, while Internet connectivity enables real-time monitoring. The system transmits data to a server, which can be accessed through a user interface. One key difference from SMS-based monitoring is that IoT-based monitoring allows multiple users to view the data. The hardware components of the system include a Spartan3AN FPGA board, Pulse sensor, LM35 temperature sensor, MCP3202 ADC, ESP8266-01 Wi-Fi module, and a 16*2 LCD. Xilinx ISE software is used for FPGA programming. In the patient monitoring system based on the Internet of Things project, real-time health parameters of the patient are sent to the cloud using Internet connectivity. These parameters are then accessible from any location in the world by accessing a remote Internet location. By entering the IP address of the server where the information is transmitted, one can obtain the heart rate and temperature of the patient at the receiving end.

There is a significant distinction between SMS-based patient health monitoring and IoT-based patient monitoring systems. In an IoT-based system, the details of the patient's health can be viewed by multiple users. This is because the data can be accessed by visiting a website or URL. On the other hand, in GSM-based patient monitoring, the health parameters are sent via SMS using GSM technology, and only one person can view them. Another advantage of using IoT is that the data can be accessed using various devices such as desktop computers, laptops, Android smartphones, or tablets. The user simply needs a working Internet connection to view this data.

There are several cloud service providers that can be utilized to access this data over the Internet. In this paper, we will focus on the local access of information, where the transmitter and receiver are connected to the same network.

II. PRE LITERATURE

Numerous research endeavors have been conducted and continue to progress daily in order to integrate IoT applications on the FPGA platform. We have extensively reviewed numerous papers that pertain to the design and implementation of IoT applications on the FPGA platform. The following is a compilation of the accomplishments detailed within those papers:

A. *A Review of FPGA implementation of Internet of Things.*

The author of the study in the International Journal explored the implementation of Internet of Things (IoT) using FPGA. The IoT has revolutionized the way people and smart devices connect, enabling a level of connectivity that was once unimaginable. However, one of the challenges faced by IoT is the handling of large amounts of data generated by resource-limited smart devices, which can be prone to missing data due to link failures.

In his paper, the author proposed the use of low-cost FPGA implementation to address this challenge, encompassing the entire subset of IoT including TCP/IP protocol, Control System, and Data Acquisition. Thisapproach has garnered significant attention from the research community in recent years, offering a comprehensive, cost-effective, and user-friendly solution for real-time monitoring and remote sensing systems that operate 24/7. The primary objective of the research is to emphasize how users can access FPGA-based design resources from any location.

Consequently, the paper introduces a concept that optimizes the utilization of momentarily unused resources to automate various tasks.

B. *FPGA Implementation of Automatic Industrial Monitoring System*

In this research paper, the authors propose an automated monitoring system for industrial systems. The system focuses on the core controller of FPGA, as well as various sensors such as gas sensors, digital sensors, and dust sensors like PIR motion sensors. These sensors, with a voltage range of 4.4V, are utilized to monitor industrial equipment, ensuring a safer monitoring system. The paper analyzes the parameters of Area, Power, and timing report. The area consumption is measured at 937 LUT's, the power obtained is 48.11mW, and the delay is 9.065ns from QUARTUS II 10.0. It is important to note that the maximum voltage required to operate the Altera cyclone board is 3.3V.

This voltage is generated from the crystal oscillator, which has an input frequency of 50 MHz. The GSM module and ADC are coded in VHDL language. The output of the system can be measured through the mobile network, and the current status is displayed on an LCD screen.

To further enhance this work, the authors suggest connecting a proximity sensor and other sensors based on the specific requirements of the industry. For future work, the authors propose considering the use of IoT (Internet of Things) in the automatic monitoring system. This research paper has provided valuable insights into the concept of IoT [2].

III. HARDWARE

The hardware components needed exhibit low power consumption and execute the tasks flawlessly. The hardware components include:

A. *Spartan3AN FPGA board*

The Spartan-3AN platform offers a unique combination of advantages, including the cost-effectiveness and extensive features of cutting-edge SRAM-based FPGAs, along with the space-saving and easy configuration benefits of non-volatile FPGAs. With advanced on-chip security features, this platform provides a reliable and affordable solution to prevent reverse-engineering, cloning, and overbuilding. Additionally, designers can enjoy enhanced system flexibility with up to 11Mb of integrated user Flash, which serves as both device configuration and a valuable system resource. Moreover, this platform includes built-in analog to digital converter and temperature sensor, which are essential for the design. Lastly, the buzzer integrated within it serves as an indicator for emergency conditions.

B. *Pulse Sensor SEN- 11574*

The heartbeat sensor operates on the principle of photo phlethysmography, which involves measuring the change in blood volume through any organ of the body. This change in volume causes a corresponding change in the intensity of light passing through the organ, specifically a vascular region.

When monitoring heart pulse rate, the timing of the pulses becomes crucial. The flow of blood volume is determined by the rate of heart pulses, and since blood absorbs light, the signal pulses from the sensor correspond to the heart beat pulses. To convert the analog output of the pulse sensor to digital, an analog to digital converter called Mcp3202 A/D Converter is used. The resulting digital output is then supplied to the FPGA board [3].

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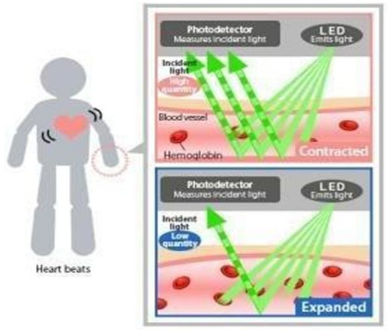

Fig.1. Working principle of pulse sensor

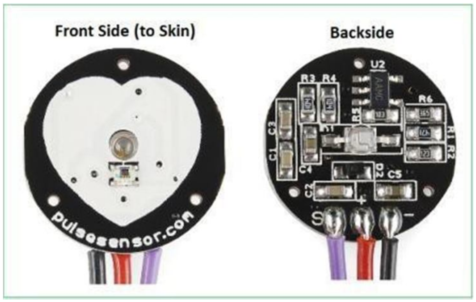

Fig.2. Pulse sensor

C. Lm35 Temperature Sensor

The LM35 sensor is utilized for precise temperature measurement. It produces a voltage of 10mv per degree Celsius. This sensor is connected to the ADC of the Spartan board. The Vref of the FPGA board will be adjusted to a value that allows it to read 10mv as 1 count. For instance, if the ambient temperature is 25 degrees Celsius, the output generated will be 250 mV, and after going through the ADC, the count will be 25. The LM35 series consists of temperature sensors that are highly accurate and integrated circuits. The output voltage of the LM35 is directly proportional to the Celsius temperature. It does not require any external calibration or trimming to provide accuracies of ±1⁄4°c at room temperature and ±3⁄4°c over a full −55 to +150°c temperature range. The LM35 ensures low cost through trimming and calibration. Its linear output, low output impedance, and precise inherent calibration make it easy to interface with readout or control circuitry. The LM35 can operate within a temperature range of −55° to +150°c, while the LM35c is rated for a range of −40° to +110°c (−10° with improved accuracy). It has a linear scale factor of +10-mV/°C and exhibits low self-heating of 0.08°C in still air [4].

D. Mcp3202 A/D Converter

The MCP3202 is an analog-to-digital converter (A/D) that utilizes successive approximation and has a resolution of 12 bits. It is equipped with a sample and hold circuitry on-board. This converter can be programmed to provide either a single pseudo- differential input pair or dual single-ended inputs. Communication with the MCP3202 is achieved through a simple serial interface that is compatible with the SPI protocol. It is capable of achieving conversion rates of up to 100 Kbps at 5V and 50 Kbps at 2.7V. The MCP3202 can operate within a wide voltage range of 2.7V to 5.5V. Its low-current design allows for operation with standby and active currents of only 500 nA and 375 µA, respectively. The digital output from pin 7 is connected to an FPGA board.

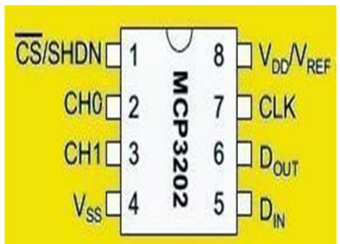

Fig.3. MCP3202 A/D C pin configuration

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Table.1. Pin description of MCP3202 A/D converter

PIN NUMBER	NAME	FUNCTION
1	$\overline{CS}$/ SHDN	/ Shutdown Input
2	CH0	Channel 0 analog input
3	CH1	Channel 1 analog input
4	Vss	Ground
5	Din	Serial data in
6	Dout	Serial data out
7	CLK	Serial clock
8	Vdd/ Vref	+2.7 to 5.5V Power Supply and Reference Voltage Input

The A/D converter generates a digital output code that is determined by both the input signal and the reference voltage. In the case of the MCP3202, the reference voltage is VDD. When the VDD level decreases, the size of the least significant bit (LSB) also decreases. The following represents the theoretical digital output code produced by the A/D converter.

EQUATION:
DigitalOutputCode=4096•
VIN/VDD where: VIN = analog input voltage
VDD = supply voltage

*E. 16*2 LCD*

An LCD, or liquid crystal display, is an electronic module that utilizes liquid crystal to generate a visible image. The 16×2 LCD display is a fundamental module frequently employed in do-it-yourself projects and circuits. It can display 16 characters per line in two lines. Each character is presented in a 5×7 pixel matrix on this LCD [8].

F. Esp8266-01 Wi-Fi module

The module comes in different variations, namely ESP8266-xx (01-13). Each module represents an advancement in hardware capabilities compared to its predecessor, with ESP8266-01 being the most affordable and having minimal features, while ESP8266-13[6] is the most expensive and offers the maximum features. These features include the number of GPIO pins, the presence of a shield, antenna type (Through-hole or Surface mount), memory capacity, and the ability to handle external analog signals. The ESP8266-01, which is the most basic board, has 2 GPIO pins, UART communication, a low-powered 32-bit CPU, and a PCB antenna. Other modules also have additional features such as ADC input capabilities, SPI, I2C, and more GPIO pins. The module is connected to an FPGA through UART communication, with the transmitter pin of the FPGA connected to the receiver pin of the Wi-Fi module.

IV. SOFTWARE

A. Xilinx ISE

Xilinx's proprietary synthesis algorithms have been proven to enhance the performance of designs by up to 30% compared to rival programs. Additionally, these algorithms enable greater logic density, resulting in reduced project time and costs. Xilinx offers a software tool specifically designed for the synthesis and analysis of HDL designs within an integrated synthesis environment. This tool empowers developers to synthesize their designs, conduct timing analysis, examine RTL diagrams, simulate the design's response to various stimuli, and configure the target device using the programmer. VHDL programming is utilized to program the Spartan FPGA, which is responsible for converting analog temperature and heart rate values to digital using an ADC. The FPGA also displays these values on an LCD and transmits information to a Wi-Fi module connected via UART. The Wi-Fi module is programmed and configured, including the assignment of a username and password. During the configuration process, an IP address is obtained, allowing users to access information from any location.

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V. PROPOSED SYSTEM

In order to continuously monitor the health status of patients, it is essential to consider real-time parameters such as heart rate and body temperature. This can be achieved by utilizing a local area network, where a Wi-Fi module creates a hotspot to establish a connection with the patient. Both the Wi-Fi module near the patient and the device used by the person monitoring the patient's condition should be connected to the same network. By entering the IP address in any browser, the user can access the patient'stemperature and pulse values. Additionally, an LCD display is available at the patient's side, allowing nearby individuals to easily check the current condition.

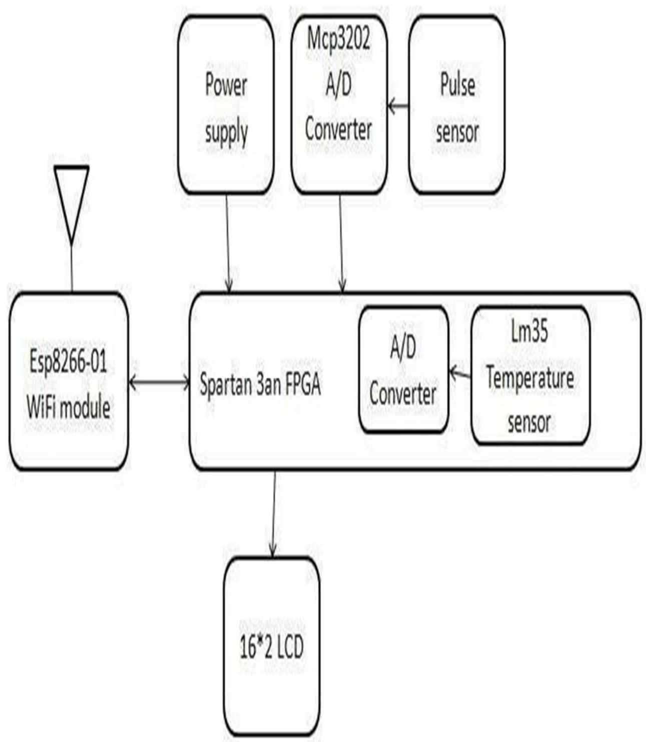

Fig6. Transmitter Section

The Spartan 3an board is equipped with a built-in temperature sensor that detects temperature, as well as an externally connected pulse sensor. The temperature and pulse values are converted from analog to digital using an ADC.

On the receiving end, various devices such as laptops, desktops, mobile phones, tablets, or tablets with internet connection can be used. The transmitter sends the information in serial form, and the Wi-Fi module, which includes an antenna, receives the serial data and transfers the data packets to the storage unit.

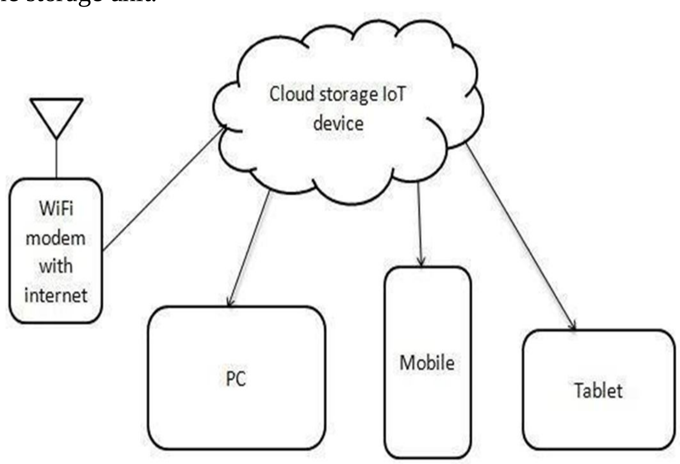

Fig7. Accessing through cloud

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VI. FLOW CHART

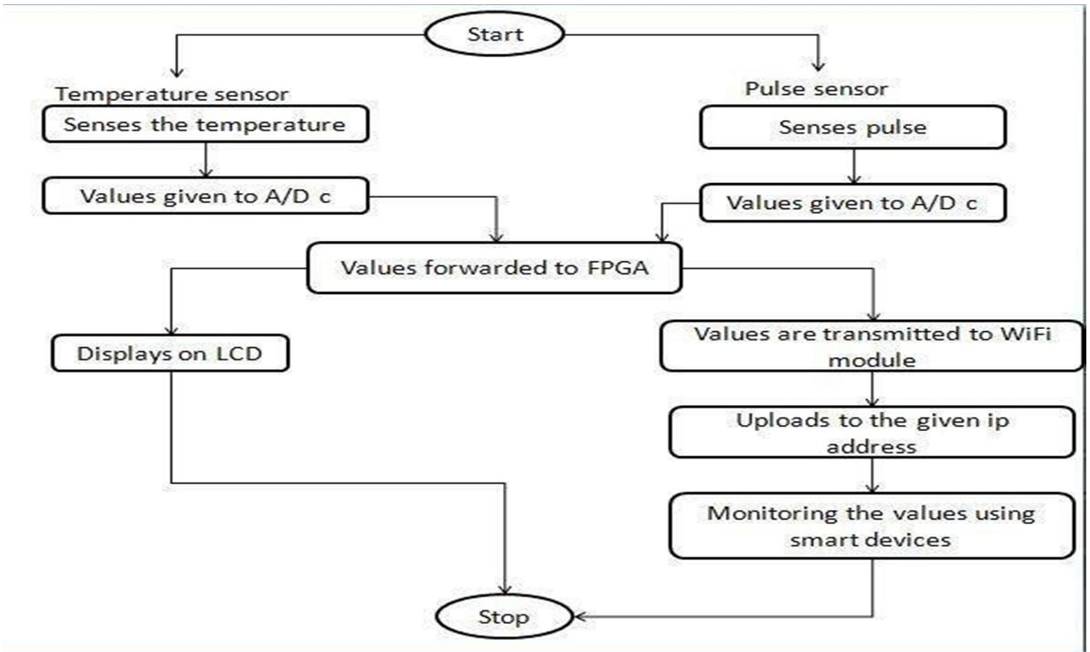

Fig8 Flowchart of the design

This is the methodology employed for designing a health monitoring system using FPGA. The system receives temperature and pulse values from their respective sensors. The analog values of both temperature and pulse are converted into digital form using the MCP3202 A/D converter, which utilizes a conventional SAR architecture. In this architecture, a sample is taken on an internal sample/hold capacitor for 1.5 clock cycles, starting on the second rising edge of the serial clock after receiving the start bit. After the sample time, the input switch of the converter opens and the device utilizes the collected charge on the internal sample and hold capacitor to generate a serial 12-bit digital output code. As previously mentioned, the MCP3202 can achieve conversion rates of 100 Kbps. The converted values are then displayed on an LCD near the patient. Additionally, a Wi-Fi module, connected externally to the FPGA through UART communication, receives data and creates a hotspot. This hotspot allows individuals to access the pulse rate and temperature of a specific person. The values are continuously updated every 5-7 seconds, and by simply entering the IP address, one can monitor the heart rate and temperature values.

VII. DESIGN IMPLEMENTATION

Earlier, we have discussed the measurement of heart rate using a pulse sensor and the acquisition of temperature values through the built-in sensor on the board. The pulse sensor is connected externally and has its own separate ADC. Additionally, there is an on-board ADC utilized for the temperature sensor. The Spartan board is connected to the LCD display, while the Esp8266-01 is externally connected through UART communication[9], with the transmitter pin of the FPGA linked to the receiver section of the Wi-Fi module

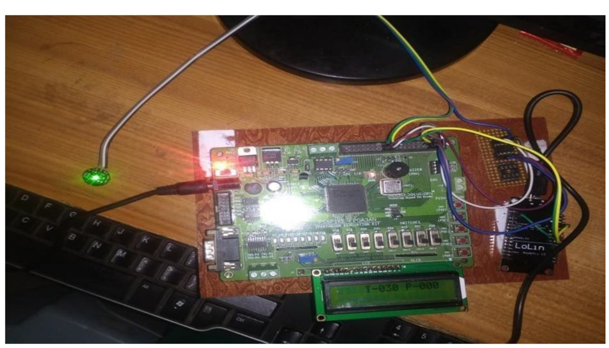

Fig 9 Hardware design

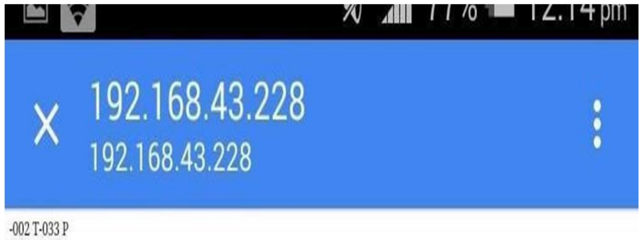

Fig 10 Output on mobile phone displaying temperature and pulse values

Device Utilization Summary				
Logic Utilization	Used	Available	Utilization	Note(s)
Number of Slice Flip Flops	424	1,408	30%	
Number of 4 input LUTs	944	1,408	67%	
Number of occupied Slices	693	704	98%	
Number of Slices containing only related logic	693	693	100%	
Number of Slices containing unrelated logic	0	693	0%	
Total Number of 4 input LUTs	1,210	1,408	85%	
Number used as logic	942			
Number used as a route-thru	266			
Number used as Shift registers	2			
Number of bonded IOBs	21	108	19%	

Fig 11 Device utilization summary

On-Chip	Power (W)	Used	Available	Utilization (%)
Clocks	0.005	5	---	---
Logic	0.000	1206	1408	86
Signals	0.000	1479	---	---
MULTs	0.000	2	3	67
IOs	0.000	21	108	19
Leakage	0.013			
Total	0.017			

Supply Summary		Total	Dynamic	Quiescent
Source	Voltage	Current (A)	Current (A)	Current (A)
Vccint	1.200	0.006	0.004	0.002
Vccaux	3.300	0.003	0.000	0.003
Vcco25	2.500	0.000	0.000	0.000

	Total	Dynamic	Quiescent
Supply Power (W)	0.017	0.005	0.013

Thermal Properties	Effective TJA (C/W)	Max Ambient (C)	Junction Temp (C)
	38.9	84.3	25.7

Fig 12 Power and voltage consumption

VIII. ADVANTAGES

It is extremely precise and dependable. Monitoring the health of patients ensures their well-being and safeguards their overall health. The health of patients and elderly individuals can be monitored remotely from any location by entering the IP address on laptops, computers, and mobile phones.

IX. FUTURE SCOPE

Additionally, this entire design setup can be condensed into a single chip for enhanced user-friendliness. Furthermore, the capabilities of this setup can be expanded by incorporating additional sensors, and a separate cloud can be utilized for storage purposes. In the future, accessing documents or reports from hospitals through IoT will become effortlessly accessible.

Moreover, as robotics continues to advance, this setup can be further extended to automatically instruct a robot when there is an elevation in temperature and heart rate values beyond normal levels.

X. APPLICATIONS

The device has the capability to be utilized in hospitals or dispensaries for patient monitoring. It offers a more precise and improved approach to measuring heart rate. By utilizing a set point, it becomes possible to determine the health status of an individual by checking their heart beat and comparing it to the set point.

Doctors have the ability to assess patient health remotely and provide instructions regarding their well-being. Additionally, family members can monitor the health of elderly individuals who are at home.

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