FPGA based Smart Wireless MIMO Control System

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Abstract: In our present work, we have successfully designed, and developed an FPGA based smart wireless MIMO (Multiple Input & Multiple Output) system capable of controlling multiple industrial process parameters such as temperature, pressure, stress and vibration etc. To achieve this task we have used Xilinx Spartan 3E FPGA (Field Programmable Gate Array) instead of conventional microcontrollers. By employing FPGA kit to PC via RF transceivers which has a working range of about 100 meters. The developed smart system is capable of performing the control task assigned to it successfully. We have also provided a provision to our proposed system that can be accessed for monitoring and control through the web and GSM as well. Our proposed system can be equally applied to all the hazardous and rugged industrial environments where a conventional system cannot work effectively.

1. Introduction

Technology is evolving on daily bases and as it evolves, the manpower reduces and the total burden fall on machines to monitor the different parameters continuously or else system failure is eminent. Safeties of plant machineries and as well as plant workers are very important matters. For example, the temperature which is the most widely monitoring parameter in the various parts of industrial processes and machines in order to obtain the quality products from these machines utilized for such tasks. If we required to monitor the underground temperature of geothermal power plant or the radiation levels in the hazardous process and some machineries installed in the basements where to keep the human presence around the clock is difficult, then for such situations we required a control system capable to monitor the temperature and other process parameters of such environments through wireless control. For such specific situations we developed a wireless smart MIMO system capable of monitoring multiple process parameters simultaneously with control actuation abilities. We have successfully developed this system by utilizing an FPGA that is capable of achieving the tasks according to our requirements.

The purpose of using FPGA instead of a conventional microcontroller is that we need to monitor multiple parameters and to control these parameters as well. For such purpose we required a specific controllers/devices that are capable of parallel processing and since the conventional microcontrollers do not support this feature of parallel processing.
2. Controllers/Devices Used

2.1.1. FPGA (Field Programing Gate Array)
FPGA is widely used in emerging control automation systems due to its promising features as controller. In the present work, we are using Xilinx XC3S500E FPGA board as shown in figure (1) developed by DIGILENT [1]. It has over 500,000 gates, Two DB9 RS-232 connectors, 64MB Micron DDR SDRAM, 16MB Numonyx Strata Flash, and 2MB ST Microelectronics Serial Flash.

![Fig. (1) Xilinx XC3S500E FPGA [1]](image)

2.1.2. GSM (SIM300)
GSM (Global system for mobile communication) is a system capable of communicating wirelessly with anyone around the globe. GSM module SIM300 is used as shown in figure (2) in our proposed system. The GSM/GPRS works on frequencies EGSM 900 MHz, DCS 1800 MHz, and PCS1900 MHz, SIM300 also provided the support of GPRS coding schemes CS-1, CS-2, CS-3 and CS-4[2]. In our system we used GSM for communicating the acquired controlled information from the automated plant/system to concerned people wirelessly; if the system detects an undesirable reading then we have also introduced a provision to control such parameters via messaging if required.

![Fig. (2) SIM300 GSM Modem](image)

3. Relevant Research
Prof. S. S. Sarade, Prof A. C. Joshi, Prof. Sachin S. Patel, and Prof. A.N. Shinda, proposed a Wireless Temperature Monitoring system based on WSN (Wireless Sensor Network). They designed a WSN
based on PIC16F877 microcontroller. There are several individual devices known as sensor nodes and each sensor node consists of TCN-75 which is a 2 wire serial temperature sensor and Thermal monitor that is interfaced to PIC16F877, and PIC is communicating with the host system via Zigbee 802.15.4 protocol. These sensor nodes are used to inform about various parameters such as temperature, sound, motion and pressure etc. [3]. Theophilus Wellem and Bhudi Setiawan have also proposed a sensing and controlling system based on ATMega8535. The sensor is continuously monitoring the temperature of the room and informing the concerned member via message using GSM modem [4]. Bing and Mwenyao also proposed a system based on Zigbee module which is wireless temperature monitoring and control system for communication room. They used JN5121 Zigbee wireless microcontroller and Sht11 Temperature sensor [5]. Manoranjan Das, and Banoj Kumar Pand presented an idea of a wireless sensor node using the field programmable gate array (FPGA) based architecture for an early detection of hazards (e.g fire and gas-leak ) in mines area[8]. SUN Yu-jia,WANG Xiao-ming,JIA Fang-xiu, and YU Ji-yan introduced an idea to implement the WSN system based on Cortex-M3 Microcontroller STM32F103RE chip [9].

In comparison to our proposed system, we have chosen FPGA for controlling the multiple inputs and output devices in parallel processing configuration and interfaced with the central monitoring computer. The basic reason for choosing FPGA instead of a conventional microcontroller is to make our processing faster by utilizing the parallel processing capabilities of FPGA. Web based database application is also developed and designed to monitor the parameters online; moreover, we have also equipped our system with GSM module as well. GSM is used for informing the concerned personnel about the status of the parameters that are needed to monitor and control at the earliest as possible.

4. Hardware Design
We have designed our system in such a way that it provides a complete knowledge of multiple process parameters that are needed to be monitored and controlled. Generally, the sensors output is an analog signal needed to be converted into digital signal via ADC (Analog to digital converter) before interconnecting to the FPGA, which was interfaced with the PC through RF transceiver and monitoring such parameters as well. If the situation is such that a certain parameter has reached to an alarming level, it will be automatically control by the main controller after a certain delay if the control actuation is not provided by that user.

GSM has interfaced with the PC in order to send the information messages to the concerned personnel if the undesired level has reached by a process parameter and at the same time we have incorporated a feature as shown in figure (3) in our proposed system that it will uploading such parameters online continuously after every 5 minutes.
Fig. (3) shown the flowchart of information uploading system

In the mean while if the dramatic change in parameters occurred within this duration, then the message will be delivered to the concerned maintenance team at plant to handle these situations at the earliest while these undesired values are stored in the online data base to keep the record of such events occurred during the plant operations. A block diagram of our proposed system has shown in figure 4.

Fig. (4) System Block Diagram
5. Results

We have tested and simulated our proposed system at room temperature. To investigate the performance of our designed system using different sensors configured and adjusted according to the multiple inputs and multiple outputs operational environments. Some tested values from few sensors are shown in table 1 below. Moreover, we have also tested the GSM services incorporated for our system that is for example if the Temperature reaches above the threshold level the incorporated GSM system generated a message to the concerned personnel for information and necessary actions about the situation. In case, if the personnel are outside the plant then they can also control the actuator via message if needed.

Table (1): Node A is LM35, Node B is Pyrometer, and Node C is PT-100 showing some operational sensors respectively.

| S.NO | Time(min) | Node A (°C) | Node B (°C) | Node C (°C) |
|------|-----------|-------------|-------------|-------------|
| 1    | 05        | 25          | 611         | 25          |
| 2    | 10        | 26          | 672         | 27          |
| 3    | 15        | 27          | 712         | 27          |
| 4    | 20        | 26          | 733         | 26          |
| 5    | 25        | 25          | 751         | 25          |
| 6    | 30        | 30          | 788         | 29          |

In table (1), the node A is showing temperature sensor LM35 and the change in temperature was monitored after every 5 minute and this time duration is adjustable through software alteration as per required conditions. Same is for the rest of the sensors like PT-100 which is node C and Pyrometer which is node B. The graphical outputs of these few sensors are shown in figure (5) below.

![Fig. (5) The graphical outputs of these few sensors](image)

It has been observed during the testing that the proposed system works well according to the industrial requirement. All the parameters are monitored and controlled successfully through this system. This system has an edge over other systems because of its capability for controlling multiple industrial process parameters using FPGA as main controller. As FPGA is capable of parallel processing therefore, this system has fast response time and fast control actuations.

6. Conclusion

We have successfully designed and demonstrated a smart wireless MIMO control system and utilized an FPGA as our main controller capable of parallel processing. Thus, resulted a fast response time for monitoring and control actuations have achieved. Multiple sensors were interfaced with our FPGA for
monitoring industrial process parameters such as Temperature, Pressure, and Pyrometers etc. We have also incorporated this feature for controlling such process parameters via messaging through GSM services. Based on all these advantageous features, we believed that this proposed system can be helpful in industrial working environments where conventional monitoring and control is difficult and time consuming and may be hazardous for human presence. Moreover, this system has the flexibility to be monitored through web as well and a data base has also been created to store the occurrence of any suspicious or undesired reading and their remedial action may also be recorded for the future smooth operations.

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