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Implementation of Data Acquisition System for fire Detection in Mines Area Using FPGA

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Abstract—This paper presents a novel approach to the design and implementation of FPGA (Field Programmable Gate Array) based DAS (Data Acquisition System) for mines safety application. This technique performs the acquisition of physical signal, conversion of analog signal to digital signal and storing of the information. The core heart of the proposed system is FPGA, which allows individual modules on a chip to work independently from each other which is configured and programmed to acquire real time data. The data for the process is acquired using suitable temperature and gas sensors. Signal conditioners are designed for each sensor and are tested in real time. The ADC0804 (analog to digital converter) is adopted for this system, which is a high speed monolithic CMOS device with an 8-bit analog-to-digital converter using successive approximation as the conversion technique.Spartan3 FPGA by Xilinx is used as the main controller from which all modules are implemented in VHDL using Xilinx ISE Design Suite13.3 and simulated using Isim.

Keywords— DAS, FPGA, VHDL

I. INTRODUCTION

Data acquisition is the process by which physical phenomena from the real world are transformed into electrical signals that are measured and converted into a digital format for processing, analysis, and storage. The required data can be collected from any peripheral input devices, such as transducers, sensors and other subsystems. In data acquisition system, it is a growing challenge to acquire the data at a required rate and to accumulate the data in an on chip memory processor. There are devices like microprocessors, microcontrollers and DSP are available which can be programmed as a data acquisition system. The main disadvantage of using these devices is their slower data acquisition speed, non availability of sufficient on-chip memory. Apart from this, the rigidity in the hardware configuration of these devices does not allow flexibility for the user in configuring these devices according to the requirement.

To overcome these drawbacks this research work proposes a novel technique of design and develop a data acquisition system using FPGA which provides flexibility in configuring the device according to the user requirement. The major defining characteristic of the FPGA is that it can be reprogrammed. Programming an FPGA is very different from a microprocessor or a DSP processor. Microprocessor is a stored program computer. A computer system contains both a CPU and a separate memory that stores the instruction and data. The FPGA program is interwoven into the structure of FPGA. An FPGA does not fetch instructions. The FPGA's programming directly implements the logic functions and interconnections. In the FPGA's there is no wait for completing the design to obtain a working chip. The design can be programmed into the chip and can be tested immediately. When an FPGA is used in final design, the jump from prototype to product is much smaller and easier. They are having a large number of input and output lines compared to microprocessors, microcontrollers and DSP's. FPGA's are having a higher processing speed compared to microprocessors and microcontrollers. With FPGA devices, it is possible to tailor the design to fit the requirements of applications.

In this work the acquisition of process parameters such as temperature and gas in mines area are considered. These parameters are measured using various sensors and those data are fed to FPGA based data acquisition system after proper conditioning. Thus, the objective of this work is the design of a data acquisition system on a FPGA chip which fetches the sensor data through an ADC and is compared with the threshold value and the output status is shown with the help of an alarm. The organization of this paper is as follows. Section II, gives block diagram, brief overview and describes about the hard ware design aspects of Data Acquisition System, Section III, describes the implementation details, synthesis and simulated results of the modules and finally Section IV, concludes the work.

II. BLOCK DIAGRAM

The design mainly involves the development of signal conditioning circuits for temperature and gas sensors used in the application and programming the FPGA using VHDL. FPGA utilized as a data acquisition system is programmed to fetch the data at the output of ADC with the help of a multiplexer and the digital data is stored in its internal RAM. The block diagram of FPGA based data acquisition system is given below in Fig. 1.

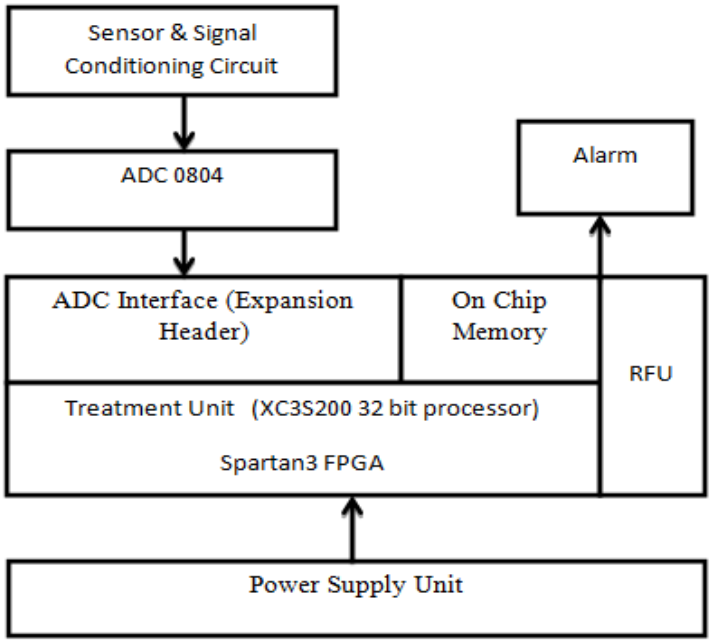

Fig.1. Block diagram of experimental setup for Data Acquisition System
RFU: Reconfigurable Functional Unit

The analog inputs corresponding to temperature and gas are given to signal conditioning circuit which consists of a multiplexer. The multiplexed analog signals are taken as analog input of ADC and corresponding 8 bit digital data is obtained. Here ADC0804 works in free running mode. So 8 bit digital data is directly obtained at FPGA ports and is stored in the Block RAM. The stored data is then compared with threshold values already stored in the FPGA. First the data corresponding to temperature and then gas is considered. After comparison when the stored data corresponding to either temperature or gas is greater than threshold value, it indicates that there is chance for fire to occur which is shown by using an alarm at the output.The hardware consists of temperature sensor LM35, Gas sensor MQ6 and their signal conditioning circuits, 2X1 multiplexer, ADC 0804 and Spartan3 FPGA.

A. Temperature Sensor

Temperature is measured with LM35 which is a precision integrated-circuit temperature sensor, whose output voltage is linearly proportional to the Celsius temperature. This sensor gives an output of 10mV for every 1°C change. Hence the need of complex signal conditioning is not necessary at the sensor output. A single load resistor connected at the output of the sensor will provide the required signal conditioning. This sensor can measure a range of temperature from -55 to 150°C that will satisfy the range needed in this work.

B. Gas Sensor

Gas is measured with MQ-6 gas sensor, which has high sensitivity to Propane, Butane, LPG and Natural gas. It requires 5V AC or DC for its operation. The sensor output needs simple drive circuit.

C. ADC0804

The ADC0804 is a CMOS 8-bit successive approximation A/D converter. It operates with 5 VDC, 2.5 VDC, or analog span adjusted voltage reference. It has differential analog voltage inputs, on-chip clock generator, logic inputs and outputs both meet MOS and TTL voltage level specifications. It provides resolution of 8 bit and conversion time of 100µs.In this work ADC0804 operates in free running mode which provides self clocking and so no control signal is needed for ADC from FPGA.

D. Spartan3 FPGA

Xilinx Spartan-3 FPGAs are highly flexible and fully user programmable logic devices that leverage advanced CMOS manufacturing technologies. Spartan-3 FPGA Starter Kit provides a low-cost, easy-to-use development and evaluation platform for Spartan-3 FPGA designs.
Xilinx Spartan-3 (XC3S200) FPGA mainly consists of 200,000 logic gates ,4,320 logic cell equivalents, twelve 18K-bit block RAMs (216K bits), twelve 18x18 hardware multipliers, four Digital Clock Managers, up to 173 user-defined I/O signals, 50 MHz crystal oscillator clock source, 1M-byte of Fast Asynchronous SRAM and FPGA configuration mode selected via jumper settings.

III. IMPLEMENTATION DETAILS

The FPGA has to work as a data acquisition system. This system included both hardware and software development. The 8 bit output of the ADC was connected to the FPGA board and it is used as the input of the source

code. The controller has already a threshold value, which gets compared with 8 bit received data. If the ADC output is greater than the threshold then alarm works. This is how the entire system is designed. This hardware design has been implemented in the FPGA and individual components have been successfully tested. Figure 2 shows the RTL schematic of entire system.

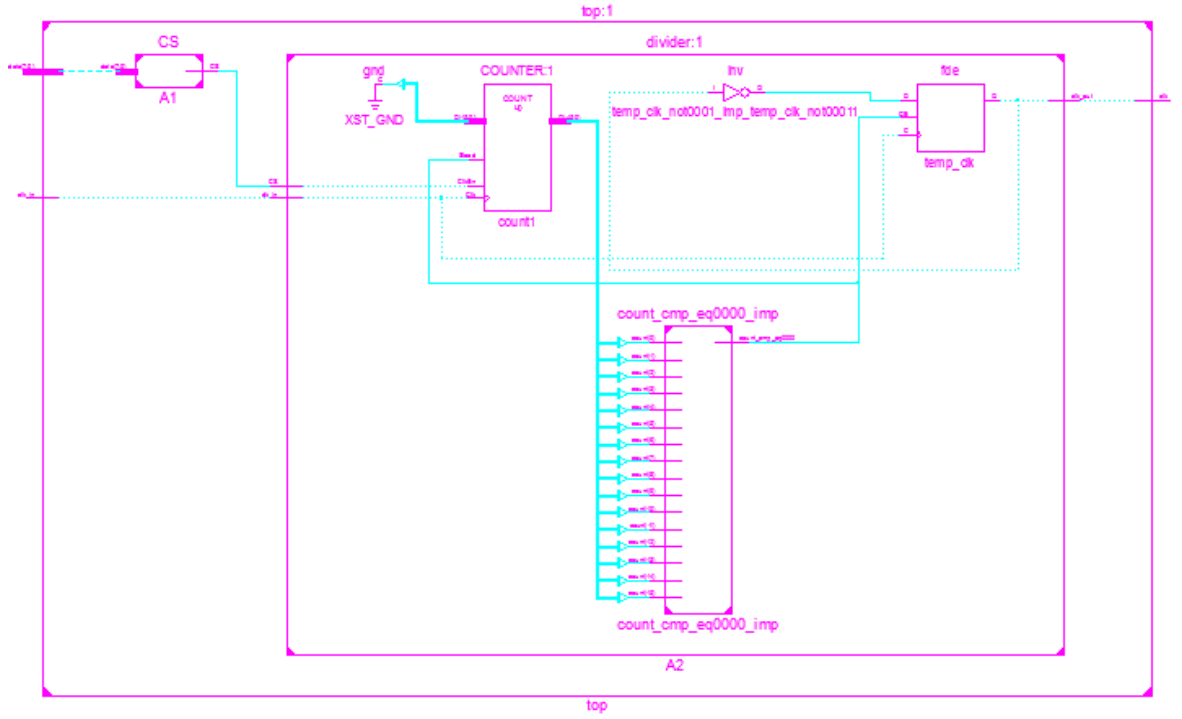

Fig 2: RTL Schematic of Data Acquisition System

A. Synthesis and Simulation Results

After synthesis and simulation process, the program has been implemented on the FPGA board. The entire VHDL system consists of an ADC block and Data acquisition block, both are connected and simulated as a whole before they were downloaded to the FPGA. Fig. 3 shows the simulation results obtained from the overall block. The device utilization and advanced HDL synthesis report information shown in Table I and II respectively shows that the component usage in the Spartan3 FPGA is quite less which results in high speed of operation.

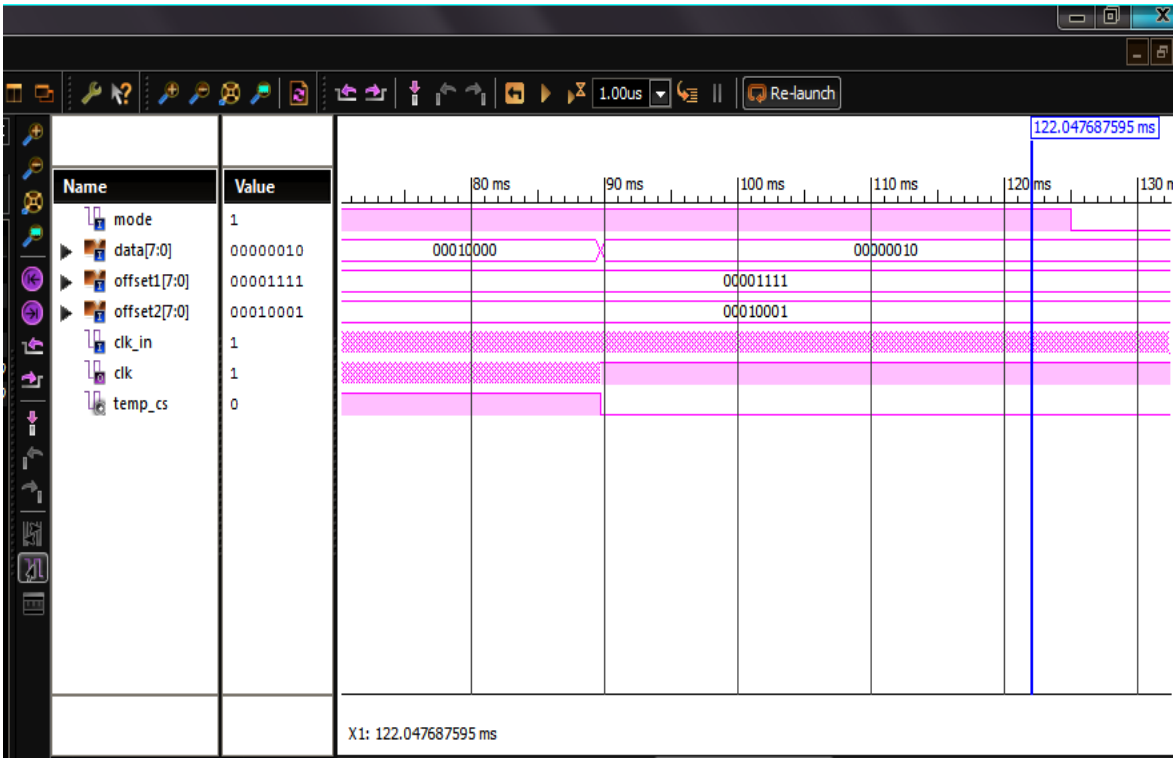

Fig 3: Simulated output of Data Acquisition System

TABLE I
THE DEVICE UTILIZATION INFORMATION

Logic Utilization	Device used	Device available
Number of Slices	20	3584
Number of Slice Flip Flops	17	7168
Number of 4 input LUTs	38	7168
Number of IOs	10	173
Number of bonded IOBs	2	173
Number of GCLKs	1	8

TABLE II
THE ADVANCED HDL SYNTHESIS REPORT INFORMATION

Logic Utilization	Device used
# Counters	1
16-bit up counter	1
# Registers	2
Flip-flops	2

IV. Conclusion

FPGA based data acquisition system for fire detection in mines area is designed and validated in real time. In this paper, and FPGA based platform is used to implement a data acquisition and processing system, as opposed to more traditional DSP or microprocessor platforms. Because of high integration level, low power consumption, design flexibility, high efficiency and user-programmability, the FPGA-based systems can greatly shorten the system's design cycle, reduce design cost and risk investment Hence this paper comes to conclude that Spartan 3 FPGA interface provide a flexible and versatile platform for building high-speed data acquisition system. The proposed system guarantees high speed of operation by utilising minimum resources. This paper has further future scope of improvement that together with a wireless communication system, the proposed system can work as a wireless sensor network for fire detection in mines as well as other remote areas.

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