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A Reconfigurable Smart Sensor Interface for Industrial WSN in IOT Environment

[1] R N S Sunil Veda ; [2] N.Veeraih & [3]S.Neelima

[1]M.Tech (VLSI & Embedded System),
[2]Asst.Professor,
[3]HOD, Assoc.Proffesor,
Gandhiji Institute of Science & Technology (Gist) – JNTU Kakinada Affiliated,
Gattubhimavaram (Village),Jaggayyapet (Mandal),Krishna (District),Andhra Pradesh, India.

Abstract-
Wireless Sensor Networks (WSN) has been employed to collect data about physical phenomenon in various applications such as habitat monitoring, and ocean monitoring, and surveillance. Internet of Things (IoT) has attracted a lot of attention and is expected to bring benefits to numerous application areas including industrial WSN systems, and healthcare systems manufacturing environmental data acquisition for IoT representation. A sensor interface device is essential for sensor data collection of industrial wireless sensor networks in IoT environments. Each sensor connected to the device is required to write complicated and cumbersome data collection code. To solve these problems a new method is is proposed to design a reconfigurable smart sensor interface for industrial WSN in IoT environment. Thus it can read data in parallel and in real time with high speed on multiple different sensor data. The standard of IEEE1451.2 intelligent sensor interface specification is adopted for this design. A new technique is provided for the traditional sensor data acquisitions. The device is combined with the newest FPGA programmable technology and the standard of IEEE1451.4 intelligent sensor with specific specification. The performance of the proposed system is verified and good effects are achieved in practical application of IoT to water environment monitoring. By detecting the values of sensors it can easily find out the Temperature, Vibration, Gas present in the industrial environment. So that critical situation can be avoided and preventive measures are successfully implemented.

Index Terms-- Wide Area Network (WAN); Read Only Memory (ROM); Electrically Erasable Programmable Read-Only Memory (EEPROM); Million Instructions Per Second (MIPS); Complex Programmable Logic Device(CPLD); Integrated Development Environment (IDE).

1. INTRODUCTION

Wireless Sensor Networks (WSN) has been employed to collect data about physical phenomena in various applications such as habitat monitoring, and ocean monitoring, and surveillance [1]. As an emerging technology brought about rapid advances in modern wireless telecommunication, Internet of Things (IoT) has attracted a lot of attention and is expected to bring benefits to numerous application areas including industrial WSN systems, and healthcare systems manufacturing [2].WSN systems are well-suited for long-term industrial environmental data acquisition for IoT representation [3]. Sensor interface device is essential for detecting various kinds of sensor data of industrial WSN in IoT environments [4]. It enables us to acquire sensor data. Thus, we can better understand the outside environment information. However, in order to meet the requirements of long-term industrial environmental data acquisition in the IoT, the acquisition interface device can collect multiple sensor data at the same time, so that more accurate and diverse data information can be collected from industrial WSN. With rapid development of IoT, major manufacturers are dedicated to the research of multi-sensor acquisition interface equipment .There is a lot of data acquisition multiple interface equipment's with mature technologies on the market. But these interface devices are very specialized in working style, so they are not individually adaptable to the changing IoT environment [4]. Meanwhile, these universal data acquisition interfaces are often restricted in physical properties of sensors (the connect number, sampling rate, and signal types). Now, micro control unit (MCU) is used as the core controller in mainstream data acquisition interface device. MCU has the advantage of low price and low power consumption, which makes it relatively easy to implement. But, it performs a task by way of interrupt, which makes these multi-sensor acquisition interfaces not really parallel in collecting multi-sensor data. On the other hand, FPGA has unique hardware logic control, real-time performance, and synchronicity, which enable it to achieve parallel acquisition of multi-sensor data and greatly improve real-time performance of the system.

FPGA has currently becomes more popular than MCU in multi-sensor data acquisition in IoT environment. However, in IoT environment, different industrial WSNs involve a lot of complex and diverse sensors. At the same time, each sensor has its own requirements for readout and different users have their own applications that require different types of sensors [5]. It leads to the necessity of writing complex and cumbersome sensor driver code and data collection procedures for every sensor newly connected to interface device, which brings many challenges to the researches. Sensor data acquisition surface device is the key part of study on industrial WSN application. In order to standardize a wide range of intelligent sensor interfaces in the market and solve the compatibility problem of intelligent sensor, the IEEE Electronic Engineering Association has also launched IEEE1451 smart transducer (STIM) interface standard protocol suite for the future development of sensors.

The protocol stipulates a series of specifications from sensor interface definition to the data acquisition [6]. The STIM interface standard IEEE1451 enables sensors to automatically search network, and the STIM promotes the improvement of industrial WSN [6]. These interface devices are usually based on relatively complex dedicated electronic boards. It is obvious that such restriction should be released, and a reconfigurable multi-sensor data acquisition interface with good compatibility and normative interface standard needs to be developed in IoT environment. By focusing on the above issue, this paper designs and realizes a smart sensor interface for industrial WSN in IoT environment. This design presents many advantages as described below. First of all, FPGA is used as the core controller to release the restriction on the universal data acquisition interface, and realize truly parallel acquisition of sensor data. It has not only improved then sensor data collection efficiency of industrial WSN, but also extended the application range of the data acquisition interface equipment in IoT environment. Secondly, a new design method is proposed in this paper for multi-sensor data acquisition interface that can realize plug and play for various kinds of sensors in IoT environment.

2. ARCHITECTURE

We design a reconfigurable smart sensor interface device that integrates data collection, data processing, and wired or wireless transmission together. The device can be widely used in many application areas of the IoT and WSN to collect various kinds of sensor data in real time. We program IP core module of IEEE1451.2 corresponding protocol in its CPLD. Therefore, our interface device can automatically discover sensors connected to it, and to collect multiple sets of sensor data intelligently, and parallel with high-speed. CPLD is core controller of the interface device. It is used to control data acquisition, processing, and transmission intelligently, and make some preprocessing work for the collected data [7]. The driver of chips on the interface device is also programmed inside the CPLD. Multiple scalable interfaces are designed on the equipment. It can be extended to 8-channel analog signal interface and 24-channel digital signal interface.

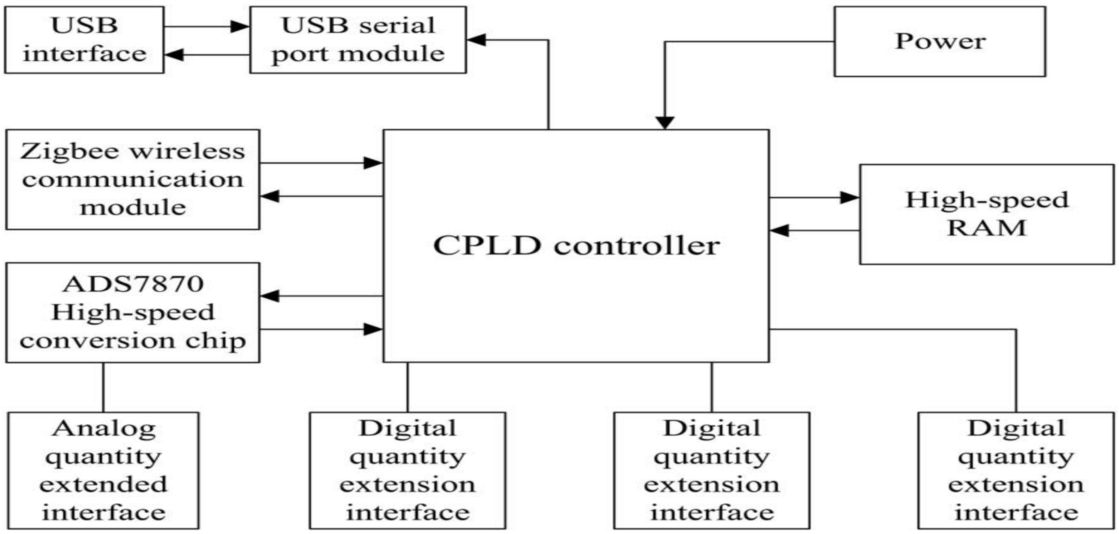

Fig. 1 CPLD hardware block diagram.

In terms of data transmission, our design can achieve wired communication through Universal Serial Bus (USB) interface and wireless communication through Zigbee module. Therefore, we can choose different transmission mode of the device in different industrial application environments. Fig. 1 is the application and working diagram of the reconfigurable smart sensor interface device. In practice, the designed device collects analog signal transmitted from color sensors, light intensity sensors, and other similar sensors through an analog signal interface. It can also collect digital signal transmitted from the digital sensors, such as temperature sensors, digital humidity sensors, and so on, through a digital signal interface. The Analog to Digital Converter (ADC) module and signal interface[7] on the interface device are controlled by the CPLD, which makes it possible to collect the 8channel analog signals and 24-channel digital signals circularly, and sets these collected data into the integrated Static Random Access Memory (SRAM) on the interface device. The collected data can be transmitted to the host computer side by way of USB serial wired communication or Zigbee wireless communication, so that the user can analyze and process the data.

3 .PROPOSED SYSTEM

The proposed method overcomes the drawback present in existing system by using wireless sensor network. The designed system is by using ARM 32-bit micro controller which supports different features and algorithms for the development of industrial automation systems. Using ARM controller we can connect all types of sensors and we can connect 8 bit microcontroller based sensor network to ARM controller using different wired or wireless technology. Many open source libraries and tools are available for ARM Linux wireless sensor network development and controlling. We can monitor and control the wireless sensor network remotely using internet and web server. The system describes the development of a wireless industrial environment measuring temperature, humidity, atmospheric pressure, soil moisture; water level and light detection. Where the wireless connection is implemented to acquire data from the various sensors, in addition to allow set up difficulty to be as reduced. To design a reconfigurable smart sensor interface device that integrates data collection, data processing, and wired or wireless transmission together. The device can be widely used in many application areas of the IoT and WSN to collect various kinds of sensor data in real time. To program IP core module in it's ARM. Therefore, our interface device can automatically discover sensors connected to it, and to collect multiple sets of sensor data intelligently, and parallel with high-speed. ARM is the core controller of the interface device. It is used to control data acquisition, processing, and transmission intelligently, and make some preprocessing work for the collected data. The driver of chips on the interface device is also programmed inside the ARM. Multiple scalable interfaces are designed on the equipment. It

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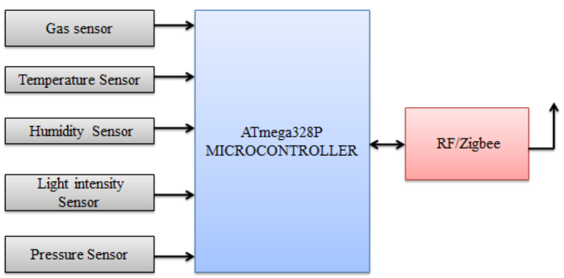

Fig.2 Monitoring unit

In terms of data transmission, our design can achieve communication through Universal Serial Bus interface. Therefore, we can choose different transmission mode of the device in different industrial application environments. The designed device collects analog signal transmitted from color sensors, light intensity sensors, and other similar sensors through an analog signal interface. It can also collect digital signal transmitted from the digital sensors, such as temperature sensors, digital humidity sensors, and so on, through a digital signal interface . The ADC[8]module and signal interface on the interface device are controlled by the ARM, which makes it possible to collect the 8-channel analog signals and 24-channel digital signals circularly, and sets these collected data into the integrated Static Random Access Memory on the interface device. The collected data can be transmitted to the host computer side by way of USB serial communication so that the user can analyze and process the data.

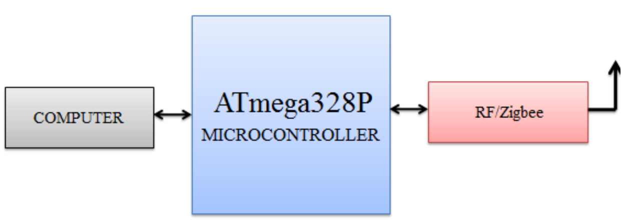

Fig. 3 Control unit

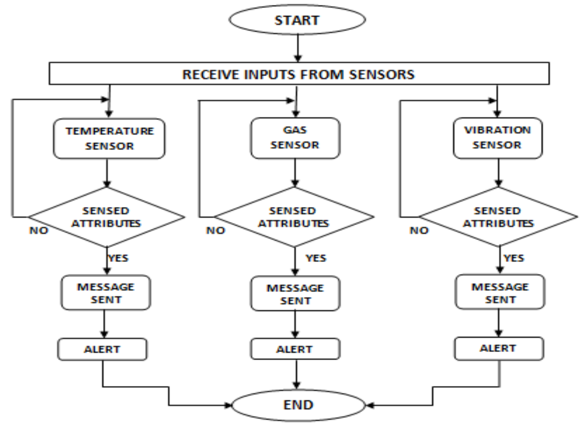

Fig 4.Configuration ADS7870 program flowchart

4 IMPLEMENTATION

4.1 The Introduction of the Hardware Architecture

The overall structure of reconfigurable smart sensor interface consists of CPLD chip (XC2C256 chip), crystals and peripheral circuit, communication circuit for turning USB to serial port (PL2303HXC chips and peripheral circuits), power supply of 1.8 and 3.3 V (LM1117 chip, voltage regulator and filter circuit), an SRAM memory (TC55V400 chip), high-speed 8-channel ADC (ADS7870 chip and peripheral circuit), LED indicator light, an analog extended interface, and three digital extended interfaces. Every extended interface among them can connect eight independent sensors, namely, the reconfigurable smart sensor interface device can access eight analog signals and 24 digital signals. Fig. 5 shows the CPLD hardware block diagram. The hardware system can also send and receive data besides the basic sensor data acquisition. It can send data to the control center via USB serial port or Zigbee wireless module. Zigbee wireless communication module can be connected with the board through the mini-USB interface or the extensible GPIO interface on the device. It can be used as wireless data transceiver node when the main controller receives trial or executive instructions[9]. After the data control center finishes further processing for the received data, it needs to feed back related actions to sensor interface device. Data communication function can also control the running status of corresponding peripheral device.

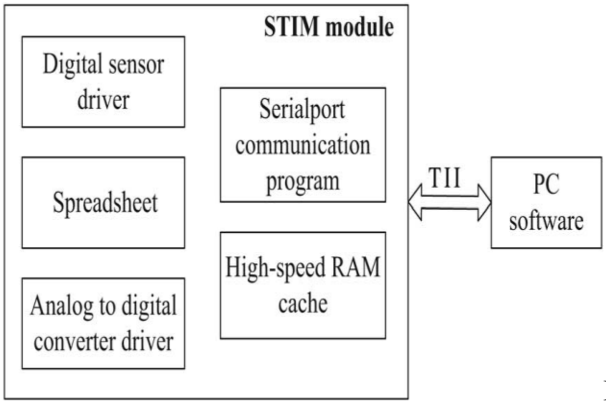

Fig.5 Overall structure diagram of VHDL part of the system

4.2 VHDL Design

Very-High-Speed Integrated Circuit Hardware Description Language (VHDL) design of the system includes two parts. One part to uses the VHDL language as the basic tool and write related features of the reconfigurable smart sensor interface device by referring to the standard of IEEE1451.2 agreement. It reflects the difference between reconfigurable smart sensor interface device and general data acquisition card, which has a great effect in intelligently collecting sensor data. The other part is programming the interface driver based on VHDL hardware description language. It mainly covers programming of each hardware chip driver and sensor driver on the device. The designed reconfigurable smart sensor interface device can not only be used to collect sensor data, but it has also added sensor compatible IEEE1451.2 protocol standard features

4.3 Overall Design of the Intelligent Transmitter STIM

The design of STIM is the key to realization of the smart sensor data acquisition part. Functional design refers to the design framework of smart sensor data acquisition put forwarded by the standard of IEEE1451.2. STIM overall design structure diagram is shown in Fig. 6.STIM contains the following four functions: 1) the spreadsheet Transducer Electronic Data Sheet (TEDS); 2) the data transmission module (the part of transducer independent interface (TII)); 3) channel trigger module; and 4) registers management module.

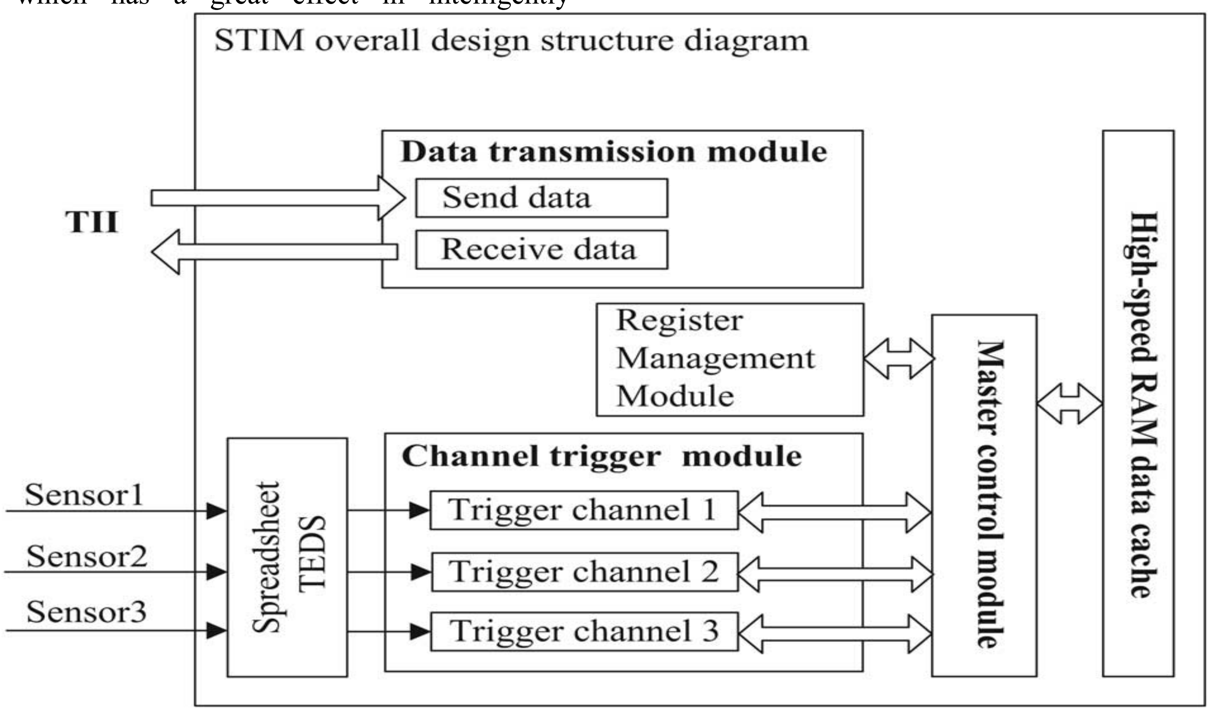

Fig. 6 STIM overall design structure diagram.

Realization of the functions of intelligent transducer is mainly controlled by three state machine modules, which are master state machine, data transmission state machine, and channel trigger state machine. Another data signal cache is also included in it. Relationship among each other is shown in Fig. 7. In

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Fig. 7, the master state machine is responsible for scheduling each function module of the acquisition system, and also has comprehensive control effect on the other two state machines.

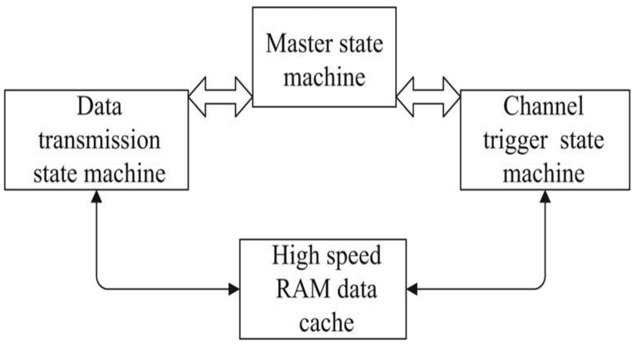

Fig. 7 STIM state machine design structure diagram.

5. CONCLUSION

The smart sensor interface for industrial WSN in IoT environment system can collect sensor data intelligently. It was designed based on ARM and the application of wireless communication. It is very suitable for real-time and effective requirements of the high-speed data acquisition system in IoT environment. The ARM greatly simplifies the design of peripheral circuit, and makes the whole system more flexible and extensible. Different types of sensors can be used as long as they are connected to the system. On setting the values of each sensors then the Temperature, Gas, Vibration values are known. The values of Temperature are 67.4c is measured. The Vibration and Gas sensor is either Low or Medium, it means Low indicates that there is no gas and vibration, then Medium indicates there is a Gas and Vibration present. By this way the critical situation can be avoided. The design system applies interface standard that is used for smart sensors of automatically discovering network. The sensors are not based on protocol standard. The data acquisition interface system can achieve the function of plug and play. High execution speed, flexible organization structure, IP design could reuse. It will have a broad space for development in the area of WSN in IoT environment.

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