ISSN XXXX XXXX

Research Article Volume 7 Issue No.10

Wireless Data Transmission cum Data Acquisition through IOT in Industrial Environment

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Abstract:
A sensor interface device is essential for sensor data collection of industrial wireless sensor networks (WSN) in IOT environments. However, the current connect number, sampling grate, and signal types of sensors are generally restricted by the device. Meanwhile, in the Internet of Things (IOT) environment, each sensor connected to the device is required to write complicated and cumber some data collection program code. In this project, to solve these problems, a new method is proposed to design a reconfigurable smart sensor interface for industrial WSN in IOT environment, in which complex programmable logic device (CPLD) is adopted as the core controller. Thus, it can read data in parallel and in real time with high speed on multiple different sensor data. Intelligent sensor interface specification is adopted for this design. A new solution is provided for the traditional sensor data acquisitions. The device is combined with the newest CPLD programmable technology and the intelligent sensor specification. Performance of the proposed system is verified and good effects are achieved in practical application of IOT to Industrial environment monitoring.

Index items: Internet of Things, Microcontroller (PIC 16f877A), ARM Processor, XBEE Module (RFX240), Temperature Sensor (LM 35), PIR Sensor.

I.INTRODUCTION

Wireless sensor networks (WSN) have been employed to collect data about physical phenomena in various applications such as habitat monitoring, and ocean monitoring, and surveillance [1]–[3]. 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 [4], [5]. WSN systems are well-suited for long-term industrial environmental data acquisition for IOT representation [6]. Sensor interface device is essential for detecting various kinds of sensor data of industrial WSN in IOT environments [7]. 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 multisensor acquisition interface equipment [8]. There are a lot of data acquisition multiple-interface equipments 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 [9]. 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 multisensor acquisition interfaces not really parallel in collecting multisensor data. On the other hand, FPGA/CPLD has unique hardware logic control, real-time performance, and synchronicity [10], [11], which enable it to achieve parallel acquisition of multisensor data and greatly improve real-time performance of the system [12]. FPGA/CPLD has currently becomes more popular than MCU in multisensor 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 [13]. 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 the improvement of industrial WSN [20]. But, the sensors with the protocol standard have a high cost and still lack popularity in industrial WSN in IOT environment.

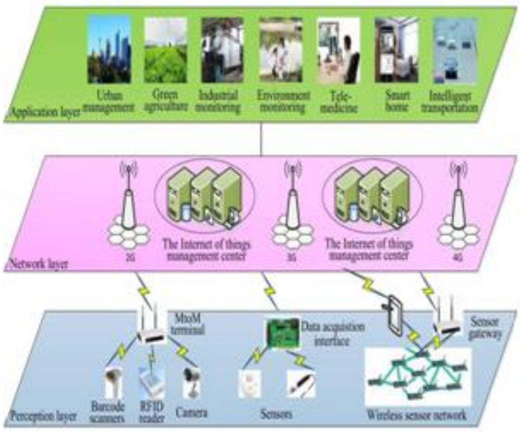


Figure.1. Architecture of IOT

Nevertheless, at present, examples of intelligent sensors available on the market and compliant with this standard are still limited [21]. To solve these problems, some dedicated hardware interfaces based on the IEEE 1451 have been recently proposed, and they are capable of interfacing with different sensor typologies [22]. These interface devices are usually based on relatively complex dedicated electronic boards [23]–[25]. It is obvious that such restriction should be released [26], and a reconfigurable multisensor 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 reconfigurable smart sensor interface for industrial WSN in IOT environment. This design presents many advantages as described below. First of all, CPLD 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 the 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 multisensor data acquisition interface that can realize plug and play for various kinds of sensors in IOT environment.

The design system applies the IEEE1451 interface protocol standard that is used for smart sensors of automatically discovering network. For the sensors not based on IEEE 1415 protocol standard, the data acquisition interface system can achieve the function of plug and play. In this paper, this design take full advantage of CPLD characteristics, such as high execution speed, flexible organization structure, IP design could reuse, etc. The design adopts IEEE1451 smart transducer (STIM) inter-face standards, which makes our device better compatible in the field of industrial WSN in IOT environment.

II.IMPLEMENTATION

A. 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. 2 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 Xbee wireless module. Xbee wireless communication module can be connected with the board through the mini-USB interface or the extensible GPIO interface the device. It can be used as wireless data transceiver node when the main controller receives trial or executive instructions [39]. After the data control center finished 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.

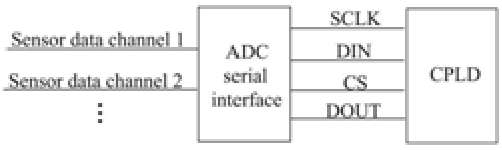


Figure.2. Independent sensor interface function schematic.

Process can be executed in parallel. It ensures minimum delay, real-time performance and reliability of data collection in the process of multiple sensor data collection. The differences of different channel types are just reflected in the independent channel types, and the last transmitted data are previously stored in the cache.

b) Module Design of the Spreadsheet TEDS:

Spreadsheet is an independent IP core module existing in CPLD in the form of circuit. Its main function is to operate various kinds of sensor data to be normatively collected by trigger sensor channel [40], [41], and make some corresponding modifications by filtering out invalid or false sensor data according to the characteristics of a variety of sensors. Schematic diagram of TED’s state machine. Initial state of the system is defined by its idle state. When the start signal ranges from state 0 to 1, the state will jump from the idle state to the reading state of spreadsheet. Data can be saved to the register through serial and parallel transformation. The state updated to the contrast state of data format after reading a set of data. At the same time, the status flag pos will automatically adds 1 and prepares for contrasting the next message. At this point, the internal sensor data information that has been defined at the initialization time will compare it with the data read from the external. Otherwise, the contrast state of data format will return to idle state. If comparative success, it will automatically start the next data comparison. In our design, the sensor channel trigger state machine is assigned with a specific ID number. At the same time, the ID also represents the priority of data collection. There are numerous methods to define priority, such as sensor conversion rate data length etc. Data length is used as the standard to set priority. When data has different length, the “short data priority” principle can effectively guarantee the overall time consumption of the whole data collection, so as to enhance real-time character of acquisition system.

c) Module Design of the Sensor Independent Interface TII:

Sensor independent interface TII is the communication part of the smart transmitter STIM and network capable application processor (NCAP) [42]. Fig. 10 is the TII interface function diagram. TII is not complicated in concept. It interconnects with NCAP through the synchronous serial interface. TII usually includes data output (DOUT) and data input (DIN), which are used to shake hands for data and communication, DCLK is used to make data synchronization, and other signal lines such as special function signals are used as alternative choice. The reconfigurable smart sensor interface device is on the left side and we expand an Xbee module on it. We use these wires around the device to attach sensors that we have used. Power of the whole system is on the right side. The two pieces of circuit boards are some corresponding configuration circuit in the middle of the figure. In our system, the ADC is mainly controlled mainly by writing signal DIN from the connected CPLD to operate registers inside the chip. First, the system controls ADC to collect analog signals of sensor input.

These digital signals after conversion are first stored in the internal registers of ADC. Then, these digital signals are sent to the CPLD through DOUT port. In this system, DOUT port is set to automatically send ADC conversion results on the SCLK clock rising edge. CPLD controls initialization of the ADC, sensor data collection, and data conversion during the whole process. After finishing ADC configuration, we implement the function of collecting analog sensor signals. This process is accomplished by sending collection command circularly.

III.SYSTEM 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.

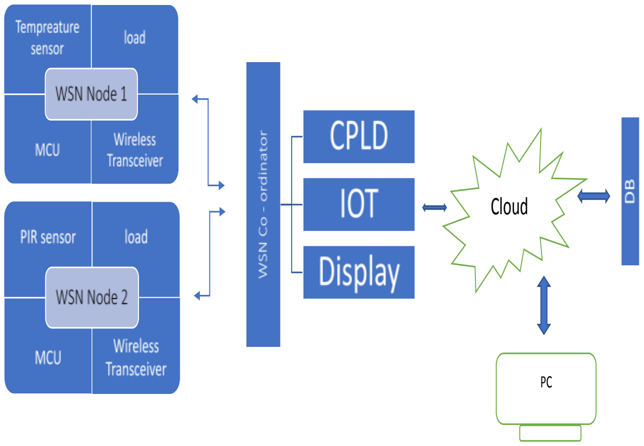


Figure.3.Block diagram of proposed system

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 [38]. 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.

This ensures that our device can connect with a number of sensors among the application of industrial IOT or WSN and guarantees the diverse collection of the information. In terms of data transmission, our design can achieve wired communication through Universal Serial Bus (USB) interface and wireless communication through Xbee module. Therefore, we can choose different transmission mode of the device in different industrial application environments. In practice, the designed device collects analog signal trans-mitted 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 on the interface device are controlled by the CPLD, which makes it possible to collect the 8-channel analog signals and 24-channel digital signals circularly, and sets +-

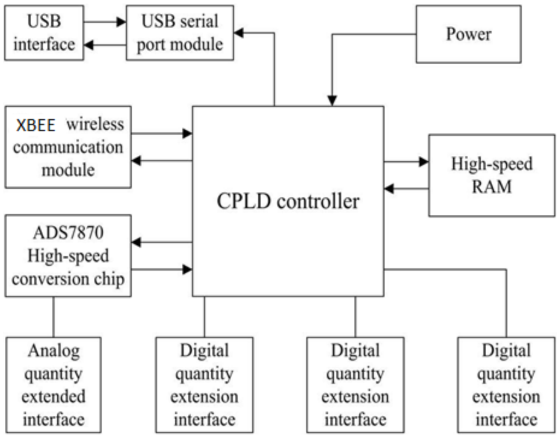


Figure.4. CPLD hardware block diagram

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 Xbee wireless communication, so that the user can analyze and process the data.

A.TEMPERATURE SENSOR MODULE (LM 35)

The LM35 datasheet specifies that these ICs are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±1⁄4˚C at room temperature and ±3⁄4˚C over a full −55 to +150˚C temperature range.

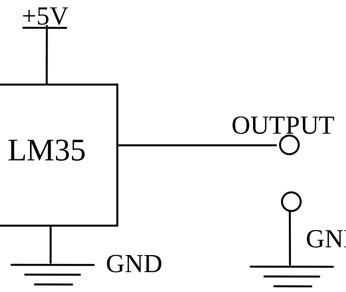


Figure.5. Circuit diagram for the LM35 temperature sensor functional module

B.PIR SENSOR

The PIR sensor circuit is used in numerous electronics projects which are used to discover a human being entering or leaving the particular area or room. These passive infrared sensors are flat control, consists of a wide range of lens, and PIR sensors can be easily interfaced with electronics circuits.

Figure. 6. PIR Sensor

The pin configuration of the PIR sensor is shown in the figure. PIR sensor consists of three pins, ground, signal, and power at the side or bottom. Generally, the PIR sensor power is up to

5V, but, the large size PIR modules operate a relay instead of direct output. It is very simple and easy to interface the sensor with a microcontroller. The output of the PIR is (usually digital output) either low or high.

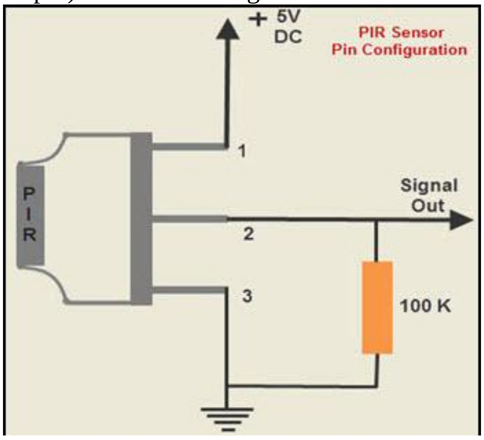


Figure.7. Pin configuration of PIR sensor

B.LIQUID CRYSTAL DISPLAY

A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data.

C.PICMICROCONTROLLER (16f877a)

The PIC microcontroller PIC16f877a is one of the most renowned microcontrollers in the industry. This controller is very convenient to use, the coding or programming of this controller is also easier. One of the main advantages is that it can be write-erase as many times as possible because it use FLASH memory technology. It has a total number of 40 pins and there are 33 pins for input and output. PIC16F877A is used in many PIC microcontroller projects. PIC16F877A also have many applications in digital electronics circuits.

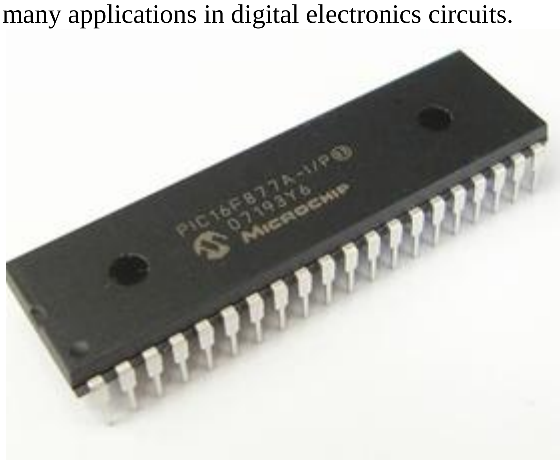
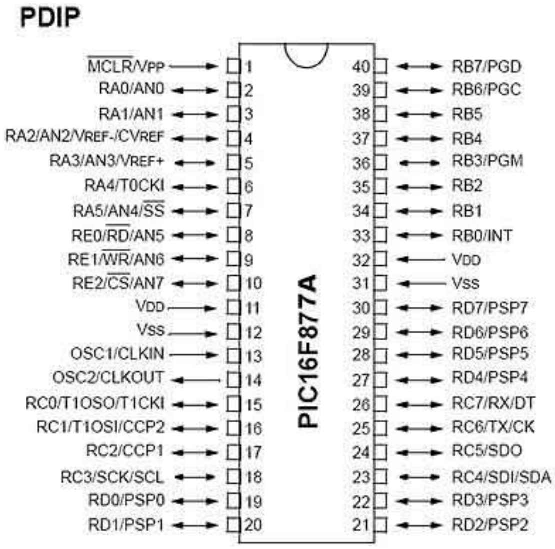


Figure.8 .PIC 16f77a microcontroller

PIN CONFIGURATION AND DESCRIPTION of PIC 16F 877A

As it has been mentioned before, there are 40 pins of this microcontroller IC. It consists of two 8 bit and one 16 bit timer. Capture and compare modules, serial ports, parallel ports and five input/output ports are also present in it.



D.XBEE MODULE (RFX240)

Serial-to-RF Packetization

Data is buffered in the DI buffer until one of the following causes the data to be packetized and transmitted:

No serial characters are received for the amount of time determined by the RO (Packetization Timeout) parameter. If RO = 0, packetization begins when a character is received. The maximum number of characters that will fit in an RF packet (100) is received. The Command Mode Sequence (GT + CC + GT) is received. Any character buffered in the DI buffer before the sequence is transmitted. If the module cannot immediately transmit (for instance, if it is already receiving RF data), the serial data is stored in the DI Buffer. The data is packetized and sent at any RO timeout or when 100 bytes (maximum packet size) are received. If the DI buffer becomes full, hardware or software flow control must be implemented in order to prevent overflow (loss of data between the host and module). API (Application Programming Interface) Operation is an alternative to the default Transparent Operation. The frame-based API extends the level to which a host application can interact with the networking capabilities of the module. When in API mode, all data entering and leaving the module is contained in frames that define operations or events within the module. Transmit Data Frames (received through the DI pin (pin 3)) include:

- RF Transmit Data Frame
- Command Frame (equivalent to AT commands)

Receive Data Frames (sent out the DO pin (pin 2)) include:

- RF-received data frame
- Command response

Event notifications such as reset, associate, disassociate, etc.

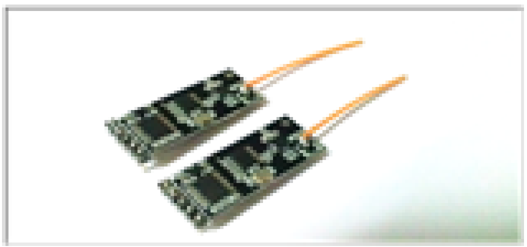


Figure. 9.Xbee RFX240 module

The API provides alternative means of configuring modules and routing data at the host application layer. A host application can send data frames to the module that contain address and payload information instead of using command mode to modify addresses. The module will send data frames to the application containing status packets; as well as source, RSSI and payload information from received data packets. The API operation option facilitates many operations such as the examples cited below:

-> Transmitting data to multiple destinations without entering Command Mode

-> Receive success/failure status of each transmitted RF packet

->Identify the source address of each received packet

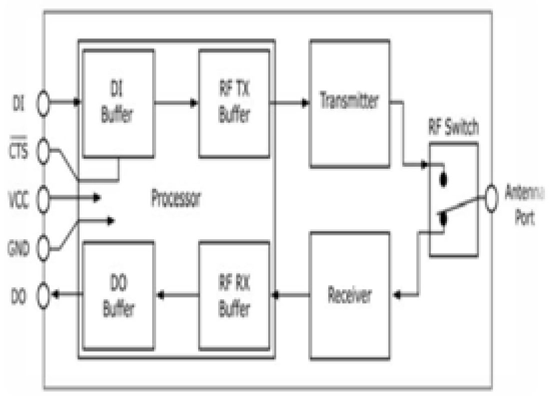


Figure.10. Internal Data Flow Diagram

E.ARM PROCESSOR (ARM 7)

1. Basic Characteristics

The principle feature of the ARM 7 microcontroller is that it is a register based load-and-store architecture with a number of operating modes. While the ARM7 is a 32 bit microcontroller, it is also capable of running a 16-bit instruction set, known as "THUMB". This helps it achieve a greater code density and enhanced power saving. While all of the register-to -register data processing instructions are single-cycle, other instructions such as data transfer instructions, are multi-cycle. To increase the performance of these instructions, the ARM 7 has a three-stage pipeline. Due to the inherent simplicity of the design and low gate count, ARM 7 is the industry leader in low-power processing on a watts per MIP basis. Finally, to assist the developer, the ARM core has a built-in JTAG debug port and on-chip "embedded ICE" that allows programs to be downloaded and fully debugged in-system.

Figure.11. ARM 7 Diagram

The pipeline has three stages; FETCH, DECODE and EXECUTE. The hardware of each stage is designed to be independent so up to three instructions can be processed simultaneously. The pipeline is most effective in speeding up sequential code. However a branch instruction will cause the pipeline to be flushed marring its performance. As we shall see later the ARM 7 designers had some clever ideas to solve this problem.

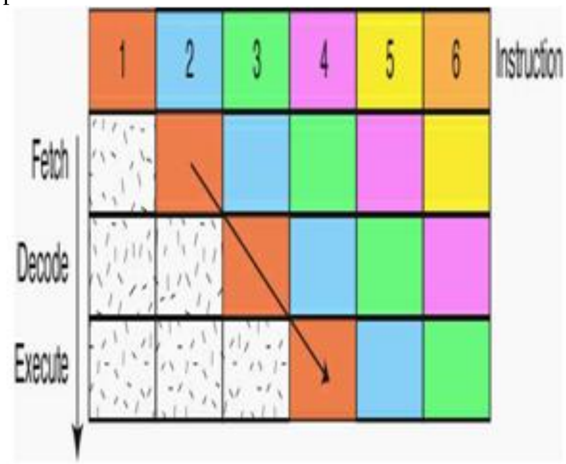
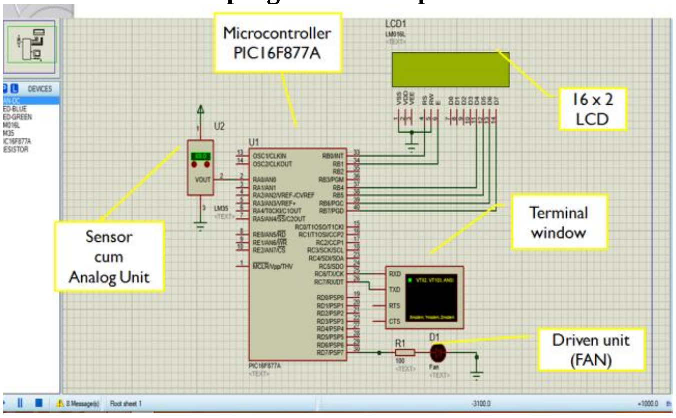


Figure.12. ARM 3-Stage Pipeline

IV.DISCUSSION AND RESULTS

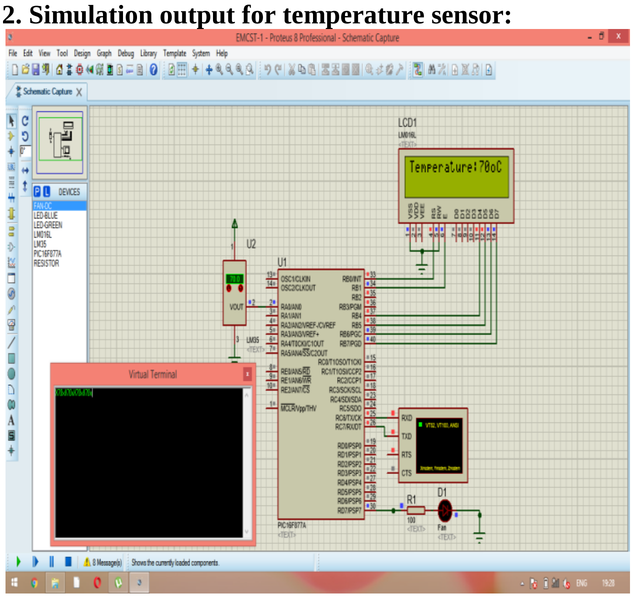
A. WIRELESS SENSOR NODE 1

1. Simulation program for temperature sensor:

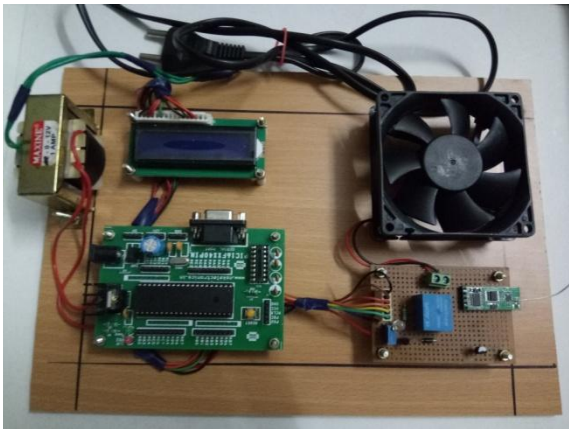


This is the simulation program for temperature sensor using PROTUES software. The sensor cum analog unit used to change the input/temperature. The microcontroller program written using MPLAB IDE. The WINPIC is a booting tool for microcontroller. We can see the real time dates in 16x2 LCD. We can see what dates are passed to the CPLD in terminal window. In WSN 1 our driven unit is fan.

2. Simulation output for temperature sensor:

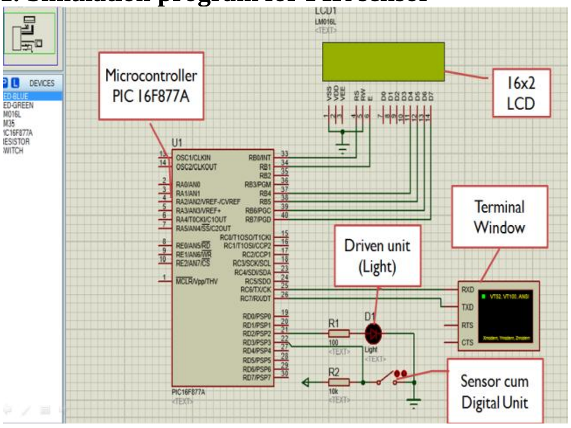


3. **HARDWARE OUTPUT FOR TEMPERATURE SENSOR:**



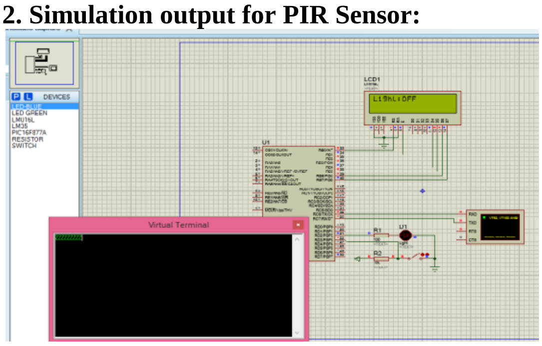
B.WIRELESS SENSOR NODE 2

1. Simulation program for PIR sensor



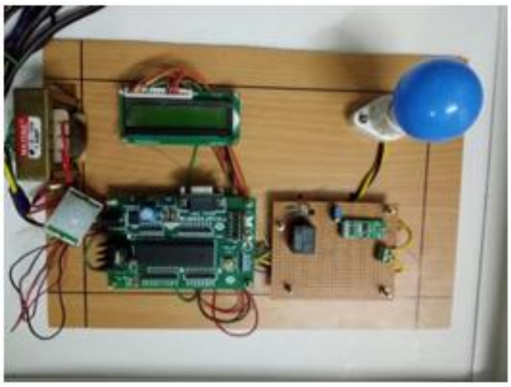
This is the simulation program for PIR sensor using PROTUES software. Here the input unit is sensor cum digital unit. When the switch is ON the driven unit Light is ON. When the switch is in OFF condition the Light is OFF.

2. Simulation output for PIR Sensor:

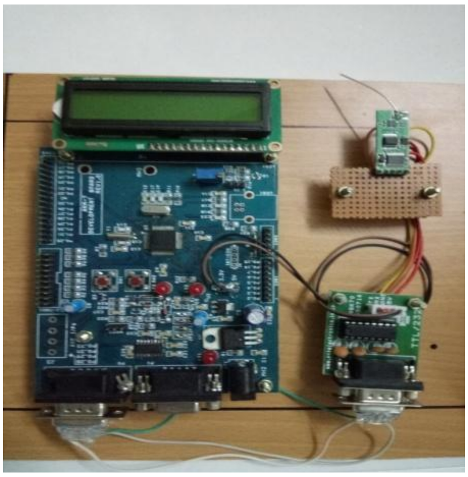


3. HARDWARE OUTPUT FOR PIR SENSOR:

C.WIRELESS CO-ORDINATOR WITH CPLD:



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. The driver of chips on the interface device is also programmed inside the CPLD.



V.CONCLUSION

This paper describes a reconfigurable smart sensor interface for industrial WSN in IOT environment. The system can collect sensor data intelligently. It was designed based on IEEE1451 protocol by combining with CPLD 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 application of CPLD greatly simplifies the design of peripheral circuit, and makes the whole system more flexible and extensible. Application of IEEE1451 protocol enables the system to collect sensor data intelligently. Different types of sensors can be used as long as they are connected to the system. Main design method of the reconfigurable smart sensor interface device is described in this paper. Finally, by taking real-time monitoring of water environment in IOT environment as an example, we verified that the system achieved good effects in practical application. Nevertheless, many interesting directions are remaining for further researches. For example, the IEEE1451 protocol can be perfected and the function of spreadsheet should be expanded. It will have a broad space for development in the area of WSN in IOT environment.

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