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Wireless Atmospheric Data Logger for a Sensor Network

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Abstract— Recording the environmental conditions continuously is a mandatory process in industries. The tracing of the environment parameters leads to the production to continue in a hassle free manner. Using the analogue meters and recording it manually is always a tedious process and non-accurate. Replacing the whole process in a digital manner along with a sophisticated software reduce the time, effort and also produces more accurate results. Embedding sensors, transceivers with microcontroller with reduced power consumption and decreases the tendency of the damage occurrence in the production equipment. Precise monitoring with wireless sensors from a remote site is developed in this project.

Keywords— Wireless communication, Transceivers, sensors, IoT, SPI, UART

1. INTRODUCTION

The advanced development of wireless sensors made monitoring various environmental parameters easy and accurate. Due to uneven distribution of temperature and humidity from one area to another, there is a more need of an environment monitoring systems. A traditional wired system causes many problems like inaccuracy and less precision.

This is the age of Internet of things where wireless sensor networking becomes the core of networking. In order to interconnect our day to day things or objects to be sensed and controlled remotely across existing networking infrastructure, creating opportunities for more direct integration between physical world and computer-based systems, resulting in improved efficiency, accuracy and economic benefit. Each thing is uniquely identifiable through its embedded computing system but it's able to interoperate with the existing Internet infrastructure.

Environmental monitoring applications of the IoT typically utilize sensors to assist in environmental protection by monitoring atmospheric or water quality, or soil conditions. This paper presents the construction and development of such Atmospheric monitoring system in which a single sensor can obtain environmental parameters like temperature and humidity and can send that data using transceivers to remote locations.

2. SYSTEM DESCRIPTION

The design and development of the system is basically divided into two units one is the transmission unit and the other is receiver unit. If more number of transmission units are connected at distant places from each other and all of these units try to communicate with a single receiver then it can be treated as sensor network node. The information received from each transmitter is to be identified using a transmitter id from that particular unit. The data that is collected from each transmitter can be stored into a memory subsystem for further analysis.

As a preliminary work we are here with considering a single transmitting unit and a receiving unit for logging data over a distance ranging from 5 feet to 2000 feet. The following are the subsystems of each of the units.

The transmitter unit consists of

a) ATmega 328P microcontroller
b) Temperature and humidity sensor (DHT11)
c) NRF transceiver (NRF24L01).

The receiver unit consists of

a) ATmega 328P microcontroller
b) NRF transceiver
c) 16X4 LCD unit
d) SD card
e) UART

The interconnections between each block of the units are as shown below

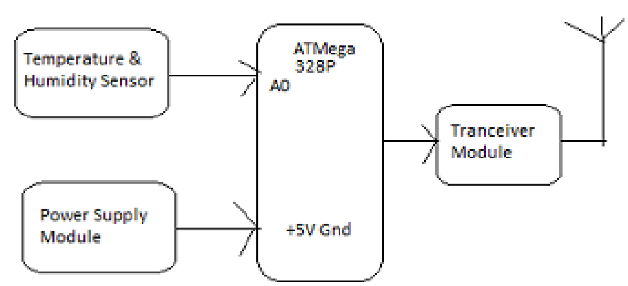

Fig 1: Block Diagram of Transmitter unit

Operation of the Transmitter Block:

DHT11 Sensor: The DHT sensor includes a resistive type humidity and temperature measurement component that can be easily connected to any microcontroller, and offers excellent quality, quick response with anti- interference ability and low cost. A single wire connection makes the integration quick and easy and hence is known as a single row pin package. The power consumption is very low and makes this device as the best choice for any application.
The most interesting fact about this module is the protocol that is used for the transfer of data. All the readings are sent using a single wire bus which reduces the cost and extends the distance. In this sensor the 1-wire data bus is pulled up with a resistor to Vcc. The power voltage should be 3- 5.5V DC and any instruction should not be sent immediately as the device has to pass the unstable state. A capacitor of 100nf can be added between V_{DD} and GND for power filtering. The communication format is divided into three stages 1.Request 2.Response and 3.Data reading.

To send the sensor readings we have to initialize a **request**. Upon initializing the request the bus is pulled down for more than 18ms so as to make the sensor understand the request and then pulled up for 40µs. The **response** from the sensor is ~54µs low and 80µs high.

The data will be packed in a packet of 40 bits consisting of 5 segmented values. The first two segments are used to describe the humidity in integral and decimal format, the next two segments describe the temperature in Celsius and the last is the checksum which is the sum of first four segments. At the end of packet a 54µs low level signal is sent by DHT pulls the bus to high and goes to sleep mode.

The received 40bit data is analysed in the following format
0011 0101 00000000 0001 1000 00000000 0100 1101
High Low Humidity High Low Temperature Parity

0011 0101+0000 0000+0001 1000+0000 0000=0100 1101
Humidity: 0011 0101=35H=53%RH
Temperature: 0001 1000=18H=24^0C

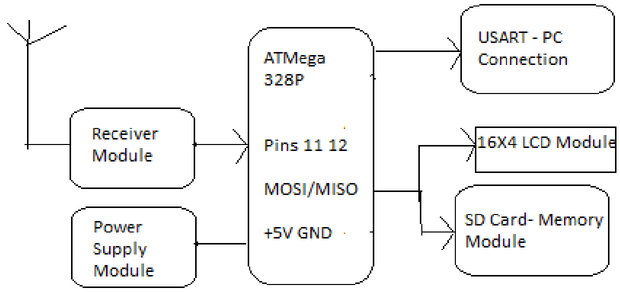

Fig 2: Block diagram of reciever unit

In this unit a transciever module is connected to AtMega microcontroller. The Rx mode is in active mode due to which the transceiver here acts as reciever which recieves the sensor values and sends to the micro controller for further processing. The reciever demodulates the signals from the RF channel constantly ,and if a valid packet is found the payload of the packet is presented in a vacant slot. The nRF24l01 + remains in Rx mode until the MCU configures it to stand by mode or power down mode. The Received Power Detector (RPD) is set high when a sign is higher than -64dBm is detected inside the receiving frequency channel. In this module, Cyclic Redundancy (CR) checking and automatic packet handlings are also done.

3. HARDWARE FEATURES

In this section we will discuss about the interfacing of each and every device with the microcontroller. The below section discusses about the interfacing part

Arduino Board:

Arduino is an open source microcontroller development board. Arduino can be used to read sensors and control things like motors and lights. This allows up load programs to this board which can then interact with things in the real world.

The **Arduino** is an ATmega328P based microcontroller board. The board comes with built-in Arduino boot loader. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 8 analogue inputs, an on-board resonator, a reset button, and holes for mounting pin headers. The board can be connected to the PC using USB port and the board can runs on USB power or batter power supply.

ATmega 328 P:

The ATmega 328 P is a low power CMOS 8- bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, ATmega achieves throughputs approaching 1MIPS per MHz allowing the system designed to optimize power consumption versus processing speed. In this paper we embed all the devices to ATmega micro controller through various connectors.

DHT 11 Sensors:

The DFRobot DHT11 temperature &Humidity sensor features a temperature and humidity sensor with a calibrated digital signal output. By using the exclusive digital-signal-acquisition technique and temperature & humidity sensing technology, it ensures high reliability and excellent long-term stability.

16X4 Liquid Crystal Display (LCD) Units:

A 16X4 LCD module is used as one of the main output unit for displaying process parameter values. After power supply is given, current temperature and humidity values will be displayed. Instead of making use of 8 width data pins, we use 1,3 as V_{ss} and 2nd as V_{cc} 4th ,5th,6^{th,} represents control pins, from 7th pin to 14th pin represents data pins and 15th pin is for Back LED and 16th pins represent Ground. By interconnecting pin no 15 and 16 to pin nos of 1,2,3 of LCD we can optimize power circuit. Instead of making use of entire 8 pin data width, the data can be displayed using 11, 12, 13, 14 data pin values D4,D5,D6,D7. The pin no 15 and 16 should be controlled by a switching circuit in order to ON and OFF backlight when not required.

nRF TRANSCEIVER 2401:

A transceiver is a device comprising both a transmitter and a receiver which are combined and share common circuitry or a single housing. As there is few circuitries are common between transmit and receive functions, the device is a transmitter-receiver. This chip uses SPI bus, chip control pins. Pin 10 remained as output, or the SPI hardware will go into ‘slave’ mode.

NRF24L01 is a series of 2.4GHz radio modules that are all based on the Nordic semiconductor nRF 24L01+ integrates a complete 2.4GHz RF transceiver, RF synthesizer, and baseband logic including the Enhanced ShockBurst hardware protocol accelerator supporting a high-speed SPI interface for the application controller.

When power problems exist in the interfacing, i.e. while connecting 3.3V power module does not have enough current capability, or current surges cause problems. This can be avoided in the following way.

1) Connect a 3.3 to 10 microfarad capacitor directly on the module from +3.3V to GND

Protocols used for communication

SPI (Serial to Peripheral Interface):

SPI is a hardware /firmware communications protocol developed by Motorola. It’s a simple 4 wire serial communications interface used by the microcontroller peripheral chips that enables the controllers and peripheral devices to communicate each other. The nRF transceiver uses 4 pins to communicate with the other transceiver.

UART (Universal Asynchronous Receiver/Transmitter)

The UART controller is the key component of the serial communications subsystem of a computer. UART is an integrated feature in ATmega 328P. When the values from the sensor are transferred to microcontroller, UART receives a clock signal from the UART hardware which wills transfers data to the PC much faster than the baud rate.

4. SOFTWARE FEATURES

All the interfacing of LCD, SD card, DHT with the transceivers are developed in Arduino IDE using Embedded C. An user interface is developed in Java which contains options displaying Temperature and Humidity options, graph displaying option and report generation. The respective action will be generated based on the button .In addition to this, Temperature and Humidity will be displayed in the LCD panel. The intermittent results are also written in the SD card. A graph will be generated according to the temperature and humidity extracted from the sensor.

5. IMPLEMENTATION

Multiple sensor nodes wide spread at various locations trying to communicate with the central monitoring unit analyser. Two possible ways can be implemented for storing the received data in the receiver.

a) To connect the receiver module directly to the PC, to analyse the received data in the form of graph in a continuous mode.
b) To store the data into a data card this can be easily transferred into any PC for further analysis as it requires less hardware & further as portability of data is possible reduces the use of the computer system.

The control monitoring unit after receiving data from nodes will log the data into SD memory module.

As the project is initially designed to test the Rx and Tx of the signals as well as to test the range of operation, we have selected nRF 24L01 as the wireless Tx Rx module which can send the signal from within 1 meter to 2000 feet distance.

A DHT 11 sensor module is used because of its high precision values and with standing temperature variation up to 55^0 C +-3^0 C

A 16X4 LCD module issued at the Rx terminal in order to display the currently logged values of temperature and humidity.

The core of the entire project is the use of a Arduino module. All the selected devices are interfaced to the development board which uses SPI protocol.

The criticality of the application lies in the design of the receiver module as the memory card that is interfaced to the module and the LCD ,NRF TxRx are to be interfaced on the same pins , but each have to be initialised based on a timing interval as Arduino uses SPI protocol.

Here the declaration of pins for use with the individual hardware modules over the existing development board is not possible hence decided to go for fabrication of a PCB which will be having the basic Atmel 328 P boot loader and all the hardware components are to be interfaced with it in simple circuit design and smaller size.

In order to draw the PCB circuit we used PCB 123 software which made the complex design into a simple circuit with great difficulty as the pin sizes , components size and the centre PCB size has to be minimized. The etching process of the PCB is done with a proper preparation of the etching chemical material (Ferric chloride).

6. EXPERIMENTAL RESULTS

After the fabrication of the PCB each and every module that we intended to use should be tested for the correct functionality and later all the modules are to be integrated into the PCB and tested as a whole.

The data that is logged into the SD module may be copied onto the desktop and by using MS Excel, a chart can be simply plotted to observe the variation of temperature and humidity basing on time/date.

If number of modules is interfaced, then the Rx circuit has to identify Tx module with an ID so as to plot the data from different sources.

The resultant values will be displayed in the LCD panel. The entire circuit extracted the atmospheric humidity and temperature within the range of 5 metres to 100 metres. The below are the screenshots of the LCD panels.

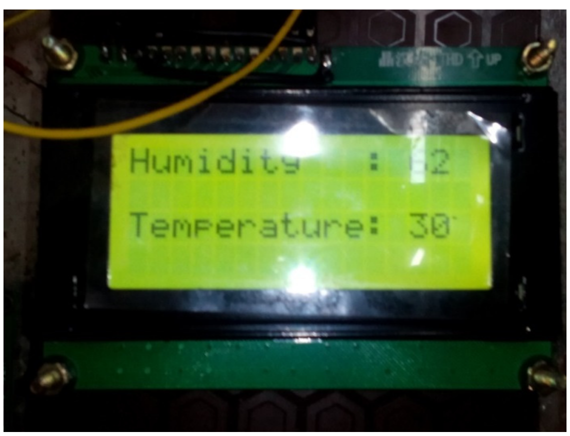

Fig 3: Humidity and temperature display

The graphical representation of the temperature and humidity with respect to time are as follows

In Bar Graph representation:

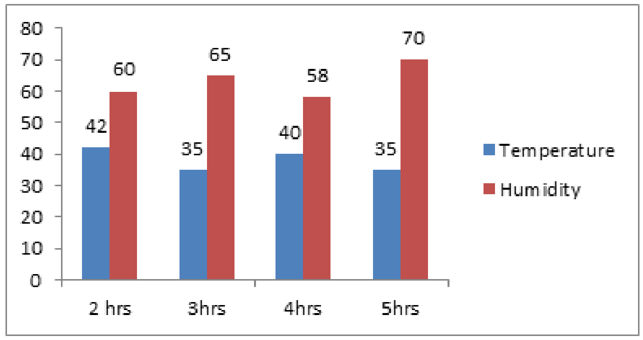

Fig 4: Temperature & Humidity Vs Time

In Line graph representation

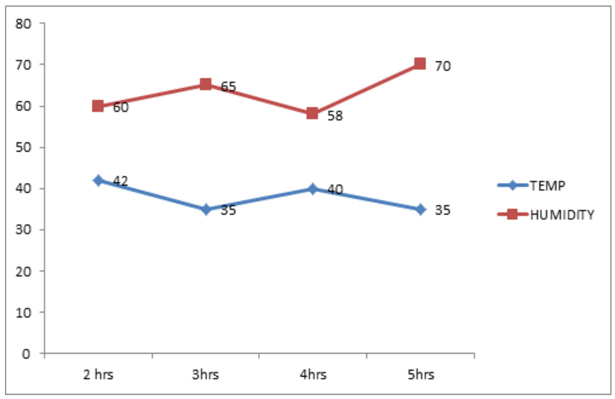

Fig 5: Temperature & Humidity Vs Time

7. CONCLUSION

The wireless embedded system for environmental data logger is designed and developed using AtMega microcontroller and DHT11 sensor. A pilot node of sensornet module is being developed and tested successfully. The developed system is simple, low cost and suitable for multiple sensor node enhancements. The developed system can range up to 3000 feet. The system can be enhanced with adding of Ethernet and WiFi functionality and can be used for industrial purposes and also developed for a sensor net application.

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