IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 5, Issue 5, May 2016

Remote Temperature Monitoring System Using ARM, Arduino and ZigBee

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Abstract: Today there is demand to monitor environmental factors almost in all research institutes and the industries. Especially in remote areas where wire communication and mobile network is unavailable such as forests, deserts, mountains etc. The analog data measurement requires manual effort to note readings and there may be a possibility of human error. Such type of systems fails to provide and store precise values of parameters with high accuracy. Analog systems are having drawback of storage / memory. So, there is an requirement to do the remote place environmental parameters monitoring system which is to be accurate, easily operated, simple, small size, cost-effective and light weight. This paper represents the wireless sensor (WS) data communication using LM35, ARM microcontroller, ZigBee module, Arduino, Graphics LCD and PC. Experimental setup includes the heating arrangement of LM35 and transmission of data using ARM microcontroller and ZigBee. Receiver receives the data using Arduino, ZigBee and displays it on GLCD and stores the same in PC for processing. Heating arrangement is used to heat and cool the temperature sensor to study its characteristics.

Keywords: Wireless communication, ARM Microcontroller, Sensor, Personal computer, GLCD, Arduino, ZigBee.

I. INTRODUCTION

Today there is demand to monitor environmental parameters almost in all the research institutes and industries. Especially in remote areas where mobile network is unavailable such as forests, deserts, mountains etc. A small environment monitoring system would prove to be a boon. But the components that are currently available to measure temperature require manual operation and are quite bulky to carry. Also the analog data which they show requires manual effort to note readings. There is a possibility of human error. For example, the thermometer used to note temperature contains mercury whose height indicates the current temperature is quite inefficient because it fails to provide precise values of temperature, also it takes a lot of time to reach a constant position So, there is an requirement of an environment monitoring system which is accurate, easily operated, simple in working, uncomplicated construction, cost-effective, comfortable to carry and lightweight [1].

The aim is to design and develop a system which fulfils all these requirements. Temperature sensor LM35 is used to sense the environmental temperature. ARM microcontroller is used to convert temperature sensor analogue signal into digital data. The digital data was transmitted wirelessly using ZigBee and the data values are displayed using ARM graphics liquid crystal display (GLCD) [2]. In ARM there are inbuilt 12-bit ADC which are used for Analog to digital conversion of data, and serial data transfer from a remote location [1]. At receiver

ZigBee with Arduino microcontroller is used to decode the serial data, which is transmitted by ZigBee of the transmitter and it was displayed using graphics LCD as well as the temperature data values are stored in PC. Transmitter and receiver block diagram is shown in Fig. 1(a) and 1(b) respectively.

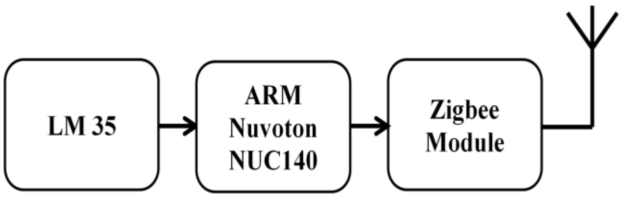

Fig. 1(a). Temperature sensor LM35 serial data transmitter

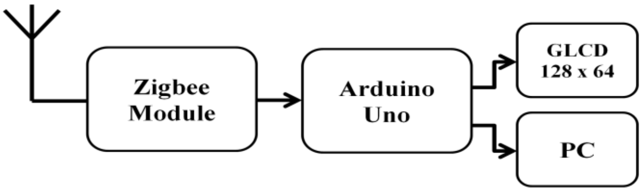

Fig. 1(b). Temperature sensor LM35 serial data receiver

II. COMPONENTS / MODULE INFORMATION

A. ARM microcontroller

The ARM architecture was originally developed by Acorn Computers in the 1980s. An ARM is Advanced RISC Machines (ARM) 32-bit and 64-bit processor. ARM controller operates at a higher speed, performing millions of instructions per second (MIPS). ARM processors are extensively used in consumer electronic devices such as smart phones, tablets, multimedia players and other mobile devices.

The ARM® Cortex®-M0 processor is the smallest ARM processor available. The exceptionally small silicon area,

IJARCCE

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low power and minimal code footprint of the processor enables developers to achieve 32-bit performance at an 8-bit price, bypassing the step to 16-bit devices with just 56 instructions. It is possible to master quickly the entire Cortex-M0 instruction and its C friendly architecture, making development simple and fast. Cortex M0 was designed to support low power connectivity such as Bluetooth Low Energy (BLE), IEEE 802.15 and Z-wave, particularly in analog devices that are increasing their digital functionality to pre-process and communicate data efficiently [3].

The NuMicro NUC140 Series is 32-bit microcontrollers with embedded ARM®Cortex-M0 core for industrial control and applications which need rich communication interfaces. The Cortex-M0 is the newest ARM® embedded processor with 32-bit performance and at a cost equivalent to traditional 8-bit microcontroller. The NuMicro NUC140 Connectivity Line with USB 2.0 full-speed and CAN functions embeds Cortex-M0 core running up to 50 MHz with 32K/64K/128K-byte embedded flash, 4K/8K/16K-byte embedded SRAM, and 4K-byte loader ROM for the ISP. It also equips with plenty of peripheral devices, such as Timers, Watchdog Timer, RTC, PDMA, UART, SPI, I2C, I2S, PWM Timer, GPIO, LIN, CAN, PS/2, USB 2.0, 12-bit ADC, Analogue Comparator, Low Voltage Reset Controller and Brown-out Detector [4]. The block diagram of NuMicro NUC140 is shown in Fig. 2.

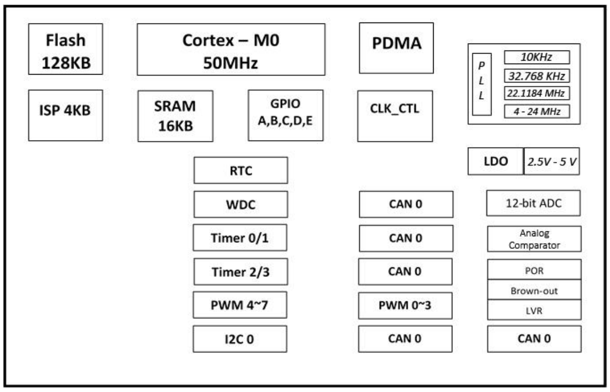

Fig. 2. Block Diagram NuMicroNUC140

Specification of Cortex M0: Runs up to 50 MHz, operating voltage ranges from 2.5 V to 5.5 V, 32K/64K/128K bytes Flash for program code, 4KB flash for ISP loader, 4K/8K/16K bytes embedded SRAM, Support 4 sets of 32-bit timers with 24-bit up-timer and one 8-bit pre-scale counter, Independent clock source for each timer, RTC, PWM/Capture, four 16-bit PWM generators provide eight PWM outputs, UART ports with flow control (TXD, RXD, CTS and RTS), Up to four sets of SPI controller, Support SPI master/slave mode, Variable length of transfer data from 1 to 32 bit [5].

B. Arduino Microcontroller

The Arduino ATmega328 is a programmable microcontroller for prototyping electromechanical devices is shown in Fig.3. It has 14 digital Input / output pins of which 6 can be used as PWM outputs, a 16 MHz ceramic Resonator, a USB connection, a power jack, an in-circuit serial programmer (ICSP) header and a reset button as shown in figure. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

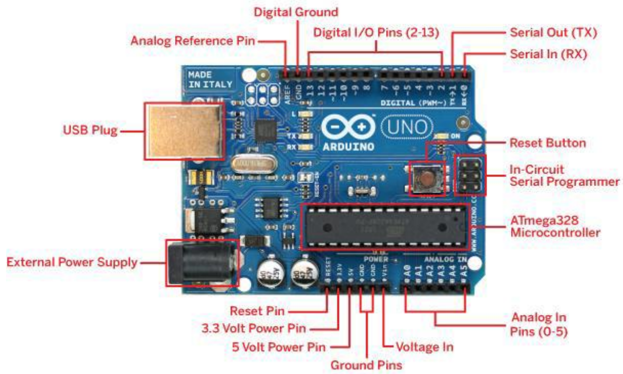

Fig.3. Arduino ATmega328 board

The Uno has 6 analog inputs, labelled A0 through A5, each of which provides 10 bits of resolution. A software serial library allows serial communication on any of the Uno's digital pins. The ATmega328 also supports I2C which is two wire interface (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus [6]. The features of ATmega328 are 5V Operating Voltage, 6-20V Input Voltage, 14 Digital I/O Pins of which provide 6 PWM output, 32 bit Flash Memory, 2KB SRAM, 1KB EEPROM, 16 MHz Clock Speed.

C. LM 35

The LM35 series are precision integrated-circuit temperature sensors. Its output voltage is linearly proportional to the Celsius temperature for a large range of temperature values. The LM35 thus has an upper hand 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. LM35 is calibrated directly in ° Celsius, Linear + 10.0 mV/°C, 0.5°C accuracy, Range: −55° to +150°C, Suitable for remote applications, Operates from 4 to 30 volts, Low self-heating [7].

D. ZIGBEE Technology

ZigBee Alliance was established in August, 2001, The ZigBee specification, officially named ZigBee in 2007 and its pin outs are shown in Fig.4. It is a new wireless technology guided by the IEEE 802.15.4 Personal Area Networks standard. It currently operates in the 868MHz band at a data rate of 20Kbps in Europe, 914MHz band at 40Kbps in the USA, and the 2.4GHz ISM bands Worldwide at a maximum data-rate of 250Kbps. It is capable of connecting 255 devices per network. The specification supports data transmission rates of up to 250 Kbps at a range of up to 30 meters. This technology allows users to set up a network quickly and allows to set up networks where it is impossible or inconvenient to wire

IJARCCE

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International Journal of Advanced Research in Computer and Communication Engineering
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cables. Wireless networks are more cost-efficient than wired networks in general [8].

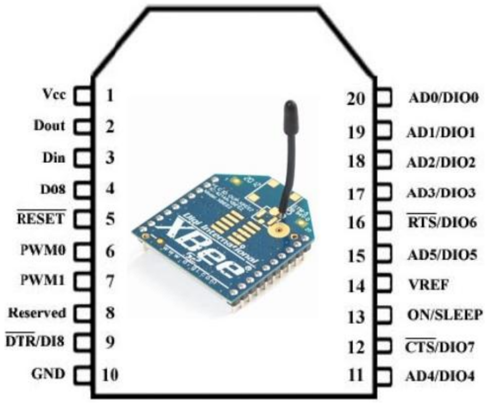

Fig.4. Pin diagram of X-Bee Transceiver

ZigBee Module is a low-cost, low-power, wireless mesh networking standard. The low cost allows the technology to be widely deployed in wireless control and monitoring applications, the low power-usage allows longer life with smaller batteries and the mesh networking provides high reliability and larger range [8]. Temco has developed a embedded antenna of wireless data communication module, which adopts standard ZigBee wireless technology.

This module can achieve transparent data transmission between many devices, and it can form a MESH network. This device has the characteristics of small volume, ultra-low power consumption and low-cost. It can be either as an independent data transmission termination or be easily embedded into a variety of products to form a short-range wireless data transmission solution.

The device network has the characteristics of electric power-saving, reliability, large capacity and security and it can be widely used in various fields of automatic control. The target application domains are industry, home automation, telemetry, remote control, vehicle automation, agriculture automation, medical care, lighting control automation, wireless data acquisition and monitoring sensor, oil field, electric power, mining and logistics management and so on [9]. The advantages are low power consumption, Low cost, low data rate, short range, short time delay, high capacity, high security and license-free frequency band. Wireless communication applications includes Sensor network, Automatic meter reading system of water, gas, heat, electricity meters, Intellectual traffic control, signal lights control and street lights control, Fire safety alarm, building monitoring, catering order, canteen's sale of food system, Access control, time and attendance system etc.

E. Graphics Liquid Crystal Display (GLCD)

The graphical LCD is made up of a grid of pixels of rows and column is shown in Fig. 5. Common resolution is 64 horizontal lines and each line has 128 pixels (128x64). These displays are monochrome. Each pixel can either be ON or OFF. ON pixels looks dark while OFF pixels are nearly invisible. The GLCD has a graphic RAM where each bit in ram corresponds to one pixel on screen. Programmer can write to the graphic RAM to modify its contents and the screen will change accordingly.

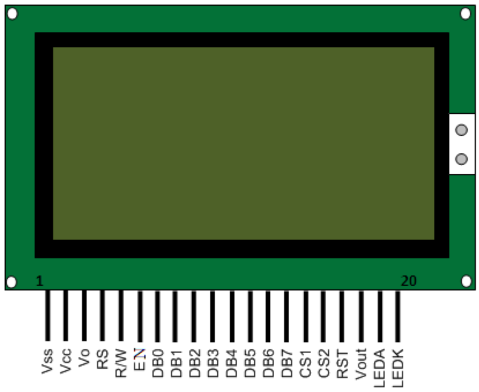

Fig. 5. Graphics LCD

Graphic primitives are like line, circles, rectangle, text drawing, image/icon drawing, double buffering, 128x64 dots/pixel and 8-bit Parallel Interface.

LCD Control Lines:

1. RS: Select Data register or a Command/Status register,
2. R/W: Read/Write select control line,
3. E: Latches information presented to it,
4. CS1&CS2: Chip Select Signals,
5. Reset: LCD Reset signal [10].

III. TRANSMITTER AND RECEIVER DESCRIPTION

Transmitter: Now a day advance microcontrollers are used to develop the low power and low cost systems. An ARM processor is one of a family of CPUs based on the RISC (reduced instruction set computer) architecture developed by Advanced RISC Machines (ARM). The main aim is to use ARM to sense the environmental parameters such as temperature and after sensing it was converted into digital to transmit the information wirelessly through Zigbee. ZIGBEE is a new wireless technology guided by the IEEE 802.15.4 Personal Area Networks (PAN) standard.

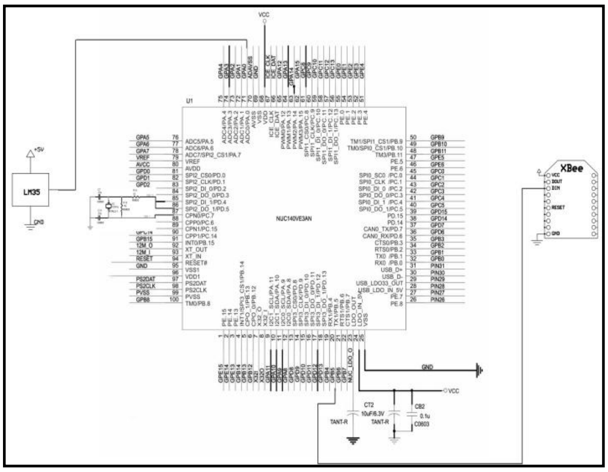

Fig. 6. Circuit Diagram of Transmitter

IJARCCE
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Interfacing of LM35 and ZigBee to ARM are shown in Fig. 6. LM35 output was connected to PA0 (Pin no.71). ZigBee was connected to PB5 (Pin no.20). ARM controller has given an input of temperature sensors LM35 in the form of analog signal, which was converted using inbuilt 12-bit ADC into digital with values from 0 to 4096. This output is calibrated in the form of percentage and sent to Rx pin of Zigbee Module. Then this data is received at receiver section using another ZigBee module.

Receiver: At receiver section ZigBee module was interfaced to Arduino controller to receive serial digital data send by transmitter. GLCD was interfaced to Arduino to display the temperature values. ZigBee and GLCD interfacing to Arduino is shown in Fig. 7. The Arduino Uno is a microcontroller board based on the ATmega328. It is a programmable micro controller for prototyping electromechanical devices. The Arduino Uno has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. Arduino USB connector was connected to PC using USB cable to display and store temperature data in PC.

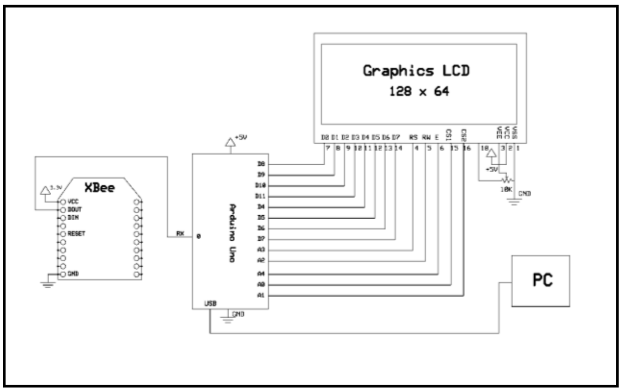

Fig. 7. Circuit Diagram of Receiver

The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). GLCD is a special type of LCD that is used to monitor the physical parameters.

IV. SOURCE CODE

Transmitter code (ARM Source Code) [8]:

```
#include <stdio.h>
#include <string.h>
#include "NUC100Series.h"
#include "MCU_init.h"
#include "SYS_init.h"
#define TOTAL_CHANNELS 8
char temp[20] = "Temperature:";
char clr[1] = "c";
volatile uint32_t u32ADCvalue[TOTAL_CHANNELS];
volatile char TX_buffer[40];
void ADC_IRQHandler(void)
{
uint8_t  i;
uint32_t u32Flag;
// Get ADC conversion finish interrupt flag
u32Flag = ADC_GET_INT_FLAG(ADC,
ADC_ADF_INT);
 if(u32Flag & ADC_ADF_INT) {
{
UART_Write(UART1, temp, 20);
u32ADCvalue[0] =
ADC_GET_CONVERSION_DATA(ADC, 0);
sprintf(TX_buffer, "%4d,",u32ADCvalue[0]);
UART_Write(UART1, TX_buffer, 40);
}
CLK_SysTickDelay(500000);
UART_Write(UART1, clr, 1);
}
ADC_CLR_INT_FLAG(ADC, u32Flag);
}
void Init_ADC(void)
{
ADC_Open(ADC, ADC_INPUT_MODE,
ADC_OPERATION_MODE, ADC_CHANNEL_MASK);
ADC_POWER_ON(ADC);
ADC_EnableInt(ADC, ADC_ADF_INT);
NVIC_EnableIRQ(ADC_IRQn);
ADC_START_CONV(ADC);
}
int32_t main (void)
{
SYS_Init();
UART_Open(UART1,9600);
Init_ADC();
while(1);
}
```

Receiver code (Arduino):

```
#include <openGLCD.h>
void setup()
{
GLCD.Init();
GLCD.SelectFont(System5x7);
Serial.begin(9600);
}
void loop()
{
char c;
if (Serial.available())
{
c = Serial.read();
Serial.print(c);
GLCD.write(c); // use Print class for output
 if(c=='c')GLCD.ClearScreen();
}
}
```

V. EXPERIMENTAL SETUP

The experimental setup of transmitter and receiver of the WSN system is shown in Fig.8 and Fig.9 respectively. Fig.8 shows the heating arrangement. In beaker, mercury thermometer and temperature sensor LM35 are placed in electrically non-conducting material at the same position. Thermometer was used to record the temperature to calibrate. Figure shows the interfacing of LM35 to ARM

NuotonNUC140 target board with inbuilt GLCD. Inbuilt ADC convert analogue signal to digital.

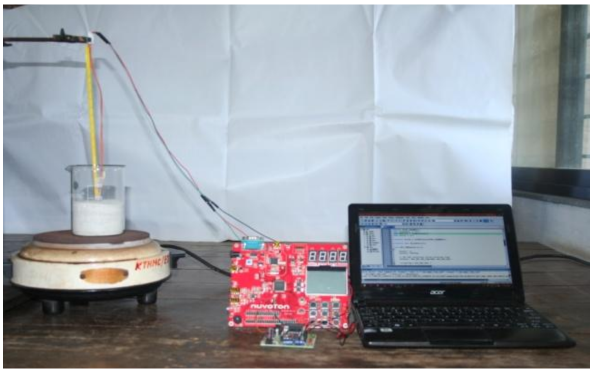

Fig. 8. Experimental setup of sensor heating arrangement and Transmitter using ARM and ZigBee

Fig. 9 shows the wire connection of ZigBee, Arduino and GLCD. Arduino software was developed to receive data from ZigBee. After processing, the temperature values are displayed on GLCD and same values are displayed serially on PC monitor. Separate power supply was used for transmitter and receiver. In experimental setup, the distance between transmitter and receiver was kept 4m.

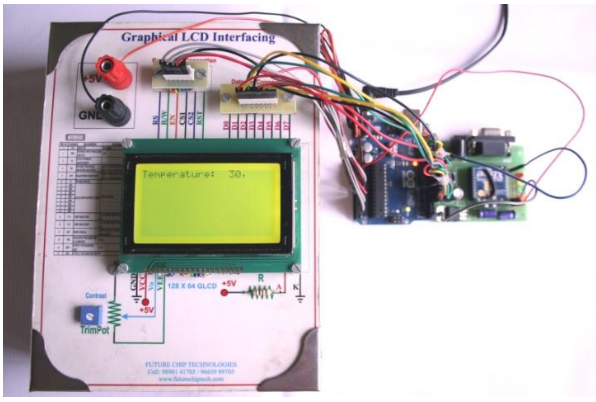

Fig.9. Experimental setup of receiver using ZigBee, Arduino and GLCD Section

VI. RESULT

. The temperature sensor LM35 is heated from 35^0C to 100^0C using heater. Its signal is fed to ARM controller. It converts analog to digital with 12 bit ADC.

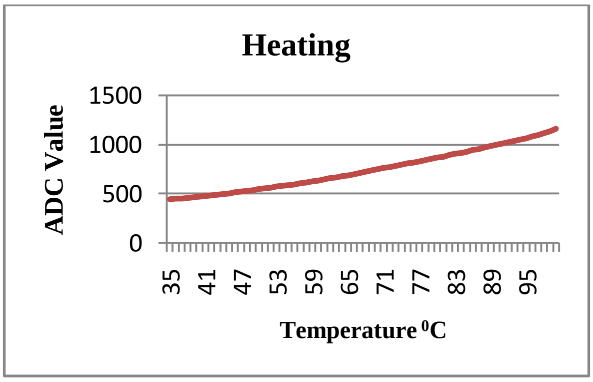

Fig.10. Heating:- Graph of Temp Vs ADC output.

The ADC values are displaed on ARM GLCD. The graph of temperature verses ADC values graph is shown in Fig. 10. The Fig. 10 shows some non-linearity. The slope of the curve is 10.90. Using same setup, cooling graph is shown in Fig.11.

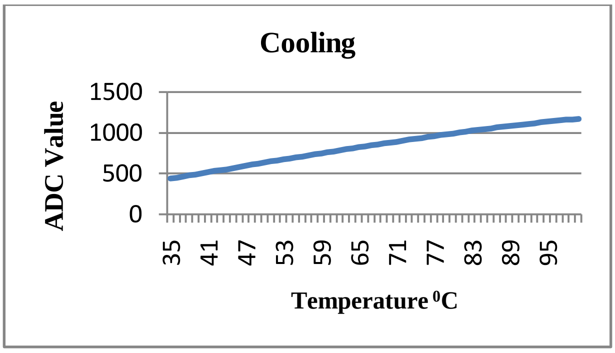

Fig.11. Cooling: - Graph of Temp Vs ADC output.

The Fig. 11 shows some non-linearity. The slope of the curve is 11.46.

VII. CONCLUSION

There is demand to monitor environmental parameters almost in all the industries and for research institutes. Analogue signal and wire communication systems are having many drawbacks. Especially in remote areas where mobile network is unavailable such as forests, deserts, mountains etc, wire communication is not suitable. The analogue data measurement requires manual effort to record and there may be a possibility of human error. Such type of systems fails to provide and store precise values of parameters. So, there is a requirement to do the remote place environmental parameters monitoring system which is to be accurate, easily operated, simple, small size, cost-effective and light weight.

In present communication the wireless sensor (WS) data communication using LM35, ARM microcontroller, ZigBee module, Arduino, Graphics LCD and PC was designed and developed. The temperature monitoring system with least number of components, less cost and less complexity has been constructed and tested. The slope of increasing temperature graph was 10.40 and of cooling 11.46. The graph shows that, the curves are having some hysteresis at the middle temperature range. The reason may be the ageing effect of the device or environmental factor effects.

Arduino Uno has mostly all the capabilities inbuilt and requires less hardware for its operation. Therefore, this makes it a perfect choice for remote parameter measurement system. Normally the sensors are linear and having high degree of accuracy. Using such type of experimental setup, sensor linearity and accuracy can be tested. Circuit complexity is less hence easy to understand. The main advantage of such system is that it was less expensive and one time investment hence it will be useful for many applications, where remote parameter measurement is needed. Also the system will be useful to test the device characteristics.

ACKNOWLEDGMENT

This research is supported by the Principal **Dr. Dilip Dhondge** of KTHM College, Nashik, Maharashtra, India.

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BIOGRAPHY

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Avinash D. Sonawnae is completed M. Sc. from Department of Electronic science, KTHM College, Nashik. He had completed project entitled Hand gesture control robot and selected for robot competition held at IIT Powai, Mumbai. Presently He is working on Wireless Environment monitoring system using ARM, Arduino and ZigBee.

Chandrakant L. Ambekar is completed M. Sc. from Department of Electronic science, KTHM College, Nashik. He had completed project entitled Wireless Environment monitoring system using Arduino. Presently He is working on Wireless Environment monitoring system using ARM and ZigBee.