Remote Temperature Monitoring Using Thermocouple Sensor Via Internet Service

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Abstract: This paper describes a network prototype of embedded wireless system with a thermocouple sensor to monitor the temperature variation in industrial operations through internet. The hardware and software selection and the sensor interfacing have been described. Using Raspberry Pi and internet service, the temperature at a remote location is continuously tracked and thus it provides a truthful and convenient mode of control. Thermocouple sensor senses the temperature variation and information is transmitted via internet to the control room. Internet based sensing and process monitoring is said to hold the key for the factories of future.

Index Terms: ADC, internet, Raspberry Pi, Thermocouple sensor.

1 INTRODUCTION

Temperature variation has a crucial effect on all the industrial application. Determination of temperature has an important role in several industrial activities. The monitoring of temperature is important in industries such as textile industry, workshops, food industry, automobile and in environmental monitoring. There are a lot of temperature sensors available for sensing temperature nowadays. Temperature can be found out by measuring temperature-dependent properties like resistance variation and thermal expansion or by using thermoelectric effect. Based on these principles, we can find different temperature sensors such as the thermistor, thermocouple, resistance temperature detector, etc. Thermocouple is having high range compared to other temperature sensors. For instance, it can measure temperature from -200°C to 2500°C and it does not require any external power. Commercially available thermocouples are simple in operation, cheap and rugged in construction. Advanced temperature sensors capable of giving digital output are needed in the industry with connectivity features suited to Internet of Things network, by which improved energy efficiency and automation can be envisaged [1]. The integrated sensor-actuator-internet framework will be the core technology to develop a smart industrial environment [2]. Culler pointed out that combining the semiconductor based low power communication devices with software based internet technology would make it possible to instrument this world with increasing fidelity while detailing the need for better power management of WSN [3]. There are temperature monitoring systems which use different microcontrollers for processing the sensor data. Goswami et al., describe the design of an embedded system for continuous monitoring of temperature and light intensity using sensors, microcontroller and LCD in a single system [4].

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Alinafe Kaliwo et al., presented a real time web based temperature monitoring system for cold chain management, which is useful in storage and distribution of food and drugs [4]. Rodrigues M et al., developed a web based system for monitoring of several temperature sensors in a rotational moulding oven used for manufacture of plastic parts. This system uses radio frequency wireless communication between the machine and monitoring station [6]. Zigbee WiFi module can be used for transmission of data from one place to another. Vijay Kale, et al., used LM35 temperature sensor connected to ARM microcontroller and Zigbee module for temperature monitoring [7]. But it is having a short range in transmitting data and is having low speed. In this context, the Raspberry Pi board with its inbuilt WiFi can performs the role of a microcontroller in processing data. So if we use Raspberry Pi, then there is no need of Zigbee module for transmission of data. This project is aiming at monitoring the temperature at an intricate location in the industry equipment with the help of thermocouple, and then communicating the same over the internet. The Raspberry Pi has been used for monitoring and processing temperature information and the programming language is Python [8]. The Sensor used here is MAX-6675 temperature sensor, which is based on a K type thermocouple. The sensor can communicate the temperature information to Raspberry Pi which in turn secures the internet connection so that the information can be accessed from anywhere. The K type thermocouple is desirable as it has a sensitivity of 41µV/°C, good linearity and a wide temperature range, long life and has found applications in oxidising atmospheres and nuclear filed. Table 1 compares the K type thermocouple vis-à-vis four other commonly used thermocouples [9].

TABLE 1
TYPES OF THERMOCOUPLES

S.No.	Type	Thermocouple material
1	E	Chromel(90Ni10Cr)-constantan(55Cu45Ni)
2	J	Iron-constantan
3	T	Copper-constantan
4	K	Chromel-alumel (95Ni2Al2Mn1Si)
5	N	Nicrosil(85Ni14Cr1Si)-nisil(977Ni3Si)

2 SYSTSEM ARCHITECTURE

GPRS is used for providing a larger coverage area for communication. This thermocouple sensor is connected with Raspberry Pi board and power is given to it through USB cable. This application consists of four stage architecture including a temperature sensor unit, Raspberry Pi, communication unit and user interface unit. This setup connects the sensor to internet server and to the control room computer, which provides a user interface for accessing temperature of the remote area. The diagrammatic representation is given in fig.1.

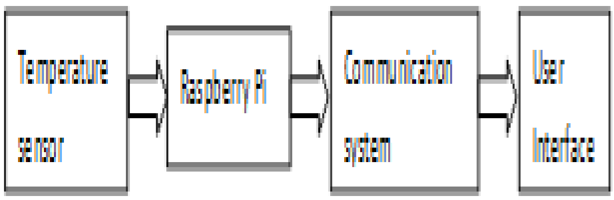

Fig. 1. *Block diagram of system architecture*

The MAX66751 sensor is kept fixed at the location where temperature is to be measured. This sensor is connected to the application server node (Raspberry Pi) which processes the data before passing to the user end. This data is received by control room computer and thus the temperature is monitored.

3 HARDWARE

A variety of embedded networks are used in the industrial, environmental and personal applications. Embedded sensor networks are an emerging technology, consisting of low cost, small, and low-power devices that help sensing and process monitoring. The reliable performance of a sensor network is dependent on the right choice of its hardware and software [10, 11]. Hiedemann identified three prime challenges in this field: first, energy consumption at the sensor node; second, sensor signal processing and interaction with physical world; and third, self-configuring features of the sensor nodes in the network [12].

3.1 Raspberry Pi

The Raspberry Pi board, shown in fig.2, is small in size capable of working as an alternative device for CPU of a computer. The language used in Raspberry Pi is Python. It has 1GB RAM memory with 512 MB SDRAM. It features the Video Core4 Graphic processing Unit, Blue-Ray quality Video, HDMI video output. It has 40 pin, 2.54mm header progress slot and USB ports [13].

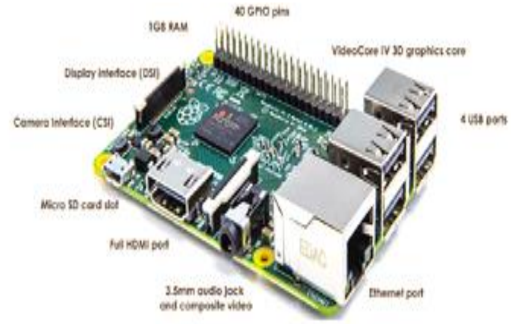

Fig.2 *Raspberry Pi board*

The operating system used in Raspberry Pi is Raspbian, which is a flexible GNU Linux system. It is more useful than any other operating system as it contains more than 35000 packages and pre-incorporated programming packages in an arranged manner for simple establishment on the Raspberry Pi. It is available at low cost, capable of video monitoring and has ample memory capacity. It can be connected to a TV or monitor for getting the display using HDMI connection. Mouse and keyboards are used for giving inputs to the device. The Raspberry Pi contains connectivity cables, SD card, power supply and internet connection. The Ethernet port of the Raspberry Pi is the main gateway for communicating with additional devices and to access the internet. The XBee socket is used in Raspberry Pi board for the wireless communication purpose.Following steps are to be followed for Raspberry Pi connection to its accessories and its programming.

(1) To start, insert SD card into the slot on raspberry pi
(2) Connect mouse & keyboard into the USB ports
(3) Connect monitor by using VGA-to-HDMI cable
(4) Give power to raspberry pi by connecting charger to the charge port
(5) Connect raspberry pi to internet

3.2 The MAX6675 Thermocouple sensor

A thermocouple is a robust and low cost temperature sensor used for temperature measurement in different processes. Thermocouples are constructed using two dissimilar metal wires connected at their ends forming two junctions. In practice, different types of thermocouples are constructed out of special alloy wires, catering to desired measurement range, accuracy and linearity. According to Seebeck effect, if the two junctions are held at different temperatures, a voltage is generated in the loop and it is a function of the temperature difference. Ideally, the measuring junction will be the hot junction of the thermocouple and the cold junction is to be maintained at 0°C, to obtain the voltage generated, based on which the temperature can be read out from calibration charts. Under practical measurement conditions, the voltage measuring terminal itself serves to be the cold junction remaining at the ambient temperature. Therefore, cold junction compensation may be required in order to correct the errors due to fluctuations in ambient temperature (at cold junction). Further calibration and study of response characteristics of thermocouple sensor are important in order to obtain accurate measurement [14]. But in this project the sensor behavior is not studied, rather a pre-calibrated sensor with integrated signal processing circuit is employed. The MAX6675 Thermocouple sensor is used, due to its low cost and wide temperature range. It is a K type thermocouple probe with integrated cold junction compensation circuit, thermocouple break detection circuit and capable of providing 12 bit digital output. It will read from 0 to 1024° C, with an accuracy of ±1.5°C and a resolution of 0.25°C.Figure 3(a) and (b) shows MAX6675 thermocouple sensor and its pin description used in this temperature monitoring system. The K type thermocouple has a sensitivity of 41µV/°C and its output voltage may be approximated by the following linear equation.

V_{out} = (41µV/°C) (T-Ta)

Where T is the junction temperature and Ta is the ambient temperature.

Fig. 3*(a) MAX6675 thermocouple sensor*

SO : Serial Output module
CS : Chip Select selects the Module and setting low tells it to supply an output that is synchronized with a clock
SCK :Serial Clock
VCC :5V supply
GND :Ground

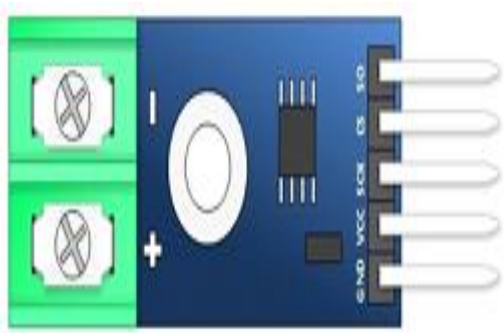

Fig.3*(b) MAX6675 Pin description*

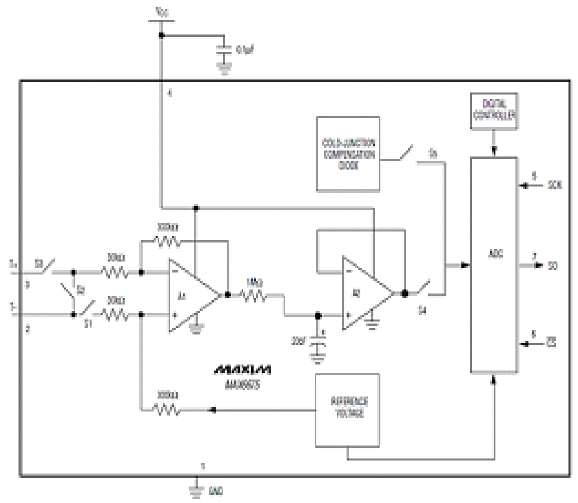

Fig. 3*(c) MAX6675 thermocouple sensor circuitry*

For cold junction compensation, MAX6675 uses a temperature sensing diode to convert the ambient temperature into voltage. The internal circuitry of MAX6675 passes the diode's voltage and the thermocouple voltage to a conversion function stored in the ADC, thereby it calculates the hot junction temperature. Figure 3(c) shows the block diagram of MAX6675 cold junction compensated K type thermocouple to digital converter. The noise introduced in temperature measurement due to thermocouple wires and extension wires is reduced by converting the thermocouple output voltage into a digital value very close to the measuring junction. The effect of power supply noise has been minimized by placing a 0.1µF bypass capacitor near the supply pin of the device.

3.3 MCP3008 ADC

MCP3008 ADC used as an analog to digital converter, its pin configuration is shown in fig.4. It consists of 8 channels. It is connected to Raspberry Pi through SPI serial connections. Here we used 4 GPIO pins in the Raspberry Pi. The steps for connecting MCP3008 ADC to Raspberry Pi are,

- MCP3008 CH0 to Raspberry Pi GROUND pin 39
- MCP3008 CH1 to Raspberry Pi GPI018 pin 24
- MCP3008 CH2 to Raspberry Pi GPI010 pin 19
- MCP3008 CH3 to Raspberry Pi GPI009 pin 21
- MCP3008 CH4 to Raspberry Pi GPI011 pin 23
- MCP3008 CH5 to Raspberry Pi GROUND pin 6
- MCP3008 CH7 to Raspberry Pi 5V pin 2

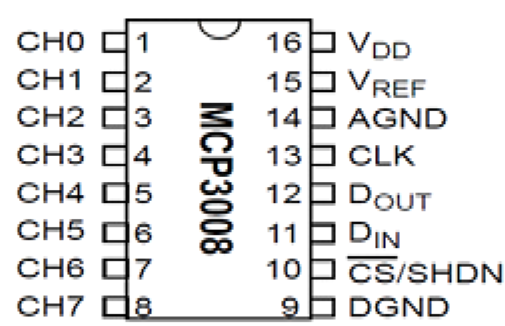

Fig.4 *MCP3008 ADC Pin configuration*

4 IMPLEMENTATION

Components that are required for the temperature monitoring system are the Raspberry Pi kit, MCP 3008 ADC, MAX 6675 thermocouple sensor, HDMI cable, USB cable and connecting wire. The connection of Pi and sensor is done by jumper wire. The DGRN of MCP3008 ADC is connected to CS of thermocouple sensor. VCC of Raspberry Pi and CH6 of MCP3008 ADC are connected. The pins CH0, CH5 of MCP3008 ADC are connected to two grounds of Raspberry Pi pin 39 & 6.

Fig.5 *Hardware setup for remote temperature monitoring*

After connections are over, we have to set up the WiFi link between the Raspberry Pi and the user's device containing internet access. Then copy the IP address of the user computer in the Raspberry Pi software and also copy the IP address of the Raspberry Pi in the monitoring system (user computer). Thus the monitoring system is connected with Raspberry Pi through internet. Raspberry Pi connection to MCP3008 ADC and MAX 6675 is shown in fig.5. The MAX6675 thermocouple sensor senses the temperature when it is placed in hot bath and the output temperature display on the monitor screen is shown in fig.6.

5 COMPARISON OF HARDWARE ALTERNATIVES

On Comparing with other microcontrollers, the Raspberry Pi is a very powerful, minicomputer with the dimensions of a credit card. It uses ARM (Advanced RISC Machine) processor. We can connect this to our network with an Ethernet Cable. The SoC (system on chip) includes a CPU, a video controller which has hardware MP4 encoder/decoder, Ethernet controller and USB controller. The Revision A boards had 1GB of RAM and Revision B boards have 512MB RAM. The Pi has SD card slot for storage purpose. One can either log in remotely to program on the device itself, we can also plug a USB keyboard and mouse to it and use it as a computer, as HDMI port allows it to be connected to a TV or Monitor. The device consumes 3.5W of power and has 40 GPIO pins, UART, SPI, I2C, and I2S for programmable I/O.

Fig.6 *User interface showing continuously monitored temperature*

From Table 2, we can see that Raspberry Pi is having good features compared to Arduino. It is having inbuilt WiFi for wireless communication. Alternatively, Arduino can be used in combination with Zigbee or Bluetooth.

TABLE 2
RASPBERRY PI AND ARDUINO BOARDS COMPARISON

FEATURES	RASPBERRY PI	ARDUINO
Processor	ARM11	ATMEL AVR
Clock speed	700 MHZ	16 MHZ
Operating system	Raspbian	None
Memory	512 MB	0.002 MB
Flash	SD Card (2 to 16 GB)	32 KB
USB	Two Peripheral	One input only

WiFi is a wireless technology that uses radio frequency waves to transmit data through air, it has a short range for wireless fidelity. It works over 20 m range. At 2.5 GHz range, it has 11 channels with three non-overlapping and supports rates from 1 to 11 Mbps. It gives stable performance and is cost effective. It Runs in 5 GHz range with less interference from other devices. Zigbee is a standard that defines a set of communication protocols for low data rate, short range (10-20 m) wireless networking. It is based on wireless devices operating at 868 MHz, 915 MHz and 2.4 GHz frequency range. The maximum data rate is 2Mbps. It can be designed for wireless control and for sensor networking. Bluetooth supports short range (10m) communication. It can be used to connect computer, mobile phone and hand held devices to each other. It transmits data via low power radio waves in the range 2.4 to 2.485GHz and the data rate is 1-3Mbps.

6 CONCLUSION

MAX6675 Thermocouple sensor with Raspberry Pi kit will be a key component in enabling smart industrial environment. By this set up the temperature information is shared to the internet and it can be accessed from any other computer at remote location. Alternatives available for remote temperature monitoring have been analyzed. Raspberry Pi with its WiFi capability is advantageous compared to an Arduino with Zigbee/Bluetooth, for this application as it can perform temperature monitoring and also control function.

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