A multi-channel temperature and humidity measurement system based on a micro-controller

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In recent years, microcontrollers are devices used widely for measuring physical quantities, processing measured values and controlling systems. Their specifications like conversion into embedded systems, quite convenient price-performance relationship and repeatable programming ability make these devices candidate for many applications. This study mainly differs from analog measurement tools since the temperature and humidity can be reliably measured from five different locations simultaneously with real-time specifications. This multi-channel system can be used specifically in places such as agricultural fields, greenhouse, server rooms etc. where different environmental conditions from apart locations need to be measured and controlled. This system can also be used for other purposes since it is open for further studies.

1. Introduction

Temperature and humidity are associated physical quantities. Temperature refers to a situation which is proportional to the kinetic energy of atoms. And, mercury or alcohol thermometers are often used in everyday life for temperature measurement. On the other hand, humidity is proportional to water vapor in the atmosphere. And moisture in the air is measured with a tool called hygrometer. These tools give measurements which are improper for the automated environmental control systems.

It is well-known that the water vapor is always present in the atmosphere due to evaporation of water at any temperature. Since the temperature and humidity are related to each other, these two physical quantities are required to be within the limits in some environments for temperature-humidity sensitive situations. Wellem et al. [1] designed and implemented a microcontroller-based computer server room temperature monitoring system using Atmel ATmega8535 microcontroller and National Semiconductor's LM35 temperature sensor. But this system has no ability to measure humidity, it has single channel property and there is no computer connection. Zhu and Bai [2] proposed a system for monitoring the temperature of electric cable interface in power transmission based on Atmel AT89C51 microcontroller. The system consists of a central PC machine, host control machines and temperature collectors. Several temperature collectors are connected to a host control machine through RS-485 communication network. The host control machine communicates and exchanges data with the central PC machine using General Packet Radio Service (GPRS) connection. But this system cannot measure any humidity data of the environment.

In this paper it is shown that measuring both temperature and humidity can be simultaneously done by the developed multi-channel system based on a microcontroller and also pc connection is available.

2. Method

Firstly, Proteus simulation software (developed by Labcenter Electronics) demo version was used for circuit simulation. Proteus is a good simulation software for various designs with microcontroller. It is mainly popular because of availability of almost all microcontrollers in it. So it is a handy tool to test programs and embedded designs. ISIS part of Proteus is a module used for circuit design and simulations. Printed Circuit Board (PCB) design can be made with ARES module in Proteus. VSM (Virtual System Modeling) is embedded software in Proteus with popular microcontrollers and hardware design [3].

PIC Basic Pro (developed by Micro Engineering Labs) compiler was used for writing codes for the microcontroller [4]. The program was loaded into memory of Peripheral Interface Controller (PIC) by using Micropro26 loader [5].

The system is designed for measuring temperature and humidity at five different measurement points and each point was selected sequentially by the microcontroller. Block diagram of temperature and humidity measurement system is given in Fig. 1.
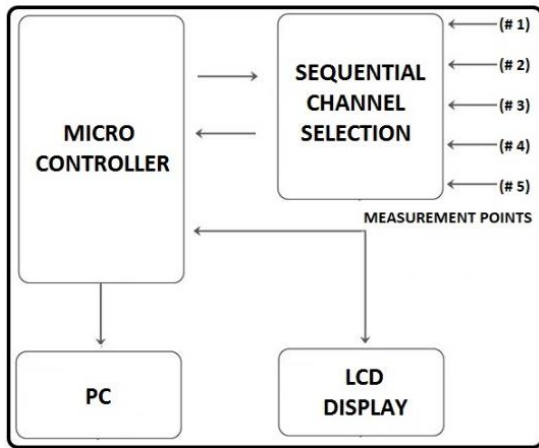

Fig. 1. Block diagram of temperature and humidity measurement unit.

4066 integrated circuit (IC) was utilized to control each sensor and 4017 IC was used to control the 4066 IC. The 4066 IC contains four analogue bilateral switches and each of them has an active-high enable input (A) and two input/outputs (X and Y). When the enable input is set high, the X and Y terminals are connected by low impedance; this is the "on" condition. When the enable is low, there is a high impedance path between the X and Y, and the switch is "off" condition. The 4017 IC is 16 pinned sequential counters which includes 5-stage Johnson decade counter. Their pin configurations are given in Fig. 2.
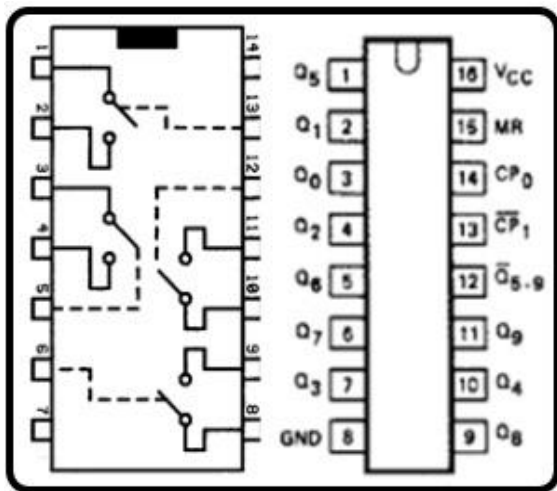
a) 4066   b) 4017

Fig. 2. Pin configurations of IC's.

3. Circuit components

Sensor named SHT11 (from Sensirion Company) is in CMOS structure. It is used for detecting temperature and humidity digitally and simultaneously. It has pins for power supply, data flow and clock input as shown in Fig. 3 [6].
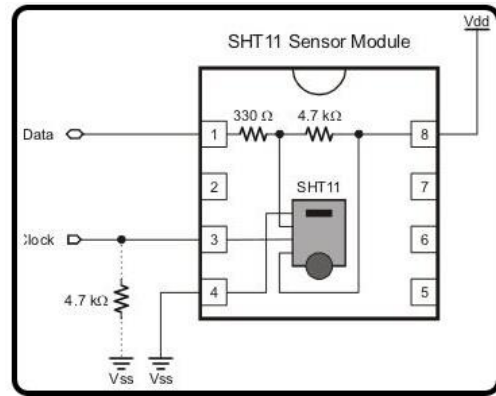

Fig. 3. Pin configuration of SHT11.

The PIC 16F628 from PIC family was selected for its low cost and high degree of integration [7]. Raw data from each sensor can be an input for the 16F628 microcontroller. When control pin of the 4066 is set high, one sensor measures one location data successfully. This operation is applied all switches sequentially in the sequence of 0.1 second so that the measurements were done almost simultaneously. All measurement readings are done when one process cycle is completed for all sensors. For the next step, reading process ensures the continuous measurement of all sensors in this way. Schematic of the application circuit created by ISIS is given in Fig. 4.
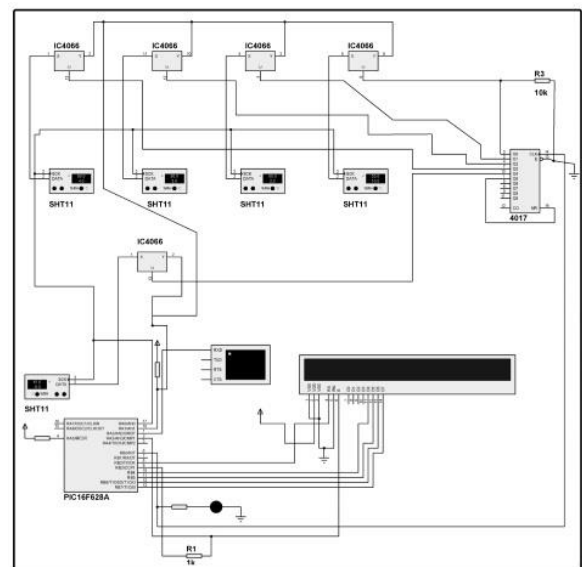

Fig. 4. Schematic working diagram of temperature and humidity multi-channel system based on a microcontroller.

4. Programming

An algorithm was developed in accordance with the designed system. Then the program was written using pic-basic-pro command system. Hexadecimal (HEX) source file was produced from the program file. This file was loaded to the 16F628 microcontroller by Micropro26 loader. Raw digital data of temperature and humidity associated with the binary code was generated in the 16F628 program algorithm. This raw data was converted into real digital value by calculation and then sent to the liquid crystal display (LCD) screen and personal computer using appropriate commands [8].

The 4017 IC starts counting the clock signal received from the 16F628 IC. Each of the counter outputs is set high when the others are low [9].

LCD screen with 2x16 character format was used in the circuit. The appropriate information about measurements appeared on LCD while simulation.

5. Reading data and calculations

First of all, at least nine clock signals from clock input is sent to delete the data from a previous reading when the data pin is high. In addition, "start protocol" should be sent to start readings. To do this, the data pin is set to low when the clock input level is high. Then, the clock signal is sent one more time and the data pin is set to low when the clock input level is high. After this starting protocol, the command related to the temperature and humidity is sent to the sensor. This process is repeated for each sensor.

5.1. Temperature reading process

(i) sending 000 address code,
(ii) sending 00011 temperature measuring code,
(iii) waiting till the level of the data pin is low,
(iv) sending the clock signal and reading 14 bits value.

After these steps, the actual digital value can be calculated in the program by substituting raw digital value "A" in the following equation [10]:

$$\text{Temperature (°C)} = 0.01*A - 40 \qquad (1)$$

5.2. Humidity reading process

(i) sending 000 address code,
(ii) sending 00101 temperature measuring code,
(iii) waiting till the level of the data pin is low,
(iv) sending the clock signal and reading 12 bits value.

After these steps, the actual digital value can be calculated by substituting raw digital value "B" in the following equation [10]:

$$\text{rH (\%)} = 28*10^{-7}*B^2 - 0.0405*B + 4 \qquad (2)$$

The digital values calculated by running the program. And data sent simultaneously not only to the LCD screen but also to the RS232 (serial communication port). The "RA2 port" on the 16F628 microcontroller is connected to the second pin (receive data) on the RS232 port. Reading data from the computer can be done in standard 8N1 format. The schematic view of a typical RS232 communication port is given in Fig. 5 [11].
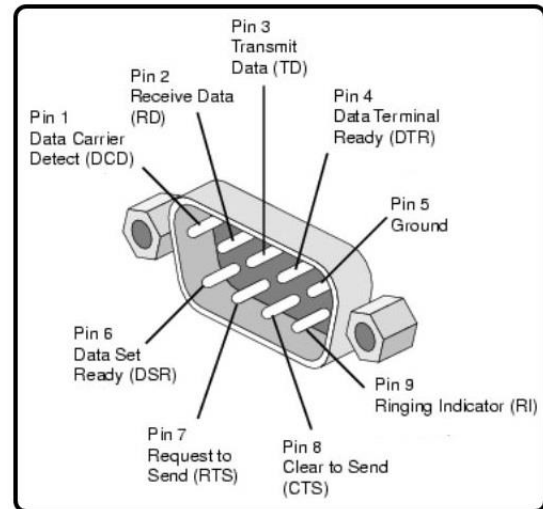

Fig. 5. View of a typical RS232 communication port.

5.3. Implementation

The multi-channel system based on a microcontroller was run with simulation program then all circuit devices were transferred on project board to verify that everything works fine. At last, system elements were mounted on printed circuit board (PCB) which was created with ARES.

While implementation of the system by using real hardware components, there was no technical difficulty we encountered. After tests which we made in laboratory, the experiment results showed that our system works successfully as expected. The system showed temperature and humidity data correctly on LCD screen.

6. Conclusions

This study presents an example of temperature and humidity measurement multi-channel system by using sequential sensors. For each sensor, designed system can measure the temperature and humidity of the medium simultaneously from five different locations. The digital data obtained from each sensor can be kept on a microcontroller for a while and evaluated independently from the computer and then sent and used for control purposes of other connected systems. Alternatively, data can also be sent to the computer for other types of usages. Structure of the system is properly designed for situations where technological control applications are needed such as agriculture, greenhouse etc. Additionally, this system can be used for other purposes since it is open for further studies.

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