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Intelligent Network Temperature and Humidity Measuring System Based on USB Interface

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Abstract

Multi digital output relative humidity and temperature sensors-SHT71 were set network monitoring points in the system, which can measure at any moment, timing, real-time temperature and relative humidity per point of the environment by-turn. Temperature-humidity value, dew-point value, date and time per point were displayed by lattice graphics LCM (Liquid Crystal Display Module) HY-12864K. At the same time, they were saved in nonvolatile FRAM (Ferroelectric Random Access Memory) FM31256, which can assure data do not lose after the power of the system fail. Acquired data can be uploaded directly to PC in the USB-HOST mode or be copied indirectly to PC far away from testing field by flash disk in the USB-DEVICE mode. The application software not only can draw temperature, humidity and dew-point curve and calculate maximum, minimum, average, but also can make further statistical analysis, report forms printing and set-up basic measure parameters of the system.

Keywords: *temperature-humidity, USB interface, network, FRAM*

1. Introduction

Temperature-humidity measurement was used extensively in industrial and agricultural production, daily life and research-development. For example, heavy humidity causes to go mouldy and go bad in grain, medicines, cigarette and tea warehouse. If temperature and humidity in cotton warehouse are unsuitable, spontaneous combustion will take place in it. The performance of the precise instrument and semiconducting device is reduced because of superheating. So temperature-humidity in much environmental fields needs to be measured and controlled strictly.

The traditional Temperature-humidity measurement adopted the method of measuring the temperature and humidity separately, which can not well get rid of the interference of temperature when measuring humidity. In addition, the interchangeability of the sensor is bad, the circuit is complicated, and it needs long-time and complicated calibration [1, 2]. At the present time, the domestic research in temperature and humidity measurement is in focal time, such as Nanjing University of Aeronautics and Astronautics, Beijing Intelligence Tuowei Technological Research Institute, Hebei Normal University of Science and Technology, Electric and Information Engineering Institute of Hunan University, HLJ August First Land Reclamation University etc. But the above-mentioned measurement was finished by discrete sensor, which was low measurement precision, single-point measuring not to be suitable to large greenhouse environment and adopts RS232 serial communication what has low data transmission bauds not to meet present trend in development of computer interface. In foreign country, the research in the field is more mature and has high degree of accuracy, such as American DeltaTRAK and QUATRONIX company, Germany Testo Company, Austria, Finland, Japan, etc. But they are so expensive that the majority users in our country can not afford them.

To the above domestic and international current situation, the system adopts late-model temperature-humidity integration digital output sensor-SHT11 to compose network measuring points, which has high measurement accuracy, good long-term stability and fast response time. Data acquired by multi SHT11 not only can be uploaded directly to PC through USB interface but also can be keep in nonvolatile FRAM-FM31256, which can not lose even if the system is

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power-fail. More important, communication between the microcomputer and the PC has replaced traditional RS232 serial interface by double-mode USB interface (USB-HOST and USB-DEVICE), which can be implemented not only directly but also indirectly through flash disk. So the system has small interface, plug and play and better universal performance.

2. The Gross Structure of the System

The system is made up of the PC and the microcomputer. The microcomputer regards AT89C52 as the core, which is made up of data acquisition network, LCD module, data memory module and USB communication module to finish acquisition, display, memory and uploading temperature and humidity data. It not only can acquire data or stop at any time by the key, but also can do through which the corresponding application software of the system set acquisition initial time, stop time and time interval. In addition, it has acousto-optic alarm function when temperature and humidity of the environment is over pre-setting range. The PC is made up of data processing and parameter setting, which can draw curve, list displaying, mathematic analysis, statistical analysis report printing and set up parameters of the microcomputer such as start and stop time, time interval, upper and lower limit value to alarm etc. The gross structure of the system is as shown in Figure 1.

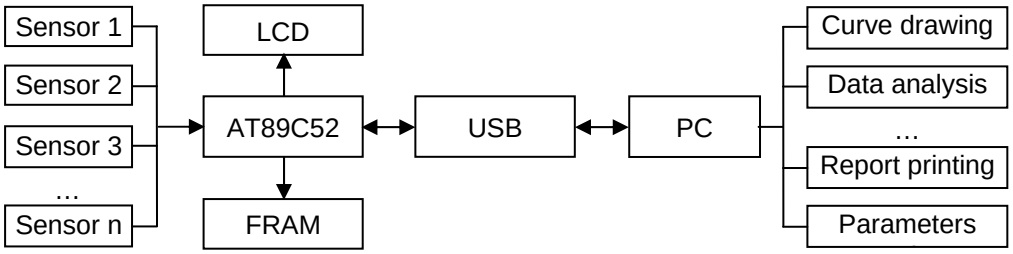

Figure 1. The Gross Structure Block Diagram of the System

2.1. Data Acquisition Network

The system uses multi temperature-humidity integration digital output sensor-SHT11 to do multiple-point measurement by-turn, which integrate temperature and humidity response element, signal amplifier, A/D converter, OTP ROM (One Time Programmable Read Only Memory), I2C bus etc. peripheral circuit. It outputs directly digital signal of the relative humidity and temperature after calibration. It strengthens signal intensity and anti-interference and long-time stability, which resolves availably deficiency of traditional temperature and humidity sensor. In addition, it can also measure dew-point accurately, which will not introduce error because of the temperature difference of temperature and humidity [3, 4].

From Figure 2 (relative humidity digital output performance curve), we can see it appears non-linearity. The system adopted method of software to compensate it to gain accurate data. The formula to amend humidity value is as follows:

$$RH_{linear} = C_1 + C_2 \times SO_{RH} + C_3 \times SO_{RH} \times SO_{RH}$$

In the above formula, SO_{RH} is relative humidity measuring value of the sensor, which is as follows (the humidity can select from 14 or 12 bit, the temperature can select from 12 or 8 bit):

12 bit SO_{RH} : C_1 = -4 C_2 = 0.0405 C_3 = -2.8×10-6

8 bit SO_{RH} : C_1 = -4 C_2 = 0.6480 C_3 = -7.2×10-4

The above formula is used to calculate humidity value in the case of 25℃, but the real measuring temperature is changed within the specific range, so temperature coefficient of the humidity sensor should be considered, which can be compensated according to the following formula:

$$RH_{true} = (T - 25) \times (t_1 + t_2 \times SO_{RH}) + RH_{linear}$$

In the above formula, T is an actual temperature value. Its coefficient is as follows:

12 bit SO_{RH} : t_1 = 0.01 t_2 = 0.00008
8 bit SO_{RH} : t_1 = 0.01 t_2 = 0.00128

The temperature linearity of the SHT71 is very good, so temperature digital output can be conversed actual value by the following formula:

$$TC = d_1 + d_2 \times SO_T$$

In the above formula, SOT is temperature output value of the sensor. The supply voltage of the system is 5V.

When the resolution of the temperature sensor is 14 bit, $d_1 = -40, d_2 = 0.01$.

When the resolution of the temperature sensor is 12 bit, $d_1 = -40, d_2 = 0.04$.

The dew-point value of the environment can be calculated according to relative humidity and temperature by the following formula:

$$LogEW = (0.66077 + 7.5 \times T)/(237.3 + T) + (\log 10(RH) - 2)$$
$$D_P = ((0.66077 - LogEW) \times 237.3)/(LogEW - 8.16077)$$

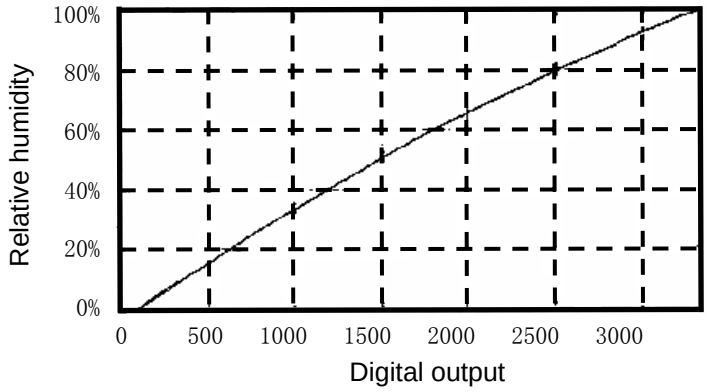

Figure 2. The Relative Humidity Digital Output Performance Curve of the SHT71

2.2. LCM (Liquid Crystal Display Module)

LCM adopts low consumed power HY-12864K module, which can display temperature, humidity, dew point, now time and date of every monitoring point together, so that it can make users monitor more conveniently the environment. The LCM adopts LED blue back lighting what is controlled by key, which can make users read temperature and humidity value under dim-beam occasion.

2.3. Data Memory Module

Under a lot of occasions (such as high risk occasion, sealed environment etc.), communication between the PC and the microcomputer can not be executed directly and real-time, so historical temperature and humidity data need recording, and then they will be done cure-drawing, analysis processing, report-printing, etc. The system adopts advanced nonvolatile FRAM-FM31256, which has 10 years retention time after power-fail, unlimited read/write endurance. So it assures historical data memory reliability. In addition, the memory integrates RTC (real-time clock), low-VDD reset circuit (instead of separate clock chip-DS1302) and watchdog timer circuit (instead of X5045 chip), which makes the system has higher integration and better reliability [5, 6].

2.4. USB Communication Module

USB interface has got extensive popularization and application with a great deal of characteristics such as its plug and play, convenience, apt expanding, high speed. But, to developers, researching USB interface is not a easy thing, because it requires developers to comprehend deeply USB standard, firmware programme and driver compiling, which restrains general hardware engineer's development to USB interface products [4]. But, in the system, universal USB interface chip CH375 is used. It only needs developers to program siglechip and PC application software, so it has many characteristics such as apt using, short development periods. More important, it supports USB-HOST mode and USB-DEVICE mode.

The system has broken through traditional single USB external device and adopts double USB plug seat mode, which enable it not only can work in USB-DEVICE mode but also be used in USB-HOST mode, so it provides more convenience to different users and occasions. The interface circuit of the CH375 and SCM is as shown in Figure 3 [7-10].

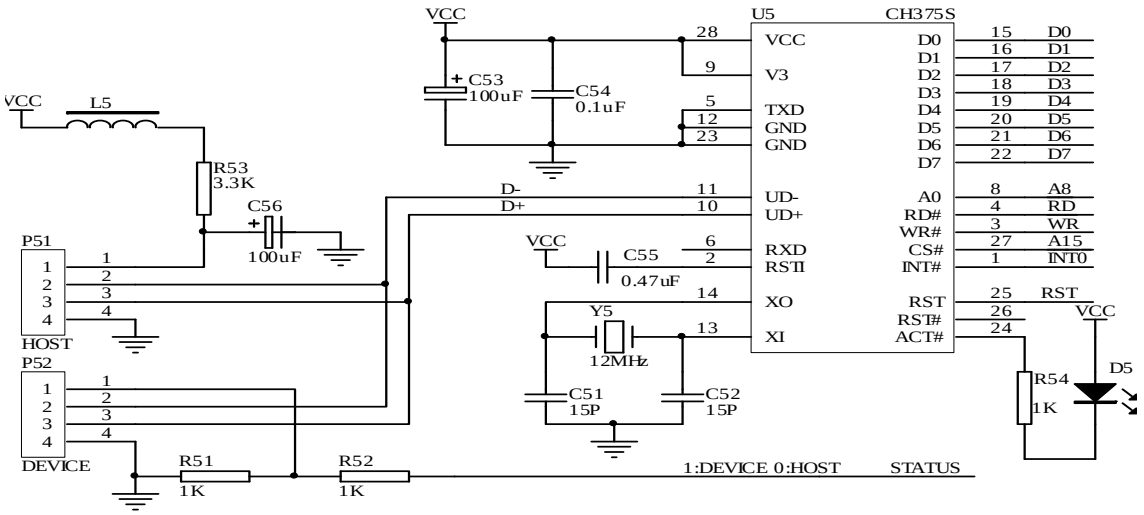

Figure 3. The Interface Circuit Diagram between CH375 and SCM

SCM judges which USB plug seat is working by high or low level of the STATUS signal, and then makes sure which communication mode the system is working in. If the port P52 joints PC, the CH375 works in device mode. If the port P51 joints USB device (such as flash disk), the CH375 works in host mode. The both can't work at the same time. Under the idle situation, STATUS signal is low level, SCM makes the CH375 works in the host mode. When USB apparatus inserts P51, the CH375 will inform automatically SCM to deal with corresponding work. When the P52 joints with USB port of the PC, 5V voltage of the PC makes the STATUS become low level, and then SCM monitors the STATUS signal to switch the CH375 to device mode [11, 12].

The double mode USB interface makes the system more universal, more convenient and meeting much occasion.

2.5. The Application Software and Driver in the PC

The PC application software and driver adopt visual programming language - Visual Basic to program. The driver finishes USB communication Protocol interface program with system software. The application software is made up of data processing and parameter setting module, which can realize the following functions: temperature, humidity and dew-point curve drawing, showing maximum, minimum and mean in any time interval, to transfer Microsoft Office Excel to display data in list, statistical analysis and report printing. In addition, the software can set many parameters of the system (such as start and stop time, time interval, startup mode, memory mode, warning threshold of temperature and humidity value etc.). The gross structure of the software interface is as shown Figure 4.

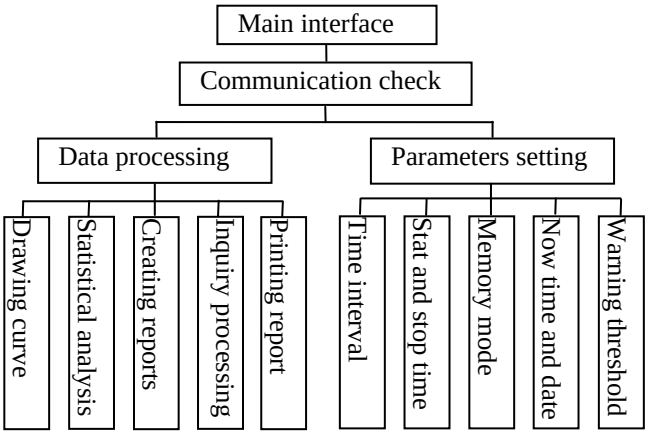

Figure 4. The Interface Structure and Function Block Diagram of PC Application Software

3. The Experimental Result and Its Analysis

Through tested in greenhouse, the system is confirmed that it has very high accuracy and measuring effect. Temperature and humidity curves in the Figure 5 were drawn according to actual acquiring data in the greenhouse. Measuring time interval of these data is 5 second. Temperature error does not exceed ± 0.4 and humidity error does not exceed ±3.0% through comparing and analyzing with the standard temperature system and hygrometer. Nonvolatile memory can store more than 16000 group data. When the system is used under the environment which temperature and humidity change slowly, it can measure for about 220 days continuously by gathering once at intervals of every 20 minutes.

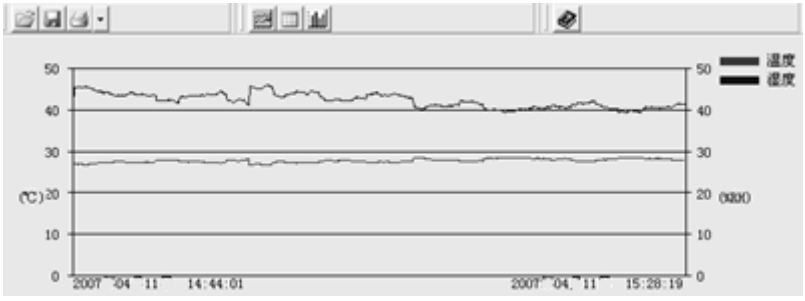

Figure 5. The Interface of Curve Drawing and Data Analysis

4. Conclusion

The system uses advanced single bus sensor, which is reliable, stable, fully calibrated and fully interchangeable. It not only can acquire and memory temperature and humidity data automatically long-time but also can do write-protect to these data that is acquired. In addition,

these data can not lose after power-fail because of the nonvolatile FRAM. More important, the system not only can acquire data automatically according to start time, stop time and time interval set by users, which need not monitoring artificially and is suitable for many dangerous occasion, but also can cast off the PC to realize start and stop as a portable measuring instrument at any time, which can make users more convenient. The double mode USB interface makes data transmission more convenient and fast. It can copy data to lab PC by flash disk under the locale without PC. The system has many characteristics such as high precision, good stability, high dependability and universality etc.

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