Design Of Green Temperature Monitor System For Telecommunication Room Based On Multi-Sensor Data Fusion

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***Abstract*—Telecommunication room always need keep appropriate environment temperature for years. This paper presents a green energy saving temperature monitor system for telecommunication room based on Freescale MCF52259 microcontroller and MQX RTOS, which is consist of three parts: temperature sensor array, controller and air conditioners. Controller periodically acquires temperature-measured value of all regions in the room, and processes data using multi-sensor data fusion technique; on this base, controller regulates every region's environment temperature into proper range. According to the result of actual application, the monitor system works reliably and the average energy saving rate reach 29 percent.**

Keywords- multi-sensor data fusion; temperature monitoring; MQX RTOS

I. INTRODUCTION

Due to long time uninterrupted work of many switches and routers in the telecommunications room, the ambient temperature will be too high, and seriously affect the normal and stable operation of the device, if without temperature regulation. Usually the telecommunications corporations maintain the room temperature in a suitable range by air conditionings. However, since the telecommunications room area is big, ordinary temperature sensor in air conditioning is difficult to make accurate measurements to ambient temperature, cause actual result is not satisfactory. More important is that unreasonable use of air conditioning often leads to unnecessary waste of energy consumption [1,2].

Energy saving and environmental protection is the hot topic in the world today，how to use modern sensor and computer technology to achieve effective monitoring for telecommunications room temperature, and reduce energy consumption is a practical significance subject. This paper describes the design of an energy-saving temperature monitoring system used in the telecommunications room based on multi-sensor data fusion.

II. THE OVERALL DESIGN OF THE SYSTEM

Fig. 1 shows the system block diagram. The entire system is composed of the temperature sensor array, controller, and air-conditionings. The telecommunication room is divided into several regions under the circumstances. Each region is arranged a sensor module array, which generally is composed of 8 temperature sensors. In addition, each region is set an air conditioner for the temperature adjustment.

The communication channels between temperature sensor modules, air-conditioning and controller are standard RS485 bus. The controller is the master of the whole system. It periodically collects the measured value of the temperature sensor from all regions, calculates these data using data fusion algorithm, once the temperature exceeds the appropriate range, controller will send commands to the air conditioning in corresponding region to adjust temperature, and finally achieves the intelligent regulation of the telecommunication room ambient temperature. In addition, the controller provides a friendly interface to allow the user to set and view the various parameters and information of the system.

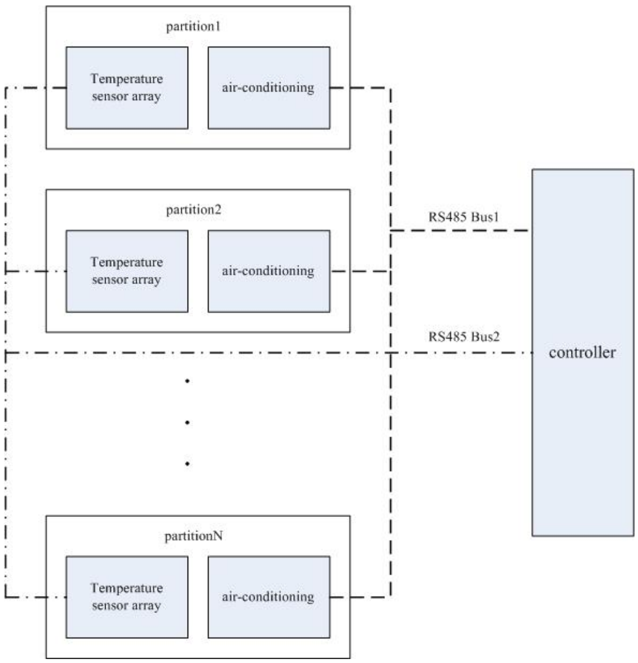

Figure 1. System Block Diagram

III. HARDWARE DESIGN OF THE SYSTEM

A. *Controller Design*

Controller, as the master of the system, uses the freescale company MCF52259 microcontroller and MQX real-time operating system as a platform [3]. Fig. 2 is an overall block diagram.

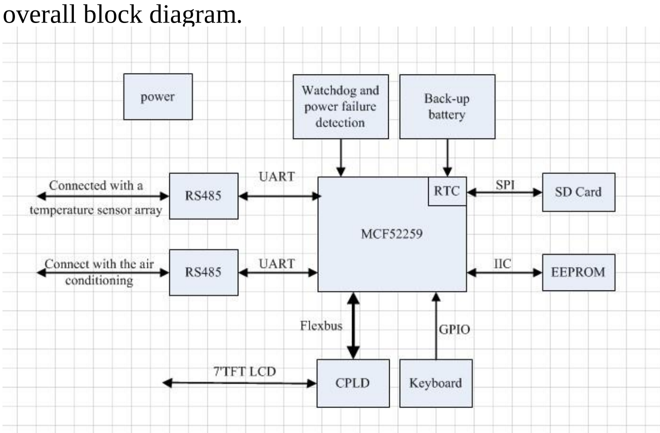

Figure 2. Controller Block Diagram

The power supply uses a wide voltage range input DC-DC converter chip LM2576 to supply 5V power to controller, and use LM1117 LDO chip to supply 3.3V power to main chip. The MCF52259 expands SD card through SPI interface to store operation log data, and uses an additional IIC interface EEPROM to store critical parameters of the system. The system uses the MCF52259 internal RTC clock with back-up battery to provide non-volatile system time.

The controller implements two channels RS 485 communication interface, one channel connects to the temperature sensor array and the other connects to air conditioner. To improve the stability, we have adopted ADI's RS485 Transceiver ADM2483, which uses magnetic coupling technique to implement full electrical isolation. Compared to conventional photoelectric isolation technique, it has advantages of smaller size, higher integration, and higher speed transmission [4,5].

The human-machine interface consists of a 7-inch, 800 x 480 resolutions TFT LCD and a keypad. Because the MCF52259 does not integrate a TFT LCD controller on chip, we have adopted the CPLD LCD controller connecting with the MCF52259 through Flexbus interface. In addition, the controller also integrates a power status monitor and hardware watchdog to prevent the power failure and the program running out.

B. *Temperature Sensor Module Design*

The system uses a proper arrangement of the sensor array for real-time measurement of the temperature of every region in the telecommunication room. According to the area of the telecommunication room, up to 64 temperature sensor modules and eight regions can be supported. In order to improve the stability of communication， An isolated RS485 communication channel is used between temperature sensor module and the controller through ADI's ADM2483 transceivers. The temperature measurement is implemented through the Dallas company's digital sensor DS18B20 [6,7]. In addition, the module also integrates an EEPROM to save the critical parameters, such as the module address. The entire module uses a low-cost and high reliability Freescale MC9S08AC16 micro-controller as the core chip, and uses the on-chip integrated watchdog to prevent runaway programs. The circuit diagram is shown in Fig. 3.

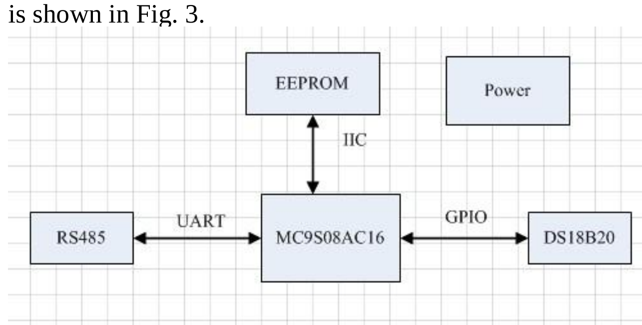

Figure 3. Temperature sensor module circuit diagram

IV. SOFTWARE DESIGN

The system software is based on freescale free real-time operating system MQX, which integrates MFS file system to support Fatfs on SD card. The main function of the system is achieved by the six tasks. The first task, init_task, is created after Operating system starts. It is responsible to initialize, create the remaining five tasks, and exit after completion. hmi_task is to achieve human-machine interaction, including keyboard scanning, user login, parameter settings and display refreshing. Once detecting a valid key press, it calls the appropriate processing module in terms of the key value. These modules include user login authentication, setting the region operating temperature range, and display the real-time values of the current region temperature and air conditioning state on TFT LCD. In order to prevent the loss when power-failure, the critical parameters are stored in EEPROM. sensor_task communicates with the temperature sensor array, acquires each sensor's measurement values periodically, and uses data fusion technique to analyze, process the measured values, and calculate the temperature of each region excluding the failure data, and save it into the SD card. The task control_task compares the values calculated by sensor_task with the preset ambient temperature range of each region. If out of range, it sends instructions to air conditioner through RS485 bus for regulating the ambient temperature into preset range. Each control operation log is saved in the SD card. In order to prevent the abnormal RS485 communication between controller and air conditioner, system takes advantage of test_task task to detect RS485 communication state periodically. Once the communication fails, an alarm signal is fired immediately, and at the same time it saves error log. Last task is the screen saver, screensave_task, the task will automatically turn off the LCD backlight to reduce power consumption when no user operation over a period of time.

The system uses a combination of hardware and software watchdogs, it's a reliability technology [8,9]. Software watchdog is a soft timer based on system ticks provided by MQX operating system. We create a software watchdog for each tasks, and specify a timeout and an overflow handler function. MQX checks each software watchdog overflow in the system tick interrupt service routine. If one software watchdog overflows, MQX calls the corresponding overflow handler. Task periodically feeds software watchdog during normal running, the interval of feed should be less than the overflow time. Corresponding software watchdog overflows when program runs away or tasks go into a zombie state. Overflow handler attempts to restart the task. If three consecutive attempts fail, it no longer feeds the hardware dog, and triggers a system reset.

V. MULTI-SENSOR DATA FUSION METHOD

In practical applications, the measured value of the temperature sensor may be wrong due to various factors. The traditional method is to use the arithmetic average of the measured values, but the practical effect of this method is often not satisfactory. In this paper, we eliminated the uncertainty in the temperature measurement of temperature region by using data fusion algorithm. A suitable data fusion algorithm can obtain high accuracy and improve the measurement reliability, even when some temperature sensor fails [10,12].

A. Negligent Data To Eliminate

In this design, because of the less data of each measurement, the temperature sensor failure data is removed using a distribution map method. The parameters reflecting the distribution structure of temperature measured data in the distribution map are median TM 、 upper quartile FU 、 lower quartile FD and quartile dispersion DS etc.

Assuming a number of sensors in the region is N, the measured values is sorted in ascending order, such as T1、T2、…TN. The median TM=T(N+1)/2 (When N is odd) or TM=(TN/2+1+TN/2)/2（When N is even. FU is defined as the median of interval [TM,TN], the FD is defined as the median of interval [T1,TN], dispersion DS=FU-FD.

The confidence interval of negligent data is:

$$\left|T_i - T_M\right| > DS \text{ , ι=1,2,3...,N .} \tag{1}$$

I.e. the measurement data is valid if $\left|T_i - T_M\right| \le DS$. This method can effectively eliminate the random disturbance in the temperature measurement.

B. Data Fusion Method Based On Bayesian Estimation

Bayesian estimation is effective parameter estimation method. We use the following Bayesian estimated formula to this system, which is introduced in reference [11].

$$T_c = \frac{\sum_{k=1}^{m} \frac{T_k}{Q_k^2} + \frac{T_0}{Q_0^2}}{\sum_{k=1}^{m} \frac{1}{Q_k^2} + \frac{1}{Q_0^2}} \tag{2}$$

in the formula m--------- the number of the sensors

T_k-------- Measured value of the k-th sensor

Q_k-------- The standard deviation of the measured values of the k-th sensor

T_0--------- the mean value of the measured values of m sensors

Q_0--------- the mean standard deviation of the m sensor measurement value

T_c--------- The best estimate of the value of the temperature

Sensor_task acquires every sensor's measured value periodically, then it removes invalid data by formula (1), finally it uses the formula (2) to calculate the best estimate of every region's temperature. These estimated values will be used by control_task to regulate temperature into preset range.

VI. CONCLUSION

The temperature monitoring energy-saving system described in this article has been tested in a telecommunications room for one year after completion of development. The test result shows that the system works well, can maintain the room ambient temperature in an appropriate range all year round. Compared to not using our system, the average energy saving is 29%, especially in July and August hot summer the energy-saving rate is up to 47%.

ACKNOWLEDGMENT

This work is supported by the China National Science and Technology major Project (2011ZX01034-001-002-003).

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