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Distributed Illuminance Measurement System Based on TMS320F28335

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Abstract—**Illumination is one of the vital environmental parameters in industrial production and daily life. However, illuminance measurement devices in the market can usually realize single measurement. Therefore, a system of distributed illumination measurement has been developed based on digital signal processor TMS320F28335, which is composed of illumination measurement modules based on MCU, a control module based on DSP chip and a LCD display module. The control module processes the measurement data and controls multiple illumination measurement modules and LCD display modules. The illumination measurement module collects environment illumination value with the integrated circuit BH1750 of the environment light sensor; multiple illumination measurement modules send the illumination values at different places via RS-485 bus to the control module; the control module sends the processed data to the LCD display module via RS-232 interface to display the results of distributed illumination measurement. The measurement results show that the distributed illumination measurement system based on TMS320F28335 can realize the measurement of multipoint illumination in wide range and real-time display.**

Keywords-DSP; illuminance measurement; serial communication; distributed

I. INTRODUCTION

Illuminance is one of the vital environmental parameters in industrial production and daily life. Thus the illuminance measurement is widely used in daily life, industrial and agricultural production, science study, i.e. the illuminance of certain surface needs measuring and the illuminance measuring range is also wide. However, the level of automatism of the illuminance measurement devices in the market is low, and the collecting range is narrow [1]-[5]. With the continuous renovation of technology, the functions of DSP (Digital Signal Processor) are gradually perfect, which can be used in the design of various devices [6]-[11]. Therefore, it is essential to design a system of distributed illuminance measurement which can measure illuminance in wide range and real-time display the results [12]-[13].

The distributed illuminance measurement system uses the digital signal processor TMS320F28335 as the control core; utilizes the new environment illuminance sensor BH1750 to obtain the corresponding environment illuminance values of local points; and communicates with multiple MCU (Microcontroller Unit) measurements subsystems via RS-485 bus. It can realize the illuminance measurement of multiple points in wide range and display the measurement results in the LCD (Liquid Crystal Display) display module.

II. THE DESIGN OF HARDWARE CIRCUIT

The distributed illuminance measurement system consists of 3 modules: the multiple illuminance measurement modules based on PIC MCU, the control module based on DSP chip and the LCD display module. Each illuminance measurement module composes of 8 new environment illuminance measurement chips BH1750 and MCU dsPIC33FJ64GS606; the MCU controls BH1750 via IIC communication protocol to realize the measurement of multipoint illuminance. The 7.0 inch capacitive touch screen is adopted as the LCD display. The TMS320F28335 of TI company is selected as the control core chip of DSP control system. It utilizes the two inner SCI serial communication ports to communicate with the multiple illuminance measurement modules and LCD display module, and finally realizes the accurate measurement of multipoint illuminance in wide range and the real-time transmission and display of illuminance data. The hardware structure of the distributed illuminance measurement system is shown in Fig. 1.

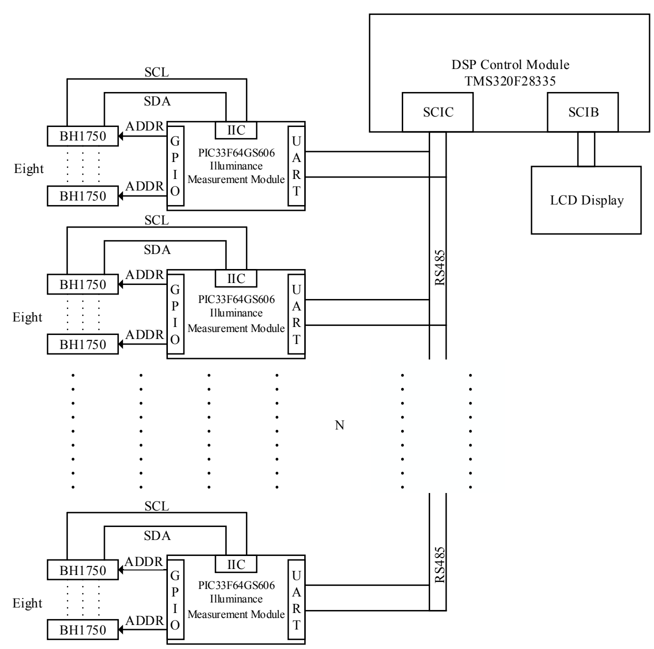

Figure 1. The structure of distributed illuminance measurement system

A. The Illuminance Measurement Module

In the design of MCU illuminance measurement subsystem, the MCU dsPIC33FJ64GS606 of MicroChip company is adopted as the controller, which communicates with 8 environment illuminance sensors BH1750 via 8 I/O ports of the MCU and IIC (Inter-Integrated Circuit) port. Illuminance measurement module receives instruction and transmits data via RS485 data bus. The MCU starts up illuminance measurement chip BH1750 via IIC communication protocol and sets up measurement model, utilizes BH1750 to change the illuminance signals to electric signals and converts them to illuminance digital signals storing in registers. After measuring the illuminance, the results are transmitted to the MCU via IIC data bus, and then the UART module transmits the data to the DSP control system via RS485 data bus. The hardware structure of illuminance measurement module is shown in Fig. 2.

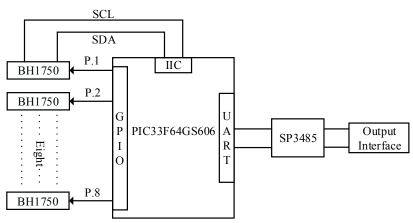

Figure 2. The structure of illumination measurement module

In the illuminance measurement module, the illuminance measurement chip BH1750 is adopted to measure illuminance [14], [15]. It is a 16 bits digital output environment illuminance sensor integrated circuit supporting IIC communication port. BH1750 has two IIC protocal slave addresses, and has a wide measurement range, i.e. without any external device, its measurement range is 1lx-65535lx. Connect the SCL and SDA pins of BH1750's IIC communication ports with the SCL and SDA pins of the MCU's IIC module, respectively; connect 4.7kΩ pull-up resistors with the SCL and SDA data bus, respectively; the ADDR pin is IIC address port, connect it with the MCU's I/O port, which can realize chip selection by changing output level; DVI port is the asynchronous reset port of the BH1750 inner register, which is corresponding to a simple low-pass filter LC circuit in the hardware circuit connecting process. Each illuminance measurement module connects with 8 BH1750 chips to measure the illuminance values of multiple points.

In the illuminance measurement module, the SDA's and SCL's pins of MCU needs setting as drain output mode; since the data signal SDA and clock signal SCL in the IIC communication module of MCU are both bidirectional data communication line, two pull-up resistors are connected with IIC to ensure when IIC communication module is enabled, any device on the data bus can pull down data bus state when outputting low level and when the data bus is free, the two lines can keep high level. Figure 3 is the connecting schema of multiple IIC communication modules.

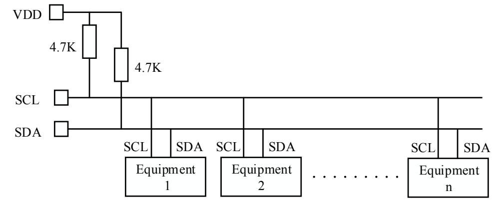

Figure 3. The connecting schema of multiple IIC communication modules

The illuminance measurement module communicates with the control module based on DSP via UART module and RS485 bus. The chip dsPIC33FJ64GS606 has two UART modules, and the illuminance measurement module uses UART1. UART1 module transmits 8 or 9 bits data via U1TX and U1RT pins. RS485 bus interface is realized by low power RS-485 transceiver SP3485. Multiple illuminance measurement modules are connected in the form of ring bus connection and constitute the structure of distributed illuminance measurement.

B. The Control Module Based on DSP Chip

The control module adopts DSP TMS320F28335 as the control core, which is the typical representative of the third-generation DSP chips developed by TI company. It combines the advantages of microcontroller and high performance of DSP. With over-strengthened signal controlling and processing ability, it can do control-algorithm complicated calculation, which is quite fit for developing high-performance digital control system. Figure 4 is the structure schema of control module based on TMS320F28335.

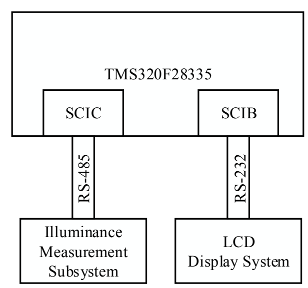

Figure 4. The structure schema of control module based on TMS320F28335

The control module communicates with multiple illuminance measurement modules and LCD display module via SCIB and SCIC, two asynchronous communication SCI modules of TMS320F28335, respectively. SCIC module realizes communications of illuminance values and operation instruction with multiple illuminance measurement modules via RS-485 bus; SCIB module realizes the interaction of illuminance values and display instruction with LCD display module via RS-232 interface, and finally realizes transmitting the illuminance values of different places collected by multiple illuminance measurement modules to the LCD display module to realize real-time display.

C. LCD Display Module

The LCD module uses the 7.0 inch capacitance shielded configuration industrial serial communication screen. The development of serial communication screen in LCD display module is operated via the interface design platform VisualTFT.

III. THE PROGRAM DESIGN OF THE SYSTEM

In the program design of illuminance measurement module, initialize the clock frequency of MCU, I/O ports, etc.; then configure the UART communication module to realize the receiving and sending of information; then dispose the IIC communication module of the MCU, i.e. the control programming of MCU to 8 BH1750 chips realizes the collection and reading of illuminance data of multiple points; and finally transmit them to DSP via UART module. In the programming design of DSP control module, dispose the system clock of TMS320F28335, and then dispose two SCI interface modules to realize the sending and receiving of data. The LCD display system displays the illuminance information from DSP.

A. The Program Design of Illuminance Measurement Module

Fig. 5 is the flow chart of the programming design of illuminance measurement module. Firstly, initialize MCU and configure the corresponding system clock, I/O ports, etc.; then initialize IIC module and UART module, monitor the instruction information from DSP control module, analyze the instructions with MCU, enable IIC module according to instructions, communicate with the point of illuminance measurement in illuminance measurement module successively, start up the corresponding BH1750 chips, and collect environment illuminance values and read data via IIC bus; finally, enable UART to transmit illuminance values to DSP control module.

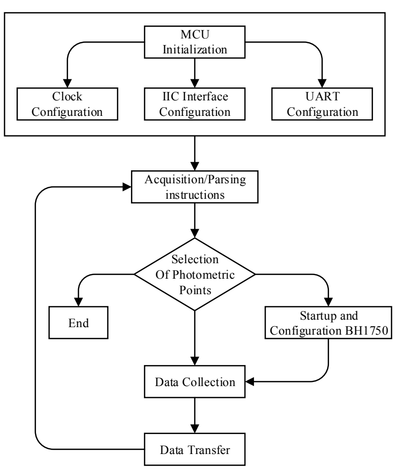

Figure 5. The flow chart of the programming design of illuminance measurement module

In the illuminance measurement module, illuminance values are obtained via BH1750 chips. Since the communication of illuminance data between BH1750 and dsPIC33FJ64GS606 is the typical IIC communication interface protocol, in which dsPIC33FJ64GS606 is the host computer in the illuminance measurement module while the 8 BH1750 chips are the slave computers, the whole illuminance measurement subsystem is in single host working mode. The dsPIC33FJ64GS606 chip changes the level of ADDR pin of the corresponding BH1750 chip by changing the level of I/O port, and thus realizes the choice of IIC communication address of BH1750. As for BH1750, select its illuminance measurement mode after its starting up, and the selectable modes include continuous high-resolution mode, continuous low-resolution mode, one-time high-resolution mode, one-time low-resolution mode, etc.

Continuous high-resolution mode 1 is selected for the illuminance measurement module, which has enough integration time and suppresses noise interference. Moreover, the resolution of continuous high-resolution mode 1 is under 1lx, which is fit for the illuminance measurement in dark environment (less than 10lx), and the system needs continuous measurement. The reset instruction in the instruction set only takes effect for the light intensity data register in BH1750, and has no influence on external clock signals. It mainly eliminates former illuminance measurement data and prepares for the storing of next measurement. However, the reset instruction can only be operated in electrifying mode, and cannot bu operated under power-off condition. Therefore, it is supposed to start up BH1750 before inputting reset instruction, i.e. electrifying. Fig. 6 is the operation chart of the illuminance measurement of BH1750 chip.

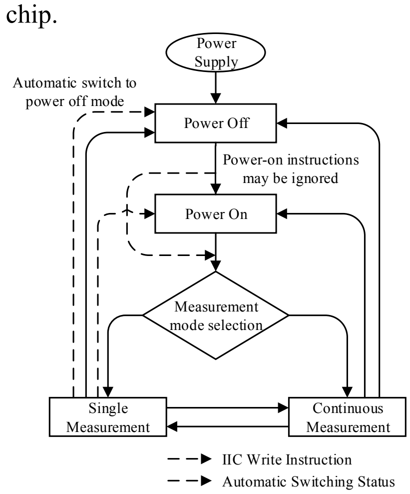

Figure 6. The operation chart of the illuminance measurement of BH1750

The process of illuminance measurement module realizing illuminance measurement of multiple BH1750 chips is as follows: firstly, initialize the UART, IIC,and I/O ports of the MCU dsPIC33FJ64GS606, and start up the chip; then, enable UART module, pull down the I/O pin which controls the receiving and sending of SP3485 chip to make it under receiving condition, and start up the monitoring of DSP control module; when monitoring the instruction signal from DSP control module, set up RS-485 serial interface communication connection with DSP; if the connection is not successful, then return and wait for the next instruction; enable IIC communication module of MCU, select the working frequency of 100KHz; meanwhile, operate on the 8 I/O ports connecting with the ADDR pins of 8 BH1750 chips, i.e. pull down one BH1750's ADDR pin and the other 7 are at high level, and thus there is only one BH1750 satisfying low order address and the other unselected BH1750 chip are at power-off mode not participating in measurement; then, dsPIC33FJ64GS606 sends address byte, electrifying and corresponding measurement mode instruction to BH1750 chips, waits for the response signals from BH1750, and implements the next step when BH1750 returns to ACK while doesn't respond to the instruction when BH1750 returns to NACK and finishes the measurement. Later, according to the operation instruction of IIC bus sending to BH1750, start up BH1750 and set the the measurement mode at the corresponding continuous high-resolution mode 1 to wait for the finish of illuminance measurement; invoke again the program of reading illuminance of IIC module in dsPIC33FJ64GS606 and read the environment illuminance data measured by BH1750. After storing, transfer the illuminance date to the defined illuminance variables arrays, and then enable UART transmitting function. Pull up the level of the I/O port connecting with SP3485, store the collected illuminance values in the transmit data register, and wait for the finish of sending. Finally, after firstly collecting and sending illuminance data successfully, return to the setting of I/O port, do piece selection again, i.e. set one low level and 7 high levels, pull down 8 BH1750 chips at different positions successively to fulfil illuminance measurement. After 8 loops, finish the whole process and wait for the measurement instruction from DSP control module.

B. The Programming Design of Control Module

The programming of control module based on DSP chip mainly consists of two parts: the receiving and sending of illuminance data between control module and multiple illuminance measurement modules, and the sending of illuminance data between control module and LCD display module. TMS320F28335 chip supplies 3 SCI interfaces: SCIA,SCIB and SCIC, among which SCIB and SCIC are selected in the hardware circuit design of DSP control module.

In the process of sending instructions to each illuminance measurement module via RE-485 bus interface, as the control core of the distributed illuminance measurement system, the control module based on DSP chip has to set separate instruction number to each communication instruction to ensure each illuminance measurement module not missing instructions or wrongly analyzing instructions when monitoring the instructions of DSP control module. When monitoring its own data instruction number from control module, illuminance measurement module starts up the nest operation. Therefore, when DSP control system is at sending state, other illuminance measurement subsystems are at monitoring state, i.e. UART module is at receiving enabling state. When illuminance measurement module monitors its corresponding data instructions, the DSP control system shifts to receiving state and the illuminance measurement module shifts to sending state; only after receiving corresponding data instruction from DSP control module, the illuminance measurement module transmits 8 illuminance values to DSP control system and waits for the finish of illuminance data transmission, and then all the illuminance measurement modules shift to receiving state again to continue the monitoring of the data instruction from DSP control system.

DSP control module realizes the communication between RS-232 interface and LCD display module via SCIB module. SCIB module only needs to realize the sending of data instruction. After processing the massive illuminance data received by SCIC module, SCIB module sends the illuminance data to the LCD display system via RS-232 interface to display the results of illuminance data collection of multiple points on the illuminance data display interface of the serial communication screen. The flow chart of the programming of DSP control module is shown in Fig. 7.

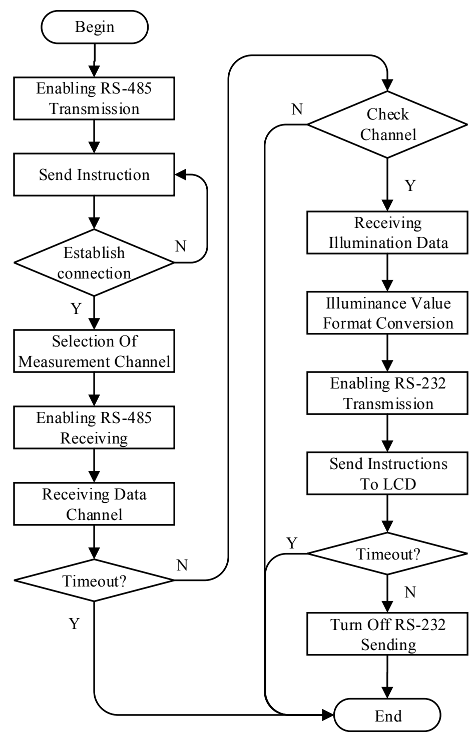

Figure 7. The flow chart of the programming of DSP control module

IV. THE VERIFICATION OF THE DISTRIBUTED ILLUMINANCE MEASUREMENT SYSTEM

When the system is power on, the illuminance measurement results will be shown on the LCD. The measurement results are shown in Figure 8. There are three sets of measured illuminance data on the serial communication screen. In the process of illuminance measurement, since 3 illuminance measurement modules are in the same environment and have little illuminance difference, the measured illuminance data are similar and the range volatility is not big.

Figure 8. The display interface of distributed illuminance measurement results

To verify the system can realize distributed illuminance measurement, place 3 illuminance measurement modules in different illuminance environments: place the first illuminance measurement module (CH1) in dark environment; the second (CH2) in the environment with indoor light; and the third (CH3) under the desk lamp. Stick a piece of black paper to avoid light to one BH1750 of each illuminance measurement module to make the measured illuminance results have great difference for easy analysis. Fig. 9 shows the illuminance data of 3 illuminance measurement modules placed in different environments.

Figure 9. The illuminance results in different environments

The analysis of the data displayed by LCD shows that since the 8 BH1750 chips of the first illuminance measurement module (CH1) are in the dark environment, the 8 illuminance data has little differences, around 1lx; the volatility of the 8 indoor illuminance values collected by the second illuminance measurement module (CH2) is also small, basically stabling at 133lx, and since the sixth BH1750 chip of CH2 is stuck with a piece of black paper, the measured illuminance data is 0lx, which corresponds to the actual situation; since the third illuminance measurement module (CH3) is under the lamp, the 8 measured illuminance data are comparatively high, 44285lx, and since the seventh BH1750 chip of CH3 is stuck with a piece of black paper, the measured illuminance data is 0lx, which corresponds to the actual situation.

V. CONCLUSION

A distributed illuminance measurement system based on TMS320F28335 is realized. The whole system consists of 3 modules: the control module based on DSP chip, the illuminance measurement module based on MCU and the LCD display module. The control module adopts the DSP chip as the control core, and controls multiple illuminance measurement modules and LCD display module via SCI module. The illuminance measurement chip BH1750 collects the illuminance values of the environment, and the data are sent to MCU via IIC protocol, then the MCUs send the data to TMS320F28335 via RS-485 bus. The TMS320F28335 processes the illuminance data and send the final results to LCD display module to realize real-time measuement and display of multi-point illuminance.

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