Hardware and Software Development of Multi-channel Environment Parameter Tester

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Abstract. A multi-channel environment parameter tester is developed in order to improve the simple testing function of domestic environment monitoring instrument. Multiple environment parameters can be acquired through multi-channel A/D, FPGA with strong data processing function is selected as the master control to achieve the data processing, and the data is transferred via USB protocol or WiFi/Bluetooth. The test results approves that all channels of multi-channel environment parameter tester designed are working normally, and the environmental data collected is real and believable.

Keywords: Multi-channel; Environment Monitoring; FPGA; Data Processing; Data Transmission

Introduction

The environmental problem has always been the hot issue worldwide, especially in China. With the rapid development of Chinese economy and the acceleration of industrialization step, China’s environmental situation is becoming increasingly serious. Some environment monitoring equipments are urgently needed in China for environment monitoring, so as to take proper countermeasures.[1]

There are many representative environment monitoring instruments in foreign countries, and those in developed countries have already been transformed from single function to multiple functions. Since late 70’s of the last century, China has enjoyed the rapid development in the environment monitoring instrument.

At the present time, TSP and PM10 gas samplers researched and developed independently in China have basically satisfied the demand of domestic environment monitoring in its performance and reliability. It is worth mentioning that our own-developed WJ-60B type pitot tube parallel automatic dust collector has reached the international advanced level. The multi-function environment monitoring instruments are small in quantity in the domestic market so far, i.e., most of them are with relatively simple function, and the measurement of multiple environment parameters just in one instrument cannot be achieved, so the development of multi-function environment monitoring instrument is an urgent errant for China.

This paper is a study of multi-channel environment parameter tester, which can achieve the gas flow, temperature, humidity, CO2 concentration, light intensity, and air pressure. The development of environment parameter tester can meet China’s current demand on environment monitoring, and the real-time environment quality information can be obtained through the measured environment parameters, providing the convenience for our further improvement on environment management or self-protection measures.

General Structure

Multi-channel environment parameter tester includes the multi-channel data acquisition, data processing and data transmission, the general structure is shown in Figure 1.
The purpose of the design is to handle the environment parameter acquired with two methods according to the different structural characteristics of sensors, and then load them into the main control unit. The first method is to handle the environment parameters acquired into 232 level output directly via the sensor with the output of 232 level, which then converted to TTL level and loaded into the main control unit. The second method is to apply the sensor with DC voltage or DC current output, input the signal into the front-end signal processing circuit by differential signal method. The front-end signal processing circuit undertakes the main function to filter and amplify the input signal, and the signal processed is loaded into the main control unit after converted by 24-bit A/D converter (A/D).

The main control unit is to handle the data loaded, and the valid data processed is transmitted to the human-computer interface in two ways.

Hardware Design

The hardware design is based on the general structure of multi-channel environment parameter tester, mainly includes the RS232 serial interface module, front-end signal processing module, A/D converter module, main control unit module, and USB data transfer module.

RS232 serial interface module. In the environmental parameter sensors, some are converted the environment parameter acquired into RS232 level output. FPGA chip, however, identifies the TTL level, so the level shall be converted. The level conversion chip selected here is SP232EEN, which can achieve the bidirectional level conversion, work in the industrial temperature range, and provide the internal ESD protection circuit.

Front-end signal processing module. Main functions of front-end signal processing part are to amplify the analog signals from the sensor, and convert the differential input to the single-ended signal output for the processing of A/D converter. INA128 instrument amplifier is applied in this design.

A/D converter module. LTC2449 is selected for AD converter, which is a 24-bit A/D chip, whose analog input channel can be configured to 8 pairs of differential input channels or 16 single-ended input channels which are applied in this design. The common terminal of the channel is the COM pin on the chip, the COM value here is set to 2.5V in order to match the operational amplifier INA128 at the front of A/D, and the input voltage from -2.5V to +2.5V can be converted to the acquisition scope of LTC2449.

Main control unit module. The main control unit consists essentially the FPGA chip, FLASH, SRAM, and SDRAM.

Cyclone chip III EP3C25F324I7 from Altera Company is selected for the main control chip, which is packed as BGA, possessing smaller size and more logical resources: 24,624 logical units, 216 user I/Os, and 608256 storage bits, with 132 9-bit multiplying units, 4 phase-locked loops, and 20 global clocks embedded.

Two FLASH chips are used in the main control board, which are models of S29AL016J and EPICS16 respectively. NIOS soft core program is very complex and needs larger program storage space and running space \[^3\], so S29AL016J with 16-bit data bus is applied as the FLASH memory. The capacity of FLASH is 2MB, and satisfies the JEDEC standard. It is also compatible with CFI interface, supports the single-byte and double-byte access, and meets the industrial operating temperature, applicable to the battery power supply for its operating voltage (2.7V-3.6V) required in
reading and writing and low power consumption. EPCS16 is used to store .jic files, namely the curing procedures, and the function of power-down save can be achieved.

IS61LV51216, also with 16-bit data base, is applied for SRAM memory, which can be multiplexed with the FLASH. IS61LV51216 is a kind of high speed and low power SRAM chip, which can be compatible with TTL and CMOS levels, and the clock signal is unnecessary during the reading and writing, i.e., completely static access. It is also the industrial temperature range and has a three-state output function.

MT48LC32M16 chip is applied for SDRAM. The capacity of such SDRAM chip is 64MB, the highest clock signal can be up to 100MHz, supporting the manual refresh and self refresh modes, and its I/O is compatible with TTL level. Due to the high working frequency of SDRAM, the serpentine curve is applied during the PCB wiring in order to ensure the consistent phases of clock line, data line and address line, guarantee the consistent length of signal wire, and thus ensure the same signal transmission time and consistent phase.[3~4].

**USB data transfer module.** CY7C68013 is selected as the USB chip in the design with 3.3V power supply used, and its work clock is 48MHz with 16-bit data input interface applied. The cache FIFO is brought in the chip. The data output from FPGA firstly enters into the internal FIFO of USB chip, and then transmits to the upper computer through the USB transmission line. The USB data transmission is with the advantages of stable transmission and fast transfer speed, suitable for multi-channel environment parameter tester.

**Software Realization**

After the realization of hardware circuit, the software program shall be cooperated to realize the functional requirements in this design completely. The software design of multi-channel environment parameter tester mainly includes the establishment of NIOS II software core, compilation of SPI communications C programs, RS232 serial communication program, and USB data transmission control program based on VHDL hardware language.

**NIOS software core design.** The realization of main control board software program is based on the development environments of Quartus II 10.1 and corresponding NIOS II 10.1 Software Build Tools for Eclipse. Under the environment of Quartus II 10.1, Verilog HDL or VHDL hardware description language is applied to complete the configuration of underlying hardware drives, logical control and NIOS II soft core. Under the environment of NIOS II 10.1 Software Build Tools for Eclipse, the embedded C language programming of NIOS II soft core is completed.[5]

NIOS soft core is made up of various IP cores, which are included under Quartus II development environment, and we only need to add the appropriate IP cores into the soft core. NIOS II soft core is created by SOPC Builder under Quartus II development environment. The following IP modules are added into the Bluetooth/WiFi communications soft core: CPU, JTAG, Tri-State Bridge, and System ID, together with SDRAM and FLASH memory, SPI communications IP core and several I/O ports IP cores. USB communications IP core increases the necessary I/O port module.

**SPI programming.** SPI is a kind of high-speed, full-duplex, and synchronous communication bus. Its communication principle is very simple, i.e., the master-slave work method, which usually has one main equipment and one or several slave equipments, and at least 4 lines are needed (actually three is also enough for just unidirectional transmission), mutually possessed by equipments based on SPI, including SDI (data input), SDO (data output), SCLK (clock), and CS (chip selection).

SPI communication protocol is applied for A/D chip LTC2449 in this design. SPI data communication function is realized from C language code under NIOS development environment, mainly including SPI data sending program module, SPI data receiving program module, and SPI initialization module.

**RS232 serial communication programming.** In the design, the serial interface is with great function, which can be used as RS232 data communications, and to provide the assistance to the Bluetooth/serial data communication. The serial interface programming is realization under NIOS environment, mainly including the serial data sending and receiving, and the serial data reception is
implemented during the interruption of serial interface. The baud rate of serial interface is set as 115200 bps, with 8 data bits and 1 stop bit, but no check bit.

**USB data transmission control program.** USB data transmission control program in the design is programmed with VHDL hardware description languages in Quartus II development environment, mainly to control the read and write of FIFO cache module. One FIFO control module is added between NIOS soft core and USB chip so as to facilitate the realization of computer interface and control the transmission to upper computer data better.

When VHDL language is used to program the FIFO control module, the FIFO module IP core included in the Quartus II development environment can be called with component instantiation in the program. The data control VHDL program of the whole USB can be divided into the entity and structures, while the component instantiation module and the state machine control module are also included in the structure [6-7].

**Summary**

This design has successfully realized the development of the multi-channel environment parameter measuring instrument based on EP3C25, and it can meet the expected function through the software and hardware.

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