# A Multi-channel Digital Temperature Acquisition System Based on SOPC

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**Abstract**— In this paper, a multi-channel digital temperature acquisition system is proposed. Based on System on a Programmable Chip (SOPC) and 1-wire bus technologies, the temperature acquisition node is designed. The data acquired is transferred to the host computer through RS232 serial interface. The software on the computer analyzes and processes the received data to achieve the real-time monitoring and display of the temperature through the User Interface (UI). Programmable resolution 1-wire digital thermometer DS18B20 is adopted in this design. The acquisition node is configured by NIOS soft core CPU using Verilog HDL and C language, meanwhile, the UI on the PC is designed in Visual Basic language. The temperature sensor has an operating temperature range of $-55^\circ$ to $125^\circ$. The resolution of the acquisition is $0.0625^\circ$ and the display resolution is $0.01^\circ$. All simulations in the design are done in Quartus and Modelsim tools. Finally, the operation of the temperature acquisition system is validated on an Altera Cyclone II series FPGA chip. The measure results are displayed on both the local LCD module of the acquisition node and the UI of the host computer. The system can also give out alarm signals when the temperature acquired exceeds the threshold set through software. Due to the use of SOPC technology, the system is of high integration, high design flexibility, small volume and low power consumption. The system can be widely used in areas such as intelligent greenhouses, temperature monitoring systems inside storehouses, equipments, or machinery, and process control systems.

## 1. INTRODUCTION

The temperature is one of the basic physical parameters, and the temperature acquisition is one of the most continually technology used in agriculture, industry and daily life. Temperature acquisition systems are widely applied in areas such as intelligent greenhouses, storehouses, equipments, machinery, and medicine, etc.. The traditional temperature acquisition systems usually use microprocessors as the central processing units. With the development of SOPC technology and the miniaturization of the electronic equipments, data acquisition systems start to introduce FPGA as the core of the systems.

In this paper, a multi-channel digital temperature acquisition system based on SOPC is proposed. The acquisition node is configured by NIOS soft core CPU using Verilog HDL and C language. The temperature sensors DS18B20 convert the temperature to digital word and the FPGA chip store it in the FIFO memory. Finally, the value of the temperature is displayed on the LCD module controlled by the NIOS soft core CPU and sent to the PC end through UART (Universal Asynchronous Receiver/Transmitter) for display. On the UI of the PC end, we can observe the real-time temperature and set the upper limit temperature. When the temperature acquired exceed the limit the UI will give out alarm signal. The integration and speed of the acquisition system are upgraded because of the introduction of the SOPC technology.

## 2. SYSTEM ARCHITECTURE OVERVIEW

The proposed temperature acquisition system is shown in Fig. 1. The system mainly consists of five parts, four DS18B20 temperature sensors, an Altera cyclone II FPGA board, a LCD12864 display module, a MAX232 UART module and a host computer.

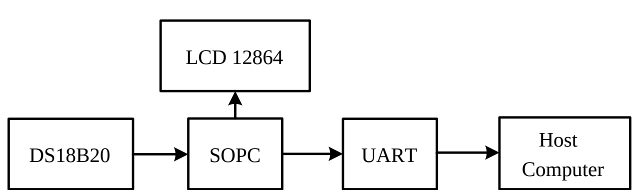


Figure 1: Functional block diagram of the temperature acquisition system.

1) The temperature sensors module includes four digital temperature sensors DS18B20. Under the control of the SOPC module, the sensors acquire the temperatures of the four channels and convert them into digits.
2) The SOPC module receives the digits sent by DS18B20 and stores them in the FIFO memory, and translates them into real values of the temperatures. After the translation, the SOPC send the data to the LCD12864 and UART module for display.
3) The LCD12864 display module consists of a liquid crystal display panel. The temperatures of the four channels are displayed on the module, so the user can observe the values of the temperature at the field even if there is no host computer.
4) The UART module implements the conversion between TTL/CMOS levels and TIA/EIA-232-F levels. Thus enable the SOPC to send data to the host computer.
5) The host computer receives the data sent by SOPC and displays the temperatures on the user interface (UI). We can also set the temperature thresholds on the UI. If the temperatures exceed the thresholds we set, the UI will give out alarm information to remind us the over temperature events.

## 3. HARDWARE DESIGN

In this section, the hardware design of the temperature sensors circuit, LCD display circuit, UART levels conversion circuit, and FPGA/SOPC system is described.

### 3.1. DS18B20 Temperature Sensors Circuit Design

DS18B20 is a 1-Wire Digital Thermometer, so that only one wire (and ground) needs to be connected from the FPGA to a DS18B20. The Data In/Out pin (pin 2) is pulled up to VCC through a 4.7 kΩ resistor, in order to provide power for reading, writing, and performing temperature conversions by the data line itself. The four sensors use the same circuits as above and parallel acquisition is adopted to improve the conversion speed.

### 3.2. UART Circuit Design

The UART circuit realizes the conversion between TTL/CMOS levels and TIA/EIA-232-F levels. So the acquisition system can communicate with the host computer through serial port. The circuit of this part is shown in Fig. 3.

### 3.3. LCD12864 Display Circuit Design

In the acquisition system, a LCD12864 module is adopted as the temperatures display device. The controller/driver of the LCD12864 is ST7920 which has a wide operating voltage (2.7 V to 5.5 V) and low power consumption. The display module has a display definition of 128×64 and works in parallel bus mode. The circuit is as Fig. 4 shows.

### 3.4. Hardware Design of SOPC System

The SOPC system is mainly comprised of the NIOS processor, the user-defined components and some peripheral. The structure of system is shown in Fig. 5. The system is created in Verilog hardware description language (HDL).

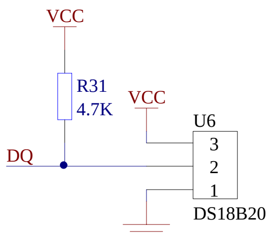


Figure 2: The schematic of temperature sensor.

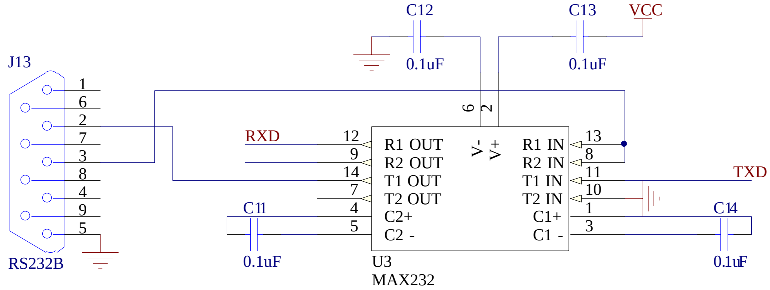


Figure 3: The schematic of the UART circuit.

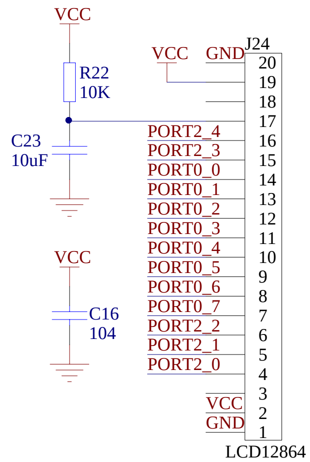


Figure 4: The schematic of the LCD12864 circuit.

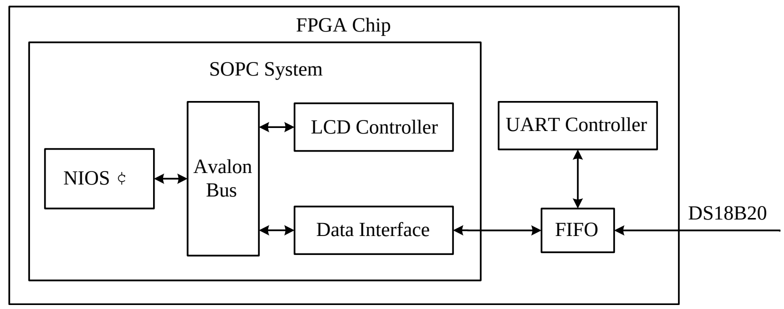


Figure 5: The structure diagram of the SOPC system.

## 4. SOFTWARE DESIGN BASED ON NIOS II

The software is designed in C language in the NIOS II IDE environment. In this system, the software mainly implements the control of the LCD display of the four channels' temperatures. When the temperature sensors DS18B20 finish the conversion, the system will call the display function and display the four temperatures on the LCD. The software flow chart is shown in Fig. 6. The control of the conversion of sensors and UART are finished by modules described in Verilog HDL.

The data sent to the serial port is made up of five bytes. The first byte is the channel label, so the UI on the host computer can recognize the corresponding temperatures of the four channels and display them on the interface correctly. The second to the fourth bytes of the data are the tens, units, tenths and hundredths of the temperature to be displayed respectively.

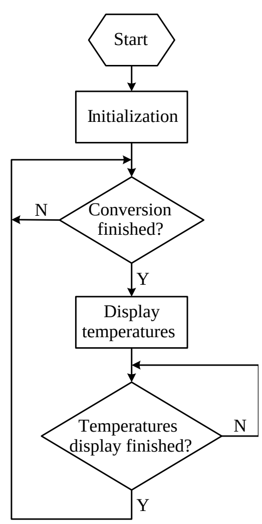


Figure 6: The flow chart of the program.

## 5. SYSTEM VERIFICATION

In order to verify the operation of the system, this paper utilizes Altera Cyclone II FPGA chip EP2C5Q208C8 to realize the system. The photo of the system is shown in Fig 7. The system mainly contains three circuit boards, a FPGA board, a LCD12864 display board and a DS18B20 temperature sensors board.

A UI on the host computer is designed in Visual Basic, the temperatures of the four channels can be displayed on the interface and temperature thresholds can be set through it. The operation

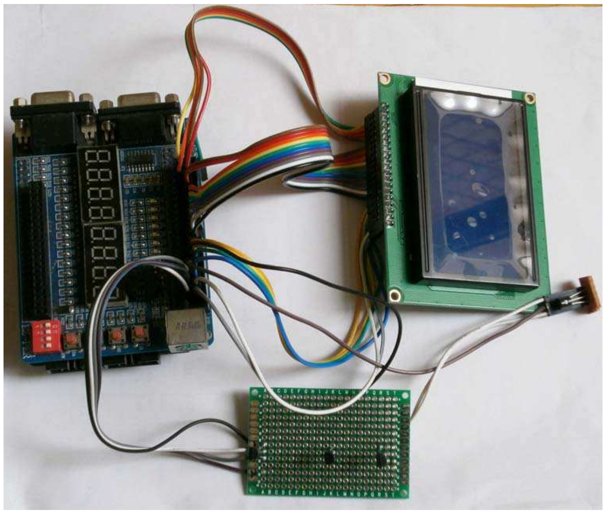

Figure 7: The photo of the system.

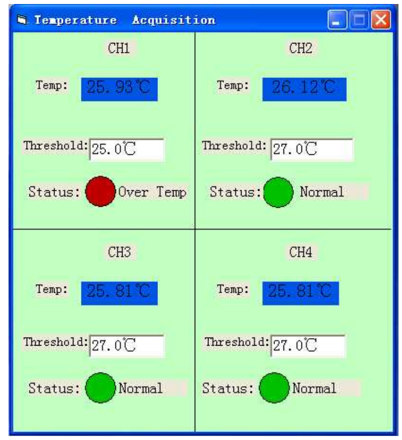


Figure 8: The operation of the User Interface (UI).

photo of the UI is shown in Fig. 8.

The temperature threshold of channel 1 is set to 25°, thresholds of channel 2–4 are set to 27°. The temperature acquired by channel 1 is 25.93° which has exceed the threshold. So the status turns to "Over Temp" from "Normal" to report the fault.

## 6. CONCLUSION

In this paper, a multi-channel digital temperature acquisition system based on SOPC is designed. The integration of the system is improved due to the use of the SOPC technology. The operation of the system is verified on the Altera EP2C5Q208C8 FPGA chip and the host computer. The system can be widely used in areas such as intelligent greenhouses, temperature monitoring systems inside storehouses, equipments, or machinery, and process control systems.

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## REFERENCES

1. Dong, H., et al., "A SOPC design for intelligent pressure sensor," *Proceedings of 2009 International Conference on Information, Electronic and Computer Science*, Vols. I and II, 327–330, 2009.
2. Xiong, G. H., et al., "Design of minimum SOPC system board," *2008 International Conference on Intelligent Computation Technology and Automation (ICICTA)*, Vol. 2, 20–24, 2008.
3. Jurgen, R. K., *Sensors and Transducers,* Society of Automotive Engineers, Warrendale, PA, 1997; Wiley-IEEE Computer Society, 1999.
4. Elrabaa, M. E. S., "A new FIFO design enabling fully-synchronous on-chip data communication network," *2011 Saudi International Electronics, Communications and Photonics Conference (SIECPC)*, 2011.
5. IEEE Standard Hardware Description Language Based on the Verilog(R) Hardware Description Language, IEEE Std 1364-1995, 1996.
6. Ciletti, M. D., *Advanced Digital Design With the Verilog HDL,* 2nd Edition, Prentice Hall, 2010.