LM75 Temperature Test Experiment

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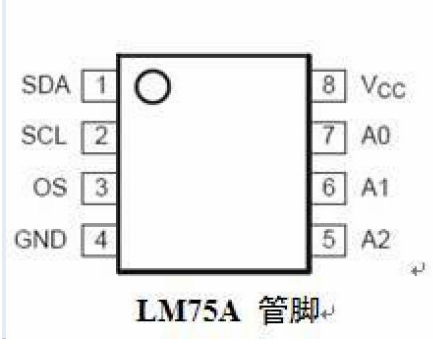
1 Experiment Introduction

This tutorial introduces the temperature sensor LM75 for temperature testing. The experiment mainly introduces the temperature sensor's FPGA driver and digital tube display.

2 Experiment Principle

2.1 Introduction to LM75 principle

The LM75A is a high-speed I2C interface temperature sensor that converts temperature directly to digital signals from -55°C to +125°C and achieves an accuracy of 0.125°C. The controller can directly read the data in its internal registers through the I2C bus, and can operate four data registers through I2C to set different operating modes. The LM75A has three selectable logical address pins that allow eight devices to be connected simultaneously on the same bus without address conflicts. The LM75A can be configured for different operating modes. It can be set to periodically monitor the ambient temperature during normal operation or enter shutdown mode to minimize device power consumption. The OS output has two selectable operating modes: OS Comparator mode and OS Interrupt mode. The OS output can be selected to be active high or low. In normal operating mode, when the device is powered up, the OS operates in comparator mode with a temperature threshold of 80 °C and a hysteresis threshold of 75 °C. Low power design, typical operating current is 250uA, power-down mode is 3.5uA; wide operating voltage range is 2.8V to 5.5V. The LM75 pin description is as follows:



LM75A 管脚

SDA： I2C 串行双向数据线，开漏口。
SCL： I2C 串行时钟输入，开漏口。
OS： 过热关断输出。开漏输出。
GND： 地，连接到系统地。
A2： 用户定义的地址位2。
A1： 用户定义的地址位1。
A0： 用户定义的地址位0。
Vcc： 电源

a) Temperature register Temp (address 0x00)

The temperature register is a read-only register containing two 8-bit data bytes consisting of a high data byte (MS) and a low data byte (LS). Only 11 of these two bytes are used to store Temp data (in the form of two's complement data) with a resolution of 0.125 °C, as shown in the following table. For the 8-bit I2C bus, just read two bytes consecutively from the "00 address" of the LM75A (the upper 8 bits of the temperature are first)

Temperature register

Temp MS 字节								Temp LS 字节							
MSB							LSB	MSB							LSB
B7	B6	B5	B4	B3	B2	B1	B0	B7	B6	B5	B4	B3	B2	B1	B0
Temp 数据（11 位）											未使用				
MSB										LSB					
D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0	X	X	X	X	X

Method for calculating Temp value based on 11-bit Temp data

1) If D10=0, temperature value (℃)=+ (Temp data) X 0.125℃

2) If D10=2, temperature value (℃)=- (Two's complement of Temp data) X 0.125℃

The table below gives examples of some Temp data and temperature values.

Temp 表

Temp 数据			温度值
11 位二进制数（补码）	3 位十六进制值	十进制值	℃
0111 1111 000	3F8h	1016	+127.000℃
0111 1110 111	3F7h	1015	+126.875℃
0111 1110 001	3F1h	1009	+126.125℃
0111 1101 000	3E8h	1000	+125.000℃
0001 1001 000	0C8h	200	+25.000℃
0000 0000 001	001h	1	+0.125℃
0000 0000 000	00h	0	0.000℃
1111 1111 111	7FFh	-1	-0.125℃
1110 0111 000	738h	-200	-25.000℃
1100 1001 001	649h	-439	-54.875℃
1100 1001 000	648h	-440	-55.000℃

b) Configuration register (Address 0x01)

The configuration register is an 8-bit readable and writable register, bit function assignment is as shown in the following table.

Configuration register function

B7	B6	B5	B4	B3	B2	B1	B0
Reserved			OS Fault queue		OS polarity	OS comparison/ Interrupt	Shut down

B7-B5: Reserved, the default is 0.

B4-B3: Used to program the OS fault queue

The values represented by 00 to 11 are 1, 2, 4, and 6. The default value is 0.

B2: Used to select the OS polarity.

B2=0, OS active low (default);

B2=1, OS is active high.

B1: Select the OS working mode.

B1=0, configured as a comparator mode to directly control peripheral circuits;

B1=1, the OS control output function is configured in interrupt mode to inform the MCU to perform the corresponding processing.

B0: Select the device operating mode.

B0=0, LM75A is in normal working mode (default);

B0=1, the LM75A enters shutdown mode.

c) Hysteresis register Thyst (0x02)

The hysteresis register is a read/write register, also known as a setpoint register, that provides the lower temperature limit for the temperature control range. At the end of each conversion, the Temp data (taken the upper 9 bits) will be compared to the data stored in this register. When the ambient temperature is lower than this temperature, the LM75A will control the OS according to the current mode (comparison, interrupt). The pin reacts accordingly. This register contains two 8-bit data bytes, but only 9 of the 2 bytes are used to store the set point data (two-part complement with a resolution of 0.5 °C). The data format is shown in the following table. The default is 75 °C.

Low/high alarm temperature register data format

D15	D14---D8							D7	D6---D0
T8	T7	T6	T5	T4	T3	T2	T1	T0	未定义

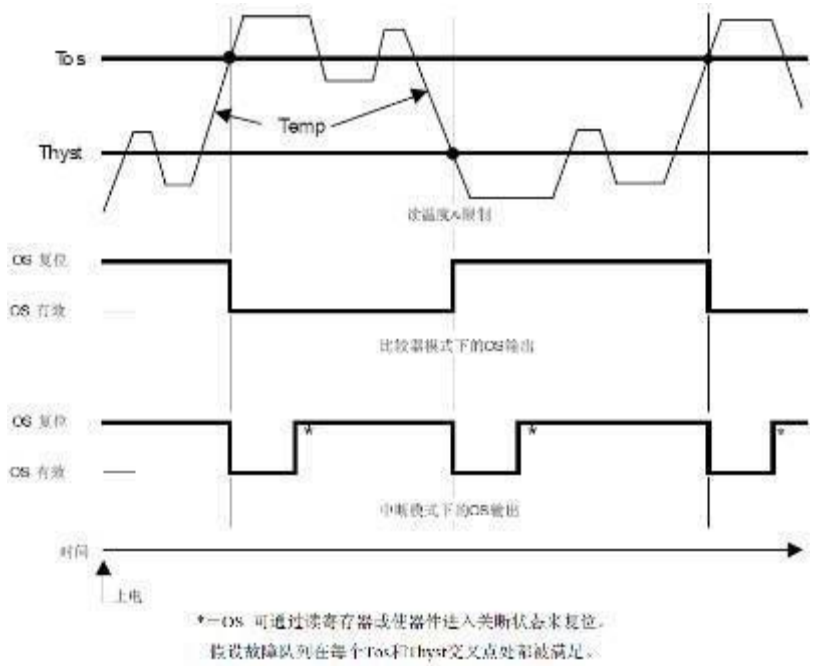
d) Exceeding the temperature shutdown threshold register Tos(0x03)

The over temperature shutdown register provides the upper temperature limit for the temperature control range. At the end of each conversion, the Temp data (taken the upper 9 bits) will be compared to the data stored in this register. When the ambient temperature is higher

than this temperature, the LM75A will control the OS according to the current mode (comparison, interrupt). The pin reacts accordingly. Its data format is shown in Table 4, the default is 80 °C.

e) OS output

The OS output is an open drain output. In order to observe the state of this output, an external pull-up resistor is required, which should be large enough (up to 200kΩ) to reduce temperature reading errors. The OS output can be set to high or low by programming the B2 bit of the Configuration register. As shown in the figure below, the LM75A responds to temperature in the OS pin in different modes. OS is set to active low.



It can be seen that when the LM75A is operating in the comparator mode, the OS outputs a low level when the temperature is higher than Tos. At this time, the cooling measures are taken to start the cooling device (such as the fan), and then the temperature is lowered to Thyst, then the cooling is stopped, so in this mode, the LM75A can directly control the external circuit to maintain the ambient temperature; In the interrupt mode, an interrupt is generated when the temperature is higher than Tos or lower than Thyst. Note: In interrupt mode, the interrupt signal will only disappear when the MCU reads the LM75A (OS goes high in the figure).

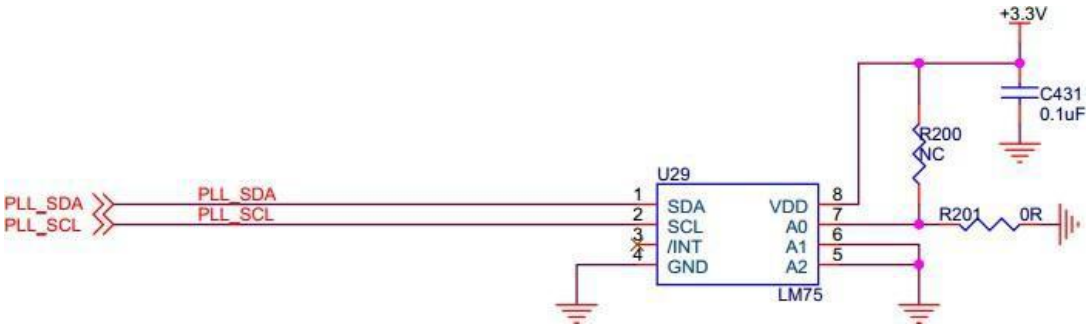
f) I2C serial interface

Under the control of the master, the LM75A can be connected to the I2C bus via SCL and SDA as slaves. The master must provide an SCL clock signal that can be used to read device

data or write data to the device through the SDA. The lower 3 bits of the LM75A slave address (7-bit address) can be determined by the logic levels of address pins A2, A1, and A0. The upper 4 bits of the address are preset to '1001'. The table below shows the full address of the device. As you can see from the table, 8 devices can be connected on the same bus without address conflicts. Since the input pins SCL, SDA, and A2-A0 are internally unbiased, they cannot be left floating in any application.

2.2 Hardware Schematic

The following is the temperature sensor of the AXKU040 FPGA development board.



LM75 schematic

3 Programming

The programming is relatively simple, the function is the FPGA driver. The LM75 temperature sensor continuously reads the temperature value and sends it to the digital tube for display.

Code description:

temp_test.v is the top-level module that contains the i2c_read_lm75, hextobcd, and smg_interface modules;

i2c_read_lm75.v is the temperature reading module of LM75, which reads the temperature value in real time;

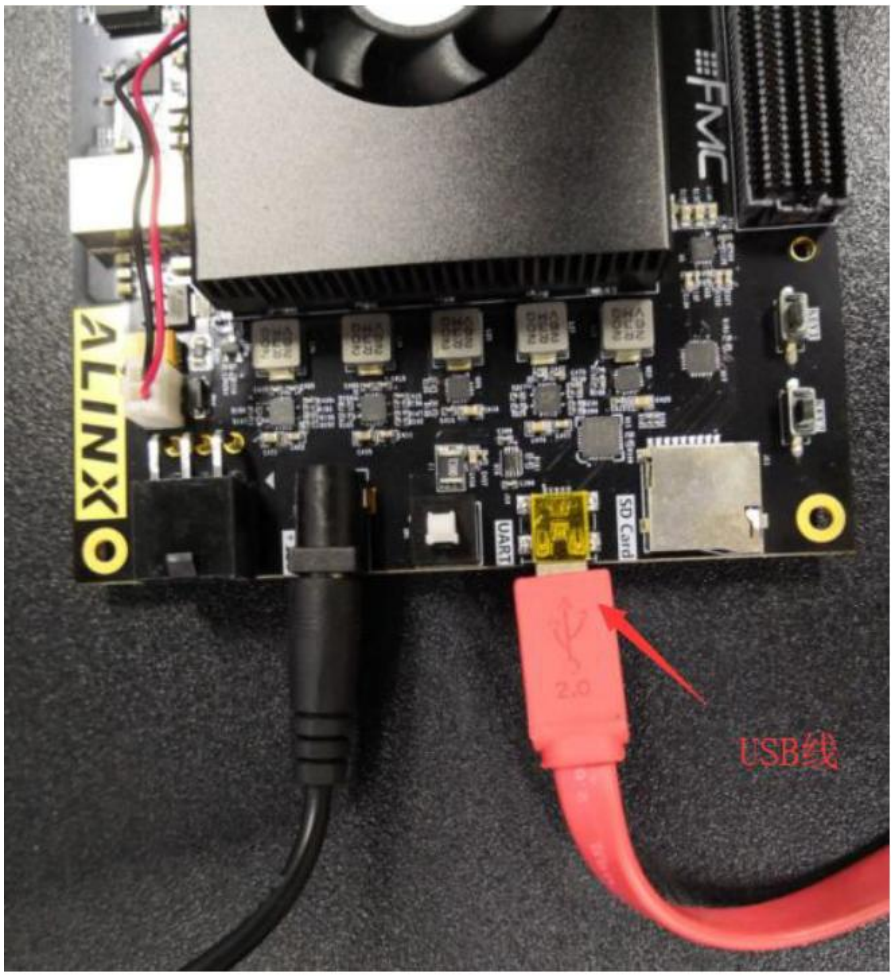
hextobcd.v is a hexadecimal to BCD module;

uart_send.v is the temperature data serial port sending module, which displays the temperature value on the serial port assistant every 1 second.

Pin Name	Functional description
sys_clk	FPGA Input Clock 50MHz
rst_n	Reset signal, active low
scl	I2C Bus clock line
sda	I2C Bus data line
uart_rx	Serial data reception
uart_tx	Serial data transmission
fan_pwm	Fan control

4 Experiment Result

After the compilation is completed, download the program to the AXKU040 FPGA development board and connect the USB cable. You can see that the serial port assistant constantly displays the current value of the temperature sensor, as shown below: (The installation and use of the serial port assistant has been described in the previous serial port transceiver experiment)



Open the serial port and display the current temperature value.