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AND9032

How to Read Temperature Through I²C Bus for NCT75-based Thermostat

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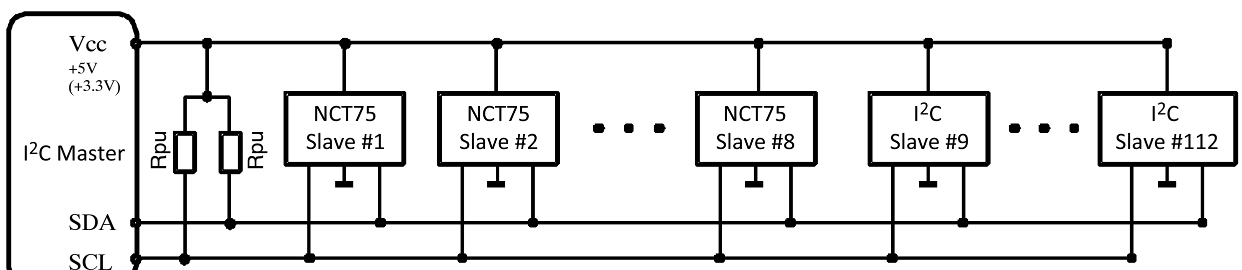
APPLICATION NOTE

Introduction

The NCT75 is a twowire serially programmable temperature sensor with an over−temperature/interrupt output pin to signal out of limit conditions. Temperature measurements are converted into digital form using a 12 bit resolution sigma−delta, analog−todigital converter (ADC). The NCT75 is ideal for extended temperature measurements over the −55°C to +125°C in a variety of industrial, instrumentation, communication, environmental, consumer and other applications. This application note outlines simple example how to read temperature from NCT75 through the I^{2}C bus and outlines NCT75 based thermostat. All supporting documents including Schematic, PCB layout, MicroC MCU (Micro controlled Unit) code are provided in separate compressed file.

I^{2}C Communication

Communication with the NCT75 is accomplished via the I^{2}C/SMBus interface. I^{2}C (Inter−Integrated Circuit, referred as “two−wire interface”) presents a multi−master serial single−ended computer bus and is used for communication with low−speed peripherals. SMBus is a subset of I^{2}C that defines the protocols more strictly. NCT75 supports both I^{2}C and SMBus with minimal re−configuration required. The I^{2}C offers a 7−bit address space with 16 reserved addresses, thus maximum of 112 nodes can communicate on the same bus as illustrated in Figure 1.



Note: I2C addresses: 7bit address space with 16 reserved addresses thus 112 nodes available

Figure 1. I^{2}C Bus Example With Single Master Individual Slave Nodes

In this application single sensor was used (all three address selection pins, A2, A1 and A0 were grounded). The number of sensors can be extended up to eight; just setting of individual I^{2}C addresses and modification of MCU code is required according to user requirements. All six NCT75 registers and communication protocol is described in details in NTC75 datasheet. NTC75 operates only as slave device and supports transmission protocol up to 400 kHz speed. In idle state both SDA and CLK lines remain high.

Each data transfer is initiated with issuing start signal (Figure 2), where SDA line changes from HIGH to LOW, while the SCL line is HIGH. Right after Serial Bus address Byte follows. This Byte is important to define slave address to who master controller need to talk and if access needs to be in write or read mode (R/W – direction bit). The direction R/W bit is used to inform the slave if the master is writing to it or reading from it. If the bit is zero are master is writing to the slave. If the bit is 1 the master is reading from the slave. The 7 bit address is placed in the upper 7 bits of the byte and the Read/Write (R/W) bit is in the LSB (Least Significant Bit). It needs to be considered that the placement of the 7 bit address in the upper 7 bits of the address byte is a source of confusion for the newcomer. It means that to write to address 0x48, you must actually send out 0x90. It is probably easier to think of the I^{2}C bus addresses as 8 bit addresses, with even addresses as write only, and the odd addresses as the read address for the same device. Both READ/WRITE modes for individual addresses are summarized in Tab 1 with corresponding hexadecimal codes. The address byte is followed by next byte which can access NCT75 registers for previously selected write or read operation.

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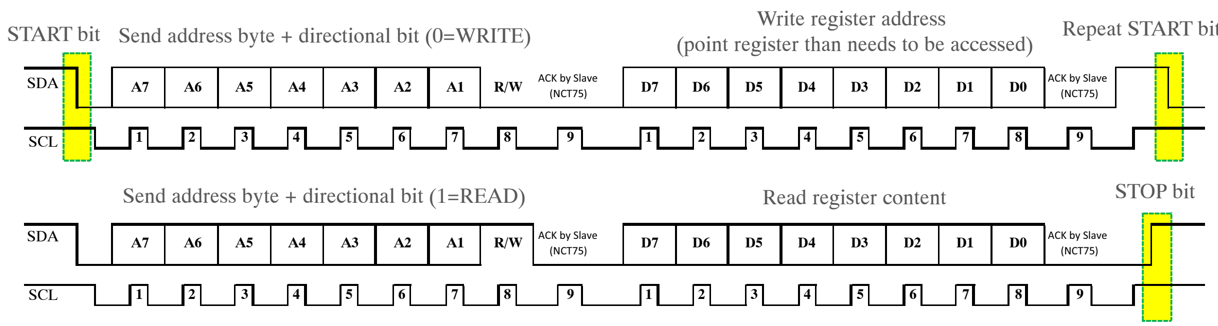

Figure 2. I²C Bus Communication Principle (included Write and Read)

Both READ/WRITE modes for individual addresses are summarized in Tab 1 with corresponding hexadecimal codes. The address byte is followed by next byte which can access NCT75 registers for previously selected write or read operation.

Tab. 1 SERIAL BUS ADDRESS BYTE

MSB A6	A5	A4	A3	A2	A1	A0	LSB R/W
1	0	0	1	0	0	0	X
1	0	0	1	0	0	1	X
1	0	0	1	0	1	0	X
1	0	0	1	0	1	1	X
1	0	0	1	1	0	0	X
1	0	0	1	1	0	1	X
1	0	0	1	1	1	0	X
1	0	0	1	1	1	1	X

Hex code	
Read x=1	Write x=0
0x91	0x90
0x93	0x92
0x95	0x94
0x97	0x96
0x99	0x98
0x9B	0x9A
0x9D	0x9C
0x9F	0x9E

Each data transfer is terminated by change in the state of the SDA line from LOW to HIGH while the SCL line is HIGH. The number of data bytes transferred between a START and a STOP condition is determined by master controller and is not limited. The receiver acknowledges the transfer of data by ACK bit, when addressed. Addressed NCT75 must pull down the SDA line during the Acknowledge clock pulse in such a way that the SDA line is stable LOW during the HIGH period of the Acknowledge Clock pulse. On a master receive, the termination of the data transfer can be signaled by the master generating a Not−Acknowledge on the last byte that has been transmitted by the slave. Setup and hold times must be taken into account, please refer to “Table 5. ELECTRICAL CHARACTERISTICS” of the NCT75 Datasheet.

In this application NCT75 is used in normal mode, where a new temperature conversion executes every 80 ms. This new temperature is then stored as a 12 bit 2s complement word in the temperature value register (address 0x00) and can be accessed by MCU. The temperature data is left justified; D15 is the MSB and is the sign bit. The four LSBs (D3 to D0) are always 0 as they are not part of the result. If the temperature value register is read during the conversion sequence the value returned is the previously stored value. A bus read does not affect the conversion that is in progress. This example was done only for positive temperatures, where temperature value from 12−bit format is calculated as Positive Temperature = ADC Code (decimal)/16 (Example 190h = 400d/16 = +25°C).

Thermostat temperature can be adjusted by global variables in C−code (Tmax and Thyst). If measured temperature is higher than Tmax T1 MOSFET is switched on (indicated by LED1) and hold till temperature drops under Tmax − Thyst, when T1 will be switched OFF as shown in Figure 3. MCU code includes watchdog and practically most of customer requirements can be easily accomplished by MCU code change.

Practical Example

The goal was to design configurable thermostat with supply voltage from 7 V up to 40 V with reverse protection and current protected open drain output to drive a fan. Schematic of the thermostat is shown in Figure 4. Temperature is read from NCT75 through I²C interface by an 8−bit microcontroller (MCU) PIC12F683 from Microchip. The value of pull−up resistors Rpu (R1 and R2 in Figure 4) is not critical. It may range from 1.8 kΩ up to 47 kΩ. Generally, most common used values are 1.8k, 4.7k and 10k. If the resistors are missing, the SCL and SDA lines will always be low (nearly 0 V) and the I²C bus will not work. GP2 MCU output is used to control gate of a protected MOSFET transistor NCV8405 (Fan is connected between pin 1 and pin 2 of “FAN 12 V” connector). This transistor was developed especially for switching applications and offers short circuit protection, thermal shutdown, integrates clamp for inductive loads and has dv/dt robustness. F1 PTC reversible fuse is used additional to limit current below ~1.6 A. Status of the output is indicated by LED1 diode. This diode is emitting if logic 1 is presented on GP2 (T1 ON). MCU and NCT75 are powered from linear regulator NCV8664, which offers 150 mA output current and has very small Quiescent Current (30 μA with 100 μA load).

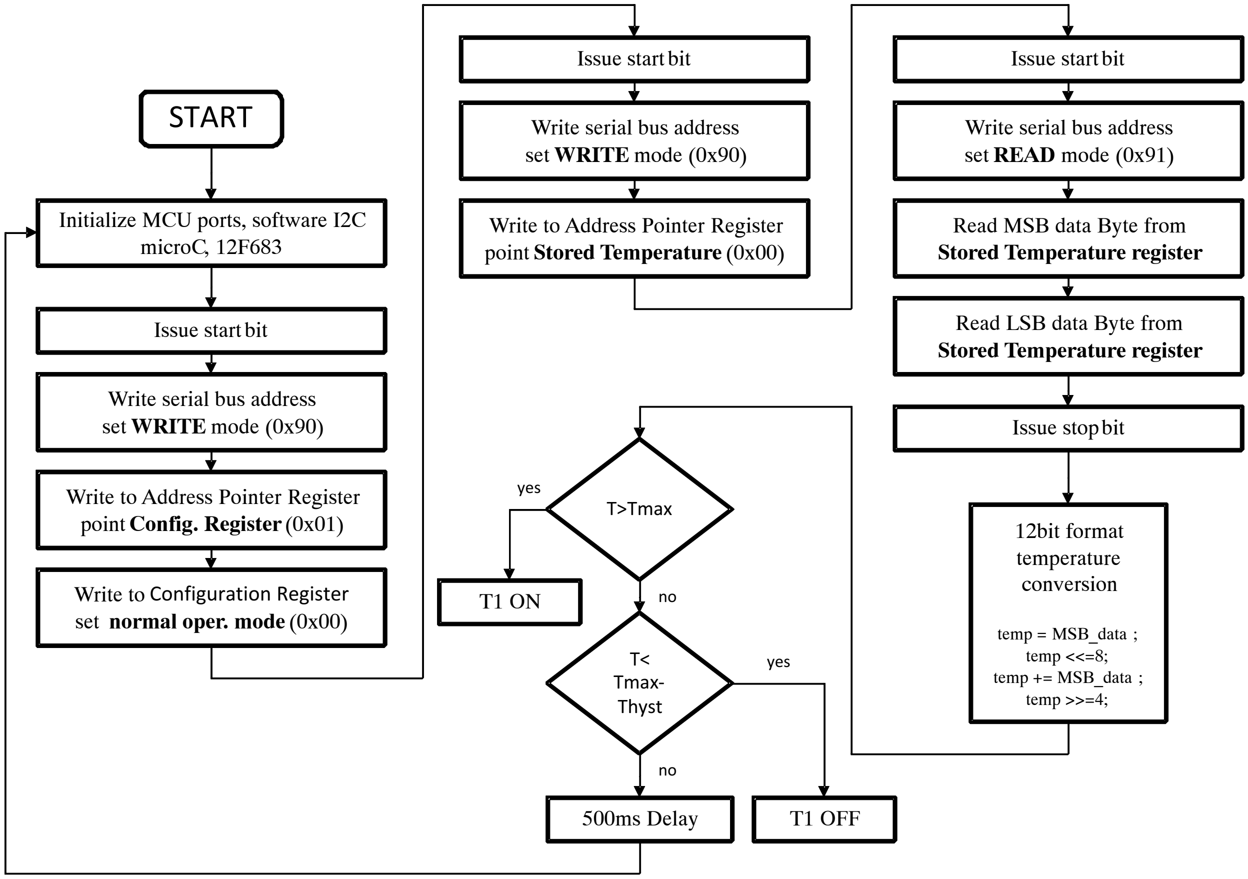

Figure 3. Program Flow Chart

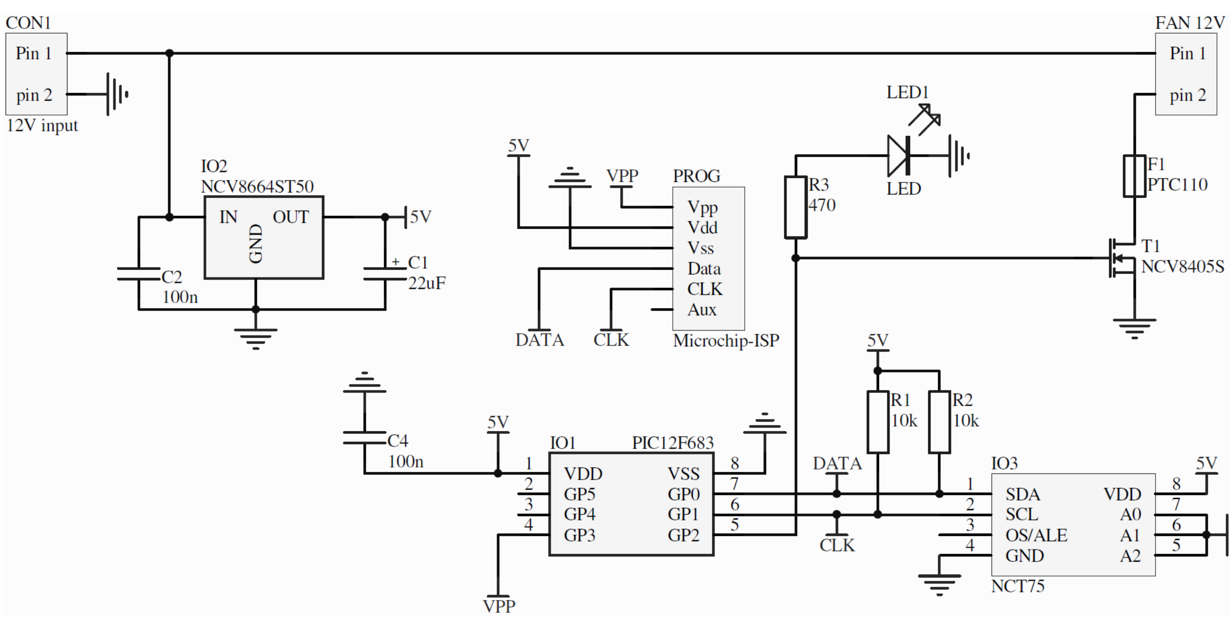

Figure 4. Schematic of the NTC75 Thermostat

Operation of the thermostat (Tmax, Thyst, output state and others) can be configured inside of user MCU code, therefore ICSP interface connector (PROG) was implemented. Just simply change microC code, compile, plug the programmer to the ICSP connector and upload new hex code. As can be seen no other external control is required. Thermostat was assembled on one side PCB board with two junctions as shown in Figure 5.

Conclusion

This note shows simple example how the NTC75 temperature sensor can be implemented for example to form simple thermostat for Fan control. MCU program was written and compiled under Microelectronica micro−C compiler and MCU was programmed by low cost Microchip PICKIT2 ICSP programmer. Such system can be used in numerous applications where temperature measurement and thermal−management is required.

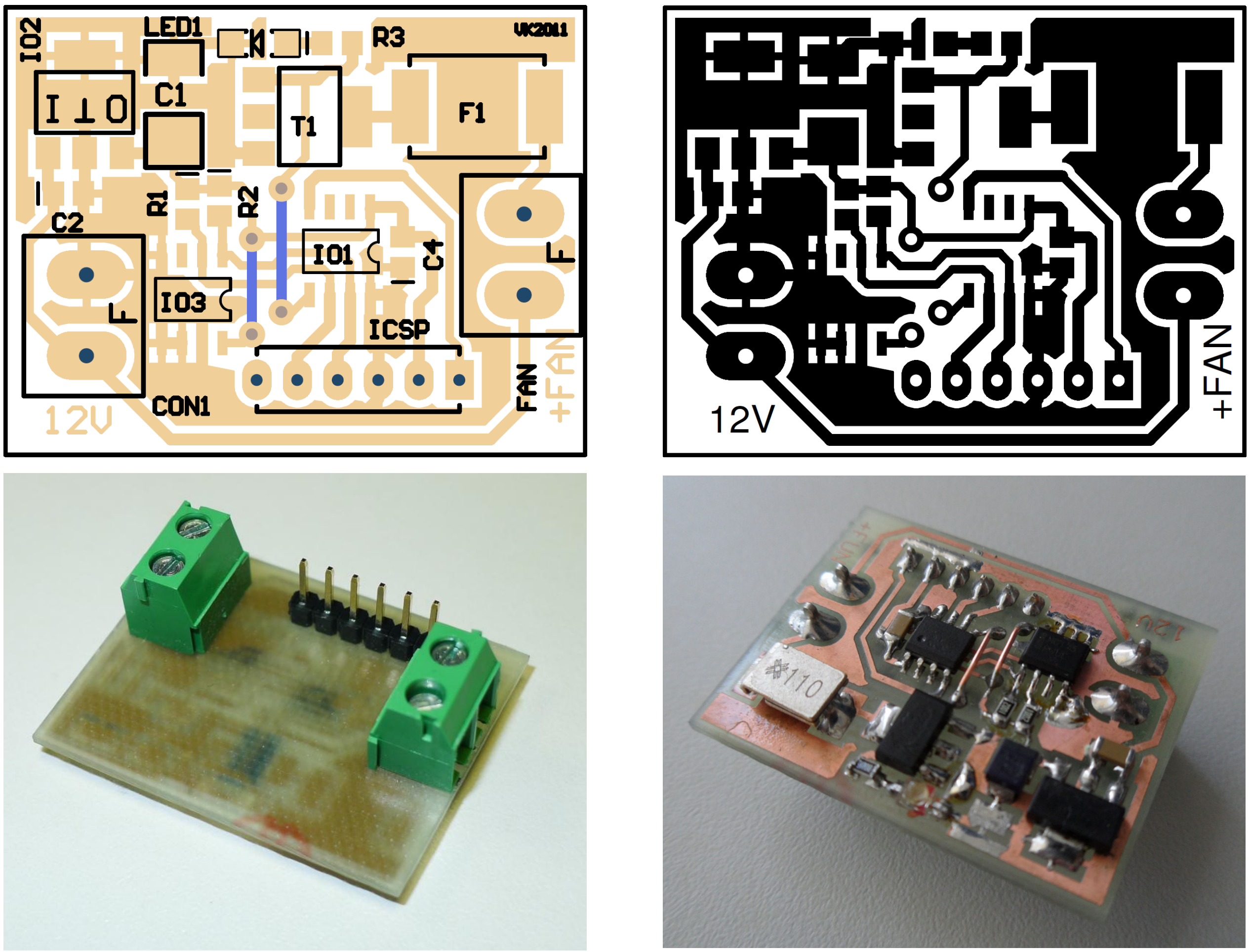

Figure 5. Thermostat PCB Layout (dimensions, 36 x 28 mm)

BILL OF MATERIAL

Designator	Comment	Footprint	LibRef
T1	NCV8405STT1G	SOT223	ON Semiconductor
R3	470	0805	VISHAY
R1, R2	10k	0805	VISHAY
PROG	6−pin connector	6−PIN, 2.54mm	Microchip−ISP
LED1	LED Green	1206	AVAGO
IO3	NCT75DR2G	SO8	ON Semiconductor
IO2	NCV8664ST50T3G	SOT−223	ON Semiconductor
IO1	PIC12F683	SO8	Microchip
FAN 12V	PCB Terminal 2P	TB2P5	Wago
F1	MF−SM100	MF−SM−3425	Bourns
CON1	PCB Terminal 2P	TB2P5	Wago
C2, C4	100n	0805	AVX
C1	22uF	TANT−60−32	AVX

References

NCT75 http://www.onsemi.com/PowerSolutions/product.do?id=NCT75
NCV8664 http://www.onsemi.com/PowerSolutions/product.do?id=NCV8664
NCV8405 MOS http://www.onsemi.com/PowerSolutions/product.do?id=NCV8405
MicroC compiler http://www.mikroe.com/eng/home/index/
PIC12F683 http://www.microchip.com/wwwproducts/Devices.aspx?dDocName=en010115
I^2C Background: http://en.wikipedia.org/wiki/I2C

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