MEASUREMENT OF TEMPERATURE AND HUMIDITY USING SHT11/71 INTELLIGENT SENSOR

Assist. Prof. Grisha Spasov, PhD, BSc Nikolay Kakanakov

Department of Computer Systems, Technical University – branch Plovdiv, 25, "Tzanko Djustabanov" Str., 4000 Plovdiv, Bulgaria, +359 32 659 576, e-mail: gvs@tu-plovdiv.bg, kakanak@tu-plovdiv.bg

Keywords: temperature and humidity measurements, intelligent sensors, distributed automation and control

The paper discusses the advantages of intelligent sensors. It presents an SHT11/71 temperature and humidity combined sensor from Sensirion. This sensor is ideal for developing distributed embedded systems for monitoring environmental parameters.

An example application using this sensor is added to present SHT11/71 in real working condition. The application is distributed system for monitoring temperature and humidity. It uses a microcontroller with integrated web server to organize the communication and management of sensors. This application is realized and tested.

1. INTRODUCTION

Measurement and control of temperature and relative humidity has significant appliance in industry, science, healthcare agriculture and controlling technological processes. These two environmental parameters strongly influence each other and it is critical in some application to measure them in parallel. Using modern technologies it is possible to combine temperature measurement element, humidity measurement element, amplifier, ADC, digital interface, calibration memory and CRC calculation logic in a single chip with very small size [1,3].

Using intelligent sensors of this kind can shorten the development time and cost. Integrating ADC and amplifier into sensor's chip allow developers to optimize sensor elements for accuracy and long-term stability. And that is not all – integrating digital interface logic simplifies connectivity and management of sensors. These advantages can reduce whole time-to-market time and even price [1,3].

In presented paper we use SHT11/71 intelligent sensor from Sensirion as an example and present its advantages and measurement procedures. An example application is also presented to demonstrate its work in real conditions. This application is realized and tested.

2. INTELIGENT SENSORS – SHT11/71

SHT11/71 is a single chip relative humidity and temperature multi sensor module comprising a calibrated digital output. The device includes a capacitive polymer sensing element for relative humidity and a bandgap temperature sensor. Both are seamlessly coupled to a 14bit ADC and a serial interface circuit on the same chip. This results in high signal quality, a fast response time and insensitivity to external disturbances (EMC). Each SHT11/71 is individually calibrated and calibration coefficients are programmed into the OTP memory. The 2-wire serial interface and internal voltage regulation allow easy and fast system integration [1].
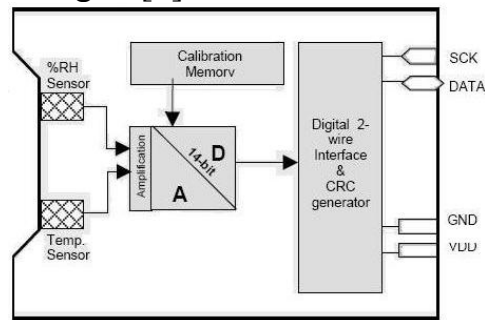
The SHT11/71 is shown on fig. 1 [1].

Figure 1: Sensor's organization

Combining temperature and humidity sensing elements in single unit enables precise determination of dewpoint, without incurring errors due to temperature gradients between elements. The signal amplification near the sensor allows the polymer layers to be optimized not for signal strengths, but rather for long-term stability. Performing analog-to-digital conversion "in place" makes the signal extremely insensitive to noise. A checksum generated by the chip itself is used for additional reliability. The calibration data loaded on the chip memory guarantees that humidity sensors have identical specifications and thus they are 100% replaceable [1].

Some of the advanced functions of the SHT11/71 are available trough the status register. Some of them are: internal heating element; regulation of measurement resolution to optimize for precision or for fast response; End-Of-Battery (EOB) detection (low voltage detection). Status register size is 8 bits but only four of them are used [1].

SHT11/71 can be connected directly to any microcontroller by means of the digital 2-wire interface. This interface is optimized for sensor readout and power consumption and is not compatible with I2C interfaces [1]. (See fig. 2)
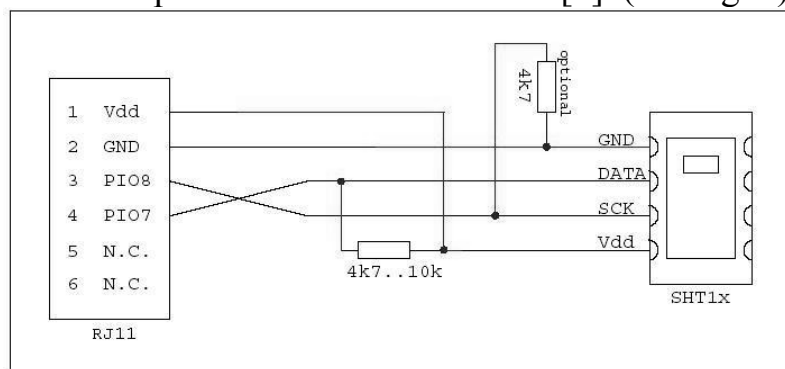

Figure 2: Connection of SHT11/71 to the μC

Two wires are used to transfer serial clock (SCK) and data (DATA). The SCK is used to synchronize the communication between a microcontroller and the SHT11/71. Since the interface consists of fully static logic there is no minimum frequency. The DATA tristate pin is used to transfer data in and out of the module. It changes after the falling edge and is valid on the rising edge of the SCK. During the transmission the DATA line must remain stable while SCK is high [1].

Signals over the two lines during an example transmission are shown on fig. 3 [1].
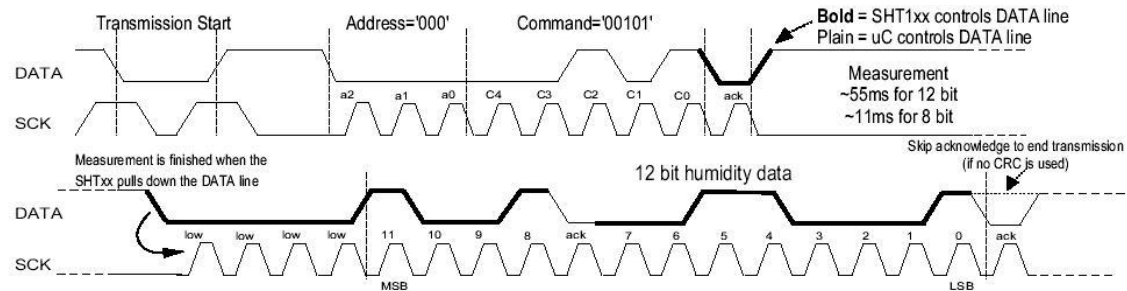
Figure 3: Example signals over 2-wire interface

3. MEASUREMENT OF TEMPERATURE AND RELATIVE HUMIDITY

A measurement using SHT11/71 is a two-step procedure. First, it is necessary to send command for measurement to the sensor and get the data through the digital interface. Second, it is necessary to convert data from sensor to real physical values and to calculate the temperature compensation of the humidity data [1].

3.1 Sending a command and receiving data

To initiate a transmission, a "transmission start" sequence has to be issued. It consists of a lowering of the DATA line while SCK is high, followed by a low pulse on SCK and raising DATA again while SCK is still high [1].

The subsequent command consists of three address bits (only .000. is currently supported) and five command bits. The SHT11/71 indicates the proper reception of a command by pulling the DATA pin low (ACK bit) after the falling edge of the 8th SCK clock. The DATA line is released (and goes high) after the falling edge of the 9th SCK clock. Two bytes of measurement data and one byte of CRC checksum are transmitted. The μC must acknowledge each byte by pulling the DATA line low. All values are MSB first, right justified. Possible commands are: "get temperature", "get humidity", "change measurement resolution", "get status register value", "set status register value" [1].

Communication terminates after the acknowledge bit of the CRC data. If CRC-8 checksum is not used the controller may terminate the communication after the measurement data LSB by keeping ACK high. The device automatically returns to sleep mode after the measurement and communication have ended. [1]

3.2 Converting Output to Physical Values

To compensate for non-linearity of humidity sensing element and to obtain the full accuracy it is recommended to convert the readout with the following formula [1,3]:

$$RH_{linear} = c_1 + c_2 + c_3.SO_{RH}^2.$$

Coefficients c_1, c_2 and c_3 depend only on measurement resolution. For 12bit resolution: $c_1 = -4$, $c_2 = 0.0405$ and $c_3 = -2.8*10^{-6}$. For 8bit resolution: $c_1 = -4$, $c_2 = 0.648$ and $c_3 = -7.2*10^{-4}$.

For temperatures significantly different from 25°C the temperature coefficient of the humidity sensor should be considered [1,3]:

$$RH_{true} = (T_{°C} - 25).(t_1 + t_2 + SO_{RH}) + RH_{linear},$$

where $t_1 = 0.01$ and $t_2 = 0.00008$ for 14bit and $t_2 = 0.00128$ for 8bit resolution [1].

The bandgap PTAT (Proportional To Absolute Temperature) temperature sensor is very linear by design. Use the following formula to convert from digital readout to temperature [1,3]:

$$Temperature = d_1 + d_2.SO_T.$$

VDD	d_1 [°C]	d_1 [°f]		SO_T	d_2 [°C]	d_2 [°f]
5V	-40.00	-40.00		14bit	0.01	0.018
4V	-39.75	-39.50		12bit	0.04	0.072
3.5V	-39.66	-39.35				
3V	-39.60	-39.28				
2.5V	-39.55	-39.23				

Table 1   Temperature conversion coefficients

Since humidity and temperature are both measured on the same monolithic chip, the SHT11/71 allows superb dewpoint measurement.

4. DISTRIBUTED SYSTEM FOR MONITORING TEMPERATURE AND HUMIDITY

On the figure 4 below a functional scheme of distributed system for monitoring temperature and humidity, based on IPC@Chip is shown [2,4].
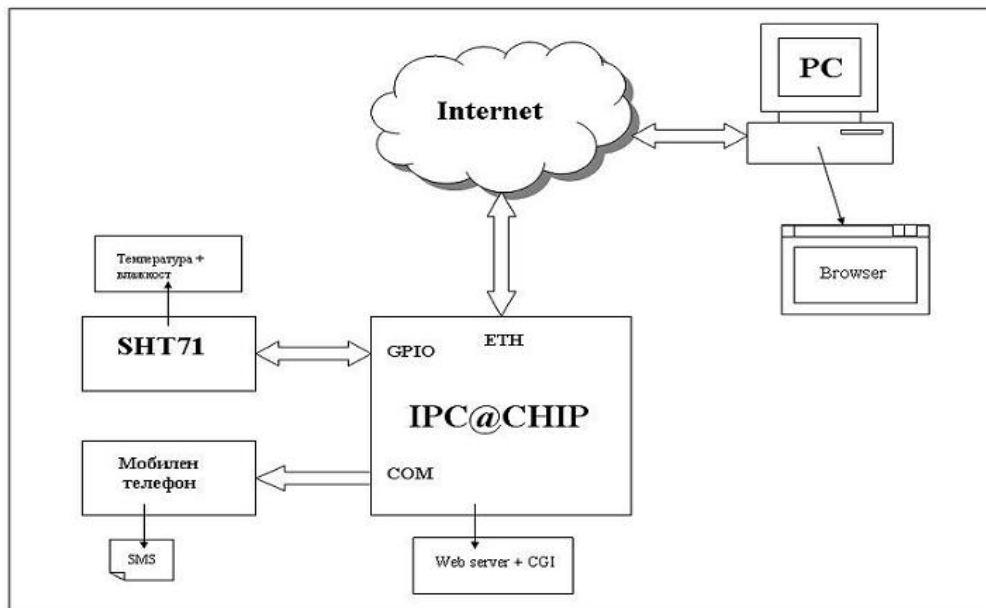

Figure 4: Functional scheme of the application

The functions of the system are separated between the four main blocks, as follows [2,5]:

− The internet browser assures that the system has a familiar user interface. The visualization of the monitored parameters is placed here.

- The integrated Web server in conjunction with the CGI deals with the control of the remote processes and the transfer of dynamic HTML pages to the client. The real-time operating system (RTOS) of the IPC@Chip manages with the Web server's tasks, TCP/IP communication, local peripherals, user tasks and interconnection between them.
- Users' applications and tasks, running on the controller, are used for automation purposes. In our case, this is the sensor driving and management of the SMS communication.

The software of this system consists of several blocks. One block is for temperature and humidity measurement, one – for communication with the GSM gateway and sending SMS and one is for generating dynamic HTML documents with the data from the sensor.

Before every measurement a software restarting of the sensor's interface take place. After that an initialization command is sent and controller waits 11ms. After this procedure a real measurement can start. The measurement block consists of two identical parts, one – for temperature measurement and one – for humidity measurement. The microcontroller sends a command to the sensor to get data. After getting data μC normalizes and stores it in the operating memory. The two identical parts are executed sequentially and are repeated together. Between every two iterations of this cycle the task "sleeps" for about one minute to free the processor for tasks with low priority (like FTP, Web, Telnet).

The communication between the controller and the sensor is trough 2-line interface (data and synchronization). A C-library based on the software interrupts of the RTOS is made for this communication. This library has the following functions:

- shttransstart() – starts a transmission;
- shtreset() – for restarting of the sensor;
- shtinit() – initializes the sensor interface;
- shtsend() – sends a command;
- shtrecv() – receives data from sensor.

These functions are used to control the sensor's work trough the 2-wire interface and to get temperature and humidity data. This data is stored in the controller memory and then converted using formulas for non-linearity and temperature compensation.

To see the results of the measurement the client sends a HTTP request to the web server and the server sends a HTML document as a reply. CGI is the instrument that connects the web server with the internal data on the controller. It runs as a task and do not use data received from the client, but rather uses data from the measurement block. This transfer of data is carried out with a block of shared memory. The measurement block writes data in this memory and the CGI task reads and use this data. It generates a short HTML document containing the temperature and humidity values from the last measurement.

Example web document sent as a reply from the integrated web server with the results is shown on figure 5.

Figure 5: Web interface of the application

For controlling the parallel execution of these tasks a small program is written. This program read initialization data from files on the controller memory, installs and uninstalls the CGI processes, declares a semaphore from RTOS and frees it, releases the unused memory and stops the unneeded tasks. The other purpose of this program is to allow adding a security to the project using identification and authorization [2].

5. CONCLUSIONS AND FUTURE WORK

Intelligent sensors with their advantages like combining temperature and humidity sensing elements, integrating ADC, amplifiers and serial interface make development of measurement systems easier. These advantages also decrease development time and cost and the size of the product. One application where these sensors find place are distributed measurement and monitoring systems like meteorological stations, HVAC systems, automotive temperature control and many others.

The SHT11/71 has an address of 3bits, which in present sensors cannot be changed from "000". This address can be used for future applications like sensor networks and adhoc sensor networks which are leading tendencies in automation and control technologies.

6. REFERENCES

[1] www.sensirion.com/sensors/humidity/ – SHT71 datasheets and info.
[2] Spasov G., Kakanakov N. – *CGI-based applications for distributed embedded systems for monitoring temperature and humidity*, CompSysTech'04, 17-18 June 2004, Rousse, Bulgaria
[3] www.measure.com/sensors/ – measurement technology.
[4] www.beck-ipc.com – IPC@Chip info and applications.
[5] Djiev, S. – *Communication Networks in controlling systems*, Automation and Informatics, No.2, pp 13-17, 2003.