Concept of an Intelligent Microsystem Structure for Communication with Real Surrounding Space

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ABSTRACT

In the paper, concept of intelligent microsystem structure is presented. This concept is applicable in general surrounding environment. Concrete model of an intelligent temperature microsystem for control purposes is designed.

Microsystem function has been verified on a realized hardware model. The system is composed of sensors, actuators and part for control and data processing. Communication is performed using wireless radiofrequency signal transmission. System activity is controlled by a microprocessor. User communicates with the system using a keyboard. A central unit enables connection of up to 15 external sensor units.

Presented system works in temperature range from 0 °C to 50 °C with precision of 0.2 °C, communication range is 50 m, control of temperature hysteresis in the range 0.2 to 6 °C.

Keywords: Microsystems, sensors, actuators, control, temperature, data communication, wireless.

1 INTRODUCTION

Sensors and actuators become basic microsystem elements working in real surrounding environment. Solving microsystem structures enables us to acquire qualitatively better properties usable in all areas of human life. In the resulting arrangement, the microsystems are realized as “micro” using suitable and available technologies. Some of the technologies are often developed directly for this purpose.

For modelling microsystem properties, it is possible to use “macromodels” as well. They can be realized e.g. using available electronic elements. With mathematical support and using analogy between physical quantities, microsystem model can be developed that are very close to real microsystem with respect to their properties.

Problems of exact data acquisition from sensors and data transmission to control elements or actuators are very topical in many areas of non-electric quantities processing. Successive integration of designed systems on one or more chips improves reliability and usability, and decreases consumption of electric energy for system feeding. A system aimed at use in control circuits, having sensor inputs, actuator outputs and exploiting software algorithms, can reach very good parameters. Systems used in interdisciplinary areas are known as microsystems nowadays.

2 DESIGN AND REALIZATION OF MICROSYSTEM MODEL

2.1 General microsystem model

We have designed a model structure of an intelligent microsystem with contactless communication between measuring sensors and control unit – Fig.1. The topic of the described work has been development of a model (design of concept and structure, realization of hardware model) of an intelligent microsystem whose structure can be modified for other energy spaces (chemistry, biology, etc.). In this phase of problem solving, the model considers activity only in one energy space - temperature domain.

Concrete solution is realization in temperature domain. The system consists of individual functional blocks. Activity control and certain level of intelligence are accomplished by the central control unit (in the model a microprocessor has been used). Sensor blocks represent electronic convertors where there is non-electric quantity on the input and the output is in digital form suitable for processing in the central control unit. Actuator(s) represents a convertor of digital control signal to signal controlling corresponding energy domain. Mutual communication inside the microsystem is performed on the communication bus.

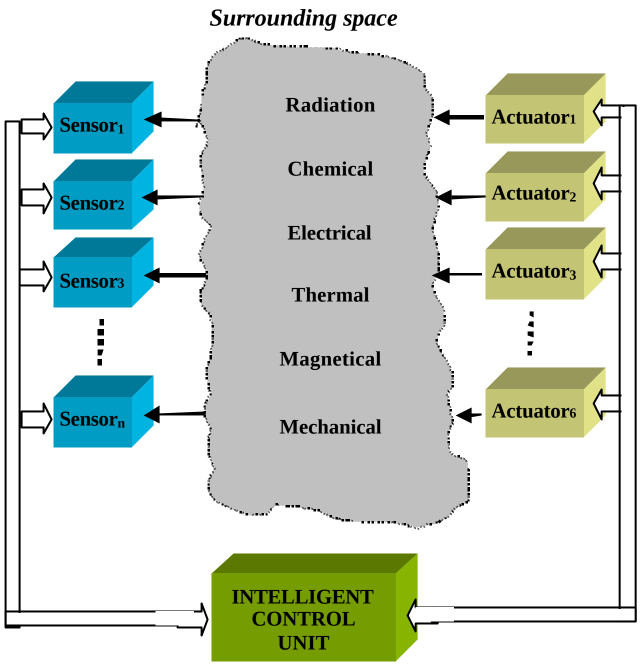

Figure 1: Concept structure of intelligent microsystems.

Activity control and certain level of intelligence are accomplished by the central control unit.

Communication of each sensor unit with the control unit is done using radiofrequency method.

2.2 Concept of temperature microsystem

Concept of an intelligent microsystem has been designed for temperature control in surrounding environment. The system is designed with independent communication with individual parts of this environment (e.g. rooms in a house). System intelligence is "hidden" in software.

Designed and realized model of the temperature sensor control system is illustrated on Fig.2.

The core of the designed system is the control unit with a microprocessor. The microprocessor controls switching of the actuator, communicates with sensor units, control keyboard and informs about system state using alphanumeric display. Communication of control unit is performed via serial communication bus. Communication of each sensor unit with the control unit is done using radiofrequency method (possibly corresponding bus standard).

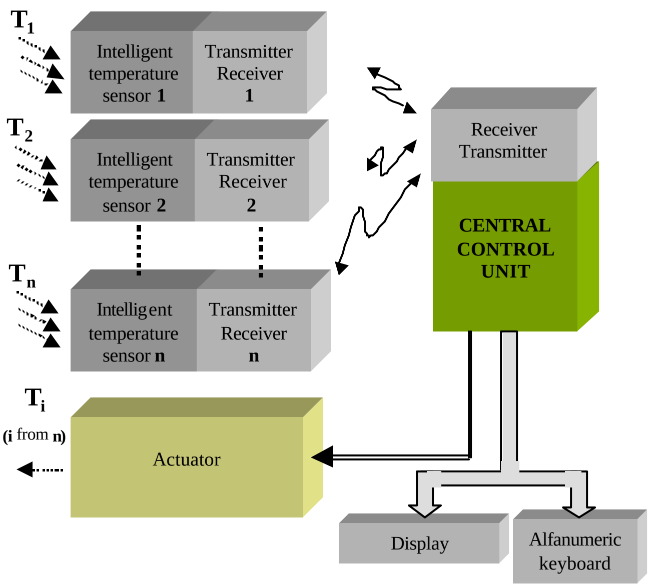

Figure 2: Block diagram of intelligent temperature control system.

2.3 Central control unit

The core is represented by one-chip microprocessor AT89C55 with 202 kB of program memory. Other parts are attached to the processor – alphanumeric display, matrix keyboard, real-time clock, wireless communication module and further circuits (e.g. optotriac MOC3404 and triac TIC225M for galvanic separation of control unit from electric network and interference minimization, etc.). The microprocessor works on the frequency 11.0592 MHz. From this frequency, standard transmission speed of the serial channel - 4800 Bd - is derived.

Real-Time Clock Circuit

Circuit PCF8583 [3] has been selected for real-time clock circuit. On one chip there are real-time clock with 2048 bits and static CMOS RAM memory. The memory uses 256 words of 8 bit length. 8 bits of RAM memory are used for clock, calendar and counter functions, 8 bits for alarm and 240 bits for user data. Addresses and data are transmitted via serial communication bus I^2C.

Alphanumeric Display

Intelligent alphanumeric display MC1602E [4] is used for communication between the system and the user. The display is controlled by the microprocessor using 8 bits and 80 bytes of RAM memory (saving 80 character).

Software equipment

For programming of required system functions, C51 language has been selected (C programming language for 8051 processor series). Software controls activity of the whole system according to defined functions. In the model, the day (24 hours) has been divided into 6 time intervals of different length. In each time interval, it is possible to specify beginning and end time of that interval, number of the sensor that will be communicating. In this way it is possible to set individually each day in week. The idea of temperature settings for one day (24 hours) is presented in Table 1. T_1 through T_6 are required set temperatures, t_1 through t_5 represent end times of individual intervals. The last interval ends automatically after 24 hours (i.e. at midnight).

Sensor No.	S_1	S_2	S_3	S_4	S_5	S_6
Temperature	T_1	T_2	T_3	T_4	T_5	T_6
End of time	t_1	t_1	T_1	t_1	t_1	24

Table 1: Setting of 6 time intervals.

In addition to these basic functions, the system enables to perform further functions, e.g. search for maximum and minimum of followed quantities, system control according to these extremes, etc. The system activity is independent on user operations (e.g. system configuration). This activity is enabled by so-called multitasking that is very demanding from the point of view of processor and other system tools. In our environment, we have used algorithms of creating ***"transit"*** function that satisfies condition of independence of system activity. Basic principle lies in automatic finishing of individual functions in case of their "idleness". It enables to perform other system functions. Individual functions are called repeatedly (in a cycle), their execution time is relatively short. Resulting program behaves as a very simple "multitasking" system.

It is necessary to use global variables for each function to save current function state and possibly further values. That puts higher demands on system data memory.

2.4 Sensor unit

Sensor unit is an autonomous system with its own power supply. Unit activity is controlled via wireless transmission. The unit is composed of an integrated temperature sensor, RF transmitter and receiver, inner data bus, microprocessor, software, battery power supply.

Integrated temperature sensor.

The core of the sensor unit is represented by the temperature/electric signal convertor. For realization of the model, integrated temperature sensor LM76 has been used. This circuit has an integrated A/D convertor with control serial interface I^2C. Integrated temperature sensor is controlled via this bus and information on current temperature is transmitted in this way as well. Required defined sensor function is set by recording data into internal registers. Information on current temperature [1] is acquired by reading content of temperature register. Implicit values are recorded into registers during rise time of supply voltage. Access to individual registers is controlled via communication bus.

Connection, including circuits of autonomous power supply of the intelligent sensor unit, is shown in Fig.3. The LTC3200 circuit serves as the DC/DC convertor. Circuit data control enables transition into stand-by mode in case that the sensor unit is not active (current consumption < 1 μA).

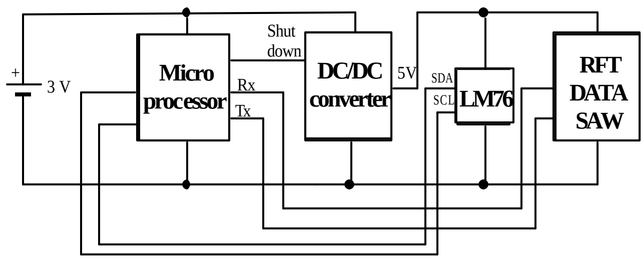

Figure 3: Connection of intelligent sensor unit.

Serial Communication Bus I^2C.

Setting of internal circuit functions and reading information on measured temperature is performed through serial communication bus I^2C. The bus is two-way two-wire with serial data transmission between individual circuit parts. Data are transmitted using data line (SDA*)*, clock line (SCL) is used for transmission of clock signal. Line outputs consist of transistors with open collectors – see Fig. 4.

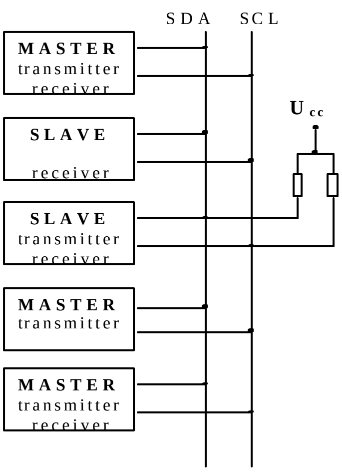

Figure 4: Basic connection of communication bus I^2C.

In the given time moment, only one MASTER circuit participates in communication through MASTER/SLAVE bus. The MASTER circuit addresses one of the subordinate SLAVE circuits. Data bit is transmitted during every clock pulse.

Communication Circuit for Wireless Communication.

The circuit of the temperature sensor is completed with a communication circuit for wireless communication RFT-DATA-SAW with working frequency 433.92 MHz. The circuit enables two-way transmission of digital data using half-duplex radiofrequency operation with fast switching between transmission and reception (< 100 ms) and encoding of carrier TTL level. Maximum transmission speed is 4800 Bd [2].

3 REACHED RESULTS

Designed model of the temperature microsystem has been realized from discrete elements. Basic system functions have been verified on the functional model, especially precision of transmitted information on measured temperature in dependence on space geometry. Information on measured temperature displayed by the system has been compared with data from precise thermometer with Pt sensor. The results are displayed on Fig. 5.

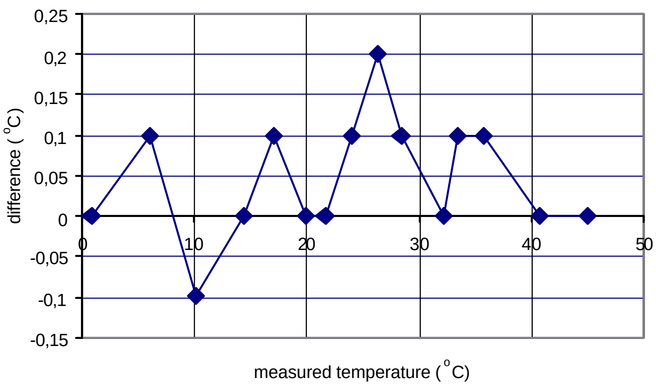

Figure 5: Difference between displayed data from the thermometer and system.

ΔT indicates difference between displayed data from the thermometer and system. Communication range has been determined in dependence on length of the antenna of communication module and geometry of obstacles in the space. The measured values are presented in Table 2.

Antenna size (mm)	85	170
Communication range *open space* (m)	25	50
Communication range *Space with obstacles* (m)	12	32

Table 2: Communication reach.

On Fig.6 there is displayed the space geometry, in which the communication range has been determined.

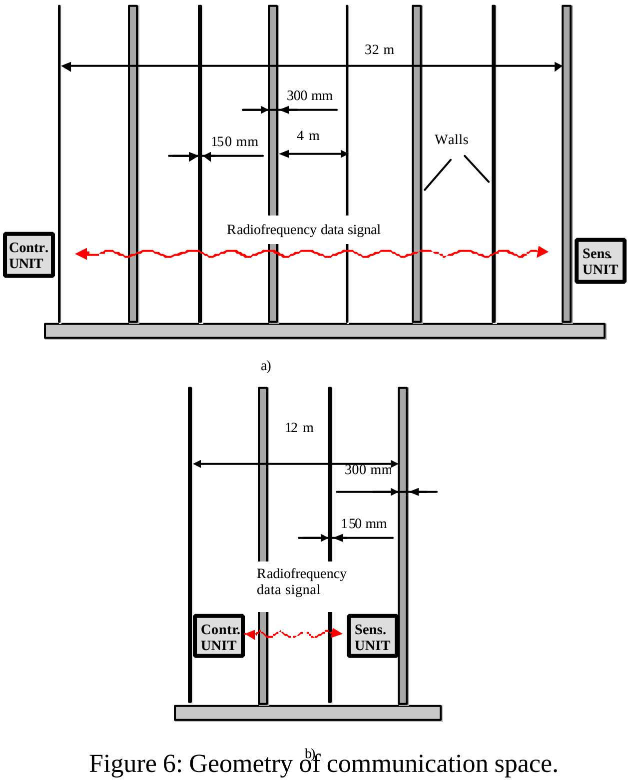

Figure 6: Geometry of communication space.

4 CONCLUSIONS

Based on general microsystem model, there has been designed a simple temperature system. System hardware model has been realized.

Designed system is controlled by a central unit. It enables connection of up to 15 external sensor units with two-way wireless communication.

It represents a simple example of one out of many microsystem solutions, generally applicable in various energy domains, possibly their overlapping.

The systems consist from the basic control unit with microprocessor, sensor units and actuator. The control unit makes sensor data processing and timing and logic function of all system.. All time dependent functions are controlled by real-time clock. Information on system state are displayed on alphanumeric display. Communication between user and the system is realized through the keyboard.

For temperature measurement, integrated temperature sensor with digital output LM76 is used. Wireless communication and data transmission between sensor units and control unit is realized by high-frequency radio signal with frequency of 433.92 MHz.

All system functions are executed by modified software. System can be configured for different time and temperature modes.

Presented hardware model works in temperature range from 0 °C to 50 °C with precision of 0.2 °C, communication range is 50 m.

The system enables control of temperature hysteresis of controlled system in the range 0.2 °C to 6 °C.

System precision has been determined by comparison of data displayed by the system and data from the precise thermometer. In the temperature range 0.8 °C to 45 °C, the maximum absolute measurement error has been 0.2 °C. Rated current consumption of sensor unit has been 330 µA at supply voltage of 3 V.

The system has automatic detection of basic fault states (sensor failures, interruption of data transmission, decrease of supply voltage, etc.).

5 ACKNOWLEDGEMENTS

This research has been supported by the Grant Agency of the Czech Republic project No. 102/00/0939 “Integrated Intelligent Microsensors and Microsystems”, by the following research programme of the Czech Technical University in Prague: No. MSM 210000012 „Transdisciplinary Biomedical Engineering Research“.

REFERENCES

[1] LM76 catalogue, http: // www.national.Com/catalog /AnalogTempSensors.html (17.10.2000)

[2] Aurel: Wireless System. Catalogue, RTF DATA SAW (http: // www. aurel. it), http: // www. aurel. It / Uk / Wireless / Wireless / Rx - Tx/ ordering _ informations _ RTX2.htm

[3] Catologue PCF8583, http: // www. philips. com, http://www-us6. semiconductors. com/ pip/ PCF8583T

[4] http://www.neumueller.com