Wireless SensorSystem with Bidirectional Communications

M. Husak, A. Boura and J. Jakovenko

Department of Microelectronics
Faculty of Electrical Engineering, Czech Technical University in Prague
Technicka 2, CZ – 166 27 Prague 6, CZECH REPUBLIC
husak@fel.cvut.cz

ABSTRACT

The system contains units: wireless, control, actuator, software equipment. RF wireless unit ensures wireless communication between control unit and sensors as well as wireless switch unit. The control unit controls system operation, i.e. communication transfer, sensor data processing as well as switching of actuator unit. Actuator switch unit is wireless controlled by control unit. There were hardware and software realized and tested in the designed system. The system was designed to operate with different type of physical sensors. The system can used PC, PDA or mobile phone to communication as well as signal processing. The control unit communicates with wireless temperature sensors and wireless switch units. The wireless temperature sensors measure temperature periodically and convey the measured data to the control unit. The actuator units communicate with the control unit. The main part is the control microprocessor. The run of the system is supported by the control programs.

Keywords: sensors, control, wireless, data communication, temperature, signal processing, actuator, microprocessor, control program

1 INTRODUCTION

The system was designed and realized. One is used as a support for wireless transfer of sensor data. The system was designed as modular with possibilities of number components extending. The system was designed for measurement and control use. There is described a new architecture of a multisensor system for remote temperature measurement using wireless communications in the paper. There are used sensors with digital outputs in the system [1]. The number of sensor can be variable. The control software of the whole system has been designed. Partial control programmes were designed for wireless unit control. There are many program functions implemented. The system contains units: wireless, control, actuator, software equipment. RF wireless unit contain integrated RF chip nRF9E5. One ensures wireless communication between control unit and sensors as well as wireless switch unit. The control unit controls system operation, i.e. communication transfer, sensor data processing as well as switching of actuator unit. Actuator switch unit is wireless controlled by control unit. There were hardware and software realized and tested in the designed system. Wireless communication is ensured in the range of 300 m in the free space. The system was designed to operate with different type of physical sensors. The system can used PC, PDA or mobile phone to communication with control unit as well as signal processing [2].

2 WIRELESS SENSOR NETWORK

The suggested wireless thermostat consists of several parts [3]. The control unit is the basic part, securing communication with the user by means of the display and keyboard. The unit communicates with wireless temperature sensors and wireless switch units. It is provided with custom-set programs “temperature intervals”, controlling the whole system. Second part of the system is represented by the wireless temperature sensors. The sensors are placed in required localities. The sensors measure temperature periodically and convey the measured data to the control unit. The third part is the wireless switch units. The units communicate with the control unit periodically and switch relays on or off according to the measured temperatures and values set by the user. A block schematic diagram of the whole system is shown in Fig. 1.

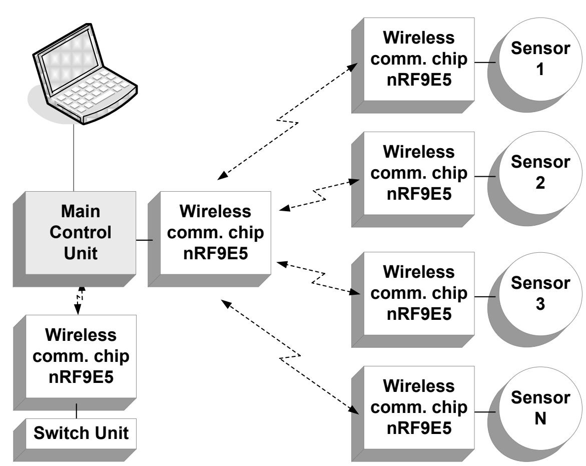

Figure 1: Wireless sensor network.

The temperature sensors and switch units can be placed at random individually and independently according to the user's needs. The only condition they have to fulfill is that they must lie within the wireless communication range. The communication with the user is performed by means of six push buttons and a 4 line display. Most user program settings and settings of further parameters is dome with the aid of a menu appearing on the display upon pressing the appropriate button. During normal operation, information from individual zones are displayed periodically. They indicate the set and measured temperature in a particular zone, sensor and control unit battery voltage as well as an indication of on or off state of the relay contacts.

3 DESIGN OF SYSTEM UNITS

The communication runs according the following scheme (by the Fig. 1): Before start of a transmission, each temperature sensor or switching unit checks if another unit is not transmitting. Then the sensor transmits its data to the control unit and waits for reception acknowledgement. If no acknowledgement arrives until a certain time interval, the whole process is repeated. When the control unit receives data from a sensor, it first checks if it can transmit and then sends the acknowledgement reply. The reply to a switch unit also contains the information on required new relay state.

3.1 Wireless Control Unit

The block diagram of the wireless control unit is in Fig. 2. A keyboard and a display serve for communication with the user. The keyboard uses matrix connection and is connected to the microprocessor through five conductors. The display is connected by means of a buffer circuit. Four data and four control signals serve for communication (one microprocessor port). The main part is the control microprocessor, through which all remaining parts of the system are connected.

The real time circuit communicates by means of a serial bus. The bus consists of the SCLK signal for clock frequency transmission, the I/O signal for data and chip select signal transmission. The transmitting and receiving parts are very similar to those of the wireless temperature sensor and the switch unit. The microprocessor, memory and antenna connections are the same, the SPI bus is used for connection with the controlling microprocessor (MISO, MOSI, SCK signals). The slave select signal is software on one of the microprocessor ports. Two voltages are needed for control unit supply, namely 3.3 V and 5 V. The 5 V supply is used for of the LCD display and its buffer circuit. All other circuits are supplied by the 3.3 V. A type HD4478U controller, common with character type LCDs is used to control the display [4]. A type AT89S8253 circuit is the core of the control unit. Since the nRF9E5 circuit has the SPI hardware as master only, the control processor must be operated in slave mode.

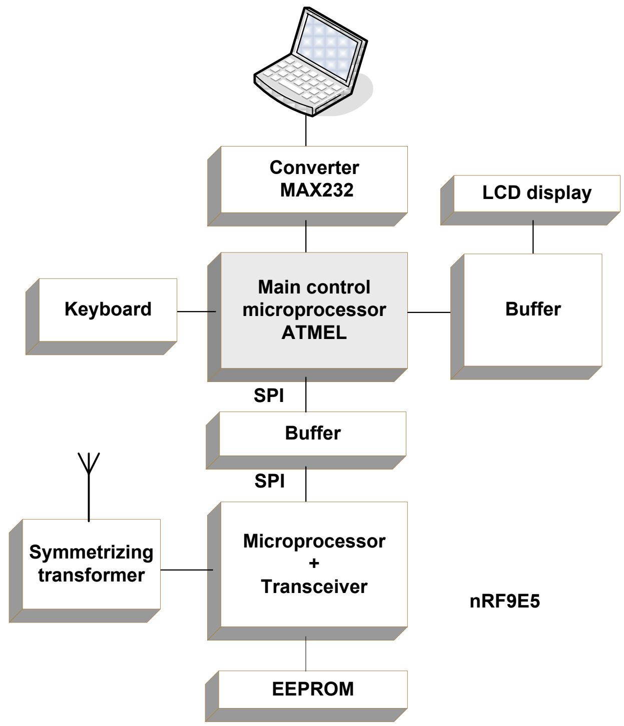

Figure 2: Wireless control unit.

A simple converter serves for communication with a PC over RS232 line. It is based on a type MAC3232 circuit. The circuit contains a doubler and voltage inverter in addition to the RS232 line drivers/converters [5].

The main microprocessor. The microprocessor is 8051 architecture compatible. It includes 4 kB program memory, 256 bytes of data memory and special function registers. The upper 128 bits are accessible by indirect addressing since they are shared with special function register addresses. The program memory is a RAM type and the program is recorded in it by the Bootloader after SPI from the EEPROM memory after resetting. A header must be present in front of the program in the memory, containing the memory speed, crystal frequency and user data.

An ATMEL 89S8253 type was selected as the control processor. It is a 8051 architecture compatible microprocessor, containing additional 2 kB data EEPROM, 12 kB FLASH program memory, SPI interface and further hardware. Both the program and data memories are In System Programmable (ISP), by series programming through the included SPI interface. Further the circuit contains a 256 byte ARM memory, whose upper 128 bits are accessible by indirect addressing since they are shared with SFR special function register addresses. The lower 32 bytes of RAM are four register banks. Instructions are fully compatible with the 8051 architecture and operate identically [6]. The instruction timing is the same as in the preceding case.

NSTI-Nanotech 2010, www.nsti.org, ISBN 978-1-4398-3402-2 Vol. 2, 2010

3.2 Wireless Sensor Unit

Every sensor unit consists of a nRF9E wireless chip, program memory and a symmetrical output element - Fig. 3. The sensor used contains an AD converter and a series interface. The communication with the microprocessor takes place over an I^2C bus.

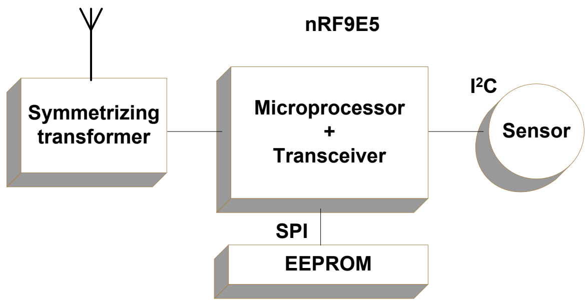

Figure 3: Wireless sensor unit.

The microprocessor with integrated transceiver processing the sensor data and communicates with the control unit. The program EEPROM memory serves to store the microprocessor program.

The DS620 sensor as example can be used for the measurement of temperature. The circuit contains a temperature sensor, A/D converter, comparator and a series interface. It does not need any external components for its operation [7]. The temperature measurement range is -55 ^{0}C to +125 ^{0}C. The A/D converter resolution can be adjusted from 10 to 13 bits, corresponding to 0.5 ^{0}C to 0.0625^{0}C resolution. The conversion duration depends on resolution and takes between 25 ms and 200 ms. A twin lead I_2C bus is used for communication. The SCL terminal serves for reception of clock pulses and the SDA terminal for data reception or transmission. The circuit also contains an EEPROM memory to which a part of registers can be copied and so preserve the setting even when the power supply is disconnected.

3.2 Wireless Switch Unit

The base of the wireless switch unit is a wireless sensor unit, followed by the power switch part. A block diagram is shown in Fig. 4. The core is a microprocessor with a transceiver, with program memory connected through SPI and an antenna connected through a balun like in the temperature sensor. The output block is a power switch unit controlled by two signals from the microprocessor. The power switch device is a polarized bistable relay. The relay is advantageous especially due to its low power consumption (battery supply). Its contacts remain in the "on" or "off" state without the need for any power. Power is consumed in the form of short pulses only, needed to change the relay state. Contact switching is performed by connecting a voltage of proper polarity to the relay.

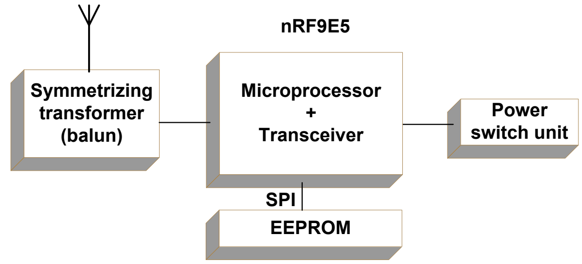

Figure 4: Wireless switch unit.

4 SOFTWARE OF MEASUREMENT INSTRUMENTATION HARDWARE

The control program is divided to different functions. Individual functions control behaviour of the corresponding instrumentation parts. The program for communication with AD converter is simple implementation of the SPI protocol. Another function performs data read-up and saving from/to the EEPROM inner memory of the processor. Another function controls character LCD display. 8-wire bus is used for data transfer. Further function performs data transfer using serial bus and communication with the sensor.

3.1 Program Operation

The PC instructions are loaded form the computer in the loop. Individual functions might be called from these instructions. All functions are periodically running in the PC interruption.

Device initialization. The program starts from the processor memory after power supply switch on. The output ports of the processor are set up to the initial state. The configuration information is read from the EEPROM memory of the processor. The configuration information contains: Number of connected sensors (1-8), interval of data record to inner memory - when data are not processed in the PC, EEPROM dimension of processor, frequency of measurement, configuration bytes of individual sensors.

The interruption service provides: reading the data, data processing, data displayed and data transmission to the PC - see Fig. 5.

The program uses three counters in that interruption. The counters are saved in the global variables. The global variables are saved during individual calls of the interruptions. The counters are: Counter with number of currently active sensor, counter for providing averaging number, counter for providing number of measured characteristics to be saved in the memory. The program decides by the two latter counters to ramify. Basic functions are displayed in the flow diagram – see Fig. 5.

Reading data from sensors. The sensor counter decides which sensor to use. The program reads data from that sensor. *Value calculation* is performed after averaging cycle. Value output is periodical after each calculation. *Values are displayed* and sent to the PC. The information contains sensor number, sensor type, measured value and quantity. *Instruction reception.* The program reads the instructions from the PC in the program loop. The functions are called by these instructions. The functions execute these instructions. The instructions are represented only by a single character (for simplicity). *Function callable from computer.* The configuration function is defined for the device configuration. The function is very simple, it overwrites fifty configuration bytes by new data. Automatic processor restart is performed after reading the new configuration.

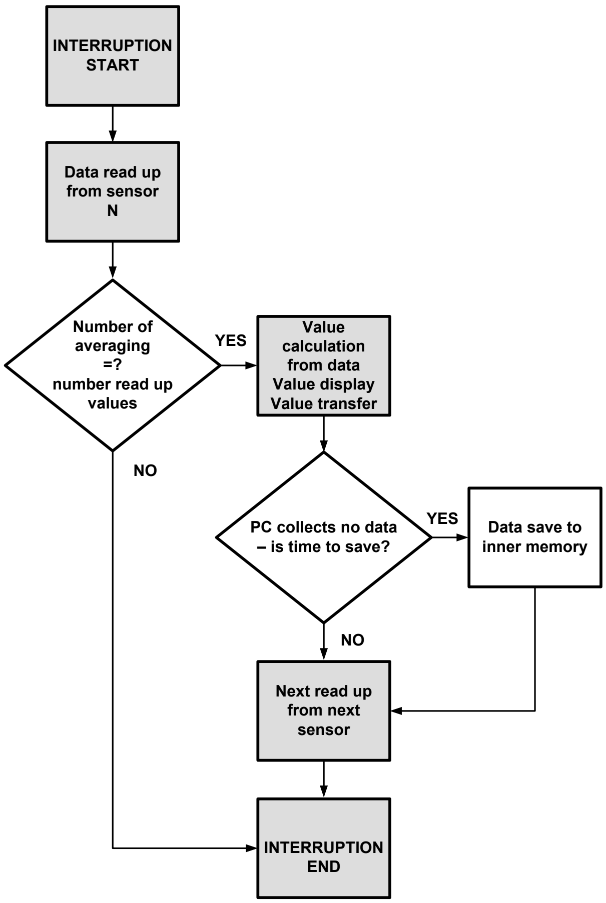

Figure 5: Interruption service

5 RESULTS AND CONCLUSIONS

The programmable RF output power can be set in four levels from -10 dBm to +10 dBm, with corresponding communication range. The highest RF, output power +10 dBm, or 10 mW, means a free space more than 300 m. The operating frequency can also be adjusted. Setting channel number 117 means a 868.2 MHz frequency.

During tests, the system worked flawlessly even in close presence of common interference sources like TV receivers, PCs, microwave ovens etc. The response time is determined, first of all, by the wakeup period and sensor and switch unit communication with the control unit. The temperature measurement resolution can be adjusted from 10 to 13 bits. This influences the conversion time, corresponding to about 200 ms in case of maximum resolution. The same way of the design was used in the other units.

The system can be used with minor modification in the all energy domains for processing of physical as well as biochemical quantities. Where is made design with other sensor type, it is necessary adjust output parameters of the sensor to input parameters of the wireless unit. Sensor with analog output must used amplifier and AD converter. Wide amount of sensors can be used for realization of the above design system. The system is designed like multisensor system to be able to work with independent thermal sensors and switch units. The reach of arrangement on of free space is 300 m, the reach decreases in housing development. The communication is two bidirectional among parts of system, i.e. the data transmission to the control unit as well as also to the wireless sensors and switch units. The cooperation with computer is possible to extend using set-up, entry programmes or transmission measured data to PC.

6 ACKNOWLEDGEMENT

This research has been supported by the Czech Science Foundation project No. 102/09/1601 “Micro- and nano-sensor structures and systems with embedded intelligence” and partially by the research program No. MSM6840770015 "Research of Methods and Systems for Measurement of Physical Quantities and Measured Data Processing" of the CTU in Prague.

REFERENCES

[1] Varadan,V.K. et al., RF MEMS and Their Applications, Wiley, 2003

[2] Kirianaki,N.V.,et.al., Data Acquisition and Signal Processing for Smart Sensors, Wiley, 2002

[3] Husak,M., Oberreiter,P., Foit,J.: Wireless temperature sensor network: Wireless sensor data transfer as well as processing, ICETE’07-WINSYS2007

[4] http://pdf1.alldatasheet.com, 2007

[5] http://datasheets.maxim-ic.com, 2007

[6] http://www.atmel.com, 2007

[7] http://datasheets.maxim-ic.com/en/ds/DS620.pdf, 2007