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Remote building control using the bluetooth technology

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In this paper, a reference is made to the subject of remote control of certain parts of a residential building via Bluetooth using the mobile device. In the first place, the wireless data transmission via Bluetooth is described. Then, the paper deals with the design of the building and the electronic system based on a microcontroller from the ATmega family that communicates with mobile devices via Bluetooth wireless data transmission. The design includes lightning system, roller blinds, a fan and a garage door. The control is based on the system consisting of a triac and an opto–triac. In addition to this, a control application for Android system is created to enable the remote control by means of a mobile device.

KEYWORDS: Bluetooth, remote building control, mobile device

1. Introduction

In the sixties of the 20th century, a break how through has been made in the way residential buildings were equipped. It consisted in the introduction of new solutions which were responsible for ventilation and heating of rooms. Previously, such systems were used only in industrial and military conditions and in the aerospace.

During the following years, IT systems, telecommunications systems and building automation systems started to be introduced (obviously after the controllers had been checked in industrial conditions). The rapid development of automation systems in the middle of the 20th century contributed to the adaptation of industrial devices in residential buildings. Owing to this, the basic user equipment for the building (electrical systems, gas systems, water supply and wastewater systems, lifts, protection systems) can be integrated with one common management system, namely the building intelligence system. The control over all the executive devices allows for the estimation of the method of use of the building by household members, and thus, allows for making forecasts with regards to energy consumption. At present, the building systems are, above all, user–oriented. All technological solutions are aimed at improvement of the comfort and safety of a household member [4].

In an epoch of computers and broadly understood electronics, people want to live comfortably, everyone is also anxious about time savings. The innovations in residential buildings and the comfort of their use become greater and greater. Therefore, the issue of remote building control is interesting as it guarantees more comfort and freedom. Owing to one device, it is possible to control practically the whole building; everything depends on the complexity level of the system, creativeness of the system designer and requirements of the owner.

Development of IT technologies has contributed to the development of computer software which controls the whole system. During the collection of information about the way in which the respective executive devices are used, the system "teaches" the household member and adapts to their needs. Intelligent building systems integrate the systems which are responsible for ensuring comfort to man (e.g. HVAC – Heating, Ventilation, Air Conditioning), and systems which ensure health and property security.

2. Intelligent building

According to the Intelligent Building Institute an intelligent building is a building which integrates various systems in order to manage the resources effectively and in a coordinated manner for the purpose of ensuring the best possible functioning of the users, maximising the savings related to investments as well as operating costs, and also enabling the maximum flexibility [9].

The possibilities of the intelligent building system include:

- Control of lighting, the user may switch on and off the lighting at any place in the building, it may also be controlled without man's intervention, based on readings from sensors, e.g. lighting intensity.
- Control of roller blinds, curtains and louvres. Depending on the time of the day, weather and temperature, system manages the setting of the roller blinds to fulfil the conditions inside.
- Control of heating. Owing to the use of temperature sensors, which enable the adjustment of temperature in single rooms in combination with the intelligent building system, depending on the needs of the user and time of the day.
- Control of air conditioning. This control is very similar to the heating control as it takes advantage of the same sensors.
- Simulation of presence. This is a system which provides the building protection. During the absence of the owner, the system simulates the presence. The house learns the behaviours of the owner for several weeks in order to imitate them in a reliable manner at a later time.

BMS is a Building Management System. It integrates various systems, controls and optimises the operation of installations and equipment constituting the integral part of the system. BMS deals, among others, with control of indoor

and outdoor lighting, heating of rooms, ventilation, air conditioning, alarm systems and monitoring, access control systems and presence simulation systems.

The system of intelligent building installations is divided into categories and classes; the description of the respective categories and classes is presented in Tables 2.1 and 2.2.

Table 2.1. Categories of intelligent buildings [10]

Cat.	Building equipment	Characteristics
A	full equipment	Full assortment of protection systems and control systems – full structural cabling
B	HVAC and protection systems, lighting control	Fire alarm system and anti–intrusion system, access control system as well as lighting and air–conditioning control systems.
C	Protection systems	Fire alarm system, anti–intrusion system and access control system

Table 2.2. Classes of intelligent buildings [10]

Class	Description of class	Characteristics
0	No control systems	No protection and control systems
1	No integrated control systems	Surveillance and/or control systems – no communication between the surveillance and control systems
2	Partial monitoring	Many surveillance and control systems – some of them connected by one joint visualisation system
3	Full monitoring	All surveillance and control systems connected by one joint information visualisation system
4	Full monitoring and partially centralised management	Features of class ”3”, additionally, certain systems can be controlled from one joint management system
5	Fully centralised management (integration)	Features of class ”4”, additionally, all systems are connected by one joint management system

3. Bluetooth technology

Bluetooth is a standard of wireless communication technology designed by Bluetooth SIG *(Special Interest Group)*, which was established in the year 1998.

The main advantages of Bluetooth are: openness, low power consumption (from version 4.0), low price and flexibility. This is a very popular wireless

communication of voice and data communication system; it can be implemented in each mobile phone, laptop or tablet and many other devices.

Bluetooth uses the free–of–charge non–licenced ISM band (*Industrial, Scientific and Medicine)* with the frequency of 2.4 GHz, intended for the industry, science and medicine. It is divided into 79 channels, 1 MHz each [3].

Three classes of devices, whose power translates directly into the communication range, are distinguished in the Bluetooth technology [7]:

- class 1: power of 100 mW (20 dBm) – range up to 100 m,
- class 2: power of 2,5 mW (4 dBm) – range up to 10 m,
- class 3: power of 1 mW (0 dBm) – range up to 1 m.

In order to enable the exchange of information, two devices must be available; one of them functions as the master device and the other one as the slave device. Communication may occurs only between the master device and the slave device. It is not possible to transmit data between two slave devices.

The system architecture consists of protocols grouped in layers. The structure of the layers is presented in Figure 3.1.

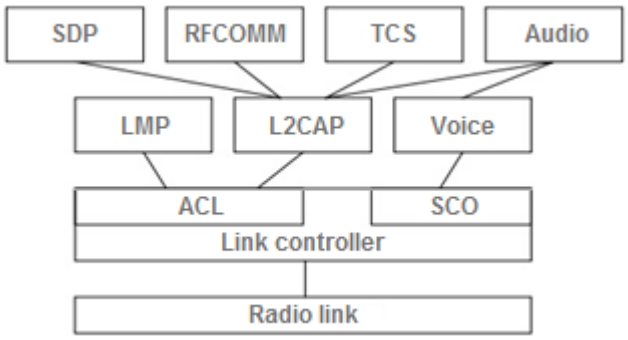

Fig. 3.1. Layers in the Bluetooth system [6]

The radio link is the lowest layer that determines the physical radio layer. It is responsible for the modulation of GFSK *(Gaussian Frequency Shift Keying)* and radio transmission in the Bluetooth system.

The second layer is the link controller. It determines the method of controlling time slots and grouping data in frames.

Another layer contains intermediary protocols. The RFCOMM (*Radio Frequency Communication*) emulates the RS–232 serial port, using the L2CAP protocol in order to connect the mouse, keypad, modem and other devices. The Telephony Control Specification protocol, which is the telephone control protocol, consists of three parts: CC *(Call Control)* – initiating and ending calls, GM *(Group Management)* – operation of a group of devices, CL *(ConnectionLess)* – signalling not related to the call. Another protocol is the Service Discovery Protocol, which is related to discovering services that are

made available by the remaining SDP servers. The remaining protocols in this layer are responsible for the cooperation with WAP and IrDA. The last layer contains protocols intended for applications and profiles [7].

All the data in the Bluetooth technology is transmitted in frames. There are several types of frames, and the frame that is most frequently used is presented in Figure 3.2.

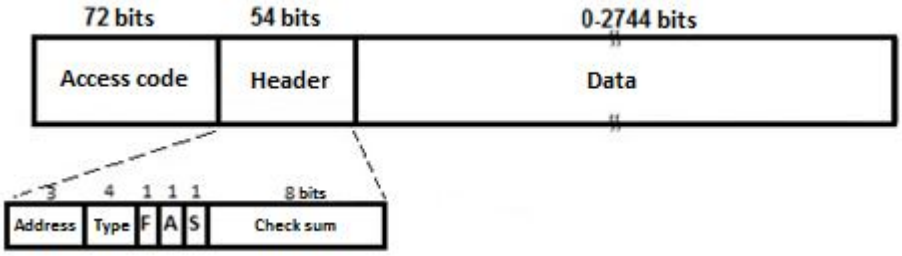

Fig. 3.2 Data frame in the Bluetooth system [8]

The frame from Figure 3.2 consists of 3 main parts:

- the access code which consists of 72 bits used for the identification and synchronisation purpose between the master and slave devices,
- the frame header, which consists of 54 bits,
- the data field depending on the type of the frame and the link which consists of maximum 2744 bits.

4. Design of the control system

4.1. Design assumptions

The design of the remote building control using the Bluetooth technology, implemented by means of the mobile device must meet a number of requirements. The building elements must be subject to remote control using the Bluetooth technology. The design will apply to a residential building, which will consist of: 2 rooms, a kitchen, a bathroom, a corridor and a garage. The elements of the building which can be subjected to control include:

- the lighting in each of the rooms,
- the roller blinds in the rooms,
- the garage door,
- the fan.

The microprocessor system will be connected with the temperature sensor that measures temperature, and the result will be displayed on the LCD display. All the elements must be controlled from one system, and in order to meet this requirement, there must be a control cabinet inside the building which will

control the microprocessor system from which the wires for the lighting, roller blinds, the garage door and the fan will be run. An inseparable part of the design is also the preparation of the control application.

The diagram and the PCB are designed in the CadSoft EAGLE software. The programme for the microcontroller is implemented in the Eclipse software, and the application for Android was created in the MIT AppInventor Version 2 environment.

4.2. Control system

The basic issue in creating the design for the remote building control is the selection of the appropriate microcontroller. A decision was taken to use the Atmega16 microcontroller manufactured by AVR Atmel [1, 2]. The parameters which were taken into consideration include the price and the number of programmable outputs and inputs, as: 7 outputs dedicated to lighting, 8 outputs for the roller blinds and the garage gate, outputs for the fan and the temperature sensor (one in each case), 2 outputs for the Bluetooth module and 6 outputs for the LCD display. It was necessary in case of building under consideration. It was also necessary to provide the microcontroller with the serial USART interface, used for the communication with the Bluetooth module.

Another critical element in the design was the Bluetooth communication module. A decision was taken to select the Bluetooth HC–05 v2.0 + EDR module – the enhanced data rate up to 2.1 Mb/s. The module consists of the BC417143B integrated circuit and the Flash memory, in which the programme is saved. In view of the fact that the module operates with the voltage of 3.3 V, it is necessary to implement the voltage converter for the purpose of smooth data transmission. HC–05 may operate both in the Master and Slave modes.

Additionally, in order to enable the control of the roller blinds via a signal from the microcontroller, it is necessary to install the system that consists of a triac and an opto–triac between the roller blinds and the microprocessor system. When the microcontroller is set at a low level, the system will cause the power supply to be switched on for the executive elements. This system has many advantages:

- as opposed to the transmitter, the switching of contacts is inaudible,
- the system will ensure galvanic separation of the microcontroller from the mains voltage owing to which it will not be damaged,
- the triac is triggered when the supply voltage goes through zero, owing to which no additional interferences in the system are present.

The motor for the roller blinds as well as the fan and the motor for the garage door have been selected for the design. The whole system is divided into several blocks: power supply of the whole system, Bluetooth module, ISP connector – KANDA, microprocessor as well as motors with the triac and the opto–triac.

The HC–05 Bluetooth module selected for the design has an already soldered male 6–pin connector. The RX and TX data transmission lines, which are connected to the microcontroller, must be supplied with the voltage equal to 3.3V, therefore it was necessary to use the voltage converter. The module power supply is also filtered by 2 capacitors. The diagram is shown in Figure 4.1.

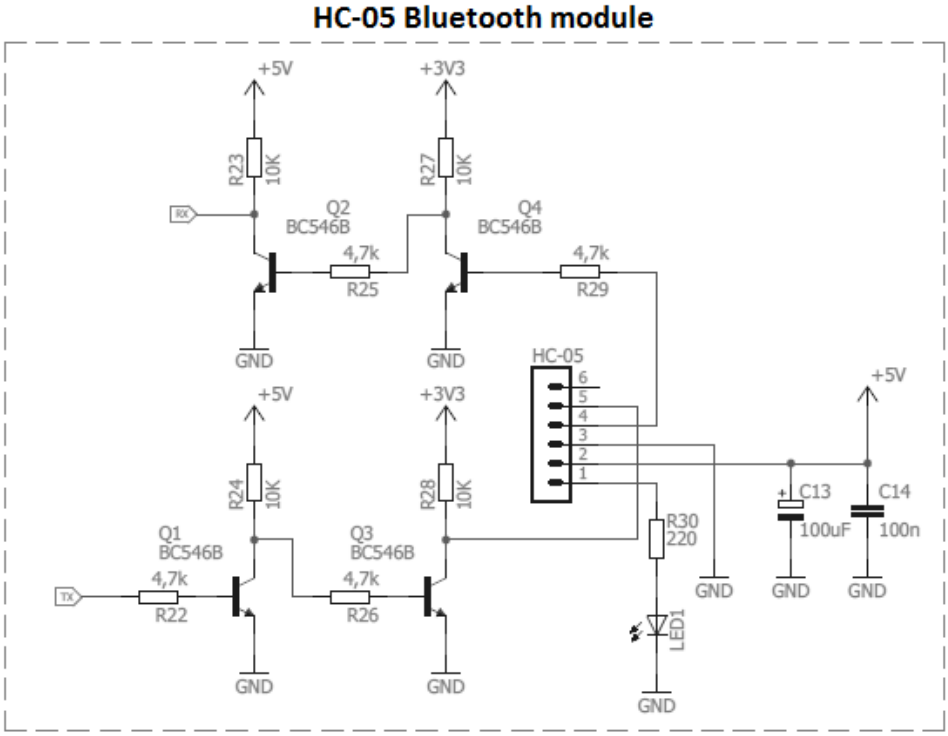

Fig. 4.1. Diagram of the connection of the Bluetooth module [5]

The diagram for the power supply is presented in Figure 4.2. The block is divided into 2 voltage levels. This is a consequence of two factors: the microprocessor system should be powered with DC voltage with the value ranging between 4.5 V and 5.4 V, in accordance with the manufacturer's data sheet. On the other hand, for the Bluetooth module, the voltage value should range between 3.0 and 4.2 V, however, it is recommended to ensure power supply at the level of 3.3 V. In order to meet the requirements mentioned above, two voltage stabilisers are used: LM7805 and LF33CV per 5 V and 3.3 V respectively. Additionally, to ensure correct power supply, there are filters in front of the voltage stabilisers, whose function is to filter the power supply from the mains.

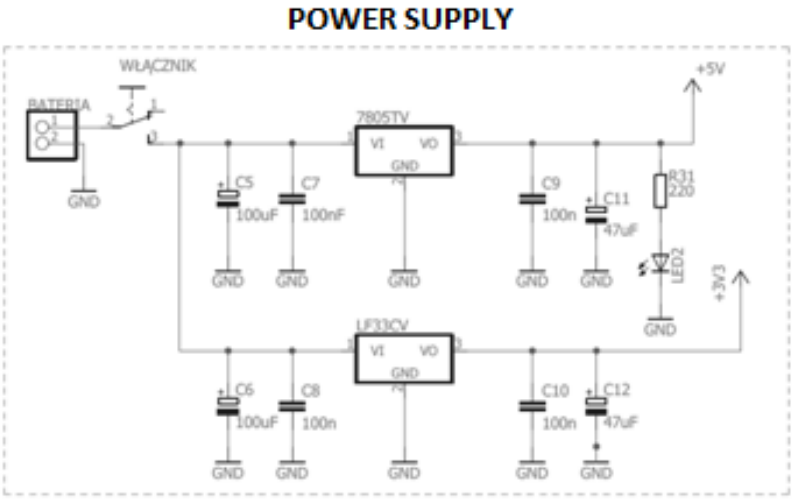

Fig. 4.2. Diagram of power supply for the system [5]

Figure 4.3 presents the power supply connection of the LCD display and the DS18B20 temperature sensor to the ATmega16 microcontroller. At the output of port A and C and pin 3 of port B, there are labels referring to the lighting, the roller blinds, the garage door and the fan.

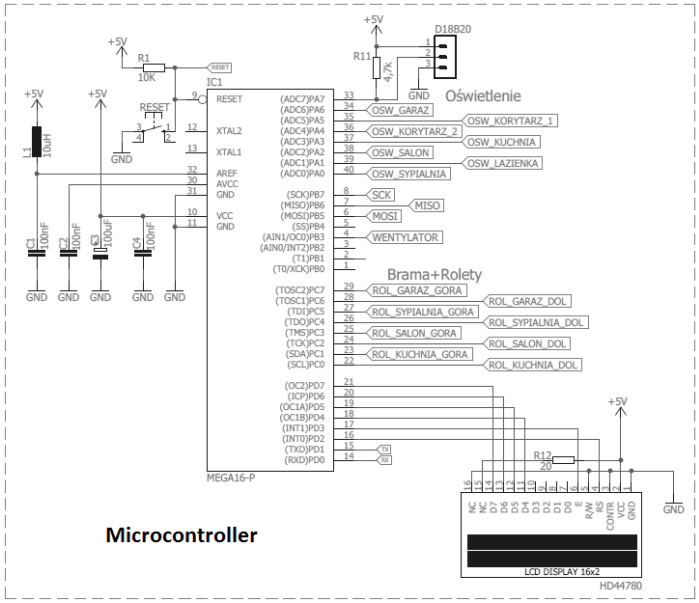

Fig. 4.3. Diagram of the microcontroller connection [5]

The LCD display was connected to port D of the microcontroller in the four–bit control mode. The mode consists in the connection of only 4 D4–D7 pins of the display to the microcontroller port, the D0–D3 pins remain unconnected. The display was set to the following mode: no occupancy flag reading, therefore the R/W pin was connected to ground.

The DS18B20 temperature sensor is the digital sensor equipped with the 1–wire interface. It was connected to port A, pin 7 of the microcontroller. The 1–wire interface means that the data is transmitted and received by means of one wire.

In order to present the method of connection of the motor to the outdoor roller blinds, the diagram shown in Figure 4.4 was created. The motor has 3 terminals: neutral, rotations to the left and rotations to the right. The power supply is switched on by the system consisting of the BT136 triac and the MOC3041T opto–triac.

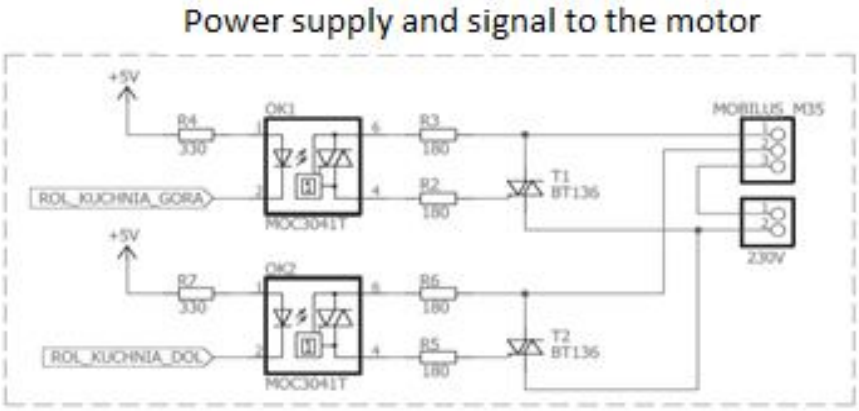

Fig. 4.4. Diagram of the control system [5]

For the proper functioning of the designed system, a control algorithm was created and the control programme was implemented, which is described in detail in [5].

4.3. Remote control application

Figure 4.5 presents the appearance of the main application screen. It includes the following buttons: one push–button to move between the rooms, another one to search and connect via Bluetooth and the last one to close the application.

The application is connected with the Bluetooth module in accordance with Fig. 4.6.

Each room has its own separate control panel, which appears after pressing the push button on the main screen. The control panel includes push buttons by

means of which, depending on the equipment of the given room, it is possible to control the roller blinds, switch on and off the light or start the fan. The panel is divided into segments such as: the lighting, the roller blinds and the fan. The appearance of an exemplary control screen is presented in Figure 4.7.

Fig. 4.5. View of the main application window (in Polish) [5]

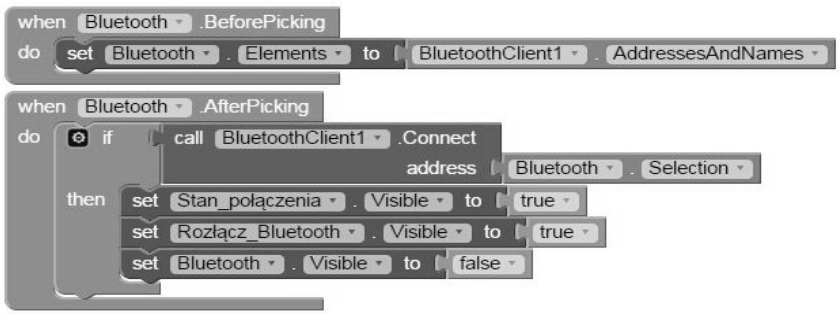

Fig. 4.6. Connections with the Bluetooth module [5]

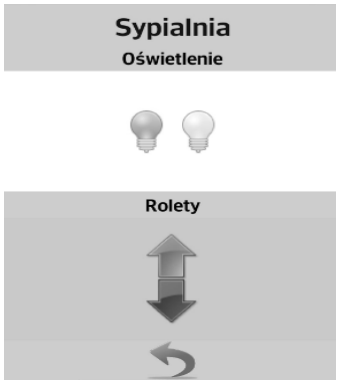

Fig. 4.7. View of the control panel for the bedroom (in Polish) [5]

Control consists in the transmission of the ASCII sign at the moment of pressing a push button in the application. The microcontroller, depending on the received signal sets the low level for a specific pin. It provides the voltage for the executive element to be supplied.

5. Summary

All the set out objectives were fulfilled, the system that communicates between the mobile device and the microcontroller functions properly. The application for the Android system was tested and, in combination with the written programme for the microcontroller and the created model, it reflects the designed remote control system. Data transmission by means of Bluetooth, fit can be successfully implemented for control processes in small buildings, as the distance of the transmission is limited to about 10 m.

The designed method of building control is innovative, control in the proposed prototype takes place exclusively from the level of the mobile device, which may be modified in the future. The design is the preliminary version of the system, which has broad options for extension, by adding other elements and improving the application. All depends on the requirements and financial capabilities of the users of the given building.

In case of building modernization, is possible to modify the system by adding temperature sensors, humidity presence sensors, fire sensors and others. As a result of this, the apartment could be more "intelligent". It would be necessary to programme so called scenes which would supervise the statuses of the sensors reflecting the situations in the building. These scenes are instructions for the strictly specified conditions. An additional facilitation would also be the control of the central heating system from mobile device level. For this purpose, it is enough to install the appropriate thermostats or to control the under–floor heating system also using the wireless data transmission in the Bluetooth standard.

References

[1] Borkowski P., AVR & ARM7. Programowanie mikrokontrolerów dla każdego, Helion, Gliwice, 2010.
[2] Kardaś M., Mikrokontrolery AVR. Język C – podstawy programowania, Atmel, Szczecin, 2013.
[3] Miller A., Uwolnij się od kabli. Bluetooth, Wyd. Helion, Gliwice, 2003.
[4] Niezabitowska E. i inni. Budynek Inteligentny: Tom I, Wydawnictwo Politechniki Śląskiej, Gliwice, 2010.
[5] Piasecki A., Zdalne sterowanie budynkiem z wykorzystaniem technologii Bluetooth, Praca dyplomowa inżynierska, Politechnika Poznańska, 2016.
[6] Zieliński B., Bezprzewodowe sieci komputerowe, Wyd. Helion, 2000.

[7] www.bluetooth.com, 24.01.2016.
[8] http://home.agh.edu.pl/~opal/sieci/instrukcje/bt.pdf, 20.01.2016.
[9] http://www.cs.put.poznan.pl/mnowak/IB/IB–2.pdf, 05.09.2016.
[10] http://www.cs.put.poznan.pl/mnowak/IB/IB–4.pdf, 05,09,2016.

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