Telemedicine: New Approach to Modern Education of Medical Electronics

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Abstract— **The paper presents new telemedical system which has been developed as a laboratory kit for educational use in electrical engineering oriented study programs. The main goal of described system is to demonstrate modern possibilities in wireless medical applications for student and to improve their experiences with this type of systems. The system is modular and consists of input modules, control unit and telecommunication modules. The input modules provide the conversion of measured vital sign like electrocardiogram, oxygen saturation or blood pressure to analog voltage, the communication modules provide data connection between portable part of system and any PC based system and the control unit serves as controller core of whole system. The input and communication modules are reciprocally interchangeable. It allows easy and quickly changes of system design. The hardware realization is supplemented by prepared software libraries for control unit, communication modules and PC based side. The system is able to use not only as educational kit, but also as a fundament for more sophisticated usage in the field of assistive technologies, smart homes etc.**

Keywords— **telemedicine, telemonitoring, biomedicine engineering, medical devices, medical electronics**

I. Introduction

Telemedicine and telemonitoring are one of the up-to-date techniques in modern medicine, home care and social care. These techniques evidently can help improve the lives and work both for patients and health professionals and also for consumers and providers of other types of cares, for example social care, care for elderly people etc.

In accessible documents there are many definitions of telemedicine. The telemedicine is described as combination of topics from the fields of telecommunication, medicine, and informatics usually [1]. The general definition of telemedicine is for example in Communication from the European Commission [2]:

"Telemedicine is the provision of healthcare services, through use of ICT, in situations where the health professional and the patient (or two health professionals) are not in the same location. It involves secure transmission of medical data and information, through text, sound, images or other forms needed for the prevention, diagnosis, treatment and follow-up of patients."

The benefits of telemedicine for patients and healthcare system are first of all the decreasing of costs and increasing of accessibility of provided care. The telemedicine has ability not only for usage in common medicine, but has also the ability to be significant support for urgent and disaster medicine [3]. But the area of use of telemedicine and telemonitoring systems does not lie only in the field of medical applications.

The telemedicine and telemonitoring systems are widely used also in the field of ambient assisted living (AAL), home care of elderly people and smart homes. Applications of these systems in AAL are transparently described in [4], the description of telemedicine applications in the care for elderly people is in [5].

The pilot project of complex telemonitoring system from medical point of view– the Telemon system – is able to support patients in home care in real time using the telemonitoring and teleconsultation applications [6].

It is fact that design and development of telemedicine systems are complex and multidisciplinary tasks which need great knowledge on many areas, not only in medicine, but also in areas of system integration, telecommunication, informatics, data analysis, signal processing, circuit theory and others [7].

Based on the information above it is evident that the telemedicine and telemonitoring are very important areas which claim our straight attention. It is clear that our effort has not to be targeted only on research and development in these areas, but also on education. It is necessary to prepare new courses, lectures, seminars and laboratories and to explain the principles, possibilities and problems of telemedicine and telemonitoring for students both in medical and engineering programs. To prepare it and to use it in educational praxis is our challenge. But in other way the telemedicine is a chance for interesting and engaging education.

The main task of this paper is to describe new prepared laboratory modules for education purposes in the field of electrical engineering. Presented modules are used during the laboratories in master study program Biomedical engineering and informatics in the Czech Technical University in Prague.

II. General Concept

The general concept of presented telemedicine system is based on few requirements. The most important ones are:

- to have modern telemonitoring system,

First of all requirement is to have telemonitoring system which is able to show the common basic concept of modern telemedicine applications.

- to have modular system,

The other important requirement is to have modular system. This concept presents a possibility to make quick and easy changes of system design and to demonstrate more applications with the same devices.

- and to have easy to use system.

The last, but not least, requirement is to have easy to use laboratory kit. It is very important, because it enables the work with system for student without the necessity of study the detailed information, device datasheets etc.

The presented system is modular and could be divided into three main parts – input modules, control unit and telecommunication modules (see Fig. 1). The main task of the system is to sense some vital signs like electrocardiograph (ECG), blood pressure (NIBP) or oxygen saturation (pulse oxymetry, SpO_2), to process acquired signals and to communicate them to PC based system (desktop PC, laptop or computer network access point) using any type of standardized wireless technologies such as Bluetooth, WiFi or GSM. The final usage of transmitted signals in the site of PC based system is not generally the aim of this project. Only the communication support and the design of communication protocol have to be done within the project.

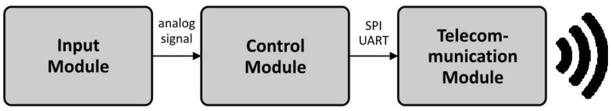

Figure 1 General concept

Input modules transduce measured biosignals to electrical value, especially analog voltage (but any type of digital data is also possible). The output of these modules could be one or more dimensional signal. It means the control unit behind the input module has to be able to process more signals in the same time, for example leads I to III for ECG signal processing or red and infrared signals for pulse oxymetry measurement.

The control unit is a core of whole system and has to provide more tasks simultaneously. The most important ones are:

- to acquire input analog signals and to convert them to digital data,
- to process these signals and/or to parameterize them,
- to prepare data packets according to defined communication protocol,
- to control the communication line (handshaking the line) and to send the data,
- and to provide the user interface of whole system.

Communication modules are the last part of the system. The main task of these modules is to support the signal transmission between control unit and PC based system in physical layer. The handshaking of the line is controlled by control unit and/or PC based part of system.

The communication interfaces between every modules are strictly defined, the modules are reciprocally interchangeable. It means it is possible to choose measured signal (for example ECG, NIBP, SpO_2) and the type of connection (Bluetooth, WiFi, GSM), choose appropriate modules and set-up the user-defined system quickly and easy.

III. Input modules

A. Electrocardiography

Electrocardiography (ECG) is a commonly used method for heart diagnostics. ECG signal, electrocardiogram, is an electrical signal reflecting heart activity. There is defined three leads system (leads I, II and III) usually used for a vital signs monitoring. The leads I, II and III are defined as a difference between the potential (voltage) of electrodes placed on upper extremities and left leg. Sometimes, the three electrode system is supplemented by the fourth electrode placed on the right leg. This electrode is used as a feedback electrode for decreasing noise.

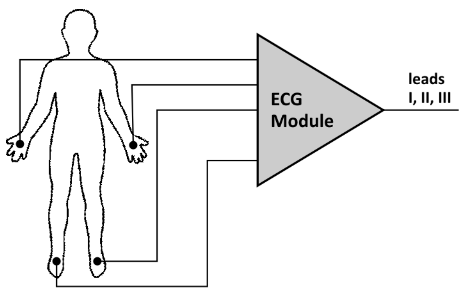

Figure 2 ECG input module

In our design the ECG input module has 4 inputs (three signal electrodes and one feedback electrode) and 3 analog voltage outputs (leads I, II and III; see Fig. 2). It means the circuit design of ECG consists of amplifiers, differentiators and anti-aliasing and supply voltage noise reduction filters.

B. Pulse Oxymetry

Pulse oxymetry is a standard measuring method for obtaining of peripheral blood oxygen saturation (SpO_2). The pulse oxymetry is based on illumination of skin and measuring the changes in light absorption. Standard pulse oxymeters use two wavelengths (red and infrared) for measuring tissue light transmission. The illumination of skin is made by red and infrared LEDs, for the light detection is usually used phototransistor. The LEDs and photodetector are placed on inner sides of finger peg often.

In our design the pulse oxymetry module has combined input/output in the patient side (driver signals for LEDs and signal from photodetector) and 4 analog voltage outputs (raw red and infrared signals –AC and DC component of each signal separately; see Fig. 3). It means the circuit design of pulse oxymetry module consists of LED driver, input amplifier, ambient light zeroing circuit and filters for noise reduction and separating of AC and DC component and anti-aliasing filters [8].

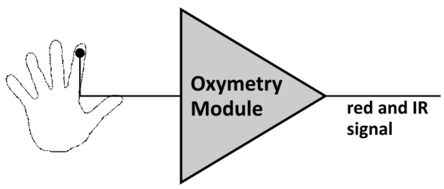

Figure 3 Pulse oxymetry input module

C. Non-Invasive Blood Pressure

Non-invasive blood pressure (NIBP) is the most often measured hemodynamic parameter. The basic measurement use electronic tonometer with cuff in left hand. In standard approach the values of systolic and diastolic pressure are evaluated using the oscillometry method. In fact the values are not directly measured, but only computed from the oscillometry curve. It is crucial, because it could be discussed that the oscillometry signal (curve) is more important than the values of systolic and diastolic pressure.

In our design the NIBP module has one input/output in the patient side (air pressure in the cuff) and one analog voltage output represents the pressure in the cuff (see Fig. 4.). It means the circuit design of NIBP module consists of driver for air pump, air pump, electronic valve controller for decreasing the air pressure in the cuff, pressure sensor with voltage output and signal amplifier [9].

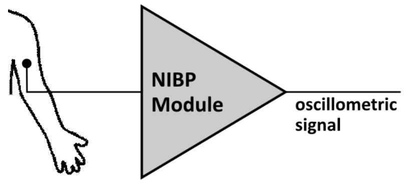

Figure 4 NIBP input module

IV. Control Unit

The main task of control unit is to acquire signals from input module, to filter and/or parameterize them, to pack them to appropriate data packets and to send them via communication module. Due to educational purposes the control unit has to be easy controlled without need for extra knowledge, maximally versatile and mechanically robust. Due to these requirements the STM32 Primer2 module from STMicroelectronics has been chosen [10]. The module includes ARM Cortex-M3 processor, 512 kB flash memory, Li-Ion battery (it provides power supply autonomy and it is important for the patient safety), touch screen display, on-board 3D MEMs accelerometer, analog and digital inputs, SPI, I2C, mini USB and USART busses and MicroSD card connector. Primer2 developers are widely supported by the producer and by the community of other developers. It provides a possibility for self-dependent student works in project oriented courses.

V. Communication Modules

Communication modules serve data transfer from control unit to PC based system using the standard wireless communication technologies. For the application the BT, GSM and WiFi modules have been developed. It provides many opportunities of usage from local (BT or WiFi connection) to long distance data transmission (GSM). The communications modules are designed based on small modules like KC Wirefree KC21 (BT) [11], ConnectOne Nano Socket iWiFi (WiFi) [12] and Cinterion TC65i (GSM) [13]. These types of modules provide fully embedded wireless communication port systems.

VI. Software Libraries

The hardware realization of telemedical system is supplemented by software libraries in our design. The prepared software libraries include code libraries for control unit, pre-prepared firmware set-ups for communication modules and software application for desktop PC. This application serves as basic gateway from system to PC based platform and provides easy way to set-up parameters of transfer and initial visualization of received data. The role of prepared software libraries is to support students in developing their own project without detailed knowledge of registry implementations in each module and assembler coding and also without need of much time. However, only applications with potential for quickly developing, easy use and smart functions could interest students.

VII. Educational Applications

The goal of presented telemedical system is to support education in master study of electrical engineering. The aim is to demonstrate the ability of small smart systems for sensing vital signs, processing signals in embedded systems and transmitting processed data.

The main usage of system lies in laboratory project oriented education. The task is to design, realize, set-up and evaluate small telemonitoring system. The type of sensed signal and the type communication protocol (or technology) is in student choice.

But this is not only one possible usage of the system. In the other way the system is able to be a fundament for more sophisticated projects for example in the field of assisted technologies and smart homes. It generates new possibilities for long-time student work in the frame of diploma (or bacheolar) thesis or larger student projects.

VIII. Conclusion

The design of new telemedical system has been presented in this paper. The system consists of three independent parts – input module, control unit and telecommunication module. The interfaces between modules are strictly defined. It allows the possibility to use different modules in each position, for example different input modules (ECG, pulse oxymetry or non-invasive blood pressure measurement module) or different telecommunication modules.

The main goal of presented system is to support education especially in electrical engineering master programs. But the system could be used also as a platform for developing of more sophisticated projects in the field of assistive technologies, smart homes, telemonitoring etc.

The whole system (both hardware and software parts) is designed as open project which is able to be appended by new modules or functions.

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