A Universal Wireless Device for Biomedical Signals Recording

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Abstract. The chapter provides a report on the wireless biomedical signal acquisition system that has been developed and applied recently in a hospital. The authors describe a universal wireless device (bioelectric amplifier) with a case study of the wireless communication. Advantages and disadvantages of considered standards have been described. The most important feature of the bioelectric amplifier is the software configuration ability towards specific requirements that occur during the registration of different signals. The study shows examples for ECG (Electrocardiography), EGG (Electrogastrography), EOG (Electro-oculography), EEG (Electroencephalography) with the same wireless device. The portable unit is under clinical trials tests and preliminary evaluation indicates acceptance by medical staff. Additional advantages are the relatively low cost of manufacture and the possibility of application of other wireless transmission standards.

Keywords: wireless networks, ECG, EOG, EEG, EGG.

1 Introduction

Recently the rapidly developing radio-communication systems provide a wide range of possibilities in improving existing medical solutions. This is mainly because of decreasing costs of wireless modules and increasing the speed and reliability of communication. Monitoring of patient health conditions in a hospital, remote monitoring of patients at their homes or monitoring of patient's diets are just few examples of many applications of a pervasive computing. One of the most important aspects during the treatment of patients is a quick response to abnormal vital signs. Remote monitoring systems allow for a direct notification of the patient's problems in the hospital, and for a quick response if the patient is at home. These systems also enable direct contact with a healthcare professional for consultation at any time.

Example applications of wireless networks in medicine are [1]:

1. WBAN (Wireless Body Area Network) – monitoring and acquisition of selected parameters of vital signs.

2. RFID (Radio Frequency Identification) – Hospital can use RFID in order to manage the facilities or patient care. Tags identify the patient and effectively

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prevent medication error. The technology can also be used to control the supply and provision.

3. WPAN (Wireless Personal Area Network) – it has a relatively small range (up to several meters). It utilizes Bluetooth standard. This solution can be used to monitor vital signs of patients. The staff can observe the performance of different patients at the same time, if necessary, may take the appropriate action. WPAN can also be used at home to monitor the basic physiological parameters such as pressure or ECG signal.

4. Sensor networks – networks of multiple sensors deployed in a certain area. They can be placed at the bedside, where they collect data on respiratory rate, heart rate, movement e.g. may indicate if the patient leaves the bed.

5. GPS/UMTS – can be used for home monitoring. Patient can freely perform daily activities and can be under constant medical supervision. The technology can also be applied for telediagnostics.

6. WLAN (Wireless Local Area Network) – This type of data can be used to provide information about patients within the hospital. It also allows remote use of computer-controlled medical equipment.

In the first part of the chapter, we describe selected types of wireless data transmission orientated on medical devices. Then, in section three, some examples of non-invasive methods in the context of medical diagnosis like ECG/EGG/EOG have been presented. Next, a prototype device with a reconfigurable front-end are described. The main part of the device has been built with ADS1298 integrated circuit (IC) which is a dedicated analog front-end for biomedical signal acquisition. This system is characterized by high CMRR (Common Mode Rejection Rate) and is equipped with auxiliary circuits, e.g. electrode-skin contact detection system, active ground circuit, and built-in test redundant part. The device is using a Bluetooth link with a host PC, however, other wireless technologies can be also applied. The communication between the microcontroller and the Bluetooth module is realized with UART, so any module (standards presented in section 2) with UART interface is acceptable. Integration of many functions into a single chip allows for input amplifiers configuration (it reduces size of the analog block) with a low power consumption and a reduction of production costs. First tests of the device on volunteers indicate high performance as well as fulfill medical requirements for signals obtained. The device is also used in the biomedical digital signal processing like ECG detector presented in [2].

2 Wireless Technologies – Selected Issues

The past decade is an enormous growth of wireless communication standards. Many of them are designed for very specific applications like for medical devices. Due to accessibility and mobility requirements wireless is the preferred medium in medical applications. Moreover, the wireless technologies are being developed to provide communication between stand-alone medical machines and make them interact. The paragraph is a brief overview of wireless data communication standards applied in medical devices. Next section is divided into two points, first reports some aspects on mobile phones data transmission, second is focused on ISM (Industrial Scientific Medical) open access standards [1, 3].

2.1 Cellular Network Standards

A cellular network is composed of a number of transceivers called base stations. A single base station offers a radio communication within area depending on operating frequency e.g. for 1800MHz network the area is around 614km^2 (the cell radius is 14km), for 950MHz frequency, the cell radius is 27km and area exceeds 2200km^2. There are several data communication standards like GPRS (General Packet Radio Service), EDGE (Enhanced Data rates for GSM Evolution also called Enhanced GPRS), UMTS (Universal Mobile Telecommunication System), etc. Due to the wide availability of GSM modules, we will discuss the main advantages and disadvantages of the aforementioned standards.

GPRS/EDGE

GPRS is a data transmission service available in the GSM technology (also called 2.5G technology). It is a packet transmission protocol that allows multiple users to send data in packets through shared channels. A dedicated channel is not reserved to subscribers for the duration of the connection, but they are allowed to a transmission at the time of sending and receiving data (full-duplex). This saves power and minimizes costs. This is a paid service to the GSM network operator. Advantages of the standard are: range which is usually wide enough for a user (exactly the same as GSM network), the patient can move and do certain exercises. GPRS wireless transmission protocols is based on the Internet protocols IP, so it can work easily with existing IP protocols in the fixed network [1]. EDGE, in turn, is an improved version of GPRS. It is a packet data transmission system, however, it offers much greater data transfer than GPRS (230kb/s, in practice less than 200kb/s). This is achieved mainly through the use of a new modulation and new ways of coding. GSM/GPRS networks used GMSK modulation while EDGE introduced more efficient 8-PSK modulation. Moreover, both are used for data transmission. The new method of modulation significantly affects the throughput, although the structure of the frame or the packet structure remains unchanged.

The weak points of GPRS/EDGE are: energy consumption by the device which causes shortening the operating time (a few hours) and data transfer limited to 115kb/s or 230kb/s. In practice, the data transmission is much lower and usually is between 30 and 80kb/s. It is paid connection so the data transfer can be expensive. The choice is good if the biomedical signal can be sampled with low frequency so the amount of data is rather small or there is no possibility to apply other standards.

UMTS

Nowadays, UMTS is the most popular standard for mobile telephony. It is characterized by high speed of data transfer, so that network offers the ability to make voice calls, video calls, and to send text messages or data. UMTS radio interface, called a UTRAN is based on the technology of broadband multiple access to the channel in the area code (WCDMA). With the new radio interface, it is possible to make better use of available radio resources and to offer higher data rate. UMTS technology can provide new multimedia services which are absent in the second generation of mobile telephony. Services such as simultaneous transmission of voice and video in real time open up new possibilities for using mobile networks. The maximum throughput in UMTS technology is about 2 Mb/s. Only UMTS enables full usage of multimedia information (including video, audio) for medical consultation purposes [1].

2.2 ISM Networks

The ISM bands are strictly defined and the use of selected frequency depends on e.g. location (USA and EU regulations are different). Generally, the ISM bands are license free if some other requirements are fulfilled, e.g. maximum power dissipation (the communication range for a particular band), however the availability of use is sometimes subjected to local acceptance.

WI-FI

Wi-Fi is the name for technologies that are based on IEEE802.11 standards. Each of the IEEE802.11 specifies a different modulation type and the corresponding data transfer. The concept of the channel has been applied in order to separate each connection. E.g. the 2.4GHz band is divided into 13 channels with a width of 22MHz [4]. The main standards are depicted in tab. 1.

Table 1. Comparison of IEEE802.11 standards

Type	Frequency [GHz]	Modulation type	Data transfer [Mbit/s]	Range (indoor/outdoor) [m]
802.11	2.4	IR/FHSS/DSSS	2	20/100
802.11a	5	OFDM	54	35/120
802.11b	2.4	DSSS	11	38/140
802.11g	2.4	OFDM,DSSS	54	38/140
802.11n	2.4 or 5	OFDN	600	70/250
802.11y	3.7	OFDM	54	-/5000

Thanks to its characteristic, Wi-Fi has found wide application at public access points, building security and control systems and home electronics. Tab. 1 shows good enough data speed and range for the medical remote monitoring systems. Greater range improves comfort because the patient can move around the apartment. IEEE802.11x does not have any limitation on the number of transmitters. There are well known systems for monitoring patient’s breath (20 sensors transmits signal to the receiver). The main weak point for portable Wi-Fi is power consumption which reduces the operating time on a battery (typical time is less than 8 hours).

Bluetooth

Wireless standard for creating secure connection between devices located nearby (depends on substandard). Bluetooth architecture is presented as a layer model [5,6]:

- Physical layer – the radio link layer control is responsible for sending and receiving data packets. Operating frequency range is 2400-2483.5 GHz and is divided into 79 independent channels with a width of 1MHz. Data packets are transmitted at schedule intervals with a length of 625us to cyclically changing frequency. Bluetooth is a full duplex standard.
- Data link layer – its task is to control the operation of the corresponding radio module. Two protocols can be distinguished in this layer: Management Protocol LMP link and L2CAP logical link.
- Higher layers – higher level protocols. It includes protocols such as SDP (Service Discovery Protocol), RFCOMM (Radio Frequency Communications Protocol), TCS (Telephony Control Protocol), OBEX (Object Exchange Protocol) and BNEP (Bluetooth Network Encapsulation Protocol).

There are three classes of the Bluetooth transmitters [5, 6]:

- Class 1 – 100mW, range up to 100m
- Class 2 – 2,5mW, range up to 10m
- Class 3 – 1mW, range up to 1m.

Bluetooth transmitters offer small data transfer, which limits their use in certain applications. On the other hand, these devices have very low power consumption, which encourages implementing such solution in mobile devices. An important advantage is the ease of use because the data link is controlled by Bluetooth stack. Recently, a Bluetooth low energy has been introduced which aim was to increase the transmission speed, low power consumption and fast access to data. With this assumption, the main recipients of such solutions may be medical industry. Devices equipped with the Low Energy standard charge 100 times less energy in comparison to standard Bluetooth solution (see tab. 2).

Table 2. Comparison of the Bluetooth and Bluetooth low energy [5]

	Bluetooth class 2/3	Bluetooth Low Energy
Frequency	2.4 GHz	2.4 GHz
Range	10-100 m	10-100 m
Data Transfer	0.7-2.1 Mbps	305 kbps
Number of devices in network	7	Unlimited
Time response	100+ ms	<6ms
Energy consumption	1(reference)	0.01-0.05
Current consumption/ (life on battery)	40 mA / 5-10 days	10-20 mA / 1 year

3 A Reconfigurable Device for Bioelectric Signal Acquisition

This section presents the concept of building a universal device for recording (acquisition) of bioelectric signals with wireless transmission to a computer. It is shown that by using currently available systems i.e. ADS1298 and Bluetooth module, it is possible to build a device that can be easily adapt to the tasks previously requiring the use of separate devices. Next, bioelectric signals for health diagnosis like ECG, EGG and EOG with the use of our reconfigurable device are discussed. The concept of building reconfigurable device for measuring a variety of diagnostic signals is shown in the fig. 1. The patient's cable defines the configuration of an analog front-end. Full signal with a constant level (direct coupling) is sent to the PC where isolation of a proper component is performed with an appropriate method of filtering. Our solution combines the features of universality and economy and is open for future application because the signal is not prefiltered by the recording equipment.

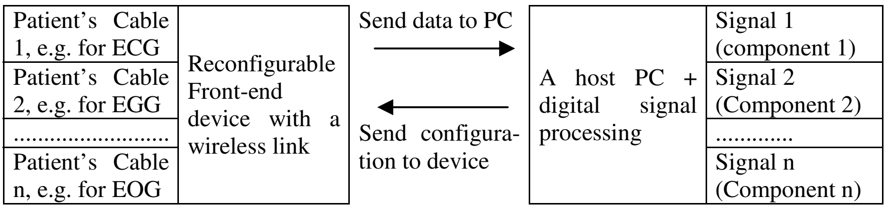

Fig. 1. The idea of a universal wireless device for bioelectric signal recording

3.1 Non-invasive Methods for Assessing the Patient's Health

Non-invasive assessment of the patient's condition lies mainly on the analysis and registration of certain biosignals from the body surface. It is an important feedback that allows assessing not only patient's condition but also treatment effects. Advances in technology create an opportunity for safe application of medical devices both in the hospital and in the natural environment (at home). The best recognized type of patient's evaluation are 24-hour Holter, remote monitoring of cardio disease, the use of external and implantable stimulators, defibrillators and infusion pumps dispensing certain substances (medications). Typical measured values are voltage, impedance, temperature, chemical composition of specific substances and movement or location of the patient. Electrical signals available on the body surface area have small values and are located in the micro- and mili-Volts range [7]. Tab. 3 shows the voltage level of the most popular bioelectric signals.

Table 3. Basic features of bioelectric signals

Signal	Peak to peak amplitude [mV]	Bandwidth [Hz]	Number of channels
ECG	1 – 3	0.05 – 100	1 - 12
EEG	0.05 – 0.3	0.02 – 35 (70)	16 - 256
EOG	< 0.3	0.02 – 17	1 - 2
EGG	< 0.5	0.015 – 0.2	1 - 4

Further processing of the electrical signals must take into account: appropriate signal amplification, selection of useful differential component which occurs in the presence of e.g. energy network (50/60Hz) and which should be suppressed. All these elements are realized through analog front-end of sufficient robustness.

3.2 Wireless Recorder Description

Most measuring devices record the signals on the surface of the patient's body and send it by a wire or wireless to a system collecting and analyzing data. Rarely, the unit stores the data in memory, still, 24-hour Holter is a good example of such device. Block diagram of a typical wireless recorder is shown in fig. 2. It consists of an input circuit, a microprocessor unit, RF (radio frequency) module and a power supply block.

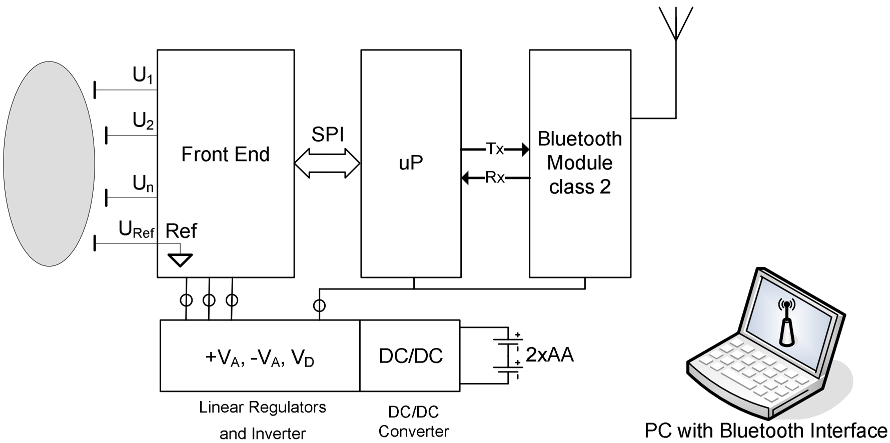

Fig. 2. Block diagram for the wireless recorder of biomedical signals

3.2.1 Signal Acquisition – Analog Front-End

The construction of a good analog front end for biomedical signal acquisition is not a trivial task. Based on the bioelectric signal section, the analog part includes a set of differential amplifiers with high CMRR ratio which allows for signal amplification and removes distorting components. Configuration of input amplifiers depends on the type of evaluation and required links with patient (channels).

Moreover, the amplifier input connected to the patient via electrodes should be protected against static discharge (ESD). The entire device must meet the requirements arising from the standards for medical equipment such as IEC60601 [9]. This is a challenge for designers of medical equipment. The next step in the signal processing diagram is A/D converter. Currently available microcontrollers contain multichannel A/D converters with a resolution of 10 – 12 bits. In many cases it is sufficient to obtain high quality signal data. In order to obtain higher resolution of 14-24 bits other and usually more expensive A/D converters should be introduced.

The authors have decided to use the integrated system ADS1298 recently developed by TI, which allows for simplification of the analog input. Its internal structure is composed of multi-channel bioelectric signals amplifier and set of high resolution A/D converters. The block diagram of the ADS1298 is shown in fig. 3. The most important advantage is the configuration of the input differential amplifiers. The programmable input multiplexer allows for configuration of the amplifier. The chip contains also eight A/D converters with a resolution of 24 bits and the control unit for setting parameters for A/D and amplifiers. The ADS1298 has been configured with the following parameters: sampling frequency 500Hz per channel, gain equals 6 and switched on the electrode-skin contact condition block for monitoring the deterioration of a signal.

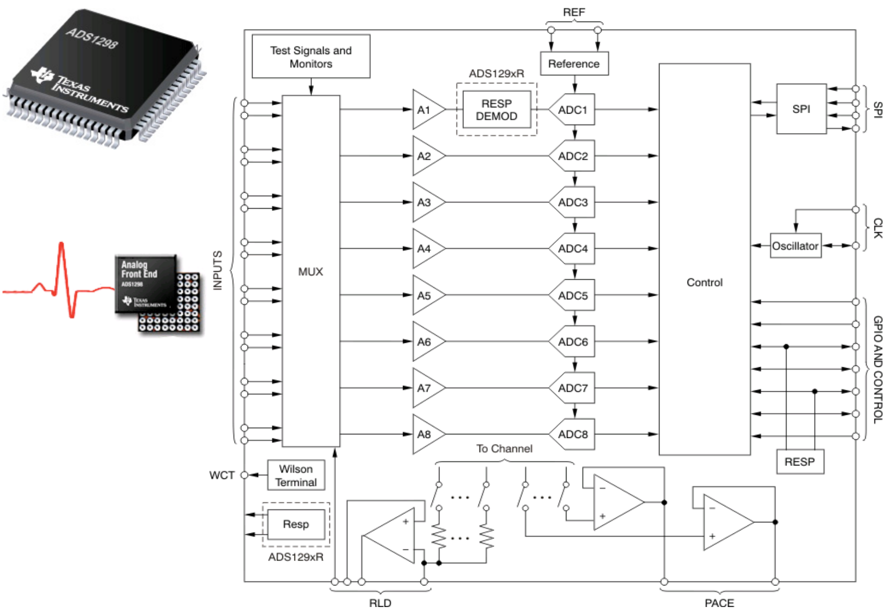

Fig. 3. ADS1298 block diagram [8]

3.2.2 Microprocessor Unit

There are many microcontrollers that can be applied for portable medical devices. Usually, the choice is dictated by the knowledge of the developers. Processor selection is not critical and most 8, 16 and 32-bit single processors can be used. The authors are familiar with Microchip processors and decide to use PIC16F883 [10]. It belongs to 8-bit family and offers low power consumption (approximately 6.5mA) at a sufficient speed. The microcontroller is responsible for ADS1298 system configuration, Bluetooth configuration, reading data from A/D converters (e.g. 8 channels), formatting a frame and sending data to a host via selected standard. General overview of the program together with time required for consequent tasks is presented in the fig. 4. The processor is waiting for a signal 'dataready' in the main loop. Then the system reads data from the ADS1298, create the data frame and sends it to the Bluetooth module. An important added value is sending information about electrode-skin state and battery level which facilitates the operation of the device. The Bluetooth speed has been set at 230.4 kb/s.

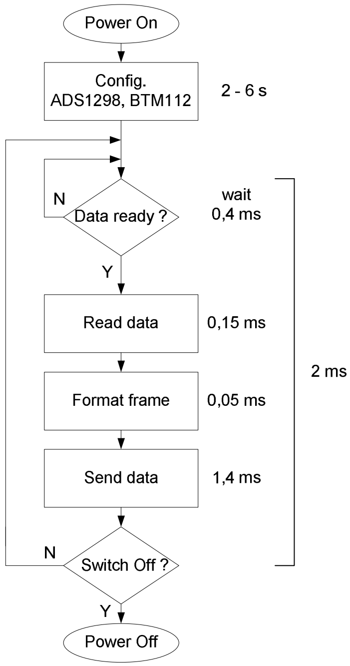

Fig. 4. Simplified block diagram of the hardware program (firmware)

3.2.3 Bluetooth Module Description

The Bluetooth technology has been used for duplex data transmission. The main advantages and disadvantages of the Bluetooth have been described in section 2. As mentioned before, it is a popular standard and many devices like notebooks, PDAs and cell phones. There are a lot of Bluetooth modules from different vendors. An example module class 2 is shown in the fig. 5. The wireless recorder has the BTM112 module which is characterized by a low current consumption and easy to use communication service i.e. SPP (Serial Port Protocol).

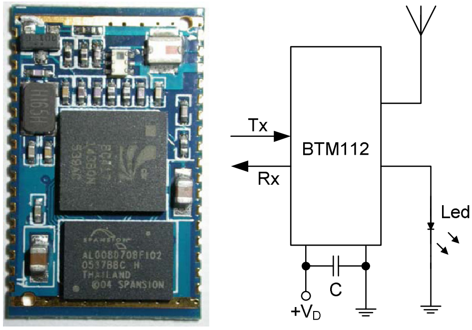

Fig. 5. An exemplary Bluetooth module BTM112 from Rayson [11]

BTM112 is configured with the use of ATA commands for the following parameters: data speed 230.4kb/s, broadcasting disabled (feedback echo off), unique module name with the 4-digit access code. These changes made possible to achieve an appropriate data rate and automatically establish link between our device and PC.

3.2.4 Communication Frame Format

Data from the ADS1298 are collected and standard frame containing 216 bits are created (24 bits of status and 8x24 bits of data from successive channels). The communication between ADS1298 and the microprocessor is realized with the SPI interface [8]. The Bluetooth module (BTM112) is fed via UART interface. The frame consists of: a channel interface, electrode bit status, data field (8x4bytes), synchronization counter state (2 bytes). It includes 34 bytes. The order of bytes is:

Ch0_data	**Ch1_data**	**……**	**Ch7_data**	**Sync. counter**
(4 bytes),	**(4 bytes)**	**……**	**(4 bytes)**	**(2 bytes)**

The synchronization counter is used to capture the lost frames. In the absence of an individual frame, the missing data are obtained by interpolation of neighboring data (it is possible because of the oversampling). The PC application offers reconfiguration of the ADS1298 amplifiers via the microprocessor unit. For this purpose, the processor creates a frame and sends it to an amplifier in the following format: 2 bytes of the header, 1 byte of the ADS register address and 1 byte of the new registry value:

Header (2 bytes)	Register Address (1 byte)	Register Value (1 byte)

The sequence 0x4F5E, 0x05, 0x05 set: the first channel of ADS1298 on with a gain equals 6 and the test signal in channel input.

3.2.5 Power Supply Module

It has been assumed that the system will be powered by one or two AA size NIMH batteries with a capacity of 2000mAh. It has been applied a common solution that consists of an impulse voltage booster converter (type boost) with high efficiency of 80-90%, a set of linear stabilizers of low drop out voltage and voltage inverting converter in order to obtain negative voltage. Power supply system provides 3.3 V for the digital part and ±2.5V for the analog part. The input battery voltage is monitored to obtain information if the battery is running out and need replacement. Total current consumption does not exceed 90mA, which means one set of batteries allows for working time over 20 hours.

3.2.6 Additional Temperature Sensor

An additional thermistor has been introduced to monitor the frequency of breathing. The thermistor is placed in the front of the mouth or nose and records changes of air temperature. The thermistor is connected to the input of ADS1298 channel via voltage divider circuit. There is a possibility to connect other sensors with digital outputs such as digital thermometers, accelerometers, pressure sensors, etc.

4 Application of the Device

The current section is focused on the device application. It has been decided to apply the device for recording bioelectric signals like ECG, EGG, and EOG. The authors would like to underline the possibility of the firmware reconfiguration and the ability to change parameters of the input amplifier.

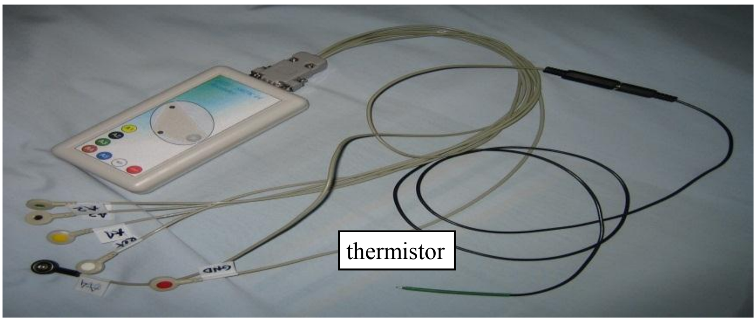

Fig. 6. 4-channel EGG – a prototype device

The last part of this section describes potential benefits that could bring the use of the proposed device. Fig. 6 shows the prototype of four-channel EGG package equipped with thermistor (temperature sensor) as breathing sensor.

4.1 ECG Configuration

ECG recording is one of the most frequently performed tests. Typical ECG system requires 10 connections (cables) with a patient under test [12, 13]. Configuration of the input amplifiers for standard ECG is shown in the fig. 7, i.e. two limb leads (I and II) and six precordial (V1-V6), the other leads are calculated in software. Our device offers this amplifier formation through firmware and ADS1298 reconfiguration.

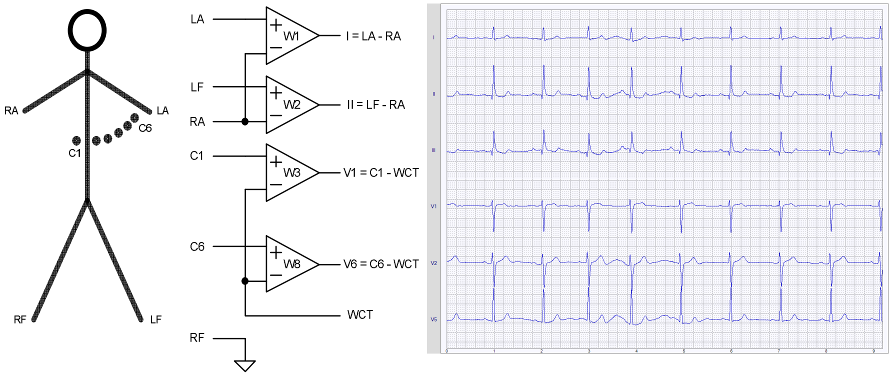

Fig. 7. ECG leads, configuration of the input amplifiers, and ECG signals

4.2 EGG Registration

Electrical activity of the stomach relates gastric contractions and plays an essential role in digestion. The main component of the myoelectric activity of the stomach is so called slow wave with a frequency of 3 cycles per minute (0.05Hz) and therefore requires a long recording time [14].

Typical EGG test takes about 2 hours and consists of three parts:

1. the first part requires usually not longer than 30 minutes and is referred to a stage before a meal (tested person should be fasting),

2. the second part takes between 5 and 15 minutes, during which time the person under test eats a standardized meal (standard depends on the health care center performing the test),

3. the third part usually takes 30-120 minutes after the meal (postprandial).

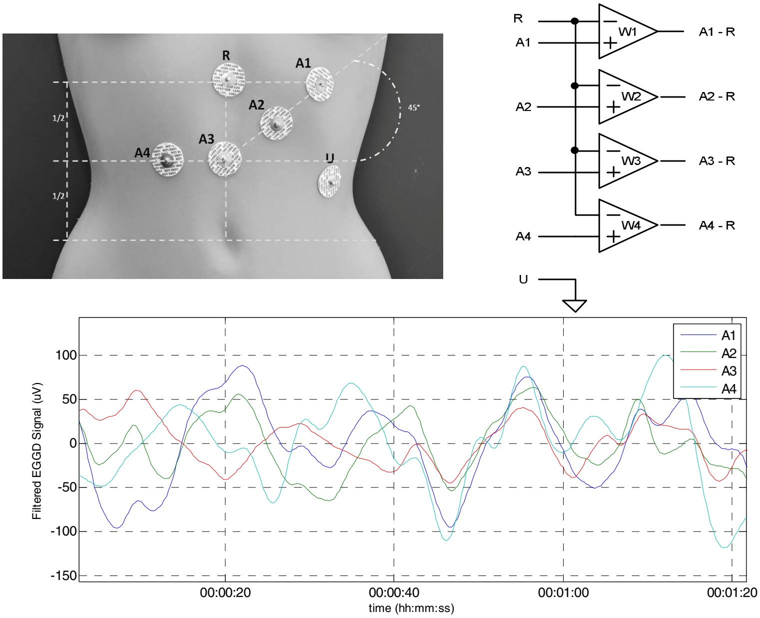

Fig. 8. EGG: electrodes arrangement, amplifiers input configuration and exemplary 80 seconds of EGG signals

The use of wireless technology significantly enhances the research process and increase patient comfort during the EGG test. Four-channel EEG signal is obtained from the electrodes correctly placed on the surface of the patient's stomach as shown in fig. 8.

4.3 EOG Configuration

There is an electric field around the eye which shape is similar to the dipole field due to the potential difference between the cornea and retina. Field vector is associated with the current position of the eyeball. EOG measurement is performed in the horizontal plane (H) and vertical (V) by means of electrodes placed appropriately on the surface of the face (around the eye) [15,16]. The principle of recording the EOG is shown in fig. 9.

The horizontal component (H) of the EOG signal during reading the text is shown in the fig. 10. Fixing the eye on the individual words and turn back of the eye to a new line of text can be noticed. The rising part of the signal corresponds to reading a single line of text and horizontal sections of the signal correspond to reading a single the individual words. The vertical axis shows the rotation angle of the eye in degrees (horizontal plane). The EOG filter parameters are in tab. 4.

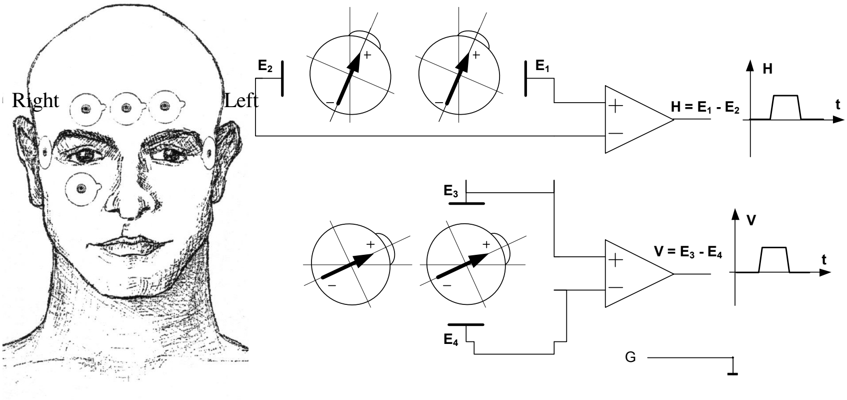

Fig. 9. EOG test: location of electrodes and configuration of the input amplifier [17]

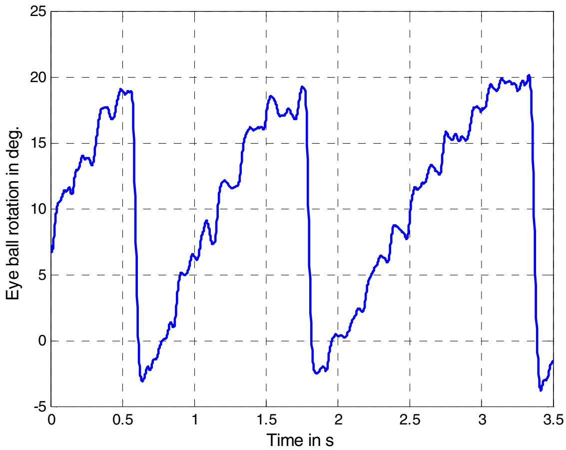

Fig. 10. Horizontal component of the EOG while reading the text

Table 4. EOG filter description

Component	LPF (Low Pass Filter)	HPF (High Pass Filter)
	Corner frequency f_0 Filter's coefficients	Corner frequency f_0 Filter's coefficients
EOG	f_0=17 Hz **b**= 10^{-3}[0.0999;0.3997;0.5995;0.3997;0.0999] **a**=[1;-3.4423;4.4771;-2.6048;0.5715]	f_0=0.02Hz **b**=[0.9998;-1.9996;0.9998] **a**=[1;-1.9996;0.9996]

Digital filters designed for signal processing, which are presented in this chapter, have the following transmittance:

$$H(z)=\frac{b_0+b_1z^{-1}+b_2z^{-2}+b_3z^{-3}+....}{a_0-a_1z^{-1}-a_2z^{-2}-a_3z^{-3}+....} \tag{1}$$

where **a**=[a_0;a_1;a_2;…] **b**=[b_0;b_1;b_2,…].

4.4 Multi-parameter Bioelectric Signals Registration

ADS1298 IC contains 24-bit A/D converter that can be used for a number of input channels. A small gain of measuring amplifier allows registration of the signal with a constant component and avoids the analog high pass filter construction which is usually required in biomedical devices. Simultaneous recording of complex signals are to be extracted with the use of band pass filters. Example of such an acquisition is shown in the fig. 11, where components: EGG, respiratory, and ECG are isolated from the recorded (complex) signal [18].

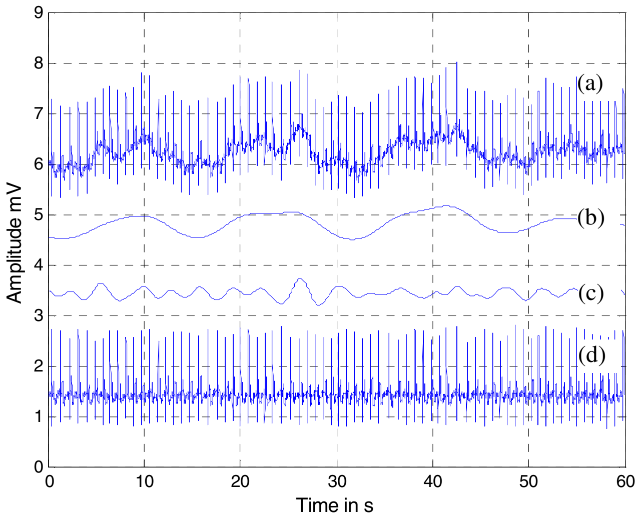

Fig. 11. Example of multi-parameter signal recording (a) and its components: EGG (b), respiratory (c), and ECG (d) signals

As mentioned before, the signal processing is performed in microprocessor on digital signal. A connection of two IIR (Infinite Impulse Response) Butterworth filters has been composed in order to isolate appropriate signals, namely LPF (Low Pass Filter) and HPF (High Pass Filter), as shown in fig. 11. All designed filters are recursive (IIR, Infinite impulse response) Butterworth type but LPF's are of 4^{th} order and HPFs are of 2^{nd} order. Parameters of the corresponding filters are gathered in tab. 5 (The coefficients correspond to formula 1).

Table 5. Filters description for a component isolation from multi-parameter signal

Component	LPF (Low Pass Filter) Corner frequency f_0 Filter's coefficients	HPF (High Pass Filter) Corner frequency f_0 Filter's coefficients
EGG	f_0=0.15 Hz **b**=10^{-11}·[0.0787;0.3148;0.4723;0.3148;0.0787] **a**=[1;-3.9951;5.9852;-3.9852;0.9951]	f_0=0.015Hz **b**=[0.999;-1.9997;0.999] **a**=[1;-1.9997;0.9997]
Respiratory	f_0=0.5 Hz **b**=10^{-9}·[0.0966;0.3865;0.5797;0.3865;0.0966] **a**=[1;-3.9836;5.9509;-3.951;0.9837]	f_0=0.15 Hz **b**=[0.9987;-1.9973;0.9987] **a**=[1;-1.9973;0.9973]
ECG*	f_0=50 Hz **b**=[0.0048 0.0193 0.0289 0.0193 0.0048] **a**=[1;-2.3695;2.314;-1.0547;0.1874]	f_0=0.5 Hz **b**=[0.9918 -3.9673 5.9509 -3.9673 0.9918] **a**=[1;-3.9836;5.9509;-3.951;0.9837]

4.5 Signal Quality Monitoring

Detachment and deterioration of the electrode-skin contact [19] is an important issue during the long term recording test. Hence, monitoring the aforementioned contact improves quality of the test. On the other hand, it ensures valuable diagnostic information. Acquiring a signal with a DC constant component is our solution to the monitoring system. Exemplary change of the constant level for EGG signal during 2-hour test has been shown in the fig. 12. For comparative purposes, the signal from the electrode without preconditioning of the skin is shown (label "RS" in fig. 11). Comparison of RS signal with other EGG leads indicates significantly greater change in DC component. It may carry addition diagnosis information, which requires further investigation.

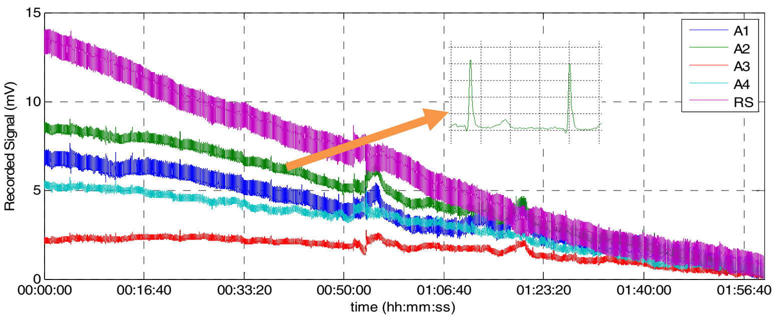

Fig. 12. Example of signals recorded with a DC component

5 Conclusions

The universal wireless device for bioelectric signal acquisition has been presented in this chapter. Using recently developed ADS1298 analog front-end IC significantly simplifies the construction of universal reconfigurable bioelectric signal amplifiers. The communication between the device and host PC has been built with the Bluetooth technology, yet, other standards presented in section 2 can be also applied. The device can be configured off-line and on-line depending on the current requirements and the test: EGG, ECG, EOG.

Thanks to a specific feature of the developed system and ADS1298 IC there is a possibility of acquiring signals with a DC component (unfiltered). It is very important because the designer does not need to construct the analog input filters (usually high pass filters). Digital post filtering can be applied which greatly simplifies the construction of the amplifier and reduces production costs. The A/D 24 bits resolution ensure high quality of the output signal and allows for extracting wide set of artifacts from signal which rises the quality of diagnosis. The use of radio communication simplifies the implementation of the tests and improves patient's comfort during the examination. It also reduces the testing procedure for medical device which is fully separated from electrical network. Note that the largest cost of implementing the device in the real environment (e.g. hospitals) is to obtain certificates of conformity to standards. The production cost of the hardware does not exceed 150USD although it may rise dramatically after obtaining the required certificates.

Currently, we are working on portable device with a GSM and WiFi links. The future of medical portable devices is wireless due to patient's comfort and relatively low cost of electronic circuits. Moreover, the pervasive computing together with such devices makes the whole health care system much more reliable, cheap and above all safer. Patients should welcome these developments with satisfaction because they save their time and effort of visiting medical centers and improve their comfort.

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