SET OF MODULAR BLOCKS FOR EDUCATION IN BIOPOTENTIAL PROCESSING

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Abstract: The main aim was to design and construct a set of modular blocks for education in biopotencial processing, especially in electrocardiography. The designed set of moduls serves as an educational aid for Biomedical engineering subjects at FEE CTU and at FBMI CTU and at 1st School of Medicine, Charles University. The set of moduls is derived from typical structure of the modern medical equipment. Demonstrative description of principles was the main goal of the design, nevertheless the standard safety requirements defined in technical standards CSN EN 60601-X-XX were applied. The most modern products of the world's leading producers were used during the design and construction.

Introduction

Nowadays, medical practice is characterized by extensive use of medical instrumentation. Therefore, it is necessary to have qualified technicians or engineers in the field of biomedical engineering. But this requires that the biomedical technicians and engineers acquaint themselves in details with many principles of functioning of constituent functional blocks of medical devices. For this purpose, it is necessary to design educational aids allowing this.

The main aim was to design a set of modules for processing of biopotentials, especially electrocardiographic ones. Such an educational aid was to be designed so that the students can acquaint themselves with the basic principles of biological signal processing. Further, the aim was to design and construct a modular structure allowing variability of connections and testing of the effect of the individual circuits on the signal being measured.

Materials and Methods

Based on the study of older as well as the latest articles and documentation [1], [2], [3], a general structure of a module set for processing of biopotentials, especially electrocardiographic ones, was defined. This structure is shown on Figure 1. According to this scheme, the set of modules was designed in such a way so that each part of the measuring chain was represented in the set of modules at least by one module.

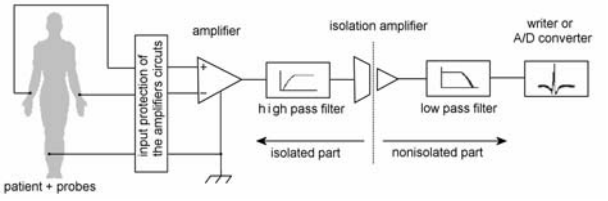

Figure 1: Simplified block scheme

The first modules in the measuring chain are protecting circuits installed before the input of the amplifier. They protect the input circuits of the amplifier against possible damage by electrostatic charges or defibrillation discharge. The next block following the protecting circuits is the lead selector switch. The next circuit is formed by the amplifiers of biological signals. The amplifiers do not only increase the signal level, but we can use them also for suppressing of undesirable disturbances by network voltage from the supply system. Therefore, differential connection is used for the measurement of biological signals [9].

Filtering is an integral part of signal processing. When processing an ECG signal, a frequency range of 0.05 Hz to 120 Hz is used. Three types of filters have been used in out measuring chain. The first one is of type "high-pass filter", which removes the DC component. The second filter is of type "low-pass filter" filtering off high frequencies. The third type of filter is so-called "notch filter", which is used to filter off the disturbing components with a frequency around 50 Hz coming into the signal from network voltage [4].

For safety reasons for the patient, the circuits have to be galvanically isolated from the supply network [6], [13]. In connection with galvanic isolation the way of power supply had to be resolved, too. The modules connected before the isolating amplifier, i.e. to the patient, have to be fed by isolated feeding.

To ensure a good contact and impedance matching, a special gel with chloride ions is used between the patient's skin and the electrode. The impedance value of this transition ranges in units to tens of kΩ. The value of this impedance is of great importance for correct reading of biopotentials and therefore it has to be monitored continuously.

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Results

A modular system was used for the construction of the whole assembly of the components of the measuring chain. We based it from the general scheme given on Figure 1. Each part is created as an individual module. Each module is in a small plastic box with a removable cover. There is a print with module name on the top of the cover and the positions of the measuring points and control elements in the module with their description can be found in the scheme from below of the cover, together with the information whether the module is fed by isolated or non-isolated voltage.

The complete connection of all modules in the measuring chain is shown on Figure 2. Different connections from each module type were made. These modules are then connected in series with 15-pin connectors, type Canon. The exceptions are isolating amplifiers, to which a supply module and a lead selector switch are additionally connected from a side; a control module for the control of the correct connection of leads is connected to the lead selector switch. Positions of signals and supplies on the connectors are defined identically for all modules. A 9-pin connector of type Canon is used for the input connector to the module with protecting circuits and for feeding to the supply module.

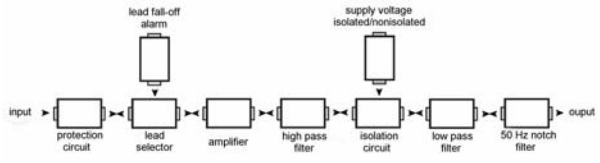

Figure 2: Typical modular set

There are several control switches, trimmers and measuring points in most of the modules. The control elements and the measuring point were located in the module to be arranged as best as possible. Each module has a light emitting diode indicating power supply. Modules with isolated supply have a green diode; modules with non-isolated supply have a yellow diode.

Most of the modules were made in several configurations. The modules with protecting circuits were designed n three configurations: protection by diodes, protection by Zener diodes and protection by The modules with lead selector switches were designed in four configurations: unipolar, bipolar, averaging and extremities leads. The modules with amplifiers were designed in six configurations: differential amplifier, instrument amplifier with two and three operational amplifiers designed by means of TL072 and TL074 circuits, INA126 and INA128 monolithic circuits and an amplifier of type Driven-Right-Leg. The modules with isolating circuits were constructed with various types of galvanic isolation: optical isolation, capacitive isolation and inductive isolation. The supply modules were designed in two configurations: with a battery and with a DC-DC converter. The module with the notch filter was made in two configurations: a tunable active filter with the TL072 operational amplifier and a tunable active filter with the UAF42 monolithic circuit. The module with the high-pass filter was designed as a passive RC element with a cut-off frequency of 0.05 Hz and the module with the low-pass filter was designed as an active filter with the TL072 operational amplifier with a cut-off frequency of 120 Hz [14]. The module for the control of the correct connection of leads was made as the last one. Typical exaples of the modular blocks are shown on Figure 3 and Figure 4.

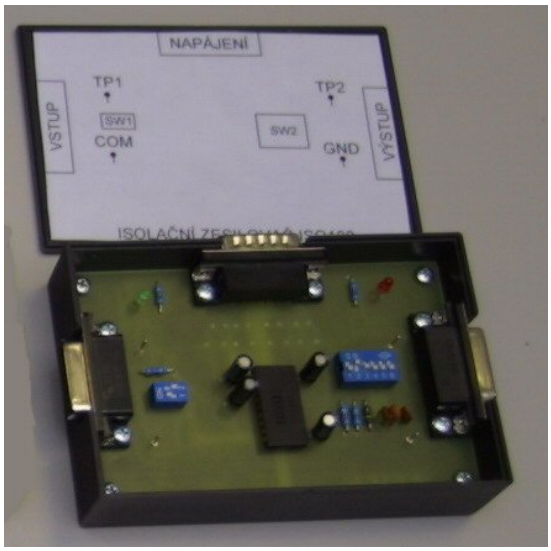

Figure 3: Galvanic isolation block with isolation amplifier ISO 100

All the necessary supply cables were made for the modules. A cable was made for the batteries for the battery supply module as well as a cable was made for voltage supply for the module with the DC-DC converter. Further, cables were made for connection of the input to the measuring electrodes and to the signal generator.

Discussion

Important characteristics of the circuits were calculated within the scope of module design and debugging. The results gained correspond to theoretical presumptions and parameters received from the manufacturers of the electronic components used and they corresponds to the present-day trends of using selected types of electronic components. There are measuring points in the modules, on which the students will be measuring these characteristics according to the assignment elaborated for each exercise.

The state-of-the-art components of the world's leading manufacturers were used in this field. The selection of the components was aimed at the components used in practise in the devices for biological signal measurement, primarily ECG. The connectors in the modules were fixed in such a way to withstand frequent use by students. Unequivocally defined signal positions and feeding on connector pins as well as appropriate combinations of connector types male - female ensure

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that the modules cannot be connected in such a way to have voltage on the signal pin or to mix up isolated and non-isolated power supply.

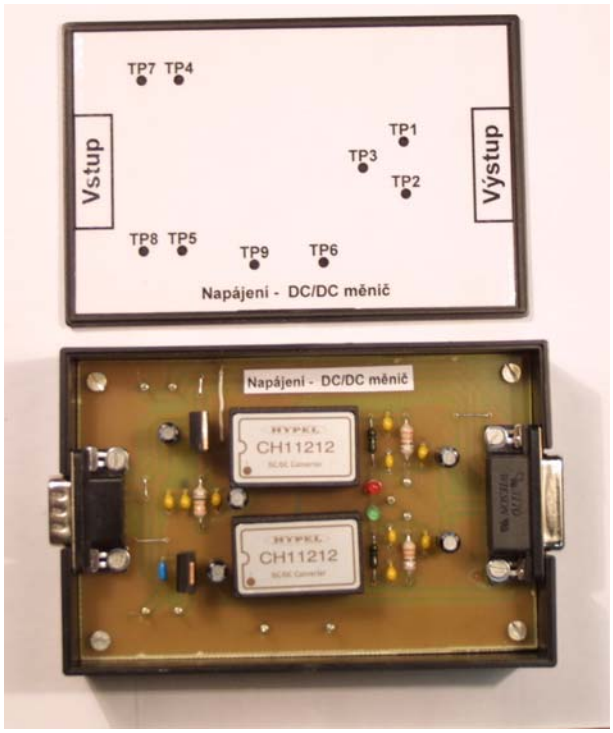

Figure 4: Power supply block with DC-DC converter

Compared to a connection with more circuits on one board, the modular system has the advantage that further modules can be added or defective ones can be changed for new ones. It is assumed for the future that the module set will be added and expanded.

Conclusions

A set of educational modules for the lessons in the field of biomedical engineering was designed, debugged and realized within the scope of this work. The module set is based on the structure of modern equipment, using modern components of the world's leading manufacturers. Stress was put on illustrative demonstration of the principle as well as on maintaining standard safety rules according to technical standards. There was created 25 modular blocks in this project and their summarization is in Table 1.

The modular system of the educational aid allows the students to modify the measuring chain in different ways and to study the effect of individual circuits on the signal being measured. At present, the educational aid is used at the CTU FEE and FBMI Prague in the subjects, in which medical equipment and biological signal processing are studied. It allows the students to verify the theoretically gained knowledge in practise.

Table 1: List of modular blocks

Modular block	Number of modification
Protection circuit	3
Lead selector	3
Lead fall-off alarm	1
Amplifier	4
High pass filter	2
Isolation circuit	6
DC/DC supply	1
Battery supply	1
Low pass filter	2
50 Hz notch filter	2

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