Incorporating human stress measurements into biomedical engineering class

Ondřej Bruna, Pavel Souček, Jan Holub

Dept. of Measurement, FEE CTU Prague, Technicka 2, CZ 166 27 Prague 6, Czech Republic

E-mail: brunaond@fel.cvut.cz, soucepa3@fel.cvut.cz, holubjan@fel.cvut.cz

Abstract: The topic of this paper is to describe the current course at Czech Technical University in Prague X38KLS (Construction of medical systems) and to describe proposed improvements and differences between novel and old approach. The changes and in a state of preparation and have not been fully implemented. The new course should take over the old in September 2013.

1. Introduction

The field of biomedical engineering is fast growing and expanding. Medical experts are equipped with sophisticated tools to examine the patient and to process patient’s data [1], [2] to decide on diagnosis. Because doctors are more often asked to interact with complex devices, there is a need for experienced technician, who would be able to understand both the data and the patient. At this level the technician is not a competition to a doctor, but partner, who should help with data, analyses and who should be able to identify corrupted data or signal affected by a technical issue to exclude wrong diagnosis. To achieve this new training including failures and person in the training loop is necessary. In this paper we describe the approach taken at our university in order to ensure the students will become this type of specialists. Current course is focused on electronics only and the aim is to expand its scope beyond this point and to describe the electronics in context of patients and process of setting diagnose.

2. Current structure

Current course is designed in a following way:

a) Lectures: the students are optionally attending lectures (organized in a lecture hall capable of accommodating 40 people at once), lectures teach students about the circuits in medical instruments and explain their operation.

b) Laboratory classes.
   a. Practical measurements in the laboratory serve other purpose, students are supposed to validate the knowledge gained during the lectures by measuring real hardware which incorporates instruments from lectures. This segment takes 7 weeks. When students are finished with the first part, they are considered eligible to proceed to second stage.
   b. Project of their own choice. This last and final step is supposed to increase students’ creativity by letting them solve a problem themselves. There were many different things designed and tested by our students.
Lectures are focused on knowledge about electronics and measurements of biological signals. Lectures do not deal with signal processing. Measurement part of the course lasts for a first half of a semester (7 weeks) while the whole semester has 14 weeks. Practical measurement takes place in a laboratory equipped with standalone training electronic circuits (training box/training board) and the students are supposed to perform measurements on each of the parts separately to study its function. They are also supposed to simulate circuits in a National Instruments MultiSim and generate results for same tasks as in case of real circuits. When all the data are obtained, students are expected to compare both results in order to conclude with the advantages and disadvantages of simulation. Simulation also allows working with the circuit in more ways and students can try things, which they could not with real application.

The individual boxes used in current curriculum cover measurements of all important electronic parts. Students would see the electronic circuit on the lecture and during the exercise it is possible to examine real circuit. Topics of measurements are:
- Band filter.
- Instrumentation amplifier.
- Modelling of parasite capacities of active and passive parts.
- Function generator.
- Mean value convertor.

The second half of the semester is dedicated to design of their own device or circuit related to biomedical engineering. Students are supposed to design, implement and test in MultiSim (verification phase), and afterwards to assemble it in a breadboard and measure its properties, which will be then compared with original design in computer program. The goal is to compare these two approaches and to realize differences, advantages and disadvantages of both of them. As a result students write a report.

Some examples of what students did in last two semesters: volume unit meter, voltage controlled oscillator, alfa-wave monitor, defibrillation pulse protection circuit, metal detector, correction amplifier, ECG amplifier and so on.

During the class some students reported some problems and provided feedback to the teacher regarding the class set-up. Some students felt the class is too software oriented and would appreciate more circuit oriented approach. Some students complained they did not see the whole picture and could not relate the knowledge from lectures to exercises. Some students also complained about virtual oscilloscopes, which were used in class – Velleman PCSU1000USB. In order to satisfy all collected data, new curriculum was designed and is discussed in the next chapter.

![Figure 1: Screenshots of screens with error (left) and without (right) when measuring ECG.](image-url)
systems include most of the blocs, which were presented in original curriculum and are connected together to create a working instrument for measurement. So the students can understand single circuits as well as the whole system. Volunteers in the class can have measured their ECG (electrocardiogram). Training boards are made of several blocks, which can be measured. These blocks are substitutions to boxes used in former approach.

### Table 1: Segments on new training boards.

| ECG, EEG, EMG Board          | GSR Board                  |
|------------------------------|----------------------------|
| Instrumentation amplifier    | Inverting amplifier        |
| Notch filter                 | Band pass filter           |
| Alpha wave filter            | Visualisation and          |
|                              | signalling segment         |
| Output amplifier             |                            |
| Optocoupler                  |                            |

First training box ECG, EEG and EMG – electromyography is a method for measurement of activity of skeletal muscles. The board allows measurement of forearm, biceps and triceps EMG. Second training box is for measurement of galvanic skin resistance. Table 1 shows segments of bought training boards.

Approach proposed in this paper is based on a similar platform as the original one. Students are still expected to attend exercises (mandatory) and lectures (optional). Exercises are divided into three sections.

a) Measuring and calibrating every single blocks of the device.

b) Measuring on a real subject.

c) Diagnosis of system failure.

The second part of semester includes measurement on students. The students are divided into groups of three and two and perform measurements on each other. When they are able to operate and measure with the device, the teacher will use a switch button to simulate one or more failures of the device – example Figure 1. Students are then asked to measure, detect and remove the error individually without any interference from the teacher. The teacher then evaluates their approach to solution of the problem. In this case, students do not have any instructions on how to proceed and they have to deal with the problem on their own. This should support their self-confidence in knowledge they have learned throughout the semester and help them improve analysis skills, which are essential for an engineer in today’s world.

**Figure 2:** Original boards for measurement.

New approach is based on instruments, which incorporate the same circuits as did the boards from original approach. The difference is that here are circuits implemented on one board. Boards DL3155BIO8 and DL3155BIO5 from company DeLorenzo have been ordered for this purpose.
DL3155BIO8 is a board for measurement of galvanic skin resistance. The comparison of both can be seen on Figure 1 and Figure 2. Galvanic skin resistance has been used as an indicator of perspiration. In some cases it is considered, that increased perspiration is an indicator not only of increased physical load, but also psychical load or stress [3],[4]. This can be one of input variables for determining people’s stress level. Board DL3155BIO5 is designed for measurement of EEG (electroencephalograph, alpha waves only), ECG (electrocardiogram) and EMG (electromyography). Both boards have special switches creating artificial defects in the system and corrupting the measurement. The DL3155BIO5 board is also equipped with board for simulation of two proper heartbeats. These two boards have been chosen for the following reason: the ECG and EEG are nowadays the most commonly measured data and students are supposed to be able to detect and remove any problems related to this electronics. When combined with the board DL3155BIO8 it can create a simple polygraph. Other equipment used was an oscilloscope HP54600, Velleman PCSU1000 digital oscilloscope and computer.

| Old                        | Status in new curriculum |
|----------------------------|--------------------------|
| Convertor to mean value     | Discontinued             |
| Instrumentation amplifier   | Continued                |
| Modelling of parasite capacities of active and passive parts | Discontinued |
| Function generator          | Discontinued             |
| Band-pass filter            | Continued                |
| Notch-amplifier             | New                      |
| Optocoupler                 | Continued                |
| Alpha wave filter           | New                      |
| Visualisation and signalling| New                      |

How will the new training boxes replace the new ones is shown in Table 2. During the first section of the class are students supposed to perform similar measurements as in the original plan, but this time the circuits are implemented in one measured board and there is clear purpose of this board. Students measure parameters of all blocks and make simulation using MultiSim as well. These measurements are performed with step by step instructions. After measuring and calibrating both boards, the students can proceed to measurements with subjects. There will be several tasks for them to accomplish. One class will be focused on measurement of human stress, next on assembling polygraph and using it as a simple lie detector, and identifying and dealing with several errors of teacher’s choice (set-up on the board control panel).
Teacher can use the boards to simulate a failure of certain blocks. Students are then supposed to use their knowledge about the boards perform measurements. Based on measurements they state a diagnosis. The diagnosis tells what the problem is and now to fix it. Part of the task is to explain, how they came to conclusion. GSR board can simulate 4 and ECG, EEG and EMG board 5 faults. Fault is for example failure of a resistor in a feedback of amplifier, disconnected output amplifier and more. Determining the failure would be the last exercise of the semester.

4. Summary
The proposed approach has not been implemented in university’s curriculum yet and is still in a preparation phase. Despite this have been already performed some experiments with students, picture taken is on Figure 4. From last semester was chosen one group of volunteers, who went through partly modified semester plan, which included new boards. Their task was to measure on new devices instead of measurement on old standalone boards. Students were asked to assess new exercise – Stress factor. Stress factor exercise will be also part of new semester plan. Its goal is to show that people under stress react differently. To achieve it, special programs were used and ECG with GSR was measured. Human factors and stress play an important role in many manned systems from flight decks to control station of power plants.
5. Conclusions
Students finished measurements successfully and reported, that they would recommend them to become a permanent part of this class. Tests with students showed, that the goal – implement all three phases will probably not be doable. During the semester students had more problems with setting up the board than anticipated. Therefore it is planned to reduce the amount of exercises and give more space to measurement on students and fault diagnosis. This approach is still under development and will be revised before launching it in classrooms. Despite some drawbacks – very time consuming and some students might not keep up with their colleagues, it has been decided to continue with implementation and to start new approach the next semester.

References
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