SCLPX - An Alternative Approach to Experiments in Physics Lessons at School

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Conducting experiments in physics using modern measuring techniques, and particularly those utilizing computers, is often much more attractive to students than conventionally conducted experiments. SCLPX (Sound Card Laser Pointer eXperiments) deals with physics experiments in which a computer sound card is used as a measuring device, along with other available physical devices, such as a laser pointer, a solar cell or an electret microphone. It is possible to perform very simple school experiments (both demonstration and multiple ones), whose high accuracy and clear final conclusions can be achieved at a very low cost. Further information is published on the specialized webpage www.sclpx.eu/index.php?lang=en.

Keywords: physics experiments, laboratory exercises, low cost of basic equipment, sound card, laser pointer, solar cell, PC microphone, Free Audio Editor (FAE), Visual Analyser (VA)

Introduction

Our work is based on the experience with the school kits such as Vernier, IP Coach or Pasco. It presents an alternative way of conducting physics experiments that can be used directly as demonstration experiments, multiple experiments or even as home experimentation. The most important advantage of the proposed experiments is a very low cost of the basic equipment as well as the fact that all of these experiments could be repeatedly conducted individually at home.

There is a wide range of computer controlled experiments. However, there are only several publications about simple and smart measurements that can be carried out by a sound card. For example, the photogate timer can be set by an optocoupler connected to an audio input in order to determine the acceleration due to gravity by timing the oscillations of a pendulum [2] or to specify the force constant k of a coil spring by timing the oscillations of a mass spring [3]. The computer sound card input and output can be used to measure the speed of sound or resistance and temperature [4 - 8].

Since 2008 we have been developing our own high school laboratory experiments by using a PC sound card. Unfortunately, these experiments have not been published yet.

Up to now, we have prepared and tested 20 experiments in the field of mechanics and sound waves. About 30 other experiments dealing with the properties of solids and liquids, electricity and magnetism or quantum physics are in the process of screening. All the experiments published at www.sclpx.eu/index.php?lang=en have been tested and evaluated at partner high schools.

How does the experiment work?

All the experiments use a simple optical gate, composed of a laser pointer and a solar cell from which the signal is transmitted through a cable to the microphone input of the sound card by a 3.5 mm jack connecter. The principle of optical gate is then obvious: the interruption of the laser beam changes the output voltage of the solar cell, and the output pulse corresponds to the course during the transient process, as shown in Figure 1. A basic review of the sound card photogates is presented in [1].

In this way, we can then measure the length even for very short periods of the order of 10^{-4} to 10^{-6}seconds.

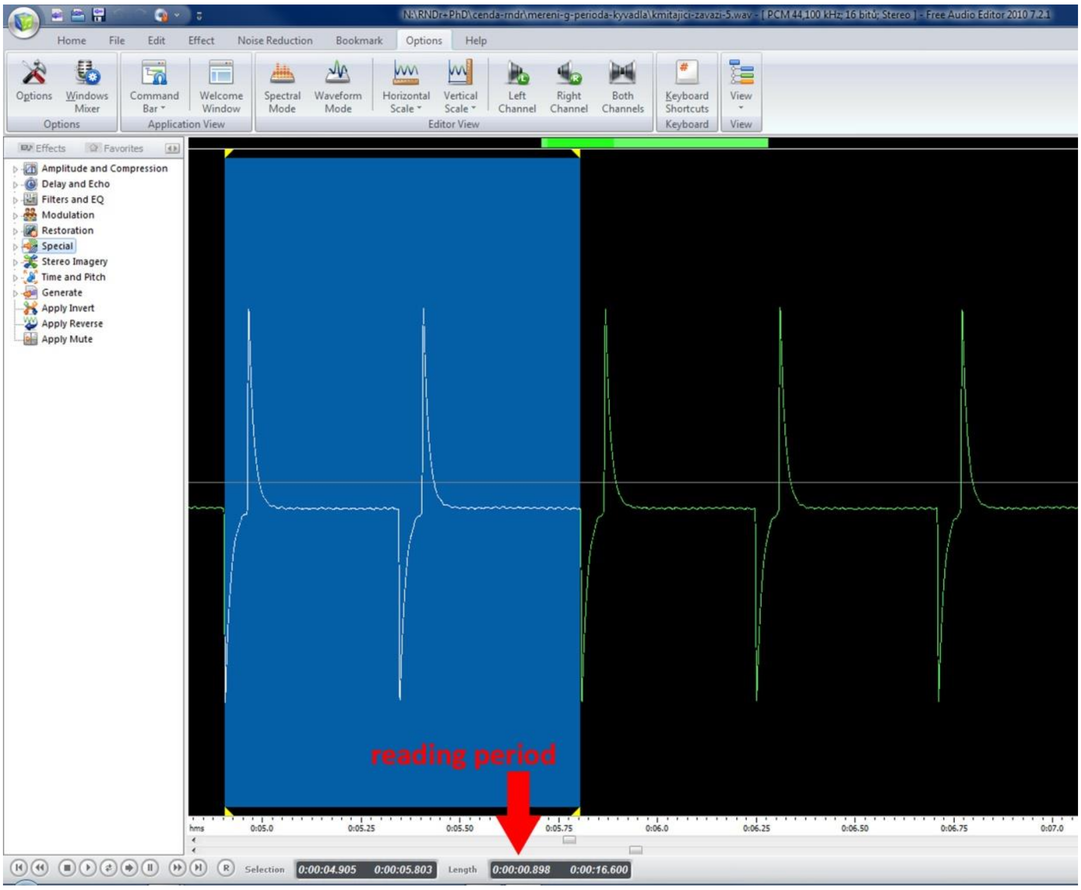

Figure 1: Output signal from solar cell with reading of the period in FAE

To record and evaluate the signal, we used a freeware program for audio editing Free Audio Editor (FAE) [9]. This program can also edit the recorded signal, so that we can make a selection of one part of the signal, after which the program calculates its length (window called Length) or we can enhance a weak signal.

Of course, the recording can also be saved in WAV format audio file, so that we can reload the experiment data at any time needed. For some experiments, especially those with sound, we used a freeware program the Visual Analyser (VA) [10].

In conclusion we would like to remind the important fact that a sound card can be used for AC voltage measurements only. The output of the solar cell is in the range of 100 mV, so there is no risk of destroying the sound card.

The advantage of using a sound card over other systems is a high sampling frequency (44.1 kHz standard, but nowadays you can go up to 384 kHz).

In the next section we will briefly describe several experiments in the field of mechanics and acoustics.

New School Physics Experiments

To carry out these experiments we always used the following tools: a notebook or PC, a photodiode or a solar cell, a laser pointer, a pendulum and a paper comb with wide teeth cut out of a cardboard. The solar cell had a larger surface than a photodiode and was therefore easier to work with. All the experiments can also be performed by using a tablet with a microphone input.

Some of our experiments, such as determination of gravity from the pendulum oscillation period, dynamic determination of a spring constant or measuring of the speed of sound, are quite known and well-documented nowadays [2 - 4], [8].

We therefore focused our attention on less-known experiments or those experiments which were carried out in unusual ways, as was the case of producing sound beats by using wine glasses.

Free fall - verification of time dependence of velocity of a falling paper comb

Apart from the usual tools, for this experiment we need to prepare a paper comb cut out from cardboard paper. All the teeth should be of the same width; in our case the width of the teeth d was 1 cm and the total length of the ridge was about 25 cm. The experimental arrangement can be seen in Figure 2.

We let the comb to perform a free fall from a constant height through the photogate. Since the width of the i-th tooth is known, the total time of passing of the i-th tooth through the laser beam can be determined in the Free Audio Editor. By the relation $v_i = d / t_i$ we can subsequently calculate the approximate value of the instantaneous speed of the i-th tooth. Since the movement is accelerated, the first tooth has the minimum speed, while the i-th tooth reaches the maximum speed. The graph of speed versus time is then a linear function, where the constant of proportionality is the value of gravitational acceleration ($v = g \cdot t$).

Figure 3 shows the recorded signal in the FAE, whereas Figure 4 offers a corresponding graph produced by MS Excel.

Figure 2: Free fall of a paper comb

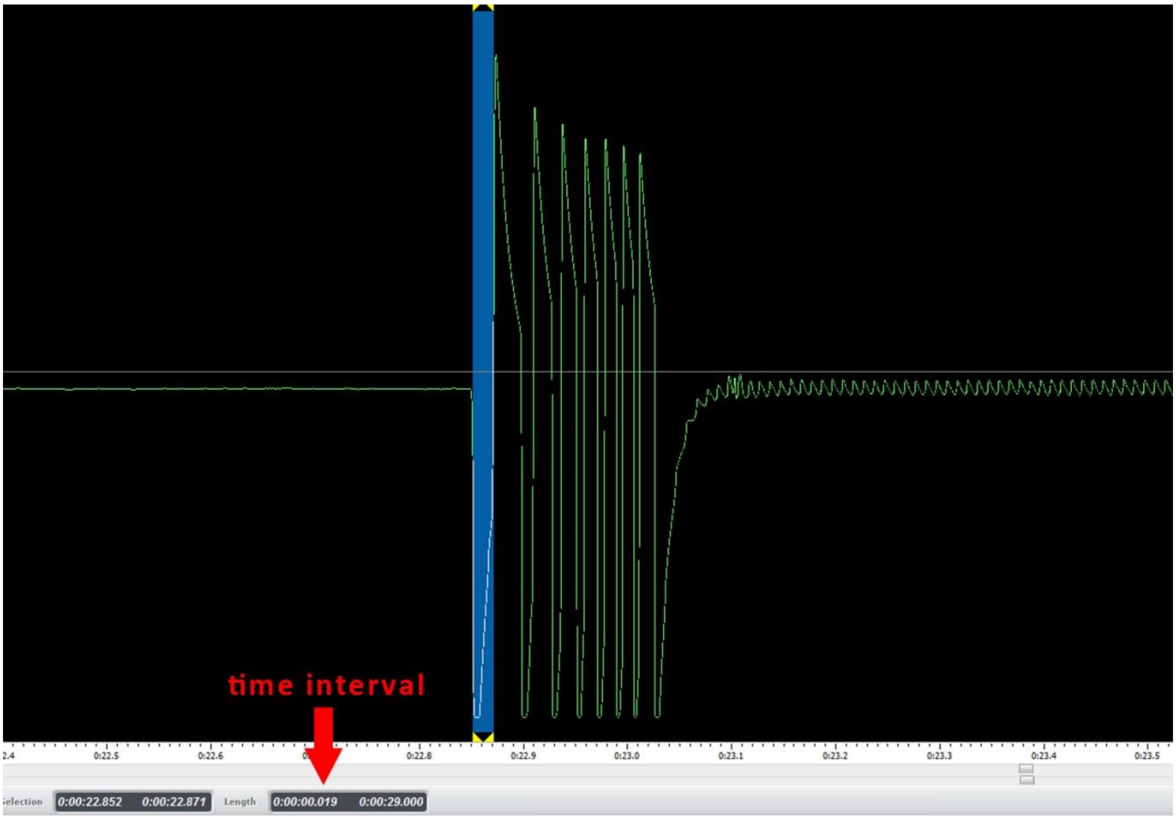

Figure 3: Free fall of a paper comb – the signal view

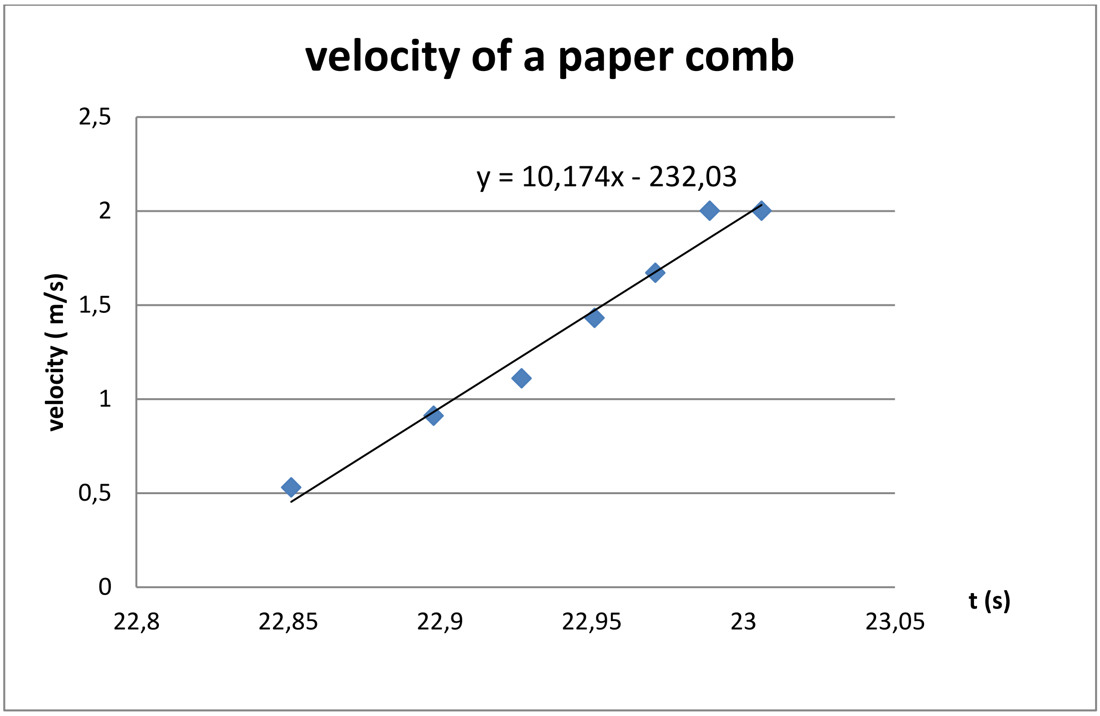

Figure 4: Free fall of a paper comb – MS Excel graph with linear regression

Determination of the coefficient of the friction from the acceleration on an inclined plane

Using plasticine (modelling clay) we affix a paper comb on a wooden block. After that we let the comb slide freely along the inclined plane. We must make sure that the laser beam intersects with the teeth of the comb. We carry out measurements for three different inclinations of the inclined plane (30 °, 35 ° and 40 °).

Next we measure in the Free Audio Editor the transit time of the first and the last tooth. After that we calculate the instantaneous velocity by using the formula $v = \Delta s/\Delta t$, where $\Delta s = 1$ cm (comb tooth width).

The acceleration is determined by the relation $a = \Delta v/t$, where Δv the speed variation of the first and the last tooth is and *t* is the time between the two teeth.

Finally, we use the following formulation of the coefficient of the friction:

$$f = tg\alpha - \frac{a}{g\ sin\alpha}$$

The experimental arrangement can be seen in Figure 5. The recorded signal in the FAE is similar to that in Figure 3.

Average value of the coefficient of the friction $\bar{f} = 0.32$ obtained by measuring is in good agreement with the tabular value $f = 0.3$ for wood on wood surface.

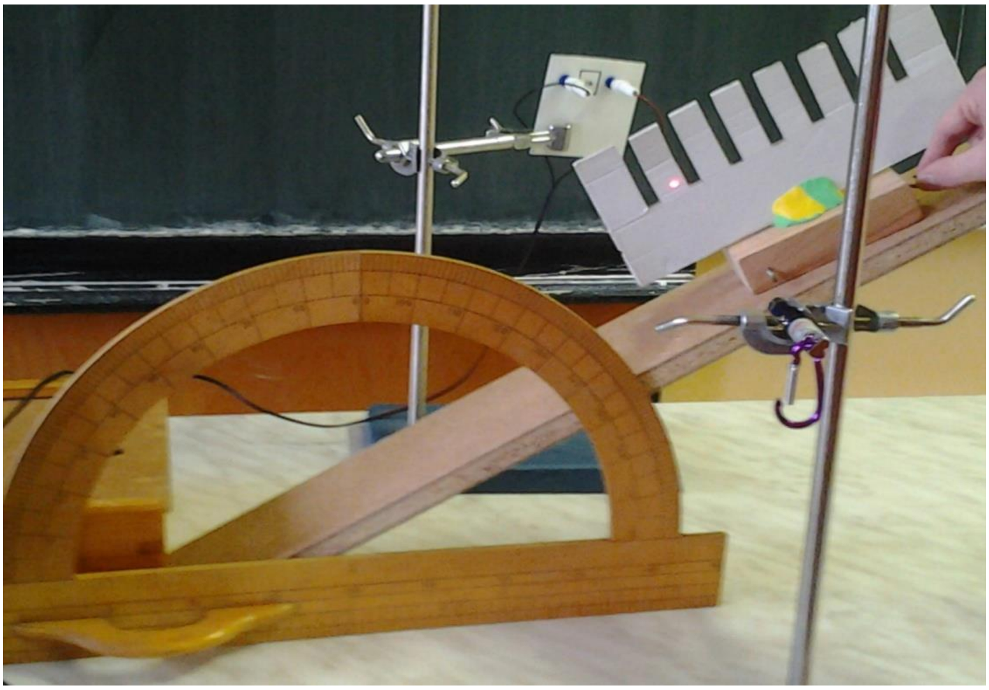

Figure 5: Measuring of the coefficient of the friction

The demonstration of sound beats by using Visual Analyser (VA)

First we connect the speakers to a sound card. The PC microphone is placed between the speakers approximately 30 cm from them.

Having started the Visual Analyser, we select the *Main* tab on the right side of the screen and click on *Wave Gen*. This opens the *Waveform Generator* window, in which we click on the *Main* tab and select *Enable* for each channel. After that we enter close frequencies for both channels.

Finally, at the bottom right of the window we set the *Main* tab on Channel (*s*) and select A + B, after which we start measuring by pressing the *On* button in the upper left corner of the screen.

To listen to the audio beats we can set the frequency at approximately 500 Hz and 505 Hz. If we want to depict it on a graph, we have to select more dissimilar frequencies in order to make sure that the amplitude decrease of the sound beats is sufficiently evident. In our case we selected 500 Hz and 530 Hz (see Figure 6). The experiment can also be performed without a speaker and a microphone, but it will of course lack the desired sound effect.

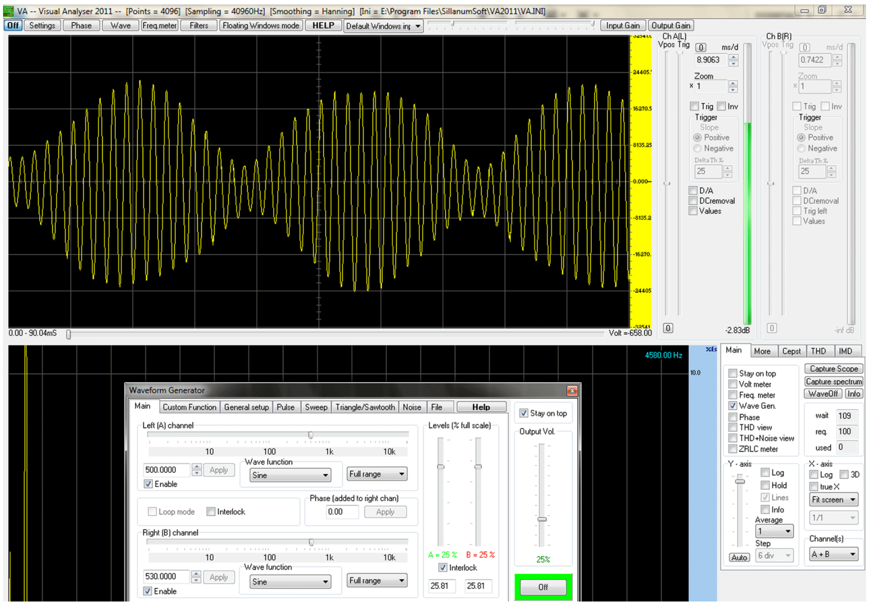

Figure 6: Sound beats by using the Visual Analyser

The demonstration of the sound beats by using wine glasses

We carry out this experiment in a similar way. As a source of sound, we can use two wine glasses filled with water. The water level in both glasses should be approximately at the same level. The microphone was positioned between the two goblets, in the middle.

The experimental arrangement can be seen in Figure 7, whereas the recording of the sound in the FAE is shown in Figure 8.

Figure 7: Sound beats produced by wine glasses

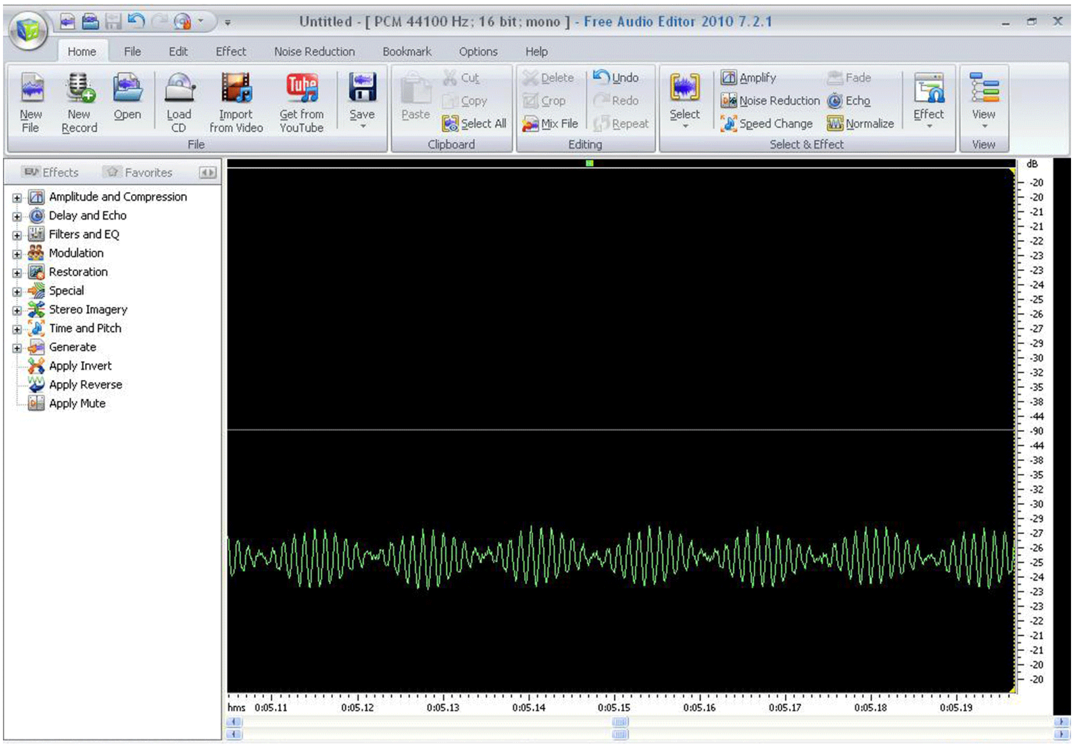

Figure 8: Preview in the Free Audio Editor

Conclusion

All computers or notebooks have a built-in sound card – the input/output interface that can directly receive or generate analogue signals. Although such sound cards have a limited potential because of the ability to process alternating signals only, it can make physics education more efficient and more interesting at a very low price. Simple sensors such as a solar cell or a PC microphone can be directly connected to the sound card input.

In this paper we have shown several experiments from the field of mechanics and acoustics. We have verified that the optical gate consisting of a solar cell and a laser pointer allows for making measurements comparable with experiments performed by using professional kits such as Vernier, IP Coach or Pasco.

The advantage of our approach is the ability to conduct experiments not only as a demonstration, but also as students' laboratory exercises. Another advantage is the affordability of the used equipment, which may offer an interesting alternative to the most expensive professional headsets for a variety of primary and secondary schools.

A very low price, ease-of-use and comprehensibility of the experiments make it possible for students to turn their computers into measurement devices, focus their attention to improve their physical skills and, last but not least, to make physics more attractive to them.

Acknowledgments

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References

[1] Gingel et al. 2011 Review of sound card photogates, *Eur. J. Phys.*, **32(4)**, 905-924
[2] Velasco S et al. 2011 Timing the oscillations of a pendulum, *Phys. Educ*. **46**, 133-134
[3] White J A et al. 2011 Timing oscillations of a mass spring, *Phys. Educ*. **46**, 378-379
[4] Khairurrijal et al. 2012 Measurement of gravitational acceleration using a computer microphone port, *Phys. Educ*. **47 (6)**, 709-714

[5] Aguiar C E, Pereira M M 2011 Using the Sound Card as a Timer. *Phys. Teach*. **49**, 33
[6] Gingel Z, Kocsis P 2011 Measure resistance and temperature with a sound card. *EDN (Elektronics Design, Strategy, News)*, **56(10)**, 58-59.
[7] Litwhiler DH, Lovell TD Acoustic Measurement Using Common Computer Accessories: Do Try This at Home. Proceeding of the 2005 American Society for Engineering Education Annual Conference & Exposition. [online]. [cit. 20. 4. 2013] Available from: http://zone.ni.com/devzone/cda/tut/p/id/3817
[8] Martin B E 2001 Measuring the Speed of Sound – Variation on a Familiar Theme, *Phys. Teach.*, **39**, 424-426
[9] http://www.free-audio-editor.com/
[10] http://www.sillanumsoft.org/