

# System for measurement using a computer in the school laboratory

Radek Němec, Jan Tříska, Josef Šedivý

**Abstract**—Measurement systems using computers in physics laboratory is possible to create a computer and demonstrate natural phenomena. Commercial systems which are supplied ready-made, are somewhat less expensive for small laboratory. The authors developed a system SMPSL, which can be built at very affordable prices. The system is supplied free control software. Commercial sensors that can be connected to the system, they are also very expensive. As an alternative, the authors again sensors designed by own research for a fraction of the price.

**Keywords**—DAQ, eProDas, measurement, experiment, education

## I. INTRODUCTION

**M**ANY systems for measuring with computer exists. Many of these systems are sold for a higher amount, and so a lot of schools not implementation expensive systems. It is in the best schools, students are introduced to computer-aided experiments to easily be able to more fully record measured values in numeric form, as well as graphical display. Also, to check how you can use the computer to control measurements. Therefore, it was based on a platform eProDas at the University of Ljubljana, Slovenia developed measurement system using a computer in the school laboratory (SMPSL), which will be very cheap to assemble the hardware and software drivers available for free.

## II. COMPUTER-AIDED EXPERIMENTS

Computer-assisted experiments- systems for the acquisition, management and processing of the variables (physical quantity) using the computer consists of hardware and software parts. In addition to measurements using a personal computer, you can still use data loggers, which are small handhelds for data collection. Both types can be found in school laboratories.

R. Nemeč, University of Hradec Kralove, Faculty of Education, Department of Informatics, Rokitanskeho 62, 500 03 Hradec Kralove, Czech Republic (phone: +420 774220193; e-mail: radek.nemec@uhk.cz).

J. Triska, University of Hradec Kralove, Faculty of Education, Department of Informatics, Rokitanskeho 62, 500 03 Hradec Kralove, Czech Republic (phone: +420 602133538; e-mail: jan.triska@uhk.cz).

J. Sedivý, University of Hradec Kralove, Faculty of Science, Department of Informatics, Rokitanskeho 62, 500 03 Hradec Kralove, Czech Republic (phone: +420 493331171; e-mail: josef.sedivy@uhk.cz).

### A. The hardware part

The hardware part consist of a sensors and A/D (analog / digital) converter. The sensors must be placed in a location where the measured value. A/D converters are either part of the computer or in an external console connected to a computer via a suitable bus (serial, USB, Ethernet, etc.).

The sensor converts a physical quantity (temperature, force, pressure, light, and many others) to voltage. Connecting the sensors should be as accurate and should not be influenced by time or by changing environmental influences. It should also have a small footprint and ease of use allow for measurement. [1]

By now there are many sensors that are made integrated circuits which directly convert input voltage to the physical quantity. This eliminates the production of physical transmitter and allows direct connection to the A/D converter.

The voltage from the sensor converts the analog digital converter to a numeric value with which a computer can work. UA / D converters is important readability and a maximum sampling frequency. The resolution is based on the number of bits on which A / D converter converts the input value. 12-bit converter is able to distinguish the 4096 values and the range of 0-5 V, the resolution is  $5/4096 = 0.0012$  V (1.22 mV). Sampling frequency of times per second the need for transfer of current at low sampling frequencies is distorted. The higher the sampling frequency, the measurement is accurate. On the contrary, at high sampling frequencies produces large amounts of data. However, faster converters are expensive. Using specific sampling frequency is dependent on the type of measurement. For example, the long-term measurement of slowly changing variables not be so frequent recording sampling frequency may be reduced.

When measuring low voltage is not required sensor voltage is connected directly to the A / D converter.

There is still the possibility of measuring with a multimeter containing embedded computer connection. Communication goes through some of the standard lines of communication, such as a USB or serial interface. Such measurements are fundamentally different from the above. It also includes sensors and A / D converter.

### C. The software part

The software part is a utility program that reads data from the A/D converter is stored in computer memory and performs further processing. This program can save the data to disk as files. You can then later view, edit or print. But is also open to other programs that allow their retrieval, editing, processing and evaluation. Programs such as spreadsheets (MS Excel, OpenOffice Calc, etc.) or more advanced programs such as Matlab.

Simultaneous measurement programs, apart from just saving the measured data allow wider use. Allow the data displayed graphically in the form of various graphs, perform various modifications or process the data using mathematical calculations, various filtering, smoothing, regression or transformation.

Some systems also allow control of the computer's own experiments. Such proceeding can be solved using D/A converter or using a binary output.

### III. PLATFORM EPRODAS

For the creation of systems for measurement using a computer in the school laboratory (SMPSL) is used eProDas platform, resulting in the University of Ljubljana, Slovenia. eProDas is very affordable system, easily attachable to a computer, offering many possibilities of measuring, processing and display of data [1]. Suitable for science experiments. eProDas is seen as a platform for providing data acquisition and signal generation for performing different experiments in the natural sciences such as physics, chemistry, biology, medicine, and engineering.

On the website eProDas [2] can find a description of the system, a description of hardware and software that you can download for free. Hardware should be compiled and software libraries is only on the basis of need program application program. Detailed guide can be found at [3].

eProDas is very affordable system, easily attachable to a computer, offering many possibilities of measuring, processing and displaying data. The system is suitable for the experiment in the natural sciences.

eProDas is seen as a platform for providing data acquisition and signal generation for performing different experiments in the natural sciences such as physics, chemistry, biology, medicine, and engineering.

This system was designed as a cheap and flexible interface for recording the value transmitted by one of the standard communication interface. After this transfer, the data transfer with a graphic display that also provides many ways of processing and preservation. [4]

The basic part of the system microcontroller is connected via the USB interface on which it is loaded firmware. A microcontroller is further controlled by commands.

The main advantages of this system are:

- Low cost - USB connection
- The optimum properties for the collection of data using electronic measuring sensors
- The optimal characteristics for control applications (control, lowering)
- Detailed documentation
- A library for developing applications in different environments (C / C ++, Delphi, Visual Basic).

### IV. ADVANTAGES AND DISADVANTAGES OF EQUIPMENT

Platform eProDas have many advantages and one of disadvantages.

Price - Probably the biggest advantage is its minimum price, depending on the components it is possible to build a structure for a tenth compared to commercial prices of finished products.

Modifiability - as described above, the system eProDas is designed so that it can be extended and the like hardware, software libraries allow the utility to create exactly the needs of the user by controlling dedicated devices to complex systems. The school is also possible to work and engage pupils.

The optimum number of input and output ports - a common measure in School Science Laboratories require one to four analog or digital sensors, as much eProDas served by a large margin. In addition to the microcomputer can connect other sensors via the SPI bus.

Communication via USB - USB interface is fast, reliable and standard, does not require reduction, and may not interfere with construction PC.

Libraries for developing applications in C / C ++, Delphi and Visual Basic - these three computing environments today are most commonly used in schools.

Detailed documentation - documentation eProDas [3] is at a very high level, ahead of the documentation for some commercial products.

Own production - that is only semi eProDas is obviously a disadvantage, because it is necessary to invest time and effort into a particular implementation.

Guarantee - as with other free products, the authors do not guarantee that everything will work properly and will not cause any damage. Also support depends only on the willingness of the authors.

### V. SYSTEM SMPSL

This system was designed as a cheap and flexible interface for recording the values of transmitting using one of the standard communication interface. After this transfer, the data transfer with a graphic display that also offers many ways to process and store.

The basic part of the system is a microprocessor connected

via USB interface on which it is loaded firmware controlled via commands.

The system is designed so that it can be used at all levels of education, from primary school to high school. An important feature of the system is the ability to produce it yourself, both due to the very low price, thanks to freely available libraries and documentation.

### VI. THE HARDWARE PART

Hardware-based microcontroller is a Microchip PIC series. With affordable price and sufficient properties was selected the PIC18F4550 (fig. 1). This microcontroller allows full speed (12 megabytes/s) USB connection, 32 KB program RAM, 2 KB of data RAM and 256 B integrated EEPROM. It offers 10-bit AD converter, 13 multiplexed input channels, two voltage comparators, 4 timers. PWM module to control the power, SPI and I2C communication, USART module. 31 general purpose digital I/O ports. Connection with other devices is mainly done through SPI interface allows connection to 12-bit AD and DA converters on Fig. 2.

section. Contains 4 analog inputs, 4 digital outputs and 1 analog output (Fig. 3). The interior of the hardware has been implemented on a printed circuit board with cable management to banana jacks on the top of the chassis.

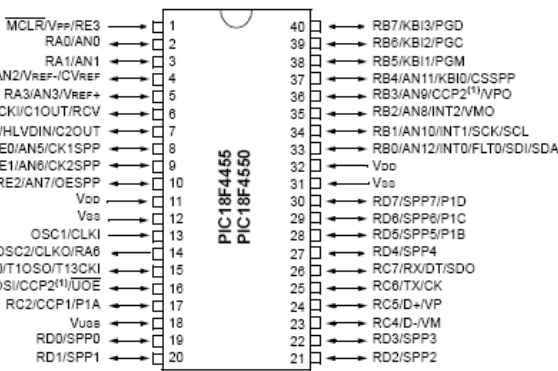


Fig. 1 – Microcontroller Microchip PIC18F4550

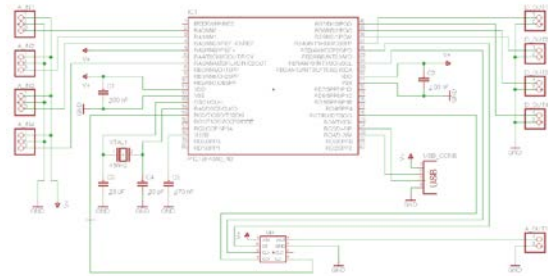


Fig. 3 a) – System SMPSL – schema of involment

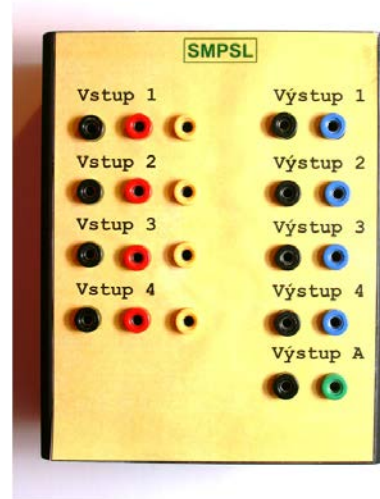


Fig. 3 b) – System SMPSL central unit

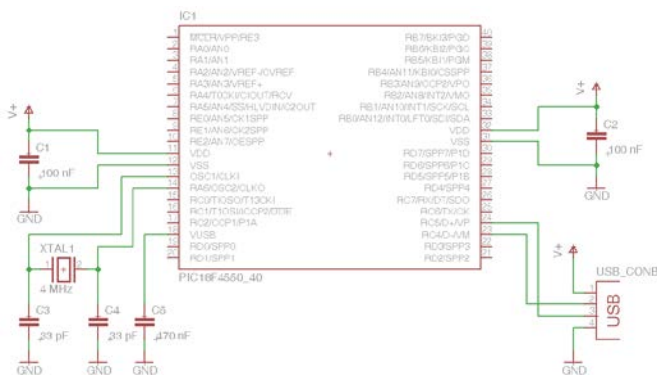


Fig. 2 – Schema of involment



Fig. 3 c) – System SMPSL – inside view

The resulting hardware part contains is stored in the chassis described a color-coded banana connectors for connecting the sensors to the input and output of the device to the output

USB connection is ideal for measuring implementation of school systems. The integrated USB interface allows easy connection to a computer system without any additional devices (USB microcontroller is usually not the usual). USB is

now standard and provides fast data transfers, if eProDas to 600 kB / s. The bus allows system power SMPSL the PC.

Integrated 10-bit A/D converters are sufficient for use in the school system, although today they are more common 12-bit converters, but these are no longer faced with external circuits. Number 13 channels is amply sufficient. School systems usually have 4 input channels external, possibly a few more internal, such as a temperature sensor.

Also, 31 digital I/O ports is a very high number, here it is important to realize that many of the pins of the integrated circuit is used more than once, and it significantly reduces the number of available ports. With the digital outputs can control a variety of digital output devices, such as light bulbs, LEDs, stepper motors or relays. When configured as input ports can be read pulses from devices such as buttons, photocells or sensors nuclear radiation.

Via SPI and I2C bus can connect other peripheral integrated circuits, such as more accurate A/D converters, D/A converters or directly various sensors of physical quantities. This is basically the only way to extend the basic hardware. For a more accurate measurement would be appropriate to involve the reference voltage, but it is a simple measurement of surplus school.

eProDas platform is able to handle up to 16 devices simultaneously, allowing greatly expand the computer lab.

## VII. THE SOFTWARE PART

The part of system is also the software that allows the connection of hardware to your computer via programming interface (API) in C / C ++, Delphi or Visual Basic.

For connection to a computer is first necessary to make the hardware part, recorded using the programmer to the microprocessor firmware and install the drivers to communicate with hardware components. [5]

Software included in the package eProDas can be divided into two parts. On the firmware that is installed in the memory of the microcomputer and the part that is installed on the PC. To program the microcontroller to be a programmer for AVR PIC 18F series, which are quite common here, but usually they can be programmed to expensive universal programmer. On the PC you need to install the communication driver and library functions.

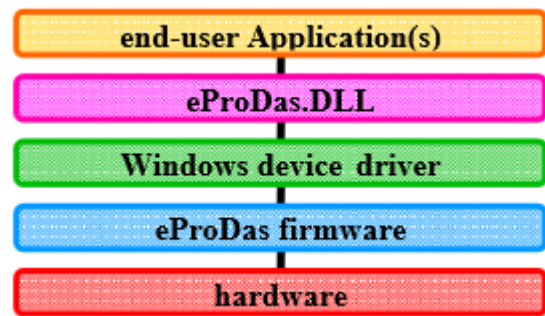


Fig. 4 – Communication terminal applications with different layers of software and hardware [3]

Figure 4 illustrates how the different parts cooperate with each other and software hardware parts. This figure schematically software separated into several layers that communicate. On the bottom layer is hardware, as described in the previous chapter. Firmware eProDas is part of the software running on the MCU PIC 18F4550.

The upper three layers running on the computer. Driver for communication is a driver for USB, developed specifically for eProDas, to optimize the throughput of USB line. EProDas.DLL Library is a library function that calls the end application. The function used to control the measurement and transmission of measured data. [6] It can be configured through them and read data from the A / D converters and digital inputs, configure and write to digital outputs including PWM control (pulse width modulation) interface SPI (suitable for adding other peripheral circuits such as sensors or A / D and D / A converters) and USART interfaces for serial line. The measured data can be transferred either individually for slow measurements, or in batches if necessary to measure fast processes.

The end user's own application program, which the user must write yourself or use applications created by third parties. User programs can be written in C / C ++, Delphi and VisualBasic for MS Windows operating system.

Installing software part PC is easy. After connecting the interface to the USB port of computer, operating system Windows itself brings up a menu to install drivers for communication. Drivers are included in the package downloadable from the website eProDas [2]. Once installed in the development environment has yet to implement the library, then you can have the documentation program.

## VIII. USER INTERFACE

Developed user interface for measurement using a computer in a school laboratory environment with which users control their own measurements, setup, operation and management of the system itself in the school laboratory. To this interface was the most acceptable for this purpose was created several versions and using research to real experiments was chosen

one of them. The selected interface is then developed based on the comments of respondents. [8]

This interface represents a system in which the main part showing the measured values, binary outputs for control, display for analog output. Basic settings for measurement and display graphical output. It also contains a menu for further settings.

The user interface of software systems for measurement using a computer - SMPSL consists of several parts.

**The main window**-there are numerically displays the input variables. Possibility to start measuring, export the current measured value. Setting the measurement and sampling. Display graphic output in a new window. Control of analog and digital output. The program menu is opening and saving settings, the actual settings and display help. Fig fifth

**Graphical output window**, where in graphical and numerical form displays measured data. There is also the option to export to a file. Fig. 7

**Display window** there you can select which elements are in the main part and the graphical output display.

**Inputs window** where inputs are configured names measurements, OS settings and calibration.

### The main part of SMPSL

The main part is used to display the input values measurement, control measurements starting measurements and settings. Fig. 5



Fig. 5 – The main part of the management system

The left part is described the *Input*. This is divided into 4 parts separated by descriptions of inputs Input 1 - Input 4. Each block shows the description of the input variables consisting of signs, calibrated numerical values and conversion (multiple). These data are named in the input.

The right part *Output control block* contains the binary

outputs divided on Output 1 - Output 4 adjusts the voltage  $U = 5 \text{ V}$  output.

The lower part is a continuation of the output for the *Analog output*. Sets the linear output voltage using a slider in the range  $U = 0$  to 4095 mV.

The middle part *Control measure* is used to control the actual measurement. In the edit boxes to set the time in seconds and sampling, i.e. how often will be gathering data in milliseconds. At the bottom of this page then displays the time of measurement. The measurement is started by pressing the *Start or Stop button* stops, appearing when you start measuring. *Button Export* actual values are used to direct the user to write values to the file.

Part the *Output of data* contains the graphical output to display a new window. There is then in graphical and numerical form displays measured data can be exported to a file.

Menu consists of parts *Program, Settings, Help* (Fig. 6).

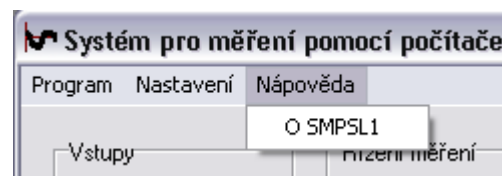
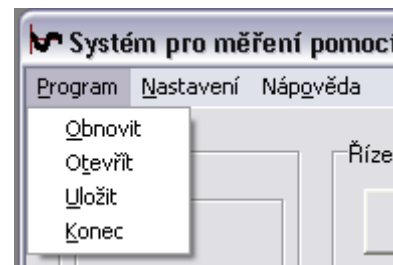


Fig. 6 – Main part of software - Menu

*Program* menu contains *Refresh* to reload the saved settings. *Open* to open the saved settings. *Save* to save and *Exit* to close the program.

"Settings" menu contains the *Display* to display a different part of the program. The *Inputs* is used to set individual input data and graphical output. *Help* menu to retrieve information about SMPSL.

### Graphical output

In this section, using the graph, according to the setting of the input measured values displayed during measurement (upper part of Fig. 7). Text input output measured value is

displayed on the bottom of the image. Right below the *Restore* button (delete) data and a button to Export. In the right part of the picture then offer to turn off / turn on the input display data in a chart. The menu is again the *Restore* (delete data). [9]

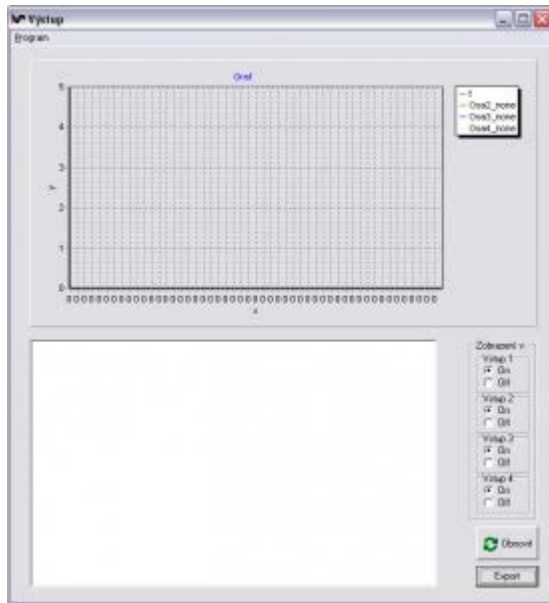


Fig. 7 – Graphical output

In the graph you can use the mouse to zoom in detail. This is done by holding down the left mouse button and drag left to bottom right. Fig. 8 View to the original appearance then proceeds similarly, but pulling in the opposite direction.

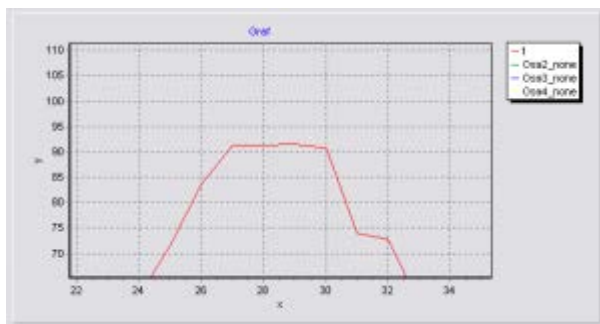


Fig. 8 – Graphical output – enlarge of chart

Export the resulting data is done using the *Export* button to generate a text file in the root directory of the program called *Mereni.txt*. Fig. 9

On the x axis of the graph are the numbers of measured samples. On the y-axis is the measured value. The sample represents the value of the measured quantity. Number of samples is the ratio of *Periods of observation* and *Sampling*. For example, when *measuring time* = 10 s *Sampling Rate* = 200 ms is the *sample* =  $10 / 0.2 = 50$

Vzorok	Uprava	Jednotka	Zobrazeni	Mnozinyho
Vzorok: 0	T = 24,83	°C	*	1
Vzorok: 1	T = 25,18	°C	*	1
Vzorok: 2	T = 26,19	°C	*	1
Vzorok: 3	T = 25,65	°C	*	1
Vzorok: 4	T = 25,65	°C	*	1
Vzorok: 5	T = 25,20	°C	*	1
Vzorok: 6	T = 25,65	°C	*	1
Vzorok: 7	T = 25,18	°C	*	1
Vzorok: 8	T = 25,18	°C	*	1
Vzorok: 9	T = 25,18	°C	*	1
Vzorok: 10	T = 25,92	°C	*	1
Vzorok: 11	T = 25,92	°C	*	1
Vzorok: 12	T = 25,65	°C	*	1
Vzorok: 13	T = 25,92	°C	*	1
Vzorok: 14	T = 25,38	°C	*	1
Vzorok: 15	T = 25,38	°C	*	1
Vzorok: 16	T = 25,10	°C	*	1
Vzorok: 17	T = 23,48	°C	*	1
Vzorok: 18	T = 11,85	°C	*	1
Vzorok: 19	T = 2,34	°C	*	1
Vzorok: 20	T = 1,13	°C	*	1
Vzorok: 21	T = 1,26	°C	*	1
Vzorok: 22	T = 1,80	°C	*	1
Vzorok: 23	T = 1,13	°C	*	1
Vzorok: 24	T = 1,80	°C	*	1
Vzorok: 25	T = 3,55	°C	*	1
Vzorok: 26	T = 1,13	°C	*	1
Vzorok: 27	T = 1,80	°C	*	1
Vzorok: 28	T = 4,93	°C	*	1
Vzorok: 29	T = 21,33	°C	*	1
Vzorok: 30	T = 38,49	°C	*	1
Vzorok: 31	T = 42,99	°C	*	1
Vzorok: 32	T = 57,99	°C	*	1
Vzorok: 33	T = 74,10	°C	*	1
Vzorok: 34	T = 86,62	°C	*	1
Vzorok: 35	T = 96,89	°C	*	1
Vzorok: 36	T = 83,24	°C	*	1
Vzorok: 37	T = 42,99	°C	*	1
Vzorok: 38	T = 27,00	°C	*	1
Vzorok: 39	T = 5,19	°C	*	1
Vzorok: 40	T = 2,88	°C	*	1
Vzorok: 41	T = 2,88	°C	*	1
Vzorok: 42	T = 2,13	°C	*	1
Vzorok: 43	T = 3,55	°C	*	1
Vzorok: 44	T = 5,42	°C	*	1
Vzorok: 45	T = 3,55	°C	*	1
Vzorok: 46	T = 10,10	°C	*	1
Vzorok: 47	T = 3,55	°C	*	1
Vzorok: 48	T = 2,88	°C	*	1
Vzorok: 49	T = 2,14	°C	*	1
Vzorok: 50	T = 2,88	°C	*	1

Fig. 9 – Exported measurements to a text file

### Display setting

In this section we use the check boxes to select which items in the *Main* part to be displayed (Fig. 10). There is also the possibility of using the *Configuration* display *Input* setting.



Fig. 10 – Display setting

### Input setting

This section sets for each input *Name of term*, *Designation of units*, *Conversion*. These settings use to the correct setting proportion of display in the chart.

*Setting axes* on which axis is the input quantity displayed.

*Calibration*, which shows the current value of the input and edit boxes for the settings to the sensor manufacturer or

manual calibration.  $U_1$  and  $U_2$  are the voltages at the input (sensor output).  $X_1$  and  $X_2$  are the corresponding values of physical quantities.

Switching the x-axis, whether it is in the graph display by time or according to two or more input values.

On the y-axis can be set negative and positive range of the vertical axis of the graph. Fig. 11

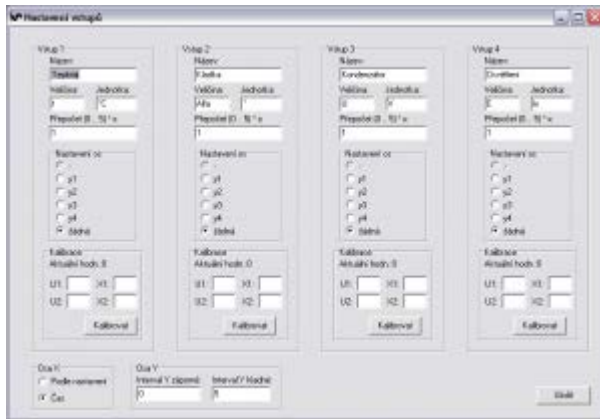


Fig. 11 – Setting the input

### About SMPSL1

This section displays information about the system for measurement using a computer in a physics lab - *About SMPSL1*. (Fig. 12)



Fig. 12 – About SMPSL1

## IX. SENSORS

Commercial sensors sold by measurement systems using computers are universal and applicable to any system operating with an input voltage  $U = 0-5$  V are thus suitable for the system SMPSL, but their cost is very high. Sensors it is possible to build yourself for a fraction of the price.

Producers sell large quantities of usable components such as

sensors, which, after simple treatment can adapt to sensors for measuring systems. Adjustments in most cases consist only hardware adjustment, especially in appropriate containers and power connectors.

### A. temperature sensor

The temperature sensor is simple sensor consisting of a sensor adapted directly to the low voltage output with a suitable voltage (power and output) for SMPSL linear characteristic  $10\text{mV} / ^\circ\text{C}$ . The sensing range of temperature ranges from  $-40$  °C to  $125$  °C. The sensor is also sold in TO92. Price sensors per piece 32,90 CZK, (over 1 euro), Fig. 13. Simply place the sensor in a suitable housing (e.g. steel tube from a ballpoint pen "China" with thermally-conductive paste for better transmission of the sensor area) and provide cables with connectors for connection to the system SMPSL (Fig. 14) and prevent fluid access to terminals components. The total price would be around 100 CZK (4 Euro). Commercial price of the same sensor ranges from 1000 CZK to 1500 CZK. (40-60 Euro)



Fig. 13 – Temperature Sensor



Fig. 14 – Temperature Sensor

**Possible use:**

- spontaneous cooling sensor (dry / wet, with / without air flow)
- melting ice cubes in fresh and salt water
- speed of heating the water in the kettle or pot - with lid or without
- speed of cooling water and process temperature changes
- how to change the temperature in the freezer or refrigerator during the day
- how the temperature changes at a certain point during the day and night (soil temperature and air temperature).

**B. Displacement sensor**

The principle of displacement sensors is based on the change in rotation of the potentiometer and the voltage change. It is therefore a shooting angle of the potentiometer is rotated. This sensor is complicated due to technical implementation. It consists of a structure holding a potentiometer at a sufficient height above the free space. The potentiometer is fitted with curtain weights (Fig. 15). To change the position of the weight axis rotates the potentiometer and the corresponding voltage change. At the potentiometer again supplies the cables and connectors. As the structure is used Czech building kit Merkur, fig. 15. Final price, depending on design solutions can range from 100 CZK to 300 CZK. (4-12 Euro)

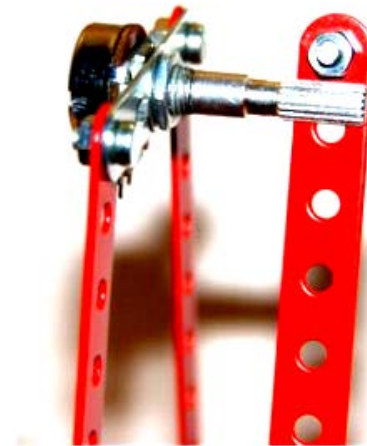


Fig. 15 a) – Potentiometer with curtain

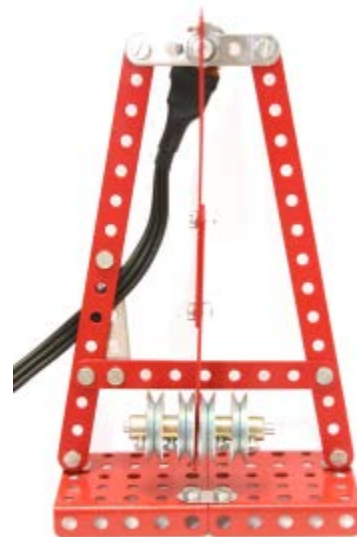


Fig. 15 b) – Potentiometer with curtain

**Possible use:**

- damped oscillations - the resistance of the environment

**C. Sensor Light**

Like the temperature sensor is the sensor made with appropriate parameters for system use SMPSL. Sensor sensitivity is up to about 780 nm, and its price is 138 CZK, Figure 16 The sensor can just again provide connectors and cables for connection to the system, Fig.17. The total price



would be around 200 CZK. Commercial price varies from 2000 CZK to 2500 CZK, ( 80-100 Euro) -i.e. tenth of the price.



Fig. 16 – Light Sensor

to produce a sensor structure. The production design was used again Merkur (Figure 19). The total price would therefore be around 400 CZK. Commercial price is around CZK 3000 – 3500 CZK, but with a different measuring principle (ultrasound).



Fig. 18 – Optical distance sensor



Fig. 17 – Light Sensor



Fig. 19 a) – Sensor and components of Merkur building kit

#### Possible use:

- dependence on the distance from the light source
- dependence on the thickness of the light absorbing filter (on the number pad, sheets)
- flashing light bulbs and fluorescent tubes
- exploration during the approaching energy saving light bulbs
- study of the reflectance of different materials
- long-term monitoring time of sunrise and sunset

#### D. Distance sensor

As the distance sensor to use an optical distance sensor. The properties are again useful for system SMPSL. The sensor is able to sense the distance from 80 to 800 mm. Price is 308 CZK, Fig. 18 The implementation is again necessary power cables and connectors. For the measurement, it is appropriate



Fig. 19 b) – Construction

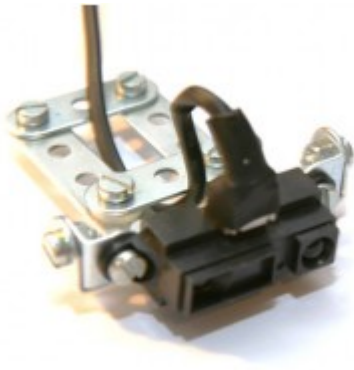


Fig. 19 c) – distance sensor

#### Possible use:

- distance of the moving object (moving people free fall ball, wheelchair)

#### E. connecting cables

In many cases, the measuring system connected to separate electrical components. A typical example is the measurement of charging and discharging capacitors. For easy connection to use alligator clips. Assembly is again very easy. It's just a cable with connectors (Fig. 20).



Fig. 20 – Connecting cables

#### X.CONCLUSION

The system SMPSL is very cheap to assemble system for measurement using a computer in a physics lab. Unlike commercial systems make our system SMPSL a fraction of the price. Similarly, the proposed sensors. Control software and instructions for assembly are available on the website: <http://smpsl.radeknemec.cz>.

#### ACKNOWLEDGMENT

This research work has been supported by specific research project of University of Hradec Kralove, Faculty of Education in 2013 No. 2141.

#### REFERENCES

- [1] JEZBERA, D., Měření a sběr dat s pomocí počítače ve školní laboratoři. Část 1: Základní přehled. Media 4U [online]. s 83-88, 2010, roč.7, č. 1 [cit. 2013-5-26], Dostupný z WWW:<<http://www.media4u.cz/mm012010.pdf>>. ISSN 1214-9187.
- [2] Laboratory for Electronics for Automatics. 2008 [cit. 2013-5-26]. Dostupný z WWW:<[http://lie.fe.uni-lj.si/index\\_en.htm](http://lie.fe.uni-lj.si/index_en.htm)>. Data Acquisition system, Users' guide and programming manual. 2007 [cit. 2013-5-26]. Dostupný z WWW:<[http://lie.fe.uni-lj.si/eProDas/eProDas\\_Version\\_1\\_0.pdf](http://lie.fe.uni-lj.si/eProDas/eProDas_Version_1_0.pdf)>.
- [3] Data Acquisition system, Users' guide and programming manual. 2007 [cit. 2013-5-26]. Dostupný z WWW:<[http://lie.fe.uni-lj.si/eProDas/eProDas\\_Version\\_1\\_0.pdf](http://lie.fe.uni-lj.si/eProDas/eProDas_Version_1_0.pdf)>.
- [4] HUBALOVSKY, S., Rectification column - mathematical modeled and computer simulated real system. In: International Journal of Mathematics and Computers in Simulation. 2012, vol. 1. ISSN 1998-0159
- [5] DOLINAY J., VAŠEK V., DOSTÁLEK P. Implementation and Application of a Simple Real-time OS for 8-bit Microcontrollers. In: The 10th WSEAS International Conference on ARTIFICIAL INTELLIGENCE, KNOWLEDGE ENGINEERING and DATA BASES (AIKED'11). Cambridge, 2011, ISBN: 978-960-474-276-9. P. 23-26.
- [6] LOKVENC, J., DRTINA, R., ŠEDIVÝ, J. Unusual involvement of operational amplifiers for measurement purposes: non-inverting amplifier integral and derivative. In: WSEAS International Conference, CSCC 2012: proceedings. Athens: World scientific and engineering academy and society, 2012, p. 125-130. ISBN 978-1-61804-108-1.
- [7] LOKVENC, J., DRTINA, R., SOBEK, M., Three-phase high overload DC power supply voltage with the mid frequency transformer ripple filter. In: POWER 2012: proceedings of the 12th WSEAS international conference on electric power systems, high voltages, electric machines. Athens: World scientific and engineering academy and society, 2012, p. 29-34. ISBN 978-1-61804-128-9.
- [8] HUBALOVSKA, M., HUBALOVSKY, Š. Implementation of the Systems Approach in Mathematical Modeling, Dynamic Simulation and Visualization Using MS Excel Spreadsheet. International Journal of Mathematics and Computers in Simulation. 2013, vol. 7, no. 2, pp. 267-276. ISSN 1998-0159.
- [9] RABE, V. - HUBÁLOVSKÝ, Š. New concepts in engineering education through e-learning. In IMETI. Orlando, USA: International Institute of Informatics and Systemics (IIS), 2010, p.181-185. ISBN 978-1-936338-02-3.

**Mgr. Bc. R. Nemeč**, was born in 1984 in Czech Republic. He is student of doctor degree in Information and communication technology in education on University of Hradec Kralove, Faculty of Education, Czech Republic. University of Hradec Kralove, Faculty of Education, Department of Informatics, Rokitanskeho 62, 500 03 Hradec Kralove, Czech Republic (phone: +420 774220193; e-mail: [radek.nemec@uhk.cz](mailto:radek.nemec@uhk.cz)). His scientific activities measurement using a computer i the school laboratory, education and informatics.

**Bc. J. Triska**, was born in 1984 in Czech Republic. He is student of master degree in Education of Informatics and technical subjects on University of Hradec Kralove, Faculty of Education, Czech Republic. University of Hradec Kralove, Faculty of Education, Department of Informatics, Rokitanskeho 62, 500 03 Hradec Kralove, Czech Republic (phone: +420 602133538; e-mail: [jan.triska@uhk.cz](mailto:jan.triska@uhk.cz)). His scientific activities measurement using a computer i the school laboratory, education and informatics.

**Ing. Mgr. J. Sedivy, Ph.D.**, was born in 1963 in Czech Republic. Doctor degree in Theory of technical education in 2006 on University of Hradec Kralove, Faculty of Education, Czech Republic. University of Hradec

Kralove, Faculty of Education, Department of Technical Subjects,  
Rokitanskeho 62, 500 03 Hradec Kralove, Czech Republic (phone: +420  
493331171; e-mail: josef.sedivy@uhk.cz). His scientific activities are  
computer graphics and communications in education and informatics.