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CD-ROM AID FOR ELECTRICAL MEASUREMENTS LABORATORY

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Abstract: This paper presents the idea of CD-ROM aid material of basic electrical measurement laboratory elaborated for the students of the second year of studies. Till now, for realisation the task in laboratory, students obtain printed materials, which contain theoretical principles of used methods, their diagrams, and information how to realise the necessary measurements. Nowadays nearly all the students have at home fast computers with suitable memory, therefore it is possible to deliver them much more effective aid materials. Using LabVIEW of National Instruments it is possible to design virtual instruments, which allow realising at home "virtual measurements", the same that student will realise later in the genuine laboratory. The necessary manipulations with the instrumentation used in each method and obtained results of measurements as even the possibility of the discussion of obtained results enable to understand better the laboratory task. Afterwards, students in the university laboratory can realise the necessary measurements faster and with better comprehension.
Keywords: virtual instruments, virtual measurements, CD-ROM laboratory

1 THE IDEA OF CD-ROM MEASUREMENT LABORATORY

In last years we observed the development of Internet laboratories for educational purposes [1, 2, 3, 4]. The main disadvantage of these laboratories is the fact, that the students must have access to the Internet. Till now, in Poland, this condition is rarely fulfilled in the group of regular students. However the Internet laboratories became to be popular in the case of so called "long distance studies" organised for working peoples. They take part in lectures and realise practical jobs in laboratories on Saturdays and Sundays and nearly all of them have access to the Internet. The Internet laboratories can not substitute genuine university laboratories, as every engineer must have contact during the studies with effective measurement technique. However they assure certain practice in measurement technique which is very helpful later when they have occasion to realise real measuring tasks in the university laboratories.

Nearly all of our regular students have fast and modern computers at home but alas only some of them have access to Internet. For this reason they can not profit from our Internet Laboratory of Basic Electrical Measurements (ILBEM). Nowadays their preparation for the work in the university laboratory is based on printed materials, which they obtain from laboratory assistants. This textbooks consist theoretical and practical information of realised tasks in the laboratory. To assure the possibility of better preparations for Electrical Measurement Laboratory our team from the Technical University of Gdansk has decided to deliver CD-ROM with "home measurement laboratory". This aid kits consists virtual instruments (Vis), and virtual systems (VSs) which enable students to realise at home virtual measurements (VMs) similar to these they will perform later during regular laboratory jobs. After such training at home students can realise the their works in the university laboratory with more experience and comprehension and in better way.

2 BASIC INFORMATION OF CD-ROM LABORATORY

Our CD-ROM Virtual Laboratory of Electrical Measurements (CD-ROM VLEM) has been elaborated for the students of the second year of studies, who for the first time have contact with the basic electrical measurements in the university laboratory. The first our step was to choose right software for creating VIs and VMs. What virtues it must have?

1. The chosen software must be fast and easy in creation of VIs.
2. It must enable to use some parts of created VIs to put to a good use in designing another VI.
3. The operation of VIs must be the same as the operation of real instruments in the university laboratory of electrical measurements and control.

4. The selected software must be cheap in use (the possibility of using VIs only in Windows environment without any software).

There is on the market a train of software, which can be used to create measuring systems. The most popular are: HP VEE for Windows of Hewlett Packard [5], LabVIEW and LabWindows/CVI for Windows of National Instruments Corporation [6], Test Point of Keithley Instrument [7]. Our team from the Chair of Electrical Measurements (Technical University of Gdansk, Electrical and Control Engineering Faculty) has experience with the LabVIEW software in scientific and student laboratories since 1994. Perhaps from this reason we decided to use it for our "CD-ROM home laboratory". However basing on our experience it is worth to underline that:

- Every VI created with this software can be stored and used as a subVI in the block diagram of a higher level VI, thus simplifies the structure and accelerates programming of new solution, makes application easy to debug, understand and maintain
- The VIs of LabVIEW transformed with Application Builder software of NS enable to use them only in Windows environment, so the students can profit with our "CD-ROM home laboratory" using computers without LabVIEW software.

The advantages of LabVIEW are also very nice underlined by Gary W. Johnson [8]:

- The productivity in LabVIEW is simple better than with conventional programming languages, the improvement factor is higher than five, sometimes even fifteen.
- The graphical user interface is built in, intuitive in operation, simple to apply and nice to look at.
- There is only minimal performance penalty when compared with conventional programming languages.
- Programmer frustration is reduced because hideous syntax errors are eliminated.
- Many important high-level operations have been encapsulated in convenient VI libraries for quick application.

Normally LabVIEW of NS is designed in two Windows. The first one contains an interactive user interface and is "front panel" because it simulates the panel of a physical instrument. There are knobs, push-buttons graph controls and indicators. Data are input by means of mouse and keyboard, results of computation are presented on the computer screen. In the second window is a "block diagram" which is constructed using graphical language G. It contains the source code for the created VI which has hierarchical and modular structure. It is possible to use VI as top level program or as subprogram within other program or subprogram. In this case it is called subVI. A complicated VI can be divided into a series of tasks represented by subVIs. Each of them can be execute by itself, apart from the rest of application. Thus debugging of VI is much easier. The created subVIs can be used frequently when one solves another measuring problem [9]. Normally a user can easily make innovation in existing VI as he has the access to front panel and block diagram. But when VI is transformed with Application Builder it is possible to use it for the designed task but it is not possible to make any changes in its performance. The user has only access to front panel window. However it is possible to use this instrument without LabVIEW software.

3 REALISATION OF CD-ROM LABORATORY

The lectures and laboratory of Electrical Measurements and Control start on the second year of study. For some of students it is the first possibility to have contact with precise instruments. So the staff of laboratory must assure to students respective help in order to protect some expensive instruments against damage due to ignorance of their users. Here the students must become the habit of safety procedure with electrical instruments and electrical measurements. This habit can be easy acquired when before realising determined job in the university laboratory a student could do the same measurements at home using training simulator in form of VLEM (Virtual Laboratory of Electrical Measurements). This training brings good results, but the student must be informed during the session if the job was realised correctly or some bad or dangerous manipulations were done.

The main problems realised in our Electrical Measurements and Control are as follow:

- Measurements of resistance by means of technical and laboratory methods,
- Measurements of inductance and capacitance by means of technical and laboratory methods,
- Measurements of power in single-phase and in three-phase circuits
- Measurements of frequency and phase difference
- Measurements of current, potential difference and power by means of potentiometer
- Digital instruments,
- Temperature measurements,
- Pressure measurements,

- Level measurements,
- Strain measurements,
- Rotational speed measurements.

For each problem are prepared on CD-ROM the exe-version of the VLEM. Some VLEM consist not only the instruments necessary to realise measuring tasks but also enable to examine the dynamic process which occur in measuring instrument in slow down time division e.g. digital measuring instruments. Some examples are presented in the next paragraph.

4 VLEM EXAMPLES

The possibilities of using of CD-ROM VLEM are presented in the following Figures 1...5. As it was already mentioned, students realising the determined measuring task must obtain also information that all manipulations and measurements were realised correctly.

The stand for measuring the frequency and the phase shift of alternating voltages using oscilloscope and standard frequency generator is presented in the figure 1. The amplitude of tested source voltage is controlled with knob *amplitude,* its frequency with a knob f*requency,* and the phase shift with a knob *phase*. Four knobs controller of coarse and fine control adjusts precisely the frequency of standard source voltage. The amplitude of this voltage is constant and equal 1 V. In the first case the frequency is measured by means of Lissajou figures – menu ring set to position f*requency.* The tested voltage feeds vertical plates (y) of oscilloscope whilst the horizontal plates (x) are fed by the tested voltage. After clicking the run button of VI it is possible, using operation tool, to set arbitrary the value of tested voltage in the range of 0...1 V, its frequency (0-100 Hz) and

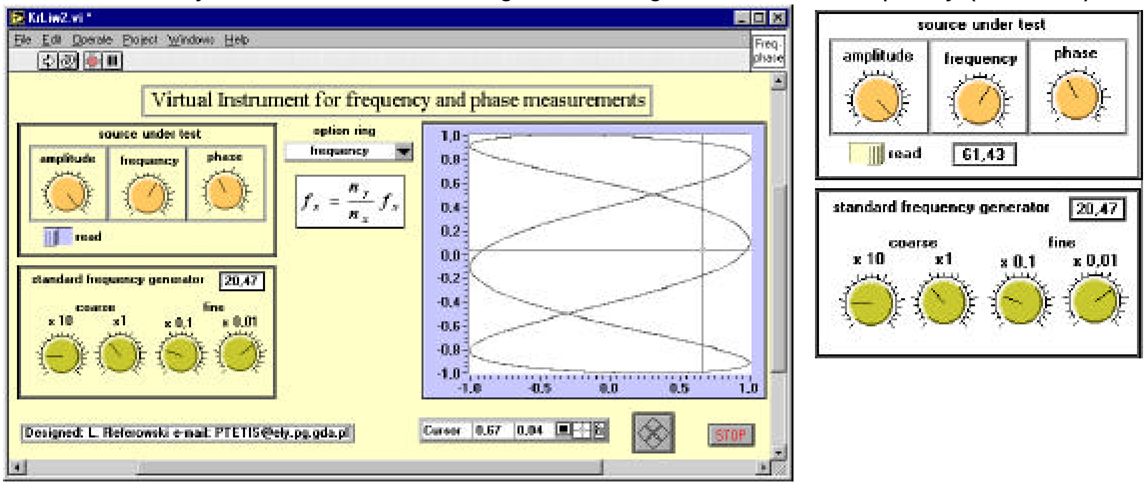

Figure 1. Frequency measurements by means of Lissajou figures

the phase shift (0...180^o). With the help of 4 knobs controller it is possible to adjust precisely the frequency of standard generator f_g in order to obtain the Lissajou figure of required shape. The value of measured frequency f_x is determined from formula 1:

$$f_x = \frac{n_y}{n_x} f_g \tag{1}$$

where: n_y and n_x - the number of intersection of the *y*- and *x*- cursor line with Lissajou curve.

In the described case the value of measured frequency f_x is

$$f_x = \frac{6}{2} \cdot 20{,}47 = 61{,}41 \text{ Hz}$$

Setting the controller in position *read* (Fig. 1it is possible to check the adjusted value of the frequency of tested voltage (61,43 Hz)) and to evaluate the quality of measurement). Here the relative error of measurement äf_x is less than 0,1%.

Another possibility of measuring frequency is to compare on the oscilloscope screen the longitude of period of measured and standard voltage of known frequency. This can be done precisely with the help of cursors, which enable to read on the x-axis, the values of the moment when measuring voltage is equal to zero. The measured frequency is calculated from formula 2.

$$f_x = \frac{x_1 - x_0}{x_3 - x_2} \cdot f_g \tag{2}$$

where: x_0, x_1 – cursor's positions for $U_g=0$ (U_g – voltage of standard generator),
x_2, x_3 – cursor's positions for $U_x=0$ (U_x – voltage of the source of measured frequency).

Setting option ring to *frequency&phase* position it is possible to realise the measurements according to formula 2. In the case presented in Fig. 2

$$f_x = \frac{181{,}0 - 0{,}0}{391{,}8 - 242{,}5} \cdot 26{,}71 = 33{,}45 \text{ Hz}$$

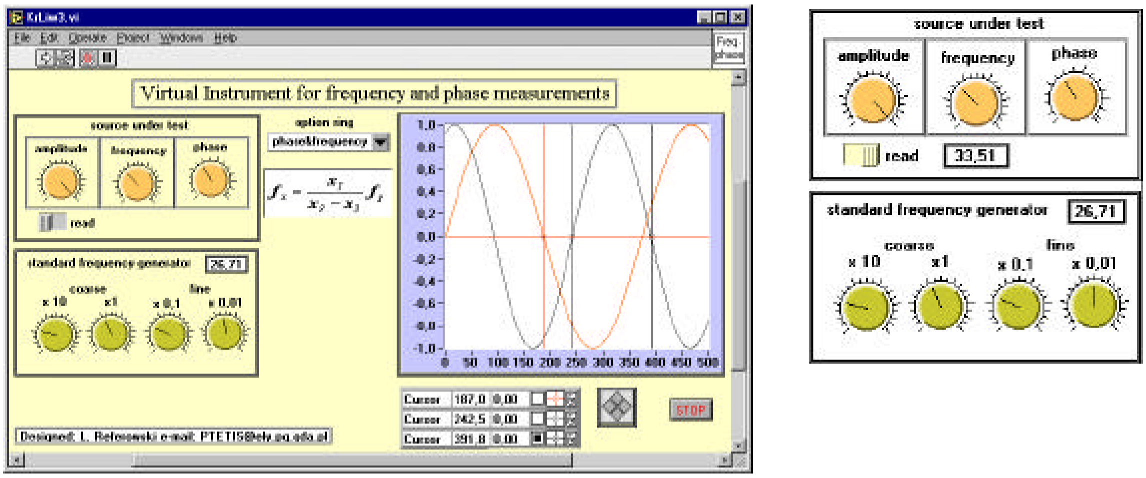

Figure 2. Frequency measurements by evaluation on the screen of oscilloscope the longitude of period of standard and tested voltage

Setting the controller in position *read* (Fig. 2) it is possible to check the adjusted value of the frequency of tested voltage (33,51 Hz) and to evaluate the quality of measurement. Here the relative error of measurement äf$_x$ is less than 0,2%.

With the same VI it is also possible to measure the phase shift between standard and tested sinusoidal waves under the condition that they have the same frequency (Fig. 3):

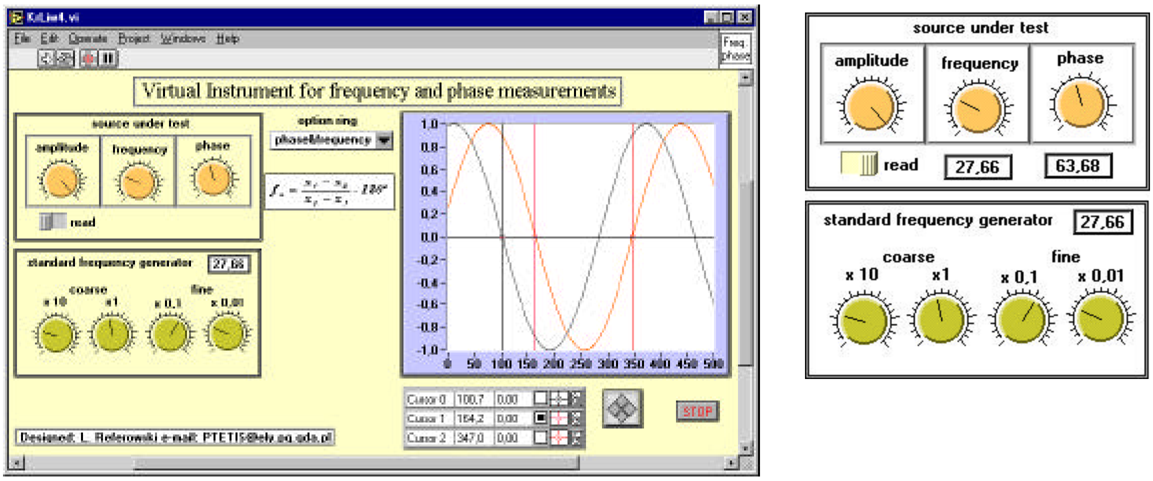

Figure 3. Phase shift evaluation by reading on the oscilloscope screen the longitude of period and displacement of two signals

The value of phase shift (Formula 3) is determined as:

$$j = \frac{x_2 - x_1}{x_3 - x_1} \cdot 180^0 \qquad (3)$$

where: x_1, x_2 – cursors' positions corresponding to the moment when both signals are equal to 0
x_3 – cursor's position determining the moment of half period of second signal

In the presented case the shift displacement is equal:

$$j = \frac{164{,}2 - 100{,}7}{347{,}0 - 164{,}2} 180^o = 62{,}5^o$$

After computation the value of phase shift of two signals it is possible to check the real values of this quantity setting controller in position *read*. As the real value of phase shift is 63,68^o (Fig 3) the relative error of measurement $äf_x$ is less than 2%.

The phase shift of two signals can also be evaluated by means of Lissajou figure of two signals with the same value of frequency. Adequate VI is selected by setting position *phase* with the option ring (Fig. 4). When both the axes of oscilloscope have the same scale and the full deflection in horizontal and vertical direction is equal 1, the phase shift is calculated as:

$$j = arc\sin y_{x=0} \qquad (4)$$

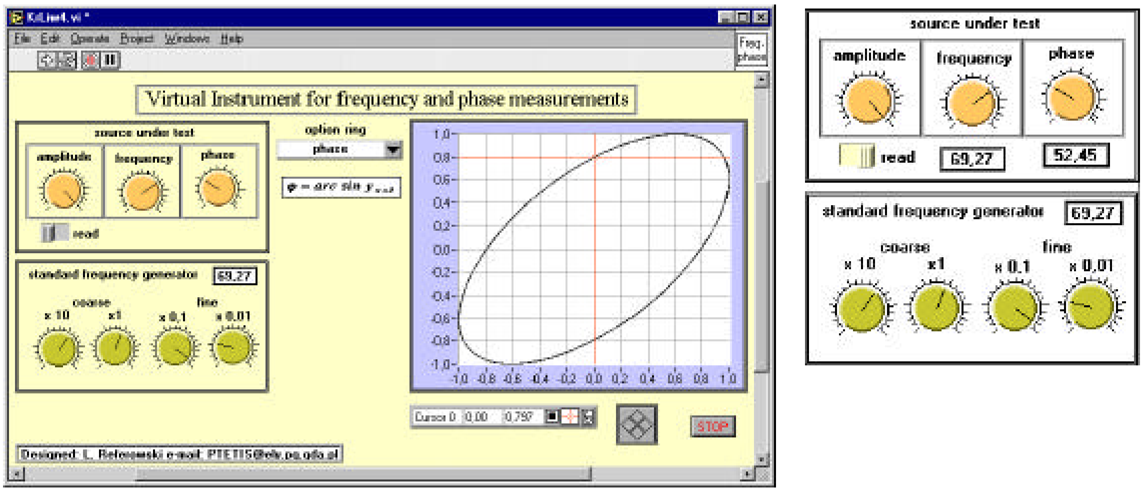

Figure 4. Measuring phase shift by means oscilloscope and Lissajou figure

In the described case the value of measured phase shift is:

$$j = arc\sin 0{,}797 = 52{,}8^o$$

With the controller in position *read* (Fig. 4)it is possible to check the real value of the phase shift between two voltages (ö=52,4^o) and to evaluate the quality of measurement. Here the relative error of measurement äö is less than 1%.

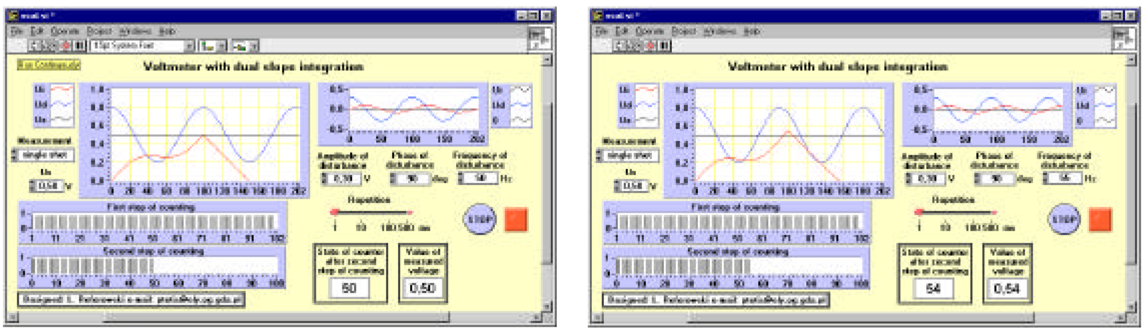

Figure 5 The principle of work of a dual slope integration voltmeter in the presence of disturbance voltage with the frequency of 50 and 54 Hz. In the first case the disturbance voltage has no influence on result of measurement

Our CD-ROM aid materials give also the possibilities of studying the principle of work of instruments, which are used for measuring tasks. As an example, in Fig 5, is presented the principle of work of double slope digital voltmeter. With this VI it is possible to check the work of instrument in slow down time division in normal condition. It is also possible to observe the influence of disturbance of sinusoidal voltage on the integration process in the case when its period is equal or different from the value of time for the first step of integration e.g. integration of input signal. This observation help to easier acquiring and better understanding the function of work of complicated instruments.

5 CONCLUSIONS

In the opinion of our students the Virtual Laboratory of Electrical Measurements on CD-ROM is a powerful tool for preparation to the laboratory sessions as it enable:

- to understand better the laboratory task which will be realised during normal sessions in real laboratory,
- to have practice in manipulation with precise or sensitive instruments which will be used during the session in the university laboratory and therefore to protect them against damage due to ignorance or stupidity,
- to mark and think over about measuring problems which could occur during measuring sessions,
- moreover it can be used with computer equipped only in Windows environment.

From our point of view t is also worth to underline that:

1. CD-ROM VLEM as an aid for preparation to laboratory tasks is much worth than thousand words in textbooks and its costs nearly nothing.
2. It is not possible to damage sensitive instruments in CD-ROM laboratory, as they are foolproof.
3. CD-ROM VLEM can not be treated as a substitute of real university laboratory; students must have contact with real instruments.

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