

Introducing Principles and developing Technologies to undergraduates by the Volt-Ammeter Method

Bruno Andò, Salvatore Baglio, Vincenzo Marletta and Nicola Pitrone

Abstract—Technical developments and innovations are brought forward at an increasingly rapid rate, therefore the educators must update the teaching work, making use of advanced instruments both hardware and software. In the last years the authors are trying to develop new hardware and software tools to enable the teacher to show to the undergraduates in an alternative and practice way the theoretical constructs explained during the lectures on Electronic Measurements. An accurate experimental training in the laboratory, using developing technologies, can stimulate the interest in the students. In particular, the experimental activity on the volt-ammeter method has been completely changed, a LabVIEW[®] based tool has been developed. It allows a deep analysis on the theoretical aspects; indeed, the experimental training can be initially carried out by using traditional electromechanical instruments, afterwards a simulation procedure can be performed, at last digital instruments will be used and a LabVIEW[®] based virtual instrument will introduce the undergraduates to the study of this environment. In this paper the tool is presented in full. The accurate details of the presentation can be useful for future application.

Keywords—Electronic measurements, Volt-ammeter method, Experimental training, Loading error, Advanced technology, Virtual Instrument, LabVIEW[®], Digital multimeter.

I. INTRODUCTION

Introducing the course of Electric and Electronic measurements, the lecturer should familiarize the undergraduates with some peculiarities of this theoretical and experimental course, among them:

- a deep knowledge of the working principle and then features of a variety of instruments is needed;
- an exhaustive understanding of the involved phenomena is required;
- an intensive training in the laboratory is determining because the experimental aspects are essential in order to clarify the theoretical concepts;
- the real meaning of the “models” should be clear.

According to their experience, the authors use to give the first lectures of the course on the volt-ammeter method for measuring resistances in direct current, in order for the undergraduates to be interested in measurements. Indeed, many different problems and basic aspects are involved, both theoretical and experimental ones.

The theoretical problems can be summarized as follows:

- definition of direct and indirect method;

- characteristics of the real instruments adopted: it is useful in this case the use of electromechanical instruments, in order to give some references on the interaction between the magnetic field and the electric current;
- analysis of a class of errors, known as the systematic errors: using electromechanical instruments the loading error can be easily understood by the undergraduates;
- the definition of the random error and the evaluation of the precision level can be easily performed.

Traditionally, the hardware already used to carry out the experimental training is shown in Fig. 1.

It should be pointed out that in this case the various theoretical aspects can be thoroughly emphasized very easily. In particular, the loading error can be easily analyzed and evaluated, because the internal resistance of the electromechanical instruments can influence the measurements.

An effective training activity will accomplish the teaching task: indeed, the students will be able to check the level of their knowledge.

The dramatic development of the technology requires updating the teaching activity, which involves using different techniques, advanced instruments, complex equipments, and also high-level software, distance learning [1-5].

A reasoned response to such pressures is essential: indeed, in the Technical International Conferences (WSEAS, IMEKO, IMTC) at least a session on education is included.

On account of these pressing requests, in the last years some tools have been developed by the authors, introducing advanced hardware and software [6-9], in various areas: three-Phase System Measurements, digital instruments, Virtual Instruments (implemented in LabVIEW[®]), microprocessors and remote learning.

The students can develop practical training by running simulation software.

This approach is very useful for beginners, because they can perform a self-training in order to acquire a limited hands-on experience with some problems correlated with the real-world experiments and hence they can test their theoretical knowledge.



Fig. 1. Electromechanical instruments already used for experimental training.

According to the authors experience, the introduction to the experimental training on Electrical and Electronic measurements can be developed in the following way, after some theoretical lectures:

- carry out the volt-ammeter method by using the hardware shown in Fig. 1;
- perform the simulation by using the first section of the tool realized on purpose and described in the following sections;
- carry out the complete training using the main part of the tool;
- analyze the characteristics of the advanced hardware used for training;
- approach the LabVIEW® environment, on the basis of the available information.

In this paper the experimental activity on the volt-ammeter method has been exhaustively developed. The previews tool, realized by a small group of students in informatics and designed during guided sessions, has been completely revised. The prototype, that will be presented in the next sections has been improved and includes new features to favour the teaching activity and to face the students with new teaching techniques and programming issues, with the purpose to grow their interest.

II. THE IMPLEMENTATION OF THE VOLT-AMMETER METHOD AS A LABVIEW® BASED APPLICATION

In the past years researchers of Department of Electric and Electronic Engineering of the University of Catania have demonstrated to retain of importance the didactic aspect and the innovation in the teaching activity to stimulate the interest in the students attending the lectures. To this purpose among their chief research activity they have always covered these aspects directly involving the students themselves. An example of software tools developed with this intention is discussed in the sequel.

During the course on electronic measures for computer

sciences engineering the students have developed two stand-alone LabVIEW® based applications implementing the volt-ammeter method.

The first application permits to simulate the method of measurement together with the instrumentation enabling the possibility to choose analogue or digital instruments. The application will change its representation of the measures according with the previous choice.

The other application instead, permits to interface the PC on which it is running with two real digital instruments (in particular two HP34401A multimeters), to measure the voltage and the current respectively, via the GPIB (IEEE488) bus. The two applications have been joined to form a single package enabling the teacher to show to the students in an alternative and practice way the theoretical constructs explained during the lecture. The students on the other part have the possibility to put in practice learning by doing. In this manner they have the possibility to interface with various concepts and problems such as the setting of a real instrument to evaluate the required measure, the development of a PC based instrument together with the LabVIEW® integrated development environment [9], the design and implementation of a resistive electronic circuit.

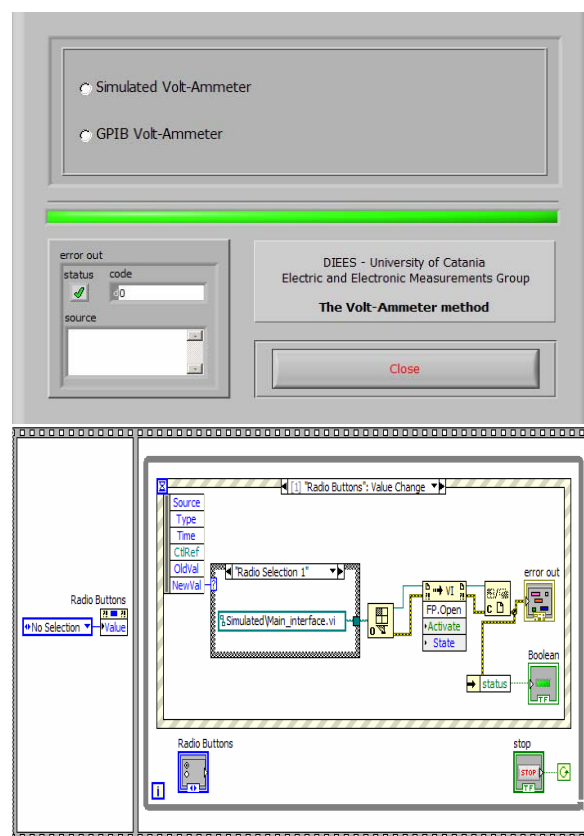


Fig.2. GUI enabling the user to choose between the two implementations of the volt-ammeter method and the related block diagram.

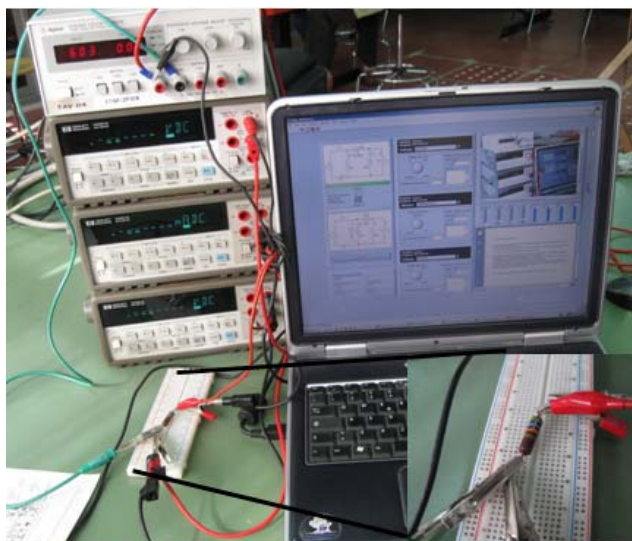


Fig. 3. The experimental setup with the PC on which the software tool is running and the hardware circuit to implement the volt-ammeter method.

To permit the user to choose between the two possible applications a simple GUI, shown in Fig.2, has been included.

The block diagram implementing the GUI has been reported in the same figure; essentially, it consists of a *event structure* that waits for an event to happen: in particular, the event it waits is the selection, by the user, of one of the two *radio buttons* on the front panel.

As a consequence of the selection, an event is issued and

handled by the event structure calling and opening the proper front panel.

The two applications, together with their user interface and the relative block diagrams, are described in the following sections.

Fig.3 shows the experimental setup with the PC on which the software tool is running and the hardware circuit to implement the volt-ammeter method.

A. The simulated Volt-Ammeter section

Selecting the simulated volt-ammeter method the GUI shown in Fig. 4 will appear. It can be subdivided in two parts.

In the left part the user can set the insertion of the instruments in the circuit and all the circuital properties such as the input voltage, the unknown resistance value together with its maximum power dissipation.

Two possible insertions of the instruments are available; both are shown in figure 5a and b (without considering the instruments enclosed in the dashed rectangles) and have been indicated as Conf.1 and Conf.2.

Depending on the user setting the software evaluates the power dissipation and in case of limits exceeding a warning advice will be issued by a led indicator.

Moreover depending on the resistance value the software suggests the optimal circuital insertion of the instruments.

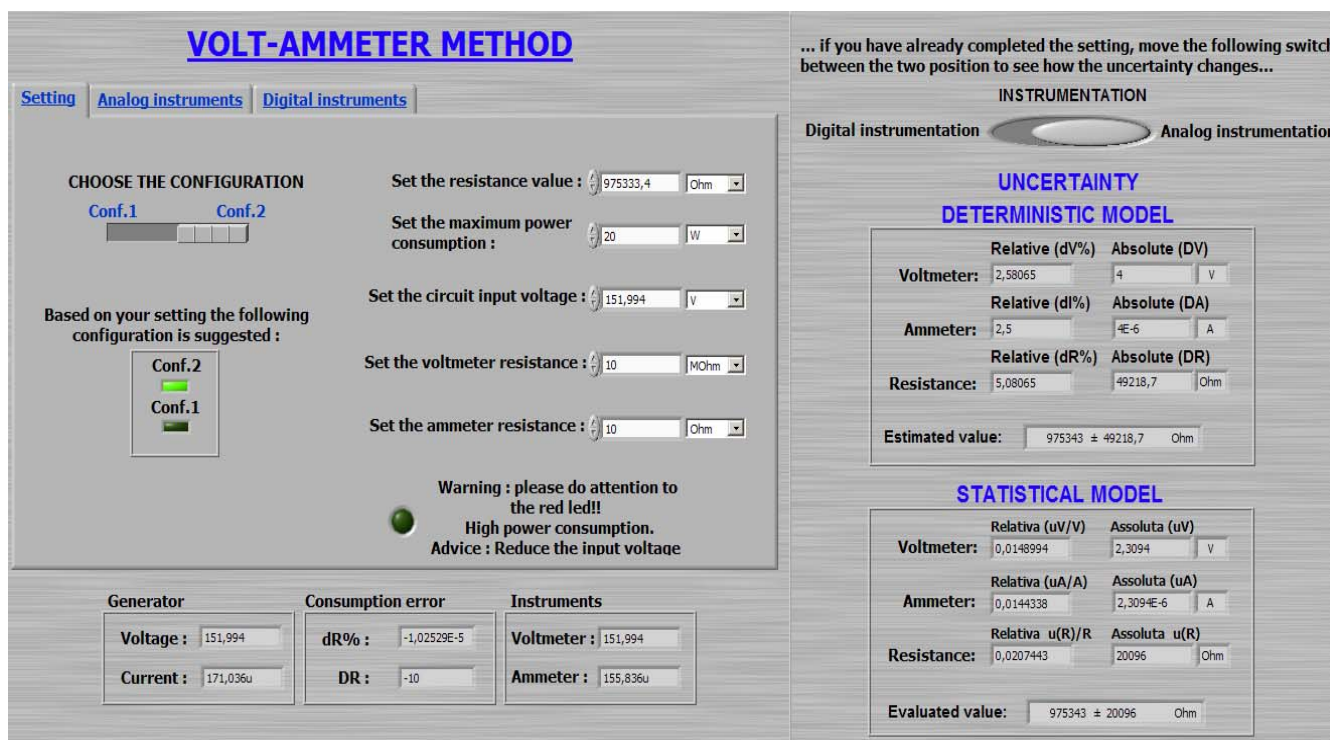


Fig. 4. The simulated Volt-Ammeter method GUI.

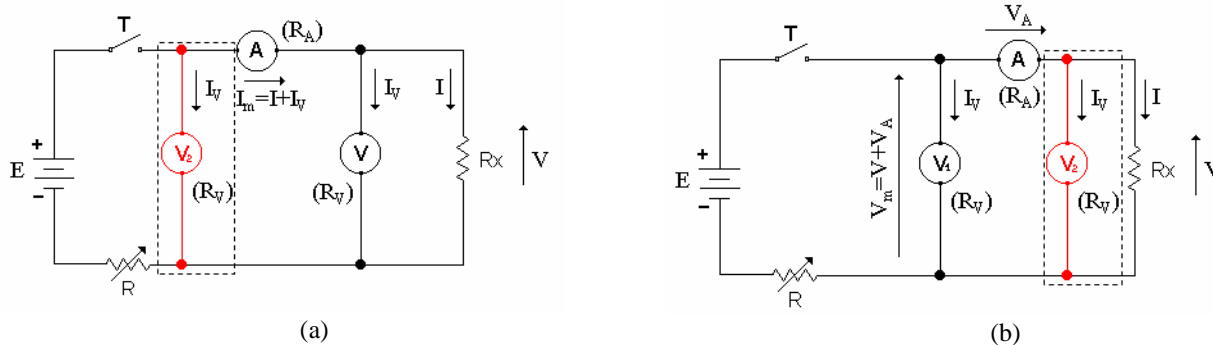


Fig. 5. Circuitual schematization of the two possible insertions of the instruments: Conf.1 (a) and Conf.2 (b)

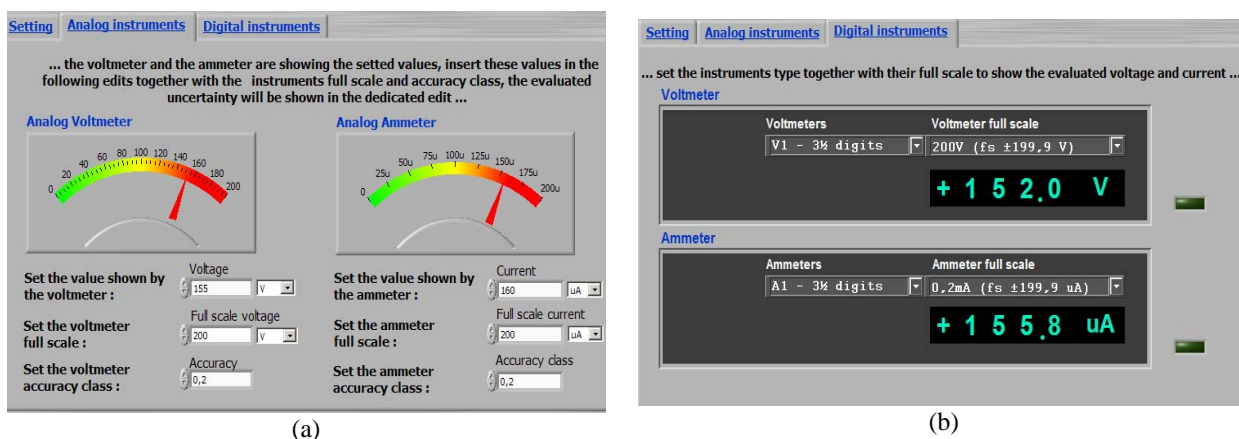


Fig. 6. The instruments: analogue (a) and digital (b).

The other two tabs, shown in Fig.6a and 6b, permit the user to choose to represent the voltage and the current measures in an analogue or a numeric format; in other words, the user can carry out the choice of an analogue instrument or a digital one. The user can set the accuracy indices and the full scale for both the voltmeter and the ammeter; moreover, when the digital instrumentation has been chosen, it is possible to set the number of digits to use for the representation of the measured quantities. In the right section of the GUI (in Fig.4) the relative and absolute errors on the voltage and the current measures are shown together with the evaluated resistance value. The deterministic and the statistical models to evaluate the uncertainty in the resistance evaluation process have been implemented.

B. The GPIB Volt-Ammeter section

This other tool permits to interface the PC on which it is running with three real instruments (in particular three HP34401A multimeters), to measure the voltage and the current respectively, via the GPIB (IEEE488) bus. Three instruments (instead of two as in the previous section and in the classic configurations) implementing the two configurations in Fig. 5a and 5b have been inserted with the purpose to implement the two well known configurations at

the same time. This choice has two relevant consequences: first, the students face with the problem of the loading error due to the instruments which must be compensated; moreover it enables the teacher, if necessary, to use a remotely located circuit (the circuit with the instruments can be located in the laboratory) handling the instruments by the user interface without needing to have the setup in the same place where he is giving the lecture to change the insertions of the instruments. The remote managing of the instruments is made possible using the internet network and the capability of the LabVIEW[®] environment to communicate by the http protocol. The Web Publishing Tool in LabVIEW[®] has been used to publish the GUI making it accessible by a web browser simply typing its URL.

The front panel shown in Fig.7 will appear when this tool is selected from the initial GUI.

The user can choose the insertion (Conf.1 and Conf.2, whose circuitual schematization are shown on the front panel for the sake of clarity) of the hard instruments to perform the measures and set the correct full scale, the full scale of the instruments will be automatically switched to the selected one. The measurement results are given in the lower left side.

To have a vision of the real setup, when a remotely located circuit is used, a video acquisition is performed by a webcam

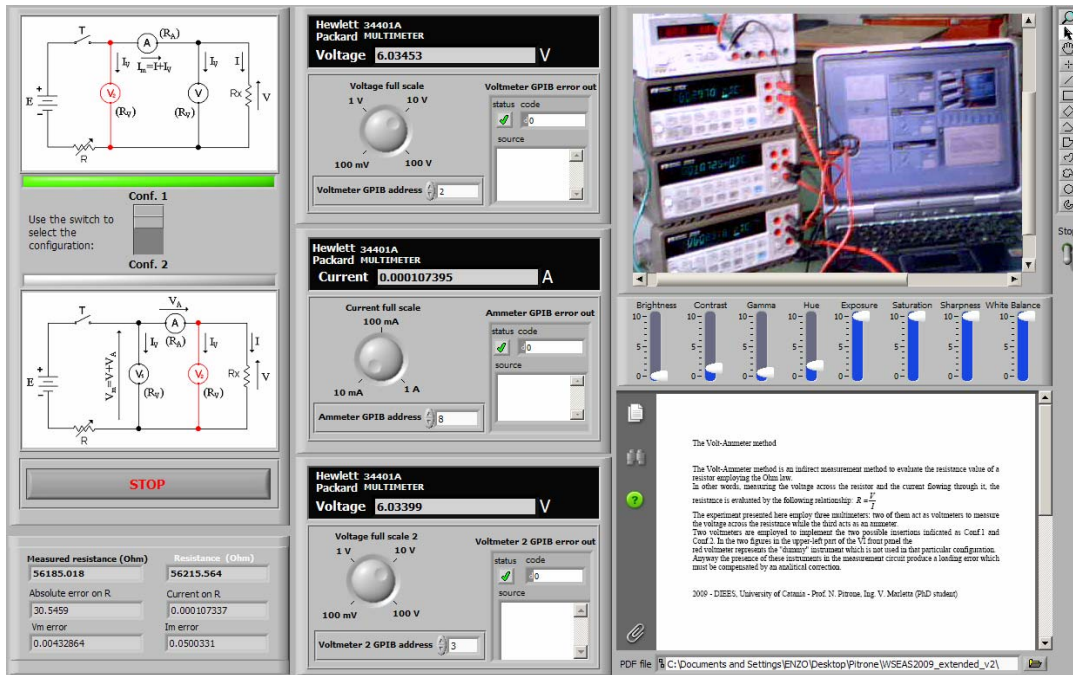


Fig. 7. The GUI of the GPIB Volt-Ammeter method implementation.

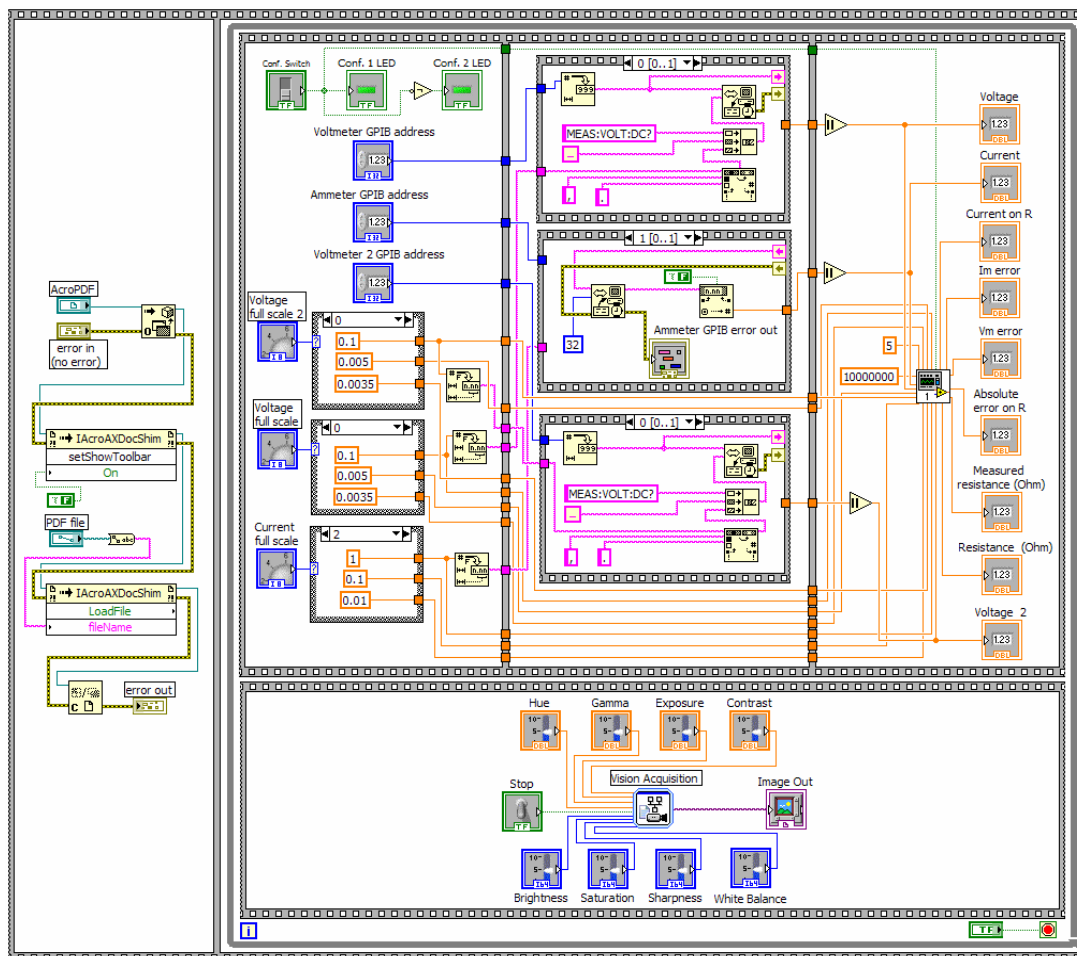


Fig.8. The block diagram of the tool implementing the GPIB Volt-Ammeter method.

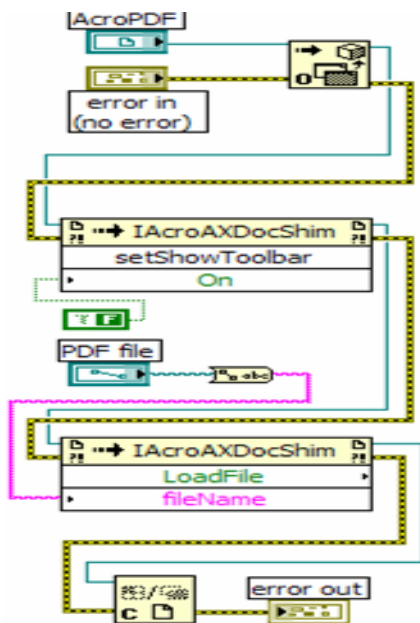


Fig. 9. The code implementing the loading and visualization of the PDF file.

located near the setup. The acquired video is shown in the upper right side of the GUI (as visible in Fig. 7). Vision settings, as brightness, contrast, exposure, gamma etc., are enabled by the *pointer slides* below the video area.

Finally, in the lower right side of the GUI a short description of the volt-ammeter method together with a quick start guide to the use of the interface is reported by the visualization of a PDF file.

1) The implementing code

The block diagram implementing the applicative is reported in Fig. 8. It consists of a main *flat sequence* structure with two *frames*.

A *flat sequence* structure consists of *sub diagrams*, or *frames*, that execute sequentially from left to right ensuring a well defined data flow.

In particular, in the first frame of the block diagram the code to load and visualize the PDF file is implemented, while the second *frame* is dedicated to the implementation of the volt-ammeter method together with the instrumentation setting and the code for the vision. Two other *frames* (one above the other) are enclosed in the latter *frame* and repeatedly executed by an external *while loop*. A more detailed description of the code is given in the following section.

Fig. 9 shows the code implementing the loading and visualization on the GUI of the quick guide in the PDF format. Essentially it consists of two ActiveX blocks named *Invoke Node* which enable to manage the ActiveX object referenced by the *Automation Open* block.

In this case the latter block returns a reference (*Refnum*) to an ActiveX object of the class *AcroPDFLib.IAcroAXDocShim*.

The two nodes invoke a method on the reference: in

particular, the first node invokes the boolean *SetShowToolbar* method which permits to set the toolbar visualization in the area dedicated to the PDF file, while the second node invokes the *LoadFile* method which permits to load the file indicated in the *fileName* attribute. At last the *Close Reference* block closes the *Refnum* associated with the ActiveX object.

As stated before, the second *frame* of the main *flat sequence* is dedicated to the implementation of the volt-ammeter method together with the instrumentation setting and to the code for the vision. The bottom *flat sequence* contained into the *while loop* manages the video acquisition from a USB webcam and the visualization of the frames on the front panel implementing the GUI. The code is shown in figure 10.

A vision acquisition express VI, making easy the video managing, has been used. This wizard makes available some acquisition settings, as the contrast, the brightness, the saturation and others, to control the video attributes. *Pointer slides* on the front panel have been used to set and adjust the values of these parameters with the purpose to the video quality under different conditions of the environmental light.

The other *flat sequence* is devoted to the implementation of the measurement method and to the instrumentation settings.

It consists of three frames which will be explained in the following.

The first frame, shown in Fig. 11, is associated to the application parameter setting.

It permits to select the configuration (Conf.1 and Conf.2) in which the multimeters have been inserted in the circuit, to set the GPIB addresses for the voltmeters and the ammeter (the three multimeters) and to set the voltage and current full scale for the instruments by two *knob controls*.

The selected full scale determines the uncertainty (or accuracy) of the instruments whose values are indicated in the related manuals and reported in the two *case structures* linked to the two *knobs* together with the selected full scale.

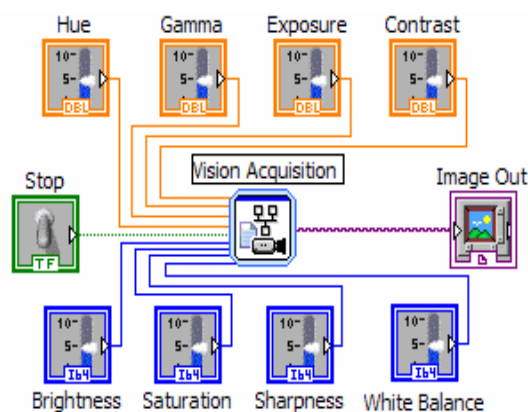


Fig. 10. The code managing the video acquisition from an USB webcam.

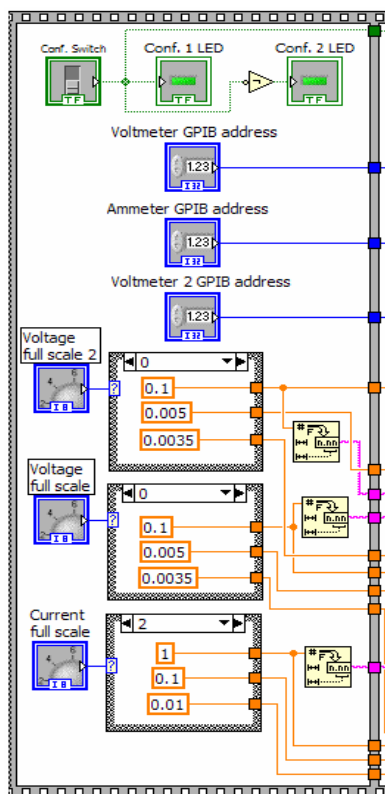


Fig. 11. The code for the instrumentation setting.

This latter value is converted in a string format and passed to the next frames.

The next frame is devoted to the communication with the instruments: the voltmeter and the ammeter. Three *stacked sequence* structures, each of them consists of two *sub diagrams* executed sequentially, are enclosed in it. In the first and the third frame the first sub diagram is shown, while the second sub diagram is shown in the second frame. The two frames are shown in Fig. 12. Essentially the first *sub diagram* of all three frames sends a *query* to the multimeter having the specified GPIB address to require the measure of the voltage and current respectively.

The communication with the instruments is implemented by two dedicated *GPIB blocks*. A first block, named “*GPIB Write*”, permits to send a query to the instrument: it requires the specification of the GPIB address of the instrument and the string representing the command to execute using the *SCPI* (Standard Commands for Programmable Instruments). The second block, named “*GPIB Read*”, enables us to read the result of the command execution reading a specified number of bytes (in this case 32 bytes) from the device having the indicated GPIB address. The command execution is monitored by the *error out blocks* which give information on the status of the communication. Finally the third frame elaborates the data coming from the previous frames and shows the results. A subVI, implementing the volt-ammeter method, has been developed.

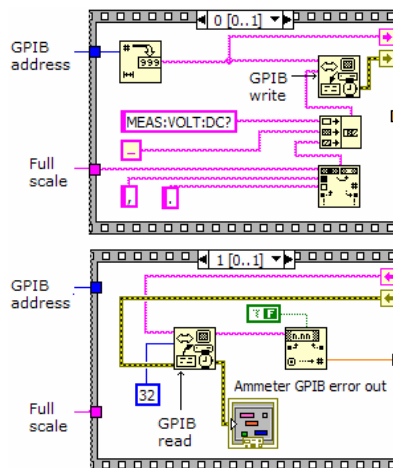


Fig. 12. The two frames of the stacked sequences devoted to the communication with the instruments.

Its block diagram is shown in Fig.13. It performs the data computation in order to estimate the resistance value taking in account the selected instruments insertion, the uncertainties and the loading error. The code consists of a *case structure* which, according to the boolean selector terminal value, executes the inner code. This latter consist (for both possible values of the selector terminal) of a flat sequence with four frames containing each one a *formula node* block. A formula node block enable the user to type in it formulas and expressions to evaluate in a C-like code.

Each of them elaborates one or more mathematical formulas to evaluate the value of the unknown resistance taking in account the loading error, due to the presence of the instruments in the circuit. The results of these evaluations are then shown on the front panel.

III. CONCLUSION

The dramatic development of the technology requires updating the teaching work, which involves using different teaching techniques, advanced instruments, complex equipments, and also high-level software and distance learning systems. To overcome these pressing needs and to stimulate the interest in the undergraduates attending the measurement courses, the authors are trying to deeply modify the training activity in the laboratory, taking into account advanced hardware and software tools.

The volt-ammeter method can be a benchmark for future development. Indeed, it exhibits some peculiarities very useful to present basic concepts in the measurement area:

- it is an indirect method;
 - loading error can be introduced, depending on the characteristics of the instruments;
 - random error, affected by the precision of the instruments.
- The following developing technologies can be adopted:
- digital instruments (working principles, precision level, connection in a network);

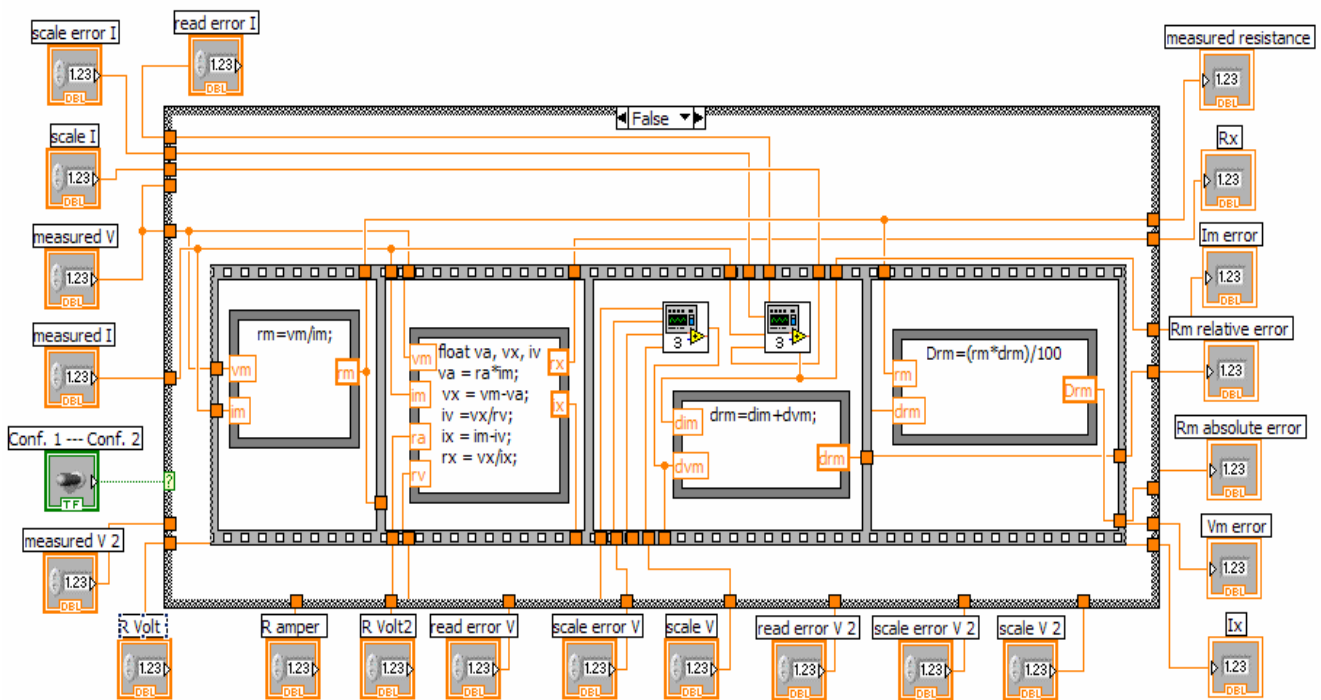


Fig.13. Experimental setup with the PC on which the software tool is running and the hardware circuit to implement the volt-ammeter method.

- o data acquisition system and virtual instrument, developed in the LabVIEW® environment;
- o analysis of various LabVIEW® instructions, used in a sampling tool, as an example for future more complex application;
- o distance learning opportunity.

In the paper the tool implemented on purpose has been presented in details, as a base for future development in other areas of electronic measurements.

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