

# Experimental Training on Advanced Technologies

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*Abstract: In the last years the authors have devoted great attention to the different aspects of the educational activity, with particular emphasis to theoretical and experimental training of the undergraduate students on measurement methods, real instruments (features and working principle), virtual instruments and related environment, useful tools (advanced software and hardware), distance learning. Therefore a number of tools have been realized in order to gradually propose to the students meaningful aspects of advanced technologies. In the paper an overview of selected tools is presented, in particular the tool presented in the last section takes into account the peculiarities of the unknown signal and also the effect of the noise signal superimposed to the signal to be measured.*

**Key-Words:** - Undergraduates, experimental training, digital frequency meter, voltage-time converters, digit error, noise effect, virtual instruments, learning LabVIEW, advanced technologies, e-learning.

## 1 Introduction

An accurate training on measurement procedures and measurement system design can be obtained by carrying out real experiments with real electronic components and circuits [1, 2]. Moreover, advanced communication technologies can greatly contribute to modify the educational approach: networking can be a key point for education on measurement. In particular, undergraduate students can test their theoretical knowledge, and can perform an useful self-training: indeed, they can use the know-how available on the Internet. Moreover, through the connection to a measuring system working in the lab the remote user can have the sensation of "distant participation" [3].

In addition to the possibility of using modern communication technology, this task will improve the availability of the laboratory, in order to overcome the drawback due to the large number of students and the short time available for a correct experimental training in few years courses.

This activity cannot replace a hands-on contact to the real measurement equipment, however such training can be a proper solution to the problem of preparing students to make reliable measurements close to real life [4].

The rapid improvement of the technology greatly improves the features of the instruments which, in turn, requires changing the way of teaching electronic measurements, updating the programs and performing the practical training of the undergraduate students. Great attention has been devoted in the last years by the authors [3-11] to the

theoretical and experimental training of the undergraduates on:

- measurement methods,
- real instruments (features and working principle),
- virtual instruments and related environment,
- useful tools (advanced software and hardware),
- distance learning.

In the research on technical education the authors have analysed the following issues:

- advanced hardware and related software;
- virtual instruments (LabVIEW<sup>TM</sup> environment);
- basic subjects of the electric and electronic measurement area.

As regards advanced hardware, a deep study has been performed on the possibility of remotely controlling connected instruments and some didactic tools have been realised: it should be emphasized that they have been satisfactorily adopted by the students [6].

The revision of this tools has been successively carried out, in order to enhance the reliability of the hardware in the laboratory. In particular, a FieldPoint<sup>MT</sup> controller has been adopted.

In a recently implemented tool for three-phase system measurements, a microcontroller has been adopted (the ST52F513) [6]; it belongs to the ST-FIVE family of 8-bit Intelligent Controller Units (ICU), by ST-Microelectronics. The needed software for programming this micro-controller is the Visual Five by the ST-Microelectronics environment (this stage is a very significant didactic improvement for electrical engineering students). In a tool realised on purpose for these measurements,

electromechanical instruments and also advanced technologies have been used; this strategy represents an attractive approach to data acquisition systems and virtual instruments: the students can compare the results supplied by the two sets of instruments, for additional clearness of the implemented method. As this tool can be used for distance learning, a web cam located in the lab will give an overview of the system adopted for carrying out the experiment, for enhancing the “presence feeling” of the remote user. As regards the software, besides the ones useful for the communication, particular attention has been devoted to the LabVIEW™ environment, mainly for the reason that it enables the realization of virtual instruments. The students can learn this software analysing already implemented virtual instruments and then they can be able to implement a new virtual instrument, after a deep understanding of the involved theoretical aspects. This approach is widely used in measurement courses.

Various basic subjects of the measurement area have been considered, in order to push the students to make a careful study of them. In particular, tools have been implemented on:

- experimental analysis of the RC and RLC circuits;
- measures on the audio amplifiers;
- frequency measurements.

The tools perform the analysis of the circuits in the time domain as well as in the frequency domain and build up a front panel for the local control and for the presentation of the results.

Some digital instruments have been recently considered: indeed, they can be quite easily used, but it is not so easy to understand how they work, as it is evident from interactive lectures.

In some guided sessions, the students have been requested to deeply analyse the working principle of the following instruments and therefore to realise the respective virtual instruments:

- the digital frequency meter;
- the voltage-time converters;
- the double slope voltmeter.

In this paper some implemented tools are presented.

In the next section the various pieces of hardware that have been taken into account in the realized tools are presented.

In the following section the software is considered. Particular consideration has been dedicated to the LabVIEW™ environment and therefore some virtual instruments are examined in some details in order to emphasize their relevant didactic aspects.

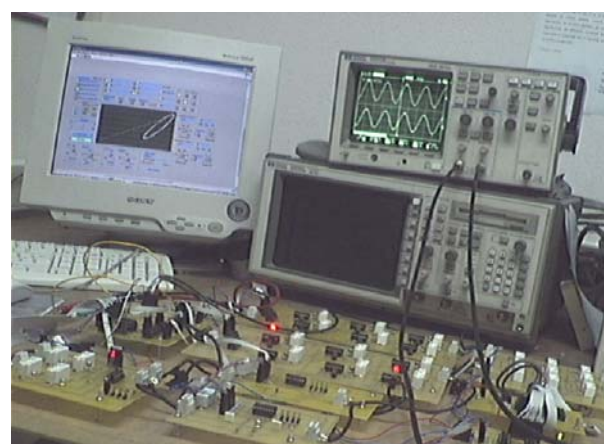
Only in few cases the precision level and the effect of the noise have been taken into consideration. The last didactic tool recently implemented (presented in

the last section of the paper) takes into account the peculiarities of the unknown signal and also the effect of the noise signal superimposed to the signal to be measured.

## 2 Hardware

Digital oscilloscopes, programmable generators completely driven by the PC are widely used. Moreover, both analogical and digital electronic circuits are designed and used during experimental training.

Figure 1 shows a tool designed for training the students on the analysis of the basic circuits by using a mother board, where the circuits are installed, it is connected to two function generators and a digital oscilloscope, completely controlled and driven by a dedicated software running on a personal computer. In a) the circuits on the mother board are connected to the instruments by using relays; in the improved version, b), the mother board is compact and more reliable: indeed, by adopting the FieldPoint™ controller a powerful system has been obtained.



a)



b)

Fig. 1: The motherboard with instruments driven by the PC (useful for remote measurement): a) the connection are carried out by relays; b) the FieldPoint™ is used for the connections.

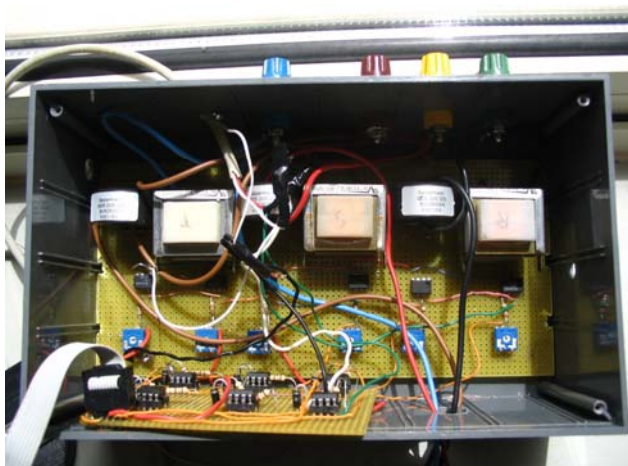


Fig.2: The first board: signal conditioning.

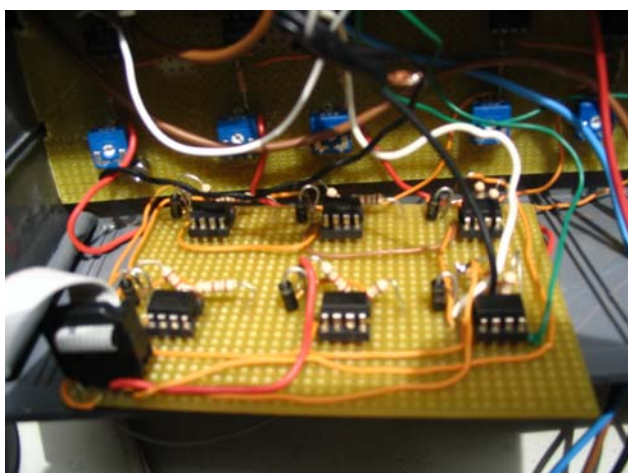


Fig. 3: The second board: sending correct signal level at the input of the microcontroller.

Experimental training on three-phase electrical systems is very important for undergraduates in the electrical engineering area: in fact, this activity can be a first approach to the power system study; indeed, they can achieve and verify an excellent basic knowledge of various theoretical aspects in different load conditions.

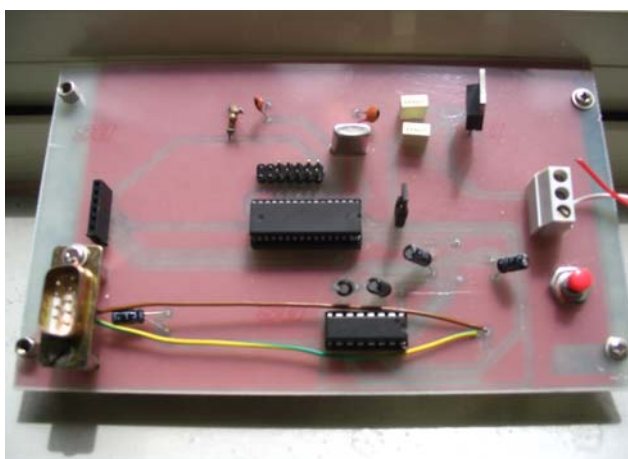


Fig. 4: The ST52F513 microcontroller board.

First of all, a very simple and reduced laboratory model has been implemented and particular attention has been devoted to the realization of a virtual instrument, which will be presented in the following section. In successive development new hardware tools have been realized.

Therefore, a stand alone laboratory session has been implemented using a micro-controller based architecture. The adopted strategy uses smart architectures, efficient paradigms for signal processing and stand alone architectures. Moreover, the limitations of existing technologies can be overcome, as they are really expensive and sometimes far from actual needs.

The hardware, realized on purpose, consists of three boards [7], designed for the conditioning of the input signals (Figure 2), for adapting the level of the signals to the correct level at the input of the microcontroller (Figure 3), and for programming the microcontroller and for managing the communication with the computer. The ST52F513 microcontroller has been adopted (Figure 4).

This tool, which includes the software, has shown to be very interesting for the students.

A further development has been obtained by the portable three-phase energy meter, adopting the microcontroller PIC18F2620: the compact board shown in Figure 5 has been recently realized.

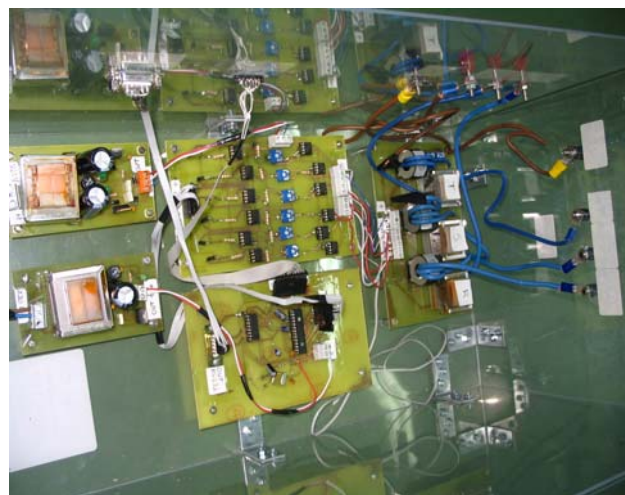


Fig. 5: The recently realized board.

### 3 Software

First of all, it should be pointed out that it is very important for the undergraduates training in the area of software for microcontroller programming.

The environment for programming the ST52F513 microcontroller is the Visual Five by ST-Microelectronics.

The software for programming the microcontroller PIC18F2620 is MPLAB IDE v7.40.



The LabVIEW™ environment is a dedicated software for implementing virtual instruments. During the training sessions each group of students is required to realize a virtual instrument, proposed by the tutor.

In order to fulfil this job, the students must undertake the following steps:

- They have to analyse in details the particular theoretical problem under study, which is one of the main purposes of the teaching activity;
- They must acquire some knowledge of LabVIEW™: in a step by step activity, the students can analyse some virtual instruments already developed and can refer to the user guide [12].

In order to emphasize their didactic value, some virtual instruments (VI) are presented in the following subsections; they deal with subjects in the areas:

- three phase systems;
- electrical and electronic circuit analysis;
- digital instruments.

### 3.1 Virtual Instruments for three phase system analysis.

The realized VI performs the procedures for the realization of the digital instruments; on the basis of the acquired electrical values it computes the values of the voltage and the power really measured by the electromechanical instruments in the lab and displays the results on the same figure; moreover it computes the values of the total active power and the reactive power, which are displayed on the proper boxes on the screen. A web-cam is located in the lab in order to deliver to the remote user the image of the traditional instruments (Figure 6), so the remote user can compare the values displayed by the two sets of instruments [7].

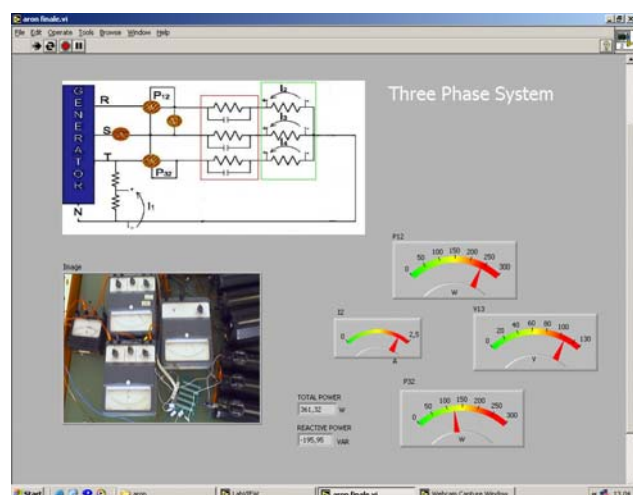


Fig. 6: VI: image on the monitor of the remote user.

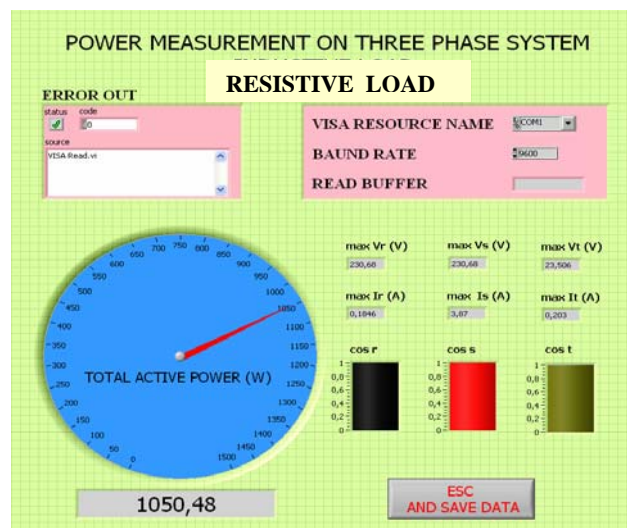


Fig. 7: User interface of the power meter.

This user friendly tool can be used in distance learning sessions, improving the availability of the laboratory.

The further developed electronic power meter, based on the ST52F513 microcontroller [8], supplies the data for computation and presentation of the results to a VI designed on purpose: the user interface of this virtual instrument is shown in Figure 7.

### 3.2 Virtual Instruments for electronic circuit analysis.

Many tools have been realized for training the undergraduates on the analysis of some fundamental electric and electronic circuits in the frequency domain as well as in the time domain; each one has been designed to meet required features. The first tool [5] enables the user carrying out measurements on the RC circuit: indeed, he can choose the values of the parameters of the circuit, the frequency and the voltage supplied by the function generator which is connected to the PC.

The VI realized on purpose allows the complete control of the motherboard (Figure 1a); the user friendly panel is shown in Figure 8.

The different values of the parameters have been chosen in order to emphasize the load effect of the input impedance of the channels of the oscilloscope. The user panel of a more complex tool is presented in Figure 9.

It enables the student training on the following subjects:

- complete analysis of the behaviour of the RC and the RLC circuits;
- frequency measurements;
- amplifier characterization.

Full management of the following interconnected instruments is enabled:

- a programmable arbitrary function generator, which will supply the circuit under study, and a second one for frequency measurements;
- a digital oscilloscope;
- the motherboard with the FieldPoint™ (Figure 1b) used for realizing a reliable connection between the circuit chosen for performing the particular training activity and the instruments to be used for the particular analysis.

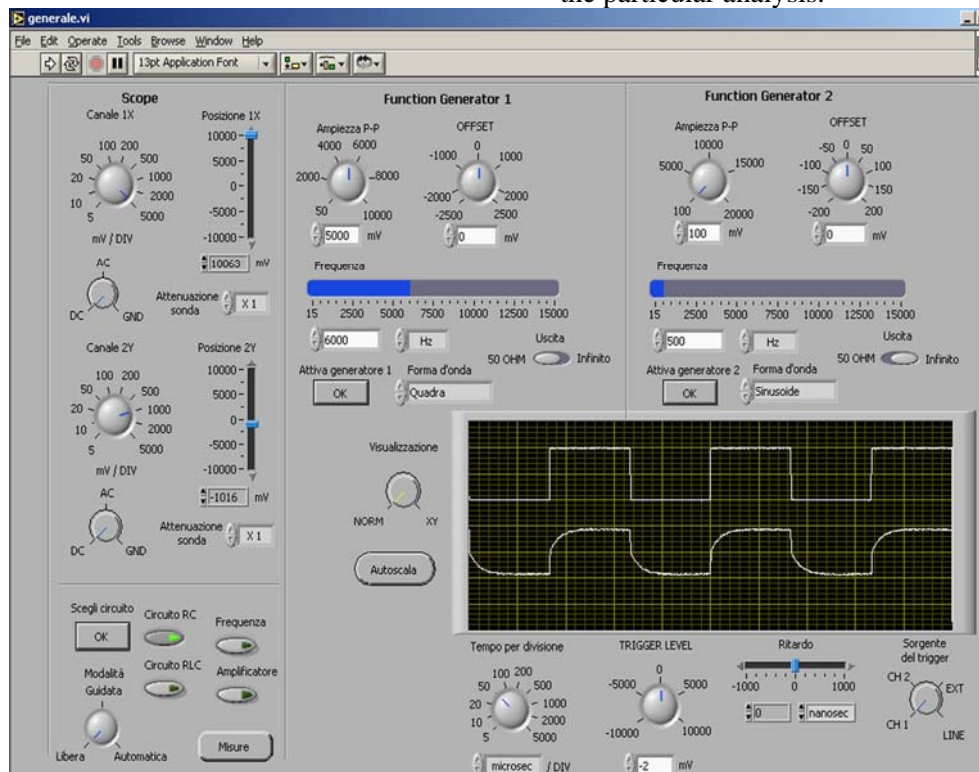


Fig. 8: User friendly panel for RC circuit analysis.

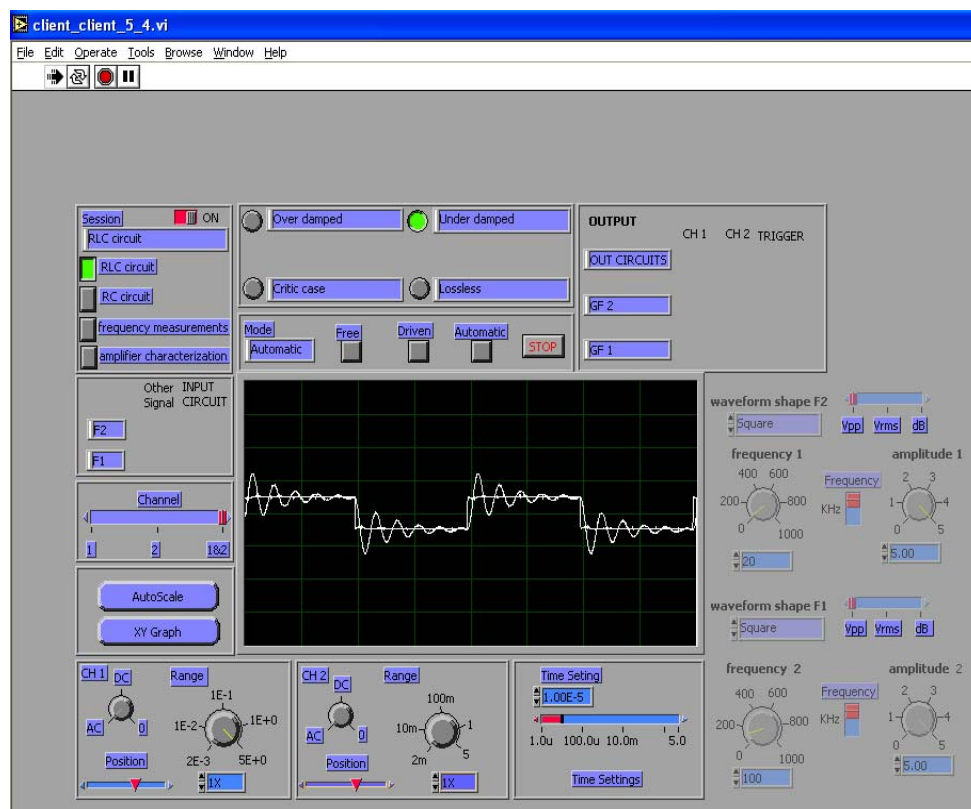


Fig. 9: Front panel of a tool for multipurpose experimental training.

From the front panel the following choices can be made:

- the specific analysis to be performed;
- the waveform shape, the frequency and the amplitude of the voltage to be supplied to the circuit under study;
- the input characteristics of the channels of the oscilloscope and the operation mode (time setting of the time base, XY mode, auto scale, trigger).

In the Figure 9 the analysis of an under damped RLC circuit in the time domain is shown: indeed, the corresponding boxes are highlighting; moreover, the automatic mode has been chosen, as well as the characteristics of both the input waveform and the channels of the oscilloscope.

This tool has been step by step realized by some groups of students, on the basis of the previous one, and has been considered to be highly valuable.

### 3.3 Virtual Instruments for training on digital devices.

Real digital instruments have been recently taken into consideration for the implementation of virtual instruments: indeed, in spite of the simplicity of their use it is not so easy to understand how they work.

As far as didactic problems for undergraduate students training on advanced technology are concerned, the following instruments have been

taken into account for the realization of virtual instruments:

- the frequency meter;
- two voltage-time converters, just as meaningful examples.

#### 3.3.1 Frequency meter.

The first tool developed on this subject is oriented to highlight some theoretical aspects on the working principle of the digital frequency meter. The front panel of this virtual instrument is shown in Figure 10.

As it is known, the digital frequency meter carries out the measurement of the unknown frequency on the basis of the values of some parameters (among them the clock frequency and the a synchronism between the unknown signal and the clock signal of the instrument).

The student can estimate the effects of both the frequency meter parameters and the characteristic of the unknown frequency signal by changing the parameter settings of the device as well as those of the unknown signal.

Moreover, in order to evaluate the effect of a noise signal superimposed to the unknown signal in terms of the frequency estimation, a noise generator has been also integrated.

It allows for experiencing how a small amount of noise as well as a large amount can affect the estimation of the unknown frequency [11].

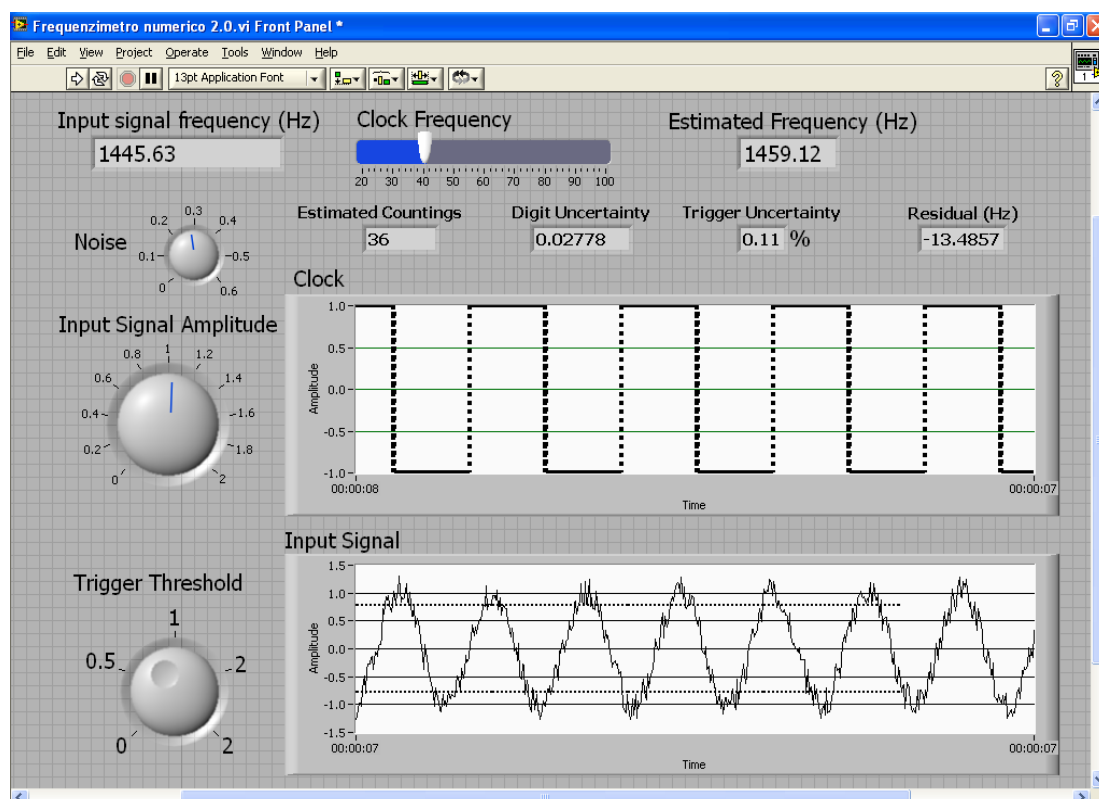


Fig. 10: Front panel of the digital frequency meter tool.

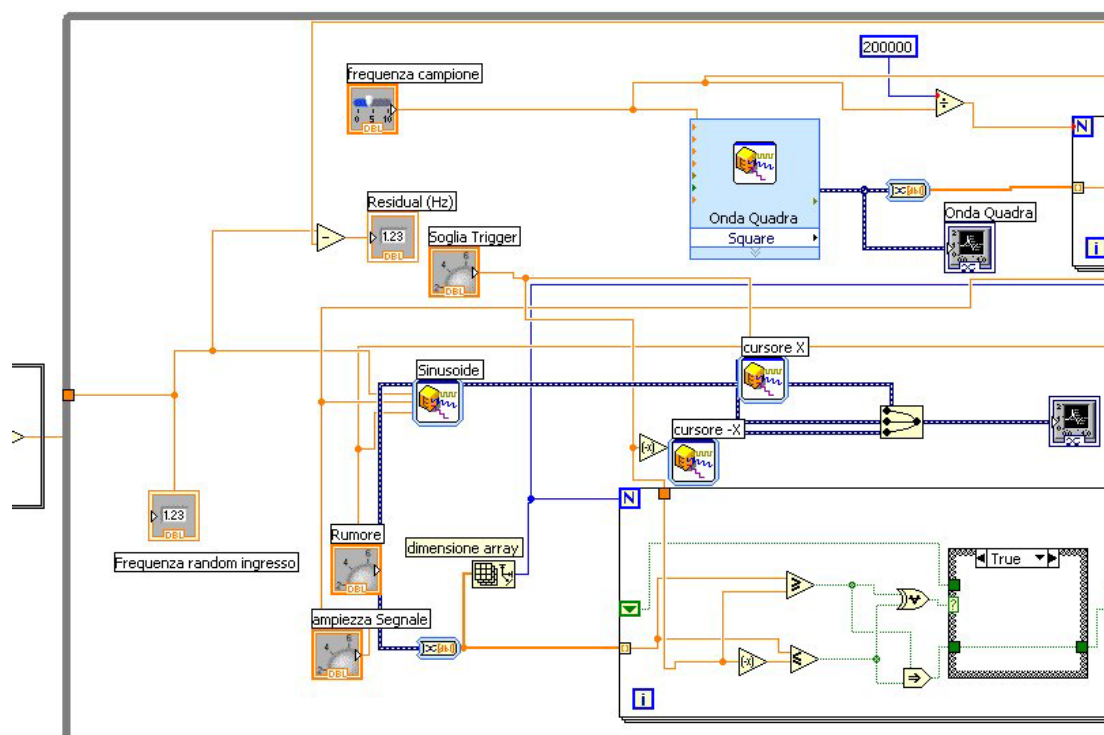


Fig. 11: The program of the frequency meter of the VI in the LabVIEW™ environment.

The implemented software in the LabVIEW™ environment is shown in Figure 11.

The realization of this VI has been a powerful practice on the LabVIEW™ environment for a group of students.

### 3.3.2 Voltage-time converters.

Great attention has been devoted by the authors to some voltage-time converters, for the following reasons:

- they can represent an introduction to the accurate study of the analog-to-digital (A/D) converters;
- there are various causes of errors;
- each converter is characterized by different speed and different resolution and precision level.

Two virtual instruments are presented here.

The first one implements the linear converter, its front panel is presented in Figure 12. The typical parameter settings are shown. In particular, the user can choose the frequency of the time base, the reference voltage for supplying the integrator and also the time constant of the integrator.

The second voltage-time converter exhibits more interesting features and has been taken into account because it is the main part of the double-slope digital voltmeter.

The working principle of the real instrument has been accurately revised and a group of undergraduates in Informatics has been requested to build a VI during some guided practical sessions.

Using this virtual instrument to understand the working operation, the students can perform many tests [10]: indeed, they can choose the value of the voltage to be measured, therefore they can modify the interval of the first integration and can change the clock frequency.

Moreover, the operator can set other parameters, such as the number of bit of the digital counter, to observe the effects on the operating range of the device.

The front panel of this interesting tool is presented in Figure 13.

The block diagram generated by the LabVIEW™ is quite complex, the complete work has been performed with the cooperation of the students. In order to improve its didactic value, two helpful sections have been implemented:

- the setting instruction section;
- the warning & suggestion.

During the experimental training, the students can observe the effects of the quantities above mentioned on the device performances both in terms of digit error and overall uncertainty.

On account of the good results obtained, according to the appreciation expressed by the students that have already tested this VI, such approach will be used extensively in the development of the didactic activity.

Indeed, by using this tool the students can deeply understand the meaning of the following theoretical sentences:



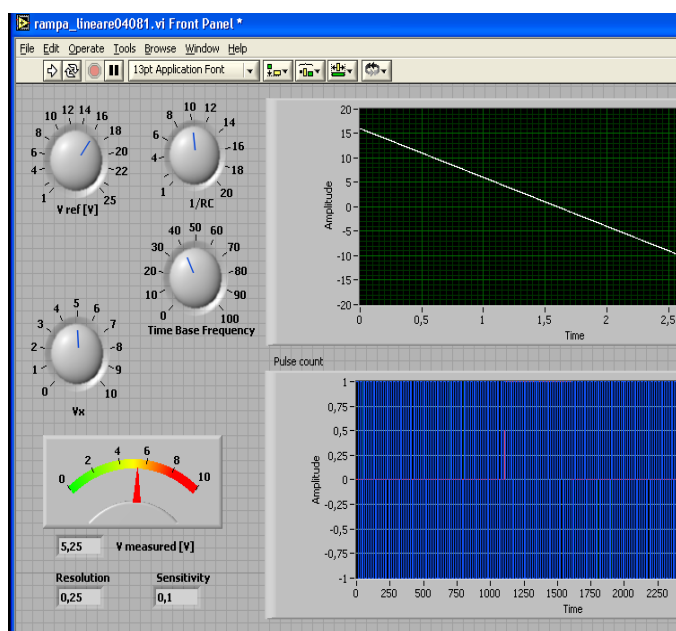


Fig. 12: Front panel of the single-slope converter.

The advantage of the dual-slope method is high noise immunity because of the integration of the input signal.

In addition, errors inherent in the single-slope method are cancelled in the dual-slope method.

The major drawback is that the conversion time is relatively long [13].

The last tool has been recently improved, in order to deeply analyse the advantages offered by this converter, in particular as it refers to the “high noise immunity”.

Therefore, the effect of a noise superimposed to the voltage to be measured can be examined in the new release.

The student can choose some characteristics of the noise and can observe the effect on the obtained result.

The front panel of this version of the double slope digital voltmeter is shown in Figure 14.

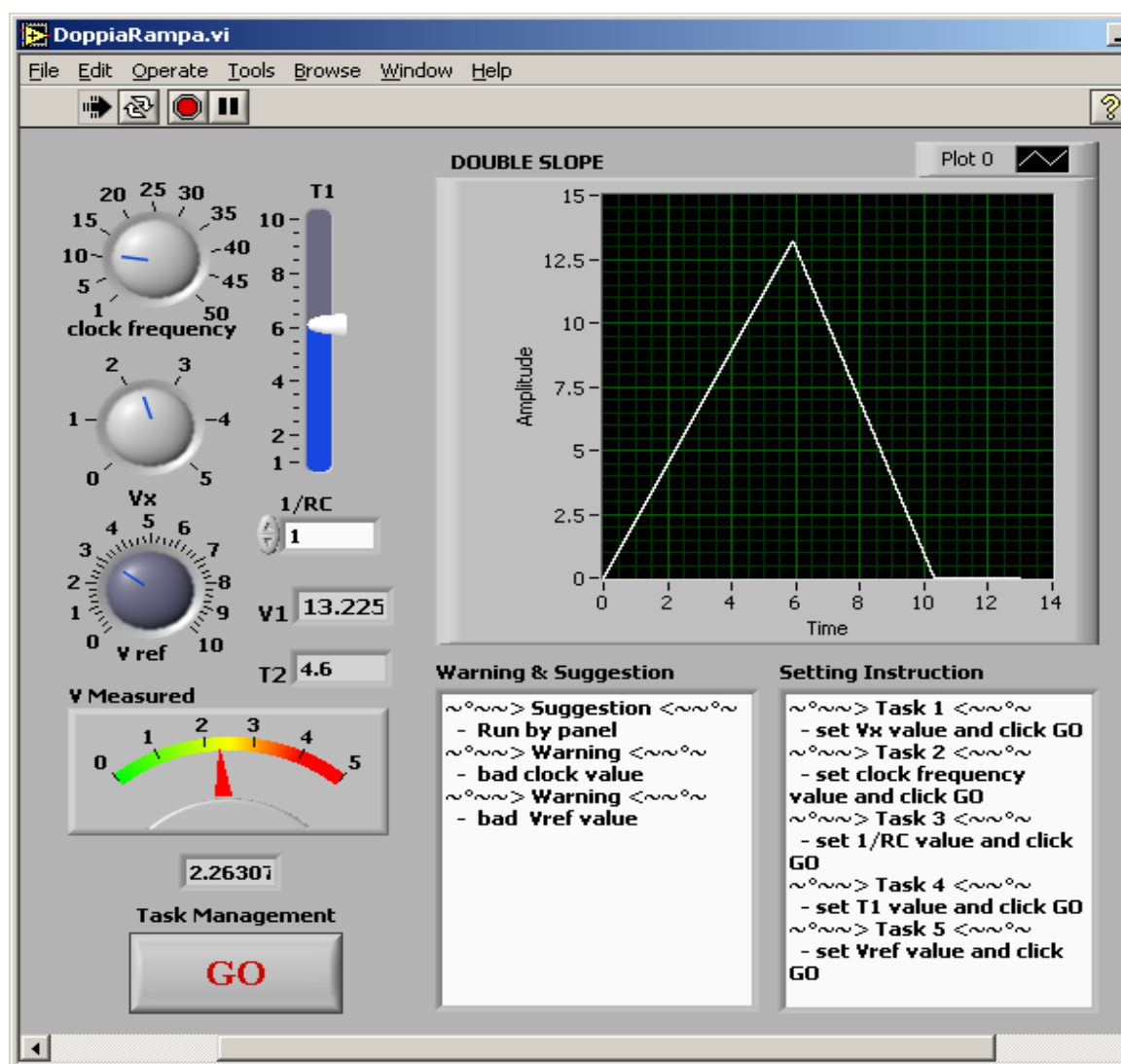


Fig. 13: Front panel of the VI of the double-slope integration A/D converter.



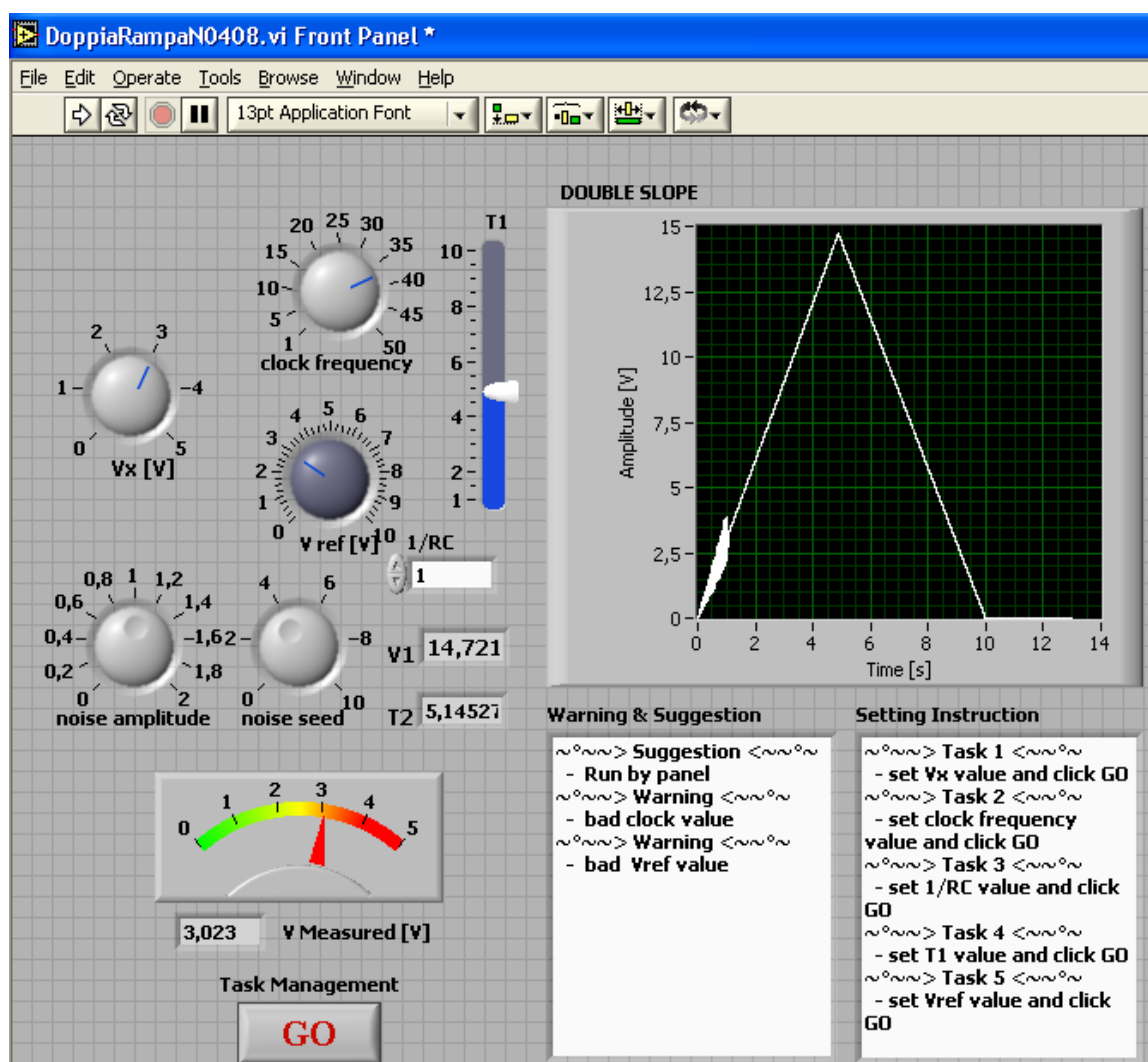


Fig. 14: Front panel of the VI of the double slope digital voltmeter: the effect of noise is shown.

## 4 Conclusion

In last years great attempt has been devoted to both theoretical and experimental training of the undergraduate students, therefore an effort has been made to improve and update didactic programs and teaching methods on measurement domain: three phase electrical system, basic electric and electronic circuits, real digital instruments (features and working principle), virtual instruments and related environment, and distance learning.

For this purpose useful tools have been implemented as a helpful introduction to advanced software and hardware knowledge.

Therefore the realized tools gradually propose to the students meaningful aspects of various samples of advanced technologies.

In the paper an overview of selected tools has been presented. At the design stage simplicity and clearness have been considered to be the main requirements, in order to stimulate the interest of the undergraduate students and to supply them with a

reliable background for future development in higher level courses.

The subjects covered by the presented tools can be summarised as follows:

- three phase electrical system measurements;
- experimental analysis of the RC and RLC circuits;
- measurements on audio amplifiers;
- frequency measurements;
- advanced hardware and related software;
- virtual instruments (LabVIEW™ environment);
- the digital frequency meter;
- the voltage-time converters;
- the double slope voltmeter.

In the recently implemented virtual instruments also the effect of a noise signal superimposed to the signal to be measured is analysed.

Some tools have been designed to improve the availability of the laboratory, therefore they can be utilised by remote users.

In preliminary tests the students have favourably accepted this didactic development.

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