



Empowering remote education: Harnessing LabVIEW software to create an immersive virtual electrical measurement bridge for distance learning

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Abstract

Nowadays, Virtual Instruments are becoming an important part of solving engineering problems in particular in the area of Automatic Control of Industrial Processes and Education. Due to the continuously increasing performance and flexibility of PC combined with their cost reduction, virtual instruments are successfully concurring the traditional instruments. During the pandemic, covid-19 as a result of adapting the emergent solution in education students and teachers should work from home. Except for lessons and seminars, doing laboratory work faced difficulties to be performed because students should be in the laboratory, which was not possible. In this work we have built a virtual instrument for electrical resistance measurement which imitates in detail the Wheatstone Bridge in our Electrical Measurement Laboratory and tested remotely to measure resistance by interacting with a virtual instrument like with the real instrument.

1. Introduction

Development of the technology rises the opportunities to facilitate the teaching aspect as well as the acquisition of knowledge by students. However, the speed of change in technology in various fields of science creates some problems for academic institutions, particularly engineering disciplines. This requires a constant updating and extension of teaching materials, which represents the greatest difficulty in engineering fields, where experimental support is required.

The main problem remains the same: To provide students valuable practice experience, being limited in laboratory equipment and infrastructure. One solution to this problem would be: to make use of techniques based on computers so that the student's interface with the real world. This manner allows further, sophistication and flexibility because the main part of the application is created on the computer and so it can be modified without the need for additional physical devices [1-2].

From the teaching point of view, to build the applications in the laboratory, all engineering problems deal with some physical quantities such as potential difference, electric current, temperature, pressure, speed, position, mechanical torque, moisture level, etc. We can see these quantities by using a computer coupled with conditioning circuits, data acquisition, transducers, and software. Moreover, these data can be processed, and stored, and even we can publish them on the Internet. [Figure 1](#) illustrates an experimental test bed supported by the computer in real-time.

At the Automation Department of Electrical Engineering Faculty in Tirana the Electrical Measurements subject includes 4 laboratory works. One of them deals with measuring and error calculation with the Wheatstone and Thomson Bridge.

The Wheatstone bridge is an instrument used to measure electric resistance in the range of 10Ω to $10^6 \Omega$ with a class of accuracy $K_U = 0.05$, with 5 digits of precision.

The Wheatstone bridge in our Electrical Measurement Laboratory is shown in [Figure 2](#).

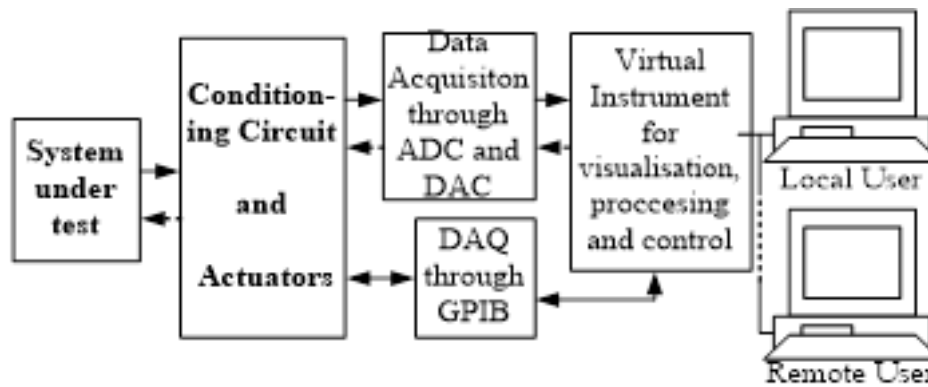


Figure 1. Block diagram of a laboratory test bench based on PC.



Figure 2. MTV Thomson-Wheatstone Bridge in the Electrical Measurements Laboratory.

During the pandemic, covid-19 as a result of adapting the emergent solution in education students and teachers should work from home. Except for lessons and seminars, doing laboratory work faced difficulties to be performed because students should be in the laboratory, which was not possible.

To overpass these difficulties, we thought to implement virtual instrumentation techniques, so students in the second year of the Bachelor's Degree in Electrical Engineering at our Faculty could perform some of the laboratory works from home in the subject "Electrical Measurements and Electronic Instrumentation".

In this work have built a virtual instrument for electrical resistance measurement which imitates in detail the instrument shown in the figure above and tested remotely to measure resistance by interacting with a virtual instrument like with the real instrument.

2. Material and Method

2.1. The Virtual Wheatstone Bridge Formula and Conditioning Circuit

To build the Wheatstone Bridge Virtual Instrument we relied on [3-4] for instrument programming.

For the Wheatstone bridge formulas and theory, there is plenty of literature which can be found on the internet. However, we are referring to literature in Albanian [5] for the equation of the current flowing in the galvanometer I_G that is (Equation 1):

$$I_G = U \frac{R_1 R_4 - R_2 R_3}{R_G (R_1 + R_2)(R_3 + R_4) + R_1 R_2 (R_3 + R_4) + R_3 R_4 (R_1 + R_2)} \quad (1)$$

Where U - is the voltage that feeds the bridge and R_1 , R_2 , R_3 and R_4 - are the resistors of the branches of the Wheatstone bridge and R_G – galvanometer internal resistance.

To acquire electrical quantities in order to measure the resistance through the “Virtual Wheatstone Bridge” we have used the NI 6008 USB DAQ from National Instruments [6].

We measure the voltage drop and the current across the unknown resistor through two analog inputs of the NI 6008 DAQ card. Since this card doesn't support analog current inputs, we used an external known resistor with a value of $1\text{k}\Omega$ and measure the voltage drop across it. Then since analog inputs have a very high impedance, we assume that the current calculation for the external resistor is equal to the current passing to the unknown resistor since the resistors are connected in series. After this, dividing the voltage across the resistor with the current calculated we obtain the resistance value in the virtual instrument.

We use the NI 6008 USB DAQ card also for feeding the interface (conditioning circuit) through one of its analog outputs and by changing the voltage of this output from the virtual instrument “Sensitivity knob” we can change the current passing through the interface and improve the sensitivity. The interface is shown in Figure 3.

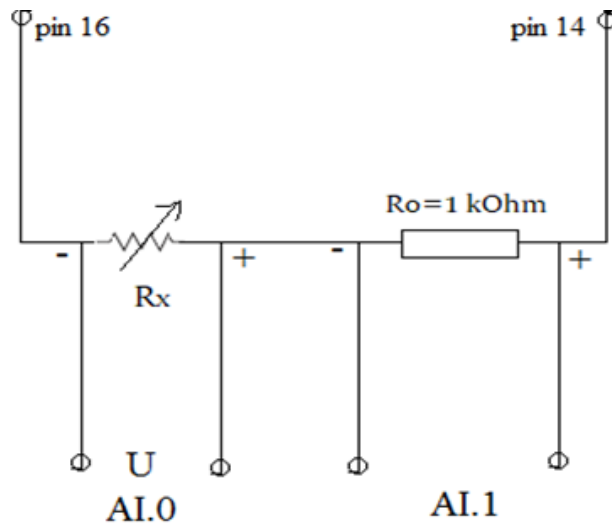


Figure 3. The interface of the virtual instrument for resistance measurement.

2.2. Wheatstone Bridge Programming in LabVIEW

Based on the schematic of Figure 3 and the NI 6008 DAQ documentation we built in the LabVIEW environment the electrical resistance measurement virtual instrument. The instrument block diagram is shown in Figure 4.

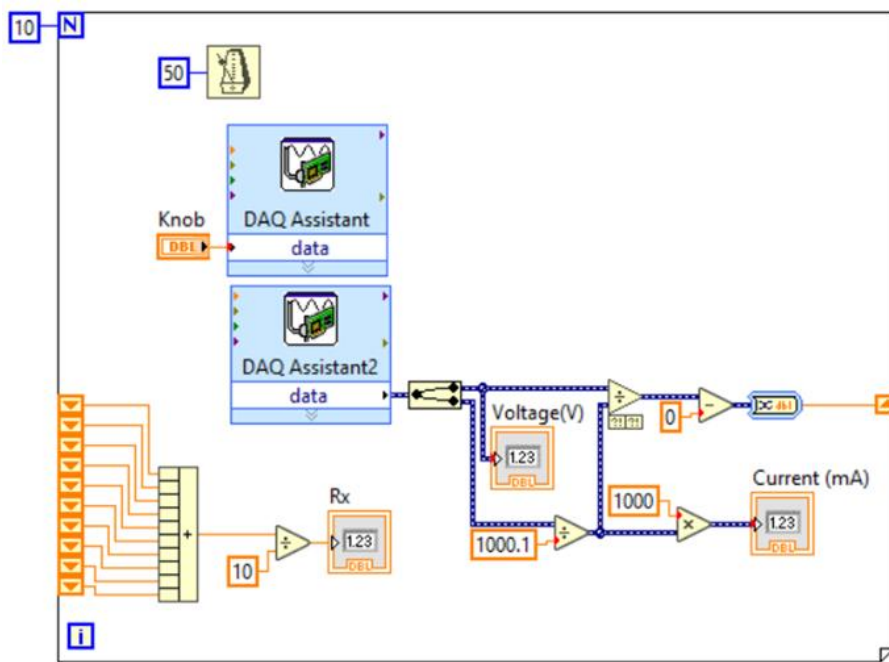


Figure 4. R_x measurement subVI.

Initially, we configure the DAQmx driver for NI 6008 USB to generate a desired voltage from 0 V to 5 V in the analog output AO 0 available at pins (14 -16). We can set the voltage value through a Knob and in this way, we can change the output current passing through the external resistor and the unknown resistor too.

Then we use the same driver is used to acquire the two voltage drops in the R_x resistor and in the external resistor of 1 k Ω .

As it can be seen the external resistor with the value of 1 k Ω is not necessary to be chosen very accurately because it is inserted in the program code and can be any real value. The same thing is valid also if we want to replace this resistor because it is very simple to update its value in the graphic code of the virtual instrument.

We intentionally show the current measured across the resistors in the Current (mA) indicator, because the maximum current supplied from the DAQ card referring to [6] is 5 mA and we have to be careful not to damage the card physically.

We have used a for loop in LabVIEW with 10 iterations which are performed every 50 ms. Using a shift register we can then average 10 measurements of unknown resistor R_x , so we have the value in LabVIEW every half of a second.

It is important to update fast enough the value of the resistance measured because we will process it again without showing it on the virtual instrument's front panel.

Finally, the meter indicator must move quickly enough so the students who interact with the virtual instrument of the Wheatstone bridge have the feeling they are measuring with the real instrument.

After calculation, the unknown resistance value is not shown in the virtual instrument front panel. It is processed again by the Wheatstone bridge formula, which requires resistances R_2 , R_3 and R_4 inputs calculation variables for the galvanometer current I_G .

The instrument block diagram of the Wheatstone bridge formula is shown in Figure 5. We have coded it based on expression (1).

It can be seen that we have added a series resistor R_s with the galvanometer resistor, so to imitate the series resistor present in the Wheatstone bridge circuit, which is used during its equilibration procedure, to limit the current in the zero-detection instrument (galvanometer). The value of R_s will be set to zero on the front panel in a horizontal pointer slide just before receiving $I_G=0$ in the galvanometer indicator.

Although practically the use of a virtual R_s resistor does nothing on the galvanometer protection because it is only a number in a mathematical expression, we ask the students during laboratory work to use initially its maximum value and then lower its value to zero as changing the bridge branches resistor during the equilibration procedure while monitoring the galvanometer indicator position regarding its scale limits.

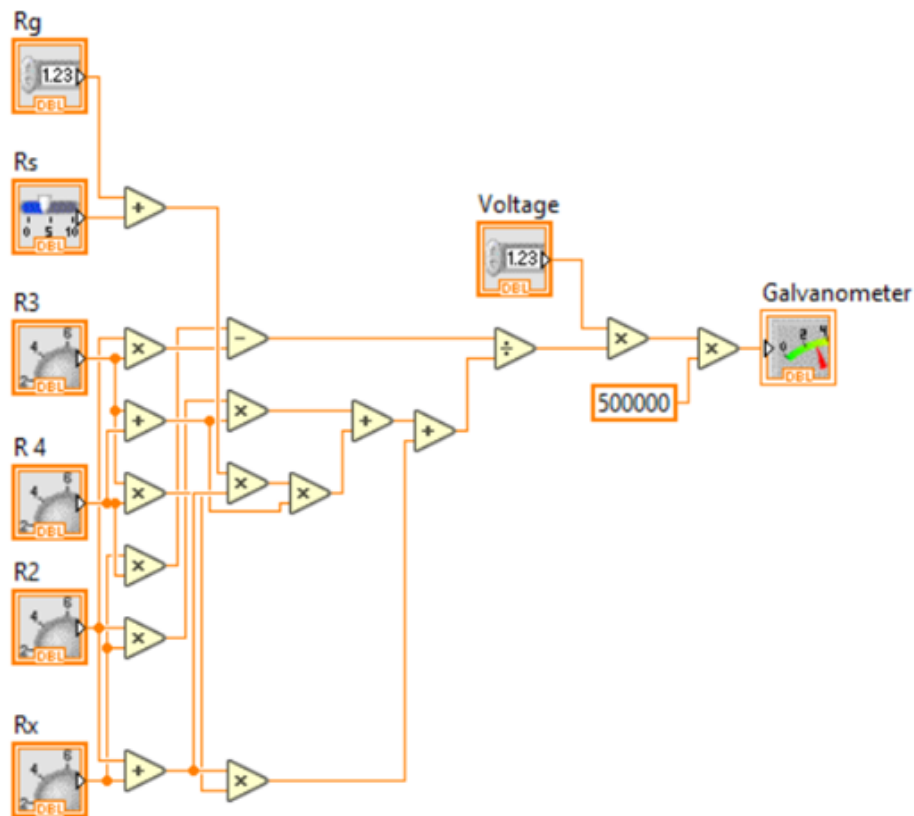


Figure 5. Wheatstone bridge formula.

R_2 is composed as the sum of $10 \times (1000 + 100 + 10 + 1 + 0.1) \Omega$; R_3 and R_4 have a discrete value of (10, 100, 1000, 10000) Ω . Combining them in the Wheatstone bridge formula we get the unknown resistance value R_x when $I_G=0$, because $R_x=R_2 \cdot R_3/R_4$.

Since we wanted that the students using the virtual Wheatstone bridge had the same feeling as working with the real instrument, we have to program the virtual instrument having into consideration this approach.

Let's turn for a moment at the real Wheatstone bridge and its main components shown in Figure 6. We will take into consideration that R_3 and R_4 can have only a discrete value at a time we have to use *event structure* in LabVIEW to use mouse click function to select their values and to clear their previous chosen values. Also, it can be seen that R_2 is composed of five blocks which are connected in series and in this way, we can compound a resistance value from 0 to 11111 Ω .



Figure 6. Wheatstone bridge elements used in the MTV Thomson-Wheatstone bridge instrument.

2.3. The Virtual Wheatstone Bridge Front Panel (GUI)

In this paragraph, we will show the Main VI of the Virtual Wheatstone Bridge.

Based on the considerations of paragraph 2.2., in Figure 7, is shown the virtual instrument front panel used to measure the unknown resistance R_x and in Figure 8, is shown the virtual instrument block diagram (graphic code)

I_G current is displayed on the virtual instrument front panel in a "Meter indicator" called Galvanometer. This value depends also on a value of 0 to 1000 to imitate the series resistor R_s with R_G which is usually present in the Wheatstone bridge to limit the Galvanometer current during equilibration. Students are warned to try not to push the galvanometer indicator to the limit of its scale during interacting with the Wheatstone bridge to find the unknown resistance values.

In the virtual instrument block diagram, the green subVI (R_x), is shown in Figure 4 and the brown subVI (formula) is shown in Figure 5.

In the example illustrated in Figure 7, we measured the unknown $R_x = 126.28 \Omega$. This value was obtained when the R_s slider was set to zero and the galvanometer indicator stop on the centre over the 0 value, which means I_G current is zero or to be more precise less than $1\mu A$.

Last, we can publish the virtual instrument online using LabVIEW G Web Server so the students can interact and perform remote laboratory work. The procedure for configuring the virtual instrument to be published on a web page is shown in [7].

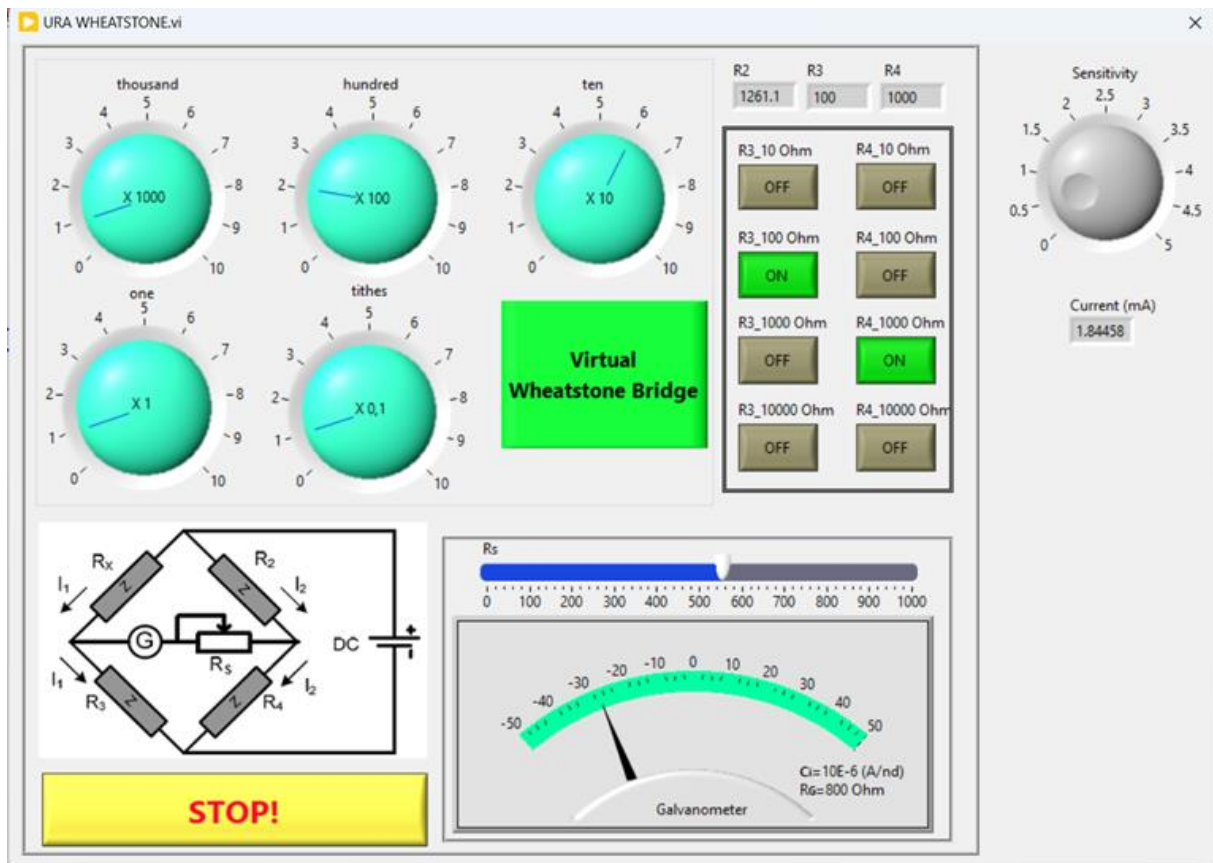


Figure 7. Virtual Wheatstone bridge built in LabVIEW front panel.

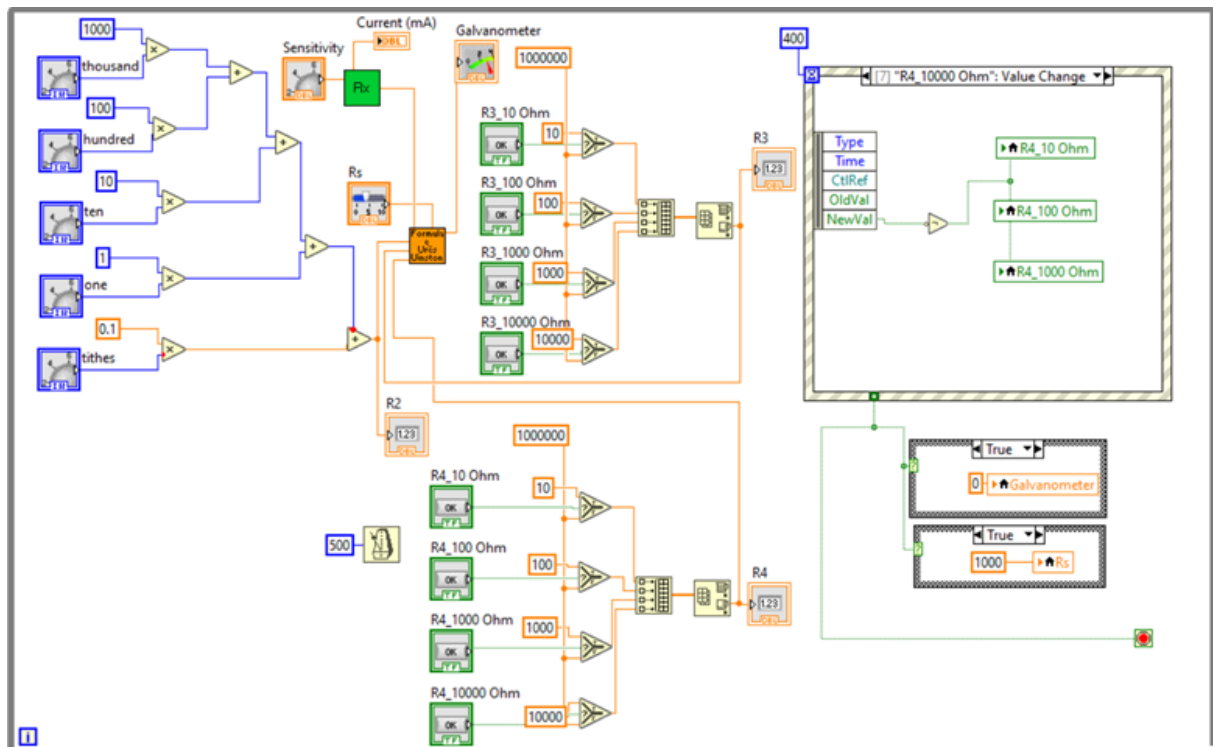


Figure 8. Virtual Wheatstone bridge built in LabVIEW block diagram.

3. Results

Using the Wheatstone bridge virtual instrument, students at Electrical Engineering Faculty in Tirana were able to perform remote laboratory work from home in the subject ‘Electrical Measurements’ during the pandemic covid-19.

4. Discussion

This approach lacks the problem that there must be always qualified personnel in the laboratory during remote measurements to perform the changes in resistance values to be measured and to survey for any problem students may face during experimentation.

The real MTV Thomson-Wheatstone bridge instrument in our Laboratory can measure smaller resistance values in the range of $1 \mu\Omega$ to 10Ω when used as a Thomson bridge, but since these values are smaller than copper wires and metal contact resistance, it is impossible to use this approach we showed here in this work for Wheatstone bridge case.

We think it will be a good start to use virtual instrumentation for all the classic instruments used to perform laboratory works in Engineering Faculties so as to be ready in every case to use techniques based on PC for remote laboratory works and other targets.

5. Conclusion

Using remote virtual instrumentation is very helpful when the number of students is larger than the respective laboratory can accommodate or when it is not physically possible for the student to be present in the lab.

From an educational point of view, using this approach it is possible to help some of the laboratories in the Electrical Engineering Faculties which lack the infrastructure to perform specific laboratory work so the students narrow the gap between theory and practice.

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Author contributions

Gentian Dume: Conceptualization, Methodology, Instrument programming, Writing-Original draft preparation.
Jurgen Metalla: Validation, Remote testing, Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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