Using VISIR Remote Lab in the Classroom: Case of Study of the University of Deusto 2009-2019

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Abstract. During the last ten years, the University of Deusto is using VISIR remote lab for analog electronics in the Faculty of Engineering. Present paper shows how we are using the VISIR with students, and its results. It is a catalog of experiments to invite other universities to join the VISIR consortium. Ongoing and future research in VISIR are also presented.

Keywords: VISIR, remote laboratory

1 VISIR at the University of Deusto

The available version of the VISIR at the University of Deusto is based on the last available distribution of the HTML5 web client, providing access to 14 component boards in the switching matrix. Two of them are boards where two components can be connected to multiple nodes of a circuit, increasing the number of combinations in the circuits.

VISIR is used or have been used by ten teachers during the last ten years in six different subjects of five different engineering degrees. During this time, the students have opened more than 80.000 VISIR sessions in which they have performed more than 2.000.000 actions and experiments, what is for sure the highest number of actions for any remote lab in the world.

Attending only to 2018-2019, more than 200 students accessed VISIR to open 10.881 sessions with 282.051 required actions without remarkable technical problems, except that we had to replace a relay due to a bad configuration of an LC circuit that burned one of them.

2 VISIR: learning process

VISIR remote lab is a complex hardware-software tool, but its use in the classroom or at home is very easy. VISIR's interface reproduces a work place in a classical handson laboratory: a breadboard with different devices (resistor, capacitors, coils, diodes, transistors, etc.) and instruments (power source, function generator, multimeter and oscilloscope). This interface is the main and powerful aspect from the student point of view (see Fig. 1). The student pick and place the devices in the breadboard, then they connected them using coloured wires and the mouse, power (DC or function generation) and multimeter or oscilloscope are connected, and finally Perform Experiment is clicked to see the measurement results.

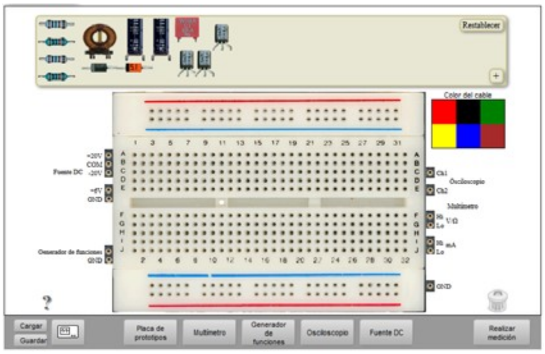

Fig. 1. VISIR interface

A remote lab can be used at the classroom as a classical hands-on lab. With VISIR a student can perform experiments for demonstrating a physical law like Ohm's Law, but also it can be used for discovering the law under an inquiry approach. In the first strategy, teacher has a central position because he explains the law and organizes the experiment, but using an inquiry approach. But a remote lab as VISIR offers the teacher a new opportunity: he can use the VISIR in the classroom with the students, so the teacher and the students can interact among them during a session using the VISIR as a central element. The VISIR also fosters the collaborative work.

VISIR has probed to have a positive effect in the students' learning process [7-8]. This paper presents the set of experiments designed and used at the University of Deusto in different subjects, but it will not discuss again the effectiveness of VISIR.

The teachers at the University of Deusto organize the experiments with VISIR in four different scenarios:

- DC circuits.
- AC circuits.
- Characterization circuits.
- Active circuits.

3.1 DC circuits

This document contains an extract from a paper that was published in the REV2020 conference. It describes some of the circuits and activities that can be conducted through the [LabsLand VISIR electronics laboratory](). Some are only compatible with the instance that is deployed [in the University of Deusto](). You can find more labs and activities at: [https://labsland.com]().

In this scenario the VISIR offers the students a basic “box” with four resistors: 2 x 1 k□ resistors and 2 x 10 k□. With four resistors the student can create all the possible connections and circuits. Then, the student is not restricted to use only some connections recommended by the teacher. Our approach is to leave the student work without restrictions or impositions.

Circuits with resistors.

At this scenario, the student can create any circuit with these four resistors and measure it with the multimeter (see Fig. 2). During this session, the teacher starts showing the student how to use the multimeter and how to use the breadboard.

Again we have two strategies: teacher explains the mathematical model of the parallel-series connection or the student discovers (guided by the teacher) this mathematical model.

After the session the students has to complete a test.

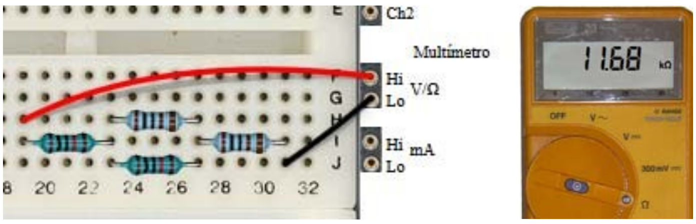

Fig. 2. Measuring resistors with VISIR

An additional experiment is to measure the resistance of the multimeter. Ideally, it is infinite, but this is not the reality. In this case the expected value was 11,91 k, but the obtained real value is 11,68 k, so we can calculate the resistance of the multimeter.

Ohm’s and Kirchhoff’s Laws.

The main objective of this session is to test or discover the Ohm’s and Kirchhoff’s laws. Starting with a basic circuit with a single resistor, then we will add new resistors in parallel and in series to measure the voltages and currents (see Fig. 3).

A secondary and instrumental objective is to learn how to measure voltage (in parallel) and current (in series).

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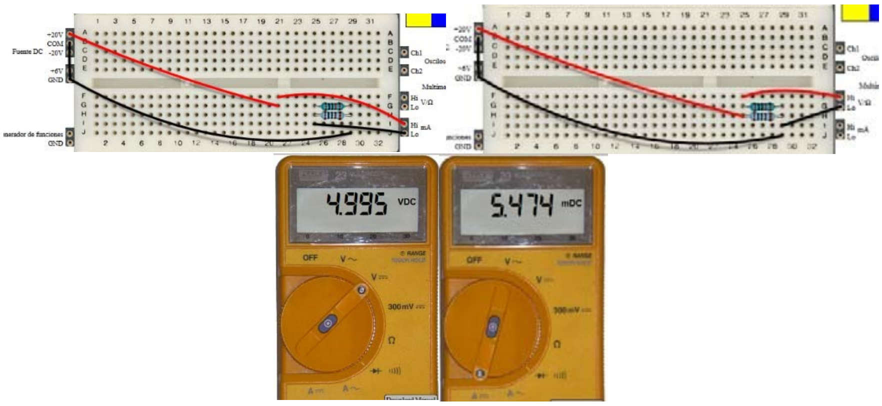


Fig. 3. Measuring voltage and current in a parallel circuit

The circuit is powered with 5 V and the circuit is a parallel connection of two resistors 1 kΩ and 10 kΩ. Theoretically the voltage must 5 V and the current must be 5.5 mA, but these are not the values obtained in VISIR because they are real values.

Again we can measure the error introduced by the multimeter (and the breadboard, etc.) in the measurement, and we can compare if this new value is similar to the previous obtained.

Some VISIR platforms (i.e., ISEP en Portugal and UFSC in Brazil) have two multimeters, in this case they can measure the voltage and the current at the same time. It is easier and faster. U. Deusto does not have the second multimeter.

DC circuits.

In this scenario the student can mathematically solved any circuit with these four resistors, and then he can measure the different signals to test if the two results match or not.

In Fig. 4 we can see that when the student makes a mistake (the cable is not in the correct hole), the VISIR does not help him. It shows a value what is incorrect, but nothing is recommended to the student. This situation replicates the real work in the lab, so there is not difference between working with VISIR and working with a real lab, and because of that the student is correctly trained with VISIR.

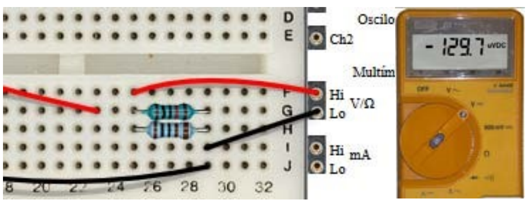


Fig. 4. Error during measurement in VISIR

Sometimes the VISIR shows a message that says that the circuit cannot be created or it is unsafe. That means that something is wrong in the circuit. In Fig. 5, the multimeter is trying to measure the current in parallel. This avoids the break of the devices, multimeter or VISIR.

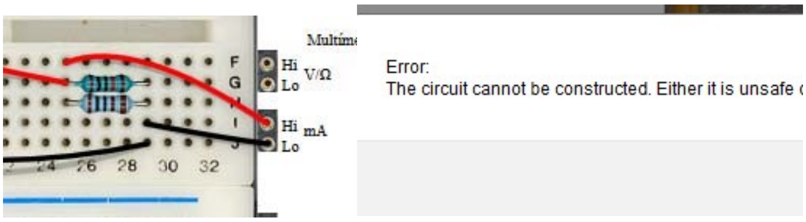


Fig. 5. Error during measurement in VISIR

3.2 AC circuits

AC circuits are less complex because in our case we need only one resistor and one capacitor or coil.

With AC circuits, the students learn how to use the function generator and the oscilloscope. In addition, the students learn how the frequency signals are characterized (rms value, average value, etc.) and how to do it with the oscilloscope and the multimeter. The main objective is to create RC and RL circuits to analyze their behaviors.

Measuring frequency signals.

Our first experiment (see Fig. 6) consists on measuring different values (minimum, maximum, peak to peak, average, and rms) of different signals (sinusoidal, square and triangle).

The main objective is to compare the different values and to explain why the rms value is the most significant value for representing AC signals. A secondary objective is to correlate the maximum and the rms values of different signals, that is, to obtain for a sinusoidal signal that $V_{rms} = \frac{V_{max}}{\sqrt{2}}$.

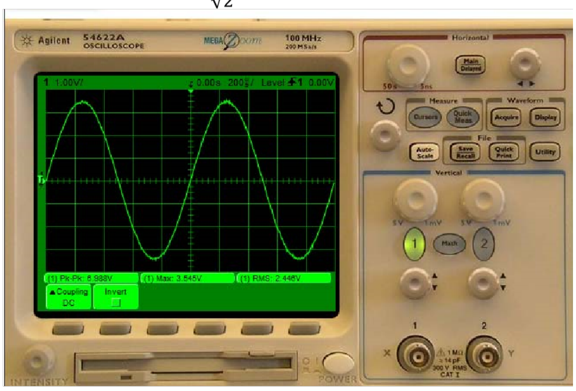


Fig. 6. VISIR Oscilloscope

RC circuit as a low pass filter.

An RC circuit depends on different variables: type of signal, amplitude, frequency, resistor and capacitor. A RC circuit is a good opportunity to explain to the student how to organize an experiment changing only one variable each time. The organization of data in tables is one of the objectives of this experiment.

From VISIR point of view (see Fig. 7), the analysis of a RC circuit is easy. Simply create the circuit, modify the function generator and measure the values with oscilloscope.

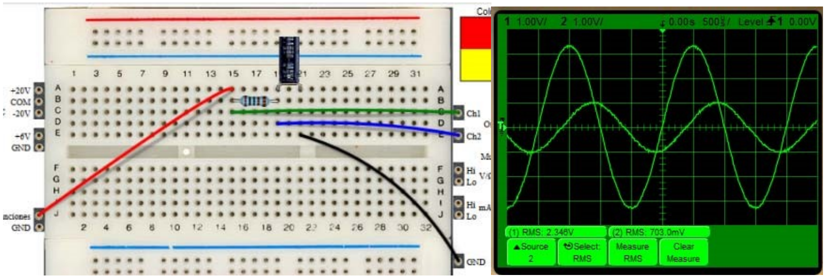


Fig. 7. RC circuit analysis

The data analysis allows the student to demonstrate that the RC circuit is a low pass filter.

Cut-off frequency and other experiments.

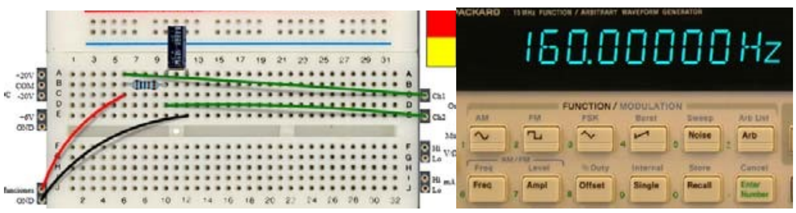
At the cut-off frequency the relation between the output Vrms and the input Vrms is $\sqrt{2}$, that is, $V_{,}$ $\frac{V_{rms,i}}{\sqrt{2}}$, or the output signal is around 70% of the input signal. The value of the cut-off frequency is mathematically obtained as f ____. For R=1 k and C=1 uF, $f \cong 160\ Hz$.

At this moment, the teacher can suggest an experiment to test if this true: create the RC circuit, excite it with a 160 Hz sinusoidal signal and measure the Vrms values (see Fig. 8).

After the experiment, ——,____ 1,42, what more or less is equal to the expected value.

The student should repeat the experiment for 1 k, 10 k, 0.1 µF, 1 µF and 10 µF to see that the formula remains correct.

After we use to provide the students the following expression, _____ = —, . They have to test if it is correct or not (it was “discovered” by two students two years ago).



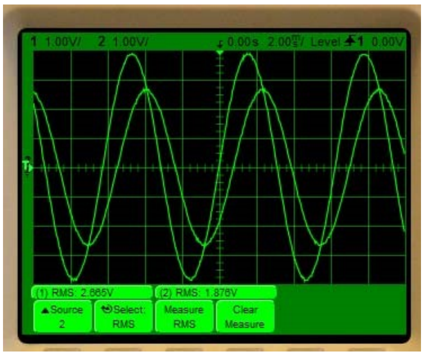


Fig. 8. Experimenting with a RC circuit

It is established that if an input signal has a frequency equal to 5·fc, then it will be 80% filtered, that is, the output will be an 20% of the input. This can easily be tested by the student. For example, for the previous RC circuit and a 800 Hz sinusoidal input (see Fig. 9).

The obtained result is $\%f$ 100 ____ 100 18,2 81,8%. It seems that the design rule is correct, but this must be tested for different values of R and C. After this, the student should be able to obtain the rule for 90%.

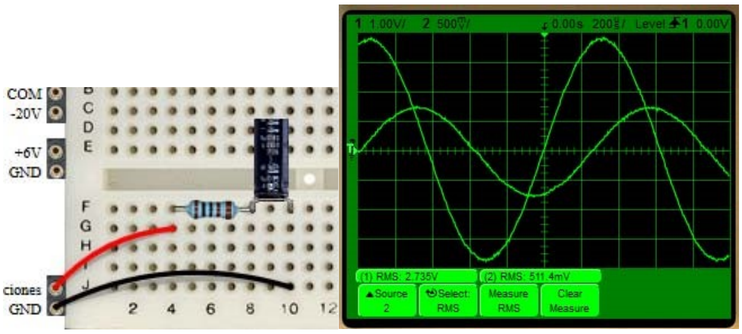


Fig. 9. Test of the cut-off frequency

RC circuit with non-sinusoidal input signals.

The student has seen that in a RC circuit if the input is a sinusoidal with A amplitude and f frequency, the output will be another sinusoidal with the same frequency f, a smaller amplitude (depending of the frequency f) and a time delay (some displacement to the right in the oscilloscope). At this moment, we can ask the students about what happens if we change the sinusoidalsinusoidal input signal by a triangle. Maybe the students will expect a smaller triangle signal of the same frequency, but it is not. After this, the teacher can introduce the concept of Fourier Transform and the misconceptions when making experiments.

Fig. 10 shows the output of an RC circuit (R=1 k□ and C= 1 µF) excited with a 6 Vpp and 500 Hz triangle signal. Clearly, the output is not a triangle, it is a "sinusoidal".

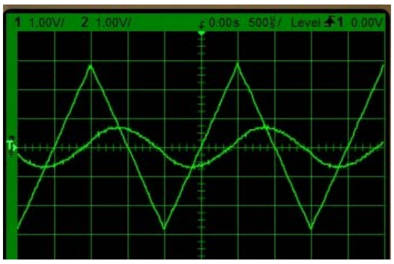


Fig. 10. RC **circuit with a triangle input signal**

CR circuit as a high-pass filter.

At this moment, the students can face alone the analysis of the CR circuit to see that only changing the order of the C and R, the behavior of the circuit is different (see Fig. 11).

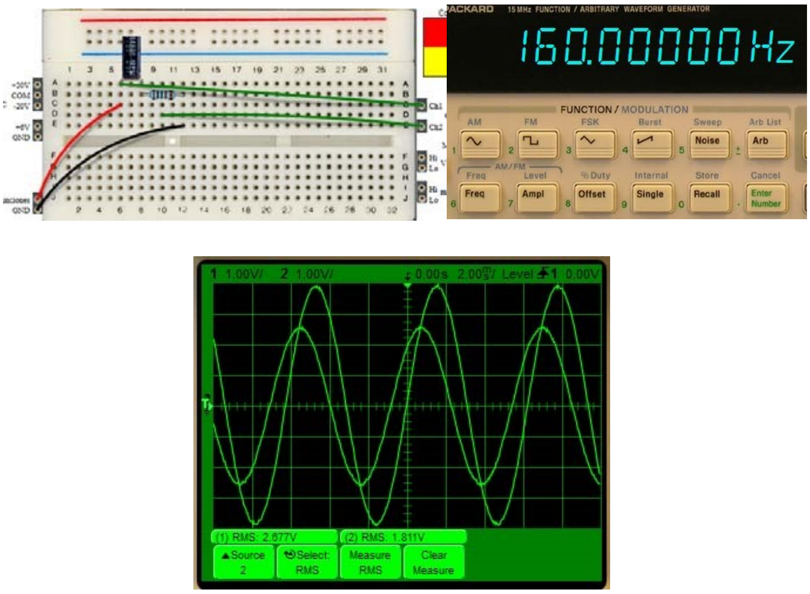


Fig. 11. CR **circuit**

Time constant in a RC circuit

When we excite a RC circuit with a sinusoidal input signal what is displayedin the oscilloscope, it represents the steady state response. To see the transient state of the RC circuit is common to use a square signal. Fig. 12 shows the output of a RC circuit (R=1 kΩ and C=1 µF) excited with a 100 Hz and 6 Vpp square signal.

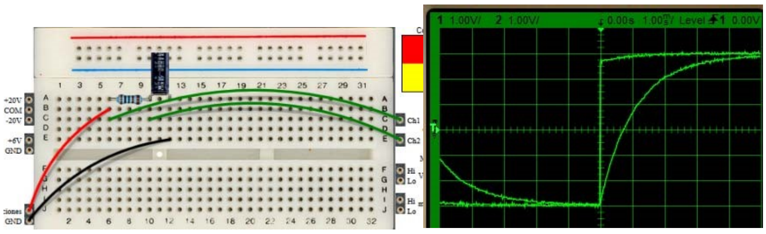


Fig. 12. Experiment with time constant of a RC circuit

The time constant,□ is defined as the time in which the signal reaches the 63% of its total excursion, Vpp. In the experiment: at what time the output reaches 3.78 V (6 V x 0.63)? Looking at the Figure 12 this is at 1 ms.

The following expression obtains the time constant of a RC circuit, $\tau\ R\ C\ 1000\ 0.000001\ 1\ ms$. This obtained value is equal to the experimental value. Also there are other important indexes for a RC circuit:

— at 0.7·□ seconds, the output is 50% of the input,
— at 5·□ seconds, the capacitor is charged,
— and at 2,2·□ seconds , the output grows from 10% to 90% of its final value.

All these values can be tested by the student with different experiments.

Analysis of RL circuit.

In this case, the student analyzes a RL circuit to analyze its behavior. With R=1 k□, L=100 mH and a 160 Hz sinusoidal (see Fig. 13) .

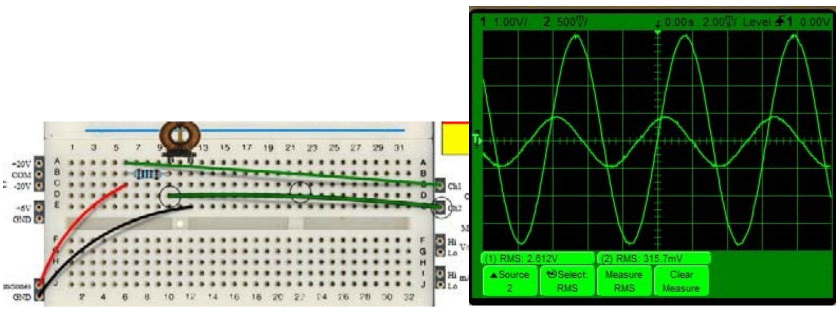


Fig. 13. RL circuit analysis

If the students have obtained the mathematical expression of the V_L, they can see that the obtained signal in VISIR is not equal to the expression. This can be tested for different R and L values.

3.3 Experiments for devices characterization

The different devices used in VISIR circuits can be characterized using circuits and instruments

Resistor characterization.

In this case, the student can power a simple circuit with a resistor with different values to measure the voltage and the current in the resistor. After this, the student can draw the characteristic curve. In the figure, we can see a 1 k□ resistor powered with 1 V (see Fig. 14).

Fig. 14. Resistor characterization experiment

The student will register all the data using a table to draw the curve.

Capacitor characterization.

Using a RC circuit the student can measure the $V_{C,rms}$ and $I_{C,rms}$ and then he can obtain X_C as the V/I, X ——. The student can discover or demonstrate the mathematical expression X ——

In Fig. 15 we can see a RC circuit with R=1 k□ and C=1 μF excite with a 160 Hz sinusoidal of 8 Vpp.

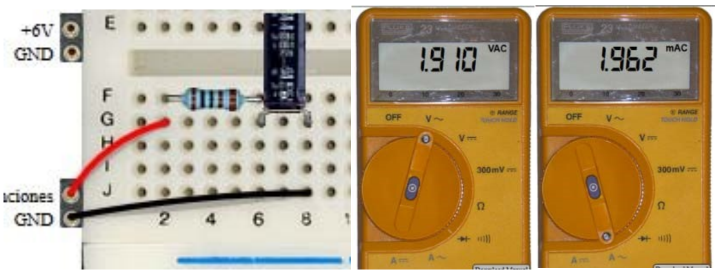


Fig. 15. Capacitor characterization experiment

With these values, X —— 973,5 □, and using the expression X —— 994,7 □. At this moment, the teacher can introduce the concept of absolute and relative errors.

Coil characterization.

Using the same previous approach, the student can repeat the experiment with a RL circuit. In this case the expression is $X \quad 2 \quad \pi \quad f \quad L$

With R=100 □ and L= 10 mL and a 160 Hz sinusoidal signal we obtain the following results in Fig. 16.

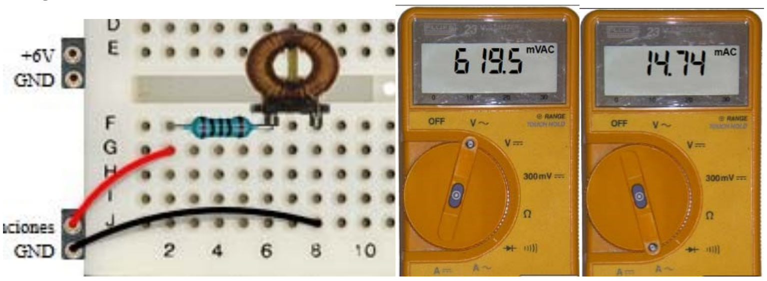


Fig. 16. Coil characterization experiment

Attending to the previous results, X ______ 42 □. Using the expression, X

2 π 160 0.01 10.05 □. The two results are not similar, maybe because they are small.

If the input signal was a 500 Hz sinusoidal signal (see Fig. 17), then using the expression, X 2 π 500 0.01 31.4 □, and looking to the figure below X

____ 67.1 □.

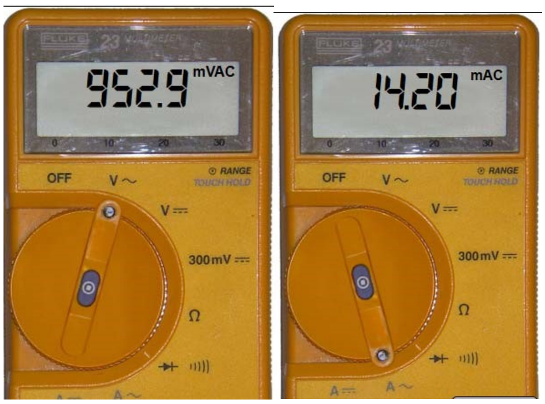


Fig. 17. New measurements for the coil characterization

Again, the differences are high, and they cannot be assigned to measurement errors. The problem is due to the coils have an additional resistor, which cannot be removed, it is intrinsic to the own coil. Using VISIR, the value of this r_l can be measured.

Diode characterization

A diode is characterized using the DC power, the diode and the multimeter. Fig. 18 shows the experiment for an input of 0.9 V. The problem with this circuit is that VISIR limits the current to safe the equipment. The maximum voltage input is 1 V, if the student power the diode with more than 1 V, then a message will inform him that the current has exceeded the limit.

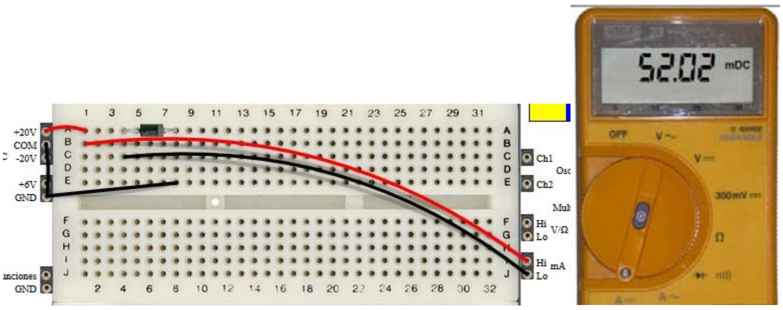


Fig. 18. Diode characterization experiment

To overcome the previous problem we have included a 6 □ (25 W) in the set of devices. Using this limit resistor we can reach higher values of input voltage (see Fig. 19).

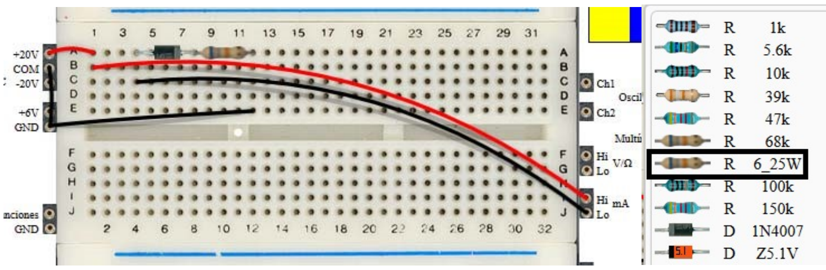


Fig. 19. Diode characterization experiment with a limit resistor

Using the two previous circuits the student can obtain the V-I characteristic curve. For doing this, the student needs to make a lot of boring measurements, but also the students can share a doc in the cloud, that is, they can work collaboratively.

Also the student can estimate the value of the rd resistor in the two curves, and both values must be similar.

Again, if VISIR had two multimeters (not in U. Deusto) the obtention of the V-I and Vi-Vo curves would be easier and better.

If we want to obtain the diode transfer curve, we have two options. The first option is to measure the voltage drop in the resistor (see Fig. 20), and then draw the Vi-Vo transfer curve. Also we can make the same with the voltage drop in the diode.

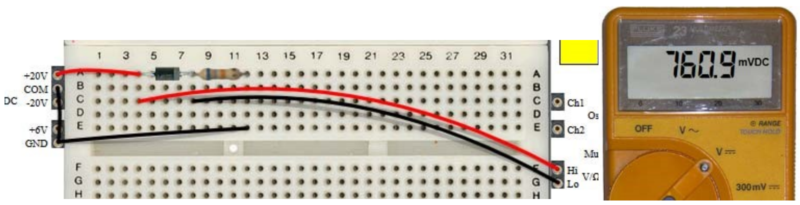


Fig. 20. Measuring the voltage drop in the diode

The second option is to power the circuit with a sinusoidal signal (see Fig. 21), i.e., 3 Vpp and 100 Hz and use the oscilloscope. In this case, we should use a 1 kΩ output resistor.

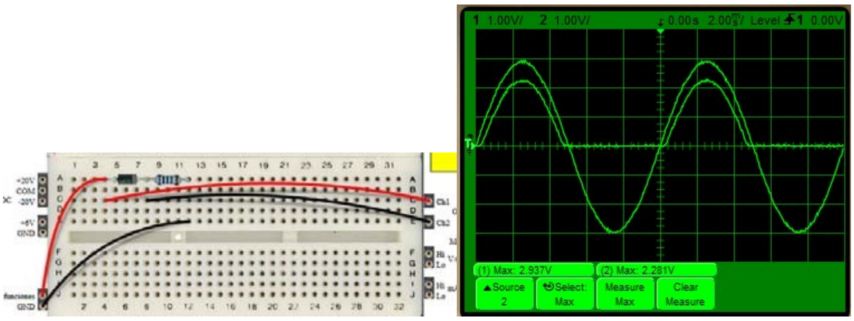


Fig. 21. Diode transfer curve with an oscilloscope

In a hands-on lab, the oscilloscope has an X-Y button to see the transfer curve. This button was in the Flash version of VISIR, but it was not in the html5 version of it. Now this button has been recently implemented by UNR in Argentina, but still we have not deployed it in U. Deusto.

Anyway, the student should test if the behavior of the diode is the same for different frequencies and amplitudes of the sinusoidal input signal.

Characterization of the function generator and the oscilloscope using the Maximum power transfer Theorem

It was recommended in the previous circuit to change the 6 Ω resistor by one of 1 kΩ. If we maintain the 6 Ω resistor we will see that the behavior is not the expected because the function generator has an associated resistor.

Creating the following circuit (see Fig. 22) and powering it with a 6 Vpp sinusoidal input signal, it is expected that the voltage drop in the 100 Ω output resistor must be the input signal, 6 Vpp, but it is not, it is 4.06 V. Why?

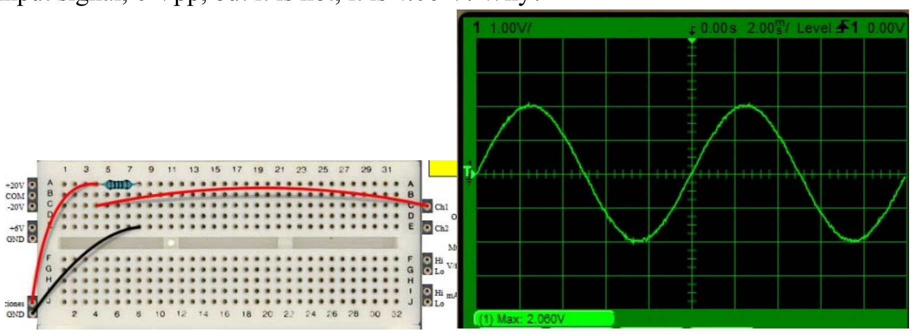


Fig. 22. Function generator characterization with an oscilloscope

Using the Ohm's Law it is clear that there is another resistor, rs, and it is in the source input, in the function generator. This resistor can be calculated and it is 50 Ω.

$Vpp \quad Vrs \quad VR \quad I \quad rs \quad I \quad R \quad I\,rs \quad R, 6\,V \quad Vrs$
$2V, so\ I$

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$4.06\,V$ 100 $\quad 40\,mA, also\,Vrs \quad 6 \quad 4 \quad 2\,V, so\,rs \quad$ $2\,V$ $40\,mA \quad 50$ □.

□

The function generator presents a rs 50 □ resistor, and attending to the maximum power transfer theorem, so the function generator expects a 50 □ output resistor. But the oscilloscope presents a high input resistance, so when the function generator is connected to the oscilloscope, it shows in the screen a signal that is the double of the selected in the function generator (see Fig. 23).

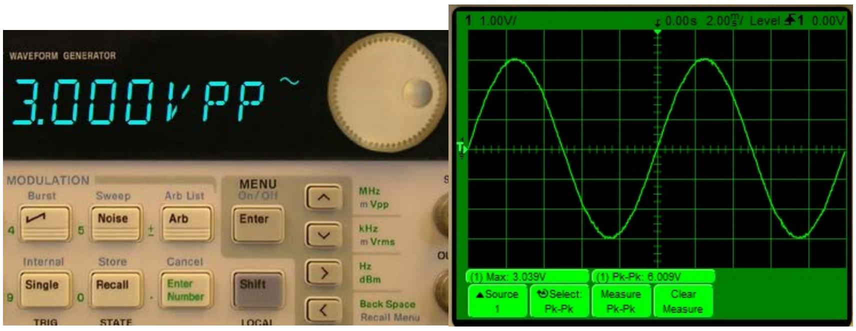

Fig. 23. Voltage drop in the function generator

Consequently, if we need a 3 Vpp input signal, we must select 1.5 Vpp in the function generator.

3.4 AC-DC converter circuit

An AC-DC circuit is the combination of a rectifier + filter. This circuit is simple and it combines active and passive devices for implementing a common circuit in engineering.

The objective of an AC-DC converter is to convert an alternate sinusoidal signal into a constant signal, in a "flat line". This means to convert a signal with 0 V average value (Vcc=0 V) into another with a higher value (Vcc>0 V).

Half-wave rectifier circuit.

First the student should analyzes, understands and measures a half-wave rectifier circuit (see Fig. 24).

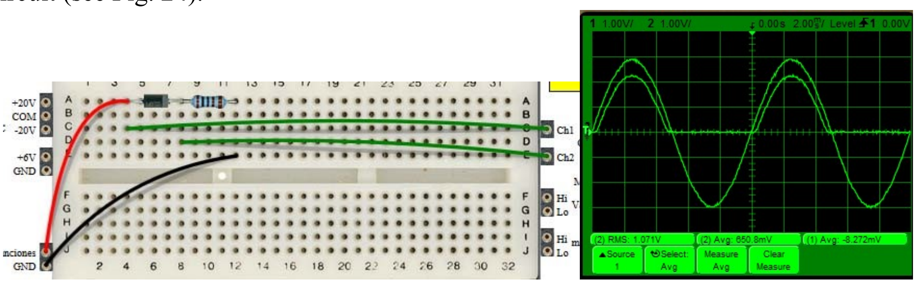

Fig. 24. Half-wave rectifier circuit

This circuit is called "half-wave" because it removes the half of the input, or it remains a half of the input.

It is clear that the output is not flat, but it is also clear that voltage average value is not 0 V, it is 0.651 V.

Two indexes describe the performance of the AC-DC converter: the ripple factor and the form factor. $Ripple\ factor$ ___ $and\ Form\ factor$ ___. The ideal values of the ripple factor and the form factor are 0 and 1 (0% and 100%), respectively

The V is the rsm voltage value of the alternate part of the output signal (AC signal), that is, $v\ t\ v\ t\ Vcc$. The student has to learn how to measure this value in the oscilloscope (see Fig. 25).

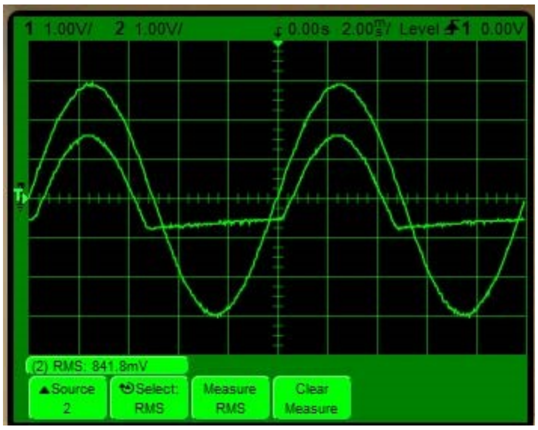

Fig. 25. Measuring the rms voltage value of the AC signal

For this rectifier, the indexes values are $Ripple\ factor$ ___ 129% $and\ Form\ factor$ ___ 164%

An additional activity for the student is to discover if the values of the ripple and form factors of a half-wave rectifier depend on the frequency and on the Vpp of the sinusoidal input signals. The same can be proposed for other signals like triangles, square, etc.

Half-wave rectifier + filter: AC-DC converter.

The next objective is to improve the quality of the two indexes, mainly the ripple factor. Simply adding a capacitor in parallel with the load resistor, the behavior is better; the output is close to a "flat signal".

Fig. 26 shows a circuit with a 1 µF capacitor and 1 k□ load resistor powered with a 1 kHz and 6 Vpp sinusoidal signal.

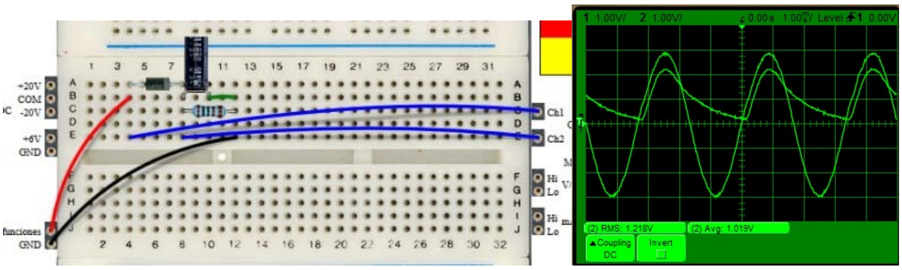

Fig. 26. AC-DC converter based on a half-wave rectifier

The output signal presents $Ripple\ factor$ ___ $64\%\ and\ Form\ factor$ ___ 120%. These values are not good enough, but are better than the obtained values without the rectifier.

What can be done to increase these indexes? The answer is increase the capacitor value. Fig. 27 shows the effect of a 10 µF capacitor.

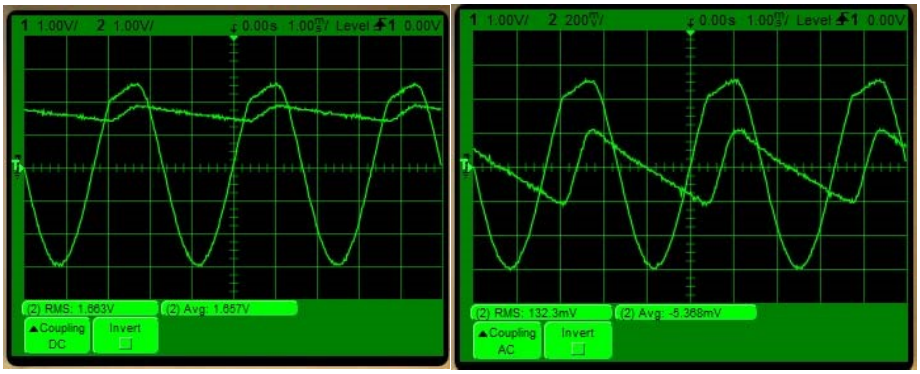

Fig. 27. AC-DC converter with a 10 µF capacitor

Using the previous values $Ripple\ factor$ ___ $8\%\ and\ Form\ factor$ ___ 100%. Now the output signal in the left is "flat", but how we can improve it? How we can improve the AC-DC rectifier? Maybe increasing the value of the capacitor?

At this moment we can include the concept of efficiency, how much of the input signal is presented in the output signal in terms of power. In this case we have to measure the voltage and currents using the oscilloscope and the multimeter, and even estimating some values because they cannot be measured using the VISIR mutimeter.

An additional task is to ask the student if the frequency of the sinusoidal input signal affects the behavior of the AC-DC converter. That is, are the ripple and form factors affected by the frequency of the input signal? Why?

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