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A CASE-STUDY VISION

# Development of remote laboratories oriented to virtual environment

*Desarrollo de laboratorios remotos orientados al entorno virtual*

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INFORMACIÓN DEL ARTÍCULO

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ABSTRACT

This article shows the process of designing a system of workbenches for laboratory practices oriented to virtual environments by using remote instrumentation techniques. The process was linked to a Research process in an Instrumentation Research Seeder in the Corporación Universitaria Minuto de Dios, Colombian University. The document also presents the design process from the concept generation and Embodiment Design to the construction of a Basic Electronics Functional Prototype, including a remote access, and a trainer. One of the most important conclusion of the project points to the fact that the Remote Laboratories system is a very powerful didactic tool, not only in Virtual Education Processes, but also it will be used in a lot of academic environments.



**Palabras clave:**
Instrumentación
Mediadores pedagógicos
Laboratorios Remotos
Educación Virtual

RESUMEN

El presente artículo muestra el proceso de diseño de un sistema de bancos de trabajo para prácticas de laboratorio orientado a entornos virtuales usando técnicas de instrumentación remota. El proceso se deriva de un proyecto de investigación desarrollado en el semillero en instrumentación industrial en la Corporación Universitaria Minuto de Dios. Se observan las etapas de diseño desde la contextualización de la información, pasando por el diseño estructural, hasta el montaje de un prototipo funcional para la práctica de la electrónica básica. Dentro de las conclusiones más importantes se encuentra el hecho de que los bancos son una poderosa herramienta didáctica, no solo para educación virtual sino en múltiples ambientes académicos.

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## 1. Introduction

This article presents the results of the investigation project called: “Development of work benches directed to the virtual education using remote instrumentation”, developed at the Engineering School of Corporación Universitaria Minuto de Dios. The project is originated at the Instrumentation Industrial Seedbed (SEMIT – in Spanish), under the idea of using instrumentation as a tool to gain remote access to laboratories, in order to virtualize not only theoretical assignments, but also those assignments which are essentially practical; like those that are common to professional studies based in electricity and electronics. So, it began looking for the most important aspects and virtual education tendencies, and it found that there are mainly two aspects characterizing the virtuality: flexibility of time and flexibility of space. The first implies that the student requires for his / her practice a 7/24 available platform, and the second means that such a platform should be accessible by using computer means and telecommunication networks, in other words, virtuality implies: “any place and any hour”. All this considered, developing of instrumental skills using the virtuality, more specifically the “Hands On” technological capabilities, turns out to be complicated, and in many opportunities, the hybrid learning called “blended learning” is preferred. In this modality, the student takes part of his theoretical learning using virtual media, while the practical component is held in classroom classes; this option implies the violation of the aforementioned main features for the virtual education (flexibility of time and space). Such a learning process affects the virtual students who are living in zones far away from the nearest educative center, or those that because of their labor situation don’t have enough time to attend the laboratory classes on a fixed horary basis. Therefore, the design and construction of benches for laboratory practices whit remote access to electricity and electronics studies, is undertaken with the aim to fulfill the requirement of flexibility of time and space, thus achieving a complete virtuality.

This document begins looking at the uses and trends in remote laboratories in section 1.1 where the state of the art is developed, then in section 1.2, the requirements to have in mind to obtain the definition of the concept are reviewed. In section 2, the development of the design is shown, starting by the creation of laboratory guides in section 2.1, the structural design in 2.2, the selection of equipment in 2.3, and the presentation of final prototype in 2.4. Finally, the conclusions are presented in section 3.

### *1.1. Uses and trends in remote laboratories.*

Once stablished the problem to solve, which deals with the improvement of virtual education in technical professions for practical skills, the specific environment of remote laboratories is analyzed. Through this analysis, the study of Graviera et al [1] was found, this study states four very important aspects that reinforce the didactical use of remote laboratories (besides the accessibility in time and space). These aspects are:

- Security of elements, data and personnel
- The possibility for an experiment to be watched by many people at the same time
- Low risk, when the experiment is dangerous
- Easy access for handicapped people.

On the other hand, in the same study, it can be seen that investigators found that the areas where there were the largest developments of remote laboratories are electronics and robotics, followed by physics and automation. Besides, there is a bibliometric study that appears in the magazine “*Computers and education*” [2] where several investigations analyze a register of about 4,422 documents and as one of their main conclusions they found an increase in the number of publications in 2014 (the study was held in 2015). In other publications, a report in 2016 made by DOCEBO [3] a firm dedicated to develop Learning Management Systems (LMS), starts looking at the fact that self-managed learning business had an increase between 2011 and 2016 of about 7.6%, going from 35,6 billion dollars to 51,5 billion dollars, Likewise, the largest increase of the use of those systems can be found in Africa and Latin America, showing a 16.9% growth. Another very important point in this report is the extension of the market environment for the remote laboratories to the model of Infrastructure as a Service (IaaS), where in the exercises used to certify the staff, as well as in training or instructional exercises, the remote laboratories have a great importance, because they are avoiding the enterprises to expend in the purchase of training equipment or in managing staff time to attend training centers.

Specific applications of laboratories were found as well, implemented before as in [4–10] where it could be observed among other features, the needed topology for these systems, and that will be detailed in the next section. The Vega et al. [4] study is highlighted, because they are developing a reconfigurable analog electronic practice, where the user may shift between the different configurations of a Common Emitter Amplifier. Besides, in [6] a remote laboratory directed to the learning of DC circuits for students from media education to university education is developed. Another highlighted work is the one of Bermudez et al [7] that uses a Raspberry Pi platform for developing a remote laboratory connected to a Control Station. It can be seen in these references the integration with Learning Management Systems (LMS), as in Fernandes et al. [9] where the relationship between remote laboratories and Massive Open On-line Laboratories (MOOLs) is analyzed. Fortunato el al [10] perform a working environment (framework) compatible with the Go-Lab platform. Likewise, in Bermudez el al. [7] NodeJS y JavaScript are used to assure a compatibly Multiplatform.

Finally, studies that observe the appropriation and effectivity of remote laboratories in the academy environment can be found, as in references [11–15]; in those studies can be seen that at the beginning the preference for remote laboratories is because of their novelty, however, they arise like a good tool for developing practical skills afterwards, because unlike the simulations, remote laboratories give the student the opportunity of being in contact whit "real word" variables that cannot be obtained through simulations, and that will be their best training for the solution of the possible problems that could arise in their professional environments.

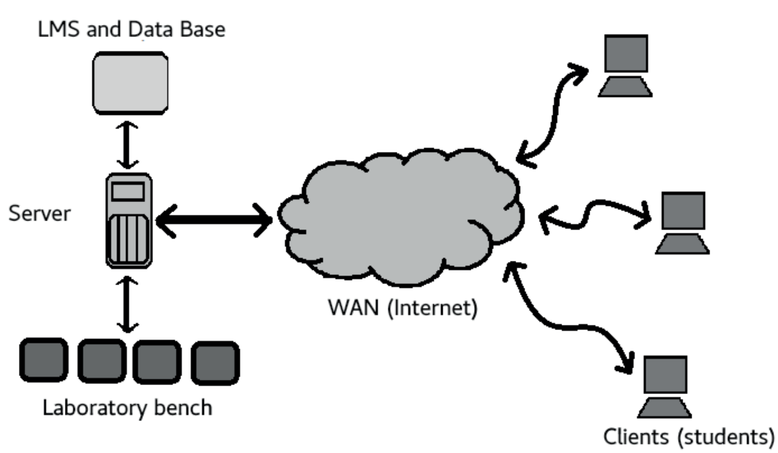
### *1.2. Definition of requirements*

#### *1.2.1. Connection Topology*

After observing the aforementioned implementations, it can be seen that a remote laboratory is a client–server application [16], so the first step is to stablish the topology of connection that the benches will have, as shown in figure 1.

In the Figure, to the left the service side can be found, where there is a server that will manage a Learning Management System, which contains the theoretical pedagogic mediators and will take the workbenches as support, learning or evaluation activities. On its time, the system gets in order the occupation of the available workbenches to be assigned during a practice time to each of the clients registered in the database. So, the server can produce statistics about its use and the advances in the learning of the students, thanks to the collected data. Likewise, when the server assigns a workbench to a student, a "point to point" bidirectional transmission is generated, where the student performs the adjustments to the workbench and it will send back the measurements via Internet.

**Figure 1.** Suggested Topology

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### *1.2.2. Topics to develop*

For knowing the most interesting topics between academic community that could be developed in this project, students and teachers of technology in electronics in Corporación Universitaria Minuto de Dios were used as the surveyed population, creating an instrument that asked them about virtual education, more specifically about which assignments would be susceptible to work by means of remote laboratories.

The results of these questions can be found in Figures 2 and 3.

**Figure 2.** Teacher's survey results of the question about the suitable formation areas.

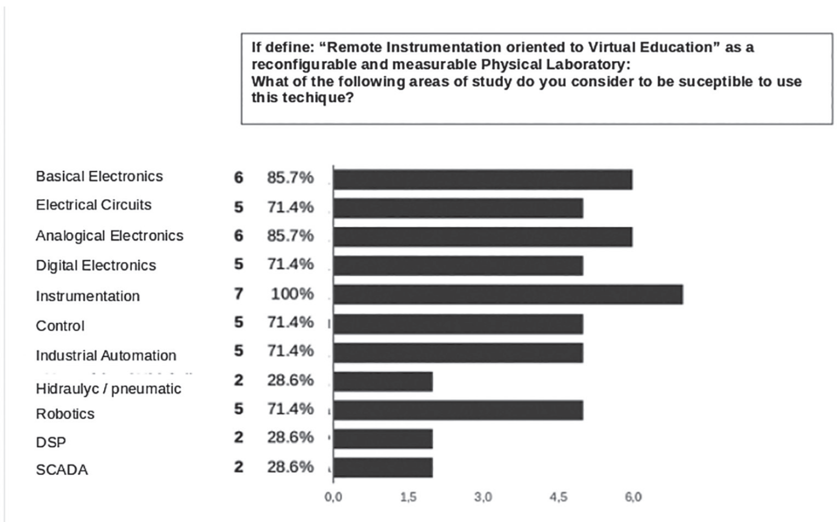


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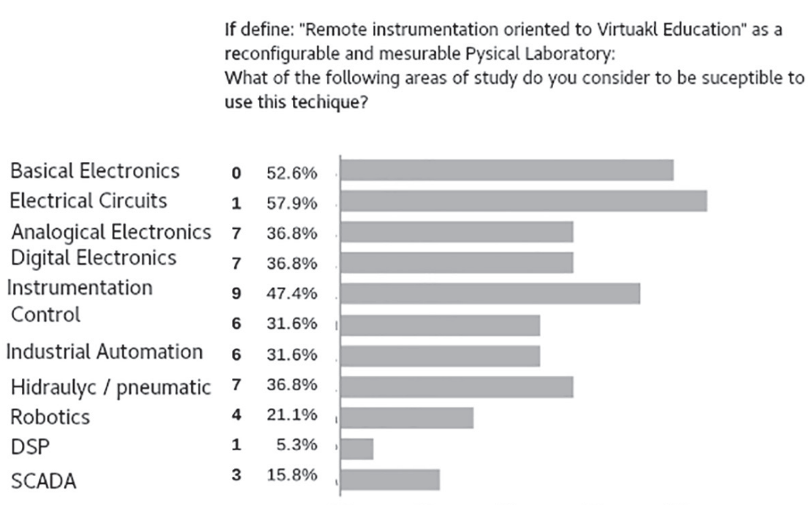
**Figure 3.** Student's survey results of the question about the suitable formation areas.

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From these results, it can be observed that both groups agree on basic electronics and instrumentation as suitable topics for the developing of workbenches.

Hence, an exercise with the work group of the project was performed to stablish the following three areas to be treated:

- Basic electronics
- Analog electronics
- Instrumentation

Analog electronics decision was taken for two reasons: first, it was among the most preferred, especially in the teachers group, and second, because it results interesting to observe that this assignment serves as an articulator axis between the basic electronics and the instrumentation topics.

So, from this phase the following requirements emerge:

- System must have access to wide networks
- Remote system configuration and variable measurement must be allowed
- The workbenches must be completely reconfigurable by means of a processing system
- The benches must be capable of being configured for different practices within a specific assignment

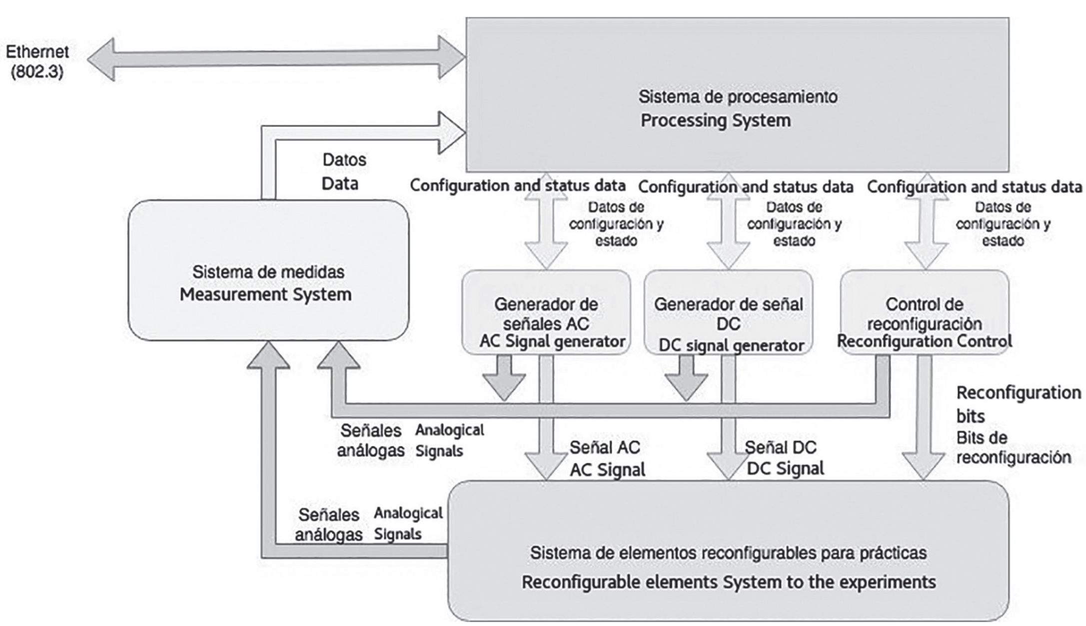
## 2. Design development

Once the basic requirements were attained, the first step is to configure a block diagram for the system, as shown in Figure 4

The Figure 4 shows that the system contains a processing system as a central unit, this component is in charge of interpreting the orders that come from the network and transform them in configuration parameters for the devices taking part of the practices. At the same time, as the measurement of variables is required, the system takes the data and transforms them in a Figure mode so the remote user can watch them. Therefore, from this part it can be stablished that the processing system should have mainly the following parameters:

- Inter-devices communication protocols like $i^2c$ or SPI.
- Ethernet or wireless LAN communication port to achieve direct compatibility with Internet
- Enough ports for the handing of several devices

**Figure 4.** Block chart for the system.

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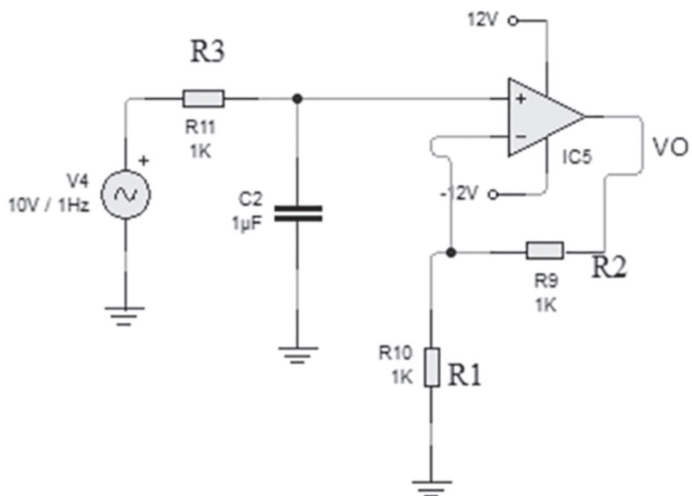
*2.1.Development of laboratory practices*

To acquire knowledge of the requirements about the type and amount of devices (resistors, condensers, OpAmps, etc.) it was necessary to develop guides for the basic practices that could be performed on each workbench. Therefore, the work team is divided in each one of the chosen assignments, and they carry on with five basic practices that could be developed, and a list of materials for each one is set up. By these means, a list of the necessary general devices is stablished as a standard for all the workbenches.

By this work, it is stablished that two types of devices are needed: Some fixed devices that will be the basis for the practice, and a group of variable devices used for any inter-devices practice reconfiguration protocol. For instance, let's take a look to the following possible experience:

**Figure 5.** Schematic for a possible analog electronics experience.

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It can be observed that it's dealing with an active low pass filter. In the filter, output amplitude depends of the relation expressed as $1+\frac{R_2}{R_1}$ and the cut frequency depends of elements C2 and R3. So, to observe changes in amplitude and frequency of this filter it is possible to leave as fixed elements the operational amplifier and the capacitor, and as variable elements the three resistors. Whit this, it may be performed a practice where only a change in the cut frequency is observed and another where a change in the output gain of the not inverter amplifier is observed.

*2.2.Architectural design.*

With the last information, the modular subdivision of the benches was performed as shown in the figure 6.

Please note that in this point, the exercise of standardize the communication protocols has already been done, it can be seen that the configuration of signal and measurement source devices communicate by the $I^2c$ protocol, while the reconfigure devices communicate using the SPI protocol. This was done aiming to make easy to create communication libraries between the processing system and the different kinds of devices.

*2.3.Specific devices selection.*

For the selection of devices, comparison exercises by groups were developed, from which the selection of the processing system is taken as example. There were seven criteria taken for this matter as seen in table 1, and four development boards were selected. Each criterion was scored between 0 and 5 by direct assignation and the result is shown in the next table:

**Figure 6.** Modular division of work Banks.

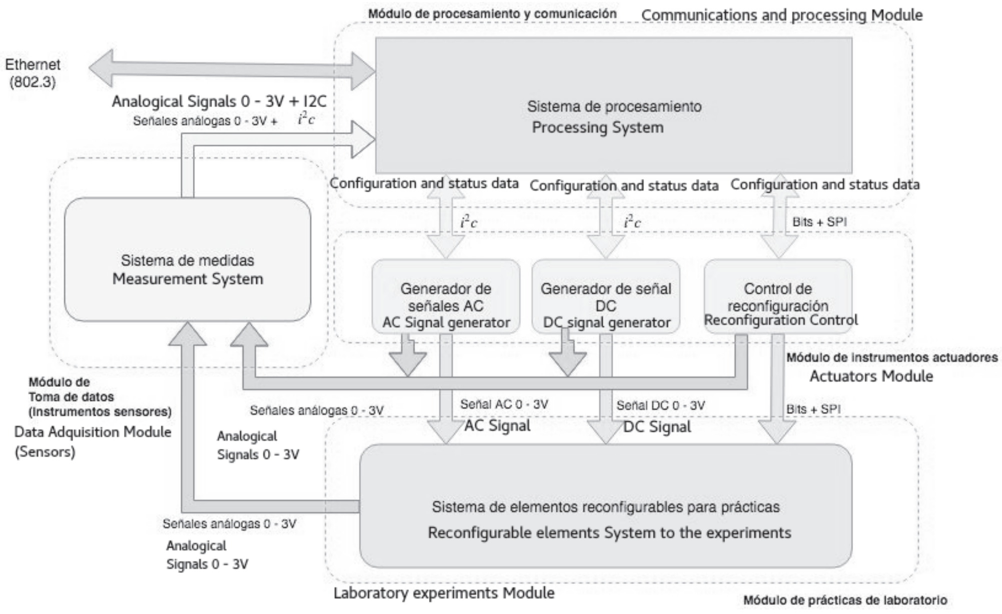


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**Table 1.** Selection of devices example.

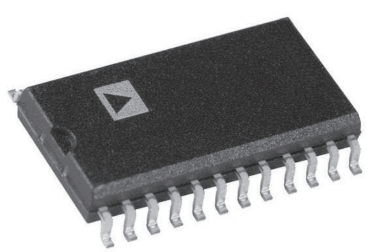
| Criterion | Arduino YUN | | Raspberry Pi V1 | | LPC 1768 | | LPC 4088 | |
|---|---|---|---|---|---|---|---|---|
| | Value | Score | Value | Score | Value | Score | Value | Score |
| ETH port | Yes | 5 | Yes | 5 | Yes (pins) | 3 | Yes | 5 |
| $I^2C$ port | 2 | 5 | 2 | 5 | 2 | 5 | 2 | 5 |
| SPI port | 1 | 3 | 1 | 3 | 2 | 4 | 3 | 5 |
| Analog inputs | 12 | 5 | 0 | 0 | 6 | 4 | 6 | 4 |
| Digital outputs | 20 | 4 | 20 | 4 | 20 | 4 | 29 | 5 |
| Storage | Micro SD | 5 | Own | 5 | Micro SD | 5 | Micro SD | 5 |
| Cost | High | 3 | Average | 4 | Average | 4 | High | 3 |
| TOTAL | | 30 | | 26 | | 29 | | 32 |

Source: own.

In this way, the processing system choice was the development board NXP LPC 4088.

Likewise, as an example of reconfigurable elements, the potentiometer series AD5204/06-BRXX is used, as shown in the figure 7:

**Figure 7.** Analog Devices AD5204 [17].



This device has as a characteristic that it is possible to program the resistance in 256 values using a SPI connection, as was standardized above. The family of resistances may come with maximum values of 10 KΩ, 50 KΩ and 100 KΩ.

*2.4. Final prototype.*

After developing the whole elements selection, the design of circuit schemes and PCB for each one of the benches was developed, as shown in figure 8:

After this, the full mounting of a functional prototype for basic electronics is made, as shown in figure 9:

**Figure 8.** PCB art example of one workbench.

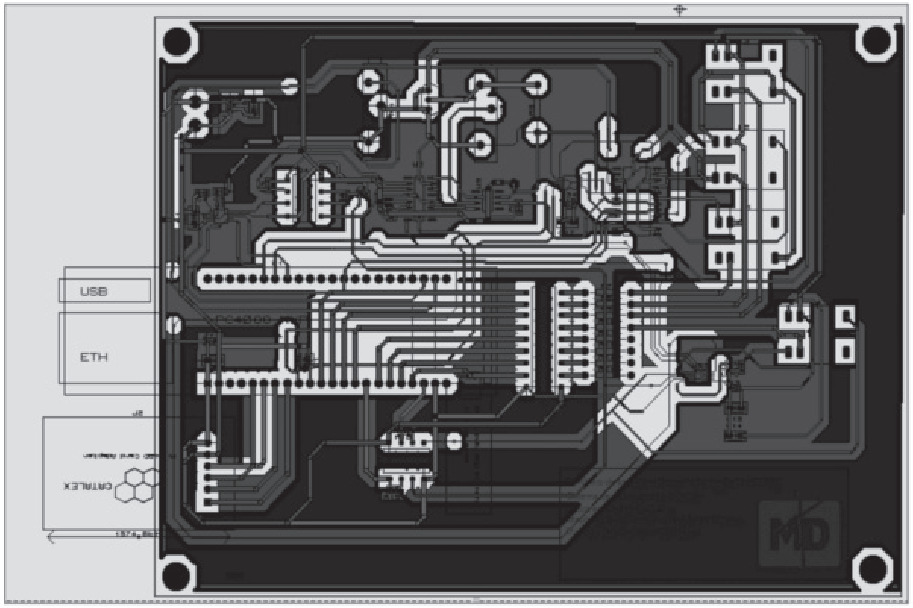



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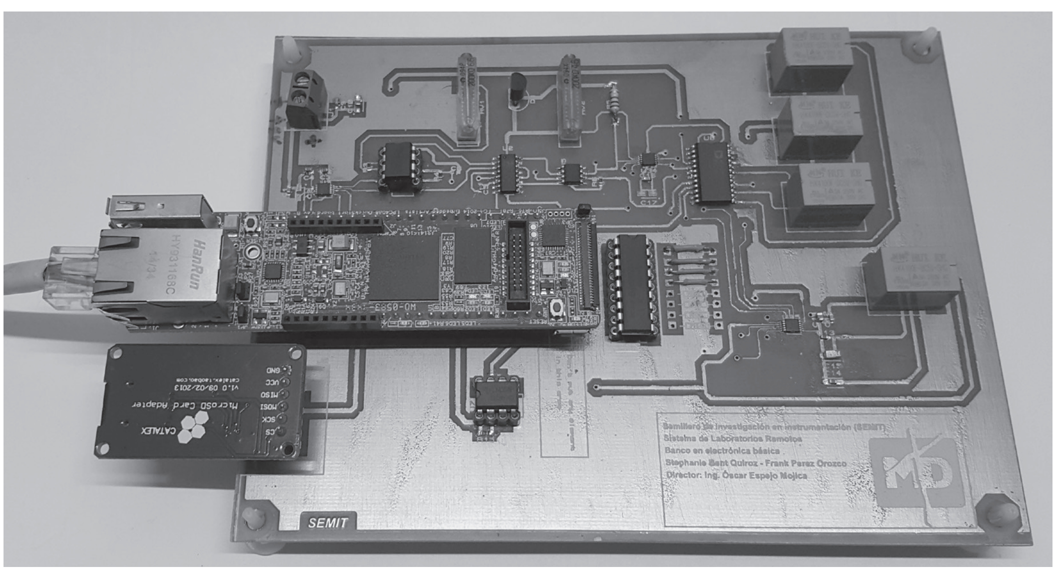
**Figure 9.** Functional prototype for basic electronics.

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The figure shows the processing system, under the interface is placed the micro SD card slot, and the rest of the plaque show the reconfigurable devices to develop the basic electronics practices.

On the other hand, the proper contents for each bench are developed, corresponding with each one of the virtual practices. These files are hosted in the bench's micro SD memory card and uses a combination of HTML5, SVG, AJAX and JavaScript to develop graphic interfaces and virtual instruments as seen in figures 10 and 11:

**Figure 10.** Example of a laboratory practice hosted in the workbench.

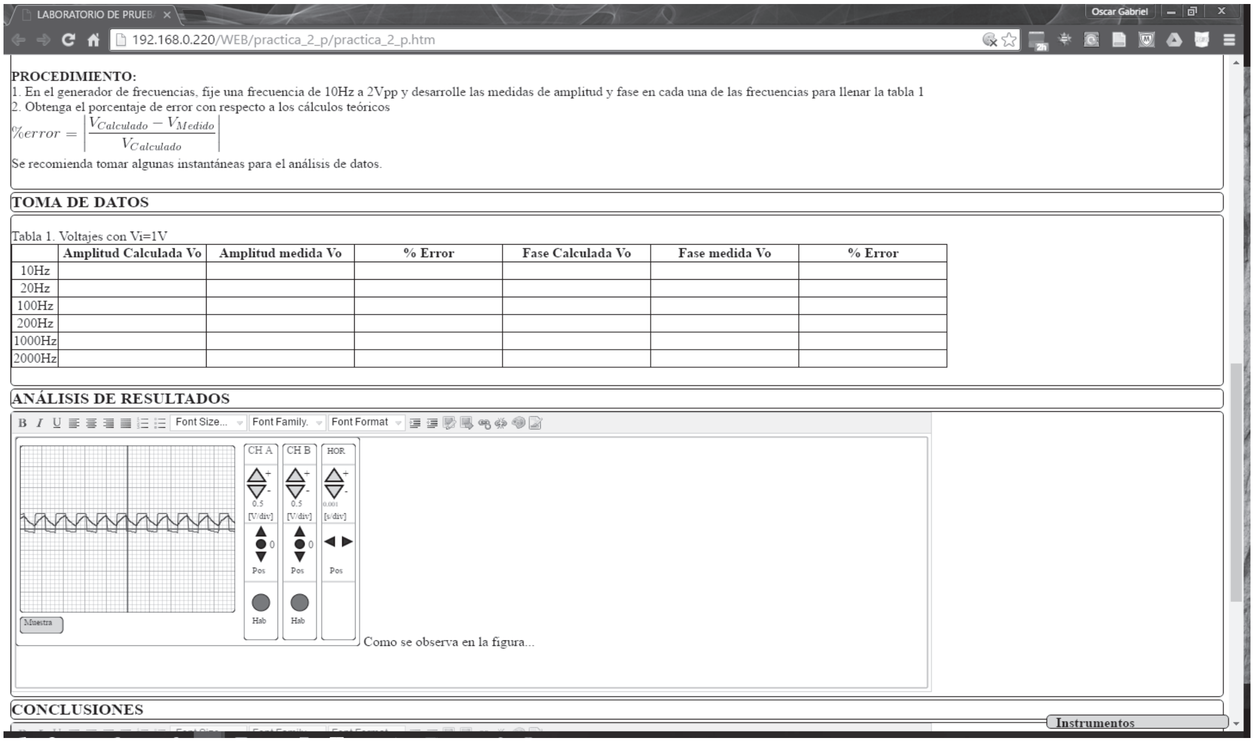


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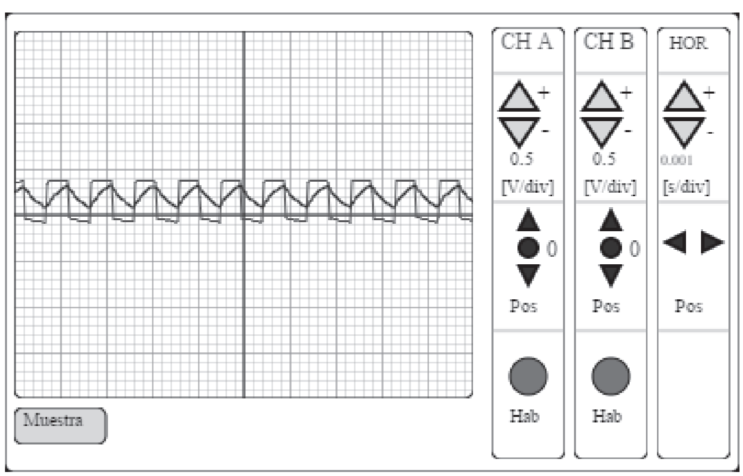
**Figure 11.** Detail of a Virtual oscilloscope from a basic electronics workbench. The graphics shown are actual data taken from a practice.

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## 3. Conclusions

Actually, the develop of remote labs is a powerful tool in the construction of instrumental skills in technological careers like electricity or electronics, and is not limited to the academic University environment, it may be used in training and staff qualification in companies as well, or in middle and professional education.

Having remote labs infrastructure has a great advantage over face to face labs, because it allows to develop a model of Infrastructure as a Service (IaaS), thus maximizing the time of use in the lapses where the traditional laboratories are out of use, for example, non-work schedule, vacation times, weekends, etc. In this way, the educational institutions may have additional income over their infrastructure.

Although, these laboratories were thought in principle for virtual education, while the practices were made and the interfaces were programed, it could be seen that remote labs can be used as a virtual learning object in other environments, for example, to strength the face to face labs dealing with the development of asynchronous practices by the students, and where the results and uses may be monitored by the teacher as a part of the independent work of the student. In the same way, in the classroom if a teacher wishes to develop a concept using inductive methods, he or she may use a remote lab to perform different tests and then induce the behavior of the systems.

As a limitation for the remote labs, it may be observed that the construction of motor abilities or skills is not easy to implement by this way. An example of this, may be the ability of learning to make a tin weld in electronic elements. However, this kind of abilities may be gained with the use of portable trainers that may be used by the students at home.

Development of technologies of access to remote environments will significantly improve the appropriation and construction of knowledge by the use of remote labs, since the experience results in a more "natural" fashion for the user.

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