

A Remote Laboratory for Electrical Engineering Education

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Abstract— This paper presents the remote laboratory “eLab”, realized at the University Bordeaux 1 and dedicated to electrical engineering education. The different lab experiments are usable for both undergraduate and graduate lab courses. The full range of measurement equipment is available on-line, which permits performing DC, AC and transient measurements. Each user (student) has his personal account and a personal user space. He can access to prior measurements, add comments and print out the data or store them in a spreadsheet form. Currently, about 100 different circuits are available for on-line investigation.

Index Terms—electrical engineering, interactive learning, practical lab courses, remote laboratories.

I. INTRODUCTION

The implementation of practical courses through eLearning needs the synergy of three main strengths. In fact, it is a trivial matter to see that the three necessary pieces are the following:

- a pool of remote controlled instruments and measurement systems,
- a group of dedicated servers and software,
- a pedagogical environment gathering courses, tutorial, practical courses.

All elements are important, but the quality of the coupling between them is essential. In that paper, we describe the pedagogical environment of this tool called eLab. A detailed description of the technological aspects is given in [4].

II. PEDAGOGICAL RESOURCES

A. Context and framework

eLab is the fruit of a progression which began at the end of the 90th in the framework of remote instrumentation.

Originally designed to perform remote measurements on electronic devices with high tech instruments, the preliminary results concerning remote instrumentation have formed the basis of the ongoing work. Without going into further detail, we decided to adapt that new technique to practical courses through the European RETWINE project [1, 3].

B. Available themes in electronics

A wide range of circuits are implemented within eLab and they address a lot of themes in electronics, like: RC filter, RLC circuit with sinusoidal signal at the input, Feedback Amplifier, Differential Pair Amplifier [2],

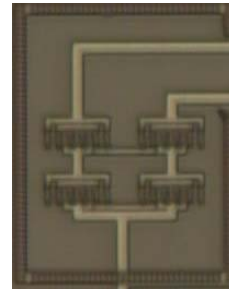


Figure 1. Layout of the Cascode current mirror with BJT transistors

Linear OpAmp operation, Various functions realized with Operational Amplifiers and, finally a whole set of integrated circuits that have been especially designed and realised on the so-called Cyberchip [5].

Monolithic circuits contain a large number of transistors that perform many functions, both passive and active. Thus it is more useful to regard the monolithic circuit as a collection of “subcircuits” or “analogue building blocks”, which perform specific functions, rather than as a collection of individual transistor stages. The subcircuits commonly used in analogue circuits are: voltage and current references, differential pair amplifiers, voltage amplifiers and output stages. For each of these subcircuits, different architectures are possible. They can be realised in both bipolar and MOS technology, or even in BiCMOS technology.

For teaching purposes, the variety of different architectures of basic building block should be investigated, their figures of merits should be discussed, and students should have the opportunity to make their own experiences in hands-on sessions.

For this, we have completed an on-line environment [6]. The realised key steps have been:

- 1) Design of the Cyberchips (about 25 different basic building blocks have been designed in a BiCMOS technology [7]). Figure 1 illustrates the layout of the Cascode current mirror in bipolar technology.
- 2) Test of the Cyberchips (after their realization, the Cyberchips have been tested and about 75 different measurement configuration have been set up). Figure 2 shows the DIL package of one of the Cyberchips. Measuring all the different building blocks requires a high number of input and output pads, so several chips have been realised.
- 3) Development of a switching matrix for on-line use: each circuit has to be connected to some specific measurement



Figure 2 DIL package of one of the Cyberchips

instruments for a given figure of merit to be measured.

Figure 3 shows the schematic instrument connection for measurement of the output characteristic of the Cascode current source.

C. Use in practical courses by students

In the University Bordeaux 1 we have experienced the use of eLab with third year undergraduate students in electrical and electronic engineering curriculum. Since 2002, about 80 students use it every year by performing experiments on *Measurement of a MOS capacitance*, *Differential pair Amplifier* and *Feedback Amplifier* assignments.

Moreover, during 2003, about 50 first year undergraduate students used eLab with *RC filter*, *RLC circuit*, *Linear OpAmp operation* and *Various functions realized with OpAmps*.

Likewise, Romanian (Universitatea “Petru Maior” Targu-Mures) and Greek (Technological Education Institute of West Makedonia, KOZANI) students use eLab from their University in the frame of their curriculum.

D. Use of eLab during a lecture

A laptop with Internet connection permits using eLab everywhere. This great quality and adaptability has been used during lectures. For instance in the University of Bordeaux 1 during a lecture about the *Differential Amplifier*, a teacher presents relevant theoretical aspects while real on-distance measurements support them.

eLab greatly simplifies the procedure of giving live illustration, since many classrooms come equipped with Internet connections and beamer systems.

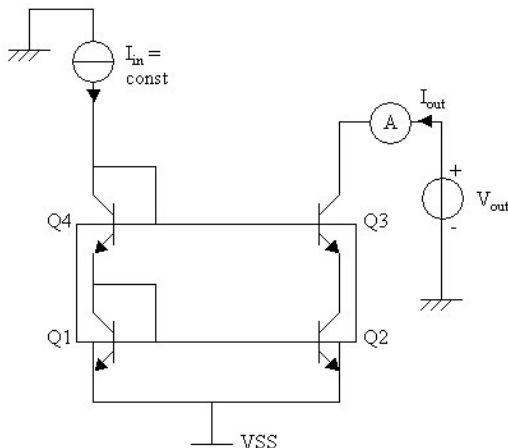


Figure 3 Schematic instrument connection for measurement of the output characteristic of the Cascode current source

III. PEDAGOGICAL ORGANIZATION

Before using eLab a meeting between the user (student) and the pedagogical team is necessary to define with accuracy the themes to be studied.

Once this step realized, a login and password are provided as well as a personal list of textbook made available to the user through eLab.

When the user first connects to eLab at the URL address: <http://centrevirtuel.creea.u-bordeaux.fr/> the homepage appears (fig 4). Note that the system works best with Netscape or Mozilla browser.

A camera located in eLab’s room captures a live view of the different instruments and servers, located physically in the University Bordeaux 1.

Click on *Enter eLab* in the panel to the right to access the identification interface. If the user is authenticated as an approved eLab user, he is directed to his own textbook list (fig 5).

Selecting the lab course from the list (fig 5) will open a new window with the textbook prepared by the teacher (fig 6). Following the explanation given in the textbook will make the measurements straightforward. We will discuss this step in the next paragraph applied to measurement of the transfer characteristics of a twoport in the frequency domain.

A. Perform a measurement

When clicking on the corresponding link in the textbook, a pop-up window is created that provides the following simplified instrument interface to the user (fig 7).

N.B. The user fills a form to set the number of data points, the start and stop frequency values, the DC bias and input voltage signal level. Some help functions are also implemented.

We implemented a very simplified interface, firstly, in order to allow even first year undergraduate students to use the lab experiments, and secondly, to focus on electronics and not on instrumentation.

Then, a new pop-up window (fig 8) appears after clicking on “GO“ It provides the results of the measurements. The measurement can be analysed on the fly using cursor functions or can be stored in as a spreadsheet for further treatment.

Moreover a « monitoring window » pops up when a measurement is performed, showing a view of the switching matrix and the instruments, and the list of queued measurement tasks. Frequent updates provide the user with a « real-time » feedback on what the eLab system is doing.

B. The notebook

To keep track of the user’s work a “notebook” is automatically created to store both graphical results of measurement and comments. The user can go through all his previous measurements and comments e.g. for preparing a report, for further analysis of the measured data and so on

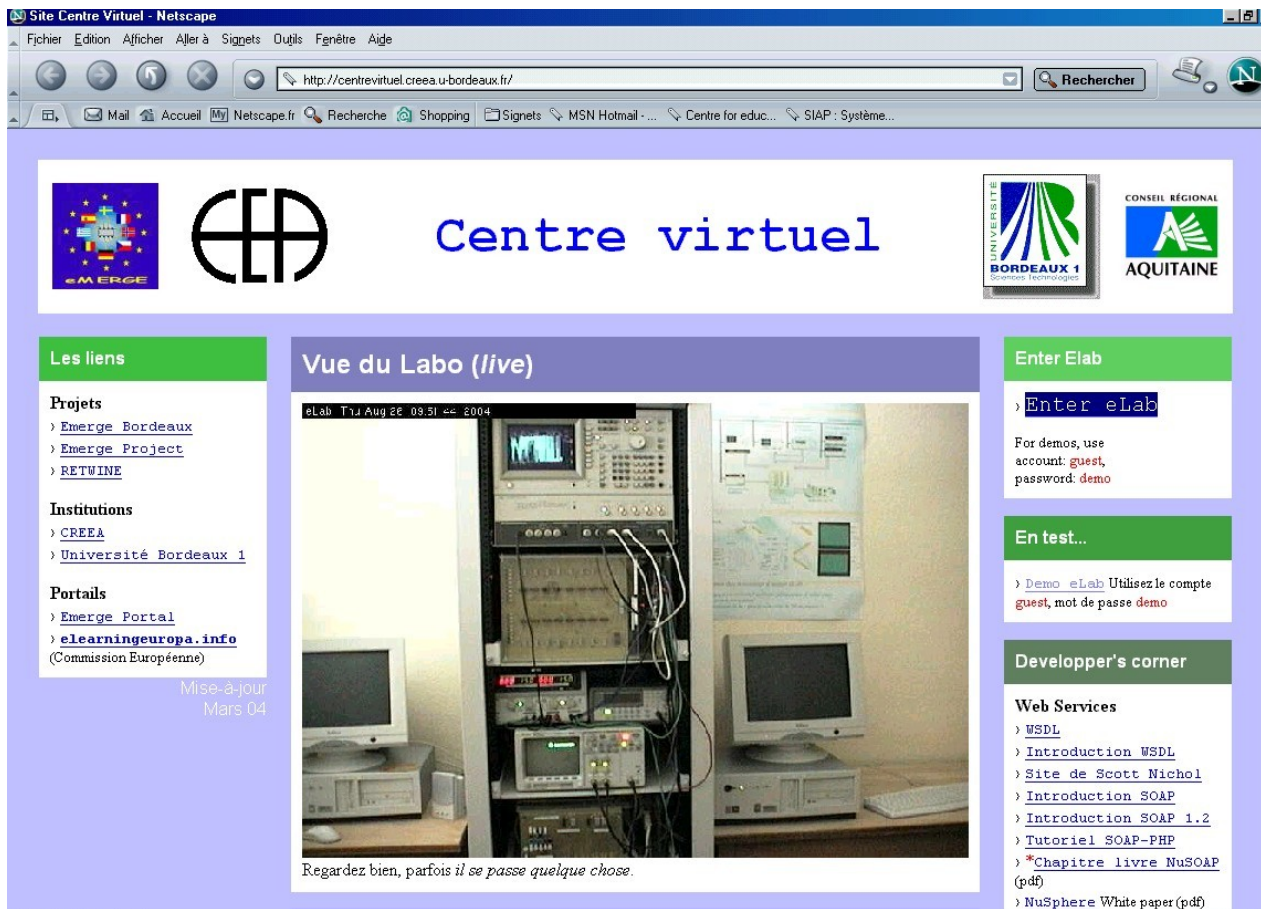
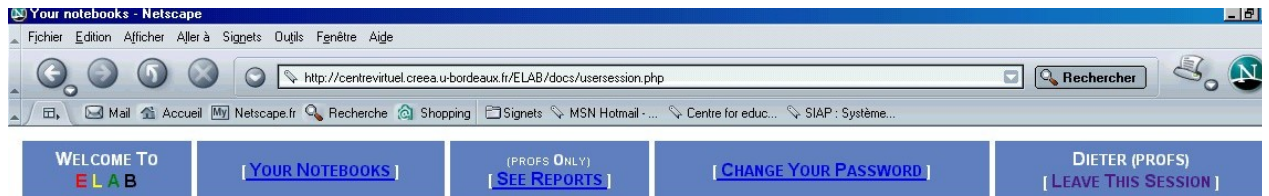


Figure 4 eLab home page <http://centrevirtuel.creea.u-bordeaux.fr>



YOUR NOTEBOOKS

Id	Title	Label	Bundle	Final report
104	Initiation à l'environnement ELAB	Initiation ELAB	profs	
119	Instruments from the RETWINE project			
113	Tests, for authorized staff only			
108	Amplificateur opérationnel en régime linéaire	AOP 1	AOP1	
100	Feedback Amplifier			
129	Measurement of the MOS capacitance	Mos. Capacitance	specimen	
135	Differential Pair Amplifier (01/2004)			
395	Circuits en régime sinusoïdal	a faire	demo	
398	Présentation d'Elab			
638	TP RLC (version de travail, ne pas diffuser)	Sinus (travail)	travail	
645	Diverses fonctions réalisées par un Amplificateur Opérationnel	AOP2	specimen	
847	RC Filters (English)	Filtres RC (english version)	english	
861	RC Filters (English)	Filtres RC (english version)	english	

Figure 5 eLab textbook list

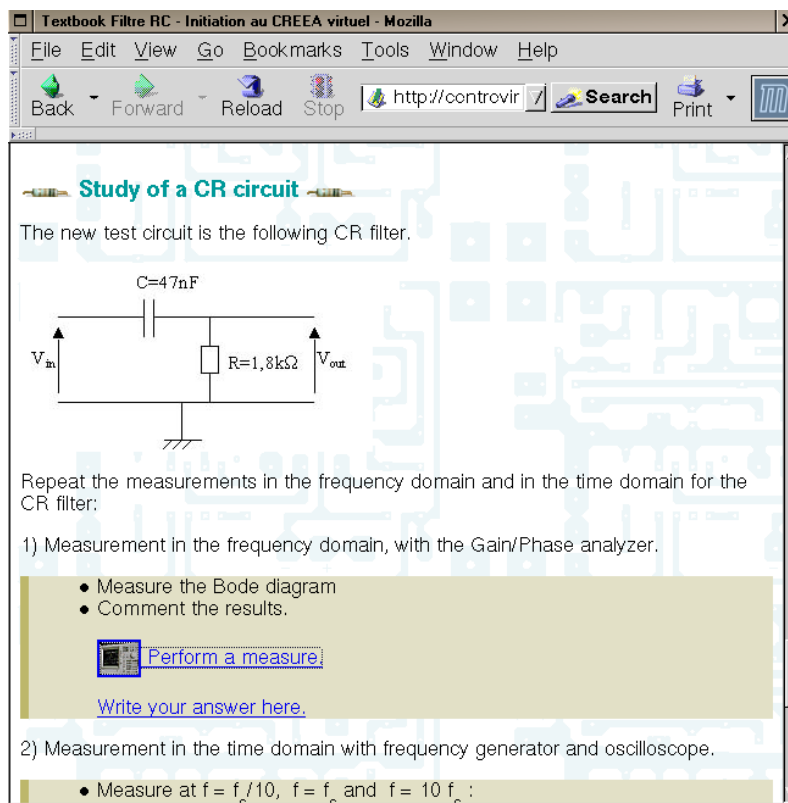


Figure 6 A textbook window

IV. CONCLUDING REMARKS AND FURTHER PLANS

In this paper we presented the pedagogical environment of our remote laboratory eLab. We focused on the available lab exercises as well on how to use them. eLab is now in use for many years and it is continually extended with new experiments. Our further plans concern a reorganisation of lab exercises in a more modular way to make the access to each circuit easier. In the same time, the password protection will be reviewed in order to allow access to everybody every time

REFERENCES

- [1] D. Geoffroy, T. Zimmer, M. Billaud, Y. Danto, J. Martinez,* F. Gomez,* H. Effinger,** W. Seifert**, *UAM Madrid, **Fachhochschule Muenster, *Travaux pratiques d'électronique via le Web*, in proc CETSIS 2001, 3ème Colloque sur l'Enseignement des Technologies et des Sciences de l'Information et des Systèmes, Clermont-Ferrand, France 29 - 30 octobre 2001.
- [2] D. Geoffroy, T. Zimmer, M. Billaud, Y. Danto, H. Effinger*, W. Seifert*, J. Martinez**, F. Gomez**, Université Bordeaux I, *Fachhochschule Muenster, **UAM Madrid, « *A practical course in a virtual Lab* », in Proc. EAEEIE 01, 12th EAEEIE Annual Conference on Innovations in Education for Electrical and Information Engineering (EIE), Nancy, France, 14 - 16 mai 2001.
- [3] T.A. Fjeldly and M.S. Shur, Editors, *LAB-on-the-WEB, Running Real Electronics Experiments via the Internet*, John Wiley & Sons, New York, London (2003). ISBN: 0-471-41375-5.
- [4] Innovations 2005, World Innovations in Engineering Education and Research. Ed, Win Aung, et al. INEER (2005), Chapter title: "Running remote lab experiments through the eLab platform" By Michel Billaud, Didier Geoffroy, Thomas Zimmer.
- [5] M. Billaud, T. Zimmer, D. Geoffroy, « *The Cyberchip for analogue integrated circuit design teaching* », 16th EAEEIE Annual Conference on Innovation in Education for Electrical and Information Engineering (EIE), Lappeenranta, Finland, June 6-8, 2005.
- [6] The eLab (on-line lab) at the University Bordeaux 1: <http://centrevirtuel.creea.u-bordeaux.fr>.
- [7] The Austria Micro Systems Foundry: <http://www.austriamicrosystems.com/>.

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Manuscript received November 21, 2005. This work was supported in part by CEE and UNIT.