

# Microelectronic Interactive Distance Course with On-line Measurement Laboratory

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*Abstract:* - This paper presents a Microelectronics Course syllabus, adapted to the criteria established by the new European Higher Education Area (EHEA). The main objectives are achieved using an e-learning methodology, which includes access to a remote laboratory for the practical work, as well as a sequential program of exercises offered by means of WebCT internet tools.

*Key-Words:* - Microelectronics Course, On-Line learning, Distance Laboratory

## 1 Introduction

The University of Cantabria in Spain is involved in an adaptation process following the criteria of the European Higher Education Area established by the Sorbonne Declaration (1998), and the Bologna Agreements (1999), affecting Engineering Curricula.

The teaching of the subjects of Microelectronic Circuits, within the syllabus of Telecommunications and Industrial Engineering needs special attention, given that it is the first contact the students have with these electronic technologies.

Following the principles of learning based on the active participation of the students, we have attempted to use interactive methods [1] for this basic Electronic Engineering Course, in such a way that all the material necessary for the development of the subject is available to every student before the start of the course.

One of the aspects we have developed is a sequential exercise program, in an interactive way through WebCT [2], with an average of twenty exercises per topic, as part of the continuous work the student must do to progress in the subject. These exercises are evaluated in real time using the facilities of these internet tools.

The automatic assessment carried out by WebCT of the progress of the students in the exercises in each topic has allowed the control of timing in the subject program, to fulfill the aims of the course. Furthermore, this enables a personalized assignment of the simulation tasks of the different electronic circuits, which precede the practical exercises to be carried out with measurements in the traditional laboratory or by

distance access using the special facilities of this course.

At the same time, given that the subjects of microelectronics have a great practical content and with the aim of extending the period of laboratory usage, and maintaining remote access for non-present students, we have developed a remote method of accessing the measurement laboratory [3], which completes the program of measurements in the traditional laboratory.

The access to the laboratory is complemented with a description in the subject's web page of all the instruments in the laboratory and the norms of its use. It is also possible to simulate the electronic circuits to be measured using Spice or MathLab, with a set of simulations previously done as examples.

The characteristic measurement of the BJT and MOS transistors is enhanced within the practical work, using advanced instruments (HP 4155B and HP16442A) within distance learning procedures using the Internet connection facilities of LabView.

The paper is organized as follows: Section 2 describe the course contents and its organization using the WebCT facilities to offer all the subjects to the student with an ordered and structured distribution of the course material. Section 3 presents some examples of the web pages that the students have available in the so-called virtual classroom. The proposed interactive laboratory based on the web site facilities is described in Section 4. In Section 5 we describe one specific aspect of the practical work concerning the measurements of BJT and MOS parameters, finalizing with conclusions in Section 6.

## 2 Development of the Teaching Contents and Exercise Program

The subjects of a Microelectronics Course, as a basic course in the Electrical and Electronic Engineering program in our University, have the aim of introducing the student to the basic concepts of analog electronics, such as the principal device characteristics and modeling and the principles of amplification, generation and processing of signals.

The student accesses the theoretical contents of the classes and all the problems dealt with in class, as well as the outlines of the practical exercises on the web page of the subject. This material can be consulted as an electronic book using WebCT facilities [4].

The teaching material is completed with the incorporation of an exercise program to be sequentially solved by the students and with the use of the remote electronic laboratory to do the measurements of the practical work.

Figure 1 shows the home page constructed with WebCT for this subject, which shows the accesses to the theoretical content, to the set of exercises selected, where the exercises have been specifically prepared for this course, and the communication tools for using with the pages that allow the students to assess their progress in the subject.



Fig. 1 Microelectronic Circuit Course Home Page.

The exercises that the students have to do are divided into modules so they can progress continuously through to the end of the course [5].

The set of these blocks covers the theoretical program and enables the observation of the progress in the different topics as they are explained in the classes

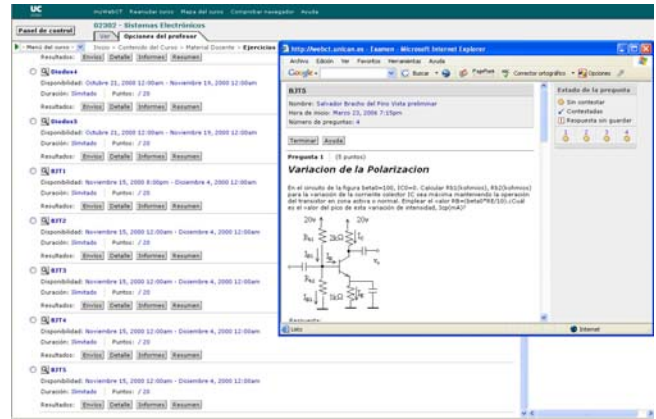


Fig. 2 Microelectronic Circuit Course Exercises.

Through the calendar in the home page of WebCT, opening and closing periods can be established for each block of exercises, in order to oblige the student participating in the program to keep up with the study of the topics in a stepped way throughout the course.

The feedback obtained from the automatic assessment is a valuable element, given that it enables the teacher to follow the systematic progress of each student in a personalized way, even in courses with more than one hundred students.

The inclusion of simulation exercises, in a first version with MathLab and Simulink, and then with Spice, has played a role as an intermediate step between carrying out the simulated exercises and the practical work with measurements in the laboratory.

## 3 Virtual Classroom

One of the objectives, applied to this course of microelectronics circuits in the engineering program, is to improve the student's access to information by the production of an "electronic book". The way to make the information more accessible is to give a multimedia format to the material available which can either be consulted or downloaded from internet. In this way, the students can access data sheets, application notes and the available exercises and simulations.

The electronic book is intended for re-enforcing the knowledge acquired in the classroom, in such a way that the student can access, from home or from the computer room, the transparencies explained in class, additional exercises and any other material which helps in the preparation of the subject. In this sense, the material supplied to the student is considered to be complementary to the explanations given in class.

In the same way, this initiative is intended to improve the quality of the teaching and to achieve a reduction in the time needed by the student for studying the subject.

Furthermore, a part of the teaching time of each teacher participating in this activity is substituted by the effort of preparing all necessary materials, transparencies explaining theory and exercises with solutions for each subject.

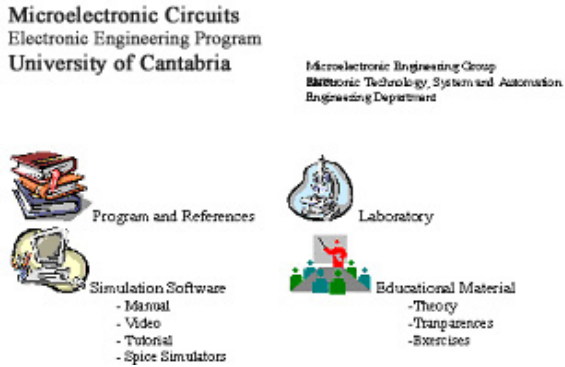


Fig. 3 Course Organization

As an example, figure 3, shows the aspect of the web page that the students find in the site dedicated to Microelectronic Circuits.

The pictures shown, program and references, laboratory, simulation software and educational material are linked to new web pages. In the program and bibliography page, the subject program and the basic selected books appear.

In the simulation software page the reference manuals, with tutorials and direct links to free student versions of IS-Spice and PSpice simulators appear, as shown in figure 4

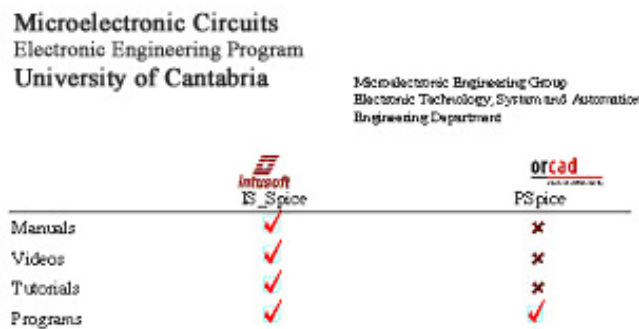


Fig. 4 Simulation Tool Access

Figure 5 shows the web page that gives the final access to the educative material made up of theoretical notes, transparencies and solved exercised of each item of the subject

	Theory	Transparencies	Exercises
Electronic Circuits	✗	✓	✓
Diodes Circuits	✗	✓	✓
Bipolar Junction Transistor	✗	✓	✓
MOS Transistor	✗	✓	✗
BJT Amplifier	✗	✓	✓
MOS Amplifier	✗	✓	✓
Frequency Response	✗	✓	✗
Operational Amplifier	✗	✓	✓

Fig. 5 Course Material Contents

From this page it is possible link to Adobe\_Acrobat pdf format files, which include the transparencies used during the theoretical classes and solved exercises that are used to reinforce the knowledge in each chapter. In this way the student can download this material about the different subjects and use it before the explanation in class in order to know previously the main difficulty of each item. After class this material can help to resolve most difficulties using exercises as complementary work to finalize the understanding of the successive items.

The hyperlink laboratory leads to different subjects of practical work, most of them prepared to be solved with the student version of the above-mentioned MathLab or Spice simulation tools. In this laboratory page, we include the laboratory work manuals, which contain the explanation and the objectives to be achieved during the progress in the subject, and a simulated, representative practical exercise of each chapter to create a reference for the simulation work to be done by the students in each practical problem.

A common tool to be used within the project by all the participating teachers of the University of Cantabria is WebCT from British Columbia University, which allows us to integrate graphic, sound and video resources through an object-oriented programming technique. The navigation system is based on a two-way access to the information as is shown in fig. 1 either directly or via a menu. Different automatic tutorials have also been included, in which there is no interaction between the application and the user and the learning is achieved by mere observation of the computer screens.

#### 4 Distance Access Laboratory through Web Pages

Most of the test equipment used is based on a VXI system, controlled by a personal computer through the IEEE 1394 bus. This VXI system includes most of the instrumentation for generation and analysis of the signals of the circuit under test.

As well as the equipment necessary to generate and capture both analog and digital signals, the measurement system has a matrix of analog switches and multiplexers. This enables the inclusion of design considerations in the laboratory work, since the students can remotely select the value of components of the circuits under test.

On the user side, the student connects remotely with a simple web browser, Figure 6.

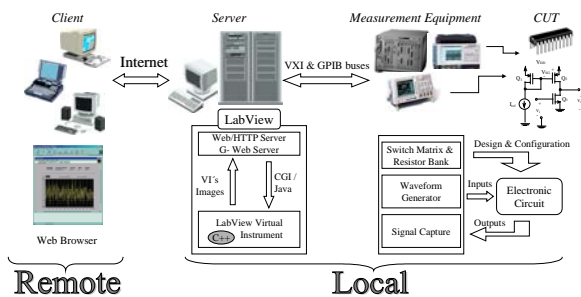


Fig. 6 Hardware connections and software interactions of the remote test laboratory

There are two interfaces where the user can send commands over the Internet to control the configuration of the laboratory apparatus. The first interface is the standard HTML form, where the student only needs to fill in the desired control values and submit the form. The second interface is through an image map of the analysis. Both methods call CGI (common gateway interface) programs for use with the G-Web Server. In this way the user will be able to gain control of the physical instrument through the web browser.

In the server environment, the commercial software LabVIEW is used to physically manage the measurement system. The web server is able to interact with applications developed in LabVIEW, which run locally. These applications control and act as an interface with the measurement equipment (Virtual Instruments, VI). By sending VI front panel images to the student's browser, the student gains remote access to the test system and can make his/her own measurements.

The user begins by configuring the measurement equipment and then fills in the form taking into account the requirements of the measurements to be done. When the web server receives the request, it

calls a CGI program to change the controls of the VI application, selects the configuration stage and executes the application. Next, the user needs to capture the data and save it to a file for later analysis.

To process the resulting data, the user selects the desired analysis in the image map. Generally, the student must verify the data taken, displaying the digital and analog waveforms, before the analysis, and tune the generator instruments if it is necessary

#### 5 Experimental Description and Characterization MOS Transistors and Differential Pair Transistors

A set of web pages is available to the student describing; the aim of the practical work, a detailed description of the theoretical basis, the measurement environment, along with the performances of the different equipment, datasheets and application notes of the CUT manufacturer, and a questionnaire to evaluate the knowledge acquired.

After the user configures the measurement equipment, processes the data obtained and selects the desired analysis in the image map, displaying the digital and analog waveforms, it is necessary to analyse the results, and to tune the generator instruments if necessary.

This methodology leads to a good interaction and participation of the student in the courses, where he/she can acquire a large part of the knowledge obtained from a traditional laboratory.

In this practical work a special emphasis has been put on the description of the BJT and MOS transistor characteristics [6]. We have used the remote access to the measurement laboratory to offer access to high-performance instruments to measure the parameters that characterize the most important electronic devices, such as the BJT and MOS transistors [7].

If we describe the first of these devices, the BJT transistor, four operative regions are considered: active, saturation cut-off and inverse. In each of these regions the dc parameters that relate the voltage and current in all the terminals of the transistor are measured presenting graphically the results in the well-known input-characteristic graphics and output characteristic graphics

In a second phase the small-signal models are introduced and all of their relevant parameters are measured

It has been necessary to develop a test program using the LabView programming facilities to automatically make the different measurements necessary to obtain the principal parameters of the device under test.

In addition to that, all these automatic measurements are offered to a distance user through the internet connection available in the actual versions of the LabView program.

## 6 Conclusions

In recent years we have introduced Internet-related features, through useful tools such as WebCT, or the extensive use of Web pages, as a system to help the students to learn the subjects of Microelectronic Circuits in the Electronic Engineering Program

The sequencing of the student's study of these subjects achieved through a program of automatically corrected exercises and the interactive use of the results during the course, along with the increase in the ease of accessing the laboratories via Internet, has led to a considerable improvement in the results obtained by the students of these subjects.

The pass rate of the students of the subjects where we have applied these methodologies has gone up from 38.2% in the 02/03 course to 63.1% and higher currently.

Complementary practical work is achieved using real measurements with on-line remote access to the electronics laboratory where we have offered an advanced methodology to characterize relevant electronic devices, such as BJT and MOS transistors

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