SUBA – An innovative pedagogical experience

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***Abstract*— In this paper we will introduce the integrated projects implemented on several courses of the Electronics Engineering Bachelor and Master programs at IST with special emphasis on stimulate students' creativity and practice of implanting prototypes. The key hardware of these projects is a car model with controlled electric engine and sensors and actuators - SUBA.**

Keywords – learning experimentally; car models; component; ubiquitous learning.

I. INTRODUCTION

In 2003/2004 academic year started at IST (Instituto Superior Técnico), Technical University of Lisbon (UTL) a new studies program: a 5 years engineering graduation program on Electronics Engineering. In 2006/2007 its curricula was adapted to Bologna system: a first cycle with 3 years leading to a Bachelor degree; followed by a second cycle with 2 years leading to a Master degree. Accordingly, the first Master on Electronics Engineering had concluded their studies in summer 2008.

The program curricula [1] is 90% similar to curriculum followed by a student on Integrated Master (5 years program) on Electrical Engineering and Computers, also from IST, if he choose Electronics as the main area of specialization and Telecommunications or Computers as secondary area of specialization [2]. However, these programs are radically different on the pedagogical approach. It was introduced in the new degrees a strong experimental integrated component from the first through the last semester. Since the "numerus clausus" for Electrical Engineering and Computers is 215 and for Electronics Engineering is only 35, the available infrastructure (laboratories and teaching staff) enables the differentiation of the pedagogical approach on both programs. Also these two programs are lectured on different Campus with different physical infrastructures. The Integrated Master on Electrical Engineering and Computers is at the old Alameda Campus close to Lisbon centre and the Bachelors and Master Degrees on Electronics Engineering are at the new industry and research Campus at Tagus Park, Oeiras, a Lisbon suburb.

The Bachelor and Master Programs in Electronics Engineering are aimed to providing students with advanced training in a vast range of knowledge and stimulate their creative skills, focused on cutting-edge technologies in electronic components, equipment and systems on all its aspects and applications (telecommunications, control, informatics, energy, etc.). These professionals should be able to meet different needs ranging from engineering design to production and commercialization of electronic products with a view to speed up the technological development of the country. Since in the first years of the Bachelor program most of the courses are on mathematics and physics and few on electrical engineering are introductory, to motivate the students and illustrate basic concepts several integrated experiments on an innovative pedagogical experience were developed such as the SUBA project [3] that will be detailed on this paper.

The novelty of this project is the integrated experimental part of several courses and its key hardware. The name SUBA comes from the basic hardware used on these experiments: a Rally car model **Suba**ru Impreza WRX scale 1:10. The initials also stated in Portuguese "Be a good student" (*Seja Um Bom Aluno)*. SUBA gives to students, from the beginning of their studies, the opportunity to learn several basic courses doing design of systems with progressive and complementary complexity, in an integrated way, benefiting from knowledge acquired in successive courses: Physics, Chemical, Logical Systems, Control, Computer Architecture, etc.

Another pedagogical innovation was the creation of open integrated laboratories very well equipped with basic common equipment that is complemented every semester with specialized equipment required by the more advanced courses. . These laboratories are responsibly used, all the day, by the students in course projects and in their own projects without limitation.

II. OVERVIEW OF ELECTRONICS ENGINEERING PROGRAMS

In the Bachelor Curriculum (3 years, 180 ECTS – European Credit Transfer and Accumulation System), all courses (CU – curricular units) are given during a semester with 14 weeks of lecturers and 4 weeks of evaluation process: finalize and discuss projects and/or written examinations. The basic courses are 10: 6 courses on Mathematics, 3 on Physics and 1 on Chemistry, all located on the first two years. Additionally, on these two first years 4 courses on computers and informatics, and 4 on electrical engineering, 2 of them on electronics (devices and circuits) are lectured. In the last year 3 courses on electronics, 4 on different areas of electrical engineering and 1 on informatics are introduced and the curriculum is completed with 5 transversal courses like management and Technical Drawing and Geometrical Modelling.

In the Master Curriculum (2 years, 120 ECTS) besides the Master Thesis that is developed along the second year (12 ECTS on the first semester and 30 ECTS on the second) the students have to be approved in 4 compulsory electronics courses and 4 optional that must be at least 2 also from electronics but the 2 other can be one from any subject on electrical engineering and other from informatics or computer technology. The curriculum is completed with 3 transversal skill courses, one of them on management.

III. THE SUBA PLATFORM

The Subaru Impreza model was selected because it can be easily modified to include an aluminium chassis under the plastic cover to support added electronics for control. Figure 1 presents a photo of a model with two breadboards side by side and an ARM microprocessor development system mounted on the aluminium chassis.

Figure 1. Car model modified to include a breadboard (1) and a printed circuit (2) without the plastic cover (3).

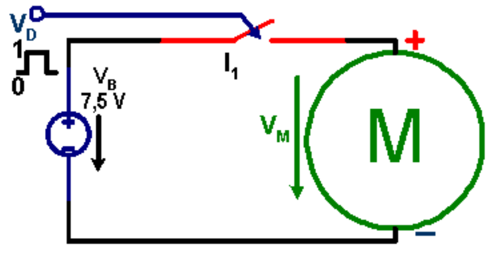
By using a reverse engineering process schematics of all the original model hardware is available for the students in the SUBA site. A special electronics board was designed with several facilities and interfaces for an ease connection of students' projects with the model electronics. SUBA has two electrical motors: one for traction and other for direction control.

The engines speeds are digitally controlled. Figure 2 presents the engine speed control basic system based on a pulse width modulation (PWM) of the engine bias. One of first student's projects is to understand and control the traction engine speed. A sequential logic machine is developed in order to simulate the operation of a mechanical gear box with several gears forward and one backward speed.

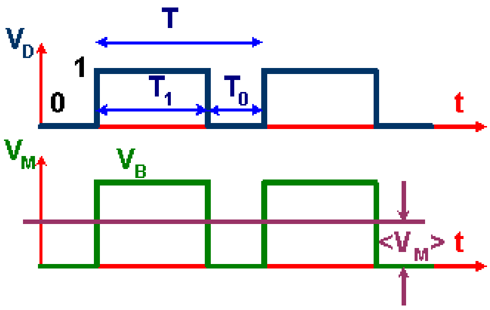
The second engine available on the model is used to control the steering movements: left and right.

In more detail are presented in figure 3 the both engines control circuits based on bipolar transistor technology DC biased by batteries (typically a 9.6 V nickel cadmium rechargeable battery).

Several sensors and actuators were added to the model namely a speed meter, a differential optical direction sensor, wheels angular speed meter and an ultra sonic obstacles sensor.



(a) DC engine power supply PWM controlled schematics



(b) Speed digital control V_D and respective supply voltage V_M

Figure 2. Car model speed control.

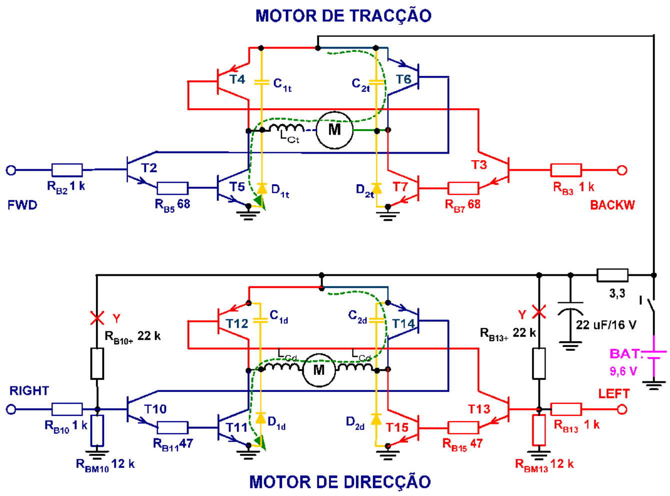


Figure 3. Car model traction and direction engines drivers.

One of the key parts of the SUBA experiments is the SUBAdrome: it is a ramp (figure 4) with 2.5 m length and 30 cm width used for several experiments (more than 20 experiments were developed for Physics course).

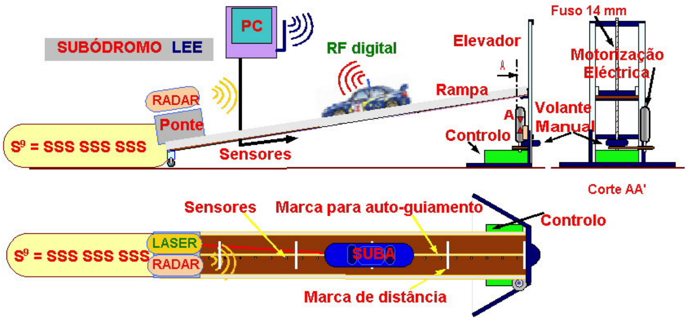


Figure 4. The SUBAdrome – ramp for experiments.

The SUBAdrome has several important features that will be following described and can be noticed on the figure 4.

The ramp slope can be changed by an electric elevator. Over a bridge is located an ultrasonic pulsed radar (30 kHz to 40 kHz signals) that allows to follow the SUBA model movements on the ramp.

The results of the telemetric system installed on board with a speed meter are transmitted via a digital radio system to a PC installed closed to the SUBAdrome. This, so called SUBAradio system has two transceivers, one connected to a PC serial port and the other is at the car model. The system is able to transmit digital data at 200 kbps on a RF carrier of 432 MHz in a range of 50 m in open space.

Also a Doppler system can be installed on the SUBAdrome: loudspeakers on the car model and an audio microphone installed on the SUBAdrome bridge allow the computer to measure the frequency shift of the sound.

Twenty five optical emission/reflection sensors are located on the ramp soil to detect the car position at any time.

All collected data is processed on a PC and allows verifying several physical kinetic laws and compare experiments with theory as it will be shown latter.

At the lower end of the SUBAdrome can be noticed the S^9 system developed to carefully hold the car and avoid any damage.

IV. EXPERIMENTS

During the first semester of the first year, students have the first contact with SUBA: the SUBA Trophy. This experiment is on the mainframe of Digital Systems course.

SUBA Trophy is a creative competition among students to stimulate them on using hardware/software combination. They use simple TTL or CMOS logic components and the breadboard and/or FPGAs (Field Programmed Gate Arrays) to control the model.

Following, as an example, some of the Trophy goals are explained.

Implementation of two sequential machines: one simulating a sequential gear box with PWM signals as explained before; and a second one that controls a predefined series of movements using all gears and the right and left turn movements keeping the SUBA model always inside a predefined area of 6 m x 6 m. A seven segments display, located at the top of the car must show at any moment of the demonstration the used gear. Figure 5 presents a SUBA model totally prepared to compete on a SUBA Trophy.

Figure 5. SUBA model ready to compete on a SUBA Trophy with TTL ICs

On the first year, second semester, SUBA experiments are carried out on the mainframe of three courses: Mechanics and Waves, Computer Architecture and Data Structure and Algorithms.

On Mechanics and Waves the experiments are all processed at the above described SUBAdrome. Calculations of different rolling conditions are tested: different pavements and/or wheels materials (rubber, aluminium and Teflon), and ramp different angle. The up and down movement on the ramp for several speeds including free wheel skid is tested. The comparison with theoretical simulations is performed using the car model movement equations in different conditions. Also energy conversion potential – kinetics along the ramp and electrical-heat when the car is braking are experimentally verified. To break the car electromagnetically the engine is working as an electric generator that supplies resistive loads digitally configurable. This is the first students contact with energy recover. The car engine power supply is controlled by PWM as explained in the previous section. Its operation was already studied at Digital Systems course. The engine power is calculated for several duty cycles, i. e., power supplies or speeds. Several experiments guides are available on the SUBA website.

For basic studies on Mechanics the SUBAdrome is also used testing the movement of coaxial cylinders with different weights, dimensions and materials. Inside cylinder may be free or fixed with the external cylinder. Cylinder fall in the SUBAdrome converts potential energy in kinetic and or revolving energy. Using the 25 sensors available in the SUBAdrome the cylinders displacement can be easily followed. Figure 6 show a student using the SUBAdrome with a cylinder rolling down (a) and the generated signal on the passage of the cylinder on te SUBAdrome sensors (b). Each student prepares his own experience. All students read the SUBAdrome signal on their computers, equipped with data acquisition systems, and model the experience conditions.

(a)

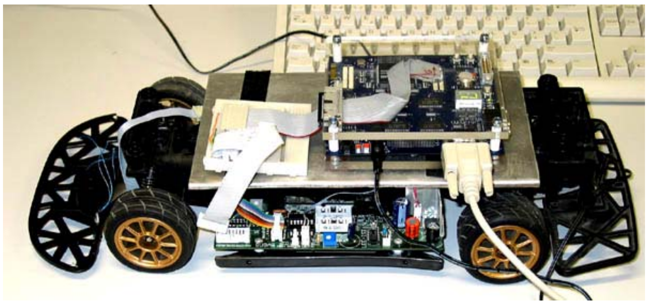
(b)

Figure 6. SUBAdrome used for basic mechanics experiments

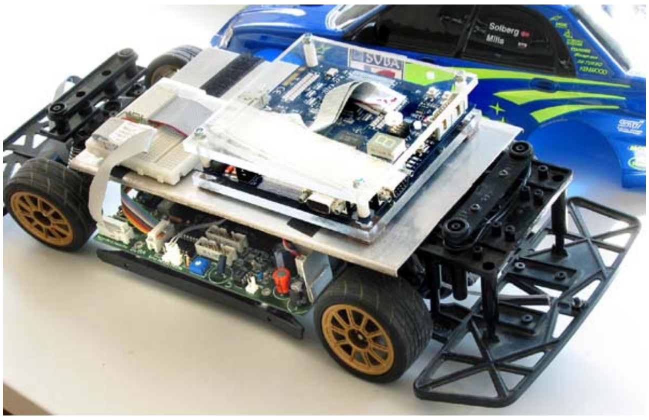
The basic Mechanics experiments can be easily implemented on secondary schools. They don't need all sophisticated and more expensive electronics associated with the study of the SUBA model movements like radio communications, 3D movements' sensors, engine PWM control and so on.

To increase the SUBA model performance, on the mainframe of the courses Computer Architecture and Data Structure and Algorithms, a 32 bit RISC microprocessor with ARM architecture was introduced.

The ARM algorithms are introduced in language C or Assembly that are studied on the courses on Basic Programming. The access to the ARM ports is implemented on the SUBA model by a connector with a flat cable that is clearly noticed on the fully armed model of Figure 7, firstly being programmed (a) and secondly ready for a more advanced SUBA Trophy (b).



(a)



(b)

Figure 7. SUBA model ready to compete on a SUBA Trophy with a RISC microprocessor

The new generation of the Subaru Impreza model direction is not only controlled by two steps L/R or straight (ahead) as in the previous ones. Accordingly, now a progressive control servo system with automatic steer alignment developed by a student on the 3rd year was implemented with a system based on a microcontroller PIC. Figure 8 presents the schematics of the SUBA model direction which has trapezoidal bars controlled by an electric engine.

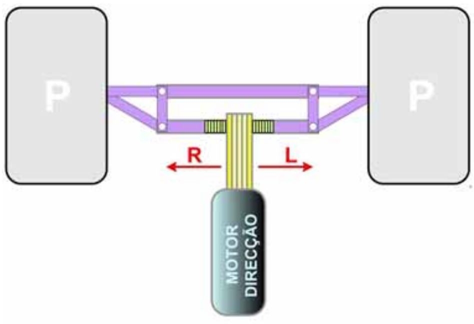


Figure 8. SUBA model trapezoidal bars direction

With this new version a SUBA Trophy where the main challenge was to program the SUBA model to follow a scaled version of the Estoril motor racing track with some short connection (figure 9) was implemented. The Estoril motor racing track is only a few kilometres from IST Tagus Park Campus.

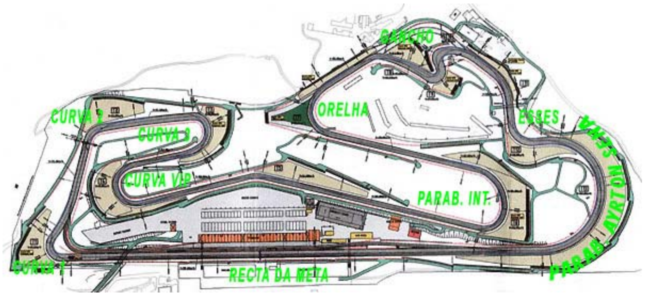


Figure 9. Racing track for advanced SUBA Trophy

V. CONCLUSIONS

Since the first year of the implementation of the new graduation program on Electronics Engineering a new integrated experimental platform has been developed. It has at least two main objectives: to allow experiments based on skills acquired in many different courses from different scientific areas to show their interdependence and the need of a 3rd century electronics engineer to have acknowledgments on a broad area of subjects; to motivate the students to develop and use electronic hardware, since the first semesters most of the courses are on mathematics and physics. The SUBA project trough their Trophies where working on a team is needed is also a good vehicle to help the engineering students loosing afraid of doing hardware, test their ideas and develop their team working skills.

Due to the SUBA experience on the first years the students are more motivated to study in detail other courses like those related to control and electronic systems to fully understand the SUBA performance on experiments of previous courses. Also the students are willing to have projects and develop prototypes on advanced Master (2nd cycle) courses.

The SUBA platform is dynamic and new features are being added. New sensors are being developed on Master courses projects. On the mainframe of one Master Thesis a SUBA car with a hydrogen cell (SUBAH) was implemented.

Also the SUBA project is used to support the Electronics Engineering program objectives presentation in secondary schools where potential future students are now studying, not only with on site demonstration but also thru the SUBA website. Two simple versions of the SUBA are being developed by students' initiative, not included in any course, to be used on the secondary schools and exhibitions, showing their own interest on the SUBA project.

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