EVOLUTION OF GUIDED ACTIVITIES IN THE TEACHING OF ANALOG ELECTRONICS IN BACHELOR'S DEGREE IN INDUSTRIAL ELECTRONICS AND AUTOMATICS TO INCREASE THE STUDENTS' MOTIVATION

H. Martínez-García [1]
Department of Electronic Engineering, Eastern Barcelona School of Engineering (EEBE), Technical University of Catalonia – BarcelonaTech (UPC)
Barcelona, Spain
0000-0002-7977-2577

Conference Key Areas: *Student Engagement, Physics and Engineering Education.*
Keywords: *Guided activities (GAs), puzzle technique, PBL.*

ABSTRACT

Within the offer of core courses of the Bachelor's Degree in Industrial Electronics and Automation Engineering of the Technical University of Catalonia (UPC), which appeared as a result of the current undergraduate study program, within the European Higher Education Area (EHEA), there is a course, Analog Electronics (EAEIA), which allows the Electronic Engineering student to delve into the knowledge of this content. This paper exposes the philosophy of this course, in such a way that it analyzes the orientation that is intended to be given, especially within the new framework of courses offered at the EEBE where, in addition to the hours of lectures and laboratory sessions, there must be room for to the guided activities (GAs) that the current syllabus contemplates.

---

[1] *Corresponding Author*

H. Martinez-Garcia

herminio.martinez@upc.edu

1 INTRODUCTION

Despite the indisputable progress and development of electronics and digital systems, it is quite true that analog electronics, and especially that which directly affects the operational amplifier and its applications, is one of the fundamental pillars on which they establish the modern curricula for electronics students in different fields of engineering (industrial, telecommunications, etc.).

Within the offer of core courses of the Bachelor's Degree in Industrial Electronics and Automation Engineering (EIA) of the Eastern Barcelona School of Engineering (EEBE) of the Technical University of Catalonia (UPC), which appeared as a result of the current undergraduate study plan, within the EHEA framework, there is a course, Analog Electronics (EAEIA), which allows the Electronic Engineering student to delve into the knowledge of this content.

In this course's guided activities (GAs), the professor introduces a series of topics to the students (for example, audio amplifiers and equalizers, the control of a small DC motor, etc.). Then, the students, usually in groups of two or three people, work together, cooperatively, according to the puzzle technique, to design, simulate, assemble, solder and test in the laboratory the circuit proposed that fulfills the design specifications.

The current communication exposes the philosophy of this course, in such a way that it analyzes the orientation that is intended to be given, especially within the new framework of courses offered at the EEBE where, in addition to the hours of lectures, problem classes and laboratory sessions, there must be room for to the aforementioned 'guided activities' (GAs) that the current syllabus contemplates.

2 EVOLUTION OF THE TEACHING OF ANALOG ELECTRONICS WITHIN THE BACHELOR'S DEGREE IN INDUSTRIAL ELECTRONICS AT THE EEBE.

The student of Electronic Engineering, within the modern curricula, must not only acquire a solid base in the knowledge of electronics and digital systems for the control of industrial plants in its different fields (microprocessors and microcontrollers, programmable logic devices, automata programmable, etc). Indeed, he must also know those analog electronic systems that will allow him/her, in his subsequent professional career, the acquisition of data or information, the control of systems and industrial plants, and communications in said environments. Under this premise, and within the degree of Engineering in Industrial Electronics and Automation (EIA), offered at the Eastern Barcelona School of Engineering (EEBE) in its study program, in the framework of the European Higher Education Area (EHEA), the courses of the area of Analog Electronics, have a key importance for the training of the future Electronic Engineer [1].

In the now extinct Study Program 72, Analog Electronics was part of a compendium of compulsory courses within the study program that formed the electronic engineer (Industrial Electronics section, within the Electricity specialty). Basically these were two: On the one hand, Basic Electronics, and, on the other, Industrial Electronics.

Once the first year of the Degree with common courses had been passed ('***Linear Algebra***', '***Infinitesimal Calculus***', '***Physics***', '***Chemistry***' and '***Technical Drawing***'), '***Basic Electronics***' was an annual 2nd year compulsory course, formed by a total of 21 credits, simultaneously with '***Circuit Theory and Electrometry***', of 15 credits (Fig. 1). It developed the necessary knowledge that must be addressed in a university course on electronic engineering: Basic electrical laws (Kirchhoff's laws, Thévenin and Norton theorems, etc.), basic discrete components and their application circuits (diodes, transistors bipolar, and field effect transistors), the basic analog systems, around the voltage feedback operational amplifier (VFOA), the basic digital systems (simplification of functions, typical combinational and sequential circuits), and the static power converter structures basic (controlled and uncontrolled rectifiers, and voltage choppers).

In addition, '***Industrial Electronics***' was an annual 3rd year course, made up of a total of 18 credits, and where the horizons of Electronics were broadened in its different fields. In particular, topics related to microprogrammed digital electronics (microprocessors), analog and digital communication techniques, power electronics, and filtering techniques, mainly analog, were discussed.

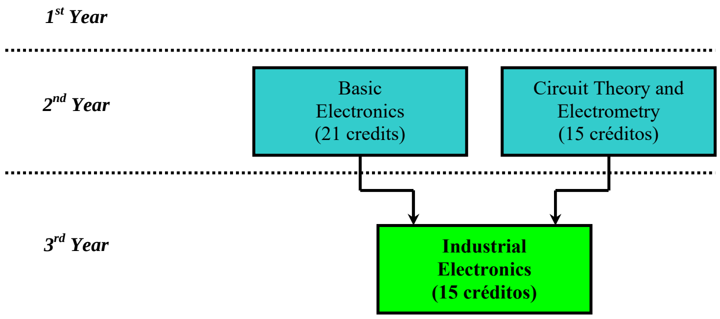

Fig 1. Teaching of electronic systems within Study Program 72 for the specialty of Industrial Electricity (Industrial Electronics section) at the EEBE.

This immense range of topics related to electronic science made that these two courses represent a difficult handicap for the student to overcome. In addition, the main teaching load was focused on lecture blackboard developments and not on practical or laboratory classes, generalizing the idea that, despite the interest aroused by the syllabus of the two courses, the knowledge of electronics taught in it was highly dense.

As a result of the implementation of the Study Program 95, a better rationalization was thought in the teaching of the courses related to Electronics. Indeed, the Electronics student, within an environment of four-month courses, was introduced to the world of Electronics with the compulsory course of 3 credits of the 1st semester '***Introduction to Electrical Circuits***' (Fig. 2.*a*), and '***Electronic Technology – 1***', this one of 6 credits. Once these courses were completed, the student's next encounter with the world of analog electronics was in the 2nd semester of the degree with the 6-credit four-month core course '***Analog Electronic Components and Circuits***', which was combined with the 6-credit courses '***Circuit Theory***' and '***Electronic Technology – 2***', this one of 3 credits. In this course, in addition to studying the basic discrete components and their application circuits (diodes, bipolar transistors, and field effect transistors), an introduction to systems based on operational amplifiers was made. Next, in the 3rd semester, the student faced the course of '***Analog and Filtering Techniques***'. In it, the knowledge related to the analog theme was expanded, such as topics related to the analysis and design of analog filters, power amplifier stages, sinusoidal oscillators and PLL (Phase–Locked Loops) systems.

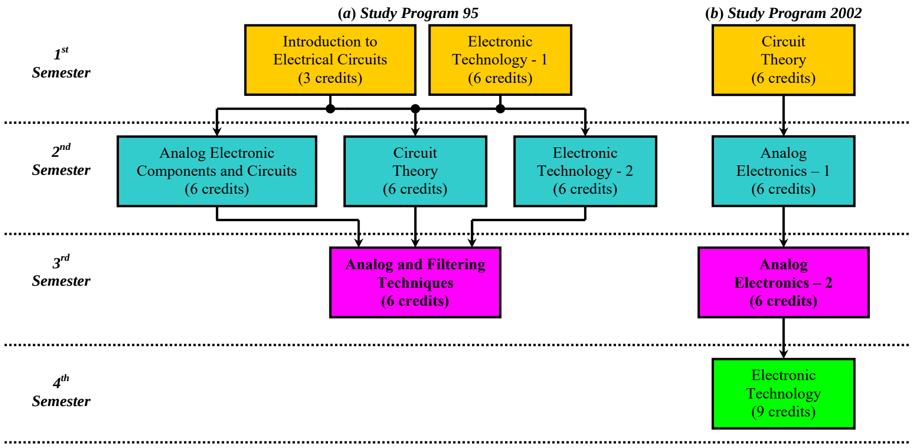

Fig 2. Teaching of analog electronic systems for the specialty of Industrial Electronics at the EEBE. (a) Within the Study Program 95. (b) Within the Study Program 2002.

In 2002, with the revision of the Study Program 95, the new Study Program 2002 was implemented in the old EEBE (the EUETIB), where an attempt was made to correct the most significant anomalies of the existing courses in the different degrees of the School. This revision also affected the courses related to Analog Electronics for the specialty of the Bachelor's Degree in Electronic Engineering. One of the main anomalies detected in relation to them lay in a certain disorder in terms of the courses taught.

In this regard, and trying to correct this anomaly, in the new 2002 Study Program, the 6-credit compulsory course '***Analog Electronics – 1***' was presented in the 2nd semester, once the course '***Circuit Theory***' had been completed in the 1st semester, also from 6 credits (Fig. 2.*b*). In this course, in addition to delving into the basic laws (Kirchhoff's laws, Thévenin and Norton theorems, etc.), the behavior of passive RLC networks, the basic discrete components (diodes, bipolar transistors, and field effect transistors), as well as their application circuits (rectifiers, power supplies, amplifiers, etc.) were studied.

Once the course '*Analog Electronics – 1*' was passed, in the 3rd semester the student studied the compulsory course, also of 6 credits, '***Analog Electronics – 2***'. This was focused on a course around the operational amplifier and its applications in different fields. Due to the course idiosyncrasy, its design was made to be approached from a highly practical point of view. This course was taken simultaneously with other courses of Electronic Engineering such as '***Power Electronics***', '***Industrial Informatics***' and '***Electronic Instrumentation***'.

3 CONTEXTUALIZATION OF THE TEACHING OF ANALOGUE ELECTRONICS WITHIN THE DEGREE OF ENGINEERING IN INDUSTRIAL AND AUTOMATIC ELECTRONICS AT THE EEBE.

With the new curricula within the European Higher Education Area (EHEA), the Bachelor's Degree in Engineering in Industrial Electronics and Automation appears in 2009. The course of '***Analog Electronics***', of 6 ECTS credits, is in the 6th semester (6Q) of the degree (see Fig. 3), coexisting with courses related to Analog Electronics such as '***Electronic Instrumentation***' and '***Industrial Informatics***' and other basic training for the electronic engineer, such as '***Power Electronics***' and '***Control Techniques***' [1].

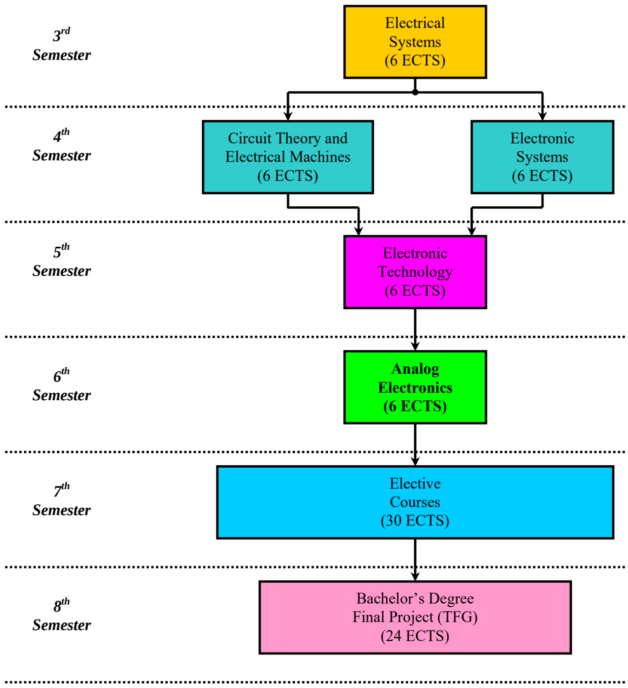

Fig. 3. Teaching of analog electronic systems for the Bachelor's Degree in Industrial Electronics and Automation Engineering at the EEBE within the current study program within the framework of the European Higher Education Area (EHEA).

4 KNOWLEDGE TO BE TEACHED IN THE COURSE 'ANALOG ELECTRONICS' WITHIN THE BACHELOR'S DEGREE IN INDUSTRIAL AND AUTOMATIC ELECTRONICS ENGINEERING AT THE EEBE.

Bearing in mind the idea mentioned in the previous section, the knowledge to be taught in this course has been divided into 5 large blocks, each with its own entity, but which together allow the student to obtain a clear idea of analog based systems based on operational amplifiers. These five blocks or chapters treated in this course are the following (Fig. 4):

1. The operational amplifier working with negative feedback.
2. The operational amplifier working with positive feedback.
3. The real operational amplifier.
4. Sinusoidal oscillators and signal generators.
5. Signal active analog filtering (continuous time and switched capacities).

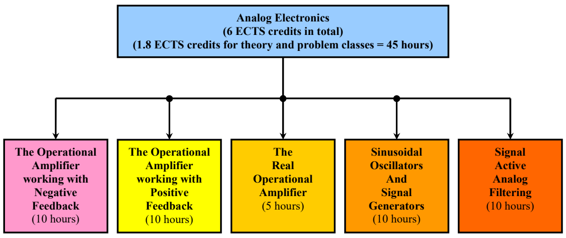

Fig. 4. Thematic distribution of the course 'Analog Electronics'. The indicated hours correspond to those of lectures and problem classes.

5 TEACHING METHOD: THE RIGHT BALANCE BETWEEN LECTURES, PROBLEM CLASSES, LABORATORY SESSIONS AND GUIDED ACTIVITIES.

With the implementation of the current Plan for undergraduate degrees within the EHEA at the EEBE, it is committed that a large part of the courses of the Bachelor's degree, especially those electives that lead the student to follow an intensification within a certain specialty, entail a percentage of credits referring to the so-called 'guided activities' (GAs). In them, it is proposed to carry out different activities (theoretical, practical or information search), in which the professor and student should not coincide in space or time. Of course, the professor tutors, guides and, if necessary, introduces elements of correction of these activities to finally assess them properly. The number of these credits is variable, depending on the course, but it ranges between 10 % and 25 % of the total credits of the course in most of them.

In particular, for the EAEIA course, of the 6 ECTS credits in total that the course has, 2.8 ECTS credits correspond to face-to-face activities in the classroom (70 total hours throughout the entire semester). Of these 2.8 credits, 0.4 ECTS (that is, 14.3 % of the face-to-face activity in the classroom) correspond to guided activities (10 face-to-face hours in the classroom throughout the semester). The other 85.7 % is divided between lectures and problem classes, with 1.8 ECTS credits (45 total hours throughout the semester), and 0.6 ECTS credits for laboratory sessions (15 total hours throughout the semester), always related to the lecture contents presented in the previous sessions of the course (Fig. 5).

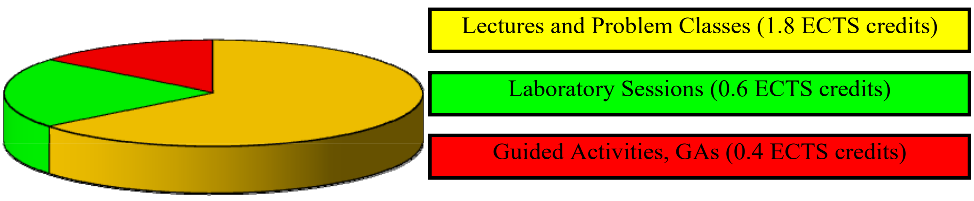

Fig. 5. Percentage distribution of face-to-face hours between lectures and problem classes (62.5 %), laboratory sessions (25 %) and guided activities (12.5 %) of the course 'Analog Electronics'.

This distribution of credits means that three hours of lectures and problem classes are taught weekly, and fortnightly laboratory sessions of two hours throughout the entire semester (considering semesters of fifteen weeks). Thus, there are available about 10 hours per week for each student to carry out the proposed guided activities during the semester.

In the guided activities of the course there is a first part of activities where the student, individually or in pairs, must analyze and simulate different circuits using the OrCAD-PSpice® program.

The second part of the guided activities proposes to the student the physical implementation of a project, using a cooperative work learning technique, in which an analog system is implemented using low-cost electronic circuitry. In effect, the teacher introduces a series of titles to the students (for example, audio amplifiers and equalizers, the control of a small DC motor, etc.) and the students, usually in groups of two or three people, ***work together, cooperatively according to the puzzle technique***. They must design, simulate, assemble, solder and test in the laboratory the circuit proposed by themselves on a test board that fulfills the task specified in the title of the work (Fig. 6).

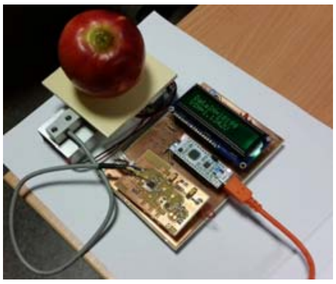

Fig. 6. Example of a prototype implemented in the Analog Electronics course as a part of the guided activities (GAs). In this case, an electronic scale.

In the 10 hours considered face-to-face of the guided activity (GA), the group of students is guided in the classroom by the professor so that the work is developed within the framework marked and scheduled in class. Now, outside the classroom, the group of students must continue working on the project, so that, in addition to the 10 “face-to-face” hours, a series of hours (around 30 more) are contemplated, where the group of students must continue with the guided activity outside the classroom (that is, “not in person”).

It has been seen in the last quarter of the course that the presentation of the prototype in front of the class as a whole is highly positive. The procedure consists of dedicating a few hours to this purpose at the end of the semester, so that for about ten or fifteen minutes the group exposes (we could even say ‘sell’) the design made by them, through the use of some slides. Once this explanation is finished, the rest of the students in the class and the teacher himself can ask the questions they deem appropriate in this regard. The evaluation can be done by the professor himself or even the students themselves can participate, personally issuing a note from the rest of the class groups. The interaction of the groups with the class as a whole, as well as the motivation due to the fact that it is the students themselves who have to defend 'their' design, are high.

6 DISCUSSION AND CONCLUSIONS

Although in general the students start the course with some reluctance regarding its content, it can be said that students’ satisfaction with the course is highly satisfactory. This is an important point despite the ambitious proposed syllabus, which entails an important work of study and assimilation of knowledge by the student, due to the relatively high load of content.

The introduction of software tools is also an important factor to consider. Especially, OrCAD-PSpice® is used for the simulation and analysis of the circuits studied both in the lecture and problem sessions as well as in the laboratory classes. However, the doors are left open for the use of different computer programs for specific course matters. This is the case, for example, of analog filters, where tools such as FilterPro, FilterLab or Filter Wiz PRO are incorporated for the synthesis of analog filters, without having to use the commonly cumbersome analytical methods or using tables for this purpose.

Regarding the guided activity (GA), and despite the considerable number of hours involved in making an electronic prototype that performs a certain task, practically all the students consider that it provides direct contact with the electronics laboratory and with the assembly, soldering and implementation of circuits, essential for future Electronic Engineers. The personal satisfaction of each of the members that make up the work groups is more than satisfied when they manage to make the prototype designed and implemented by themselves work.

With regard to what is indicated in the preceding paragraph, it should be noted and emphasized that, despite the fact that students dedicate 10 'face-to-face' hours per semester to the GA, at home they dedicate a considerably greater number, in order to carry out the guided activity successfully.

As we have commented previously, let us think that these hours of "non-contact" activity of the GA outside the classroom are considered in the ECTS credits of the course. Specifically, of the 6 ECTS credits of the course, only 2.8 ECTS credits correspond to face-to-face activities in the classroom (70 total hours throughout the semester). As we have also previously mentioned, of these 2.8 credits, 0.4 ECTS correspond to guided activities (10 face-to-face hours in the classroom throughout the semester); 1.8 ECTS correspond to lectures and problem classes (45 total hours throughout the semester); and 0.6 ECTS credits for laboratory practices (15 total hours throughout the semester). The other 3.2 ECTS credits correspond to 80 hours of activity outside the classroom, divided between the study of the lecture material of the course, preparation of reports and previous laboratory questions, and the continuation of the guided activities.

Despite this workload for the student, the number of passes is highly satisfactory, thanks in large part to the completion of these guided activities. In the last calls of the course, the percentage of students approved in the course is around 75 % – 85 % of the total number of students enrolled.

Finally, it should be noted that the fact of carrying out the guided activities in groups entails putting into practice one of the objectives of the course and, in general, of all the courses of the Degree curriculum put into operation at the EEBE: Personal and student motivation for group work and cooperativism in learning.

REFERENCES

[1] Escuela Universitaria de Ingeniería Técnica Industrial de Barcelona (EUETIB), www.euetib.upc.edu/els-estudis/estudis-de-grau/grau-en-enginyeria-electronica-industrial-i-automatica (access: June 20th, 2021).