Reflections on Content to be Included in the “Basic Electronics” Proficiency of Industrial Engineering degrees

Carlos J. Jiménez
Dept. Of Electronic Technology, Universidad de Sevilla / Instituto de Microelectrónica de Sevilla (CSIC)
Seville, Spain
cjesus@us.es

Gloria Miró, Carlos León, Antonio López
Dept. Of Electronic Technology
Universidad de Sevilla
Seville, Spain

***Abstract*—Industrial Engineering degree course syllabuses include a series of basic, common skills which must be acquired by those studying for any of the five qualifications that can be obtained in the subject.**

This paper presents a reflection on the content which should be included in the subject that cover the proficiency “Basic Electronics”, analysing the content of the subjects taught to develop skills in this field in some Spanish universities and detailing the subject content offered by the “Escuela Politécnica Superior” (Advanced Polytechnic School) at the University of Seville.

Keywords: Degrees, basic electronics, Industrial Engineering.

I. INTRODUCTION

Adaptation of Spanish university qualifications to make them compatible with the European Higher Education Area (EHEA) has motivated considerable reflection in Spanish universities regarding teaching methodologies [1] and the adaptation of content to new degree course structures [2]. However, this reflection is neither new nor limited to Spanish and European universities. A glance at bibliographical data bases suffices to show that numerous papers have been presented on this theme, both recently and further in the past [3][4].

One of the many issues raised by the EHEA is the need for students on Industrial Engineering degree courses leading to professional qualification as an Industrial Engineer to acquire a series of skills common to all specializations. The resulting situation offers a number of groundbreaking new possibilities, some of which have not hitherto been considered.

Students’ acquire these skills mainly through subject content. If the skills are to be common, the subjects which develop them should therefore be identical, with the same content, in the different degree courses. This is not, however, the only alternative. The same skills can also be developed through subjects in which content varies to take into account the needs of the specific target qualification. This makes much more sense in subjects developing basic common skills for certain degree courses.

Both alternatives offer advantages and disadvantages. The creation of subjects different in content is positive in that their content can be adapted to meet the needs of the specific degree course in which they are taught, but hinders students’ mobility between different Industrial Engineering degree courses in the early years of study. In contrast, if content is unified students find it easier to change from one course to another right at the beginning and teachers are better able to collaborate in the setting up and imparting of the subject. The main difficulty is the choice of content, because the material included must be suitable for students who are studying courses that are quite different.

If the subject covering the skills included in the module common to all Industrial Engineering courses is to be identical for each of the target qualifications, its content must be chosen very carefully. In some courses, the material taught will be initial content and will be studied in more depth later in the course, whereas in others that same material will be terminal content: that is to say, it will not be studied further. This is one of the problems affecting the common “Basic Electronics” skills subject that has to be imparted in Industrial Engineering degree courses.

The aim of this paper is to stimulate reflection on the different alternatives that are available with respect to the subject in which these skills are developed in the different Engineering courses. The first consideration concerns the content that should be included in the subject, because the definition of the skills is so broad that the subject syllabus itself offers a huge amount of scope. Secondly, we examine the solutions that have been implemented in some Spanish universities to see whether the subjects proposed for the different degree courses have the same content and to see what material has been included. Finally we look at the solution offered by the Escuela Politécnica Superior (Advanced Polytechnic School) at the University of Seville.

II. SUBJECT CONTENT

Choosing subject content is no trivial task. A subject in which students are intended to acquire "a basic knowledge of electronics" needs to be based on very carefully selected content because, at the very most, it will only be able to scratch the surface of what is a vast field of study. The first thing to include is a basic understanding of both analogue and digital electronics. Both of these can be addressed in different ways:

A. Device-based approach

One way of introducing subject content is through basic devices: diodes, transistors and operational amplifiers for analogue electronics, and logic gates, bistables and combinational and sequential subsystems for digital electronics.

The objectives here would be for students to learn how these devices work and how they are modelled, and to acquire some experience of basic applications and their associated circuits. The advantage of a device-based approach is that much of the basic bibliography for Electronics, including such widely used books as those by Sedra-Smith [5] and Sorber Malik [6], already addresses the subject from this perspective.

B. System-based approach

A second way of approaching content design is from a system-based perspective. In this case, learning objectives would include the basic elements of an electronic system (frequency response, sampling, feedback, etc.), basic operations (amplification, filtering, etc.), and the differentiation of analogue and digital systems.

The system-based bibliography is not so extensive. One possible bibliographical source might be the book published by Neil Storey [7], a very far ranging volume which starts off looking at systems and then moves on to individual devices.

Each of the two approaches has its own advantages and drawbacks. When designing a completely homogeneous subject that is to form part of five different engineering degree courses (Electronic, Electrical, Mechanical, Chemical and Textil), the *system-based* approach is advantageous for students doing courses not directly related to electronics because it enables them to acquire a general knowledge of the discipline in a short period of time and without needing to go into the subject in any great detail. In the Electronic Engineering degree course, however, a more gradual approach may be more suitable: a corpus of knowledge can be built up starting with basic notions (a *device-based* approach) and then later subjects can be designed to extend that knowledge.

III. IMPLEMENTATION IN OTHER UNIVERSITIES

This section looks at how some Spanish universities have set up subjects which specifically cover the "Basic Electronics" skills common to Electrical, Electronic, Industrial and Mechanical Engineering degree courses. For this analysis, we chose the top five universities offering the aforementioned degree courses in the ISI ranking of Spanish Universities by scientific fields (Engineering) [8]. We used the information available in the RUCT (Registro de Universidades, Centros y Títulos – Register of Universities, Educational Institutions and Qualifications) maintained by the Spanish Ministry of Education, Culture and Sport, together with the information that is available on the selected universities' respective websites. The universities we looked at were: Universidad Politécnica de Cataluña (Polytechnic University of Catalonia) (UPC), Universidad de Zaragoza (University of Zaragoza) (UNIZAR), Universidad Politécnica de Valencia (Polytechnic University of Valencia) (UPV), Universidad de Vigo (University of Vigo) (UVIGO) and Universidad del País Vasco (University of the Basque Country) (EHU). The Universidad Politécnica de Madrid (Polytechnic University of Madrid), despite fulfilling all the established criteria, was not considered because we could find no public information (website) about the corresponding subject.

Generally speaking, the universities examined can be divided into two groups: those in which the syllabus for the subject in question varies in each of the different degree courses mentioned (UPV and UVIGO) and those which use the same syllabus (UPC, UNIZAR and EHU). In those universities in the second group in which the course is taught at different locations (UPC and EHU), the syllabus is different at each location.

The workload assigned to this subject is usually 6 ECTS, the only exception being UPV, where it accounts for 9 ECTS.

The subject is taught either in the third term (UPC, UNIZAR, UPV and EHU) or the fourth term (UPC and UVigo).

Although subject content is approached in a wide variety of ways, there are certain aspects which are common to almost all the syllabuses. To aid description, content has been arranged in Table 1 to differentiate material corresponding to analogue electronics from that corresponding to digital electronics.

The "Components" row shows those devices studied as terminal content, with function models being introduced but no in-depth analysis of internal circuit structures. The analogue components included in almost all the subjects are diodes, transistors and operational amplifiers. The digital components included are logic gates and bistables.

"Function blocks" refers to circuits which, although based on components, are described only in terms of their external terminals, with no analysis of their internal arrangement. Here, only digital circuits or assemblies known as subsystems (combinational and sequential) are included. All the subjects looked at covered decoders, encoders, multiplexers, demultiplexers, meters and registers.

"Applications" shows circuits which are also component-based, but in which the internal arrangement is studied. The only elements included here are analogue amplification and rectification circuits and operational amplifier applications (both linear and non-linear).

However, although some of the content in the subjects offered by the different universities under analysis is common to them all, the syllabuses also include material that varies from one university to another. The differences are as follows:

	Analogue Electronics	Digital Electronics
Components	Diodes Transistors (BJTs and FETs) Operational amplifiers	Logic gates Bistables
Function blocks		Decoders Encoders Multiplexers Demultiplexers Counters Registers
Applications	Rectifiers Amplifiers Linear Op-Amp applications Non-linear Op-Amp applications	

Table 1: Common content.

At the UPC the subject is called Electronic Systems and is taught as part of degree courses offered at five different locations. The subject content is different at each of those five locations. That offered at the Escuela Universitaria de Ingeniería Técnica Industrial (University School of Industrial Engineering) in Barcelona differs from that shown in Table 1: the components studied also include thyristors, and the applications studied also include DC/DC, DC/AC, AC/DC and AC/AC converters.

At the University of Zaragoza (UNIZAR) the subject is called Basic Electronics. It covers thyristors but does not include operational amplifiers and their applications. Neither does it include any material to do with Digital Electronics, which is covered in a separate subject called Digital Electronics, although the skills developed in this subject do not include "Basic Electronics".

The subject covering basic electronics skills at the UPV (Degree in Electronic, Industrial and Automatic Engineering) is called Electronics Technology. In this subject the content related to analogue electronics is the same as that shown in Table 1. In the area of digital electronics, however, nothing is taught about sequential systems, which are presumably covered in the subject called Digital Electronics (the study guide is not yet available; the subject is taught in the third year).

The subject covering basic electronics skills at UVIGO (Degree in Electronic, Industrial and Automatic Engineering) is called Basic Electronics. It also includes circuit simulation, thyristors, active filters and controlled power supplies. However, it does not include any material to do with Digital Electronics, which are also presumably covered in the subject called Digital Electronics and Microprocessors (the study guide is not yet available; the subject is taught in the third year).

At EHU (Escuela Universitaria de Ingeniería Técnica Industrial – University School of Industrial Engineering – in Bilbao) the subject covering basic electronics skills is called Industrial Electronics and it also includes resistors, capacitors, thyristors, IGBTs, heat sinks, stabilized power supplies, three-phase rectifiers, and electromagnetic compatibility.

IV. THE SOLUTION IMPLEMENTED AT THE ESCUELA POLITÉCNICA SUPERIÓR (ADVANCED POLYTECHNIC SCHOOL) AT THE UNIVERSITY OF SEVILLE

The Escuela Politécnica Superior (Advanced Polytechnic School) at the University of Seville offers four Industrial Engineering degree courses: Electrical Engineering, Mechanical Engineering, Chemical Engineering and Industrial Electronics.

Its approach has been to develop a subject covering the same content for all four courses. The second decision was to call the subject "Industrial Electronics", although in some situations this name may be more closely associated with power electronics.

The third decision concerned content. Right from the start it was accepted that choosing subject content to cover such a generic field as "Basic Electronics" in just 6 ECTS is a very challenging task, and that much material considered very important for students would inevitably have to be left out. Of the common content shown in Table 1, everything is included except for diodes and transistors (in the analogue components section) and operational amplifier applications (although students do see amplification and filter applications with operational amplifiers).

Several steps have been implemented:

- Content has been divided into three blocks: an introductory block offering an overview of the subject, an analogue block and a digital block.
- In the analogue block, the two principal operations have been chosen: amplification and filtering.
- The digital block familiarises students with the nature and development of digital design and components.

The subject also includes laboratory practice, which accounts for 1.5 ECTS and is designed to cover three core aspects:

- The handling of laboratory instruments (power supplies, multimeters, function generators and oscilloscopes).
- The carrying out of simulations to verify circuit behaviour.
- The setting up and measuring of analogue and digital systems.

The content covered in each of the blocks is detailed below, and also listed by topic. Information on this subject is available at [9].

A. Basic concepts in Electronics.

The objective of this first block is to provide basic definitions for an electronic system and present the system components as a series of blocks, very concisely explaining those elements which are not covered elsewhere in the subject. This block comprises two topics:

- Topic 1: Introduction and basic concepts.

This topic presents a brief history of electronics, and establishes the basic definitions all students are expected to know, and the essential components and functions of an electronic system. The advantages of electronic systems over other types of systems (mainly mechanical and electrical) are explained, together with the differences between analogue and digital systems. Analogue and digital signals are analysed with regard to their form and the information they carry. Students are made aware of the advantages of digital systems and analogue applications.

- Topic 2: Electronic Instruments and Measurements.

  This topic provides a brief introduction to electronic instruments, principally those associated with process control. A general block diagram is used to show the main operations that are carried out, from sensors or transducers through to actuators. Basic concepts related to sensors are explained, including their static characteristics and their different types (resistive, capacitive and inductive sensors). Some of the most commonly used conditioning circuits are also shown. Finally, the concept of digitalization is introduced, with attention to its two components, sampling and quantification.

B. Analogue electronic systems

This block explains the two most widely used analogue operations: amplification and filtering. Both operations are analysed through mathematical modelling. The basic circuit component employed is the operational amplifier. The content of this block is divided into two topics:

- Topic 3: Amplifiers.

  Amplifiers are defined and explained, together with the different models used to describe them. Aspects covered include linearity, saturation, frequency response and noise. Common configurations examined include cascade amplification and feedback configurations. Finally, students are introduced to the differential amplifier and the operational amplifier which is, albeit ideally, the most effective device used to perform this function.

- Topic 4: Frequency response.

  Students are first familiarised with the signal frequency spectrum, before going on to analyse amplifier frequency response, its representation by means of Bode diagrams and operational amplifier frequency response. First-order filters are then analysed and designed.

C. Digital electronic systems

This block deals with digital system design. It comprises three topics, covering combinational circuits, sequential circuits and the real characteristics of digital circuits. The material covered in each topic is listed below:

- Topic 5: Binary encoding and switching algebra.

  Introduction to binary encoding. Switching algebra. Circuits performing basic operations (AND/OR gates, inverters. NAND, NOR, XOR and XNOR gates). The use of boolean algebra to design combinational circuits. Combinational subsystems (encoder, decoder, multiplexer and demultiplexer).

- Topic 6: Sequential design and state machines.

  Definition of a sequential circuit. The need to include memory elements. Concept of state. D bistable: Behaviour description, edge-triggered D bistables. Asynchronous inputs. Synchronous sequential circuits: Moore and Mealy FSMs. Description using state diagrams. Sequential subsystems: counters (basic function) and registers (parallel-in to parallel-out PIPO and serial-in to serial-out SISO).

- Topic 7: Digital circuits: real characteristics and technologies.

  Electrical characteristics: bias voltage, power dissipation, voltage ranges, noise margins, current ranges, fan-out. Time characteristics: Rise-time/fall-time, delay time. Bistable time characteristics. Asynchronous input time limits. Synchronous input time limits, set-up and hold times. Other characteristics: encapsulation, decoupling capacitors, unused inputs. Industrial interfacing with transistors or relays. Digital technologies: SSI implementations, the use of programmable devices (from PLDs to FPGAs) and microprocessors.

V. CONCLUSIONS

This paper has analysed ways of implementing the "Basic Electronics" skills common to all engineering degree courses. The first issue involved is the difficulty of choosing suitable content, a problem manifest in the wide range of material covered in the subjects dedicated to developing these skills. On analysis of the subjects offered by some universities, we found that while some of their content does coincide, there is nevertheless a very high degree of diversity. Some universities use the same content for their different degree courses, but in others this content varies. We also found that in those universities which offer the same degree courses on different campuses content varies from one campus to another.

Some universities prefer their "basic electronics skills" subject to include only content related to Analogue Electronics, and to leave Digital Electronics for another subject. This is possible in the Electronics degree course, where prescribed learning outcomes specifically include knowledge of digital electronics, but not in other engineering courses, where there is no specific requirement for such skills.

Finally, we have described the content of "Industrial Electronics", the subject which covers "basic electronics skills" at the Escuela Politécnica Superior (Advanced Polytechnic School) at the University of Seville. This subject, which is common to all this particular institution's engineering degree courses, includes content which encompasses both analogue and digital electronics; although the components studied do not include diodes or transistors.

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