A DESIGN-IMPLEMENT CAPSTONE PROJECT IN ELECTRONICS ENGINEERING

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ABSTRACT

Starting from the first bachelor, CDIO projects are planned every bachelor year in the curriculum of our Electronic Engineering educational program. Students are expected to participate in gradually more demanding projects over the progress of their bachelor years. In this paper, the capstone project in the third bachelor is presented.

For this bachelor's dissertation, students are required to conceive, design, implement, document and present a technically advanced project. First, a literature review is performed, followed by a functional analysis. Based on this analysis, a technical implementation is proposed, discussed and realized. The implementation is fully documented, with enough details to reproduce the work afterwards. Accurate scientific reporting and documenting are required, including proper references as well as using correct spelling, grammar and language. To present the work, a written document is produced, complemented by an oral presentation and demonstration, as well as by an academic poster. All aspects mentioned above play a role in finally grading the project work.

In this paper, the organization of the project is documented, including a project example with summarized technical information. Further sections document assessment and feedback, as well as concluding remarks to highlight the project's benefits but also some project issues.

KEYWORDS

Design-Implement Experiences, Engineering Workspaces, Integrated Learning Experiences, Active Learning, Learning Assessment.
(Standards: 5, 6, 8, 11).

INTRODUCTION

Design-built projects are at the core of our Electronic Engineering educational program, complementary and illustrative to the more theoretic courses. These projects start from the first year of our four-year educational program. Gradually, the projects become technically more demanding, evolving from the first to the third year of the academic bachelor program, as is also the case in (Kjærgaard C et al., 2012), according to **CDIO Standard 5**. Additionally, reporting skills and literature analysis become more important and refined.

At the previous CDIO conference in Turku, Finland, design-built projects in the second bachelor year were presented in (Verhaevert & Van Torre, 2016). In this paper, the capstone project in the third bachelor year is presented, a project resulting into the bachelor's dissertation. Here students are required to perform an extensive literature review and document their work using the proper references. Additionally a fully detailed functional and technical analysis should be presented in separate chapters of the bachelor's dissertation text. The link to the (Course Specifications, 2016) is listed in the reference section.

The students work in teams of three people and select a project presented by their professors at the beginning of the second semester. The projects are linked to the research groups of our department, with specific research domains depending on the group. Coaching throughout the projects is provided by the professor as well as a number of assistants.

A full afternoon is reserved for lab work each week. Students generally see their coaches in the lab, but can also contact them outside lab hours. Feedback and communication between students and coaches are very extensive.

At the end of the project, the bachelor's dissertation documents the results and also reflects on them. This has to be a very complete report, as outlined further in this paper. A poster is also produced by the students, presenting an overview of their work in a structured way.

A final presentation, optionally including a demonstration as a proof-of-concept, concludes the project. Grading is also commented in the last section of this paper.

Compared to all previous projects in our educational program, the bachelor's dissertation is characterized by a larger responsibility for the student, supported by much more extensive and complete reporting, including a literature review with proper referencing. Different ways of active learning are included, as also is reported in (González et al., 2016). Considering the grading of the project, not only technical content, but also writing and presentation skills are taken into account.

ORGANIZATION OF THE PROJECTS

Project Proposals

Project proposals for the bachelor's dissertation are produced by the different research groups supporting the Electronic Engineering educational program. The proposals are presented to the students by their professors, who also taught them previous courses. The list of projects covers the following research domains at our university:

- Wireless communication
- Image processing
- Acoustics
- Automation
- Radiofrequency circuits
- Electronics design

The students can ask further questions to the professors who presented projects which interest them to obtain more detailed information. In the next step they present a priority list of their three most preferred projects. Based on this list, students are assigned to the different projects, respecting their preferences as much as possible. Hence, the project groups of three persons per project are composed.

Literature Review

Once the teams are formed and have been assigned a project, the first action is to perform an extensive literature review. All three students in the team are required to perform and write separate literature reviews on different aspects of the project, of which they have to hand in a ten-page text after four weeks.

This approach guarantees a quick start, where every student comes into action. Additionally, because they perform their literature research independently and on different issues, numerous sources are discovered and are collected to be compared at a later stage.

Technical Description and Functional Analysis

An in-depth technical description and functional analysis should be provided by the team in the final dissertation. Students are encouraged to spend time on this part from the start, as it helps structuring their further work. Intermediate feedback from the coaches is of course also continuously available.

Students are made aware from the start that the functional analysis should be written in order to make it understandable for users of the designed system. Technical and implementation details should be presented predominantly in the technical description section.

Hands-on Project Work

Project work, as illustrated in Figure 1, is performed in the lab at our university on a weekly basis. According to CDIO standards, the workspaces used are student-centered, user-friendly and always accessible. One afternoon a week is reserved for the bachelor’s dissertation, and at this time the coaches are always present, promoting early success, of which the importance is indicated in **CDIO standard 5**. Students are also allowed to work in the lab anytime, outside project hours. The importance of hands-on learning is stressed in **CDIO standard 6.** Weekly project meetings are organized with the coaches, resulting in a written report after each meeting, which is produced by the students.

Hands-on project work is divided between all students in the team. Depending on the specific task, a part can be performed by a single student, or by several students together. For example, drawing a printed-circuit board (PCB) is a task which is generally performed by one person. This person of course communicates with the other team members about the electrical as well as mechanical requirements.

Figure 1: Hands-on project work

Creative ideas between students and coaches are extensively exchanged, depending on the literature reviews as well as on the results from the first practical setups and tests. Often changes in planning and approach are necessary, to come to a working product.
The list of hands-on project tasks includes, but is not limited to:

- Breadboarded or soldered test setup of proposed circuitry
- Measuring the performance and properties of these circuits
- CAD of schematics and printed-circuit boards
- Etching, drilling and soldering of PCBs
- Measuring the properties of the PCB version of the circuit
- Mechanical design, including static setups as well as the use of motors and gears
- Implementation of the mechanical design
- Integration of mechanical and electronic designs
- Implementation into a working system
- Testing and measuring system components, such as antennas and their radiation pattern
- Testing and measuring the complete system

Given the variety of the tasks, the project is a valuable Integrated Learning Experience, developing multidisciplinary knowledge simultaneously with personal and interpersonal skills, corresponding to **CDIO Standard 8**.

Illustration of a Project Example and a Short Technical Description

As an illustration of the practical work, four figures are included of a project for radio direction finding. Here, a system is designed and implemented in order to automatically rotate a pair of antennas towards a signal source. The direction of the source is assessed, depending on the phase offset between received signals. All tasks included in the preceding list are required for this project.

In short, the project involves a pair of antennas, switched alternating to an FM receiver. If the signal source is not modulated, the sound intensity produced on the FM receiver is proportional to the phase difference between the signals impinging on the two antennas. As the phase difference is proportional to the difference in physical distance travelled by the radio waves, it is possible to orient the antennas in order to find the minimum sound intensity. When this point is reached, both antennas are at the same distance to the source and hence the direction of the source is known, however, with a 180 degree ambiguity in azimuth, an ambiguity which is resolved and explained further.

Figure 2 shows a PCB implementing the electronic antenna switching network. No moving parts are involved into the switching. Figure 3 displays the base of the system, including the electronics and mechanical setup using a stepper motor to rotate the antennas by means of a microcontroller. The device in front of the image is the FM receiver, of which the audio output is sampled by the microcontroller and the input is connected to the antenna switching network. Figure 4 shows the complete system for test and measurement into an anechoic chamber. Figure 5, finally, displays a measurement illustrating the phase difference between the switching control waveform and the output of the FM receiver. Based on this phase difference, the 180 degree azimuth ambiguity is resolved in the embedded software. Signals are in phase or have opposite phases, depending on whether the signal source is in front of, or at the back of the antenna pair.

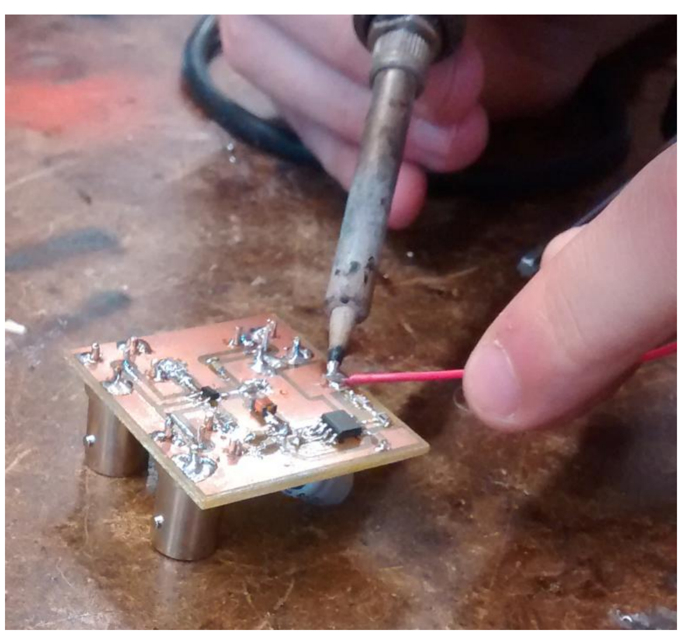

Figure 2. Student soldering his designed PCB

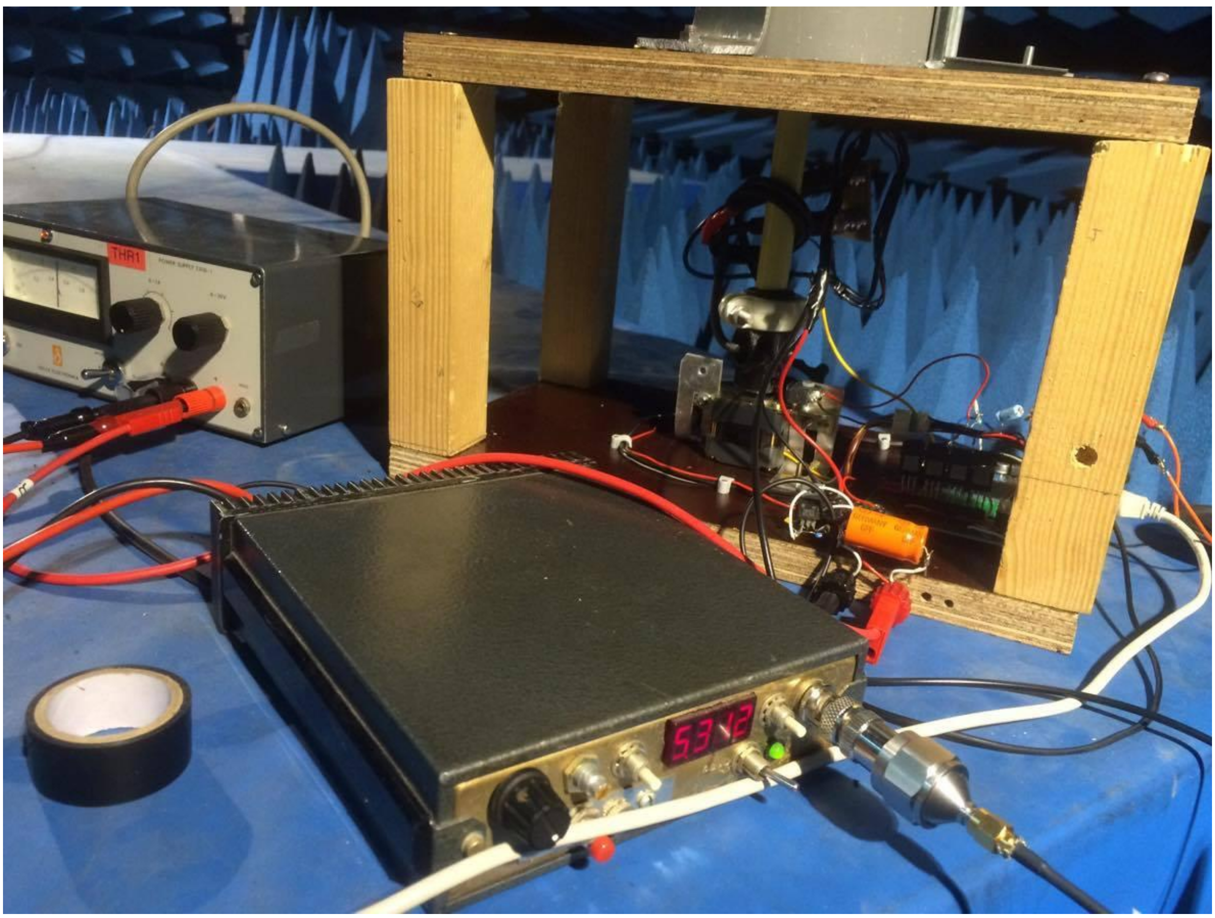

Figure 3. Electronics and mechanical construction

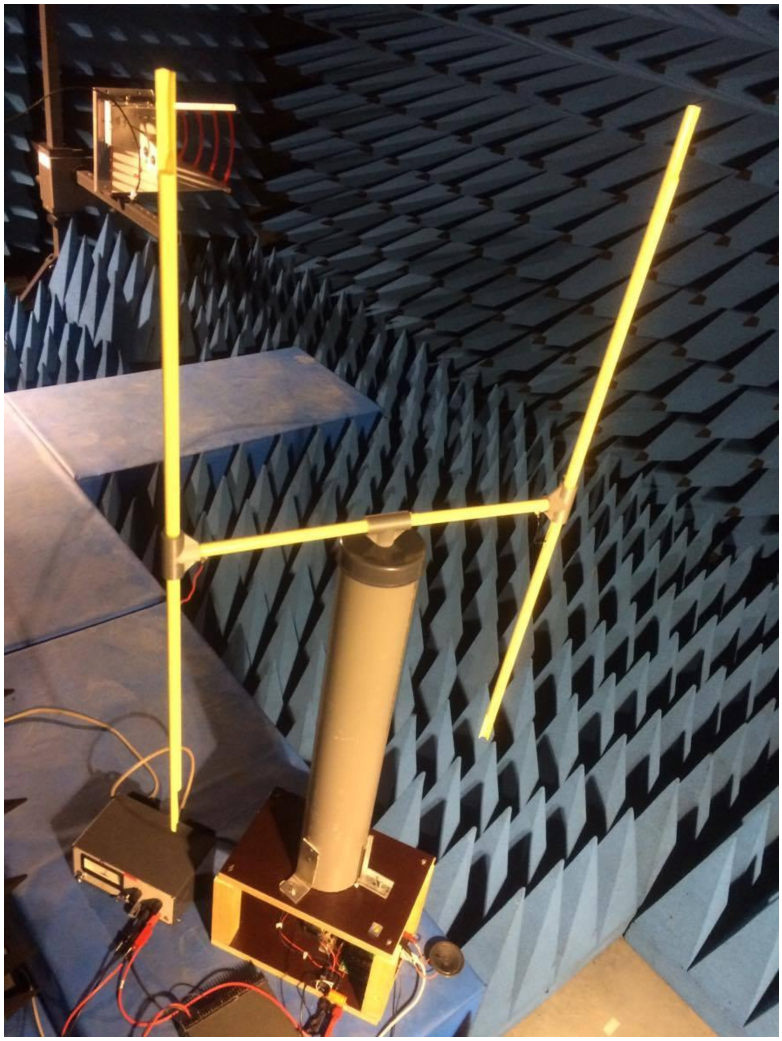

Figure 4. Measurement of the complete system

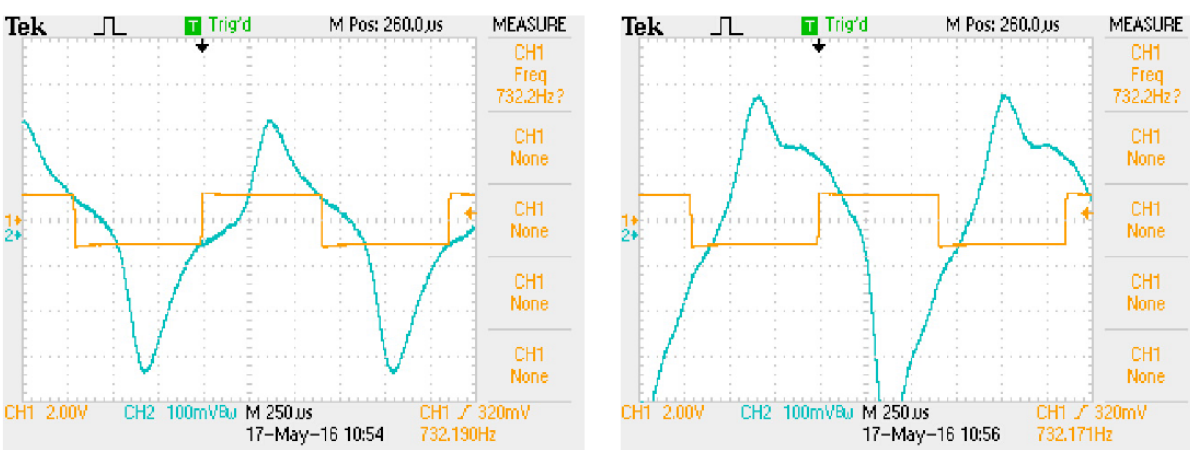

Figure 5. Measurement results illustrating the importance of phase relationships, and resolving the 180 degree azimuth ambiguity (see text)

DOCUMENTING THE PROJECT

Literature Review

In the first weeks of the project an extensive literature review is performed by each team member. The information collected at this stage is reviewed and summarized into the final bachelor's dissertation, which is presented as one document and thus one literature review per team.

Poster

An academic poster is required and should be included as a folded A5 formatted page in the bachelor's dissertation, which is an A4-format document. Guidelines are available for a good poster design and feedback from the coaches is also available during the semester.

Bachelor's Dissertation

At the end of the semester, the bachelor's dissertation is handed in, structured into the following sections:

- Literature review (summary of the three separate reviews)
- Problem description
- Functional analysis
- Technical analysis
- Measurements and results, including figures and tables
- Conclusions
- References

All these parts have to be included and are separately assessed in order to calculate the overall grade for the project.

PROJECT ASSESSMENT AND FEEDBACK

Weekly Project Meetings

Weekly project meetings during the semester allow continuous feedback, without presenting marks or grades. In these project meetings the coaches also monitor how the project advances compared to its planning, which is represented on a Gantt chart. Project planning is generally dynamic during the course of the project, and the students are guided by their coaches in regularly updating their planning according the current status of the project, in order to set intermediate deadlines and reach their targets.

Presentation

Only one presentation is performed for the whole team, but every team member should have an equal oral contribution. The presentation is assessed by the coaches as well as by a language professor, specialized in presentation skills and correct writing and reporting.

Therefore the feedback does not only concern the contents of the work, but also the presentation of the work itself.

Demonstration

An optional demonstration can be performed, for those projects to which this is applicable. Projects leading to a successful hardware or software development are ideal for these demonstrations.

If hardware setup should be too elaborate or complicated on the presentation day, a movie can be an interesting and accepted alternative. Students are encouraged to document results in pictures and movies whenever possible, which should also be available as a backup when a planned live demonstration fails.

Assessment

Assessment is arguably the most important part of the project.
Of course, the main goal of the project is to allow the students to learn as much as possible.

However, according to **CDIO Standard 11**, it is highly important to have an effective assessment process for measuring the different learning outcomes. Therefore a strict system is used, which is known to the students from the beginning of the semester. The final marks are composed as follows:

1st exam chance:

- 20 % Individual assessment on personal literature review and report
- 20 % Permanent assessment during contact hours
- 10 % Group score on poster
- 30 % Group score on final report
- 20 % Presentation and demonstration

2nd exam chance (in case of failure in the 1st exam chance):

- 50 % Report on additional individual assignment
- 50 % Oral presentation and demonstration of additional individual assignment

Feedback

Feedback to the students is provided in a variety of ways.

During the semester all students are trained in small groups (different from the bachelor's dissertation groups) in their presentation and writing skills by the language professor. Considering writing and presentation skills, immediate oral feedback is presented to the team at the end of their bachelor's dissertation presentation, by the coach who is specialized in these topics.

Additionally, the professors and assistants who operated as coaches during the semester provide feedback about technical contents of the presentation and ask technical questions to further assess the student's insight into the project work.

After reading the text and assigning the overall marks, further detailed feedback is available to the students on demand. This extra feedback is only requested by students who do not agree with their marks, which is generally not the case because of the transparency of the system.

COMMENTS

The bachelor's dissertation project is a multidisciplinary educational experience, further stimulating teamwork and developing project planning and management skills. Engineering skills are also refined, according to CDIO principles. Additional to previous projects in the Electronic Engineering curriculum, research skills are required to perform a literature review and to write and present a scientific document, including the proper references in IEEE format. Written and oral communication are explicitly assessed and taken into account for grading the project. The project allows the students for the first time to perform a full scientific project development cycle, which is a clear strength of this course.

Some weaknesses also exist, but are hard to exclude, given the nature of the project. For example learning is very concentric, focusing predominantly on those topics that are necessary for the project. Students tend to choose a role in the project, corresponding to their own strengths, which are then further developed, while their weaknesses stay uncompensated. However, as the students advance further in their curriculum they generally develop their own priorities and later choose jobs where they can employ their specific strengths. In this context it is probably not required to aim for more diversity in their work for subsequent projects. Note that, although each student has specific tasks, each student is also required to have a good overview of the complete project.

At the moment, projects are mostly linked to research work performed by the professors. An opportunity exists to perform project work that is more closely related to specific industrial demands. Providing an industrial link could go as far as having students perform part of the project work in a company. In such an environment, students could acquire experience which is complementary to the knowledge which exists in the academic world. Another issue is that the pool of projects linked to the professors' research is limited. Therefore it is difficult to propose entirely different projects each academic year. An industrial link could provide new ideas and relevant project topics, as described in (Lundheim et al., 2016).

CONCLUSIONS

This article described the bachelor's dissertation CDIO project, performed as a capstone project for the 3rd bachelor year. For the first time in the curriculum, the project offers the students a full development cycle. This cycle starts with an extensive literature review, with proper referencing, and includes project planning and management, engineering and scientific reporting in a written as well as oral form.

The project is very successful and motivating for the students. In a regular curriculum, the third bachelor year is followed by a master year, including a master's dissertation. Therefore the CDIO course discussed in this paper is not only serving as a bachelor program's capstone project, but is also an excellent preparation to the master's dissertation and its corresponding more extensive research project.

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BIOGRAPHICAL INFORMATION

Patrick Van Torre, Ph.D. received the Electrical Engineering degree in 1995 and the doctoral degree at Ghent University, Belgium in 2012. He has been employed by Ghent University, at the Faculty of Engineering and Architecture since 1999, where he teaches theory courses in Electronics and ICT, organizes project-oriented lab sessions and is involved in hardware development projects for third parties. He is active as a researcher, in the field of wireless communication, focusing on body-centric multiple-input multiple-output (MIMO) and beam-forming systems.

Jo Verhaevert, Ph.D. received the Engineering degree and doctoral degree in Electronic Engineering at the Katholieke Universiteit Leuven, Belgium, in 1999 and 2005, respectively. He currently teaches courses on telecommunication at the Faculty of Engineering and Architecture at Ghent University, Ghent, Belgium, where he also performs research. His research interests include indoor wireless applications (such as Wireless Sensor Networks), indoor propagation mechanisms, and smart antenna systems for wireless systems. He is currently also program leader of the electronic engineering curriculum at Ghent University.

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