Development of a Controller Platform for Educational Projects
A Case Study

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Conference Key Areas: education concepts specific for engineers, attract youngsters to engineering education, industry and engineering education

Keywords: Solders of Fortune, Controller Platform, Engineering Challenge

INTRODUCTION

Due to the huge growth of the electronics industry, an increasing shortage of electronic engineers is experienced. The authors believe that educational projects, connecting electronics to real-life problems and applications, can convince students to choose for an education in the field of electronics. Furthermore, most students have insufficient insight in the contents of their studies at the moment they have to make their choice. A positive experience, for instance in the form of a team game, can have a huge impact on students' career choices [1]. The game contains several technical challenges and allows young people to experience and understand the possibilities and huge variety within the field of electronics.

1 MOTIVATION

1.1 Why a Challenge?

Around thirty years ago, the traditional bottom-up teaching approach was most obvious. Starting from the theoretical fundamentals of mathematics and physics, going towards circuit theory and applications [2]. However, nowadays, students are increasingly prepossessed: in early-life they are already confronted with technology, i.e. computers are an essential part of their environment and technological progress is also increasingly addressed in newspapers and on television. This results in two main problems at the moment they have to make their career choice:

- A gap exists between what they learn at school during the first years and their highly technological environment. Most students do not see the link between their theoretical courses and the applications. As shown in [2] this problem is partially addressed by organising project-based education. However,

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electronics-related projects only exist after they have chosen electronics as their specialization and not in the early years of the engineering program.

- Since students are mostly attracted to high-tech computers or gaming devices with highly complex and challenging games, it is increasingly difficult to make them aware of the challenges technology can bring. It is not enough to spoon-feed the students or to just tell them how interesting and challenging things can be, they must be involved and experience problems before they become eager to know the truth behind them [3].

These two problems are both addressed by the presented game. First of all, by implementing different challenges, fitting in different areas in the broad field of electronics, students will become aware of the huge amount of possibilities and applications of electronics. Most challenges in this game are based on a strongly simplified version of real-life technological devices, standards and principles. By experiencing these problems, they become aware of the ever existing difficulties and the fact that available technologies are often far more complex than how they look at first sight when bought in the electronics store. Secondly, the challenging aspect of this game is in the competition. Many teams are trying to solve the same technological problems; within the teams they have to work together to be able to combine a lot of theoretical principles they were taught in early years in order to be the fastest, the smartest and the best. The winning teams are rewarded at the end of this game, which is an extra stimulant.

1.2 Project Goals

The goals of this multidisciplinary game can be summarized as follows:

- Give the students a better insight in what electronics really are.
- Bridging the gap between the theory and practical implementations.
- Make students aware of the huge amount of applications within the field of electronics.
- Show that technology is not for free, many applications demand a high amount of development, often less trivial as it looks.
- Make students aware of the high demand of electronic engineers in industry.

To the authors belief, if students can be made aware of these aspects, it can shift their career choice towards electronic or electrical engineering.

1.3 Overview

In the next section the educational framework in Belgium is sketched. Next to that, a script is needed to make the game more attractive and to fit the different parts of the game together. This script, together with the implemented challenges, is discussed in section 3. Since the scope of this game is to bring the students into contact with electronics, the presented engineering challenge makes use of a discrete component, controller platform using a PIC18F4620 [4]. The printed circuit board (PCB) contains different peripherals for human interfacing, communication, controlling issues and data logging. A more detailed description of the hardware platform can be found in section 4. On this platform, software and data for the different challenges is uploaded. This software is presented in section 5. All information and clues to help the students are centralized on an Element14 online forum [5], [6]. Since the demand to develop this game was coming from industry, the companies and spin-offs linked to our university sponsored the major part of the project. The practical organisation and publicity was done at the university. This is briefly discussed in section 6. In the last section, section 7, some experiences are discussed and conclusions are drawn.

2 EDUCATIONAL FRAMEWORK

The electrical engineering program at universities in Belgium consists of a 5-year curriculum. An overview of the complete program is shown in figure 1. It consists of a three-year bachelor program and a two-year master program. The first three semesters of the bachelor are common for all engineering students. Fundamental courses such as mathematics, chemistry, physics, mechanics and electrical networks are concentrated in these three semesters. However, at this stage, most courses are rather theoretical [7]. After the third semester, a first choice has to be made. A student can choose a major and a minor (see figure 1). The courses in the fourth, fifth and sixth semester are mainly fitting within these two specializations. However, since a student can only choose a master in one of these two disciplines afterwards, this choice is already important and career determining. After the third year, the students choose their master program. At the Catholic University of Leuven (KULeuven), 11 different master programs are available in engineering. The Master of Electrical Engineering is just one of them and requires a major or minor in electrical engineering during the bachelor years.

The Solders of Fortune event is situated in the third semester. This is important because it offers all students still the opportunity to choose for an electronic or electrical specialization afterwards. After they made their choice, during the third year, the students will get some practical electronic experience in the form of some project-based teaching courses. From the statistics of previous years, it is clearly visible that almost all students choose a master program following on their major specialization in the bachelor. This is also an important reason to try to influence their choice in an early stage.

Bachelor program	1st phase	First Semester	Common, fundamental courses of all engineering students: mathematics, physics, chemistry, mechanics, ...										
		Second Semester											
	2nd phase	Third Semester											
		Fourth Semester	First choice of major and minor specialization. Courses within both specializations, main focus is on major. Choices are Electrical Engineering, Civil Construcions, Materials Engineering, Mechanical Engineering, Computer Sciences, Chemical Technology and Geotechnical Engineering										
	3rd phase	Fifth Semester											
		Sixth Semester											
Master program	4th phase	Seventh Semester	Energy	Electrical Engineering	Computer Sciences	Chemical Technology	Civil Constructions	Biomedical Engineering	Materials Engineering	Mechanical Engineering	Math. Engineering	Bioinformatics	Nanosciences and -techn.
		Eighth Semester											
	5th phase	Ninth Semester											
		Tenth Semester											

Fig. 1. Overview of the Engineering Program at the KU Leuven. In order to choose for a master in Electrotechnical Engineering, already in the 4th semester the Electrotechnical major or minor has to be chosen. Therefore the challenge is situated in the third semester.

3 THE GAME ARCHITECTURE

The main challenge is to motivate the students not only to participate but also get involved till the very end of the game. In order to do so, a script was written describing an intriguing story. All implemented challenges have to fit within this story. The script for the first game was about the October 1927 Fifth Solvay Conference on Electrons and Photons. On the Element14 online forum some information about this congress was posted, next to biographies of several conference attendees. Apart from that, some extra fictional information, letters and conversations were generated concerning a dangerous invention which was part of the discussion on the conference. At this moment, the participants become eager to know the complete story. The following challenges helped them to discover it. Note that they get no instructions on how to solve a challenge, they need to discover the working principle of each challenge on themselves.

3.1 The Challenges

The very first challenge is in the soldering of their own hardware platform during a centrally organised soldering evening. After programming the platform and successfully running the self-test, the real game can start.

- *Receive the time-wave:* When starting up the platform, a code must be cracked following the same principle of Master Mind. This in order to discover the different inputs of the platform. After this, a message containing useful information needs to be received. The message only appears once every 4 hours. On the display output, the participants see a scrambled, binary counter counting down from 4 hours to zero. During the last 10 minutes, the display output changes, and the board can be unlocked.
- *A Morse message:* In this challenge, the participants have to decode a message which is produced by the Morse module on the board. The morse code is actually shown by a blinking LED. To decrypt it, the use of a webcam and a computer can be useful, especially because of the high speed of the morse signs. The text leads the participants to a secret location where they find the info to solve the next level.
- *Next is a Text*: On the online forum the students can find some information on RSA encryption which they have to use to decrypt an encoded message. When they enter the correct prime keys in their game computer, the decryption will appear on the display. This message leads them to a location where they get the audio and RF expansion board.
- *Digital Audio and Error Correction*: When connecting the audio board to the game computer, it is automatically detected and the next level is activated. At first some information about sampling analog signals appears. After hearing a poorly encoded digital audio track they have to solve some problems about the Nyquist frequency and error correction. This makes them able to understand the spoken message encoded in the board.
- *An audio FSK message*: For the next level they have to find out how to use the microphone on the expansion module to receive an FSK message. The encoded text message will explain them the use of the RF receiver.
- *Find the RF transmitter*: In this one but last challenge, they have to locate the RF transmitter in the building. This transmitter gives them the solution to completely understand the true story behind the fifth Solvay Conference.
- *The Final Game*: All teams come together again to solve the final game. They have to track two RF beacons in a nearby forest. After this, a short presentation and the award ceremony is organised.

4 THE HARDWARE PLATFORM

The question is what kind of platform do we need for this game? To make a good choice, several aspects need to be taken into account. The platform needs to be:

- good-looking, fancy and interactive
- easy to solder for students
- flexible and reconfigurable

A choice was made for an in-house developed PIC platform using only through-the-hole components. This made the students able to solder the platform themselves. A photograph is shown in figure 2. The on-board peripherals are needed for the human-machine interaction but also for communication, data-logging and controlling issues. In the following two sections the platform is discussed into more detail.

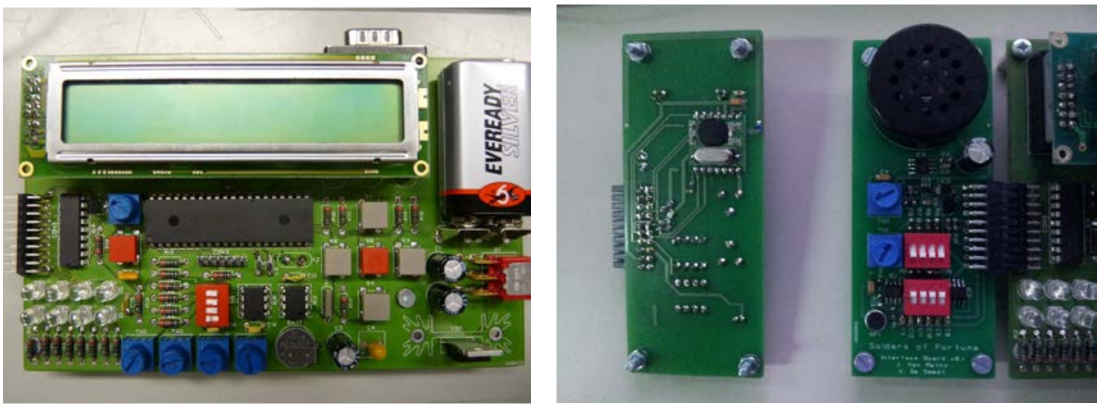

Fig. 2. Photograph of the hardware platform. The main board (left) and the Audio- and RF- Module (right) can be connected through the expansion board connector.

4.1 The Main Board

A block schematic of the main board is shown in figure 3. A real-time clock with backup battery is provided to keep track on date and time [8]. This allows the user to implement time dependent software such as deadlines and unlocking timeslots. A memory was installed to contain text strings, menu information and level, score and sound data [9]. This memory can be accessed through a serial link. For human interaction the platform contains an alphanumeric display which serves as the main output device. Next to that, some LEDs are available in order to output binary data. The 5 button keypad, combined with the potentiometers, allow the user to navigate through the menus and input some numeric values such as codes. A 20-pin connector allows the user to connect expansion boards, such as the audio and RF board depicted in fig. 2. Sixteen analog and digital I/O lines are wired to this connector, including the I²C/SPI, UART and LED lines.

4.2 The Audio and RF Module

To input and output audio data, an audio expansion board was developed. A block schematic is shown in figure 4. The module contains a microphone with an adjustable gain amplifier with an anti-aliasing filter. The output of this amplifier is connected to an analog input of the PIC controller. Also an audio output is provided, containing a high speed I²C digital-to-analog converter. This analog signal is amplified and sent to an output speaker. The audio output is used to play sounds programmed in the external flash memory. An extra component on this expansion board is the 433 MHz Hope-RF receiver [10]. The receiver is connected through the SPI bus to program the required settings as well as reading out the received data. Some single line control signals are used to enable or disable the different components on this expansion board, in order to save battery power.

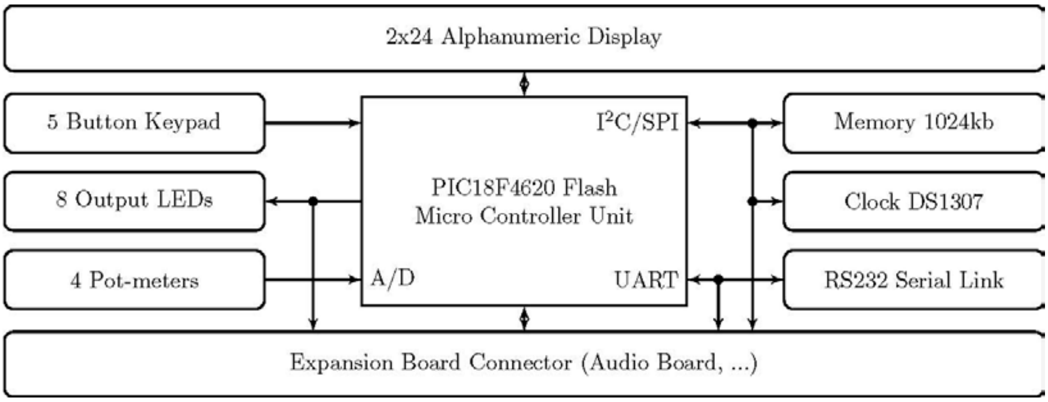

Fig. 3. Block Schematic of the hardware platform.

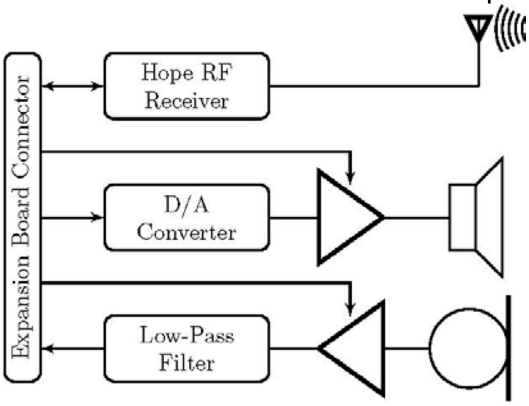

Fig. 4. Block Schematic of the Audio- and RF-module. It has a connector to plug-in on the main board.

5 THE SOFTWARE PLATFORM

As shown in the previous section, the hardware platform has all features to implement the previously discussed challenges. In order to do so, some software on the controller is needed. The software is designed in a modular way; it can easily be adapted to future projects. Some special functions are available, for instance to do specialized calculations or to show text strings and menus on the alphanumeric display. Next to that, a self-test was foreseen. Since the first step in the game exists in 'soldering your own game computer', testing all the different hardware features can be very helpful to discover possible bugs. To do some data analysis, for instance on incoming audio, a fast-Fourier-transform was implemented.

To optimize the flexibility of the software, all text strings and menus are handled in a special way. Rather than programming them in the software code on the controller itself, the external flash memory was used to save all strings. In this way, the memory use of the controller can be diminished. When adapting the software for a new game script, the necessary strings of each level can easily be adapted in a Matlab m-file which can be serially programmed to the external flash memory.

The game itself contains different procedures for controlling the availability of the different levels and features. Each level can only be unlocked after a certain moment in time. When the unlocking is done, the level will appear in the menu structure and can be played. When a player succeeds to finish a level the level score is stored in the external memory. The specific procedures needed for each level are available in separate files. Only these files and the text string need to be adapted when making a new script for the game. All the other files can be left as such.

6 PRACTICAL ORGANISATION

Different timing constraints were applied on the different challenges to prevent the teams from solving all challenges in one evening. Since the score is related to the time to solve a challenge, solving everything at once would be unfair compared to teams who have hardware problems, etc. Also a deadline was programmed to solve each challenge. If the deadline is not reached, the platform automatically advances to the next level. These timing constraints are, according to the author's experience, important to keep every team involved in the game. When a team is getting behind of schedule, they will be able to rejoin in a higher level. An overview of the different time constraints is shown in figure 5.

Day #

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Level 1	■	■	■	■																	
Level 2			■	■	■	■	■	■													
Level 3						■	■	■	■	■											
Level 4											■	■	■	■	■	■					
Level 5														■	■	■	■	■			
Level 6																■	■	■	■	■	
Meeting	S									P											E

Fig. 5. Overview of the timing constraints during the game. To keep all teams on track, every level can only be solved in a certain timeframe. Also the start (S), pizza (P) and Final (E) event are shown in the table.

6.1 Contact Moments

Three contact moments are organised to make sure every team is getting on track and to solve possible hardware or software problems. This also allows the organisers to check the scores and to solve potential bugs in the program code. The first contact moment is the soldering evening itself. At this event the different functions are tested through the self-test. A movie night was organised as a second event. During this event a read-out of the board was done, and all the functions are tested again and fixed if needed. Since levels 4 to 6 are the ones where most of the points could be earned, this second testing is important to keep the game fair for all teams. The last event is the end game and reception, where a second read-out is done and the end scores are calculated automatically.

During the award ceremony, for the first time, the sponsoring companies identify themselves in a short presentation and explain the purpose of the game. In this way, it is not only shown that electronics can be fun, but the participants are also aware of the huge availability of job opportunities in this field in the neighbourhood of their home university.

6.2 Company Sponsorship

To be able to organize the event, the necessary funding was found by the neighbouring companies. Most companies are very eager to attract young engineers and are conscious of the fact that the problem is at the input of the master program. The first idea to organize an event was therefore also coming from a neighbouring chip design house. In order to address this problem on the long term, 9 companies invested in this game. In this way, enough funding was found to sponsor all logistics, going from electronic components and PCB-production to the reception. The development of the hardware and the game itself was done at the MICAS research lab, by research and teaching assistants.

7 RESULTS AND CONCLUSION

The game itself was successful in the sense that 14 teams of 3 to 4 students participated. Mainly due to the time-scheduling of the different challenges all teams showed up at the final event. Most of them managed to solve all or one-but-all challenges. Furthermore, 4 teams afterwards bought the necessary devices to reprogram and reuse the platform for their own applications. At least some of the participants have chosen the electrical engineering program, however, the impact of the game will be measured during the coming years when the students complete their master program. Their marks on mainly the electronics-related courses will be compared to the marks of other students and gives an insight in the effectiveness of this challenge. Finally, the participants will be questioned about their motivation and experience and/or if they think this challenge influenced their career choice or study performance during the master program. The game was built around a Microchip PIC controller platform in which different electronic challenges were implemented. In order to make the challenge more attractive a story considering a hidden truth was written. The game was sponsored by industry since it is mainly an advantage for them that more electronic engineers will graduate.

8 ACKNOWLEDGMENTS

The authors would like to thank all sponsoring companies: AnSem, ICsense, Essensium, NXP, Easics, Invomec, Target Compiler Systems and Farnell. Special thanks go to Stefan Gogaert for doing all company relations.

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