Introduction to Electronics as a Minor Subject

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Abstract — **Technical knowledge should not be limited to computer scientists and engineers. Also people outside these professions should have a basic understanding of technical concepts, trends and challenges. This paper describes a module of electronics for technical journalists and shows that electronics can be successfully communicated finding a balance between simplification and accuracy.**

Keywords – electronics, technological literacy, life-long learning, educational methods

I. INTRODUCTION

Technology has a major impact on today's life. Electronic circuits help us through the day, starting in the alarm clock that wakes us in the morning and the radio that gives us the news during breakfast. And the electronics in a smoke detector guards us during the night.

Below the surface, the advancement of electronics has a significant impact on society and economy. Looking at society first, a number of current developments are consequences from new technology. This can be illustrated with the MP3 coding and the internet. These two technologies enable an easy sharing of music with programs like Napster. The music industry objected and copyright laws were changed in a number of countries. So, technological advancement led to a major change in legislation.

Figure 1. Camera for video surveilance

Another example are closed-circuit television (CCTV) systems for surveying public areas (Fig. 1). While already in use, the increasing computing power will lead to new applications like automatic detection of "suspicious" behaviour or tracking of persons through a city. Here society needs to discuss, whether those systems are a valuable help for the protection against crime and terrorism or a threat to the privacy of citizens.

Looking at the economic impact, electronics is a key technology that enables other products. A modern car is only competitive with an anti-lock braking system and electronic stability control. Car manufacturers without access to those systems will not be able to sell their products.

The same applies to other product categories. A washing machine in the higher market segment certainly has a more stable mechanical body and more powerful motor compared to a budget washing machine. Nevertheless, a customer paying the higher price for the advanced machine also expects a sophisticated appearance, e.g. a small display giving the remaining runtime. Such electronics costs little but are required to sell the expensive machine.

This impact of electronics on our lives and the economy however is contrasted by a lack of interest in society as a whole. People outside engineering and computer science are often unaware of the role modern electronics plays. This lack of communication and understanding between two important groups in society, the scientists and the literary intellectuals, has been described in the influential 1959 talk of C.P. Snow "The Two Cultures" [1].

There are a number of reasons why we, the engineers and computer scientists, should try to change this situation. If we want appreciation or remuneration for our work, we need people to understand what we do and where our work has an impact. Furthermore, visibility of our profession draws prospective students. And we also want to interact with society and discuss the risks and benefits of new technologies.

Such a basic understanding of engineering and science is termed technological literacy and has been proposed in [2], [3], [4]. Individual courses are described in [5], [6] and a comparison of different approaches teaching technological literacy is given in [7].

Many of the described courses cover the broad subject area of physics and technology. Other dwell on systematic procedures in engineering by programming exercises. The course described here specifically focuses on electronics, which is a subset of technology, but a significant subset.

The paper reflects teaching electronics as a minor subject and gives experience based on a course held for technical journalists. The same approach could be used for students studying economy, law or political science.

II. Educational Objectives

While for every course its objectives should be defined, this is especially important when teaching a broad topic in limited time. Also a balance must be found between simplification and accuracy. For the course of electronics as a minor the following educational objectives were defined.

The students shall,

- be able to explain basic terms and components in the field of electronics,
- know the main tasks in design and manufacturing of electronic circuits,
- be able to assess new information about trends in electronics.

However, it must be noted that it is no course objective that students shall be able to design electronic circuits themselves. This will not be their task in their aspired professions.

III. Teaching Approach

A. Target Group

The most important recipients to have a basic knowledge about electronics are decision makers, like managers and politicians, as well as knowledge multiplier like journalists. The approach described in this paper covers a module of electronics for technical journalists, held at the Bonn-Rhein-Sieg University of Applied Sciences. The course has been held for five years with about 60 students each year. A similar course can be used in other degree courses and is offered as continuous education.

The teaching approach has to consider a heterogeneous group of students, both in respect of previous knowledge and interest. Graduates and students of the described study courses are normally quite familiar with applications of electronics, such as computers, mobile devices and automotive electronics. However, they often do not realize the technology behind the product.

B. General Teaching Approach

Looking at the complete field of electronics, students could consider it too broad to be covered in just one module. The first task of the instructor is therefore to structure the contents in smaller topics [8], [9]. Each topic corresponds more or less to a teaching block of 90 minutes.

The individual topics serve several purposes. Besides structuring the complete course, they help motivating students, because for every teaching block they are told the relevance and impact of “today’s topic”. This is important, as the motivation of students for a minor subject can be limited.

Also each topic provides a new entry for students who have missed the last lecture or could not keep up. Consequently it is possible to give some more in-depth lecturing for each topic, as students who do not fully comprehend more advanced concepts have the chance of catching up with the begin of a new topic at the next lecture.

C. Structure of Topics

Teaching time for the module are six lectures and six seminars, each having 90 minutes. The seminar also contains small lab exercises.

The complete subject has been structured into the following six topics, each approximately taking 90 minutes lecture [8].

1) Introduction, Basics

This topic motivates the course by discussing the impact on society and economy similar to the argumentation in chapter I of this contribution. Then the basic components like resistors, capacitors, diodes, transistors as well as printed circuit boards are explained. Additional to an introduction to electric circuits some considerations for manufacturing and device selection, such as packages and tolerances are discussed.

If students did not have a previous physics course, also electric charge, voltage and current can be covered. In this case, this topic could be extended to two 90 minute blocks.

2) Analog and Digital Electronics

Signals and circuits of analog and digital electronics are contrasted in this topic. The sine wave as the fundamental analog signal and the concept of calculating with zeros and ones are presented. Basic circuits for rectification and amplification as well as logic gates and flip-flops are introduced.

3) Semiconductors

After having learned about the function of diodes and transistors, this topic looks “under the hood” and explains the p-n junction as the physical effect that is active in diodes and transistors. While this is rather abstract, the complete field of electronics is based on the p-n junction, so it needs to be covered.

Also solar cells are explained which receive high interest from students due to the economic and environmental importance of renewable energy.

4) Design and Manufacturing

People not working as engineers have limited conception about the different steps during a design project but need a certain level of understanding when discussing the development of new products. Tasks like specification, circuit concept, circuit entry and verification are explained. Furthermore, sourcing of components and manufacturing is covered. The topic also looks at the introduction of new products and questions why a product can be a success or fail.

Especially this section is an addition to courses described in literature [7] as it emphasizes the economic impact of technology.

5) Micro- and Nanoelectronics

With the knowledge of semiconductors (topic 3) and electronics design and manufacturing (topic 4) this topic explains integrated circuits, covering technology, design and manufacturing.

Semiconductor memories are also explained and receive good students' interest, as the advancements in this field are apparent, e.g. in the rising memory capacity of USB flash drives.

6) Automotive Electronics and Embedded Systems

These two subjects should not be missing in an electronics course, representing an important application and the integration of electronics in a machine. Again, based on the previously discussed general knowledge of designing electronics some special considerations for embedded systems are explained.

D. Repetition of Important Concepts

Structuring the complete course into topics also allows reiterating basic concepts of electronics. Thus, students get a repeated chance for understanding.

For example, the transistor is discussed in topics 1, 2, 3 and 5. In the "introduction" (1) the basic function of the transistor as a switch and amplifier is explained. In "analog circuits" (2) a simple amplifier is presented. The topic "semiconductors" (3) explains the physics of a transistor and "microelectronics" (5) covers the integration of millions of transistors on a single device. Each time the transistor is discussed, giving stronger students the chance to apply their knowledge and weaker students to ask questions and get another explanation.

IV. SIMPLIFICATION AND ACCURACY

As the target group only needs an overview about electronics and will not themselves design circuits, the lecturer has the right and the duty to simplify the presented information. However, a balance has to be found so that the simplified information is still accurate.

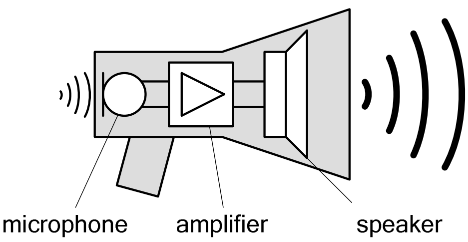

Figure 2. Megaphone as example for an amplifier

A. Transistor as Amplifier and Switch

How such a balance between simplification and accuracy has been established shall be discussed for presenting the function of a transistor. First, the need for an amplifier is illustrated with a megaphone (Fig. 2). The weak input signal shall come from the microphone and the sound is given to a speaker.

Then Fig. 3 shows the simplified function of an amplifier with a transistor. Controlled by the weak input signal the transistor opens the path from the power supply through the speaker. For an electrical engineer, the circuit might seem trivial, but it helps students grasping the concept of an amplifier. By discussing the circuit it becomes clear, that the transistor does not provide energy to the speaker but switches the flow of energy from the power supply through the speaker. Nevertheless, it is explained that a real amplifier, e.g. of a megaphone, has several amplifier stages and some more components like resistors and capacitors.

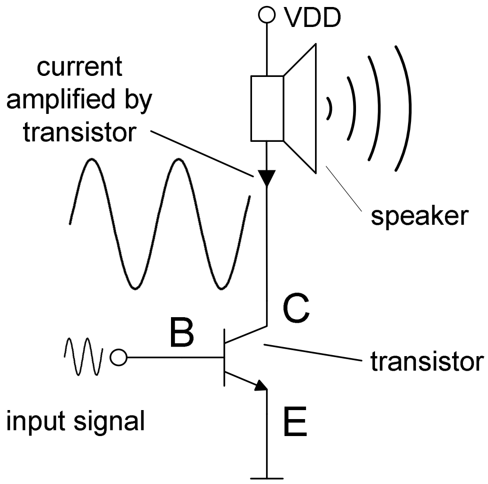

Figure 3. Transistor as an amplifier

Based on the simplified amplifier a real circuit is presented later in the seminar. It is a light sensor where a photoresistor senses brightness and the transistor switches an LED (light-emitting diode) on or off (Fig. 4). It is similar to a street lantern that automatically switches on during darkness. Compared to a real lantern again this circuit is simplified but it is a working circuit.

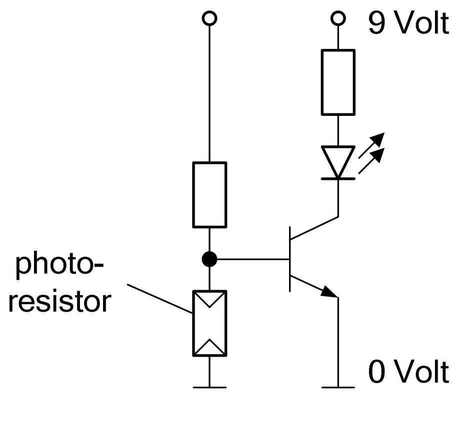

Figure 4. Street lantern with light sensor

During the seminar, the function of the light sensor is explained by discussing the two cases of brightness and darkness. In brightness, the photoresistor pulls the base of the transistor to ground and closes the transistor. In darkness the left resistor pulls the base of the transistor to 9 Volt and opens the transistor, the LED lights.

This explanation is simple enough for non-engineering students to comprehend. The circuit is also soldered on a printed circuit board in a hands-on lab during the seminar. This activity is motivating and gives the students the possibility to personally interact with electronics.

B. Digital Circuit

Another small example is used to illustrate the principal function of a digital circuit. A small dice shall be implemented that draws between four possible outcomes.

While a button T is pressed, the circuit switches between four states name A, B, C, D (Fig. 5). These states correspond to the four possible results of the dice. Switching is so fast, that a person pressing the button generates a random state upon release.

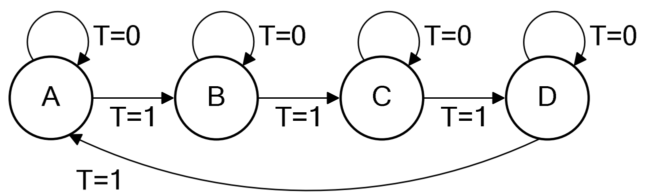

Figure 5. State diagram for simple dice

The circuit is implemented with two flip-flops storing the current state, some gates calculating the next state from the current state and some further gates calculating four outputs A, B, C, D that light LEDs giving the result of the dice (Fig. 6).

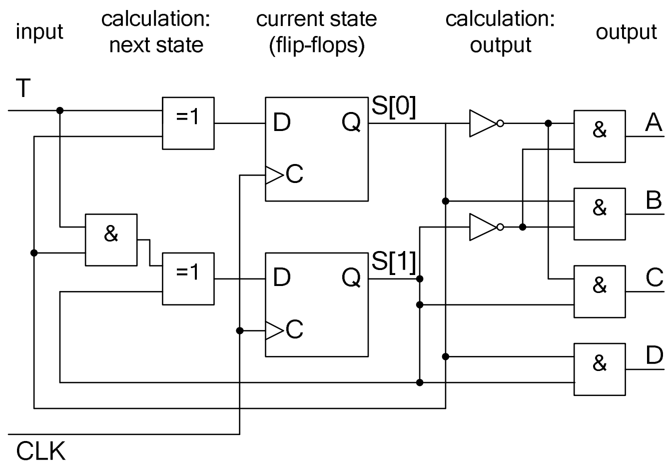

Figure 6. Circuit diagram of simple dice

The circuit is discussed with the students during the seminar and switching from one state to another state is calculated with paper and pen. A real hardware model of the dice has been constructed in a student's project. It shows the digital circuit at work and allows playing with the dice. As an addition a web based simulator is used to further demonstrate the circuit's behaviour [10], [11].

Again it must be noted that the digital circuit is working, but for a real application probably a small microcontroller would be used.

V. APPLICATION EXAMPLES

A. USB Flash Drive

Relating electronics to prior knowledge about technical systems is important to involve students in the module content. Also it underlines how the course is linked to topics outside the classroom. For this purpose application examples are used.

As an application example a USB flash drive is used to illustrate design and manufacturing of electronics. It is well suited due to several properties:

- As an everyday item it is well known to students.
- It only contains two integrated circuits with clearly defined tasks plus some small components.
- The product category undergoes rapid technological developments, especially with rising memory capacities.

B. Specification and Circuit Concept of USB Flash Drive

Different types of USB flash drives are known to students. They come as a simple mass storage or as an MP3-player with the option to store data. The design can be simple or fashionable. Optional features are a switch for write protection or data encryption.

All these options give the possibility to discuss the economic impact of the product specification with students. Which features are expected by customers? What is the cost impact? At which end of the market will the product be placed?

Based on the specification the circuit concept can be discussed. The block diagram of a USB flash drive (Fig. 7) is fairly easy to understand. A controller communicates via USB with the PC and stores information in a flash memory. Some LEDs are used as a status display.

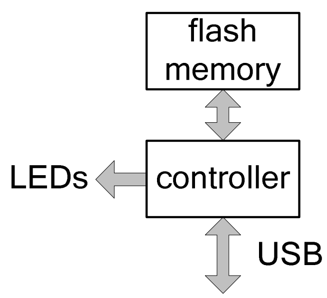

Figure 7. Block diagram of USB flash drive

With the block diagram further considerations for product design can be discussed. Often several controller can be used, some already available, others announced. Which shall be chosen? Should a small display be used instead of simple LEDs? These question will not be answered in the course, but illustrate the decisions engineers are faced during product design.

C. Design and Implementation of USB Flash Drive

Having discussed the block diagram the further steps in circuit design can be presented. Again, the students shall not learn how to perform these design steps but should be aware of the engineering tasks.

Implementation details from a commercial USB flash drive are available in a reference design [12]. This design is used to show students a complete set of engineering and manufacturing data including schematic, layout of the printed-circuit board (Fig. 8) and bill of material. A product photo (Fig. 9) shows the complete product.

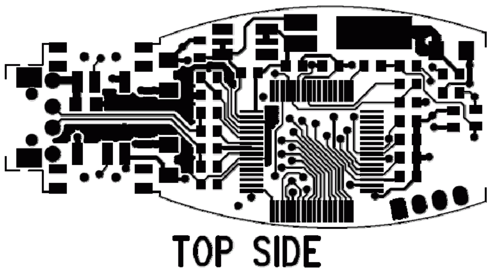

Figure 8. Printed-circuit board layout of USB flash drive [12]

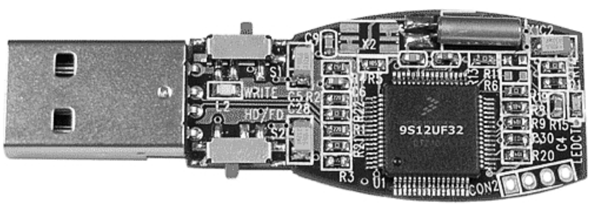

Figure 9. Product photo of USB flash drive [12]

Finally, also start-up of a prototype design is explained using the USB flash drive. In a first step an engineer will address the controller and try to read a device number and switch on/off the LEDs. Only if this works, the flash memory will be put into operation. Students can discuss to what extent parallel work of several engineers is possible and whether it makes sense trying to start-up the memory when the correct function of the controller has not yet been achieved.

D. Role of Application Examples

As discussed in chapter IV simplified examples are used for basic concepts, like transistor functionality or principle function of digital circuits. The application examples use a real design to relate the course to industrial products.

Other application examples use a stopwatch to illustrate programming of an embedded microcontroller [13] and the driver's door of a car to explain use and function of automotive bus systems.

VI. Observations and Evaluation

The experience of five years teaching electronics as a minor subject shall be given as personal impressions during teaching and discussing with students as well as a formal evaluation using a questionnaire.

A. Experience during lectures and seminar

During the course students showed significant differences in their abilities and motivation. Some students are already familiar with electronics, while others are very reluctant to engage with the subject.

This heterogeneity has been anticipated and led to structuring the course into different topics. For the weaker students it has shown to be helpful repeating important concepts several times. Students with previous knowledge were eager to discuss advanced problems.

B. Students' motivation and "weaker students"

Some more thoughts shall be given here about students' motivation and working with weaker students. Of course, every instructor wishes for students with high motivation who follow every word that is said and take the initiative to further dwell into the subject.

However, students' interest in minor subjects is often limited as they focus on the main subject of their studies. Also, they do not invest much time to compensate missing previous knowledge. While this is regrettable from the instructors viewpoint, it is an understandable approach from the students side.

Nevertheless, the experience of teaching an interdisciplinary course as a minor has been and still is very positive. Students with little previous knowledge might not reach a very high level of knowledge but often show a very steep learning curve and reach the educational objectives.

Also they might come up with interesting ideas for applications. For example, during discussing the electronic dice, a student asked whether the dice could be extended to give 20 different values. Such twenty-sided dices are used in role-playing games. So, while the student learned about electronics, the lecturer learned about role-playing games.

C. Formal Evaluation

In addition to discussions during the lab, a formal evaluation has been undertaken, to investigate to what degree students accept complex topics. In one degree program students also attend a hands-on lab and after the written test at the end of the term they were asked to judge three different lab exercises.

- A: "current–voltage characteristic" – This is a typical engineering exercise where the students measure the characteristics of resistors and diodes.
- B: "light sensor" – A very interesting exercise, where students solder a small circuit on a board (as discussed in chapter IV-A and with Fig. 4).

- C: “embedded system” – Here the students should modify C-code to program a stopwatch [13].

For the three exercises students have given marks in two categories. They should indicate whether the exercise helped for understanding the lecture contents and whether they could transfer the knowledge to real life. The value 1 means “excellent” and 5 is “poor”. Evaluating three exercises allows a better assessment of the embedded systems lab.

The results of the evaluation are shown in Fig. 10. A total of 56 students responded. As expected the interesting and entertaining experiment “light sensor” (B) gets a better evaluation than the a bit tedious “current–voltage characteristic” (A). These values are used as reference.

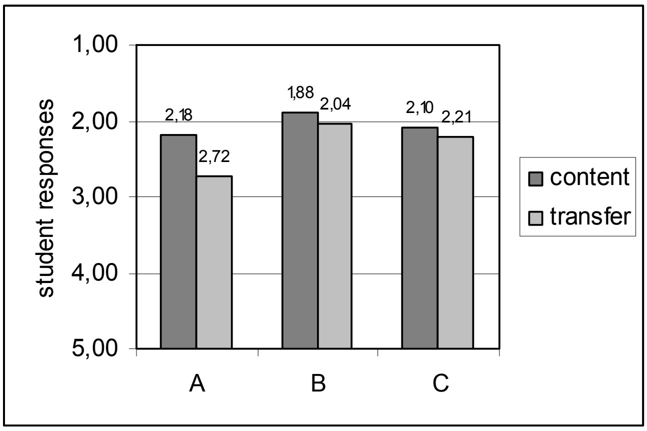

Figure 10. Evaluation of three lab exercises

The relevant result is the evaluation of the “embedded system” exercise (C). Here students without previous programming experience were a bit overchallenged. However the evaluation showed, that they accept small frustrations and give this exercise good ratings.

This becomes especially apparent looking at the different responses for content and transfer to real life. Exercise A (“current–voltage characteristic”) is accepted as giving knowledge for the exam. However, the students do not see much value of this information for their professional life. In contrast, for the “embedded system” exercise (C) students realize that they can transfer the knowledge they gained outside the classroom.

VII. Conclusion

The basic concepts of electronics have been successfully taught as a minor subject to non-engineering students. Key to the lecture is a strong focus on the educational objectives, accepting that students will not design electronics themselves. They rather have to comprehend and assess information about electronics and be able to professionally interact with engineers and computer scientists.

In addition to other technological literacy courses, the economic impact of electronics is emphasized, linking the course content to other subjects. Also this provides the application for the students, as their assessment of technology will be based on economic merit.

Organizing the course into clearly differentiated topics allowed coping with the heterogeneity of students. To students with previous knowledge, more advanced information could be given, while enabling students with little previous knowledge can catch up at the beginning of a new topic. Discussions with the students and the evaluation show that students engaged in the topic and believe they can transfer knowledge from class to real life.

Acknowledgements

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