A Case-Study Approach in Microcontroller Education

Valentina Rankovska[1]

Abstract – **In this paper an application of the case study approach in the microcontroller education is given. It is applied in the Bachelor's degree of Electronics in the Technical University of Gabrovo and it is implemented using various labkits. This approach is attractive for the students; it helps them to understand better the taught material and increases their motivation to study.**

Keywords – **Microcontrollers, Education, a Case-Study Approach, Development Boards.**

I. INTRODUCTION

The progress of the microprocessor devices and systems is extremely dynamic since the occurrence of the microprocessors in the early 70's of the XX century to the modern microcontrollers and embedded systems.

The latter are applied in a wide range of areas - home and office appliances, automobiles, media and communication equipment, industrial applications, "smart home" and others. In many areas they solve monitoring and control problems, which have been solved formerly using for instance mechanical and electrical switching systems. This explains the wide variety of microcontrollers with a wide range of functionality and also the need for studying them. Moreover - the necessity of their inclusion in the curricula of disciplines such as biological engineering, agricultural engineering, forest resources, etc. [3], [10].

There are generally two main approaches to implement embedded microprocessor systems depending on the components used:

- Based on the traditional microcontrollers (single-chip microcomputers);
- Embedded systems integrated in programmable logic – Field-Programmable Gate Arrays (FPGA), Systems-On a Programmable Chip (SOPC), etc.

Regardless of the wide possibilities, which the innovative programmable logic integrated circuits give, the traditional microcontrollers will not soon be substituted by them generally because of the following reasons:

- The high level of complexity of the programmable logic devices, the development boards and software and their comparatively high price;
- In order to achieve optimal features and parameters of the designed systems, it is recommended to use Hardware Description Languages (HDLs). To study and apply them however additionally makes the design process more complex and expensive.

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That is true especially when designing embedded systems of low and middle level of complexity, when it is necessary to achieve low cost price, when a low number of the devices will be produced, etc.

In the same time the microprocessor circuits education is plagued with problems, a result of various reasons:

- The abstract architecture of the microcontrollers and their programmability;
- The more and more complex architecture of the modern microcontrollers;
- The increasing volume of the supplied documentation;
- The adjustments and thinking of the present and future learners (students), who want to achieve quick and visible results at decreased analytical thinking;
- Additionally, to everything listed above – the presented results are for the education in Electronics. In many cases abroad microcontrollers are studied in Computer architectures-like courses, in which hardware and software of the digital and microprocessor systems are studied more detailed and for more time.

Microcontrollers have a much more complex architecture with various functions in comparison to integrated circuits that implement basic logic functions, or present simple logical nodes and blocks and can more easily be studied and researched. Furthermore, to study a block operation, for example a serial interface, is impossible without a control program for it. Or the students are required to obtain knowledge and skills both in the field of hardware and programming.

Along with all of this it is very difficult to appreciate immediately the end use of the microcontroller studied, and this further reduces the motivation of learners. One simple, but real application microprocessor unit presents not so complex electrical scheme, but is controlled by a program consisting for example of 100-200 lines (if it is in Assembler).

In the present work the application of the case-study approach in the Microprocessor Circuits course for the students in the bachelor's degree in Electronics at the Technical University of Gabrovo is presented.

II. MODERN TRENDS IN THE MICROCONTROLLER EDUCATION

In order to increase the effectiveness of the microcontroller education innovative means and approaches are continuously found and applied in terms of reducing workload of subjects, increasing prices of the development boards and kits and the above-mentioned problems in education:

- *Using complex and expensive development boards, applied in several courses* [4].

In Oregon State University a TekBots™ (a robotic base), is developed and implemented. It serves as a platform for learning in electrical and computer engineering (The students

purchase their own TekBot). Several years after a mechatronic variant for Mechanical Engineering is made and applied.

- *Possibilities to test the designed projects remotely*, via web, using development boards in the laboratory [2], [6], etc.

A good example is the possibility provided in the Siberian State University of Telecommunications and Information Sciences for remote experimentations [2]. The students (and not only as the access is free) can program the microcontroller ADuC842 on a development board, which includes peripherals, like 7-segment display, LEDs, real-time clock, digital thermometer, etc. The results could be monitored via webcam in real time. The necessary information and some examples are provided on the site.

- *Home Experimentation* [1], [2], [4]:

In the Institute of Computer Engineering at Vienna University of Technology the students studying Embedded systems, are supplied with labkits which they can borrow for a deposit of 70 euros [2]. They also could buy them if they wish. The labkits include a CD ROM with the necessary open source software and the Linux operating system. This helps them to begin working immediately without the necessity to install some software.

In the Electrical & Computer Engineering Department at Mississippi State University the students should purchase the parts kits ($65) used for the hardware labs [1].

- *A gradual implementation of a complete embedded system*, including a control unit (microcontroller), sensors and actuators – for instance a simple robot, performing elementary functions [3], [10], [11].

This variant is applicable at the gradual growing of the knowledge and the skills in studying the selected microcontroller [11]. It is possible also to use it in making the course projects and applying a team-based design approach. Then several students could accomplish different operations implemented by the robot.

III. The Case-Study Approach in the Microcontroller Education

Designing a course relates generally two aspects: structure and content, taking into account the input connections, and the methodological tools used:

- **Concerning the structure and content of the course**

Microprocessor systems course is taught in the bachelor degree of Electronics (VI semester). Some of the input connections in the curriculum are related to high-level language programming (C language), pulse and digital circuits, sensors. That is the students have already learned a high-level programming language and the design and operation principles of basic digital circuits and blocks used in microcontrollers and embedded systems. The only other subject concerning these widespread control devices and systems is Embedded microcomputer systems studied in the eighth semester, but it is optional. This means that the students should be acquainted with a general purpose microcontroller and its application within only one discipline throughout the whole course. The workload of Microprocessor systems course is 45 hours of lectures and 30 hours laboratory work. There are no seminars (as in the old curriculum), which could be used to design programs, used in the laboratory classes.

That is why the number of hours for some topics has been reduced drastically in the curriculum. They are related to the number formats, number systems conversions; phases of existence and design stages of microprocessor devices and systems, and some others. All this is in order to preserve the practical nature of the course - to have enough time for the students to learn the hardware, the programming of the microcontroller and to examine some simple case studies microprocessor devices.

The emphasis is on learning the hardware of the selected microcontroller and at the end of the course on practical aspects such as human-machine (microcontroller) interface and modern interfaces used in embedded microcomputer systems.

- **Concerning the used methodological tools**

The Microprocessor systems education for over 10 years is based on the widespread Microchip's 8-bit general purpose microcontrollers PIC12/16/18 which have a number of advantages [1].

Regarding to the programming languages studied at the universities and colleges various strategies are applied: using an assembler and a high-level language or only a high-level language (mostly C). In the presented course an assembly language and a C language are studied. Approximately two thirds of the workshops an assembler is studied and implemented and about one third of the hours - C. The students are already familiar with C from a former discipline. Presented in [1] study shows that this approach is correct.

The first four hours of the labs are devoted to the features and usage of the free integrated design environment MPLAB IDE (Microchip) and the software design stages. Immediately after that the students are involved into the realization of simple designs with simple assembler programs. The aim is to demonstrate them elementary microcontroller applications such as using buttons and LED indication. A variety of hardware tools is used: from simple models developed in the laboratory (Fig. 1 and Fig. 2), to more complex development systems containing a microcontroller and various peripherals and hardware debugging tools like In-Circuit Debuggers (ICD).

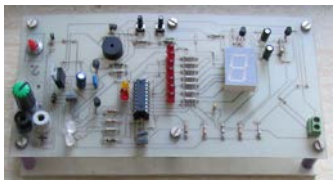


Fig. 1. Labkit 1 (with PIC16F84)

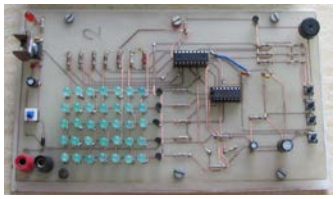


Fig. 2. Labkit 2 (with PIC16F84)

Some examples used in the Microprocessor systems lab: a development system with Microchip's ICD, and a development board BIGPIC5, produced by Mirkroelektronika [9] (Fig. 3).

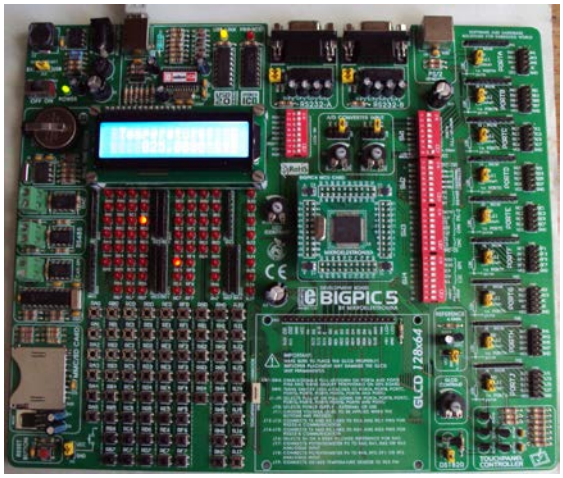


Fig. 3. BigPIC5 development board with PIC18F8520

Initially, in introducing the assembly language, it is appropriate to use ready models. The purpose is to allow the students to test their own elementary programs.

Thereafter the case study approach is applied, beginning with simple circuits to more complex projects, although the students are still not completely familiar with the hardware and the features of the microcontroller. This is done mainly in order not to lose the motivation of the students, because the consistent study of the individual microcontroller blocks operation (an old approach) seems an end in itself, abstract and not interesting for them.

Initially the students begin with using model boards (breadboards), on which they assemble simple circuits. The next task is to design and test simple programs which control the circuits (Fig. 4). The goal is to not accept the hardware as something given for granted, and to acquire skills to design, assemble and test an electrical schematic diagram.

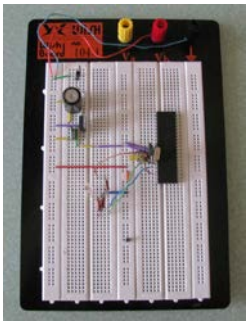
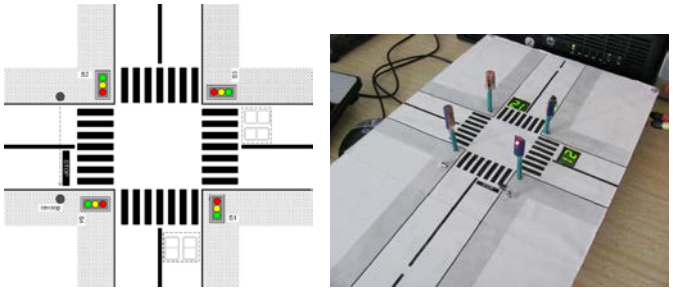


Fig. 4. The first breadboard project (with PIC16F874)

Traffic Lights Control System

It is appropriate to use the traffic lights as a case study in education [8], [12], [13]. It is an object well known to the students, and on the other hand relatively easy to control.

Fig. 5 shows a model of traffic lights used in the Microprocessor systems course. It also includes functions like displaying the time left before changing the state of the traffic lights and detecting a stopped car in a street with low traffic. The detection is made by an infrared LED and a photodiode (shown in the left in Fig. 5 a).



a) b)

Fig. 5. Traffic Lights control with PIC16F627A

The control of the model can be configured for different variants: as an intersection of streets with equal priority where the time for the green and the red light is one and the same; when the traffic in one of the streets is with a higher priority (with more time for the green signal from that of the red); using the function for detecting a stopped vehicles.

There are possibilities to implement various algorithms: making time delays of different durations, generating control signals, controlling a 7-segment display, receiving and handling information from a sensor, etc. More complex variants are also possible such as changing the time durations according to the different parts of the day (for instance taking into account peak traffic intervals) and only a flashing warning signal at night, weekends, etc.

A DC Motor Control

Stepper and DC motors for low power applications are applied in a wide range of areas. Fig. 6 shows a DC motor controlling model based on PIC12F683. There are two goals: to control the object via a microcontroller and to present the features of the low-end microcontrollers of Microchip which have a low number of pins. There is also a potentiometer that can be used to change the rotation speed of the motor and a general purpose button, which can be used for example to change the mode of operation (e.g., the speed of the motor). These features also allow a variety of simple control algorithms implemented in C or Assembler.

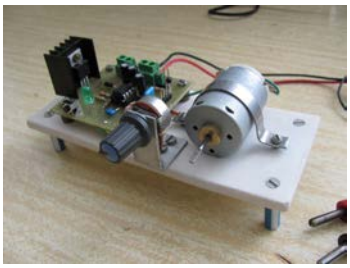


Fig. 6. A DC motor control with PIC12F683

An Electronic Badge

An effective real device, causing an interest among the students, is the Electronic badge (Fig. 7), realized with the PIC16F876A.

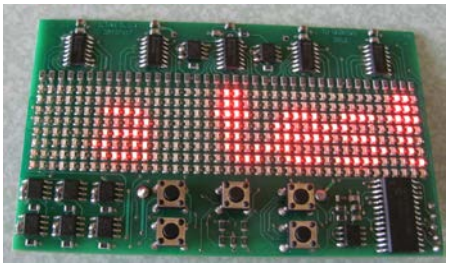


Fig. 7. An electronic badge with PIC16F876A and ICSP

The indication is implemented as a LED matrix 8x40. There is an opportunity for ICSP programming, allowing the students to easily reprogram the microcontroller to display different symbols.

The badge has five buttons that can be used for different operation modes and sub-modes. For example, initially it is shown to the students a ready, more complex operation algorithm, comprising two main modes: displaying information stored in the EEPROM with a lower or a higher speed, and changing the information in the EEPROM memory by using a kind of a stored character set. Then they can reprogram the microcontroller for different variants of simpler algorithms controlling the LED matrix.

Future work

It is necessary to enlarge the opportunities for the students to work alone and to increase the time for the practice. Since it is impossible to increase the time of the discipline, it is possible to give them the opportunity to work at home. It is difficult to supply them with labkits for home work in our conditions (either to borrow, or to buy them) because they are expensive. But it is possible to allow them to use the development boards and test their projects remotely, via a web server. That is our further goal, together with enlarging the variety of the boards used.

IV. Conclusion

In this paper an application of the case study approach in the microcontroller education is given. It is applied in the Bachelor's degree of Electronics in the Technical University of Gabrovo. It is implemented using various labkits, which number and variety should be increased. This approach is attractive for the students; it helps them to understand better the taught material and increases their motivation to study.

Of course it is not the only thing which should be done. The students are also supplied with course materials, which are an object of a continuous improvement [14].

The next step is to give them the opportunity to use remotely a "web-lab" at home.

Acknowledgement

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