

## Teaching Microcontrollers by Means of Industrial Processes

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**Abstract.** This paper presents a modality to shorten the gap existing between the industrial requirements regarding the qualifications of future engineers and the actual academic provided education. We present the case of Embedded System laboratory developed at Computer and Software Engineering Department, Faculty of Automation and Computers, “Politehnica” University of Timisoara, Romania. The results are very encouraging both from students, but also different employers’ point of view.

**Keywords**—embedded systems, undergraduate, laboratory, industrial approach

### 1. Introduction

Embedded systems industry has become one of the most spread and profitable industries. Actually, the present cars are but a complex computer, aircrafts are relying on a plethora of interconnected computers and so on. In this regard, the most important employers are urging the universities to adjust their curriculum so as to prepare the future engineers for the needed tasks. The tendency in the late years is to obtain a highly qualified engineer, ready to assume complex tasks, even from the final years of academic studies. The corporations are investing different amount of finances to actually train the students. In this way, the coaching period in the company is minimized as much as possible. It’s actually a double benefit: the students have state-of-the-art industrial-oriented knowledge and hands-on experience, while the employers obtain high-qualified employees.

Such a problem of adjusting the academic curriculum has been previously defined as being of “skill mismatch” importance [1]. In other words, there should be a continuously curriculum adjustment to the needs of industrial requirements. Different universities have undergone program modification just to meet with this problem. We can note the case from [1] where important steps and methodologies are presented just to condense the gap between the two systems. Other interesting solutions are presented in [2] and [3]. The conclusion presented in [2] is mandatory to be taken into consideration: the experience that one is receiving in the industrial domain is holistic, while the offered training in the academia is characterized by a systematic approach. So, a combination of the two systems should be employed by a first class instructional system.

This paper presents the development of an industrial-oriented Embedded Systems Laboratory. Continental Automotive Romania, part of Continental AG [4] was interested in developing such a laboratory and invested in the needed infrastructure. The infrastructure of the laboratory is presented in Figure 1 and also Figure 2. Every working point (out of a total of 7) is supplied with a TG120 Function Generator, a Tektronix TDS1001 Oscilloscope, a Mastech DC Power Supply, a Janatech Logic Analyzer, a Code Warrior IDE license, a ZK-S12-B board, a USB to CAN device and a license for PcanView (associated with USB to CAN device). The ZK-S12-B board is equipped with an 80 pins Freescale MC9S12DJ256 microcontroller.

This paper is structured as follows: section II presents the used methodology; section III is concerned with the laboratories' content. The following part of the paper offers an experimental study regarding the impact of the employed methods during the lab and the last section offers some conclusions and future work.

## 2. Used Methodology

A common process used in the development of embedded systems takes into consideration the following steps:

- Specifications phase: the customer presents the desired concept of the future product. Different discussions are taking part so as to finally agree upon all the details.
- Development phase: the company is developing the product as agreed in the first point.
- Testing part: can be viewed as part of the Development phase, but for pedagogical reasons, we established to mark it as a special segment in the presented process.
- Delivery stage: the product is complete and can be supplied to the customer. Some change requests are still possible in this part.

The above mentioned process has been used during the lab sessions. Every laboratory is targeted on a certain theme, with precise specifications. These specifications will be presented to the students. Following next, they will have to proceed to the development phase by using datasheets and their lab papers. A very important part is the testing stage. Every student will have to monitor the obtained results and will have to write them down on their hand-outs.

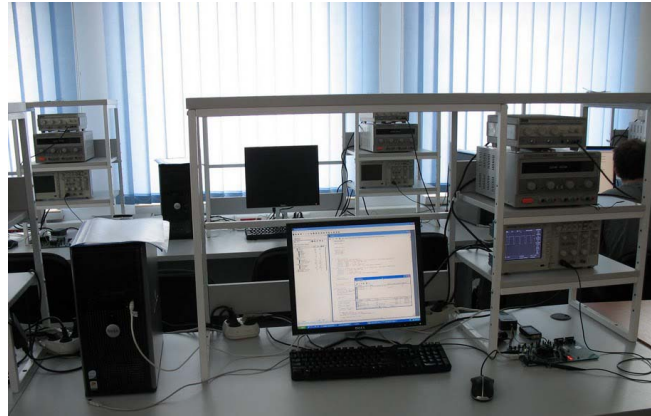


Figure 1. Example of a working point

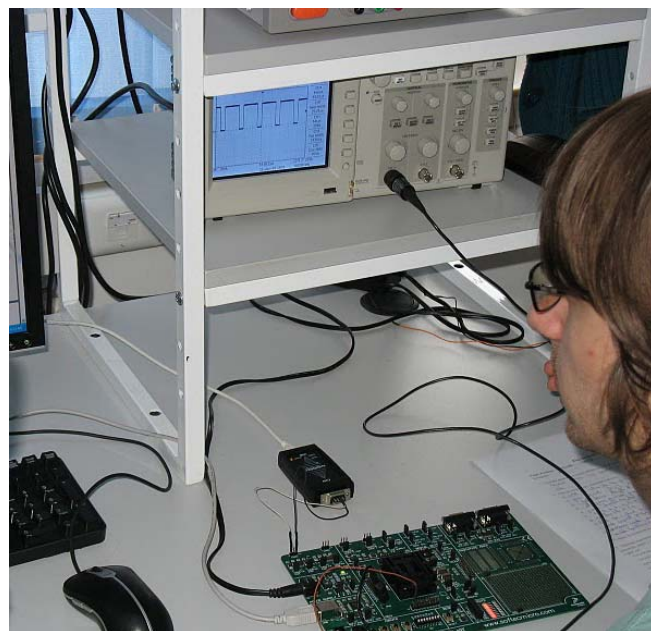


Figure 2. ZK-S12-B board during a lab session

In order to actually illustrate this process in a given example from a certain lab, let us discuss the system which was used during the sessions and then detailing the appliance of the above mentioned methodology.

## **2.1. Applying the methodology on the S12 system**

Giving the fact that S12 microcontroller is widely spread in the development of equipments based on embedded systems, together with the industrial partner, we decided to work on ZK-S12-B board

This board has a large range of features, namely two CAN connectors with transceivers (MC33388), header connectors with all microcontroller signals, LQFP ZIF socket, built-in USB to BDM interface (USB 2.0), power supply section (3.3 V or 5.0 V), two LIN connectors with transceivers (MC33661), two RS-232 connectors with transceivers, eight user DIP-switches, eight user LEDs, potentiometer for analog input, four push-buttons, reset supervisor circuitry with push-button, prototype area [5]. The communication between the board and the personal computer is built using a CAN bus transmission (Figure 2). The device that connects the board and the PC is a USB to CAN adapter from Systec Electronic, namely USB-CANmodul. This equipment is supplied with a software tool, PcanView, that can send different hexadecimal messages on the CAN bus.

The microcontroller is functioning based on a piece of software that we developed in such a way that can accept requests through the CAN bus, perform a certain required task and send back the results over the same media. So, the microcontroller is equipped with a software that can receive requests from the PcanView via CAN bus; when a certain request is received, a particular task will be performed. This task is related to the students' activity, namely programming the ports, the analogue-to-digital converter, PWM or interrupt module, communicating with a sensor and so on. Next, the microcontroller will send back the results obtained by performing the tasks.

According to the received response, every student will determine if the task has been correctly programmed or not. This response can be visualized according to the task that should be developed, therefore the results can be observed on PcanView or on the oscilloscope, depending on the peculiarities of each lab.

The concept based on sending/receiving messages is implementing the proposed methodology, being specific to the industrial process of developing products based on embedded systems. In the same time teaches the students how to use and program a microcontroller because they have to understand the specifications and then study the microcontroller in order to complete the development part. In order to test their tasks, they use the message-based method. Every message is in hexadecimal format. Every lab will have its own specific set of messages both for the sending and receiving parts.

In other words, the students will have to understand the functioning of a certain part of the microcontroller and will implement and test the correct functioning of their tasks on an industrial fashion.

Following next, we will present the content of each laboratory (Table 2) and also a detailed example of sending/receiving messages.

## **3. Content of Laboratories**

### **3.1. Laboratory 1**

The first lab is oriented on the TG120 Function Generator, Tektronix TDS1001 Oscilloscope and Janatech Logic Analyzer. The aim of this lab is that students have to gain hands-on experience using these equipments. Such equipments are used during the development and testing parts of different projects based on microcontrollers. The allocated time for the lab is 2 hours (Table I).

TABLE I. LABORATORY CONTENTS

Objective	Lab content	No. of hours
Embedded-related instrumentation	Every student should become familiar with different Embedded-related instrumentation	2
HCS12 Ports	The students will be introduced to the industrial-related methodology of developing an embedded-related application	2
HCS12 ATD converter	The functioning of ATD converter will be tested by means of send/receive messages	2
HCS12 PWM	The obtained signal will be monitored on the oscilloscope	2
HCS12 Interrupts	The number of interrupts will be monitored as a message received during the testing part	2
Distance monitoring	Application using HCS12	2

### 3.2. Laboratory 2

This lab introduces the presented methodology used in industrial applications and offers a first glimpse in the working details with PcanView, Code Warrior and hexadecimal messages. During this activity, the students will have to understand how the ports of S12 microcontrollers are functioning and how they can be configured. The testing part is based on sending hexadecimal messages and monitoring the received response. The general format of the request for this lab is Digital\_Read Port Pin whenever we want to read a certain pin from a port or Digital\_Out Port Pin Value when we intend to write to a port.

#### Examples

1) Suppose we intend to send the following request (message): 02 42 07 01. This means that on port 42 (B), pin 07, we send value 1. If we have correctly configured the programming part of the ports, the students will have to observe that LED number 7 has been turned on. In this case, the development has been realized in a proper manner. The test is successful. Otherwise, the entire process has to be reapplied from the beginning

2) We intend to test if we can read from port B which has been configured as output port. In this case, we will send in PcanView the following request: 01 42 01. This means that we want to read from port 42 (B), pin 1. The response will be an error because port B is configured as an output port.

### 3.3. Laboratory 3

This lab is aimed at understanding how the analogue-to-digital converter is functioning. The same process based on requests and responses is applied. The students will have to configure the proper registers of the ATD converter and after that, test their tasks using PcanView software and suitable messages described in the lab paper.

### 3.4. Laboratory 4

This laboratory session is presenting the functioning of PWM module from S12 microcontroller. The students will be given a programmed code and will have to understand how to configure the PWM module, based on this code. It's actually the opposed process that has been applied to the previous laboratories. Such a process is applied whenever it is necessary to address a problem report concerned with topics from the project that are not familiar to the developer. In this way, the students will come to understand how to cope with a part of a complex project that is not familiar with and in the same time how to solve such a challenge. The general format of the request for this lab is PWM\_Out PWM\_Channel Period Duty\_Cycle. The response will be the generated signal and it will be monitored on the oscilloscope.

#### Examples

3) Code example for setting the PWM module:

```
void set_pwm(unsigned char ch, unsigned char per, unsigned char dc)
{
    unsigned char pwm_e;
    pwm_e = PWME;
    switch (ch)
```

```

{
  case 0:
  {
    unsigned int dc_v;
    PWME=pwm_e&0xFE;
    if (!per || !dc) break;
    dc_v= per * dc / 100;
    PWMPER0=per;
    PWMDTY0=dc_v;
    PWME=pwm_e|0x1;
    break;
  }
}
...

```

4) Suppose we intend to send the following request (message): 04 00 64 19. This means that we intend to generate a PWM signal (04) on channel 0 (00), having a period of 100 ms and a duty cycle of 19%. Using the oscilloscope probe, we can test if the obtained signal is correct or not. If the signal's parameters are not accordingly to what we expect to be from the request's values, the programming part is incorrect and is will have to be again addressed.

### 3.5. Laboratory 5

This lab is centered on the interrupts module from MC9S12DJ256. Every student will have to examine how to handle an interrupt from port P. The testing part will illustrate on PcanView the number of interrupts introduced from pull-up devices connected to port P.

### 3.6. Laboratory 6

This lab is a final one and the goal is to present the students how to work with MC9S12DJ256 microcontroller in a real application. In this regard, GP2Y0A21YK0F proximity sensor is used and the distances to certain obstacles are obtained. Being a final lab, the students will have to work on their own without tutor's help or assistance.

## 4. Obtained Results

One of the main challenges in assessing the results of applying the industrial methodology to the teaching process in the undergraduate technical studies was to establish the impact this action had both on students and future employers.

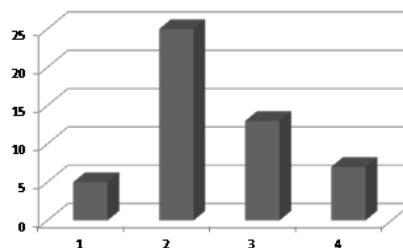


Figure 3. This lab made me understand the functioning of a microcontroller: 1 – strongly agree; 2 – agree; 3 – neutral; 4 – disagree

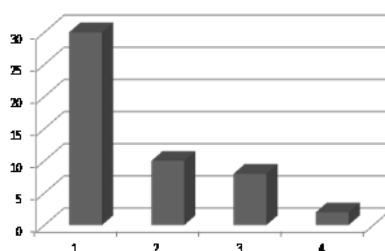


Figure 4. This lab made me to understand the methodology of developing embedded systems: 1 – strongly agree; 2 – agree; 3 – neutral; 4 - disagree

In this regard, a number of 50 students agreed to participate in a survey regarding the lab content. We aimed at two main points: understanding the functioning of a microcontroller and understanding the methodology of developing embedded systems. The results are presented in Figure 3 and Figure 4.

It can be noted that the students' feedback is very promising. Most of the students answered that this laboratory prepared in a proper way for their future career and activity as an engineer. The industrial partner opinionated that the students are better prepared to face the industrial processes used in the development of products based on embedded systems.

## 5. Conclusions

This paper presents a modality in which the "skill mismatch" problem can be addressed. It proposes a way of organizing the laboratory content based on industrial processes.

Our main idea was to shorten the gap existing between the academic modality of teaching the students and the industrial requirements. Based on the received feedback, we tend to say that we managed to implement a modality by which the gap can be surmounted.

## 6. Acknowledgment

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