

**AC 2010-294: A NOVEL TEACHING APPROACH FOR UNDERGRADUATES IN  
MICRO-CONTROLLER APPLICATION COURSES**

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# A Novel Teaching Approach for Undergraduates in Micro-Controller Application Courses

## Abstract

The micro-controller application technologies have become more and more important for engineering students, especially with respect to the field of Electric Engineering, in the age of knowledge-economics. This paper presents a novel teaching approach for undergraduate students in the micro-controller application course. The presented approach could not only induce the interests of students in the micro-controller application technologies, but also improve the design capabilities of students in the micro-controller application. The handy pre-packaged experiments of hardware and software program designs are also incorporated in the teaching process. The results of student evaluation conducted before and after applying the presented approach demonstrated the fact that it is efficient and successful.

## Introduction

The purposes of micro-controller application course for undergraduate-level students at universities in Taiwan are that the students should learn to grasp the essential concepts of operational principle of micro-controller devices and its applications for both hardware and software design. In Taiwan, there are many world-class IC design houses as well as semiconductor foundries which mandate high manufacturing efficiency and advanced design capabilities. Given this context, it is obvious that the students in Taiwan are enjoying an excellent learning environment for them to develop the skills of micro-controller application.

In the past, a number experiment kits were designed for respective aspects of the course<sup>1-5</sup>. Some papers were aimed at teaching methodology<sup>6-8</sup>. Carina Savander-Ranne and et al.<sup>6</sup> presented a redesigned implementation of *Active RF Circuits* based on interactive teaching methods as well as the impact of these changes on student learning. An innovative systematic and comprehensive approach to teaching digital system timing for graduate-level computer engineering courses at Oregon Health and Science University was proposed by John D. Lynch<sup>7</sup>. Additionally, a proposal which allows students to use specially-developed hardware kits to perform real-life experiments in their own homes where they could analyze given problems, create appropriate solutions, and validate the actual circuit in a distance learning context was presented by Juan P. Oliver and et al.<sup>2</sup>.

The traditional teaching process has been centered around the principle of enlightening by engaging primarily the paper study first and then follow up with an experiment course for students to practice hardware and software design. The downside is that students could be hard to get a clear realization concerning the principle of micro-controller operations during the instructing process. In the mean time, during the experiment class, the principal instruction of micro-controller must be repeated, resulting in lower learning efficiency of students.

This paper presents a more efficient teaching approach which would both induce student's interests and make the course period more compact. That means the students could develop high-performing technical skills in the micro-controller course within a shorter class period. The teaching approach had been applied in a micro-controller course for undergraduate students at Mingchi University in Taiwan. The evaluation results from the students measured before and after using the approach are very encouraging which demonstrate its efficiency and success.

### **The goals of micro-controller application courses**

The goals of presented teaching approach for micro-controller application course are that students should gain knowledge of the principle of micro-controller operations and could design a real-world application project based on micro-controller topics. The period of the micro-controller application course at Mingchi University in one semester is a total of 51 hours (3 hours per week times 17 weeks.) The syllabus of this industry-oriented micro-controller course is described in Table 1. We teachers have already integrated lectures on theory with lab experiments in a single course for undergraduate engineering students.

By understanding the operating principles of micro-controller, students are expected to learn hardware architecture of a micro-controller and related software programming. A popular industry-grade 8-bits micro-controller, HT46R24, was selected as the lecturing target. The features of HT46R24 contain a rich set of functionalities such as pulse width modulator (PWM), analog to digital (A/D) converter, interrupts, I<sup>2</sup>C bus serial interface, halt and wake-up mode and watchdog timer (visit the website [www.holtek.com.tw](http://www.holtek.com.tw) for more details). These are the most important features of a micro-controller that the students have to know it.

The second goal of the course is that the students should acquire the ability to design a real-world application project based on some micro-controller topic. The technologies such as hardware circuit design, PCB layout and software design are all prepared by the teacher for training students in the class. Students are expected to design and complete a useful project such

as a timer, a wireless remote controller, an LCD display controller, a music box, etc. which accounts a significant portion in the final grade.

The concept of industry-oriented application is deeply embedded in the design of the course. We have consulted with industry leaders about what skill set is essential for equipping students who are about to enter into the workforce. According to their viewpoint, the students should possess both design and debugging abilities from initial circuit design, PCB layout, all the way to software programming. Hence the exercise of practical experiments plays an important role in the teaching process. We have thus figured out the goals of the micro-controller application course; based on these established goals, a novel teaching approach and a new teaching content have been developed to be described next in this paper. Please refer to Table 1 for the course syllabus.

Table 1 Syllabus of an industry-oriented of micro-controller course.

Sections	Description	Contents
Principle of micro-controller	Students should gain in-depth knowledge of the principle of micro-controller operations. An off-the-shelf micro-controller, HT46R24, widely used with an industrial specification, is used to prepare lectures for undergraduate students. All contents of the course are listed on the right side. Two tests on micro-controller principles are required which account 30% in total grade. The experiment laboratory occupies another 40% of total grade. Students should practice each experiment unit for understanding the principle of micro-controller technology.	<ul style="list-style-type: none"> <li>● Hardware structure of micro-controller</li> <li>● System architecture</li> <li>● Program memory</li> <li>● Data memory</li> <li>● Special function registers</li> <li>● Input/output ports</li> <li>● Timer/event counters</li> <li>● Pulse width modulator</li> <li>● Analog to digital converter</li> <li>● Interrupt</li> <li>● I<sup>2</sup>C bus serial interface</li> <li>● Halt and wake-up mode</li> <li>● Watchdog timer</li> </ul>
Product design based on micro-controller application	Students should develop the ability to design and implement a real-life project based on micro-controller application as the final report which accounts for 30% of total grade. The techniques of circuit design, PCB layout and software programming are all utilized.	<ul style="list-style-type: none"> <li>● Timer</li> <li>● Extra-sonic distance measurement</li> <li>● Wireless remote control</li> <li>● LCD display control</li> <li>● Music box</li> </ul>

### Course Structure and Teaching Process

The course structure of micro-controller application is shown in Figure 1. The nine categories within it consist of what we consider as the most important skills for students to learn: LED control technique, interrupt control technique, LCD display control technique, music control technique, watchdog technique, A/D control technique, PWM control technique, wake-up

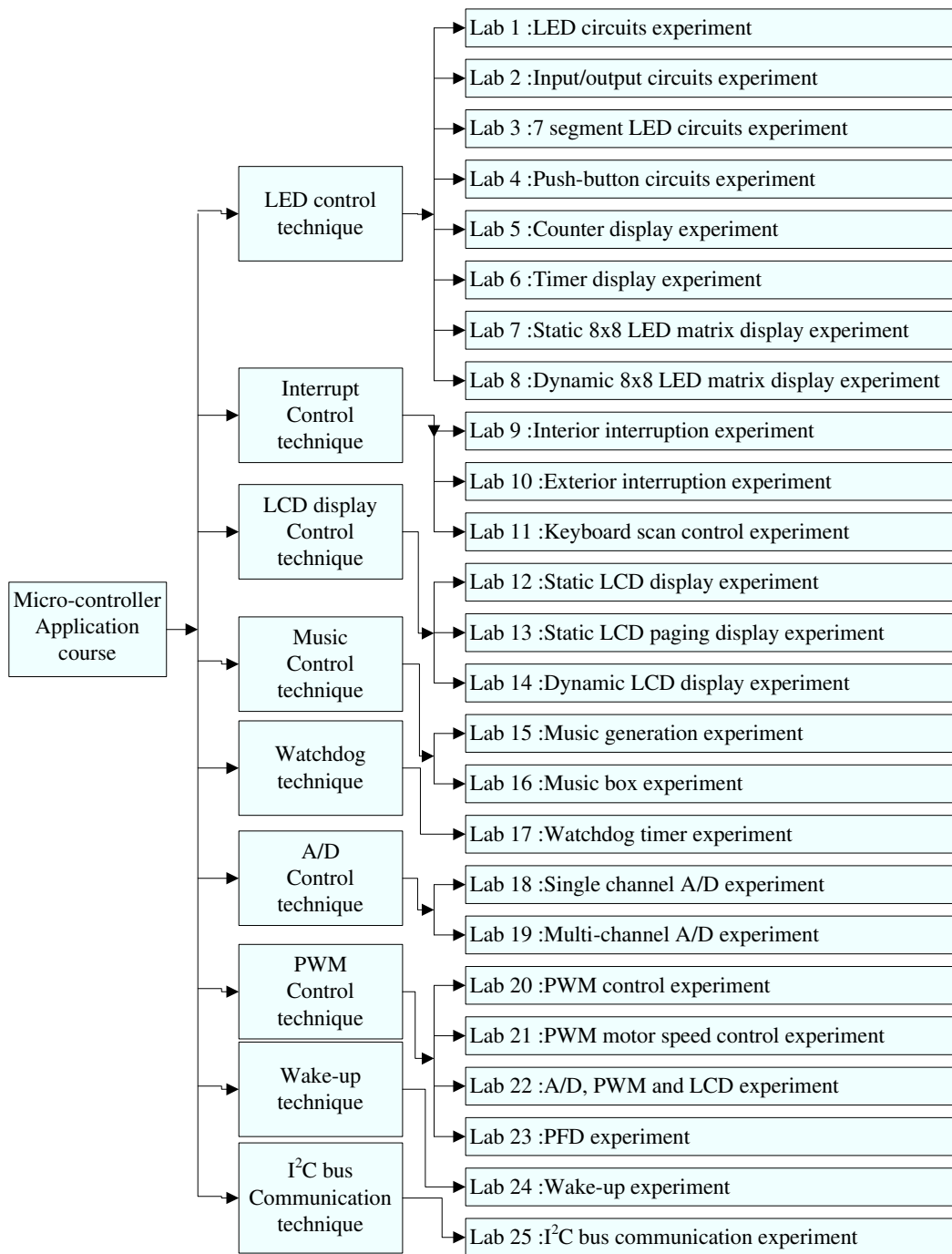


Figure 1 Course structure of micro-controller application.

technique and I<sup>2</sup>C bus communication technique. Totally 25 laboratory experiments were designed for hands-on practicing. These contain all the most significance principles which should be known by students.

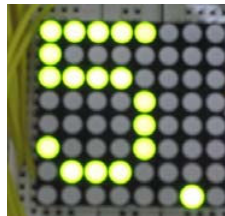
Teaching contents per each lab are listed in Table 2. We intended to combine the lecturing section with the laboratory experiment as an integral unit to ease the learning experience of students. The result is that 10 teaching items are addressed in each lab. Firstly, the goal of experiment is introduced, and then the action of the experiment is clearly described. For example, sometimes photographs are provided to aid the students to visualize the action of experiment. As illustrated in Figure 2 (a), which shows the action results of Lab 7 and Lab 12, and (b) for Lab 7 which demonstrates a static 8x8 LED matrix display experiment. Note that both pictures in Figure 2 (a) and (b) are clear and of high quality to show what the results of experiment should be.

Figure 3 depicts the flow of teaching steps in this proposed approach for course of micro-controller application. We will give a lecture about the hardware structure of micro-controller in the beginning, and continue on in performing a sequence of incremental experiments to build up students' pertinent knowledge base. The instructing lecture of experiment will be continuously given through all experiments. At the end, the project examples in micro-controller application are presented for training students who would own design capabilities for micro-controller application. A final report which submitted by students is required for evaluation of the grade. Figure 4 describes the teaching practice flowchart of each experiment. Note that in here we focus on lecturing the relationship between hardware and software. It is the most important matter we need to do for giving students a deep impression and solidifying their knowledge.

Some product oriented project examples were designed in the teaching contents to inspire students to apply the micro-controller technology to the real-world products. Figure 5 has shown the extra-sonic distance measurement system which could measure the distance between 20 mm up to 3,000 mm with resolution of 1 mm. The students need to know how to design the circuit and how to layout the PCB. To complete the project, the students have to design the software program and learn how to debug the code.

Table 2 Teaching contents of each lab in micro-controller application course.

Item		Description
1	Goal of experiment	It is necessary to mention the theme for each experiment so that students can understand what purpose of the topic is.
2	Action of experiment	The descriptions of action of experiment were presented for students to check the correctness of experiment results. At same time, the action could help students to realize how the hardware and software work together to finish a function of goal.
3	Relation knowledge of experiment	The knowledge which is necessary in the experiment is introduced in this part. An excellent impression on students could be made when the pertinent knowledge of experiment was comprehensively instructed. For example, we have to lecture about the frequency of each musical scale in the music generation experiment. The students also need to know how to generate the sound by performing program control.
4	Circuit diagram of experiment	The circuit diagram tells students how to connect the hardware. The circuit will be jointed with wires by students in the laboratory experiments.
5	Program flowchart of experiment	Program flowchart describes the working flow of software. The flowchart could help students to internalize how the program works.
6	Program of experiment	The program is designed and coded in C language. We list the sample program of experiment in this section.
7	Function description of program	The function will be illustrated step by step for each software instruction presented in this part of lecturing.
8	Steps of experiment	We describe the experiment process in a step-by-step manner.
9	List of experiment elements	We list all materials which will be needed in the experiment for teacher and students to be efficient in working thru the steps.
10	Homework	Some homework will be prepared for training the students.



(a)



(b)

Figure 2 Examples of expression of action in experiments. (a) 8x8 LED matrix display experiment, (b) LCD display experiment.

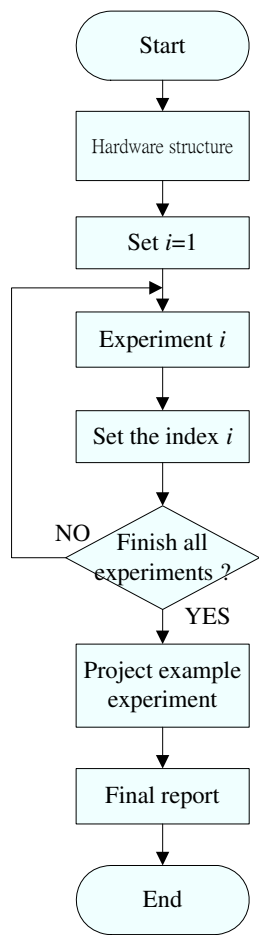


Figure 3 Teaching process of the course of micro-controller application.

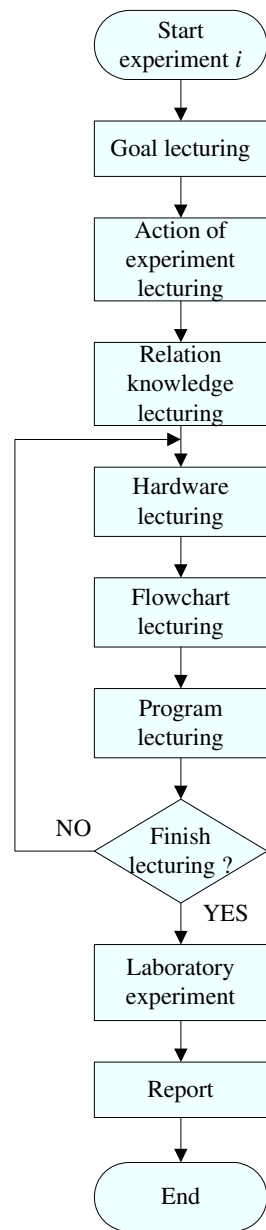


Figure 4 Teaching practice of each experiment.



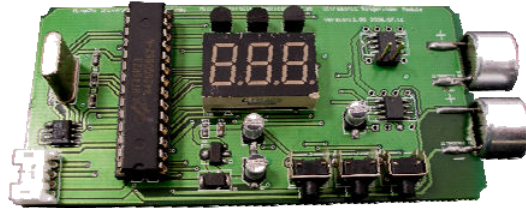


Figure 5 Photograph of the extra-sonic distance measurement system project.

### Results and Discussion

The teaching approach presented in his paper has been formally conducted into the undergraduate course at Mingchi University in Taiwan. The length of the course is one semester which consists of totally 51 hours (3 hours per week times 17 weeks). This new teaching approach was applied to the new semester in year 2008. We have collected the empirical data for the most recent three years: 2006, 2007 and 2008 for us to evaluate the performance of this teaching approach.

Figure 6 shows the total number of students in the class of micro-controller application course at Department of Mechanical Engineering in Mingchi University in recent three years. It is obvious that the total number of students has a steep growth in the year of 2008. That implies the students had shown more interests in this class than previous years. We could presume that the presented teaching method is a success because more students expressed desire to learn the technology of micro-controller.

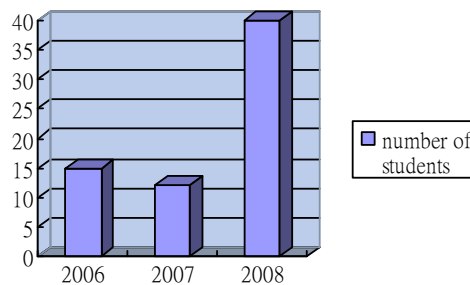


Figure 6 The total number of students in the class in recent three years.

Figure 7 depicts the average score of students in recent years. It can be seen also that obviously the average score in the year of 2008 is higher than in the year before. The results demonstrate the efficiency of learning results of the students in the year of 2008. In here we also find that the average score of final project performed by students in year 2008 is higher than previous years of 2006 and 2007. At the same time, we also discovered that the students who spent more time on the final project in the new teaching method. That implies the students get more interests in the micro-controller application course than those years before 2008.

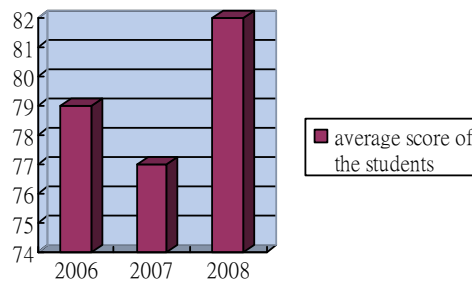


Figure 7 The average score of the students in recent years.

Table 3 The questions of feedback questionnaire of the course of micro-controller application.

Question	Scale(0=Do not agree, 10=Agree very much)
Do you think the course design which is helpful to you?	
Do you think the learning process is efficient?	
Do you think the teaching process can induce your interests?	

The students had been asked in a feedback questionnaire to evaluate the course design and teaching process at the end of the class. Table 3 lists the questions of feedback questionnaire for the course of micro-controller application; given the scale of each item from 0 to 10 (Here 0 implies “Do not agree” and 10 “Agree very much”.) We had three questions to ask the feeling of students about the course at the end of semester. The first question, “Do you think the design of the course is helpful to you?”, because we would like to know how helpful is the course for students learning the micro-controller technology. The second question: “Do you think the learning process is efficient to you?”, because we would like to know the learning efficiency of the students in the learning procedure. “Do you think the teaching process could induce your interesting?” is the last question in which we want to know whether the design of the teaching process could induce student’s interests or not. The results of answers to questionnaire could be used to modify the teaching contents and teaching process to be more expedient to students.

The evaluation results of the feedback questionnaire of the course by students are described in figure 8. The results show that the students gave a higher score when the new teaching method was applied.

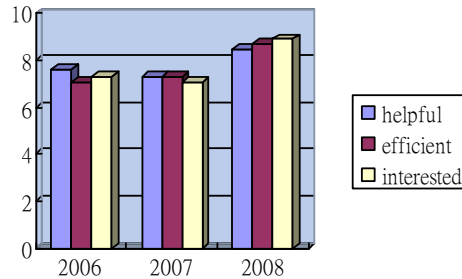


Figure 8 The evaluation results of the course by students.

## Conclusion

A novel teaching approach for undergraduate study of the micro-controller application is presented in this paper. We integrated the lecturing instructions with lab experiments in the teaching process for a deeper impression and realization to students. The course contains the lecturing of project examples which can be the real-world products of application in the market. Both hardware and software trainings are implemented in the course. The high evaluation results of the grade by the students are presented to demonstrate the performance of the teaching approach. The benefits of the presented teaching method are that we obtain a shorter period of the micro-controller application course and, at the same time, achieve higher efficiency in teaching the course. The scores of the students are obviously elevated when the presented teaching approach is applied.

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