FPGA/Embedded System Training Kit Targeted to Graduate Students Towards Industry Level Short Training

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Abstract— **The wide application of embedded systems become a trend in the post-PC era. In the College of Engineering, Universiti Tenaga Nasional (UNITEN), embedded system education is one of the characteristic subjects, so "practical training" is the brand new characters as the most important process in the embedded system education towards industry-geared training. The training is an on-campus process toward gaining the practical experiences which are suitable for the real engineering design or IT related companies, especially so for the students without past work experiences. Practical training using single industrial grade kits on embedded system has expanded to most Electrical and Electronic Engineering for both undergraduate and graduate students. The course has been updated towards industry employees training especially to meet their design aspects. Embedded systems course have been deployed in numerous fields which have different requirements of embedded systems architecture. In this paper, a project-based learning strategy using single training kit is proposed as a pedagogical tool for embedded system education. The proposed project-based learning can motivate students to integrate and formulate the multi-disciplinary knowledge previous learned into a real-world embedded system project development. The course development focused on lecture–lab integration and laboratory learning. Course and lab activities were designed using a learning model that captures lower-order and higher-order cognition levels of Bloom's taxonomy.**

Keywords-Embedded Systems, FPGA, Training KIT, and Graduate education.

I. INTRODUCTION

Many universities offer introductory courses that focus on microcontroller-based systems and embedded programming using different training kits. Advanced courses often do not have a common focus and are not available until the graduate level, leaving a gap in training undergraduates. The courses are integrated through a coordinated set of learning outcomes and the use of related tools and technologies. In addition, the courses are designed with special attention to integrating the lecture and laboratory experiences, making explicit the relationships between lecture topics and laboratory exercises.

A single kit can provide training for various domains such as programming language, digital system (hardware descriptive language) and basic image processing. It comes with an option for future updates. Since the training modules are designed with the objectives to reduce learning efforts and industry relevant, it will benefit many students.

II. COURSE OVERVIEW

The embedded system is a science of the theory and practice regarding as equally important. Figure 1 shows the overview of the course materials related to the training courses. A tutorial course will introduce the domain knowledge and common research issues to students. Programming skills training is necessary when learning embedded systems. It is a good method to practice programming skills through the laboratory (*Lab*). To practice Labs needs an auxiliary tool, *target platform*, a prototype of the hardware of embedded systems. ARM architecture [6] is very popular for embedded system products. The programming skills are necessary skills for advanced research in the future.

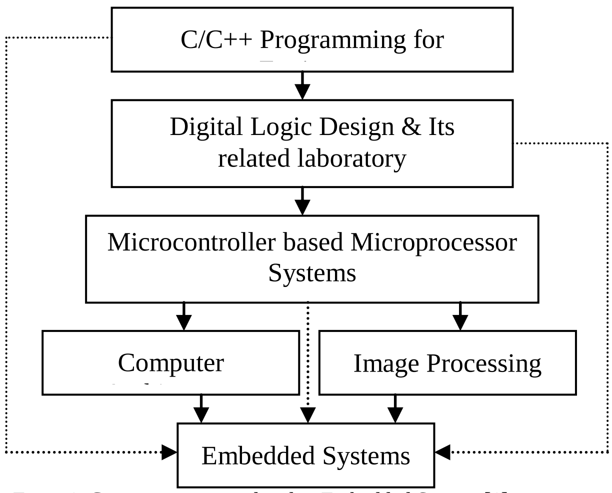

Figure1. Course overview related to Embedded System [1]

Full training course is divided into few sections. Table1 shows the overall structure of the training materials. In embedded C programming, pointers technique, serial communication implementation (UART), interrupt handlers, and image processing is covered. In HDL, combinational logic design, synchronous and asynchronous state machine design, RISC processor design, and custom IP design is included. In SW/HW design, architecture of the soft core and its buses, interfacing with timers IP, UART IP, configurable parallel port, interrupt controller are covered.

TABLE1. CONTAIN OF THE TRAINING COURSES

Embedded "C" Programming	a. Pointers (Accessing content of memory locations) b. Serial communication + Byte Transfer + Array-type Variable c. Ethernet: Send/Receive Data Byte to an IP node d. Interrupt handlers e. Image Processing (algorithms such as depicted in Figure 5)
HDL	a. Combinational logic (examples: decoder, mux, DFF) b. Synchronous state machine / State machine c. Embedded Processor & Hierarchical Buses d. Custom IP cores & Bus Interfaces e. Image Processing (Implementation of algorithms on hardware such as on PLD or FPGA)
HW/SW Co-design	a. Architecture b. Processor Buses & Busses Protocols c. IP cores: 1. Timers 2. Serial Communication 3. Configurable Parallel Port 4. Interrupt Controllers d. Interrupt Handlers/ Processor context switch
System Software	a. Script Linker file, make file b. System timer c. Multitasking & multithreading d. Device Drivers (Device interface, polling/ interrupt driven)

III. PROFESSIONAL ENGINEERING PRACTICE BASED ON PROBLEM SOLVING

Student survey shows that development of student design skill, engineering practice quality, self learning ability, and communication and team work skills, course assignment is not sufficient. Hence, a series of progressive engineering learning skill is necessary. Three stages learning are focused to fulfill all skills. At the first stage, examples based design, which in some extent of a cognitive leaning process is covered. In this stage, students can be experience and have a better knowledge about general hardware design using VHDL, embedded system concepts, design components, design IP, subsystems and design procedures. The aim of the second stage targeted to prepare students with effective use of existing workbench, platform and tools for embedded system design, development and research, and students can grasp how to design, build and troubleshoot an embedded system by existing tools or components based on progressive design and development specification. Student involved in experiential learning emphasized on two section: "simulated" and "authentic" [5]. Simulated experiential learning contains carefully guided learning activities in order to create a specific learning outcome. Authentic experiential learning often made the student engaged in completely open-ended learning and sometimes with limited guidance. Since Engineering practice play important role in embedded system, high level synthesis engineering experiential learning is necessary for students, and the students complete designs within strict hardware design and embedded software programming conventions which are similar to those on which industry engineers are currently working on. In this respects, comprehensive integration design projects is chosen from industry, university-sponsored research, or other practical application environment. Sufficient number of students is made a group so that Working in teams is helpful for building cooperation, leadership, and communication skills which is necessary in student's future work. A cooperative, practical and structured embedded systems design experience was needed in embedded system education. The design experience is based on a problem-based learning approach that motivates student learning and develops skills required by the student in a future professional capacity. Engineering practice should play a more important role in embedded system education. Design software included in training courses included "industrial-strength" features such as real-time, in-circuit debugging and field programmability, and students should be trained to conform to corporate design practices, such as design and coding conventions. The experience can be created, in part, to give students exposure to strict design specifications and the need to follow them faithfully, which is one of the most popular request for an engineering project development.

IV. PRACTICAL TRAINING

The act of rehearsing a behavior over and over, or engaging in an activity again and again, for the purpose of improving or mastering it, as in the phrase "practice makes perfect"[2]. Practical training on embedded system is an on-campus process to gain the practical experiences which are suitable for the real design companies. The propose training interacted between the theoretical courses and the real company practices. Generally, in the design companies, practice means work for the real projects [3]. Even if the work is quite simple, to implement the basic functions or to write the documents, the results will be used into the software products finally. The term training refers to the acquisition of knowledge, skills, and competencies as a result of the teaching of vocational or practical skills and knowledge that relate to specific useful competencies [4]. So, people within many professions and occupations may refer to this sort of training as professional development. The offered embedded system training can be on-the-job or off the-job as the focus on jobs [5]. On-the-job training takes place in a normal working situation, using the actual tools, equipment, documents or materials that trainees will use when fully trained. On-the-job training has a general reputation as most effective for vocational work. Off-the-job training takes place away from normal work situations, implying that the employee does not count as a directly productive worker while such training takes place. Off-the-job training has the advantage that it allows people to get away from work and concentrate more thoroughly on the training itself. This type of training has proven more effective in inculcating concepts and ideas.

To give the clear concepts and the feasible analysis, the relative definitions, such as practice and training, are discussed carefully, and the advantages are carried out.

In Practical Training, the educational philosophy is based on "learning by doing", which means that the practical training heavily focuses on the students actually performing the tasks. Software engineering is a fundamentally practical activity and students find it difficult to see the value of activities without them being placed in a realistic context. The attempt at providing an assignment that has significant similarities to a real-world project.

For the practical training, the courseware has much difference with the common textbooks. The use of courseware according to its design intent: stated learning objectives and audiences, would by definition be the only use the developer can evaluate and assess. The instructors should plan on providing appropriate documentation and understanding of how to evaluate the use of the courseware.

V. DESIGN EXAMPLES

Embedded System based practical training to the graduate students towards industry level is focused on Xilinx Microblaze and PowerPC platform integrated system [6]. Figure 2 shows the XILINX hardware architecture to design embedded system. Most of the practical embedded system design for this training materials are used this architecture.

In training materials, few issues are covered which are significant affects on industrial design. At initial stage for beginners trainee, hardware design using FPGAs is covered so that at any stage in peripheral hardware can be designed and interface with processor to achieve expected embedded system. Next stages, standard peripheral hardware available as a Intellectual property (IP) such as USART, BRAM, SRAM and its controller interfacing techniques are trained. In addition, on-chip processor software design using C/C+ for Microblaze soft core processor is covered so that HW/SW design experience can be applicable to the any embedded design company.

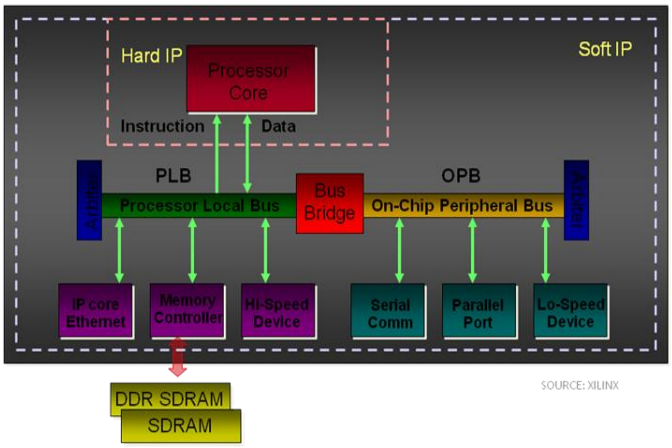

Figure 2. Xilinx embedded system hardware architecture [6]

A. EXPERIMENTAL SETUP: ON-CHIP GAME DESIGN

This experimental setup is intended to cover full hardware design using VHDL in FPGA platform. Trainee is given required schematic diagram for the game design. Figure shows the given hardware setup for the light chasing game design. Figure 3 shows the hardware setup using VHDL.

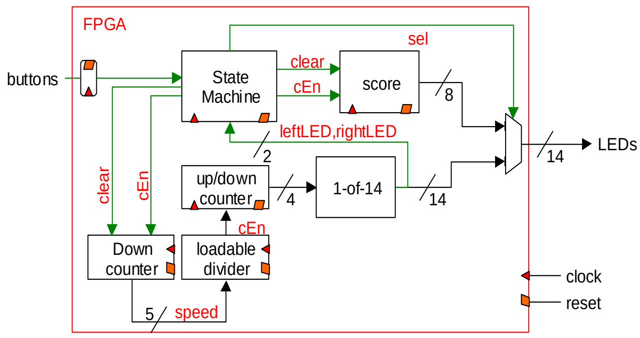

Figure 3. On-chip hardware setup for simple Game design

Trainee will design individual module using VHDL including state machine. After complete all modules, they need to design top-level module to interconnect all modules as required. After complete this module, they will be able to know how to design HW module and controlled by state machine.

B. EXPERIMENTAL SETUP: TRANSCEIVER VIA SERIAL PORT

This experimental setup is to expose students to interfacing of Universal Asynchronous Receiver Transmitter (UART) to XILINX soft core Microblaze processor. Data transferring over the bus is between two UARTs and saved in pointer variables. The C programming was emphasized for processor.

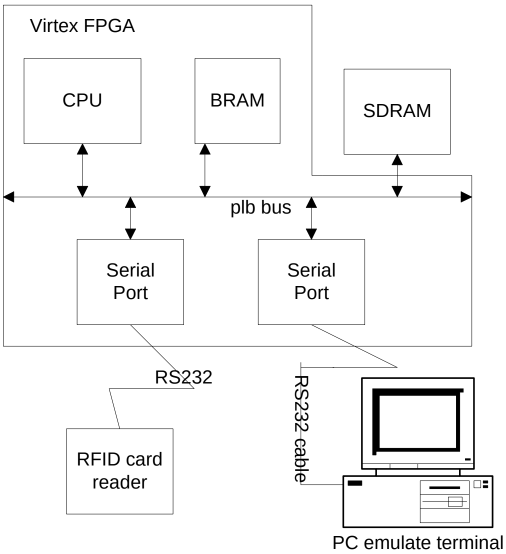

Figure4. Example design of UART interfacing with PLB bus

C. Experimental setup: Image Processing

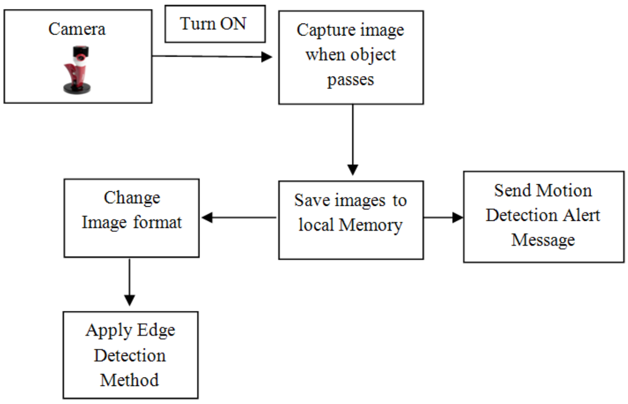

Figure5. Example design of interfacing camera for capturing images and detecting edge

Figure 5 is on the image processing module. The experimental setup is to make camera turn on and capture images when there is a motion. After taking pictures, it is saved on local memory and also sent to alert messaging system through internet and Application Programming Interface (API). The images are needed to convert to portable network graphics format. Then enhanced Sobel edge detection method is applied to detect edges of the images.

VI. Students results on works

Figure 6 shows the students examination results on the course for previous semester. Over three semester evaluation period, most students have able to enhance their understanding, consistent with the excellence examination results and project presentations.

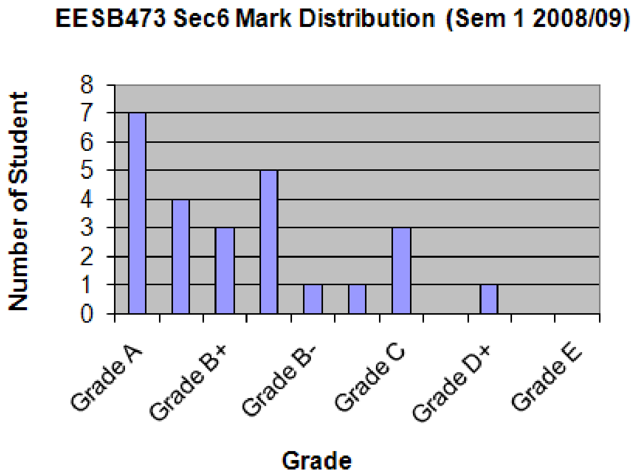

Figure6. Student result on embedded system design course

Figure 7 shows the snap shots of the student project on embedded system. In the picture, students are testing there projects on RFID projects.

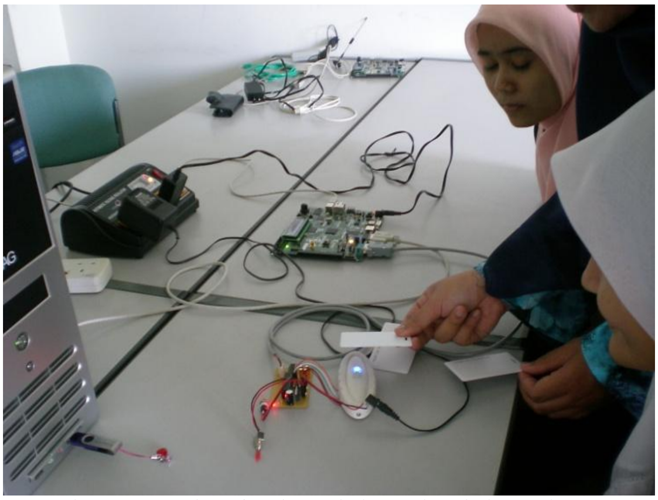

Figure7. Snap shot of student's design project during testing

VII. Conclusion

An integrated kit for both hardware and software lesson modules can assist student to grasp difficult abstract concept, thereby improve learning outcomes especially on programming language, microprocessor, digital system. The hardware and software modules include several level of Bloom taxonomy especially to help students to learn difficult concepts toward achieving the synthesis level learning outcome and at the same time expose them to in industrial-grade design environment.

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