QUBE: A Practical Education Program for System LSI Designers

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ABSTRACT

The System LSI Research Center (SLRC), Kyushu University, has launched a project educating System LSI designers referred to as QUBE since 2005. The intended applicants for the QUBE are senior engineers who are required to have wide knowledge and practical skills on hardware, embedded software, and system design. QUBE made a curriculum that students can learn advanced hot topics in each technical region and exercise to design and implement System LSI which consists of hardware and embedded software. QUBE originally developed an exercise centric course material for latter program in the curriculum. QUBE provides 16 classes (35 days) in 18 weeks according to the plan in 2005 school year. 106 applicants ware submitted to classes. 89% students ware satisfied with QUBE classes according to questionnaire.

Keywords

Education, SoC, System LSI, Architect, Co-Design

1. INTRODUCTION

The importance of System LSI is increasing. System LSI are embedded to various products such as cellar phones, TV, *etc*. It is, however, difficult to design appropriately System LSI considering aspects of hardware, software, and also business. It requires wide knowledge and know-how of technology in such multiple areas for engineers to design and develop System LSI. In Japan, universities provide classes in which professors lecture individual technologies only. The class integrating various technologies to learn designing System LSI was not provided. There is no other education organization to educate engineers required to develop System LSI. Industry under heavy cost competition cannot use budgets for educating engineers.

The System LSI Research Center (SLRC), Kyushu University, has launched a project educating System LSI designers referred to as QUBE since 2005. The intended applicants for the QUBE are senior engineers who are required to have wide knowledge and practical skills on both hardware and embedded software design. The QUBE also intends researchers who want to know technologies used in the field as its target.

This paper is organized as follows: Section 2 introduces the QUBE project and Section 3 describes related works and QUBE properties. Section 4 describes its missions and Section 5 shows the curriculum of the QUBE. Section 6 explains newly developed course referred to as System LSI Design Training Course. Section 7 reports the activities of the QUBE in 2005. Finally, section 8 concludes this paper.

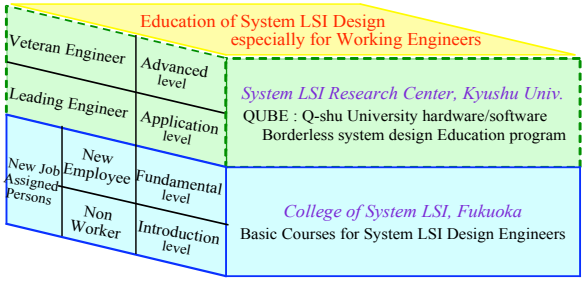

Figure 1 The consistent curriculum of the QUBE and College of System LSI, Fukuoka

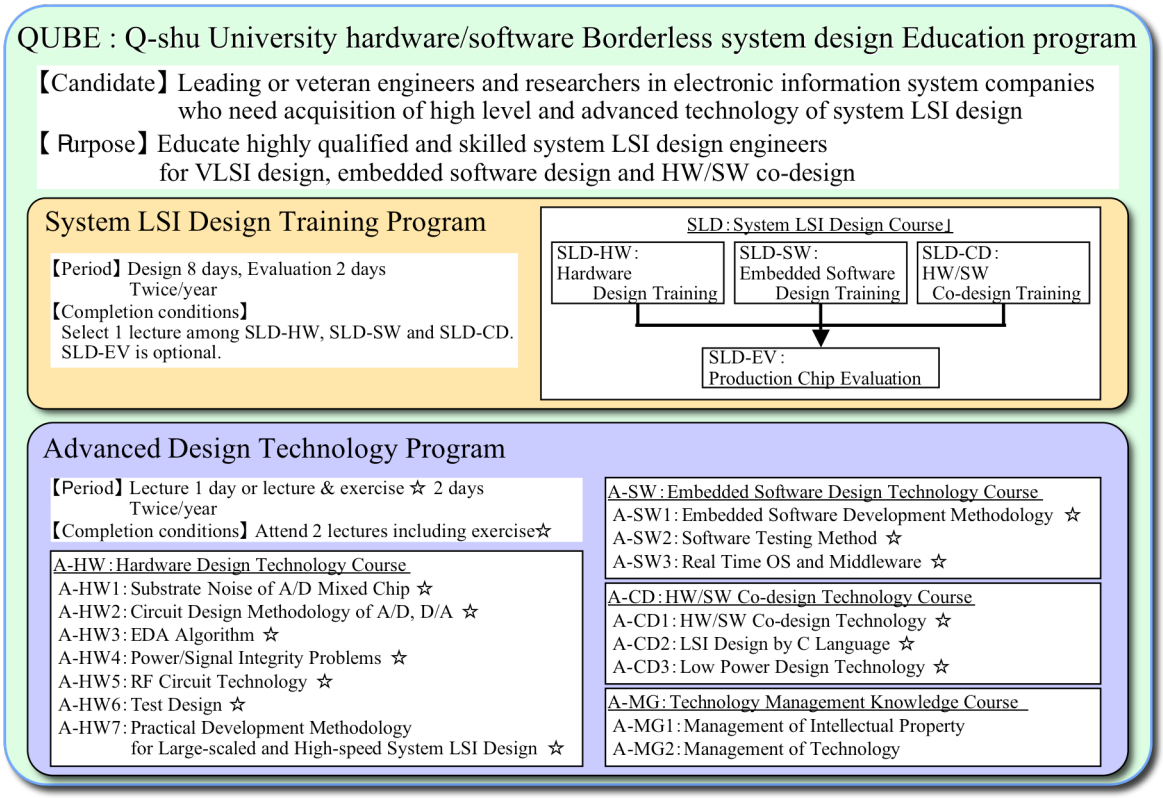

Figure 2 The Curriculum run in 2005

2. PROJECT OVERVIEW

This section explains the QUBE project overview.

The QUBE has begun as a one of a unit in System LSI Research Center, Kyushu University funded by Ministry of Education, Culture, Sports, Science and Technology, Japan. The QUBE is a five year project from July, 2005 to March, 2010. The QUBE is administered by the QUBE project members consisted of four full-time staffs and three concurrent staffs. The QUBE has a advisory committee, which consists of the QUBE project members, professors invited from Kyushu University, other universities, and industries for the QUBE classes, and members Teaching Staff Meeting of College of System LSI, Fukuoka[1].

Before QUBE, Prof. Yasuura who is a leader of the QUBE began College of System LSI, Fukuoka for educating entry-level hardware designer since 2001[1]. The QUBE has begun to provide advanced-level education for System LSI designers, hardware engineers, and embedded software engineers. To educate those engineers from entry-level to advanced level QUBE cooperates with College of System LSI, Fukuoka and make a consistent curriculum as shown in Figure 1. College of System LSI, Fukuoka provides entry and basic level classes and QUBE provides advanced-level classes.

3. RELATED WORKS

This section introduces some related works that educates SoC design, LSI design and embedded software. There are many education courses to educate these topics in the world. The SoC Consortium of Taiwan[2] is developing curriculum and course materials to educate LSI design and embedded software for master course students. NEXCESS[3] is developing them to educate embedded software for industrial engineers.

The specialty of the QUBE is that the targets of the QUBE are industrial engineers. Most targets of education courses like SoC consortium of Taiwan are students who belong to universities. It is required to design QUBE courses especially for industrial engineers. For example, each lecture for them should keep short since they are too busy to take long lecture. One of merits to set a target to industrial engineers is that the QUBE can obtain industrial needs directly. In feature, curriculum and course materials developed by the QUBE according to industrial needs will be used as one for educating master course and/or undergraduate students.

The next specialty is that QUBE has a integrated curriculum including hardware design, embedded software, hardware / software co-design, and also managements skills for engineers who develop System LSI.

4. MISSIONS

The mission of QUBE is to educate System LSI designers who can design value added System LSI considering with both of hardware and embedded software. System LSI designers consists of hardware engineers, embedded software engineers, and hardware / software co-design architects. The targets of our program is senior engineers who would like to learn advanced technical topics. These engineers are basically employed by electrical and/or information related industry.

The goal of QUBE is to educate 180 engineers after 3 years, 360 engineers after 5 years who have skill levels as follows:

a) Hardware Engineers:

Hardware engineers are not only able to design a part of hardware of the System LSI, but they also can understand requirement specifications and solve problems related with hardware / software interfaces.

b) Embedded Software Engineers:

Embedded Software Engineers are not only able to design and implement a part of software of the System LSI, but they also can understand requirement specification and solve problems related with hardware / software interfaces.

c) Hardware / Software Co-Design Architects:

Hardware / Software Co-Design Architects can design System LSI and write requirement specifications both of hardware and embedded software appropriately. Architects can understand tradeoffs between hardware and embedded software implementation and design System LSI considering with these tradeoffs.

QUBE provides practical exercise centric classes to educate these engineers and architects as follows: a) QUBE invites top professors those who research and develop something related to hot topics. b) QUBE develops exercise centric classes in which students can use EDA tools and development environments employed at fields in industries. QUBE employs tools provided by VDEC (VLSI Design and Education Center, Tokyo University) [4] and design and verification lab serviced by Industry Science Technology Foundation, Fukuoka to compress costs using these tools[5].

5. CURRICULUM

In this section, we describe the curriculum of QUBE project. QUBE curriculum aims at educating three technical domain of System LSI; hardware engineer, embedded software engineer, and hardware / software co-design architect as mentioned in previous section. The curriculum run in 2005 is shown as Figure 2.

The curriculum consists of two parts as follows:

(1) System LSI Designer Training Program

System LSI Designer Training Program aims at educating engineers who can design systems considering both aspects of hardware and embedded software. This program consists of two classes: a) System LSI Design Training and b) Trial Chip Evaluation Lab. b) will be run in 2006.

System LSI Design Training class aims at educating all of hardware design, embedded software design and implementations, and co-design. This class also aims that students can be learned practical design and implementation skills through exercise. In this exercise, students implement something using hardware and embedded software on the processor embedded FPGA board.

In this class, students form some teams and each team implement a system. A team member consists of hardware design engineers, embedded software engineers, and hardware/software co-design architects. Engineers can understand other technical domains and get a chance to learn how to work with engineers in other technical domains. Architects can learn co-design skills and try them in a team.

This class is originally developed by QUBE. We describe detail of this class and its material in section 4.

(2) Advanced Design Technology Program

Advanced Design Technology Program aims at educating deeply professional design technology in each technical domain. In this program, QUBE also provides System LSI related management classes. Classes in this program are provided by professors engaged in System LSI related advanced research and development. These professors are invited from Kyushu University, other universities, and industry. In this program,

This program consists of four courses:

1) Hardware design technology course

   This course provides hot topics related to hardware design technologies for System LSI such as noise, power/signal integrity, RF, large-scaled design, *etc*.

2) Embedded software design technology course

   This course provides topics about development methodologies, test, RTOS, and middleware for software embedded into System LSI.

3) Hardware / software (HW/SW) co-design technology course

   This course provides topics for co-design technologies such as development methodology using ASIP, C-based design and low-power design for System LSI.

4) Technology management knowledge course

   This course provides topics for managing System LSI projects such as intellectual properties and management of technology.

We make session time of classes in this program short and provide multiple classes in one year to ease taking classes for engineers who have business. Session time of classes are between one day and a week.

6. SYSTEM LSI DESIGN TRAINING CLASS

This section explains the System LSI Design Training Class.

6.1 Lecture Plan

This class consists of four parts; lecture, tutorial, exercise (analysis, design, implementation), and presentation. QUBE plans to maximize exercise time to make this course practical. QUBE provides tutorials to make students familiar with the target board and development environment like [6].

AM of 1st , 2nd day: The Lecture

At AM of 1st and 2nd day, QUBE lectures knowledge to design and implement System LSI as follows:

1) About System LSI

2) Viewpoint of System Design

3) Basics of Hardware Design

4) Basics of Software Design and Implementation

5) Cost model of System LSI

6) Low Power Design for System LSI

7) HW / SW Co-Design

PM of 1st, 2nd day: Tutorial

At PM of 1st, 2nd day, QUBE provides tutorials to make students familiar with development environment and to learn skills to develop System LSI.

Professors lecture to use development environment step by step. Professors incrementally give students exercises to connect a processor and original hardware both of designing hardware and developing device drivers as follows:

1) Write a device driver for given LED controller

2) Design a original LED controller

3) Design a push button switch controller and Write device driver for it

3rd, 4th day: Analysis / Design

At first of the 3rd day, professors explain the exercise target. Students analyze and design it and make documents at the 3rd and 4th day.

4th – 7th day: Implementation / Verification / Test

At the 4th to 7th day, students design hardware and/or implement embedded software. Hardware and software components such as OS, middleware, *etc.,* are provided in order to decrease developing time. Students develop an exercise target using these components.

8th day: Presentation

At the last day, each team gives presentations including the results of analysis and design. They also demonstrate a system implemented by them. Professors request a peer review to their documents. Students discuss about their design based on their documents.

6.2 Multimedia Phone

QUBE select Multimedia Phone (MMP), which is a multi functional phone, as exercise target. Overview of MMP is shown as Figure 2. MMP has call / hook function, voice communication function, MMP discovery function, and white board sharing function. MMP equips microphone and speaker for voice communication. MMP also equips a LCD and a mouse for white board sharing. There are multiple MMPs in a network, and MMPs are connected via Ethernet.

To make exercise target scalable, QUBE provide two function profiles: basic profile and extended profile. First, students implement MMP according to the basic profile. If exercise time remains, they extend it according to the extended profile. Thus, the exercise target can be applicable to students who have various skill levels.

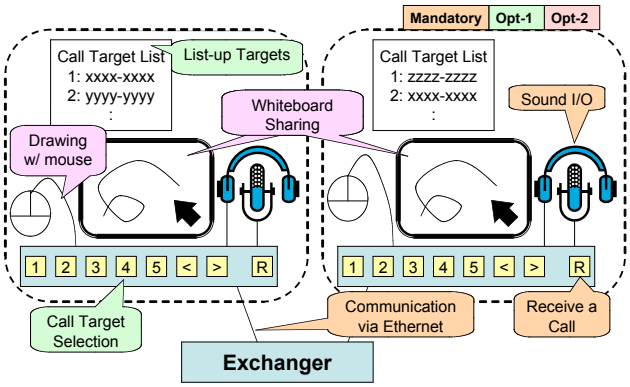

Figure 3 Overview of the Multi Media Phone

For the exercise environment, in which students can implement MMP, QUBE provides Xilinx XUP Virtex II Pro board and its development environment. The board equips a FPGA (Virtex II Pro) embedded two PowerPC 405 processors, an ethernet interface, an audio codec based on AC97, two serial interfaces, some buttons, a VGA interface, a keyboard interface, and a PS/2 mouse interface. QUBE employs ISE and EDK as a development environment. QUBE also provides some debug tools such as Ethereal which is a packet capturing tools, WinPcap which is a library to develop software dealing with ethernet frame, and MMP emulator executed on PCs.

6.3 1st run Report

This subsection reports briefly the 1st run of System LSI Design Training Class at March 1 to 10, 2006. Five applicants from industries and two applicants from a university subscribed to this course. QUBE made two teams from them.

Basically, professors lectured according to the plan mentioned in section 5.1. QUBE also provide short lectures in which professor lecture basic topics requested by students who want to know such topics. In this time, mechanism of interrupt, OS, and drivers are requested. The students want the short lecture due to engineers are not educated enough about basic topics at fields in industries in Japan.

After lectures, each team designed and implemented the MMP respectively. Development speed was slower than supposed one at course designing phase.

Finally, each team gave the presentation of the design of MMP and demonstrated their MMP. They designed and wrote

Table 1 Statistics of the applicants

	organizations		registered		total applicants						Diploma		taken classes /a student	pass ratio
					applicants		cancelled	absenced	passed					
Total	40		106		149		15	2	98		20		1.25	74%
Non students	37	93%	87	82 %	124	83%	14	2	89	91%	20		1.24	82%
Industries	32	80%	76	72 %	101	68%	12	2	76	78%	16	80%	1.14	87%
Non industries	5	13%	11	10 %	23	15%	2	0	13	13%	4	20%	1.91	62%
Students	3	8%	19	18 %	25	17%	1	0	9	9%			1.26	38%

documents satisfactorily. The team of students from industries designed according to eUML[7], which is a development methodology for embedded system based on UML. Another team designed according to PLUS[8], which is a one of the product lines development methodology. Each team implemented the MMP based on basic profile only. They could not implement functions as hardware logics.

To run this 1st class, QUBE developed course materials such as lecture slides, software and hardware components for learning knowledge and know-how to lead projects in which engineers should design both of hardware and software.

QUBE found a problem through running this 1st class that the exercise time is too short to implement functions using both of hardware logics and software. The reason is that skill levels of students are lower than supposed one. QUBE has a plan to extend exercise target to cover students who are in entry level.

7. PROJECT ACTIVITIES in 2005

In this section, we report results of QUBE classes run in 2005. Its statistics are shown as Table 1.

We provided 16 classes (35 days) in 18 weeks according to the plan. 106 applicants ware registered to QUBE classes. Most of registered applicants ware belong to Fukuoka area as same prefecture as QUBE. Total 132 applicants took these classes and the average applicants in each class are 8.3.

98 students passed these classes. We supposed the pass ratio is over 90% at designing the QUBE curriculum. But real pass ratio was 74%. Its reason is that levels of each class ware higher than students' skills. The pass condition is that taken point is over or equal 70 points. The points consist of 40 attendance points, 10 report submission points, and 50 lecturer points.

Diploma students are 20, through the set points of diploma students are 360 in 5 years. These reasons are numbers of students is less than supposed one and the supposed pass ratio is too high as mentioned. The diploma condition is that a student should pass one class in System LSI Designer Education Program or two classes in Advanced Design Technology Program.

QUBE requested writing questionnaires to the students. The result of the questionnaires is as shown in Table 2. Most of the motivation to take QUBE class was applicants' wish for learning knowledge and skills supposed to use in near feature. Engineers in fields in industries have motivation to learn new knowledge and skills themselves. Satisfaction for their prospect is 74%, which is sum of percentage of very good and good. Their feelings of the levels of the classes, however, are distributed by class. Total points of their satisfaction are 89%, which is sum of percents of very good and good.

QUBE can provide classes satisfied by students according to this questionnaire. However, QUBE should tackles to improve pass ratio. One of the cause of such low pass ratio is applicants don't know required skill level to understand classes enough. QUBE have a plan to improve it to clarify target skill level that applicant can understand lectures and to clarify the goal skill level that applicants can understand to take lectures according to the Embedded Technology Skill Standard[9]. QUBE also tackles to adjust levels of classes to applicants needs. QUBE also make publicity to industries in Kyushu area to increase applicants.

8. CONCLUSIONS

This paper introduced the Education Program for System LSI Designers referred to as QUBE. QUBE aims at educating system LSI designers who have wide knowledge and practical skills both of hardware and embedded software.

QUBE made a curriculum that students can learn advanced hot topics in each technical region and exercise to design and implement System LSI which consists of hardware and embedded software. QUBE originally developed an exercise centric course material for latter program in the curriculum. QUBE provides 16 classes (35 days) in 18 weeks according to the plan in 2005 school year. 106 applicants ware submitted to classes. 89% students ware satisfied with QUBE classes according to questionnaire.

In the feature, QUBE will improve course materials constantly to adapt new technologies. QUBE also will tackle to improve pass ratio adjusting a level of classes to applicants needs. QUBE make publicity to industries in Kyushu area to increase applicants.

Table 2 The result of questionnaire to the students

1. Motivations	1.1 What occasion did you take this class.	a) As an induction course	7	6%	2. Remarks to the class (cont'd)	2.3-1 How did you understand topics in the lecture?	a) Very good	28	26%
		b) Advice from your boss	24	22%			b) Good	38	35%
		c) Your wish	75	69%			c) Average	32	29%
		d) Others	4	4%			d) Bad	11	10%
	1.2 Why did you take this class?	a) for current bussiness	36	33%			e) Very bad	0	0%
		b) for business in near feature	45	41%		2.5 How did you feel about the text?	Describe good points	67	61%
		c) not for your business	31	28%			Describe bad points	47	43%
		d) Others	7	6%		2.6 What did you find something while the lecture?	Describe good points	66	61%
2. Remarks to the class	2.1-2 How was you satisfied with your prospect?	a) Very good	37	34%			Describe bad points	40	37%
		b) Good	48	44%		2.7-1 Time of the lecture	b) not appropreately	12	11%
		c) Average	19	17%		2.8 Total point	a) Very good	47	43%
		d) Bad	5	5%			b) Good	50	46%
		e) Very bad	0	0%			c) Average	12	11%
	2.2 How did you feel about level of the lecture?	a) Easy	57	52%			d) Bad	0	0%
		b) Difficult	52	48%			e) Very bad	0	0%

REFERENCES

[1] Yasuura, H., Tsukizoe, A., Hirakawa, K., Ito, N., and Nakano, S., ``College of System LSI, Fukuoka: A Callenge to Sillicon Sea Belt (in japanese)", Journal of IEICE, Vol.86, No.11, pp.857-863, 2003.

[2] Huang, T., King, C., Lin, S. Y., and Hwang, Y.,: The Embedded Software Consortium of Taiwan, ACM Transactions on Embedded Computing Systems, Volume 4, Issue 3, pp. 612 – 632, 2005.

[3] Yamamoto, M., Tomiyama, H., Takada, H., Agusa, K., Masa, K., Kawaguchi, N., Honda, S., Kaneko, N.: NEXCESS: Nagoya University Extension Courses for Embedded Software Specialists, Proc. 2005 Workshop on Embedded System Education (WESE2005), pp.16-20, 2005.

[4] VLSI Design and Education Center: About VDEC, http://www.vdec.u-tokyo.ac.jp/English/index.html.

[5] Institute of System LSI Design Industry, Fukuoka: The design and verification lab (in Japanese), http://www.ist.or.jp/lsi/.

[6] Edwards, S. A.: Experiences Teaching an FPGA-based Embedded System Class, Proc. 2005 Workshop on Embedded Systems Education (WESE2005), 2005.

[7] Watanabe, H., *et al* : Embedded UML: Object Oriented Development Using eUML(in Japanese), Syoueisya, 2002.

[8] Gomma, H.: Designing Software Product Lines with UML: From Use Cases to Pattern-Based Software Architectures, Addison-Wesley, 2004

[9] IPA, Japan: Embedded Technology Skill Standard (ETSS), http://sec.ipa.go.jp/std/skillex_eb.php (in Japanese).