A Practical-Oriented Industry Relevant Teaching of Microelectronic Engineering In Malaysia: A Complete First Cycle Experience

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Abstract – **Significant change in Malaysia's Microelectronic industry at the turn of the century has created new challenges for the institutions in the region. To cater for the resulting workforce market changes, the development and implementation of a new four year Bachelor of Engineering in Microelectronic Engineering curriculum at the Kolej Universiti Kejuruteraan Utara Malaysia is herein reported. The curriculum incorporates general electronics subjects with specialized subjects on microelectronic design, fabrication, MEMS and failure analysis. Skills development is increased through inclusion of significant practical components in every technical course. 'Teaching-fab', chip design and failure analysis facilities plus a fully functioning 'teaching-factory' are build for educational purposes. Active collaborations with the industry are the key elements of the implementation. The total enrolment is 408 students and the first batch of 108 students will be graduating in July 2006. This paper will address the issues and challenges faced in the design, approval and implementation of the program.**

Index Terms – Practical oriented, Industry relevant, Microelectronic engineering, Complete cycle.

INTRODUCTION

Kolej Universiti Kejuruteraan Utara Malaysia (KUKUM) is the 17th public university and is currently among the youngest universities in Malaysia. Being categorized as a university college, a new breed of university offering mainly science and technology based degree courses, KUKUM only offers bachelor of engineering programs in various strategic fields such as microelectronic, computer, communication, material, bio-process, mechatronic and manufacturing. In addition to great demand for highly skilled electronic engineers from the already booming and established semiconductor packaging industry nationwide, the set-up of five semiconductor fabrication facilities in Malaysia mostly after the year 2000, has caused a dramatic change in the job market requirement. Due to the emerging great need for a more industry ready microelectronic engineers, KUKUM took a leading step by offering a unique Bachelor of Engineering degree program in Microelectronic Engineering beginning the year 2002.

CHANGES IN THE SEMICONDUCTOR INDUSTRY

The semiconductor and the related electronic industry in Malaysia began in early 1970s when Intel and several other major players ventured into chip packaging and related activities in Penang Island. The industry then flourished with about 46 companies in operation in 2003 and contributed more than USD20 billion or more than 43% of electronic export of the country. As of 2003, Malaysia's semiconductor industry has become the main sector for full-fledged growth of information and communication technology with wafer fabrication and integrated circuit design as two major core activities [1]. Since the job market was mostly into semiconductor and electronic assembly before 2000, the more general electronic engineering degree programs offered by the six already available public universities was considered satisfactory.

However, as Altera, Intel, AMD and various other major companies started their design activities just before the turn of the century, the need for more specialized and highly skilled microelectronic engineers began to appear. This is then followed by the successful operation of four semiconductor fabrication facilities led by Silterra, 1stSilicon, On Semiconductor and MIMOS [1]. In 2005, Infineon started the construction of its 300mm fabrication plant which increased the need for such highly skilled microelectronic engineers. As the available microelectronic engineering programs are not emphasizing so much in practical oriented microelectronic education, KUKUM, while still at its infancy, took the responsibility to close the gap by designing a new curriculum in 2002 [2].

SUPPORTING ORGANIZATIONAL STRUCTURE

For successful implementation of the curriculum, the university has formed various departments to enhance quality of services and ensure smooth implementation of its academic program. The Academic Affairs Unit is a unit directly under the Chancellery focusing on academic affairs. It is running under the administration of the Deputy Rector of Academics office. Key departments under this unit that are heavily involved in academic implementations include:

- **School of Microelectronic Engineering:** The school is the main institution in the university with roles as the owner of the academic program and as the governing body of the program implementation. The faculty member acts as lecturers for the core engineering subjects plus student academic advisors. The progress of each student is monitored by the advisor and related advise and assistance will be given through scheduled and unscheduled consultation. On the other hand, the school administration through the supporting staff member coordinate student databases with the central unit called the Registrar Office.
- **Centre for Industrial Collaboration (CIC)**: Industry related activities are managed mostly by this department. The industry database and communication is performed through this unit whereby active industry participation is encouraged. All activities are monitored and recorded. To promote industry participation, Memorandum of Understanding (MoU) and Memorandum of Agreements (MoA) are sealed with key industry players throughout the country. Major companies such as Altera , Silterra, On Semiconductor, Intel, AMD, Agilent Technology Freescale Semiconductor, Motorola participated actively in the implementation of KUKUM's academic program.
- **Engineering Centre**: This is the centre where fundamental and common engineering skills are taught. All students from various engineering programs are required to undergo several common courses whereby common skills such as workshop skills are taught. Engineering centre boasts ICT laboratories and complete workshops for electrical wiring workshop, Printed Circuit Board workshop, CAD/CAM and mechanical workshop for various specific skills such as welding, lathing and others.
- **Centre for Skills of Communication and Entrepreneurial:** This department provides courses that are not of engineering discipline but critical to produce well rounded students. Courses such as communication skills, entrepreneurial skills, religious/cultural studies and sports are offered by this centre.
- **ICT Centre:** Information and Communication Technology Centre provides communication backbone for internet base application. E-learning is implemented using this special department with faculty members as information and material providers. Teaching materials are uploaded into the E-learning server for student access at the convenience of their hostel rooms. Student access to the internet is realized using the provided integrated infrastructure. Student attendance is also monitored and recorded using the service provided by this department.
- **Library**: The library is fully supported by interactive and easy to use databases through dedicated ICT backbone. Access to online databases such as IEEE and Engineering Village databases promotes research focus mindset. The library loan system is also strengthened by use of automatic loan kiosks and internet based collection search and account management.

CURRICULUM DESIGN AND ACCREDITATION

Several steps involved in the curriculum design and this involve the industry, local academicians and local regulations and requirements.

- **Initial design**: The design is developed based on general structures obeying the rules and requirements of local education regulations. This includes the Board of Engineers Malaysia and the Ministry of Education requirements.
- **Academician and Industry input**: Meetings with the industry experts and renowned academicians were conducted on yearly basis since the first inception. Major players in Malaysia microelectronic industry such as Intel, AMD, Altera, On Semiconductor and Silterra participated in the formal meetings and forums.

The final curriculum table designed with industry and academician input is as shown in Table 1. The subjects are divided into two categories namely core engineering subjects and university required subjects. All engineering subjects fall into the core engineering category and contribute a total of 120 units, while other courses that include entrepreneurship, languages, communication, religious/civilization study, sports and cultural are classified as university required subjects, with total contribution for graduation of 15 units.

The approval for execution of the program initially involves the Ministry of Education internal mechanism called Higher Education Committee. Upon approval of the committee in 2002, the first intake of 108 students registered with the university in June 2002. Another step to be obtained is the accreditation of Board of Engineers Malaysia special committee named Engineering Accreditation Council. This accreditation is crucial for enabling employment of the graduates upon completion of four years study. However, the accreditation process is only applicable for programs which have undergone at least a complete full cycle of implementation.

ACADEMIC ACTIVITIES

The curriculum table is as shown in Table 1. The basic electronic engineering content in the curriculum is similar to the other electronic engineering programs offered by conventional universities in Malaysia. This means the theoretical content is basically similar to the other programs. However, practical sessions and industry participation is included in the formal academic meetings as can be seen in the following paragraphs. This section is divided into three sections as follows:

I. Theoretical and practical contents of the curriculum

The theoretical contents satisfied the standard of an engineering degree as outlined by both Ministry of Higher Education and Malaysian Board of Engineers. The learning process is applying the outcome based learning principle with seamless integration of theoretical lectures and practical laboratory activities. This requires an extra student time of

about 25% when compared with conventional universities learning, with a resulting total of 3000 contact hours for graduation. Since lectures and practicum is done back-to-back, the learning process is becoming more effective.

II. Industry involvement

Under the monitoring of the Academic Affairs Unit of the Chancellery, CIC, together with the respective school administration will organize academic programs with industry participation. Active industry involvement help students' understanding and appreciation of the tasks an engineer will perform and related development in industry application of theoretical academic content. With implementation of a series of activities with industry support, the industry involvement in education is increased. For example, the students will have to undergo such programs beginning with a one week industry exposure program (IndEx) performed between semester breaks of the first year, subject based industry relevant industrial technical lectures (InTeLect), subject based industry visits and a dedicated one full semester industrial training and placement program (InTra). The five major activities above are performed in ways as described below:

- **IndEx**: Industrial exposure is approximately a one week program. The industry experts and management will be invited to hold sessions with the first year students. The sessions are conducted in the forms of talks on updates from the industry and application of the theoretical content in daily engineers' life. Forums, workshops and hands-on sessions are also included. The question and answer sessions are very beneficial for the students understanding and appreciation of the life of an engineer.
- **InTeLect**: This is a program involving guest/visiting lecturer from the industry. Topics to be covered are part s of the syllabus of a particular subject. Lecturers will put up a request to conduct special sessions with the industry experts and both the guest/visiting lecturer will agree on topic selection. This normally takes at least two hours of the allocated subjects' lecture hours. The implementation is dependent on the dean's approval so as to ensure smooth running of the program.
- **Industry visits**: Industry visit is also done as part of a subjects teaching implementation. Similar to the previously mentioned program, lecturers are encouraged to apply for the visit through the dean and CIC will assist on the logistic and industry contact.
- **InTra**: A dedicated one semester placement in the industry is a subject on its own in the curriculum. Each student will apply for a place in the industry with coordination of the school's champion and CIC officials. The students will be placed under industry supervisors' guide for at least four months. A long report and a daily activities record in the form of a logbook will be submitted to the school supervisor and industry supervisor at the end of the training. In addition, a university level presentation will be conducted by each of the student at the end of the semester to improve their communication skills such as presentation and language skills.

III. Entrepreneurial skills

Entrepreneurial skills are becoming more important as the country is now trying to boost development of small and medium enterprises to spur further development of national economy. In this respect, engineering education is considered as an important channel to promote enthusiasm of young graduates towards entrepreneurship. In fact, should the graduates choose to be employed rather than setting up of own companies, their entrepreneurial skills will still be of use in execution of daily responsibilities [3]. A program implemented with assistance of successful entrepreneurs and run as part of a specially designed entrepreneurial subject is industrial entrepreneurship (**IndEnt**). **IndEnt** involves a series of about four individual programs in the form of talks, forums and group activities facilitated by several successful entrepreneurs during class hours.

FACILITIES SET-UP

For successful implementation of the curriculum, the university has built various facilities for effective teaching and learning implementation. This university is also unique in Malaysia in the sense that the campus is divided into five distinguished and spread zones located throughout the state of Perlis, which is the smallest state in Malaysia located in the northern most part of the country, bordering Thailand. Among the facilities developed are such as:

- **Computer Laboratories**: Programming in C++ language is performed in dedicated laboratories where each student is given access to a computer each time classes are run.
- **Electronic Laboratories**: Fundamental electronic subjects such as Analog Electronics and Electronic Devices involve the use of this laboratories and each students will have access to one set equipment in each practical session.
- **VLSI Design Laboratory**: This laboratory is equipped with 35 licenses of Mentor Graphics Design Tool packages and each student will have access to each license each time laboratory session is performed.
- **Digital Laboratories**: Practical sessions for digital electronic subjects will be performed in dedicated laboratories which is equipped with Altera donated design boards for each students.
- **'Teaching Fab'**: Each student will take at least two subjects which require the use of this class 100 cleanroom laboratory. Practical sessions involve processing of different layers for realization of monolithic transistors and also device characterization.
- **Failure Analysis Laboratory**: Industry involvement in supplying of malfunctioned integrated circuits in critical in practical sessions for this laboratory.
- **Microprocessor Laboratory**: The practical sessions for the subject named Microprocessor is performed in a dedicated laboratory. Here, students practice assembly language programming and Intel microprocessor system boards are used.

- **Communication Laboratory**: For the Communication subject, the students will undergo practical sessions in this special laboratory. Experiments encompassing various communication concepts are performed here.
- **Teaching Factory**: In addition to the other mentioned laboratories, KUKUM has also built an industry standard factory managed by the teaching staff. This factory produces small electronic gadgets such as Personal Digital Assistant and pocket sized radios. The product design from concept to production involve student input and this makes them more enlightened with entrepreneurial and manufacturing skills.
- **MEMS Technology Laboratory**: A dedicated laboratory for 10 licenses of SoftMEMS and 5 licenses of ANSYS is also developed.

ACADEMIC STAFF

To support smooth implementation of the academic program, various posts have been introduced inclusive of full time faculty members and term-based external industry lecturers. The uniqueness of each academic post is as described below:

- **Full time lecturers**: Full time lecturers are similar to the other universities. This job category includes Associate Professors, Professors and other lecturers.
- **Teaching Engineers**: In contrast to conventional universities, special post known as Teaching Engineer is only available in university colleges such as KUKUM. Due to the unique implementation of the curriculum, the university is allowed to hire enough number of this so called Teaching Engineers. Most of the engineers are formerly working in various industries throughout the country. These experienced engineers assist lecturers in laboratories based practical sessions. Usually, the engineers will sit in the classroom together with the students to enable smooth delivery of the required skills during practicum. Special meetings to coordinate laboratory activities are conducted by the lecturers whereby the engineers feedback and attention is crucial.
- **Guest/Visiting Industry Lecturers**: Experts mostly from the industry will be appointed by the university through CIC linkage to participate actively in teaching of relevant subjects. This term-based appointment creates special opportunities for the students to recognize the real application of various concepts in industry.

QUALITY

The university implements its own quality standards since the beginning of the first cycle implementation. Within just a year, KUKUM managed to lay the required foundations for quality assurance practice [4]. A special post, Dean, Academic Management under the Deputy Rector of Academics office, created in June, 2003 is responsible for all quality related tasks. Compliance to the Quality Assurance Code of Practice, which is established by the Ministry of Higher Learning, is one of the key quality assurance mechanisms. The Engineering Accreditation Council requirements established by the Board of Engineers Malaysia is another significant quality assurance program administered by the Academic Management office.

OVERALL OBSERVATIONS

After a complete first cycle of four years implementation, the university has gained valuable experience in all preparation and operational aspects especially in terms of industry participation and recognition. In addition, a study on the workload of student in terms of time spent is performed to gauge the impact of the new education approach.

I. Preparation

Our experience has shown that preparation of the university for getting the program running is not an easy task. Various challenges that require a lot of concerted effort emerge especially from availability of physical infrastructure in the state. Fully developed physical spaces are scarce in the area and forcing the university to rent most of the available vacant buildings and office spaces which are mostly far separated. Luckily, the state government, through various departments lends their hands in accelerating physical development. In addition, the practical orientation of academic activities necessitates the availability of highly specific laboratories and enough sets of experimentation tools. However, blessed with federal government financial support, excellent physical set-up is currently already a reality for complete execution of the program.

II. Operational

In operational aspect, the highly distributed physical infrastructure demands sophisticated system of transportation for students and staff. To overcome this challenge, KUKUM operates a fleet of about twenty buses that shuttles between different zones. Information and communication technology infrastructure is also another key solution in satisfying the demands of distributed operation. Maintenance of these infrastructures is also high.

III. Industry involvement

Being a new university is really a challenge especially in obtaining the recognition of the main customer, which is the industry. An effective branding strategy is important as a start-up university. For that reason, the university actively engages with the industry through various channels such as signing of mutual agreements, joining industry gatherings and meetings, conducting activities for the industry and also publications in local media. The number of activities with industry participation increases each year and the active industry involvement significantly help the realization of efficient university-industry relationship in spite of its infancy. So far, many activities are successfully performed jointly with the industry, however, still there many spaces for improvement. Continuous development of linkages and possible governmental initiatives may further strengthen this linkages and industry participation.

VI. Student workloads

A research conducted by the university to study student time usage pattern gives us another good understanding of the impact the new engineering education approach [5]. Even with more hours needed by the students for official academic meetings, their daily timetable are still quite loose whereby only 32% of time is spent for that activities. This figure shows that the new approach does not at all increase the students workload but instead enables a more systematic and rather more experiential type of education.

CONCLUSION

All aspects of program implementation such as job market observation, organization structure optimization, curriculum design, accreditation, academic activities, facilities set-up, academic posts created and quality assurance are described. In addition, an explanation of the overall observations covering challenges faced and the performed solutions during the complete first cycle of implementation of the program is also presented.

ACKNOWLEDGMENT

The authors would like to thank KUKUM's Rector and Deputy Rectors for various supports and also special thanks to Professor Jack Singh for his valuable advise in completing this writing.

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TABLE I

CURRICULUM TABLE

	FIRST YEAR			SECOND YEAR			THIRD YEAR		FOURTH YEAR	
	First Semester	*Second Semester*		*First Semester*	*Second Semester*		*First Semester*	*Second Semester*	*First Semester*	*Second Semester*
ENGINEERING CORE SUBJECTS	EUT 101/3 Engineering Mathematics I	EUT 102/3 Engineering Mathematics II	INDUSTRIAL EXPOSURE (IndEX) – ONE WEEK	EUT 203/3 Engineering Mathematics III	EKT 222/4 Micro-prosessor System	INDUSTRIAL ENTREPRENEURSHIP – ABOUT ONE WEEK	EMT 361/3 Reliability & Failure Analysis	EIT 300/6 Industrial Training (InTra)	# EMT 451/4 Analog Integrated Circuit Design *OR* # EMT453/4 Semiconductor Packaging	EMT 444/6 *Final Year Project
	EET 101/4 Electrical Circuit I	EET 102/4 Electrical Circuit II		EKT 230/4 Signal and System	EKT 241/4 Electromagnetic Theory		ENT 364/4 Control System		EKT 422/4 Computer Architecture	EUT 440/3 Engineer in Society
	EKT 120/4 Computer Programming	EKT 121/4 Digital Electronics I		EKT 221/4 Digital Electronics II	EKT 231/4 Communications Sistem		EMT 362/4 Microelectronic Fabrication		# EKT 430/4 Digital Signal Processing *OR* # EMT473/4 Advanced Microelectronic Material	EMT 452/3 MEMS Technology
	EUT 122/2 Communication & IT Skills	EMT 112/4 Electronic Analog I		ECT 200/3 Engineering Skills II	EMT 251/4 Introductory Integrated Circuit Design		# EMT 351/4 Digital Integrated Circuit Design		EMT 471/3 Semiconductor Physics	
	EMT 111/4 Elektronic Devices	ECT 100/3 Engineering Skills I		EMT 212/4 Electronic Analog II	EMT 261/3 Semiconductor Processing Technology				EMT 444/6 * Final Year Project	
120	17	18		18	19		15	6	15	12
15	*University Required Subjects (Registration for subjects in this category will be allowed dependent on subject offering and timetable suitability)*									
135	**Total units for graduation =**				**120** *(Engineering Core Subjects)*	**+**		**15** *(University Required Subjects)*		

* Subject registered/begin in the first semester (6 units will be credited upon completion in the second semester) # Elective subjects