KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

College of Computer Science and Engineering

COMPUTER ENGINEERING Department

Ph.D. PROGRAM IN
COMPUTER ENGINEERING

DEPARTMENT OF COMPUTER ENGINEERING

May 7, 2013

1 Program Summary

The Ph.D. degree in Computer Engineering will be awarded to candidates who fulfill the requirements specified by the Deanship of Graduate Studies, as well as the following additional requirements imposed by the Computer Engineering Department:

1. Satisfaction of provisional status requirements; if any,
2. Satisfactory completion of the course requirements (30 credit hours),
3. Passing the written and oral comprehensive examinations by the end of the 4th semester for full-time students, or the 5th semester for part-time students, after joining the program, and
4. Successful completion and defense of an original research work (dissertation).

The program provides the student with specialization in one of 4 areas of competency in the Computer Engineering discipline. Each student must select one of the following as his major area, and another as a minor area:

Area 1: Computer Architecture and High Performance Computing,
Area 2: Computer Networks and Security,
Area 3: Digital System Design & Automation, and
Area 4: Computer Systems and Applications.

The following table summarizes the degree requirements of the proposed Ph.D. program

Course Requirements of the Ph.D. Program in Computer Engineering

	Min Requirement	**Notes***
Major Area	**3** Courses (9 cr. hrs.)	• Major area may be any of the 4 COE areas of competency.
Minor Area	**2** Courses (6 cr. hrs.)	• Any COE specialization area other than the
COE Electives	**2** Courses (6 cr. hrs.)	• Any COE specialization area.
Technical Electives	**2** Courses from COE-related disciplines (6 cr. hrs.)	• Should be taken from outside the COE department.
Free Elective	1 Course (3 cr. Hrs.)	• May be either a COE or a non-COE course.
Comprehensive Exam	Comprehensive Exam	• To be passed by the 4th semester (FT students), or the 5th semester (PT students)
Seminar	**COE** 699: Seminar	• Zero credit hour (P/F).
Dissertation	**COE** 711, and **COE 712**: Dissertation	• 12 credit hours (3 + 9) • Dissertation topic is to be selected from the student major area of specialization.

** No more than 4 non-COE courses are allowed*

2 Program Objectives

The PhD program offers students opportunities to develop levels of expertise and knowledge consistent with a career of technical leadership. The doctoral program emphasizes the acquisition of advanced knowledge and the fostering of individual experience of significant intellectual exploration. The educational objectives of the PhD program are to develop:

1. Expertise in core areas of computer engineering;
2. The ability of independent learning and advancing knowledge,
3. The ability to identify pertinent research problems, formulate and execute a research plan, and generate and analyze original research results,
4. The ability to lead research and to *communicate* the results in scientific publications and forums.

3 Learning Outcomes

By the time a student completes all requirements of the program, he will have acquired the following learning outcomes:

1. Ability to review, analyze, assimilate and interpret scientific literature and innovations in his Computer Engineering major area of expertise,
2. Ability to apply and validate innovations and discoveries in the lab or real world settings in effective ways,
3. Ability to produce original research in Computer Engineering, evaluate its performance, and objectively compare it to others, and
4. Ability to effectively communicate scientific and engineering research findings and knowledge both in the form of formal presentations and professional publications, through diverse channels such as international journals, conferences, patents, research proposals, etc.

4 Program Requirements

The Computer Engineering Ph.D. Program requirements are summarized in Table 1. Students enrolled in this program are required to complete 30 graduate credit hours of courses (*excluding the dissertation*). These courses should be selected from a program of study approved by the student's Graduate Committee, the Department Chairman, and the Dean of Graduate Studies. The program of study for each student should be documented in an approved degree plan, a sample of which is given in *Sction 5*.

The Ph.D. degree in computer engineering will be awarded to candidates who successfully complete all requirements of the degree, listed below:

1. Satisfaction of provisional status requirements; if any,
2. Completion of course requirements (30 credit hours) with a minimum GPA of 3.0 (on a scale of 4.0),

3. Passing the written and oral comprehensive examinations by the end of the 4th semester for full-time students, or the 5th semester for part-time students, after joining the program,
4. Successful completion and defense of original research work documented as a dissertation, and
5. Other requirements as specified by the Deanship of Graduate Studies.

The Ph.D. program in computer engineering provides specialization in four areas of competency. These areas are chosen to provide coverage of well-recognized established areas of COE and at the same time allow for coverage of anticipated future progress in the discipline. Each student must select one of the following as his major area, and another as a minor area:

Area 1: Computer Architecture and High Performance Computing,
Area 2: Computer Networks and Security,
Area 3: Digital System Design & Automation, and
Area 4: Computer Systems and Applications.

A full-time Ph.D. student is expected to spend around two years to complete the course requirements. In addition, the dissertation work is expected to require about two more years. The maximum period permitted for a full-time student to complete all requirements of the Ph.D. degree is five years. For part-time students, the maximum period to complete all requirements of the Ph.D. degree is seven years. A part-time student must spend a minimum of one year in residence on-campus while doing his Ph.D. dissertation work.

The completion of at least **30** credit hours of course work beyond the M.S. course work and beyond remedial courses is required for all Ph.D. students. Each student must select major and minor areas. The student may take for credit any of the COE 500-level (or higher) courses listed under the four specialization areas, provided that such courses have not been taken for credit by the student for a previous degree at KFUPM. To ensure depth of knowledge, a minimum of three courses (9 credit hours) must be taken from the student's selected major area (Table 2). In the minor area, a student must take a minimum of two courses (6 credit hours). To provide breadth of knowledge, the student is required to take two graduate *technical elective* courses which must be taken from outside the COE department. In addition, two COE elective courses (6 credit hours) should be taken from any of the four COE specialization areas. Furthermore, a graduate *free elective* course may be either a COE or a non-COE course. The graduate technical elective courses may be taken from other related disciplines, e.g. ICS, SWE, EE, SE, or Math. The maximum number of courses that may be taken from outside the COE department is 4 courses (12 credit hours).

Students are also required to present a seminar that describes recent research findings in Computer Engineering as well as attend the technical seminar series organized by

the COE Department. This requirement is fulfilled by the zero credit hour seminar course COE 699 (1-0-0). Students have to pass the PhD Comprehensive Exam in order to secure a passing NP grade in the Seminar Course. If a student who is registered in the Seminar Course fails the PhD Comprehensive Exam his assigned seminar grade will be IC (incomplete), which is changed to a passing NP grade once he passes the PhD Comprehensive Exam latest by the subsequent semester to avoid having the IC grade changed into F.

The student should select his Ph.D. dissertation topic from his major area. Twelve credit hours are assigned to the Ph.D. dissertation which is split into two courses; COE 711 and COE 712. In COE 711 (3 credit hours) the student prepares his dissertation proposal, while in COE 712 (9 credit hours) the student works on his proposed research subject. The dissertation is expected to involve original scholarly research applied to a carefully defined problem.

Table 1 summarizes the course requirements.

TABLE 1: Course Requirements of the Ph.D. Program in Computer Engineering

	Min Requirement	**Notes***
Major Area	**3** Courses (9 cr. hrs.)	• Major area may be any of the 4 COE areas of competency.
Minor Area	**2** Courses (6 cr. hrs.)	• Any COE specialization area other than the major area
COE Electives	**2** Courses (6 cr. hrs.)	• Any COE specialization area.
Technical Electives	**2** Courses from COE-related disciplines (6 cr. hrs.)	• Should be taken from outside the COE department.
Free Elective	1 Course (3 cr. Hrs.)	• May be either a COE or a non-COE course.
Comprehensive Exam	Comprehensive Exam	• To be passed by the 4th semester (FT students), or the 5th semester (PT students)
Seminar	**COE** 699: Seminar	• Zero credit hour (P/F).
Dissertation	**COE** 711, and **COE** 712: Dissertation	• 12 credit hours (3 + 9) • Dissertation topic is to be selected from the student major area of specialization.

* *No more than 4 non-COE courses are allowed*

5 Sample Degree Plan

Courses in the degree plan must be approved by the student's Graduate Committee, the Department Chairman, and the Dean of Graduate Studies.

Semester 1

Course	Description	Credit Hours
COE *xxx*	COE (major Area)	**3**
COE *xxx*	COE (minor Area)	**3**
COE *xxx*	COE Elective 1	**3**
	Total	**9**

Semester 2

Course	Description	Credit Hours
COE *xxx*	COE (major Area)	**3**
COE *xxx*	COE (minor Area)	**3**
XXX[*] *xxx*	Technical Elective 1	**3**
	Total	**9**

Semester 3

Course	Description	Credit Hours
COE *xxx*	COE (major Area)	**3**
XXX[*] *xxx*	Technical Elective 2	**3**
	Total	**6**

Semester 4

Course	Description	Credit Hours
COE 699	Seminar	**0**
COE *xxx*	COE Elective 2	**3**
YYY[◊] *yyy*	*Free* Elective	**3**
	Total	**6**

[*] The two XXX *xxx* courses are the graduate technical elective courses.

[◊] The **YYY** *yyy* free elective may be either a COE or a non-COE course.

Semester 5

Course	Description	Credit Hours
COE 711	Ph.D. Pre-Dissertation	**3**
	Total	**3**

Semester 6

Course	Description	Credit Hours
COE 712	Ph.D. Dissertation Work	**9**
	Total	**9**

Semester 7

COE 712 PhD Dissertation Work (Continued)

Semester 8

COE 712 PhD Dissertation Work (Continued)

- **Dissertation Defense**

6 List of Courses under the four COE Specialization Areas

Courses for Area 1. Computer Architecture and High Performance Computing			
COE	**501**	Computer Architecture	(3-0-3)
COE	**502**	Parallel Computing	(3-0-3)
COE	**504**	Heterogeneous Computing	(3-0-3)
COE	**509**	Special Topics in Computer Architecture and HPC	(3-0-3)
COE	**586**	Computer Arithmetic	(3-0-3)
COE	**601**	Massively Parallel Computing	(3-0-3)
COE	**602**	Design and Modeling of Massively Parallel Architectures	(3-0-3)
COE	**603**	Parallel Computer Architecture	(3-0-3)
COE	**604**	Interconnection Networks	(3-0-3)
COE	**605**	Reliability and Fault Tolerance of Computer Systems	(3-0-3)
ICS	**556**	Parallel Algorithms	(3-0-3)

Courses for Area 2. Computer Networks and Security			
COE	**520**	Queuing Theory and Network Applications	(3-0-3)
COE	**540**	Computer Networks	(3-0-3)
COE	**541**	Local and Metropolitan Area Networks	(3-0-3)
COE	**543**	Mobile Computing and Wireless Networks	(3-0-3)
COE	**544**	Wireless Ad hoc Networks	(3-0-3)
COE	**545**	Wireless Sensor Networks	(3-0-3)
COE	**546**	Computer Network Design	(3-0-3)
COE	**547**	Network Management	(3-0-3)
COE	**551**	Computer and Network Security	(3-0-3)
COE	**553**	Fault Tolerance and Reliability in Computer Networks	(3-0-3)
COE	**554**	Modeling and Analysis of Computer Networks	(3-0-3)
COE	**555**	Protocol Engineering	(3-0-3)
COE	**559**	Special Topics in Computer Networks and Security	(3-0-3)
COE	**642**	Computer Systems Performance	(3-0-3)
COE	**644**	Radio Resource Management	(3-0-3)
COE	**645**	Wireless Network Security	(3-0-3)
COE	**647**	Multimedia Networks	(3-0-3)
EE	**571**	Digital Communications I	(3-0-3)
EE	**573**	Digital Communications II	(3-0-3)
EE	**577**	Wireless and Personal Communication	(3-0-3)
ICS	**553**	Advanced Computer Algorithms	(3-0-3)
ICS	**554:**	Applied Combinatorics and Graph Theory	(3-0-3)
ICS	**555**	Data Security and Encryption	(3-0-3)
ICS	**571**	Client Server Programming	(3-0-3)
ICS	**572**	Distributed Computing	(3-0-3)
ICS	**575**	Application Development for Internet Based Services	(3-0-3)
SEC	**528**	Security in Wireless Networks	(3-0-3)
SE	**518**	Deterministic Modeling and Simulation	(3-0-3)
SE	**522**	Stochastic Simulation and Queuing Models	(3-0-3)
EE	**672**	Satellite Communications	(3-0-3)
EE	**674**	Telecommunication Networks	(3-0-3)

Courses for Area 3. Digital System Design & Automation			
COE	**561**	Digital System Design & Synthesis	(3-0-3)
COE	**562**	VLSI System Design	(3-0-3)
COE	**563**	Digital System Synthesis and Optimization	(3-0-3)
COE	**567**	Digital System Modeling & Verification	(3-0-3)
COE	**568**	Design of Re-Configurable ASICs	(3-0-3)
COE	**571**	Digital System Testing	(3-0-3)
COE	**572**	Computer-Aided Design of Digital Systems	(3-0-3)
COE	**579**	Special Topics in Digital Sys. Design and Automation	(3-0-3)
COE	**661**	System-on-Chip Modeling and Design	(3-0-3)
COE	**663**	Applied Functional Verification of Digital Systems	(3-0-3)
COE	**665**	Hardware/Software Co-design of Embedded Systems	(3-0-3)
COE	**686**	Applied Cryptography: Techniques and Architectures	(3-0-3)

Courses for Area 4. Computer Systems and Applications			
COE	**581**	Digital Forensics	(3-0-3)
COE	**586**	Computer Arithmetic	(3-0-3)
COE	**587**	**Performance Evaluation and Analysis**	(3-0-3)
COE	**588**	Modeling and Simulation	(3-0-3)
COE	**589**	Special Topics in Computer Systems and Applications	(3-0-3)
COE	**593**	Multimedia Architectures	(3-0-3)
COE	**596**	Intelligent Computing	(3-0-3)
COE	**597**	Real Time Systems	(3-0-3)
COE	**683**	Information systems Planning	(3-0-3)
COE	**684**	Robotics	(3-0-3)
COE	**686**	Applied Cryptography: Techniques and Architectures	(3-0-3)
COE	**696**	Advanced Intelligent Computing	(3-0-3)
EE	**555**	Neural Networks Theory and Applications	(3-0-3)
EE	**556**	Intelligent Control	(3-0-3)
ICS	**543**	Advanced Computer Graphics	(3-0-3)
ICS	**555**	Data Security and Encryption	(3-0-3)
SE	**515**	Distributed Computer Control	(3-0-3)
SE	**532**	Industrial Robots	(3-0-3)
EE	**663**	Image Processing	(3-0-3)
EE	**665**	Signal and Image Compression	(3-0-3)
ICS	**625**	Advanced Neural Networks	(3-0-3)
ICS	**627**	Advanced Computer Vision	(3-0-3)
SE	**660**	Artificial Intelligence and Expert Systems in Control	(3-0-3)
SE	**662**	Image Processing and Pattern Recognition in Automation	(3-0-3)

7 Course Descriptions

COE 501: Computer Architecture (3-0-3)

Computer architecture fundamentals, trends, and performance. Hardware and software approaches to ILP, dynamic, speculative, VLIW, and superscalar execution models. Examples and case studies. Dynamic branch prediction techniques. Memory hierarchy, cache and virtual memory, cache coherence, memory system performance. Parallel architectures models, coherence protocols, and interconnection networks. The students are expected to carry out research projects in related field of studies.

Prerequisite: Graduate Standing.

COE 502: Parallel Computing (3-0-3)

Introduction to parallel processing architecture, sequential, parallel, pipelined, and dataflow architectures. Parallel program models. Basic parallel programming techniques, problem decomposition, assignment, orchestration, and mapping. Examples and case studies of static, semi-static, and dynamic application parallelism. Performance: evaluation, scalability, and workload selection. The students are expected to carry out research projects in related field of studies.

Prerequisite: Graduate Standing.

COE 504: Heterogeneous Computing (3-0-3)

Taxonomy of heterogeneous computing. Introduction to Hard-RT, Soft-RT and Firm-RT heterogeneous systems. Network heterogeneous computing: design issues, architecture, programming paradigm and environment and Middleware Technologies. Applications and case studies. The students are expected to carry out research projects in related fields of study.

Prerequisite: Graduate Standing.

COE 509: Special Topics in Computer Architecture and HPC (3-0-3)

Advanced topics selected from current issues in Computer Architecture and High-Performance Computing.

Prerequisite: Graduate Standing and Consent of Instructor

COE 520 Queuing Theory and Network Applications (3-0-3)

Introduction to network applications, discrete random variables, continuous random variables, characteristic functions. Introduction to stochastic processes. Discrete-time Markov chains, continuous time Markov chains. Introduction to queuing theory, M/M/1 and derivative queues, and M/G/1 queues. Burke's theorem. Jackson's theorem: open and closed network of queues. Applications to computer networks and case studies.

Prerequisite: Consent of Instructor.

COE 540 Computer Networks **(3-0-3)**

Review of Computer networks layering concepts and quality of service requirements. Physical Layer, Data Link Layer; ARQ Strategies; Analysis of ARQ Strategies. Multi-access communication. Network layer. Routing in Data Networks. Flow and Congestion Control. Transport layer. Application Layers: peer-to-peer networking, Content Distribution networks. Studying a number of classic and current papers on these subjects.

Prerequisite: Graduate Standing.

COE 541 Local and Metropolitan Area Networks **(3-0-3)**

Local and Metropolitan Area Networks classes, standards, and network architectures. Physical layer for LAN and MANs. Multiple access techniques and protocols for advanced Local and Metropolitan Area Networks. Design issues, and performance modeling and analysis. Interworking and network management for LAN and MAN. Case studies including Gigabit/Terabit Ethernet, Gigabit WiFi, G/EPONs, etc. Emerging LAN and MAN technologies.

Prerequisite: COE 520.

COE 543 Mobile Computing and Wireless Networks **(3-0-3)**

Introduction to radio frequency propagation models. Physical layer for advanced mobile systems. Cellular configurations and interference mitigation and coordination methods. Multiple access techniques for wireless networks. Wireless network architecture. Cooperative communications. Mesh networks. Ad-hoc networks. Mobility solutions for mobile networks (Mobile-IP, Session Initiation Protocol, mobile-Stream Control Transport Protocol, etc.). Quality of service, reliability, and security in mobile computing environment. 5^{th} generation wireless networks. Case studies including Wireless Personal Area Networks (e.g. Bluetooth, Zigbee, etc.), Wireless Local Area Networks (e.g. 802.11n, 802.11ac, etc.) Wireless Metropolitan and Wide Area Networks (e.g. WiMAX-2, Long-Term Evolution and Long-Term Evolution Advanced).

Prerequisite: COE 520.

COE 544 Wireless Ad hoc Networks **(3-0-3)**

The basic hardware and software platforms for sensor networks and will address in detail several algorithmic techniques for deployment, localization, synchronization, MAC, sleep scheduling, data routing, querying processing, topology management and energy aware protocols. hands-on experience through programming projects involving different platforms. In addition, different microcontrollers, such as Ardunio will be used to interface different wireless communication transceivers with sensors..

Prerequisite: Graduate Standing.

COE 545 Wireless Sensor Networks **(3-0-3)**

Introduction to the most recent advanced Mobile Ad hoc Networks (MANETs) routing protocols. Issues that are related to design protocols such as scheduling, capacity, medium access, QoS, topology control, and mobility tracking will be covered. In addition, modeling techniques as well as delay models will be covered using Linear Programming.

Prerequisite: COE 540.

COE 546 Computer Network Design **(3-0-3)**

Network Development Life Cycle. Network Analysis and Design Methodology. Traffic Flow Analysis and Performance Evaluation. Network Simulation and Traffic Measurement Tools. Topology Design. Terminal Assignment. Concentrator Location and Servers Placement. Traffic Engineering. Structured Enterprise Network Design. Hierarchical Network Design Model. LAN and WAN Network Design. Backbone Design: Centralized vs. Distributed. Addressing and Routing. Network Management and Security. Network Reliability. Technology Choices. Structured Cabling Systems. Case Studies.

Prerequisite: Graduate Standing .

COE 547 Network Management **(3-0-3)**

Network Management Standards and Models. Network Management Protocols. Network Management Applications. Network Management Tools and Systems. Abstract Syntax Notation One (ASN.1).Structure of Management Information (SMI). Management Information Base (MIB). Simple Network Management Protocol (SNMP). SNMPv2 and SNMPv3. Remote Monitoring (RMON).RMON 1 and 2.Web-Based Management. Recent Network Management Advances

Prerequisite: COE 540 or Consent of the Instructor.

COE 551 Computer and Network Security **(3-0-3)**

Overview of Online Attacks, Malware, Social engineering, Physical and Communication security, Access Control techniques, Cryptography: Classical Cipher, mathematical cipher, Stream cipher, Block cipher, public key , Other Information security: Stegnography, Hashing , Secret Sharing , Software reverse engineering & Program Security, Firewalls & IP sec, Security Policy & Risk Management , Advanced security topics.

Prerequisite: Graduate Standing.

COE 553 Fault Tolerance and Reliability in Computer Networks (3-0-3)

Introduction to concepts of faults, errors, and failures. Basic concepts of dependable computing including dependability attributes, means, and validation. Stochastic modeling techniques in the context of network reliability analysis. Error detection and correction techniques. Fault-tolerant topology design. The practices of reliable and fault-tolerant computer networks design. Case studies.

Prerequisite: Graduate Standing

COE 554 Modeling and Analysis of Computer Networks (3-0-3)

Numerical and analytical modeling. Performance evaluation and prediction. Exponential queuing systems; single and multiple servers, finite and infinite system size. Queuing networks. Cost-effective design and operation. Characterization of relations between system parameters. Conventional and non-conventional measures of system performance. Using modern computational packages like Mathematica and Matlab for building models and performing analysis. Case studies in areas like resource sharing, multiplexing and stochastic control..

Prerequisite: COE 520 or Consent of the Instructor.

COE 555 Protocol Engineering (3-0-3)

Protocols and languages. Protocol structure. Structured protocol design. Fundamentals of Protocol Engineering. Specification and modeling. State Machines and Reachability Analysis. Formulation of desirable properties of protocols. Formal Logic and Deduction. Verification techniques. Formal description languages. Protocol synthesis. Protocol Design. Validation and conformance testing. Computer aided design tools for protocol engineering (simulation and validation tools). A major project involving comprehensive design and verification of a non-trivial protocol.

Prerequisite: COE 540

COE 559 Special Topics in Computer Networks and Security (3-0-3)

Any state of the art topics or topics of recent interest in any areas in computer systems and applications that may not fit well with the description of the previously mentioned courses.

Prerequisite: Consent of the Instructor.

COE 561 Digital System Design & Synthesis (3-0-3)

Overview of modern digital systems; Systems-on-chip, virtual cores, design reuse and IP's (soft, firm and hard), ASIC design methodologies. Digital system hierarchy & abstraction levels, Hardware Modeling using HDL, Design optimization and performance criteria, HDL coding for synthesis, Testability of digital systems and High-Level synthesis.

Prerequisite*:* Graduate Standing.

COE 562 VLSI System Design (3-0-3)

Review of MOS transistors, modeling, scaling, sizing, physical design (layout). Combinational and sequential logic, static CMOS, Dynamic circuits, pass-transistor logic. Clocking strategies, clock skew, setup, hold & propagation delays, self-timed logic, I/O design. Design considerations of regular structures: ROM's, PLA's, arithmetic circuits. CAD tools used in VLSI design (schematic, layout, DFT …etc.). CMOS memory architecture, design constraints. ROM, SRAM and DRAM cells. Single and double-ended bit line sensing. Multiport register files. The course is project-oriented stressing the use of CAD tools through class projects.

Prerequisite*:* **COE 561**

COE 563 Synthesis and Optimization of Digital Systems (3-0-3)

Digital design styles, design representations, abstraction levels & domains, Binary Decision Diagrams, Satisfiability and Covering problems, Two-level logic synthesis and optimization: Exact and heuristic techniques, Testability properties of two-level circuits, Multi-level logic synthesis and optimization, Observability and controllability don't care conditions, Testability properties of multilevel circuits, Synthesis of minimal delay circuits, Sequential logic synthesis: state minimization, state encoding, retiming, Technology mapping, High level synthesis: data flow and control sequencing graphs, scheduling, allocation..

Prerequisite*:* **COE 561**.

COE 566 VLSI ASIC Design (3-0-3)

Review of MOS transistors, modeling, scaling, sizing, physical design (layout), and static versus dynamic logic. MOS logic optimization of delay and area. ASIC design flows. ASIC design with HDL. ASIC library design, cell characterization, design area and delay. Standard-cell design methodology, propagation delay, design area, critical path, placement and routing of cells, design optimization and back annotation. HDL modeling, technology mapping and synthesis. ASICs test techniques, fault models, boundary scan and DFT. The course emphasizes hands on experience through the use of available design tools for the design of ASIC VLSI.

Prerequisite*:* **COE 561**.

COE 567 Digital System Modeling & Verification (3-0-3)

Introduction and approaches to digital system verification. Simulation versus Formal verification. Levels of hardware modeling (circuit, switch, gate, RTL, and Behavioral levels).Principle of Formal hardware modeling and verification. Model checking; binary and word-level decision diagrams, symbolic methods, Mathematical logic (First order logic, Higher Order Logic, Temporal Logic). Abstraction mechanisms for hardware verification. Automated theorem provers. Verification using Specific Calculus. Formal verification versus formal synthesis. Future trends in hardware verification.

Prerequisite*:* COE 561.

COE 568 Design of Re-Configurable ASICs (3-0-3)

Review of modern digital systems and their designs. ASIC design flows. Field programmable gate Arrays: Architectures, Configuration Techniques, Design Parameters and Models. FPGA design Flow. Application Domains, Custom computing machines and FPGA-based hardware accelerators. Case studies and contemporary issues in reconfigurable computing.

Prerequisite*:* COE 561.

COE 571 Digital System Testing (3-0-3)

Basic principles and practice of digital system testing, Test Economics, Fault models, Fault simulation, Test generation for Combinational and Sequential circuits, Test compaction, Test Compression, Fault Diagnosis, Delay-fault testing, Design for testability, Boundary Scan, Built-in self-test: logic BIST and memory BIST, Testing of system-on-chip.

Prerequisite*:* COE 561.

COE 572 Computer-Aided Design of Digital Systems (3-0-3)

The VLSI Design Process. Layout Styles. Graph and Circuit Partitioning. Floorplanning Approaches. Placement Heuristics. Routing: Maze Routing, Line Search Algorithms, Channel Routing and Global Routing. Layout Generation. Layout Editors and Compaction. Solutions to NP-Hard Problems in CAD. 3D VLSI Physical Design Automation. CAD for current issues and emerging technologies.

Prerequisite*:* Graduate Standing

COE 579 Special Topics in Digital Sys. Design and Automation (3-0-3)

Advanced topics selected from current issues in the area of digital system design and automation.

Prerequisite*:* Consent of Instructor.

COE 581 Digital Forensics **(3-0-3)**

A research-oriented graduate course in digital forensics. It aims to provide an extensive background suitable for those interested in conducting research in this area, as well as for those interested to learn about digital forensics in general. The course focuses on the technical issues and open problems in the area. Topics include fundamentals of digital forensics; digital forensics models, multimedia forensics; OS artifacts forensics; file carving; live and memory forensics; network forensics; mobile devices forensics; current tools and their limitations; legal and ethical issues.

Prerequisites: Graduate standing.

COE 586 Computer Arithmetic **(3-0-3)**

Fixed point arithmetic: addition/subtraction, multiplication, and division. Modular multiplication, division and exponentiation. Floating point arithmetic: normalization, rounding, addition, subtraction, multiplication, division. Elementary functions; trigonometric, logarithmic, hyperbolic. Interval arithmetic, arbitrary-precision algorithms, modular arithmetic (multiplication, exponentiation, inversion), arithmetic in Galois Fields.

Prerequisite*:* **COE 561**.

COE 587 Performance Evaluation and Analysis **(3-0-3)**

Performance evaluation techniques. Measurement techniques and tools. Summarizing measured data. Data representation, Experimental design. Factorial designs. Simulation of computer-based systems. Analysis of simulation results. Analytical and queueing modeling. Operational laws and mean-value analysis. Decomposition of large queueing networks. The modeling cycle. Flow analysis. Bottleneck analysis. Hierarchical modeling. Case studies.

Prerequisite*:* Graduate Standing
Not to be taken for credit with: ICS 532.

COE 588 Modeling and Simulation **(3-0-3)**

Approaches to the simulation problem (event scheduling, process-based, …). Modeling and simulation of queuing systems. Probability, stochastic processes, and statistics in simulation. Random number generation. Monte Carlo methods. Building valid and credible simulation models. Output data analysis. Simulation formalisms. Software techniques for building simulators. Using contemporary tools like Matlab and SimEvents. Case studies.

Prerequisite*:* Graduate standing.
Not to be taken for credit with*:* ICS 533, SE 518.

COE 589: Special Topics in Computer Systems and Applications **(3-0-3)**

Advanced topics selected from current issues in the area of digital system design and automation.

COE 593 Multimedia Architectures (3-0-3)

Time-Frequency Representation, Predictive Coding, Speech Analysis and Synthesis, Image Understanding and Modeling, Image Compression Techniques, Color Models and Color Applications, 3-D Representation, Illumination Models, Graphics Systems, MPEG Standards, Video Compression, Video Conferencing, Digital Rights Management.

Prerequisite: Graduate standing and Consent of Instructor.
Not to be taken for credit with:ICS 538

COE 596: Intelligent Computing (3-0-3)

Introduction to the Fundamental Principles and Practices of Intelligent Computing. The Use of Intelligent Computing Algorithms such as Artificial Neural Networks, Instance-based Learning Techniques, Uncertain reasoning, Machine Learning, Intelligent Agents, Evolutionary Algorithms, Associative Memories and Contemporary Bio-Inspired computing for Computer Engineering Applications such as Network topology design, Network Security, Thermal modeling of CPUs, and Digital Logic Functions.

Prerequisite: Graduate standing **and** Consent of Instructor[1].

COE 597: Real Time Systems (3-0-3)

Introduction and Concepts, System Specifications and Architecture, Types of Real Time System, Embedded RT Systems Modeling and Analysis with Time Constraints, Real-Time Systems Design, Performance metrics, Performance evaluation under extreme conditions, Hardware/Software trade-off for Real Time Systems, Applications and Case Studies.

Prerequisite: Graduate standing **and** Consent of Instructor[2].

COE 599: Seminar (1-0-0)

Graduate students are required to attend the seminars by faculty members, visiting scholars, and fellow graduate students. Additionally, each student must present at least one seminar on a timely research topic. Among other things, this course is designed to give the students an overview of research in COE, and a familiarity with research methodology, journals and professional societies in his discipline. Graded on a Pass or Fail basis.

Prerequisite: Graduate standing

[1] The course requires some background in Algorithms and a few Computer Engineering / Science concepts. Depending on the school where the student is coming from, he may or may not be able to grasp all concepts. Therefore, consent of instructor is required before registering for this course.

[2] The course requires some background in Algorithms and a few Computer Engineering / Science concepts. Depending on the school where the student is coming from, he may or may not be able to grasp all concepts. Therefore, consent of instructor is required before registering for this course.

COE 601: Massively Parallel Computing (3-0-3)

Introduction to massively parallel multiprocessors and their programming models. Streaming multiprocessor, SIMD and multithreading. Highly multithreaded architectures, thread-Level parallelism, resources sharing, thread scheduling, score-boarding, transparent scalability. Data dependence analysis, recurrences, races. Shared-memory, atomicity, mutual exclusion, barrier, and synchronization. Memory hierarchy optimization, locality and data placement, data reuse, loop reordering transformations, shared-memory usage, global memory bandwidth and accesses. Control-flow, SIMD, thread blocks partitioning, vector parallel reduction, tree-structured computation, serialized gathering, Predicated execution, and dynamic task queues. Applications of static, semi-static, and dynamic parallel computations: dense and sparse linear Algebra, bucket sorting, N-body simulation, and ray-tracing.

Prerequisite: COE 501 or equivalent

COE 602: Design and Modeling of Massively Parallel Architectures (3-0-3)

The MIMD and SPMD models, Multithreading, Mapping to Massively Parallel Architectures (MPA), The Application-specific vs. Multi-purpose Architectures, Interconnection Networks, Computation Scheduling and Distribution Paradigms, Memory hierarchy models, Core complexity, System Modeling, Architecture Exploration using SystemC, The untimed model, the TLM model, Mixing models to explore architectures, The system modeling design flow, From modeling to prototyping: FPGAs as a platform for MPA and FPGA infrastructure.

Prerequisite: COE 501 or equivalent

COE 603: Parallel Computer Architecture (3-0-3)

Parallel computer architecture and programming models. Shared memory multiprocessors and message passing. Data-parallel and vector processing. Memory hierarchy design, cache coherence, and memory consistency. Synchronization and scalability. Network design. Students are expected to carry out a research project in their related field of study.

Prerequisite: COE 501 or equivalent

COE 604: Interconnection Networks (3-0-3)

This course explores the architecture and design of interconnection networks including topology, routing, flow control, and router microarchitecture. Impact on communication requirements of various parallel architectures and cache coherence mechanisms. Recent research on interconnection networks used in multiprocessor systems and on-chip many-core designs.

Prerequisite: COE 501 or equivalent

COE 605 Reliability and Fault Tolerance of Computer Systems (3-0-3)

Reliability and fault-tolerance of computer networks such as FDDI, double loop, hypercube, multi-stage interconnection network, multiprocessor systems, etc. Reliable and fault-tolerant routing, Reliability evaluation algorithms, Availability and survivability of computer systems, Reliability models of JPL-STAR, FTMP, ESS No. 1, PLURIBUS, etc. Software fault tolerance and reliability. Projects using network reliability evaluation tools such as SYREL, SHARPE and SPNP.

Prerequisite: Graduate Standing.

COE 606: Independent Study (3-0-3) (P/F)

This course is intended to allow MS students conduct research-related independent study. The faculty offering the course should submit a research plan to be approved by the COE Graduate Program Committee. The student is expected to deliver a public seminar and a written report on his research outcome at the end of the course. The course is graded on a Pass or Fail basis. To select adequate subject, prior arrangement with the instructor is required.

COE 610: Computer Engineering Master Thesis (0-0-6) (P/F)

The student has to undertake and complete a research topic under the supervision of a faculty member in order to probe in depth a specific problem in Computer Engineering.

Prerequisite: COE 599.

COE 642 Computer Systems Performance (3-0-3)

Queuing theory. Stochastic Petri nets and Markov Chains. Separable queuing networks. Priority queuing systems. Queuing networks, product forms and various solution techniques. Matrix geometric solutions to queuing theory. Bounds and approximations. Fluid analysis and diffusion processes. Evaluation studies: monitoring techniques, modeling methods and model validation. Simulations and variance reduction techniques. Application of queuing theory to computer time-sharing & multi-access systems, multiprocessor systems, interconnection networks. Computer communication networks. Case studies of several distributed and network system configurations.

Prerequisite: COE 520 or SE 541.

COE 644 Radio Resource Management (3-0-3)

Radio resource management and performance analysis in transporting homogenous/heterogeneous traffic in wireless communication networks. Traffic characteristics, connection admission control, packet scheduling, access control, and mobility and handoff management. Cases studies on mobile wireless networks and wireless sensor networks.

Prerequisite: COE 543.

COE 645 Wireless Network Security (3-0-3)

Security for contemporary wireless communication networks such as cellular networks, wireless LANs, mobile ad-hoc networks, wireless sensor and mesh networks. Study of diverse attack types such as radio signal jamming, MAC-layer attacks, routing attacks, Sybil, Blackhole attacks, and O/S dependent attacks. Study of countermeasures and scope for each of these attacks. Light-weighted security for resource-constrained wireless devices. Secure multi-casting. Key management techniques for wireless networks.

Prerequisite: COE 551.

COE 647 Multimedia Networks (3-0-3)

Fundamentals concepts in multimedia systems. Resource management issues in distributed/networked multimedia systems, QoS routing and multicasting. Traffic shaping, Traffic engineering, Task and message scheduling, Internet QoS. Adaptive multimedia applications over the Internet. Operating system support for multimedia. Storage architecture and scalable media servers. Compression techniques, synchronization techniques, processor architectures for multimedia.

Prerequisites: COE 540.

COE 661 System-on-Chip Modeling and Design (3-0-3)

A current-day system on a chip (SoC) consists of several different microprocessor subsystems together with memories and I/O interfaces. This course covers SoC design and modeling techniques with emphasis on architectural exploration, assertion-driven design and the concurrent development of hardware and embedded software. This is the 'front end' of the design automation tool chain.

Prerequisite: **COE 561**.

COE 663Applied Functional Verification of Digital Systems (3-0-3)

This is a hands-on project-based course using state of the art EDA tools covering complex system verification (e.g. SoC). Functional specifications, the verification Plan. Simulation Based Verification, HDLs and simulation-based verification, test benches and Verification Coverage, stimulus generation, Re-Use Strategies and System Simulation, Regression1, Problem Tracking, Tape-Out Readiness, Escape Analysis. Formal Verification, Comprehensive Verification; case studies.

Prerequisite*:* **COE 561**.

COE 665 Hardware/Software Co-design of Embedded Systems (3-0-3)

Embedded System Design Considerations, Classical Design Methods, co-representation, Performance Modeling, Co-design Trade-offs, Functional Decomposition, Partitioning, Design methodologies, Co-design Environments, Abstract Models, Recent Techniques in Co-design, Case Studies.

Prerequisite*:* **COE 561**.

COE 683 Information Systems Planning (3-0-3)

Concepts of organizational planning related to IT Systems. The IT Planning process. Understanding information systems planning: functions, processes, information groups, subject databases. Information systems planning strategies and standards. Information needs analysis. Strategic planning of information systems. IS planning for office automation and industrial automation. Make or Buy strategy. Students should conduct a research project.

Prerequisite*:* Graduate Standing

COE 684: Robotics (3-0-3)

Computational approaches to motion, vision, and robotic intelligence. Configuration space, algebraic decompositions, motion coordination, trajectory planning under uncertainty, and task-level planning. Robotic programming models. Models of cognitive systems, robotic intelligent control and programming, and behavior design and programming. Multi-robot cooperation systems.

Prerequisite: Graduate Standing.

COE 686 Applied Cryptography: Techniques and Architectures (3-0-3)

Hardware and architecture of cryptosystems, crypto-processors and accelerators. Stream ciphers, Block ciphers, the Advanced Encryption Standard (AES), Feistel network based block ciphers, modes of operation, hardware implementation and trade-offs. Public-Key Cryptosystems, the RSA crypto-processors, the discrete logarithm problem, Diffie-Hellman key exchange protocol and Elgamal Cryptosystem, elliptic-curve cryptography (ECC), digital signatures, hash functions, Message Authentication Codes (MACs). The course focuses on communicating the essentials and keeping the mathematics to a minimum quickly moving from explaining the foundations to describing practical implementations, including recent topics such as lightweight ciphers for RFIDs and mobile devices.

Prerequisite: COE 561

COE 691 Special Topics in Computer Engineering - I (3-0-3)

Advanced selected topics in computer engineering.

Prerequisite: Graduate standing and Consent of Instructor.

COE 692 Special Topics in Computer Engineering - II (3-0-3)

Advanced selected topics in computer engineering.

Prerequisite: Graduate standing and Consent of Instructor.

COE 693 Special Topics in Computer Engineering - III (3-0-3)

Advanced selected topics in computer engineering.

Prerequisite: Graduate standing and Consent of Instructor.

COE 696 Advanced Intelligent Computing (3-0-3)

Use of Advanced Intelligent Computing Concepts such as Memetic Algorithms, Particle Swarm Optimization, Ant Colony Optimization,, Fuzzy Logic (Type-1 and Type-2), Fuzzy Neural Networks, Adaptive Resonance Theory for Computer Engineering Applications such as Network Routing Tree Designs, Network Security, Wireless Sensor Network Topology Design, and Computer Network Load Balancing.

Prerequisite: COE 596.

COE 699 Seminar (1-0-0) (P/F)

PhD students are required to attend Departmental seminars delivered by faculty, visiting scholars and graduate students. Further, each PhD student should present at least one seminar on a timely research topic. The course is graded as pass or fail. To secure a passing NP grade in this course, the student should have passed the PhD Comprehensive Exam. A student registered in the Seminar Course will be assigned an IC (incomplete) grade in case he fails the PhD Comprehensive exam in that semester. The IC grade will be changed to a passing NP grade once he passes the PhD Comprehensive Exam latest by the following semester to avoid having the IC grade changed into F.

Prerequisite: Graduate standing.

COE 701 Directed Research I (3-0-3) (P/F)

This course is intended to allow students conduct research in advanced problems in their Ph.D. area of specialization. Among other things, this course is designed to give the students an overview of research in COE, and a familiarity with research methodology, journals and professional societies in his discipline. At the end of the course, the student must deliver a public seminar to present his work and findings. The course is graded on a Pass or Fail basis. To select adequate subject, prior arrangement with the instructor is required.

COE 702 Directed Research II (3-0-3) (P/F)

This course is intended to allow students to conduct research in advanced problems in their Ph.D. area of specialization. Among other things, this course is designed to give the students an overview of research in COE, and a familiarity with research methodology, journals and professional societies in his discipline. At the end of the course, the student must deliver a public seminar to present his work and findings. The course is graded on a Pass or Fail basis. To select adequate subject, prior arrangement with the instructor is required.

COE 711 Computer Engineering Ph.D. Pre-Dissertation (0-0-3)

This course enables the student to submit his PhD Dissertation Proposal and defends it in public. The student passes the course if the PhD Dissertation committee accepts the submitted dissertation proposal report and upon successfully passing the Dissertation proposal public defense. The course grade can be NP, NF or IP.

Prerequisite: Ph.D. Candidacy
Co-requisite: COE-699.

COE 712 Computer Engineering Ph.D. Dissertation (0-0-9)

This course enables the student to submit his PhD Dissertation Proposal and defends it in public. The student passes the course if the PhD Dissertation committee accepts the submitted dissertation proposal report and upon successfully passing the Dissertation proposal public defense. The course grade can be NP, NF or IP.

Prerequisite: COE 711.