## **EE 421 / CS 425 – Digital System Design**

**(Fall 2025)**

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| Instructor | Dr. Shahid Masud |
| Room No. | EE Dept. 9-223A, Maxwell Wing |
| Office Hours | TBA |
| Email | [smasud@lums.edu.pk](mailto:smasud@lums.edu.pk) |
| Telephone | 8199 |
| Secretary/TA | Will be announced on LMS |
| TA Office Hours | Will be announced on LMS |
| Course URL (if any) | LMS will be used |
| Support Services | LUMS offers a range of academic and other services to support students. These are mentioned below, and you are encouraged to use these in addition to in-class assistance from course staff. For a complete list of campus support services available for you [click here](https://advising.lums.edu.pk/#supportservices) (https://advising.lums.edu.pk/#supportservices) |

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| Course Details | |
| Credit Hours | **3 (Theory)** + **1 Lab** (separate enrolment required) |
| Core | MS EE (Electronics and Embedded Systems Stream), MS DES (Digital Embedded Systems) |
| Elective | BS EE / CS , MS EE Elective |
| Open for Student Category | Senior / MS |
| Closed for Student Category | Freshman / Sophomore / Junior |

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| Course Catalog Description |
| This course explains how to go about designing complex, high-speed digital circuits and systems. Complete digital design-flow using modern design automation tools in description, simulation, logic synthesis and implementation technology are explored. Application of a modern hardware description language such as *SystemVerilog* to model and verify digital systems at Behavior and RTL level is studied. Advanced methods of logic minimization and state-machine design are discussed. Design and implementation of digital functional building blocks such as arithmetic circuits, datapaths, microprocessors, I/O modules, interfacing, UARTs, frequency generators, memories, encryption, etc. is included. BIST and Scan techniques for testing of digital systems are also covered. Study of architecture of modern FPGA devices is included. An introduction to contemporary testing methodology *UVM* is provided. |

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| Course Prerequisite(s)/Co-Requisite(s) |
| Pre-requisites: EE 324 *OR* CS 225 *OR* CS 320/EE320 *OR* Grad Standing  Co-requisites: EE 421 Lab / CS 325 Lab |

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| Course Offering Details (online offering may require some changes) | | | | | | |
| Lecture(s) | Nbr of Lec(s) Per Week | 2 | Duration | 75 min | Timings and Venue | TBA |
| Recitation (per week) | Nbr of Rec (s) Per Week | X | Duration |  | | |
| Lab (if any) per week | Nbr of Session(s) Per Week | X | Duration |  | | |
| Tutorial (per week) | Nbr of Tut(s) Per Week | X | Duration |  | | |

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| Course Learning Outcomes | | | | | |
| CLO1:  CLO2:  CLO3:  CLO4: | The students completing EE 421 / CS 425 should be able to:  Describe the concepts of timing hazards and how timing and other factors influence digital system performance.  Analyze and synthesize complex digital circuits like advanced binary adders, integer and FP multipliers, binary dividers, DSP filters, UART, ASM charts, other digital system design case studies, etc.  Describe different techniques, design, and applications for testing faults in digital systems such as stuck-at faults, ALFSR, BILBO, Scrambler, SCAN test, BIST, JTAG, etc.  Understand the design, construction and resources available in modern programmable logic devices such as CPLD and FPGA. | | | | |
| Course Learning Relation to EE Program Outcomes | | | | | |
| **EE/421 CLOs** | | **Related PLOs** | **Levels of Learning** | **Teaching Methods** | **CLO Attainment checked in** |
| CLO1 | | PLO1 | Cog-3 | Instruction, Assignments | Midterm, Final, Quizzes |
| CLO2 | | PLO1 | Cog-3 | Instruction, Assignments | Midterm, Final, Quizzes |
| CLO3 | | PLO2 | Cog-3 | Instruction, Assignments | Midterm, Final, Quizzes |
| CLO4 | | PLO2 | Cog-3 | Instruction, Assignments | Final, Quizzes |

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| Grading Breakup and Policy |
| Class quizzes: (5 – 6 quizzes, one dropped): 20%  Assignments: (1 - 2): 10%  Midterm exam: 30%  Final exam: 40%  \*Note: The lab component for MS students will be included in the final overall grade of course as explained in the class!  \*\* Lab details available separately |

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| **Examination Detail** | | |
| Midterm Exam (online modalities) | | Yes/No: Yes  Combine Separate: NA  Duration: TBD based on practical modalities  Preferred Date: TBA  Exam Specifications: TBA |
| Final Exam (online modalities) | | Yes/No: Yes  Combine Separate: NA  Duration: TBD based on practical modalities  Exam Specifications: TBA |

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| **Campus supports & Key university policies** |
| **Campus Supports**  Students are strongly encouraged to meet course instructors and TA’s during office hours for assistance in course-content, understand the course’s expectations from enrolled students, etc. Beyond the course, students are also encouraged to use a variety of other resources. (Instructors are also encouraged to refer students to these resources when needed.) These resources include Counseling and Psychological Services/CAPS (for mental health), LUMS Medical Center/LMC (for physical health), Office of Accessibility & Inclusion/ OAI (for long-term disabilities), advising staff dedicated to supporting and guiding students in each school, [online resources](https://advising.lums.edu.pk/advising-resources) (https://advising.lums.edu.pk/advising-resources), etc. To view all support services, their specific role as well as contact information [click here](https://advising.lums.edu.pk/#supportservices) (https://advising.lums.edu.pk/#supportservices).  **Academic Honesty/Plagiarism**  LUMS has zero tolerance for academic dishonesty. Students are responsible for upholding academic integrity. If unsure, refer to the student handbook and consult with instructors/teaching assistants. To check for plagiarism before essay submission, use [similarity@lums.edu.pk](mailto:similarity@lums.edu.pk). Consult the following resources: 1) [Academic and Intellectual Integrity](https://www.youtube.com/watch?v=3zAteKu1DhY) (<http://surl.li/gpvwb>), and 2) [Understanding and Avoiding Plagiarism](https://docs.google.com/document/d/18mBC8aP6qJtGzOxrbubtp4nI3tlIv6MIBVlaahxdeao/edit) (<http://surl.li/gpvwo>).  **LUMS Academic Accommodations/ Petitions policy**  Long-term medical conditions are accommodated through the Office of Accessibility & Inclusion (OAI). Short-term emergencies that impact studies are either handled by the course instructor or Student Support Services (SSS). For more information, please see Missed Instrument or ‘Petition’ FAQs for students and faculty (<https://rb.gy/8sj1h> )  **LUMS Sexual Harassment Policy**  LUMS and this class are a harassment-free zone. No behavior that makes someone uncomfortable or negatively impacts the class or individual's potential will be tolerated.  To report sexual harassment experienced or observed in class, please contact me. For further support or to file a complaint, contact OAI at [oai@lums.edu.pk](mailto:oai@lums.edu.pk) or [harassment@lums.edu.pk](mailto:harassment@lums.edu.pk). You may choose to file an informal or formal complaint to put an end to the offending behavior. You can also call their Anti-Harassment helpline at 042-35608877 for advice or concerns. *For more information:* [*Harassment, Bullying & Other Interpersonal Misconduct: Presentation*](https://docs.google.com/document/d/1-ezB24bJO2Ywy8lsnCoE8Sr-qKDyWQoE37zoo0khMfo/edit) *(*[*http://surl.li/gpvwt*](http://surl.li/gpvwt) *)* |

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| **Lecture / Week** | **Course Topics** | **Readings** | **Lab / Quiz** |
| 1 / Wk 1 | Introduction to digital systems and their design flow | Ciletti |  |
| 2 / Wk 1 | Review of combinational logic, logic minimization | Ciletti |  |
| 3 / Wk 2 | Advanced Logic Minimization Techniques | Ciletti |  |
| 4 / Wk 2 | Timing in Combinational Circuits, Hazards and Glitches | Notes |  |
| 5 / Wk 3 | Review of sequential logic | Ciletti |  |
| 6 / Wk 3 | Design using flip-flop and latches, State machines | Ciletti |  |
| 7 / Wk 4 | State reduction, timing issues | Ciletti |  |
| 8 / Wk 4 | Design of Adders and Subtractors, Carry Lookahead Adders | Ciletti |  |
| 9 / Wk 5 | Serial Adders, Array Multipliers, Critical Paths | Ciletti |  |
| 10 / Wk 5 | Booth and Radix-4 Encoded Signed Multipliers |  |  |
| 11 / Wk 6 | Further *SystemVerilog* modeling, parameterization | Notes |  |
| 12 / Wk 6 | Design of dividers and other arithmetic circuits | Notes |  |
| 13 / Wk 7 | Circuits for Floating Point Implementation | Ciletti |  |
| 14/Wk 7 | Serial Multipliers, Signed Multiplication of Fractions |  |  |
| 15 / Wk 7 | **Midterm Exam** |  |  |
| 16 / Wk 8 | Introducing Programmable logic, PAL, PLA, CPLD | Ciletti |  |
| 17 / Wk 8 | Construction, operation, examples of FPGA and CPLD | Ciletti |  |
| 18 / Wk 9 | Controller design using ASM charts | Ciletti |  |
| 19 / Wk 9 | Controller Design for Sequential Multipliers and Dividers | Ciletti |  |
| 20 / Wk 10 | Faults and Testability – BIST and SCAN techniques | Notes |  |
| 21 / Wk 10 | Design for test – JTAG | Notes |  |
| 22 / Wk 11 | LFSR, BRM, Function Generators, Design Examples | Notes |  |
| 23 / Wk 11 | Parity and Error Detection, Correction Circuits | Note |  |
| 24 / Wk 11 | HDL Synthesis Issues / Xilinx DSP Blocks | Notes |  |
| 25 / Wk 12 | Advanced HDL / Examples of Digital Systems / UART | Notes |  |
| 26 / Wk 13 | Asynchronous Sequential Design / Introduction to *UVM* test methodology | Notes |  |
| 27 / Wk 14 | Digital Design Case Study / Frequency Synthesizer | Notes |  |
|  | **Final Exam Week 15 or 16** |  |  |

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| Textbook(s)/Supplementary Readings |
| Textbook:  Michael D. Ciletti, *Advanced Digital Design with the Verilog HDL,* Prentice Hall  Supplementary Reading**: (Additional Notes, articles, and slides will be provided where needed)**  1. V Taraate, *SystemVerilog for Hardware Description RTL Design and Verification*, Springer, 2020  2. Ashok B. Mehta, *Introduction to SystemVerilog,* Springer, 2021  3. Donald Thomas, *Logic Design and Verification Using SystemVerilog*, 2021  3. Brent E. Nelson, *Designing Digital Systems With SystemVerilog v2.1, Department of Electrical and Computer Engineering Brigham Young University (online available)* |

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| **Prepared by:** | **Dr. Shahid Masud** |
| **Date:** | **Updated 6 August 2025** |