National University
Of Computer and Emerging Sciences

2021-2022

Master of Science / Graduate Diploma in Electrical Engineering *with* ***Specialization in Integrated Circuits***

"A Training from Idea to Product Design"

Salient Features and Objectives:

- **Pioneer of Integrated Circuits (IC) design graduate program** in Pakistan.
- First time in Pakistan an academic opportunity for IC designing on **Licensed Cadence Tool Suite.**
- **Established collaboration** with public and private industrial partners.
- **25 fully industrial funded MS students** already enrolled in Spring-2020, will, tape-out 8 group projects on two ICs in Spring-2021.
- Offers hands on design experience on **TSMC officially provided 65nm, 130nm and 150nm** CMOS process development kits **(PDKs)**.
- **Fully developed ICD lab and curriculum** with four full time faculty members with degrees in IC design and cumulative experience of **over a dozen IC tapeouts**.
- A comprehensive experience from project conception to the **working silicon microchip**.
- A **bridge between the industry-and-academia** to pave the way to FAB-less innovations resulting in IC design startups.
- **Fully equipped to conduct International standard IC design Industrial / academic training.**
- **Bright prospect of jobs at National and International Level**.

MS EE Program Objectives:

This program prepares a graduate in Electrical Engineering to acquire expertise in the area of Integrated Circuits. This program is fully dedicated and focused on the IC design knowledge and skills, each student in this program will do the real world tape out from project conception to the working silicon microchip under the guidance of faculty supervisor from university and industry experts.

Eligibility:

Bachelor's degree in a relevant engineering discipline (Electrical, Electronics, Telecommunications, or Computer engineering, etc.), recognized by Pakistan Engineering Council (PEC).

Minimum CGPA of 2.0, Preferably 2.5 (on a scale of 4.0) or at least 60% marks.

Scholarships:

Full and partial fee waiver for high achievers and deserving candidates

A student has the option to pursue MS by undertaking either a 6-credit hour MS Thesis or MS Project, spread over two regular semesters.

Tentative Study Plan:

Semester I		
SS 505	Core Course-I(RM)	1
EE	Core Course-II	3
EE	Core Course-III	3
EE	Elective -I	3
	Total	10 credits

Semester-II		
EE	Core Course-IV	3
EE	Core Course-V	3
EE	Elective -II	3
	Total	9 credits

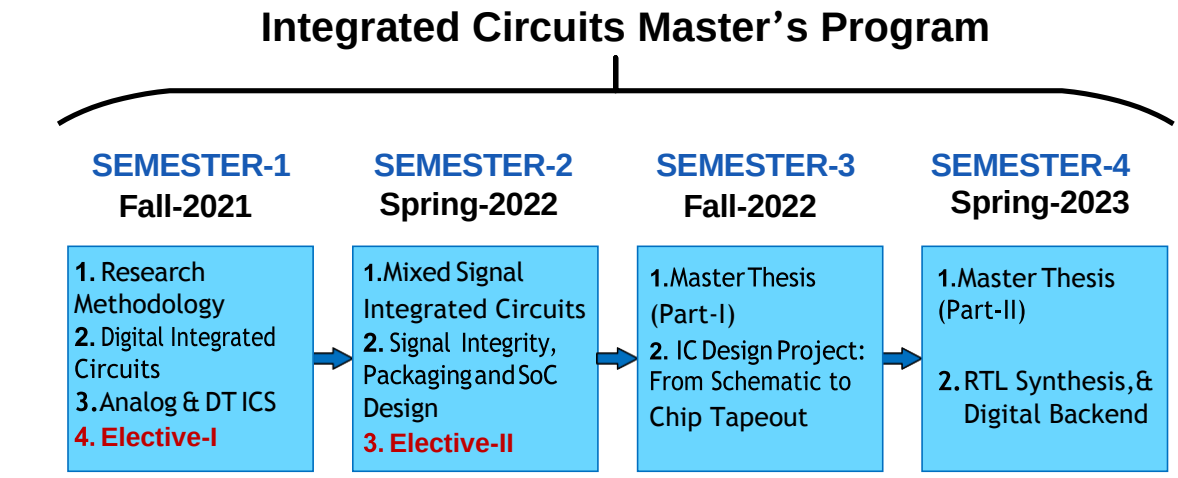
Semester-III		
EE	Core Course-VI	3
EE 591	MS Thesis-I	3
	Total	6 credits

Semester-IV		
EE	Core Course-VII	3
EE 592	MS Thesis-II	3
	Total	6 credits

The total credits of the MS programs are 31, which includes the 25 credits of the course work including the 01 credit Research Methodology Course and 06 credits of the MS thesis work.

Note: Registration in "Project – I" is allowed provided the student has:

- Earned at least 19 credits
- Passed the "Research Methodology" course;
- CGPA is equal to or more than 2.5



Recommended Electives
1. Advance Digital Signal Processing
2. Advance Embedded Systems
3. Printed and Flexible Electronics

MS (Electrical Engineering – Specialization in Integrated Circuits):

Core Courses for MS-EE with Specialization in Integrated Circuits:

1. Research Methodology (01 Credits) (HEC Requirement)
2. Digital Integrated Circuits (03 Credits)
3. Analog & DT Integrated Circuits (03 Credits)
4. Mixed Signal Integrated Circuits (03 Credits)
5. Signal Integrity, Packaging and SoC Design (03 credits)
6. IC Design Project: From Schematic to Chip Tapeout (03 credits)
7. RTL Synthesis,& Digital Backend (03 Credits)

Elective Courses (One must select minimum of 3 courses from this list of Electives)

1. RF Integrated Circuits (03 Credits)
2. Nano Electronics (03 Credits)
3. Printed and Flexible Electronics (03 Credits)
4. Advance Microwave Engineering (03 Credits)
5. Advance Embedded Systems (03 Credits)
6. Advance Digital Signal Processing (03 Credits)
7. Advanced Wireless Communication (03 Credits)
8. IC Marketing and Business Management (03 Credits)

Graduate Diploma Program Objectives:

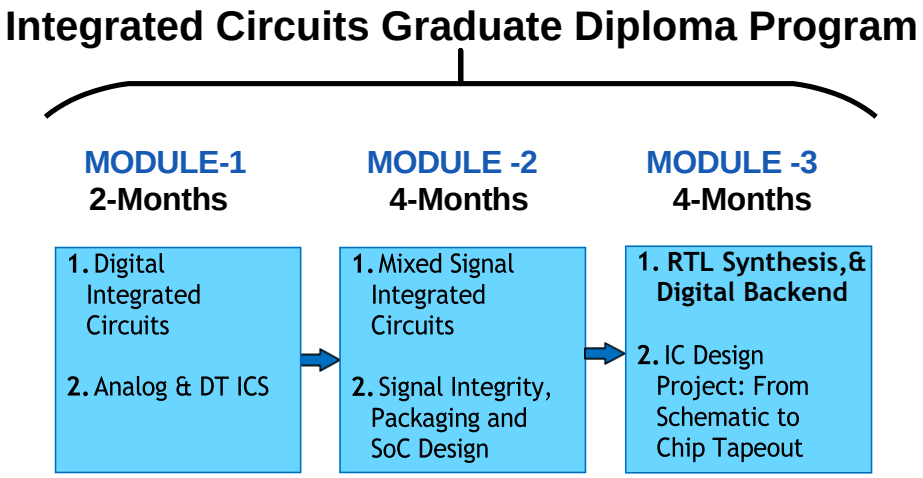
The graduate diploma program is especially crafted for industrial/academic organizations to develop skilled IC design in a short period. This program is fully dedicated and focused on the IC design knowledge and skills. Each student in this program will be taught comprehensive IC design curriculum, and a comprehensive IC design cycle, with hands on experience in IC design and testing tools/equipment in ten months. The program will help to develop the IC design echo system in Pakistan by training human resource which is a critical bottleneck in establishing IC design business in Pakistan.

Eligibility:

Graduation in EE/TE/Mechatronics/CS or equivalent.

Admission:

The diploma program will be offered on demand.



Graduate Diploma in Integrated Circuits Design:

Courses for Graduate Diploma in Integrated Circuits:

1. Digital Integrated Circuits
2. Analog & DT Integrated Circuits
3. Mixed Signal Integrated Circuits
4. Signal Integrity, Packaging and SoC Design
5. RTL Design Synthesis
6. IC Design Project: From Schematic to Chip Tapeout

Teaching Faculty for Compulsory Courses:

Teaching faculty is hands on IC designer with cumulative experience of over dozen IC tapeouts in different technologies.

For CVs of faculty, please see (http://isb.nu.edu.pk/rfcs2/team.htm)

- Prof. Dr. Rashad Ramzan
- Dr. Hassan Saif
- Dr. Shazad Saleem
- Dr. Arshad Hassan
- Engr. Sidera Saeed (PhD Fellow)
- Engr. Hamza Atiq (MS EE)
- Engr. Daniyal Ali (MS EE)

07 Compulsory Courses (19 Credit Hours):

1. **Research Methodology:** The course is mandatory for all graduate programs offered under HEC umbrella. The course covers central aspects of the research process, as well as principles and questions related to sate of art search, research planning, problem formulation, statistical data analysis, quality assessment, presentation of a research project, and research ethics. (01 credits; HEC requirement)

2. **Digital Integrated Circuits:** Review of integrated circuit fundamentals, CMOS Device Characteristics, Layout Rules, CMOS Inverter, Basic Gates, Combinational Logic Multiplexers, Transmission Gates, Sequential logic circuits, Latches, Flip Flops, Adders, Multiplier, Accumulators, Memory cells, Layout strategies, Basic of Logic synthesis and use of CAD tools.
   Lab Tutorials: Design of Basic Logic Gates, Flip Flop, Adders, Multiplexer, Demultiplexer, Memory Cells, Complex Digital Circuits, and Layout in Cell Library Format in Cadence Tool Suite. (03 credits)

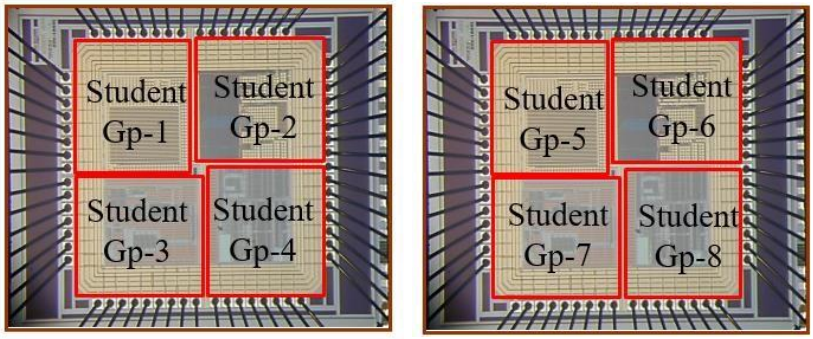
3. **Analog & DT Integrated Circuits:** Review of fundamentals, Analog Building Blocks, CMOS Device and Noise – Fundamentals, Single-Stage (CS, CG, CD), Differential Pair and Multistage Amplifiers, CMOS Operational Amplifier, Noise in CMOS Circuits, Feedback Principles, Current Sources and Current Mirrors, MOS Switched- Capacitor (SC) Circuits, OTA, and Gm Cells.
   Lab Tutorials: CMOS DC Analysis, Common Source Amplifier, Common Gate Amplifier, Multi Stage Amplifiers, Common Drain Amplifier, CMOS Current Mirrors, Differential Amplifiers, Two Stage Op-Amp, CMOS Noise Analysis, Advanced Layout Techniques in Cadence Tool Suite. (03 credits)

4. **RTL Synthesis, & Digital Backend:** Basics of HDL (Verilog) Coding. Synthesizable RTL, State Machine Design, HDL Testbench Design, RTL Code Compilation Scripts Development, Placement and Routing, Static Timing Analysis (STA), CLK Insertion, RISC-V for Embedded Systems.
   Lab Tutorials: Introduction to Verilog and Modelsim, State Machine Design, RTL Synthesis using Standard Cell Libraries, Place, Route, and Static Timing Analysis, Physical Layout using Cadence Genus, Innovus etc. Fullchip Physical Verification (DRC/LVS), Post Layout Simulations. (03 credits)

5. **Mixed-Signal Integrated Circuits**: Non-Linearity and Mismatch, CMOS Processing Technology, Layout Fundamentals, Sample & Hold Circuits, Voltage Comparators, Band-gap References, Data converters – Fundamentals and Performance Metrics, Nyquist Digital-to-Analog Converters, Nyquist Analog-to-Digital Converters, Z-Transform, Oversampling ΣΔ Data Converters, PLL and Frequency Synthesizers
   Lab Tutorials: Advanced Operational-Amplifier Design & Simulation, CMOS Comparators Design, Bootstrap Circuits Design, Switched Capacitor Circuits Design, Discrete Circuits Layout Techniques, Nyquist Rate DAC Design, Nyquist Rate ADC Design, Sigma-Delta Converters, Oscillator & PLL circuits, Bandgap Reference Circuits in Cadence Tool Suite. (03 credits)

6. **Signal Integrity, Packaging and Chip Design**: Signal Integrity Principals, Chip Interconnect and Transmission Lines, PCB and IC Materials, Impedance Matching, Power Distribution Network, Parallelism & Cross Talk. EMI and EMC, Reflections and Termination and IO Pads, On-Chip Passives, ESD Protection Management, IC and Discrete Component Packaging, Thermal Consideration, IC Failure and Reliability, Microsystems Packaging and Applications.
   Lab Tutorials: Impedance Matching using Lumped Model, Impedance Matching using Microstrip Model, EMC and TL Discontinuity Modeling and Simulation, Bond-wire Modeling and Simulations, Power Distribution Network Modeling, Parallelism Transmission Line Modeling & Analysis, Crosstalk and Noise Analysis, EMI/EMC Interference Analysis, On-Chip Passives and Corner Analysis.

7. **IC Design Project: From Schematic to Chip Tapeout**: Project selection, Pre-study, and Floor-planning, Schematic/HDL Capture, Architectural level, Gate/Transistor level, Synthesis and Simulations, Pad Frame Selection and Design, Library Mapping and Optimization, Analog ad Digital Layout Strategies, DRC, Post-Layout Verifications, Back Annotations, Generation of Mask data-base for Chip-Layout, Final Tapeout. (03 credits)
   This is hand-on IC design course, which needs intensive LAB work.



Elective Courses (6 Credit Hours)

Teaching Faculty for Elective Courses:

- Prof. Dr. Rashad Ramzan
- Prof. Dr. Ata-ul-Aziz
- Dr. Hassan Saif
- Dr. Shazad Saleem
- Dr. Arshad Hassan
- Dr. Farhan Khalid

1. **RF Integrated Circuits:** Basics Concepts of RF Electronics, Linearity (1dB CP and IIP3) and Noise (Noise Figure) in Radio Circuits, High Frequency Model of the CMOS and BJT Circuits, IC Technology Suitable for Radio Circuit Design, Radio Standards, Radio Transceiver Architectures, Radio Transceiver Calculations, Transmission lines and Impedance Matching, Wideband and Narrow band Design Issues, Low Noise Amplifiers (LNAs), Active and Passive Mixers, Voltage Controlled Oscillators and Phase Lock Loops, Power Amplifiers. (03 credits)

2. **Printed and Flexible Electronics:** Flexible and Printed Electronics and their Materials Systems, Thin-film Deposition and Processing Methods, Substrates for Flexible Electronic Devices and Circuits, Resistive Switching Devices (Memristors) and their Applications, OLEDs and their Applications in Thin-film Transistor-based (OTFTs) Displays, Flexible Organic Photovoltaics (OPVs), Thin-Film Transistors, Flexible Batteries, Interfaces to Organic and Inorganic Electronic Devices, Energy harvesting Technologies, Flexible Electronic Packaging. (03 credits)

3. **Nano Electronics:** Fundamentals of Quantum Mechanics, Quantum Wells, Quantum Wires and Quantum Dots, Electronic, Optical, Transport Properties of Nanostructures, Quantum Semiconductor Devices. Fabrication and Characterization Techniques of Nanotechnology. Introduction and Applications of Quantum Computing, Nanotechnology, Nanomaterial Fabrication Techniques, Design of Basic Circuit Elements in the Nano Domain, Nano Electronics and Carbon Nanotubes. (03 credits)

4. **Advance Embedded Systems:** Basics of Processor Architectures. Memory Organization and Caches. Worst-Case Execution Time (WCET) Analysis, Compositional Timing Analysis for Embedded Systems, Embedded Software Platforms, Performance Analysis, Memory Hierarchy, Buses, Peripherals, Wireless Sensor Networks, Internet of Things, Embedded Systems Platforms: MCUs, DSPs, GPU, FPGAs, Code Optimization, Factors Affecting Execution Time, Multi-tasking and Real-time Operating Systems, Scheduling Algorithms and their Performance. (03 credits)
   Lab Tutorials/Class Project: Design and Implementation of Simple RISC-V Processor on FPGA.

5. **Advance Digital Signal Processing**: Introduction, Discrete-time Fourier transform (DTFT), Sampling & Reconstruction, Fast Fourier transform (FFT), Using Z-Transform to Represent Linear Time-Invariant (LTI) Systems, Digital Filter Design Fundamentals, IIR, FIR and CIC Filter Design and Implementation, DSP Algorithm Implementation Issues and Optimization, Linear Prediction and Optimal Linear Filters, Power Spectrum Estimations. (03 credits)
   Lab Tutorials/Class Project: Implementation of FIR, IIR or CIC Comb. Filter on FPGA.

6. **IC Marketing and Business Management:** Trends in the IC Business: Technology and Manufacturing Trends, Demand, Applications and Product Trends. Market Appearances: The Customers, Overall Business Cycles, The Bull-whip Effect, IC Industry, Supply & Value Chain, Geo Distribution of Technology and Fabrication Centers, The Dis-integration of the Value Chain, Outsourcing Trends, Managing the Marketing Function: The Sources of Product Ideas, Role of Standard and Intellectual Property, The Strategic Partnership, Distributorship and Matching Supply with Demand. (03 credits)

7. **Advanced Microwave Engineering:** Introduction to Microwave Engineering, Microelectronics Device and Device Models, Transmission Lines Theory, Reflection and Transmission Analysis, Microwave Network Analysis, Impedance Matching Networks and Tuning, Wideband Impedance Matching Issues, Microwave Resonators, Power Dividers and Directional Couplers, Microwave Filters and their Implementation, Noise in Microwave Circuits, Microwave Amplifier Design, Microwave Oscillators and Mixers Circuits. (03 credits)

8. **Advanced Wireless Communication:** Introduction to Wireless & Mobile Communications, Propagation Models, Channel Models, Channel Sounding, Equalization, Transmission & Multiple Access techniques: OFDM/OFDMA, SC-FDMA etc., Multi-Antenna Systems: MISO, SIMO, MIMO, Diversity, Beamforming, Spatial Multiplexing, Space-Time Coding (STC), BLAST Architecture, Massive MIMO, MIMO-OFDM Transceiver Design, Current Wireless Standards: IEEE 802.11n/ac WiFi, 4G Mobile: 3GPP LTE, 3GPP LTE- Advanced (Emphasis on Radio Access Network (RAN) Part), 5G RAN, Satellite Communications. (03 credits)

Our Students:

Jaffar Hussain: After bachelors I was looking for graduate program that can enhance my technical skills in practical domain. The Master program in IC Design at FAST provided me that opportunity. IC design is a field in which Pakistan need qualified human resource and this Master program at FAST is working towards it. This program is perfect for, Engineers seeking in-depth training from concept to tape-out in analog and digital IC design.

M. Usman: I have very unique experience while studying IC Design at FAST-NU. It was the only program of its kind in Pakistan, where I was able to learn IC design from scratch to tape out. The program offered me a variety of skills including; design, plan, management, economy, and art of designing practical circuits, that are much needed while designing real world chips. Definitely, it is a lot of work, but the experience worth it.

M. Waleed: The MS IC design has been an exceptional experience. The courses covered all the fundamentals and advanced topics on IC design, which really helped me in grasping complex concepts. Faculty was very professional and well equipped to teach the subjects, which exposed me to a new dimension of designing circuits. Having a hands-on training on state of Art software has given me a wider edge to showcase my skills in solving industrial design problems.

Hamza Saleem: All the faculty members at FAST are dedicated, passionate and supporting, especially Prof. Rashad Ramzan. He's more than a teacher for me. He changed my way of thinking, helped me develop my intuitions about design concepts. Besides, I remember the time when I asked a question to Dr. Hassan via WhatsApp message. He called me back and discuss the issue briefly. I did several meetings with faculty about Tape-out project and thesis and remember the positive criticism and highlighting the design issues from faculty. In a nutshell, I learnt several new concepts and developed design intuitions under the guidance of all faculty member. One thing I must say! After working with the faculty, if you put your whole effort too, you will be a practical Chip designer.

Lubna Shah: Being a research fellow under the supervision of highly dedicated and enthusiastic faculty has been an overwhelming opportunity for me. A perfectly planned program. The subjects taught are balanced approach to analog and mixed signals starting from the core, building up the main concepts, practicing it on the highly extensive industrial standard EDA tools to attain affluence with over more than 30 Labs assignments and eventually ascending towards tape out of a real IC. Evolving through every single step has been an eye opening unique experience.

Shahid Jamil: I used to be good at electronics and now I am humbled by the knowledge gained through this program that how much of electronics I did not know! With the first of its kind electronics program, with specialization in integrated circuit design, I have learned electronic circuit design from the first step of ideal schematic to packaging. It's been a journey of learning, hard work and team. Under the supervision of very highly qualified and very helpful faculty, we have designed our own state of the art ICs. Without their guidance it would've been impossible. For every electronics aspirant, this is a must have degree as it equips us with the knowledge, intuition and then with the skills to translate that intuition into practical electronic design using various tools from schematic simulation to package to IC testing. The ICD/RFCS2 lab has state of the art tools and advanced CMOS node for IC design.

M. Sohaib: IC designing is the degree which needs a lot of hard work, dedication and strong knowledge of various electrical engineering concepts. Under the supervision of teachers like Dr. Rashad and Dr. Hassan the journey to learn IC designing looks easy. In this program we have learned how to translate a concept in to real world IC using Cadence tools. FAST administration provided cooperative faculty and learning environment which really helped us to achieve our academics goals.