# Master of Science
# in Electrical Engineering
# with *Specialization in Integrated Circuits*

## "A training from Idea to Product Design"

## Salient Features and Objectives:

- First dedicated Integrated Circuits (IC) design 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** 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 commercialization IC design houses.
- **Bright prospect of placement** in public and private organizations after MS completion

## 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 (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 |

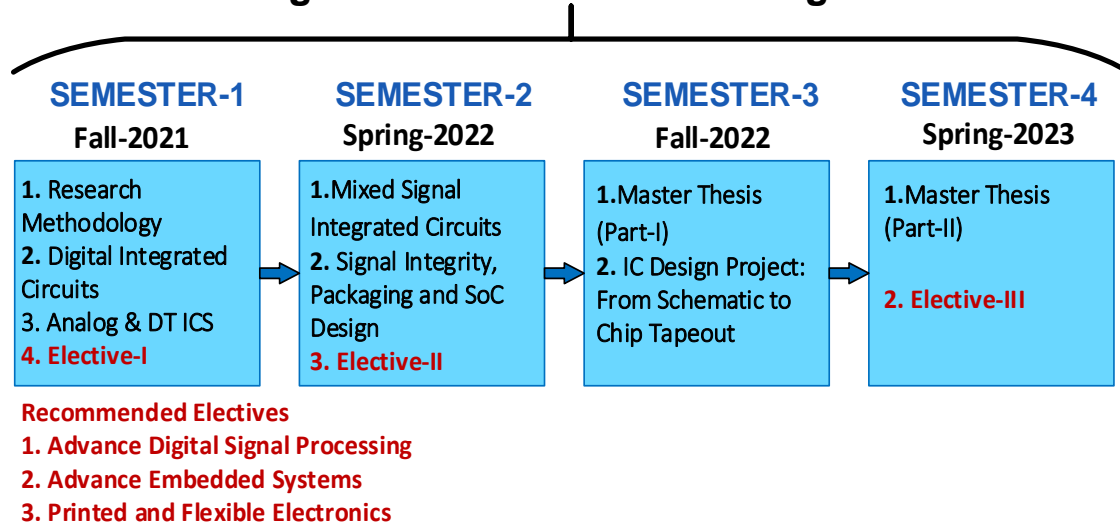| Semester-III | | |
|---|---|---|
| EE | Core Course-VI | 3 |
| EE 591 | MS Thesis-I | 3 |
| | Total | 6 credits |

| Semester-IV | | |
|---|---|---|
| EE | Elective -III | 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

# Integrated Circuits Masters Program

| SEMESTER-1 | SEMESTER-2 | SEMESTER-3 | SEMESTER-4 |
|---|---|---|---|
| **Fall-2021** | **Spring-2022** | **Fall-2022** | **Spring-2023** |
| **1.** Research Methodology **2.** Digital Integrated Circuits **3.** Analog & DT ICS **4. Elective-I** | **1.** Mixed Signal Integrated Circuits **2.** Signal Integrity, Packaging and SoC Design **3. Elective-II** | **1.** Master Thesis (Part-I) **2.** IC Design Project: From Schematic to Chip Tapeout | **1.** Master Thesis (Part-II) **2. Elective-III** |

**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

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

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

## Teaching Faculty:

- Prof. Dr. Rashad Ramzan
- Prof. Dr. Ata-ul-Aziz
- Prof. Dr. Mukhtar Ullaha
- Dr. Baber Minhas
- Dr. Arshad Hassan
- Dr. Shazad Saleem
- Dr. Durdana Habib
- Dr. Farhan Khalid
- *Visiting Faculty from Industry including the industrial partners*
- *New Faculty (IC Design Specialist)*

## 06 Compulsory Courses (16 Credit Hours):

**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 quality assessment, research planning, problem formulation, statistical data analysis, presentation of a research project, and research ethics. (01 credits; HEC requirement)

**Digital Integrated Circuits:** Review of integrated circuit fundamentals, CMOS devices characteristics, Design Layout rules, CMOS Inverter, Construction of multiplexers, Transmission gates, latches, flip flops, Combinational Logic, Sequential logic circuits, Adders, Multiplier, and accumulators, Memory cells, Layout strategies, Logic synthesis and CAD tools.
**Lab Tutorials:** Design of Basic Logic Gates, Flip Flop, Adders, Multiplexer, Demultiplexer, Memory Cells, and Complex Circuits and layout in cell library format in Cadence tool suite (03 credits)

**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, Voltage comparators, Sample & Hold Circuits, Band-gap voltage references , MOS Switched- Capacitor (SC) circuits, Continuous-time Filters, 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)

**Mixed-Signal Integrated Circuits:** Non-Linearity and mismatch, CMOS Processing Technology, Layout Fundamentals, Sample and hold circuits, Data converters – Fundamentals and performance metrics, Nyquist Digital-to-Analog Converters, Nyquist Analog-to-Digital Converters, Z-Transform, Oversampling ($\Sigma\Delta$) Data Converters.
**Lab Tutorials:** Advanced op-amp Design & Simulation, CMOS Comparators Design, Bootstrap Circuits Design, Switched Capacitor Circuits Design, Discrete circuit Layout Techniques, Nquist Rate DAC Design, Nyquist Rate ADC Design, Sigma-Delta Converters, Oscillator & PLL circuits, Bandgap Reference Circuits in Cadence tool suite (03 credits)

**Signal Integrity, Packaging and Chip Design:** Signal Integrity Principals, Chip interconnect and Transmission Lines, Clock Distribution, IO Pads, Pad Driver Circuits type and standards, Pad Protection management. SoC Modules, multichip and 3D packaging. IC assembling, sealing and encapsulation. IC packaging failure and reliability. Microsystems packaging and applications

<u>Lab Tutorials:</u> Impedance Matching using Lumped Model, Impedance Matching using Microstrip Model, Bond wire Modeling and Simulations, Power Distribution Network Modeling, Parallelism Transmission Line Modeling & Analysis, Crosstalk and Noise Analysis, EMI/EMC Interference Analysis, EMI Shield Design, PAD Frame & ESD Protection, CMOS Packaging Assembly Selection & Analysis (03 credits)

**IC Design Project: From Schematic to Chip Tapeout:** Project selection, Pre-study, and planning, Schematic or HDL Capture, Architectural level, Gate/Transistor level, Synthesis and simulations, Pad Frame selection and design, library mapping and optimization, Layout and DRC, Post-layout verifications, Back Annotations, Generation of mask data-base for chip-layout, Final tapeout. (03 credits) *This is self-paced lab based course. Each student will have a real hands on tapeout experience.*
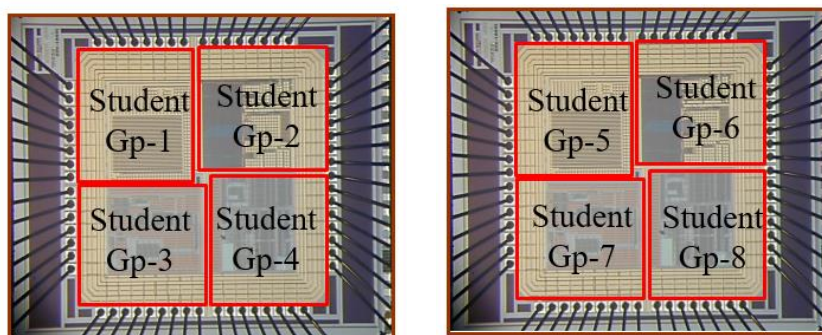


### Elective Courses (9 Credit Hours)

**RTL Design Synthesis:** Basics of Verilog coding, State Machine Design in Verilog, Verilog Testbench Design, Verilog RTL Code Compilation Scripts Development, Integrated Circuit Automatic Placement and Routing, Verilog code to ASIC Synthesis, Netlist based Design in Cadence, Lookup Tables Design, Digital Controller Design (03 credits)

**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)

**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)

**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)

**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 processor on FPGA.

**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.

**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, The role of standard and intellectual property, The strategic partnership, distributorship and matching supply with demand. (03 credits)

**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)

**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)