Department of Electrical Engineering

Ph.D. Admissions 2025-26 (Autumn Semester)

List of TAP/RAP Topics (Project Positions)

Project Investigator: Prof. Laxmeesha Somappa

Title of the project: Analog/Mixed Signal/RF and High-Voltage IC Design for Brain-computer-Interface SoCs

Desired specialization: EE 6 (Integrated Circuit & Systems)

Abstract of the project:

For analog HV BCI chip design: CMOS implementation of deep brain stimulators (DBS) for multiple target applications including Parkinson's and epilepsy. Work includes designing a programmable DBS (with compliance as high as 12V with a 2.5V technology), fabrication, and electrical testing of the DBS. Final in-vivo testing will be done on rats with the help of neurosurgeon to validate the design. Will also have a digital block for a small processor and programmability of the analog circuit.

For RF BCI chip design: Implantable chips for brain computer interface (BCI) needs autonomy in terms of power and data transfer to a local hub. In this project, we explore design of an energy harvesting and uplink/downlink channel using a shared on-chip inductor. For high density BCI, on chip compression engine must also be designed to reduce the link data rate for the given power budget. Post fabrication and electrical testing, in-vivo experiments with rats will be performed for final validation.

For analog front-end for BCI chip design: CMOS implementation of recording front-end for BCI applications. The design will support, EEG, ECoG, LFP and AP bands with channel count

> 256. Tradeoffs associated with the design include: noise, power, area, channel count, dynamic range. Calibration and trimming infrastructure on-chip to enable the digital back-end to be independent of front-end mismatch. Final in-vivo testing will be done on rats with the help of neurosurgeon to validate the design.

Project Investigator: Prof. Maryam Shojaei Baghini

Title of the project: AMS IC Design for Magnetic Field Sensing

Desired specialization: EE 5 (Electronic Systems), EE 6 (Integrated Circuit & Systems)

Abstract of the project:

The aim of this project is to design, develop, test and prototype a novel signal conditioning integrated circuit (IC) for the magnetic sensing technology based on the Hall effect for a set of target applications. Other parts of the this novel IC will include the interfacing and protection solutions. The project will also bring techniques for enhancing the operating temperature range.

Project Investigator: Prof. Rahul Singh

Title of the project: Integrated Circuits for Interfacing with Quantum Systems

Desired specialization: EE 6 (Integrated Circuit & Systems), EE 5 (Electronic Systems)

Abstract of the project:

- Part of National Quantum Mission
- RF/Analog/digital IC design of read-out/control circuits from system-level specifications to highly-integrated chip prototypes.
- Measurement and testing, access to complex RF instrumentation).
- Multiple tapeouts in CMOS/SiGe process nodes.

Project Investigator: Prof. Rahul Singh

Title of the project: High-frequency/mmWave Integrated Circuit Design

Desired specialization: EE 6 (Integrated Circuit & Systems)

Abstract of the project:

- Agile RF receiver/transmitter front-ends (up to 15 GHz)
- mmWave (>24 GHz) beamforming phased-arrays
- Calibration Circuits
- Skills: Strong interest in RF/Analog/Digital IC Design

Project Investigator: Prof. Rahul Singh

Title of the project: High-speed Integrated Circuits for 6G (wireless) optical links

Desired specialization: EE 6 (Integrated Circuit & Systems), EE 5 (Electronic Systems)

Abstract of the project:

- GoI's initiative on accelerated 6G research
- High-speed/wide bandwidth TIAs and modulation drivers
- Tapeouts in SiGe/CMOS process nodes
- Interfacing with Photonic systems
- Skills: Strong interest in RF/Analog/Digital IC Design

Project Investigator: Prof. Dwaipayan Mukherjee

Title of the project: Resilience of vehicular swarms to malicious attacks: a robust control approach

Desired specialization: EE 2 (Control & Computing)

Abstract of the project:

This project will aim to address robustness and resilience issues in swarms of heterogeneous vehicles (both ground and aerial vehicles). The proposed robustness results will be tested on actual experimental set-ups.

Project Investigator: Prof. Sandip Mondal

Title of the project: Memory Technology for Artificial Intelligence

Desired specialization: EE 5 (Electronic Systems), EE 6 (Integrated Circuit & Systems), EE 7 (Solid State Devices)

Abstract of the project:

The 3-D NAND flash device has become an essential fragment of the cyber-physical systems to manage the enormous data bang in the era of the Internet of Things (IoT). Moreover, hardware security primitives such as physical unclonable function (PUF) have become crucial in the functional circuits of these cyber-physical systems for defense in contradiction of security susceptibilities and adversary attacks.

Project Investigator: Prof. Ashwin A. Seshia

Title of the project: Micro/nano-electromechanical sensors and sensor systems

Desired specialization: EE 5 (Electronic Systems), EE 7 (Solid State Devices)

Abstract of the project:

This project will explore nanofabrication processes, device design, characterization, and the construction of MEMS-based sensor systems. Applications include chemical sensors (gases, other analytes), and physical sensors (flow, pressure). Multiple transduction modalities will be investigated including electrochemical, resistive, and gravimetric, based on a micro-hot plate platform and other approaches. The project will involve aspects that are more device/process oriented involving exploring the integration of new materials into a platform technology (EE-7) in the IITB Nanofabrication facility, and separately that are packaging/system oriented involving the design of suitable packages for gas, flow, and other MEMS sensors (both at the die and wafer levels) and associated interface electronics and data processing (EE-5/7).

Project Investigator: Prof. Jayanta Mukherjee

Title of the project: High Efficiency Power Amplifier Design

Desired specialization: EE 1 (Communication & Signal Processing), EE 6 (Integrated Circuit & Systems)

Abstract of the project:

High efficiency power amplifiers are a prime requirement for 5G systems. In this project we will explore novel PA topologies using GaN transistors to find configurations that can lead to current and voltage waveforms that provide better efficiency.

Project Investigator: Prof. Ashwin A. Tulapurkar

Title of the project: Energy efficient spintronic devices

Desired specialization: EE 7 (Solid State Devices)

Abstract of the project:

Semiconductor devices are based on electronic charge. These devices are facing serious challenges as the device dimensions are scaled down. Spintronics is based on the spin degree of electron along with its charge. Spintronic devices are highly energy efficient and also non-volatile. MRAM (magnetic random access memory) is a typical example of spin-based device, which comprises a magnetic tunnel junction, and be efficiently switched by spin current. A student working in this project will explore new materials like topological materials, 2d materials etc. and also investigate novel effects such as unconventional spin torques etc. The project would involve considerable work in the clean room towards fabrication of devices and also their characterization by different tools. The students can also undertake simulations of their devices depending upon their interest and time. Overall work would be a combination of basic and applied research.

Project Investigator: Prof. Apurba Laha

Title of the project: Growth, Fabrication, and Characterization of Scandium-doped Aluminum Nitride (ScAlN) Thin Films for Next-Generation Piezoelectric and Optoelectronic Applications

Desired specialization: EE 7 (Solid State Devices)

Abstract of the project:

Scope and Significance of work:

Scandium-doped Aluminum Nitride (ScAlN) has emerged as a promising material for high-performance piezoelectric and optoelectronic applications due to its enhanced piezoelectric response, high thermal stability, and tunable electronic properties. This research will focus on:

1. Growth: Optimizing the deposition of ScAlN thin films using techniques like Molecular Beam Epitaxy (MBE) and Magnetron Sputtering.

2. Fabrication: Developing high-quality ScAlN-based devices such as MEMS/NEMS resonators, SAW/BAW filters, and energy harvesters.

3. Characterization: Investigating the structural, electrical, optical, and mechanical properties using XRD, SEM, AFM, XPS, PL, and PFM.

Types of AlScN-Based Advanced Sensors to be explored

a. Surface Acoustic Wave (SAW) and Bulk Acoustic Wave (BAW) Sensors

• Used in wireless sensing for detecting pressure, humidity, temperature, and gases.

• Higher electromechanical coupling coefficient than AlN, leading to better sensitivity and efficiency.

• Applications: 5G filters, IoT sensors, and chemical sensors.

b. MEMS/NEMS Pressure and Force Sensors

• High sensitivity and miniaturization, making them ideal for aerospace, automotive, and biomedical applications.
• AlScN-based piezoelectric MEMS pressure sensors show improved linearity and response time.

c. Biosensors
• Used in lab-on-a-chip and medical diagnostics.
• Enables highly sensitive detection of biomolecules, pathogens, and environmental contaminants.

d. Energy Harvesting Sensors (Piezoelectric Energy Harvesters)
• Converts mechanical vibrations into electrical energy for self-powered IoT devices and wearables.
• AlScN improves power generation efficiency compared to AlN.

Project Investigator: Prof. Kasturi Saha

Title of the project: Development of Magnetic Field Image Processing

Desired specialization: EE 1 (Communication & Signal Processing), EE 7 (Solid State Devices)

Abstract of the project:

A quantum diamond microscope (QDM) utilizes nitrogen-vacancy (NV) centers in diamond to image magnetic and electric fields at the nanoscale akin to a normal light microscope. Operating at room temperature, the QDM offers non-invasive, real-time imaging with exceptional sensitivity. This technology has diverse applications, including studying biological systems, materials science, and magnetic domains, providing insights at the atomic and molecular levels without damaging the samples.

This project focuses on designing and developing a magnetic field imaging system for detecting currents in semiconductor chips to identify faults. The work involves creating image processing algorithms for 2D and 3D magnetic field reconstruction. Additionally, it includes developing noise models to enhance reconstruction algorithms and optimize dictionary-based techniques. The project can be further extended to incorporate AI-based training models for magnetic field reconstruction, current density mapping, and magnetization reconstruction. The student will also be responsible for acquiring experimental data using the Quantum Diamond Microscope (QDM) and implementing reconstruction algorithms on the collected data.

Project Investigator: Prof. Kasturi Saha

Title of the project: Development of ultra-sensitive magnetic field microscope

Desired specialization: EE 1 (Communication & Signal Processing), EE 7 (Solid State Devices)

Abstract of the project:

A quantum diamond microscope (QDM) leverages nitrogen-vacancy (NV) centers in diamond to image magnetic and electric fields at the nanoscale. These NV centers serve as quantum sensors, detecting shifts in their spin states in response to external fields. By illuminating the diamond with a laser and measuring the resulting fluorescence, the QDM generates high-resolution field maps across a surface. Operating at room temperature, it enables non-invasive, real-time imaging with remarkable sensitivity. This advanced technology has broad applications in biological systems, materials science, and magnetic domain studies, offering atomic and molecular-level insights without causing damage to samples.

This project aims to design and develop a highly sensitive magnetic field imager. The research will focus on two key aspects: theoretical modeling and noise characterization, as well as the fabrication of nano-pillars on diamond for neuron sensing. Additionally, the project will involve working with optical components and designing RF and microwave subsystems to enhance the imager's performance.

Project Investigator: Prof. Kasturi Saha

Title of the project: Adaptive optics for super-resolution imaging

Desired specialization: EE 1 (Communication & Signal Processing), EE 7 (Solid State Devices)

Abstract of the project:

A quantum diamond microscope (QDM) leverages nitrogen-vacancy (NV) centers in diamond to image magnetic and electric fields at the nanoscale. These NV centers act as quantum sensors, detecting shifts in their spin states in response to external fields. By illuminating the diamond with a laser and measuring the resulting fluorescence, the QDM generates high-resolution field maps across a surface. Operating at room temperature, it enables non-invasive, real-time imaging with remarkable sensitivity. This advanced technology has broad applications in biological systems, materials science, and magnetic domain studies, providing atomic and molecular-level insights without damaging samples.

Building on this foundation, the project focuses on integrating adaptive optics into quantum diamond microscopy to achieve super-resolution imaging in widefield NV-based magnetometry. The research involves developing theoretical frameworks, exploring computational techniques such as wavefront correction and optical phase manipulation, and refining models in collaboration with Prof. Saikat Guha at UMD. Additionally, it includes designing experimental protocols based on theoretical insights and coordinating with the experimental team to develop a structured implementation plan. These advancements aim to push the limits of QDM resolution and enhance its capabilities for high-precision imaging applications. Students with signal processing, optics and computational imaging background are encouraged to apply.

Project Investigator: Profs. Sandeep Anand, Shiladri Chakraborty, Kishore Chatterjee, B.G. Fernandes, Anil Kulkarni

Title of the project: Silicon Carbide (SiC) based medium voltage solar inverter

Desired specialization: EE 3 (Power Electronics & Power Systems)

Abstract of the project:

Power electronics converters play a very important role in renewable generation. The ever-increasing demand for better efficiency, reliability, and compactness has made the requirement of innovation in the area of power electronics very important. The wide band gap (WBG) devices are a new disruptive technology which would drastically change the power electronic industry. Silicon Carbide (SiC) based power devices are now commercially available and offer better performance in terms of on-state resistance and gate capacitance. These advantages help in achieving high efficiency and power density in power converters. However, there are interesting research problems in designing and developing power electronic converters using these SiC devices. This project aims to carry out research in the area of advanced power electronic converters. There are 5 open PhD positions in this project.

If you find any one or more of the following topics interesting, then you must apply for this project:

- Design and development of Gate driver for SiC-based devices
- Topology selection and circuit design for medium voltage solar inverter
- Magnetics design for medium-voltage medium-frequency transformers development
- Controller for medium voltage solar inverter, along with grid integration
- Condition monitoring techniques in solar inverter
- Accelerated aging and failure models of SiC devices
- Futuristic technologies for improving reliability (Active Power Decoupling and Active Thermal Control)

Project Investigator: Profs. Sandeep Anand, Shiladri Chakraborty, Kishore Chatterjee, B.G.Fernandes

Title of the project: Electric Vehicles: Motors, Controllers and Chargers

Desired specialization: EE 3 (Power Electronics & Power Systems)

Abstract of the project:

EVs is the stepping stone towards truly sustainable transportation solutions. The electric drivetrain consists of electric motor, its controller and onboard charger. Range anxiety and performance are some of the concerns among EV users. Hence, for a high performance and long range EV, a light weight, compact and energy efficient drivetrain is essential.

- This calls for active research for development of efficient and low-cost electric motor technologies. These attempts may include reduction in the magnet requirements or to go purely magnet-less.
- Control of motors for efficient operation is another possible area of research within this project.
- The third possible area of research in this project is on EV fast chargers and EV on-board chargers. This invokes the need of high conversion efficiency and high switching frequency. In addition, the volume of offboard EV chargers should also be reduced to make them suitable for installation in urban settings. Use of wide bandgap devices is expected to simplify this task. Wide bandgap devices allow selection of higher switching frequency and hence, reduce the size of passive components required for power filtering.

This project has multiple aspects and therefore we have multiple open PhD positions for the project.
If you find any one or more of the following topics interesting, then you must apply for this project:

- Motor Design
- Motor Drives / Inverters
- Onboard EV charger circuits
- EV fast chargers
- GaN & SiC based EV powertrain

Project Investigator: Prof. Dipankar Saha

Title of the project: Wide bandgap GaN-based high electron mobility

Desired specialization: EE 7 (Solid State Devices)

Abstract of the project:

Wide bandgap GaN-based high electron mobility radio-frequency transistors are useful for radar, satellite, and 5G/6G communications. These transistors operate at over 20 GHz, and the operating frequency can increase to 80 GHz. The channel length for these transistors is shrunk to 20 nm and below. This work involves optimizing these transistors' operation for still higher performance.

Project Investigator: Prof. Dipankar Saha

Title of the project: Quantum technologies

Desired specialization: EE 7 (Solid State Devices)

Abstract of the project:

Quantum technologies have emerged for various applications, including computation, sensing, and communication. Quantum bit readout is an indispensable need for various quantum technologies where InP-based transistors have found immense applications where they are operated at cryogenic temperatures. This work involves optimizing these transistors for quantum technologies.

Project Investigator: Prof. Veeresh Deshpande

Title of the project: Advanced oxide channel transistors for 3D integration

Desired specialization: EE 7 (Solid State Devices)

Abstract of the project:

Amorphous oxide channel transistors (based on Indium tin oxide, IGZO etc.) are gaining interest for 3D integration for DRAM, advanced memory, and in-memory computing applications. Many industries are investigating these channel materials (Micron, TSMC, IMEC etc.). We have developed ITO channel transistors and demonstrated in-memory computing and eDRAM with them. However, there is still many developments going on all over the world for their reliability, high performance operation. In this project, there is opportunity to develop new devices architecture, study in detail reliability of these transistors, and develop novel concepts for in-memory computing.

Project Investigator: Prof. Veeresh Deshpande

Title of the project: Resistive RAM (RRAM/Memristor) devices and 3D monolithic integration

Desired specialization: EE 7 (Solid State Devices)

Abstract of the project:

Emerging non-volatile memories are gaining significant attention for embedded non-volatile storage and in-memory computing. In this project, we will work on development of multi-level RRAM with amorphous oxide materials and characterize them. There will also be opportunity to collaborate with US and Netherlands universities for on-chip integration of these devices and demonstrate prototype circuits.

Project Investigator: Prof. Veeresh Deshpande

Title of the project: Advanced packaging technology and chiplet design

Desired specialization: EE 6 (Integrated Circuit & Systems), EE 7 (Solid State Devices)

Abstract of the project:

In this project, there are two opprotunities:

1. To develop advanced chiplet packaging technologies with newly developed semiconductor packaging laboratory at IIT Bombay. These will allow one to demonstrate multi-chip systems through 2.5D and 3D integration. There is significant collaboration with industries (in India and Abroad) for these technologies.

2. Chiplet based system design (Digital): Leveraging the technologies being developed at our chiplet packaging laboratory, we would like to develop a nano GPU system design and prototype. This will be based of use of novel in-memory computing blocks combined with RISC V processor including die-to-die communication.

Project Investigator: Prof. Veeresh Deshpande

Title of the project: Chiplet based quantum computing system development

Desired specialization: EE 7 (Solid State Devices)

Abstract of the project:

In this project, the student has the opportunity to develop new technologies for chiplet based quantum computing system assembly. The project involves development of superconducting mulitchip module through 2.5D and 3D integration with readout electronics. There is opportunity to collaborate with one of the major semiconductor company and various partners in National Quantum Mission. It has huge potential for developing new quantum technologies.

Project Investigator: Prof. Debanjan Bhowmik, Ashwin Tulapurkar

Title of the project: Neuromorphic and Ising Computing using Spintronic Nano-Oscillators for Machine Learning and Optimization Applications: Experiments and Modelling

Desired specialization: EE 7 (Solid State Devices)

Abstract of the project:

To address the problems with conventional transistor-based computing, various novel materials, devices and architectures have been explored to carry out computing in unconventional ways. Spintronic nano-oscillators form one such kind of devices. These nanoscale devices exploit quantum phenomena (like spin-orbit torque) happening at the interface of the heavy metal and the ferromagnetic metal to exhibit auto-oscillations. The oscillators can be synchronized using dipole coupling or spin-wave coupling between the precessing magnetizations. In this project, through a combination of experiments and modelling, we want to demonstrate the application of spintronic nano-oscillators in two kinds of unconventional computing schemes: neuromorphic computing (for energy-efficient implementation of neural network algorithms for edge devices) and Ising computing (heuristically solving combinatorial optimization problems).

Project Investigator: Prof. Debanjan Bhowmik, Abhijeet Sangle (MEMS)

Title of the project: Self-assembled vertically aligned nanocomposites for memory and neuromorphic computing applications

Desired specialization: EE 7 (Solid State Devices)

Abstract of the project:

With the explosive growth of IoT and connected a tremendous amount of data is constantly generated, which needs not just space to store it, but also energy efficient fast processing, which is inherently not possible with the traditional von Neumann type modular computing architecture. Development of neuromorphic or brain-like computing has been touted as the ultimate computing frontier, with every 'neuron' connected to multiple others through 'synapses.' Here we propose to develop non-volatile memory solutions based on nanocomposite films and to demonstrate neuromorphic computing using devices made from these films.

Project Investigator: Prof. Debanjan Bhowmik, Bhaskaran Muralidharan

Title of the project: High speed multiple-input multiple-output (MIMO) symbol detection in large MIMO systems for wireless communication using electronic and spintronic oscillator Ising machines (OIM) (and associated teaching and research with Synopsys's tools)

Desired specialization: EE 7 (Solid State Devices)

Abstract of the project:

In this project, we would like to design, simulate (at schematic and post-layout level using Synopsys's HSPICE tool), fabricate and test an electronic ring-oscillator Ising machine integrated circuit chip and show its superiority to both conventional computing methods (ML, ZF, MMSE techniques) and other Ising machines (quantum annealers and CIM) for solving the MIMO detection problem for huge MIMO systems used in wireless communications. The main superiority we expect, as discussed above, is in terms of speed/ time complexity, while providing the same level of accuracy.

Also, in this project, we would design and simulate spintronic oscillator Ising machines with spintronic domain-wall devices as coupling elements. Coming up with appropriate conductance range and values for the coupling elements is very
important for getting high accuracy/ low BER for our designed OIM because conductance values determine the oscillator-to-oscillator coupling and hence the mapping of the given MIMO problem to the hardware. The magnetic tunnel junction structure needed both for the oscillator and the coupling element, along with the spin transfer toque (STT) physics in it, needed for the operation will be simulated at an atomistic level using Synopsys's Quantum ATK solver, which combines density functional theory (DFT) and non-equilibrium Green's function (NEGF). Not only the more explored heavy metal-ferromagnetic metal heterostructures will be explored but exotic two-dimensional (2D) spintronic materials will also be explored in the process. Then behavioural SPICE models will be created from these device results and then incorporated into system-level OIM designs using Synopsys's HSPICE tool.

Associated teaching plan and Relevance of Synopsys's Tools: Teaching and research will go hand in hand in the project. The PIs and the student who will get MTech/ PhD fellowship in this project (PhD is preferred) will work as instructors and teaching assistant respectively in various courses offered by Department of Electrical Engineering, IITB, and use Synopsys's tools like Qunatum ATK and HSPICE.

Project Investigator: Prof. Bhaskaran M.

Title of the project: ML-integrated device modeling for 2D-single photon detectors

Desired specialization: EE 7 (Solid State Devices)

Abstract of the project:

The project will aim to develop a detailed device modeling platform based on quantum transport theory to side-by-side support fabrication and characterisation experiments performed in the domain of 2D-material based single photon detectors. This is under the national quantum mission (NQM). The project will involve various levels of device modeling and will ultimately be coupled with a Machine learning based solver for advanced device design.

Project Investigator: Profs. Prasanna Chaporkar, Gaurav S. Kasbekar

Title of the project: Maharashtra Drone Mission

Desired specialization: EE 1 (Communication & Signal Processing)

Abstract of the project:

The objective of this project is to conduct research to enable efficient and secure drone communication, including ground station to drone and drone to drone communication. It includes the design, analysis, and implementation of protocols and algorithms that can be used to achieve effective drone communication.

Project Investigator: Prof. Prasanna Chaporkar

Title of the project: NSF-Meity: NeTS: Small: Towards Learning Enabled Sustainable Service Handling in 6G

Desired specialization: EE 1 (Communication & Signal Processing)
Abstract of the project:

Speedy digitization and rising demand for communication services are driving increased energy consumption in cellular networks. Energy-aware network design is crucial for reducing energy use and improving efficiency, contributing to sustainability.

This project focuses on three key research themes:

1. Energy-aware ML-driven core network – Developing a learning-based framework for efficient resource allocation in the core network.
2. Energy-aware ML-driven radio access network – Enhancing real-time resource allocation in RAN

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to support massive connectivity efficiently.
3. Service-aware adaptive security mechanism – Implementing tailored security strategies for individual data flows.

These efforts aim to build a resource-efficient and sustainable 6G system.

Project Investigator: Prof. Rajesh Zele

Title of the project: CMOS high-performance Digital IC design for RF communications SOC (System-On-Chip)

Desired specialization: EE 5 (Electronic Systems), EE 6 (Integrated Circuit & Systems)

Abstract of the project:

The student will get end-to-end exposure to CMOS digital IC design flow using cutting-edge nanometer semiconductor technology. You will start from architecture, Matlab simulations, RTL to gds flow, FPGA implementation,— all the way to Place and route, sign-off verifications and then tapeout. The student will closely work with RF/Analog/Mixed-Signal IC design team for system spec. The students will spend time in the industry for internships and work closely with Industry mentors.

Project Investigator: Prof. Rajesh Zele

Title of the project: RF/Analog Circuit design for next-generation beamformer system for MIMO/6G/Radar applications

Desired specialization: EE 5 (Electronic Systems), EE 6 (Integrated Circuit & Systems)

Abstract of the project:

After training in our aiCAS lab, the students will work on RF transceiver design for phased array/ MIMO systems to build efficient wireless communication chips. The student will work with senior PhD mentors for hands-on training, eventually leading to a tapeout of their ideas in nanometer CMOS technologies. The students will spend time in the industry for internships and work closely with Industry mentors.

Project Investigator: Prof. Rajesh Zele

Title of the project: Mixed-signal (ADC/DAC) CMOS IC design for ultra-low-power Biomedical applications

Desired specialization: EE 5 (Electronic Systems), EE 6 (Integrated Circuit & Systems)

Abstract of the project:

The students will focus on data communication IC design for biomedical implants. After training, the students will build upon the previous chips designed in the aiCAS lab. They will design ultra-low power ADC/DAC for power-efficient biomedical links. The students will spend time in the industry for internships and work closely with Industry mentors.

Project Investigator: Prof. Saurabh Lodha

Title of the project: Development of 2D single photon detectors for national quantum mission

Desired specialization: EE 7 (Solid State Devices)

Abstract of the project:

The research is for a 6 year national quantum mission funded project to develop novel 2D-semiconductor based avalanche single photon detectors. It involves cutting-edge research and technology development on emerging 2D materials with close collaboration on simulations, growth and characterization of 2D semiconductors across six institutes. Device physics and good experimental skills/experience are a plus for interested candidates.

Project Investigator: Prof. Arun Surendran

Title of the project: Fiber Lasers

Desired specialization: EE 7 (Solid State Devices)

Abstract of the project:

Development of novel fiber laser sources.

Project Investigator: Prof. Shiladri Chakraborty

Title of the project: Integrated SiC power modules for next-gen. EV power electronics

Desired specialization: EE 3 (Power Electronics & Power Systems)

Abstract of the project:

State-of-the-art system-level packaging for power modules limits the benefits of wide bandgap devices (e.g., SiC, GaN) due to parasitic loop inductances. This can be addressed by advanced integrated power packaging solutions, as envisaged in this work. Specifically, this project aims to design and demonstrate a DBC-based, integrated SiC half-bridge featuring

1. Planar power interconnects (no power wire-bonds enabling enhanced thermo-mechanical reliability)

2. Integrated gate-drive ICs and decoupling capacitors (low inductances leading to faster, efficient, glitch-free switching)

3. Ag-sintered drain interface (leading to enhanced thermal and reliability performance)

Project Investigator: Prof. Parthib Khound

Title of the project: Design and Development of Cooperative Adaptive Cruise Control under a Stochastic Framework

Desired specialization: EE 2 (Control & Computing)

Abstract of the project:

A platooning control system is a collective system of intelligent vehicles following one another using automatic control technologies. This system improves traffic flow, enhances safety, reduces fuel consumption, and lowers pollutant emissions. Adaptive Cruise Control (ACC) and Cooperative Adaptive Cruise Control (CACC) are prominent technologies used for platooning. ACC systems rely on onboard sensors for autonomous control, while CACC systems enhance this functionality by integrating vehicle-to-vehicle (V2V) or vehicle-to-infrastructure (V2I) communication to exchange critical feedback and feed-forward information among vehicles. Both technologies can facilitate car-following maneuvers, with CACC being particularly more effective for addressing collective dynamic challenges in platooning. A key requirement for such systems is the string stability criterion, ensuring that temporary perturbations in any vehicle are attenuated as they propagate through the platoon, suppressing stop-and-go waves. While significant progress has been made, many advanced existing models are still deterministic and do not account for stochastic factors arising from model inaccuracies, sensor noise, cut-in/cut-out maneuvers, external disturbances, and more. This project aims to develop a robust control algorithm for CACC systems that maintains uncompromised collective dynamics under stochastic conditions. The primary deliverables will include theoretical modeling, dynamic simulations for validation, and the construction of a scaled-down experimental setup using several mobile robots to demonstrate physical collective driving dynamics. The findings are expected to significantly contribute to the feasibility and practical implementation of CACC-based control schemes in real-world vehicles.

Project Investigator: Prof. Saurabh Lodha

Title of the project: Design and development of B-Ga2O3 high power devices and circuits

Desired specialization: EE 7 (Solid State Devices)

Abstract of the project:

B-Ga2O3 is a wide bandgap semiconductor that is fast emerging for high power device applications beyond SiC and GaN. The student will be involved in device design using TCAD and experimental demonstration of high voltage diodes and transistors. The project also involves reliability tests and spice-level circuit simulations for various power electronic applications. Understanding of device physics and interest in experimental research are required. We have published several papers in this area and past students are placed in companies such as Micron (India), TI (India), Cambridge GaN devices (UK), and Post-doctoral fellowship (US).

Project Investigator: Prof. Apurba Laha

Title of the project: III-Nitride LASER diodes: The most essential component of optical atomic clock and quantum sensors technology

Desired specialization: EE 7 (Solid State Devices)

Abstract of the project:

This project aims to design, grow, and fabricate a III-Nitride laser diode tuned for the application of optical atomic clock and quantum technology. InAlGaN lasers with tunable emission ranging from UV to visible wavelength have been a great enabler of new-generation precision sensors, optical atomic clocks, and secure communication systems [S. P. Najda et al." Proc. SPIE 11914, SPIE Future Sensing Technologies 2021, 1191407] for applications such as next-generation navigation, gravity mapping, and timing. Laser-cooling of ions and atoms has played an unprecedented role in the development of quantum technologies. Ions/cold atoms are potential candidates for a wide range of applications: optical clocks for precise timing measurements, atomic interferrometers for gravitational measurements, and qubits in ion-trap quantum computing [Chen, W., Lu, Y., Zhang, S. et al. Nature. Phys. (2023). https://doi.org/10.1038/s41567-023-01952-5]. Typically, these technologies employ multiple lasers, operating at well-defined wavelengths and with narrow line widths. For popular atom/ion species, specific examples include those emitting at 422 nm, for the [5s2S1/2-5p2P1/2] cooling transition in strontium+ (Sr+) ions, at 461nm, for the [5s2 1S0-5p1P1] cooling transition in neutral Sr atoms, at 420 nm, for the [5s2 s1/2 – 6p2P3/2] transition in rubidium atoms, and at 369 nm/399 nm, for transitions of ytterbium ions/atoms [S. P. Najda, at al." Proc. SPIE 10104, Gallium Nitride Materials and Devices XII, 101041L]. Direct-generation external cavity diode lasers (ECDL), based on GaN and associated III-Nitrides (AlN, InN, and their alloys), are better-suited than traditional frequency-doubled alternatives for the development of compact, narrow-linewidth, high-power precision emission sources, required to excite transitions for a diverse set of atomic/ionic species. However, only a handful of manufacturers can provide these laser diodes, none of them being within the country. This project, to the best of our knowledge, is the first of its kind, aiming to develop III-Nitride-based laser-diodes, emitting at (two) specific wavelengths, critical for Sr atoms and Sr+ ions.

Project Investigator: Prof. Virendra Singh

Title of the project: Security of Futuristic Technologies (AI/ML/AR/VR/CPCS/Hardware Design/Quantum Computing)

Desired specialization: EE 1 (Communication & Signal Processing), EE 2 (Control & Computing), EE 5 (Electronic Systems), EE 6 (Integrated Circuit & Systems)

Abstract of the project:

Artificial Intelligence (AI) is creating a huge impact on the world by integrating its service into all possible facets of our daily life needs. Many sectors like finance, healthcare, automobiles, marketing, social media, chat-bots, etc., are using AI models like Neural Networks(NN), Large Language Models (LLMs), Reinforcement Learning(RL), etc., for their decision-making process. As it is known that with pros come cons, even a single vague decision of the model will lead everything to stake. An example of this can be a self-driving car identifying a stop sign as a speed sign which leads to de-struction. There are many more such scenarios where the decisions of the AI models are making the world miserable. So, finding the vulnerabilities, providing security to the model, and making the model robust in any scenario is very crucial. In this growing machine-dependent world securing those machines is on high priority else it may lead to massive human destruction.

This project examines instances where adversarial attacks on AI systems have been employed to manipulate decision-making processes, compromise data integrity, and erode public trust. By understanding these vulnerabilities, we can draw connections to their broader implications for addressing pressing global challenges such as cyber-security, misinformation, and ethical

considerations in AI deployment and thus explore potential countermeasures and defensive strategies to fortify AI systems against adversarial threats. This includes advancements in robust model architectures, enhanced training methodologies, and the development of explainable AI to increase transparency and accountability.

On the other hand, CPS (Cyber Physical Systems), which is composed as system of systems, has to be intelligent and trustworthy. The main aim of this research is to develop effective and efficient design methodologies for trustworthy cyber physical cognitive systems. It can be seen as a system of systems with dependable cyber physical system and trustable AI as a core components. The examples of such systems can range from Autonomous vehicles, Smart grids, Smart cities, Smart agriculture, Drone based Surveillance to sophisticated Pacemakers. Hence, the project will aims at developing design methodologies for intelligent trustworthy Cyber Physical Cognitive Systems (T-CPCS) to enable Smart-X in societies.

Project Investigator: Prof. Shalabh Gupta

Title of the project: High-speed integrated circuits for wireline/optical communication links

Desired specialization: EE 5 (Electronic Systems), EE 6 (Integrated Circuit & Systems)

Abstract of the project:

In this work, you would be designing and testing high-speed electronic integrated circuit for optical links & wireline interconnects. Circuits such as phase-locked loops, clock and data recovery circuits / SerDes, drivers, trans-impedance amplifiers etc. will be designed and integrated at a system level. You would be collaborating with other team members.

Good knowledge in the area of analog circuits, analog/digital communication systems, and interest in working with high-speed experimental setup will developed. Good fundamentals and some hardware skills are important, others skills can be picked up after joining the group.

Sample publication:

S. Chugh, R. Ashok, P. Jain, S. Naaz, A. Sidhique and S. Gupta, "An Analog EIC-PIC Receiver with Carrier Phase Recovery for Self-Homodyne Coherent DCIs," IEEE Transactions on Circuits and Systems II: Express Briefs (2022). https://doi.org/10.1109/TCSII.2022.3167673

Project Investigator: Prof. Shalabh Gupta

Title of the project: High-speed photonic circuits for optical communication links

Desired specialization: EE 6 (Integrated Circuit & Systems), EE 7 (Solid State Devices)

Abstract of the project:

In this work, you would be designing and testing photonic integrated circuits for high-speed optical communication links. Building blocks such as electro-optic modulators, drivers, photodetectors, optical filters etc will be designed integrated at a system level. You would be collaborating with other team members.

Requirements: Good fundamentals and some hardware skills are important, others skills can be picked up after joining the group.

Sample publication:

S. Chugh, R. Ashok, P. Jain, S. Naaz, A. Sidhique and S. Gupta, "An Analog EIC-PIC Receiver with Carrier Phase Recovery for Self-Homodyne Coherent DCIs," IEEE Transactions on Circuits and Systems II: Express Briefs (2022). https://doi.org/10.1109/TCSII.2022.3167673

Project Investigator: Prof. Shalabh Gupta

Title of the project: Communication signal processing and electronics for high-speed wireline/optical communication links

Desired specialization: EE 1 (Communication & Signal Processing), EE 5 (Electronic Systems)

Abstract of the project:

In this work, you would be developing communications/signal processing algorithms and techniques, and developing hardware for high-speed optical/wireless links. The work would also involve playing with advanced digital modulation schemes and carrying out experiments with state-of-the-art equipment with other team members.

Good knowledge in the area of analog/digital communication systems, and interest in working with high-speed experimental setup will developed. Good fundamentals and some hardware skills are important, others skills can be picked up after joining the group.

Sample publication:

R. Kamran, S. Naaz, S. Goyal, and S. Gupta, "High-Capacity Coherent DCIs using Pol-Muxed Carrier and LO-Less Receiver," IEEE/OSA Journal of Lightwave Technology, 38(13), 3461 - 3468 (2020). https://doi.org/10.1109/JLT.2020.2972913.

Project Investigator: Prof. Anirban Sarkar

Title of the project: RF Beam Scanning antenna and circuits based Joint Communication and EM Sensing

Desired specialization: EE 1 (Communication & Signal Processing), EE 5 (Electronic Systems), EE 6 (Integrated Circuit & Systems)

Abstract of the project:

Considering the emerging demand of B5G/6G in wireless communications and sensing, the beam scanning antennas and advanced RF circuits play a pivotal role. To fulfill this, the antennas and smart surfaces need to be designed along with RF sensors with advanced sensing signatures. Targeting the essential parts of the healthcare and defence industry, the projected research area surely serve for combating different diseases using advanced wireless smart sensing as well as for the current defence industries. Overall, the total system will be under the joint communication and sensing.
