## Department of Electrical Engineering

**Ph.D. Admissions 2021-22 (Autumn Semester)**

### Contents

<table>
<thead>
<tr>
<th>Description</th>
<th>Page no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overview</td>
<td>2</td>
</tr>
<tr>
<td><strong>List of TA topics</strong></td>
<td></td>
</tr>
<tr>
<td>EE1 - Communications and Signal Processing</td>
<td>3-10</td>
</tr>
<tr>
<td>EE2 - Control and Computing</td>
<td>11-15</td>
</tr>
<tr>
<td>EE3 - Power Electronics and Power Systems</td>
<td>16-18</td>
</tr>
<tr>
<td>EE5 - Electronics Systems</td>
<td>19-24</td>
</tr>
<tr>
<td>EE6 - Integrated Circuit and Systems</td>
<td>25-29</td>
</tr>
<tr>
<td>EE7 - Solid State Devices</td>
<td>30-38</td>
</tr>
<tr>
<td><strong>List of RA Topics</strong></td>
<td>39-42</td>
</tr>
</tbody>
</table>
Abstracts of Research Topics and Projects

Detailed descriptions of TA and Sponsored Project Positions

This document lists the research topics available for TA positions (who will receive government scholarship) as well as sponsored project positions under the RA/TAP category. For explanation of different categories, please check [here].

If you get selected under Institute TA (called TA from here on), then you have full flexibility of choosing your PhD supervisor and your PhD area of research at a later time. If you get selected under RA/TAP (meaning, a sponsored project position), then the project investigator(s) (PI) is your supervisor and the PhD area is aligned with the sponsored project.

If you are selected as Institute-TA, then all EE faculty members, including the PIs of the sponsored projects, are available for you to choose as your guide. The choice of research topic and guide for institute TAs is done later, typically within one year of taking admission, based on mutual consent between the student and the guide. On the other hand, a student taking admission under a particular RA/TAP project can not change the topic or guide later. If you are interested in TA, you still need to choose it as a preference (first, intermediate or last). Please read the project abstracts in detail while filling the RA/TAP choices. It is not possible for PhD students to change their project or guide once admission is given against a particular RA/TAP position. Please consider these aspects while filling your preferences in the form. Once submitted, these preferences can not be changed. Also note that the number of institute TA positions or seats is, usually, not correlated to the number of topics listed in the same category (but is limited by the MHRD funds) while the number of RA/TAP positions correlate well with the number of topics listed in the same category.
List of TA topics: EE1

(Communications and Signal Processing)

In addition to the specific projects listed in this section, the following faculty members are willing to take PhD students on topics to be decided by mutual consultation in the broad research areas mentioned against their names:

<table>
<thead>
<tr>
<th>Faculty</th>
<th>Research Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subhasis Chaudhuri</td>
<td>Machine Learning in Computer Vision (upto 2 students)</td>
</tr>
<tr>
<td>Bikash Kumar Dey</td>
<td>Information theory, Error correcting codes, Network codes, Distributed coded computing, Secret sharing</td>
</tr>
<tr>
<td>Manoj Gopalkrishnan</td>
<td>Molecular communication systems, information theory, network theory</td>
</tr>
<tr>
<td>Shalabh Gupta</td>
<td>High-Speed Optical Communications, Radar Systems and Signal Processing in these systems.</td>
</tr>
<tr>
<td>Gaurav S. Kasbekar</td>
<td>Wireless Networks, Communication Networks, Network Security</td>
</tr>
<tr>
<td>Animesh Kumar</td>
<td>Signal Processing, Data Driven Signal Processing, Spatial Sensing</td>
</tr>
<tr>
<td>D Manjunath</td>
<td>Social Network analysis and opinion dynamics, Multi arm bandits, Learning algorithms</td>
</tr>
<tr>
<td>Jayakrishnan Nair</td>
<td>Demand response in smart power grids, Internet economics, Queueing systems</td>
</tr>
<tr>
<td>Harish Pillai</td>
<td>Coding theory, Information theory</td>
</tr>
<tr>
<td>Sibi Raj B Pillai</td>
<td>Biological Information Transfer, Epigenetic Communication, Network Information Theory, Wireless communication, Deep learning decoders</td>
</tr>
<tr>
<td>Virendra Sule</td>
<td>Cryptography application with coding and communication.</td>
</tr>
<tr>
<td>Nikhil Karamchandani</td>
<td>Online Learning and Statistical Inference, Codes for distributed caching and computing, Networks and Information Theory</td>
</tr>
</tbody>
</table>

**Topic #1**

Faculty Name: Subhasis Chaudhuri

Title of Project: **Solving classical computer vision problems through machine learning**

Specialization: Communications and Signal Processing; Control and Computing
Description: Various image processing problems like edge detection, depth recovery, blind deblurring, etc are currently being investigated as machine/deep learning problems, and very often, they offer much improved results. In this project we would like to investigate the applicability of ML in such image processing problems. The project will require a good depth of understanding of the following topics - linear algebra, optimization theory, probability and random processes and programming skills.

**Topic #2**

Faculty Name: Bikash Kumar Dey

Title of Project: **Coding for fault tolerant computing**

Specialization: Communications and Signal Processing

Description: Suppose a large computation is to be performed with the help of many available computers. The server can distribute the work among these "worker" computers. The worker computers can send the results of their computations to the server, which can then combine them to compute the final result. However, some worker computers may not return their results or return wrong results if they are either running very slow due to other jobs or due to faults. Can we design schemes such that the server may recover the correct result in spite of a few slow or faulty workers. The approach will use principles and techniques of error correcting codes.

**Topic #3**

Faculty Name: Bikash Kumar Dey

Title of Project: **To share or not to share secrets**

Specialization: Communications and Signal Processing

Description: In the classical sharing framework, a secret message is encoded into many shares. These shares are then distributed among some parties. If the shares of sufficient number of parties are combined, then it is possible to discover the secret. Now, what if some of the parties provide wrong share? Can the encoding guard against such cheating parties? The techniques from coding theory and information theory will be used to study such problems.

**Topic #4**

Faculty Name: Gaurav S. Kasbekar
Title of Project: **Enabling Millimeter Wave (mmWave) Communications for 5G Cellular Networks**

Specialization: Communications and Signal Processing

Description: While low frequency bands are crowded, a huge amount of free bandwidth is available in the mmWave bands (30 GHz to 300 GHz), and it is expected that these bands will be an important part of the emerging 5G cellular networks. However, there are fundamental differences between mmWave bands and low frequency bands: e.g., mmWave communications suffer from high propagation losses and are sensitive to blockage by objects in the environment. Also, usually highly directional communication is used on mmWave bands. Some challenges that need to be addressed in order to enable mmWave communications for 5G cellular networks are as follows: schemes must be designed for optimally assigning mobile users to base stations, interference management and achieving spatial reuse; also, blockages must be effectively dealt with. The objective of this project is to design algorithms for enabling mmWave communications and to evaluate their performance via mathematical analysis and simulations.

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**Topic #5**

Faculty Name: Gaurav S. Kasbekar

Title of Project: **Applications of Game Theory to Wireless Networks**

Specialization: Communications and Signal Processing

Description: Several tasks in a wireless network can be effectively performed if different users cooperate with each other. For example, data can be rapidly transferred from a base station to a user with poor coverage if another user acts as a relay. However, typically users are selfish and try to maximize their own utilities instead of seeking to achieve a socially beneficial outcome. E.g., a user may refuse to act as a relay since relaying consumes battery energy. An objective of this project is to understand the behaviour that can be expected from selfish users in a wireless network, and to design mechanisms to achieve socially beneficial outcomes despite the presence of selfish users, using tools from game theory and mechanism design. Another objective is to use game theoretic formulations to design distributed algorithms for wireless networks. A combination of mathematical analysis and simulations will be used in the project.

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**Topic #6**

Faculty Name: Nikhil Karamchandani

Title of Project: **Large-scale Inference and Network Analytics**
Specialization: Communications and Signal Processing; Control and Computing

Description: There are several applications where one would be interested in estimating underlying system parameters, by observing and analysing large quantities of possibly noisy data. For example, consider inferring the ranking of players in an online gaming system from the results of head-to-head matches, or the detection of communities in a social network from pairwise node interactions, or finding the source of a rumour propagating along the edges of a graph. This project will focus on creating statistical models for such applications, analysing them, and proposing efficient algorithms, using techniques from probability and graph theory amongst others. Links to some of our previous work in this direction are given below and are also available at https://sites.google.com/site/nikhilkaram/home/publications

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**Topic #7**

Faculty Name: Jayanta Mukherjee

Title of Project: **Antenna, filters and other passive microwave design**

Specialization: Communications and Signal Processing; Integrated Circuits and Systems

Description: We work in the field of passive microwave component design. This is especially critical nowadays where the frequency of operation is scaling up and newer standards like 5G have arrived. The focus is on novel antennas, filters and other microwave components like mode converters, diplexers, power dividers, couplers etc. Some of the specific topics of interest are:

1. Advanced metamaterial based antenna design
2. mm wave antenna design
3. Phase array antenna design

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**Topic #8**

Faculty Name: Jayanta Mukherjee

Title of Project: **RF Front end design**

Specialization: Communications and Signal Processing; Integrated Circuits and Systems

Description: 1. Advanced topologies in LNA, Mixer and PLL design in CMOS
2. Advanced topologies in LNA, RF switch in GaN
**Topic #9**

Faculty Name: Preeti Rao

Title of Project: **Music information retrieval**

Specialization: Communications and Signal Processing; Electronic Systems

Description: The ready availability of vast audio archives of music across genres opens up the need for powerful tools for search and navigation. Signal processing offers the possibility of generating a variety of computational encodings of music that facilitate search and navigation. The same computational tools can serve the needs of musicological research from audio archives as well as provide for powerful pedagogical aids. Our work is specifically directed towards investigating signal processing and machine learning methods for vocal and instrumental music applications.

**Topic #10**

Faculty Name: Virendra Sule

Title of Project: **Sensitivity optimization in distributed high frequency circuits by port compensation using modern control theory**

Specialization: Control and Computing; Integrated Circuits and Systems

Joint Supervisor: Prof. Maryam Shojaei

Description: This research is concerned with designing compensation for high frequency distributed circuits to reduce their sensitivity to parametric variations, external noise and parasitic paths. This problems is complicated due to the fact that interconnection of active networks can make the combined network unstable and hence compensation design has to be done under the constraint of stability. Such a problem is recently formulated and solved by the proposing faculty and their student for lumped circuits using methods from mathematical systems theory and H-infinity control concept. The present project is aimed at solving analogous problem for the distributed network models of high-frequency circuits of interest to circuit designers.

**Topic #11**

Faculty Name: Virendra Sule

Title of Project: **Boolean modeling of algorithms and applications**

Specialization: Communications and Signal Processing; Control and Computing
Description: Boolean systems of equations are a powerful language to formulate a large class of computational problems of NP class. Despite this practical approaches to solve them is of prime importance due to their applications in Cryptology, Life Sciences and Data Sciences. In this research a methodology developed by the proposer called implicant based solver for Boolean systems shall be developed further to address application problems from Finite state systems, Prediction for healthcare from data or even solutions of number theory problems computationally. The student must be passionate to learn mathematics and computational methods required for the problems to be worked on.

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**Topic #12**

Faculty Name: Siddharth Tallur

Title of Project: **Embedded systems for non-invasive structural health and condition monitoring applications**

Specialization: Communications and Signal Processing; Electronic Systems

Description: We are looking to complement our team of passionate and dedicated students working on sensor design for structural health monitoring and condition monitoring applications. Currently our focus is on sensor design optimization, for which we use bench-top test setups, suitable for laboratory experiments, but not for field testing. Problems encountered in the field are of a very different from the ones that manifest in lab, and as such it is important for any project to rapidly progress towards field testing with large number of prototypes to uncover and then solve such issues. We are looking for candidates with good experience and interest in embedded system design and digital signal processing to develop hardware and algorithms for such systems. We are currently focused on corrosion monitoring inside reinforced concrete structures, and vibration based condition monitoring of machinery. Interested students are encouraged to engage us in a discussion to explore other applications.

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**Topic #13**

Faculty Name: Saravanan Vijayakumaran

Title of Project: **Privacy in Cryptocurrencies**

Specialization: Communications and Signal Processing

Description: Ensuring privacy in public blockchains is a challenging problem. Existing privacy-preserving techniques use zero knowledge proofs, ring signatures, and other cryptographic
primitives. Our goal is to improve upon existing techniques or use them for new applications. This is a theoretical topic requiring familiarity with abstract algebra and cryptography.

**Topic #14**

Faculty Name: Rajesh Zele

Title of Project: **Super High Speed DAC (Digital to Analog) Converter Design for HDTV/Cable/Satellite Communication System Applications**

Specialization: Communications and Signal Processing; Integrated Circuits and Systems; Electronic Systems

Description: As everything including RF/Analog and Digital Systems are getting integrated on a SOC (System-On-Chip), there is a strong desire to convert real world analog (RF) signals to digital using high sampling rate and do the signal processing in the digital domain as early as possible. Similarly there is need to convert the digital data to analog at a very high sample rate before transmitting over the air/cable using power amplifiers. High performance Digital to Analog Converters play a critical role in the overall product development.

The student will be involved in the system implementation along with developing various circuit techniques in the design of super high speed Digital to Analog Converters with very good linearity. This project will provide high performance Integrated Circuits and System design experience culminating in sending out their chip for fabrication in 28nm CMOS technology. Student will also get good experience in testing their chips.

**Topic #15**

Faculty Name: Rajesh Zele

Title of Project: **Ultra-Low power Ultra-miniaturized Radio for Wireless Body Area Sensor Network (WBAN) using ISM Bands**

Specialization: Communications and Signal Processing; Integrated Circuits and Systems; Electronic Systems

Description: Increasing demand for higher data rate communication has led to opening up 57-64 GHz unlicensed spectrum in many countries. Due to high path loss, the 60 GHz signal has very short range (few meters). Short range facilitates low interference from other 60GHz radios, enabling the WPAN (Wireless Personal Area Network) applications. Due to very high frequency of operation, the antenna size is small leading to an ultra- miniature form factor - a requirement for Wireless Body Area Networks.
Traditionally millimetre wave devices have been implemented in III-V semiconductor technologies such as GaAs or InP. Today’s nm CMOS technologies can provide sufficient high frequency performance to implement 60 GHz radios. CMOS technology offers an easy path to efficiently integrate digital baseband enabling single chip solution. Our goal in this project proposal is to implement a fully integrated 60 GHz wireless transceiver using standard CMOS technology by providing new design techniques to overcome the challenges. PhD candidate will be involved in communication system design, 28 nm CMOS chip design/layout and testing.

**Topic #16**

Faculty Name: Prof. Shalabh Gupta

Title of Project: **Signal Processing Techniques in CMOS and Silicon Photonic Integrated Circuits for High-Speed Optical Fiber Interconnects.**

Specialization: Communications and Signal Processing; Electronic Systems; Solid State Devices

Description: The project aims to develop signal processing techniques for very high data rate short reach optical interconnects. The project also aims at developing state-of-the-art high-speed CMOS integrated circuits and silicon photonic integrated circuits for such interconnects. Prior knowledge of optical communications (or fiber optics) is not required. Interested candidates should interested either in communications signal processing or in CMOS IC design/silicon photonic IC design (along with interest in working with the high-end equipment available in the lab).

**Topic #17**

Faculty Name: Manoj Gopalkrishnan, Narendra Shiradkar

Title of Project: **Fundamental thermodynamics of batteries and power management**

Specialization: Communications and Signal Processing; Control and Computing

Description: We live in a world on the cusp of an electric vehicles revolution, as well as a renewable energy revolution, with integrated intelligent power systems spanning single devices to entire grids. In this scenario, several groups are developing algorithms that allow exploiting even greater efficiencies out of such systems. We ask the question: what are the fundamental limits of such attempts? Are there fundamental laws of batteries? Is there an inevitable energy cost to uncertainty in power supply, and can it be quantified? Our approach is based on theoretical ideas that provide a dictionary between information theory and thermodynamics, and allow us to think of power management systems in analogy with multilevel memory caching systems.
List of TA topics: EE2
(Control and Computing)

In addition to the specific projects listed in this section, the following faculty members are willing
to take PhD students on topics to be decided by mutual consultation in the broad research areas
mentioned against their names:

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<td>Machine Learning in Computer Vision (upto 2 students)</td>
</tr>
<tr>
<td>Bikash Kumar Dey</td>
<td>Distributed coded computing, Error correcting codes</td>
</tr>
<tr>
<td>Manoj Gopalkrishnan</td>
<td>Pontryagin maximum principle, KL control, deep learning</td>
</tr>
<tr>
<td>S V Kulkarni</td>
<td>Computational Electromagnetics</td>
</tr>
<tr>
<td>D Manjunath</td>
<td>Social Network analysis and opinion dynamics,</td>
</tr>
<tr>
<td>Dwaipayan Mukherjee</td>
<td>Topics related to, but not limited to, fault detection in and monitoring of</td>
</tr>
<tr>
<td></td>
<td>networked dynamic systems, formation control, Robust consensus in multi-agent</td>
</tr>
<tr>
<td></td>
<td>systems, and other similar topics based on mutual consultation.</td>
</tr>
<tr>
<td>Debasattam Pal</td>
<td>Switched Singular Systems, Data-driven Robust Control, Numerical Issues in</td>
</tr>
<tr>
<td></td>
<td>Singular Optimal Control, Algebraic Analysis of Distributed Parameter Systems</td>
</tr>
<tr>
<td>Harish Pillai</td>
<td>Any area of control theory, Numerical Linear Algebra, Finite Fields Applications</td>
</tr>
<tr>
<td>Virendra Sule</td>
<td>Boolean and finite state dynamical systems, Boolean approach to computation.</td>
</tr>
<tr>
<td></td>
<td>Finite state dynamical and control systems. Control theory of multiport networks.</td>
</tr>
</tbody>
</table>

Topic #1

Faculty Name: Madhu N Belur

Title of Project: **Elimination of impulses using feedback control**

Specialization: Control and Computing

Description: Feedback control is the standard and robust way to achieve various control objectives like stabilization, pole-placement. Elimination of impulsive behavior has been important and feedback control has received less attention as a control technique. This Ph.D. topic
aims to work in the theoretical, algorithmic and numerical aspects that arise during impulse elimination controller design.

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**Topic #2**

Faculty Name: Madhu N Belur

Title of Project: *Congestion control using feedback in railway networks*

Specialization: Control and Computing

Description: Congestion control is important in many applications where we have buffer and we can choose one out of many scheduling policies. Internet congestion control has TCP/IP and router packet drop strategies as an example. Highway traffic dynamic re-routing also uses feedback control to dynamically divert traffic through alternate routes when congestion is detected along one route. Feedback control helps in having better capacity utilization while reducing congestion. In the context of railway networks, congestion control tends to be more centralized since the units to be dispatched are not small packets, nor small vehicles, but are large and long vehicles. Use of feedback control can help in railway networks too: but more intricate analysis and optimization is needed before deployment. This PhD topic pursues feedback based congestion control policies for railway networks.

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**Topic #3**

Faculty Name: Subhasis Chaudhuri

Title of Project: *Solving classical computer vision problems through machine learning*

Specialization: Communications and Signal Processing; Control and Computing

Description: Various image processing problems like edge detection, depth recovery, blind deblurring, etc are currently being investigated as machine/deep learning problems, and very often, they offer much improved results. In this project we would like to investigate the applicability of ML in such image processing problems. The project will require a good depth of understanding of the following topics - linear algebra, optimization theory, probability and random processes and programming skills.

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**Topic #4**

Faculty Name: Manoj Gopalkrishnan, Narendra Shiradkar
Title of Project: **Fundamental thermodynamics of batteries and power management**

Specialization: Communications and Signal Processing; Control and Computing

Description: We live in a world on the cusp of an electric vehicles revolution, as well as a renewable energy revolution, with integrated intelligent power systems spanning single devices to entire grids. In this scenario, several groups are developing algorithms that allow exploiting even greater efficiencies out of such systems. We ask the question: what are the fundamental limits of such attempts? Are there fundamental laws of batteries? Is there an inevitable energy cost to uncertainty in power supply, and can it be quantified? Our approach is based on theoretical ideas that provide a dictionary between information theory and thermodynamics, and allow us to think of power management systems in analogy with multilevel memory caching systems.

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**Topic #5**

Faculty Name: Nikhil Karamchandani

Title of Project: **Large-scale Inference and Network Analytics**

Specialization: Communications and Signal Processing; Control and Computing

Description: There are several applications where one would be interested in estimating underlying system parameters, by observing and analysing large quantities of possibly noisy data. For example, consider inferring the ranking of players in an online gaming system from the results of head-to-head matches, or the detection of communities in a social network from pairwise node interactions, or finding the source of a rumour propagating along the edges of a graph. This project will focus on creating statistical models for such applications, analysing them, and proposing efficient algorithms, using techniques from probability and graph theory amongst others. Links to some of our previous work in this direction are given below and are also available at [https://sites.google.com/site/nikhilkaram/home/publications](https://sites.google.com/site/nikhilkaram/home/publications).

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**Topic #6**

Faculty Name: Debasattam Pal

Title of Project: **Stability and stabilization of distributed parameter systems**

Specialization: Control and Computing

Description: This topic is theoretical. Algebraic analysis of PDEs is expected to play a central role in the study. There is ample scope of extending/generalizing various system theoretic ideas pertaining to lumped parameter systems to the case of distributed parameter systems.
**Topic #7**

Faculty Name: Debasattam Pal

Title of Project: **Study and resolution of singularities in theory of dissipativity**

Specialization: Control and Computing

Description: Dissipativity theory plays a crucial role in several control problems. The theory is well-understood, however, under some regularity assumptions. The project is aimed at studying the issues when these regularity assumptions are relaxed.

**Topic #8**

Faculty Name: Debasattam Pal

Title of Project: **Analysis of switched systems via non-commutative algebra**

Specialization: Control and Computing

Description:

**Topic #9**

Faculty Name: Virendra Sule

Title of Project: **Boolean modeling of algorithms and applications**

Specialization: Communications and Signal Processing; Control and Computing

Description: Boolean systems of equations are a powerful language to formulate a large class of computational problems of NP class. Despite this practical approaches to solve them is of prime importance due to their applications in Cryptology, Life Sciences and Data Sciences. In this research a methodology developed by the proposer called implicant based solver for Boolean systems shall be developed further to address application problems from Finite state systems, Prediction for healthcare from data or even solutions of number theory problems computationally. The student must be passionate to learn mathematics and computational methods required for the problems to be worked on.
Topic #10

Faculty Name: Siddharth Tallur

Title of Project: Synchronization methods for chaotic oscillators and their applications

Specialization: Control and Computing; Electronic Systems

Description: Chaotic oscillators can enable several applications in cryptography. Such applications require synchronization of a network of such oscillators. We have recently obtained interesting results applying LQR control theory to design linear partial state feedback controller to synchronize electronic oscillator circuits. The thesis will involve extending these ideas to explore systems with richer dynamics for a variety of applications.
List of TA topics: EE3

(Power Electronics and Power Systems)

In addition to the specific projects listed in this section, the following faculty members are willing to take PhD students on topics to be decided by mutual consultation in the broad research areas mentioned against their names:

<table>
<thead>
<tr>
<th>Faculty</th>
<th>Research Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kishore Chatterjee</td>
<td>Power evacuation from solar photovoltaic systems, Chargers for Electric vehicles</td>
</tr>
<tr>
<td>S V Kulkarni</td>
<td>Power Transformers: Analysis and Diagnostics, Electromagnetic and coupled field computations in electrical equipment, Modeling of hysteresis, High voltage engineering/insulation diagnostics</td>
</tr>
</tbody>
</table>

**Topic #1**

Faculty Name: Pramod Murali

Title of Project: **Contamination Sensor System for Wind Turbines**

Specialization: Power Electronics and Power Systems; Electronic Systems

Description: India plans to generate 60GW of wind-energy by 2022. Each wind-turbine can generate upto 1MW under optimal conditions. Unfortunately, contaminant accumulation on wind turbine blades, particularly in India, causes 20% efficiency loss (200kW loss). In this project you will build a complete wireless, solar powered sensor system, to measure contaminant thickness upto 5mm with 0.1mm resolution, for preventive maintenance of wind-turbine blades. This system can also be tailored for solar farms or for food processing industries.

**Topic #2**

Faculty Name: Anshuman Shukla

Title of Project: **Development of Smart Inverters using Wide-Bandgap Devices**

Specialization: Power Electronics and Power Systems
Description: The goal of this project is to develop the next generation of smart inverters using Wide-Bandgap Devices (Silicon Carbide and Gallium Nitride devices) for the renewable energy, electric vehicle and energy storage applications. They will be more efficient, modular, cost-effective, fault-tolerant, compact and able to self-diagnose and self-repair. Moreover, they will be specifically adapted for the harsh environments.

**Topic #3**

Faculty Name: Anshuman Shukla

Title of Project: **Integration of Renewable Energy Resources in Microgrid Systems using Power Electronic Transformer**

Specialization: Power Electronics and Power Systems

Description: The aim of this project is to develop a Microgrid system enabled by Power Electronic Transformer (PET). In a traditional ac microgrid system, a transformer is used to interconnect the ac main grid and the distribution system. However, additional inverters are needed to connect PV and the other dc type renewable energy sources to the ac main grid. Similarly, the dc loads need an addition power electronic converter to generate dc voltage, while the ac loads can be connected directly with the ac main grid. The same requirement of additional power electronic converters is also true for dc microgrid systems for the respective ac/dc sources and loads. A PET is a three port power converter that includes an ac to dc conversion stage, a high frequency dc to dc conversion stage and a dc to ac conversion stage. Therefore, in a PET enabled microgrid system, the number of converters can be reduced and additional control flexibility can be introduced. This project will focus on the most effective control schemes and the most optimal PET topologies for microgrid systems.

**Topic #4**

Faculty Name: Anshuman Shukla

Title of Project: **Fast Chargers for Electric Vehicles**

Specialization: Power Electronics and Power Systems

Description: The aim is to design and develop a fast charging station prototype. It is expected to be best in class in terms of technical features, charging speed, affordability, efficiency and compactness.
Topic #5

Faculty Name: Anshuman Shukla

Title of Project: Design, Control and Implementation of Modular Multilevel Power Electronic Converters

Specialization: Power Electronics and Power Systems

Description: In this project, the most suitable converter and submodule configurations for the modular multilevel converter for different applications will be identified and characterized. The corresponding modulation and control schemes will be developed and verified using both simulation and experimental studies.
List of TA topics: EE5

(Electronic Systems)

In addition to the specific projects listed in this section, the following faculty members are willing to take PhD students on topics to be decided by mutual consultation in the broad research areas mentioned against their names:

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<th>Faculty</th>
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<tbody>
<tr>
<td>Sibi Raj B Pillai</td>
<td>Biological Information Transfer, Deep learning decoders</td>
</tr>
<tr>
<td>Maryam Shojaei</td>
<td>Compact Sensor Systems for Healthcare Technologies, Agri-Tech systems, energy autonomous water quality monitoring systems, Instrumentation and Signal Conditioning for Emerging Applications with focus on IoT (IoE), MEMS based photo acoustic systems, Energy harvesting systems</td>
</tr>
</tbody>
</table>

**Topic #1**

Faculty Name: Pramod Murali

Title of Project: **Electro-Optical PLL for FMCW LiDARs**

Specialization: Integrated Circuits and Systems; Electronic Systems

Description: The goal of this project is to design a CMOS chip capable of driving a 1550 nm tunable laser to generate a well defined frequency chirp.

**Topic #2**

Faculty Name: Pramod Murali

Title of Project: **Contamination Sensor System for Wind Turbines**

Specialization: Power Electronics and Power Systems; Electronic Systems

Description: India plans to generate 60GW of wind-energy by 2022. Each wind-turbine can generate upto 1MW under optimal conditions. Unfortunately, contaminant accumulation on wind turbine blades, particularly in India, causes 20% efficiency loss (200kW loss). In this project you will build a complete wireless, solar powered sensor system, to measure contaminant thickness
upto 5mm with 0.1mm resolution, for preventive maintenance of wind-turbine blades. This system can also be tailored for solar farms or for food processing industries.

Topic #3

Faculty Name: P C Pandey

Title of Project: **Speech enhancement and voice conversion for improving speech intelligibility**

Specialization: Communications and Signal Processing; Electronic Systems

Description: Speech comprehension gets severely affected by interfering sources in the talker's environment, communication channel, and listening environment. Hearing-impaired listeners face additional difficulties due to reduced dynamic range of hearing and increased level of spectral and temporal masking. Real-time speech processing for enhancing the speech signal by suppressing the interfering sources and processing based on voice conversion techniques to enhance the perceptually salient features of the speech signal can be used for improving speech intelligibility under adverse listening conditions. Some of these techniques have been developed by our group and we are looking at further enhancements of the signal processing techniques and their implementation using cell phone processors for their widespread use.

Topic #4

Faculty Name: P C Pandey and V R Rajbabu

Title of Project: **Lip contour detection for estimation of mouth opening area for use in speech training aids**

Specialization: Communications and Signal Processing; Electronic Systems

Description: In speech training aids for providing visual feedback of the articulatory efforts, time-varying vocal tract shape during speech production is generally estimated by linear prediction (LP) analysis of the speech signal and assuming a constant area at the glottis end as a reference. Variation in the glottis-end area during speech production causes errors in the estimated vocal tract shape. The problem can be overcome by using area of the mouth opening as the reference. This area can be estimated by detecting the inner lip contour from the video recording of speaker's face during speech utterance. We have earlier developed a technique for detection of inner lip contour, based on color transformation and template matching. Building on this work, further research will involve developing a technique that is not affected by skin hue and presence of teeth and tongue, and implementation of the technique as part of a speech training aid.
**Topic #5**

Faculty Name: Preeti Rao

Title of Project: **Music information retrieval**

Specialization: Communications and Signal Processing; Electronic Systems

Description: The ready availability of vast audio archives of music across genres opens up the need for powerful tools for search and navigation. Signal processing offers the possibility of generating a variety of computational encodings of music that facilitate search and navigation. The same computational tools can serve the needs of musicological research from audio archives as well as provide for powerful pedagogical aids. Our work is specifically directed towards investigating signal processing and machine learning methods for vocal and instrumental music applications.

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**Topic #6**

Faculty Name: Maryam Shojaei

Title of Project: **Autonomous Wireless Sensor Network for Real-time Water Quality Monitoring**

Specialization: Electronic Systems

Description: Field oriented sensor system integration for wireless sensor networks and IoT applications is on demand. In this direction this project aims at a complete Indigenous and modular multi-parameter instrumentation and electronics for the sensor signal conditioning and networking for water quality monitoring in the selected waterways. The developed solution will be economical and low power so as to be scalable for different waterbodies.

The project will also bring several new interesting research and development aspects in the areas of the circuits and systems for this application and in the real field.

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**Topic #7**

Faculty Name: Siddharth Tallur

Title of Project: **Bulk acoustic wave (BAW) resonator based gyroscopes**

Specialization: Electronic Systems; Solid State Devices
Description: Nature of work: Experimental (control electronics design and characterization). BAW gyroscopes have been the hot topic in MEMS gyroscope research around the globe in the past decade (notable groups include Ayazi at Georgia Tech, Najafi at UMich, Kenny at Stanford, Shkel at UC Irvine), but only one unsuccessful attempt to commercialize the technology was made (by Qualtre Inc., now part of Panasonic Corp.) There are several technical challenges pertaining to resonator design and fabrication and control electronics, that remain open problems in this area. Many of the problems are limited by fabrication technology, which continues to improve with time, calling upon innovations at the electronic design level. This project will involve working on one of more of these aspects together with other students, in a group that is passionate about solving these issues. This project may involve collaboration with a research group in Taiwan and a commercial foundry for interested candidates.

**Topic #8**

Faculty Name: Siddharth Tallur

Title of Project: **Embedded systems for non-invasive structural health and condition monitoring applications**

Specialization: Communications and Signal Processing; Electronic Systems

Description: We are looking to complement our team of passionate and dedicated students working on sensor design for structural health monitoring and condition monitoring applications. Currently our focus is on sensor design optimization, for which we use bench-top test setups, suitable for laboratory experiments, but not for field testing. Problems encountered in the field are of a very different from the ones that manifest in lab, and as such it is important for any project to rapidly progress towards field testing with large number of prototypes to uncover and then solve such issues. We are looking for candidates with good experience and interest in embedded system design and digital signal processing to develop hardware and algorithms for such systems. We are currently focused on corrosion monitoring inside reinforced concrete structures, and vibration based condition monitoring of machinery. Interested students are encouraged to engage us in a discussion to explore other applications.

**Topic #9**

Faculty Name: Siddharth Tallur

Title of Project: **Synchronization methods for chaotic oscillators and their applications**

Specialization: Control and Computing; Electronic Systems
Description: Chaotic oscillators can enable several applications in cryptography. Such applications require synchronization of a network of such oscillators. We have recently obtained interesting results applying LQR control theory to design linear partial state feedback controller to synchronize electronic oscillator circuits. The thesis will involve extending these ideas to explore systems with richer dynamics for a variety of applications.

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**Topic #10**

Faculty Name: Rajesh Zele

Title of Project: **Super High Speed DAC (Digital to Analog) Converter Design for HDTV/Cable/Satellite Communication System Applications**

Specialization: Communications and Signal Processing; Integrated Circuits and Systems; Electronic Systems

Description: As everything including RF/Analog and Digital Systems are getting integrated on a SOC (System-On-Chip), there is a strong desire to convert real world analog (RF) signals to digital using high sampling rate and do the signal processing in the digital domain as early as possible. Similarly there is need to convert the digital data to analog at a very high sample rate before transmitting over the air/cable using power amplifiers. High performance Digital to Analog Converters play a critical role in the overall product development.

The student will be involved in the system implementation along with developing various circuit techniques in the design of super high speed Digital to Analog Converters with very good linearity. This project will provide high performance Integrated Circuits and System design experience culminating in sending out their chip for fabrication in 28nm CMOS technology. Student will also get good experience in testing their chips.

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**Topic #11**

Faculty Name:

Title of Project: **Ultra-Low power Ultra-miniaturized Radio for Wireless Body Area Sensor Network (WBAN) using ISM Bands**

Specialization: Communications and Signal Processing; Integrated Circuits and Systems; Electronic Systems

Description: Increasing demand for higher data rate communication has led to opening up 57-64 GHz unlicensed spectrum in many countries. Due to high path loss, the 60 GHz signal has very short range (few meters). Short range facilitates low interference from other 60 GHz radios,
enabling the WPAN (Wireless Personal Area Network) applications. Due to very high frequency of operation, the antenna size is small leading to an ultra-miniature form factor - a requirement for Wireless Body Area Networks.

Traditionally millimetre wave devices have been implemented in III-V semiconductor technologies such as GaAs or InP. Today’s nm CMOS technologies can provide sufficient high frequency performance to implement 60 GHz radios. CMOS technology offers an easy path to efficiently integrate digital baseband enabling single chip solution. Our goal in this project proposal is to implement a fully integrated 60 GHz wireless transceiver using standard CMOS technology by providing new design techniques to overcome the challenges. PhD candidate will be involved in communication system design, 28 nm CMOS chip design/layout and testing.

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**Topic #12**

Faculty Name: Prof. Shalabh Gupta

Title of Project: **Signal Processing Techniques in CMOS and Silicon Photonic Integrated Circuits for High-Speed Optical Fiber Interconnects.**

Specialization: Communications and Signal Processing; Electronic Systems; Solid State Devices

Description: The project aims to develop signal processing techniques for very high data rate short reach optical interconnects. The project also aims at developing state-of-the-art high-speed CMOS integrated circuits and silicon photonic integrated circuits for such interconnects. Prior knowledge of optical communications (or fiber optics) is not required. Interested candidates should interested either in communications signal processing or in CMOS IC design/silicon photonic IC design (along with interest in working with the high-end equipment available in the lab).
List of TA topics: EE6  
(Integrated Circuit and Systems)

In addition to the specific projects listed in this section, the following faculty members are willing to take PhD students on topics to be decided by mutual consultation in the broad research areas mentioned against their names:

<table>
<thead>
<tr>
<th>Faculty</th>
<th>Research Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Udayan Ganguly</td>
<td>Spiking Neural Network Devices and Circuit; Non-volatile Memory Devices e.g. Resistance RAM, Ferroelectric RAM, Flash; Transistor Design</td>
</tr>
<tr>
<td>Maryam Shojaei</td>
<td>Analog/Mixed-Signal CMOS IC Design for Impedance Spectroscopy ASICs, Data Converters for Emerging Applications, Energy efficient CMOS RF modules for the IoT within the 5G plans, Energy harvesting and CMOS power management for emerging applications</td>
</tr>
</tbody>
</table>

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**Topic #1**

Faculty Name: Jayanta Mukherjee

Title of Project: **Antenna, filters and other passive microwave design**

Specialization: Communications and Signal Processing; Integrated Circuits and Systems

Description: We work in the field of passive microwave component design. This is especially critical nowadays where the frequency of operation is scaling up and newer standards like 5G have arrived. The focus is on novel antennas, filters and other microwave components like mode converters, diplexers, power dividers, couplers etc. Some of the specific topics of interest are:

1. Advanced metamaterial based antenna design
2. mm wave antenna design
3. Phase array antenna design

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**Topic #2**

Faculty Name: Jayanta Mukherjee
Title of Project: **RF Front end design**

Specialization: Communications and Signal Processing; Integrated Circuits and Systems

Description: 1. Advanced topologies in LNA, Mixer and PLL design in CMOS

2. Advanced topologies in LNA, RF switch in GaN

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**Topic #3**

Faculty Name: Pramod Murali

Title of Project: **Electro-Optical PLL for FMCW LiDARs**

Specialization: Integrated Circuits and Systems; Electronic Systems

Description: The goal of this project is to design a CMOS chip capable of driving a 1550nm tunable laser to generate a well defined frequency chirp.

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**Topic #4**

Faculty Name: M.B. Patil

Title of Project: **Automatic design and optimization of integrated analog circuits**

Specialization: Integrated Circuits and Systems

Joint Supervisor: Prof. Maryam Shojaei

Description: In analog circuit design, transistor sizes need to be chosen in order to meet certain specs. In general, this is a complex problem, requiring simulation and optimisation. In some cases, the specs can be combined in the form of a single objective function to be optimised; in others, the specs may need to be treated as multiple objectives. In this project, the student would be expected to learn about optimisation techniques, particularly evolutionary algorithms, and apply them to the domain of analog circuit design.

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**Topic #5**

Faculty Name: Maryam Shojaei

Title of Project: **Design, fabrication and integration of impedance spectroscopy ASIC**

Specialization: Integrated Circuits and Systems
Description: The purpose of this project is to make one (or two) customized CMOS impedance spectroscopy ASIC(s) for the selected agritech and biosensing applications.

**Topic #6**

Faculty Name: Maryam Shojaei

Title of Project: **Energy efficient CMOS RF modules for the IoT within the 5G plans**

Specialization: Integrated Circuits and Systems

Description: The IoT (IoE) is going to change life of many people in the near future. In this project we will design, fabricate and test various CMOS RF modules based on the recommendations and band allocations for IoT.

**Topic #7**

Faculty Name: Maryam Shojaei

Title of Project: **Energy harvesting and CMOS power management ASIC for artificial smart skin**

Specialization: Integrated Circuits and Systems

Description: Artificial smart skin is a growing area finding its applications in robotics and medical applications. This technology also brings new aspects of energy provision for the artificial skin. In this project we will work on the flexible layers of generators with a CMOS power management ASIC which will be designed, fabricated and integrated on the artificial skin.

**Topic #8**

Faculty Name: Maryam Shojaei

Title of Project: **Novel energy efficient noise-tolerant analog and mixed-signal CMOS signal conditioning ASIC or sensing applications**

Specialization: Integrated Circuits and Systems

Description: Various emerging sensing applications need energy efficient and noise-tolerant analog signal conditioning for the high performance, followed by novel hybrid low-energy high-resolution architectures for the analog to digital conversion (ADC). The purpose of this project is
to extend such functionalities with high performance to the various domains of information for better tolerance to the internal and external noise as well as calibration for the selective analog to digital conversion.

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**Topic #9**

Faculty Name: Virendra Sule

Title of Project: *Sensitivity optimization in distributed high frequency circuits by port compensation using modern control theory*

Specialization: Control and Computing; Integrated Circuits and Systems

Joint Supervisor: Prof. Maryam Shojaei

Description: This research is concerned with designing compensation for high frequency distributed circuits to reduce their sensitivity to parametric variations, external noise and parasitic paths. This problems is complicated due to the fact that interconnection of active networks can make the combined network unstable and hence compensation design has to be done under the constraint of stability. Such a problem is recently formulated and solved by the proposing faculty and their student for lumped circuits using methods from mathematical systems theory and H-infinity control concept. The present project is aimed at solving analogous problem for the distributed network models of high-frequency circuits of interest to circuit designers.

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**Topic #10**

Faculty Name: Rajesh Zele

Title of Project: *Super High Speed DAC (Digital to Analog) Converter Design for HDTV/Cable/Satellite Communication System Applications*

Specialization: Communications and Signal Processing; Integrated Circuits and Systems; Electronic Systems

Description: As everything including RF/Analog and Digital Systems are getting integrated on a SOC (System-On-Chip), there is a strong desire to convert real world analog (RF) signals to digital using high sampling rate and do the signal processing in the digital domain as early as possible. Similarly there is need to convert the digital data to analog at a very high sample rate before transmitting over the air/cable using power amplifiers. High performance Digital to Analog Converters play a critical role in the overall product development.
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**Topic #11**

Faculty Name: Rajesh Zele

Title of Project: *Ultra-Low power Ultra-miniaturized Radio for Wireless Body Area Sensor Network (WBAN) using ISM Bands*

Specialization: Communications and Signal Processing; Integrated Circuits and Systems; Electronic Systems

Description: Increasing demand for higher data rate communication has led to opening up 57-64 GHz unlicensed spectrum in many countries. Due to high path loss, the 60 GHz signal has very short range (few meters). Short range facilitates low interference from other 60GHz radios, enabling the WPAN (Wireless Personal Area Network) applications. Due to very high frequency of operation, the antenna size is small leading to an ultra-miniature form factor - a requirement for Wireless Body Area Networks.

Traditionally millimetre wave devices have been implemented in III-V semiconductor technologies such as GaAs or InP. Today’s nm CMOS technologies can provide sufficient high frequency performance to implement 60 GHz radios. CMOS technology offers an easy path to efficiently integrate digital baseband enabling single chip solution. Our goal in this project proposal is to implement a fully integrated 60 GHz wireless transceiver using standard CMOS technology by providing new design techniques to overcome the challenges. PhD candidate will be involved in communication system design, 28 nm CMOS chip design/layout and testing.

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List of TA topics: EE7
(Solid State Devices)

In addition to the specific projects listed in this section, the following faculty members are willing to take PhD students on topics to be decided by mutual consultation in the broad research areas mentioned against their names:

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<tr>
<td>Subhananda Chakrabarti</td>
<td>Compound (III-V and II-VI) semiconductor materials and devices</td>
</tr>
<tr>
<td>Udayan Ganguly</td>
<td>Spiking Neural Network Devices and Circuit; Circuits for Non-volatile Memory Devices e.g. Resistance RAM, Ferroelectric RAM, Flash; Variability resistant circuits</td>
</tr>
<tr>
<td>Shalabh Gupta</td>
<td>Ionizing radiation tolerant integrated circuits in CMOS technologies.</td>
</tr>
<tr>
<td>Souvik Mahapatra</td>
<td>Reliability of semiconductor devices</td>
</tr>
<tr>
<td>Dipankar Saha</td>
<td>Single photon sources using quantum dots for quantum communication.</td>
</tr>
<tr>
<td>Maryam Shojaei</td>
<td>Reliable and robust sensor and bio-sensor fabrication for agri-tech applications, MEMS based photo acoustic sensor fabrication and characterization, MEMS switch design and fabrication for energy-efficient integrated systems</td>
</tr>
<tr>
<td>Siddharth Tallur</td>
<td>GaN based MEMS (utilizing the rich properties of GaN viz. electro-optic coefficient, optical nonlinearity, piezoelectricity etc. for various resonator based sensing and timing applications)</td>
</tr>
<tr>
<td>Ashwin Tulapurkar</td>
<td>spintronics, spin based devices and phenomena</td>
</tr>
</tbody>
</table>

Topic #1

Faculty Name: Prof. SP Duttagupta

Title of Project: **Rapid imaging and pattern recognition system for biomarker classification**

Specialization: Solid State Devices

Description: The objective is machine learning enhanced biomarker classification for sub-surface analysis of organic carbon in order to predict and estimate arsenic release pathways in groundwater. In parallel, biomarker classification will be useful for health-care applications such as analysis of dengue pathogenesis mechanism and serotype diagnosis to identify single or mixed infection at early stage of infection. The proposed system comprises of imaging, micro-fluidic and computational modules to enable high definition image capture, stabilization, analysis, and retrieval.
Topic #2

Faculty Name: Prof. SP Duttagupta

Title of Project: **Design and development of a compact Tera-Hertz spectroscopy set-up for biomarker discovery**

Specialization: Solid State Devices

Description: Terahertz (THz) radiation has many applications in condensed matter physics, medical diagnostics, high-bandwidth communication etc. In the electromagnetic spectrum, THz spans from 3mm to 30micron (wavelength). This radiation is capable of penetrating through opaque materials such as plastics, paper and textiles. Image resolution in the order of mm is possible. Unlike other imaging radiation like gamma rays, THz radiation does not exhibit an ionizing effect. Due to this reason these frequencies are considered to be biologically innocuous. However, at present Thz components (emitter, filter, mixer, detector) are difficult to source and require to be designed, fabricated and tested in-house. Accordingly we propose to develop a compact, cost-effective THz spectroscope which will be utilized for bio-marker imaging.

Topic #3

Faculty Name: Swaroop Ganguly

Title of Project: **Quantum electronic nose sensors**

Specialization: Solid State Devices

Description: Natural olfaction (sense of smell) is more sensitive and powerful than the artificial (electronic) nose sensors available today. The goal here is the development of biomimetic electronic nose sensors which will rival biological olfaction. One thrust involves biophysical models, and device design inspired by those. The work involves theory and computation. Background and/or strong interest in quantum mechanics, and solid-state device physics is required. Some knowledge of graph theory and interest in biophysics would also be useful. The second thrust is experimental, involving device fabrication, and characterization. For this, interest in semiconductor devices, and background in circuits, instrumentation and measurements would be useful.

Topic #4

Faculty Name: Anil Kottantharayil
Title of Project: **Spacial mapping of losses in solar cells and modules using advanced characterization techniques**

Specialization: Solid State Devices

Description: The work would involve the development of appropriate models and tools for the analysis of the characteristics of solar cells (current - voltage, quantum efficiency, luminescence images, infrared thermography images, ...) and evaluate the losses in solar cells. The student is expected to measure the characteristics and also develop the theoretical framework and analysis.

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**Topic #5**

Faculty Name: Apurba Laha

Title of Project: **Design, grow and fabricate III-Nitride based Ultraviolet Nano LED**

Specialization: Solid State Devices

Description: Disinfection of water by ultraviolet light (UV-C) exposure is the most effective and non-invasive mean of water purification. However, the currently available UV light sources are large, expensive and require large power to run. Due to these constraints, the UV sources are centrally located as disinfection hubs and therefore, leaving more than one third of the world population without a viable UV disinfection solution. Apart from water purification UV lights are also used for air purification, surface disinfection, free-space non-line-of-sight covert communication, epoxy curing, counterfeit detection, light therapy and fluorescence identification of biological/chemical agents. The first part of this project is grow AlGaN nanowires designed for UV light emission by state of the art Molecular Beam Epitaxy technique. Second part primarily involves fabrication of the LED using these nanowires.

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**Topic #6**

Faculty Name: Saurabh Lodha

Title of Project: **2D Materials for Neuromorphic Computing**

Specialization: Solid State Devices

Description: The past decade has seen explosive growth in 2D materials such as graphene as well as synaptic/neuronal devices for artificial intelligence and neuromorphic computing. This project will explore experimental and analytical approaches towards harnessing unique electronic, optical and mechanical properties of 2D materials for building neuromorphic devices. It will target flexible and smart sensing and computing applications.
This work will leverage significant experimental and computational expertise in our research group on electronic and optoelectronic devices. Please visit http://www.ee.iitb.ac.in/~slodha/ for more details.

**Topic #7**

Faculty Name: Saurabh Lodha

Title of Project: **Gallium oxide devices for next generation power electronics**

Specialization: Solid State Devices

Description: Large band gap and ease of growth of gallium oxide has led to a new wave in wide bandgap power devices and electronics. At the same time, many fundamental challenges in gallium oxide processing and device fabrication offer an opportunity to explore new device physics and engineer high impact solutions. This project will explore the fabrication of normally off high power gallium oxide transistors for power switching applications. It will involve experimental device fabrication, characterisation and TCAD simulations.

In collaboration with Ohio State University (OSU) we have established basic process flows and demonstrated early successes in gallium oxide device fabrication. Please visit http://www.ee.iitb.ac.in/~slodha/ for more details.

**Topic #8**

Faculty Name: Souvik Mahapatra

Title of Project: **Reliability of advanced CMOS logic and memory devices**

Specialization: Solid State Devices

Description: Experimental + Physics-model development / Simulation, Work with leading industries to incorporate models in practice.

**Topic #9**

Faculty Name: Bhaskaran Muralidharan

Title of Project: **Topological Electronics**

Specialization: Solid State Devices
Description: Modern nanoelectronic device design for the upcoming “Beyond Moore” era calls for radical and innovative ideas at the device engineering level that feature the interplay of spin and charge while simultaneously exploiting the exciting day-to-day development in material structures. During the past decade or so, the search for “topological phases” in materials has gained a significant ground and is a topic of intense and active worldwide pursuit. These phases feature electronic states that are “topologically stable” and hence “disciplined” despite the presence of the agents such as defects and impurities that normally result in power dissipation in logic and memory devices and qubit decoherence in quantum computing. The aim of this work is to develop an atomistic computational platform to facilitate a comprehensive exploration of material hetero-structures and interfaces from a nanoelectronic device design perspective in order to realize “topotronic” devices and engineer such topological transitions for ultra-low-power logic and spin based quantum computing.

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**Topic #10**

Faculty Name: Bhaskaran Muralidharan

**Title of Project:** Quantum information processing with hybrid systems

**Specialization:** Solid State Devices

Description: Quantum technologies including quantum computing and information processing will form a very important aspect of the next generation technology. In this project we aim at the realization of quantum information processing using hybrid systems. Research on quantum hybrid systems strives to combine the benefits of different quantum objects into a new entity that is more useful than each of the systems by itself. That includes properties like storage of quantum states, ability to sense very small forces, fast gate times in quantum computational application and many more.

In our project we will take up the modeling and simulation aspect of some of the current hybrid system and focus on how to achieve information manipulation and distant information transfer using quantum dot spin qubits.

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**Topic #11**

Faculty Name: Bhaskaran Muralidharan

**Title of Project:** Nanomagnetics and spintronics

**Specialization:** Solid State Devices
Description: Magnetic RAM (MRAM) is a state-of the art non-volatile memory technology based on the electron spin that caters to low-power dissipation, non-volatility and stability. The aim of this project is to set up an advanced device simulation platform for some of the industry level devices that are currently under production. This is typically what is known in the industry as spin-transfer torque MRAM (STT-MRAM). Along with device models, we also expect to advance modular spintronics via circuit theory such that integrated functionalities may be realized.

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**Topic #12**

Faculty Name: Bhaskaran Muralidharan

Title of Project: **Fast gate pulse designs in nanowire networks for realizing topological qubit logic**

Specialization: Solid State Devices

Description: The field of topological quantum information is expected to overcome the obstacles of traditional quantum computing. An important engineering aspect of the same is the hardware realisation using nanowire networks. This project deals with the simulation aspects of designing effective nanowire networks that can perform topological quantum computing logic gates.

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**Topic #13**

Faculty Name: Pradeep R. Nair

Title of Project: **High efficiency low cost Solar cells**

Specialization: Solid State Devices

Description: Novel Photovoltaic concepts like organic-inorganic metal halide perovskites and Silicon based heterojunction solar cells have emerged as low cost and high efficiency alternatives to c-Si technology. However, given the promises, several important system level concerns needs to be addressed for this emerging technology to become a mature technology â€“ with issues ranging from the fundamental operating mechanism of the device, performance optimization pathways, and degradation mechanisms which contribute to device failure. Here, we aim to address these system level concerns through predictive modeling with detailed numerical simulations. Close collaboration with other experimental groups could be a key feature of this research. Related information can be found at [https://www.ee.iitb.ac.in/wiki/faculty/prnair](https://www.ee.iitb.ac.in/wiki/faculty/prnair)
**Topic #14**

Faculty Name: Dipankar Saha

Title of Project: **Few Electron and Photon Quantum Devices**

Specialization: Solid State Devices

Description: The work will involve quantum devices involving electrons and photons for improved performance in future applications. The work involve a balance of both experimental and theoretical works. The student should be hardworking and willing to learn new things.

**Topic #15**

Faculty Name: Dipankar Saha

Title of Project: **GaN based nanowire transistors**

Specialization: Solid State Devices

Description: This work will involve various properties of Gallium Nitride based nanowire transistors. Some of the properties include quantum transport, quantum capacitance, and sub-band resolved phenomena.

**Topic #16**

Faculty Name: Kasturi Saha

Title of Project: **Precision magnetic field sensing using wide-field microscopy with wide-bandgap semiconductors**

Specialization: Solid State Devices

Description: Tremendous research activity worldwide is focused to develop engineered quantum systems for precision magnetic field sensing. In our group, we use wide-bandgap semiconductors such as diamond and SiC with atomic defects that work as ultra-precise sensors for magnetic field. In this project, we will use an ensemble of such sensors to build a wide-field microscope for magnetic field sensing of 2D-magnetic thin films and superconductors. The project will involve simulations, setting up experimental setups, fabrication of microcoils for RF and MW, optical characterization and experimentation, analysis and comparison with theoretical models.
**Topic #17**

Faculty Name: Kasturi Saha

Title of Project: **Optical and spin properties of color defects coupled to photonic devices for quantum computation**

Specialization: Solid State Devices

Description: Atomic defects in wide bandgap semiconductors such as SiC, and diamond have shown great promise as solid state qubits for quantum computing. We wish to investigate the optical properties and spin coherence properties of such defects with applications to quantum computation and communication. The project will involve simulation and design using Comsol, Lumerical. Fabrication in the IITBNF and characterization using home built microscopy setup.

**Topic #18**

Faculty Name: Prof Maryam Shojaei

Title of Project: **Design and development of MEMS based photoacoustic sensor & system for the environmental monitoring**

Specialization: Solid State Devices

Description: The objective of this project is to design, fabricate and characterize sensitive MEMS photoacoustic gas detectors for photoacoustic spectroscopy (PAS) aimed for the environmental monitoring applications.

**Topic #19**

Faculty Name: Siddharth Tallur

Title of Project: **Bulk acoustic wave (BAW) resonator based gyroscopes**

Specialization: Electronic Systems; Solid State Devices

Description: Nature of work: Experimental (control electronics design and characterization). BAW gyroscopes have been the hot topic in MEMS gyroscope research around the globe in the past decade (notable groups include Ayazi at Georgiatech, Najafi at UMich, Kenny at Stanford, Shkel at UC Irvine), but only one unsuccessful attempt to commercialize the technology was made (by Qualtre Inc., now part of Panasonic Corp.) There are several technical challenges pertaining to resonator design and fabrication and control electronics, that remain open problems.
in this area. Many of the problems are limited by fabrication technology, which continues to improve with time, calling upon innovations at the electronic design level. This project will involve working on one of more of these aspects together with other students, in a group that is passionate about solving these issues. This project may involve collaboration with a research group in Taiwan and a commercial foundry for interested candidates.

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**Topic #20**

Faculty Name: Prof. Shalabh Gupta

Title of Project: *Signal Processing Techniques in CMOS and Silicon Photonic Integrated Circuits for High-Speed Optical Fiber Interconnects.*

Specialization: Communications and Signal Processing; Electronic Systems; Solid State Devices

Description: The project aims to develop signal processing techniques for very high data rate short reach optical interconnects. The project also aims at developing state-of-the-art high-speed CMOS integrated circuits and silicon photonic integrated circuits for such interconnects. Prior knowledge of optical communications (or fiber optics) is not required. Interested candidates should interested either in communications signal processing or in CMOS IC design/silicon photonic IC design (along with interest in working with the high-end equipment available in the lab).

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List of RA Topics

Project Investigator: Prof. Sandeep Anand

Title of the project: **Solar Inverter using Wide Band Gap (WBG) devices**

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

*Abstract of the project:*

The electricity demand of nations around the world is rapidly increasing, fuelled by the sharp proliferation of electric vehicle, renewable energy integration, data centers, and consumer electronics industries. Power electronics converters play a very important role in the above industries. The ever-increasing demand for better efficiency, reliability, and compactness has made the requirement of innovation in the area of power electronics a need of the hour. The wide band gap (WBG) devices are a new disruptive technology which would drastically change the power electronic industry. This proposal aims to develop power electronic converters, specifically solar inverter using WBG devices such as GaN and SiC.

Project Investigator: Prof. Kishore Chatterjee, Prof. Sandeep Anand

Title of the project: **Electric vehicles and fast chargers**

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

*Abstract of the project:*

This project aims to develop power electronic converters and machines, specifically for electric vehicles applications.

Project Investigator: Prof. Kasturi Saha

Title of the project: **Quantum computing and sensing with color defects in diamond**

Desired specialization: EE 7 (Solid State Devices)

*Abstract of the project:*

This project is related to the development of single photon sources. Further the work will involve control of spin and photonics qubits and demonstration of quantum computing and sensing protocols.

Project Investigator: Prof. Siddharth Tallur

Title of the project: **Development of novel ultrasonic guided wave transducers for structural health monitoring**

Desired specialization: EE 1 (Communication & Signal Processing), EE 5 (Electronic Systems), EE 6 (Integrated Circuit & Systems), EE 7 (Solid State Devices)
Abstract of the project:

We are looking for a motivated and dynamic team member who can develop novel ultrasonic guided wave transducer and interface system for structural health monitoring. The project deals with understanding wave propagation mechanism and physics of damage-induced scattering, dispersion and attenuation of the acoustic waves, and development of embedded systems for transducer interfacing and damage index computation (signal processing). As a stretch goal, the Ph.D. candidate will also explore fabrication of flexible piezoelectric transducers that can be reused and attached on-demand for structural health monitoring.

Project Investigator: Prof. Virendra Singh

Title of the project: AI Powered adaptive cyber defence framework & solution for national CII

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

Abstract of the project:

With sophisticated cyber-attacks all over the world, it is clear that the attackers are well-funded through organized crimes, nation–support, etc. Thus, it has become important to address cyber threat intelligence to prevent some of the ulterior motives of the attackers to use attacks as weapons, in particular, when most of the public infrastructures are driven by sophisticated IT systems and further with the policy of building several smart-cities to address various societal issues. The latter naturally will lead to growth of Internet of Things (IoT), which in turn will increase the attack surface of the underlying infrastructure due to their vulnerabilities, malware susceptibility, and an emergence of denial-of-service (DoS) attacks will be acutely felt.

Primary purpose is to build a scalable system with proactive sensing of cyber-physical systems using data from physical sensors and integrated from other relevant resources, combined via a broad-based intrusion alert system and architecture, adaptable/tunable for a spectrum of applications like, attack predictions in the context of vulnerabilities, security alerts in IoT/SCADA, insider attack correlations etc. To realize properties of speed and accuracy using intelligence from a spectrum of resources, use cognitive security solutions using AI/Deep Learning Systems. This project also envisage the development of techniques of privacy-preserving merging/integrating different datasets and privacy preservation training.

Project Investigator: Prof. Virendra Singh

Title of the project: Architecting Intelligent Dependable Cyber Physical System Tageting IoT and Mobile Big Data Analysis

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

Abstract of the project:

Today, Cyber Physical Systems (CPS) are touching upon day to day life. Development of CPS includes hardware-software co-systems as well as some kinds of mechanical or physical systems, and are used in many places of social systems, such as automobiles, power plants, air control systems, and others. When CPS is modelled, there are logic parts, where computer systems are mostly in charge of, and physical parts, where mostly differential equations are used for modelling. IoT and even big data processing can be modeled as CPS, as now they have both
cyber (logic) parts as well as physical parts in order to manage huge data from various sensors and other peripherals. We develop unified and open design environments for designing, programming, verifying, testing, and diagnosing CPS. The key technical issues are: (a) CPS architectures for IoT and mobile big data analysis with ultra-low power systems based on non-volatile memory and MEMS, (b) Neural inspired flexible and deep learning architected in CPS, (c) Formal analysis of CPS, (d) Dependable systems based on analyzability guided design, (5) New programming paradigm based on non-volatile memory and sophisticated supports for MEMS.

Project Investigator: Prof. Jayakrishnan Nair, Prof. Nikhil Karamchandani

Title of the project: Constrained Online Learning

Desired specialization: EE 1 (Communication & Signal Processing), EE 2 (Control & Computing)

Abstract of the project:

Online learning algorithms, including bandit algorithms and reinforcement learning algorithms, have attracted considerable attention in the research community as well as the industry over the past few years. The setting of online learning algorithms is that of a learning agent (a.k.a., algorithm) interacting with an initially unknown environment by playing certain actions sequentially across time, making observations that are triggered by these actions, and collecting rewards, seeking to optimize a prescribed objective. The goal of this project is to analyse several generalizations of the classical online learning settings, where there are additional, practically motivated constraints on the actions, observations, and/or objective. These constraints might manifest themselves as restricted precision in choosing actions, noisy/quantized observations, or additional criterion in the definition of the objective.

Project Investigator: Prof. Maryam Shojaei

Title of the project: Nanoelectronics Network for Research and Application (NNetRA)

Desired specialization: EE 5 (Electronic Systems)

Abstract of the project:

The objective of this project, which is a part of NNetRA, is to design, develop, test and deploy the specific sensor-systems for remote management of resource-limited agriculture fields for enhancing the productivity.

Project Investigator: Prof. Jayanta Mukherjee

Title of the project: Power Amplifier design for 5G applications

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

Abstract of the project:

5G standard has brought new challenges in hardware design and the power amplifier forms an integral part of such design. High PAPR requirement, linearity and efficiency are some of the
conflicting factors. In this scenario, novel design methodologies especially using GaN technology are needed. The student will get the support of experts in industry and academics from North America.