Syllabus for B.Sc. Engineering Honours Degree Programme

Electronic and Telecommunication Engineering Specialization

Department of Electronic and Telecommunication Engineering,
University of Moratuwa

(Effective from Intake 2020)

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Semester 2

EN1014: Electronic Engineering

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
2	EN1014	Electronic Engineering		C	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
3	2	4	None	40	60

Learning Outcomes

1. Explain functional blocks and elements of an electronic system.
2. Explain simple systems using block level integration.
3. Analyse the op-amp circuits and their performances using the ideal op-amp model.
4. Comprehend diode and transistor datasheets.
5. Design diode application circuits.
6. Analyse simple transistor amplifier circuits.
7. Design simple combinational and sequential logic circuits.

Syllabus Outline

1. Introduction to Basic Electronic Devices

Lumped element abstraction of basic components such as R, L, C, diode, BJT, FET, and op-amp.

2. System Level Introduction

A simple audio system and its building blocks. Lumped abstraction and functional description of the building blocks: input signal generating circuit, pre-amplifier, DC power supply, power amplifier, filters, and equalizers.

3. Ideal Op-amp Circuits

Ideal op-amps, concept of negative feedback, inverting amplifier, noninverting amplifier, summing amplifier, integrator, differentiator, peak detector, negative impedance circuit, logarithmic and anti-logarithmic (exponential) amplifiers.

4. Diodes and Diode Applications

Diode characteristics, diode models, rectifiers and smoothing, clipping circuits, clamping circuits, Zener diodes and voltage regulation, DC power supplies using diodes, source switching and protection circuits using diodes, voltage multipliers, light emitters and light sensors, Schottky diodes.

5. Transistors and Simple Transistor Amplifiers

Device structures of Bipolar Junction Transistor (BJT), Junction Field Effect Transistor (JFET) and its characteristics, simple biasing methods (fixed bias and source bias), analysis of DC load line, amplifier gain calculations.

6. Simple Combinational and Sequential Logic Circuits

Boolean algebra, Karnaugh maps, half adder, full adder, ripple-carry adder, multipliers, comparators, multiplexers and demultiplexers, encoders and decoders, latches and flip-flops, Mealy and Moor machines, sequence detectors.

EN1054: Introduction to Telecommunications Engineering

Intake	2020 onwards	**Specialisation**	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
2	EN1054	Introduction to Telecommunications Engineering		C	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
3	2	4	None	50	50

Learning Outcomes

1. Recognize the functional blocks in a telecommunication system.
2. Discuss the analytical framework for representation and analysis of the functional blocks.
3. Identify the protocol stack as a model for implementing the functional blocks of communications systems.
4. Identify the functional requirements and behaviour of communications networks, and how they are facilitated via the protocol layers.
5. Recognize the historical evolution of telecommunications, the industry environment, and future trends

Syllabus Outline

1. Introduction
Building blocks of a point-to-point communication link and their functions. Extension to communication networks, their requirements, capabilities, and applications.

2. Signals
Introduction to signal sources, analog and digital signals, deterministic and random signals. Introduction to source encoding. Pulse Code Modulation, the ASCII code. Probabilistic concepts in source coding, with Morse code, Huffman coding as illustrative examples.

3. Frequency Domain Concepts
Introduction to Fourier analysis of deterministic signals, trigonometric and complex exponential representations. Signal power and bandwidth.

4. The Communication Channel
Physical media including radio spectrum and its usage, classification of channels, channel bandwidth. Distortion and attenuation. Introduction to AWGN and its effect on signals. S/N ratio and channel capacity. Introduction to link budget calculations.

5. Baseband Digital Transmission
Two-level and multilevel baseband signals. Qualitative evaluation of the impact of channel impairments on baseband signals, occurrence of errors. Introduction to error control.

6. Modulation

Need for modulation. Overview of analog and digital modulation techniques. Introduction to ASK, FSK, PSK, and their constellations. Qualitative evaluation of bandwidth and the effect of noise. Introduction to multiplexing.

7. Communication Protocols
Introduction to the layered communication protocol stack. Mapping of the functional blocks of a point-to-point link to the layered protocol stack. OSI and the TCP-IP models.

8. Introduction to Communication Networks
Broadcast and switched networks. Circuit and packet switching. Topologies with examples from different types of networks. Need to handle multiple users and the resulting requirements (medium access, congestion and flow control, addressing, routing) and mapping to the protocol stack. Introduction to network traffic concepts.

9. Medium Access
FDMA and TDMA as deterministic and ALOHA and CSMA as random-access techniques. Comparisons and extensions. Examples of applications. Mapping to the protocol stack.

10. Networks in Real Life
Core and access networks. Wired vs. wireless, fixed vs. mobile, wide-area, local-area, body-area networks. Network devices and their use. Examples and applications (e.g., voice over fixed/mobile networks, web access, email, health/fitness applications). Roles of the transport and application layers.

11. Industry
Historical milestones, current status and future trends of the telecommunications industry, the regulatory environment.

EN1020: Circuits, Signals, and Systems

Intake	2020 onwards	**Specialisation**	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
2	EN1020	Circuits, Signals, and Systems		C	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	40	60

Learning Outcomes

1. Explain the fundamental tools in electrical circuit analysis.
2. Apply network theorems in analysing electrical circuits.
3. Differentiate between continuous-time, discrete-time and digital signals, and techniques applicable to the analysis of each type.
4. Use Fourier series techniques to understand frequency domain characteristics of signals.
5. Apply appropriate theoretical principles to characterize the behaviour of Linear Time Invariant (LTI) systems.

Syllabus Outline

1. Circuit Theory
Circuit vs. wavelength, circuit as a graph/network. Charge, current, voltage, power, and energy. units of measurement. LTI resistor, capacitor, and inductor. KCL and KVL. Ideal current and voltage sources,

dependent sources, device modelling, RLC transient solutions using differential equations, concepts of transients vs. steady state. Resonance, mutual inductance, electromagnetic coupling, and analysis. Transformer as a coupled element.

2. Circuit Analysis Using Network Theorems
Ground as a node, nodal analysis, Y matrix, node voltage and stimulus vector, super nodes, mesh analysis. Network theorems: superposition, Thevenin's, Norton's, Millman's. Source transformation and network equivalence, source transportation, substitution theorem, maximum power transfer, Y-Δ transformation. Two-port theory: impedance, admittance, hybrid, and ABCD parameters.

3. Introduction to Signals and Systems
Classification of signals as continuous-time, discrete-time and digital. Introduction to impulse and step functions. Introduction to systems and input-output relationships. Simple classes of signals such as sinusoid and exponential signals. Characterizing Linear Time-Invariant (LTI) systems. Overview of the analysis techniques applicable to each type of signal/system and their interrelationships.

4. Linear Time-Invariant (LTI) Systems
Characteristics of LTI systems. Characterizing the input-output relationship of continuous- and discrete-time LTI systems in the time domain. The convolution theorem and its application to LTI systems. RLC circuit an LTI system.

5. Fourier Series
Overview of Fourier analysis as the representation of signals with complex sinusoids. The Fourier series representation of periodic signals. Properties of the Fourier series. Characterizing LTI systems in the frequency domain.

EN1094: Laboratory Practice

Intake	2020 onwards	**Specialisation**	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
2	EN1094	Laboratory Practice		C	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
-	4	2	None	100	-

Learning Outcomes

1. Use laboratory instruments and simulation tools effectively for the study of basic electronics and telecommunications.
2. Apply experimental and simulation techniques to understand the core phenomena and concepts in analog and digital electronics.
3. Apply experimental and simulation techniques to understand the core phenomena and concepts in telecommunications.
4. Apply time domain and frequency domain analysis tools to simulate and analyse signals and Linear Time Invariant (LTI) systems.
5. Apply network theorems to simulate and analyse electronic circuits.
6. Design, construct, test, and demonstrate a given project and present the work orally and as a written report in small groups.

Syllabus Outline
1. Orientation to the Use of Laboratory Instruments and Simulation Tools DC power supply, oscilloscope, spectrum analyser, multimeter, breadboard, signal generator, software simulation tools. **2. Electronic Engineering Concepts** 1. Building a simple audio system using its building blocks. 2. Building and taking measurements of op-amp circuits in order to identify applications of op-amps. 3. Construction of a simple Zener-regulated DC power supply. 4. Building and taking measurements on a simple BJT amplifier. 5. Constructing combinational logic circuits: half adder, full adder, encoder, multiplexer. 6. Designing a sequence detector using sequential logic circuit. **3. Introduction to Telecommunication Engineering Concepts** 1. Observing communication channel characteristics and effects of noise. 2. Simulating and studying the baseband transmission. 3. Introducing and simulating AM and FM schemes using simulation tools and hardware platforms. 4. Implementing digital modulation schemes using simulation tools and hardware platforms. 5. Building and testing a point-to-point communication system. 6. Studying a simple communication network using a network simulation tool. **4. Circuits, Signals and Systems Concepts** 1. Numerically analysing the properties of continuous-time and discrete-time signals in the time domain. 2. Simulating and analysing the properties of continuous-time and discrete-time signals in the frequency domain 3. Numerically analysing and observing the properties of LTI systems, such as impulse response, step response, convolution, and frequency response. 4. Implementing RLC circuits to understand the transient response. 5. Implementing circuits and taking measurements that demonstrate the concepts of Thevenin equivalents and superposition. 6. Calculating the y parameters of single and cascaded networks using resistive two-port networks. **5. Group Design Project in Digital Electronics**

EN1971: Communication Skills

Intake	2020 onwards	**Specialisation**	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
2	EN1971	Communication Skills		C	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
1	2	2	None	100	-

Learning Outcomes
1. Make a short public speech confidently. **2.** Write clearly and concisely to convey meaning. **3.** Communicate professionally in writing. **4.** Communicate effectively via electronic forms.

Syllabus Outline
1. Public Speaking Fundamentals Effective speech writing comprising an opening, a body, and a conclusion. Vocal variety and body language. Effectively using visual aids and providing evidence. **2. Writing on a General Topic**

Writing a synopsis, a critique, and an abstract. **3. Communicating in a Professional Setting** Communicating politely. Writing a personal mission statement, curriculum vitae, facing an interview effectively, conducting a meeting, writing letters in a professional setting. **4. Communicating Online** Conducting a meeting online, communicating through videos and other forms of popular electronic communication.

EN1190: Engineering Design Project

Intake	2020 onwards	**Specialisation**	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
2	EN1190	Engineering Design Project		C	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
1	4	3	None	100	-
Learning Outcomes					
1. Use modularity and abstraction in solving engineering problems. **2.** Explain basic engineering design principles. **3.** Use design tools for electronic product prototyping. **4.** Identify various manufacturing processes involved in electronic product manufacture. **5.** Design a product prototype to comply with given technical specifications. **6.** Analyse the performance and manufacturability of the developed prototype.					
Syllabus Outline					
1. Handling Complexity through Modularity and Abstraction Modularity and abstraction as the bases for handling complexity in engineering design. **2. Engineering Design Principles** Introduction to engineering design, life cycle of engineering products and processes, design processes and design tools, concurrent engineering, creativity and reasoning, analysis and synthesis, simulations, evaluation and decision making. **3. Basic Software Tools Needed for Electronic Design and Manufacture** Electronic circuit design software, simulation software, solid modelling software and thermal analysis software. **4. Product Dissection** Electronic product disassembly and identification of manufacturing processes. **5. PCB Manufacturing** Schematic design, layout design, design rules, photo-tool creation, drilling, plating, etching, solder masking. **6. Essential Processes in PCB Assembly** Component mounting: through-hole component forming, component insertion, surface mounting. Soldering methods: hand soldering, wave soldering, reflow soldering.					

7. Enclosures
Injection moulding, metal forming, metal punching.

8. Guided Design Project
a) Gathering of data and information from various sources as a preliminary step to the design. b) Preparing a work plan and delegating duties. c) Working with others and producing results by given deadlines and within given budgets. d) Learning the basic procedures required for conceptual, preliminary, and detailed designs. e) Learning the importance of the cost component in the manufacturing process. f) Learning the importance of considering the limitations of the manufacturing process during design. g) Preparing a report and making a presentation on the work done. h) Demonstrating the working of the prototype. i) Analysing the performance and manufacturability of the prototype.

Semester 3

EN2014: Electronic Circuits and Analysis

Intake	2020 onwards	**Specialisation**	Electronic and Telecommunication Engineering			
Semester	**Code**	**Module Title**			**C/E/O**	**GPA / NGPA**
3	EN2014	Electronic Circuits and Analysis			C	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**		**Evaluation %**	
Lecture	**Lab/Tutes**				**CA**	**WE**
3	0	3	None		40	60

Learning Outcomes

1. Explain the constraints and limitations of transistors.
2. Explain the limitations of op-amps.
3. Analyse the op-amp circuits and their performance.
4. Select a logic family to suit a given application.
5. Design and implement simple sequential circuits.

Syllabus Outline

1. DC Operation of Transistors
Characteristic curves, beta uncertainty and temperature effects in DC biasing. BJT and JFET biasing circuits that involve feedback. MOSFETs (structure, comparison, operation). Current mirrors, constant current source, Darlington pair, differential amplification.

2. Small Signal Analysis [10 hours]
AC load line, transistor configurations, mid-frequency equivalent circuit and analysis, high- and low-frequency equivalent circuits and analysis, Bode plots, multi-stage amplifiers.

3. Op-amp Analysis [5 hours]
Feedback analysis of op-amp circuit, inverting and non-inverting amplifiers (analysis with non-ideal op-amps), practical op-amp characteristics (gain-bandwidth product, slew rate, CMRR, offsets, voltage drifts, and corrections, power-supply rejection ratio). 2., 3.

4. Analog-to-Digital and Digital-to-Analog Converters [3 hours]
Digital-to-analog converters: R-2R ladder DAC, weighted-resistor DAC. Analog-to-digital converters: counter-type ADC, flash ADC converters, dual-slope (integrating) ADC, successive approximation (SAR) ADC. 3.

5. Logic Families [5 hours]
Saturated logic and unsaturated logic, output stages (active, passive, tri-state), propagation delay, fan-out and fan-in, noise margin and power, current trends. 4.

6. Sequential Circuits with Basic HDL (HDL in Verilog) [11 hours]
Latches, flipflops and HDL code. SR, JK, D and T flipflops. Edge triggering, master-slave flipflops. Designing finite state machines, Mealy and Moore machines, analysis of sequential circuits, counters (up/down/bi-directional), sequence detectors, applications of sequential circuits. 5.

EN2054: Communication Systems and Networks

Intake	2020 onwards	**Specialisation**	Electronic and Telecommunication Engineering			
Semester	**Code**	**Module Title**			**C/E/O**	**GPA / NGPA**
3	EN2054	Communication Systems and Networks			C	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**		**Evaluation %**	
Lecture	**Lab/Tutes**				**CA**	**WE**
3		3	None		50	50

Learning Outcomes

1. Explain analogue modulation techniques and their practical use.
2. Analyse the issues in sampling and reconstruction of waveforms.
3. Evaluate data link layer functions.
4. Demonstrate knowledge of practical use of data link layer functions in serial interfaces and standards.

Syllabus Outline

1. Analog Modulations
Amplitude Modulation (AM) and demodulation, derivatives of AM such as DSBSC and SSB. Angle modulation and demodulation, heterodyne and superheterodyne receivers, FM broadcasting system.

2. Sampling and Reconstruction of Signals
Sampling theorem, Ideal reconstruction, interpolation, practical issues in sampling and reconstruction, anti-aliasing filter, pulse code modulation.

3. Line coding Techniques
Need for line coding, line coding schemes such as RZ, NRZ, Bi-phase, Manchester, AMI, B8ZS and HDB-3. Illustrative examples of the use of line encoding in physical layer implementations from selected serial interfaces and standards.

4. Flow Control in the Data Link Layer
Need for the flow control, Stop-and-Wait method, sliding window method, delay, throughput, and line utilization.

5. Error Control in the Data Link Layer
Introduction to basic error detection and error correction techniques, forward error control, block codes, performance comparison between Stop-and-Wait ARQ, Go-back-N ARQ and Selective-Reject ARQ. High-Level Data Link Control (HDLC) protocol and its implementation in different networks.

6. Medium Access Techniques
Medium access mechanisms in the data link layer such as token-based, CSMA/CD and CSMA/CA. Examples of their implementation in different types of shared-medium networks.

7. Data Link Layer Switching
Need for switching in data link layer, data link layer addressing and framing, switching methodologies. Store-and-forward, cut-through and fragment-free, half-duplex and full-duplex switching, implementation of L2 switches.

8. Case Study
Case of Ethernet to illustrate the use of data link layer and physical layer functions. Performance improvement techniques used at high speeds.

EN2031: Fundamentals of Computer Organization and Design

Intake	2020 onwards	**Specialisation**	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
3	EN2031	Fundamentals of Computer Organization and Design		C	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	50	50

Learning Outcomes

1. Discuss functional blocks and performance metrics of a computer system.
2. Use integer and real number representations to perform arithmetic operations in the context of hardware constraints.
3. Analyse Instruction Set Architectures (ISA).
4. Design a 32-bit processor for a given ISA.
5. Design a memory hierarchy for a computer system.
6. Discuss the operating system as a resource manager.

Syllabus Outline

1. Building Blocks of a Computer System
Computer as a data processing system, functional blocks of a computer system, low- and high-speed peripherals, internal and external bus architectures.

2. Performance Metrics of a Computer System
Throughput, speed, response time, Amdhal law, quantitative principles of computer design.

3. Computer Arithmetic
Integer and real number representation: two's complement, IEEE754, arithmetic operations using twos complement, Booth Algorithm. Hardware implementation: ripple adder, carry look-ahead adder (CLA), carry save adder (CSA), binary multipliers, multiply-accumulator (MAC).

4. Instruction Set Architectures (Processor Architectures)
Von-Neumann model, Instruction Set Architecture (ISA), Flynn's taxonomy, evolution of ISA – CISC, RISC, VLIW, EPIC.

5. Processor Design
Micro-architectures: hardwired and microprogramming.

6. Memory
Principles of DRAM, SRAM and their construction, organization of memory, principle of cache memory and its design considerations, specification of memory, interfacing and performance issues.

7. Operating System
Processes and threads, memory management, virtual memory, scheduling, concurrency.

EN2063: Signals and Systems

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
3	EN2063	Signals and Systems		C	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
3		3		40	60

Learning Outcomes

1. Characterize signals and LTI systems in the frequency domain using the Fourier transform techniques.
2. Determine steady state and transient characteristics of a causal LTI system subject to a causal input signal using the Laplace transform techniques.
3. Analyse discrete-time LTI systems using the z-transform.
4. Evaluate digital processing of analog signals using physically realizable A/D and D/A conversions.
5. Design and analyse analog/digital filters, electrical circuits, and communication transmitters/receivers using the transform domain techniques.

Syllabus Outline

1. Continuous-Time Fourier Transform
Response of an LTI systems to a complex exponential, synthesis and analysis forms, finite energy signals and Fourier transform, uncertainty principle, properties of the Fourier transform. Frequency domain characterization of continuous time signals and LTI systems: log magnitude and Bode plots, filteration and nonideal analogue filters, applications in communication systems.

2. The Laplace Transform
The Laplace and inverse Laplace transforms, the region of convergence, poles and zeros, properties of the Laplace transform, transfer function, steady state and transient responses of a causal LTI system, stability, introduction to linear dynamical systems, applications in electrical circuit analysis.

3. Frequency Domain Analysis of Discrete-Time Signals [5 hours] Synthesis and analysis forms of discrete-time Fourier transform (DTFT), convergence, properties of the DTFT, theorems of the DTFT, Evaluation of the DTFT of finite-duration discrete-time signals using discrete Fourier transform (DFT).

4. The z-Transform [5 hours] The z- and inverse z-transforms, properties of the region of convergence, properties of the z-transform, representation of discrete-time LTI systems using the z-transform, stability of discrete-time LTI systems.

5. Digital Processing of Analog Signals [6 hours] Periodic sampling, representation of sampling in the frequency domain, Shannon-Nyquist theorem, aliasing, reconstruction, A/D conversion, quantization errors, D/A conversion.

6. FIR and IIR Filter Design [8 hours] Frequency-domain representation of LTI systems, magnitude response and phase response, filter specifications, classification of discrete-time filters and design methods, design of linear-phase FIR filters using windowing method, design of IIR filters using the impulse invariance and bilinear transform methods.

EN2091: Laboratory Practice and Projects

Intake	2020 onwards	**Specialisation**	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
3	EN2091	Laboratory Practice and Projects		C	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
-	4	2	None	100	0

Learning Outcomes

1. Evaluate the constraints and limitations of the transistors and op-amps.
2. Design and implement sequential circuits and digital circuit design using programmable ICs.
3. Construct fundamental building blocks of a computer.
4. Develop an understanding of programming in assembly language.
5. Design, appraise and analyse the knowledge of physical and datalink layer network planning and simulation.
6. Design and implement a simple communications network.
7. Design, construct, test, demonstrate a given project using analog components and present the work orally and as a written report, in small groups.

Syllabus Outline

1. Electronic Circuit Design and Analysis

1. BJT configurations, DC biasing, and analysis of small-signal amplifiers, frequency characterization.
2. Build and take measurements on op-amp circuits in order to identify frequency characteristics, gain-bandwidth product, offsets of op-amps.
3. Implementing a 3-bit up-down counter.
4. Implementing a sequential circuit to handle a simple real-life application (e.g., colour lights at an intersection).

2. Computer Organization

1. Use digital electronic simulator software to simulate the operations of basic adder circuits .
2. Use a 4-bit ALU to perform different binary arithmetic and logic operations
3. Identify and construct basic memory cells: SRAM and DRAM.
4. Implement basic programming constructs like conditional statements, control loops (for, while) in assembly language in x86 and micro-controller environments.

3. Communication Systems and Networks

1. Network Design and Operations: Design and build a simple Layer 2 (switched) networks utilizing the concepts explained. This will enable to see how star topology, aggregation, Spanning Tree protocol and VLANs are designed and operated using either Omnet++ or any other suitable simulation software.
2. Protocol Analysis: Inspecting packet flow using Wireshark network analysing software in different physical ports (Ethernet, Wi-Fi).

4. Analog Design Project

Design and implement an electronic circuit for a given or student-proposed application using analog components (e.g., analog line-following robot, battery charger).

EN2533: Robot Design and Competition

Intake	2020 onwards	**Specialisation**	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
3	EN2533	Robot Design and Competition		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
1	4	3	None	70	30

Learning Outcomes

1. Identify the composition of a basic robot system and explain the functionality of each component.
2. Select suitable sensors, actuators, mechanisms, and a power source for a simple robot design to perform a given task.
3. Design and build a small robot and its control system for the required functionality.
4. Tune, test and troubleshoot the robot to achieve best performance.
5. Demonstrate teamwork and collaborative efforts to achieve a common goal and complete a task in the given time frame.

Syllabus Outline

1. Introduction to Robotics

Evolution of robotic systems. Robot anatomy. Modular architecture. Robot system design. Multidisciplinary nature of robotics. Robotics applications.

2. Robot Mechanical Design

Basic mobile robot platforms: wheeled, tracks. Wheels. Steering systems: differential-drive, skid-steering, Ackermann steering. Mechanisms: translational and rotational mechanisms, gears, belts and chains, springs and dampers, suspension mechanisms for uneven terrain—rocker, rocker bogie. Computer Aided Design.

3. Robot Behaviour
Basic robot architectures: sense-plan-act (SPA) architecture, subsumption architecture. Microcontrollers. Fundamentals of microcontroller programming.

4. Robot Sensors
Sensor classification. Sensor characteristics. Operating principles of different robot sensors and interfacing with microcontrollers. Switch sensors. Opto-sensors: photoconductive, photovoltaics, photodiode, phototransistor. Encoders. Range sensing: ultrasonic, IR, laser range.

5. Robot Motion
Robot actuators. Operating principles and control techniques of brushed/brushless DC, stepper, and servo motors. Interfacing motors to microcontroller boards. Motor controllers. Robot arms and grippers. PID controller basics.

6. Robot Power
Robot battery types. Component voltage levels. Rechargeable batteries: NiMH, NiCd, LiPo, Li-ion, Lead Acid. Battery concepts: voltage, capacity, cell arrangement, discharge rate.

7. Robot Communication
Robot digital communication protocols and interfaces: universal asynchronous receiver transmitter (UART), serial peripheral interface (SPI), inter-integrated circuit (I2C).

8. Building Robots
Design and build a robot for a given competition task. Robot task planning. Working with microcontroller-based robot programming boards. Sensors and actuator integration. Programming control algorithms. Tuning controller gains. Troubleshooting sensors, motors and control algorithms.

EN2130: Communication Design Project

Intake	2020 onwards	**Specialisation**	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
3	EN2130	Communication Design Project		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
1	4	3	None	70	30

Learning Outcomes

1. Identify the requirements and limitations of a basic communication system.
2. Differentiate between different network architectures, topologies, and technologies.
3. Select a suitable communication technology to cater to a given simple application.
4. Select necessary components to build a simple communication system (wired/wireless) to solve a given problem.
5. Realize a simple communication system to enable successful end-to-end connectivity.

Syllabus Outline

1. Introduction
Elements of a communication system, reliability objectives, Error detection and correction coding, line coding, synchronization, simple digital modulation and demodulation methods, channels.

2. Network architectures and Topologies
Review of networks, layered architecture, protocols, and standards.

3. Introduction to Communication Hardware
Hardware components of a transmitter, receiver, chipsets, off-the-shelf components, antennas, interfaces and their usage, connectors, software defined radios.

4. Communication System Design Process
Link budgets, setting transmitter/receiver parameters, selecting a suitable technology.

5. Introduction to Design Tools
Introduction to simulation tools, simulation of simple networks, performance evaluation and obtaining insights, measurements and measuring equipment.

Semester 4

EN2111: Electronic Circuit Design

Intake	2020 onwards	**Specialisation**	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
4	EN2111	Electronic Circuit Design		C	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
3	2	4	None	40	60

Learning Outcomes

1. Analyse the core performances of analog modules.
2. Explain DC-DC power conversion.
3. Analyse feedback, thermal, and noise effects in electronic circuits.
4. Explain the basics of LNA.
5. Apply the RTL coding, verification, and timing concepts in digital designs.
6. Select and use programmable logic devices to implement digital systems.

Syllabus Outline

1. Analog Filters
First and second order filters, active and passive filters, filter categories, transfer functions, amplitude, and phase responses, bode plots, and filter approximations.

2. Feedback
Effect of negative feedback, feedback topologies, feedback properties, amplifier circuits with feedback, loading effects.

3. Oscillators
Wien bridge oscillator, relaxation oscillator, ring oscillator, astable, mono-stable, and bi-stable multi-vibrators.

4. Analog PLL, Linear Power Supplies
Basics of analog PLL, voltage regulators, and protection circuits.

5. Power Amplifiers
Class A, class B, class AB, class C, and class D amplifiers, DC-DC power conversion.

6. Thermal Management, Noise Analysis, Basics of LNA
Types of noise, thermal analysis, noise modeling, signal to noise ratio, noise temperature, noise figure, low noise amplifiers.

7. Coding and Verifications
RTL coding and verifications, timing analysis of digital circuits, critical path, operating speed, clock synchronization.

8. Programmable Devices
ROM, PALs and PLAs, PAL Macrocell, CPLD, FPGA, UART implementation in FPGA.

EN2074: Communication Systems Engineering

Intake	2020 onwards	**Specialisation**	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
4	EN2074	Communication Systems Engineering		C	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
3	2	4	None	40	60

Learning Outcomes

1. Identify discrete representation of continuous-time signals.
2. Apply fundamentals of probability theory for performance analysis of memoryless digital modulation techniques.
3. Design signals to control the effect of ISI in digital transmission over band-limited channels.
4. Design optimum receivers for digital transmission in AWGN channel.
5. Compare and contrast different memoryless digital modulation schemes based on their reliability, spectral and power efficiencies.
6. Evaluate the performance of a digital transmission system using simulation tools.

Syllabus Outline

1. Signal Representations for Communication Systems
Review of signals and digital transmission systems. Complex envelope representation of real band-pass signals and its energy relationships. Signal space representation.

2. Random Variables and Processes for Communication Systems
Review of a single RV and related operations (expected value, moments, central moments). Pairs of RVs: Joint distributions, conditional distributions, covariance and correlation. Multivariate Gaussian distribution. Introduction to random processes, statistical characterization and classification. Spectral characteristics. Random processes through LTI systems. Gaussian processes and AWGN. Capacity of the AWGN channel.

3. Baseband Digital Transmission Over Band-Limited Channels
Intersymbol interference (ISI), Nyquist's criterion, partial response signalling, data detection for controlled ISI. Eye diagrams. Applications to practical baseband systems.

4. Passband Digital Transmission
Linear digital modulation techniques: ASK, PSK, and QAM. Constellation diagrams. Nonlinear modulation techniques: FSK. Spectra of modulated signals, spectral and power efficiencies. Optimum receivers: MAP and ML principles, receiver implementation, matched filter and correlation realizations, error performance. Comparison of different modulation schemes. Applications to practical passband systems.

EN2143: Electronic Control Systems

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
4	EN2143	Electronic Control Systems		C	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	40	60

Learning Outcomes

1. Identify everyday life applications as well as historical apparatus where feedback control is used.
2. Model and analyse physical systems using laws of nature.
3. Design a feedback control system and analyse its performance in terms of transient response, steady-state error, and stability.
4. Implement an electronic controller for a given specification.

Syllabus Outline

1. Introduction to Control Systems Engineering
Applications of control systems in everyday life. Historical apparatus based on negative feedback mechanism (water clock, flyball governor). Open-loop vs. closed-loop control. Definitions: reference, controlled variable, feedback, plant, disturbance, performance (transient response, steady-state response and stability)

2. System Modelling
Mathematical modelling of dynamical systems: translational and rotational mechanical systems (Newton's laws), electrical systems (Kirchhoff's laws), electromechanical systems—DC motor systems with gears. System model ODE. Transformation to Laplace domain. Transfer function. Poles and zeros. Introduction to system reduction. Block diagrams—cascaded forms, parallel forms, feedback forms

3. Time Response
First-order systems: time constant, performance specifications, experimental transfer function. Second-order systems: overdamped, underdamped, undamped, critically damped systems. Damping ratio and natural undamped frequency. Transient specifications of underdamped systems: rise time, peak time, percent overshoot %, setting time.

4. Stability and Steady-State Errors
Introduction to stable (BIBO), unstable and marginally stable systems. Routh-Hurwitz criterion. Routh table. Stability design via Routh-Hurwitz criterion. Test inputs for steady-state error analysis and design. Steady-state error for unity feedback systems. Static error constants and system type. Steady-state error for non-unity feedback systems

5. Feedback Controller Design

Single feedback gain controller. Root locus—properties, sketching and refining. Control systems analysis and design by the root locus method. Pole location by gain tuning. PID controller design. Frequency response techniques: Bode plots, Nyquist stability criterion, gain and phase margin, Nichols chart, lead compensation, lag compensation, lag-lead compensation, notch filter design. Pole-zero cancellation. Controller simulation using software tools. Servo controller design for a given specification

6. Electronic Controller Implementation

Implementation of electronic controllers. OP-Amp implementation of analog controllers

EN2150: Communication Network Engineering

Intake	2020 onwards	**Specialisation**	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
4	EN2150	Communication Network Engineering		C	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	60	40

Learning Outcomes

1. Explain the operational performance measures in networks.
2. Explain key application layer protocols such as DNS, HTTP and SMTP and the importance of network security.
3. Design local area network (LAN) and WAN (as an extension to LAN) to meet given specifications.
4. Analyse routing protocols and algorithms.
5. Analyse transport layer protocols and algorithms.
6. Explain fundamental concepts in SDN.

Syllabus Outline

1. Operational Performance Measures in Networks

Propagation delay, latency, jitter, packet losses, throughput, convergence time, availability, path utilization, Quality of Service (QoS)/Quality of Experience (QoE).

2. Application Layer and Network Security

Domain Name Service (DNS), Simple Mail Transfer Protocol (SMTP), Hyper Text Transfer Protocol (HTTP) and others (DHCP, FTP, IMAP, POP). Introduction to network security: Transport Layer Security (TLS).

3. Design of Networks

Requirement analysis, network topologies for LAN and WANs, IP addressing for LAN, VLAN: virtual partitioning of networks, redundant links in network topologies (Spanning Tree Protocol – STP).

4. Routing Protocols and Algorithms in Intra- and Inter-networks

Introduction to routing, distance vector and link state protocols (RIP, OSPF, IS-IS), Border Gateway Protocol (BGP).

5. Transport Layer Protocols (End-to-End) and Algorithms

Connection-oriented and connection-less protocols. Multiplexing and demultiplexing, reliable and best effort, TCP, UDP, QUIC, flow control, congestion avoidance and control, queuing disciplines: FIFO and fair queuing.

6. Software Defined Networks (SDN)
Fundamental concepts: separation of control and data plane, layers of abstraction: specification, distribution and forwarding.

7. Introduction to Traffic Engineering
Fundamental concepts: queuing theory and network optimization.

EN2160: Electronic Design Realization

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
4	EN2160	Electronic Design Realization		C	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	EN1190	70	30

Learning Outcomes

1. Identify a suitable design model for a given problem.
2. Design testable PCBs complying with industry standards.
3. Explain testing methodologies used in electronic manufacturing.
4. Design product enclosures complying with industry standards.
5. Prepare proper documentation for electronic design.
6. Apply the knowledge gained to a commercial design project resulting in a working prototype.

Syllabus Outline

1. Design Models
User centred design, design driven innovation.

2. User Centred Design
Need analysis, conceptual design, detail design, design iterations.

3. Design Driven Innovation
Existing meaning, quiescent meaning, technology epiphany, design interpreters.

4. Circuit Design and Prototyping
Top-down/bottom-up approaches, schematic design, HDL design, simulation and verification, PCB prototyping.

5. Testing
Test coverage, boundary scanning, test vector generation, prototype testing and design verification, product testing and quality assurance.

6. Enclosure Design
Solid modelling and visualization, rapid prototyping, mould design, tool design.

7. Documentation
User manuals, maintenance manuals, QC manuals, design manuals.

8. Design Assignment

Group based commercial design project covering following aspects:

a) User need surveys/quiescent meaning,

b) PCBs meeting industry standards/norms,

c) Enclosures meeting industry standards/norms,

d) Design documentation.

Semester 5

EN3880: Engineer and Society

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
5	EN3880	Engineer and Society		C	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
1	4	3	None	100	-

Learning Outcomes

1. Explain the proper professional conduct as an engineer.
2. Interpret the role of an engineer as an agent in balancing interests.
3. Assess the basic health and safety aspects of a premise or product.
4. Assess the environmental impact of a product or a project.

Syllabus Outline

1. Introduction

Social motivation for law and ethics, basic definition of law, morality, conscience and ethics, holistic view of engineering in terms of balancing the interests of the client, society and the environment.

2. Legal Fundamentals

Types of law, sources of law, interpretation of laws, natural justice and due process of the law, evidence, relevant laws in engineering (industrial relations, commercial law, contract law, intellectual property laws), regulations, legal remedies, jurisprudence for good policy making.

3. Ethics

Types of ethics based upon formulation and application, ethics in academic, professional, and engineering environments, conflicts of interest, role conflicts, misconduct, ethics of experimentation (e.g., clearance requirement, informed consent).

4. Health and Safety in Engineering

Ethical and legal background, occupational safety, product safety, negligence, case studies.

5. The Environment

Human ecology theory, environmental impact assessment, principles of environmental law and ethics in engineering (sustainable development, precautionary principle, prevention principle, polluter-pays principle, inter-generation equity, greenwashing).

EN3580: Electromagnetics

Intake	2020 onwards	**Specialisation**	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
5	EN3580	Electromagnetics		C	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
3	2	4	None	50	50

Learning Outcomes

1. Explain concepts of static electric and magnetic fields in material including the ability to deal with boundary condition.
2. Apply appropriate techniques to calculate the capacitance and inductance for simple geometrical structures, transmission lines, and waveguide geometries.
3. Apply Maxwell's equations to electromagnetic wave propagation in free space, dielectric media, conducting media and waveguides.
4. Apply concepts of electromagnetics to antennas.

Syllabus Outline

1. Static Electric and Magnetic Fields
Poisson's and Laplace's equations and their applications. Integral and differential forms of Gauss's and Ampere's law applied to static electric and magnetic fields. Capacitance and inductance of twin lines and coaxial lines, boundary conditions, effect of earth on transmission line properties.

2. Dynamic Fields
Faraday's law, Maxwell's equations, and their application in the real world.

3. Plane Wave Propagation
Concepts of electromagnetic wave propagation, uniform plane wave propagation in a dielectric and conducting media, intrinsic impedance of a medium, phase velocity, group velocity, propagation constant, Poynting's theorem, skin depth, boundary conditions, reflection and transmission coefficients of electromagnetic waves at normal incidence, oblique incidence, Brewster angle, critical angle, polarization.

4. Transmission Lines
Distributed component model, characteristic impedance, propagation characteristics, reflection, voltage standing waves, Smith chart and impedance matching.

5. Antennas
Radiation fields of elemental dipoles, antenna patterns, and antenna parameters.

EN3551: Digital Signal Processing

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
5	EN3551	Digital Signal Processing		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	40	60

Learning Outcomes

1. Determine the discrete Fourier transform (DFT) of finite-duration discrete-time signals using fast Fourier transform (FFT) algorithms.
2. Apply discrete cosine transform (DCT) for data compression.
3. Analyse discrete-time linear time-invariant (LTI) systems in transform domains.
4. Realize discrete-time LTI systems using basic structures.
5. Implement discrete-time LTI systems using suitable structures by evaluating finite-precision numerical effects.

Syllabus Outline

1. Discrete Fourier Transform and Fast Fourier Transform Algorithms
Review of discrete Fourier series. Definitions of the DFT and IDFT., properties of the DFT, linear convolution using the DFT, direct computation of the DFT, radix-2 FFT algorithms. Application of the DFT to estimate frequencies of sinusoidal signals and orthogonal frequency division multiplexing (OFDM).

2. Discrete Cosine Transform
Definitions of the DCT, relationship between the DFT and the DCT, energy compaction property, overview of approximate DCT algorithms, applications of the DCT in data compression.

3. Transform Analysis of Discrete-Time LTI Systems
Frequency response for rational transfer functions. Relationship between magnitude and phase responses. All-pass systems, minimum-phase systems, properties of all-pass and minimum-phase systems, minimum-phase all-pass decomposition.

4. Structures for Discrete-Time Systems
Block diagram representation of discrete-time LTI systems, signal flow graph representation, basic structures for discrete-time LTI systems: direct forms, cascade form, parallel form, transposed forms.

5. Finite-Precision Numerical Effects
Review of number representations, quantization in digital filters, the effects of coefficient quantization, effects of round-off noise, zero-input limit cycles in IIR digital filters.

EN3013: Analog Circuit Design

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
5	EN3013	Analog Circuit Design		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	50	50

Learning Outcomes

1. Design and analyse oscillators, current source, and VCO.
2. Design and analyse analog mixers and phase locked-loops.
3. Design linear power supplies with current limiting.
4. Analyse low noise amplifier.
5. Explain the parasitic effects in layouts.

Syllabus Outline

1. Oscillator Circuits
Wien bridge oscillator design, design concerns, component tolerance, frequency of oscillation, applications, ring oscillator design, characterization, limitations, circuit simulations.

2. Current Source
Principles, voltage controlled current source, circuit design, simulations, and applications.

3. Analog Mixers
Operating principles, approximations, phase detector.

4. Phase Locked Loop
Operating principles, PLL classifications, theory of linear PLL, theory of digital PLL, PLL circuit design, frequency synthesis.

5. Linear Power Supplies
Regulations, stabilization, adjustable outputs, and protection circuits.

6. Low Noise Amplifiers
Equivalent noise generators, LNA topologies, noise analysis.

7. Parasitic Effects in Layouts
Crosstalk, mutual inductance effect, signal integrity issues and fixes, frequency limitations, IC layout and PCB layouts.

EN3021: Digital Systems Design

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
5	EN3021	Digital Systems Design		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	50	50

Learning Outcomes

1. Implement combinational and sequential systems using the RTL based approach.
2. Utilize analysis and verification tools for digital circuits.
3. Design and implement a custom processor.
4. Design and analyse asynchronous sequential circuits.

Syllabus Outline

1. Introduction to Reconfigurable Computing
Introduction to reconfigurable computing, use of HDL packages.

2. RTL Design, Implementation, and Verification
Combinational and sequential system design using RTL based approach and its HDL implementation, introduction to functional and logic verification.

3. Timing Analysis
Determination of operating speed of digital systems (longest delay path), different delay types, clock synchronization issues.

4. Processor Design and Implementation
Instruction set architecture, microinstructions, state diagrams, data path and controllers, memory interfacing, memory design.

5. Asynchronous Sequential System Design
Introduction to asynchronous sequential systems, race conditions, stability issues, state reductions.

EN3533: Electronic Instrumentation

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
5	EN3533	Electronic Instrumentation		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	EN2014	50	50

Learning Outcomes

1. Explain the concepts and properties of measurements and electronic measuring instruments.
2. Choose transducers for a given application and select the relevant method of interfacing and digitizing.
3. Apply signal conditioning methods to improve the quality of measurements.
4. Explain noise and interference on measurements and minimization techniques.

Syllabus Outline

1. Characteristics of Measurement Systems
Static and dynamic characteristics, types of errors and estimation of errors, measures for improving electronic systems.

2. Measurement Concepts of Instruments
Voltmeters and ammeters, signal sources and function generators, oscilloscopes, electronic counters power supplies, spectrum and network analysers, logic analysers.

3. Transducers
Characteristics and operating principles of transducers based optical, mechanical, thermal, magnetic, and chemical energy.

4. Review of Noise and Interference in Instrumentation System
Noise in instrumentation systems, interference sources, effects of ground loops, observing noise and interference effects from measuring instruments.

5. Signal Conditioning
Guarding and shielding, null deflection methods, amplification/attenuation, offset correction, filtering, linearizing and isolation. Selection considerations of op amps, use of low noise and low drift series op amps for sensitive measurements. Key considerations: integration, connectivity, expandability, isolation, bandwidth, configuration, and calibration.

6. Schematic and PCB Design Practices for Instrumentation Systems
Schematic design practices, PCB stack, mounting holes, design rules and design rule checking, ground planes and PCB design practices.

7. Display of Measurements and Metrology
Human perception of information, testing, calibration, and standards.

EN3150: Pattern Recognition

<table>
<tr><th>Intake</th><td>2020 onwards</td><th>Specialisation</th><td colspan="3">Electronic and Telecommunication Engineering</td></tr>
<tr><th>Semester</th><th>Code</th><th colspan="2">Module Title</th><th>C/E/O</th><th>GPA / NGPA</th></tr>
<tr><td>5</td><td>EN3150</td><td colspan="2">Pattern Recognition</td><td>E</td><td>GPA</td></tr>
<tr><th colspan="2">Hours/Week</th><th rowspan="2">Credits</th><th rowspan="2">Prerequisites / Corequisites</th><th colspan="2">Evaluation %</th></tr>
<tr><th>Lecture</th><th>Lab/Tutes</th><th>CA</th><th>WE</th></tr>
<tr><td>2</td><td>2</td><td>3</td><td>None</td><td>70</td><td>30</td></tr>
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Learning Outcomes

1. Explain the process of learning from data and related challenges.
2. Characterize a wide class of pattern recognition/machine learning (ML) algorithms by the underlying mathematical structures and limitations.
3. Demonstrate the utility of pattern recognition/ML algorithms with the help of publicly available software libraries and data sets.
4. Implement different pattern recognition/ML algorithms in a range of practical applications.
5. Build a simple convolutional neural network to perform classification.

Syllabus Outline

1. Introduction

Learning from data and related challenges, supervised vs unsupervised learning, model selection and bias-variance trade-off.

2. Linear Models for Regression

Linear regression models and least squares, subset selection, regularized linear models (e.g., Ridge, LASSO), prediction and related confidence intervals.

3. Classification

Linear models of classification, discriminant functions, generative models, probabilistic discriminative models, optimal separating hyperplanes and SVM.

4. Kernel Methods

Feature maps, representer theorem, kernels and kernel trick, kernel density estimation.

5. Additive Models and Mixtures

Tree based methods, boosting, ensemble methods, mixture of Gaussians, EM algorithm.

6. Unsupervised Learning Techniques

Cluster analysis, principal components analysis, independent component analysis, multidimensional scaling.

7. Deep Neural Networks

Introduction to neural networks (NN) and backpropagation, architecture of convolutional neural networks, implementing NN using frameworks, training neural networks and performance analysis.

EN3160: Image Processing and Machine Vision

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
5	EN3160	Image Processing and Machine Vision		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	40	60

Learning Outcomes

1. Apply image processing algorithms for image enhancement.
2. Apply classic vision techniques in feature detection and applications.
3. Apply machine vision algorithms for classification and detection.
4. Design machine vision solutions for common industry problems.

Syllabus Outline

1. Introduction and Digital Representation of Images
Grayscale digital image as a 2-D array of numbers, representation of colour images, concepts of resolution and DPI, interpolation algorithms for image scaling.

2. Image Processing
Point operations, neighbourhood operations, image enhancement using point and neighbourhood operations, 2-D Fourier techniques to replicate spatial domain operations, morphological operations, introduction to image compression.

3. Features and Applications
Detection of edges, corners, and blobs. Fitting: least squares and total square line fitting. RANSAC. Hough lines. Alignment and image stitching.

4. Multi-View Geometry
Cameras, field of view, resolution mapping, minimum feature size, and camera calibration. Epipolar geometry, two-view stereo, structure from motion.

5. Image Segmentation
Thresholding, region growing, watershed segmentation. Mean-shift, k-means segmentation. Snakes, DP snakes, live-wire. Introduction to level-set and graph-cut segmentation.

6. Classification
Bag of visual words, deformable parts model. Simple convolutional neural networks for classification.

7. Object Detection
Classical face detection and eigen-face based face recognition. Classical detection of pedestrians and other objects. Object detection using convolutional neural networks.

EN3251: Internet of Things

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
5	EN3251	Internet of Things		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	A course in communications, and/or networking is preferable	100	-

Learning Outcomes

1. Compare and contrast the Internet, the Internet of Things (IoT), M2M systems and their envisioned future evolution.
2. Demonstrate understanding of the constraints and opportunities in the IoT and how electronics and communication technologies have evolved to overcome the constraints and exploit the opportunities.
3. Use standard application layer protocols for the IoT.
4. Select appropriate hardware platforms for devices and network technologies for connectivity for IoT applications.
5. Identify appropriate techniques and platforms for management of data in IoT systems.
6. Use appropriate devices, software and tools to implement an end-to-end IoT system.

Syllabus Outline

1. Introduction to the Internet of Things

Converting everyday objects to smart objects. The Things – Connect – Collect – Learn – Do paradigm. Typical IoT applications. Differentiating the Internet, IoT and M2M systems. A system view of IoT. IoT components, requirements and challenges. Roles of hardware and communication protocols in handling challenges. Enabling technologies.

2. The Internet for IoT

Overview of networking and protocols. The TCP/IP protocol stack with emphasis on the application and transport layers. Application-to-application interaction on the Internet. The REST architecture and web technologies. Adaptation of the TCP/IP protocol stack to the IoT. The Constrained Application Protocol (CoAP) and its usage in the IoT. The publish-subscribe architecture. Message Queuing Telemetry Protocol (MQTT) and its usage in the IoT.

3. Wireless Technologies for IoT

Wireless connectivity for IoT, network architectures for different applications. Wireless network standards and technologies for wide-area, local-area, body-area networks, mesh networks. Adaptation of wireless technologies to handle the challenges of IoT systems. Wireless technologies for IoT, characteristics, capabilities and applications.

4. IoT Devices

Typical IoT device architecture. Commercially available devices (e.g., sensor module and wireless MCU families for IoT), how they address the challenges of IoT, the communication technologies supported, characteristics and target applications.

5. Data Management in IoT

Tools and techniques for collecting data from IoT devices, for controlling IoT devices and for visualizing data in IoT systems.

6. IoT Case Studies
Application examples from a range of areas (selected from: consumer applications, industry and manufacturing, health, fitness and sports, energy, transportation and logistics, finance and marketing, agriculture and the environment, government, and military).

7. Future Trends
Trends leading to the Internet of Everything. Opportunities for IoT in Industry 4.0. IoT in 5G systems.

EN3250: Wireless Networks

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
5	EN3230	Wireless Networks		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	EN1054	50	50

Learning Outcomes

1. Identify the key challenges in wireless network design.
2. Articulate various types of wireless/cellular networks and their trends.
3. Analyse the throughput and delay performances of MAC and transport layer protocols in wireless networks.
4. Compare and contrast different wireless network standards and provide recommendations for practical applications.
5. Evaluate wireless network performance using simulations.

Syllabus Outline

1. Challenges for Wireless Communications
Challenges imposed on system design by the wireless channel, mobility, resource constraints, hardware limitations, user demands and regulatory aspects.

2. Protocol Design for Wireless Networks
How the above challenges are addressed in the design of MAC, network and transport layer protocols. Performance analysis: average throughput, average delay.

3. Wireless Local Area Networks
PHY and Data link layer designs of IEEE 802.11 and subsequent standards: Spread spectrum, OFDM, CSMA-CA, QoS provisioning, ARQ.

4. Cellular Systems
Cellular concept, frequency reuse, coverage and capacity planning, overview on cellular standards (1G to 5G)

5. Wireless Ad-hoc Networks
Introduction to ad-hoc networks and applications, issues in ad-hoc networks in comparison to conventional wireless networks, special design considerations in energy conservation, routing and operation.

6. New Trends in Wireless Network Design
New trends in wireless network design: device-to-device networks, massive machine type communications, cooperative relay networks, cognitive radio networks, internet-of-things, vehicular networks, Application scenarios and design challenges.

EN3563: Robotics

Intake	2020 onwards	**Specialisation**	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
5	EN3563	Robotics		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	EN2143 or an equivalent module related to control systems	50	50

Learning Outcomes

1. Identify and describe different types of robots and their applications.
2. Execute kinematic analysis of robot arms.
3. Plan a motion profile for a robot manipulator.
4. Apply control techniques to robot manipulation.
5. Discuss emerging and modern applications of robotics.

Syllabus Outline

Introduction to Robotics
The history and background of robotics. Numerous robotic systems and applications: robot arms, mobile robots—terrain, aerial, underwater, humanoid robots. Industrial robot manipulators: articulated, spherical, SCARA, cylindrical, Cartesian.

Spatial Descriptions and Orientation Representations
Rigid bodies. Spatial descriptors: position, orientation. Rotation matrix and direction cosine matrix. Composition of rotations. Notion of current and fixed frames. Similarity transformation. Parameterization of rotations: Euler angles, fixed angles, roll-pitch-yaw angles. Rigid motion. Homogeneous transformation. Composition of homogeneous transformations.

Forward and Inverse Kinematics
Kinematic chains. Denavit-Hartenberg (DH) parameters. Forward kinematics of robot manipulators using DH parameters: two-link planar manipulator, three-link cylindrical robot, spherical wrist. Inverse kinematics problem. Kinematic decoupling: inverse position, inverse orientation.

Velocity Kinematics
Linear and angular velocities. Derivative of a rotation matrix. Manipulator Jacobian. Singularities. Decoupling of singularities. Velocity mapping between joint and Cartesian spaces.

Motion Planning
Path vs. Trajectory. Motion planning in workspace. Motion planning in joint space. Polynomials: cubic, quintic polynomial trajectories. Problems with polynomial trajectory planning. Linear segments with parabolic blends (LSPB). Minimum time trajectories. Splines.

Manipulator Control
Joint space dynamics. Equations of motion. Joint motor selection. Encoder selection. Joint position control. Inverse Jacobian control. Stiffness and compliance. Force-position compliant control. Simulation and verification.

Advanced Robotic Systems
System design of advanced robotic systems: telesurgery robots, flying robots, telepresence robots, self-driving cars, humanoid robots and other emerging robot technologies.

Semester 6

EN3901: Seminar and Technical Presentations

Intake	2020 onwards	**Specialisation**	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
6	EN3901	Seminar and Technical Presentations		C	NGPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
1	2	2	None	100	0

Learning Outcomes

1. Explain five emerging research and development areas in electronic and telecommunication engineering.
2. Evaluate emerging research and development areas critically in technical, social, health, and cultural contexts.
3. Present a seminar on a technological topic for a technical audience.
4. Demonstrate skills of defending an argument, constructive criticism, and accepting feedback as part of the process of peer review.
5. Demonstrate project management, teamwork, and communication skills in oral and graphical presentation.

Syllabus Outline
1. Seminars on Emerging R&D Areas Invited seminars presented by faculty members and practicing engineers. **2. Aspects of a Good Presentation** Interest and knowledge, organization, visual aids, presentation skills, responding to questions. **3. Technical Presentations** 30 groups (each with 4 students), 20 min. presentation (each student 5 min.) + 10 min. Q&A session for each group.

EN3260: Industrial Electronics and Automation

Intake	2020 onwards	**Specialisation**	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
6	EN3260	Industrial Electronics and Automation		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	50	50

Learning Outcomes
1. Determine the feasibility of automation. 2. Realize a solution for an industrial automation problem using design thinking.

Syllabus Outline
1. Introduction Driving forces and technical, societal, regulatory, and economic feasibility of industrial automation. **2. Sensors and Actuators** Sensors, actuators (electric, hydraulic, and pneumatic), specifications for measurement and actuation, design of interfacing circuits, mechanical aspects. **3. Industry Communications** Noise reduction, reliability, industrial communication protocols, sampling methods (e.g., periodic, event based). **4. Controlling Techniques** Logical control, ladder diagrams, programmable logical controllers, SCADA, concurrent control, holistic design examples. **5. System Reliability and Protection** Failure modes, redundant design, maintenance planning, protection methods (e.g., surge protection, lightning protection).

EN3111: Introduction to Semiconductor Physics

<table>
<tr><th>Intake</th><th>2020 onwards</th><th>Specialisation</th><th colspan="4">Electronic and Telecommunication Engineering</th></tr>
<tr><th>Semester</th><th>Code</th><th colspan="3">Module Title</th><th>C/E/O</th><th>GPA / NGPA</th></tr>
<tr><td>6</td><td>EN3111</td><td colspan="3">Introduction to Semiconductor Physics</td><td>E</td><td>GPA</td></tr>
<tr><th colspan="2">Hours/Week</th><th rowspan="2">Credits</th><th rowspan="2" colspan="2">Prerequisites / Corequisites</th><th colspan="2">Evaluation %</th></tr>
<tr><th>Lecture</th><th>Lab/Tutes</th><th>CA</th><th>WE</th></tr>
<tr><td>3</td><td>2</td><td>4</td><td colspan="2">None</td><td>50</td><td>50</td></tr>
<tr><th colspan="7">Learning Outcomes</th></tr>
<tr><td colspan="7">1. Apply basic quantum theory to simple idealized models.
2. Use the Kronig-Penney model to analyse semiconductors in 1-D.
3. Use of band theory to explain the principles underlying the behaviour of semiconductors.
4. Explain the basic principles of operation of lasers and other optical devices.</td></tr>
<tr><th colspan="7">Syllabus Outline</th></tr>
<tr><td colspan="7">1. Quantum Mechanics
Principles of quantum mechanics, wave-particle duality, uncertainty principle, Schrödinger wave equation applied to various potentials and boundary condition problems.

2. Quantum Theory of Solids
Conduction in metals and semiconductors, Kronig–Penney model, E-k diagram, Fermi-Dirac statistics and Fermi level, density of states.

3. Semiconductors in Equilibrium and Non-equilibrium
Equilibrium distribution of electrons and holes, carrier generation and recombination, ambipolar transport equation, P-N junction, and diodes.

4. Lasers and Optical Resonators
Energy levels and stimulated emission of radiation.</td></tr>
</table>

EN3224: Electronic Manufacturing Systems

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
6	EN3224	Electronic Manufacturing Systems		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	50	50

Learning Outcomes

1. Design an electronic product manufacturing process.
2. Carryout production planning and production control.
3. Carryout raw material control.
4. Prepare proper documentation for electronic product manufacturing process.
5. Apply productivity improvement techniques and manufacturing information management techniques.

Syllabus Outline

1. Electronic Product Manufacturing Process
Manufacturing process design and engineering. Translation of product design information to manufacturing information, design for manufacturing (covering product reliability and testing, standard compliance, panelling) manufacturability.

2. Production processes
Production planning: planning parameters, equipment utilization, scheduling, production strategies: make-to-order, make-to-stock.

3. Material Control System
Incoming raw material control, material ordering and stocking, Cumban system, shop floor life cycle management, component life cycle management (maturity stage of components), ROHS, REACH, Conflict Mineral Reporting Template (CMRT).

4. Product Fabrication, Assembly, Testing, Repair and Quality Control
IPC guidelines, wave soldering, hand soldering, SMT, THT – manual, THT automated , PCB Washing, production constraints (equipment suitability), Production Part Approval Process (PPAP) – Level 1,2,3, Copy exact manufacturing, heat dissipation testing, PCB depanelling.

5. Productivity Improvement: Manufacturing Information Management , Digital Transformation
Kaizen, customer requirements, planning parameters, identifying bottlenecks, Information archival duration (10 to 25 years), lot traceability, item traceability , Manufacturing Execution System (MES), digital transformation (Industry 4.0): capturing information from all stages of manufacturing process, statistical process control.

EN3270: Internet of Things Systems Engineering

<table>
<tr><th>Intake</th><td>2020 onwards</td><th>Specialisation</th><td colspan="3">Electronic and Telecommunication Engineering</td></tr>
<tr><th>Semester</th><th>Code</th><th colspan="2">Module Title</th><th>C/E/O</th><th>GPA / NGPA</th></tr>
<tr><td>6</td><td>EN3270</td><td colspan="2">Internet of Things Systems Engineering</td><td>E</td><td>GPA</td></tr>
<tr><th colspan="2">Hours/Week</th><th rowspan="2">Credits</th><th rowspan="2">Prerequisites / Corequisites</th><th colspan="2">Evaluation %</th></tr>
<tr><th>Lecture</th><th>Lab/Tutes</th><th>CA</th><th>WE</th></tr>
<tr><td>2</td><td>2</td><td>3</td><td>EN 2150 Communication Network Engineering
EN 2561 Internet of Things Systems Engineering
EN3230 Wireless Networks (preferable)</td><td>50</td><td>50</td></tr>
</table>

Learning Outcomes

1. Analyze the performance requirements of different Internet of Things (IoT) applications, and the device and network constraints faced by them.
2. Evaluate the approaches and countermeasures adopted in IoT device hardware design to overcome the above constraints.
3. Evaluate the approaches adopted in adaptation of the TCP/IP protocol stack at each level to overcome the above constraints.
4. Select wireless technology standards and network topologies for IoT in different application scenarios.
5. Study the performance of a large scale IoT systems as applicable to advanced IoT applications.

Syllabus Outline

1. Introduction to advanced IoT applications

Case studies of the *Things – Connect – Collect – Learn – Do* paradigm in practice. Identification of requirements and constraints. Shortcomings of TCP/IP and associated conventional Internet protocols and physical layer standards for IoT. Introduction to the IETF protocol stack for IoT. Massive Machine-Type Communications (MMTC) in 5G.

2. The Physical and Medium Access Layers for IoT

Handling computational resource constraints in the Physical Layer. Energy consumption in the Physical and MAC layers. Energy saving mechanisms, trade-offs. Energy harvesting. Physical/MAC layer standards (e.g., IEEE802.15.4, Bluetooth versions, LoRAWAN, NBIoT and CAT-M1) characteristics and application scenarios. Case studies of IoT device design. Thermal management and packaging for IoT devices.

3. Adaptation of the Network Layer for IOT

Challenges in implementing addressing and routing in IoT. Adaptation of the Network Layer for IoT. IETF standards for adaptation of the Network Layer (e.g., IPv6, 6LowPAN, RPL), characteristics and application scenarios.

4. Transport and Application Layer Protocols for IoT

TCP vs. UDP for IoT. Design principles of CoAP and MQTT in handling IoT requirements. Comparison of HTTP, CoAP and MQTT for IoT and application scenarios.

5. Edge and Cloud computing for IoT

The need for Cloud and Edge level computing in IoT networks. Cloud computing platforms. Cloud and Edge topologies, partitioning, typical configurations. Hardware and software components for edge-level computing infrastructures. PAN-to-WAN bridging, cellular gateway functions.

6. Security and Privacy in IoT

Security issues and challenges associated with IoT-enabled infrastructure. Overview of physical, network and data security from device to cloud.

EN3330: Introduction to Engineering Optimization

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
6	EN3330	Introduction to Engineering Optimization		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	70	30

Learning Outcomes

1. Recognize the concept of optimality with respect to objective, decision variables, and constraints.
2. Mathematically formulate certain design problems in engineering by using the decision variables, objective, and constraints framework.
3. Rationalize the disparity between an optimal design and a feasible design.
4. Propose solution methods to an optimization problem by capitalizing on off-the-shelf algorithms.
5. Implement numerically the solution methods and compare them.

Syllabus Outline

1. Optimization Process with Examples
Shannon capacity as an optimization problem, minimum energy signal design in digital communication, interference mitigation via power control, determining the shortest path in a communication network, processor-task assignment problem in multiprocessor environments, synthesis of the control command for state targeting, transistor sizing for digital CMOS circuits, digital filter designs by reference matching, machine learning (e.g., optimal separating hyperplane, binary classification, matrix completion problem, non-negative matrix factorization), image denoising.

2. Fundamental Characteristics of an Optimization Problem
Decision variables, objective function, constraint functions, basic optimization problem, unconstrained optimization, constrained optimization, solution of a problem, a feasible point of an optimization problem.

3. Euclidean Geometric Interpretation of an Optimization Problem
Graph of a function, level sets of a function, implications in gradient, directional derivatives, and Hessian on optimality.

4. Solution Algorithms for Unconstrained Optimization Problems
One-D search methods (e.g., bisection method, Newton's Method, bracketing, line search in multidimensional optimization), descent/ascent methods (steepest descent, gradient descent, Newton’s method, cyclic/block coordinate search), conjugate direction methods (conjugate direction/gradient algorithms), quasi-Newton methods (DFP algorithm, BFGS algorithm).

5. Introduction to Stochastic Methods for Unconstrained Optimization Problems

Noisy descent, stochastic gradient, cross-entropy method.

6. Solution Algorithms for Constrained Optimization Problems
Equality constrained (e.g., Newton's method, infeasible start Newton method, method of Lagrange multipliers).

EN3340: Random Signals and Processes

<table>
<tr><td>Intake</td><td>2020 onwards</td><td>Specialisation</td><td colspan="3">Electronic and Telecommunication Engineering</td></tr>
<tr><td>Semester</td><td>Code</td><td colspan="2">Module Title</td><td>C/E/O</td><td>GPA / NGPA</td></tr>
<tr><td>6</td><td>EN3340</td><td colspan="2">Random Signals and Processes</td><td>E</td><td>GPA</td></tr>
<tr><td colspan="2">Hours/Week</td><td rowspan="2">Credits</td><td rowspan="2">Prerequisites / Corequisites</td><td colspan="2">Evaluation %</td></tr>
<tr><td>Lecture</td><td>Lab/Tutes</td><td>CA</td><td>WE</td></tr>
<tr><td>2</td><td>2</td><td>3</td><td>None</td><td>50</td><td>50</td></tr>
</table>

Learning Outcomes

1. Derive statistical properties of linear/non-linear functions of random variables and vectors.
2. Characterize a random vector by its joint CDF and joint characteristic function.
3. Explain random processes in terms of their statistical properties
4. Analyse the spectral characteristics of wide sense stationary random processes.
5. Apply the knowledge of random variables and processes for modelling, design, and evaluation of engineering systems

Syllabus Outline

1. Single Random Variable
Review of a single RV. PDF. Operations on a single RV: mean, moments, central moments, characteristic/moment generating functions. Transformation of random variables.

2. Multiple Random Variables
Pairs of RVs: Joint and conditional distributions, operations on a pair of RVs, conditional expectation, transformations. Complex random variables. The Gaussian random vector and its properties. Expectations involving random vectors. Sum of RVs and the central limit theorem. Engineering applications of multiple RVs.

3. Random Processes
Introduction, characterization and classification of RPs. Multiple RPs. Gaussian RPs. Poisson processes and introduction to Markov processes. Engineering applications of RPs.

4. Spectral Characteristics of Random Processes
Definition, Weiner-Khintchine theorem, and bandwidth of RPs. Transmission of a RP through LTI systems. Bandpass processes. Applications: noise in analogue communications.

EN3350: Software Design Competition

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
6	EN3350	Software Design Competition		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
-	6	3	None	100	0

Learning Outcomes

1. Analyse requirements and design a software solution for a given task with a complexity applicable to a senior undergraduate.

2. Modularize and simplify the system design through appropriate use of OOP concepts and design patterns.
3. Verify the functionality of the modules and the system through well-structured testing.
4. Deploy the software on the web or hardware platform as applicable to the selected task.
5. Apply industry-standard practices for collaborative software development with well-documented development history.

Syllabus Outline

1. Module Overview and Requirement Analysis

Overview of the module

Description of the alternative tasks (tasks to choose from: full-stack web-design (frontend + backend + database), hardware level (C++, CUDA). Overview of software development process. Requirement Analysis: RR, SRS, SDS. Need for documentation.

2. Modular System Design

Refresher on OOP concepts (via UML diagrams), design patterns and database design (via ER diagrams).

3. Source Control

Intuitive understanding of git data model, hands on introduction to version control, collaborative development, self-documenting the development history via commit messages, branching (feature/bugfix branches), merging and pull requests.

4. Software Development

Build systems, make files, code refactoring, code readability, self-documenting code (descriptive identifiers, docstrings, proper comments), style guides (e.g., pep8), coding for testability.

5. Testing and Issue Tracking

Minimizing errors, unit testing, integration testing, continuous-integration pipelines, code reviews, git blame, alpha testing, issue tracking.

6. Deployment and Documentation

Re-structuring the development history (git rebase), fixing bugs in production (hotfixes), code documentation.

EN3211: Self-Initiated Innovation

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
6	EN3211	Self-Initiated Innovation		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
-	6	3	None	100	0

Learning Outcomes

1. Generate self-motivation and enthusiasm in identifying, analysing and solving a problem of a complexity appropriate for a senior undergraduate.
2. Discover creative ways of solving the identified problem.
3. Apply a multidisciplinary approach as appropriate towards solving the identified problem.
4. Demonstrate correct scientific and engineering approach in problem solving.
5. Present the solution orally and in writing.

Syllabus Outline

1. Problem Identification
Identify an existing problem in industry or in society in a relevant discipline of a complexity appropriate for a senior undergraduate.

2. Domain Knowledge
Gather domain knowledge related to the identified problem and collaborate with resource persons having domain knowledge.

3. Problem Solution
Adopt the correct scientific and engineering problem solving approach towards solving an identified problem.

4. Case Study
Study and critically evaluate existing solutions to identified problems and propose improvements.

5. Technical Presentation
Present the solution to the identified problem in a professional manner. Prepare a technical report describing the solution.

Semester 7

EN4203: Project

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
7	EN4203	Project		C	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
		10	None	100	

Learning Outcomes

1. Identify a real-world problem of sufficient complexity that can be solved using the technologies learnt during the undergraduate career within a given time frame.
2. Appreciate the need for group work in solving real-world problems and the role of the individual.
3. Demonstrate the skills required for writing a project proposal and associated business plan for the problem identified, if necessary.
4. Defend the proposal drafted for solving a real-world problem.
5. Apply the knowledge gained to determine alternative approaches to solving the problem.
6. Analyse different approaches to solve the identified problem.
7. Evaluate different approaches to find the most suitable one.
8. Design and develop a solution using the selected approach.
9. Evaluate the effectiveness of the solution in terms of technical capabilities, social and environmental aspects, and sustainability.
10. Justify the methods adopted in the solution.
11. Compile a comprehensive document detailing all aspects related to the project.

Syllabus Outline

1. Investigation Stage

The student should be capable of independently referring to books, papers, patents, academic literature, and electronic resources to justify their choice of the project. Conduct a literature survey in order to academically support any claims, technologies and methods used in the project. This phase should also be used to determine if there are other methods that have been used to address the same or similar implementation aspects of the selected project. As a consequence of this activity, the student should have multiple sources of information upon which to base the work that is to follow. Identifying or estimating the hardware and software resources required for the successful implementation of the proposed project should also be carried out within this stage.

2. Implementation Stage

Once the preliminary investigation is carried out and a project of appropriate complexity is chosen, the next stage is to design and implement the prototype. Identifying the proper approach of implementation is also key to completing the project successfully. Use of design software, and simulations to support the proposed design strategies is important. The implementation phase includes construction and testing of the prototype. A major portion of the time should be spent with this phase. At the implementation stage, the student is allowed to alter or modify the methodologies proposed in the previous phase depending on any new information available at this stage.

3. Presentation Phase

Placing the work in context and presenting it effectively is also an important part of the project. Effective presentation of the project material and a well-structured report is expected for the satisfactory completion of the final year project. The documentation and knowledge preservation includes a presentation, report, as well as a viva

4. Intellectual Property
Understanding on University IP policy and ethics.

EN4933: Technical and Scientific Writing

Intake	2020 onwards	**Specialisation**	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
7	EN4933	Technical and Scientific Writing		C	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
1	2	2	None	100	

Learning Outcomes

1. Explains the different types of technical reports.
2. Apply the elements of the general structure of technical reports.
3. Explain the criteria of a basic Literature survey.
4. Apply proper referencing techniques to avoid plagiarism and maintain originality of writing.
5. Write paragraphs effectively.

Syllabus Outline

1. Criteria for Technical Writing
Language criteria: How easy it is for people to understand the words
Design criteria: The visual impact of the document and the way its design influences usability
Relationship criteria: How far the document establishes a relationship with its users

Content criteria: How the content and the way it is organized deliver the document's purpose.

2. Difference between Fiction Vs Technical Writing
Learn & apply the basics of an abstract
Write a comprehensive introduction

Understand the importance of the first pages (List of figures, tables, abbreviations, Table of Contents)

3. Elements of a Literature Review
Critically analyse the background of a topic
Select and source the information that is necessary to develop a context for a research

Write important facts to show how an investigation relates to previous research.

4. Ensuring Originality in Writing
Avoiding *plagiarism*. Cite sources correctly, use quotation marks, good paraphrasing. Using writing assistance tools (e.g., Grammarly) and similarity check tools (e.g., Turnitin)

5. Writing Paragraphs Coherently
Unify paragraphs by making every sentence contribute to a controlling idea, which is usually stated in a topic sentence (paragraph unity).

Write a coherent paragraph organizing facts, creating a logical argument that makes sense from idea to idea (paragraph coherence). Paragraph development.

EN4604: Digital IC Design

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
7	EN4604	Digital IC Design		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	40	60

Learning Outcomes

1. Explain the digital IC design concepts.
2. Recognize the technical challenges in digital IC design.
3. Demonstrate the proficiency in VLSI design tools widely used in industry.
4. Design and analyze VLSI circuits at various design stages from functional design, logic design, circuit design, to physical design.

Syllabus Outline

1. Digital design concepts
Introduction to digital IC design, digital design basics, clocks and resets.

2. RTL to netlist mapping
Advanced RTL coding and hardware interpretations, RTL synthesis, Static timing analysis, timing violations and fixes.

3. Design for test
Define test modes, DFT insertion techniques, BIST, scan and boundary scan tests.

4. Backend design
IO Design, floor plan, placement, clock tree synthesis, routing, layout verifications, design issues and fixes.

5. RTL2GDS flow
Familiarize with tools required for synthesis, place & route, timing analysis, and layout verification, design related problems and fixes, engineering change order.

EN4214: Power Electronics

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
7	EN4214	Power Electronics		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	EN2111	50	50

Learning Outcomes

1. Describe the fundamental principles of power electronics.
2. Analyse DC-DC converters having single, multiple coupled, and uncoupled inductors.
3. Design DC-DC converters for a given specification.
4. Explain the operation of rectifiers and inverters.

Syllabus Outline

1. Introduction
Limitations of traditional voltage regulation. PWM signals and spectrum. Requirement of L-C filters.

2. DC-DC Converters and Analysis
Small ripple approximation. Concepts of flux and charge balance. Buck, boost, buck-boost, and Ćuk converters along with topology derivation techniques. Effect of parasitic resistances to output. DCM operation

3. Overview of Power Semiconductor Devices
Switch realization, fundamental challenges of design, conductivity modulation, power diode, power MOSFET, and power BJT.

4. Magnetic Devices
Introduction, inductance of a toroidal inductor (with and without an air gap), magnetic circuits, transformers and coupled inductors, non-idealities and models, losses.

5. Power Converters with Transformer Isolation
Flyback, push-pull, and forward converters.

6. Capacitors, Snubbers, Gate Drivers, And Thermal Management
Capacitor properties and limitations, introduction to snubbers, gate drivers and operation. Thermal management: introduction, thermal circuits, natural and forced cooling.

7. Introduction to Rectifiers and Inverters
Introduction to rectifiers with resistive and inductive loads. Introduction to inverters and their modulation schemes.

EN4440: Embedded Systems Engineering

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
7	EN4440	Embedded Systems Engineering		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	100	

Learning Outcomes

1. Analyse the building blocks of embedded systems.
2. Differentiate embedded systems and explain their design choices.
3. Apply hardware and software optimization techniques to meet application-specific requirements in an embedded system.
4. Design efficient and trustworthy embedded systems.

Syllabus Outline

1. Introduction to Embedded Systems Design
Components and characteristics of embedded systems. Major challenges and inter-operability constraints (performance, power, area, security). Embedded design flow. Design automation opportunities.

2. Modelling and Specification
Models of computation. Specification languages. Levels of hardware modelling.

3. Embedded Systems Hardware
Components of embedded systems. Embedded processors. Reconfigurable logic and platforms.

4. Real-time Scheduling and Embedded Operating Systems
Prediction of execution time. Scheduling in real-time systems. Real-time operating systems. Kernels and drivers. Compilers and compiler optimization.

5. Hardware-Software Co-Design
Hardware-software partitioning. Performance, power, area, and temperature estimation. Resources and design constraints. Design space exploration.

6. Validation and Verification
Simulation-based techniques. Formal methods. Concolic testing. Validation of non-functional requirements.

7. Security
Threat models: eavesdropping, spoofing, denial-of-service, buffer overflow and side-channel attacks. Designing and validating countermeasures against threats. Verification of security and trust.

EN4460: Communication Circuit Design

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
7	EN4460	Communication Circuit Design		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	EN3013/ Recommended: EN4364	70	30

Learning Outcomes

1. Explain the operation of the RF transceiver.
2. Explain the concepts of impedance transformation.
3. Analyse the impact of noise in RF circuit designs.
4. Explain the use of mixer circuits in RF signal down/up conversion.
5. Explain the operation of modulator circuits.
6. Analyse the circuit design principles of RF power amplifiers.

Syllabus Outline

1. Introduction
Typical communication system, receiver, spectrum seen by a receiver, transmitter, transmitter spectrum.

2. Matching Networks and Impedance Transformation
Passive devices in RF perspective, RLC circuits, RLC series-parallel resonance, Q factor, Smith chart, s-parameters, impedance matching.

3. RF Low Noise Amplifiers
Review of noise, noise in active and passive devices, noise figure, Friis formula for noise factor, review of amplifier configurations, LNA architectures.

4. Frequency synthesis
Oscillators, voltage-controlled oscillator, phase noise in oscillators, PLL, harmonic distortion, applications in modulation.

5. Non-linear circuits and mixers
Frequency down/up conversion, frequency shift as time domain multiplication, mixer circuit configurations: two-, four-quadrant cells, Gilbert cell: BJT realization. Translinear principle, and CMOS realization. Requirement of using an IF stage.

6. RF Power amplifiers
Review of basic concepts: efficiency, loss, RF PA design considerations, current and voltage swing, optimum load, inductor loaded PA. PA configurations: Class A, Class B, Class C, Class D, Class F, and Class S.

EN4324: Photonic Communication Components

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
7	EN4324	Photonic Communication Components		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	50	50

Learning Outcomes

1. Investigate and evaluate the capabilities of photonic communication components used in practical networks and R&D.
2. Review the different functional capabilities of photonic communication components and how they are implemented in different scenarios.
3. Apply the knowledge in field activities by identifying the practical aspects of the photonic communication components.
4. Analyze the performance of key functions of photonic components and describe their implementation in applications.

Syllabus Outline

1. Introduction to photonic communication
History of photonic communication systems, comparison with other wired and wireless media.

2. Photonic Media
Free space propagation, optical fiber as a dielectric waveguide, optical fiber construction and types, multimode and single mode fibers, geometric and ray optics (Snell's law, total internal reflection, numerical aperture, and V-number), wave optics (wave equation and its solutions, fiber modes), introduction to other photonic waveguides (e.g., LiNbO3, GaAS).

3. Photon Generation
Energy absorption and emission, light emitting diodes (LEDs) and characteristics, laser diodes and characteristics, different types of LDs such as DFB, DBR, ECL, VCSEL, MLL and tunable lasers.

4. Photon Detection
Optical absorption mechanism, photodiodes (PIN and APD), characteristics of photodiodes, other types of photo detectors.

5. Optical Modulation and Modulators
Direct and external modulation, different types of modulators (electro optic, electro absorption, and acousto-optic) and their characteristics.

6. Optical Amplification and Amplifiers
Optical amplification theory, REDFA characteristics and noise (ASE), noise figure, different types of optical amplifiers (RA, SOA, PSA) and their applications.

7. Active and Passive photonic components
Introduction to passive and active optical components. Optical couplers, multiplexers and demultiplexers, Isolators, circulators, filters, optical switches, optical add-drop multiplexers.

8. Photonic component design Introduction to simulation software: VPI component maker. Case study of design and simulation of a photonic based simple component (e.g., couplers, AWG or MMIC).

EN4470: Probabilistic System Analysis

Intake	2020 onwards	**Specialisation**	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
7	EN4470	Probabilistic System Analysis		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	60	40

Learning Outcomes

1. Explain the concept of probability from a measure-theoretic point of view.
2. Characterize the limiting behaviour of a sequence of random variables with respect to different modes of stochastic convergence.
3. Determine various probabilistic bounds for random variables.
4. Model a wide range of physical process in terms of Markov chains and Brownian motion.
5. Probabilistically assess the uncertainties associated with certain engineering system analysis problems.

Syllabus Outline

1. Introduction to Probability Measures
Probability spaces, axiomatic probability theory, cumulative distribution function, random variables, expected value, independence.

2. Stochastic Convergence
Weak convergence, convergence in probability, almost sure convergence, characteristic functions, central limit theorem, delta method.

3. Conditional Expectation and Martingales
Conditional expectation, Martingales, Martingale convergence.

4. Bounding and Ordering Probabilities
Introduction to concentration inequalities, order statistics, stochastic majorization, stochastic ordering, reliability theory.

5. Markov Chains
Discrete-time and continuous-time Markov chains, first step analysis, some special Markov chains, limiting behaviour of Markov chains, time reversibility, Markov chain Monte Carlo.

6. Brownian Motion and Stochastic Differential Equations
Brownian motion and Gaussian processes, max variable and reflection principle, geometric Brownian motion, Brownian motion with a drift, stochastic analogues of classical differential equations, diffusion and stochastic integrals, fundamentals of Itô calculus, stochastic differential equations, applications in financial engineering.

EN4394: Applied Information Theory

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
7	EN4394	Applied Information Theory		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	40	60

Learning Outcomes

1. Explain information by utilizing appropriate information measures.
2. Design a suitable lossless source code for a discrete memoryless source.
3. Evaluate the information capacity of discrete memoryless channels and Gaussian channels.
4. Model a wide range of physical process in terms of Markov chains and Brownian motion.
5. Discuss the importance of information theory for emerging technologies.

Syllabus Outline

1. Information Measures
Entropy, joint and conditional entropy, relative entropy, mutual information, chain rules for entropy, inequalities: Jensen's, Fano's, data processing.

2. Lossless Data Compression
Classes of codes, average length, Kraft's inequality, optimal codes, optimality of Huffman codes, Shannon-Fano-Elias coding, arithmetic coding, practical examples for data compression.

3. Capacity of Discrete Memoryless Channels
Information capacity and operational capacity, capacity calculations of simple discrete memoryless channels, symmetric channels, preview of channel coding theorem.

4. The Gaussian Channel
The Gaussian channel, differential entropy, preview of the extension of the channel coding theorem for Gaussian channels, capacity of the Gaussian channel, bandlimited and parallel Gaussian channels.

5. Applicability of Information Theory to Diverse Areas in Engineering
Network information theory: multiple access channels, broadcasting channels, interference channels. Security, machine learning.

EN4314: Telecommunication Core Networks

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
7	EN4314	Telecommunication Core Networks		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	70	30

Learning Outcomes

1. Discuss the requirements of core networks.
2. Discuss core network technologies.
3. Evaluate the use of SDN and NFV in core networks.
4. Discuss design issues in core networks.
5. Design SDN algorithms for core network requirements.
6. Discuss emerging and future Internet Architectures.

Syllabus Outline

1. Core Network Requirements
Scalability, reliability, predictability, quality of service, traffic engineering, fault detection and monitoring, support of multiple services such as virtual private networks, optimal utilization of infrastructure, Internet architecture.

2. Evolution of Core Networks
PDH, SDH, SONET, Frame Relay, ATM, IP.

3. Core Network Technologies
Multi-Protocol Label Switching (MPLS), routing and traffic engineering in core networks: Segment Routing (SR). Ethernet for WAN: analyse the limitation of LAN technologies in terms of scalability and monitoring and solutions, multicasting, synchronization techniques in mobile backhauling.

4. Software Defined Networks and Network Function Virtualization
Review of fundamentals of SDN, evaluate the suitability of SDN for core networks, intent based networking (capturing intent). Software defined WAN (SD-WAN), introduction to NFV, NFV implementations: ETSI NFV and OpenStack.

5. Design of Core Networks
Design decisions related to core network requirements, Convergence of multiple services to IP (voice, video conferencing, video streaming, video on demand), quality of service expectations, best effort nature of packet networks, design of SDN algorithms for traffic engineering, QoS, fast re-routing, L2/L3 VPLS/VPN

6. Internet Architecture: Past, Present and Future
Evolution of Internet Architecture, Named Data Networking (NDN) : from host centric (IP) to data/information centric network architecture

EN4384: Wireless and Mobile Communications

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
7	EN4384	Wireless and Mobile Communications		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	50	50

Learning Outcomes

1. Assess the effects of the propagation channel on the received signal in a fixed/mobile wireless system.
2. Recommend appropriate techniques to counter the detrimental effects of the propagation channel.
3. Analyse multiple antenna techniques, and propose solutions to achieve spatial multiplexing, diversity, and interference mitigation.
4. Propose cross-layer designs for wireless networks.
5. Evaluate performance of wireless systems using analytical and simulation tools.

Syllabus Outline

1. Wireless Propagation Channel

Introduction to wireless communications: Propagation mechanisms, Propagation loss computation techniques: free-space loss, ray tracing models, classical empirical models, new models for mm-wave frequencies, propagation in vehicular networks, device-to-device propagation, statistical characterization of wireless channels. Fading: small-scale and large-scale, Channel characterization.

2. Fading Countermeasures

Diversity schemes: space, frequency, polarization, angle, time, and multipath diversity. Receiver diversity: selection, switched, maximal-ratio and equal-gain combiners, hybrid schemes. Analysis of diversity schemes: analytical and simulation techniques. Signal and transceiver design principles for wireless channels: spread spectrum, multicarrier.

3. Multiple Antenna Systems

MIMO system model, MIMO transceiver techniques: for spatial multiplexing, for diversity, for interference reduction, space-time coding, capacity, and role of feedback. New trends: massive MIMO, network MIMO.

4. Design Aspects of Advanced Wireless Networks

Modelling and analysis of heterogeneous wireless networks, issues related to spectrum allocation, user association and power allocation, cross-layer design approach.

EN4640: Statistical Signal Processing

Intake	2020 onwards	**Specialisation**	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
7	EN4640	Statistical Signal Processing		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	EN3340 Random Signal and Processes or Equivalent	60	40

Learning Outcomes

1. Characterize discrete random processes in terms of the statistical properties
2. Formulate an engineering decision-making problem with the help of statistical decision theoretic framework.
3. Device different decision statistics depending on the respective assumptions.
4. Determine an optimal estimation technique from a multitude of techniques for a given problem.
5. Assess the performance of different detectors and estimators analytically as well as numerically.

Syllabus Outline

1. Introduction to Random Vectors and Matrices
Multivariate Gaussian density, Wishart density, spectral decomposition.

2. Classical Detection Theory
Log-likelihood ratio, Neyman-Pearson Lemma, maximum a posteriori probability (MAP) criterion, Minimax criterion, nuisance parameters.

3. Modern Detection Theory of General Gaussian Signals
Eigenvalue based detectors, high dimensionality and phase transition.

4. Deterministic Parameter Estimation
Maximum likelihood (ML) method, method of moments, deterministic least squares.

5. Random Parameter Estimation
Bayes risk, aposteriori mean and MMSE, MAP, stochastic least squares.

6. Discrete-time Random Processes and State Space Models
Stationary and nonstationary processes, z-transform, DTFT, state variables, spectral representation.

7. Linear Estimation of Discrete-time Random Process
Wiener filtering, Kalman filtering, extended Kalman filtering.

8. Introduction to Adaptive Filtering Techniques
FIR adaptive filters, adaptive recursive filters, recursive least squares.

EN4554: Deep Learning for Vision

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
7	EN4554	Deep Learning for Vision		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	60	40

Learning Outcomes

1. Uses classic vision techniques for classification, detection, and segmentation.
2. Solve classification, detection, and segmentation problems using convolutional neural networks.
3. Apply recurrent neural networks and other applicable deep networks for problems that involve sequences such as image captioning.
4. Propose extensions to existing neural networks in the context of a vision tasks.

Syllabus Outline

1. Classic Techniques in Classification and Detection

Features such as SIFT, and HOG. Bag of visual words (BoVW), support vector classifiers for BoVW.

2. Classic Techniques in Segmentation

Review of k-means, mean-shift, snake, and live-wire techniques. Level set methods and image segmentation. Graph-cuts method and image segmentation. Region proposal algorithms such as selective search.

3. Convolutional Neural Networks (CNNs)

Structure of a CNN, convolutional layers, fully connected layers, pooling layers, activation functions, loss functions, back propagation, regularization, batch normalization and data augmentation. Constructing, training, and testing CNNs using deep leaning frameworks. Computations in a deep network and hardware resources

4. Image Classification

Neural networks that classify images such as AlexNet, VGG, GoogLeNet, ResNets, other popular networks, and recent extensions.

5. Object Detection and Instance Segmentation

Region-proposal CNNs and developments, fully convolutional networks, instance segmentation. Single-shot detectors and fast implementations of object detectors.

6. Recurrent Neural Networks

Deep learning for sequences, LSTM, GRN, and other units. Image captioning.

7. Generative Networks

Autoencoders, generative adversarial networks, image generations.

EN4594: Autonomous Systems

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
7	EN4594	Autonomous Systems		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	A first course in {probability and statistics, control theory}	50	50

Learning Outcomes

1. Identify essential constituents of an autonomous system and describe implementation challenges
2. Design and implement state estimation algorithms.
3. Formulate the localization, mapping and navigation framework for an autonomous mobile agent.
4. Apply planning and control techniques for action execution in autonomous systems.

Syllabus Outline

1. Introduction to Autonomous Systems

Introduction. Autonomous vs. automated systems. Example autonomous systems. Basic system design of autonomous systems, control algorithms and challenges. Handling uncertainty: probabilistic approach.

2. State Estimation

Representation of state: state, state variables, state transition, complete state, recursive state estimation. Environment interaction: control actions, sensor measurements. Bayes filter. Gaussian filters: Kalman filter, Extended Kalman filter. Sensor fusion. Nonparametric filters: particle filter. Calibration techniques: least squares.

3. 3D Spatial Orientation (CNNs)

Rotation matrix. Derivative of a rotation matrix: analytical solution, approximation. Inertial measurement unit (IMU) theory: preserving properties of rotation matrix, drift cancellation. Error characteristics of inertial sensors: biases, scale factors, error models. Gimbal lock. Introduction to quaternions. Quaternion algebra. Rotation through quaternions. Quaternion rotation operator.

4. Localization, Mapping and Navigation

Localization: Gaussian, Grid, Monte Carlo. Occupancy grid mapping. Simultaneous localization and mapping (SLAM). Dead reckoning. Inertial navigation. GNSS/INS navigation.

5. Planning and Control

Task planning. Probabilistic planning techniques. Markov decision processes. Behaviour-based control. Controller fusion. Fuzzy logic based control techniques. Control under modelling errors and uncertainties.

EN4923: Research Project

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
7	EN4923	Research Project		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
	10	5	None	100	

Learning Outcomes

1. Compose a detailed literature survey for a chosen research topic through cross referencing of related research material.
2. Compile a proposal based on the literature review by critically comparing with similar research topics and highlighting the contributions.
3. Demonstrate analytical, programming, and experimental skills required for scientific research
4. Write a research paper that meets the standard of an indexed conference or a journal.
5. Defend the research in front of an appropriate audience.
6. Identify ethical issues in research such as research misconduct, intellectual property rights, plagiarism, and professional responsibility.

Syllabus Outline

1. Literature Reviews

Research methodologies, significance of literature survey, search methodologies, formulating research ideas, referencing research, ethics in research.

2. Research Methods

Reading and reviewing research articles, formalized methods of conducting research, developing and implementing algorithms, theoretical evaluation and performance comparisons, reproducibility of results, experimental-, simulation-based validation of results.

3. Writing a Research Article

Writing research reports, preparing a paper for publication based on research outcomes, peer-review process.

4. Research Presentations

Semester 8

EN4021: Advanced Digital Systems

Intake	2020 onwards	**Specialisation**	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
8	EN4021	Advanced Digital Systems		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	100	

Learning Outcomes

1. Analyse complex digital systems.
2. Discuss the mapping of performance requirements to design decisions.
3. Discuss the methods for functional and logic verification.
4. Design of System on Chip (SoC) for an application specific processor with cache-based memory hierarchy.
5. Design and implement bus architecture for low-speed and high-speed peripherals.

Syllabus Outline

1. Complex Digital Systems

i. Analysis of characteristics such as throughput, timing, stability, memory and area footprints, power budget, signal integrity, clock recovery and synchronization, Multiple clock domains, inter-connectivity of modules using FIFOs. ii. Analyse example systems such as processors (non-pipelined and pipelined), video decoders and encoders, their timing and throughput requirements, connectivity to other dependent modules. iii. Basic principles and methodologies for implementation of SoC and NoC.

2. Verification

Functional and logic verification, Open Verification Methodology (OVM) and Universal Verification Methodology (UVM), coverage, introduction to formal verification methodologies.

3. Design and Implement Complex Digital Systems

Design methodologies (RTL and high-level synthesis), design of SoC for an application specific processor and its interfacing to memory hierarchy (cache and primary memory).

4. Design and Implement Simple Bus Architectures

EN4650: Computer Systems Architecture

Intake	2020 onwards	**Specialisation**	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
8	EN4650	Computer Systems Architecture		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	70	30

Learning Outcomes

1. Discuss performance measures of computer systems.
2. Discuss instruction pipelining, associated problems, and solutions.
3. Design a control unit for a pipelined processor.
4. Evaluate application specific architectures in terms of performance, price, and power.
5. Design a memory hierarchy for a given specification.
6. Discuss the exploitation of parallelism in computing.

Syllabus Outline

1. Introduction
Quantitative principles of computer design, performance measures of computer systems: processor, memory, disk sub-system, trade-offs: performance, price, and power.

2. Instruction pipelining
Simple pipelining and hazards, complex pipelines.

3. Review of RISC ISA and single cycle implementation
RISC-V ISA as the reference, instruction encoding.

4. RISC pipelined processor implementation
Pipelined data path and control, design of control unit for pipelined processor, HDL representation of pipeline (modelling) and examples of different pipelines.

5. Application Specific (Domain Specific) Architectures
The need, examples in the areas of vision, neural networks, networking, and data centre accelerators.

6. Cache Memory Design
Review of cache memory fundamentals, cache performance: measurements, cache optimization techniques: design of cache controller using FSM, cache coherence in multi-processor systems (parallelism).

7. Memory Hierarchy
Basics of memory hierarchy and memory technologies (SRAM, DRAM, flash memory), memory management: partitioning techniques: fixed, dynamic, segmentation, paging. Virtual memory: address translation, TLB. Integration to a full memory system: virtual memory, TLB and cache, virtual address cache and aliasing. Disk storage: RAID and performance analysis, design of memory hierarchy, virtual machines and sharing of memory.

8. Instruction Level Parallelism
Instruction level parallelism (ILP), branch prediction, static and dynamic scheduling, multiple issue, out of order execution, speculation, thread level parallelism and synchronization basics.

9. Data Level Parallelism
SIMD vs MIMD, SIMD: vector, multimedia SIMD extensions, GPU architectures.

EN4480: Advanced Power Electronic Design

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
8	EN4480	Advanced Power Electronic Design		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	50	50

Learning Outcomes

1. Analyse and model the small-signal behaviour of a DC-DC converter.
2. Design a controller of a DC-DC converter for stabilized output.
3. Design a controller of a power electronic system to maximize the energy harvest
4. Explain the operation and use of multiport converters.
5. Explain the grid connection of renewable sources.

Syllabus Outline

1. Converter Dynamics and Control
AC modelling approach, small signal equivalent model, PWM modulator, state-space averaging model, canonical models, converter transfer functions, controller design.

2. Photovoltaic Energy Conversion Systems
Introduction to PV power systems, interfacing power electronic converters, maximum power point tracking.

3. Multiport Converters
Introduction, converter architectures, power modulation methods, energy storage: storage methods and interfacing converters, grid connected power converters and modulation.

EN4660: Advanced Electronic Control Systems

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
8	EN4660	Advanced Electronic Control Systems		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	60	40

Learning Outcomes

1. Formulate state-space representations of linear dynamical systems.
2. Demonstrate the understanding of discrete-time control systems.
3. Analyse structural properties of control systems with respect to stability, observability, and controllability.
4. Design state-feedback controllers and observers for a given specification.
5. Discuss emerging and modern control techniques.

Syllabus Outline

1. Introduction to State-Space Representations

Linear dynamical systems. State-space perspective: state, state variables, state-space, MIMO systems, block diagrams. Analysis of the state equations: continuous-time, discrete-time. Canonical forms. Solving the state equation. Matrix exponential. State-space related vector-matrix analysis

2. Discrete-Time Control Systems

Signal forms in a digital control system. Sample-and-hold. A/D and D/A conversion. Quantization. z-transform. z-plane analysis of discrete-time control systems. Impulse sampling and data hold: zero-order hold, first-order hold. Pulse transfer function. Realization of digital controllers.

3. Structural Properties of Control Systems

Stability: Lyapunov stability, stability of linear state-space models, input-output stability. Controllability: controllability matrix, complete state controllability, output controllability. Observability: observability matrix, complete observability.

4. Advanced Feedback Systems

Pole placement: control system design by pole placement. Design of servo systems. State feedback. State observers: design of control systems with observers. Tracking and disturbance rejection.

5. Advanced Control Techniques

Introduction to advanced control topics: robust control, adaptive control, optimal control—linear quadratic regulator (LQR), model predictive control.

EN4670: Photonic Communication Networks

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
8	EN4670	Photonic Communication Networks		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	50	50

Learning Outcomes

1. Investigate and evaluate the capabilities of photonic communication networks.
2. Identify and asses the different impairments and measurement techniques used in photonic networks.
3. Identify the practical implementation of different optical technologies used in photonic communication networks and apply the knowledge in field activities
4. Distinguish between different photonic network systems, architectures, configurations, and critically assess them.
5. Analyse the performance of key functions and describe their implementation in design and implementations.

Syllabus Outline

1. Introduction to Photonic Communication Networks
Introduction to photonic communication systems, evolution of communication networks as for today and future trends. Brief introduction to photonic communication components.

2. Photonic Channel Impairments
Optical fiber attenuation, dispersion, inter-symbol interference and introduction to non-linear effects.

3. Photonic Measurement Techniques
Eye opening factor (EOF), optical signal to noise ratio (OSNR), Q-factor, and bit error rate (for ideal condition and with different impairments).

4. Optical Technologies
Optical transmitters, receivers, and modulation formats for photonic communication.

5. Optical Networks and Transmission Standards
Network terminology, network hierarchy, optical/photonic layer, transmission standards (SDH, SONET, OTN, 100/400/800G), network survivability, multiplexing techniques (SDM, SCM, OTDM, WDM).

6. Optical Access Networks
Different types of optical access networks (direct fiber, shared fiber, FTTx, and PON), passive optical networks (PON) and standard, PON switching techniques (OBS).

7. WDM Networks
Evolution of WDM networks, introduction to CWDM, CWDM standards, CWDM channel plans, introduction to DWDM, DWDM standards and channel plans, DWDM network configurations, DWDM issues (gain tilting, FWM effect).

8. All Optical Networks
Broadcast and select networks, wavelength routed networks, linear lightwave networks, coherent optical communication.

9. Photonic Network Link Design
Link budget calculations and selection of optical components for a linear, ring and mesh network.

10. Photonic Communication System Design
Introduction to simulation software – VPI Transmission maker. Case study of design and simulation of a photonic base simple network.

EN4334: Microwave Engineering

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
8	EN4334	Microwave Engineering		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	50	50

Learning Outcomes

1. Realize a microwave device for a given specification.
2. Incrementally improve a design using a Taguchi like approach.

Syllabus Outline

1. Introduction
High frequency electron transport.

2. Microwave Transmission Lines
Coaxial cables, slotlines, microstrips, striplines, design techniques.

3. Rectangular Resonance Cavities
Rectangular cavity standing wave field solution, source excited cavities, transverse electric and transverse magnetic modes, wall currents, cavity design.

4. Rectangular Waveguides
Rectangular waveguide travelling wave field solution, transverse electric and transverse magnetic modes, wall currents, slots and mode filters, attenuation losses, flared and corrugated horn antennas, information velocity, waveguide and ferrite suppressor design.

5. Cylindrical Waveguides and Resonance Cavities
Overview of cylindrical waveguide standing wave field solution, modes, the cylindrical horn antenna and dielectric resonance cavities.

6. Microwave Antennas
Dipole antennas, log-periodic antennas, discone antennas, microwave arrays, reflector antennas, dielectric lens antennas.

EN4354: Radar and Navigation

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
8	EN4354	Radar and Navigation		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
3		3	None	60	40

Learning Outcomes

1. Distinguish between different radar system architectures and configurations, and critically assess their specializations.
2. Critically assess system parameter values needed for successful operation of radar and navigational systems under different operating environments.
3. Apply the underline principles and techniques of pulse compression, target detection, Doppler processing and moving target indication signal processing algorithms for a given scenario.
4. Distinguish between different navigation system architectures and configurations, and critically assess them.
5. Demonstrate knowledge of practical implementation techniques and challenges in radar and navigational aid systems.

Syllabus Outline

1. Radar System Overview

Overview of different types of modern radar systems. Classification of radar systems. Radar equation with necessary correction factors.

2. Radar Receiving System and Radar Signal Processing Techniques

Noise performance of the receiving chain. Target detection in noise. Constant False Alarm Rate (CFAR) detection. Integration of echoes. Radar data matrix/volume. Resolution. Matched filter ambiguity function. Pulse compression using waveform modulation. Doppler processing. Moving Target Indication (MTI) and Moving Target Detection (MTD).

3. Practical Implementations Of Different Sub-Systems Of A Radar

Modules of a radar transmitter. Modulator circuits. Different implementations of duplexer, rotating joint. Implementation of antenna systems. Display systems.

4. Introduction MIMO Radar Concepts

Phase array radar. Adaptive beam forming. Cognitive radar. Radar networks. Synthetic Aperture Radar (SAR). Over the Horizon (OTH) -MIMO radar concept.

5. Secondary Surveillance Radar (SSR)

Principle of SSR. Sidelobe suppression. Different modes of operation. SSR implementations.

6. Electronic Navigational Aids

En-route electronic navigational aids: Conventional and Doppler VHF Omnirange (CVOR and DVOR), Distance Measuring Equipment (DME), Instrument Landing Systems (ILS).

7. Satellite Based Navigation Systems Satellite based navigation, Global Navigational Satellite Systems (GNSS), GPS system, architecture and navigation message, Ground Based Augmentation Systems (GBAS), Satellite Based Augmentation Systems (SBAS)

EN4364: Microwave Communications

<table>
<tr><th>Intake</th><td>2020 onwards</td><th>Specialisation</th><td colspan="4">Electronic and Telecommunication Engineering</td></tr>
<tr><th>Semester</th><th>Code</th><th colspan="3">Module Title</th><th>C/E/O</th><th>GPA / NGPA</th></tr>
<tr><td>8</td><td>EN4364</td><td colspan="3">Microwave Communications</td><td>E</td><td>GPA</td></tr>
<tr><th colspan="2">Hours/Week</th><th rowspan="2">Credits</th><th rowspan="2" colspan="2">Prerequisites / Corequisites</th><th colspan="2">Evaluation %</th></tr>
<tr><th>Lecture</th><th>Lab/Tutes</th><th>CA</th><th>WE</th></tr>
<tr><td>2</td><td>2</td><td>3</td><td colspan="2">None</td><td>50</td><td>50</td></tr>
<tr><th colspan="7">Learning Outcomes</th></tr>
<tr><td colspan="7">1. Explain the theory, practice and technologies that are used in microwave communication systems.
2. Describe the use of satellites for communications.
3. Design RF links in terrestrial and satellite microwave communication systems and propose suitable protection methods for system reliability.
4. Plan and propose microwave link solutions to the communication problems in the industry.</td></tr>
<tr><th colspan="7">Syllabus Outline</th></tr>
<tr><td colspan="7">1. Principles of Terrestrial Microwave Communication
Principles of tropospheric wave propagation: reflection, refraction, diffraction, and absorption effects.

2. RF Link Design for Terrestrial Microwave Communication
Path design, fading and fade margin, link power budget.

3. Reliability Measures
Protection methods and link configurations.

4. Introduction to Satellite Systems
Concept, history, orbits, footprints, frequency bands, constellations, subsystems in a satellite, satellite payload, digital modulation techniques, applications.

5. Satellite Communication Link Design and Analysis
Satellite RF link path design, fading and fade margin, satellite link power budget, antennas.

6. Codec Design for Satellite Communications
Basic principles of speech/video coding and their usage in satellite communication systems. Error control for satellite communication</td></tr>
</table>

EN4421: Advanced Signal Processing

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
8	EN4421	Advanced Signal Processing		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	EN2063	50	50

Learning Outcomes

1. Design sampling rate changing systems and uniformly and maximally decimated filter banks.
2. Implement multi-rate systems using efficient structures.
3. Analyse multi-dimensional (M-D) signals and linear and shift-invariant (LSI) systems in the M-D space and M-D transform domains.
4. Apply M-D LSI FIR filters designed using windowing and optimization techniques for attenuating noise and interferences.

Syllabus Outline

1. Multi-Rate Systems
Downsampling and upsampling. Decimation and interpolation. Rational sampling rate changes. Noble identities. Polyphase representation of signals and LTI systems. Efficient decimation and interpolation. Efficient rational sampling rate changes.

2. Uniformly and Maximally Decimated Filter Banks
Structure of an M-channel UMD filter bank. Aliasing and perfect reconstruction, time-domain and z-domain input-output relationships. Modulation and polyphase representations. Modulation-domain and polyphase-domain conditions for alias-free and perfect-reconstruction UMD filter banks, design of UMD filter banks. Overview of the design techniques of DFT, modified-DFT and cosine-modulated UMD filter banks. Lattice and Lifting realizations of perfect-reconstruction UMD filter banks, applications of multi-rate systems banks: digital audio systems, subband coding of speech and image signals, implementation of the discrete wavelet transform, design of multi-dimensional filters.

3. Multi-Dimensional Discrete-Space Signals and Systems
Elementary signals: unit impulse, unit step, sinusoid and complex exponential, separable signals. Periodic signals, region of support, LSI systems, separable LSI systems, stability.

4. Multi-Dimensional Discrete-Space and z Transforms
Definition of the M-D discrete-space Fourier transform. Properties and theorems of the M-D discrete-space Fourier transform. Frequency response of LSI systems. Definition of the M-D z-transform, system function of LSI systems, stability.

5. Sampling of Two-Dimensional Continuous-Space Signals
Sampling with rectangular geometry, sampling with arbitrary geometry, frequency domain representation of sampling.

6. Design of M-D LSI FIR Filters
Windowing method. Optimization techniques for minimax and weighted least-square filter designs. Applications of LSI filters in 2-D/3-D array signal processing, 3-D video, 4-D light field and 5-D light field video processing for attenuating noise and interferences.

EN4563: Traffic Engineering

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
8	EN4563	Traffic Engineering		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	70	30

Learning Outcomes

1. Describe the different queuing theories related to telecommunication systems and their impact on modelling of telecom networks.
2. Apply appropriate queuing models to analyse a real-world application.
3. Assess the need for traffic engineering in core networks.
4. Model different types of network traffic by using various statistical models
5. Apply the knowledge of traffic theory to simulate real networks.
6. Analyse the performance of scheduling algorithms used in networks.

Syllabus Outline

1. Review of Stochastic Processes [2 hours]
Definition of stochastic processes, classification of stochastic processes, expectations, transforms, generating functions, and characteristic functions.

2. Important Stochastic Processes for Queuing
Markov processes, birth-death processes, Poisson processes.

3. Elementary Queuing Theory
Specification and measure of queueing systems, birth-death queueing systems in equilibrium, M/M/x queues.

4. Introduction to Intermediate/Advanced Queues and Their Approximate Behaviour
The M/G/1 queue, the G/M/1 queue, the G/G/1 queue, the heavy-traffic approximation, the fluid approximation.

5. Introduction to Network Optimization
Network as a graph, flows, the minimum cost flow problem, the shortest path problem, the maximum flow problem.

6. Modelling Network Traffic
Flow traffic models, continuous-time modelling, discrete-time modelling, self-similar traffic, heavy-tailed distributions, Pareto traffic distribution.

7. Modelling Traffic Flow Control
The leaky bucket algorithm, the token bucket algorithm.

8. Traffic Simulation
Random number generation, discrete event simulation, time driven simulation, event driven simulation.

9. Traffic Measurement
Common traffic parameters, measurements recommended by ITU-T, impact of time resolution, traffic estimation.

10. Application Examples
Active Queue Management (AQM): queue disciplines in practice, traffic and mobility modelling in communication networks, switches and routers.

EN4054: Digital Communication

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
8	EN4054	Digital Communication		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	60	40

Learning Outcomes

1. Identify the communication process as fundamentally a discrete process and channel capacity as a critical natural barrier for reliable communication.
2. Compare different digital transmission schemes with respect to their spectral efficiency, power efficiency, and reliability.
3. Derive the optimum receiver structures for a given digital transmission scheme over the AWGN and wireless fading channels.
4. Design linear equalizers for ISI channels.
5. Differentiate the performance of different digital receivers using Monte Carlo simulations.

Syllabus Outline

1. Introduction to Digital Communication
Communication sources, communication channels, standardized interfaces and layering, digital interfaces, source channel separation.

2. Source Coding
Measure of information, coding for discrete sources, quantization, and coding for analogue sources.

3. Signals and Systems Analysis
Bandpass and lowpass signal representations and their energies, signal space representation and the Hilbert space, bandpass systems, bandpass sampling, random signals and spectral analysis, KL expansion of a random process.

4. Digital Modulation Schemes
Mapping bits to waveforms, constellations, lattices and trellis diagrams, M-PAM, M-QAM, M-FSK, M-PSK, M-CPM, power spectra, spectral and power efficiencies.

5. Optimum Receiver Principles
Vectors channels, waveform channels, band limited linear filter channels, theorem of irrelevance, matched filter receiver, correlator, maximum likelihood (ML) sequence detector, incoherent receivers, probability of error analysis (reliability), comparison of digital modulation techniques, channel equalization, linear equalizers.

6. Coded Communication Systems
Channel models and channel capacity, transmitter implementation, receiver quantization, channel coding schemes: block codes, convolutional codes, turbo codes, the Viterbi algorithm.

7. Wireless Digital Communication
Channel modelling, fading and diversity, capacity of wireless channels, detection in flat fading channels, space-time communication.

EN4680: Telecommunication Technology Management

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
8	EN4680	Telecommunication Technology Management		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
3		3	None	70	30

Learning Outcomes

1. Explain the importance of the proper interplay of telecommunication technology, business, and policy in the societal modernization.
2. Classify telecommunication networks and services.
3. Apply knowledge on different methods of telecommunication technology absorption and transition.
4. Appraise the use and impact of telecom technology on business development.
5. Demonstrate knowledge in telecom project management techniques.
6. Demonstrate the understanding of the technical, social, economic, and legal perspectives of telecommunication policy and regulations

Syllabus Outline

1. Telecommunication Industry Overview
Environmental analysis of the global and local telecommunication industry landscape. Identifying all stakeholders and their roles.

2. Telecommunication Networks and Services
Classification of telecommunication networks, classification of the services provided by telecommunication networks.

3. Telecommunication Standards and Recommendations
Role of standards, role of recommendations, standardizing institutions, process of making standards and recommendations, use of standards and recommendations in deploying telecom networks and services.

4. ICT Business and Services Models
Service models in telecommunication, determinants of a business model, telecommunication markets, value chain, value creation, traditional operator model, managed service model, brand cooperation model, application store model, etc.

5. Technology Absorption and Managing Technological Transitions
Management models, methods and practices used for acquisition diffusion and utilization of telecommunication technologies and knowledge by an organization/society. Preparation of proposals, evaluation of proposals.

6. Telecommunication Project Management
Nature of telecommunication projects, project design, specifications, risk assessment, resource management, implementation strategies.

7. Service Quality and Measurements
Measures of service quality in different types of telecommunication services, measurement techniques, standards, and regulations. Service quality management models.

8. Dynamical Behaviour of the Stakeholders in the Telecommunication Industry
Introductions to games and equilibria: games, Nash equilibria, mixed and dominant strategies. Introduction to auctions: types of auctions, the winners curse, bidding strategies, all-pay auctions, selling at auctions. Bargaining: Nash's cooperative solutions, variable-threat bargaining, alternating offers, manipulating information in bargaining, bargaining with many parties and issues.

9. Telecommunication Policy and Regulations
Roles of policy, policies at different levels, telecommunication/ICT regulations, regulation tools and mechanisms, legal enforcement of regulations in the telecommunication sector.

EN4720: Security in Cyber-Physical Systems

Intake	2020 onwards	**Specialisation**	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
8	EN4720	Security in Cyber-Physical Systems		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	100	

Learning Outcomes

1. Explain the key concepts and security concerns in cyber-physical systems (CPS).
2. Explain basic cryptographic concepts and their applications.
3. Describe different threat models and corresponding countermeasures in CPS.
4. Examine CPS for their security vulnerabilities.
5. Apply cryptographic concepts to CPS design.

Syllabus Outline

1. Introduction to Cyber-Physical Systems
Key Concepts in Cyber Physical Systems (CPS). Introduction to CPS security and privacy. Attack Models for CPS. Security issues in Real-world CPS.

2. Cryptography
Introduction to modern cryptography. Block ciphers and key recovery security. Pseudo-random functions. Symmetric key encryption. Modes of operation. Hash functions. Message authentication. Analysis of encryption schemes and provable security. Background on computational number theory. Key agreement and key distribution. Public-key cryptography. Certificates. Digital signatures. Access control concepts. Authentication. Passwords and common attacks on passwords.

3. Network Security
Applications and protocols. TCP/IP Security problems and countermeasures (ARP poisoning, DNS spoofing, Ping of Death, TCP attacks, Telnet, FTP, Email, HTTP).

4. Hardware Root-of-Trust
Security in computation, storage, and communication. Threat models eavesdropping, spoofing, denial-of-service, buffer overflow and side-channel attacks. Designing and validating countermeasures against threats.

5. Privacy
Security vs Privacy. De-identification. Differential privacy. Anonymous communication.

6. CPS Security in Commercial Products

7. Emerging Concepts in CPS Security
Machine learning based malware detection. Post-quantum cryptography.

EN4574: Advanced Pattern Recognition

Intake	2020 onwards	**Specialisation**	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
8	EN4574	Advanced Pattern Recognition		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	Pattern Recognition (EN3150)/Introduction to Engineering Optimization (EN3330) or Equivalent	60	40

Learning Outcomes

1. Explain a learning problem from the point of view of statistical decision theory.
2. Investigate various regularized and un-regularized optimization methods for fitting models to data.
3. Analyse the performance of a heterogenous collection of machine learning techniques in terms of statistical decision theory.
4. Implement techniques for selecting among different models for a given prediction problem.

Syllabus Outline

1. Characterizing the Learning Problem
Statistical decision theory, the learning problem setup, types of learning, feasibility of learning, errors, and noise.

2. Training vs Testing
Introduction to the theory of generalization, interpretation of the generalization bound, bias-variance trade-off, the learning curve, overfitting, regularization, validation.

3. Bayesian Statistics
Posterior distributions, Bayesian model selection, priors, empirical Bayes, Bayesian decision theory, Markov chain Monte Carlo (MCMC).

4. Linear Model
Linear regression, Bayesian linear regression, linear classification, non-linear transformations, sparse linear models.

5. Kernel Methods
Kernel functions and examples, reproducing kernel Hilbert spaces, support vector machines, kernels for generative models.

6. Dimensionality Reduction
PCA, probabilistic PCA, kernel PCA, Johnson-Lindenstrauss lemma, effects of high dimensionality, phase transition.

EN4730: Convex Engineering Design

Intake	2020 onwards	**Specialisation**	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
8	EN4730	Convex Engineering Design		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	EN3330 or equivalent	70	30

Learning Outcomes

1. Identify the convexity as a useful feature based on which optimization problems can be classified into two broad categories.
2. Determine whether a given problem has a convex equivalence.
3. Characterize the consequences of convexity with respect to optimality.
4. Incorporate the principle of duality into the design of optimization algorithms.
5. Develop efficient and reliable numerical solutions for a convex problem.

Syllabus Outline

1. Practical Convex Applications
Engineering design, machine learning, finance, and control applications.

2. Convexity
Convex sets, convex functions, convex optimization problems, Schur-convexity.

3. Optimality Conditions
Optimality conditions for unconstrained problems, optimality conditions for equality-constrained problems, optimality conditions for inequality-constrained problems.

4. Duality
Lagrangian, the Lagrange dual function, dual problem, weak duality, constraint qualification and strong duality, Karush-Kuhn-Tucker (KKT) conditions, max-min inequality and saddle points.

5. Convex Optimization Models
Linear programs (LP), quadratic programs (QP), second order cone programs (SOCP), semidefinite programs (SDP), geometric programs (GP)

6. Numerical Algorithms for Convex Problems
Interior-point methods, coordinate descent methods, ellipsoid method, introduction to CVX modelling system and Julia programming language.

EN4584: Advances in Computer Vision

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
8	EN4584	Advances in Computer Vision		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	EN3160 or equivalent	60	40

Learning Outcomes

1. Identify open computer vision problems.
2. Review current literature in computer vision.
3. Implement a recent algorithm in computer vision.
4. Propose novel solutions to open computer problems.

Syllabus Outline

1. Introduction
Doing a literature search, journals, and conferences in vision, solved problems in vision, areas of current research interest in vision, data sets, and grand challenges. Backpropagation and optimization algorithms in current deep learning frameworks.

2. Classification
Classic methods in image classification. Existing convolutional neural network (and residual network) architectures for classification.

3. Object Detection
Classic methods in object detection. Existing convolutional neural network architectures for object detection.

4. Segmentation
Existing convolutional neural network architectures for image segmentation, semantic segmentation, instance segmentation.

5. Recurrent Neural Networks
Current recurrent neural network architecture for sequence prediction problems such as image captioning.

8. Reconstruction, Graphics and Other Vision Applications
Contributions in reconstruction, graphics, point cloud processing, autonomous driving, and other applications of interest.

EN4431: Analog IC Design

Intake	2020 onwards	Specialisation	Electronic and Telecommunication Engineering		
Semester	**Code**	**Module Title**		**C/E/O**	**GPA / NGPA**
8	EN4431	Analog IC Design		E	GPA
Hours/Week		**Credits**	**Prerequisites / Corequisites**	**Evaluation %**	
Lecture	**Lab/Tutes**			**CA**	**WE**
2	2	3	None	50	50

Learning Outcomes

1. Explain the analog IC design concepts.
2. Explain the technical challenges in analog IC design.
3. Demonstrate the proficiency in schematic and layout design.
4. Design and analyse analog IPs at schematic and layout stages.

Syllabus Outline

1. Basic concepts
CMOS devices and the fabrication process, Analog design techniques, Analog IC design flow.

2. Analog devices
Schematic design and simulations of CLOCK, PLL, CDR, POR, DAC/ADC, and LNA modules.

3. Circuit simulations
Define test modes, simulation techniques.

4. Analog IP development
Analog IP design flow, floorplan and IO Selection, mixed signal design flow.

5. Design layout
Familiarize with tools required for layout, and layout verification, design related problems and fixes.