Syllabi of Course Units

Module Code	**EN5840**	**Title**	**Signal Analysis**	**Credits: 3**
Learning Outcomes: On completion of this module, students should be able to;				
1	Discriminate between deterministic and random signals and associated analytical techniques.			
2	Explain the different characteristics of various important random processes.			
3	Derive deterministic limits of certain random sequences.			
4	Analyze the consequences of the filtration of a random process/deterministic signal through a linear time invariant (LTI) system.			
5	Simulate random variables and stochastic processes with certain properties.			
Outline Syllabus:				
1	**Analysis of deterministic signals:** Various representations, transformations, frequency domain characterization (i.e., FS and FT), filtration through an LTI system, sampling and reconstruction.			
2	**Random signal analysis and stochastic processes:** Random variables: real and complex random variables/vectors, univariate and joint density functions, linear and non-linear transformations, conditional densities, multivariate Gaussian density (real and complex), limit theorems (CLT and LLN); stochastic processes: classifications, time and frequency domain characterizations, filtration through an LTI system, various important processes (e.g., Gaussian, Poisson etc.).			
3	**Simulation of random variables**.			

Module Code	EN5830	Title	Engineering Decision Theory	Credits: 4

Learning Outcomes:

On completion of this module, students should be able to;

1	Discriminate between deterministic and data-driven models.
2	Apply linear algebraic and statistical concepts to formulate optimization problems in decision making.
3	Make optimal/suboptimal decisions for a given problem by using appropriate optimization techniques.
4	Manipulate the state-of-the-art optimization software tools.

Outline Syllabus:

1	**Vectors and matrices:** Vector algebra, matrix algebra, properties of matrices, spectral decomposition.
2	**Probability and statistics:** Review of probability, sampling and sample statistics, hypothesis testing, multivariate statistical techniques.
3	**Optimization as a tool in engineering decision making:** Different classes, different viewpoints: geometric, analytical, algorithmic.
4	**Convex optimization models:** Convexity: convex sets, convex functions, convex optimization problems, introduction to duality, optimality conditions; classes of optimization problems: linear models, quadratic models, other models.
5	**Algorithmic approaches:** Descent methods, Newton's method, other methods (e.g., interior-point methods).
6	**Modeling systems for constructing and solving convex programs:** CVX.

Module Code	EN5361	Title	Advanced Networking Concepts	Credits: 3

Learning Outcomes:

On completion of this module, students should be able to;

1	Evaluate OSI protocols in terms of their ability to scale in modern context.
2	Compare legacy and software defined networks.
3	Evaluate QoS of a network through appropriate use of network measurement techniques.
4	Apply suitable network management techniques to meet network KPIs.
5	Explain the working of new high-performance protocols.

Outline Syllabus:

1	**Review of OSI layer protocols, evaluation of their resilience and packet processing:** L2-L7 protocols, internet topology and effects of scaling (IPv4, IPv6), packet processing frameworks such as DPDK.
2	**Software defined networking (SDN) and network function virtualization (NFV):** Concepts and implementation.
3	**Network performance measurements and quality of service:** Requirements, measurement mechanisms, QoS parameters: delay, jitter and throughput; reasoning for QoS and potential solutions.
4	**Network management:** Active: deep packet inspection; passive: SNMP, NetFlow.
5	**High performance new protocols:** QUIC, data center specific protocols to support N-S and E-W traffic.

Module Code	EN5261	Title	Telecommunications Technology Management	Credits: 3

Learning Outcomes:

On completion of this module, students should be able to;

1	Assess the role of telecommunication in the societal modernisation.
2	Classify telecommunication networks and services and their evolution.
3	Analyze markets and consumer behaviour for telecom services in Sri Lanka.
4	Plan technological transitions and the management process.

Outline Syllabus:

1	**Classification of telecommunication networks and services.**
2	**Telecommunication industry overview: Global and local industry landscape.**
3	**Evolution to next generation networks:** Fundamentals of fixed and mobile technology, 5G evolution, managing technological transitions.
4	**Practical aspects of modernisation and the role of telecommunication networks.**
5	**Quality of service and quality of experience in telecommunication services.**
6	**Marketing concepts for telecommunication products and services.**
7	**Telecommunication project management.**
8	**Role of the standards and regulation.**

Module Code	EN5601	Title	Digital Communications	Credits: 3

Learning Outcomes:

On completion of this module, students should be able to;

1	Identify the communication process as fundamentally a discrete process.
2	Analyze various digital base-band/band-pass transmission schemes.
3	Derive the optimum receiver structure for a given digital transmission scheme over AWGN channel.
4	Design waveforms and receiver structures for an ISI channel.
5	Simulate various digital transmission techniques and compare their performance numerically.

Outline Syllabus:

1	**Review of analog modulation techniques.**
2	**Digital base band transmission.**
3	**Real pass band signals: representation and sampling.**
4	**Discrete representation of continuous signals.**
5	**Digital band pass transmission techniques.**
6	**Optimum receiver structures for AWGN channel.**
7	**SER/BER analysis of digital transmission techniques.**
8	**The effect of channel:** ISI.
9	**ISI mitigation techniques.**

Module Code	EN5371	Title	Network Design	Credits: 3

Learning Outcomes:

On completion of this module, students should be able to;

1	Justify the need for full stack (L2-L7) considerations in network design.
2	Design high performance networks to meet a given QoS KPI.
3	Evaluate the network performance using appropriate simulation tools.

Outline Syllabus:

1	**Full stack considerations for network design.**
2	**Design of software defined networks (SDN).**
3	**Design of following Networks:** LAN, campus networks, MPLS based enterprise networks, WANs (core networks) to meet QoS KPIs.
4	**Network simulation tools.**
5	**Design of multicast services in SDN context – IPv4 and IPv6.**

Module Code	EN5611	Title	Wireless Communications	Credits: 3

Learning Outcomes:

On completion of this module, students should be able to;

1	Explain various effects of the propagation channel on the received signal in a given application/propagation scenario.
2	Select appropriate measures to countermeasure the harmful effects of the propagation channel.
3	Evaluate the performance of wireless communication systems using analytical and simulation techniques to compare different systems.
4	Plan a wireless system to satisfy the coverage and capacity requirements.

Outline Syllabus:

1	**Signal propagation in wireless channels**: Propagation mechanisms, propagation loss computation techniques: free-space loss, ray tracing models, classical empirical models, new models for mmwave frequencies, propagation in vehicular networks, device-to-device propagation; statistical characterization of wireless channels, fading: small-scale and large-scale; channel characterization.
2	**Propagation countermeasures**: Diversity schemes: space, frequency, polarization, angle, time, multipath diversity; receiver diversity: selection, switched, maximal-ratio, equal-gain combiners; analysis of diversity schemes: analytical and simulation techniques; signal and transceiver design principles for wireless channels.
3	**Multiple antenna (MIMO) systems**: MIMO system model, MIMO transceiver techniques: for spatial multiplexing, for diversity, for interference reduction; new trends: massive MIMO, network MIMO.
4	**Coverage and capacity planning**: frequency reuse, co-channel interference analysis, coverage probability, user capacity evaluation, techniques to improve coverage and capacity, heterogeneous networks.

Module Code	EN5850	Title	Advanced Stochastic Processes	Credits: 3

Learning Outcomes:

On completion of this module, students should be able to;

1	Discriminate various stochastic processes depending on their utility.
2	Characterize certain physical systems with uncertainties as stochastic models.
3	Analyze the performance and the limitations of certain useful stochastic processes.
4	Simulate random processes.

Outline Syllabus:

1	**Stochastic models:** Markov chains, Poisson processes.
2	**Markov chains:** Branching processes, time reversible Markov chains, hidden Markov chains, Monte Carlo simulations, continuous-time Markov chains.
3	**Poisson process:** Counting processes, inter-arrival and waiting time distributions, further properties of Poisson processes, conditional distribution of the arrival times.
4	**Elementary queuing systems**: M/M/1, M/M/∞, M/M/m, M/M/1/K, M/M/m/m.
5	**Monte Carlo simulations.**

Module Code	EN5821	Title	Applied Information Theory	Credits: 3
Learning Outcomes: On completion of this module, students should be able to;				
1	Design a suitable lossless source code for a discrete memoryless source.			
2	Evaluate the information capacity of a discrete memory less channel.			
3	Calculate the rate distortion function of a given source.			
4	Apply principles of information theory to evaluate communication systems.			
Outline Syllabus:				
1	**Information measures**: Definition of information, information sources, information measures: self information, entropy, relative information, mutual information, information rate, inequalities: Jensen's, Fano's, data processing.			
2	**Lossless data compression:** Classes of codes, average length, Kraft's inequality, Huffman codes, existence of Huffman codes, optimality of Huffman codes, Shannon-Fano-Elias coding, arithmetic coding, practical examples for data compression.			
3	**Capacity of discrete channels:** Information capacity and operational capacity, capacity calculations of simple discrete memoryless channels, symmetric channels, preview of channel coding theorem: asymptotic equipartition property, jointly typical sequences, channel coding theorem.			
4	**The Gaussian channel**: The Gaussian channel, differential entropy, extension of the channel coding theorem for Gaussian channels, capacity of the Gaussian channel, bandlimited and parallel Gaussian channels.			
5	**Rate distortion theorem**: Rate distortion, rate distortion function, rate distortion theorem and its converse, computation of the rate distortion function.			

Module Code	EN5860	Title	Applied Statistical Learning	Credits: 3
Learning Outcomes: On completion of this module, students should be able to;				
1	Discriminate among different statistical learning techniques and related tools.			
2	Make inferences/predictions on parameters by using appropriate learning techniques.			
3	Analyze datasets by using state-of-the-art software tools.			
Outline Syllabus:				
1	**Supervised versus unsupervised learning.**			
2	**Bias-variance trade-off.**			
3	**Resampling techniques.**			
4	**Supervised learning techniques**: Linear regression, classification, SVM.			
5	**Unsupervised learning techniques:** Principal component analysis, K -mean clustering, nonnegative matrix factorization.			

Module Code	EN5461	Title	Statistical Signal Processing	Credits: 3

Learning Outcomes: On completion of this module, students should be able to;	
1	Classify various detection and estimation techniques and related analytical tools.
2	Derive optimal test statistics for a given detection scenario.
3	Estimate parameters of broad class of signals embedded in noise.
4	Estimate parameters of certain random processes.
5	Simulate detectors/estimators by using computational software.
Outline Syllabus:	
1	**Detection theory:** Statistical decision theory: Neyman-Pearson fundamental lemma, Minimax test; binary and M-ary hypotheses tests, detection of signals in noise (General Gaussian problem).
2	**Estimation theory:** Various estimators and their properties: Least squares, BLUE, ML; method of moments, Bayesian estimators (general/linear estimators), Kalman filters.
3	**Monte Carlo simulations.**

Module Code	EN5271	Title	Telecommunications Policy	Credits: 3

Learning Outcomes: On completion of this module, students should be able to;	
1	Evaluate the importance of telecom/ICT policy in Sri Lanka, and the process of successful policy development.
2	Assess ICT policies in other countries through case studies.
3	Identify the current telecommunication related policy issues in Sri Lanka and develop policy directives.
4	Evaluate investments proposals in telecommunications.
Outline Syllabus:	
1	**Role of telecommunications policies**: Global, regional, national and sectoral entities.
2	**Telecom/ICT policy initiatives:** At global and regional level, in Sri Lanka, lessons from the telecom/ICT policy initiatives of other countries.
3	**Process of public policy making.**
4	**Digitization and digital convergence.**
5	**Business and socioeconomic implications of telecommunications.**
6	**Arguments over natural monopoly, oligopoly and market competition.**
7	**The privatization of telecommunications.**
8	**Foreign direct investment in telecommunications.**
9	**Barriers to entry and strategic competition**
10	**Regulation**: Spectrum regulation, regulation of future networks, regulation over network interconnection, necessity and feasibility of telecommunications deregulation.

Module Code	EN5651	Title	Microwave Systems	Credits: 3

Learning Outcomes:

On completion of this module, students should be able to;

1	Design basic microwave components: Waveguides, antennas etc.
2	Realize a terrestrial microwave link for a given specification.

Outline Syllabus:

1	**Introduction**: Review of vector calculus, the electric and magnetic fields, Maxwell's equations.
2	**Rectangular waveguides**: Mode solutions, transverse electric and magnetic modes, cutoff wavelength, guide wavelength, phase and group velocity characteristics, wall currents, attenuation characteristics, design problems.
3	**The horn antenna**: The horn antenna as an impedance matching device, flared horn characteristics, corrugated horns.
4	**Microwave antennas**: Radiation, wire antennas: dipole, longwire antennas, axial mode helix; log periodic antenna, discone antennas, reflector antennas: corner, parabolic, cosecant; feeder design, realization of large reflector antennas, lens antennas, design problems.
5	**Terrestrial Microwave Links**: Tropospheric propagation, link power budget, diversity techniques.

Module Code	EN5631	Title	Wireless Networks	Credits: 3

Learning Outcomes:

On completion of this module, students should be able to;

1	Analyze and evaluate MAC, network and transport layer protocols designed for wireless networks.
2	Design algorithms for efficient implementation of resource constrained wireless networks
3	Compare different wireless network standards and provide recommendations on wireless networking solutions for a given application.
4	Use network simulators to evaluate advanced wireless networks.
5	Optimize the performance of wireless networks.

Outline Syllabus:

1	**Wireless networking systems and standards**: Wireless LANs, MANs, PANs and BANs, PHY, MAC, network and transport layer issues in wireless networks, challenges in wireless network design: power constraints, medium unreliability, mobility management, localization.
2	**Wireless networking protocols**: Development of MAC, network and transport layer protocols for wireless networks, performance evaluation, case study: wireless LANs.
3	**Advanced wireless networking techniques:** 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; modeling and analyzing: spatial modeling of wireless networks, performance evaluation, cross-layer design and optimization.
3	**Simulation of advanced wireless networks**: Simulation of wireless networks: OMNET++ simulator, implement algorithms, performance evaluation.

Module Code	EN5761	Title	Emerging Technologies	Credits: 1

Learning Outcomes:

On completion of this module, students should be able to;

1	Describe the set of technologies that are considered to be emerging.
2	Explain technical operation of emerging technologies.
3	Analyze the impact of emerging technologies on current telecommunication systems.

Outline Syllabus:

1	Guest lectures on the latest technologies used in communication systems.

Module Code	EN5870	Title	Pattern Recognition	Credits: 3

Learning Outcomes: On completion of this module, students should be able to	
1	Apply a few classic learning techniques in solving simple problems.
2	Describe the importance of concepts of deep networks to be able to implement in a simple form without using a framework.
3	Apply deep convolutional networks to solve common vision problems.
4	Apply deep recurrent networks to solve common natural language processing and similar problems.
Outline Syllabus:	
1	**Introductions to learning**: Probability and random variable, basics of pattern recognition, types of learning algorithms, datasets, training, gradient descent, stochastic gradient descent, linear regression, Baye's inference, bias-variance tradeoff, logistic regression.
2	**Deep networks**: Feed-forward networks, backpropagation, vanishing- exploding-gradients, activation functions, parameter norm penalties, regularization, data augmentation, dropout, parameter initialization, optimization algorithms, loss functions, performance metrics, selecting hyperparameters.
3	**Deep convolutional networks**: Convolution, pooling, padding, strided convolution, up-sampling, case studies of successful convolutional networks.
4	**Recurrent neural networks**: Recurrent neural network (RNN) models and notation, backpropagation through time, deep recurrent networks, vanishing gradient problem in RNNs, long short-term memory and gated recurrent units, bi-directional RNNs.
5	**Applications**: Applications in computer vision, natural language processing, telecommunications and autonomous driving.

Module Code	EN5281	Title	Network Planning and Management	Credits: 3

Learning Outcomes: On completion of this module, students should be able to;	
1	Describe the different stages in the network planning process.
2	Dimension a high level network for a given application considering all aspects of network planning and design.
3	Design an end to end network plan.
Outline Syllabus:	
1	**Network planning and dimensioning**: Link budget analysis, service area and morphology analysis, CW test and propagation model calibration, nominal radio network design, site acquisition, service deployment.
2	**Radio network planning.**
3	**Operation, administration, management and maintenance of services**: Network-level OA&M, configuration management, fault management, performance management, security management.
4	**Transport and core network planning.**

Module Code	EN5621	Title	Broadband Wireless Systems	Credits: 3

Learning Outcomes:

On completion of this module, students should be able to;

1	Design an OFDM system for given specifications.
2	Implement an OFDM system in software and evaluate its performance.
3	Analyze single-user and multiuser broadband systems.
4	Recommend and design broadband wireless solutions for a given requirement.

Outline Syllabus:

1	**Spread spectrum communications**: Spread spectrum principles: frequency-hopping spread spectrum, direct sequence spread spectrum, CDMA systems, CDMA transceiver techniques for single user and multiuse scenarios.
2	**Multicarrier modulations (MCM)**: Principles of MCM, OFDM systems: implementation, channel estimation, power allocation; issues: peak-to-average power ratio, timing and frequency offset, OFDM and MIMO.
3	**Advanced techniques wireless broadband:** Limitations of current systems, adaptive transmission, beamforming, interference coordination schemes, single carrier FDMA, filter bank multicarrier systems, cooperative communications, spectrum sharing systems, chirp spread spectrum.
3	**Broadband techniques in standards**: Spread spectrum techniques: 3G cellular, wireless LANs, LoRa WAN, MCM, LTE, wireless LAN, LTE-A, WiMAX.

Module Code	EN5981	Title	Industrial/Research Project	Credits: 5

Learning Outcomes:

On completion of this module, students should be able to;

1	Explain specific issues related to the chosen project by cross referencing with the literature.
2	Demonstrate analytical skills required for advanced research.
3	Write a comprehensive survey paper.
4	Prepare a detailed proposal for M.Sc. research

Outline Syllabus:

1	Literature survey relevant to the topic selected under the guidance of a senior staff member.

Module Code	EN5691	Title	Network Security	Credits: 3

Learning Outcomes:

On completion of this module, students should be able to;

1	Explain principles related to modern cryptography and network security.
2	Identify various encryption concepts, ciphers, symmetric/asymmetric key encryption schemes, and digital signatures used in practical systems.
3	Compare and contrast methodologies that are currently being used to secure network communications in practice.
4	Detect security threats and propose state-of-the-art attack detection and prevention mechanisms for a system.

Outline Syllabus:

1	**Symmetric ciphers:** Symmetric encryption: classical and modern algorithms, data encryption standard (DES), advanced encryption standard (AES), stream encryption algorithm: RC4, pseudorandom number generation.
2	**Asymmetric ciphers:** Public-key algorithms: RSA and elliptic curve.
3	**Cryptographic data integrity algorithms:** Cryptographic hash functions, message authentication codes, digital signatures.
4	**Mutual trust:** Key management, key distribution, user authentication techniques.
5	**Network security and internet security:** Using cryptographic algorithms and security protocols for network security, transport-level security, wireless network security, e-mail security, IP security.
6	**System security:** Protecting a computer system from security threats: intruders, viruses, worms; firewall technology.
7	**Novel applications:** Security issues related to 5G, software defined networking (SDN) and blockchain based systems.

Module Code	EN5681	Title	Optical Communication and Networks	Credits: 3
Learning Outcomes: On completion of this module, students should be able to;				
1	Describe different properties of optical fiber that influence characteristics of propagation.			
2	Explain the operation of different optical devices used in an optical communication systems.			
3	Analyze the effectiveness of the modulation techniques, optical amplification and other optical aggregation and dynamic routing methods.			
4	Analyze the impact of noise and different optical impairments in designing optical systems.			
5	Design an optical communication system for a given set of requirements.			
Outline Syllabus:				
1	**Guided optical media:** Optical fibers and classification, Ray theory, theory of optical wave propagation, fiber attenuation, fiber absorption, polarization, chromatic and polarization mode dispersion.			
2	**Transmission system components:** Optical sources, optical receivers, couplers, isolators, optical modulators, wavelength converters, fiber amplifiers, arrayed waveguide grating, fixed/reconfigurable optical add drop multiplexer.			
3	**Optical measurement techniques**: Optical signal to noise ratio (OSNR), eye diagrams, bit error rate (BER).			
4	**Optical fiber communication systems:** WDM architecture, OTDM architecture, OTN architecture, optical access networks, digital modulation formats, direct optical detection, receiver concepts in optical communication, coherent optical transmission, optical burst switching.			
5	**Optical system design**: Link budget calculation, noise considerations, impairment consideration.			

Elective Modules from PG. Diploma/M.Sc. in Electronics and Automation

Module Code	EN5450	**Module Title**	Digital Signal Processing	**Credits:** 3
Learning Outcomes At the end of the module the student will be able to:				
1	Analyze discrete-time (DT) linear and time-invariant (LTI) systems in transform domains.			
2	Determine the discrete Fourier transform (DFT) of finite-duration discrete-time signals using fast Fourier transform (FFT) algorithms.			
3	Design FIR and IIR DT filters for prescribed specifications.			
4	Analyze basic muti-rate systems and design sampling rate changing systems.			

5	Examine errors associated with the physically realizable A/D and D/A conversions.	
6	Implement digital filters using suitable structures by evaluating finite-precision numerical effects.	
Outline Syllabus		
1	**Review of time-domain and frequency-domain analysis of DT signals and systems** Basic DT signals; properties of DT systems; LTI systems and convolution summation; discrete-time Fourier transform; frequency domain analysis of LTI systems. continuous-time to DT conversion; Nyquist-Shannon sampling theorem; reconstruction of continuous-time signals from DT signals.	
2	**Analysis of LTI systems using z-transform** Review of 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; Jury-Marden stability criterion; properties of pole-zero plots of special DT LTI systems: finite-duration impulse response (FIR) filters; infinite-duration impulse response (IIR) filters; minimum-phase filters; all-pass filters.	
3	**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, orthogonal frequency division multiplexing (OFDM), and narrowband multi-beam beamformers.	
4	**FIR and IIR Filter Design** Frequency-domain representation of LTI systems; magnitude response and phase response; importance of linear-phase response; filter specifications; classification of DT filters and design methods; design of FIR filters using windowing method; design of IIR filters using the impulse invariance and bilinear transform methods. Design of FIR and IIR filters using optimization techniques.	
5	**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 changing systems.	
6	**Digital Processing of Analog Signals and Finite-Precision Numerical Effects** A/D conversion, quantization errors, D/A conversion, basic structures for DT LTI systems: direct forms, cascade form, parallel form, transposed forms; quantization in digital filters, effects of coefficient quantization, effects of round-off noise, zero-input limit cycles in IIR digital filters.	

Module Code	EN5204	**Module Title**	Vision Based Automation	**Credits:** 3
Learning Outcomes At the end of the module the student will be able to:				
1	Apply image processing algorithms for image enhancement			
2	Apply machine vision algorithms for detection and recognition			
3	Apply visual SLAM for mapping and autonomous navigation			
4	Design machine vision solutions for common industry problems.			
Outline Syllabus				
1	**Introduction** (a) Introduction to computer vision (b) Getting started with OpenCV using Python (c) Projection, cameras, light, shading, and colour (d) Representation of a grayscale and colour images (e) concepts of resolution and DPI			
2	**Digital representation of images** (a) Interpolation algorithms for image scaling (b) Morphological operations (c) Frequency domain processing (d) Point operations, histograms, linear filtering (e) Spatial filtering (f) Edges, corners, blobs, lines			
3	**Multiple-view geometry** (a) Camera calibration, measurements using a camera (b) Epipolar geometry (c) Two-view stereo (d) Structure from motion			
4	**Segmentation** (a) Thresholding (b) Region growing (c) Watersheds (d) Active contours (optional) (e) Introduction to mean-shift, level-sets, and graph-cuts (optional) (f) Introduction to semantic segmentation			

5	**Vision-based automation** (a) Introduction to SLAM (b) Recursive state estimation (c) Parametric Filters: Kalman filter and extended Kalman filter (d) Visual SLAM (e) Visual servoing	

6	**Recognition** (a) Classifiers, multi-layer perceptions, and convolutional neural networks (b) Image classification (c) Object detection	
7	**Applications** (a) Set-up of a vision system in industry (b) Typical industry problems and solution**s**	

Module Code	EN5202	**Module Title**	Electronic Circuit Design	**Credits:** 2
Learning Outcomes At the end of the module the student will be able to:				
1	Analyze the control-to-output transfer function of a switched-mode power converter			
2	Investigate a suitable compensator to close the feedback loop			
3	Implement the feedback loop using analog and digital techniques			
Outline Syllabus				
1	**Derive transfer functions** Derive control-to-output, output impedance and input-to-output small and large-signal models using state-space model and average switch models, use the software tools to obtain transfer functions			
2	**Compensator types** Analyse the properties of proportional, proportional-integral and proportional-integral-derivative compensators, their realisation using analog and digital techniques			
3	**Design the feedback loop** Design the voltage and current feedback sensors, model the feedback circuit, analyse the stability of the open-loop and closed-loop system using Bode and Nyquist plots			

Module Code	EN5102	**Module Title**	Digital Systems Design	**Credits:** 3
Learning Outcomes At the end of the module the student will be able to:				
1	Design sequential circuits using Verilog HDL.			
2	Apply the digital design concepts to programmable logic devices.			
3	Analyze the concepts of asynchronous sequential systems.			
4	Analyze the concepts of SoC and NoC.			
Outline Syllabus				
1	**Introduction** IC design process, testing and yield, packing techniques, and timing considerations.			

2	**RTL Coding and Verification** Background, module and port definitions, coding styles, Verilog syntax, test methodology.	
3	**System Bus Architecture** Bus definitions, background, computer system bus, PCI, PCIe, reusable IPs, bus design parameters, AMBA bus APB, and AHB protocol.	
4	**Reconfigurable Hardware** Introduction, PROM, PAL, PLA, NOR-NOR PLA, NAND-NAND PLA, PAL Macrocell, and GAL, , SPLD vs CPLD, FPGA.	
5	**Embedded Systems** ES design. SW development, accelerated system architecture, RT control systems, low power designs, dynamic power management, and task scheduling.	
6	**Hardware Software Codesign** Codesign benefits, power comparison, low power design, reusable IPs, HW-SW co-design flow, and co-design environments.	
7	**Asynchronous Sequential Systems** Synchronizer circuits, Metastability, clock domain crossing, asynchronous data transfer, handshake techniques, and FIFO design.	
8	**SoC & NoC** System on chip, interconnect modelling, Bus pros and cons, network on chip, network topologies, and switching techniques.	

Module Code	EN5008	**Module Title**	RF Circuit Design	**Credits:** 2
Learning Outcomes At the end of the module the student will be able to:				
1	Estimate the link budget for a radio-frequency (RF) system consisting of active and passive components.			
2	Analyze and design transmission lines and impedance matching circuits for microwave circuits with prescribed specifications.			
3	Analyze and design microwave filters for prescribed specifications.			
4	Estimate the noise figure and dynamic range of RF systems.			
Outline Syllabus				
1	**Introduction to RF circuit design and Review of Electromagnetic Theory** History of RF engineering; applications of RF (microwave and mmwave) engineering; modern software tools; Maxwell's equations; fields in media and boundary conditions; basic plane wave solution, energy, and power; polarization; plane wave reflection from a media interface.			

2	**Transmission Line Theory** The lumped-element circuit model; field analysis of transmission lines; the smith chart; the quarter-wave transformer; generator and load mismatches; lossy transmission lines.	
3	**Introduction to RF Systems** System aspects of antennas; antenna parameters: e.g., radiation pattern, beamwidth, directivity, efficiency, gain, and impedance; antenna types: dipole, microstrip, horn, parabolic; the Friis formula; link budget and link margin; radio receiver architectures.	
4	**Transmission Lines and Waveguides** General solutions for TEM, TE, and TM waves; rectangular waveguides; circular waveguides; surface waves on a grounded dielectric sheet; strip lines and microstrip lines.	
5	**Microwave Network Analysis** Impedance and equivalent voltages and currents; impedance and admittance matrices; the scattering matrix; the transmission (ABCD) matrix.	
6	**Impedance Matching and Tuning** Matching with lumped elements; single-stub tuning; double-stub tuning; the quarter-wave transformer; multi section matching transformers: binomial and Chebyshev.	
7	**Microwave Filters** Periodic structures; filter design by the image parameter method; filter design by the insertion loss method; filter transformations; filter implementations.	
8	**Noise and Nonlinear Distortion** Noise in microwave circuits; noise power and equivalent noise temperature; noise figure; noise figure of a cascaded system; nonlinear distortion: gain compression	
	harmonic and intermodulation distortion, third-order intercept point; linear and spurious free dynamic range.	

Module Code	**EN5730**	**Title**	**Machine Learning for Communications**	**Credits: 3**
Learning Outcomes: On completion of this module, students should be able to;				
1	Understand the fundamentals of machine learning (ML) and its applications in communication systems.			
2	Identify different machine learning approaches relevant to the physical layer.			
3	Design and implement machine learning models to solve physical layer problems.			
4	Discuss 3GPP standardization on machine learning in communication technologies.			
Outline Syllabus:				

1	**Introduction and ML basics:** What ML is, supervised learning, unsupervised learning, reinforcement learning, gradient descent and backpropagation, deep neural networks, convolutional neural networks, graph neural networks, autoencoders, deep reinforcement learning, ML tools for communication system design
2	**Review Fundamentals of Wireless Communications :** Source coding, channel coding, signal detection, channel capacity, multiple-input multiple-output (MIMO) systems, orthogonal frequency division multiplexing (OFDM)
3	**Applications of ML for Communications :** Signal detection, channel estimation, channel coding, capacity estimation, model-based machine learning, model-free machine learning, radio resource allocation
4	**3GPP Standardization on Machine Learning Activities, Open Problems and Challenges :** 3GPP Rel. 18 ML activities, remaining challenges, and opportunities in applications of machine learning in communications

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