DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

Ph.D. Entrance Test (Written) (Spring 2018-19)

Instructions for Candidates

1. The written examination duration is 1 hour (10 – 11 AM).

2. Candidates are required to attempt questions from **ONLY ONE SECTION**, out of these three sections:

   (A) Microelectronics and VLSI
   (B) Communication Systems
   (C) RF and Microwave Engineering

3. Candidates having their M.Tech. degree from IITs/IISc with CGPA 7.5 or more **NEED NOT** to appear the written test and they can directly come for the interview to be held on 16th October 2018. Candidates should bring the original certificate to verify the CGPA.

4. Candidates having valid fellowships like CSIR JRF, UGC NET, DST INSPIRE etc. **NEED NOT** to appear the written test and they can directly come for the interview to be held on 16th October 2018. They should come with the original fellowship letter.

Syllabus: (A) Microelectronics and VLSI

I. Semiconductor Devices and Basic Physics:

Energy band and diagrams: Intrinsic and extrinsic semiconductors, carrier statistics, and thermal equilibrium carrier concentration.
Excess carriers in semiconductors: Excess carriers, lifetime, and carrier transport by drift and diffusion; Continuity equation and its solution under different injections; Solution of diffusion equation in uniformly doped base long and short base limits.
Theory of PN junctions: Steady state I-V characteristics under forward bias, reverse bias and illumination; Dynamic behavior under small and large signals; Breakdown mechanisms (qualitative); Metalsemiconductor junctions, ohmic and rectifying contacts.
MOS Capacitor: Energy band diagram of Metal-Oxide-Semiconductor contacts, Mode of Operations: Accumulation, Depletion, Mid-gap, and Inversion, 1D Electrostatics of MOS, Depletion Approximation, Accurate Solution of Poisson's Equation, CV characteristics of MOS, LFCV and HFCV, Non-idealities in MOS, oxide fixed charges, interfacial charges, Mid-gap gate Electrode, Poly-Silicon contact, Electrostatics ofnon-uniform substrate doping, ultrathin gate-oxide and inversion layer quantization, quantum capacitance, MOS parameter extraction.
Physics of MOSFET:Drift-Diffusion Approach for IV, Gradual Channel Approximation, Sub-threshold current and slope, Body effect, Pao&Sah Model, Detail 2D effects in MOSFET, High field and doping dependent mobility models, High field effects and MOSFET reliability issues (SILC, TDDB, & NBTI), Leakage mechanisms in thin gate oxide, High-K-Metal Gate MOSFET devices and technology issues, Intrinsic MOSFET capacitances and resistances, Meyer model.

Special devices: Introduction to solar cells, light emitting diodes, semiconductor laser and related devices.
Fundamental Concepts: Scalar and vector fields; Physical interpretation of gradient, divergence and curl; Coordinate systems; Review of static fields; Current continuity equation; Displacement current; Maxwell's equations.
Statistical distributions: Maxwell-Boltzmann, FermiDirac distributions;
Quantum mechanics: Basic postulates of quantum mechanics and physical meaning of the wave function, Schrödinger wave equation, stationary states, expectation values, Particle in a 1-D box.

II. Logic Elements/Systems and Mathematics:

Number systems and Boolean algebra: Introduction to number system and Boolean algebra; Boolean identities, basic logic functions, standard forms of logic expressions, simplification of logic expressions.
Combinational logic: Arithmetic circuits, decoders, encoders, multiplexers, de-multiplexers, and their use in logic synthesis; Hazards in combinational circuits.
Sequential logic circuits: Latches and Flip Flops (SR, D, JK, T); Timing in sequential circuits; Shift register; Counters – synchronous, asynchronous.
Finite state machines: Basic concepts and design; Moore and Mealy machines examples; State minimization/reduction, state assignment.
Review of Fourier series and its exponential representation; Fourier transform and its properties, relationship between Fourier transform and Fourier series; Generalized Fourier transform; Amplitude and phase spectra, energy and power spectral density, signal bandwidth.
Relationship of Laplace and Fourier transforms; Transfer function and its block diagram representation, convolution integral and the Fourier transfer function; System properties, linearity and time invariance, bandwidth.
Review of z-transform and its properties, geometric evaluation of Fourier transform from pole-zero plot; Discrete time Fourier transform and its properties; Discrete convolution and duality; Discrete Fourier transform and its properties; Computation of discrete time Fourier transform and discrete Fourier transform, approximation of Fourier transform and discrete convolution using discrete Fourier transform.
Difference equation, impulse response, convolution sum and transfer function representation of discrete time linear time invariant systems; Transform analysis and networks structures for discrete-time systems.
Distortion less transmission, ideal and non-ideal filters, Butterworth and Chebyshev filters; Time and frequency domain analysis of continuous time LTI systems.
Concept of probability, random variable and distribution function: discrete and continuous, moments and moment generating functions.
Matrix Algebra: Elementary operations and their use in getting the Rank, Inverse of a matrix and solution of linear simultaneous equations. Orthogonal, Symmetric, Skew-symmetric, Hermitian, Skew-Hermitian, Normal & Unitary matrices and their elementary properties. Eigen-values and Eigenvectors of a matrix, CayleyHamilton theorem, Diagonalization of a matrix.
Differential Calculus: Limit, Continuity and differentiability of functions of two variables, Euler's theorem for homogeneous equations, Tangent plane and normal. Change of variables, chain rule, Jacobians, Taylor's Theorem for two variables, Error approximations. Extrema of functions of two or more variables, Lagrange's method of undetermined multipliers.
Integral Calculus: Review of curve tracing and quadric surfaces, Double and Triple integrals, Change of order of integration. Change of variables. Gamma and Beta functions. Dirichlet's integral. Applications of Multiple integrals such as surface area, volumes, center of gravity and moment of inertia.

Vector Calculus: Differentiation of vectors, gradient, divergence, curl and their physical meaning. Identities involving gradient, divergence and curl. Line and surface integrals. Green's, Gauss and Stroke's theorem and their applications.

III. Circuits and Network Theory:

Basic Diode Circuits and MOSFET models: Equivalent circuit of PN junction diode, half and full wave rectifiers, voltage regulation, limiting circuits, level shifters, Review of large signal I-V relations, trans conductance, output resistance, device capacitances, small-signal equivalent circuit, transit frequency.
Single-stage Amplifiers and Current Mirrors: Brief overview of biasing of MOS amplifiers, Common Source (CS) amplifiers, CS amplifier with source degeneration, common gate amplifiers, common drain amplifiers, MOS cascode amplifiers, MOS current mirrors, cascode current mirrors.
Differential Amplifiers: MOS differential pair's large signal analysis, small signal analysis of differential pairs, cascode differential amplifiers, common-mode rejection, and differential amplifiers with active load.
Frequency Response: Brief overview of poles and zeroes in transfer functions and Bode's rules, association of poles with nodes in multistage amplifiers, frequency response of single-stage amplifiers (common source, common emitter, common gate, common base, source follower, emitter follower), frequency response of cascode and differential amplifiers, input and output impedances of amplifiers.
Feedback and Oscillators: Impact of negative feedback on properties of amplifiers (Gain, linearity, bandwidth and I/O impedances), feedback topologies (voltage-voltage, voltage-current, current-voltage and current-current), examples circuits for each feedback topology, stability in feedback amplifiers (stability condition, phase and gain margins, frequency compensation), Ring oscillators, LC Oscillators (LC tanks, cross-coupled), phase shift oscillators, wien-bridge oscillators, brief discussion on crystal oscillators.
CMOS Design Examples: Two-stage OPAMP, Gilbert cell, phase shift oscillator.
OPAMP Basics an d Applications: Basic OPAMP configurations and characteristics, OPAMP non-idealities, digital to analog and analog to digital converters - basic conversion techniques and errors, precision amplifier, logarithmic amplifier, square-root amplifier.
CMOS inverter: Static characteristics, power consumption, dynamic behavior.
Combinational logic: Transistor sizing in static CMOS logic gates, static CMOS logic gate sizing considering method of logical effort, dynamic logic, pass-transistor logic, common mode and other cross-coupled logic families.
Sequential logic: Static latches and flip-flops (FFs), dynamic latches and FFs, sense-amplifier based FFs, NORA-CMOS, Schmitt trigger, monostable and astable circuits.
Memories and array structures: MOS-ROM, SRAM cell, memory peripheral circuits, signal to noise ratio, power dissipation.
Network Theorems: Basic nodal and mesh analysis, linearity, superposition and source transformation, Thevnin's, Norton's and maximum power transfer theorem and useful circuit analysis techniques, network topology, introduction to SPICE in circuit analysis.
Transient Analysis: Source free RL and RC circuits, unit step forcing function, source free parallel and series RLC circuit, complete response of the RLC circuit, lossless LC circuit.
Frequency Domain Analysis: The phasor concept, sinusoidal steady state analysis; AC circuit power analysis.
Two Port Networks: Z, Y, h and ABCD parameters, analysis of interconnected (magnetically coupled) two port, three terminal networks.
RL & RC Network Synthesis: Synthesis of one-port networks, transfer function synthesis, basics of filter design.

Syllabus: (B) Communication Systems

Networks, Signals and Systems

Network solution methods: nodal and mesh analysis; Network theorems: superposition, Thevenin and Norton's, maximum power transfer; Wye-Delta transformation; Steady state sinusoidal analysis using phasors; Time domain analysis of simple linear circuits; Solution of network equations using Laplace transform; Frequency domain analysis of RLC circuits; Linear 2-port network parameters: driving point and transfer functions; State equations for networks.

Continuous-time signals: Fourier series and Fourier transform representations, sampling theorem and applications; Discrete-time signals: discrete-time Fourier transform (DTFT), DFT, FFT, Z-transform, interpolation of discrete-time signals; LTI systems: definition and properties, causality, stability, impulse response, convolution, poles and zeros, parallel and cascade structure, frequency response, group delay, phase delay, digital filter design techniques.

Communications

Random processes: autocorrelation and power spectral density, properties of white noise, filtering of random signals through LTI systems; Analog communications: amplitude modulation and demodulation, angle modulation and demodulation, spectra of AM and FM, superheterodyne receivers, circuits for analog communications; Information theory: entropy, mutual information and channel capacity theorem; Digital communications: PCM, DPCM, digital modulation schemes, amplitude, phase and frequency shift keying (ASK, PSK, FSK), QAM, MAP and ML decoding, matched filter receiver, calculation of bandwidth, SNR and BER for digital modulation; Fundamentals of error correction, Hamming codes; Timing and frequency synchronization, inter-symbol interference and its mitigation; Basics of TDMA, FDMA and CDMA.

Syllabus: (C) RF and Microwave Engineering

Electrostatics:

Maxwell's equations: differential and integral forms and their interpretation, boundary conditions, wave equation, Poynting vector;

Plane waves and properties: reflection and refraction, polarization, phase and group velocity, propagation through various media, skin depth;

Transmission lines: equations, characteristic impedance, impedance matching, impedance transformation, S-parameters, Smith chart;

Waveguides: modes, boundary conditions, cut-off frequencies, dispersion relations;

Antennas: antenna types, radiation pattern, gain and directivity, return loss, antenna arrays;

Radar Systems: Detection of signals in noise, Basic Radar Functions, Elements of a pulsed radar system, Matched filter and Radar waveforms, MTI and Pulse Doppler radar

Microwave Network Analysis and Circuits Design: Impedance and admittance matrices, common microwave 2-port, 3-port and 4-port networks and their properties, impedance matching, transistor amplifier design, low noise amplifier and mixers.

Light propagation in optical fibers.