Syllabus for Ph.D. Written Test (May 2018)

Part A:
This part deals with general mathematical ability for Ph.D. level research in Electrical Engineering. Some topics that could be tested are: Principles of Calculus: Maxima/minima, derivative, integral, elementary multivariate calculus. Basic Transform Theory: Laplace and Fourier transforms. Elementary Linear Algebra and Matrix Theory. Basic probability theory. Basic differential equations.

Vector analysis and vector calculus: divergence, gradient, curl. Complex analysis.

Basic Series expansions: Taylor series. In addition, mathematical principles learned at high school and in the first couple of years in an Undergraduate Degree, could be tested.

Part B:

EE1 (Communication and Signal Processing):

Basic Electrical and Electronic Circuits
Basic Network Theory

Signals and Systems:
- Continuous-time and discrete-time signals and systems
- LTI systems and representations
- Sampling and reconstruction
- Transform domain analysis (Fourier, Laplace, and Z-transforms),
- Basics of filter design

Signal Processing:
- Representation of signals on orthogonal basis
- Discrete systems: attributes, Z-Transform
- Analysis of LSI systems, Frequency analysis, Inverse Systems,
- Discrete Fourier Transform (DFT)
- Fast Fourier Transform algorithm

Probability and Random Processes:
- Random variables, Expectation Theory, Generating functions,
- Cumulative distribution functions (CDFs), Probability density functions (PDFs), conditional CDFs and PDFs, conditional expectation, functions of one and two random variables
- Probability inequalities (e.g., Markov, Chebyshev, Chernoff, Schwartz)
- Random vectors, Joint CDFs and PDFs, Joint moments, Joint characteristic functions
- Laws of large numbers, Central limit theorem
- Gaussian processes, Power spectral density
- Basics of detection and estimation.

Analog and Digital Communications:
- Modulation techniques, Signal representation, Quantization,
- Power and bandwidth considerations
- Noise in communication systems
- Entropy and mutual information, Data compression techniques
- Probability of error in digital communications

Communication Networks:
- ARQ strategies
- MAC protocols
- Routing algorithms

Electromagnetic Waves and Antennas:
- Maxwell’s equations
- TEM modes in a linear homogenous isotropic medium
- TEM waves incident on a boundary, Snell’s laws, wave propagation inside a conductor
- Transmission lines, impedance matching, Smith chart
- Rectangular and cylindrical waveguides
- Electromagnetic radiation, antenna gain, radiation resistance, radiation pattern
- Study of some standard antennas – dipole, array, aperture, horn and optical

**EE2 (Control and Computing):**

Electrical and Electronic Circuits
Basic Network Theory

Signals and Systems:
- Continuous-time and discrete-time signals and systems
- LTI systems and representations
- Sampling and reconstruction
- Transform domain analysis (Fourier, Laplace, and Z-transforms),
- Discrete Fourier transforms (DFT)
- Basics of filter design

**Basics:** Maxima/minima, polynomials and their roots.

**Linear algebra:** Rank of a matrix, solutions to Ax=b, vector space, basis, eigenvalues, eigenvectors.

**Mathematical modelling:** Dynamical equations of passive electrical systems, mechanical systems with spring-mass-dashpot, electromechanical systems. Transfer functions. Block diagrams.

**Stability:** Routh-Hurwitz criteria.

**Analysis in time-/frequency-domain:** Impulse/step response, poles and zeros, root-locus, Bode-plots, Gain/phase margins, low-pass/high-pass characteristics, Nyquist plots, Nyquist criterion for stability.

**Design:** Controller synthesis for reduced steady state error, faster transients:
PD, PID, lead, lag compensators.

**State space systems:** Controllability/observability: definition and tests, pole-placement using state-feedback, PBH test.
Optional topics for candidates with CS background: Modelling systems through graphs, use of elementary graph algorithms such as depth first search and breadth first search, shortest path etc.

EE3 (Power Electronics and Power Systems):

(i) Basic Electrical and Electronic Circuit Analysis, Signals and Systems and Electric and Magnetic Fields.

(ii) Basic Concepts of Feedback Control Systems (Transfer Function and State Space Analysis, Step Response, Transient and Steady State analysis).

(iii) Principle of operation and speed control of Electric machines: dc, induction, synchronous and special machines.

(iv) Power electronics: Principle of operation of line commutated ac to dc converters, unity power factor voltage source ac to dc converters, dc to dc converters like buck, boost, buck-boost and Cuk converters, isolated dc to dc converters like flyback, forward and push pull converters, dc to ac inverters. Various pulse width modulation techniques like SPWM, Space vector pulse width modulation technique etc.


EE4 (Microelectronics):

There will be 2 question papers in EE4. One paper predominantly based on circuits & VLSI, and another on devices. Students will have to choose one of the papers.

I. Circuits and VLSI division

Circuits and VLSI division of EE4 will have questions based on the following topics.
- Basic Electrical and Electronic Circuits
- Basic Network Theory
- Linear and Non-linear Circuits (discrete and integrated)
- Basic CMOS analog circuits
- Basic CMOS digital circuits
- Basics of semiconductor devices, for example P-N junctions.

Suggested references:
1) Basic electronic devices and circuits by Mahesh B. Patil
2) Microelectronic circuits by Sedra and Smith
II. Devices

Devices division of EE4 will have questions based on the following topics.
(a) Crystal structure basis, basic quantum mechanics (particle in a box, barrier tunnelling), electrons in solids, energy band theory, charge carriers in semiconductors, drift-diffusion theory, p-n junctions, MOS capacitors, field-effect transistors, bipolar junction transistors, LEDs and solar cells.

Suggested references:
1) Semiconductor devices fundamentals by R. Pieeret
2) Solid state electronic devices by Streetman and Banerjee
b) Basic electronic circuits (suggested reference: Basic electronic devices and circuits by Mahesh B. Patil)

EE5 (Electronic Systems):

Basic Electrical and Electronic Circuits
Basic Network Theory

Signals and Systems:
- Continuous-time and discrete-time signals and systems
- LTI systems and representations
- Sampling and reconstruction
- Transform domain analysis (Fourier, Laplace, and Z-transforms),
- Basics of filter design

Signal Processing:
- Representation of signals on orthogonal basis
- Discrete systems: attributes, Z-Transform
- Analysis of LSI systems, Frequency analysis, Inverse Systems,
- Discrete Fourier Transform (DFT)
- Fast Fourier Transform algorithm

Funding support for PhD

Project Research Assistant (PA) positions may also be available through sponsored research projects being undertaken by faculty members of the department. Normally, research work leading to PhD may be closely related to the objectives of the respective project and the supervisor of the PhD thesis will be the principal investigator/investigator of the project. The information about such sponsored projects along with their titles, project investigators and a brief abstract of the projects will be made available at the time of written test. Candidates will be required to give their preferences about the projects at the time of interview.