Syllabus for ECE Qualifying Examination
Subject Area: Circuits and Devices

The Circuits and Device area Subject Area Exam tests for the physical understanding of the behavior of semiconductor electronic devices and the principles underlying the behavior, and the ability and understanding of the design, analysis, and limitations of fundamental circuits.

This therefore includes the breadth of the behavior of electrons and holes and their transport in devices; modeling of that behavior in static, low frequency and high frequency conditions; and the application of such devices to circuits. Students are expected to demonstrate an understanding of devices (diodes, transistors and memories), transfer functions, feedback, and the limitations to the analysis of the physical behavior and models and the limits this places on their applicability.

A list of Topical Areas in Circuits includes:

- Derive transfer functions of RLC circuits in Laplace and Fourier domains and be able to sketch the Bode plot of a transfer function.
- Apply Millers theorem to an amplifier with feedback (This includes real amplifiers such as common-source, common drain, etc).
- Analyze basic op-amp circuits assuming an ideal op-amp.
- Draw complete (with capacitors) small-signal model of a MOSFET or BJT.
- Bias and Analyze a i) common source/common emitter amplifier, ii) common drain/common collector amplifier, and iii) common gate/common base amplifier for small signal gain, Zin and Zout for both low- and high-frequency cases (ie with and without including capacitors)
- Analyze a CMOS inverter in large signal, low frequency behavior, both single and multi-stage
- Analyze a cascode amplifier at low frequency for small signal gain, Zin and Zout.
- Analyze a differential pair at low frequency for small signal gain, Zin and Zout.
- Perform small-signal high-frequency analysis of an active current mirror.
- Calculate common-mode gain of a differential pair biased with a current mirror.
- Calculate the gain and transfer function of a simple op-amp.
- Be able to estimate the input impedance of an op-amp or other large amplifier.
- Calculate open- and closed-loop transfer function of a feedback loop in the following situations
  - Op-amp circuits
  - Common mode feedback
- Be able to describe the benefit of feedback for:
  - Increase bandwidth
  - Improve linearity
  - Stabilize unstable systems
- Understand noise sources due to pn-junctions, BJTs, MOSFETs, and flicker.
A list of Topical of Areas in Devices includes:

- Electrons and holes in semiconductors (donors, acceptors, carrier populations, thermal equilibrium, electrostatic potential, Fermi energy, quasi-Fermi energy, temperature dependences, transport by drift and diffusion, generation and recombination).
- Energy description of device structures via band diagrams (conduction and valence band edges, quasi-Fermi energy and heterostructures).
- Junctions and diodes (metal-semiconductor junctions, ohmic contacts based on tunneling and interface recombination, p/n junction) in static, quasistatic, dynamic, and at high frequencies and their models.
- MOS junction (charge analysis, low-frequency, high frequency, deep depletion behavior, inversion layers, quantum-confinement effects).
- MOSFET (sheet charge modeling of MOSFET, gradual channel approximation, characteristics in sub-threshold and supra-threshold conditions with drift and diffusive flow, quasistatic and small-signal models).
- MOSFET at small scale (scaling, short channel effects, parasitic bipolars, gate tunneling, drain-induced barrier lowering, gate-induce drain leakage, hot electron effects, Instabilities and stress-induced leakage currents, and transistors based on SOI, double-gate, strain, high-permittivity and fins).
- Memories (static and dynamic random access memories, non-volatile FLASH memories)
- Bipolar transistors (Design, polysilicon emitters, Ebers-Moll models, breakdown, Gummel plots, graded heterostructure bases, SiGe, IIIV, high frequency and digital models).
- Noise (Thermal, shot and 1/f noise, and such noise in MOSFETs and bipolar transistors)