Some Prerequisites in Electrical Engineering and Information Technology

- Analogue Circuit Analysis
- Electronic Devices and Circuits
- Solid State Electronics
- Electromechanic Fields and Waves

Analogue Circuit Analysis

Prerequisits: Linear algebra, vector analysis, matrix analysis and complex calculus.

Course objectives:
The student will gain an insight in the analysis and evaluation of DC as well as AC circuit analysis. The course will discuss linear analogue networks, ideal operational amplifier networks, bridge networks, one and two–port networks, RLC networks, transformers and polyphase circuits. Power considerations will be made as well as frequency response of sinusoidal signals. Frequency plots and Bode plots are introduced. At the end of the course, the student is supposed to recite, paraphrase and apply the concepts in problem solving of all topics covered. Also, the student is supposed to be able to analyse, design, evaluate and optimise a circuit with repect to a certain parameter such as power or frequency response.

Contents in key words:

1. Introduction to circuit analysis
Definitions, Kirchhoff's Laws, Physical Resistors, Simple networks with resistances, Current and voltage sources, Power, power transfer and optimisation of the power factor in DC

2. DC circuit analysis
Mesh and Nodal analysis, Graph of a network, trees and cotrees, Superposition, ⊗ – Y Transform, Y – ⊗ Transform, Thévenin's Theorem and Norton's Theorem

3. Operational amplifier circuits
Input and output parameters, Amplifier circuits

4. AC circuit analysis
Introduction to sinusoidal analysis – Phasors, Sinusoidal responses of simple R, L and C networks, Complex Numbers, Complex Excitation – AC steady-state analysis, Impedance – Admittance, Complex response to of simple R, L and C networks

5. Power
Average Power, apparent power, reactive power, Effective values, Complex Power, Power Measurement, Power transmission in AC (source to load)

6. Bridge networks

7. Frequency response plot of impedance and admittance
Frequency response plot of simple R, L, C networks, $\underline{Z}$ ™ $\underline{Y}$ conversion

8. RLC networks
Series RLC networks, Parallel RLC network, General form of the quality factor Q

9. One–port networks
Linear one–port networks with passive elements, Linear one–port networks including dependent sources, Source transformation, One–port networks including independent sources

10. Two-port networks
Definition of two-port networks, Parameters, Calculus of two-port matrices, Series, parallel and cascaded connection of two-port networks, Impedance transformation and transmission lines

11. Frequency response plots of $\underline{U}_2/\underline{U}_1$
First order filter, Second order filter

12. Bode-plots
Logarithm and Decibel, Bode plots

13. The Transformer
Transformer equations, Equivalent circuits of transformers, Frequency response of transmitters, Power transformer

14. Polyphase Circuits
Three-phase circuits

Literature:

(1) Johnson, DE, Johnson, JR and Hilburn, JL: Electric Circuit Analysis. Prentice Hall, 2nd edition, 1992 [JJH92]
(2) Hyat, WH jr and Kemmerly, JE: Engineering Circuit Analysis. McGraw Hill International Editions, Electrical Engineering Series, 1993 [HK93]
(3) For chapter 3 “Operational Amplifier” only: Price, TE: Analogue Electronics – an integrated PSpice approach. Prentice Hall, 1997 [P97]

Electronic Devices and Circuits

Prerequisits: Analog Circuit Analysis

Course objectives:
This course provides substantial knowledge of the function pn junctions, pn- and zener diodes, bipolar and field-effect devices, basic analog and digital circuits. The course will discuss the device parameters of diodes, BJT's, field effect transistors,

single stage amplifiers using common emitter, common base and common collector configurations as well as all configurations of FET amplifiers including CMOS and multi stage amplifiers, differential amplifier and output stages. In the next step a basic operational amplifier circuit and the use of these amplifiers at different applications are discussed. Furthermore all basic digital circuits (inverter, NAND, NOR, tri state inverter and transmission gates) at transistor level are introduced. Sequential logic circuits RS-, D- and JK- flip flops including truth tables and timing diagrams are shown for use at different type of counters, frequency dividers and shift registers. Finally principles of digital-to-analogue and analogue-to-digital converters are shown. At the end of the course, the student is supposed to recite, paraphrase and apply the concepts in problem solving of all topics covered. Also, the student is supposed to be able to analyse, design, evaluate and calculate parameters at analogue and digital electronic circuits e.g. dc biasing of single stage amplifiers, combined operational amplifier stages, drawings of digital circuits, timing diagrams of flip flops and counters and so on.

Contents in key words:

1. Introduction
Definitions and Symbols, Basic Elements and Circuits, Kirchhoff's Laws

2. Passive Circuits
Decarations, Properties and Labeling of Circuits, Resistors, Capacitors and Inductors

3. Semiconductor Circuits
Diode, Bipolar Junction Transistors, JFET devices, MOSFET Devices,
CMOS Devices

4. Amplifier Circuits
Amplifiers, Current Sources an Current Mirrors, Differential Amplifier, Class AB Amplifier, Feedback Amplifiers

5. Operational Amplifiers
Structure, Basic Amplifiers, Offset Voltage and Offset Current, Input and Output Impedance, Frequency Characteristics, Op Amp Applications

6. Multivibrators
Multivibrator with Transistors, OPA Schmitt-Triggers, OPA free running Multivibrator

7. Digital Circuits
Declarations, Timing Declarations, Power Dissipation, Fan Out, Positive and negative Logic, Logical Symbols

8. Logic Circuits
Bipolar Circuits, MOS Circuits

9. Sequential Logic
Flipflops, Counters, Shift Registers

10. Decoders, Multiplexers
Decoders, BCD-to-7 Segment Decoders, Priority Encoder, Multiplexers, Demultiplexers

11. Digital-to-Analog and Analog-to-Digital Converters

Digital-to-Analog Converters, Analog-to-Digital Converters

Literature:

(1) Johnson, DE, Johnson, JR and Hilburn, JL: Electric Circuit Analysis. Prentice Hall, 2nd edition

(2) R Boylestad and L Nashelsky: Electronic Devices and Circuit Theory, Prentice Hall

(3) Thomas L. Floyd: Digital Fundamentals, 8th Edition, Prentice Hall

(4) David F. Hoeschele: Analog-to-Digital and Digital-to-Analog Conversion Techniques, 2nd Edition, John Wiley & Sons

Solid State Electronics

Prerequisites: Analysis, complex calculus, statistics, differential equations, Fourier transformation, basics of mechanics and electrodynamics.

Course objectives:
In the first part of the course the student will gain insight into the basic quantum mechanical and solid state physics principles of semiconductor devices. The second part of the course aims at an understanding of the basic processes and equations being necessary for semiconductor device modelling. Intrinsic and doped semiconductors are discussed and the pn-diode is introduced as the prototype semiconductor device. At the end of the course, the student is supposed to recite, paraphrase and apply the concepts of quantum mechanics and band electrons in semiconductors and he/she should be in problem solving of all topics covered.

Contents in key words:

1. **Fundamentals of Quantum Mechanics (QM)**
   History, The Schroedinger equation (SE), The infinite quantum well, The measurement process in QM, The finite quantum well, Potential barriers, The harmonic oscillator

2. **Structure of Matter**
   The hydrogen atom, The periodic table of the elements, From atoms to the solid state

3. **Electrons in Crystals**
   From molecules to the solid state, Crystal lattices, Fabrication of crystals, Bloch electrons, Band structure

4. **Electrons in Semiconductors**
   Acceleration of Bloch-electrons, Electron mobility, Currents in semiconductors, Metals, semiconductors and isolators

5. **Quantum Statistics for Electrons and Holes**
   Density of states (DOS), Fermi-Dirac distribution, Occupation of bands

6. **Doped semiconductors**
   Donors and acceptors, Doping Technologies, Carrier statistics in doped semiconductors, Temperature dependence of the resistivity

7. **Fundamental equations of semiconductors**
   Currents in semiconductors, Generation and recombination, Continuity equations, Poisson equation

8. **The pn-junction**
   The electrochemical potential, Band diagram of a pn-junction, Einstein relation, The Schottky model

Literature:

(1) Semiconductor Fundamentals by Robert F. Pierret, G. W. Neudeck, Addison-Wesley
(2) Online-ressources: http://ece-www.colorado.edu/~bart/book/book/title.htm
http://www.lti.uni-karlsruhe.de/seite_1818.php

Electromechanic Fields and Waves

Prerequisits: advanced mathematics

Course objectives:
Electromagnetic Fields and Waves are based on Maxwell's theory. The complete Maxwell electric and magnetic fields are introduced including material equations, continuity equation and boundary conditions.
Mathematical properties are discussed and different kinds of fields are classified with respect to their energies: static, stationary, low frequency harmonic and full wave fields.
Dynamic harmonic fields and their approximations for capacitive and inductive problems, e.g. skin effect are analysed and calculated in detail.
Super conductivity is introduced as an example of non classical material behaviour. Full-wave analysis of harmonic fields is given on waveguides (TE-, TM-waves). Plane waves are examined referring to reflection, energy and losses. Furthermore the radiation of Hertzian dipoles is introduced. Electrodynamic potentials and Poynting vector concepts are covered.

Contents in key words:

1. The Electromagnetic Model.
The Electromagnetic Model. Si Units and Universal Constants.

2. Vector Analysis.
Orthogonal Coordinate Systems. Integrals Containing Vector Functions. Gradient of a Scalar Field. Divergence of a Vector Field. Divergence Theorem. Curl of a Vector Field. Stoke's Theorem.

3. Static Electric Fields.

Fundamental Postulates of Electrostatics in Free Space. Coulomb's Law. Gauss's Law and Applications. Electric Potential. Conductors in Static Electric Field. Dielectrics in Static Electric Field. Electric Flux Density and Dielectric Constant. Boundary Conditions for Electrostatic Fields. Capacitances and Capacitors. Electrostatic Energy and Forces. Solution of Electrostatic Boundary-Value.

4. Solution of Electrostatic Problems.
Poisson's and Laplaces' Equations. Uniqueness of Electrostatic Functions. Method of Images. Boundary-Value Problems in Cartesian Coordinates. Boundary-Value Problems in Cylindrical Coordinates. Boundary-Value Problems in Spherical Coordinates.

5. Steady Electric Currents.
Current Density and Ohm's Law. Electromotive Force and Kirchoff's Voltage Law. Equation of Continuity and Kirchoff's Current Law. Power Dissipation and Joule's Law. Boundary Conditions for Current Density. Resistance Calculations.

6. Static Magnetic Fields.
Fundamental Postulates of Magnetostatics in Free Space. Vector Magnetic Potential. The Biot-Savart Law and Applications. The Magnetic Dipole. Magnetization and Equivalent Current Densities. Magnetic Field Intensity and Relative Permeability. Behavior of Magnetic Materials. Boundary Conditions for Magnetostatic Fields. Inductances and Inductors. Magnetic Energy. Magnetic Forces and Torques.

7. Time-Varying Fields and Maxwell's Equations.
Faraday's Law of Electromagnetic Induction. Maxwell's Equations. Potential Functions. Electromagnetic Boundary Conditions. Wave Equations and their Solutions. Time-Harmonic Fields.

8. Plane Electromagnetic Waves.
Plane Waves in Lossless Media. Plane Waves in Lossy Media. Group Velocity. Flow of Electromagentic Power and the Poynting Vector. Normal Incidence of Plane Waves at a Plane Conducting Boundary. Normal Incidence of Plane Waves at a Plane Dielectric Boundary.

9. Waveguides and Cavity Resonators.
General Wave Behaviors Along Uniform Guiding Structures. Parallel-Plate Waveguide. Rectangular Waveguides.

10. Antennas and Radiating Systems.
Hertzian Dipole. Near-Zone Fields. Far-Zone Fields.

Literature:

- Cheng D.K.: Fields and Wave Electromagnetics. Addison-Wesley, 2nd edition, 1989
- Ida N. and Bastos J.: Electromagnetics and Calculation of Fields. Springer-Verlag, 1992
- Inan U.S. and Inan A.S.: Engineering Electromagnetics. Addison-Wesley, 2nd edition, 1999

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- Jackson J.D.: Classical Electrodynamics. John Wiley & Sons, 3rd edition, 1999