The University Of Sheffield.

Electronic & Electrical Engineering.

EEE118 ELECTRONIC DEVICES AND CIRCUITS

Credits: 20

Course Description including Aims

This module introduces the underlying solid-state physical principles that govern the properties of the active and passive circuit components that comprise all electronic and electrical circuits. Issues affecting the practical behaviour of resistors, capacitors and especially diodes and transistors are discussed. The circuit environments in which diodes and transistors are used, and the models describing their internal behaviour and external interactions, are introduced. It is shown how transistors and diodes can be used in both switching circuits and amplifier circuits and the important concept of small signal modelling is introduced in the context of the latter.

The module aims to:

1. describe the key conduction mechanisms - drift and diffusion - in solids and in a vacuum.
2. introduce students to the differences between conductors, semiconductors and insulators.
3. to describe the various technologies of resistor and capacitor manufacture and the relative performance issues associated with them.
4. establish a distinction between mobile charge and space charge in semiconductors and their respective roles in electronic devices.
5. develop in students a thorough understanding of the basic mechanisms of the p-n junction.
6. show students how to use their knowledge of semiconductors to create models that relate physical mechanisms in semiconductors to the terminal characteristics of electronic devices, in particular transistors.
7. introduce the idea of non-linear circuit elements and how to handle them.
8. present piecewise linear models and standard circuit symbols used to represent active circuit elements such as p-n junctions, BJTs, JFETs and MOSFETs.
9. explore the application areas of p-n junction diodes and examine their behaviour in a range of circuit contexts.
10. introduce the notion of electronic switches and the application of BJT and MOSFET devices as switches in various circuit environments.
11. introduce the idea of amplification and explain the need for biasing and the concept and use of small signal modelling.
12. introduce the ideal op-amp and basic op-amp circuits and to examine the effects of finite gain.

Outline Syllabus

Electrons in a Vacuum : force on electron in an electric field, energy, velocity, current and current density. **Electrons in Solids :** transport mechanisms, drift, diffusion. Resistivity of metals and physical origin, temperature coefficient. **Insulators :** breakdown strength, dielectrics and relative permitivity, different types of capacitors and their uses. **Semiconductors :** intrinsic and extrinsic, doping, charge carriers, holes, basic relationships of J for bulk semiconductors. **PN Junctions :** structure, junction potential, forward bias behaviour, charge injection, diode equation. Idea of space charge, Poisson's equation, internal fields, reverse breakdown mechanisms. Diode characteristics and temperature effects.

Transistors : JFETs and MOSFETs, basic mechanisms and characteristics, transconductance. BJT, transport mechanisms, charge control model, characteristics, simple circuits to obtain gain. Simple equivalent circuits. **Basic Diode Behaviour** : large and small signal diode models. **Diode Applications** : rectifiers, capacitor input smoothing, ripple, zener diode regulators. Clipping, clamping, voltage doublers, voltage multipliers. **Transistors :** BJT, JFET and MOSFET characteristics, similarities and differences. **Switching Applications** : on-state and off-state behaviour, drive considerations for BJT and MOSFET, inductive loads and back emf, switching AC power, bridge topologies for motor control. **Amplifier Applications** : amplification, biasing, designing dc conditions, thermal stability. Small signal ideas, generation of simple model (g_m based), equivalent circuits, coupling and decoupling, mid-frequency examples. **Operational Amplifiers** : advantages of - ideal performance. Basic circuit shapes, idea of feedback, follower circuits, virtual earth circuits, effect of finite gains. Use of superposition to handle multiple source amplifiers.

Time Allocation

48 lectures, 24 problem classes and 124 hours of independent study

Recommended Previous Courses

entry qualifications

Assessment

mid term test (January) - 9%, exam (June) answer 4 questions from 6 in 3 hours - 91%

Recommended Books

Horowitz & Hill	The Art of Electronics 2nd Ed	Cambridge
Sedra & Smith	Microelectronics	Oxford
Millman & Grabel	Microelectronics	McGraw Hill
Streetman & Banerjee	Solid State Electronic Devices	Prentice Hall
John Allison	Electroinc Engineering Materials and Devices	McGraw Hill

Objectives

"By the end of the unit, a candidate will be able to"

1. determine the differences of electron motion in a vacuum and in solids (drift and diffusion).
2. outline the properties and uses of metals, semiconductors and insulators.
3. identify the physical processes which are important in semiconductor electronic devices.
4. describe the p - n junction and the concept of electron and hole current.
5. appreciate the use of a diode for the emission and detection of light.
6. identify the physical mechanisms within the JFET and BJT that lead to the transconductance and output characteristics.
7. identify under what conditions a diode will conduct and what its effect will be on the behaviour of the circuit as a whole.
8. design simple capacitor input filtered power supplies, understand the significance of the approximations involved and specify voltage ratings for the components used.
9. predict the behaviour of circuits containing resistors, capacitors and diodes such as voltage doublers, peak detectors and differentiators.
10. discuss the similarities and differences between the characteristic behaviour of BJTs, JFETs and MOSFETS.
11. determine key operational parameters of a simple switching circuit and design simple circuits - including ones with inductive loads - to achieve specified goals.

12. analyse and synthesise the two practically useful bias circuits used in BJT amplifiers.
13. apply small signal model ideas to complete circuits and make quantitative estimates of a circuit's small signal performance.
14. calculate circuit gain for inverting, non-inverting operational and multiple input amplifier circuits for both ideal operational amplifiers and ones with a finite gain.

Detailed Syllabus

1. Force on electrons in an electric field, equations of motion, velocity, energy.
2. Formal definitions of current and current density, vacuum devices (just as illustration).
3. Solids - insulators, conductors, semiconductors.
4. Conduction mechanisms in solids, drift, diffusion.
5. Resistivity in conductors, temperature coefficient in metals and intrinsic semiconductors.
6. Insulators, breakdown strength, dielectrics, relative permittivity.
7. Capacitors - different types and uses.
8. Semiconductor conduction, intrinsic and extrinsic.
9. Doping, electrons and holes, p-type and n-type, drift and diffusion.
10. Conductivity, mobility, drift velocity.
11. Recombination effects, diffusion length.
12. P-n junction, space charge and mobile charge, Poisson's equation.
13. Junction potential, internal field, space charge, capacitance, voltage dependence.
14. Charge injection, diffusion, recombination, forward current.
15. Reverse characteristics, breakdown, Zener and avalanche.
16. Diode characteristics, relation to semiconductor characteristics, temperature dependence.
17. Junction field-effect transistor, current control, channel depletion.
18. Current saturation, qualitative explanation of characteristics.
19. Derivation of drain current versus voltage below saturation.
20. Operation as an amplifier, small signal equivalent circuit, uses.
21. MOSFET, simple explanation, enhancement and depletion modes, characteristics, uses.
22. Bipolar transistor, physical explanation of operation, biasing of junctions.
23. Junctions linked by narrow base, diffusion length, base current components, current gain.
24. Charge control model, output characteristics, small signal equivalent circuit.
25. What the course is about, what sort of ideas it is intended to transmit, what skills students should begin to have attained by the end of it. Books, review of booklist, how to use books. Assumed background knowledge. Beginning of an introduction to diode behaviour.
26. Piecewise linear diode models, identification of conduction state of a diode in a circuit.
27. Clipping circuits. Purpose of this type of circuit, action of basic clipping circuit. Protection applications. Shaping circuits or soft clipping, application in function generators; triangle to sine converters.
28. Clipping and clamping with R-C circuits. Behaviour of first order R-C circuits handout and discussion.
29. Peak detector applications, low power rectifier, effect of time constant on ability to respond to some frequencies but not to others; a.m. detector applications. Clamping circuits, purpose, top level clamps, bottom level clamps, description of behaviour.
30. Differentiating circuit. Combinations of clipping and clamping circuits, peak to peak detector (voltage doubler). Voltage multipliers.
31. Half wave rectifier circuit shapes - nature of output signal, average value. Full wave circuit shapes starting with centre tapped secondary and two diodes, ending with full wave bridge. Average value of full wave output with sinusoidal drive.

32. Smoothing - necessity of smoothing for most equipment - purpose of smoothing filter, idea of ripple. Capacitor input smoothing - basic circuit shape and description of ideal behaviour. Design models for capacitor input filters. Objectives of the model for choosing C - statement of assumptions and their justification - evaluation of C and general comments.
33. Regulation and stabilisation, definition of terms which are used quite loosely. Purpose of a regulator. Zener diode as simplest form of regulator - characteristics - typical circuit, explanation of its operation and application of basic principles to the circuit to enable design.
34. Power dissipation in circuit components of a zener diode regulator. Effect of zener diode regulator on ripple - idea of using a small signal equivalent representation of the zener to work out ripple attenuation. Other comments ---- behaviour of knee for voltages above and below 6.2V, temperature coefficient.
35 Introduction to transistors using a handout giving the characteristics of BJTs, JFETs and MOSFETs. Transconductance characteristic, output characteristic.
36. Ideal switches, mechanical versus electronic switches, advantages and shortcomings. Transistors as switches, driving BJT and MOSFET switches (not including transient effects).
37. Simple switching circuit topologies, switching AC power, bridge switching topologies. Switching inductive loads, back emfs, freewheeling diodes.
38. Explanation of amplification taking a graphical approach based on the device characteristics, including the need for biasing.
39. Setting up the bias conditions for a BJT. The two realistic bias circuits and their analysis and synthesis - the control of collector current by negative feedback - usefulness of the "0.7V drop".
40. Idea of small signal models. Generation of a simple g_m based small signal model (suitable for all devices) for a BJT together with the BJT specific notion of current gain.
41. Applying the small signal model - drawing the small signal equivalent circuit of a real transistor circuit. The notion that the power supply is a ground point to small signals. SS analysis to find key circuit parameters like gain.
42. Operational amplifiers as ideal circuit elements. Basic circuit connections, inverting circuit connections. Concept of a virtual earth and its justification.
43. Non-inverting circuit connections. The voltage follower. The effects of finite gain (treated quantitatively).
44. Amplifiers with multiple inputs. Use of superposition to analyse multiple input summers and subtractors.