EEE225 ANALOGUE AND DIGITAL ELECTRONICS

Credits: 20

Course Description including Aims

This module brings together the underlying physical principles of BJT, JFET and MOSFET devices to show how structural decisions in device design affect performance as a circuit element. Basic circuit topologies such as long - tailed pairs, Darlington transistors and current mirrors are described as a precursor to exploring the internal design of a typical op-amp. Common applications of op-amps are discussed. The relationship between device structure and performance in simple CMOS circuits is explored and applied to real digital circuit applications. Digital system design strategies are introduced with examples drawn from everyday embedded digital systems.

The specific aims of the unit are . .

1. Give students an understanding of common transistor device structures and of the way that their design affects the application areas for which a device is useful.
2. Provide foundation knowledge of the operating principles of LEDs, lasers and photo-voltaics.
3. Introduce multi transistor circuit blocks that together can be used to form an operational amplifier.
4. Explore a wide range of linear and non-linear op-amp applications
5. Introduce the concept of noise in analogue circuits and systems.
6. Introduce multi transistor circuit blocks that are the basis of the majority of the logic gates that together form complex VLSI digital systems.
7. Outline the differences between various digital logic families with reference to their input/output properties, speed and power consumption. Highlight currently popular families.
8. Review the area of finite state machines and their relationship to programmable systems and extend the discussion to programmable logic and FPGAs.
9. Explore the anatomy of a simple microcontroller system including memory organisation, hardware/software trade-off and speed and present some everyday examples of embedded controller systems.

Outline Syllabus

Band model of materials, metals, insulators and semiconductors. Intrinsic and doped semiconductors, p-n junction diode, BJT and MOSFET device structures and internal operation, modelling for analogue and digital applications, Electrons as waves, LEDs, lasers and solar cells. Noise. Digital circuit organisation. Microcontrollers and embedded systems, practical system organisation and interfacing. Software - hardware trade-offs, power consumption. Introduction to packaging and reliability.

Time Allocation

48 hours of lectures (inc case studies), 24 hours problem classes, 125 hours of guided independent study.

Recommended Previous Courses
Knowledge equivalent to first year EEE117, EEE118 and EEE119.

Assessment
three hour examination answer 4 questions from 6 in three hours

Recommended Books

Edwards-Shea, L.	The Essence of Solid-State Electronics	Prentice-Hall
Streetman & Bannerjee	Solid State Electronic Devices	Prentice-Hall
J. Crowe & B. Hayes-Gill	Introduction to Digital Electronics	Prentice Hall
T. L. Floyd	Digital Fundamentals	Prentice Hall
D. D. Gajski	Principles of Digital Design	Prentice Hall
M Morris Mano	Digital Design 3rd ed.	Prentice Hall
Sedra A S & Smith K C	Microelectronic Circuits	Oxford
Horowitz and Hill	The Art of Electronics	Cambridge
Smith, R.J.	Circuits Devices and Systems	Wiley

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

1. Use basic device relationships to predict the performance of some common semiconductor devices in the analogue, digital and optical arenas.
2. Explain the key issues in device packaging and appreciate the effects of electrical and thermal stress on device reliability.
3. Write down equivalent circuit representations of diodes, BJTs and MOSFETs and use these to predict device behaviour in a circuit context.
4. Recognise the circuit diagrams of and make simple quantitative performance predictions for a number of multi-transistor circuit blocks in both the analogue and digital domains.
5. Design linear and non-linear op-amp circuits for conditions well inside the amplifiers performance envelope.
6. Understand the nature of electronic noise and make quantitative predictions of noise magnitudes and of system noise parameters such as S/N and noise factor.
7. Discuss the merits and disadvantages associated with a number of logic families and be able to design using open collector (drain) logic devices and comparators.
8. Design at high level a simple embedded system and demonstrate awareness of key issues such as speed, power consumption, environment and hardware/software trade-off.

Detailed Syllabus

Lecture	**Topic**
1 - 2	Band model of electrical materials. Metals, insulators, semiconductors.
2 - 3	Intrinsic and doped semiconductors, transport properties, Ohmic and Schottky contacts
4 - 5	Junction diodes, BJT operating principles and terminal characteristics, relationship between device design and equivalent circuit parameters.
6 - 7	JFETs/MOSFETs, simple models and terminal relationships, relationship between device design and equivalent circuit parameters.
8	Wave nature of electron, de Broglie relation, energy quantisation
9 - 10	Optical devices, absorption, emission, quantum LEDS and lasers. Photodiodes, solar cells. Materials choices.
11 - 13	Electronic device performance limitations (frequency, current and voltage handling,

	temperature). Thermal aspects/relationship with reliability. Power consumption and motivation for management. Device packaging and parasitics.
14 - 15	Basic analogue building blocks: current mirrors, differential amplifier: opamp organisation.
16 - 17	Op-Amp properties and linear circuit applications, bandwidth, gain-bandwidth product and slew rate.
18 - 19	Non-linear op-amp applications, limiters, shaping circuits, precision rectifiers, comparators, schmitt triggers, relaxation oscillators
20 - 22	Introduction to noise in analogue circuits and systems: available noise power, signal to noise ratio, noise factor, noise factor of a cascade, noise temperature.
23 - 24	Basic digital building blocks: CMOS logic circuits and their design.
25 - 27	Input/output properties of digital circuits, open collector (drain), DAC and ADC topologies, signal conditioning
28 - 29	Introduction to noise in digital circuits: sources, effects, noise margins and relationship with logic families
38 - 39	Case study 2: Analogue system
30 - 31	I/O considerations: grounding, protection
32 - 33	Review of Finite State Machines and relationship to programmable systems
34	Programmable logic and FPGAs
35	Microcontrollers: anatomy of a simple system
36 - 37	Organisation and ISA
38	Memory organisation
39 - 40	Software/hardware trade-off, processing speed
41 - 42	Embedded systems, (examples washing machines, car engine management, etc)
43 - 44	External speakers/case studies

UK-SPEC/IET Learning Outcomes

Outcome Code	Supporting Statement
SM1p/SM1m	The behaviour of electrons in solids and the ways in which that behaviour can be manipulated in order to achieve useful engineering devices which themselves must be modelled to enable predictions of performance is a key aspect of Engineering Science covered in this module. The outcome is tested by exam.
SM2p/SM2m	The models that describe the behaviour of electrons in solids and the modelling of analogue circuits provide a variety of opportunities to apply mathematics to achieve solutions to engineering problems. The outcome is tested by examination
SM3p/SM3m	This module demands knowledge and understanding of internal device physics and circuit modelling for both analogue and digital systems and components. Basic thermal and optical properties of solids and some software system ideas are integral to the module. The outcome is tested by exam.
SM4m	Some awareness of trends, particularly in the rapidly developing area of opto-electronic devices is included to put the topic in context and to transmit some of the excitement derived from working in this dynamic area. The outcome is tested by exam.
SM6m	The introduction to quantum well based optical devices leans heavily towards physics and contributes to this outcome. The outcome is tested by exam.
EA1p/EA1m	Device models at the electron level, at the terminal characteristic level and at the behavioural level together with their application to estimating device, circuit or system performance for both digital and analogue environments contributes to

this outcome. The outcome is tested by exam.

EA2p/EA2m	Analytical device models and how to use them intelligently in a engineering context is a thread that runs throughout this module. The outcome is tested by exam.
EA3p/EA3m	Problem sheets, exam questions and worked examples are based on engineering practice and scenarios where possible.
EA4p/EA4m	Op-amp circuit analysis and the microcontroller/embedded systems parts of the module contribute to systems engineering ideas. The outcome is tested by exam.
EP2p/EP2m	Knowledge of semiconductor materials contributes to this outcome. The outcome is tested by exam
EP4p/EP4m	Device data sheets are used extensively throughout the module to demonstrate how to obtain the key information needed by the models used to predict device, circuit or system performance. The outcome is tested by exam
D3p/D3m	Some problems are posed using real world scenarios in which data is incomplete or intermediary data must be derived from specifications or other parameters. Students are provided with an intellectual toolbox to assess their analogue and digital circuits and electronic device design's ability to meet their design parameters using derived information or testable assumptions where necessary. This outcome is tested by exam.