2E6 ELECTRONICS [5 credits]

Lecturer(s): Associate Prof. Brian Foley (brian.foley@tcd.ie)

Module organisation
The module runs for the first half (12 weeks) of the academic year and comprises of three lectures and one tutorial per week plus two two-hour laboratories (total of 48 hours contact time).

Module description, aims and contribution to programme
This module is an introduction to the general principles and applications of contemporary analogue and digital electronics and is taken by the full complement of SF Engineering and Engineering with Management students. The module is sufficiently general in content and broad in application to serve as a suitable foundation not just for students who wish to subsequently pursue electronic/computer engineering but also for those who opt for civil or mechanical engineering.

The module introduces the concepts of the digital signal and system, and progresses through standard combinational and sequential logic design with particular reference to arithmetic processing. Complexity, speed and power consumption are employed as the main parameters of system performance. Electrical implementation is considered through a qualitative treatment of Complementary Metal Oxide Semiconductor (CMOS) circuit principles. While the module gives a solid grounding in traditional pencil-and-paper design methodologies, the important reality of modern computer aided design (CAD) methodologies and field programmable gate arrays (FPGAs) is also recognised.

The module provides a systems-oriented foundation in the principles of analogue integrated circuits again emphasising the information-bearing nature of analogue signals and the concept of the electronic circuit as a signal processing system. The characterisation of analogue signals and systems is covered. The idea of modelling amplifier functionality by means of a controlled voltage source together with input and output resistance is treated, and many practical examples are given. The ideal operational amplifier is selected as an illustrative electronic subsystem of considerable application importance. The methodology for analysing a linear application circuit is treated as a major objective of the module. The student is introduced to the effects of finite performance characteristics such as finite open loop gain and input resistance. Frequency selectivity in RC-circuits is studied, with characterisation based on Bode plots. Analogue-digital conversion systems are introduced.
Learning outcomes
Upon completion of this module, students will be able to:
1. Convert between binary and decimal representations and carry out binary addition, subtraction and multiplication.
2. Manipulate Boolean expressions so as to minimise the number of literals using algebra or Karnaugh maps.
3. Design standard and iterative combinational logic circuits.
4. Evaluate the complexity and speed of combinational designs.
5. Explain the operation of basic sequential elements — latch, master-slave flip-flop and analyse simple sequential circuits.
6. Describe the operation and determine the logic function of basic CMOS gate circuits.
7. Analyse and solve simple propositional logic problems.
8. Describe the concept of an information-bearing electrical signal, calculate the average and root mean square values of regular periodic signals and carry out power calculations given the frequency content.
9. Determine the output of simple linear and non-linear systems for given inputs.
10. Design and analyse source-amplifier-load configurations to meet given specifications.
11. Characterise and plot the frequency response of first-order RC-circuits.
12. Characterise the properties of the ideal operational amplifier; calculate the closed loop gain and carry out design manipulations for basic linear operational amplifier applications including the effects of finite open loop gain and first-order frequency response.
13. Explain the operation of basic analogue-to-digital and digital-to-analogue converters.
14. Carry out basic experimental test procedures, record the results and write a laboratory report.

Module content

Digital Systems and Binary Numbers
• Digital signals and systems
• Number systems
• Positive/negative representation
• Binary arithmetic

Boolean Algebra
• Definitions and basic theorems
• Algebraic simplification
• Sum of products and product of sums formulations
• Gate primitives
• Karnaugh maps
**Combinational Logic**
- Combinational design
- Assessment of complexity and speed
- Code converters, multiplexors, decoders
- Addition circuits, priority encoder

**Sequential Logic**
- Bistable latch, master-slave and edge-triggered flip-flops
- Asynchronous and synchronous counter design
- Registers and shift registers

**Digital Circuits**
- n- and p-channel MOS transistors
- CMOS inverter, NAND, and NOR gates
- General CMOS logic

**Characterisation of Analogue Electronic Signals and Systems**
- Signals and electronic signal processing
- dc and rms calculations
- Resistive circuit analysis review and the Maximum Power Transfer Theorem
- Thevenin theorem, Superposition Principle, and maximum power transfer
- Signal transmission through linear and non-linear systems

**Amplifiers and their Equivalent Circuits**
- Equivalent circuit of ideal and real amplifiers
- Cascades of amplifiers

**Frequency Response**
- Decibel notation
- Classification of filters
- RC-circuits and their Bode characterization

**Operational Amplifier Circuits**
- The ideal operational amplifier
- The inverting, non-inverting, differential and integrating configurations
- Effect of finite open loop gain and input resistance
- Introduction to analogue-digital conversion systems

**Teaching strategies and student learning**
This module is formally delivered through a combination of lectures and tutorials, with two supporting practical laboratory sessions. The tutorial sessions are based on problem solving exercises with trained tutorial assistance available to provide guidance and feedback to the students.
Some of the core module material is documented in a set of notes which is provided via the web and in advance to all students. This core material incorporates not just...
the concepts and methodologies, but also worked illustrative problems. Tutorial problem sheets and solutions are also provided. Students are expected to read through the material in advance so that lecture time can be allocated to:

- explaining carefully the more difficult concepts and derivations;
- illustrating the material with sample problems and applications of wide interest;
- responding to student questions and inviting student input to choice of analysis strategy, etc;
- setting short but focused class-time problems.

From the point of view of teaching and learning strategy, the delivery approach would be characterised by:

- endeavouring to ensure that each session, lecture or tutorial, is an active learning experience for the student;
- keeping the formal presentation and associated activities varied so that the experience, while challenging, is also enjoyable;
- in principle following a “constructivist” philosophy, the idea being to get the students to themselves construct as much of the new material as possible from what they already know.

The basic module materials are provided in electronic form and care is taken to ensure that all materials are both accessible to and usable by all students.

**Associated laboratory/project programme**
- Digital Logic Circuits;
- Operational Amplifier Circuits.

**Assessment**
85% of the mark returned for 2E6 is derived from a formal written two-hour examination held at the end of the academic year. The examination paper is divided into two sections (digital and analogue) each comprising three questions. In answering four questions out of six, students are required to answer two questions from each section. The remaining 15% of the marks are derived from a laboratory programme of two experiments. A portion of the 85% examination mark may be based on allocated assigned work.

Student progress will be monitored through their participation and performance at the tutorial sessions. Feedback will be provided both by the lecturer and/or the module teaching assistants.

**Recommended textbooks**
Supplemental textbooks


Further information

http://www.tcd.ie/Engineering/undergraduate/baiyear2/2E6