Engineering Tripos Part IIA, 3B3: Switch-mode Electronics, 2021-22

Module Leader

Dr T Long [1]

Lecturer

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Lecturer

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Lab Leader

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Timing and Structure

Michaelmas term. 2 lectures/week.

Prerequisites

2P5

Aims

The aims of the course are to:

- Introduce power electronics and some of its main applications (power conversion in renewable energy, electric vehicles, power supply unit (PSU))
- Introduce typical topologies for AC-DC, DC-DC and DC-AC power conversion
- Give basic and useful skills in analysing and designing power electronics based power converters (PLECS modelling)

Objectives

As specific objectives, by the end of the course students should be able to:

- Know typical applications and requirements of power electronic based power converters (switch-mode power conversion)
- Know the characteristics of the diodes and power transistors and their functions in switch-mode power electronic circuits
- Know the functions of inductors and capacitors in switch-mode power conversion
- Know typical switch-mode power conversion circuit topologies: DC-DC, DC-AC, AC-DC
- Know how to reduce voltage and current ripple using smoothing circuits.
- Know high frequency transformers and their functions in power converters
- Understand the principle of pulse-width modulation and simple ways of generating pulse-width modulated

waveforms.
- Know the structure and working principle of MOSFET, BJT, and IGBT as power transistors
- Describe various losses and estimate the efficiency of a power electronic system.
- Gain skills of power electronic system modelling (PLECS)
- Conduct basic tests of power electronic systems and use digital oscilloscope, pulse generator, probes and be familiar with typical power electronic and passive component devices and packages in real systems (via Lab)

Content

This module will also introduce PLECS modelling, all module students are offered free license (full function) of PLECS for 12 months.

Lecture 1: Introduction of power electronic systems and their applications, common math and physics used in analysing power electronic systems

- Non-isolated DC-DC converter

Lecture 2: Non-isolated DC-DC converters (BUCK, BOOST and BUCK-BOOST) in Continuous Current Mode (CCM) their operating principles

Lecture 3: Non-isolated DC-DC converters in Discontinuous Current Mode (DCM) their operating principles

- Bridge based DC-AC inverter/rectifier

Lecture 4: Bridge converter, the circuit, working principle and applications

Lecture 5: Single phase DC-AC inverter and Sinusoidal Pulse Width Modulation (SPWM)

Lecture 6: Three phase DC-AC inverter/rectifier and AC line filter design

Lecture 7: Tutorial 1: DC-DC and DC-AC converters (two Tripo level questions)

- Diode based AC-DC rectifier

Lecture 8: Uncontrolled single AC-DC rectifier with ideal AC source, diode bridge circuit and principles, capacitor filtering techniques

Lecture 9: Uncontrolled three AC-DC rectifier with ideal AC source, diode bridge circuit and principles, capacitor filtering techniques

- Isolated DC-DC converter

Lecture 10: Isolated DC-DC converter: high frequency transformers, push-pull converter

Lecture 11: Flyback DC-DC converter: working principles and design requirements

Lecture 12: LLC Resonant converter: working principles and design requirements

Lecture 13: Tutorial 2: AC-DC diode based rectifier and isolated DC-DC converters (Flyback and LLC Resonant)

- Power electronic devices

Lecture 14: Power diodes and bipolar junction transistor

Lecture 15: The Insulted Gate Bipolar Transistor (IGBT): modes of operation. trade-offs.

Lecture 16: The power MOSFET: Concept, modes of operation. trade-offs.

Examples papers

4 examples papers issued at 2 week intervals to coincide with the lecture material.

Coursework

DC-DC converter (upgraded new lab kit and facility from 2020)

Objectives:

- Be familiar with real power electronic and passive devices and their packages
- Use digital oscilloscope for power electronic system testing and data acquisition
- Use voltage and current probe of measuring switching voltage and current
- Observe and operate Pulse Width Modulation (by pulse generator) of controlling power electronic system
- Observe and operate passive components in power electronic systems and understand their functions

Pre-requisite

- Watch introductory video prior lab
- Read lab sheet prior lab

Full Technical Report:

- Optional tasks and questions are given for FTR

Booklists

Please refer to the Booklist for Part IIA Courses for references to this module, this can be found on the associated Moodle course.

Examination Guidelines

Please refer to Form & conduct of the examinations [2].

UK-SPEC

This syllabus contributes to the following areas of the UK-SPEC [3] standard:

Toggle display of UK-SPEC areas.

GT1

Develop transferable skills that will be of value in a wide range of situations. These are exemplified by the Qualifications and Curriculum Authority Higher Level Key Skills and include problem solving, communication, and working with others, as well as the effective use of general IT facilities and information retrieval skills. They also include planning self-learning and improving performance, as the foundation for lifelong learning/CPD.

IA1

Apply appropriate quantitative science and engineering tools to the analysis of problems.

KU1

Demonstrate knowledge and understanding of essential facts, concepts, theories and principles of their engineering discipline, and its underpinning science and mathematics.

KU2

Have an appreciation of the wider multidisciplinary engineering context and its underlying principles.

E1

Ability to use fundamental knowledge to investigate new and emerging technologies.

E2

Ability to extract data pertinent to an unfamiliar problem, and apply its solution using computer based engineering tools when appropriate.

E3

Ability to apply mathematical and computer based models for solving problems in engineering, and the ability to assess the limitations of particular cases.

P1

A thorough understanding of current practice and its limitations and some appreciation of likely new developments.

P3

Understanding of contexts in which engineering knowledge can be applied (e.g. operations and management, technology, development, etc).

US1

A comprehensive understanding of the scientific principles of own specialisation and related disciplines.

US2

A comprehensive knowledge and understanding of mathematical and computer models relevant to the engineering discipline, and an appreciation of their limitations.

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Links
[1] mailto:tl32t@cam.ac.uk
[2] https://teaching22-23.eng.cam.ac.uk/content/form-conduct-examinations
[3] https://teaching22-23.eng.cam.ac.uk/content/uk-spec