Engineering Tripos Part IIB, 4G2: Bioelectronics, 2025-26

Module Leader

Prof George Malliaras [1]

Lecturers

Prof George Malliaras [1]

Timing and Structure

Michaelmas term. Lectures and coursework. Assessment: 100% coursework.

Aims

The aims of the course are to:

- To provide an introduction to the field of bioelectronics.
- To highlight the application of bioelectronic devices in the medical and consumer sectors.

Objectives

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

- Extend principles of engineering to the development of bioelectronic devices.
- Understand the principles of signal transduction between biology and electronics.
- Appreciate the basic configuration and distinction among bioelectronic devices.
- Demonstrate appreciation for the technical limits of performance.
- Make design and selection decisions in response to measurement and actuation problems amenable to the use of bioelectronic devices.
- Be able to evaluate novel trends in the field.

Content

One of the most important scientific and technological frontiers of our time is the interfacing of electronics with living systems. This endeavour promises to help gain a better understanding of biological phenomena and devliver new tools for diagnosis and treatment of pathologies including epilepsy and Partinson's disease. The aim of this course is to provide an introduction to the field of bioelectronics. The course will link science and engineering concepts to the principles, technologies, and applications of bioelectronics. The fundamentals of electrophysiology and electrochemistry will be applied to implantable and cutaneous bioelectronic devices and to in vitro systems to explain the principles of operation. Examples from current scientific literature will be analysed.

COURSE CONTENT

1. Introduction

Drivers for bioelectronics
What is bioelectronics?
Organisation of the module

Part I: Fundamentals

2. Elements of anatomy and function

The nervous system

The neuron
Neural circuits
Other systems of interest

3. Signal transduction across the biotic/abiotic interface

Types of electrodes

Electrochemical impedance
Electrochemical reactions
Neural recording and stimulation
Transistors as transducers
Complete systems

Part II: Technology

4. Implantable devices

Cardiac pacemaker

Auditory and visual prostheses
CNS and PNS implants
Implantable sensors and drug delivery systems
The foreign body response

5. Cutaneous devices

Recording devices for brain, heart, muscle

Stimulation devices for brain, heart, muscle
Wearable electronics and electronic skins

6. In vitro devices

Electrochemical biosensors

In vitro electrophysiology
Impedance biosensors
Body-on-a-chip

Part III: Translation and ethics

7. Translation

From the drawing board to patients at scale

Device discovery
Preclinical research and prototyping
Pathway to approval
Regulatory review
Post-market monitoring

8. Ethics

Medical ethics
When a device becomes part of you
What happens to the data?
Animal research

Further notes

The course will be interdispersed with discussions highlighting the state-of-the art in the field.

Coursework

The coursework will be assessed on two marked assignments. The first assignment will involve a laboratory session illustrating the functional demonstration of glucose sensor technology. The second assignment will involve a laboratory session illustrating the principle of a quartz crystal microbalance and related acoustic sensor technologies.

Coursework	Format	Due date & marks
Coursework activity #1 : Cutaneous electrophysiology <u>Learning objectives:</u> • To introduce students to sensors employed for the measurement of electrophysiology. • To explore different recording configurations. • To quantitatively analyse measurements conducted using cutaneous electrodes. • To extend the principles to the design of a sensor for the measurement of biopotentials.	Individual Report anonymously marked	Typically wee [30/60]
Coursework activity #2 : Mock design of a bioelectronic system <u>Learning objectives:</u> • To give stduents a holistic view of bioelectronic system design. • To explore different stimulation protocols used in neuromodulation. • To explore different materials involved in the design of electrodes. • To understand the process of translation.	Individual Report anonymously marked	Typically wee [30/60]

Booklists

Please refer to the Booklist for Part IIB 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.

IA2

Demonstrate creative and innovative ability in the synthesis of solutions and in formulating designs.

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.

D1

Wide knowledge and comprehensive understanding of design processes and methodologies and the ability to apply and adapt them in unfamiliar situations.

D4

Ability to generate an innovative design for products, systems, components or processes to fulfil new needs.

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.

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.

US3

An understanding of concepts from a range of areas including some outside engineering, and the ability to apply them effectively in engineering projects.

US4

An awareness of developing technologies related to own specialisation.

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