Carleton UNIVERSITY | Department of Systems and Computer Engineering

SYSC 3610
Biomedical Systems, Modeling, and Control

Calendar description

Properties of linear systems. Linear dynamic models of biomedical systems. Biomedical application of the Laplace transforms. Transfer functions. Block diagram. Frequency and time response. Feedback, control, and stability. Biomedical systems modeling and control.

Includes: Experiential Learning Activity.

Lectures three hours a week, laboratory three hours a week.

http://calendar.carleton.ca/undergrad/courses/SYSC/

Prerequisites

MATH 1005 and ((ECOR 1051 and ECOR 1052 and ECOR 1053 and ECOR 1054) or ECOR 1101) and enrolment in Biomedical and Electrical Engineering or Biomedical and Mechanical Engineering, and second-year status in Engineering.

Precludes additional credit for SYSC 3500 or SYSC 3600.

Prior knowledge

Students should have knowledge of:

- Integral calculus (MATH 1004).
- Differential equations (MATH 1005).
- Euler's formula and complex exponential functions, basic mechanics and dynamics, masses, springs, dampers, free body diagrams (ECOR 1053/ECOR 1054/ECOR 1101).
- Basic knowledge of electrical components such as resistors, capacitors, inductors, electrical concepts such as Ohm's law, Kirchhoff's voltage law and Kirchhoff's current law (ECOR 1052).
- Basic programming knowledge for simulations (ECOR 1051/ECOR 1606).
- It would be beneficial to also have knowledge of the Laplace transform although the basics will be taught, as well as nodal analysis and mesh analysis.

Course objectives

Simple mathematical models of the world around us lets us understand how things work and how they will react to different types of input stimuli. This course studies simplified models for mechanical, electrical, fluid, and thermal systems with a focus on biomedical applications and biological systems. For example, the cardiovascular system can be modelled as a fluid system with liquid being pumped through tubes of various dimensions and with various elastic properties. Similarly, the cardiovascular system can also be modelled using electrical circuits with electrical current analogous to fluid flow. As another example, the musculoskeletal system can be modelled as masses, springs, and dampers given the interaction and connections between bones and muscles. As a third example, we can model how medication is absorbed and distributed throughout the body, including the gut, blood stream, and various organs. As a fourth example, we can model a prosthetic limb in terms of mechanical function, electrical function, and sensor capture function.

With simplified mathematical models that approximate the real system, exploratory questions can then be asked. For example, how would the body respond to travelling over a bumpy road given different suspension systems or seat construction? How long would it take a medication to be metabolized by the body and then eliminated through the urinary tract? What sort of control would be needed for a prosthetic leg? If a heart-lung machine were designed, how could the machine be modelled and refined and how would stable control of the heart-lung machine be done for proper operation when attached to a patient?

Modelling of systems is made possible by understanding techniques and tools including the Laplace transform, transfer functions, and block diagrams. How the modelled systems reacts to inputs is done through understanding concepts like the impulse response, step response, and frequency response. Stable control of any modelled system requires understanding feedback loops and target design criteria.

List of topics

- Basic system properties; fundamental continuous-time signals
- Laplace transform; solutions of ordinary differential equations
- Linear dynamic models of biomedical systems, compartmentalization
- Transfer functions
- State space representations
- Block diagrams, multicompartment models
- Time responses, dynamics of systems
- Frequency response and Bode plots
- Feedback systems and design criteria
- Stability of systems
- Classical control systems: basic properties (P, I, PI, PID)
- Applications of biomedical systems modeling (throughout course)

Learning outcomes

By the end of this course, students should be able to:

- Understand concepts behind linear systems including causality, superposition, time-invariance, and memory.

- Understand basic dynamic system elements for modeling including resistors, capacitors, inductors, batteries, transformers, masses, springs, dampers, motors, gears, pumps, pipes, flow restrictors, reservoirs, heat masses, etc.
- Model dynamic systems including biological, electrical, mechanical, fluid, and thermal systems.
- Model dynamic systems using linear constant coefficient ordinary differential equations.
- Model dynamic systems using state-space representations with first-order coupled linear constant coefficient ordinary differential equations.
- Model dynamic systems in the Laplace domain and with transfer functions.
- Model dynamic systems using block diagrams and compartment models.
- Develop some common models for some biological systems including muscles, muskoloskeletal, circulatory system, drug absorption, etc.
- Use engineering tools for simulation of dynamic systems.
- Simulate and interpret time responses of dynamic systems including impulse response, step response, and ramp response.
- Determine, plot, and interpret the frequency response of dynamic systems as well as create and use Bode plots.
- Become familiar with pole-zero diagrams and relationship to time responses.
- Analyze and understand open-loop and closed-loop dynamic systems.
- Determine the stability of a modeled system.
- Understand basic feedback system models.
- Become familiar with a few classical controllers and preliminary control theory concepts for stable control.

Graduate Attributes (GAs)

The Canadian Engineering Accreditation Board requires graduates of engineering programs to possess 12 attributes at the time of graduation. Activities related to the learning outcomes listed above are measured throughout the course and are part of the department's continual improvement process. Graduate attribute measurements will not be taken into consideration in determining a student's grade in the course. For more information, please visit: https://engineerscanada.ca/.

Graduate Attribute	Learning outcome(s)
1.6.S: Knowledge Base: Developed: Signals and systems	1-16
1.11.S: Knowledge Base: Developed: Biomedical systems	3, 8
2.1: Problem Analysis: Developed: Problem definition	3-8
2.2: Problem Analysis: Developed: Approach to the problem	3-8, 13
2.3: Problem Analysis: Developed: Use of assumptions	3-8
2.4: Problem Analysis: Developed: Interpreting the solution - validity of results	10, 11
5.1: Use of Engineering Tools: Developed: Diagrams and engineering sketches	9-11, 13
5.3: Use of Engineering Tools: Developed: Tools for design, experimentation, simulation, visualization, and analysis	9-11, 13
5.5: Use of Engineering Tools: Developed: Limitations of such tools and the assumptions inherent in their use	9

Accreditation Units (AUs)

For more information about Accreditation Units, please visit: https://engineerscanada.ca/.

The course has a total of 55 AUs, divided into:

- Engineering Science: 75%
- Engineering Design: 25%

Instructor and TA contact

Specific to course offering (tbd)

Textbook (or other resources)

Specific to course offering (tbd)

Evaluation and grading scheme

Specific to course offering (tbd)

Breakdown of course requirements

Specific to course offering (tbd)

Tentative week-by-week breakdown

Specific to course offering (tbd)

General regulations

Specific to course offering (tbd)