

IBEHS 4A03

Biomedical Control Systems

Winter 2022 Course Outline VERSION 1.0

FORMAL CALENDAR DESCRIPTION

IBEHS 4A03 focuses on the modelling of control systems in the continuous-time domain; state space representations; model linearization; performance of control systems in time and frequency domains; stability; control design. Particular emphasis will be given to biomedical and engineering applications.

INFORMAL COURSE DESCRIPTION

Control systems are everywhere, from the furnace in your home, to cruise control in a commercial airliner, to the pressure and temperature regulation of a pharmaceutical bioreactor, to the many control systems working to achieve homeostasis in the human body. This course will investigate how these systems work, and how this understanding will allow us to engineer solutions for industries, patients, and everything in-between.

PRE-REQUISITES AND ANTI-REQUISITES

Prerequisite(s): IBEHS 3A03

Antirequisite(s): ELECENG 3CL4, MECHENG 4R03, CHEMENG 3P04

INSTRUCTOR OFFICE HOURS AND CONTACT INFORMATION

Dr. Jake Nease
BSB B105
neasej@mcmaster.ca
+ 1 (905) 599-3165

Office Hours:
Wednesdays 14:00 – 17:00
By appointment (The *door* is open when possible!)

TEACHING ASSISTANT OFFICE HOURS AND CONTACT INFORMATION

Bodee Quansah
MS Teams
quansahb@mcmaster.ca
Hours: Fri 14:00-16:00

Rehmat Grewal
MS Teams
grewar15@mcmaster.ca

Daniel D'Souza
MS Teams
dsouzd16@mcmaster.ca

Sainan Chelvarajah
MS Teams
chelvars@mcmaster.ca
Hours: Sun 10:00-12:00

Varun Jain
MS Teams
jainv8@mcmaster.ca
Hours: Wed 18:00-20:00

COURSE WEBSITE

IBEHS 4A03 will use Avenue to Learn as the primary repository for notes, assignments, tutorial activities, and grades. Grades posted on Avenue to Learn are unofficial until posted on MOSAIC. Students can log in via the link: <http://avenue.mcmaster.ca/>

COURSE LEARNING OBJECTIVES

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

- LO.1. Identify the fundamental components of linear and nonlinear dynamic models with biomedical and industrial applications.
- LO.2. Apply linearization methods to achieve locally linear dynamic models.
- LO.3. Apply Laplace and Inverse-Laplace transforms to convert between time-domain and frequency-domain models as appropriate.
- LO.4. Perform fundamental open-loop analyses of dynamic systems to assess stability, damping effects, disturbances, and time delays.
- LO.5. Build closed-loop block diagrams of dynamic systems.
- LO.6. Design feedback controllers for linear systems, including proportional, proportional-integral, and proportional-integral-derivative and comment on their appropriateness given the application.
- LO.7. Simulate and tune closed- and open-loop systems using simulation software such as MATLAB Simulink.
- LO.8. Perform various stability analyses on closed-loop systems and comment on an appropriate control structure to optimize performance.
- LO.9. Convert a linear(ized) time-domain model to state-space representation.
- LO.10. Identify the parameters of linear models in state-space form using appropriate model fitting techniques.

ACCREDITATION LEARNING OUTCOMES

The Learning Outcomes defined in this section are measured for Accreditation purposes only and will not be directly taken into consideration in determining a student's actual grade in the course. IBEHS 4A03 will measure the following graduate attribute indicators through the indicated learning outcomes below.

Indicators	Mapped Learning Outcomes
1.1: Knowledge of engineering mathematics	LO1, LO2, LO3, LO9, LO10
1.3: Knowledge of fundamental engineering sciences	LO1, LO3, LO4, LO5, LO8
5.1: Evaluates and selects appropriate modern tools	LO6, LO7, LO10
5.2: Demonstrates an ability to use modern/state of the art tools	LO7, LO8
5.3: Creates, adapts, modifies, and extends tools to solve problems	LO6, LO7, LO9

For more information on Accreditation, please visit: <https://www.engineerscanada.ca>

MATERIALS AND FEES

Required Texts:

There is no required textbook for this course.

Calculator:

Students are welcome to use any calculator desired.

Other Materials:

This course will require the use of MATLAB and SIMULINK. A full version of MATLAB with SIMULINK is available to McMaster students from the Mathworks website: <https://www.mathworks.com/products/matlab/student.html>

ASSESSMENT

The Grading for this course will be broken down according to the following components.

Component	Weight	Notes
Assignments	30%	5 assignments worth 6% each
Midterm Tests	25%	2 tests - best is worth 15%, worst is worth 10%
Final Exam	40%	A final exam scheduled during the exam period
Participation	5%	Attendance in tutorials (0.5% each). Can be re-weighted to exam.
Total	100%	

ASSIGNMENTS

Assignments will be released on a bi-weekly basis and will cover the most up to date relevant lecture material. Assignments can be completed in groups of **up to three students** maximum. You are entitled to choose your own groups for every assignment. Assignment submissions are expected to be electronic and take the form of a professional short-form report and will be graded as such.

MID-TERM TESTS

Midterm tests will be in-person written problem sets completed individually.

Midterm 1 will be held during Feb 16 @ 18:30-20:30 in T13 123.

Midterm 2 will be held during Mar 30 @ 18:30-20:30 in T13 123.

Each midterm will be proceeded by an OPTIONAL in-class group re-write of the same exam in the next lecture hour. If you participate in the re-write, your official midterm grade will be weighted as 85% your individual result and 15% the group's result, **if your group result is higher**. Your midterm will be weighted as 100% your individual result otherwise.

You have the right to skip the in-class re-write without penalty. Should you be taking this class online asynchronously and be unable to attend the live lecture session, you forego the chance to participate in the re-write.

TUTORIALS AND PARTICIPATION

Tutorial participation will be tracked according to attendance for the TA tutorial lesson and your willingness to attempt the practice problems included with the lesson. Each tutorial is worth 0.5% up to a maximum of 5% of your final grade. You do not have to go to your assigned tutorial session on MOSAIC to receive credit, but you must come to ONE tutorial in a weekly cycle, or you will forfeit the credit.

Should you not be able to make tutorials or would like to opt out of participation, you may notify the instructor at any time. In doing so, your tutorial credit will automatically be rolled into the weight of the final examination. This happens for the ENTIRE 5% and will not be pro-rated.

COURSE OVERVIEW

IBEHS 4A03 will follow the following list of topics as closely as possible. Note that the instructor reserves the right to change the order and coverage of topics as they feel appropriate and possibly even at the request of the class.

Date/Week	Topics covered (subject to change!)
Week 01	Introduction; Review of biomedical control applications; math review
Week 02	Model building from first principles; Linearization; Introduction to Laplace transforms
Week 03	Laplace transforms; Transfer functions; Inverse Laplace Transforms; Partial fractions review
Week 04	Transfer function characteristics; Damping; Stability analyses; Poles and zeros
Week 05	Block diagram representations; Block diagram algebra; Closed loop systems
Week 06	Stability of closed loops; Introduction to feedback control
Week 07	Feedback controller performance; P, PI, and PID control
Week 08	Closed loop stability of controlled systems; Routh-Hurwitz test; Pole placement
Week 09	Controller tuning and performance; Introduction to feed-forward control
Week 10	Feedforward control; Model identification
Week 11	State space representation; Multi-input/Multi-output systems
Week 12	Model identification using state space notation; Loop pairing; Interacting systems
Week 13	Review and wrap-up

CONDUCT EXPECTATIONS

As a McMaster student, you have the right to experience, and the responsibility to demonstrate, respectful and dignified interactions within all of our living, learning and working communities. These expectations are described in the [Code of Student Rights & Responsibilities](#) (the “Code”). All students share the responsibility of maintaining a positive environment for the academic and personal growth of all McMaster community members, **in person or online**.

It is essential that students be mindful of their interactions online, as the Code remains in effect in virtual learning environments. The Code applies to any interactions that adversely affect, disrupt, or interfere with reasonable participation in University activities. Student disruptions or behaviours that interfere with university functions on online platforms (e.g. use of Avenue 2 Learn, WebEx or Zoom for delivery), will be taken very seriously and will be investigated. Outcomes may include restriction or removal of the involved students’ access to these platforms.

ACADEMIC INTEGRITY

You are expected to exhibit honesty and use ethical behaviour in all aspects of the learning process. Academic credentials you earn are rooted in principles of honesty and academic integrity. **It is your responsibility to understand what constitutes academic dishonesty.**

Academic dishonesty is to knowingly act or fail to act in a way that results or could result in unearned academic credit or advantage. This behaviour can result in serious consequences, e.g. the grade of zero on an assignment, loss of credit with a notation on the transcript (notation reads: "Grade of F assigned for academic dishonesty"), and/or suspension or expulsion from the university. For information on the various types of academic dishonesty please refer to the [Academic Integrity Policy](https://secretariat.mcmaster.ca/university-policies-procedures-guidelines/), located at <https://secretariat.mcmaster.ca/university-policies-procedures-guidelines/>

The following illustrates only three forms of academic dishonesty:

- plagiarism, e.g. the submission of work that is not one's own or for which other credit has been obtained.
- improper collaboration in group work.
- copying or using unauthorized aids in tests and examinations.

AUTHENTICITY / PLAGIARISM DETECTION

Some courses may use a web-based service (Turnitin.com) to reveal authenticity and ownership of student submitted work. For courses using such software, students will be expected to submit their work electronically either directly to Turnitin.com or via an online learning platform (e.g. A2L, etc.) using plagiarism detection (a service supported by Turnitin.com) so it can be checked for academic dishonesty.

Students who do not wish their work to be submitted through the plagiarism detection software must inform the Instructor before the assignment is due. No penalty will be assigned to a student who does not submit work to the plagiarism detection software. **All submitted work is subject to normal verification that standards of academic integrity have been upheld** (e.g., on-line search, other software, etc.). For more details about McMaster's use of Turnitin.com please go to www.mcmaster.ca/academicintegrity.

ACADEMIC ACCOMMODATION OF STUDENTS WITH DISABILITIES

Students with disabilities who require academic accommodation must contact [Student Accessibility Services](http://www.mcmaster.ca/student-accessibility-services) (SAS) at 905-525-9140 ext. 28652 or sas@mcmaster.ca to make arrangements with a Program Coordinator. For further information, consult McMaster University's [Academic Accommodation of Students with Disabilities](http://www.mcmaster.ca/academic-accommodation) policy.

ACADEMIC ACCOMMODATION FOR RELIGIOUS, INDIGENOUS OR SPIRITUAL OBSERVANCES (RISO)

Students requiring academic accommodation based on religious, indigenous or spiritual observances should follow the procedures set out in the [RISO](http://www.mcmaster.ca/riso) policy. Students should submit their request to their Faculty Office **normally within 10 working days** of the beginning of term in which they anticipate a need for accommodation or to the Registrar's Office prior to their examinations. Students should also contact their instructors as soon as possible to make alternative arrangements for classes, assignments, and tests.

ACADEMIC ACCOMMODATIONS FOR RELIEF FOR MISSED ACADEMIC TERM WORK

Students requiring academic accommodation based on religious, indigenous or spiritual observances should follow the procedures set out in the [RISO](#) policy. Students should submit their request to their Faculty Office **normally within 10 working days** of the beginning of term in which they anticipate a need for accommodation or to the Registrar's Office prior to their examinations. Students should also contact their instructors as soon as possible to make alternative arrangements for classes, assignments, and tests.

INCLUSIVE ENVIRONMENT STATEMENT

We consider this classroom to be a place where you will be treated with respect, and we welcome individuals of all ages, backgrounds, beliefs, ethnicities, genders, gender identities, gender expressions, national origins, religious affiliations, sexual orientations, ability – and other visible and non-visible differences. All members of this class are expected to contribute to a respectful, welcoming, and inclusive environment for every other member of the class. We will gladly honour your request to address you by an alternate name or gender pronoun. Please advise us of this preference early in the semester.

The instructor is certified with the McMaster Professor Hippo on Campus Program for mental health awareness and aid to students in need. My office (or online video portal) is a **safe space** to discuss issues both academic and otherwise, and you are welcome to contact me at any time to chat. If I reach out to you at any time, be aware that it is not to embarrass or penalize you; it is because I care.



COURSES WITH AN ON-LINE ELEMENT

Some courses may use on-line elements (e.g. e-mail, Avenue to Learn (A2L), LearnLink, web pages, capa, Moodle, ThinkingCap, etc.). Students should be aware that, when they access the electronic components of a course using these elements, private information such as first and last names, user names for the McMaster e-mail accounts, and program affiliation may become apparent to all other students in the same course. The available information is dependent on the technology used. Continuation in a course that uses on-line elements will be deemed consent to this disclosure. If you have any questions or concerns about such disclosure please discuss this with the course instructor.

ONLINE PROCTORING

Some courses may use online proctoring software for tests and exams. This software may require students to turn on their video camera, present identification, monitor and record their computer activities, and/or lock/restrict their browser or other applications/software during tests or exams. This software may be required to be installed before the test/exam begins.

REQUESTS FOR RELIEF FOR MISSED ACADEMIC TERM WORK

McMaster Student Absence Form (MSAF): In the event of an absence for medical or other reasons, students should review and follow the Academic Regulation in the Undergraduate Calendar “Requests for Relief for Missed Academic Term Work”.

COPYRIGHT AND RECORDING

Students are advised that lectures, demonstrations, performances, and any other course material provided by an instructor include copyright protected works. The Copyright Act and copyright law protect every original literary, dramatic, musical and artistic work, **including lectures** by University instructors

The recording of lectures, tutorials, or other methods of instruction may occur during a course. Recording may be done by either the instructor for the purpose of authorized distribution, or by a student for the purpose of personal study. Students should be aware that their voice and/or image may be recorded by others during the class. Please speak with the instructor if this is a concern for you.

REFERENCE TO RESEARCH ETHICS

The two principles underlying integrity in research in a university setting are these: a researcher must be honest in proposing, seeking support for, conducting, and reporting research; a researcher must respect the rights of others in these activities. Any departure from these principles will diminish the integrity of the research enterprise. This policy applies to all those conducting research at or under the aegis of McMaster University. It is incumbent upon all members of the university community to practice and to promote ethical behaviour. To see the Policy on Research Ethics at McMaster University, please go to <https://reo.mcmaster.ca/>.

EXTREME CIRCUMSTANCES

The University reserves the right to change the dates and deadlines for any or all courses in extreme circumstances (e.g., severe weather, labour disruptions, etc.). Changes will be communicated through regular McMaster communication channels, such as McMaster Daily News, A2L and/or McMaster email.

NOTICE REGARDING POSSIBLE COURSE MODIFICATION

The instructor and university reserve the right to modify elements of the course during the term. The university may change the dates and deadlines for any or all courses in extreme circumstances. If either type of modification becomes necessary, reasonable notice and communication with the students will be given with explanation and the opportunity to comment on changes. It is the responsibility of the student to check their McMaster email and course websites weekly during the term and to note any changes.

Integrated Biomedical Engineering & Health Sciences (IBEHS) Labs/Design Studio Safety

Information for Laboratory Safety and Important Contacts

This document is for users of IBEHS instructional laboratories at the following locations:

- ETB - 533/534 (Medical Imaging & Medical Instrumentation Labs)
- ABB - C104 (Design Studio)
- HSC - 4N72 (Genetic Engineering Lab)

This document provides important information for the healthy and safe operation of IBEHS instructional laboratories. This document is required reading for all laboratory supervisors, instructors, researchers, staff, and students working in or managing instructional laboratories in IBEHS. It is expected that revisions and updates to this document will be done continually. A McMaster University [lab manual](#) is also available to read in every laboratory.

General Health and Safety Principles

Good laboratory practice requires that every laboratory worker and supervisor observe the following:

1. Food and beverages are not permitted in the instructional laboratories.
2. A Laboratory Information Sheet on each lab door identifying potential hazards and emergency contact names should be known.
3. Laboratory equipment should only be used for its designed purpose.
4. Proper and safe use of lab equipment should be known before using it.
5. The course TA leading the lab should be informed of any unsafe condition.
6. The location and correct use of all available safety equipment should be known.
7. Potential hazards and appropriate safety precautions should be determined, and sufficiency of existing safety equipment should be confirmed before beginning new operations.
8. Proper waste disposal procedures should be followed.
9. [Personal ergonomics](#) should be practiced when conducting lab work.
10. [Current University health and safety](#) issues, and protocols should be known.

Location of Safety Equipment

Fire Extinguisher

On walls in halls outside of labs or
ABB C103/A

ETB 534/A, ABB C103/A, HSC 4N72 or dial
"88" after 4:30 p.m.

Telephone

On the wall of every lab near the door

Fire Alarm Pulls

Near all building exit doors on all floors

First Aid Kit

Who to Contact

Emergency Medical / Security:

On McMaster University campus, call Security at extension **88** or **905-522-4135** from a cell phone.

Hospital Emergency Medical / Security:

For McMaster HSC, call Security at extension **5555** or **905-521-2100** from a cell phone.

Non-Emergency Accident or Incident: Immediately inform the TA on duty or Course Instructor.

University Security (Enquiries / Non-Emergency):

Dial 24281 on a McMaster phone or dial 905-525-9140 ext. 24281 from a cell phone.

See TA or Instructor: For problems with heat, ventilation, fire extinguishers, or immediate repairs.

Environmental & Occupational Health Support Services (EOHSS): For health and safety questions dial 24352 on a McMaster phone or dial 905-525-9140 ext. 24352 from a cell phone.

IBEHS Specific Instructional Laboratory Concerns: For non-emergency questions specific to the IBEHS laboratories, please contact appropriate personnel below from a McMaster phone...

- Leela Pilli – 26888
- Parmveer Bola – 23521
- Alexa Huang – 24548

In Case of a Fire (Dial 88)

When calling to report a fire, give name, exact location, and building.

1. Immediately vacate the building via the nearest Exit Route. Do not use elevators!
2. Everyone is responsible for knowing the location of the nearest fire extinguisher, the fire alarm, and the nearest fire escape.
3. The safety of all people in the vicinity of a fire is of foremost importance. But do not endanger yourself!
4. In the event of a fire in your work area shout "*Fire!*" and pull the nearest fire alarm.
5. Do not attempt to extinguish a fire unless you are confident it can be done in a prompt and safe manner utilizing a hand-held fire extinguisher. Use the appropriate fire extinguisher for the specific type of fire. Most labs are equipped with Class A, B, and C extinguishers. Do not attempt to extinguish Class D fires which involve combustible metals such as magnesium, titanium, sodium, potassium, zirconium, lithium, and any other finely divided metals which are oxidizable. Use a fire sand bucket for Class D fires.
6. Do not attempt to fight a major fire on your own.
7. If possible, make sure the room is evacuated; close but do not lock the door and safely exit the building.

Clothing on Fire

Do not use a fire extinguisher on people.

1. Douse with water from safety shower immediately or
2. Roll on floor and scream for help or
3. Wrap with fire blanket to smother flame (a coat or other nonflammable fiber may be used if blanket is unavailable). Do not wrap a standing person; rather, lay the victim down to extinguish the fire. The blanket should be removed once the fire is out to disperse the heat.

Equipment Failure or Hazard

Failure of equipment may be indicative of a safety hazard - You must report all incidents.

Should you observe excessive heat, excessive noise, damage, and/or abnormal behaviour of the lab equipment:

1. Immediately discontinue use of the equipment.
2. In Power Lab, press wall-mounted emergency shut-off button.
3. Inform your TA of the problem.
4. Wait for further instructions from your TA.
5. TA must file an incident report.

Protocol for Safe Laboratory Practice

Leave equipment in a safe state for the next person - if you're not sure, ask!

Defined Roles

TA	The first point of contact for lab supervision	
IBEHS Lab Technician	Leela Pilli	pillil@mcmaster.ca
IBEHS Instructional Assistant	Parmveer Bola	bolap1@mcmaster.ca
IBEHS Co-Directors	Dr. Greg Wohl	wohlg@mcmaster.ca
	Dr. Michelle MacDonald	macdonml@mcmaster.ca
IBEHS Administrator	Alexa Behar-Bannelier	huanqa2@mcmaster.ca
IBEHS Course Instructor	Please contact your specific course instructor directly	