College of Engineering

1. COURSE NAME AND NUMBER

ME/ECE 577 – Automatic Control Laboratory

2. CREDITS AND CONTACT HOURS

4 credits, 6 contact hours per week

3. CANVAS COURSE URL

https://canvas.wisc.edu/courses/388493

4. COURSE DESIGNATIONS AND ATTRIBUTES

None

5. MEETING TIME AND LOCATION

Lecture: M/W/F 1:20PM - 2:20PM, Location: 2534 Engineering Hall

Lab: M/W 2:30PM - 5:00PM, Location: 2145 Mechanical Engineering

Note: some lectures may be scheduled in the lab when a demo is planned. Some Friday lectures may be planned as discussion sessions for prelab prep

6. THE COURSE IS

Graduate level course for Mechanical Engineering and Electrical Engineering

7. INSTRUCTIONAL MODE

In person

8. CREDIT HOUR POLICY

8.1 How the course meets the credit hour policy

- This class meets for **three, 60-minute lectures** and **one 2.5-hour labs each week** over the fall semester
- Some lab assignments can be completed during the lab hours, and some may take longer

- The students are expected to work on extra course learning activities (e.g., reading assignments, pre-lab assignments, lab reports, etc)
- The total estimated amount of time that students are expected to spend on ME/ECE 577 study is **12-16 hours/week** (inside lecture/labs and outside), which well reflects the workload of a 4 credit course

8.2 Regular and Substantive Student-Instructor Interaction

- Regular interaction occurs weekly during scheduled **lecture hours** in addition to **scheduled lab times**, **attendance required (and graded).**
- Substantive Interaction is provided in the form of direct instruction, providing feedback on student work, instructor provided course content, and facilitation of course content discussion.

9. INSTRUCTORS AND TEACHING ASSISTANTS

9.1 Instructor Title and Name

Lei Zhou, Ph.D.

Assistant Professor, ME & ECE Department
lei.zhou@wisc.edu
Please write emails to me starting with **[ME 577] or [ECE 577]** in the caption which helps getting more timely response

9.4 Teaching Assistants

Jingjie Wu jingjie.wu@wisc.edu

TA Office hours: Lab session time at ME 2145

10. OFFICIAL COURSE DESCRIPTION

This is a **laboratory-based** course introducing the **design, analysis, and implement of control of mechatronic elements and systems**, which require integration of the mechanical and electrical engineering disciplines within a unified framework. There are significant laboratory-based design experiences.

Topics
Low-level interfacing of software with hardware;
Use of high-level graphical programming tools to implement real-time computation tasks;
Design and implementation of realtime feedback system;
Analog interfacing and power amplifiers;
Measurement and sensing;
Electromagnetic and optical transducers;
Grounding and shielding
Precision design principles

Goals

Fundamentals of DC and AC circuit analysis and design, stressing tools needed to understand circuits typically used in instrumentation and control of physical systems (sensors/actuators); an introduction to the design of active and passive linear circuits for buffering and filtering signals; an introduction to digital circuits, Boolean logic, programming, especially as needed for computer interface operations in mechanical engineering applications (example: embedded microcontrollers). Laboratory exercises.

11. REQUISITES

- ME 446 or ECE 332 or equivalent (classic control theory)
- ME/ECE 376 or ECE 230 or equivalent (circuit analysis)

12. LEARNING OUTCOMES

12.1 Course Learning Outcomes

- Learn knowledge on electrical, electromechanical, and feedback control principles
- Develop abilities to design and analyze mechatronic systems
- Gain hands-on experience in the design, control, integration, and tests of mechatronic systems
- Communicate with experts in the various disciplines associated with instrumentation of and computer control of machines and processes.

12.2 ABET Student Outcomes

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

3. an ability to communicate effectively with a range of audiences

5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

13. REQUIRED TEXTBOOK, SOFTWARE & OTHER COURSE MATERIALS

Textbooks:
We don't have a textbook for this course. Weekly lecture notes and reading materials will be posted on the course website.

Other references:

- Franklin, Gene F., et al. Feedback control of dynamic systems. Vol. 4. Upper Saddle River, NJ: Prentice hall, 2002.
- Schmidt, R. Munnig, Georg Schitter, and Adrian Rankers. The design of high-performance mechatronics-: high-Tech functionality by multidisciplinary system integration. Ios Press, 2020.
- Slocum, Alexander H. Precision machine design. Society of Manufacturing Engineers, 1992.
- Evans, Chris. "Precision engineering: an evolutionary view." Bedford: Cranfield Press (1989).
- Piersol, Allan G., and Thomas L. Paez. Harris' shock and vibration handbook. McGraw-Hill Education, 2010.

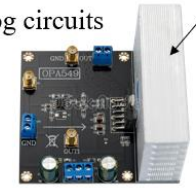
- Novotny, Donald W., and Thomas A. Lipo. Vector control and dynamics of AC drives. Vol. 41. Oxford university press, 1996.

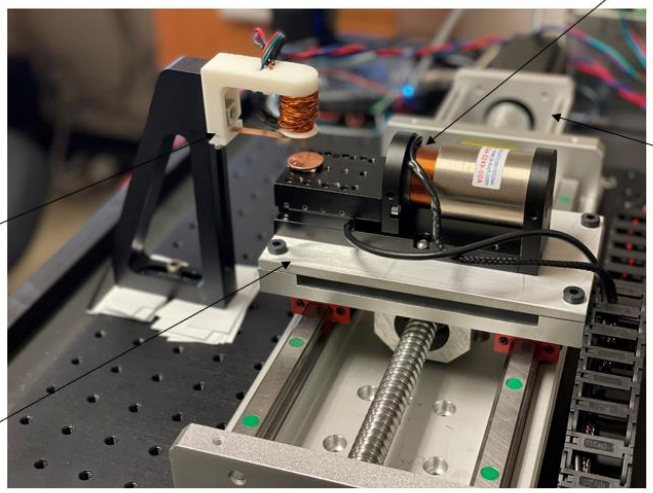
14. LABORATORY SESSIONS

Graphical Intro to our Labs:
Design, Building, and Control, and Testing for a Macro-scale Atomic Force Microscopes

Lab 1: Feedback system analysis and design review; get familiar with LabVIEW programming for control prototyping

Lab 2: Current feedback control using analog circuits





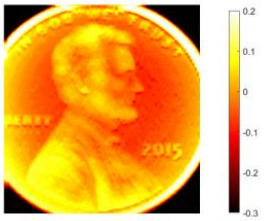
Lab 3: Encoder reading and interpolation & Voice coil stage position feedback control

Lab 4: Stepper motor stage control and commutation

Lab 5: AFM tip sensing, self-resonance control, tracking control, and calibration

Lab 6: Raster scan trajectory generation for xy stage

Lab 7: Imaging of your favorite sample



15. ASSESSMENTS

- There are approximately **7 lab assignments** in this course. Each lab assignment takes 1~2 weeks depend on the load of the specific lab.
- There are **no exams** in this course.
- All labs are done in groups of 2-3 students.
- Every lab has a **pre-lab assignment** due before starting to work on the experiment. The prelab assignment includes calculations, simulation, and reading for completing the lab work. **Everyone needs to submit pre-labs independently.**
- Each lab assignment involves connection, test, and measurement of existing hardware and program, measure, evaluate your control systems.
- You need to be in the lab during one of the two lab sessions during the lab hours. Members of one group need to be in the same lab session.
- You are allowed to work in the lab assignments outside the structured course lab sessions. We will give the lab access (ME 2145) to you later in the semester, and you can work in the lab at times that is convenient for you. **Note: Tuesdays and Thursdays are lab sessions for another course. Do not use the lab on Tuesdays and Thursdays.**
- After the experiment work, there is a **lab report due** and a **check-off** (20 minutes interview with the instructor/TA) for each group. You need to have your hardware running during the check off,

experimentally demonstrate your work, and go through your lab report to show your understanding to the questions. All members must be present at the check off time. **One group only need to submit one lab report.**

- **Missing 2 lab activities or checkoffs will automatically get an "F" in the class.**
- Your estimated average hours outside of the lecture on this course is **10 hour/week**.

Grading policy

- Pre-labs: 25%
- Lab check-off: 50%
- Lab report: 25%

16. Late Submission Policy

Late submission for prelabs or late checkoff are typically not permitted. In case of special circumstances (for example sickness or traveling due to conferences), please email the instructor and TA ahead of time.

17. Lecture Format

- Lectures will be given in-person at the classrooms during the class hours.
- The recorded videos of the lectures will be posted on Canvas site through the classroom recording. Coming to in-person lectures is required. Note: this video recording is **not realtime**.
- In-person lab session attendance is required. Students need to register in one of the lab sessions. Missing 2 lab session or checkoff will receive an automated F in the grade.

18. Lab Policies

1. No food allowed in the labs.
2. You are welcome to come in the lab and work on your lab assignments outside the structured lab sessions including weekends. However you are not allowed to bring parts and hardwares except for the lab kit that you checked out from the lab.
3. Clean up the bench after working on the lab: do not leave a mess. Do not play with the lab setups for other courses.

19. TENTATIVE COURSE SCHEDULE

Lec #	Topic	Lab assignment	deliverables
1	Introduction: Syllabus, Precision Mechatronics		
2	Review for dynamic systems, transfer functions, transient and frequency responses, importance of negative feedback	Lab 1 out	
3	Frequency domain analysis for feedback systems, Loop shaping for feedback systems		
4	LabVIEW for realtime control, FPGA programming		PreLab 1 due
5	Operational amplifier review		
6	Controller implementation via operational amplifiers	Lab 2 out	Lab 1 Checkoff
7	Current control for linear power amplifier		
8	Introduction to Encoders; Quadrature encoder and its interpolation using FPGA		Prelab 2 due
9	Lorentz force, magnetic circuits, voice coil actuators (VCAs)		
10	Position control for VCAs, bearing and its impact	Lab 3 out	Lab 2 Checkoff
11	Introduction to feedforward in motion tracking control		
12	Introduction of stepper motor and their control, PWM		Prelab 3 due

13	Stepper motor control using FPGA		
14	AC electric machines, commutation, field-oriented control	Lab 4 out	Lab 3 Checkoff
15	Linear bearing selection: linear slide, air bearing, flexures		
16	Introduction to self-resonance control: atomic force microscope tips		Prelab 4 due
17	Continue: AFM intro, resonance in control systems		
18	AFM tracking control with sensors	Lab 5 out	Lab 4 Checkoff
19	Sensorless estimation in resonance with back-emf		
20	Calibration of the height measurement using Macro-scale AFM tip		Prelab 5 due
21	Introduction to piezo-based AFM and STM, atomic precision manufacturing		
22	Static error budgeting: deterministic machine design	Lab 6 out	Lab 5 checkoff
23	Static error budgeting continue		
24	Signal processing fundamentals		Prelab 6 due
25	Dynamic error budgeting		
26	Introduction to iterative learning control	Lab 7 out	Lab 6 checkoff
27	Grounding/shielding		
28	Vibration isolation		Prelab 7 due
29	Invited industrial guest lecture or Advanced topics (TBD)		
30	Invited industrial guest lecture or Advanced topics (TBD)		Lab 7 checkoff
31	TBD		
32	End-of-Semester Poster Session		

RULES, RIGHTS & RESPONSIBILITIES

· See the Guide's to Rules, Rights and Responsibilities

ACADEMIC CALENDAR & RELIGIOUS OBSERVANCES

Academic Calendar & Religious Observances

Establishment of the academic calendar for the University of Wisconsin-Madison falls within the authority of the faculty as set forth in Faculty Policies and Procedures. Construction of the academic calendar is subject to various rules and laws prescribed by the Board of Regents, the Faculty Senate, State of Wisconsin and the federal government. For additional dates and deadlines for students, see the Office of the Registrar's pages. Students are responsible for notifying instructors within the first two weeks of classes about any need for flexibility due to religious observances.

ACADEMIC INTEGRITY STATEMENT

By virtue of enrollment, each student agrees to uphold the high academic standards of the University of Wisconsin-Madison; academic misconduct is behavior that negatively impacts the integrity of the institution. Cheating, fabrication, plagiarism, unauthorized collaboration, and helping others commit these previously listed acts are examples of misconduct which may result in disciplinary action. Examples of disciplinary sanctions include, but are not limited to, failure on the assignment/course, written reprimand, disciplinary probation, suspension, or expulsion.

ACCOMMODATIONS FOR STUDENTS WITH DISABILITIES

The University of Wisconsin-Madison supports the right of all enrolled students to a full and equal educational opportunity. The Americans with Disabilities Act (ADA), Wisconsin State Statute (36.12), and UW-Madison policy (UW-855) require the university to provide reasonable accommodations to students with disabilities to access and participate in its academic programs and educational services. Faculty and students share responsibility in the accommodation process. Students are expected to inform faculty of their need for instructional accommodations during the beginning of the semester, or as soon as possible after being approved for accommodations. Faculty will work either directly with the student or in coordination with the McBurney Center to provide reasonable instructional and course-related accommodations. Disability information, including instructional accommodations as part of a student's educational record, is confidential and protected under FERPA. (See: McBurney Disability Resource Center)

COURSE EVALUATIONS

Students will be provided with an opportunity to evaluate their enrolled courses and their learning experience. Most instructors use AEFIS a digital course evaluation survey tool. In most instances, students receive an official email two weeks prior to the end of the semester, notifying them that anonymous course evaluations are available. Student participation is an integral component of course development, and confidential feedback is important. UW-Madison strongly encourages student participation in course evaluations.

DIVERSITY & INCLUSION STATEMENT

Diversity is a source of strength, creativity, and innovation for UW-Madison. We value the contributions of each person and respect the profound ways their identity, culture, background, experience, status, abilities, and opinion enrich the university community. We commit ourselves to the pursuit of excellence in teaching, research, outreach, and diversity as inextricably linked goals. The University of Wisconsin-Madison fulfills its public mission by creating a welcoming and inclusive community for people from every background – people who as students, faculty, and staff serve Wisconsin and the world.

MENTAL HEALTH AND WELL-BEING STATEMENT

Students often experience stressors that can impact both their academic experience and personal well-being. These may include mental health concerns, substance misuse, sexual or relationship violence, family circumstances, campus climate, financial matters, among others.

Students are encouraged to learn about and utilize UW-Madison's mental health services and/or other resources as needed. Visit uhs.wisc.edu or call University Health Services at (608) 265-5600 to learn more.

PRIVACY OF STUDENT RECORDS & THE USE OF AUDIO RECORDED LECTURES STATEMENT

View more information about FERPA.

Lecture materials and recordings for this course are protected intellectual property at UW-Madison. Students in courses may use the materials and recordings for their personal use related to participation in class. Students may also take notes solely for their personal use. If a lecture is not already recorded, students are not authorized to record lectures without permission unless they are considered by the university to be a qualified student with a disability who has an approved accommodation that includes recording. [Regent Policy Document 4-1] Students may not copy or have lecture materials and recordings outside of class, including posting on internet sites or selling to commercial entities, with the exception of sharing copies of personal notes as a notetaker through the McBurney Disability Resource Center. Students are otherwise prohibited from providing or selling their personal notes to anyone else or being paid for taking notes by any person or commercial firm without the instructor's express written permission. Unauthorized use of these copyrighted lecture materials and recordings constitutes copyright infringement and may be addressed under the university's policies, UWS Chapters 14 and 17, governing student academic and non-academic misconduct.

STUDENTS' RULES, RIGHTS & RESPONSIBILITIES

Rights & Responsibilities

TEACHING & LEARNING DATA TRANSPARENCY STATEMENT

The privacy and security of faculty, staff and students' personal information is a top priority for UW-Madison. The university carefully reviews and vets all campus-supported digital tools used to support teaching and learning, to help support success through learning analytics, and to enable proctoring capabilities. View the university's full teaching and learning data transparency statement.