ME 392Q-9 Mechatronics II

Walker Department of Mechanical Engineering
The University of Texas at Austin

Classroom: ETC 5.132
Lab: ETC 3.148
Lectures: 2:00pm – 3:30pm, Monday & Wednesday
Lab hours: Two sessions: **3:30-5:30 pm, Mondays/Wednesdays at Lab: ETC 3.148**

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Description
This is a **laboratory-based** course introducing the **design and 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
- 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

Prerequisites
- ME 340 or its equivalent (circuits and electronics)
- ME 344 or its equivalent (dynamic system modeling and analysis)
- ME 338 or its equivalent (machine element and machine design)
- ME 364L or its equivalent (feedback system design and analysis)

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

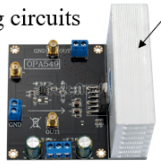
References

- 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.

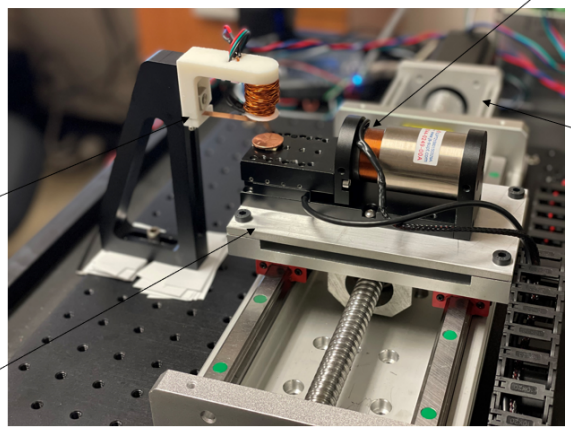
Graphical Intro to our Labs:
Design, Building, and Control, and Testings for a Macro-scale Atomic Force Microscopes

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

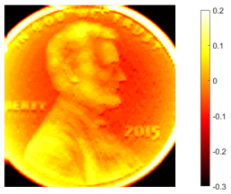


Lab 4: Stepper motor stage control and commutation

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



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 working 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 (ETC 3.148) to you later in the semeseter, and you can work in the lab at times that is convenient for you. **Note: Tuesdays and Thursdays are lab sessions for another course at ETC 3.148. 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. **One group only need to submit one lab report.**
- **Missing 2 labs 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%

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 conference), please email the instructor and TA ahead of time.

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 are required. Students need to register in one of the lab sessions. Missing 3 lab sessions will receive an automated F in the grade.

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.

Course website

Course materials including syllabus, lecture notes, lab assignments, and suggested reading will be posted on Canvas.

Lab Assignments (subject to changes)

- Lab 1: Digital control for analog circuits
- Lab 2: Current-controlled power amplifier
- Lab 3: Voice coil stage position control
- Lab 4: Stepper motor stage
- Lab 5: AFM tip and self-resonance control and tracking

- Lab 6: Raster scan programming for x-y stage
- Lab 7: Imaging

Class Schedule (subject to changes)

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		