TEXAS A&M UNIVERSITY
DEPARTMENT OF MECHANICAL ENGINEERING
FALL 2023

MEEN 433/667 Mechatronics

Basic principles of digital logic and analog circuits in mechanical systems; electrical-mechanical interfacing; sensors and actuators; digital control implementation; precision design and system integration. Three credit hours (2-3).

Instructor:

Won-jong Kim, Ph.D.
Associate Professor
223 MEOB
(979)845-3645, phone
wjkim@tamu.edu, email
http://alum.mit.edu/www/wjkim, webpage

TA:

Mr. Arunachalam Venkatachalam
arun23venkat@tamu.edu, e-mail

Lectures:

MW 11:30 AM–12:20 PM at 205 JCAIN

Labs:

W 5:30 PM–8:20 PM at 230 ZACH (Section 501/601)
R 5:30 PM–8:20 PM at 230 ZACH (Section 500/600)

Each lab consists of a 1-hour lab instruction followed by a 2-hour hands-on experiment. Lab attendance is mandatory.

Office Hours:

Dr. Kim:	T 4:00 PM–6:00 PM ONLINE, or by appointment. The ZOOM meeting ID and passcode are posted at Canvas.
Arunachalam:	M 5:00 PM–6:00 PM and F 5:00 PM–6:00 PM at TBA, or by appointment.

Textbooks (required):

- D. G. Alciatore and M. B. Histand (AH), *Introduction to Mechatronics and Measurement Systems*, 5th Ed., McGraw-Hill, 2019 (4th, 3rd, or 2nd Ed. OK).
- G. F. Franklin, J. D. Powell, and A. Emami-Naeini (FP), *Feedback Control of Dynamic Systems*, 8th Ed., Chap. 8, Prentice Hall, 2018 (7th, 6th, or 5th Ed. OK)—for digital control.

We will cover Chaps. 3, 5–7, and 9–11 of AH and Chap. 8 of FP in class. Chaps. 1–2, 4, and 8 of AH are assigned to read in the first week.

References:

- M. M. Mano and C. R. Kime (MK), *Logic and Computer Design Fundamentals*, 4th Ed., Prentice Hall, 2008—for digital logic and system design.
- P. Horowitz and W. Hill (HH), *The Art of Electronics*, 2nd Ed., Chaps. 1–12, Cambridge University Press, 1989—for analog electronics and interface.
- A. S. Sedra and K. C. Smith (SS), *Microelectronic Circuits*, 5th Ed., Chaps. 2–5, Oxford University Press, 2004—for analog electronic devices.
- B. W. Kernighan and D. M. Ritchie (KR), *The C Programming Language*, 2nd Ed., Prentice Hall, 1988—for C programming.
- G. S. May and S. M. Sze (MS), *Fundamentals of Semiconductor Fabrication*, Chaps. 1 and 9, Wiley, 2004—for semiconductor manufacturing.
- H. H. Woodson and J. R. Melcher (WM), *Electromechanical Dynamics*, Part 1, Chap. 4, Krieger, 1990—for electromechanics.
- I. J. Busch-Vishniac (BV), *Electromechanical Sensors and Actuators*, Chaps. 1 and 3–5, Springer-Verlag, 1999—for sensors and actuators.
- H.-D. Chai (C), *Electromechanical Motion Devices*, Chaps. 4–7, Prentice Hall, 1998—for sensors and actuators.
- A. H. Slocum (S), *Precision Machine Design*, Prentice Hall, 1992—for precision design.

Reading assignments will be given from these references. All references can be checked out for four hours from the Reserved Books Desk at Evans Library. Some of the materials are also accessible electronically. Visit https://reserves.library.tamu.edu and click on "Course Reserves Login" and log in with your NetID and password.

On-Line Course Materials:

A course website is being established at canvas.tamu.edu. You should be able to access the website if you are registered for the course. All course-related material you will need, e.g. lecture slides, handouts, homework sets, solutions, lab descriptions, photographs of previous term projects, data sheets, manuals, and other useful materials will be placed at this website.

Prerequisite: MEEN 364

- Dynamic systems and controls (MEEN 364)
- Sophomore-level electronics (ECEN 215)
- Hands-on instrumentation labs (MEEN 260)

Both ECEN 215 and MEEN 260 are prerequisite to MEEN 364. I expect you to be familiar with the following topics.

Dynamic systems and controls:

- Writing equations of motion and finding transfer function
- Determining system (time and frequency) responses
- Designing simple controllers (PID, etc.)
- Determining system stability

Sophomore-level electronics:

- Constitutive equations for passive elements, such as R, L, and C.
- Applying KVL and KCL for circuit analysis.
- Analyzing basic RLC circuits

- Analyzing basic OP Amp circuits

Hands-on instrumentation labs:
- Using basic instruments, such as oscilloscopes, function generators, power supplies, etc.
- Designing and performing basic engineering experiments.
- Writing technically sound proposals and reports.

I also expect that you are fluent in any programming language, such as C, Matlab, Python, C++, Java, Fortran, or any assembly language.

Course Objectives:

- Understand key contemporary issues in system integration with sensors, actuators, and real-time controllers.
- Cultivate confidence in your capability to design a microcontroller-based mechatronic system.

Course Learning Outcomes:

Upon successful completion of this course, you will be able to:

- Understand state-of-the-art microcontroller structures and their applications.
- Understand basic working principles of active electronic devices, such as BJT, FET, CMOS, and OP amp.
- Read and understand manufacturers' data sheets.
- Design combinational and sequential digital logic circuits with off-the-shelf ICs.
- Build analog and digital interface.
- Develop working knowledge in key sensors and actuators and their applications.
- Design and implement simple digital controllers.

Grading:

- Mid-term exam for 28%
- Final exam for 35% (approximately 6% from lab materials)
- Homework for 10% total
- Term project for 27%
- Lab attendance (If you miss a lab without university-approved excuses, 3% *of the total grade* per absence will be deducted. See the Absences section on page 5.)
- Lab safety (Upon each lab-safety violation, 1% *of the total grade* will be deducted. See the Laboratory Safety section on page 4.)

Exams:

- Mid-term exam: 5:30 PM–7:30 PM on Thursday, November 2, 2023 at TBA.
- Final exam: 10:30 AM–12:30 PM, Tuesday, December 12, 2023. Comprehensive. Covers all lecture and lab materials.

All exams are open-book, open-note. No electronic device except a calculator is allowed. In other words, you may bring any materials written or printed on paper media to the exams. However, *any materials authored or collected by anyone else who took or is taking this course are strictly prohibited. In addition, you may not share any materials with your classmates during the exams*. You should expect

substantial design problems (in hardware and software) that require creative application of the course materials.

Homework:

There will be 14 homework sets to be handed out every week. Each homework set is due 11:59 PM on its designated due date and should be submitted on Canvas electronically. Homework sets may contain design problems (in software and hardware) to prepare you for the labs, exams and term project. Your homework must represent your own work. *No late homework will be accepted*.

Laboratory Procedures:

Each lab group will be assigned a lab kit at the start of the semester. The lab kit contains all necessary components for completing the laboratory experiments, except for some instrumentation. Students must bring the lab kits to every lab session. Students will also need to use their personal laptop for all experiments.

Laboratory Safety:

Refer to the document titled, *Laboratory Safety: Basic Student Guideline*, posted at Canvas. You are asked to sign and return the safety contract to me by the first lab. Safety glasses are required in the lab space at all times. *Each student must acquire their own safety glasses*.

Term-Project Grading:

Term-project evaluations are scheduled on Wednesday/Thursday, November 8/9, 2023 and during the term-project presentation on Wednesday/Thursday, November 29/30, 2023. Your entire project will be graded based on the following percentages.

- Term-project proposal for 4% (clear idea and goal (2%), well-thought-out milestones (2%))
- Satisfactory progress by November 11 for 4% (show that you are meeting your project milestones)
- Successful use of course materials for 8% (analog electronics (2%), digital logic (2%), sensors (2%), actuators (2%)). You must demonstrate the full functionality of each item in your final project presentation to get the full credit.
- Presentation for 5% (quality of presentation, (2%), achieving the project goal (3%))
- Term-project report for 6% (lab notes (3%), term-project report (3%))
- Bringing a novel idea not covered in the course for bonus up to 5%

How to Choose Term-Project Topics:

See the above term-project grading policy and design your project so that you can demonstrate your knowledge and capabilities. If you borrow someone else's ideas in part, you must cite proper references. Otherwise, it will be considered plagiarism. All term-projects must employ a microcontroller development kit or equivalent.

Term-Project Expenses:

There will be small funds available for your term project, and you can purchase materials and supplies up to your budget. You should complete the purchase-order form posted in Canvas. Once the staff on the second floor of the Zachry Common Labs receives the package, they will notify you by email so that you can pick it up. It is advisable for you to plan ahead and allow a week time to get things

purchased and shipped. Note some key parts may have a long lead time. You will be responsible for the consequence from any late delivery of parts.

Additional facilities at the Fisher Engineering Design Center in ZACH will become available in the fall semester. Students who need to use these facilities will need to complete the EIC safety PowerPoint and take the safety quiz. For details, visit
https://engineering.tamu.edu/academics/fedc/index.html

Term-Project Proposal:

Each group brings an idea and submits a term-project proposal by 11:59 PM on Thursday, October 5, 2023. *No late proposal will be accepted.* The proposal must be *type-written* and may not exceed 5 single-spaced pages with 12-point fonts. Include sections representing (1) Objective and significance, (2) Design concept with representative diagrams, (3) Work plan with detailed milestones, (4) Budget and budget justification, and (5) Anticipated results.

Term-Project Satisfactory Progress:

Wednesday/Thursday, November 8/9, 2023 at 230 ZACH (during the lab). Demonstrate that your group is meeting your project milestones. You are encouraged to bring items from your ongoing project.

Term-Project Presentations:

Wednesday/Thursday, November 29/30, 2023 from 5:30 PM in 230 ZACH. An approximately 15-minute time slot will be assigned to each group by random drawing.

Term-Project Report:

Each group must hand in lab notes and a *type-written* term-project report by 11:59 PM on Thursday, November 30, 2023. *No late submission will be accepted.* The report must not exceed 10 single-spaced pages with 12-point fonts. Include sections representing (1) Objective and significance, (2) Professionally done engineering drawings for final design, (3) Experimental results, (4) Discussion and conclusions, and (5) Contributions of individual group members. On the report cover page, put the percentage effort made by each lab member and include the signatures of all lab members. Term-project proposals and reports will not be returned, so ensure you make copies for yourself.

Policy on Grading Complaints:

If you feel a mistake was made in grading any material, please first contact the person doing the grading within a week after the graded paper is distributed. If you are not satisfied with the resolution of the matter then talk to me. *After the one-week discussion period, we will not review your exams or change grades.* Make your complaint to me in writing and via e-mail. Be specific about your complaints. Please note I do not negotiate my partial-credit policy with students.

Tentative Grading Policy:

- A: greater than 80%
- B: greater than 60% and less than 80%
- C: greater than 40% and less than 60%
- D, F: less than 40%

Absences:

Work missed due to absences will only be excused for University-approved activities in accordance with TEXAS A&M UNIVERSITY STUDENT RULES (see https://student-rules.tamu.edu/rule07). Specific arrangements for make-up work in such instances will be handled on a case-by-case basis. In accordance with recent changes to Rule 7, please be aware that in this class any "injury or illness that is too severe or contagious for the student to attend class" will require "a medical confirmation note from his or her medical provider" (see Rule 7.3.2.1). Also refer to Rule 7.2.2.6 in regard to job interviews.

The university views class attendance and participation as an individual student responsibility. Students are expected to attend class and to complete all assignments. Please refer to Student Rule 7 in its entirety for information about excused absences, including definitions, and related documentation and timelines.

Students will be excused from attending class on the day of a graded activity or when attendance contributes to a student's grade, for the reasons stated in Student Rule 7, or other reason deemed appropriate by the instructor. Please refer to Student Rule 7 in its entirety for information about makeup work, including definitions, and related documentation and timelines.

Absences related to Title IX of the Education Amendments of 1972 may necessitate a period of more than 30 days for make-up work, and the timeframe for make-up work should be agreed upon by the student and instructor" (Student Rule 7, Section 7.4.1).

"The instructor is under no obligation to provide an opportunity for the student to make up work missed because of an unexcused absence" (Student Rule 7, Section 7.4.2). Students who request an excused absence are expected to uphold the Aggie Honor Code and Student Conduct Code. (See Student Rule 24.)

To Earn Graduate Credit:

MEEN 433/667 is a stacked course. University policy FS.18.033 requires that more rigorous activities be provided for graduate students to ensure work at the graduate level. To earn the MEEN 667 credit, you are required to design and successfully implement a real-time digital feedback controller in your term project. Failure to meet the graduate requirement will lead to 10% point deduction in the overall course grade.

Useful Websites:

- Textbook: https://mechatronics.colostate.edu
- Arduino: https://www.arduino.cc
- Fairchild Semiconductor Corp.: https://www.fairchild-semiconductor.com
- Texas Instruments, Inc.: http://www.ti.com
- ASCII Code Table: http://www.asciitable.com or http://www.jimprice.com/jim-asc.htm
- Resistor Color Code: https://www.mouser.com/technical-resources/conversion-calculators/resistor-color-code-calculator

Academic Integrity Statement and Policy:

"An Aggie does not lie, cheat or steal, or tolerate those who do."

"Texas A&M University students are responsible for authenticating all work submitted to an instructor. If asked, students must be able to produce proof that the item submitted is indeed the work of

that student. Students must keep appropriate records at all times. The inability to authenticate one's work, should the instructor request it, may be sufficient grounds to initiate an academic misconduct case" (Section 20.1.2.3, Student Rule 20).

You can learn more about the Aggie Honor System Office Rules and Procedures, academic integrity, and your rights and responsibilities at aggiehonor.tamu.edu.

On all course work, assignments, and examinations at Texas A&M University, the following Honor Pledge shall be preprinted and signed by the student:

"On my honor, as an Aggie, I have neither given nor received unauthorized aid on this academic work."

Signature of Student

Americans with Disabilities Act (ADA) Policy:

Texas A&M University is committed to providing equitable access to learning opportunities for all students. If you experience barriers to your education due to a disability or think you may have a disability, please contact the Disability Resources office on your campus (resources listed below) Disabilities may include, but are not limited to attentional, learning, mental health, sensory, physical, or chronic health conditions. All students are encouraged to discuss their disability related needs with Disability Resources and their instructors as soon as possible.

Disability Resources is located in the Student Services Building or at (979) 845-1637 or visit disability.tamu.edu.

Title IX and Statement on Limits to Confidentiality:

Texas A&M University is committed to fostering a learning environment that is safe and productive for all. University policies and federal and state laws prohibit gender-based discrimination and sexual harassment, including sexual assault, sexual exploitation, domestic violence, dating violence, and stalking.

With the exception of some medical and mental health providers, all university employees (including full and part-time faculty, staff, paid graduate assistants, student workers, etc.) are Mandatory Reporters and must report to the Title IX Office if the employee experiences, observes, or becomes aware of an incident that meets the following conditions (see University Rule 08.01.01.M1):

- The incident is reasonably believed to be discrimination or harassment.
- The incident is alleged to have been committed by or against a person who, at the time of the incident, was (1) a student enrolled at the University or (2) an employee of the University.

Mandatory Reporters must file a report regardless of how the information comes to their attention – including but not limited to face-to-face conversations, a written class assignment or paper, class discussion, email, text, or social media post. Although Mandatory Reporters must file a report, in most instances, you will be able to control how the report is handled, including whether or not to pursue a formal investigation. The University's goal is to make sure you are aware of the range of options available to you and to ensure access to the resources you need.

Students wishing to discuss concerns in a confidential setting are encouraged to make an appointment with Counseling and Psychological Services (CAPS).

Students can learn more about filing a report, accessing supportive resources, and navigating the Title IX investigation and resolution process on the University's Title IX webpage.

Statement on Mental Health and Wellness:

Texas A&M University recognizes that mental health and wellness are critical factors that influence a student's academic success and overall wellbeing. Students are encouraged to engage in proper self-care by utilizing the resources and services available from Counseling & Psychological Services (CAPS).

Students who need someone to talk to can contact Counseling & Psychological Services (CAPS) or call the TAMU Helpline (979-845-2700) from 4:00 p.m. to 8:00 a.m. weekdays and 24 hours on weekends. 24-hour emergency help is also available through the National Suicide Prevention Hotline (800-273-8255) or at suicidepreventionlifeline.org.

Covid Statement:

To help protect Aggieland and stop the spread of COVID-19, Texas A&M University urges students to be vaccinated and to wear masks in classrooms and all other academic facilities on campus, including labs. Doing so exemplifies the Aggie Core Values of respect, leadership, integrity, and selfless service by putting community concerns above individual preferences. COVID-19 vaccines and masking — regardless of vaccination status — have been shown to be safe and effective at reducing spread to others, infection, hospitalization, and death.

Schedule:

On the next page is a tentative schedule. The pace or sequence of the lectures will be adjusted as the semester progresses. The numbers in parentheses to the right of the topics indicate the corresponding chapters of the textbook. Reading assignments are given *in addition to* corresponding textbook reading.

Wk	Lectures	Lectures	Labs (Wednesday/Thursday)
1	**Course Overview (1)** AH 1–2	**Semiconductor Electronics (3)** semiconductor physics, band theory, doping, PN-junction diode, Zener diode, light-emitting diode (LED)	No lab AH 4; SS 3
2	**BJT (3)** bipolar-junction transistor (BJT), BJT common-emitter operation HH 1–2.9; SS 4	**BJT Applications (3)** BJT applications for switching, semiconductor manufacturing MS 1, 9	**µC Overview (7)** microcontroller architecture, instruction set AH 7.1–7.4; MK 10–12; HH 11
3	**Digital Circuits (6)** DL (diode logic), DTL, TTL (transitor-transitor logic)	**Combinational Logic (6)** number system, Boolean algebra, truth table, DeMorgan's theorem, bubble pushing, half adder, full adder	**C Programming** C language, communication AH 7.7; KR
4	**Combinational Logic (6)** Karnaugh map, logic minimization, binary subtractor MK 1–5	**Combinational Logic (6)** binary parallel adder, carry look-ahead, comparator, parity generator/checker	**Digital I/O and A/D (8)** I/O and data acquisition AH 8; HH 9.15–9.26; MK 13
5	**Combinational Logic (6)** decoder/demultiplexer, multiplexer/data selector, encoder	**Sequential Logic (6)** timing chart, RS latch, D flip-flop (FF), JK FF, T FF, switch debounce circuits	**Interrupts** polling and interrupts HH 10
6	**Sequential Logic (6)** master-slave FF, edge-triggered FF, FF with data lockout MK 6	**Sequential Logic (6)** shift register, data converter/ transmitter, binary ripple counter MK 7; HH 8	**Encoder** interface with polling and interrupts
7	**Sequential Logic (6)** synchronous counter, BCD (binary-coded-decimal) counter, counter applications	**Field Effect Transistor (FET) (3)** JFET, MOSFET (metal-oxide semiconductor FET), MOSFET switch, CMOS (complementary MOS), SS 5	**Logic Gates and FFs (6)** RS latch, D FF, JK FF, binary counter AH 7.6
8	**Large-Scale IC (6)** CMOS logic and memory, flash memory, TTL-CMOS interfacing HH 3, 9.1–9.14; MK 9, 14	**Position Sensors (9)** capacitance probe, LVDT, laser distance sensor, laser interferometer, optical encoder	Reserved for Fall Break
9	**Specialty Sensors (9)** strain gauge, accelerometer, thermocouple, load cell, pyrometer S 3–4	**Electromechanical Actuators (10)** voice-coil actuator, DC motor, PM motor, stepper motor WM 4; BV 1, 3, 4–5; C 4–7	**555 Timer and OP Amp** monostable and astable oscillators HH 5.12–5.20
10	**Smart-Material Actuators (10)** piezoelectric, magnetostrictive, ionic-polymer actuators	**Analog Signal Processing (5)** voltage regulator, OP amps, differential amplifier, instrumentation amplifier, anti-aliasing filter, active filter HH 2.15–2.25, 4, 5.1–5.11, 6–7	**Sensors and Actuators** interface with temperature sensor, IR range sensor, and solenoid valve/relay
11	**Analog Signal Processing (5)** low-frequency amplifiers, pulse-width modulation (PWM) amplifier, ground-loop elimination AH 7.8–7.9; HH 15	**Discrete-Time Systems (FP 8)** difference equation, Z-Transform	Mid-Term Exam 5:30 PM–7:30 PM, Thursday, November 2, 2023
12	**Digital Control (FP 8)** design by emulation, digital PID and lead-lag compensators	**Digital Control (FP 8)** root locus, zero-order-holder (ZOH) equivalence	**PWM** PWM, DC motor driving AH 10.5
13	**Real-Time Control (FP 8)** real-time control implementation	**Mechatronic Systems (11)** precision design, interfacing, sensor mounting. S 1–2	**DC Motor Control** digital controller design and implementation
14	**Reserved for Term-Project Preparation/Presentation** HH 12	Thanksgiving Holiday	**Term-Project Presentation**

MEEN 433/667 Mechatronics

Fall 2023

Instructor: Prof. Won-jong Kim

Questionnaire

Name:

Email address:

Phone number (optional):

TAMU ID:

TAMU Department:

Are you a senior, a master's student, or a doctoral student?

Advisor (if applicable):

Have you taken ECEN 215 (or equivalent)?	Yes.	No.
Have you taken MEEN 260 (or equivalent)?	Yes.	No.
Have you taken MEEN 364 (or equivalent)?	Yes.	No.

What would you like to learn from this course?

Will the course materials be useful for your research? If so, please tell me about your research briefly.