ME 454

MECHATRONICS

COURSE SYLLABUS

Spring 2021

All lectures, labs and office hours held by instructor or TAs will be online using the same zoom:
https://psu.zoom.us/j/847975790

Lectures: Delivered *synchronously* on Zoom (Instructor: Dr. Bo Cheng)
W/F 10:10 AM – 11:00 AM

Labs:
Section 1: **Tu** 08:00 AM - 11:00 AM (TA: Liming Gao)
Section 2: **Tu** 11:15 AM - 02:15 PM (TA: Wesley Huff)
Section 3: **Tu** 02:30 PM - 05:30 PM (TA: Sasha Yaskolko)
All sections are held online, but for those needing in-person facilities, these are available in 339 Reber only with coordination with the teaching assistants and Dr. Cheng. For lab access, you want to make sure that you have an ME account, we will be requesting swipe access for the class (or at least those need lab access).

Instructor: **Dr. Bo Cheng**
Office: 228 Reber BLDG
E-mail: buc10@psu.edu
Office Hours: **W/F** 11:00 AM – 12:00 PM (following the lectures),
M 10:10 AM – 11:00 AM (at the scheduled lecture time), or by appointment.

TAs: **Liming Gao**
E-mail: lug358@psu.edu
Lab Session 1 **Tu** 08:00 AM - 11:00 AM;
Office Hour: **M** 01:00 PM - 2:00 PM

Wesley Huff
E-mail: wch5098@psu.edu
Lab Session 2 **Tu** 11:15 AM - 02:15 PM;
Office Hour: **Th** 01:00 PM - 02:00 PM

Alexander (Sasha) Yaskolko
E-mail: axy5104@psu.edu
Lab Session 3 **Tu** 02:30 PM - 05:30 PM;
Office Hour: **Th** 10:00 AM - 11:00 AM

Bryan Habas
E-mail: bvl5211@psu.edu
Homework Grading
Office Hour: **F** 01:00 PM - 03:00 PM

NOTES ON CONTACTING US:

- For lab-related questions, please send messages to the TA of your session and cc the instructor.
- For lecture-related questions, please send messages to both the instructor and TA Bryan Habas.
- Please put ME454 somewhere in the subject of the E-mail. For example: "ME454: I need to miss class on Friday 01/10/2018 for an interview". We search for the term "ME454" when looking for emails from the class.
- We understand that we may NEED to meet in the lab, especially if coding or hardware is involved. The TA's office hours – if in person – might be held in the lab, 339 Reber if COVID restrictions allow (total three people, including TA are currently allowed in the lab).

Prerequisite: M E 348 (previously ME 345). Failure to meet the prerequisites may result in automatic removal from the course, so students in violation of this must carefully coordinate with Dr. Cheng during the registration process.

Prerequisite Knowledge: Each student should remember primarily two things:

1) We expect a basic familiarity with formal programming methods (e.g., C language and/or Arduino programing language). If you do not know how to correctly code an *if/then/else* statement or *for/do* loop, nor know how to functionalize your code, then you do not have a basic familiarity with coding methods.
2) We expect some memory of the basics of circuitry (e.g., those covered in ME 348), specifically Ohm's law, low-pass and high-pass filters (passive form), and the basic KVL and KCL methods of circuit analysis from physics. We'll review some of these topics, as this course together ME 348 are intended to replace EE 212.

Some assignments will require the use of MATLAB, so knowledge of this software is beneficial but not expected. For students who are not familiar with this software, extensive tutorials are provided and a very affordable student license is available for your personal computers (it's free as well in some cases).

Topics: This class introduces the electrical and mechanical building blocks of a mechatronic system (e.g., passive electrical components, transistors, logic gates, microcomputers, sensors and motors), how to interface these analog or digital devices, the computer logics and theories for controlling mechatronic systems and techniques for data acquisition and data analysis.
This class has total 7 modules with 22 lectures and 10 labs. See the detailed course schedule and topics on the last page of the syllabus.

Course Objectives: Upon completion of the course, students should be able to:

1. Analyze, design and build analog DC and AC circuits using resistors, capacitors, inductors, diodes and transistors.
2. Understand the basic computer logic (combinational and sequential).
3. Analyze, design and build digital TTL circuits
4. Build and trouble-shoot analog and digital circuits connected to single chip microcontrollers using prototype wiring and printed circuit board layout
5. Interface common transducers (sensors) and actuators to microcontrollers
6. Filter, digitize and analyze electronic signals using analog anti-aliasing filters, A/D converters, and digital filters.
7. Understand and connect computer peripherals using standard interfaces (RS-232, USB)
8. Communicate well using verbal, written and electronic methods

Textbook: There is no textbook for this course; however, students are required to purchase the following two lab kits (per the first course announcement)

- "Student Kit" developed by Arduino,
  The Arduino Student Kit is shared between ME 348 and ME 454, and I believe the many of you already have it.
- "ME 454 Supplemental Kit"
  This kit is developed by Pitsco specifically for labs in ME 454

After this course, the students are free to sell the kits to future students of this course, similar to textbooks, assuming the kits are in good conditions.

For those that really want a textbook for a reference, the following books are suggested.

[1] David G. Alciatore and Michael Histand. *Introduction to Mechatronics and Measurement Systems, 2nd Edition.* McGraw-Hill, Boston, 2003. (Good starter undergrad book, nice discussion of semiconductor electronics).

[2] Robert H. Bishop. *The Mechatronics Handbook*, CRC Press, 2002.

[3] Horowitz, P., Hill, W., *The Art of Electronics, 2nd ed.*, Cambridge University Press, New York, 1989. (This is the de-facto standard book on electronics, and one everyone should own if they plan to do extended work in this area)

[4] D.M. Kaplan and C.G. White. *Hands-On Electronics,* Cambridge University Press, 2003

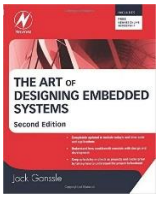
[5] Takashi Kenjo and S. Nagamori. Permanent-Magnet and Brushless DC Motors (Monographs in Electrical and Electronic Engineering) (Very good book on DC motors)

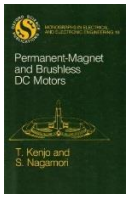
[6] Bolton, W., *Mechatronics: Electronic Control Systems in Mechanical Engineering,* Addison Wesley Longman, Edinburgh Gate, England, 1995.

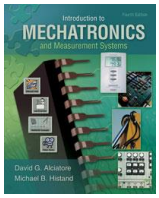
[7] Tamal Bose, *Digital Signal and Image Processing.* Wiley Interscience, 2004.

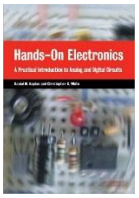
[8] Charles Fraser and John Milne, *Electro-Mechanical Engineering, An Integrated Approach.* IEEE Press, New York. (This book is a general overview of mechatronics, and has a great discussion of electrical motors)

[9] Ganssle, Jack. *The Art of Designing Embedded Systems, 2nd ed.* Newnes / Elsevier. Amsterdam. 2008.









Grading:

- 2 exams on lecture materials (14% each) 28%
  Individual effort
- 1 exam on practicum - lab materials (16%) 16%
  Individual effort
- 10 Labs (3.5% each) 35%
  Team effort
- 7 Homework Assignments (3% each) 21%
  Team effort

Note: Grades in this class follow the "thirds" rule of percentages: A is 100 to 93.33, A- is 93.33 to 90. B+ is 86.67 to 90, etc. This is a bit different than some classes, but it is recommended to PSU faculty as it reflects more accurately how cumulative GPA is calculated.

Lecture details:

Lectures will be offered via *remote synchronous mode* on Wednesdays and Fridays.
Lectures are organized into 7 modules, see course schedule below.
Pdfs of the lecture slides will be posted to Canvas before each lecture.
Recorded lecture videos will be uploaded to Canvas after each lecture.

Homework Assignments:

There are total 7 homework assignments (about one for each module)
Homework is also based on team effort, with the **same lab team** (one submission each lab team)
Submit homework online through Canvas upload.

No late homework will be accepted. Homework regrades must be requested in writing within one class period after its original return.

Exams: There will be total three exams, see course scheduled for the exams dates (tentative).

The first two exams will be based on material from the lecture materials, homework and any assigned reading or video lectures, with particular focus on lecture topics. The first two exams will be closed-book, closed-notes.

The third exam in the class is a practical exam, one that tests the student's ability to recognize and debug common Mechatronic problems – both in hardware and in code. So it is best if all lab partners know how to do the labs completely, and *it is not advisable to separate lab responsibilities* into "one person codes, and the other does hardware / writing." Teams that have split work in the past have resulted in one or both students doing very poorly on the third exam. The third exam will be offered during the scheduled lab sessions in week 15. This exam will be open notes (any materials provided in this course can be used), however students should not use the internet for answers.

Makeup exams will only be arranged for students with valid excuses provided at least one class period before the scheduled exam. If you have a valid conflict, please let us know as soon as possible.

Lab Details: There will be total 10 labs. Please attend your scheduled lab sessions on Tuesdays, you can work on the labs both inside and outside the scheduled lab sessions.
(*some have prelabs, due before each lab, see course schedule below*)

Labs are based on team effort, each team can have 2-3 students
(*previous offerings of this course with a smaller class size indicate that students from team of 2 outperform students from team of 3*)

Lab checkoffs (via videos or by TA at scheduled lab sessions), checkoff items are detailed in the lab instructions.
Lab reports are due on 11:59pm on Monday, one week after the lab, submit through Canvas upload, one submission each lab team.

Lab work should be done in teams of two or three for non-COVID in-person situations and done alone if working remotely but partnered virtually with another student if COVID isolation is active. Both partners are expected to participate in and understand all lab work. The breakdown of responsibilities is up to lab partners (see lab teaming process below), but all students may be tested on any lab content in the third exam. A lab check-off is assumed to cover all students in a lab group, but each individual may be questioned on specific items by the TA or instructor.

Lab Teaming Process:

1) Self teaming: please try to find your teammates on your own and create lab groups on Canvas before 11:59PM Wednesday (01/20). Go to People -> Lab Session#
Name your group using the following format:
Session#_Group_LastName1-LastName2-LastName3,
For example, Session2_Group_Cheng-Habas-Yaskolko
2) **TA-assisted teaming**: for those who need TA's assistance for the teaming, please notify the TA of your session before 11:59pm Wednesday (01/20), we expect all teaming to finish on Friday (01/22), first week of the semester.

Teamwork process for homework assignments and labs:
Before meeting in teams to work on the homework/labs together, every student **must** make a significant attempt to solve every problem/tasks on their own. To confirm that this was done, **the *leader* will receive each team member's written work from their individual attempts and append this to the uploaded PDF, following the team's final answers**.

In accomplishing each homework or lab, each team should assignment a *leader* and the rest of the team member(s) will be the *checker(s)*. These roles will rotate among team members on each assignment or lab.

- *Leader* – The leader will make sure that all team members know their responsibilities and understand all problems, tasks and solutions. The leader will also prepare the team's final answers. Once all other team members are satisfied with them, the leader will submit these as a PDF to Canvas by the due date, with a cover page. To make logistics easier for the graders, ***only the leader should upload the team's final document to Canvas.***

- *Checker(s)* – The checker(s) will check the answers for accuracy and proper formatting before the assignments are handed in. A team with 3 students will have 2 checkers.

Every homework assignment or lab report will be submitted with a cover page listing all participating team members and their designated roles. If a team member does not participate, then that person's name should not appear on the cover page.

Lab Basics (non-COVID rules)

1. The lab is open whenever Reber Building is open. While each semester seems to improve our efficiency in presenting the labs, on average you will need 4 hours per week to complete the lab portions of the class. Each lab team will be assigned a lab station for the duration of the semester. Keep your lab station clean - cleaning products will always be available for this purpose.
2. NO smoking, eating or drinking in the lab. Violation of this policy will result in a 1/3 lab assignment grade reduction for each violation. One reason liquids are not allowed in the lab is that each computer station costs around $2000, plus another $500 worth of someone's time to set it up properly.

3. Wash your hands after lab. Wiring and electronics have historically been a large source for mercury and lead contamination. For mechatronics students, lead or mercury poisoning almost exclusively occurs due to students putting items in their mouth without washing hands after handling electronics.
4. Do not remove any manuals, hardware or software from the lab without explicit permission of the TA. Electronics and hardware designated for ME 454 stock should not be carried outside the lab nor used for any outside research projects. Such activity is a violation of several financial rules that Penn State uses to fund the lab, and thus violation of this rule can result in complete removal of all financial support for the lab equipment and project work.
5. Only students registered for ME 454 should be in the lab, due to safety/training requirements.
6. Backup all your work. We assume no responsibility for hard disk failures, lost USB drives, or viruses.
7. You are responsible for the tools, hardware and manuals at your workstation. They have been marked corresponding to stations and will be checked at the end of the semester. Please help us insure that next semester's class has an equally well equipped place to work. Your grade will be docked by one letter grade for each $50 worth of equipment that is missing.

Questions: Please feel free to ask questions before, during, or after class, since this saves E-mail exchanges, scheduled meetings, etc. E-mail works as well, and if the question is good, the TA or the professors will CC the entire class.

But one request: include a hypothesis. In other words, don't simply ask "What do I do here?" or "What do you mean?" or "I don't understand…". Instead, write, "I think you mean X here, is this correct?" or, "I think I should do Y, right?" A good question is one where we can reply with a yes or no answer (or a number), since this shows that you have a good understanding of both the material, and what type of answer you want.

Finally, the homework is meant to challenge you, but don't bang your head against a wall, especially on a software issue. If you or your team aren't getting anywhere after a reasonable effort (20-30 minutes is a reasonable amount of time to work on a problem section), please just ask!

Policy on cheating:

Standard (required) statement: (see https://senate.psu.edu/faculty/syllabus-statement-examples/#academicintegrity) Academic integrity is the pursuit of scholarly activity in an open, honest and responsible manner. Academic integrity is a basic guiding principle for all academic activity at The Pennsylvania State University, and all members of the University community are expected to act in accordance with this principle. Consistent with this expectation, the University's Code of Conduct states that all students should act with personal integrity, respect other students' dignity, rights and property, and help create and maintain an environment in which all can succeed through the fruits of their efforts.

Academic integrity includes a commitment by all members of the University community not to engage in or tolerate acts of falsification, misrepresentation or deception. Such acts of dishonesty violate the fundamental ethical principles of the University community and compromise the worth of work completed by others.

For this class: I want you to teach each other, but not give solutions to each other. Students are free to discuss about the homework problems and lab tasks within the teams, but they should make sufficient individual efforts prior to discussion and teamwork. Discussions are also allowed across teams, however, each team should develop their solutions independently. When looking at solutions, the person grading can clearly tell that the work of two different teams is the same, then cheating has occurred. Where cheating is evident, all students/teams will receive a 0 for the assignment at the first warning, a letter grade deduction for the class plus a zero for the assignment on second warning, and dismissal from the class on the third warning. The second warning and third warnings will be processed as academic integrity violations per PSU policy above.

********* Standard required elements **********

Students with Disabilities:

Standard required statement: (see https://senate.psu.edu/faculty/syllabus-statement-examples/#disability)

Penn State welcomes students with disabilities into the University's educational programs. Every Penn State campus has an office for students with disabilities. Student Disability Resources (SDR) website provides contact information for every Penn State campus (http://equity.psu.edu/sdr/disability-coordinator). For further information, please visit Student Disability Resources website (http://equity.psu.edu/student-disability-resources/).

In order to receive consideration for reasonable accommodations, you must contact the appropriate disability services office at the campus where you are officially enrolled, participate in an intake interview, and provide documentation: See documentation guidelines (http://equity.psu.edu/sdr/guidelines). If the documentation supports your request for reasonable accommodations, your campus disability services office will provide you with an accommodation letter. Please share this letter with your instructors and discuss the accommodations with them as early as possible. You must follow this process for every semester that you request accommodations.
For this class: Please know that my goal is to help you succeed in learning the material, however we can make this happen. Please let me know how to do this for you!

Psychological Services: (see https://senate.psu.edu/faculty/syllabus-statement-examples/#caps)

Many students at Penn State face personal challenges or have psychological needs that may interfere with their academic progress, social development, or emotional wellbeing. The university offers a variety of confidential services to help you through difficult times, including individual and group counseling, crisis intervention, consultations, online chats, and mental health screenings. These services are provided by staff who welcome all

students and embrace a philosophy respectful of clients' cultural and religious backgrounds, and sensitive to differences in race, ability, gender identity and sexual orientation.

Counseling and Psychological Services at University Park (CAPS) (http://studentaffairs.psu.edu/counseling/): 814-863-0395

Counseling and Psychological Services at Commonwealth Campuses (https://senate.psu.edu/faculty/counseling-services-at-commonwealth-campuses/)

Penn State Crisis Line (24 hours/7 days/week): 877-229-6400
Crisis Text Line (24 hours/7 days/week): Text LIONS to 741741

Educational Equity and Bias: (see https://senate.psu.edu/faculty/syllabus-statement-examples/#reportbias)

Penn State takes great pride to foster a diverse and inclusive environment for students, faculty, and staff. Acts of intolerance, discrimination, or harassment due to age, ancestry, color, disability, gender, gender identity, national origin, race, religious belief, sexual orientation, or veteran status are not tolerated and can be reported through Educational Equity via the Report Bias webpage (http://equity.psu.edu/reportbias/).

Mask Wearing and Attendance:

We know from existing scientific data that wearing a mask in public can help prevent the spread of COVID-19 in the community (Lyu and Wehby, 2020; CDC, 2020; Johns Hopkins Medicine, 2020). Just as you're expected to wear a shirt and shoes to class every day, everyone -- including the instructor and TAs -- are required to wear a face mask in any University buildings, including classrooms and labs. You MUST wear a mask appropriately (i.e., covering both your mouth and nose) in the any building. You will not be permitted into classrooms or lab spaces without a mask if you are attending class in person. Masks have been provided for students, faculty, and staff, and everyone is expected to wear one while on campus or out in the community.

All students, faculty and staff are expected to maintain social distancing (i.e., maintain at least six feet of space between individuals) when possible. Seating patterns and attendance patterns, including assigned seating and closed-off desks/chairs/room sections, have been established to help allow for this distance for your safety. It is also important to follow related guidance communicated by the University and via public postings/signage related to directional traffic flow and limiting the maximum occupancy of spaces.

Nobody is are not permitted to consume food or drink in labs: note -this includes water. If you must drink something, please step outside of the lab space before removing your mask. And if possible, use a straw. Cooperation from EVERYONE will help control the spread of the virus and help us get back to the previous version of campus life as quickly as possible.

Anyone attending labs in person without a mask will be asked to put one on or leave. Refusal to comply with University policies is a violation of the Student Code of Conduct. Students who refuse to wear masks appropriately may face disciplinary action for Code of Conduct

violations. See details here: https://studentaffairs.psu.edu/support-safety-conduct/student-conduct/code-conduct

References:
Centers for Disease Control and Prevention. (2020, April 3) Recommendation Regarding the Use of Cloth Face Coverings, Especially in Areas of Significant Community-Based Transmission. https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/cloth-face-cover.html

Johns Hopkins Medicine. (2020, June 17) Coronavirus Face Masks & Protection FAQs. https://www.hopkinsmedicine.org/health/conditions-and-diseases/coronavirus/coronavirus-face-masks-what-you-need-to-know

Lyu, W. and Wehby, G.L. (2020, June 16) Community Use Of Face Masks And COVID-19: Evidence From A Natural Experiment Of State Mandates In The US. Health Affairs. https://www.healthaffairs.org/doi/full/10.1377/hlthaff.2020.00818?url_ver=Z39.88-2003&rfr_id=ori%3Arid%3Acrossref.org&rfr_dat=cr_pub++0pubmed&

Webcam usage:
During any regular remote instruction, cameras are encouraged when possible, but note that the class has a camera-optional practice for teaching through Zoom. As a parent working from home, I'm very sensitive to the fact that not all students will be attending online classes from environments conducive to webcam operations. This camera-optional approach seeks to respect student issues, such as equity (e.g., some students may not have cameras on their devices), personal safety and security (e.g., some students may be deployed on active military service or be in need of safety or privacy), privacy concerns, and religious beliefs. When on Zoom, students should assume that all activities are being recorded immediately on entry into the class.

Tentative Course Schedule

The following course schedule includes the planned modules for lecture and lab sequences and the associated dates. This will form the basis for this semester's activity; however, modifications are always being made to the content, and so it may occur that the content in some places will drift away from this schedule, particularly for the last few lectures where new content and topics are often tested as time permits.

Date	Week	Topics and Labs	Major Assignements Due
Jan 19	Week 1	Lab 00: Prelab activity - safety, grouping, grading, hardware kits and lab basics	
Jan 20		L01: Module 1 -- Course Intro - Syllabus and Intro to Mechatronics	
Jan 22		L02: Module 2 -- Electronic Systems - Passive Elements and Applications	
Jan 26	Week 2	Lab 01: Playing with Lights - Introduction to Analog I/O, Transistor and Feedback Control	
Jan 27		L03: Module 2 -- Electronic Systems - Transistors	
Jan 29		L04: Module 2 -- Electronic Systems - Transistors and Applications	Homework 1 out
Feb 2	Week 3	Lab 02: Moving Upward Binary Addition with Logic Circuit	Lab 01 due
Feb 3		L05: Module 3a -- Computer Logic - Combinational Logic (Logic gates and Boolean Algebra)	
Feb 5		L06: Module 3a -- Computer Logic - Combinational Logic (Logic circuits and Boolean Implementation)	Homework 2 out, Homwork 1 due
Feb 9	Week 4	**Wellness Day (no lab)**	
Feb 10		L07: Module 4 -- System Interfacing - Overview and AD Conversions	
Feb 12		L08: Module 4 -- System Interfacing - Impedance and Power Transfer	Homework 3 out, Homwork 2 due
Feb 16	Week 5	Lab 03: Etch-a-Sketch - Arduino-MATLAB Interface	Lab 02 due
Feb 17		L09: Module 4 -- System Interfacing - PWM and Motor Drive	Exam 1 Materials ends
Feb 19		L10: Module 5 -- Sensors & Filtering - Ecoders	
Feb 23	Week 6	Lab 04: Encoders - Interrupts and quadrature	Lab 03 due
Feb 24		L11: Module 5 -- Sensors & Filtering - Sensor Theory (supp video and materials on sebsor election)	
Feb 26		L12: Module 5 -- Sensors & Filtering - Analog and Digital Filters (supp video and materials on signal and noise)	Homework 4 out, Homwork 3 due
Mar 2	Week 7	Lab 05: Signal Filtering - Analog and Digital Filters	Lab 04 due
Mar 3		**Exam1 - Lecture materials (M1,2,3a,4)**	
Mar 5		L13: Module 6 -- Actuators - Servos	
Mar 9	Week 8	Lab 06: Servos - Hobby Servo Position Control	Lab 05 due
Mar 10		L14: Module 6 -- Actuators - Motor Bascis	
Mar 12		L15: Module 6 -- Actuators - Motor Gearing	Homework 5 out, Homwork 4 due
Mar 16	Week 9	Lab 07: DC motors - Motor Drive and Performance	Lab 06 due
Mar 17		L16: Module 6 -- Actuators - Motor Types	
Mar 19		L17: Module 3b -- Computer Logic - Sequential Logic and Finite State Machines	
Mar 23	Week 10	Lab 08: RedBot - Introduction	Lab 07 due
Mar 24		L18: Module 3b -- Computer Logic - Finite State Machines: Design Examples	
Mar 26		L19: Module 3b -- Computer Logic - Robot Behavior and Control	Homework 6 out, Homwork 5 due
Mar 30	Week 11	Lab 09: RedBot - Robot control for emergency braking and parking	Lab 08 due
Mar 31		L20: Module 7 -- Other Selected Topics - Serial Communications	
Apr 2		L21: Module 7 -- Other Selected Topics - Robot Learning and AI	Homework 7 out, Homwork 6 due
Apr 6	Week 12	Lab 10: RedBot - Wall Following	Lab 09 due
Apr 7		**Wellness Day (on lecture)**	
Apr 9		L22: Module 7 -- Other Selected Topics - Kalman Filter and Bayesian State Estimation	Exam 2 Materials ends
Apr 13	Week 13	**Class Review**	
Apr 14		Return Redbot/Lab materials (if needed)	Lab 10 due
Apr 16		Return Redbot/Lab materials (if needed)	Homwork 7 due
Apr 20	Week 14		
Apr 21		**Exam2 - Lecture materials (M5,6,3b,7)**	
Apr 23			
Apr 27	Week 15	**Exam3 - Lab Exams Starts**	
Apr 28			
Apr 30			
May 4	Week 16	**Exam3 - Lab Exams Ends**	
May 5			
May 7			