Data Acquisition and Instrumentation for Infrastructure Systems

12-740 Sec. A1 Fall 2020

TR 11:40PM - 1:00 PM
Location: Virtual (Zoom Link)

Instructor: Mario Bergés, PH 123L, Phone: x8-4572
Office Hours: Wednesdays 1:00 PM - 2:00 PM and by appointment.

Teaching Assistants: Bingqing Chen
Office Hours: TBD

Textbook (optional):

1. H. Rosemary Taylor, Data Acquisition for Sensor Systems, Vol. 5. Springer Science & Business Media, 1997. ISBN: 978-1-4419-4729-1
2. Jack Holman, Experimental Methods for Engineers, 8th Edition, McGraw-Hill, 2011. ISBN: 0073529303.
3. Alan S. Morris and Reza Langari, Measurement and Instrumentation: Theory and Application, 1st Edition, Butterworth-Heinemann, 2011. ISBN: 0123819601.
4. Jacob Fraden, Handbook of Modern Sensors: Physics, Designs, and Applications, 4th Edition, Springer, 2010. ISBN: 1441964657.

Prerequisites: An open, inquisitive and resilient mind; true learning disposition. In addition to this, you will need to be comfortable programming in a procedural language such as Python. Plus, you will need to know about differential equations (and their solutions), calculus and basic physics. But, then again, you probably would not have made it this far without knowing that, right?

Course description:
In recent times, there has been a considerable increase in the number of sensors and actuators being embedded in the environment, electronic devices, and throughout all the infrastructure that supports modern human life. All this instrumentation allows today's practitioners to push the boundaries of traditional design, operation and management through faster and more precise measurement and control. For civil engineering, for example, these technologies provide incredible opportunities to increase the precision and/or automate existing measurement processes (e.g., laser scanning technologies vs. theodolites), as well as to measure phenomena that were previously very difficult or impossible to measure (e.g., real-time measurements of strains in structural elements).

This course intends to introduce the student to a variety of subjects that are required to make proper use of modern sensors. These topics include physical principles of sensors, data acquisition,

signal processing and engineering measurements. The course will cover both theory and practice, as a considerable portion of the grade is based on a final project in which the student should implement a simple instrumentation system and visualize the measurements on a graphical user interface.

The course is intended to be a introductory course, as the time limitations prohibit us from exploring any one topic in detail. Should you find yourself interested in building an expertise in instrumentation, this course should prepare you well for a full-semester graduate course on the topic. Specifically, by the end of the class, if given a well-understood physical phenomena, and a well-defined sensor, students of this course should be able to:

(a) **Select** an appropriate Data Acquisition hardware (DAQ)

(b) **Select** an appropriate sampling rate

(c) **Specify** the requirements for the signal conditioning circuit

(d) **Put together** an instrumentation system to measure the phenomena and store digital measurements

(e) **Select** a simple signal processing algorithm to detect a particular characteristic of the signal

Grading:

Class participation	10%
Project (Report)	30%
Project (Presentation)	20%
Assignments	40%

Assignments:
A total of four assignments will be given out. The topics covered in each assignment will closely follow the ones listed in the schedule of classes.

All assignments are to be solved individually. Discussions and conversations with other students regarding the problem sets are encouraged. However, the final solutions along with the reasoning behind them need to come from you and be clearly explained in the submitted documents.

Lateness. All assignments have due dates indicated on the syllabus. In general, submitting assignments on time lets the instructional team provide feedback in a more timely and efficient manner. Assignments build on each other, so timely submissions are crucial to your progress in the class. However, sometimes life happens. If you cannot submit an assignment on time, the default will be that you will be eligible for 90% of the grade the first 48 hours that the assignment is late. If you have to submit beyond 48 hours past the due date, please contact me as soon as possible so we can make arrangements.

Each assignment will be worth 10%.

Group Projects:
A large portion of the grades for the course will be based on a group project, which consists of a

written report and a presentation.

Course Policies:

Collaboration
Collaboration is expected within the limits of discussing concepts and problems. However, each student must produce his/her own solution to the problems. Copying from another student's assignment is clearly plagiarism. Using information directly from websites, books, papers and other literary sources without appropriate attribution is also plagiarism. Assignments submitted for this class will be reviewed by the instructor and TA and may be scanned through web-based academic integrity software. Occurrences of cheating or plagiarism will be handled according to the university policy on Academic Integrity, https://www.cmu.edu/policies/documents/Academic%20Integrity.htm. Students are expected to have read this policy and conform to the highest standards of academic integrity. For incidents of academic misconduct, the University Academic Disciplinary Actions Policy, found at https://www.cmu.edu/student-affairs/theword/acad_standards/creative/disciplinary.html, will be followed.

Class Participation
Students are expected to be in class on time and participate in class discussions. Participation will be loosely monitored and used to calculate the participation grade. If you cannot make class, please inform your instructors and group members ahead of time. In class, students are expected to be courteous and respectful of the views and needs of other students and instructors.

Students with disabilities
If you have a disability and have an accommodations letter from the Disability Resources office, I encourage you to discuss your accommodations and needs with me as early in the semester as possible. I will work with you to ensure that accommodations are provided as appropriate. If you suspect that you may have a disability and would benefit from accommodations but are not yet registered with the Office of Disability Resources, I encourage you to contact them at access@andrew.cmu.edu.

Posting of course materials
All the material used in the course (syllabus, readings, problem sets, reports) is intended for use in the class only. No unauthorized posting, publication or redistribution is expected. Uploading course materials to Course Hero or other web sites is not an authorized use of the course material.

Take care of yourself
This semester is unlike any other. We are all under a lot of stress and uncertainty at this time. Attending Zoom classes all day can take its toll on our mental health. Make sure to move regularly, eat well, and reach out to your support system or me (marioberges@cmu.edu) if you need to. We can all benefit from support in times of stress, and this semester is no exception.

In general, do your best to maintain a healthy lifestyle this semester by eating well, exercising, getting enough sleep and taking some time to relax. This will help you achieve your goals and cope with stress.
All of us benefit from support during times of struggle. You are not alone. There are many helpful resources available on campus and an important part of the college experience is learning how to

ask for help. Asking for support sooner rather than later is often helpful.
If you or anyone you know experiences any academic stress, difficult life events, or feelings like anxiety or depression, we strongly encourage you to seek support. Counseling and Psychological Services (CaPS) is here to help: call 412-268-2922 and visit their website at http://www.cmu.edu/counseling/. Consider reaching out to a friend, faculty or family member you trust for help getting connected to the support that can help.

Course Schedule:

Tuesday	Thursday
Sep 1st **1** **THEORY: Introduction**	Sep 3rd **2** **THEORY: Principles of Sensors** **Assignment #1 Out**
Sep 8th **3** **THEORY: Dynamic Characteristics of Sensors, Electric Circuits**	Sep 10th **4** **PRACTICE: Acquiring Analog and Digital Signals** **(Tutorials 1 and 2)**
Sep 15th **5** **THEORY: Fundamentals of Data Acquisition** **Assignment #1 Due** **Assignment #2 Out**	Sep 17th **6** **PRACTICE: Analog Signals**
Sep 22nd **7** **THEORY: Signal Conditioning** **Assignment #2 Due** **Assignment #3 Out**	Sep 24th **8** Project Proposal Presentations
Sep 29th **9** **THEORY: Measurement Errors and Uncertainty**	Oct 1st **10** **PRACTICE: The Internet of Things** **Assignment #3 Due** **Assignment #4 Out**
Oct 6th **11** No Lecture: Assistance for Project	Oct 8th **12** No Lecture: Assistance for Project
Oct 13th **13** **THEORY: Signal Processing: Fourier Analysis**	Oct 15th **14** **PRACTICE: Putting it All Together** **Assignment #4 Due**
Oct 20th **15** No Class: Finals Week	Oct 22nd **16** Project Reports Due Project Demos

Additional Dates:

Week-by-week Goals:

1. **Week 1**: Transducers
   By the end of this week you should be able to:

   - Understand the overall goals of the course and how we will achieve them.
   - Interpret a techincal specification sheet for a transducer, or at least know what most of the details in it mean.
   - Explain the difference between dynamic and static characteristics of a system.

   Suggested readings:
   References #1, #2, #3 and #5.

2. **Week 2**: Data Acquisition
   By the end of this week you should be able to:

   - Connect an analog sensor with voltage output to a general purpose data acquisition system, and obtain measurements at a given sampling rate.
   - Explain why it is sometimes necessary to condition analog signals.
   - Explain the concept of sampling.
   - Understand why aliasing occurs and how to mitigate it.

   Suggested readings:
   References #3, #5, #6, #7 and #11.

3. **Week 3**: Signal Processing: Frequency Domain Analysis and Signal Conditioning
   By the end of this week you should be able to:

   - Explain to a friend what Fourier Analysis is and why it is important.
   - Deduce the frequency spectrum of simple periodic signals.
   - Implement a Frequency Spectrum analyzer in LabVIEW.

   Suggested readings:
   Reference #10.

4. **Week 5**: Signal Processing: Frequency Domain Analysis and Frequency Response Functions
   By the end of this week you should be able to:

   - Correctly interpret the effect of a linear filter on a signal based on its frequency response.
   - Comprehend more than one reason for why frequency analysis is useful.
   - Understand the importance of the impulse response and frequency response of linear time-invariant systems.

Suggested readings:
Reference #10.

5. **Week 6**: Uncertainty Analysis
   By the end of this week you should be able to:

   - Distinguish between bias and precision errors.
   - Explain the difference between error and uncertainty.
   - Compute the zero and first order (design-stage) uncertainty for a measurement system.

   Suggested readings:
   Reference #16.