Data Acquisition and Instrumentation for Infrastructure Systems

12-740 Sec. A1 Fall 2019

TR 3:00PM - 4:20 PM
Location: POS 153

Instructor: Mario Bergés, PH 118L, Phone: x8-4572
Office Hours: Tuesdays 11:00 AM - 12:00 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	5%
Project (Report)	30%
Project (Presentation)	15%
Assignments	40%
Mini-quizzes	10%

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. In order to verify that the student understands the concepts and did not submit work other than his/her own, there will be mini quizzes each day an assignment is due. These quizzes will consist of a single problem, similar to one of the problems in the assignment, for which the student will be given 10 minutes to solve.

Lateness. Your assignment is due before class on the due date. The Canvas timestamp on your file is the submission time. Please notify me if you have personal, professional, or religious reasons for being unable to meet an assignment deadline. **No late submissions will be accepted**.

Each assignment will be worth 10%, while each of the mini-quizzes will be worth 2.5%.

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.

Late Submissions
Written assignments are due at the beginning of class on the date that is indicated in each assignment. No late assignments will be accepted. No exceptions. In case a major problem is anticipated, please talk to the instructor.

Students with disabilities
Students requesting classroom accommodation must first register with the Dean of Students Office. The Dean of Students Office will provide documentation to the student who must then provide this documentation to the Instructor when requesting accommodation.

Recording of Class Sessions
No recording or taping of any classroom activity is permitted without the express written consent of Prof. Bergés. Any student who needs to record or tape classroom activities because of a disability should contact the Carnegie Mellon Office of Equal Opportunity Services to request an appropriate accommodation.

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
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
Aug 27th **1** **THEORY: Introduction**	Aug 29th **2** **PRACTICE: Setting up your Environment** **Assignment #1 Out**
Sep 3rd **3** **THEORY: Principles of Sensors, Electric Circuits**	Sep 5th **4** **PRACTICE: Acquiring Digital Signals**
Sep 10th **5** **THEORY: Fundamentals of Data Acquisition** **Assignment #1 Due** **Assignment #2 Out**	Sep 12th **6** **PRACTICE: Analog Signals**
Sep 17th **7** **THEORY: Signal Conditioning** **Assignment #2 Due** **Assignment #3 Out**	Sep 19th **8** Project Proposal Presentations
Sep 24th **9** **THEORY: Measurement Errors and Uncertainty**	Sep 26th **10** **PRACTICE: The Internet of Things** **Assignment #3 Due** **Assignment #4 Out**
Oct 1st **11** No Class: TA Assistance for Project	Oct 3rd **12** No Class: TA Assistance for Project
Oct 8th **13** **THEORY: Signal Processing: Fourier Analysis**	Oct 10th **14** **PRACTICE: Putting it All Together** **Assignment #4 Due**
Oct 15th **15** Project Demos	Oct 17th **16** Project Reports Due

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 #4.

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, #4, #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.