EE617 Sensors in Instrumentation

Course Logistics

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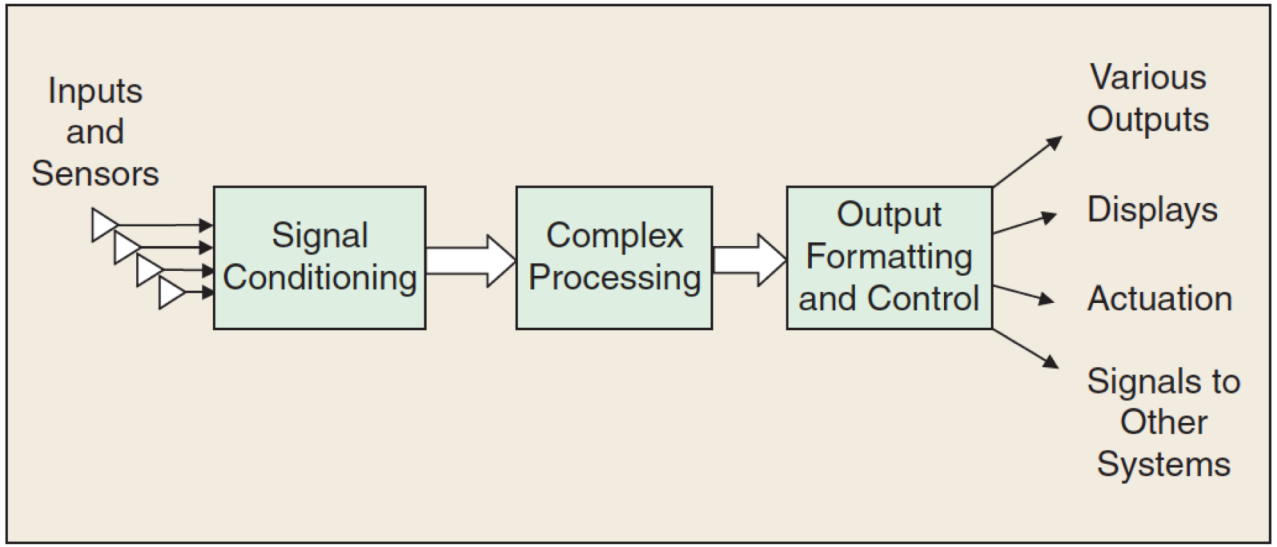
Course objectives

- Learn how to design sensor systems
  - Three components: Sensors, Instrumentation, Measurements
- Design for spec (performance) and design for test
  - Selecting the right sensors
  - Auxiliary design determinants
- Familiarization with some sensors used in modern instrumentation; signal conditioning techniques (as case studies)
- Learn how to collect, analyze and report experimental data for sensor systems
- ~~Overcome mental block for hardware design~~

Relevance of this course

- We are entering the age of ubiquitous sensing; knowing how data is collected will help you decide how to use such data
- Interpreting datasheets for sensor ICs requires insights into how the measurements are performed and analyzed
- An exercise in system design, testing and analysis



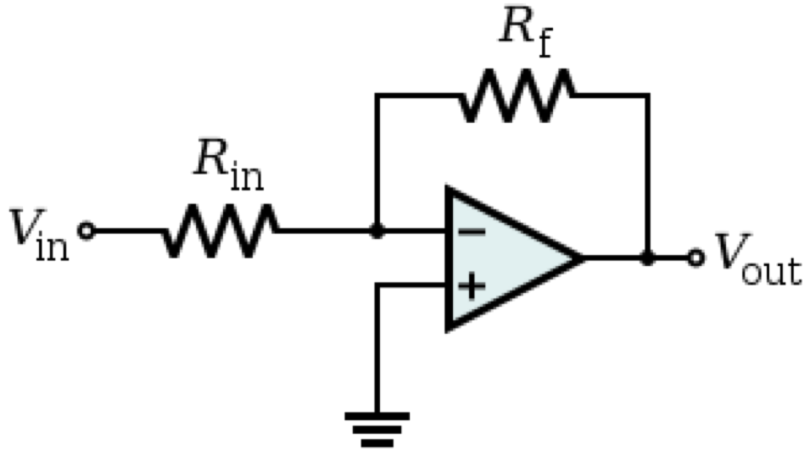
Fowler, Kim R., and John Schmalzel. "Why do we care about measurement?." *IEEE instrumentation & measurement magazine* 7.1 (2004): 38-46.

Who should take this course?

- Desire to learn how to build sensor systems
- Likes “breadth” more than “depth”, multi-tasker
- Pre-requisites
  - Basic mechanics, electromagnetism (JEE level)
  - Signals and systems (Fourier transform, statistics, transfer functions etc.), basic analog circuits (electronic devices, amplifiers)
  - Prior hands-on electronics lab experience is a bonus
- Audit/Sit through in this course are not allowed

Background/pre-requisites

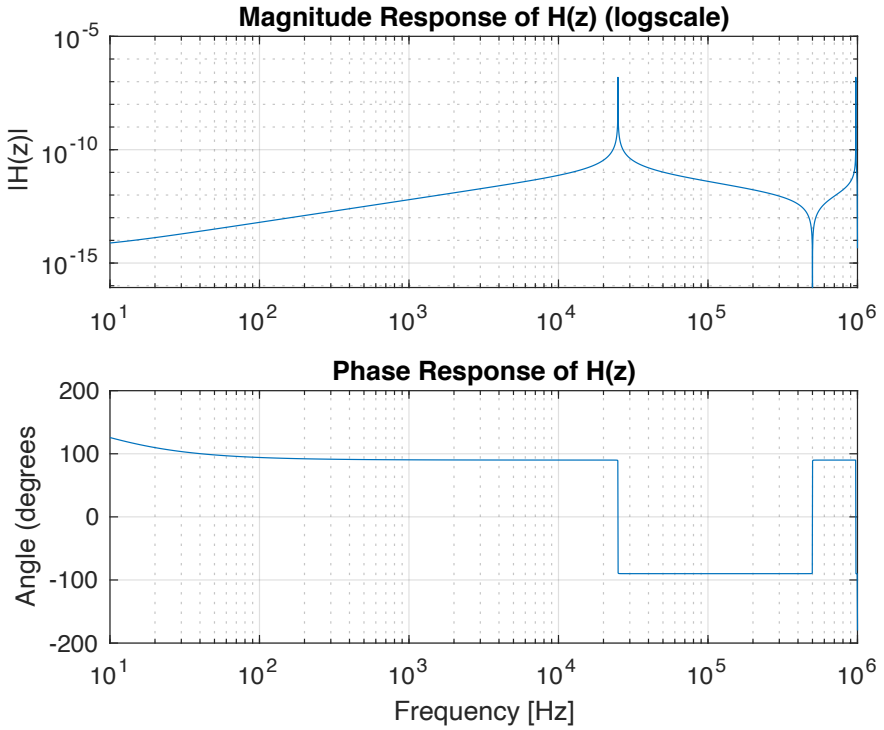
If you are unable to answer the questions below, you may find this course very difficult



1. What output does the circuit produce for a sinusoidal input signal?

2. While connecting the circuit on breadboard, I accidentally interchanged the connections of the inverting and non-inverting terminals. What output does the circuit produce now?

3. What is the input impedance of the circuit?



Consider the narrow-band filter shown here with center frequency 25kHz. I connect a square wave signal (1Vp-p, 5kHz) at the input of the filter. What should I expect to see on an oscilloscope at the output of the filter?

Course outline

- Pre-midsem: Concept heavy
  - Instrumentation – characteristics and operational modes
  - Measurement accuracy and error sources
  - Spatial and temporal measurements
  - Instrumentation: Signal conditioning and signal processing
  - Course project – I
- Post-midsem: Information and application heavy
  - Sensors case studies
    - MEMS inertial sensors
    - Electro-chemical sensors
  - Instrumentation case studies
    - Phase sensitive detection (lock-in amplifier)
    - Electro-chemical measurements (potentiostat)
  - Course project – II

Course logistics

- Course will be administered through Microsoft Teams
  - Please familiarize yourself with MS Teams
- Course will operate in flipped class style
  - Lecture videos and slides will be uploaded every week; you are expected to go through the videos and assigned reading material
  - Discussion sessions will be conducted during Slot-2 (i.e. Monday 9.30-10.25am; Tuesday 10.35-11.30am; Thursday 11.35am-12.30pm) to answer questions and discuss material based on slides uploaded in previous week
- Instructor and TAs (Durgesh Tamhane, Pallabi Das) will conduct online office hours; slots TBD based on mutual convenience

Homeworks (assignments)

- Homework and technical writing assignments will be given most weeks
- Solutions/writeups have to be uploaded as soft copy (.pdf) by deadline (typically 1 week)
- All assignments will be uploaded on Teams. You will have to submit your work on Teams. Grades will also be assigned on Teams.
- Assignments may involve circuit simulation (in SPICE simulator of your choice) and programming for data analysis (highly recommended that you use Anaconda distribution for python)

Course projects

- Course project – I (pre mid-sem)
  - Literature survey of any aspect of sensor systems
  - Topics must be finalized in advance
  - You will be graded based on following: literature search strategy, depth of critical understanding of papers, quality of report and presentation
- Course project – II (post mid-sem)
  - Measurement and data analysis using sensors in your smartphone/hardware available
  - Your project must attempt to solve a practical problem
  - You will be graded based on following: design review (how much thought has been put in the idea), design of experiments (how thoughtfully have you performed the experiments), analysis of measurements, documentation (report and presentation)
  - E.g. YouTube channel set up by Vivekanand (2nd year M.Tech. WEL RA) showing some DIY sensors projects he did during lockdown: https://www.youtube.com/channel/UCllZXbFy-lc6GxKg0R3K-rw
- Additional guidelines will be communicated in due course
- Projects should be executed individually; helping each other is encouraged

Grading scheme (tentative)

- Grading scheme for exams will be in accordance with institute norms (to be announced)
- The following components will be considered for evaluation:
  - Examinations (likely, take-home style)
  - Assignments (periodic evaluation)
  - Course project – I
  - Course project – II
- **Reference books:**
  - J.G. Webster, The Measurement, Instrumentation and Sensors Handbook, CRC Press, 1999 (assorted sensors)
  - T.B. Jones and N.G. Nenadic, Electromechanics and MEMS, Cambridge, 2013 (MEMS inertial sensors)
  - A. J. Bard and L. R. Faulkner, Electrochemical methods: Fundamentals and Applications, Wiley, 2000 (electrochemical sensors)
  - A Designer's Guide to Instrumentation Amplifiers, 3rd edition, Analog Devices 2006 (comprehensive reference for instrumentation amplifiers)
  - Zurich Instruments, 2016: Principles of lock-in detection and the state of the art (lock-in amplifiers)
  - Class notes, resources uploaded on Teams for up to date information

Ground rules

- Submission links will be deactivated at deadline; no late submissions
  - Few seconds late is also technically, late
  - If you miss a deadline, do not email your submission to instructor or TAs
- Discussion sessions during Slot-2
  - Instructor will initiate the meeting; you are expected to join and participate in discussions/doubt-solving etc.
  - Punctuality is important. Instructor will end the meeting if no students join in the first five minutes.
  - Please be punctual. Course will cover a lot of material in a short span of time. Performance in this course will be directly proportional to preparation and seriousness.
- Check MS Teams at least once a day for notifications and updates. It is highly recommended that you install Teams mobile app to not miss out on important notifications.