

## MTRE 4100 / 001 – Instruments and Controls – Fall 2015

**Instructor:** Kevin McFall, PhD (lecture) and Ying Wang, PhD (laboratory)

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**Office Hours:** MTWRF 10:00-11:00 am or by appointment

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**Location:** Lecture Q 315 / Laboratory Q 312 and Q 110

**Meeting times:** Lecture 5:00-6:15 pm MW, Laboratory 6:30-9:15 pm M or W

**Start Date:** 08/17/2015

**Pre-requisites:** EE 2501 (digital logic), EE 3401 (electronics), and MATH 2306 (differential equations)

**Textbook:** The required textbook is Experimental Methods for Engineers, by J.P. Holman, 8<sup>th</sup> edition, McGraw Hill, 2012. An earlier edition of the textbook is permissible with the understanding the student is responsible for accounting for discrepancies in end of chapter homework problems between versions; homework problems refer to those in the 8<sup>th</sup> edition. A supplemental textbook Programmable Logic Controllers, by Frank D. Petruzella, 4<sup>th</sup> edition, McGraw Hill, will also be used but is not necessary to buy.

**Course Catalog Description:** Characteristics of instruments used in mechanical systems for determining parameters such as temperature, pressure, and flow are studied. The use of these devices in automated systems is covered. Furthermore, the elements of control theory, selection of control modes, and application to mechanical systems are studied. Laboratory exercises illustrating the use of pertinent instrumentation for determining the performance of mechanical equipment are conducted.

### Learning Outcomes:

- 1) Demonstrate proficiency in engineering data collection, data regression, compilation of results, and technical report writing.
- 2) Analyze the uncertainty in measurement systems using statistical and other analytical principles.
- 3) Demonstrate competence in programming for data acquisition using LabVIEW software.
- 4) Identify, calibrate and use measurement instruments (pressure, temperature, and flow).
- 5) Evaluate different control methodologies, apply design principles for mechanical systems including pneumatics/hydraulics, and create industrial automation control solutions using programmable logic controllers.

### Topics Covered Include:

- 1) Measurement Systems
  - a) Measurement Standards  
NIST, ISO, ANSI
  - b) Generalized Measurement Systems  
Sensors, Signal Conditioning, Results, Sensor Performance (Static, Dynamic)
  - c) Mechanical Measurements  
Temperature, Pressure, Mass / Force / Torque, Fluid Flow, Motion, Strain
- 2) Analyzing Measurements  
Statistical Analysis of Experimental Data, Uncertainty Analysis of Measurements
- 3) Measurements with Computerized Data Acquisition Systems (LabVIEW)
- 4) Design for Industrial Automation
  - a) Instrumentation & Control System Documentation  
Process Flow Diagrams, Piping & Instrumentation Diagrams, Instrument Lists, Specification

- Forms, Logic Diagrams, Loop Diagrams
- b) Safety Standards of Industrial Automation
  - c) Programming Programmable Logic Controllers Hardware Configuration, Programming Languages (Ladder Diagrams, Function Block Diagrams)
  - d) Control applications for industrial automation
    - (1) Open loop control
    - (2) Feedback control

### **Grading Policy**

*Homework (15%):* Homework is an essential component of the learning experience in this course. Students who successfully complete and understand all the assigned homework problems will find themselves well prepared for the written tests. Content and numerical results are certainly important in homework problems, but problem presentation is of equal importance. This includes a well-conceived diagram when appropriate, an algebraic solution for the desired quantity in terms of given/known quantities, correct and consistent use of notation, units, and significant figures, as well as overall neatness and clarity. The assigned homework sets will be collected during class periods as detailed in the course schedule, and approximately half of the problems will be graded. The lowest homework problem grade for the semester will be dropped. Each submission may include two students' names. A grade of zero will be recorded for any problem whose solution appears copied, even in part, from any source. Be sure to write the solution "in your own words" when collaborating with students from other groups on the solution method. Students who feel they are unfairly assessed a zero for copying homework may request referring the matter to be resolved by the SPSU Honor Council. The instructor may decide to refer directly to the Honor Council in especially egregious cases or when a student is involved in multiple incidences of copying. Problems are graded according to the rubric:

- Problem solution is neat and legible (1 point)
- Proper and consistent use of units (1 point)
- All work necessary to complete the problem is presented (2 points)

*Group exercises (10%):* Most lecture periods with a reading assignment will begin with a "five-minute" group exercise. The purpose of these exercises is to stimulate learning of new material in groups of two members. Questions on group exercises will be short and generally require only that students have thoroughly read the day's reading assignment and studied the lecture notes. Examples of question topics include definitions, identifying symbols or notation, and drawing/interpreting diagrams. The lowest group exercise grade for the semester will be dropped. Group exercises are graded as follows:

- Student(s) names appear on submission (1 point)
- Some effort was made (1 point)
- Some part of the question is appropriately addressed (1 point)
- The answer is reasonably close to the correct answer (1 point)

*Laboratory exercises (15%):* All students are expected to attend the lab sessions and will be assigned zero grades for missed sessions. Lab reports will be submitted in D2L dropboxes and are due at the beginning of the next lab session. The results of one lab will be submitted as a professional quality lab report in practice for the final project lab report. Each lab assignment will count equally.

**Tests (3x15%):** Three in-class tests will be used to assess progress in the course. Calculators will be allowed on the test, as will one 8½"×11" page equation sheet. The equation sheet may only contain the bare minimum of text to identify the equations or diagrams. The tests, in general, will be curved in an attempt to maintain an overall class average of a mid C. Each problem is graded according to the rubric:

- 0 No content relevant to solving the problem
- 30 (F) Some relevant content but no indication of how to solve the problem
- 60 (D) Some indication that the correct solution method is being followed
- 70 (C) Significant work showing understanding of how to approach the problem
- 80 (B) Primary details of solving the problem are complete but significant mistakes are made
- 90 (A) Problem is answered correctly except for minor mistakes such as sign or algebra errors
- 100 Problem is answered completely with the correct answer

**Final project (15%):** A final project will be assigned for which a report must be submitted in a D2L Dropbox by the end of the semester. Project performance is assessed by a fully word-processed technical report of professional quality. Information retrieved from any source other than the course textbook must be cited in the report. Reports will be assessed 80% for content and 20% for presentation.

The scale for the final course grade is as follows, but the final grade cannot be more than one letter grade higher than the highest test score.

- A 90-100
- B 80-89
- C 70-79
- D 60-69
- F 0-59

### **Attendance Policy**

Forcing everyone to come to every class is not practical. Each student bears responsibility for material covered in class. If students choose to miss class, that is their decision. However, completion of group exercises goes hand-in-hand with attendance. Note also that late arrival to class will result in working alone on group exercises. Class time will be spent explaining the day's content and working problems, under the assumption that all students have read and understood the reading assignment. In general, late assignments are not accepted nor can make-up tests be administered. Laboratory attendance is mandatory; students will receive a grade of zero for missed lab sessions. Extenuating circumstances can result in exceptions to these rules, but agreement must be reached with the instructor in advance of the assignment, test, or lab that will be missed.

### **Academic Misconduct**

The Code of Academic Integrity at KSU states that

*As a member of the Kennesaw State University community of scholars, I understand that my actions are not only a reflection on myself, but also a reflection on the University and the larger body of scholars of which it is a part. Acting unethically, no matter how minor the offense, will be detrimental to my academic progress and self-image. It will also adversely affect all students, faculty, staff, the reputation of this University, and the value of the degrees it awards. Whether on campus or online, I understand that it is not only my personal responsibility, but also a duty to the entire KSU community that I act in a manner consistent with the highest level of academic integrity. Therefore, I promise that as a member of the Kennesaw State University community, I will not participate in any form of academic misconduct.*

**All acts of academic misconduct will be documented with the Student Academic Misconduct Incident form and included on the student's academic record.** The application of the definition of academic misconduct for each category of assignment in this course is described as follows:

Discussion of homework problems among peers and even other sources is wholeheartedly encouraged. A single homework submission is allowed for groups of no more than two members. Note, however, that this submission must be a reflection of the group's work alone. Multiple submissions may follow the same solution process, but they may not be copied, not even in part. If more than one group collaborates on the homework, be sure each group sits down individually to write the solution so that each is written in their own words. Be aware that copying of any part of a problem from any source, including solution manuals, will be considered a violation of academic integrity. If you have a copy of the solution manual, you are strongly recommended to delete it. Using the solution manual as a crutch when solving homework is detrimental to your learning, and the temptation is great to rely heavily on it when rushed to complete a homework set. The majority of reported academic integrity violations in this course result from students copying from the solution manual. Additionally, possession of the solution manual is unnecessary as you will be provided with solutions of all homework problems after they are due, as well as for non-assigned problems upon request.

Collaboration among group members during group exercises, laboratory assignments, and the final project is obviously encouraged, but assistance of any kind from outside the group will be considered a violation of academic integrity unless properly cited. Information from the course textbooks need not be cited; it can be assumed the reader is familiar with such content.

Tests are to be reflections of the individual's work alone. Assistance other than a calculator and the approved equation sheet, including mobile devices, other class members, etc. will be reported as a violation to the Honor Council.

All instances of academic misconduct will be formally submitted to the Honor Council and be filed with the students' permanent academic record.

### **Disability Statement**

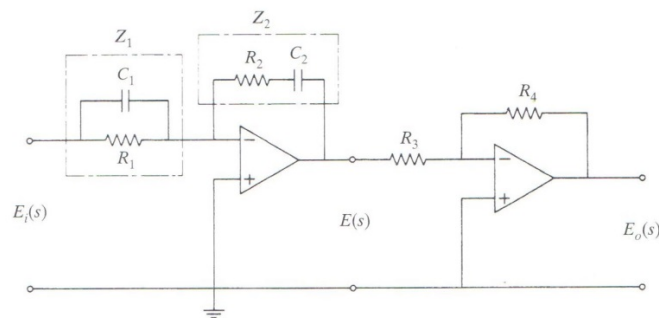
Any student who, because of a disabling condition, may require some special arrangements in order to meet the course requirements should contact the instructor as soon as possible to arrange the necessary accommodations. Students should present appropriate verification from KSU Student Disability Services. No requirement exists that accommodations be made prior to completion of this approved University process.

### **Communication**

Course material will be disseminated in D2L including lecture notes, homework solutions, old tests, etc. All official course announcements, including instructions when class may be cancelled, will be posted in the D2L course news. Be sure to check D2L regularly.

## Course Schedule

| Day | Date  | Description          | Reading             | Homework due                    |                           |
|-----|-------|----------------------|---------------------|---------------------------------|---------------------------|
| Mon | 08/17 | Introduction         |                     |                                 |                           |
| Wed | 08/19 | Measurement systems  | 1-2.6               |                                 |                           |
| Mon | 08/24 | Dynamic measurements | 2.7-2.10            |                                 | Dynamic measurement       |
| Wed | 08/26 | Fourier analysis     | 2.11-2.12           |                                 |                           |
| Mon | 08/31 | Uncertainty analysis | 3.1-3.5             | 2.2/4/15/27/38/41/56            | Fourier series            |
| Wed | 09/02 | Recitation           |                     |                                 |                           |
| Wed | 09/09 | Probability          | 3.6-3.7             | $x1^1$ , 3.3/14/15/45           |                           |
| Mon | 09/14 | Normal distribution  | 3.8-3.10, 3.14-3.15 |                                 | Time constant measurement |
| Wed | 09/16 | Recitation           |                     |                                 |                           |
| Mon | 09/21 | Review               |                     | $3.25/26/49/60/64^2/x2^3/x3^4$  | Draft report              |
| Wed | 09/23 | Test 01              |                     |                                 |                           |
| Mon | 09/28 | Regression/measuring | 3.11-3.13, 4.1-4.6  |                                 | Accelerometer             |
| Wed | 09/30 | Amplifiers           | 4.7-4.9             |                                 |                           |
| Mon | 10/05 | Signal conditioning  | 4.12                |                                 | Motor control             |
| Wed | 10/07 | A/D conversion       | 14.1-14.5           | $3.74/78/4.11/32/34/38/44/x4^5$ |                           |
| Mon | 10/12 | Transducers          | 4.21-4.31           |                                 | Digital Acquisition       |
| Wed | 10/14 | Pressure and flow    | 6.1-6.6, 7.1-7.7    | $14.1/14, 4.23/25^6/47^7/58$    |                           |
| Mon | 10/19 | Temperature          | 8.1-8.5             |                                 | Pressure measurement      |
| Wed | 10/21 | Force and torque     | 10.1-10.10, 11.3    | 6.27/37, 7.3/24                 |                           |
| Mon | 10/26 | Review               |                     | 8.12, 8.36, 14.6, 10.8/17       | Strain measurement        |
| Wed | 10/28 | Test 02              |                     |                                 |                           |
| Mon | 11/02 | PLC basics           | 1.1-1.6*            |                                 | Introduction to PLCs      |
| Wed | 11/04 | Ladder logic         | 5.1-5.8*, 6.1-6.11* |                                 |                           |
| Mon | 11/09 | Timers and counters  | 7.1-7.6*, 8.1-8.6*  |                                 | Windshield wiper          |
| Wed | 11/11 | State machines       |                     |                                 |                           |
| Mon | 11/16 | Recitation           |                     |                                 | HMI                       |
| Wed | 11/18 | Process control      | 14.1-14.5*          | 5.1/9*, 6.9/10*, 7.13*, 8.14*   |                           |
| Mon | 11/20 | Test 03              |                     |                                 | Project                   |
| Wed | 11/30 | Project              |                     |                                 | Project                   |
| Mon | 12/02 | Project              |                     |                                 | Project                   |



$$E_o(t) = K_p \left[ E_i(t) + \frac{1}{T_i} \int_{-\infty}^t E_i(t) dt + T_d \frac{dE_i(t)}{dt} \right] \quad G(s) = \mathcal{L} \left[ \frac{E_o(t)}{E_i(t)} \right] = K_p + \frac{K_p}{T_i} \frac{1}{s} + K_p T_d s$$

<sup>1</sup> Download the file FourierHW.txt from D2L which contains several sinusoids sampled at 1 kHz, and estimate the mathematical function generating the data using the fast Fourier transform.

<sup>2</sup> Assume the known precision to be "one sigma".

<sup>3</sup> A tire company has determined that its tires have a 1% premature rate of failure on the road. What is the chance that none of the 16 tires shipped to a retailer will have a premature failure?

<sup>4</sup> Circuit boards are manufactured on sheets and tested. On average, there are 3 defects per sheet. What are the chances of 10 defects on a given sheet, no defects on a sheet, and more than 1 defect on a sheet?

<sup>5</sup> For the cascaded op-amp circuit shown above, find the PID gains  $K_p$ ,  $T_i$ , and  $T_d$  in terms of  $R_1$ ,  $R_2$ ,  $R_3$ ,  $R_4$ ,  $C_1$ , and  $C_2$ .

<sup>6</sup> Uncertainty in the thickness measurement is  $\pm 0.0003$  in. and uncertainty in the voltage is 0.5 V.

<sup>7</sup> Note the capitalization typo:  $\Omega T$  should be  $\omega T$ .

\* These reading and homework assignments are from Programmable Logic Controllers 4<sup>th</sup> edition by Frank D. Petruzella. See <http://www.scribd.com/doc/72908166/Programmable-Logic-Controllers>. Another great resource is the Siemens Easy Book, also posted on D2L.