ET 438b
Sequential Digital Control Systems and Data Acquisition

Instructor: Dr. Carl Spezia, PE

Office: Engr. D110
Phone: 453-7839
E-mail: powerguy@siu.edu

Office Hours: 10:00 am - 11:00 am  M-W-F
2:00 pm - 3:00 pm  M-W-F

LabVIEW 2009 Student Edition, Robert H. Bishop

Reference: Industrial Controls and Manufacturing, E. W. Kamen

Grading Scale:

<table>
<thead>
<tr>
<th>Grade</th>
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<tbody>
<tr>
<td>A</td>
<td>100-90%</td>
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<td>B</td>
<td>89-80%</td>
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<td>C</td>
<td>79-70%</td>
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<tr>
<td>D</td>
<td>69-60%</td>
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<tr>
<td>F</td>
<td>59-below</td>
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Lecture Quizzes (6 at 50 points each. One drop score allowed) 40%
Final Exam 20%
Lesson Quizzes (Online) 10%
Homework 10%
Laboratory Projects/Activities 20%
Total 100%

Course Policies
1. **Late Work, Makeup Exams, Electronic Submission Requirements**
   No make-up exams. All homework handed in electronically in Desire-2-Learn prior to the due date/time. No late homework accepted. Lab reports submitted electronically in Desire-2-Learn. Submit all homework and lab assignments by scanning your work into a pdf format file. DO NOT take pictures of the pages using a camera or submit any other file format. The online course materials give a link to a cell phone app that scans written work into pdf files. The course instructor will not grade work submitted in an incorrect format. Late lab grades are reduced by 5% per working day starting from due date.
2. **Attendance Policies**  
Class attendance is required and attendance will be taken at the beginning of every period. Students are allowed **four** unexcused absences. Any further absences will reduce the TOTAL grade by 0.25% per day absent.

3. **Cell Phone/Electronic Device Usage**  
Cell phone usage during meeting periods is prohibited. Devices should be TURNED OFF prior to entering class. Other electronics devices (Tablets, iPads, Readers etc) are only allowed for academic/research purposes. No electronic devices other than calculators are allowed during exams. Those violating this policy are subject to disciplinary action under the Student Conduct Code. Follow this link to review this code: [http://policies.siuc.edu/policies/conduct.html](http://policies.siuc.edu/policies/conduct.html)

4. **Nicotine Consumption**  
No use of electronic cigarettes during class.

**Note:** the final exam is required for all students in this course. It consists of a national assessment test over the fundamentals of EET. It will be given online during finals week and is scheduled for three hours.

**Course Description and Prerequisites**

This course covers the fundamental concepts and components used in computer-based data collection and control systems. The course has two sections: digital data acquisition and sequential control systems. The first part introduces components of a digital measurement system. These components include sensors, signal conditioning, analog-to-digital, and digital-to-analog conversion. Student then use this knowledge to perform measurement and control functions in practical laboratory projects. These projects will require both hardware and software skills. The second section of the course covers staged control processes. Students learn a methodology for designing staged control processes. Relay logic diagrams are covered and used to implement these designs in typical industrial projects. The course introduces the structure and operation of Programmable Logic Controllers (PLCs). The course examines programming and interfacing of external sensor to PLCs. A laboratory demonstrates the lecture topics and gives students experience in programming with a high-level language data collection and control language. Students use simulation software to test the operation of ladder logic designs.

Prerequisite: Engineering Technology 304b and 438a
Course Content Overview

This course is an introduction to digital control systems. Digital control systems can be divided into two categories: digital process control and discrete event control. The mathematical tools used to model and design each of these types of systems are quite different.

In digital process control, the basic structure of the control is similar to analog systems. Sensors measure a process variable and that is fed back to a controller. The controller compares the measured value to an operator-defined value. In analog control, all signals are continuous functions of time. Digital control uses signals that are a series of samples derived from continuous signals.

A digital computer can implement control algorithms that modify the process under control using the obtained series of digital samples. The modification of the sampled signals is called digital signal processing. The first part of this course will focus on acquiring digital signals from an analog process. These inputs may include a number of mechanical and electrical signals, converted into a digital signal, and used to make control decisions for simple on/off or continuous outputs.

The second part of the course focuses on the hardware and design methodology of discrete event control. In this type of control, discrete tasks take place one after another until a process is completed. An example of this type of control is a washing machine. The design of this class of control system is similar to sequential digital design. These types of systems are implemented using industrially hardened microcomputers called Programmable Logic Controllers, (PLCs). PLCs are programmed using industry standard languages. The simplest type of PLC programming is ladder logic. This language uses the schematic symbols of electromechanical relays to implement the control logic.

These techniques are useful in the analysis and design of a large number of control and data acquisition systems used in industry.
ET 438b
Sequential Digital Control Systems and Data Acquisition

Course Performance Criteria
At the end of this course, you will be able to:

1) Identify digital control and data acquisition system components
2) Determine the frequency spectrum of a sampled signal
3) Determine the bandwidth necessary to accurately reproduce a sampled signal,
4) Identify aliasing and frequency folding in sampled signals
5) Identify an on/off controller
6) Select digital-to-analog converters to meet design specifications
7) Select analog-to-digital converters to meet design specifications
8) Design a on/off gap controller using OP AMPS
9) Interface field devices to a TTL compatible input/output device
10) Select instrumentation amplifiers for analog signal conditioning
11) Design and test dc bridge circuits for sensor applications
12) Write simple programs using LabVIEW software to collect sensor data and
    control outputs.
13) Select sensors to measure force, position, velocity, pressure, acceleration, level
    and temperature
14) Identify the components of a sequential control system
15) Read ladder diagrams
16) Convert ladder logic into digital logic
17) Design ladder diagrams given a performance specification
18) Identify the components of a PLC
19) Develop a PLC program and load it into PLC hardware
20) Develop a sequential control program given a process specification

Emergency Procedures
SIUC is committed to providing a safe and healthy environment for study and work. Because some
health and safety circumstances are beyond our control, we ask that you become familiar with the SIUC
Emergency Response Plan and Building Emergency Response Team (BERT) program. Emergency
response information is available on the BERT website at [www.bert.siu.edu](http://www.bert.siu.edu),
Department of Public Safety’s website [www.dps.siu.edu](http://www.dps.siu.edu) (disaster drop down)
and in the Emergency Response Guidelines pamphlet. Know how to respond to each type of emergency.

Instructors will provide guidance and direction to students in the classroom in the event of
an emergency affecting your location. **It is important that you follow these instructions and stay with your instructor during an evacuation or sheltering emergency.** The Building Emergency Response Team will assist your instructor in evacuating the building or sheltering within the facility.
ET 438b
Sequential Digital Control Systems and Data Acquisition

Final Examination Schedule Policy

This course will follow the University schedule for final examinations. The course instructor will not administer the final exam prior to the published University date.

Academic Dishonesty Policy:

Students may be subject to disciplinary proceedings resulting in an academic penalty or disciplinary penalty for academic dishonesty. Academic dishonesty includes, but is not limited to, cheating on a test, plagiarism, or collusion. References to the Student Conduct Code, (e.g. plagiarism policy).

ADA Statement for Students Requiring Special Accommodations:

As per Section 504 of the Vocational Rehabilitation Act of 1973 and the American Disabilities Act (ADA) of 1990, if accommodations are needed, inform the instructor as soon as possible.
ET 438b
Sequential Digital Control and Data Acquisition
Course Outline

Digital Control and Data Collection
Digital control systems
Computer-based data acquisition and control

Data Flow Programming Languages
LabVIEW programming
Analog input blocks
Computed blocks
Digital I/O blocks

On/off Control
Ideal OP AMP model
Non-linear OP AMP circuits
  Voltage comparators
  Voltage comparators with hysteresis
  Window comparators
  Discrete control-on/off controllers

Sampled Signal Fundamentals
  Spectrum representation of signals
  Nyquist Sampling Theorem
  Aliasing and Folding of sampled signals
  Filters
  Aliasing control using analog filters

Digital Signal Conversion and Conditioning
Resolution and accuracy of digital signals
Digital conversion subsystems
  Sample and hold circuits
  Digital-to-analog conversion
  Analog-to-digital conversion
  Interface of digital signals

General Characteristics of Sensors
Operating Characteristics
  Error
  Span/Sensitivity
Static Characteristics
Dynamic Characteristics
  Time constants
  Rise time

Class notes and handouts
LabVIEW documentation
Class handouts
Online Tutorials
Class notes and Handouts
Sections 6.2-6.4 Bateson
Section 6.5 Bateson
Class notes and handouts
Sections 5.3-5.5 Bateson
Course Outline

Analog Signal Conditioning
Common mode voltages
Difference Amplifiers
Analog-to-Analog Conversion
Instrumentation Amplifiers
Bridge circuits

Sensors For Data Acquisition and Control
Position measurement
  potentiometers
  linear variable differential transformers
  Synchros
  optical encoders
Velocity Measurements
  Dc tachometers
  Ac tachometers
  Optical tachometers
Acceleration Measurement
Force Measurements
  Strain gages
Temperature Measurement
  Temperature transducers
  Resistance Temperature Devices
  Thermocouples
  IC temperature sensors
Pressure Measurement
  Strain gages
  Deflection types
Level measurements

Discrete Event Control Systems
Introduction to Programmable logic controller hardware
  Input and output devices for PLCs
Ladder logic introduction
Designing discrete event control
  state-transition techniques
  ladder logic implementation
  ladder logic simulation software
Assessment Review
  National Assessment
  Exam (comprehensive)

Sections 6.3-6.4 Bateson
Sections 7.2-7.3 Bateson
Section 8.1 Bateson
Section 8.3 Bateson
Sections 9.1-9.3 Bateson
Chapter 11 Bateson
Appendix C  653-667
PLC Book 5.1
Chapter 12 Bateson
ET 438b
Sequential Digital Control and Data Acquisition
Course Outline

Quiz Schedule
Quizzes are scheduled after approximately 6 lecture periods. They will take between 30-40 minutes. Schedule is subject to change.

Quiz 1: Wednesday, February 1, 2017
Quiz 2: Friday, February 17, 2017
Quiz 3: Monday, March 6, 2017
Quiz 4: Wednesday, March 29, 2017
Quiz 5: Monday, April 14, 2017
Quiz 6: Wednesday, May 3, 2017
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<th>Lesson</th>
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* Use resistance range of 149-151 ohms from 6.21
1. Name

1.1 Sample Homework Format
Always use engineering paper unless otherwise instructed.

Included Problem numbers:

- Transcribe all key values here with units:
  - $R_i = 1052$
  - $V_i = 100V$
  - $I_i = 3A$

- Include sketches and schematics with values if useful.

b.) Label Subsections of problem.

Include enough work so that grader can follow logic:

- Answers with no support or invalid support receive no credit.
- $E_a = V_T - I_a R_a$
- $E_a = 120V - (3A)(0.152)$
- $E_a = 119.2V$

- Box final answer.

Staple multiple pages. Unstapled work not accepted.

- Pencil is better than ink for problem solutions.

Organize work in logical ways. This helps graders follow work and promotes maximum points for partial credit.

- Use lecture examples as guides for proper layout.
1.) **Introduction to LabVIEW Programming Environment**

**Learning Objectives:**
After performing this lab the student will be able to:

- Navigate the LabVIEW development environment, create a simple program, run it, and save it for later use.
- Identify the front and back panels, use component and programming palettes to build a user interface and program functionality.
- Identify data types used in LabVIEW
- Create and utilize local variables to simplify programming
- Use basic mathematical and Boolean operators to produce functional programs

2.) **Programming Structures in LabVIEW**

**Learning Objectives:**
After performing this lab the student will be able to:

- Identify and utilize advanced programming structures such as CASE (IF-THEN-ELSE), FOR loops, WHILE loops and Sequence structures
- Construct state machines in LabVIEW.
- Write a program using a state machine to implement a sequential process

3.) **Analog Data Acquisition Using LabVIEW and the Measurement and Automation Explorer (MAX)**

**Learning Objectives:**
After performing this lab the student will be able to:

- Identify and utilize the Measurement and Automation Explorer (MAX) to create virtual data acquisition channels and tasks.
- Use the MAX to test the functionality of a DAQ board installed in a PC.
- Link virtual channels and tasks to a LabVIEW program.
- Identify the sampling limits of a data acquisition board by injecting a signal and observing aliasing.
- Design and install an anti-aliasing filter to prevent aliasing due to undersampling.
- Write a LabVIEW program to analyze and display collected data.
4.) **Analog Measurement and Digital Control Integration Using LabVIEW**

**Learning Objectives:**
After performing this lab the student will be able to:

- Develop a LabVIEW program from a given specification to gather analog data and control digital outputs
- Identify the digital outputs’ voltage and current limitations and design appropriate interface circuits
- Identify the voltage and current limitations of the analog inputs and design a scaling circuit to utilize the full range of the analog inputs
- Configure analog inputs for both differential and single ended operation

5.) **Dc Bridges in Measurement and Data Acquisition**

**Learning Objectives:**
After performing this lab the student will be able to:

- Explain how a dc bridge can be used to make measurements in both the balanced and unbalanced modes.
- Construct a dc bridge circuit and automate the measurement process using a data acquisition board and a LabVIEW program.
- Scale the bridge measurements to display measured quantity.

6.) **Introduction to Connected Component Workbench and RSLogix Software**

**Learning Objectives:**
After performing this lab the student will be able to:

- Navigate the Connected Component Workbench and RSLogix Software.
- Create and save a simple ladder logic program using the software packages.
- Download the program to a PLC and monitor its operation using debug/monitor functions in the software.
7.) PLC Function Programming Using Ladder Logic

Learning Objectives:
After performing this lab the student will be able to:

- Explain the operation of on and off delay timers used in ladder logic and use them in programming exercises.
- Explain the operation of up/down counters used in ladder logic programs and use them in programming exercises.
- Define operating states of a given physical system.
- Write Boolean state equations for a physical system and use them to program ladder logic.

8.) IEC 1131 PLC Programming Languages 1: Introduction to Function Block Programming of a PLC

Learning Objectives:
After performing this lab the student will be able to:

- Explain the differences between the PLC programming languages specified in the IEC 1131 standard.
- Identify simple function blocks and utilize them in a PLC control program.
- Use Connected Components Workbench software function block programming to implement a control program.
- Convert an electromechanical ladder logic diagram into an equivalent function block PLC program.
- Convert a ladder logic program into structured text using the Connected Components Workbench software.
9.) **Analog Input and Output Using PLCs**

**Learning Objectives:**
After performing this lab the student will be able to:

- Identify comparison and arithmetic PLC instructions in both ladder logic and function block use to manipulate digital data derived from analog inputs.
- Create a program to read analog input values and scale them to meet given specifications.
- Create a program to write analog output values.
- Create a program that reads analog inputs processes the data and writes digital outputs and/or analog output to meet a given specification.

10.) **Implementing Motor Control and Speed Measurement Using PLC’s**

**Objectives:**
Student will be able to:
- Integrate hardware and software to create a working motor control system.
- Wire inputs and or outputs to a PLC to make a working control system.
- Use IEC 1131 programming languages to develop a working control system with control and monitoring capabilities.
- Given specific control functions, write, debug, and demonstrate working software.

**Laboratory Work Submission Policies**

Students will submit all laboratory work in electronic format using dropboxes located the learning management system (LMS). The dropboxes will be opened for a specified time period after the scheduled lab completion date. Once the dropboxes close no work will be accepted toward the given lab.

All lab work submissions will be in pdf format, preferably collected into a single file unless otherwise specified. Most programs used for documenting lab work have a save to pdf option. Free software exists, such as PrimoPDF that converts software output into pdf format if the program does not save to this format directly.

Each laboratory project document includes a list of items required for submission. Carefully review this list and submit only the items required.
There is a quiz associated with each lab project in the course. These quizzes make up between 20 to 30% of the lab assignment grade. The quizzes are located in the LMS under the associated laboratory topic. The quizzes are timed, open book/note tests that cover the material in the lab handouts. Some may require a calculator. The quizzes allow two attempts with an average of the two attempts recorded as the final quiz grade.

The quizzes have limited availability on the LMS. They will typically be available only during the time the work is performed for the current lab assignment. Check the calendar in the LMS frequently to identify the final due dates the quizzes are available. Anyone missing a quiz receives a zero for that part of the lab assignment.
IMPORTANT DATES *
Semester Class Begins: .................................................. 01/17/2017
Last day to add full-term course (without Dean’s signature): 01/22/2017
Last day to withdraw from the University with a full refund: 01/27/2017
Last day to drop a full-term course for a credit/refund: .......... 01/29/2017
Deadline to apply to graduate at the end of this term: ........ 04/2/2017
Final examinations: ................................................. 05/8–5/12/2017
Commencement: ..................................................... 05/13/2017

Note: For more detailed information on the above deadlines, please visit http://registrar.siu.edu/calendars. For add/drop dates that apply to shorter-than-full-term courses, please look at the Schedule of Classes search results at http://registrar.siu.edu/schedclass/index.php

SPRING SEMESTER HOLIDAYS
Martin Luther King Jr.’s Birthday Holiday 01/16/2017
Spring Break 3/11–3/19/2017

WITHDRAWAL POLICY ~ Undergraduate only
Students who officially register for a session must officially withdraw from that registration in a timely manner to avoid being charged as well as receiving a failing grade for those classes. An official withdrawal must be initiated by the student, or on behalf of the student through the academic unit, and be processed by the Registrar’s office. For the proper procedures to follow when dropping courses and when withdrawing from SIU visit: http://registrar.siu.edu/students/withdrawal.php

INCOMPLETE POLICY~ Undergraduate only
An INC grade may be assigned when, for reasons beyond their control, students engaged in passing work are unable to complete all class assignments for the course. An INC must be changed to a completed grade within one full semester (undergraduates), and one full year (graduate students), from the close of the term in which the course was taken or graduation, whichever occurs first. Should the student fail to complete the remaining course requirements within the time period designated, the incomplete will be converted to a grade of F and such grade will be computed in the student’s grade point average. For more information visit: http://registrar.siu.edu/grades/incomplete.php

REPEAT POLICY
An undergraduate student may, for the purpose of raising a grade, enroll in a course for credit more than once. For students receiving a letter grade of A, B, C, D, or F, the course repetition must occur at Southern Illinois University Carbondale. Effective for courses taken Summer 2013 or later, only the most recent (last) grade will be calculated in the overall GPA and count toward hours earned. This policy will be applied to all transferrable credit in that only the last grade will be used to calculate grade point average. Only those courses taken at the same institution are considered repeats under this policy. See full policy at http://registrar.siu.edu/students/repeatclasses.php

GRADUATE POLICIES
Graduate policies often vary from Undergraduate policies. To view the applicable policies for graduate students, please refer to the graduate catalog at http://gradschool.siu.edu/about-us/grad-catalog/

DISABILITY POLICY
Disability Support Services provides the required academic and programmatic support services to students with permanent and temporary disabilities. DSS provides centralized coordination and referral services. To utilize DSS services, students must contact DSS to open cases. The process involves interviews, reviews of student-supplied documentation, and completion of Disability Accommodation Agreements. http://disabilityservices.siu.edu/

PLAGIARISM
Student Conduct Code http://srr.siu.edu/student-conduct-code/

SAFETY AWARENESS FACTS AND EDUCATION
Title IX makes it clear that violence and harassment based on sex and gender is a Civil Rights offense subject to the same kinds of accountability and the same kinds of support applied to offenses against other protected categories such as race, national origin, etc. If you or someone you know has been harassed or assaulted, you can find the appropriate resources here:
http://safe.siu.edu

SALUKI CARES
The purpose of Saluki Cares is to develop, facilitate and coordinate a university-wide program of care and support for students in any type of distress—physical, emotional, financial, or personal. By working closely with faculty, staff, and students and their families, SIU will continue to display a culture of care and demonstrate to our students and their families that they are an important part of the community. For Information on Saluki Cares: call(618) 453-1492, email siucares@siu.edu, or http://salukicares.siu.edu/

SIU’S EARLY WARNING INTERVENTION PROGRAM (EWIP)
Students enrolled in courses participating in SIU’s Early Warning Intervention Program might be contacted by University staff during a semester. More information can be found at the Core Curriculum’s Overview webpage: http://corecurriculum.siu.edu/program-overview/

EMERGENCY PROCEDURES
We ask that you become familiar with Emergency Preparedness @ SIU. Emergency response information is available on posters in buildings on campus, on the Emergency Preparedness @ SIU website, and through text and email alerts. To register for alerts visit: http://emergency.siu.edu/

STUDENT MULTICULTURAL RESOURCE CENTER
The Student Multicultural Resource Center serves as a catalyst for inclusion, diversity and innovation. As the Center continues its work, we are here to ensure that you think, grow and succeed. We encourage you to stop by the Center, located in Grinnell Commons, to see the resources available and whenever you can get involved on the campus. Visit us at http://inclusiveexcellence.siu.edu/

LEARNING AND SUPPORT SERVICES
Help is within reach. Learning support services offers free tutoring on campus and math labs. To find more information please visit the Center for Learning and Support Services website:
Tutoring: http://tutoring.siu.edu/
Math Labs http://math.siu.edu/courses/course-help.php

WRITING CENTER
The Writing Center offers free tutoring services to all SIU students and faculty. To find a Center or Schedule an appointment please visit: http://write.siu.edu/

AFFIRMATIVE ACTION & EQUAL OPPORTUNITY
Our office’s main focus is to ensure that the university complies with federal and state equity policies and handles reporting and investigating of discrimination cases. For more information visit: http://diversity.siu.edu/

MILITARY COMMUNITY
There are complexities of being a member of the military community and also a student. Drill schedules, calls to active duty, complications with GI Bill disbursement, and other unforeseen military and veteran related developments can complicate academic life. If you are a member of the military community and in need of accommodations please visit Veterans Services at http://veterans.siu.edu/

Additional Resources:
ADVISEMENT: http://advisement.siu.edu/
SIU ONLINE: https://online.siu.edu/
SALUKI SOLUTION FINDER: http://solutionfinder.siu.edu/
MORRIS LIBRARY HOURS: http://libguides.lib.siu.edu/hours