ET 438b
Sequential Digital Control Systems and Data Acquisition

Instructor: Dr. Carl Spezia, PE

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

Textbooks: Introduction to Control Systems Technology, 7th Edition, Robert N. Bateson
LabVIEW 2009 Student Edition, Robert H. Bishop

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

Grading Scale:

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

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.

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Course Policies (continued)

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)
   Nicotine Consumption
4. 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

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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.

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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, Department of Public Safety's website 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.

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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.

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Course Outline

Digital Control and Data Collection	Class notes and handouts
Digital control systems	
Computer-based data acquisition and control	
Data Flow Programming Languages	
LabVIEW programming	LabVIEW documentation
Analog input blocks	Class handouts
Computed blocks	Online Tutorials
Digital I/O blocks	
On/off Control	
Ideal OP AMP model	Class notes and Handouts
Non-linear OP AMP circuits	Sections 6.2-6.4 Bateson
Voltage comparators	
Voltage comparators with hysteresis	
Window comparators	
Discrete control-on/off controllers	
Sampled Signal Fundamentals	Section 6.5 Bateson
Spectrum representation of signals	Class notes and handouts
Nyquist Sampling Theorem	
Aliasing and Folding of sampled signals	
Filters	
Aliasing control using analog filters	
Digital Signal Conversion and Conditioning	Section 6.5 Bateson
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	Sections 5.3-5.5 Bateson
Operating Characteristics	
Error	
Span/Sensitivity	
Static Characteristics	
Dynamic Characteristics	
Time constants	
Rise time	

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Analog Signal Conditioning	Sections 6.3-6.4 Bateson
Common mode voltages	
Difference Amplifiers	
Analog-to-Analog Conversion	
Instrumentation Amplifiers	
Bridge circuits	
Sensors For Data Acquisition and Control	Sections 7.2-7.3 Bateson
Position measurement	
potentiometers	
linear variable differential transformers	
Synchros	
optical encoders	
Velocity Measurements	
Dc tachometers	
Ac tachometers	
Optical tachometers	
Acceleration Measurement	
Force Measurements	
Strain gages	Section 8.1 Bateson
Temperature Measurement	
Temperature transducers	
Resistance Temperature Devices	
Thermocouples	
IC temperature sensors	
Pressure Measurement	
Strain gages	Section 8.3 Bateson
Deflection types	
Level measurements	
Discrete Event Control Systems	
Introduction to Programmable logic controller hardware	Sections 9.1-9.3 Bateson
Input and output devices for PLCs	Chapter 11 Bateson
Ladder logic introduction	
Designing discrete event control	Appendix C 653-667
state-transition techniques	PLC Book 5.1
ladder logic implementation	Chapter 12 Bateson
ladder logic simulation software	
Assessment Review	**National Assessment Exam (comprehensive)**

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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

438B Homework list

Homework #	Source	Assignment	Lesson	Turned in?	Grade Received
1	Handout	P2.3, P2.4	2		
2	Handout	P2.8	2		
3	Handout	slew.wp5	3		
4	6 Bateson	6.4 6.5	3,4		
5	Handout	gaphw.wp5	4		
6	Handout	window.wp5	5		
7	6 Bateson	6.31, 6.32	6		
8	Handout	amhw.wp5, specan.wp5	6,7		
9	Handout & 6 Bishop	6.33, dachw2.wp5, dac_hw1.wp5	8,9		
10	Handout	bonus3.wp5	8,9		
11	6 Bateson	6.34	9		
12	Handout	diohw1.wp5	9		
13	Handout	mask.wp5	9		
14	5 Bateson	5.5, 5.7, 5.19	10		
15	Handout	differ.wp5	11		
16	Handout	diffsen.wp5	11		
17	6 Bateson	6.22 *	12		
18	7 Bateson	7.1, 7.2, 7.3, 7.4	13		
19	7 Bateson	7.17, 7.18	13		
20	7 Bateson	7.20	13		
21	8 Bateson	8.4, 8.6	12		
22	8 Bateson	8.12, 8.16	12		
23	Handout	seqhw38.wp5	14		
24	Handout	ladder.wp5	14		
25	Handout	xorlad.wp5	15		
26	Handout	lad2log.wp5, log2lad.wp5	15		
27	Handout	addrplc.wp5	18		
28	Handout	plcpgm1.wp5	18		

* Use resistance range of 149-151 ohms from 6.21

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Homework 1

NAME ↗

← Course

← HW NUMBER

1.1 Sample Homework format
Always use engineering paper unless otherwise instructed

↑ included Problem numbers

Transcribe all key values here with units

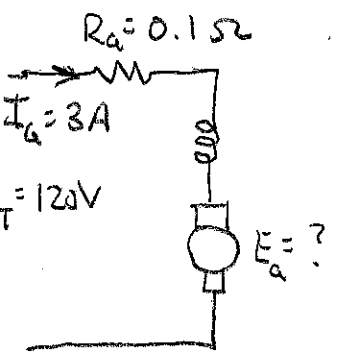
$R_1 = 10\Omega$

$V = 100V$

$I = 3A$

include sketches & 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

$E_a = V_T - I_a R_a$

$E_a = 120V - (3A)(0.1\Omega)$ always include units

$\boxed{E_a = 119.7V}$

↑ Box final answer

Staple multiple pages. Unstapled work not accepted

Pencil is better than ink for problem solutions

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

Use lecture examples as guides for proper layout

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Lab Projects

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.

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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.

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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.

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Lab Projects

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 indentify the final due dates the quizzes are available. Anyone missing a quiz receives a zero for that part of the lab assignment.

SIU Southern Illinois University
CARBONDALE

Syllabus Attachment

Spring 2017

Office of the Provost: http://pvcaa.siu.edu/

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:……**5/8–5/12/2017**
Commencement: ……..…**5/13/2017**

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/
Guidelines for Faculty http://pvcaa.siu.edu/_common/documents/Plagiarism/Guide%20to%20Preventing%20Plagiarism.pdf

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, 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 though 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 discover ways 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