CAMOSUN COLLEGE
Trades and Technology
Electronics and Computer Engineering
ELEN 146
Control Systems
Summer 2019
COURSE OUTLINE

The calendar description is available on the web @ Camosun.ca

IN-CLASS WORKLOAD: 7 lecture, 2 lab hrs/wk
OUT-OF-CLASS WORKLOAD: 8 hrs/wk

Please note: This outline will not be kept indefinitely. It is recommended students keep this outline for their records, especially to assist in transfer credit to post-secondary institutions.

1. Instructor Information

(a) Instructor	Justin Curran		
(b) Office hours	Open Door and by Appointment		
(c) Location	TEC 216A		
(d) Phone	250-370-4432	**Alternative:**	
(e) E-mail	jcurran@camosun.bc.ca		
(f) Website	www.elex.camosun.bc.ca		

2. Intended Learning Outcomes

The objective of this course is to introduce fundamental concepts of control systems and the use of data acquisition to achieve this. Fundamental analog circuit techniques as used in control systems are covered from signal conditioning of transducers, data acquisition systems and actuators. Feedback and its effects on the system performance are studied. Stability is analyzed for second and higher order systems. PID controllers are studied as well as the techniques used to optimize them. Disturbances and their effects on open and closed loops are reviewed. Discrete control systems are covered including digital controllers and PLCs.

Upon successful completion of this course a student will be able to:

- identify the components forming a data acquisition system and explain their function;
- demonstrate necessary skills to analyze an op amp based data acquisition;
- demonstrate the ability to make proper measurement of different parameters of interest;
- describe the different Power semiconductor devices used in motor controls;
- explain the function of different motors and their drives;
- enumerate the different sensors used in a DAQ system onboard a frigate; and
- demonstrate how DAQ sensors are used and function in industry;
- explain feedback and its effect on the parameters of the system;
- analyze the stability of a control system;
- explain and apply PID techniques used to tune a control system;
- identify a discrete controller;
- explain how an analog controller works
- explain how a digital controller works and demonstrate how PLCs work;

3. Required Materials

a. Access to Camosun D2L online course materials
b. Bateson, Robert N.
c. “Introduction To Control System Technology", Prentice-Hall Inc., Fifth Edition, 1996
d. Handouts (will be distributed as required)
e. Student File Share: \\elexsrv1\elexpub\elen 146 or \\142.31.204.249\elexpub\elen146

4. Course Content Total Lecture Hours 14 * 7 = 98

0. **Course Introduction**

1. **Measuring Instrument Characteristics** (4 hrs)
   - 1.1 Introduction
   - 1.2 Statistics
   - 1.3 Measurement
   - 1.4 Static Characteristics
   - 1.5 Dynamic Characteristics

2. Signal Conditioning (8 hrs)
   - 2.1 Introduction
   - 2.2 The Operational Amplifier
     - 2.2.1 Comparators
     - 2.2.2 Inverting Amplifiers
     - 2.2.3 Non-Inverting Amplifiers
     - 2.2.4 Voltage Followers
     - 2.2.5 Summing Amplifiers
     - 2.2.6 Differential Amplifiers
     - 2.2.7 Common Mode Rejection
     - 2.2.8 Instrumentation Amplifiers
     - 2.2.9 Integrators and Differentiators
     - 2.2.10 Slew Rate
     - 2.2.11 BJT/FET Input Op-amps
   - 2.3 The Wheatstone Bridge
   - 2.4 Applications

3. Analog Filters (5 hrs)
   - 3.1 Fundamentals, Definitions and Terminology
   - 3.2 First Order Active Filters
   - 3.3 Second Order Active Filter Model
   - 3.4 The Sallen Key Filter

4. Data Acquisition Systems (7 hrs)
   - 4.1 Sampling Theorem
   - 4.2 Aliasing
   - 4.3 Analog To Digital Converters
     - 4.3.1 Dual Slope Integrating ADC
     - 4.3.2 Successive Approximation ADC
     - 4.3.3 Flash or Parallel ADC
     - 4.3.4 Resolution of the ADC
   - 4.4 Digital To Analog Converters
     - 4.4.1 Resolution of the DAC
   - 4.5 Recovery Filters
   - 4.6 Multiplexers /Demultiplexers

5. Sensors (8 hrs)
   - 5.1 Introduction
   - 5.2 Temperature Sensors
     - 5.2.1 Thermocouples

- 5.2.2 RTD
- 5.2.3 Thermistor

5.3 Displacement Sensors
- 5.3.1 Position Sensors
  - 5.3.1.1 LVDT
  - 5.3.1.2 Potentiometer
  - 5.3.1.3 Interferometer
  - 5.3.1.4 Position Encoders

5.4 Velocity and Acceleration Sensors
- 5.4.1 Velocity Sensors
- 5.4.2 Acceleration Sensors

Sensors continued (5 hrs)

5.5 Force and Pressure Sensors
- 5.5.1 Pressure Sensors
- 5.5.2 Strain Gauges
- 5.5.3 Piezoelectric Sensors

5.6 Proximity Sensors
- 5.6.1 Inductive Proximity Sensors
- 5.6.2 Capacitive Proximity Sensors
- 5.6.3 Optical Proximity Sensors
- 5.6.4 Eddy Current Proximity Sensors
- 5.6.5 Hall Effect Proximity Sensors

5.7 Flow Sensors
- 5.7.1 Positive Displacement Flow Sensors
- 5.7.2 Magnetic Flow Sensors
- 5.7.3 Vortex Shedding Flow Sensors
- 5.7.4 Differential Pressure Flow Sensors
- 5.7.5 Doppler Flow Sensors
- 5.7.6 Time of Flight Flow Sensors
- 5.7.7 Scintillation Flow Sensors

5.8 Level Sensors

5.9 Calibration

6. Actuators (5 hrs)

6.1 Electric Motors
- 6.1.1 DC Motors
- 6.1.2 AC Motors
- 6.1.3 DC Stepper Motors

6.2 Mechanical Switches

6.3 Solid State Switches

6.4 Electro Mechanical Switches

6. Examples of Control Systems Using Sensors and Actuators (1 hr)

Review: (1 hr)

Term Test 1 ***(2 hrs)***

7. Introduction to Control Systems (7hrs)
    - 7.1 What is a control system?
    - 7.2 Examples of control systems (water level in a tank, temperature in a room)
    - 7.3 Open Loop Control and Closed Loop Control
    - 7.4 Feedback and its effects
    - 7.5 Benefits of Control
    - 7.6 Factors Affecting Control
    - 7.7 Stability
    - 7.8 Block Diagram of a complete control system
    - 7.9 Transfer Functions
    - 7.10 Frequency Response

8. Control models - Describing Processes (7 hrs)
    - 8.1 Signals in control systems
        - 8.1.1 Time Domain and frequency domain
        - 8.1.2 The unit step function
        - 8.1.3 The impulse step function
    - 8.2 First Order Lag Processes
        - 8.2.1 Step response
        - 8.2.2 Frequency response (magnitude and phase-The Bode plot)
    - 8.3 Second Order Lag Processes
        - 8.3.1 Step response
        - 8.3.2 Study of response for different damping factor values
        - 8.3.3 Poles and stability
        - 8.3.4 Frequency response (magnitude and phase-The Bode plot)

9. Stability of control systems (7 hrs)
    - 9.1 Higher order systems
        - 9.1.1 Stability. The Routh-Hurwitz criteria
    - 9.2 Stability in the frequency domain
        - 9.2.1 Gain margin
        - 9.2.2 Phase margin
        - 9.2.3 The Nyquist criteria

10. Steady state output and steady state error (7 hrs)
    - 10.1 Definitions of steady state output and steady state error
    - 10.2 First order in a unity feedback. Steady state vs gain
    - 10.3 Second order system in a unity feedback.

11. Control of Continuous Processes (7 hrs)
    - 11.1 Simple Control. ON/OFF controller. Continuous controllers
    - 11.2 The proportional Controller. Advantages and drawback
    - 11.3 The P-I controller
    - 11.4 The P-I-D controller
    - 11.5 Tuning the PID – The Ziegle Nichols method

12. Control and Disturbances (3hrs)
    - 12.1 Introduction and definitions
    - 12.2 Effect of feedback on disturbances
    - 12.3 Practical examples

13. Control of Discrete Processes (4hrs)
    - 13.1 Time-Driven Sequential Processes
    - 13.2 Event-Driven Sequential Processes
    - 13.3 Switching relays and PLCs
    - 13.4 Different types of relays
    - 13.5 Semiconductor switches (SCRs Triacs, Optocouplers…)

14. Digital Control (3hrs)
    - 14.1 Fundamentals of digital processing of error signals
    - 14.2 Discrete PID algorithm
    - 14.3 Comprehensive digital controller using PID

15. PLCs (4hrs)
    - 15.1 Introduction and Definitions
    - 15.2 Ladder and rungs
    - 15.3 Examples

Review: (2 hr)
Midterm Test (2 hrs)

LABORATORY EXERCISES

1. INTRODUCTION

- Introduction to ELEN 146 Lab requirements.
- Identification of components and ICs.
- Issue and checking of parts kits.

2. BASIC OPERATIONAL AMPLIFIERS

- Study the AC characteristics of the non-inverting op amp configuration.
- Study the AC characteristics of the inverting op amp configuration.
- Observe the 180^{o} phase shift associated with the inverting op amp configuration.
- Simulate the non-inverting and inverting op amp circuit behavior.

3. ACTIVE FILTERS

- Observe first order low pass and high pass filters.
- Measure filter cutoff frequency.
- Build a second order low pass and high pass filters.
- Observe the increased roll off of a higher order filter.

4. DIGITAL-TO-ANALOG CONVERTERS (DAC)

- Experimentally investigate the properties of an integrated circuit DAC.

5. ANALOG-TO-DIGITAL CONVERTERS (ADC)

- Experimentally investigate the properties of a successive approximation ADC.
- Experimentally verify ADC and DAC conversion by using one device to drive another.

6. TEMPERATURE SENSOR

- Observe the behavior of a temperature sensor.
- Design and build a conditioning circuit.
- Calibrate a sensor.
- Observe the interaction of the zero and span controls.

7. ACTUATORS

- Observe a stepper motor controlled by a computer
- Observe a phase angled fired AC supply driving a universal motor to give speed control.
- Observe a pulse width modulated speed control of a DC servo motor (a model train).

8. MOTOR BEHAVIOR

- Be introduced to the Feedback lab equipment;
- Verify that the equipment is functioning properly;
- Examine steady state motor response;
- Examine motor loading;
- Examine transient motor response.

9. STEP RESPONSE, FREQUENCY RESPONSE, AND FEEDBACK

- Examine motor step response;
- Examine motor frequency response;
- Examine the effect of feedback.

10. PROPORTIONAL CONTROL OF FIRST ORDER LAG PROCESSES

- Examine proportional motor control and its effects;
- Examine negative feedback and the associated signals.

11. POSITION AND VELOCITY FEEDBACK

- Measure the dead band of a motor;
- Examine the second order step response of a motor system;
- Apply various feedbacks including velocity feedback to the system;
- Examine following error with changes to feedback.

12. PID CONTROL TECHNIQUES

- Investigate PID control techniques using a pre-built PID circuit board.

13. PLC SIMULATION

- Become familiar with how relay and ladder logic work.
- Investigate the LogixPro PLC Simulator
- Demo your exercises and answer questions.

14. PLC HARDWARE

- Become familiar with programming Allen-Bradley PLCs;
- Create simple ladder logic programs;
- Demo your exercises and answer questions.

5. Basis of Student Assessment (Weighting)

(a)	Assignments / Quizzes	=	10%
(b)	Mid-term Test 1	=	15%
(c)	Mid-term Test 2	=	15%
(d)	Labs	=	20%
(e)	Final Exam	=	40%
	Total	**=**	**100%**

Attendance is required for all classroom, lab, and D2L activities. It is the student's responsibility to communicate with the instructor, preferably prior to any absence. Any absence not sufficiently justified will result in a loss of 5% of the overall course grade.

Professionalism: "the skill, good judgment, and polite behavior that is expected from a person who is trained to do a job well" (Merriam Webster online). Students will be evaluated on the above as well as their ability to work well in a team.

Assignments and/or Quiz are based on the lecture topics and hands on lab exercises – Quizzes will occur towards the ending of lab or class period.

You are encouraged to use the D2L discussion area to ask questions as this will be monitored by the instructor.

Laboratory evaluation is based on the following criteria:

- 1/2 mark is given for attendance, cleanliness, deportment, group work, equipment treatment of your lab grade for each lab period.
- 1/2 mark is given for completion of lab activities based on demonstration and/or journal work of your lab grade for each lab period.

You need to keep a journal for any information relating to this course such as terminology, lab exercises, observations, and procedures.

Please note the following:

1. A grade of 60% or better is required in all assignments, quizzes and term-test to be able to pass the course.
2. A grade of 50% or better is required in the final examination to be able to pass the course.
3. No late materials will be accepted past midnight of the last day of the course.
4. A student is required to inform the instructor prior to being late or missing a class, or as soon as possible.

6. Grading System

[x] Standard Grading System (GPA)

[ ] Competency Based Grading System

7. Recommended Materials or Services to Assist Students to Succeed Throughout the Course

LEARNING SUPPORT AND SERVICES FOR STUDENTS

There are a variety of services available for students to assist them throughout their learning. This information is available in the College Calendar, Student Services or the College web site at http://www.camosun.bc.ca

STUDENT CONDUCT POLICY

There is a Student Conduct Policy. It is the student's responsibility to become familiar with the content of this policy. The policy is available in each School Administration Office, Registration, and on the College web site in the Policy Section.
http://www.camosun.bc.ca/policies/policies.html

A. GRADING SYSTEMS *http://www.camosun.bc.ca/policies/policies.php*

The following two grading systems are used at Camosun College:

1. Standard Grading System (GPA)

Percentage	Grade	Description	Grade Point Equivalency
90-100	A+		9
85-89	A		8
80-84	A-		7
77-79	B+		6
73-76	B		5
70-72	B-		4
65-69	C+		3
60-64	C		2
50-59	D		1
0-49	F	Minimum level has not been achieved.	0

2. Competency Based Grading System (Non GPA)

This grading system is based on satisfactory acquisition of defined skills or successful completion of the course learning outcomes

Grade	Description
COM	The student has met the goals, criteria, or competencies established for this course, practicum or field placement.
DST	The student has met and exceeded, above and beyond expectation, the goals, criteria, or competencies established for this course, practicum or field placement.
NC	The student has not met the goals, criteria or competencies established for this course, practicum or field placement.

B. Temporary Grades

Temporary grades are assigned for specific circumstances and will convert to a final grade according to the grading scheme being used in the course. See Grading Policy at http://www.camosun.bc.ca/policies/E-1.5.pdf for information on conversion to final grades, and for additional information on student record and transcript notations.

Temporary Grade	Description
I	*Incomplete*: A temporary grade assigned when the requirements of a course have not yet been completed due to hardship or extenuating circumstances, such as illness or death in the family.
IP	*In progress*: A temporary grade assigned for courses that are designed to have an anticipated enrollment that extends beyond one term. No more than two IP grades will be assigned for the same course.
CW	*Compulsory Withdrawal*: A temporary grade assigned by a Dean when an instructor, after documenting the prescriptive strategies applied and consulting with peers, deems that a student is unsafe to self or others and must be removed from the lab, practicum, worksite, or field placement.