C A M O S U N   C O L L E G E

ELECTRONICS & COMPUTER ENGINEERING DEPARTMENT

COURSE OUTLINE

CALENDAR DESCRIPTION

ELEN 146 Control Systems

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.

OFFERED:	Summer Semester
CREDIT:	3
IN-CLASS WORKLOAD:	7 lecture, 2 lab
OUT-OF-CLASS WORKLOAD:	5 hrs/wk
PREREQUISITES:	Reserved for DND MARTECH Program
Instructor:	**Solomon Lindsay**
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LEARNING OUTCOMES:

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

- demonstrate necessary skills to analyze an opamp-based data acquisition.
- 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.
- 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.
- explain how an analog controller works.
- explain how a digital controller works and demonstrate how PLCs work.

OUTLINE:

The following schedule and course components are subject to change with reasonable advance notice, as deemed appropriate by the instructor.

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** **(13 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
   - 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** **(6 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
   - 6.5 Examples of Control Systems Using Sensors and Actuators

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
    - 10.2 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

Time Allocation

Lecture/Seminar	(7hrs/week x 14)	96
Term Test	(1hr x 2)	2
Final Exam	(3hrs x 1)	3
Labs	(2hrs x 14)	28
Total Hours		**129**

LABORATORY

Lab 1 Basic OpAmp
Lab 2 Active Filter
Lab 3 DACs
Lab 4 ADCs
Lab 5 Temperature Sensor
Lab 6 Stepper Motor
Lab 7 Motor Behaviour
Lab 8 Step Response
Lab 9 Speed Control
Lab 10 Position and Velocity Feedback
Lab 11 PID Control Techniques
Lab 12 Introduction to PLC (Simulation)
Lab 13 Introduction to PLC (Hardware)

EVALUATION (Grading according to College policy):

Marks will be assigned to assignments, laboratory exercises, term tests and the final exam. These marks will be weighted according to the criteria defined in **Table 1: Evaluation Criteria** to obtain a composite percentage mark.

A passing grade must meet following three criteria:

1) Overall lab mark is equal to or greater than 60%;
2) Overall theoretical mark (assignments, tests, final exam) is equal to or greater than 60%;
3) The final exam mark is equal to or greater than 50%.

The percentage mark will be translated to a college standard letter grade according to **Table 2: Percentage to Letter Grade Translation**. Table 2 is applicable in this year and to this course only. The course outline identifies concepts and abilities that will be evaluated in this course.

Table 1: Evaluation Criteria*

Assignments	10%
Quizzes	30%
Final Exam	30%
Total theoretical marks	**70%**
Laboratory Evaluation	**30%**
Total	**100%**

**Labs and assignments delay levy: -10%*

Table 2: Percentage to Letter Grade Translation

GRADING (in accordance with College policy):

A+	90 – 100%	**B-**	70 – 72%
A	85 – 89%	**C+**	65 – 69%
A-	80 – 84%	**C**	60 – 64%
B+	77 – 79%	**D**	50 – 59%
B	73 – 76%	**F**	< 50%

TEXT BOOKS AND REFERENCES:

- Course notes and handouts
- Textbook:
  - Bateson, Robert N. “Introduction to Control System Technology", Prentice-Hall, Fifth Edition, 1996