JEFFERSON COLLEGE

COURSE SYLLABUS

ETI236

Industrial Control

4 Credit Hours

Prepared by:
Dennis Eimer

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By
Dennis Eimer

Division of Technology
Dr. John Keck, Dean
Ms. Brenda Russell, Associate Dean
I. Course Description

Title: ETI236 Industrial Control

Curriculum: Electronics and Industrial Automation Technology Core

Semester Hours: 4

Prerequisite: ETC133 Semiconductors II
Corequisite: ETC255 Introduction to Digital Circuits

Catalog Description: Industrial Control will involve a study of AC motor and DC motor theory as well as control devices and symbols, ladder diagrams, common motor control circuits, sensors and transducers, closed-loop process control, synchro components, and servo systems.

II. Expected Learning Outcomes with Assessment Measures

1. Demonstrate knowledge and understanding of the concepts and characteristics of the various types of DC and AC motors. *(Evaluate by written exams, quizzes and observation of lab performance)*

2. Demonstrate knowledge and understanding of electro-mechanical and solid state motor controls. *(Evaluate by written exams, quizzes and observation of lab performance)*

3. Demonstrate ability to construct, read, and analyze motor control diagrams typically found in industrial applications. *(Evaluate by written exams, quizzes and observation of lab performance)*

4. Demonstrate the ability to apply the principles of operation of the various forms of sensors and transducers. *(Evaluate by written exams, quizzes and observation of lab performance)*

5. Demonstrate an understanding of closed-loop process control systems. *(Evaluate by written exams, quizzes and observation of lab performance)*

6. Demonstrate ability to construct, analyze, and troubleshoot industrial control systems. *(Evaluate by written exams, quizzes and observation of lab performance)*
III. Course Outline

Unit: 1
Lesson: 1
Title: Industrial Control Overview

Objectives: Upon completion of the lesson, you should be able to, by written examination;
1. List the classifications of industrial control systems.
2. Describe the differences between the different industrial control systems and provide examples of each type.
3. Define the following terms associated with industrial control systems:
   a. Servos,
   b. Batch,
   c. Instrumentation,
   d. Servomechanisms,
   e. Continuous
4. Describe the differences between open loop and closed loop systems.
5. Define the following terms associated with open and closed loop systems:
   a. Negative Feedback,
   b. Controlled Variable,
   c. Measurement Device,
   d. Feedback Single,
   e. Set Point,
   f. Error Detector,
   g. Error Signal,
   h. Controller,
   i. Actuator,
   j. Manufacturing Process,
   k. Disturbance,
   l. Measured Variable,
   m. Manipulated Variable,
   n. Controller Output Signal.
6. List the factors that affect the dynamic response of a closed loop system.
7. Describe the operation of Feedback Control.
8. Describe the operation of Feed-Forward Control.
9. List three factors that cause the controlled variable to differ from a set point.

Reading Assignment: Bartelt, Industrial Control Electronics, 3rd edition, Chapter 1.
Unit: 2
Lesson: 1
Title: Interface Devices

Objectives: Upon completion of the lesson, you should be able to, by written examination;
1. Identify the schematic diagrams, and describe the operation of the following:
   a. Inverting Op Amp
   b. Summing Op Amp
   c. Non-inverting Op Amp
   d. Op Amp Integrator
   e. Op Amp Differentiator
   f. Open Loop Op Amp
   g. Difference Op Amp
2. Describe the wave-shaping capability and operating characteristics of a Schmitt Trigger.
3. Explain the operation and isolating function of optoelectronic devices.
4. Explain the operation of A to D Converter and D to A Converter devices.
5. Explain the characteristics and operation of the following thyristors
   a. SCR
   b. UJT
   c. Diac
   d. Triac
   e. IGBT
6. Draw the current-voltage characteristic curve for the above thyristors
7. Draw the input and associated output waveforms for the above thyristors
8. Explain the operation of the sample circuits which use the above thyristors

Reading Assignment: Bartelt, *Industrial Control Electronics*, 3rd. edition, Chapters 2 and 3

Unit: 3
Lesson: 1
Title: The Controller Operation

Objectives: Upon completion of the lesson, you should be able to, by written examination;
1. List the four control modes used by the controller section.
2. Define the following terms associated with the control modes of a close-loop system:
   a. Hysteresis.
   b. Fuzzy Logic.
   d. P I D
   e. Proportional Band.
   f. Stable/Unstable.
   g. Steady-State Error.
   h. Proportional Gain.
   i. Offset.
   j. Deadband.
3. Describing the operation of each type of mode control function.
4. Explain the operation of the operational amplifier of circuitry that performs each of the three P I D mode functions.
5. Describe the operation of Time-Proportioning control

Reading Assignment: Bartelt, *Industrial Control Electronics*, 3rd. edition, Chapter 4
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Unit: 4
Lesson: 1
Title: Industrial Safety and Three-Phase AC Power Distribution (no reading assignment)

Objectives: At the completion of the lesson, the student should be able to, by demonstration and written examination:

1. State the cautions and dangers designated by the following OSHA safety color codes:
   a. red,
   b. yellow,
   c. orange,
   d. purple,
   e. green,
2. State the factors that contribute the severity of an electrical shock,
3. List the general safety precautions that must be observed when working with electrical equipment,
4. State the purpose and process involved in grounding an electrical system,
5. Identify the purpose of an isolation transformer,
6. Outline the basic steps in a lockout procedure,
7. State the phase relationship between the phase voltage of a three-phase distribution system,
8. Given phase voltage for a balanced wye connected system:
   a. state phase-to-phase voltage,
   b. state phase-to-neutral voltage,
9. State the relationship between phase current and line current for a balanced wye connected system,
10. Given phase voltage for a balanced delta connected system, state phase-to-phase voltage,
11. State the relationship between phase current and line current for a balanced delta connected system,
12. Given phase voltage for a balanced delta connected system, state the voltages available if a center-tapped phase is used.

Reading Assignment: Rockis and Mazur Electrical Motor Controls, Chapters 3 and 8
Unit: 5
Lesson: 1
Title: DC Motors

Objectives:  At the completion of the lesson, the student should be able to, by demonstration and written examination:

1. State the purpose of the commutator-brush assembly,
2. State the armature-field connections for:
   a. series,
   b. shunt,
   c. cumulative compound,
   d. differential compound dc motors,
3. State the definition of the term armature reaction,
4. State the purpose of interpole (compensating) windings and their connection to the armature
5. State the factors affecting armature CEMF,
6. Describe the methods for controlling the speed and speed regulation characteristics of
   a. series,
   b. shunt,
   c. compound dc motors,
7. Describe the method(s) for reversing:
   a. series,
   b. shunt,
   c. compound dc motors
8. Describe the principal theory of operation of the following dc motor control circuits:
   a. starting,
   b. reversing,

Reading Assignment: Bartelt, Industrial Control Electronics, 3rd. edition, Chapter 5
Reading Assignment: Rockis and Mazur Electrical Motor Controls, Chapters 6 pp.141-151
Unit: 5  
Lesson: 2  
Title: AC Motors

Objectives: At the completion of the lesson, the student should be able to, by demonstration and written examination;
1. Describe the purpose of the centrifugal switch used in single-phase ac induction motors,
2. Describe the construction and relative starting and running torque of:
   a. resistive start (split-phase),
   b. capacitive start,
   c. capacitive start/capacitive run (permanent capacitor),
   d. two-value capacitor ac induction motor,
3. Describe the method for reversing single-phase ac induction motors,
4. Describe the indications for an open starting winding or open centrifugal switch,
5. Describe the construction and principal theory of operation of the Universal motor,
6. Describe the construction of a squirrel cage rotor 3-phase ac induction motor,
7. Describe the construction of a wound rotor 3-phase ac induction motor,
8. Compute the synchronous speed of the stator field of a ac induction motor,
9. Compute the percentage of rotor slip of an ac induction motor,
10. Describe the relationship between rotor torque and rotor slip of an ac induction motor,
11. Describe the no-load power factor of an ac induction motor,
12. Describe the starting current in terms of full-load current for a 3-phase ac induction motor,
13. Describe the starting torque in terms of full-load torque for a 3-phase ac induction motor,
14. State the motor breakdown point (stall) as a percentage of synchronous speed for a 3-phase ac induction motor,
15. State the relationship between rotor torque and rotor current for a wound rotor 3-phase AC motor,
16. Describe the relationship between synchronous motor rotor current and motor power factor,
   a. under excited,
   b. over excited,
17. Describe the use of the synchronous motor as a synchronous condenser,
18. State the requirements for reversing a three-phase AC motor,

Reading Assignment: Bartelt, Industrial Control Electronics, 3rd. edition, Chapter 6
Reading Assignment: Rockis and Mazur Electrical Motor Controls, Chapters 7 pp.167-191
Unit: 5  
Lesson: 3  
Title: Servo and Other Motors  

Objectives:  At the completion of the lesson, the student should be able to, by demonstration and written examination;  
1. Describe the construction and general characteristics of the permanent-magnet dc motor,  
   a. wound armature  
   b. wound field  
2. Describe how speed is controlled in the wound armature DC motor.  
3. Describe how the direction of rotation is controlled in the wound armature DC motor.  
4. Describe the construction and general characteristics of the moving-coil dc motor.  
5. Describe the principal theory of operation of the Hall-effect brushless dc motor.  
6. State the two types of stepper motors with respect to rotor construction,  
7. State the definition of the term holding torque,  
8. State the definition of the term dynamic torque,  
9. State the definition of the term residual torque,  
10. State the relationship between step rate and dynamic torque,  
11. Describe the drive requirements for a full-step, half-step, and micro-step stepper motor driver.  

Reading Assignment: Bartelt, Industrial Control Electronics, 3rd edition, Chapter 7
Unit: 6
Lesson: 1
Title: Motor Control Circuits

Objectives: At the completion of the lesson, the student should be able to, by demonstration and written examination;
1. State the function of the line diagram,
2. Identify the line diagram symbols for:
   a. push button (momentary),
   b. auxiliary contacts (normally open, normally closed),
   c. overload relay contacts,
   d. contacts (instant operating),
   e. control and power connections,
   f. pilot light,
   g. circuit disconnect, interrupter, breaker (thermal and magnetic overload,
3. State the manner in which a load is connected in the line diagram,
4. State the maximum number of loads in the control circuit on any one line of the line diagram,
5. State the manner in which multiple loads are connected in the line diagram,
6. State the manner in which control devices are connected in the line diagram,
7. State the manner in which lines are numbered in the line diagram,
8. Describe the construction, and principal theory of operation of a magnetic solenoid,
9. Describe the effects of above normal and below normal solenoid coil voltage,
10. Describe the difference between a contactor and a magnetic motor starter,
11. State the two classifications of overload relays,
12. State the two types of thermal overload relays.
13. Describe the construction and principal theory of operation of the electromechanical relay,
14. State the definition of the term pick-up point relative to the electromechanical relay,
15. State the relative difference between the pick-up current (voltage) and the drop-out current (voltage),
16. Identify the basic relay contact forms,
17. State the relative advantages and disadvantages of solid-state relays,
18. Draw the switch logic for AND, OR, NOT, NAND, NOR, and Exclusive OR,
19. Draw the NEMA logic symbol for AND, OR, NOT, NAND, NOR, ON-delay, OFF-delay,
20. Identify both NEMA and relay contact symbols:
   a. instant operating,
   b. normally open,
   c. normally closed,
   d. time delay,
   e. normally closed timed open,
   f. normally open timed closed,
   g. normally closed timed closed.
   h. normally open timed open.
21. Describe the three types of interlocks used in reversing magnetic motor starters,
22. State the purpose of jogging controllers,
23. Describe the operation of a jogging control,
24. State the purpose of plugging controllers,
25. Describe the operation of a plugging control using a:
   a. zero speed switch,
   b. time-delay relay,
26. Describe the operation of antiplugging control for reversing magnetic motor starters,
   a. zero speed switch,
   b. time delay relay,
27. Describe the techniques for reduced voltage starting:
   a. primary resistor,
   b. part winding,
c. autotransformer,
d. wye-delta,

**Reading Assignment:** Bartelt, *Industrial Control Electronics*, 3rd edition, Chapter 18 pp. 429-445

**Reading Assignment:** Rockis and Mazur *Electrical Motor Controls*, Chapters 9, 11, 12, 14, 18 and 19

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**Unit:** 7  
**Lesson:** 1  
**Title:** DC Motor Drives

**Objectives:** At the completion of the lesson, the student should be able to, by demonstration and written examination;

1. Describe the types of control functions performed by DC drives.
2. Describes the purpose of the following sections of DC drives:
   a. operator control.
   b. drive controller.
   c. DC motor.
   d. speed regulator.
3. Explain the operation of the variable voltage DC drive circuits that perform the following functions.
   a. motor speed control.
   b. speed regulation.
   c. IR compensation.
   d. current limiting.
   e. high/low speed adjustment.
   f. acceleration/deceleration adjustment
   g. field current speed control.
4. Identify three classifications of motor breaking techniques and describe the operation of each.

**Reading Assignment:** Bartelt, *Industrial Control Electronics*, 3rd edition, Chapter 8

**Reading Assignment:** Rockis and Mazur *Electrical Motor Controls*, Chapters 10
Unit: 7
Lesson: 2
Title: AC Motor Drives

Objectives: At the completion of the lesson, the student should be able to, by demonstration and written examination;
1. List the reasons for using AC drives.
2. Explaining the methods of controlling the speed of AC motor.
3. Describe the purpose of the following sections of AC drive.
   a. operator control.
   b. drive controller.
   c. AC motor.
4. Explaining the difference between the VVI, PWM, and Flux Victor AC drives.
5. Describe the operation of the following major sections of the VVI drive.
   a. converter.
   b. intermediate circuit.
   c. inverter.
6. Describe the operation of the following VVI circuits.
   a. control circuit.
   b. phase control rectifier.
   c. overcurrent protection.
   d. auto boost.
   e. chopper control.
7. Describe the operation of a Flux Vector drive and its advantages over VVI and PWM. drives.
8. Explaining the following drive functions of an AC variable speed drive.
   a. acceleration.
   b. deceleration.
   c. S-Curve.
   d. slip compensation.
   e. critical frequency rejection.
   f. power ride-through.
   g. automatic reset.
   h. self protection.
9. Describe the operation for motor breaking techniques used for stopping motors quickly.

Reading Assignment: Bartelt, Industrial Control Electronics, 3rd edition, Chapter 9
Reading Assignment: Rockis and Mazur Electrical Motor Controls, Chapters 10
Unit: 8  
Lesson: 1  
Title: Process Control – Pressure Systems  

Objectives: At the completion of the lesson, the student should be able to, by demonstration and written examination;  
1. Define Pressure and fluid  
2. Given force and area, calculate the pressure exerted by a fluid  
3. Identify the factors that affect the pressure exerted by a fluid  
4. Using specific gravity and depth of a liquid calculate pressure  
5. List the reference value for gage, absolute, and vacuum pressures  
6. Convert psia to psig and psig to psia  
7. Calculate differential pressure  
8. Describe the difference between direct and indirect measurements  
9. Explain the operation of electrical and nonelectrical pressure measuring sensors and devices  
10. Explain the operation of common pressure systems  

Reading Assignment: Bartelt, Industrial Control Electronics, 3rd. edition, Chapter 10  

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Unit: 9  
Lesson: 1  
Title: Process Control – Temperature Control  

Objectives: At the completion of the lesson, the student should be able to, by demonstration and written examination;  
1. List and explain the three types of heat transfer  
2. Describe the operation of both heat and cold energy sources  
3. Identify the Fahrenheit and Celsius scales and convert values from scale to the other  
4. Describe the method of use of various chemical temperature indicators  
5. Define BTU  
6. Explain the operation of electrical and nonelectrical temperature measuring sensors and devices  

Reading Assignment: Bartelt, Industrial Control Electronics, 3rd. edition, Chapter 11
Unit: 10
Lesson: 1
Title: Process Control – Flow Control

Objectives: At the completion of the lesson, the student should be able to, by demonstration and written examination;
1. Define flow
2. Describe the importance of measuring and controlling flow
3. Explain the difference between volumetric flow rate and mass flow rate and how they are used
4. List the common measurement units of flow rate
5. List the factors that affect the flow rate of liquids
6. Explain the operation of electrical and nonelectrical flow measuring sensors and devices
7. State the rule for placement of flow sensors in a pipe system

Reading Assignment: Bartelt, *Industrial Control Electronics*, 3rd. edition, Chapter 12

Unit: 11
Lesson: 1
Title: Process Control – Level Control

Objectives: At the completion of the lesson, the student should be able to, by demonstration and written examination;
1. Define level
2. Describe the importance of measuring and controlling level
3. Describe the types of interface that may be measured for level sensing
4. List level measurement units.
5. Define direct and indirect level measurements and their applications.
6. Explain the difference between continuous and point level measurements.
7. Describe the operation of electrical and nonelectrical sensors and devices.
8. Select appropriate level measuring device for application.

Reading Assignment: Bartelt, *Industrial Control Electronics*, 3rd. edition, Chapter 13
Unit: 12  
Lesson: 1  
Title: Process Control – Industrial Process Techniques

Objectives: At the completion of the lesson, the student should be able to, by demonstration and written examination;

1. Describe the following types of manufacturing processes
   a. Batch
   b. Continuous
   c. Chemical reaction
   d. Separation
   e. Polymerization
   f. Perfect composition

2. Define the following terms;
   a. Endothermic, Exothermic, Response time, Precision, Accuracy, Repeatability, Data acquisition, Air-to-close, Air-to-open, Linearity, Sensitivity, Static, Dynamic, Zero, Span, Hysteresis

3. Explain the operation of the following types of equipment.
   a. Heat exchanger,
   b. Indicator,
   c. Evaporator,
   d. Reactor,
   e. Transmitter,
   f. Agitator,
   g. Positioner,
   h. Transducer,
   i. Recorder,
   j. Alarm,
   k. Square root extractor,
   l. Final control element,
   m. I/P, P/I, I/V, V/I, transducers.

4. Describe the different types of standard electronic and pneumatic transmission signals and their numerical ranges.

5. List calibration process of a process instrument.

6. Read and explain piping and instrumentation diagrams (P&ID)

Reading Assignment: Bartelt, Industrial Control Electronics, 3rd. edition, Chapter 15
**Objectives:** At the completion of the lesson, the student should be able to, by demonstration and written examination:

1. List the operational characteristics of an open-loop system.
2. List the operational characteristics of a closed-loop system.
3. Define the following terms:
   a. primary element, heat exchanger, feedback loop, final control element, disturbance, rate time, manipulated variable, controlled variable, measured variable, load demand, time proportioning, amplitude proportional.
4. List of factors which contribute to the dynamic response.
5. Describe the following terms associated with dynamic response of a control loop:
   a. Bump test
   b. Step change
   c. Time lag
   d. Dead time
   e. First order time lag
   f. Ultimate period
   g. Ultimate proportional value
   h. Dynamic settling time
   i. Pure lag
   j. Inertia
   k. Time constant
   l. Process gain
   m. Head pressure
   n. Process identification
   o. Process reaction rate
   p. Effective delay
   q. Unit reaction rate.
6. Explain the operation and characteristics of an on-off control system.
7. Describe the operational principles and characteristics of the following control loads:
   a. Proportional
   b. Integral
   c. Derivative.
8. Use the following methods to tune a controller:
   a. Trial-and-error
   b. Autotuning
   c. Ziegler-Nichols continuous cycling

**Reading Assignment:** Bartelt, *Industrial Control Electronics*, 3rd edition, Chapter 16
Unit: 14
Lesson: 1
Title: Process Control – Industrial Detection Sensors and Interfacing

Objectives: At the completion of the lesson, the student should be able to, by demonstration and written examination;
1. Defining an industrial detection sensor.
2. Explain the operation of the inductive and capacitance proximity detectors.
3. Explain the operation of a hall-effect sensor.
4. Explain the operational theory of photoelectric sensor.
5. Explain the operation of the following photoelectric methods of detection;
   a. Opposed sensing
   b. Retroreflective scanning
   c. Diffuse sensing
   d. Convergent sensing
   e. Specular sensing
   f. Color mark sensing
6. Properly interface electromechanical relays and other electronic sensors to load devices.
7. Define the following terms;
   a. Excess gain
   b. Concentrator
   c. Negative switching
   d. Positive switching
   e. Current sourcing
   f. Load
   g. Current sinking
   h. Two wire system
   i. Three wire system
   j. Four wire system
   k. Hysteresis
   l. Zero
   m. Target
   n. Contrast
   o. Sensitivity
   p. Field-of-view
   q. Sensor response time
   r. Span.

Reading Assignment: Bartelt, Industrial Control Electronics, 3rd edition, Chapter 17
Objectives: At the completion of the lesson, the student should be able to, by demonstration and written examination;
1. Describe the differences between angular velocity, angular displacement, and linear displacement feedback devices.
2. Explain the operation of the following motion control feedback devices;
   a. Tachometer
   b. Potentiometer
   c. Optical encoder
   d. Resolver
   e. LVDT
   f. Linear displacement transducer.
3. Describe the difference between incremental and absolute optical encoders
4. Describe the difference between ratiometric tracking and phase digitizing resolvers.
Reading Assignment: Bartelt, Industrial Control Electronics, 3rd. edition, Chapter 21
IV. Methods of Instruction

Lecture, Demonstration, Discussion, Assignments, Computer simulation software and Hands-on activities.

V. Required Textbook

Bartelt, Industrial Control Electronics 3\textsuperscript{rd} edition

VI. Required Materials

Safety glasses

VII. Supplemental References

Miller and Miller, Electric Motor Controls, Chapter 2

VIII. Method of Evaluation

A. Distribution of the Final Grade:

- 60\% - Theory (written exams and quizzes)
- 30\% - Laboratory (observing work habits, safety habits, follow verbal instructions and perform the exercises assigned)
- 10\% - Instructor evaluation of observed traits and characteristics

B. Assignment of Final Letter Grade:

- A - 90 to 100\%
- B - 80 to 89\%
- C - 70 to 79\%
- D - 65 to 69\%
- F - Below 65\%

IX. ADA Statement

Any student requiring special accommodations should inform the instructor and the Coordinator of Disability Support Services (Library; phone 636-797-3000, ext. 169).

X. Academic Honesty Statement

As a student in the Electronics Department, you are advised of the Statement of Academic Honesty published in the Jefferson College Student Handbook. Plagiarism, Cheating, and Computer misuse violate the College’s standards of academic honesty, and the expectations for conduct in the Electronics Department. Conduct related to assignments, examinations, or computer usage during the completion of assignments or examinations in violation of the standards of academic honesty may result in a failing (F) grade given for the assignment or examination, and potentially, the course.