ECT 27
COURSE

LANEY COLLEGE
ENVIRONMENTAL CONTROL TECHNOLOGY

Commercial HVAC Systems Program

ECT 27 Advanced Direct Digital Controls Course Development

National Science Foundation - National Center for Building Technician Education

LANEY COLLEGE

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5/14/14

ADVANCED DIRECT DIGITAL CONTROLS

Course Documentation

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Catalog description

Introduction to advanced concepts and operation of DDC controls: input and output devices, programming strategies and translating sequence of operation documents for an HVAC system into an operations program for a DDC system.

Class hours

Lecture 26.25 hours | Lab 26.25 hours

Units

Lecture 1.5 semester units | Lab 0.5 semester unit

Entry skills needed

- Reading level: college-level English technical reading and ability to decode new technical terminology with reference help.
- Writing level: ability to express complex technical concepts in English.
- Math level: college technical math
    1. Perform mathematical operations using real numbers, fractions, decimals and percentages.
    2. Solve simple linear equations.
    3. Demonstrate knowledge converting fractions to decimals and decimals to fractions.
    4. Solve basic math and geometry problems involving area, angles, volume and percentages.
    5. Use algebraic equations to solve heating and cooling load calculation problems.
    6. Solve problems involving ratio and proportions.
    7. Interpret data in graphs in rectangular coordinate systems.
    8. Use and apply Imperial and Metric systems of measurement.
    9. Solve problems involving area and perimeter.

- Introduction to Direct Digital Controls skills:
    1. Define and understand the purpose of device types, software types, protocols, and diagnostic codes.
    2. Diagram simple, common control systems.
    3. Select, set up, and describe the inputs and outputs of control devices.
    4. Explain what equipment is needed to connect direct digital controls to an existing pneumatic system.
    5. Set up and operate a converted pneumatic system.

6. List and explain common control system applications and terminologies.
7. Describe the operation and benefits of proportional vs. proportional + integral + derivative (PID) control algorithms.
8. List and explain strategies to implement for energy conservation.
9. Describe building automation systems.
10. Select & apply proper instruments for diagnosing electrical and control system problems.
11. Manipulate control system software and interpret output and error codes.
12. Demonstrate safe electrical field work and wiring practices.

Syllabus

See Appendix A for sample Syllabus, course schedule, and policies. For Lesson Topics to include in course, see Exit Skills.

Student learning outcomes

The exit skills listed in the next section support these 4 outcomes:

Theory

Describe the theory and operation of a DDC system.

Architecture

Explain DDC system architecture and identify all DDC control components.

Networking

Explain networking fundamentals.

Sequence of operations

Write sequences of operations for AHUs, chilled water and hot water systems.

Exit skills

Course content to achieve 4 outcomes listed above:

System types

1. List and describe overall system types, their operation and purpose.

Course Content for this objective:

a. Systems and controllers
b. Operator interfaces

Lesson Topics:

- Central vs distributed systems
- Supervisory systems
- Application-specific and universal controllers
- Network communication modules
- On-site and off-site interfaces
- Wireless interface
- Interface selection and training

Devices

2. List and describe the function and application of control devices and network devices.

Course Content for this objective:

a. System inputs and outputs
b. Networking fundamentals

Lesson Topics:

- Analog and digital inputs: temperature, humidity, pressure, light, current
- Analog and digital outputs
- Accumulators, timed override initiators, transducers, incremental outputs, pseudopoints
- Network topology
- Ethernet hardware and software
- Arcnet and mixed networks
- Lab: 3 applications of relay logic
- Lab: RSLogix timers
- Lab: Utilizing TON timers
- Lab: Word compare instructions and application
- Lab: RSLogix counters
- Lab: Batch Mix lab utilizing PLC counters
- Lab: Advanced Batch Mixing lab
- Lab: Dual compressor student exercises
- Lab: Advanced Bottle Line exercise
- Lab: Multifloor elevator exercise
- Lab: Interfacing to 7-segment numeric displays

Implementation & management

3. Explain spectrum of DDC uses and how these are managed.

Course Content for this objective:

a. Supervisory control strategies
b. System retrofit of existing control systems
c. Building system management
d. Utility rates and costs
e. Building surveys

Lesson Topics:

- Life safety supervisory control
- Time-based supervisory control
- Optimum start/stop supervisory control
- Duty cycling supervisory control
- Electrical demand supervisory control
- Multiple control strategy integration
- Retrofit stages
- Package unit retrofit application
- VAV retrofit application
- VAV terminal box retrofit application
- Boiler control retrofit application
- Chiller retrofit application
- Alarm monitoring, classification and reporting
- Data trending
- Preventative Maintenance
- Building system documentation
- Building system Management Software
- Utility rates
- Electricity consumption and demand
- Power factor and fuel recovery rates
- Tiers, negotiated rates, ratchet clauses
- Seasonal and time-of-use rates
- Natural gas rates and metering
- Energy utilization index and energy cost index
- Statistical use of energy bills
- Utility cost calculation
- Surveys
- System proposals

Sequence of operations

4. Read and write sequence of operations for HVAC systems.

Course Content for this objective:

a. DDC strategies
b. PLC programming

c. DDC system programming

Lesson Topics:

- Loops
- Algorithms
- Tuning PI and PID loops
- DDC applications
- LogixPro Lab - RSLogix timers
- LogixPro Lab - Utilizing TON timers
- LogixPro Lab - Word compare instructions and application
- LogixPro Lab - RSLogix counters
- LogixPro Lab - Batch Mix Lab Utilizing PLC Counters
- LogixPro Lab - Advanced Batch Mixing lab
- LogixPro Lab - Dual compressor student exercises
- LogixPro Lab - Advanced Bottle Line exercise
- LogixPro Lab - Multifloor elevator exercise
- LogixPro Lab - Interfacing to 7-segment numeric displays
- WorkPlace Tech (WPT) Lab 1b - MicroNet controller with S4 sensor
- WPT Lab 2b - Standard application to learn controller-object relationship
- WPT Lab 3b - Roof-top unit control loop sequenced object.
- WPT Lab 4c - AHU valve control select objects to perform sequence.
- WPT Lab 5b - HW reset, create program
- WPT Lab 6 - Cooling tower, create program
- WPT Lab7 - Binding Network Variables - create bindings with LON network management tool
- WPT Lab 8c - MNL800 microcontroller program create schedule based program
- WPT Lab9 - Schedule setup linking to time-based controller
- WPT Lab10 - MNB BACnet exercise, getting familiar with features of I/A Series MNB BACnet controllers

Testing

5. Create comprehensive commissioning test procedures for testing control systems.

Course Content for this objective:

a. System installation wiring and testing

Lesson Topics:

- Transformer isolation to ground testing
- RS-485 communication testing
- Communication network isolation to ground testing

- Analog input resistance value testing
- Digital input and output testing
- Jumpers

Course materials

Principal text

Ronnie J. Auvil, HVAC Control Systems, American Technical Publishers, Inc. 2003 (Chapters 15 thru 24)

Bill Whitman, Bill Johnson, John Tomczyk, Eugene Silberstein, Refrigeration and Air Conditioning Technology 7th Ed., Delmar, Cengage Learning, 2003.

Lecture materials and handouts

- 9 Presentations: Controls, DDC hardware & software, circuits, relays & gates, PLC's, relays, and devices

- Reading: **Introduction to HVAC Control Systems** - Need, history, loops, modes, loop tuning, actions, range,sequencing, maintenance

- Reading: **Logic and Math folder** -boolean logic, symbols, numbering systems

- Reading: **Electrical and Wiring folder** - Basic electricity, understanding current loops, basic circuit diagrams and function, electrical and PI&D symbols, device wiring guides

- Reading: **Devices folder** - Introduction to hardware & software, PLCs, microcontrollers, sequences, ladder diagrams, Siemens article on control system components

- Reading: **WorkPlaceTech folder** - Pre-course reading, WPT manual TOC only, engineering guide, LONworks LONmaker, intro to Visio, MicroNet800 manual

Other reference materials

None listed for this course.

Software needed

Simulators used in labs to practice programming controllers and DDC setup:

- "WorkPlace Tech" by Schneider Electric - simulator for DDC controls installations and modeling building systems

- LogixPro: PLC microcontroller input/output simulator

Lab materials

Pencils, colored felt tip pens, graph paper with 1/8" squares, circle template, line paper, safety glasses, gloves, small and medium flat blade and Phillips screwdrivers, two adjustable wrenches one 8" and one 12", combination wire cutter, stripper and crimper, one roll of electrical tape, wire connectors, fuse puller, multi-meter, pocket thermometer and tool box or pouch.

Lab equipment & instruments required

Generally, hands-on implementation of concepts is key to successful learning of equipment function and relationships. Laney ECT department's lab has a fully functional commercial building central plant system for demonstration purposes. All components of the system are accessible to students for operation, measurement, diagnosis, servicing, and commissioning. See Laney College - Commercial HVAC Systems program documentation for lab layout and more detailed information on equipment and instruments.

A connected and functional commercial HVAC system should include a boiler, chiller, water pumps, air handling units, terminal units, cooling towers, control systems(pneumatic and/or DDC), sensors, and actuators. Monitoring access point computers accompanied by one or more control system trainer boards (with equivalent connected controls and actuators) will provide students with maximum access.

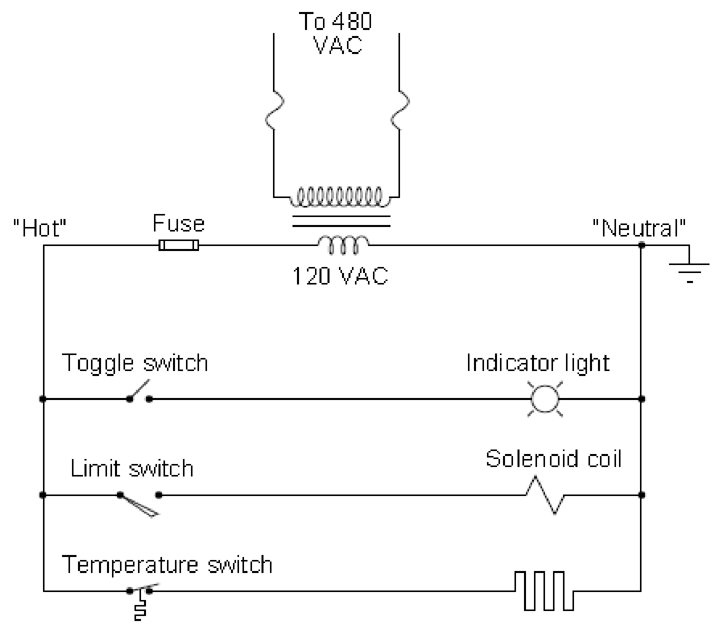
Samples of weekly assignments

3 hours/week. Requires two (2) hours of independent work outside of class for each unit/weekly lecture hour. Outside assignments are not required for lab-only courses although they can be given.

- 16 basic homework sets covering AC motors, basic electricity, math, logic, DC motors, Ohm's Law, PLCs, relays, sensors, switches and wiring

Question 1

An alternative to the conventional schematic diagram in AC power control systems is the *ladder diagram*. In this convention, the "hot" and "neutral" power conductors are drawn as vertical lines near the edges of the page, with all loads and switch contacts drawn between those lines like rungs on a ladder:



As you can see, the symbolism in ladder diagrams is not always the same as in electrical schematic diagrams. While some symbols are identical (the toggle switch, for instance), other symbols are not (the solenoid coil, for instance).

Re-draw this ladder diagram as a schematic diagram, translating all the symbols into those correct for schematic diagrams.

- Essay questions in Review Questions accompany each chapter of the text, HVAC Control Systems. Answer key is included.

- Numbering systems exercises and problems. See Assessment - Quiz 1 for types of questions.

Out-of-class assignments: readings from text books, projects in mechanical and electrical applications, research of specialty items.

Project

The problem-based learning (PBL) scenario, "Why is the Light On", focuses on how to determine a sequence of operation; it also investigates why a red light remains on continuously within the laser laboratory at the University of California, Berkeley.

Some of the PBL learning outcomes include: Identify applicable equipment documentation, interpret control documentation for a particular job, and locate necessary research information.

See ECT 27: Advanced Direct Digital Controls, "Why is the Light On" (PDF – 435 KB) at http://www.laney.edu/wp/environmental_control_tech/ect-nsf-initiative/ect-nsf-labs/pbl/scenarios/#ect27

Assessment

Methods

- Pre- and post-tests that accompany text
- DDC lab projects
- Problem-based case study exercise
- Class participation
- Homework assignments
- Final, midterm, quizzes

Sample test questions

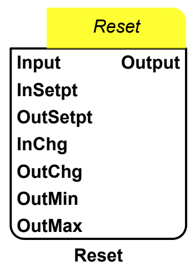
Quiz 1- Numbering systems and logic gates

1) Convert (0.625)10 to ( )2.
   A. 0.110
   B. 0.101
   C. 0.111
   D. 0.001
   E. 0.010

2) OR gate is equivalent to which operation?

   A. Logical Addition
   B. Logical Multiplication
   C. Logical Complement
   D. Logical Division
   E. Logical Subtraction

Programming Quiz: Determine microcontroller output based on given inputs and set points.



Midterm: Numbering systems and logic gates

Final Exam: Multi-tiered microcontroller output based on given inputs and set points

Adaptability to on-line format

The practicum is not adaptable for web format. Interactive distance learning implementation is possible.

Appendix A – Sample syllabus

(See Exit Skills section for lesson topics.)

LANEY COLLEGE

Environmental Control Technology

Course: Advanced Direct Digital Controls
Course Number/code: ECT 027
Time: 3 classroom hours/week
Instructor:
Office: **Office Hours:**

Phone: **Units:** 2 units.

Course Description: Introduction to advanced concepts and operation of direct digital controls, input and output devices, programming strategies and translating sequence of operation documents for an HVAC system into an operations program for a DDC system.

Student Outcomes:

1. Describe the theory and operation of a DDC system.
2. Demonstrate understanding of DDC system architecture.
3. Demonstrate understanding on DDC components.
4. Demonstrate understanding of networking fundamentals.
5. Become familiar with typical sequences of operations for AHUs, chilled and hot water systems.

Prerequisites: ECT 021 – Introduction to Direct Digital Controls

Text: HVAC Control Systems, Ronnie J. Auvil, ATP Pub.

Supplies Needed: Safety glasses, small and medium flat blade and Philips screwdrivers, combination wire cutter, stripper and crimper, one roll of electrical tape, wire connectors, multi-meter, pocket thermometer and tool box or pouch.

Topics: Chapters 15 through 26

1. Building Automation Systems and Controllers
2. Operator Interfaces
3. Building Automation System Inputs and Outputs
4. Networking Fundamentals
5. Direct Digital Control Strategies
6. Supervisory Control Strategies

7. Building Automation System Retrofit of Existing Systems
8. Building System Management
9. Utilities and Surveys
10. Building Automation System Troubleshooting
11. Advanced HVAC Control Technologies and Interoperability

Evaluation: The following classroom work and projects will be evaluated as follows.

1.	DDC lab projects	200
2.	Problem Based Case Study Exercise	150
3.	Class Participation	200
4.	Homework assignments	100
5.	Final, Midterm, Quizzes	350
		Total: 1000 points

Grading:

91% -100% A
81% - 90% B
71% - 80% C
61% - 70% D
50% - 60% F

Attendance: Students may be dropped from the course if the number of absences exceeds two days' worth of class meetings. However, extenuating circumstances may warrant consideration.

Note: During class, no cell phones, eating, drinking or talking are allowed. There will be two ten minute breaks.

Note: Students are required to wear safety glasses in the lab work area.

Note: It is student's responsibility to drop classes.

Appendix B – Sample project rubric

For project-based learning framework, see **PBL Worksheets** web page at http://www.laney.edu/wp/environmental_control_tech/ect-nsf-initiative/ect-nsf-labs/pbl/worksheets/

BEST Center Curricula, Resources & Recordings

Academic Programs
Georgia Piedmont Technical College - Building Automation Systems
Milwaukee Area Technical College - Sustainable Facilities Operations
Laney College - Commercial HVAC Systems
City College San Francisco - Commercial Building Energy Analysis & Audits

Professional Development Materials, Presentations & Videos
National Institutes
Building Automation Systems Instructor Workshops
Webinars (e.g., BEST Talks)

Faculty Profile Videos
Reports & Case Studies
Marketing Resources