BUAS 2010 COURSE

GEORGIA PIEDMONT TECHNICAL COLLEGE
INDUSTRIAL & TRANSPORTATION TECHNOLOGIES

Building Automation Systems Program

BUAS 2010 Building Automation Systems Commercial HVACR & Controls

National Science Foundation - National Center for Building Technician Education

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BUILDING AUTOMATION SYSTEMS FUNDAMENTALS

Course Documentation

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Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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Table of Contents

Catalog description

Building Automation Systems (BAS) Commercial HVACR and Controls introduces the student to the major types of HVAC systems found in commercial buildings. There is particular focus given to the sequences of operation of mechanical systems and the associated control strategies used in their management. Control theory is also explored in depth.

Class hours

Lecture Hours: 31

Laboratory Hours: 31

Units

Semester Credit Hours: 3

Entry skills needed

- BUAS 1030 – Building Automation Systems Electrical Concepts II
- Basic computer skills
- College-level reading and writing skills
- College-level math skills

Syllabus

See Appendix A for sample syllabus, course schedule, and policies. For lesson topics to include in course, see Exit Skills.

Student learning outcomes

Psychrometrics

Develop an understanding of the properties of air, their measurement, and application to system design and performance.

All-Air Systems

Gain an understanding of the major types of all-air HVAC systems.

All-Water Systems

Gain an understanding of the major types of all-water HVAC systems.

Air & Water Systems

Gain an understanding of the major types of air & water HVAC systems.

Boiler Principles & Types

Understand the major classifications of boilers and their principles of operation.

Chiller Principles & Types

Understand the major classifications of commercial chillers and their principles of operation.

Water-Side Devices

Identify and state the function of water-side devices.

Air-Side Devices

Identify and state the function of air-side devices.

Control Theory

Learn the principles of control theory for commercial building systems.

Control System Standards

Understand standard control system inputs and outputs.

Applied Control Theory

Learn the principles of tuning a control loop.

Control Loop Application

Tune a control loop in a live application.

Exit skills

Course content to achieve outcomes listed above:

Psychrometrics

1. Define the following terms: dewpoint, enthalpy, dry-bulb, wet-bulb, grains of moisture, relative humidity, partial pressure, ideal gas law, saturation temperature, sensible heat, latent heat, and specific volume.

2. Determine an unknown psychrometric value when given two known values of other properties.

3. Evaluate the factors of human comfort as defined by ASHRAE and offer comments on the relative effect of each.

All-Air Systems

1. List the various classifications of all-air systems.
2. Explain the difference between variable air volume and constant air volume systems and the advantages of each.
3. Explain the common components found in all-air systems.
4. Identify examples of all-air systems in the laboratory.

All-Water Systems

1. Identify the various types of all-water systems.
2. Describe system components typically found in all-water systems.
3. Draw a diagram representing 2, 3, and 4-pipe systems and configurations for both direct and reverse-return variations.
4. Observe an instructor as s/he demonstrates the major components in an all-water system.

Air & Water Systems

1. Name the common components found in an air & water system.
2. Summarize how an air & water system delivers heating and/or cooling to a conditioned space.
3. Observe an instructor as s/he demonstrates the major components in an air & water system.

Boiler Principles & Types

1. Identify major boiler components on various types of boilers.
2. Name the various types of boilers available for commercial applications.
3. Summarize the function of a boiler and how its efficiency is calculated.
4. Differentiate components serving one boiler sub-system from another.
5. Compare and contrast common boiler types like scotch-marine and list their strengths and weaknesses.

Chiller Principles & Types

1. Name the major chiller types used in commercial building applications.
2. Discuss the advantages and disadvantages of each of the major commercial chiller types.
3. Distinguish one chiller type from another based on physical appearance.
4. Compare and contrast common commercial building chiller types.

Water-Side Devices

1. Identify the major water-side devices in a commercial building like pumps, valves, cooling tower, heat exchanger, water treatment system, strainers, gauges, etc.
2. Describe how water-side devices work together to keep a commercial building comfortable.
3. Perform differential pressure, voltage, and amperage draw tests on a pump under instructor supervision.

Air-Side Devices

1. Name the major air-side devices from memory and state their function.
2. Identify air-side devices pointed out by an instructor and describe their function.
3. Discuss how air-side devices work together in a variable air volume system to create a complete system.
4. Draw a diagram of a variable air volume system and label all the air-side components and include a description of each component's function.

Control Theory

1. Define the terms input, output, reverse-acting, direct-acting, open-loop, closed-loop, feedback, and calibration.
2. Draw block diagrams of real-world examples of open and closed loop control systems.
3. Observe an instructor's demonstration of real-time, closed-loop control of static pressure on a variable air volume system.

Control System Standards

1. State all the industry standard inputs.
2. State all the industry standard outputs.

3. Draw industry standard input and output wiring diagrams for all the basic input and output types.

4. Observe an instructor's demonstration of wiring industry standard inputs and outputs to an existing building automation system.

5. Construct standard input and output wiring circuits and connect to an existing building automation system.

Applied Control Theory

1. Define the terms: direct and reverse acting controllers, setpoint, offset, overshoot, system lag, error, proportional band, gain, reset rate, rate of change, proportional controllers, proportional-integral controllers, and proportional-integral-derivative controllers.

2. Construct an operating control loop with an input, output, and a controlled, real-time response to changing conditions.

Control Loop Application

1. Observe an instructor design, install, commission, and tune a real-time control loop in the laboratory.

2. Construct a real-time, real-world control loop to include design, installation, commission, and loop-tuning activities under the supervision of an instructor.

Course materials

Principal text

Auvil, R.J. (2007). *HVAC Control Systems* (2nd ed.). Homewood, IL: American Technical Publishers, Inc. ISBN #: 978-0-8269-0757-8

Auvil, R.J. (2007). *HVAC Control Systems Workbook* (2nd ed.). Homewood, IL: American Technical Publishers, Inc. ISBN #: 978-0-8269-0758-5

Grondzik, W., Kwok, A., Stein, B., & Reynolds, J. (2010). *Mechanical and Electrical Equipment for Buildings (11th ed.)*. Hoboken, NJ: John Wiley & Sons, Inc. ISBN #: 978-0-470-19565-9

National Joint Apprenticeship & Training Committee for the Electrical Industry. (2008). *Building Automation Control Devices and Applications*. Homewood, IL: American Technical Publishers, Inc. ISBN #: 978-0-8269-2000-3

Lecture materials and handouts

This course is strictly an overview course and makes significant use of online resources.

DDC Online (Intro. to digital control systems, Input/Output tutorials):
www.ddc-online.org

Purdue Owl writing & style resources: https://owl.english.purdue.edu

Presentation tools by Prezi: www.prezi.com

Other reference materials

None required

Software needed

www.controlspecbuilder.com

Controls software of any brand – GPTC used several (Delta ORCAview V3.20 most often)

Lab setup and materials

- Workstations with electrical outlets
- Sample submittal packages
- Sample set of project specification
- Sample set of project plans
- Control screwdrivers
- Regular size screwdrivers
- Multi-meter
- Control point (thermistor, pressure transmitter, or something that can be controlled for loop tuning)
- Various HVAC systems (access to mechanical rooms on campus works best)
- Scale models of buildings and building systems

Equipment & instruments required

- Multi-meter & clamp-on meter
- Voltage proximity sensor
- Scopemeter
- Oscilloscope
- Power analyzer

Samples of weekly assignments

BUAS 2010 – BAS HVAC & Controls Assignment # 1 -

Location: C-building BAS / Refrigeration laboratory

Purpose: Properly tune a control loop

Materials: Laboratory variable air volume (VAV) air-handling unit with variable frequency drive, duct static pressure sensor, BACnet-based control system

Description: Students are presented the problem of tuning a Proportional – Integral – Derivative (PID) control loop. The problem is presented on a VAV air-handling unit with a frequency drive that controls fan speed. Students are given an initial static pressure set-point of 1.5 inches of water column, with a control loop object that is pre-set for a hunting condition. Students must change the proportional band and integral reset rate setting to tune the loop and prevent hunting. Once the initial problem is solved, the set-point, proportional band, and reset rates are all reset to new settings, forcing the student to once again tune the loop. Final settings and the final frequency drive signal are recorded.

Grading:

Students are graded via rubric as to the following criteria:

- Process used to tune the loop
- Ability to accurately tune both loop problems
- Final frequency drive signal comparison to known solution range for problem
- Adherence to all personal safety considerations

Project

BUAS 2010 – BAS HVAC & Controls Course Project Assignment

Location: B, C, D buildings of GPTC Clarkston campus

Purpose: Characterize the mechanical and electrical systems of the B, C, and D buildings, comparing and contrasting the systems present in each.

Materials: Hard hat, ladder, safety gloves, eye protection, flashlight, notepad, basic hand tools, multi-meter

Description: Students will use classroom learning and apply it to real-world situations by investigating the systems present in the B, C, and D buildings.

Students will work in teams of three, working from scale architectural drawings of each building provided by drafting program students. Students will hand draw all the major electrical and mechanical systems of the three buildings in their appropriate location using industry accepted symbols for ductwork, lights, diffusers, air-handling units, and electrical / mechanical rooms.

Drawings should be as close to scale as possible given the time restraints, but all major components of the mechanical systems should be shown such as air-handling units, exhaust fans, chillers, boilers, pumps, strainers, water heaters, and the like.

Student access will be provided during weekly lab hours, but specific requests for access to restricted areas like mechanical and electrical rooms must be coordinated in advance with the instructor.

Each of the major building systems should be characterized as to size, efficiency, advantages, disadvantages, electrical demand, and age. The buildings should be compared and contrasted with one another. Presentation of findings will be made at an end-of-semester event open to the college and public.

Grading:

Grading will be by rubric which is available for review in Angel LMS. Elements of the rubric include completeness of report, accuracy of findings, descriptions of methods, neatness, conclusions drawn, returning all materials and controllers to their original state.

Presentation grading will be by standard communications rubric and available on Angel LMS. Each group will have 15 minutes at the end of the semester to present their findings.

Assessment

Methods

- Discussion board participation (Each week in Angel learning management system)
- Homework – Pre-lab completion prior to class
- Classroom participation & attendance
- Quizzes (12) – Delivered through Angel learning management system & due by Sunday night of each respective week
- Course exams (2, mid-term & final exams) – Delivered through Angel learning management system & due by Sunday night of each respective week
- Student team presentations (1 at term end, using Prezi) – Presenting their project findings
- Course project (1 assigned at mid-term) – Turned in prior to student team presentations at the end of the term

Sample test questions

From final exam:

1. What psychrometric quantity refers to the total heat content of air? (ANS: Enthalpy)

2. What is 20^0 Celsisus in the Fahrenheit scale? (ANS: 68^0 F)

3. What ASHRAE standard dictates the amount of outside air required in buildings?

- ☐ 55.0
- ☐ 62.1 – (correct answer)
- ☐ 90.1

4. A terminal reheat unit receives air from a common air-handling unit which should be at a constant temperature of _____. (ANS: 55^0 F)

5. What organization sets the standards for fuel oil grades?

- ☐ ASHRAE
- ☐ ANSI
- ☐ ASTM – (correct answer)

6. What type of chillers are most commonly found in medium- and large-size systems?
(ANS: Centrifugal chillers)

7. What type of cooling coil utilizes the vaporization of refrigerant in a closed system?
(ANS: Direct expansion (DX) coil)

8. What type of hydronic system has a common return and can provide heating and cooling simultaneously?

- ☐ 2-pipe system
- ☐ 3-pipe system (correct answer)
- ☐ 4-pipe system

9. The difference between a set-point and the actual value of the control point is known as _____
(ANS: offset)

10. What essential element do closed loop systems have that open loop systems do not?
(ANS: feedback)

11. In reset control, what key element of the loop is modified as ambient conditions change?
(ANS: The set-point)

12. What term is used to denote the free cooling available to buildings when air conditions are appropriate? (ANS: Economizer)

13. To balance out run-time on equipment, what control strategy is often employed? (ANS: Lead / Lag control)

14. What element of a PID control loop is typically not used in HVAC applications? (ANS: Derivative)

15. Starting the HVAC systems in a building 'just in time,' based on historical calculations of how a building responds is an example of what control strategy? (ANS: Optimum Start)

Adaptability to on-line format

Much of this course content can be delivered online with links to soft skills videos, manufacturer's presentations, tutorials, wholesaler websites, and others.

Appendix A – Sample syllabus

Georgia Piedmont Technical College
BAS COMMERCIAL HVAC/R AND CONTROLS
COURSE BUAS 2010 CRN 51113
SEMESTER SPRING 2012
OUTLINE, SYLLABUS, & ORIENTATION INFORMATION

FACULTY INFO

Mr. Brian Lovell / Mr. Leroy Daniels
Clarkston Campus C-13 Email: lovellb@gptc.edu / danielsl@gptc.edu
Phone: 404-297-9522 Ext.: 1265
Office Hours: M, T 9:00 am - noon (by appointment)

Division Chair: Ms. Natalie Kostas
Clarkston Campus Office: Industrial Dept.
Email: kostasn@gptc.edu Phone: 404-297-9522 Ext.: 1216

CLASS TIMES

Tuesday / Thursday 8:30 pm - 9:45 pm

CREDIT HOURS & PREREQUISITES

The federal definition of a semester credit hour is one hour of classroom instruction and two hours out of class student work each week.
3 / BUAS 1030

INTRODUCTION& COURSE DESCRIPTION

Course will explore topics related to the various types of HVAC/R systems commonly encountered in commercial buildings and explore introductory topics related to control systems

STUDENT LEARNING OUTCOMES

Understand and Apply Psychrometric Principles / Classify All-Air Systems as defined by ASHRAE / Classify All-Water Systems as defined by ASHRAE / Classify Air & Water Systems as defined by ASHRAE / Survey Boiler Principles & Types / Survey Chiller Principles & Types / Survey Water-Side Devices / Survey Air-Side Devices Examine Basic Control Theory / Apply Control System Standards / Show Application of Control Theory / Show Control Loop Application

EXIT SKILLS/COURSE COMPETENCIES

1. Define the following terms; dewpoint, enthalpy, dry-bulb, wet-bulb, grains of moisture, relative humidity, partial pressure, ideal gas law, saturation temperature, sensible heat, latent heat, and specific volume.
2. Determine an unknown psychrometric value when given two known values of other properties.
3. Evaluate the factors of human comfort as defined by ASHRAE and offer comments on the perceived relative effect of each.

4. List the various classifications of all-air systems.
5. Explain the difference between variable air volume and constant volume systems and where each might be best applied.
6. Describe the common components found in all-air systems.
7. Observe examples of all-air systems in the laboratory.
8. Identify the various types of all-water systems.
9. Describe system components typically found in all-water systems.
10. Draw a diagram representing 2, 3, and 4-pipe systems and configurations for both direct and reverse-return configurations.
11. Observe an instructor demonstrating the major components in an all-water system.
12. Name the common components found in an air & water system.
13. Summarize how an air & water system delivers heating and/or cooling to a conditioned space.
14. Observe an instructor demonstrating the major components in an air & water system.
15. Identify major boiler components on various types of boilers.
16. Name the various types of boilers available for commercial applications.
17. Summarize the function of a boiler and how its efficiency is calculated.
18. Differentiate components serving one boiler sub-system from components serving another.
19. Compare and contrast common boiler types and chart their relative positives and negatives.
20. Name the major chiller types used in commercial building applications.
21. Discuss the advantages and disadvantages of each of the major commercial building chiller types.
22. Distinguish one chiller type from another based on physical appearance.
23. Compare and contrast common commercial building chiller types and chart their relative positives and negatives.
24. Identify the major water-side devices in a commercial building like pumps, valves, cooling tower, heat exchanger, water treatment system, strainers, gages, etc.
25. Describe how water-side devices work together to keep a commercial building comfortable.
26. Perform differential pressure, voltage, and amperage draw tests on a pump under instructor supervision.
27. Name the major air-side devices from memory and state their function.
28. Identify air-side devices pointed out by an instructor and describe their function.
29. Discuss how air-side devices work together in a variable air volume system to maintain human comfort.
30. Draw a diagram of a variable air volume system and label all the air-side components and include a description of their functions.
31. Define the terms input, output, reverse-acting, direct-acting, open-loop, closed-loop, feedback, and calibration.
32. Draw block diagrams of real-world examples of open and closed-loop control.
33. Construct a real-time closed-loop control system to maintain a given set-point over time.
34. State all the industry-standard inputs.
35. State all the industry-standard outputs.
36. Draw industry-standard input& output wiring diagrams for all the basic input & output types.
37. Observe an instructor wiring industry-standard inputs & outputs to an existing BAS system.
38. Construct standard input& output wiring circuits and connect to an existing BAS system.
39. Define the terms direct & reverse-acting controllers, set-point, offset, overshoot, system lag, error, proportional band, gain, reset rate, rate of change, proportional controllers, proportional-integral controllers, and proportional-integral-derivative controllers.

40. Construct an operating control loop with an input, and output, and a controlled real-time response to changing conditions.
41. Observe an instructor design, install, commission, and tune a real-time control loop in the laboratory.
42. Construct a real-time, real-world control loop to include design, installation, commission, and loop-tuning activities under the supervision of an instructor.

TEXTBOOK TITLE (required)

"Mechanical and Electrical Equipment for Buildings, 2e" ISBN: 978-0-470-19565-9
"HVAC Control Systems" ISBN: 978-0-8269-0757-8
"HVAC Control Systems Workbook" ISBN: 978-0-8269-0758-5
"Building Automation Control Devices & Applications" ISBN: 978-0-8269-2000-3

OTHER TEXTBOOK INFORMATION

N/A

ADDITIONAL RESOURCES

Throughout the semester, additional resources may be used. They may include the Internet, newspapers, and professional publications.

EVALUATION

Discussion Board Activity……10%
Classroom Participation……10%
Homework Assignments……. 20%
Weekly Quizzes…....10%
Course Assessments…….20%
Written Final…….15%
Course Project……...15%

SCHEDULE

1/10 - Review Syllabus

1/17 - Lecture: Human Comfort
Homework: "M&E Equip. for Bldgs" Read Chapter 4 – "Comfort & Design Strategies"
Quiz 1 - Due Sunday, 1/22 NLT 11:55 pm

1/19 - Lab 1 - (Pre-lab to be completed prior to class - Access from Angel LMS)

1/24 - Lecture: Psychrometrics / ASHRAE's Classifications / Comfort & Design Strategies
Homework: "M&E Equip. for Bldgs." Chapter 25 & Chapter 10, pages 393–396 & 429-442 on All-Air Systems
Quiz 2 - Due Sunday, 1/29 NLT 11:55 pm

1/26 - Lab 1 - (Pre-lab to be completed prior to class - Access from Angel LMS)

1/31 - Lecture: All-Air Systems / Principles of Electricity in Buildings
Homework: "M&E Equip. for Bldgs." Read Chapter 10, pages 397 – 398 & 452-463

Quiz 3 - Due Sunday, 2/5 NLT 11:55 pm

2/2 - Lab 1 - (Pre-lab to be completed prior to class - Access from Angel LMS)

2/7 - Lecture: All-Water Systems
Homework: "M&E Equip. for Bldgs." Read Chapters 5 & 10, pages 396, 397 & 442-451
Quiz 4 - Due Sunday, 2/12 NLT 11:55 pm

2/9 - Lab 1 - (Pre-lab to be completed prior to class - Access from Angel LMS)

2/14 - Lecture: Air & Water Systems / Indoor Air Quality (IAQ)
Homework: "M&E Equip. for Bldgs." Read Chapter 10, pages 401 - 407
Quiz 5 - Due Sunday, 2/19 NLT 11:55 pm

2/16 - Lab 1 - (Pre-lab to be completed prior to class - Access from Angel LMS)

2/21 - Lecture: Boilers
Homework: "M&E Equip. for Bldgs." Read Chapter 10, pages 407 - 414
Mid-Term Assessment - Due Sunday, 2/26 NLT 11:55 pm

2/23 - Lab 1 - (Pre-lab to be completed prior to class - Access from Angel LMS)

2/28 - Lecture: Chillers
Homework: TBA
Student Project Assigned
Quiz 6 - Due Sunday, 3/4 NLT 11:55 pm

3/1 - Lab 1 - (Pre-lab to be completed prior to class - Access from Angel LMS)

3/6 - Lecture: Control Systems / Control Theory / Definitions
Homework: TBA
Quiz 7 - Due Sunday, 3/11 NLT 11:55 pm

3/8 - Lab 1 - (Pre-lab to be completed prior to class - Access from Angel LMS)

3/13 - Lecture: Block Diagrams / PID Loops I
Homework: TBA
Quiz 8 - Due Sunday, 3/18 NLT 11:55 pm

3/15 - Lab 1 - (Pre-lab to be completed prior to class - Access from Angel LMS)

3/20 - Lecture: P/I/D Control Loops II
Homework: TBA
Quiz 9 - Due Sunday, 3/25 NLT 11:55 pm

3/22 - Lab 1 - (Pre-lab to be completed prior to class - Access from Angel LMS)

3/27 - Lecture: Review of Schematics / Pictorials / Sequences of Operation / Symbols
Homework: TBA

Quiz 10 - Due Sunday, 4/1 NLT 11:55 pm

3/29 - Lab 1 - (Pre-lab to be completed prior to class - Access from Angel LMS)

4/3 - Lecture: Digital Control Systems Components & Fundamentals I
Homework: TBA
Quiz 11- Due Sunday, 4/8 NLT 11:55 pm

4/5 - Lab 1 - (Pre-lab to be completed prior to class - Access from Angel LMS)

4/10 - Lecture: Digital Control Systems Components & Fundamentals II
Homework: Prepare for Final Assessment
Quiz 12 - Due Sunday, 4/15 NLT 11:55 pm

4/12 - Lab 1 - (Pre-lab to be completed prior to class - Access from Angel LMS)

4/17 - Lecture: Review for Final Assessment

4/24 - Student Project Presentations in Class
Final Assessment due 4/25 by 11:55pm - (No exceptions / No excuses)

COLLEGE POLICIES

Please refer to documentation for courses BUAS 1010, 1020, 1030 or 1040 for specifics of GPTC's policies re: grading, attendance, etc.

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

BEST
Building Efficiency for a Sustainable Tomorrow

NSF National Science Foundation