MECH3023: Building Energy Management and Control Systems

http://www.hku.hk/bse/mech3023/

Self-evaluation Exercise – Suggested Solutions

1. (a) What are the six fundamental steps of direct digital control (DDC) design? Briefly describe each of them

(6 marks)

Answer: (* Outline of the solution only)

The six fundamental steps of DDC design are:

1. System schematic
   - communicate and show the configuration of the system
   - all major components are clearly shown

2. Control point designations
   - identify the required control points and designate them on the system schematic
   - keep it simple and clear

3. Point list
   - identify the total number of each category of control points

4. DDC system architecture
   - indicates the configuration, location, type, and number of controllers required

5. Sequence of operation
   - provides the adequate information for programming the control system codes

6. Specifications
   - put appropriate information in the drawings and specifications

Identify the type of signals for the following points in a direct digital control (DDC) system by indicating DO (digital output), DI (digital input), AO (analogue output) and AI (analogue input).

1) Room temperature sensor
2) Filter alarm of air handling unit
3) ON/OFF command for a fan
4) Flow meter
5) Flow switch
6) Air flow modulation command
7) Fire alarm bell activation command
8) Differential pressure switch
9) Differential pressure sensor
10) ON/OFF status of a chilled water pump

(5 marks)

Answer:

Half a mark for each of the followings:

1)	Room temperature sensor	AI (analogue input)
2)	Filter alarm of air handling unit	DI (digital input)
3)	ON/OFF command for a fan	DO (digital output)
4)	Flow meter	AI (analogue input)
5)	Flow switch	DI (digital input)
6)	Air flow modulation command	AO (analogue output)
7)	Fire alarm bell activation command	DO (digital output)
8)	Differential pressure switch	DI (digital input)
9)	Differential pressure sensor	AI (analogue input)
10)	ON/OFF status of a chilled water pump	DI (digital input)

(b) Describe briefly the basic characteristics of the five types of control methods commonly used for building and HVAC control systems. Illustrate with simple diagrams or figures.

(10 marks)

Answer: (* Outline of the solution only)

1. Pneumatic controls [plus a simple system diagram]

- utilize low pressure compressed air, 0-30 psi (or 0-207 kPa)
- naturally proportional
- requires clean dry air
- air lines may cause trouble below freezing
- explosion roof
- simple, powerful, low cost, reliable actuators for valves and dampers
- common for simple zone (VAV box, etc) control
- simplest modulating control

(2 marks)

2. Electric controls [plus a simple system diagram]

- most common for simple on-off (two-position) control
- modulation may be provided by means of rheostats or bridge circuits
- integral sensor/controller
- simple sequence of control
- broad environmental limits
- complex modulating actuators, especially when spring-return

(2 marks)

3. Self-powered controls [plus a simple system diagram]

- require no outside source of energy to operate
- energy is provided by the controlled variable, such as based on expansion and contraction characteristics of their internal components
- for example, the self-contained VAV diffusers and pressure-sustaining valve

(2 marks)

4. Electronic controls [plus a simple system diagram]

- precise control, utilize low voltage electricity (24 V or less)
- solid state repeatability and reliability
- sensor may be up to 90 m from controller
- simple remote setpoint
- high per-loop cost
- complex actuators and controllers

(2 marks)

5. Direct digital or microprocessor-based controls [plus a simple system diagram]

- precise control, receives electronic signals from sensors and switches, and converts signals to digital numbers and performs a mathematical analysis
- inherent energy management
- inherent high order (proportional plus integral) control
- compatible with building management system
- easily performs complex sequence of control
- global (inter-loop) control via communication bus
- simple remote setpoint and display
- can use pneumatic actuators

(2 marks)

(c) Flow measurement devices are important components of control and piping systems. Name the common types of flow meters and briefly describe their operation principles and typical applications.

(10 marks)

Answer: (* Outline of the solution only)

Common types of flow meters are: (* may use simple diagrams to illustrate)

1. Turbine

- types: inline turbine and insertion turbine
- operation is based on the speed of rotation of the turbine, driven by the fluid
- low cost and easy to install
- typical applications: chilled water and condenser water piping systems

(2 marks)

2. Differential pressure

-types: orifice, venturi and pitot tube

- orifice type is based on pressure drop across an orifice plate; it is durable but has high pressure loss and energy loss within the system
- venturi type is based an orifice with an aerodynamic shape, to create lower pressure loss
- pitot tube is a small tube inserted into the pipe to determine velocity pressure by

determining the difference between total and static pressure; flow is measured by converting velocity pressure to volume; very cost-effective with negligible head loss

(2 marks)

3. Vortex shedding

- vortex shedding makes use of a naturally occurring vortices when a turbulent fluid stream comes in contact with a cylindrical object; low cost and simple
- popular in HVAC DDC systems

(1 marks)

4. Ultrasonic

- types: doppler and transit time
- typically clamp-on devices and convenient for existing applications since no piping modification is required
- doppler type flow meter senses the pulse created by air or dirt trapped in the fluid; should avoid using this type of flow meter for very clean fluids or gases
- time transit type flow meters require a relatively clean fuild; more expensive and mainly applied in an industrial use

(2 marks)

5. Electromagnetic

- it measures the velocity of an electrically conductive liquid
- ideal method without pressure loss within the pipe
- accuracy of +/- 1.5% and a turn-down ratio of 10:1
- preferred choice for corrosive fluids

(1 marks)

6. Special

- a wide variety of special flow meters
- for example, positive displacement type which transfer a known volume of fluid from the inlet to the outlet side of the flow meter and measure the flow rate; generally for industrial applications and suitable for fluids with higher viscosity

(2 marks)

2. (a) Explain the basic concept of the Open System Interconnection (OSI) seven-layer reference model. Describe the commonly used topologies for building automation systems.

(13 marks)

Answer: (* Outline of the solution only)

Basic concept of the Open System Interconnection (OSI) seven-layer reference model is:

Level 1 – Physical Layer
- Defines physical/actual connections
- Purpose: electrical interconnection (e.g. ‘wire’)

- Services: media-specific details, transceiver type

Level 2 – Data Link Layer
- Defines local network access methods
- Purpose: media access and framing
- Services: framing, data encoding, media access, error checking

Level 3 – Network Layer
- Defines destination addressing
- Purpose: destination addressing
- Services: destination addressing, packet routing

Level 4 – Transport Layer
- Defines status & two-way communication
- Purpose: end-to-end reliability
- Services: acknowledgments, service type, duplicate detection

Level 5 – Session Layer
- Defines types & quality of services
- Purpose: remote actions
- Services: dialogue, remote procedure calls, connection recovery

Level 6 – Presentation Layer
- Defines, coverts & decodes messages
- Purpose: data interpretation
- Services: network variables, application messages, foreign frames

Level 7 – Application Layer
- Defines application network service
- Purpose: application program
- Services: standard objects & types, file transfer, network service

(7 marks)

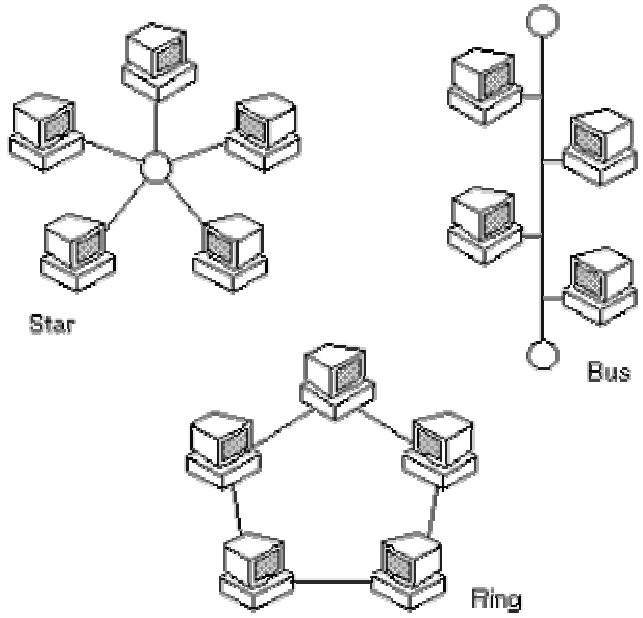
2. Commonly used topologies for building automation systems:

Bus topology: simple, but if a break in the bus, communication across the break is not possible.

Star topology: every node connected to a central point (hub); if a wire break, only the device attached to the broken wire is down

Ring topology: it connect each device to a loop of wire; advantage is that if there is a break in the loop wire, the network continue to communicate

Free topology: the physical wiring on the network can combine any combination of topologies; advantage is the flexibility and freedom of wiring



(6 marks)

(b) What is the meaning of "interoperability" for building automation and control systems? Describe the methods of local-area network (LAN) technologies used in the data link layer and physical layer of BACnet.

(12 marks)

Answer: (* Outline of the solution only)

1. Meaning of "interoperability":

- The ability of two or more systems or components to exchange information and to use the information that has been exchanged [from IEEE]

- The ability of equipment to work together & communicate mutually
  - Between different manufacturers' control equipment
  - Different versions of control equipment
  - Equipment for different purposes (HVAC, fire, lights)

(2 marks)

2. Methods of local-area network (LAN) technologies in the data link layer of BACnet:

BACnet allows five LAN technology methods and data link layer as follows:

- Ethernet (ISO 8802-3)
- ARCNET (ANSI 878-1)
- Master/slave token passing (ANSI/ASHRAE 135)
- Point-to-point (ANSI/ASHRAE 135)
- LonTalk (Echelon Corporation)

(4 marks)

3. Methods of local-area network (LAN) technologies in the physical layer of BACnet:

BACnet allows a wide variety of standard physical media such as twisted shielded pair (TSP), fibre optics, and coaxial cable. BACnet allows for six methods of LAN technologies for physical layer.

- Ethernet
  - both the data link and physical layer
  - speed: 10 to 100 Mbps
  - peer-to-peer connection: carrier sense multiple access w/ collision detection (CSMA/CS)
  - highly efficient unit the system becomes heavilt loaded; an underdeterministic system

- ARCNET
  - both the data link and physical layer
  - speed: 2.5 Mbps
  - star or bus topology, peer-to-peer token-passing; is a deterministic system

- EIA 485 (or RS 485)
  - EIA 485 is solely a physical layer standard, at low speed of 9.6 to 78.4 kbps
  - a master/slave token passing often operates on it as the data link layer
  - often used for application specific controllers; low cost and simple

- EIA 232 (or RS 232)
  - EIA 232 is a physical layer and operates at a low speed of 19.2 to 115 kbps
  - a point-to-point (PTP) protocol defines the method for communication
  - typically used for dial-up access through a modem

- Internet and IP
  - IP (Internet Protocol) is a data link layer for BACnet through the Internet

- LonTalk
  - a full seven-layer protocol. BACnet only uses it to pass datalink frames, just like Ethernet

(6 marks)