MECH3023: Building Energy Management & Control Systems

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

Introduction and Basic Cocepts

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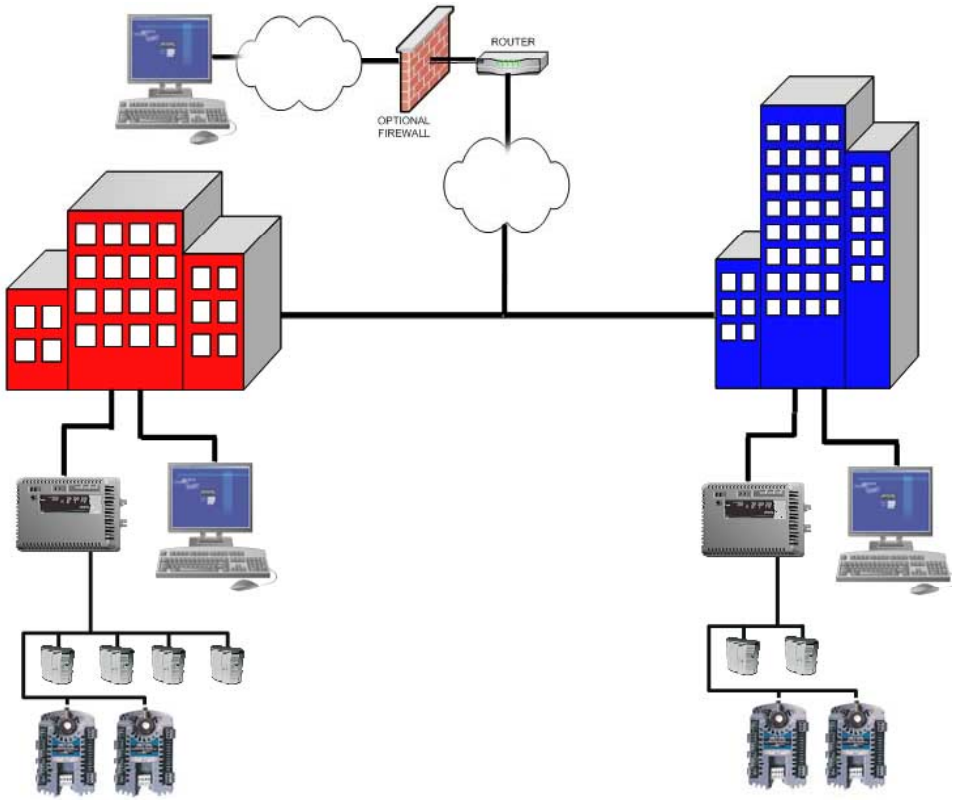


Study Guide

- Educational Objectives
  - To introduce basic concepts of computer-based integrated monitoring, control and energy management for building services installations
  - To study the principles of design and operation of building energy management and control systems (EMCS) and their applications to buildings
  - To understand methods of performance analysis of building services systems using building EMCS

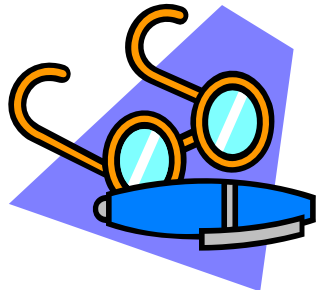
Study Guide

- Learning Outcomes
  - Know the basic concepts & components of building energy management & control system
  - Able to explain the system designs and practical applications for building controls
  - Appreciate the recent trends and future development of the management systems for intelligent buildings

Study Guide

- Main topics taught by Dr. Sam C. M. Hui
  - Basic Concepts
  - Hardware Components
  - System Architecture
  - Networking
  - Communication Protocols
  - Control Strategies and Applications
  - Intelligent Buildings
- Related courses
  - BBSE2005/3006 Air Conditioning and Refrigeration
  - MECH3005 Building Services

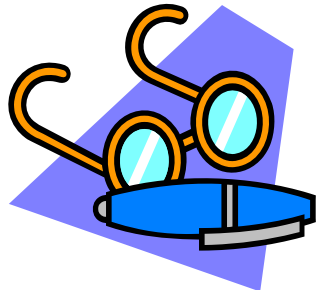
Overview



- Terminology
  - Building automation system (BAS)
  - Building management system (BMS)
  - Building energy management system (BEMS)
  - Energy management system (EMS)
  - Central control and monitoring system (CCMS)
  - Direct digital control (DDC)
  - Intelligent building (IB)

A term coined by HK Govt. depts.

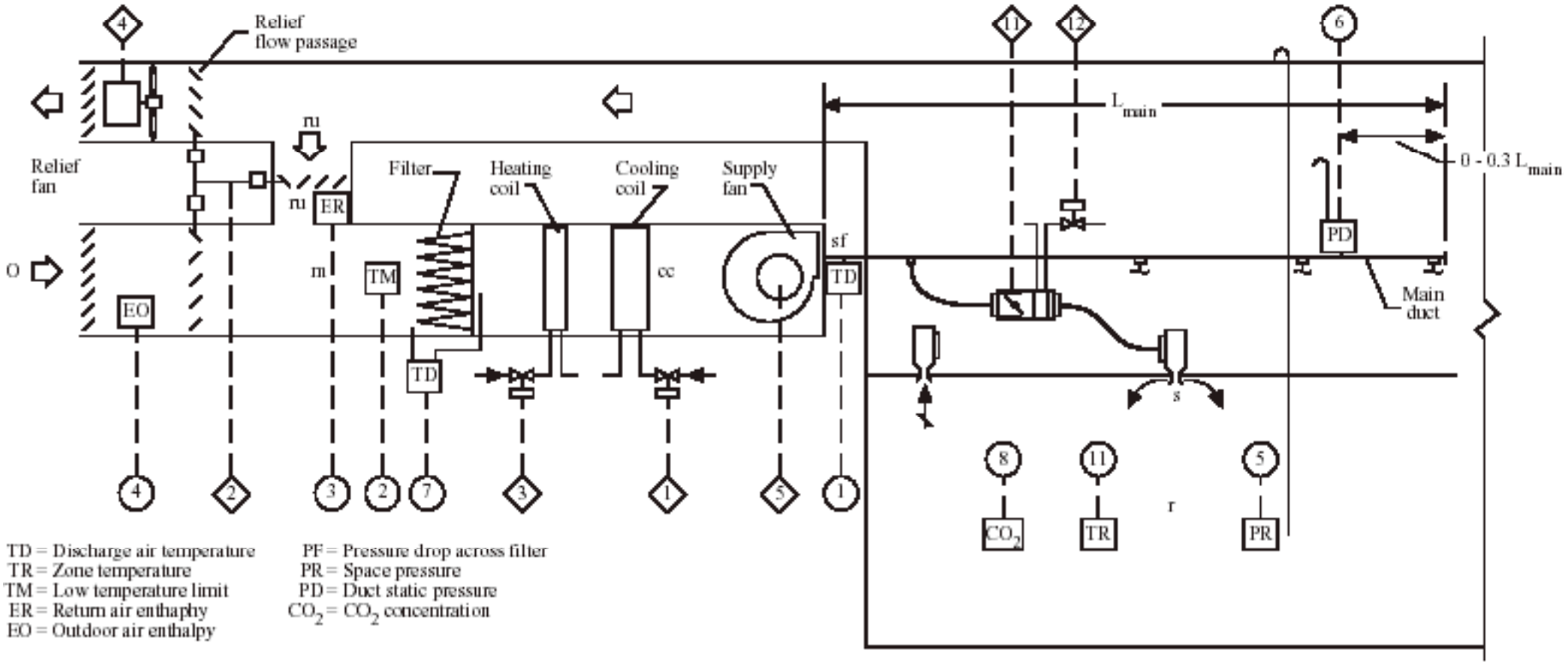
Overview



- Building services systems being controlled
  - **HVAC** (heating, ventilation & air-conditioning)
  - Fire services
  - Plumbing & drainage
  - Electrical installations
  - Lighting
  - Lifts & escalators
  - Security & communication
  - Special systems e.g. medical gas

Most important one

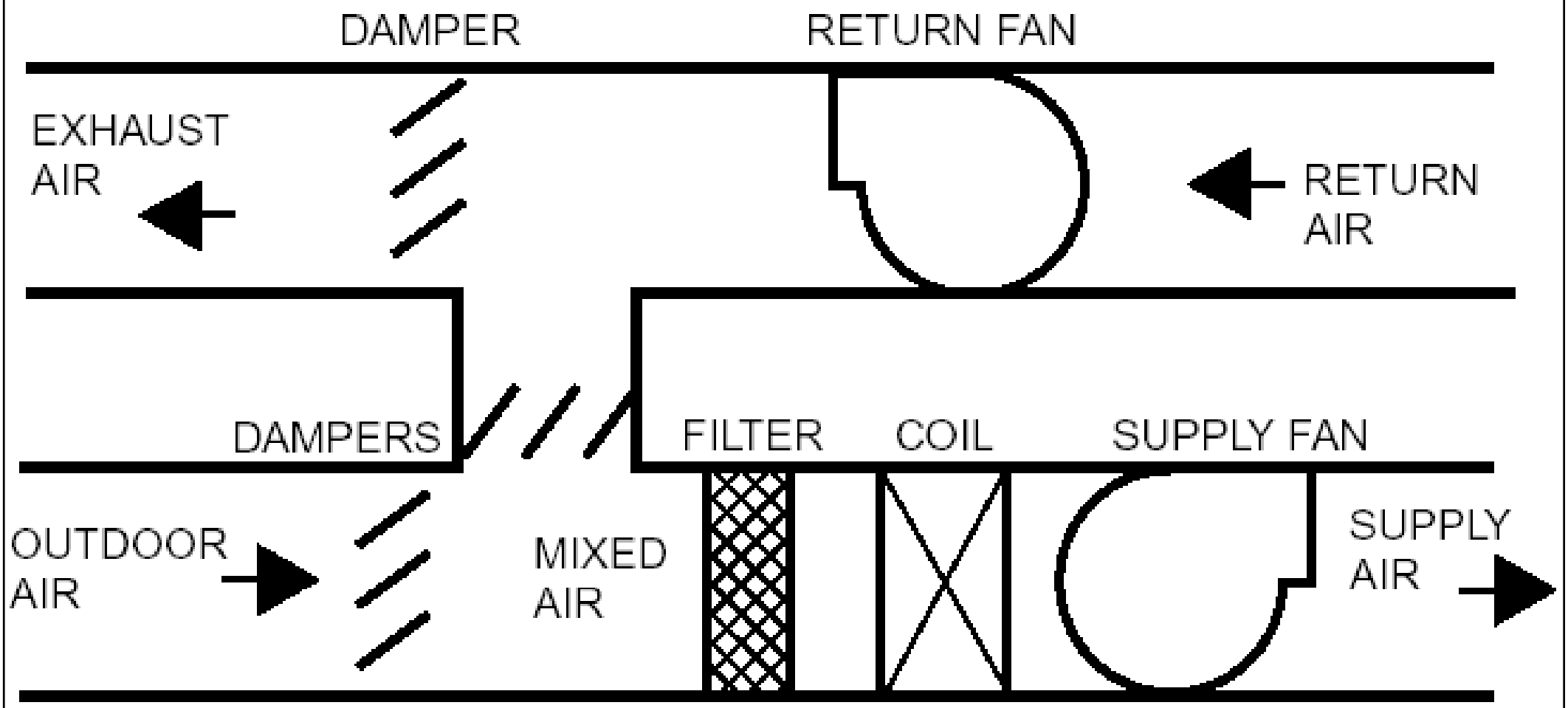
Can you understand all the symbols & abbreviations?



Control diagram of a VAV reheat system for year-round operation

[Source: Wang, S. K., 2001. *Handbook of Air Conditioning and Refrigeration*]

Can you identify the components when you visit a AHU room?

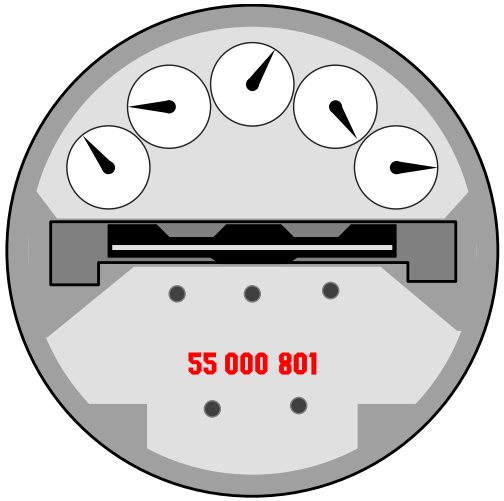


Schematic diagram of a typical air-side system

[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]

Building Energy Management System

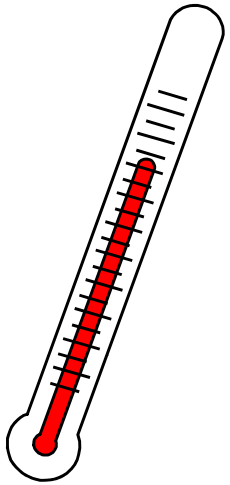
Lower energy cost



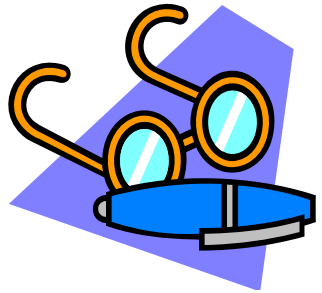
Lower operations cost

Increase flexibility

Ensure quality building environment

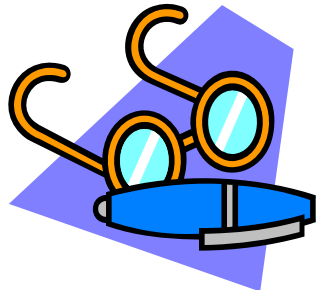


Overview



- Why use BEMS?
  - Growing complexity of building systems
  - Demand for more efficient building operation
  - Need to save energy & operating costs
  - Need to increase flexibility & reliability
  - Improve indoor environment & productivity
- Connect BEMS to major building equipment to
  - Control air conditioning & lighting to save energy
  - Monitor all equipment to improve efficiency of operations personnel & minimise equipment down time

Overview

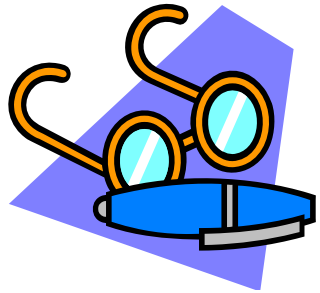


- Early development history

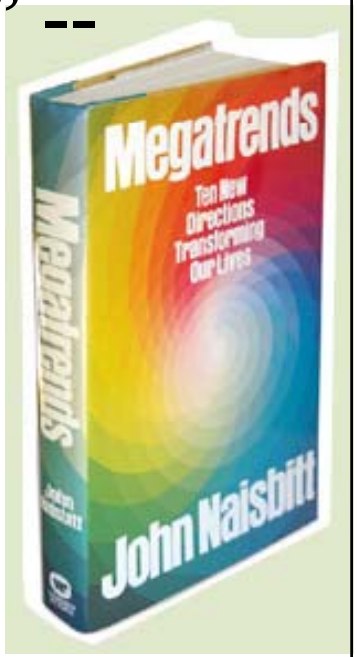
Influenced by computer & inform. technology

  - 1st generation (1950's)
    - Remote monitoring panels with sensors & switches (hard wire)
  - 2nd generation (1960's)
    - Electronic low voltage circuits
  - 3rd generation (1960's-1973)
    - Multiplexed systems with minicomputer stations
  - 4rd generation (1983)
    - Microcomputer-based systems
  - 5th generation (1987)
    - Direct digital control (DDC) with microprocessor & software

Overview

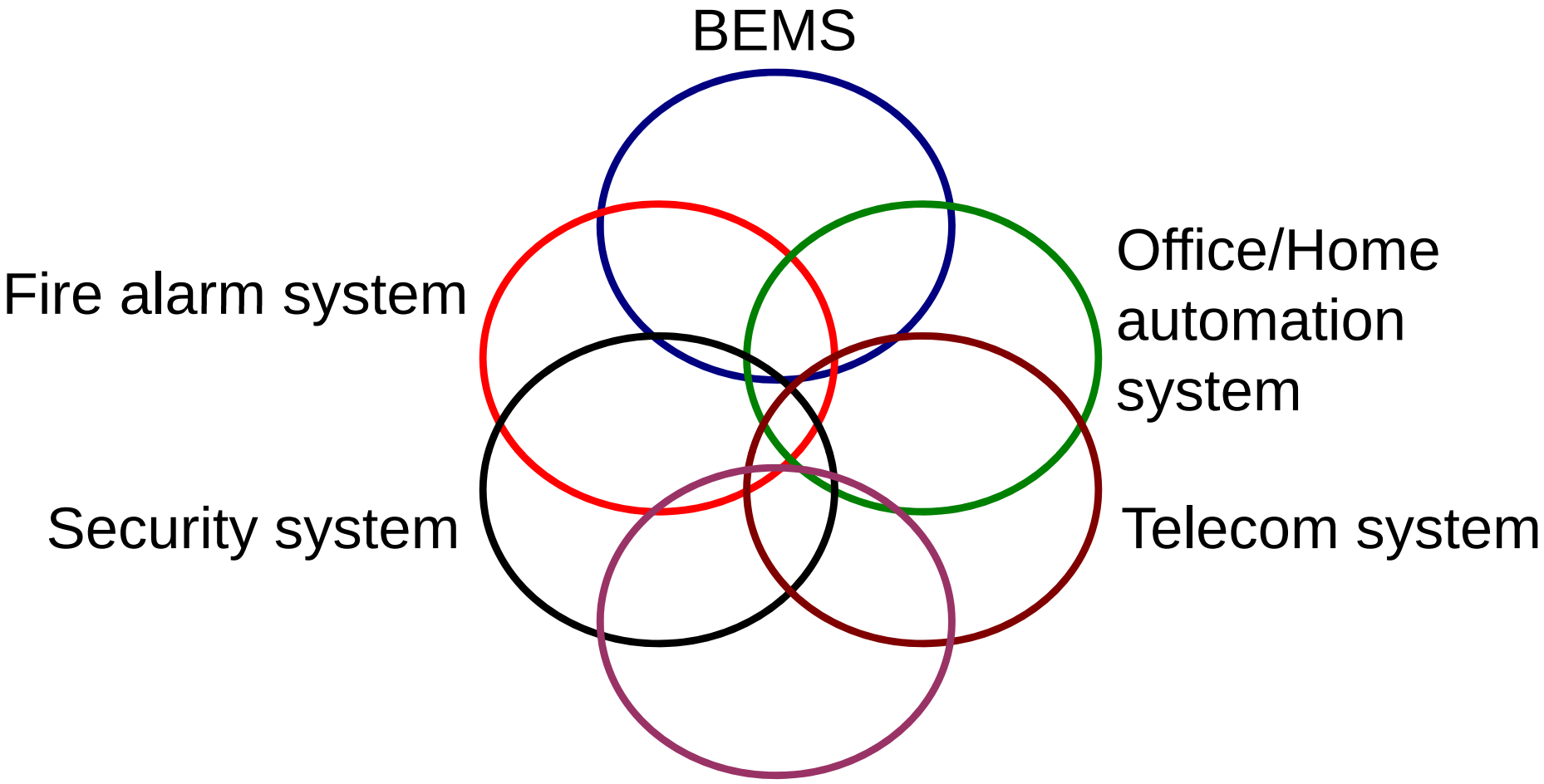


- "Computer technology is to the information age what mechanization was to the industrial revolution." -- *Megatrends* (1982) by John Naisbitt



- Recent trends of BEMS
  - Conventional system (front end based)
    - Central computer + "dumb" field panels
  - Distributed intelligence BEMS
    - Central computer + field panels (limited standalone)
  - Fully distributed BEMS
    - Multifunction microprocessor close to the equipment (complete standalone)

Building Services Engineer needs to integrate all the systems



Potential overlap of microprocessor-based systems

Control Fundamentals

- Definitions
  - **Automatic control system**: A system that reacts to a change or imbalance in the variable it controls by adjusting other variables to restore the system to the desired balance.
  - **Controlled Variable**: The quantity or condition that is measured and controlled.
  - **Controller**: A device that senses changes in the controlled

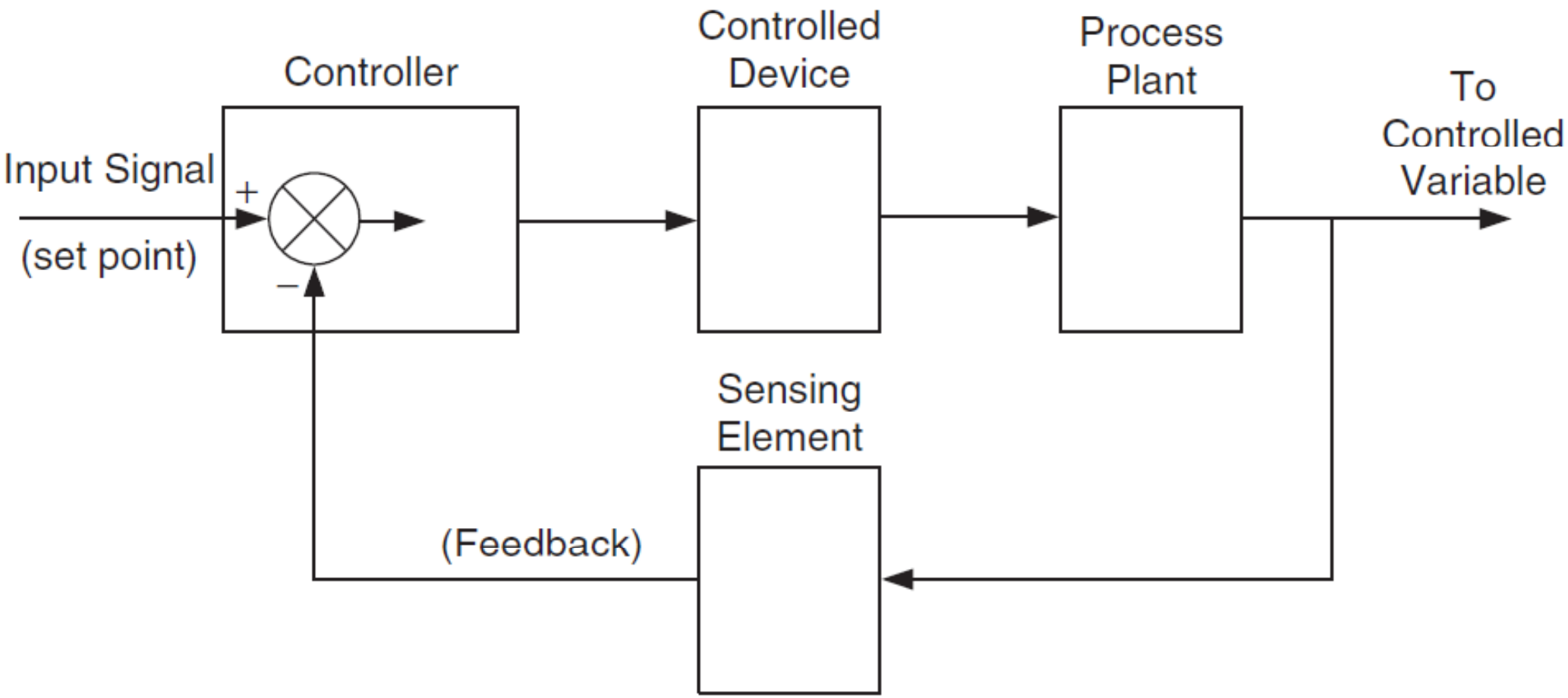
Control Fundamentals

- Pneumatic controls
  - Traditional form of control used in buildings
  - Pneumatic controllers, sensors & actuators
  - Electronic devices may be integrated
- Direct digital control (DDC)
  - Entered the HVAC industry in late 1980's
  - Use a programmable microprocessor as controller
    - 'Direct' = microprocessor is directly in the control loop
    - 'Digital' = control is accomplished by the digital electronics

Control Fundamentals

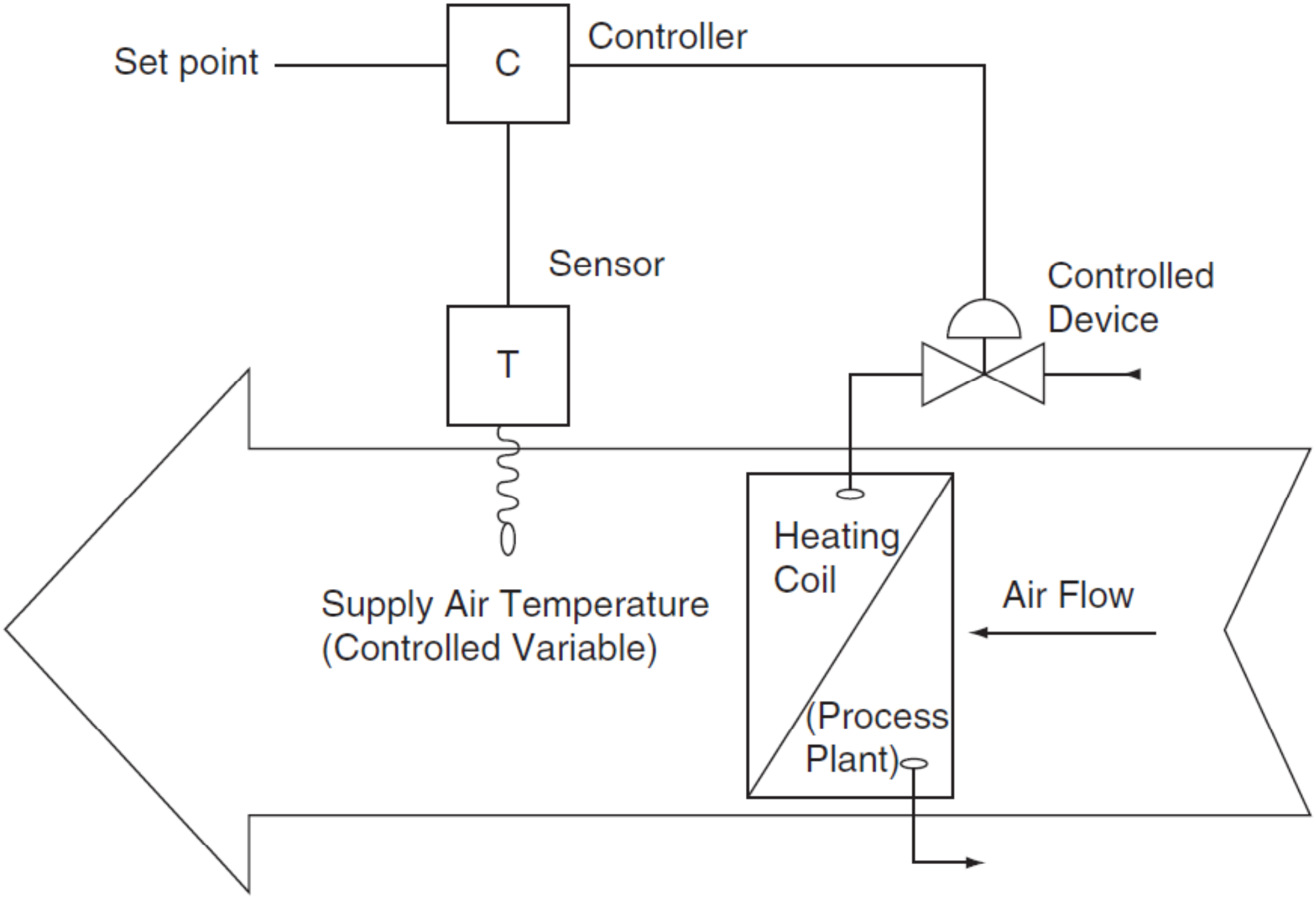
- Basic elements
  - Sensor
    - Measure some variables, e.g. temperature
  - Controller
    - Process & compute an output signal
  - Controlled device
    - Act to change the output of the load
- Typical situation for BEMS
  - Close loop systems (w/ feedback loop)

Basic elements of a feedback control loop



[Source: Montgomery, R. and McDowall, R., 2008. *Fundamentals of HVAC Control Systems*]

Simple heating system



[Source: Montgomery, R. and McDowall, R., 2008. *Fundamentals of HVAC Control Systems*]

Control system diagram

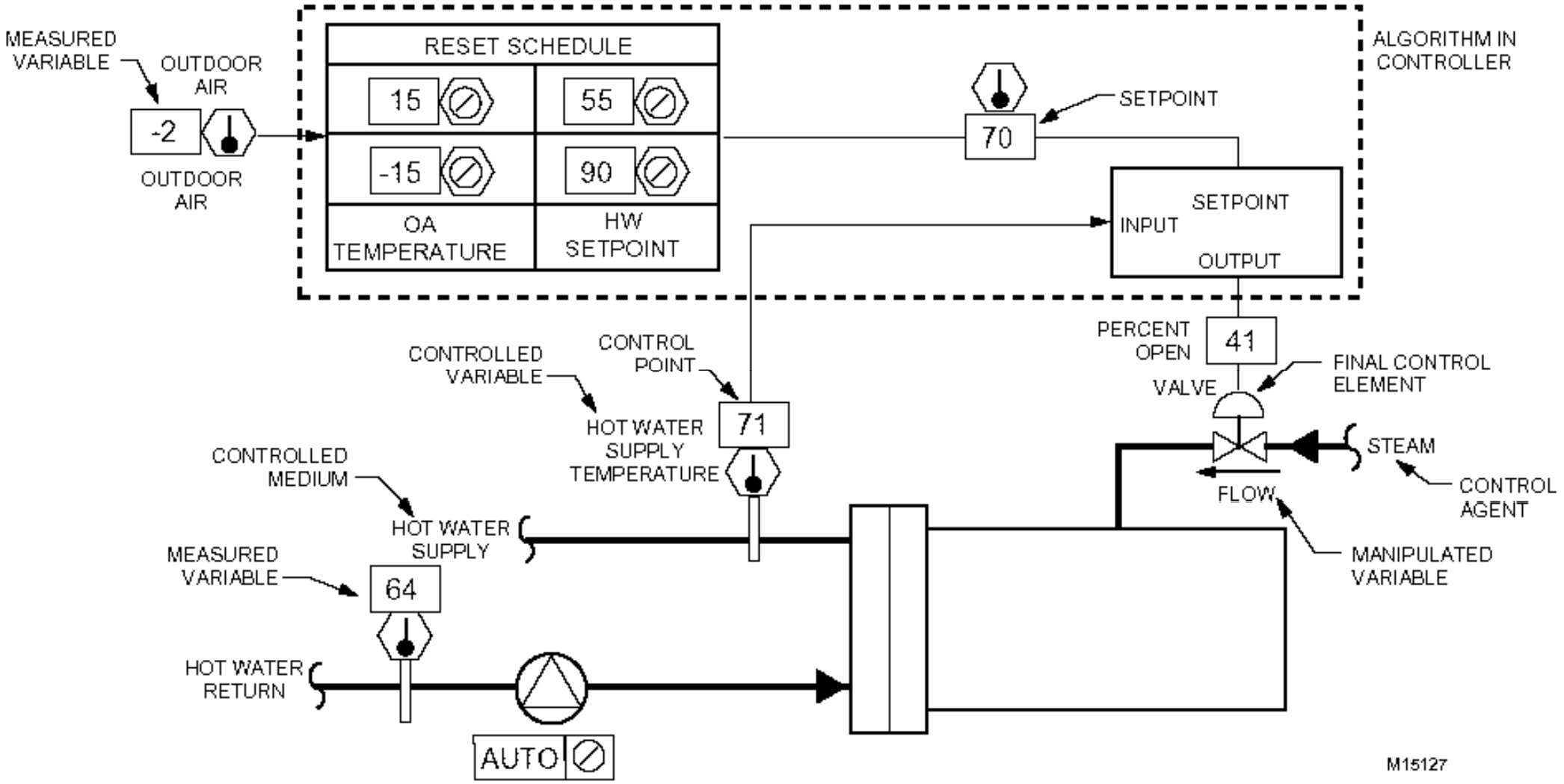
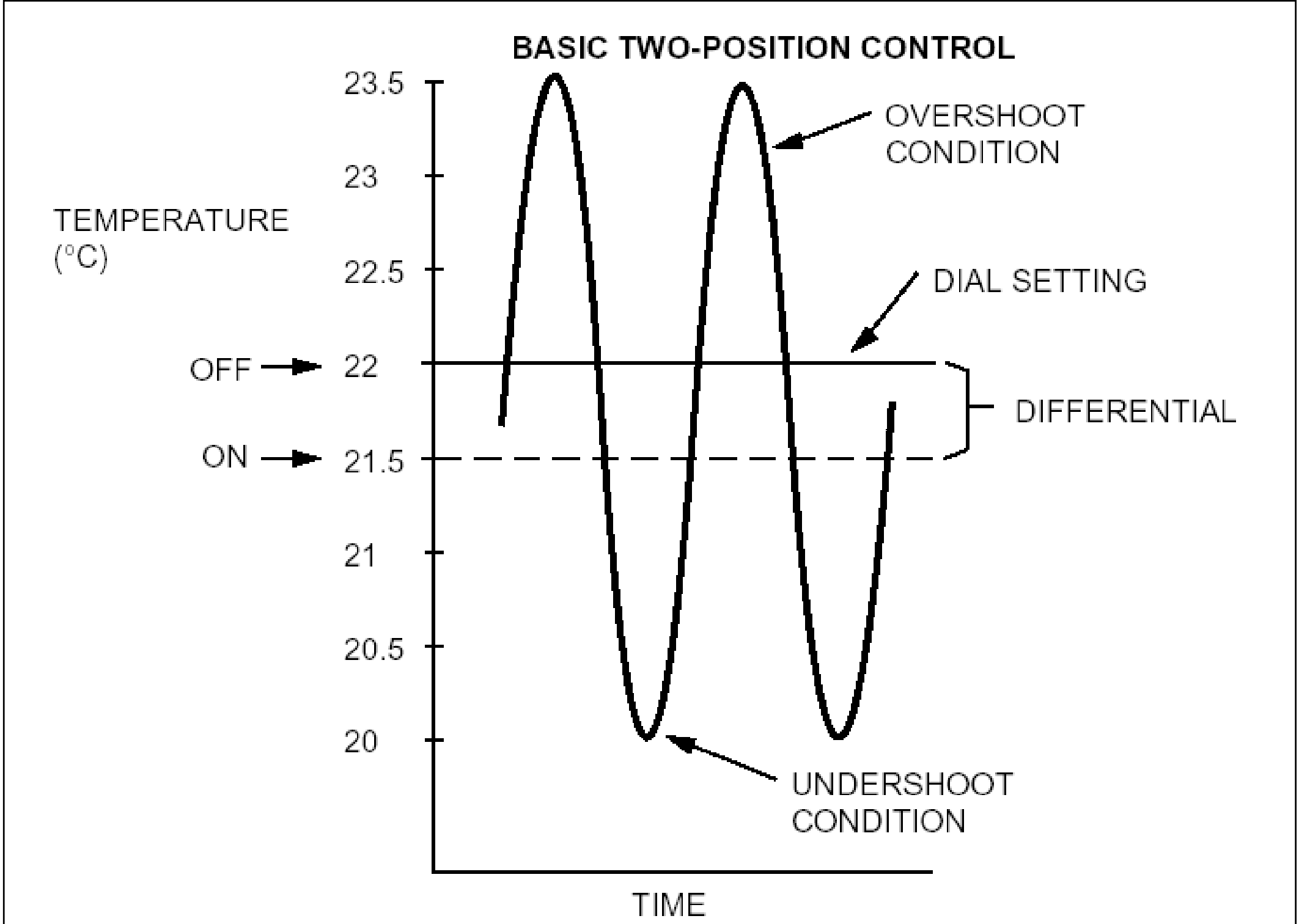


Fig. 1. Typical Control Loop.

[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]

Control Fundamentals

- Control modes
  - Two position (on/off) control
  - Proportional control
  - Integral control
  - Proportional + integral (PI) control
  - Proportional + integral + derivative (PID) control
- Technical terms
  - Set points, dead band, throttling range, offset, proportional band, integral time



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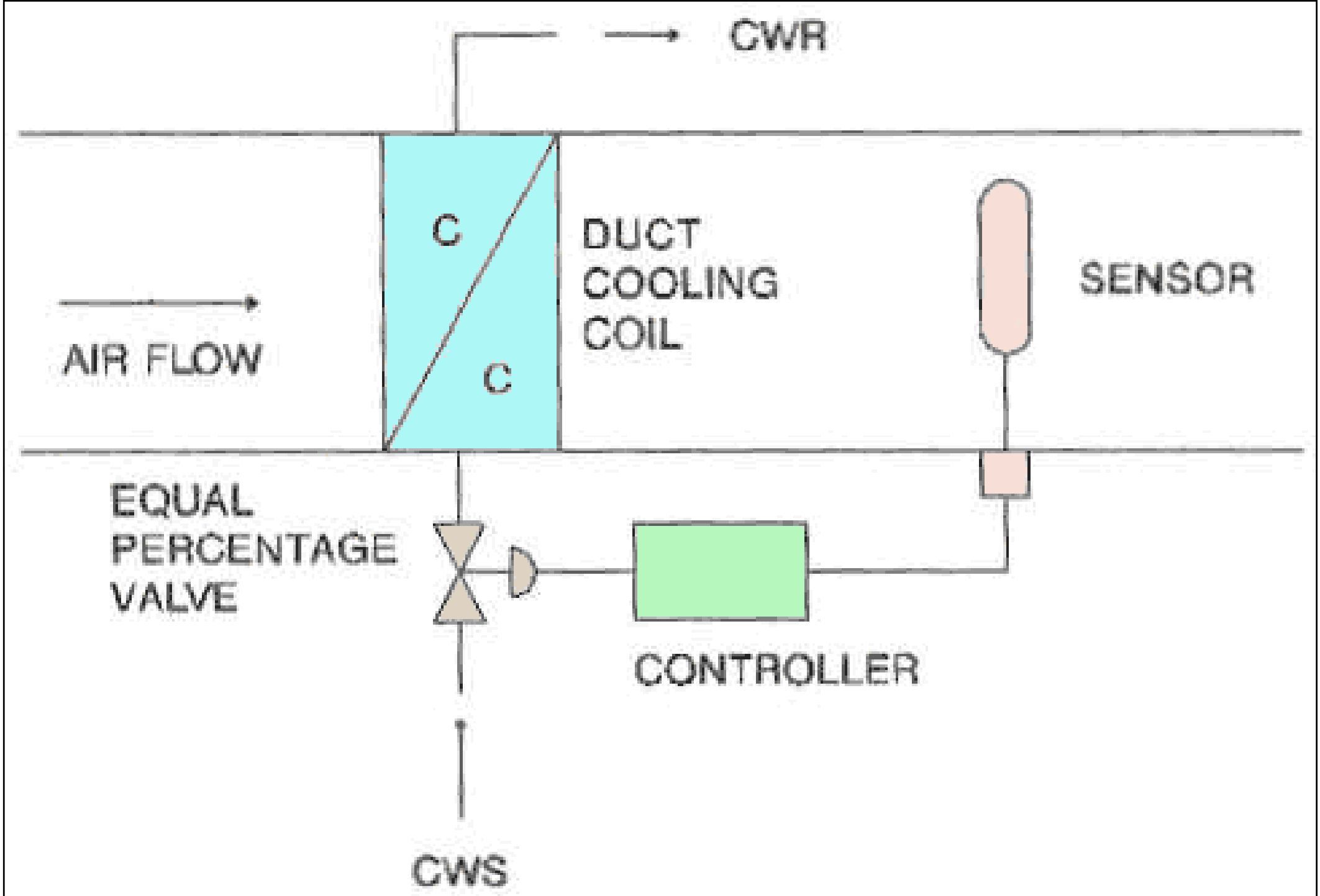
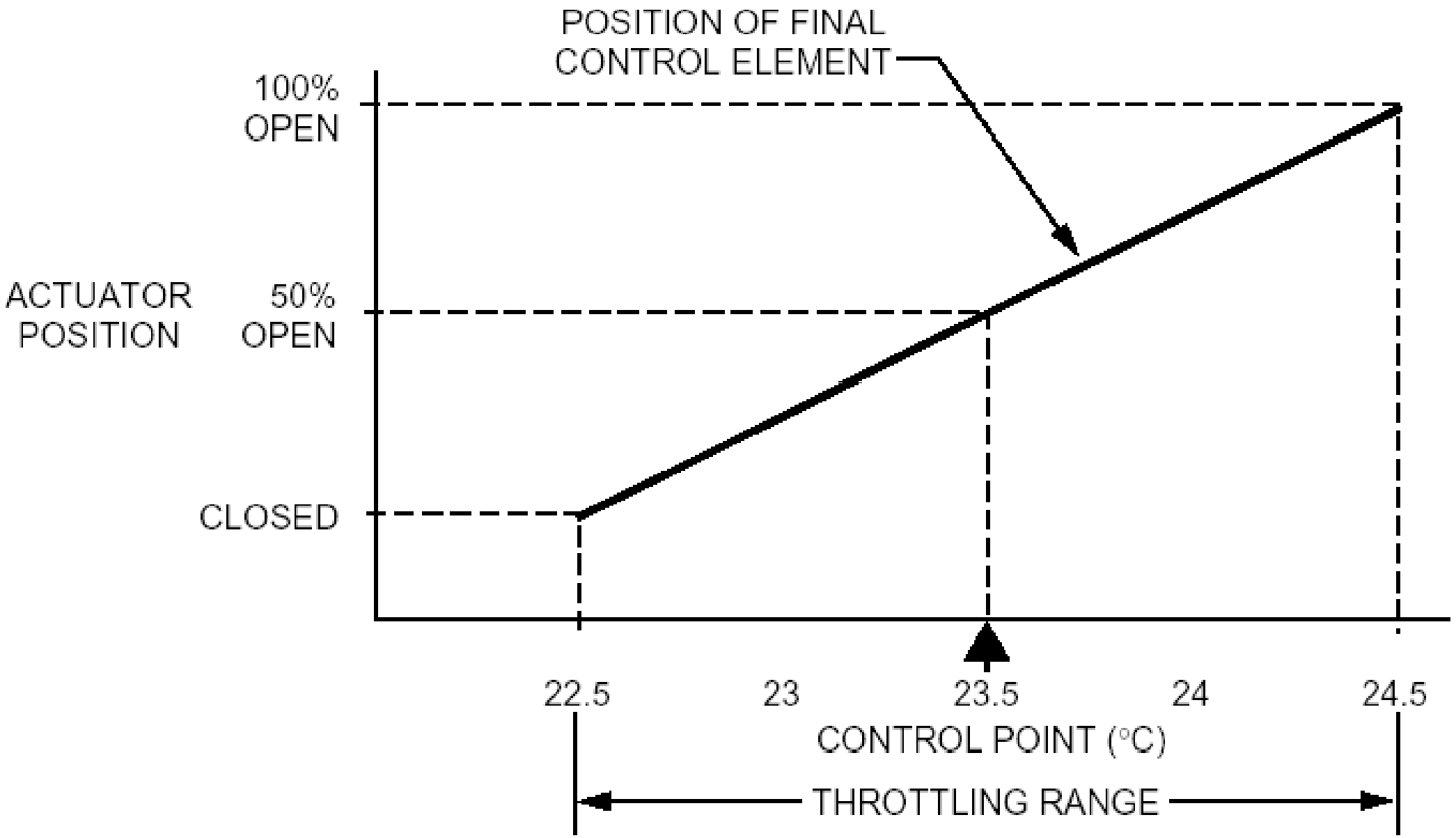
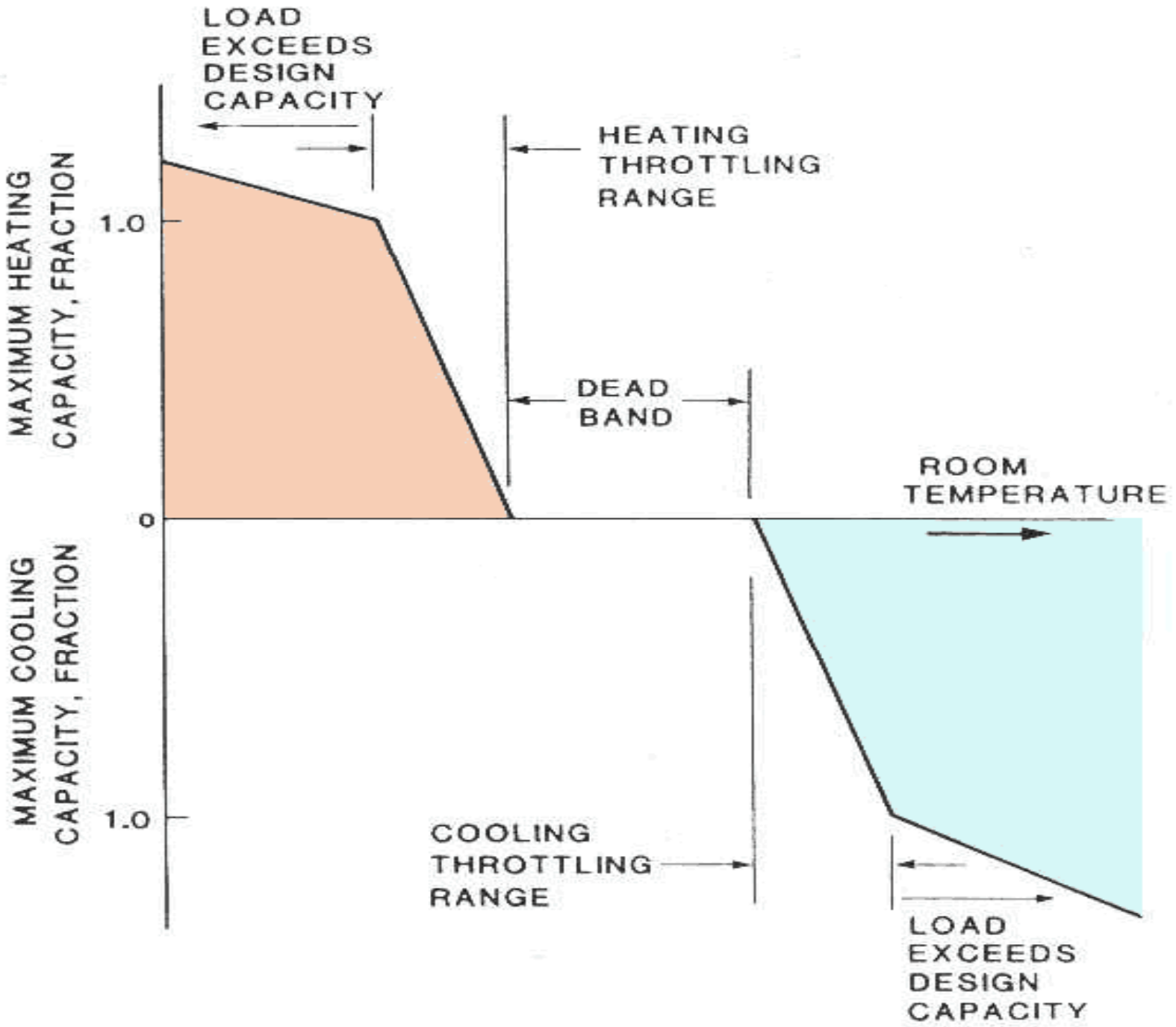


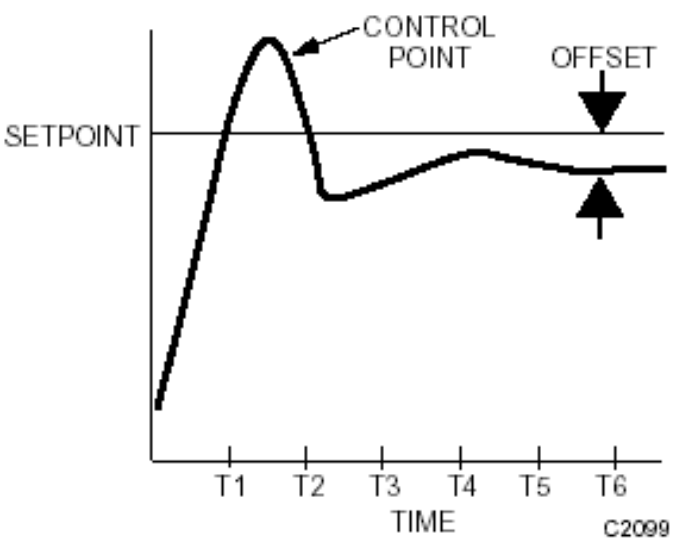
Example: Discharge air control system



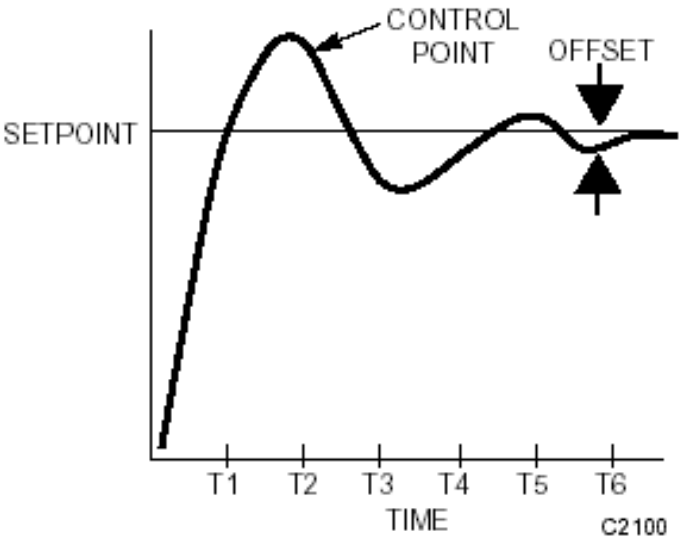
[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]



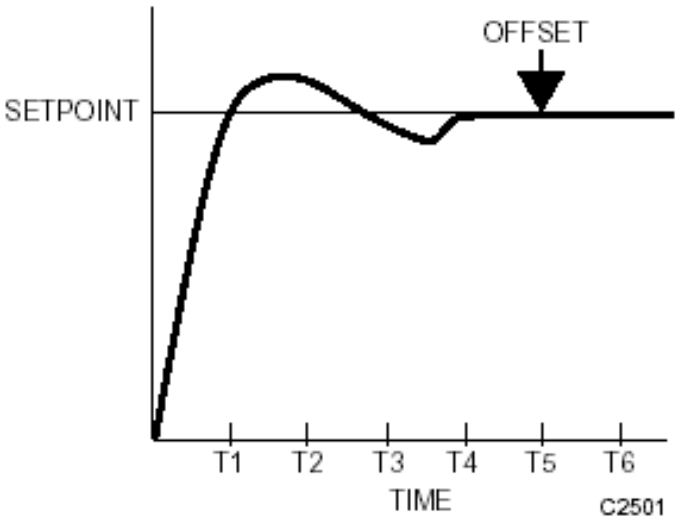
Thermostat model of proportional control with deadband and dual throttling range



Proportional Control



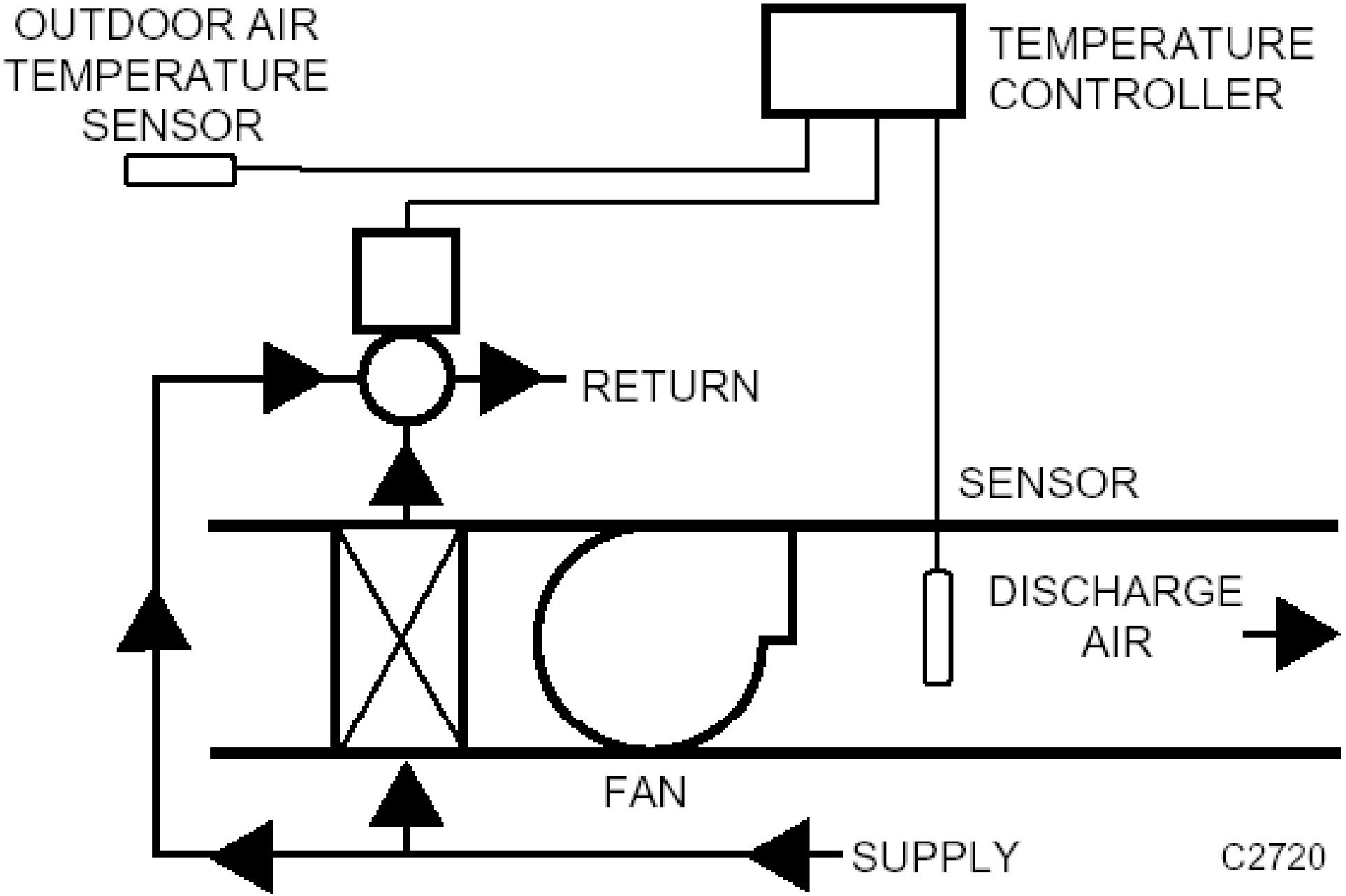
Proportional-Integral (PI) Control



Proportional-Integral-Derivative (PID) Control

$$V = \underbrace{KE}_{\text{Proportional}} + \underbrace{\frac{K}{T_1}\int E dt}_{\text{Integral}} + \underbrace{KT_D\frac{dE}{dt}}_{\text{Derivative}} + M$$

[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]



Discharge air control loop with reset

[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]

Condition	Outdoor Air Temperature (°C)	Discharge Air Temperature (°C)
Outdoor design temperature	–20	40
Light load	20	20

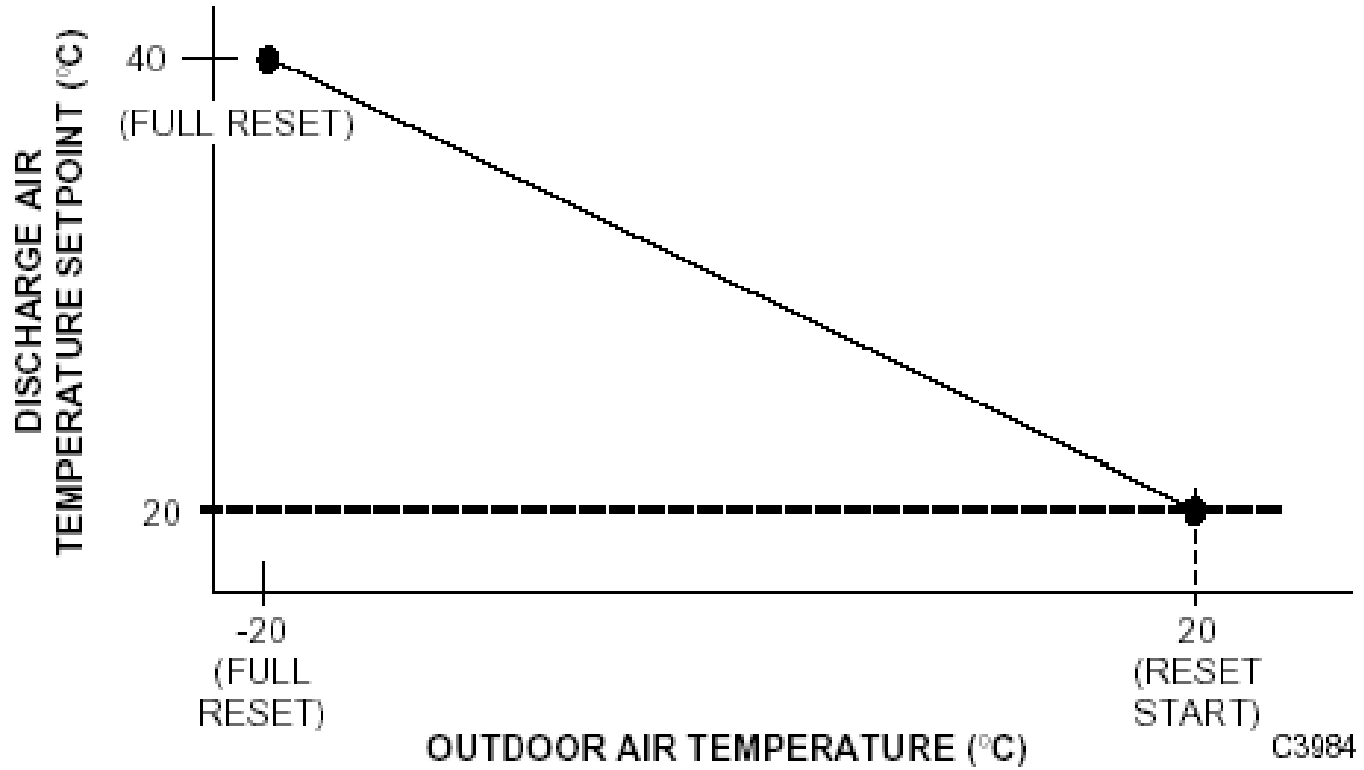


Fig. 34. Typical Reset Schedule for Discharge Air Control.

[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]

Control Fundamentals

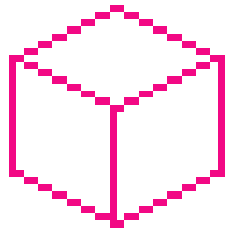
- Choice of control mode
  - Degree of accuracy required; amount of offset
  - Type of load changes expected
    - Including amplitude, frequency & duration
  - System characteristics
    - Such as no. & duration of time lags, speed of response
  - Expected start-up situation
- In general, use the SIMPLEST mode

Recommended control modes for HVAC system

Application	**Control mode**
Space temperature	P, PID
Mixed air temperature	PI, Enhanced PID
Coil discharge temperature	PI, Enhanced PID
Chiller discharge temperature	PI, Enhanced PID
Air flow	PI (use wide proportional band & a fast reset rate), PID
Fan static pressure	PI, Enhanced PID
Humidity	P, possibly PI for tight control
Dewpoint temperature	P, possibly PI for tight control

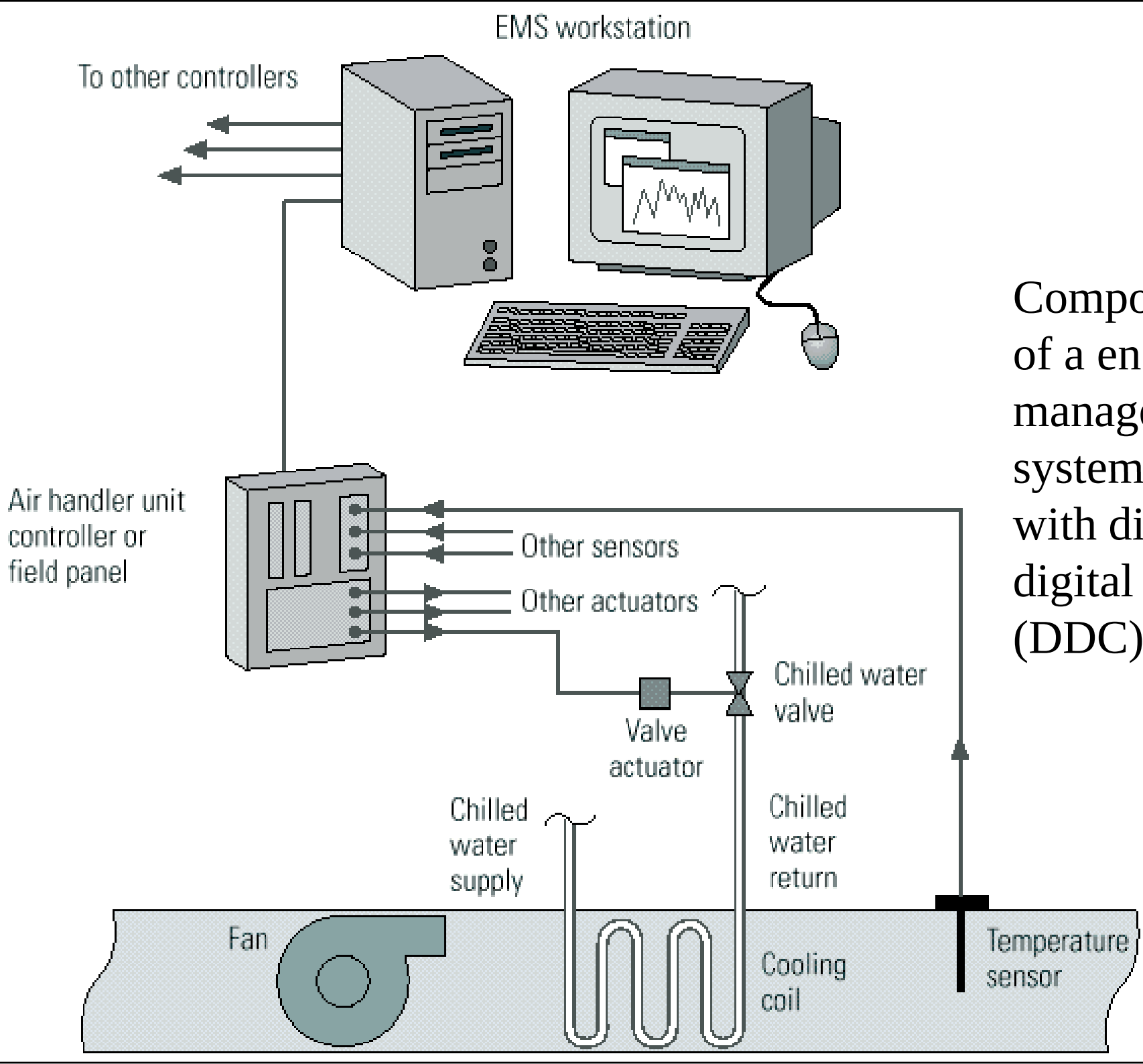
[Source: Honeywell, 1997. *Engineering Manual of Automatic Control: for Commercial Buildings*]

System Concepts

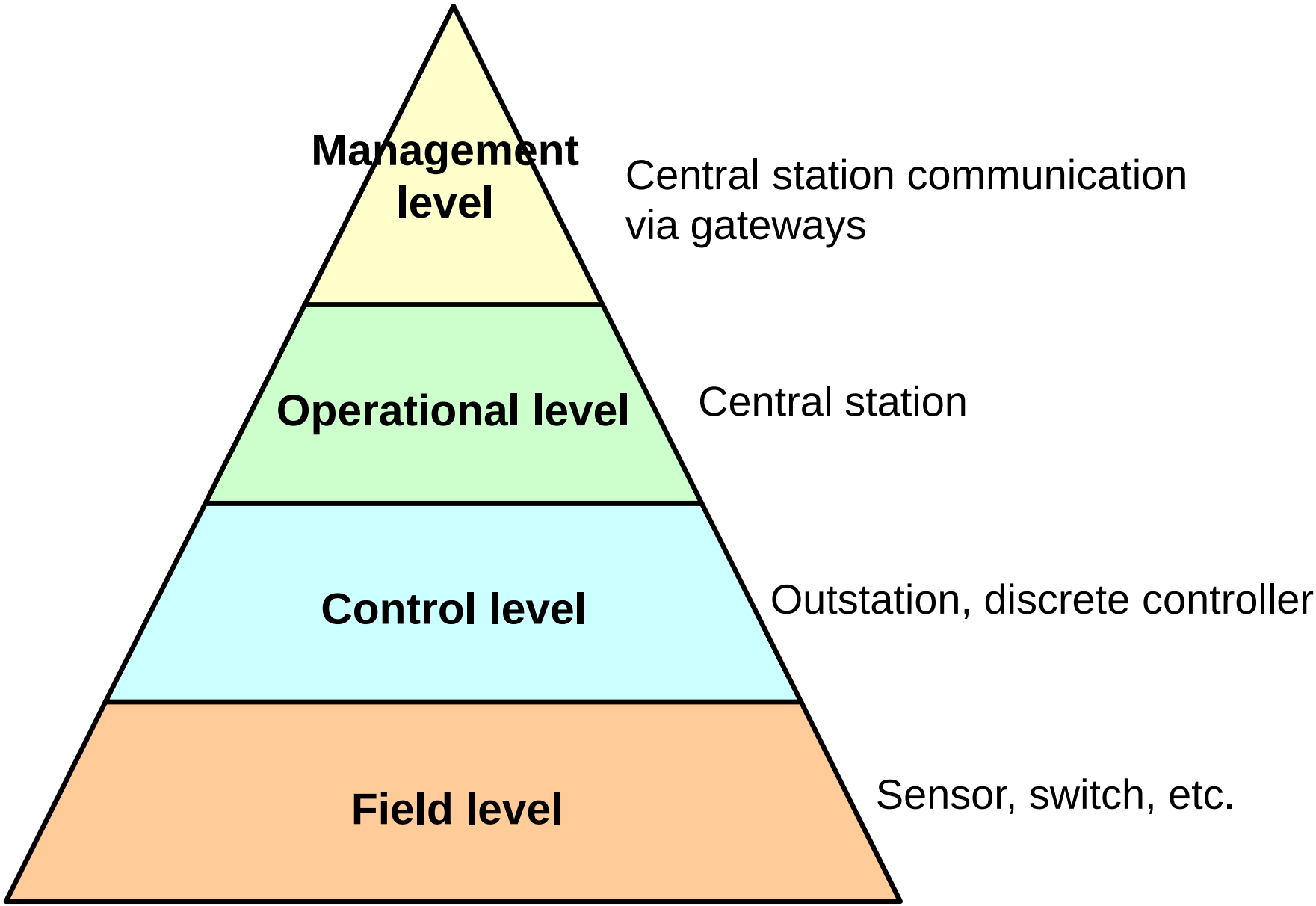


- Typical procedure for a BEMS project
  - Initial concept
  - Information retrieval
  - Candidate buildings & system selection
  - Field survey
  - Design
  - Prepare contract documents
  - Contract
  - Installation & training
  - Acceptance
  - Operation & maintenance

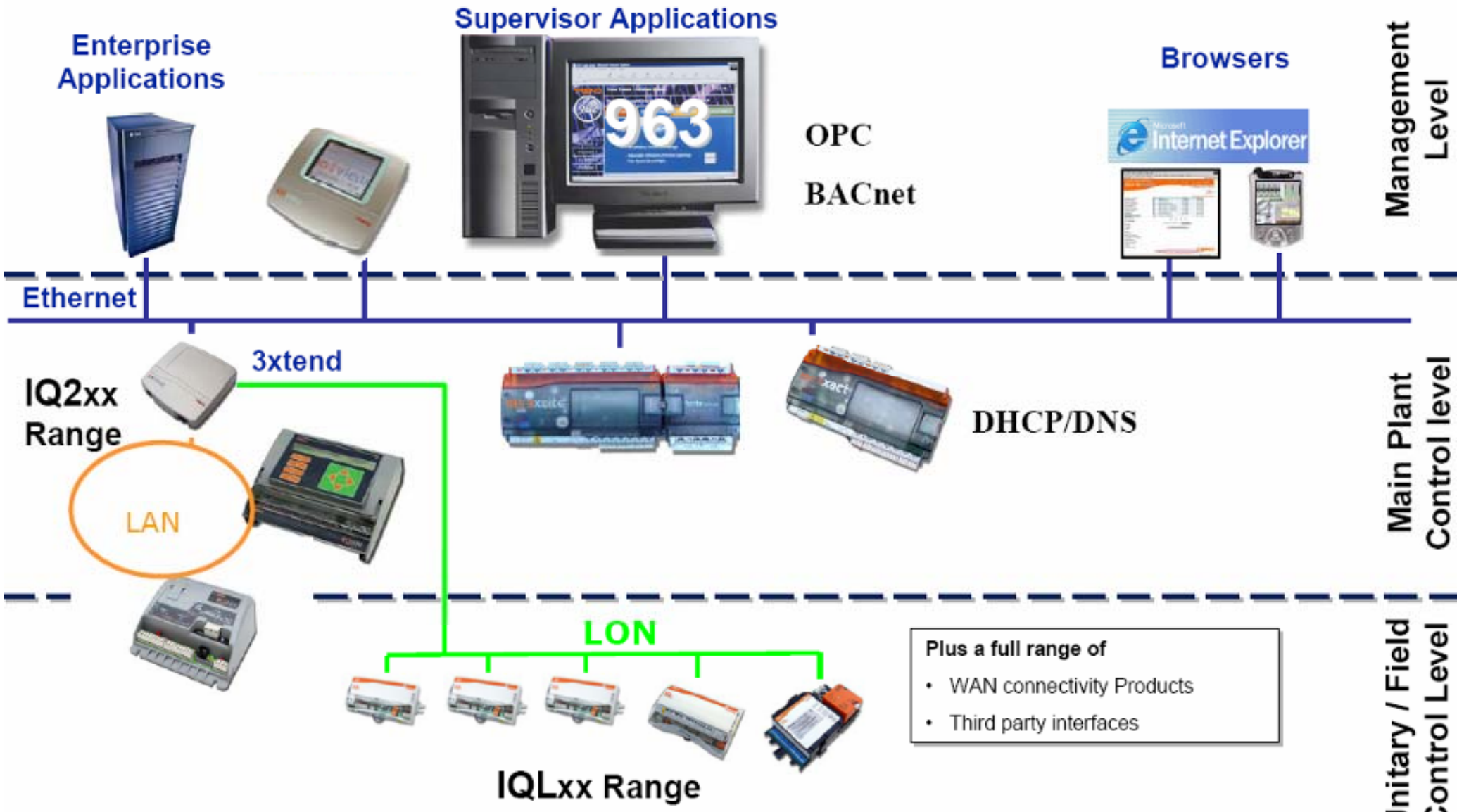
Carried out by consultants, control companies & HVAC contractors



Components of a energy management system (EMS) with direct digital control (DDC)

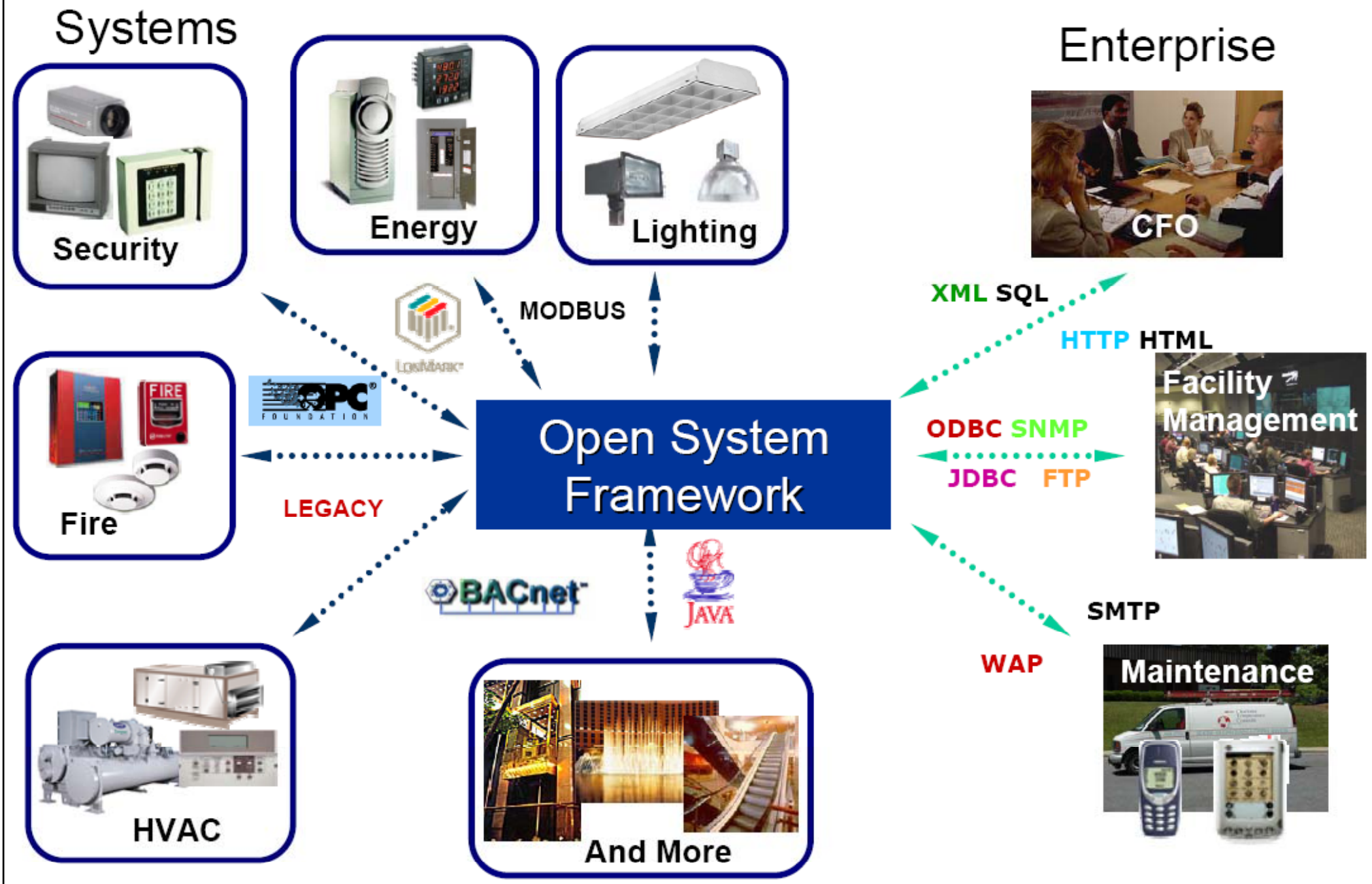


Levels of control in building energy management system



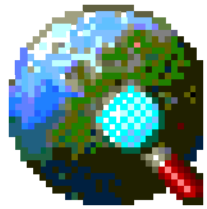
Example of system architecture for building management system

[Source: Trend Control Systems]



[Source: Tridium Software Solutions]

Useful References



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- Honeywell, 1997. *Engineering Manual of Automatic Control for Commercial Buildings - Heating, Ventilating, Air Conditioning*, SI Edition., Honeywell, Inc., Minneapolis, MN.
- Montgomery, R. and McDowall, R., 2008. *Fundamentals of HVAC Control Systems*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA.

(* Please download them for your reference.)