Xi'an Jiaotong-Liverpool University
西交利物浦大学

EEE220 Instrumentation and Control System

2018-19 Semester 2

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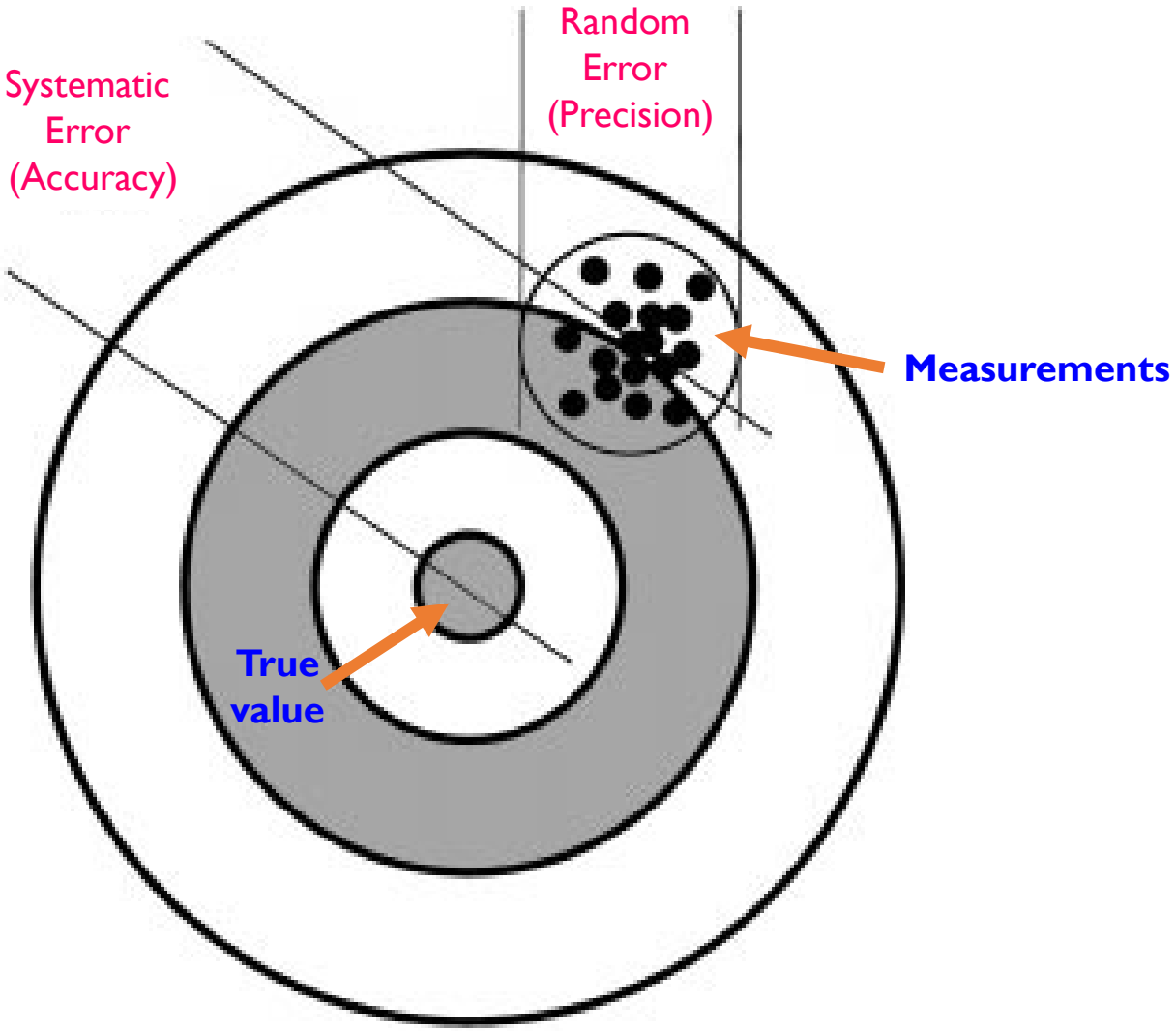
Lecture 2

Outline

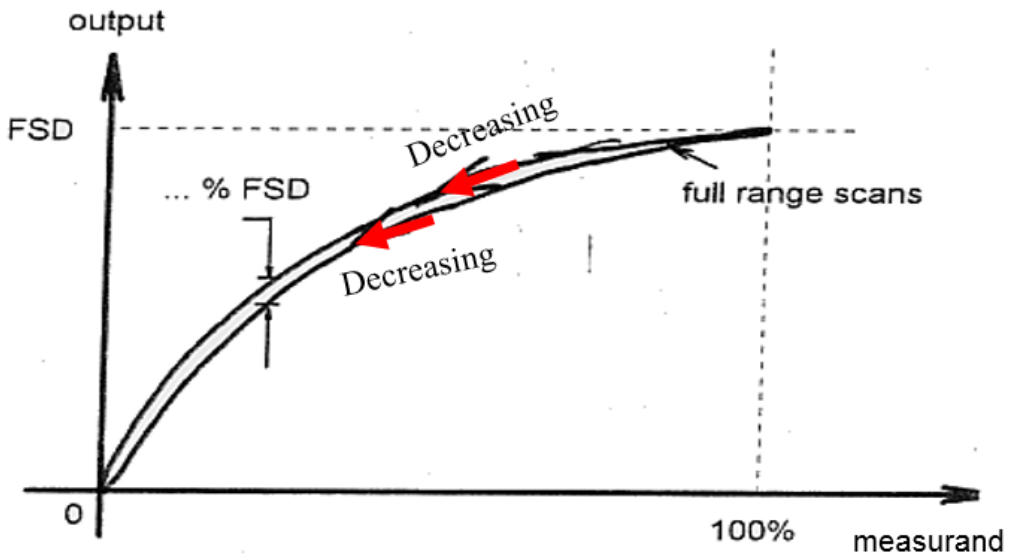
- Brief Review
- Open-loop and Closed-loop Control Systems
- Analogue vs. Digital Systems
- Control System Design

Accuracy vs. Precision

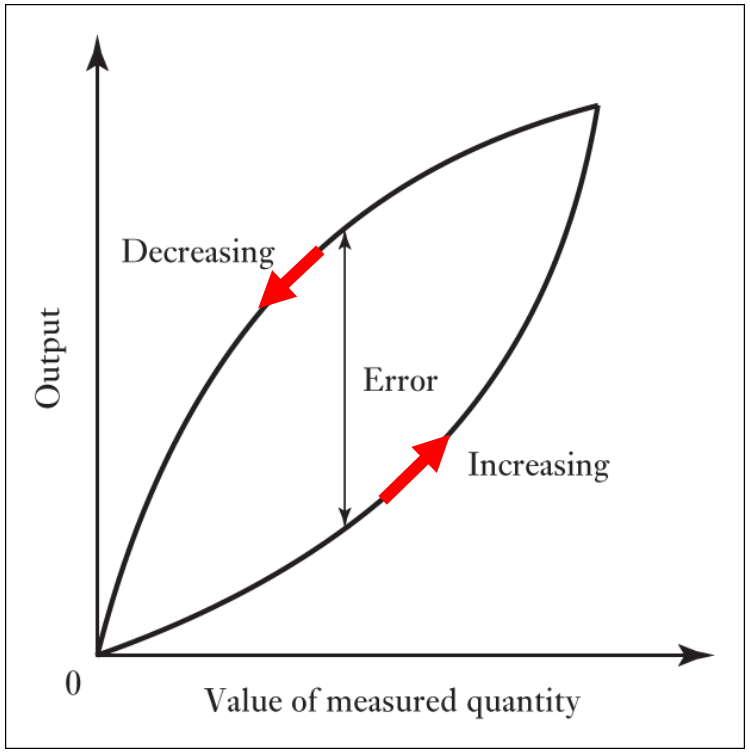


Repeatability vs. Hysteresis Error

Repeatability



Hysteresis



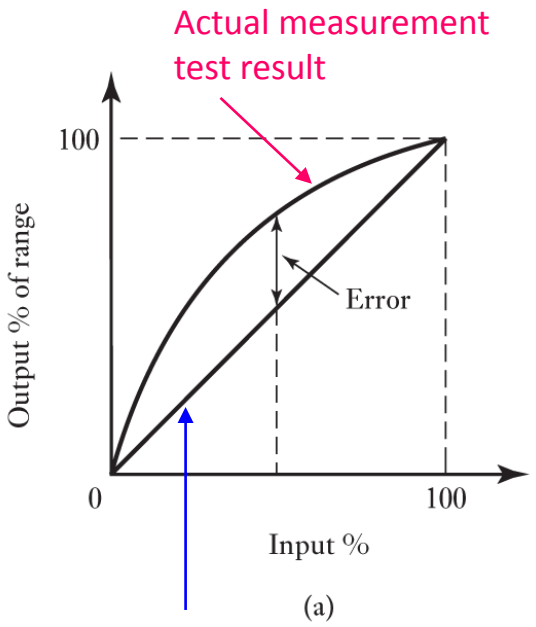
Note:

FSD (Full Scale Deflection): full range of measurement output (reading);

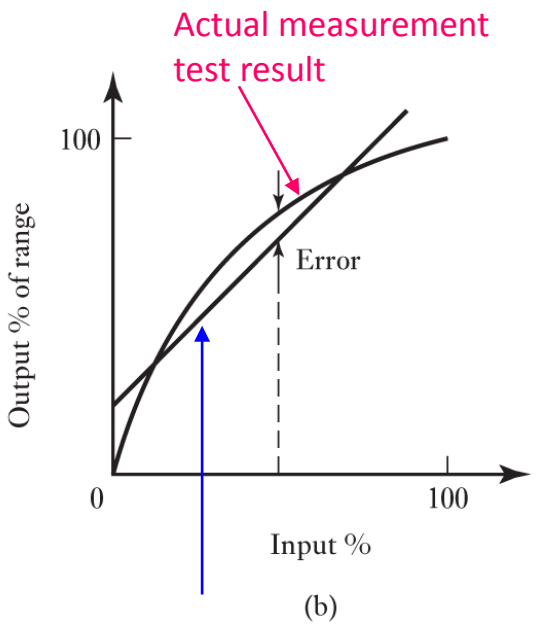
% FSD: an unit commonly used in instrumentations.

Non-linearity Error

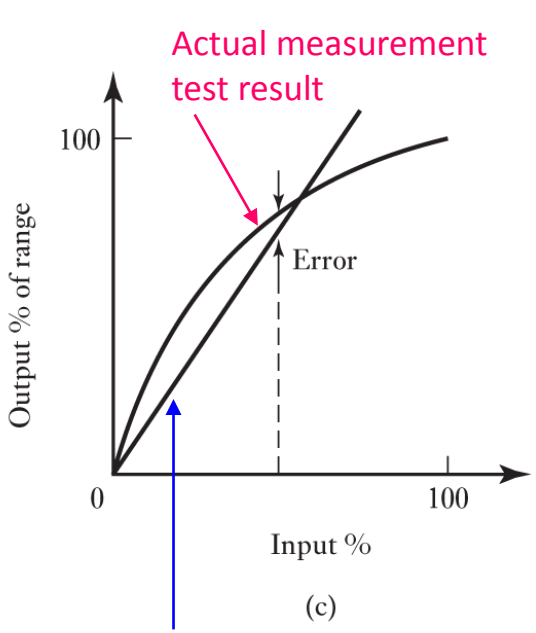
- Nonlinearity becomes an error only when assuming the input and output has a linear relationship;
- There are many ways to define non-linearity error, all depend on how to define the straight line.



Straight line defined as the linear line connects the end points;



Straight line defined as the best fit linear line based on all measurement data;



Straight line defined as the best fit linear line based on all measurement data and also passes through the zero point.

Quiz 2.1

A pressure sensor has a range of 0 to 1,000 kPa and a non-linearity error of $\pm 0.15\%$ FSD and a hysteresis error of $\pm 0.05\%$ FSD. The error for a reading of 300kPa is

A. ± 0.3 kPa

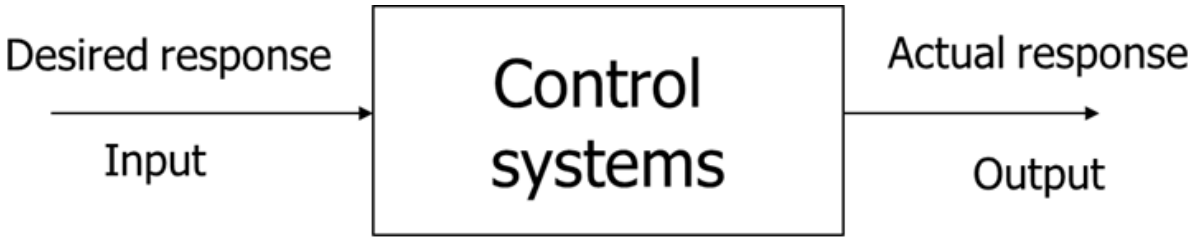
B. ± 0.6 kPa

C. ± 1.0 kPa

D. ± 2.0 kPa

Control Systems

A Control system is an interconnection of components forming a system configuration that will provide a **desired** system response.



- The component to be controlled is called **process**.
- The input-output relationship represents the cause-and-effect relationship of the process, which in turn represents a processing of the input signal to provide a desired output signal.
- The basis for analyzing a system is linear system theory. Control system is designed based on mathematical background, there are various methodology to solve a given problem.

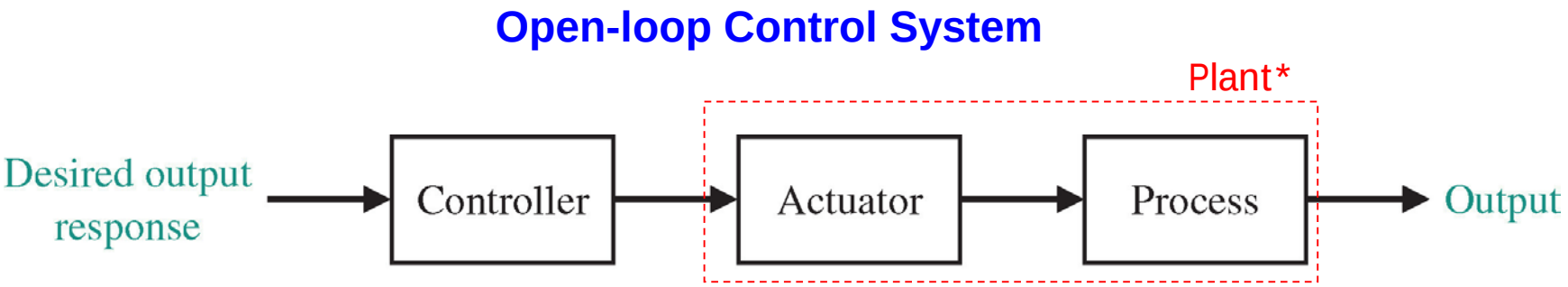
Where Control Systems are Used?

- Generation and transmission of energy
- Communication

  - In mobile the power adjustment of the handset according to the received power
- Transportation
  - Aeroplanes
  - Cars
  - Traffic control
- Industrial process
- Medical applications (automatic drug administer)
- Social, economic and political system modelling etc.

Open-loop Control System

- An open-loop control system utilizes an actuating device (actuator) to control the process directly without using feedback to obtain the desired response.
- An open-loop control system is a control system **without** feedback.



**The plant is the to-be-controlled system.*

Example 2.1: Toaster

To adjust the desired toast colour, the user adjusts the input time or the preset temperature for toasting.

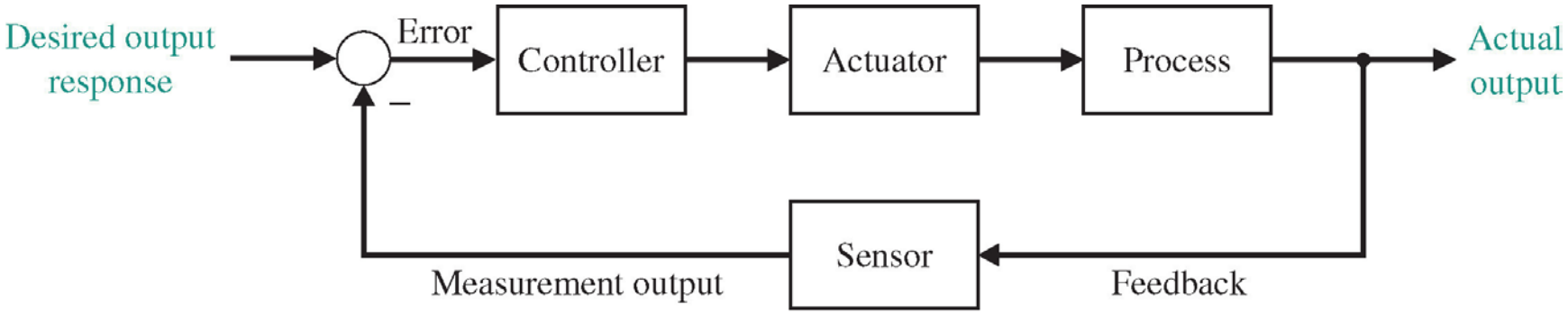
Is it OPEN-loop or CLOSED-loop system ?

- **Input**: toast desired color → user adjusts input time.
- **Output**: toasted bread
- What will happen if the components (consequently the system characteristics) changes with time ?

Closed-loop Control System

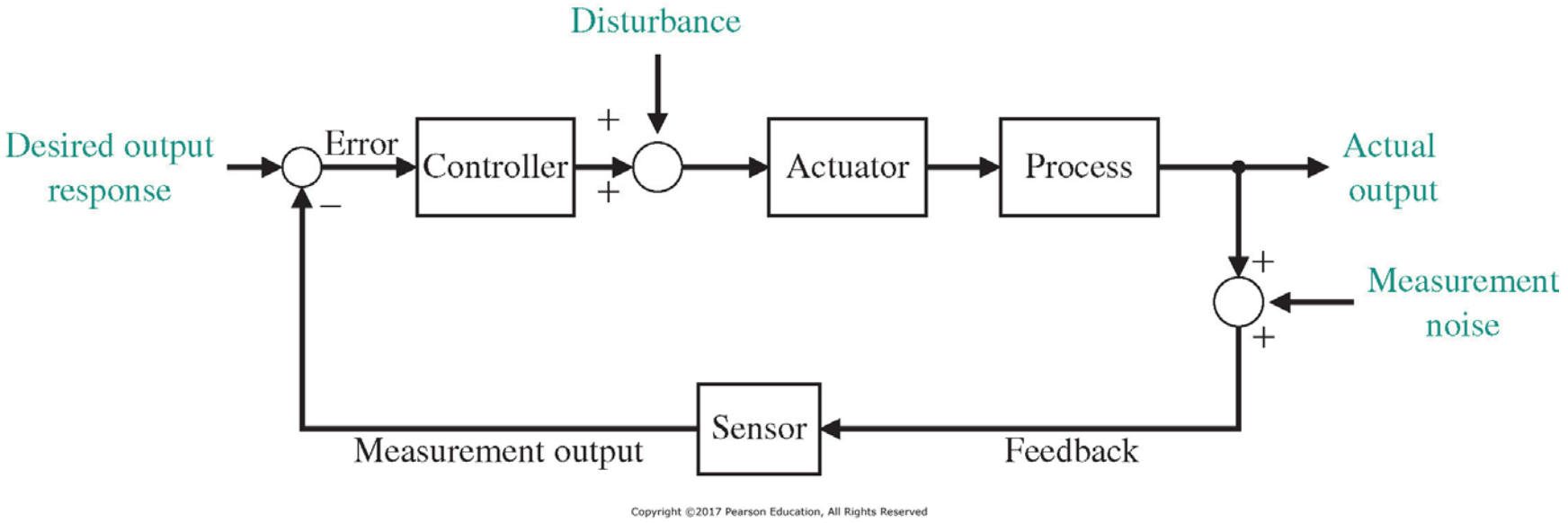
- In contrast to open-loop control system, a closed-loop control system uses a measurement of the output and feedback of this signal for compare it with the desired output (reference or command).
- The measure of the output is called the feedback signal.
- When the output is subtracted from input and the difference is used as the input signal to the controller, it is called a negative feedback control system.

Closed-loop Control System

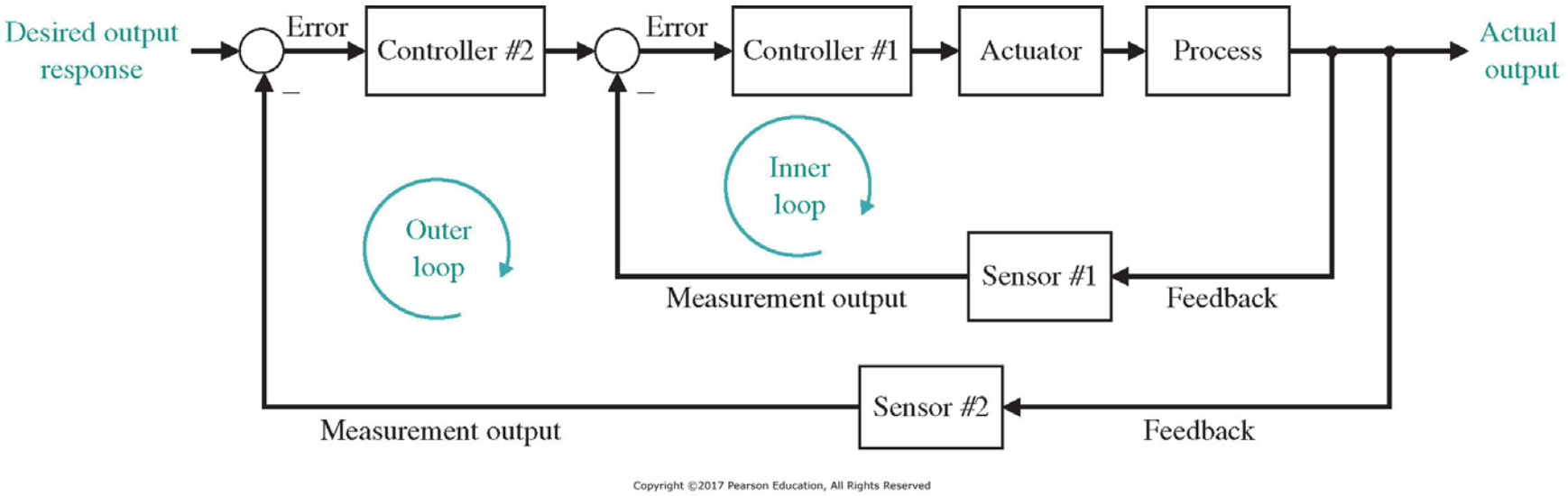


Advantages of Closed-loop Control System

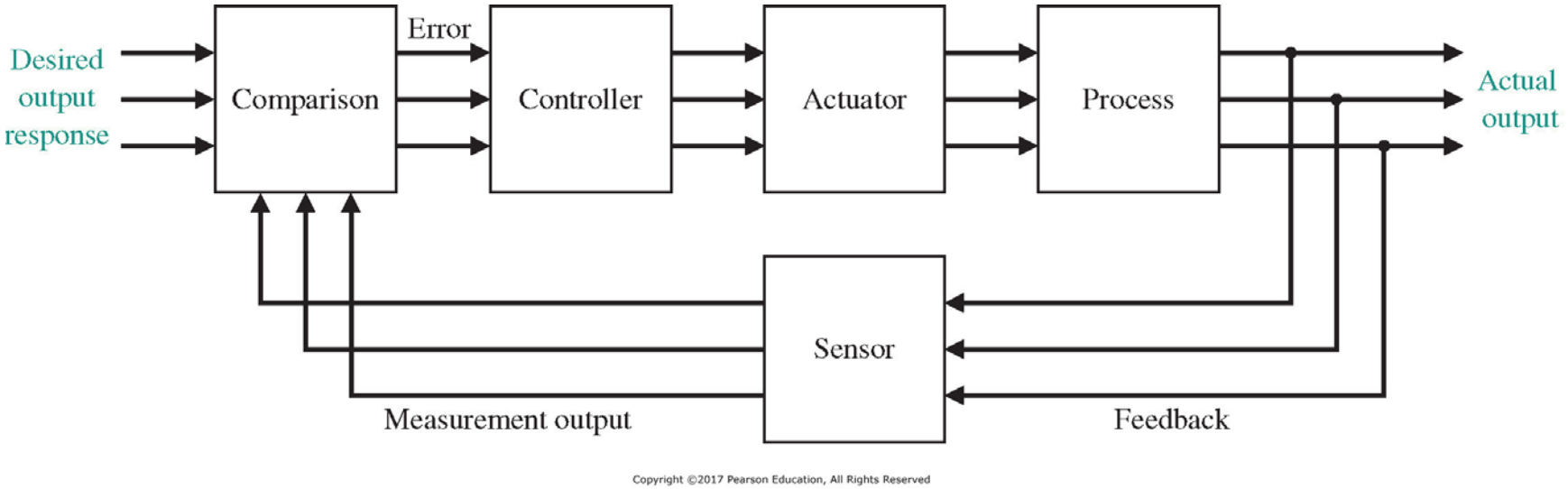
As we will discuss in later lectures, closed-loop control system has many advantages over open-loop control systems, including the ability to reject external disturbance and attenuate measurement noise, which are inevitable in real-world applications and must be addressed in practical control system designs.



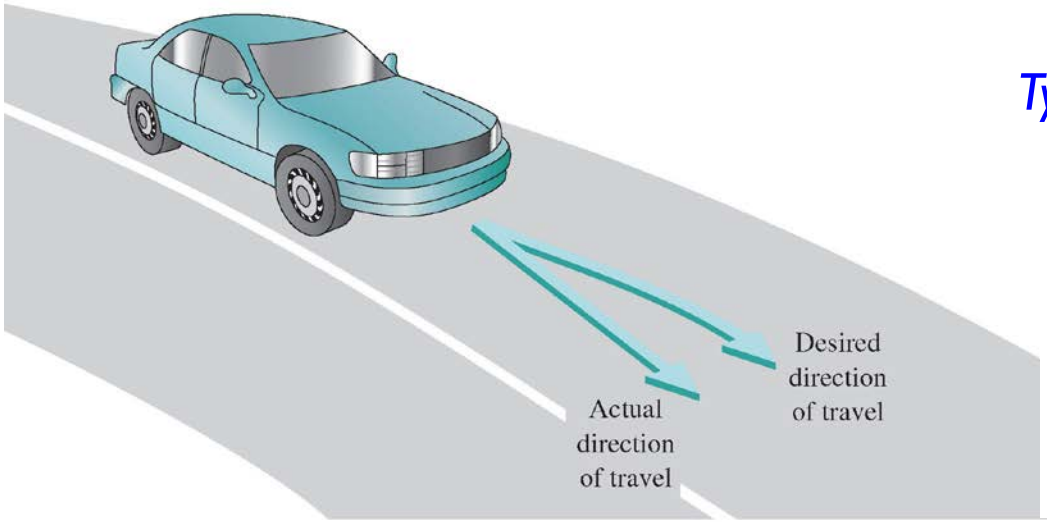
Multiloop Feedback Control System



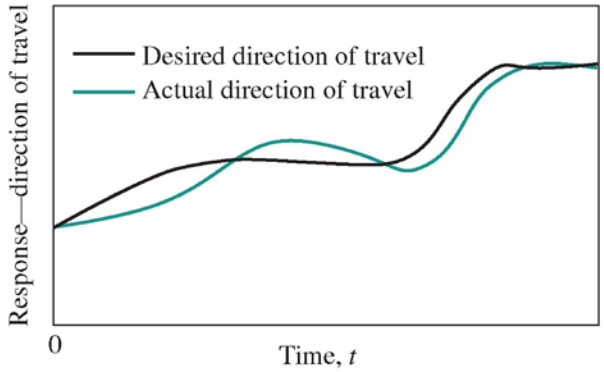
Multivariable Control System



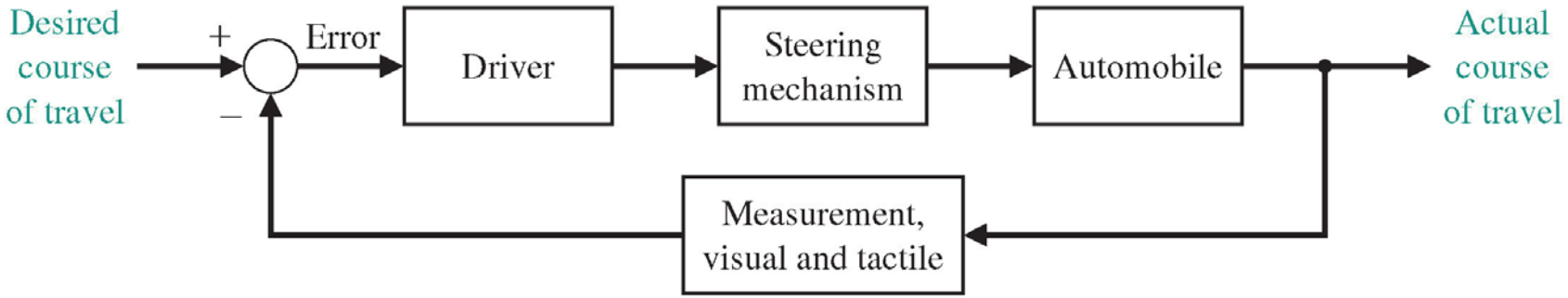
Example 2.2 Automated Vehicles



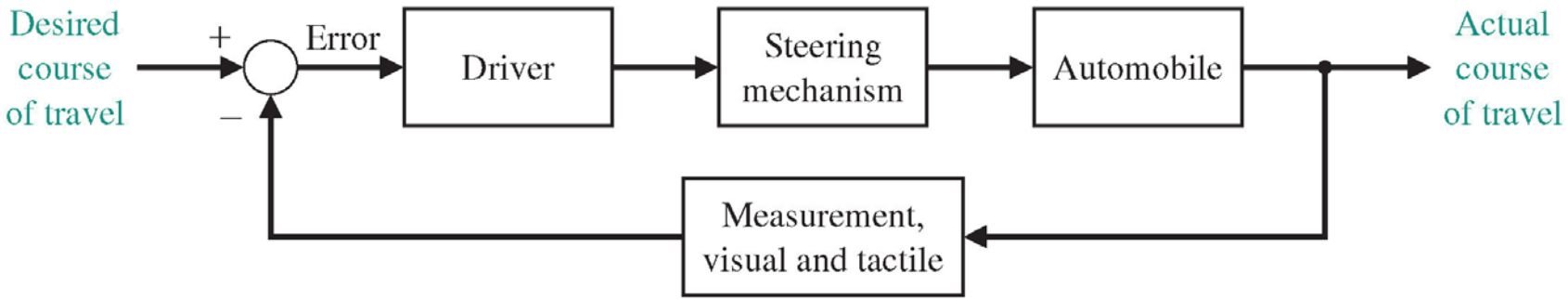
Typical direction-of-travel response.



Automobile steering control system



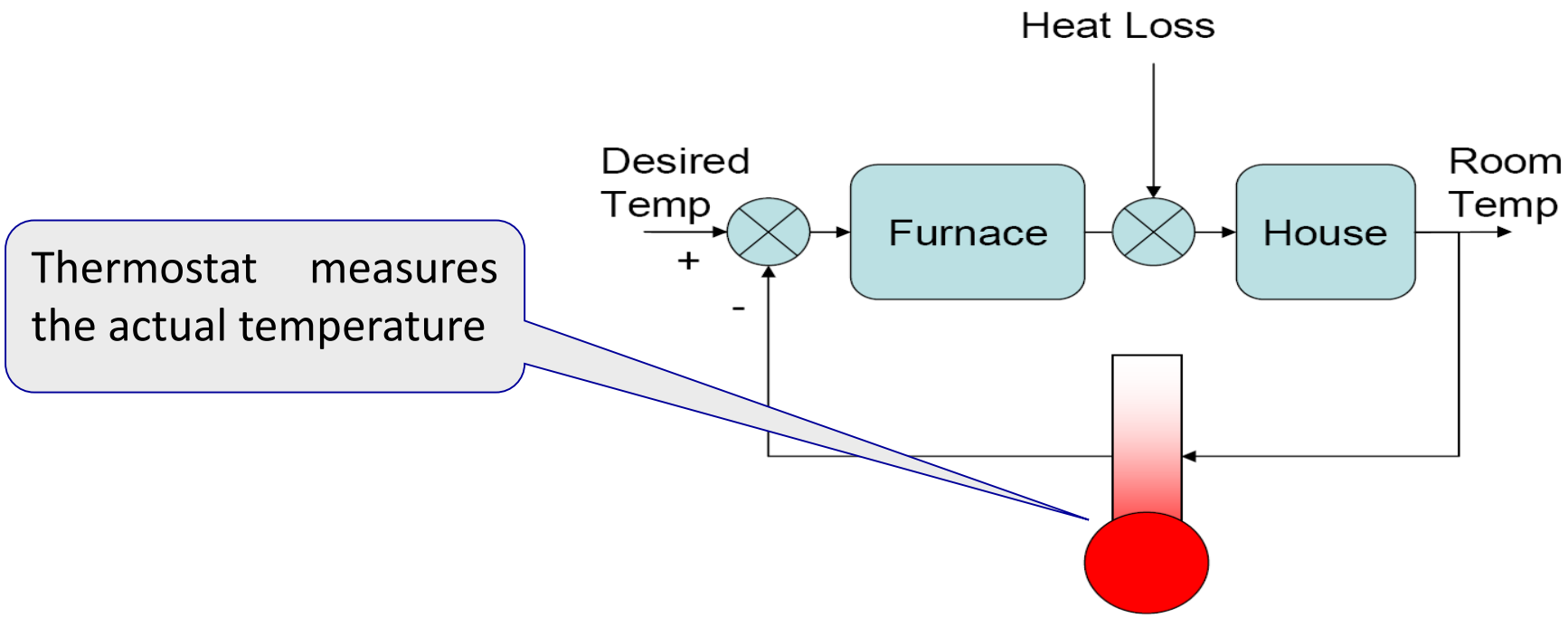
Automobile steering control system



- **Input:** desired course of travel
- **Output:** actual course of travel
- **Sensor:** visual and tactile
- **Actuator**: steering wheel mechanism

Example 2.3: Room Temperature Controller

Room Temperature Controller



The feedback system reaches different steady state depending on environment:

- Rate of heat dissipation through the walls, etc.

Control System Design

Engineering design is the central task of the engineer.

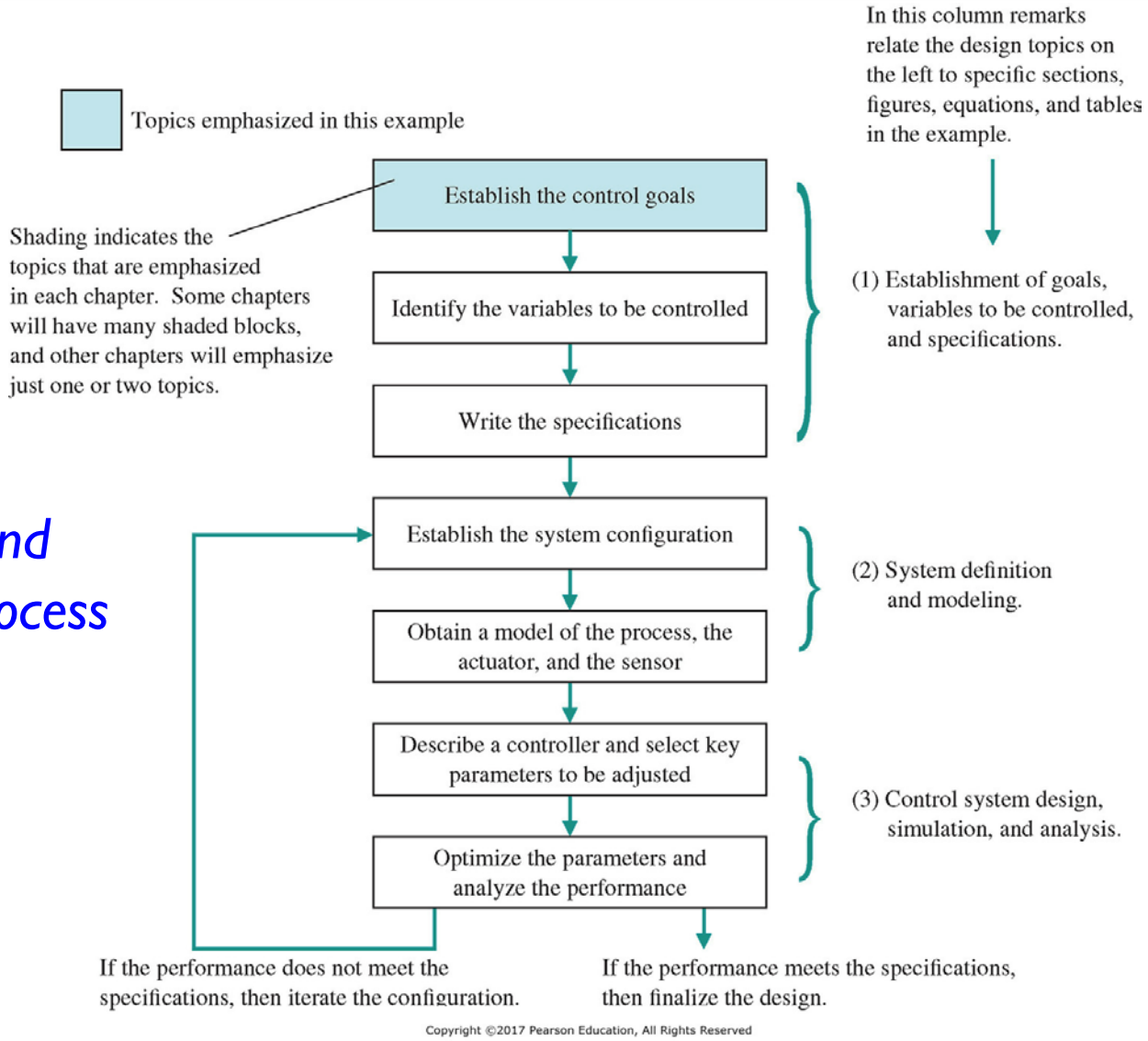
Design is the process of conceiving or inventing the forms, parts, and details of a system to achieve a specified purpose.

The design process consists of seven main building blocks, which we arrange into three groups:

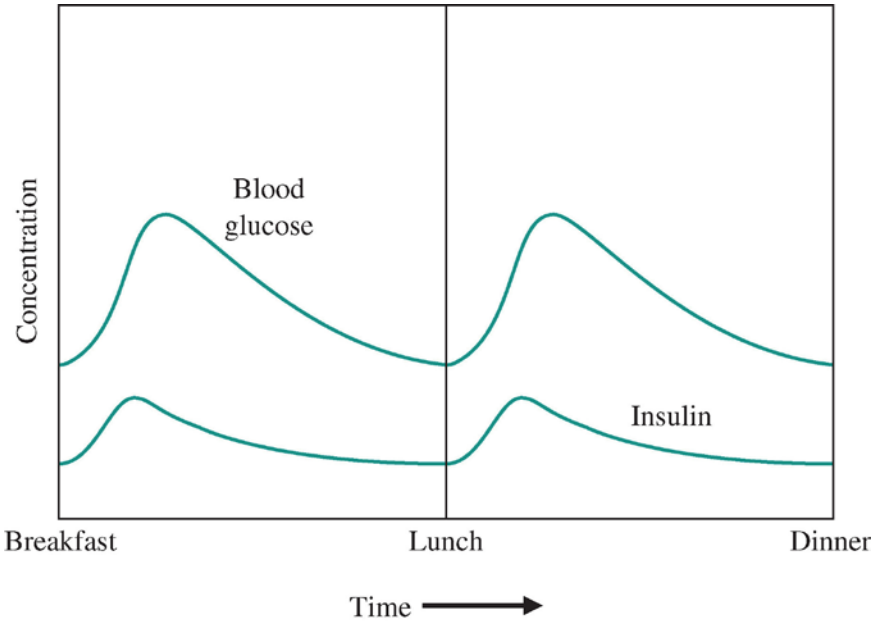
1. Establishment of goals and variables to be controlled, and definition of specifications against which to measure performance
2. System definition and modeling
3. Control system design and integrated system simulation and analysis

Control System Design Process

Iterative and Nonlinear Process



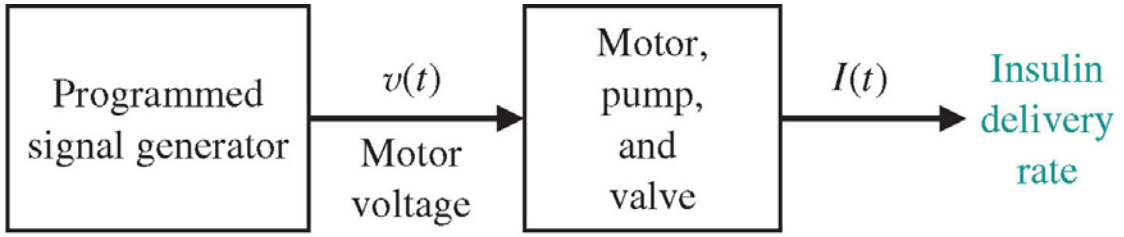
Example 2.4: Design of Insulin Delivery Control System



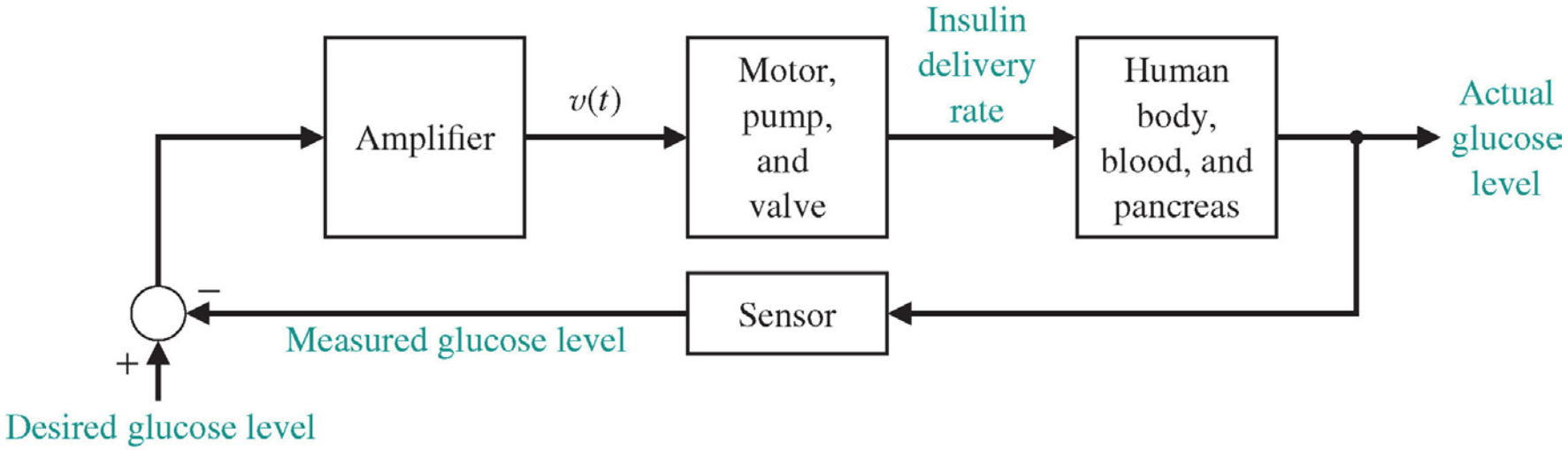
The blood glucose and insulin levels for a healthy person.

- **Control goal**: Design a system to regulate the blood sugar concentration of a diabetic by controlled dispensing of insulin
- **Variable to be controlled**: Blood glucose concentration
- **Control design specifications**: Provide a blood glucose level for the diabetic that closely approximates (tracks) the glucose level of a healthy person.

Example 2.4 (cont'd)



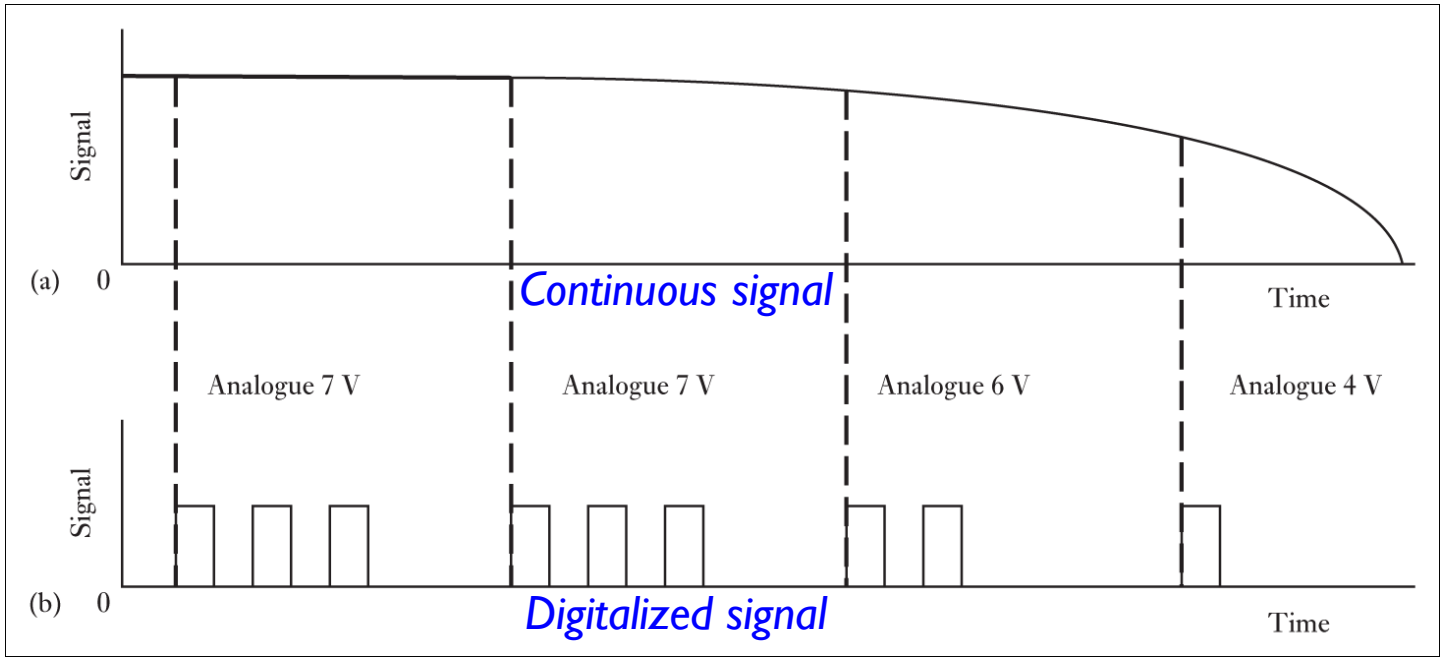
(a)



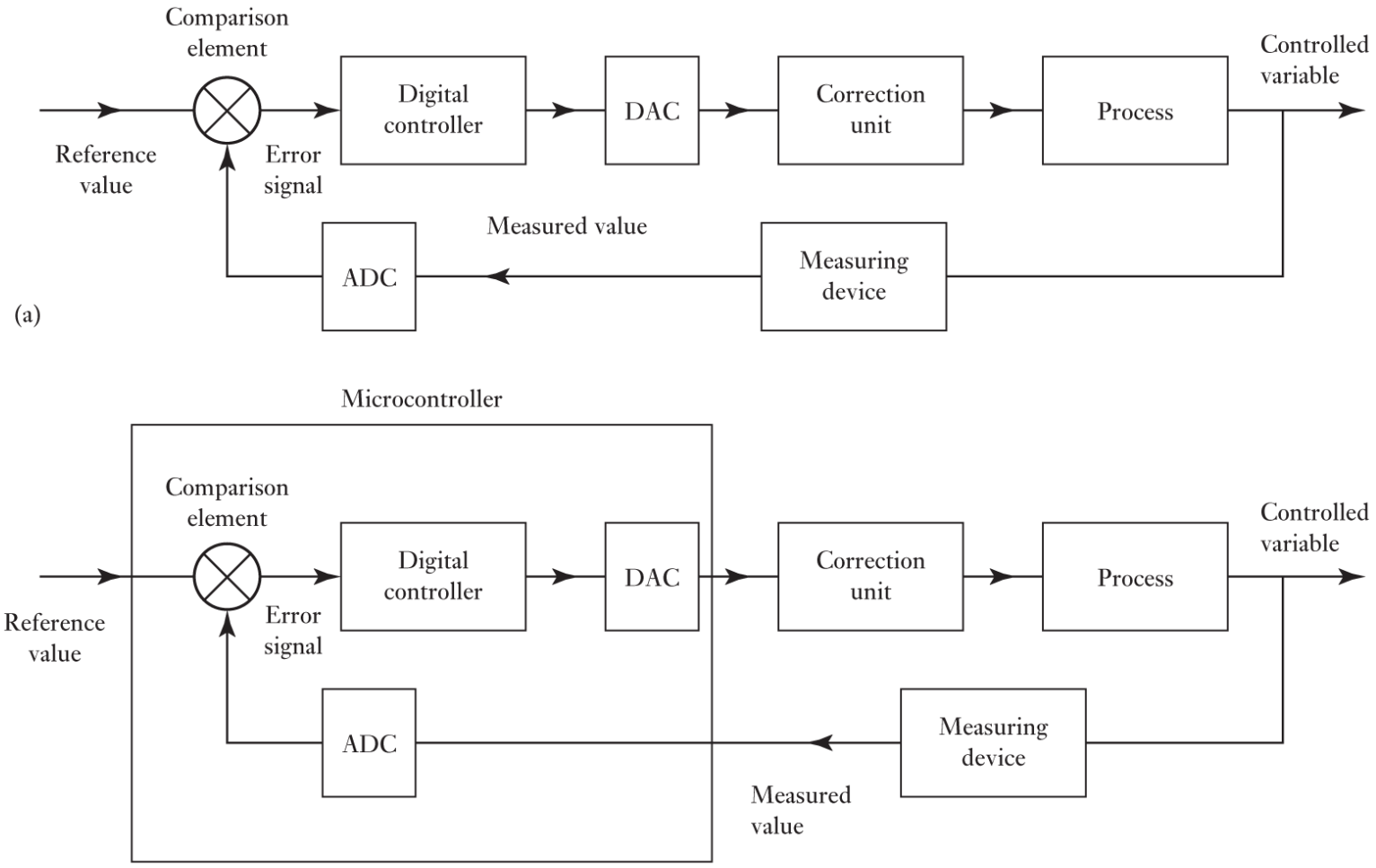
(b)

Analogue and Digital Control System

- **Analogue systems** are systems where all the signals are continuous functions of time;
- **Digital systems** are ones where all the signals can be considered to be a sequence of on/off signals.

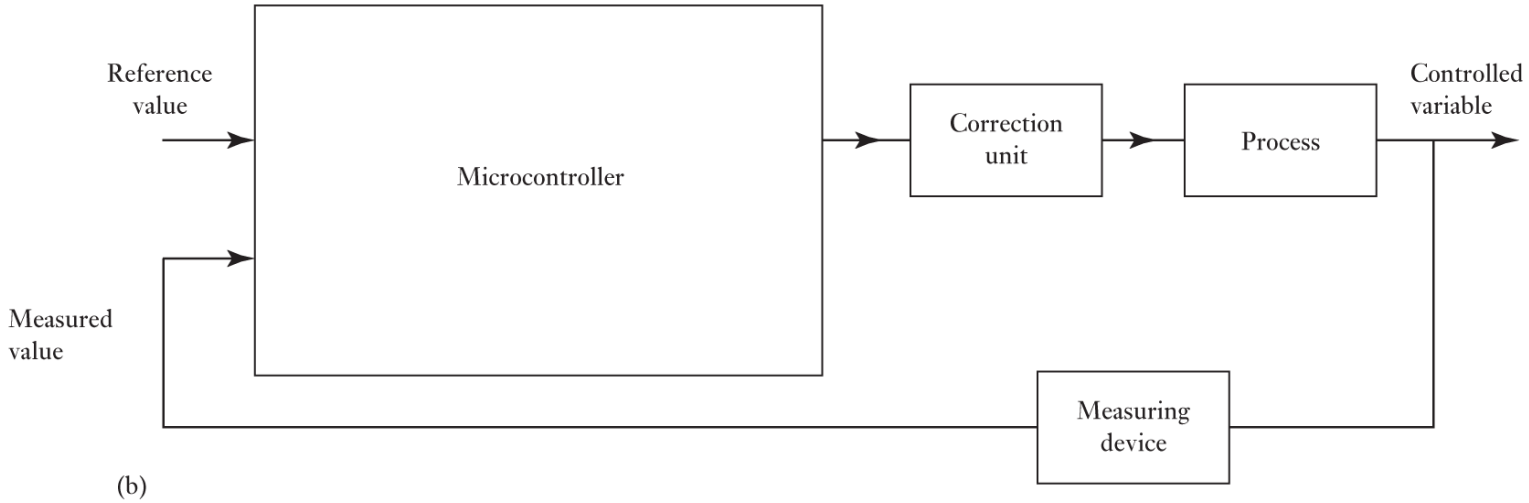


Basic Elements of a Digital Closed-loop Control System



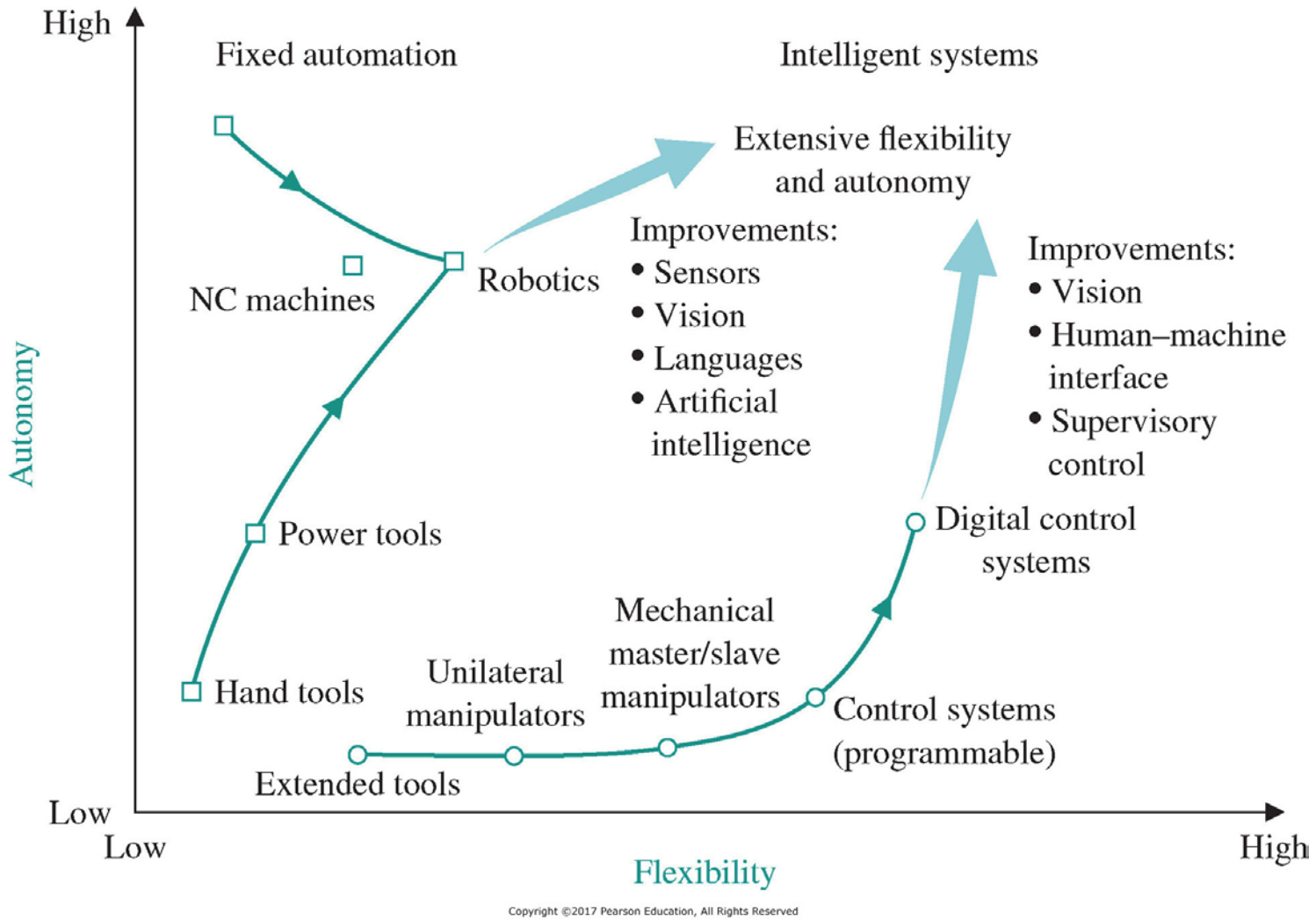
ADC: analogue-to-digital converter; DAC: digital-to-analogue converter.

Features of Digital Control Systems



- Most of the situations being controlled are analogue in nature, it involves ADCs and DACs for digital control systems, it might seem to be adding a degree of complexity;
- However, there are some very important advantages: digital operations can be controlled by a program, i.e., a set of stored instructions; information storage is easier, accuracy can be greater, digital circuits are less affected by noise and also are generally easier to design.

Future Evolution of Control System and Robotics



Thank You !