PROCESS DYNAMICS AND CONTROL

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RECAP

- Control Instrumentation

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OUTLINE

- Stability of dynamic systems
- Closed-loop stability
- Closed-loop transfer functions
  - Block diagram representation
- Stability analysis methods
  - Root locus
  - Bode method

Seborg's book 3rd ed (Int'l ed): Chapter 10
Nikazar's book: Chapters 6, 8, 9, 10.

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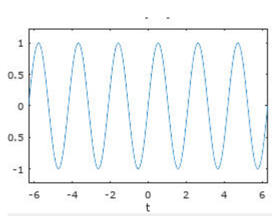
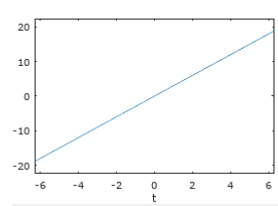
STABILITY OF DYNAMIC SYSTEMS

Bounded-input bounded-output (BIBO) stability

- **Definition**: with all inputs bounded, all outputs must be bounded.
  - sine input
  - Step input
  - Ramp input?





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UNBOUNDED PROCESS OUTPUT

- Unbounded process variables hit a physical limitation (they do not go to infinity!)

- Examples
  - Tank overflow
  - Explosion
  - Vessels burst
  - Product degradation
  - …

These are serious consequences!

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STABILITY VS. GOOD OPERATION

- Stability is a **minimum** requirement for control performance.
- A stable system can have a poor operation (or control performance)

- **Example:**

Reactor with step increase of 1 C in inlet temperature → Steady-state increase of 100 C in outlet temperature!

Stable but very sensitive

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STABILITY OF LINEAR DYNAMIC SYSTEMS

- General form of a linear dynamic system

$$\frac{d^nY}{dt} + a_1\frac{d^{n-1}Y}{dt^{n-1}} + \cdots + a_nY = f(t)$$

Ignore input (assuming bounded)

- Laplace transform (zero initial conditions)

$$(s^n + a_{n-1}s^{n-1} + \cdots + a_1s + a_0)Y(s) = 0$$

- Inverse Laplace

Thomas marlin's Process Control book

$$Y(t) = A_1e^{\alpha_1 t} + \cdots + (B_1 + B_2t + \cdots)e^{\alpha_p t} + \cdots + [C_1\cos(\omega t) + C_2\sin(\omega t)]e^{\alpha_q t} + \cdots$$

All exponents (α) must be negative for BIBO stability

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STABILITY OF LINEAR DYNAMIC SYSTEMS

- Example 1

$$\frac{d^2T'}{dt^2} - 1.23\frac{dT'}{dt} - 1.38T' = 0$$

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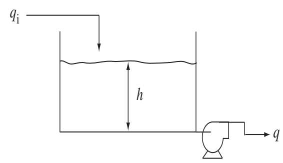
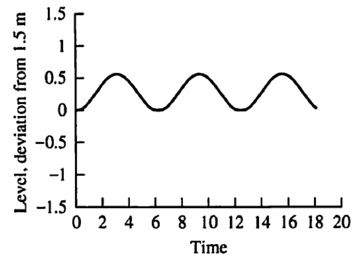
STABILITY OF LINEAR DYNAMIC SYSTEMS

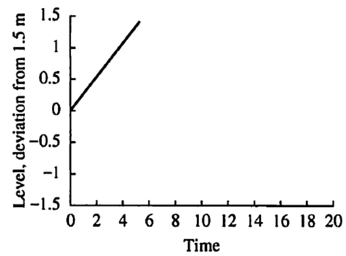
- Example 2



➢Sine response
  ➢Stable
➢Step response
  ➢Unstable

Why different behaviors?





Marlin's Process Control book

SOME REMARKS

- By definition, a stable system must have bounded output for <u>all types </u>of bounded inputs.

- Almost all processes have nonlinear dynamics
  - Use linearized model
    - Local stability (around steady state)
    - Valid <u>only</u> near linearization point.

LOCATION OF ROOTS AND STABILITY

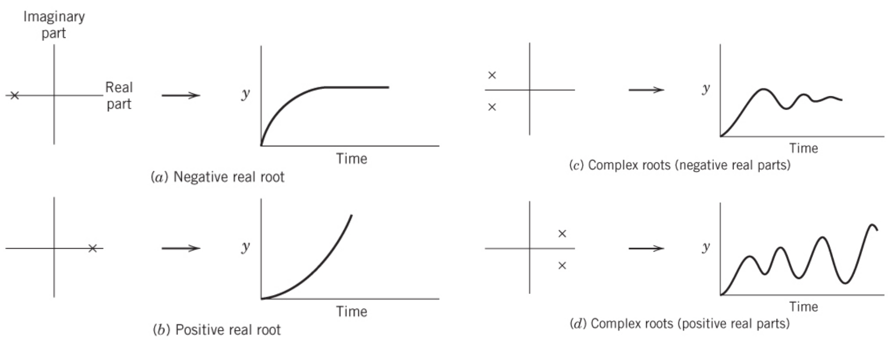


Figure 11.26 Contributions of characteristic equation roots to closed-loop response.

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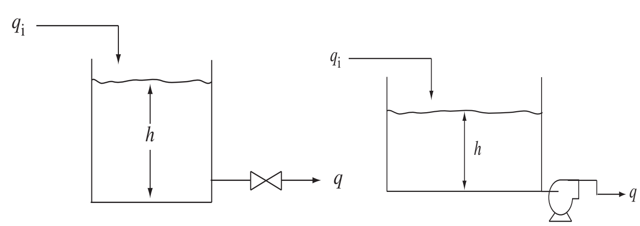
OPEN-LOOP VS. CLOSED-LOOP STABILITY

- **Open-loop stability**: stability without controller
- **Closed-loop stability**: stability with controller

Examples



Importance of closed-loop stability

✓Stability of control designs
✓Tuning of controllers
✓Analysis of control performance

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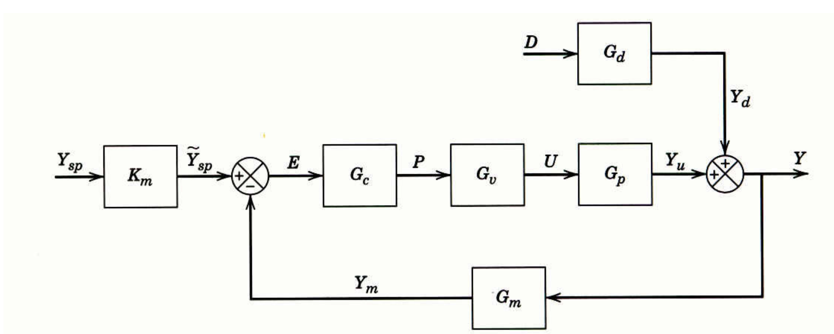
STABILITY OF CLOSED-LOOP SYSTEMS

- Analyze the overall transfer function for stability
- Can a system with a controller go unstable?

STANDARD CLOSED-LOOP BLOCK DIAGRAM



Seborg's el a. Process Dynamics and Control book