

EE 370 Control Systems I

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Outline

- What is a control system?
- History of control.
- Examples of control systems.
- Feedback control.
- What is covered in this course?
 - Modeling, analysis, and design.

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Control System

- System designed to control variables of interest (outputs, controlled variables) through the manipulation of other variables (inputs, control variables).
- Naturally occurring: ecological, physiological
- Man-Made.

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History of Control Systems

- Water clocks, door openers.
- Watt's governor and Maxwell's analysis.
- Vacuum tube amplifiers (Nyquist, Bode, Black).
- World War II.
- Aerospace and military systems.

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Watt's Governor

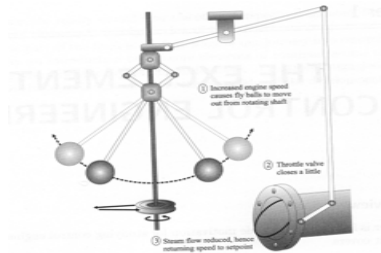


Figure 1.1. Watt's fly-ball governor

Goodwin, Graebe, Salgado, *Control System Design*,
Prentice Hall, 2001.

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Examples of Control Systems

- Temperature control in a furnace.
- Elevator position control.
- Antenna positioning system.
- Robotic manipulator control.
- Control of IC engine.

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Temperature control in a furnace



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Elevator position control



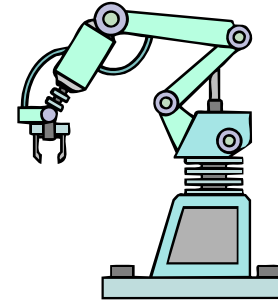
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Antenna Positioning System



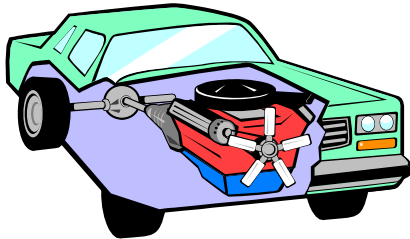
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Robotic Manipulator Control



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Control of IC Engine



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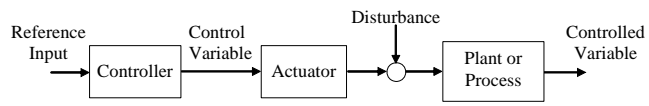
Classification of Control Systems

- **Open-loop control:** No feedback.
- **Closed-loop control:** Feedback control.

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Open-loop Control

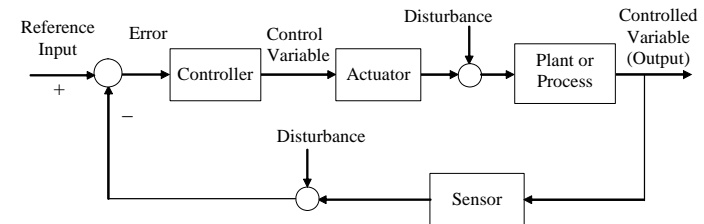
- Controller selects appropriate values for the control variable to produce the desired output e.g. toaster



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Closed-loop (Feedback) Control

- Select appropriate values for the control variable to produce the desired output based on actual and desired output values e.g. position control.



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Closed-Loop Control

Advantages

- *Robustness*: corrects for *modeling errors* and *disturbances*
- Can be designed for a specified *time response*
- Works for an unstable *plant*

Disadvantages

- Additional hardware
- May become *unstable*

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What is covered?

- Mathematical modeling.
- System analysis.
- Control system design.

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Modeling

- Electrical (brief), mechanical (translation & rotation), electromechanical.
- Input-output differential equations.
- Transfer functions: block diagrams.
- State equations
 - Set of first order differential equations.

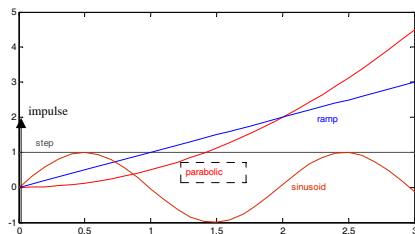
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Analysis

- **Topics:** Stability, transient and steady state response, frequency response.
- **Direct:** Solve the system equations.
 - Laplace transformation.
 - Simulation (numerical solution: EE 370L).
- **Indirect:** Predict behavior without solution.
 - Final value theorem.
 - Routh-Hurwitz criterion: where are the poles?

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Reference Inputs

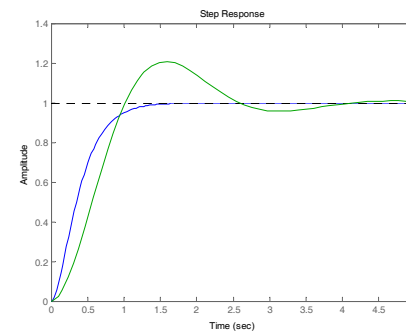


- Use standard mathematical forms:
 - Impulse $A\delta(t)$
 - Step $\mathbf{1}(t)$
 - Parabolic $t^2/2$
 - Sinusoid $\sin(\omega t)$ or $\cos(\omega t)$

Notation: Assume all time functions zero for negative time.

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Step Response: Elevator



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Design

- **Open-loop control:** blind as a bat.
- **Closed-loop control:** feedback.
 - Better control.
 - Possible instability.
 - More difficult design.
- **Controller design:** add controller to loop to obtain satisfactory behavior.
- **Controller type:** analog or digital.

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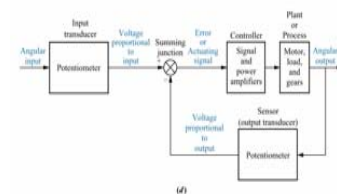
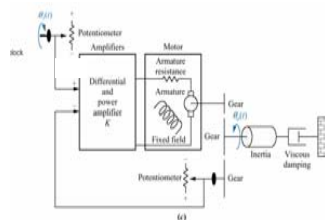
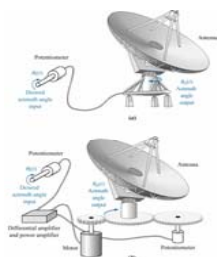
Modeling, Analysis, Design

1. Determine system specifications.
2. Draw schematic.
3. Draw block diagram.
4. Mathematically model components.
5. Simplify block diagram.
6. Verify model and analyze system behavior.
7. Design and check controller.

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Fig. 1.9: Antenna azimuth position control system

- a. system concept;
- b. detailed layout;
- c. schematic;
- d. block diagram



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Conclusion

- Control systems: in nature & man-made.
- Feedback control.
- Modeling.
- Analysis.
- Design.

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