Creating Simulation Diagrams

Basic concepts and methods

ES205 Analysis and Design of Engineering Systems
Rose-Hulman Institute of Technology

Why use block/simulation diagrams?

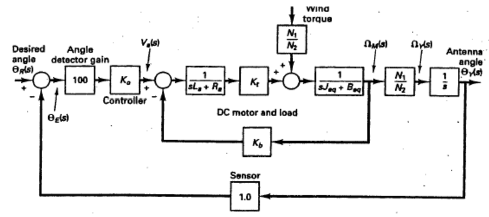
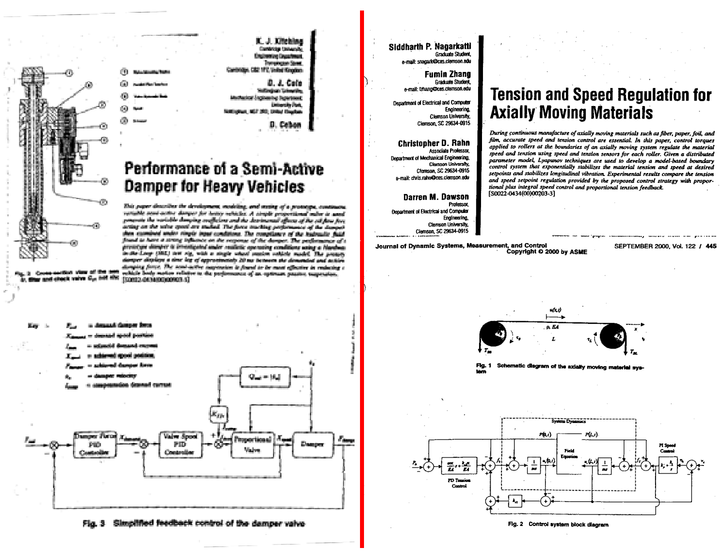


Figure 3.21 A system to control the angular displacement of an antenna.

- Required for Simulink
- Provides a visual representation and shows causal relationships
- Handles non-linearity easily



Basic terminology

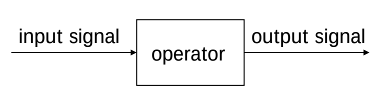
- Simulation diagram
  - a graphical representation of a set of EOM
  - linear or nonlinear, algebraic, 1st-order, 2nd-order, or higher-order ODEs
- Block diagram
  - a graphical representation of a set of EOM using transfer functions (linear, s-domain, zero ICs)

Skills to practice

- You should be able to convert
  - ODE model ⇆ sim-diag model
  - ODE model ⇆ TF model
  - 1st- and 2nd-order TFs to standard form
- Also
  - Learn basic terminology
  - Given a TF, draw its block diagram

Blocks, inputs, and outputs

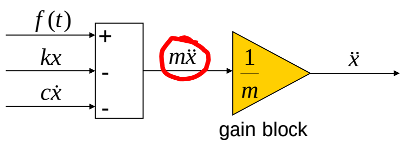
- A *block* is a symbol that represents a mathematical operation
- A *signal* is represented by an arrow
- The *input signal* (to the block) is operated on to produce the *output signal* (of the block)



Coefficient

$$m\ddot{x} = f(t) - c\dot{x} - kx$$

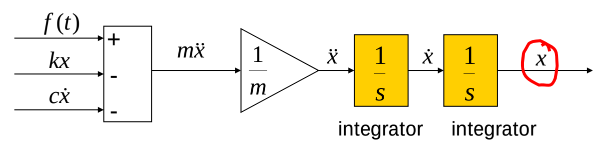
- Does the output of the summer have a coefficient?
  - Add a gain (multiplier) block to eliminate the coefficient and produce the highest-derivative alone



Integrators

$$m\ddot{x} = f(t) - c\dot{x} - kx$$

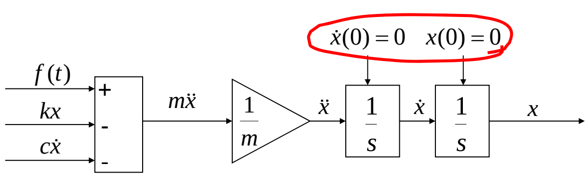
- Add integrators to obtain the desired output variable



ICs

$$m\ddot{x} = f(t) - c\dot{x} - kx$$

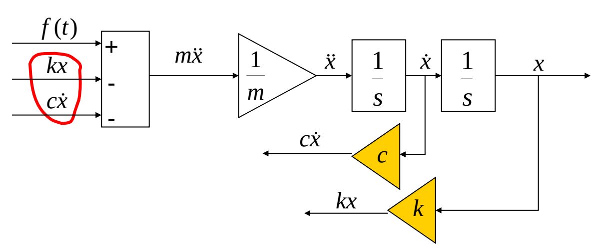
- Add initial conditions to the integrators



Feedback

$$m\ddot{x} = f(t) - c\dot{x} - kx$$

- Do any signals feedback to the summer?
  - Yes. Connect to the integrated signals with gain blocks to create the necessary signals



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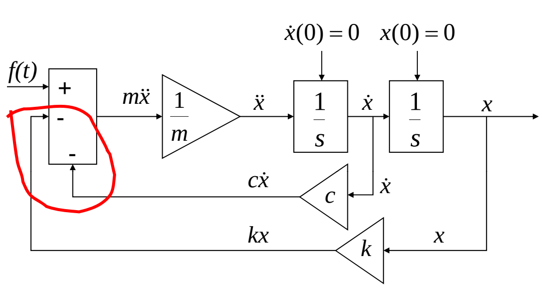
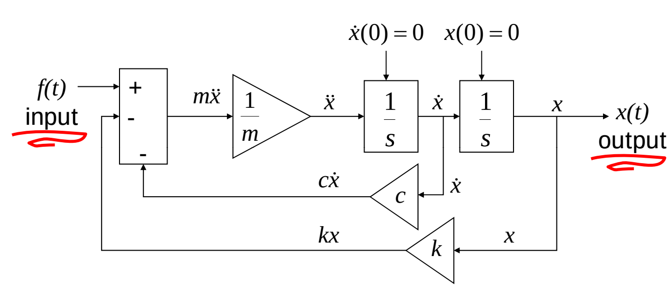
- Connect the feedback signals to the summer



Inputs/outputs

$$m\ddot{x} = f(t) - c\dot{x} - kx$$

- Identify inputs and outputs

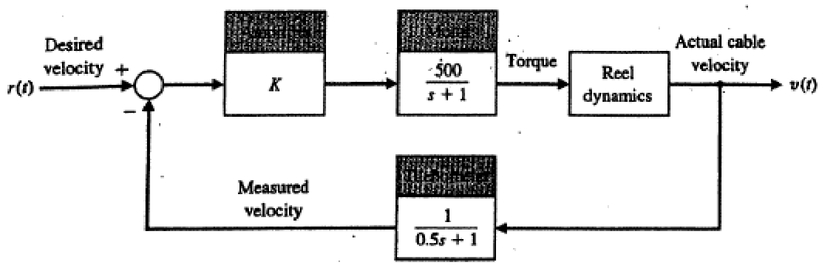


Example 1

- Identify for the examples shown:
  - summing points
  - branch points
  - gain blocks
  - transfer function blocks
- On example block diagrams
  - locate inputs and outputs

P2.31 A cable reel control system uses a tachometer to measure the speed of the cable as it leaves the reel. The output of the tachometer is used to control the motor speed of the reel as the cable is unwound off the reel.

QUICK EXAM



Example 2

- Identify for the examples shown:
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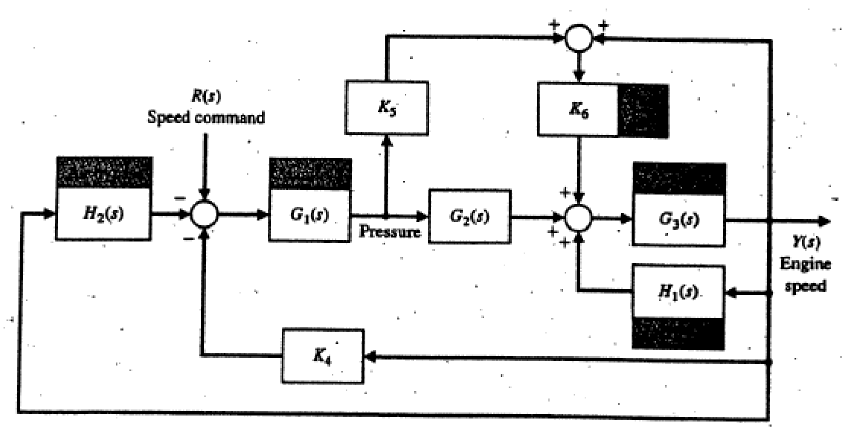


Simulation diagram examples

- 2nd-order ODE, by example
- 1st-order ODE, your turn

Example 1

- Create a simulation diagram model that solves the following ODE
  - 2nd-order mass-spring-damper system
  - zero initial conditions
  - input $f(t)$ is a step with magnitude 3
  - parameters: $m = 0.25$, $c = 0.5$, $k = 1$

$$m\ddot{x} + c\dot{x} + kx = f(t)$$

Solve for highest derivative

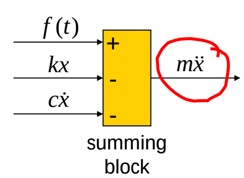
- Solve for the term with highest-order derivative

$$m\ddot{x} = f(t) - c\dot{x} - kx$$

Summer

$$m\ddot{x} = f(t) - c\dot{x} - kx$$

- Make the left-hand term the output of a summing block
- Make the right-hand term(s) the input(s) to the summing block



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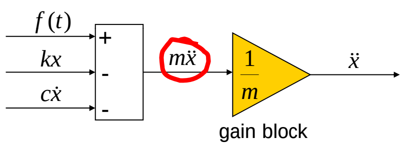

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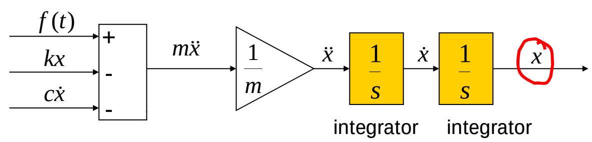

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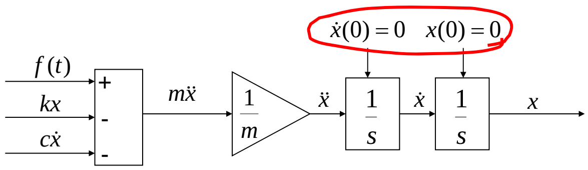

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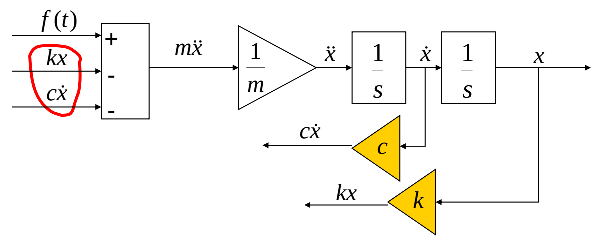

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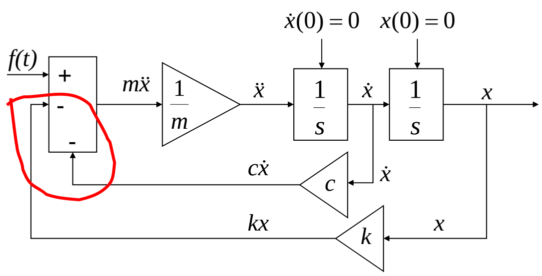

Inputs/outputs

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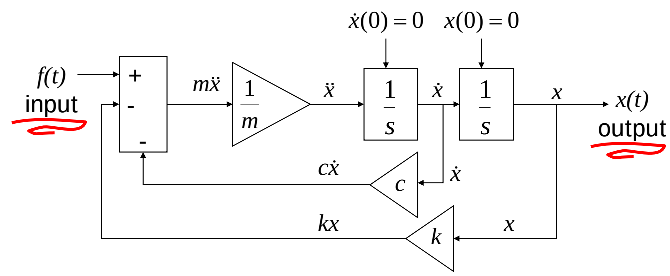
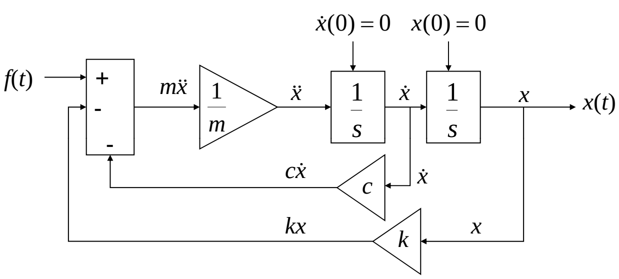
- Identify inputs and outputs



Simulation

$$m\ddot{x} = f(t) - c\dot{x} - kx$$

- Simulation diagram is complete
- Run in Simulink



Example 2 (your turn)

- Create a simulation diagram model that solves the following 1st-order ODE
  - IC: $x(0) = 2$

$$\tau\dot{x} + x = u(t)$$

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$$\tau \dot{x} + x = u(t)$$

Terms used on the worksheet

Steady State Value is the final value of the system settles at after transient behavior has dissipated.

Overshoot is characterized as the maximum response swing past the steady state value.

Rise time is time required for the system to rise from ten to ninety percent of the steady state value.

Settling time is the amount of time the system takes to value settle close to the steady state condition (to within approximately 2% of the step size).