Creating Simulation Diagrams

Basic concepts and methods

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

Why use block/simulation diagrams?

- 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

Feedback

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

- 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

Example 2

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

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

Coefficient

- 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

- Add integrators to obtain the desired output variable
**ICs**

\[ m\ddot{x} = f(t) - cx - kx \]

- Add initial conditions to the integrators

![ICs Diagram]

**Feedback**

\[ m\ddot{x} = f(t) - cx - kx \]

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

![Feedback Diagram]

**Inputs/outputs**

\[ m\ddot{x} = f(t) - cx - kx \]

- Identify inputs and outputs

![Inputs/outputs Diagram]

**Simulation**

\[ m\ddot{x} = f(t) - cx - kx \]

- Simulation diagram is complete
- Run in Simulink

![Simulation Diagram]

**Example 2 (your turn)**

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

\[ \tau \dot{x} + x = u(t) \]
Example 2 (your turn)

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

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

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 settle close to the steady state condition (to within approximately 2% of the step size).