Introduction to Simulink
What is a System?

- A **system** is an assemblage of components or elements intended to act together to accomplish an objective.

- The view of a system as a set of interconnected elements is what has been called the **“systems approach”** to problem solving.

- The behavior of a system is specified by its **input-output relation**, which is a description – usually mathematical – of how the output is affected by the input.

- There are two types of systems: **static and dynamic**.

- Engineering dynamic systems can be **small-scale** and **large-scale**.
What is a Block Diagram?

• **Block Diagram**
  – A block diagram of a system is a pictorial representation of the functions performed by each component and of the flow of signals. It describes a set of relationships that hold simultaneously.
  – A block diagram contains information concerning dynamic behavior, but it does not include any information on the physical construction of the system.
  – Many dissimilar and unrelated systems can be represented by the same block diagram.
  – A block diagram of a given system is not unique.
Electro-Pneumatic Transducer: An Engineering System

Note the three methods of engineering communication: picture, schematic, & block diagram!

Block Diagram of an Electro-Pneumatic Transducer
Temperature Feedback Control System: A Larger-Scale Engineering System

Block Diagram of a Temperature Control System

Desired Temperature (set with $R_V$)

Actual Temperature (measured with $R_C$)

$T_C$
What is Simulink?

- **Simulink** is an extension to MatLab that allows engineers to rapidly and accurately build computer models of **dynamic physical systems** using **block diagram** notation.
  - linear and nonlinear systems
  - continuous-time and discrete-time components
  - graphical animations are possible
- **Previously**, a block diagram of the dynamic system mathematical model was created and then the block diagram was translated into a programming language.
- **In Simulink**, the computer program is the block diagram and this eliminates the risk that the computer program may not accurately implement the block diagram.
Simulink uses the Mathematical Model represented in Block Diagram form and predicts the dynamic response (solves the equations) of the physical model (not the actual physical system).

Focus of Our Attention Here

Introduction to Simulink
Physical System Simplifying Assumptions
- Rigid support
- Pure and ideal spring
- Pure and ideal viscous damper
- One degree-of-freedom motion; x direction
- Rigid attached mass
- System is vertical; g acts down in +x direction

\[ \sum F = ma \]
\[ Ma = -Bv - Kx + F(t) \]
\[ Ma + Bv + Kx = F(t) \]
\[ a = \frac{1}{M} (-Bv - Kx + F(t)) \]
Simulink Block Diagram

Spring-Mass-Damper System

1/s means integration in Simulink

To Workspace Block sends selected output to workspace for plotting, analysis, etc.

Gain Block multiplies the input by the gain value

Gain Block: K spring constant

Gain Block: 1/mass

Integration: acceleration to velocity

Integration: velocity to position

To Workspace

Position: X

Gain Block: B damping coefficient

Summation Block

Step Input: Force F

Gain Block

1/M

acc

vel

pos

Introduction to Simulink

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Why is Simulink Important?

- The potential productivity improvement and cost savings realized from the block diagram approach to programming is dramatic.
- There are two principal strategies for Simulink employment.
  - **Rapid Prototyping**
    - This is the application of productivity tools to develop working prototypes in the minimum amount of time. Here we optimize for development speed, rather than execution speed or memory use. A hierarchy of physical models is used in this phase. Physical system design and control design are optimized simultaneously.
– **Rapid Application Development**

  • Here the final computer program is the Simulink model or is derived from the Simulink model through automatic C-code generation.
Introduction to Simulink

MatLab Desktop

Current Directory / Workspace

Command Window

Command History

Simulink Icon
Introduction to Simulink

File → New → Model
Simulink Block Diagram Manipulations

Left click, hold, drag and drop to bring a block from the Simulink Library to the model workspace.

Left Double Click anywhere on the model workspace and start typing to add annotations.

Right single click on a block, hold, and move away to duplicate it.

Left single click on the output port of a block, hold, and move to input port of another block to connect two blocks.

Right single click on a line and hold to branch off to connect to another block.

Right Single Click on any block to change its appearance and format. Left Double Click on any block to set its parameters and functions.
• **Some Simulink Block Diagram Suggestions**
  – Careful arrangements of blocks and signal lines can make relationships easier to follow.
  – Naming blocks and signal lines and adding annotations to the model can make the purpose of the model elements easier to understand.
  – The Best Way to ensure that your Simulink Block Diagram accurately represents your mathematical model equations is to write your mathematical model equations directly from the Simulink Block Diagram and then compare your result to the actual equations. This will uncover any errors before you start to use your block diagram to investigate model behavior.
Spring-Mass System Mathematical Model

\[ \sum F = ma \]
\[ Ma = -Bv - Kx + F(t) \]
\[ a = \frac{dv}{dt}, \quad v = \frac{dx}{dt} \]
\[ v \rightarrow \int \rightarrow x \]
\[ Ma + Bv + Kx = F(t) \]
\[ a = \frac{1}{M} (-Bv - Kx + F(t)) \]

Introduction to Simulink
Initial Conditions

a \rightarrow \int \rightarrow v \quad v \rightarrow \int \rightarrow x
\[ a = \frac{1}{M}(-Bv - Kx + F(t)) \]
\[ a = \frac{1}{M}(-Bv - Kx + F(t)) \]
\[ a = \frac{1}{M} (-Bv - Kx + F(t)) \]
\[ a = \frac{1}{M}(-Bv - Kx + F(t)) \]
\[
a = \frac{1}{M} (-Bv - Kx + F(t))
\]
\[ a = \frac{1}{M} (-Bv - Kx + F(t)) \]
\[ a = \frac{1}{M} (-Bv - Kx + F(t)) \]
\[ a = \frac{1}{M} \left( -Bv - Kx + F(t) \right) \]
Simulation → Configuration Parameters → Solver
Simulation → Configuration Parameters → Data Import/Export
% Spring-Mass-Damper System KCC 2008

F = 100;  % force in N
K = 491.1;  % spring constant in N/m
B = 20;  % damping constant in N/m/s
M = 5.23;  % mass in kg
x0 = 0;  % x initial condition
v0 = 0;  % v initial condition

M-File for Parameters

Start Simulation
>> whos

<table>
<thead>
<tr>
<th>Name</th>
<th>Size</th>
<th>Bytes</th>
<th>Class</th>
<th>Attributes</th>
</tr>
</thead>
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<td>8</td>
<td>double</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>1x1</td>
<td>8</td>
<td>double</td>
<td></td>
</tr>
<tr>
<td>K</td>
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<td>M</td>
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<td>tout</td>
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<td>24008</td>
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<tr>
<td>v0</td>
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<td>x</td>
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<td>x0</td>
<td>1x1</td>
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<td>double</td>
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</tr>
</tbody>
</table>

>>
```matlab
>> whos
    Name      Size Bytes Class Attributes
    B         1x1     8 double          
    F         1x1     8 double          
    K         1x1     8 double          
    M         1x1     8 double          
    tout      3001x1  24008 double      
    v0        1x1     8 double          
    x         3001x1  24008 double      
    x0        1x1     8 double          

>> plot(tout, x);
>> grid
>> xlabel('time (sec)')
>> ylabel('x position (meters)')
>> title('Spring-Mass-Damper System Force Step Response: F = 100 N')
```
Spring-Mass-Damper System Force Step Response: $F = 100$ N