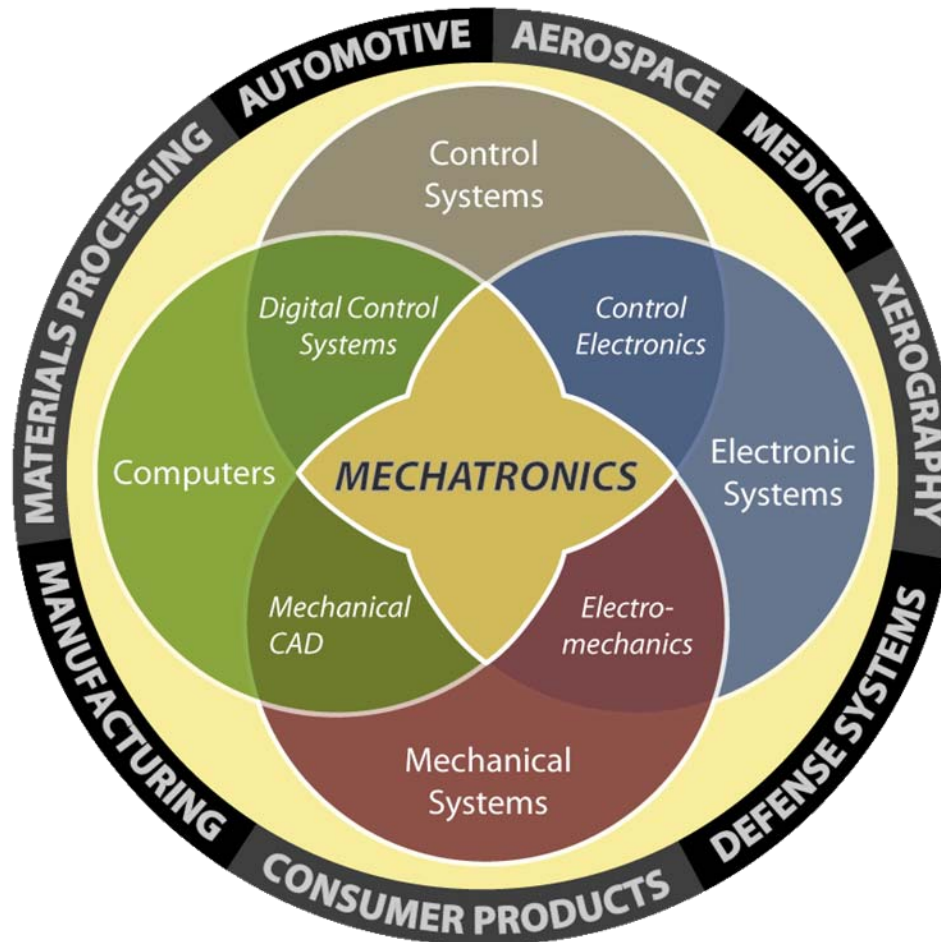


Introduction to Simulink

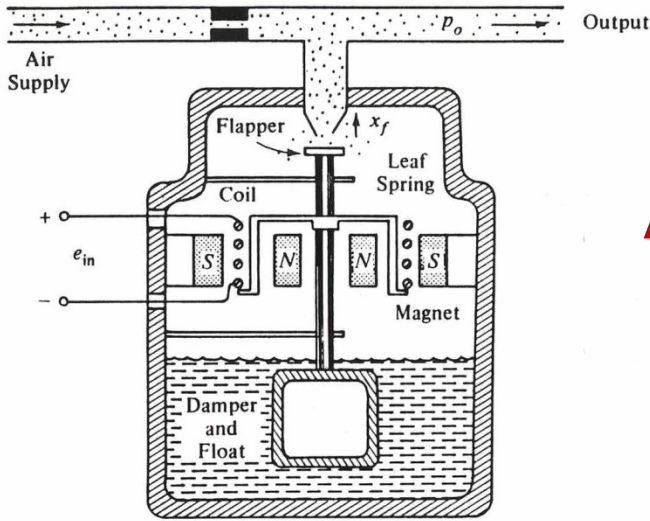


What is a System?

- 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.

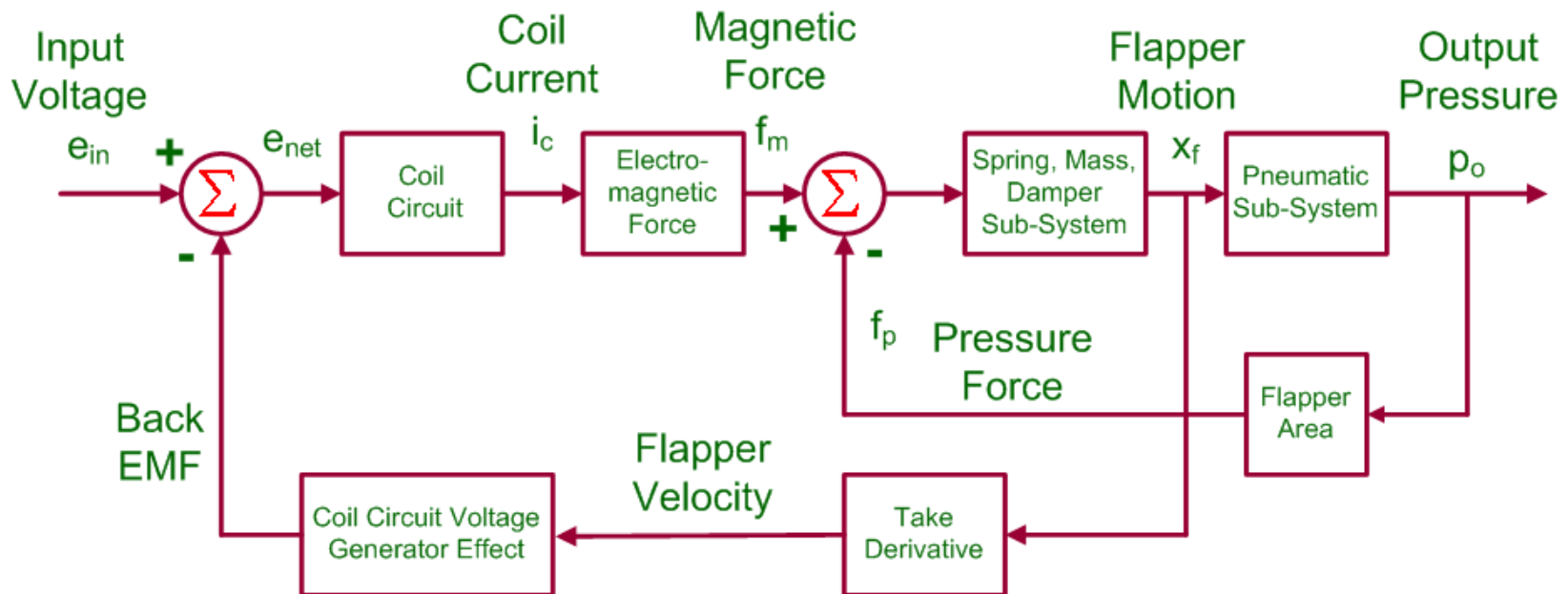


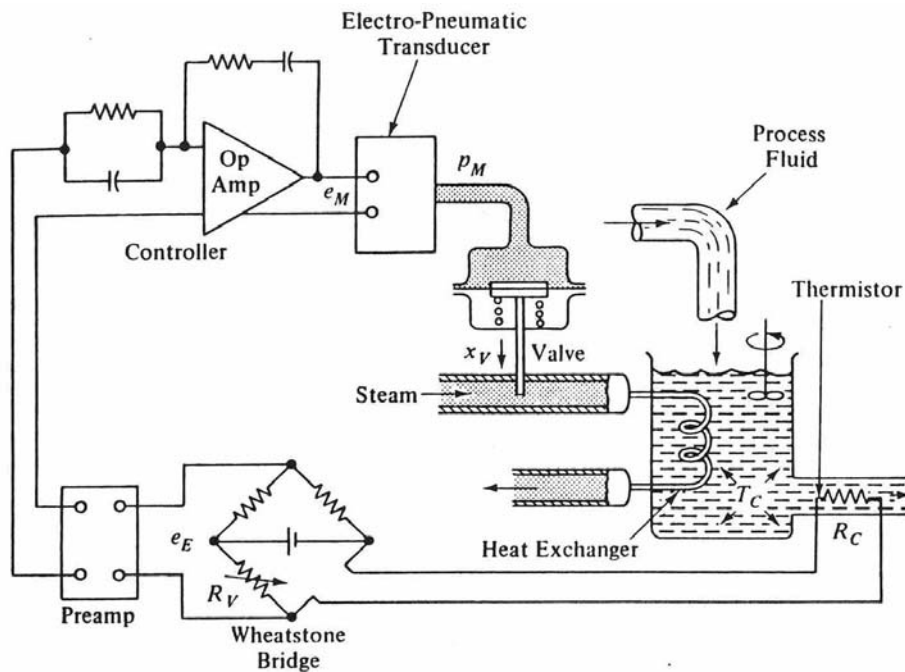
Electro-Pneumatic Transducer: An Engineering System

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



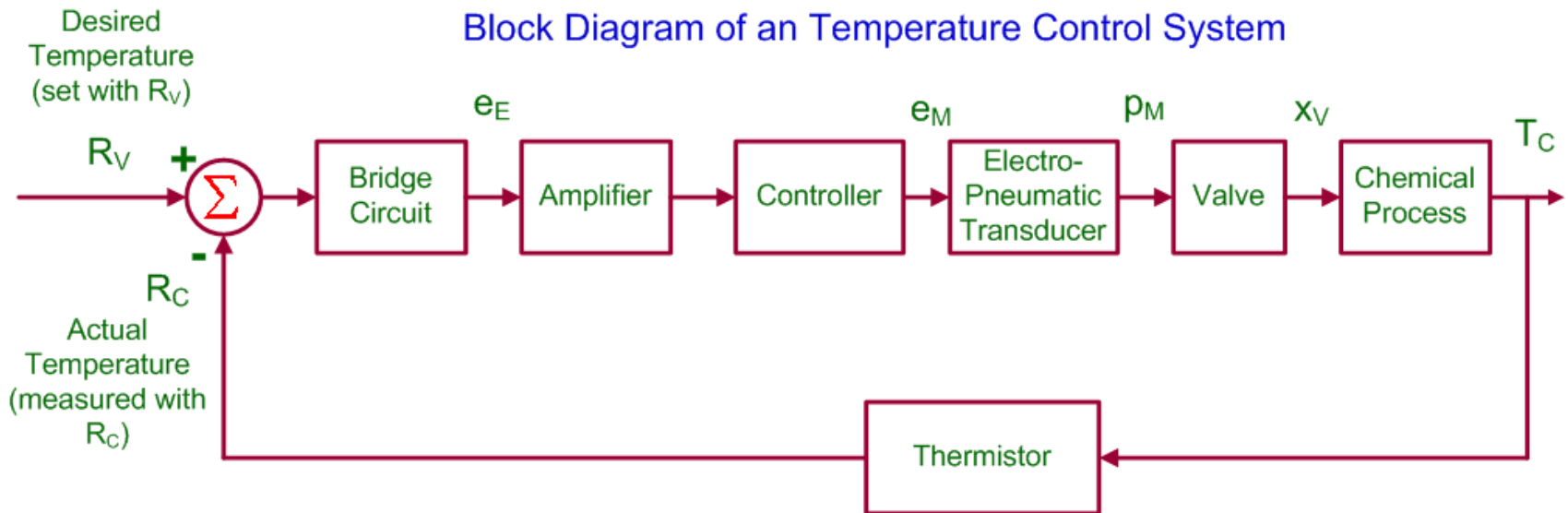
Block Diagram of an Electro-Pneumatic Transducer



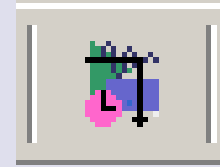


Temperature Feedback Control System: A Larger-Scale Engineering System

Block Diagram of an Temperature Control System

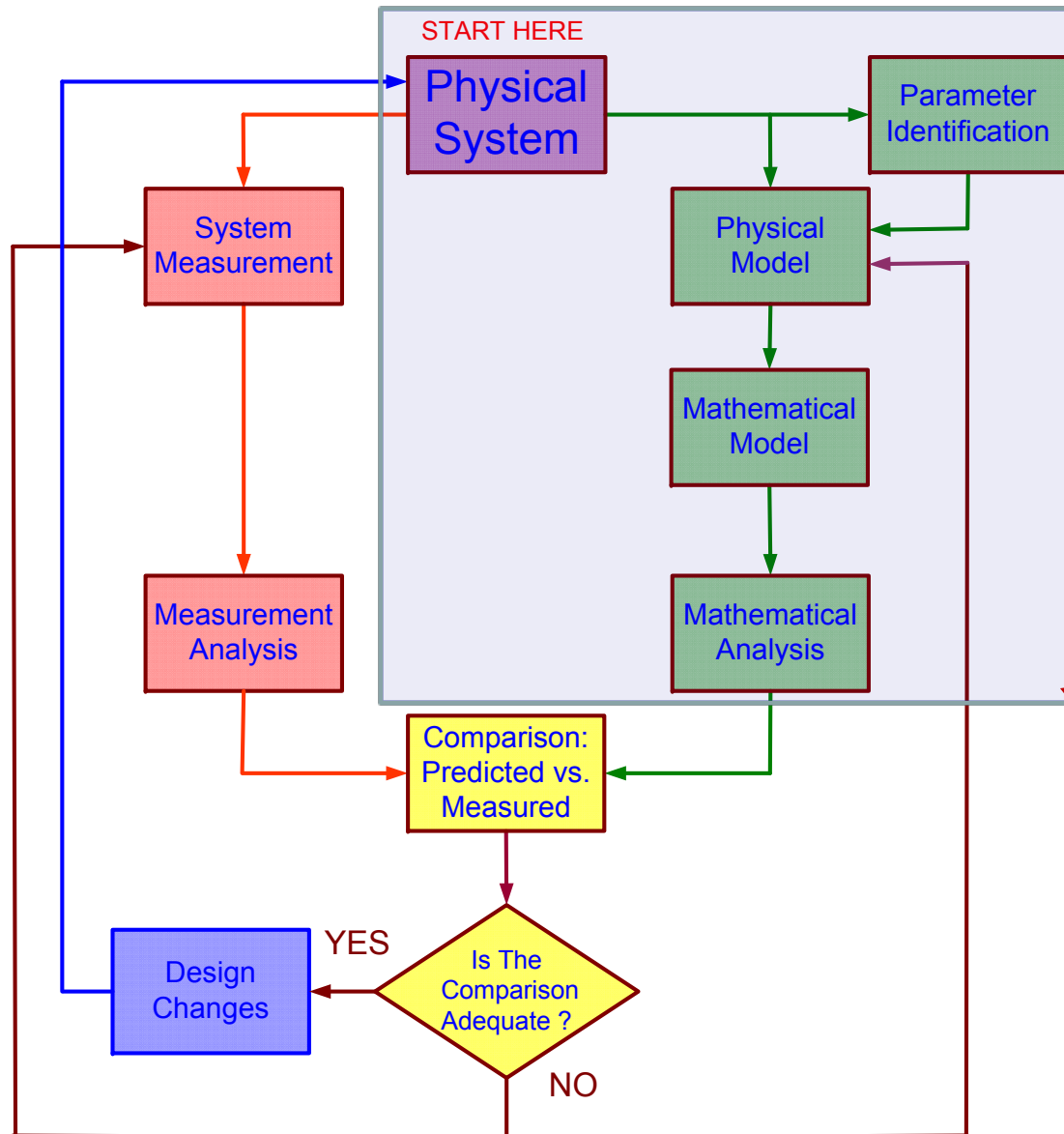


What is Simulink?



- 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.

Engineering System Investigation Process

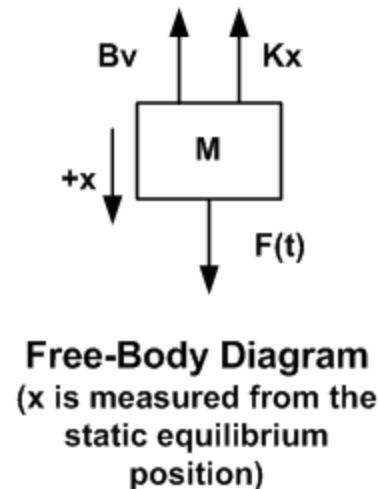
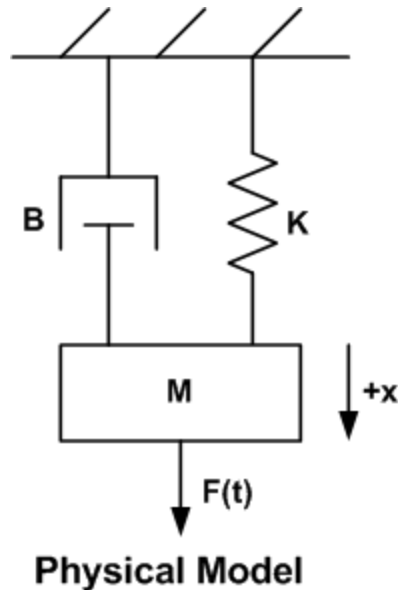


Simulink uses the Mathematical Model represented in Block Diagram form and predicts the dynamic response (solves the equations) of the physical model (not the actual physical system).

**Focus
of
Our Attention Here**

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



Mathematical Model



$$\sum F = ma$$

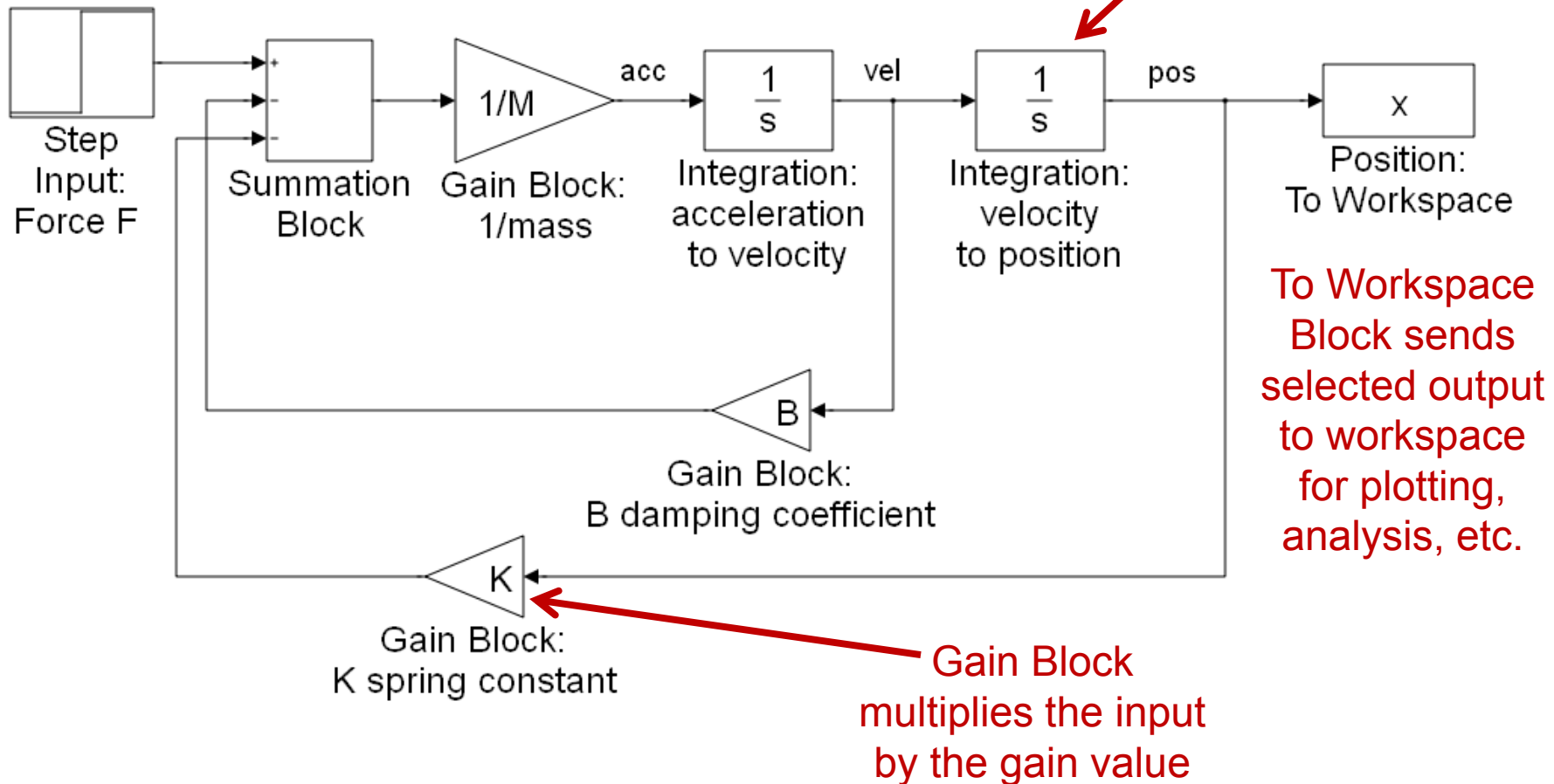
$$Ma = -Bv - Kx + F(t)$$

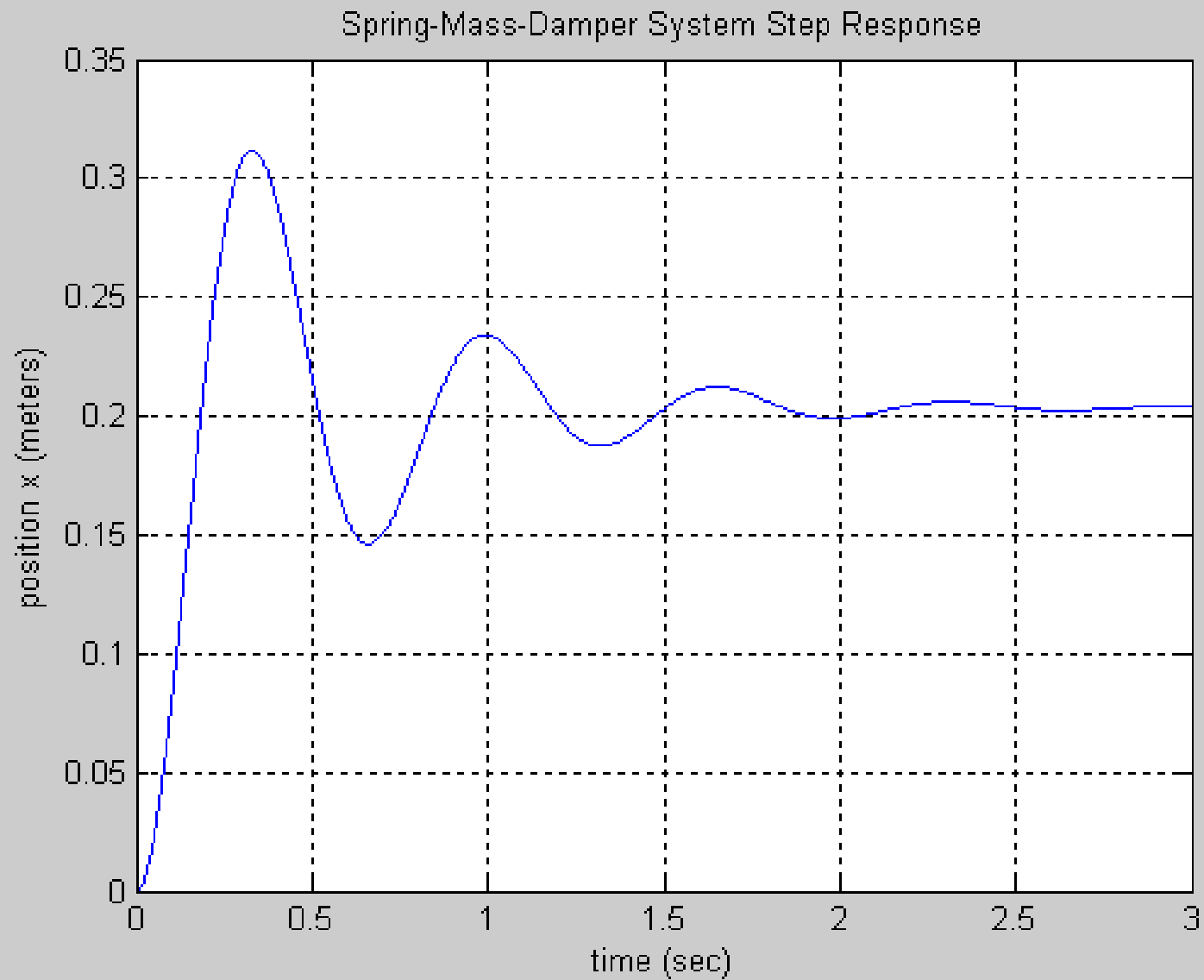
$$Ma + Bv + Kx = F(t)$$

$$a = \frac{1}{M}(-Bv - Kx + F(t))$$

Simulink Block Diagram

Spring-Mass-Damper System



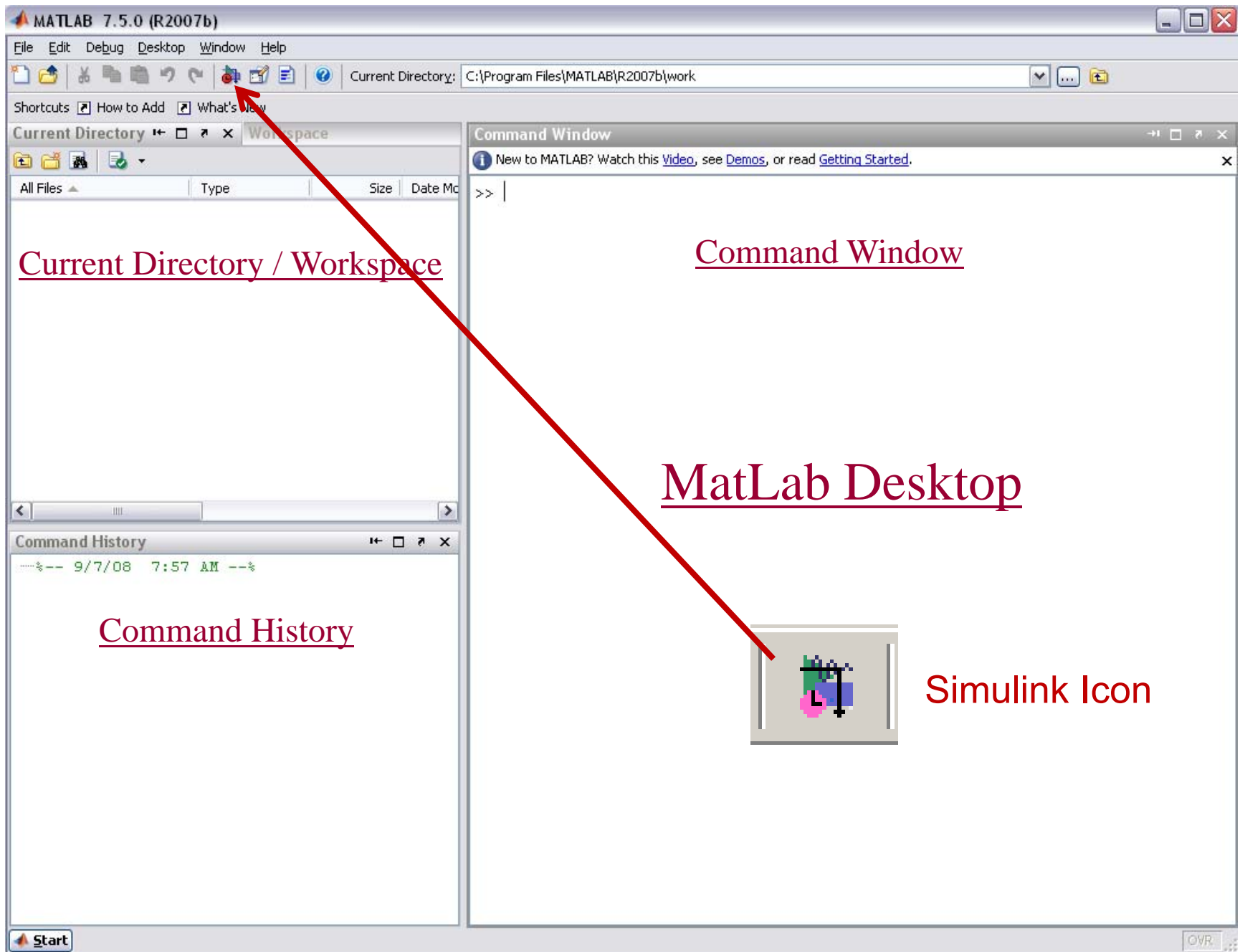


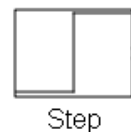
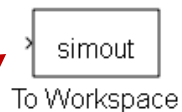
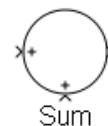
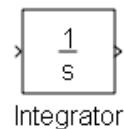
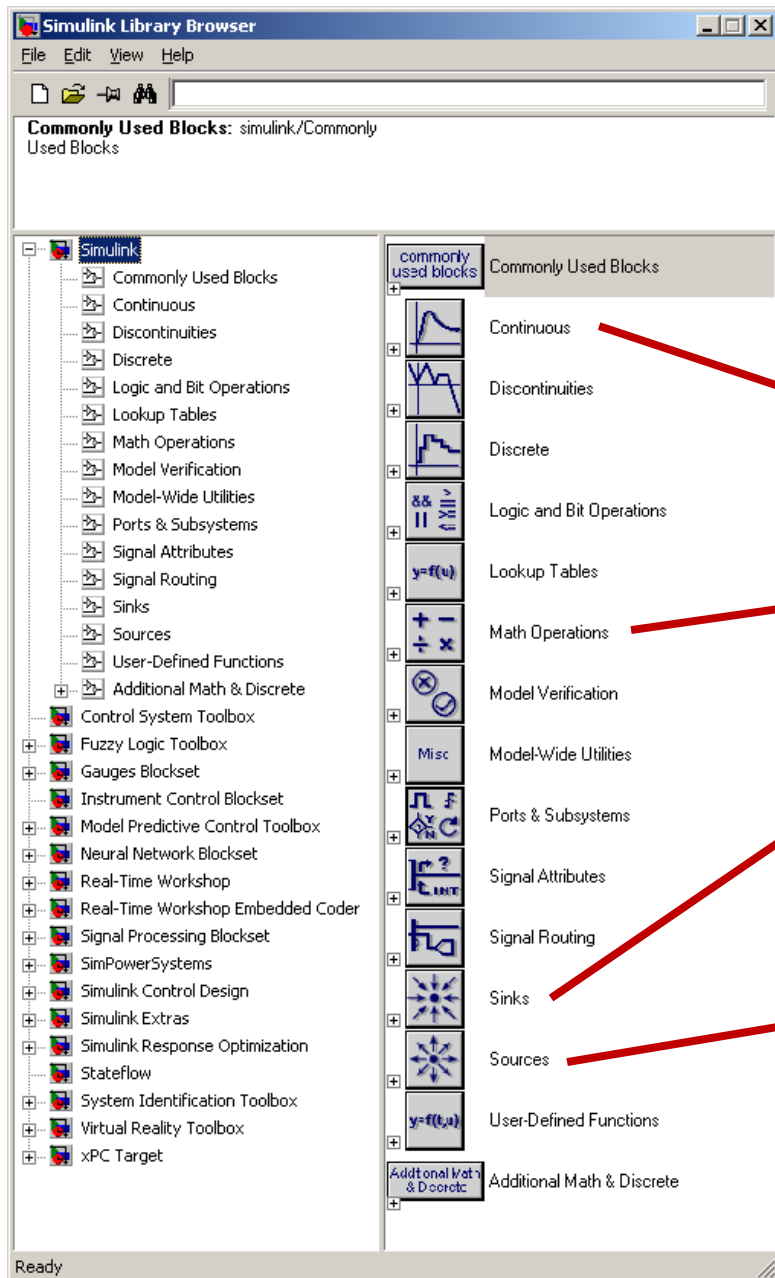
Why is Simulink Important?

- 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.

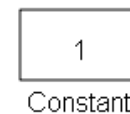
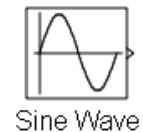
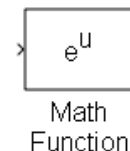
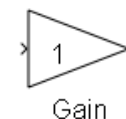
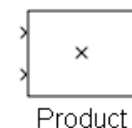
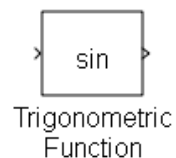
– Rapid Application Development

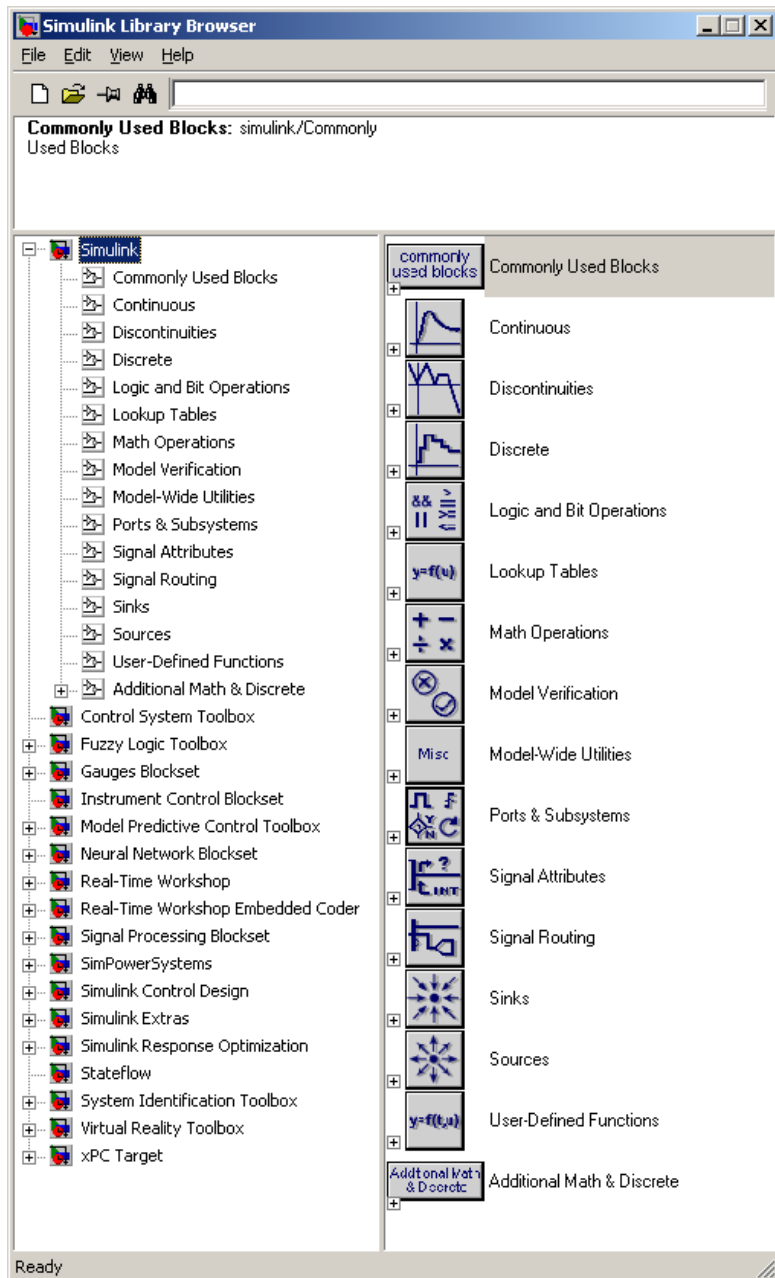
- Here the final computer program is the Simulink model or is derived from the Simulink model through automatic C-code generation.



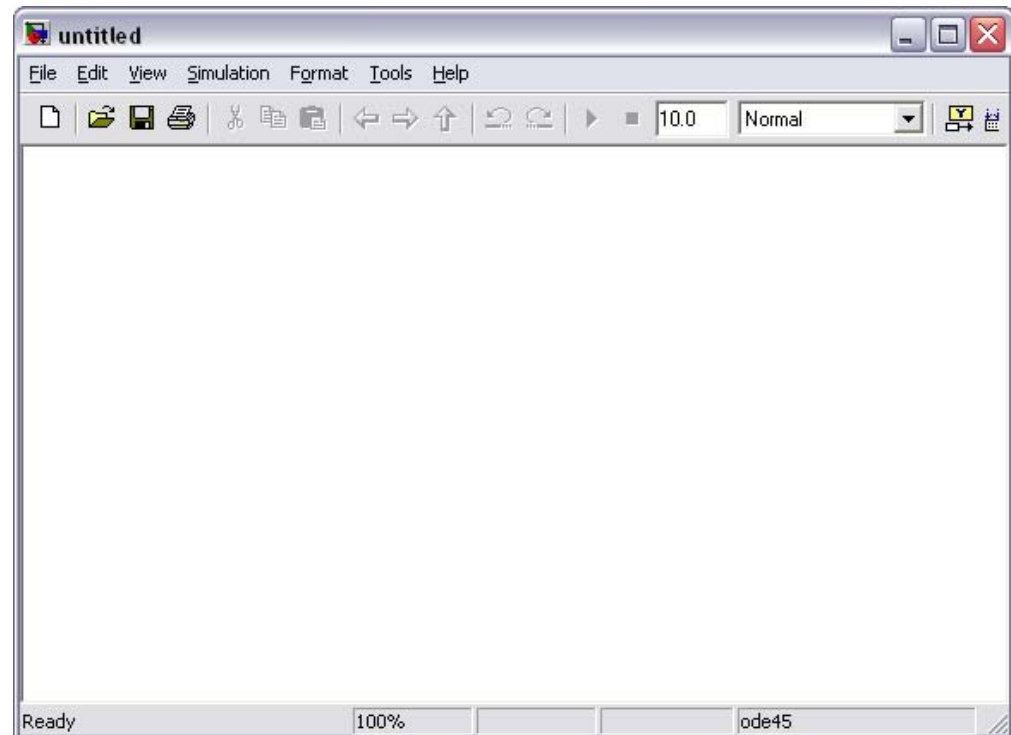


Commonly Used Simulink Blocks





File → New → Model



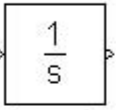
Simulink Block Diagram Manipulations

spring_mass_damper_2008_example


File Edit View Simulation Format Tools Help

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

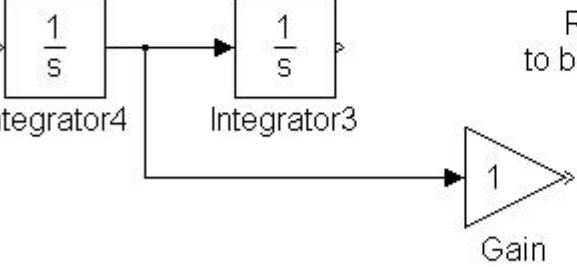
Left Double Click anywhere on the model workspace and start typing to add annotations.

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

Integrator

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

Integrator2 Integrator1

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

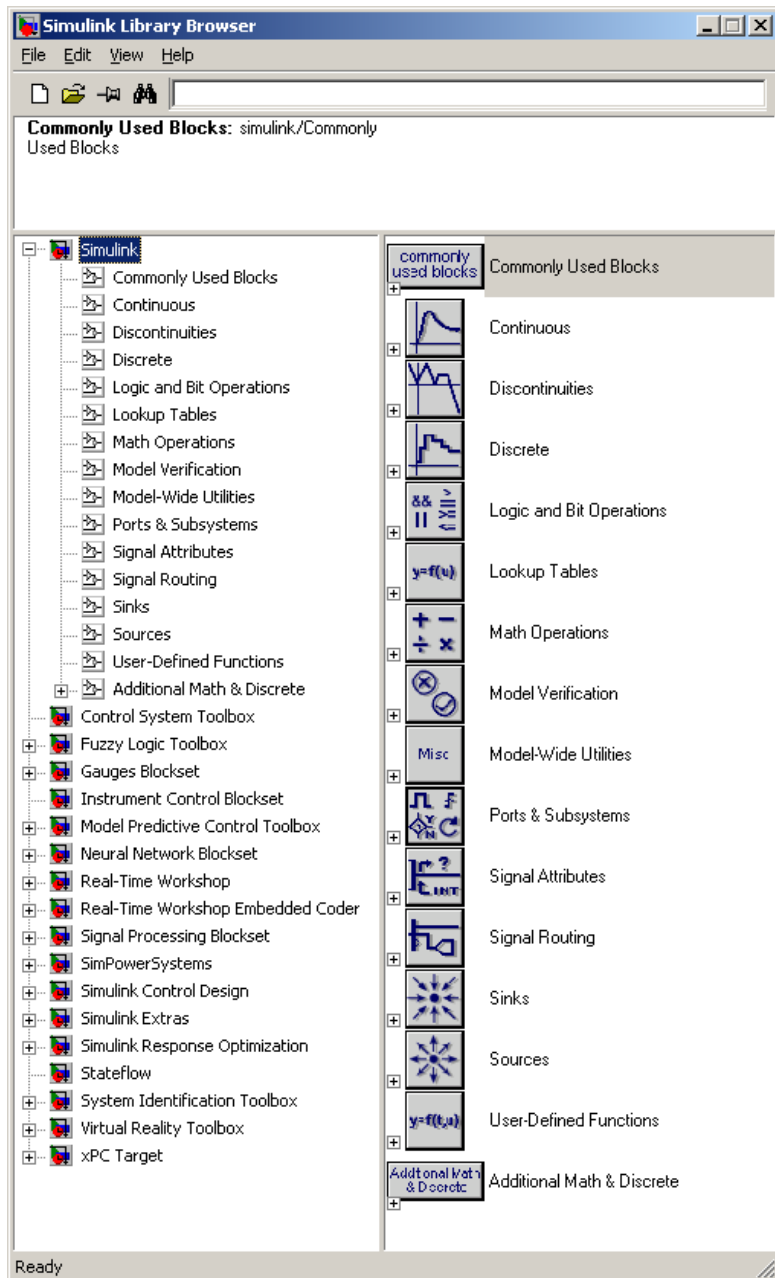
Integrator4 Integrator3 Gain

Right Single Click on any block to change its appearance and format.

Left Double Click on any block to set its parameters and functions.

Ready 100% ode5

- 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

$$\sum F = ma$$

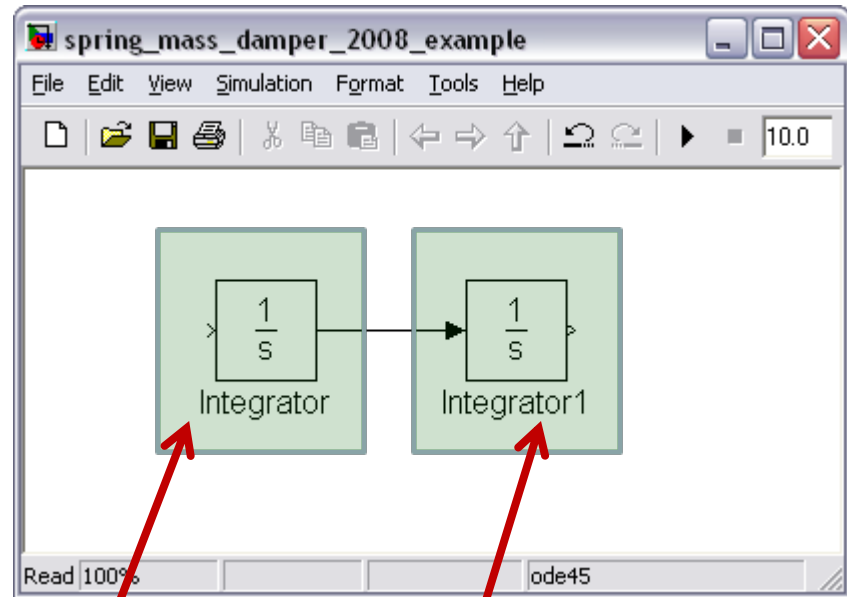
$$Ma = -Bv - Kx + F(t)$$

$$a = \frac{dv}{dt} \quad v = \frac{dx}{dt} \quad a \rightarrow \int \rightarrow v$$

$$v \rightarrow \int \rightarrow x$$

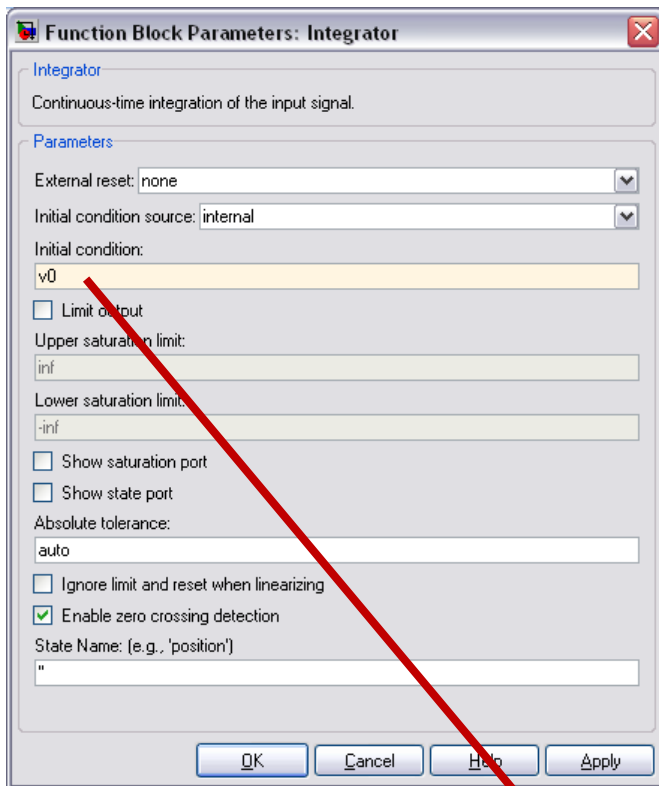
$$Ma + Bv + Kx = F(t)$$

$$a = \frac{1}{M}(-Bv - Kx + F(t))$$

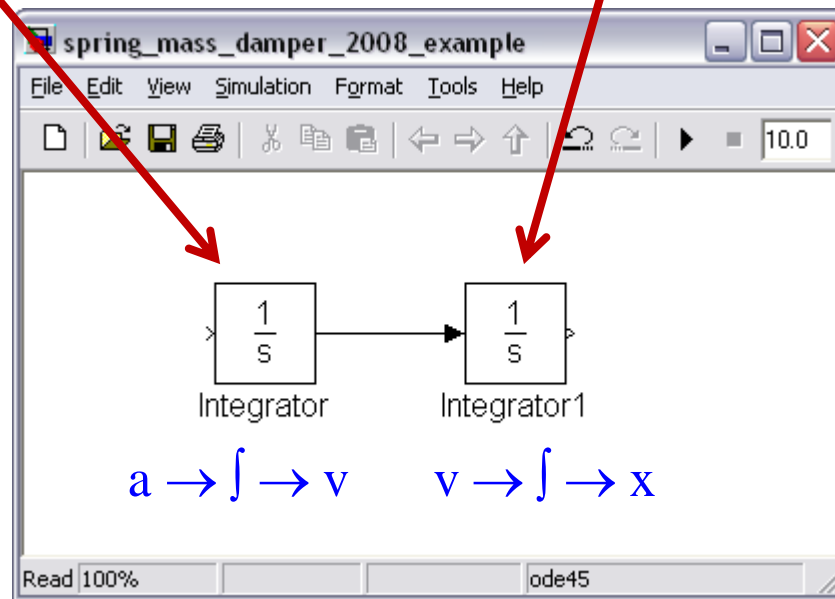
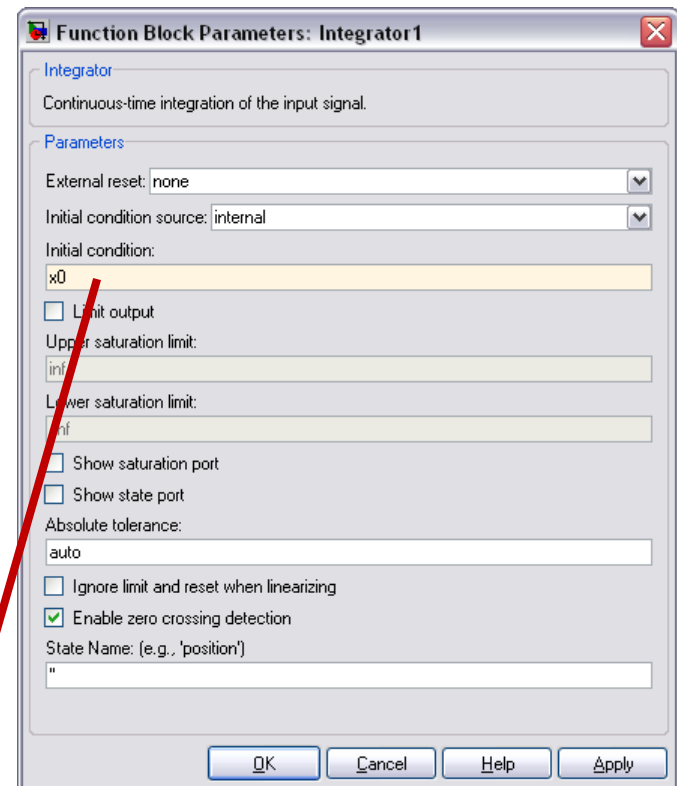


$$a \rightarrow \int \rightarrow v$$

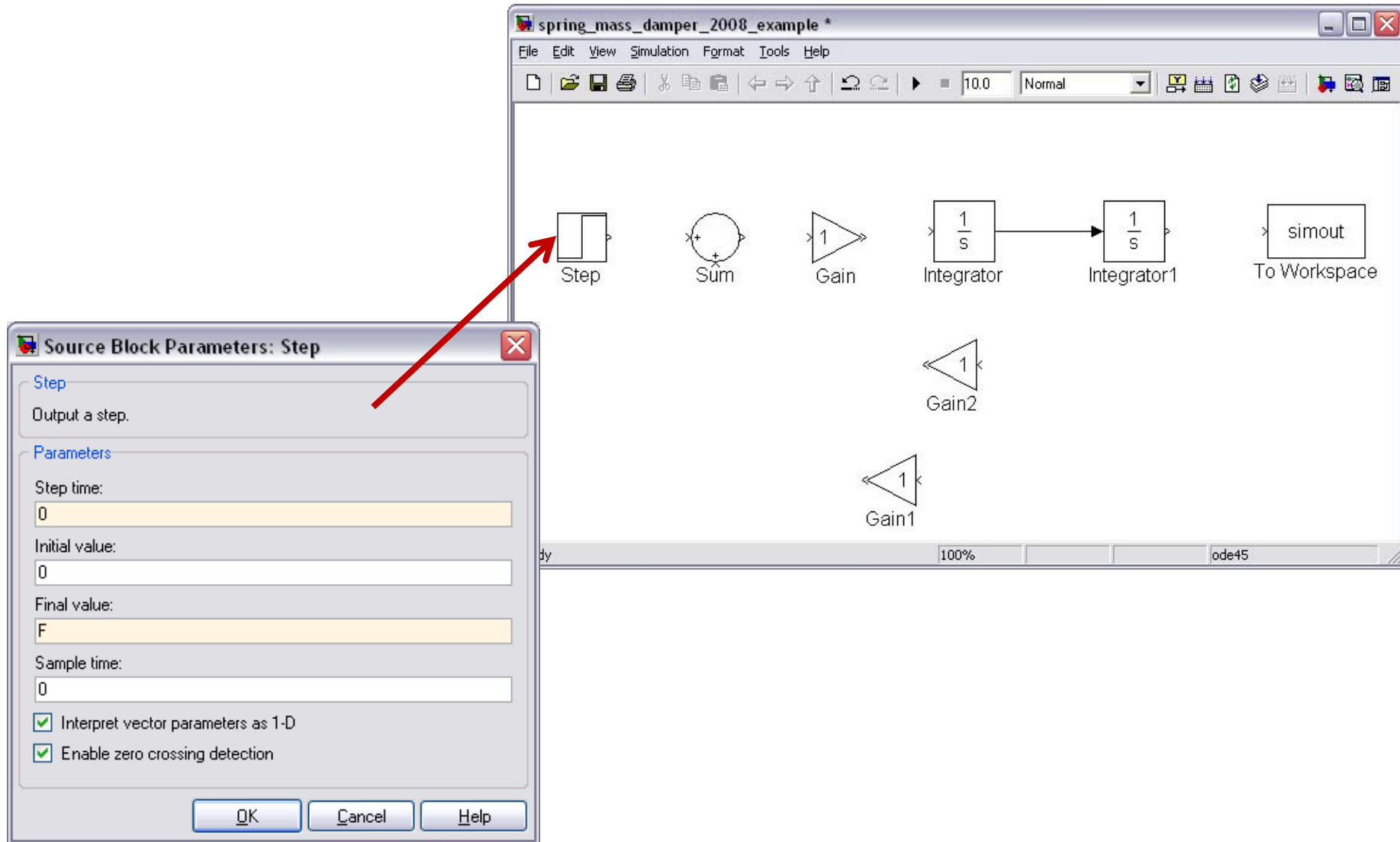
$$v \rightarrow \int \rightarrow x$$



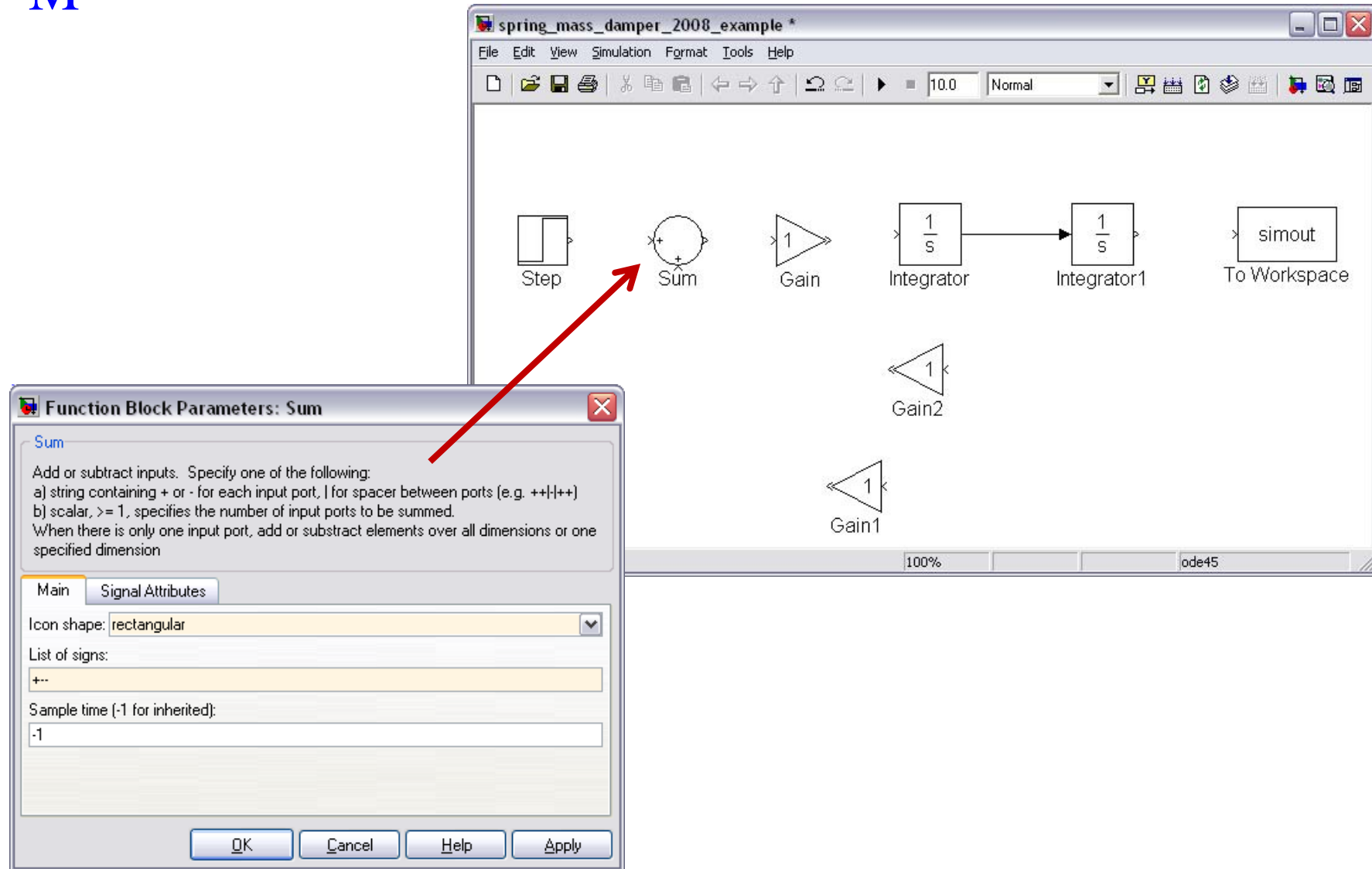
Initial Conditions



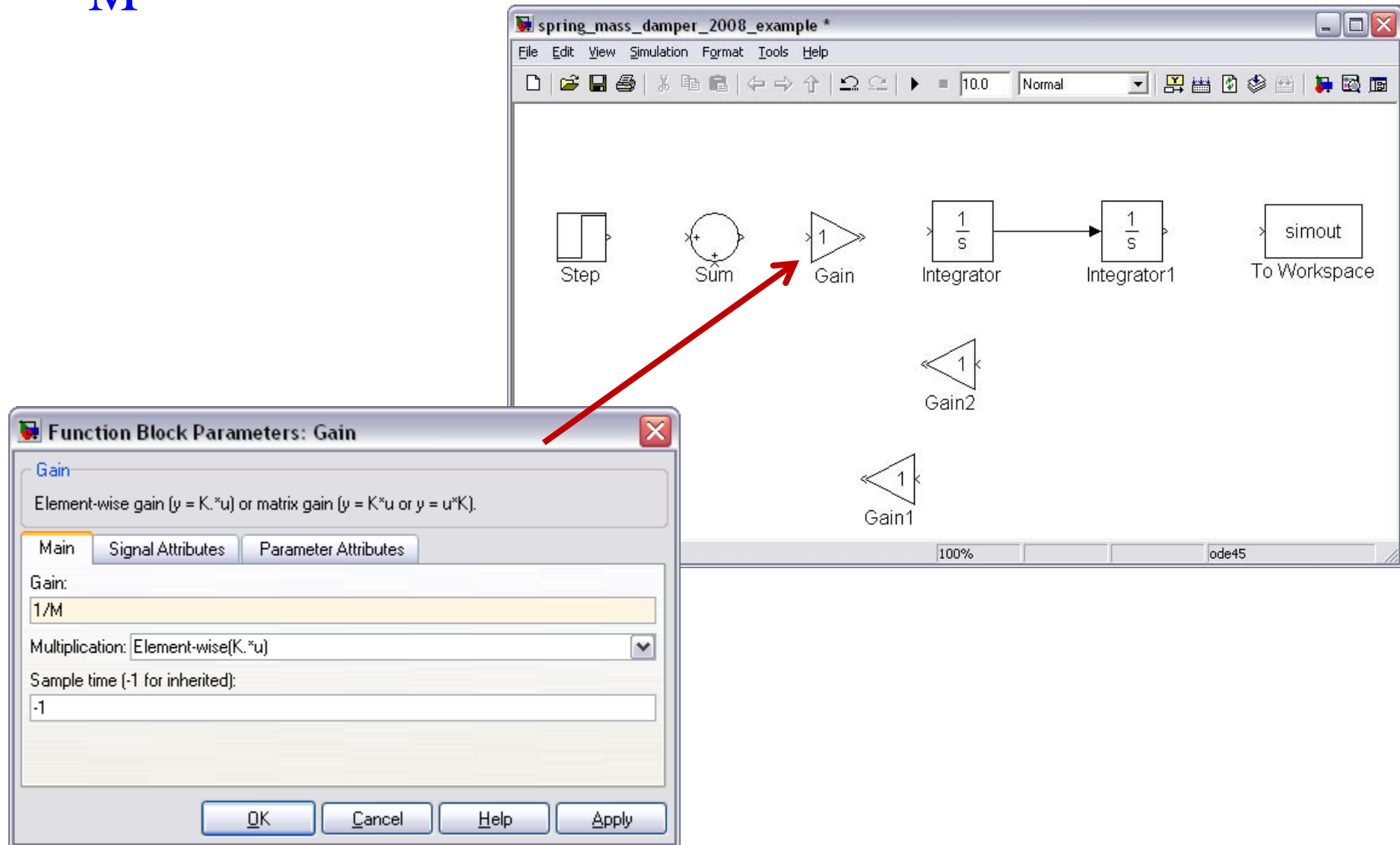
$$a = \frac{1}{M}(-Bv - Kx + F(t))$$



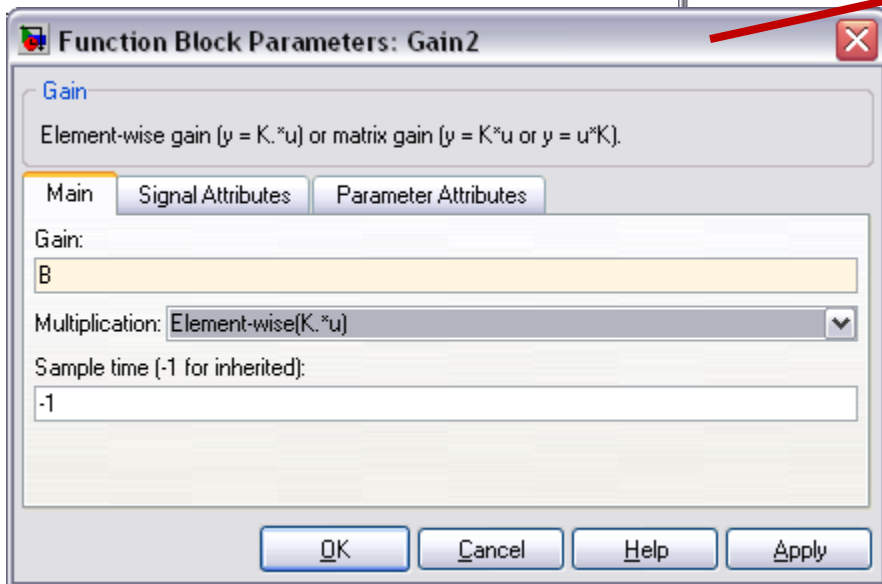
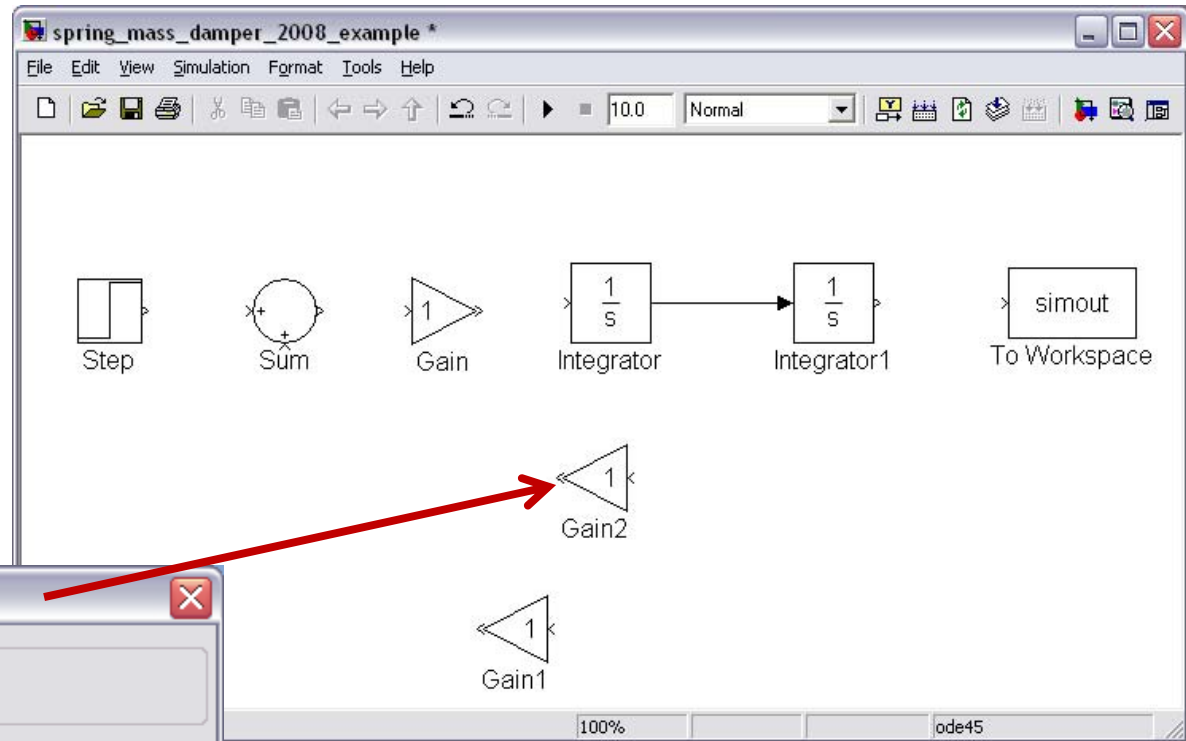
$$a = \frac{1}{M}(-Bv - Kx + F(t))$$



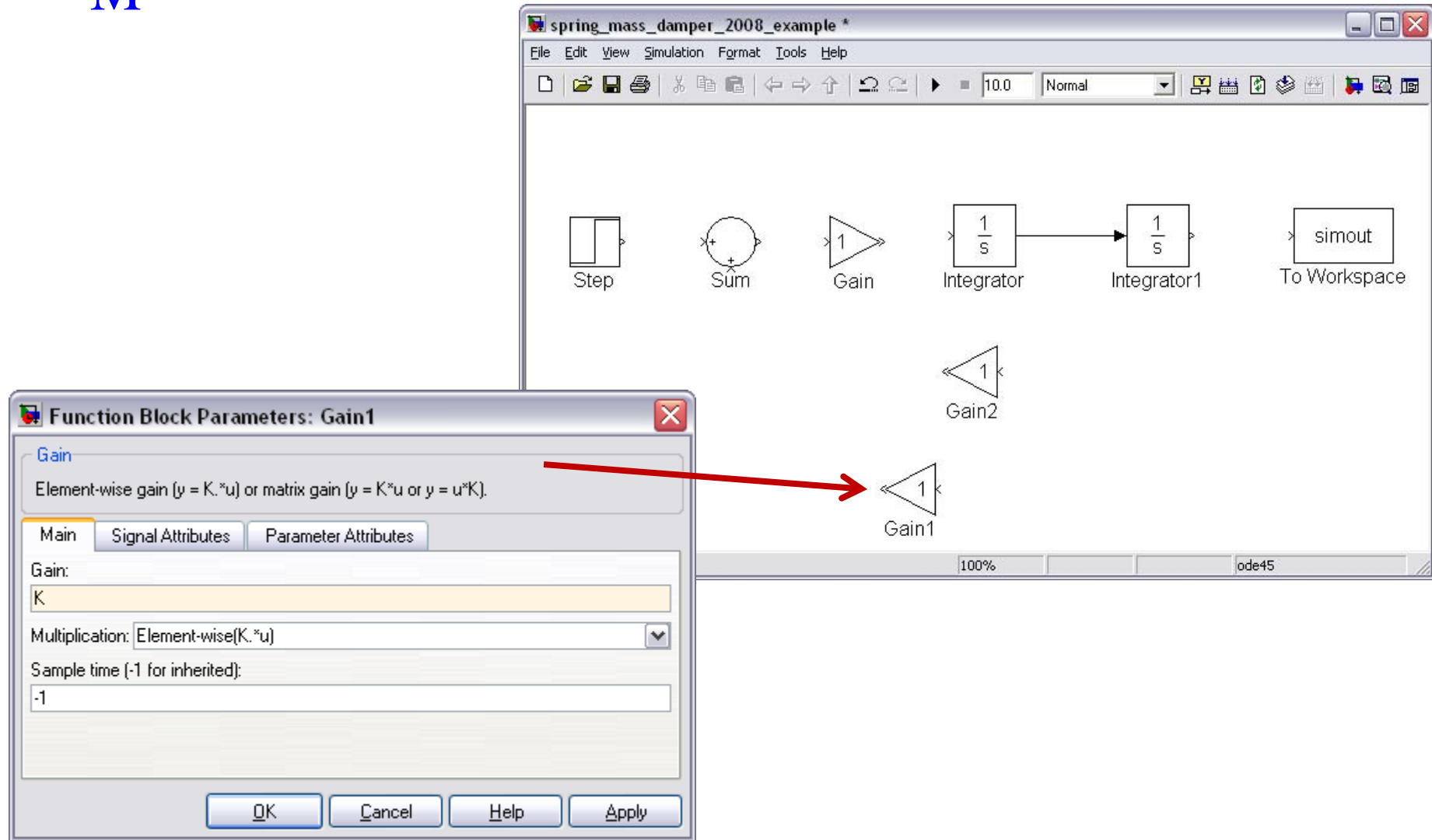
$$a = \frac{1}{M}(-Bv - Kx + F(t))$$



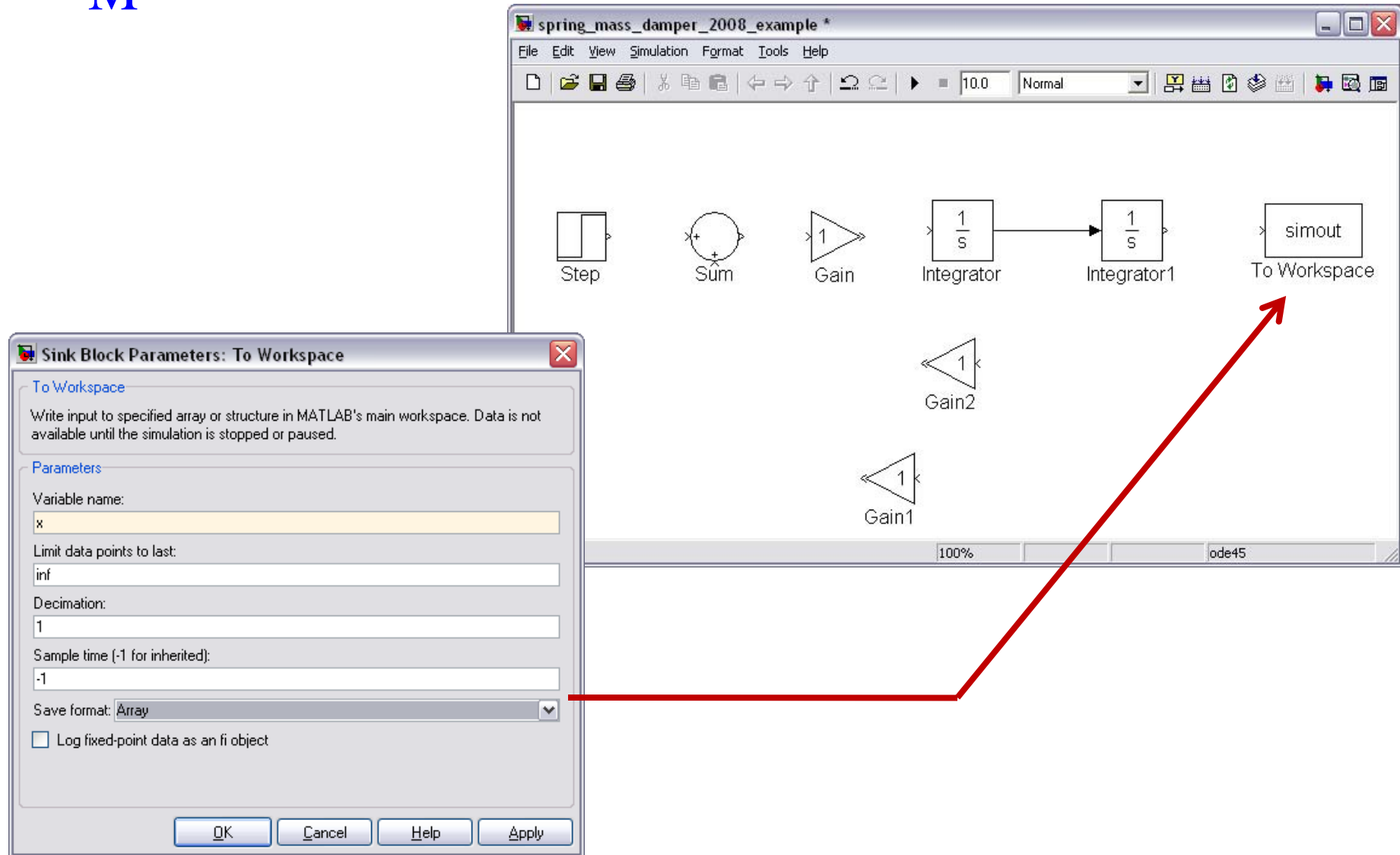
$$a = \frac{1}{M}(-Bv - Kx + F(t))$$



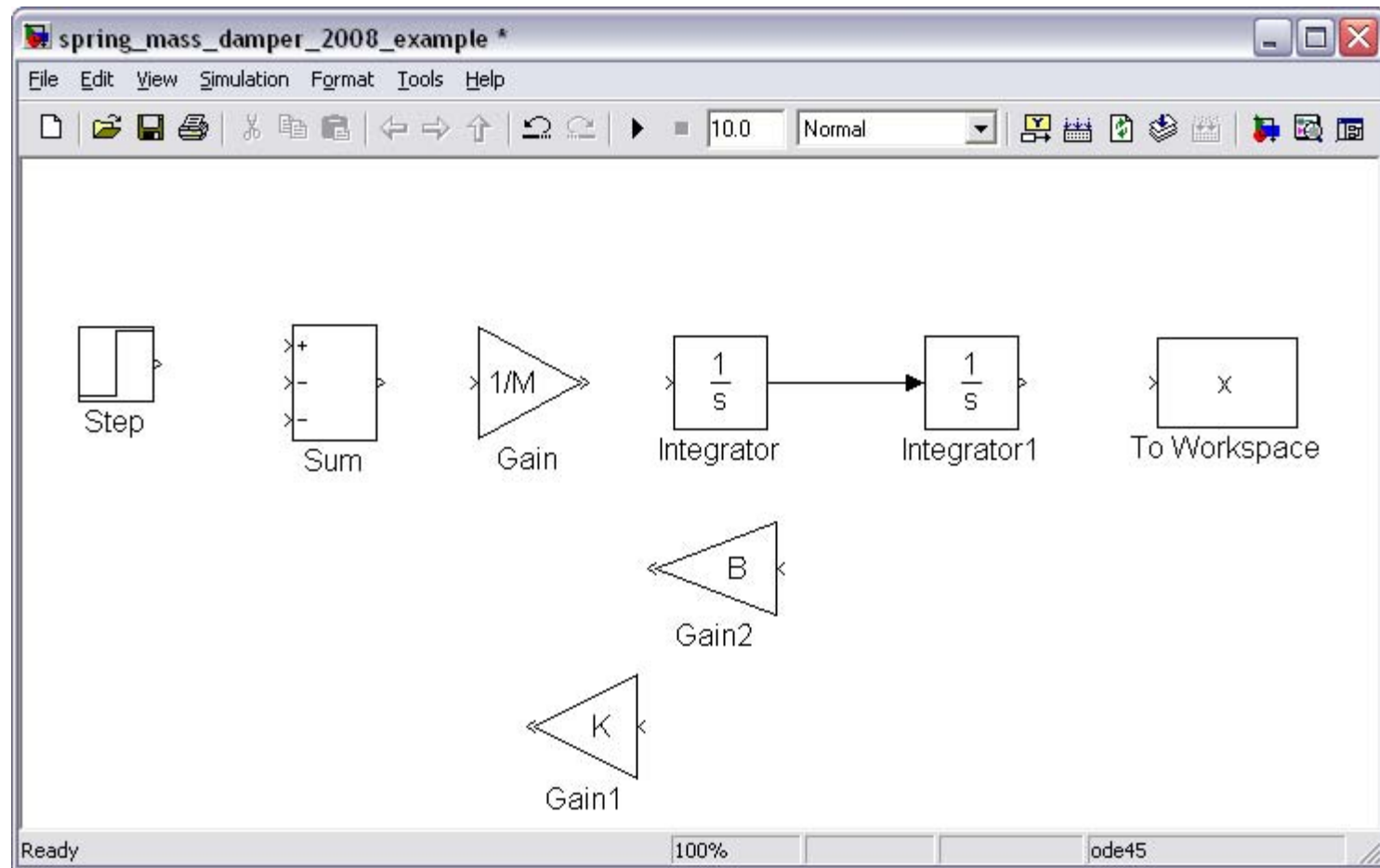
$$a = \frac{1}{M}(-Bv - Kx + F(t))$$



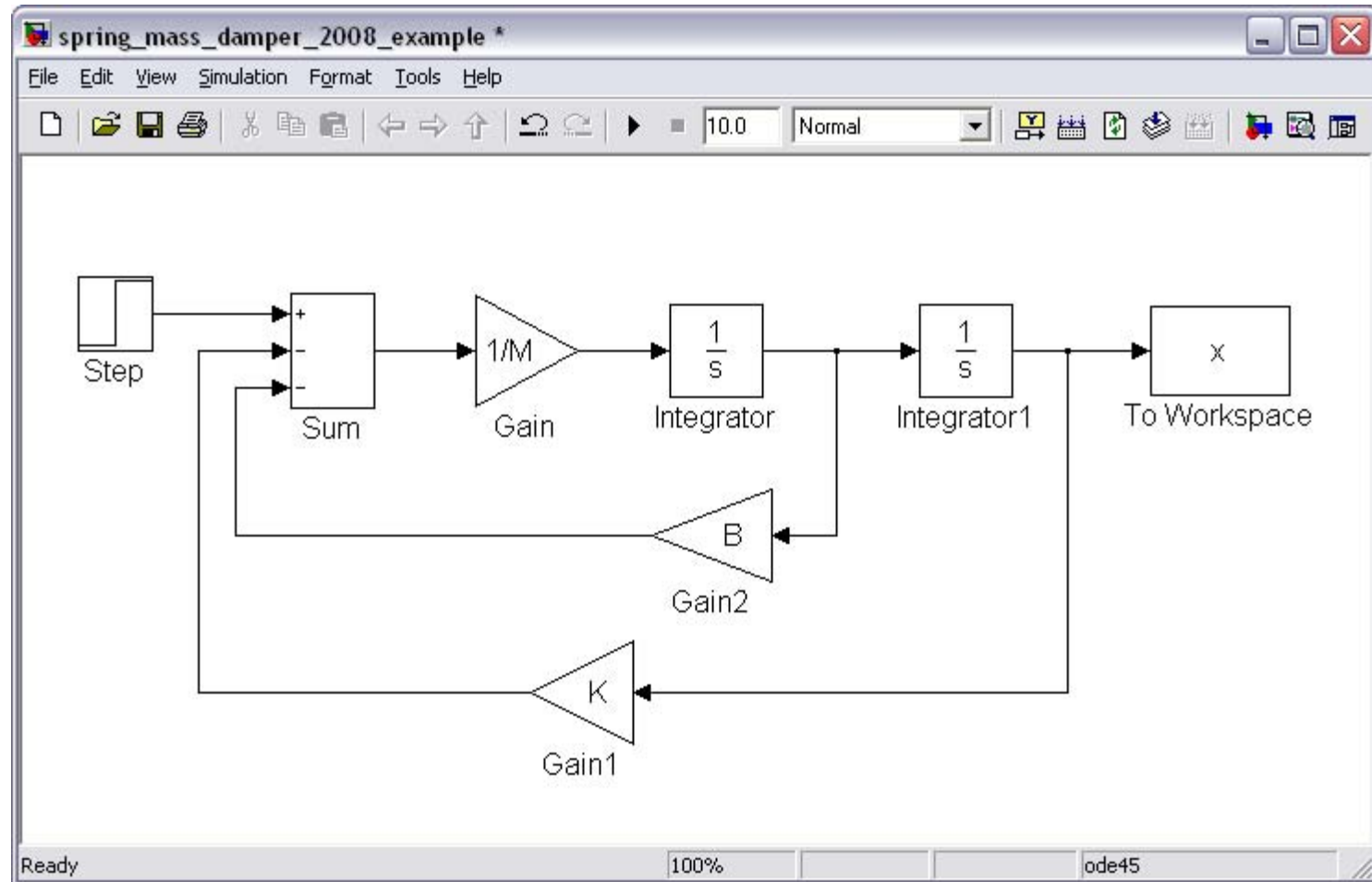
$$a = \frac{1}{M}(-Bv - Kx + F(t))$$



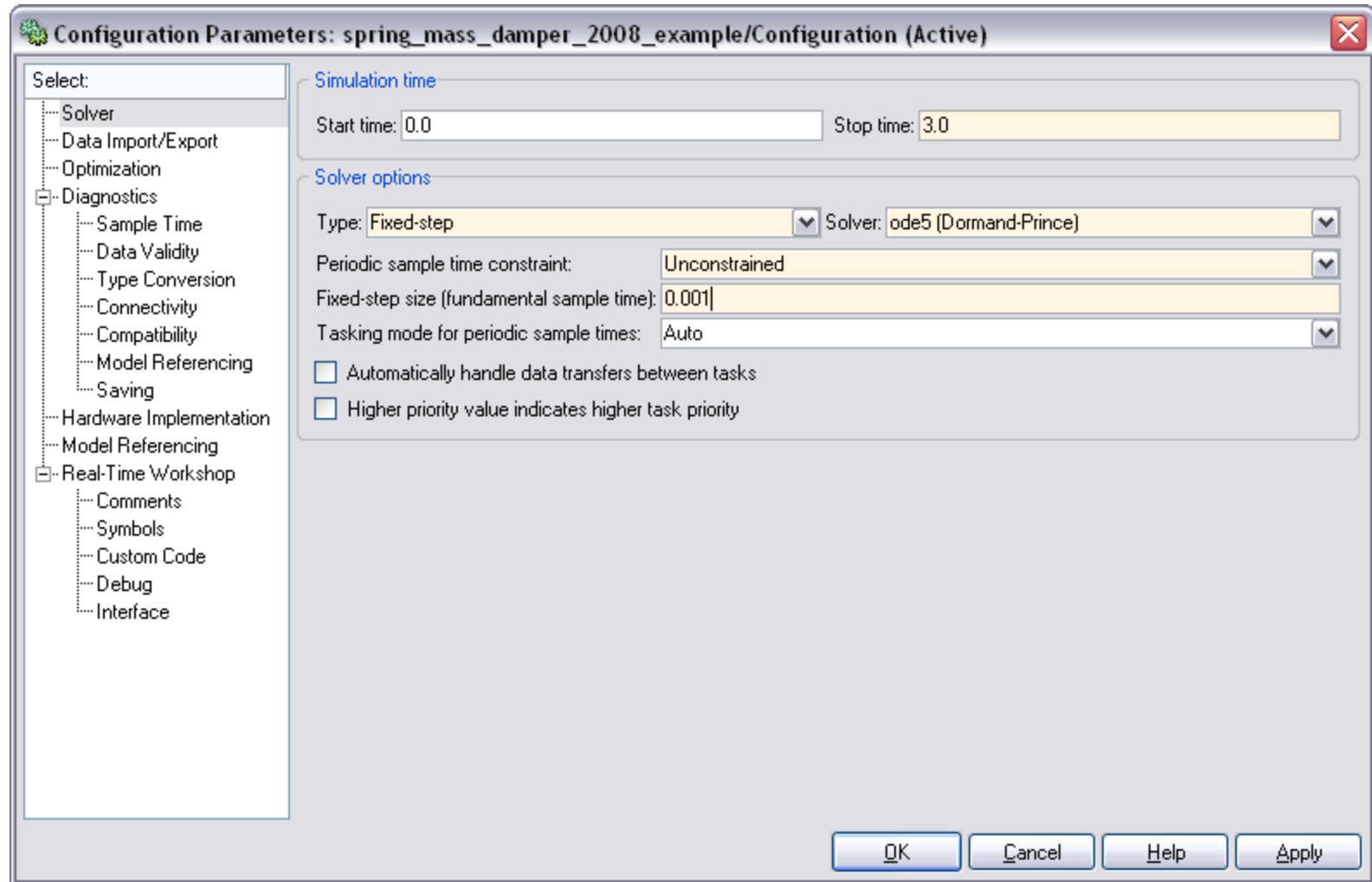
$$a = \frac{1}{M}(-Bv - Kx + F(t))$$



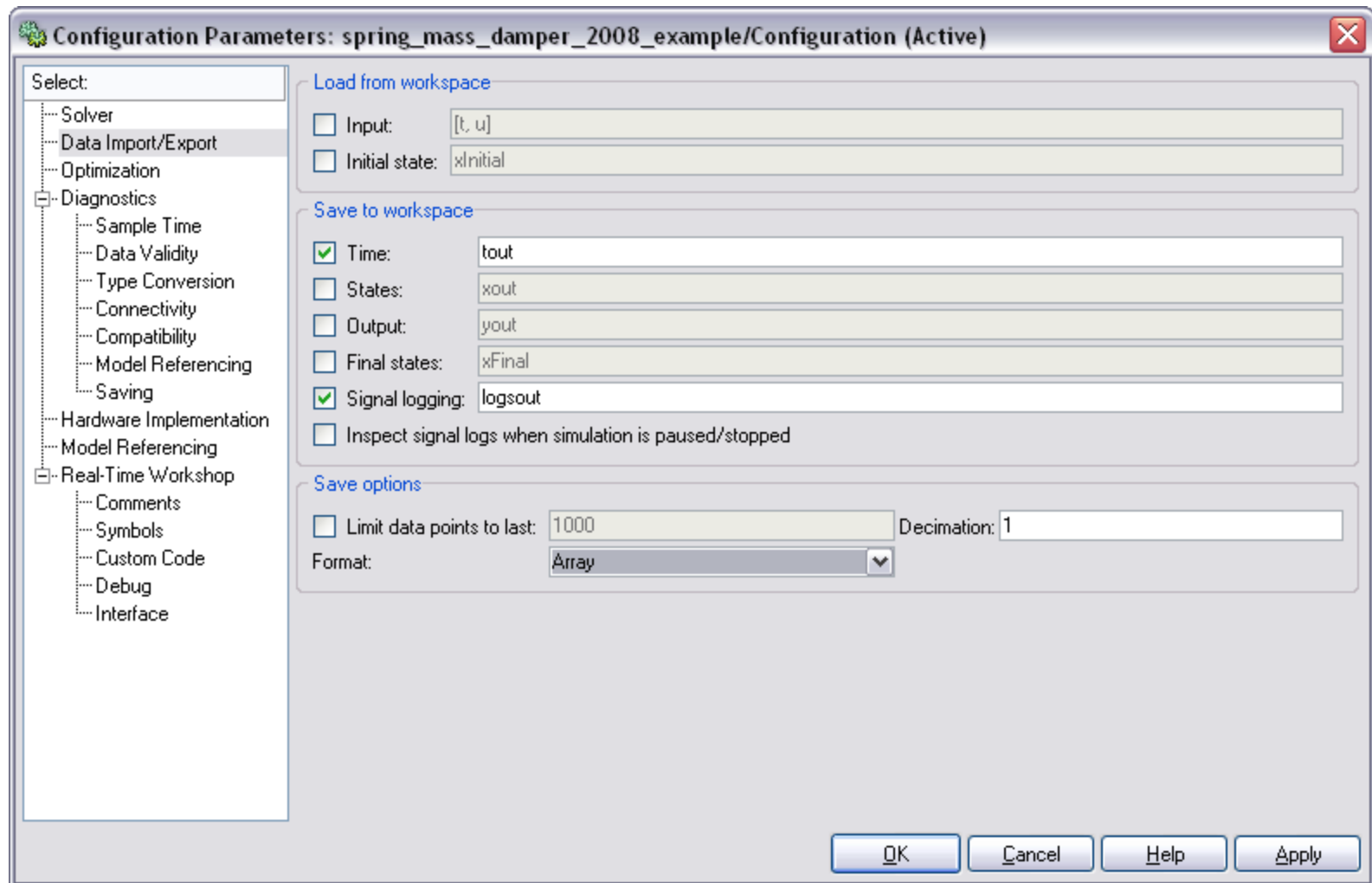
$$a = \frac{1}{M}(-Bv - Kx + F(t))$$



Simulation → Configuration Parameters → Solver



Simulation → Configuration Parameters → Data Import/Export



Editor - D:\K Craig 2007\Freshman Engineering\Marquette\Fall 2008\Engineering Discovery\General\MatLab\sp...

File Edit Text Go Cell Tools Debug Desktop Window Help

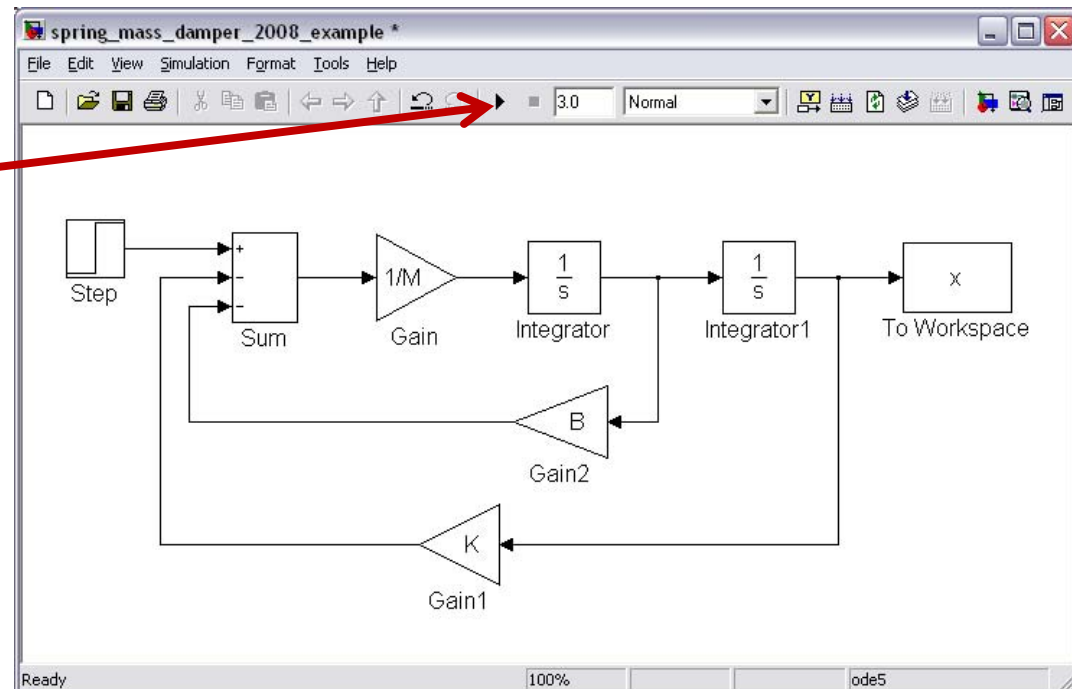
Stack: Base

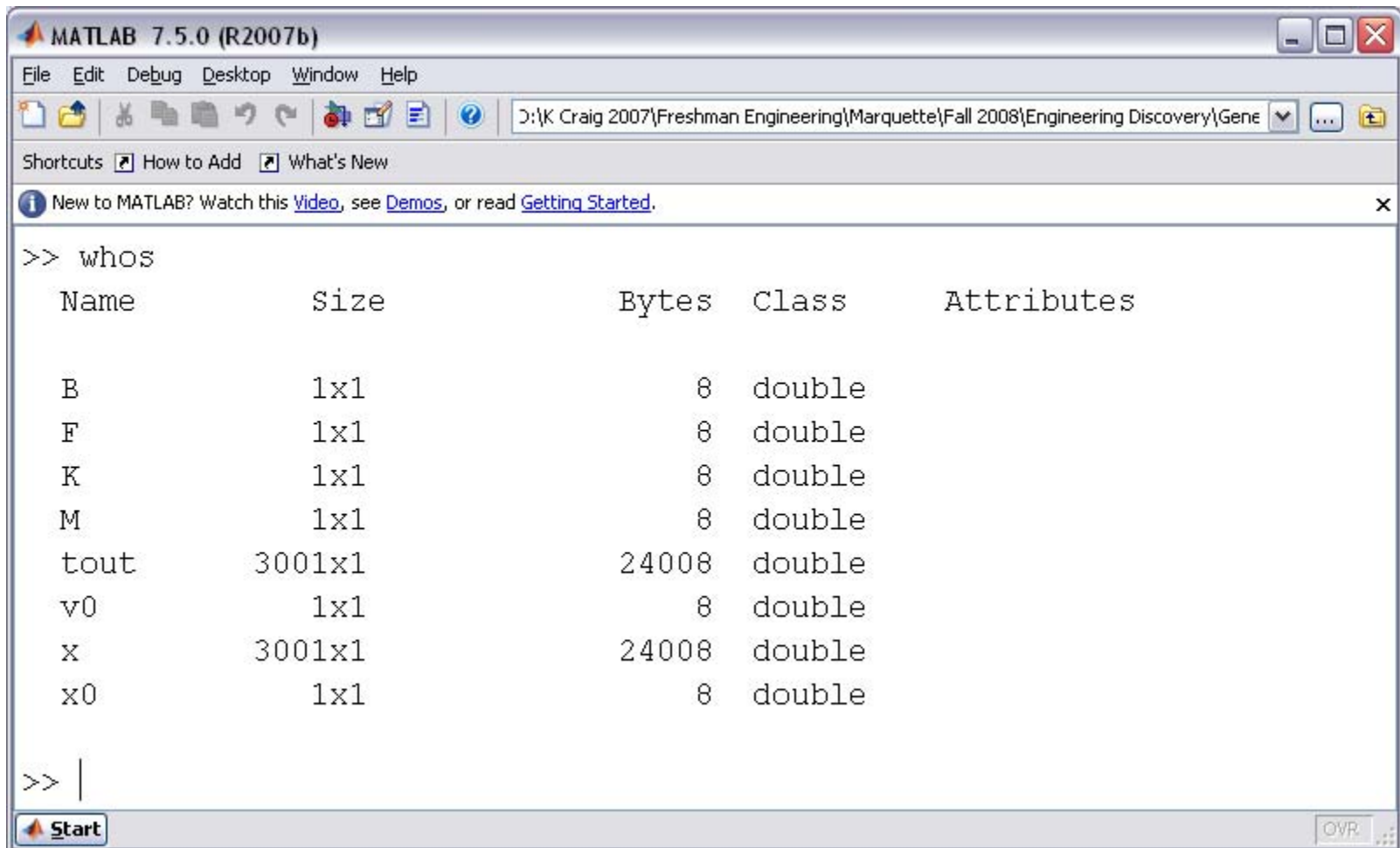
```
1 % Spring-Mass-Damper System KCC 2008
2
3 F = 100; % force in N
4 K = 491.1; % spring constant in N/m
5 B = 20; % damping constant in N/m/s
6 M = 5.23; % mass in kg
7 x0 = 0; % x initial condition
8 v0 = 0; % v initial condition
```

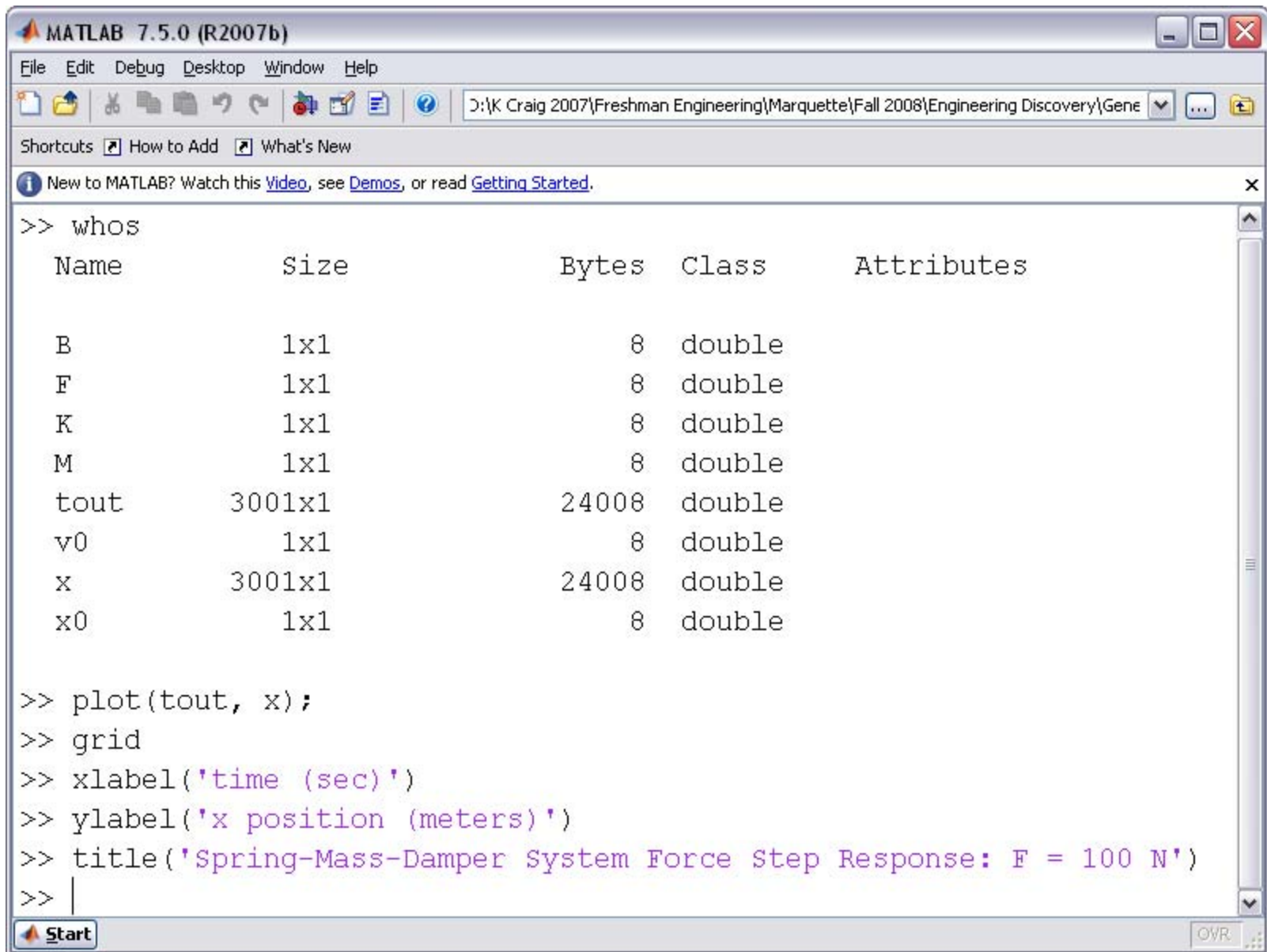
script Ln 8 Col 34 OVR

M-File for Parameters

Start
Simulation







The image shows a MATLAB 7.5.0 (R2007b) window. The title bar reads "MATLAB 7.5.0 (R2007b)". The menu bar includes File, Edit, Debug, Desktop, Window, and Help. The toolbar contains icons for file operations and MATLAB-specific functions. The current directory is D:\K Craig 2007\Freshman Engineering\Marquette\Fall 2008\Engineering Discovery\Gene. A message bar at the top says "New to MATLAB? Watch this [Video](#), see [Demos](#), or read [Getting Started](#)." The command window shows the following commands and output:

```
>> 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')
>> |
```

The status bar at the bottom shows a "Start" button and a "OVR" indicator.

