

INTRODUCTION TO SIMULINK

ECE 524E-WIRELESS & MOBILE COMMUNICATION

Thursday, 28 March 2024

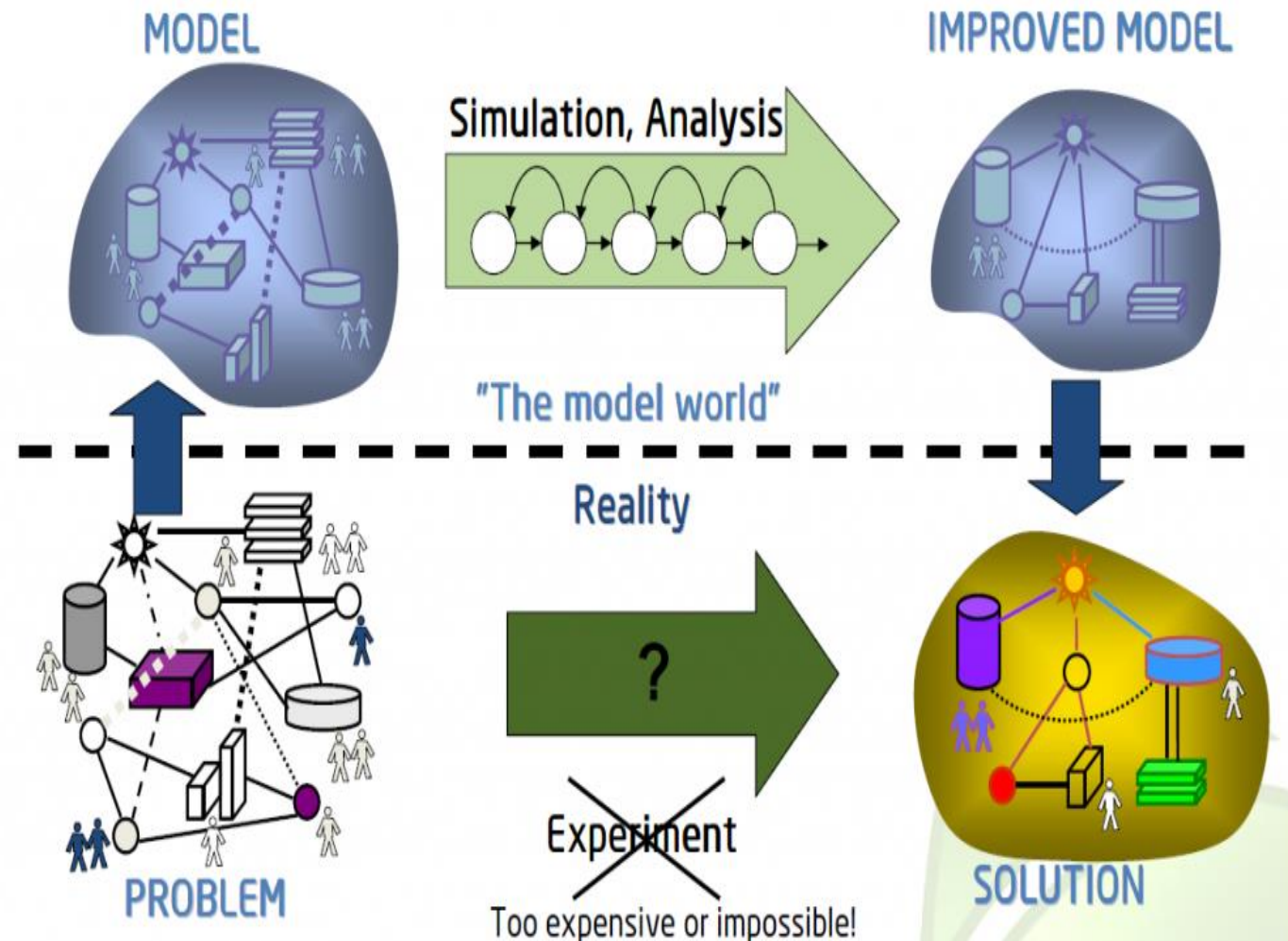
WHAT IS SIMULINK?

1. **Simulink** is a software package used during the design of dynamic systems for:
 1. modeling
 2. simulating
 3. analyzing
2. **Simulink** supports linear and nonlinear systems, modeled in continuous time, sample time, or a hybrid of the two.
3. **Systems in Simulink** can be multirate (i.e. different parts that are sampled or updated at different rates)

WHY WE NEED SIMULATION?

Main advantages of simulation include:

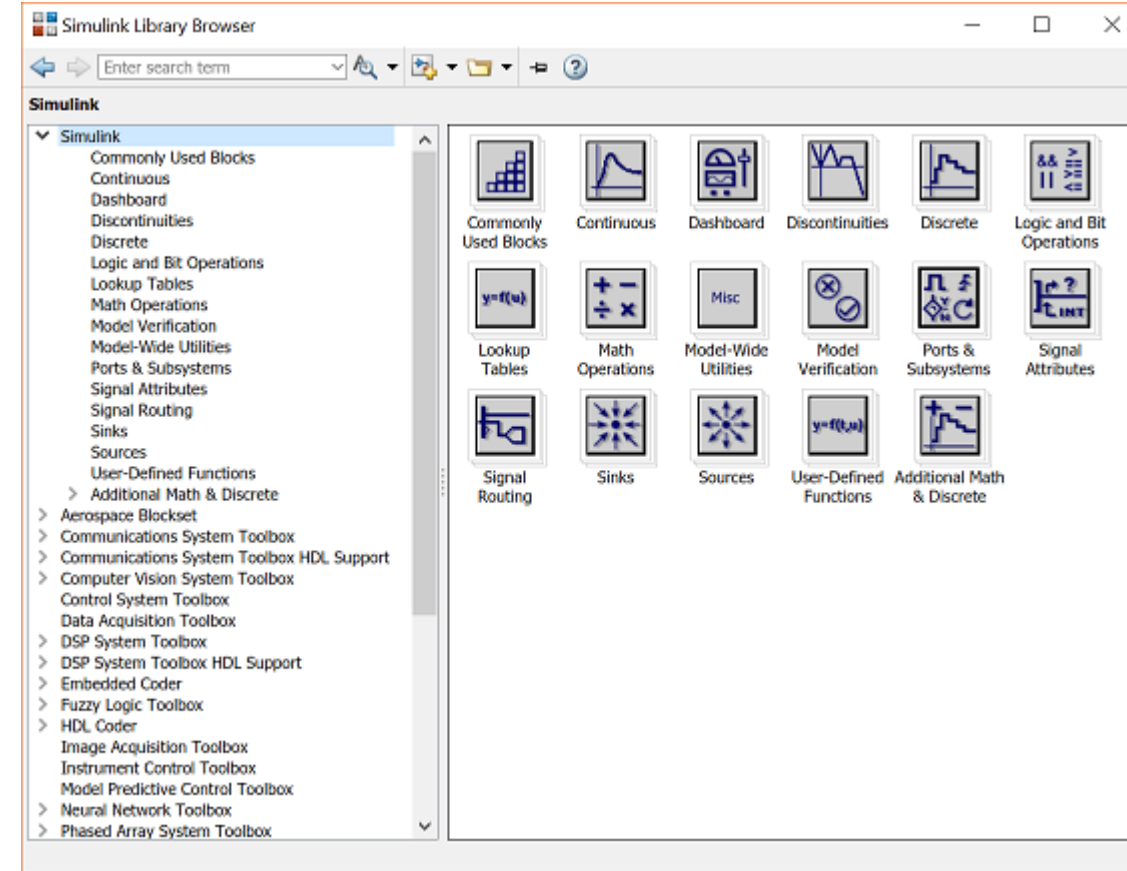
1. Study the behavior of a system without building it.
2. Results are accurate in general, compared to analytical model.
3. Help to find un-expected phenomenon, behavior of the system.
4. Easy to perform ``What-If'' analysis.



ADVANTAGES OF USING SIMULINK

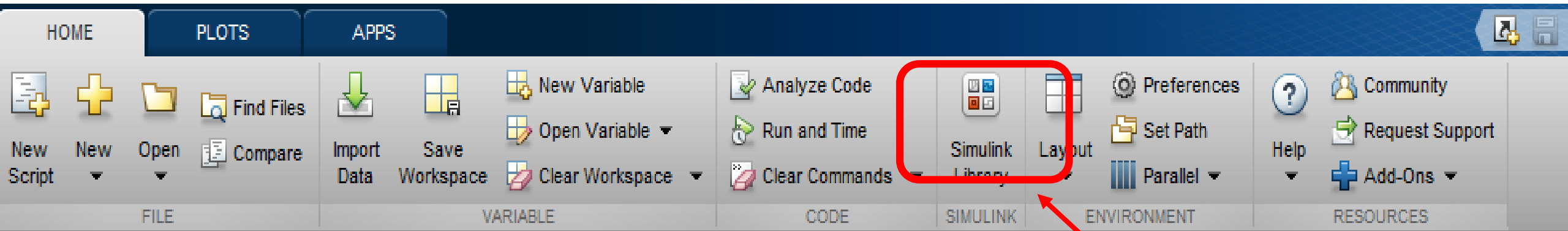
Simulink provides the following advanced features:

1. **Graphical user interface** for building models as block diagrams
2. Ability to **design models in hierarchical fashion** (using both top-down and bottom-up approaches)
3. **Ability to simulate, analyze the output results**
4. **Ability to explore, revise your models.**



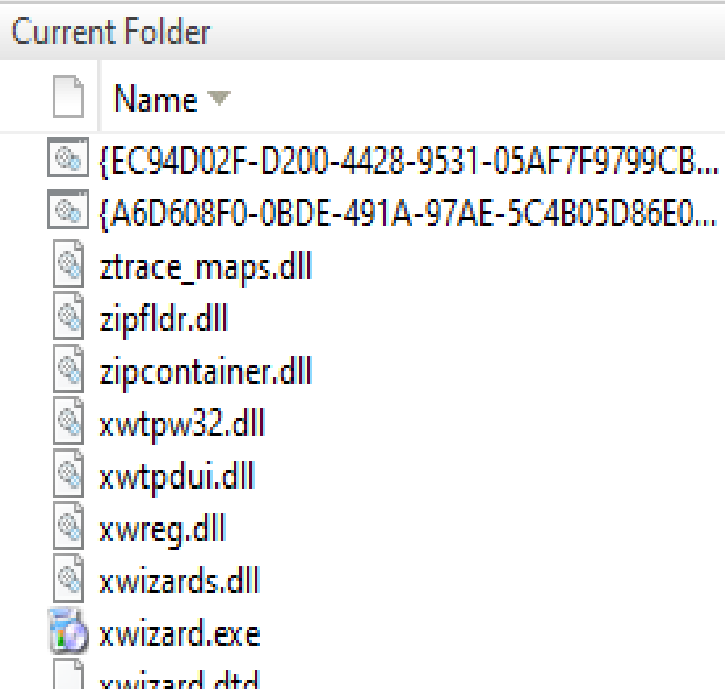
STARTING SIMULINK

MATLAB R2015a



Current Folder

C:\WINDOWS\system32



Command Window

```
>> simulink
```

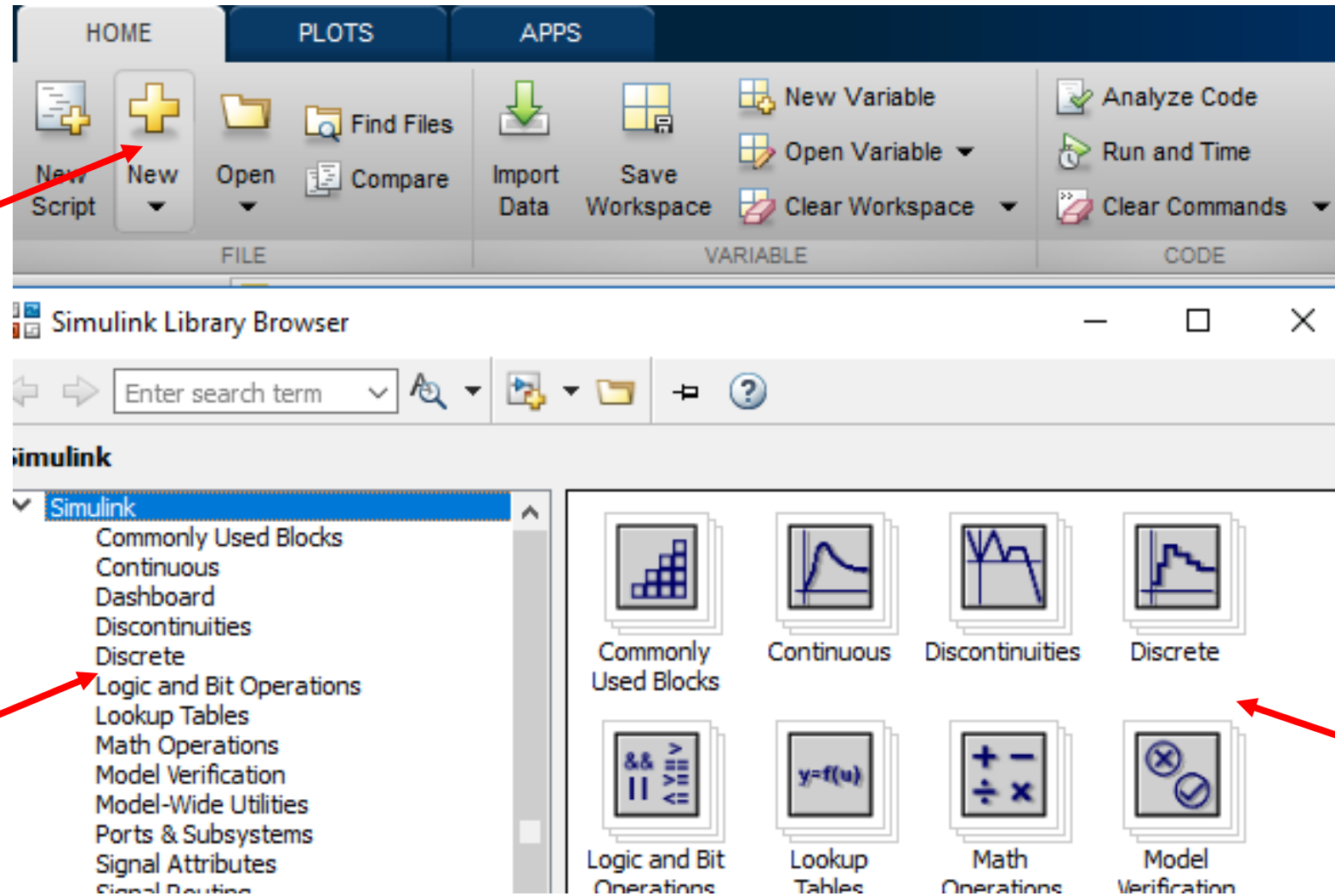
OR
Type simulink
on Matlab command window

Click on the SIMULINK icon on toolbar

SIMULINK ENVIRONMENT

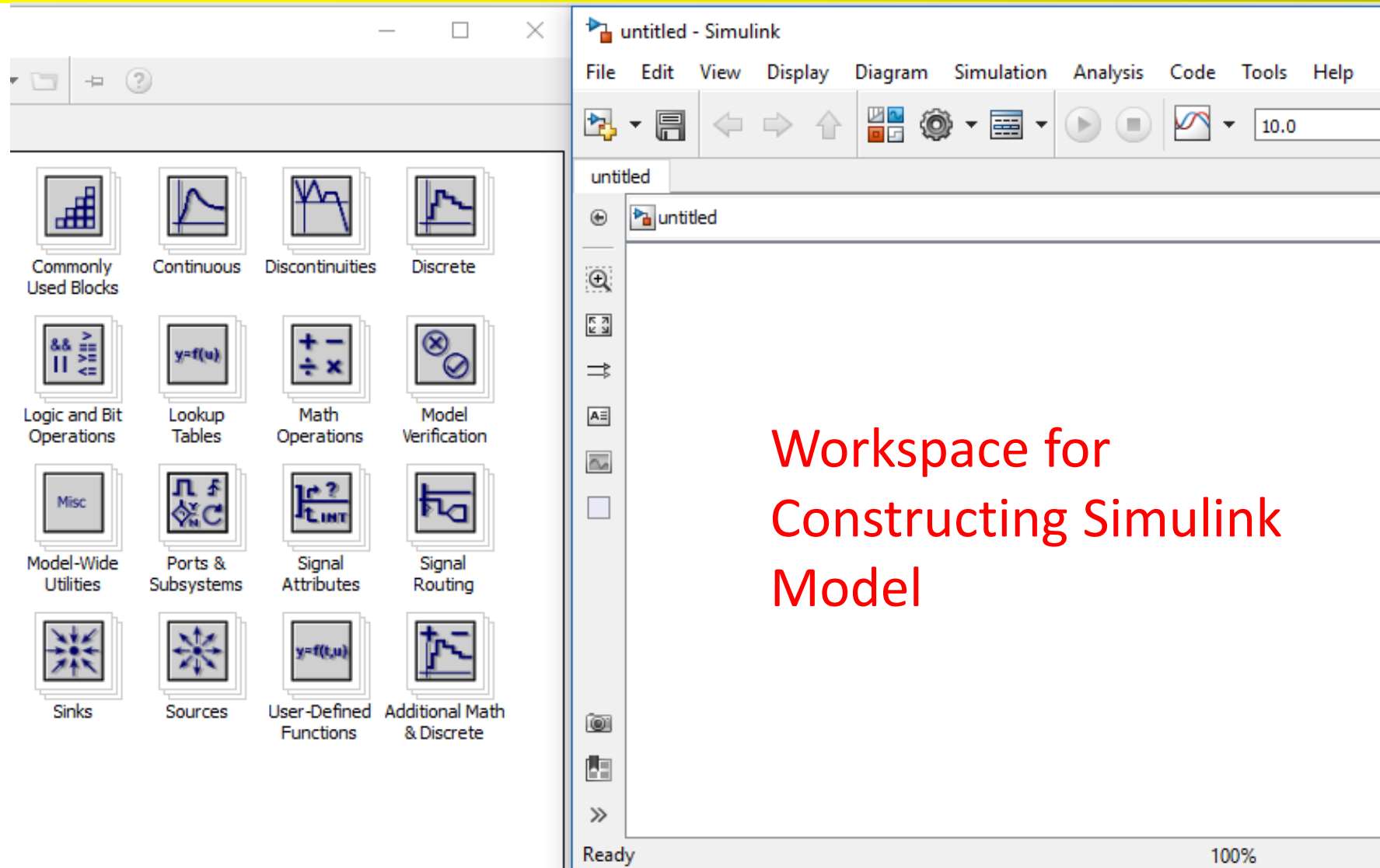
Create New Model Icon

Library



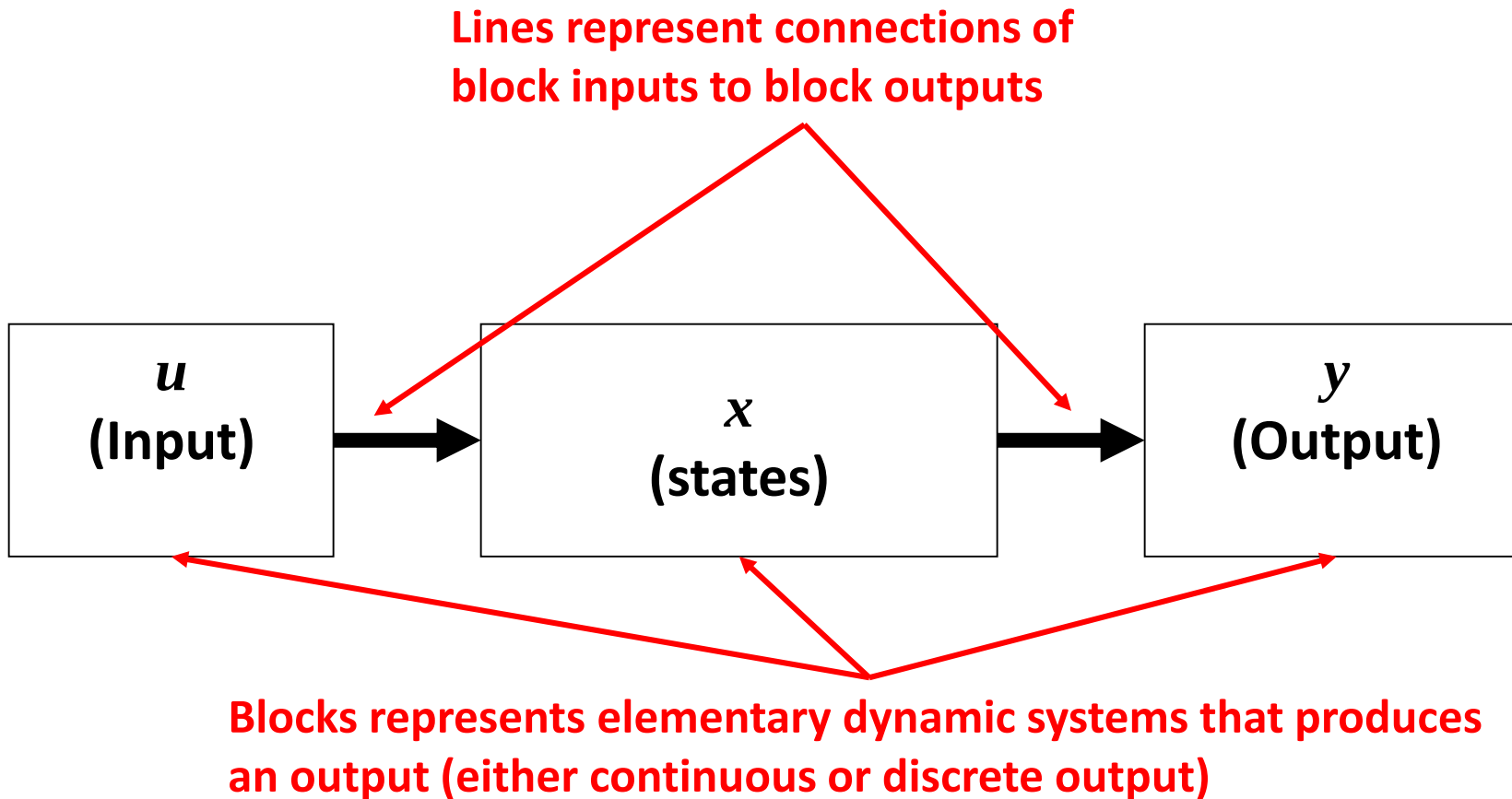
Block Set for Model Construction

CREATING A NEW SIMULINK MODEL



BUILDING A SIMULINK MODEL

Simulink Block Diagram is a pictorial model of a dynamic system.



BUILDING A SIMULINK MODEL / 02

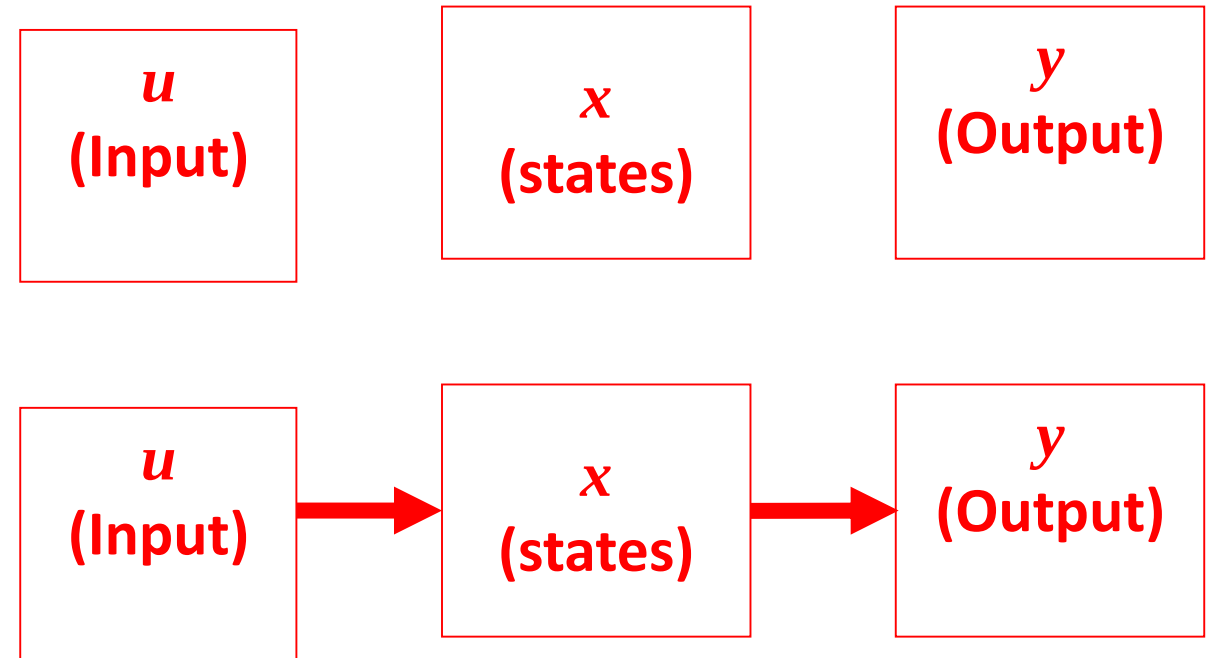
The following steps will guide you to construct a system/model:

STEP 1: Creating Blocks

STEP 2: Making connections

STEP 3: Set Parameters

STEP 4: Running Simulation



BUILDING A SIMULINK MODEL / 03

STEP 1: CREATING BLOCKS

The image shows two Simulink windows. On the left is the 'Simulink Library Browser' with the 'Sources' category selected and the 'Sine Wave' block highlighted. On the right is the 'untitled' workspace window with a 'Sine Wave' block placed on the canvas. Annotations include a 'Save this model' callout pointing to the save icon, a 'Sources library' callout pointing to the library browser, and a 'Click-Drag-Drop the Sine Wave block to Workspace Window' callout pointing to the block on the canvas.

Save this model

Sine Wave: Output a sine wave where the sine type determines the computational technique used. The parameters in the two types are related through:
$$\text{Samples per period} = 2\pi / (\text{Frequency} * \text{Sample time})$$

Simulink Library Browser

- Simulink
 - Continuous
 - Discrete
 - Functions & Tables
 - Math
 - Nonlinear
 - Signals & Systems
 - Sinks
 - Sources**
 - Subsystems
- Control System Toolbox
- Fuzzy Logic Toolbox
- Neural Network Blockset
- Real-Time Workshop
- S-function demos
- Simulink Extras
- System ID Blocks
- xPC Target

untitled *

File Edit View Simulation Format Tools Help

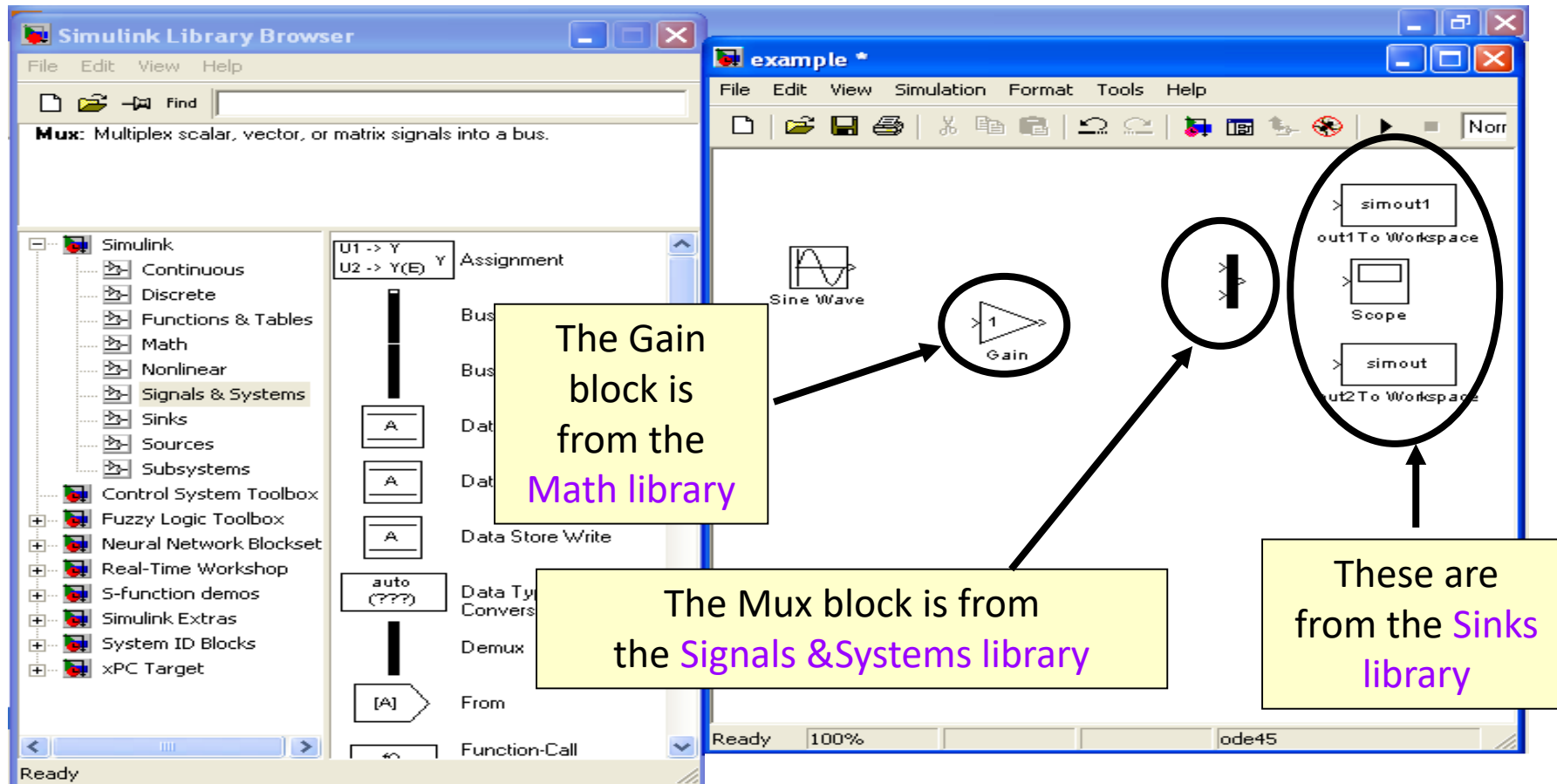
This is the Sine Wave block is from the Sources library

Click-Drag-Drop the Sine Wave block to Workspace Window

Sources library

BUILDING A SIMULINK MODEL / 04

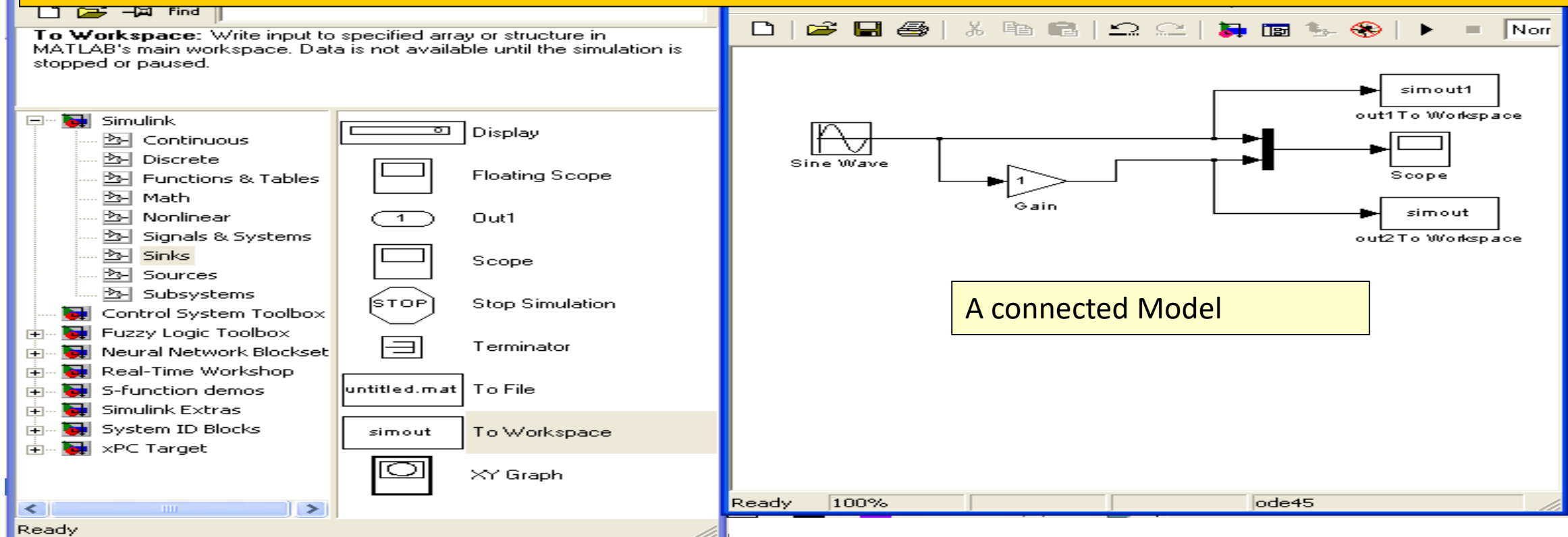
STEP 1: CREATING BLOCKS



BUILDING A SIMULINK MODEL / 04

STEP 2: MAKING CONNECTIONS

To make connection: left-click while holding down *control* key (on keyboard) and drag from source port to a destination port



BUILDING A SIMULINK MODEL / 05

STEP 3: SET PARAMETERS

Double click the Gain block to set the parameter for the Gain block

The screenshot shows a Simulink model window titled 'example'. The model contains a 'Sine Wave' block connected to a 'Gain' block (represented by a triangle with the number 1 inside). The output of the Gain block is connected to a 'Scope' block and two 'To Workspace' blocks. The 'To Workspace' blocks are labeled 'out1To Workspace' and 'out2To Workspace'. The 'Scope' block is labeled 'Scope'. The 'Gain' block is circled in orange, and two red arrows point from the yellow instruction box to it.

Two dialog boxes are open:

- Block Parameters: Gain**: This dialog box is open for the Gain block. It shows the 'Gain' parameter set to 5. A black arrow points from the text 'Gain value = 5' to the input field containing '5'. The 'Multiplication' dropdown is set to 'Element-wise(K.*u)'. The 'Saturate on integer overflow' checkbox is checked.
- Block Parameters: out1To Workspace**: This dialog box is open for the 'out1To Workspace' block. It shows the 'Variable name' set to 'out1'. A black arrow points from the text 'Name the output parameter as "out1"' to the input field containing 'out1'. Other parameters like 'Limit data points to last' (set to 'inf'), 'Decimation' (set to '1'), 'Sample time' (set to '-1'), and 'Save format' (set to 'Structure') are also visible.

BUILDING A SIMULINK MODEL / 06

STEP 4: RUNNING SIMULATION

The screenshot displays the Simulink environment with a model titled 'example'. The model consists of a 'Sine Wave' block, a 'Gain' block with a value of 5, and a multi-input summing junction. The outputs of the summing junction are connected to 'out1' (labeled 'out1 To Workspace'), a 'Scope' block, and 'out2' (labeled 'out2 To Workspace'). The 'Simulation' menu is open, showing options: 'Start' (Ctrl+T), 'Stop', 'Simulation parameters...' (Ctrl+E), and checkboxes for 'Normal' and 'External'. A red circle highlights the 'Start' button on the Simulink toolbar, with a yellow callout box stating 'Click here to run the simulation'. The 'Simulation Parameters: example' dialog box is open, showing the 'Solver' tab. The 'Simulation time' section has 'Start time' set to 0.0 and 'Stop time' set to 10.0. The 'Solver options' section shows 'Type' as 'Variable-step' and 'ode45 (Dormand-Prince)'. The 'Output options' section shows 'Refine output' as a dropdown and 'Refine factor' as 1. A yellow callout box points to the 'Stop time' field with the text 'You can change the "stop time" and then click the "OK button"'. Another yellow callout box points to the 'Simulation parameters...' menu item with the text 'click "simulation parameters" to set up the desired parameters'. At the bottom left, a green button labeled 'Show the simulation parameters dialog' is visible.

Click here to run the simulation

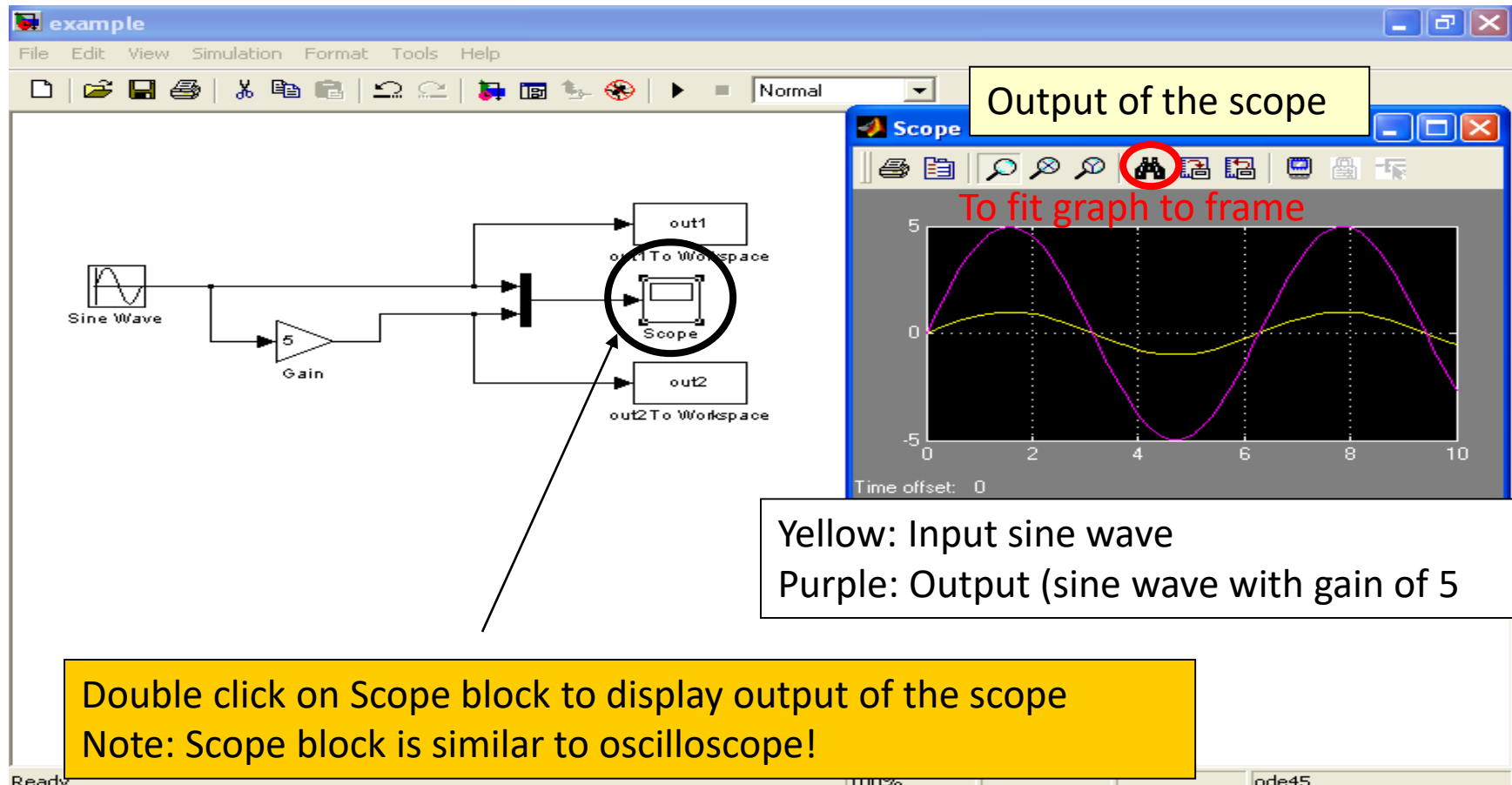
click "simulation parameters" to set up the desired parameters

You can change the "stop time" and then click the "OK button"

Show the simulation parameters dialog

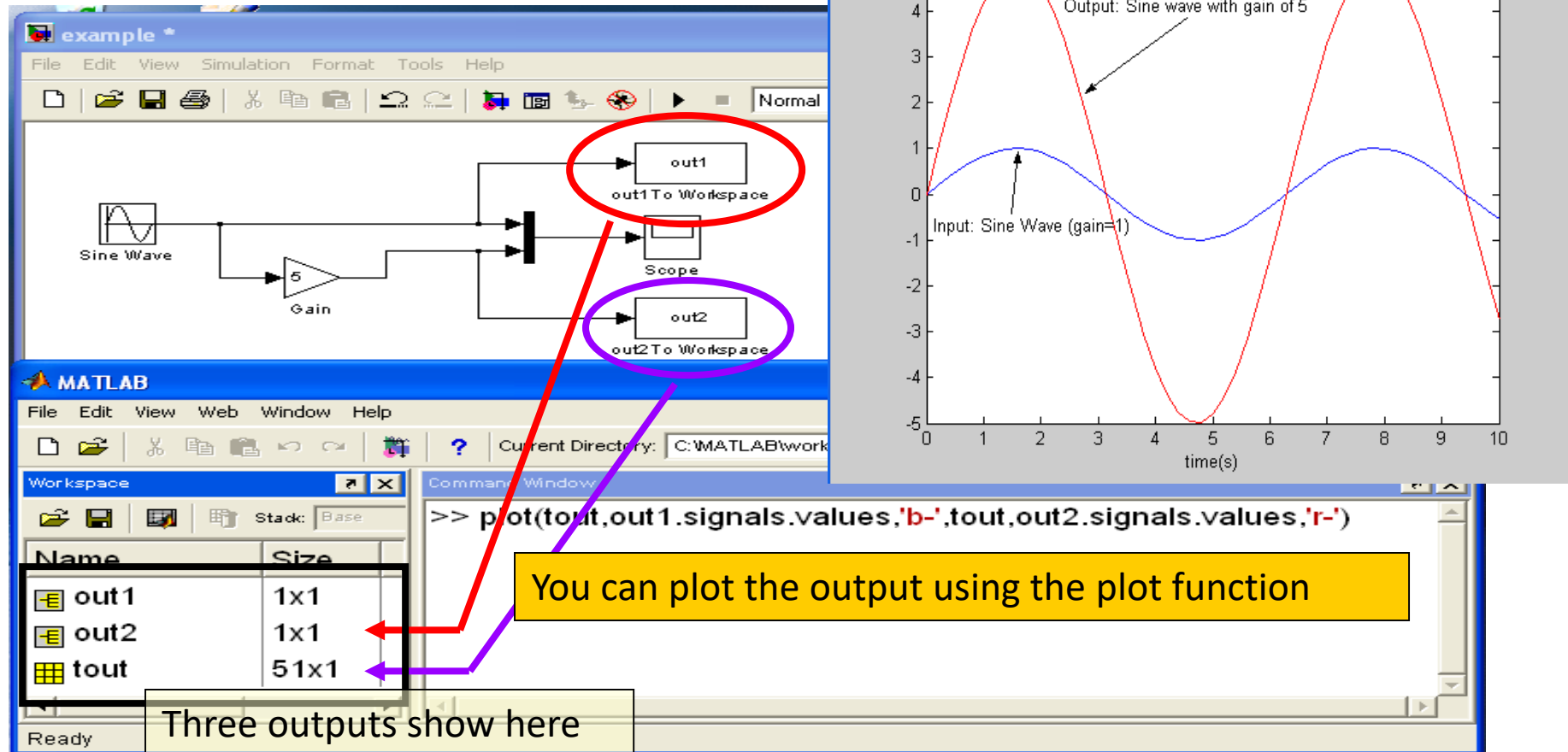
BUILDING A SIMULINK MODEL / 07

STEP 5: VIEW OUTPUT VIA SCOPE BLOCK



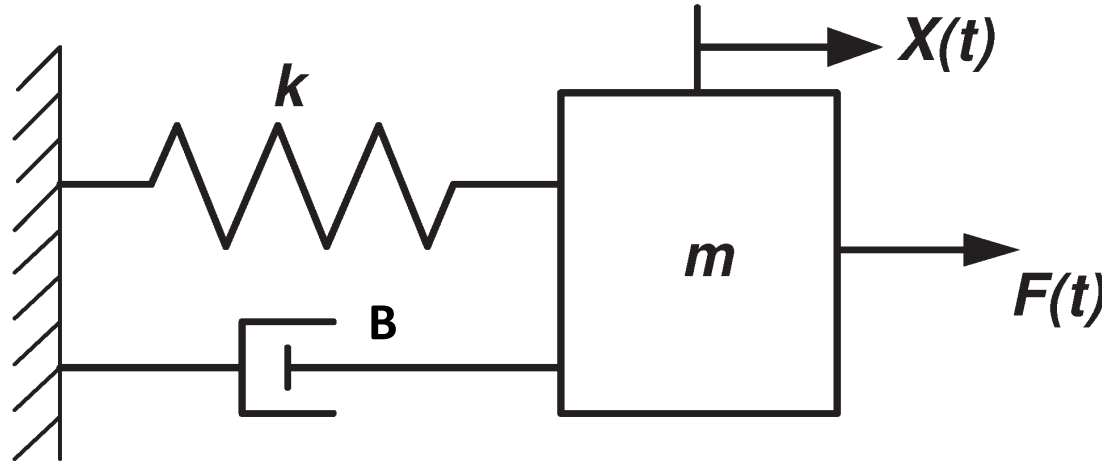
BUILDING A SIMULINK MODEL / 08

VIEW OUTPUT (WORKSPACE)



EXAMPLE 1: DIFFERENTIAL EQUATIONS (1)

Example of a dynamic system: A mass-spring-damper system



The Mathematical model of the system is described by the equation:

$$\ddot{x} = \frac{1}{M} (-B\dot{x} - Kx + f(t))$$

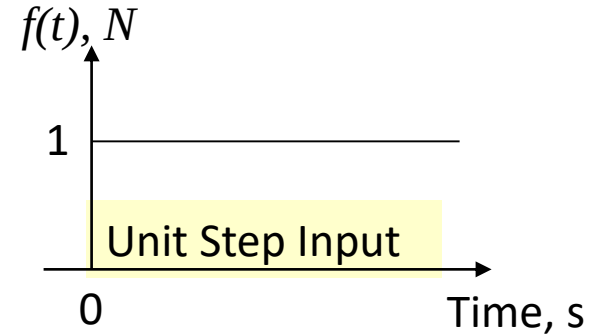
If $M=2\text{kg}$, $B = 2 \text{ Ns/m}$, $K=2 \text{ N/m}$, then

$$\ddot{x} = \frac{1}{2} (-2\dot{x} - 2x + f(t))$$

EXAMPLE 1: DIFFERENTIAL EQUATIONS (2)

- Use Simulink to simulate the step response of the system, i.e.

$$\ddot{x} = \frac{1}{2}(-2\dot{x} - 2x + f(t))$$

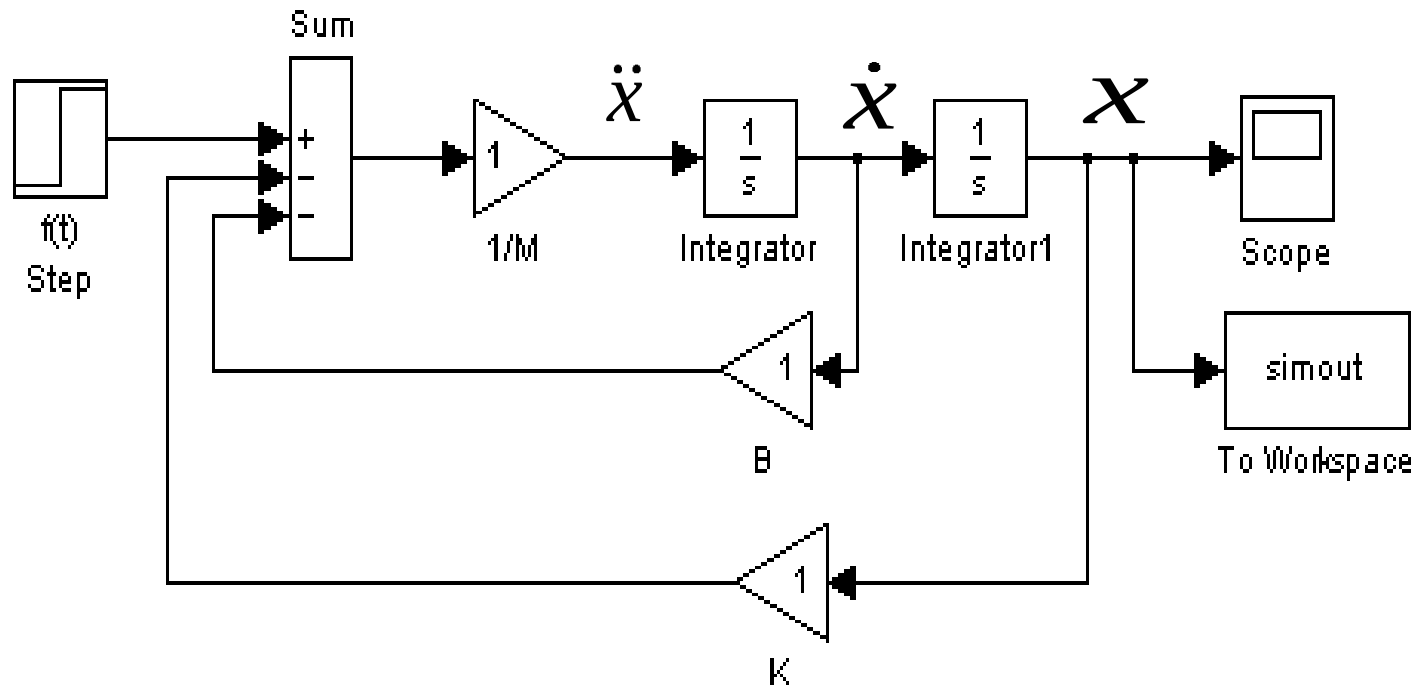


STEP 1: Creating Blocks

Select BLOCK set	Location in Simulink Library
Step	Sources
Sum	Math Operation
Gain	Math Operation
Integrator	Continuous
Scope & To Workspace	Sinks

EXAMPLE 1: DIFFERENTIAL EQUATIONS (2)

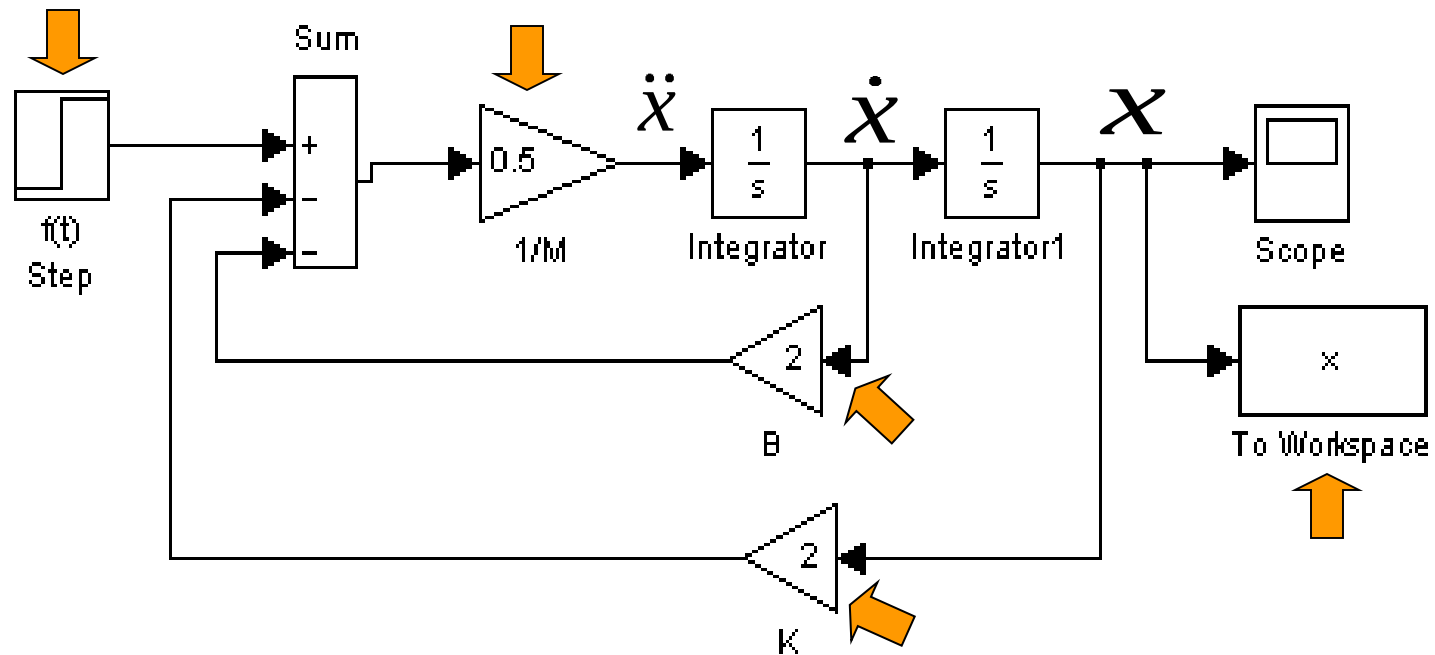
STEP 2: Making connections



EXAMPLE 1: DIFFERENTIAL EQUATIONS (3)

STEP 3: Set Parameters

Set Step time = 0



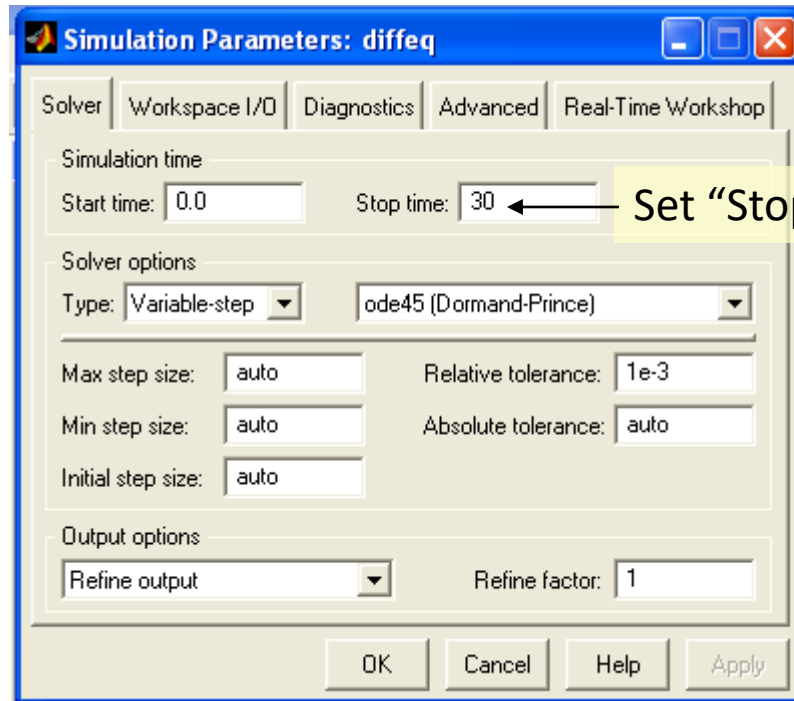
Note: Assume all initial conditions = 0

EXAMPLE 1: DIFFERENTIAL EQUATIONS (4)

STEP 4: Running Simulation

1

Open “simulation parameters” window

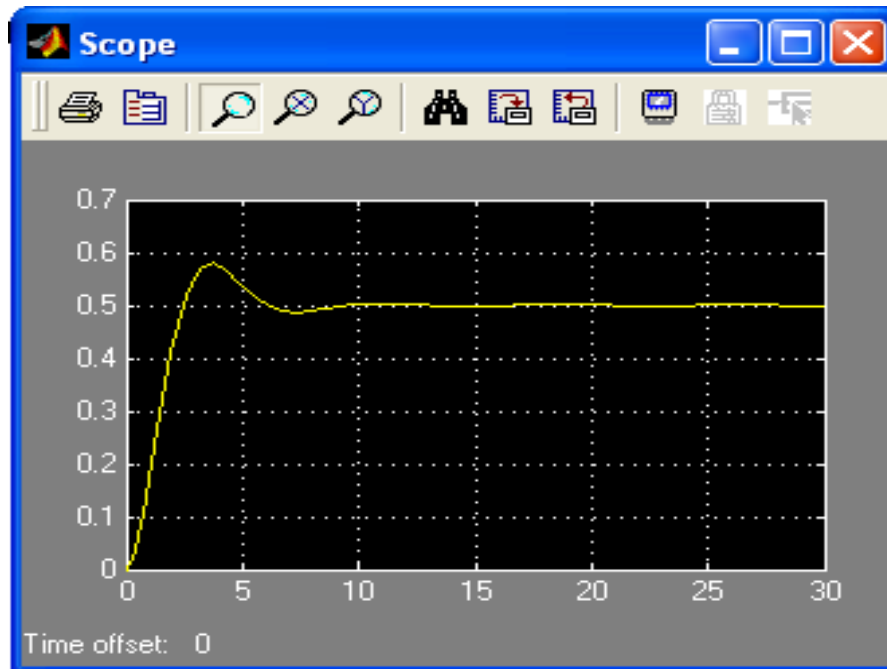


2

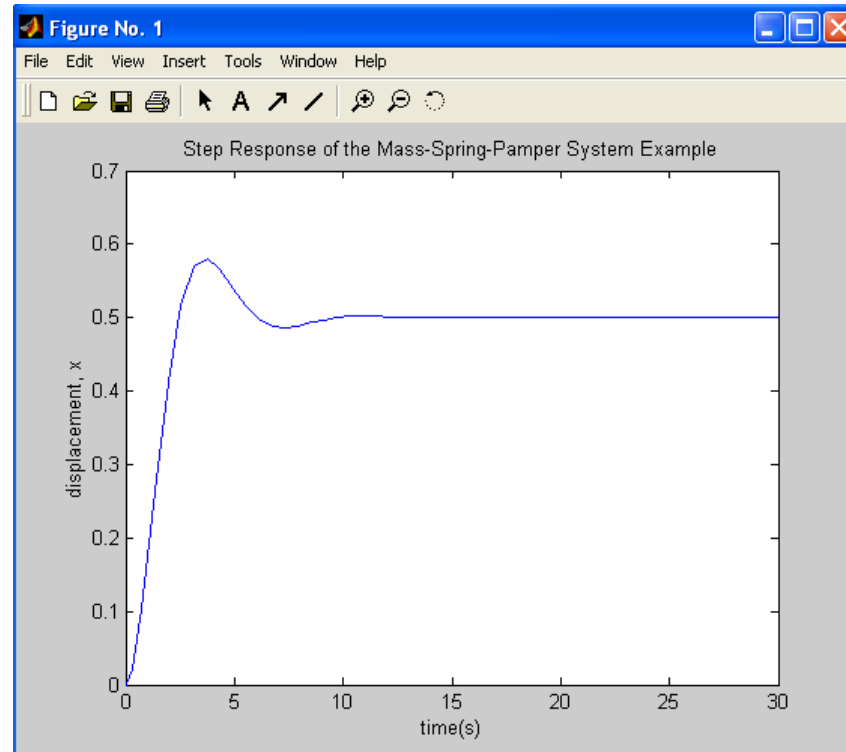
RUN
Simulation

EXAMPLE 1: DIFFERENTIAL EQUATIONS (5)

Step Response for the mass-spring-damper system example



Output from Scope block

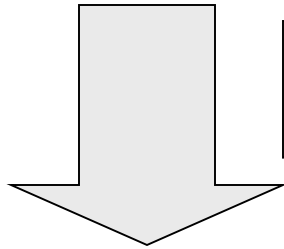


Plot system response

EXAMPLE 2: TRANSFER FUNCTION (1)

- Use the same mass-spring-damper system example and simulate the response using transfer function approach

$$\ddot{x} = \frac{1}{2}(-2\dot{x} - 2x + f(t))$$



The transfer function of the equation
(assume all initial conditions =0)

$$\frac{X(s)}{F(s)} = \frac{1}{2s^2 + 2s + 2}$$

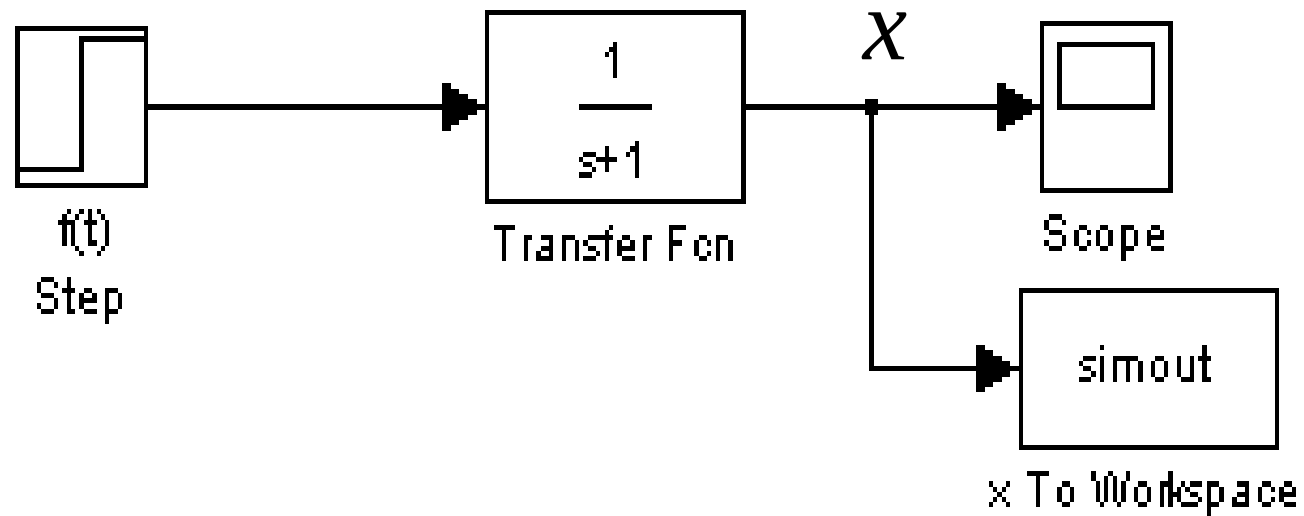
EXAMPLE 2: TRANSFER FUNCTION (2)

STEP 1: Creating Blocks

Select BLOCK set	Location in Simulink Library
Step	Sources
Transfer Function	Continuous
Scope & To Workspace	Sinks

EXAMPLE 2: TRANSFER FUNCTION (3)

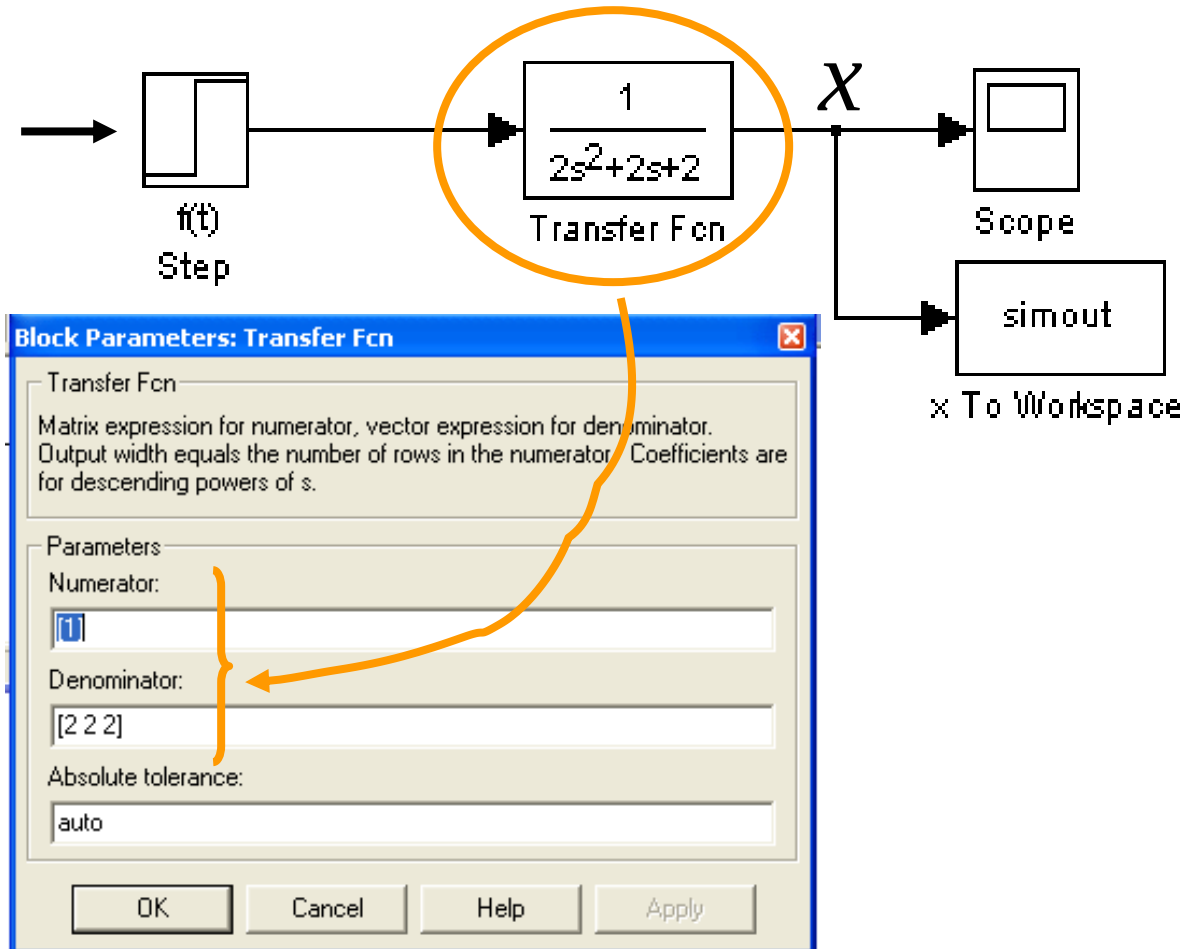
STEP 2: Making connections



EXAMPLE 2: TRANSFER FUNCTION (4)

STEP 3: SET PARAMETERS

Set Step time = 0

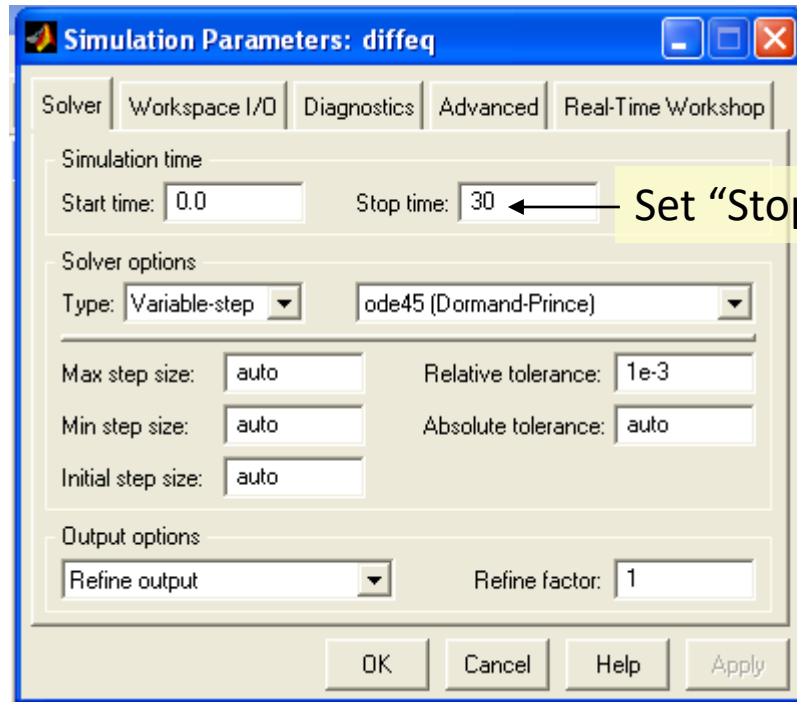


EXAMPLE 2: TRANSFER FUNCTION (5)

STEP 4: Running Simulation

1

Open “simulation parameters” window

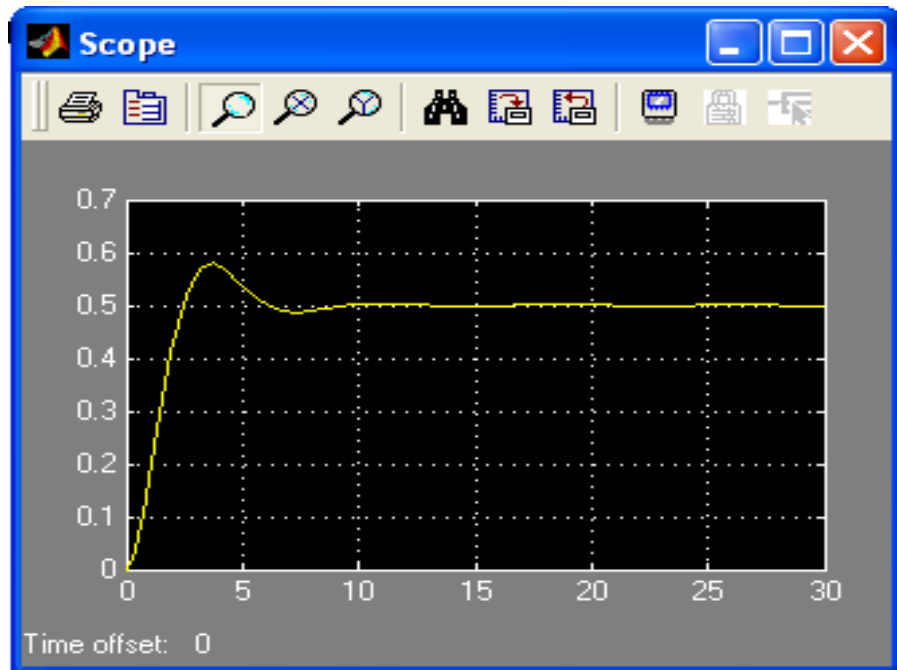


2

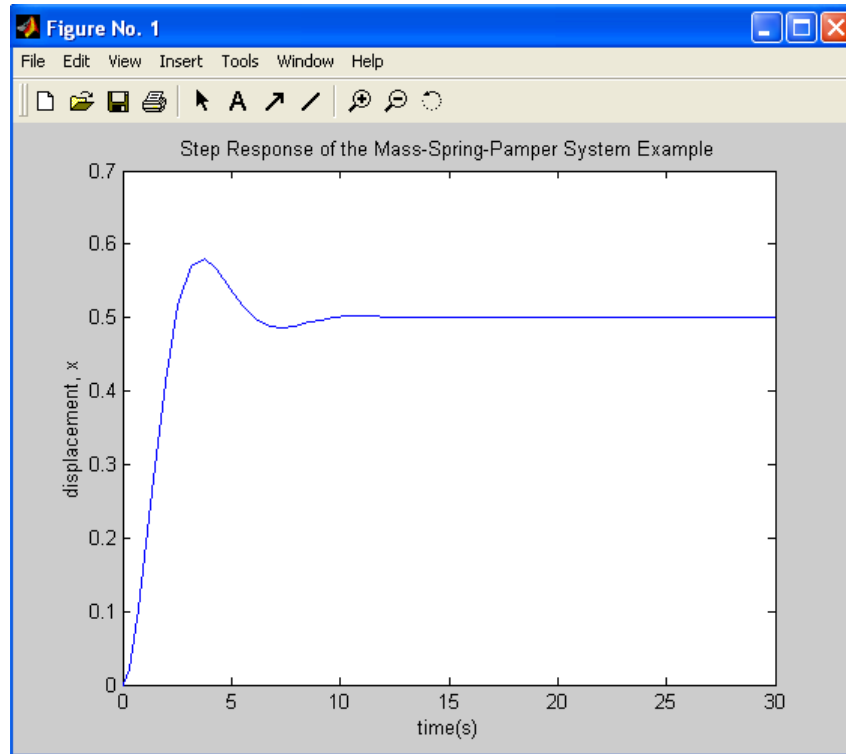
RUN
Simulation

EXAMPLE 2: TRANSFER FUNCTION (6)

VIEW OUTPUT (SCOPE & WORKSPACE)



Output from Scope block



Plot system response