Computer Aided Design (CAD)

Lecture B-02

Introduction to Simulink

Dr.Eng. Basem ElHalawany

Schedule (Draft)

Topics	Estimated Duration (# Lectures)
Introduction	1
Introduction to Matlab Environment	1
Matlab Programing (m-files) (1)	5
Modeling using Matlab Simulink Tool	4 (1/4)
Communication Systems Simulation (Applications)	3
Midterm	8th Week
Introduction to FPGA + Review on Digital Logic/Circuits	2
VHDL Modeling Language	4
VHDL Application	2
Introduction to OPNET Network Simulator	3
Course Closeout / Feedback/ project (s) Delivery	1

The Lecture is based on :

B. Modeling of Digital Communication Systems Using SIMULINK

This book:

- Introduces the reader to Simulink (An extension of the widely-used MATLAB modeling tool, and
- Introduces the use of Simulink in modeling and simulating digital communication systems, including wireless communications systems.

In contrast with other books that treat MATLAB in depth but treat Simulink only at an introductory level

- This book enables the communication systems engineer to l**earn and use the extensive capabilities** of Simulink to model a wide selection of **digital communications systems** and **evaluate their performance** for many important channel conditions.

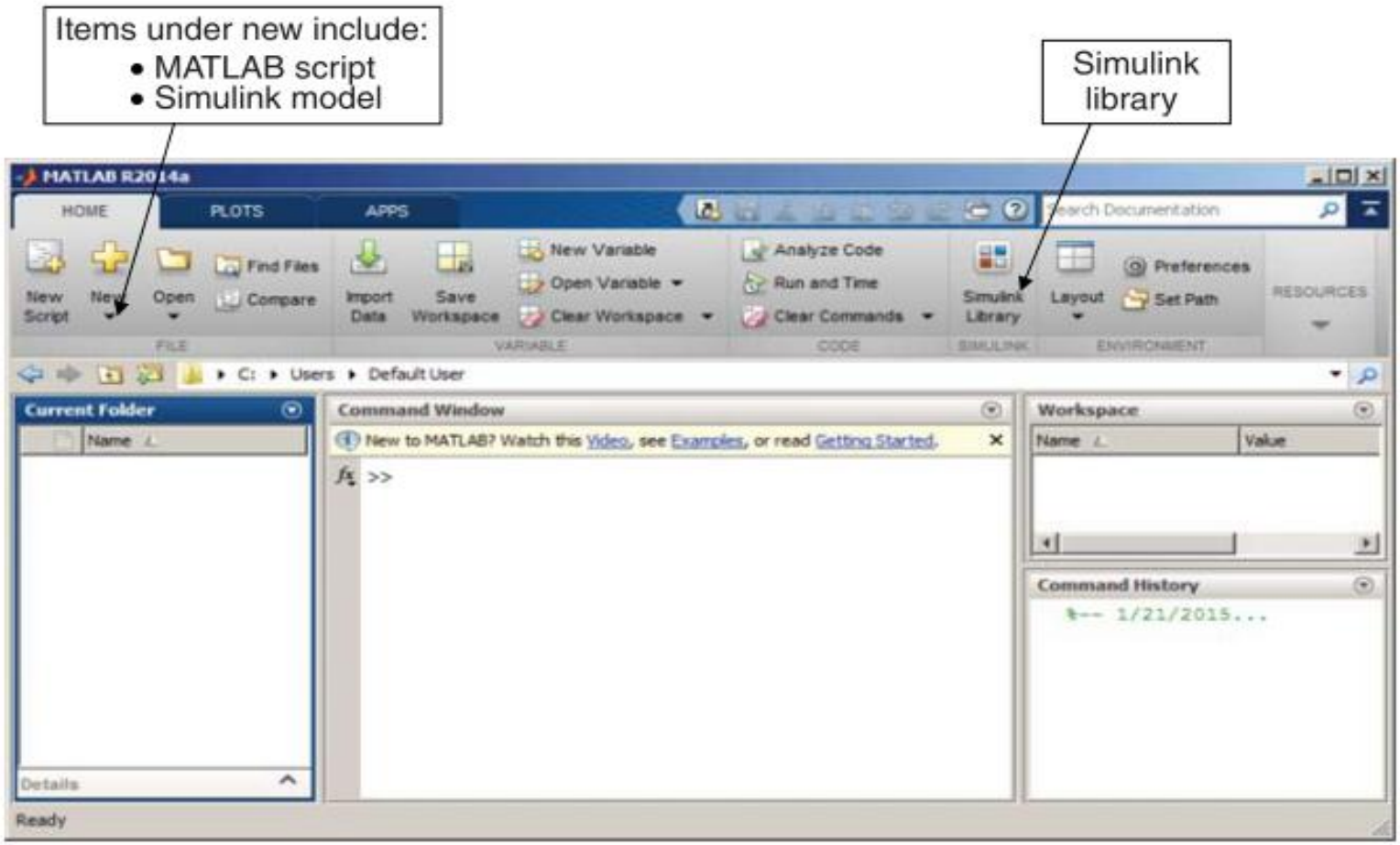
1

GETTING STARTED WITH SIMULINK

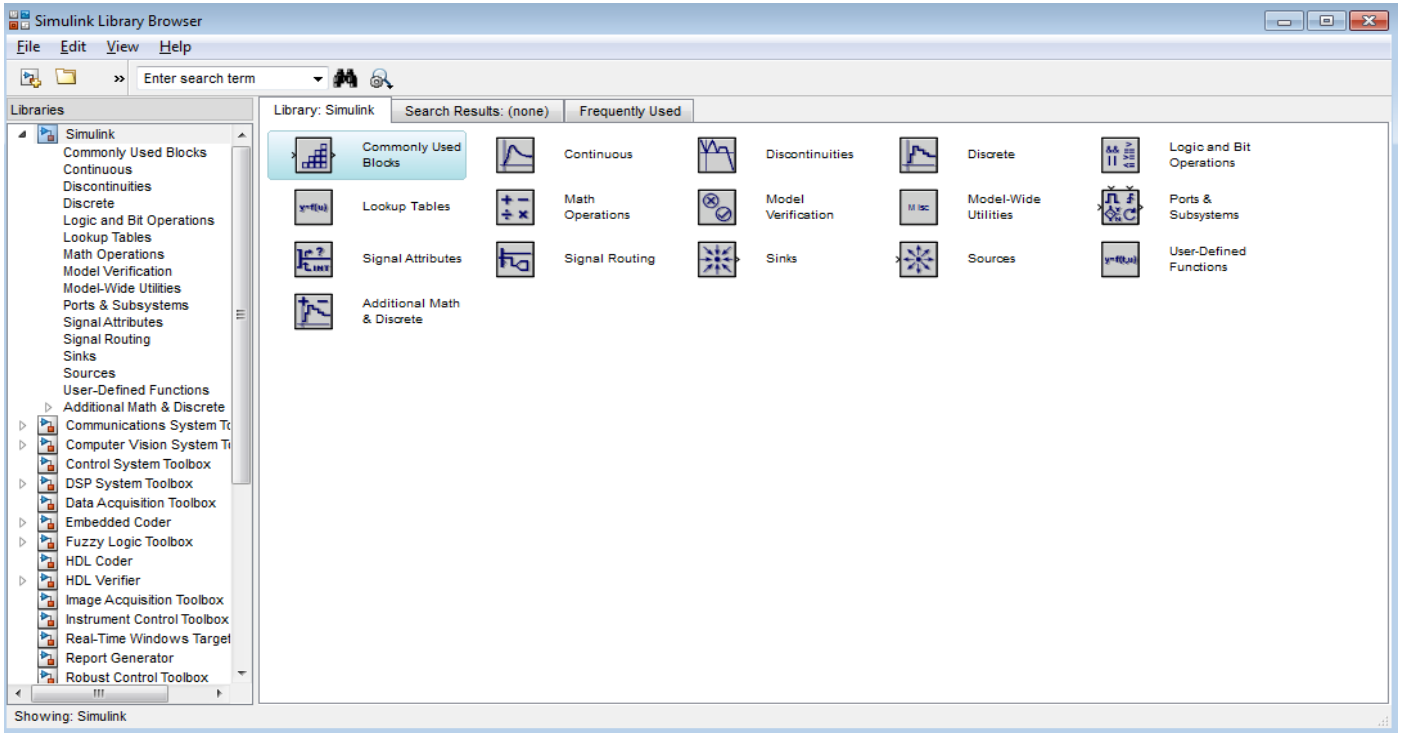
- Simulink is a block diagram environment for multi-domain simulation and Model-Based Design.
- It supports system-level design, simulation, and continuous test and verification of embedded systems.
- Simulink provides a graphical editor, customizable block libraries, and solvers for modeling and simulating dynamic systems.
- It is integrated with MATLAB, enabling you to incorporate MATLAB algorithms into models and export simulation results to MATLAB for further analysis.

1.3 SIMULINK BLOCK LIBRARIES

- Building a Simulink model consists of selecting individual blocks contained in libraries and joining them in a block diagram of the system to be simulated.



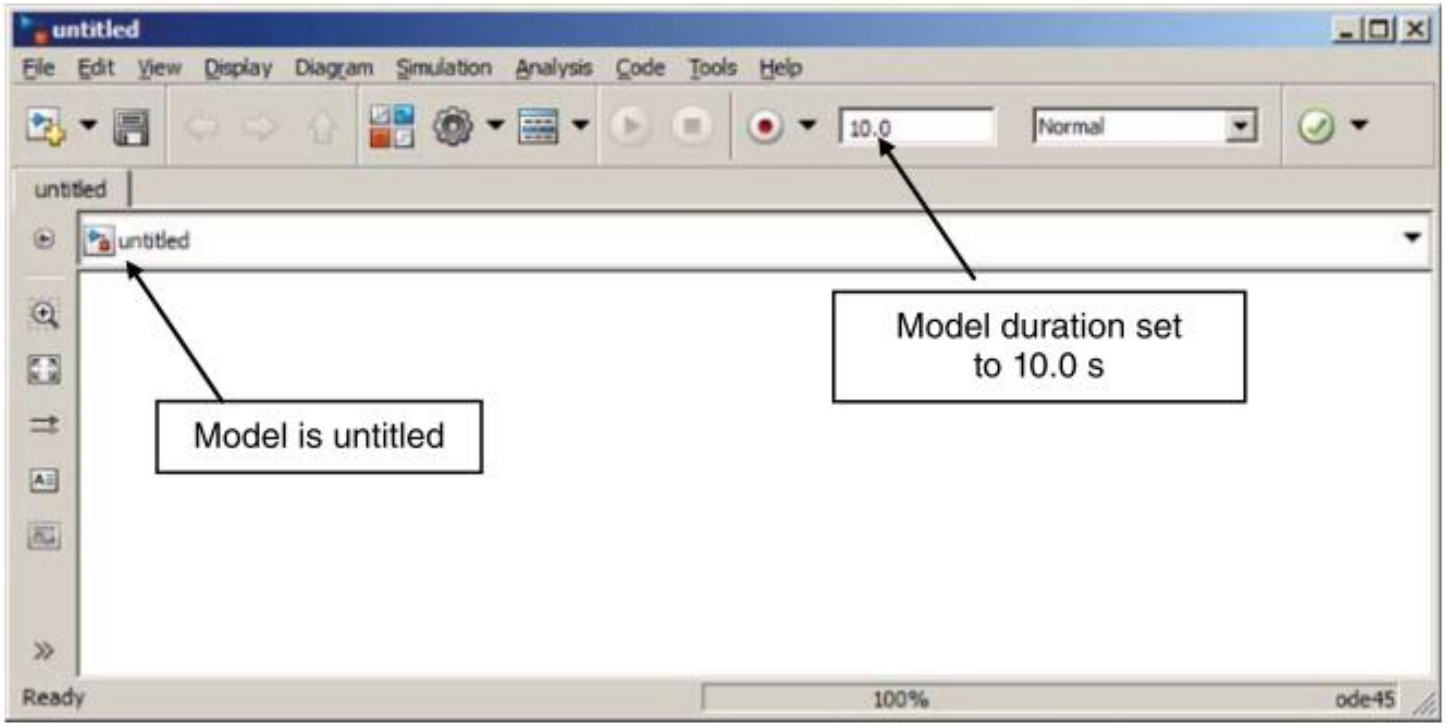
- **To view available blocks, select Simulink Library on the MATLAB toolbar.**
- **This opens the window shown in Figure 1.2.**



- The Simulink Library Browser shows a listing of available Simulink blocks.
- The focus in this book is on modeling digital communication systems, and the blocks you will find most useful are contained in:
  - ✓ The basic Simulink block library
  - ✓ The Communications System Toolbox and
  - ✓ The DSP System Toolbox.

1.4 BUILDING A NEW SIMULINK MODEL

- To begin building a new Simulink model, on the MATLAB toolbar, under the HOME tab, pull down New and select Simulink Model.
- This will open a blank Simulink model window, shown in Figure 1.3.



The duration of the model execution, is set to 10.0 s

Figure 1.3 Simulink Model Blank Window.

1.4.1 Inserting Signal Source and Scope

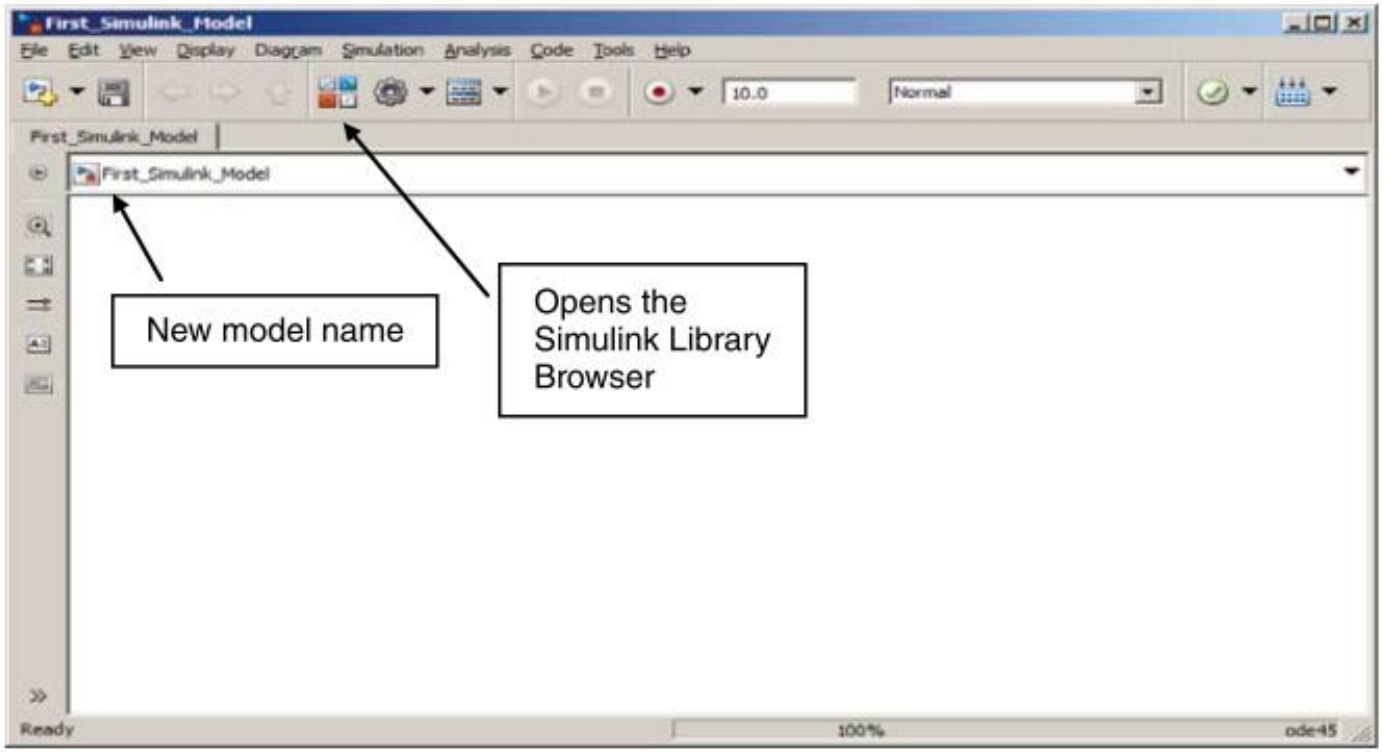
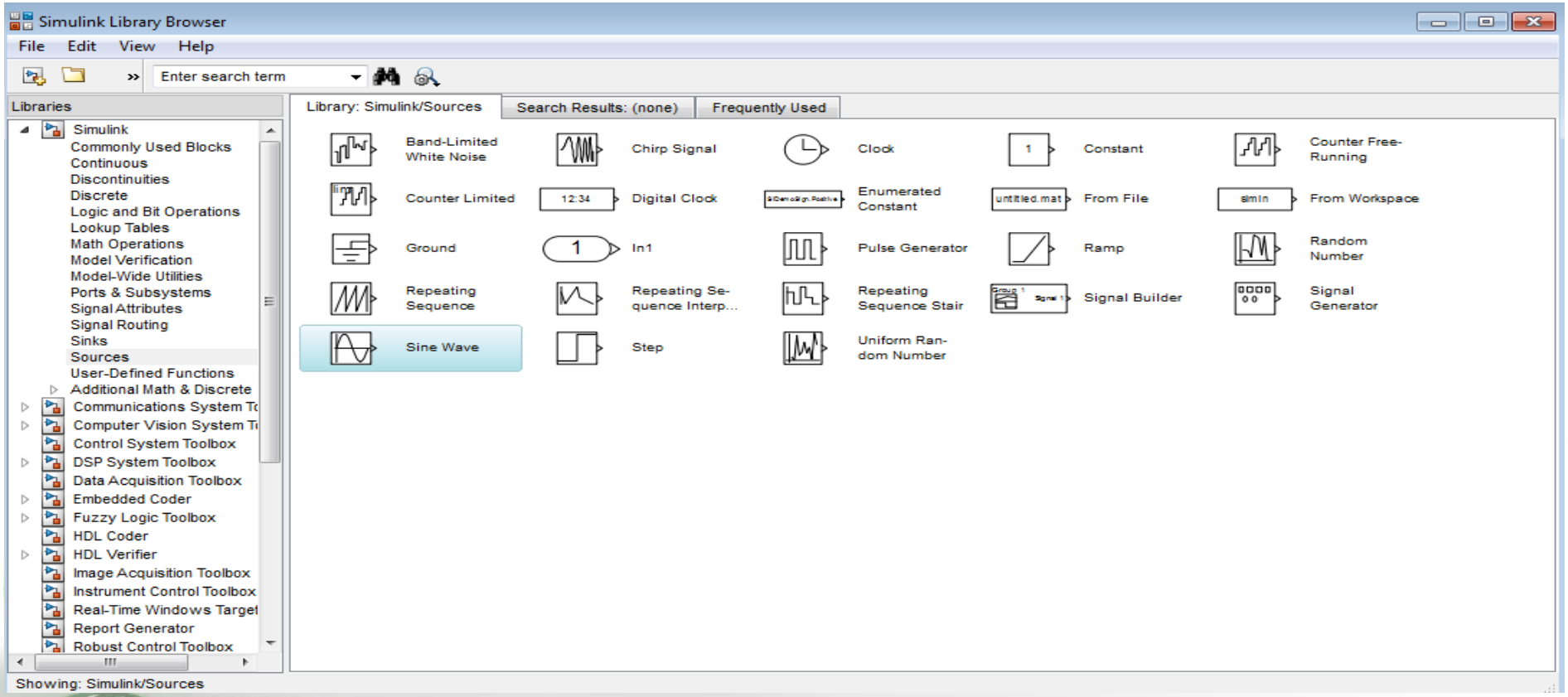


Figure 1.4 Simulink Model Window Renamed First_Simulink_Model.

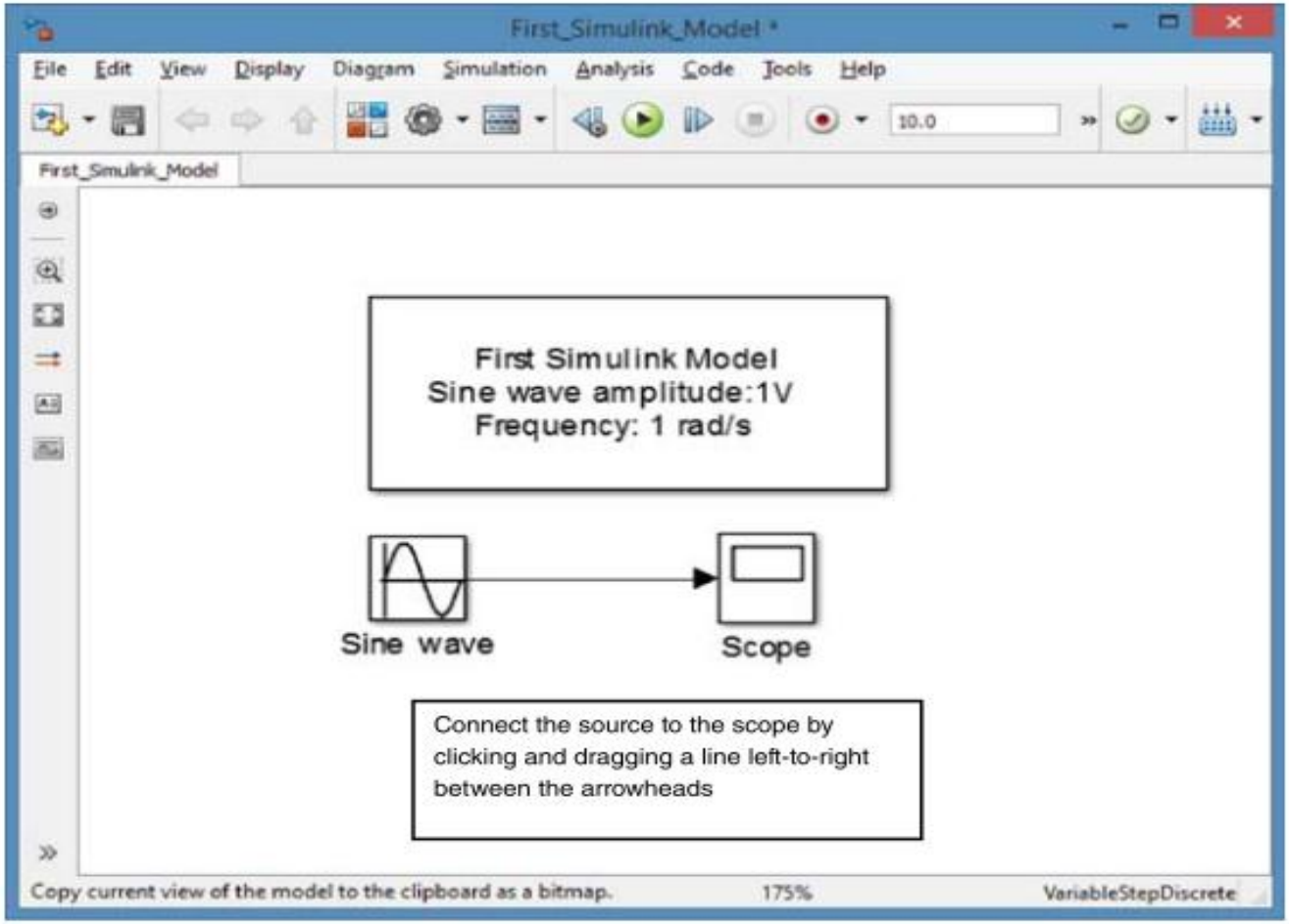
1.4.1 Inserting Signal Source and Scope

- First, in the library window, click on Sources to open the window shown in Fig. 1.5.
- With both the First_Simulink_Model window and the Simulink Library Browser window open, left-click on the Sine Wave icon and drag a copy into the model.
  - ✓ Alternatively, you can right-click on the icon in the library and select Add to First_Simulink_Model.



1.4.1 Inserting Signal Source and Scope

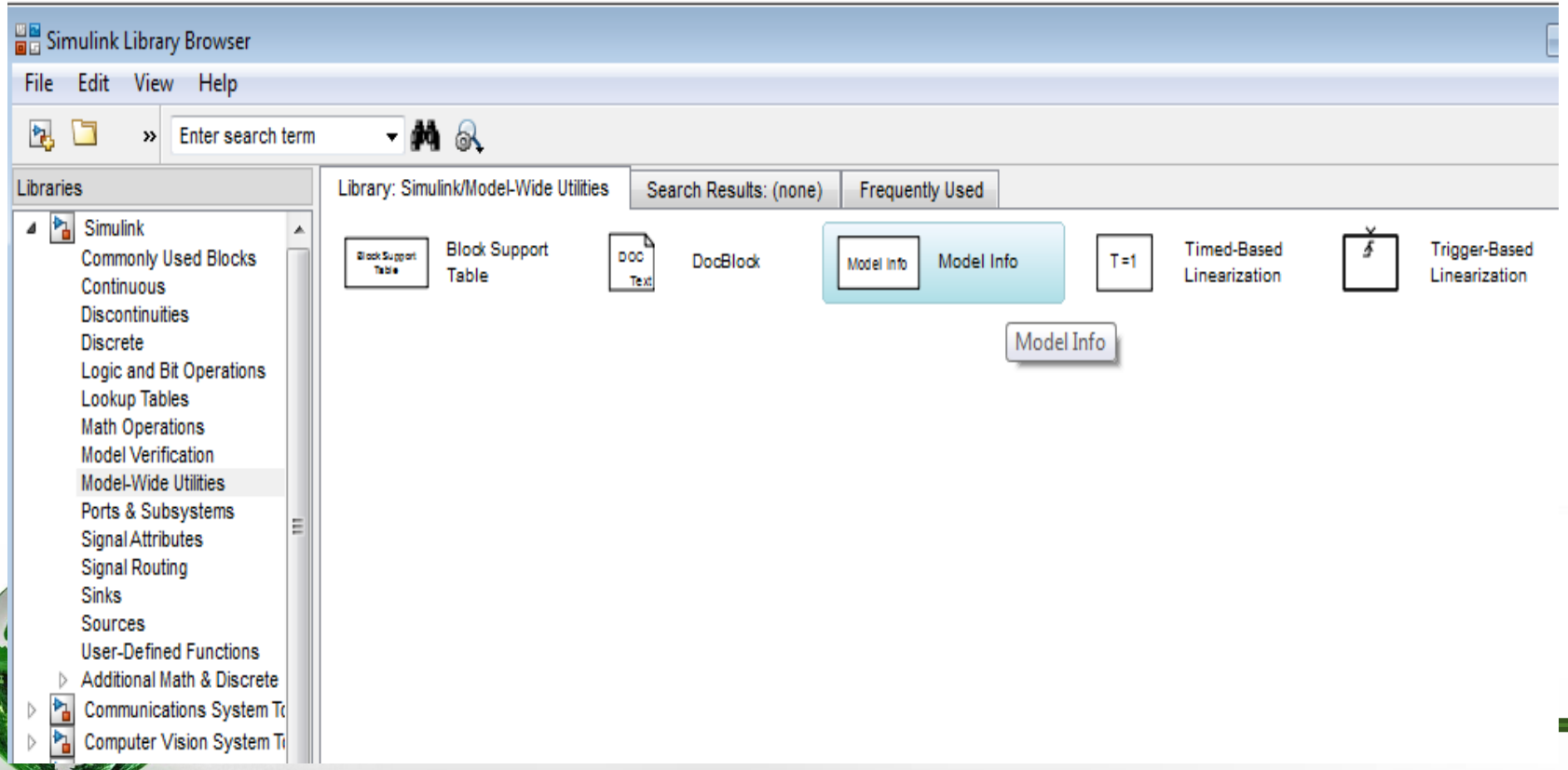
- Next, add a scope to the model by returning to the Simulink Library Browser and clicking on -**Sinks**, selecting scope, and dragging a copy into the model window, now shown in Figure 1.6.



In the figure, the Sine Wave block has been connected to the Scope by clicking on the arrow head at the Sine Wave output and dragging a line to the corresponding arrow head at the input to the Scope

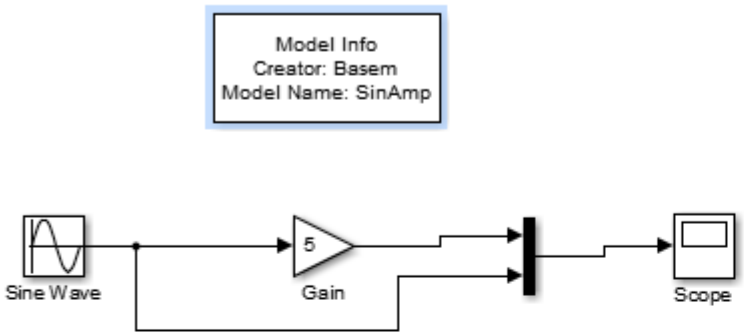
1.4.1 Inserting Signal Source and Scope

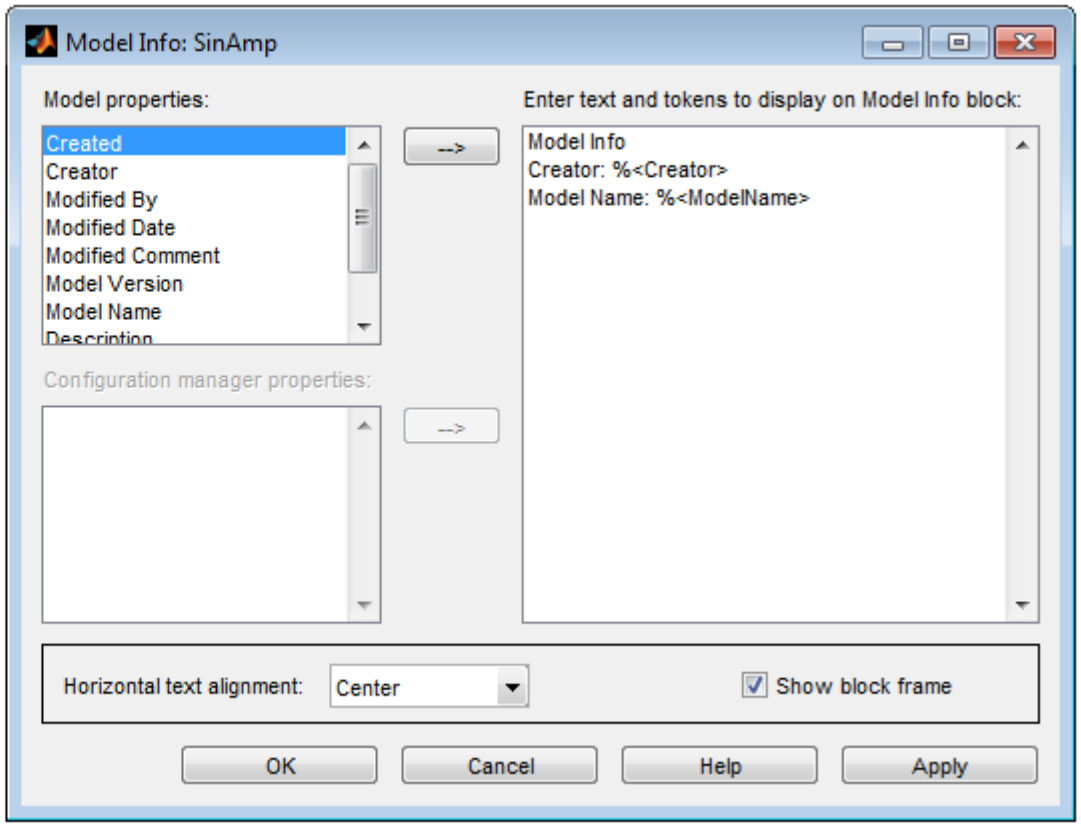
- Another block, entitled Model Info, is previous Figure and is available in the Simulink library under Simulink Model-Wide Utilities.
- Dragging it to your model and double clicking on this block opens a text box.
- This utility is very useful for conveniently displaying the parameters of each simulation model



1.4.1 Inserting Signal Source and Scope

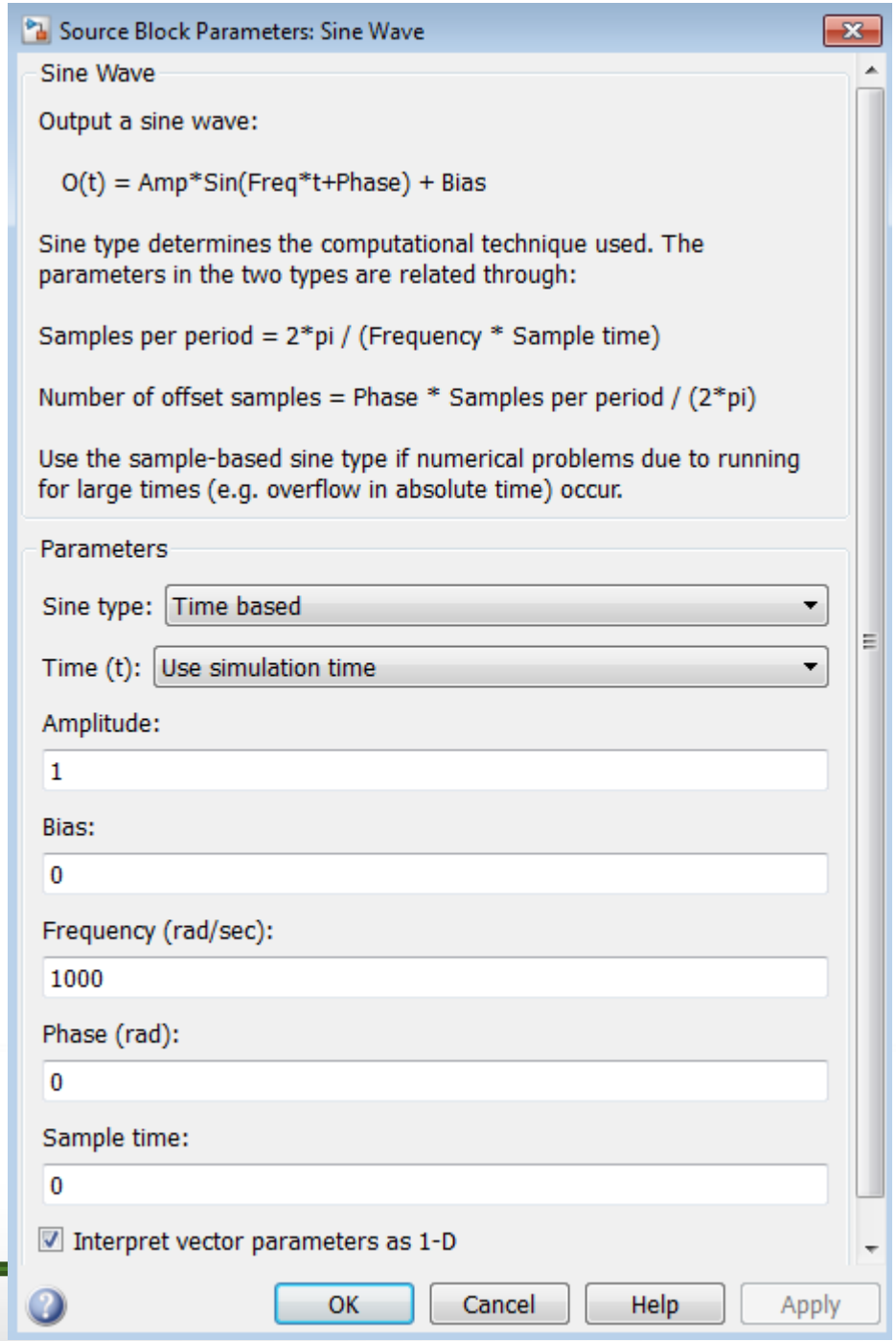
- Model Info under Simulink Model-Wide Utilities.





1.4.2 Setting the Source Block Parameters

- In the model window, double-click on the Sine Wave icon; this opens an information window for the Sine Wave
- Many types of options and parameters can be changed
- For more details, you need to open help for the Simulink documentation, accessible by clicking on the Help button.



1.4.3 Setting Scope Parameters

- In the model window, double-click on the Scope icon, opening the Scope display, shown in Figure 1.8.
- At this point, the display is blank, since no simulation has been started with this model.

- The gear-like icon on the toolbar opens the Scope Parameters window, which has three pages.

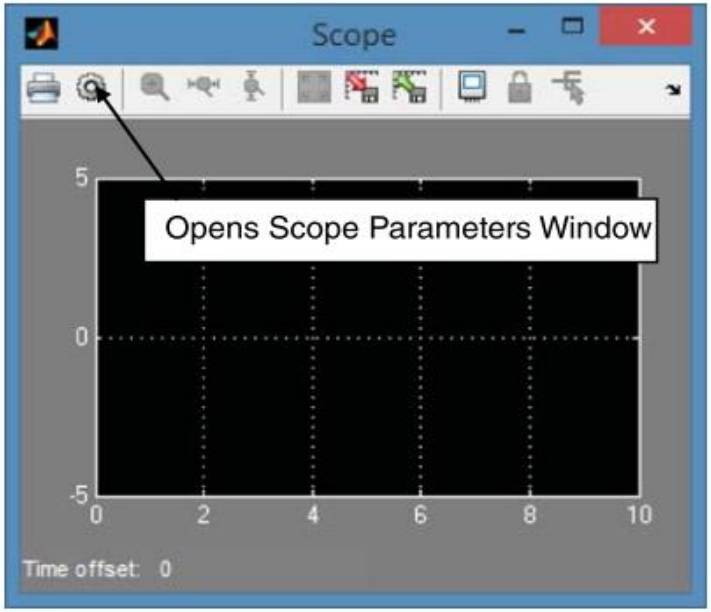
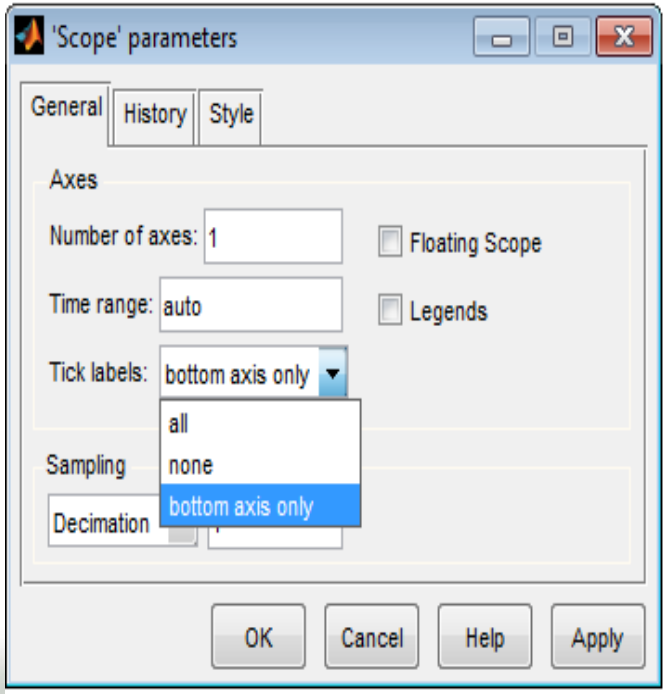
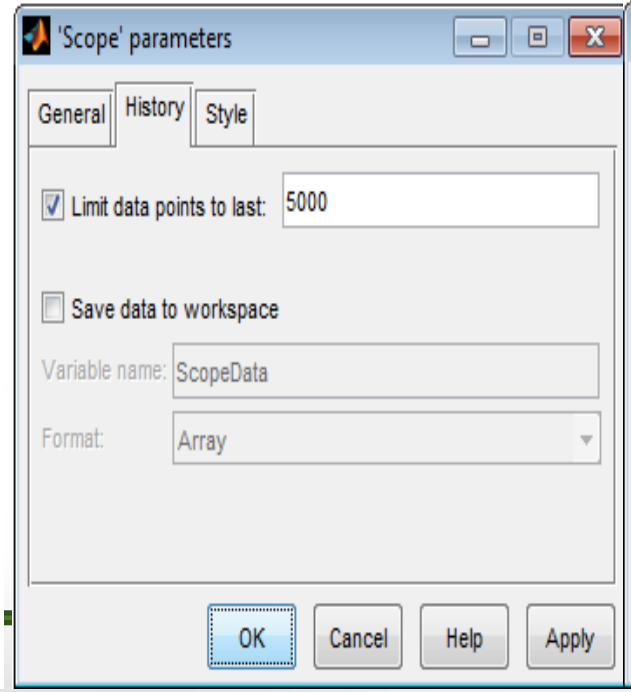
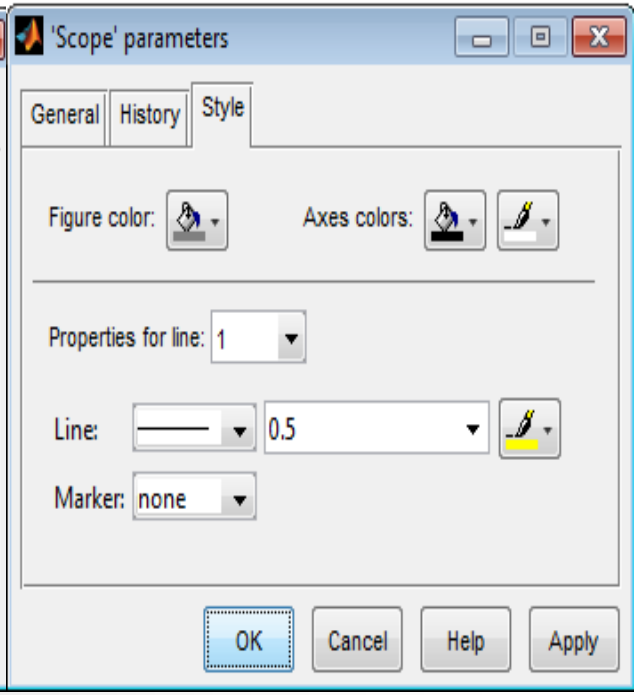


Figure 1.8 Scope Display.







1.5 EXECUTING THE SIMULINK MODEL

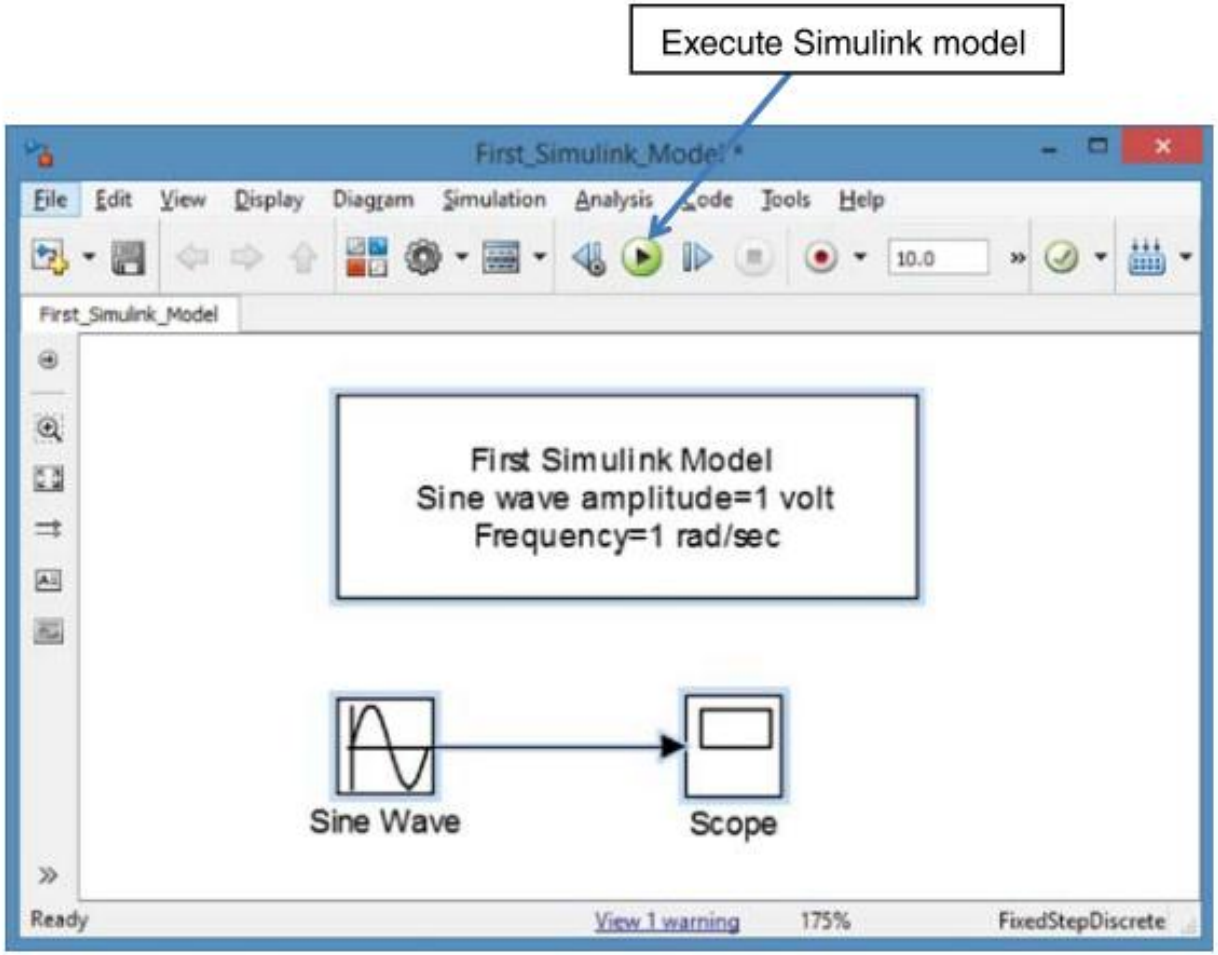


Figure 1.12 Executing the Simulink Model.

1.5 EXECUTING THE SIMULINK MODEL

- After execution for 1 rad/sec sine wave

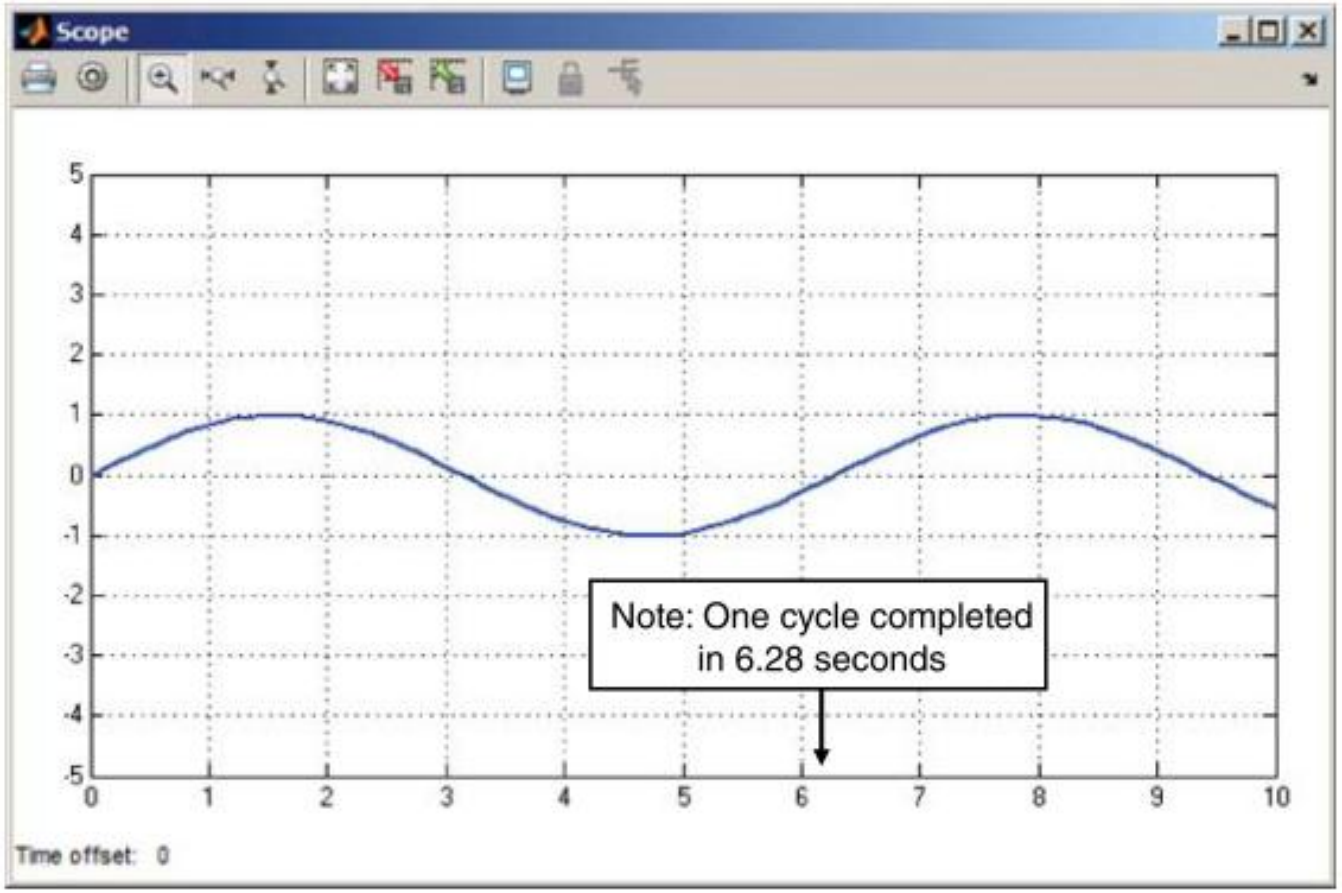
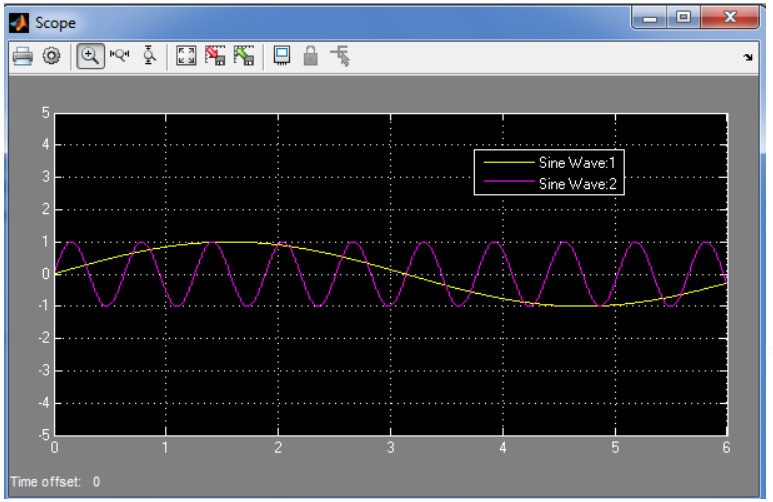


Figure 1.13 Scope Display After Executing the Sine Wave Model.

1.6 RECONFIGURING THE SIGNAL BLOCK

- An important feature of Simulink: **Simulink blocks are designed to accept signals and parameter values as vector inputs.**
- The time-based Sine Wave model in Figure can be modified to **generate two sinusoids** instead of just one.
- A simple way of doing this is double-clicking on the Sine Wave block, opening the block parameters window, and changing the frequency (rad/s) setting by inserting the two-element vector [1 10].

This configures the Sine Wave block to generate two sinousoids, one at 1 rad/s, the other at 10 rad/s.



1.6 RECONFIGURING THE SIGNAL BLOCK

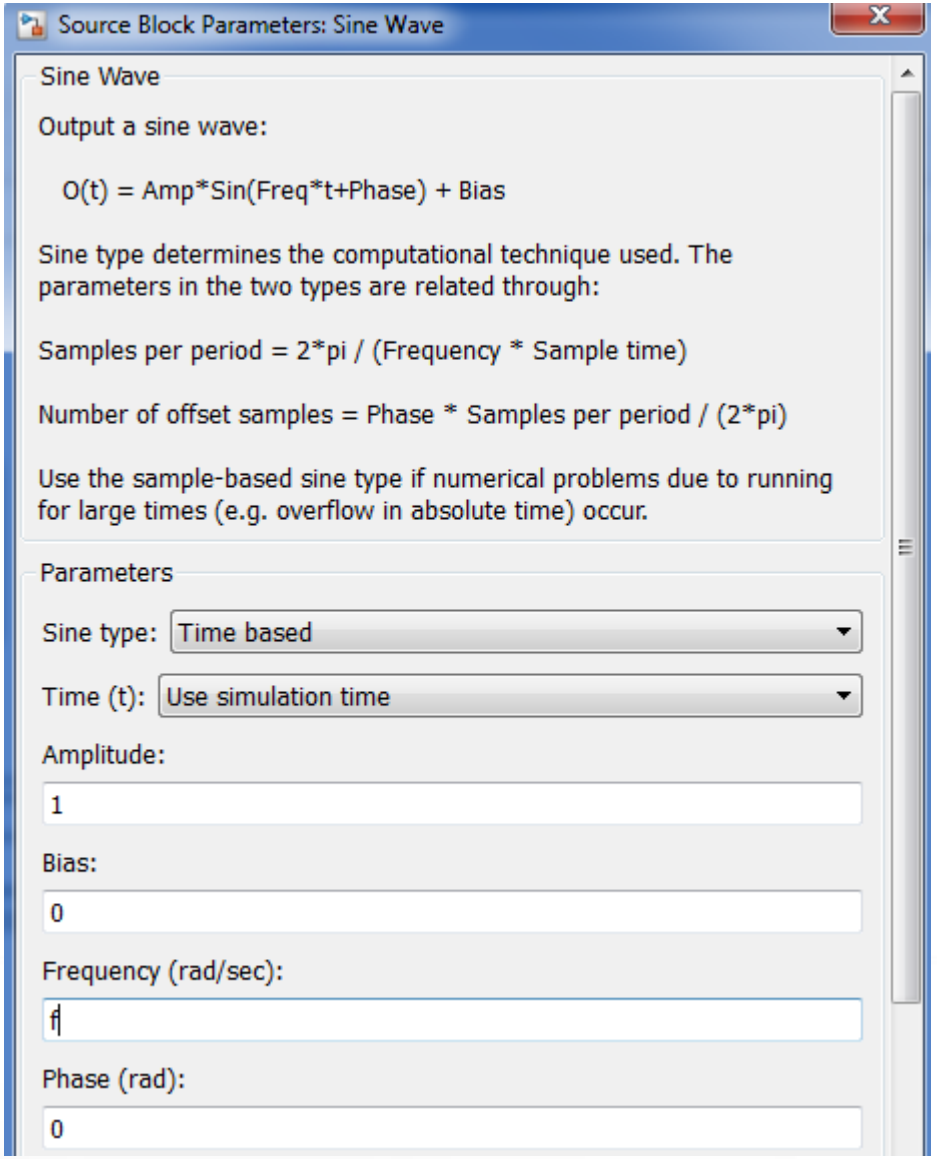
- Another way of configuring the Sine Wave block to generate the two sinusoids is to specify the frequency (rad/s) as f in the block parameters window,
- and define the variable f by inserting the statement f = [1 10] into the MATLAB Command Window.

```
>> f =[10 20]

f =

    10    20

>>
```



1.7 SAMPLE-BASED SIGNALS

- If the simulation model is changed by selecting **Sample based** in the Sine type Parameters
- the Sample time is set to 0.1 (seconds) and the number of samples per period is set to 10.

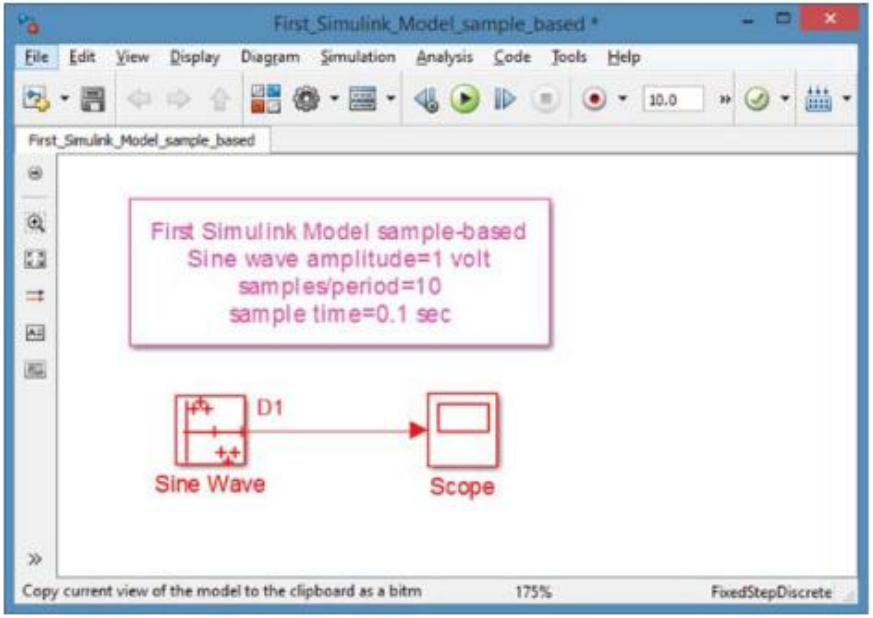


Figure 1.19 First Simulink Model Modified for Sample Based computation.

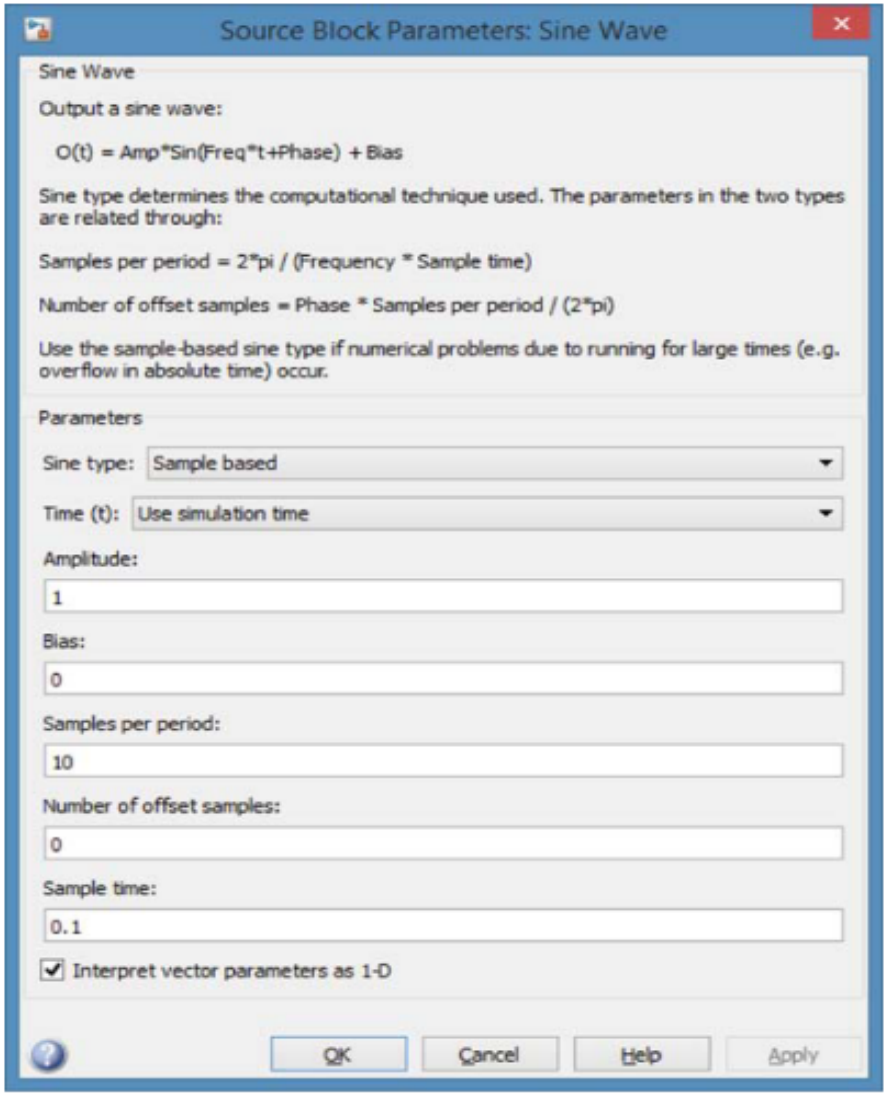
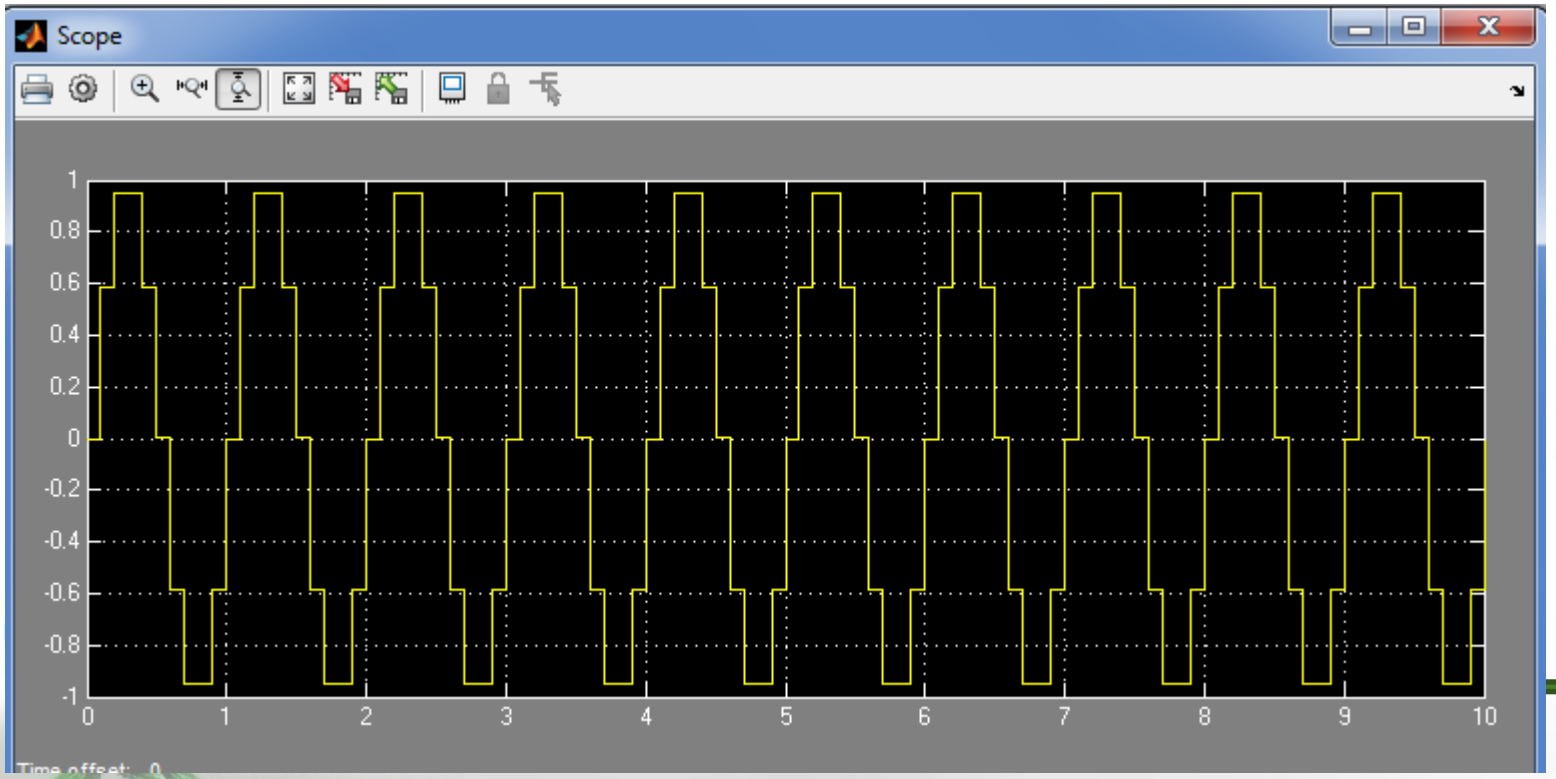


Figure 1.18 Sample Based Selection in Sine Wave Block.

1.7 SAMPLE-BASED SIGNALS

- If the simulation model is changed by selecting **Sample based** in the Sine type Parameters
- the Sample time is set to 0.1 (seconds) and the number of samples per period is set to 10.

resulting sample values



1.8 SENDING DATA TO WORKSPACE

- By adding the "**To Workspace**" block from Simulink **Sinks**
- The To Workspace block causes the output data from the Sine Wave block to be saved and examined for subsequent use such as plotting.

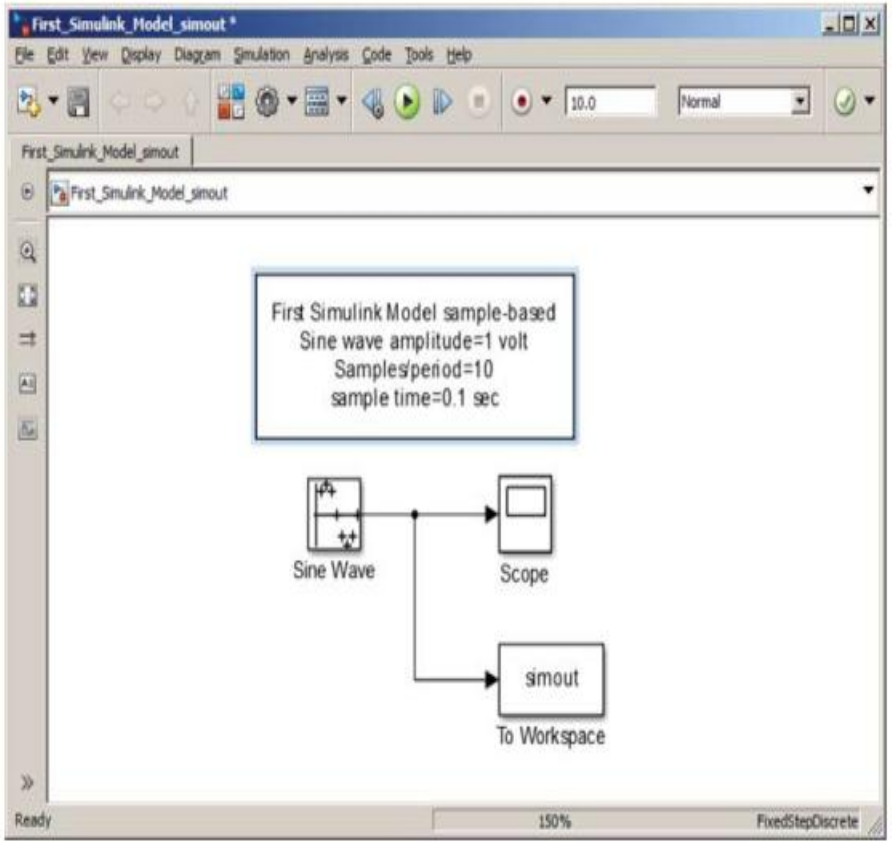
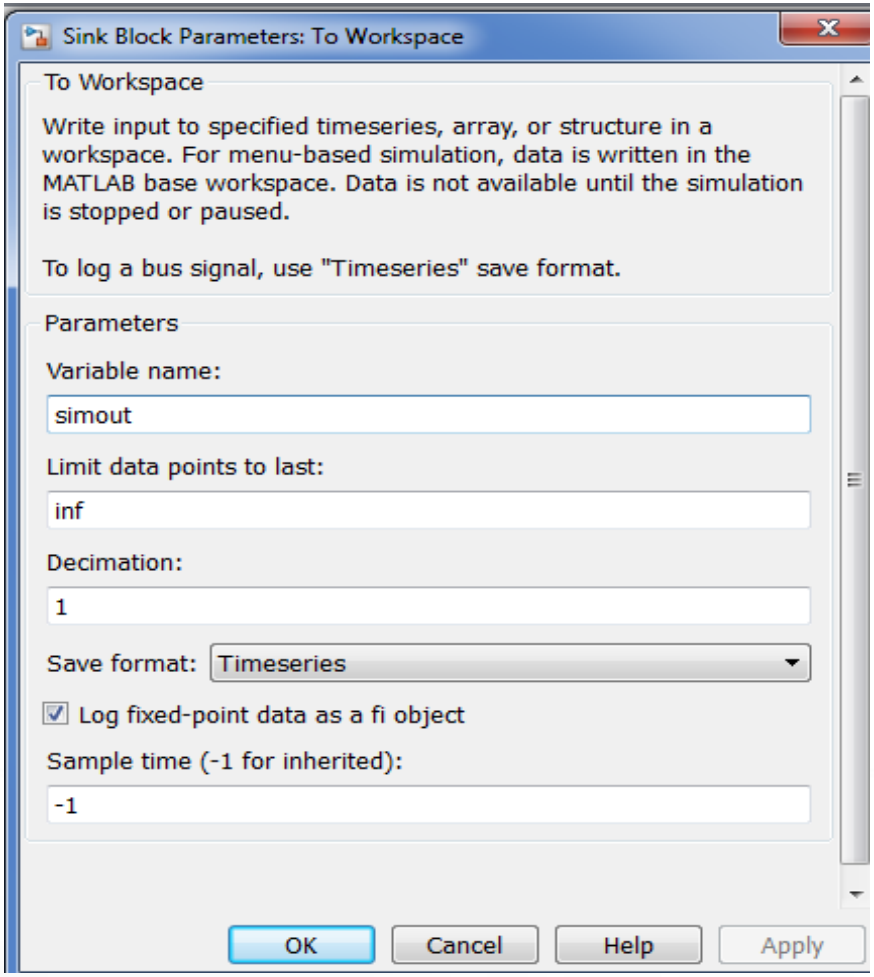
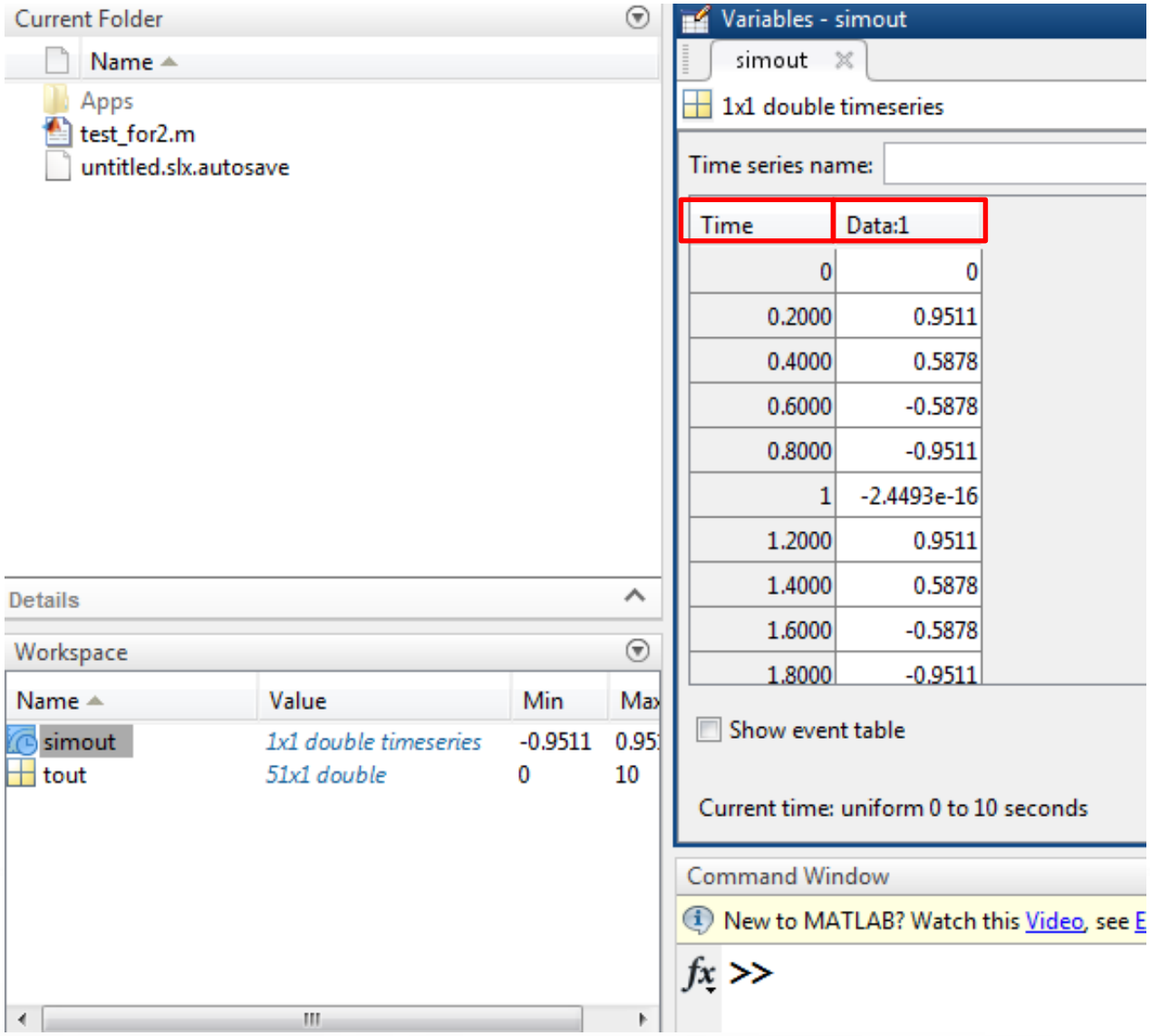


Figure 1.22 Sending Simulation Data to Workspace.



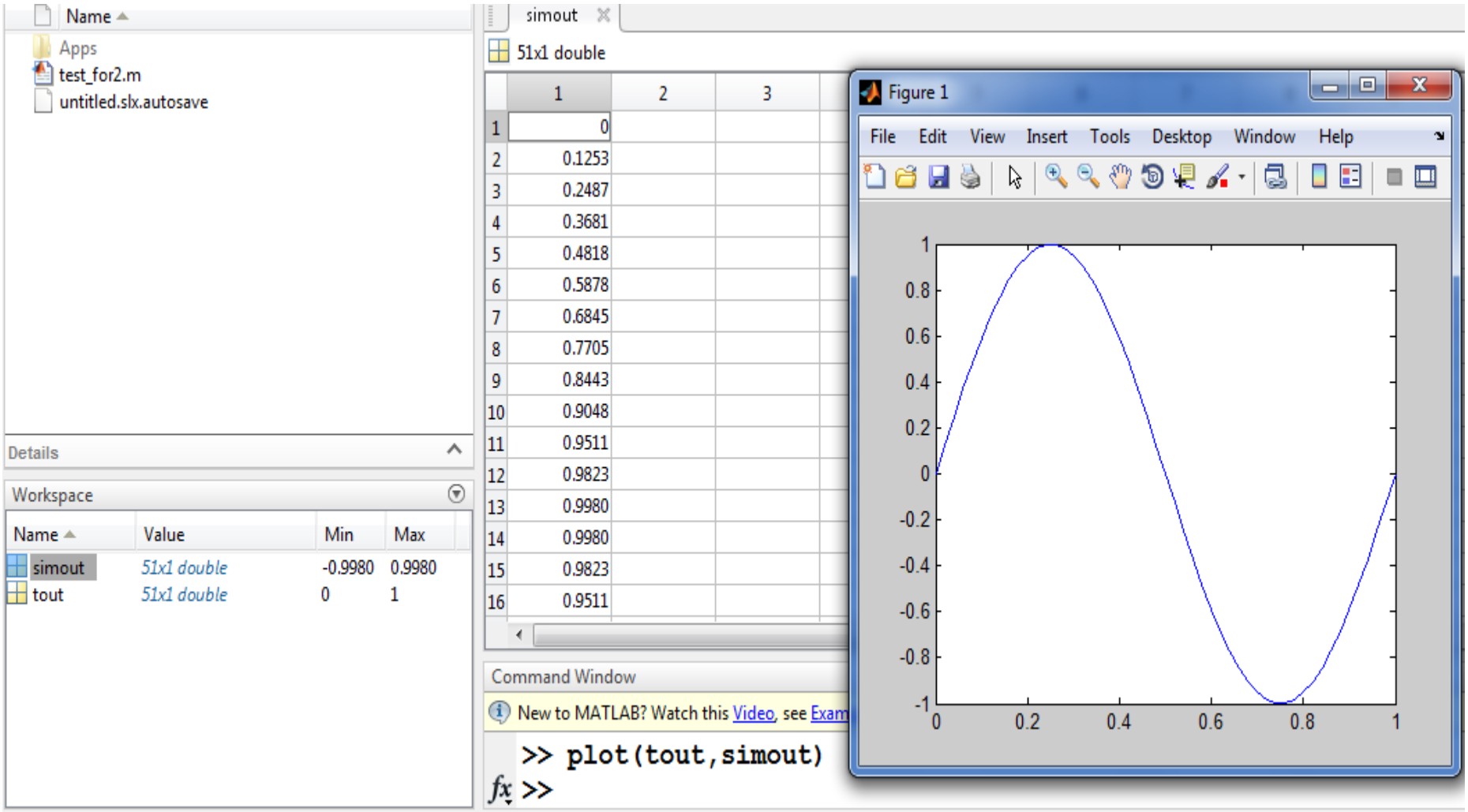
1.8 SENDING DATA TO WORKSPACE

Option: Timeseries



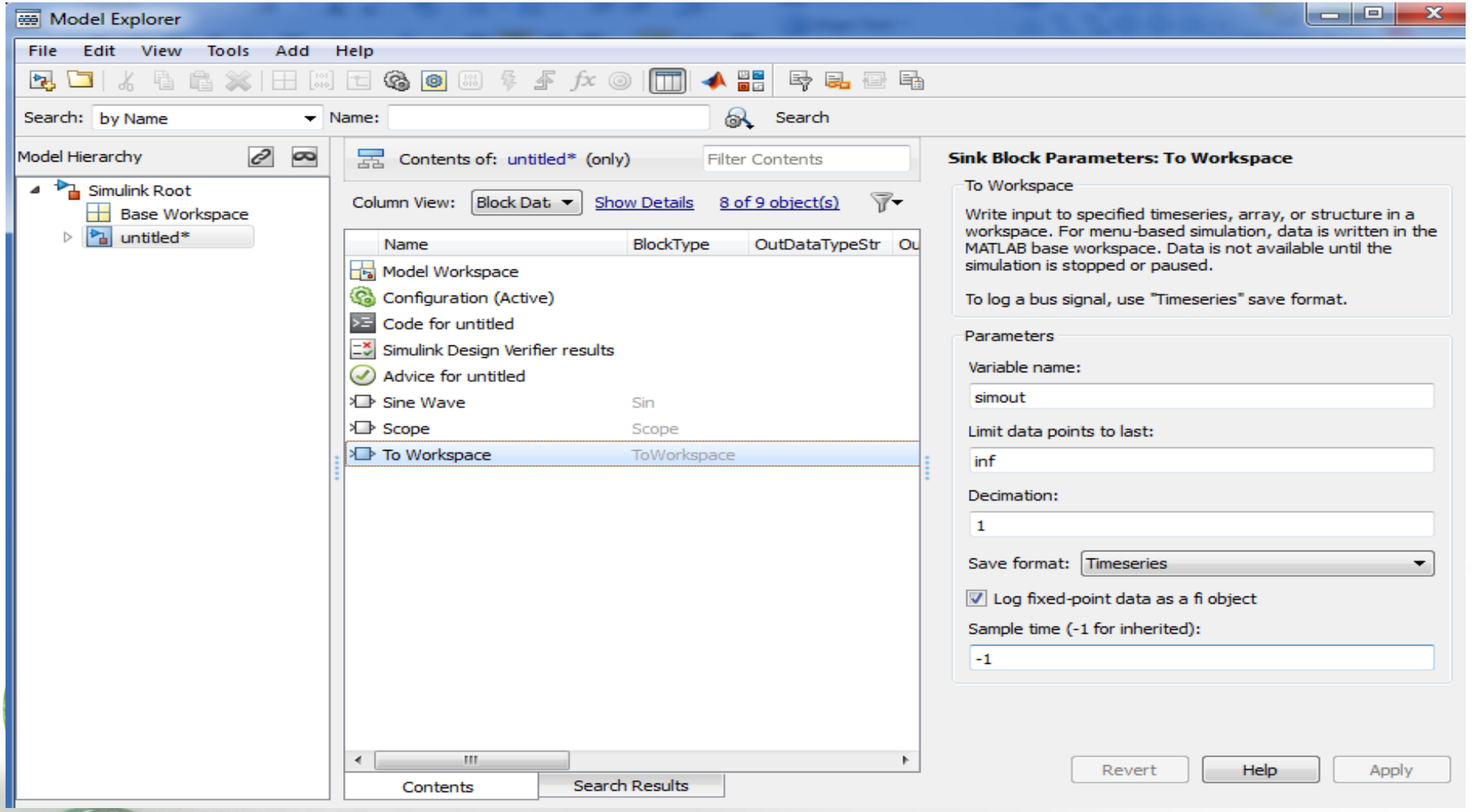
1.8 SENDING DATA TO WORKSPACE

Option: Array



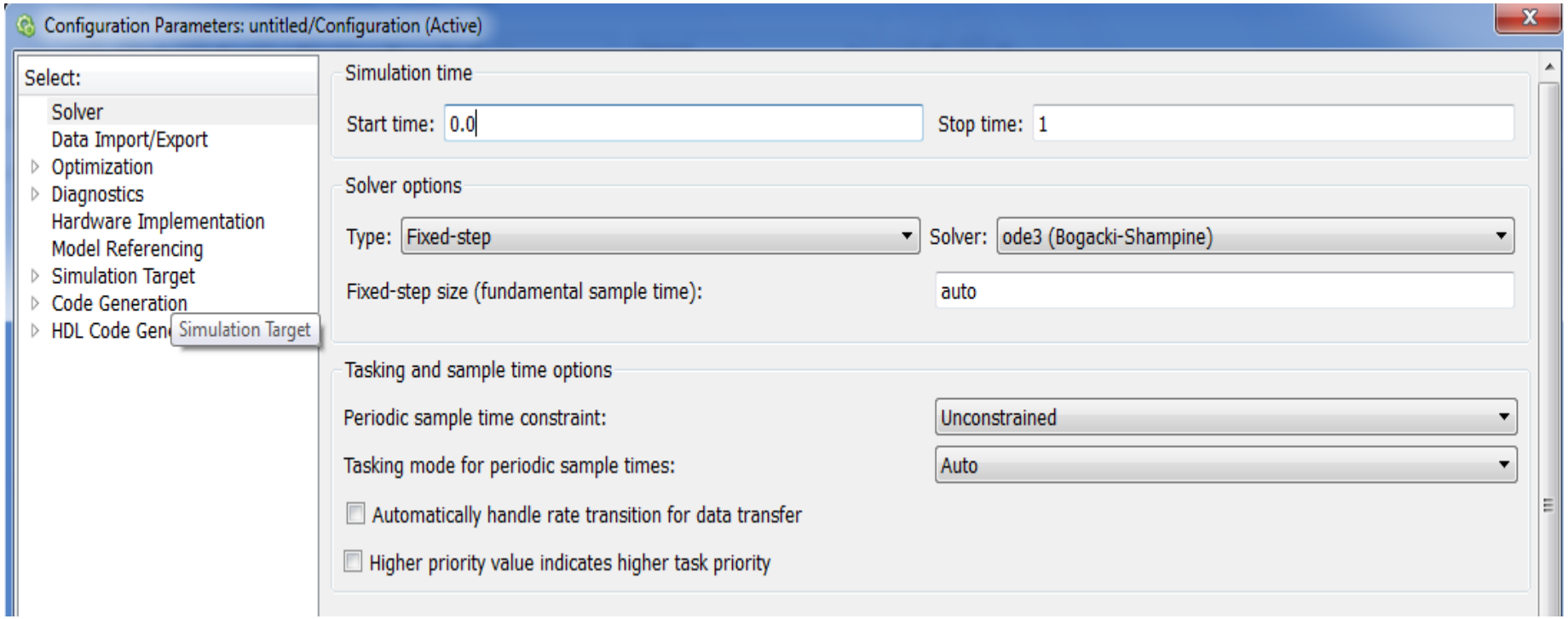
1.9 USING MODEL EXPLORER

- Model Explorer is a tool available to provide the user with the ability to view, modify or add elements in the Simulink model and workspace variables.
- To open the Model Explorer, select Model Explorer under the View tab in the Simulink model window.



1.11 Selecting Model Configuration Parameters

- In the Simulink model window, pulling down the Simulation tab and selecting Model Configuration Parameters

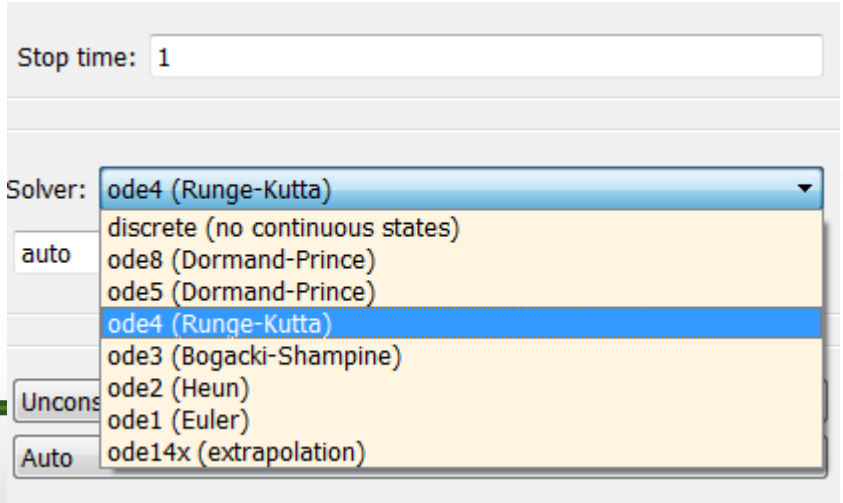


- User can specify the:
  - ✓ simulation start and stop time and
  - ✓ choose the solver for the simulation

Simulation: Simulink Solvers

- A dynamic system is simulated by computing its states at successive time steps over a specified time span, using information provided by the model
- This entails repeatedly solving a set of difference or differential equations describing component blocks in the model of the system being simulated
- The process of solving the model at successive time steps is referred to as **simulating** the system that the model represents
- Simulink provides an assortment of solvers, each geared to solving a specific type of model

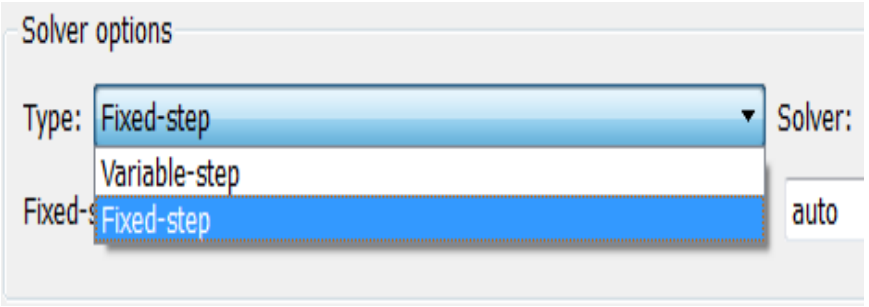
✓ The Solver here is selected as ode-45, which, in general is the best first choice as a solver for most Simulink models.



1.11 Selecting Model Configuration Parameters

- Solver Options:

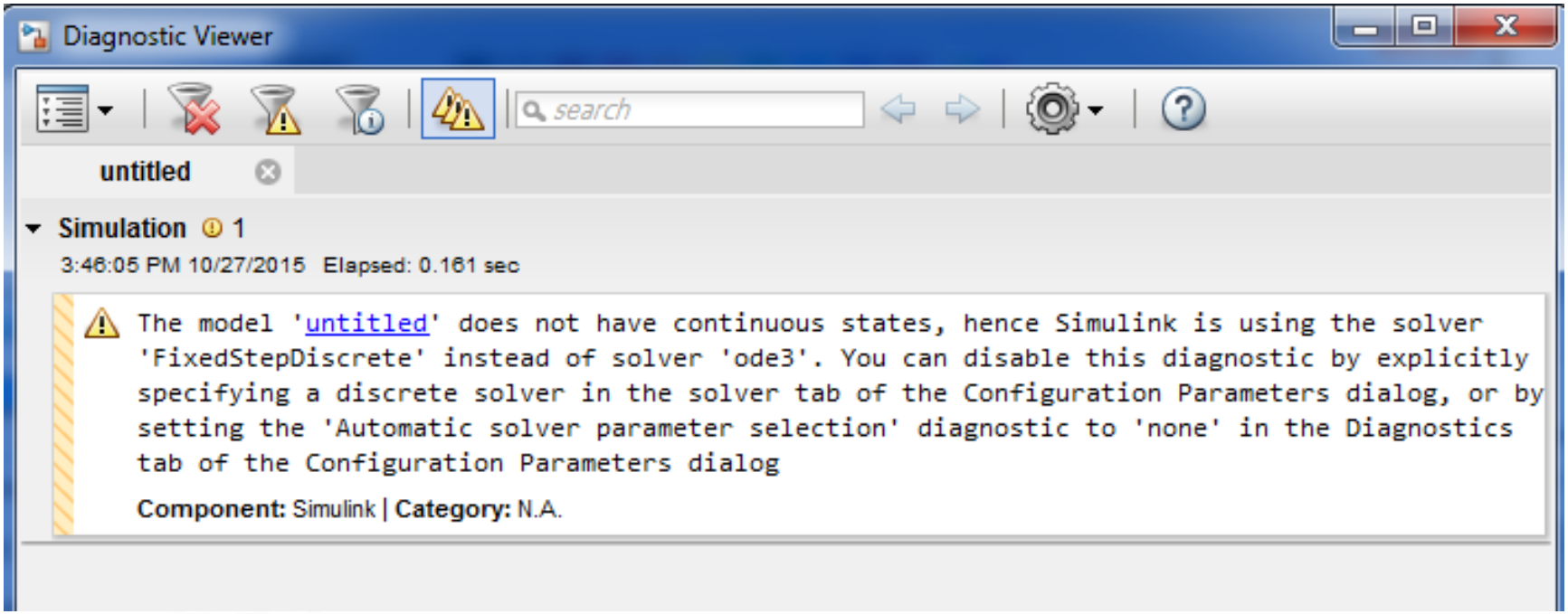
- For both fixed-step and variable-step solvers, the next simulation time is the sum of the current simulation time and the step size.



- With a fixed-step solver, the step size remains constant throughout the simulation
- With a variable-step solver, the step size can vary in an adaptive fashion from step to step to maximize efficiency, while meeting specified error tolerances

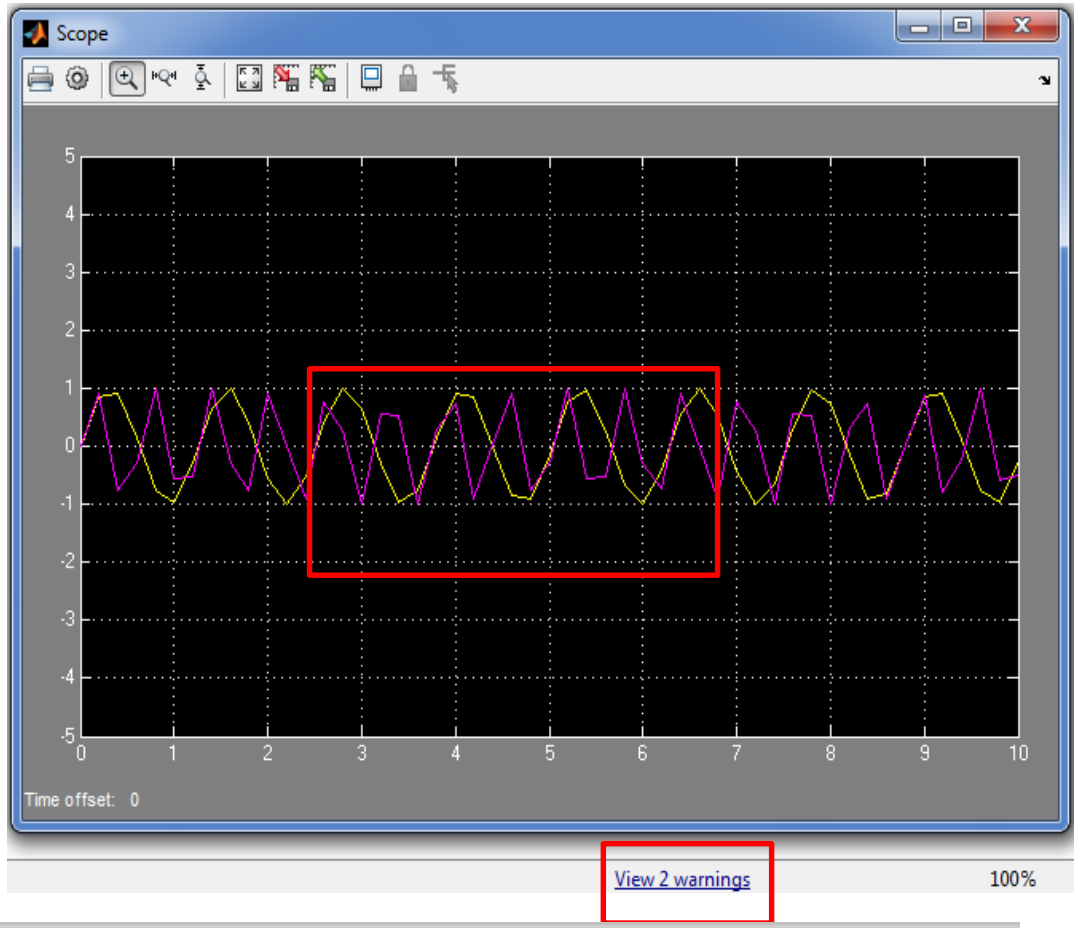
➢ Solver Warning Example (1)

- If the model is modified where the Sine Wave block is chosen to have a Sample-based Sine type and a 0.1 s Sample time is entered,
- The model execution will produce a warning message seen at the bottom of the Simulink model.



- The model 'untitled' does not have continuous states, hence Simulink is using the solver 'FixedStepDiscrete' instead of solver 'ode3'.

➢ Solver Warning Example (2)

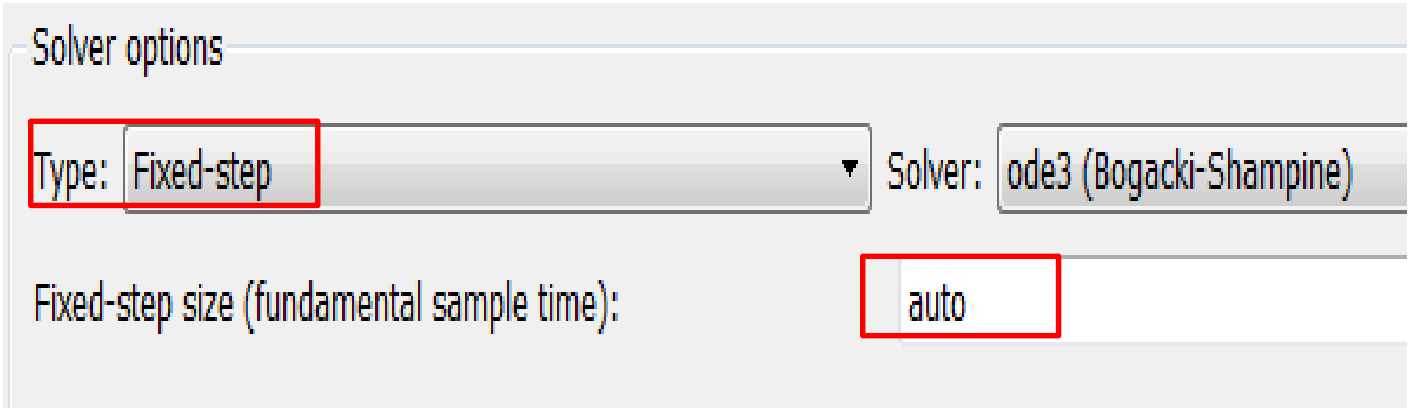


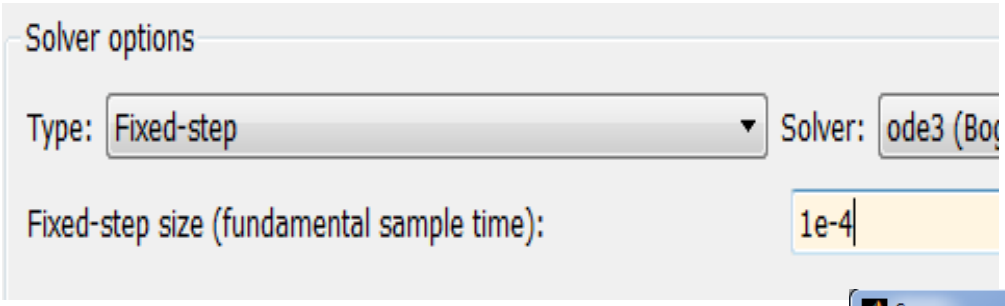
➢ Bad resolution

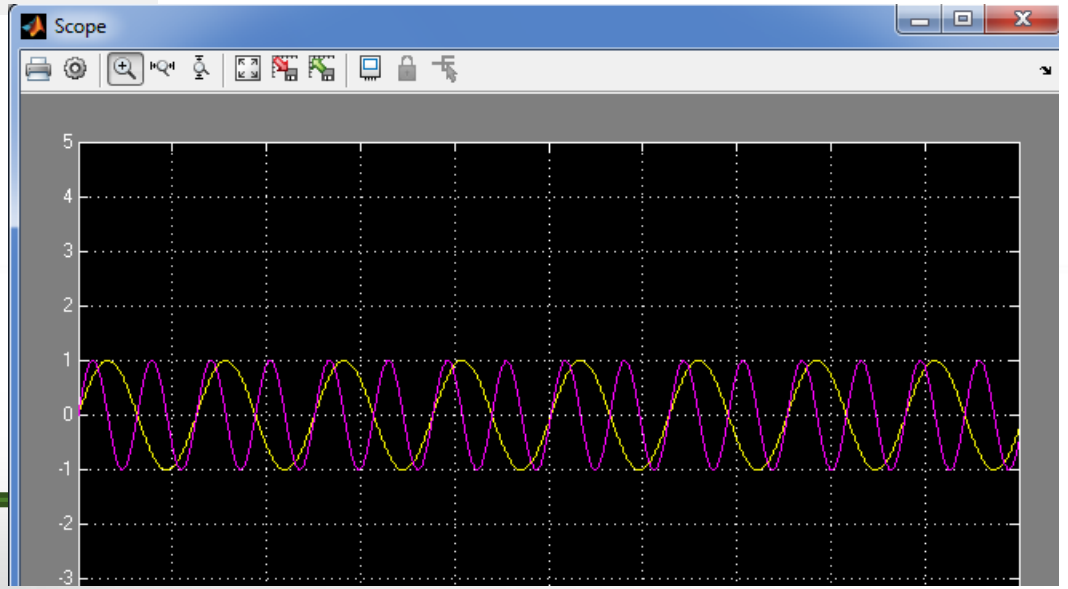
⚠ Unable to determine a fixed step size based on the sample times in the model 'untitled', because the model does not have any discrete sample times. Picking a fixed step size of (0.2) based on simulation start and stop times. You can disable this diagnostic by explicitly specifying a fixed step size in the Solver pane of the Configuration Parameters dialog box, or setting the 'Automatic solver parameter selection' diagnostic to 'none' in the Solver group on the Diagnostics pane of the Configuration Parameters dialog box.

➢ Solver Warning Example (1)

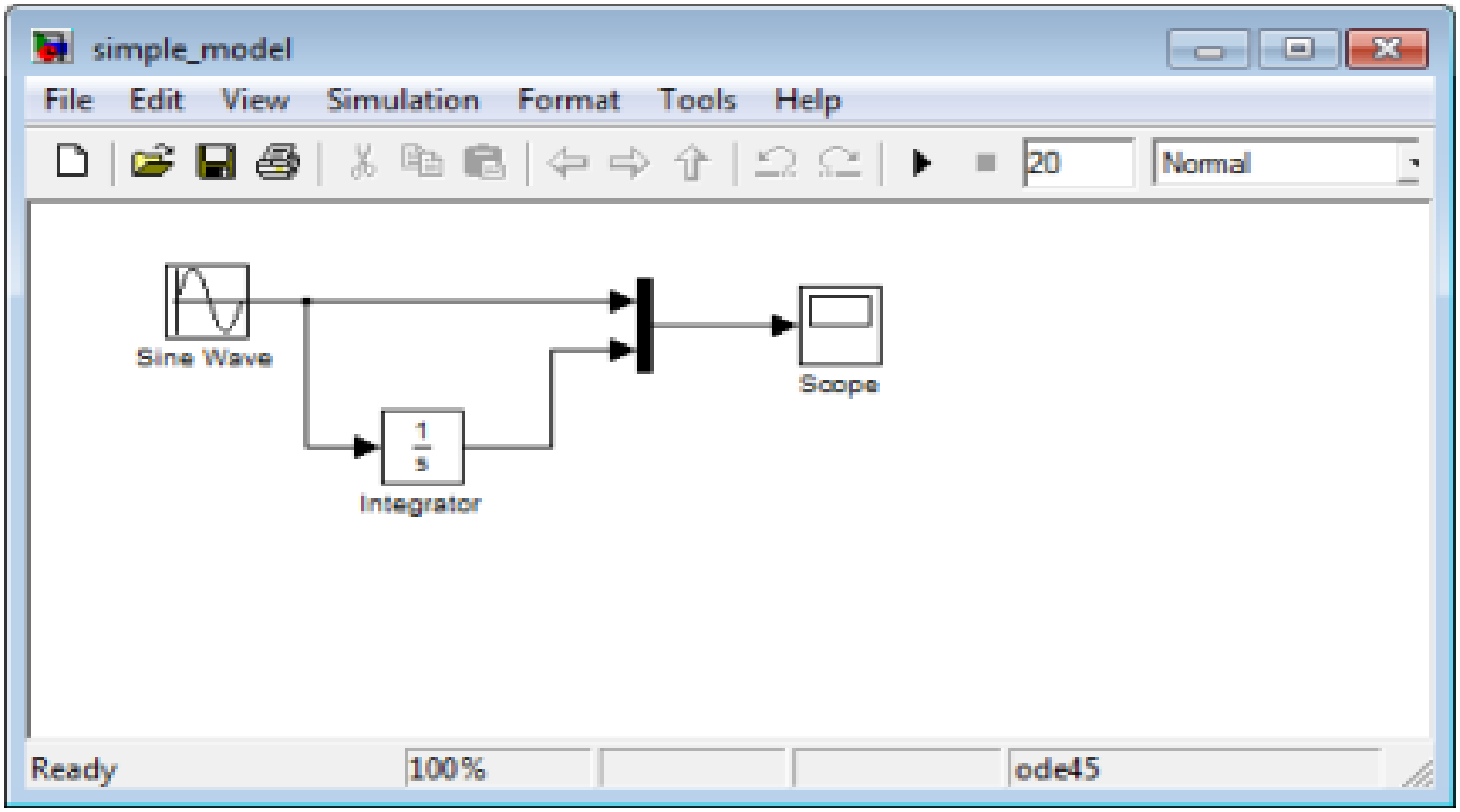
- Bad resolution can be solved by changing the step size to improve the resolution







Examples
(1) Integration and Signals Multiplexing

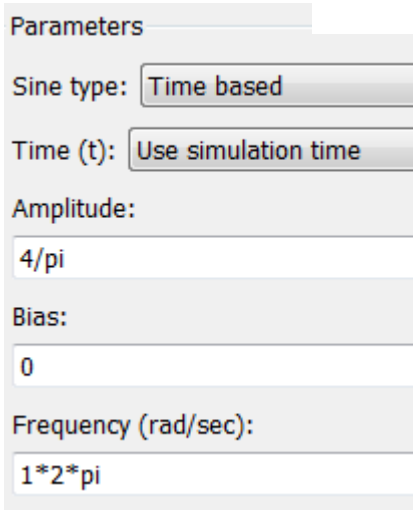


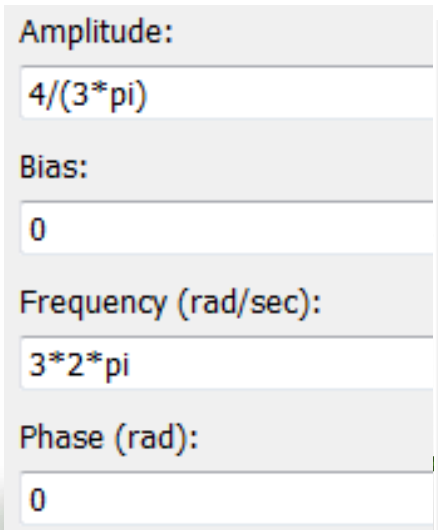
- Integrator: Simulink- Continuous
- Integrator: Simulink – Commonly used Blocks

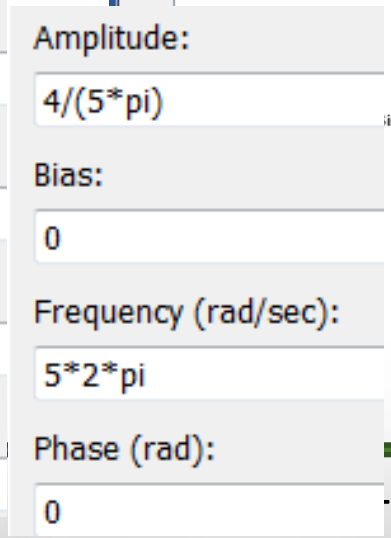
Examples: (2) Fourier Series

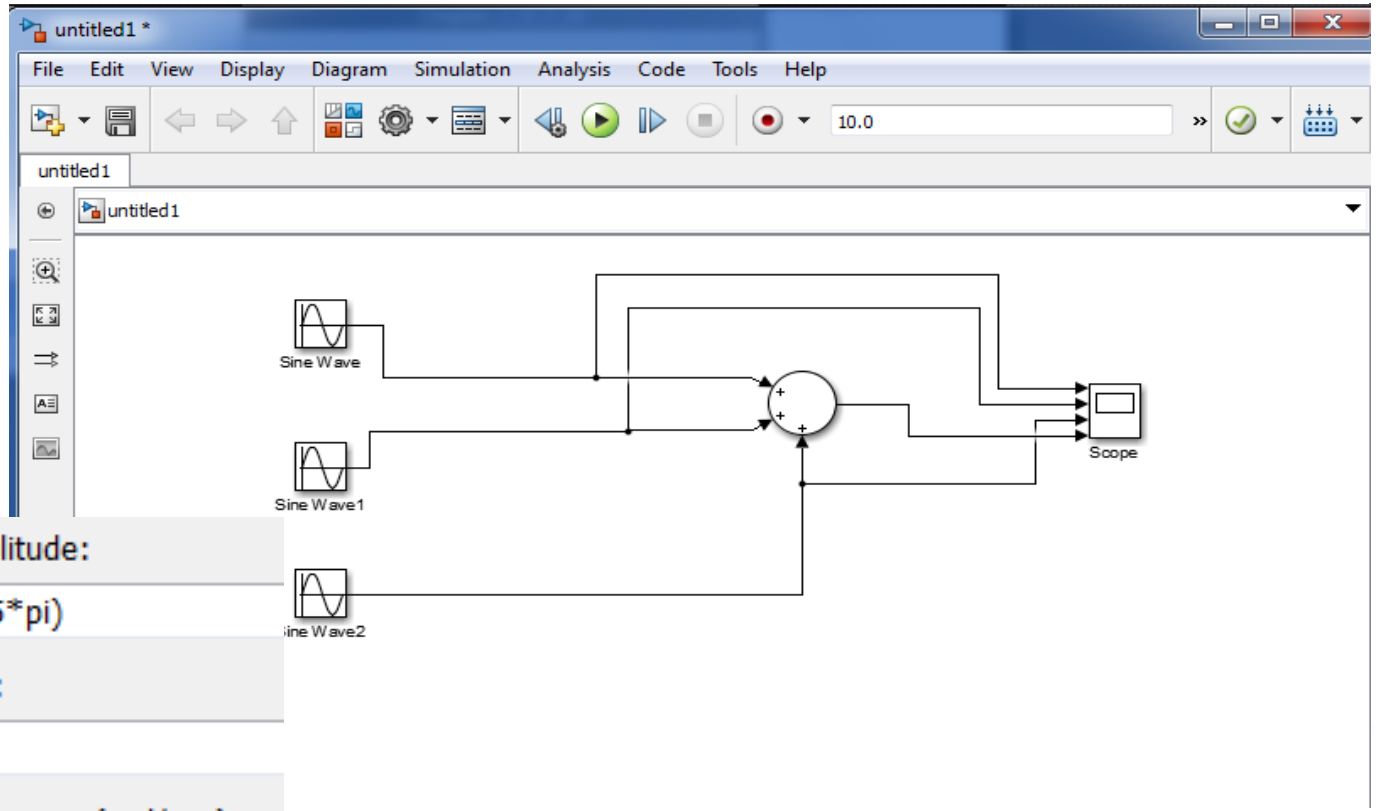
1.2 Let $x(t) = \frac{4}{\pi}\left[\sin(t) + \frac{1}{3}\sin(3t) + \frac{1}{5}\sin(5t)\right]$.

a. Develop a Simulink model for $x(t)$ with an included information block. Assume a 10 s simulation time.

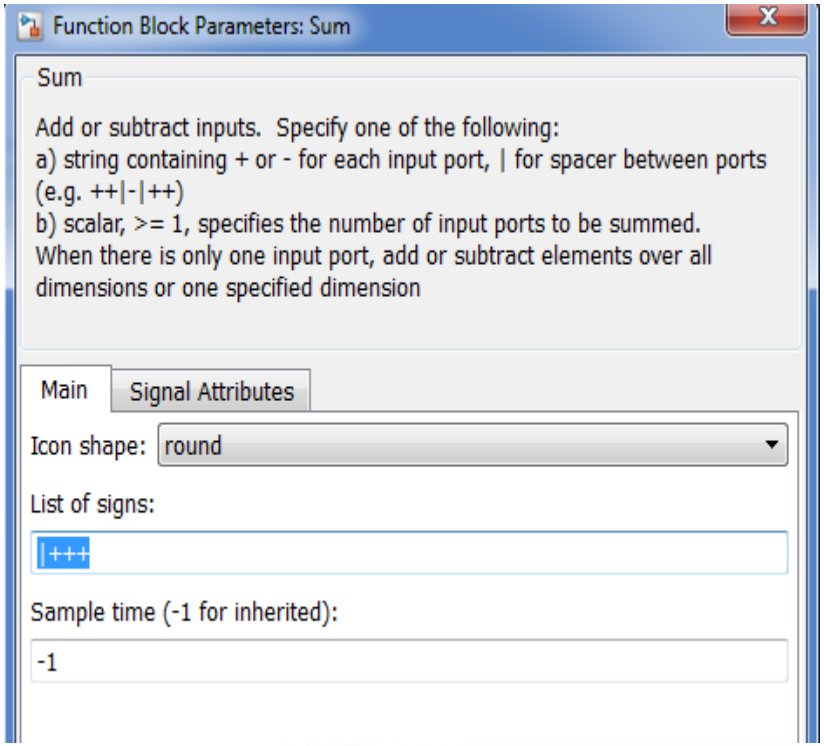


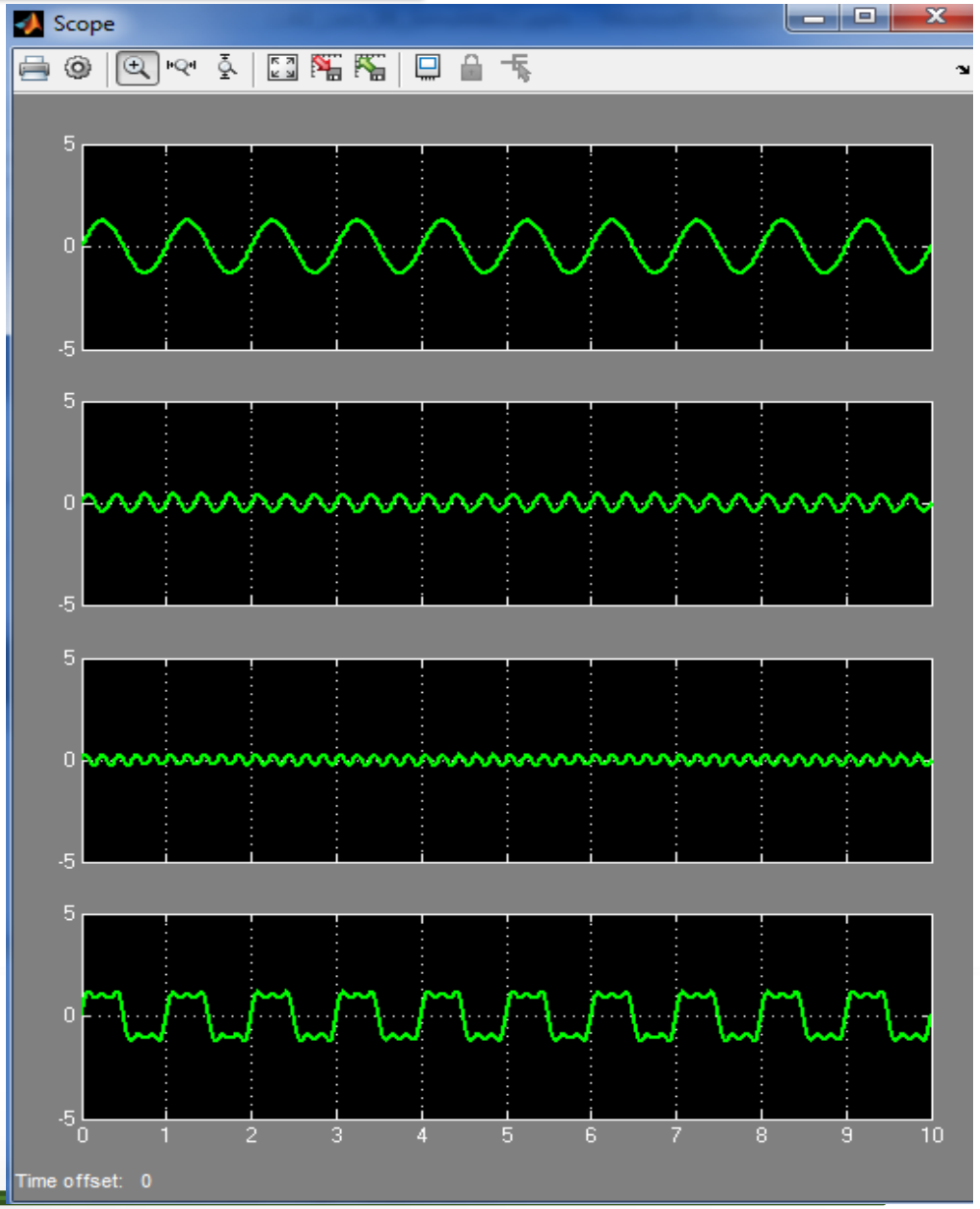






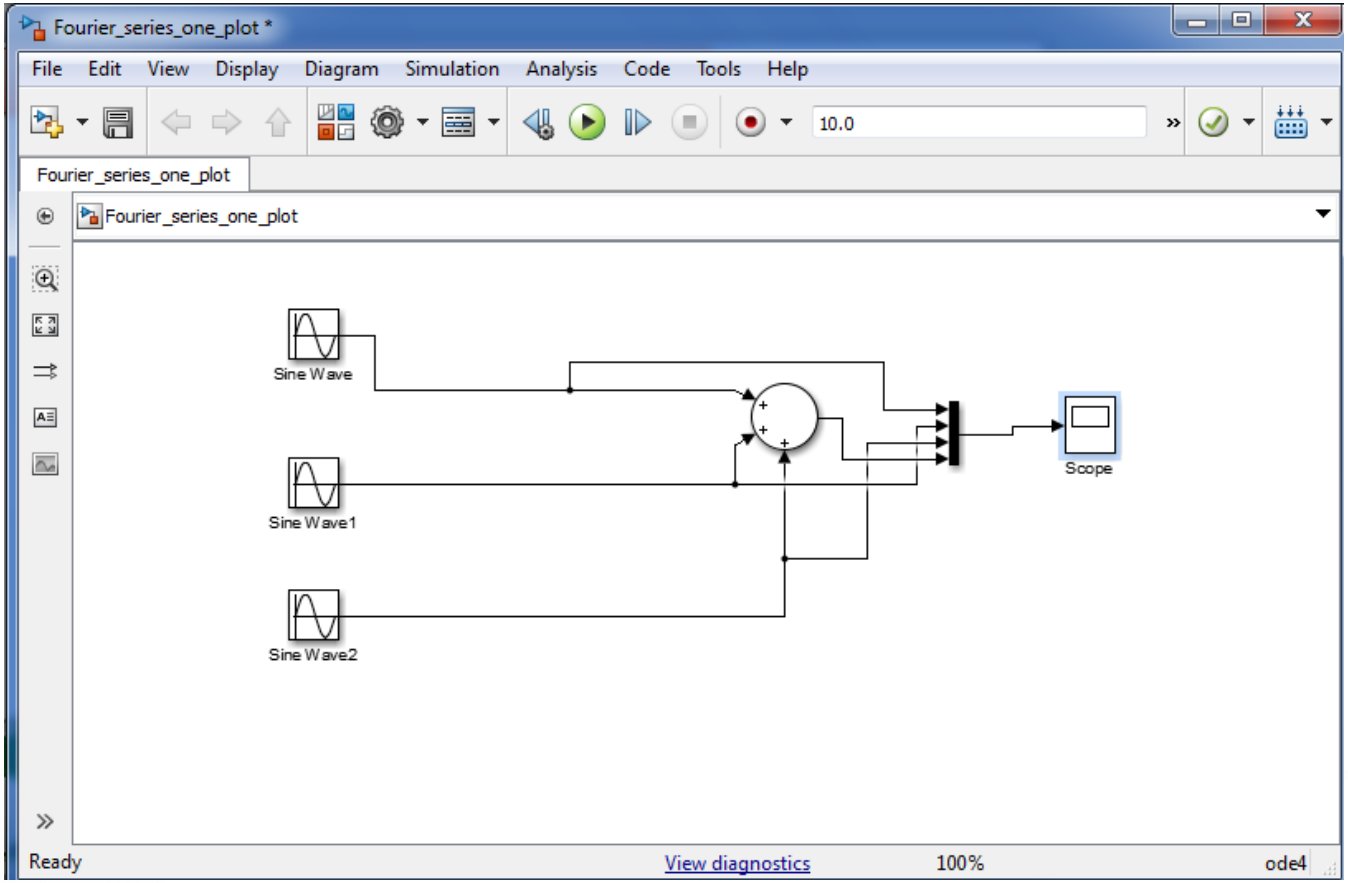
Examples: (2) Fourier Series





Examples: (2) Fourier Series

- Different Plotting



Examples: (2) Fourier Series

- Different Plotting