SIMULINK Tutorial

2nd Order Systems

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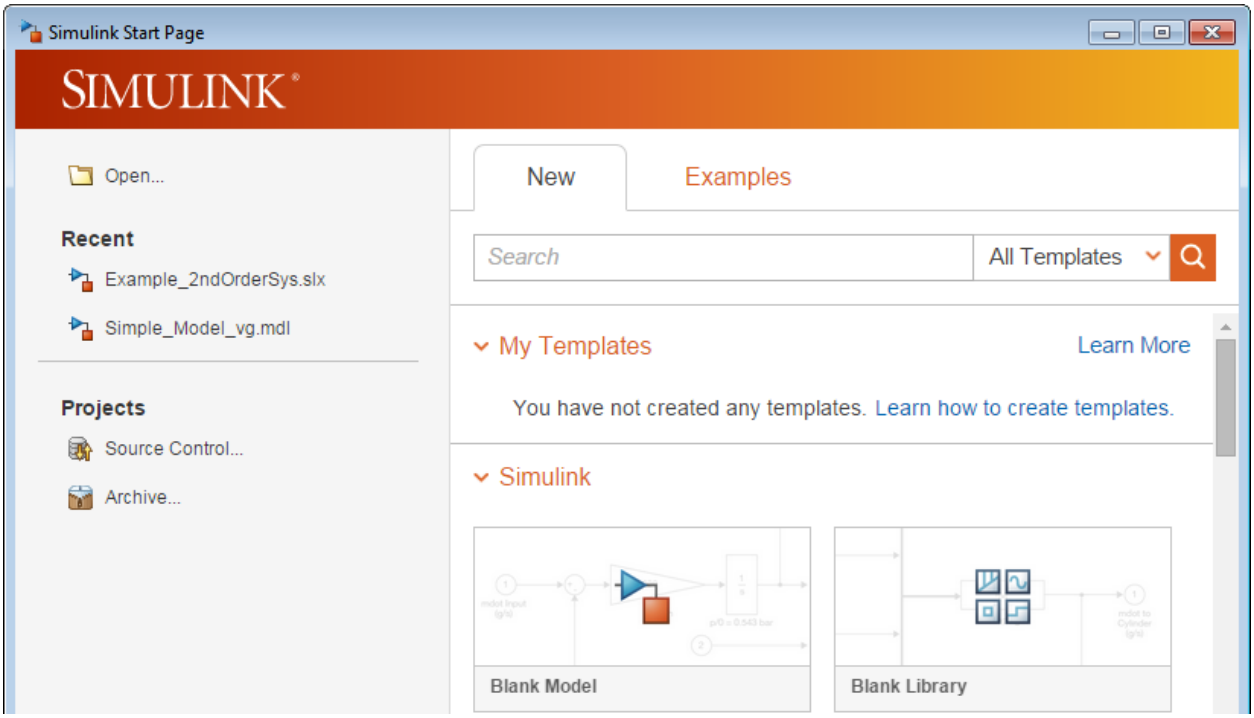
1 START SIMULINK

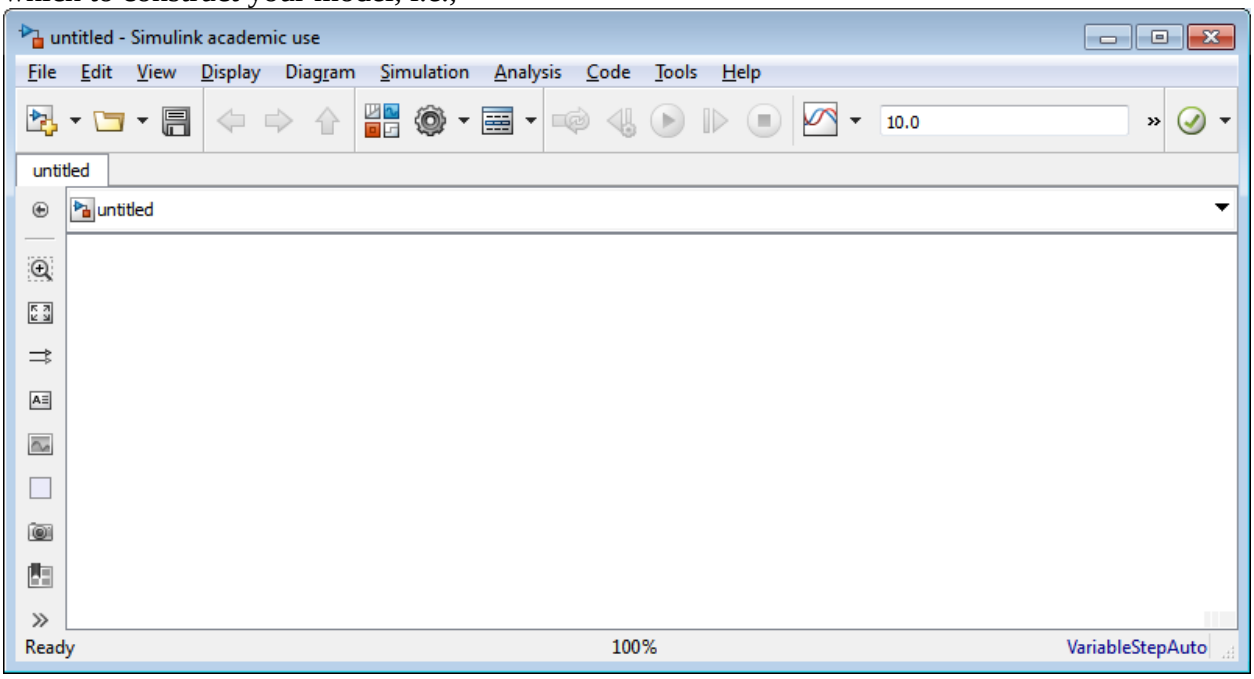
In the Command window, type ‘simulink’ and press Enter
>> Simulink

The SIMULINK start page should open, i.e.,



Note: use ‘Alt+PrtSc’ to capture the current window on the clipboard and paste it as shown above.

Press the ‘New’ tab and select ‘Blank Model”. A new windows open with a blank canvas on which to construct your model, i.e.,

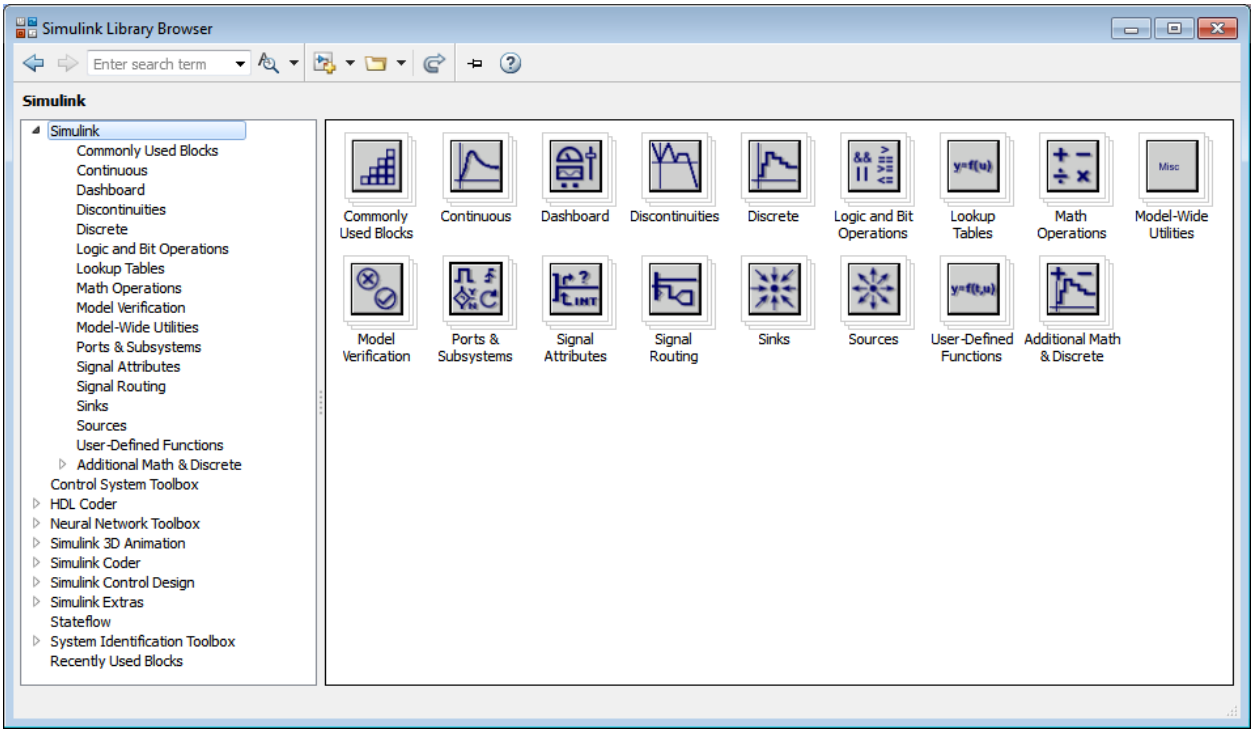


Save the model with a name of your choice
Note: remember MATLAB file name rules:

- cannot start with a number
- cannot have blanks in the file name (may want to use underscores _ to separate words…)

1.1 LIBRARY BROWSER

Start building your model. Open Library Browser from the pulldown menu: 'View → Library Browser'



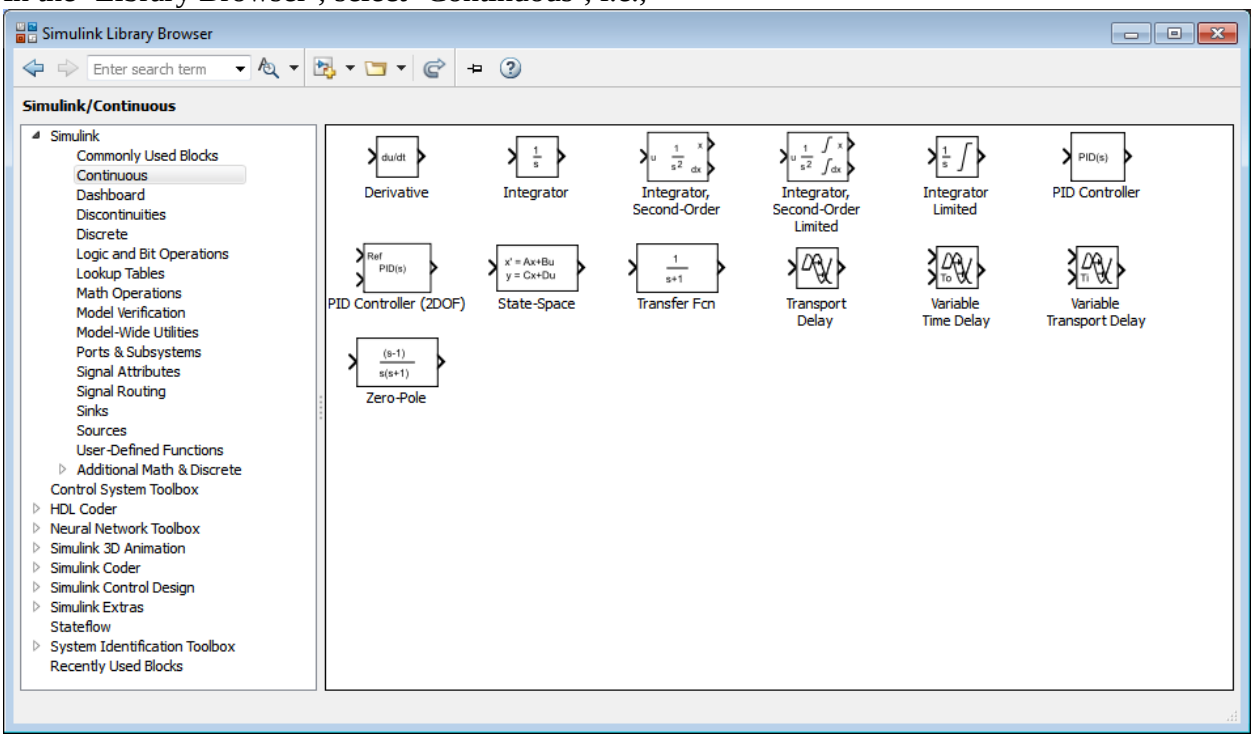
2 BASIC ELEMENTS

The basic elements of your model will be:

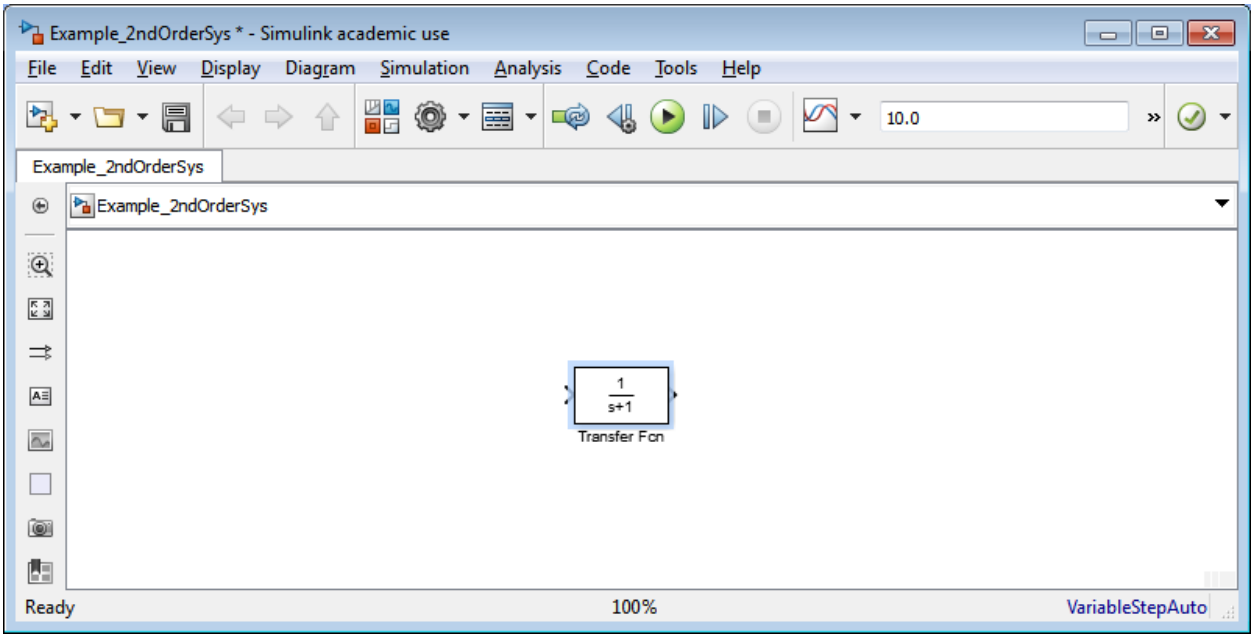
- input signal (source)
- system transfer function
- output display (sink)

2.1 SYSTEM TRANSFER FUNCTION

In the ‘Library Browser’, select ‘Continuous’, i.e.,



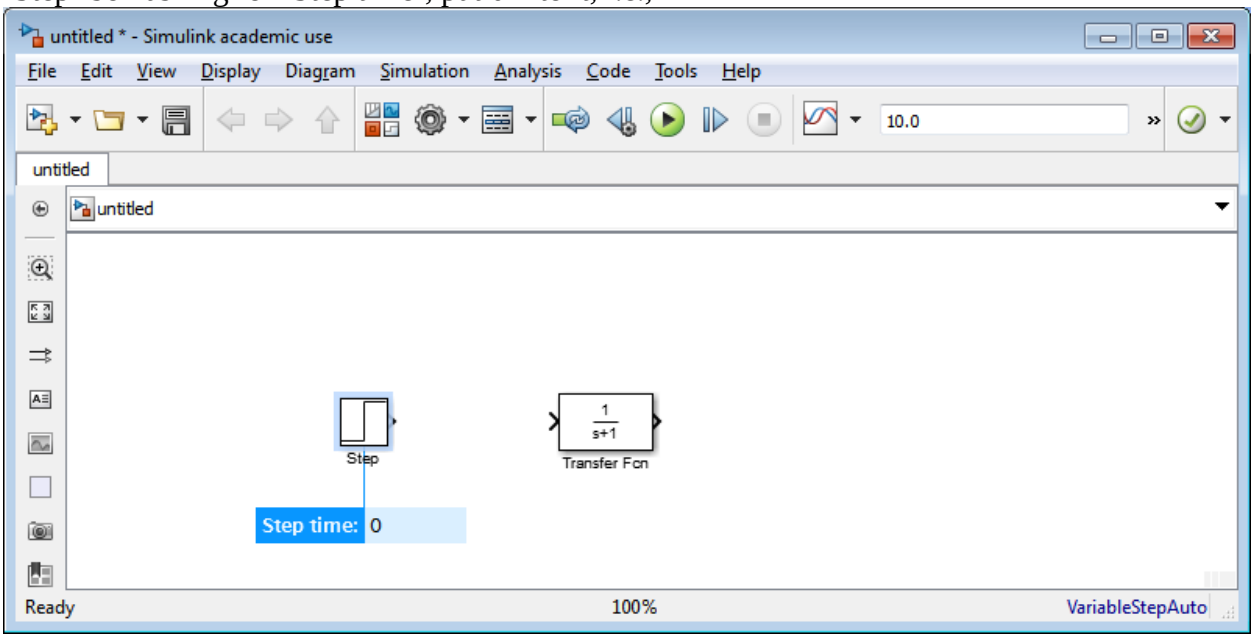
Select the ‘Transfer Fcn’ block and drag it into the model canvas, i.e.,


Example_2ndOrderSys * - Simulink academic use
File Edit View Display Diagram Simulation Analysis Code Tools Help
10.0
Example_2ndOrderSys
Example_2ndOrderSys
1
s+1
Transfer Fcn
Ready
100%
VariableStepAuto

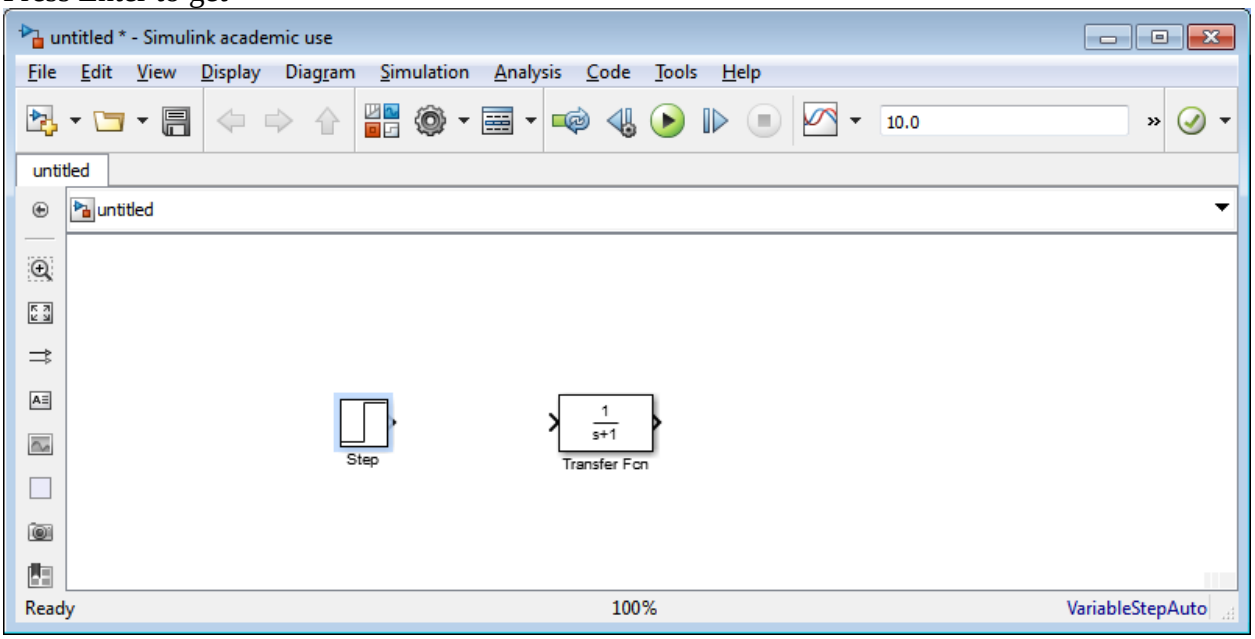
2.2 INPUT SIGNAL = SOURCE

In the ‘Library Browser’, select ‘Sources’
Then, select a source box and drag it onto the canvas.

For example, select ‘Step’ and drag the box onto the canvas; if a dialog box appears under the ‘Step’ box asking for ‘Step time’, put 0 into it, i.e.,



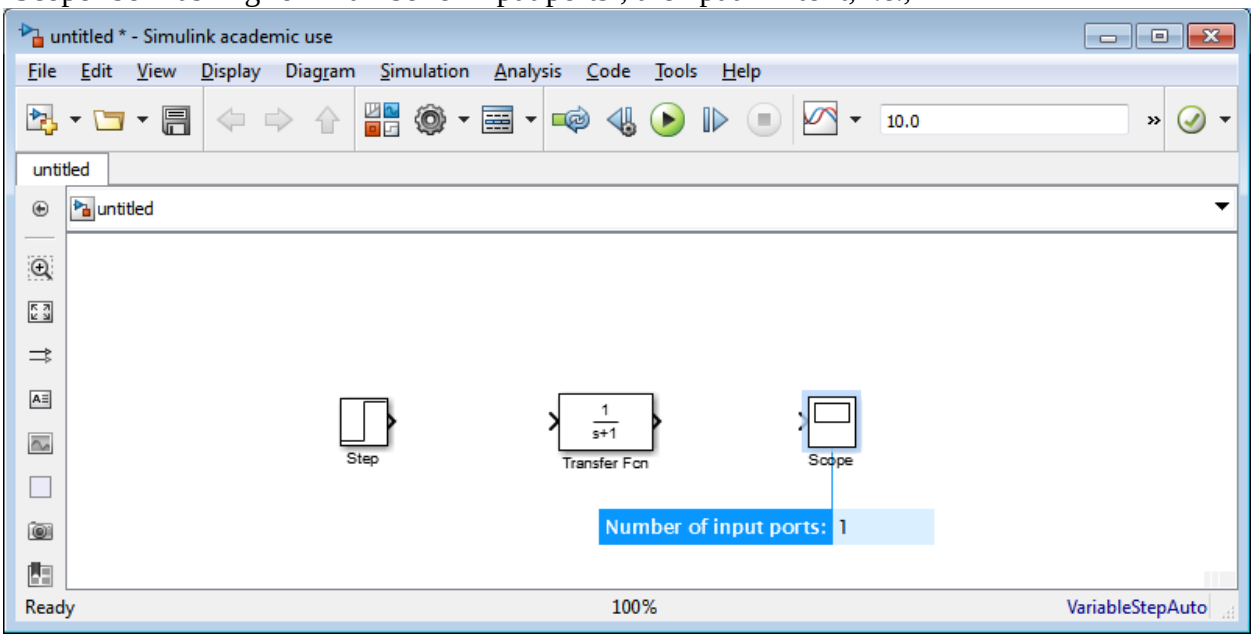
Press Enter to get



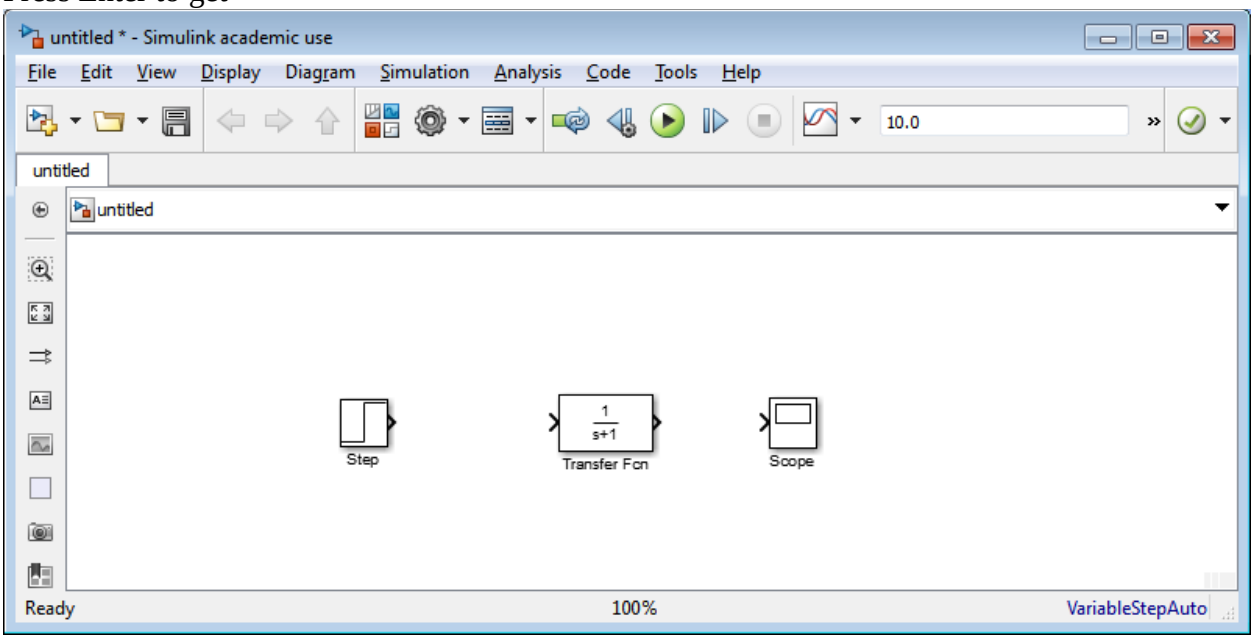
2.3 OUTPUT DISPLAY = SINK

In the ‘Library Browser’, select ‘Sinks’. Then select a sink box and drag it onto the canvas.

For example, select ‘Scope’ and drag it onto the canvas; if a dialog box appears under the ‘Scope’ box‘ asking for ‘Number of input ports’, then put 1 into it, i.e.,



Press Enter to get

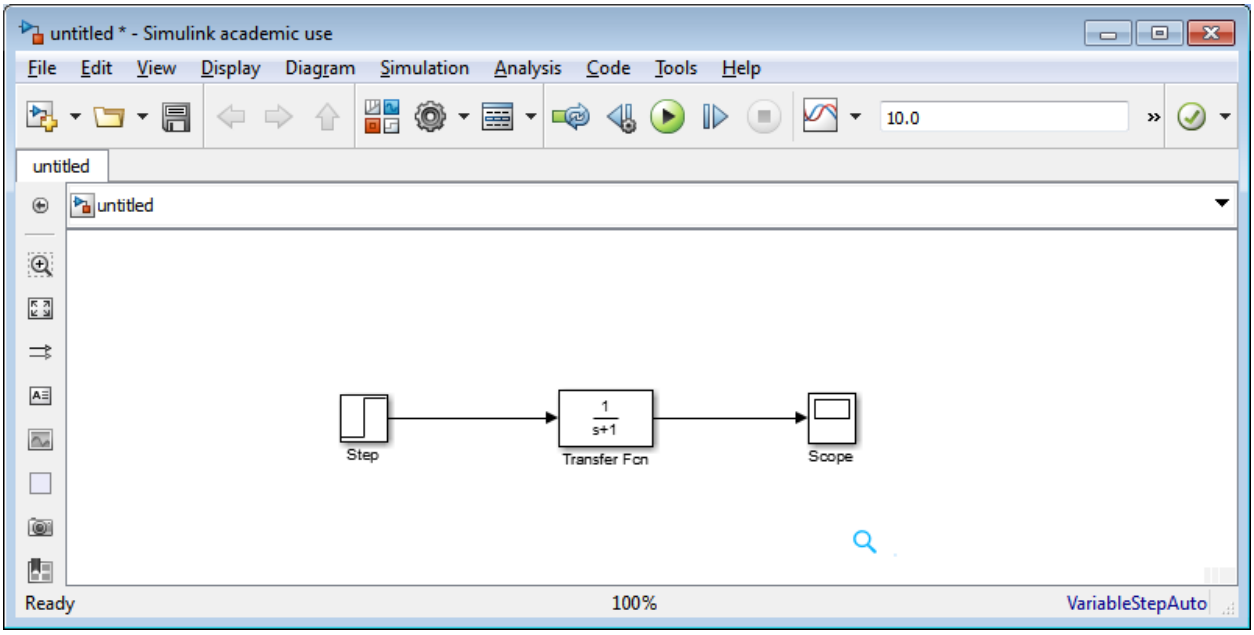


2.4 CONNECT THE BOXES IN THE MODEL

Connect the components using the mouse: click on the left item, hold down Ctrl and click on the right item: a connection line should appear between the output > of the block on the left and the input > sign of the block on the right.

Alternatively, drag with the mouse from one block port to the next block port

Do this for all the blocks to get



3 TRANSFER FUNCTION MODEL

3.1 TRANSFER FUNCTION MODEL DESCRIPTION

The transfer function block should be now adjusted to represent the mathematical model of the transfer function. In general, one has

$$G(s)=\frac{B(s)}{A(s)}=\frac{b_m s^m+b_{m-1}s^{m-1}+\ldots+b_1 s^1+b_0 s^0}{a_n s^n+a_{n-1}s^{n-1}+\ldots+a_1 s^1+a_0 s^0}$$

where $s^1=s$ and $s^0=1$. Thus, the transfer function is usually written as

$$G(s)=\frac{B(s)}{A(s)}=\frac{b_m s^m+b_{m-1}s^{m-1}+\ldots+b_1 s+b_0}{a_n s^n+a_{n-1}s^{n-1}+\ldots+a_1 s+a_0}$$

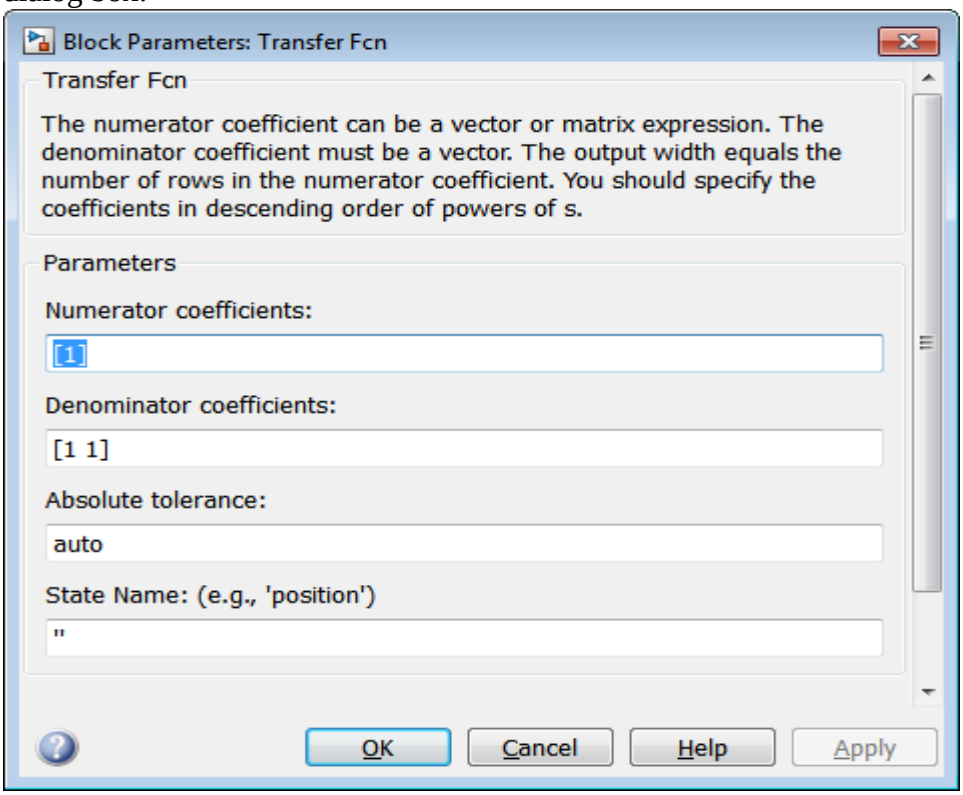
Hence, the numerator coefficients and the denominator coefficients are

$\begin{bmatrix} b_m & b_{m-1} & \ldots & b_1 & b_0 \end{bmatrix}$ 'Numerator coefficients'

$\begin{bmatrix} a_n & a_{n-1} & \ldots & a_1 & a_0 \end{bmatrix}$ 'Denominator coefficients'

Note: Start from the left with the highest power coefficient. If a subsequent coefficient is zero, enter 0, down the last coefficient. For a polynomial of power *m* one should have *m* coefficients.

To enter the coefficients, double click the 'Transfer Fcn' block to open 'Block Parameters' dialog box:



Enter the 'Numerator coefficients' and the 'Denominator coefficients' as well as a name for 'State Name'

3.2 TRANSFER FUNCTION MODEL EXAMPLE

As an example, assume that the transfer function corresponds to a 2nd order system, i.e.,

$$G(s) = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

Assume that the numerical values of the transfer function model are

- natural frequency: $f_n = 5$ Hz
- damping ratio: $\zeta = 3.5\%$

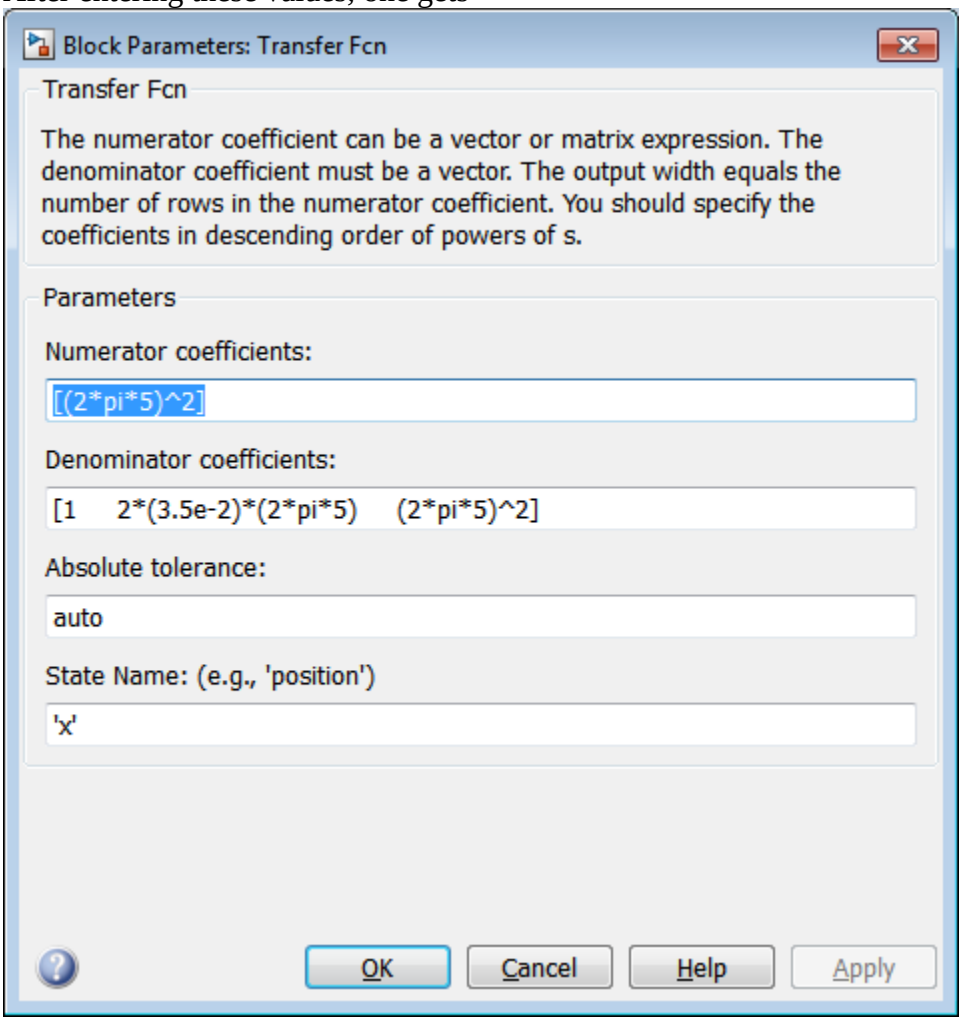
To enter this model, remember that $\omega_n = 2\pi f_n$. hence,

- 'Numerator coefficients' = [(2*pi*5)^2]
- 'Denominator coefficients' = [1 2*3.5e-2*(2*pi*5) (2*pi*5)^2]

In addition, we recall that the model represents the system position variable x; hence

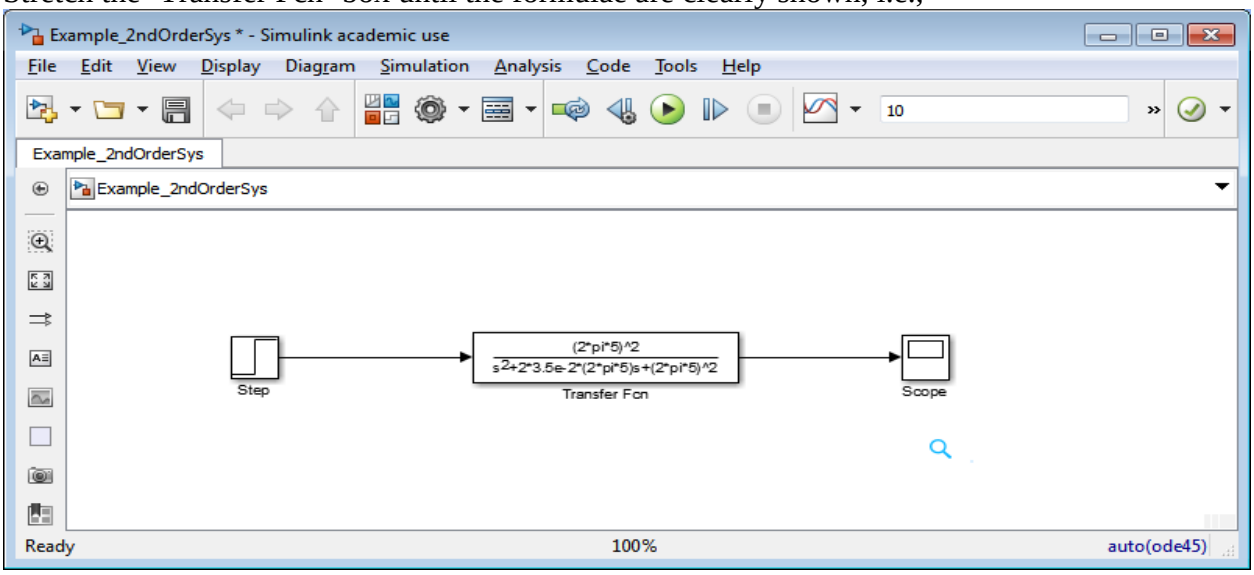
- 'State Name' = x

After entering these values, one gets

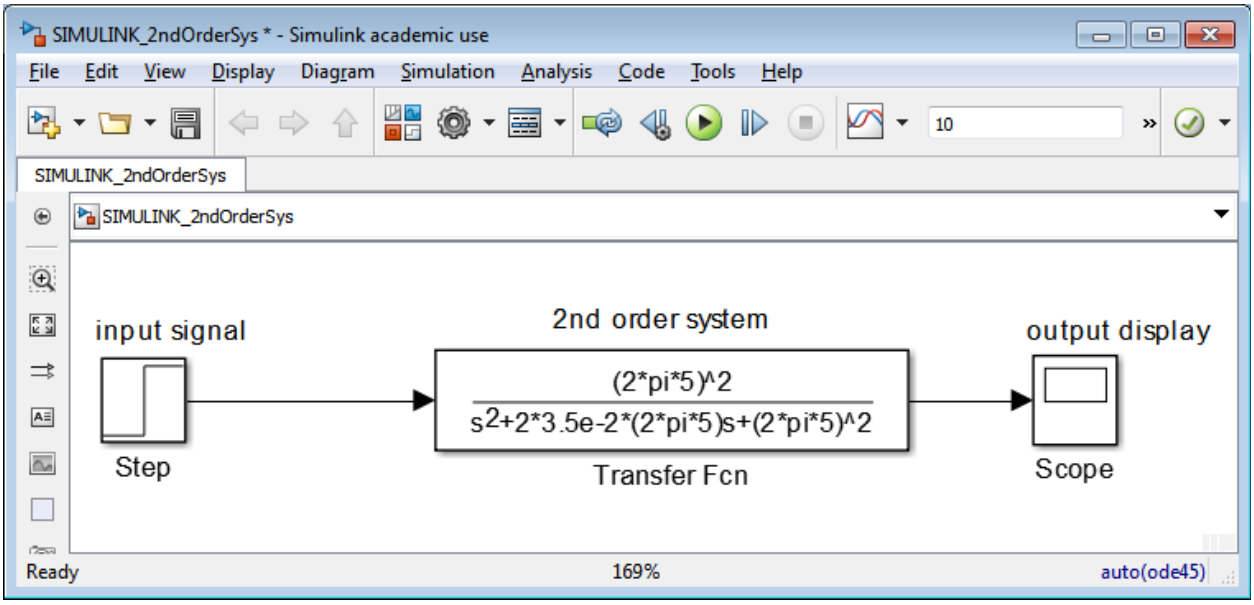


Press enter.

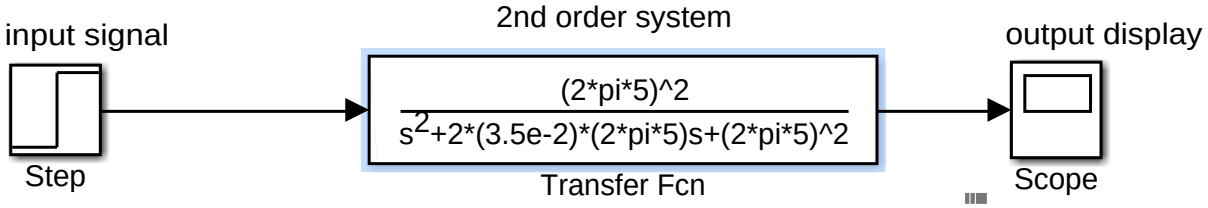
Stretch the ‘Transfer Fcn’ box until the formulae are clearly shown, i.e.,



Add annotations on top of the blocks: ‘input signal’, ‘2nd order system’, ‘output display’. Use ‘View → Zoom’ to fill the canvas with the model



Use the pull down menu: ‘Edit → Copy Current View to Clipboard → Metafile’ to capture only the model, i.e.,



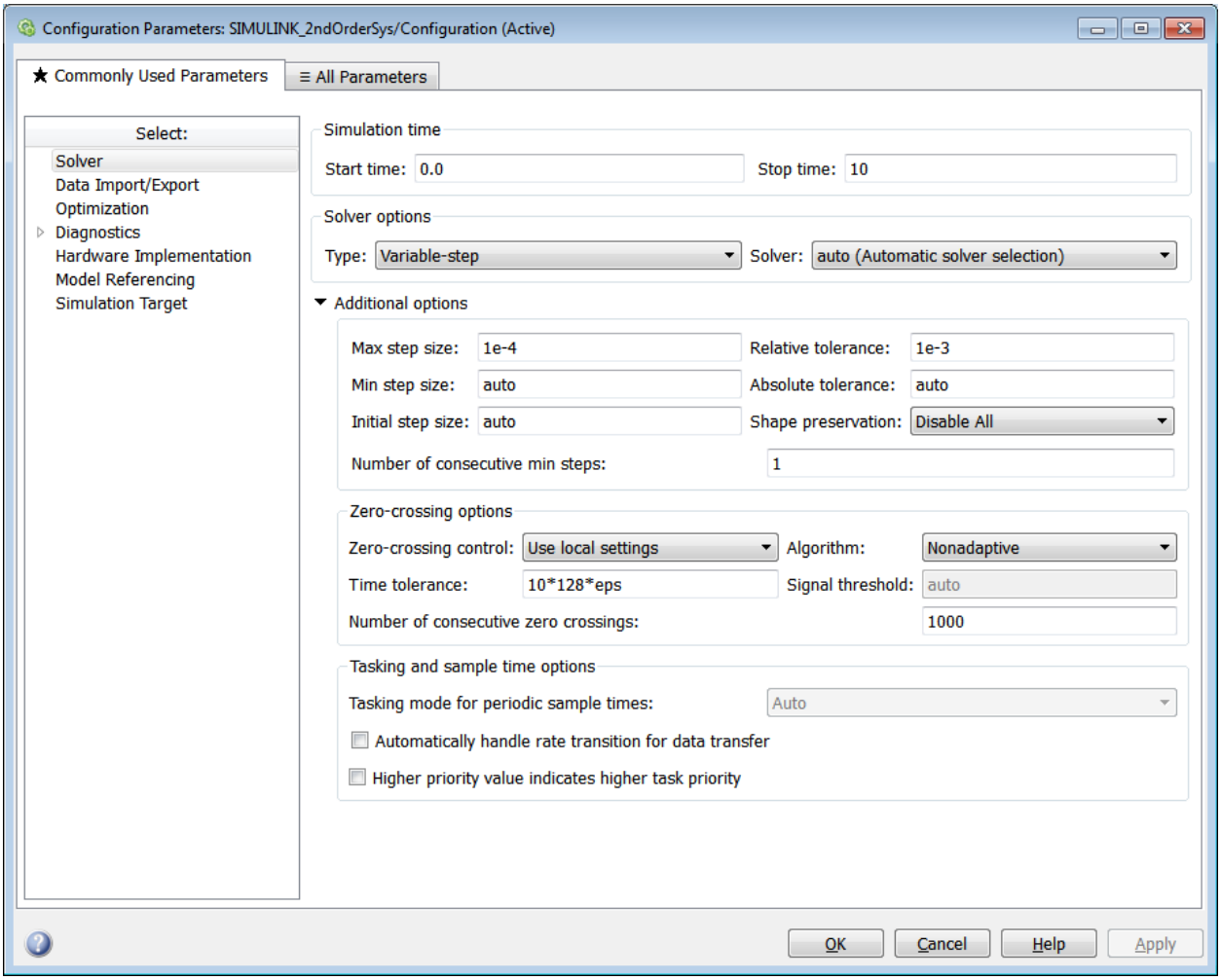
4 RUNNING THE SIMULINK MODEL

1.1 SIMULATION PARAMETERS

Use the pull down menu 'Simulation → Model Configuration Parameters' to open Configuration Parameters window. Make:

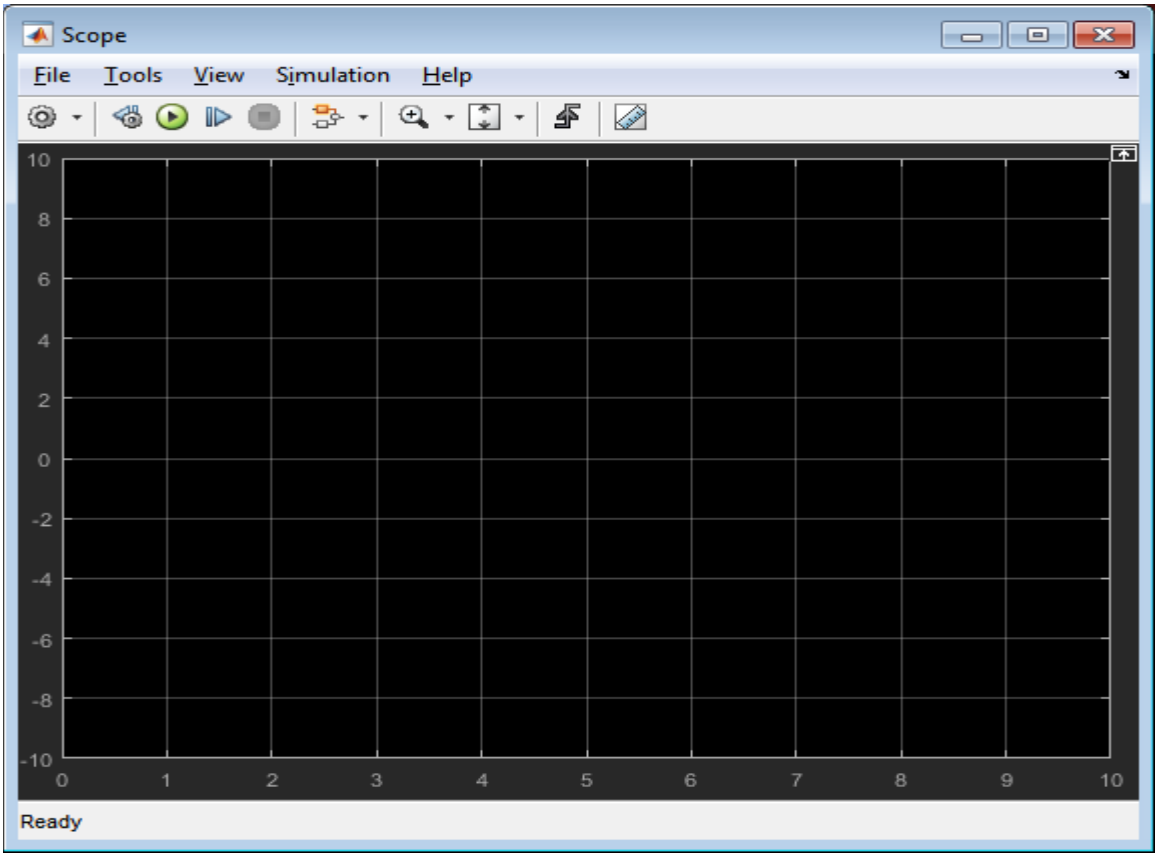
- Max step size: 1e-4
- Stop time: 10

The rest should remain unchanged (verify that they are the same as in the figure)



4.1 OUTPUT DISPLAY

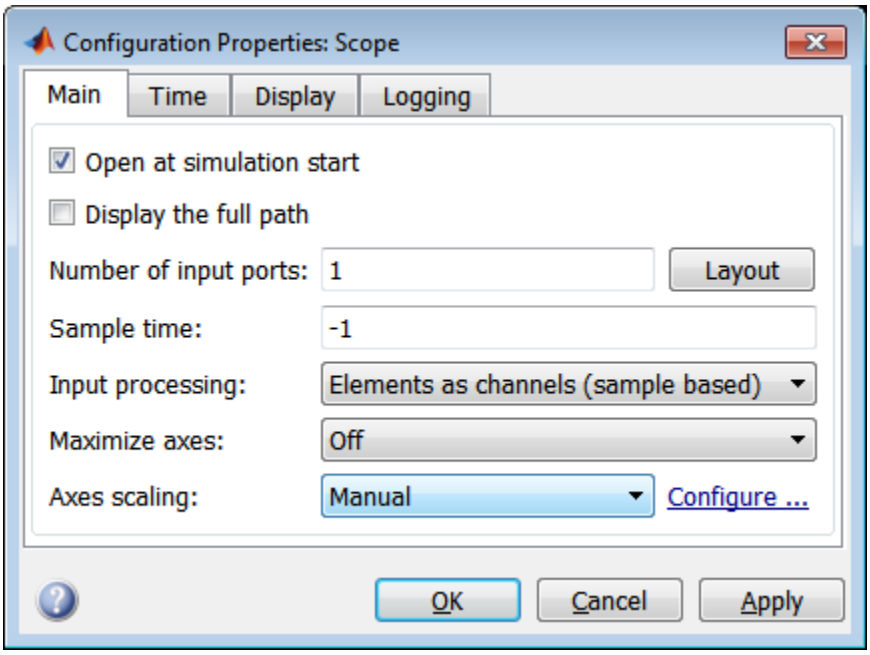
Double click on the ‘output display’ block of the model; a separate window opens, i.e.,

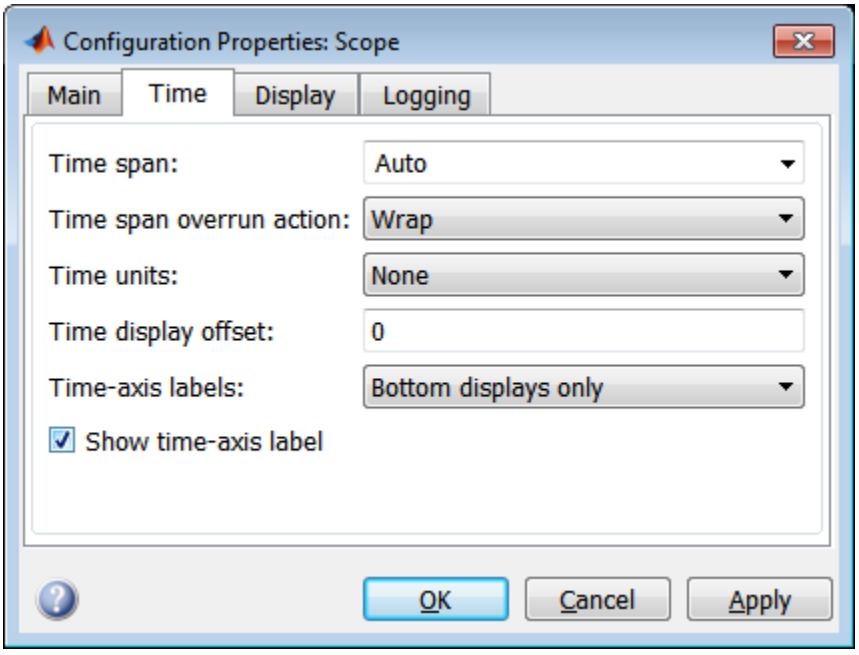


1.1.1 Display setup

The pulldown menu allows one to adjust the display parameters. Do the following:
'View →Configuration properties'

- In 'Main' tab, check the box 'Open at simulation start'
- In 'Time' tab, check the box 'Show time-axis label'

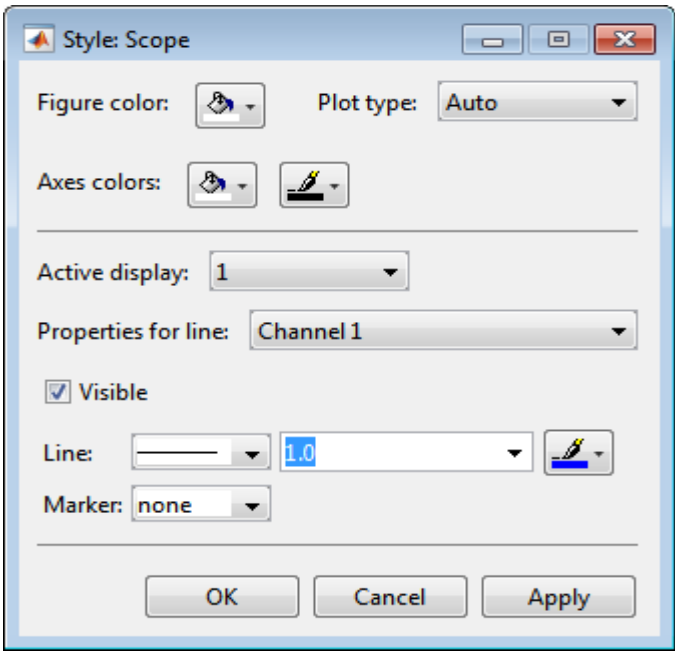




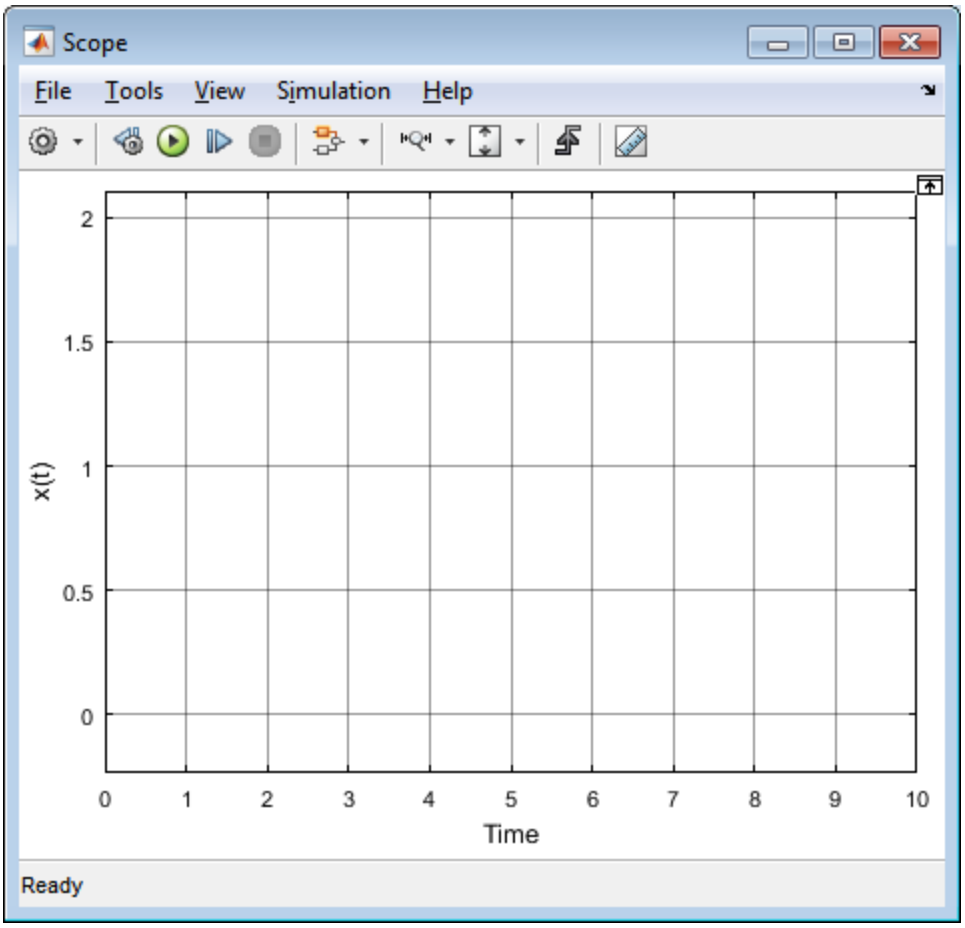
‘View →Style’:
Set color white for:

- Figure color
- Axes colors: bucket

Set color black for Axes colors: brush
Set color blue for line with weight 1.0



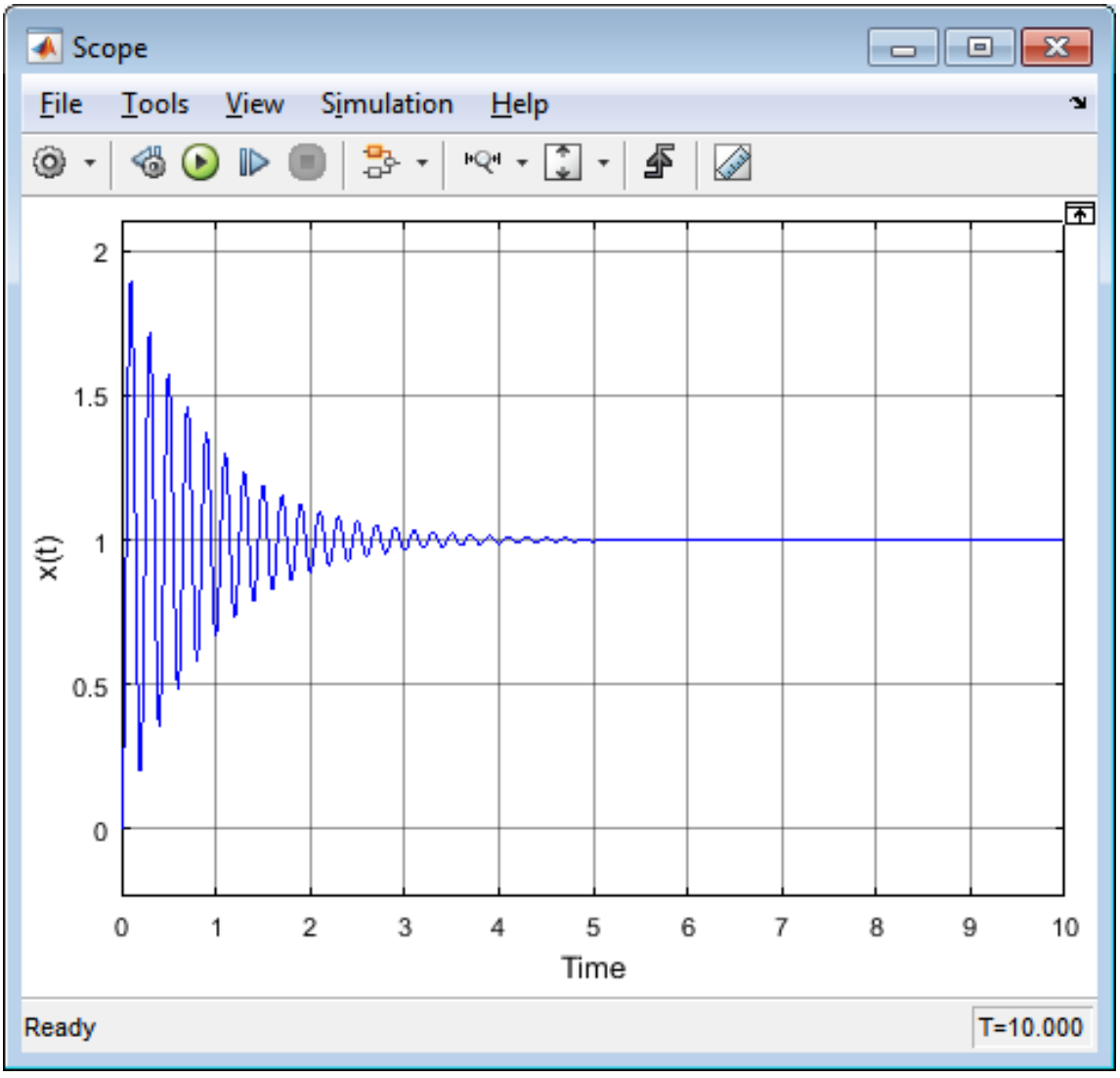
The display should look as follows:


Scope
File
Tools
View
Simulation
Help
2
1.5
1
0.5
0
x(t)
0
1
2
3
4
5
6
7
8
9
10
Time
Ready

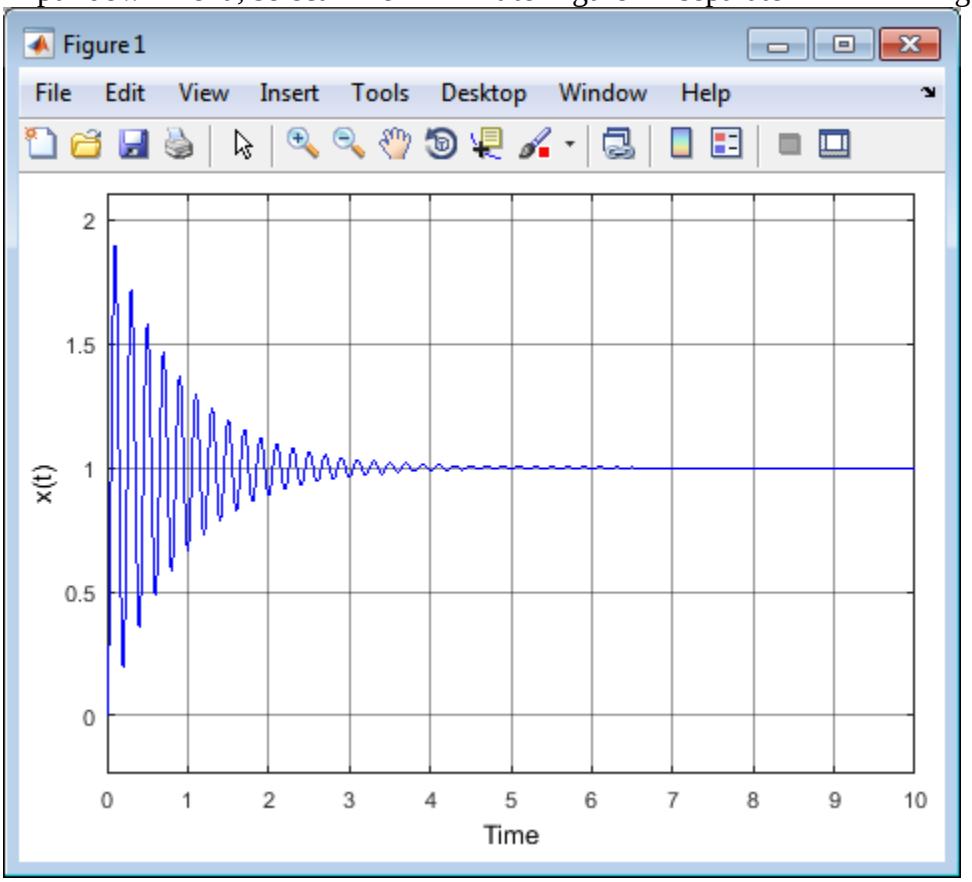
4.2 RUN SIMULATION

Press the ‘Run’ button to start the simulation.

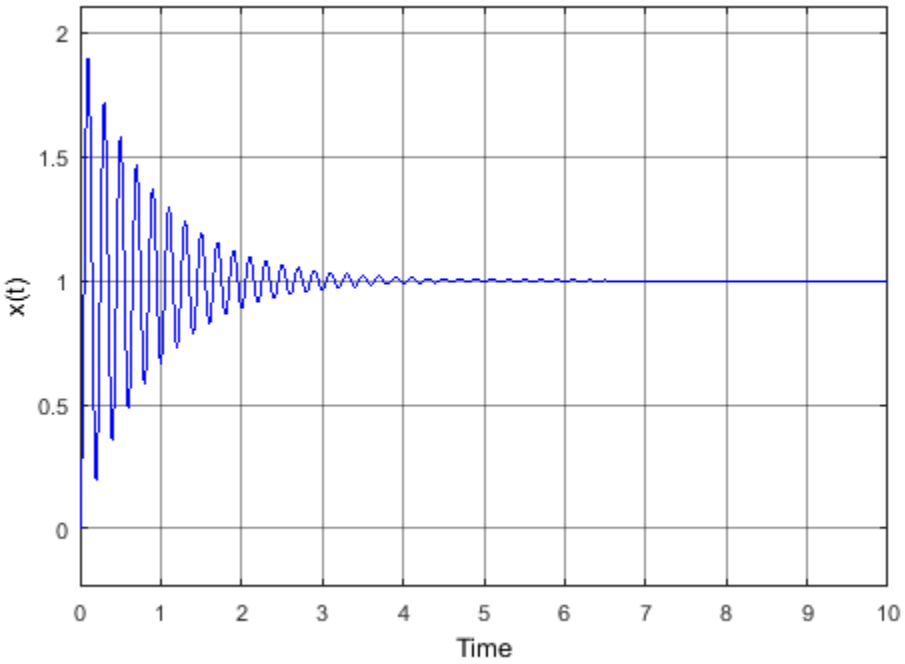
The ‘Scope’ will display the time response of your system. (The simulation is done using numerical integration.)



In pulldown menu, select ‘File → Print to Figure’ A separate MATLAB figure window opens



In pulldown menu of this figure, select ‘Edit → Copy Figure’ and paste, i.e.,



Notice that the signal steady state value of the signal is $x_{ss} = 1$. The signal has many oscillations before it settles down to $x_{ss} = 1$ because the system damping is small.

4.3 ZOOM INTO THE SIGNAL BEGINNING REGION

Use the Zoom tool to zoom into the 0—1 sec region to see details of the signal beginning. Use the 'pan hand' to adjust to zero time, i.e.,