

# Chapter 10: Simulink

- Simulation Diagrams
- Simulink Models
- Library Browser
- Commonly-Used Blocks
- Transfer-Function Models
- Linear State-Variable Models
- Piecewise-Linear Models
- Subsystems

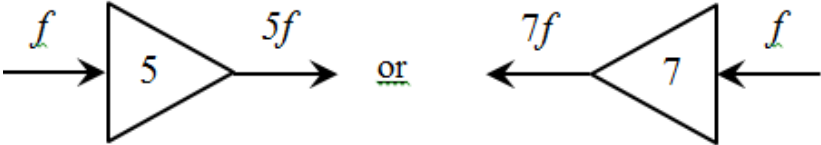
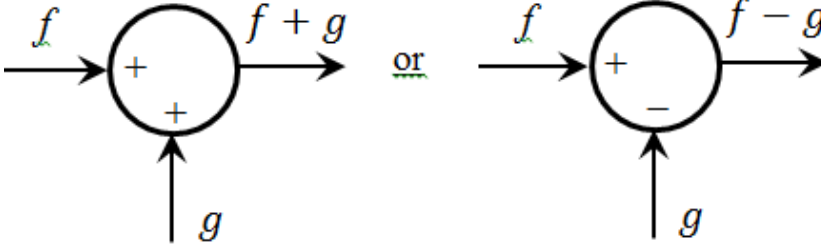
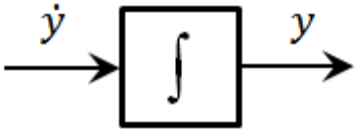
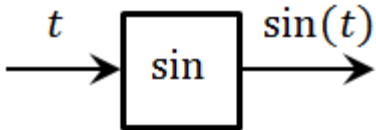
# Simulink: Introduction

- Graphical User Interface built onto MATLAB
- Blocks and interconnecting wiring create a dynamic system
- Simulation Diagrams describe the differential equation
- A Simulink Model can solve the differential equation subject to initial conditions
- Results can be exported to the MATLAB environment for further processing

# Simulation Diagrams

- A Simulation Diagram is used to represent a mathematical equation
- Blocks are used to modify the flow of data
- Interconnecting wiring and arrows indicate the direction of the flow of data
- Blocks have either Inputs or Outputs or Both
- Many differential equations are solved using a Feedback Loop

# Simulation Diagrams

Object	Graphical Description	Function
Gain Block		Multiplies Incoming Signal by a Constant Value
Summer		Adds or Subtracts Multiple Signals
Integrator		Integrates Incoming Signal
Trig Functions		Computes the Sine of the Incoming Signal

# Simulation Diagrams

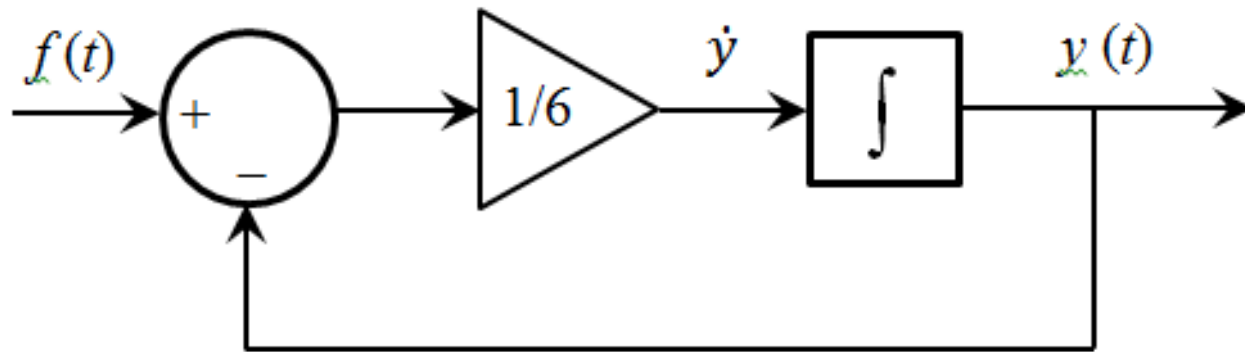
22. Plot the solution of the equation

$$6\dot{y} + y = f(t)$$

if  $f(t) = 0$  for  $t < 0$  and  $f(t) = 15$  for  $t \geq 0$ . The initial condition is  $y(0) = 7$ .

$$\dot{y} = \left(\frac{1}{6}\right) [f(t) - y]$$

$$y = \int \left\{ \left(\frac{1}{6}\right) [f(t) - y] \right\}$$



# Simulation Diagrams

30. The following equation describes the motion of a certain mass connected to a spring, with viscous friction on the surface

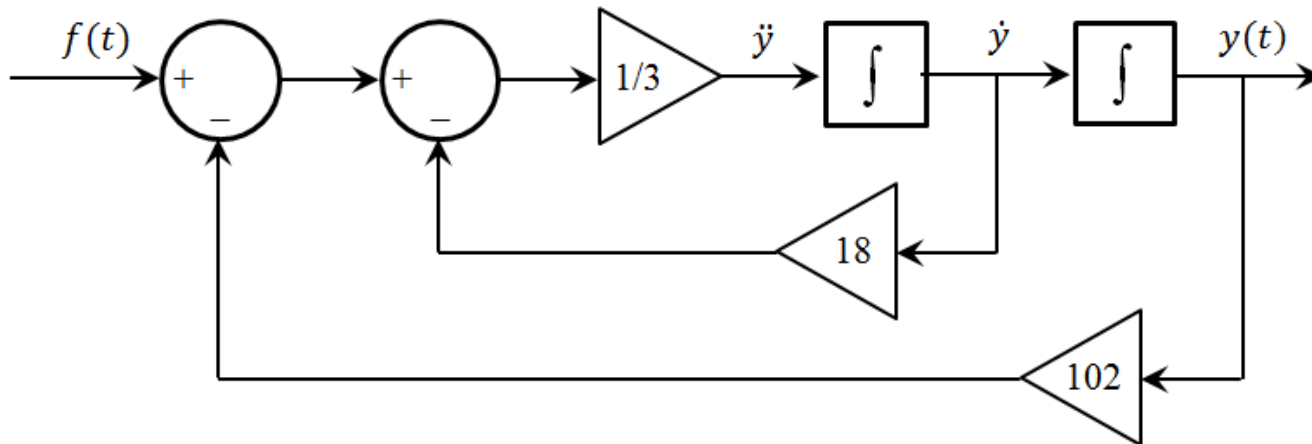
$$3\ddot{y} + 18\dot{y} + 102y = f(t)$$

where  $f(t)$  is an applied force. Suppose that  $f(t) = 0$  for  $t < 0$  and  $f(t) = 10$  for  $t \geq 0$ .

- Plot  $y(t)$  for  $y(0) = \dot{y}(0) = 0$ .
- Plot  $y(t)$  for  $y(0) = 0$  and  $\dot{y}(0) = 10$ . Discuss the effect of the nonzero initial velocity.

$$\ddot{y} = \frac{1}{3}[-18\dot{y} - 102y + f(t)]$$

$$y = \iint \left\{ \frac{1}{3}[-18\dot{y} - 102y + f(t)] \right\}$$



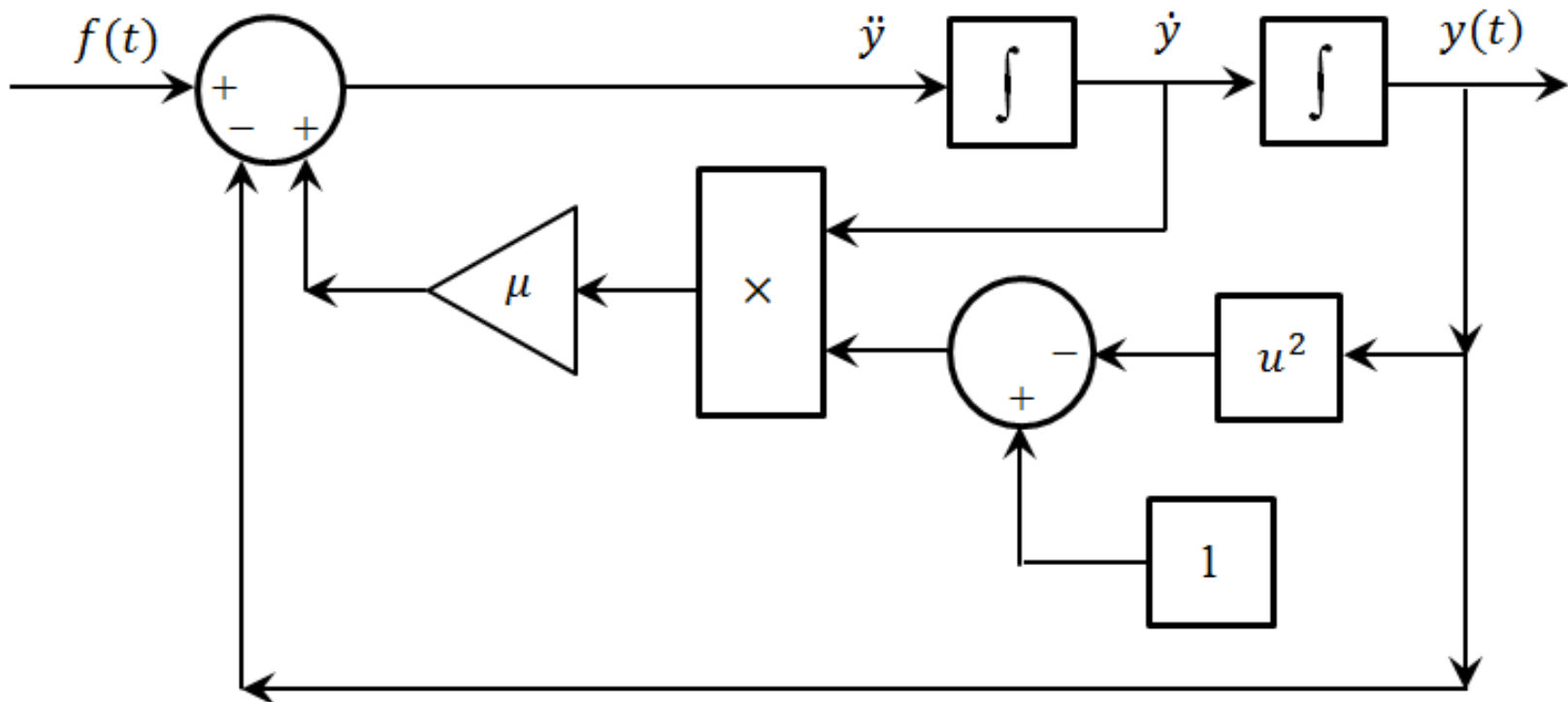
# Simulation Diagrams

33. Van der Pol's equation has been used to describe many oscillatory processes. It is

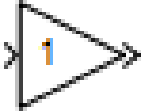


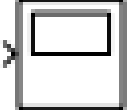
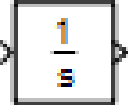


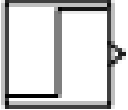
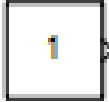



$$\ddot{y} - \mu(1 - y^2)\dot{y} + y = f(t)$$

$$\ddot{y} = \mu(1 - y^2)\dot{y} - y + f(t)$$

$$y = \iint [\mu(1 - y^2)\dot{y} - y + f(t)]$$



# Simulink Blocks

Object	Graphical Symbol	Object	Graphical Symbol
Gain Block		Mux (Multiplexer)	
Summer		Scope	
Integrator		To Workspace	
Trig Functions		Step	
Constant		1-D Lookup Table	
Clock		User-Defined Function	

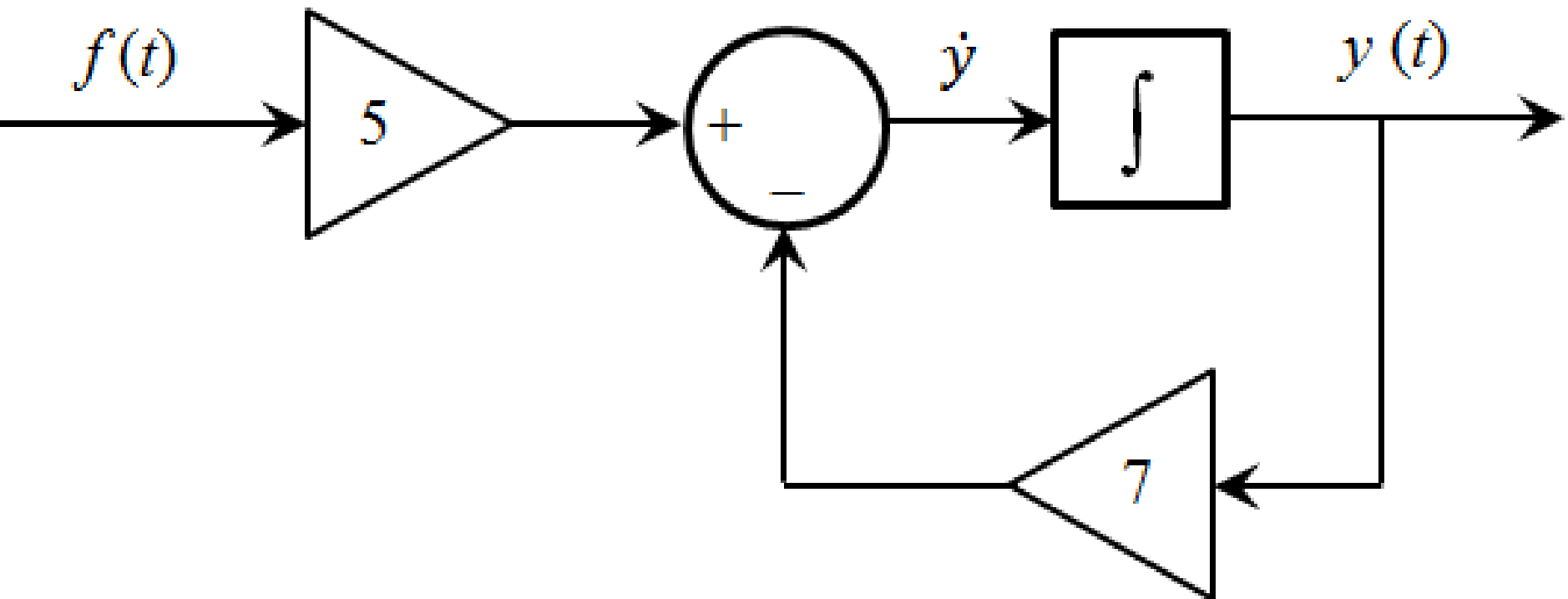


# Simulink Models

Use Simulink to solve the following differential equation:

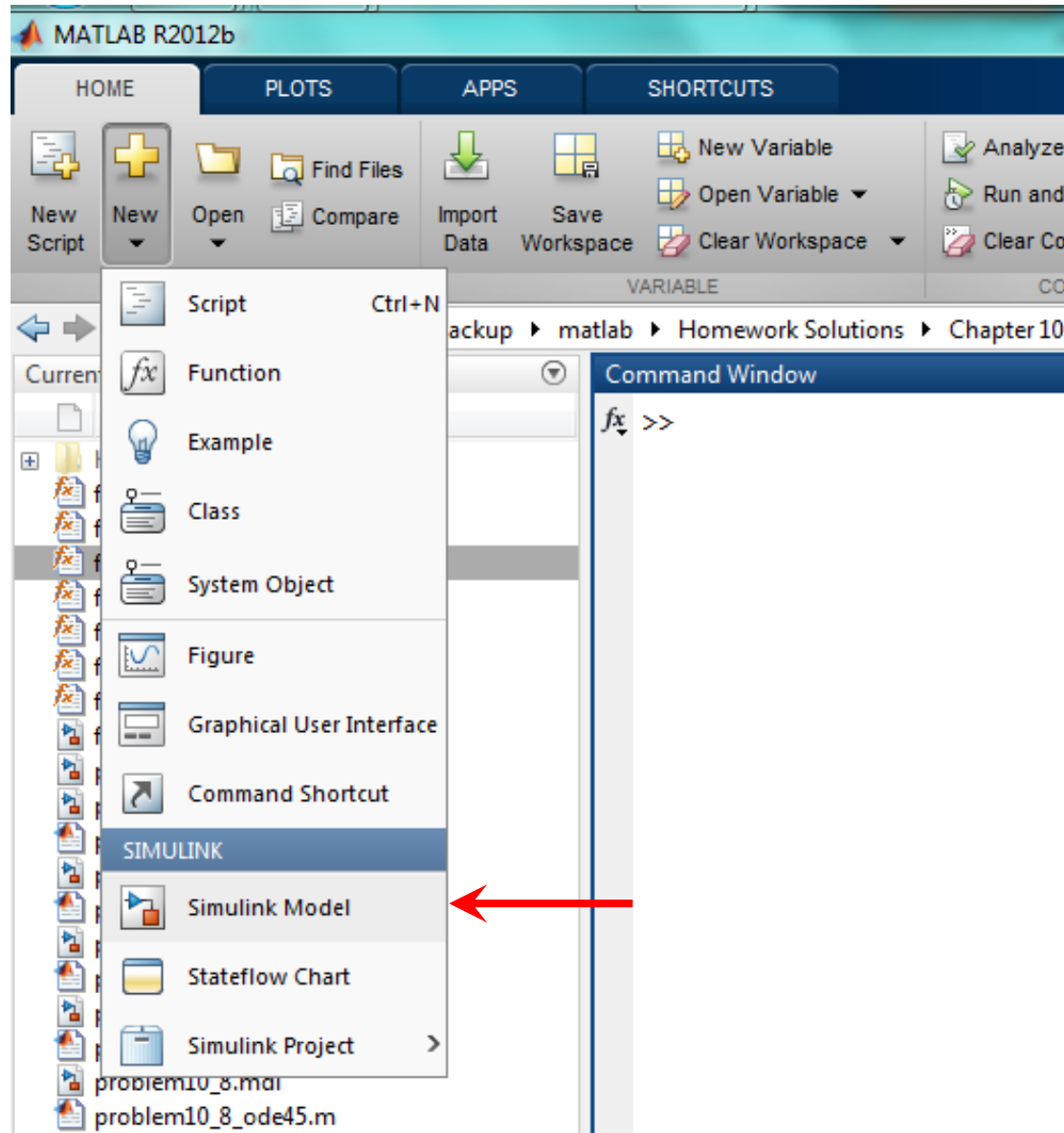
$$\dot{y} = 5f(t) - 7y; \quad y(0) = 3$$

$$f(t) = \begin{cases} 0 & \text{for } t < 2.0 \\ 5 & \text{for } t \geq 2.0 \end{cases}$$



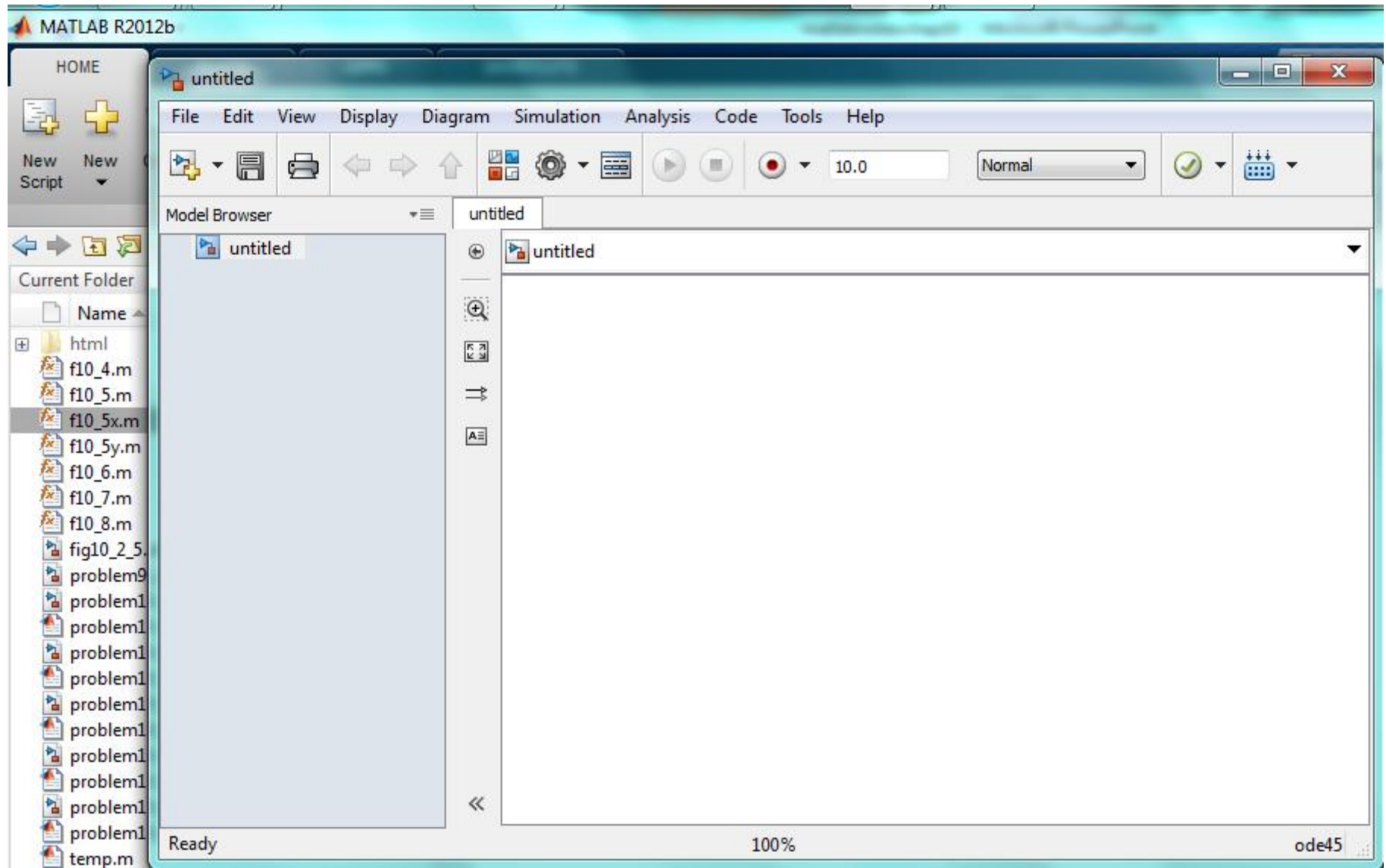
# Simulink Models

## Create a new Simulink Model



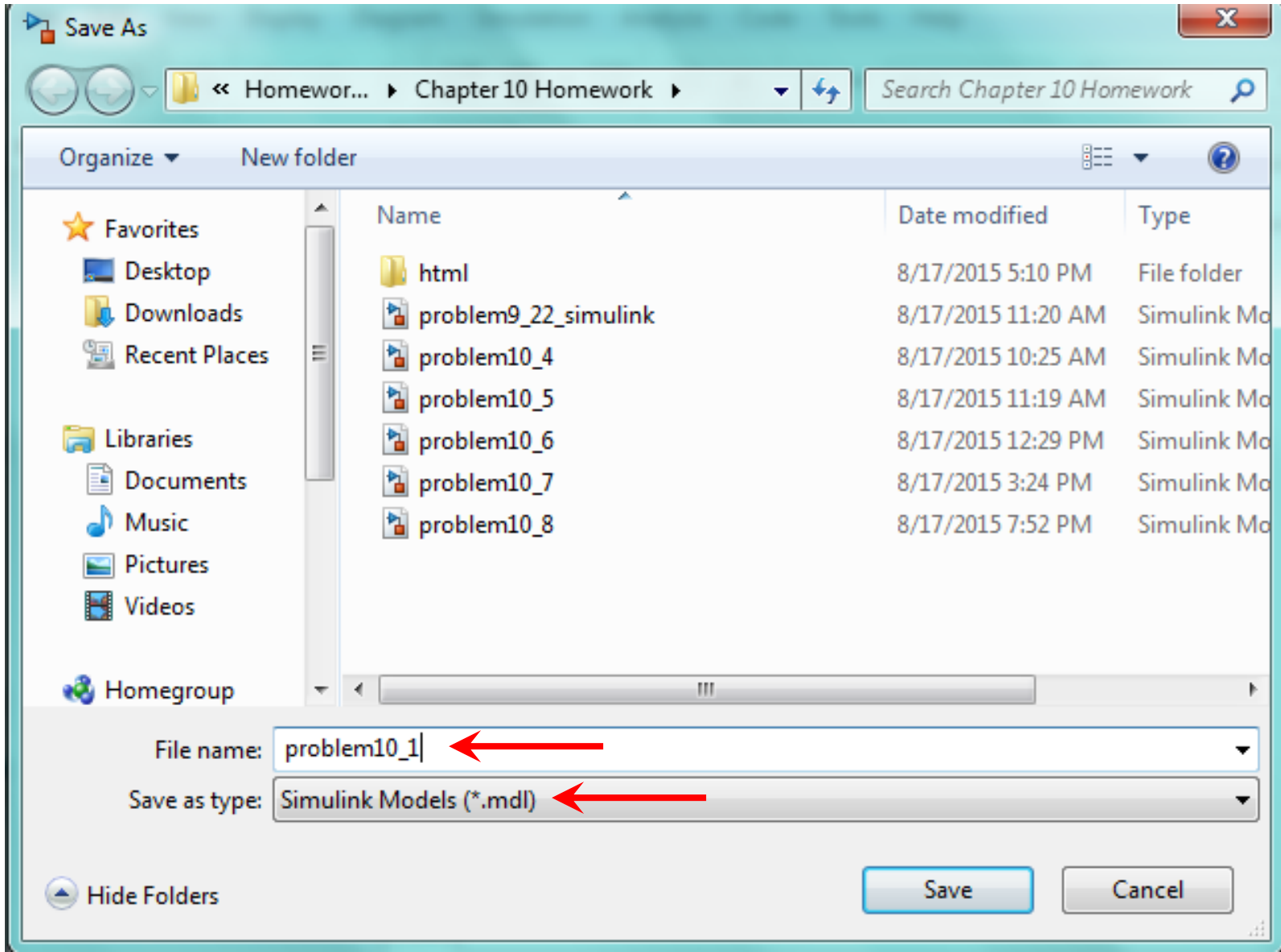
# Simulink Models

The Simulink Model Window appears



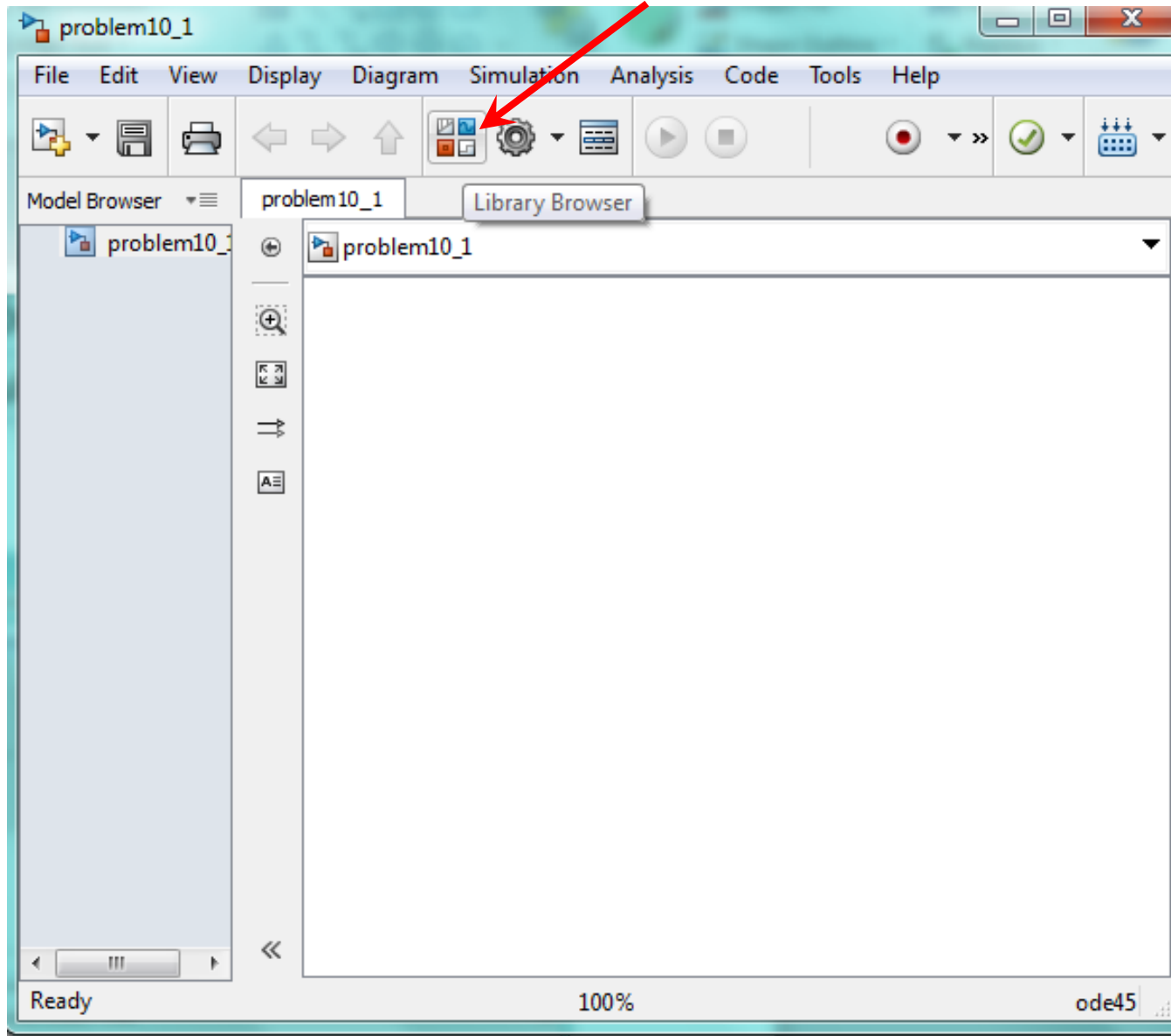
# Simulink Models

Save As a new Simulink Model (problem10\_1.mdl)



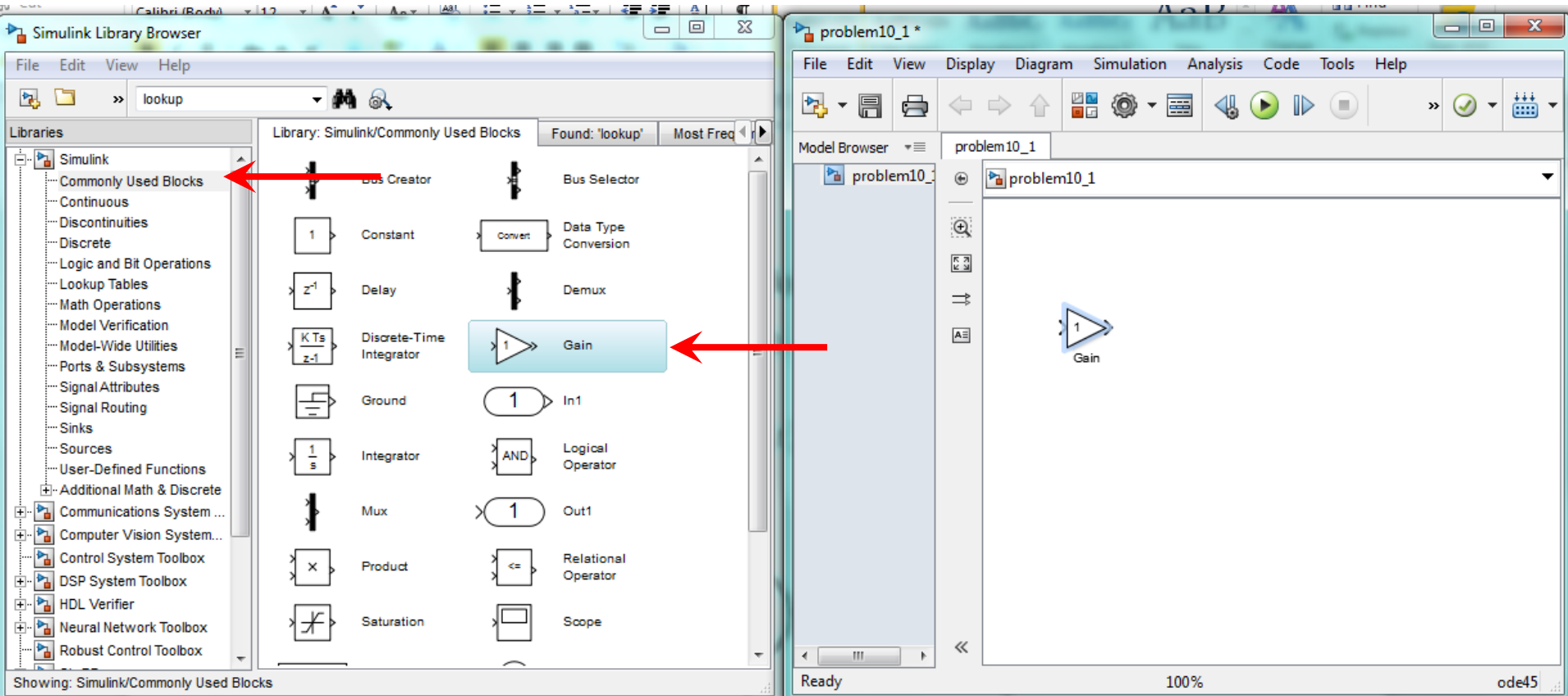
# Simulink Models

Open the Simulink Block Library Browser



# Simulink Models

Under the Commonly Used Blocks tab, drag-and-drop a Gain Block onto the Model Window by left-click-drag



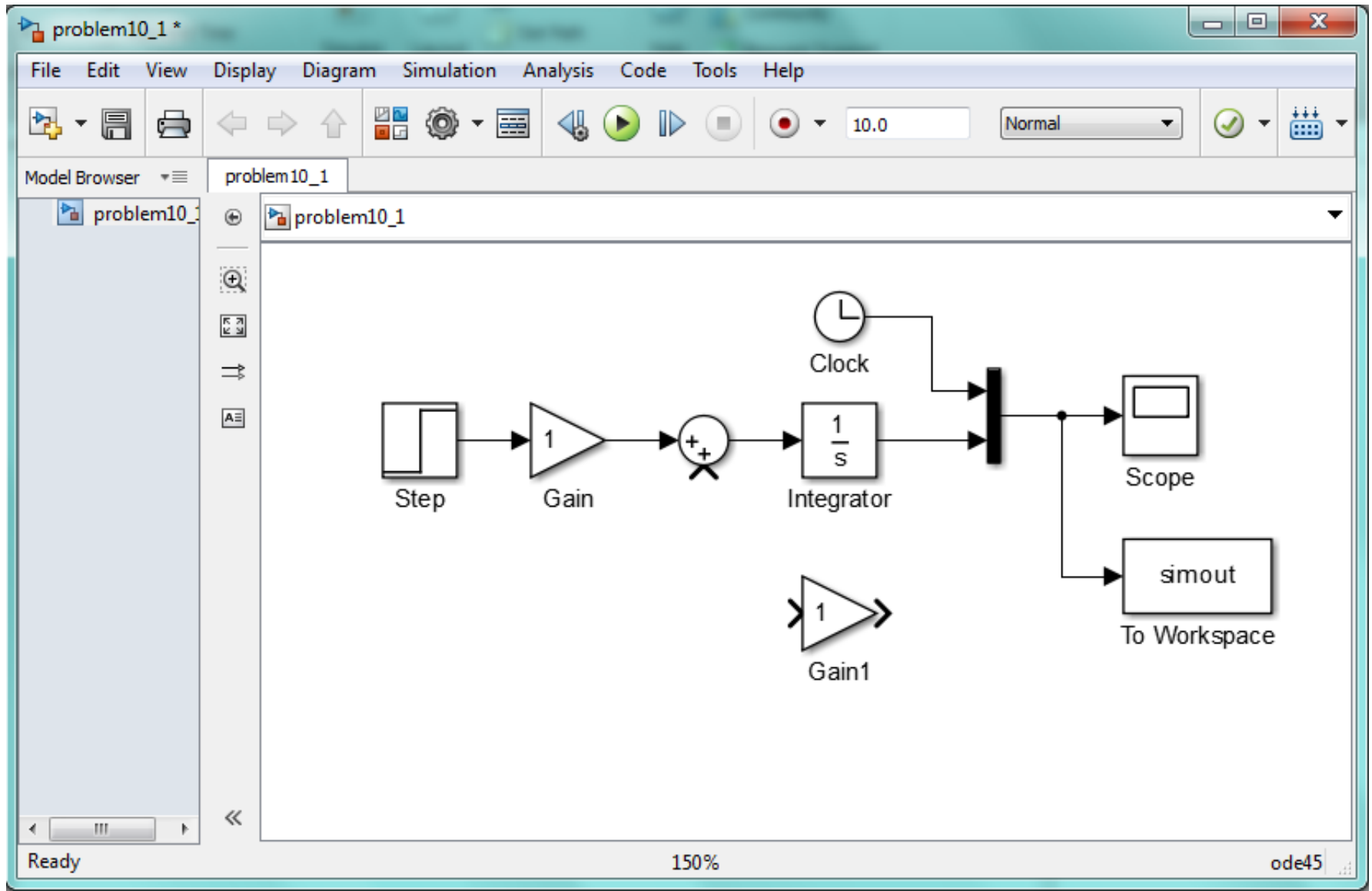
# Simulink Models

Place the following blocks onto the Block Diagram Window.  
Search for the Clock Function using the Search tab

The image displays two windows from the Simulink software interface. The left window is the 'Simulink Library Browser', which has a search bar containing the text 'clock'. A red arrow points to this search bar. Below the search bar, the 'Sources' category is selected, and the search results show three blocks: 'Clock' (under Simulink), 'Digital Clock' (under DSP System Toolbox), and 'Clock' (under Simulink Extras). The right window is the 'Block Diagram Window' for a model named 'problem10\_1'. The diagram contains several blocks: a 'Step' block, a 'Gain' block with a value of 1, a summing junction, an 'Integrator' block with a transfer function of  $\frac{1}{s}$ , another 'Gain' block with a value of 1, a 'Scope' block, and a 'simout To Workspace' block. The status bar at the bottom of the right window shows 'Ready', '150%', and 'ode45'.

# Simulink Models

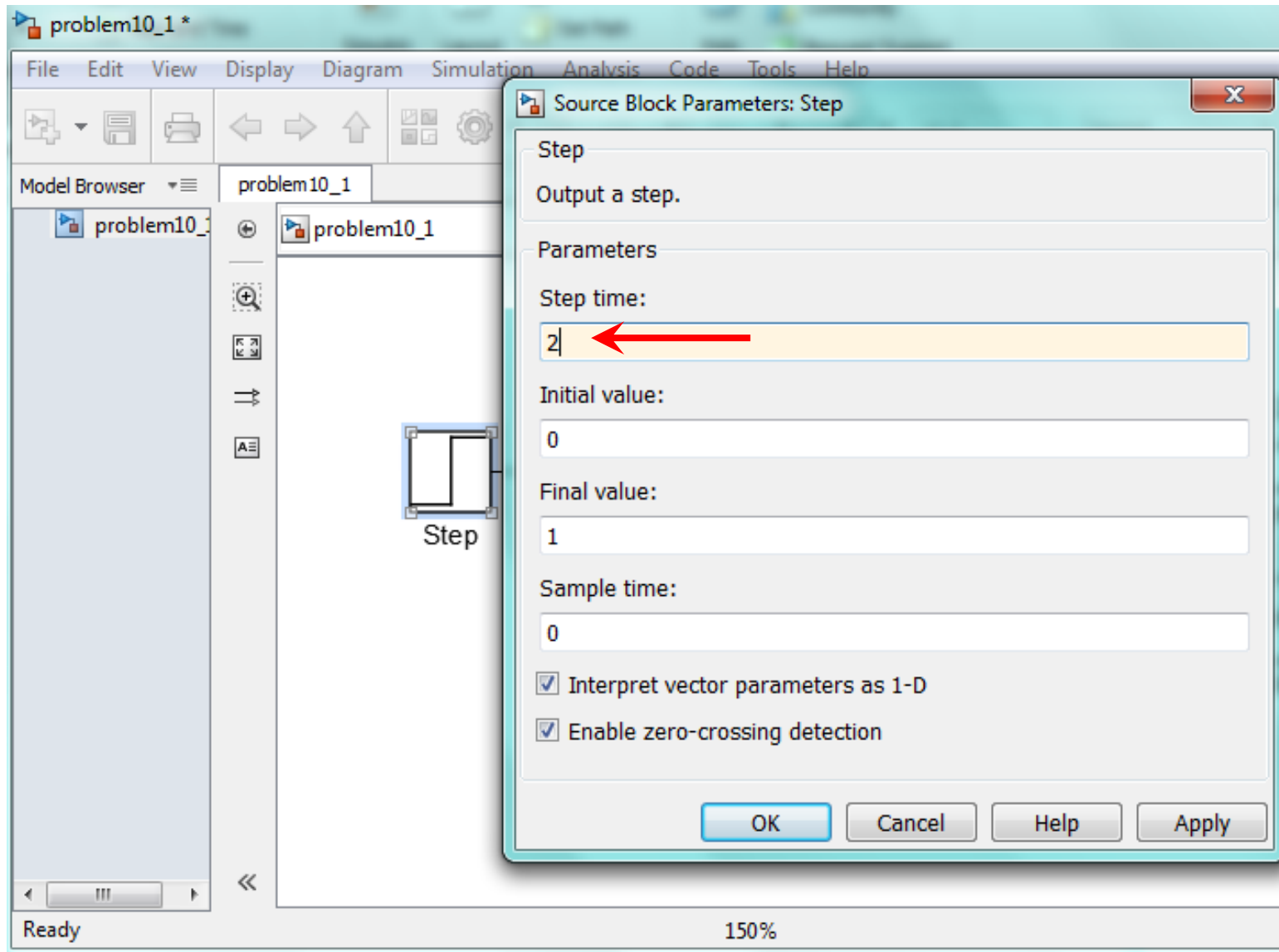
Wire up the blocks





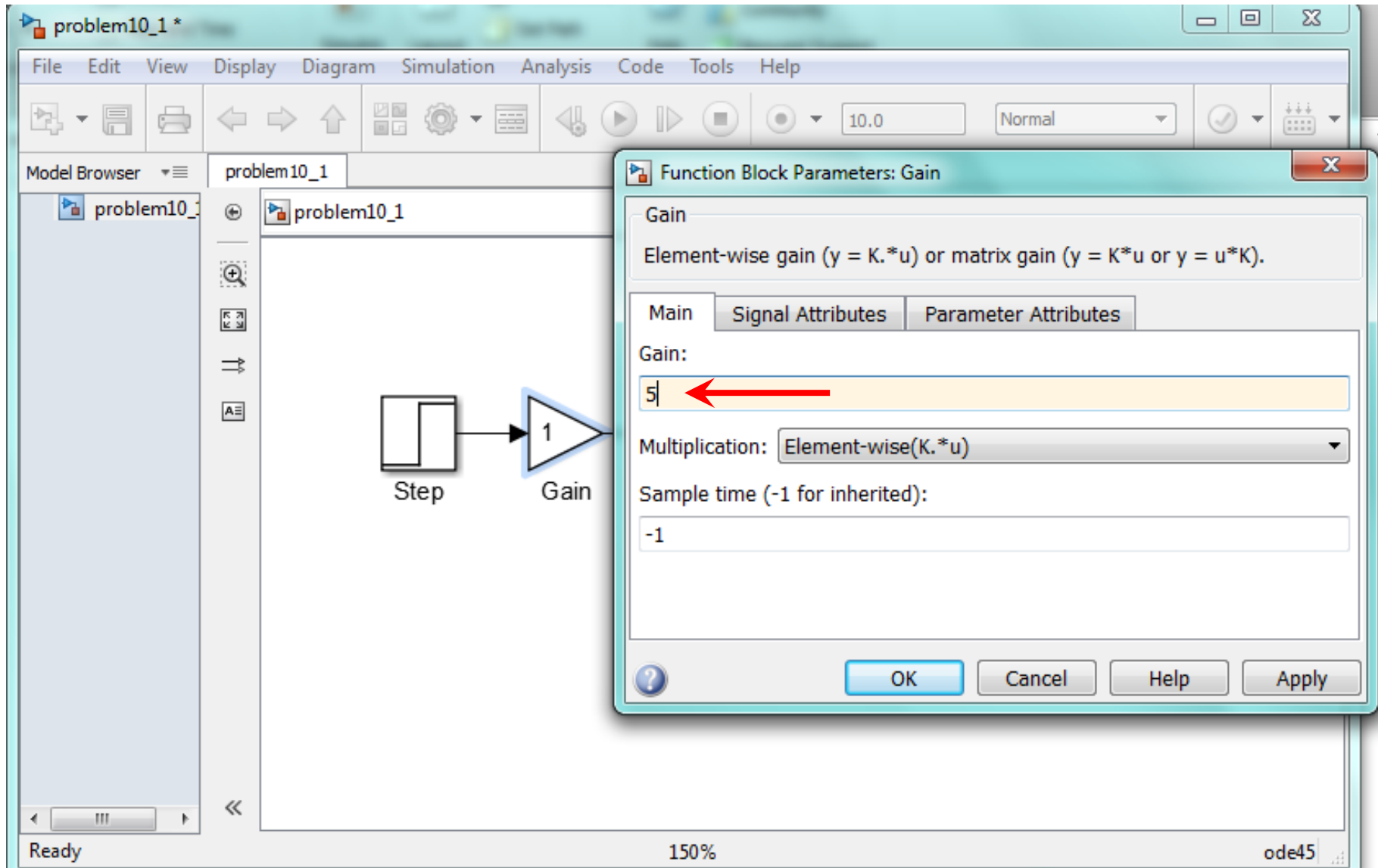
# Simulink Models

Double-Click on the Step block and set the Step Time to 2 sec



# Simulink Models

Double-Click on the Gain block and set the gain to 5



The image shows the Simulink software interface. In the background, a Simulink model named "problem10\_1" is open, displaying a "Step" block connected to a "Gain" block. The "Gain" block has a value of "1" inside it. A dialog box titled "Function Block Parameters: Gain" is overlaid on the model. The dialog box has a "Main" tab selected, and the "Gain" parameter is set to "5", with a red arrow pointing to the input field. The "Multiplication" dropdown is set to "Element-wise(K.\*u)" and the "Sample time (-1 for inherited)" is set to "-1". The dialog box has "OK", "Cancel", "Help", and "Apply" buttons at the bottom.

problem10\_1 \*

File Edit View Display Diagram Simulation Analysis Code Tools Help

Model Browser problem10\_1

problem10\_1

Step Gain

Function Block Parameters: Gain

Gain

Element-wise gain ( $y = K.*u$ ) or matrix gain ( $y = K*u$  or  $y = u*K$ ).

Main Signal Attributes Parameter Attributes

Gain:

5

Multiplication: Element-wise( $K.*u$ )

Sample time (-1 for inherited):

-1

OK Cancel Help Apply

Ready 150% ode45

# Simulink Models

Double-Click on the Integrator block and set the Initial Condition to 3

The image shows a Simulink model window with a 'Function Block Parameters: Integrator' dialog box open. The dialog box is titled 'Function Block Parameters: Integrator' and contains the following settings:

- Integrator: Continuous-time integration of the input signal.
- Parameters:
  - External reset: none
  - Initial condition source: internal
  - Initial condition: 3 (highlighted with a red arrow)
  - Limit output:
  - Upper saturation limit: inf
  - Lower saturation limit: -inf
  - Show saturation port:
  - Show state port:
  - Absolute tolerance: auto
  - Ignore limit and reset when linearizing:
  - Enable zero-crossing detection:

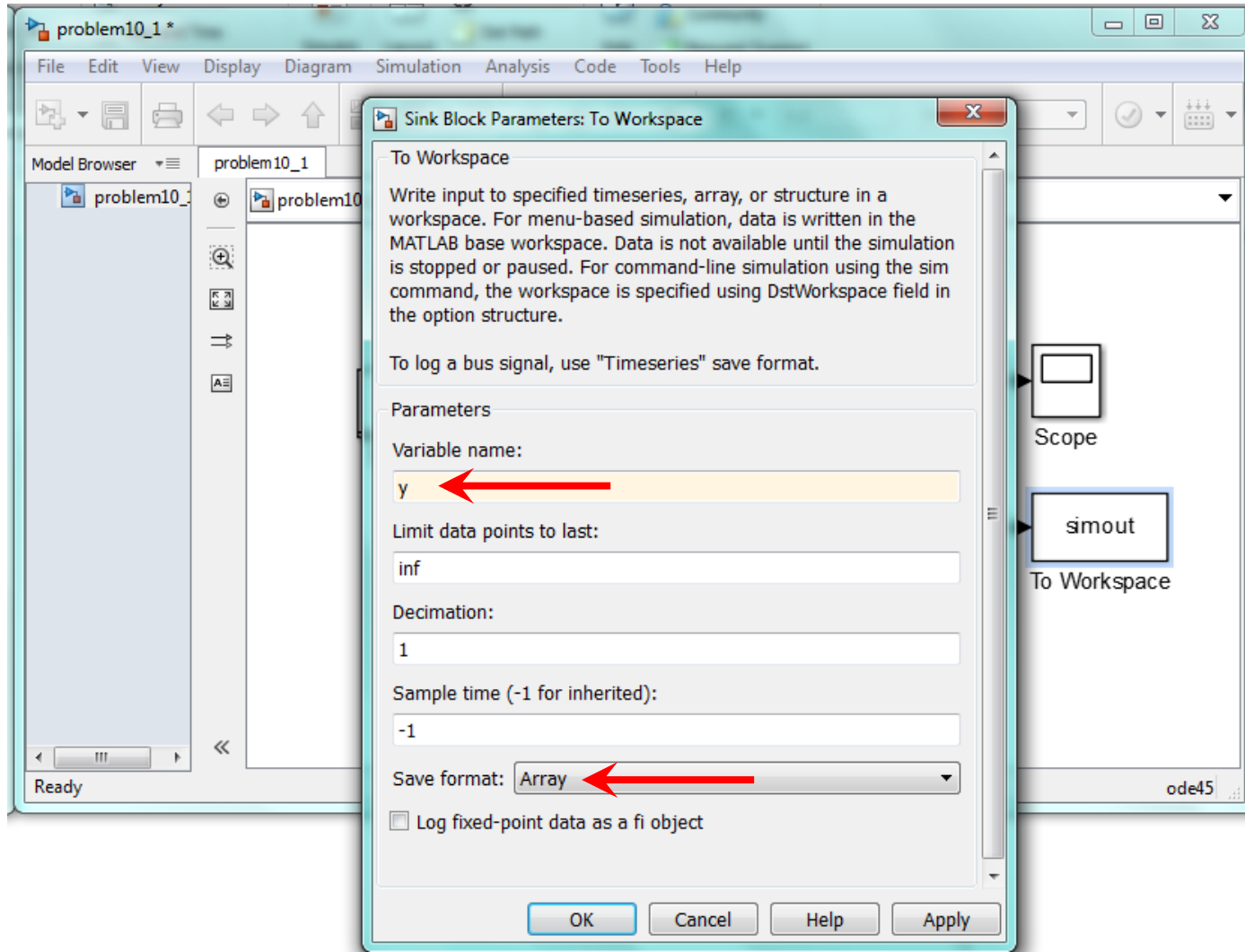
The background shows a Simulink model with the following blocks and connections:

- A 'Clock' block connected to a summing junction.
- An 'Integrator' block (1/s) connected to the summing junction.
- A 'Gain1' block (1) connected to the summing junction.
- The output of the summing junction is connected to a 'Scope' block and a 'simout' block (To Workspace).

The 'Integrator' block is highlighted with a blue border, indicating it is the active block in the dialog.

# Simulink Models

Double-Click on the To Workspace block and set the Variable Name to y and set the Save Format to Array



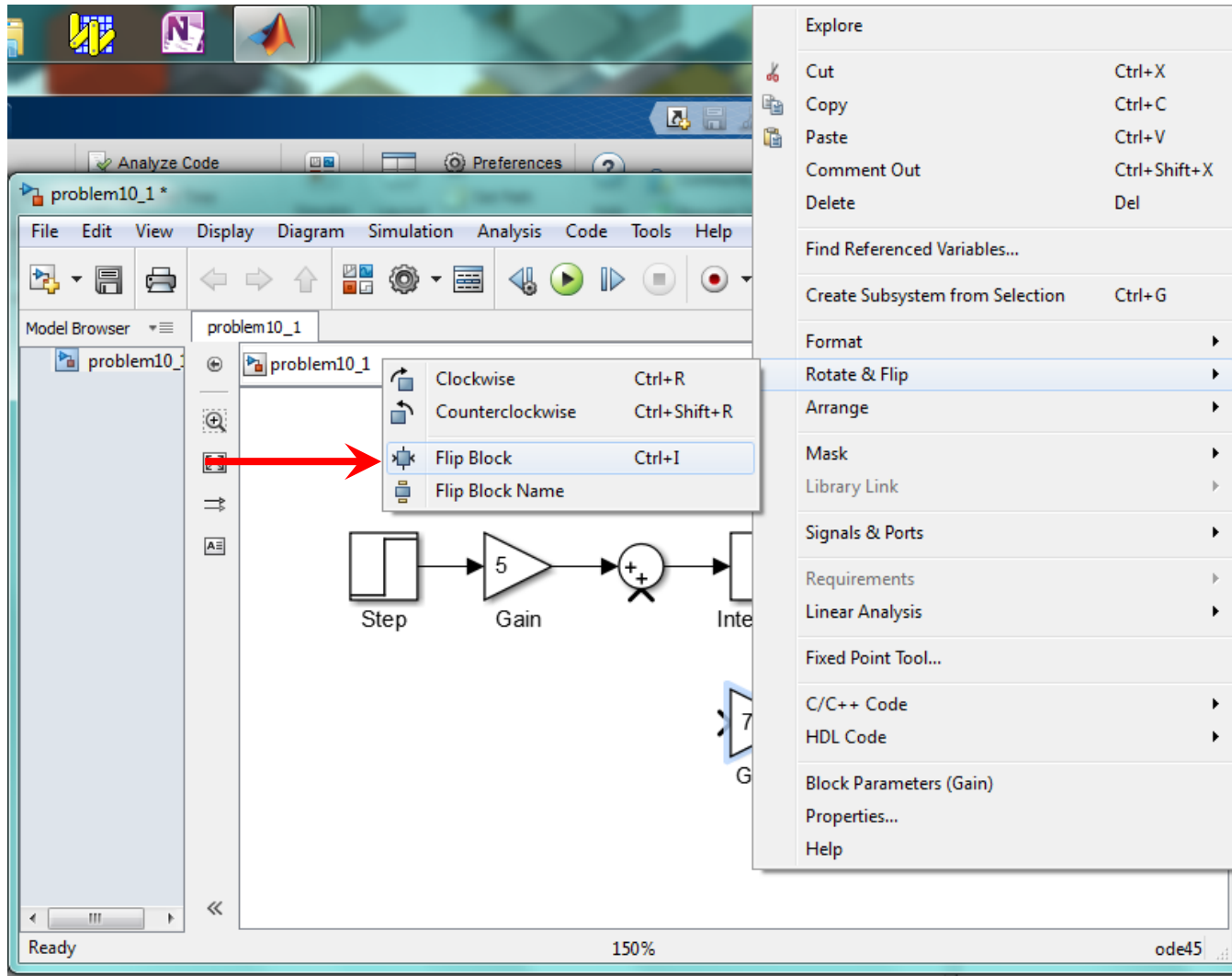
# Simulink Models

Double-Click on the lower Gain block and set the value to 7

The image shows a Simulink model window titled "problem10\_1". The model diagram includes a Clock block, an Integrator block (1/s), a Gain1 block (value 1), a summing junction, a Scope block, and a "simout To Workspace" block. A dialog box titled "Function Block Parameters: Gain1" is open, showing the Gain parameter set to 7. A red arrow points to the value 7 in the Gain field. The dialog box also shows the Multiplication method as "Element-wise(K.\*u)" and the Sample time as -1. The Simulink interface includes a menu bar (File, Edit, View, Display, Diagram, Simulation, Analysis, Code, Tools, Help) and a toolbar with various simulation and editing tools. The Model Browser on the left shows the current model structure.

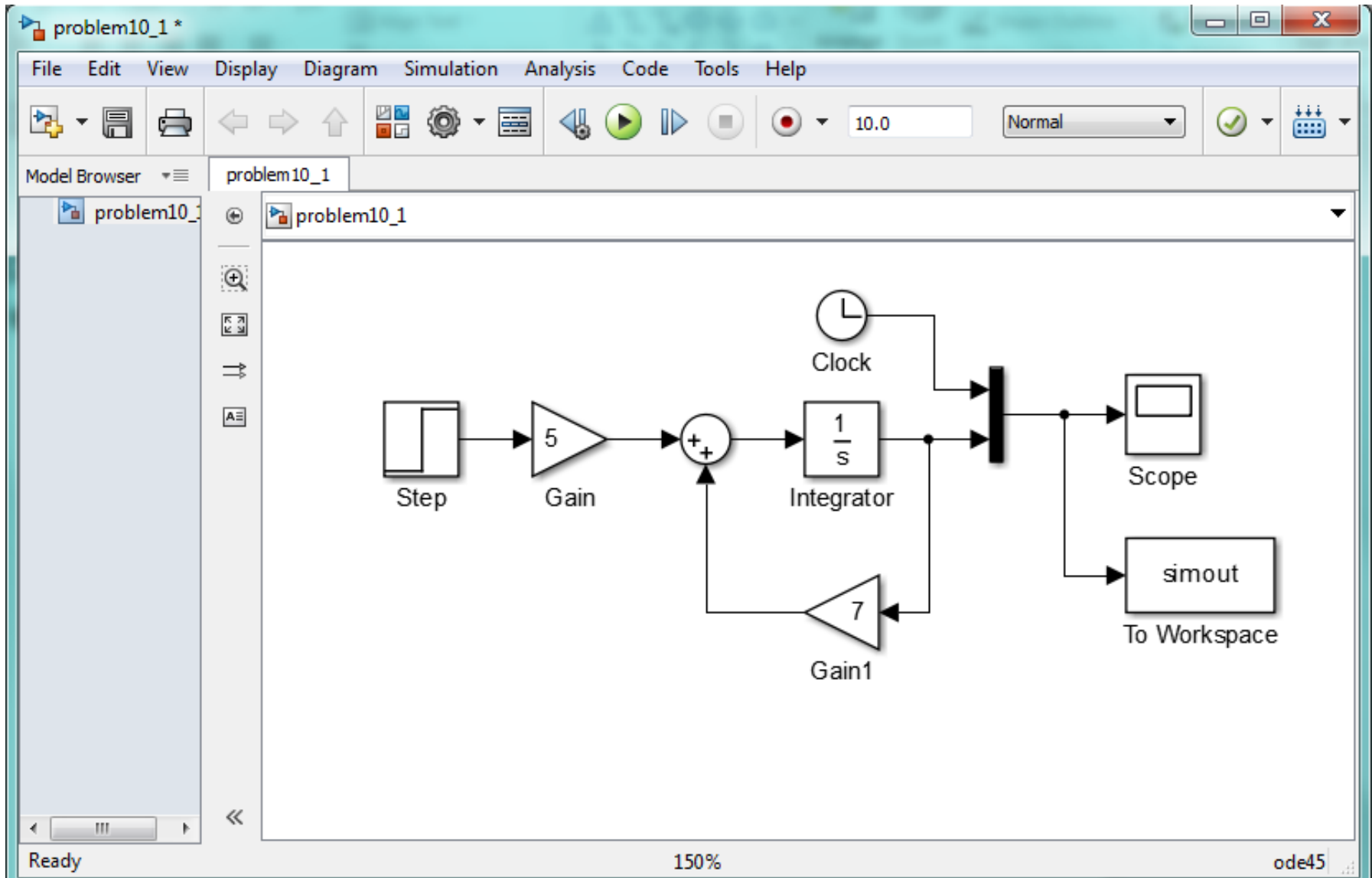
# Simulink Models

Right-Click on the lower Gain block and flip the block direction



# Simulink Models

Complete the wiring on the model



# Simulink Models

Double-Click on the Summer block and change the signs

The image shows a Simulink model window with a 'Function Block Parameters: Sum' dialog box open. The dialog box has two tabs: 'Main' and 'Signal Attributes'. The 'Signal Attributes' tab is active, showing the 'List of signs' field with the value '|+' selected, indicated by a red arrow. The 'Sample time (-1 for inherited)' field contains '-1'. The 'Main' tab is also visible, showing the 'Icon shape' set to 'round'. The background shows a Simulink model diagram with the following components: a Clock block, a Gain1 block (value 7), an Integrator block (1/s), a Sum block (with two '+' signs), a Scope block, and a 'simout' block (To Workspace). The Sum block is highlighted with a blue circle. The Simulink window title bar shows 'Tools' and 'Help' menus, and the status bar at the bottom indicates 'Ready', '150%', and 'ode45'.

Function Block Parameters: Sum

Sum

Add or subtract inputs. Specify one of the following:

- a) string containing + or - for each input port, | for spacer between ports (e.g. ++|-|++)
- b) scalar,  $\geq 1$ , specifies the number of input ports to be summed. When there is only one input port, add or subtract elements over all dimensions or one specified dimension

Main Signal Attributes

Icon shape: round

List of signs:

|+ ←

Sample time (-1 for inherited):

-1

OK Cancel Help Apply

Tools Help

10.0 Normal

Clock

Integrator

Gain1

Scope

simout To Workspace

Ready 150% ode45



# Simulink Models

Save the model often

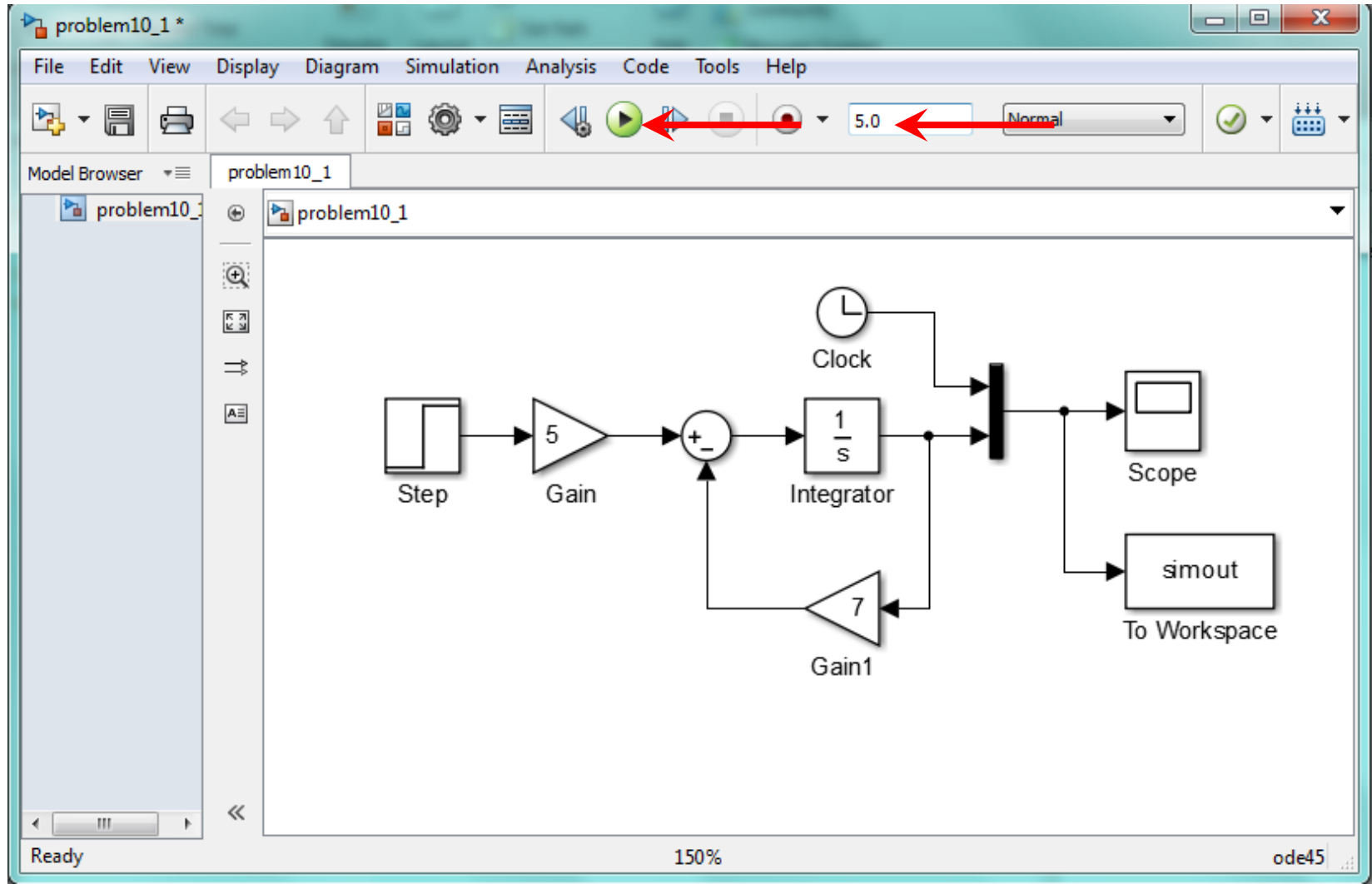
The image shows a screenshot of the Simulink software interface. The window title is "problem10\_1 \*". The menu bar includes File, Edit, View, Display, Diagram, Simulation, Analysis, Code, Tools, and Help. The toolbar contains various icons, with the Save icon (a floppy disk) highlighted by a red arrow. The Model Browser on the left shows the current model "problem10\_1". The main workspace displays a Simulink model diagram with the following components and connections:

- A **Step** block is connected to a **Gain** block with a value of 5.
- The output of the Gain block is connected to a summing junction (+/-).
- The output of the summing junction is connected to an **Integrator** block with a transfer function of  $\frac{1}{s}$ .
- The output of the Integrator block is connected to a **Gain1** block with a value of 7.
- The output of Gain1 is connected back to the summing junction, forming a feedback loop.
- The output of the Integrator block is also connected to a **Clock** block.
- The outputs of the Clock and the Integrator are connected to a bus.
- The bus is connected to a **Scope** block and a **simout To Workspace** block.

The status bar at the bottom shows "Ready", "150%", and "ode45".

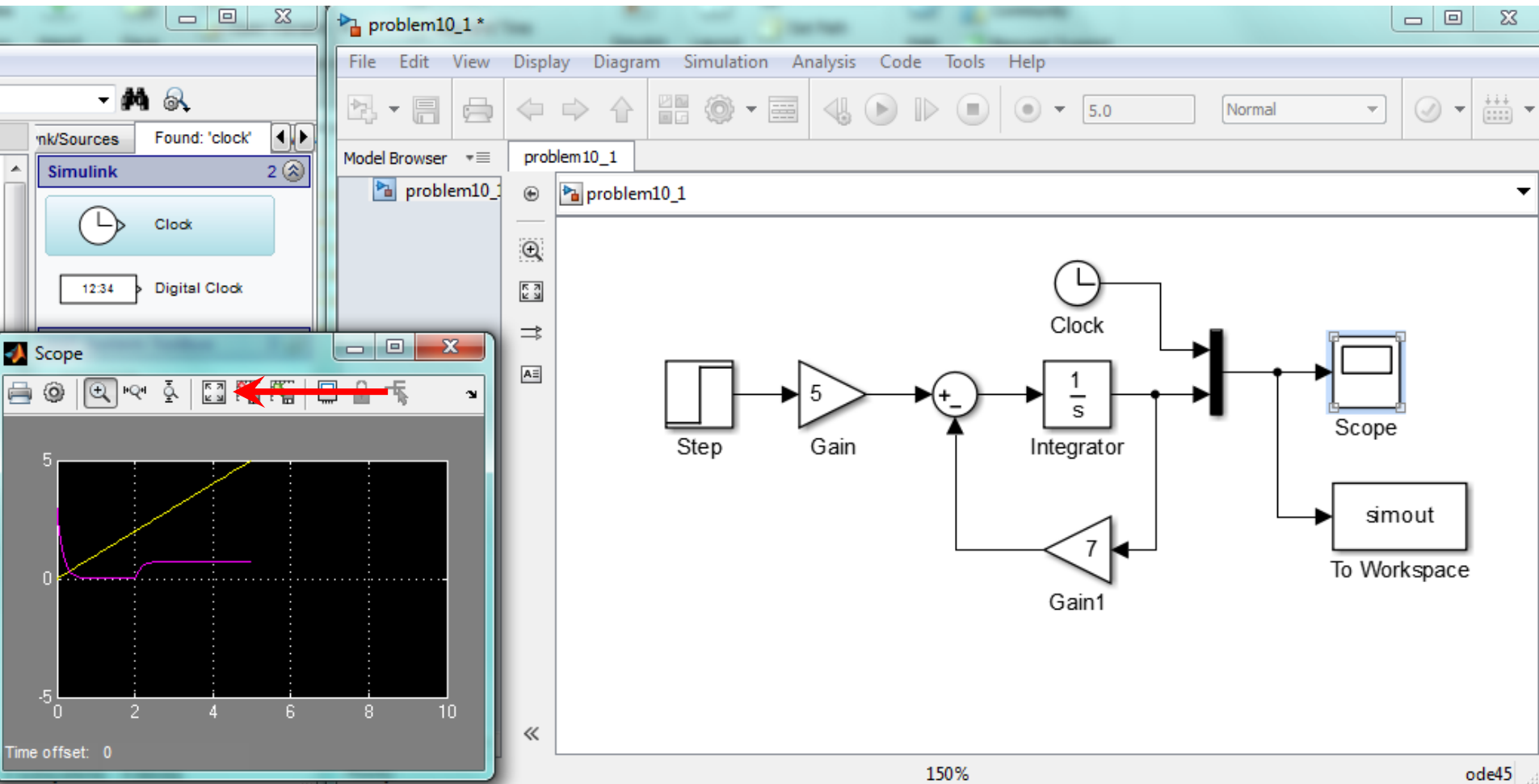
# Simulink Models

Change the Run Time to 5 sec and Run the model. Wait for the Ding! Double-click on the Scope block to plot the output.



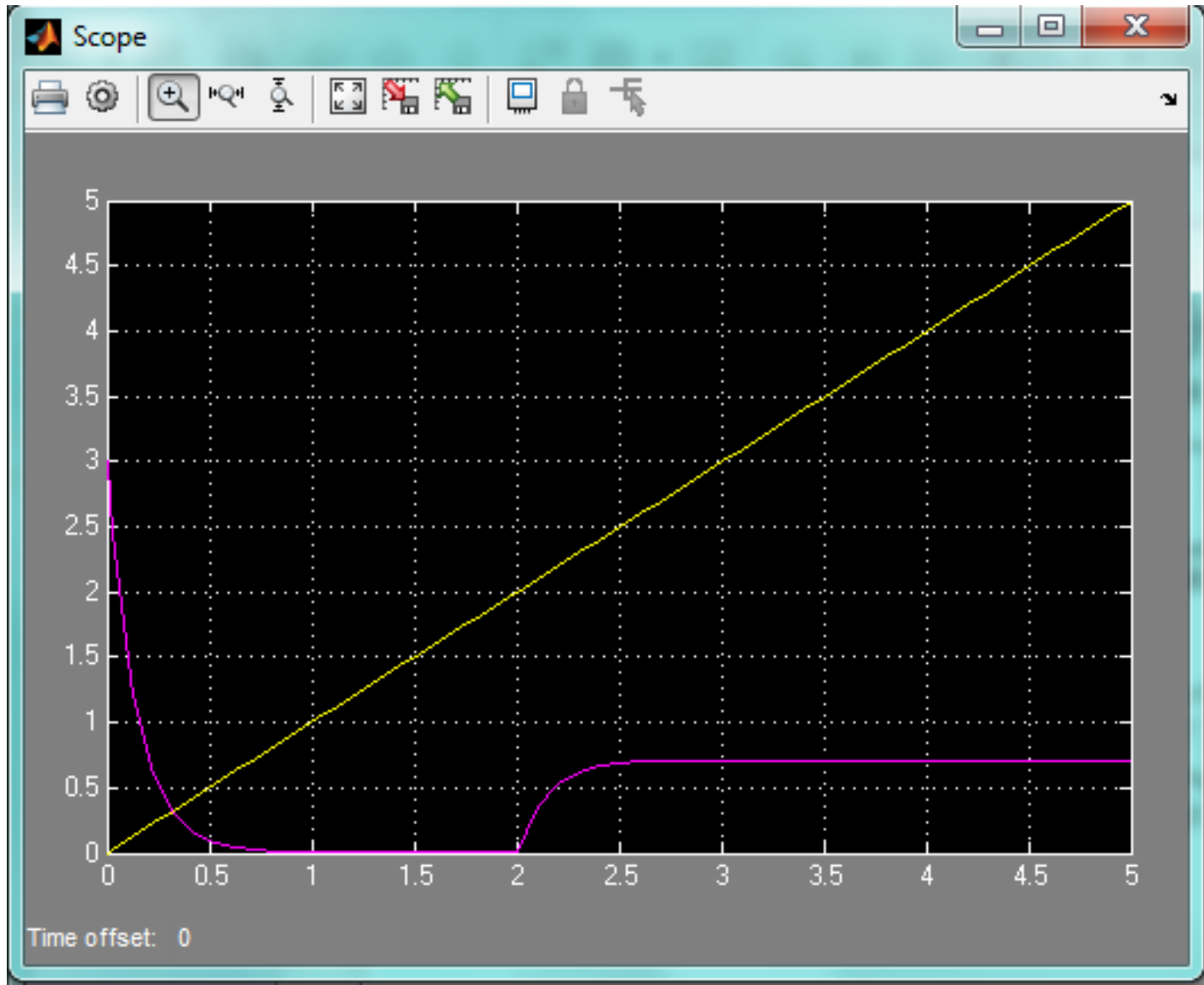
# Simulink Models

Press the Autoscale button and expand the size of the output graph



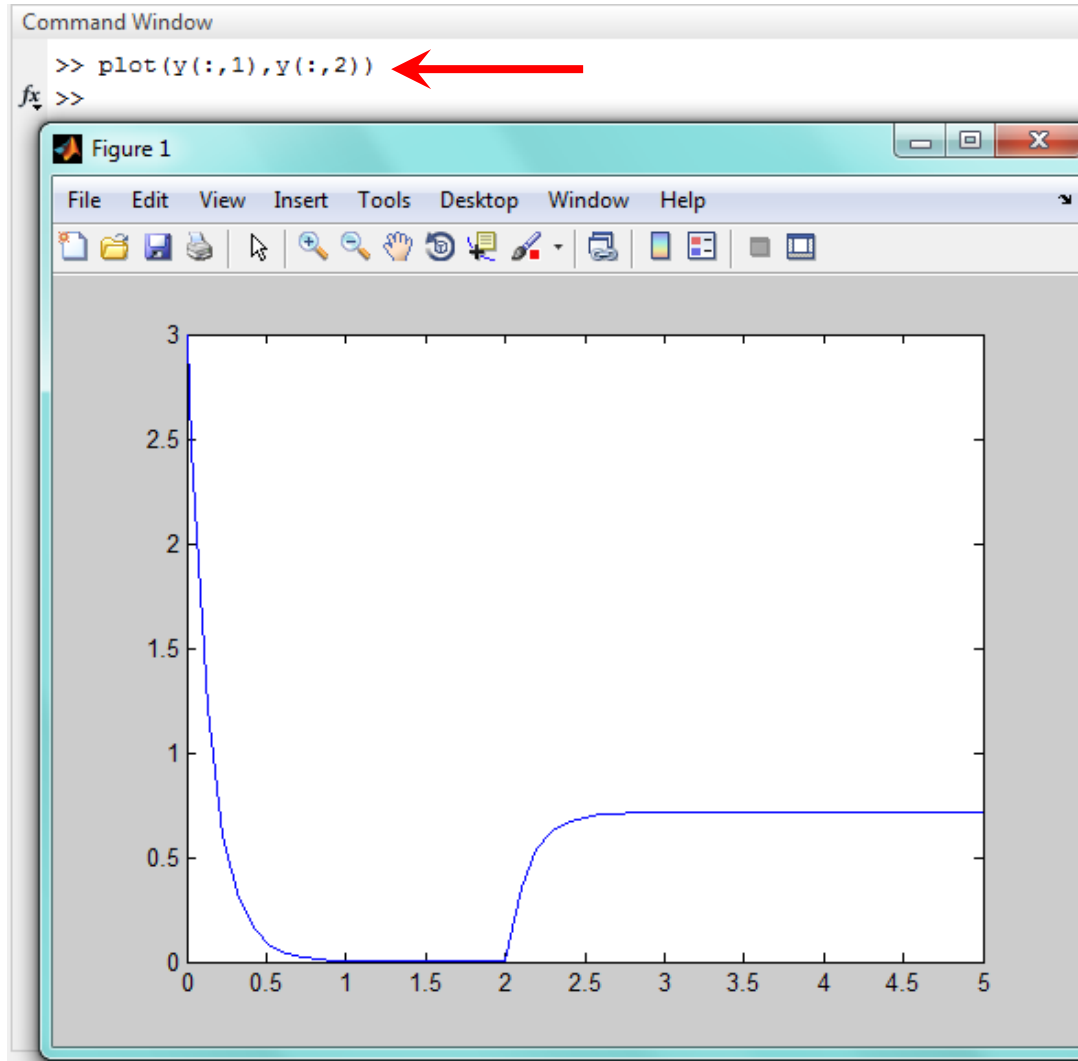
# Simulink Models

The purple line is  $y(t)$  and the yellow line is  $t$



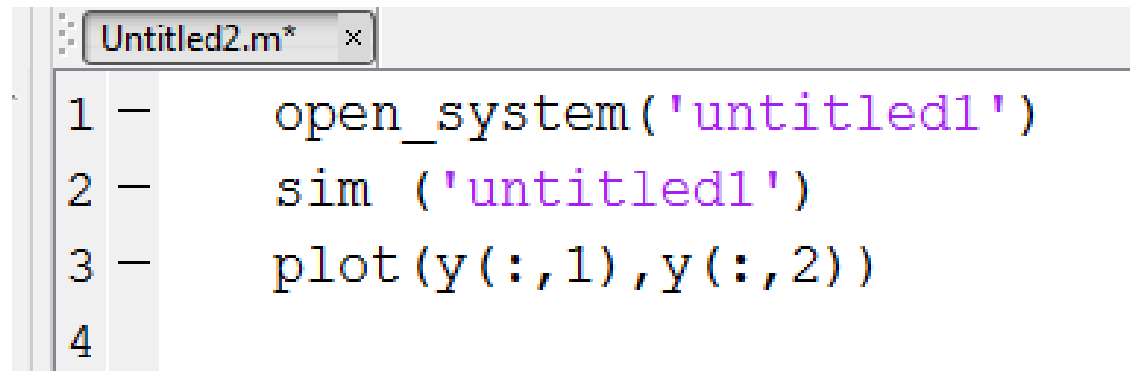
# Simulink Models

Click on the MATLAB Command Window and type in the following command: `>> plot(y(:,1),y(:,2))`



# Simulink Models

You can publish the Simulink model and the results by creating a MATLAB Script file that calls it. First, close the Simulink model. The name of the Script file must be different than the Simulink model. Open the Script file and use the Publish function.

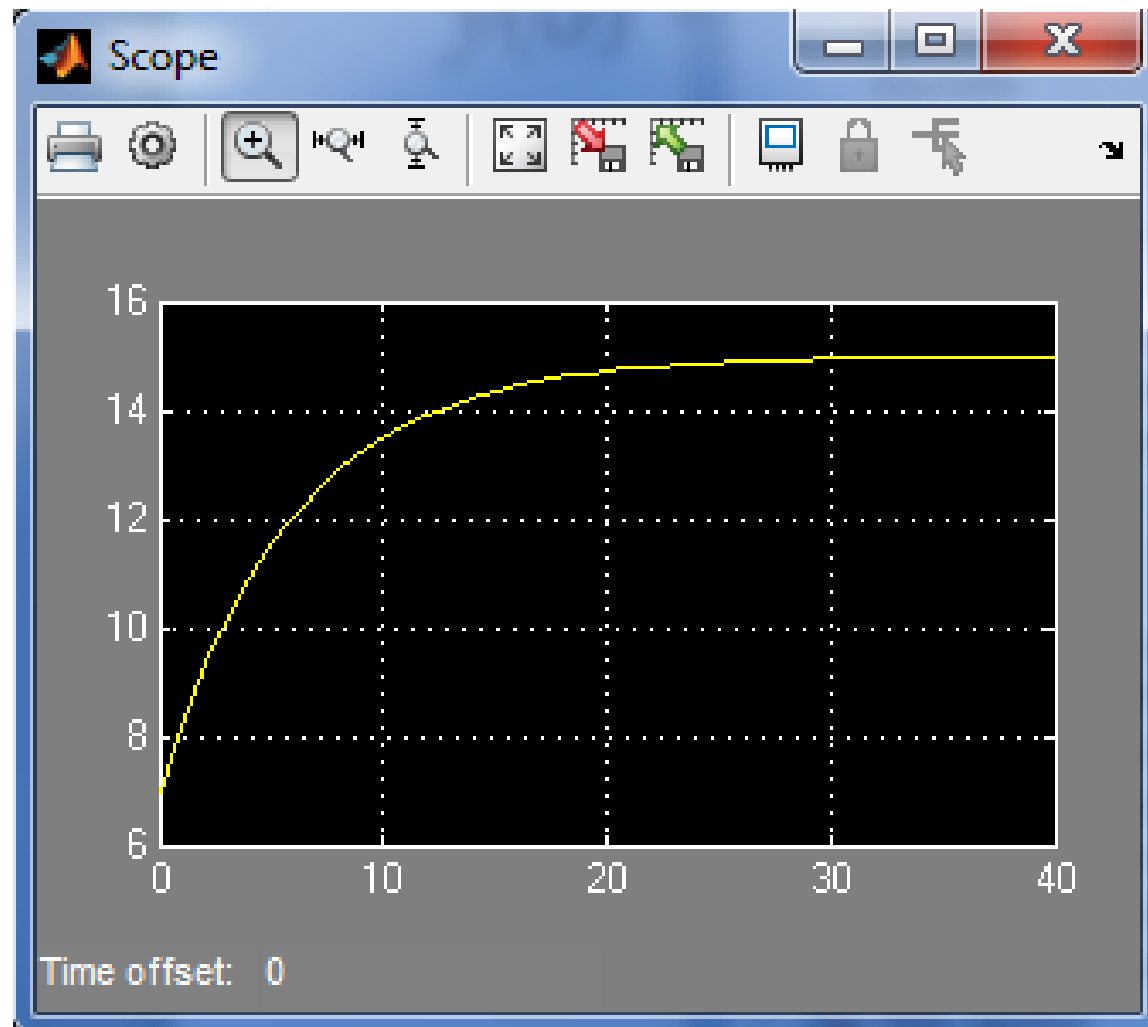


```
1 - open_system('untitled1')
2 - sim('untitled1')
3 - plot(y(:,1),y(:,2))
4
```

22. Plot the solution of the equation

$$6\dot{y} + y = f(t)$$

if  $f(t) = 0$  for  $t < 0$  and  $f(t) = 15$  for  $t \geq 0$ . The initial condition is  $y(0) = 7$ .



30. The following equation describes the motion of a certain mass connected to a spring, with viscous friction on the surface

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where  $f(t)$  is an applied force. Suppose that  $f(t) = 0$  for  $t < 0$  and  $f(t) = 10$  for  $t \geq 0$ .

- Plot  $y(t)$  for  $y(0) = \dot{y}(0) = 0$ .
- Plot  $y(t)$  for  $y(0) = 0$  and  $\dot{y}(0) = 10$ . Discuss the effect of the nonzero initial velocity.

