

Simulations in Matlab

Simulink, differential equations in Simulink

Simulink

- Simulink is a graphical interface to Matlab
- Its results are time courses of variables depending on one variable, typically time
- Simulink contains built in differential equation solvers, so the discretization of differential equations is not necessary

Running Simulink

The image shows the MATLAB R2014b software interface. The top menu bar includes HOME, PLOTS, and APPS. The ribbon contains several tabs: FILE, VARIABLE, CODE, SIMULINK, and ENVIRONMENT. The SIMULINK tab is active, and the Simulink Library button is circled in red. Below the ribbon, the Command Window displays the text "New to MATLAB? See resources for [Getting Started.](#)" and the command `simulink` entered at the prompt. The Command Window also shows a yellow warning banner. The left sidebar shows the Current Folder and Workspace panels.

Current Folder

Name
aaa
Admin
inetpub
install
jebatlalabmatlabmech
Mechovno

Workspace

Name	Value
abc toolbox_version	'maple'

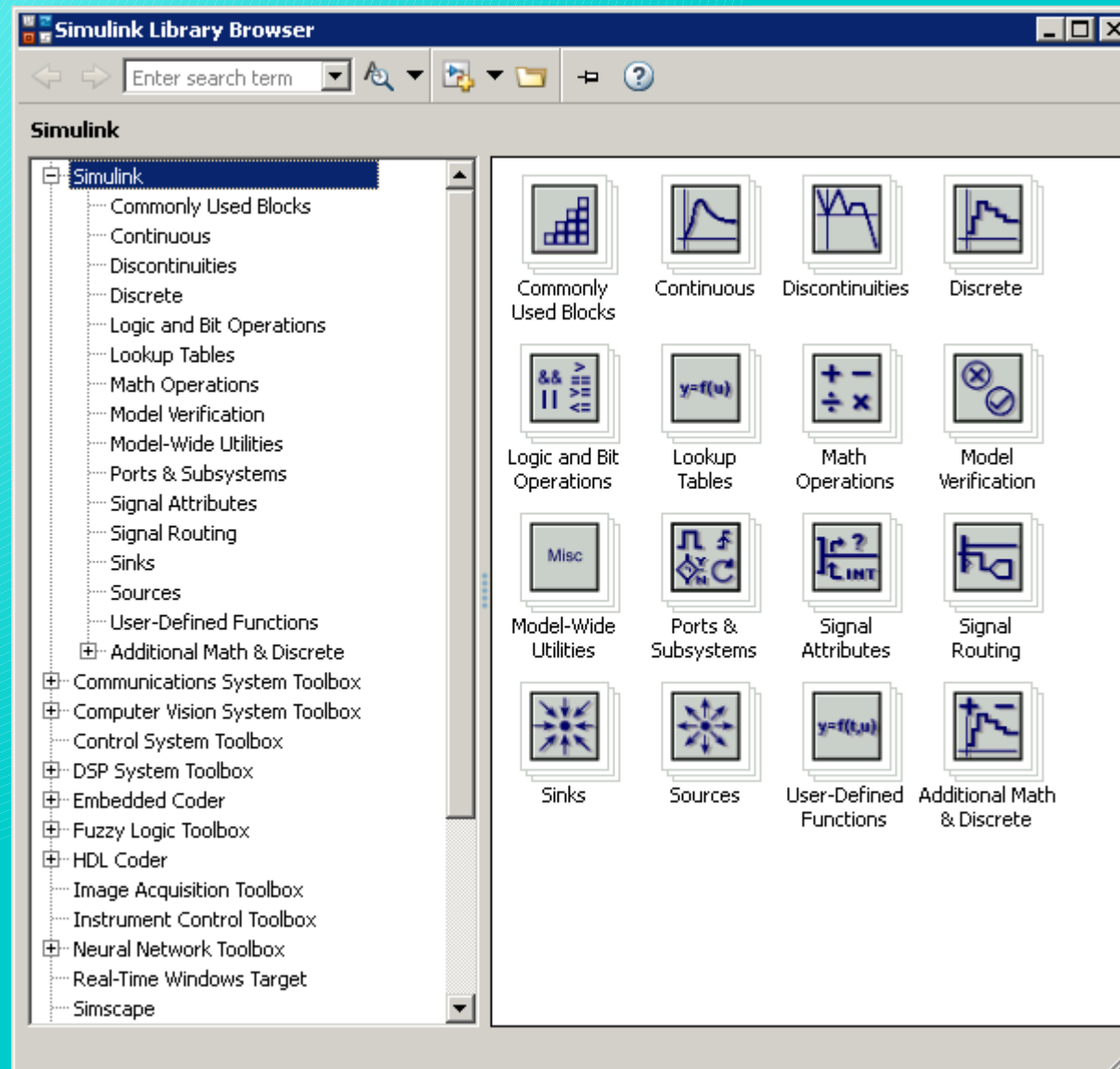
Command Window

```
New to MATLAB? See resources for Getting Started.  
/x >> simulink
```

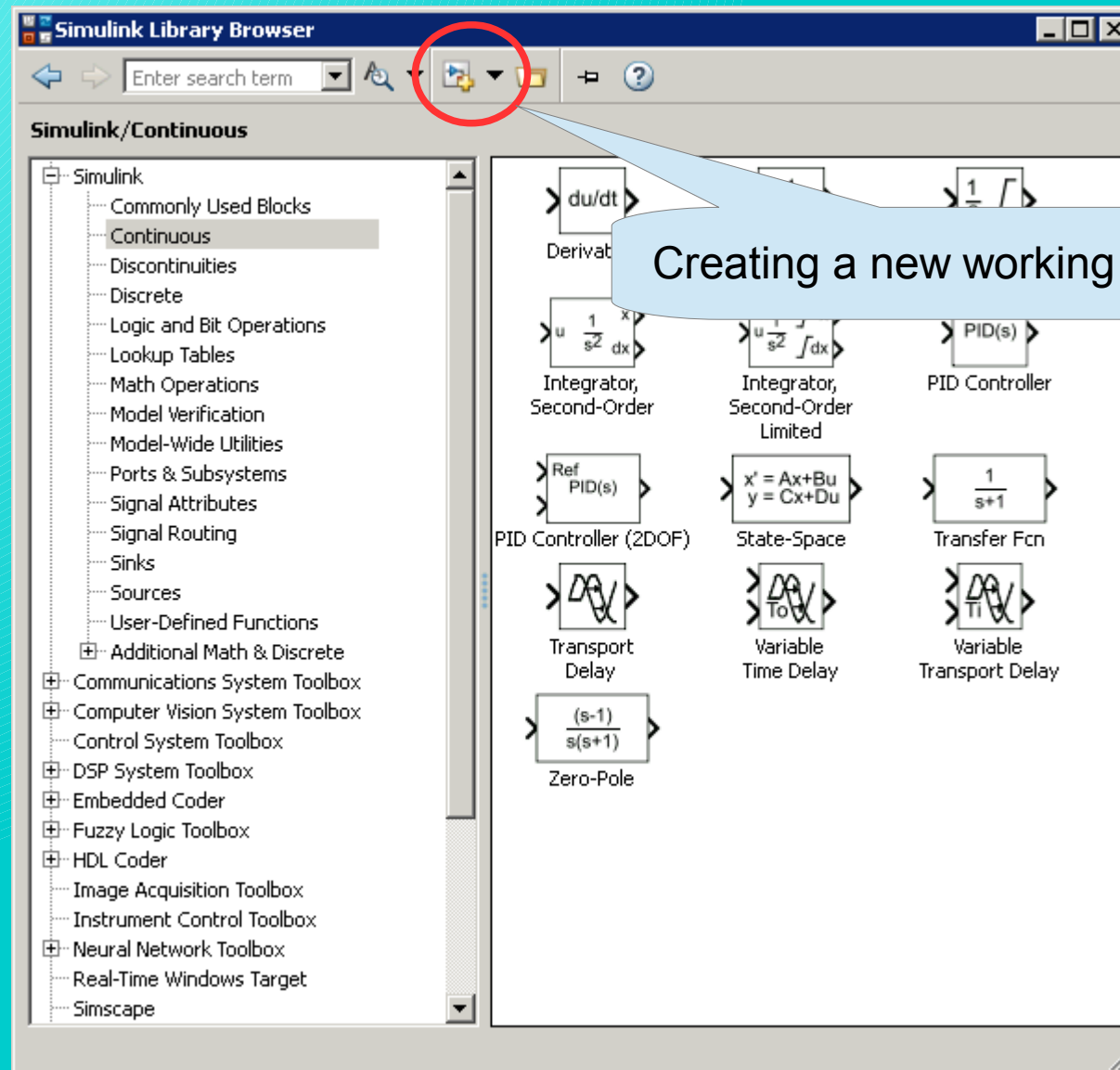
Programming in Simulink

- It is in a graphical form and it is based on placing and connecting blocks
- Blocks represent functions, connections represent variables
- Some blocks have only the output and are designated to generate variable values
- Some blocks have only the input and are designated to process the results – showing, saving, and others

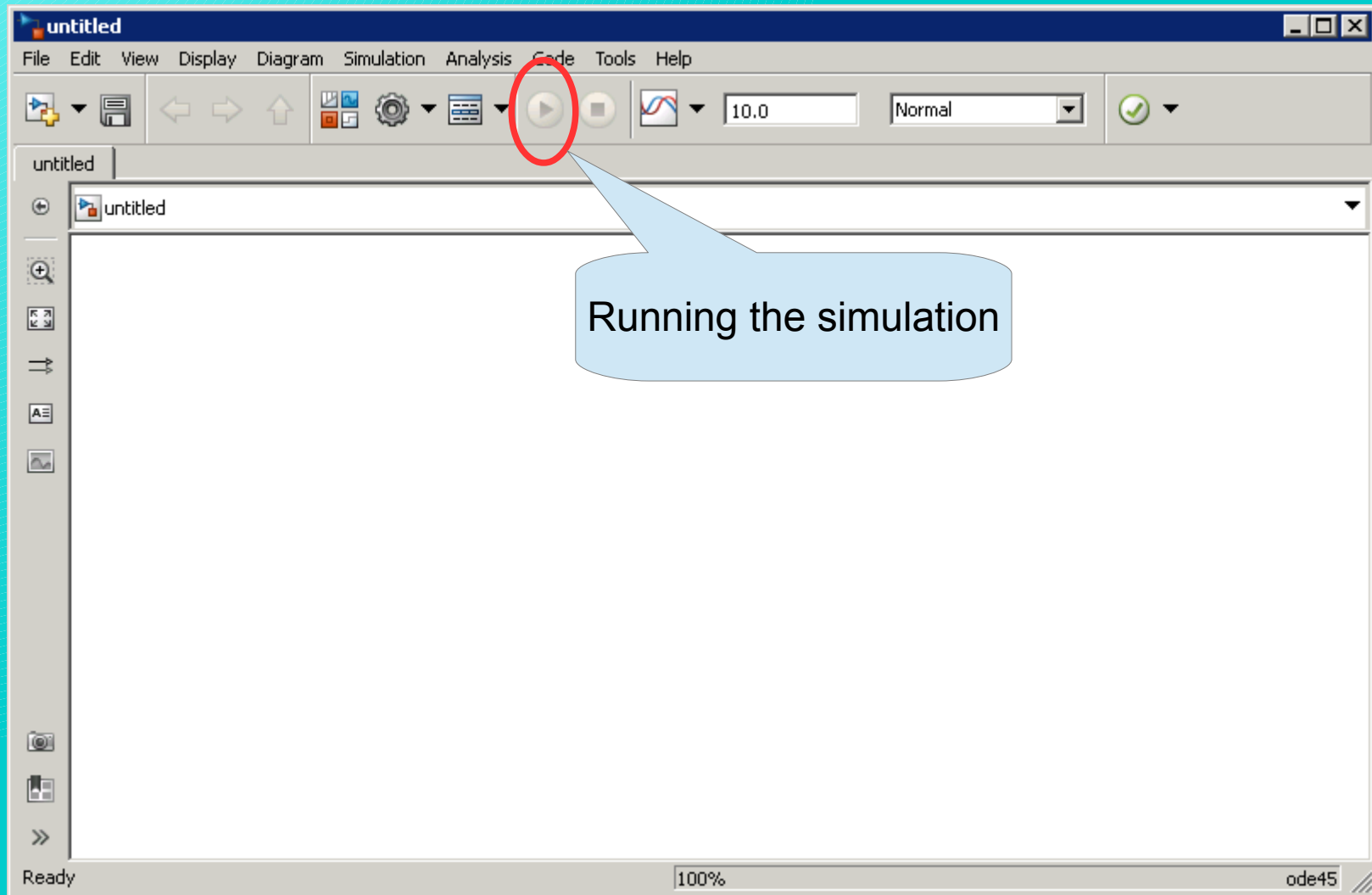
Block library



Block library



Working area for building a model

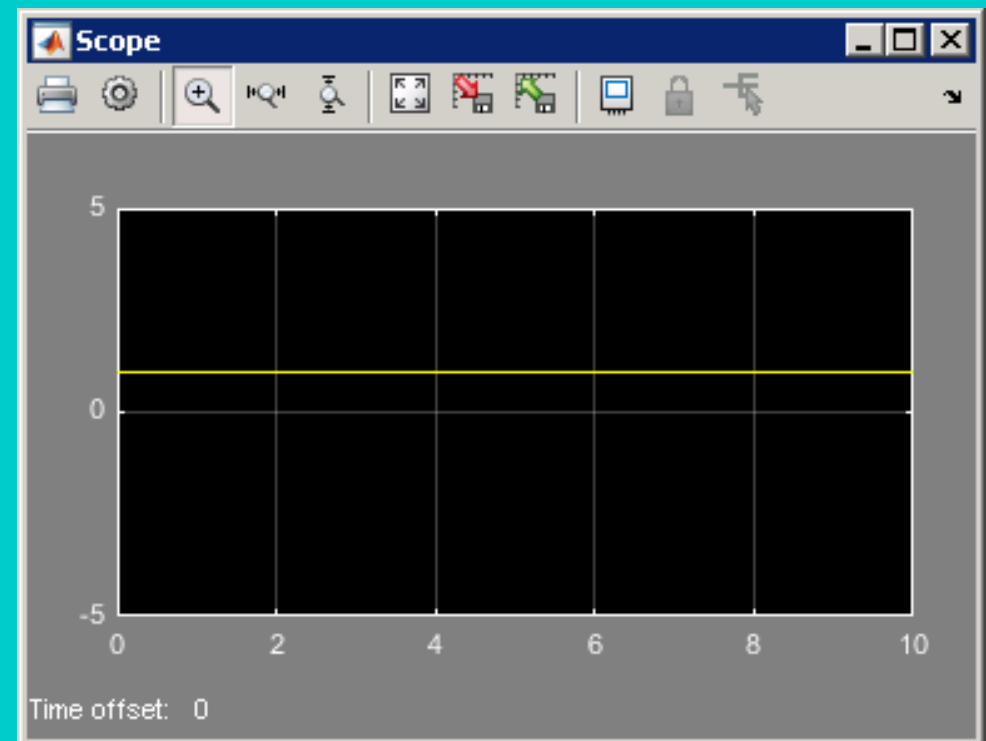


Model/scheme in Simulink

Simple scheme is possible to build with the use of the block Constant (from Simulink/Sources) and the block Scope (from Simulink/Sinks)

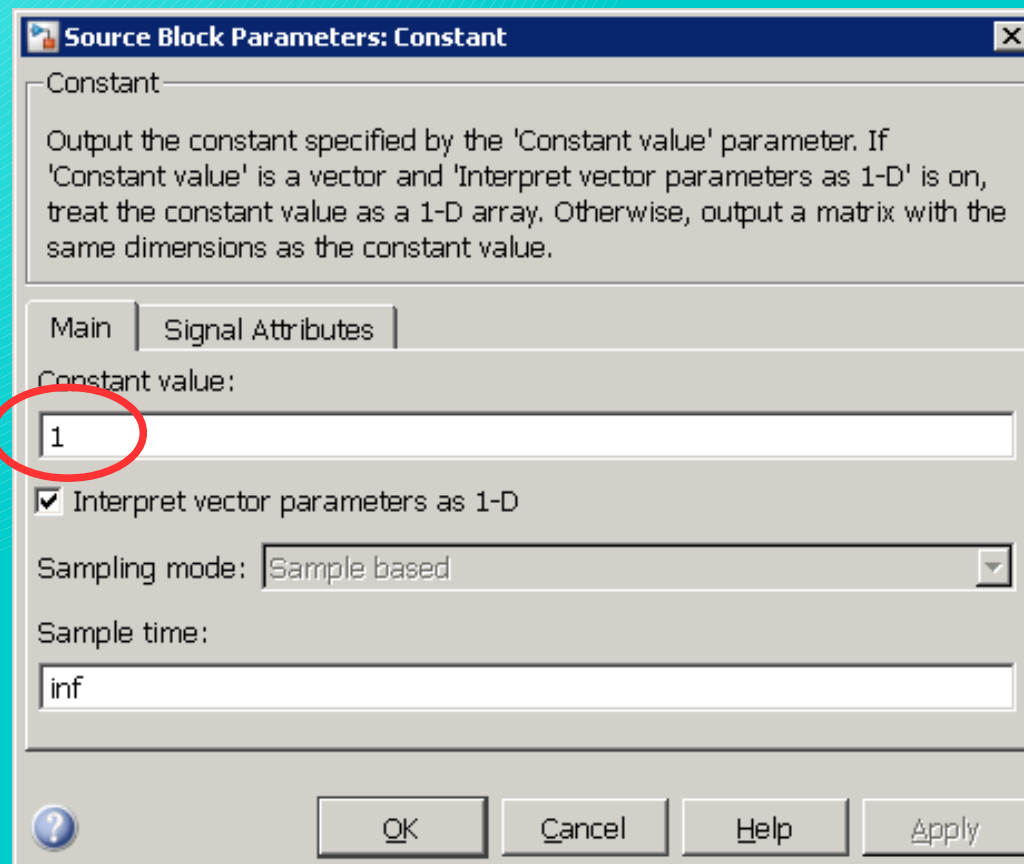


After the simulation run and double click on the block Scope, the results are shown.



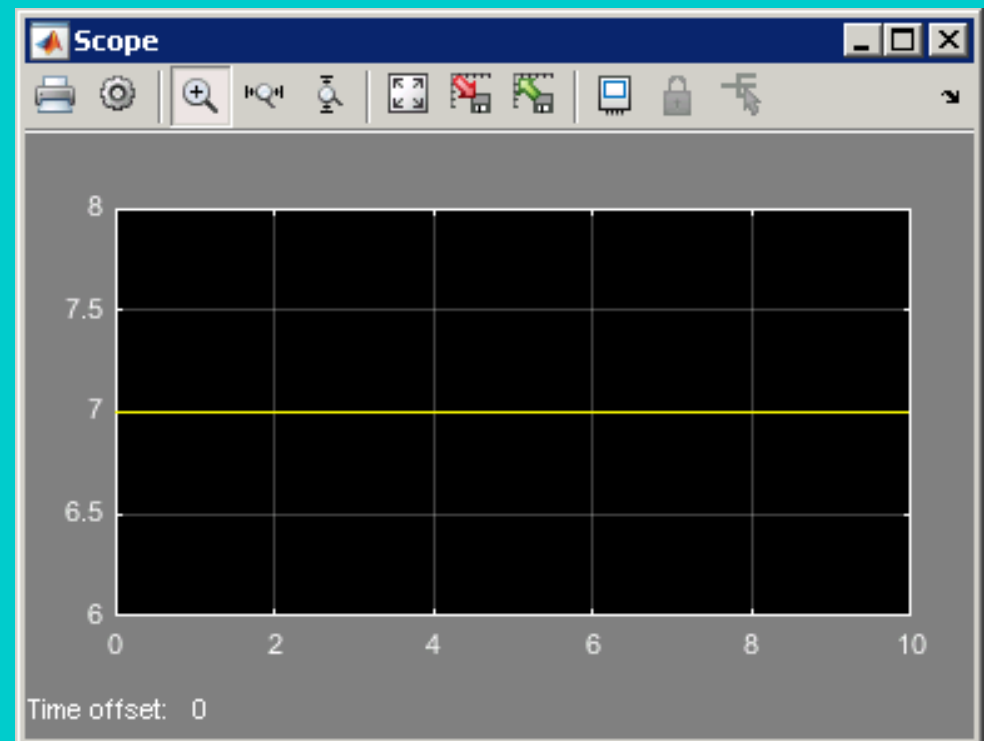
Block parameter settings

The parameters of majority of the blocks are possible to set in the dialog window that appears after double click on the chosen block.



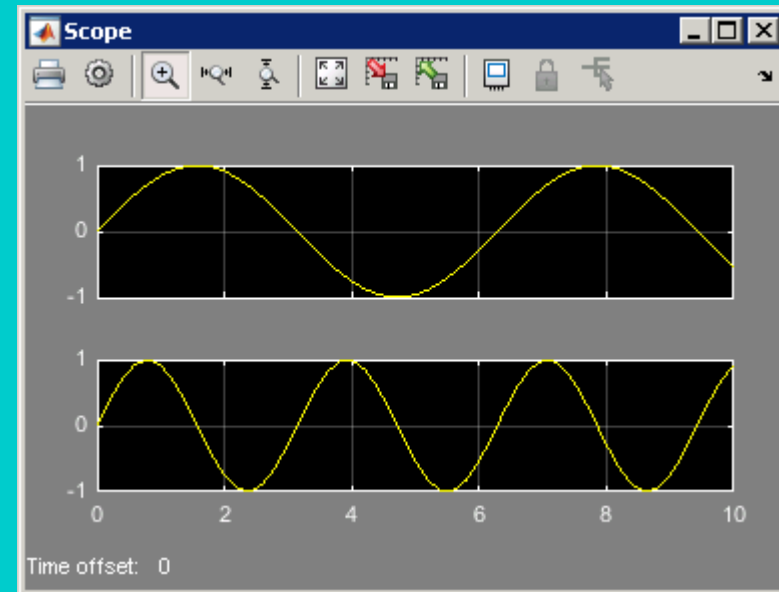
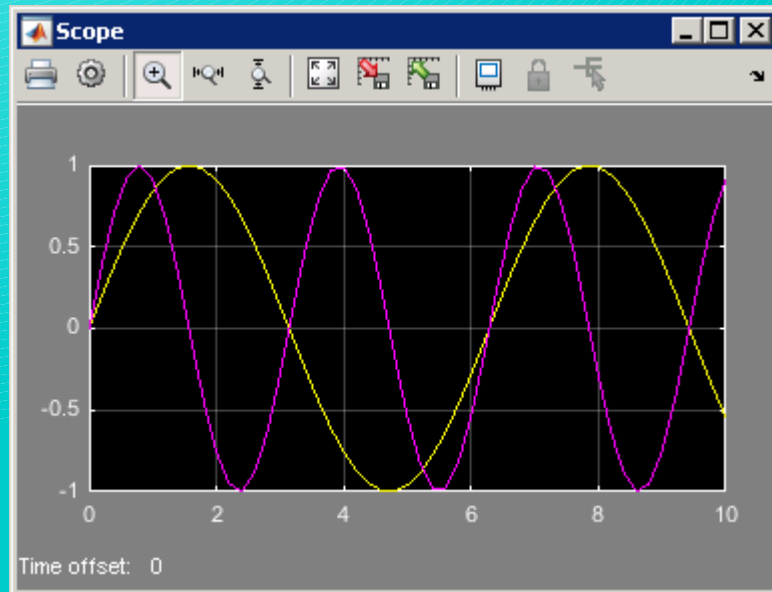
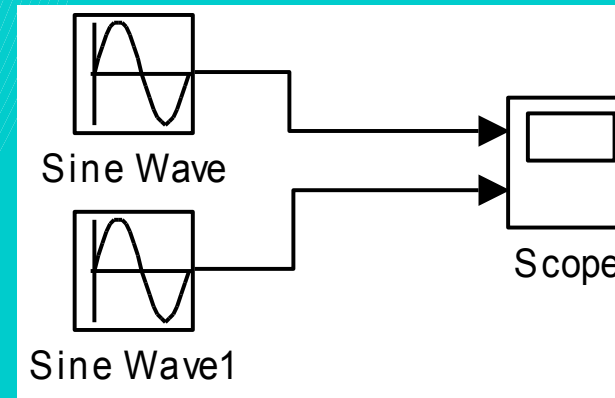
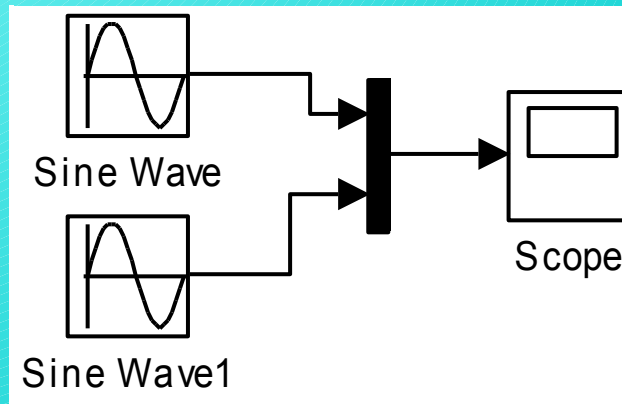
Model/scheme in Simulink

After the change of predefined value in the block Constant, the result is changed (it is necessary to run the simulation again)



Showing more courses in one block Scope

By the use of a block Mux (from Simulink/Signal Routing) or by setting of more inputs to the block Scope



Showing more courses in one block Scope

The image shows a screenshot of a 'Scope' window and its 'Scope parameters' dialog box. The 'Scope' window displays two vertically stacked plots of a sine wave. The top plot shows one full cycle, and the bottom plot shows two full cycles. The x-axis is labeled 'Time offset: 0' and has tick marks at 0, 2, and 4. The y-axis ranges from -1 to 1. The 'Scope parameters' dialog box is open, showing the 'General' tab. The 'Number of axes' field is set to 2, which is circled in red. Other settings include 'Time range: auto', 'Tick labels: bottom axis only', and 'Decimation' set to 1. The 'OK', 'Cancel', 'Help', and 'Apply' buttons are visible at the bottom of the dialog box.

Scope

'Scope' parameters

General History Style

Axes

Number of axes: 2

Time range: auto

Tick labels: bottom axis only

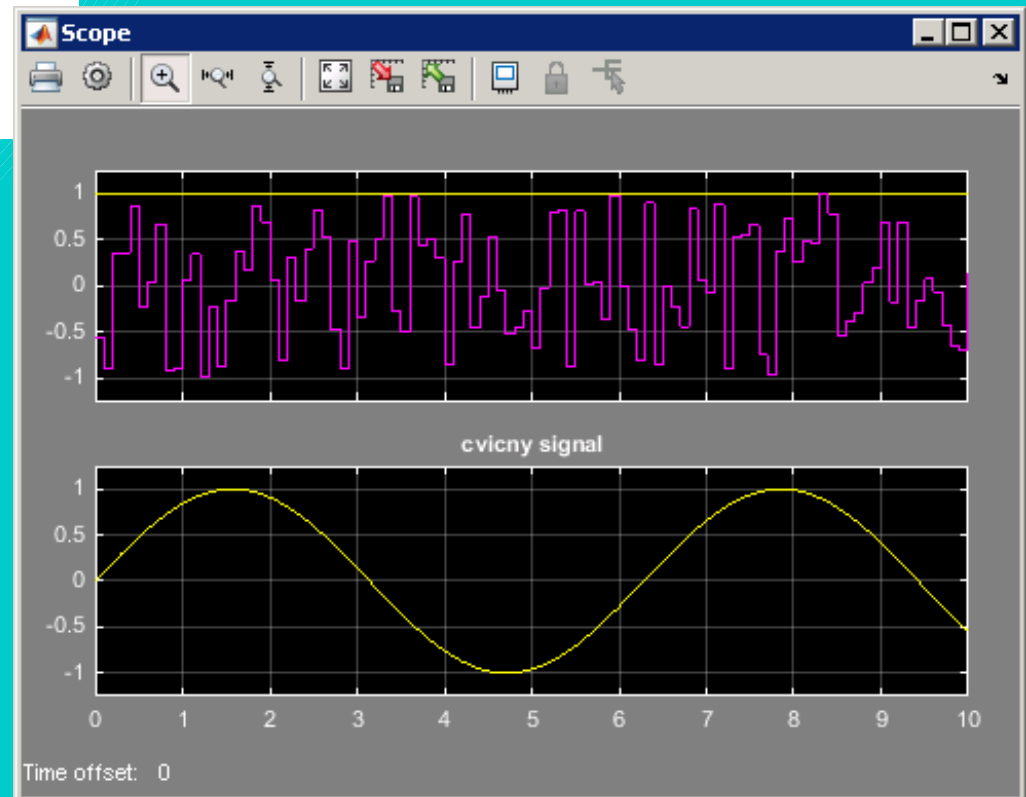
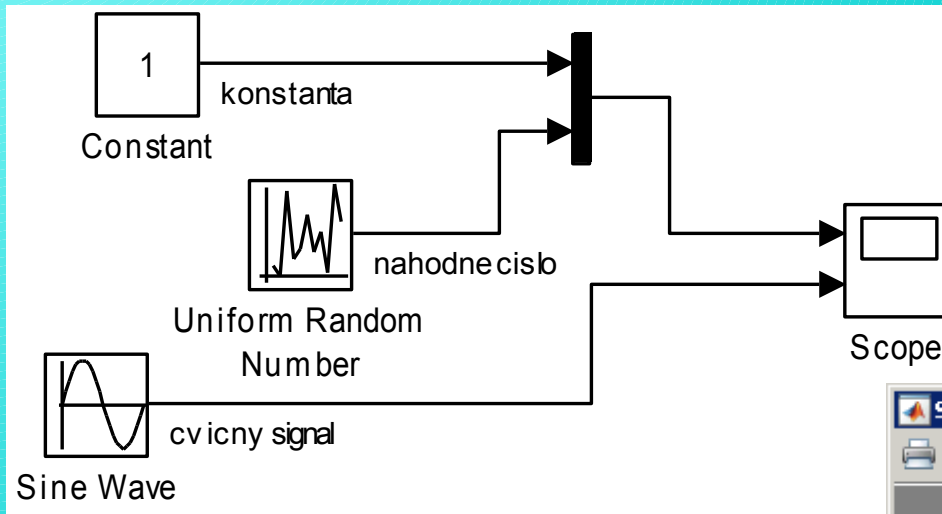
Scroll Legends Floating Scope

Sampling

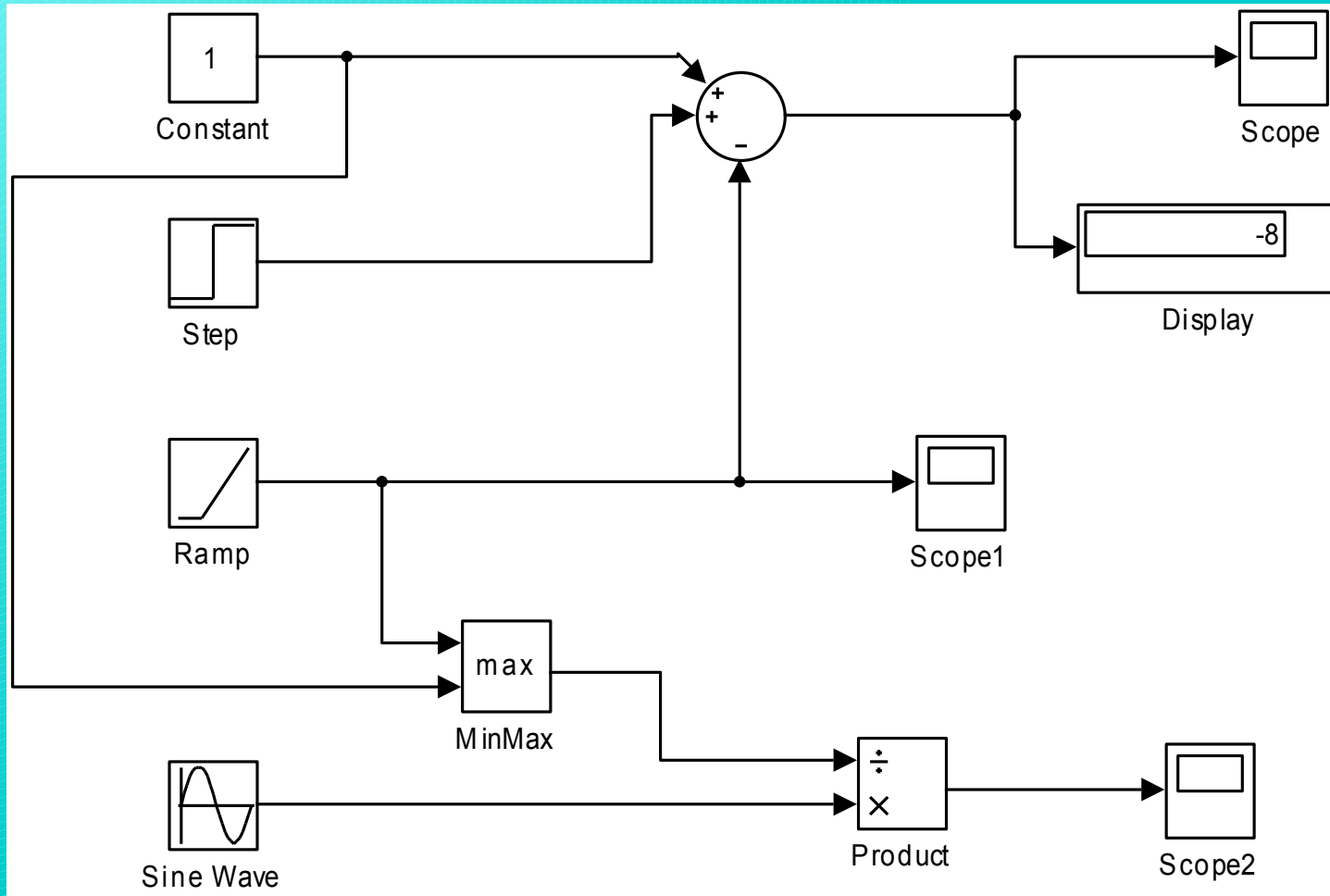
Decimation 1

OK Cancel Help Apply

Showing more courses in one block Scope



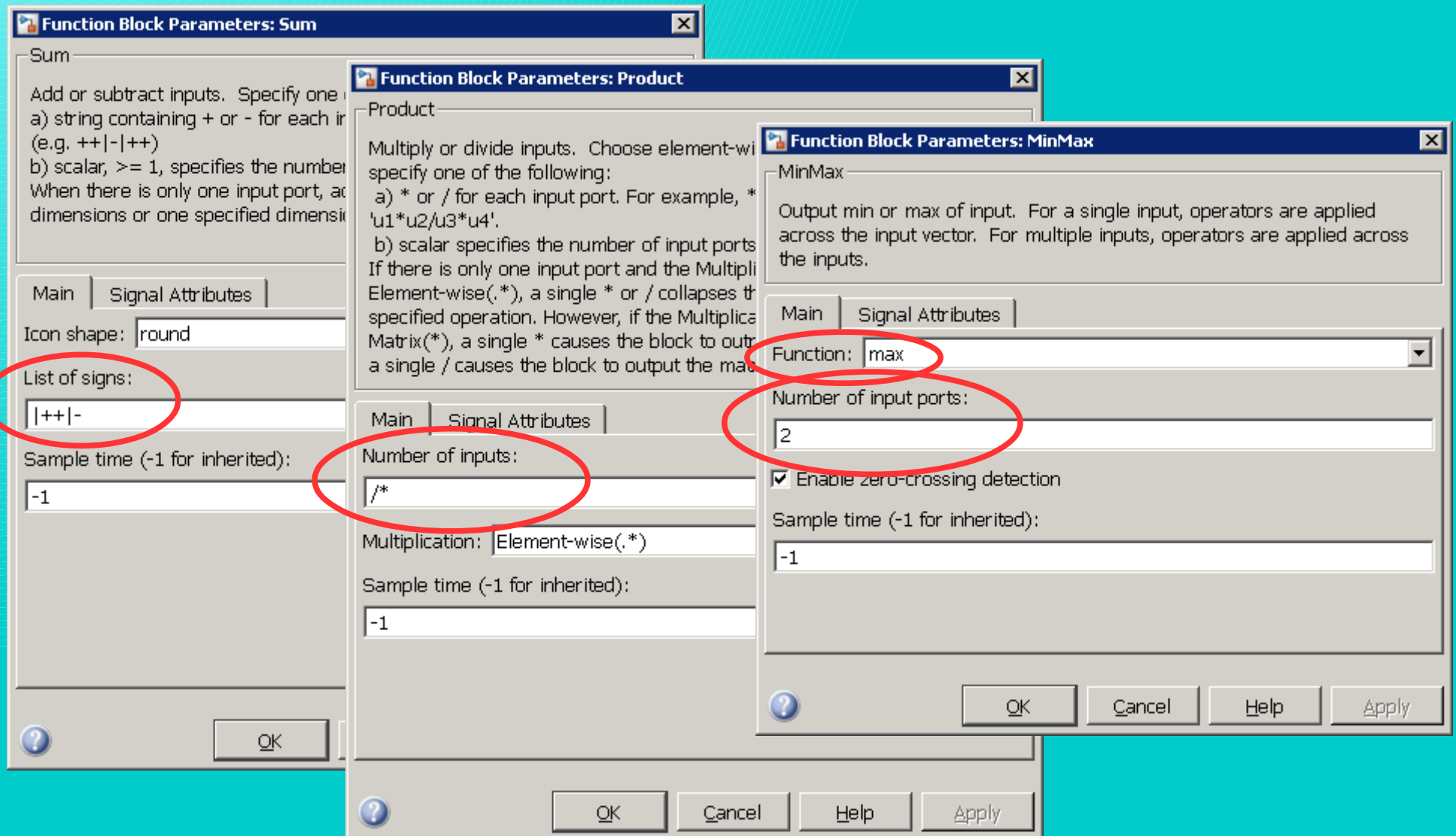
Demonstration scheme



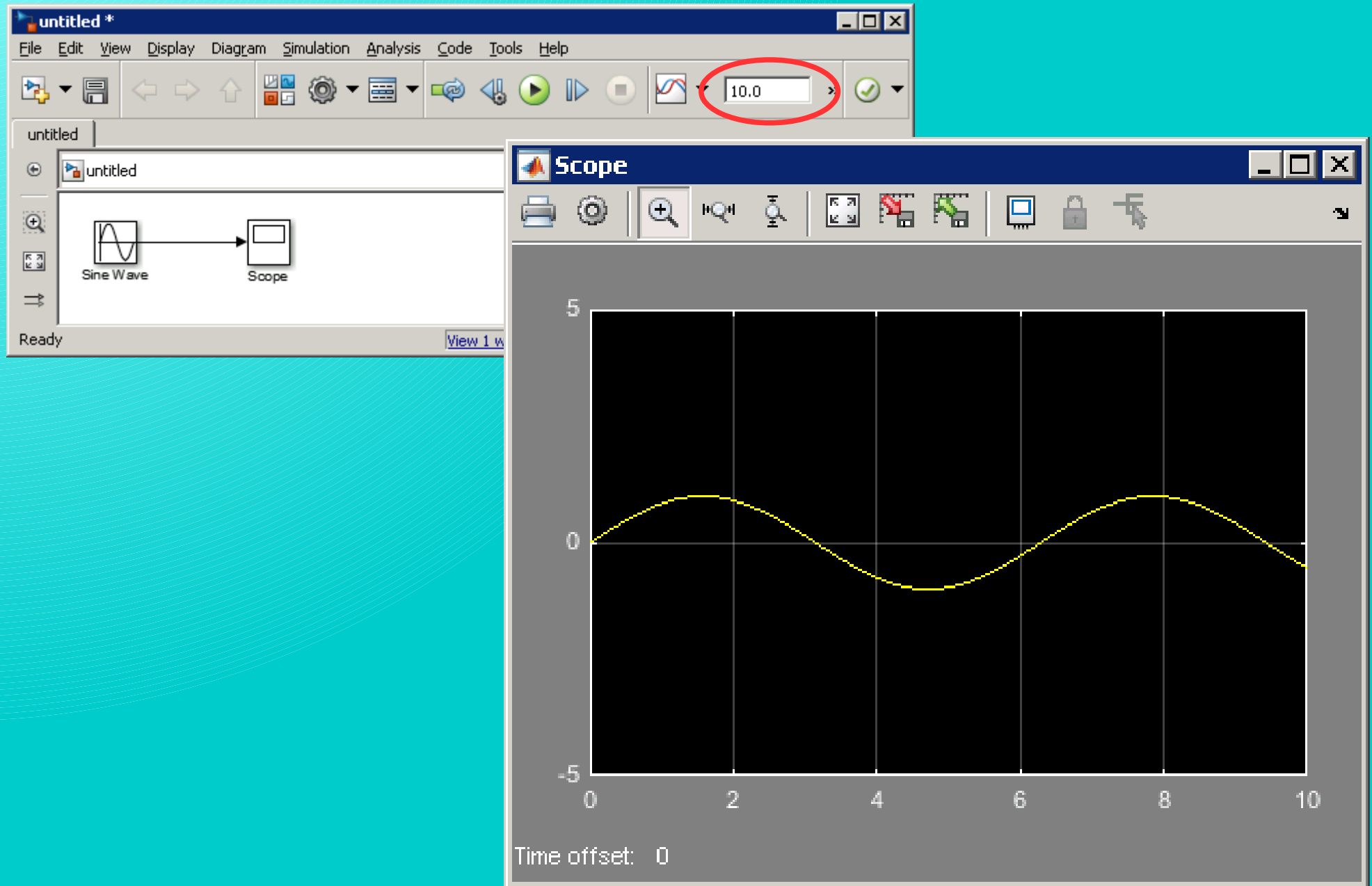
Scheme contains blocks from libraries
Simulink/Sources, Simulink/Sinks a Simulink/Math
Operations

Demonstration scheme

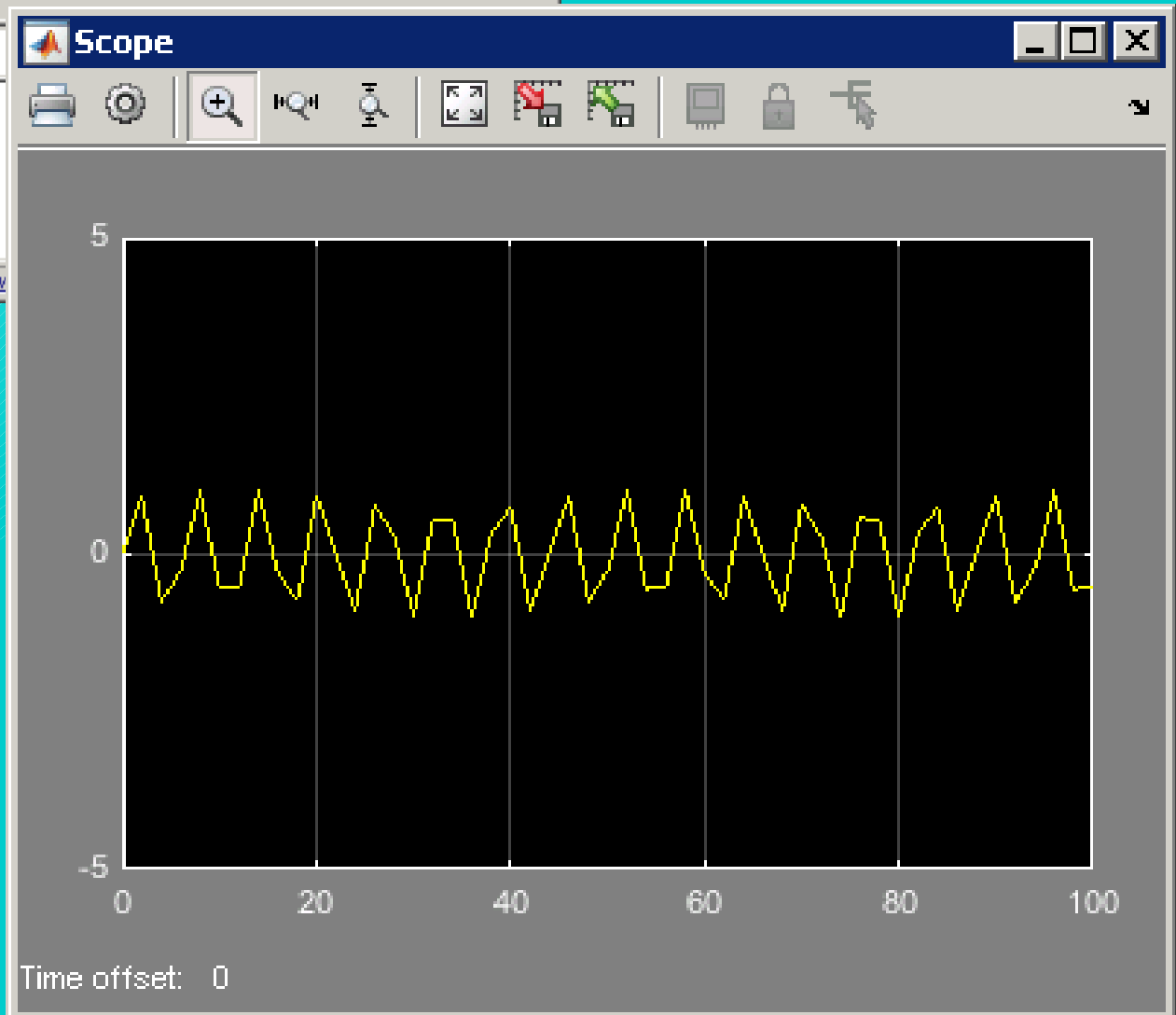
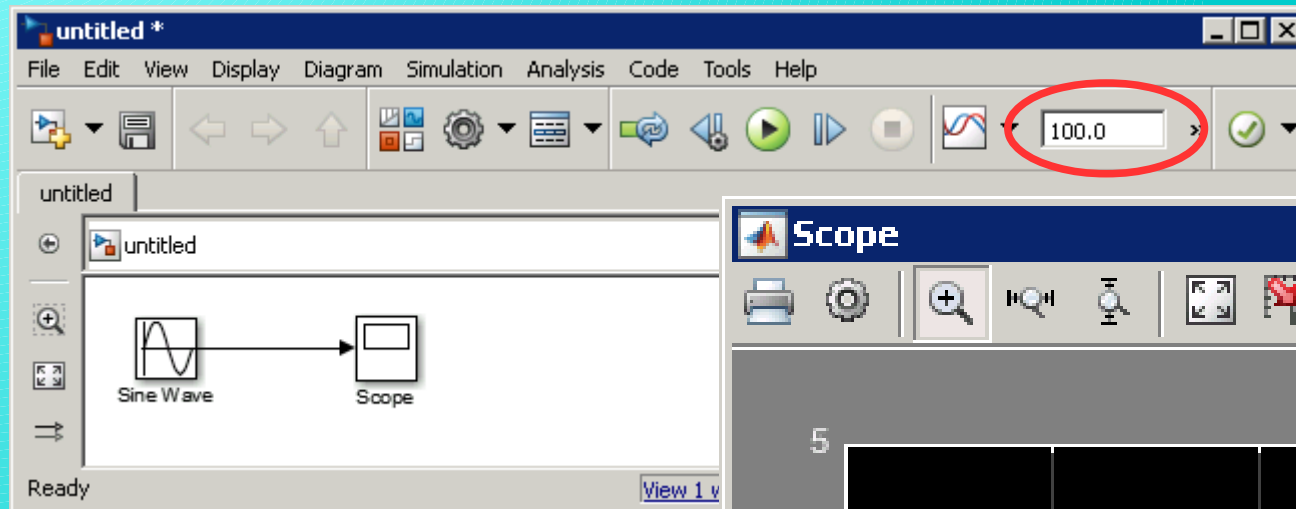
Block parameter settings in the demonstration scheme:



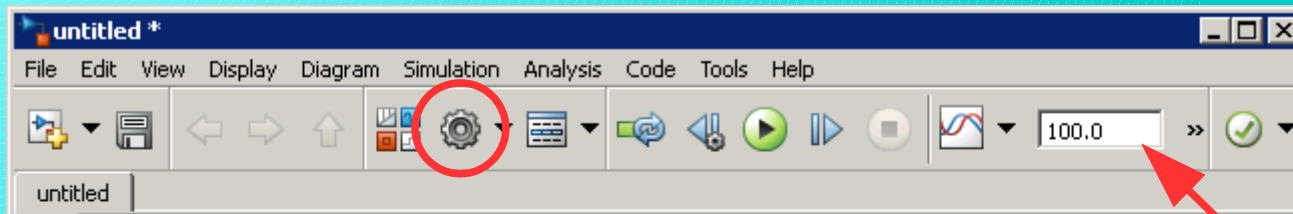
Simulation time and simulation step



Simulation time and simulation step



Simulation time and simulation step



Configuration Parameters: untitled/Configuration (Active)

Select:

- Solver
- Data Import/Export
- Optimization
- Diagnostics
- Hardware Implementation
- Model Referencing
- Simulation Target

Simulation time

Start time: 0.0 Stop time: 100.0

Solver options

Type: Variable-step Solver: ode45 (Dormand-Prince)

Max step size: auto Relative tolerance: 1e-3

Min step size: auto Absolute tolerance: auto

Initial step size: auto Shape preservation: Disable All

Number of consecutive min steps: 1

Tasking and sample time options

Tasking mode for periodic sample times: Auto

Automatically handle rate transition for data transfer

Higher priority value indicates higher task priority

Zero-crossing options

Zero-crossing control: Use local settings Algorithm: Nonadaptive

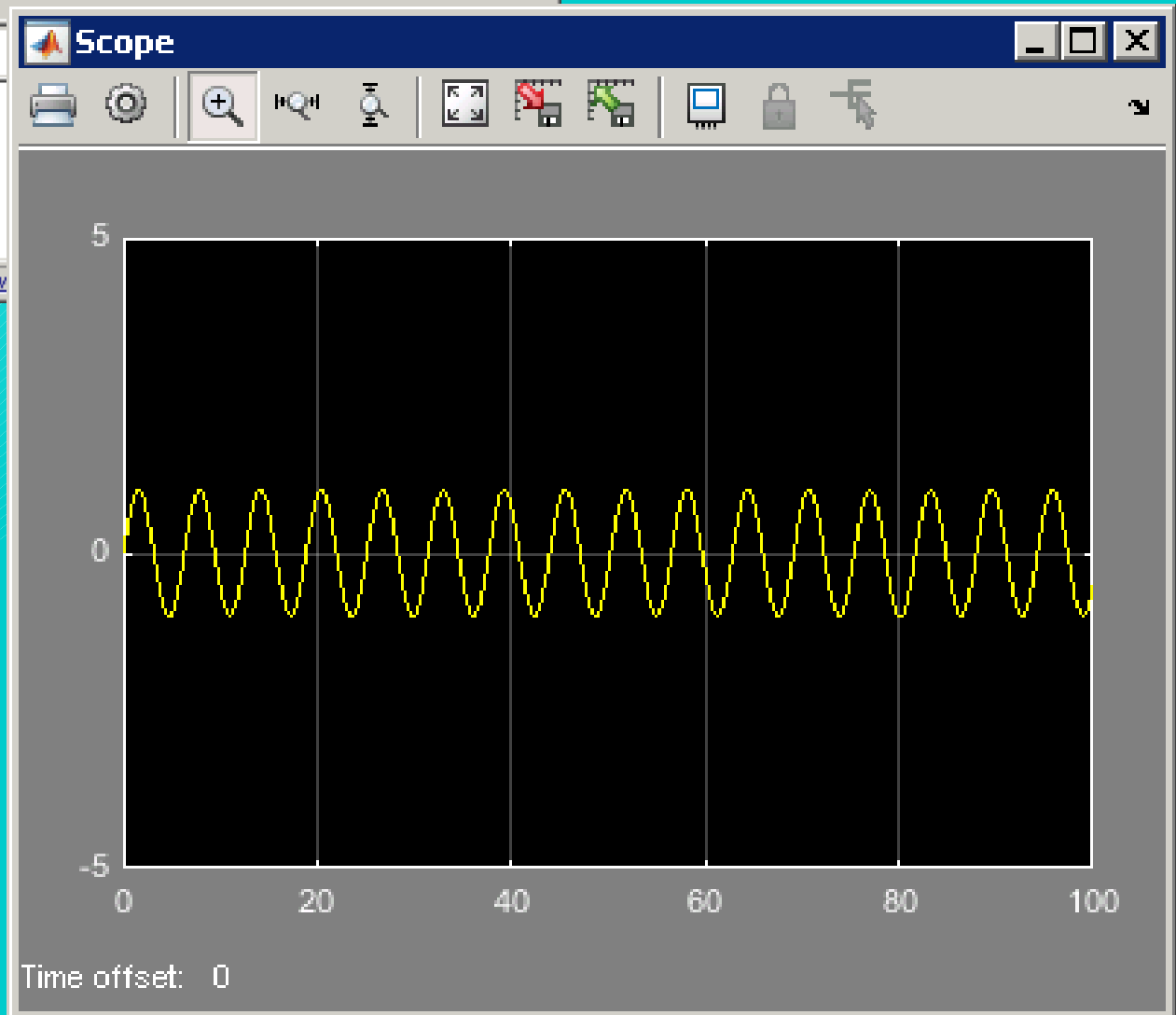
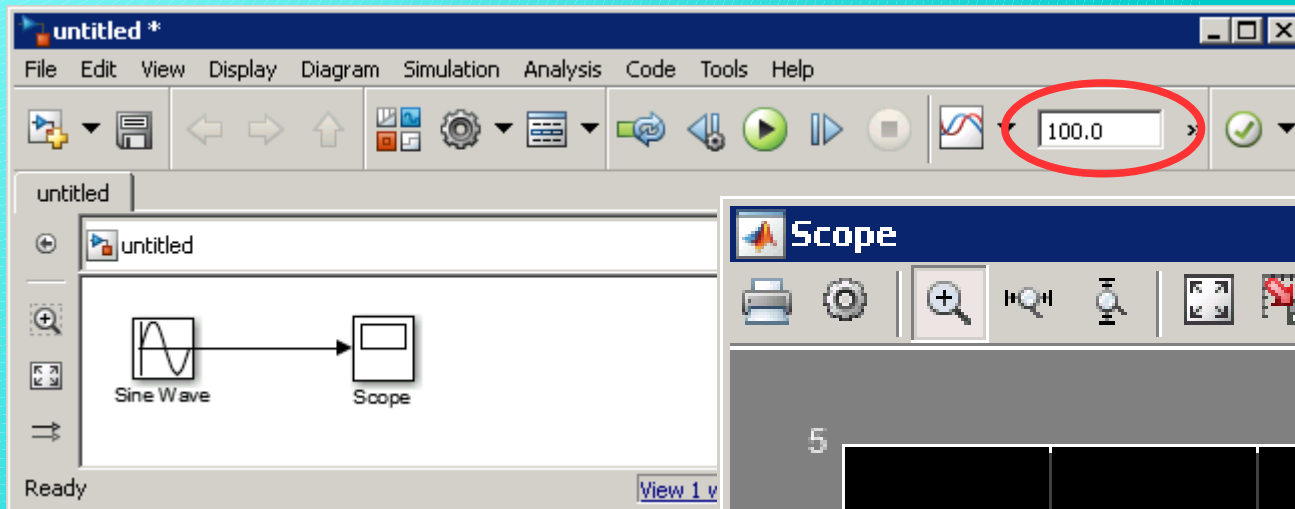
Time tolerance: 10*128*eps Signal threshold: auto

Number of consecutive zero crossings: 1000

OK Cancel Help Apply

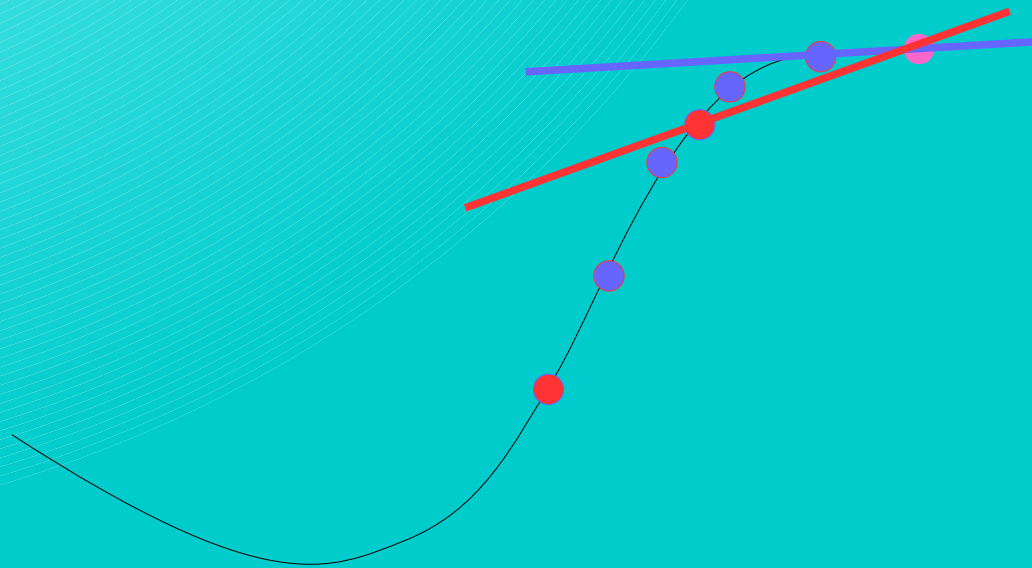
Set suitable value, e. g. 0.1

Simulation time an simulation step



Conversion of a differential equation into a Simulink model

There is one rule – avoiding block Derivation if it is possible.



Conversion of a differential equation into a Simulink model

The first step is separation of the highest derivation.

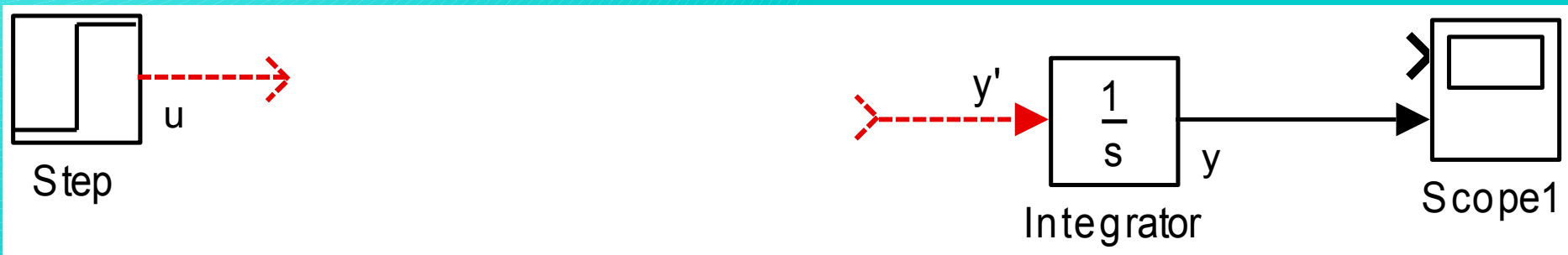
$$2\dot{y} + 3y = 0,5u$$

$$\dot{y} = \frac{0,5u - 3y}{2}$$

Conversion of a differential equation into a Simulink model

Then it is suitable to put all necessary variables into the scheme.

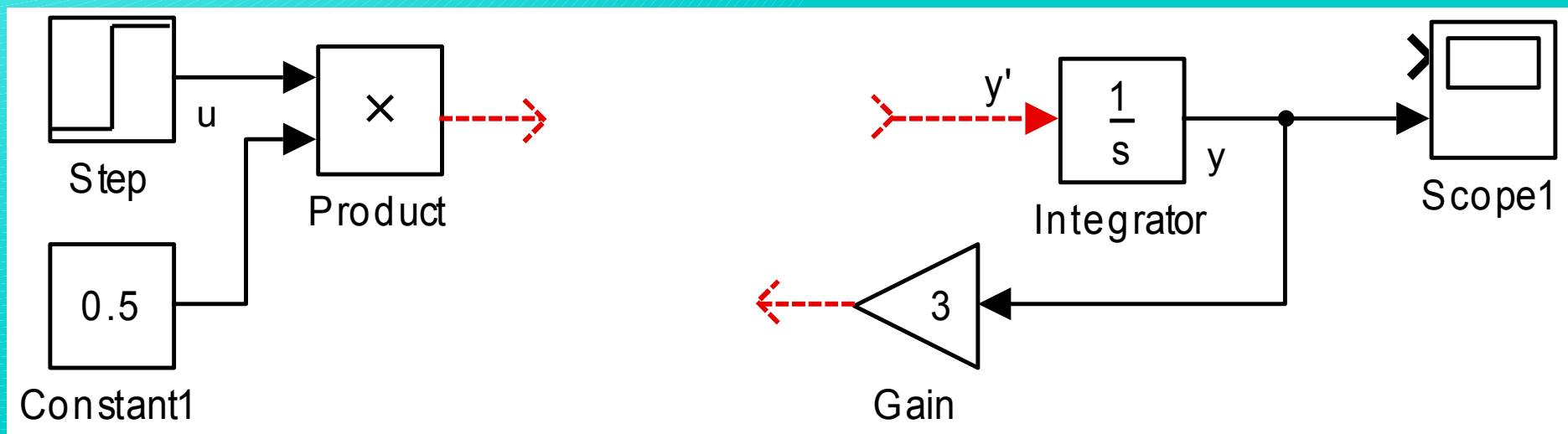
$$\dot{y} = \frac{0,5u - 3y}{2}$$



Conversion of a differential equation into a Simulink model

The next step is to multiply the variables by constants.

$$\dot{y} = \frac{0,5u - 3y}{2}$$

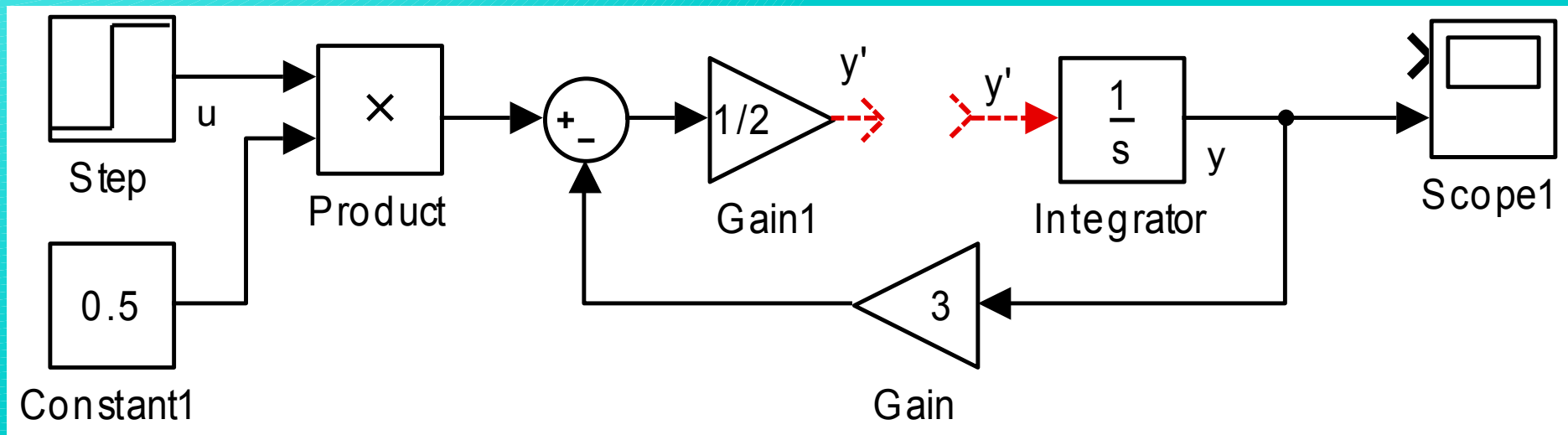


When multiplying by a constant, it is possible to use either the block Gain or the blocks Product and Constant.

Conversion of a differential equation into a Simulink model

Then the conversion of the fraction can be finished.

$$\dot{y} = \frac{0,5u - 3y}{2}$$

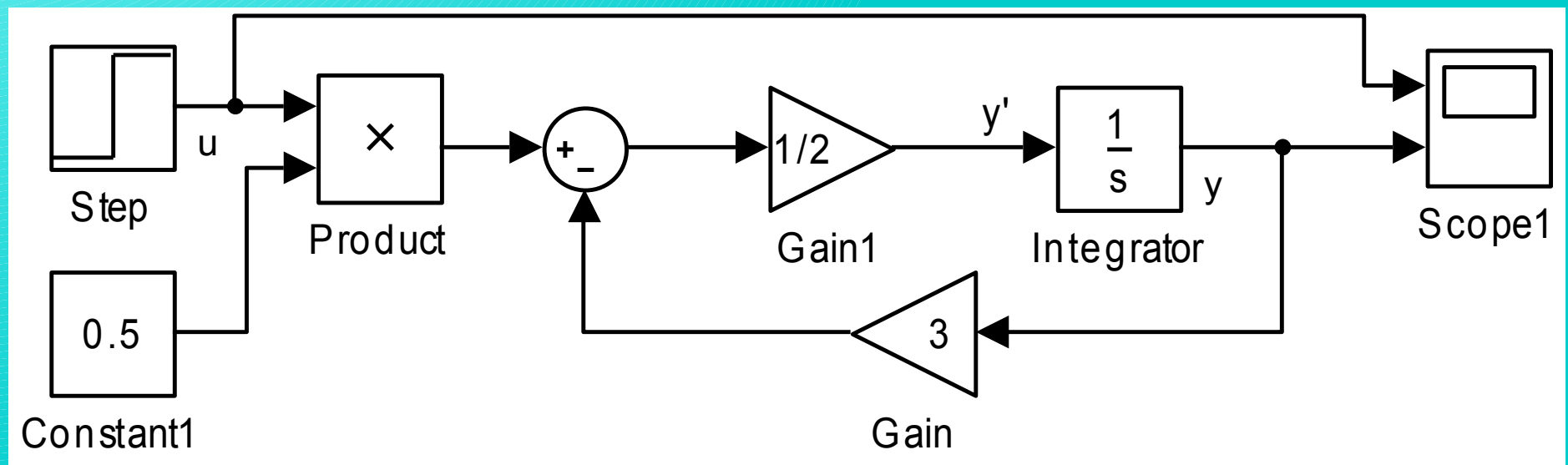


Both, the left side and the right side of the equation are finished now. As the values of both sides must be equal, both sides can be connected.

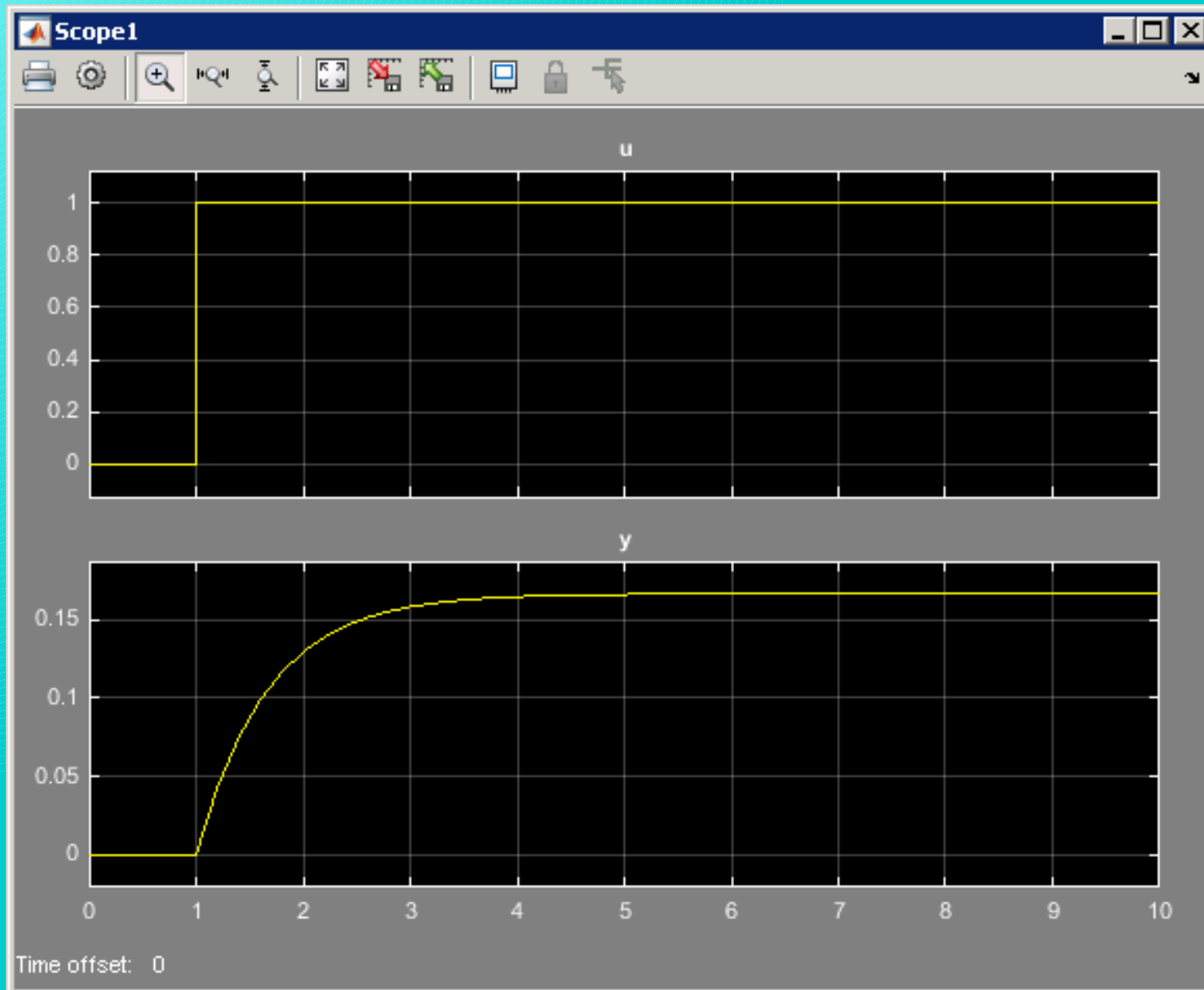
Conversion of a differential equation into a Simulink model

The final Simulink model is get by connecting left and right side of the scheme. Then the simulation can be run.

$$\dot{y} = \frac{0,5u - 3y}{2}$$



Conversion of a differential equation into a Simulink model



Conversion of a differential equation into a Simulink model

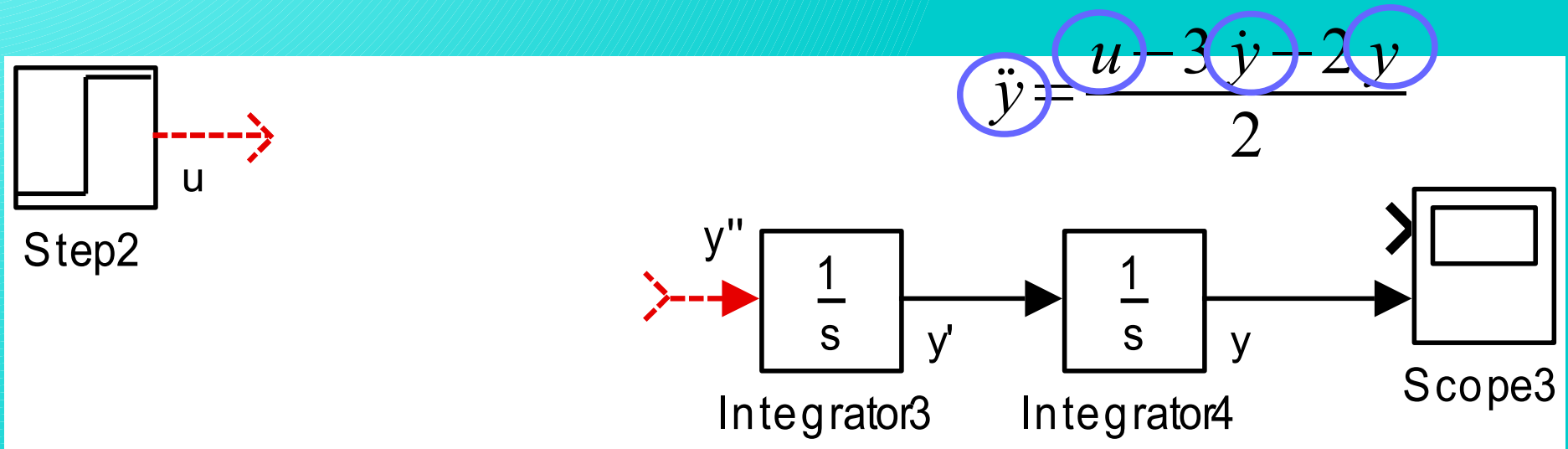
Similar procedure can be used also for differential equations of higher orders.

$$2\ddot{y} + 3\dot{y} + 2y = u$$

$$\ddot{y} = \frac{u - 3\dot{y} - 2y}{2}$$

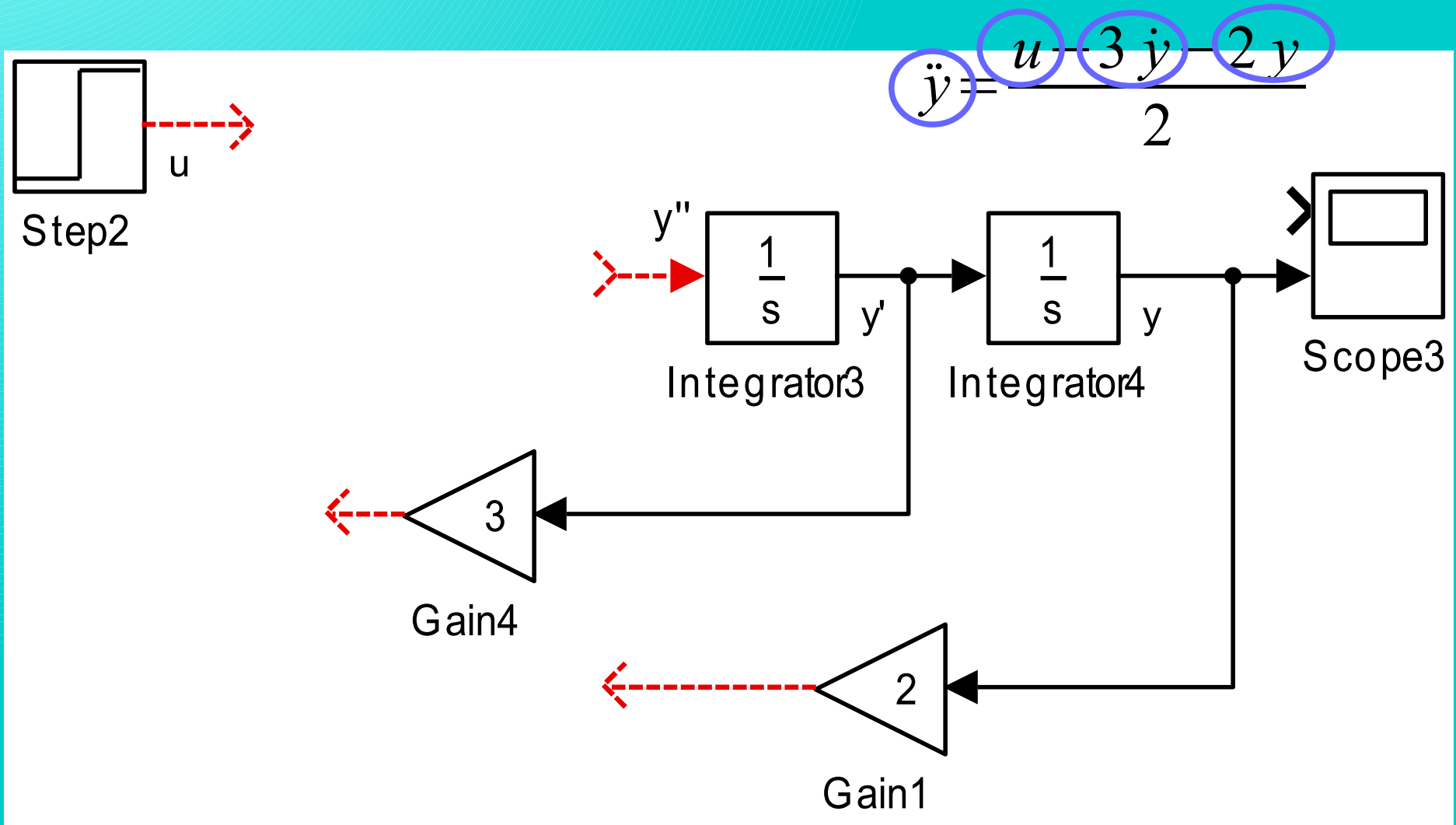
Conversion of a differential equation into a Simulink model

Preparing the variables into the model:



Conversion of a differential equation into a Simulink model

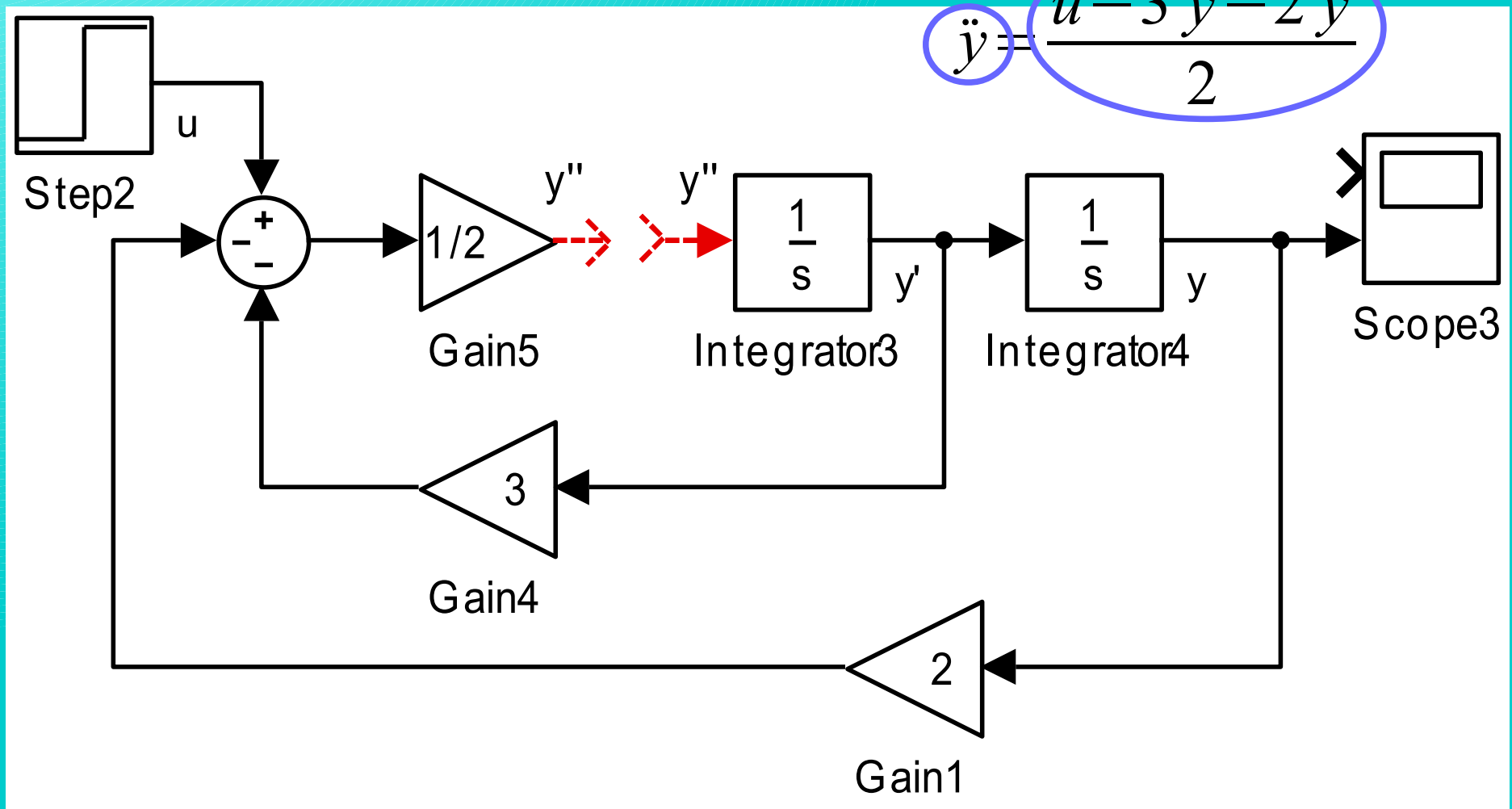
Multiplying variables by constants:



Conversion of a differential equation into a Simulink model

Finishing the fraction:

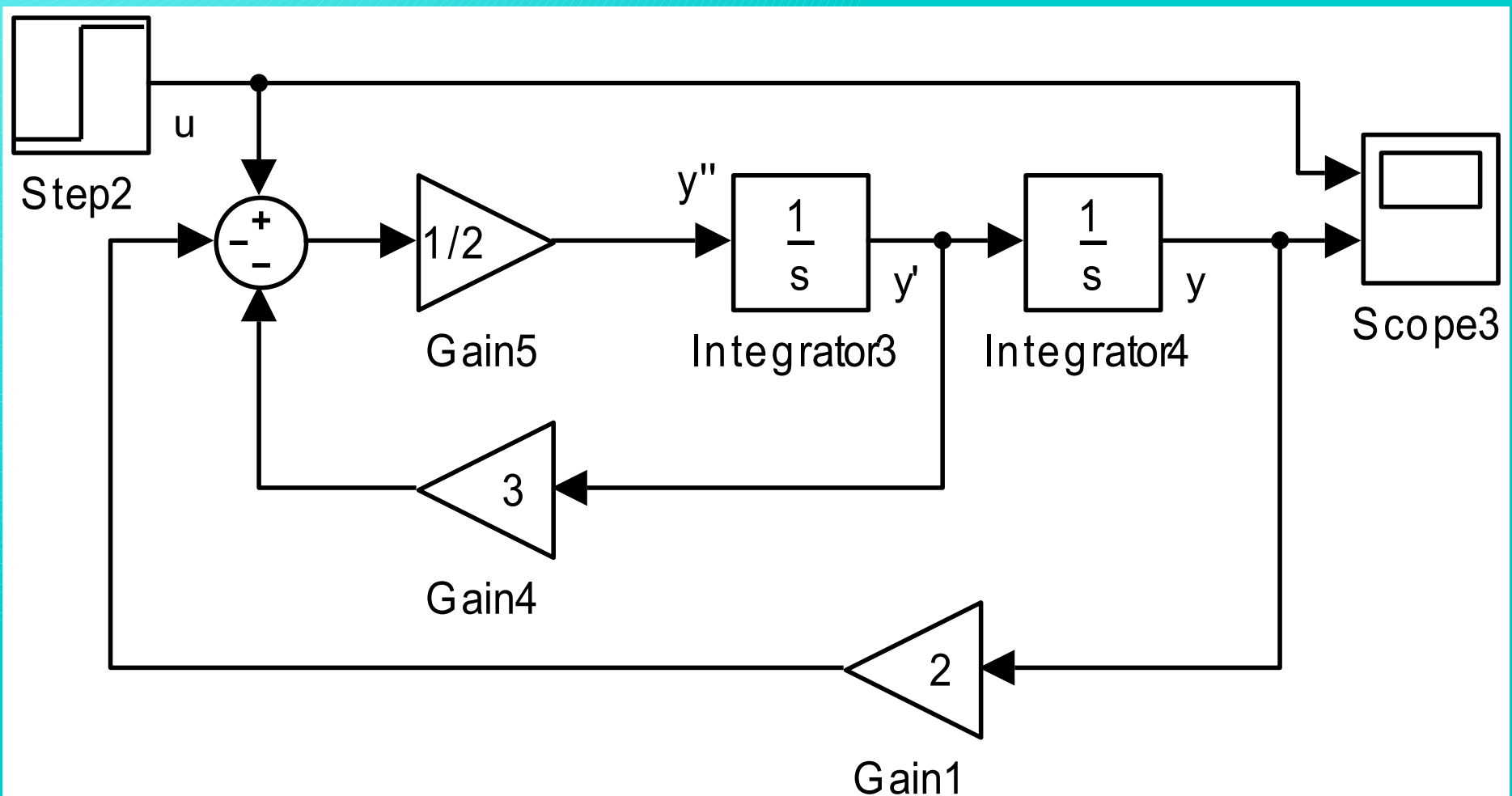
$$\ddot{y} = \frac{u - 3\dot{y} - 2y}{2}$$



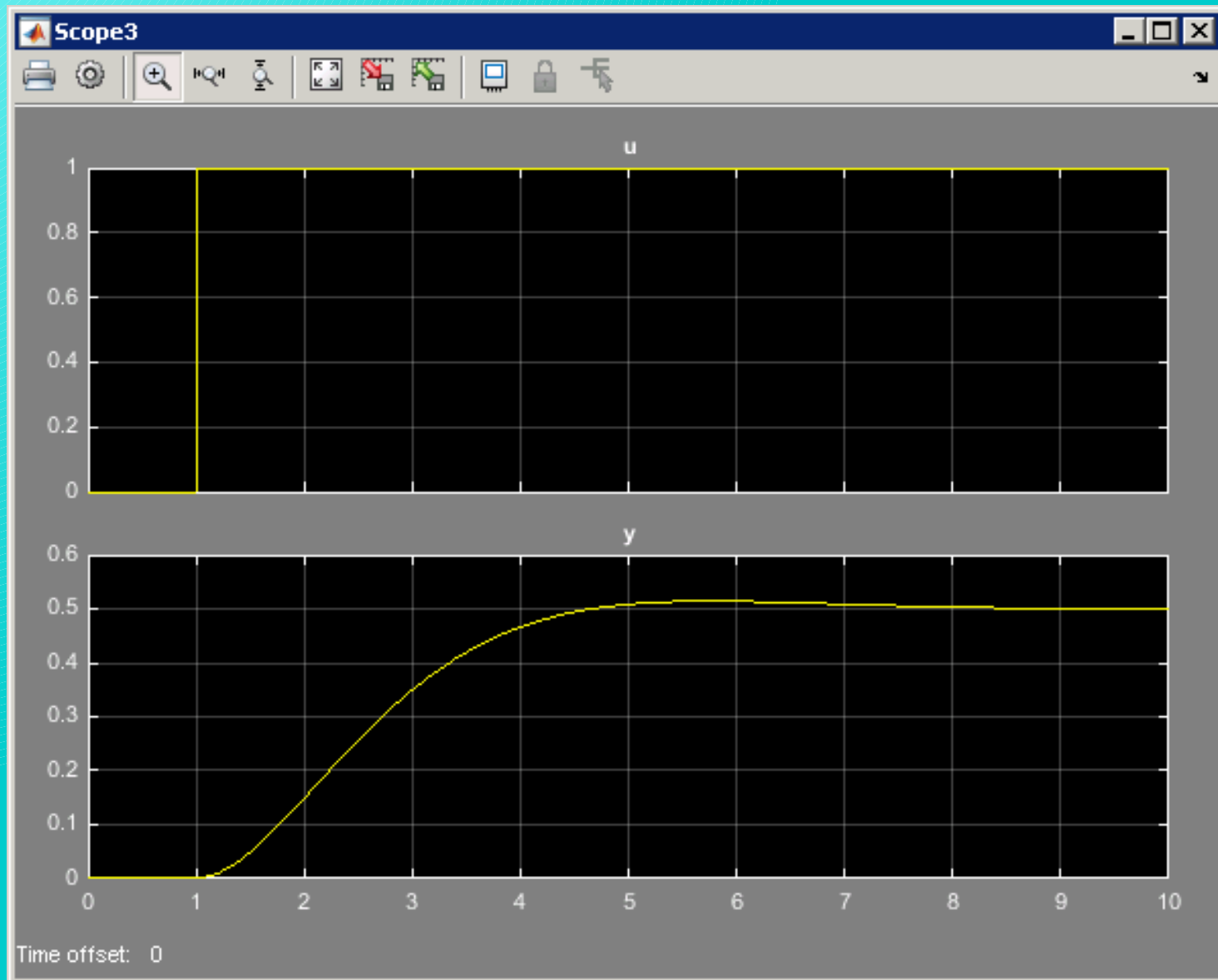
Conversion of a differential equation into a Simulink model

Finishing the model:

$$\ddot{y} = \frac{u - 3\dot{y} - 2y}{2}$$



Conversion of a differential equation into a Simulink model



Conversion of a differential equation into a Simulink model

Similar procedure can be used also when the differential equation is non-linear

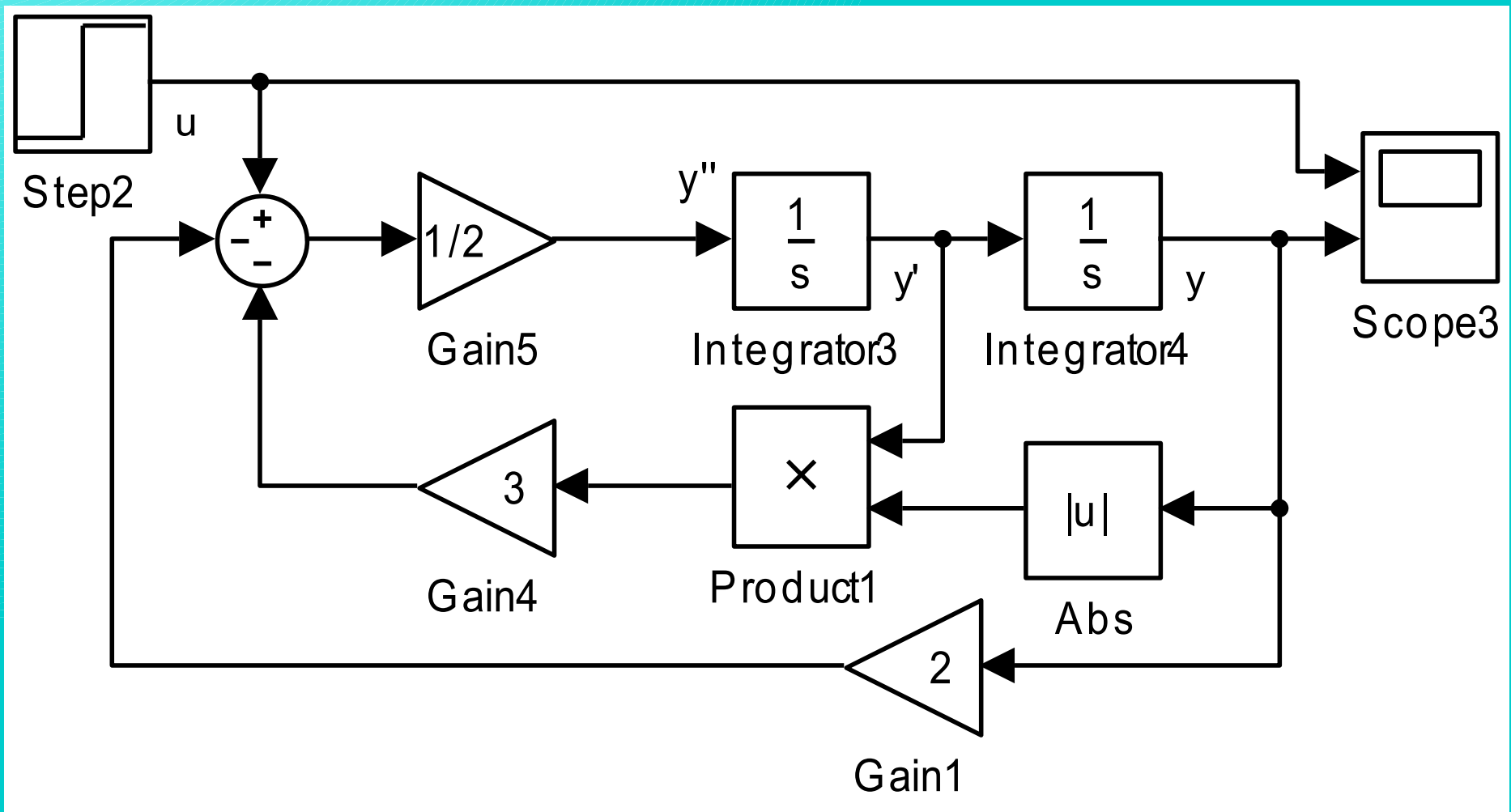
$$2\ddot{y} + 3\dot{y}|y| + 2y = u$$

$$\ddot{y} = \frac{u - 3\dot{y}|y| - 2y}{2}$$

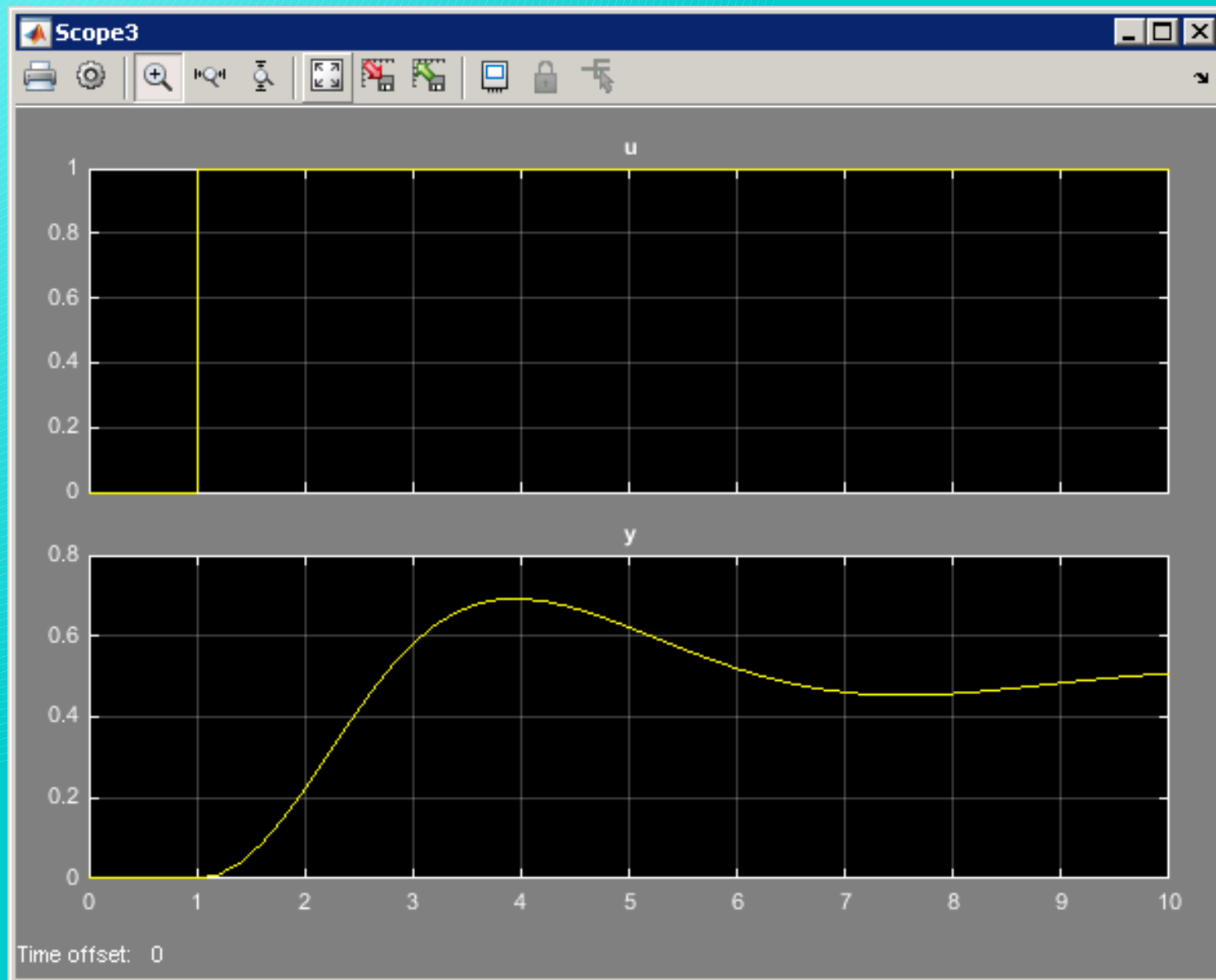
Conversion of a differential equation into a Simulink model

... that leads to a model:

$$\ddot{y} = \frac{u - 3 \dot{y} |y| - 2 y}{2}$$



Conversion of a differential equation into a Simulink model



Individual task

Create a Simulink model representing following differential equation:

$$\ddot{y} + 5,5 \dot{y} + 3,5 y + 5 \ddot{y} + \dot{y} + y = u$$