

# Simulink 기초

## 2<sup>nd</sup> order system

Computational Design Laboratory  
Department of Automotive Engineering  
Hanyang University, Seoul, Korea



한양대학교  
HANYANG UNIVERSITY



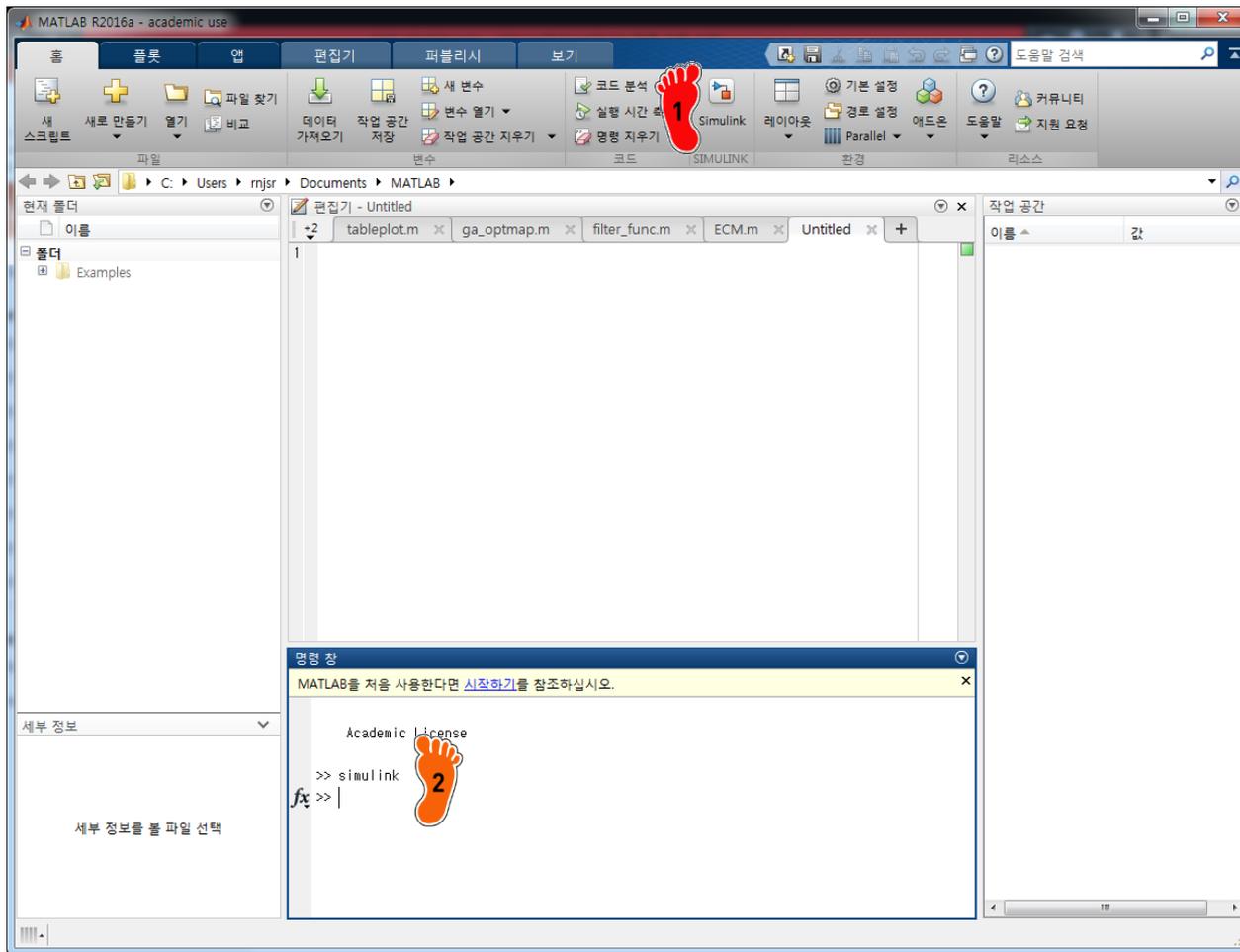
# CONTENTS

- **Overview**
- **Simulink Environment**
- **Commonly Used Blocks**
- **2<sup>nd</sup> order system**
- **Model Based Design**
- **Case Study**
- **Assignment**

# OVERVIEW

- **Simulation and Model-Based Design**
  - **Block diagram environment for multi-domain simulation and Model-Based Design**
  - **Integrated with MATLAB, enabling to incorporate MATLAB algorithms into models and export simulation results to MATLAB for further analysis**
  - **Video : [Simulink Overview](#)**

# SIMULINK ENVIRONMENT



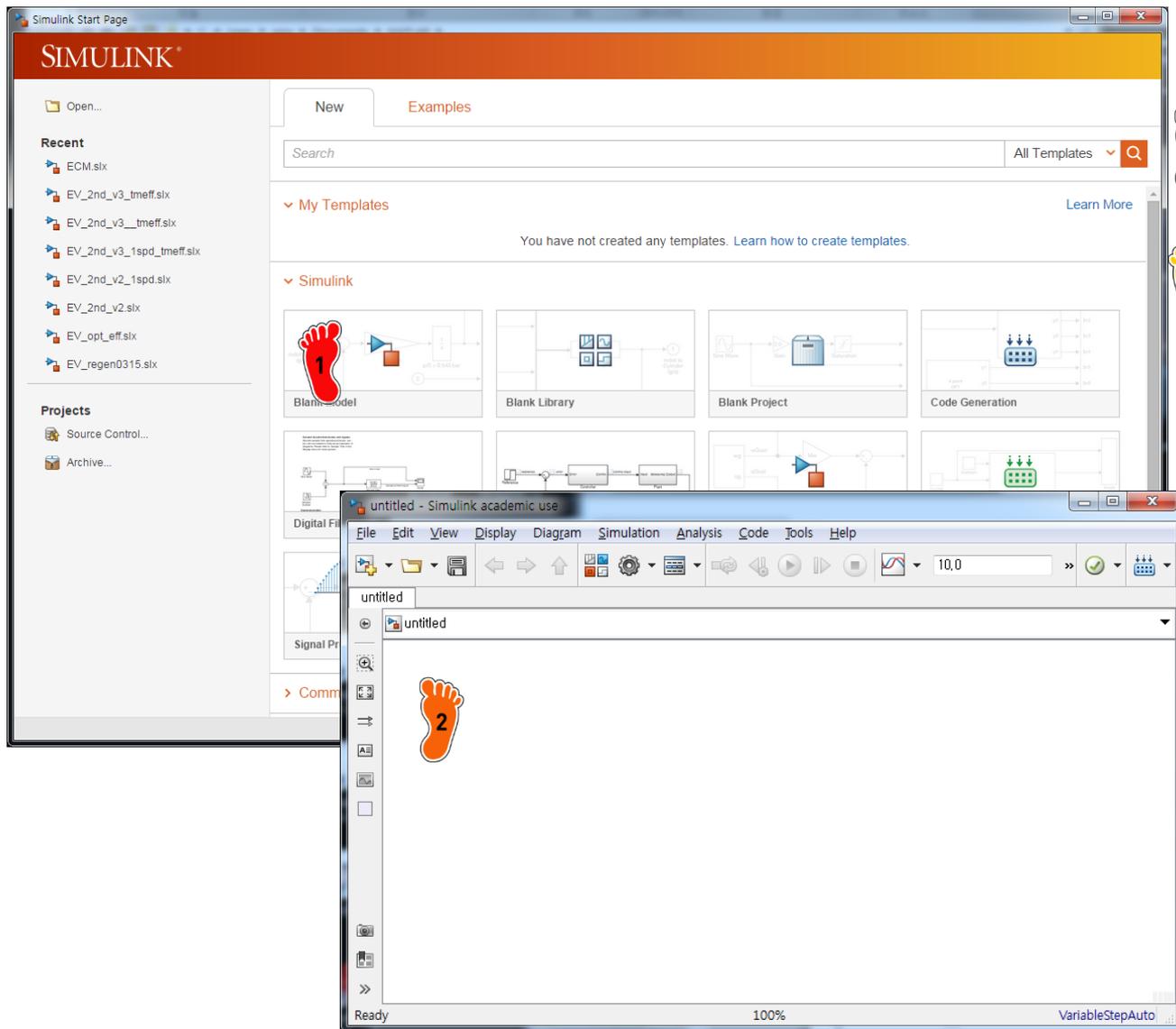
1 Simulink Icon 클릭 또는

2 명령 창에 'simulink' 입력

3

4

# SIMULINK ENVIRONMENT



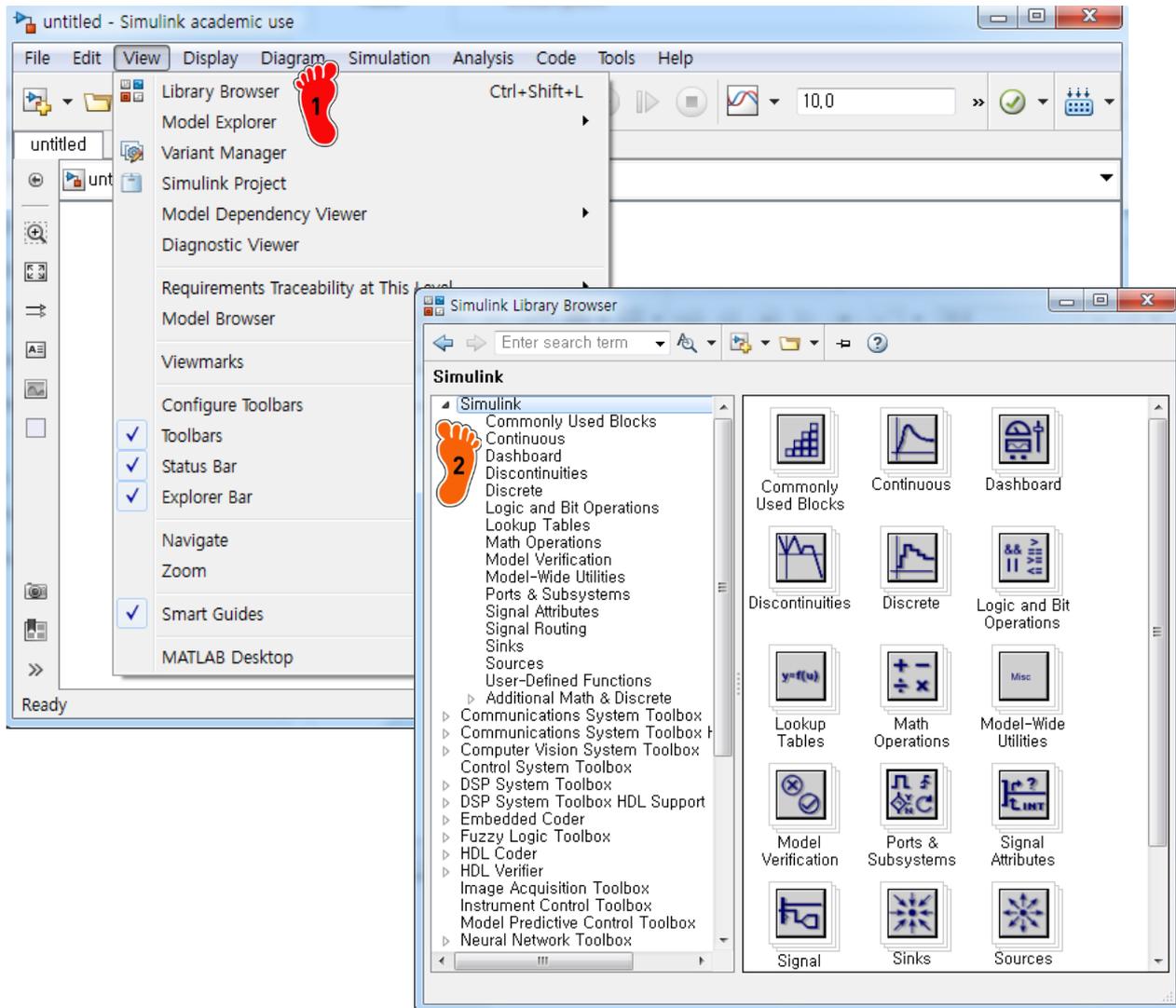
1 Blank Model 클릭

2 모델링 화면 생성

3

4

# SIMULINK ENVIRONMENT



1 View-Library Browser 클릭

2 원하는 모듈 선택

3

4

# SIMULINK ENVIRONMENT

The image shows the Simulink environment with three windows:

- Simulink Library Browser:** Displays the 'Commonly Used Blocks' category. A red footprint icon labeled '1' points to the 'Commonly Used Blocks' folder, and an orange footprint icon labeled '2' points to the 'Constant' block.
- Block Diagram:** Shows a 'Constant' block (labeled '1') and a 'Data Type Conversion' block (labeled 'Convert'). A yellow footprint icon labeled '3' points to the 'Constant' block in the diagram.
- Block Parameters: Constant:** A dialog box for configuring the 'Constant' block. It includes a 'Constant value' field with the value '1', a checked 'Interpret vector parameters as 1-D' option, and a 'Sample time' field with the value 'inf'. A green footprint icon labeled '4' points to the 'Constant value' field.

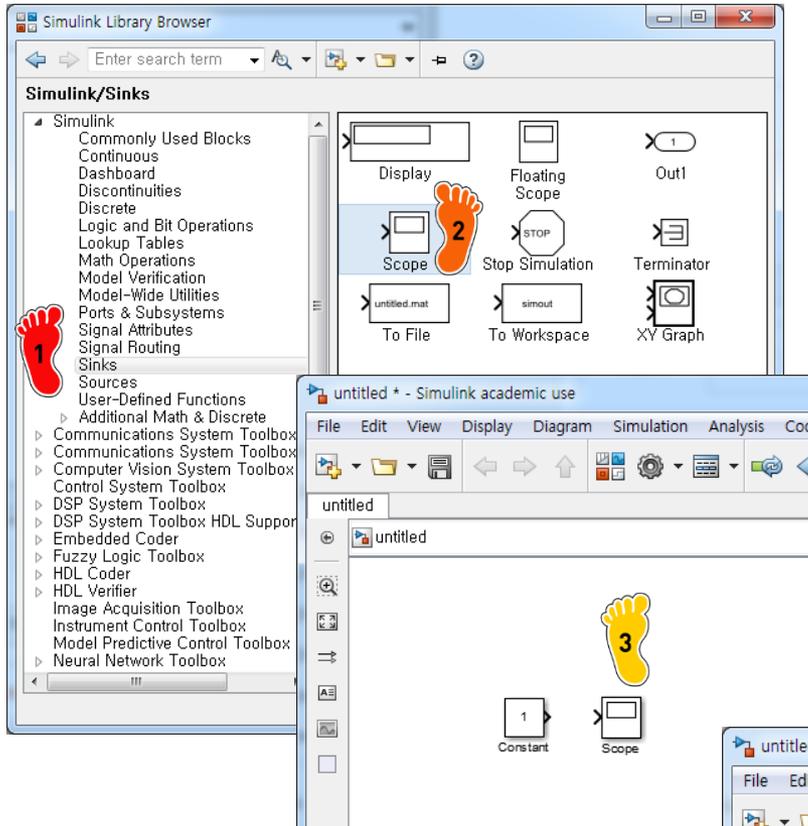
1 'Commonly Used Blocks' 클릭

2 'Constant' block 클릭

3 모델링 화면으로 Drag&Drop

4 'Constant' block 더블클릭  
Parameter 창 생성  
원하는 값 입력

# SIMULINK ENVIRONMENT



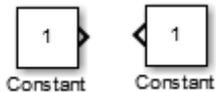
1 'Sinks' 클릭

2 'Scope' block 클릭

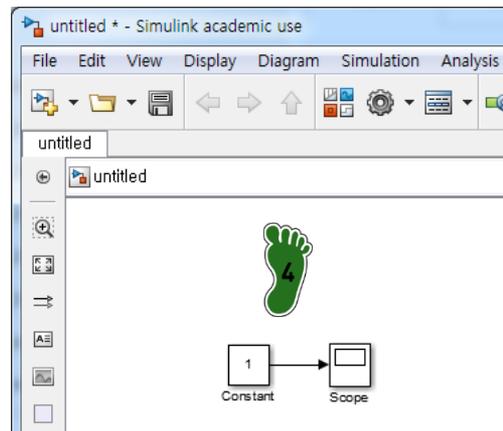
3 모델링 화면으로 Drag&Drop

4 'Constant' block 의 오른쪽 화살표를 누른 상태에서 'Scope' block 왼쪽 화살표에 Drag&Drop

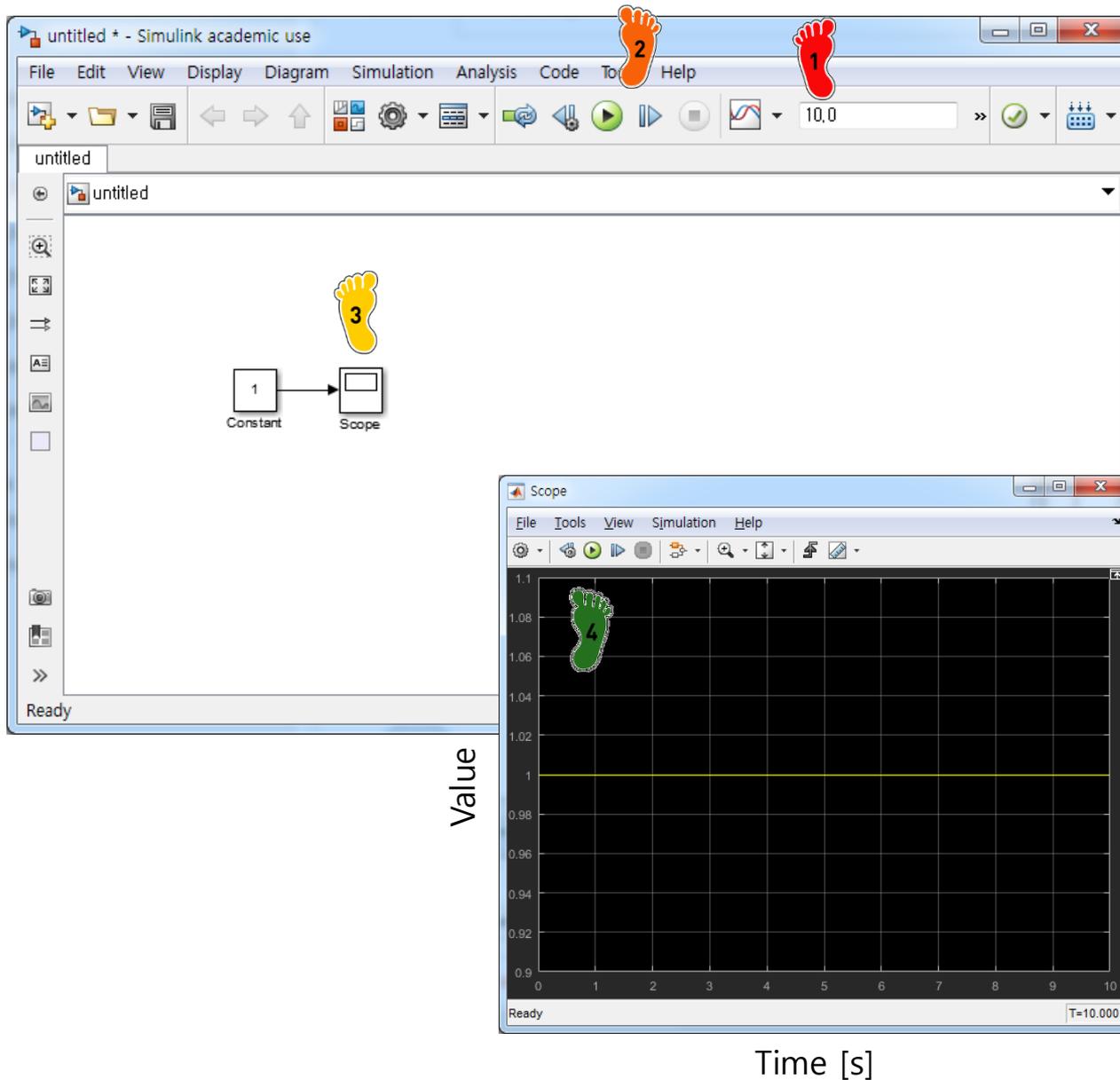
Ctrl+I : block flip



Ctrl+R : block rotate (CCW)



# SIMULINK ENVIRONMENT



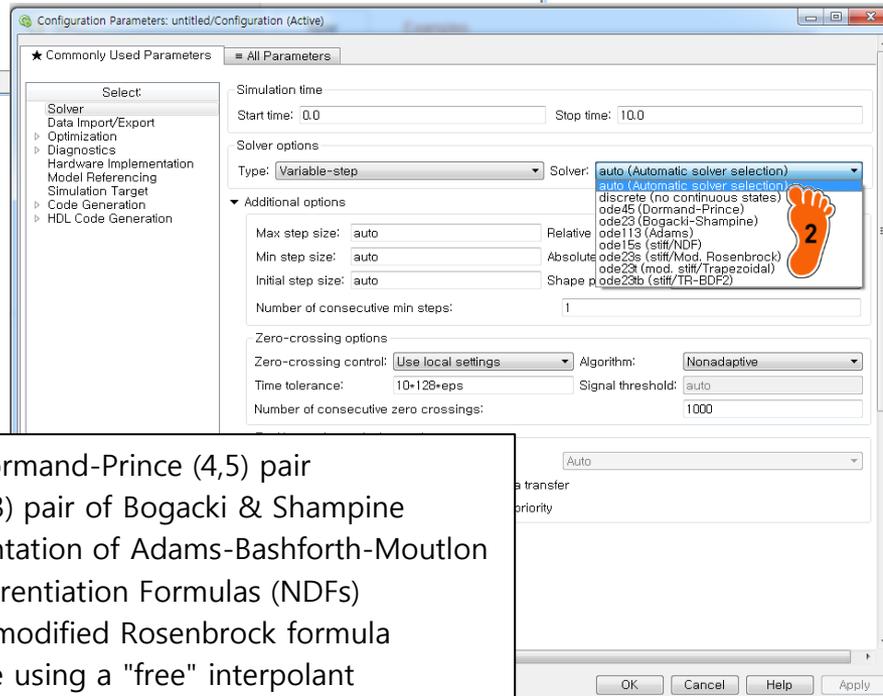
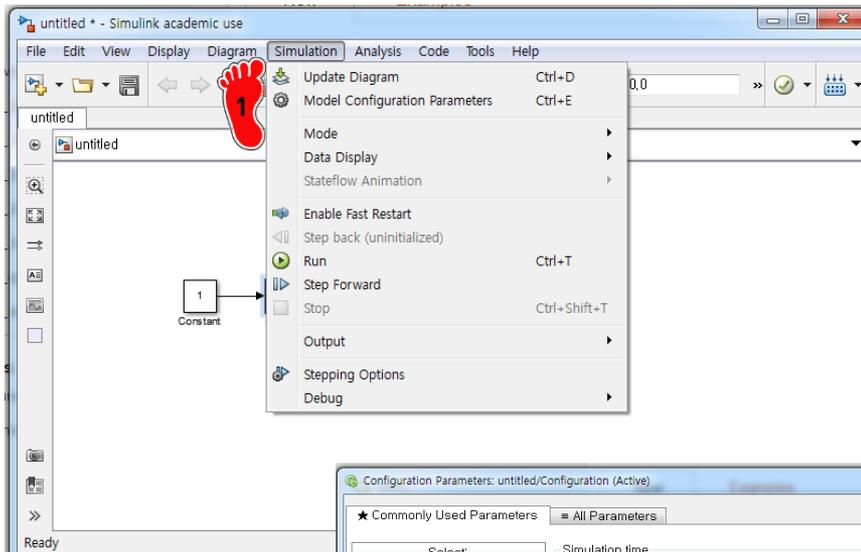
1 Simulation Time [s] 설정

2 'Run' 클릭

3 'Scope' block 더블클릭

4 Scope window에서 결과 확인

# SIMULINK ENVIRONMENT



ode45 : Runge-Kutta, Dormand-Prince (4,5) pair  
 ode23 : Runge-Kutta (2,3) pair of Bogacki & Shampine  
 ode113 : PECE Implementation of Adams-Bashforth-Moulton  
 ode15s : Numerical Differentiation Formulas (NDFs)  
 ode23s : Second-order, modified Rosenbrock formula  
 ode23t : Trapezoidal rule using a "free" interpolant  
 ode23tb : implicit Runge-Kutta formula with two stages

1 Simulation-Model Configuration Parameters 클릭

2 Solver Type 및 다양한 옵션 설정 가능

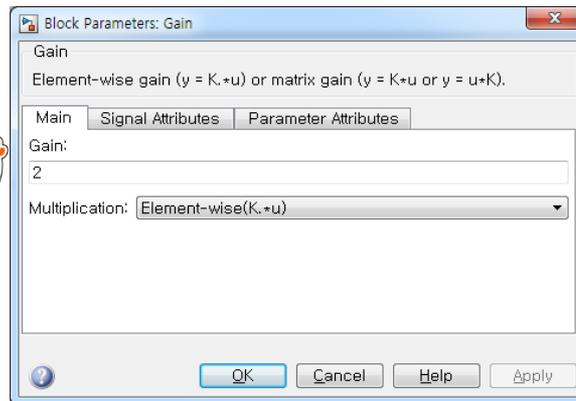
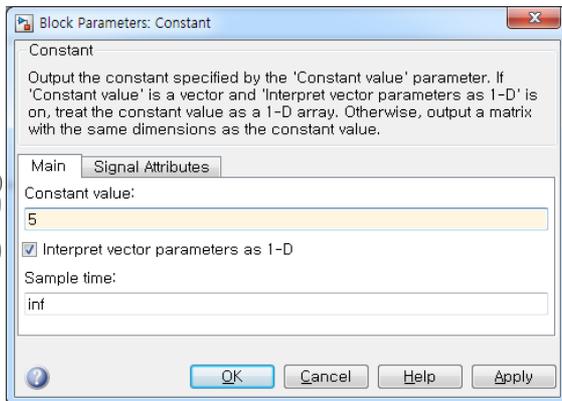
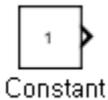
3

4

# COMMONLY USED BLOCKS

ICON	Description
 Constant	상수 입력
 Gain	$y(\text{output})=a*u(\text{input}), a : \text{gain}$
  Integrator Derivative	적분기 : $y = \int u dt$ , 미분기 : $y = \frac{du}{dt}$
   Product Divide Sum	사칙연산자 (곱하기, 나누기, 더하기, 빼기)
  Logical Operator Relational Operator	비교문 (and, or, less than, more than, equal)
 Saturation	입력신호 범위 제한
  Mux Demux	신호 → 벡터 합성, 벡터 → 신호 분해
  1-D Lookup Table 2-D Lookup Table	입력에 대한 출력을 사전에 정의한 table(1-D) 또는 map(2-D)에 의해 정의
 Fcn	입력에 대한 출력 신호를 사용자가 지정한 함수에 의해 정의

# COMMONLY USED BLOCKS

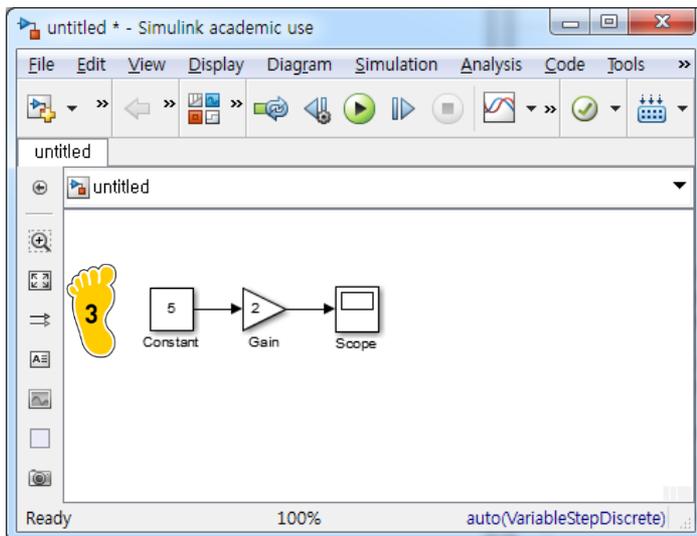


1 Constant value '5' 입력

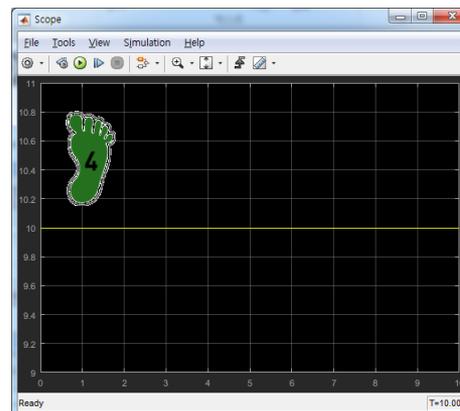
2 Gain '2' 입력

3 Block Diagram 구성

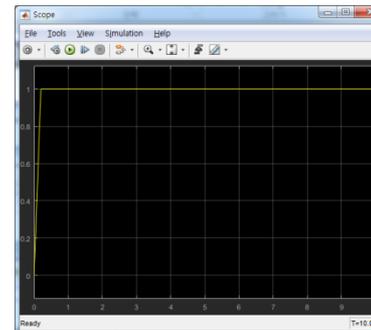
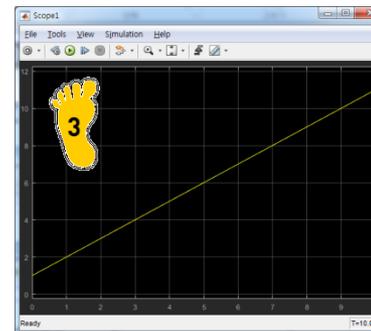
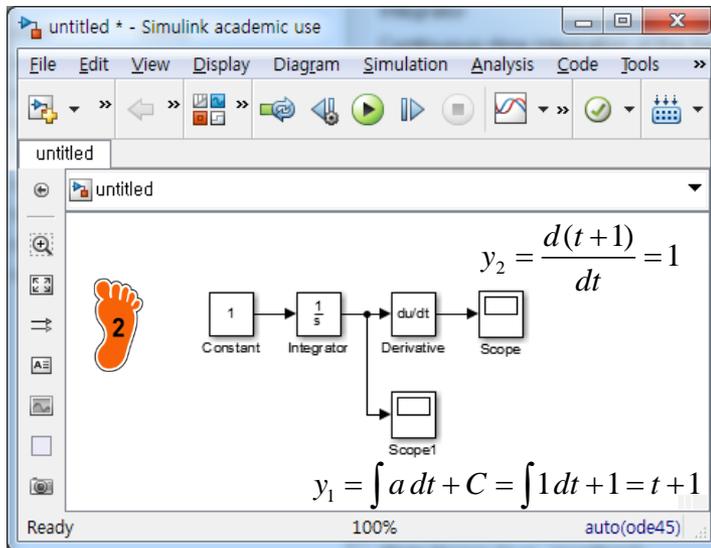
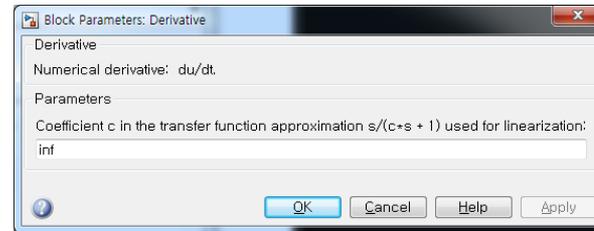
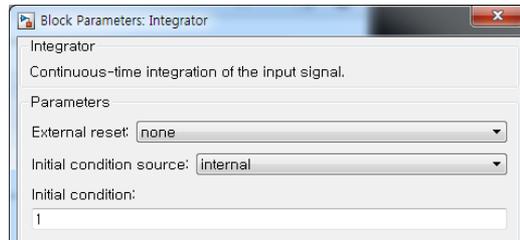
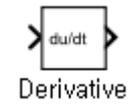
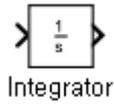
4 Scope window에서 결과 확인



$$5 \times 2 = 10$$



# COMMONLY USED BLOCKS



Initial Condition '1' 입력



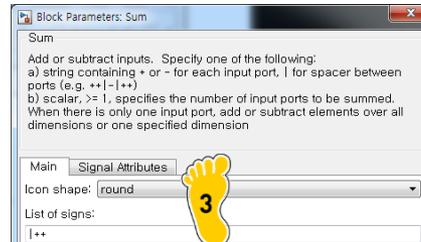
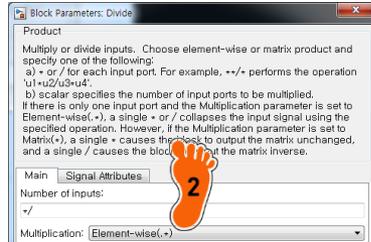
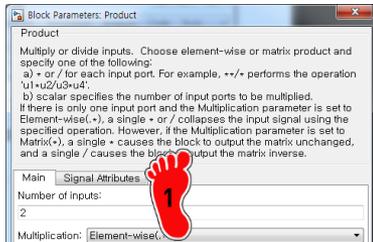
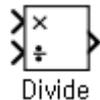
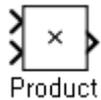
Block Diagram 구성



Scope window에서 결과 확인



# COMMONLY USED BLOCKS



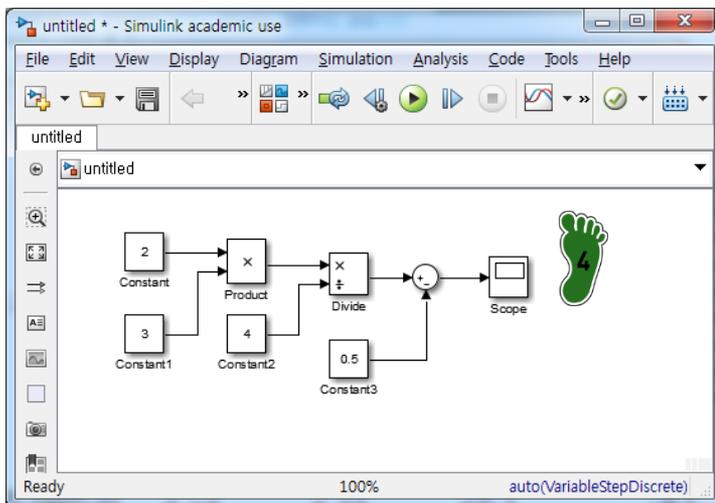
Ex1) Input Port 4



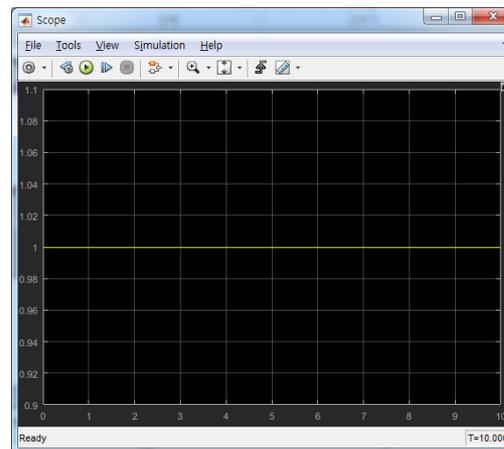
Ex2) Input 연산자 '\*//\*'



Ex3) Input 연산자 '+-+-'



$$y = \{(2 \times 3) \div 4\} - 0.5 = 1$$



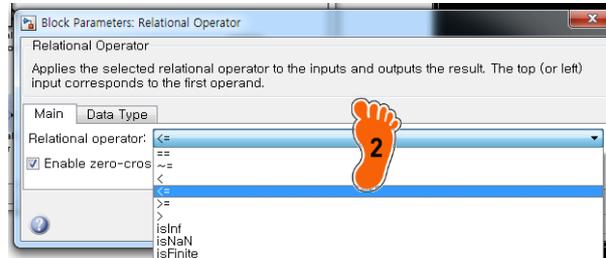
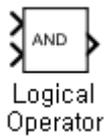
1 Input Port 숫자 (입력 변수의 개수) 입력

2 각 입력변수에 대한 \*/입력

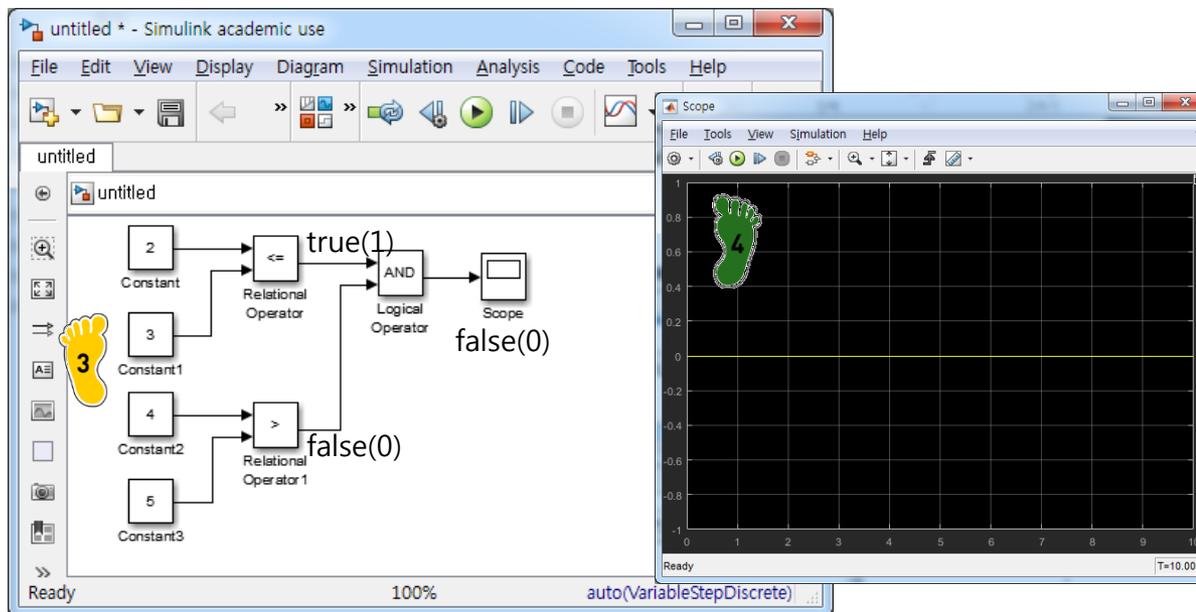
3 각 입력변수에 대한 +-입력

4 Block Diagram 구성 및 결과 확인

# COMMONLY USED BLOCKS



출력값 (true인 경우 : 1, false인 경우 : 0)



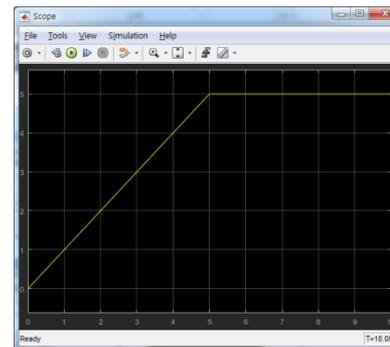
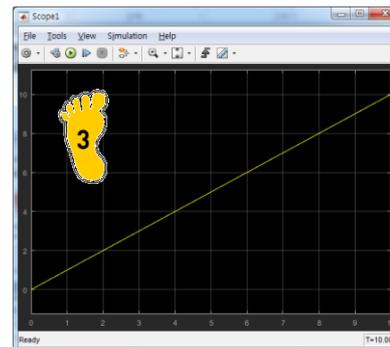
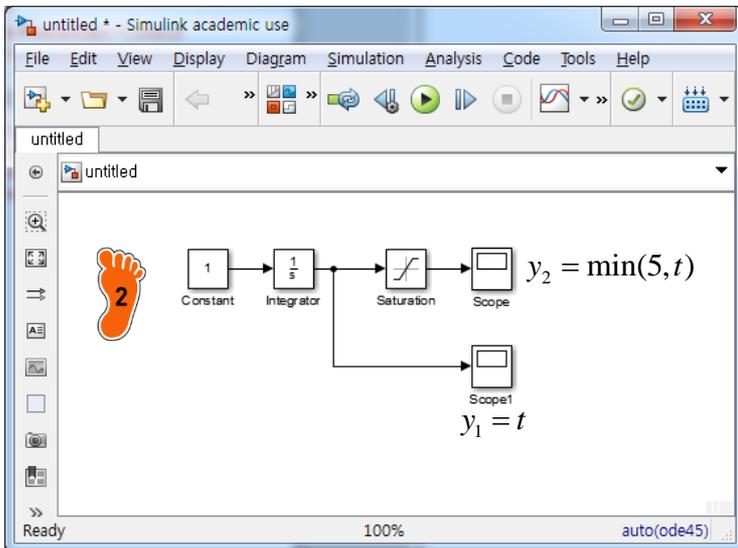
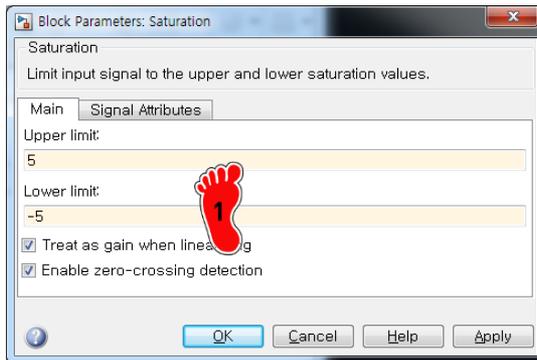
1 로직(and, or, not...)과 입력 변수 개수 입력

2 로직(>=, ==, ~=...) 입력

3 Block Diagram 구성

4 결과 확인

# COMMONLY USED BLOCKS



1 Upper/lower limit 입력

2 Block Diagram 구성

3 결과 확인



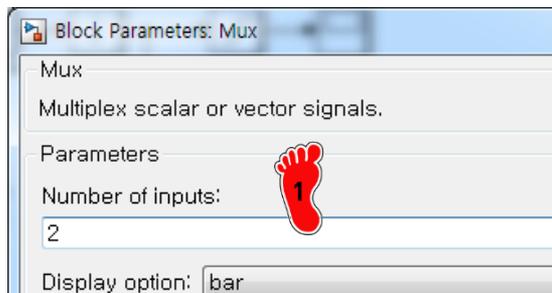
$y_1$

$y_2$

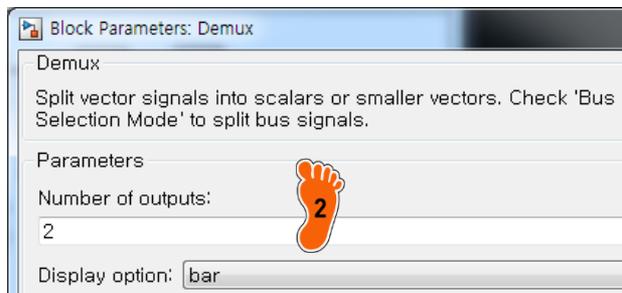
# COMMONLY USED BLOCKS



Mux



Demux



입력 신호 수 입력



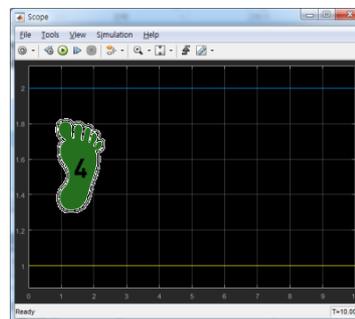
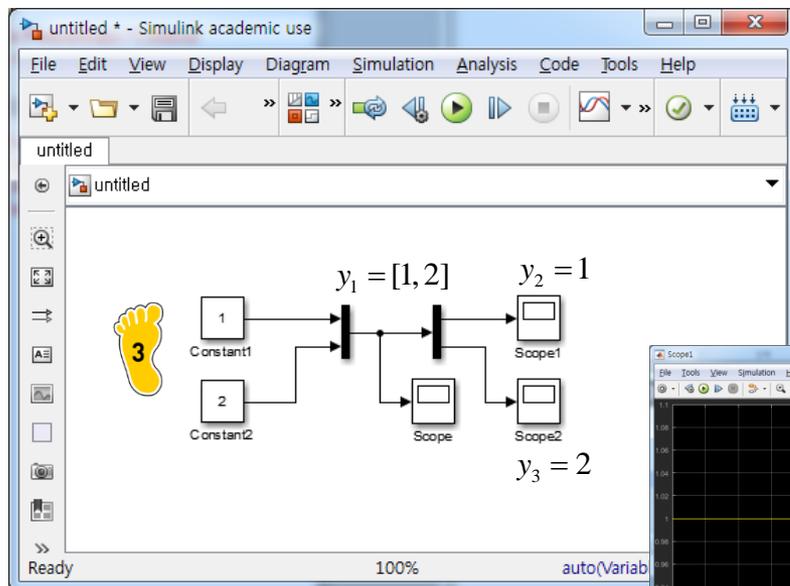
출력 신호 수 입력



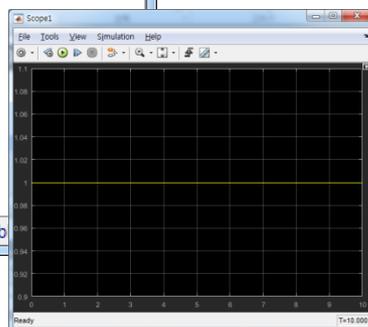
Block Diagram 구성



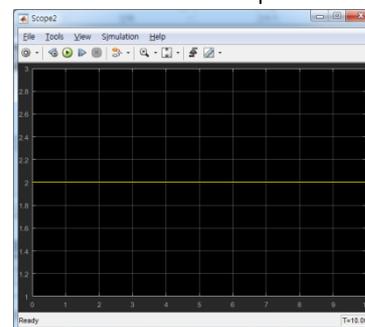
결과 확인



$y_1$

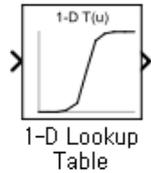


$y_2$



$y_3$

# COMMONLY USED BLOCKS



Block Parameters: 1-D Lookup Table

Lookup Table (n-D)

Perform n-dimensional interpolated table lookup including index searches. The table is a sampled representation of a function in N variables. Breakpoint sets relate the input values to positions in the table. The first dimension corresponds to the top (or left) input port.

Table and Breakpoints Algorithm Data Types

Number of table dimensions: 1

Table data: tanh([-5:5])

Breakpoints specification: Explicit values

Breakpoints 1: [-5:5]

Edit table and breakpoints...

Lookup Table Editor: untitled/1-D Lookup Table

File Edit Plot Help

Models: untitled

Table blocks: 1-D Lookup Table

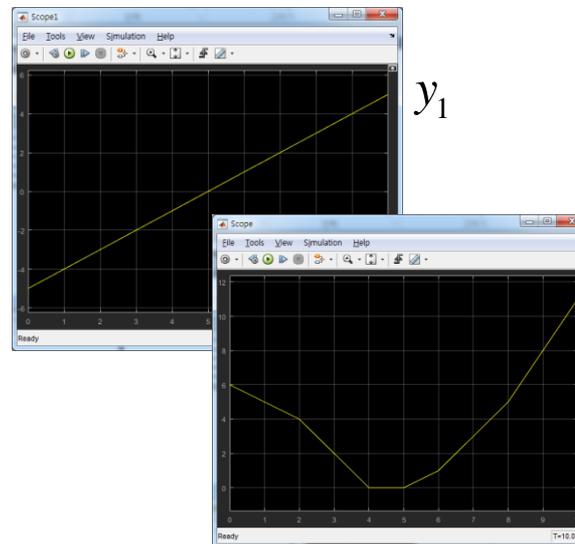
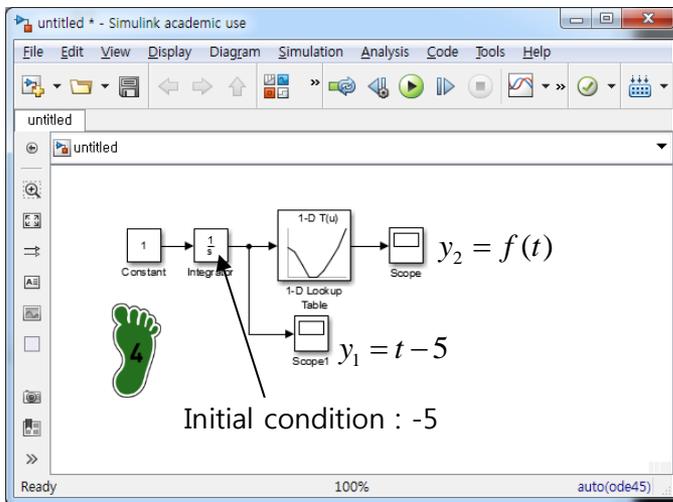
Row	Column (1)
(1)	-4
(2)	-3
(3)	-2
(4)	-1
(5)	0
(6)	1
(7)	2
(8)	3
(9)	4

1 Table 차원 입력

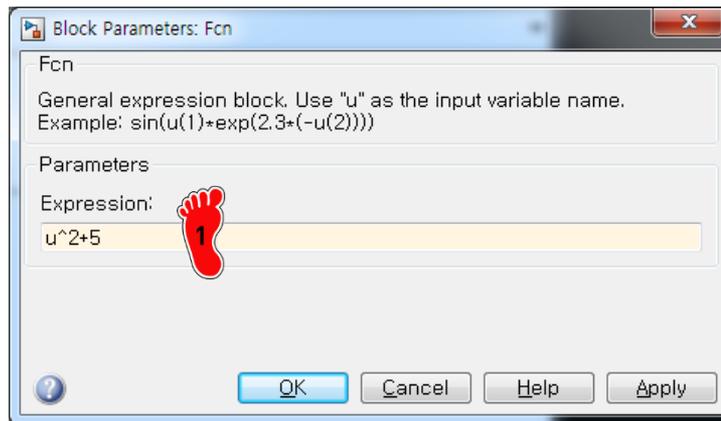
2 'edit table' 클릭

3 Table 값 입력

4 Block diagram 구성 및 결과 확인



# COMMONLY USED BLOCKS



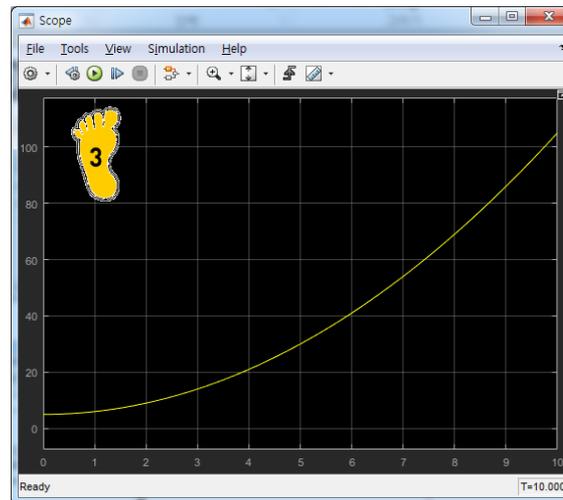
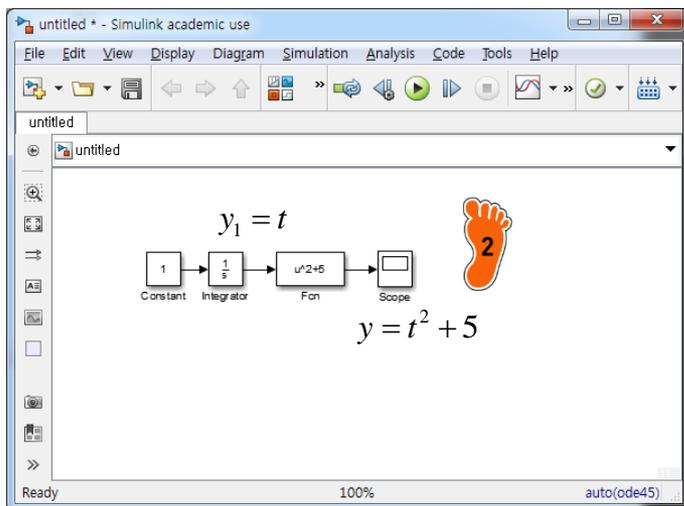
1 출력 함수 입력

2 Block diagram 구성

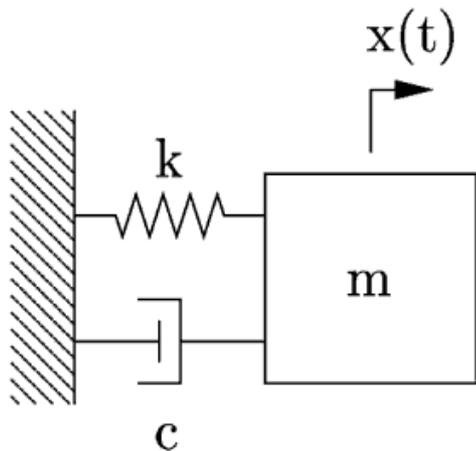
3 결과 확인



$y_2$



# 2<sup>ND</sup> ORDER SYSTEM

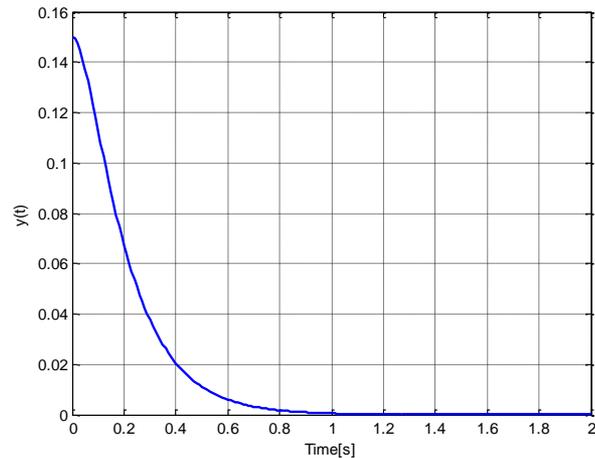


$$m \frac{d^2 x}{dt^2} + c \frac{dx}{dt} + kx = F(t)$$

$m=9.072 \text{ kg}$  ,  $c=200 \text{ kg/s}$ ,  $k=889.96 \text{ N/m}$ ,  $y(0)=0.15 \text{ m}$

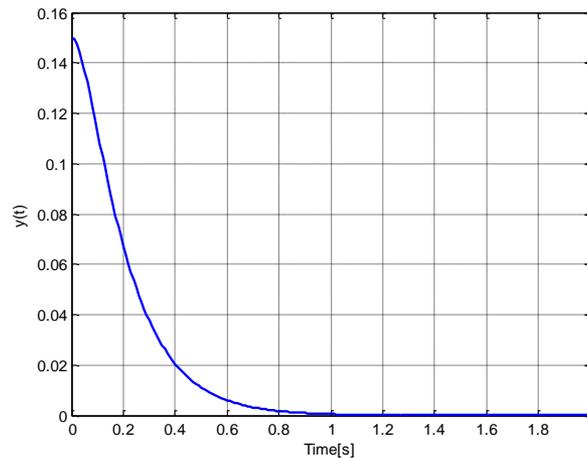
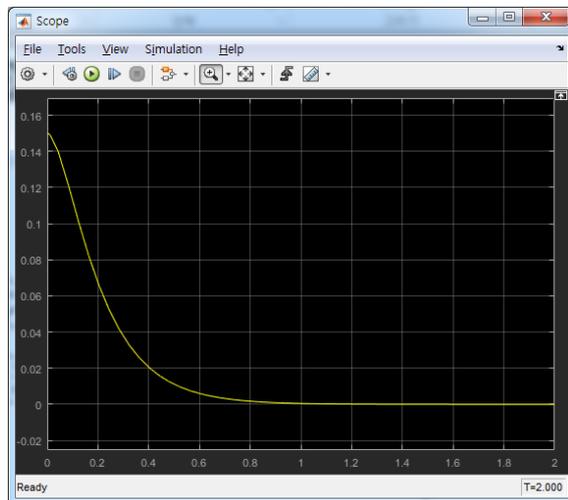
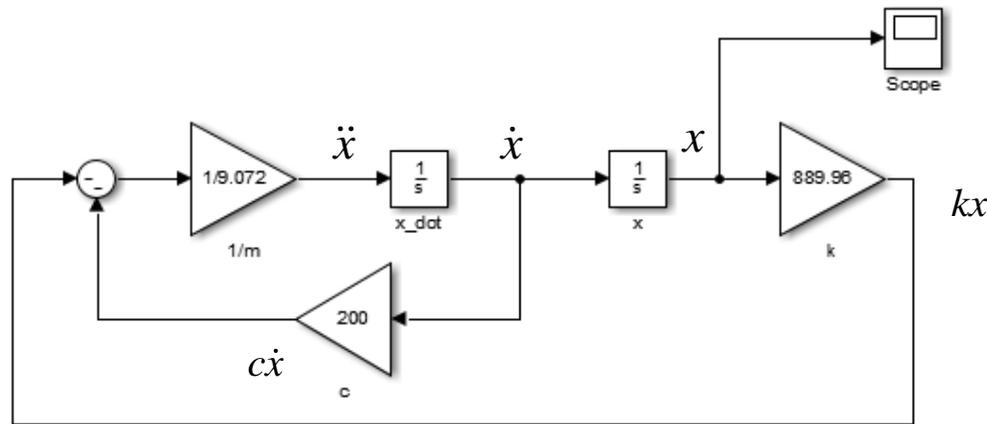
※ Analytic Sol.

$$y(t) = 0.2463e^{-6.190t} - 0.0963e^{-15.83t}$$



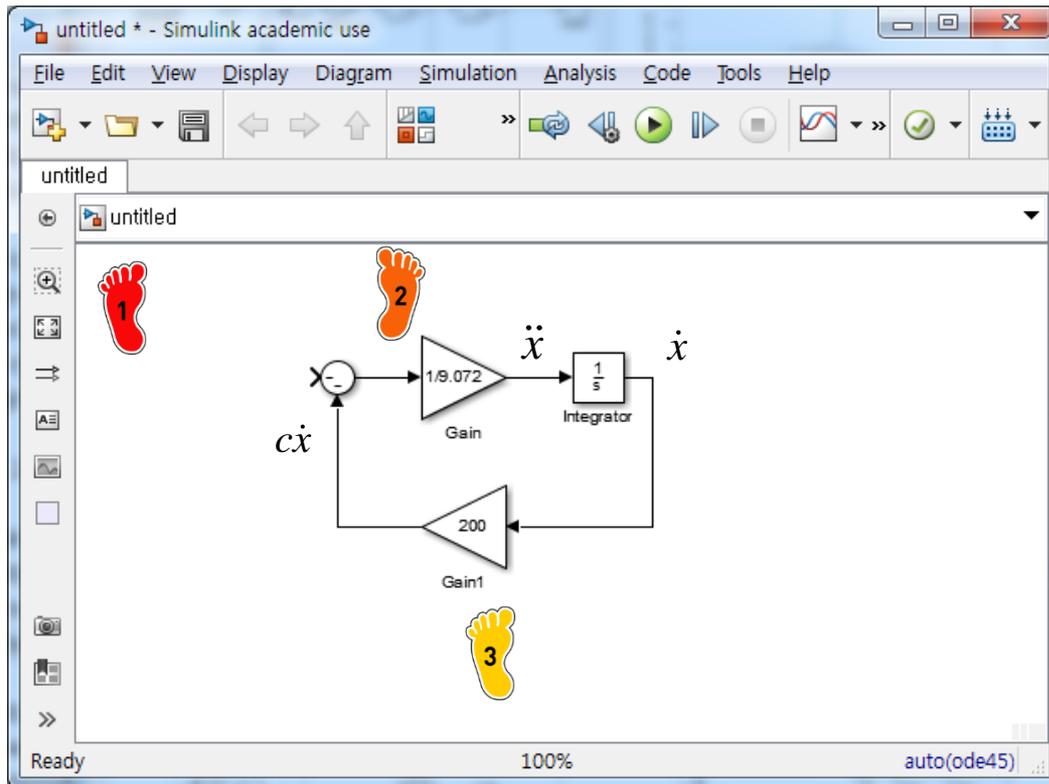
# 2<sup>ND</sup> ORDER SYSTEM

$$m \frac{d^2 x}{dt^2} + c \frac{dx}{dt} + kx = 0 \quad \longrightarrow \quad \ddot{x} = -\frac{c}{m} \dot{x} - \frac{k}{m} x$$



# 2<sup>ND</sup> ORDER SYSTEM

$$\ddot{x} = -\frac{c}{m}\dot{x} - \frac{k}{m}x$$



1 Block diagram 구성

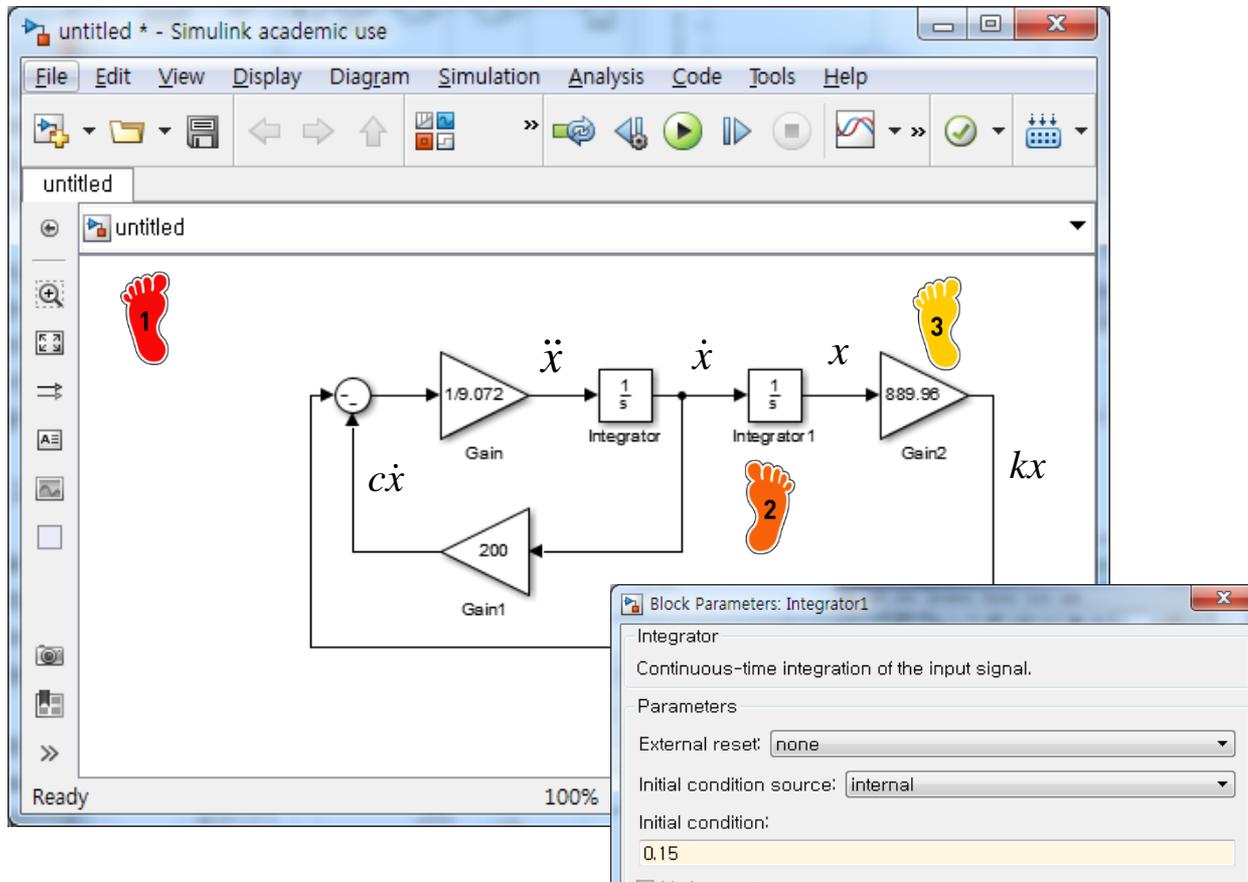
2 Mass값 입력(1/m)

3 Damper값 입력

4

# 2<sup>ND</sup> ORDER SYSTEM

$$\ddot{x} = -\frac{c}{m}\dot{x} - \frac{k}{m}x$$



1 Block diagram 구성

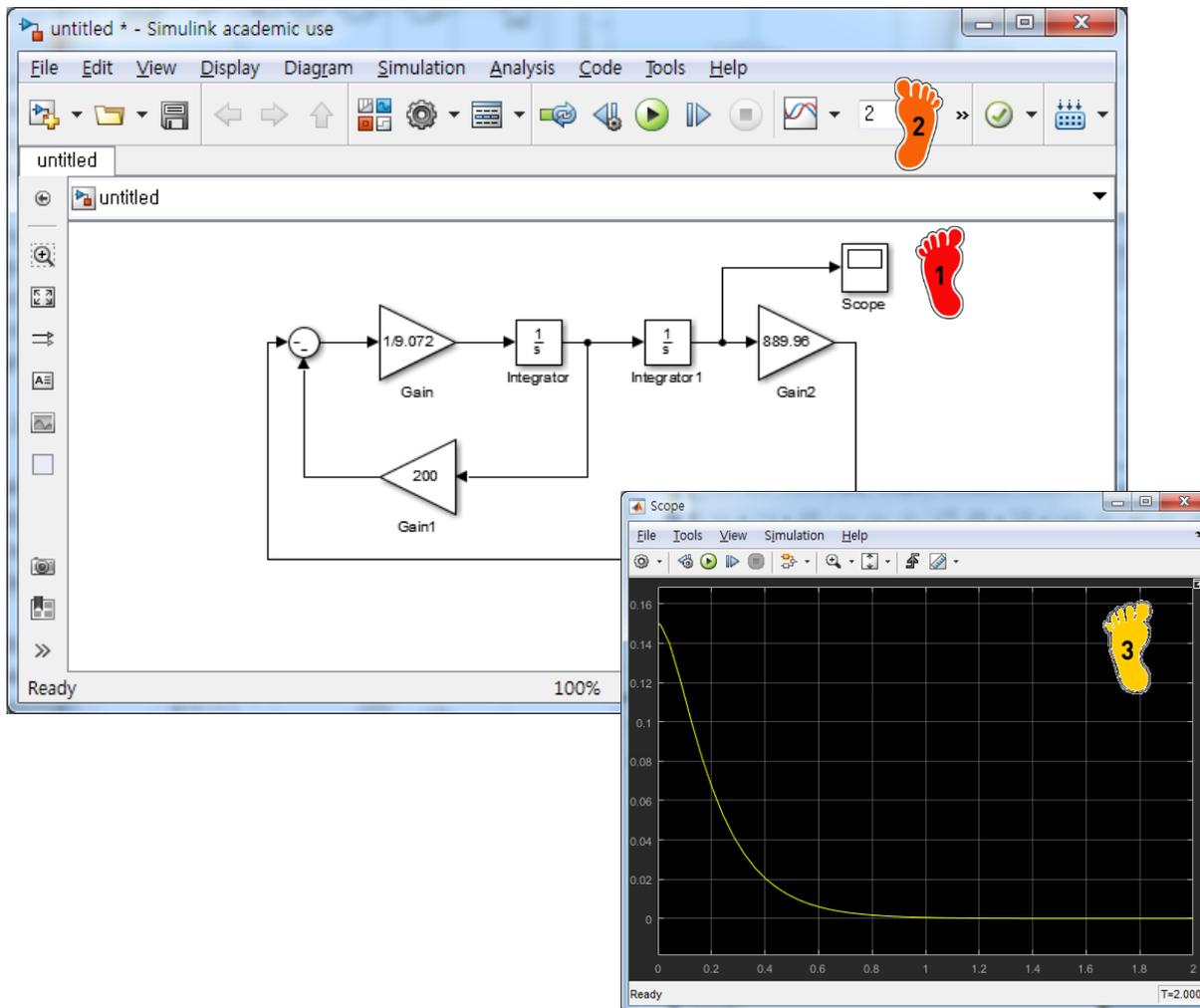
2 초기 변위 입력

3 spring값 입력

4

# 2<sup>ND</sup> ORDER SYSTEM

$$\ddot{x} = -\frac{c}{m}\dot{x} - \frac{k}{m}x$$



1 Scope 구성 (x)

2 시뮬레이션 시간 조정 (2 s)

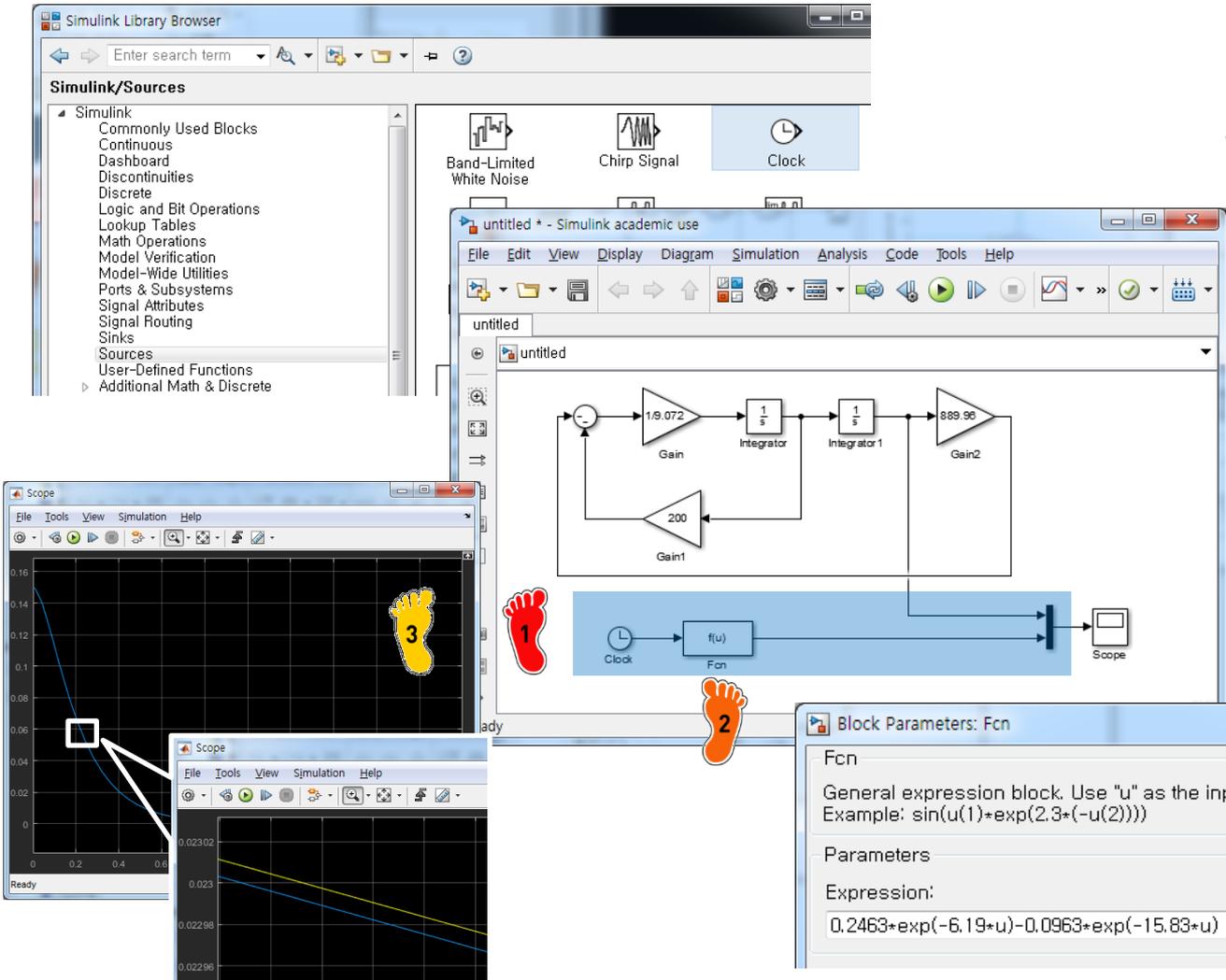
3 Run & 결과 확인

4

# 2<sup>ND</sup> ORDER SYSTEM

※ Analytic Sol.

$$y(t) = 0.2463e^{-6.190t} - 0.0963e^{-15.83t}$$



1 Block diagram 구성

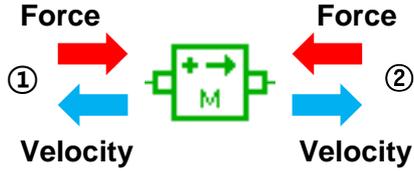
2 Fcn block내 analytic sol. 입력

3 Run & 결과 확인

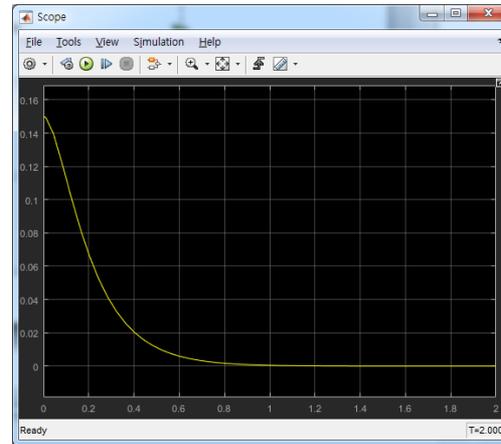
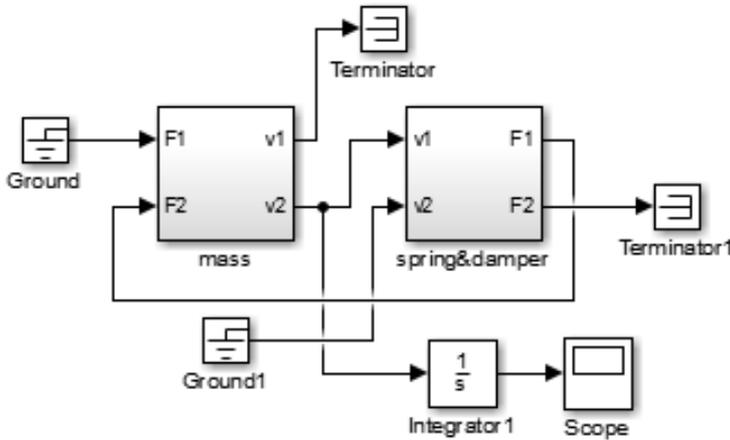
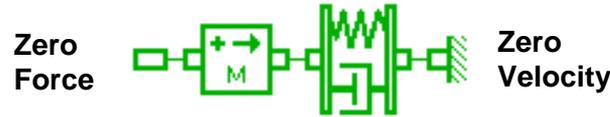
4

# MODEL BASED DESIGN

Mass Component

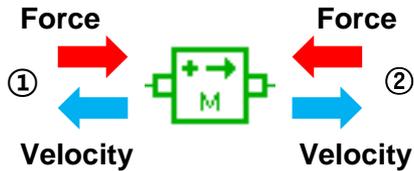


Spring&Damper Component



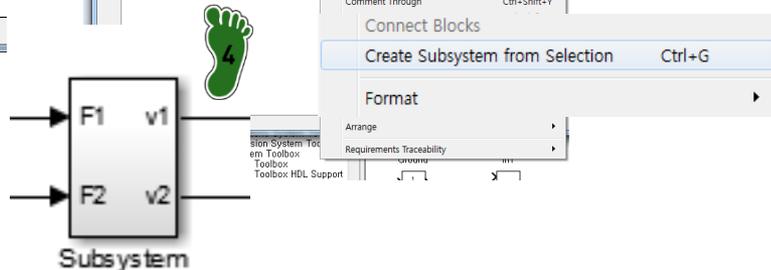
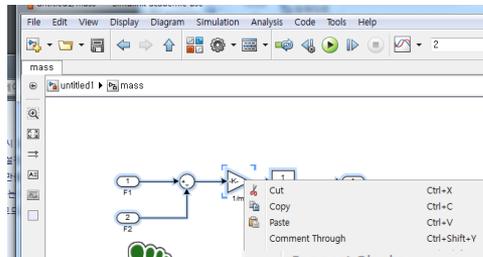
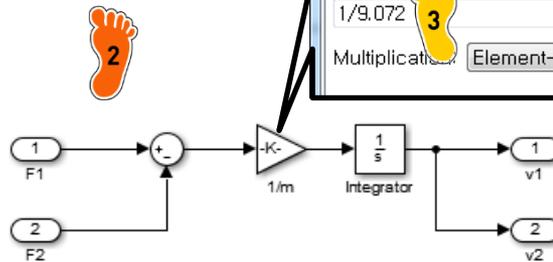
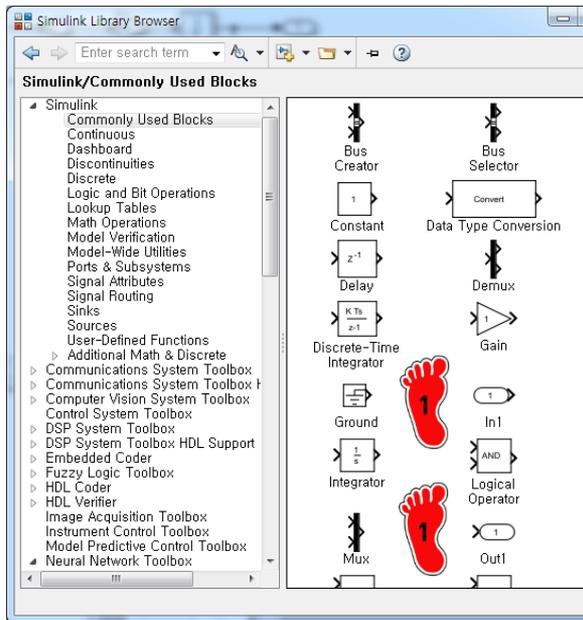
# MODEL BASED DESIGN

Mass Component



$$F_1 - F_2 = m\ddot{x} \quad \ddot{x} = \frac{(F_1 - F_2)}{m}$$

$$\dot{x} = \int \frac{F_1 - F_2}{m} dx$$



1 Commonly Used Blocks에서 In1, Out1 block 이용

2 Block Diagram 구성

3 Parameter 값 입력

4 모델 전체 선택 후, 우클릭 Create Subsystem 클릭

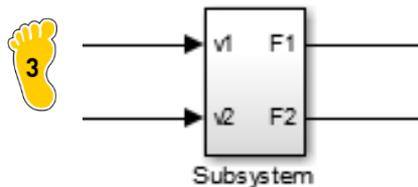
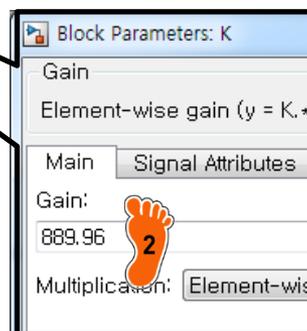
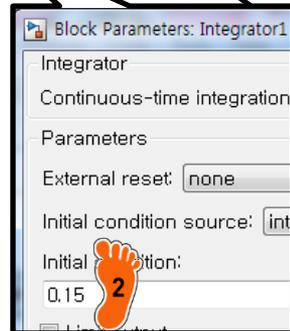
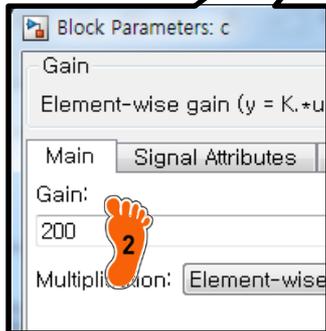
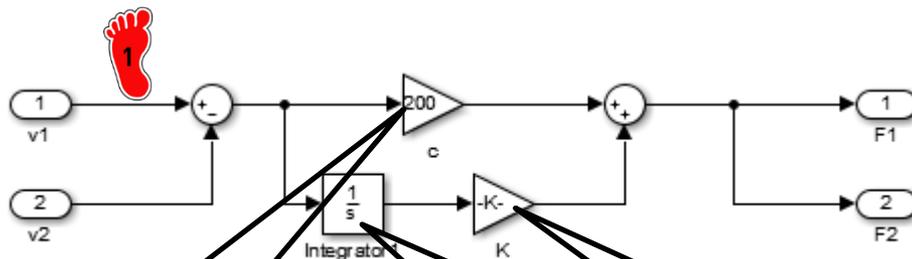
# MODEL BASED DESIGN

Spring&Damper Component



$$F = c(\dot{x}_1 - \dot{x}_2) + k(x_1 - x_2)$$

$$F = c(\dot{x}_1 - \dot{x}_2) + k \int (\dot{x}_1 - \dot{x}_2) dx$$



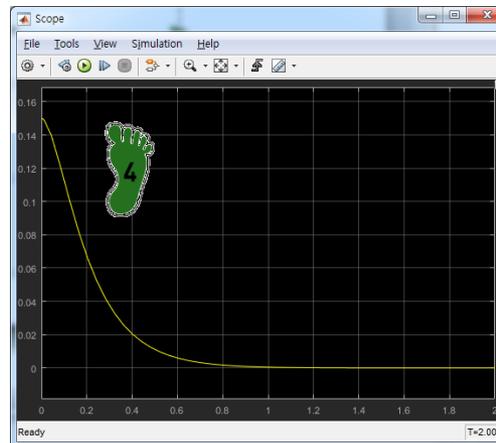
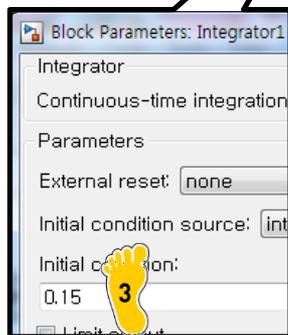
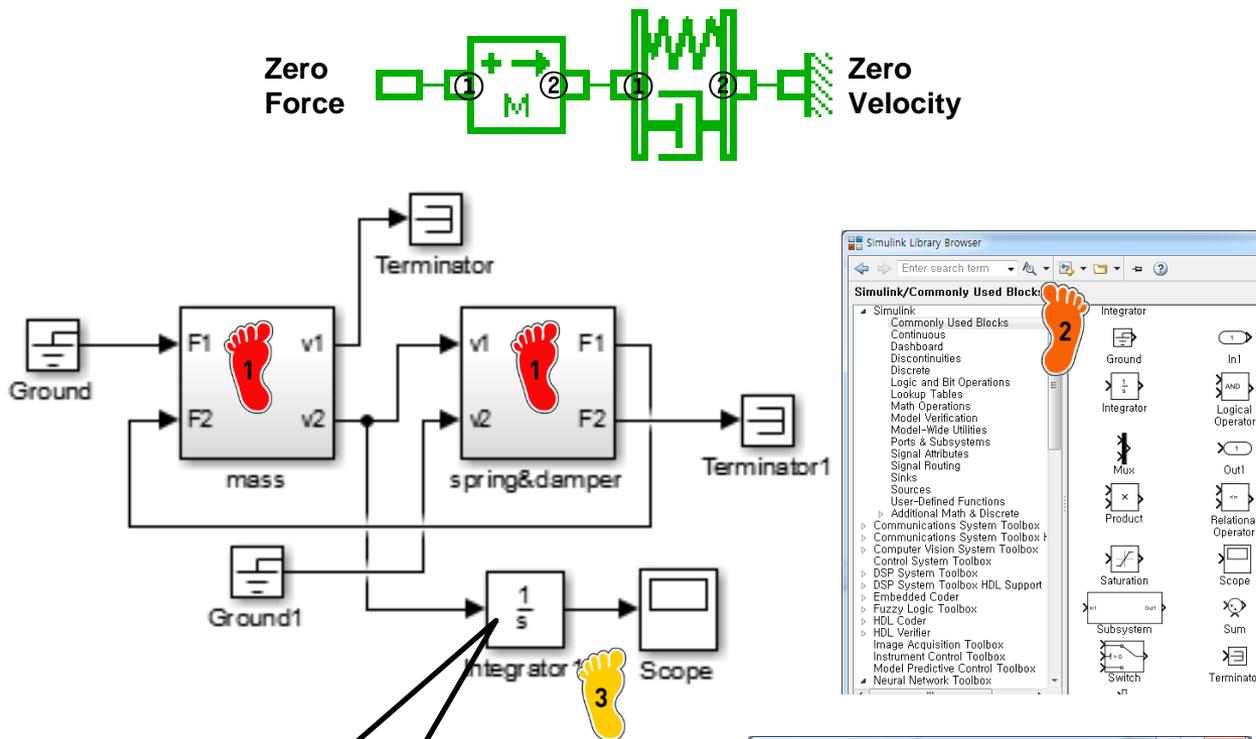
1 Block Diagram 구성

2 Parameter 값 입력

3 모델 전체 선택 후, 우클릭  
Create Subsystem 클릭



# MODEL BASED DESIGN



1 구성된 Mass, Spr.&Damp. system을 이용, In, Out에 맞게 포트 연결

2 Mass 1번, Spr.&Damp. 2번에 Ground, Terminal 연결

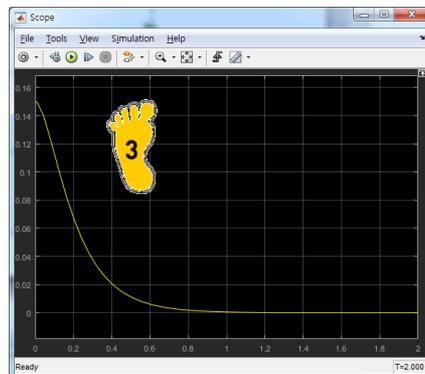
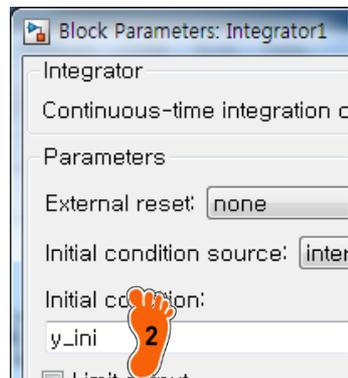
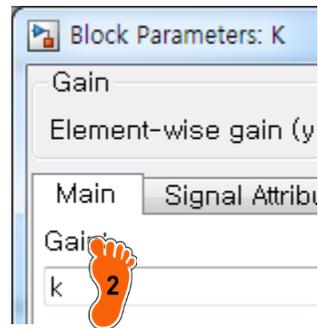
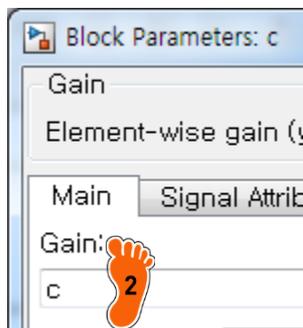
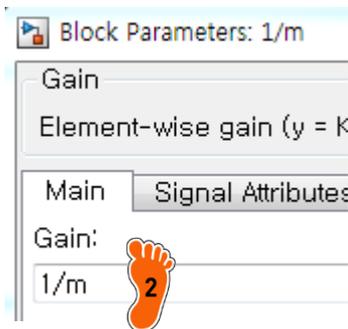
3 Mass의 v1 or v2를 이용해서 변위 출력

4 Run 및 결과 확인

# MODEL BASED DESIGN

MATLAB Workspace에 Parameter 설정

이름	값
c	200
k	889.9600
m	9.0720
y_ini	0.1500



Command Window에  
Parameter값 입력



모델 Parameter값에 설정한  
변수명 입력

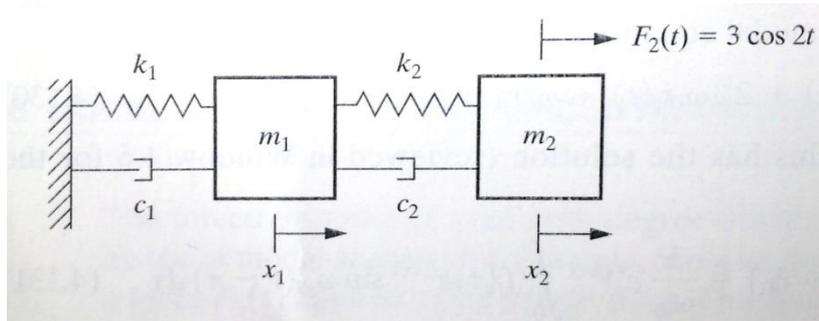


Run 및 결과 확인



# CASE STUDY

2-DOF system



$$m_1 = 9 \text{ kg}, m_2 = 1 \text{ kg}$$

$$k_1 = 24 \text{ N/m}, k_2 = 3 \text{ N/m}$$

$$c_1 = 2.4 \text{ Ns/m}, c_2 = 0.3 \text{ Ns/m}$$

$$F_2(t) = 3 \cos 2t$$

※ Ref. : Daniel J. Inman, "Engineering Vibration",  
Prentice Hall International, Inc., pp 296-298, 2001

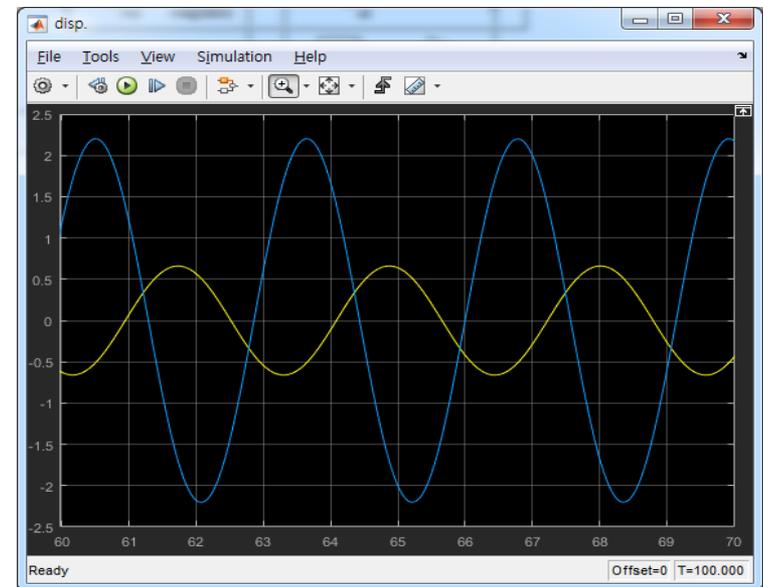
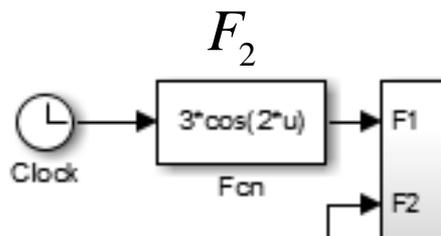
$$m_1 \ddot{x}_1 = -k_2(x_1 - x_2) - c_2(\dot{x}_1 - \dot{x}_2) - k_1 x_1 - c_1 \dot{x}_1$$

$$m_2 \ddot{x}_2 = k_2(x_1 - x_2) + c_2(\dot{x}_1 - \dot{x}_2) + F(t)$$

※ Analytic Solution (Steady State)

$$x_1(t) = 0.2451 \cos(2t - 0.1974) - 0.6249 \sin 2t$$

$$x_2(t) = 0.7354 \cos(2t - 0.1974) + 1.8749 \sin 2t$$



# ASSIGNMENT(3WEEK ODE)

**Background.** Electric circuits where the current is time-variable rather than constant are common. A transient current is established in the right-hand loop of the circuit shown in Fig. 28.11 when the switch is suddenly closed.

Equations that describe the transient behavior of the circuit in Fig. 28.11 are based on Kirchhoff's law, which states that the algebraic sum of the voltage drops around a closed loop is zero (recall Sec. 8.3). Thus,

$$L \frac{di}{dt} + Ri + \frac{q}{C} - E(t) = 0 \quad (28.9)$$

where  $L(di/dt)$  = voltage drop across the inductor,  $L$  = inductance (H),  $R$  = resistance ( $\Omega$ ),  $q$  = charge on the capacitor (C),  $C$  = capacitance (F),  $E(t)$  = time-variable voltage source (V), and

$$i = \frac{dq}{dt} \quad (28.10)$$

$$E = E_0 \sin(\omega t)$$

$$L = 2 \text{ H}$$

$$E_0 = 5 \text{ V}$$

$$C = 0.25 \text{ F}$$

$$\omega = 5 \text{ rad/s}$$

$$R = 3 \text{ Ohm}$$

