AMESim 기초
Quarter Car Modeling

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

OUTLINE

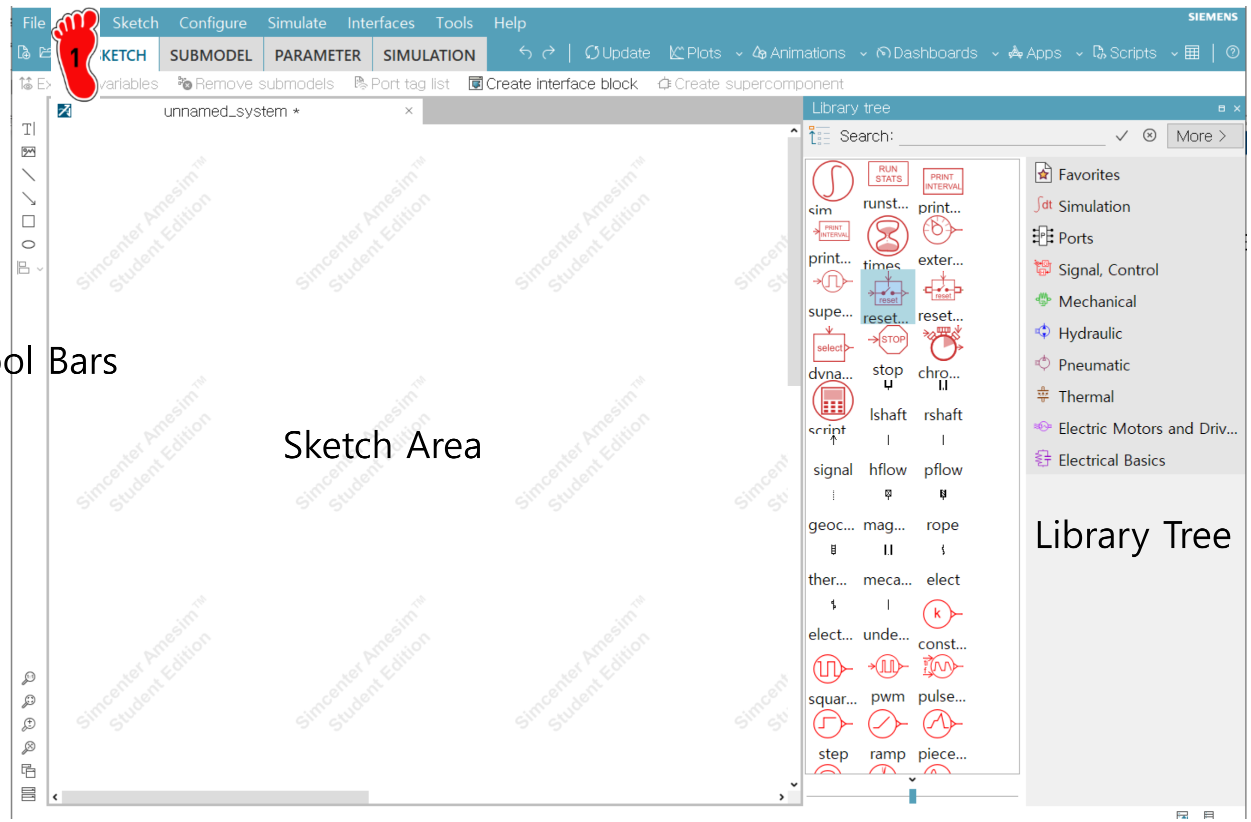
- **Lecture Goals**
  - ✓ 모델 기반 설계 상용 도구인 AMESim의 기초 학습을 통해 기계, 전기 시스템 모델링과 시뮬레이션을 실습하고 Simulink와 비교하면서 물리적 의미를 파악한다.
- **Content**
  - ✓ Overview
  - ✓ AMESim Environment
  - ✓ Signal, Control
  - ✓ Mechanical Basics
  - ✓ Electrical Basics
  - ✓ Quarter Car Model
  - ✓ Case Study – Half Car Model
  - ✓ Assignment

OVERVIEW

- **AMESim : Advanced Modeling Environment for Simulations**
  - **Integrated simulation platform for multi-domain mechatronic systems simulation**
  - **Powerful and user-friendly platform for modeling and analysis**
  - **Assess functional performance of intelligent, mechatronic systems beginning in early development stages**
  - **Provide physical domain libraries for fluids, thermodynamics, electrics, electromechanical, mechanics and signal processing**
  - **Video : AMESim Overview**

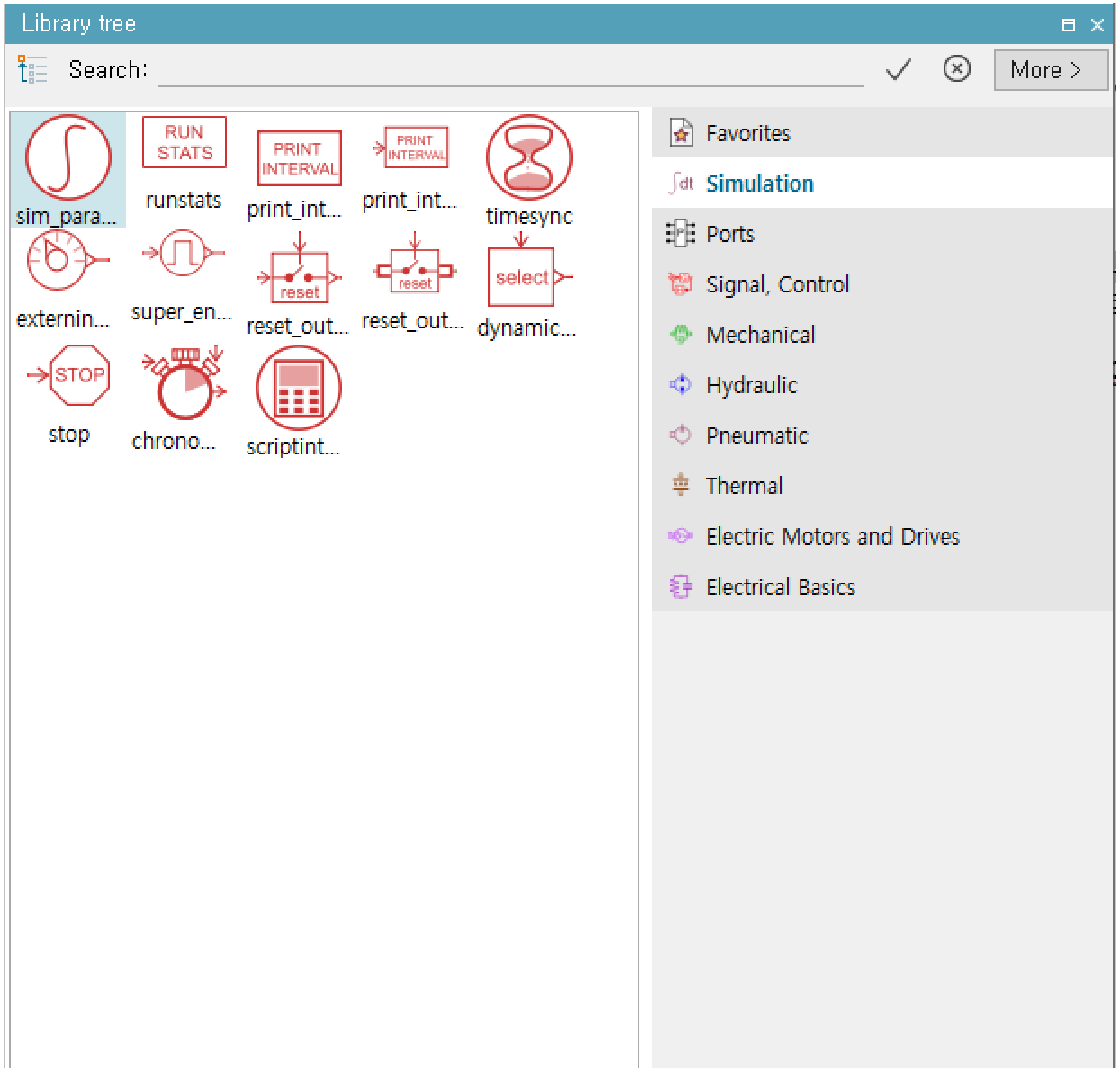
AMESIM ENVIRONMENT

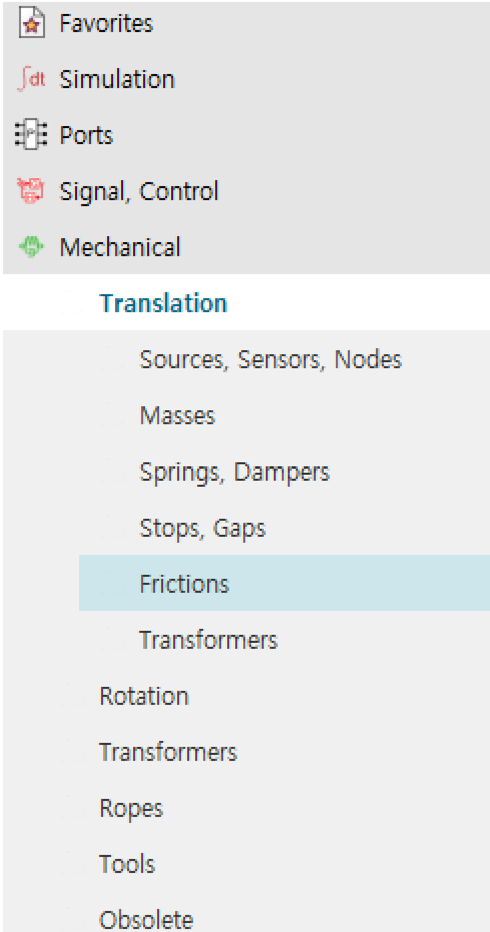
Modes Tool Bar



1 AMESim은
Modes Tool Bar을 이용
모델을 구성하고
파라메터를 설정하고
시뮬레이션을 수행함

AMESIM ENVIRONMENT





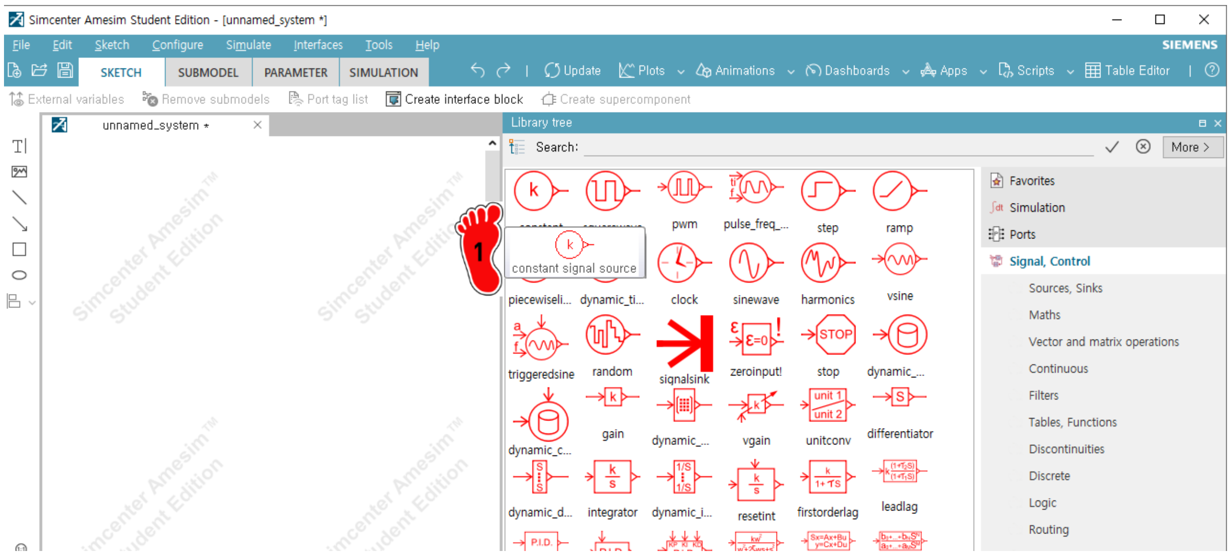
AMESIM ENVIRONMENT

Student Edition

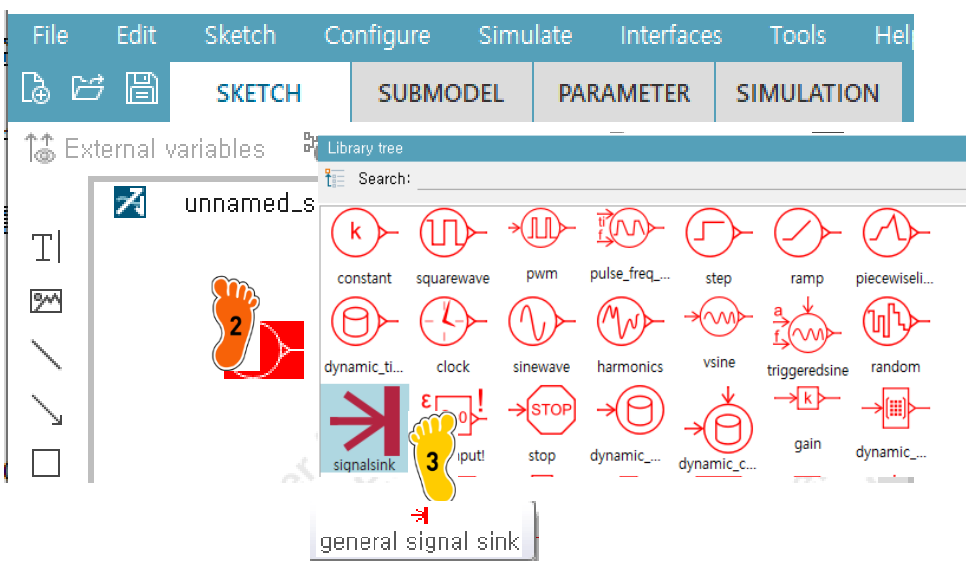
- Simulation
- Ports
- Signal, Control
- Mechanical
- Hydraulic
- Pneumatic
- Thermal
- Electric Motors and Drives
- Electrical Basics

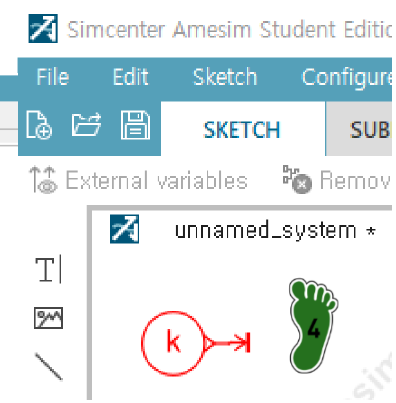
Libraries	
3D Mechanical	Hydraulic
Aeronautics and Space	Hydraulic Resistance
Air Conditioning	Hydraulic Component Design
Aircraft Electrics	IFP-Drive
Aircraft Fuel System	IFP-Engine
Automotive Electrics	IFP-Exhaust
Cams and Followers	Liquid Propulsion
CFD1D	Mechanical
Cooling System	Moist Air
Discrete Partitioning	Planar Mechanical
Electric Motors and Drives	Pneumatic
Electrical Basics	Pneumatic Component Design
Electrical Static Conversion	Powertrain
Electric Storage	Signal, Control
Electrochemistry Components	Simulation
Electromechanical	Thermal
Engine Signal Generator	Thermal Hydraulic
Filling	Thermal Hydraulic Resistance
Fuel Cell	Thermal Hydraulic Component Design
Gas Mixture	Two-Phase Flow
Gas Turbine	Vehicle Dynamics
Generic Co-Simulation	Vehicle Dynamics iCAR
Heat Exchangers Assembly Tool	

AMESIM WORKFLOW

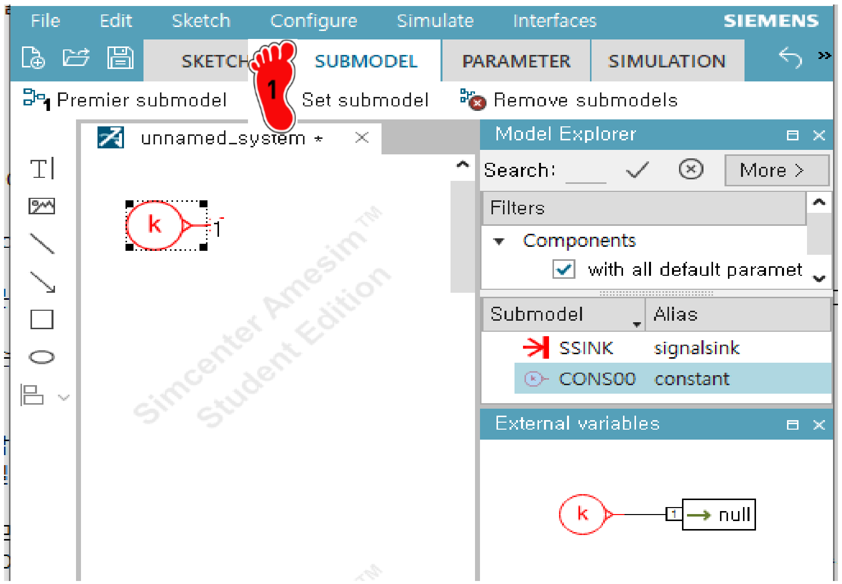


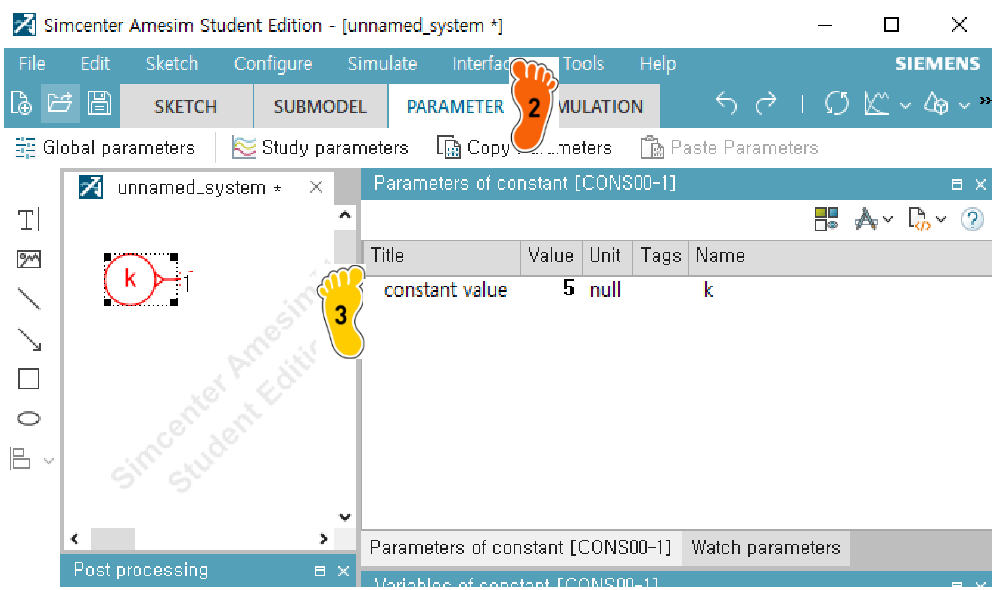
1. Library tree에서 signal, control 클릭
2. Constant block을 drag&drop 또는 클릭 → 스케치 화면에 다시 클릭
3. Signal Library에서 signalsink를 클릭
4. Constant block 옆에 연결





AMESIM WORKFLOW





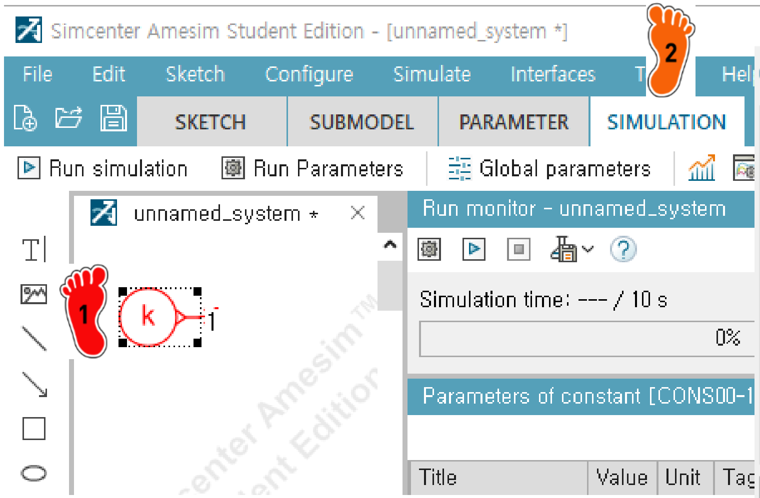
1 서브모델 탭 클릭
→ 추가된 서브모델들의
상세기능을 고급 설정
(일반적으로 default값 사용)

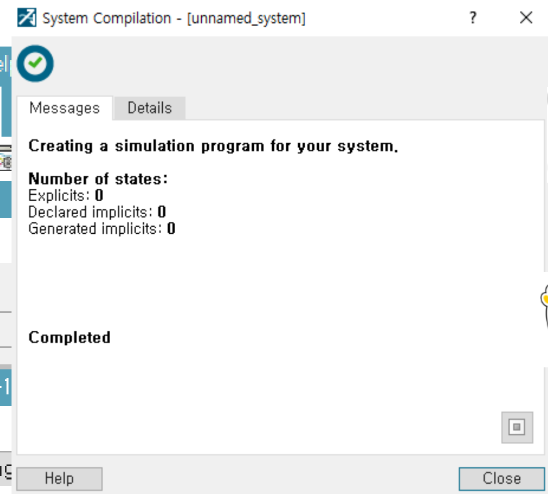
2 파라미터 탭 클릭

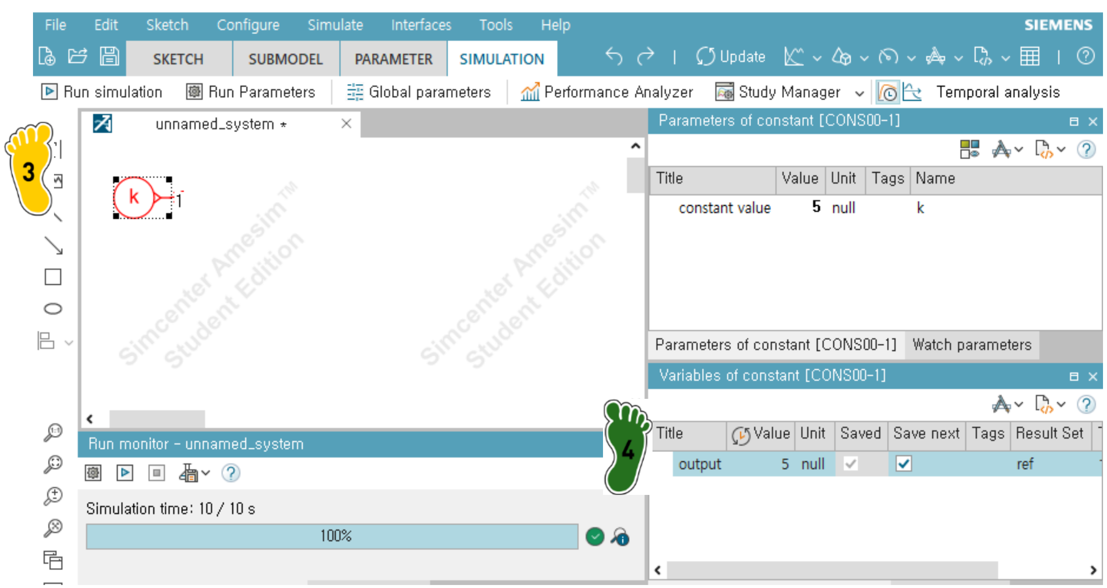
서브 모델들의
파라미터를 입력하는 단계

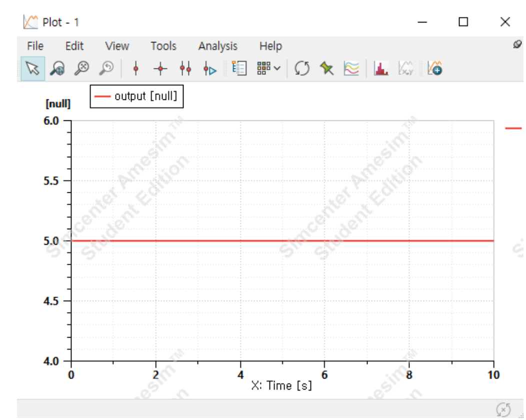
3 Constant block을 클릭하여
파라미터(Constant value)
5로 변경

AMESIM ENVIRONMENT



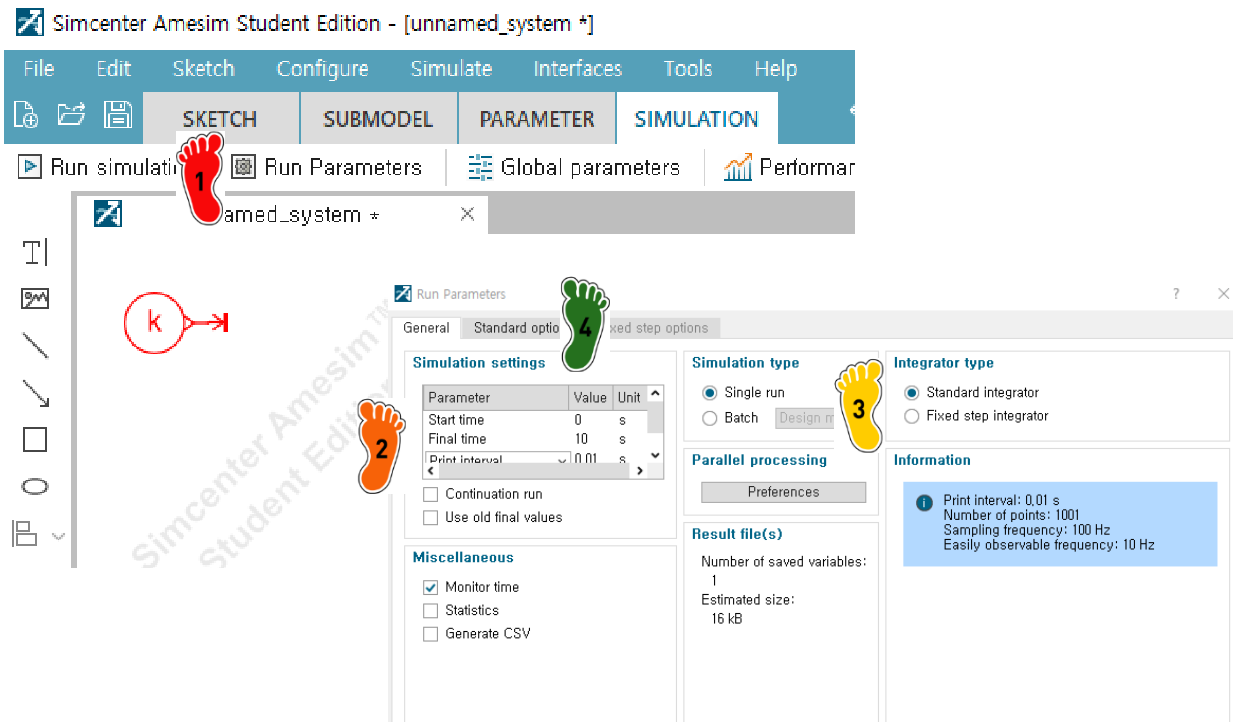


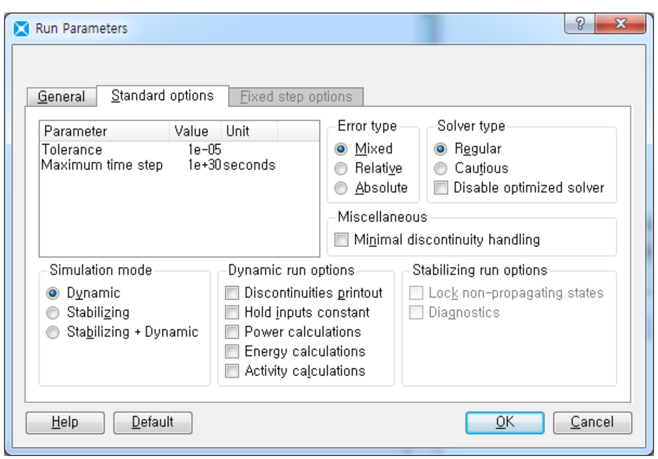


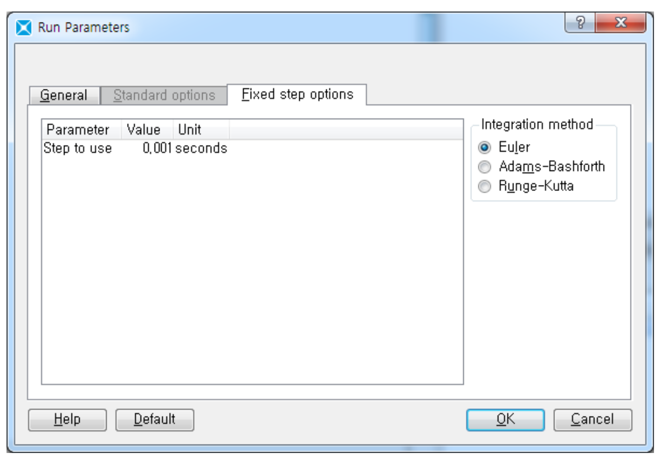


1. Simulation 클릭
2. Simulation 탭 클릭 시 모델 컴파일 진행
3. Run simulation 클릭
4. Constant block 클릭, output 클릭 후, 스케치 화면에 drag&drop, 결과 확인

AMESIM ENVIRONMENT

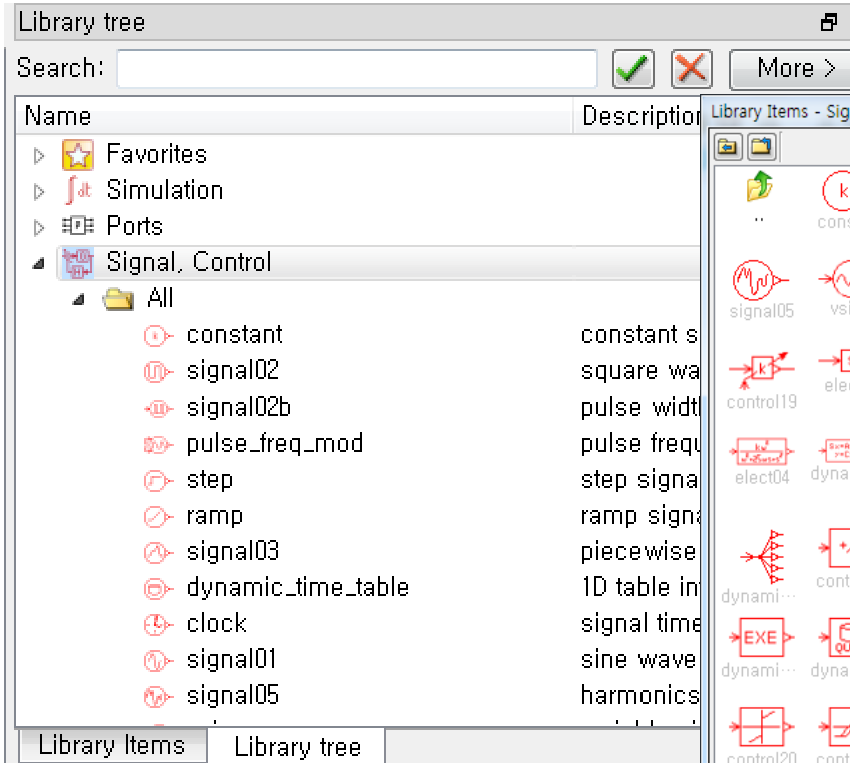


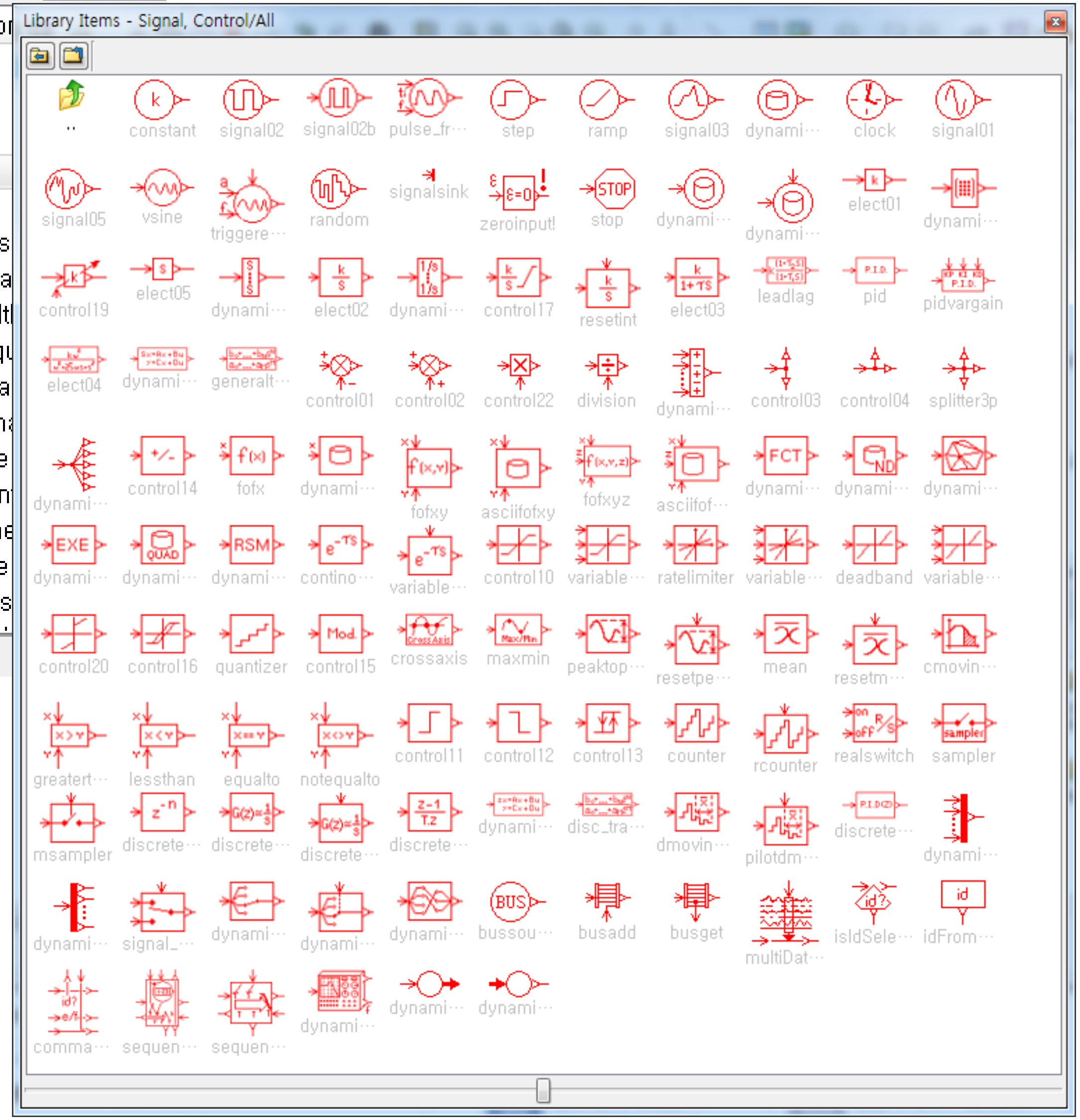




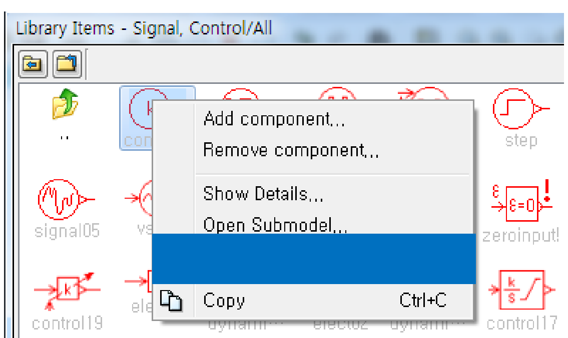
1. Run Parameter 클릭
2. 시뮬레이션 시간, plotting point 설정
3. Solver type 설정
4. Solver type에 대한 옵션 설정

SIGNAL, CONTROL

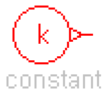
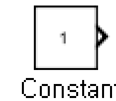
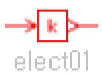
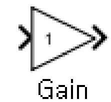
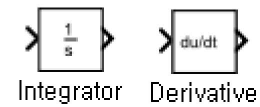
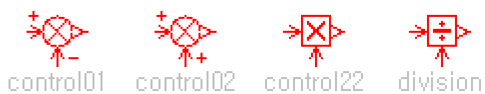
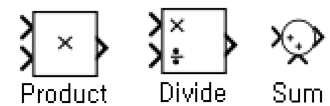
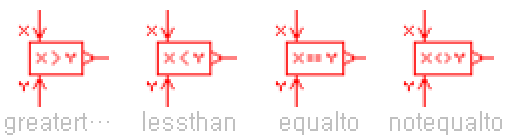
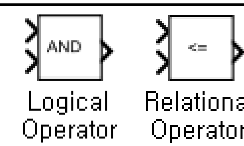
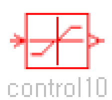
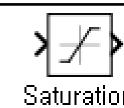
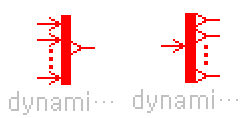
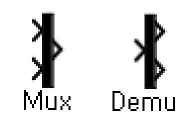
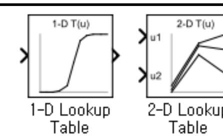
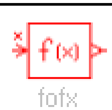
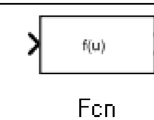




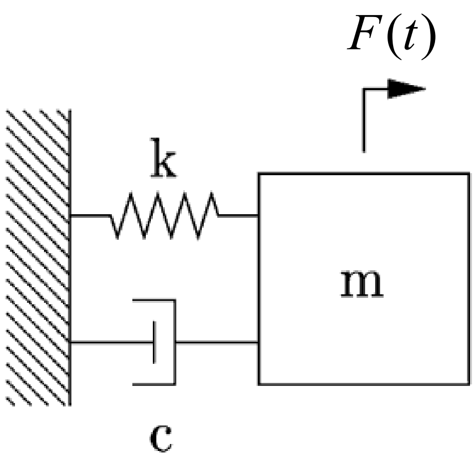
아이콘 클릭 후 오른쪽 버튼



SIGNAL, CONTROL

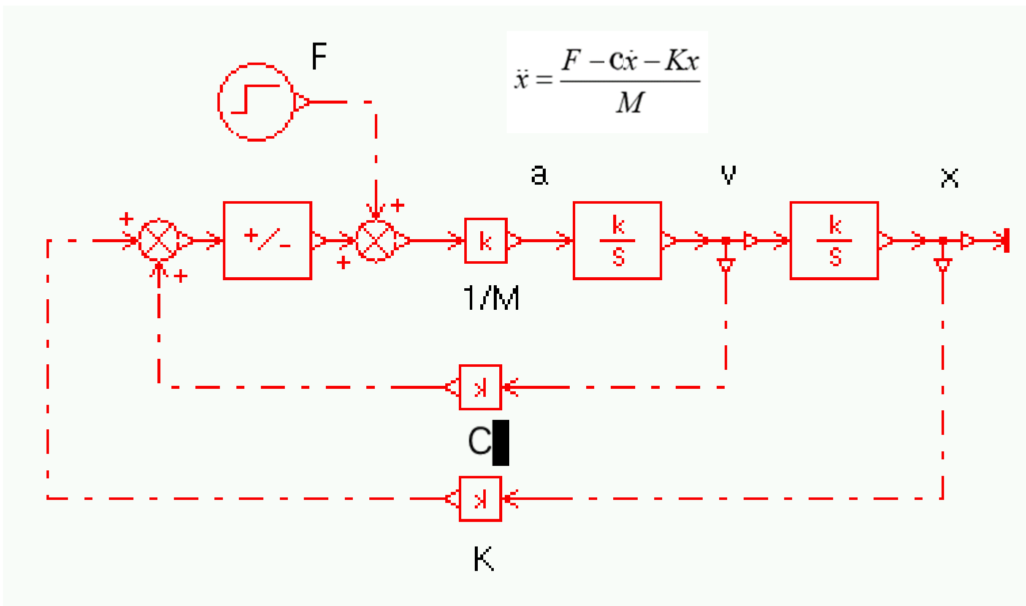
ICON	Description	Simulink
	상수 입력	
	y(output)=a*u(input), a : gain	
	적분기 : $y=\int u\,dt$, 미분기 : $y=\dfrac{du}{dt}$	
	사칙연산자 (곱하기, 나누기, 더하기, 빼기)	
	비교문 (and, or, less than, more than, equal)	
	입력신호 범위 제한	
	신호 → 벡터 합성, 벡터 → 신호 분해	
	table(1-D or 2-D)에 의해 정의	
	사용자가 지정한 함수	

SIGNAL, CONTROL



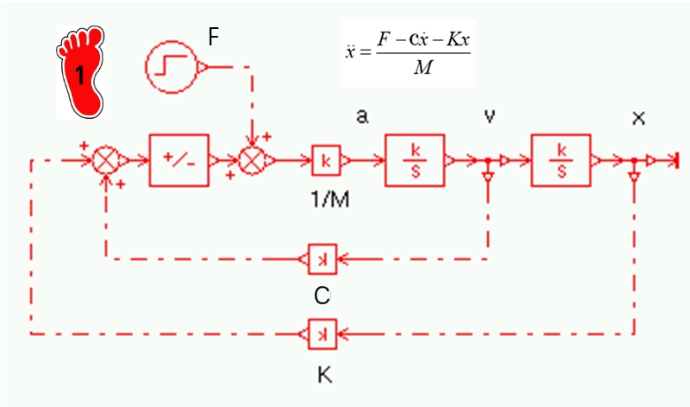
$$M\frac{d^2x}{dt}+c\frac{dx}{dt}+Kx=F(t)$$

$$\ddot{x}=\frac{F-c\dot{x}-Kx}{M}$$



Mass-Spring-Damper로 구성된 2차시스템 (1DOF)

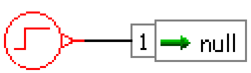
SIGNAL, CONTROL

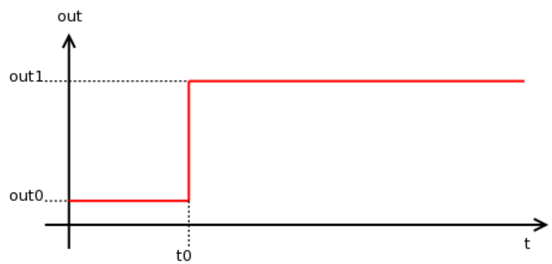


Parameter Values

M = 10 kg
c = 400 N/(m/s)
K = 100000 N/m

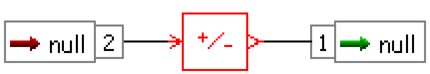
Step Input



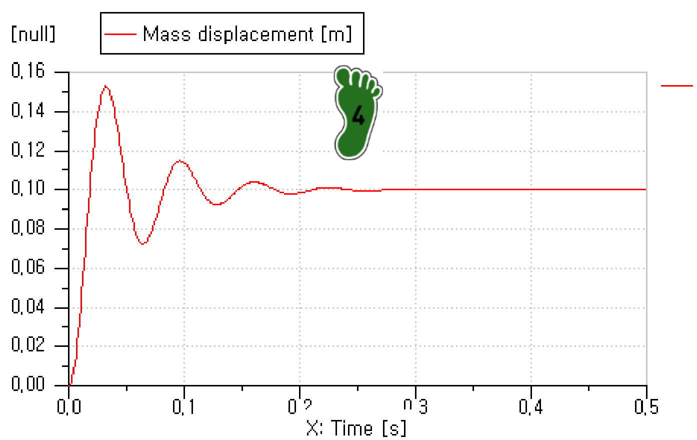


out0=0
out1=10000
t0=0

Reverse the sign

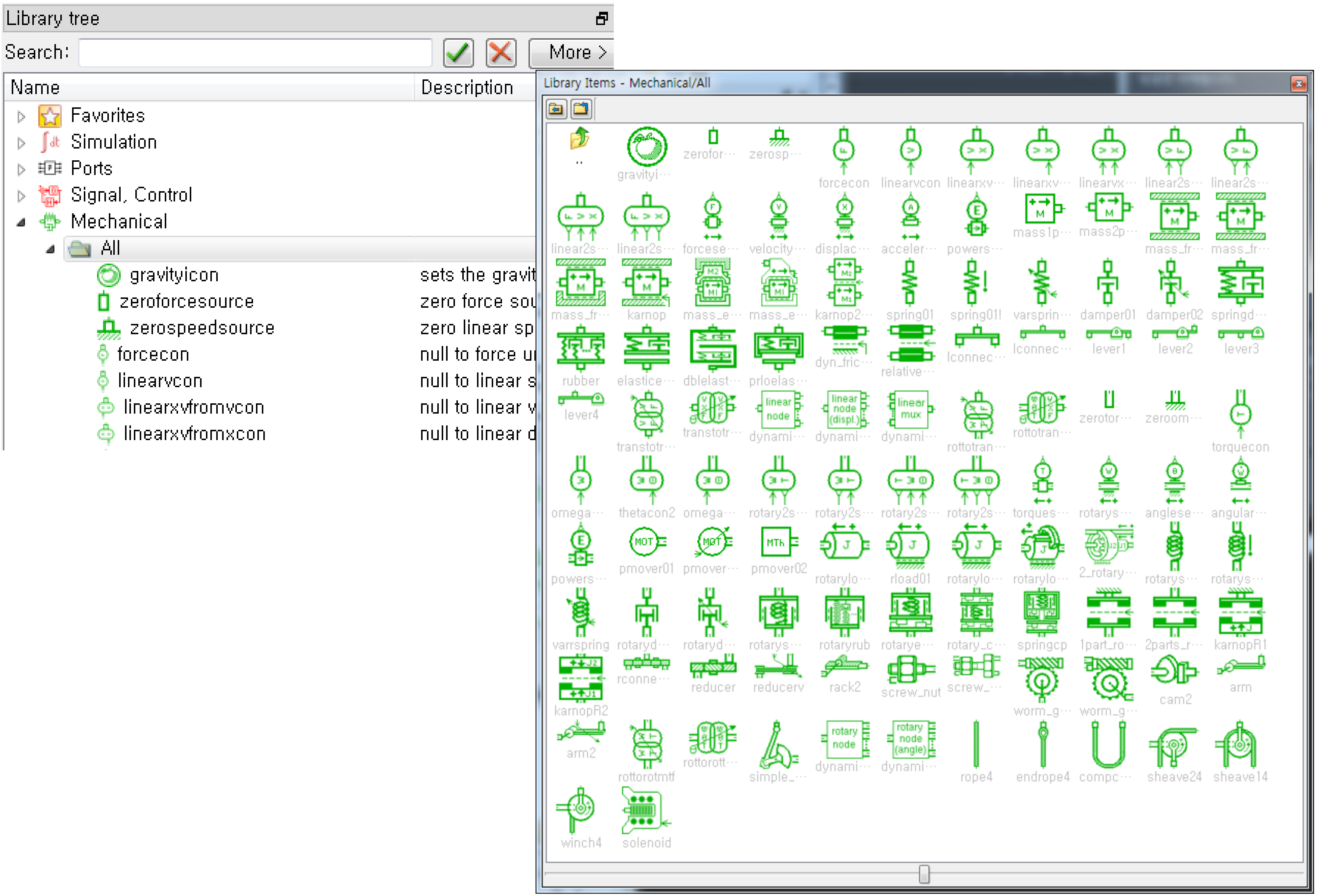


outp = -inp



1. Block Diagram 구성
2. Gain block에 Parameter값 입력
3. Step Input block에 값 입력
4. Run 및 결과 확인 (simulation time 0.5 s 로 set)

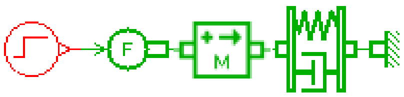
MECHANICAL BASIC



MECHANICAL BASIC

- Block Diagram 구성
- Parameter값 입력 (Force Input은 copy-paste)
- Run 및 결과 확인

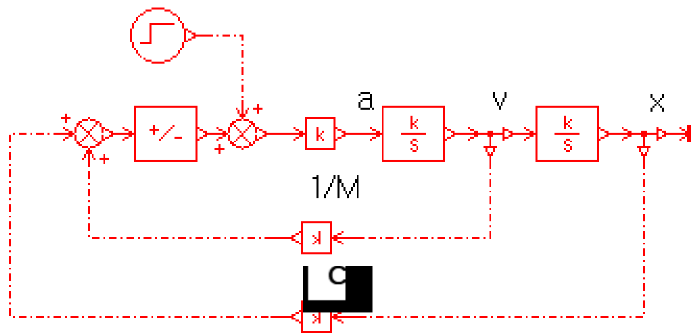
out0=0
out1=10000
t0=0



M = 10 kg

K = 100000 N/m

400 N/(m/s)



Mass Parameters

Parameters of mass_friction2port [MAS004-1]

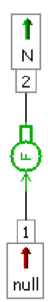
Title	Value	Unit
velocity at port 1	0	m/s
displacement port 1	0	m
mass	**10**	kg
coefficient of viscous friction	0	N/(r

Spring&Damper Parameters

Parameters of springdamper01 [SD0000A-1]

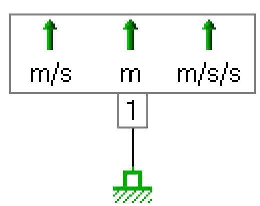
Title	Value	Unit	T
spring stiffness mode	numerical value		
spring force with both displace···	0	N	
spring rate	100000	N/m	
damper rating	**400**	N/(m/s)	

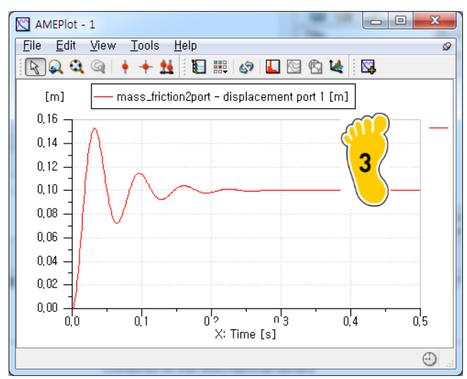
Force Input

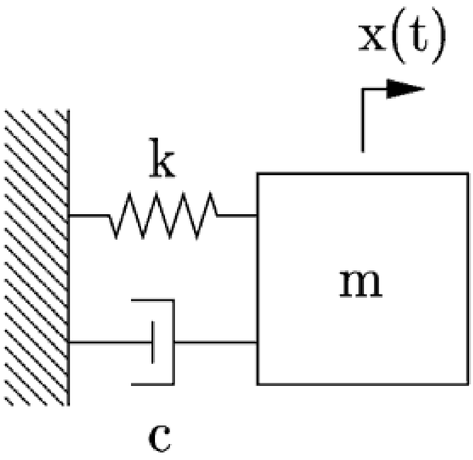


force = input

Zero speed







Simulink Example

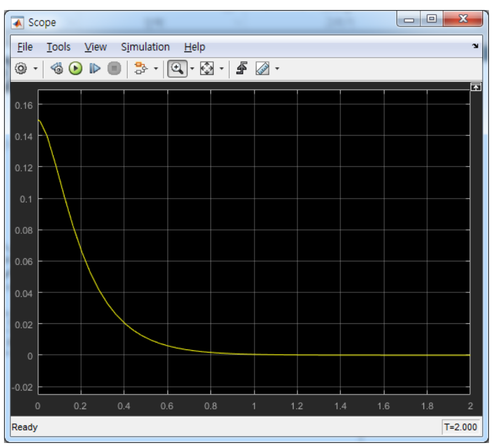
$$m\frac{d^2x}{dt}+c\frac{dx}{dt}+kx=F(t)$$

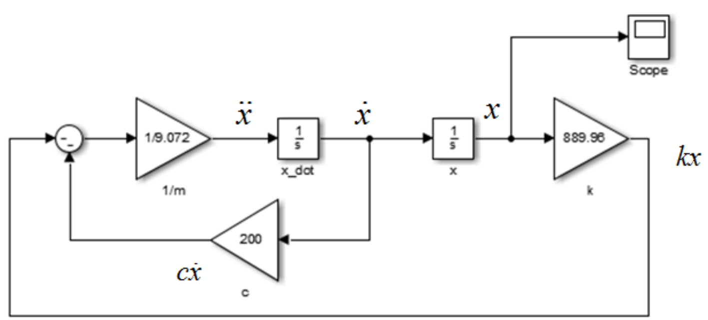
Simulink에서 수행한 Mass-Spring-Damper로 구성된 2차시스템을 Mechanical Component를 이용해 구현하여 이론해와 비교

m=9.072 kg , c=200 kg/s, k=889.96 N/m, y(0)=0.15 m

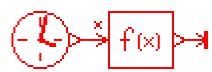
※ Analytic Sol.

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





MECHANICAL BASIC



Force Input Parameters

Parameters of step_2 [STEP0-2]

Title	Value	Unit
value before step	0	null
value after step	**0**	null
step time	0	s

Mass Parameters

Parameters of mass_friction2port [MAS004-1]

Title	Value	Unit
velocity at port 1	0	m/s
displacement port 1	**0.15**	m
mass	**9.072**	kg
coefficient of viscous friction	0	N/(m/s)
coefficient of windage	0	N/(m/s)**2
Coulomb friction force	0	N

Spring&Damper Parameters

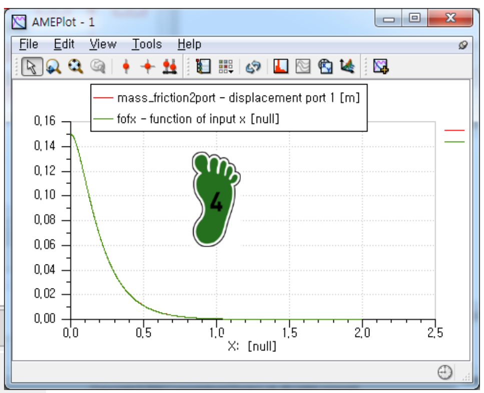
Parameters of springdamper01 [SD0000A-1]

Title	Value	Unit
spring stiffness mode	numerical value	
spring force with both displace…	0	N
spring rate	**889.96**	N/m
damper rating	**200**	N/(m/s)

Function Output Parameter

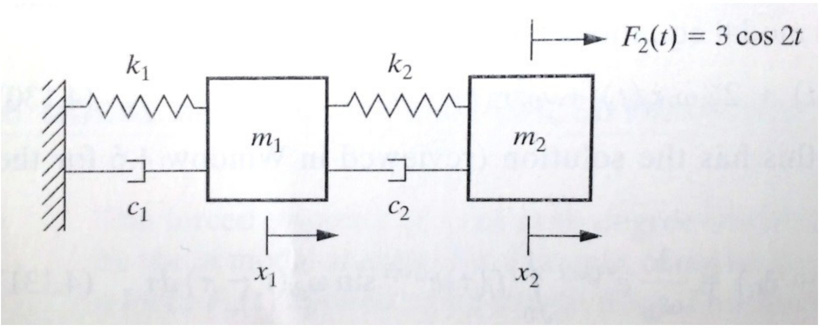
Parameters of fofx [FX00-1]

Title	Value
expression in…	**0.2463*exp(-6.19*x)-0.0963*exp(-15.83*x)**

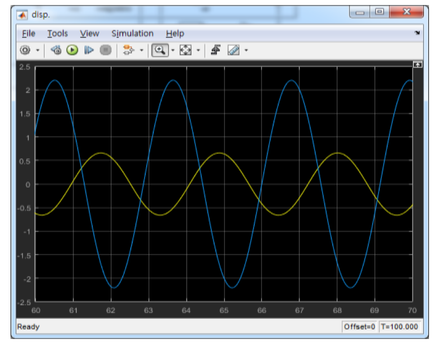


1. Mec. Model은 그대로 사용, Analytic Sol. 모델 구성
2. Mec. Model Parameter 값 입력
3. Signal Function Block에 Analytic sol. 수식 입력
4. Run 및 결과 확인 (겹쳐서 plot)

2-DOF system (Simulink Case Study)

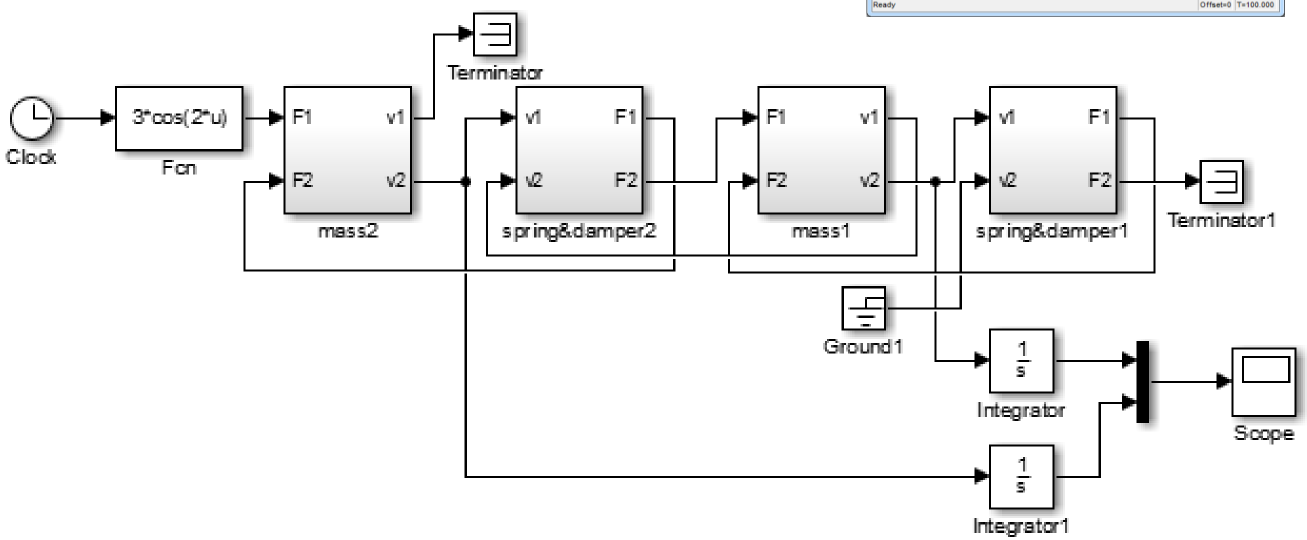


$$m_1 = 9\,\text{kg}, m_2 = 1\,\text{kg}$$
$$k_1 = 24\,\text{N/m}, k_2 = 3\,\text{N/m}$$
$$c_1 = 2.4\,\text{Ns/m}, c_2 = 0.3\,\text{Ns/m}$$
$$F_2(t) = 3\cos 2t$$

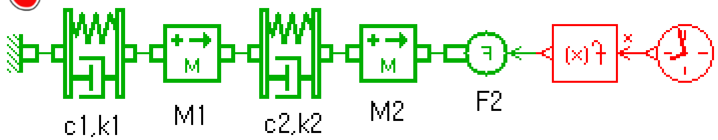


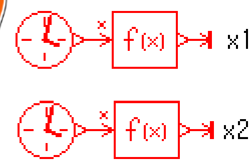
※ Analytic Solution (Steady State)

$$x_1(t) = 0.2451\cos(2t - 0.1974) - 0.6249\sin 2t$$
$$x_2(t) = 0.7354\cos(2t - 0.1974) + 1.8749\sin 2t$$



Simulink에서 수행한 Mass-Spring-Damper로 구성된 2 자유도 시스템을 Mechanical Component를 이용해 구현하여 이론해와 비교





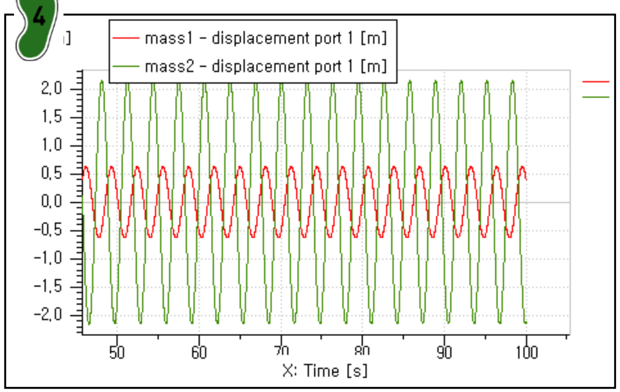
1. 2-DOF Mec. System 구성
2. Analytic sol. function 구성
3. 각 block에 알맞은 parameter 값 입력
4. Run 및 결과 확인

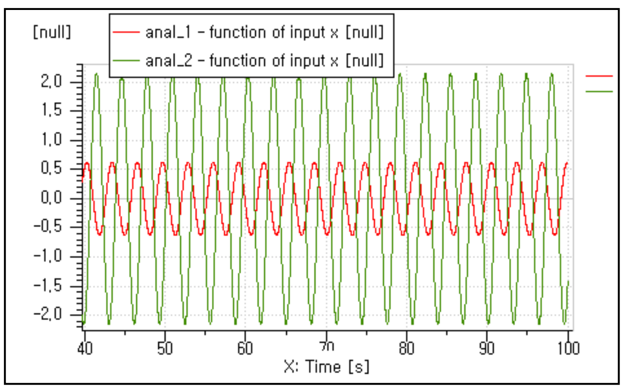
Parameter Set (Mechanical)

$$m_1 = 9\,\text{kg}, m_2 = 1\,\text{kg}$$
$$k_1 = 24\,\text{N/m}, k_2 = 3\,\text{N/m}$$
$$c_1 = 2.4\,\text{Ns/m}, c_2 = 0.3\,\text{Ns/m}$$
$$F_2(t) = 3\cos 2t$$

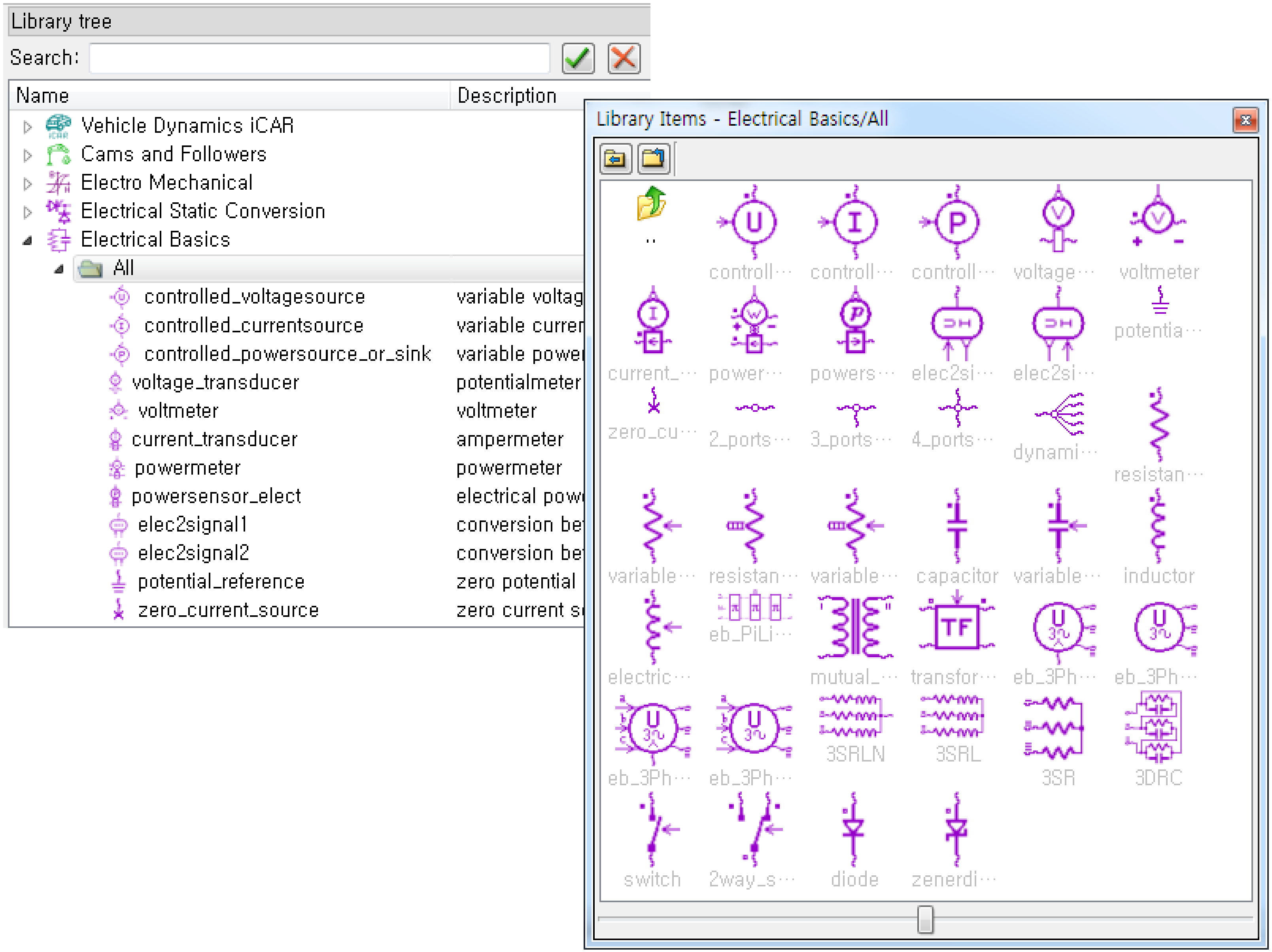
Parameter Set (Analytic)

$$x_1(t) = 0.2451\cos(2t - 0.1974) - 0.6249\sin 2t$$
$$x_2(t) = 0.7354\cos(2t - 0.1974) + 1.8749\sin 2t$$



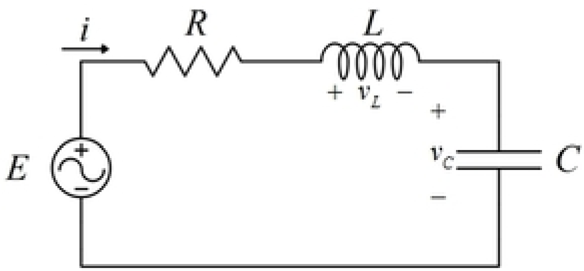


ELECTRICAL BASIC



RLC 회로 시스템 예제 (1DOF)

RLC circuit

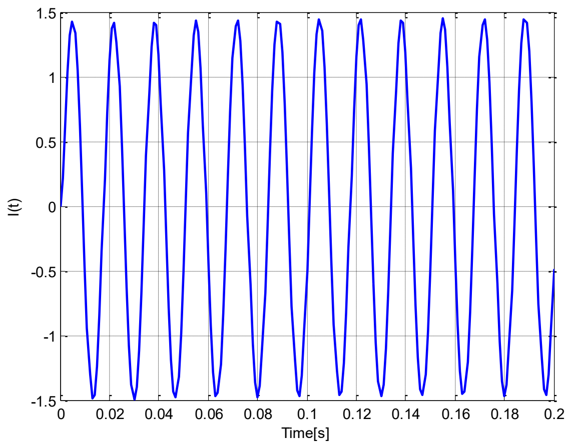


$$L\frac{dI}{dt}+RI+\frac{1}{C}\int I\,dt=E(t)$$

R=100 ohm, L=0.1 H, C=0.01 F, E(t)=155sin377t V

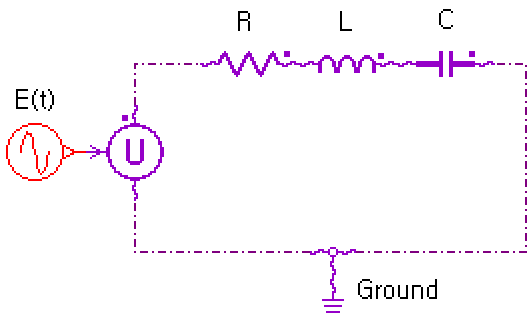
※ Analytic Sol.

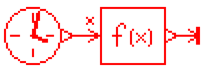
$$I(t)=-0.042e^{-10t}+0.526e^{-990t}-0.484\cos 377t+1.380\sin 377t$$



Time =[0,2]

ELECTRICAL BASIC





1. RLC circuit 모델 구성, Analytic Sol. 모델 구성
2. Circuit Model Parameter 값 입력
3. Signal Function Block에 Analytic sol. 수식 입력
4. Run 및 결과 확인 (겹쳐서 plot)

Voltage Input Parameters

Parameters of signal01 [SIN0-1]

Title	Value	Unit
sine wave frequency	377	rad/s
mean level	0	null
sine wave amplitude	155	null
phase shift	0	degree

Function Output Parameter

Parameters of fofx [FX00-1]

Title	Value	Unit
expression···	-0.042*exp(-10*x)+0.526*exp(-990*x)-0.484*cos(377*x)+1.38*sin(377*x)	

RLC Parameters

Parameters of resistance [EBR03-1]

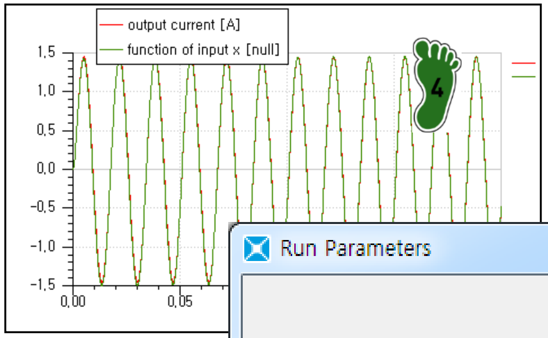
Title	Value	Unit
type of refe···	···e user	
resistance	100	Ohm

Parameters of inductor [EBL01-1]

Title	Value	Unit
output c···	0	A
inductance	0.1	H

Parameters of capacitor [EBC02-1]

Title	Value	Unit
output v···	0	V
capacitance	0.01	F

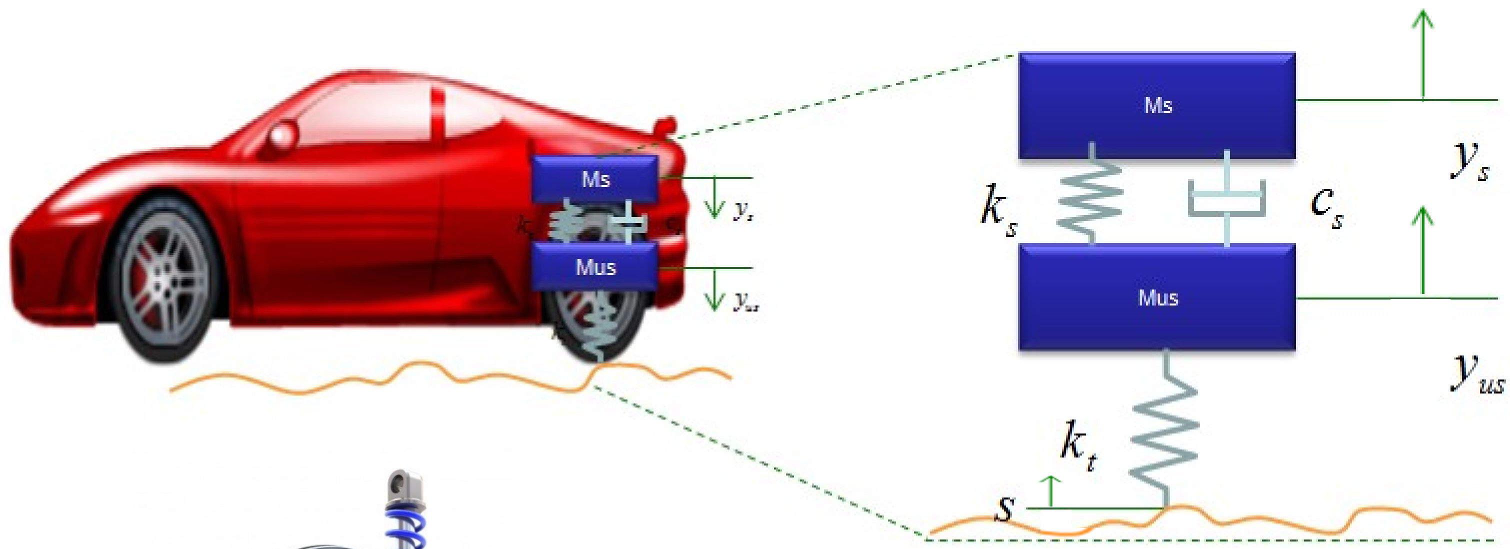


Run Parameters

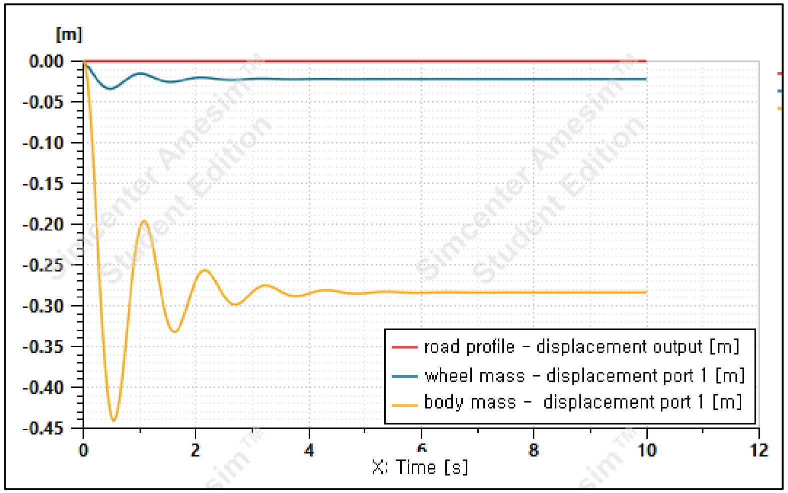
General | Standard options

Parameter	Value	Unit
Start time	0	seconds
Final time	0.2	seconds
Print interval	0.0001	seconds

QUARTER CAR MODEL



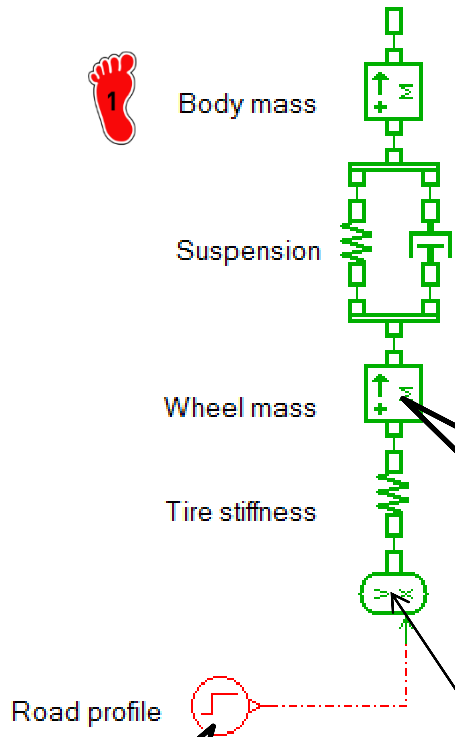
$$m_s \ddot{y}_s = -k_s (y_s - y_{us}) - c_s (\dot{y}_s - \dot{y}_{us})$$
$$m_{us} \ddot{y}_{us} = k_s (y_s - y_{us}) + c_s (\dot{y}_s - \dot{y}_{us}) + k_t (s - y_{us})$$



Flat road profile simulation

QUARTER CAR MODEL

QUARTER CAR



$$m_{body} = 400\,\text{kg}$$

$$k_{sus} = 15000\,\text{N/m},\ c_{sus} = 1000\,\text{Ns/m}$$

$$m_{wheel} = 50\,\text{kg},\ k_{tire} = 200000\,\text{N/m}$$

Parameters of mass2port_2 [MAS002-2]

Title	Value	Unit
velocity at port 1	0	m/s
displacement port 1	0	m
mass	50	kg
inclination (+90 port 1 lowest, -90 port 1 highest)	-90	degree

accel = der(va) = (fb – fa – 9,81 . mass .sin(theta)) / mass

der(x) = va

conversion of signal to displacement

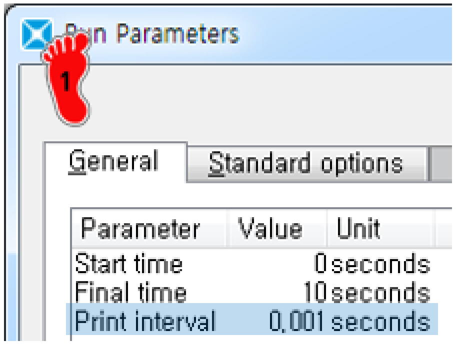
$$a = \frac{dv}{dt} = \frac{F_b - F_a - mg\sin\theta}{m}$$

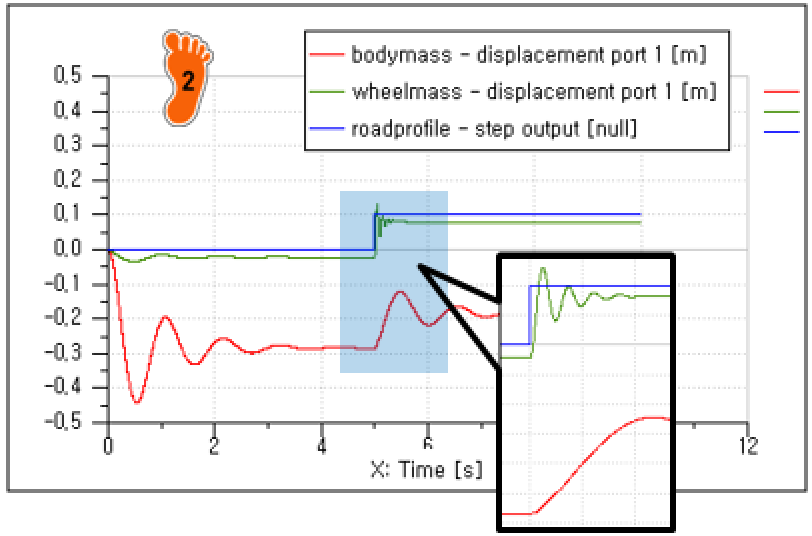
Parameters of step [STEP0-1]

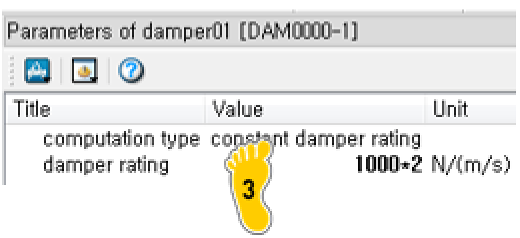
Title	Value	Unit
value before step	0	null
value after step	0.1	null
step time	5	s

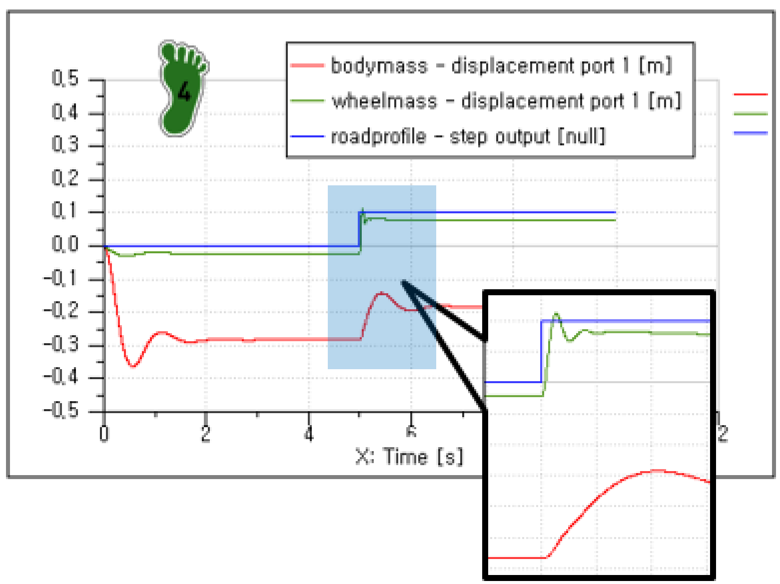
1. Quarter Car model 구성
2. Model Parameter 값 입력
3. body mass와 wheel mass에 중력효과 입력
4. step function parameter 입력

QUARTER CAR MODEL







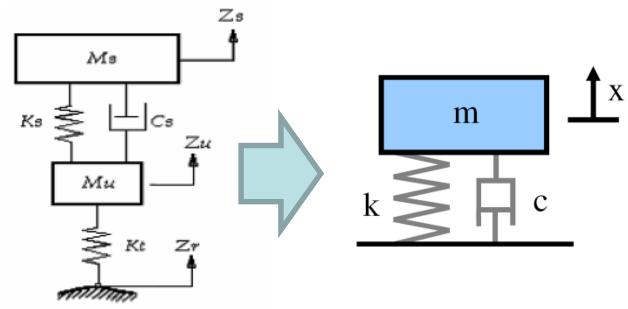


1. Run Parameters에서 Print interval 0.001로 set
2. Run 및 body, wheel, road 변위 확인
3. suspension damper rating 을 2배로 증가
4. Run 및 결과 확인

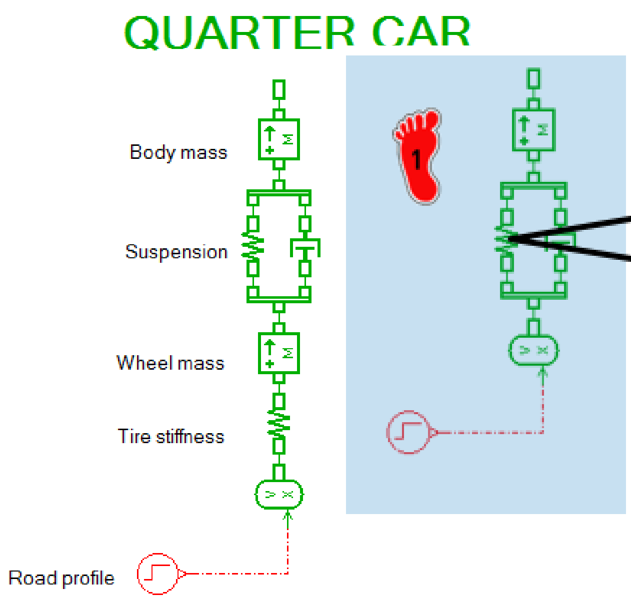
QUARTER CAR MODEL

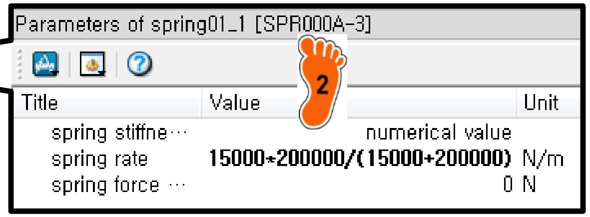
$$k_{sus} << k_{tire}$$

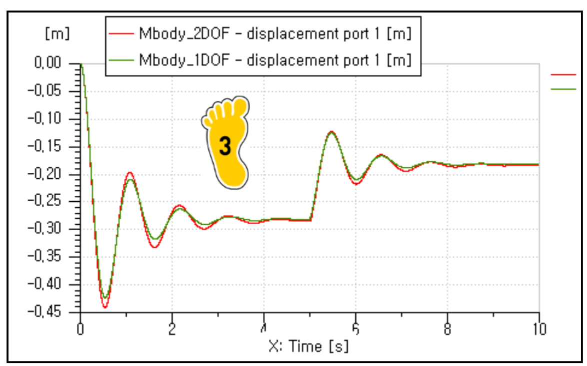
$$k_{eq} = \frac{1}{1/k_{sus} + 1/k_{tire}} = \frac{k_{sus}k_{tire}}{k_{sus} + k_{tire}}$$



1. 1-DOF 모델 구성
2. Spring rate에 등가강성 값 입력
3. Run 및 두 모델의 body mass의 변위 값 비교
4.

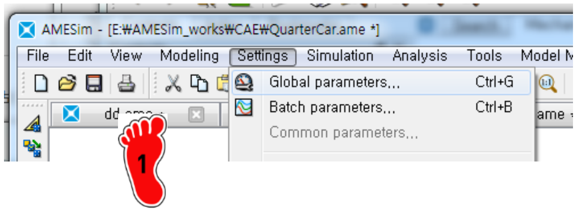


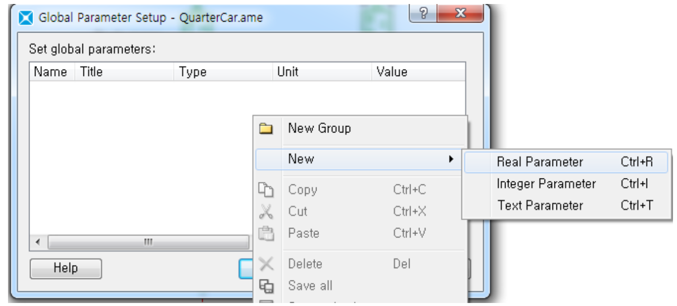


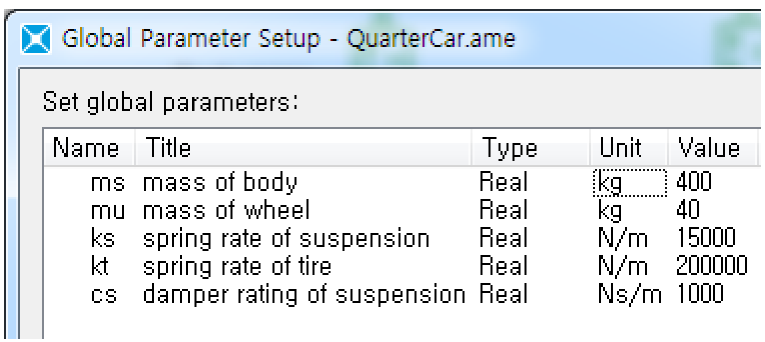


QUARTER CAR MODEL

Parameter Setting



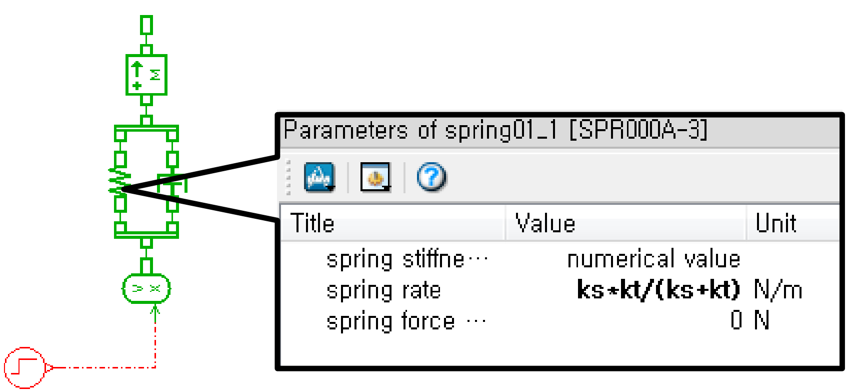




Global Parameter Setup - QuarterCar.ame

Set global parameters:

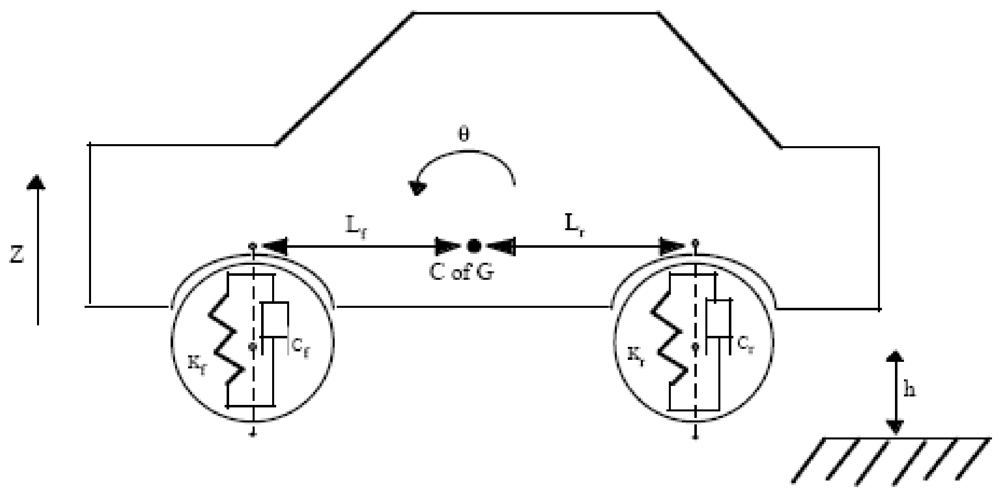
Name	Title	Type	Unit	Value
ms	mass of body	Real	kg	400
mu	mass of wheel	Real	kg	40
ks	spring rate of suspension	Real	N/m	15000
kt	spring rate of tire	Real	N/m	200000
cs	damper rating of suspension	Real	Ns/m	1000



1. settings->Global parameters 메뉴 클릭
2. 화면에서 오른쪽 클릭, New->Real Parameter 클릭
3. parameter 이름과 value 입력(title, type, unit는 옵션) 입력 후 'ok'버튼 클릭
4. 각 컴포넌트에 parameter 이름 입력 후 결과 확인

CASE STUDY

Half Car Model



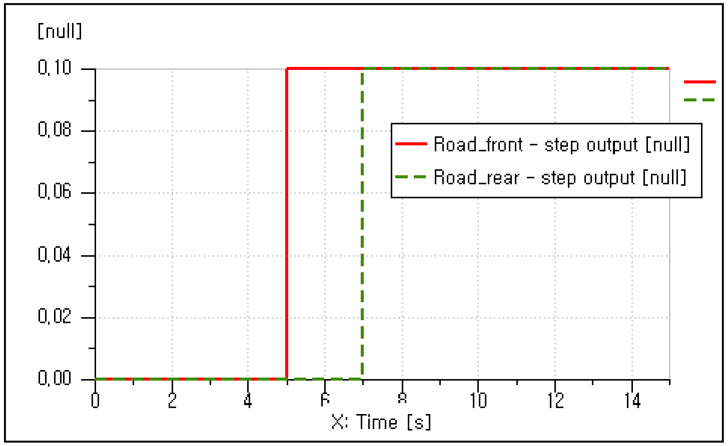
$$J_p = 2000\,\mathrm{kg\,m^2}$$

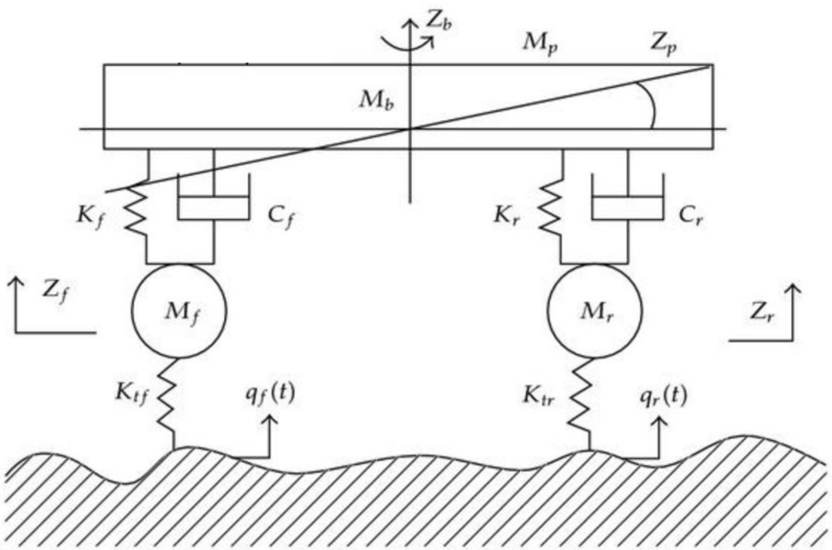
$$L_f = 1.2\,\mathrm{m},\ L_r = 1.5\,\mathrm{m}$$

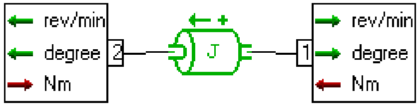
$$k_f = 15000\,\mathrm{N/m},\ c_f = 1000\,\mathrm{Ns/m}$$

$$k_f = 20000\,\mathrm{N/m},\ c_f = 1500\,\mathrm{Ns/m}$$

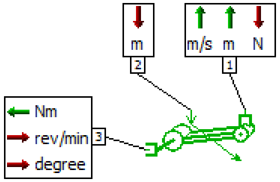
$$m_{wheel} = 50\,\mathrm{kg},\ k_{tire} = 200000\,\mathrm{N/m}$$





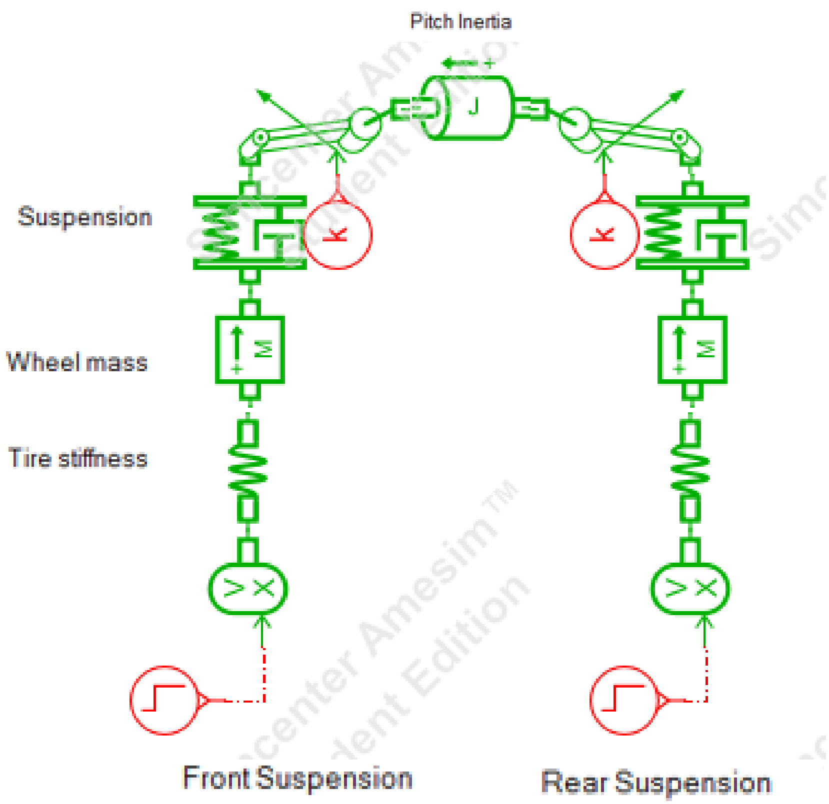


rotary inertia



mechanical arm

CASE STUDY SOLUTION



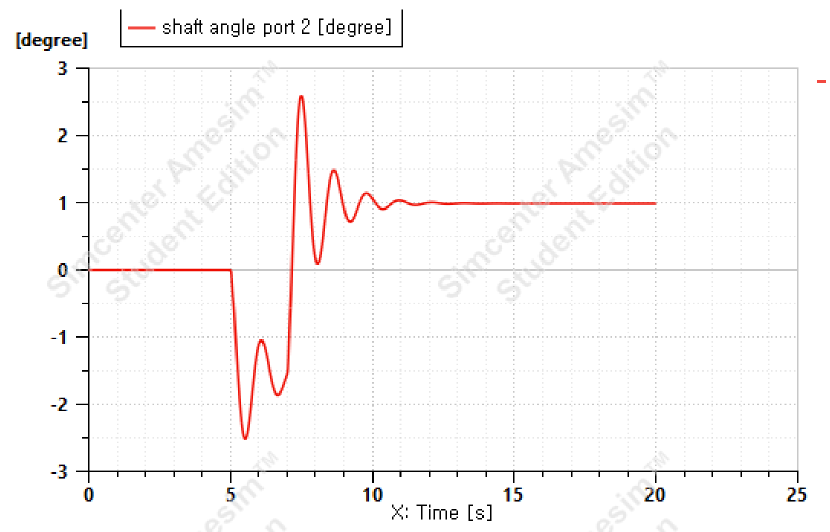
$$J_p = 2000\,\text{kg m}^2$$

$$L_f = 1.2\,\text{m},\; L_r = 1.5\,\text{m}$$

$$k_f = 15000\,\text{N/m},\; c_f = 1000\,\text{Ns/m}$$

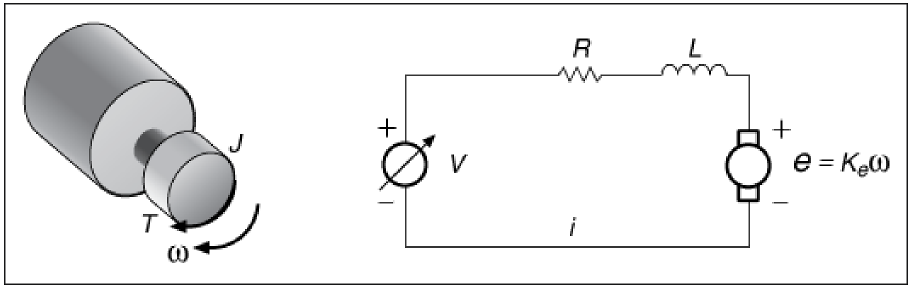
$$k_f = 20000\,\text{N/m},\; c_f = 1500\,\text{Ns/m}$$

$$m_{wheel} = 50\,\text{kg},\; k_{tire} = 200000\,\text{N/m}$$



ASSIGNMENT

The following figure shows an electrical circuit model of a brushed direct current (DC) servomotor.



where V is the source voltage of the DC power supply.

R is the resistance of the DC servomotor armature circuit.

L is the inductance of the DC servomotor armature circuit.

i is the circuit armature current.

ω is the shaft speed of the DC servomotor.

T is the torque of the DC servomotor.

V=100, R=20, L=0.1
J=1, b=0
Kt=200, Ke=0.18

In this dynamic system, the source voltage, V, is the input and the DC servomotor shaft speed, ω, is the output.

According to Faraday's Law of electromagnetic induction, the circuit armature current i, motor torque T, motor shaft velo and motor back-EMF voltage e, have the following relationship:

$$T = K_t i$$
$$e = K_e \omega$$

where K_t is an electromotive force constant.

K_e is a motor back-EMF constant.

You can obtain the following equations by using Newton's Law and Kirchhoff's Law.

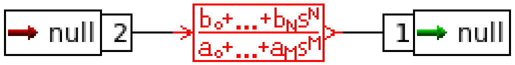
$$J\frac{d\omega}{dt} + b\omega = K_t i$$
$$L\frac{di}{dt} + Ri = V - K_e \omega$$

where J is the moment of inertia of the rotor.

b is the damping ratio of the mechanical part of the DC servomotor.

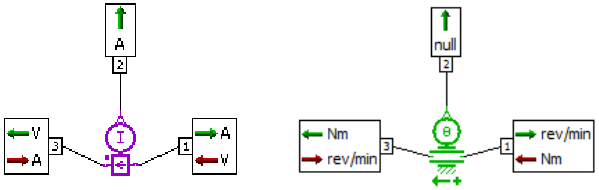
※ Transfer Function
(Ref. : System Dynamics - Chapter 6.5)

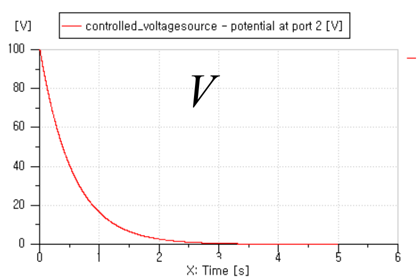
$$\frac{\theta(s)}{V(s)} = \frac{K_t}{s[LJs^2 + (Lb + RJ)s + Rb + K_t K_e]}$$

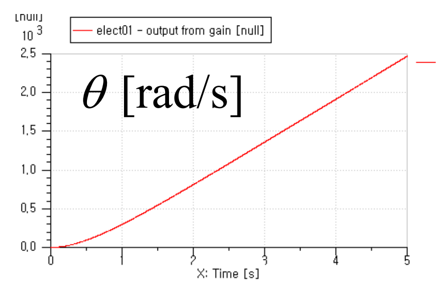
V  θ [rad/s]

$$\frac{output}{input} = \frac{B(s)}{A(s)} = \frac{B_0 + B_1 s + B_2 s^2 + \ldots + B_N s^N}{A_0 + A_1 s + A_2 s^2 + \ldots + A_M s^M}$$

θ [deg]







Ref. : LabVIEW 2013 System Identification Toolkit Help, Part Number : 372458D-01