AMESim 기초
Quarter Car Modeling

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CDL Computational Design Lab

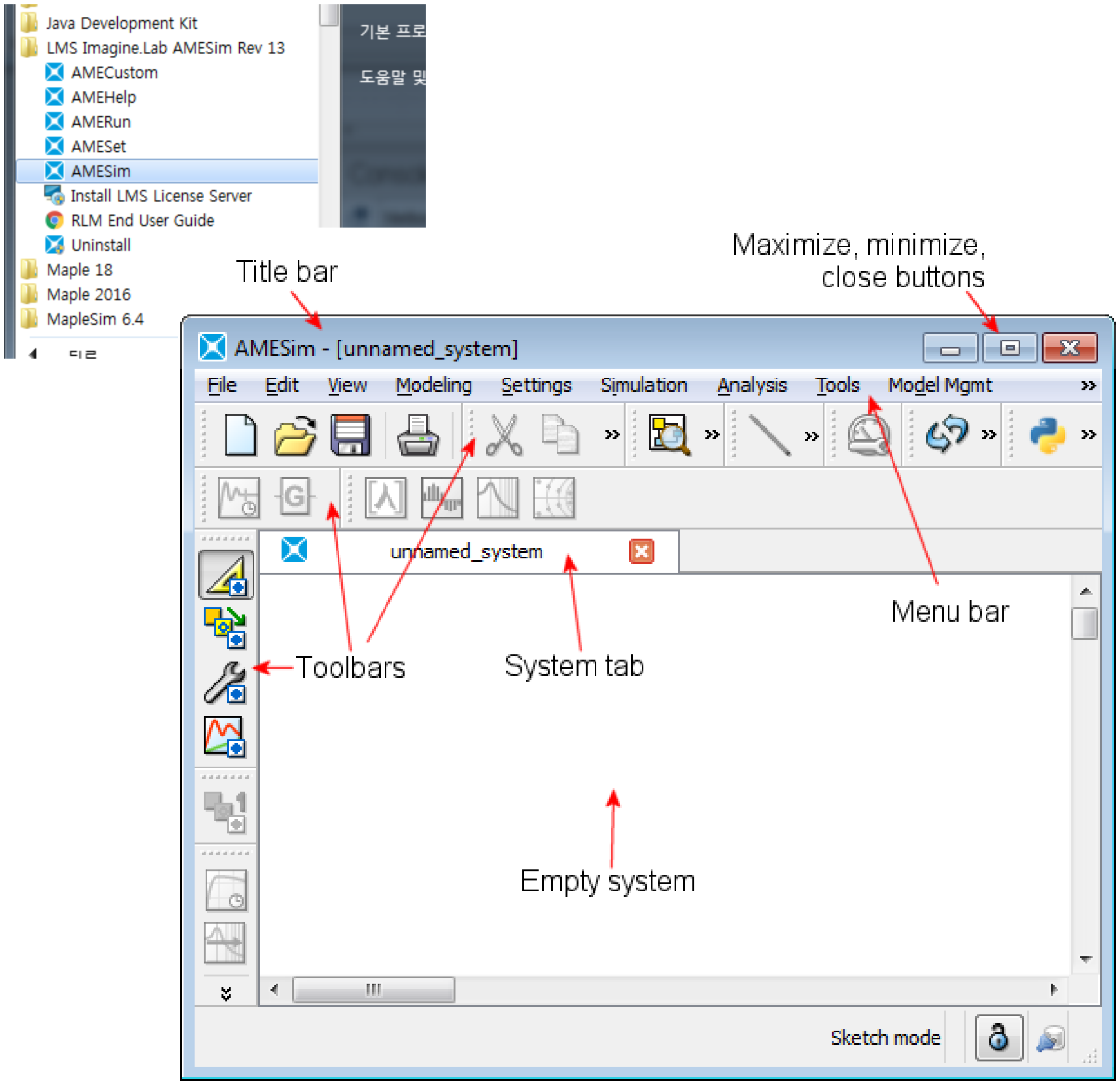
CONTENTS

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

1 시작메뉴에서 'AMESim' 클릭



The File toolbar

Figure 2.6:The File toolbar

The *File* toolbar gives you access to four basic functions

	Start a new system in order to build a sketch.
	Open an existing system in order to modify or to complete it.
	Save your system.
	Print your system

The Edit toolbar

Figure 2.7: The Edit toolbar

	The *Cut* button allows you to cut the selected objects and to copy them into the current system, into another one or into an auxiliary system.
	The *Copy* button allows you to copy the selected objects to paste them into the current system or into another one.
	The *Paste* button allows you to paste the objects you have cut or copied in the current system or into another one.
	The *Delete* button allows you to delete the selected objects. Be careful with this option, you cannot recuperate deleted objects.
	The *Create supercomponent* button allows you to copy the selected objects to an *Auxiliary system* window in which you can create a supercomponent from them.
	The *Undo* button allows you to undo the last action performed.
	The *Redo* button allows you to repeat the last action performed.
	The *Find* button opens the Find dialog box with which you can search for a component in the sketch.

The Modes toolbar

Figure 2.8: The Modes Toolbar

The *Modes* toolbar changes depending on the mode you are working in. The available features of each mode are different.

	In *Sketch* mode, you can build your sketch using the components that are available in the categories. The categories are displayed in a vertical toolbar on the left of the main window of **AMESim**.
	In *Submodel* mode, you can choose the submodels you want to attach to each component.
	In *Parameter* mode, you can set the parameters of the submodels. You can save the parameters from one submodel to use them for another submodel. In this case, **AMESim** will load only the common parameters.
	Simulation mode enables you to run a simulation and to analyze the results of the simulation.

The Simulation toolbar

Figure 2.9: The Simulation toolbar

The *Simulation* toolbar gives you access to the options you require for running a simulation and analyzing the results.

	The *Temporal Analysis* button is selected by default.
	The *Linear Analysis* button enables a new toolbar to set up the linear analysis process.
	Run Parameters displays a dialog box in which you can set the parameters of the simulation.
	Click on this button to start the simulation run. At the end of the simulation, a window displays the details of the run. This information is important if you need to find out why a simulation has failed.
	The *Stop* button stops a running simulation.

AMESIM ENVIRONMENT

The standard library

AMESim is delivered with a standard library consisting of three categories:

	Simulation: contains components for analyzing statistics of runs, setting simulation parameters, print intervals, interactive components and for 3D models.
	Signal, Control: contains all the components necessary to control, measure and observe your system. The *Signal, Control* category may be used to create block-diagram models of systems.
	Mechanical: complements other AMESim libraries. The *Mechanical* category is often used in isolation to simulate complete mechanical systems. Linear and rotary motion elements are included.

The extra libraries

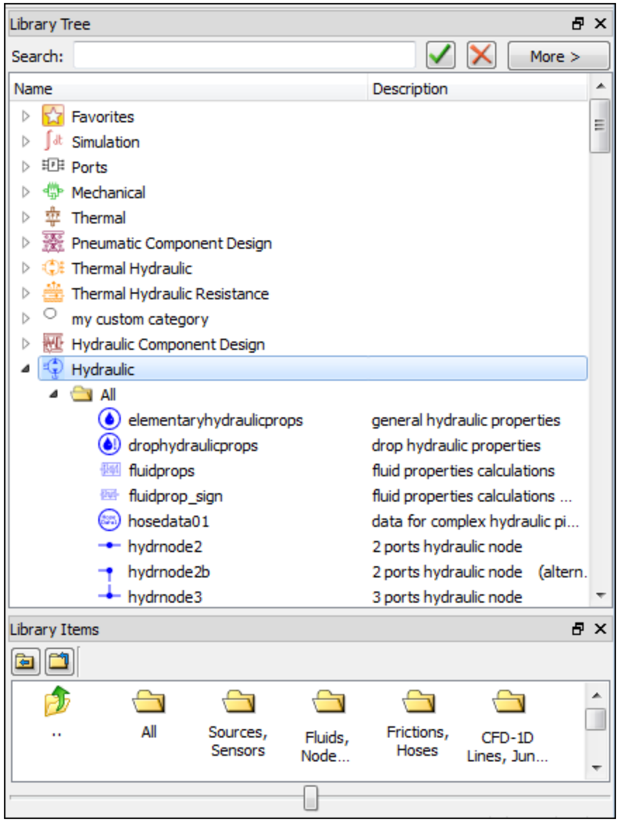
You can complete the basic application with the following categories. The categories are available in the menu **Modeling > Category path list**. When the *Path List* dialog box opens, you can select the categories you want to add to the path list from the available category list. Then the category bar is updated and displays the available categories. You can display the category bar on the right, on the left or on the top of the AMESim interface at your convenience.

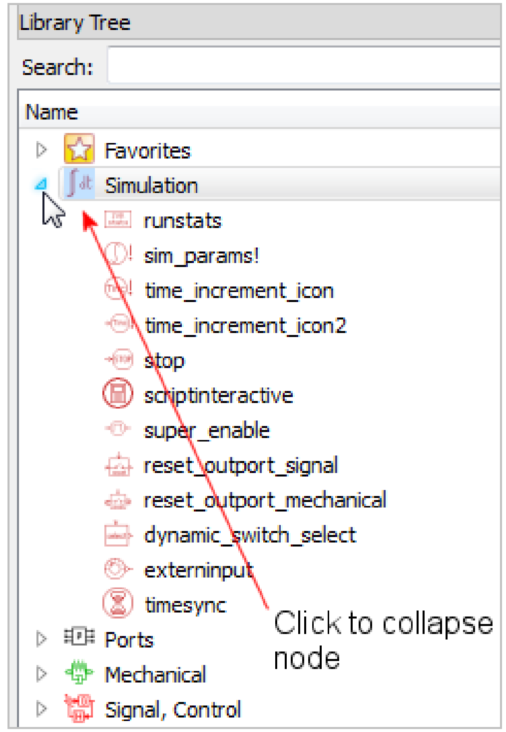
You will find further details in the user manual of each category.

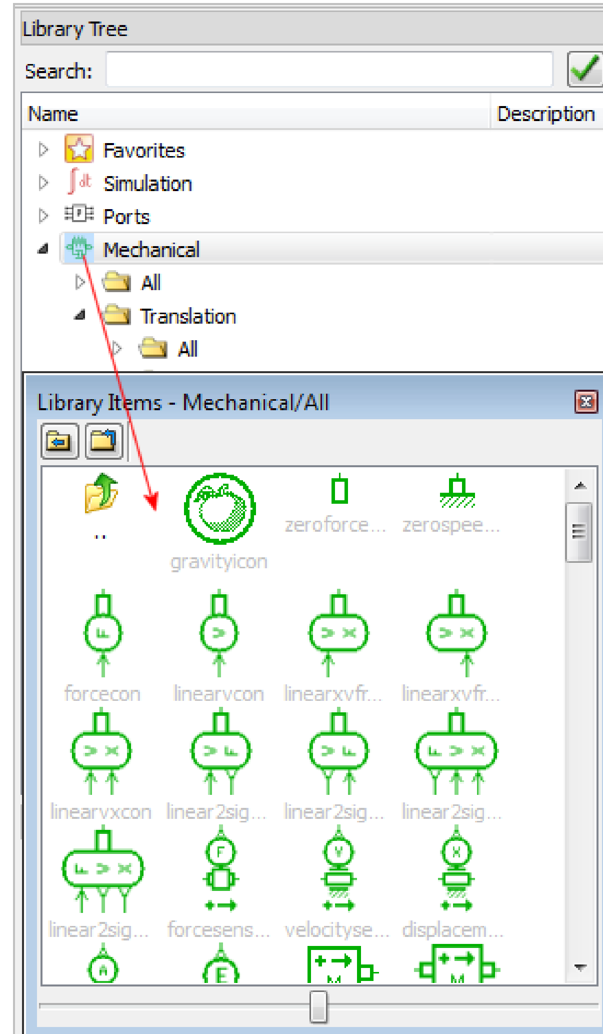
	Air Conditioning: used to model steady state and dynamic behavior of air conditioning systems.
	Aeronautics and Space: used to provide flight mission definition, atmosphere models, sensors and power generation models for assessing system performance in realistic conditions.
	Aircraft Electrics: used to model aerospace electrical systems.
	Aircraft Fuel System: a basic set of components dedicated to fuel system applications.
	Automotive Electrics: used to model automotive electrical components.
	Cam and Followers: used to model cams and followers.
	CFD1D: used to simulate gas flows in pipes and networks.
	Cooling System: allows you to combine models for the cooling system, lubrication system, and exhaust system to study the complete thermal behavior of an engine.
	Discrete Partitioning: used to divide big hydraulic systems into smaller sub-systems. This makes it possible to run a simulation as a form of co-simulation, improving simulation times.
	Electric Motors and Drive: used to model electric parts of the car which replace mechanical and hydraulic actuation.
	Electrical Storage: contains detailed dynamic models of electric storage systems, enabling the representation of high frequency phenomena.
	Electrical Basics: contains the elements that cover basic needs for electrical components.
	Electrical Static Conversion: contains the elements that cover power electronics components for electrical motors.

	IFP Exhaust: used to model exhaust systems, and study fuel consumption and emissions of vehicles.
	Moist Air: contains a set of thermal-pneumatic and thermal-hydraulic components for modeling systems dealing with moist air.
	Planar Mechanical: used to model dynamics of bodies in two dimensions.
	Pneumatic: contains component level models to model large networks, and basic elements to design complex pneumatic components.
	Pneumatic Component Design: contains the basic building blocks of any pneumatic-mechanical system. The interpretation of the model layout is very easy and intuitive.
	Powertrain: used to model systems such as driveline or complete manual, automatic or specialized gearboxes, including vibration and loss effects.
	Thermal: used to model traditional heat transfer modes between solid materials and to study the thermal evolution in these solids when submitted to different kinds of heat sources.
	Thermal Hydraulic: used to model thermal phenomena in liquids and to study the thermal evolution in these liquids when submitted to different kinds of heat sources and power sources.
	Thermal Hydraulic Component Design: used to study the pressure levels, the flow rates distribution, the temperatures and the flow rates evolution in the system.
	Two-Phase Flow: used for modeling thermo-hydraulic systems where there is a change of phase (liquid-vapor).
	Vehicle Dynamics: is dedicated to ECU design, testing, robustness and fault diagnostics, ride and handling, behavior related to steering systems, behavior related to braking, and pre-sizing of vehicles.
	Vehicle Dynamics iCAR: is dedicated to chassis and subsystem specification, design and validation.

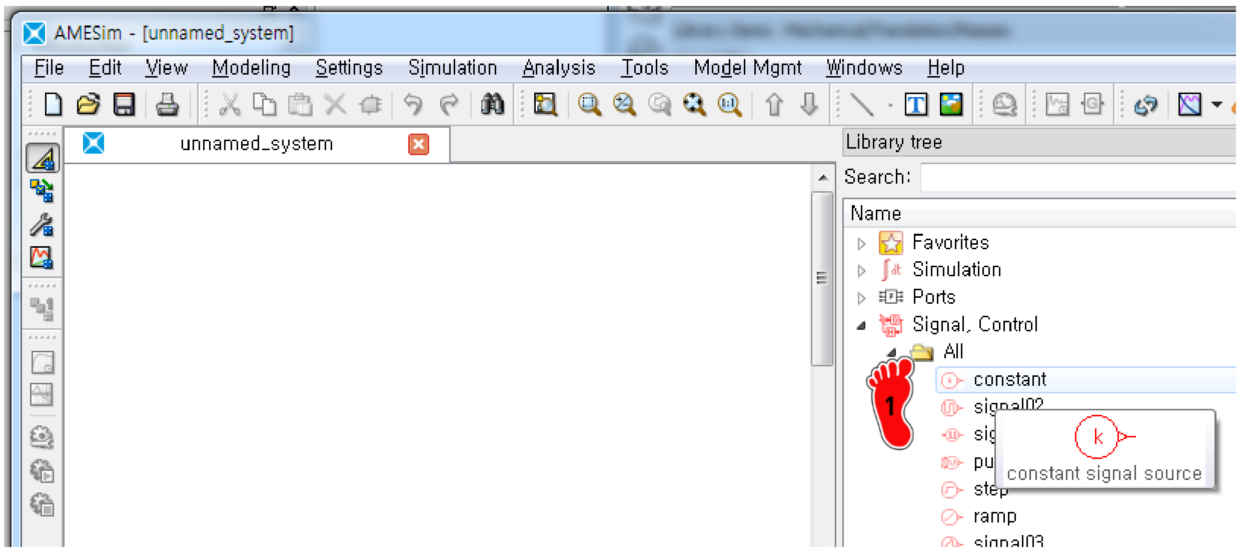
AMESIM ENVIRONMENT

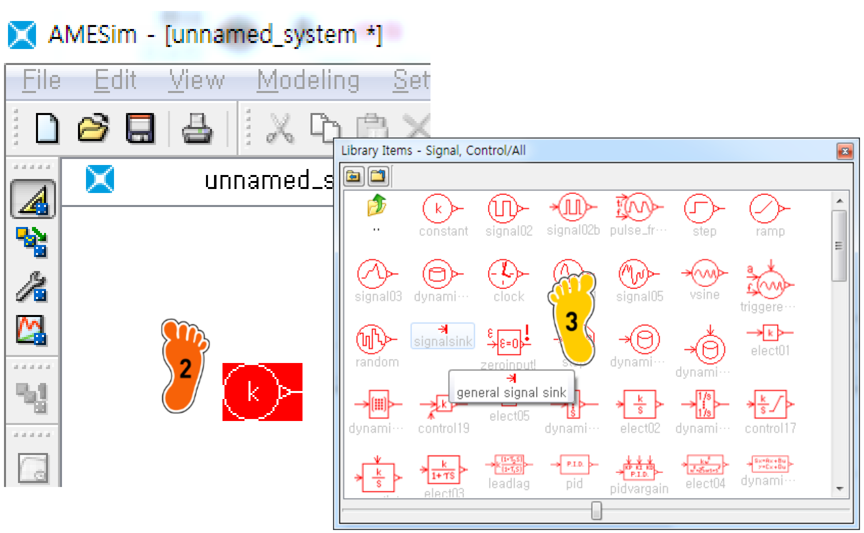


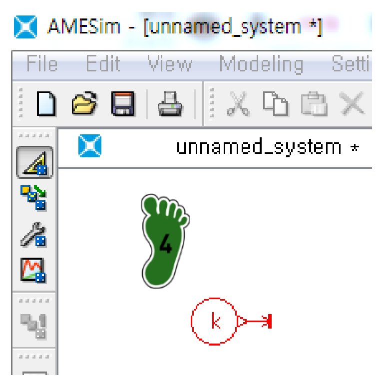




AMESIM ENVIRONMENT

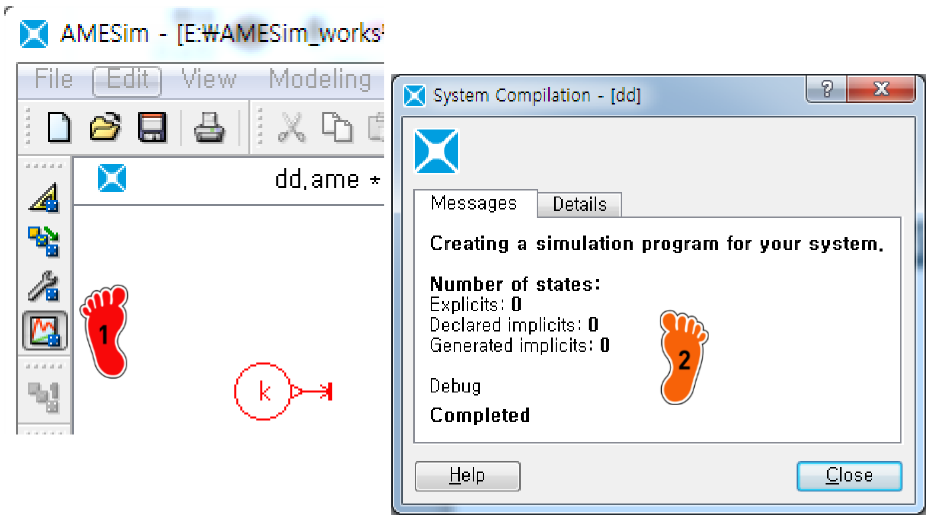


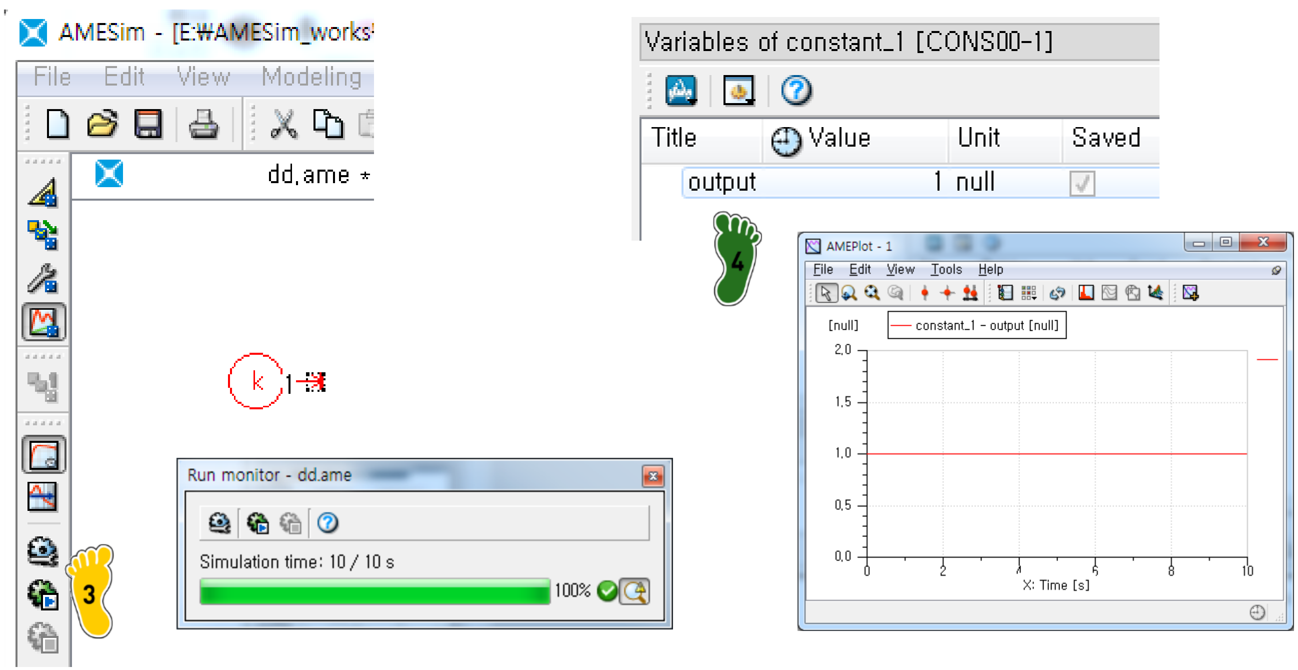




1. Library tree에서 signal, control 클릭
2. Constant block을 drag&drop 또는 클릭 → 스케치 화면에 다시 클릭
3. Signal Library에서 signalsink를 클릭
4. Constant block 옆에 연결

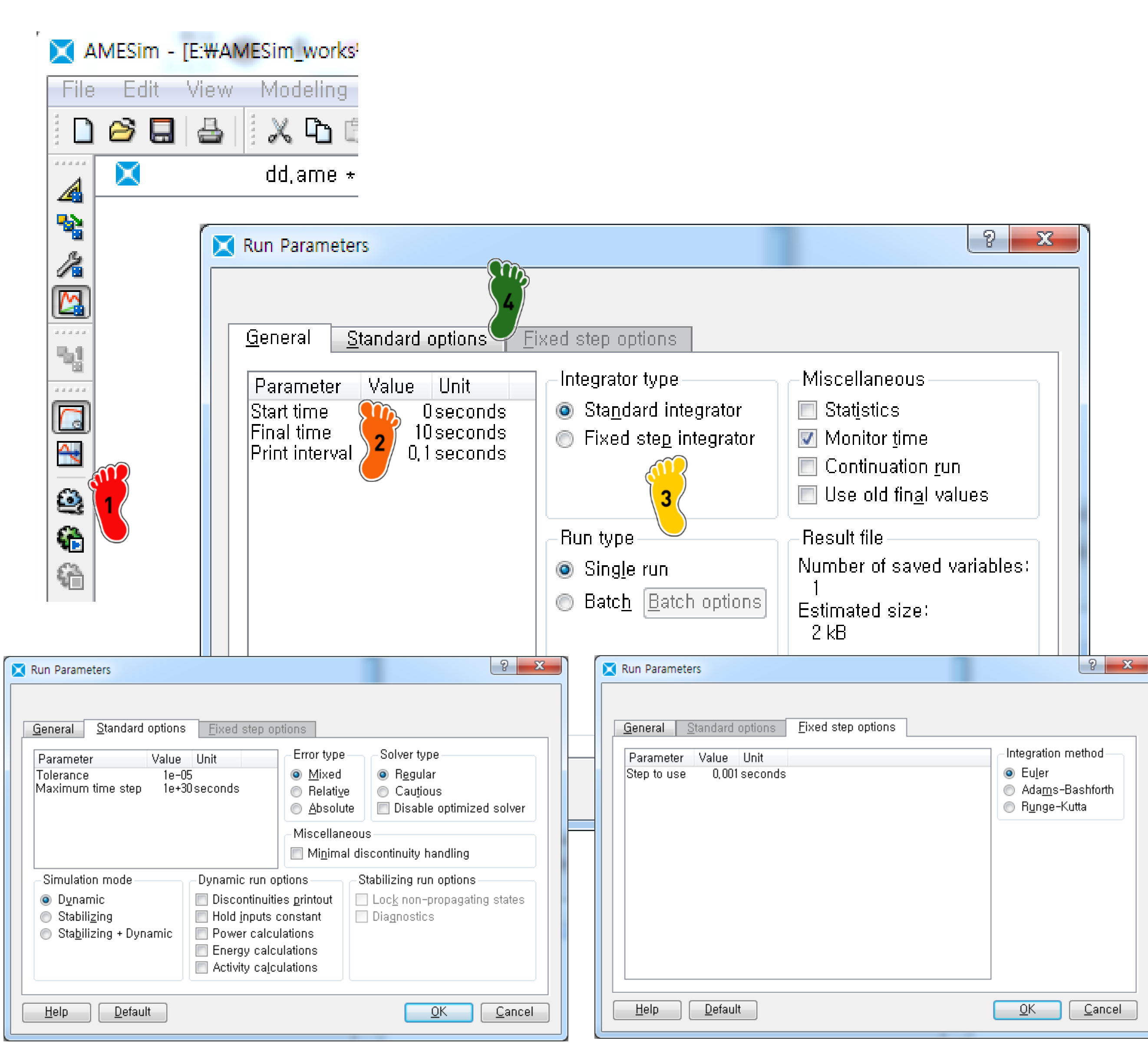
AMESIM ENVIRONMENT





1. 왼쪽 simulation mode 클릭
2. 파일 저장화면 생성 시, 저장 후 System Compilation 완료 확인
3. Start a simulation 클릭
4. Constant block 클릭, output 클릭 후, 스케치 화면에 drag&drop, 결과 확인

AMESIM ENVIRONMENT



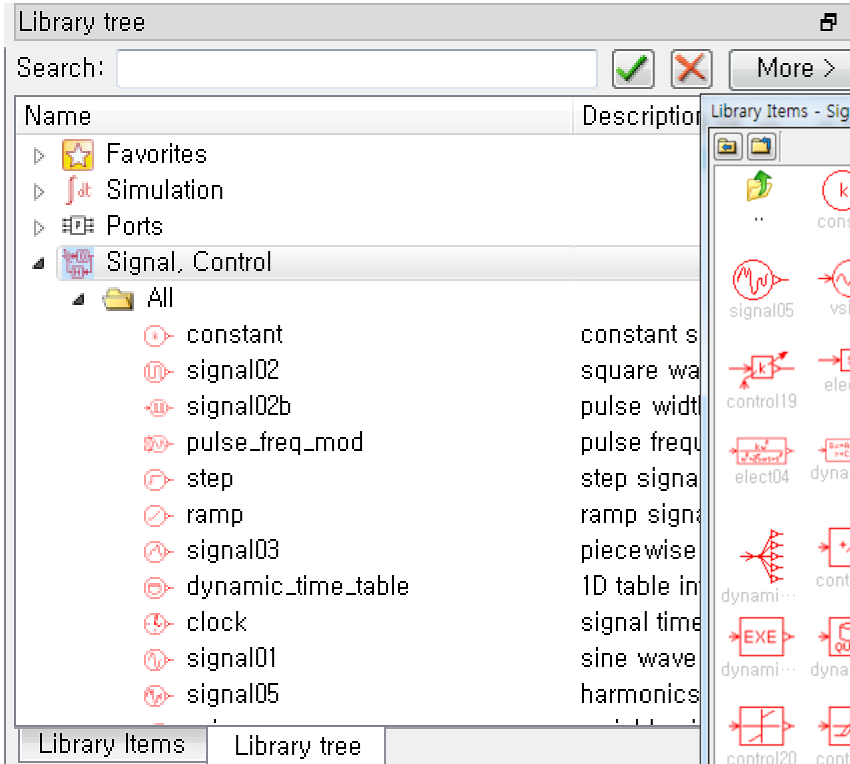
1 왼쪽 Run Parameter 클릭

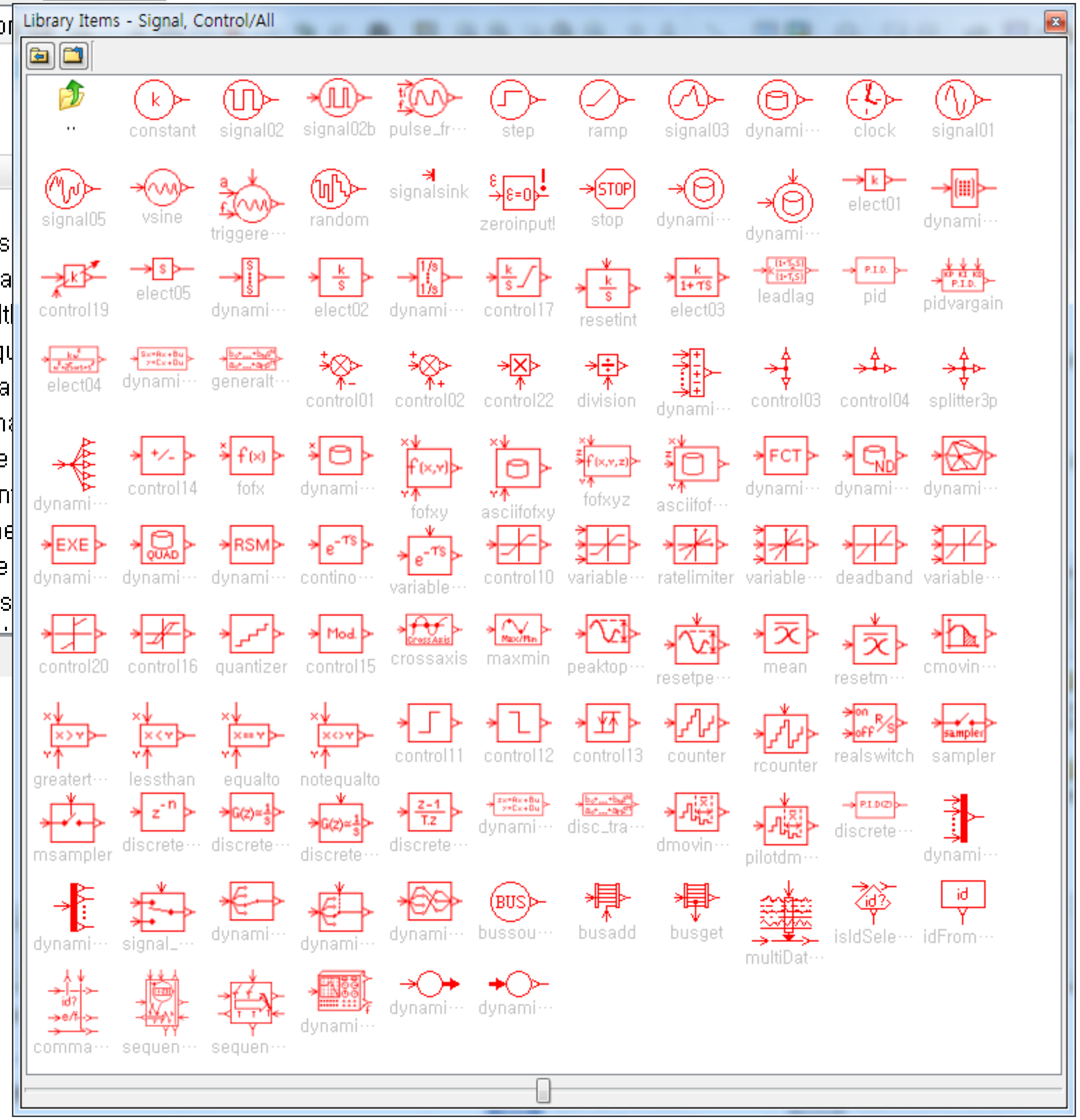
2 시뮬레이션 시간, plotting point 설정

3 Solver type 설정

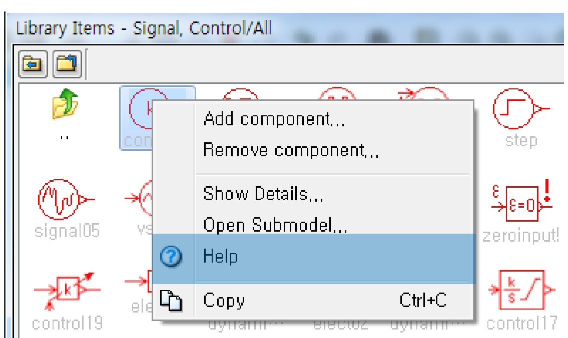
4 Solver type에 대한 옵션 설정

SIGNAL, CONTROL





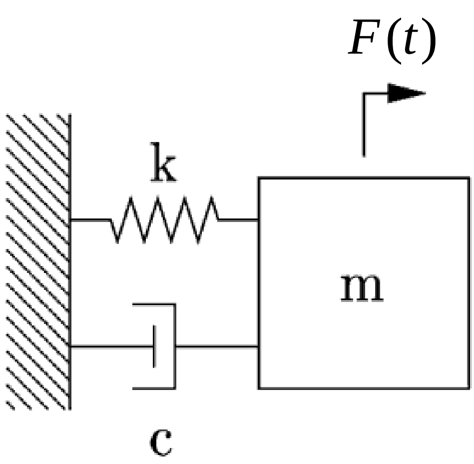
아이콘 클릭 후 오른쪽 버튼



SIGNAL, CONTROL

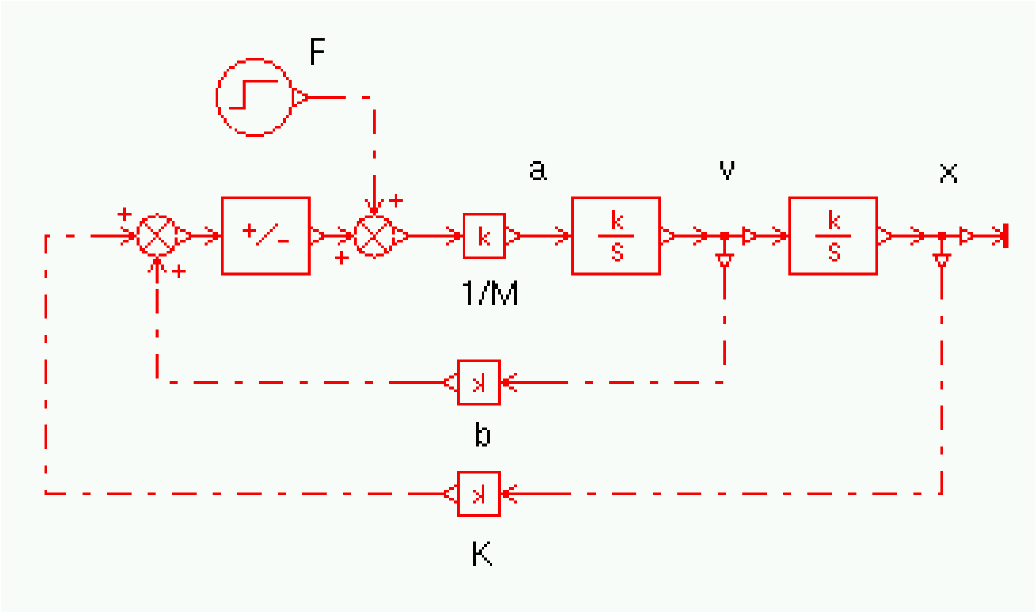
ICON	Description	Simulink
constant	상수 입력	Constant
elect01	y(output)=a*u(input), a : gain	Gain
elect02, elect05	적분기 : $y=\int u\,dt$, 미분기 : $y=\frac{du}{dt}$	Integrator, Derivative
control01, control02, control22, division	사칙연산자 (곱하기, 나누기, 더하기, 빼기)	Product, Divide, Sum
greatert···, lessthan, equalto, notequalto	비교문 (and, or, less than, more than, equal)	AND Logical Operator, <= Relational Operator
control10	입력신호 범위 제한	Saturation
dynami···, dynami···	신호 → 벡터 합성, 벡터 → 신호 분해	Mux, Demux
dynami···, asciifofxy	table(1-D or 2-D)에 의해 정의	1-D Lookup Table, 2-D Lookup Table
fofx	사용자가 지정한 함수	f(u) Fcn

SIGNAL, CONTROL



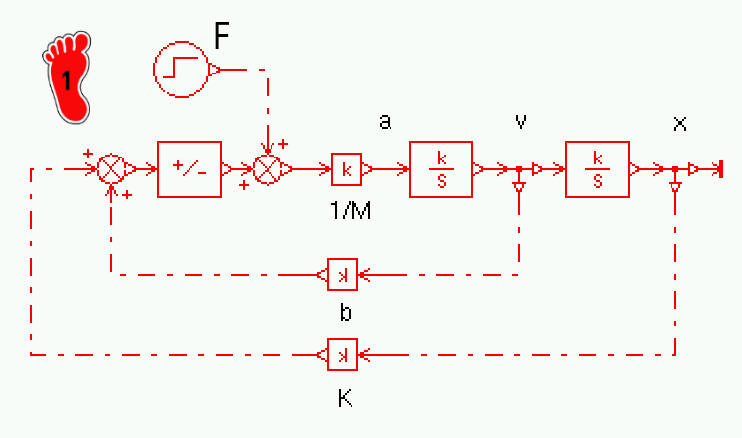
$$M\frac{d^2x}{dt}+b\frac{dx}{dt}+Kx=F(t)$$

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



Mass-Spring-Damper로 구성된 2차시스템 (1DOF)

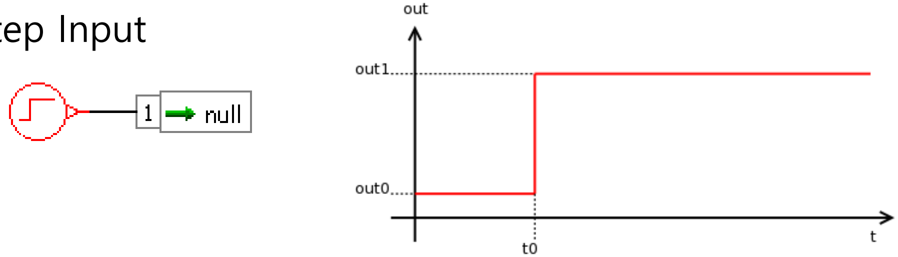
SIGNAL, CONTROL



Parameter Values

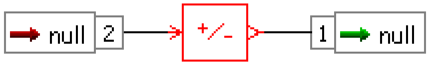
M = 10 kg
b = 400 N/(m/s)
K = 100000 N/m

Step Input

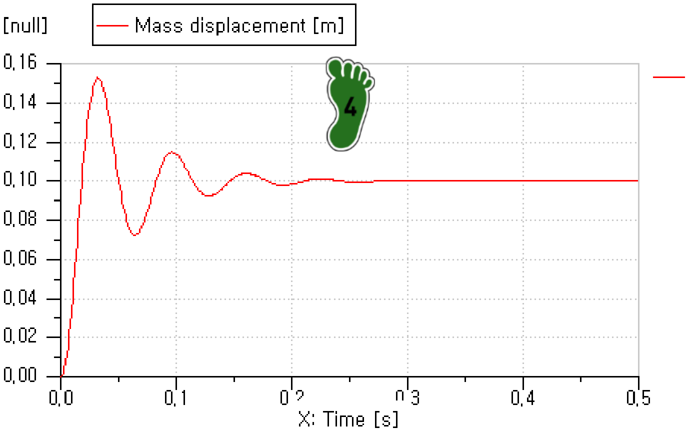


out0=0
out1=10000
t0=0

Reverse the sign

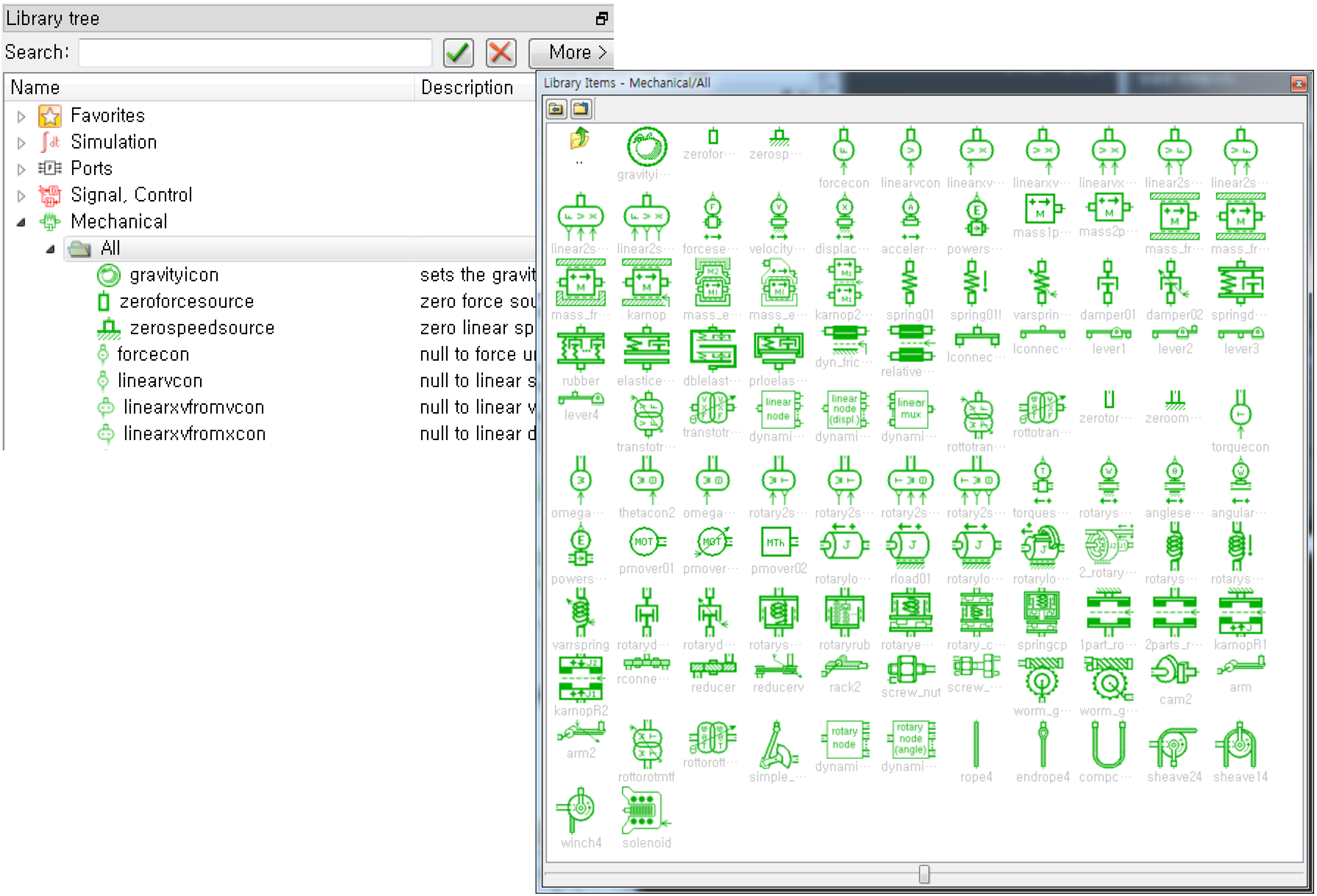


outp = -inp



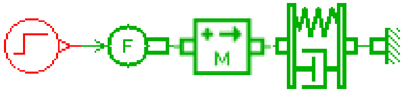
1. Block Diagram 구성
2. Gain block에 Parameter값 입력
3. Step Input block에 값 입력
4. Run 및 결과 확인 (simulation time 0.5 s 로 set)

MECHANICAL BASIC



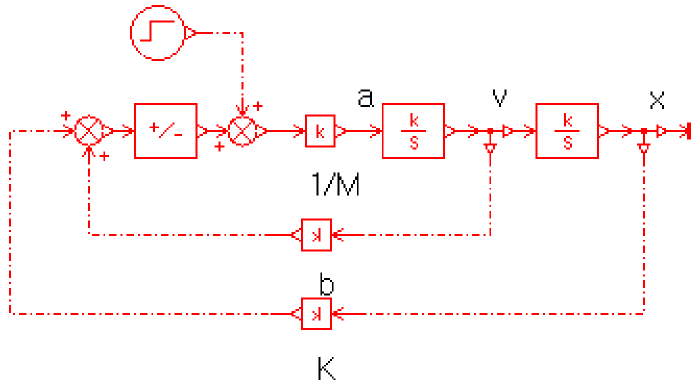
MECHANICAL BASIC

1. Block Diagram 구성
2. Parameter값 입력 (Force Input은 copy-paste)
3. Run 및 결과 확인
4.



M = 10 kg

K = 100000 N/m
b = 400 N/(m/s)



Mass Parameters

Parameters of mass_friction2port [MAS004-1]

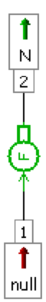
Title	Value	Unit
velocity at port 1	0	m/s
displacement port 1	0	m
mass	**10**	kg
coefficient of viscous friction	0	N/(r

Spring&Damper Parameters

Parameters of springdamper01 [SD0000A-1]

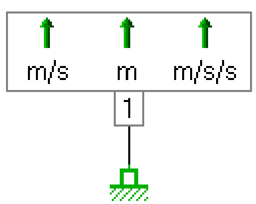
Title	Value	Unit	T
spring stiffness mode	numerical value		
spring force with both displace···	0	N	
spring rate	100000	N/m	
damper rating	**400**	N/(m/s)	

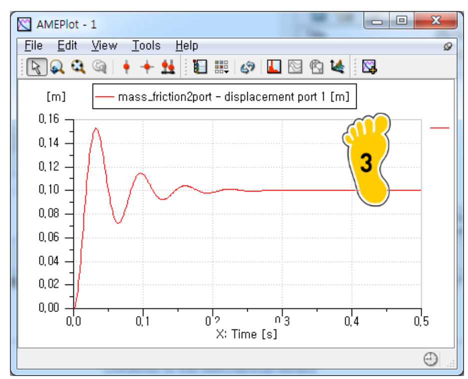
Force Input



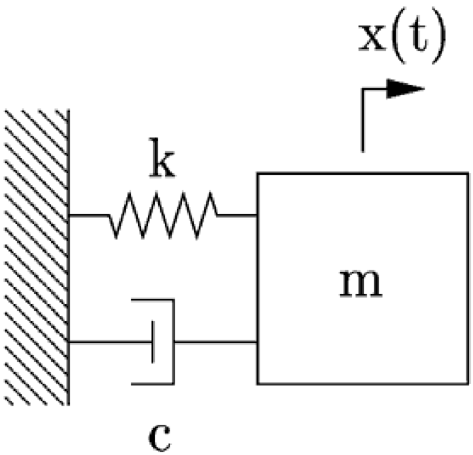
force = input

Zero speed





MECHANICAL BASIC



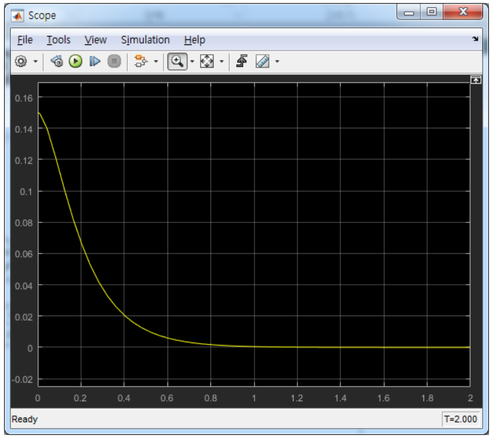
Simulink Example

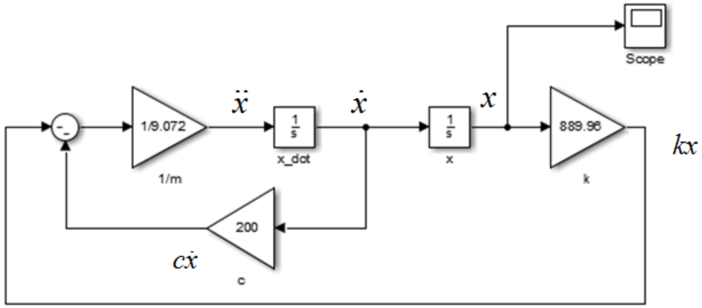
$$m\frac{d^2x}{dt}+c\frac{dx}{dt}+kx=F(t)$$

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

※ Analytic Sol.

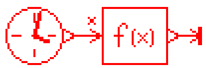
$$y(t)=0.2463e^{-6.190t}-0.0963e^{-15.83t}$$





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

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

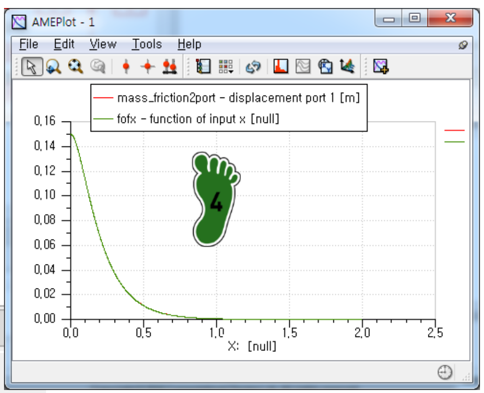
Parameters of springdamper01 [SD0000A-1]

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

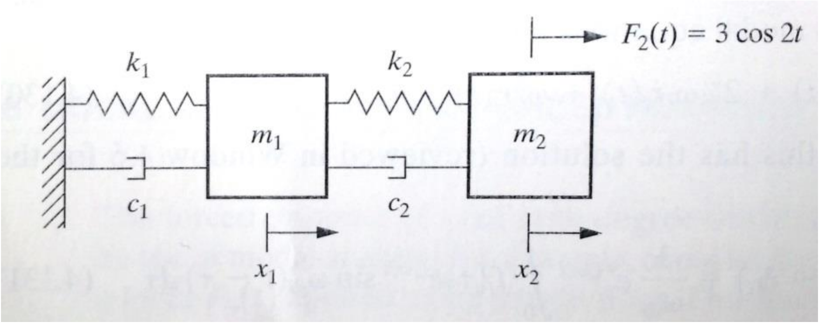
Parameters of fofx [FX00-1]

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

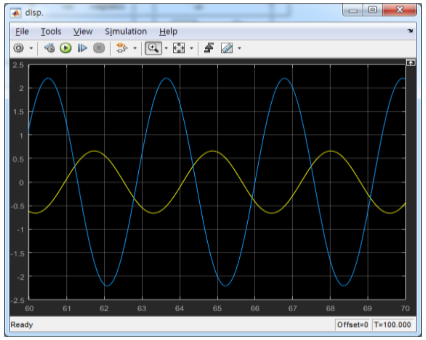


1. Mec. Model은 그대로 사용, Analytic Sol. 모델 구성
2. Mec. Model Parameter 값 입력
3. Signal Function Block에 Analytic sol. 수식 입력
4. Run 및 결과 확인 (겹쳐서 plot)

2-DOF system (Simulink Case Study)

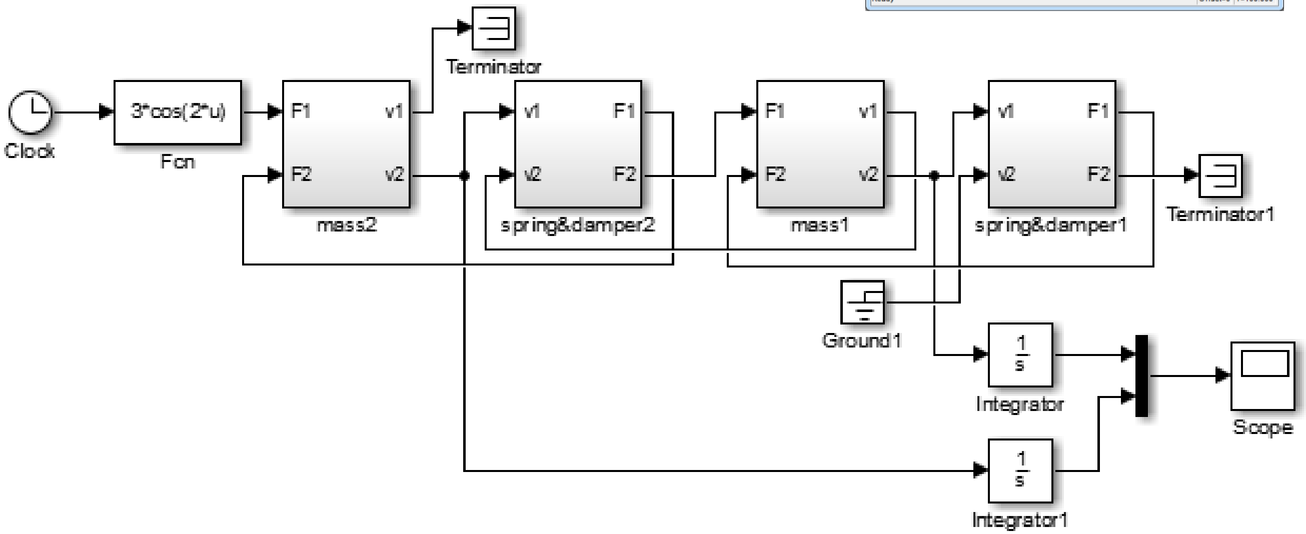


$$m_1 = 9\,\text{kg}, m_2 = 1\,\text{kg}$$
$$k_1 = 24\,\text{N/m}, k_2 = 3\,\text{N/m}$$
$$c_1 = 2.4\,\text{Ns/m}, c_2 = 0.3\,\text{Ns/m}$$
$$F_2(t) = 3\cos 2t$$



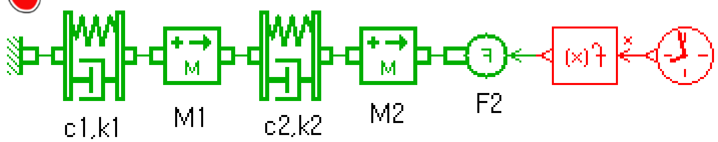
※ Analytic Solution (Steady State)

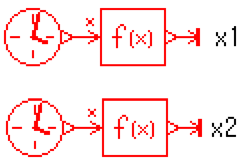
$$x_1(t) = 0.2451\cos(2t - 0.1974) - 0.6249\sin 2t$$
$$x_2(t) = 0.7354\cos(2t - 0.1974) + 1.8749\sin 2t$$



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

MECHANICAL BASIC





1 2-DOF Mec. System 구성

2 Analytic sol. function 구성

3 각 block에 알맞은 parameter 값 입력

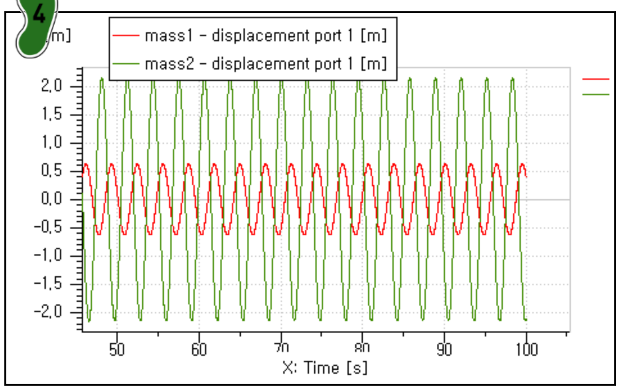
4 Run 및 결과 확인

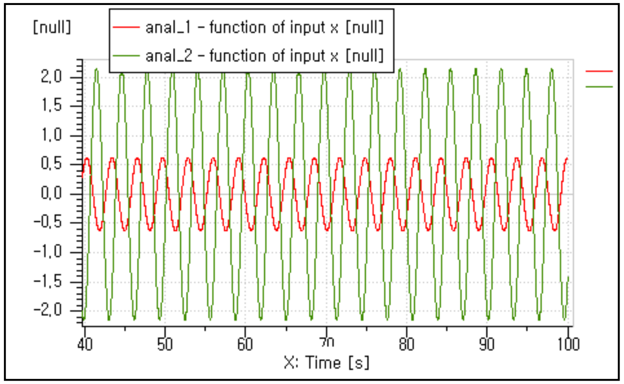
Parameter Set (Mechanical)

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

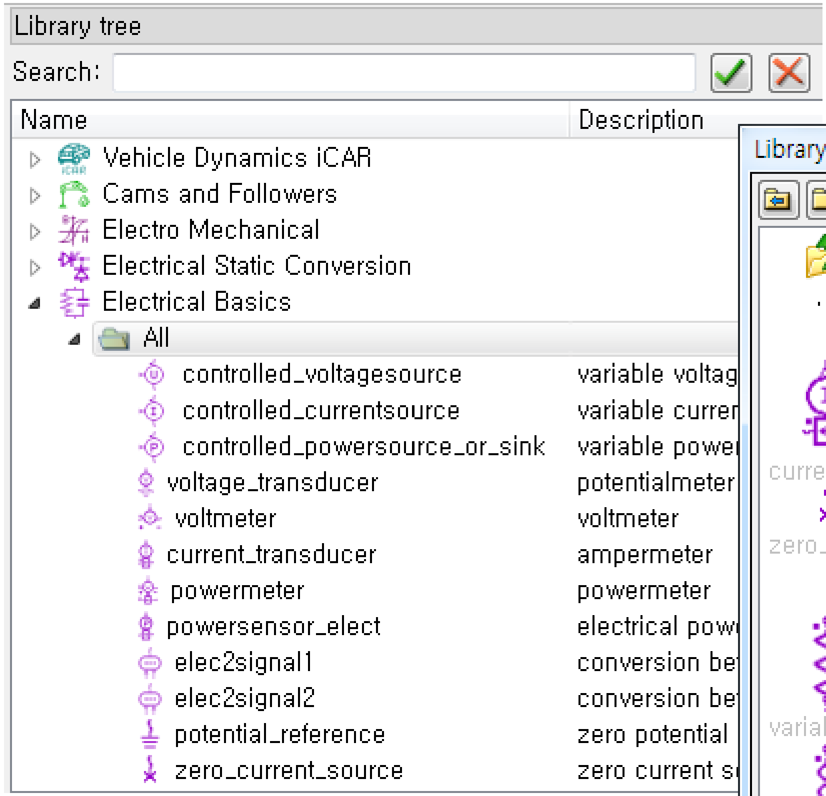
Parameter Set (Analytic)

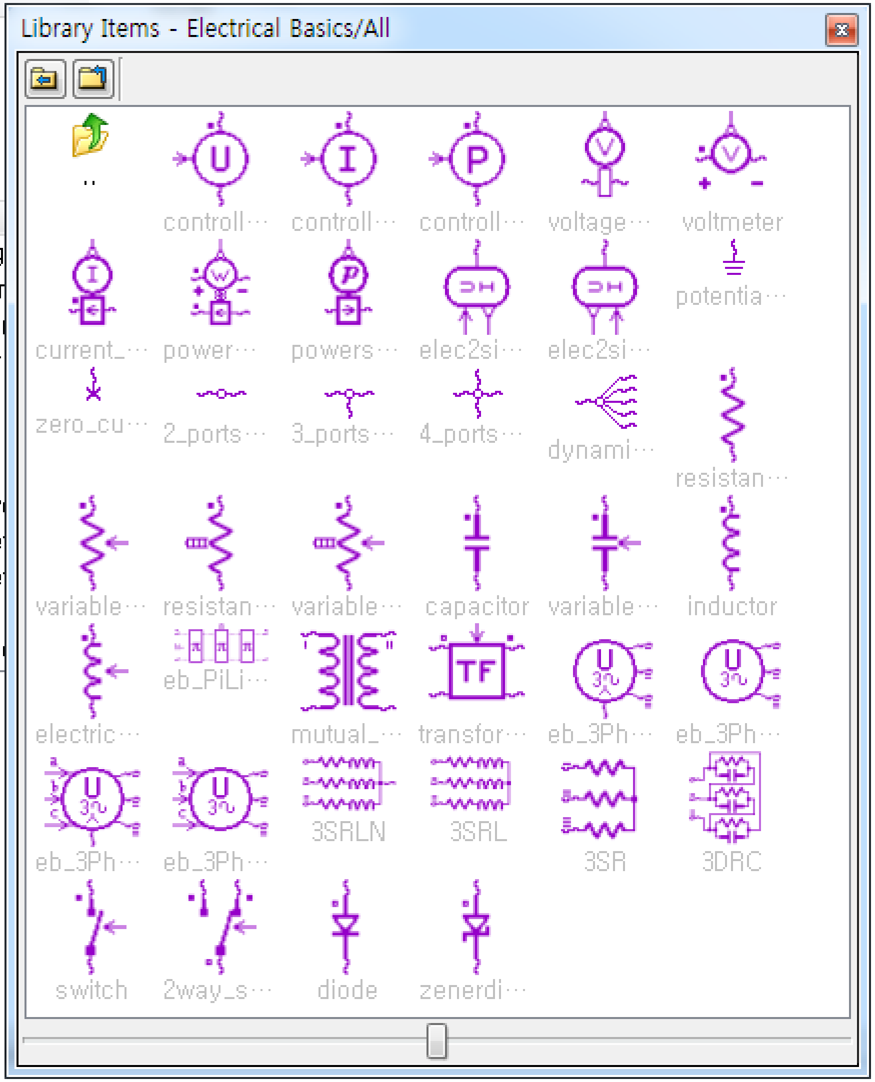
$$x_1(t) = 0.2451\cos(2t - 0.1974) - 0.6249\sin 2t$$
$$x_2(t) = 0.7354\cos(2t - 0.1974) + 1.8749\sin 2t$$





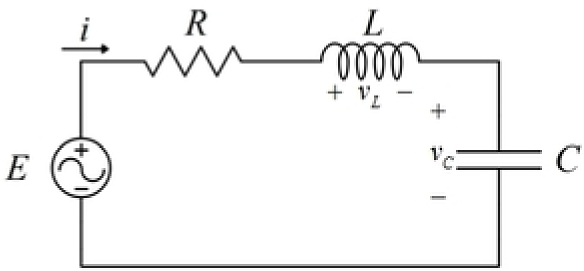
ELECTRICAL BASIC





RLC 회로 시스템 예제 (1DOF)

RLC circuit

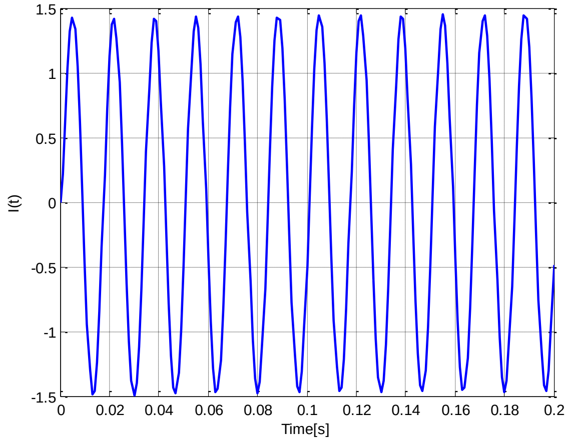


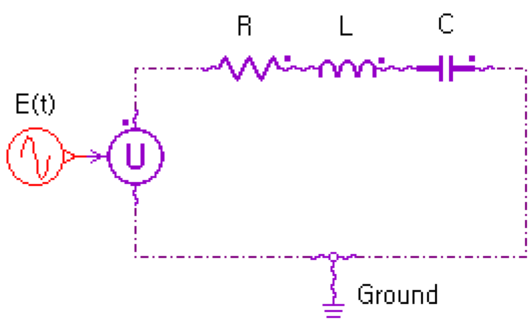
$$L\frac{dI}{dt} + RI + \frac{1}{C}\int I\,dt = E(t)$$

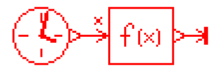
R=100 ohm, L=0.1 H, C=0.01 F, E(t)=155sin377t V

※ Analytic Sol.

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







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]

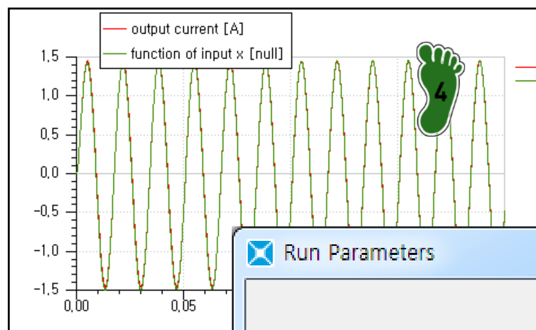
Title	Value	Unit
type of refe···	···e user	
resistance	100	Ohm

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

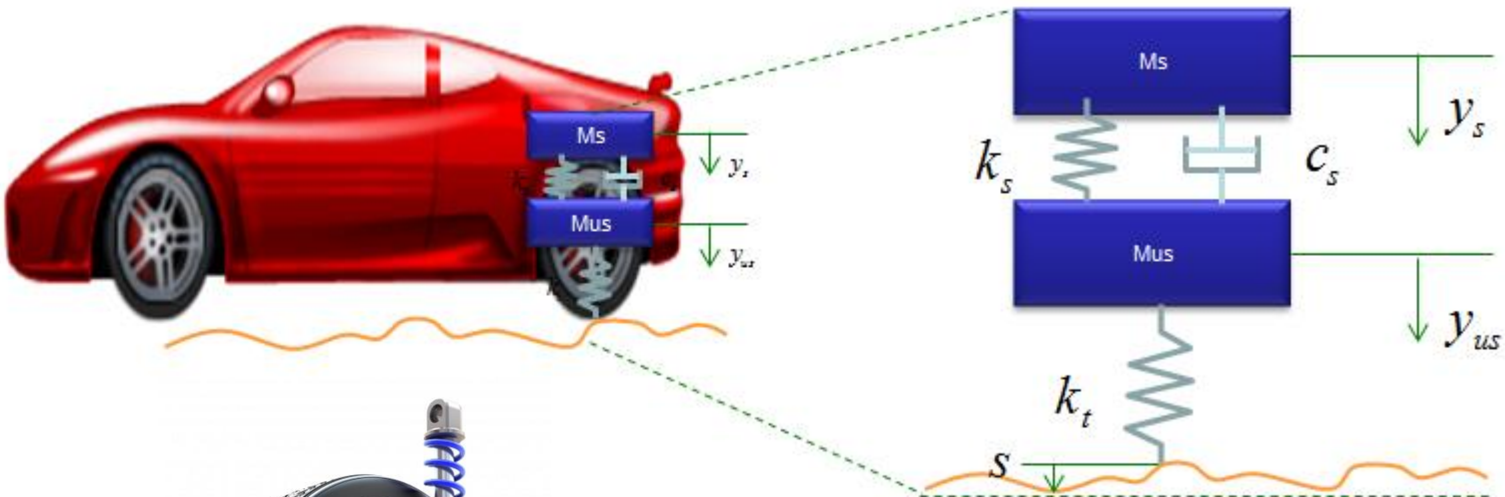


Run Parameters

General | Standard options

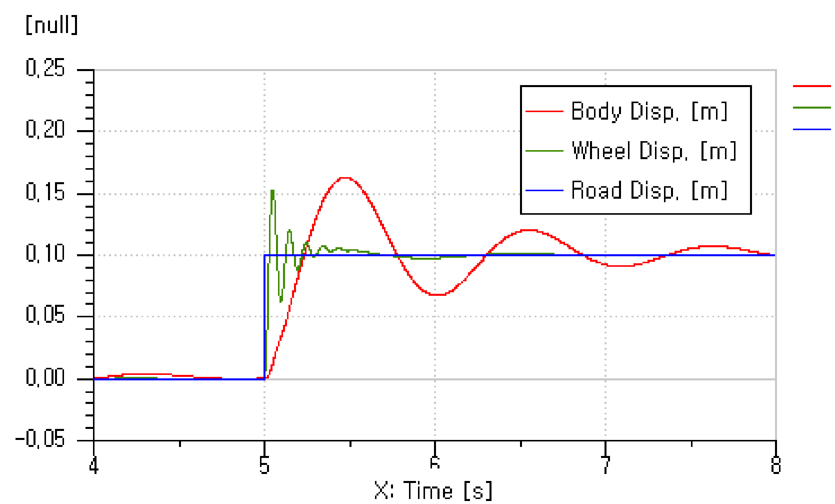
Parameter	Value	Unit
Start time	0	seconds
Final time	0.2	seconds
Print interval	0.0001	seconds

QUARTER CAR MODEL



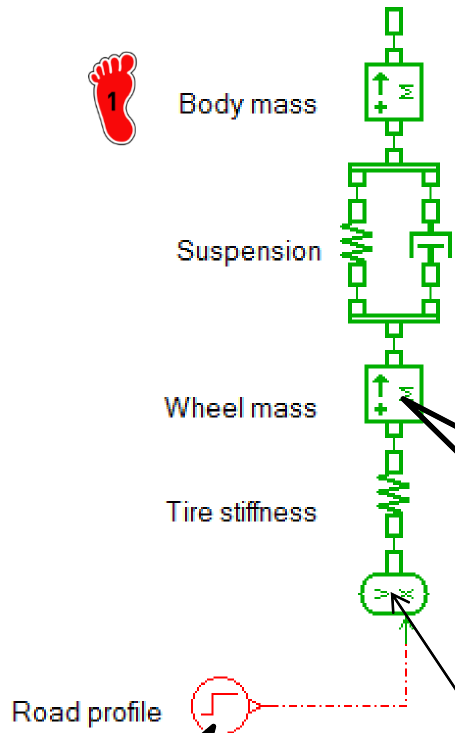
$$m_s \ddot{y}_s = -k_s(y_s - y_{us}) - c_s(\dot{y}_s - \dot{y}_{us})$$

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



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

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

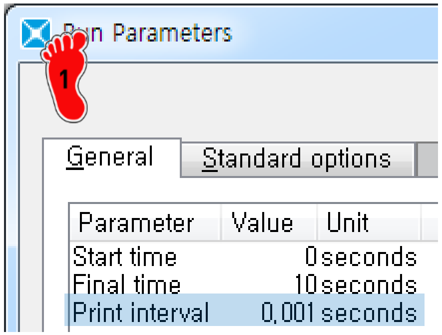
conversion of signal
to displacement

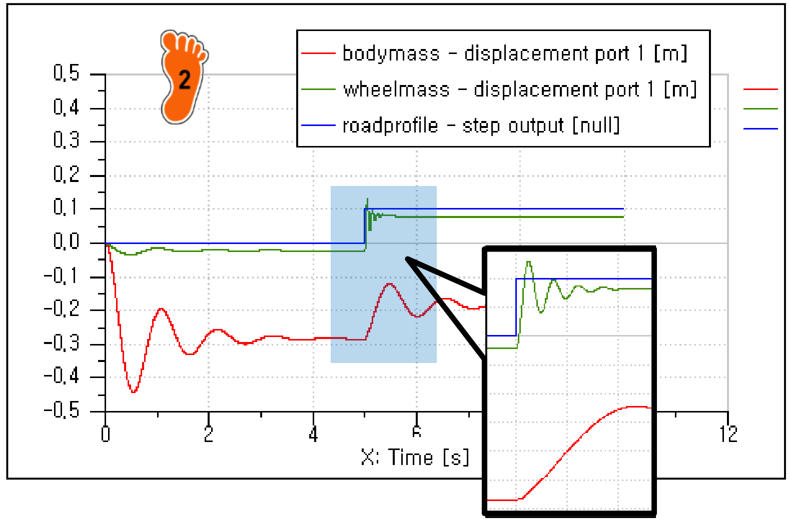
Parameters of step [STEP0-1]

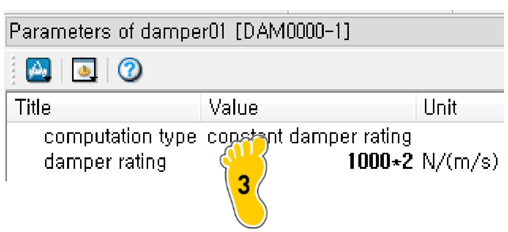
Title	Value	Unit
value before step	0	null
value after step	**0.1**	null
step time	**5**	s

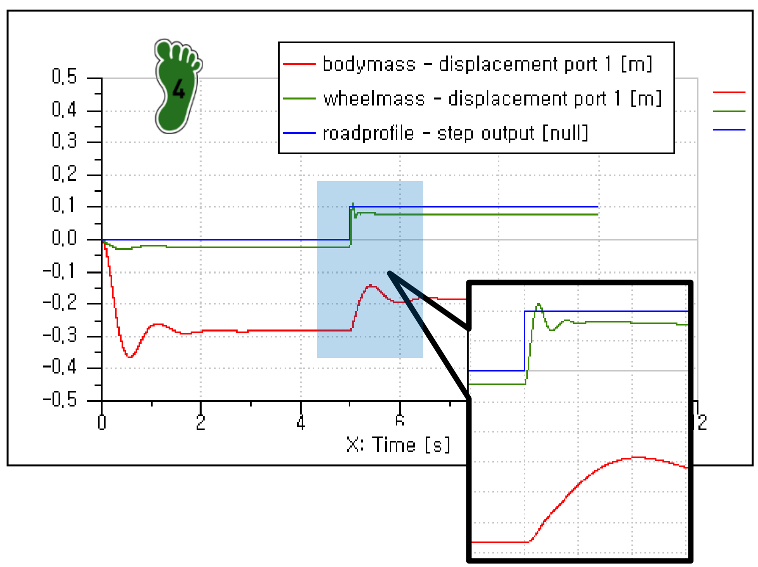
1. Quarter Car model 구성
2. Model Parameter 값 입력
3. body mass와 wheel mass 에 중력효과 입력
4. step function parameter 입력

QUARTER CAR MODEL







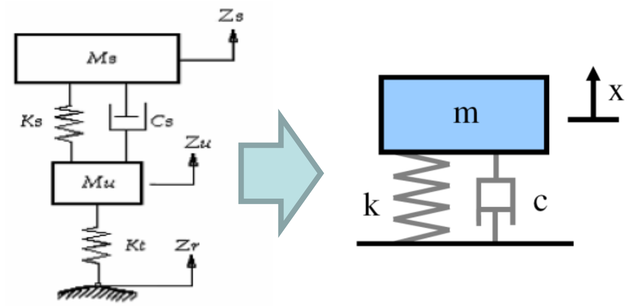


1. Run Parameters에서 Print interval 0.001로 set
2. Run 및 body, wheel, road 변위 확인
3. suspension damper rating을 2배로 증가
4. Run 및 결과 확인

QUARTER CAR MODEL

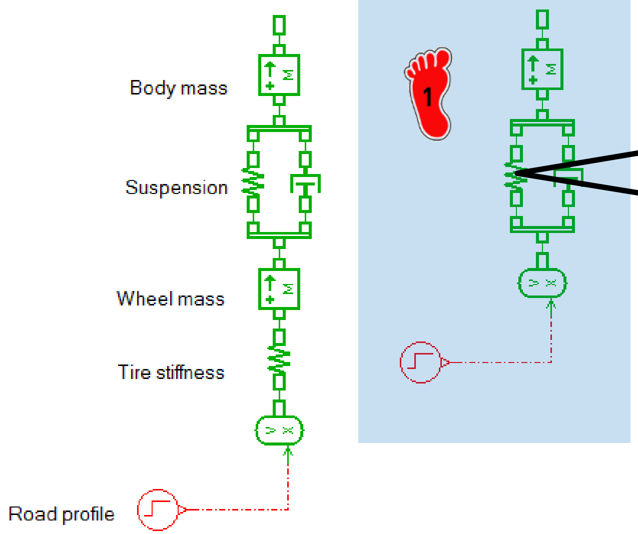
$$k_{sus} << k_{tire}$$

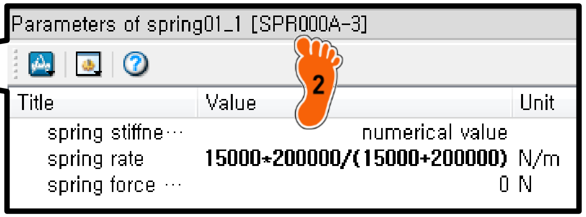
$$k_{eq} = \frac{1}{1/k_{sus} + 1/k_{tire}} = \frac{k_{sus}k_{tire}}{k_{sus} + k_{tire}}$$

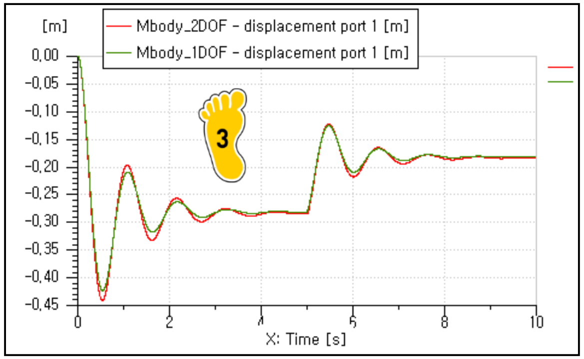


1. 1-DOF 모델 구성
2. Spring rate에 등가강성 값 입력
3. Run 및 두 모델의 body mass의 변위 값 비교
4.

QUARTER CAR

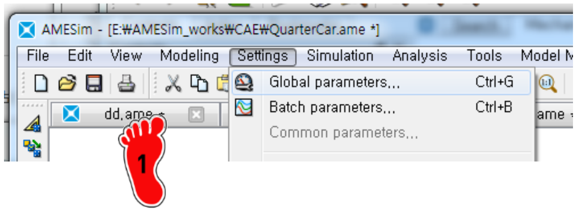


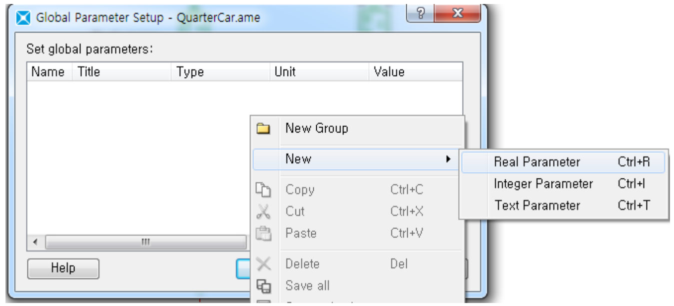


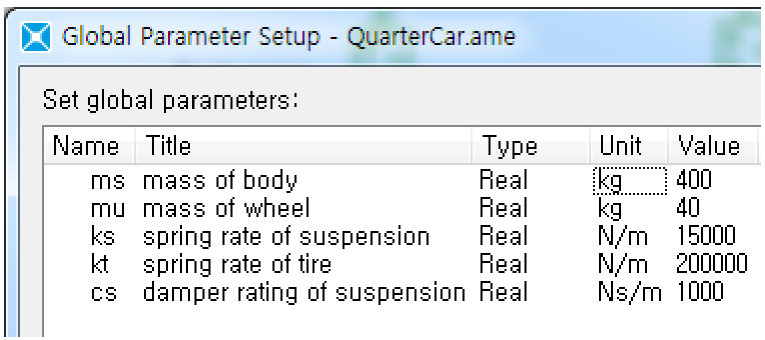


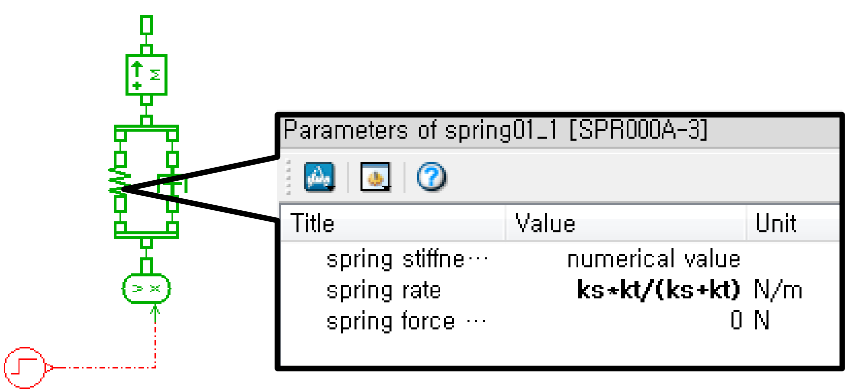
QUARTER CAR MODEL

Parameter Setting





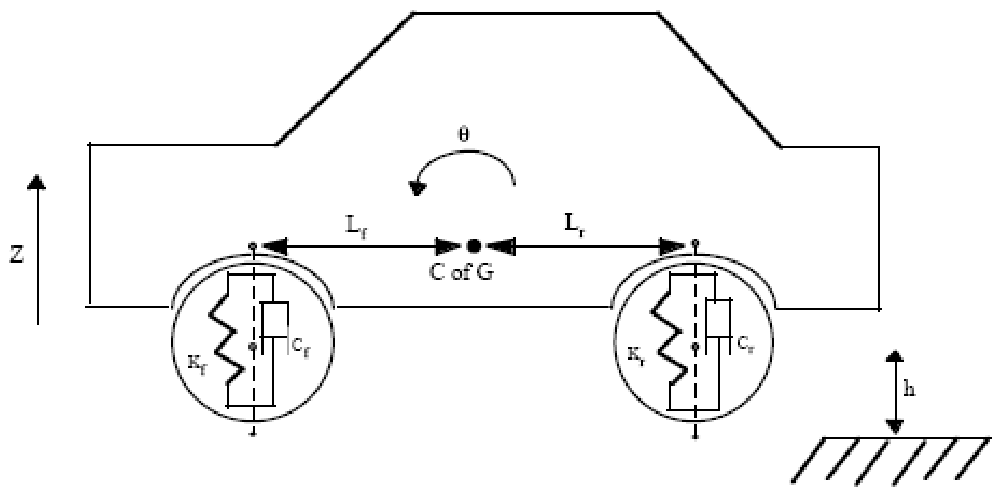


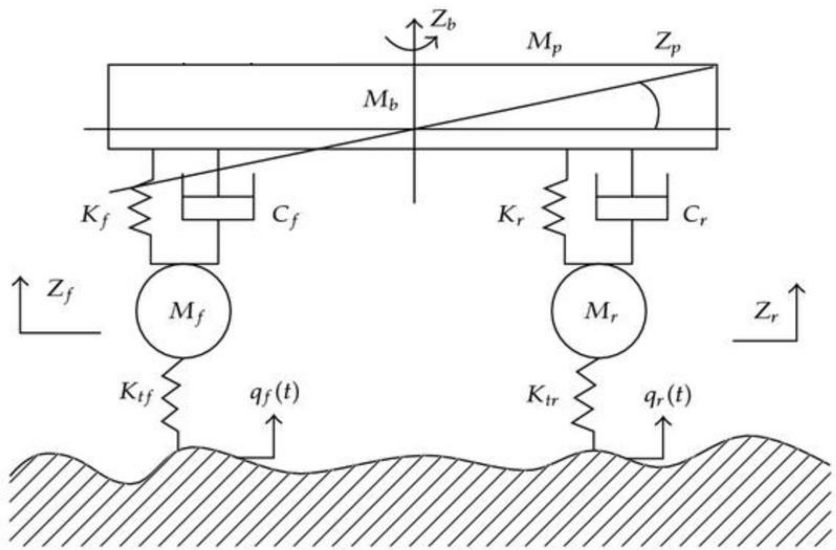


1. settings->Global parameters 메뉴 클릭
2. 화면에서 오른쪽 클릭, New->Real Parameter 클릭
3. parameter 이름과 value 입력(title, type, unit는 옵션) 입력 후 'ok'버튼 클릭
4. 각 컴포넌트에 parameter 이름 입력 후 결과 확인

CASE STUDY

Half Car Model





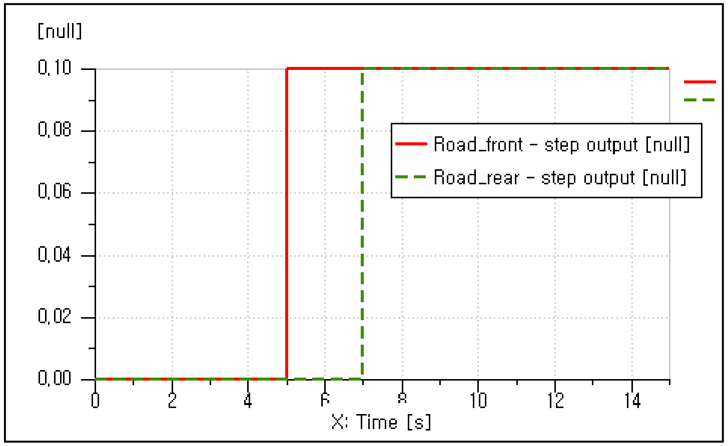
$$J_p = 2000\,\mathrm{kg\,m^2}$$

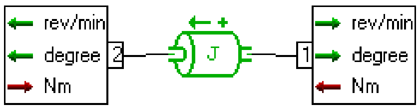
$$L_f = 1.2\,\mathrm{m},\ L_r = 1.5\,\mathrm{m}$$

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

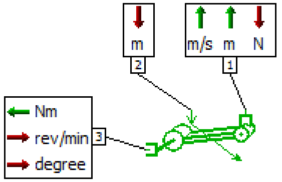
$$k_f = 20000\,\mathrm{N/m},\ c_f = 1500\,\mathrm{Ns/m}$$

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





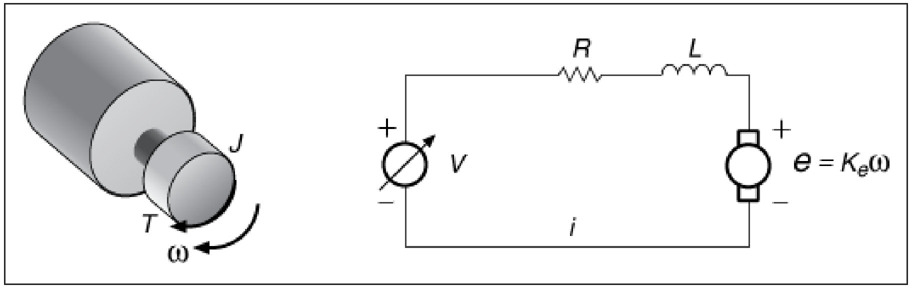
rotary inertia



mechanical arm

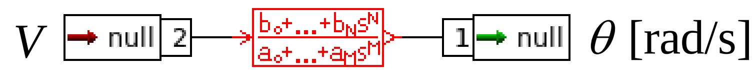
ASSIGNMENT

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



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

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



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

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.

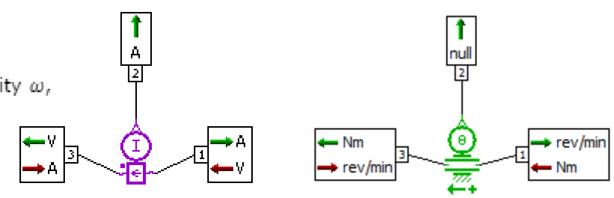
i is the circuit armature current.

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

θ [deg]



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 velocity ω, 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.

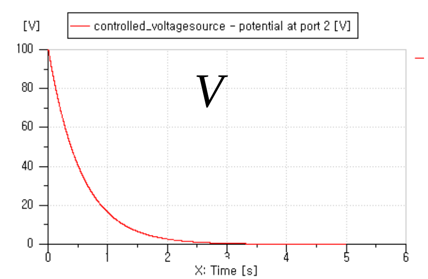
K_e is a motor back-EMF constant.

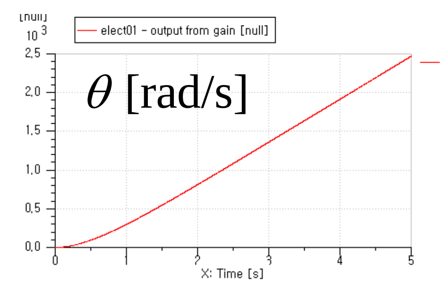
You can obtain the following equations by using Newton's Law and Kirchhoff's Law.

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

where J is the moment of inertia of the rotor.

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





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